The Astronomers' World

The Practice and Failure of the Scientific Universe

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Declaration

I, Patrick Edgley, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

In this project, I approach ‘western’, scientific cosmology within an anthropological framing. To explore how this cosmos is sought out and engaged with practically and phenomenologically, I conducted fieldwork with amateur astronomers in London, UK, and interrogated the particular positionality of these people and their practices within science and the world at large. In particular, this thesis is an exploration of scientific and cosmological failure, emerging from the claim consistently made or affirmed by astronomers that “the perfect image is impossible”. By following the process of astronomical image-making through astronomers’ engagement with place, practice, and images, I chart the course of this material failure, as they seek to manage photons into an objective view of the cosmos. Here, I approach astronomical practice as a revolutionary effort to access the obscured nature of the world, and approach its failure through the impossible task astronomers set themselves of effacing the human world—the biases and assumptions understood to do this obfuscation—from their images. Understood in this way, I assert that astronomy, and indeed science more broadly, is fundamentally cosmopolitical, seeking to reorient the relationship between humans and the world they study. Broadening the scope of this failure, therefore, I explore here how this reorientation and the world it produces fails—how the scientific natives and would-be-moderns that perform astronomy face a world that seems to no longer function both in and beyond astronomy—and how this cosmological failure is felt and contextualised on the ground in and around astronomical practice. I claim that while astronomy continually and inescapably fails as an effort to produce perfect, objective images of the cosmos, this seemingly futile practice can be made sense of in terms of a therapeutic function: as a practice that identifies and explores the particular troubling and apocalyptic nature of ‘now,’ and produces earthly communities that can collectively muddle through and manage the pessimistic condition in which they find themselves.

Impact Statement

We live in turbulent times. The particularly pessimistic condition of living now has been variously described as one of “trouble” (Haraway 2016[b]), “coming barbarism” (Stengers 2015), and “capitalist ruins” (Tsing 2015). There appears to be a distinct sense in which nothing seems to function: that human efforts to manage their worldly conditions are no longer meaningful or effective, and that human action is no longer, or perhaps never was, capable of adhering to the complexities of the social and natural world. This pessimism is often diffuse, but emerges around loci where anxiety is material and acute: around impending climate disaster and the inertia of actions to mitigate it; cyclic economic crises and our impotence to enact systemic change that might avoid such mismanagement; growing inequalities and political tensions particularly within western societies; and, perhaps most fundamentally, the growing challenges to epistemological and governmental authority posed by the phenomenons of ‘fake news’, misinformation, and various forms of science denialism.

In this project, I offer astronomy and its failure as another site at which these pressing and pertinent concerns are articulated. Astronomy, and science more broadly, once offered us legitimate and authoritative processes by which the world could be made knowable and manageable. In bringing astronomy down to earth and discussing its social and historical materialities, I claim in these pages that these practices both inform and are informed by the concerning mood described above. In taking particularly amateur astronomy as my site of work, I here discuss my informant’s work as a critical juncture between the scientific and public worlds, where the authority of the former is ‘at stake’ (Crease 2019). By following astronomers’ engagement with scientific failure, and applying anthropological discussions of failure more broadly (Carroll, Parkhurst, and Jeevendrampillai 2017), this thesis is oriented towards exploring the kind of social projects that emerge from these ruins: what is worked upon by astronomers in their effort to resolve such turbulence?

By framing the problem of astronomy as one of cosmopolitics, locating its failure in the particular presumed relationship between humans and the world they seek to manage, this project seeks to participate in the ongoing discourse around identifying what precisely is going wrong, such as that of Tsing, Stengers, Haraway and Stewart mentioned above, and begin to work towards the question of what can be done about it. My hope is that the understanding of cosmopolitical failure forwarded here might be applied elsewhere to make sense of these various problems as anxieties about the capacities of humans to domesticate an increasingly complex world. To this end, various aspects of this work have been adapted for talks I have given on the role of space and science culture in society, such as at the Centre for Outer Space Studies at the Institute for Advanced Studies at UCL, and the ETHNO-ISS Off-Earth Atlas Workshop. This fieldwork is also intended to be a starting point for further collaborative work directed at forwarding discussions of outer space within the discipline of anthropology.

Acknowledgements

Essays are arguments. This dissertation is not a statement of fact, but a concerted effort to convince you, the reader, that my positions have merit, in that they present a useful way of thinking about and making sense of the world. And they are *my* positions. This is not just to affirm that I believe what I say or that this work is not plagiarised, but also to assert the central tenet of this essay: that you cannot simply scrub knowledge clean of the human conditions of its making. I have been told repeatedly by my colleagues in the hard sciences that statements such as “I claim” or “I believe” are far too self-referential. As with the spacecraft we meticulously clean before shooting into the void, humans are contaminants that gum up the machinery of our theories on an onto-epistemological level. However, the simple activity of removing our stated participation in our theories does not render them post-human. There is a dishonesty in these conventions.

It is for this reason that, in many works, the acknowledgements section is one of the most honest. Here, the humans that undertake this work recognise its fundamentally human nature and the social grounds upon which they, their convictions, and their work are built. So this work is my work, but it is not purely my work. It was a collaborative effort, both directly or indirectly, on the part of all those who made it possible, and all of whom should be recognized for the part they played in situating this work. Indirectly, I would like to recognise my parents, who enthusiastically nurtured my interest first in physics, and later in anthropology, making me who I am, capable of the thoughts within these pages. Directly, I would like to express my deepest gratitude firstly to all of my academic colleagues for their guidance and patience throughout this project, particularly my supervisors Victor Buchli, Allan Abramson and Timothy Carroll, as well as members of the ETHNO-ISS team such as Aaron Parkhurst and David Jeevendrampillai, all of whom helped me navigate my PhD both intellectually and institutionally. I would also like to thank my friends both within and outside the discipline. Without their contributions to this work, both directly and indirectly, it would not be half of what it is today. Finally, and most significantly, I would like to thank the astronomer friends I made in the course of

my fieldwork for their time and collaboration, for the incredible patience and generosity they showed me, for all the conversations about space and our future in it, and for guiding me in my journey into the cosmos.

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Prologue

In the northern hemisphere of the planet Earth, lies the wet, cold island of Britain. In the south of this island, along the banks of the river Thames, dwells one of the largest concentrations of human lives on Earth, some thirteen million souls, in the metropolis of London. Amongst these souls, there are those who enjoy looking at the night sky.

This is by no means a unique vocation. Across time and cultures, humans have had a longstanding fascination with the sky and the objects and beings that populate it, though they have often come to very different conclusions about its contents, its structure, and their position in relation to it. The groups of people of whom I speak here are, in theory, not unique even within their own practice, which, for lack of a better term, I shall be following Clive Ruggles in calling “western” or “scientific” astronomy (2009). Through the cultivation of a certain kind of authority, backed by a robust epistemological methodology, this tradition has managed to manoeuvre itself into a position of being considered by many to be the singular legitimate, true account of the content of the sky. This is partly achieved by a cadre of elite, specialised intellectual vanguards, who use precise instruments and techniques to manipulate its content, and thereby unveil and map the universe. As such, the particular practices and understandings that go into this particular way of looking at the sky are, largely, ubiquitous, standardised, and found across the world.

The people I discuss in this work are not this elite cadre that established these standardised practices, but largely, through a process I will describe in these pages, adopt these routines and understandings. In spite of the talent they display, they are not at the forefront of rendering the sky’s contents visible. They simply lack the equipment offered by the scientific observatory. They can nonetheless be found across the world, and throughout the history of scientific explorations of the heavens. They are the people who undertake this work out of raw enthusiasm, curiosity, and a desire to engage with the contents of the sky practically and first-hand: amateur astronomers. In my fieldwork, I have interacted with amateur astronomers from many different parts of the globe, all of

whom share a clear understanding of what it is they are trying to access and a common methodology for doing so. These are people who look at and produce images of the sky for fun, in their own time. This production of images is crucial: visualising the cosmos, and critically rendering it available to be shared, is at the core of the work of these people. These amateur astronomers, in spite of their limitations, seek opportunities to come face-to-face with the cosmos that professionals so often reference, but lingers beyond unaided vision, and share that experience with others. As such, they stand between worlds, aspiring to countenance the sky, but endlessly embroiled in life as it is lived down here on Earth. For the last 4 years, I have worked amongst some of these people, attempting to learn their practices and rituals of cosmic revelation and transcendence by charting the Earthly grounds on which they take place.

I will, in time, outline my reasons for picking this place, these people, and these practices in full. For now, I will say that I believe that this nexus offers a certain cosmological positionality: a certain perspective on and set of conditions for the cosmology of scientific modernity. Their work is not only cosmological, but it is also cosmopolitical: these earthly conditions and the practices performed under them cultivate a particular kind of relationship between an imagined human totality and the world they inhabit. In this dissertation, I explore amateur urban astronomers in London as a tense and paradoxical nexus for cosmological action: for the production, circulation, and failure of worlds through the production, circulation, and failure of images. This process is the most clear and explicit example of modern cosmology in action and describes a cosmopolitical reorientation which, to my mind, is directed towards re-negotiating the place of humans within the astronomer's cosmos. Through their tense and interstitial position between ground and sky, science and society, astronomers find themselves looking towards objective transcendence while trapped by the subjective contexts of Earth that intrude upon their work, and in this tension find a means of making sense of how and why the Earthly world they inhabit seems to be falling apart.

1. Introduction

I have spent an inordinate amount of time over the past 4 to 5 years looking at images of outer space. So much time, in fact, that I assumed that by this point I would have developed something of an eye for the aesthetic standards of the medium: what counts as a 'good' astronomical image. Working out the standards of astronomical imaging was one of the first tasks I set myself in a broader ethnographic project to engage with amateur urban astronomers working in and around London, in an effort to understand the cosmological orientations of their visual practices. Despite this early recognition, and after all this time pursuing this understanding, the only thing I have to show for myself is a growing disappointment in the images I have created. Taste in astrophotography, as in everything, is a treadmill: a receding horizon of perfection which seems to speak more explicitly of our insufficiencies than our capabilities. Rather than getting us closer to perfection, developing taste seems only to underscore our distance from it, and just how out of reach it is. As such, astronomy is often as frustrating as it is rewarding. However, this frustration—the painstaking hours of work and hundreds of failed attempts—is often missing from our understanding of astronomy, as central and inescapable as it might be to the experience of its practice. There are few processes I am familiar with where there exists such a vast gulf between the wondrous images that reach the public and those that never see the light of day, a gulf traversed by the meticulous work of selection, composition and doctoring (Kessler 2012) that obscures the troubled origins of these pictures. These practices work to erase all evidence of the imperfections which astronomers struggle to overcome.

My interest lies in this hidden aspect of astronomy: the bit that comes before the public image, where all the failures take place and are subsequently made to disappear. I am interested in all the images that lay by the wayside, casualties in the endless project to make the universe visible. It is this interest that drove me to ask the aforementioned question of standards and taste. What makes an image of space *good*, or at least *good enough*? What is perfected, or seeks perfection, in the endless reproduction of these images of celestial objects? To me, it seemed that the answers to

these questions are central to understanding the practices performed by astronomers—the ends to which astronomy is the means. It is for this reason that, when I first set out to interrogate astronomy as a practice, these were the questions I actively pursued.

In the context of this pursuit, I came across one of the more interesting statements which, in reiterating the point I made above, came to define my discussion of astronomical practice, serving as that moment where the efforts of my informants that I had observed up until that point crystallised. John[1] was a seasoned astronomer with a penchant for astrophotography. He used to work in one of those stressful but highly paid jobs in the city of London and had then used astronomy as an opportunity to unwind, as a kind of escapism. Upon finding that there were things he would rather be doing with his time than work, most notably astronomy, and that he had the means to live comfortably, John made his escape permanent and retired early. When I met him in a coffee shop near the heart of the city, he was living in north London, spending his abundant free time exercising and looking at the stars. He regularly took trips abroad to take pictures of the Aurora Borealis or find sites with the optimal conditions for him to perform and perfect his craft.

In our meeting, John talked broadly about outer space. He spoke about where his fascination came from, how he started, and how astronomy is done. At this point, despite my longstanding enthusiasm about outer space, my knowledge of astronomy extended no further than the images I had seen, the books I had read, and the public lectures I had attended. I had only the vaguest idea of how the images that circulated around me as I grew up came to be. Rectifying this state of affairs was one of the critical goals of my early fieldwork. John was cheery and authoritative, giving the sense that he knew what he was talking about and felt strongly about it. He had a contagious enthusiasm, and a blunt, matter-of-fact confidence about what he was saying that seemed to lay claim to it. This was clearly not his first time walking a curious but

[1] All of the names used in this project are pseudonymized to protect the identities of participants.

ignorant member of the public through the inner workings of astronomy, a process that would emerge as a critical core of amateur astronomy.

He then shared with me some of his images. They were all stunning, inspiring that familiar sense of wonder that many feel when the contents of the sky are laid bare before them. Then he presented me with one image, a dramatic starscape featuring as its centrepiece a colourful and ghostly nebula. When I voiced my admiration for the image, however, he pulled a face. He said that he wasn't happy with it. The stars, he claimed, were too fuzzy. They should be sharp pinpricks of light, while he pointed out the distortions which, he said, meant that the internal workings of his telescope were interfering with the photons and that his alignment wasn't quite right. I followed this line of inquiry, hoping to get a glimpse of the methodologies that could be employed to improve the image. Fatefully, I phrased the question slightly awkwardly, asking what one would have to do to resolve all the troublesome aspects of this picture, to produce a *perfect image*. His answer was one that has been recited and attested to by many informants independently throughout my fieldwork: that *"the perfect image is impossible".*

I was in some ways relieved when I first heard this. At least my frustrations at the practice of astronomy reflected a more general experience of capturing pictures of the cosmos. My engagements had been authentic astronomical experiences, worthy of discussion. It took a while for the full gravity of this statement to sink in, however. Before I had managed to discern the nature of the astronomer's task in producing the image of space, they were already telling me that they had failed in it. Not only failed, but failed so fundamentally that it could not be rectified or salvaged. The perfect image was not even possible, and the effort to produce it was seemingly defined by unmet and indeed unmeetable goals.

Given the centrality of images and vision in scientific astronomy, this problematic and apparently pedantic statement and the questions that arise from it have come to frame my entire project to make sense of astronomical practice. What is this

unreasonable task that astronomy sets itself? What are the conditions for success that render it impossible? How and why do astronomers come to such a defeatist conclusion? How is this task and set of conditions for success manifested and rendered insurmountable in their practices? And, given that the cosmos is something that permeates our world, how is this failure made sense of and managed on the ground? To briefly summarise the answer to these questions as I have deduced from my time with astronomers, the unreasonable task they set themselves is the production of truly objective views of the cosmos, this task is unreasonable because its success is conditional on the paradoxical abstraction of these views from the human conditions of their creation. This impossibility is evidenced in the grounded, earthly, and crucially human practices that go into their making, as they are performed by astronomers. And, critically, this troubled epistemological relationship between humans and the world they seek to know and manage serves as a microcosm, allegory, and means of making sense of a similarly troubled world that at once built upon those same cosmopolitical grounds, and serves as the backdrop for astronomer's work. The failure of astronomy speaks to a broader condition of pessimism, anxiety and confusion about the status of the human in the world because, as I shall explore here, they are both symptoms of the same paradoxical set of cosmopolitical assumptions.

In this thesis, I argue that Western, scientific astronomy, its place in the world, the tasks that astronomers set themselves that guide their practice, and ultimately its failure, can be understood in revolutionary terms. Insofar as the revolutionary form, following Chersich, Holbraad and Tassi, can be understood as an active intervention in the social and political order aimed at disrupting that order so that a new, better world can be brought into being (2020: 4), the revolutionary model for social action can be used to make sense of all scientific practice, but it's cosmogonic element is most clearly visible in the practices of astronomers. These actions are directed at accessing and presencing (bringing into social being) the objective world—the world as it exists on its own terms, obscured as it so often is by the idiosyncrasies, biases, assumptions and superstitions of human thought. This world which lingers ever-present in the background, indifferent and impervious to opinion and interpretation, waiting to be

discovered, but that discovery is contingent upon the erasure of the human world which obscures it. As such, the revolution of astronomers and scientists more generally is not a political revolution to which we normally attribute this term, but a *cosmopolitical* revolution, which seeks to upturn and reorient our assumed position in relation to the universe in which we dwell. The impetus, driving force, and underlying principle for such a revolution is the recognition that, as Thomas Nagel notes, if we seek to get at the objective world, "we ourselves are the first obstacles to such an ambition" (1986: 13).

This revolutionary aspect of astronomy permeates its practice from start to finish. Western, scientific astronomers that I have interacted with enthusiastically and self-consciously participate in a revolutionary and world-shaping project that began with the Polish astronomer Nicolaus Copernicus—a critical figure within science's mythological pantheon, to whom I shall return shortly. Their practices are, to my mind, best understood as seeking to establish contact with the deeply hidden reality of things on the conditions of overcoming the local, specific, and particular knowledges and practices that otherwise disrupt such contact, and lead us to a world of delusion and dogma. In understanding astronomy in such a way, we can begin to approach the questions raised above. The failure of the image is the failure of this revolutionary project to overcome the social and human trappings of the Earth, and this failure points us towards what emerges from this failed revolution.

To illustrate this, and begin to work my way towards bringing together astronomy-as-revolution and the failure of the image, I offer here a couple of illustrative pictures. One is a picture, popular in astroculture and a mainstay of astronomical discussion, which highlights the task of astronomy in visual form. The other, one of my own inept creation, serves inadvertently as a caricature of astrophotographic failure, exaggerating what I believe to be the features that ruin all astronomical photographs, and pointing us towards understanding the impossibility of their perfection.

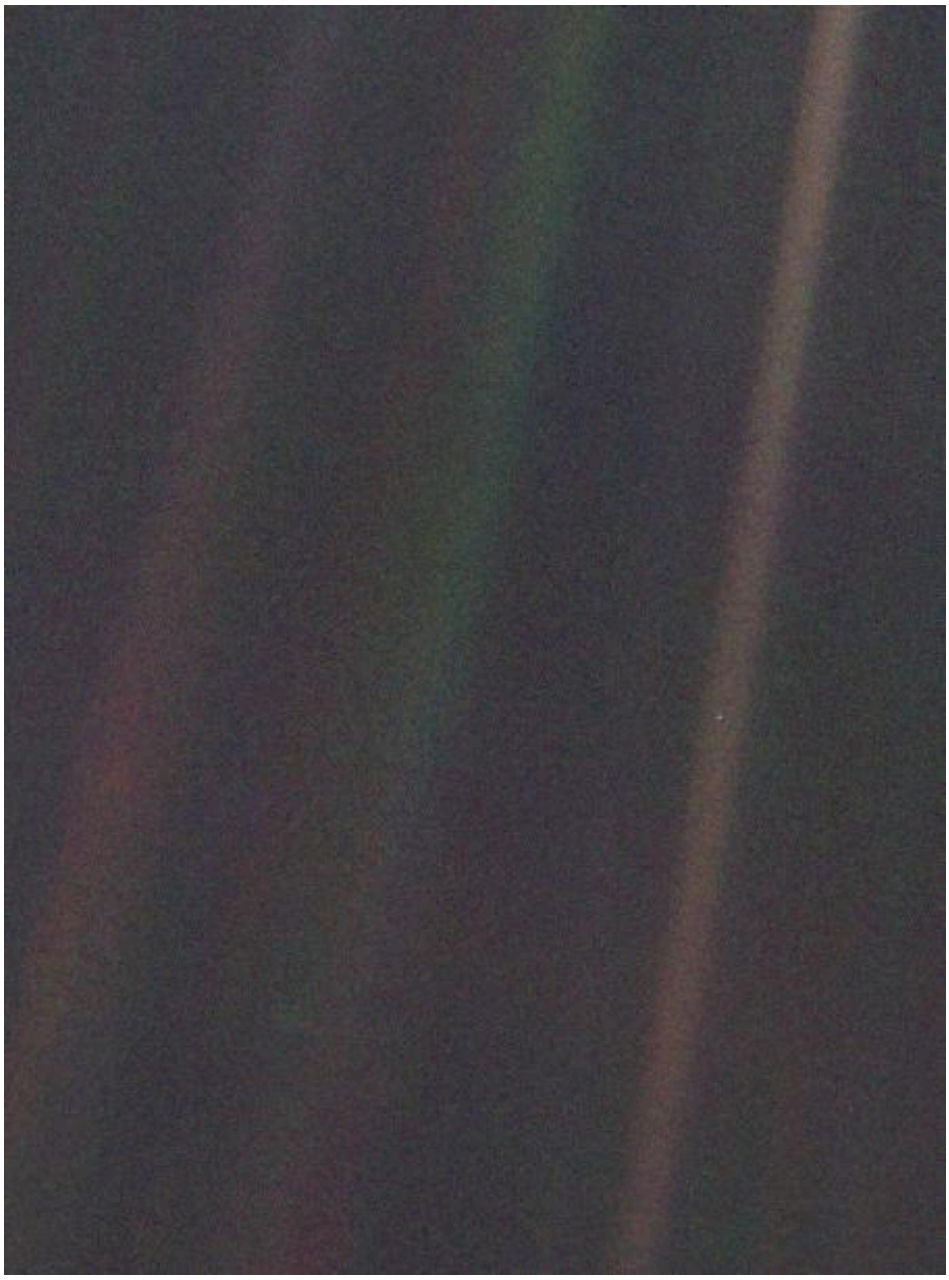

Fig. 1: The Pale Blue Dot image taken by Voyager 1. In it, the earth appears in the middle right as a pixel of light. Carl Sagan, the astronomer who consulted for NASA's space projects and was a member of the Voyager imaging team, wrote about the implications and contextualising power of this image (Image from NASA/JPL 1996)

The first is the famous *Pale Blue Dot* image, taken by the Voyager 1 probe and its operators at the National Aeronautics and Space Administration (NASA) on the 14th of February 1990 (*fig. 1)*. This image was both seminal in my journey into the scientific

cosmos, and, as I have since found throughout my fieldwork, to the journeys of many others. Such is the significance of this image that it can be found in abundance, on walls, phone cases, and online forums, to name a few of its incarnations. The image was a part of the “family portrait” series, which consists of images of all the celestial bodies in our solar system from a radically different position to that of the Earth. The significance of the Pale Blue Dot image is that it is the picture in this series that features the Earth itself, imaged from somewhere near Saturn. In it, our planetary home can barely be made out, appearing as a point of pale blue light (for which the image is named) in the middle right of the frame.

This image fits into a long tradition that permits us different vantage points on the Earth. Before it, the *Blue Marble* and *Earthrise*, each had their own marked impact on culture, cultivated conceptions of the Earth in its totality, divorced from the geopolitics and relations of power that were produced by a life lived from a grounded, human perspective, what Benjamin Lazier described as “globe talk” (2011). While these perspectives on the Earth can be said to cultivate notions of the Earth as a whole, from a global perspective, I claim that they hint at a more extreme scalarity realised more clearly in the Pale Blue Dot image: a more radical, more *cosmological* reorientation of view. One member of the NASA team that took the Pale Blue Dot image was Carl Sagan. Sagan’s influence on astroculture as an advocate for science and space enthusiasm was recognized in my fieldwork everywhere and without exception. He wrote a book reflecting upon and named for this image, contextualising it within the history of science and humanity more broadly (1997). So significant and wide-reaching is the influence of the book *The Pale Blue Dot* that I will refer to it repeatedly throughout this work not only as a prolific text within the astroculture community, but also for its capacity to capture and reflect the historical imaginary of astronomy and science that I saw in the minds of astronomers. In Sagan’s poetic reflections, he insists what is to be taken away from this image is the immense smallness of the human species within the cosmos:

> “There is no sign of humans in this picture, not our reworking of the Earth's surface, not our machines, not ourselves: We are too small and our statecraft is too feeble to be seen by a spacecraft between the Earth and the Moon. From this vantage point, our obsession with nationalism is nowhere in evidence. The Apollo pictures of the whole Earth conveyed to multitudes something well known to astronomers: On the scale of worlds [..] humans are inconsequential, a thin film of life on an obscure and solitary lump of rock and metal.” (Sagan 1997: 11).

The context that Sagan seeks to emphasise with this image is the cosmopolitical point of challenging the triumphalism and “planetary imperialism” that people like Martin Heidegger associate with a more global perspective (Oliver 2015: 111). In particular he situates this image as the latest in a series of “great demotions” that define the world since Copernicus, these demotions being “downlifting experiences, demonstrations of our apparent insignificance, wounds that science has, in its search for Galileo's facts, delivered to human pride” (1997: 20). What this image insists upon is what we might call, following another astronomer and science communicator Neil deGrasse Tyson, a “cosmic perspective” (2012: 254). I claim that these great demotions, and indeed the cosmic perspective that affords them, are cosmopolitical reorientations that lie at the heart of what astronomy does.

The most notable aspect of this cosmic perspective, its historical context included, is that it is about transcending the intuitive understandings of the world cultivated by people through their lives lived on the ground and the perspectives afforded by those lives, an idea on which I shall expand in the next chapter (2. Cosmos). We might say that the cosmic perspective afforded by astronomy, and the broader scientific project that it articulates, challenges our *lifeworld* and the assumptions present in it, insofar as the term “lifeworld” references this more phenomenological understanding of our apprehension of the world around us (Iwaniszewski 2015: 6; Ihde 2010). In describing the cosmic perspective, deGrasse Tyson quotes James Furguson in saying “Of all the sciences cultivated by mankind, Astronomy is acknowledged to be, and undoubtedly is, the most sublime, the most interesting, and the most useful. For, by

knowledge derived from this science, not only the bulk of the Earth is discovered ... but our faculties are enlarged with the grandeur of the ideas it conveys. our minds exalted above [their] low contracted prejudices." (cited in Tyson 2012: 254).

The cosmic perspective garners legitimacy from this function of existing outside of and beyond these prejudices, calling to mind Thomas Nagel's framing of an objective view as a "view from nowhere" (1986). In this sense, the Pale Blue Dot image is one taken from, or gestures towards, a position that is 'nowhere,' beyond subjective and cultural constraints, a void. What I have found throughout this project is that astronomy, as it is performed by my collaborators, seeks endlessly to replicate this displacement: to, in the pursuit of an objective view of the world—a cosmic perspective—plausibly abstract their images from the local conditions under which they were produced. In particular, as I shall substantiate, these conditions that must be erased are human conditions, the conditions of the human world. The human and its work must be effaced and cast aside in the cultivation of a cosmic perspective, and this injunction permeates and determines the practices in which amateur astronomers engage. This rendering of the cosmic perspective is, to my mind, the ideal outcome of revolutionary astronomical practice; it is an almost divine viewpoint that exempts itself from the distorting social trappings of earthly life which otherwise seclude and obscure the objective world. This is the view that I believe that astronomers seek to reproduce in the form of crisp, clear images that are true to the cosmic forms as they are understood to exist.

The cosmic perspective is not only a matter of epistemology, but also grounds a cognitive and ethical shift. The writer and space philosopher Frank White describes the way in which looking back to Earth from space reportedly instils in spacefarers an "overview effect," associated with feelings of planetary unity and transcendence. Likewise, Sagan emphasises that the insignificance of the stature of the human from this vantage point reorients considerations of geopolitical concerns, and renders them petty and inconsequential in the grand schemes of the universe. "Think of the rivers of blood spilled by all those generals and emperors so that, in glory and triumph, they could become momentary masters of a fraction of a dot. Think of the endless cruelties

visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner, how frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds" (1997: 13).

This ethical shift can be understood as a move away from human standards to ones that aspire to take into account our cosmic context. The philosopher Martin Heidegger responded to the Earthrise image with horror, stating "I at any rate was frightened when I saw the pictures coming from the moon to the earth. We don't need any atom bomb. [...] This is no longer the earth on which man lives" (Cited in Oliver 2015: 152). Concerns have been raised about the "detachment" and "decontextualisation" of the human that is afforded by such a vantage point (Valentine 2016). deGrasse Tyson's discussion of the cosmic perspective contains just such a reflection:

> "Who gets to think that way? Who gets to celebrate this cosmic view of life? Not the migrant farmworker. Not the sweatshop worker. Certainly not the homeless person rummaging through the trash for food. [...] The cosmic view comes with a hidden cost. When I travel thousands of miles to spend a few moments in the fast-moving shadow of the Moon during a total solar eclipse, sometimes I lose sight of Earth."

Understanding astronomical practice as an effort to take up a cosmic perspective by actively losing sight of the Earth draws me to my second image and my discussion of the failure of this project. This image (*fig. 2)* is the first picture I ever took of space, and as such, it falls far short of any aesthetic standard that astronomers set themselves. It was never going to be good; I knew that when I took it, as I lacked the appropriate equipment. I had just acquired my first camera capable of taking images of space, and, pointing it at the three bright stars that made up Orion's belt, the photograph I present here emerged.

What this image shows is obviously far from an accurate representation of Alnitak, Alnilam and Mintaka, the stars that line up to constitute this familiar

astronomical feature. The wandering, “smearing” effect results from the shaking of my hands as I held the camera over the long exposure time (a process to which I will return in 4.4. Cosmic Torsion: Sedentising the Cosmos). Etched into this image is both the mark of the cosmic, the photons I collected from these stars, and a part of myself, the micro-adjustments of my hands, which, without the steadiness of a mount, ‘ruined’ the photograph. They resemble John’s far more minor errors, where a misaligned mount caused the slight fuzziness of those stars. These marks are the intrusion of our flawed humanity into an image that is supposed to depict the deeply inhuman—the polluting of the cosmic with traces of the local and earthly contingencies of the image’s production.

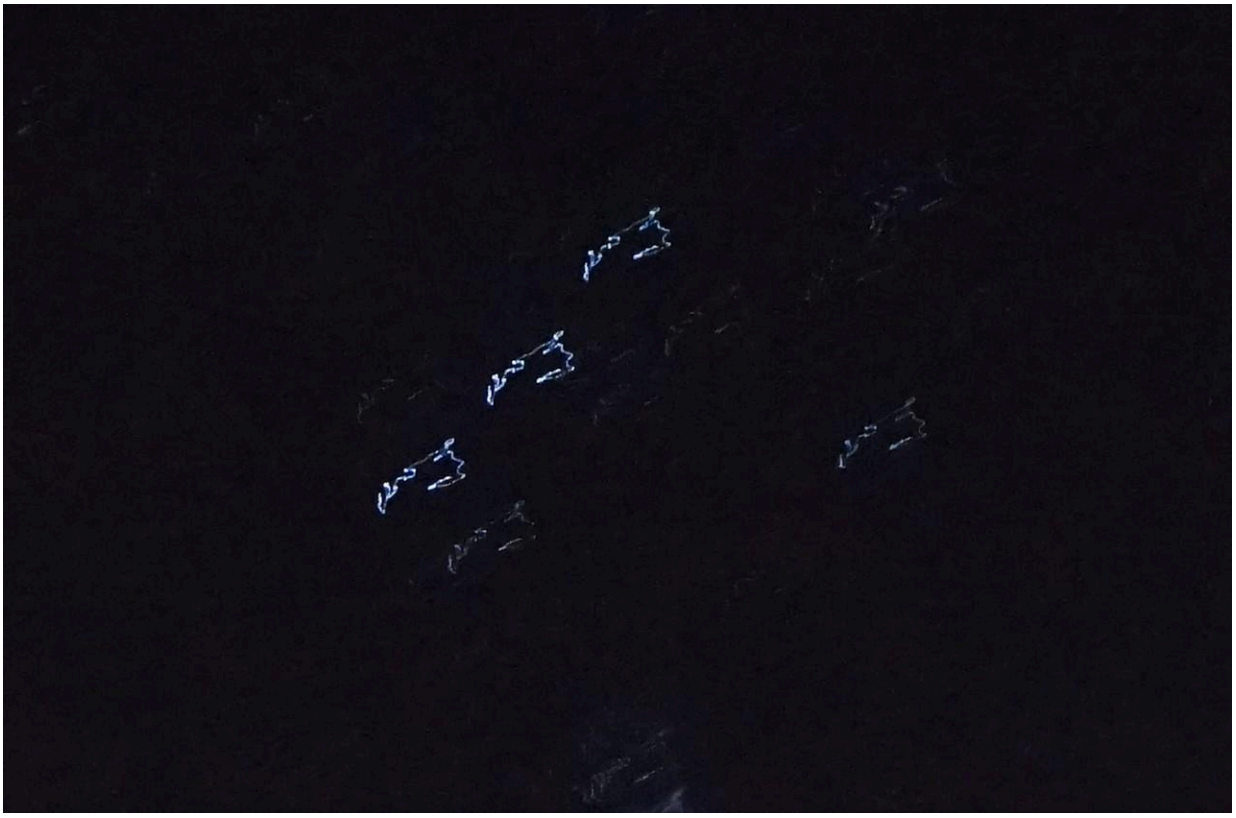

Fig. 2: *the imperfect image.* My very first attempt at astrophotography, taken of Orion’s belt at the beginning of this project. I had set my camera to automatically detect the levels of light available, which left me with an exposure of approximately 15 seconds. Without a tripod, the wandering of my hands as I tried to hold the camera still became clear in the image.

It is this intrusion, made clear here in the inept handling of my equipment, that I claim profanes and undermines every astronomical image by drawing astronomers inevitably back down to Earth, breaking the fantasy of transcendence. Learning to do astronomy means learning all of the practical and social contingencies here on Earth for the visibility of the cosmos: all the ways in which such a view, foundational to the cosmos itself, is deeply mediated through *infrastructures of visibility* (substantiated in 1.2. Locating the Cosmos in the World (and Vice Versa)). These infrastructures are evidenced by the flaws in the image, and are in turn evidence of the Earth and of the human limitations which render this view out of reach. They highlight the paradoxical nature of a 'cosmic perspective', at once situated (by virtue of being a perspective) and unsituated (by virtue of being cosmic).

To frame this in terms of our revolution, we find that my revolutionary astronomers are faced here with the same problem as many who seek to destroy the old and undesirable world in order to establish the new (Groys 1992: 3-4). What are the grounds on which we could even produce such newness? How can we possibly hope to produce perfection from the materials and practices at hand in the old, imperfect world? What a cosmic perspective demands is practice without practitioners, vision without observer, knowledge without knower, and access without mediation, for all of the latter pollute their transcendent project with their intrusive provinciality. In this dissertation, I would like to explore how, in their practices, astronomers seek to undertake their revolutionary work by effacing these situated and provincial concepts from it, and how these efforts ultimately fail.

What has emerged from this project is the deeply social and human nature of this world. In their work, and particularly within the bounds of the city, astronomers endlessly seek to negate the human influences on their work. However, in this process, they find themselves endlessly entangled in the trappings of life down here, and that it intrudes upon their images and practices in ways that can be mitigated but never truly erased, forever marked by the trace of the human. I assert here that as much as astronomers seek to disentangle themselves from the social world in pursuit of the objective,

disenchanted world, the cosmos is, as my colleague Dan Artus once put it, “always already and never not social”—that it has only ever been “blinkered from our view by the myth of modernity” (Farman 2012: 1084).

Failure is nothing new to science. Quite the contrary, it is essential to its function. It seeks out failure, straining the limits of its models and the assumptions they are based upon so that they can be reworked to better align with the cosmos. The impossibility of objective images, I claim, disrupts this function: it is absolute failure, failure with no possibility of reconciliation because the fundamental gesture of getting away from the human world emerges as a fiction through the image. As such, I claim that there is more at stake here than a few pretty pictures. The impossibility of the perfect image is an epistemological problem with far-reaching cosmopolitical repercussions. It exists, as I shall explore, within a context of systematised doubt that science and the knowledge it produces can allow humans to effectively and meaningfully manage the world around them, and a sense in which much of modern life adjacent to astronomy no longer functions. As I shall discuss, I believe that this absolute failure, framed in anthropological understandings of the world as something that is practised into being, constitutes an apocalyptic challenge to the modern world.

One of the critical features of failure, as discussed by Timothy Carroll, Aaron Parkhurst and David Jeevendrampillai in their work *The Material Culture of Failure* (2017: 14) is that it is never final, but rather productive of new social forms in all instances. Failure raises questions about the understandings and systems that failed: about how they came to fail, and how these failures can be addressed and those systems reconfigured. In this way, science as described above operationalises failure to produce innovative models that are more true to the nature of the world. It is clear in astronomy that this generative process is underway, evidenced by astronomer’s persistence in the face of apparent futility. Objective images cannot emerge from their efforts, which renders the question of what it is that these practices offer my informants—what is it that these practices and images *do* if they cannot provide a cosmic perspective? By situating astronomy within its social and worldly context here, I

claim that what contemporary astronomy and its failure offers its practitioners is a therapeutic allegory for making sense of a broader pessimism and anxiety about contemporary life: that it is a practice which raises and identifies the tensions that define their modern world. Astronomical work stands metonymically for the work of moderns to visualise, know, and manage the cosmos, and in its failure, we can also see the failure of that project in all of its other manifestations. As I shall discuss, astronomy offers moments when these anxieties, such as those about ecology, labour, and truth, are thrown into sharp relief, and can be made sense of as symptoms of the same systemic dysfunction that render their images impossible. This systematic dysfunction is cosmopolitical in nature, based on the conceit that through the application of reason and technical interventions, humans can manage the cosmos into view, and the social world into a utopia. While astronomy settles nothing, and rather its failure unsettles that which was once solid and immovable—the scientific cosmos—it offers an opportunity to locate and work on the unsettling conditions of the world after modernity—the conditions that contextualise my informants' work. What is at stake in the image, and negotiated in its production, is our cosmopolitics: the relations of power between humans and the human world—'human' in its most expansive, totalising, modern sense—and the natural world that contains them. As I shall explore in this thesis, astronomy draws its participants' attention to sites of conflict between the human and nonhuman world—in the moral urban landscapes of light, in questions of ecology, and in the tacit discipline that goes into making the cosmos legible, to name a few—so that they might identify and reconsider what is so unsettling about the cosmopolitics of now. This project is therefore an account of an emergent and organic practice of working out the stature of the human in the world through the microcosm of astronomer's efforts to bring it into view, and how the future might be reconfigured in light of their inevitable failure.

Much of this dissertation will go into unpacking the final image I presented here, and the claim that it can serve as a model for the failure of astronomy, and be used to approach this negotiation. It will consist of three movements over five sections. These three movements, orienting themselves around the failure of the image and the modern, technoscientific world, follow the structure of failure laid out by Roy Wagner in *The*

Invention of Culture and later taken up by Carroll, Jeevendrampillai and Parkhurst in the aforementioned *Material Culture of Failure* (2017). Here, failure is proposed to follow a tripartite structure:

$$Culture \rightarrow Failure \rightarrow Invention$$

While Carroll, Jeevendrampillai and Parkhurst emphasise that Wagner's structure deviates from the classical Hegelian dialectic, it nonetheless closely resembles that classical progression of thesis-antithesis-synthesis. That is to say that these structures posit an initial concept (*thesis*, or *culture* in Wagner's formation), which is disrupted by an inadequacy or counterfactual (*antithesis*, or *failure*), and the resolution of this antagonism or tension between these two concepts with something new (*synthesis*, or, qua Wagner, *Invention*). As such, Carroll, Parkhurst and Jeevendrampillai emphasise that in order to chart any particular failure, such as, say, the failure of an image, it is reasonable to explore it through this structure. The three movements that constitute the following work therefore correspond to these different parts of the process of failure and invention.

As such, my first movement is a description of the positive statement made about the world by scientists: that idealised form which the astronomer seeks to capture, but which is untenable and will inevitably fail. It is the perfection that they work tirelessly to bring into being, but will always remain elusive. In this case, this perfection is the representation of the world, which is our means of accessing and therefore producing the scientific cosmos. I have therefore opted to name this section *Cosmos*, for what is described here is the understanding of the cosmos that astronomers hold in their mind, which astronomy promises to materialise. What is described here are the conditions for the success of the image. This section will be dedicated in part to understanding this cosmos as a historical phenomenon which emerged from a particular kind of origin myth (namely the Copernican Revolution) which still defines the terms of knowledge to this day. One fundamental aspect of this cosmos, I claim, is that it is inhuman: that the human subject and human interpretation are so ontologically and epistemologically

opposed to the objective of knowing the world that our interference in knowledge-making practices is treated as a pollutant, to be erased from the work of representation. As I shall describe in the terms of ascetic traditions, the fate of the image rests upon our capacity to plausibly detach it from the provincial human conditions of its making so that it can more appropriately synthesise a cosmic perspective—to signify the transcendent, the universal, and the absolute.

As this project dwells on failure, and in particular the failure of the image and the cosmo-epistemological movement it stands for, it will be the second movement which forms the core of this project by describing the precise nature of this failure. It is here that I intend to explore fully the practice of astronomy as the site at which the abstract concept of cosmos I described in the first movement is actualised in practice: where astronomers make contact with the world. This movement is made up of three chapters, each of which describes one part of the process of astronomy, and altogether is intended to take the reader chronologically through the work that precedes and succeeds the photon-event—that moment when the photon makes contact with the instrument that registers and collects its visual payload, be that the retina of the eye or the camera's sensor. These sections are about place (finding a site that is appropriate to do astronomy), practice (the deployment of the body and technologies such as the telescope in producing the image) and the image (describing the processing that takes place after the data is collected). In each of these sections I endeavour to 1) describe these localisations of cosmic work, 2) describe how the work of astronomers seeks to abstract the cosmos from these local conditions so that they can plausibly transcend earthly, human, subjective knowledge, and 3) describe the particular ways in which these various projects fail in that effort. In these sections I also discuss the work that goes into the cultivation of an ethos of work: into cultivating the judgement required to take up the cosmic perspective, and how these capacities and experiences are shared amongst the astronomical community.

In their analysis of failure, Carroll, Parkhurst and Jeevendrampillai lay out a critical distinction between "material failure" and "the materiality of failure". While they

insist that material is always “inherently social”, materiality is the “social impact of the ‘material’ “ (2017: 5). The distinction between the two, therefore, is a matter of scale: while material failure is a singular instance of materials misbehaving, a materiality of failure describes the social repercussions of these instances, “as failures on one scale ricochet ‘up’, as it were, into larger social spheres” (6). While the second movement seeks to explore the material failure of the astronomical image, the third and final part of this work is dedicated to exploring the materiality of this failure: how it is experienced and internalised on the ground, and how it fits into a broader apocalyptic context. I argue here that the material failure of the image is an epistemological failure with far-reaching cosmopolitical materialities. In the same way that, as Dimitris Dalakoglou claims in the forward of *The Material Culture of Failure*, the failing infrastructures of Soviet Albania in the 1980s evidenced and stood metonymically for a failing economic and political system, so too does the imperfect cosmic image stand for “an ever-present reality of a world that is breaking” (2017: xiv). If astronomy is to be made sense of as a revolutionary and therefore cosmogonic practice—one which seeks to participate in bringing the modern world into being—then its failure stands metonymically for the failure of such a world to emerge. Here, I make sense of this stalling of the future in terms of an apocalypse, and, through a discussion of the contextualising anxieties of work and ecology in the modern world, seek to chart the materialities of uncertainty, dysfunction, pessimism, and futility which gives rise to such a mood. In doing so, following my statement above, I argue here that what astronomy produces, in the absence of any possibility of objective visualisation, is communities directed towards addressing this failure, reconfiguring our relationship with the world in its context, and muddling through the wreckage of modernity together.

Before I do so, however, I begin by laying the groundwork of discussing how I went about conceptualising this work. By placing amateur astronomy, anthropology, and cosmology within the context of one another, I go about triangulating this work in a way that can serve as the basis for the core of this text, thereby justifying my methodological choices. Here, as a preamble, I seek to establish this work as one that both recontextualises the astronomer’s cosmos in anthropological terms and describes this

process as something already underway in astronomy communities. I also justify my focus on both the image, as a point of contact between the lifeworlds of people and the universe to which they seek access, and on amateur astronomers, exploring their particular position and role in the broader context of scientific cosmology.

1.1. Locating Astronomy in Anthropology (and Vice Versa)

> "As the sun goes down every evening, a whole new world opens up. One by one, hundreds of tiny pinpricks of light appear. Tonight, we're going to show you how to journey into that world, and how even a complete beginner can begin to learn the wonders of the sky" (*The Sky At Night*, 2020)

This project is not about images. This is not to say that images are unimportant to this project. On the contrary, the image is the critical site at which the true object of this project materialises and can be observed both by my informants and myself. In this sense, I will follow my informants' treatment of the image here in seeing it as a means to an end, an interstitial artefact. Like religious Christian relics (Buchli 2016) and scientific models (Myers 2015), they offer a momentary and imperfect glimpse into the inner workings of the universe, which presents the transcendent, the absolute, and the divine—something to be looked *through* rather than *at.* The true object of both my and my informants' work, that thing that can be seen through the image, or to which the image points, is the cosmos. Though we both pursue an understanding of cosmology, I suspect our understandings of that crucial word are quite different yet overlapping, in ways that I will expand upon here. It is this overlapping, contested term 'cosmology'—the way in which it takes on subtly different meanings to physicists and anthropologists—which served as the original impetus for this work. The overriding task I set myself when I began this project was to turn anthropological understandings of cosmology back on the Western intellectual tradition that produced it: to think about scientific, astronomical, western cosmology—the world that "opens up" in the statement above—in the same terms that we might treat any other indigenous cosmology.

It is on these grounds that I felt that the statement above sheds critical light on astronomy as a cosmological practice that can be understood anthropologically. By early 2020, when these lines opened that year's first episode of the long-running BBC programme *The Sky at Night*, I was just over one year into this project. At the time I remember thinking that these lines captured, perhaps inadvertently, the essence of astronomy as I had come to understand it. In the common understanding of the astronomer's cosmos, the reality of the world is something that has always been there, lingering just beyond our view, ready to be discovered by techniques and technologies that can pierce these "extremes of vision" (Hoeppe 2012). This is what it means for this world to be 'objective'. In this context, the idea that the technoscientific cosmos is a "new world" that is "opened up" by astronomy makes no sense. This world is not new, it is simply new *to us*. Further, we know that these are not "tiny pinpricks of light," but the colossal structures of fusing hydrogen and helium we call stars. No doubt, these lines are an example of those poetic flourishes so common to popular science, a couching of scientific work in the wording of myth that is clearly intended more to accentuate the wonder of the cosmos rather than relay facts about its nature (Schrempp 2012). They rather recite an account of the phenomenological experience of being an astronomer, on the ground, having this cosmos unveiled to them.

In thinking through the astronomer's world anthropologically—in thinking about it as a subject of human engagement rather than a transcendental object 'out there'—I seek to take this statement, and its tacit recentering of the human and its experiences in discussions of the astronomers' cosmos, seriously. What is the nature of this world that astronomers access in their work? How is it different from the daytime world, insofar as we might call it new? By what processes and practices do astronomers go about journeying into it? And, crucially, what does this movement upwards, away from the Earth, mean for those pilgrims who participate in it?

Before stepping into my analysis, therefore, I would like to lay out the grounds for discussing astronomy, beginning with this troubled term 'cosmology,' and distinguishing between anthropological understandings of the term and that of

astronomers and physicists—whom Allen Abramson and Martin Holbraad refer to as “cosmologists proper” (2014: 3). In doing so, I would like to make clear what it means to reconsider the scientific cosmos in this way, namely, to perform the provocative move of re-centring the human in a cosmos that, as I shall explore, seems deeply allergic to anthropocentrism. It is on these grounds that I ask the equally provocative question of what it means to be human in such a disenchanted world: I claim that despite the supposed erasure of the human, its re-emergence in the statement above gives us a glimpse into the way in which astronomer’s work is moral work, with moral and cosmopolitical repercussions for the lives and worlds of modern scientific natives.

The astronomers’ cosmos—the cosmos of stars and galaxies and nebulae, of dark matter and cosmic rays—is my native cosmos. As a child, I was introduced to the technoscientific cosmos early. For a period in my childhood, my father would take me to public stargazing events every Wednesday at the observatory on the outskirts of the city in which we lived. There, we would attend lectures on astrophysics given by fellows at the local university, then head out to the grounds to get a tour around the sky. Wielding a powerful laser pointer, one of the astronomers would outline constellations and linger on points of light, describing a blend of their social history and material nature. Anticipating my discussion of the social role of images here, my father’s objective was clear: like so many other parents I have engaged with, he brought me to these events to cultivate me into the kind of person for whom scientific thought is second nature, in whom the scientific skyscape and universe was naturalised, and to whom the nature of the cosmos and the place of humans within it was obvious.

As a result, for much of my life (and indeed the lives of many science enthusiasts) the term ‘cosmology’ has specifically been used to describe a subdiscipline of physics which concerns itself with the study of of the physical processes of the universe, its origins, history, substances, and structures, how they behave, the universal laws such as gravitation and thermodynamics that govern them, and the particular

epistemic framework through which these things can come to be known[2]. While I will discuss the nature of the scientific cosmos more thoroughly in the next section, it is worth briefly outlining some of its features in order to contrast it with its anthropological counterpart. For scientific natives, the astronomers' cosmos is naturalised *sine qua non*. It is that which contains the natural world—it *is* the natural world. To be naturalised is to be shielded and exempted from questions of the social conditions of its coming to be, to be placed in a separate ontological category from the social world. John Law describes the scientific, and particularly "European" universe as a "one-world world," which exists externally to the social practices conducted in it: "In a European way of thinking the world carries on by itself. People do not *perform* it. It is *outside* us and we are *contained* within it" (2015: 126). While natural phenomena are often contextualised by the stories of their discovery, these are largely framed as revelations, and only as constructions of particular social conditions when they are rendered obsolete and our errors of judgement need explaining. As Latour notes, "Error, beliefs, could be explained socially, but truth remained self-explanatory" (1993: 92). As such, this cosmos is one in which the social and the human are largely absent, erased from, or secondary to, accounts of the universe.

Anthropological cosmology, on the other hand, reorients these discussions to the social. It deals with distinct understandings of the world espoused by different people in different times and/or places and thereby treats the world as a social object and work of human artifice. We might hear accounts of the world according to Lele or Neur or Yanomami peoples (Douglas 2010; Evans-Pritchard 1940; Kopenawa & Albert 2013), all of which will differ radically from scientific descriptions of the world, and indeed each other. In Abramson and Holbraad's words, "cosmologies were thought to provide the overall coordinates within which the people anthropologists studied conceived of themselves and their social practices" (2014: 5). While the universe presented by

[2] I will here be making many claims about the nature of the technoscientific cosmos. This is intended as a brief sketch of scientific cosmological orthodoxy, reciting the kind of understanding exhibited by and informing the work of astronomers, and therefore presents this cosmos as a singular and monolithic entity. While this orthodoxy and singularity of vision is critical to the functioning of scientific authority, it is important to note that it has been challenged elsewhere (eg. Law 2015).

science is considered to be universal, singular, and definitive, contemporary anthropological discussions work to make sense of 'world' as one account amongst many (Abramson & Holbraad 2014: 7).

This account of the world as a work of social artifice in which the human is re-centred can be found throughout western and particularly continental philosophical traditions. In *Being and Time*, Martin Heidegger rejects any concept of the world that exists prior to the beings that dwell in it, and asserts a complex symbiotic relationship between the kind of being he calls *Dasein* (meaning *There-being*, suggesting a necessary situatedness) and the world, into which they are both 'thrown' and which they produce through their dwelling (A function that Heidegger calls "world-forming" (1998: 123)). Similarly, Jaques Derrida forwards an understanding of 'world' that is radically limited to each individual: that understandings of the world are so formulated by experiences and particular cultivated interpretive frames that we can never truly access or understand the worlds of others. The fiction of a shared world is, for Derrida, established and enforced by "stabilising apparatuses" (Oliver 2015: 180) such as language and tradition. Derrida emphasises that all such supposed unified worlds, the world of the astronomer included, are always a fictional construction that is stabilised in such a way. As Kelly Oliver puts it, "As we have learned from Derrida, perhaps above all others, the very appeal to nature and what is given in nature is a construct that can be deconstructed" (2015: 181).

I will return to both of these thinkers in time, but to underline this anthropological understanding of the cosmos and the central role played by humans in its coming to be, I find it useful to place it within the context of the psychoanalytic framework of Jaques Lacan, and in particular his discussion of subject formation and the "mirror stage". In this discussion, Lacan follows a philosophical trend that rejects any idea of an essential and in-built identity which is present prior or external to the world, a claim which "sets us at odds with any philosophy directly stemming from the Cogito" (Lacan 1949: 94). Rather, Lacan asserts that the newborn is faced with a set of disparate and discordant phenomena which it lacks the faculties to make ordered and coherent. During the

“mirror stage”, in which the child learns to recognize themselves in the mirror—an act of “identification” in Lacan’s terms (*Ibid*. 95)—the infant learns to identify with themselves as a unified entity oriented around a singular image. Through this act of auto-subjectivization, they make themselves the nexus of these abstract signifiers, linking them to other signifiers through their experience of them, constructing a web that makes these phenomena intelligible. This web, the sinews of experience, is how I make sense of the anthropological understanding of ‘world’, as a socially constructed entity that brings the chaotic and disparate things with which we are faced into relationships with one another and ourselves.

Anthropological ‘world’, therefore, is *perspectival*; it is an understanding of the world that is contingent upon the work and point of view of subjects that render it visible, or even construct it. As such, anthropological accounts of the cosmos place humans front and centre, as those who dwell in the world and bring it into being. The scientific cosmos simply exists, while the anthropological *world* is practised into being (Law 2015). The distinction between the astronomer’s world and anthropological cosmology, therefore, is one between the emic and the etic: the former is an account of the way the world is, while the latter endeavours to make sense of the way in which people construct and understand their world. As a young anthropologist, this rendered the relationship between the two obvious: for me, it is the task of anthropological cosmologists to make sense of precisely the kind of claims made by these cosmologists ‘proper’, and explore the practices that go into producing and reproducing this world. This understanding of the world as a matter of perspective grounds my discussion of astronomy and techno-scientific cosmology being oriented around the cultivation of a cosmological perspective: by exploring how such a perspective is cultivated, we can speak of how this cosmos is practised into being, and therefore place it on an anthropological footing.

Placing the astronomer’s world on such a footing participates in a tradition in the social sciences of seeking out what Bruno Latour calls “symmetrical” anthropology (1993). The tendency of scientific practice, given the description of its cosmos described

above, is to treat the cosmos revealed to us by Western astronomers as the definitive and essential nature of things which all other cosmological efforts are limited and mistaken attempts to access. This trend can be seen in Abramson and Holbraad's critique of classical anthropological discussions of cosmology, which they claim was "an exercise in cosmology through and through" (2014: 3). They claim that these projects were efforts to collect local accounts of the world and incorporate them into a world, the anthropologist's world, which contains and transcends them, another one-world world. They describe this cosmos as having a "topology of reflexive ethnocentrism" for its tendency to incorporate indigenous cosmologies into it as limited attempts to access the world we *know* to be true. It is reflexive because it "contains *within* itself multiple perspectives *on* itself," (*Ibid.* 4) and it is ethnocentric because all of these perspectives are partial accounts of the 'real' world to which only the anthropologist is privy. Supposedly, all astronomical traditions, of which there are many (Ruggles 2009) attempt to reach the same truth of the cosmos, the 'natural' world, but it is Western astronomy, unique in its superior techniques and technologies, that has attained the true vision after which all of these projects strive. This is also what Latour calls "particular universalism" where "one of the cultures has a privileged access to nature which sets it apart from all the others" (1993: 105).

Such a world is therefore fundamentally hierarchical. "If what holds the basic image together is the idea of a single and uniform world that acts as both ground and object for the diverse perspectives different societies may take within and upon it, it follows that such perspectives can be ranked in relation to how far they partake in this *a priori* grounding and truly apprehend the world *as it is*" (Abramson & Holbraad 2014: 6). Anthropologists, in this understanding, not only wield the power to determine what counts as cosmology, but also how far its representations can be treated as 'successful'—how well it manages to adhere to the abstract conceptions presented to us by science. It is for this reason that they identify in contemporary anthropology a kind of "cosmo-weiriness," as the concept falls further out of favour (2014: 2).

Latour's call for a symmetrical anthropology argues to breaking such a hierarchy, through recognizing and overcoming the asymmetries that exist between indigenous cosmologies and that of the scientific world which is so often venerated over them. Latour calls for a "great repatriation" (1993: 100) of anthropologists to assess this world in the way that he did in his classic ethnography of scientific work with Steve Woolgar *Laboratory Life* (1986). In her analysis of astronomical work, Rosalie Allain identifies these practices as a critical site at which this great repatriation can take place by speaking to the heart of the scientific world rather than lingering on its margins (2013).

This makes the effort to treat the astronomers' world as an indigenous cosmology—to think about it anthropologically— something of a provocation. It is to put it in the social terms it actively seeks to efface, against which its legitimacy is grounded. The asymmetry of cosmoses has shielded the category of nature from scrutiny as to the social conditions for its coming to be. As Allain notes, "the sociology of scientific knowledge approach is analogous to methodological atheism in the study of religion and methodological philistinism for art" (2013: 14). It is, as a correlate of the anthropologist's call to 'take the other seriously', an effort to take the master-cosmos of scientific work *less seriously*, as it were, by unseating it from its lofty and privileged position, so that its social dimensions can be better examined. This work is by no means new: the sociology of science has been exploring the norms and communities at work within scientific practice since at least the 1940s with the work of Robert Merton (Godfrey-Smith 2003: 122). This project is aimed in its own small and specific way to contribute to this long line of questioning. Notably, this is not a work of scientific anti-realism: I do not claim whether or not science truly grasps some underlying fact of the matter of the world. I only claim that the world of science is possible only within a particular socially constrained horizon of meaning—within what Michel Foucault would call an *episteme* (2001)—outside of which science wishes to place itself. I claim, as all social scientists would, that science and its world cannot fully be made sense of outside of this social setting. It is this social context that I seek to examine here.

To do this is to take claims to universality and totality and inquire as to its locality and its contingencies: in what practices and under what conditions are they produced. Most particularly, this is not a work of critique levelled by myself against scientific accounts of the world, but rather an account of the way in which this challenge to the hegemony of the scientific world is countenanced by astronomers themselves in their work through the way in which it makes apparent and insists upon the social dimensions of nature. In this sense, there is a parallel between my work and that of my collaborators. It is an account of astronomers 'discovering' anthropology in astronomy, in the sense that the failure of the image is a failure to uproot the image from its earthly and human contingencies, and here we are both placed in the position of trying to come to terms with (and take account of) the intractable humanity of scientific accounts of the cosmos. As such, this project is an account of the indigenous practices of astronomers and how they deal with the implications of that practice on the ground. Here, I shall discuss how this "rooting" of the cosmos on the Earth and in human matters takes place, and ask, with my collaborators, *what it is that the scientific cosmos actually has to say about the human*.

1.2. Locating Cosmos in the World

In his study of Cuban Ifá practices, Martin Holbraad took truth to be his ethnographic object (2012). In doing so, he immediately notes the difficulty of getting at and localising such an abstract and diffuse concept, noting that, given the fact that "all claims are truth claims," truth itself is "latent everywhere by implication" (*Ibid.* 1). This simultaneous partiality and totality leads Holbraad to his study of Ifá divinationary practices. As he notes, "Unlike politics, love, and what-have-you, divinationary practices provide a firm ethnographic handle onto truth since in them truth, and people's concern for it, features not as an implied corollary but as an explicit and overriding objective" (*Ibid*: 2).

In my pursuit of cosmology, I found myself faced with a similar issue of expansiveness. In the same way that all claims are truth claims, all claims are, in one way or another, claims about the state of the world. The concept of cosmos pertains to

the Earthly everyday as well as the extra-terrestrial, permeating our everyday world in the natural phenomena we see around us and the technologies we build upon our understanding of them (Czerski 2017). Not only does the scientific cosmos pervade all things definitionally, but it is also obscured by the taken-for-granted assumptions of the everyday, pertaining to layers of reality that do not include us (Scharf 2014; see also Morton 2013), and therefore requiring practices that reveal it to us. Edmund Husserl makes this point by, like the narrator of *The Sky at Night*, reorienting our view to one that is phenomenological, and asserting that the Universe with which we are dealing is not one that is often experienced: "overthrow the Copernican theory in usual interpretation of a world view. The original arc, Earth, does not move" (Himanka 2005: 621). As I shall explore in the next chapter, this call to refute the Copernican move is deeply heretical within the context of the scientific cosmos, yet his point is one of the ways in which the world is experienced. Here, the concept of 'lifeworld' might help us, in that it refers to the phenomenological and experiential aspect of the world, the "environment (material, social, and intangible) where people live as social agents" (Iwaniszewski 2015: 6), and can be contrasted with the underlying nature of the cosmos astronomers seek to reveal.

The fact that the cosmos needs revealing through specific and directed astronomical efforts suggests that, as Don Ihde reiterates, the cosmos of science exists externally to the lifeworlds of people on the ground (2010). Anthony Aveni attests to this vast gulf between moderns and the sky (2008). He argues that we have produced technologies, from calendars to electric bulbs, that have systematically led to a "detachment" from the natural world and the night sky (*Ibid.* 8). "Mindless of the solar course, we look at our watches to tell the time and set our appointments electronically by desktop or pocket calendar" (*Ibid.* 7). Notably, he points at science as a reorientation of our relationship with the world, claiming that humans turned the cosmos into a mathematical abstraction, imagining that it could be "an entity to be described and understood 'as it is' and 'for itself' " (*Ibid.* 8). Don Ihde claims that Husserl's fundamental point is the same: "Husserl's crisis argues that modern science, exemplified by Galileo, separates the lifeworld from the world of science by forgetting its origins in bodily

perception on the one side, and the practices which found the science on the other" (2010). The way in which everyday life is a clear and distinct realm from the cosmic world is, I claim, fundamental to the appeal of astronomy, which promises the opportunity to forsake the former in pursuit of the latter.

Just like the Ifa divination ritual, these sites of revelation and the images produced there, where the astronomer's world is brought into our lifeworld and supplants it, offer a firm ethnographic handle on the cosmos. In Ihde's words, "Husserl's Galileo needed a telescope" (2010). In reorienting our view back to these neglected practices, we find the opportunity to make better sense of astronomy and the images it produces as techniques and technologies of mediation that seek to bridge the gulf between lifeworld and cosmos, and bring the latter, albeit momentarily, into the former. In making sense of astronomy as works of meditation and visualisation, we can locate and localise the cosmos in the management of electromagnetic radiation, and particularly astronomer's material engagement with the streams of photons that arrive at Earth from outer space.

In framing my informant's practices as such, I follow the work of Rosalie Allain (2013) and Götz Hoeppe (2018). Both have produced work based on ethnography conducted with professional astronomers, and attend to their practices in the same way that I hope to for their amateur counterparts. In Hoeppe's discussion of astronomy, he emphasises images and the sky as an *infrastructure* which affords astronomers access to the cosmos. Infrastructures and infrastructural thinking have been prominently discussed in anthropology as technologies that afford access to and interrelation between things. While roads, bridges, and internet cables are the most intuitive examples of infrastructure, this logic also expands to other forms of connectivity, including, and most notably for our purposes, knowledge infrastructures deployed by scientific work in accessing otherwise obscured phenomena. Hoeppe describes such infrastructures as "human-made networks or ecologies of people, artefacts and institutions that enable the production, calibration, storage, dissemination and re-use of data" (2018: 25). Drawing upon existing works on infrastructure, Hoeppe notes that

organisms and natural phenomena can be appropriated into infrastructures, giving the example of fruit flies being used as “markers” for air pollution, a phenomenon which is often difficult to get at (*Ibid.* 27). In his analysis, he claims that the sky can be understood as a resource that astronomers use to calibrate their machines, repair their data, and manage their infrastructures. In particular, following the philosopher Sybille Krämer, Hoeppe distinguishes representation from mediation: while representations and signs stand in for the object *in absentia*, media seek to afford access to the object directly, and also draws attention to the materiality of the medium through which the object is accessed (*Ibid.* 32). As such, Hoppe makes sense of images as a “mediated environment” or “mediated object” (*Ibid.* 26). He notes that the professional astronomers with whom he worked are “usually removed from the phenomenal night sky, and rarely look at it directly” (*Ibid.* 31). A critical feature of the astronomical image as I have come to understand it is that it plausibly affords and sustains contact with those objects through traces of photons which are captured and transformed within the telescope and the camera. As we shall see, the standards for the success or failure of the image can be said to rest upon this notion that astronomy is a work of direct mediation rather than representation.

While amateur astronomers do engage with the phenomenal night sky, their work is no less a matter of managing infrastructures between themselves and the cosmos. Human sense organs are insufficient alone to render the content of the sky visible. To access the very distant and, indeed, the very small, Robert Hooke noted in his work *Micrographia* that we must use sensory prostheses and “artificial organs”, and “supplying their infirmities with instruments” (1665). To access the radiation that is otherwise beyond our range of view, and thereby render it useful as an infrastructure, we must supplement our wetware with hardware: telescopes are substituted for eyes, cameras for retinas, and SD cards for memory, all of which serve as parts of a infrastructure which mediates the distant and the inaccessible into view.

Turning to Rosalie Allain’s analysis of astronomy, we can identify the material nature of these infrastructures. When working with professional astronomers at Imperial

College London, Rosalie Allain describes her work as “a visual culture of astronomy via the material culture of light” (2013: 7). Light and photons, she emphasises, sit at the crucial point between image and referent. “The large ‘black hole’ so to speak, between referent and sign, star and image, is shown on closer inspection to be filled with photons” (*Ibid*. 17). She identifies the “photon-event”—the moment when the photon makes contact with and is collected by the detector surface within the camera—as the critical point of consideration, “where/when matter is transformed” (*Ibid.* 30). She describes the process that is undertaken by astronomers after this event as a series of transformational steps: “from photons to data,” “from data to images,” and “from light to sight”. Allain’s work crucially emphasises these steps as a process of mediation and intervention, where “the end product of reference [...] cannot be separated from its formation—its technical coming into being—via techniques that *transform* matter into form, stars into images” (*Ibid.* 18). To properly explore the image, we must attend to the steps which were taken in order to transform the raw photons that are the matter of astronomer’s work into the image.

Understanding astronomy as infrastructural work and skies as mediated environments can help us by not only locating the site at which the cosmos is at stake and making the work that goes into making it available, but also in properly contextualising Western, scientific astronomy as one amongst many astronomical traditions. There are a multiplicity of skies observed by different people across the world and described by ethno- and archaeo-astronomers. One striking example is the “Celestial Emu” in the skies of aboriginal groups in Australia, which is constituted not by a series of lights in the sky but a patch of dark produced by cosmological dust clouds (Leaman 2010: 387). This feature is the product not only of a different set of instruments, but a different *way of looking*. These different skies are the products of different infrastructures that are as much conceptual and practical as they are technological. The archaeoastronomer Fabio Silva captures this mediated contingency in the concept of the “skyscape” (2015). Drawing on the similar concept of the landscape in archaeology, Silva emphasises that the skyscape is crafted by human agency from the raw material of the sky, and is thus marked by cultural work. This

cultural work is the work of mediating infrastructures. As he claims, “different cultures might have “access” to the same sky but “see” completely different skyscapes”. To make sense of the way in which the astronomer’s cosmos is made visible and therefore comes to be, we must therefore pay close attention to these infrastructures.

By understanding astronomy in terms of infrastructures, therefore, we can locate astronomical work in the material practices that go into appropriating and managing flows of electromagnetic radiation—of photons, to give it a particular material solidity—and ultimately into the way in which the cosmos is made immanent. While Allain’s work focuses on the aftermath of the photon event, particularly the processing which turns data into meaningful images, she also emphasises the “pre-history” of the photon event, which involves the launching of satellites, the booking of time on telescopes, and the journey taken by the photon from phenomenon to instrument. This affords us an understanding of the photon event as something that is distributed in time. I would like, in my study of the imperfect image, to attend most particularly to this pre-history of establishing and managing infrastructures of which these images are the overriding product, in order to explore the precise material engagements that make these flows of photons not only amenable to vision, but legitimate for the kind of vision that constitutes a cosmic perspective.

To understand the failure of this process, we might emphasise how these infrastructures are expected to operate. Within a project such as science, which seeks to attain an objective view of the cosmos *in itself*, these mediating processes must intervene only insofar as they can render the object visible, and not themselves encroach upon that view. This is a form of objectivism which Lorraine Daston and Peter Galison refer to as “noninterventionist” objectivity (1992: 82). In short, these infrastructures and our management of them must remain “transparent” (Hoeppe 2018: 32) so that the content of the cosmos can be made available but remain unchanged by the process by which it is accessed. This emphasis on the transparency of media has emerged in my fieldwork, not only in the effort of astronomers to omit all disruptive noise that might emerge from the mediums in which they work and through which their

photons travel, but also in the desire to become an astronomer. The move from enthusiast to amateur is one from a person who consumes secondary media such as books, documentaries, and talks about cosmology, to one who sees it first-hand, where these mediations are plausibly eschewed. Astronomers come to astronomy from an enthusiasm for space and a desire to see it for themselves. As Hoeppe notes of his professional interlocutors, their work in observatories asserts "the reality of the cosmic objects they study" (2012: 1141). This troublesome bind of at once transforming data and insisting that it plausibly remains true to the mediated object that it represents is crucial to the failure of the image. It must appear to remain beyond human intervention while being possible only through human intervention and inevitably marked by it. In charting the materiality of these media here, I chart the way in which this tension is made present in the infrastructural work of astronomy.

Given the vast gulf between the lifeworld of people living 'down here' and the cosmos 'out there,' I also make sense of these infrastructures and the images they produce as *worlding* technologies. I here return to Martin Heidegger, whose concept of worlding emphasises the social dimensions of the world in their production of representations of reality (2010). As Mei Zhan notes, "Heidegger coined the term "worlding" in his thesis on phenomenology to signal that the world takes place in things—a critical enmeshment of things and world" (2009: 23). I argue that astronomy as an infrastructural practice—as one which evidences and affords contact with the otherwise abstract and transcendental 'true' nature of the world—is foundational to both producing the scientific cosmos as a coherent representation of things and making it socially efficacious. This is what it means for the image to be where the cosmos is 'at stake': observing the sky is the foundation for astronomical knowledge, and the practice with which my informants engage to make the world real to themselves. It is also in this sense that we may make sense of astronomy as a revolutionary practice, in the sense that its world-forming (cosmogonic) process is achieved through the systematic re-ordering of our episteme—of what 'counts' as legitimate knowledge of the world and what can be discarded. If we follow Maralyn Strathern's claim that images are "meanings made available, we might say, for consumption" (2022: 46), then we can

understand the social function of these images—the sharing of both them and the practices that produce them as a means of accessing the universe— as an effort to share ‘the world’, the astronomer’s world, with others, so that they may become fellow travellers in this cosmogonic effort.

1.3. Locating Astronomy in the World

The fieldwork I conducted for this study was originally imagined as a study of the scientific cosmos and astroculture. This remit, as one can imagine, is broad and ill-defined, requiring pinning down to a particular place, time, people and set of practices. With the definitionally expansive nature of the scientific cosmos, one could reasonably claim that any scientific work is a work of contact. What I needed was a nexus where the technoscientific cosmos was ‘at stake’, where it was grounded and engaged actively. It is with this in mind that I settled on amateur astronomers in London as my subjects.

I selected amateur astronomers with an eye to their particular position within the internal politics of science. The term ‘amateur’ often carries with it connotations of the unimpressive, the unspecialised, and the less skilled. For something to be called ‘amateurish’ is to deride its value and its craft. In the case of astronomy, I, amateurs, and all of the astronomy community I have engaged with, roundly reject this association. It is a craft into which people pour tens of thousands of hours and failed exposures, and produce exquisite renderings of the cosmos. Rather, the use of the term ‘amateur’ in the astronomical community is very specifically someone who does astronomy in a non-professional or unpaid capacity: who is not employed by a research institute, university, or observatory to conduct astronomical or cosmological research. Included in my informants are astronomy journalists, telescope salespeople, and science educators, all of whom possess an immense degree of practical and theoretical knowledge of their craft, and indeed the cosmos. These communities of amateurs often also include professionals seeking a community of like-minded practitioners.

Indeed, in amateur astronomers I have met, a strong and very particular self-image emerges, in which they position themselves in relation to their professional counterparts. While the scientist 'proper' is imagined as a university-educated expert, the amateur tends to style themselves as a more working-class, salt-of-the-earth and autodidactic virtuoso. While the professional exists within and navigates the structures of big institutions, amateur work is informal, stochastic and decentralised. While the professional does their stirling and well-respected work in their far-flung observatories and laboratories, the work of the amateur is in the world 'itself', amongst the public. They are the lay foot soldiers of science, bearing witness to the science on the ground amongst fellow travellers, out of a love for its practice and their awe for its world.

Notably, western astronomy began as an amateur practice. Given the great expense of early telescopes, the earliest astronomers such as Tycho Brahe, William Parsons, William Lassell and James Naysmith were all nobles or bourgeois entrepreneurs who spent their personal funds on the pursuit of better telescopes and the views of the cosmos they would afford, and would therefore be counted as amateurs (Williams 2000: 49-53). Allen Chapman notes that in the romantic age of science, professionals were treated as less reliable than amateurs, the latter not being subject to the interests of their employers (1998).

Since these times, science has undergone a centralisation and professionalisation. In astronomy, this began in Europe, where, as George Biddell Airy's 1832 report claimed:

> "science was becoming a centralised, directed activity, which demanded a ticket of entry for all those who aspired to be taken seriously - usually a PhD. - and which moved inexorably towards professionalisation" (Chapman 1998: 6)

What marked Britain out in this period of astronomy was the persistence of a libertarian and pro-amateur attitude towards scientific work, which led to a greater focus on measurements while continental astronomers produced a higher degree of theoretical work (*Ibid*. 3-4). Chapman attributes this divergence to the geopolitics of

post-Napoleonic Europe, where extensive warfare inspired the construction of centralised state science institutions, from which Britain was largely spared.

Since then, scientific centralisation has gone from strength to strength, as state and corporate funding has bolstered the material means to peer deeper into the fathoms of reality. Today, the forefront of science has largely become what has been called “Big sciences” (Ihde 2010: 69) As Don Ihde notes, “Late modern science, first with chemistry, then physics and engineering, but today the biological sciences as well has become a science of corporate groups; of large state funding; of complex technologies and instrumentation; and implied major social-political dimensions for its operations” (*Ibid.*).

As science becomes professionalised and centralised, it becomes more and more something that happens elsewhere, its laboratories and observatories sequestered from public view. The philosopher Robert P. Crease describes this growing distance by describing these obscured sites from which science emanates as “workshops” and contrasting them with the world more broadly (2019). In his discussion of prominent scientific thinkers from Sir Francis Bacon to Hannah Arendt, he charts the establishment of this conceptual space, the laying out of the rules for its function, and the ongoing management of the troubled borderlands between the workshop and the world at large. This exclusive nature of the workshop as the site of particular expertise is both fundamental to and troublesome for scientific authority. Crease’s original work on the workshop and its relationship with the world is expressly contextualised by “science denialism” which challenges the authority of the workshop from without. Science’s claim to legitimate knowledge rests at once on the work of skilled experts and on the capacity of members of the public to, in the terms Steven Shapin and Simon Shaffer attribute to Robert Boyle, “witness” the production of knowledge (1985: 25). As they recount Boyle’s position in his foundational work that established the grounds of scientific practice:

> “Matters of fact were the outcome of the process of having an empirical experience, warranting it to oneself, and assuring others that grounds for their belief were adequate. In that process a multiplication of the witnessing experience was fundamental. An experience, even of a rigidly controlled

> experimental performance, that one man alone witnessed was not adequate to make a matter of fact. If that experience could be extended to many, and in principle to all men, then the result could be constituted as a matter of fact." (*Ibid*.)

At the same time, science must defend its borders—the borders of the workshop—and exert a discipline upon what may and may not be counted as knowledge in order to remain legitimate. It must enact what Foucault calls a "regime of truth", which he describes as "the types of discourse which [the society] accepts and makes function as true; the mechanisms and instances which enable one to distinguish true from false statements; the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; the status of those who are charged with saying what counts as true" (Foucault, in Rabinow, 1984: 73).

It is because of this tension between interiority and exteriority with respect to the scientific workshop that the position of the amateur is of great interest to me. Amateur astronomers, in theory, reside somewhere in between the two. Many amateur astronomers I have interacted with engage fully with the products of the workshop in the form of academic papers on astronomy and astrophysics. Some participate in studies, whether they are sought out by professionals for their skills, or as volunteers in 'citizen science' projects. By far the most interesting and crucial aspect of their work, however, is their public-facing orientation, serving as a means for people outside of the workshop to interface with it. While institutions working on space projects have their own PR projects directed towards public engagement, and indeed some amateurs distribute images on behalf of these institutions, most amateurs represent a stochastic space enthusiasm that emerges from a compelling belief in science, the promises of outer space, and a desire to share that world with the public of which they are a part. This has led me to centre much of this fieldwork on public events, in which astronomers gather with their telescopes and invite the public to join them, to open up the workshop, and in doing so make good on the epistemologically democratic ideals of Boyle's witness. One of London's most prominent amateur astronomy societies has as its foremost goal to "share the outstanding natural beauty of the universe with London's population who

might otherwise be unaware of it." (BSIA[a] 2023). It is this sharing, I claim, that is the social function of the image, and the crucial function of the amateur image, which justifies its constant reproduction. The image need not be a perfect reproduction of the astronomical object, only plausibly *good enough* to participate in an objectivist aesthetic through which it can offer a cosmic perspective and share the technoscientific cosmos.

1.4. The Field

Given this context—that this project seeks to explore the Astronomer's cosmos through attending to the infrastructures and practices that orient themselves around the image to explore both their failure as an effort to represent the cosmos and their social function—I would like to outline my precise methodology here. The vast majority of astronomy has historically been and continues to be a largely solitary affair, performed alone in the dark spaces my informants find in London. However, with my focus on the social dimension of astronomy, I set out at the start of this project to find the places where astronomers come together to perform their work and share their images as a community: where astronomers came together to share my world. At the outset, I set myself the task of exploring two key overlapping areas of astronomical practice: the cultivation of faculties and aesthetic standards that go into becoming an astronomer, which I have followed Natasha Myers in calling an "ethos" of anthropological work, and the explicitly social dimensions of image production and circulation, in public meetings and the sharing of pictures of the night sky and its contents.

To explore the communities that surround amateur astronomy I began on social media. I joined public Facebook groups for astronomy from the UK and around the world. These would serve as both a rich fieldsite for exploring the kind of things that astronomers shared with one another, from images, to advice, to the way in which astronomers organised to stargaze in a more social capacity. These groups also afforded opportunities to find further non-virtual fieldsites.

While these online groups offered deep insights into what astronomers shared, as well as a useful forum for learning to do astronomy, I also sought out events where I could experience astronomy and astronomy communities in person. London is home to an abundance of amateur astronomy communities, all of whom organise regular meetings with various structures and orientations that were reminiscent of my early experiences with my father. For example, I attended an event at the Flamsteed Astronomy Society (FAS), hosted in the Greenwich Maritime Museum, within view of the historically significant Greenwich Observatory. While they run some observing nights, the FAS runs a broad range of talks and workshops about astronomy and Outer space. On my night at the FAS, for example, I was treated to a talk by a prominent global expert on the study of exoplanets.

In pursuit of a space that maximises my opportunity to explore the particular public-facing position of amateur astronomy, and engage with astronomical practice, I oriented the majority of this study around one particular group, the Baker Street Irregular Astronomers (BSIA). I was initially drawn to the group because of the way their name—a play on the “Baker Street Irregulars,” the informal network of informants that provided information to the fictional character Sherlock Holmes in the books by Arthur Conan Doyle—exuded and captured much of the playful and stochastic knowledge-brokering that amateur astronomy is about. They were also named for the fact that one of their founding members—themselves referred to as the “unofficial force,” another term for the Baker Street Irregulars—had, at the time of its establishment, run a telescope shop on Baker Street, which had since been priced-out of central London’s exorbitant rental market. When arrived, he had been making his way to central London once a month to run BISA events in Regent’s Park in the heart of the city. These events consisted of a core group of astronomers setting up their telescopes around a coffee shop called The Hub, which stayed open to accommodate them, and inviting members of the public to join them. Here, between 50 and 300 astronomers and enthusiastic members of the public gather once a month to meet, catch up, and catch a momentary glimpse of the universe.

I selected the BSIA meetings as my core site of study precisely because of their commitment to this public-facing aspect of astronomy. These events were attended by all kinds of people, from veteran amateur astronomers to professionals from London's universities, to On their website, they emphasise an idealistic set of aims to "bring astronomy to central London" and "to be free, for everyone, *forever,*" (BISA[a] 2023) asserting their focus on outreach to the general public and the night's sky as a commons to which all should have access. To quote their "about us" section:

> "We aren't going to let urban light pollution stop us from bringing astronomy to Central London, where millions of potential stargazers go about their lives unaware of the stunning natural beauty hanging above their heads, just beyond the sky." (BISA[2] 2023)

At these events, I found a community of enthusiastic astronomers who were deeply committed to these goals, expressed in their passion for sharing the cosmos with anyone interested in seeing it, and science for the sake of science. Once they had set up their telescopes, queues of attendees would appear behind them to get a glimpse of Jupiter or the Moon or some other celestial body, while the astronomers shared with them their knowledge about astronomy and cosmology. Astronomers would sometimes take it upon themselves to plan demonstrations or talks. I once saw John, who set me on this course of exploring the impossibility of the image, giving a crash course on astrophotography to a crowd of onlookers. Every night at the BISA felt like an optimistic celebration of the role of the witness in scientific work, as one is surrounded by an inviting community that gives the sense that the universe really is there for everyone and anyone who would care to look.

My time with the BISA was largely spent as one of these members of the public. There, I learned about the cosmos as my informants understand and share it, about the practices that they use to access it, and about the communities that gather around it. I spent as much time sitting in groups with a hot chocolate discussing astronomy and the social contexts that surround it, that will make up this study. It is here that I found a group of enthusiasts and friends that became the core of my ethnographic work. While

much of this work extends far beyond this group, these were the people who would consistently and reliably attend these events, with whom I discussed my work, and gathered reflections on an anthropologist's intuitions about astronomy. This included, notably, Kara, an outspoken and intelligent international student with little knowledge and a lot of curiosity about astronomy and the cosmos; Simon, a Chemistry teacher who, during this project, transitioned into working as a space engineer, with whom I shared a deep enthusiasm for Sci-fi and thinking about the kind of futures humans might build for themselves in space; Isaac, a successful artist and business owner, who, like me, had returned to cosmology as a subject that he had loved at school, but never seemed to get the hang of; and Samantha, an actress and science enthusiast who enjoyed the community of like-minded "space geeks" that these events attracted. In this sense, this thesis is a product of collaboration with these people who, in sharing a scientific syntax and interest with me, eagerly engaged with an anthropologist's impressions and questions about astronomical practice.

My in-person fieldsite extended beyond these events. The BISA would sometimes organise events outside of the remit of astronomy, when members would go to the pub or for a meal, offering me further opportunities to sit and chat with veteran astronomers and space enthusiasts. The smaller group of astronomers I had met also regularly organised outings to space exhibits or astrophotography galleries, and indeed to the pub, that staple of British social life.

While these events and the numerous sub-events that orbited around them afforded me insights into the social dimensions of astronomy and astroculture, they offered me little in terms of practical engagement with astronomy. I had decided early in this project that, in order to pursue an understanding of the more practical dimensions of astronomy, I wanted to take the process of becoming an astronomer as a key site of study, and thereby understand the work that goes into learning to see from a cosmological perspective. In exploring the practices that one has to develop to do astronomy, my intent was to attain a more firm ethnographic grasp on the standards for astronomical success and the means of getting there. I sought, in short, to explore what

Natasha Myers calls an “ethos” of astronomical work, which she describes, in the context of the protein crystallographers she worked with, as “the tangle of affects, values, attitudes, sentiments, styles and sensibilities that shape practice and laboratory culture” (2015: 41)

Initially, I planned to attend a course on astronomy in an attempt to both learn astronomy for myself and to find a cohort of aspiring stargazers with whom I could work. Finding the course I had initially intended to take discontinued, and looking around for alternatives, I learned from my early informants that this is a relatively uncommon way to learn. Rather, learning astronomy as an amateur, as one might expect, is often an informal process of drawing on resources from different parts of the community to put together a bricolage of knowledge about astronomical practice. Given this informal structure, and wanting my experience of astronomy to be as true to the experience of most astronomers as possible, I set myself the task of learning to do astronomy in precisely this way.

As such, and given the often antisocial nature of astronomical practice, this part of my work is largely auto-ethnographic: I took the process of my own body being made an instrument of astronomical work as itself an instrument of ethnographic work. I read books, consulted forums, asked collaborators and drew on resources suggested by them such as useful videos on the internet. Given the broad interest in outreach amongst the astronomy community, I found myself surrounded by thorough and robust knowledge infrastructures designed precisely for people like me. I acquired my own telescope approximately a year into this project and set out to experience the arduous work of urban astronomy for myself. This was supplemented by sharing these experiences with my collaborators, who were themselves learning the art of astronomy. What I have developed and written here is an understanding of astronomical practice gleaned from my own and my collaborator’s experiences in learning to see the universe.

All of these experiences were supplemented with interviews, which were conducted largely towards the latter end of this project, once I had attained a grasp on

how astronomy and its communities functioned. These served to correlate and contrast my experiences with those of other astronomers, ensuring my auto-ethnographic work reflected the broader astronomical community's engagement with their practices. These were also largely oriented around exploring the broader cultural context of astronomy, expanding upon themes that had emerged in my prior fieldwork at public events. I inquired about what inspired my collaborators to begin astronomy, how it fitted into their everyday lives, and the particular difficulties they faced in making room for their practices in a modern and particularly urban environment.

In total, this fieldwork was conducted over approximately three years between the beginning of 2019 and late 2021. During this time I engaged with three urban astronomy groups to varying extents, the most prominent being the BSIA, for the reasons described above. The BISA events ran once a month in one of London's central parks and each lasted for approximately 5 hours of stargazing and socialising. They were often supplemented with more irregular social events and an active social media community. I had two overriding goals when it came to these events. The first was to observe: to get a feel for how astronomy was conducted, how views of the cosmos were shared, and how the community was composed, enacted, and navigated by both regulars and members of the public. My second goal was to engage with that community with a view to finding potentially insightful interlocutors from whom I could learn the specifics of astronomical practice and explore the broader social context in which it exists. This involved becoming one of those 'regulars'. I attended almost every one of these events when they ran, and spoke both with astronomers and members of the public about their understanding of astronomy, their relationship with the community and the BSIA, and beyond, to make sense of the general shape of astroculture as it is practised on the ground.

Once I found a smaller friend group of regular enthusiasts, I supplemented BISA meetings with stargazing trips, the specifics of which I shall discuss in greater detail in the following chapters, as well as social trips to the pub. Here, alongside learning to do astronomy, we discussed astronomy and astroculture, the latest discoveries in

astrophysics, what science fiction each of us were reading, and, as will be crucial to my later discussions, our lives and the world more broadly, the future of humans, and how what we were doing fit into that broader scale. We aimed to organise these events once a month, but as I also discuss further later, this rhythm was often interrupted by the disharmony of our collective lives. Like the BISA meetings, this smaller community was also sustained between meetings by an active WhatsApp group chat where we discussed astronomy and astroculture.

I sought to approach both these fieldsites in an informal way out of concern for my presence becoming intrusive to my informants, as I am aware that astronomy can often offer its practitioners the semblance of respite from the everyday world (a critical aspect of astronomy's promise, as it emerged). While I openly discussed my project with my informants, to the point of actively speaking about what I was writing/reading at the time, and if they had any thoughts, I made efforts to remain 'in the moment', as it were, hoping to cultivate a sense of comfort (or at least avoid causing discomfort) in my presence. As such, I took few on-site notes, opting instead to write up my findings once I had made my way home, and only pulling out paper and a pen when a particularly pertinent statement was made. Having opted for observing the organic functioning of an astronomy group, I performed fewer than 20 informal interviews, reserved for the more irregular or inaccessible members. I found that the ample time we had while stargazing was more than enough to raise any questions I had. What emerged, therefore, was a broad sense of the shape of the astroculture community, its participants, appeals, aesthetic standards, practices, and imagined place within the world.

2. Cosmos

Failure is a rupture, a “radical and forceful discontinuity” in an expected order of events (Holbraad, Kapferer & Sauma 2019: 1). It is, in the words of Carroll, Parkhurst and Jeevendrampillai, “when objectification ceases to adhere. This may be the point at which an object slips from its object position, or when it becomes clear that an artefact will never quite fit correctly into that desired object position” (2017: 10). Making sense of any given failure is, therefore, a matter of understanding this ideal or expected outcome—this ‘objectification’—that fails to emerge. This means setting out the expected chain of events that is aborted, the ideal outcome towards which my informant’s doomed efforts are directed. An object’s slippage from an object position can, after all, only be made sense of through an understanding of that object position. If failure is when the conditions of success go unmet, then impossibility can reasonably be understood as a recognition that these conditions *could never have been met;* that the demands of the project are, in principle, unreasonable; when it becomes clear that, in the words of Carroll *et al*., the artefact was never going to quite fit correctly into the position prescribed to it.

To make sense of the problem of the imperfect astronomical image, therefore, it is critical to first understand the conditions that are set for the astronomer’s success. If astronomy is a practice that seeks to access and visualise the content of the night sky, and therefore the cosmos beyond our planet, we must first set out the standards for that mediation which are going to inevitably and intractably fail. In short, we must ask what the scientific cosmos *should* look like, and what features of these infrastructures of access must be present in order for the image to be deemed successful.

This requires a little more preamble, for which I hope the reader will forgive me. However, I claim that this questionable format of describing the universe before I go into how it is practised in earnest, a reversal of the usual anthropological order of events, is more authentic to the experience of my collaborators than beginning on the ground.

Almost all of the astronomers with whom I have spoken have come to astronomy from an interest in the cosmos with which they have already been familiarised in the abstract. Whether they are photographers who have decided to turn their eyes to the sky, or science enthusiasts who want to experience the cosmos first-hand, these practices are always used to supplement an existing interest in something that has already been researched through other media. Indeed, the sophisticated nature of the kind of astronomy I discuss, which goes beyond naked-eye stargazing and involves the deployment of telescopes, cameras and other visual aids, requires prior familiarity with the concepts at work and the content that they seek to make visible. Here, in discussing the nature of the cosmos theoretically, as it is understood by my astronomers *a priori*, I seek to represent and replicate this chain of engagement, beginning with learning, and then moving on to experiencing.

We may speak about the conditions for astronomical success as a certain *aesthetic of truth*, a rough understanding of what a matter of fact or phenomenon is *supposed to look like*, or at least some of the features it is supposed to sport, decided a-priori and grounded in the historical and cultural understandings that contextualise it. This is particularly clear in the case of the extremes of vision such as the very small and the very large: as Elizabeth Kessler notes in her discussion of images produced by the Hubble Space Telescope, these pictures of space have no prototypes on which we can draw to work out how accurate their representations are. We have no unmediated experiences of nebulae with which we can compare astronomical images (2012: 128). Absent such phenomenological baselines, aesthetic judgements become matters of traditional and cultural aesthetics. In particular, Kessler argues that the starscapes and images of nebulae produced by the Hubble Telescope draw upon the aesthetic traditions, including compositions and colour schemes, that she identifies with the romantic art of the American West (*Ibid*. 38).

In his discussion of the history of visuality, Jonathan Crary makes a similar point about the cultural grounds for the success of images. In *Techniques of the Observer*, he foregoes a discussion of disembodied vision for a discussion of seeing situated firmly in

the person doing the seeing, as “the field on which vision in history can be said to materialise, to become visible” (1992: 5). He refers to this person engaging in these practices of visualisation specifically as an “Observer” for its double meaning as both one who sees and one who conforms to a set of conventions or rules, precisely to emphasise this cultural prefiguring of sight and its situatedness within regimes that predetermine what is worth being seen.

> “Though obviously one who sees, an observer is more importantly one who sees within a prescribed set of possibilities, one who is embedded in a system of conventions and limitations. And by "conventions" I mean to suggest far more than representational practices. If it can be said there is an observer specific to the nineteenth century, or to any period, it is only as an effect of an irreducibly heterogeneous system of discursive, social, technological, and institutional relations There is no observing subject prior to this continually shifting field” (*Ibid.* 6).

This gets at the disciplinary aspect of sight, first emphasised by Robert Hooke in *Micrographia*, and emphasised also in Shapin and Shaffer’s Classic *The Leviathan and the Air Pump* (1985: 37), as well as more contemporary works such as Natasha Myers’ *Rendering Life Molecular* (2015: 14). All of these works emphasise the “generative” and “corrective” nature of this discipline, by which the scientific labourer's senses are “enlisted, honed, cultivated, and trained, rather than merely controlled or constrained” (*Ibid.*). There already exists a term for this field in neuroscience and psychology, the *Visual field* (Smythies 1996: 369). This visual field is opposed to the external and internal “stimulus field” in that while the latter two refer to the raw sense data available to the eye and the physiological response to those stimuli within the retina and the nerves respectively, the latter refers to what is available given a set of cultural constraints: the output that is run through a set of value-oriented filters that we might call an aesthetic of truth. As John Smythies puts it, “these [outputs] are powerfully affected by ‘top-down’ influences modified by prior experience, expectation etc[…]” (*Ibid*.).

While these examples of the visual field pertain to an aesthetic of truth associated with sight, I claim that an aesthetic of truth is not necessarily so visual. We might take the example here of beauty or more particularly *elegance*, a term that emerges regularly in discussions of theory amongst my informants. Elegance in this sense refers to a powerful simplicity. The simplicity in this case is the articulation of Occam's razor, and science's resistance to complications and theoretical extravagance when a more straightforward explanation is available (a concept which will emerge again and find its scientific grounding in our discussion of the myth of the Copernican revolution). A theory's power refers to its capacity to describe and thereby link multiple discrete phenomena, pointing towards a more fundamental reality that undergirds these seemingly distinct examples. We might say, therefore, that elegance is an aesthetic of structuralist truth—that the legitimacy of a structuralist theory rests, in part, on a prefigured emphasis on its simplicity and power.

The concept of the visual field as I use it here is close to the concept of Judgement as deployed by Immanuel Kant in his *Critique of Judgement* in that it is "the faculty for thinking the particular as constrained by the general" (2001: 279). This is to say, judgement is the faculty that applies general rules and principles to particular circumstances so that they can be thought through, worked upon, and subsumed by overarching systems and contexts. Judgement is, therefore, a generalising mode, through which phenomena are brought into relations with one another, and are thereby granted a symbolic excess—the capacity to point beyond themselves to more transcendental registers or underlying processes. As Kant notes, the work of judgement is imaginative work, requiring not only the raw matter of the world but also the mental faculties to make these linkages (292). Through judgement, the work of art, for instance, is situated within traditions, styles, sets of worldly phenomena, and social relations. Likewise, through judgement, the astronomical image is produced and judged to be appropriate or inappropriate by its capacity to mediate its objects and afford conceptual access to them—that is to say, within a particular visual field. It became clear to me in this work, as I have already suggested, that learning to be an astronomer is a matter of developing the faculties of judgement and taste for both producing and consuming

astronomical images, so as to understand and readily perform this imaginative and scaling work, understanding these references reflexively and perhaps even charting novel ones grounded in the pre-existing visual field. The judgement of astronomers allows the image to scale up and refer to the cosmos that it at once mediates and participates in. But judgement, by the same token, roots truth in the human faculties and traditions that do this contextualising work, and grant these images their symbolic excess. Astronomy needs judgement, but at the same time cannot abide that judgement, for judgement is a feature of the human mind. It is this tension, as I have noted, that becomes the locus of the astronomer's work: through their engagement, they seek to work out the implications of this particular tension for the more general social context they inhabit.

As a chapter directed at discussing the conditions for the success of the image in affording access to a cosmic perspective, I here intend to discuss the visual fields and aesthetics of truth at work on the astronomer as observer. As I have suggested in my discussion of the associations that swirl around the cosmic perspective, what has emerged throughout my fieldwork with astronomers is that the success of the image rests upon an aspect of practice designed to erase the human from the resultant work. This erasure, or the absence of the influence of the human from the final image, emerges from a very particular ontological and cosmopolitical orientation of fractures and bifurcation that can be traced from monotheistic religion to the Copernican heritage in Western astronomy. This orientation, being central to my conceptualisation of astronomical imaging and worlding practices, culminates in what I call the *Copernican Engine*. The Copernican Engine is a function which seeks the completion of the Copernican revolution and the realisation of the world that was promised in it, the utopian state of attaining true objective access to the world through the erasure of the human subject from the project of knowing. The Copernican engine seeks to capture that aspect of science which Gregory Schrempp describes as a "culture-transcending venture" (2012: 4). As such, the engine is a part of this horizon of meaning which science seeks to efface, but I claim nonetheless defines what counts as appropriate knowledge, and particularly an appropriate image. I refer to this practice as an *engine*

because it is the grounds for progress, which seeks to endlessly upturn historical understandings and defamiliarize the cosmos in pursuit of an infinitely receding horizon of truth. It is, in this sense, working against and always opposed by the equally strong impulse to make the world known and legible, which I later describe as *Territorialisation*. Drawing on the work of Eugene Thacker, I associate the defamiliarization and antihumanism of the Copernican impulse with the territorialisation's opposite, *Horror* (2011). In this section, I shall elaborate on the nature of the Copernican Engine, describing its central role in the astronomer's cosmos, and in doing so set the grounds for identifying it in my astronomer's practices.

This notion that the cosmic perspective is anti-human emerges in astronomy from many quarters. Primarily, it emerges from the aforementioned discussion of science communicators such as Sagan and deGrasse Tyson, in which they established the nature of the cosmic perspective. It also, as I shall spend much of this work describing, can be seen most prominently in the way in which astronomical visualisation is conducted. We can see it also in the mythology of scientific modernity, and particularly in its origin myth, the Copernican Revolution, the original great demotion, which I shall discuss shortly in order to contextualise this aesthetic of truth historically. Notably, however, it emerges also in discussions of the value of astronomy. One of my informants was a woman named Wendy who was, amongst other things, a mother. She started her journey into astronomy in earnest shortly after her child was born. She had always been interested in astronomy, but the birth of her child had inspired her to develop a hobby that she could share with her child. She also said that she valued astronomy because it was "a good way to get away from people." her attitude towards astronomy seems ambivalent, at once concerned directly with kin and explicitly antisocial. This tension makes more sense if we read the "people" from whom she seeks to escape as a metonym for the human world, for her busy work (of which she often complained) and the stresses of city life. This reading is substantiated further by other statements about the value that people find in astronomy. One member of the public told me that "it's nice to be reminded that there's more to the world than just us". These statements seem to reiterate the transcendent nature of a cosmic perspective:

that astronomers often value their practices precisely *because* it is so removed from their modern, urban lifeworld.

As a conceptual tool, this Copernican Engine sheds light upon the failure of the image by outlining the tension central to the process of making visible: a strained hybridity of purpose (namely the making legible) and content (the need for that thing that is made legible to also be unmolested by human transformations). Astronomers are therefore trapped between the impulse to know and the impossible demand that that knowledge be inhuman. The Copernican Engine is therefore a problem, an unreasonable demand that is grounded in a presumed relationship between the human and the world. It is, as I shall explore, the root of the failure of the cosmic image. As such, if we seek not only the cause for the image's failure but also the questions that failure raises—the social projects that this failure generates amongst astronomers, following Carroll, Jeevendrampillai and Parkhurst—then we must make sense of the Copernican Engine as a critical feature of not only astronomical practice, but all the practices of worldly and technical management which rest upon the idea of objective knowledge, which run in parallel to astronomy and are likewise subject to a crisis of legitimacy. Making sense of astronomy as a social project that identifies and addresses the Copernican Engine as the root of such a failure, and the cosmopolitical questions that emerge from it, troubling not only astronomy itself but the worldly context that surrounds it, can help us to make sense of the apparent futility of astronomy, and astronomer's perseverance in spite of it.

In the chapters following this one (3. Places, 4. Practices and 5. Images), I describe this engine in practice: how it sets the technical standards for success, how it is enacted in the practices of my informants, and how this enactment is always partial and insufficient. That is to say, how my informants go about the paradoxical work of cleaning their knowledge artefacts of human residue, and how these efforts always fall short. In this section, however, in an effort to make sense of this Copernican Engine as a historical phenomenon which describes the cosmogonic work of astronomy, and by

extension, how that world-making takes the form of a revolution against the human world.

2.1. The Copernican Myth and the Origins of the Astronomer's World

The myth of the Copernican Revolution is perhaps one of the most widely known and influential in the scientific canon. No astronomer I have ever met has been unaware of the story of Nicolaus Copernicus, the Polish astronomer who upturned our understanding of the world and reoriented our position within it. Both in my fieldwork and my own initiation into astronomy as a teenager, the public re-telling of this story has been a mainstay of an oral tradition of enthusiastic raconteurs seeking to contextualise astronomical practice within a broader historical and pan-human movement. While its literal reference is most often reserved for talks directed at educating predominantly young initiates as to the origins of modern Western astronomy and cosmology, its influence as the foundational myth of that world emerges throughout statements and practices I have witnessed.

What I will outline here is what I refer to as the 'myth' of the Copernican Revolution. I refer to it as 'myth' because my concern, and the concern of those re-telling the story, is not primarily with its history—with the facts of the event as they occurred at the time. Rather, I am more interested in the Copernican Revolution as a moral fable, one which tells a story that grounds and contextualises the work of those who identify their work with it and the world it brought into being. This story asserts not only a particular relationship between the human species and the world it inhabits, but also a particular relationship between contemporary human subjects and their ancestors, laying the grounds for the revolution embodied and continued in astronomical practice. Given its contextualising function, astronomers often understand themselves as working within a Copernican tradition, towards the completion of a task that the Copernican event laid before us, which is to see the cosmos on its own terms by specifically declining to see it on the terms of the human.

The story is simple. Before Copernicus, humans, in their pride, imagined that they were made by God in his image, to occupy the exalted position at the centre of the cosmos, and constructed intricate models to imagine that to be our place. While these precepts of humans being the products of divine intervention and cosmic centrality are found in cosmological myths across the world, the Copernican myth is often placed in opposition to the Western, Christian renderings of the cosmos from which it directly emerged. This idea that the Earth, the home of humans, sits in the centre of the cosmos, orbited by the planets in perfect (divine) spheres became known as the terracentric or 'Ptolemaic' model of the cosmos. Over time, and through further examinations of the sky, this model of the cosmos seemed less and less plausible. Some planets seemed to move in "retrograde," doubling back on themselves in predictable ways that were nonetheless impossible for bodies moving in perfect circles. These were theorised as moving in "epicycles," orbiting these perfect circles, as an attempt to retain this perfect model of the cosmos. These complications, termed "ptolemizations" by Slavoj Zizek (2008: vii) are seen as ideologically driven attempts to put off the inevitable realisation of the true nature of the cosmos, to reject failure rather than learning from it, and to sustain a model that was unworkable but allowed us to retain our imagined stature at the centre of the cosmos. It is in the Copernican Revolution that these unwieldy complications become unbearable.

The cosmos Copernicus proposed in his work *De Revolutionibus Orbium Coelestium* (On the Revolutions of the Heavenly Spheres) is often referred to as "heliocentric". Grounded on the astronomical observations of the Dutch astronomer Tycho Brahe, Copernicus proposed a cosmos in which the sun, rather than the Earth, sat at the centre. This view, the myth goes, was controversial, because it relegated the Earth to just another planet amongst many (Kragh 2007:47; Wallace, in Blumenberg 1987: xlii), stripping us of the symbolic power afforded by centres (Geertz 1983: 121). The Copernican moment, therefore, stands for a reorientation of our cosmos. It is for this reason that Hans Blumenberg describes Copernicus' status at the time as one of a

"perpetrator," who was, to quote a statue of Copernicus erected in his hometown of Torun, "mover of the earth and stayer of the sun and the heavens" (1987: 264)

This reorientation provokes concerns about how we ever got into a position of such self-delusion in the first place, and indeed why, following the publication of Copernicus' theory, it was still met with such opposition from many, particularly the Catholic Church, who famously placed the astronomer Galileo Galeli under house arrest and forced him to recant his advocation of a heliocentric cosmos. The moral of the Copernican fable is that we as humans are too ready to imagine the cosmos to resemble us, that "we seem compelled to project our own nature onto nature" (Sagan 1997: 24). In other words, we *anthropomorphize* the world around us, imagining natural processes to be the works of gods with minds not unlike our own. As the philosopher Eugene Thacker puts it: "when the non-human world manifests itself to us in these ambivalent ways, more often than not our response is to recuperate that non-human world into whatever the dominant, human-centric worldview is at the time. After all, being human, how else would we make sense of the world?"

The Copernican myth is a cautionary tale about how, in pursuit of truth, we must be constantly sceptical of this impulse, a scepticism which is foundational to the scientific project and the Copernican Engine. Gregory Shrempp claims that we can see this concern in the way in which science often opposes itself to myth[3]. He states that "myth portrays the cosmos anthropocentrically, that is, *not as it truly is, but in our own image—skewed by human passion, parochialism and self-infatuation*" (2012: 3, Shrempp's emphasis), while "science connotes the opposite: in the interest of objectivity, the purging of such anthropocentric conceits from the idea of nature" (*Ibid.* xiii). It is in this impulse that we can identify the human subject becoming an epistemological pollutant. The call of the Copernican revolution is taken by astronomers to be a call to go beyond the intuitive and countenance the world in its inconvenient reality.

[3] It should be noted here that Schrempp himself is a mythologist who, in his work, seeks to identify the residue of mythological thought which has not been purged by this opposition, and is instead actively deployed in popular science writing. In my discussion of the copernican myth, I would also like to emphasise that the

This process is framed in the Copernican myth as a matter of comfort, giving reason to the dogmatic rejection by our ancestors of the true nature of the world (a simplistic rendering of the discussions at the time as outlined by William Drees (1996:56)). It is why, it is imagined, the Copernican revolution was so *revolutionary*. As Sagan describes the event:

> "Then science came along and taught us that we are not the measure of all things, that there are wonders unimagined, that the Universe is not obliged to conform to what we consider comfortable or plausible. We have learned something about the idiosyncratic nature of our common sense. Science has carried human self-consciousness to a higher level. This is surely a rite of passage, a step towards maturity. It contrasts starkly with the childishness and narcissism of our pre-Copernican notions." (1997: 32)

In Sagan's description here we can find a prominent feature of the Copernican myth: the revolutionary and moral history it constructs. The history of science here is framed as a bildungsroman of the entire human species. Imagined to be a singular and monolithic whole, our species comes of age when it casts aside our comforting myths and faces the true conditions of our existence. It is here that a kind of courage becomes associated with astronomy and scientific endeavour that lingers to this day. It is the bravery to face our true stature in the cosmos—the radical alterity of the universe to us and our insignificance within it—that we might call a kind of *existential heroism*. It is recognized that such a revelation can be unpleasant and unsettling. Again, Sagan comes to our aid in understanding this myth:

> "If it takes a little myth and ritual to get us through a night that seems endless, who among us cannot sympathise and understand? But if our objective is deep knowledge rather than shallow reassurance, the gains from this new perspective far outweigh the losses. Once we overcome our fear of being tiny, we find ourselves on the threshold of a vast and awesome Universe that utterly dwarfs—in time, in space, and in potential—the tidy anthropocentric proscenium of our ancestors." (1997: 36)

In the contrast between the heroic modern scientist and their deluded or ignorant ancestors, and the imperative to move from the latter to the former, we find the foundational revolutionary form of astronomical practice. Copernicus' heliocentric world has long since been rendered obsolete. Abramson and Holbraad put it, "the modern cosmos that was delivered from its womb by astronomers and philosophers from the Renaissance onward became increasingly de-centred," (2014: 11), in that the modern revolution "spiritualized and then abolished the Godhead, decentering the cosmos as a whole, first by promoting the sun and then by cutting loose the heliocentric system itself within an open and expanding cosmos" (2012: 42). While heliocentrism did not last, as the first great demotion, it laid the groundwork for the structure of a cosmos in which the human and nature are radically at odds with one another, and all of our assumptions about the world required systematic challenge. As I shall explore further in this dissertation, it is this division set out by the Copernican event that is at the core of how astronomers conduct their work, as it endlessly seeks to establish the world into which Copernicus gave us our first glimpse.

It is notable here that I discuss the story of the end of myth as a legitimate form of knowledge-making and sharing in terms of a myth. There has been much discussion of the persistence of myth in a supposedly post-mythical age. Roland Barthes' expansive account of pertinent myths of French everyday life (1972), Gregory Shrempp's discussion of the deployment of mythical forms in contemporary popular science (2012), and Theodor Adorno and Max Horkheimer's insistence that modernity "reverts to mythology" (1997: xvi) are but a few. I take the retellings of the Copernican event to be mythical on two accounts. In Barthes' aforementioned discourse, he identifies myth as a kind of signification or speech which adds to the raw description and pure matter of things a social excess: mythologized things are "decorated, adapted for a certain type of consumption" (1972: 108). On this level, I have described the way in which the Copernican myth is not simply concerned with the facts of the event, and is often misguided on the attitudes and responses of peoples to *De Revolutionibus*. Rather, the function of its retelling is to disaggregate moderns from their ancestors, and lay at their

feet the moral task of continuing that disaggregation. Secondly, in Mircea Eliade's account, myth is a temporal category outside of normal, everyday time, which is called upon, inhabited, and "reactualized" during the ritual (1957: 69). Myth is, in this sense, the story that grounds the special category of time referred to as the sacred. As I shall explore (3.5. The Astronomy Ritual), this model of the ritual as the re-enactment of a mythical, often cosmogonic event, can be used to make sense of the way in which astronomers actively take up and participate in this Copernican task, becoming themselves the momentary movers of the sun and stayer of the Earth in the heavens. This mythical aspect of the Copernican story demonstrates for us in microcosm the failed revolution of astronomy, as its project rests upon the very forms it sought to expunge.

2.2. The Dual Cosmos

One of the critical repercussions of the Copernican event was the fallout that it had for worldly politics. In the Copernican myth, one of the ways in which the reorientation of the cosmos troubled religious institutions such as the Catholic church was that it challenged ecumenical authority on the nature of the world. It was a natural philosopher, not the Pope, who unveiled the true nature of the cosmos to us. How was the church to see this as anything other than a challenge to their power?

In their account of this fallout, Nancy Abrams and Joel Primack assert that there emerged a "policy of non-interference with religion", which they refer to as a "Cartesian bargain" between those who resisted the Copernican model (mythically imagined as the Catholic Church) and those who embraced it (the early natural philosophers and later scientists) (2011: xiv). This bargain, according to the Copernican myth, fractured the world into different regimes of authority. The Church retained dominion over the divine, meaning, value, and spirit, and the natural philosophers took up a position of authority over the mundane, the profane, and matters of fact. Matters of value, understanding things in human terms, are for the religious, the superstitious, and the pre-modern.

Getting at the world in itself, external to human preferences and interpretations, is the work of scientists.

One of the most critical features of the astronomer's cosmos (critical, at least, for making sense of the failure of the perfect image) is that it is what Allen Abramson and Martin Holbraad called a "dual cosmos" (2014: 11). This is to say it is bifurcated between two distinct realms that follow the lines drawn by the cartesian bargain: matters of fact and matters of value. Scott charts this distinction along a set of "analogous oppositions: mind/body, transcendent/immanent, animate/inanimate, subject/object, linguistic sign/'real-world' referent, nature/culture etc." (2014: 34) This bifurcation is not particular to scientific conceptions of the world: we can (and will) chart this bifurcation back to an Abrahamic, monotheistic cultural firmament. It is in this monotheistic heritage that we can observe the conceptual limits of the human, and here I endeavour to explore the binarism that structures the astronomer's cosmos, and to establish the historical context for the Copernican Engine.

We can see this boundary recurring and being reaffirmed in many different places by many different people. The Scottish Philosopher David Hume asserted that facts and values occupy two distinct realms insofar as one can never assert a moral imperative based on the nature of things or vice versa, dubbed "Hume's Guillotine" or the "is-ought gap" (Hume 1896: 469). One of the progenitors of early science Francis Bacon justified Scientific endeavour by claiming that God offered humans "two books" with which we might inquire into the world we live in: the bible, and nature. As Robert Crease describes, "the first book is for those who want to focus on how best to live in the world of social, moral, and religious life. The other book is for those who want to understand nature apart from the issue of how to live well." (2019: 35). The evolutionary biologist Stephen Jay Gould asserts that religion and science reign over "non-overlapping magisteria" of matters of fact and matters of value (1999). The anthropologist Bruno Latour identifies in modernity an impulse for "purification," to demarcate and police the boundaries between nature and culture (1993: 10). Similarly, Donna Haraway notes in *A Cyborg Manifesto* that "in the traditions of 'western' science

and politics [...] the relationship between organism and machine has been a border war" (2016[a]: 292). She goes on to claim that this border cannot hold, that "the cyborg is our ontology" (*Ibid*.).

Within this binary logic, a step towards one pole is a step away from the other. If one hopes to get at the natural world, one must therefore align themselves with that side of this binary, forsaking the other in order to abide by this purification. Otherwise, one risks contaminating it with subjective interpretation. As the historians of science Simon Shapin and Steven Shaffer note, "in common speech, as in the philosophy of science, the solidity and permanence of matters of fact reside in the absence of human agency in their coming to be. Human agents make theories and interpretations, and human agents therefore may unmake them. But matters of fact are regarded as the very "mirror of nature." [...] what men make, men may unmake; but what nature makes no man can dispute." (1985: 23).

Perhaps the most useful rendition of this distinction, however, emerges from the philosopher Eugene Thacker, and his discussion of horror, and it is in Thacker's rendition that we can begin to get a glimpse of how the task of the astronomer begins to fray at the edges. For Thacker, horror gains its affective power from its radical alterity, its capacity to represent the inhuman in human terms, to provide partial representations of the extremes which linger between that which is understood and that which is unthinkable. It is about what resists incorporation into our schemes of knowledge. The term "extreme" is here drawn from the work of David Valentine, Valerie Olson and Debbora Battaglia (2012) as a trope that, like horror, references the externalities of the human world, denoting conceptual or geographic territories that are at once beyond us and mark potentials for future expansion (*Ibid.* 1008). As such, I claim that both horror and the extreme are crucially the stuff of scientific work.

To illustrate the concept of horror, Thacker proposes three conceptual registers which describe particular relations with or understandings of the world: the world-for-us, the world-in-itself, and the world-without-us. The world-for-us is what we might call the

subjective world, “the world that we, as human beings, interpret and give meaning to” (2011: 4). I find the idea of such a world being construed as ‘for us’ compelling and useful insofar as it works double-shifts, lending itself both to an epistemological reading—the world as it appears to and is understood by us—and to a cosmopolitical reading—the world understood as if it were made for us, either by a deity or by a set of technical fixes, to be governed or owned. This formulation therefore has an aspect of anthropocenic logic to it—a world that is ‘for us’ is one that is marked and/or claimed by the human species through its works.

Secondly, and opposed to the world-for-us, is the *world-in-itself*. This register can be thought of as the objective world, the world that exists beyond and outside of human meaning-making and interpretation. As such, access to the world-in-itself is the objective of scientific work. The scientific method is geared towards finding facts about the world that exist independently of our interpretation—what does not change with a change of perspective. If the pre-Copernican world is the world-in-itself which led us astray, it is a refocusing on the world-in-itself that is the task laid before us by the Copernican event, and the stuff of producing a cosmic perspective. We might say that the objective of astronomy is to reveal to us the world-in-itself through access to the radical alterity of outer space. The problem with this process is the problem with any effort to get at the world-in-itself, namely the “paradoxical nature” of the world-in-itself as a concept: that, as Thacker puts it, “the moment we think it and attempt to act on it, it ceases to be the world-in-itself and becomes the world-for-us” (*Ibid.* 5). As he writes elsewhere, “we cannot help but think of the world as a human world, by virtue of the fact that it is we human beings that think it” (*Ibid.* 2).

It is this paradox that leads Thacker to posit his third register, the *world-without-us*. In order to get anywhere near the world-in-itself, as impossible as it is to get at, we must imagine the world as if we did not exist to experience it. The world-without-us is the “subtraction of the human from the world” (5). If the problem of getting at the world-in-itself (and therefore the fundamental work of science) is the intrusive force of human interpretation—our tetheredness to the world-for-us—then the

world-without-us “allows us to think the world-in-itself, without getting caught up in a vicious cycle of logical paradox” (*Ibid*.). For Thacker, the world-without-us is central to escaping the bind that ties us to the world-for-us.

Horror is therefore an unpleasant and anxious condition, marked by uncertainty, which narratives and schemas of knowledge, illusory as they are, seek to alleviate. In particular, he notes the “therapeutic function” of Socratic philosophy, “which is to dispel the horrors of the unknown through reasoned argument” (2015: 3). Indeed, Sagan asks, “What do we really want from philosophy and religion? Palliatives? Therapy? Comfort?” (1997: 33).

If we are to think about the world-in-itself, therefore, we must think in terms of limits and extremes, in terms of what lingers beyond the human world. We must think about where we might go to dislodge the disruptive force of the human subject. This is what leads him to the discussion of horror, which, for Thacker, “*is a non-philosophical attempt to think about the world-without-us philosophically*” (2011: 9 emphasis from original text). It is not just the thought of the thought of what is not yet known, but the “thought of the unthinkable”. In his second book, *Starry Speculative Corpse*, he notes that Descartes, in his classic meditations, walked up to this abyss and stared into it, facing the impossibility of knowledge. He claims that Descartes’ attempts to then ground knowledge in God were a step away from that precipice.

This impulse, in the face of radical alterity, to metabolise and incorporate that otherness into something more conceptually manageable—into the world-for-us—is something that already exists in the anthropological canon, namely in Claude Levi-Strauss’s formulation of the symbolism of cannibalism. In *Tristes Tropiques*, he posits two types of society based precisely upon their symbolic means of processing the radical other. The first, whose solution to the problem of the other could be called *anthropophagic*, and “regard the absorption of certain individuals possessing dangerous powers as the only means of neutralising those powers and even turning them to advantage” (1973: 508). The second, which we could call *anthropemic* (from the Greek

emein, to vomit), treats the other in the opposite fashion, by expelling and isolating them. These practices are symbolic by virtue of providing a framework for action within or comprehension of many novel environments that concern dangerous others. For instance, Levi-Strauss uses the example of systems for dealing with criminality, identifying Western justice systems as predominantly anthropoemic insofar as it isolates and excludes perpetrators, compared to the “plains Indians of North America" whose ritual destruction of property and subsequent gifting of property to that same perpetrator functions to reforge and solidify social ties, incorporating them back into the social fold (*Ibid.*). This is the Recuperation of which Thacker speaks, and the “possibility of naming and maintaining control over that territory” implicit in the concept of the extreme (Valentine, Olson & Battaglia 2012: 1008).

The call of science, on the other hand, can be made sense of as a third path: neither to transmute it into something comprehensible nor to reject it, but rather to revel in that horror, to engage with it in itself, to allow it to persist, and perhaps to picture it. It seeks to engage with that horror without compromising its essence, and its practitioners take pride in their brave resistance to the anxiety it supposedly induces. This is the essence of the existential heroism of the imagined scientist.

Astronomers, therefore, in aligning themselves with nature, and seeking out the world-in-itself must produce visions of the world that are plausibly from the world-without-us. As I shall describe here, the nature of the human as an epistemological pollutant drives astronomers to produce places, practices and images that are washed clean of such contamination. However, this presumes the possibility of doing so. Can we actually transcend our mortal and provincial conditions and touch the absolute and the horrific? Such a question is critically pertinent to the possibility of the perfect image.

In his discussion of cosmology, Don Handleman argues for a discussion of cosmology that orients itself around structure, around “the logic or logics of connectedness and separation that organise the cosmos” rather than its content (2008:

182). In His account of the modern cosmos, he claims, as we have identified, that “the distinction between subject and object is reignant—human beings in the main are subjects (and others) to one another. All else is classified pretty much as an object of one sort or another, following enlightenment values, largely dependent for its future, its fate, on the will of the sentient human.” (*Ibid.* 183). This is to say, this cosmos is built upon a clear line drawn between the human and its world.

Handelman’s account is of how this state of affairs emerged from religious and particularly monotheistic accounts of the cosmos. In reference to the modern world, he claims that “beyond and in back of this cosmos is the generative crucible of monotheism that insisted in the first ontological instance on the boundary, indeed, the near impenetrable barrier, between God and the human being” (*Ibid*.). The Abrahamic God “encompasses” the cosmos he created, holding it together from the outside, with access to the world, the capacity to breach this boundary. However, the reverse action is not possible: humans are ultimately and absolutely excluded from the realm of the divine. Handelman speaks to Terry Evens’s account of Genesis, which describes the Fall as the mythical origin of this cosmic fracture between God and the human. In Catholic Mass, the human worshippers prepare themselves to approach the divine, and then, in the taking of the Body and Blood of Christ into the worshipers, “the penetration is that of the Divine” (*Ibid.* 186). Handelman also gives the example of Mary, whose contentious position between human and divine demanded that the church resolve the “paradoxical character of her being” (*Ibid*.) by revoking her human attributes.

The recurring theme of such a cosmos is that the boundary between God and humans can be “momentarily effaced” (*Ibid*.) but only by God and not the human. This, I argue, resembles closely the relationship between the human and the world or ‘nature’ after the Copernican Revolution. Nature encompasses the human, penetrates them, defines their actions and the terms of their being, but (as I shall show) refuses their efforts to approach it. Handelman notes the significant implications that this boundary has for monotheistic morality, and, significantly for us, its pursuit of perfection. “In the Hebrew cosmos, harmony, *eudaimonia*, disappears, given God’s requirement that the

human being become more morally perfected—unending efforts doomed to fail over and over again. The revolution of Christianity, the revolution of Islam, the revolution of the Reformation, despite their radical formations of monotheism and individualism, never altered the logic of the cosmic design of the infinite God encompassing, holding together, the cosmos of his creation from its exterior. Despite modifications, the rupture forming the exterior and interior of cosmos, the absolute boundary of this rupture, of separation, endures" (*Ibid.* 185). I claim that in the same way that moral perfection is undermined by the radical division between humans and the cosmos, so too is the epistemological perfection of the perfect image endlessly curtailed by the boundary between humans and their world, described by Thacker as an endless intrusion of the world-for-us into our representations of the world-in-itself. This boundary, the status of the human as a permanent exile from the world just as they were once a permanent exile of Eden, emerges and is sustained by the myth of the Copernican Revolution.

In their work, Primack and Abrams claim that there is a "gaping hole" in contemporary cosmology that was otherwise filled by the enchantment of previous cosmologies, marked by the retreat of cosmologists from the social and the human (2011: xi). They call for the production of a "cultural cosmology" that properly contextualises human work within the cosmos and reintegrates humans with it. It is my claim that we never left the cosmos: that the work of astronomers and 'cosmologists proper' is designed to *plausibly* produce images and a world that is disenchanted, to sustain a willful suspension of disbelief about the success of their revolution, but in reality, we have only been "blinkered out of our view from the myth of modernity" (Farman 2012: 1084). In this world, culture is treated much like its political analogue of ideology: that it disrupts and distorts our view of the world, and that if only we could overcome it, we would be capable of seeing things as they truly are. I here take up the position on culture that Slavoj Zizek advocates for ideology: that "it is not just a question of seeing things (that is, social reality) as they 'really are,' of throwing away the distorting spectacles of ideology; the main point is to see how the reality itself cannot reproduce itself without this so-called ideological mystification. The mask is not simply hiding the real state of things; the ideological distortion is written into its very essence"

(2008: 25). Just as Zizek sees ideology as a fundamental and constitutive part of the reality we see—the thing that provides us with the context for knowledge to be judged as good and appropriate—so too is the social critical in understanding this cosmos that is supposedly allergic to the cultural conditions of its being. The recurring intrusion of the human world of values into the pristine project of knowing reiterates that crucial insight from David Hume:

> "'Tis evident, that all the sciences have a relation, greater or less, to human nature; and that however wide any of them may seem to run from it, they still return back by one passage or another. Even *Mathematics*, *Natural Philosophy*, *and Natural Religion*, are in some measure dependent on the science of Man; since they lie under the cognizance of men, and are judged of by their powers and faculties." (Hume 1896: xix)

2.3. The Astronomer as Ascetic

The endeavour of the scientist, and as we shall shortly see, the astronomer in particular, is to create knowledge artefacts that are plausibly of the necessary nature of reality, rather than contingent upon any particular knowledge practice, infrastructure, or mediation. Ostensibly, such practices bring these artefacts into view, but they do not bring them into being: their being exists outside and beyond us, in the realm of the world-without-us. This marks an essence to all things that is external to human interpretation, which scientists seek to get at through subtractive methods: through practices which seek to strip away their human aspect applied to them as they swirl in the semiotics of our lifeworld. I claim that such a process bears an uncanny resemblance to the work of the religious ascetic, and as such I would like to use the figure of the ascetic here to make sense of the figure of the astronomer. In particular, to the ascetic humans are inescapably profane beings. It is the business of the ascetic to access the sacred, just as it is the business of the astronomer to get at the cosmos. The worldliness of both severs them from their desired goal. The work of both the astronomer and the ascetic, therefore, becomes a matter of escaping that profane

essence. Understanding astronomy as ascetic practice means understanding astronomy as the enactment of those abstracted ideals of science, and the production of the conditions under which the human might be transcended.

Ascetic practitioners are found across the world in many different cultures. For the purposes of making sense of astronomers, I draw specifically on the work of Geffory Harpham, whose discussion orients itself around the early Christian ascetic tradition, and a group of believers known as the “Desert fathers” who, beginning in the 3rd century, entered the deserts of Egypt to perform feats of self-denial and “programmatic self-abuse” (Harpham 1987: xiv), foregoing sleep and sustenance, and inflicting extreme wounds and hardships upon themselves. The object of such practice, as described by Harpham, was a “more perfect communion with God” and to “approach the transcendental power of unmediated thought” (*Ibid*: 20).

Harpham’s claim is that this behaviour stands as the most dramatic example of a broader, more fundamental form of practice, an “ascetic imperative” which constitutes a “primary, transcultural structuring force” (*Ibid.* xiii). This imperative calls on those who wish to contact the absolute—be it God or the system of systems that is the cosmos—by effacing the base materiality and limiting capacities of the human subject. In other words, the ascetic asserts a binary which runs alongside the sacred and profane world, associating God, spirit and the soul with the former, and the human, culture, and the base materiality of the body with the latter. As Harpham notes, “What distinguishes all forms of asceticism is the idea that the self is a composite structure containing an essence that transcends, and yet is intimately conjoined with, a substance or medium that is mutable, degraded, and rebellious” (*Ibid*. 36).

What defines asceticism, and therefore helps us to speak about astronomy, is its antagonistic position towards the human as a concept. In the case of the desert ascetic, this effacement of the human is accompanied by a literal mortification of the living flesh of the human subject, so that the divine can shine through the lacerations inflicted upon their bodies. For astronomers, this rejection of the material is far less literal:

astronomers neither forego sustenance nor harm themselves as a part of their work, though it often means sacrificing sleep and braving the fierce cold of astronomy season. But this effort to efface and deny the materiality of the world is, I argue, no less a material endeavour.

In his discussion of asceticism, Buchli discusses the work of the Desert fathers as a pursuit of the *immaterial*: that asceticism describes "those aspects of human activity that consciously attempt to intervene within the material world in order to deny it" (2016: 1). Following this insight that this denial, like any revolution, must be enacted within the medium that it seeks to deny, the following sections follow the embedded, material engagements that make up the astronomer's effort to efface the Anthropocene, and the ways it would intrude upon and disrupt a clear cosmic perspective. The wounds astronomers inflict are not literal ones directed against their own bodies, but upon the anthropocenic world we have built for ourselves, which ties us down to earth and obscures the cosmic perspective. The self-denial of this cosmic asceticism guards practitioners against the scientific sin of "seeing *as* rather than *that*" (Daston & Galison 1992: 82).

As I will describe, the ritual of astronomy might therefore be understood as a set of practices which seek out gaps, wounds and liminalities within the city and the human world it stands for. It finds and establishes "wild places" (Macfarlane 2007 cited in Dunnett 2015: 625) where the cosmos shines through the cloud cover of the pre-Copernican world. As I have already noted, the great appeal of astronomy for many informants is precisely this capacity to puncture the world 'down here', and afford us glimpses of the world 'up there'. As I shall explore here, this requires extensive and strained work upon the loci where the cosmos is manifested precisely to mortify and transcend their locality. Like ascetics, astronomers must leave the city, the seat of the human world, either literally or figuratively through the production of particular sites where the city's effects might be mitigated and, ideally, erased. While ascetics sought "anti-landscapes" in the caves of the Egyptian desert (Della Dora 2011), the work of the astronomer, I claim, begins with bringing the desert to the centre of London. Astronomy

also follows asceticism in being marked by a strained ambivalence towards the body, at once relying upon its deft, virtuoso, and skilled operations, and at the same time rejecting its limiting dimensions and capacities on principle. As such, astronomy is defined by an *askesis*, "a sustained and intensive kind of intervention in the material world" (Buchli 2016: 51) which, a victim of its own success, only emerges when it fails. The development of such deft movements therefore becomes an effort in obscuring the bodily work of astronomy. And finally, asceticism, like astronomy, is centrally concerned with form and representation. The body is made to be an artefact that is both the reproduction of previous ascetic examples (Harpham 1987) and for "representing unrepresentability by using the material at hand, the body" (Buchli 2016: 38). Both the body of the ascetic and the image of space mortify the living flesh of the human and the dynamic vitality of the cosmos in their effort to index the divine.

One of the crucial aspects of asceticism as Harpram describes it is that it is a paradoxical concept, given the ambiguity of the signifier of 'human'. For example, Harpham discusses the particular positionality of language in the divine/human binary. According to the hagiographer Athanasius, the early desert father Saint Anthony remained voluntarily illiterate because of the corporeal and worldly nature of writing: that the word is "polluted by the ink" (Harpham 1987: 6). The spoken word, or even the word read aloud, however, is capable of "redeeming" language, redeeming the aligned incorporeality of the soul from the 'body' of the text. As such, Harpham identifies ascetic linguistics with the logocentrism described by Jaques Derrida (*Ibid.* 8). However, he also notes that the inverse interpretation can also be true: that speech "reactives the body, destabilising the meaning by tangling it up in time and the flesh," grounding spoken language in its materiality, while the text raises the departed by presencing them, and deadens the material (*Ibid.* 15). Our binaries pile up around us, yet rather than dividing the world neatly in two as they should, they are messy and unclear, some chains of signification cross boundaries, connecting opposites. The deadness of writing and the aliveness of speech can both, based on context, be inverted. "No matter what is said about the areas of language we have been looking at, the opposite is also justified"

(*Ibid.* 17). As Harpham notes, “the durability of asceticism lies in its capacity to structure oppositions without collapsing them, to raise issues without settling them.” (*Ibid.* xii)

This notion is discussed by contemporary theorists in terms of the ‘torque’, and is a concept which will be useful for us in our discussion of the binary-work of astronomy. The torque describes internal tensions that exist in the world which problematize the internal consistency of projects such as that to efface the human. This is often described in explicit reference to materiality: Timothy Carroll puts it, the way in which “objects (and images) have the capacity to turn in unexpected ways” (2018: 2). Carroll here draws on the work of Christopher Pinney, who, in his discussion of materiality, expresses concern over how, in the age of “late purification,” social theory has socially determined objects, to the extent that the object becomes erased, replaced with their social construction. He proposes that we might discuss “materiality” in terms of an inscrutable or uncooperative aspect, as “that (figural) excess, or supplementarity, which can never be encompassed by linguistic-philosophical closure.” (2005: 266) Similarly, Victor Buchli draws his discussion of the torque directly from Harpham’s discussion of an indeterminacy of signification, and points it towards the way in which “the rejection and mortification of the world is, despite what it appears to refute, a profoundly sensuous and embodied activity” (2016: 18). To return to our revolutionary framing, asceticism, as a revolution against the worldliness of the human in pursuit of the divine, is troubled by its inevitable participation in that world, and its necessary use of the “ready-to-hand” in its execution (*Ibid*.). If astronomy is to be conducted in a predictable way—if errors are to be put to work and built upon in pursuit of a more perfect image—then the material and semiotic alterity described in the torque troubles this effort. As I shall describe, astronomical practice is always intruded upon by its human worldliness, a cyborgian mixing-up of nature and culture, causing photons and images to move in unpredictable ways that both ascetics and astronomers grapple with in their respective practices.

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This section has had one overriding task: to explore the history and meaning of the tense process that I call the *Copernican Engine*. To my mind, the Copernican Engine is a moral orientation that sets the standards for what counts as legitimate knowledge. This moral orientation opposes the subjective to the objective, and asserts that we cannot have the former while we tolerate the latter, so insidious is its capacity to disrupt and undermine our task to know the world-in-itself. The Copernican engine is a mechanical and revolutionary social device, demanding the constant overturning and challenging of given and assumed knowledge in pursuit of the utopia of objectivity. In outlining what I believe to be the fundamental ideological force behind not only astronomy but modern scientific endeavour more broadly, I here identify the idealised form of the relationship between human and cosmos: a relationship which, through the mastery and curtailing of our social and subjective excesses, affords us the capacity to render the social and natural world visible and workable through technical interventions. In the following chapters, I shall explore how this engine is put to work in astronomy, how this practical application strains it to breaking point, and how this strain affords astronomers insight into why the broader projects it informs seem to also be falling apart.

3. Places

For the last 5 years (save for the COVID-19 lockdown beginning in March 2020) I have made the same walk on the last Wednesday of every month to the same meeting. While this is by no means the limit of my astronomy, it has formed the backbone of my experience, and served as my own little ritual of access to that other world we call the universe. I would stay at my university department, before setting off at around 5:30 for the 30-minute walk to the site at which we would all meet. For most other people, this walk was slightly different and a little shorter from Camden Town underground. Some others, travelling from outside of the city or blessed (or perhaps cursed) with a car would park right outside the park. For me, this walk varied from bright and pleasant to cold and dark depending on the time of year. It was held in the large royal park in central London. On most days the park was closed by the time the event started, but the organisers had an agreement with the Royal Parks charity that one gate and a coffee shop would be left open until 10 pm once a month so that astronomers and members of the public could gather and stargaze. This agreement was, as one of the organisers regularly complained, a tense relationship, which he got the distinct impression that the park's managers resented for practical and particularly fiscal reasons. This particular gate was, of course, on the opposite side of the park from my starting point, and, with my strange inability to be on time enough to catch the others before they closed, I always ended up going the long way around, skirting the playing fields and broad hedges of the island of green in the sea of concrete and asphalt.

Stargazing season is generally considered to be in the darker months, from around October to March. Seeing conditions are better then with less humidity in the atmosphere, and the nights are longer, while at the height of summer, the 6 pm start meant that there was more sitting around and chatting than stargazing. This suited me fine, as it gave me an opportunity to soak in the kinds of discussions that were had—to hear what was happening in the sky that month, recent discoveries in science, the recent trip someone took to Chile to take pictures in the pristine conditions there, the news of the day, or whatever else swirls around that small, sheltered part of the world.

In the winter, on the other hand, arriving at 6 meant the sun had already set 2 hours ago, giving the place an entirely different character. The bright clear sky is replaced by the sodium glow of London street lamps that bathed the street in an orange hue that petered out a couple of metres into the park. The dark expanse around which I walked had, for someone so used to a nighttime reclaimed by electric lighting, a slightly ominous character. There are few places in the city where such absolute darkness is possible, and few of them are the kind of places I would usually want to venture.

Arriving at the ‘monkey gate,’ left open for the event, attendees are greeted by a sign bearing the name of the group, illuminated by a pure white bulb that stands out in the yellowish ambiance of nighttime London. Beyond it, in the distance between the trees that hug the hedged edges of the park, sits the Hub. It is a squat, cylindrical, metallic building, sitting upon a clearly man-made mound of earth and grass in an otherwise flat expanse of green. It almost had the visage of a UFO from old sci-fi movies that had once intruded upon this place and had since been buried by time and repurposed as a coffee shop by the indigenous species. During the summer, the Hub looked out over the playing fields filled with games of cricket and football, but in the winter it shines like a lighthouse in the middle of a pitch-black void. It is about 300 metres of path from the monkey gate to the Hub and the walk can be disconcerting at the best of times. I have on several occasions been asked to walk certain (particularly female) friends from the nearby tube station because of it. Entering the park feels almost like leaving the familiar and mundane visibility of the city for a dangerous gloom.

In contrast, the Hub is inviting, its warm lights spilling over the immediate surroundings through its glass walls. Like that of the streetlamps, this peters out around the point where the concrete ends and the grassy slope begins. If you were to arrive any time after half past six you would likely find a ring of telescopes and their astronomers occupying this twilight zone between the light of the Hub and the darkness of the surrounding fields, looking out into that dark, but ready to hurry back to the warmth of the coffee shop, where it was just about illuminated enough to operate, but

dark enough for the operator's eyes to begin to acclimate to the dark. This stark contrast between bright, social spaces, where old friends can chat and meet members of the public enthused about the night sky, and dark spaces where that sky can be observed, makes this setup perfect for a particular kind of social stargazing. Astronomy is often a solitary, cold, and dark exercise: long, drawn-out adjustments of instruments performed under conditions that still permit astronomers to make out some of the faint objects they observe. The Hub's luminous liminality—its combination of light and dark—positions it as both a social and a cosmic space.

This dark space beyond the ring of telescopes spans around 300-700 metres on all sides to the park's edge. This green space is lined with trees and hedges which shield the area from the first 20 or so feet of the surrounding urban landscape, preserving some of the space's gloom. Beyond that, buildings erupt through the treeline, the lights of human lives shining in the distant London night, harsh and glaring once one has turned away and become accustomed to the dark. The skyscape is dominated by a couple of prominent central London towers, one of which shines with advertising screens twenty-four hours a day, seven days a week, and inevitably serves, alongside the moon, as an inevitable point on which eager stargazers train their scopes as a joke or when they get bored on overcast nights. They all have a halo of slightly bluer and sometimes even yellowish light than the sky directly above our heads. While it doesn't deter them, many find it disquieting, and I have more than once heard the night sky in London referred to as "sickly".

On a regular night, the Hub and the surrounding space hosts around 100 people, with some nights seeing upwards of 300 flood the coffee shop looking for a view of the stars. The vast majority of these are members of the curious public, who mill around the regulars and their equipment, watching their work, asking questions, and every so often stooping to look through a telescope. For the regulars, it is an option not only to help members of the public inch closer to a cosmic perspective, but also to catch up, compare images, and compete with each other to capture the best view of a given object. Throughout the night, queues will form behind particularly elaborate setups. One

favourite, which I and a group of my regular fellow travellers nicknamed ‘the cannon’ was a particular favourite; it was a custom build that looked like two oil barrels strapped together and mounted on a set of casters, and its impressive size translated directly into some of the clearest views of Jupiter and the Orion Nebula, objects which ‘lesser’ telescopes can struggle with. Demonstrations of radio astronomy and John’s crash course on astrophotography were also major hits. His setup swapped an eyepiece for a camera, which trailed cables to a laptop which rendered images of nebulae before the onlooking crowd. Many of the regulars I met there exuded the enthusiasm of natural educators sharing their passion and, indeed, their world. with curious witnesses.

This is a space for this particular, social kind of astronomy. It is by means of this outreach, this stated goal to “share the outstanding natural beauty of the universe with London’s population who might otherwise be unaware of it” (BSIA[a] 2023), that this location is permitted by the London park authorities to be turned into a conduit to the cosmos. While this fieldsite speaks closely to a particular sociality of astronomy—to certain notions of publics, access and heritage—it is only part of the astronomical picture. The ‘real’ astronomy, the astronomy that produces the views and images which swirl around our astroculture (as if we would ever call this kind of social astronomy any less real) happens elsewhere, in the dark recesses of London, where individual astronomers or small groups strain to bring the cosmos into focus. It is here that astronomers push themselves to really reveal the content of our skies. Astrophotography is a long and painstaking practice inappropriate for a social setting. John only managed to capture photographs in the timeframe of the meeting by taking short exposures of the Orion nebula, a relatively bright and easy-to-image object.

This chapter concerns itself with the first step of the process of astronomy: finding a place that is appropriate for seeing the sky. All astronomers must to a certain extent attune themselves to the environment in which they work, but the urban landscape is unique for its hostility to good conditions for seeing. Here, I will outline the sustained and intimate work both with and on the environment that goes into navigating such obstacles and, ultimately, causing them to disappear. I claim that this labour is

directed towards finding and producing spaces that are phenomenologically, symbolically, and affectively separated from the city. As work that is at odds with the usual function of a city, I would like to discuss how their practices lead astronomers to learn to see their urban environment in a new light, and how this reorientation raises moral concerns about the tense cosmopolitical relationship between human and natural world at play in such landscapes.

3.1. The Problem of Locality

> "Truth is a matter of context, and if we place ourselves outside of it—as the man of science is bound to do—what appeared as experienced truth first becomes confused and finally disappears altogether." (Levi-Strauss 1966: 254)

Astronomy is not generally seen as a local practice. As I have explored extensively, and hope to explore further here, astronomy is generally thought of as a super-cosmopolitan practice which reaches beyond even the global, for the universal. In this pursuit, science in general, and astronomy in particular, has always been an effort to erase "artefacts of local conditions" (Hoeppe 2012: 1142). Here I intend to identify the ways in which the local becomes a critical and inescapable point of engagement: how astronomers seek to delocalise the knowledge they produce, and how this inevitably requires a sustained and intense engagement with the landscape and their environment. As such, a part of the intractable failure of the image comes from this inability to erase these artefacts of the local: how it can be mitigated but never truly transcended. This allergic stance to the particularities of the provincial and the local comes from astronomy's aspiration to the universal, from the need to bring all things into one another's context and link them by an undergirding structure that is critical to making sense of the cosmos. Before we explore how the astronomer is dragged down to earth, I would like to explore why they aspire to escape it.

Scientific cosmology is defined, as an axiomatic principle, by a singularity or unity. This unity is defined by two ontological modes, nature and culture. All things

within naturalism are a function of and participate in the natural ontological category or pole, and all other things are derivative of it. Events and entities, being singular instances of a broader structure, can therefore only offer partial images of broader trends, patterns and rhythms in reality, which call upon us to infer and test their linkages. Put in the terms of Charles Sanders Pierce's semiology, we investigate the cosmos through following iconic relationships (resemblances) to their indexical source (causal connections) (Keane 2005: 186). These structures are essential to the firm ground which permits us to codify, know, and work within the cosmos. As Alfred North Whitehead puts it, "In the first place, there can be no living science unless there is a widespread instinctive conviction in the existence of an *Order of Things*, and, in particular, an *Order of Nature*" (1928: 4).

The prevalence of animals with four legs, for instance, is a pattern of iconic resemblances that can be observed in the natural world, and charted back to indexical, causal chains, be they a shared evolutionary history or convergent development linked by common environmental pressures. Another example, more pertinent to discussions of the cosmos, are given by Helen Czerski in her popular physics book *Storm in a Teacup: The Physics of Everyday Life* (2016). This book is oriented towards making sense of just the kinds of impositions made by cosmic structures upon the world 'down here,' how they manifest themselves in our 'plane of existence' and how we go about scaling up by tracing those connections. As she notes in the opening of her book, "We live on the edge, perched on the boundary between planet Earth and the rest of the universe" (*Ibid.* 1). It is this marginal position which means that special efforts must be made to discern the rhythms of the cosmos: it is the business of science, astronomy included, to manage the scalar work between the cosmos and everyday life, to extrapolate experiences into structures and recover them back into our everyday experiences (Rovelli 2017: 249). The titular 'storm in a teacup' describes the resemblance across scales between the swirl of milk into tea, the spin of a hurricane, and the spiral of galaxies, and the way in which the form of a spiral constitutes a pattern which recurs suggests a deeper structure which links these different instances. This is

the move between what Pierre Bourdieu called “phenomenological” and “objectivist” knowledge (1977).

Within this rhythmic ordering of the cosmos, there is, of course, syncopation: rhythms which misalign, which seem to belong to different melodies, which occupy radically different and decoherent realms or scales of the cosmos. Shahn Majid establishes the production of coherence and the resolution of this syncopation as the driving force behind the history of physics:

> “Physics is in a sense dynamic, with theories merging into more general ones as physics evolves. I think a key element to the dynamic here is an ‘urge’ coming from the nature of being a physicist that structures should interact. One is not really happy with X and $\dot{X}$ as independent bits of reality. So long as they are both ‘real’ they should be a part of some more unified structure. This creates a kind of ‘engine’ that could be viewed as driving the evolution of physics,” (Majid 2008: 117).

It might be said, therefore, that this unity that defines science drives a search for structuralism: it seeks to take seemingly disparate and changing phenomena and systems and find consistency within them: to construct conceptual infrastructures. When something changes in space or in time, what is the governing rule which stays the same, which informs the nature of that change? This quest to find the structures that underpin all phenomena can be said to be an effort to make knowledge *durable* (ordered through time) and *mobile* (ordered through space) (Law, cited in Allain 2013: 34). Key concepts within scientific cosmology are the ideas of *homogeneity* and *isotropy*. These concepts, respectively, claim that, on a broad enough scale, the cosmos looks the same at each point, and in each direction (Liddle 2003: 8). The cosmic perspective, in theory, should be one from anywhere, and should replicate the same cosmos from each point. We might say that the cosmic perspective is one of *indifference*, in that it presents the unity (lack of difference) across the cosmos by being independent of (not caring about) its particular position within it. It therefore looks to stabilise knowledge by uprooting it, making it alienable and fungible in the same way

that mechanical reproduction does for the work of art (Benjamin 1969) or capitalist extraction does for matter (Tsing 2015: 5).

This unification gives the scientific cosmos a diffuse and entangled aspect. Phenomena always recede deeper into the cosmos, existing with reference to other aspects that are conjoined by their being subject to similar forces and impulses. To make sense of this web of influences, we might think of the cosmos in terms of *systems*. Valerie Olson, in her ethnography of the various environmental considerations involved in space-oriented projects at NASA, discusses "systematicity" as "a modern ordering schema that relates different parts and makes those interrelations sensible as systems both of and with other systems" (2018: 37). A system is a 'cut' made in the world where it can be said that a system is, to a certain extent, an entity in itself, consisting of its own inter- and inra-relations. Consisting of 'cuts,' systems are works of artifice, and while natural boundaries assist in legitimising these cuts their intra-relations mean that their distinction is only a matter of functional and analytic utility (*Ibid.* 6). This is to say that the boundaries of systems are *porous*, affording movement into and out of those systems. They are nested, so that they are contained within systems of systems or "metasystems". The human body is a system which at once contains myriad systems of organs and organisms, while also being encapsulated within broad overlapping systems of ecology, politics, social works, constructions, "surrounds" (Turner 2013: 3) and material movements and forces. The human body is contained within the ecological system of systems that is the Earth, which is in turn encapsulated within the system of bodies we call the *solar system*. Scale up far enough, and we reach the greatest metasystem, the cosmos. We might understand this entity as a being defined by its nature as a container system, a system which encapsulates all other systems. This nested quality of systems means that thinking about the cosmos on these terms means scaling up and down into dimensions and proportions otherwise unavailable to humans—to come into contact with what Timothy Morton calls *Hyperobjects* (2013).

What we can identify here is a broad emphasis in scientific theory on the expansive, the cosmic, and the structural, at the expense of the local. It is an attitude

that is reflected in Stephen Shapin and Adi Ophir's discussion of the relationship between scientific work and place, when they identify the "idealist orthodoxy" that "if it is maintained that ideas have worth by virtue of the disconnectedness of their production from practical affairs or from the customs, conventions, and interests of particular cultural contexts, then the display of their location can be mobilised as criticism" (1991: 4). Götz Hoeppe identifies this impulse in astronomical work, and particularly with reference to the observatory as a site of scientific work. "Practices at the observatory are inevitably specific to local arrangements of instrumentation and modes of usage, but they are generally directed at producing data of trans-local epistemic use, and at making these data—purified as much as possible from the traces of the local—mobile and accessible for combination with data from other instrumentation elsewhere" (2012: 1149-1150). While amateur astronomers are not blessed with the technologies or positionings of professional observatories, I claim that their goal is similar: to produce images that are trans-local, by erasing the 'noise' of the city so that they can get at the 'signal' of the cosmos.

3.2. Establishing Infrastructures

As I previously noted, astronomy is fundamentally the work of establishing transparent infrastructures: of getting at and guiding flows of photons that enter the Earth's atmosphere from the cosmos in a way that retains the primordial truth of their origins. This retention is made problematic by a whole host of local artefacts and idiosyncrasies that might trouble these infrastructures. These phenomena are by no means unique to the city, but here their impact is more acutely felt. It is for this reason that both myself and the BISA chose the city as the site of our work: I am interested in the particular ways in which astronomers engage with this antagonistic relationship, while the BISA members feel that this is the place most in need of reconnecting to the cosmos.

When planning a night of stargazing, astronomers are concerned, broadly, with two variables: *transparency* and *seeing* (Scagell 2014: 15). Both, as suggested before, are about managing the photons that make it to Earth so that the photon-event can do

its transformative work. Maximising both means producing an ideal setting for image-making. Of their many light-years of crossing the vacuum of interstellar space, it is the last 100 kilometres or so of the photon's journey—through the Earth's atmosphere—that are the most turbulent. The ubiquity and insubstantiality of light and atmosphere belies the materiality of both, and the fact that these two materials often get in each other's way. Seeing refers to the steadiness of the image, referencing the stillness of the air, while transparency, as one might expect, refers to a medium's affordance of radiation to pass through it. Poor seeing manifests in images which wobble and undulate as if behind a heat haze, as the photons are jostled by the stuff of the atmosphere, and gives rise to the star's characteristic twinkle. Seeing tends to be worse when objects are low in the sky, because the fastest way through the atmosphere is directly up, at the zenith of our position. Poor transparency can be anything from light cloud cover to a huge building that obscures your view.

Atmosphere is here a crucial concept, in that it is the medium in which astronomers operate, and a key point of cosmopolitical and ecological concern; it is all-encompassing, inescapably shared, increasingly fragile, and crucially precious. As one informant reminds me, other planets offer perspective on this: the faltering of Mars' core and by extension magnetosphere allowed its atmosphere to be stripped by cosmic radiation, while the hellscape of Venus arises from an overabundance of greenhouse gases. The particularities of our atmosphere are the great gift bestowed upon us by our planet. By means of all of our participation in it, we are inescapably entangled and our well-being is displaced into others, human and nonhuman. But it is also something around which they must work. They must be attuned to its particular conditions, and learn to read not only the sky, but the medium that stands between us and it.

As such, ecological concerns are felt closely by the astronomer, because in order to find a place for astronomy, they must be uniquely attentive to its phenomenology. The atmosphere is also a key constituent of place: as David Valentine notes, it can refer both to the mixture of gases and particulates that serve as the medium for our lives, and a "metaphor for context" (2016: 513), emphasising the radically recontextualising

capacities of leaving the Earth and taking atmospheres with us. Atmosphere is also used as an affective term. As Tim Edensor notes, “As well as light, the quality of air, temperature, sound, smell, and textures adds to the tone of a place and event” (2017: 140). Atmosphere therefore serves as an amorphous, multiple and dynamic entity which resists purification. In Edensor’s words, “atmospheres thus circulate between the objective and the subjective,” (*Ibid*.). This makes it even more semiotically crucial that the duty of the astronomer, ultimately, is to transcend atmosphere: to attain perfect seeing and transparency—a cosmic perspective—as if situated in the void.

Many factors go into the quality of seeing and transparency, and in finding a place for astronomy one must contest endlessly with such factors. Weather, itself being that ‘stuff of the atmosphere’ is perhaps the most prominent example. “Astronomers,” Robin Scagell reminds us, “are always at the mercy of the weather,” (2017: 11) a fact that immediately became quickly apparent to me, as the great British pastime of chatting about the weather took on a role beyond mere small talk. It is a running joke among many astronomers, born doubtlessly from experience, that if something interesting is happening in the sky, there is going to be cloud cover (see *Fig. 3*). Aside from moving air, water vapour is problematic. Warm, humid air which might make a stargazing night less bitter tends also to lead to ‘milky’ skies which lower transparency. The weather, like many things in astronomy, is a trade-off; looking at ‘planetary’ objects like the Moon and Mars means you want humid, misty nights with steady air, while ‘deep sky’ objects which lie beyond our solar system are best seen on cold, arid nights when seeing tends to be at its worst (*Ibid.* 16). My nights of astronomy both alone and with others were endlessly frustrated by unpredictable weather conditions, and indeed agreements to meet up and stargaze were always tempered by a light-hearted scepticism about the weather that I picked up quickly from other astronomers.

Being an astronomer often means not only understanding astronomy but also chasing its traces down lines of interconnection to the systems in which it works. Doing astronomy effectively almost inevitably leads to a familiarisation with the landscape of scientific disciplines which lie on its borders. While this familiarisation and the dynamic

and virtuoso management of place and light forms the basis of practical knowledge (which I will discuss more fully in 4. Practices) it is of note that learning to plan a night of stargazing means developing a particular understanding of weather systems and forecasts. The light to which astronomy is so attentive also makes tangible particular weather conditions which would otherwise be inconsequential to us. Systems of high and low pressure are, for many, secondary to the brute question of what the weather will be like, but for astronomers these systems produce particular seeing qualities and degrees of transparency which are crucial to planning. Amateur Astronomers, out of practicality, often find themselves also as meteorologists, and plans must be made flexible enough to call the whole thing off at the last minute when the forecast is inevitably wrong.

British astronomers, of course, must come to terms with the unique weather conditions they find themselves subjected to. As I was told repeatedly, British weather is particular due to its position as an island bordering the Atlantic, buffeted by low pressure, high moisture “troughs" from the tropics which bring rain and clouds, and cold, dry polar air from the north, which generally marks the most transparent nights. Being in the firing line of the jet stream which brings these fronts to London makes astronomers particularly attentive to it. As one informant noted, “British weather is either terrible or excellent. It's never really just alright.” Atmosphere, therefore, shifts from being something broad and global, which envelops us all and contextualises our actions, to something particular to place, insofar as we can have ‘British’ or even ‘London’ weather. Astronomers must, in being at the mercy of the weather, contend with the specificity of these meteorological folds in our atmosphere in a deeply particular and localised way.

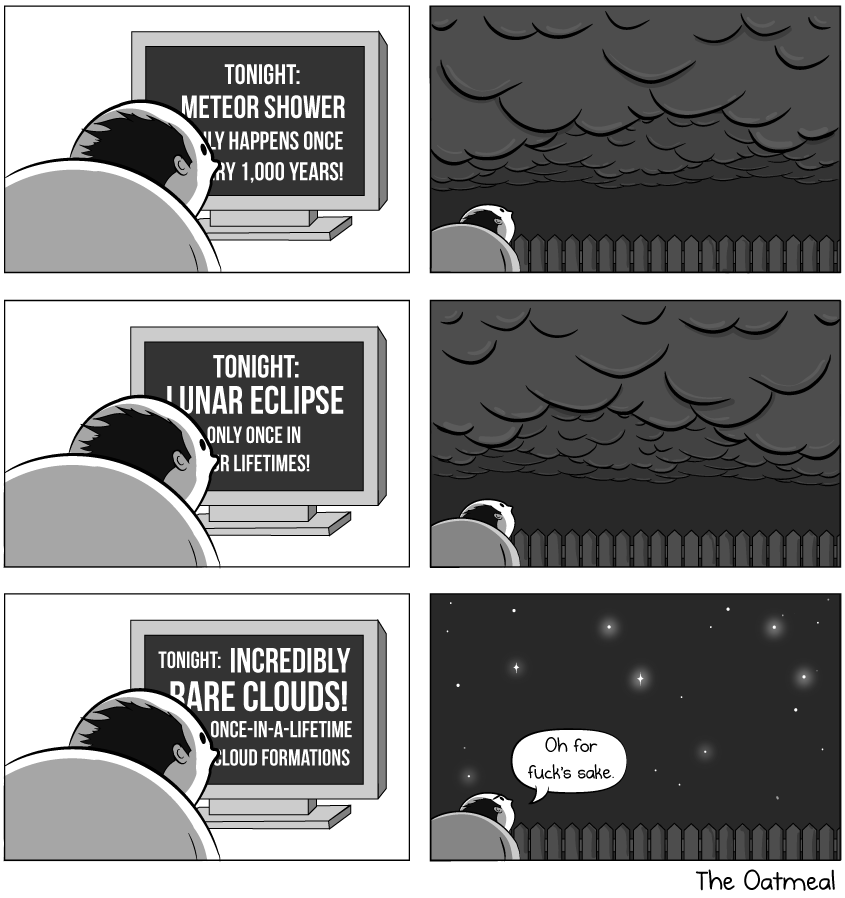

Fig. 3: Celestial Events, a cartoon by 'the Oatmeal', which finds itself shared regularly on astronomy-oriented social media, and displays in clear terms the frustration of astronomers' dealings with atmosphere (The Oatmeal 2020).

One of the crucial obstacles specific to urban astronomy is the issue of light pollution. Astronomy is not just about gathering faint light, but also making a judgement about that light as to its appropriateness. Often, other light sources can infiltrate these infrastructures, feeding the telescope photons that are not from the desired source. Machines and instruments have an array of advantages over the human organs they supplant, but at the end of the day, they largely lack the judgement of humans. They have no means in themselves of differentiating the sources of any given light. The business of astronomy, traditionally, has been to gather photons which carry the genuine 'signal' of the phenomenon and try to minimise the 'noise' of other light sources that one might capture. This, again, is the trade-off that must be made in doing astronomy. Astronomers have a set of practices at their disposal to maximise their

light-gathering capacities, but boosting signal always boosts noise with it (see Fig. 4 & 5). Imaging the cosmos means making cuts between objects and surplus signals, namely, purifying the natural light of cosmic objects from synthetic man-made sources. Sometimes, these processes of purification can be outsourced to imperfect computer programs through particular processing techniques, or even done 'by hand' (see 2.4 Producing an image) but concern for appropriate and inappropriate light runs through the entire process of astronomy.

When talking about how to do urban astronomy Scagell implores stargazers to "know your enemy" and counts streetlights alongside the weather as a primary antagonist against which we must work. There are several forms of light pollution. The "glare" of naked bulbs that give streetlights their harshness is one with which city dwellers are all closely familiar, but the worst by far is "skyglow," whereby the whole sky is turned an ambient and murky brown/orange by large light sources (See *fig. 4*) (Dunnett 2015: 620; International Dark-Sky Association). This ambient, all-pervading light pollution is part of the reason that so few cosmic objects are visible in London's night sky. Often, only some of the planets and the brightest stars are visible to the naked eye.

Light pollution is often conceptualised as a troublesome human intrusion into the natural world. On their page about light pollution, the International Dark-Sky Association quote Havelock Ellis in saying "the sun, the moon and the stars would have disappeared long ago… had they happened to be within the reach of predatory human hands" (International Dark Sky Association). When speaking about light pollution, astronomers despair over the moral conundrum it poses us. They describe it as the result of "irresponsible city planning," yet also recognize that there is no individual blame to be attributed, and as a result few avenues for its correction beyond appealing to local councils. This is also problematized by the acknowledged benefits of nighttime illumination: the reclaiming of the urban night for legitimate and, most critically, safe human activity—a historical process Craig Koslofsky calls "nocturnalization" (2011: 2)—is part of an idealistic modernising process by which humans rework the world

around them to make it more appropriate for their lives. The ambivalent status of light as both a focus of work, a tool for colonising the night and unwanted excess leaves many astronomers resigned to the fact that skyglow is here to stay. They have come to terms with the idea that it is, unfortunately, an ugly feature of the city. They are a constituent feature of what Oliver Dunnett calls the “contested landscapes” and “moral geographies” of the British night.

Fig. 4: London Skyline, an image I took of the view of London from the Hub looking southeast. Taken around 9 PM, two hours after sunset, the overcast sky displays the trademark orange skyglow of light pollution projected onto particulates in the air from the centre of the city.

One of the more sinister obstacles that light pollution highlights is the swirl of particulates and gases that encompasses the city, which we more often refer to as “pollution” or “air pollution”. Scagell asks pointedly, “Have you ever wondered what the city lights are shining on? The atmosphere contains more than just air. It carries gases, aerosols and dust particles from industry, aircraft, wind-blown soil, forest fires, volcanoes, and meteoroids, maybe pollen grains, and, above all, water vapour” (2014:

11). In its traversal of the earth's atmosphere, photons are buffeted and reflected not only by air particles, but also by the airborne byproducts of human technology, concentrated as they are in the city landscape, and contributing to both skyglow and the wobble that constitutes poor seeing. London has a rich and well-charted history being associated with pollution of various kinds as far back as the 1600s (Corton 2015; Porter 2000). Astronomers are acutely familiar with this historical and ongoing feature of London's airscape, often referring to it by the old adage "the big smoke".

Fig. 5: *High Exposure,* a photograph taken moments later with an increased ISO (camera sensitivity, see 2.3.1 The Anatomy of a telescope) to demonstrate the effect of excessive noise. When I showed this image to my informant, they said that it looked "like a nuclear bomb had gone off". This is not too far from the truth, as the camera sensor, overloaded with stray ambient radiation from the city, loses the ability to distinguish the sky from London lights.

No visible cues announce the presence of air pollution in everyday life. London is not (or at least, is no longer) prone to smog. As an invisible and malign force, known to inflict harm on both the planetary environment and human bodies, air pollution becomes a site of threatening uncertainty. In her work on uncertainty, Michelle Murphy notes the

emergence in the 1970s and 80's of a nebulous set of symptoms: "a messy litany of runny noses, scratchy rashes, endless fatigues, burning inhalations and queasy stomachs" (2006). While the cause of these ailments was initially a mystery, it emerged that these were the result of repeated exposures to the carcinogens and contaminants present in a new design of environmentally self-contained buildings. It is only through the ailing bodies of those who used them that this threatening register of reality emerges. Like those bodies, astronomy, with its close attentiveness to the medium of the air, serves inadvertently as an infrastructure that affords access to this dangerous register. Astronomers are made aware, through their practice, that the orange glow over London is not simply the ugly remnants of our wasted light, but also evidence of this otherwise hidden aspect of our atmosphere.

All astronomers that I have met, uniquely attuned as they are to the environment, have expressed a deep concern about the prominent issue of pollution in contemporary life, and indeed the broader problems of climate change, to which I shall return. Similarly to light pollution, however, it is worth noting that this concern orients itself around human mismanagement of the environment in which they, and indeed the whole species, operate. As Andreas Malm notes, "Global warming is the unintended by-product par excellence" (2016: 1). It is just another element of the human world which must be effaced in order to get at the cosmos.

On top of all of these conditions, there is the issue of practicality. While I have already noted that while the astronomy community is effusively inclusive, there are certain constraints placed on prospective astronomers in the form of money and time, both of which astronomy seems to consume in abundance. Here emerges a particular class dimension of astronomy, wherein access to the cosmos is curtailed by not only education but also available resources for investment. The astronomy community is aware of such a problematic component of their work, troubling a self-image of lay expertise and inclusivity, and much work is put into mitigating these barriers. There is, for instance, an abundance of advice for "budget rigs," while this concern no doubt inspires the commitment of many to pedagogy, at least in part.

These barriers *can* be mitigated, but they can never really be removed (see 5.2 for a discussion of balancing money and time in the operation of telescopes). The fact that astronomy must be conducted in the dark, often late into the night, sets certain restrictions for people with busy work schedules. From the discussions I have had, it seems like most astronomers manage far less astronomy than they would like, largely as a result of work pressures. One key example is Wendy, the astronomer I discussed previously, for whom her child was a major impetus to begin doing astronomy. Wendy was a high-level manager, working in one of the skyscrapers that dot the London skyline, and for our interview, she invited me to her place of work during her lunch break, so busy was her schedule. She told me of how she liked her work, but how overwhelming it could be. She told me that her dream was one day to leave her job, and the city, and make astronomy her job, perhaps selling prints or running classes. I asked her if she thought that was a common dream. Her answer was unequivocally affirmative. From my time with astronomers, I can see where her answer came from. There is a whole cohort of astronomers who are eager for retirement, as an opportunity to flee the oppressive relationship with work, to spend more time, in part, doing astronomy. There are others, John included, who have already made good their escape and retired early. They are the envy of others, having the means to shed some of their worldly (or at least urban) trappings and live as the gentleman Victorian astronomers did, doing astronomy for the love of it.

Added to the issue of time and effort is the challenge and time investment of literally navigating the city, transporting expensive and cumbersome equipment to a place appropriate for stargazing. Given the impracticality of owning and operating a car in London, this is often by public transport. This was such an issue that my telescope saw less action than I would have liked, as I often opted to try capturing images with a camera and tripod alone. On top of this is the question of whether a site will even be open. Parks often hold the most promise, but many close at night. When it first came to looking for a place to do astronomy, I found myself at a loss, and had to turn to the community for guidance.

Another issue of practicality is safety. These parks are often closed for a reason: because unlit areas at night tend to attract criminal behaviour. Finsbury Park, one of the few central London parks that are left open at night, has a reputation in the astronomy community and beyond for being particularly dangerous at night. Indeed, this is a particularly noted issue for female astronomers, who often see themselves as particularly vulnerable in such spaces. I have known many informants, Kara included, who have asked me to walk with them from a place of safe luminosity into these dark spaces for stargazing, troubling further the question of accessibility to astronomy. This speaks further to the politics of light in which astronomers engage: They are caught between, on the one hand, the safe light that will ruin their images, and on the other, the threatening dark that makes them possible.

All of these conditions are set to the calendar of the sky, a practice which, as Anthony Aveni notes, is largely lost on the lives of contemporary people, made obsolete by technologies which supplant its traditional roles (2008). There is no point in aligning all of these disparate conditions only for there to be nothing to view. This became a point of particular concern when particular cosmological events took place. One key example was the emergence in our sky of the comet NEOWISE in July of 2020. Astronomers scrambled on online groups to secure lifts to dark sky sites or find appropriate stargazing spots during this event. For me, this event became a matter of trying to coordinate with other astronomers for an opportunity to do fieldwork that was ultimately in vain, and I observed the comet with a friend with experience in photography (*fig. 6*).

Fig. 6: *Neowise*. One of the unprocessed images I captured of the comet NEOWISE. The comet itself can be seen in the centre-right of the image. I left this image unprocessed so that the skyglow of London can be clearly seen in the gradient of darkness in the image.

3.3. Navigating the City

Once I had established myself at the Hub, finding a regular group of friends eager to share the cosmos with each other, we set about the optimistic task of organising smaller meetings amongst ourselves. It was here, and in all such meetings since, that the practical issues discussed above, which I was vaguely aware of in theory, presented themselves to me properly. In the warm, bustling, brightly lit interior of the Hub, my friends educated me, with the exasperation of experience, about these pitfalls, pointing out at the distant city lights to illustrate their points. Without the kind of purpose-built structures at the disposal of professional astronomers, their amateur counterparts must

conduct a kind of stochastic astronomy, seeking out places neglected by the nocturnalizing regime. One astronomer once described it to me as “kind of like guerrilla warfare,” smirking at his own joke. Fortunately for me, they and the broader astronomy community are a ready and eager resource on not only the nature of these problems, but the steps that could be taken to overcome them.

The recurring advice that I received was that it is completely useless to astronomers to think of a place in the abstract. My first intuition when thinking about finding a place to do astronomy was to pull out Google Maps, a habit from 5 years of navigating underground lines and bus routes. I quickly realised that this was grossly inadequate for anything beyond the practicalities of getting from A to B. The top-down representations with which we are faced when we do so tell us nothing of the light quality or skyline of any given space. It reiterated to me something that I had heard the archaeoastronomer Fabio Silva say in a talk he gave at the UCL Anthropology department in 2018: that if we want to understand a people’s relationship with the sky, we need to understand what it is like to be on the ground, to situate ourselves within their landscape not as an abstract representation but as a site of phenomenological experience (Radical Anthropology 2018).

Finding spaces for astronomy, it emerged, meant familiarising yourself with different phenomenological aspects of the landscape. As such, I immediately followed one piece of advice that I was given by Ian, an older, experienced regular, which was to “scope out" promising locations, going there ahead of time with no or minimal equipment to check out what the seeing is like there. One helpful astronomer used the Hub to illustrate what constituted a promising location. It was relatively far from light sources, or at least as far as one could organise a large gathering. It was in an open space with few blocking structures or trees, but that open space was also encompassed by a treeline that shielded it from the worst of the ground-level light that might illuminate it. With this in mind, I set about the groundwork of exploring parks for spaces that might fit this description.

I was advised that while I did so I should look out for and seek to familiarise myself with some of the other factors that might affect seeing. The first and most important thing was to familiarise myself with the night sky. Understanding where a given object will be and when is crucial to working out whether a location will afford a clear line of sight to the object. This kind of familiarity with the night sky has never been a strength of mine: I was always more interested in the abstract representations of the content of the sky than its actual phenomenological appearance, and less the movements of bodies across it. Fortunately for me, there is much assistance to be had in this regard. While many astronomers familiarise themselves with such movements, there are also a wealth of apps that display the night sky and its contents in real-time, of which I ended up favouring SkySafari and SkyView Free. After a couple of outings, I had a routine sorted, orienting myself with a compass, then using the app to identify some of the brighter objects I could see to get my bearings. For this, the fact that only a few objects were visible actually became an asset. After a couple of nighttime excursions on Hampstead Heath, one of the larger London parks that were left open at night, I had tagged a series of spots on Google Maps from which different sections of the sky were visible.

I was also told how to read pressure fronts on weather forecasts, what kind of weather events they produced, what they might feel like, and when relative to them would be best for organising an astronomy outing. For instance, some astronomers rush out to do astronomy on nights with short, sharp downpours of rain, because that rain “clears” particulates from the air. As I have noted, astronomers are largely at the mercy of the weather, but developing an understanding of such systems can largely help to dodge the worst of it. Light and air pollution are more difficult to contend with, as they tend to be a more constant factor. However knowing where any spot is relative to the dense, brightly lit core of London means that one can position themselves so that its skyglow is less intrusive. In the interest of observing the southern hemisphere of the sky, I ventured south of the river on a couple of nights to ‘scope out’ some potential viewing spots.

Another key piece of advice I was given was to attune myself to different qualities of light. In his work on the phenomenology of light and darkness, Tim Edensor notes the way in which lighting regimes reconfigure the way in which spaces are occupied and produce experiences, and that jumbled city lightscapes can be disorienting, themselves being the products of an uneven and "improvisational" process (2017: 55). London is perhaps one of the best examples of such a process, given that the metropolis is the result of hundreds of hamlets and villages consumed by a process of urban sprawl, with each borough managed by its own authority, often sporting their own lighting regimes and streetlights. This is often referred to as "light clutter" (International Dark-Sky Association). Edensor notes of the comments of the light designer Mark Major, that in London "a chaotic jumble of different forms of light are subject to no overall plan or regulation. Major points to the overlaying of different technologies and styles for more than a century, as well as a lack of distinctively local designs tailored to characterful areas and an overwhelming focus on functionality" (*Ibid.* 56). These qualities and regimes of lighting are an aspect of London to which astronomers are acutely attentive. Different streetlights or illuminated shop signs give off different amounts and spectrums of light. It is noted, for instance, that more modern LED street lamps, marked by their whiter light, produce far less light pollution, and lack the aggressive glare of their yellow low-pressure sodium counterparts. Learning to navigate the London nightscape meant also paying a level of attention to the different kinds of light that populate nocturnal London.

I found myself putting this advice to work whenever I was out at night, attempting to judge the quality of a space for astronomy. Once one has learned to see the urban landscape as an astronomer, in terms of evading all of the excesses of the city that obscures the sky, you can sometimes happen across places that stand out as optimal for viewing. This sometimes happened to me when walking to get a bus home from a friend's house in the suburbs. Learning to see urban landscapes like an astronomer also gave me a certain appreciation for the rural. On the rare occasions that I managed to escape the city, I was struck as I never had been before by the darkness that surrounded me.

The practicalities of getting to and from any given site remained the most stubborn problems of navigating the city as an astronomer. While I was travelling light with the intention of getting a feel for potential astronomy sites I had few qualms with an hour-and-a-half night bus journey home, but the prospect of making this trip long after the faster and more convenient tube lines had closed, and with a complete telescope rig in tow, is a more intimidating ordeal. As I suggested, this compounds the busyness of city life, where schedules are often hectic and mismatched. During some of this project, I worked making coffee, meaning I had to wake up at 6 AM on certain days. On others, Kara had lectures. Simon and Dave had coveted salaried jobs with more regular hours, but those hours were often long and arduous, and once Dave had a child, around the midway point in my fieldwork, coordinating was even harder. Such negotiations over when and where we would make time for astronomy, given all of the other considerations that must be made for the environment in which we would perform it, made collective stargazing outside of the hub difficult and, as a result, scarce. It was always frustrating for all parties involved that modern, city life was once again intruding upon the cosmos.

The few times we did make it out to an appropriate site together we usually agreed on a nearby train station or transport link at which to meet. From there, we made our way on foot, gear in tow in suitcases or purpose-made carriers, into the dark, secluded part of the city we had chosen. Often this means a good 10-20 minute walk through a level of darkness many of us would usually never encounter. My first time doing so to scope out these sites was the first time in 7 years I had been in an open space that was almost pitch black, so far removed from the warm convenience of nighttime city life, illuminated only by the moon and the ever-present skyglow. After a while in the dark, the pupils of the eye dilate, increasing their aperture and allowing more photons in, adjusting to low light that makes it easier to both find our way and pick out faint points of light when we get there. As a result, as we walk, more stars appear in the sky that we would otherwise have had to squint to see.

Fig. 7: *The view from the heath.* An image of the London skyline taken on a scouting mission to Hampstead Heath with a friend. My friend, an experienced photographer, used this as a training opportunity, trying to adjust exposure times and depth of field to get all of the different lights into focus at once. We believed that the brighter light in the sky was Venus, while the dimmer one to its left travelled steadily and perceptibly across the sky, identifying itself as the International Space Station.

As we walked deeper into whichever park we had selected, the usual sounds of the city—the traffic, the people, the trains, and the other background ambience that makes up the cacophony to which urban dwellers are naturalised—died with the light, leaving us with another unfamiliar phenomenon: almost complete silence. All the usual phenomenological markers of the city were gone, or at least rendered distant.

Usually, we tried to aim for a high point in whichever given park we had chosen, for the simple reason that they offered great views of the city from a new, elevated

perspective (See *Fig. 7*). Once set up, we would often spend 3-4 hours stargazing depending on weather conditions, a process to which I will give due attention in the next chapter. By the time we packed up and made our way back into the city, it was usually around 1 or 2 in the morning, depending on the time of year. The phenomenological experience was the same in reverse, with even the muted sounds and lights of London nighttime often feeling disproportionately loud and bright by contrast.

3.4. Obliterating the City

On one occasion, I was sitting in a pub with my regular astronomy friends. We had agreed to meet partly just to catch up, but also to make plans for another astronomy outing. We were all feeling pessimistic about it: our last attempt had been scuppered by a last-minute turn in the weather. Looking at weather forecasts and trying to align them with people's schedules and the visibility of celestial objects, one of my informants chose that moment to say "you know, this is why professionals don't do astronomy in cities anymore".

This is of course true, for all the reasons noted above. The one true way to avoid all of the ailments of city stargazing without the unreliable practices we have to deploy is to leave it. This was recognized long ago by the institutions that build observatories. As Allain notes, the old city observatories such as Greenwich, or indeed the Cambridge observatory where I spent those nights learning about the cosmos are "now too small, old, obsolete and misplaced" (2013: 19). For most professionals, remote telescopes gather data and provide it to the researchers in their home countries (*Ibid.*) or those researchers travel out to the arrays to oversee the observing (Hoeppe 2012). The sites for these observatories are particularly selected so that they can avoid many of the excesses I have described, placed "into pristine environments, where signals from deep space can be recorded and separated from artefacts, "negative signals" caused by the pollutants of civilisation or specific disturbing conditions of their environments" (*Ibid*: 1149-1150). This includes sites at high altitude, with low humidity, that are far from any urban centres—sites that can produce images that can plausibly be taken from

‘nowhere’. Favoured places include the arid Atacama desert in Chile, home to European Southern Observatory telescopes such as at La Silla (Hoeppe 2012) and the controversial Mauna Kea site in Hawaii, considered to have some of the best sites in the world, and the proposed site of the Thirty Metre Telescope (Graham-Smith 2016: 61). Better still, one could leave the planet entirely, foregoing the disruptive power of the Earth’s atmosphere, and this is the reason that the Hubble Space Telescope has set aesthetic standards for astronomical work for years (Kessler 2012).

Given the favourable conditions here, it would be understandable if astronomers were to leave the city entirely, and indeed many of them do. In spite of the logistical inconvenience, many spend bank holidays hauling their equipment to “dark sky sites” around the country, where population density is low, and skies are proportionally undisturbed. Some even leave the country, the Great Rift Valley in Africa, the Atacama in Chile, and a variety of islands around the world being popular destinations. While few can blame those who flee, this work speaks to the people who remain within the bounds of one of the worst places in the world to do astronomy.

While we might be tempted to think of urban astronomers as more ‘in nature’ than the huge infrastructures of telescope arrays, they have far more atmosphere—far more *context*—to fight their way through. Amateur astronomers must therefore make do with the conditions we are given, and render themselves *plausibly* without atmosphere. I use the term plausibly here because of this impossible demand, an impossibility which returns to bite us. As Edensor notes, “Though we may only become conscious of it when we are immersed in an especially potent setting, atmospheres pervade all the spaces and times we experience" (2017: 160). By making themselves more sensitive to light, astronomers make themself more sensitive to the atmosphere and its contextualising force, which takes more fine, protracted work to plausibly overcome. To do so, we must find and make our own mountain tops and deserts in the city. It is only by finding dark and shaded places, where the streetlights don’t reach and where the sky suffers a little less from ambient glow, that we might follow Hubble in “relocating vision

to a plane severed from the human observer" (Crary 1992: 1). In other words, astronomy calls on us to discover wilds within the heart of the city.

The city is the site of a very particular cosmopolitics. Perhaps more than anywhere else, they are places where the world has been transformed into a human world. They are the Anthropocene given shape; cities are a site of management that we have refashioned into our domain with concrete and rebar. Their construction denotes the "arrival of a civilising order" (Holston 1989: 202) through which things are put in their right and functional place (Jacobs 1961: 25). It is in this sense that they stand against nature, in all its wildness. Unlike the rural, and especially the wilderness, they are spaces that we seem to have made entirely our own, achieved through the taming and clearing of wilds so that land may be made functional for human work. As such, they are the realisation of the "double task" of modernity to emancipate humans and dominate nature (Latour 1993: 11). It at least *seems* that the city is artefactual, by the standards set out by Marx: that they are the externalisation of an internal mental model or plan (Ingold 2000: 540). Cities represent our capacity to enact ourselves in and inscribe ourselves upon the world, placed as they are on one side of the "tension between the turbulence and uncertainty of nature's ferocity and the firmness and solidity of a human-made shell" (Akkerman 2009: 206).

My informants place the production of the city within the same trajectory as geoengineering, terraforming, and the colonisation of other worlds. As one informant explained to me, "We've gotten really good at controlling the environment in variously sized boxes. That's what air conditioning and central heating are. It's a bit reductive, but in theory, we just need to scale the same basic principles up." To colonise another planet, it just needs the appropriate geological and ecological systems, like making any other place habitable. Both cities and planets are optimal targets for increasingly refined human agency.

This discussion of cities is optimistic. It places them within a speculative historical trajectory of which many astronomers (but crucially not all, as I shall discuss in 6.

Apocalypse) are fond. However, the humanness of the city is also deeply problematic, in the ways I have described. It is an excess of humanity, embodied in the city, that sets it apart from nature, and obscures the night's sky, making it a space of ambivalent antagonism for them. It is at once the model for many of their desired futures, and the thing that makes it so that they cannot see the sites of those futures. The efforts I have described above can go some way towards symbolically erasing the city, but they can never erase it, and always work against the process that colonises other worlds. For those concerned with nature, the lights, pollution, and busyness of the city drags them down to Earth with the precise concerns against which the cosmic perspective casts itself.

For a model of how one is to deal with such an antagonistic space, we might turn to the work of Timothy Carroll, who conducted fieldwork with Orthodox Christians at St Æthelwald's church in central London, in which he speaks of efforts to produce sacred spaces in a landscape that is hostile to (or at least unfit for) the moral projects they seek to undertake there. Carroll highlights the historical grounds for this hostility: how an "ecclesiastical rift" emerged when the Catholic William the Conqueror brought his particular form of Christianity to Britain (2018:19). This rift forms the backdrop for St Æthelwald's Parish Church, and is made more prominent by the fact that, lacking a dedicated site of prayer, they congregate for their ceremonies in an Anglican church. As one parishioner claims, St Æthelwald's "plays church-in-the-box" (*Ibid:* 4). Carroll emphasises the central problem of such a situation: that the orthodox temple is supposed to be a sacred space, an "ikon of the universe" (*Ibid*: 131) operated in such a way that the cosmos might be manifested and interacted with by parishioners. It is precisely this capacity to stand for the cosmos—to manifest the radical scalarity of a unified world— which grants such sacred spaces their radical social power. The question these Christians face is, in Carroll's words, how they might "make heaven" in a heretical space, a project which, like astronomy, concerns making room for their social projects within the cluttered social and material space of London.

Carroll's ethnography outlines the process by which his informants 'make do' with the material at hand to produce a space of their own, in which they can practise their rituals and manifest their cosmos. In particular, Carroll's analysis focuses on the use of fabrics to sanctify the space and make it appropriate for manifesting the absolute reality of heaven. One key example Carroll uses to demonstrate this "middle-managed bricolage" (*Ibid*: 92) is the plan for a baptism, which would ordinarily be held in a fountain near the church that is used by the congregation, disrupted by maintenance work being done on the day of the ceremony. Carroll describes the process by which a cask is identified as an alternative baptismal vessel, and a means of making it appropriate for the occasion is worked out. As a part of this, one of the parishioners offers to decorate the cask with a white analogia cover.

While the particular practical work of manifesting heaven is something I will go into in more detail in the next chapter, what is important here is how this work is discussed by the parishioners with respect to the cosmos and the city: specifically about how the two are contrasted, and how, through practice, the former can be manifested and the latter can be erased. When the parishioner voiced concern about the decorative fabric being damaged by the water, the Priest who was to conduct the service decided that such decoration was unnecessary: "It was, he reminded them, 'the desert', and they had to make do with what they had." (*Ibid.* 93). As Carroll explains, in discussions of the city (often described metaphorically as a "wasteland") the desert is used as a motif that references ascetic practice as "a place of oasis and spiritual excellence" (*Ibid.* 94). The desert here stands both for the trials in which they must make do, and for the bare or blank space that can be produced, erasing the wasteland through the barren transcendence of the desert.

Elsewhere, Carroll refers to the work of Orthodox parishioners of St Æthelwald's in terms of an "axis of incoherence" in the "material register" (2017: 158). The space within the church is one of contestation in which two competing cosmoses jostle for space. Such a contestation between worlds can be seen throughout the division between the astronomers' cosmos and the lifeworlds of people down here which it tries

to transcend. Perhaps the best example of this is the “cosmological traffic jam” that contests the peak of Mauna Kea, Hawaii (Overbye 2016). The summit of the volcano, with its arid, remote, and high-altitude environment, boasts some of the best conditions in the world for astronomy, and as such has been a site on which many observatories have been constructed. The peak is also, however, sacred to indigenous Hawaiians who, in 2014, protested the proposed construction of the “thirty-metre telescope.” As David Jeevendrampillai once noted in passing, the issue of Mauna Kea is an issue of cosmological clash: the opening up of one world, the astronomer’s world, means the destruction of another.

The parallel between my astronomers and Carroll’s orthodox Christians is therefore clear. The social project of both is to access the obscured reality of the cosmos. In both cases, that reality is obscured by the city in which they seek that access and the social projects which contend with theirs for space and time. In the case of the parishioners of St Æthelwald’s, the city is thus reoriented into something to be overcome, even conceptually destroyed, so that the desert could be manifested and the reality available there could shine through. What I have described here can be made sense of best in just such a way: as an effort to symbolically render London a desert by finding or producing spaces in which its evidence can be eliminated so that they can attain a position/perspective that is closer to an absolute reality. We see here a kind of symbolic asceticism in astronomical practice, wherein it is the human world, and not the human itself, that must be mortified in the pursuit of the absolute. In her discussion of astern Christian ascetic traditions, Veronica Della Dora notes the significance of caves as “anti-landscapes,” in which physical vision is curtailed so that spiritual sight can be achieved, recognizing the incomprehensible and unspeakable torque of the divine resists literalisation. “Visual presence conceals spiritual absence; visual absence invites divine presence” (2011: 762). We can see in the ascetic work of astronomers a similar substitution of vision: of a practical, worldly vision for a transcendent way of seeing afforded by nighttime anti-landscapes.

This chapter, therefore, can be understood as an inversion of Lisa Messeri's work, in which she frames the practices of Mars scientists at NASA with whom she conducted participant observation as "place-making" (2016: 2). Their project is to turn the abstract data we have about these planets into locations amenable to imaginative occupation—the qualitative and intimate nature of *being there*. I argue that this is the inverse of the work my informants do: that in their repression of particularity, their relationship with London is an *unplacing*, of *place obliteration*. Places, Messeri notes "have a specific character that might change over time or be differently perceived from person to person" (*Ibid*.). Repressing the specificity of place—making astronomy mobile and durable—means repressing its *placeness*. Astronomy, here, becomes an effort to actualise a feeling described by Robert MacFarlane, who describes the feeling of looking up into a dark, clear sky as "a sudden flipped vertigo, the sensation that your feet might latch off the Earth and that you might plummet upwards towards space" (cited in Dunnett 2015: 625). In other words, astronomy seeks out analogues of the ascetic desert, bringing outer space down to earth and producing voids for ritual separation from the world of the city, and serve, like the desert, as a "nonplace from which the world could be condemned" (Harpham 1987: 21).

In discussing the work of the parishioners of St Æthelwald's with direct reference to failure, Carroll notes that while the incoherence which manifests around the material axis of the church is managed well enough for the liturgy to be performed, their work nonetheless fails. "the materials [...]—a parish church building, to be exact—never fully matches the aspirations of the community," and "the sensual quality of the space is not able to cohere to the Anglican material ecology of the place" (2017: 157-8). Like the fabric of the Orthodox temple, it is the darkness of the astronomy site which renders it practically and affectively appropriate, perhaps even sacred (see the following section). In the same way as in St Æthelwald's, I claim that the astronomer's work with place is a failure: that the plausible displacing of the city is approached, but never truly absolute. While relatively secluded, these astronomy sites are nonetheless always shared with the city and its denizens. Buildings are rarely out of sight. Noises are muffled and distant, but silence is never absolute. The glare of lights disappears, but that

ever-present skyglow still hangs over the heavens. Even in such spaces, one is often not alone. The work of finding these spaces can never fully be a negation, but an active engagement with the city, a production of place, rather than a displacement. This active engagement refuses attempts to side-step the cosmopolitical problems that haunt astronomy and rather raises them as explicit and overriding questions, offering an opportunity for astronomers to actively engage with the question of the relationship between humans and their world.

3.5. The Astronomy Ritual

In making sense of this symbolic work, I have always been tempted to call what I described above the "ritual" of urban astronomy. This use is somewhat tongue-in-cheek: rituals, like myths, are often considered features of a pre-Copernican world, playing on symbolism and superstition. As Mary Douglas notes, "ritual has become a bad word signifying empty conformity" (1973: 19). Moderns, of course, act with purpose and conviction, while their ancestors, misguided as they are, act out of blind duty, animalistic conditioning and machinic social programming. Not only is it the case that, as Douglas notes, such an assumption is "disabling to a sociology of religion" (*Ibid*. 21), but also it gives us far too much credit to imagine that we have transcended symbolic action in our Copernican 'coming of age'. While the astronomy ritual is ostensibly secular, it treats in the same categories of an everyday, illusory, world of the city (the profane), and special times and places, defined by a distinct quality that effaces the former, and their access to an underlying and absolute reality (the sacred). As we shall see, bringing ritual into the modern world, itself nothing new (Cherstich, Holbraad & Tassi 2020), is useful for making sense of the astronomy process' management of different qualities of time and space, and indeed the kind of symbolic movements that take place there.

The ritual in classical anthropological theory, is a transitory movement. In *The Rites of Passage* (1961), Arnold Van Gennep describes a particular kind of ritual intended to move individuals between different social roles. This can be the transition to adulthood, the initiation into a warrior or religious caste, or into the afterlife through the evocation of sacred moments in the profane world, thereby managing these two

primordial registers (Durkheim 2001: 36). As he states, “For the layman to enter the priesthood or for a priest to be unfrocked calls for ceremonies, acts of a special kind, derived from a particular feeling and a particular frame of mind. So great is the incompatibility between the profane and the sacred worlds that a man cannot pass from one to the other without going through an intermediate stage.” (Van Gennep 1961: 1).

This movement, as described by Van Gennep, and expanded upon later by Victor Turner in *The Ritual Process*, consists of three stages: the *separation* of the initiate from the social order, the *liminality* of that sacred and special position external to the social order and the rites performed there to prepare them for the third movement, the *aggregation* of the initiate back into society, bearing the treasures and wisdom of that sacred world (Turner 1969: 94). In his discussion, Turner emphasises this liminality as the crucial aspect of the ritual process: its capacity to suspend and upend the social order and its rules, giving way to an ambiguous and dangerous condition. The function of the ritual, it could be said, is to produce these moments of anti-structure in which conditions and capacities can be shifted and society reworked.

This separation is apparent in the events that I experienced, described in aggregate above, and indeed in the journey to the Hub, described in the beginning of this chapter. This separation is marked by a phenomenological shift, by a movement from light to unfamiliar darkness in which all the usual markers of the city are absent. Like so many religious rituals (Christian mass comes to mind) the object of the ritual of astronomy is to approach the absolute (we might say the divine) in the form of the cosmic perspective: to transcend the locality of the city and witness the cosmos above. Following their witnessing, they return to the profane world bearing experiences and images so that contact might be sustained and reminisced upon. In doing so, the astronomer moves back and forth across the gulf that bifurcates our cosmos, momentarily severing themself from the cultural world and returning to nature. In their social function as people who provide access to the cosmos for members of the public, the astronomer takes up the position of the hierophant: one who brings others into the presence of the sacred and the absolute.

Crucially, the ritual is not only a progression but also a performance. It is, as Mircea Eliade notes, the reproduction of a mythical event in history, its re-enactment that can re-assert its morals in the social world (1963: 68-9). The salience of this understanding is clear in the context of astronomy and its ongoing effort to complete the turn of Copernicus's original revolution. In this work, marked by the phenomenology of lightscapes and its associated affect, we can see the astronomer taking up the position of perpetrator, and momentarily, in destroying/overcoming the city and the human world, becoming the movers of the Earth and the stayer of the sun in the heavens.

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In exploring these particular engagements between astronomers and their environment, we can begin to discern the outline of how the astronomical image fails. The ideal conditions for seeing are no conditions: a void that does not impose itself upon or disrupt the flows of photons that astronomers seek to capture and manage. The cosmic perspective is, after all, a view from nowhere, that transcends locality and particularity. Here, I have described the ways in which astronomers go about finding and occupying spaces which approximate such a void in which they can 'make heaven', and in doing so find themselves deeply attuned to the urban landscape they seek to negate. Finding a space for astronomy means coming face-to-face with the contested moral landscapes of cities, and raises pertinent questions about the relationship between humans and the environments they occupy and navigate. At the core of this failed epistemological practice we find a practical engagement with the kind of existential questions that linger on the fringes of astroculture, but are also pertinent to our broader efforts to manage their environments: how should humans conduct themselves in the world, and, if we cannot fully meet the demands of the Copernican Engine, how can we go about acting meaningfully within it?

4. Practices

I always preferred the nights at the hub that were practically days. the out-of-season stargazing sessions when the sun went down at 9 pm, the atmosphere was humid, and the seeing was poor. This was in part because I can't stand the cold: stargazing season covers the winter months, with long, cold nights I would regularly come to meetings woefully unprepared, and every time I would complain my informants would joke that I picked the wrong thing to study. But I mostly preferred the summer days because they meant that there were a good three hours between meeting and observing. Organising to meet is usually for the express purpose of observing, and while participating in and watching the operation of a telescope is insightful, it doesn't necessarily tell me much about the context that surrounds that practice. I have, if anything, learned more about astronomy from trips to the pub and those summer evenings than I have from looking at the sky. My interest is not just in the world up there, but also the world down here, and it is in these moments when the cosmos seeps into the everyday.

Being unable to see the stars didn't put off stargazers, and their ranks usually swelled during these more pleasant days. It was here that the communitarian aspect of these events was presented most clearly: they are as much social events for astronomers as they are astronomy events for the public. The Hub was not just a space for science but also for making kin through a shared interest in discovering the universe, which we had consistently failed to capture with our instruments. It is a space for circulating images of the universe, and for cultivating a broader context for the act of observing.

At a certain point, one member of the community decided to make the best of this downtime to put on a show. While I was happy to bask in astronomy's social penumbra, they took it upon themselves to make good on the mission statement of the group and have a demonstration. As I approached the gathering of people, I immediately recognized the setup from demonstrations I had observed as an enthusiastic child. A series of pipes tied together with string formed a circular frame, over which a smartly

dressed man was stretching a large black sheet, clipping it to the circumference so that it was taut. This trampoline-like structure will be familiar to many as the standard means by which Einstein's theory of gravitation, and with it the concept of space-time, is demonstrated.

Perhaps one of the most significant figures associated with gravity is Sir Isaac Newton, one of the mythical heroes of the scientific canon. His great achievement, or at least his most famous, was the formulation of what is now known as classical mechanics: a system of modelling the movement of bodies in space mathematically. This classical understanding has stood the test of time, more or less, but the mechanism by which gravitation occurred remained a mystery, a matter which Newton openly "left open to the consideration of my readers" (2014: 103). It was into this gap that Einstein's theory of relativity stepped. In his account of physics, "time and space must be considered as different aspects of the same four-dimensional structure" (Penrose 1997) which he, following his teacher Hermann Minkowski, imaginatively called *space-time*. In this "general relativity," the mechanism by which gravitation functioned was understood as a gradient created in the cosmic medium of space-time, as it curved under the influence of mass. By distorting the surrounding spacetime, mass produced gravity wells into which mass falls, like a ball down an incline.

This kind of understanding of the universe as a curved medium in not just three but *four* dimensions can be difficult for people to wrap their heads around, and it is at this point that science teachers break out their frames and black sheets. Having laid out the information I have recited above with the trademark enthusiasm and eloquence of many public-facing astronomers, the man demonstrating had brought with him an assortment of 'masses,' from marbles to 5-kilo weights, which would bend the sheet and produce curvature in three dimensions in the same way that masses bend space-time in four, so that he could present to the crowd a whole host of phenomena that could be made sense of using this model. He unleashed a cascade of marbles across the sheet and watched them clump up to demonstrate the formation of stars in nebulae, explaining accretion disks as the marbles circled and the deeper inclines of larger

clusters attracted more marbles together to form ‘planets.’ He talked us through the life-cycle of stars, how large masses are kept from collapsing by electromagnetic forces, and how, when those forces themselves cannot maintain the star, the formation which occurs, a black hole, could be demonstrated if he could stretch the sheet a mile below the point at which it was when he placed all his weights in the centre. At one point he asked the crowd if they wanted to “see what dark energy is?” When he received a positive response, he stuck the stick he had been using to manipulate his weights under the sheet and pushed it upwards, sending marbles flying in all directions and dramatically proclaiming “That!”

What I found most interesting, however, were the particular moments which required finesse to bring his materials into communion with the physical laws he hoped to demonstrate. In one instance, he hoped to show the onlookers how the movement of moons occurs naturally given Einstein's descriptive model. “That's the sun, there,” he said, placing two weights in the centre of the sheet so that the entire surface curved towards them, straining the clips that held the fabric in place. “Now,” he said with a nervous but excited grin, “watch these marbles.” He held out the two spheres, one about half the size of the other, before grasping them in his palm, closing one eye, and running his hand back and forth along the surface of the fabric, feeling its curves like a snooker player winding up for a big shot. Once he seemed satisfied, he released the marbles, sending them spinning across the sheet and away from each other, and immediately concluding that the experiment was a failure. “No wait!” he exclaimed, catching the marbles as they completed an orbit, and winding up a second time, “let me try that again.”

He tried twice more, building up the tension in his muscles before incorrectly scaling the inertia to fit into his system. On the fourth attempt, however, his eyes brightened with excitement: “Look, there!” He pointed at the pair of marbles as gasps and cheers rose from the crowd, who joined his excitement. As the larger marble sailed around the perimeter of the weights, the centrifugal force imbued in it by the demonstrator keeping it in orbit, the smaller clung to its surface, spinning as it circled

the larger one, as what could only be described as a satellite. He had successfully replicated within his model a three-tiered orbit system, channelling the laws of nature through his body to produce a microcosm of the solar system before our very eyes. A wave of nostalgia washed over me. I recognized the excitement of seeing the mechanics of the universe brought down to Earth in this very tangible way. It was as if he had touched something deep and significant in the fabric of the cosmos.

Later, he repeated the process to demonstrate an even more abstract concept. “Spaghettification” is a (technical) term for what hypothetically happens to a human body (or any object) as it approaches the event horizon of a black hole. The fact that the intensity of gravity abides by the inverse square law (that its intensity is inversely proportional to the distance from its point of origin) means that it operates over long distances but dissipates quickly, the implication of which is that our feet experience slightly more gravity than our head. This is largely a negligible difference but, in extreme circumstances, such as at the Schwarzschild radius of a black hole, where the curvature of space-time is particularly steep, this difference is exaggerated. It is therefore speculated that if a person were to fall into a black hole feet-first, the gravity differential would pull them apart, stringing their body out like a piece of spaghetti. Apparently, one of our favourite theoretical pastimes is throwing fictional people into cosmic anomalies and seeing what falls out, or at least what happens when they fall in. The question is always what it would be like to be there, to “place” these extremes and bring them into contact with the human, asking questions of the most unknowable parts of the cosmos, the limits of human knowledge.

The demonstration of spaghettification delineates the limit of human understanding in a relatively mundane way. As with the demonstration of orbits, he gathered into his palm a handful of marbles, and after several attempts to channel the correct mechanical configuration, he managed to demonstrate spaghettification. As the cloud of marbles orbited the weights in the middle, those closer to the centre dropped faster, feeling the incline of the ‘curved space-time’ more strongly than those on the periphery. The result of this was that the formation shifted from a disorderly cloud to a

line before each marble fell out of orbit one by one until they all came to rest in the gravity well. Again, this achievement raised excitement from both the demonstrator and the crowd, all of whom whooped as they saw reality line up with the predictions they had been told; they were watching science function in real-time.

Much has been made in the anthropology of space about the work done by analogues in the process of trying to make sense of and work upon the cosmos (Messeri 2016, 2017; Olson 2018). One of the most enduring facts about space is that it is incredibly difficult to access. So we build representations of what might be out there down here, in the Utah desert to test long-term Martian living (Messeri 2016: 25), under the ocean for the occupation of extreme spaces and the production of systematicity (Olson 2018: 36), or in parks where rovers navigate approximations of alien regoliths. These systems "align forms and functions across spaces" (*Ibid.* 37). This demonstration was, in this sense, a textbook analogue of an abstract piece of spacetime, indifferent and malleable for explanatory purposes.

The intention here is clear: to step into the breach at the moment when the bodily grounds for practical knowledge fail. The structure that the demonstrator is working with is a *model* for the workings of spacetime within a relativistic cosmos—a set of "manageable systems, or systems thought to be comprehensible, that stand in for unruly or opaque ones" (Sismondo 1999: 248). As Thomas Grissom likewise notes of models, "We live in a time when it has become common to replace reality with some abstract creation of the human mind. In place of the real world we substitute a depiction of reality derived from a limited portion of our total experience." (2011: 5). Dealing with the radical dimensionality of spacetime is difficult for humans, not only in the sense that such "hyperobjects" occupy such radically larger spaces and spans of time than humans (Morton 2013; Grissom 2011), but that we are largely 3 dimensional beings. We simply lack the ontological intuition to process a fourth dimension. The only point of reference we might have is to imagine how we might appear to a two dimensional being, such as in Edwin Abbot Abbot's classic novella *Flatland: A Romance in many Dimensions* (1884). We have no grounds to comprehend such vast scales, and the

extreme dimensionalities of the cosmos as science describes it, and the deployment of this model demonstrates that this limit is recognized. It is for this reason that the model becomes a crucial tool in understanding the world. The limited human body restricts our capacity to know, weighing us down, and tying us to the here and now, on the earth. The model serves to make functional simplifications and “abridged maps” which were never intended to be taken as reality (Scott 2020: 2).

This demonstration closely resembles what Natasha Myers describes as a “body experiment,” a counterpart to the more cerebral thought experiment which takes “getting tangled—kinesthetically and affectively” as a serious means of doing science and thereby engaging with the cosmos. It is about finding the bodily grounds to comprehend these scales, be it through the tensions that run down the demonstrator's arm as he sets those planets spinning around the sun, or the nerve impulses and strained sinews that are involved in the delicate operation of a telescope.

This chapter is about the practice of astronomy: about how, when we have found our secluded void where we can pretend the city doesn’t exist, we can set about making the human body, with all of the restrictions it sets upon our capacity to know, disappear too. It is about how my informants work at achieving, like ascetics, an “unworldly mode of being, a radical dissociation from social customs, norms, and habits,” (Harpham 1987: 21), and thereby occupy and come to terms with a cosmos that is deeply inhuman. Crucially, it is about the contradictory way in which this mode of being requires and is undermined by a deeply embodied and worldly engagement with astronomical practice. This is a process of learning how to see, and internalising it so totally that it does not even appear as a construction, but as the unveiling of reality. Returning to Don Ihde’s claim that “Husserl’s Galileo needed a telescope” (2010), this section is about the operation of those telescopes: how this operation, far from being an ephemeral and cerebral practice, encodes the cosmos within our muscles and connective tissues and nerve fibres. It is about how, far from denoting a hard limit to human understanding, it is the body that steps into the breach when knowledge fails. As a discussion of how the body is attuned to the cosmos, how one learns to see as an astronomer, it also emerges

as a site of discipline that cuts both ways: which at once disciplines the operator and the world, so that the two can be held still and brought briefly into alignment through protracted and sensuous askesis. As such, and like the work on place described previously, the body emerges as a site of negotiation, where questions of our presumptions about the body, and thereby the relations between the world and the human subject, are raised, troubled, and serve as grounds to question our conduct in the cosmos more broadly.

4.1.“I don’t want to be Human”: the Body in Science

The body occupies a position of particular torsion within scientific and indeed other ascetic traditions. It is, after all, the point at which the humanity of the human and the inhumanity of the world must reconcile their differences and learn to occupy one another. Much like light, the body is a clear site of torque, where the human and its erasure are at stake. The body is that part of the human which ties us to the profane world and must be mortified in order to transcend that profanity and reach for the divine, but it also serves as the matter of that transcendence, in which that divinity is given form (Buchli 2016: 38). The body and its materiality is defined in science by precisely this strained ambivalence. On the one hand, it is the part of the human that occupies that region of the world over which scientists were given dominion by the Cartesian bargain: the material world to which many scientists readily reduce the cosmos. It is for this reason that many humanists such as Christopher Hitchens claim that “I don’t *have* a body. I *am* a body” (2012: 41). On the other hand, the body is the base, animal part of the human, opposed to the rational and ephemeral mind—the substance which makes up the other half of the Cartesian dyad—that is the faculty that defines and distinguishes humanity. The body, its accompanying senses, and its a-posteriori knowledge offers us only partial, local, and situated knowledges, directly at odds with a cosmic perspective. “Scientific objectivity,” notes Natasha Myers, “is conventionally understood as a neutral, rational, and so disembodied practice. Scientists are expected to dissociate their cognitive activities from their bodies’ complicating passions and proclivities” (2015: 2). It

is my claim that this partiality that the body makes prominent informs the particular performance of the astronomy ritual: that, like place, the perfectibility of this ritual rests upon the plausible erasure of the body's part in its performance.

Bodies impose physiological and sensory limitations upon astronomers that serve as a kind of cosmic ballast: they are the things upon which the gravity of context and the pressures of atmosphere act, and as such they drag us down to Earth and prevent our transcendence to cosmic realms. The greatest sin in scientific objectivism, as Daston and Galison remind us, is "seeing *as* rather than *that*" (1992: 83), reflecting the "ideological doctrines of disembodied scientific objectivity" (Haraway 1988: 576). Astronomy, being a site at which the tension between bodily, sensory work and objectivism is clear, ends up being a crucial place where the work of the body must be repressed.

This orientation was clearly articulated by many of my informants when I told them that I was interested in the body and astronomy. It was not uncommon for the response I got to be a polite confusion and curiosity, of the kind one would expect from people who had not considered how the body is deployed as a matter of concern within astronomy. The cosmos is so distant, and the space between us and it so vacuous, that of course we can't engage our bodies with it. Sure, we can make 3D models of cosmic structures that we can touch (Arcand *et al.* 2019) and speculate on the tastes and smells of distant dust clouds (Sample 2009), but at its core, it is by means of the streams of photons and other forms of radiation, managed by the infrastructures of our sense organs (artificial or organic) that we come to know the cosmos. When I clarified that my interest was in the limits imposed by the body on our capacity to know the world, one informant was Simon, as he often was, with a piece of sci-fi trivia in which this concept had already been explored. In this case, it was the character John Cavil, a robot from Battlestar Galactica who resented the human form he had been given:

> "I don't want to be human. I want to see gamma rays, I want to hear X-rays, and I want to smell dark matter. Do you see the absurdity of what I am? I can't even express these things

> properly, because I have to—I have to conceptualise complex ideas in this stupid, limiting spoken language, but I know I want to reach out with something other than these prehensile paws, and feel the solar wind of a supernova flowing over me."

Since the rise of its public popularity during the Romantic period, astronomy has been set apart from its contemporaries in geology and botany by its lack of tangibility, vibrance, and sociality (Chapman 1998). Astronomy is a *visual* practice, not a *bodily* practice. Managing this seemingly impossible juxtaposition between sight and the body is what Donna Haraway calls the "god trick" of scientific myth, "seeing everything from nowhere" (1988: 581). Haraway notes that astrophotography, alongside microscopy, is emblematic of precisely this god trick (582), and it is precisely this god trick that gets us at the cosmic perspective. The effort here is, like with the management of place, cosmopolitical. It is the modern effort to occupy nowhere. Astronomers seek in their work to step outside of the body and the cosmos, and thereby "claim the power to see and not be seen, represent while escaping representation" (581). It is within the particular tradition of *visualism*, identified as the veneration of sight as the "noblest sense" (Fabian 1983:106), and whereby vision is associated more closely with cerebral processing than bodily organs (Burkett 1999: 51). It is by this means that the process of coming to know the cosmos properly and objectively is divorced from the confounding and limited body of the human.

This god trick has a very particular history, charted by Ian Burkitt, whereby modern conceptions of the body emerge from a conceptual "closing" of its boundaries. He situates this emergence (or closure) at the crossroads between Mikhail Bakhtin's discussion of the mediaeval "grotesque" body and Norbert Elias's "civilising process" and accompanying "armoured body" (1999: 46-52). "Grotesque realism," Bakhtin claims, is a feature of mediaeval carnival imagery which emphasises the body as a porous and permeable vessel, where "the boundaries between inside and outside the body, and the dividing line between the individual and the collective, were not as sharply drawn as they are today" (46). For Bakhtin, this relationship with the body and its sensorium is seen as a more authentic, direct, and unmediated than what was to come.

Likewise, Elias associates the premodern or pre-'civilised' body with similar expressive flows: while the grotesque body emphasises orifices and flows of matter and waste, Elias's discussion concerned the externalising of a person's internal world, typified by emotional outbursts and articulations (50). The emergence of the 'modern' body is described by both of these theorists as a conceptual sealing of the bodily shell, and the severance of these flows. The passing of matter through the boundaries in the skin became taboo, while private matters and the self became increasingly the subject of "emotional restraints" as a part of this "civilising process". This movement follows the Latourian model of "purification," as the human retreats from the world and secludes itself within an inert and stoic body which becomes a "fleshy machine with which humans could hardly identify" (45). The individual is rendered alone and other to its own bodily machinery which is made more and more numb to and extracted from the world and by extension the being of their owners. At the same time, Burkitt identifies this retreat of the human from the world with the rise of visualism: "bodily sensations are concentrated on visual perception, which is linked more directly to intellectual understanding, and other senses of the body are less central" (51).

This section, therefore, in being a discussion of the role played by the body in astronomy, is about how this "god trick" is performed, whereby the closed body is established and maintained (or rather, obscured) in the pursuit of the disembodied and absolute cosmic perspective. In this section I hope to do for the body what I did in the last section for place: outline that aspect of the astronomical ritual which concerns its erasure, and locate the work that goes into that project. But also, it is to highlight the failure of this god trick: how the necessarily cyborgian and transgressive nature of astronomy—how it must at once expand the body to include instruments within its habitus and make it permeable to the streams of photons that it manages—cracks the hard shell of the closed body, and establishes it as a fold of the cosmos rather than its own purified entity.

As one might expect, Haraway is dubious of this disembodied vision, referring to it as “illusory”. It turns the body into a void, which, as with all voids, is occupied by latent and gendered structures of power, in which feminists are the “embodied others, who are not allowed to *not* have a body, a finite point of view, and so an inevitably disqualifying and polluting bias” (Haraway 1988: 575). The status of the body as a theoretical void—as an object of knowledge rather than a means of attaining it—serves only to obscure and thereby secure these latent assumptions rather than erase them. In opposition to this false transcendence, Haraway proposes a “feminist objectivity [which] means quite simply *situated knowledges*” (*Ibid*.). This section, in discussing the body, its deployment, its repression, and its reemergence, seeks not only to participate in this feminist objectivity but also to account for the organic emergence of such situated knowledges on the ground. It seeks to explore, following Myers, how the torque of the human body is experienced and dealt with affectively and kinesthetically by participants in these ascetic rituals. In doing so, I hope to explore how the habitus of the appropriate astronomical body is cultivated and manoeuvred into alignment with the cosmos, so that it can, become situated within the universe, along that mythical continuum between “cosmos, settlement, and self” (Schrempp 2012: xii).

4.2. The Anatomy of a Telescope

The human body, and its particular position relative to conscious action, is an entity that lends itself to neglect. For many people, it is the matter with which we are most closely familiar, simply enacting our will without thought. It only really re-emerges (or perhaps intrudes) into conscious thought when it becomes at stake: when it is the subject of pain, the focus of anxiety, or the site of failure. When we lack the bodily dispositions to perform something, our bodies crash back into view. The operation of a telescope, that defining practice of Western astronomy, consists of a set of particular and precise actions that have few analogues elsewhere on which we can draw or from which we can transfer skills. For an early astronomer, the body is always at stake because the body is always failing. As one learns to effectively interact with the apparatus of a

telescope—as one incorporates this synthetic organ into their systems of bodily dispositions, their *habitus*—the body ceases to be at stake, and both of these organs disappear as infrastructural objects. In order to discuss how this happens, I would like to describe the anatomy of the telescope and how it is supposed to be used in the abstract.

Astronomical work constitutes a double engagement with the cosmos. It is both *of* the cosmos in the sense that it is the work of representing the cosmos and in the sense that it operates within the natural systems that constitute it. In this sense, the cosmos is doubly at stake here. The practice of astronomy, as I shall describe here, requires an engagement with both the cosmos in the abstract and a navigation of its systems, namely, the process of optics. Just as in finding a place for astronomy required us to familiarise ourselves with weather patterns and engaged us phenomenologically with the environment in which we operated, so too does the operation of our body-telescope-assemblage require us to embed ourselves with and appropriate the infrastructures of light that link the Earth to the cosmos.

Early on, it became clear that understanding the particularities of astronomy in London meant learning to do it for myself: to subject my own body to the same discipline as my informants, that might allow me to see 'properly'. Going to the Hub was always an exciting, enjoyable experience, all the wonder of getting to see Jupiter or Saturn 'live', with none of the hassle of having to operate the fiddly and delicate gear. They made it seem so easy as well. Once again, like with the abstracted image, members of the public are shielded from the messy awkwardness of trying to get at the cosmos. If I wanted to get at this awkwardness, the stuff of astronomy as it is experienced, I would have to get stuck in for myself.

Telescopes are delicate, complex, and expensive objects, and much of an astronomer's time is spent working out precisely what is happening (mostly what is going wrong) with them. This makes specific telescopes at once something one has to get used to, and something over which one could understandably become protective. It

is good etiquette at the Hub to touch a telescope as little as possible, not only because it might knock the object at the other end out of view, but also for fear of damaging the equipment. Learning by doing with someone else's telescope would require a great deal of trust and responsibility that I did not want to risk, but also a great deal of coordination. I didn't want to restrict my learning to once a month at minimum, and aligning busy schedules reliably outside of that allotted time is, as I have noted, difficult.

It quickly became clear that the best way to learn to use a telescope was by getting and operating one of my own, and this thought immediately became problematic. I have always been a practical learner; I prefer to learn by doing, and develop an intuitive, bodily understanding of the operation of any given equipment. In other words, I have always tended more towards implicit, intuitive, and practical knowledge rather than learning skills through an explicit, analytic framework passed to me by someone else. In theoretical terms, I like to develop a *habitus* from first principles. The notion of habitus comes primarily from Marcel Mauss, who discussed the particular cultural aspects of bodily movements, and how the specificities of these practices might be taken as the locus of social and cultural influences (Farnell 2003). Pierre Bourdieu expands upon this understanding by discussing habitus as "the strategy-generating principle enabling agents to cope with unforeseen and ever-changing situations" (1977: 72). Bourdieu also describes it as "the 'art' of the necessary *improvisation* which defines excellence" (*Ibid*. 8). It is this durability and reflexivity—this capacity to troubleshoot on the fly—which always made practical knowledge appeal to me. What I wanted was to internalise that social structure—that habitus—which offers me an adaptive model for how my informants see, and is appropriate for the doomed work of overcoming specificity, and making its singular correctness plausible.

Unfortunately for me, telescopes tend to be expensive pieces of equipment with particular strengths and weaknesses. This specialisation means that getting the right telescope is important, a decision which, of course, requires a certain level of basic knowledge that would require precisely the kind of learning I had hoped to avoid. Setups

can be cheap if people have the know-how to bodge or make do with equipment from second-hand auction sites, or even make their own, but this, if anything, requires an even more extensive working understanding of how telescopes operate. Again, as I have discussed before, we find a classed aspect of astronomy: the less money one has, the more time one has to spend acquiring the prerequisite knowledge to be able to perform the bricolage of putting together a rig from wisely acquired parts. I found myself in the bind of wanting to develop practical knowledge by doing, but needing that practical knowledge to even begin.

One of the great assets of working with a community of enthusiasts, however, is their enthusiasm. Space communities online are overflowing with useful information and helpful people eager to make getting at the cosmos easier for aspiring astronomers. I have attended and been linked to many talks on how telescopes work and how we can go about operating them, and it is easy to get an astronomer to give you a one-on-one crash course on stargazing. One of the most significant resources was undoubtedly the community. No matter how I cut it, however, I would need to rely on the kinds of abstractions and symbolic systems which allowed science to so efficiently transfer knowledge between minds. In short, and to my dismay, I ended up having to do maths. Being unable to learn the way I would like to, I had to settle for the more ethnographically appropriate method: that which my informants espoused, in the form of an abstract calculus which models the telescope and its optical work. What follows is this calculus, the common knowledge accrued from the community and their resources, repeated hundreds of times, with which most astronomers must familiarise themselves in order to operate their telescope and understand what it is capable of. In other words, it is the calculus by which light and the universe are modelled and managed.

Naked eye stargazing is possible, even recommended by some of the more committed enthusiasts. I have fond memories of being given a tour around the cosmos as a child by people with laser pointers at the observatory I visited. The beam would stream photons up to match those raining down, and it would flit from point to point as they described each object, often through a combination of its physical properties (what

kind of star/nebula it is) and its social history (what it was named for/who named it/what it has been associated with in the past) and talked through how to navigate the night sky. Follow the end of the big dipper straight, and you will find Polaris, and so on. I was happy to see that this oral tradition had survived. In an age of computerised mounts, the practice of reading the stars to find one's way around the heavens—sometimes referred to as *star-hopping*—seems archaic, but in a momentary lull, finding one's bearings turns the cosmos into something familiar.

The naked eye is, however, woefully limited. At particular scales and distances, the human body starts to fail. This is, of course, the foundation of the Copernican Revolution; aside from demonstrating to us that there could perhaps be other worlds out there, challenging our singularity (Kragh 2007: 47) the telescope and the microscope also demonstrated that these delusions were the result of our epistemological limits. Van Leeyuwenhoek's microscope and Galileo's telescope were crucial in revealing "a layer of reality that didn't include us" (Scharf 2014: 7). In his book discussing the findings made using the microscope, Robert Hooke speaks to the way in which the pursuit of true vision (perhaps a cosmic perspective) levies cyborgian demands upon the observer: that comprehending the cosmos was only possible through "a supplying of their infirmities with instruments, and, as it were, the adding of artificial organs to the natural" (1665). By means of these instruments, we could probe the depths of matter and of interstellar space, and capture electromagnetic radiation undetectable by human eyes, so as to examine the folds of nature that exist there.

All mobile optical telescopes follow a single general form: a tube for collecting photons, a mount that attaches it to a tripod which stands it on the ground, and an attachment that renders the visual data, be it an eyepiece or a camera. Astronomy can be done otherwise—astronomers are rarely so particular as to discount naked eye or binocular stargazing—but this discussion focuses on the telescope and the camera as the real workhorses of western astronomy. It is through the manipulation and arrangement of these parts, and the addition of particular other parts if needed, that an astronomer goes about their practice of directly manipulating light.

The “business end” of a telescope, as some have referred to it, is the barrel. While I refer to the entire assemblage as the telescope, the telescope proper is the tube which manipulates the light that flows down it so that it is concentrated for the photon-event. Photons constantly rain down upon the Earth from all manner of sources in the cosmos, and it is the business of astronomy to capture that rain and sift through it so that a singular original signal can be made clear. To catch this rain, the telescope is a bucket, capturing and focusing those photons in a particular way to produce an image. There are several kinds of telescope, each of which manipulates light in their own particular way, and have their own strengths and weaknesses. The common wisdom constantly recited to me was that “the best telescope is the telescope that you use the most.” This statement often came with an acknowledgement of the awkwardness of place referred to in the last section. Doing urban astronomy in a city so geared towards public transport means abiding by the restrictions of what you can get on a bus or the tube, and sometimes bundled in a late-night taxi. The consistent suggestion is that picking a telescope, as with so many things in astronomy, is a trade-off, not only in terms of the capacities of the telescope, but in terms of how it fits into the rest of someone's life: their capacity to move, use, store, and afford it. The work of urban astronomy is a work of compromise between the demands of the city and the call to the cosmos.

The features of these telescopes and what they can do is described by a particular set of equations, which relate the *aperture* of the telescope (the size of the opening that receives light) the *focal length* (the distance over which the light is focused within the barrel), the magnification power, and the focal ratio. The art of astronomy is in understanding how these variables combine and affect the image, and knowing how to manipulate them in order to manipulate the image. For instance, ‘faster’ telescopes (with a lower focal ratio) will be better for deep-sky imaging of things beyond our solar system, because they will collect the appropriate number of photons faster, but also have a field of view inappropriate for objects like Saturn.

Fig. 8: My telescope: at the end, I purchased a Skywatcher Skymax-127 Maksutov-Cassegrain, with an alt-az go-to mount.

Learning the calculations for these features proved challenging with no practical engagement to ground them. In the end, I found someone I trusted, with an extensive knowledge of how telescopes operate, and asked for advice. I said that I wanted to start small, with planetary imaging, with a little room for improvement, and that I wanted to bring it to the stargazing meetings. The telescope we settled on was a Sky Watcher Skymax-127, a relatively slow, f/11.8 Maksutov-Cassegrain (see *Fig. 8* & *fig. 9)* perfect for looking at Mars or Jupiter. Its smaller construction was a consideration of the particular cluttered awkwardness of operating in London: folding light within the telescope meant that I could more easily get it to the remote sites at which I met my informants.

While it is easy to think of astronomy as an abstract and cosmic practice, it is in the operation of these various tubes, knobs, lenses and mirrors that light is captured

and manipulated, and the universe is made visible. Doing astronomy is overwhelmingly a practice of trying to work out which part of this apparatus is throwing off my images, understood through the concrete manipulation of this equipment and by extension the abstract manipulation of these properties. While astronomy is certainly about managing these variables, manipulating those variables is about translating bodily movements and material interactions into the movement of light through a tube and onto a sensor.

Fig. 9: The Anatomy of a Telescope. My telescope, broken down into its constituent parts, which are 1) the barrel, 2) the tripod, 3) the mount, 4) the eyepiece, 5) the T-ring for replacing the eyepiece with cameras, 6) the finderscope, and 7) the diagonal prism.

It is in the operation of these very material parts of the telescope that the body is at first a very prominent obstruction. It has not yet learned how to interact with this very delicate piece of kit. This is most prominent in attempting to line up an image. Telescopes look at very specific parts of the sky and very small objects that occupy them. This means that the adjustments one makes to the telescope in order to manipulate the framing of the image are magnified, and one is forced to make

micro-movements in order to better align the telescope. On top of this, all telescopes have a ‘stickiness’ to them. They must at once have a mechanism which fixes them in place and offers some resistance to knocks or other movements, but also have enough ‘give’ to adjust the image in this way. What results is an anxious tension felt throughout the body as one attempts to exert enough force to budge the image, but not so much that one overshoots. I will return to this tension in earnest in the next section.

This “stickiness” becomes most clearly at stake when it comes to the process of aligning a telescope. The first part of this process means aligning the barrel with the general part of the sky that the target occupies. Many telescopes come with a “finderscope” which features some degree of magnification and can be used to more closely align the telescope if it is itself aligned correctly with the telescope itself. The next part of the process is the most difficult: bringing the object into the visual range of the telescope. This often means “scanning” the sky, moving the barrel backwards and forwards, and seeking out the object. Here, again, the tension of micro-adjustments becomes more and more prominent, as one scales down their movements as alignment is approached. Such tension re-emerges again when the object inevitably drifts beyond the ‘frame’ of the telescope, and one must re-align. Such engagements are particular to each telescope and their specific ‘stickiness’. When I did try using someone else’s telescope, I found that my bodily judgements, so attuned to my own, were completely off for theirs, and I lost the object completely.

The crucial point being made is that the tactility of astronomy is crucial to its success, but that criticality is easily forgotten once astronomers familiarise themselves with the precise amount of force needed to adjust these telescopes—when these micro-movements become second nature. The telescope and the particular demands involved in using it impose a discipline upon the body of the astronomer that informs a particular kind of visual and tactile engagement. This is, of course, a generative kind of discipline, as is common in science. Natasha Myers, for instance, describes this discipline as the way in which “modellers’ senses are enlisted, honed, cultivated, and trained, rather than merely controlled or constrained. Once this discipline is internalised,

it becomes tacit and ex-nominated. Once the awkward disjuncture between the body's capacities and the demands of practice are resolved, the body can once again disappear.

The concept of habitus, now the mainstay of anthropological discussions of practice, concerns the socially acquired forms of knowledge that are embodied in the fibres, sinews and neurons of the body, as inclinations and dispositions that we might compare to 'muscle memory'. Most critically, Habitus is habitual and unreflexive: "The principles embodied in this way are placed beyond the grasp of consciousness, and hence cannot be touched by voluntary deliberate transformation, cannot even be made explicit" (Bourdieu 1977: 93). Allain describes this process on the ground in her account of astronomical work, when she describes "the invisibility of technical processes" (2013: 37) which means that all we have left is the image at the end, which is "opaque in their coming into being," to which she attributes their aura of wonder and awe. The move from enthusiast to amateur lays these technical processes upon which the cosmos is contingent bare, and they must therefore be made invisible once again. Their work is therefore directed towards incorporating the particular tangible materialities of their telescope—its weight, its balance, its 'stickiness'—into their habitus, to make it a part of their cyborgian bodily systems, and thereby to make its mediation seem insubstantial.

4.3. Learning to See

Along the side of the face runs the facial nerve. Just before the ear, there is a junction in which the nerve splits into five pathways. Each of these delivers signals to distinct parts of the face, and given different sets of impulses, manages the muscles which contort the flesh and sinews into different expressions. The Zygomatic nerve crosses the zygomatic arch (cheekbone) and supplies signals to the Orbicularis oculi, the ring of muscles that surround the eye. These muscles are responsible for opening and closing the eyelids, or, most relevantly for astronomy, for exerting pressure on the eyeball to manually adjust the lens within, which we refer to as *squinting*.

Squinting usually indicates a pathology. People with eyes that can't focus on a given object (such as with myopia, hyperopia or astigmatism) can use the muscles around the eye to manually adjust their eyesight by applying pressure to the eyeball to change its shape and the focal properties of the lens within. The inadequacy of our sense organs is, however, inevitable when it comes to looking at the sky. I have already discussed how stargazing is at odds with everyday seeing down here on Earth. All human sight is rendered pathological at the extremes of vision—inappropriately large or small scales—and must be remedied with "artificial sense organs" (Hooke 1665). For example, binocular vision provides focus and depth through parallax, by providing and synthesising two images from two different positions. By looking at the position of objects in the sky 6 months apart, for instance, astronomers can calculate the distance of that object using the parallax produced by the earth's orbit around the Sun. The parallax between the human eyes, however, is so small that we can only really do this at a distance of about 20 feet, beyond which is known as 'focal infinity'. Just as we remedy visual pathologies down here on Earth with glasses, the telescope and the microscope are artificial organs that endeavour to make our eyes appropriate for the very large and the very small.

Squinting also has a second function. In the process, the eye half-closes, limiting the number of photons that can enter the eye. It is here that we can locate in the body the process of elimination that we discussed in the previous chapter; the impulses that run down the zygomatic nerve and the strain in the Orbicularis oculi seek to obscure the city lights and erase the evidence of the local. Astronomers spend much of their time squinting, and often come away with aching faces and necks. This is particularly true of attempting to make out astronomical objects with the naked eye, but it is also the case when using a telescope. Whenever the astronomer bends down to use the eyepiece, they squint to focus their view on the referent object, and block the noise from other sources. The stillness and micro-adjustments that I have described as critical to astronomy here articulate themselves in the strain astronomers must put their bodies under as the eye meets the eyepiece and the hand adjusts alignment. In his discussion of the interaction between the bodies of Royal Marines and the landscape of Wood,

Christopher Tilley speaks of how the recruits must attune their ankles to the landscape of the Woodbury Common training area, encoding the landscape in their muscles to manage their movements and acclimate to the terrain (2017: 104). In just such a way, astronomers must encode the management of light into the muscles and nerves of their faces, managing their movements to eliminate the city. We find the tension of the morally disputed landscape of light here embodied in the tension of the muscle. Such a phenomenon is an *askesis*, a bodily work that produces a corporeal form—ways of seeing—appropriate for touching divinity (Buchli 2016: 38).

There are further techniques for seeing that must be internalised by astronomers. Eyepieces are very specific devices, focusing the beams of light they manage into one particular 'focal point.' Getting one's eye to that point is a difficult process, and there are many enthusiasts (myself included) who, on their first time doing astronomy, worry that the telescope isn't working because they can't see anything. I learned quickly that the easiest and surest way to align my eye with the eyepiece was always to use it much like a telescope as I described before, moving it back and forth across the eyepiece, slowly zeroing in on the point at which the astronomical object suddenly appeared.

One of the most critical aspects of seeing as an astronomer is learning to deal with the faintness of objects. A problem universal to all forms of detection is the trade-off between *accuracy* and *sensitivity*. Accurate systems will yield low quantities of high-quality data, excluding noise but also excluding some actual signals it zealously cuts out of its detection process. Conversely, sensitive systems yield high quantities of data but are prone to false positives. To resolve this question of sensitivity vs accuracy, the human eye developed a dual system, based on two kinds of photosensitive cells. The fovea, a small part of the retina at the back of the eye, contains all of the *cones* we use to produce detailed, accurate images, and splits light to produce colours. When we focus on something, we focus light onto the fovea, which can render a piece of the world the size of one's thumbnail held at arm's length at any one time. Surrounding the fovea are the *rods*, which can produce low accuracy, high sensitivity images in low light.

Our inability to use our cones effectively is the reason that everything appears in monochrome in the dark.

Everyday life largely depends on detailed vision. We have, as I will discuss, made the prospect of working in the dark vanishingly limited. This system means that working in low light or with small light sources such as cosmic objects means doing the counterintuitive work of trying to use the part of the eye that we do not usually 'look' with to see such sources. Attempting to focus light on a part of the retina that is not the fovea is a strange sensation. The experience of learning to look is much like the experience of looking at a grid illusion, in which you chase away ghostly dots by looking directly at them (*fig. 10*). It is by learning to see *without looking*, with what Joshua Reno refers to as "averted vision," (2018) that astronomers must overcome their impulse to look at distant objects as if they were proximate.

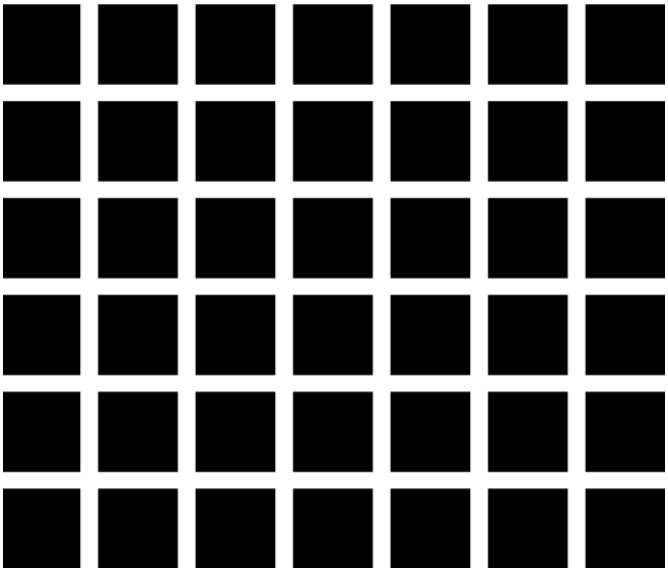

Fig 10. The Herrman grid illusion, in which the brain produces dots at the intersection of the grid, illustrates the impulse of the eye to focus on the object of observation which the astronomer must overcome.

Learning to look as an astronomer is a difficult and counterintuitive process. However, like the micro-adjustments of the telescope, these movements are eventually internalised, and made to disappear. However, these movements re-emerge in the

aching faces and backs of astronomers, evidence of the cosmic torsion at work in astronomy.

4.4. Cosmic Torsion: Sedentising the universe

Given that I have spent so long talking about astronomy as a matter of movements—as the crossing of thresholds, the astronomer's passage into the cosmos, the movement of bodies across the sky, and the rite of passage—it is worth lingering upon how much of the actual practice of astronomy is one of producing stillness. When it actually comes down to looking at the sky and its contents, the astronomer's success or failure comes down, largely, to their capacity to place themselves and their telescopes in alignment with the cosmos (to 'attune' themselves bodily, in the terms used by Reno 2018) and, at the moment this is achieved, to hold themselves and the world there in tenuous harmony so that the photon event might take place. Indeed, unwanted movement is one of the most common causes of the failed image. It was, after all, the failure to hold this alignment that in part caused the imperfection in John's image which set me off on this project back in the coffee shop. Producing images that appropriately represent the cosmos requires stillness, and it is in the bodily torsion of stillness that the troubling conditions for visual perfection emerge.

The crucial example of this is that staple of astrophotography, the long exposure. I have already discussed the difficulties of catching photons of distant and faint objects. The crucial problem of astronomical practice is shepherding these photons, sparse as they are, into the correct configuration so that they might unveil the true conditions of the cosmos. To return to the analogy that compares this practice with catching rain, a bigger bucket (aperture) may indeed permit us to catch more rain, but we might equally leave a bucket out to collect water for longer in order to collect a greater quantity. Pointing the camera at an object and leaving the shutter open for extended periods—a couple of seconds, whole minutes, or even hours at a time—is the photographic equivalent of doing so.

Conducting long exposures, however, adds to the already considerable potential for things to go wrong. On the one hand, I have already discussed the way in which the detectors in cameras indiscriminately collect photons from all sources, and increasing the capacity of a photon collector often means increasing noise as well as signal. Most prominent, however, is the issue of stillness and movement. Long exposures take visual imprints over periods of time, and if the frame of the camera moves in those moments, one ends up with the objects in the frame 'wandering' or 'smearing' across the image, and it is here that we return to the image I produced of Orion, with which I opened this dissertation (*fig. 2*).

My image was disrupted by my hands failing to keep the frame of the image steady, but this is not just an issue with my hands, or the hands of any astronomer. This image can be remedied by the simple application of a solid tripod, a piece of kit as crucial as the telescope itself. However, there is still the fact that much of the content of the sky also drifts as the Earth rotates on its axis. These movements are the literalisation of Carroll, Parkhurst and Jeevendrampillai's aforementioned description of failure as the slippage of the object from its object position (2017: 5), that position being a particular place within the frame of the image. This means that views of astronomical telescopes need constant maintenance as their objects wander out of frame. At astronomy meetings, as queues of people line up to peer through the eyepieces of astronomer's telescopes, the owner will regularly have to jump in and restore the precarious alignment they have produced. For astrophotography, this demands further pieces of kit that can "track" these objects, and ensure that the object stays at the same place in the frame. Some mounts come with manual trackers which require careful adjustments using precise gears, while others "autotrack" which, once aligned, use computerised systems and GPS to avoid a smeared image. With these systems the skill resides in the alignment: how well or poorly aligned the telescope is will determine how sharp the resultant image will be. Such skills and technologies are the infrastructures which stave off failure. They are deployed to prevent the cosmic object from, quite literally, slipping from its "object position" within the frame.

This problem of smearing has long been an issue in photography, but was particularly notable when its early forms were based on chemical reactions that required extended periods of time to produce an image. For example, the daguerreotype was an early precursor to the photograph, which used silver-plated copper, iodized vapour, mercury vapour and saltwater in a process that required between three and thirty minutes of exposure. As David Lulka notes, while this imaging form was usually used for static subjects such as buildings or landscapes, it was also sometimes used for portraits, leading to a visual style determined by the fact that the subject was required to stay perfectly still for up to thirty minutes (2014: 39). Often, special mechanisms were built and deployed to discipline the subject into stillness, while children, most prone to fidgeting, were tied to chairs. As Lulka notes, there exists a tension in this form of portraiture that in pursuit of a clear image, the vitality of the subject must be robbed of them. “A clear paradox emerges here in that the assumption of an unnatural (because corpse-like) disposition is required to produce what is considered an accurate image” (2014: 40). Astronomy features this same paradox. In the image, we find a medium incapable of capturing the fourth dimension of its object without rendering itself unclear and inadequate. In producing and maintaining the tenuous alignment of eye, telescope, and sky, the astronomer forces the cosmos into a position of legibility by erasing one of its most essential features. To be appropriate to produce a cosmological perspective, the cosmos must be rendered corpse-like, and the astronomer finds themselves trapped between two failures of mediation.

In returning to Myers’ work with protein crystallographers, we find scientists who, in working at the extremes of vision, similarly produce strained and unnatural models of their objects. In one particular passage, Myers recounts one crystallographer describing the training process involved in producing appropriate models. Myers describes how her informant uses her body to demonstrate what a good and a bad molecular model look like, as she “contorted her body into the shape of a misfolded model” with a “cosmically anguished look on her face” (100). Myers also notes that the scientist extended affective states to the molecule, describing them as “happy”, “relaxed” or “in pain.” As Myers puts it, “She is clearly affected by the strain a protein would experience if it were forced to

fold into an awkward configuration", and, through this 'sympathy', the informant "traverses the wide chasm between her body and that of the molecule" (101).

Astronomers express a less explicit sympathy for planets and nebulae. The content of the cosmos is more impersonal, less explicitly subject to our discipline, and the methodologies of astronomers are plausibly less intrusive. Nonetheless, they, like protein crystallographers, carry the sympathetic strain of their work in their bodies. Holding the cosmos and the human eye in alignment takes a particular combination of stillness, micro-gestures and tension that is particular to astronomers. These strains are felt most acutely in the painful after-effects of astronomy: the aching face and back from squinting and bending over for protracted periods, the stiff joints from excessive stillness, and the muscular ache that emerges in the tense sinews deployed in the micro-adjustments to the stickiness of equipment. These sensations, along with the more immediate cold of winter nights, evidences the tension involved in forcing the eye and the body into a position that is appropriate for viewing the cosmos. Here, we find the tense askesis—the prolonged and disciplined bodily engagement in the material world that constitutes the enactment of asceticism (Buchli 2016: 50)—between movement and stillness, between legitimacy and verisimilitude, running down the nerves and the muscle fibres of astronomers, as they strain to maintain their tenuous cosmic attunement.

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In this section I have explored the bodily comportments that must be cultivated and deployed by astronomers in their efforts to make the cosmos visible, and how this practical engagement returns the human to the cosmos, undermining the strict boundaries between the two. As I discussed in 4.1., western and scientific traditions have historically troubled the body as a locus of epistemological work, a move that is grounded in a particular dualist and oppositional understanding of the relationship between the body and the thinking subject. In exploring how astronomers both train their bodies for more appropriate seeing and expand their habitus to incorporate their

telescopes and other sensory prostheses, I have highlighted some of the ways in which this neglect of the body is at once sustained by the reflexive nature of habitual practices, and troubled by the moments when these practices fail, presencing the body in its limits. Success is made all the more difficult by the tenuous alignments that must be produced and sustained in astronomy, holding both telescope and object in synchronous motion so that infrastructures of light can be made workable. In these practices, and particularly in their failure, we find a point at which the intrusion of the human into the image becomes inevitable and almost impossible to ignore, as constant efforts must be made to maintain the habitual skills that efface it. The body and its deployment therefore becomes yet another site at which the local and the human aspects of astronomy become intrinsic to its practice: how they make the cosmic perspective an inescapably human perspective. It is here, again, that we find the grounds for the failure of the cosmic image, of the Copernican Engine, as it struggles to transcend human particularity. As a site of engagement between humans and the cosmos, however, the body is also a critical place at which the questions raised by this failure can be addressed: if our presumptions about the relationship between humans and the world that are latent in objectivism have lead us to this point, how can we redress those presumptions, and reconfigure those cosmopolitics? How can we go about apprehending the cosmos in a way that is not disciplinary, as described above? How are we to deal with the tenuous nature of this attunement, which demonstrates our limited capacities rather than our mastery over the cosmos? In the absence of the possibility of objective vision, it is this reorientation that is worked upon in the bodily work of my informants, as they attempt to feel the contours of the cosmos through flows of photons.

5. Images

After all of this work—all of this agonising over place, fiddling with telescopes, and crucially pretending that we are, in fact, doing neither—we return to that problematic matter that started all this: the image. We have now, by the means described above, gathered all of our raw data. For some, astronomy ends with the photon-event, which is left fleeting and transient, but some wish to immortalise and mobilise this experience, to give the photon event an afterlife, as it were. This is an opportunity to perfect, reproduce, and distribute the data that they have collected, to uproot and share the experience they have had of the cosmos with others, as much as such an uprooted and decontextualised image can. Such a capacity, alongside the instruments that extend the senses, is one of the defining features of Western astronomical practice: the capacity to fiddle with images and bring forth different aspects of their content.

In this section, I will explore this afterlife of the photon event: how the image is processed, perfected, made ready for public consumption, and then circulated around the community. While ethnographically these processes are relatively mundane, even dull, they are theoretically where the tensions that have been so problematic up until this point reach fever pitch. In the processing and circulation of images, the conflicting injunctions to accurately represent the world *in itself*, which is to say *without us*, runs headlong into the demand to render it legible, to incorporate it into the world *for us*. What's more, it is here that the work of obscuring practice begins in earnest, with processing, the act of making ready for public consumption, erasing all the blemishes, imperfections, and "artefacts of local conditions" (Hoeppe 2012) that would otherwise locate its perspective here, limited by the conditions of the earth (Allain 2013 39). This deeply ambivalent relationship with visualisation is felt closely in the mixed attitudes towards this aspect of astronomy: For some, it is a waste of time, while for others it is the moment at which the object of their work finally truly emerges. Some become almost obsessively particular about correcting the places where process juts through the image, others appreciate what they refer to as the "rawness" of the unprocessed image, choosing instead to bask in those limitations and points of failure. Through the

discussion of this tense positioning of the image within the history of science, and the way in which this torsion is felt in this afterlife of the photon-event, I will outline how these practices, in their performance, contribute to the endless failure of the perfect image.

For the purposes of this discussion, I shall be drawing upon the longstanding discussion of the "two cultures" of art and science, and the distance that is often placed between the concern for aesthetics associated with the former, and the concern for reproduction associated with the latter. While these two representational modes emerged from a similar visual standard, Michael Lynch and Samuel Edgerton identify that the sharing of conventions and styles largely ended with the Renaissance. As they put it:

> "Modern science and modern art have both diverged from a common foundation in techne: with artistic innovation no longer limited by a single representational standard, and scientific technique being subordinated to independent standards of rationality. While modern artists may mimic, parody, or metaphorically appropriate scientific innovations, we are told, scientists do not correspondingly borrow from art." (1987: 184).

What I hope to explore here is the way in which this hard distinction between science and art is troubled by the work done by astronomers—that their work demands "artistic" and "aesthetic" judgements to be made, and for a particular representational tradition to be followed (e.g. Kessler 2012) that is plausibly objective and representational of the secluded post-Copernican world.

Here we return to the concept of the visual field in earnest, for it is here that it is articulated most clearly in the manipulation of images. These images are, in their afterlife, processed into alignment with a certain set of prefigured forms asserted as appropriate by particular earthly observing traditions (Kessler 2012). Here, then, I would like to discuss the visual field as it pertains to the astronomical image and is articulated in their processing: the particular aesthetic and social considerations that go into making

an image ready to be shared, so that it might be a means to also circulate a certain experience or cosmological perspective. This means understanding where the contemporary understandings of the image deployed by my informants come from, how they inform my informant's processing of images into a more optimal form, and the particular way this processing is understood in the project to mediate between the human and the cosmos. Like place and the body, the image is yet another site which exhibits the tension between the desire for objective and unmediated vision and the need for human interference and judgement in their production, highlighted particularly in amateur astronomy by the social and therefore aesthetic orientation of their work. While failing to provide objective visions of the cosmos, therefore, the image and its processing offers my informants a site at which the constructed and socially grounded nature of scientific cosmology is made clear, where they must consider the tension between allowing the cosmos to stand for itself and intervening in it to make it more visible, and where they are called upon by their work to engage with and reconstitute their world in the context of these considerations.

5.1. The History of the Image

The image has always held a particular and often venerated position within scientific work. Particularly mechanical reproduction lends itself to be understood as a work of pure objectivity; just as we have supplemented our eyes with telescopes that see farther and fainter objects, so have we replaced our retinas and frail memories with cold, hard machines which simply capture what is there (Hooke 1665; Daston & Galison 1992; Kessler 2012). In some cases, particularly in the case of the very small and the very large, images often do a better job of representing reality than what can be provided by our senses. As I will discuss shortly, certain processing techniques such as "stacking" can produce images of phenomena that even telescopes would struggle to deal with. The lay understanding of the epistemology of images, therefore, is that they are often a kind of magical window which presents to us that which is more real than the reality that we perceive with our naked eyes.

Such a singular and simple account of images is however challenged by the historical debates surrounding the image that have existed in science; a "pervasive uncertainty about their validity and trustworthiness" (Kessler 2012: 11). The image, it seems, is held in a critical point of tension between human and world; between abstraction and the concrete, between accessibility and epistemological rigour. In this sense, just as place and body became the critical site of ascetic torsion, so too does the image, trapped between the transcendent objectivity that it gestures towards and the base and limited materiality of their making and their substance. Here, we return to the torque, that indeterminacy of signification which means that the critical binary between culture and nature can be interpreted changeably by different people to have different epistemological qualities. Is the image too human, or is it a critical tool for escaping our limited perspective?

The historian and philosopher of science Peter Galison summarises this tension with the line "We must have images; we cannot have images" (2002: 300). As he expands, "We *must* have images because only images teach us. [...] By mimicking nature, an image, even if not in *every* respect, captures the richness of relations in a way that a logical train of propositions never can. [...] And yet: we *cannot* have images because images deceive. Pictures create artifactual expectations, they incline us to reason on false premises. [...] Truth is something wider and deeper than the pictorial imagination can ever hope to encompass" (*Ibid*.). For Galison, this debate has been core and prominent in the history of science. The image therefore sits teetering between two extremes. It is flanked on the one hand by linguistic description, which leaves itself far too open to interpretation and subjective readings. As the physiologist E.J. Marey noted, "born before science, language is often inappropriate to express exact measures and definite relations" (Cited in Daston & Galison 1992: 81). On the other stands data, which is precise but grossly unintuitive. Rather than finding the image to be a good middle-ground, however, the image remains trapped in a deeply ambivalent condition. The debate over the status of the image rages between what might be thought of as the puritanical and ascetic scientists on the one hand who disavow the all-too-human image such as, for example, the physicists Werner Heisenberg and Neils Bohr, and those

devoted to the accessibility of the image, such as Henri Poincare and Erwin Schrodinger. As Galison summarises his own efforts to understand this debate, he claims that he wishes to "explore the ways in which the sciences find themselves locked in a whirling embrace of iconoclasm and iconophilia" (*Ibid*. 301).

Working with another historian of science, Lorraine Daston, Galison also wrote a notable account of the very particular historical link between the image and the notion of objectivity, and specifically how this account has shifted over the last 300 years. Such an account is critical to understanding the problematic torque of the image and how we have reached the point of my informant's relationship with images. Specifically, they discuss the image as a site of moralisation, as their epistemological efficacy becomes debated. They note that the notion of objectivity in its current form consists of a hodge-podge of different understandings of what makes knowledge legitimately objective, which modern objectivity "mixes but does not integrate" (1992: 82). While I have traced anti-human aspects of epistemological legitimacy to the ascetic traditions of early Christian monks, Daston and Galison emphasise how, in the late 1800s, a new "mechanical" and "noninterventionist" objectivity appeared, which demanded that the scientists disengage themselves from the work of imaging for risk of contaminating it with their subjective biases; the work of the scientist, just like the work of the ascetic, must become the work of "self-restraint" and "a struggle with inward temptation" (82).

This approach is contrasted with the work of 17th-century epistemologists, who took it upon themselves to shamelessly alter and mediate the image. Imaging practices in the period discussed, by contrast, reduced the scientist from a genius visionary who channelled their insight through their manipulation of images to a worker whose job it was to operate the far more reliable and accurate machines which do the actual measurements. Images were published unadulterated, "warts and all". As Galison and Daston describe this distinction, "seventeenth-century epistemology aspired to the viewpoint of angels; nineteenth-century objectivity aspired to the self-discipline of saints." (*Ibid*.). This shift in the status of the image stands as yet another step in the Copernican engine—yet another challenge to the privileged position of the human, yet

another place where our work cannot be trusted to not pollute the result of knowledge-making, and therefore yet another call to efface humans from that process. The camera is therefore a crucial tool in this ongoing great demotion, in that “patient, indefatigable, ever-alert machines would relieve human workers whose attention wandered, whose pace slackened, whose hand tremble” (*Ibid*. 83).

Since then, however, intervention in the image-making process has doubtless found a resurgence, breaking the hold, at least in the processing of images, of mechanical and noninvterventionalist objectivity, and in this, astronomy is the most prominent example of such intervention. It is common knowledge that the sublime images of nebulae, the staples of astrophotography, are composed entirely of false colour, representing different wavelengths of light. In her work on Hubble images, Elizabeth Kessler notes how these images were meticulously doctored into a form that resembled the romantic landscapes of the American West, a familiar aesthetic form that can ground and serve as a point of reference for more abstract starscapes (2012). Similarly, it has been noted by Benjamin Lazier that famous pictures of the Earth from space were rotated to give them a greater familiarity (2011). The Earthrise image, featuring the Earth viewed from the far side of the moon, initially featured our satellite to the right of the frame, but is regularly presented turned 90 degrees, so that the moon is at the bottom of the image, and that the observer can imagine themselves standing on the surface of the moon, looking back at our planetary home. Likewise, the Blue Marble image, initially taken with the Earth ‘upside down’ (a meaningless statement in space) was rotated a whole 180 degrees so that the continents would be familiar and recognizable. As Lazier notes, “this view was invented. It was made available only by a reorientation of the frame so that the lunar horizon appears below, as our everyday experience of our earthbound condition would lead us to expect” (625). These images, we might say, were intervened in so that they can be made legible and amenable to our existing sensibilities; their verisimilitude is sacrificed for accessibility and experience.

Such interventions in the imaging process denote a sense in which the world must be assisted into view: that an annotated reality is better than the raw reality of

nature, which is often difficult to decipher. Such images allowed humans to meet the universe halfway, to borrow a turn of phrase from Karen Barad, or in the words of Henri Poincare, “bridge the abyss between symbol and reality” (cited in Galison 2002: 301). Galison describes this in terms of another shift in how the scientific subject is understood. If prior to the turn to mechanical objectivity, the scientist was a visionary genius whose intervention was almost one of divine inspiration, and the subject of this novel objectivity was a labourer who tended to machines, the new scientist that emerged in the twentieth century is a skilled expert whose work is one of carefully honed judgement and taste, constructed and disciplined by years of dogged commitment to the production of astronomical images. The production of the astronomer requires, as I have noted previously, the inculcation of a sense of what I have called the *aesthetic of truth* of scientific astronomy. In her work on the production of protein crystallographers, Myers calls this the production of an “ethos” of scientific work, a “tangle of affects, values, attitudes, sentiments, styles, and sensibilities that shape practice and laboratory culture” (2015: 41). As I have seen, experienced, and indeed described in the opening of this work, becoming an astronomer, particularly given that the objects being imaged, lingering as they do in the extremes of vision, have no original or fundamental representation with which they might be compared and judged (Kessler 2012: 128) requires a disciplined and shared understanding of what the cosmos *should* look like.

5.2. Processing the Image

It is worth, at this point, briefly outlining some of the techniques available to the astronomer in their processing of images. There is here a tension in astronomer’s understanding of processing: it is at once understood as a process of ‘cleaning’ these infrastructures between referent and signifier, and an active imposition upon the image, reworking it into a form that is more appropriate for circulation and consumption. It is here that the image is perfected, cleaned, and intervened in, in aid of producing hyperreal images that can sustain the idea that science functions as imagined by erasing its faults.

Processing is a relatively solitary process. As such, I had to work hard to find a space in which I could conduct ethnography. The actual practice of processing is excessively dull. This dullness is not simply a function of my gross inadequacy in this practice (though I certainly found this work tedious and unintuitive). While the painstaking work of 'real' astronomy is often reserved for solitary nights when the relatively mundane and 'boring' work of alignment and exposures can be conducted without an expectant audience, the processing of an image takes this aspect to its extreme. In practice, it is a lot of selecting files, adjusting sliders, and clicking buttons. As such, many enthusiasts come away from an astronomy meeting with no idea that processing ever takes place in the production of images. It is an aspect of image production that is obscured from public view. Much of my discussion here, therefore, is an auto-ethnographic account of my own experience working with images, grounded upon and supplemented by discussions I have had with astronomers about how they make sense of this process. In order to perform this grounding, however, I sought to learn to process images under the tutelage of someone more experienced.

This is not how most people learn to edit images, and John was very surprised, if pleased, when I asked him to show me the ropes. Most people opt for this practice to be fully eremitic, shutting themselves in offices or bedrooms, watching and reading tutorials on the usage of processing software. As informants noted, John included, this is in part out of a concern for the safeguarding process and an anxiety about the state of their pretty pictures before they are touched up. "I wouldn't want to show people the state of some of these images before they're processed," he said, chuckling.

In spite of this, we sat down one day in the Hub for a tour of some image-processing software. This is pretty much never a manual job. There are a plethora of apps, both free and 'premium' that will do the work of processing for you. Much of the work of processing is learning to navigate this software and the background processes that it performs for you. In this sense, processing is much like the practices I discussed in the previous chapter: developing an internal model for what can be done

with an image, how to identify and troubleshoot issues, and how to deploy particular technologies to fix that problem. Given the particularities of how these operations are performed on any given piece of software, I ended up using most of the software I was shown for most of my astronomy career.

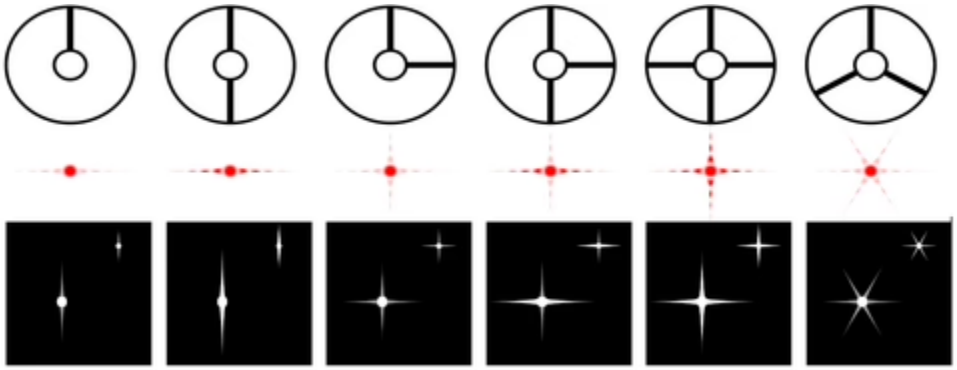

Fig 11: *Diffraction spikes.* A table describing the way in which different configurations of support beams within a telescope lead to visual distortions in the image, one example of undesirable 'instrumental effects' which are "visual presentations which turn out to be effects of the instrument rather than of the referent thing (Ihde, cited in Allain 2013: 39). This image is provided by the telescope maker Celestron (2018).

It is here that the work of the Copernican Engine—the impulse to erase practice from the image—spins up in earnest. In her discussion of practices of visualisation amongst professional astronomers, Rosalie Allain makes sense of processing as a translation, as a move "from data into images". She notes explicitly, through a Latourian analysis of imaging as a network, that these processes function to obscure and erase the artefacts of the work that had gone into the image described in previous chapters, which mark images in distortions and other "instrumental effects". One example of this is, for instance, the diffraction spikes (see *Fig. 11*), which are distortions produced by the interaction of light with the support beams within the telescope that hold the mirror in place, denoting an intrusion of local conditions into the image. As Allain puts it, "The second half of the networks of light, where raw data is translated into images, is in so many ways mobilised to the task of erasing the first half, where light was converted into data. In one stroke, the latter set of visualisation techniques renders the former invisible,

whilst enabling the visualisation of images and rendering them amenable to analysis. This is done most notably through the erasure, rejection and concealment of what astronomers call ‘noise’ through image processing techniques.” (2013: 39). The object of such work, it seems, is to plausibly make the image seem like a view from at once nowhere and anywhere, a cosmic perspective not from Earth, but floating free in space, isotropic and homogeneous.

As dull as this work is, however, it is theoretically fascinating in that, as described above, this is the place where the tension between the ascetic injunction to present the world-in-itself comes into conflict with the need to make the world intelligible. In her work on the production and processing of Hubble images, Kessler discusses the judgments that are made as to how much an image might be processed in more detail: “When observing with the Hubble Space Telescope, astronomers are forced to consider what constitutes a legitimate image. What modifications to contrast, colour, and composition are acceptable and which ones are not?” (2012: 128). When faced with such an inquiry into the nature of such processing, many informants see this intervention as a correction made to the problematic process of imaging, but recognize that their representations are rendered unfaithful by that translation. It is, for instance, common knowledge that most stunning images of nebulae are false colour: that, in reality, they appear as slightly brighter or fuzzy objects. However, this false colour is extrapolated from different wavelengths of radiation that these bodies emit, colour-coded by greens, blues and reds. There is an aspect of this practice that therefore continues the work of revealing the true nature of the cosmos in abstracted form: that different folds of the cosmos are laid bare by this colour-coding. Yet also, images without this intervention would be less ‘just,’ conveying less of the affective experience of wonder that the astronomer seeks. It is here that, for the practitioner, the innocent dream of pure and unmediated representation dies, killed by the inescapable recognition that, for reality to be legible, the work of shepherding light must continue, and the cosmos must be disciplined, adjusted, and annotated into view, aligned with that visual field discussed previously.

Not all images need to be processed, but all images, almost by definition, would benefit from it. Processing is a term for a whole host of often digital practices, directed at ‘cleaning’ images and making them ready to be seen by the public. Often, this means distinguishing signal from noise, boosting the former, and erasing the latter. As such, some objects, such as Jupiter, Saturn, or the Moon, are close and/or bright enough that one can capture a great deal of detail with a single long-exposure shot. For these entities, one can largely capture images in much the same way one might a landscape, albeit with some extra equipment and technique. However, even these images, being at the extremes of sight, can benefit from processing. By feeding the raw data into software such as Photoshop, astronomers can sharpen features, adjust contrast, correct colour balance, add colour, and remove aberrations to their taste. For example, one can produce incredibly high-detail images through a practice called “stitching”. By taking multiple partial shots of an object such as the moon at high magnification, astronomers can later collage those frames together to produce a singular image with a level of detail that would otherwise be missed by a wider shot.

Processing can also be used to push our limited senses and sensors even further, to see even dimmer images through a process called “stacking”. The problem with simply turning up the contrast on any image in order to make dim features brighter is that, as I mentioned previously, such a process has no means of differentiating between signal and noise. As such, turning up the signal also magnifies any interference that upsets the image. One correction to this is to take multiple images with the same framing and use a specialised piece of software such as *Deepskystacker* (the free software that my informants pointed me towards). Stacking images takes an average of the provided frames, allowing the program to automatically identify one-off distortions and aberrations and eliminate them, allowing the photographer to turn the contrast up without risking amplifying noise.

These practices, as I have suggested, can largely be made sense of as a process of “cleaning.” In their work on the use of data in scientific (specifically ecological) work, Tone Walford takes note of how this process of interfering with and applying

judgement to data is not only common but necessary for producing legible outputs. They propose an "aesthetic" approach to data, inquiring about "what constitutes a 'persuasiveness of form' in any cultural or social context" (2021: 205). They emphasise the idea of data as an artefact: as something that is made rather than gathered or harvested, and point towards the processes by which their informants in the Large Biosphere Atmosphere Experiment in Amazonia develop a sense of judgement about what qualifies as legitimate data and which outliers are to be discarded.

While the specifics of this process of omission are largely automated away for astronomers, there is still a judgement that must be made about what kind of processing an image needs, and this judgement is grounded in an internalised model of what an image should look like and how it can go wrong. As I have noted, following Kessler, this internalised image cannot be based upon some primary sense data: sitting at the extremes of vision, we cannot witness these objects first-hand, and therefore have no prototype with which to compare them (2012: 128). These judgments are therefore firmly rooted in a context of model images and a visual tradition largely emerging from instruments such as the Hubble space telescope, which are the true subject of this reproduction. It is openly acknowledged that images are compared and used as aesthetic inspiration for further iterations. Indeed, as Buchli claims, this is the crucial function of imperfectibility in asceticism: perfect reproduction of the ascetic model is the work of demons (Harpham 1987: 10), but imperfection is productive:

> "The act of interpretation, by virtue of being flawed, necessarily facilitates further interpretative work and thence continuation and iteration. Its incompleteness requires constant reiteration and work, enabling it to be sustained indefinitely into the future. It would have no social power if it did not need to be reiterated and interpreted in order to be sustained and thereby act as an impetus for emulation" (Buchli 2016: 40)

This is what sets the visual field for astronomy, and lays the foundation for my informant's work, calling on them to reiterate forms and build upon them. But it also explicitly works within a tradition, which "cleans" images of their imperfections, and

therefore intervenes in them. It is for this reason that some astronomers sport imperfect and fuzzy images with pride: for them, the “rawness” of the image.

5.3. People and the Sky

Astronomer’s engagements with images, as I have noted here, are not limited to their production, but also their circulation. One key site I found particularly interesting was the *astrophotographer of the year* competition, an exhibit held in the Royal Maritime Museum in Greenwich, where some of the most impressive works of astronomy in the world were shown. On display here were some of the most innovative and fascinating deployments of this aesthetic judgement, pushing the boundaries of technical ability and aesthetic traditions, all of which function on that base impetus to reveal some aspect of the natural world in a visually appealing way. For several years, a group of astronomers and I, usually Simon and Kara at least, would go to wonder at these images. I found that my experience of the event shifted as I familiarised myself with astronomical practice. Over the years I found my gaze beginning to move from the images to the accompanying description of their technical specifications, having acquired a context for what it meant to work with this aperture or that exposure time. We found ourselves marvelling together over the practices deployed in producing these images. Was the exposure time really a whole year?

The display is subdivided into different categories. Consistently, the category that we found ourselves drawn to was the section “people and the sky”. This section is exactly what you would expect: impressive vistas of the sky with people or buildings in the foreground (see *Fig. 13*). I raise this category and its popularity here because it seems to trouble the anti-human image of astronomy I have laid out thus far. If astronomers put so much effort into erasing the marks of human interference from their work, why would they go to such lengths to re-insert themselves into such images, and why would it have such popular appeal? Answering this question promises insights into what it is that the image actually does.

Fig. 12: Ben, Floyd and the Core by the astronomer Ben Bush, one of the award-winning images from the 2019 *Astrophotographer of the Year* competition. The image was my personal favourite of the lineup, and a print of it currently hangs in my office (Ben Bush 2021).

To do so, we might return to Immanuel Kant's concept of judgement, and further his concept of the sublime. In *Critique of Judgement*, Kant distinguishes between the beautiful and the sublime in the sense that, while the beautiful is known to be produced by and for our judgement—purposefully crafted and placed within the visual field—the sublime "may appear in point of form to contravene the ends of our power of judgement, to be ill-adapted to our faculty for imagining, and to be, as it were, an outrage on the imagination, yet it is judged all the more sublime on that account" (1793: 307). The sublime is, in other words, an experience of the world-without-us, where that which is radically external to the human world lurches into view. In this sense, the sublime is the affective experience of our contact with extremes as described by Valentine, Olson and Battaglia (2012), and another term for what Thacker calls horror (2011). Kant describes the experience of the sublime to be one grounded in a relationship with its object quite

distinct from the beautiful: “Delight in the sublime does not so much involve positive pleasure as admiration or respect” (1793:306). The sublime effaces our judgement, but instils delight nonetheless, a “negative pleasure” of being put in our place by the raw power and finality of nature.

In this sense, the sublime is a cosmopolitical experience, which is to say that it is effective insofar as these extremes of vision are available to be judged as a commentary on the particular relationship between humans and the world implicit in the Copernican Engine. Here, we might draw parallels between the images included in the people and the sky category of astronomy with another prominent work associated with the sublime experience: *Wanderer above the Sea of Fog* by Caspar David Freidrich (see *fig. 14*). This painting depicts a figure in the foreground gazing at an expansive landscape shrouded in fog. The sublime effect of such an image arises, theoretically, from the scalar shift between these two features of the painting: from the contrasting scales of the lone human and the overwhelming landscape he surveys. This image, and indeed astronomical images like the one above, literally place humans within the context of these powerful and potentially “limitless” natural environments (Kant 1973: 306), the work that other astronomical images do only by implication. In contrasting these vast scalar differences, the sublime evokes in the observer an “extreme aesthetic experience, one that threatens to overwhelm humans even as it affirms humanity’s potential” (Kessler 2012: 5).

The concept of the sublime has been applied elsewhere to astronomical images by Elizabeth Kessler. In her discussion of Hubble images, she identifies “an emphasis on the powerful forces of nature, compositions that convey great size and scale, dramatic lighting to heighten the intensity of the scene” (2012: 20) which, in cosmopolitical terms, “encourage the viewer to see the cosmos visually *and* rationally, to see the universe as simultaneously beyond humanity’s grasp and within reach of our systems of knowledge” (2012: 5). Here, Kessler highlights Kant’s claim that the sublime experience operates through both the senses and reason, requiring a simultaneous engagement of both, and pitches them against one another, “challenging the former and

elevating the latter" (20). In presenting us with ambiguous objects that exist somewhere between the familiar and the other, the sublime calls on the observer to reconsider their world. I have described this tension at play here, in the need to make the image at once legible—to incorporate it into the human world—and true to reality—to allow it to exist 'out there' in its radical alterity. As such, the sublime is marked by the tension that I have discussed permeating astronomical work thus far—between impotence and agency—and articulates itself in images of space.

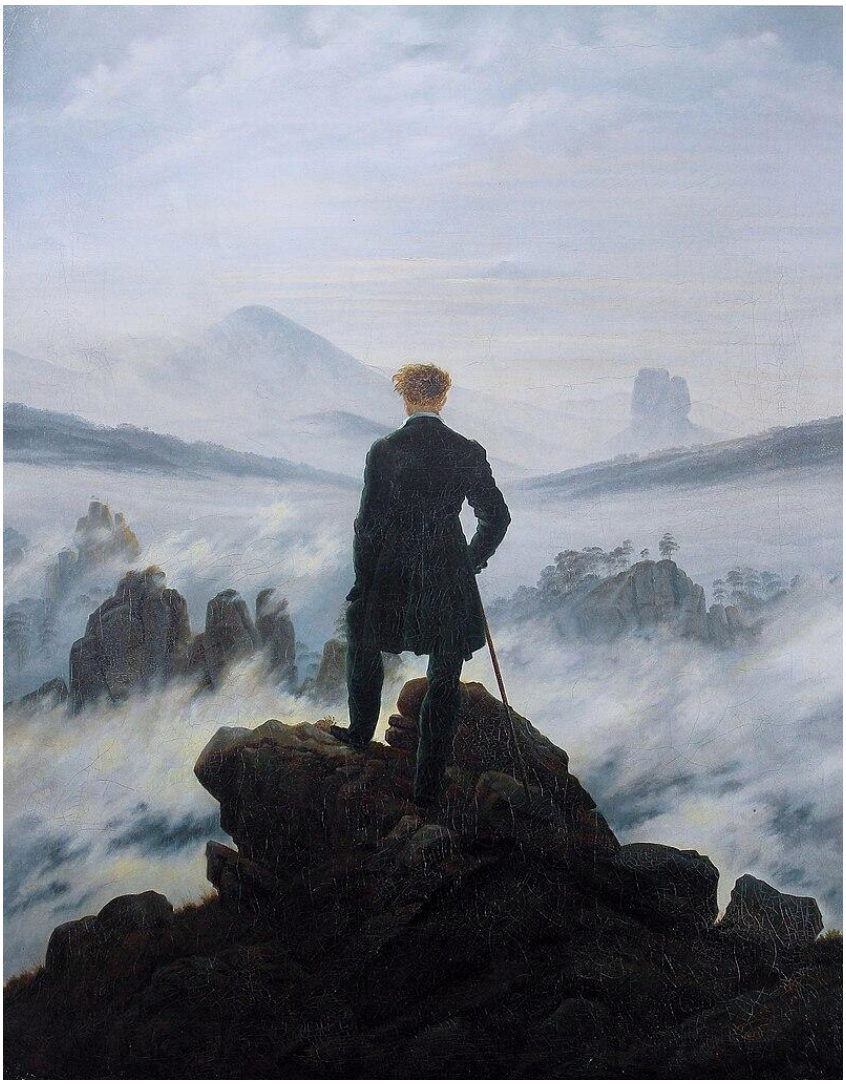

Fig. 13: Wanderer above the Sea of Fog, by the romantic painter Caspar David Friedrich, is often associated with the sublime in its contrast between the human subject and a vast, expansive nature. Just as Kessler draws parallels between Hubble images and nineteenth-century landscapes, one can also

draw formal parallels between this famous sublime image and those we see in the category of *people and the sky.*

What Kessler's discussion of the sublime and its applicability to the *people and the sky* section emphasises is the critical affective aspect of the astronomical image. The work of astronomers, particularly in their processing of the image, is directed at the entangled projects of capturing not only the reality of the cosmos but also the wondrous experience of the transcendental. This resembles what Roland Barthes discussed as the "just" image in *Camera Lucida*: the way in which an image can evoke a particular kind of affective resemblance, defined by "both justice and accuracy" (2000: 70). In Barthes' example, he claims that he "rediscovered" his mother through images of her as a child, a visage with which he had no familiarity, yet still carried some of her aspect, something which we can use our judgement to extrapolate out of these particulars into the general concept of his parent. In astronomy, the affective power of an image is its capacity to likewise do justice to the transcendental experience of the cosmic perspective: to be appropriate to a certain kind of judgement, taste, or symbolic excess, and to offer the viewer lines of coherence between it and the more general underlying principles of nature it references. This affective aspect of the image is, as I note, dependent upon their plausible access to this higher, more 'real' plane of reality, in part predicated upon the insubstantiality of the mediating processes at work in their revelation. By contrasting people with the sky, these images evoke just such a sense of wonder about the grandness of the cosmos, and our infinitesimal smallness in its context. Drawing upon my previous discussion of the Copernican Engine and the fundamental drive of scientific work to seek the world beyond the human world, it appears that this affective response, this experience, is fundamental to astronomy, and a sense of awe and wonder at the vast scales of the cosmos is often referenced by astronomers as an experience that is evoked by such images. It seems to me that astronomers seek to be overwhelmed by their images of the cosmos, and the relationships between it and themselves that they evoke. These are the experiences and evocations that the sociality of the image seeks to share.

It should, however, be noted that this concept of beauty that exists beyond the bounds of human standards is questionable. The images of people and the sky operate clearly by contrasting the figure of the human with outer space, that signifier of the world-without-us. However, like any visual field, this appeal operates within a very particular conceptual tradition, one I described in section *2. Cosmos* as the Copernican Engine. These images, like all astronomical images, albeit more clearly, are the Copernican Engine in visual form. And like the Copernican engine, they levy an impossible demand for escape from the horizons of human thought. These images function (which is to say, induce an experience of the sublime) insofar as they are *plausibly* objective, that the overwhelming nature they mediate is *plausibly* the world-without-us. As Kant noted, Judgement is the imaginative work of contextualising the particular within the general, of situating phenomena within transcendental systems. We need look no further than Kessler's work to find the deeply familiar and human bounds of such work. While Kant insists that the sublime transcends or even offends the imagination, we can clearly see in these images and their alignment with the Copernican Engine, pre-existing skeins of judgement from which it draws in order to produce such experiences. The consistent tension of astronomy is presented here, again, in the need to render such images at once super-historical and work within a very particular genealogy of cosmopolitics and aesthetics.

As such, and most notably for my discussion here, the category of *people and the sky* is perhaps the most explicit place where what astronomy actually does is articulated. As I have noted, in the absence of the possibility of objective vision, astronomy appears to us as an effort to engage with the grounds upon which these images fail in that project, which are fundamentally cosmopolitical. The sublime as Kant uses it and Kessler applies it to astronomical images refers directly to the relationship between humans and the cosmos, charting the extremes and limits of our world from without. This challenge to human worlds is precisely what I have observed being raised aesthetically in the *people and the sky* format of astrophotography, and practically in astronomy more broadly. These efforts are caught between the simultaneous demand to present something very specific which speaks to a particular orientation of human and

world, and to appear as if it does not. This subgenre of astrophotography therefore demonstrates to us what astronomy is supposed to do—namely establish clear and solid boundaries between humans and nature—and contains within it the challenges this purification denotes. The sublime is the overwhelming of the human by nature, but also, the appropriation of that overwhelming experience into prefigured interpretations of that experience.

5.4. The Sociality of the Image

As Galison noted, the image lies in a tense relationship with data, with the former serving as an intuitive means of access and the latter boasting greater verisimilitude to the world in itself. Galison refers to this as the "strain of the abstract-concrete" (2002: 302). The rough distinction I drew was between ascetic scientists driven by puritanical objectivism and those who deploy images in the pursuit of intuitive understanding. These two positions reflect two very different understandings of the core function of the image. The former sees the image as a means to get at the world-in-itself—as a matter of epistemological rigour—and finds it wanting. The latter, on the other hand, displays an emphasis on the pedagogical function of images: their capacity to transfer information between minds in a way that is accessible and intuitive. This is to say, the latter emphasises the social capacity of images to provide access to a cosmic perspective, and through that image-experience share access to the technoscientific cosmos. As Michael Lynch and Samuel Edgerton report in their study of scientific astronomers, a firm line is drawn between the "two cultures" of research images and the "pretty pictures" that are produced for public consumption (1987).

It is not hard to discern which of these camps most of my informants fit into. Their stated goal, after all, is rarely to push the frontiers of scientific knowledge, because such a frontier has been pushed so far beyond the scope of what is accessible to the equipment available to amateurs by the huge arrays available to physicists. Rather, they opt to re-tread ground already established, reiterating it, and making it accessible to members of the public. Alongside public communicators such as Carl Sagan and Brian Cox, amateurs often function as the public relations arm of the scientific project, as the

place where the workshop spills out into the world. If images are, as Maralyn Strathern claims, “meanings made available, we might say, for consumption” (2022: 46), then in this context, the impulse to transfix the cosmos in the material of the image that can be (and are) shared on social media and in prints that are brought to events and hang on the walls of my informants is a social project for the circulation of these meanings—this world—throughout the astronomical community. One of the amateurs I met proudly let me know that he was actively in communication with NASA, who provided him with images that they produced so that he could use his social networks to distribute them to members of the public. This circulation is the sharing of experiences, particularly experiences of the sublime, that raise with them the questions that haunt astronomy of the place of humans within and their relationship with the world.

While there are many who relentlessly seek the perfect image, there is a clear emphasis within the amateur community (which particularly shows in the work of processing) upon the sharing of images, and therefore experiences. Of all of the different proponents of visualism described by Galison in his historical account of this epistemological strain, one of the best known seems to be Richard Feynman, an American quantum physicist known for his (in)famous ‘Feynman diagrams’ that present the transition of particles between states as they interact in simplified drawings (see *fig. 12*). At the time of his work, Feynman’s diagrams and his dedication to simplicity and accessibility in physics was something of a scandal, deemed by the physicist Julian Schwinger to be a tool that permitted the physicist to believe that they could do physics without thinking (Galison 2002: 308). Quite the contrary, for many of my informants, Feynman is something of a hero for much the same reason. Treated as a maverick, standing up to a stuffy old guard of puritanical physicists, Feynman’s appeal to many of my informants is precisely his dedication to bringing transcendental and divine physical laws down to Earth and making them available to members of the public, mediating this godly register of the world for a lay audience in the same way a preacher might. People like Feynman are the patron saints of amateurism, forwarding the inclusive message that anyone can do physics, and grasp the true nature of the cosmos.

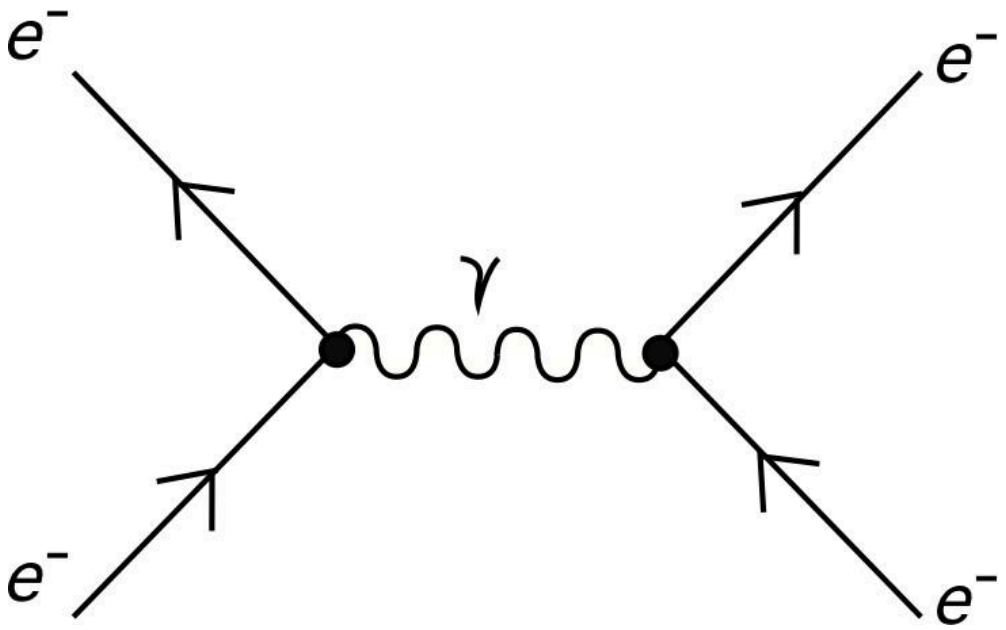

Fig. 14: *The electron interaction.* An example of a Feynman diagram, representing a mathematical calculation in pictorial form. This particular diagram describes the interaction and repulsion of two electrons and how in the process one 'virtual photon' is exchanged between the two. Because of the way in which all of the components of the diagram correspond directly to a calculation, the image serves as an accessible representation which can also be easily abstracted into numerical form (Galison 2002: 308).

As such, there is an overlapping binarism at work in the amateur astronomy community. On the one hand, there exists a focus on the objective work of mediating reality as it truly is. For this, the ongoing debate over whether the pictorial form is even fit for purpose when compared to data still rages. On the other, is a function that elicits a particular sublime and wondrous affective response, which inspires enthusiasm and engages enthusiasts with the professed revelatory power of astrophotography. For this purpose, the anxiety of producing crisp, clean images is clearly present in the work of processing, but the image form itself, and its interstitial position between the familiar and the unfamiliar makes it a crucial tool for such work. The image mobilises the cosmic perspective so that it can be shared and utilised to cultivate dispositions and practices that can properly engage with the technoscientific cosmos. The capacity of the image to

elicit such responses and perform such cultivation rests largely upon its capacity to plausibly render something fundamental and secluded about the cosmos, while also participating in an aesthetic tradition which is at once *of* science (Lynch & Edgerton 1987; Kessler 2012) and obscured as a matter of aesthetics by this plausible objectivity.

The afterlife of images is therefore crucial here. While many images are simply produced for the sake of their production, only to be stored away on hard drives, much of the astronomy community (particularly online) congregates around the sharing of such images. They are used as screensavers and stored on phones to be shown to friends. In my time learning to do astronomy, such images were pulled out countless times to give visual grounds for a particular object or illustrate a particular technique. These images are also posted to Facebook groups and forums with the technical specifications of their production, to participate in the aesthetic tradition of astronomy and share achievements. Often, such pictures are posted with requests for help or guidance. “How can I avoid this chromatic aberration” one might ask. Lastly, the images of which people are particularly proud are printed, framed, and placed on walls in the astronomer’s house. I remember once visiting Isaac’s house, where I was shown some of his favourite images, and given explanations of exactly what the object was and how he captured it. For him, the value of such images was precisely their humanity: they were often significant markers in his progression as an astronomer, waypoints on his journey into the cosmos. Notably, he also said that he put them up for his newborn child. “I want him to grow up around this. I want him to see this stuff all around him and understand the world he lives in”. Like my father, Isaac’s practices seem directed, at least in part, towards furnishing his child with the capacity to make judgements about the cosmos and his relation to it.

5.5. Image as Art

When I was young I was told a joke about science and its relationship with art. While its origins are lost to me, its content has always stuck with me and informed a particular understanding of the place of science in the world. It asks what the difference is between science and poetry. The punchline is that science attempts to say something

that no one has ever heard before in a way that everyone understands, and that poetry does the exact opposite.

This joke is, of course, flippant and insincere; few science advocates would dismiss the huge cultural value produced by and derived from the work of art. Indeed, there is much to be said about art as a medium for the expression of scientific truth. Yet, as with all humour, there is some grain of truth embedded deeply within this joke. Art is often situated on the other side of the dichotomy that I have been working with here, the subjective counterpoint to science's objectivity. By dealing in complications and implicit knowledge, art is even sometimes seen as an elitist practice challenged by science's egalitarian emphasis on explicit and accessible knowledge. This, after all, is why some of my informants have such affection for Richard Feynman and his aforementioned diagrams.

Given such a contrast, a comparison between art and science that does not juxtapose the two is not necessarily intuitive, and fits in nicely with the provocative nature of this project. However, the problems we face here with the matter of representation are issues that have previously been faced and discussed within art theory, particularly in Alfred Gell's discussion of the Art Nexus and Hans Belting's analysis of the masterpiece within modernity. By considering what it is that the astronomical image is trying to represent through the frame of what the work of art tries to represent, and particularly the torque implicit in that representation, we might understand better how this process could be deemed to be impossible.

Like much anthropology, this insight was not mine, but rather emerged from a conversation I had with one collaborator, Isaac. As I discussed earlier (specifically in the methodology section of the introduction), the really useful aspect of working with scientists is the proximity of our projects; working within the same project, informed by the Cartesian engine, means that we share a conceptual grammar and an understanding of what we are trying to do. If I am curious about the astronomical image and why so many astronomers believe that the perfect image is impossible, I need only

ask what they think might be meant by this statement. It is in this sense that this project is truly collaborative, insofar as I get to work through these questions *with* my informants explicitly, without the need for interpretation.

Often, when I ask about why the perfect image may be impossible, I get a technical response about the limits of the materials and practices that I have discussed in the preceding sections (3.2. And 3.3.). While these problems are significant, they do not have the finality that renders images impossible (though as I have discussed, these problems do also point towards a metaphysical problem that does). However, what Simon had to say about art does speak to a fundamental issue with the problem of representation. He was himself an artist by trade, placing them in a particularly useful position to straddle these two supposedly non-overlapping magisteria (Gould 2010). He claimed that the function of images is to capture something of the "substance" of the subject—something essential and worth transmitting to others. A portrait, for instance, should express something about the character of the person being pictured. The problem with the astronomical image, they suggested, is that it seeks to compress too much into a medium that is inappropriate for that substance.

He offered examples of their work to demonstrate this point. The first was a pattern that featured images of peacocks and tigers, golden filigree and a colour palette that unmistakably denotes South Asian aesthetics. "Look at this pattern" he said, "It's clearly supposed to be about India. You probably thought that the moment I showed it to you. But I never *told* you it's about India. I didn't need to. Now look at this one…". He flicked his finger and the phone scrolled to the next image, similar in form, only this time featuring sea creatures and bubbles and seaweed on a field of dark blue. "It's the same thing, right? This is really unrealistic. I'm pretty sure you will never see these animals together, and half of these are based on creatures that live so deep you would never be able to see them. Plus, I'm pretty sure seahorses can't even play trumpets!"

What he was trying to get at here is that in his work, interpretation and implicit associations do much of the heavy lifting. They treat explicitly in the kind of inference

that is, in orthodox scientific understandings, the business of art. This implicit knowledge is, in essence, a resource that his work and the work of art in general can draw upon for signification. This is what Slavoj Zizek refers to as the "sublime object" of materiality[4], a surplus that transcends the corporeality of the object 'itself'. One can infer that my informant was saying that, by treating only in the explicit, scientific imaging rescinds its access to such resources of signification.

My comparison here between the work of art and the work of science (the scientific image included) is that both are works of reproduction; both are concerned with articulating the forms and concepts we find in the world as phenomena. The distinction, illustrated by my informant's contribution, is the tools and resources at the disposal of their respective practitioners. The work of art, with its navigating of the implicit knowledge embedded within cultural forms, leaves open to itself a whole host of subjects and means of signification which the (orthodox) work of science, seeking to transcend this cultural particularity, has a doctrinaire aversion to. While the subject of art might be more abstract and conceptual at times, it is still nonetheless a work of reproduction, even mediation, and it is for this reason that Alfred Gell took to referring to the art artefact as the "index," as something that points to something else. Making sense of representation and mediation as a process might therefore be helped by exploring the index and in particular the astronomical image *as* index.

[4] In his most significant work, *The Sublime Object of Ideology*, Slavoj Zizek uses the example of money to define what he means by the titular sublime object. He identifies in the use of money, as well as in many other practices, the disenchanted materialism of the naturalistic worldview undergoes a particular "fetishistic disavowal," a certain 'as if' in which the excesses of enchantment re-intrude upon the materiality of the object. He claims that this follows a syntactic formula that is "I know very well, but still...". Returning to the example of money, the claim is that while currency has a materiality, it also has a semiotic excess, an intangible and immaterial value that can withstand harm that might be done to the material from which it is made. "I know that money is a material object like others, but still... [it is as if it were made of a special substance over which time has no power]" (2006: 9). As Zizek puts it, "here we have touched a problem [...], that of the *material* character of money: not of the empirical, material stuff money is made of, but the *sublime* material, of that other 'indestructible and immutable' body that persists beyond the corruption of the body physical [...]. This immaterial corporeality of the 'body within the body' gives us the precise definition of the sublime object." (*Ibid*.) It is in the persistence of this sublime object that the paradox of the material and the immaterial—described by Buchli and upon which this project is based—reemerges. In this particular case, the sublime object of the image, as I shall discuss, is its surplus of signification, the context it can draw upon in order to signify its referent. As we shall also see, scientific imaging also participates in this fetishistic disavowal which re-enchants its content.

Concerned about exclusive and institutional definitions of *the work of art*, Gell uses the term *index* and *art nexus* to forward an understanding of art as "entities in whose neighbourhoods social relationships are formed," (1998: 12). Gell's discussion in *art and agency* situates the index within a set of interactions and intentionalities that he calls the *art nexus*. It is, in his words, the "nexus of relations in the neighbourhood of art objects" which can be used to discern the choreography of social action that emerges around the work of art or index (28). We might say that the art nexus is an attempt on the part of Gell to map the infrastructures of relations that surround the art object. Alongside the index, the entities within this nexus include the artist or 'originators', whose agency brings the object into being (or to whom that agency and responsibility for the index is attributed), the recipients, to whom the index is presented, and upon whom the index is "considered to exert agency," and, critically for the matter of reproduction, the prototype (Küchler & Carroll 2021: 22). The prototype is the model of the index, the thing being copied and pointed to, the subject of the artist's mimetic efforts. In classical artistic understandings, the artist reproduces the prototype or some aspect of the prototype in the index which they then present to the recipient(s). This whole nexus, notably, is held together through the logic of abduction. While deductive reasoning works forward from the cause to the event (in the example given by Gell, if we see a fire we should expect smoke), *abductive* reasoning works backwards and infers the phenomenon from the effect (if we see smoke we should anticipate a fire). As Gell identifies, abduction therefore requires the application of general theories to existing phenomena. For Gell, abduction is the means by which agency is attributed within the art nexus: that, having been acted upon by the index, the recipient infers (abduces) both the prototype and the intent of the agent that produced that index—the artist that is understood to confer animacy to that art object (Gell 1998: 13-14). It is notable here that, in describing abduction, Gell points specifically to the process of interpreting the motions of planets in scientific astronomy (14).

As Gell himself noted, this classical image of the art nexus and its interrelations is readily problematized. He notes the example of the portrait of King Louis XIV of France. Here, the commissioned artist produces the work, of which the prototype is the

likeness of the French King, for the recipient of his subjects. Yet the figure of the king complexifies this relationship. By commissioning the work, his agency also makes him an originator: “One may readily conceive that the great king [...] regards himself as the author of the scene before his eyes [...]. The patron is the conduit of the social causation of such works of art; his agency is therefore readily abducted from it” (Gell 1998: 33). Yet he also produced the work for his own consumption, so he also holds the position, in part, of the recipient. Not only this, but the prototype is also not simply the king, but is mediated by the need of the material originator (the artist in the classical sense) to please the king and accentuate his majesty: “his glorification is its final cause” (*Ibid.*). Therefore, “the painting of a king will not be a portrait in the strictest sense,” capturing also the more abstract “regal ideal” of the French monarchy which is attributed to Louis (Carroll & Kuchler 2021: 20).

This example opens up the possibility (or perhaps inevitability) of the multiplicity of the prototype. Indexes, it seems, can point at multiple things at once, and gather them together into a singular form, structuring sometimes disparate phenomena in the act of signification. This is demonstrated more forcefully in Gell’s example of the Rokeby Venus, a work of art by Diego Velasquez which was slashed by the suffragette Mary Richardson while on display in 1914 in the National Gallery in London. In her court hearing, Richardson claimed that this act of vandalism was an effort to draw attention to Emmeline Pankhurst, a fellow suffragette who was on hunger strike in the prison at the time. In her statement, Richardson draws a whole new set of prototypes for the image, between Pankhurst and Venus, the injustice of her predicament to that of Jesus’s death, and of the government to Judas Iscariot (Gell 1998: 64-5), an act that Küchler and Carroll describe as “a masterful example of artistic creativity” (2021: 27). In doing so, Richardson produces a new index, with a new “compound prototype of venus - Mrs Pankhurst” which structures (or perhaps *sutures*) these different aspects of the art nexus and its political surround together.

To return to the astronomical image then, we can see how it might fit into the intuitive understanding of the art nexus. Through the practices I described, the

astronomer (artist), seeks to reproduce the prototype (the cosmic object) in the work (the astronomical image) for their own consumption, and that of other astronomers and the wider public. Yet the problematic bit, the aspect of representation, is the process by which the index mediates the prototype. The ideal of scientific reproduction embodied most clearly in Daston and Galison's discussion of mechanical reproduction, is a clean signification or transparent media which, with precision and rigorous verisimilitude, captures the phenomenon, without all these excessive and indeterminate cultural trappings.

We could, of course, say that there is more humility to the scientific project than this: that it is recognized that these images are an annotated reality, and that the scientist never entertained the notion that they could ever attain the ideal of perfect reproduction/mediation. As Eric Francoeur noted, no reasonable chemist "would propose that models, even in their most elaborate forms, are about what molecules 'really' look like," claiming that they are meant as "homology" rather than "homomorphy" (Cited in Myers 2015: 126). Models were never meant to truly represent the form, but rather the essence or conceptual content, to make it available. This has, according to Shapin and Shaffer, been understood since the mid-seventeenth century, when all human knowledge was relegated to provisional theories that could be subject to change, a move that was "celebrated as a wise rejection of a failed project" rather than "a regrettable retreat from more ambitious goals" in that it shielded the matter of fact from absolute commitment (a move which, in a sense, we see the ultimate culmination of here) (1985: 24). However, there is a certain plausible deniability that exists in the mechanical reproduction of astronomy that does not exist in chemistry. For certain, astronomy has its share of abstractions in solariums and representative images, but images taken through observation go to great pains to reach towards this realism. It is the revelation of the 'really real' that gives astronomy its affective power. Even if it is unattainable, it is nonetheless their ideal, a goal towards which they strive, sustained by a defiant *as if*. They will always at once openly say that their images are doctored, and also in doing so fervently cover their tracks.

The relationship between the index of the cosmic image and the prototype of the cosmic object is, however, troubled. This illusion of realism is disrupted, in a way that I have previously described, by the blemishes that inevitably emerge from the imaging process: by the emergence of the infrastructures which made them available and indicate its conditionality. In this sense, the relationship between the index and the prototype is always dubious, a problem worsened by the fact that the prototype is, as Elizabeth Kessler notes, largely absent, in that there is practically no alternative access to these objects by which this reality can be verified (2012). Natasha Myers notes that protein crystallographers similarly struggle with “indirect molecular vision” and must therefore rely on models (2015: 126).

The matter of the prototype and therefore representation goes beyond this, for there is undoubtedly (and perhaps more fatally) a surplus of messy, multiple and indefinite significations here. The cosmic object that is the prototype of the image is never *simply* the object. Just as Louis XIV is not only the French king but also a paragon of royal majesty, so too is the cosmic object always a fragment of, and embedded within, that system of systems we call the cosmos. It is always, through the abduction of those versed in astroculture, a fragment of a greater system of systems that we call the cosmos—a partial view of a greater collage. The reality that the cosmic image unveils and stands for goes far beyond the entity itself into the absolute structuring power of natural laws that govern its existence: the life-cycle of stars that ended in the nebula’s formation, the planetary and cosmic motions which resulted in the spiral of a galaxy. It is in this sense that the index is also, as I have mentioned previously, split between representation and the material artefact of the image, both of which make reference to this absolute structuring reality in different ways. Again, through the abduction of one versed in the techniques I previously described, the image and its form stand for the optical and mechanical laws which must be engaged with, and the photons that need shepherding. Why else would it be that when images are shared, be it on social media or in one of the many astronomy exhibits I attended with my informants, they come with the specifications of their making: the model of telescope, the length and number of exposures etc.

To see this excess of signification in action, we might turn to “star trail” images, produced by leaving the shutter of a camera open, allowing cosmic objects to leave trails in the image as they process across the heavens with the turning of the Earth. These images have none of the verisimilitude that one would typically imagine to be the goal of mechanical reproduction. They do not reproduce the sky as we are familiar with it. It features those same streaks that disrupted the image with which I opened this thesis, which astronomers usually put so much effort into avoiding, as I described in section 4.4. Yet here, these smears circling Polaris are not errors but rather features, the desired outcome of the image. The prototype here is not the night sky as it appears to us, but rather its value rests in its masterful use of exposures to both extend the image into the 4th dimension—to capture temporality in a still image—and in doing so also capture the spin of the Earth, something with which we are theoretically familiar but phenomenologically ignorant. In these images, the Copernican cosmos, in which the Earth moves, crashes into view.

The problematic element of this conscious effort to render the absolute finds its analogue in Hans Belting’s discussion of the similar modern artistic effort to capture the absolute work of art. In *The Invisible Masterpiece*, Belting discusses the dire condition of the concept of the artistic masterpiece within a modernity which seeks to force the “ideal of absolute art” into view (2001: 12). He uses the story of the artist Frenhofer, who “sought to realise an art-work that triumphed over reality and the constraints imposed on every work that could be said to be finished or completed” (11). The result was a subjectless and unfinished mess. The moral of this story, Belting claims, is the impossible nature of the prototype as it is imagined. As he opens his work, “the masterpiece cannot be invisible. If it were, we could not discuss it”. He goes on to claim that this titular impossible concept illustrates the desire to create “a work that comprises art in the absolute—a state beyond the reach of every tangible art-work” (1). The parallel with the astronomical image and its abstract, conceptual, and absolute excess of signification is clear here. The masterpiece is imagined here to be a work which speaks to or accesses the ideal of absolute art, a concept that “persistently drove

artistic production but always eluded it," (*Ibid*.). The perfect work, like the perfect image, seems impossible because both seek to actualise a cultural construction as if it were a thing *in itself* rather than something that emerged from a set of cultural practices and artefacts. That which seeks, like the ascetic, to transcend the human finds itself crashing back down to Earth, unable to escape the trappings of human work. As with the ideal of art, the absolute nature of the cosmos "defied the scope of any single work" (*Ibid*.). The prototype is always inevitably a messy excess which is in itself unattainable.

In scientific work, this absolute is the hidden structure of the cosmos. The function of the image is supposed to be to reveal this structure, an *invisible thread* which ties together the disparate, particular and singular phenomena of the cosmos into one coherent whole. It is the material of that engine that Majid claims drives physics to bring things together into a single unity. I like this image of the invisible thread as a counterpoint to Deleuze's concept of the Fold. For Deleuze, the fold is a means for making sense of why a singular metaphysical cosmos can seem multiple: how one can get multiplicity from unity without breakage, cutting or tearing. The suture performs the inverse operation that is at the core of scientific cosmology: to combine and affix disparate elements forcefully. This thread is invisible because of its absolute nature, like the absolute work of art, which effaces rendering in any singular work.

The failure to reproduce the prototype in the index, fundamental to Isaac's interpretation of the impossible image, returns us to the question of what is generated in this failure. This is discussed with explicit reference to the prototype in Buchli's analysis of asceticism. He notes specifically the anxiety of Athanasius over his hagiography of the ascetic desert father St. Anthony. Athanasius worries that his work would not faithfully reproduce the life of the desert father, but consoles himself with the fact that his work, and particularly its imperfection, can act as a model for others to reproduce. A perfect work needs no elaboration, but the imperfect work "necessarily facilitates further interpretive work and thence continuation and iteration" (2016: 40). Herein lies the social force of imperfect translation and reproduction: "It would have no social power if it did not need to be reiterated and interpreted".

This idea goes some way to making sense of the repetitive way in which my informants and astronomers around the world undertake. They recognize that the images they produce are always works in progress, that their goal can never be attained, and that, in those critical words from my collaborator, “the perfect image is impossible”. They aspire to reproduce the cosmos, but ultimately must reproduce the forms produced by others, be it the prototype of the Hubble image or some other earthly art style (Kessler 2012). And yet, as with Ascetic mimesis, “the obstacles to a perfect imitation are absolute” but “virtue resides in the effort” (Harpham 1987: 5). So they produce and reproduce their images of their favourite celestial objects, every time slightly different but never quite good enough, always participating in an ongoing discussion of how we might better mediate the cosmos’ hidden depths, and the part we should play in doing so. But this reproduction, this always-a-work-in-progress, is what gives astronomy its staying power. In identifying the underlying cosmopolitical problem of which the failed image is a feature, astronomy finds its virtue as a means to locate, identify, and address broader troubles. This project, as I said before, was never about the image, but about its coming to be, its process, and what it stands for, which is to say, a process of figuring out the conditions for human engagement with and knowledge of the world.

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The image is the most immediate end-point of Western, scientific astronomy—the culmination of all of the astronomers' efforts into a solid and static artefact. In this artefact we find the tension that defines astronomy expressed most explicitly: the tension between intervention and objectivism, sociality and empiricism. While the image is, for most amateurs, predominantly social in that it is a means for sharing sublime experiences, I have discussed here how these images must retain their plausible reference to the extremities of the human world in order to evoke such feelings of awe, wonder and reverence. Performing this balancing act between legibility and verisimilitude through the processing and cleaning of images makes the illusory nature

of objective knowledge present to astronomers. Some learn to appreciate the “rawness” of unadulterated images, and others to manipulate the rules of optics to produce more abstract images such as the star trails. But all come face-to-face with the ethical question that recurs constantly within the work of astronomy: what power, if any, should humans enact over the world in pursuit of knowing it, and how far does this disciplinary work undermine that very effort? These questions, I believe, are the true function of astronomy, given the impossibility of objectivity on these cosmopolitical grounds, which offers us an understanding of its reiteration in the face of such apparent futility. From beginning to end, the issues raised by astronomy are questions of cosmopolitics: of reconsidering these relationships of power and knowledge, and asking how humans can reposition and reconfigure their place in the world more appropriately.

6. Apocalypse

Up until this point, I have discussed the material failure of astronomy. In exploring the positions of place, practices, and images within astronomical work, and the way in which they are endlessly intruded upon by the conditions of life 'down here', I have charted the ways in which the revolutionary efforts to access the cosmos in itself are curtailed, and the standards for success astronomers set themselves prove unattainable. While these individual instances highlight interesting relationships between amateur scientists and the sites in which they operate, the most significant aspect of this failure for me is its expansive, cosmic scope, to which I now turn. This is to say, my shift here is one, as I suggested before, from material failure to the *materiality* of this failure: the way in which it "ricochets up" into wider contexts, with implications for the broader social context in which it operates and the way in which people imagine their world. Given that the work of Western, scientific astronomy is grounded on a project of reorienting the relationships of power between the human and the world it inhabits, this materiality of failure presents itself as a further cosmopolitical reorientation. As I noted before, I believe that the failure of astronomy is an epistemological problem about how we are to do the objective work of getting at the world-in-itself, with broad cosmopolitical repercussions. Science, as a practice which produces knowledge with which we ground our actions in the world, is a critical juncture at which cosmopolitics is at stake, and lays the foundations for a particular configuration of relations between humans and the world that we might refer to as 'modernity'. In order to explore the materiality of the imperfect image, therefore, I frame scientific work, including scientific mediation, within the cosmopolitics of modernity, before making sense of how this cosmopolitics is challenged by the experiences of astronomers on the ground.

This project emerged, like so many anthropological works, as a study in alterity. It concerns how the modern and scientific project, embodied in the act of astronomy, deals with different registers of otherness—in particular the otherness of humans from the world that is constitutive of cosmopolitical relations. This is to say, how scientific work mediates between an otherness that is is familiar and of our world, that can be

imagined to be ‘like us’, to have an internal world resembling ours, and thereby function as a mirror for us (designated typically with a lower-case ‘o’) and an Otherness that is radically at odds with our understandings, that refuses our world (the ‘Other’). The tension that I have described here in astronomical work is the tension between engaging with the Otherness of the cosmos—retaining its fundamental alterity that defines the Copernican Engine and distances modern human projects from the anthropomorphism of premodern myth—and the need to appropriate it—to render it merely other. It is between the anthrophagia of reconstituting the world into the world-for-us and pretending that it is the world-in-itself, and the recurring intrusion of the human which reiterates the radical Otherness of the world-without-us and our inability to comprehend it. The function of the amateur astronomical image as I have rendered it is fundamentally revolutionary: it is about attempting to overthrow the human world and install a regime of objectivity through an engagement with the world-without-us. As we have seen, and I shall explore further here, this effort fails to escape the compromising grasp of the world-for-us.

This effort to deal with otherness, this tension between appropriation and rejection, might be conceptualised, with the continued help of Jaques Derrida, in terms of *hospitality*. Hospitality, as opposed to hostility, offers the stranger or the foreigner (*l’etranger*, in Derrida’s terms) asylum and/or care, wherein the host Invites the stranger into their house or, in the case of the foreigner, their country. Derrida asks a seemingly simple question in reference to hospitality:

> “Does hospitality consist of interrogating the new arrival? Does it begin with the question addressed to the newcomer [...] what is your name? [...] or else, does hospitality begin with an unquestioning welcome, in a double effacement, the effacement of the question and the name?” (Duformantelle & Derrida 2000: 27-8)

The apparent simplicity of this question belies what Derrida sees as the tense paradox of hospitality, between and within conditional and unconditional hospitality. For hospitality to be conditional is to place limits upon the guest: they must identify

themselves, use the language of the host, and enter into a contract that disciplines their activity within the host's house/country. It is for this reason that Derrida refers to conditional hospitality as "the law of hospitality as right or duty, [...] the "pact" of hospitality" (25). Demanding these things as conditions for hospitality points us towards a particular implied hostility in the act of conditional hospitality that paradoxically undermines the status of 'foreigner'. To receive conditional hospitality, the Other must neuter their alterity, make themselves known and their actions predictable, and therefore render themselves simply other. They must, in other words, cease to be a stranger. Derrida notes this transmutation in reference to language:

> "Must we ask the foreigner to understand us, to speak our language, in all the senses of this term, in all its possible extensions, before being able and so as to be able to welcome him into our country? If he was already speaking our language, with all that that implies, if we already shared everything that is shared with a language, would the foreigner still be a foreigner and could we speak of asylum or hospitality in regard to him?" (15-17)

At the same time, by setting the conditions of their hospitality, the host must incorporate the Other. There is therefore, in the terms used by Claude Levi-Strauss, something "anthropophagic" to hospitality within limits. To host within these limits, one must symbolically consume their guest-as-Other, a process central to modernity, which I shall, following Gilles Deleuze and Felix Guattari, refer to as "territorialisation" (1987).

Unconditional hospitality, on the other hand, is absolute hospitality without these limits. It does not demand that the stranger identify themselves, permits them to remain Other. As Derrida puts it, "Absolute hospitality requires that I open my home and that I give not only to the foreigner (provided with a family name, with the social status of being a foreigner, etc.) but to the absolute, unknown, anonymous other [...] without asking of them either reciprocity (entering into a pact) or even their names" (Doufourmantelle & Derrida 2000: 25). This concept of hospitality is also marked by a paradox: while conditional hospitality diminishes the Otherness of the stranger, absolute

hospitality diminishes the homeliness of home. To give over the “interiority” (53) of the home to the outsider without condition is to erode the boundaries that make it a home.

> “The perversion or pervertability of this law (which is also the law of hospitality) is that one can become virtually xenophobic in order to protect or claim to protect one's own hospitality, the home that makes possible one’s own hospitality. I want to be master at home [...], to be able to receive whomever I like there. Anyone who encroaches on my "at home," on my ipseity, on my power of hospitality, on my sovereignty as host, I start to regard as an undesirable foreigner, and virtually as an enemy” (53)

In this sense, the general concept of hospitality is trapped on the one hand between the paradox of home and Other: these are two ontologically opposed concepts, one of which must be diminished if they are to be brought together. It is in the hinterlands of hospitality that this negotiation takes place.

Scientific practice generally, and astronomy in particular, is riven by this paradox, which manifests itself clearly in the effort to produce an image of the cosmos. The pursuit of the cosmic image and a cosmic perspective is an act of unconditional hospitality to the cosmos as Other: a good-faith effort to set no conditions to our engagement with the radical Otherness of the cosmos, to let it stand for itself, to accept it into our world in such a state, to allow it to become our world. At the same time, as I shall explore further here, there is a need and a desire which is on distinct display in scientific endeavour and the world that it constructs to alleviate the anxiety of a world of radical Otherness, framed by Heidegger as a “homesickness,” or a need, shared with philosophy, to make ourselves “at home everywhere” (Heidegger, cited in Oliver 117). Science works to make the cosmos familiar, by setting the conditions of our hospitality to the cosmos, in the form of a set of preconditions, mediations and simplifications for making it legible—to put the cosmos in the human terms of its host. The labours of science question its guest, ask its name, demand that it speaks in the language of its host, and thereby seek to erode its radical Otherness.

The illusion of human objectivity, the grounds for making the world our home, rests upon the demand for unconditional hospitality to the cosmos. It demands that we allow it, unadulterated and unmediated, to make itself known. In the work of astronomy as I have described it, we find ourselves incapable of absolute hospitality. No matter how hard astronomers try, their images are still marked by the artefacts of the local, their own polluting fingerprints. What I have described in this study of astronomy, in particular through the analysis of the particular locations and practices that go into the production of the astronomical image, is the way in which its very process, by virtue of it being a human process, is endlessly and intractably intruded upon by the human conditions for knowledge, and therefore the conditions for our hospitality *for* the cosmos. The conditionality of our hospitality to the cosmos reveals it as a world in the anthropological sense, as a fundamentally phenomenological entity which is only rendered visible through a pact we make with reality, through a set of laws that we impose upon it that discipline it into view, to make it speak our language, as it were. The way in which the world both in and around the practice of astronomy resists our attempts to domesticate it—moves in unpredictable and surprising ways which I have followed Pinney and Buchli in referring to as the *torque*—attests to this conditionality. They are evidence of the deeper Otherness of the world that conditional hospitality obscures but can never eradicate, that re-emerges endlessly. If astronomy is the enactment of this unilateral pact made between scientific humans and the cosmos which permits us to see it, the impossibility of the perfect image describes a rejection of this pact on the part of that cosmos.

In this, the final chapter of this thesis, I would like to explore what I mean by making ourselves at home in the world (insofar as we are in a position to offer hospitality *to* nature, and not vice versa), the place of astronomy in this process, and what the systematic failure of astronomical imaging means for such a project. This is the point at which, as promised in the introduction of this work, I turn from the material practice of astronomy to its *materiality*: to how all that I have accounted here, and particularly the sense of failure that has pervaded it, “ricochets up” into broader social strata. In other words, it is here that I explore the anthropologically cosmological

aspects of astronomy, following the sinews of experience and threads of signification that link the failed image to the world and find what it stands for.

These lines of signification, through imagined futures, mythic histories of the human species, and cosmopolitical signification, lead us from the image to what I, drawing on a body of contemporary work, call modernity. As I shall explore, modernity is a ethical orientation towards both time and human relationships with the world (our cosmopolitics) which places overwhelming primacy with human lives and the futures in which they can be optimised. The project of modernity is, here, understood as one of applying human reason and technologies to map, understand, manage, and domesticate the world so that it can be turned to human ends—a process that I call *territorialisation*. A world that is territorialised, that is mastered, is one in which humans can be said to be at home: one in which humans are in a position to offer hospitality to the other entities that inhabit it. It is therefore by means of science, as modernity's overwhelming means of coming to know and manipulate the world, that such territorialisation and home-making take place. It became clear to me throughout this work that western, scientific astronomy is intractibly entangled with such a project, as a result of its historical and contemporary position at the frontiers of science. The image, as a manipulation of photons, a mediation of the cosmos, and a signifier of potential utopian futures, appears to stand metonymically for such modern futures.

Far from the kind of optimism that one would expect from such an imagined trajectory, however, Amateur astronomers in London find their practices surrounded by a world full of anxiety, confusion and pessimism. When conversations return from the cosmos back to Earth, they are often dominated by concerns about the state of the world and where it is going. My fieldwork took place during turbulent times: while Donald Trump's presidency in the USA provoked a sense of unease in my informants about political extremism abroad and Boris Johnson's premiership in the UK evoked similar concerns about political ineptitude at home, the hangover of the 2008 financial crisis, the Covid 19 pandemic and its Anti-Vaxxer detractors, and the ever-present environmental crisis hung over this project like a thick fog, always in the background,

always one moment away from being mentioned. These are but a few of the issues raised, but they were by far the most frequent. More telling was the tone in which these conversations were had; a sense of helplessness and desperate resignation always concluded discussions of the state of things. All of these troubling phenomena were often summarized to be the results of a set of diverse factors and perverse incentives which are often too big, too complex, and too systematic to reasonably resolve. As I explored in 3. Places, and shall expand shortly, the confusing ethical landscapes of light pollution illustrate this tense paralysis perfectly. This pessimism is theoretically summarized in one statement made by an interlocutor at the end of one such conversation where they shrugged defeatedly and said “its all just a bit fucked, isn’t it?”

These feelings are often not directly related to astronomy. Quite the contrary, astronomy is often a welcome means of escapism, as evidenced by statements such as Wendy’s claim that the value of astronomy is that “it’s good to get away from people.” Indicative of astronomy’s tense duality, these practices are simultaneously associated with a progress that promises human futures and a naturalism which eschews the cultural trappings of such worlds. The concerns I describe are, however, linked to astronomy by a shared cosmopolitics and the resultant world of which they are a part. The mood described above is not one of a people who are at home in the world. It is, rather, of people who feel closely our failure as humans to make ourselves at home through rational intervention and management. The metonymic linkage between the production of the perfect image and the production of a rational, functional world is one of management: just as appropriate astronomical visualisation requires the delicate management of the conditions of seeing and infrastructures of photons, so too does an optimised and rationalised world require the effective management of the conditions and infrastructures of life. In turn, the inadvertent products of these infrastructures—light pollution, climate crisis, and the business of urban life, to name a few—are precisely what undermines these images, and, as unintended side-effects, represent just how poor our grasp on the world is. As such, while the failure of the image alone does little to disrupt the marvels of the modern world, in this chapter I will substantiate how this failure participates in and informs a broader sense in which the modern world has failed.

It charts how, rather than producing better, more rationalised conditions for life, human interventions can often produce unexpected and unwanted side effects that disrupt both astronomy and the modern utopian futures it points towards.

As an exploration of the symbolic repercussions—the *materiality*—of what I have described up to this point, this chapter serves as a microcosm of this thesis. It means laying out the world that should have been affirmed by astronomy and is instead in the process of falling apart, which I refer to as the modern world, or, following Tsing, the "modern human conceit" (2015: 19). As I shall argue, this modern world is defined by the process of making ourselves at home through a particular agentive relationship with nature and with time that defines its parts, particularly astronomy. Crucially, this world is directed towards the production of more optimal conditions of life for the humans that live within it: a utopia, as it were. Like astronomy, this world is trapped in the bind of hospitality, at once demanding a conditional and unconditional relationship with nature, built as it is on an escape from human conditions for knowledge and the production of human conditions for life. Following this, I explore two crucial ways in which the failures of this modern world to produce better, more rational outcomes, intrude upon astronomy, deny its efforts at escapism, and make these concerns present to my informants in their practices. Namely, these are the increasing pressures of modern labour and growing concerns about environmental degradation. Finally, I explore my informant's response to these concerns. If modernity, and astronomy by extension, are revolutionary efforts in world-making, then I claim that the failure of this process is the failure of a world—an *apocalyptic* event. Making sense of these responses means therefore speaking to an apocalyptic condition in astronomers that emerges through the way in which they discuss and despair over the world they inhabit.

What emerges in these discussions is a community that is no longer certain about the future, who live with a sense in which the futures they were promised by modernity are, one way or another, lost. Here I explore the futures that were denied, undermined, or made undesirable through an exploration of the ethics of space-adjacent future imaginaries. In doing so, I trace a significant ethical tension in the

astronomy community about what these futures should look like, and explore how this rift constitutes a reconfiguration of modern cosmopolitics in the wake of an unworkable epistemological bind in which we find ourselves. While, as I shall explore in the following section, modernity treats the human world as the locus of ethics, there are those, faced with countless risks, uncertainties, and man-made catastrophes (e.g. Beck 1992; Giddens 1991), that see this as a moment in which we must challenge such an anthropocentric framework, along with the idea that human interventions in the world are always good. These externalities to our actions stand, to some, as a marker that the world was never, can never, and should never truly be ours, as human activities have become more damaging, their outcomes more unpredictable, and their repercussions more disruptive to an imagined harmonised order. Through an exploration of the anxieties of those who dwell within the apocalypse of modernity, we find a sense that we can never truly be at home in the cosmos: that the world was never ours to offer hospitality in. We find here yet another great demotion, in the form of an apocalyptic destruction of the human world as a basis for ethics, articulated in discussions of what our future—and particularly our future in space—should look like. What is left is an uncertain paralysis, in which the present is full of ambiguous and threatening crises, and no one can seem to see a way to a desirable future that would resolve them.

6.1. Modernity

The image stands metonymically for the success of science. To make the world visible and therefore workable is one of science's fundamental symbolic gestures (Heidegger, cited in Hoeppe 2012: 1152). In order to describe the wider implications of this failure, we must understand the broader social context within which science is nested: the world that emerged from the performance of Copernicus's ongoing task and its astounding successes. This is to say, we must understand science, the image, and its failure, within the broader social context of *modernity*. By understanding the relationship between science and modernity, and in particular the status of the human that is tacitly asserted within modernity, we can understand how the failure of the image participates in the broader phenomenon by which modernity unravels, to which my collaborators, as I shall

substantiate, bear close witness in their engagements with the human contexts which, like light pollution, impose themselves upon their work. their transcendental work. In short, I claim that I have laid out here one small part of the procession by which moderns are inculcated into the postmodern condition, by which their projects are rendered futile, and the kind of cosmopolitical questions that are raised by the nature of that futility.

Modernity is a diverse and expansive concept which largely defies normative descriptions. As Paul Rabinow puts it, “The debates about modernity are endless: since it has no essence, and refers to so many diverse things, it seems futile—or simply part of the modernising process—to worry extensively about abstract definitions” (1989: 9). This lack of essence is something to which I will return in my discussion of the revolutionary form. He goes on to say that it is perhaps better to discuss how the term is used by its self-proclaimed practitioners. While my astronomer collaborators would undoubtedly answer in the affirmative if they were asked if they are moderns, I doubt that many if any would actively call themselves advocates of the abstract “practices of reason” and “fields of knowledge” to which Rabinow refers. Yet they are all doubtlessly subject to them, and as abstract as modernity is as a concept, it has been noted that it is a condition that is felt in and “radically alters the nature of day-to-day social life and affects the most personal aspects of our experience (Giddens 1991: 1). While it is perhaps futile to attempt to divine some essence from modernity, I find utility in the term here to describe two traits that can be found in astronomer’s relationship with the world, which I intend to lay out and put to work making sense of the way in which my informants are subject to their disciplining ideological powers—how modernity informs the project to produce the perfect image, and what is tacitly implied about the human as a being that can undertake such a task. Most critically, it is in modernity that we can identify the particular cosmopolitics of management and domestication of which both the failed image and the ailing social context of astronomy (which I shall explore in this chapter) are symptoms. What follows is therefore a description of the presumptions which fail in their astronomical applications—how, by the standards of modernity they

set themselves, human projects seem to fail—and must be reconfigured in the light of such a failure.

It should be noted that a full and exhaustive discussion of modernity here is beyond both the scope of this study and the limits of my word count. It is acknowledged here that modernity is multiple and diverse (itself an anti-modern stance), and that I continue to use the terms ‘modern’ and ‘modernity’ with the caveat that they refer to a very particular kind of Western modernity which emerged in the nineteenth and twentieth centuries. Here, it is largely a container concept by which I can gather together two particular features that are commonly attributed to modernity, and can be used to make sense of the practice of astronomy as I have seen it and my informants experience it. First is its moral orientation towards the human capacity to master and control our natural conditions. The second is its nature as a temporal phenomenon defined by the structure of revolution. These two points are critical for understanding the nature of astronomy as a revolutionary practice which seeks to bring about the utopia of human mastery and objective vision associated with the cosmological perspective, and by extension what is at stake in the failure of that project.

6.1.1. Modernity and Agency: territorialisation

Modernity orients itself around a very particular antagonistic binarism between nature and culture, between the human and the inhuman, that I have already discussed (2. Cosmos). This binarism is accompanied by a particular cosmopolitics—a particular moral orientation towards the relationship between humans and the world, which we have seen at work in astronomical practices. Its activities are directed towards the sovereignty of human reason and its deployment in our mastery over nature—the discipline exacted over the place, body and image that make the cosmos legible. Modernity is an age of technical fixes and interventions in the world that shape it to our will that is summarised in that troublesome geological epoch referred to as the ‘Anthropocene’ (troublesome, in part, in the question of to whom ‘our’ refers is suspect). It is for this reason that Bruno Latour equates the modern project with the “double task

of domination and emancipation" (1993: 10) that runs along the "great divide" of nature and culture, which is to say domination of our natural conditions and emancipation from our natural limits (11-12). In this sense, I argue that modernity is a process which continues the emancipatory work of the Enlightenment as it is described by Immanuel Kant. In his words, "Enlightenment is man's emergence from his self-imposed nonage. Nonage is the inability to use one's own understanding without another's guidance. This nonage is self-imposed if its cause lies not in lack of understanding but in indecision and lack of courage to use one's own mind without another's guidance." (1784). Here, again, scientific heroism finds its genealogy in a series of figures imagined to show the courage to face the nature of things in all their unsightly and unsettling reality.

I argue that there are few places where this process is more clear than in the work of astronomy, and its forceful forsaking the intuitive nature of the world. Through attaining an unintuitive but epistemologically rigorous cosmological perspective, astronomers understand their work as one of bravely facing inconvenient truths about the disenchanted cosmos and our stature in it, of living "without the handrails of stories that tell where everyone is going and, also why" (Tsing 2015: 2) usually provided by the "reassuring fables" of myth and religion (Sagan 1997: 33). To be modern is to believe in and take up the task of grasping hold of the world *in itself* and bending it to our rational will. To be a human subject within modernity, therefore, is to be a rational agent capable of doing this work of domesticating the cosmos. This, I claim, is the mantle that the astronomer ceaselessly works to take up through the act of astronomy.

In the sense that I have described above, modernity is a cosmopolitical phenomenon. It concerns the relationships of power between people and things, the human and the non-human. This relationship also informs what we would more traditionally call politics, and first understanding this more intuitive articulation not only affords it more readily to us conceptually, but effectively grounds this otherwise abstract concept. The cosmopolitics of modernity can arguably not be understood without reference to the emergence of the modern state, because it is in the modern state that the power to master the conditions of life is put to work on the grand and systematic

scale that defines its function. Modernity is a process which seeks to make the world and its occupants legible and manageable through technical fixes and standardisation. We might, to borrow a term from Gilles Deleuze and Felix Guattari, make sense of this process in terms of *territorialisation*. Modernity makes territories of places that are "carved out and colonised" (Giddens 1991: 4). While 'space' describes abstract extension or container medium, and 'place' or 'landscape' adds to it the surplus of subjective human interpretation and relationality (Tilley 2017), 'territory' is an explicitly political category. It is the site of administration and census, one that is claimed, annexed, and owned. As I shall explore, the making of a territory is an epistemological process which constructs the world as a space that is amenable to technical interventions: the making of a space in which human agency and intervention are both effective and meaningful.

Maps are always, to some extent, insufficient abstractions. A map that attempts to record the vast density of the world will quickly become a jumbled and unwieldy mess. To be useful, a map cannot be exhaustive, but must rather select information that is important and what information should be left out. Mapping, as an abstract practice not only of making a map but of creating a representation of the world with which we can work, is always an act of judgement about what counts and what doesn't. Scott describes this process of judgement and exclusion as "simplification": "Officials took exceptionally complex, illegible, and local social practices, such as land tenure customs or naming customs, and created a standard grid whereby it could be centrally recorded and monitored. [...] these state simplifications, the basic givens of modern statecraft were, I began to realise, rather like abridged maps. They did not successfully represent the actual activity of the society they depicted, nor were they intended to; they represented only that slice that interested the official observer" (2020: 3). A critical failure of modernity therefore emerges when these simplifications turn from descriptions of the world into prescriptions—when the map or territory is mistaken for the true and complete nature of things rather than one of many potential framings.

These simplifications and abridged mappings are also the business of scientists, whose job it is to render the world knowable so that it can then be manageable. If territorialisation is an epistemological process first and foremost, scientists are the agents that enact this process. As I have noted, for instance, the uprooting and abstraction of concepts—what has been called making knowledge 'mobile' and 'durable'—is not only a feature of science, but also of the modernity that deploys it to its own ends of management: simplifying the world into abstract essences that can be extracted and moved and transplanted and sold. I have discussed this mobility in conceptual terms, as a means by which information can be applied to other realms so that they can be linked and used to make structuring models, but this work is also seen literally in the equally modernist practice of extractive capitalism. This is what Anna Tsing calls the "modern human conceit," which "entangles us with the ideas of progress and with the spread of techniques of alienation that turn human beings and things into resources" and "won't let a description be anything more than a decorative footnote" (2015: 19). This simplification or erasure in science, where a decision is made as to what is worth recording and what is not, it is most clearly visible in aforementioned discussions of the place of the human (or a lack thereof), defined by a prescription of "what it's authorised to cover and what it's forced to leave blank" (Farman 2012: 1078).

Scott claims that what emerged during the twentieth century was what he calls "high modernism" or "high modernist ideology", which is a "strong (one might say muscle-bound) version of the beliefs in scientific and technical progress that are associated with industrialisation in western Europe and North America from roughly 1830 until World War I. At the centre was a supreme self-confidence about continued technical progress, the development of scientific and technical knowledge, the expansion of production, the rational design of social order, the growing satisfaction of human needs, and, not least, an increasing control over nature (including human nature) commensurate with scientific understanding of natural laws" (Scott 2020: 89-90).

It is in this sense that we might make sense of astronomy, and indeed all science, as a work of territorialisation. The term territorialisation links epistemology with politics and describes the way in which even observation is garbed in the trappings of discipline and espouses a particular cosmopolitics. In Scott's words, every measurement is "marked by the play of power relations" (27). Astronomers, in their work, as I have described it, seek to territorialise the cosmos, to make it legible as an act of craft so that it can therefore be made manageable. My informants will speak extensively about the contributions made by scientific projects in space to life down here: how technologies we take for granted such as GPS were developed for and are facilitated by our understanding of and activities within the cosmos. Indeed, in *Dying Planet: Mars in Science and the Imagination*, Robert Markley claims that the great appeal of colonising new worlds is that it works within the mythical imaginary of the classic tale of Robinson Crusoe: "as the urtext of western "man's" conquest of the wilderness, *Robinson Crusoe* offers its readers a thought experiment to ponder on the resourcefulness and ingenuity that an individual needs in order to thrive in an alien environment. Though Defoe's novel has been read as an exemplar of the protestant ethic, an adventure tale, and a colonialist parable, it is also the tale of European "man" transforming an island ecology into a proto economy, exploiting the indigenous resources necessary to live in comfort" (2005: 32). The prospect of territorialising other worlds, and the promise of exporting our "variously sized boxes" off-planet plays directly upon these tropes, and find their grounding in speculative imaginaries about terraforming other worlds that I shall describe shortly.

My informants would probably reject the framing that their work is one of mastery. Their work is not explicitly one that acts on or changes the world. My informants speak in terms of "finding space" for astronomy, and while they "capture" images, it is always framed in terms of a passive observer, watching a natural phenomenon from afar, never interfering. How could they even interfere with something so solid, so vast, and so far beyond our reach? The modernist practice of "bringing facts into line with representations" (Scott 2020: 90) is the antithesis of the work of the observer, who simply witnesses the cosmos in a plausible non-interventionist way. This attitude of pure

observation that I observed in my informants was also described by Reno in his similar discussion of amateur astronomers. As he puts it, “becoming a good astronomer does not mean asserting mastery over the universe, but becoming attuned to terrestrial and cosmic temporalities” (2018: 6). Astronomy, crucially, asserts our relative impotence, not only conceptually by rendering our vast smallness in the cosmos, but also practically, in the ways in which we are subject to and at the mercy of all of the conditions that are outside of our control, articulated every time we had to .

It is in this sense that astronomy enacts the Copernican Engine which diminishes the stature of the human. Yet it also exhibits the tension between human agency and human impotence by being nonetheless an act of territorialisation. Astronomy is, as I shall explore in the next section, and drawing upon my previous discussion of the Copernican myth, the ground upon which modernity was built, the original act which asserted our capacity to break away from notions of the natural and the intuitive and take our fate into our own collective hands. As I have explored in this text, particularly in my discussion of images in section 5, ample work is put into rendering[5] the cosmos, exerting a discipline which makes these images legible enough to be put to work. While it is understood in terms of attunement, it is nonetheless at the very least the mastery of the kind of conditions which *can* be controlled, which is to say place, body, and the processing of the image. A complete lack of agency would lead to apathy which is the opposite of my informant’s actions, and their work towards mastery exhibits in its own small way the broader modern injunction to territorialise.

6.1.2. The Temporality of Modernity

Modernity does not only territorialise; Modernity also deterritorialises. It endlessly uproots established orders and traditions, making them available for correction through more appropriate rationalisation (Berman 2010). This deterritorialisation is made evident in the revisionism of science and the creative destruction of capitalism which, by making

[5] Here I follow Natasha Myers in her use of the word ‘render’ in both the sense of making visible (rendering an image) and dominating (e.g. render unto Caesar)

everything we thought we knew up for grabs both epistemologically and economically, constructed the splendour of our modern world. Karl Marx and Friedrich Engels described the disorienting nature of this deterritorialisation in the Communist Manifesto with specific reference to capitalist production:

> "Constant revolutionising of production, uninterrupted disturbance of all social conditions, ever-lasting uncertainty and agitation distinguish the bourgeois epoch from all earlier ones. All fixed, fast-frozen relations, with their train of ancient and venerable prejudices and opinions are swept away, all new-formed ones become antiquated before they can ossify. All that is solid melts into air, all that is holy is profaned," (2002: 223)

This deterritorialisation does not undermine or act against the territorialisation that is supposedly at work in modernity but is rather its essential prerequisite. The capacity for critical analysis of fundamental concepts such as, say, the centrality of the Earth in the cosmos, is what clears the ground of old, outdated ideas so that we can build new better worlds in their place. Rather than a brittle, dogmatic rejection of failure, modernity's great strength is that it embraces and operationalises its productive power to produce an ever-shifting world with all the suppleness of reflexivity. In the case of capitalism, all traditions might be cast aside in the pursuit of economic and productive efficiency, while in science those same traditions are challenged as ways to effectively know and engage with the world. We can see the latter in Shapin and Shaffer's account of the matter of fact, and the way in which they chart a movement, in the mid-seventeenth century, from a model of science which distanced itself from opinion, into the production of the idea of 'theory' as provisional, probabilistic, and human. Science, they claim, is a process of endless revisionism:

> "In the conventions of the intellectual world we now inhabit there is no item of knowledge so solid as a matter of fact. We may revise our ways of making sense of matters of fact and we may adjust their place in our overall maps of knowledge. Our theories, hypotheses, and our metaphysical systems may be jettisoned, but matters of fact stand undeniable and permanent. We do, to be sure, reject particular matters of

> fact, but the manner of our doing so adds solidity to the category of the fact. A discarded theory remains a theory; there are "good" theories and "bad" theories—theories currently regarded as true by everyone and theories that no one any longer believes to be true. However, when we reject a matter of fact, we take away its entitlement to the designation: it never was a matter of fact at all." (1985: 23)

This revisionism points us towards the fact that modernity is inescapably a temporal phenomenon. It is a moment in time, spanning approximately two hundred years between 1789 and 1989. These dates, offered by Francois Hartog (2015: 104), are intended to be symbolic. The progression of one age to another is rarely marked by some singular cataclysm, but rather by a gradual change in the social and material relations that constitute our cosmopolitics. These two dates (the storming of the Bastille and the fall of the Berlin Wall, respectively) merely stand for a broader movement. For Hartog, this broader movement is a crisis of time: a shift in our understanding of and moral orientation towards history, and the emergence of what he calls a new "regime of historicity". For Hartog, our relationship with history prior to 1789 might be understood as traditionalist, or even conservative (such a claim seems an overgeneralisation, but serves us as a crude point of contrast). Such a regime points backwards, looking to the past and seeking to reproduce ancient social and political forms for the betterment of society. In such a world, things are a certain way because that is the order of things, and that order of things is ordained and timeless. We might institute rituals which disrupt this order of things momentarily, such as the rituals of rebellion described by Gluckman (2004: 110) or the carnivalesque from the writings of Mikhail Bakhtin (1984) but these rituals always return society to its original state and serve to reproduce its forms and relationships. In such a world, practical, technical interventions mean little in the grand scheme of things, because this scheme is etched in the essence of the world, as solid as the mountains that we would one day flatten.

This characterisation of the past by Hartog may well be an example of that equally modern impulse to produce primitive ancients against which we may contrast ourselves (those who do rituals and believe in myths, and those who do technical

actions and believe in science). Latour describes this as an “asymmetrical” aspect of modernity, produced by a “break in the regular passage of time” (1993: 10). For Hartog, this all came to an end around the 18th century. With the emergence of modernity, this moral orientation flips, situating the utopian ideal not in the traditions of the past, with those vanquished and backward ancients, but in the future, and the radically new. This reorientation was facilitated by human reason, through the application of which the new future would be designed and attained. This is the age of revolutions, when old regimes are cast down and the radically new is, through the application of reason, built in its place. Rather than the inevitable apocalypse so prevalent in past regimes, people became enamoured with the promise of growth and utopia, looking to the future rather than the past for social orders:

> “As the ideal of perfection became temporalised, the idea of the future and progress, and the openness they represented, began gradually but increasingly to split off from the promise incarnated by the end. Perfection then gave way so completely to perfectibility and progress that not only the past—considered outmoded—but also the present were devalorized in the name of the future. The present, as nothing but the eve of a better if not a radiant morrow, could, and indeed should, be sacrificed” (13)

Modernity is, in this sense, defined in part by a critique of the past, challenging the seemingly fixed and naturalised social forms that constituted tradition—an enlightenment. For example, the anthropologist James Holston notes a parallel between modernity and anthropological practice along the lines of their “subversive intent”. As he describes, “Their aim was to disrupt the imagery of what bourgeois society understood as the real and the natural, to challenge the taken-for-granted, to defamiliarize, disorient, decode, deconstruct and de-authenticate the normative, moral, aesthetic, and familiar categories of social life” (1989: 6). Holston also notes modernity’s particular temporality that arises from its utopian and future-oriented historical order: “As it works backward from this imagined end to preconditions, its view of history is teleological” (9). Using this understanding, we can make sense of Rabinow’s claim that modernity does not have an essence, but rather a function or process. It is a means to an end: it

dissociates and dislocates, and endlessly drives our practices towards something other than itself. It is necessarily interstitial, a stepping stone towards some elusive yet proximate future.

This temporal orientation, in a single word, is revolutionary. It is defined by a radical break with the past that produces a future of our own making. The revolution, it has been observed, is itself the myth of modernity, the social form which gives efficacy to action within the modernist frame by placing it within a moral understanding of the history that it occupies (Claude Levi-Strauss, cited in Cherstich *et al*. 2020: 4). In this sense, the Copernican Revolution is the event by means of which the meaning of revolution shifts from its original meaning as a cycle or a return, to its contemporary form used predominantly, as Cherstich *et al* note, by political scientists and agitators, that is a singular and radical break with the past: “projects of total and radical transformation, expressed characteristically as a desire to bring about a “different world”—sometimes an altogether “new” one.” (2020: 4). This “deeply cosmogonic character” is built on the destruction of the old world so that the new one can be untainted by its flawed, imperfect logics.

These bookends proposed by Hartog are, as noted above, not meant to be the fixed and definitive dates for the inauguration of modernity. This shift towards the future is a gradual process, and the groundwork for the belief that the world could be radically changed and the past could be radically disavowed was laid in modernity long before it drew people to the barricades of Paris. Within the myth of the Copernican Revolution, it is in the moment when we decentered the cosmos and defied traditional understandings of the universe that this particular relationship to the past and belief that a forceful discontinuity in the social order was produced. It was the Copernican revolution that set the stage for the very idea of what a revolution to gradually be reoriented, turned from the endless cycle of the stars across the heavens into a break in the order of history (Koselleck 2004: 46)

It is in this sense that modernity, as a preoccupation with progress and the future, as well as a process that is oriented towards the production of new and better worlds, astronomy can easily be established as modern. This is first simply the modern contextualisation with which my informants deal every day. We live in a world that has been endlessly and thoroughly territorialised. There are many ways in which my informants are die-hard modernists (though critically not in every aspect, as I shall discuss). They are embedded within a world built on progress and the endless revolutionising of technical innovation and knowledge. Britain was, after all, one of the epicentres of the modern project, and the development of what is sometimes referred to as 'high modernity' is something through which many of my informants lived. As the British journalist Andrew Marr puts it,

> " 'Modern' does not not simply mean the look and shape of the country formed during 1964-79, most of which is still here around us, essentially unaltered—the motorways, the mass car economy, the concrete architecture, the rock music, the high street chains. It also means belief in planning and management. This is the time of practical men, educated in grammar schools, sure of their intelligence, rolling up their sleeves and taking no nonsense. They were going to scrap the old and fusty, whether that meant the huge Victorian railway network, the grand Edwardian government palazzos in Whitehall, the historic regiments, terraced housing, hanging theatre censorship, the prohibitions on homosexual behaviour and abortion, the ancient coinage and the quaint county names. Bigger in general was better. Huge comprehensive schools would be more efficient than the maze of selective and rubbish-dump academies. The many hundreds of trade unions would resolve themselves into a few leviathans, known only by their initials. Small companies would wither and combine and ever-larger corporations would arise in their place, ruthless and managed on the latest scientific, American lines. Britain herself would cease to be a small independent trader and would merge into the largest corporation then available, the European community." (2007: 231).

As Marr describes, this rationalisation and emphasis on efficiency was and still is grounded in the experiences of British citizens. My informants are the beneficiaries of a world that is so territorialised through modern infrastructure, modern architecture, modern communication systems etc. As technophiles they are acutely aware of the incredible achievements afforded by what we would call modernism. Simon, for

example, described the way in which seeing a big space event, such as an image from the James Webb telescope or the landing of the Perseverance rover on Mars brings home to him all the progress we as a species have made; it throws into sharp relief all of the ways in which making the Earth 'ours' (that modernist human conceit of the anthropocene (Tsing 2015)) and just how impressive that is.

Modernity is not only something that my informants dwell in, but also something they enact. While I would claim that the act of astronomy is a work of modernist territorialisation, this is also something many of them do for their work. I have discussed how the material limits on the lives of those who wish to have access to the sky means that many who have both the capital and the time to do astronomy must be from a particular class. While the astronomy community is diverse and proudly inclusive, it is also heavily weighted with the professional classes—with architects, managers, scientists and lawyers. It is these people who, as I have noted, can more readily spare the time and resources to do astronomy in an amateur capacity. They are not simply modernists, they are *modernizers*, the instruments by which these technical interventions are enacted and perfected in the world.

More deeply, however, this work connects them to this revolutionary process of modernity. They self-consciously participate in the Copernican tradition, that original and unrealised revolution. Copernicus' task, passed down by the tradition of astronomers, is taken to be the realisation of the true nature of the cosmos, abstracted from the contingencies of human life that might lead us astray. The act of astronomy is a revolutionary act, the *mythical, original* revolutionary act, reenacted in ritual form so that my informants can participate in Copernicus' great work. The myth of Copernicus, as I suggested earlier, is one of the origin myths of modernity in that it is understood to have provoked us into enlightenment by showing us that we must go beyond the intuitive and the given (given by elders and ancients as something that has "always been true") if we are to properly take responsibility for our own lives.

Perhaps the clearest place in which this modern futurity can be observed in astronomers, however, is the way in which observing outer space seems to inevitably draw their minds to speculate on our futures there. As noted in the previous section, the prospect of colonising other worlds in the near future emerges in astroculture as a presumed next step in the territorialising teleology of humankind. As put by Carl Sagan, “Maybe it’s a little early. Maybe the time is not quite yet. But those other worlds—promising untold opportunities—beckon.” (1997: 7). For many—inspired, as we shall see, by science fiction—making the leap to outer space, and the technologies that must be developed along the way, promises a new start for humanity: a radical break in our history that offers the opportunity to remake ourselves and decide what kind of species we want to be, and what kind of world we want to inhabit. As I shall explore shortly, however, this optimistic utopianism is tempered by ethical concerns about what the shape of such futures should be. There are some who, acutely aware of human failures to manage the world, fear and even dread these ‘utopian’ futures, and their potential to become nightmares. In the following section, I discuss some of the utopias that seem to be failing, and the anxieties expressed about the potential of transplanting those failures into space.

6.2. Horror and the Failure of Modernity

Modernity, as I have described it here, is fundamentally a future-oriented project. The modern world and the territorialisations that constitute it are all processes turned towards the systematic improvement of the conditions of human life towards utopian goals: the production of a better world. The clearest way in which we can see this modern impulse in astronomers is in their preoccupation with such futures, particularly the imagined futures offered to them in space. As noted in the previous sections, the prospect of colonising other worlds in the near future emerges in astronomers’ cultural and imaginative penumbra as a presumed next step in the territorialising teleology of humankind. In various renditions, both fictional and philosophical (e.g. Parkhurst & Jeevendrampillai 2021; Siddiqi 2010: 74-113), space and the technologies required to get there have been conceptualised as a blank slate that offers the opportunity to

remake ourselves and decide what kind of species we want to be, and what kind of worlds we want to live in. As Carl Sagan noted in *The Pale Blue Dot*, “It will not be we who reach Alpha Centauri and other nearby stars. It will be a species very like us, but with more of our strengths and fewer of our weaknesses [...] more confident, farseeing, capable, and prudent” (1997: 185). And, indeed, the terraforming implied and imagined in such projects are works of territorialisation *par excellence*, literally reworking an entire world towards human utility. For many, it seemed that this emphasis on the future constituted the value that astronomy brought to their lives. As one informant put it, “It is good to understand where we came from, where we are, and where we’re going. Astronomy gives us that. That's better than making up some story that doesn’t get us anywhere.” For them, mapping the sky paves the way for the colonisation of the cosmos, where untold riches lie, and can be mobilised in the service of human lives.

When I was faced with a broad mood of pessimism I saw around myself, I initially struggled with the fact this attitude seemed at once at odds with this traditional optimism, but also orthogonal to astronomy itself: while they took place in the presence of astronomy, they were only abstractly linked to astronomy, and more often an aside while long exposures ran or observers sheltered from the cold. It is in this sense that closer attention to the ways in which astronomers imagined and speculated about their futures presented itself as an interesting ethnographic exercise. At once, these discussions offered an opportunity to see how contemporary fears and anxieties interfaced with more traditionally optimistic visions of scientific optimism, and a way to draw conversations out of the realm of the factual and towards ethical discussions of what human futures in space *should* look like.

What became immediately apparent to me when pursuing this line of questioning is that these anxieties had already migrated to outer space and troubled visions of the future there. It is in this section that I intend to explore some of the specific ways in which earthbound problematics and anxieties conflict with and disrupt my informants hopes about space futures. Many accounts I had seen up until this point had been relatively neutral. For instance, early in the project, such discussions had led Simon to

suggest a series of Youtube channels to me. The most prominent of these was Isaac Arthur, whose content was all about the technologies and techniques for such space colonisation. Many of his videos, being speculative, are couched in the language of how future humans 'will problably' and 'could' but rarely ventures towards questions of 'should'. The emergence of such anxieties about space futures are indicative of my informant's move towards this ethical terrain that I had presumed to be neglected.

One illustrative example of this emerged when I attended an exhibition on Mars at a large London museum with a group of astronomers. The exhibit covered historical and cultural imaginations of the red planet, its contemporary exploration, natural features, and its proposed and speculative futures. Once we had finished looking at mock Martian habitats and reading about potential flora for terraforming efforts, we all sat down in the coffee shop, as we usually did on such outings, to chat about what we had seen. It was at this point I attempted to prompt a cautionary discussion of the optimistic futurism we had just witnessed by raising a concern that had been rattling about in my head for a couple of years. Early in the project, I had attended a talk by an ESA astronaut and science communicator, who had claimed that, due to the high levels of radiation in space, the agency was considering screening astronauts for genetic predictors of susceptibility to cancer. While a pragmatic move on its face, this nonetheless points at the more fundamental ethical issue of selection. As I put it to my informants, outer space is exceptionally difficult to get to and live in, and, given that difficulty, decisions have to be made, either explicitly or tacitly, about who gets to go, who has to stay, and on what grounds. The question emerges, given that the shape of humanity's future is at stake in such a decision, whether those who have a say in this process are capable of correctly and ethically do so, or, for that matter, if there *even is* a correct and ethical way of managing something as incredibly broad as humanity's future. Is outer space not meant to be a commons, available to all? Or must such a dream be sacrificed when faced with the cold, hard hostility of outer space?

Kara nodded along enthusiastically, in a way that suggested she knew exactly where I was going. Confirming my suspicions, she finished my thought for me: "It

doesn't matter whether we acknowledge that we're making the decision or not, its still going to be made. Choosing which people get to go is like choosing which bits of humanity are valuable enough to keep. And the people that colonise Mars are still going to have to live with the consequences." This was another of those intractable problems: who goes to space—who gets to participate in that future—is a decision that will be made, actively or incidentally, and it will define what part of humanity that future will feature, and which part of humanity will be left out. Actively producing futures is an act of territorialisation. The question Kara poses is who gets to perform such territorialisations, and how?

It was clear from the response of Kara and others that at least some of my informants are under no illusions that outer space is a space of 'innocence'. It is already the subject of human projects, imaginaries, politics and anxieties, and this will doubly be the case when it comes time to venture into it, transplanting our histories and cultures there. Kara related these concerns to her own experience as someone from the Middle East: "I know how it feels to be kind of left out of history. We hear about it all the time. This sounds like another opportunity for that to happen all over again." For Kara, the idea of outer space as a blank slate, promising a new start for humanity, is already an illusion. She is deeply aware that the humans that colonise the cosmos will carry more with them than tools and supplies: they will take their traditions and cultures, for good or for ill.

Simon, as ever, suggested Science fiction as a point of reference for such cautionary attitudes towards the future. He suggested that I have a look at the Mars Trilogy, a series of books by Kim Stanley Robinson that were a fictional near-future account of the colonisation and terraforming of the red planet. "Just have a read of the first chapter" he said, "its literally an account of a race riot in space." Both of these accounts iterate an accute awareness that the move to outer space is not some kind of all-encompassing panacea for the Earth's problems. Quite the contrary, if performed incorrectly, it threatened to transpose them into novel environments. More than simply

recognizing this, this acknowledgement of the way in which earthly problems can be transposed into cosmic futures were a real cause of anxiety for my informants.

I should not have been surprised by these revelations: in hindsight, concerns over the manner in which humans enter space have existed in astroculture for a long time. Carl Sagan wrote his book *The Pale Blue Dot* writing in a similarly tumultuous time, at the end of the Cold War, and had anxieties about space colonisation as my informants do today. Speaking of the "great many matters pressing in on us" he asked "Should we solve those problems first? Or are they our reason for going?" (1997: 8-9). It seems to be recognised that our movement into space and the production of futures there requires an exceptional degree of consideration and management. The question of whether we are even capable of doing so clearly weighs heavily on the minds of my informants.

When it came to the critical question of whether we should go to space, both Kara and Simon were torn, albeit to different degrees. Simon was adamant that the potential promised by outer space offered untold solutions to problems found here on Earth, but tempered this enthusiasm with caution. Speaking to the discussion at hand "Space has to be for everyone, we need to find some way to make sure of that." Kara was more hesitant still. "Its a nice idea" she said "but I can't see it ending well. I feel like half the stuff we see about colonising Mars is half-baked. It seems too romantic, y'know? How are we gonna make sure we don't mess up everything there too?" The uncertainty they expressed over what has, in some conversations, been a long-settled question, typifies an uncertainty about the future, and indeed with the entire project of modernity as I have described it. Space enthusiasts find their preoccupation with the future and the utopias built there marred by the real and often overwhelming issues here and now on Earth.

This section is therefore dedicated to exploring some of the problems that undermine and disrupt these spacebound dreams, as well as the responses my informants have to these lost futures. For this, I have selected two issues that most

clearly speak to astronomy and astronomers: their relationship with work, and the contemporary environmental crisis. These have been selected for a set of reasons. Primarily, these are issues that are most present to astronomers in their work: both actively intrude upon my collaborator's efforts at stargazing and, by extension, escapism. Secondly, these problems are man-made problems, and, as I shall explore, consciously undermine my informant's faith in our capacity to territorialise the world into a utopia. How are we to make the future when our actions keep having unanticipated and harmful outcomes? Their statements below clearly suggest that their concerns about the future come from a worry that we will not fix these issues when we go to space, but transport them there with us, with unknown consequences. The issue of creating the future, much like creating the image, is one of territorialisation. Both are revolutionary efforts at capturing and operationalising the pure, clean, innocent nature of space, a *terra nullius* that can be worked towards human mastery of the world. After all, imaging the cosmos is the first step towards mastering it. Both are territorializations: one of the the natural world, and one of the future. In both cases, as I explore here, the trappings of the Earth intrude upon this innocence, and prove, in their mind, that such clean images and futures were always already spoiled by human intervention. These two phenomena and my informant's understanding of them represent a broader failure of human efforts into which the failure of the image clearly fits. In describing them here, I do the scaling work of extrapolating material failure into a materiality of failure, charting the social repercussions of the individual instances I have described in the failure of images. They are the ruptures that, I claim, contextualise and are in turn contextualised by the failure of astronomy, and that astronomy, in turn, crystallises into a form that can be countenanced.

6.2.1. Finding Time for Astronomy

Throughout my fieldwork, and this thesis, I have noted a consistent concern that astronomers have for their relationship with work. This is, of course, not particular to astronomy by any stretch of the imagination. Complaining about the stresses of labour and the ways in which it seems to make increasing demands on one's time has been an ever-present undercurrent of discussion throughout all social arenas in my life. I find

astronomer's concerns about work particularly compelling, however, because of the particular symbolic position that work holds within this cosmology, between production and innocence, escapism and lost utopian futures.

Labour can easily be construed as existing in opposition to amateur astronomy. Indeed, this opposition is in a way definitional: amateurs are specifically those who do astronomy in a non-professional, unpaid capacity. But it is also because astronomy and work compete for the same sparse resources: energy, time and money (or opportunity cost). As I have noted these three factors can be shifted in relation to one another—one might, for instance, buy expensive equipment that automates part of the process and saves on effort, or, conversely, put extra energy into researching how to observe with minimal gear—but ultimately astronomy makes demands on all of these factors to varying degrees. Because of these demands, astronomy tends to attract a particular demographic of people—specifically the old, the rich, or the exceptionally enthusiastic.

Attentive to these conditions, and with a genuine advocacy for inclusion without limits, astronomers are eager to offer guidance on how to best navigate these demands. The production of guides for beginners, "budget rigs," automation, as well as a community eager to share their knowledge, evidence a shared concern for carving out time for astronomy from the busy lives of urban dwellers.

The time pressures exerted upon astronomers from outside of their special viewing time is most evident in simply coordinating a night of viewing. Once I was established at the monthly meetings at the hub and in contact with several of the regulars there, it seemed like their wasn't a single week when all of us managed to get together. At least one person had something else they needed to do, be it some kind of preparation for the next work day or a prior engagement. This issue is exacerbated when trying to pin down a date for viewing. As I noted earlier in this work, the group of astronomers I usually went out with regularly tried to plan outings, which were always a difficult negotiation about which day is least inconvenient for everyone or even anyone. With a practice so at the mercy of natural conditions as outlined in chapter 3, and lives

so out-of-sync with those natural conditions, it was often hard to find time to stargaze at all. When this concern is raised I am always reminded of Wendy, who I never met in an astronomy setting, and instead agreed to talk to me during a lunch break. Her offices were situated on an upper floor in a building on the border of the park in which the BSIA held their events, and I remember her noting that it was so “disappointing” that she was regularly so close, but so rarely found the time to make it to stargazing nights.

This issue is admittedly not one of work in particular, but rather one of a multitude of time pressures. Yet of all of these time pressures, I focus on work as it is the most prominent in my informant’s complaints, and, following the nature of these complaints, most indicative of a broader concern with the direction in which the world seems to be heading. Many astronomers I have spoken enjoy and value their jobs but not only speak regularly of how stressed and overworked they are, but also of the creeping feeling that this situation is deteriorating rather than improving. The time and energy to do astronomy is, for many, increasingly scarce.

I have raised this problem of finding time for astronomy with my informants. As usual, it was Simon who came through for me with insightful commentary from the world of Science Fiction. Like many science enthusiasts, as a child, Simon had been enthralled with *Star Trek*, a show that followed the adventures of various spaceship crews employed by the United Federation of Planets, a fictional future interstellar government, to explore the universe. I somehow avoided watching Star Trek for my entire life, but from Simon’s description, alongside bits and pieces I have picked up here and there, it fits neatly into a late 20th century vision of a utopian future. The United Federation of Planets is a representative and liberal democracy, dedicated authentically to equality, peace, and justice—a clear idealised allegory for western democracies or perhaps the United nations.

Most notably, as Simon informed me, the people of the Federation did not have currency: they rather lived in a post-scarcity world in which they were free to pursue their passions as they saw fit. This dream also has a historical context to it. In the early

twentieth century, the economist John Maynard Keynes predicted the same optimistic trajectory for the world of work. He claimed that technical advancements and efficient management would, by the end of the century, mean that people in the UK and USA would be working an average of 15 hours a week (Graber 2019: xiv). For all manner of complex reasons, however, this future has eluded us, and the clear sense that emerges from astronomers is that it will continue to elude us indefinitely. Simon described this state of affair as "strange." As with many of these conversations, Simon attributed this strangeness to a complex system (the economy) behaving in a different way not only to how many thought it would, but also to how people thought it should. As a result of this strangeness, he also struggled to see a way to overcome these conditions. He fully acknowledged that he didn't even fully understand how we got to this place, let alone how we can get out of it. Embroiled in an ongoing struggle to carve out time for astronomy, and with no systematic resolution available, it is hardly surprising that my informant's outlook seems broadly pessimistic.

Throughout this fieldwork, I have constantly been reminded that astronomy serves, in part, as a kind of escapism. What is abdicated in this process are the self-serious and all-encompassing trappings of the human world. This desire is articulated in the kind of statements with which I opened chapter 2—that astronomy is "a good way to get away from people" that reminds us that "there's more to the world than just us." This effort to escape the human world is also performed literally and symbolically in the work of astronomy itself, as stargazers seek to evade and erase all evidence of the city and the human from their images. With reference to work, we find another place where astronomers's efforts to make good their escape from the human world can again be seen. Throughout this project I have noted the preoccupation with retirement amongst my interlocutors: from astronomers like John who have decided to retire early, to those who self-report feeling "burned out" and actively and vocally anticipate the day that they can vacate the world of work. For these people, work has joined light pollution and buildings as another thing that threatens to sever their connection with the sky. Alongside them, there are people like Wendy who hope to rework their relationship with labour: to move to the countryside and subsist off

astronomy-related work, or even just work that does not eat so significantly into their free time. Such dreams accompany literal flight from the city with a figurative abdication from the “daily grind.”

Notably, all of these solutions are individualistic escapes from systemic problems. As I note, many recognise that this troubling condition is a widespread result of perverse incentives and productivity quotas that cause utopian dreams of the future to recede before them. Idealistic worlds such as those described in Star Trek have been stolen from them by a set of systems unfit to bring such a future about, and such systems leave little room for those subject to them to change anything beyond their own future. As is suggested by the BSIA’s goals to bring astronomy back to the city, my informant’s vocation often feels radically at odds with much of the modern urban world, beset on all sides by challenges of our own making. Human progress and management have not produced more optimal conditions for human life. Quite the contrary, the systems we implemented in the economy have escaped our grasp and taken on a life of their own, becoming people’s masters rather than their tools. This is what it means to recognise that one does not live in the Anthropocene—a human age, where agency is located squarely within the remit of human action—and rather lives, as Jason Moore calls it, *capitalocene*—a world in which power rests with the abstract and obtuse systems and institutions of the economy, as much as they may curtail the futures that astronomers once dreamt of.

The sense of resignation—that one must find one’s own way to escape these conditions rather than resolve them in some meaningful way—is telling. They bring to mind Mark Fisher’s analysis of what he calls “capitalist realism” (2009). Fisher takes up Francis Fukuyama’s claim that, with the fall of the soviet union and the ascent of liberal democracies in the late 20th century, humans had reached the “end of history” (Fukuyama 2012), the apex of social organisation which requires only tweaking to perfection. For Fisher, the end of history represents not a climax, but the emergence of an imaginary deficiency, as capitalism becomes “accepted, even assumed, at the level of the cultural unconscious” (Fisher 2009: 6). To illustrate this sense in which “capitalism

seamlessly occupies the horizons of the thinkable" Fisher deploys a refrain from Margaret Thatcher, that "there is no alternative" (8). Because this imaginative deficiency is synonymous with an inability to imagine alternative futures that could be brought into being, Fisher later speaks of the temporality of capitalist realism as one of "slow cancellation of the future," haunted by "lost futures" that were once promised but now linger far out of reach (2014).

Amongst astronomers, the inability to imagine workable and achievable systematic alternatives to their relationship with work seems to be symptomatic of precisely this kind of capitalist realism. They work tirelessly to emancipate themselves from the human world in order to spend more time amongst the stars, but they do so alone, in a world they cannot meaningfully change or work upon. Not only do the pressures of a busy life drag one away from astronomy, but these increasing pressures stand in contrast to the futures that modernity promised, and challenge its two fundamental cornerstones. On the one hand, the human systems that were meant to territorialise the world have become opaque and maladaptive. On the other, that opaqueness has reduced the ability of people to imagine alternatives, and restricted their arena of meaningful action in the world to the level of the individual. In astronomy these troubles become particularly pronounced, in that this dysfunctional aspect of the human world endlessly encroaches upon their work, obliterating the futures promised both on Earth and in outer space.

6.2.2. Environmentalism and the Intractable Problem of Complexity

Alongside labour, the environment repeatedly proved to be a crucial and pressing point of concern for astronomers throughout this fieldwork. As I have described, particularly within my discussion of astronomer's efforts to navigate the city, their delicate management of photons reveals the light and air pollution that humans inflict upon my planetary environment in a unique and tangible way, actualising otherwise abstract and broad anxieties. Ecology draws our attention to the interfaces between humans and the world. Like the issue of work and time, man-made environmental crisis and the anxieties

that surround it troubles modern utopian dreams: far from the anticipated progression of technological advancement into a better world, the climate crisis demonstrates how human interventions can go wrong, have unintended consequences, and jeopardise our futures. As I shall discuss here, the fact that these ecological issues are the unintended consequences of human actions draws people into an ethical discussion of rights that problematize the future: *who gave us the right to remake the world?* What emerges from these discussions of environmentalism is a contested ethical landscape, in which polarized futures informed by polarized ethical orientations are supplemented by a pessimistic belief that there is nothing that can be done to achieve such aims. Here, I will discuss how anxiety and pessimism about the man-made environmental crisis and what is to be done about it present themselves amongst astronomers and how this links astronomy to this broader concern.

As a part of this effort to explore tarnished futures in outer space, I chose an off-season stargazing event to bring in a prop that might prompt discussions. It was a thematic board game called Terraforming Mars, in which players take on the role of corporations tasked with raising the water, heat and oxygen levels on Mars to habitable levels. They do so by playing cards that represent certain technical interventions, including the introduction of plants and animals, shipping in greenhouse gasses, creating artificial magnetospheres and crashing comets into the planet. The game was clearly well-researched, and drew on believable interventions that could prepare Mars for human habitation, straddling the border between Sci-Fi and reality. Because I knew at least a few of my informants would be interested in this plausible realism, I thought that the game would be a great starting point for a discussion of colonising other worlds.

We never managed to play the game in the end. I pulled it out of my bag with a small group of regulars at the hub, about 2 hours before sunset, and the possibility of any stargazing. My friends tore into it, visibly excited about the content of the box. They all agreed to a game, but learning the rules was swiftly derailed once we got to the cards. Some of my informants wanted to go through each card in turn, talking about its feasibility. Many of these cards were ideas they were familiar with, while others inspired

speculation. “Can we really install an artificial magnetosphere? How would we even do that?”

All the time this was happening, people from around the hub wandered over curiously and joined in talking about the concepts embedded in the game. Many of these responses were excited, but certain ideas, such as the aforementioned shipping of greenhouse gasses, raised some eyebrows, doubtless because of the negative associations they had garnered on Earth. The most clear example of this was an astronomer, Dave, who came to sit down with us and chat about the game. Dave said that the idea of colonising Mars was “a horrible idea” and justified it by imploring me to “look at what we’ve done here on Earth. Look at the damage we’ve done. We can’t be trusted with another world. At least not yet”. Interestingly, by contrast, Simon then challenged him: “What is there left to ruin on Mars? What could we do that hasn’t already happened? Mars is where the apocalypse has already happened!”

I found this exchange very telling. It reminded me of a discussion that Aaron Parkhurst and David Jeevendrampillai reported of their work with architects designing Mars habitats. When trying to deal with the deadly amounts of radiation on Mars, and work out how to mitigate its harmful effects, one scientific advisor suggested blasting caverns out of a rock face using nuclear bombs (2021: 39). Parkhurst and Jeevendrampillai report the “shock” and “ethical tension” that faced such a proposition from some in the meeting, while others said that “anyone who is worried about radiation shouldn’t be going to Mars anyway” (Ibid.).

These discussions of the impact humans might have on an already barren place indicate an interesting ethical parallax that emerges from the issue of ecology. The opposition between the scientific advisor and their detractors, and my terraforming enthusiasts and the astronomer who raised concerns, is an ethical distinction about how humans should act in the world and upon the environment. This contention seems to emerge from concerns about ecology here on Earth, whether we should radically reorient our ethics away from an anthropocentric model in light of those concerns, and

how, if at all, this reorientation should inform the nature of our spacefaring future. This Juxtaposition of Mars as a new Eden-in-waiting with the apocalyptic associations of greenhouse gasses and nuclear bombs is enough to give anyone ideological whiplash, but I do not think that this is the issue my informants have. What emerged from discussions of environmental degradation and spacefaring futures is that these concerns rest with the failures of human territorialisation.

Without fail, the man-made environmental crisis on Earth is a critical concern for every astronomer I have spoken to. The recognition of the environmental crisis is at once one of the towering achievements of scientific endeavour and its graveyard, in that its discovery was the result of impressive climatological and statistical work, and how we deal with it provides us with an almost seemingly intractable problematic, that I shall describe here. Many astronomers, being demographically older, lived through the emergence and intensification of the climate crisis. All of them are believers in man-made climate change, a clarification they would no doubt add to their despair. For them, climate denialism represents a latent anti-scientific backwardness that exists in supposedly modern populations, and its existence troubles an already troubling condition. Climate denialism is tantamount to a denialism of the clarity of view that is associated with the cosmic perspective; it is an anti-Copernican effort to turn away from the reality of the world as it presents itself to us, and turn inward to a human view of the world.

I will not go into the specific processes by which man-made climate change came about or was discovered here. What is most important for us is the nature of the climate crisis as a social phenomenon which my informants discuss, engage with, and agonise over. In broad terms, the climate crisis is understood to be the aggregate of inadvertent changes caused by humans to the ecosystems of the planet, and the resultant damage done to the life that depends upon them. These changes are almost universally framed as a negative disruption of a harmonious and pristine nature by our clumsy meddling. Such impacts run along systems and systems of systems. The interconnection of the Earth system means that no part of it is safe from the influence of our impacts, and

these impacts are difficult to manage, understand, and contain. In theory, our cultural adaptations and strategies of ecological management, from warm clothes to agriculture to air conditioning and water purification, produce a buffer that spares us from the impacts and places us beyond the reach of such changes. There is a sense that emerges from the discussions with my informants, however, that on the one hand, there will come a point where our technologies cannot save us, and on the other, even if we could save ourselves, the damage we have wrought is unacceptable and unethical in itself.

The state of our natural environment and our impact upon it is a point of particular anxiety for astronomers for two identifiable reasons. The first is the profound relationship with the Earth that my informants and others (see also Sagan 1997, White) have reported emerging from contextualising our planetary home in the wider cosmos. While seeing the Earth from space can signify our insignificance, it can also bring to mind the singular uniqueness of the Earth itself, and with it the fragility of that uniqueness. This contextualisation has been framed to me in terms of "comparative planetology," a discussion of the differences between planets and how they produce the diverse forms we see (Sagan 1997: 104). When made mobile, the concept of a planet is a gravity well with different physical parameters applied to it that produce its different properties. In this framing, the cosmos is populated with countless alternative Earths, which serve as visions of what the Earth could have become, and what it may one day be turned into. When comparative planetology was described to me, they took our closest planetary neighbours as poignant examples of this. Earth is flanked on both sides by two alternative timelines. On the one hand, Mars, where the core cooled, the magnetosphere failed, and the atmosphere evaporated into space. On the other, and most pressingly, Venus is a planet where the same processes we inadvertently synthesise here have caused a positive feedback loop and produced a hellscape so hot that metals melt on its surface. Venus is a particularly poignant example because it is a vision of an all-too-real future. Such visions of how Earth could be otherwise underscore the precarity of our planetary home and undermine the apparent stability of the climate

here and now. As Carl Sagan puts it, “Other worlds provide vital insights about what dumb things not to do on Earth” (*Ibid.* 104).

Secondly, and as I have previously suggested, astronomy offers a practical engagement with some of our more intangible impacts on our world. While the city stands clearly for a mastery that we have exacted over our world, some of the more malignant aspects of this mastery remain abstract, in broad shifts in temperature, invisible emissions, and extreme but freak weather events. The environment is, in the words of Timothy Morton, a *hyperobject*, often operating on physical and temporal scales well beyond the everyday experience of those who dwell within it (2013). I have already discussed some of the ways in which this abstract phenomenon is made tangible to astronomers in their work, particularly in the ways in which light and air pollution disrupt their efforts to see the cosmos. Like few other people, air pollution intrudes into the lifeworlds of astronomers, because it appears to them as a distorting haze that makes the objects of their vision twinkle. Their practices mean that they can literally *see* this otherwise invisible phenomenon that threatens our world. I have discussed the moral quandary that the issue of pollution poses to astronomers in chapter 3: how these issues are at once in need of a remedy, but their cause is so diffuse that responsibility or blame cannot easily be allotted.

The ideological and symbolic damage done to the project of modern territorialisation by the environmental crisis is found perhaps most clearly in the ambivalent nature of light pollution. To reiterate, the illumination of our streets, and the extension of our activities into the new spaces made available by it, is undoubtedly a territorialisation of the night, claiming it as a place for human work (Koslofsky 2011). However, by claiming the night with street lamps and floodlights, moderns also obscure our access to the heavens, the very access which served as the grounds for the modern project at its inception.

Discussions of environmental crisis naturally lead to discussions of environmental fixes, which range from contemporary technologies such as insulation

and carbon capture and green energy to the near-future of fusion, and futuristic geoengineering projects. In the discussion of these fixes, we find a deeper, more troubling pessimism about our capacity to even remedy the situation we find ourselves in, rooted in the inscrutable complexity of the environmental systems we must work. This scepticism is referenced by many in their concerns about contemporary environmental fixes such as carbon capture (e.g. Schlosberg & Hart 2021) or recycling (e.g. Franklin-Wallis 2019) which, in implementation, turn out to be less effective or produce unforeseen side-effects. The environment, being as interconnected as it is, is an incredibly complex phenomenon that is difficult, even perhaps impossible to territorialise. Dave called the effort to render this complexity in numbers, expressed in terms such as “net zero” and “carbon offsetting” an immense “environmental calculus” which he was sceptical we had the capacity to perform. Working with incomplete data about environmental systems and how they function means risking further unforeseen side effects with which this calculus is endlessly playing catch-up. The infrastructures of science abound, but only to trouble any sense of territorial agency. Even Simon, as optimistic as he usually was about the prospects of technology, said of prospective future fixes, “The problem with geoengineering is that it's a threshold. Once you’ve started managing the environment you can’t stop. You’re stuck there, and you’re responsible for it. And who knows what the side-effects of the stuff we do will be.”

What my informants express here is what the journalist Mike Pearl calls “climate despair,” wherein those concerned about the environment feel a deep concern and pessimism about the prospect of resolving these issues (2019). It is a position concerning the capacities of humans to manage the environment which, he notes, is also sometimes called “climate nihilism” or, appropriately, “human futilitarianism.” It is a direct challenge to the notion of progress promised by modernity and its revolutionary form, experienced by astronomers in their ambivalent and troubled relationship with light and the prospect of colonisation.

It is in this sense that the moral orientation of territorialisation is troubled: it no longer necessarily produces better futures, but, because of our inability to fully predict

the effects of our actions within complex systems, they may end up destroying whatever futures we may have. It is for this reason that I found the discussion about the prospect of colonising Mars compelling. It is in this ambivalent heritage of territorialisation efforts here on Earth that the disagreement I describe above finds its roots. When I entered the field, I imagined that I would be faced with enthusiasts who would uniformly buy into the idyllic imaginaries of off-world colonisation, as a critical checkpoint for the teleological story of the human species. The territorialising impulse that takes a wasteland and makes it our own in the style of Robinson Crusoe is noted by Robert Markley as one of the critical myths that give the colonisation of Mars its salience. An extension of this logic was articulated by Simon when he said that he saw the ultimate destiny of humanity (the end-point of its teleological ascent towards rationality) was to "mulch all the matter in the universe into one space-station, built to our specifications". Space stations, he argued, are far superior to planets because we build them from scratch to the specifications we need rather than retrofitting hostile planets. In his mind, they are optimal because they afford efficient total mastery of our environmental conditions.

This expectation was, however, undermined by Dave, for whom it seemed that the complete mastery of nature and the prospect of manipulating other planets to fit human needs was horrific. This disagreement describes two diverging paths concerning the morality of colonisation. Simon's ethic seems to be explicitly human-centric, or at least life-centric. His concern for nature extends to the ecosystems of the Earth, but The barren landscape of Mars does not interest him. It is where "the apocalypse has already happened." The value of a place is its capacity to sustain life, and the value of Mars—or indeed any "mulchable" matter—lies in its potential to be turned to this end. For Dave, on the other hand, human space colonisation no longer stands for utopian visions of pristine glass domes and a Mars turned green, but for a discarded coffee cup or an oil spill on the surface of the red planet. The morality of the figure of the human, for him, seems inverted, no longer standing for progress but for the destruction and disruption of pristine environments. There is an intrinsic value to untouched nature, even barren nature, that is undermined by efforts to territorialise and domesticate it. Mars may be

horribly irradiated, but to add *human* radiation through the use of nuclear bombs is profanity.

The ambivalence of these concerns reflects the tense asceticism of the Copernican Engine: the impulse of progress to serve the human on the one hand and to disregard the human and produce an ethic divorced from human good alone on the other. To my mind, the call to leave Mars alone and pristine illustrates the valourisation of the organic over the conditions of humans—a noble savagery or natural purity to the nature of the world, as faith dwindles in the mechanical, the synthetic, and the contrived. It is a call to allow the red planet, and indeed all nature, to stand on its own terms, for humans to find value in that nature in itself, as the Copernican Engine traverses the gap between fact and value and calls on us to adopt a morality as well as an epistemology and a practice that is more naturalistic and in tune with the cosmos. This practice is already latent in astronomy, in the way in which Joshua Reno describes astronomers "attuning" themselves to the cosmos (2018). This morality is a morality that goes beyond and inverts the moral orientation of modernity, in which, at its extreme, it is incumbent on humans to forge utopias for humans alone.

Whether or not there is legitimacy to these concerns—whether humans can truly be trusted to care for other worlds better than they have the Earth—what matters is the fact that they exist, that they seem to dominate the discussion of the climate, and that they run so contrary to the logic of rationalisation and mastery that otherwise define modernity as I have described it here. It represents a turn in how the actions of humans in the world are construed on a moral level: from the bringers of light and civilisation to the false and clumsy hubris of the "masters of broken Earths" (Yusoff 2018: 2). In this sense, the futures of optimised colonisation and pristine geoengineering become a human corruption. When I asked Dave if he would say that the colonisation of Venus—a process that, I noted, would probably mean the removal of greenhouse gasses from its atmosphere—he said that it would be "equally horrible". Radiation and carbon dioxide are not bad in themselves. The issue is that it is *our* radiation and *our* carbon dioxide, managed by fallible humans, with a proven ineptitude for such

management, observed in horror by those with an acute awareness of just how wrong such projects can go.

6.2.3. Dealing with Uncertainty

In 2019, yet another world-spanning event emerged to once again show humans that we are not masters of the world. This time, it was a novel virus, dubbed COVID-19, which damaged the respiratory systems of those infected and caused unprecedented and devastating harm. To make matters worse, as one of my informants described it, and many others agreed with, the British government was “a tad slow on the uptake”. As British residents were confined to their homes as a part of ‘lockdown’, allowed out only for essential shopping and a singular walk per day, the landscape of the astronomy community shifted. At once, travel restrictions made the kind of navigation of the city described in Chapter 3 impossible, as well as the usual BSIA in-person meetings. People compensated by moving to online platforms; I noted an uptick in the frequency of social media posts on groups dedicated to astronomy, even as the opportunities to take photographs dropped. Many documented the trials of doing astronomy from a balcony, garden, or even out of a window. There were also more posts from people looking for advice on how to get into astronomy for the first time, be it a use for their new-found free time or something to occupy their similarly housebound children. The BSIA ran meetups on group calls, but these often ran into the same issues as other social meetings that defined the time, being largely a mixture of people chaotically talking over one another interspersed with periods of awkward silence as people tried to work out how to socialise in such a contrived and limited setting. It was a period of profound strangeness, as people tried to acclimatise to the “new normal” (Corpuz 2021) of simultaneous over-exposure to one’s ‘bubbles’, isolation from the wider community, and novel habits and settings for everyday activities, all overshadowed by a lingering sense of fear, uncertainty, and doubt about the underlying illness that caused it all.

This was a difficult period of my fieldwork; for over a year I was unable to stargaze outside, let alone with other people. This was when I got my own telescope

and began learning to operate it in earnest, performing some autoethnography in the absence of others. This was also when most of my formal interviews took place, as social interaction with other astronomers was only possible through messaging apps or in pre-planned video calls. It was during this period that I managed to get a meeting with Kevin. It was an interview that I had hoped to get for a long time because I thought his particular astronomical style was particularly pertinent to the idea of making ourselves at home, and the cosmopolitical questions it raised. I was not disappointed.

I had first met Kevin at the BSIA astronomy meetings before lockdown. He was one of the regulars of what I would have called the “core group.” These were the most regular regulars, the organisers included, who were there to facilitate the event and took it upon themselves to make the meetings a welcoming place for members of the public. My desire to organise an interview emerged, however, from a public talk he gave in a central London library. There, he spoke about how he got into astronomy, and the kind of astronomy he did. Kevin was one of those outliers who had entered astrophotography not out of an enthusiasm for space, but out of an interest in photography and a desire for a more challenging subject. In this search, he settled on the International Space Station (ISS), the only contemporary human habitat off-Earth.

The first half of his talk was about how his endeavours to image the ISS had sparked a fascination with the habitat, how it worked, and space projects more broadly. Following this, he outlined how he went about the difficult task of imaging such an object. In section 4.4. I outlined the problems that movement poses to astronomers. The ISS orbits the Earth every 90 minutes. There had been several nights of stargazing in which I and other astronomers had watched it as a point of light, identifiable by its brightness and the speed of its movement. It had taken approximately 15-20 minutes to pass from horizon to horizon. At such speeds, automated mounts are exceptionally hard to calibrate, and Kevin had opted to manually track the space station using a telescope design called a ‘Dobsonian,’ that could turn 180 degrees through a single axis. The images that emerged were all the more striking, given my awareness of how difficult they must have been to capture.

What interested me about Kevin's work was that it was specifically directed towards something that was so universally totemic of the project of human progress—so clearly a work of territorialisation *par excellence*, so profoundly *modern*. Amongst the towering achievements that stand for the incredible capacities of humans, reaching space and finding a place for ourselves in the extreme habitats off-Earth are often at the forefront. The incredible technical demands of making ourselves a literal home in space make it one of the clearest examples of making ourselves figuratively at home in the world. But also, astronomy sits, as I have emphasised in this thesis, somewhere between nature and culture: technical interventions that seek to make natural phenomena visible in their organic form. Given this usual emphasis on nature and its unadulterated representation, I was intrigued by someone who almost exclusively photographs human structures in space. What I wanted to find out from Kevin was whether his astronomical excursions had informed a particular attitude towards the relationship between humans and the world. Given these curiosities, I contacted him and set up a date to meet him remotely via video call.

Kevin was precisely the kind of person I expected as a member of the BSIA core group: agreeable, articulate, and deeply passionate. Kevin was a busy man. He was an accomplished engineer, whose work had him travelling about constantly, even during lockdown. During our interview, he reiterated much of the relationship with work I described above: though he was not avidly awaiting retirement, he did note that time to stargaze, amongst other things, was becoming increasingly sparse. That being said, he seemed happy to find the time to talk to me about astronomy, and eager to share what he found so compelling about it. Alongside the satisfaction of mastering a craft by doing something very technically tricky, Kevin said that during his astrophotography career, he had been inspired by learning about the historical trajectory of space travel, and how far we, as a species, seem to have come. "From my work, I kind of have an idea of how hard these kinds of projects can be," he said of the ISS, "it seems crazy that we've managed to get to this point in such a short, a relatively short, space of time."

I came away from my conversation with Kevin with the impression that he was a die-hard modernist. His work afforded an understanding of precisely how one could go about manipulating certain things in the world, and, much like Simon, he seemed overflowing with confidence and enthusiasm for doing so. This confidence, was, like Dave, also tempered with a particular anxiety, albeit quite different. When I asked Kevin that critical question of whether we *should* go to space, he gave me a quizzical look, as if the answer was self-evident. “Why not?” he asked. I told him that I had met some people who had reservations on the topic, that some people were concerned about the manner in which we might go to space, how little say people would have in that process, and that I was unsettled on the matter. I asked him to convince me that we should. “So the most compelling reason for me is how fragile human life on Earth is. One asteroid, one pandemic, one…” he waved his hands, gesturing broadly to a myriad of possible apocalypses “world-ending catastrophe, and that’s it. Humans are gone forever. If we manage to go to space, at least the Earth getting destroyed, for whatever reason, won’t be the end of us.” Hanging over Kevin’s optimism is a sense of real concern about, largely, the same kinds of things that concern Dave, though approached from a very different angle. While Dave is concerned for the wellbeing of the other entities that inhabit the world, and the capacity of humans, either actively or inadvertently, to overpower and destroy them, Kevin’s concern is, in a sense, self-interested, or perhaps species-interested. Space is not only a glorious ascent to the heavens but also a flight from impending Earthbound doom.

Most interesting for me, however, was the point at which the conversation turned to other satellites, and the SpaceX Starlink array. Starlink is a satellite constellation, initially launched in 2019, intended to provide worldwide internet coverage. The satellites were released from a SpaceX Falcon 9 rocket in a line that was visible from Earth, and then slowly moved into position. Just before lockdown, I had witnessed the Starlink array with my own eyes on one stargazing excursion as a series of lights travelling across the sky. Kara articulated the surreal nature of the spectacle: “It's like something from Sci-Fi, like a space train or something.”

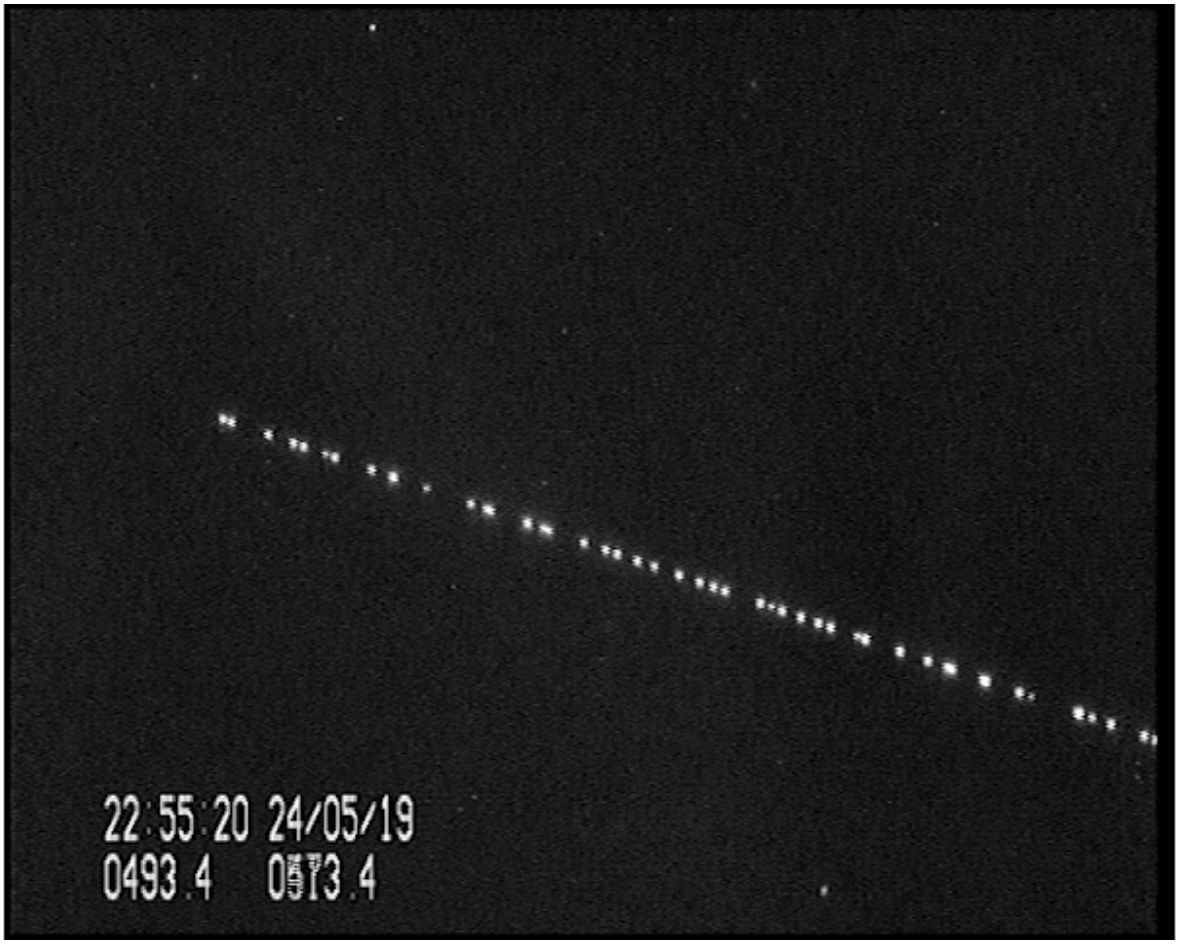

Fig 15: Starlink. An image captured of the SpaceX Starlink train captured from a satellite tracking station in Leiden, the Netherlands, and shared on their blog (SatTrackCam Leiden 2019)

Amongst the astronomers I have spoken to about Starlink, and indeed in the wider astronomy community, many were concerned about its effect on their vocation (see also Pultarova 2023; Howell & Pultarova 2024). The lights, they argued, had the potential to disrupt observing, and sparked a broader discussion about space debris and other pollution left by human space missions over the last 50 years. Here, again, I found the theme of human environmental degradation worrying astronomers when they thought about human prospects in space. How will this detritus affect future efforts to leave Earth? And, more abstractly, is what we discard really the mark we want to leave on the world?

Kevin was dismissive of these concerns. “People are acting like it’s the first time we’ve put things in space that can get in the way. And even so, you’ll only be able to see the Starlink satellites as they get into position. Their orbit starts pretty low, but once the constellation is set up they should be invisible.” Kevin was right, at least about previous satellites being visible. In other conversations, I was made aware of old Motorola “Iridium” communications satellites which had antennas that “flashed” as they passed overhead (Chien 2003). Some, like Kevin and the ISS, actively sought out these satellites for imaging, and treated their passing with the same excitement as any other celestial event. As the astronomer who took the image above wrote in the blog post that accompanied it, “What a SPECTACULAR view it was! It started with two faint, flashing objects moving into the field of view. Then, a few tens of seconds later, my jaw dropped as the "train" entered the field of view. I could not help shouting "OAAAAAH!!!!" (followed by a few expletives...)” (SatTrackCam Leiden 2019).

Most notable in Kevin’s complaint about these worries about Starlink was what he had to say about the people who were worried. “I just wish people would think less in terms of tribalism. We’re supposed to have moved beyond that. It's petty. We’re supposed to celebrate stuff like this.” When I pushed him on this ‘tribalism’ that he attributed to his sceptical colleagues, he said that “I think they just don’t like Elon Musk.” Musk’s name had been difficult to avoid in conversations about space prior to this, given that he, as the founder and CEO of SpaceX, had pushed the envelope on space projects in prior years. Musk made his name as something of an arch-modernist, using his massive wealth to push technical fixes for contemporary problems in search of a better future: first popularising the idea of the electric car with his company Tesla, then was instrumental in a resurgence of space-bound dreams with SpaceX and lofty rhetoric about colonising Mars. Depending on which astronomers you ask, Musk is either a heroic pioneer picking up NASA’s dropped torch, or a very rich child pursuing a self-indulgent quest to become emperor of Mars and cynically enrich himself with what he finds there. Some, echoing closely Dave’s concerns for ecological damage, have even gone so far as to call Musk’s plans for Mars “cosmic vandalism” (Focht 2023). I found it intriguing, but perhaps not surprising, that Kevin did not believe that concerns

about Starlink could be authentic. It seemed that they only made sense to him as proxies for a deeply irrational personal hatred of its figurehead. When I asked him how we could approach the issue as he perceived it, he shrugged defeatedly, then smiled as an answer came to mind: “If I knew the answer to that we we would have far fewer problems in the world.”

This interview, and particularly Kevin’s rationalisation for other people’s concerns, solidified something that had been in my mind since I had brought that board game to the stargazing night and witnessed the disagreement about human futures in space: that the astroculture community, rather than being unified in their enthusiasm not only for space but also the prospect of human futures there, was deeply divided about what those futures should look like. While not exhaustive of the positions held in these conversations, we can use these two interactions, serving as the most prominent examples of an underlying tension I have seen throughout my time in the astronomy community, to establish two rough camps or caricatures of positions in relation to the future and the problems that face our entry into it. These trends are by no means exclusive, and can be held by different people on different issues. Both camps register an overwhelming sense that things seem to be going wrong, that progress has stalled. What distinguishes them is the reason to which they attribute this dysfunction, and how they respond to it.

One is a position, extrapolated from the responses of Simon and Kevin, but found throughout the astronomy community, that clings to the dreams of modernity. They see such problems and believes that there are clear fixes to them, often found in space. The anxiety of this response, however, concerns our capacity to enact those fixes in the contemporary political, economic, or social climate. Between vested interests, irrational policy, misled governments, and uninformed, ‘petty’ people, we lack the collective political will or capacity to enact the required changes on the required scale in the required time. They are often frustrated by gridlock and inaction, and are troubled by the social and political obstacles that exist to what needs to be done. More than once, informants expressed incredulity at the way in which space projects had

slowed since the height of the space race. Many expressed understanding, of course, that the Apollo missions were part of a broader geopolitical strategy during the Cold War, but this only seemed to deepen their concern that the only thing that could push humans to space is conflict rather than utopia. Their futures recede before them endlessly: we could almost reach out and grasp them, if only petty human politics could stop disrupting the pure innocence of space projects.

The second trend in responses align with the comments of Dave and others about the intractable problem of environmentalism, but also describes attitudes towards other such problems. This respondent is far more pessimistic about the state of territorialisation: they are dubious about the solutions proposed by their counterpart, and doubly dubious about the certainty with which those solutions are put forth. They are not only sceptical of technical fixes for our problems, but also about our capacity to even comprehend the nature and scope of our problems, or indeed the repercussions of the actions we might take to remedy them. It is not simply an issue of implementation, but an issue of knowledge and complexity. Unlike the modern, whose faith in territorialisation had been suppressed or deferred to some abstract elsewhere in space where we can fix everything, the faith of these figures has been utterly crushed under the weight of conflicting narratives, discourses of power, and the excesses of the systematic doubt that is the cornerstone of modernity, crystalised, for instance, in the moral ambiguity of light. Anthony Giddens claims that modernity rests largely on trust: trust in institutions, in practice, and in systems and procedures. He claims that trust "'brackets out' potential occurrences which, were the individual to seriously contemplate them, would produce a paralysis of the will, or feelings of engulfment" (1991: 3). For the latter of my rough taxonomy, this trust is in short supply. territorialisation can only succeed if it sets its own standards for success, and those standards are often at odds with and detrimental to reality, evidenced by a whole host of inefficiencies and inconveniences that emerge from our best-laid plans. These figures are postmodern, in that they have internalised the sense in which all of these accounts of the world are just that: imperfect renditions and illusions that do not (and arguably cannot) fully adhere to the matters of fact of the world. They are not postmodern in their advocacy—while I

assume many will have heard of postmodernity and even know its meaning, I doubt many would lay claim to it—but in their condition. It is not an abstract theory to which they adhere, but a relationship with the world and our capacity to understand and act meaningfully within it that has emerged organically from the failure of territorialisation.

It is for this reason that I found the disputed figure of Elon Musk to be such a compelling touchstone for this divide. The troublesome and ambivalent stature of figures such as Musk crystalises a political divide in an ostensibly apolitical movement. On the one hand, he is an economic strongman, with pockets deep enough to overcome the constraints of the Earth and realise potentially utopian visions of humans as a multi-planetary species. In an environment of systematic paralysis and anxieties grounded in misunderstanding that concerns the likes of Kevin, such a figure is welcome to do what needs to be done. For others, he represents the excesses of a fundamentally dubious project.

Both of these responses can be read as answers to Sagan's crucial question, cited above, of whether we should resolve our problems here on Earth, or must we go to space to do so. For people like Kevin, the answer would be the latter: they are under no illusion that the problems that face us on Earth are dire, but the technologies and resources that promise our salvation linger in futures beyond our atmosphere. For people like Dave, far more pessimistic, this answer is deeply irresponsible, threatening to transpose these problems into space, because these problems are fundamentally intractable. It is understandable that Kevin would express anxiety about such pessimism. Surely something, anything, must be done in the face of potential armageddon.

What unifies these two figures is that their anxieties are human anxieties, which is to say they are anxieties about the way in which human irrationality or limitation obstructs and undermines their desired futures. These are human systems that we built, and much like the city, they *should* be a logical system by that token. Instead, they slip from our grasp, misbehave, spiral and torque out of our control, and prove too complex

to fully get a handle on in any way that might make them predictable and manageable. Modern faith in our capacity to territorialise better futures into being, it seems has long since dissipated, leaving a void where utopia once stood. For many, the colonisation of outer space is inevitable: a meme too deeply entrenched in the modern psyche to not happen. When I asked Dave if we should go to space at all, he said “Not if we’re gonna act up there the way we act down here. But that's kinda moot, isn’t it? Most people don’t really get a say in these kinds of things.” Even Simon, usually a great advocate of space programs, had reservations inspired by the cautionary tales of Sci-Fi, evidenced by his aforementioned statements about geoengineering. Others, such as Kevin, seemed concerned that these reservations emerged from a deeply irrational place, and worried about what these irrationalities signify and the threat they pose to space projects.

Who, then, gets their future? Both Kevin and Dave are deeply concerned by each other’s visions for space. Both promise a kind of destruction that cannot be countenanced by the other. Both of these kinds of concerns are about the manner in which this project is undertaken, framed by an acute awareness of what is at stake in our move into outer space. What I have attempted to chart here is the rough shape of these two kinds of responses that emerge from the interstitial position that these ambivalent problems place us in. Both of these responses articulate the same position on the territorialisation of work, the environment, the economy, and politics, as astronomer’s position on the territorialisation of the cosmos through the perfect image: that this effort is impossible.

6.2.4. The Temporality of Failure

It is here, following the discussion of responses to the context of failure that swirls around astronomical practice, that I would like to momentarily return to the relationship between moderns and temporality. Primarily following the work of Francois Hartog, I described this relationship as one of revolutionary futurism; modernity is defined by an order of time which “presents itself as constantly accelerating” (2015: 107). The work of modernity is the work of the future, and this futurist residue can be seen in astronomer’s

emphasis on future-oriented projects, and the prospects off-world that we have not quite yet attained. Through technical, social, and political interventions, the modern seeks to rationally construct a new, better world. What I have described here, however, is a disruption of this orientation: a distinct despair about the failure of such futures to emerge on the one hand, and a dread about their form and inevitability on the other.

Such a temporal reorientation has been discussed extensively. We might recall how Hartog, in his rough bookending of the modern era, claimed that the time of revolutions came to an end in 1989, with the fall of the Berlin Wall. He claims that the twentieth century saw a move from this futurist order of time to a new orientation: presentism. While he emphasises that “every group and society, today and in the past, can only ever build on its present” (109), he nonetheless claims that the time following the latter third of the twentieth century is defined by a uniquely “distended and bloated “now" (113). He identifies many movements as contributing to this condition, including the “bankruptcy of history” made evident by two world wars, and the mythological and illusory nature of progress, for which he points to the relativism of anthropology. In particular, he references Claude Levi-Strauss’s classic work *Tristes Tropiques*, in which he sees a challenge to the idea of progress: “History is only occasionally cumulative and, moreover, that we only recognise as cumulative what resembles our own development” (112). Caught between a past that can only ever be narrative, subject to the powers and epistemes of the writer—an internalised sense that, as the author Bruce Sterling puts it, “history is not a science; history is an effort in the humanities” (2010)—and a future that endlessly slips from our grasp, the realm of meaningful action retreats to the present.

Presentism is an orientation towards time that is often associated with failure. Material hardships have been identified by both Jane Guyer (2007) and Hartog himself (113) as something which eviscerates the future, forcing those subjected to them to live in the present. Indeed, this effect of scarcity is identified by Marshall Sahlins as one deployed (in this case wrongly) in explaining the apparent lack of ‘progress’ in hunter-gatherer communities (1972: 3). Guyer points to Freidrich Von Hayek and the

Austrian school of economics as advocates for the presentist temporal mode. Their work, particularly that of Carl Menger (1985) to Ludwig Von Mises (1990), constituted a critique of human capacities to manage complex macroeconomic systems—often called the "economic calculation problem" (*Ibid.*)—and advocated for an organic and self-organising approach to economic affairs. Our capacities to territorialise economic activity, they claimed, is fundamentally limited, evidenced by the failure of Soviet-style demand economies. This translated into a call for market-oriented management and limited state intervention, which ultimately became the raft of economic policies that came to be known as "neoliberalism," which found extensive national and international purchase in the 20th century (eg. Ganti 2014). Guyer points towards such macroeconomic shifts, arising from a perceived failure of modern efforts to manage economic activities, as causes for what she calls the "evaporation of the near future," claiming that contemporary temporality is defined by a "fantasy futurism and an enforced presentism," and that the near future is only repopulated by the "punctuated time" of specific dates and events (2007: 410).

Similarly, Michal Kravel-Torvi and Yoram Bilu discuss the response of Jewish ultraorthodox Chabad Hasidim and their response to failed prophecy in terms of a temporal reorientation towards the present. Followers of the Chabad movement followed a charismatic and messianic leader who died unexpectedly in 1994, at the "peak of a messianic surge that he had instigated and orchestrated" (65: 2008). This death, the failure of prophecy, is described as a "traumatic loss of their messiah-to-be" (76). Kravel-Torvi and Bilu identify the work of contemporary Chabad as a "work of the present," which manages the relationship between the past, present and future, blurring the lines between now, the past presence of their leader, and an imagined future of redemption, constituting a "complex coping pattern fraught with tension and contradictions" (69).

Perhaps most notable in the discussion of astronomers and their relationship with the future is, however, the aforementioned work of the social theorist and philosopher Mark Fisher. Fisher's painting of a world so dominated by capitalism that no alternative

seems possible speaks clearly not only to the frustration that astronomers regularly express frustration at struggling to make time for their stargazing, but also to this broader sense of paralysis about trying to territorialise our or other worlds when outcomes are so uncertain. Fisher's discussion attests to this attitude within at least a Western context: "While 20th-century experimental culture was seized by a delirium, which made it feel like newness was infinitely available, the 21st century is opposed by a crushing sense of finitude and exhaustion. It doesn't feel like the future. Or, alternatively, it doesn't feel like the 20th century has started yet." (2014: 8).

Astronomers and their efforts to territorialise the universe into an image express not only this sense of paralysis or stagnation, but also a sense of loss, described by Fisher in terms of "lost futures" (2014). These are futures, such as utopias in outer space, that were promised but failed to materialise, and whose passing is deeply felt. It is for this reason that Fisher makes sense of lost futures in terms of Derrida's concept of *Hauntology*, described by Fisher as the "agency of the virtual [...] that which acts without (physically) existing" (*Ibid.* 18). This sense of loss, and longing for the surety of a (perhaps fictional) bygone space age, is expressed clearly in the anxieties my informants express above. For both Kevin and Dave, and indeed the many other astronomers carrying this same sense of pessimism about their future, the utopias in which these problems could have been resolved linger over their heads, for some an obscure and obstructed possibility, for others turned into an inevitable nightmare.

In the practice of astronomy and the traces of broader society that intrude upon it, the promises of modernity seem to have been broken. It seems to my informants that the structure of things either occludes very plausible utopias in space or demonstrates how these utopias were ideological delusions. What I have described here is a sense, felt by many astronomers, that the future is no longer something that humans actively craft, but something that happens to or is done to them. It is an emergent understanding of the critiques that have been levelled against the concept of the Anthropocene in the past: that broadly attributing agency over the future of the Earth to all humans offers a "shallow historicization" and belies the automated and systemic ways in which futures

are made, leading us to perhaps better locate such agency with systems such as capitalism (Moore 2017). Here, the agency to perform revolutions against the human world is once curtailed by the overwhelming agency of the systems of that very world, to which potential revolutionaries are subject.

Astronomers undoubtedly occupy a punctuated time, marked by the discoveries and events about which Simon and many like him still retain much enthusiasm. The problem emerges when the question of how one is to broaden these technologies and discoveries into a more expansive understanding of the future is raised: how they are to be deployed, what future they should serve, and how. What I have described above is a sense in which these visions of the future become disjointed, pessimistic, and unavoidable. Humans are stuck, it seems, between an inescapable paralysis on Earth, and an undesirable and tainted, but equally inevitable future amongst the stars. Like the ambivalent moral landscapes of light, work, and ecologies, the landscape of the future is riven with moral and seemingly intractable contradictions, rendering individual astronomers in a position of impotence, left to navigate these spaces rather than produce them. Dave's statement about how "most people don't really get a say in these kind of things" illustrates a deep sense of presentism. He acutely feels his lack of agency in the future of the species.

This perceived condition of stasis may be described as one of incommensurability. As Carroll, Parkhurst and Jeevendrampillai assert, incommensurability is not failure, but one of its potential results: it is "failure drawn out and given permanency as a structural element" (2017: 7). The work of astronomers and science more broadly can be understood as a work of seeking commensurability with the world. The project of acting effectively in the world and bringing about desirable futures rests upon the success of this effort. What is manifested in microcosm in the material failure of the image and in macrocosm in its social and ecological context is an inability to achieve this communion. Incommensurability is framed by Elizabeth Povinelli as the realisation that "undistorted translation cannot be produced between two or more denotational texts" (2001: 300). It is a condition in which we cannot find the grounds for

hospitality on either side, because we cannot make nature speak our language, and we cannot be sure that we can achieve the reverse. This incommensurability emerges not only from the failure of these projects but also the failure of the revolutionary systems by which this failure is recouped and harnessed to agentively produce new worlds and futures.

This incommensurability is not only a gap between the social projects of humans and the content of the cosmos, but also in the interpretations of the content of the future I have described. The two visions I have discussed are united in their despair at our capacity to manage the world, but divided along moral lines. These moral lines can be seen to emerge directly from the tense and paradoxical nature of the Copernican Engine. This cultural foundation for the modern project exhibits a contradiction of content and purpose: to affirm the human in the cosmos through its erasure. The two moral orientations towards the future described above—one longing for the promised utopias of space, the other despairing in their false redemption—fall firmly along these lines, the former aligning itself with the engine's humanistic ends, and the latter with its anti-human means, pushing them towards a morality that extends beyond the human. To me, these incommensurate responses to the Copernican Engine signify a system in retrograde: at once the unreasonable demands of its means undermining its ends, and informing a moral division over how we ought to proceed into the future, culminating in two divergent futures, and a deep pessimism about them both.

6.2.5. The Horror of the Earth-image

The demotion of the human that I have described here (just another in a long line of them) can perhaps be best understood in the context of the work of Martin Heidegger, and the confluence of his work with Eugene Thacker. In particular, this problem speaks to the particular relationship between Dasein and the world that Heidegger described, and Thacker's concept of Horror. I have already described Heidegger's concepts of World and Earth in incredibly rough terms but is here worth substantiating them more thoroughly. Heidegger's concept of World is not as any particular location, but rather a

mode of being particular to Dasein: it is, as Kelly Oliver puts it, “pre ontological insofar as everything that appears to us does so because we already are in the world” (2015: 115). It is in this sense that I referenced it before as a social, interpretive relationship of the human with its environment, and on that ground compared it to the anthropological concept of cosmos. However, Oliver identifies an ambiguity in the concept of world, insofar as Dasein is at once “world-forming” and “thrown” into a world not of their making. Dasein at once produces and claims the world, and is also subject to it and can never fully grasp its expansive complexity. Oliver claims that this leads Heidegger to introduce the concept of Earth, which represents that unfathomable, nebulous aspect of the world which defies our grasp—that ambiguity into which we are thrown and over which we can exert no control. The earth is our complex and unknowable heritage. As such, the earth “refuses” and “withdraws” from us, and “shelters unconcealment and continually reminds man that he is not the master of Being” (124).

Heidegger also claims that Dasein is never at home in the world, a condition of anxiety and that philosophy is an effort to alleviate this “homesickness”. We do so by defying the refusal of the earth, seeking to “penetrate” it with our technoscientific gaze. “Technology aims its sites at ordering the entire planet through global communications and global markets.” according to Oliver (152). This ordering can be correlated with what Thacker called the “therapeutic” function of philosophy: to chart the bounds of this ambiguous realm and make it known and stable, to *territorialise* it (2015). This impulse to make ourselves at home in the world and defy the Earth can also be seen in Anthony Giddens’ discussion of “ontological security” as a crucial concept of modernity. The development of a subject with what he calls “practical consciousness”—a capacity to monitor their world and interface reflexively and effectively with it — is crucial for the stability of that subject and the stability of the world: “On the other side of what might appear to be quite trivial aspects of day-to-day action and discourse, chaos lurks. And this chaos is not just disorganisation, but the loss of a sense of the very reality of things and of other persons.” (1991: 36).

Heidegger expresses concern about this modern tendency to defy the Earth. The Earth and world exist in "strife", locked in a tense opposition of revealing and concealing, and the victory of one over the other leads either to the triumph of history or its complete disavowal. This technoscientific gaze, which I have been calling territorialisation, seeks to penetrate the Earth and turn it into a planet, a set of purely relational objects. This, he claims, is the danger of images of Earth from space: that they threaten to provide us with the illusion that our world has triumphed over and supplanted the Earth and its ambiguity. In his famous line from an interview with *Der Spiegel*, he reflects on the images sent back to Earth by Lunar Orbiter 1:

> "Everything is functioning. That is exactly what is so uncanny . . . that technology tears men loose from the earth and uproots them . . . I at any rate was frightened when I saw the pictures coming from the moon to the earth. We don't need any atom bomb. The uprooting of man has already taken place. The only thing we have left is purely technological relationships. This is no longer the earth on which man lives"

This uprooting comes from planetary thinking which threatens to reproduce the Copernican move of making the earth one planet amongst many "rather than uniquely our home" (153). This uprooting is the abstraction that is at the core of modernity, which mobilises and makes durable all things so that they can be used to exchange for and make sense of other things.

Heidegger would perhaps be relieved to see the experiences of my informants here, for they are under no illusions that they have conquered the Earth. Rather, the Earth juts through their work, troubling it and the matters that surround it. We find this trouble in the inescapable human trappings that disrupt our futures and our images. The images that they produce have rather had the inverse effect from uprooting: they are marked intractably by the Earth, and tied to our planetary home. Yet he would also perhaps be concerned by the sharp movement in the opposite direction. We might also interpret the overwhelming anxiety of my informants as the victory of the Earth, of what we might perhaps think of as the death of the world as a concept which renders all things knowable and managable.

This condition is, in the sense Eugene Thacker uses it, one of horror. The start of his book, *In the Dust of this Planet*, opens with the telling line that "the world is increasingly unthinkable" (2011: 1). For him, the injunction placed upon us by the desire for objectivity, which I discussed in my setting out of the nature of the *Copernican engine*, is to think the world beyond the human remit of thought that defines territorialisation, of the *world-without-us.* This bind of trying to comprehend the inhuman *as humans* places us in a position that he equates to horror: "Horror is the paradoxical thought of the unthinkable" or, "horror is a non-philosophical attempt to think about the world-without-us philosophically". Notably, he draws upon the works of H. P. Lovecraft, a horror writer whose work on cosmic horror, with motifs of the unknowable, the unthinkable, and the insignificance of humanity is an explicitly modern take on horror, standing as a direct challenge to territorialisation. Externalities, in this sense, are horrific, in that they demarcate the limits of human thought and comprehension, and the Copernican Engine which endlessly drives us towards this precipice is unquestionably an engine for horrors. Heidegger's Earth is, in this sense, horrific, and it is the anxiety of this horror that leads to our homesick quest to stabilise and territorialise the world, and to make ourselves at home in it by making it human. The work of my informants can also therefore be seen as horrific: the impulse towards the edge of the human world is met flatly with the sense that we are both trapped in it, incapable of escaping our earthly moorings, and at the same time incapable the true territorialisation that escape would permit. For Heidegger, the Earth is unthinkable because it is a nebulous abyss of unknowable and ambiguous human activity, while for Thacker, the world-without-us is nonhuman. What causes my informants' anxiety is the confluence of the two: the illogical inhuman that can be found in human systems.

What therefore emerges from astronomy and its worldly contexts is, as I have suggested, a sense in which these two sites of failure are analogously linked by a common territorialising effort, a common modern grounding, a common future, and a common failure. All of these projects seek to manage the social and natural world into a form that can be understood and worked with, and all of them are met with a deep

sense that the proponents of these projects over-promised and under-delivered. What astronomy offers its practitioners, in lieu of a truly cosmic perspective, is a site at which the complex, confusing, and unpleasant experiences of such a world are made comprehensible and legible (are, in a sense, territorialised) through familiar and practical processes. The troubled nature of astronomy raises underlying cosmopolitical issues that can then be abstracted and generalised to make sense of why our other efforts to manage the world fail. Through astronomy, my informants can be seen to engage with and work upon the more general sense that the world as moderns imagine it is ending.

6.3. The End of the World

In this work, I have established astronomy as a cosmogonic effort, which endeavours to overcome a limited and flawed worldview, oriented around our grounded experiences down here (our lifeworld), and in doing so establishes a cosmic perspective that aligns more clearly with the 'true' nature of things, completing Copernicus' revolutionary task. Their concern with sharing and propagating this 'objective' view, evidenced by their emphasis on outreach and accessibility, is a concern with bringing this abstract and distant cosmos into our lifeworld and making it tangible. This effort, as I have described in this section, aligns with a broader effort to domesticate the cosmos by making it knowable and manageable, to make it a place at which we can be at home—in a word, to territorialise it. Astronomers participate in, benefit from, and fantasise about the future of such a process, to the point that it defines their worlding project. Their cosmogonic work is therefore revolutionary and utopian: they seek, in escaping our pre-Copernican conceits both in their practice and in our understandings of the cosmos, to give their world a social reality befitting and in alignment with its natural reality.

In this sense, there is something in what I have described here, articulated in the chronic failure of the image but linked to and contextualised by a broader failure of the modern project, that is distinctly apocalyptic. It describes the failure of an effort—indeed a world—dedicated to bringing a certain kind of world into being, manifested in astronomy and its worldly contexts. To understand what it means to be human in such a

cosmos, I would like to make sense of astronomers as apocalyptic subjects, occupying and working within a wasteland left by the cataclysm described above. To my mind an apocalypse is not necesarily some material devastation of the world, though, in this case, is brought about by that threat, and the way it seems to undermine my informants surity about the future. Rather, drawing on the anthropological understanding of cosmos with which I have been working, apocalypse comes to describe the materiality of failure: when the failure of a social project (a world) is so substantial that its fundamental coordinates, such as how one relates to the world and imagines their future in it, must be radically revised. As I have experienced here, the apocalypse of modernity, as a world overwhelmingly preoccupied with the future, is defined by the various ways in which possible futures are closed down, disavowed, 'lost', and rendered uncertain or impossible.

Apocalypse is not the term astronomers would directly use, at least in reference to their failed images, though they would undoubtedly agree with Harraway's claim that "we live in disturbing times, mixed up times, troubling and turbid times" (2016: 1). Rather, conceptualising their condition as apocalyptic is extrapolated from the status of their project of modernist worlding, and how they have characterised similar hostility. The apocalypse in which they live is the failure of a project, a worlding project that itself constitutes the modern world. Attending to the lost futures my informants agonise over in such a way draws our attention to what is at stake in them: the very consistency of the world and astronomer's sense of agency within it.

Before I do so, I would like to chart exactly what I mean by apocalypse. The concept of apocalypse has left a deep and longstanding mark on many human cultures. The cosmos, being the way in which any given social group makes sense of and engages with their environment, almost always comes with some sort of imagined end. The term apocalypse has its origins in religious language, specifically from Christian mythology, derived from the Greek *apokalypsis*, meaning revelation or uncovering (Himmelfarb 2010). Its eschatological connotations emerge from the book of Revelation in which the return of the son of God, the "*apokalypsis* of Jesus Christ," ends the world

and establishes the Kingdom of God on Earth. From this concept, numerous millenarian cults have emerged, which draw their name from their anticipation of the end of the world and the thousand-year reign of Jesus that follows (or sometimes precedes) it (Court 2008: 3). From this, the concept of apocalypse has been secularised and used to describe the end of the world in multiple forms of media and from multiple causes. In this usage, it refers more directly to the end of human dominion over the Earth, the end of the Anthropocene, the fall of civilisation, and the return to a *state of nature* in which life is nasty, brutish, and short. Part of the reason for my use of the term, however, is this religious origin. In its modern, secular formulation, it represents the failure of progress, a dark inversion of utopia in which all social orders we have painstakingly built collapse. The return of pre-Copernican religiosity in an age that had supposedly moved past such human conceits is a gesture which typifies the particularly modern apocalypse, with the re-emergence of that anti-modern concept of myth (Adorno & Horkheimer 1997: 8).

I use the term apocalypse relatively loosely here, to refer to the end of the world, with that operative term ‘world’ used in the anthropological sense with which we have been working. It is when a particular social order of things and beings becomes untenable. It is, in this sense, a social phenomenon, less necessarily material than it appears in Christian mythology or modern media, and more of a condition, mood, and, as a failure, a call to action. It is defined by a sense of loss of such a social order or structure. Notably, I am not alone in this description, and the apocalypse concept has become a point of significant interest for social theorists looking to make sense of the particular condition of would-be-moderns living now (e.g. Haraway 2016; Fisher 2009; Tsing 2015). In making sense of the mood of astronomer-moderns as an apocalyptic condition, I seek to participate in this movement by describing its experience on the ground.

In this sense, if we were capable of stripping the term of its Christian baggage, such a phenomenon can be identified in many different cosmologies, from the precarity that Inga Clendinnen describes as defining Aztec cosmology (2014), to Yanomami

conceptualisations of the ecological devastation of the Amazon rainforest as the “time of the falling sky” (Kopenawa & Albert 2013), and the claim of one indigenous Ohkay Owingeh Pueblo-descended science fiction writer that “we’ve already survived an apocalypse” (Alter 2020: 3). As Rosalyn Bold suggests in her discussion of indigenous apocalypse, an apocalyptic mood is the product of a set of stories that we tell ourselves that make sense of the bleak trends we see around us. “Despite the darkness of the context we inhabit, the “end of the world” is something we are led into by narratives we tell ourselves” (2019: 3)

When Simon claims that Mars is a place where “the apocalypse has already happened”, I claim that he invokes a particularly modern understanding of apocalypse. In particular, he references the geological history of Mars, as a planet which was once host to oceans, rivers, and the promise of life, curtailed by the cooling of its core, the dissipation of its magnetosphere, and the evaporation of its atmosphere. This reference draws most clearly on the more recent permeation of apocalyptic rhetoric into discussions of the climate crisis: the way in which ecological devastation threatens the human habitability of the Earth. This is one of the very literal apocalypses that Kevin actively fears, that, in part, informs his desire for humans to become a multiplanetary species. While ecological harm is rendered as morally negative in itself, it is clear that, for Kevin and Simon, its apocalyptic aspect arises from the destruction of the human world—the systems that we have built, the territories we have claimed, the futures we have imagined. Mars is apocalyptic because it is hostile to human life and no longer fit for human colonisation. Such colonisation, a territorialisation not unlike the production of the perfect image, would be the articulation and affirmation of the modernist dream of making the world hospitable and appropriate for human projects. The apocalyptic condition, I claim, emerges as the inversion of this project: when such territorialisation becomes futile or undesirable. If the modern world is a world in the process of being conceptualised in modern terms and appropriated for human ends, then the apocalypse of modernity, which I have described here, is an inhuman world that resists such conceptualisation and appropriation, the inhuman and insurmountable world-without-us. It is being faced with agencies and forces, sometimes of our own creation, that cannot

(or should not) be domesticated or mastered. In this sense, the apocalypse stands for the end of the supposed human dominion over the Earth. This modern apocalypse echoes the death of the human world articulated in Christian and modern myths. The apocalypse of modernity is the recognition of the essential and persistent horror of a world defined by the Copernican Engine, the death of the possibility of a world that can ever truly be territorialised.

What I have endeavoured to describe here is how the limits of the human world, manifested most clearly in the blasted wasteland of Mars, are found by astronomers and would-be-moderns down here on Earth. While astronomers, as I note, would not use the term 'apocalyptic' to describe their condition, I claim that their preoccupation with lost futures—the fact that they are so clearly haunted by the outer space as either a precarious utopia or a lost ideal—indicates that something many astronomers value in their work has been undermined. Astronomy no longer offers clear signification to spacebound fixes and utopias. Through their work, such dreams are troubled, proposed solutions recede or are proven to have never been solutions at all, and my informants are left with a sense that "it's all a bit fucked, isn't it?"

This sense of the apocalypse has already been described broadly by several theorists, most notably Anna Tsing (2015), Donna Haraway (2016), and Isabelle Stengers (2015), to name a few. These theorists speak to an apocalyptic collapse of the stability that has defined, knowledge, agency, and consensus, that forces us to confront a world that is radically alien to us. Often, they seek out naturalistic analogies through which they can think of the world in a less human way. In *In Catastrophic Times*, Stengers identifies the 2008 financial crisis and ecological devastation as two examples of how we are "going, as one says, straight to the wall" (2015: 19), and identifies "ordinary victims" that are "sacrificed on the altar of growth to the service of which our lives are dedicated" (21). In *Staying with the Trouble,* Donna Haraway sets out a manifesto for dealing with our "troubled" and "disturbing" times, and to do so she seeks to displace and supplant concepts of the Anthropocene and the capitalocene with the *chthulucene*, which challenges "the dictates of both Anthropos and capital" and in doing

so implores us to make “kin with oddkin” (2016: 2). Similarly, in *The Mushroom at the End of the World*, Anna Tsing likewise makes reference to a precarious worldly position not unlike that described by my informants, that we collectively “confront the condition of trouble without end” (2015: 2). She claims that “I find myself without the handrails of stories that tell where everyone is going and, also, why.” Like the ptolemizations of the past, modernity has offered humans a comforting story of progress and territorialisation that defers the Copernican Engine while appearing to function within its remit. Also like Haraway, she seeks to offer a way out, and uses the matsutake mushroom, which grows exclusively in places that have been disturbed and abandoned, as an analogy for thinking through “the imaginative challenge of living without those handrails” (*Ibid*.). These escape hatches offered by Tsing, Harraway and Stengers are directed towards evading a more literal apocalypse by reorienting the cosmopolitical relationship between humans and the world, but align clearly with Dave’s effective call for the end of modernity. We cannot go on in the world as we have up until now, either here or in space. The way in which moderns projected themselves into the future is untenable. The heritage of a future humanity cannot be a long trail of polluted and devastated worlds through the stars. Those futures must be killed before they kill us and the worlds we inhabit.

6.3.2. What’s Left: Apocalypse Ethics

Failure is always generative. This is the mantra of the aforementioned work by Carrol, Parkhurst and Jeevendrampillai (2017). Failure always asks questions, for which we must reconstitute our world, to either obscure or to answer it, and sometimes both. This is the insight that was internalised by modernity: that failure need not be the devastation of the world, as it would be if science were more rigid and dogmatic, but can rather be the opportunity for iteration and development towards perfection. A cosmos of endless revolutions is, in theory, a cosmos of small apocalypses, as one world gives way to another. In my rendering of apocalypse not as some material annihilation but as the point at which a social project (a world) becomes untennable and must be reoriented, such If we reconstitute the dynamic of failure I discussed earlier, derived from the

theorists above, in terms of the revolution, we can render it in a cosmological context as the following form.

$$Cosmos \rightarrow Apocalypse \rightarrow Cosmogenesis$$

These apocalypses, however, have rarely been on the scale of what I describe here. Or perhaps what I describe here seems more cataclysmic because they take place in 'our' times. The small apocalypses that constitute what Sagan calls "great demotions" (1997), from the 17th century move towards probabilistic knowledge (Shapin & Shaffer 1985: 24) to the Pale Blue Dot, are structured, stabilised and made durable by the progression they afford and the more perfect territorialisation they constitute. What I describe here, I believe, is perhaps not necessarily a new phenomenon (after all, it is simply the organic emergence of a postmodern condition) but is nonetheless more significant. It is the destruction, or perhaps the deconstruction of these methods of stabilisation. The Copernican engine, as an engine of horrors that demands further and further great demotions, is a system that leads us inevitably to the apocalypse of human knowledge and agency. This leads us to an incommensurable space: a stasis that emerges not only from material failure but also the failure of the effort to imagine a resolution to that failure. We are trapped, it seems, in a state where we have destroyed the world, but feel incapable of constituting a more perfect iteration—the limbo between cosmos and cosmogenesis that I refer to as 'apocalypse'.

This is why it is not the failure of the image that immediately caught my attention when researching this work. The failure of the image is a necessary step in the learning process, an essential part of progress. What interested me, so far as it became the central focus of this project, is the impossibility of the perfect image, the asymptotic way in which humans approach the objective world, and its pursuit by astronomers who are fully aware of their work's futility. What emerged was a context of broken optimism about how far the same fundamental process of knowledge production and mastery—of territorialisation—can be applied to the world: that the two overriding modern injunctions that define Western scientific modernity, one which seeks to empower the human world

and appropriate the natural one into our regimes of knowledge, and another which seeks access to the world in itself by way of the world-without-us, purged of the epistemological pollution of the human, cannot coexist. The latter is the only legitimate means by which the former can be achieved, but they are locked in a tension that undermines this symbiosis: human utility and interpretation always intrude upon the world, and undermines any hopes of getting at the one definitive world that modernity craves.

The Copernican revolution—a heritage that astronomers actively work to uphold and reinstate—can never shake the old that it must disavow, neither in the images nor in the utopias they seek to produce. The operationalisations of what we have discovered about the world as a result of it have been great technical achievements, but also stand as "ptolemizations" that complicate the system that is to be overthrown and put off the natural conclusions of the revolution: that we are not only not the centre of the cosmos, we are not even, as Carl Sagan famously quipped, "a way for the cosmos to know itself" (*Cosmos: a Personal Voyage Episode 1: On the Shores of a Cosmic Ocean* 1980); we are locked out of that knowledge, and the mastery it affords.

It is perhaps valuable here to put the destruction of worlds in the same terms that I used to describe their construction in the opening of this discussion. When I discussed the anthropological concept of worlds, I, following Jaques Lacan, characterised the cosmos as the sinews of experience, in which the subject serves as the nexus for the phenomena which signify a symbolic network or order of things. This symbolic order "guarantees the consistency" of the subject's experiences insofar as it can be a coherent world (Zizek 1999: 266). The objective of psychoanalytic treatment, as reported by Zizek, is the destruction of this symbolic world, to disclose the contradictions upon which this consistency rests. In psychoanalysis, this condition of suspending the symbolic regime is referred to as "subjective destitution" (*ibid.*). The apocalypse I describe here is a symbolic destitution: the disintegration of the order of things within modernity which guarantees the meaningfulness of action within it.

This is not, however, necessarily some cataclysmic end. I do not doubt that moderns have weathered such storms before, and rallied our faculties and our hopes for the future. Indeed, neither do many of my informants. Dave, the astronomer who told me that colonising Mars was a “horrible idea” also noted that he does not doubt that it will happen. If anything, this is a deeper cause for concern: for him, it seems that the march of humanity towards the stars is an inevitable and unstoppable evil.

Further than this, I do not doubt the ongoing human capacity to reconstitute worlds: that this is but a momentary setback in our endless deterritorialisations and reterritorialisations, and this optimism for the ongoing generative nature of the apocalypse emerges forcefully in the work of Jaques Derrida. For Derrida, the world becomes far more isolated and solipsistic than that of Heidegger. Every being, for Derrida, occupies their own radically isolated world, which can never truly come into contact with or be compared to the worlds of others. We simply lack the experiential grounds to understand how another truly comprehends the world (Oliver 2015: 179). We can build symbolic bridges—what Derrida calls “stabilising apparatuses” or “prostheses” (*Ibid,* 180)—that make worlds in some ways commensurable with our own: “The realm of the symbolic transcends every individual” (*Ibid*. 180). Worlds are also, however, deeply interdependent. They are associated with traditions, conventions and languages. Derrida also discusses the end of the world. He claims that the world is destroyed with every death and the world as a way of life and beliefs is at stake in every war. As Oliver recites, “All war, then, is ideological, in that the combatants are not just vying for territory or a certain part of the Earth but also for their way of life and beliefs, which is to say their world.” (189).

Derrida recognises also that this destruction of the world is productive: that it affords a particular ethical work to take place. In his discussion of the end of the world, he refers constantly to a fragment from the poem *Vast Glowing Vault* by Paul Celan: “*Die Welt ist fort, ich muß dich tragen*” (the world is far away, I must carry you) (Oliver 2015: 172). Derrida reads this distant world as the end of the world, and the fact that Celan claims that he must carry the other is an insistence that responsibility to the other

persists once the world is gone (194). He reads this as a particular possibility that is opened up by the death of the world, the possibility for ethics. Oliver raises the issue of Eichmann, the Nazi whose morality began and ended with the orders he was given. As she notes, “To be without world is to step into the void where ethical decisions cannot be made based on accepted rules and conventions” (195). Eichmann’s appeal to authority cannot stand in the wasteland, where such authorities are vacated. Ethics, particularly, describes a flexibility that resists the overbearing singularity of world that Heidegger decries. “Unlike morality that is decided once and for all—what is right is right for all time—ethics requires us to dwell in the undecidable space of the impossibility of knowing what is right and yet being obligated to do it nonetheless,” (198). Stripped of the conventions and the traditions of the world, the apocalyptic subject stands face-to-face with the other, and must face the responsibility they have for them.

It is, for Derrida, the threat of the end of the world, our imagined apocalypse, that causes us to do ethical work, to produce new relations and understandings of one another. The apocalyptic subjects that must live through these times are wracked with the anxiety of a world that has been snatched from their grasp and that they can never truly claim back. The perfection of the image is impossible, yet, as with all ascetics, “virtue resides in the effort” (Harpham 1987: 5). From what I have seen in my time with astronomers is that this virtue is the ethical work that can be done at the end of the world, considering what the human is together. I asked David, after all his pessimism about the colonisation of space, its inevitable troubles, and his sense of powerlessness to do anything about it, what he can even do in such a state of affairs. With all the defeatism of someone resigned to their presentism, he looked around and said “this,” referring to the people milling around the hub, peering through telescopes, chatting about the cosmos, and catching up over hot chocolates. “People at NASA and ESA are going to do what they do. They’re too big for us to do anything about. This is real though. This is what’s important to me.” For him, the modern world is big and cumbersome and unassailable. No one person could ever derail the trajectory of humanity, for better or worse. It is almost as if it, ironically, is out of human hands, predetermined by some gestalt amalgam of human hopes and fears. All that David can

do is be part of a community with whom he can witness the end of modernity. What is produced here seems to be a reorientation of perspective: with the far future and the expansive greatness of other worlds trapped behind opaque structures, his attention turns to here, now, and facing those with whom he shares these lost futures.

This reorientation is a process: a move away from the grand and sweeping images of the future and the 'globe talk' with which astronomy and modernity are often associated. What has emerged from the divisive topic of human futures and what they should look like is an ongoing destabilization of where human focus should lie: amongst the stars, as Kevin urges, or here, on the ground, producing communities down here on Earth. Do we resolve these problems, or are they our reason for going? The apocalyptic conditions under which my informants live entreat them either to imagine alternative ways of relating to the world, or redouble our efforts to complete our mastery, at any cost.

I have only the means here to gesture vaguely towards this work of reconfiguring the relationship between humans, the world, and each other. I have made an effort to lay out the process, its context, practical grounding, and the attitudes about it, but I cannot say where it will lead. I lack this means because my informants also lack this capacity: they anticipate environmental doom or tarnished utopias in space, but they see few pragmatic ways out of this bind. Such is the nature of the apocalypse in which they live, tied up with seemingly intractible cosmopolitics. It seems to be a mood that strips them of any optimistic vision for the future. Rather, what I do observe is them learning to make do without a clear future, and live back down on the ground. In the absence of an abstracting and territorializing cosmic perspective, the local, the parochial, and the Earthly cycles back into view, enchanted with a new value for those who once longed to think and see on a cosmic scale.

7. Conclusion

This dissertation has been an effort to bring the scientific cosmos down to Earth. For many scientific natives, the scientific cosmos exists 'out there,' beyond the earth's atmosphere, in a state of pristine and objective nature. In reality, the scientific world permeates the earth and its inhabitants, describing the fundamental conditions of their lives and actions, and is rooted deeply in a set of technological, social and historical engagements. Understanding these social conditions for the possibility of scientific cosmology falls firmly within the field of anthropology, and it is here, in the practices of those who seek to access the cosmos, that I ground my anthropological exploration of this cosmos. Amateur astronomers in London offer a particular positionality to this exploration: not only are their practices fundamentally cosmological, but their amateurism and the location of their work places them between the mundane world of the city and modern life and the abstract and transcendental world of the cosmos.

I discovered in this fieldwork that the distinction between these two worlds is fundamental to how my informants understood their own work. They find themselves, by virtue of the modern urban environment they live in, the structure of their lives it demands, and the ecologies it produces, cut off from the scientific cosmos, and self-consciously work to re-establish contact with it. In chapter 2. Cosmos, I substantiated this distinction within the "dual cosmos" of modernity (Abramson & Holbraad 2014: 11) in historical, epistemological, and cosmopolitical terms, and established the grounds for making sense of astronomy as a practice which seeks to do this infrastructural work through escaping, erasing, and revolting against the human, mundane world. Here, I identify this anti-human, ascetic impulse with a "noninterventionist" form of objectivism (Daston & Galison 1992), describing in historical terms as a "Copernican Engine" that strains to break out of the provincial context of the Earth and reach the stars. The task astronomers set themselves, when contextualised in such a way, is to participate in the Copernican task of bringing our lifeworld into alignment with the objective, natural cosmos of science by bringing the latter down to Earth.

This infrastructural work of access and mediation can be seen materially in the way in which astronomers manage flows of photons into a form that renders the cosmos visible. Just as the road in Penny Harvey and Hannah Knox's analysis of Ocongate, Peru, allows them to speak about how the abstract and distant institutions of the state are manifested and engaged with materially and on the ground, so too do these infrastructural practices allow me to locate the precise places, times, and techniques in which the scientific world is manifested and materialised, and the human world is correlatively erased. In chapters 3-5, I charted how astronomers go about establishing these infrastructures: the places, practices, and images that are navigated, manipulated, and ultimately effaced so that access to the cosmos can be attained.

It is also here, where abstract theory meets the hard materiality of the world. Following Hoeppe (2019), I argue that the function of such infrastructures is to render themselves invisible and transparent, to plausibly afford direct views of the thing being accessed. Objective mediation requires these objects to appear as unmediated, rendered outside of human intervention. It is here, in the practices of astronomers, that the inevitable failure of their work manifests itself. In chapter 3. Places, I explored how the navigation of the urban landscape is directed towards but never truly achieves its effacement. In 4. Practices, I substantiated how the body is deployed and incorporated into the functioning of these infrastructures in a way designed to align it with the cosmos and therefore make that too disappear, only to be troubled by its endless intrusion. In 5. Images, I discussed how the image as a medium sits in a troubled and ambivalent position within scientific traditions, and how the work of making the cosmos visible—of making these infrastructures function—requires further synthetic interventions on the part of astronomers. In all of these places, the revolution against earthly and mundane grounds for knowledge in pursuit of a cosmic perspective is always curtailed, as all revolutions are, by the fact that this project must be undertaken from within that world, by its inhabitants, and are therefore marked by the artefacts of the local. In other words, the infrastructures of astronomers fail materially here because they re-emerge and disrupt the illusion of pristine mediation.

Following the model of failure proposed by Carroll, Parkhurst and Jeevendrampillai in *The Material Culture of Failure*, this dissertation is not only directed at charting the material failure of these infrastructures of light, but also the *materiality* of that failure: how it is made sense of and used to constitute understandings of the world. By placing astronomy and science more broadly within a historical context in 6. Apocalypse, I highlighted the particular cosmopolitical dimensions of the modern project, which sought to produce systems of knowledge that could enframe the natural world, and thereby afford humans the agency to work within it. By rendering the content of the cosmos known and legible through objective practices of visualisation, modernity and the anthropocenic conceit works to domesticate and manage the natural world. Contextualised by a world in which these projects of management have been found lacking, the material failure of the astronomical image can be understood as one amongst many manifestations of the failure of the cosmogonic modern project. Here, by framing this cosmic failure as an apocalypse, I charted some of the dimensions of the affective repercussions of this cataclysmic event in the pessimistic mood and temporal realignment of would-be moderns. The ambivalent attitudes of astronomers towards the future and the moral status of humans in the world have, as I have described, developed into a static and incommensurable condition of either inevitable and morally bankrupt colonial expansion we have no power to avert, or bureaucratic paralysis. Here, no one gets their promised futures, and outer space remains a tragic site of lost utopias, and the hopes astronomers had for their images remain as relics of these futures, their failure a symptom of a world which no longer functions.

This project has therefore been, as I have suggested, about the Copernican Engine as a system in retrograde. The Copernican Engine is a paradoxical system that sets the moral standards for knowledge in the erasure of the human, and directs that knowledge towards the affirmation of human agency in the cosmos. This paradox emerges in the strained and ambivalent relationships astronomers have with the cosmos and that very agency within it: in the reconsideration of whether objective knowledge and the practices of management predicated upon it, be it the management

of light, economies, ecologies, or futures, are even plausible. It causes some to reconsider the moral grounds for our projects in outer space, and, as demonstrated in the concern for the pristine landscapes of Mars, expand their judgement of what is 'good' beyond what serves humans. Here, the tense contradictions of the Copernican engine Undermine its very purpose, and lead to the sense of uncertainty, incommensurability, and pessimism described above.

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In closing, we might therefore return to and answer the central questions with which I opened this work. Why, then, is the perfect image impossible? Because it is an image of Otherness, and as such is trapped in this paradox of attempting to treat hospitably with the Other. My informants find themselves between, on the one hand, the absolute hospitality of the cosmic perspective and the Copernican Engine, and on the other, the conditional hospitality of territorialisation and making ourselves at home. The cosmic image seeks to escape the conditionality of knowledge, of hospitality, but can only momentarily efface it in a way that is made manifestly illusionary by the imperfections in their images. Where, then, does this leave the status and stature of the human in the technoscientific cosmos? It leaves us as an Other, a stranger in the strange land of the universe, intractably cut off from fulfilling the conditions of being at home in it, and from comprehending its being-in-itself in the terms set by modernity. In the broader scheme of things that I have set out here, this seems just another turn of the Copernican Engine, yet another in a long list of great demotions that once again shatters not only the world, but any possibility of constructing a world for ourselves within the cosmos. I do not doubt that this will stop anyone from attempting to find a home in the future, and to produce further re-enchantment cosmologies (Farman 2012).

As I have noted, I do not have the means here to speculate fully about what might emerge from this total failure of the world. Perhaps it will be an understanding of

the human, informed by the ceaseless turning of the Copernican Engine, that has more clearly internalised its diminutive stature in the cosmos, that is more abiding of intractable Otherness, more capable of "making kin with oddkin" to use a phrase from Haraway (2016: 2), in spite of the anxiety that comes with it. Perhaps what I report here is a momentary lapse of confidence, rapidly resolved or, more likely, obscured in a continued and endless march into the cosmos. Predicting the future is a capacity of moderns that I do not possess, and neither do my informants. Such is the very nature of the apocalypse we both find ourselves in. All that I can presently do here is describe the beginnings and conditions of this process here and now, as it is played out in small gatherings in the dark recesses of London, as astronomers contemplate themselves and the stars.

Bibliography

Abbott, E. A. 1884. *Flatland: A Romance in Many Dimensions.* Seeley & Co., London

ABC 1999. *That Photograph.* [Available at: http://www.abc.net.au/science/moon/earthrise.htm] [Accessed on: 02/03/2021]

Abrams, N. E. Primack, J. R. 2011. *The New Universe and the Human Future: How Shared Cosmology Could Transform the World*. Yale University Press, London

Abramson, A. & Holbraad, M. 2014. *Framing Cosmologies: The Anthropology of Worlds*. Manchester

- 2012. *Contemporary Cosmologies, Critical Reimaginings*. In *Religion and Society: Advances in Research*. 3: 35-50.

Adorno, T. Horkheimer, M. 1997. *The Dialectic of Enlightenment*. Verso, London.

Akkerman, A. 2009. *Urban Void and the Deconstruction of Neo-Platonic City-Form.* In *Ethics Place and Environment*. 12(2):, 205-218

Allain, R. 2013. *Spectrum of Visibility: An Exploration of Astronomical Techniques of Visualization.* Unpublished paper, UCL

Alter, A. 2020. *'We've Already Survived an Apocalypse': Indigenous Writers Are Changing Sci-Fi*. New York Times, New York, NY

Arcand, K. K. Jubett, A. Watzke, M. Price, S. Williamson, K. T. S. Edmonds, P. 2019. *Touching the Stars: Improving Nasa 3D Printed Data sets with Blind and Visually Impaired Audiences*. In *Journal of Science Communication* 18(4): 1-22

Artus, D. Forthcoming. *Stuck on Needles: an Ethnographic Enquiry into Information, Immunity and Vaccines in Dublin, Ireland*. Unpublished Thesis, UCL

Assembly of First Nations 2018 *Dismantling the Doctrine of Discovery*. Assembly of First Nations, Ottawa

Aveni, A. 2010. *People and the Sky: Our Ancestors and the Cosmos.* Thames & Hudson, London University Press, Manchester.

Bakhtin, M. 1984. *Rabelias and His World*. Indiana University Press, Bloomington

Barad, K. 2007. *Meeting The Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Duke University Press, London

Barthes, R. 1972. *Mythologies*. Noonday Press, New York, NY

- 2000. *Camera Lucida: Reflections on Photography*. Vintage, London

Beck, U. 1992. *Risk Society: Towards a New Modernity.* Sage Publications, London.

Belting, H. 2001. *The Invisible Masterpiece*. Reakton Books, London

Ben Bush 2021. *Ben, Floyd and the Core* Available at: https://benbush.photos/product/ben-floyd-and-the-core/ Accessed on: 03/02/2023

Benjamin, W. 1969. *The Work of Art in the Age of Mechanical Reproduction.* Schocken Books, New York.

Berman, M. 2010. *All That Is Solid Melts Into Air: The Experience of Modernity*. Verso, London

BSIA 2023[a]. *Society Aims*. Available at: [https://www.bakerstreetastro.org/about-us/society-aims/] Accessed on: [05/01/2023]

BSIA 2023[b]. *About Us.* Available at: [https://www.bakerstreetastro.org/about-us/] Accessed on: [05/01/2023]

Blumenberg, H. 1987. *The Genesis of the Copernican World*. MIT Press, Cambridge, MA.

Bold, R. 2019. *Creating a Cosmopolitics of Climate Change*. In Bold, R. (Ed.) *Indigenous Perceptions of the End of the World: Creating a Cosmopolitics of Change*. Springer, London

Bourdieu, P. 1977. *An Outline of a Theory of Practice.* Cambridge University Press, Cambridge.

Buchli, V. 2007. *Astana: Materiality and the City* In *Urban Life in Post-soviet Asia* UCL Press, London.

- 2014. *The Contemporary past, Translation and Mercy* In *Architecture, Photography and the Contemporary Past.* Art and Theory Publishing, Stockholm

- 2016. *An Archaeology of the Immaterial.* Routledge, London

Burkitt, I. 1999. *Bodies of Thought: Embodiment, Identity and Modernity*. Sage, London.

Carroll, T. 2017. *Axis of Incoherence: Engagement and Failure between Two Material Regimes of Christianity*. In Carroll, T, Jeevendrampillai, D. Parkhurst, A. Shackelford, J. (Eds.) *The Material Culture of Failure: When Things Do Wrong* Bloomsbury, London.

- 2018. *Orthodox Christian Material Culture: Of People and Things in the Making of Heaven.* Routledge, London

Carroll

Carroll, T. Jeevendrampillai, D. Parkhurst, A. 2017 *Introduction: Towards a General Theory of Failure*. In Carroll, T, Jeevendrampillai, D. Parkhurst, A. Shackelford, J. (Eds.) *The Material Culture of Failure: When Things Do Wrong* Bloomsbury, London.

Celestron, 2018. *What is a Diffraction Spike?* Available at: https://www.celestron.com/blogs/knowledgebase/what-is-a-diffraction-spike Accessed on: 03/02/2023

Chakrabarty, D. 2000. *Provincializing Europe: Postcolonial thought and Historical Difference.* Princeton University Press, Oxford.

Chapman, A. 1998. *The Victorian Amateur Astronomer: Independent Astronomical Research in Britain 1820-1920*. Wiley, Hoboken, NJ.

Cherstich, I. Holbraad, M. Tassi, N. 2020. *Anthropologies of Revolution: Forging Time, People, and Worlds.* University of California Press, Oakland, CA

Chien, P. 2003. *Have You Ever been Flashed By Iridium?* Sky & Telescope, available at: [https://skyandtelescope.org/observing/celestial-objects-to-watch/have-you-been-flashed-by-iridium/] Accessed on: [26/02/2024]

Clendinnen, I. 2014. *Aztecs: An Interpretation*. Cambridge University Press, Cambridge.

Cohen, A. & Cox, B. 2014. *Human Universe.* William Collins, London.

Corpuz, J. C. G. 2021. *Adapting to the Culture of 'New Normal': an Emerging Response to COVID-19*. In *Journal of Public Health* 43: 2 344-345

Corton, C. L. 2015. *London Fog: A Biography*. Harvard University Press, Cambridge, MA.

Cosgrove, D. 2001. *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination.* Johns Hopkins University Press, Baltimore

Cosmos: a Personal Voyage Episode 1: On the Shores of a Cosmic Ocean 1980. PBS

Court, J. M. 2008. *Approaching the Apocalypse: a Short History of Christian Millenarianism* I. B. Tauris, London

Crary, J. 1992. *Techniques of the Observer: On Vision and Modernity in the Nineteenth Century* MIT Press, Cambridge, MA.

Crease, R. P. 2019. *The Workshop and the World: What Ten Thinkers can Teach us about Science and Authority.* W.W. Norton & Company, New York, NY.

Czerski, H. 2016. *Storm in a Teacup: The Physics of Everyday Life.* Penguin, London

Dartnell, L. 2022. *How Big a Problem are Starlink Satellites for Astronomers?* In *Sky at Night Magazine* Available at: https://www.skyatnightmagazine.com/space-science/spacex-starlink-problem-astronomy/ Accessed on: 13/12/2022

Daston, L. Galison, P. 1992. *The Image of Objectivity*. In *Representations* 40: pp. 81-128

De Boeck, F. 2015. *"Poverty" and the Politics of Syncopation: Urban Examples from Kinshasa (DR Congo).* In *Current Anthropology* 56(11): 146-158

Deleuze, G. 1994. *Difference and Repetition.* Columbia University Press, New York.

Deleuze, G. Guattari, F. 1987. *A Thousand Plateaus: Capitalism and Schizophrenia*. University of Minnesota Press, Minneapolis, MN

Della Dora, V. 2011. *Anti-landscapes: caves and apophasis in the Christian East*. In *Environment and Planning D: Society and Space* 29: 761/779

Derrida, J. 1973. *Speech and Phenomena: and Other Essays on Husserl's Theory of Signs.* Northwestern University Press, Evanston.

Douglas, M. 1966. *Purity and Danger: An Analysis of the Concept of Pollution and Taboo*. Routledge, London.

- 1973. *Natural Symbols: Explorations in Cosmology*. Barrie & Jenkins, London

- 2010. *The Lele of the Kasai*. Routledge, London

Drees, W. 1996. *Religion, Science and Naturalism*. Cambridge University Press, Cambridge.

Dufourmantelle, A. Derrida, J. 2000. *Of Hospitality*. Stanford University Press, Stanford, CA

Dunnett, O. 2015 *Contested Landscapes: The Moral Geographies of Light Pollution in Britain*. in *Cultural Geographies* 22(4):619-636

Durkheim, E. 1982. *The Rules of Sociological Method.* The Free Press, London.

- 2001. *The Elementary Forms of Religious Life*. Oxford University Press, Oxford.

Durkheim, E. Mauss, M. 2009. *Primitive Classification* Routledge, London.

Edensor, T. 2017. *From Light To Dark: Daylight, Illumination and Gloom.* University of Minnesota Press, London.

Eliade, M. 1952. *Images and Symbols: Studies in Religious Symbolism.* Sheed & Ward, New York.

- 1957. *The Sacred and the Profane: The Nature of Religion* Harcourt, Brace & World

Evans, B. 2020. *The Great Debate of Shapley and Curtis — 100 years Later* In *Astronomy* [Available at: https://astronomy.com/news/2020/04/the-great-debate-of-shapley-and-curtis--100-years-later] [accessed on: 01/06/2021]

Evans-Pritchard, E. E. 1951. *Social Anthropology*. Cohen and West, London.

- 1940. *The Neur: A Description of the Modes of Livelihood and Political Institutions of a Neolithic People* Clarendon Press, Oxford.

Fabian, J. 1983. *Time and the Other: How Anthropology makes its Object.* Columbia University Press, New York, NY.

Farman, A. 2012. *Re-Enchantment Cosmologies: Mastery and Obsolescence in an Intelligent Universe*. In *Anthropological Quarterly*, 85(4): 1069-1088.

Farnell, B. 2000. *Getting out of the Habitus: An alternative model of Dynamically Embodied Social Action.* In *The Journal of the Royal Anthropological Institute* 6(3): 397-418

Fisher, M. 2009. *Capitalist Realism: Is there No Alternative?* Zero Books, Ropley.

- 2014. *Ghosts of My Life: Writings on Depression, Hauntology, and Lost Futures*. Zero Books, Ropley

Fishman, R. 1982. *Urban Utopias in the Twentieth Century: Ebenezer Howard, Frank Lloyd Wright and Le Corbusier.* MIT Press, Cambridge, MA.

Focht, M. 2023. *4 Experts Explain why Elon Musk's plan to Colonize Mars is 'Romanticized', not 'realistic', 'Cosmic Vandalism'.* Business Insider. Available at: [https://www.businessinsider.com/elon-musk-plan-colonize-mars-plan-unrealistic-scientists-explain-2023-10] accessed on: [24/02/2024]

Foucault, M. 2001. *The Order Of Things: An Archaeology of the Human Sciences.* Routledge, London.

Fox, C. 1995. *Inventing Human Science: Eighteenth-Century Domains.* University of California Press, London.

Franklin-Wallis, O. 2019. *'Plastic recycling is a Myth': What Really Happens to Your Rubbish?* [Available online: https://www.theguardian.com/environment/2019/aug/17/plastic-recycling-myth-what-really-happens-your-rubbish, Accessed on: 15/12/2022]

Fukuyama, F. 2012. *The End of History and the Last Man.* Penguin Books, London.

Galison, P. 2002. *Images Scatter into Data, Data Gather into Images*. In *Iconoclash: Beyond the Image Wars in Science*. MIT Press, Cambridge MA.

Gandy, M. 2017A. *Urban Atmospheres* In *Cultural Geographies* 24(3): 353-374

- 2017B. *Negative Luminescence*. In *Annals of the American Association of Geographers*. 107(5): 1090-1107

Ganti, T. 2014. *Neoliberalism*. In *Annual Review of Anthropology* 43 89-104

Geertz, C. 1983. *Local Knowledge: Further Essays in Interpretive Anthropology*. Fontana press, London.

Gell, A. 1998. *Art and Agency: An Anthropological Theory.* Clarendon Press, Oxford

Gibney, E. 2020. *How One Astronomer Hears the Universe: Wanda Diaz Merced is a blind astronomer who says that converting astronomical data into sound could bring discoveries that conventional techniques miss.* In *Nature* 577:156

Giddens, A. 1991. *Modernity and Self-Identity: Self and Society in the Late Modern Age* Polity Press, Cambridge.

Gluckman, M. 2004. *Order and Rebellion in Tribal Africa.* Routledge, London

Godfrey-Smith, P. 2003. *Theory and Reality: An Introduction to the Philosophy of Science*. University of Chicago Press, Chicago.

Gould, S. J. 2010. *Rocks of Ages: Science and Religion in the Fullness of Life*. Ballantine Books, New York, NY

Graber, D. 2019. *Bullsh*t Jobs: The Rise of Pointless Work and What We can Do About it.* Penguin Books, London

Graham-Smith, F. 2016. *Eyes on the Sky: A Spectrum of Telescopes*. Oxford University Press, Oxford

Gribbin, J. & Gribbin, M. 2000 *Stardust: The Cosmic Recycling of Stars, Planets and People.* Penguin Books, London

Gribbin, J. 2006. *The Universe: A Biography.* Penguin Books, London.

Grissom, T. 2011. *The Physicist's World: The Story of Motion and the Limits of Knowledge*. Johns Hopkins University Press, Baltimore.

Groys, B. 1992. *The Total Art of Stalinism: Avant Garde, Aesthetic Dictatorship and Beyond.* Princeton University Press, Princeton, NJ.

Guyer, J. 2007. *Prophecy and the near future: Thoughts on macroeconomic, evangelical, and punctuated time*. In *American Ethnologist* 34:3 409-21

Hacking, I. 1989. *Extragalactic Reality: The Case of Gravitational Lensing* In *Philosophy of Science* 56(4): 555-581

Hamacher, D. W. de Napoli, K. Mott, B. 2020. *Whitening the Sky: Light Pollution as a Form of Cultural Genocide* In *Journal of Dark Sky Studies* 1

Handelman, D. 2008. *Returning to cosmology - Thoughts on Positioning Belief.* In *Social Analysis* 52(1):181-195

Haraway, D. 1988. *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective*. In *Feminist Studies* 14(3): pp. 575-599

- 2016[a]. *A Cyborg Manifesto*. In *Manifestly Haraway* University of Minnesota Press, Minneapolis

- 2016[b]. *Staying With the Trouble: Making Kin in the Chtulucene*. Duke University Press. London.

Harman, G. 2011. *On the Undermining of Objects: Grant, Bruno and Radical Philosophy*. In *The Speculative Turn: Continental Materialism and Realism* Re.Press, Melbourne.

Harpham, G. G. 1987. *The Ascetic Imperative in Culture and Criticism*. University of Chicago Press, London

Hartog, F. 2015. *Regimes of Historicity: Presentism and Experiences of Time*. Columbia University Press, New York, NY

Harvey, P. Knox, H. 2015. *Roads: An Anthropology of Infrastructure and Expertise* Cornell University Press, Ithaca, NY

Heidegger, M. 1977. *The Question Concerning Technology and Other Essays.* Garland Publishing, London.

- 1998. *On The Essence of Ground*. In Mcneill (ed.) *Pathmarks.* Cambridge University Press, Cambridge

- 2010. *Being and Time.* State University of New York Press, Albany, NY.

Himanka, J. 2005. *Husserl's Argumentation for the Pre-Copernican View of the Earth.* In *The Review of Metaphysics* 58(3): 621-644.

Himmelfarb, M. 2010. *The Apocalypse: a Brief History*. Blackwell, Chichester.

Hitchens, C. 2012. *Morality*. Atlantic Books, London.

HKW 100 Years of Now, 2017. *Nikolai Fedorov's Project of Universal Salvation and "Russian Cosmism"* | *Michael Hagemeister* Available at: https://www.youtube.com/watch?v=RAezHLqCl9A&t=1192s Acessed on: 11/01/2023

Hoeppe, G. 2012. *Astronomers at the Observatory: Place, Visual Practice, Traces* In *Anthropological Quarterly* 85(4):1141-1160

- 2018. *Mediating Environments and Objects as Knowledge Infrastructure*. In *Computer Supported Cooperative Work*, 28: 25-59

Holbraad, M. 2012. *Truth in Motion: The Recursive Anthropology of Cuban Divination*. University of Chicago Press, Chicago.

Holbraad, M. Kapferer, B. Sauma, J. F. 2019. *Ruptures: Anthropologies of Discontinuity in Times of Turmoil*. UCL Press, London

Holbraad, M. Pedersen, M. A. 2017. *The Ontological Turn: An Anthropological Exposition*. Cambridge University Press, Cambridge.

Holston, J. 1989. *The Modernist City: An Anthropological Critique of Brasília.* University of Chicago Press, London

Hooke, R. 1665. *Micrographia: or some Physical Descriptions of Minute Bodies made by Magnifying Glasses with Observations and Inquiries Thereupon.* The Royal Society, London.

Howell, E. Pultarova, T. 2024. *Starlink Satellites: Facts, Tracking and Impact on Astronomy.* Available at: [https://www.space.com/spacex-starlink-satellites.html] accessed on: [26/03/2024]

Hume, D. 1896. *A Treatise on Human Nature* Clarendon Press, Oxford

Ihde, D. 2010. *Husserl's Galileo Needed a Telescope!* In *Philosophy and Technology* 24(1): 69-82

Ingold, T. 2000 *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill.* Routledge, London

International Dark Sky Association *Light Pollution* [Available at: https://www.darksky.org/light-pollution/] [Accessed on: 05/05/2021]

Iwaniszewski, S. 2015. *Concepts of Space, Time and Cosmos*. In: Ruggles, C. 2015. *The Handbook of Archaeoastronomy and Ethnoastronomy.* Springer, London

Jacobs, J. 1961. *The Death and Life of Great American Cities*. Vintage books, New York.

Jeevendrampillai, D. 2015. *Making The Local: Anthropology & The Suburban Citizen* Unpublished paper, UCL.

- 2019. *The Making of the Suburb* In *London's Urban Landscape* UCL press, London

Jofreeman.com *The Tyranny of Structurelessness* [Available at: https://www.jofreeman.com/joreen/tyranny.htm] [Accessed on: 10/05/2021]

Joshi, S. T. 1999. *Introduction* In *The Call of Cthulhu and other Weird Stories.* Penguin Books, London.

Kant, E. 1784 *What Is Enlightenment?* Available at: http://www.columbia.edu/acis/ets/CCREAD/etscc/kant.html Accessed on: 23/04/2022

- 2001. *Selections from Critique of Judgement [1793]* In Wood, A. W. [ed] *Basic Writings of Kant.* The Modern Library, N.Y.

Keane, W. 2005. *Signs are not the Garb of Meaning: On the Social Analysis of Material Things*. In Miller, D. (Ed.) *Materiality* Duke University Press, London.

Kessler, E. A. 2012. *Picturing the Cosmos: Hubble Space Telescope Images and the Astronomical Sublime.* University of Minnesota Press, London.

Khun, T. S. 1962 *The Structure of Scientific Revolutions.* University of Chicago press, Chicago.

Kopenawa, D. Albert, B. 2013 *The Falling Sky: Words of a Yanomami Shaman.* Harvard University Press, Cambridge, MA.

Koselleck, R. 2004. *Futures Past: On the Semantics of Historical Time.* Columbia University Press, New York, NY

Koslovsky, C. 2011. *Evening's Empire: A History of the Night in Early Modern Europe.* Cambridge University Press, Cambridge.

Koyré, A. 1957 *From the Closed world to the Infinite Universe* The Johns Hopkins University Press, London

Kragh, H. S. 2007. *Conceptions of Cosmos: From Myths to the Accelerating Universe: A History of Cosmology*. Oxford University Press, Oxford.

Kravel-Torvi, M. Bilu, Y. 2008. *The Work of the Present: Constructing Messianic Temporality in the Wake of Failed Prophecy among Chabad Hasidim*. In *American Ethnologist* 35:1 64-80

Kuchler, S. Carroll, T. 2021. *A Return to the Object: Alfred Gell, Art, and Social Theory.* Routledge, London.

Lacan, J. 1949. *Écrits*. W.W. Norton & Company, London

Lambeck, M. 2008. *General Introduction* in *A Reader in the Anthropology of Religion*. Wiley-Blackwell, Oxford.

Latour, B. 1993. *We Have Never Been Modern.* Harvard University Press, Cambridge, MA.

Latour, B. Woolgar, S. 1986. *Laboratory Life: The Construction of Scientific Facts*. Princeton University Press, Princeton, NJ.

Law, J. 2015. *What's Wrong with a One-World World?* In *Distinktion: Journal of Social Theory*. 1:126-139

Lazier, B. 2011. *Earthrise; or, The Globalization of the World Picture*. In *The American Historical Review* 116(3): 602-630

Leaman, T. *Harmonizing Land and Sky in Aboriginal Dreamings*. In Campion, N. (Eds.) *The Harmony Debates*. Sophia Centre Press, Ceredigion.

Levi-Strauss, C. 1966. *The Savage Mind.* University of Chicago Press, Chicago.

- 1973. *Tristes Tropiques.* Pan Books, London.

Liddle, A. 2003. *An Introduction to Modern Cosmology: 2nd Ed.* Wiley, Chichester.

LIGO *What are Gravitational Waves?* [available at https://www.ligo.caltech.edu/page/what-are-gw] [accessed on: 26/05/2021]

Lulka, D. 2014. *Animals, Daguerreotypes and Movement: The Despair of Fading and the Emergence of Ontology*. In *Journal of Material Culture* 19:1 35-58

Lynch, M. Edgerton, S. Y. 1987. *Aesthetics and Digital Image Processing: Representational Craft in Contemporary Astronomy.* In *The Sociological Review* 35(1): 184-220

Majid, S. 2008. *Quantum Spacetime and Physical Reality*. In Majid, S. (Ed.) *On Space and Time* Cambridge University Press, Cambridge.

Malm, A. 2016. *Fossil Capital: The Rise of Steam Power and the Roots of Global Warming*. Verso, London.

Markley, R. 2005. *Dying Planet: Mars in Science and the Imagination.* Duke University Press, London.

Marr, A. 2007. *A History of Modern Britain*. Pan Books, Oxford

Marx, K. Engels, F. 2002. *The Communist Manifesto.* Penguin Books, London

Melbin, M. 2978. *Night as Frontier* In *American Sociological Review* 43(1): 3-22

Melhuish, C. 2005. *Towards a Phenomenology of the Concrete Megastructure: Space and Perception at the Brunswick Centre, London.* In *Journal of Material Culture* 10(1): 5-29

Menger, C. 1985. *Investigations into the Method of Social Sciences with Special Reference to Economics*. New York University Press, New York, NY.

Mercer, D. 1993. *Terra Nullius, Aboriginal Sovereignty and Land Rights in Australia: The Debate Continues* In *Political Geography* 12(4): 299-318)

Merk, F. Merk, L. B. 1995 *Manifest Destiny and Mission in American History: A Reinterpretation* Harvard University Press, Cambridge, MA.

Messeri, L. 2016. *Placing Outer Space: an Earthly Ethnography of Other Worlds*. Duke University Press, London.

- 2017. *Resonant worlds: Cultivating Proximal Encounters in Planetary Science* In *American Ethnologist* 44(1): 131-142

Miller, R. J. 2019. *The Doctrine of Discovery: The International Law of Colonialism* In *The Indigenous Peoples' Journal of Law, Culture & Resistance* 5(1): 35-42.

Moore, J. W. 2017. *The Capitalocene, Part I: on the Nature and Origins of our Ecological Crisis.* In *The Journal of Peasant Studies* 44:3, 594-630

Morton, T. 2013. *Hyperobjects; Philosophy and Ecology after the End of the World.* University of Minnesota Press, London.

Murphy, M. 2006. *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience and Women Workers.* Duke University Press, London.

Myers, N. 2015 *Rendering Life Molecular: Models, Modellers and Excitable Matter.* Duke University Press, London.

Von Mises, L. 1990. *Economic calculation in the Socialist Commonwealth*. Mises Institute, Auburn, AB

Nagel, T. 1986. *The View From Nowhere.* Oxford University Press, Oxford.

NASA/JPL 1996. *PIA00452: Solar System Portrait - Earth as 'Pale Blue Dot'* [Available at: https://photojournal.jpl.nasa.gov/catalog/PIA00452] [Accessed On: 24/02/2021]

NASA/JPL-Caltech 2019. *Resources: Voyager 1's Pale Blue Dot*. [Available at: https://solarsystem.nasa.gov/resources/536/voyager-1s-pale-blue-dot] [Accessed On: 24/02/2021]

NASA. 2021. *Watch NASA's Perseverance Rover Land on Mars!* [Available at: https://youtu.be/gm0b_ijaYMQ?t=3748] [Accessed on: 25/02/2021]

NASA 1969. *1969 Apollo 11 News Release.* [Available at: https://www.nasa.gov/centers/glenn/about/history/apollo_press_release.html] [Accessed on: 02/02/2021]

NASA 2018. *Blue Marble - Image of the Earth from Apollo 17.* [Available at: https://www.nasa.gov/content/blue-marble-image-of-the-earth-from-apollo-17] [Accessed on: 28/02/2021]

Natarajan, P. 2016. *Mapping the Heavens: Radical Scientific ideas that Reveal the Cosmos* Yale University Press, London.

Needham, R. 2009. *Introduction* In *Primitive Classification* Routledge, London.

Newton, I. 2004. *Correspondence with Bentley* In *Newton: Philosophical Writings* Cambridge University Press, Cambridge.

Nietzsche, F. 2006. *The Gay Science*. Dover Publications, New York.

Oatmeal, The 2020. *Celestial Events* [available at: https://theoatmeal.com/comics/celestial_events] [accessed on: 09/06/2021]

Oliver, K. 2015. *Earth & World: Philosophy after the Apollo Missions.* Columbia University Press, New York, NY

Olson, V. 2018. *Into the Extreme: U.S. Environmental Systems and Politics Beyond Earth* University of Minnesota Press, London

Orr, R. 2020. *Astronomy Boom as Stargazers Look to Sky for Solace*. [Available at: https://www.ft.com/content/7466008d-0dd1-4206-856c-2f77096fa2b1] [Accessed on: 18/03/2021]

Overbye, D 2016 *Under Hawaii's Starriest Skies, a Fight over Sacred Ground*. [Available at: https://www.nytimes.com/2016/10/04/science/hawaii-thirty-meter-telescope-mauna-kea.html] [accessed on: 14/04/2021]

Pearl, M. 2019. *'Climate Despair' Is Making People Give Up on Life*. Vice, Available at: https://www.vice.com/en/article/j5w374/climate-despair-is-making-people-give-up-on-life Accessed on 21/01/2023

Penrose, R. 1997. *Introduction* In *Six Not-So-Easy Pieces: Einstein's Relativity, Symmetry, and Space-Time.* Basic Books, New York.

- 2008 *Causality, Quantum Theory and Cosmology.* In *Space and Time*. Cambridge University Press, Cambridge

Pinney, C. 2005. *Things Happen: Or, From Which Moment Does That Object Come?* In Miller, D. (Ed.) *Materiality.* Duke University Press, London

- 2012. *Seven Theses on Photography*. In *Thesis Eleven*. 00(0) 1-16.

Pmilat. 2014. *Mark Fisher: The Slow Cancellation of the Future*. Available at: [https://www.youtube.com/watch?v=aCgkLICTskQ&t=49s] accessed on: 3/12/2022

Pollock, E. 2006. *Stalin and the Soviet Science Wars*. Princeton University Press, Princeton, NJ

Pomerantsev, P. 2017. *Nothing is True and Everything is Possible: Adventures in Modern Russia*. Faber & Faber, London

Porter, R. 2000. *London: A Social History* Penguin Books, London.

Povinelli, E. A. 2001. *Radical Worlds: The Anthropology of Incommensurability and Inconceivability*. In *Annual Review of Anthropology*. 30 319-34

Pultarova. T. 2023. *SpaceX's Starlink internet satellites 'leak' so much radiation that it's hurting radio astronomy, scientists say*. Available at: [https://www.space.com/starlink-electronics-hum-disturbs-radio-astronomy] accessed on: [26/03/2024]

Rabinow, P. 1984. *The Foucault Reader*. Pantheon Books, New York, NY.

- 1989. *French Modern: Norms and Forms of the Social Environment.* University of Chicago Press, Chicago.

Radical Anthropology 2018. *Fabio Silva: 'On Earth as it is in Heaven': What is Archaeoastronomy, 19 June 2018* [Available at: https://www.youtube.com/watch?v=j503iNhw9V4] [Accessed on: 04/04/2021]

Redfield, P. 2002. *The Half-Life Empire of Outer Space* In *Social Studies of Science* 32(5/6): 791-825

Reno, J. 2018. *Making Time with Amateur Astronomers and Orbital Space Debris: Attunement and the Matter of Temporality*. In *Journal of Contemporary Archaeology* 5(1): pp. 4-18

Robert, A. Mickey, S. 2013. *Comopolitics: An Ongoing Question* paper presented at *Political Theory and Entanglement: Politics at the Overlap of Race, Class, and Gender*

Rovelli, C. 2017 *Reality is not what it Seems: The Journey to Quantum Gravity.* Riverhead, NY.

Ruggles, C. 2009. *Indigenous Astronomies and progress in Modern Astronomy*. Norris, R. Ruggles, C. (eds.) *Accelerating the Rate of Astronomical Discovery*. Rio De Janeiro, 2009

- 2015 *Handbook of Archaeoastronomy and Ethnoastronomy*. Springer, London

Sagan, C. 1995. *Cosmos: The Story of Cosmic Evolution, Science and Civilization.* Abacus, London.

- 1997. *The Pale Blue Dot: A Vision of the Human Future in Space*. Ballantine Books, New York.

Sahlins, M. 1972. *Stone Age Economics*. Tavistock Publications, London

SatTrack Cam Leiden. 2019. *WOWOWOW!!!! A SPECTACULAR view of the SpaceX Starlink satellite train!* Available at [https://sattrackcam.blogspot.com/2019/05/wowowow-spectacular-view-of-spacex.html] accessed on: [26/03/2024]

Scagell, R. 2014. *The Urban Astronomy Guide: Stargazing from Towns and Suburbs*. Philip's, London.

Scharf, C. 2015. *The Copernicus Complex: The Quest for Our Cosmic (In)Significance*. Penguin, London

Schlosberg, M. Hart, P. 2021. *Top 5 Reasons Carbon Capture and Storage is Bogus*. (available online: https://www.foodandwaterwatch.org/2021/07/20/top-5-reasons-carbon-capture-and-storage-ccs-is-bogus/ Accessed on: 15/12/2022

Schrempp, G. 2012. *The Ancient Mythology of Modern Science: A Mythologist Looks (Seriously) at Popular Science Writing.* McGill-Queens University Press, Montreal.

Scott, J. C. 2009. *The Art of Not Being Governed: An Anarchist History of Upland Southeast Asia.* Yale University Press, London.

- 2020. *Seeing Like A State: How Certain Schemes to Improve the Human Condition Have Failed* Yale University Press, London

Scott, M. W. 2014. *To Be A Wonder: Anthropology: Anthropology, Cosmology and Alterity* In *Framing Cosmologies: The Anthropology of Worlds*. Manchester University Press, Manchester.

Sennett, R. 1993. *The Fall of Public Man*. Faber, London.

Shapin, S. Ophir, A. 1991. *A Place of Knowledge: A Methodological Survey.* In *Science in Context* 4(1): 3-21.

Shapin, S. Schaffer, S. 2011. *Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life.* Princeton University Press, Princeton, NJ

Sherover, C. M. 1967. *Heidegger's Ontology and The Copernican Revolution* In *The Monist* 51(4): 559-573

Shklovsky, V. 2015. *Art as Device.* Poetics Today 36(3): 151–174

Shrödinger, E. 2012. *What is Life?* Cambridge University Press, Cambridge

Siddiqi, A. A. 2010. *The Red Rocket's Glare: Spaceflight and the Soviet Imagination 1857-1957*. Cambridge University Press, Cambridge.

Silva, F. 2015. *The Role and Importance of the Sky in Archaeology: An Introduction*. In Silva, F. Campion, N. 2015. *Skyscapes: The Role and Importance of the Sky in Archaeology.* Oxbow books, Oxford.

Simple, I. 2009 *Galaxy's Centre Tastes of Raspberries and Smells of Rum, Say astronomers* available at: https://www.theguardian.com/science/2009/apr/21/space-raspberries-amino-acids-astrobiology accessed on: 20/05/2021

Sismondo, S. 1999. *Models, Simulations, and Their Objects*. In *Science in Context*, 12(2): 247-260

Smolin, L. 2008. *The Trouble with Physics: The Rise of String Theory, the Fall of Science, and What Comes Next*. Penguin Books, London.

Smolkin, V. 2018. *A Sacred Space is Never Empty: A History of Soviet Atheism*. Princeton University Press, Princeton, NJ

Smythies, J. 1996. *A Note on the Concept of the Visual Field in Neurology, Psychology and Visual Neuroscience*. In *Perception* 25(369-371).

Stengers, I. 2010. *Cosmopolitics 1*. University of Minnesota Press, Minneapolis.

- 2015. *In Catastrophic Times: Resisting the Coming Barbarism*. Open Humanities Press

Sterling, B. 2010. *Atemporality for the Creative Artist*. Wired, available at [https://www.wired.com/2010/02/atemporality-for-the-creative-artist/] accessed on: [10/03/2023]

Strathern, M. 2022. *Property, Substance and Effect.* Hau Books, Chicago.

Tactile Universe. [available at: https://tactileuniverse.org/] [Accessed on: 07/04/2021]

Taleb, N. N. 2007. *The Black Swan: The Impact of the Highly Improbable*. Penguin, London

Thacker, E. 2011. *In The Dust of this Planet: Horror of Philosophy vol. 1.* Zero Books, Winchester.

- 2015. *Starry Speculative Corpse: Horror of Philosophy vol. 2.* Zero Books, Winchester.

The Sky At Night, 2020. *A Beginner's Guide*. Available at [https://www.bbc.co.uk/programmes/m000db8r] accessed on [20/02/2020]

Tilley, C. 2017. *An Anthropology of Landscape*. UCL Press, London

- 2019 *London's Urban Landscape: Another Way of Telling.* UCL Press, London.

Tsing, A. L. 2015. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins.* Princeton University Press, Princeton, NJ

Turner, V. 1969 *The Ritual Process: Structure and Anti-Structure.* Cornell University Press, Ithaca.

Tyson, Neil deGrasse. 2012. *Space Chronicles: Facing the Ultimate Frontier.* Norton, NY.

Valentine, D. 2016. *Atmosphere: Context, Detachment and the View from Above Earth*. In *American Ethnologist* 43(3): pp. 511-524

Valentine, D. Olson, V. Battaglia, D. 2012. *Extreme: Limits and Horizons in the Once and Future Cosmos.* In *Anthropological Quarterly* 8(4) 1007-1026

Van Gennep, A. 1961. *The Rites of Passage*. Routledge, London.

Walford, T. 2021. *Data Aesthetics*. In Carrol, T. Walford, T. Walton, S. [Ed] *Lineages and Advancements in Material Culture Studies: Perspectives from UCL Anthropology*. Routledge, London.

White, F. 1987 *The Overview Effect: Space Exploration and Human Evolution.* American Institute of Aeronautics & Astronautics, Reston VA

Whitehead, A. N. 1928. *Science and the Modern World.* Cambridge University Press, Cambridge.

Williams, T. 2000. *Getting Organized: A History of Amateur Astronomy in the United States*. PhD Thesis, Rice University.

Witze, A. 2020. *How the Fight over a Hawaii Mega-telescope could Change Astronomy*. In *Nature* 577:457-458

Yurchak, A. 2005. *Everything was Forever, Until it was no More: The Last Soviet Generation*. Princeton University Press, Princeton, NJ

Yussof, K. 2018. *A Billion Black Anthropocenes or None*. University of Minnesota Press, Minneapolis, MN

Zhan, M. 2009. *Other-Worldly: Making Chinese Medicine through Transnational Frames*. Duke University Press, London.

Žižek, S. 1999. *The Ticklish Subject: The Absent Centre of Political Ontology*. Verso, London

- 2008. *The Sublime Object of Ideology*. Verso, London.