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Sustaining local opposition to Big Science: A case study of the Thirty Meter Telescope controversy

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ABSTRACT

Big Science projects, which are extremely costly and typically revolve around large and complex instruments, are increasingly common in research. Proponents often frame Big Science as a "win-win" for all stakeholders, including for local communities. Yet local opposition to Big Science projects is common, although it is often either short-lived or fails to raise wider awareness. The story is different for the kia'i mauna (protectors of the mountain), a group largely composed of Native Hawaiians. This group has sustained opposition to the Thirty Meter Telescope (TMT) on Mauna Kea, Hawai'i Island, since 2011 and has raised widespread attention for its advocacy. Combining social movement theory and the concept of place attachment, I investigate why the kia'i have been able to sustain such momentum. Based on 16 interviews that I conducted with Native Hawaiians, local community members, policymakers, and astronomers, I argue that six factors have been decisive for the resilience of opposition: multi-generational leaderful organization, grassroots resources, versatile tactics, anti-science counterframing, local and national political opportunity, as well as place attachment-driven commitment.

1. Introduction

Big Science is increasingly common in research, especially in astronomy where scientists rely on ever bigger research instruments in ever greater numbers [1]. Big Science is typically defined as science made big in three dimensions, namely organizations, politics, and machines ([2]: 17). Such a conceptualization reflects that large scientific projects need substantial funding, which usually comes from the highest political level ([3]: 750). Moreover, it indicates that the organization of these projects often centers around large scientific infrastructures ([2]: 108). It is through such infrastructure but ideally also through economic contributions and societal outreach that Big Science is embedded in local communities.

Proponents of Big Science tend to frame it as a "win-win" for all stakeholders, including for local communities [4], but research has shown that local opposition to Big Science is common [5,6]. In most cases, however, local resistance is either short-lived or fails to raise wider awareness. In the case of the European Organization for Nuclear Research, for example, Robinson [7] mentions that local opposition only "gained traction *for a while*" (p.88; emphasis added). Writing on the European Spallation Source (ESS), a multi-disciplinary research facility worth 1.8 billion euros, Kaijser [8] concludes that environmentalists were unable to raise popular support for their opposition because in Lund, a university town with "a deeply rooted self-image of being at the cutting edge of science", the project was positively connoted (p. 54). The story is different for the kia'i mauna[1] (protectors of the mountain), a group which is predominantly composed of Native Hawaiians, and their opposition to the Thirty Meter Telescope (TMT). With a price tag of nearly 4 billion US dollars, TMT is Big Science "at its biggest" ([9]: 294). The kia'i have opposed the construction of TMT on Mauna Kea, Hawai'i Island, since 2011 and have raised widespread attention for their advocacy. In this paper, I investigate why they have been able to sustain such momentum.

To explain the resilience of local opposition to TMT, I draw on social movement theory and the concept of place attachment. Sixteen interviews that I conducted with Native Hawaiians, local community members, astronomers, and policymakers form the empirical backbone of this paper. I also analyze kia'i testimonies that were collected for two documentaries [10,11], five interviews that Kuwada and Revilla [12] conducted with kia'i as well as academic and grey literature. Based on this empirical material, I argue that six factors have been decisive for the resilience of local opposition: multi-generational leaderful organization,

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[1] From here on referred to as (the) kia'i.

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grassroots resources, versatile tactics, anti-science counterframing, local and national political opportunity, as well as place attachment-driven commitment.

The article's remainder is structured as follows: In section two, I provide an overview of the existing scholarship on local opposition to Big Science. Thereafter, in section three, I outline my theoretical framework that combines insights from scholarship on opposition to renewable energy projects (REPs) and social movements. I discuss research ethics, methods, and data in section four. Then, in section five, I provide a detailed account of the TMT controversy, starting off with a contextualization of astronomy development on Mauna Kea, outlining the scientific case for the TMT, and closing this section with a description of kiaʻi activities in opposition to the project. I present the six factors that have been decisive for the resilience of kiaʻi opposition in section six. Finally, in section seven, I discuss my findings and outline future research avenues.

2. Local opposition to Big Science

There is little research on local opposition to Big Science, possibly because it is expected to resemble resistance to more "conventional" large construction projects, and especially REPs, given that both Big Science and REPs are typically considered "good in principle" ([13]: 2706). At the same time, there are several important differences between REPs and Big Science projects that affect why and how opposition against the latter is voiced.

REPs like wind turbines are profitable and often built by commercial actors that are rarely embedded in the local community past an REP's construction phase. Big Science projects, in contrast, are promoted by a research community that often relies on such large projects to push the frontier of its field but does not benefit from Big Science commercially. Moreover, a Big Science research community typically uses a Big Science project for years if not decades and is therefore embedded in a local host community for a long period of time. As a result, Big Science research communities are expected to engage with and contribute to the local host community. Typically, the local engagement of a Big Science research community has a distinct scientific-educational dimension, for example, when it includes setting up mentorship or internship programs for local school children. Seen as being bound and guided by their ethical obligations and social responsibility as scientists ([14]: 4), Big Science research communities may also be held to higher standards by the local host community than other actors (i.e. commercial ones). When local opposition to Big Science emerges, community members are likely to pick up at least some of the unique characteristics of Big Science (research communities) to buttress their arguments against a project. For instance, if the local community perceives Big Science as negatively affecting the local environment, community members may argue that the scientists in favor of building the project are disregarding the scientific norm of nonmaleficence (do no harm).

Within the Big Science literature, local opposition has mostly been dealt with in passing. Two exceptions are Stenborg and Klintman's [5] as well as Kaijser's [8] studies on local environmental opposition to ESS. According to Kaijser [8], opponents of ESS mainly failed to raise wider resistance because it was hard for them to appear legitimate to the public while criticizing a project that was associated with "development and progress" (p. 53–54). In addition to the above two studies, there is a growing body of research which investigates why and how marginalized communities voice opposition to Big Science. This research mainly focuses on the Square Kilometer Array (SKA), an astronomy project currently under construction in Australia and South Africa's Karoo region, and TMT.

Examining SKA's local impact, Walker and Chinigò (2020) contend that there are two main reasons why parts of the host community in the Karoo oppose the project. First, they point to conflicts over SKA's land acquisition process (p. 401–402). Second, Chinigò and Walker [15] argue that clashing interests and expectations between SKA's funders and the local community led to mistrust at the local level (p. 402). According to the authors, a lack of involvement in decision-making processes and untransparent communication between the local community and SKA galvanized this mistrust ([16]: 595). Although several scholars [17,18] highlight SKA's efforts to address these issues, Chinigò and Walker [15] conclude that SKA's beneficiaries are "powerful constituencies in faraway metropoles", not SKA's host community (p. 393).

Scholarship on local opposition to TMT focuses on the "how" and "why" of resistance. The Hawaiian scholars Case [19], Maile [20], and Goodyear-Kaʻōpua [21], for example, provide overviews of the different protest activities that the kiaʻi engaged in after 2014 (for a detailed description of kiaʻi activities see section 5). Moreover, they describe how these activities were organized, which tactics were used, and how local, national, and international actors reacted to the protests. With respect to the latter, Case [19] and Maile [20] highlight how the kiaʻi received and lent support to indigenous movements in New Zealand and on the US mainland. In doing so, they underline the great cultural, spiritual, and ancestral significance that Mauna Kea, a dormant volcano on Hawaiʻi Island that stands 4205 m above sea level, holds for Native Hawaiians. Salazar [22] and Swanner [23], in turn, more broadly investigate the history of local opposition to astronomy development on Mauna Kea, focusing on TMT and the Keck Outrigger telescopes, which due to funding issues and local protest in the early 2000s were not built. Both scholars emphasize that a multitude of factors triggered opposition to astronomy development on Mauna Kea. Salazar [22] argues that past mismanagement of the mountain, that has seen the construction of 13 telescopes over the last 40 years, and environmental concerns weigh heavily in the controversy. Casumbal-Salazar [24] further contends that protests against astronomy development on Mauna Kea mirror a broader struggle to decolonize Hawaiʻi, whose annexation by the US in 1898 is politically and legally contested [25]. Swanner [9] argues that, in Hawaiʻi, science, embodied by telescopes and astronomers, is perceived "as the newest agent of colonization" (p. 294). She also maintains that astronomers' lack of engagement with Native Hawaiians has fueled local discontent.

Adding to the literature on local opposition to astronomy development on Mauna Kea, this study examines why the kiaʻi have been able to sustain opposition to TMT and raise wider awareness of their advocacy. In doing so, it illuminates how marginalized communities make their voices heard in relation to Big Science, which is a neglected yet fundamental issue, considering that Big Science not only requires large capital investments but also public acceptance ([26]: 22 ff.).

3. Theoretical framework

In my analysis, I bridge diverse theorizing strands, which is believed to generate more flexible interpretative frameworks with a broader explanatory scope [27]. Specifically, I use structuralist and cultural approaches to social movement emergence. Compared to studies that exclusively rely on one or the other, my framework helps to capture both the meaning-making and material dimensions of collective action. Social movement theory lends itself to my purposes because although it is predominantly concerned with the question of when and why collective action emerges, research has shown that the factors which help collective action to emerge also play a role in it persisting [28–30]. Given that local resistance to Big Science is a form of collective action, I assume that social movement theory is a useful lens to guide my analysis. I combine social movement theory with the ideational concept of place attachment. As Mauna Kea is a place of great cultural, spiritual, and ancestral significance to Native Hawaiians, I assume that the concept may help to explain why local resistance to a project planned for construction on this particular mountain has persisted.

3.1. The role of resources, political structures, and framing in collective action

Influential approaches to the emergence of collective action and social movements are resource mobilization, political opportunity, and framing theory. Resource mobilization theory (RMT) underlines the role of organizational structures and processes ([31]: 11). Theorists working in this structural-material tradition emphasize that collective action "if it is to be sustained for any length of time, requires some form of organization" ([32]: 6). This includes leadership and resources, the latter of which can be tangible and intangible [33]. Important material resources for activists are money and supplies ([31]: 11), while people, their time, and tactics are vital in-kind resources ([31]: 11). Tactics are "noninstitutionalized forms of political expression" with which activists try to garner public support and put pressure on those in positions of power ([34]: 263). They may range widely from strikes to campaigning on social media [35]. Organizational features of a social movement may likewise lie on a continuum between formal and informal. Formally organized social movements are highly professionalized, while informal movements are usually grassroots efforts with volunteer staff, no clear leadership, and limited resources ([31]: 12). Organization and leadership are crucial for collective action because they facilitate coordination. Strong leaders are instrumental, as they help formulate strategies and deal with targets of collective action ([36]: 171).

Similarly structural in focus as RMT, political opportunity theory (POT) holds that the broader political context determines which objectives and tactics are chosen and how likely it is for them to succeed ([37]: 127). The social movement scholar Tilly [38] defines political opportunity as "the extent to which other organized groups, including state institutions, accept or oppose the objectives of collective action and reduce or increase its costs" ([31]: 14).

The "cultural turn" in the study of social movements, finally, introduces the concepts of framing and frames. Framing "refers to the meaning-making processes associated with the construction and interpretation of grievances, the attribution of blame, and the creation of rationale for participation" in social movements, while frames are the outcomes of those meaning-making processes ([31]: 16). They tell the public what is at stake and outline the boundaries of the debate ([31]: 16).

3.2. Place attachment

In the pertinent literature, place attachment is broadly defined as "emotional bonds between people and places" [39], where "place refers to space that has been given meaning through personal, group, or cultural processes" ([40]: 252). The concept is used to explain why people object to REPs, arguing that opposition to REPs is driven by place-protective attitudes ([41]: 432) rather than "not-in-my-backyard"-ism [39,41–43].

According to the literature, place-protective attitudes and action can intensify or wane over time because place attachment is not a static phenomenon but involves a complex "interplay of emotions, cognition, and behavior" ([40]: 252). Moreover, place-protective attitudes do not necessarily culminate in local opposition. If a project is seen to be "place enhancing" in a physical, symbolic, or economic sense, place attachment may even correlate with project support ([41]: 434). Opposition only emerges if individuals with strong attachment to a specific place perceive a project as having a negative impact on it ([41]: 434). This may be the case if a project infringes on how individuals experience a cherished place or if a place is symbolic of home and a project is seen as being imposed upon it without genuine public engagement ([41]: 434) in the form of information, consultation, and involvement in decision-making processes ([44]: 2 ff.).

4. Research ethics, methods, and data

Researching indigenous-led activism as a non-indigenous scholar raises ethical issues which I approached in a critical-reflexive manner throughout the research process. This included familiarizing myself with decolonial methodologies [45,46] and constantly reflecting on my positionality as a community outsider and a non-indigenous researcher.

Research on indigenous communities that is conducted by community outsiders has been and continues to be problematic for these communities ([46]: 158), particularly if it lacks integrity. To ensure that my research is ethical, I first asked all interviewees for their written consent to participate in my research. Second, I perpetually considered how my research could benefit the local community. As I did not want to impose an approach, I asked my interviewees for feedback on this issue. In doing so, I learned that different community members have different conceptions of how research on Big Science may benefit their community. Some interviewees, for instance, underlined that academic research from community outsiders is in and of itself beneficial (INT11). Others stressed the importance of making my research accessible to a non-academic local audience (INT13). Third, wherever possible, I engaged in a "community review" process ([45]: 140), which meant that I sent interview transcripts to my interviewees and asked them for feedback on my draft article. As a result of this process, I received several comments that helped me sharpen my account of the emergence and development of local opposition to TMT.

I chose local opposition to TMT as a case study based on the deviant case selection technique [47]. According to this technique, a case is selected because "by reference to some general understanding of a topic, it demonstrates a surprising value" ([48]: 105). This applies to opposition to TMT, as it has lasted longer and has raised wider awareness than opposition to Big Science typically does. Investigating a deviant case and explaining why it diverges from theoretical and/or empirical expectations is useful, as it may help refine these expectations, extend them, or formulate new ones ([47]: 13). Yet findings from a single case study cannot be easily generalized beyond the case under investigation.

For the description and analysis of my case study, I triangulate data from reactive (interviews) and non-reactive (documents) sources, a strategy which is believed to increase the reliability of inferences (in [49]: 2). Overall, I conducted 16 semi-structured interviews with Native Hawaiians, local community members, policymakers, and astronomers in-person and online between August 2022 and March 2023 (see Table 1). Such a "multiperspectival orientation" is vital to understand collective action as it is usually "embedded within a multiorganizational field consisting of protagonists, antagonists, and bystanders" ([50]: 154). I also draw on five transcribed interviews that Kuwada and Revilla [12] conducted with kiaʻi for a University of Hawaiʻi (UH) publication. Moreover, I transcribed and analyzed kiaʻi testimonies that were

Table 1
Overview of conducted interviews.

Interviewee Code	Actor Group	Length of Recording
INT01	Environmental NGO	76 min
INT02	Big Island Community	64 min
INT03	O'ahu Community	84 min
INT04	Astronomy Community	36 min
INT05	Big Island Community	67 min
INT06	O'ahu Community	45 min
INT07	O'ahu Community	46 min
INT08	Big Island Community	44 min
INT09	Big Island Community	51 min
INT10	Big Island Community	133 min
INT11	O'ahu Community	56 min
INT12	Hawaiian Policymaker	44 min
INT13	O'ahu Community	60 min
INT14	Astronomy Community	49 min
INT15	Kai'i Supporting Group on US Mainland	54 min
INT16	Astronomy Community	49 min

collected for two documentaries [10,11]. All conducted interviews were structured by interview guidelines which varied depending on which stakeholder group I was talking to.

I used MAXQDA as well as Deterding and Waters' [51] flexible coding method to analyze my sources. As Deterding and Waters [51] recommend for projects with fewer than 30 interviews, I refrained from indexing my interview transcripts. Instead, I began analytic coding on the first reading. The coding scheme that emerged after several rounds of analysis contained three types of codes. First, a set of deductive codes (e.g. the organization, resources, and tactics of the kiaʻi) that I developed based on my theoretical framework, second, several inductive codes which arose organically from the empirical material (e.g. outcome of the opposition), and third, an independent code which pointed to passages where interviewee statements were particularly poignant (see also Appendix A).

5. Contextualizing TMT and local opposition to it

TMT is planned for construction on Mauna Kea's northern flank. At roughly 55 m wide and 50 m tall [52], TMT would be the biggest addition to the existing Mauna Kea observatories and would rival imposing landmarks like the Parisian Arc de Triomphe in size.

Astronomy development on Mauna Kea started as early as 1967. At the time, the local economy of Hawaiʻi Island was recovering from the devastating effects of a tsunami ([23]: 180). To attract investment to the island, local authorities encouraged the development of an astronomy precinct on Mauna Kea and entrusted the newly established Institute for Astronomy (IfA) of UH with a 65 year "master lease" for a substantial area on Mauna Kea's summit. Until a reform of Mauna Kea's stewardship was enacted in 2022, IfA was authorized to sublease Mauna Kea lands to other institutions through this master lease ([23]: 183).

TMT is being designed and developed by the TMT International Observatory (TIO), a non-profit international partnership consisting of US, Chinese, Japanese, Canadian, and Indian stakeholders [53]. TIO chose to build TMT on Mauna Kea because its stable, dry, and cold climate ensures pristine observing conditions. Under these conditions, TMT's 30 m mirror would allow scientists to peer into the universe with sharper vision than most of today's largest telescopes and to probe many open, fundamental questions in astronomy [53]. Originally, TMT's construction was planned to begin in 2014 and to complete by 2021 ([54]: 82). Local resistance to TMT, however, has considerably stalled project development.

Opposition began to emerge around 2011, shortly after UH first applied for a construction permit for TMT on behalf of TIO [55]. At the time, a group of Native Hawaiian cultural practitioners and environmentalists filed for a contested case hearing regarding TMT's construction permit, a proceeding during which the legal rights, duties, or privileges of specific parties are required to be determined by law [56]. Later, they also contested UH's proposed sublease of Mauna Kea lands to TIO [55] because they feared that TMT would threaten endemic flora and fauna and contaminate the island's aquifers and watersheds. Moreover, the petitioners argued that the telescope would infringe on Native Hawaiian cultural practices and rights.

In October 2014, after the legal challenges of local environmentalists and cultural practitioners had been dismissed, TIO tried to break ground for TMT. A group of Native Hawaiians who had gathered for prayers at the mountain's base spontaneously decided to disrupt the groundbreaking ceremony (INT10). In spring and summer of 2015, opposition intensified as TIO prepared to begin constructing TMT. On two occasions in 2015, hundreds of protestors – who by then referred to themselves as kiaʻi – blocked Mauna Kea's access road, preventing crews from reaching the construction site. In the process, 31 kiaʻi were arrested ([57]: 5). To enable TMT's construction, authorities issued emergency rules which restricted the public's access to Mauna Kea. In October 2015, however, these rules were invalidated in court. TMT's construction permit and the sublease of Mauna Kea lands to TIO were likewise remanded in December 2015 and March 2016 [58], prompting TIO to look for an alternate project site [55]. Such an alternate site, albeit from a scientific point of view a less promising one, was found in La Palma, Spain [59].

After TMT's construction permit had been remanded, a second contested case was initiated in 2016. Hearings lasted several months, but in October 2018, the construction permit was eventually upheld in court [60], even after numerous appeals (INT10). TMT's construction was to commence shortly after, but once again the kiaʻi blocked access to the construction site. This time, protestors prevented construction through non-violent direct action (INT10) and by installing a permanent encampment at Mauna Kea's base. This area was a type of "refuge", called Puʻuhonua o Puʻuhuluhulu, and included a medical tent, kitchen, make-shift university, and sanitary installations. As in 2015, 38 kiaʻi – most of them kupuna (elders) – were arrested, which galvanized local opposition further. The arrests also led to a wave of international and national solidarity, with some US-based astronomers signing an open letter condemning the use of force and a "science at all costs" approach, which in their view could endanger public support for science [61]. The kiaʻi finally vacated their encampment on Mauna Kea in early 2020 when COVID-19 hit (INT10).

6. Explaining the resilience of local opposition to TMT

My analysis, which is informed by social movement theory and the concept of place attachment, reveals six factors which explain the resilience of kiaʻi opposition. The first three factors – multi-generational leaderful organization, grassroots resources, and versatile tactics, as well as local and national political opportunity – correspond with the structural-material assumptions of RMT and POT. Anti-science counterframing and place attachment-driven commitment add cultural-ideational elements to these four factors (see also Table 2).

6.1. Multi-generational leaderful organization

The kiaʻi have been able to sustain and raise wider awareness of their opposition to TMT because their efforts have been supported across generations and led by several savvy leaders. When opposition to TMT began to emerge in 2011, it mostly came from Native Hawaiians who were part of a vocal generation with considerable experience in activism. This generation had lived through the Hawaiian Renaissance, a movement which revived Hawaiʻi's cultural practices and language during the 1970s after generations of Hawaiians had been beaten for speaking their native tongue ([62]: 225). Some of the cultural practitioners who first petitioned for a contested case hearing to challenge TMT's construction permit participated in the movement to demilitarize the island of Kahoʻolawe (INT10), which is considered a major success of the Hawaiian Renaissance ([62]: 269). The US military had used

Table 2
Overview of how explanatory factors correspond with used theories and concepts.

Theory/Concept	Underlying Logic	Explanatory Factor
Resource Mobilization	Structural–Material	
		Multi-Generational Leaderful Organization
		Grassroots Resources
		Versatile Tactics
Political Opportunity	Structural	
		Local and National Political Opportunity
Framing	Cultural–Ideational	
		Anti-Science Counterframing
Place Attachment	Cultural–Ideational	
		Place Attachment-Driven Commitment

Kahoʻolawe, which lies southwest of Maui and is considered sacred by Native Hawaiians, as a bombing range from the early 1940s until 1990 ([62]: 269).

Later, during the 2014, 2015, and 2019 protest cycles, here defined as "phases of heightened conflict across the social system" ([63]: 284), kiaʻi came from all generations (INT10, INT11, INT07, INT06). Several interviewees underlined that this multi-generational support was vital to sustain momentum for the struggle to stop TMT because different generations could contribute different skillsets which, in turn, were crucial for the effective organization of collective action:

> *"We have been advocating for justice for a long time. And we have been doing it trans-generationally. So we have passed on experiences from one generation to the next and every generation that comes after has greater experience than the prior. […] So even our grassroots movements have begun to look extremely organized. And that is because at this point, we just are."*(INT07)

Interviewees mentioned that kupuna were able to contribute the knowledge of which tactics had proven effective in previous Hawaiian struggles, while younger kiaʻi were savvy social media users able to disseminate information to the public via channels like Twitter and Instagram (INT11).

As suggested by RMT, both when local opposition emerged and when it gained momentum, leadership has been instrumental for the kiaʻi to formulate strategies, coordinate action, and deal with local authorities. Cultural practitioners were among those who first petitioned for a contested case hearing on TMT's construction permit in 2011 (INT10) and remained instrumental during front line action on Mauna Kea in 2014, 2015, and 2019. Moreover, a kiaʻi who was part of a media team that reported on kiaʻi activities on Mauna Kea underlined that kumu (teachers) played important roles as spokespersons:

> *"So you look at people that were put on camera and I feel like if not all of them, most of them, they were teachers* [including faculty]. *You had* [enumerates a few kiaʻi]. *We have these really articulate people, and it was so natural for them to just be able to speak in front of people."* (Ryan Gonzalez quoted in: Kuwada and Revilla, [12]: 648).

In addition, interviewees mentioned that leadership roles were first and foremost given to individuals and organizations that had direct ancestral connections to Mauna Kea:

> *"[…] we do have a tendency to elevate certain organizations, and that is because culturally we respect who comes from where. So we like to elevate the families that exist on that land. And we let them be the leaders, the ones who have a say and the rest of us stand with them."* (INT07)

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However, not everyone agreed with this principle (INT11), which led to tensions between O'ahu- and Big Island-based activists (INT13).

Finally, a member of the kiaʻi media team mentioned that the kiaʻi leadership included "a larger group" (Kehaunani Abad quoted in: Kuwada and Revilla, [12]). When, as described by this kiaʻi, "multiple leaders […] share power […] and drive collective decision making", collective action is considered "leaderful" ([64]: 120). In the case of local opposition to TMT, leadership was first restricted to a few individuals, but then became leaderful from 2015 onward (INT10). An interviewee indicated that a growing leadership base meant that people could take on different responsibilities (INT10) which facilitated effective task division over time.

6.2. Grassroots resources

Equally in accordance with RMT, local opposition to TMT has sustained momentum because between 2011 and 2019 a steady flow of resources ensured that the kiaʻi could engage in protest activities on and off Mauna Kea. The most valuable resources that the kiaʻi have been able to rely on were in-kind, as one interviewee underlined:

> *"But it is the people that just came to donate their time to clean the bathrooms, to sweep the roads, to feed everyone* [at the encampment]*."* (INT09)

Material resources like monetary contributions also played a role. Interviewees stressed that most contributions, monetary or otherwise, came from the local community (INT11, INT10, INT03, INT13, INT01). Funds needed to challenge TMT in court were initially "out of pocket" expenses covered by the petitioners (INT01, INT03). Later, Hawaiian organizations, such as The Hawaiian-Environmental Alliance and the Office of Hawaiian Affairs, chipped in to support kiaʻi that were engaged in legal battles (INT01, INT11).

6.3. Versatile tactics

As indicated by RMT, the kia'i have managed to maintain opposition to TMT and attract widespread attention to their advocacy because they employed versatile tactics. What is noteworthy is that some of these tactics were borrowed from past Hawaiian struggles, such as the movement to demilitarize the island of Kahoʻolawe (INT13, INT16), and other indigenous efforts to protect indigenous lands and cultural practices. The Dakota Access Pipeline Protests led by the Standing Rock Sioux in Dakota in particular had considerable influence on the kiaʻi (INT01, INT03, INT10, INT11). Some of the kiaʻi leadership lent support to Standing Rock and participated in workshops that were organized during the Dakota Access Pipeline Protests to learn how to engage in "peaceful resistance" (INT11, INT08). A Hawaiian policymaker said that the parallels between the tactics used in Standing Rock and on Mauna Kea were palpable:

> *"And the folks who were organizing the protests on the Mauna were very consciously using the same techniques that they used in Standing Rock […]."* (INT12)

The tactics that the kiaʻi used throughout their efforts to stop TMT from being built ranged widely. When opposition first arose in 2011, it was mainly voiced within "state sanctioned spaces" ([22]: 341–342), such as the courtroom. Later, in 2014, 2015, and 2019, when protest activities mainly took place on Mauna Kea, the kiaʻi considerably extended their tactical repertoire. This repertoire included but was not limited to campaigning on social media, front line action, chanting, and hula performances ([24]: 2–4 [20];: 332). A kiaʻi summarized the change between tactics that were employed in early phases of the struggle and those that were used during the later stages as follows:

> *"What shifted is that before we were operating within their scheme of life. So we were talking about the court case, the laws and the reports. And with the Mauna, we were living our truth, we were living our culture, we were being who we are. […] When protocol is happening […], that is such a different story than us saying what is flawed in that report. Like, to heck with your process."* (Kehaunani Abad cited in: Kuwada and Revilla, [12]: 680)

Interviewees moreover underlined that during later protest cycles, social media was crucial to inform people in Hawaiʻi and elsewhere about events on Mauna Kea, to keep them engaged in the struggle to halt TMT, and to gain sympathetic support:

> *"[…] the Native Hawaiian people were able to sustain opposition to the telescope, probably because of modern technology, the ability to get the word out there, get more people involved."* (INT07)

As opposed to local authorities that used classic information dissemination formats, such as press conferences, using noninstitutionalized formats like social media helped the kiaʻi to reach people beyond Hawaiʻi, including celebrities like Jason Momoa, who joined kiaʻi activities atop Mauna Kea [65] and policymakers like former presidential candidate Elizabeth Warren, who tweeted her support [66].

6.4. Anti-science counterframing

As suggested by framing theory, local resistance to TMT has sustained momentum because the kiaʻi frame the TMT controversy in a way that effectively counters (popular media) frames that reduced it to a struggle of "science vs religion" and depict the kiaʻi as anti-science. These frames surfaced in their most extreme form during the 2015 protest cycle. For instance, in 2014, a *New York Times* commentator implied that the opposition to TMT resembled the persecution of eminent scientists by biblical creationists (cf. [67]). Moreover, in spring 2015, an e-mail leaked in which a US astronomer stated that TMT is "in trouble, attacked by a horde of [lying] Native Hawaiians" (quoted in: [68]). The e-mail triggered widespread outrage, including among astronomers, and especially those of a younger generation [69].

Instead of engaging in this discourse and reducing the TMT controversy to a simple dichotomy of science vs. religion, the kiaʻi – particularly those in faculty positions – framed their struggle as a multidimensional issue in which economic and environmental concerns, as well as the question of indigenous consultation, were at stake (for example Jonathan Osorio quoted in: [70]). Kiaʻi particularly made a point of framing their struggle as a fight against "the process [of how astronomers and politicians pushed for TMT], not the science [itself]" ([71]: 7). In line with this framing, the kiaʻi criticized "mainstream" science, the TMT and its proponents seen to be part of it, for not honoring essential research practices and ethics like getting (indigenous) consent for TMT as well as for "disregarding historical context [and] power dynamics" [71,72]. As a result, to the kiaʻi, the TMT controversy also reflected "an erosion of trust in the […] scientific establishment" [73]. Science per se, at least if done pono (righteously), was not up for debate. Making this distinction in framing the TMT controversy was crucial for the kiaʻi because it helped them to be perceived as legitimate while criticizing a type of big scientific project that is typically considered "good in principle" ([13]: 2706) and is generally associated with "progress and development" ([8]: 53–54).

In their media strategy, the kiaʻi made a conscious effort to clarify that it is possible "to love" science while being critical of how it is conducted. Their media team also invested considerable energy into getting this message out in "smaller, bite-size" social media posts that were easy to spread and "digest", thus rendering kiaʻi messages accessible to a wide audience (Ryan Gonzalez cited in: Kuwada and Revilla, [12]: 641). In doing so, the kiaʻi outlined the boundaries within which they deemed it acceptable for the debate around TMT to occur:

> *"The framing of the TMT conflict* [culture vs. science] *in public and science circles was the most painful of it all.* […] *These statements that equate science to progress and upholding cultural values as backward are* […] *not only incorrect but also dehumanizing.*" [72]

As this excerpt from an opinion piece on the TMT controversy clearly demonstrates, depicting the kiaʻi as anti-science did not fall within the aforementioned boundaries.

6.5. Local and national political opportunity

Moreover, the kiaʻi have succeeded in sustaining momentum for their advocacy because, as POT suggests, the local and the broader political context in the US were conducive to it in three respects. First, efforts to protect a place of great significance to an indigenous population resonated with a greater awareness of indigenous (land) rights throughout the US, as this statement illustrates:

> *"One of the big reasons that I see that it […] has stuck around for so long is probably due to an increasing focus on Native rights. A lot of the protesting coincided just chronologically with the Standing Rock protests […] and a lot of other injustices against native peoples really being brought into the public spotlight."* (INT02)

Second, Hawaiians in favor of TMT were not as well organized or media-savvy (INT02) as the kiaʻi. In addition, they experienced considerable pushback and, in some cases, (INT02) verbal aggression from some community members for their pro-TMT activism. According to interviewees, it was this pushback which led many Native Hawaiians in favor of TMT to remain silent:

> *"There are a lot of people who support TMT, but they are not going to be coming out and shouting it in front of a camera or in front of other people. And part of the reason for that is because the people who did come out in support were receiving death threats. And just the social capital that you lose in being supportive of this project was not necessarily worth it.* (INT05)

Third, the response from local authorities was piecemeal and uncoordinated (INT13), making it easier for the kiaʻi to push their agenda more effectively. Several interviewees commented that local authorities, such as the mayor of Hawaiʻi Island, Hawaiʻi's then governor, and UH were caught off guard by the intensity of the protests in 2014, 2015, and 2019 (INT10, INT13, INT16). As a result, reactions, especially from the local authorities, were ad-hoc and not conducive to easing tensions around TMT.

6.6. Place attachment-driven commitment

Finally, local opposition to TMT has persisted and raised awareness beyond Hawaiʻi because, over time, the kiaʻi have remained committed to the objective of preventing further astronomy development on Mauna Kea. In practice, this has meant that they are willing to take risks and entertain inconveniences to achieve their objectives ([33]: 173). For instance, the kiaʻi have "to take time off from work, rearrange their schedules, organize childcare, and spend money on flights or gas to get" to Mauna Kea (Kuwada and Revilla, [12]: 519). Between 2011 and 2020, this willingness to spend time, energy, and resources to uphold opposition to TMT did not waver. For instance, when opposition first began to emerge around 2011, the petitioners in the first contested case hearing invested considerable time and resources:

> *"For us, it is our own time and expense that covered everything. More than anything it is the time. You got to write a brief. […] The first time around* [during the first contested case hearing for the construction permit]*, we were up until the wee hours of the morning to file our briefs and everything. […] We were doing it from scratch."*(INT10)

In 2015 and 2019, when local opposition to TMT peaked, commitment remained similarly strong, as an interviewee who joined the protest activities at this later stage confirms:

> *"[…] people lived up there* [the base camp at Mauna Kea] *for months in tents and in the backs of their cars. And like that kitchen one* [the person in charge of the kitchen tent at the base camp]*, she stayed there, lived there and just cooked and cooked […] I think it's the dedication and people recognize that."* (INT08)

That dedication was strengthened through a deep cultural, ancestral, and spiritual attachment to Mauna Kea. Interviewees articulated place attachment in different but strong ways. Two kiaʻi that I interviewed for this paper, for example, referred to Mauna Kea as their piko (umbilical cord; INT06) or as "sacred" (INT11). In line with what the literature on REP opposition suggests, this strong attachment to Mauna Kea helped to fuel and sustain opposition because TMT was seen as having a direct negative impact, particularly on the mountain's ecosystem and cultural sites (INT10):

> *"There are really serious environmental impacts we need to consider: the impact to our water. Much of the water for this island is fed from that Mauna. As the state and other agencies […] try to break ground on that Mauna they threaten that water, they threaten our native plants, our native animals."* (Jamaica Osorio in [10]: 00:01:16)

As scholars working on opposition to REP suggest, place attachment

further triggered opposition to TMT because local community members felt that the project was imposed on a place that they cherished without involving them. They also felt that the scientists wanting to build TMT and living among them did not bother to engage with them:

> *"I am 63 years old. I have always lived in the community here, right here in Hilo. Why are you the first* [telescope person] *ever* [to] *come talk to us? […] You have 500 scientists on the island. Where are you?"* (Recounted by INT16)

Finally, the kiaʻi remained committed to their objectives because by participating in protest activities they felt connected to likeminded community members:

> *"And while it was a protest, it was a time for us to reconnect with people we have not chatted with or talked* [to] *in a long time. Share stories. Teach each other new chants and dances and teach the broader community."*(INT11)

This connection to place and sense of community motivated the kiaʻi to take risks and endure inconveniences, such as camping on "pocky" lava fields (INT06). At the same time, the TMT controversy put some (Native) Hawaiians working in the science, technology, engineering, and mathematics (STEM) field in a difficult position, as they felt torn between their identities as local community members and as STEM researchers (INT06).

7. Discussion, conclusion, and outlook

In previous studies on local resistance to Big Science, scholars have argued that Big Science opponents typically struggle to appear legitimate while criticizing Big Science because it is often associated with "development and progress" ([8]: 53). My analysis reveals that this legitimacy problem can be overcome, and local resistance can persist and spread, if six factors are present. These six factors are: multi-generational leaderful organization, grassroots resources, versatile tactics, local and national political opportunity, anti-science counterframing, as well as place attachment-driven commitment.

Some of these factors seem to interact (see Table 3). For instance, during the early phases of the protests, legal challenges to TMT were dominant. Later, when the national context was more attentive to indigenous struggles, legal challenges were combined with more attention-attracting tactics like non-violent direct action and ritual performances. The fact that kiaʻi leaders were individuals with strong connections to Mauna Kea likewise indicates an interaction between the leadership and the place attachment dimension of local resistance. Finally, it is unlikely that the frames that the kiaʻi used would have been as successful, if they had not also been magnified through unorthodox tactics, such as the use of social media. Additional research should further explore these interactions.

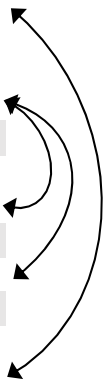
To get a better understanding of how local opposition plays out in different contexts as well as why local opposition does not materialize in contexts that resemble Hawaiʻi (e.g. Australia where a part of the SKA is currently under construction on indigenous land), additional case studies are needed. Such studies could help address the question of whether Big Science can be governed in a way that takes each stakeholder's most important interests into account. A closer examination of recent developments in the TMT controversy may prove insightful in this regard.

In 2020, a working group of community, business, and astronomy representatives was established with the objective of reforming Mauna Kea's stewardship. This working group issued a report on how Mauna Kea's governance could be reformed to mirror the diverse interests of local stakeholders. Based on the report, Hawaiʻi State Act 255 was passed, and a new stewardship authority was installed. The authority consists of eleven voting members, two of which must be Native Hawaiian and recognized practitioners of Native Hawaiian traditional practices [74]. Moreover, the authority is guided by Hawaiian principles and values [75]. Several interviewees were skeptical whether the new authority would adequately represent local interests (INT10, INT05, INT06, INT11), amongst other things because they perceived its establishment as a symbolic move rather than a genuine attempt to include local stakeholders in Mauna Kea's stewardship. At the same time, just as many were cautiously optimistic that the establishment of the new authority would help address local grievances around Mauna Kea (INT02, INT07, INT08, INT09, INT12, INT13). One interviewee commented that the stewardship reform would likely not have occurred without local protests because the kiaʻi raised "awareness and recognition [among] state and county elected leadership that something need[ed] to be done" (INT13).

Almost in parallel, TIO revised its approach to community engagement. As part of the process, it first decided to move its core management team to Hawaiʻi Island. Previously, the team was based in California. Second, after 2020, TIO quietly and personally reached out to the kiaʻi and Hawaiʻi's most deprived communities to get a better understanding of local needs and concerns (INT16). Prior to this, TIO had almost exclusively engaged with its local supporters, often using classic media like TV and newspapers to reach the public. Through its revised

Table 3
Interactions between explanatory factors; double headed arrows indicate interaction.

Theory/Concept	Underlying Logic	Explanatory Factor
Resource Mobilization	Structural–Material	
		Multi-Generational Leaderful Organization
		Grassroots Resources
		Versatile Tactics
Political Opportunity	Structural	
		Local and National Political Opportunity
Framing	Cultural–Ideational	
		Anti-Science Counterframing
Place Attachment	Cultural–Ideational	
		Place Attachment-Driven Commitment



outreach efforts, TIO hopes to have a lasting impact on how the astronomy and science community relate to indigenous people, culture, and lands. Ultimately, however, only time can tell what impact its new approach to community engagement as well as the reform of Mauna Kea's stewardship system will have.

Conflict of interest

The author has no conflict of interest to declare.

Research data

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Appendix

Table 1
Coding Scheme

Code System	Memo
Potential Quotes	This code captures passages where interviewees are particularly poignant.
Local Opposition	This code captures different dimensions of how kia'i organized local opposition to TMT.
Local Opposition > Organization	This subcode captures how kiaʻi organized collective action.
Local Opposition > Organization > Characteristics	This code captures what characterized those that participated in local opposition (e.g. age, part of Native Hawaiian community, profession).
Local Opposition > Organization > Activities/Division of Tasks	This code captures in what activities kiaʻi engaged to halt TMT and who took over which tasks to sustain local opposition.
Local Opposition > Organization > Principles	This code captures which principles and values guided local opposition and kaiʻi activities.
Local Opposition > Organization > Resources	This code captures which resources local opposition to TMT could rely on over time.
Local Opposition > Organization > Resources > Aloha Aina	
Local Opposition > Organization > Resources > Human Capital/Community/Familial	
Local Opposition > Organization > Resources > Moral	Moral resources include sympathetic groups, organizations, policymakers and celebrities.
Local Opposition > Organization > Resources > Material	
Local Opposition > Organization > Leadership	
Local Opposition > Organization > Leadership > Authority	
Local Opposition > Tactics	This code captures which tactics kiaʻi employed over time to protest TMT.
Local Opposition > Tactics > Non-Violent Direct Action	
Local Opposition > Tactics > Legal Challenges	
Local Opposition > Tactics > Social Media Campaigning	
Local Opposition > Opportunity Structure	This code captures the general political context in which kiaʻi activities took place.
Local Opposition > Opportunity Structure > Past/Other Hawaiian Struggles	This code captures to what extent other and past Hawaiian struggles influenced local opposition to TMT.
Local Opposition > Opportunity Structure > Connections to Other Indigenous Struggles	This code captures to what extent local opposition to TMT received support and inspiration from other indigenous struggles.
Local Opposition > Opportunity Structure > General Awareness for Native Rights	
Local Opposition > Opportunity Structure > Elite Support	This code captures to what extent elite groups supported local opposition to TMT.
Local Opposition > Opportunity Structure > Pro-TMT-Group	This subcode captures how the group campaigning for TMT was organized, on which resources it could rely, which tactics it employed, how it framed its claims, in what ways it was attached to Mauna Kea and how committed it was to its cause.
Local Opposition > Opportunity Structure > Pro-TMT-Group > Resources	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Resources > Human	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Resources > Moral	

(*continued on next page*)

Table 1 (*continued*)

Code System	Memo
Local Opposition > Opportunity Structure > Pro-TMT-Group > Organization	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Place Attachment	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Framing	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Framing > Frames	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Commitment	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Tactics	
Local Opposition > Opportunity Structure > Pro-TMT-Group > Tactics > Social Media Campaigning	
Framing	This code captures the meaning-making processes that are associated with the construction and interpretation of grievances, the attribution of blame, and the selection of collective action targets and tactics.
Framing > Frames	Frames are the central organizing ideas through which kia'i tell the public what their grievances in relation to TMT are.
Framing > Frames > Not Enough Community Engagement	
Framing > Frames > Us Against Them	
Framing > Frames > Consent	
Framing > Frames > Anti-Corporation	
Framing > Frames > Counter-Frames	
Framing > Frames > Environmental	
Framing > Frames > No Benefits	
Framing > Frames > Mismanagement	
Framing > Frames > One Too Many/Enough is Enough	
Framing > Frames > Spiritual/Ancestral/Religious	
Framing > Frames > Political/Sovereignty	
Collective Identity/Sense of Community	This code captures passages in which interviewees describe how the protests on and off Mauna Kea strengthened a sense of collective identity and community.
Motivation to Participate	This code captures passages in which interviewees describe why they got involved in local opposition to TMT.
Commitment	This code captures passages in which interviewees describe how committed they (kia'i) were to halt the construction of TMT.
Place Attachment	This code captures passages where interviewees describe their attachment to Mauna Kea.
Policymaker/UH/TMT Response to local opposition	This code captures how local policymakers as well as the Universtiy of Hawai'i and TMT have reacted to local opposition.
Outcome of Local Opposition	This code captures what the outcomes of local opposition to TMT are.
Outlook	This code captures passages where interviewees describe how they think local opposition to TMT will develop, whether TMT will eventually be built and how a planned stewardship reform of Mauna Kea might impact local opposition.
History of Protests	This code captures how local opposition to astronomy development on Mauna Kea has evolved since the 1960s.

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