An Everettian Account of Modality

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Abstract:

In this thesis I propose that if Everettian Quantum Mechanics (EQM) is correct, then ordinary-objects contained within Everettian worlds ground the truth of nomic *de re* modal statements in a desirable way.

Guided by desiderata set out following a brief assessment of notable modal accounts, I outline one way in which an Everettian account of objective *de re* modality can be formulated. By applying Eternalism and a formulation of Worm Theory to branching EQM with overlapping worlds, I arrive at an Everettian account of modality whereby concrete ordinary-objects – perduring 'Branching-Worms' – ground the truth of *de re* modal statements, in virtue of having parts which exemplify properties that the modal statement asserts of the ordinary-objects.

I conclude that the Everettian modal account I have outlined requires further development in certain areas but hopefully shows some promise as a contending account of modality.

Impact Statement:

This thesis provides the groundwork for further development of an alternative modal account premised on the truth of the Many-Worlds Formulation of Quantum Mechanics. It contributes to an understanding of the metaphysical implications of the Many-Worlds Formulation of Quantum Mechanics with overlapping worlds.

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Dedicated to my family and friends

as a token of appreciation for their unwavering support.

Chapter One

Introduction, Notable Modal Accounts and the Everettian Quantum Mechanics

§0: Introduction

In this thesis I propose that if 'Everettian Quantum Mechanics'[1] ('EQM henceforth) is correct, then ordinary-objects contained within Everettian worlds ground the truth of nomic *de re* modal statements in a desirable way. I outline one way in which an Everettian account of objective modality can be formulated.

My 'Everettian account of modality' ('EAM' henceforth) is guided by desiderata set out following a brief assessment of notable realist accounts of modality in Chapter One, where I also outline the version of EQM I adopt.

In Chapter Two I formulate EAM by applying Eternalism and Worm Theory to EQM with overlapping worlds. The account I ultimately arrive at is one whereby concrete ordinary-objects – perduring 'Branching-Worms' – contained within an Eternalist branching EQM universe ground the truth of *de re* modal statements, in virtue of having parts which exemplify properties of which the modal statement asserts of the ordinary-objects.

In Chapter Three I briefly compare EAM with the modal accounts assessed in §1 and outline areas in need of further development. I conclude that EAM hopefully shows potential to be a viable contending account of modality.

My account focuses on the metaphysical underpinnings of modal semantics and provides the truth conditions – not the meaningfulness – of modal statements. I primarily talk of how objects 'ground the truth' of modal statements. However, like Wilson I assume it makes little difference whether we are seeking an account of what constitutes modal facts, or what grounds them or of what makes them true (Wilson 2020, 21).

As the modal account I outline is premised on the truth of EQM, I focus on physical or nomological modality (I use these terms interchangeably); what is possible or necessary given the laws of physics.[2] Any modal terms used while outlining my account refer to physical modality, unless stated otherwise. Specifically, I take a "*de re* first" approach, similar to Vetter (2015) and Wang (2020, 188-91), by focusing on the particularly important class of *de re*

[1] First proposed in 1957 by Hugh Everett (Everett et al. 1973, 141-50).

[2] I briefly address options for metaphysical possibility in *§9.3.1*.

modality. I also focus discussion on possibility, as opposed to necessity, as I take possibility statements to require more explication than necessity statements. As I assume the duality of possibility and necessity – *p* is possible iff it's not necessary that not-*p* – I indirectly provide an account of necessity.

§1: Notable Modal Accounts

In this section I briefly assess some notable modal accounts which assume realism about modal truths. I focus my assessment on realist accounts of modality which ground *de re* modal statements about ordinary-objects around us in concrete ordinary-objects, as these accounts ground modal and non-modal truths in the same kind of entities.[3]

The aim of this assessment is to present my motivations for outlining an alternative account of modality and to aid in determining what desiderata this alternative account of modality will aim to meet. Due to space limitations, I cannot conduct an exhaustive or thorough assessment of modal realist accounts, my brief assessment consists of outlining what I deem to be the positive and concerning aspects of each account. Although my assessment is not exhaustive or thorough, it hopefully suffices to arrive at desiderata for an alternative account.

I don't claim the concerns outlined deal decisive blows to these accounts. I note that some of the concerns are driven by an unargued for intuition that *de re* modal truths are – like *de re* non-modal truths – located in the very objects we are talking about, rather than distinct objects. I take this intuition to be a powerful one, but readily accept that intuitions may well be misplaced and not unanimously shared. This assessment is then partially driven by an unargued for intention to seek unity in this area.

[3] I assume that non-modal *de re* statements about objects around us are grounded in concrete ordinary-objects – such as tables and chairs – which are causally and spatiotemporally related to ourselves. I further assume that it is preferable to ground modal and non-modal truths in the same kind of entities, hence achieving theoretical unity in this regard. However, I acknowledge these assumptions aren't uncontroversial. Given space limitations I cannot adequately assess accounts which ground modal statements in the kinds of things which aren't – I assume – concrete ordinary-objects, such as mental objects (Berkeley 1968), facts (Russell 1994; Wittgenstein 2014), sets of sentences (Carnap 1947), sets of propositions (Plantinga 1974), states-of-affairs (Stalnaker 1984) or fictions (Armstrong 1989; Rosen 1990).

First, I assess Lewis' Modal Realism. Second, Wilson's Quantum Modal Realism. Third, Meg Wallace's Lump Theory. Fourth, Vetter's Potentialities account. Finally, I outline the desiderata for an alternative account of modality.

§1.1 Lewisian Modal Realism

Possible worlds are near unanimously used to explain modal talk. Lewis' Modal Realism takes quantification over possible worlds literally and ontologically commits to all logically possible worlds really existing, described completely by sentences in some maximally consistent set (Lewis 1986, 2-9).

According to Lewis, modal statements about what is possible – 'possibly *p*' – existentially quantify over at least one relevant world and are true iff *p* is true in at least one possible world. Modal statements about what is necessary – 'necessarily *p*' – universally quantify over all relevant worlds and are true iff *p* is true in all relevant possible worlds. Modal statements about what is impossible – 'impossibly *p*' – are equivalent to 'necessarily not-*p*' and true if *p* is false in all worlds (Lewis 1986, 5-20).

As Lewis assumes Eternalism, possible worlds consist of an equally real past, present and future. Lewis states that possible worlds are a mereological maximal sum of concrete objects – objects with spatiotemporal relations – and a sum X is a world iff:

1) Any two parts of X are spatiotemporally related to each other; and
2) If anything is spatiotemporally related to a part of X, it is part of X too.

Lewisian possible worlds therefore have no causal or spatiotemporal relations between them. They are completely 'causally and spatiotemporally isolated' ('CST-isolated' henceforth) from one another (Lewis 1986, 69-86).

According to Lewis, possible worlds are ontologically equal with no world being privileged in any way. Our world – the 'actual' world – is one possible world amongst many. Our world doesn't have a special property of actuality, instead 'actuality' is indexical like 'here' or 'now'. The term 'actual' refers to – and is relative to – the possible world in which the word is uttered (Lewis 1986, 92-6).

Lewis holds that the things we normally quantify over – 'ordinary-objects' like tables and chairs etc. – are 'causally and spatiotemporally related' ('CST-related' henceforth) to one another within a world. But ordinary-objects in different worlds are CST-isolated from one another and there is no identity across worlds. In other words, ordinary-objects don't have 'trans-world

identity' as no one ordinary-object exists in more than one possible world (Lewis 1986, 69-81 & 198-220).[4]

So, for Lewis modal statements about ordinary-objects in the 'actual' world quantify over counterparts – concrete ordinary-objects that are sufficiently similar in relevant respects – which exist in other possible worlds. It is CST-isolated counterpart ordinary-objects and the properties they exhibit which ground the truth of modal statements about ordinary-objects in the actual world (Lewis 1986, 6-12, 32-52, 69-77 & 194-8).

For example, "I might win the lottery" is true given there is some possible world in which a counterpart of mine does in fact win the lottery. This counterpart is very much like me in a number of relevant respects as he has many of the same properties as me. Yet this counterpart differs from me as he has the property of winning the lottery whereas I do not.

Lewis holds that modal knowledge arises from our tacit knowledge of the Recombination Principle. We come to know what possible worlds are like by imagining states of affairs and recombining them to form an understanding as to what exists in possible worlds (Lewis 1986, 87-116).

§1.1.1 Positives

Lewis argues for Modal Realism on the grounds of its explanatory power and theoretical benefits. It is a reductive account of modality which avoids circular appeal to modal notions and provides unified modal semantics; what grounds the truth of all modal statements are concrete entities.[5] For Lewis, concrete entities don't have fundamentally modal properties and are described without needing to appeal to modal notions. So what is possible is reductively explained by, and grounded in, what there is i.e., what exists in the plurality of concrete worlds.

Lewis' account is ontologically (qualitatively) parsimonious in that it doesn't posit the existence of new general kinds but only admits more of what is already in our ontology; concrete entities. Many semantic accounts of modality, such as Kratzer (2012), adopt Lewisian Modal Realism given its serviceability in neatly explaining the truth of a whole array of modal discourse with very few principles (Lewis 1973 84-91; 1986, 3, 81-6).

[4] However, as Lewis accepts unrestricted mereological composition whereby any two objects can compose a third object, he accepts trans-world identity of unimportant 'unordinary objects' across CST-isolated worlds (Lewis 1986, 210-220).

[5] Cameron (2012) defends Modal Realism's reductivity.

I take the concreteness, reductivity and parsimoniousness of Lewis' account to be particularly positive features. I hold that an account which explains modal talk in a similar way to non-modal talk is – all other things being equal – preferable to an explanation where there is a stark difference. Where we can, we should prefer an explanation which reductively grounds the truth of modal talk about physical ordinary-objects in physical ordinary-objects – just as the truth of non-modal talk about physical objects is grounded in physical ordinary-objects. So, the fact that on Lewis' account nomic modal and non-modal statements are reductively grounded in concrete entities is particularly appealing.

§1.1.2 Concerns

Although Lewisian Modal Realism has many positive qualities, there are some concerning aspects.

Given that Lewis posits the existence of a plurality of CST-isolated possible worlds on metaphysical and semantic grounds, this raises epistemic concerns. Furthermore, given the CST-isolated nature of worlds, there is also a fairly significant disparity between modal and non-modal semantics and epistemology.

Lewis posits the existence of unobservable possible worlds on the basis of metaphysical and semantic conjecture alone, without any appeal to natural sciences. However, semantic serviceability alone is not a strong enough reason to posit the existence of a plurality of concrete worlds.

As O'Leary-Hawthorne puts it, even if serviceability confers some degree of justification of a theory – and even if that theory is true – this isn't sufficient for knowledge (O'Leary-Hawthorne 1996, 190-1).

Wilson voices similar concerns stating that Lewis never satisfactorily addresses Modal Realism's inability to account for the envisaged epistemic access to the plurality of worlds. The problem being that Lewis' epistemology fails to identify evidence that counts in favour of the principle of recombination in the first place. It provides us with no epistemic evidence for why the epistemic practice of recombination got started (Wilson 2020, 9-10).

So, Lewis' justification for positing the existence of a plurality of concrete worlds is on shaky epistemic grounds. I take it that when it comes to positing the existence of infinitely many concrete worlds other than our own, a naturalistic theory which is scientifically backed is epistemically preferable to one that doesn't appeal to science and is justified one semantic serviceability alone.

Another potential epistemic concern put forward by Skyrms (1980, 326) is that as Lewisian worlds are CST-isolated from one another, we can't have knowledge of them. O'Leary-Hawthorne states that if our modal talk is made true by goings on in CST-isolated worlds, then such worlds seem epistemically inaccessible – we have no way of knowing such worlds or the objects contained within them (O'Leary-Hawthorne 1996, 185).

Wilson voices a similar concern, stating that given the very CST-isolated nature of possible worlds we cannot provide a causal explanation for how we know of such worlds and objects. Unlike with non-modal cases, there is no causal chain between the utterer and what they are talking about. How we have modal knowledge remains a mystery (Wilson 2020, 10-1).

The truth of non-modal talk about the ordinary-objects around us is – for the most part – grounded in those ordinary-objects and the properties they exemplify; ordinary-objects which are – I assume – in some way CST-related to the utterer of the statements. The utterer has causal knowledge of ordinary-objects given they aren't CST-isolated.[6]

Lewis admits there is a causal constraint on our knowledge for contingent matters but claims that much like we have mathematical knowledge without direct inspection of mathematical objects, there is no causal constraint on modal knowledge either. For Lewis, the principle of recombination and the serviceability of Modal Realism – assuming the theory is true – is good enough for knowledge of possible worlds (Lewis 1986, 108-115).

It may be so that mathematical knowledge doesn't have a causal explanation, nor that knowledge requires causal explanation. However, it doesn't follow that our modal knowledge of possible worlds doesn't, or can't, feasibly have some kind of causal explanation like our non-modal knowledge.

Intuitively, our knowledge of the modal properties of ordinary-objects around us seems more akin to our non-modal knowledge of such objects than to mathematical knowledge. At the very least, modal knowledge seems more accessible and readily acquired than mathematical knowledge.

That said, even if we don't require CST-relatedness for knowledge, we typically understand it to play an important part in the case of non-modal talk. There is then a disparity between modal and non-modal epistemology,

[6] Although I assume ordinary-objects are CST-related to ourselves, I acknowledge this isn't unanimously agreed upon, nor is the nature of causality.

and what grounds the truth of statements on Lewis' account, particularly in the case of *de re* statements about ordinary-objects around us.

For Lewis, non-modal *de re* statements are about – or refer to – a particular ordinary-object which is CST-related to the utterer. The truth of such statements is grounded in that particular ordinary-object itself with CST-related temporal parts exemplifying properties which the utterer asserts of that ordinary-object.

However, for Lewis the truth of *de re* modal statements about a CST-related ordinary-object in our world isn't grounded in that very ordinary-object and its parts. Rather they are grounded in that ordinary-object and some wholly distinct counterpart of it; CST-isolated ordinary-objects which exists in some CST-isolated world and are knowable via *a priori* mathematical-like epistemology.

So, although Lewis seeks theoretical unity, on Lewis' account there is a rather significant disparity between what grounds the truth non-modal and modal *de re* statements about ordinary-objects around us, as well as a disparity in how we know of such objects.[7]

This isn't to say that unity in this area is required or preferable to other forms of unity the Lewis's Modal Realism does in fact achieve. Nor is this to suggest that this disunity in Lewis' account is inherently problematic and that Modal Realism should be rejected on this basis. Instead, this disunity is a moderately concerning aspect which seems at odds with our intuitions and is hence a motivating factor for seeking an alternative account where there isn't disunity of this kind.

The epistemic and semantic disparity between modal and non-modal *de re* statements is arguably due to the CST-isolated nature of worlds on Lewisian Modal Realism. So, although the truth of both modal and non-modal statements are grounded in the same kind of thing – concrete entities with fundamentally non-modal properties – there remains a stark difference between where these entities are located and our knowledge of them.

I claim that the counterintuitive nature of Lewis' account – which Lewis dismisses as an 'incredulous stare' – is indicative of the disparity we see

[7] Kripke's Humphrey objection similarly tries to capture the intuition that *de re* modal statements about an object are grounded in that very object itself (Kripke 1980, 45). However, my objection isn't based on relevance but rather seeking unity in this area, identifying modal and non-modal statements about an object with that very object itself and the properties it itself exemplifies.

between modal and non-modal semantics and epistemology, as well as the epistemic concerns with positing such worlds in the first place.

§1.1.3 Summary

Even though very few legitimately subscribe to Modal Realism, Wilson notes that there is a deep-rooted and ingrained practice of reasoning under the pretence and supposition that it is correct (Wilson 2020, 12). However, just because Modal Realism is incredibly serviceable, it doesn't therefore make it true or representative of what exists.

Lewis posits the existence of possible worlds without appealing to science. As Lewisian modal semantics are based on metaphysical and semantic conjecture alone, they're built on shaky epistemic grounds. A desirable modal account must have firmer foundations.

The CST-isolated nature of possible worlds also brings about concerns of how we can have epistemic access to possible worlds. Even if these epistemic concerns aren't conclusive and our knowledge of such worlds can be explained by an *a priori* mathematical-like epistemology, there remains a disparity between how we know about modal and non-modal truths.

This disparity is one area in which Lewis doesn't achieve theoretical unity and is motivation for seeking an alternative account which does achieve this unity. Even if it ultimately results in disunity elsewhere, I take it to be worthwhile exploring what an account which is scientifically backed and doesn't have this disunity would look like, one whereby modal and non-modal statements are grounded in CST-related objects which share a causal epistemology. Again, this isn't to say this kind of unity is better than the unity that Lewis does achieve, but it is an area worthy of further exploration.

That said, Lewis' account certainly has many desirable qualities, namely that it reductively and parsimoniously grounds the truth of modal statements – in a unified way – in concrete entities. A desirable account should aim to emulate such qualities.

In Chapter Two I outline a realist account which avoids the epistemic concerns of Lewisian Modal Realism while reductively and parsimoniously unifying modal and non-modal *de re* semantics about ordinary-objects.

§1.2 Wilson's Quantum Modal Realism

Wilson's Quantum Modal Realism ('QMR' henceforth) is similar to Lewisian Modal Realism except that the existence of possible worlds is based on the Everettian Quantum Mechanics (EQM), as opposed to serviceability alone.

Wilson holds that the fundamentally non-contingent and deterministic laws of EQM posit the existence of infinitely many concrete CST-isolated Eternalist 'Everett worlds' (or 'universes'). Any way that EQM permits a world to be is a way in which some world is and collectively these worlds fit together like pieces in a jigsaw puzzle to make up the 'Everettian multiverse'. Our 'actual' Everett world is just one among many whereby 'actual' is indexical and our location within the multiverse is contingent (Wilson 2020, 22-68).

Wilson doesn't take causality to be fundamental and worlds are instead law-governed patterns rather than features of a causal process. Furthermore, as worlds are isolated from one another, we know of them due to a common ground epistemology, as described by Ismael & Schaffer (2020) (Wilson 2020, 60 & 85-6).

Wilson equates metaphysical modality with physical modality and on QMR Everett worlds are possible worlds whereby Everett worlds ground the truth of all modal statements. Like with Lewis' account, modal statements about particular ordinary-objects are grounded in their counterpart relations between CST-isolated Everett worlds (Wilson 2020, 26 & 52).

§1.2.1 Positives

Wilson's QMR shares a lot of the same positive features as Lewisian Modal Realism. It is ontologically parsimonious in that it doesn't posit entities or new general kinds (which aren't already accounted for by science). It is reductive in that it grounds modal truths in concrete objects, without circular appeal to modal notions. Although not as serviceable as Lewis', it can account for a whole array of modal statements including advanced modalizing.

Furthermore, Wilson's account addresses the main epistemic concern relating to Lewisian Modal Realism. On QMR the existence of possible worlds is posited on the basis of rigorous science and not on metaphysical speculation and semantic serviceability alone. Therefore, QMR has much firmer epistemic foundations than Lewis' as it provides a naturalistic and scientifically backed Modal Realism, while reaping many of the same rewards as Lewis' (Wilson 2020, 3-4).

§1.2.2 Concerns

One potential epistemic concern with QMR, as with Lewisian Modal Realism, is that possible Everett worlds are CST-isolated from another. Even if Wilson invokes a common ground epistemology, there seems to be a disparity between how typically understand to have non-modal knowledge of objects within our world to modal knowledge across worlds.

That said, even if we were to eradicated this apparent disparity by understanding our modal and non-modal knowledge to be via a common ground epistemology, there remains a disparity between what objects ground modal and non-modal *de re* truths, and where these objects are located.

The truth of *de re* non-modal statements about an ordinary-object is grounded in that very ordinary-object and the properties it itself exemplifies. Whereas the truth of *de re* modal statements about an ordinary-object is, on Wilson's account, grounded in that ordinary-object and its counterpart relations with some wholly distinct counterpart ordinary-object which exists in some CST-isolated world.

Again, this isn't to say this disparity is an inherently problematic aspect of QMR. Nor is it to claim that unity in this area is preferable to other forms of unity that QMR achieves, but there is disunity here. Simply put, I take it to be worth exploring what an alternative account would look like where there isn't this disunity, even if such an account ultimately brings about other forms of disunity. There is however room to do this on a EQM framework.

Wilson notes that EQM doesn't itself determine the structure of the many-worlds and this is to some degree open to metaphysical interpretation. Wilson adopts a 'diverging' conception of worlds – similar to Lewis' – whereby 'Everett worlds' are CST-isolated from one another and have no parts in common with one another. However, Wilson also notes that worlds can be understood as 'overlapping' with one another, as opposed to diverging from another. On the overlapping conception, different worlds share parts in common and collectively have a branching structure (Wilson 2020, 86-96).

Adopting a EQM with overlapping worlds can result in an account of *de re* modality that grounds modal statements about an ordinary-object in that very object itself, in vitue of its properties and not come distinct counterpart ordinary-object, hence resulting in a unity between modal and non-modal *de re* statements about ordinary-objects around us.

As McDaniel notes, the main motivation for embracing the claim that possible worlds literally overlap is the intuition that the truthmaker for claims such as 'It is possible that Al Gore won the 2000 U.S. presidential election' must include, in some intimate sense of 'include', the object that the claim is about (McDaniel 2004, 137 & 139).

Saunders and Wallace also note that a principal attraction of EQM with overlapping worlds is there is an exact similarity in *de re* modal claims, for example Al Gore might have won the 2000 US presidential election, if he has

a temporal part which is a part of a person who won (Saunders & Wallace 2008, 298).

However, Wilson adopts diverging worlds as he argues that they best allow for non-modal future for future tensed talk to have a determinate truth value, they avoid the problem of accidental intrinsics relating to trans-world objects and Wilson claims diverging worlds can best account for objective probability on EQM (Wilson 2011, 19-21; 2020; 86-92).

Although Wilson provides persuasive arguments in favour of diverging worlds – which I address in *§5.2.2* and *§6.3.2* – they aren't sufficient to altogether rule out the prospect of overlapping worlds. Suffice to say, the case isn't closed and there remains the feasible option of adopting overlapping worlds. I follow McDaniel's sentiment that it is worthwhile to see how far alternatives of modal realism can be pushed and I take it to be worth outlining an account of modality that uses the EQM framework but adopts overlapping worlds, hence providing an alternative to Wilson's account.

§1.2.3 Summary

Wilson's cutting-edge account certainly emulates many positive aspects of Lewis', all while addressing the biggest epistemic concern of Lewisian Modal Realism. The reductive, concrete and parsimonious nature of Wilson's account are particularly positive qualities. Furthermore, the fact that QMR is based on rigorous highly regarded science and the existence of possible worlds is a matter of science makes QMR a particularly epistemically viable Modal Realist account.

Even if the potential epistemic concerns relating to CST-isolated worlds are addressed, there does remain a disparity between where the objects that ground modal and non-modal truths are located, due to the invoking of counterpart theory across CST-isolated worlds. This isn't to say that this is an inherently problematic feature of QMR, but the framework of Many-Worlds does itself allow for a modal account which avoids disunity in this area by adopting overlapping worlds instead of diverging worlds. I take it to be worth exploring what this account would look like.

In Chapter 2 I outline one such account which unifies modal and non-modal *de re* semantics about ordinary-objects around us, while emulating some of the positive aspects of QMR.

§1.3 Meg Wallace's Lump Theory

Meg Wallace adopts Modal Realism (Lewisian or otherwise) whereby CST-isolated concrete Eternalist possible worlds exist and ground modal truths

(Wallace 2019, 404).[8] Wallace argues that if we are to accept unrestricted mereological composition across such worlds then we arrive at Lump Theory for ordinary-objects which are trans-world mereological sums worthy of our attention (Wallace 2014, 358; 2019, 410).

Lump Theorists hold that ordinary-objects are lump sums – 'Lumps' – of spatial, temporal and modal parts.[9] Ordinary-objects aren't wholly located in one particular possible world but are trans-world mereological sums of world-bound modal parts spread across CST-isolated possible worlds (Wallace 2014, 355; 2019, 403-6).[10]

On Lump Theory differences between modal parts of ordinary-objects ground the truth of modal statements about an ordinary-object. For example, it is true that some individual could be president as that trans-world individual has at least one modal part – located in a possible world – that is president. Ordinary-objects have a rich modal profile, what is possible for an ordinary-object is determined by what modal parts they have in various possible worlds (Wallace 2014, 359; 2019, 405-6).

§1.3.1 Positives

Given that Lump Theory adopts Lewisian Modal Realism it benefits from the aforementioned positive features: reductive, concrete and parsimonious.

It also goes some way to addressing the disparity in what objects ground modal and non-modal statements. On Lump Theory, the truth of *de re* modal statements about a particular ordinary-object is grounded in that ordinary-object itself, in virtue of its parts, albeit CST-isolated parts.

Wallace is right that even though we don't typically think of ourselves as trans-world individuals, we think modally about ourselves and care about what is possible or impossible for us, considering such things a part of who we are (Wallace 2014, 371; 2019, 431).

Lump Theory appeals to the intuition that what we say modally about an ordinary-object – what is possible for that ordinary-object – is really about that

[8] Wallace notes that abstractionist Lump Theory is coherent. Yet Wallace assumes Modal Realism for explanatory purposes and claims Lump Theory gives support to Modal Realism (Wallace 2019, 420).

[9] Wallace maintains one can commit to Lump Theory without committing to spatial or temporal parts (Wallace 2014, 359; 2019, 405).

[10] McDaniel puts forward a similar but different view where three dimensional ordinary-objects are wholly present at multiple worlds (McDaniel 2004). However, Wallace assumes the parthood relation is generally univocal, whereas McDaniel's Modal Realism with overlap does not. Given space limitations I cannot assess this further.

ordinary-object itself and not about some wholly distinct counterpart ordinary-object.

Lewis admits that if we accept unrestricted composition then there are trans-world objects. But Lewis regard these as metaphysically irrelevant unordinary objects that we don't typically quantify over and are undeserving of our attention (Lewis 1986, 210-20).

However, Wallace argues that adopting modal parts has the advantage of providing a theoretically elegant and unified solution to traditional metaphysical puzzles of constitution, composition and co-location which classical Worm Theory alone cannot solve. Given the utility of the theoretical advantages of Lump Theory, trans-world objects are worthy of our attention (Wallace 2014, 360; 2019, 420-1).

Wallace argues that a rich modal profile is integral to ordinary-objects whereby the persistence conditions of ordinary-objects are often defined and distinguished by what ordinary-objects can and cannot do. A modal profile plus Leibniz's Law distinguishes coincident entities. For example, the statue and lump have exactly the same spatial parts at exactly the same time, yet the lump can survive being squished while the statue cannot. As these ordinary-objects have different modal profiles, we assume they're distinct ordinary-objects. Modal profiles are then part of the ordinary-object; how it could or could not be is part of what it is (Wallace 2019, 416).

Wallace explains the distinction between the statue and the lump by appealing to the trans-world ordinary-objects having parts which overlap and parts which don't. The statue cannot survive being squished because in all worlds where it is squished it ceases to exist. But the lump can survive being squished because in all worlds where it is squished it continues to exist. The statue and lump are distinguished as not all of their parts overlap. The modal difference between the statue and lump is accounted for by the qualitative differences of their modal parts which mirrors the explanation of spatial and temporal coincidence. So Lump Theory provides a unified and theoretically elegant solution to the puzzle (Wallace 2019, 422-3).[11]

§1.3.2 Concerns

One of the biggest concerns, which Wallace identifies, is that Lump Theory assumes the existence of CST-isolated diverging worlds.

Wallace assumes that concerns about adopting Modal Realism come from an abstractionist position and addresses the worry by maintaining that

[11] McDaniel's view benefits from the same theoretical benefit (McDaniel 2004, 150-1).

abstract possible worlds are coherent with Lump Theory; whereby ordinary-objects are trans-world mereological sums of concrete objects and parts of abstract possible worlds (Wallace 2019, 412-3, 419-20).

However, my concern to Lewisian Modal Realism doesn't come from an abstractionist position, rather the fundamental epistemic concern regarding the positing of possible worlds. Wallace doesn't address the epistemic concern but instead claims that given the utility concrete modal parts offer, prejudices against Modal Realism should be reconsidered (Wallace 2019, 420).

Even if concrete modal parts provide explanatory utility, the epistemic concerns with Modal Realism are unprejudiced and legitimate. To suggest that such utility is reason to accept Modal Realism is putting the cart before the horse. Wallace's response to the Modal Realism worry is unsatisfactory.

Even if we are to sub in QMR for Lewisian Modal Realism on Lump Theory in an effort to address the fundamental epistemic concern, there remains a disparity in where the parts that ground modal and non-modal statements are located.

Wallace intends for modal and temporal parts to be analogous in appropriate ways, whereby any view that is committed to modal parts is parallel in structure to that of temporal parts (Wallace 2014, 358-60). However, given Lump Theory assumes CST-isolated worlds, Lump ordinary-objects have CST-isolated parts. The only relation between such parts is similarity. Standard temporal parts however are similarity and CST-related. So, there is a disanalogy between classical ordinary-objects and Lump ordinary-objects. This is what Wallace calls the 'Causal Isolation Worry' (Wallace 2019, 423-4).

Wallace claims that the principled reason for rejecting Lump Theory on the basis of causal isolation, is that causal relations are integral to accounting for gradual change over time of temporally extended objects. Gradual change is classically explained by causal relations between parts located at different times. Trans-world lumps are not related in such ways so cannot account for change over worlds (Wallace 2019, 408 & 423-4).

Wallace claims that causal relations between relevant parts aren't required to account for change over possible worlds. She claims change over possible worlds is like that of change over spatial regions; characterised by incremental qualitative differences and similarity closeness relations between relevant parts (Wallace 2019, 425-6).

However, Wallace's depiction of 'change over a spatial region' is a mischaracterisation of change. Qualitative difference between spatial parts of an object isn't real change. Wallace is describing the observation of different spatial regions and the differences between them: change in what is being perceived over time, not change of the object itself. Change inherently involves a temporal and causal element, which Wallace's characterisation cannot account for. So, there remains a stark difference between temporal parts and modal parts on Lump Theory; different temporal parts of an object can account for change while modal parts cannot.

Even if the epistemic concerns relating to CST-isolated worlds can be addressed, Wallace's response to the issue of gradual change misses the mark and there remains a disparity between modal parts and temporal parts.

§1.3.3 Summary

Wallace's account benefits from the positive features of Lewis' while also trying to appeal to the intuition that modal properties are parts of ordinary-objects themselves. Lump Theory also has the bonus of neatly dealing with the aforementioned metaphysical puzzles.

However, despite attempting to unify modal and temporal parts in an appropriate way, there remains a disparity in how they account for change as well as where such parts are located: temporal parts are CST-related while modal parts are CST-isolated.

In Chapter Two I outline an alternative account for modal parts which reaps the additional rewards of Lump Theory while unifying the nature of modal and temporal parts without the same disparities as on Lump Theory.

§1.4 Vetter's Potentialities

An alternative modal account is Vetter's Potentiality approach (Vetter 2015). Unlike previously assessed accounts, Vetter's is a non-reductive approach which doesn't appeal to possible worlds.[12]

Vetter's approach comes from an anti-Humean position whereby the world is irreducibly dispositional, it isn't made up of non-modal materials at its base. Given this starting point, Vetter holds there is no reason to outsource modality to (Humean) possible worlds (Vetter 2015, 7-10).

[12] I set out to assess realist accounts of modality, although Vetter's account isn't 'Modal Realism' like the aforementioned accounts, it is a realist account as it grounds modal truths in concrete ordinary-objects.

On Vetter's account, individual ordinary-objects are concrete entities which have fundamentally modal properties called 'potentialities', dispositions to act in certain ways. Potentiality is 'localised' in the sense that it is a property of individual ordinary-objects, as opposed to non-localised 'possibility' being about things in general and not primarily a fact about a particular object. Potentiality is what an object can do (Vetter 2015, 2, 7-10).

For Vetter, potentiality is a primitive notion that doesn't require further definition or reduction. Vetter claims that the parsimonious notion of potentiality is fruitful as it can offer an account of metaphysical modality with potentiality as the explanans. Possibility, necessity (non-localised modalities) and all other modal notions are reduced to, and explained in terms of, the fundamental and primitive modal property of potentiality. Vetter's account is then a dispositionalist view, accounting for modality in terms of dispositional properties; potentialities (Vetter 2015, 3 & 10).

So, something is possibly P iff something has a potential for it to be the case that P. Something is necessarily N iff nothing has, had, or will have a potential that not N.

Potentiality ascriptions come in a variety of degrees ranging from barely possible to necessary which is determined by background potentialities i.e., the context. However, potentiality itself isn't context dependent. So 'x is combustible' means that 'x can combust (easily)', without any specification of what causes the combustion. The differing degrees explain why certain objects are regarded as having certain dispositions over others.

§1.4.1 Positives

One particularly positive feature of Vetter's account, which previously assessed accounts don't achieve to the same degree, is that the truth of *de re* modal statements about concrete individual ordinary-objects around us are grounded in those very ordinary-objects themselves and the properties they exhibit. *De re* modal truths about ordinary-objects are localised in those very ordinary-objects, not distinct CST-isolated ordinary-object counterparts or parts.

As Vetter puts it, the potentiality account anchors possibilities in concrete ordinary-objects that are part of the actual world and which we are in regular epistemic contact with (Vetter 2015, 11).

Vetter's '*de re* first' approach captures intuitions around *de re* modality that other modal realist views do not. The localised picture is intuitively appealing as individual objects have modal properties in virtue of something about that

very object itself, rather than explaining modality by invoking counterpart theory across CST-isolated worlds.[13]

For example, the fact that I have the potential to finish this thesis is a fact about me; it is a property that I myself possess, it isn't some relational property to some similar but distinct people in CST-isolated worlds.

This localisation of modal truths is particularly appealing as it means there isn't a disparity between modal and non-modal epistemology, nor a disparity between where objects that ground modal and non-modal statements are located; concrete ordinary-objects which ground modal and non-modal statements are CST-related to ourselves.

§1.4.2 Concerns

Vetter claims that if the world is fundamentally dispositional, we don't need possible worlds to account for modality and we can invoke the parsimonious primitive of potentiality. However, as Vetter herself notes, this requires accepting that the world is indeed fundamentally dispositional in order to be sold on the theory.

Despite the notable positives of Vetter's account, it is a big buy-in for someone – like myself – who is not sold on the idea that the world is (or is best described as being) fundamentally dispositional.

Furthermore, one of Vetter's reasons for rejecting a plurality of possible worlds is that it is hard to see what evidence, beyond theoretical utility, could be adduced for the initially rather implausible claim (Vetter 2015, 5-6).

However, Wilson's account provides a very strong and convincing reason to believe a plurality of worlds exists, namely rigorous scientific work in EQM. EQM theory provides us with strong independent reasons (or at least more convincing reasons) for thinking a plurality of worlds exists, beyond their semantic utility. So, in light of this, Vetter's rejection of possible worlds on the grounds that there is no independent evidence for their existence doesn't quite hold up.

Grounding modal truths in non-modal truths is a particularly appealing feature of Modal Realism accounts, something which Vetter's cannot – and does not try to – benefit from. Vetter's account is a non-reductive approach

[13] This isn't to say I take issue with counterpart theory *per se*, rather the utilisation of counterpart theory across CST-isolated worlds when making *de re* modal statements about ordinary-objects in the actual world. Invoking counterpart theory between CST-related counterparts is far less concerning i.e., as with Stages in Sider's Stage Theory (Sider 2001, 188-208).

which results in a disparity between what kind of properties modal and non-modal statements are true in virtue of: in the first instance it is irreducibly modal properties, in the second it is reducible non-modal properties.

I take it that an epistemically viable account which reduces the modal to the non-modal is – all other things being equal – preferable to one which has both irreducible modal and non-modal notions. The non-reductivity, although not the be all and end all of a modal account, is an unappealing feature of Vetter's account.

Another potentially concerning feature worth noting, is that the potentialities framework isn't as serviceable as aforementioned accounts and isn't clearly able to account for certain modal statements. For example, Vetter admits difficulty accounting for the possibility that there were never any of the actually existing objects. Vetter notes that this may be considered the greatest theoretical cost of her theory and is the most pressing area for further research (Vetter 2015, 290-1).

Although this may be regarded by some as a particularly concerning feature of Vetter's account, I am sympathetic to Vetter's unsubstantiated claim that such metaphysical modal statements – although commonly discussed within the realms of philosophy – are not at the centre of our modal intuitions or common garden modal discourse. I am also sympathetic to Vetter's claim that, although such states of affairs may be conceivable, they may not in fact be possible (Vetter 2015, 290-1).

In light of the very appealing positive feature of localising the truth of *de re* modal statements about ordinary-objects in the actual concrete ordinary-objects around us, I don't take the cost of a reduced serviceability of certain modal statements to be too great.

§1.4.3 Summary

Vetter's account provides an intuitively appealing approach whereby *de re* modal statements are localised: grounded in concrete ordinary-objects that exist in the actual world around us and are CST-related to ourselves. On Vetter's account there is then epistemic unity between modal and non-modal statements, as well as unity in where the objects that ground such statements are located.

However, given that Vetter assumes the world to be fundamentally dispositional and potentiality to be a primitive modal notion, there is a disparity in the kind of properties that ground modal and non-modal statements. Non-modal statements are grounded in non-modal properties whereas modal statements are grounded in fundamentally modal properties.

I take it is worth outlining an account which achieves the same as Vetter's but which reductively and uniformly grounds modal and non-modal statements in non-modal properties.

In Chapter Two I outline a reductive account of modality which localises modal and non-modal statements in concrete ordinary-objects located in the actual world, while also retaining some of the utility of possible worlds.

§1.7 Desiderata

My assessment of modal realist accounts wasn't exhaustive or thorough, nor did it include an assessment of modal accounts which don't ground modal truths in concrete ordinary-objects. However, it hopefully indicated my motivations for seeking an alternative account and provided some reasoning for arriving at desiderata that my alternative account will aim to meet.

My alternative account will aim to emulate the positive aspects of notable modal accounts, while attempting to avoid the concerning aspects. The reductivity, concreteness and parsimony of Lewis' and Wilson's account are certainly positives worth emulating, as is the scientifically backed nature of Wilson's account. Vetter's localisation of modal and non-modal *de re* truths in the same actual concrete ordinary-objects which are CST-related to ourselves is also a particularly positive feature worth emulating, as is Wallace's reductive utilisation of concrete modal parts to ground modal statements instead of distinct counterparts. These positive features reflect a unity between modal and non-modal *de re* statements about ordinary-objects around us.

These features can be outlined as five desiderata which I will use as a guide when outlining an alternative account of nomic *de re* modality.[14] I will aim to meet the following desiderata:

1) Reductive & unified: the account explains the modal by invoking entities of the same kind, without invoking modal notions, hence providing a unified modal semantics.
2) Ontologically parsimonious: the account doesn't posit new general kinds which aren't already in our ontology, but invokes apparatus readily available in science and metaphysics.
3) Concrete: the entities that ground modal statements are concrete physical entities.

[14] I will touch upon *de dicto* modality in *§7.3*, metaphysical modality in *§8.1.2* and advanced modalizing in *§8.2.1*.

4) Naturalistic & CST-related: the modal account itself is scientifically backed and not based on semantic serviceability alone. The entities that ground modal statements are CST-related to the utterer of the modal statements, not CST-isolated.
5) Localised & unified: modal (and non-modal) statements about an ordinary-object are directly grounded in, and identified with, that ordinary-object itself and the properties it itself exemplifies (not some distinct but similar ordinary-object), hence providing a unified modal and non-modal semantics.

Henceforth I collectively refer to these five desiderata as 'the desiderata', whereby each one is numbered as above. I don't take these desiderata to be the be-all or end-all of a modal account, they simply provide some guidance when developing an alternative account of modality.

To clarify, I attempt to outline an account which is scientifically backed beyond metaphysical and semantic reasoning, hence is naturalistic and epistemically viable.

I also specify seeking an account whereby the entities which ground modal statements are concrete and CST-related to the utterer of modal statements. By concreteness I mean the kind of physical objects that are around us and we come in contact with. While I don't claim that CST-relatedness is required for an epistemically viable account, I assume that non-modal statements are grounded in concrete entities that are CST-related to the utterer of the statements and assume there is a causal element to our non-modal epistemology. Therefore, for the sake of unity between modal and non-modal epistemology, I aim to provide an account with a causal explanation for both.

I acknowledge that – in light of seeking a naturalistic account – an epistemology that relies on CST-relatedness isn't uncontroversial. For example, the increasingly prevalent thought in quantum gravity questions whether spacetime and spatiotemporal relations are fundamental. Were this to pose a problem, one option would be to fall back on causal ordering which – as discussed in Wilson (2021) – is arguably more fundamental. But I acknowledge that this option may be unconvincing to those who hold there aren't any causal relations.

The aim is to achieve unity between the semantics of modal and non-modal *de re* statements about ordinary-objects around us: localising modal and non-modal statements about an individual object by grounding them in the properties of that individual object itself and not some distinct object.

The aim for this kind of unity here is, at least partially, driven by the strong intuition that modal truths about an ordinary-object, like non-modal truths, are grounded in that very object itself. An intuition which I admit may be misguided, but one that is shared by authors like Vetter, McDaniel, Meg Wallace and many others. Even if this intuition isn't unanimously shared and may be mistaken, or that it may even be wrongheaded to appeal to intuitions at all, I still take it to be worthwhile exploring what an alternative account which attempts to achieve this unity could look like.[15]

Furthermore, I acknowledge the complexity of appealing to considerations of theoretical unity. Seeking unity of one kind can (and in my case will) be at tension with, other forms of theoretical unity. I do not claim that the form of unity I aim to achieve is preferable to other forms of unity, I simply claim it is worth outlining an account which aims to meet the desiderata.

I acknowledge that, as Hajek puts it, we strive to understand the universe we live in and the language we use, but there is no guarantee that both projects will harmonize (Hajek 2014, 1).

I claim that one way of meeting the desiderata is by developing an Everettian account of modality, which I now outline.

§2: Everettian Quantum Mechanics

As briefly outlined in *§1.2* Wilson's QMR utilises the plurality of worlds posited by EQM. In this section I broadly and neutrally outline a feasible formulation of EQM, taken from David Wallace (2012) and Carroll (2019).[16]

While Wilson interprets EQM as positing diverging worlds, I outline EQM whereby worlds overlap and the Universe has a branching structure (Wallace in fact explicitly outlines EQM in this way). EQM henceforth assumes overlapping worlds, unless stated otherwise.

I now outline how EQM arrives at a plurality of overlapping worlds in order to show in Chapter Two that if EQM is correct, then adopting the many-worlds posited by EQM can result in an 'Everettian account of modality' (EAM) that

[15] Appealing to intuitions arguably comes in conflict with the naturalistic desiderata, given that naturalism involves throwing out intuitions that conflict with science (Ladyman & Ross 2007). However, appealing to this intuition doesn't conflict with EQM *per se*, rather with Wilson's QMR (2020).

[16] I don't claim EQM is correct and cannot justify this here, but I do provide some reasons why it is preferable to other theories of Quantum Mechanics.

grounds the truth of *de re* modal statements in a way that meets the desiderata.

First, I outline features of Quantum Mechanics (QM). Second, I outline EQM and some motivations for it over alternative formulations of QM. Third, I explicate the terminology and diagrams I use throughout this thesis when outlining EAM.

§2.1 QM

QM is held as being the most powerful, comprehensive, accurate and fruitful theory of physics and which underlies the rest of science. QM describes everything from fundamental elementary particles like electrons to the entire universe (Wallace 2012, 13; Carrol 2019, 1-6).

However, QM revels a disparity between what the theory describes and what we observe, fundamental realist is very different to what classical mechanics describes (Carroll 2019, 17-8).

Classical mechanics, for the most part, can make deterministic predictions about, say, a determinate future position of an object if we know things like its position and velocity. QM however, can only predict the probability of, say, an electron's future position.

At the quantum level, things like electrons have a quantum state known as a 'wavefunction'. When expressed in the position basis, the wave function evolves smoothly and deterministically according to the 'Schrödinger equation', which assigns a probability to each outcome associated with a given observable. For every possible measurement outcome – like the position of a particle – the wavefunction assigns a specific number to that outcome called the 'amplitude'. Only upon observing the particle do we obtain a definite result. The probability of getting a certain outcome when we perform a measurement of a given observable is determined by the state, via what is known as the 'Born Rule': in the position observable it is the norm squared of the wavefunction (Carroll 2019, 19-24).

Although the mathematical formalism of QM is well defined and its practical applications well understood, there are conceptual difficulties as to the nature of QM. Specifically, there is no consensus as to what happens when we measure the wavefunction: why the wavefunction is spread out before observed but when measured we get a determinate result (Wallace 2012, 13-4; Carroll 2019, 17)

Attempts to address this measurement problem result in different formulations of QM: competing distinct and incompatible scientific theories which make sense of the physical world in different ways.

According to Wallace there are broadly two viable alternative formulations of QM to EQM: 'Hidden Variables' and 'Dynamical-Collapse' theories. Hidden Variables theories leave the formalism of QM but add hidden variables as extra structure, the best developed formulation being Pilot-Wave theory (also known as Bohmian or de Broglie-Bohm mechanics). Dynamical-Collapse theories modify the Schrödinger equation so that it leads to a collapse of the wavefunction resulting in one determinate outcome, the best known being GRW (Wallace 2012, 32-3).

However, advocates of EQM claim that it is an extremely conservative approach which doesn't modify the mathematical formalism of QM by introducing collapse or by adding additional hidden variables (Wallace 2012, 36-8; Carroll 2019, 32-42).

§2.2 EQM

EQM, first proposed in 1957 by Hugh Everett (Everett et al. 1973, 141-50), takes the indeterministic outcomes associated with the wavefunction seriously as a direct ontological representation of reality. So even though we only see measurement outcomes and not the wavefunction itself, EQM holds the whole wavefunction really exists and describes a multiplicity of non-interacting approximately classical worlds (Wallace 2012, 38; Carroll 2019, 32-33).

According to QM when using a measuring device to observe some two-state quantum system, such as the spin of an electron, the measuring device will either read spin-up or spin-down, as these are the two possible states of that system (Wallace 14-6, 23).

However, according to EQM, even though the measuring device only reads one specific state of the electron at one time, either 'measure up' or 'measure down', the electron is in a 'superposition': a combination of all possible outcomes. In this instance the electron is in a superposition of spin-up and spin-down.

Furthermore, EQM holds that given atoms obey the rules of QM and macroscopic objects are made of atoms, macroscopic objects – such as measuring devices – also obey the rules of QM. The device measuring the electron's spin is then also a quantum system.

QM also holds that different quantum systems are not described by individual wavefunctions but are connected. So, when the measuring device interacts with an electron in a superposition of 'spin up' and 'spin down', the two systems become entangled with one another meaning that the measuring device is also in a superposition, of 'measure up' and 'measure down'.

Not only do the electron and the measuring device interact to become entangled and in a state of superposition, but so does their 'environment': all the stuff that can't be measured, everything from the air molecules in the room to the rest of the universe. The whole system – the whole universe – has a wavefunction. This is a process known as 'decoherence' which, on EQM, (approximately) picks out the basis to which the superposition of a quantum state is defined (Wallace 2012, 40, 77 & 88; Carroll 2019, 35-7).

According to Wallace, decoherence is the process by which the system continually interacts with its environment and becomes irreversibly entangled with it, suppressing interference between the different states of the system and approximately developing a branching structure. This means that the different states of the system are in superpositions of macroscopically definite states, as there is no interference between spin-up/measure-up and spin-down/measure-down states, both macroscopically definite structures continue to be present but on different branches. Macroscopic superpositions describe multiplicity rather than indefiniteness (Wallace 2012, 36-37, 62, 77 & 88).

Branching of the Universe is caused by any process which magnifies microscopic superpositions up to a level where decoherence kicks in, so happens any time a quantum system becomes entangled with its environment and decoheres. Branching is then ubiquitous and unfolds as time moves towards the future, measured by something like the increase of entropy starting from the Big Bang. Branching isn't the duplication and creation of more universe, rather the dividing of the existing universe into near identical slices (Wallace 2012, 99; Carroll 2019, 148, 158-60 & 214).

How often branching happens is currently an unanswered question in fundamental physics, but branching is an extraordinarily rapid process so there is a lot of branching going on. For example, Carrol states that "In a typical human body, about 5,000 atoms undergo radioactive decay every second. If every decay branches the wave function in two that's 2^{5000} new branches every second" (Carroll 2019, 119-20).

After the wavefunction branches – post decoherence – branches can no longer interact with one another, even though they are related by a

common past branch. As these branches can no longer interact, they are described as have a structure of approximately classical worlds which never interact again. So decoherence is what results in the emergence of quasi-classical worlds which are constantly splitting into multiple versions of themselves. We fail to observe these other worlds as they do not interact with ours strongly enough for us to detect them (Wallace 2012, 62, 64-5 & 87; Carroll 2019, 117-9).

So to recap, what happens with the electron is that the electron rapidly becomes entangled with the many degrees of freedom of the measurement-device and the environment, decoherence which results in the wavefunction of the universe branching into multiple copies whereby there is one branch where the measuring device reads the electron as 'spin-up' and another branch where it reads the electron as 'spin-down'. The spin-up branch and spin-down branch co-exist but can never interact again, as such they can be understood as parts of separate quasi-classical emergent worlds.

To observers in each world – say a 'spin up' world or a 'spin down' world – the wave function appears to have collapsed and produced one determinate outcome. In reality, both measurement outcomes are produced but in different worlds and the apparent definite measurement is only relative to a particular world. So, although we never have first-hand experience of the Universe branching or of other worlds, if you know how a system evolves, then you know that system will evolve into the superposition of its possible states in different worlds. We can distinguish different individual worlds by what they're like.

Wallace notes that just because worlds are emergent, it doesn't mean they're not unquestionably real objective physical objects. Worlds instantiate localised structures that describe the universal quantum state at a certain level of description which is explanatorily useful: worlds break down and describe the incredibly complex wavefunction of the universe by capturing real patterns of the fundamental dynamics without needing to appeal to microscopic descriptions. The multiplicity of quasi-classical worlds are emergent from the underlying quantum physics, they are instantiated structures within the quantum state: macroscopically definite quantum states represent classical states of affairs. So even though worlds aren't fundamental on EQM, the Universe has a tree-like structure and the plurality of worlds are real (Wallace 2012, 40, 47-8 & 53-63).

No world is ontologically privileged over any other and what worlds exist are all those permitted by the laws of QM. So there is a limit to what worlds can

exist, for example, there will never be worlds in which an electron spontaneously converts into a proton, given that electric charge is strictly conserved (Carroll 2019, 167 & 169).

To conclude, as Wallace puts it if the quantum state or wavefunction is an faithful description of physical reality, then it consists of a vast number of distinct branches and worlds which are dynamically independent of one another and behave approximately classically. The worlds and their inhabitants are not abstracta, fiction or mere unrealised possibilities, they are as real as our own concrete world and our world is just one amongst the plurality; only a tiny slice of a much larger reality. Although this may seem absurd, science has continued to show us that the Universe is an incomprehensibly large place and much larger than we once thought (Wallace 2012, 3, 13, 22, 37-8 & 46).

§2.3 Terminology and Diagrams

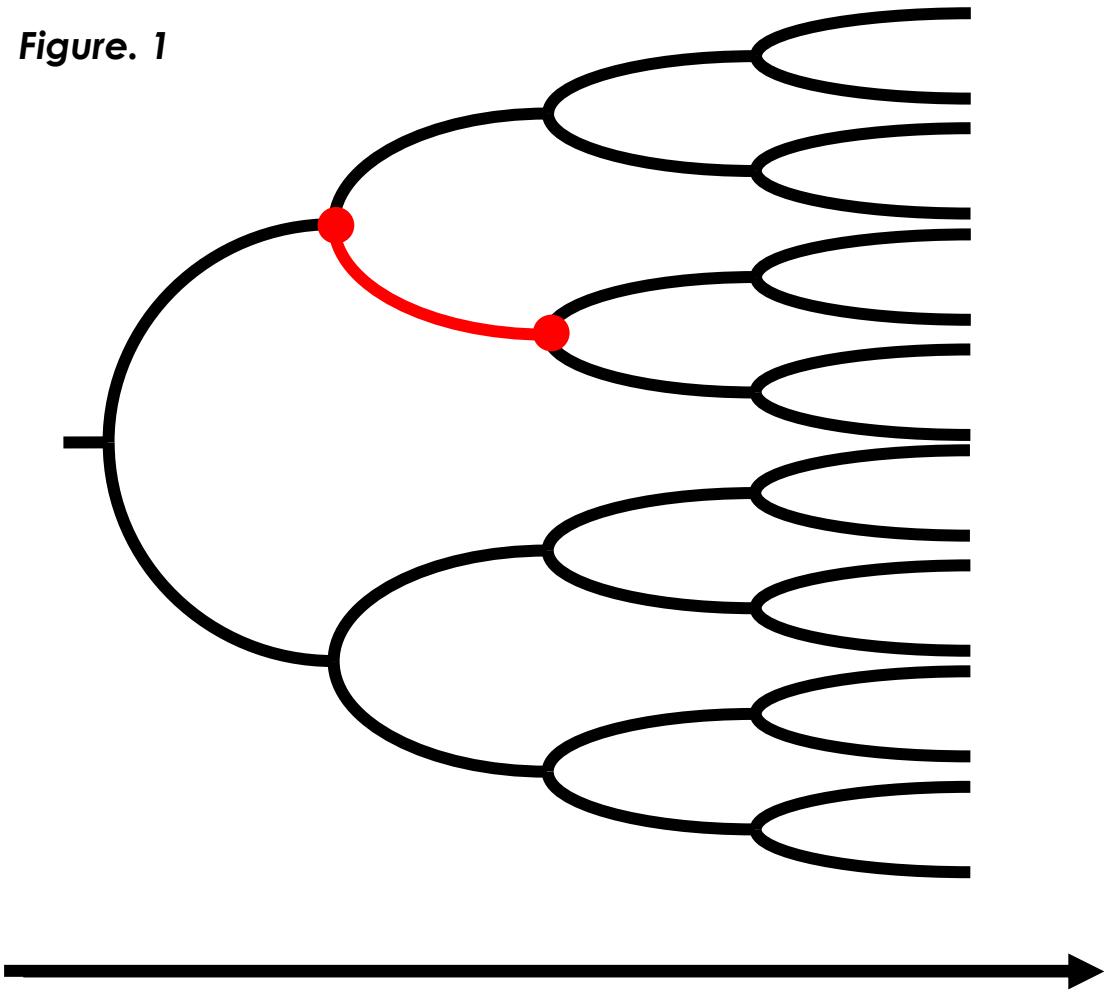
In this subsection I outline the terminology and diagrams I use henceforth. The diagrams are visual representations of important aspects of EQM which aid in explicating EAM. The X-axis represents the arrow of time (a Y-axis isn't required). I also clarify the representational limits of the diagrams and how it relates to Belnap's semantics.

§2.3.1 A 'branch' and 'branching point' (lowercase 'b')

A 'branching point' (plural; 'branching points') – highlighted by the red dots in *figure. 1* below – is a point in spacetime where the wavefunction splits and 'branching' (noun) occurs.

A 'branch' (plural; 'branches') – highlighted by the red line in *figure. 1* – is an irreducible bit of spacetime between two branching points.

Figure. 1

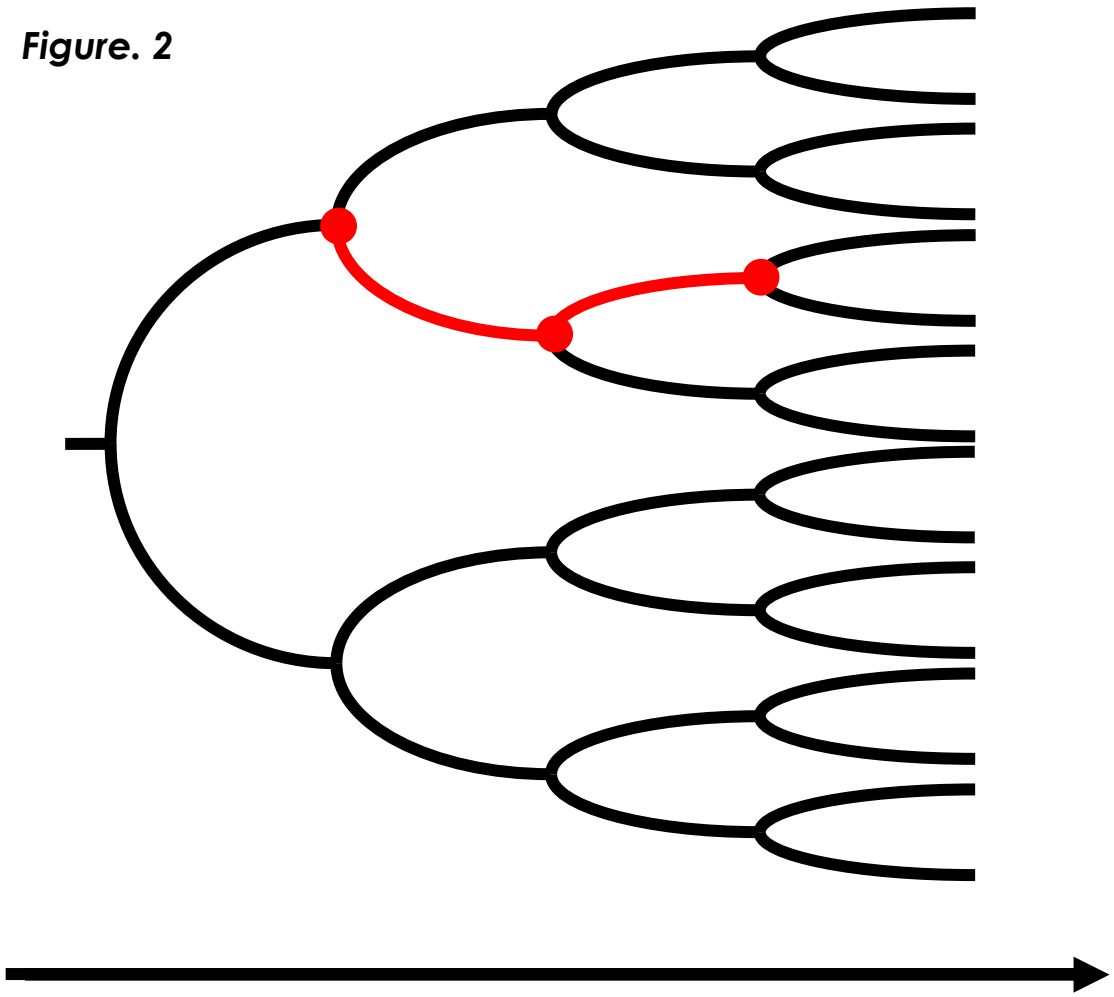


§2.3.2 A 'Branch' (uppercase 'B')

A 'Branch' (plural; 'Branches') – highlighted red in *figure. 2* – is a temporally extended linear set of multiple branches (lowercase 'b'). A Branch is linearly composed of a number of spatiotemporally connected branches and branching points.

When talking of temporally extended objects or events, I talk of them belonging to or occurring in a Branch. Henceforth, as discussion throughout focuses on Branches rather than branches, for the sake of simplicity a Branch will henceforth be visually represented in the same way as a branch is represented, in *figure. 1*.

Figure. 2



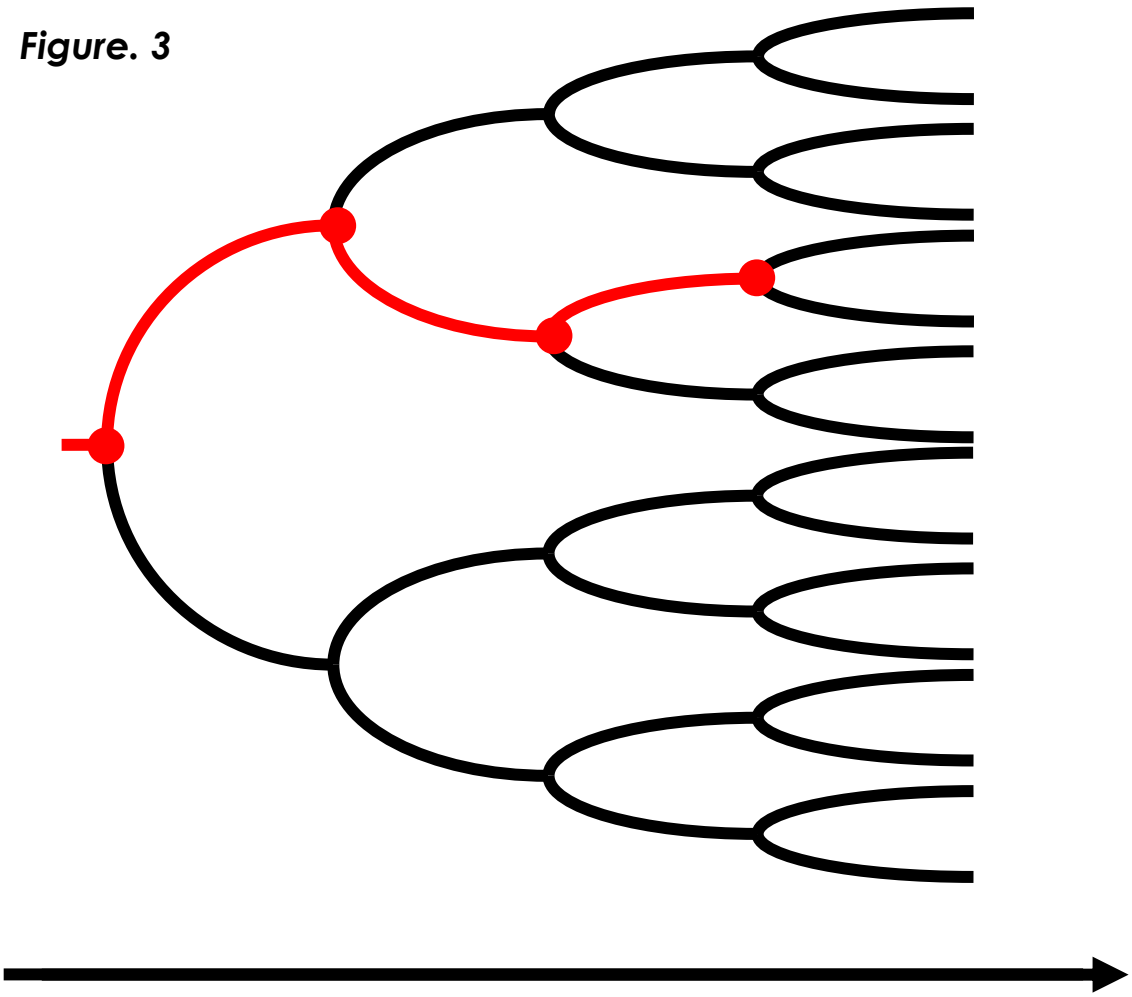
§2.3.3 A 'history'

A 'history' (plural; 'histories') – highlighted red in *figure. 3* – is a Branch which extends from the beginning of time up until a certain specified point.[17]

Throughout this thesis I talk of an 'utterer's history'; a Branch extending from the beginning of time up until the time of an utterance.

[17] I assume there is a beginning of time i.e. the Big Bang.

Figure. 3



§2.3.4 A 'world'

An Everettian 'world' (plural; 'worlds') – highlighted red in *figure. 4* – is a Branch of maximal extent; a maximal linear order extending from the beginning of time until the end.[18]

A branch (lowercase 'b') is a irreducible part of a world and a Branch (uppercase 'B') is a temporally extended part of a world.

Given the structure of worlds there is mereological overlap between different parts of worlds. I label overlapping CST-related worlds as 'Everettian worlds' to distinguish them from Wilson's diverging CST-isolated 'Everett worlds'. I claim Everettian worlds are possible worlds.

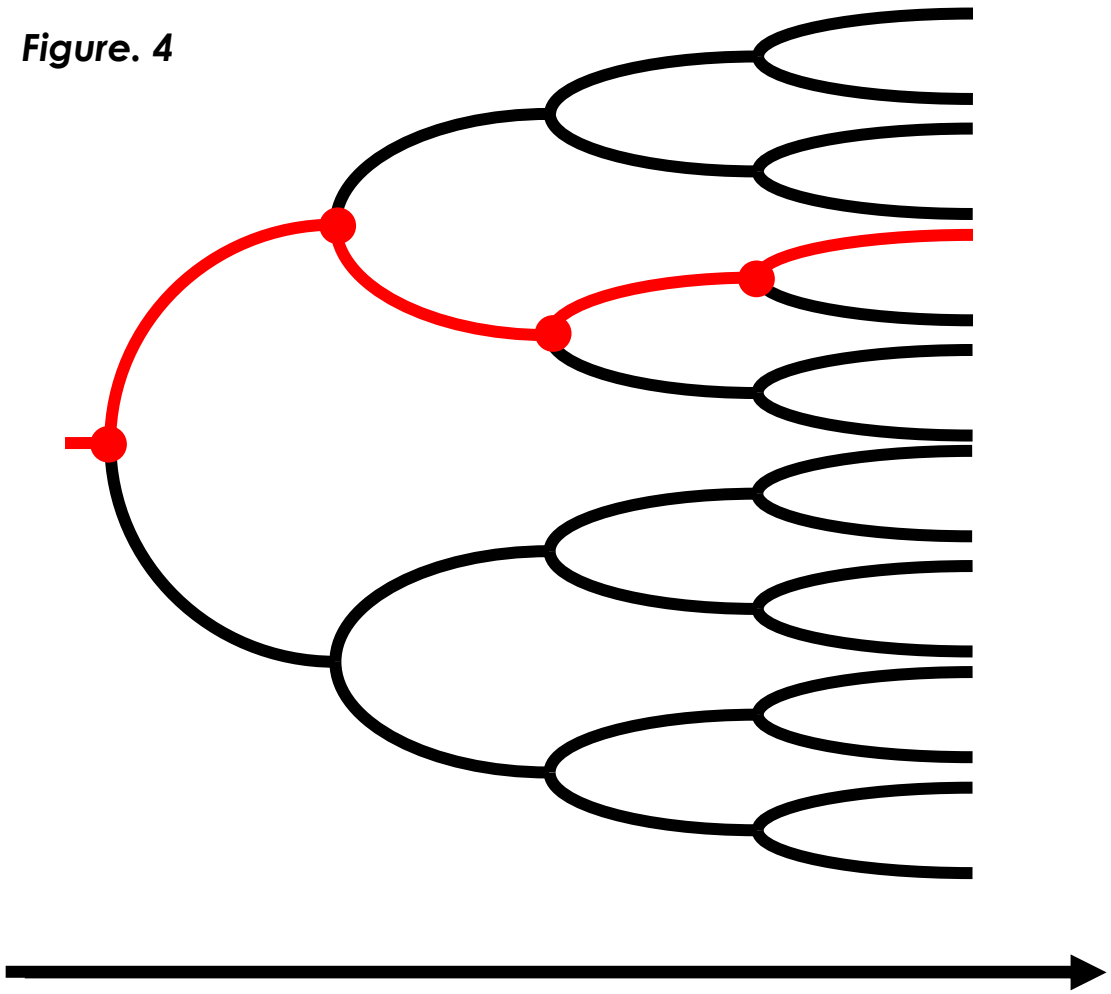
A Branch is then a part of multiple worlds, as is a branch unless it is the final part of a world with no branching points after it. Earlier branches/Branches

[18] I assume there is an end of time i.e. the Big Freeze.

compose parts of more worlds than later parts. But all worlds share an initial part.

Given that a branch/Branch is a part of multiple worlds due to mereological overlap of worlds, objects belong to multiple worlds. In order to distinguish between which worlds an object belongs to, I talk of objects belonging to a certain 'world set'; a certain set of worlds. I also talk of objects belonging to a certain world, even though it belongs to multiple worlds in a world set. This is to retain some possible world semantics.

Figure. 4

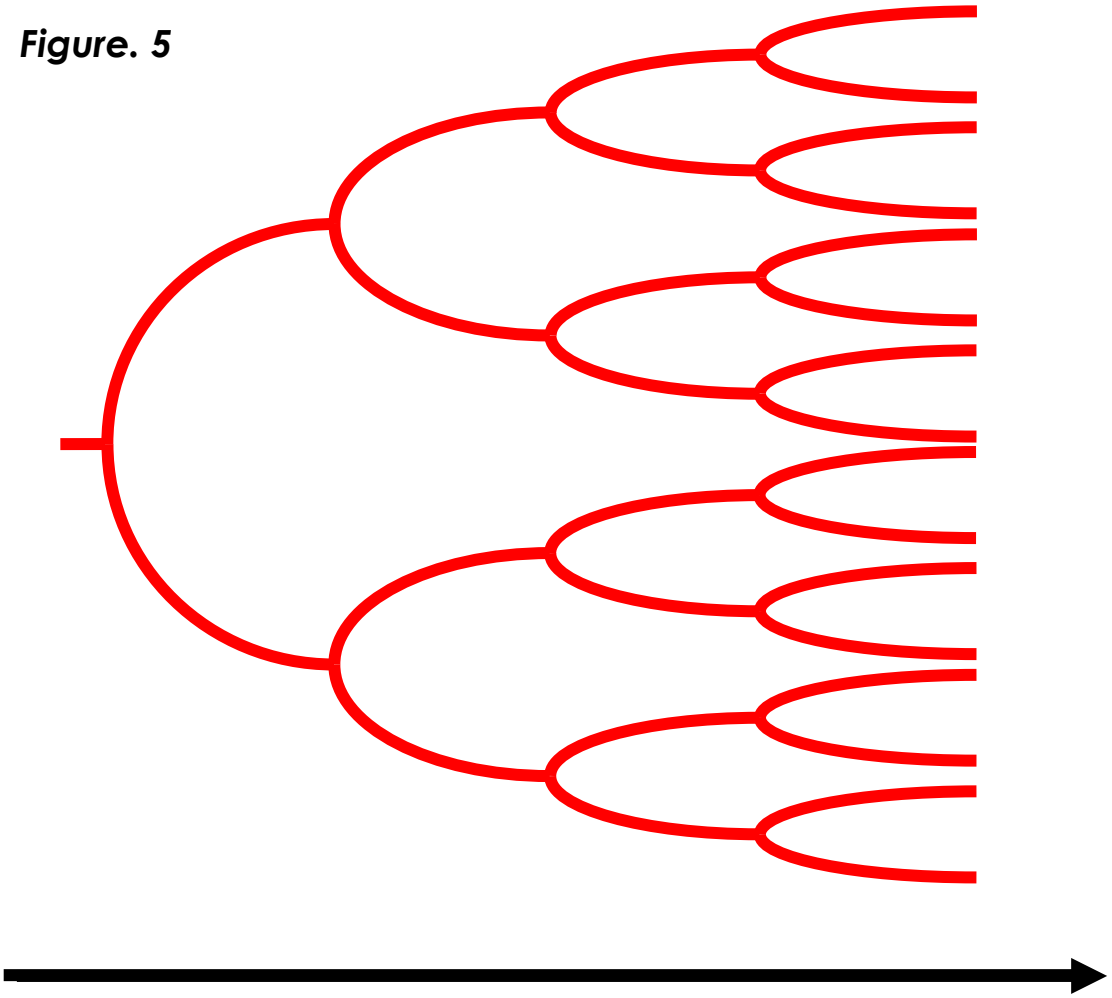


§2.3.5 The 'universe' and 'parallel branches'

The 'Universe' – highlighted red in *figure. 5* – is all the Everettian worlds which share the same initial conditions and are governed by the same physical

laws. In other words, the totality of all the branches of the universal wavefunction.

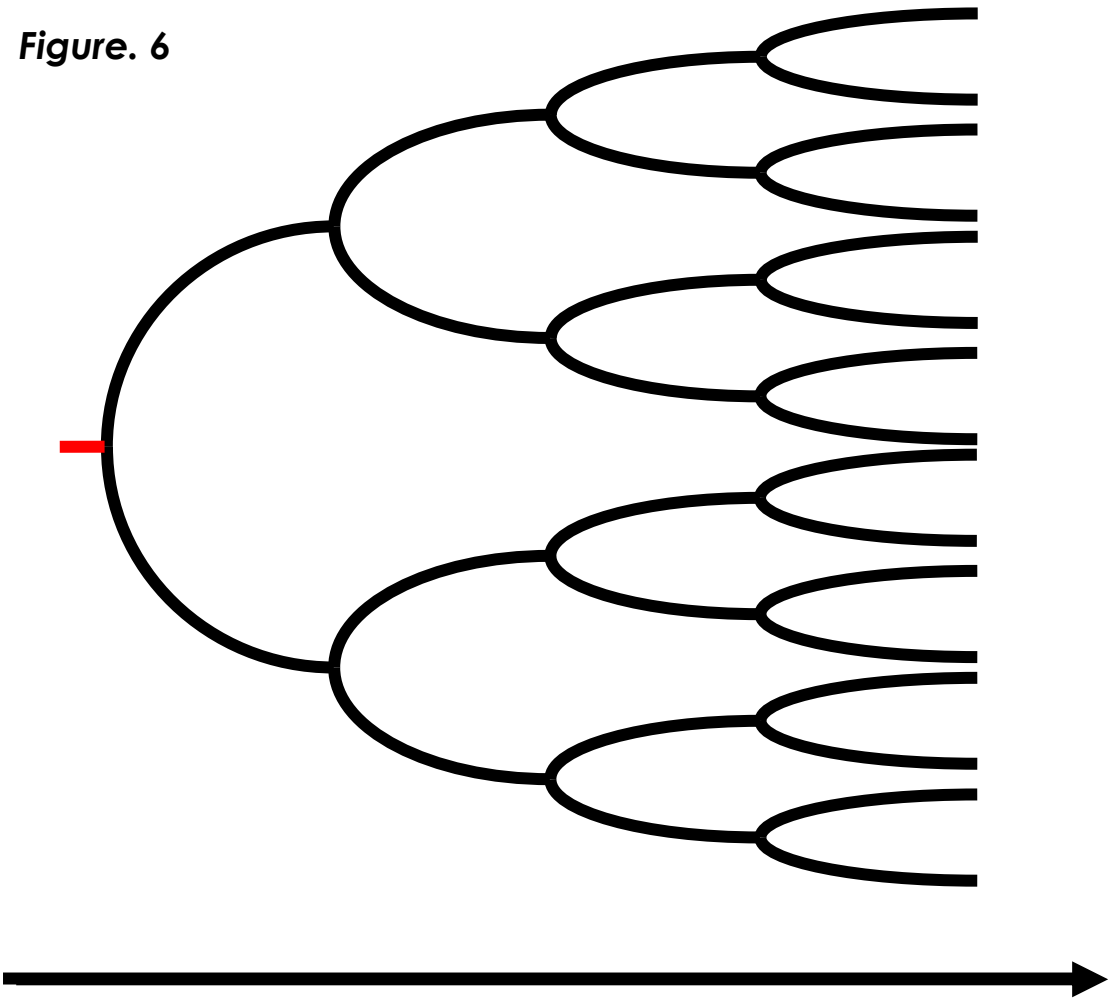
Figure. 5



The initial conditions of the universe – highlighted red in *figure. 6* – is the point from which all histories and worlds stem. Given the initial conditions of the Universe and its super-deterministic nature – absence of randomness – this Universe couldn't be any way other than it in fact is. The universe is necessarily the way that it is.[19]

[19] I leave open the possibility that there are alternative universes to our own, collectively forming a 'multiverse'. These universes may have different initial conditions with the same laws of physics; or different laws of physics with the same initial conditions; or the same initial conditions and laws; or differ entirely. If the possibility of the multiverse is a real possibility then it is – if anything – a metaphysical possibility, as opposed to a physical possibility. Physical possibilities are those which occur within our own universe governed

Figure. 6



Given that all worlds stem from the same point, one way of approximately identify times across worlds following the big bang would be measured by something like the little-t parameter in Schrödinger evolution.

As such, I talk of 'parallel branches' or 'parallel Branches' – highlighted red in *figure. 7* – where approximate times are identified across possible worlds.

Idealised temporal comparisons across branches are used throughout this thesis for explanatory purposes, but I note that exact time comparisons cannot be relied upon in general. Problems may arise when it comes to identifying times across very distinct parallel branches in this way, comparisons may become more problematic but aren't core to my proposal.

Although parallel branches/Branches are illustrated as being the same length, they may not be in reality.

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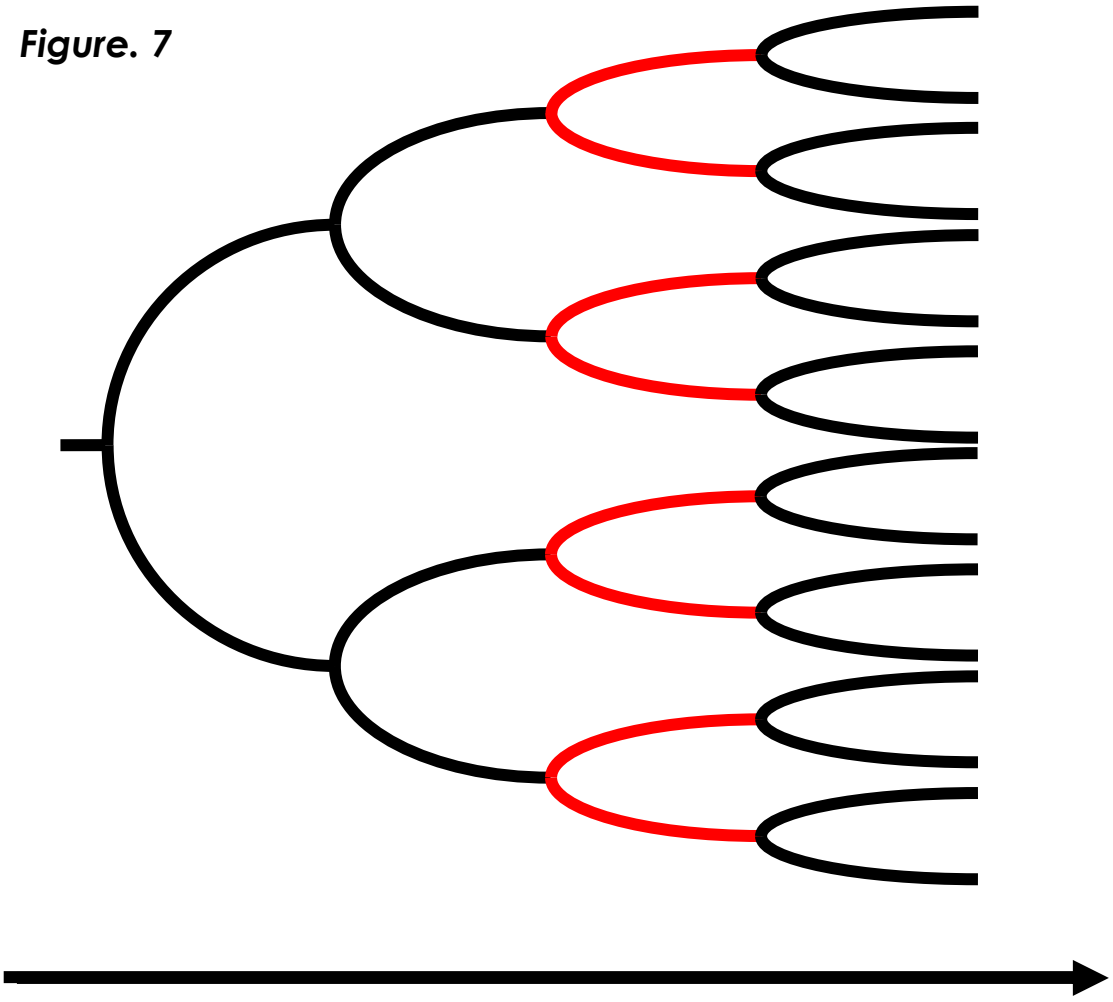
by the laws of physics and its initial conditions. I briefly address the nature of metaphysical possibility in *§8.1.2*.

Figure. 7



§2.3.6 Spatiotemporal and causal relations

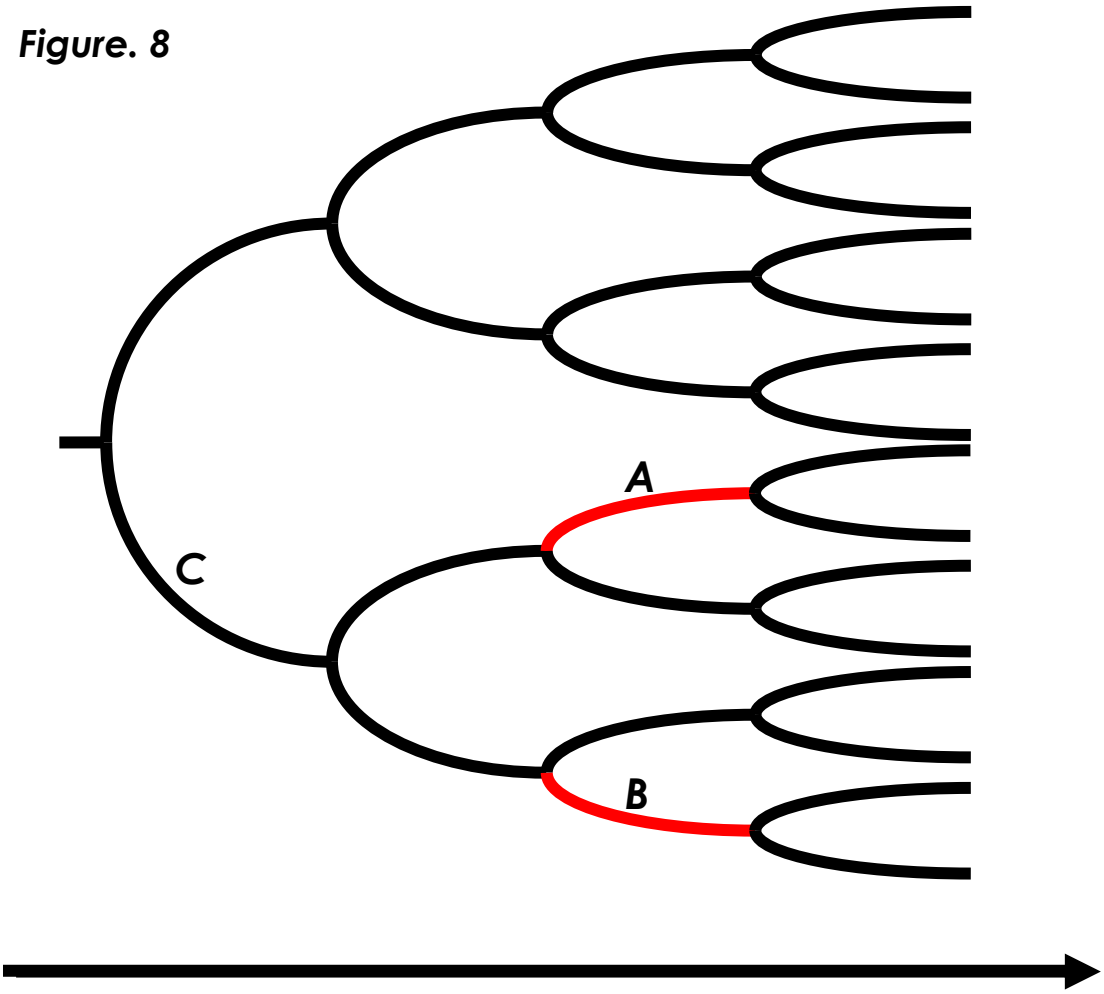
Throughout this thesis I talk of branches, Branches or worlds – including the objects contained within – being CST-related with one another.

Although post branching, parallel branches cannot interact with one another and events in one branch cannot directly cause events in another parallel branch as they are separate bits of non-interacting spacetime, different parallel branches are indirectly CST-related to one another by a common past in just the same way the future can be said to be CST-related to the past on a classical understanding.

Two parallel branches *A* and *B* – illustrated in *figure. 8* – are related by some earlier bit of spacetime, branch *C*. The deterministic evolution of branch *C* of the wavefunction causes – leads to or brings about – branches *A* and *B* of the wavefunction.

So, although branch *A* of the wave function cannot interact with branch *B* of the wave function, they are related by some prior branch of the wavefunction, branch *C* which deterministically evolved into – or caused – *A* and *B*. As such, parallel branches are related by a common past and hence CST-related.

Figure. 8



As different worlds are parallel Branches of maximal extent with overlap, they too are CST-related and share common related parts. All objects and events in the Universe are CST-related to one another via the common cause of the initial conditions of the universe.

§2.3.7 Diagram limitations

The diagrams are extremely over-simplified representations of aspects of EQM in order to convey relevant information.

Although the branches are represented as branching into pairs, in reality this isn't necessarily the case. Branching may result in more than two branches.

Although this isn't represented in the diagrams, it makes little difference to my proposal. The relevant information can be represented by bifurcating branches.

An accurate representation of the EQM has infinitely more branches and branching points. This is impossible to accurately represent here and again isn't required in order to convey the relevant information.

Scaling of branch measurements like length and arc don't represent some real feature of EQM, such measurements are purely aesthetic.

§2.3.8 Belnap's semantics

Belnap (Belnap et al. 2001; Belnap & Müller 2010) has written extensively about the semantics of branching-time (or as he prefers 'branching-histories', simply 'BT' henceforth) which has a similar structure to EQM Universe with overlapping worlds.

Belnap's project provides a unified modal and temporal BT semantics with focus on agents and their choices. Belnap's temporal-modal logic includes propositional contents (*p, q, r, …*), propositional connectives (*not, and, or, if…then*), temporal operators '*it was the case that*' ('*Was:*') and '*it will be the case that* ('*Will:*') and modal operators of '*settledness*' or '*historical necessity*' ('*Sett:*') and '*historical possibility*' ('*Poss*') (Belnap et al. 2001, 220-52; Belnap & Müller 2010, 687-8).

My proposal focuses on outlining an ontology of ordinary-objects, in an EQM universe with overlapping worlds, which grounds the truth of *de re* modal statements in a way that meets the desiderata.

While there are countless similarities between the account I outline and Belnap's BT, some of which I make note of throughout, I don't claim the two projects harmonise in their entirety, nor is this the aim of my proposal. The account I outline utilises certain aspects of Belnap's semantics, but I remain neutral on other areas, and instead focuses on arriving at an ontology of ordinary-object that can ground *de re* modal statements in as similar a way as *de re* non-modal statements.

It is however worth outlining the terminological differences between what I have outlined so far and BT as they both carve at similar joints. The terminology I choose is more akin with that used in EQM. Where Belnap (et al. 2001) talk of 'Tree' (or 'our world'), 'histories', 'a chain', (instantaneous) 'moments', 'transition' and an 'instant'; I talk of the 'Universe', 'worlds', 'histories' and 'Branches', (irreducible) 'branches', 'branching points' and 'parallel branches' roughly respectively.

Similarly, the 'Tree' or 'Universe is bound together by causal order, however Belnap et al. refrain from postulating a common lower bound like the Big Bang and a history is regarded as being from time immemorial to forever (Belnap et al. 2001, 181 & 187-9).

In *§7.2.5* I briefly note how Belnap's semantics, outline above, fit with the semantics for *de re* modal statements I outline, however a thorough comparison is beyond the scope of this thesis.

Chapter Two

Proposal, Ontology of Time, Broad vs. Narrow Future Possibilities, 'Actuality', Ontology of Persistence and Modal Statements

§3: Proposal

I propose that if EQM is correct, ordinary-objects contained within CST-related overlapping Everettian worlds ground the truth of *de re* modal statements in a way that meets the desiderata.[20]

I don't claim that the account I outline is the only or correct formulation of an Everettian account of modality which assumes overlapping worlds (EAM), alternative formulations are coherent and I allude to some throughout. Nor do I claim that because the account I outline meets the desiderata it is therefore preferable to others. I simply take it to be worthwhile outlining an account which meets the desiderata, even if just to see more clearly what such an account amounts to.

For starters, as EAM is premised on the truth of EQM, EAM is ontologically parsimonious as it doesn't posit new general kinds but utilises what is already established by EQM, hence it meets desiderata 2). Furthermore, as EAM utilises EQM it is naturalistic as the many-worlds EQM posits are scientifically backed and not posited on semantic serviceability alone, hence partially meeting desiderata 4).

Furthermore, as the many-worlds posited by EQM are made up of the kinds of things like our world and I assume our world to be composed of CST-related concrete ordinary-objects, it follows that the many-worlds to be composed of CST-related concrete ordinary-objects too: classically defined macroscopic objects like tables, chairs, people, planets and so on.[21] How many of these kind of objects exist is determined whether past, present and future branches exist.

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[20] I interchangeably talk of ordinary-objects that are contained within Everettian worlds and ordinary-objects that compose Everettian worlds.

[21] I note that although EQM arrives at a plurality of concrete worlds via various levels of mathematical abstraction, I don't take the concrete objects it posits to be any less concrete than the objects around us which we classically deem to be concrete physical objects. As Wallace notes, the inhabitants of worlds aren't abstracta, fictions, or mere unrealized possibilities – they are as real as you and I, and our mutual surroundings (Wallace 2012, 3).

In order to provide an account of Everettian modality which further meets the desiderata, a suitable ontology of time needs to be adopted.

§4: Ontology of Time

EQM itself doesn't determine an ontology of time: whether the past, present or future exist. Guided by the desiderata, I adopt an Eternalist ontology of time whereby the past, present and future all exist. I don't take Eternalist-EQM to be unquestionably right nor the only way to provide an EAM, but in this section I outline why adopting an Eternalist ontology meets desiderata 1) – 4). In contrast, non-Eternalist ontologies invoke more complex explanations and at least fail to fully meet desiderata 1). I don't claim that because Eternalist-EQM provides us with an account of modality that meets desiderata 1) – 4) that it is therefore correct.[22]

First, I outline Eternalism, apply it to EQM and show, at first pass, how this results in EAM meeting desiderata 1) – 4). Second, I outline non-Eternalist ontologies of time and apply them to EQM to show how non-Eternalist Everettian accounts fail, at least, to fully meet desiderata 1).

§4.1 Eternalism

Eternalism holds that past, present and future exist *simpliciter*: times don't come into and out of existence. All times – the past, present and future – are equally real and no time is ontologically privileged.

Eternalism holds that reality consists of a four-dimensional spatiotemporal manifold of events and objects known as the block universe where dinosaurs and Mars outposts are as real as present objects (D.H. Mellor 1981; Sider 2001, 11).

Sider notes that Eternalism utilises tenseless B-concepts such as 'before' and 'after'. Tenseless B-judgements don't change in truth value through time, hence Eternalism is a 'static' theory of time as opposed to 'dynamic'.[23] For

[22] There are also numerous strong independent reasons for rejecting non-Eternalist ontologies of time and adopting Eternalism (Sider 2001).

[23] Moving Spotlight is a dynamic Eternalist A-theoretic ontology of time described by Broad (1923, 59-60), Skow (2015, 45-69) and Cameron (2015). Moving Spotlight holds that the past, present and future exist but doesn't reduce tensed talk to tenseless talk. Instead Moving Spotlight holds that A-theoretic tensed talk picks out something real in the world. Although all times are ontologically on a par, reality is highlighted in some way by the moving spotlight of the present. I set this view aside as it doesn't offer anything more than Eternalism and as Sider notes it is arguably unmotivated when tenseless talk can explain tenseless talk (Sider 2001, 17-22).

example, it is, always has, and always will be the case that I am writing this thesis on 08/07/20 after I was born on 13/01/96 and before the presidential election on 03/11/20.

Tensed A-judgements like 'now', 'was' and 'will' are reduced to untensed talk and given tenseless truth conditions. For example, the tensed sentence 'I am now typing' uttered or thought at time *t* is given a tenseless truth condition of being true that I am typing at *t*. It is tenseless as it is and always will be true that the event of me typing happened at *t*.

Much like the indexical 'I' refers to the person who utters it and 'here' refers to the place of utterance. A-concepts such as 'past', 'present', and 'future' are indexical words reduced to untensed talk where context determines the truth conditions of the words.

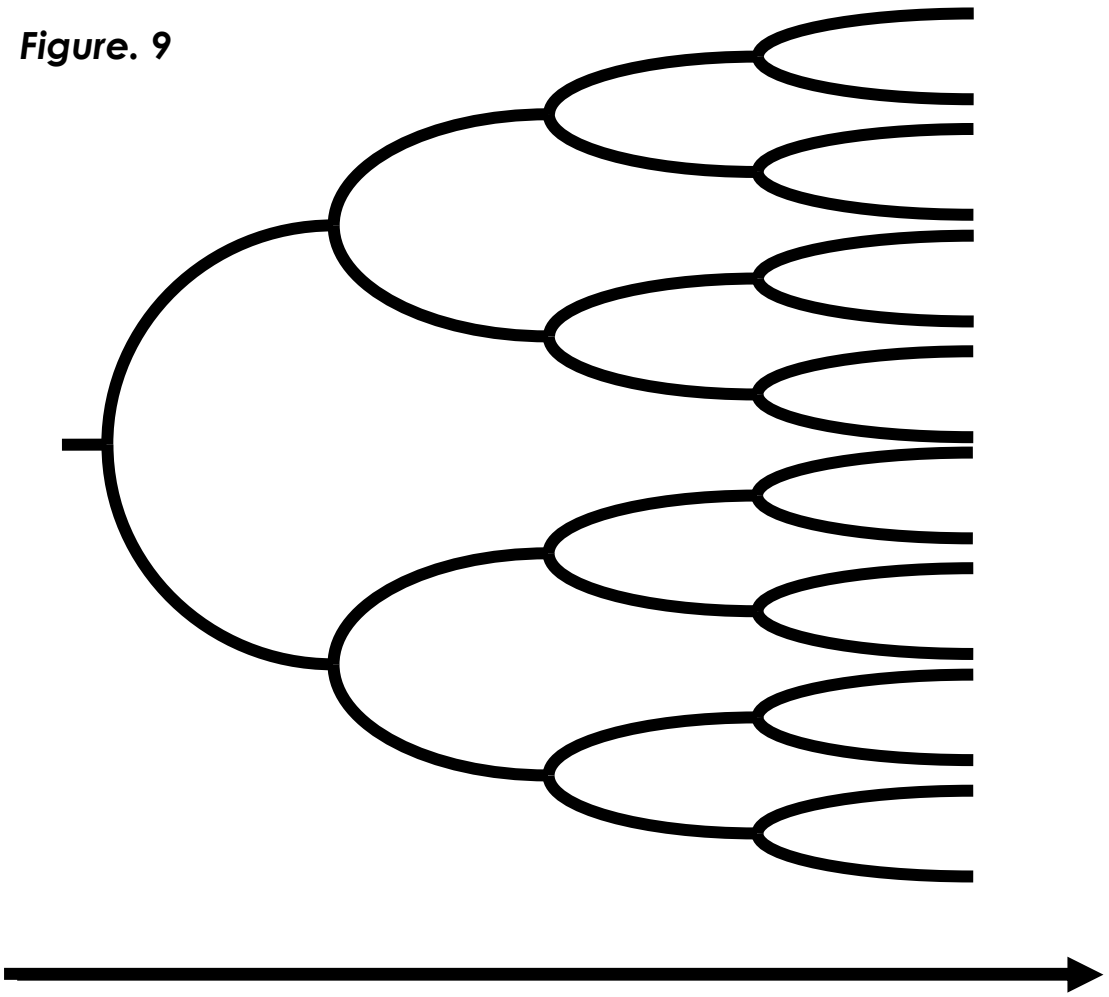
In the case of A-concepts 'present' refers to the time of utterance, 'past' refers to something before the utterance, and 'future' refers to something after the utterance. B-judgements capture all the changeless facts about time without admitting tense as a fundamental feature of the world (Sider 2001, 12-4).

§4.1.1 Applied to EQM

Combining EQM with Eternalism is most naturally understood as meaning that all branches of the universe – past, present and future – exist and are ontologically on par.[24] Eternalist-EQM is an expansion of what we classically deem to exist. The Universe is an ontologically rich tree-like structure consisting of four-dimensional worlds – as illustrated in *figure*. 9 – rather than a much smaller four-dimensional block. The Universe is a spatiotemporal manifold of branches which consist of concrete objects and events. Branches compose worlds, consisting of concrete objects and events.

[24] Thin Red Line ontology – coined by Belnap & Green (1994) and defended by Borghini & Torrengo (2013) – retains a branching Eternalist understanding of the Universe whereby past, present and future branches exist, but holds that – much like with Moving Spotlight – a certain Branch is highlighted or privileged in some way. However, I set this view aside. Nothing in EQM suggests Thin Red Line and it doesn't offer anything more than what the natural reading of Eternalist EQM can offer for my account.

Figure. 9



So, not only are there future Branches in which humans have outposts on Mars, there are future Branches in which humans never erect outposts on Mars exist, future Branches where humans have floating outposts in Venus' atmosphere instead, and so on *ad infinitum*.

Not only is there the present Branch in which a pandemic is taking place, there are parallel present Branches in which there is no pandemic, parallel Branches where humans already live on Mars, and so on *ad infinitum*.

Not only are there past Branches in which dinosaurs exist, there are past Branches in which dinosaurs were never wiped out and continue to exist for 66 million years, past Branches in which dinosaurs never came to be, and so on *ad infinitum*.

These are examples of the kind of macroscopic classically defined determinate concrete ordinary-objects – and events consisting of such ordinary-objects – which exist as result of Eternalist-EQM. As a world is a Branch of maximal extent, Eternalist-EQM consists of a breadth of

ontologically rich worlds made up of concrete ordinary-objects which explain modal statements while meeting the desiderata.

§4.1.2 Eternalist Everettian account

In this subsection I provide examples of tensed modal statements in order to exemplify and illustrate – at first pass – what grounds modal statements generally on EAM. I use overtly tensed modal statements to prevent ambiguity as to the tense of such statements and to prevent confusion as to where the objects that ground the truth of the statement are located. For everyday modal statements that aren't overtly tensed, some interpretation of the context of the statement is required to determine the location of the grounding objects.

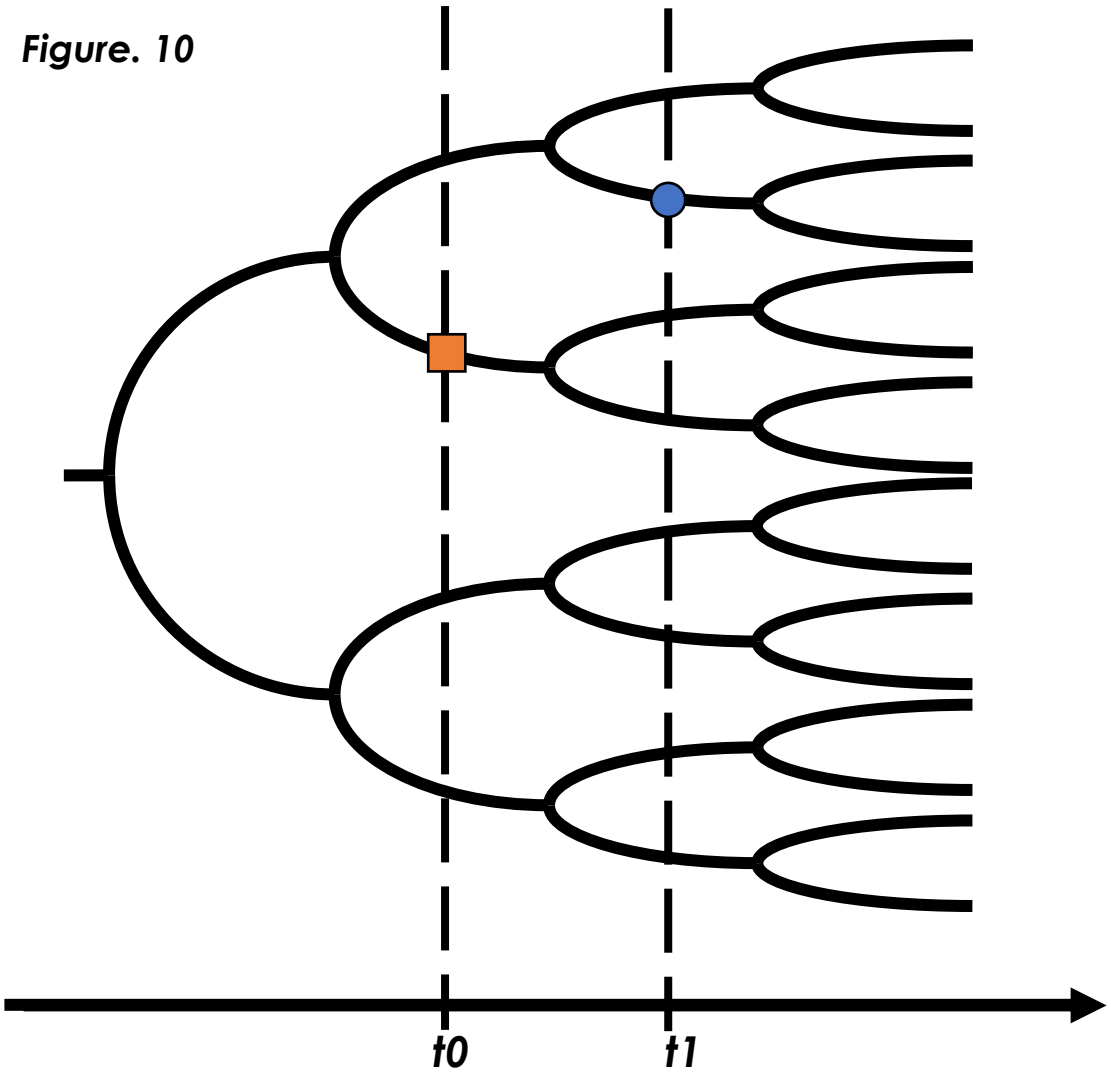
Adopting an Eternalist understanding of EQM means that all branches that compose the universe – past, present and future – exist and consist of concrete ordinary-objects at different locations. As Everettian worlds are a Branch of maximal extent, they consist of ordinary-objects at different spatiotemporal locations. The Universe – the totality of Everettian worlds – then consists of a wealth of concrete ordinary-objects with no ontological difference between them. These Everettian worlds and concrete ordinary-objects are a suitable candidate for grounding the truth of modal statements while meeting desiderata 1) – 4).

On my account, when one makes future tensed modal statements, it is ordinary-objects contained within Branches that are in the utterers future which ground the truth of the utterers statement.[25] (Just as on a classical Eternalist picture it is future ordinary-objects which ground the truth of future tensed non-modal statements).

For example, when an utterer makes a future tensed modal statement like "the moon could collide with Earth", this statement involves quantification over all future branches relative to the location of the utterer and is true if this event occurs in at least one future Branch. In *figure. 10* the orange square represents the utterer making the statement at time *t0*. The statement is grounded in the event occurring at time *t1*, represented by the blue circle.

[25] I talk of 'ordinary-objects' grounding the truth of modal statements. I take this to include talk of 'events', given events are composed of ordinary-objects.

Figure. 10

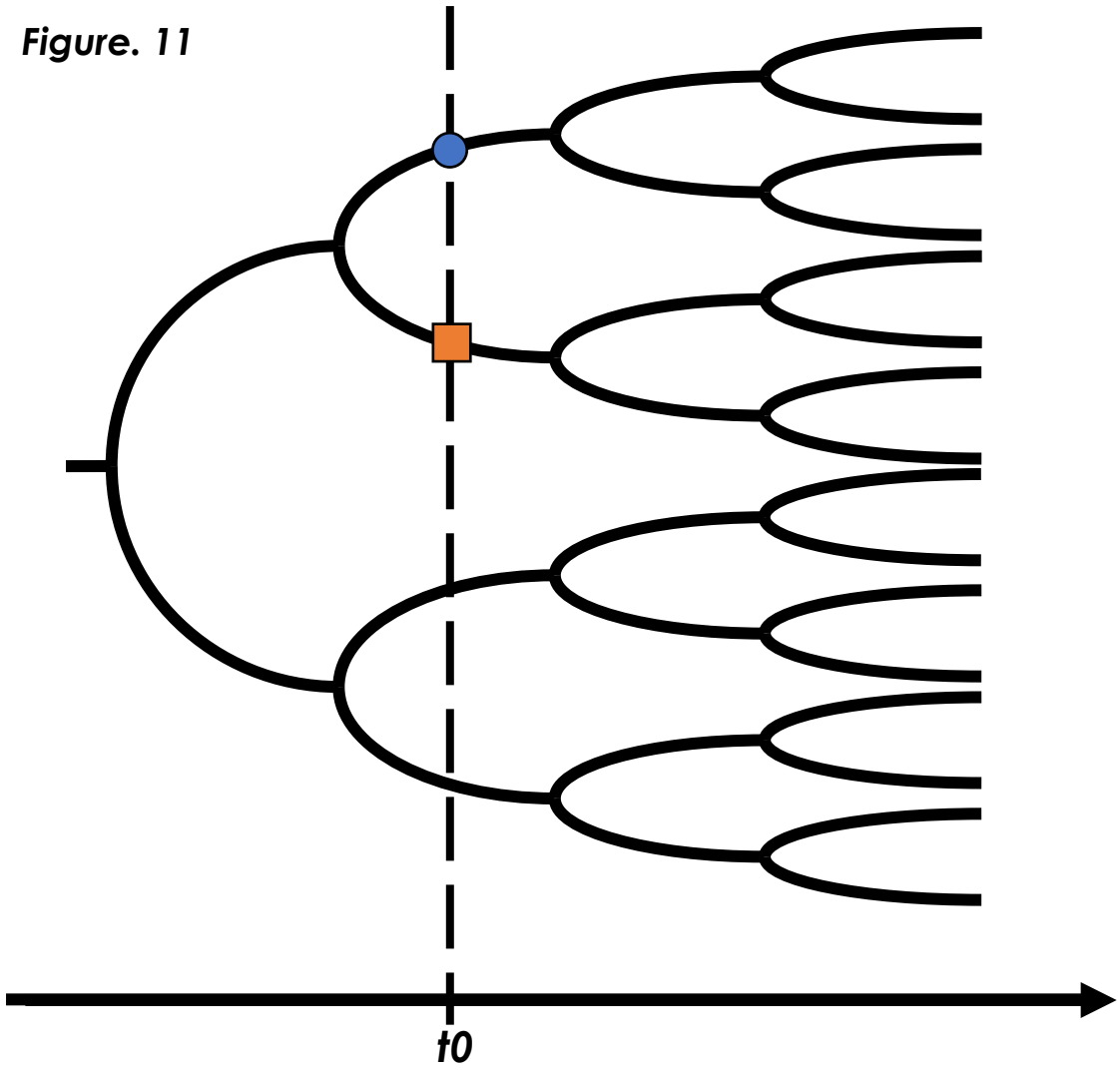


When one makes present tensed modal statements, it is ordinary-objects contained within parallel present Branches which ground the truth of the modal statements. (Just as on a classical Eternalist picture it is present ordinary-objects which ground the truth of present tensed non-modal statements).

For example, when an utterer makes a tensed modal statement like "the moon could collide with Earth right now".

This statement involves quantification over all parallel Branches relative to the location of the utterer and is true if this event occurs in at least one parallel Branch. ("Right now" might go vague as to what time is being identified, if it is understood as 'just after the utterance' then this statement has the future tensed truth conditions). In *figure. 11* the orange square represents the utterer making the statement at time *t0*. The statement is grounded in the event occurring at time *t0*, represented by the blue circle.

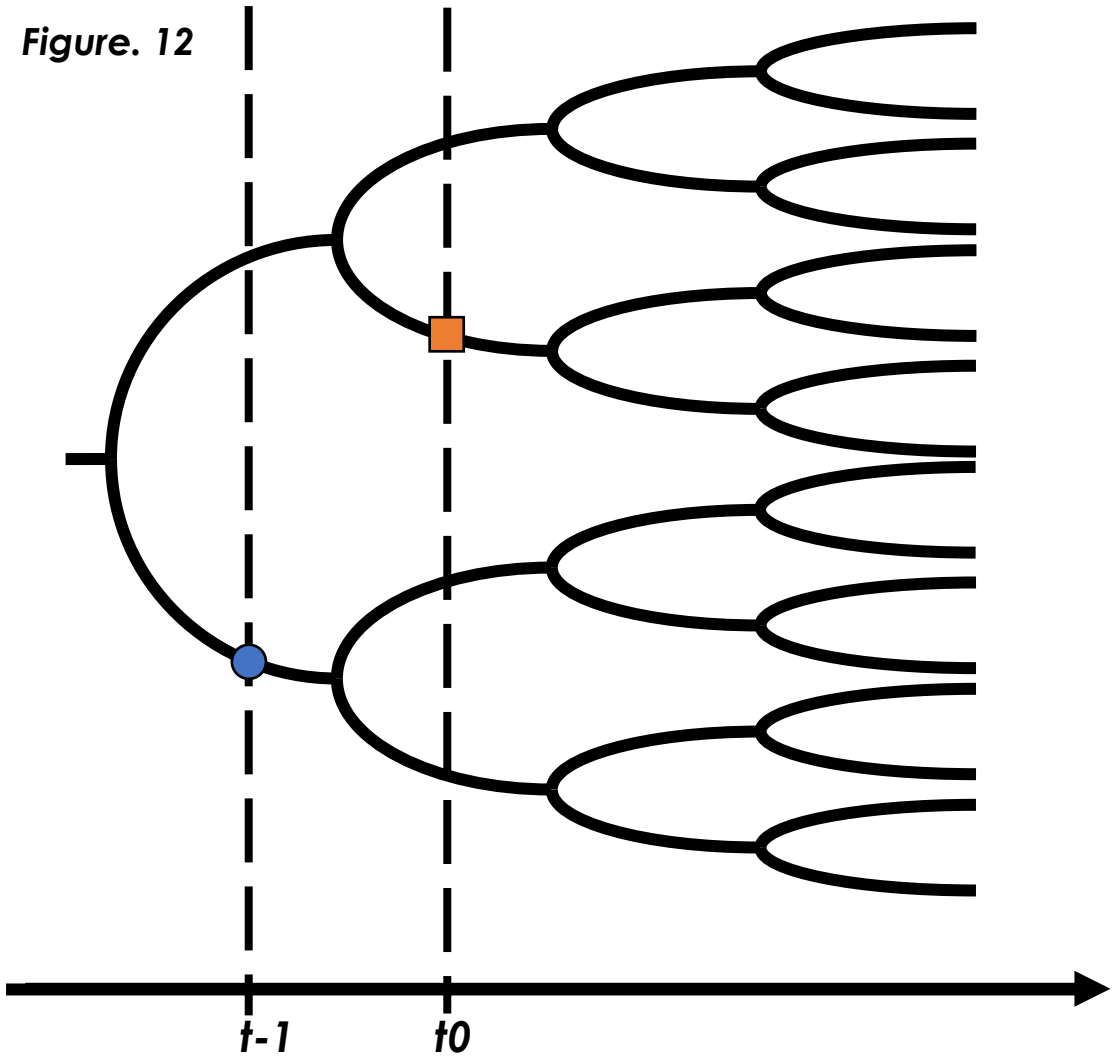
Figure. 11



When one makes past tensed modal statements, it is ordinary-objects contained within Branches that are in the utterers past which ground the truth of the utterers statement. (Just as on a classical Eternalist picture it is past ordinary-objects which ground the truth of past tensed non-modal statements).

For example, when an utterer makes a past tensed modal statement like "the moon could have collided with Earth". This statement involves quantification over all past Branches relative to the location of the utterer and is true if this event occurs in at least one past Branch (presumably one that doesn't compose the human utterers history). In *figure. 12* the orange square represents the utterer making the statement at time *t0*. The statement is grounded in the event occurring at time *t-1*, represented by the blue circle.

Figure. 12



When an utterer makes a tenseless modal statement or a statement of which the tense is unclear. Such statements are grounded in some ordinary-object or event which exemplifies properties that the statement asserts of them which exists on some branch or Branch somewhere in the universe.

Necessity statements are the duality of possibility statements. The scope of necessity statements can be narrowed with qualifiers as to what the necessity claim is restricted to.

The ordinary-objects which ground the truth of the modal statements are CST-related concrete entities which are posited by EQM. So, EAM provides a reductive, concrete, ontologically parsimonious, naturalistic and CST-related explanation of modal statements. The account I have briefly outlined so far meets desiderata 1) – 4). I explicate this further throughout the thesis.

Given the objective mind independent nature of Everettian worlds and the concrete ordinary-objects contained within them. The modal facts they

constitute are objective mind independent modal facts, modality is an objective mind independent feature of reality.

In §6 I further explicate the nature of persistence of ordinary-objects, to specify what grounds the truth of tensed and tenseless modal statements on EAM. For now, suffice to say that an Eternalist-EQM provides an EAM where differently tensed modal statements are grounded in the same kind of ordinary-objects, namely concrete classically defined entities which are ontologically on par and exist on some branch or Branch somewhere in the Universe.

As I now outline, the same cannot be said for non-Eternalist ontologies of time as they at least fail to meet desiderata 1).

§4.2 Non-Eternalist Accounts

Applying non-Eternalist ontologies to EQM results in accounts of modality which invoke disanalogous and more complex explanations for differently tensed *de re* modal statements. Non-Eternalist accounts aren't uniform as they don't invoke the same kind of objects to ground the truth of different tensed *de re* modal statements, so they fail to fully meet desiderata 1).[26] I now briefly outline this for each non-Eternalist ontology of time.

§4.2.1 Presentism

Presentism – defended by Markosian (2004, 47-82) – holds that only the present is real, the past and future don't exist. Reality consists of an objective universe wide present. As such, there are no past or future objects, only present objects exist. A-judgements talk of the present picks out this objective thing and cannot be reduced to tenseless talk.

Presentists ground the truth of present statements in present objects. However, as past and future objects don't exist on a Presentist picture, statements about the past or future cannot be grounded in past or future objects given there are none. Presentist's cannot explain the truth of statements like "there were once dinosaurs" with quantification over past dinosaurs. This is known as the truthmaker objection.

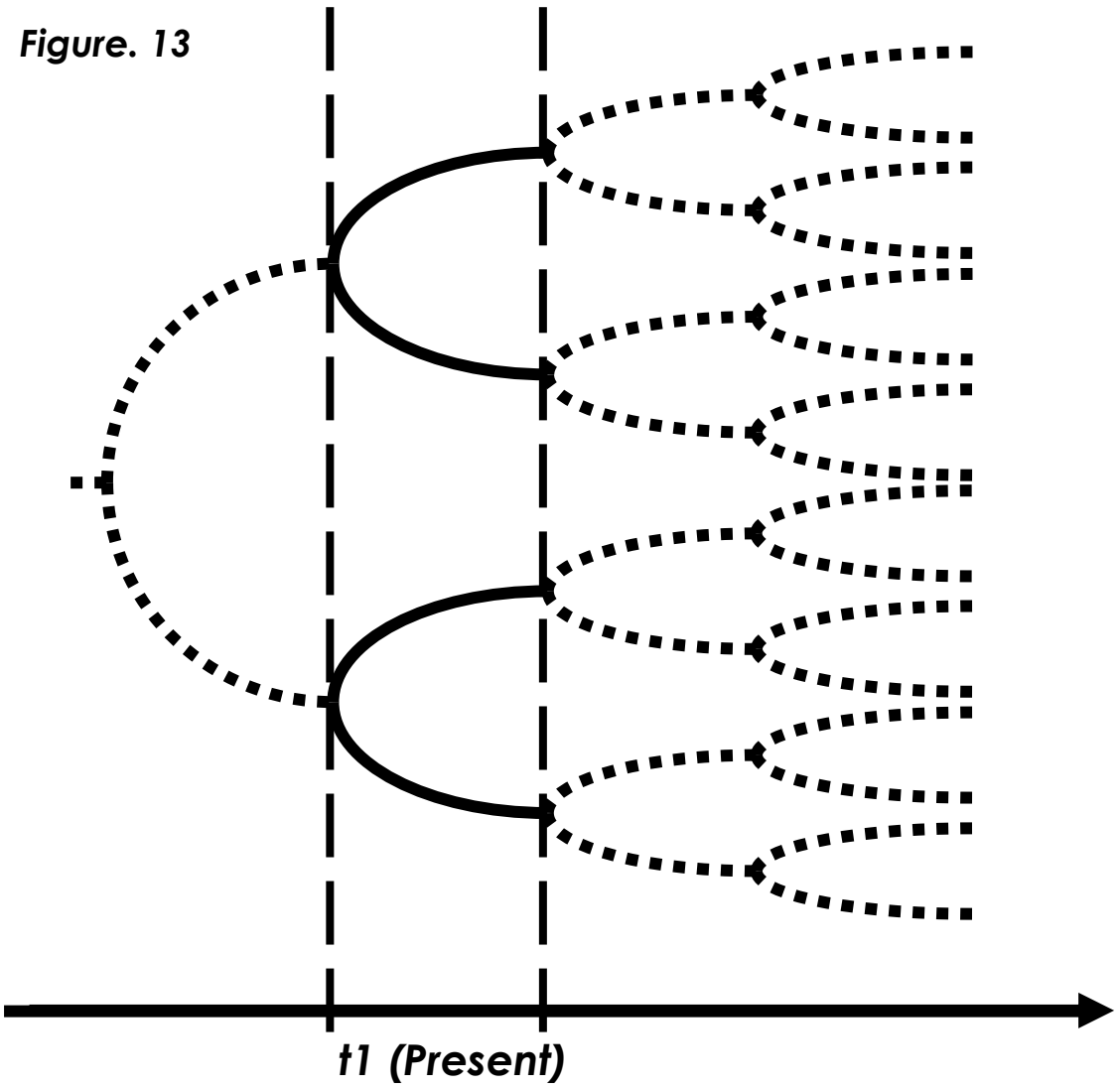
Instead Presentist's hold that statements involving the past and future are still true, but invoke a different explanation to statements involving the present. Quantification of such statements is grounded in something like tense

[26] Whether or not desiderata 2), 3) and 4) are met depends on whether non-Eternalist explanations invoke concrete or abstract entities, whether these entities are CST-related, and of a kind already a part of one's ontology. Given the variety of non-Eternalist accounts, I focus only on the uniformity part of desiderata 1) which all fail to meet.

operators like 'WAS' or 'WILL', without ontologically committing to the existence of past and future things. Such operators pick out something like 'facts' or 'states of affairs' in the present world as grounding the truth of past and future statements (Sider 2001, 11-5).

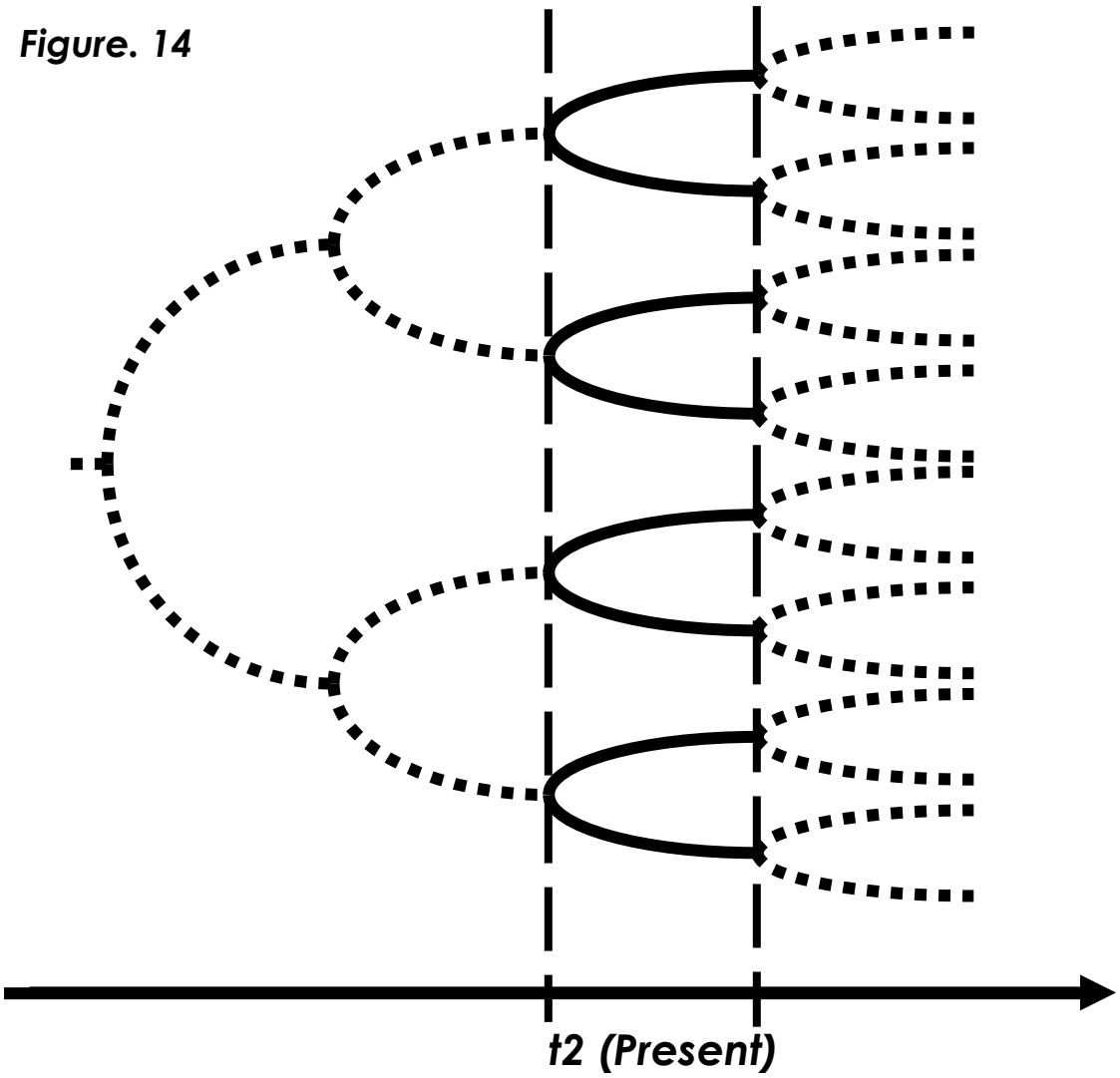
Applying Presentism to EQM means that only present parallel branches exist and which branches these are changes by increasing in number over time as more branching occurs (illustrated in *figure. 13* & *figure. 14*).[27]

Figure. 13



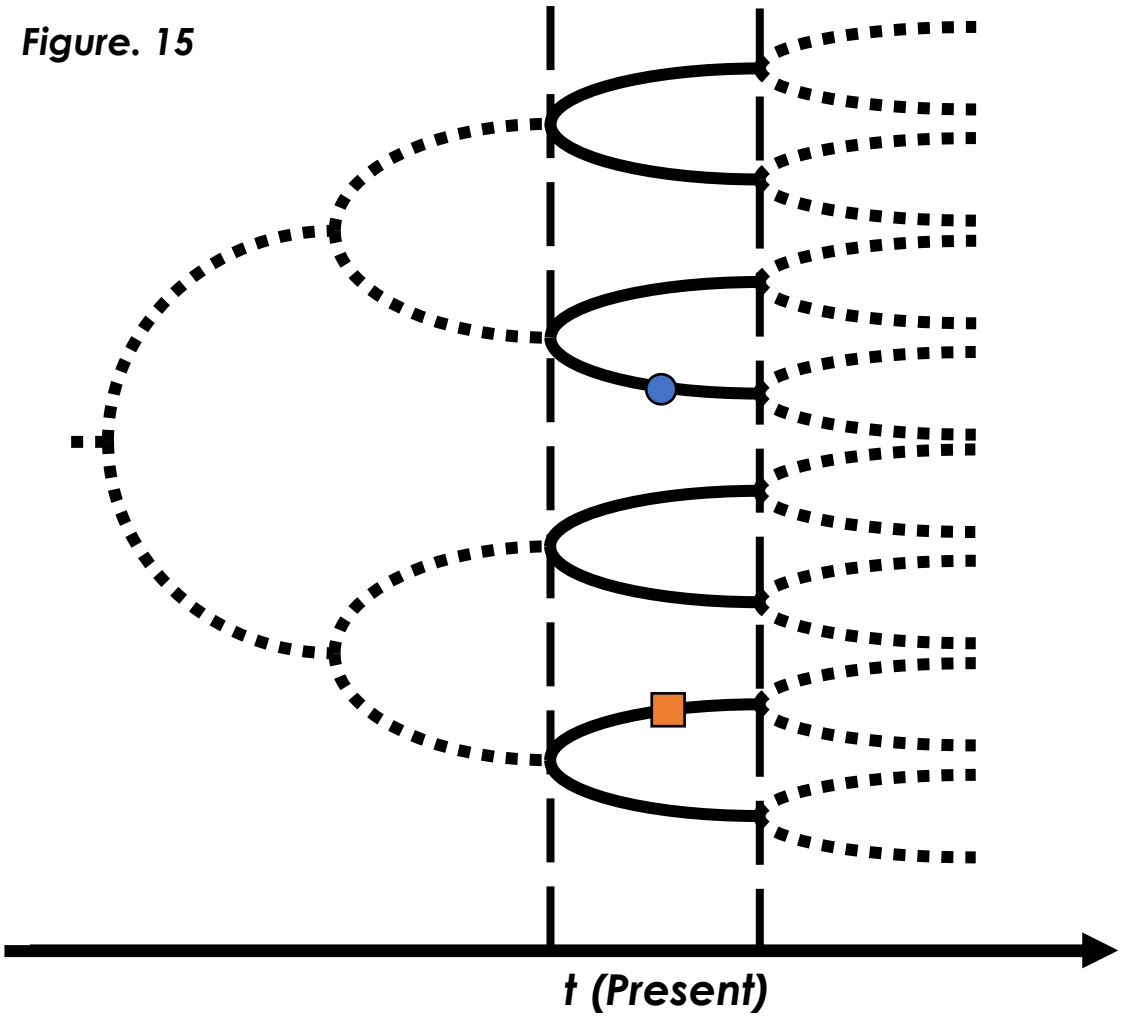
[27] The solid branches represent what exists and the dotted branches represent what doesn't exist when compared with Eternalism. Although the present appears temporally extended in the diagram, it can be understood as a slice of irreducible branches.

Figure. 14



A Presentist Everettian account of modality can ground present tensed modal statements in concrete objects themselves and properties the statement asserts of those objects which exist on present parallel branches. For example, the modal statement "the moon could collide with Earth right now" is grounded in some parallel present branch in which this event occurs. In *figure. 15* the orange square represents the utterer making the statement at time *t*. The statement is grounded in the event occurring on a parallel Branch at time *t*, represented by the blue circle.

Figure. 15



However, given that past and future objects don't exist, a Presentist Everettian account of modality cannot ground the truth of past or future tensed modal statements in concrete past or future objects.

I maintain that a desirable account of modality is one that doesn't significantly limit the number of true modal statements based on their tense. Such an account should unanimously account for the truth of all tensed modal statements, given they make up an important part of our modal talk.

So, in order for the Presentist Everettian account to retain the truth of past and future tensed modal statements they require an alternative explanation. Such statements – as with non-modal past and future tensed statements – are grounded in something like presently existing facts or states of affairs. Invoking the primitive tense operators WAS and WILL quantifying over all parallel branches. For example, "the moon could have collided with Earth" is grounded in something like the tense operator WAS'moon collides with Earth' applying to at least one present parallel branch. Alternatively, "the moon

could collide with Earth" is grounded in something like the tense operator WILL'moon collides with Earth' apply to at least one present parallel branch.

The Presentist account invokes two kinds of thing to ground the truth of our modal statements. First, in the case of present tensed modal statements, concrete objects themselves which don't point beyond themselves and exist in parallel branches, they alone explain the truth of such statements. Second, in the case of past and future tensed modal statements, facts or states of affaires of objects which exist on present parallel branches but point beyond themselves and utilise primitive tense operators. As a Presentist Everettian account fails to uniformly ground the truth of different tensed *de re* modal statements in the same sort of thing, it at least fails to fully meet desiderata 1).

The same sort of problems arise for other non-Eternalist ontologies which I now briefly outline.

§4.2.2 Growing-Block

Growing-Block theory – described by Tooley (1997) – holds that the past and present are real but the future is not. Reality consists of a four-dimensional manifold which grows over time. The present is the objective brink of existence which moves as time goes on.

True statements about the past and the present are grounded in existing objects themselves. But given there are no future objects, if the Growing-Block theorist is to retain the truth value of future statements then these cannot be grounded in future objects.

On Growing-Block, statements about the future work in the same way as the Presentists future statements using the primitive WILL tense operator. For example, what makes it true that Mars outposts will exist on Mars are something like facts or states-of-affairs today which point beyond themselves to Mars outposts existing in the future.

Applying Growing-Block to EQM we end up with a Growing-Tree view. Reality consists of a growing four-dimensional tree manifold. Past and present branches exist but future branches don't. Reality grows over time as more branching occurs and the number of branches increases. *Figure. 16* & *figure. 17* illustrate Growing-Tree-EQM.

Figure. 16

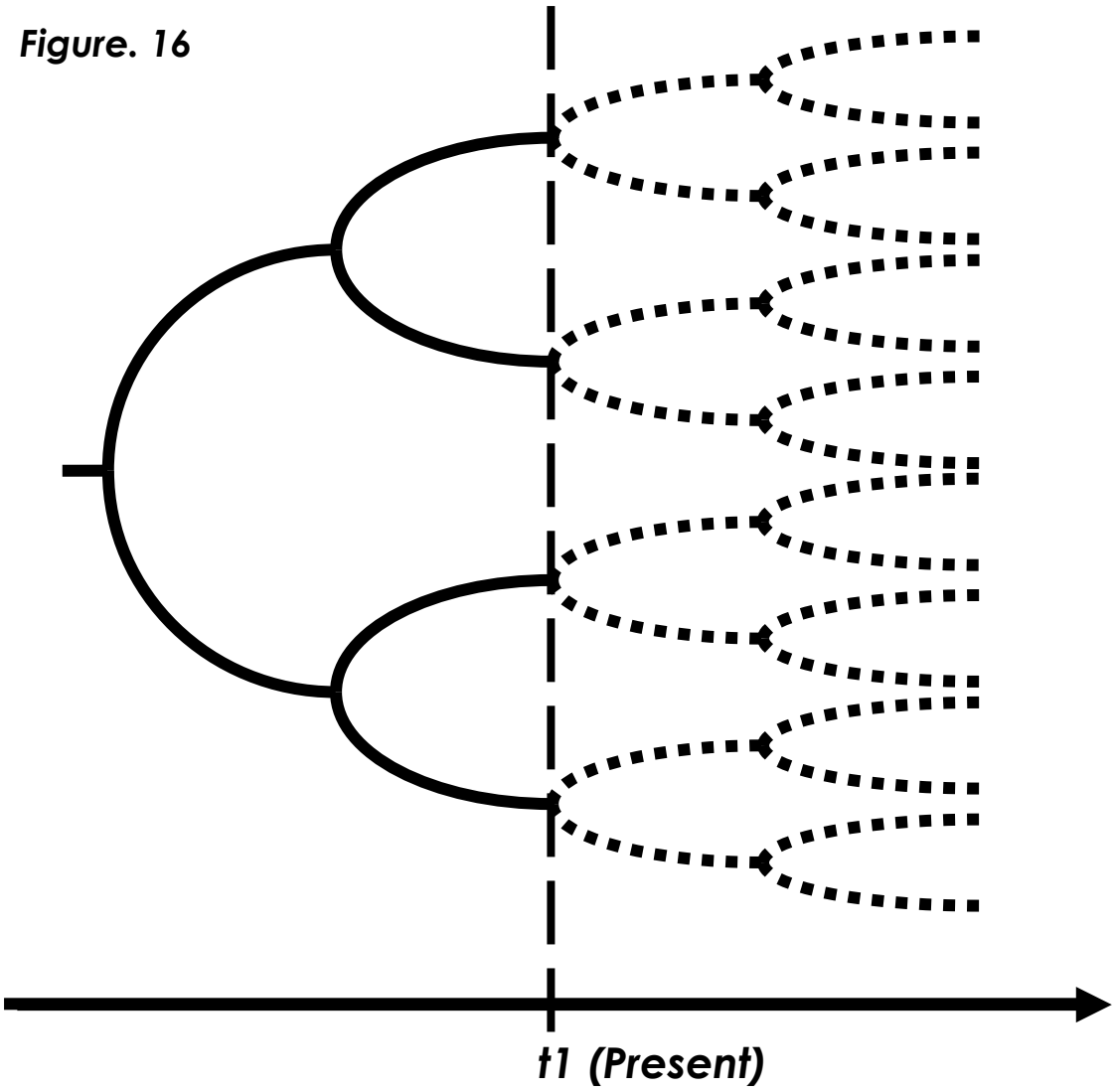
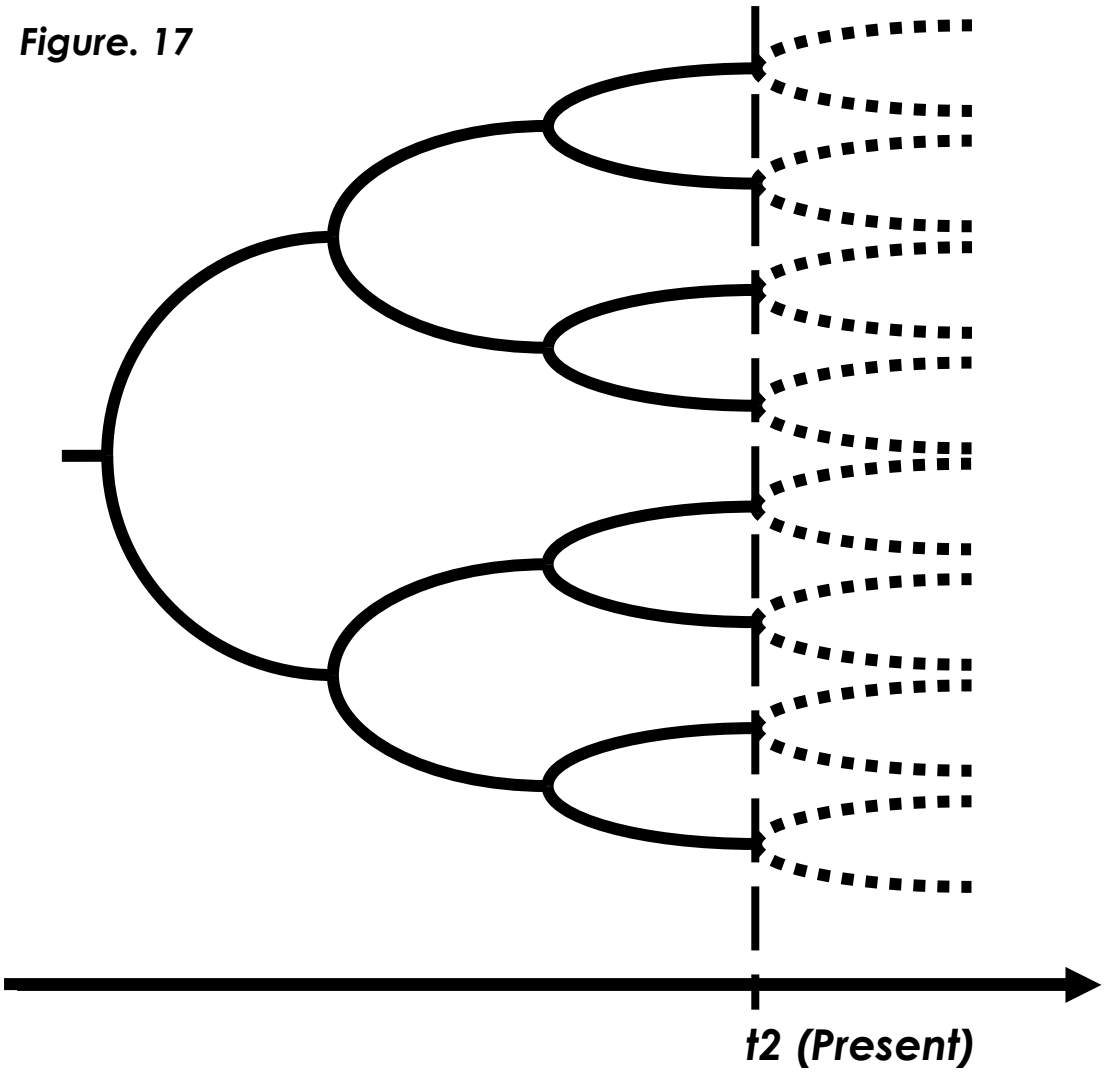
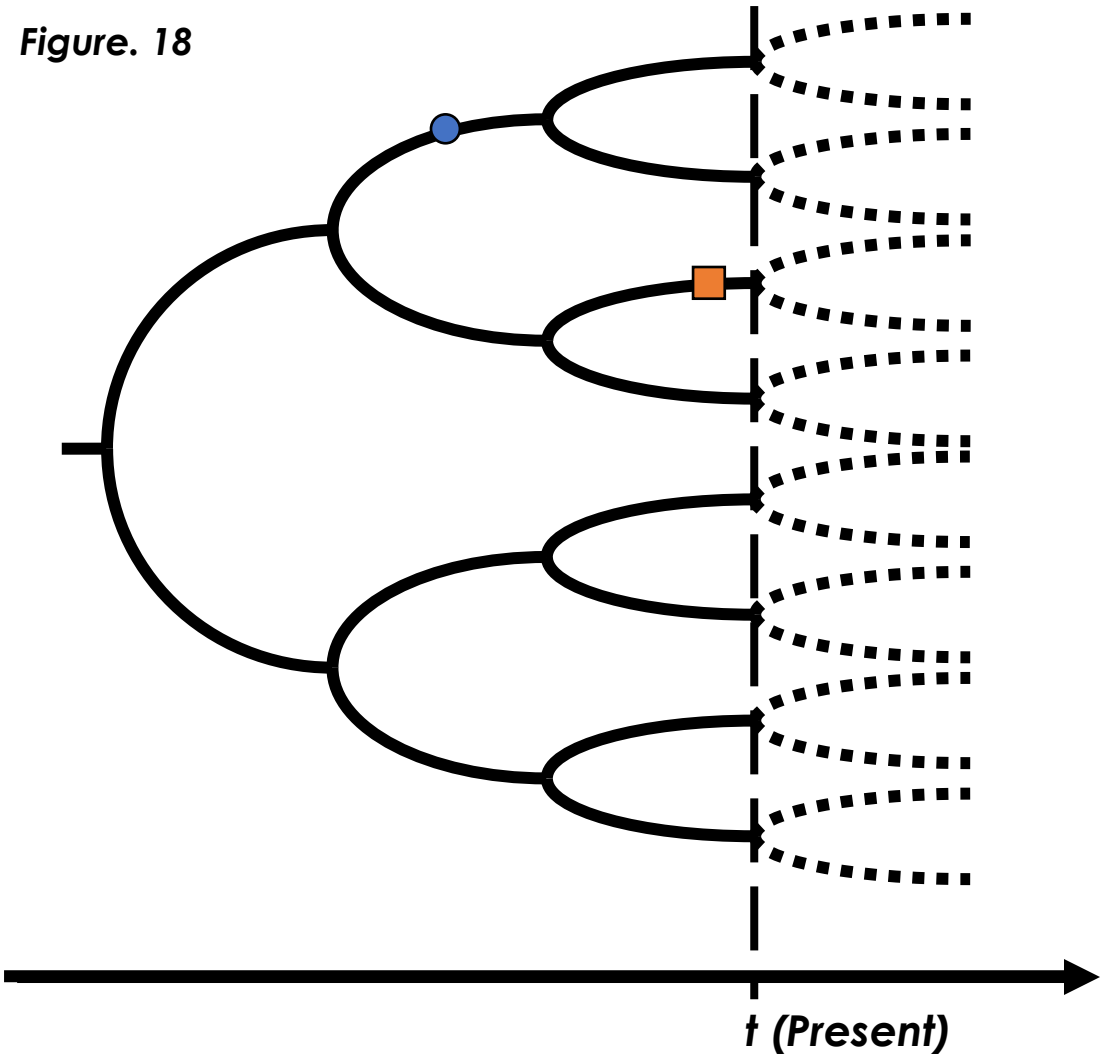


Figure. 17



A Growing-Tree Everettian account of modality can ground past and present tensed modal statements in concrete objects themselves which have properties the statement asserts of them and which exist on past or present parallel branches. For example, the modal statement "Earth could have been hit by a meteor which wiped out humanity" is grounded in some past branch in which this event occurs. In *figure. 18* the orange square represents the utterer making the statement at time *t*. The statement is grounded in the event occurring in some past Branch represented by the blue circle.

Figure. 18



However, given future objects don't exist, a Growing-Tree Everettian account of modality cannot ground the truth of future tensed modal statements in concrete future objects. So, if the Growing-Tree theorist wishes to retain the truth of future statements then they must ground the truth of such statements in something like presently existing facts or states-of-affairs. Invoking the primitive tense operator WILL quantifying over the present parallel branches which exist.[28]

For example, "the moon might collide with Earth" is grounded in something like the tense operator WILL'moon collides with Earth' applying to at least one parallel branch.

[28] Indeterminate truth values about the future may be an appealing aspect of Growing-Block, retaining the idea of an 'open future'. Yet even on an Eternalist understanding of EQM there is a sense in which the future is open: there is no one determinate way the future will be, but many different ways, none more privileged than any other. I discuss this further in *§5.2.2.*

However, as with the Presentist account, a Growing-Tree Everettian account of modality at least fails to fully meet desiderata 1) as it invokes two different kinds of explanation for differently tensed modal statements.

§4.2.3 Shrinking-Tree

Shrinking-Tree ontology of time – described by McCall (1994) – is counter to the Growing-Tree view. It holds that reality consists of a linear set of past branches, composing the trunk of the tree, and multiple parallel future branches. All these branches exist and the objective present is where the trunk meets the branches. As time moves forwards and future branches move to the present either; they fall away and cease to exist, resulting in the tree of reality to shrink, or a certain linear set of branches continue to exist and form new parts of the trunk.

Although McCall's branching structure is not based on the structure of EQM universe and is more akin with alternative 'collapse' theories of QM, the guiding principle that reality shrinks over time as branches fall away can be applied to EQM, as illustrated in *figure. 19* & *figure. 20*.

Figure. 19

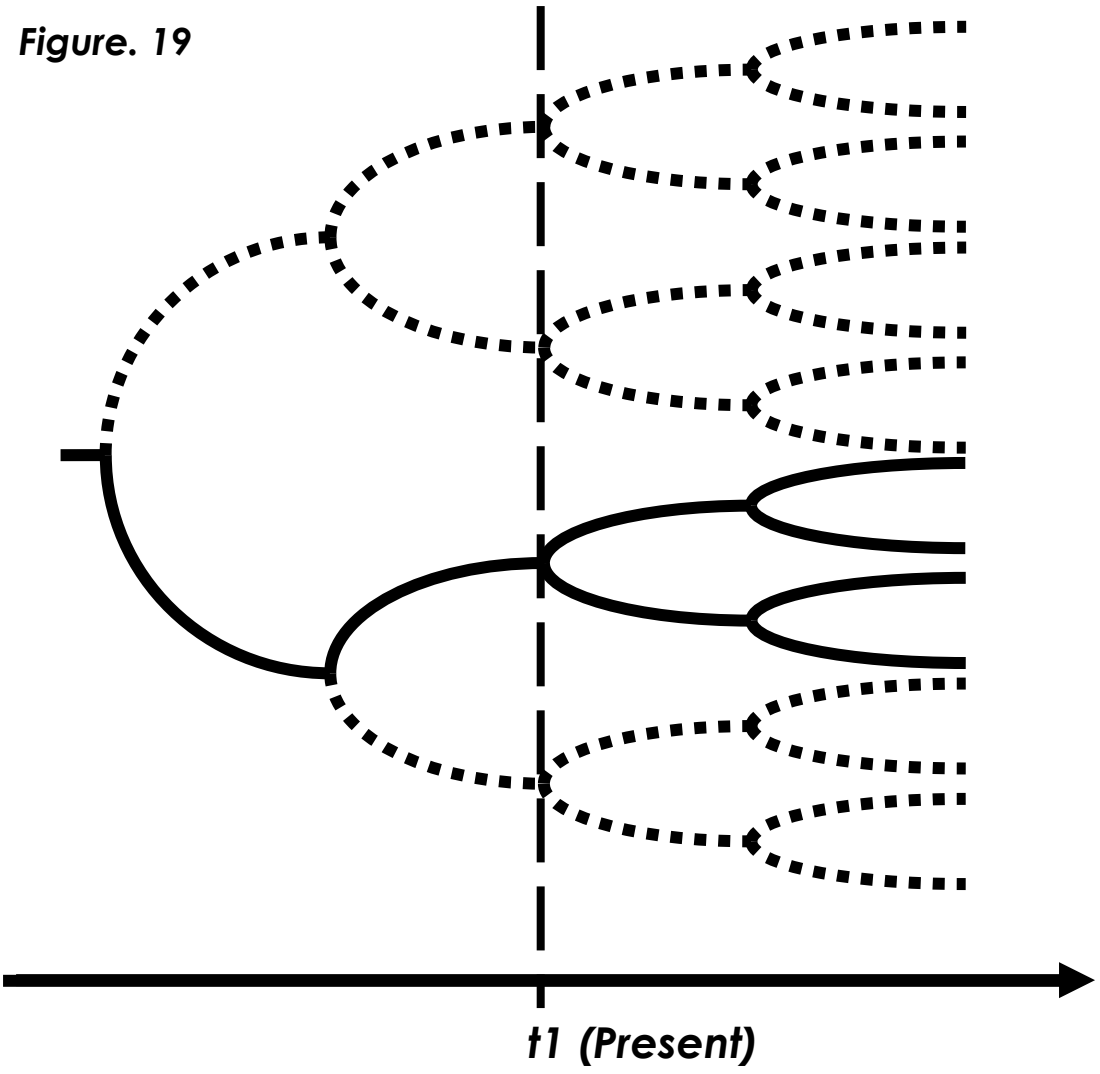
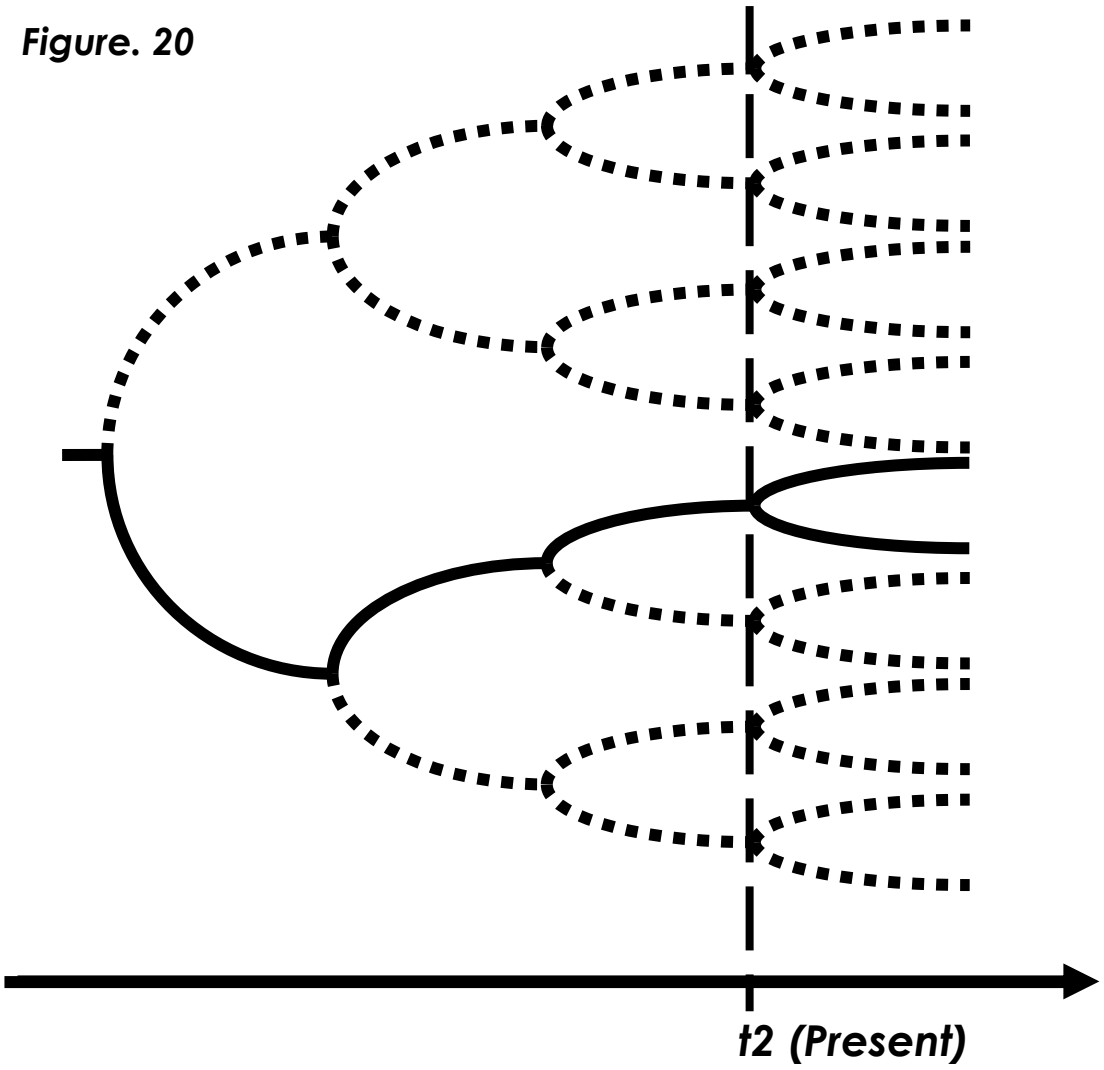
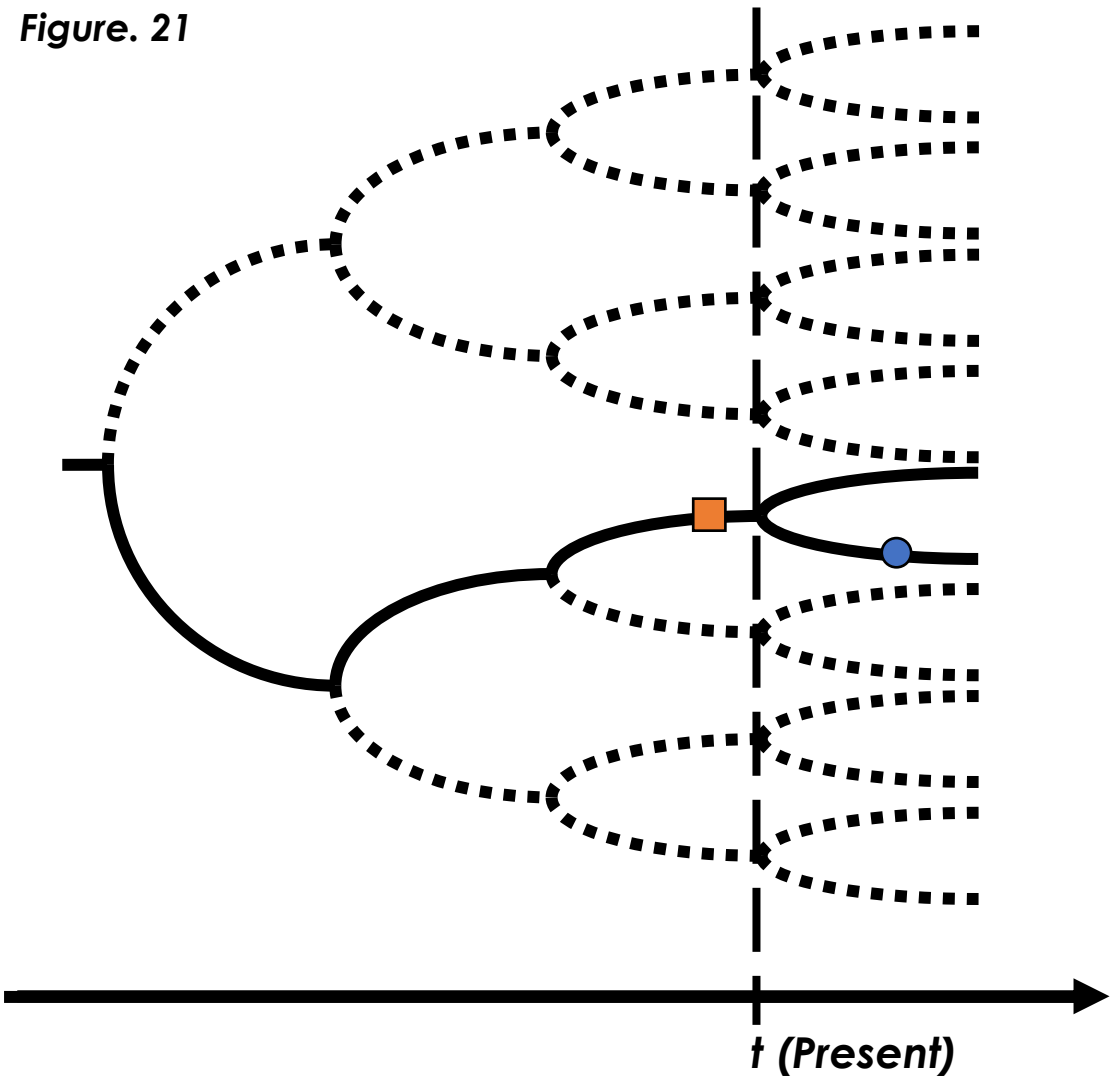


Figure. 20



A Shrinking-Tree Everettian account of modality can ground future tensed modal statements in concrete objects themselves which exist on future branches. For example, the modal statement "the Moon might collide with Earth" is grounded in some future branch in which this event occurs. In *figure. 21* the orange square represents the utterer making the statement at time *t*. The statement is grounded in the event occurring in some future branch represented by the blue circle.

Figure. 21



However, given only past and present branches which compose an utters history exist. Other than those in the utterer's history, there are no past or present concrete objects to ground the truth of past and present modal statements.

Furthermore, given that certain future branches fall away as the present moves through time, Shrinking-Tree Everettian accounts are limited to only certain future tensed modal statements being true. Depending on whether these branches fall away or not determines their truth value over time.

Retaining the truth of past and present modal statements is a little less clear with Shrinking-Tree view given there are no present parallel branches. Whatever way the truth value is retained, it invokes a more complex explanation for different tensed statements so fails to fully meet desiderata 1).

§4.3 Summary

In conclusion, non-Eternalist accounts either involve accepting the indeterminate or false value of certain tensed modal statements, or they involve different explanations for different tensed statements. As such they fail to fully meet desiderata 1), at the very least, depending on the explanation they may also fail to meet 2) – 4).

However, if Eternalist-EQM is true then it allows for modal statements to be reductively, uniformly and parsimoniously grounded in CST-related concrete ordinary-objects which exist somewhere in the EQM universe. It therefore provides the simplest EAM which meets desiderata 1) – 4). I henceforth assume Eternalism-EQM (simply 'EQM' henceforth) when further explicating EAM.

§5: Narrow-Future vs. Broad-Future Possibilities and 'Actuality'

On EQM there is no ontological difference between branches. However, given the branching structure posited by EQM, from the perspective of an utterer there is a distinction between two kinds of future branches. Future branches which stem from the Branch where the utterer is located and branches which don't stem from the Branch where the utterer is located. I label them 'stemming future branches' and 'non-stemming future branches' respectively.

Furthermore, given there is no ontological difference between branches, there is the question of what is meant when talking of branches – including the objects and events within them – being 'actual'.

In this section I draw the distinction between stemming and non-stemming future branches. I outline their implication for EAM. I then outline a suitable candidate for the semantics of 'actual'.

I henceforth talk of an 'utterers Branch': the Branch where the modal utterance is located. I specify 'Branch' – as opposed to 'branch' – as utterances are temporally extended (I leave open the utterer's nature of persistence until §6).

§5.1 Narrow-Future vs. Broad-Future Possibilities

Given the branching structure of EQM there is a distinction between future branches. Stemming future branches which stem from the utterers Branch and non-stemming future branches which don't stem from the utterers Branch. This distinction is illustrated in *figure. 22* & *figure. 23* where the orange

square represents the utterer. Stemming future branches are highlighted red in *figure. 22*. Non-stemming future branches are highlighted red in *figure. 23*.

Figure. 22

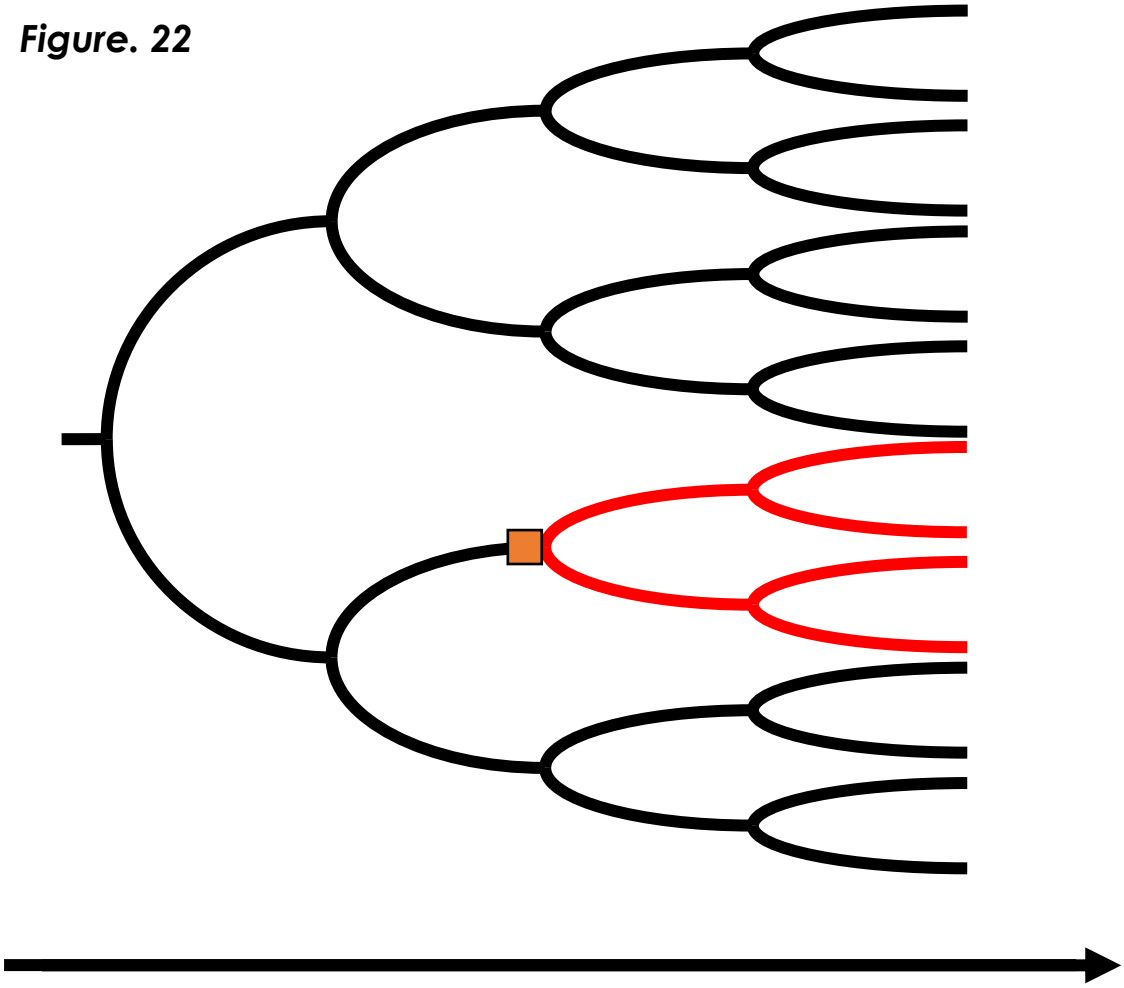
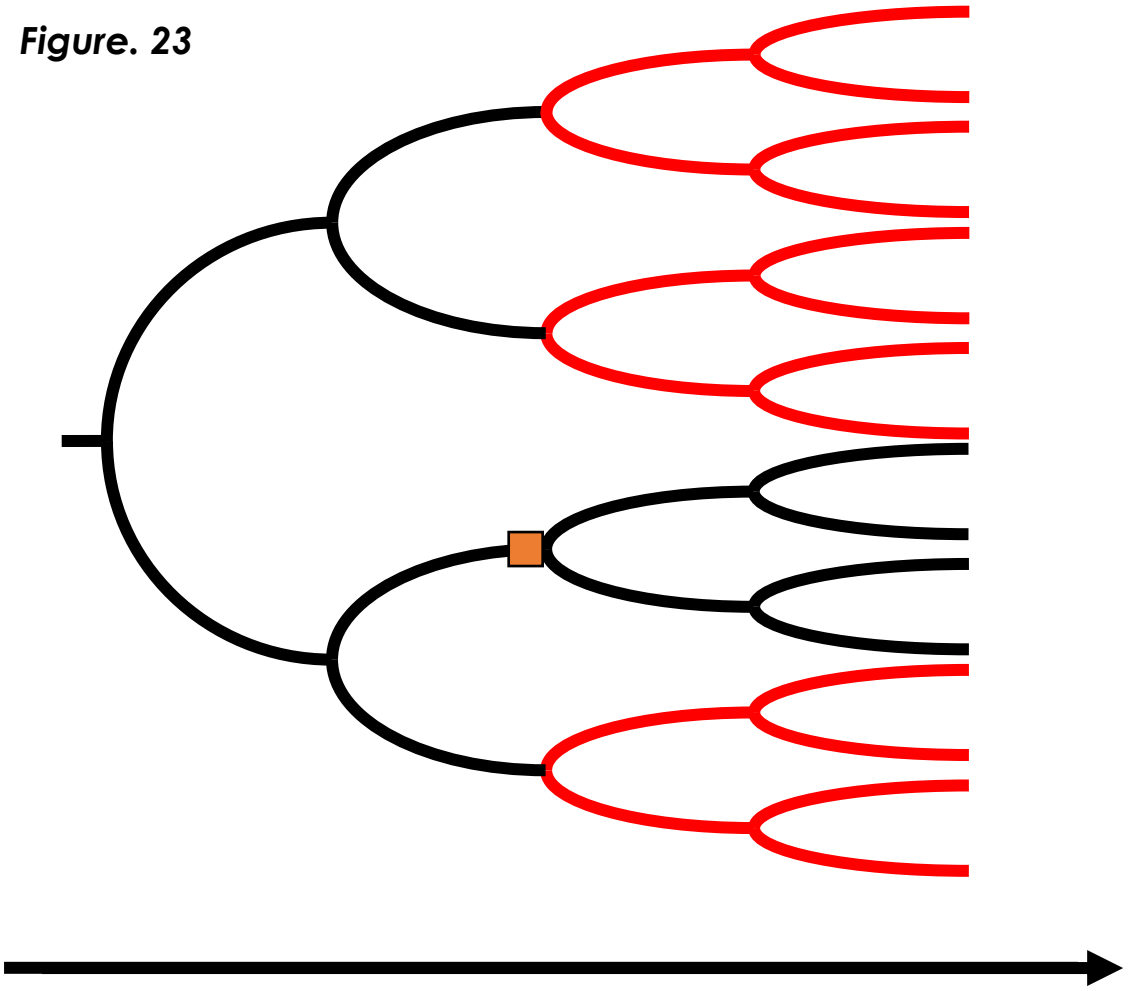


Figure. 23



EAM, some future tensed modal statements are grounded in ordinary-objects contained in future stemming branches, while other future tensed modal statements are grounded in ordinary-objects contained in non-stemming future branches. As such there is a distinction between narrow-future possibilities and broad-future possibilities.

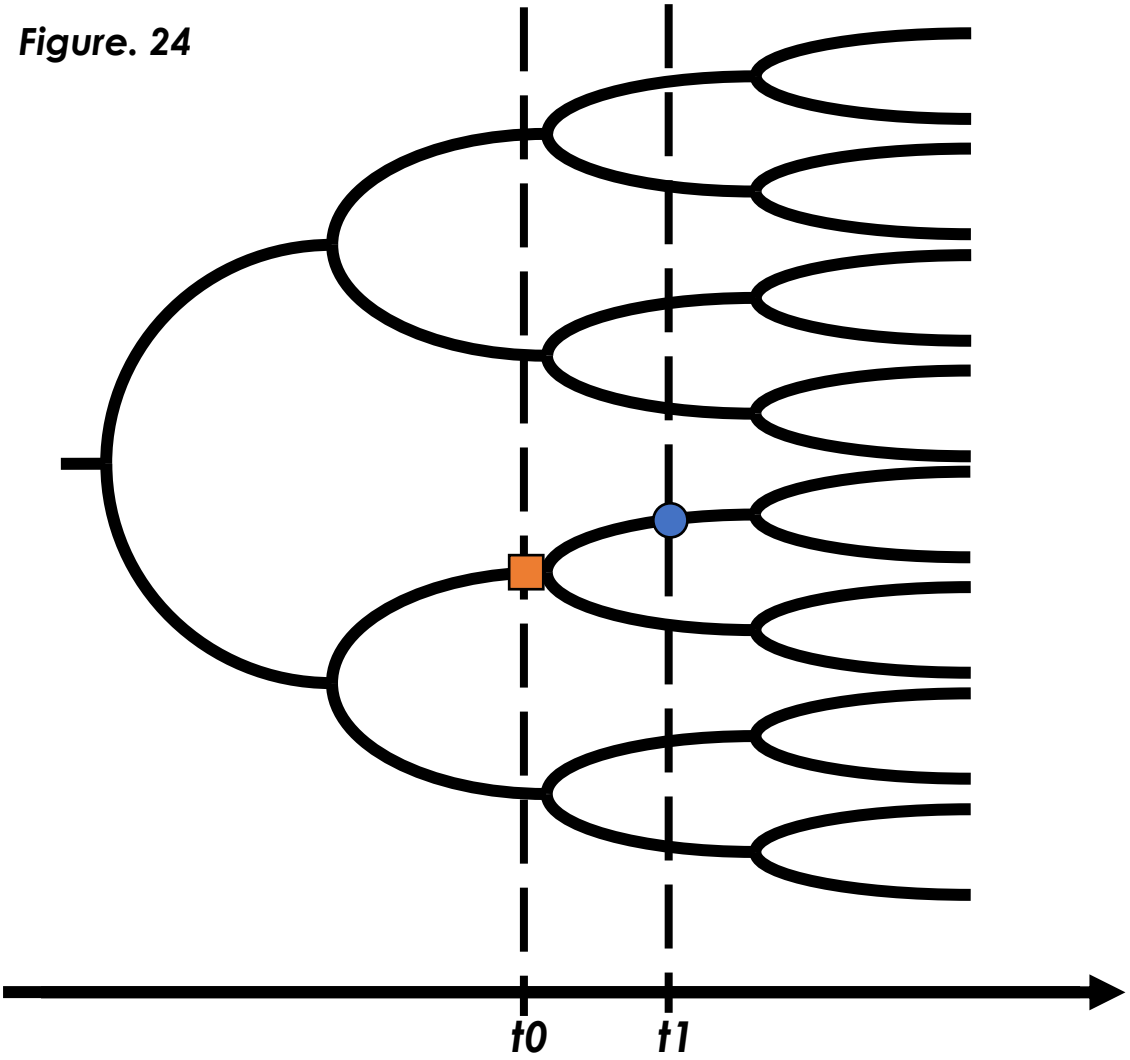
Narrow-future possibilities are future possibilities given the state of utterers history at the time of the utterance and such statements are grounded in ordinary-objects contained within stemming future branches

For example, "it might rain tomorrow" is most naturally understood as a narrow-future possibility whereby the truth of the statement depends upon the state of the world at the time of utterance.[29] Such a statement is grounded in some future 'tomorrow' Branch – which stems from the utterers Branch – in which it does in fact rain. In *figure. 24* the orange square

[29] This statement can also be understood in a broad sense.

represents an utterer at *t0* and the blue dot at *t1* represents the event of it raining the day after the time of utterance in a stemming future Branch.

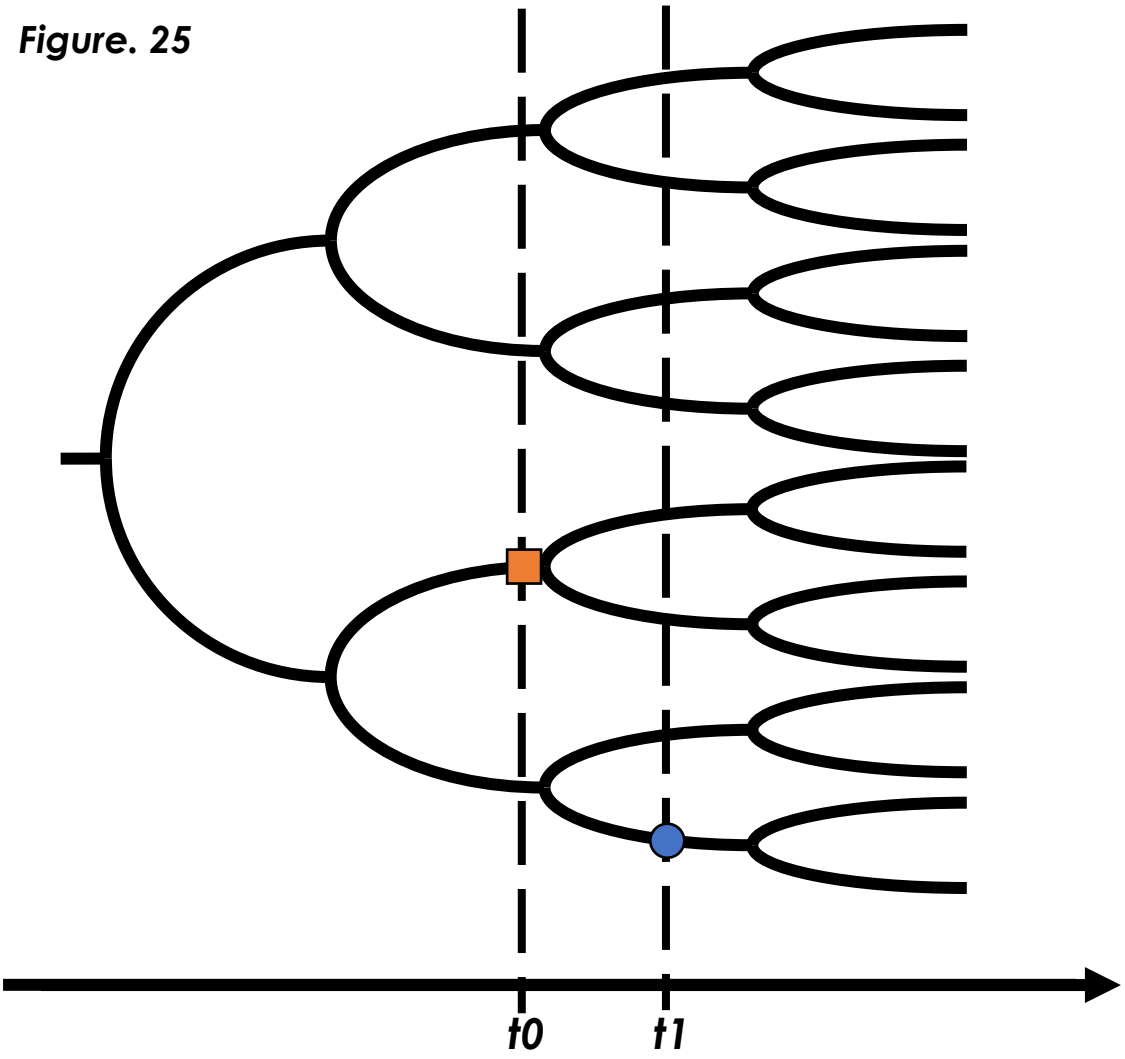
Figure. 24



Broad-future possibilities are possibilities that don't depend on the state of the utterer's history and such statements are grounded in ordinary-objects contained within non-stemming future branches. Broad-future possibilities are future possibilities *simpliciter*.

For example, "Donald Trump could have passed a presidential bill to ban the app 'TikTok' tomorrow" is a broad possibility. Donald Trump is no longer president in the utterer's history (assume our own). The truth of the statement is grounded in a future Branch which stems from some parallel Branch, not the Branch where the utterer is located. In this case, a Branch in which Donald Trump won the re-election and banned TikTok the day after the utterance. In *figure. 25* the orange square represents the utterer at *t0* and the blue dot at *t1* represents the event of President Donald Trump banning TikTok.

Figure. 25



So, all future tensed modal statements are grounded in ordinary-objects that are future related to the utterer of the modal statement. The distinction between narrow-future and broad-future possibilities is simply an indexical one bearing on whether the ordinary-objects that ground the truth of the modal statement are contained within stemming or non-stemming future branches.

Given the structure of the EQM universe whereby branching increases over time, the same distinction between narrow and broad senses of possibility cannot as easily be drawn in the case of past or present possibilities.

Instead, the distinction is simply between those past and present branches which compose an utterers history, and those which don't. There is then a feasible distinction between which past and present branches are regarded as 'actual' and those which aren't.

§5.2 'Actuality'

Given all branches – and hence all objects contained within branches – are ontologically on par, I take there to be no objective property of being actual that things possess.[30] I take a similar approach to Lewis and Wilson with regards to the semantics of 'actual' (Lewis 1986, 92-101 & Wilson, 2020, 68-73)

Rather than 'actual' picking out something ontologically or otherwise privileged, 'actual' is an indexical, like 'here' or 'now': the truth or meaning of the word is determined by the context in which it is uttered. So, on EAM what branches, events or objects an utterer regards as 'actual' depends on where in the universe the utterer is located.

Given the overlapping and branching structure of the CST-related worlds, what 'actual' applies to is a little more complicated than on Lewis' or Wilson's account. As there is an asymmetry between an utterer's history and their future, there is also an asymmetry between what branches – including the events and objects contained within them – an utterer regards as 'actual'.

I now outline one suitable candidate for the semantics of which branches – including the objects and events contained within them – are truthfully regarded 'actual', which I use throughout the remainder of the thesis. I further discuss the semantics of 'actual' applied to ordinary-objects and events, including their identity across worlds, in *§7.1*. I maintain that alternative 'actual' semantics are feasible and wouldn't impact the core features of EAM.[31]

§5.2.1 The past and present

When making statements about what is 'actual' in the past or present. I take 'actual' to refer to all branches – including all objects and events contained within them – which compose the utterer's history. In other words, a unique linear set of past and present branches – or Branch – starting from the beginning of time which contain a unique set of objects and events, leading up to the utterance.

So, when an utterer truthfully talks of events that 'actually happened' or are 'actually happening' (or objects that 'actually exist') they are talking about

[30] Thin Red Line ontology suggests there is some special property of actuality. But I adopt Eternalist EQM in which there are no such privileged branches.

[31] One such account – which may appeal to Actualists but which I cannot assess – is whereby all things in the EQM universe are regarded as 'actual' or have a special property of actuality.

the set of events (or objects) contained within the branches which compose their history.

What branches utterers regards as 'actual' differs depending on which branch an utterer is located on. When a different utterer – located on a different Branch – truthfully talks of what is 'actual', they are talking about a different set unique of branches which compose their own history.

Given the structure of overlapping worlds, there is some overlap in terms of what different utterers located on different branches regard as 'actual'. For example, all utterers truthfully regard the initial conditions of the universe – say the Big Bang – as an event that 'actually happened'.

Past and present parallel branches which don't compose the utterers history are not truthfully regarded as 'actual' by that utterer. Instead, I take these branches – including objects and events contained within them – are regarded as 'non-actual'. It is these past and present 'non-actual' branches which ground the truth of an utterers past or present tensed counter-to-fact modal statements.

Figure. 26 & *figure. 27* illustrate which branches an utterer – represented by the orange square – regards as 'actual' and 'non-actual', and how this changes over time. Orange branches represent the utterers history and hence what is 'actual'. Purple branches represent what is 'non-actual'.

Figure. 26

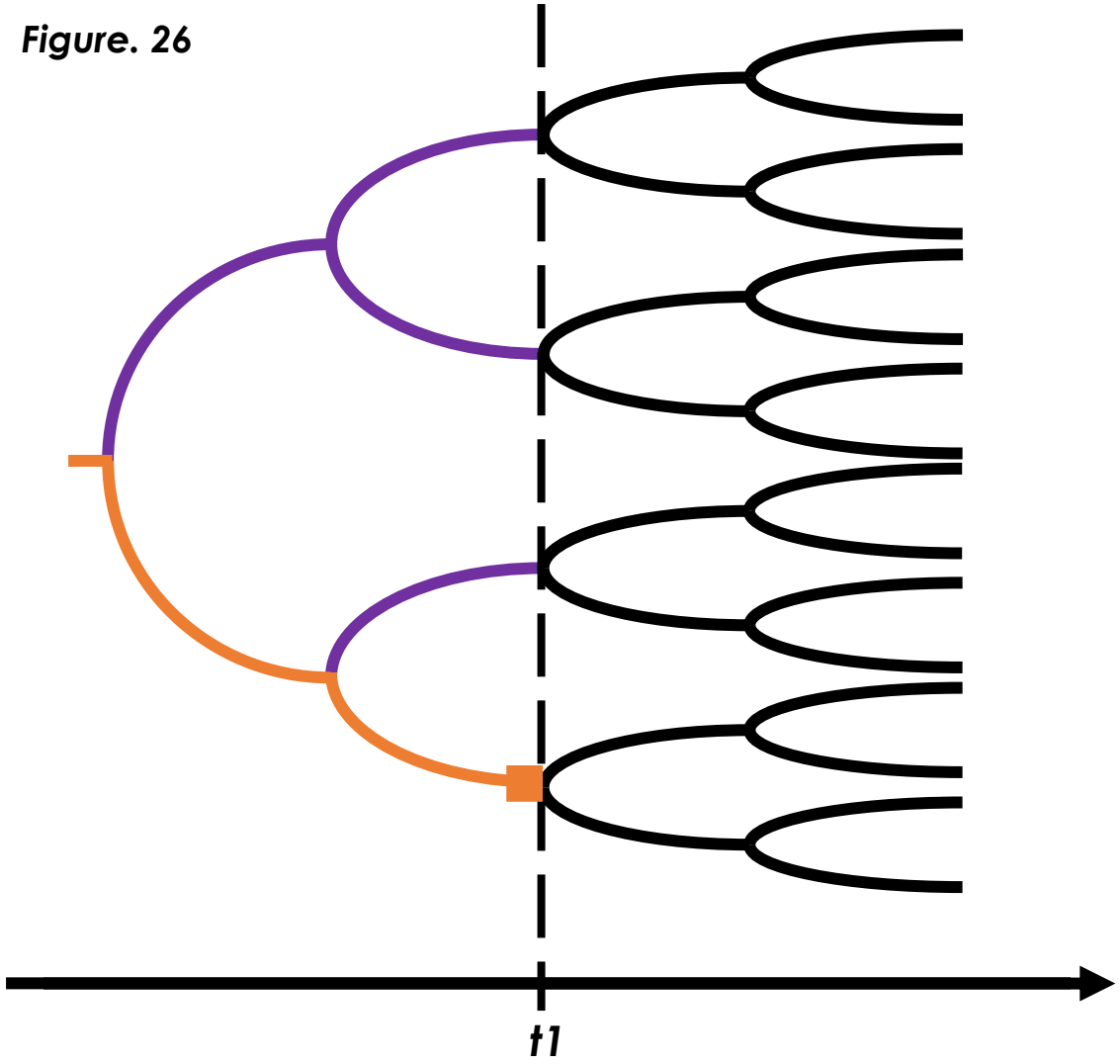
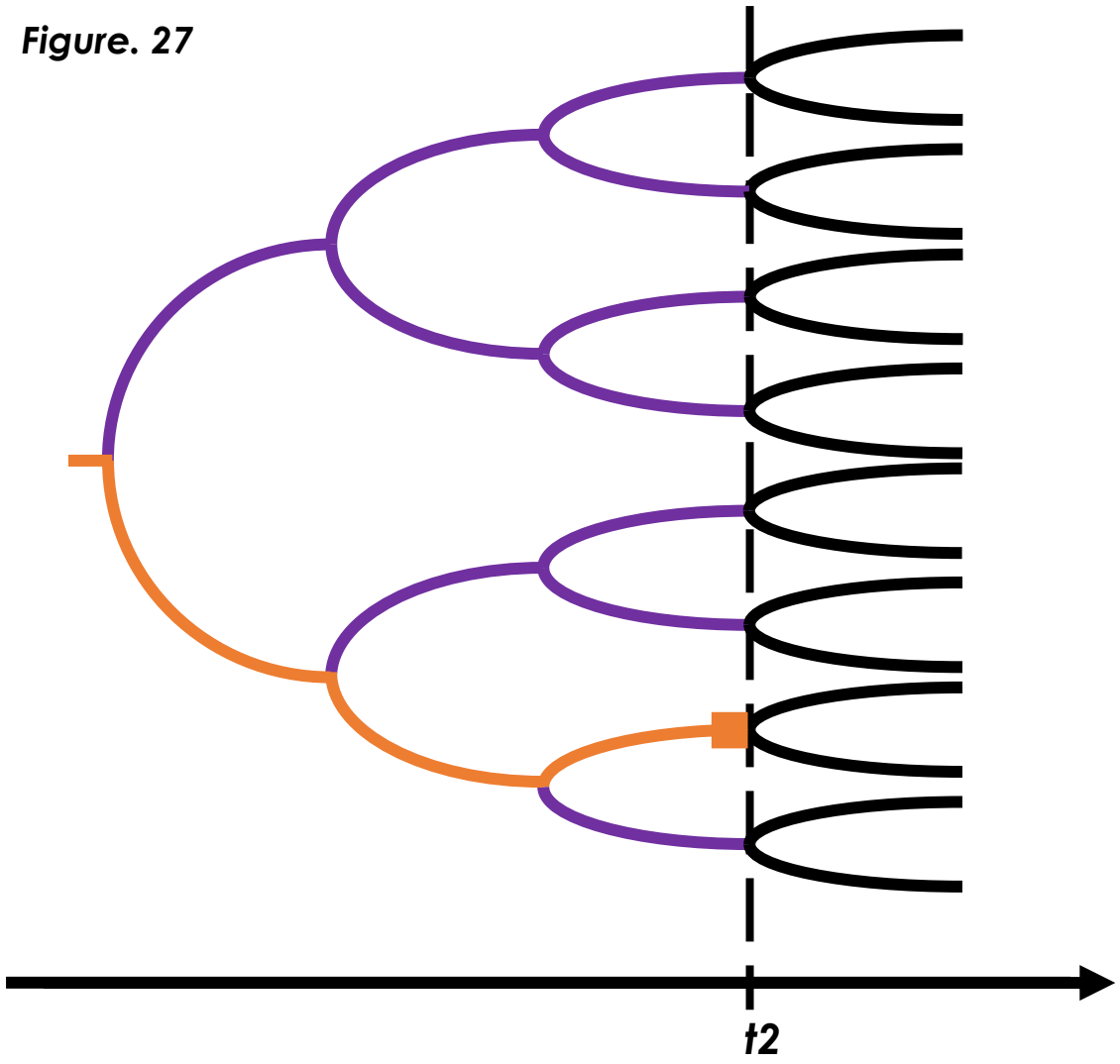


Figure. 27



§5.2.2 The future

Although I adopt an Eternalist ontology of time, from the perspective of an utterer, future events are yet to occur. Given future branches don't compose an utterers history, determining whether future branches – including the events and objects contained within them – are 'actual' is less clear.

In order to answer what – if anything – an utterer regards as 'actual' in the future, a more general understanding of the truth conditions for future tensed statements on EQM is required. I focus my discussion on 'will' semantics, given they're closely related to future 'actual' semantics. In common parlance there is little difference between talk about what 'will happen' and what 'will actually happen'. A candidate semantics of 'will' then suitably determines the future semantics of 'actual'.

Determining the semantics of future tensed statements on EQM is more complicated than determining the – not uncontroversial – future tensed

semantics of a classical universe.[32] In a classical deterministic (non-branching) Eternalist conception of the universe the future consists of one determinate linear set of events. Statements about what events 'will' happen are true or false depending on whether or not they occur. 'Will' statements are akin with necessity statements, they typically concern what necessarily happens given the state of the world at the time of utterance.[33]

On EQM however, there isn't one determinate future linear set of events from the perspective of the utterer. Instead, given the branching structure there are multiple parallel future Branches which stem from the utterer's branch.[34]

As branches aren't privileged in any way, the utterer cannot claim that the events in any one stemming future Branch 'will' occur – or are 'actual' – over any other.

What occurs in an utterer's stemming future are all events permitted by EQM given the state of the utterer's history. An utterer cannot claim they 'will' end up on any one stemming future branch over another. Assuming the utterer doesn't suddenly cease to exist, they 'will' – in a sense – end up on both stemming future parallel Branches.

The sense in which they 'will' end up on both stemming future parallel Branches depends on which ontology of persistence one adopts and the nature of identity across worlds, which I discuss in §6. But suffice to say, before branching occurs there is one utterer. After branching occurs there are two, one utterer located on one Branch and another utterer located on another parallel Branch. The two utterers located on separate parallel Branches both correspond to – and are future related to – the initial pre-branching utterer. The pre-branching utterer cannot claim that one or the other future utterers is really them, or which one branch they 'will' end up on.

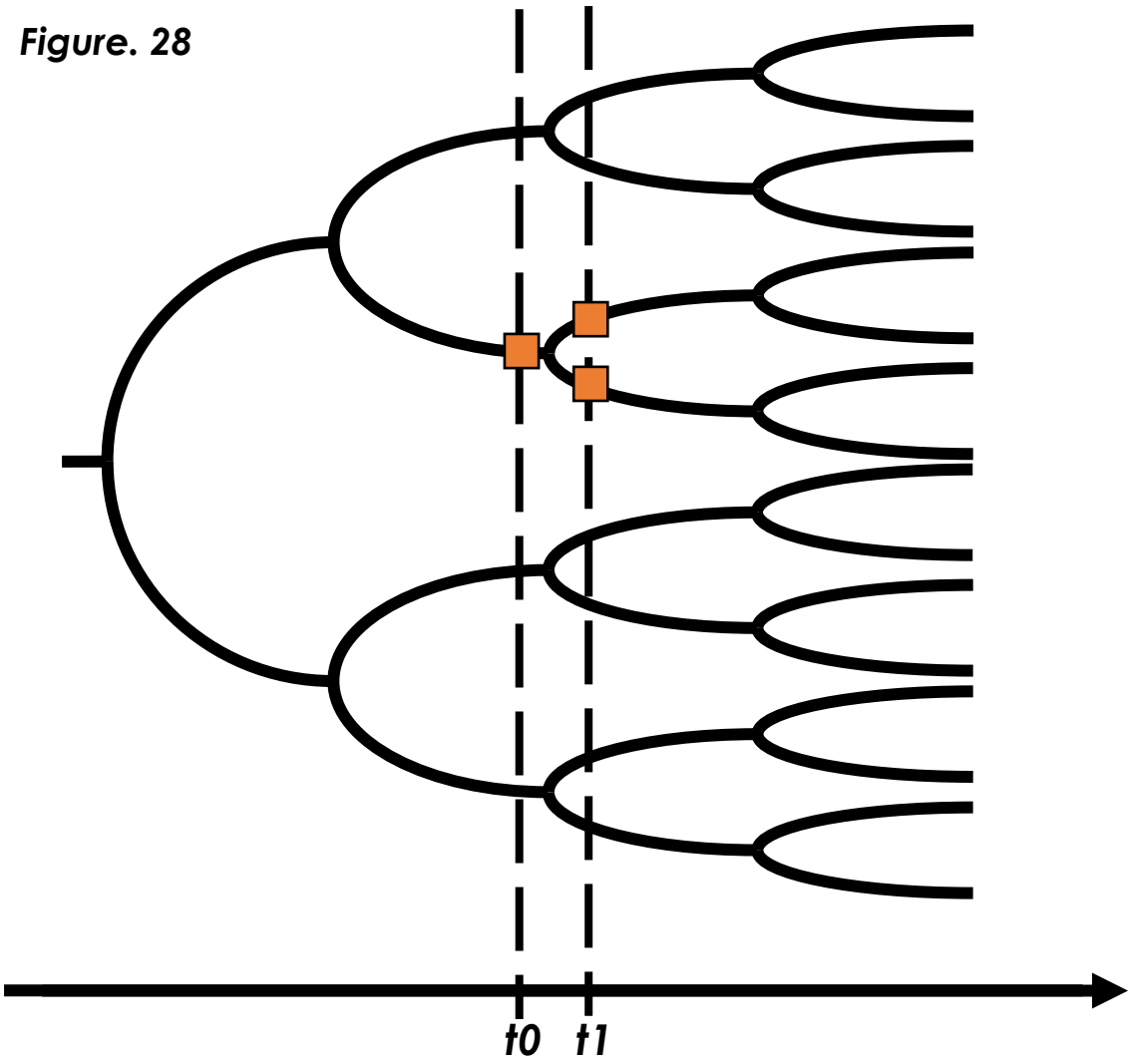
The *figure. 28* illustrates this with the initial pre-branching utterer represented by the orange square at *t0*. The corresponding two post-branching future related utterers represented by the orange squares at *t1*.

[32] Müller (2014, 5-6) provides a discussion in relation to Ockhamist BT, which similarly applies to EAM.

[33] For discussion see Cariani & Santorio (2018).

[34] I specify stemming future branches as these depend on the state of the utterer's world at the time of utterance, as with the classical semantics of 'will'.

Figure. 28



So, when it comes to future tensed semantics for statements like "the sun will rise tomorrow", there are roughly five options on EQM. I briefly assess each and ultimately adopt option five.

Option one: future tensed statements are false, given what is being described happens in some Branches but not others. The laws of QM determine there is some stemming tomorrow Branch in which the sun doesn't rise. The statement fails to denote or refer uniquely to a certain Branch over another (Lewis 1986, 207). However, as this renders a significant part of our talk as false. I reject option one.

Option two: future tensed statements are true, given they denote neither future Branch but the disunited sum of future Branches (Lewis 1986, 207). In which case the truth conditions of future tensed statements are the same as with narrow-future 'might' statements, true if what's described occurs in at least one future stemming Branch.

However, contradictory statements about what 'will' happen both come out as true. Furthermore, 'will' semantics are classically understood as being more akin with necessity statements than possibility statements like 'might'. I reject option two.

Option three: future tensed statements are true iff what is being described necessarily happens on all relevant future stemming branches. For example, a statement about what 'will' happen tomorrow is true iff it occurs in all future stemming tomorrow Branches. This is arguably most similar to the classical understanding of 'will' semantics given it is based on what necessarily happens.

However, many seemingly true statements about what 'will' happen come out as false. For example, "the sun will rise tomorrow" is false as there is, given the laws of QM, a stemming tomorrow Branch in which the sun doesn't rise. Only statements like "all electrons will have a negative charge tomorrow" are guaranteed to be true given this is necessarily the case according to QM. Furthermore, we end up with odd cases where statements like "the sun will rise tomorrow" are false one day, but a day later statements like "the sun rose [/is rising] today" are true. I reject option three.

Option four: future tensed statements are true iff they have a higher probability of occurring than other outcomes, whereby far-fetched low probability possibilities that would falsify the statement are suitably ignored. Similar to the Epistemic Contextualists use of 'know',[35] when asserted in certain contexts 'will' statements are more truth demanding than in other contexts. This maintains the truth of statements like "the sun will rise tomorrow" as it rules out low-probability future Branches in which the sun doesn't rise.

However, the truth conditions of these semantics rely heavily on objective probability which is arguably the most controversial aspect of EQM, what David Wallace calls the probability 'incoherence problem' (D. Wallace 2003, 417). Given all outcomes that can occur do in fact deterministically occur on EQM, the seemingly objective probability of each outcome is trivially 1. So, it arguably makes no sense talking about what events have a higher or lower objective probability of occurring.

There is no consensus on how to understand objective probability on EQM and detailed discussion is beyond the scope of this thesis. Wilson adopts diverging worlds as he claims they more adequately account for emergent objective probability or 'chance' (Wilson 2020, 74-144). But authors like Wallace (2012, 148-56) and Carroll (2019, 129-50) argue that objective

[35] See McKenna (2015).

probability on an overlapping worlds view can be determined by the Born rule and determined by branch weights.

However, even with an understanding of objective probability, a semantics which relies on it still encounters problems. Determining the truth value of future tensed statements would require unreasonably complex empirical tests. Such statements would have an indeterminate truth value until the test results are acquired.

Furthermore, assuming the tests can be done, there will be cases – like with option three – whereby a statement about what will happen tomorrow is true one day, but false the day after. Also, in cases where the probability of each outcome is 50/50 it is unclear what the truth status of the statement is. I reject option four.

Option five: future tensed statements (that fall outside of what necessarily happens on all relevant future stemming branches) have an indeterminate truth value, given the utterer isn't talking about any particular Branches as there are different incompatible events on different Branches. This means that non-modal future tensed statements are neither true nor false but have an indeterminate truth value. For example, "the sun will rise tomorrow" is indeterminate, until the event either does or doesn't become a part of the utterer's history. In which case the event described has a determinate truth value.

Taking from Belnap (et al. 2001 and 2002) and applying it to EQM, Belnap & Müller apply a date-time semantics with double time references which distinguishes the moment of evaluation of a future tense sentence from the moment defining the set of histories (or Branches in my case) required for settledness. An utterance of a future tense sentence at a certain time won't have a settled truth value at the time of utterance, even though it will be settled one way or another later on.

For example, 'the sun will rise tomorrow' can be assigned a settled truth-value after the event has (or hasn't taken place) i.e. in a tomorrow branch, but before tomorrow, there is no settled fact of the matter as to which way it will turn out. We may have all the knowledge there is to know, but it is impossible to know at the moment of utterance whether the proposition is not settled true or false, such is the nature of a universe with a tree-like structure. Such statements then have an indeterminate truth value (Belnap & Müller 2010, 691 & 694-5).

Wilson adopts diverging worlds because he argues they can retain a determinate truth value of future tensed statements (Wilson 2013, 19-21; 2020,

89-92). However, even though this option defies the law of the excluded middle, I don't take option five to be reason for ruling out worlds with overlap. It doesn't follow that because we sometimes talk as though there is one determinate future that therefore there is one. This kind of talk can be explained by our experience of a single past and present which results in the (arguably mistaken) assumption that there is also a single determinate future. Although we may wonder whether the sun will rise tomorrow, as Belnap et al. put it, wondering is wanting to know and one must bide one's time (Belnap et al. 2001, 209).

These unusual, but not implausible, semantics are arguably just a consequence of overlapping worlds. I take option five to be the most suitable and adopt it henceforth for future tensed semantics.[36]

Applying these semantics to 'actual' results in statements about what is 'actual' in stemming future branches being neither true nor false, but having an indeterminate truth value. For example, statements about what 'will actually happen' are indeterminate.

As 'actual' statements about future objects and events have an indeterminate truth value. I regard such objects and events – as well as the branches that contain them – as 'unactual': neither determinately 'actual' nor 'non-actual'. Although these branches contain objects which determinately ground the truth of narrow-future modal statements, future tensed non-modal statements about such objects and events have an indeterminate truth value.

As for non-stemming future branches, they contain no objects or events that an utterer truthfully regards as 'actual' or 'unactual'. I also regard these branches as 'non-actual'. These future non-actual branches contain objects and events which ground the truth of broad-future modal statements. Non-modal broad-future tensed statements are also indeterminate in truth value.

Figure. 29 & *figure. 30* illustrate which branches an utterer – represented by the orange square – regards as 'unactual and 'non-actual', and how this changes over time. Green branches represent 'unactual' branches. Future purple branches represent what is also 'non-actual'.[37]

[36] Lewis regards this the most preferable option were ours a branching universe (Lewis 1986, 207).

[37] Note, the structure of 'actual' and 'unactual' branches is reflective of McCall's Shrinking Tree ontology, but without the ontological implications.

Figure. 29

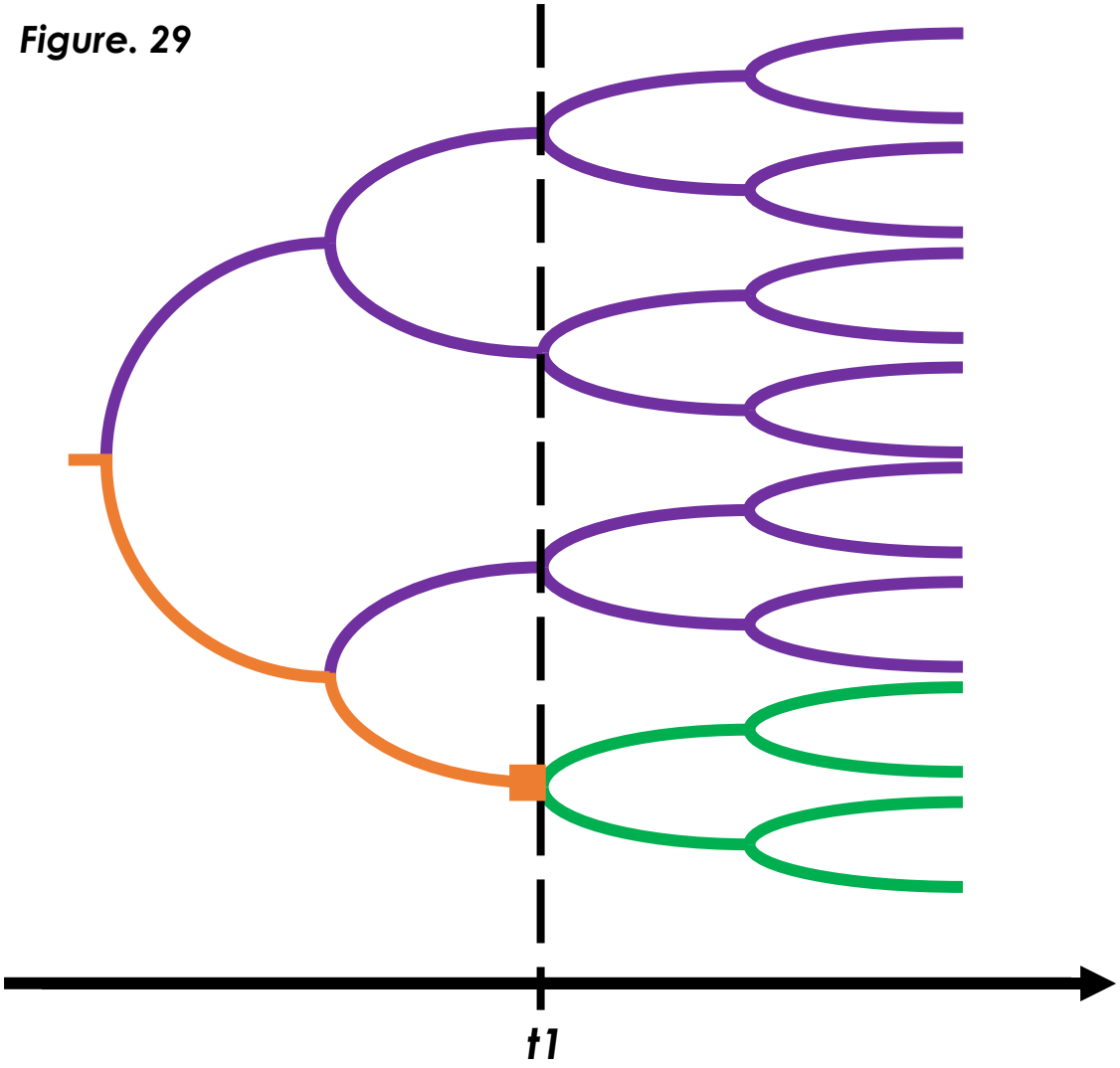
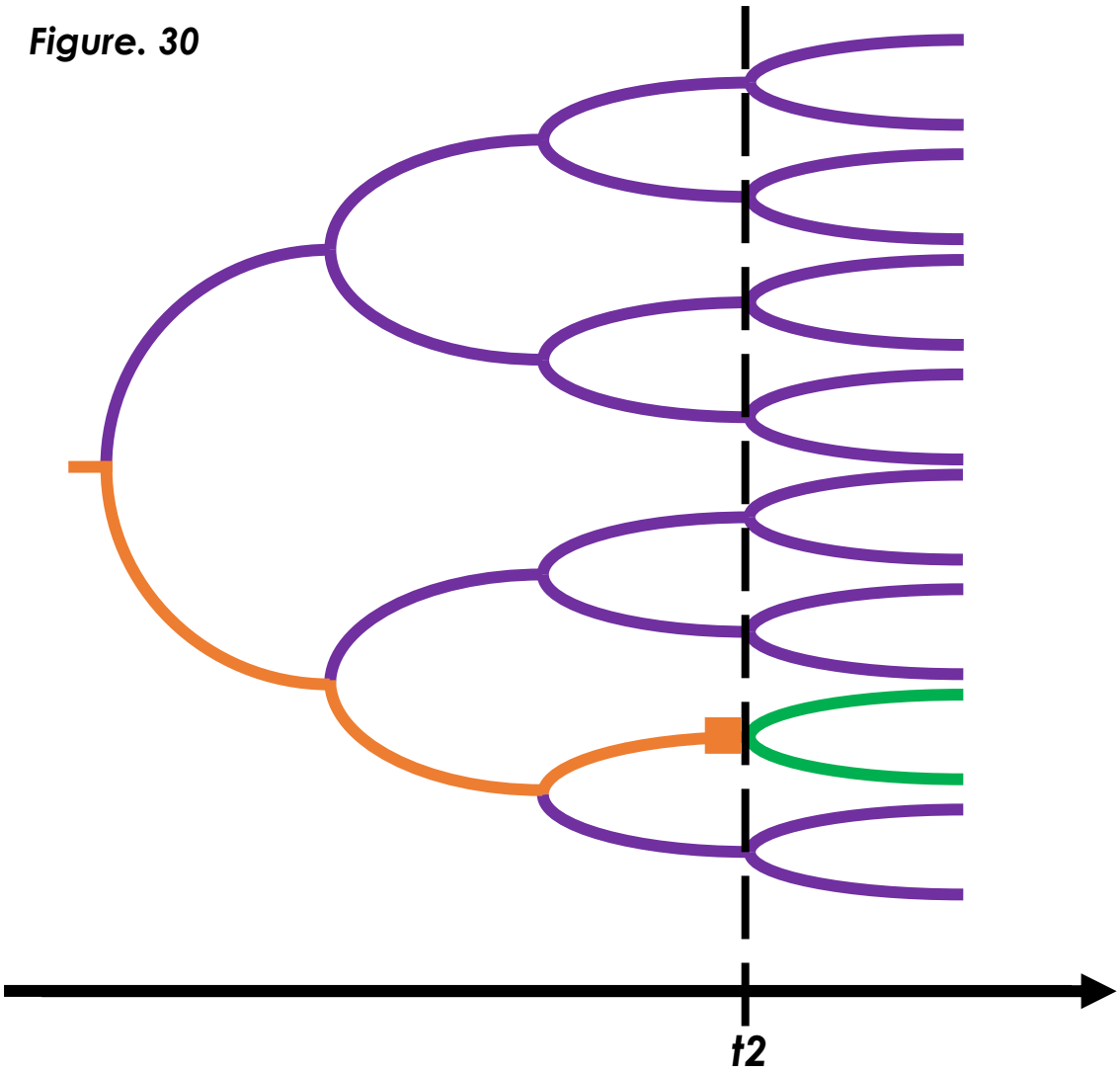


Figure. 30



§5.2.3 Summary

In summary, 'actual' refers to all branches which compose an utterers history, including objects and events contained within them. 'Unactual' refers to stemming future branches, including all objects and events contained within them. 'Non-actual' refers to non-stemming future branches as well as past and present branches which don't compose an utterers history, including all objects and events contained within them.

A consequence of these 'actual' semantics is that an utterer cannot regard a whole world as the 'actual' world (unless they are located on the final branch of that world). Only certain parts of a world – an utterers history – is 'actual'. Talk of the 'actual world' means an utterer's history (which – strictly speaking – composes a part of many worlds).

I use these semantics henceforth for the sake of explanation, in order to distinguish between the location of objects and events which ground the truth of an utterer's modal statements. I don't take these semantics to be the

only suitable semantics nor essential EAM, alternative semantics are coherent.

§6: Ontology of Persistence: Worm Theory

So far, I've illustrated how ordinary-objects within branches ground the truth of modal statements, without outlining the nature of these ordinary-objects over time. In this section I apply an ontology of persistence to further explicate EAM.

EQM itself doesn't uniquely determine how ordinary-objects persist. Given space limitations, I cannot assess multiple ontologies of persistence. I adopt Spacetime Worm Theory and apply a formulation of it to EQM, what I call 'Branching-Worm Theory'. I use Branching-Worm Theory to further explicate how ordinary-objects ground the truth of *de re* modal statements and show in §7 how this avoids counterpart theory and meets desiderata 5).

I don't claim Branching-Worm Theory to be correct – nor outright preferable to alternative formulations – simply because it meets desiderata 5). I claim only that were Branching-Worm Theory correct, then it results in EAM which meets desiderata 5).[38]

§6.1 Spacetime Worm Theory Outlined

Spacetime Worm Theory holds that ordinary-objects – continuants which we ordinarily refer to and quantify over – are four-dimensional Spacetime Worms which perdure through time. So ordinary-objects like people, tables, trees, planets and so on are Spacetime Worms. Ordinary-objects have temporal parts, as well as spatial parts, located at different spatiotemporal locations. The sum of these parts – or 'Stages' – compose the whole ordinary-object: the Spacetime Worm.[39]

Temporal parts are either irreducible or temporally extended. Temporally extended parts are 'worm segments' made up from irreducible parts, taken together these parts compose the full Spacetime Worm. For example, there is

[38] McDaniel's account which utilises endurant objects arguably meets desiderata 5). However, I prefer perdurantism to endurantism so set this aside and present an alternative account.

[39] Sider notes that Worm Theory is naturally accompanied with unrestricted mereological composition whereby any group of objects have a sum and form a different larger object, even if parts aren't unified in any particular way. However, one can accept Worm Theory with more restricted mereological composition (Sider 2001, 7-8). As my account doesn't require unrestricted composition I remain neutral on the issue.

a 2020 part of me which extends over a year, a smaller January 2020 part of me which extends over the month of January 2020, and so on down to irreducible parts.

Sider notes that temporal parts of an object are not just related to certain times, but parts of an object *simpliciter*. Temporal parts have genuine atemporal parthood with the Worms they compose. Past and future parts are just as much a part of an object as present parts (Sider 2001, 56).

Sider states that an object *x* is an irreducible temporal part of an object *y* if *x* is part of *y*, *x* exists only at a certain time *t* and *x* overlaps with every part of *y* that exists at that certain time *t*. An object *x* is a temporally extended part of object *y* if *x* exists only at times in time interval T, is part of *y* at every time during T, and at every moment in T *x* overlaps everything that is part of *y* at that moment (Sider 2001, 59-60).

Worm Theorists hold that ordinary-objects – Spacetime Worms – continue to exist and persist through change. Sider states that intrinsic change is simply the difference between successive temporal parts of a Worm. For example, I change from walking to running by having a temporal part that walks followed by a temporal part than runs. Relational change is whereby one temporal part bears a certain relation to some other spacetime worm while another temporal part does not. Mereological change is like relational change, my long hair ceases to be a part of me when a later part has short hair (Sider 2001, 2, 4, 56).

There are two feasible formulations of Worm Theory when applied to EQM, what I call 'Coincident-Worms' and 'Branching-Worms'. Given space limitations I briefly outline Coincident-Worms and note that Coincident-Worms cannot ground the truth of modal statements while meeting desiderata 5). I then outline Branching-Worms in detail in order to show in §7 that they ground the truth of modal statements while meeting desiderata 5).

§6.2 Applied to EQM: Coincident-Worms

'Coincident-Worms' are linear Worms, as on classical Worm Theory, which don't bifurcate as they perdure through time and the universe branches.[40] All parts of any one Coincident-Worm are located on a particular Branch and only that Branch.

Coincident-Worms that stem from the same spatiotemporal location and branch share some of their earlier parts – or coincide – with other Coincident-Worms which exist along different parallel Branches. Parts of the Coincident-

[40] This interpretation is akin with Lewis' proposed solution to Fission Cases (Lewis 1983).

Worm that an utterer comes in contact with are parts shared by potentially infinite distinct Coincident-Worms existing in different worlds.

In short, grounding modal statements in Coincident-Worms fails to meet desiderata 5). When an utterer makes a past or present tensed *de re* modal statements about a Coincident-Worm in front of them, that statement cannot be grounded in that very Coincident-Worm itself in virtue of its parts, as all of its parts are 'actual' according to the utterer. Something like counterpart theory is required and Coincident-Worms cannot meet desiderata 5). Therefore, I assess the Branching-Worm formulation in detail instead.

§6.3 Applied to EQM: Branching-Worms

Just as classical linear Worms are ordinary-objects in a classical linear universe, it neatly follows that Branching-Worms are ordinary-objects in a branching universe. Rather than being linear, 'Branching-Worms' are continuant ordinary-objects which bifurcate and branch along with the universe as they perdure through time. Branching-Worms have different temporal parts located on different consecutive and parallel branches, which taken together compose the whole ordinary-object.

If we assume Branching-Worms are ordinary-objects, then ordinary-objects like people, tables, planets and so on, are Branching-Worms.[41] I now explicate the nature of Branching-Worms and their identity across worlds. In §7 I show how ordinary-objects – Branching-Worms – ground the truth of modal and non-modal *de re* statements.

A Branching-Worm is illustrated by the blue branching structure in *figure. 30*, which illustrates the Branching-Worm mapped onto some part of the universe, and *figure 31*, which illustrates the standalone ordinary-object. The blue dots illustrate the beginning and ends of the ordinary-object. The initial linear part of the Branching-Worm (prior to branching) is reflective of a classical linear worm but is by no means necessary, Branching-Worms could be conceived of as initially branching. The ordinary-object also ceases to exist at the same time on different parallel branches. This isn't a necessary feature of Branching-Worms either, they may cease to exist on some branches at a certain time but not others, I discuss this further in *§6.3.2*.

[41] I assume that people etc. are ordinary-objects and that ordinary-objects are Branching-Worms. However, more nuanced distinctions between Branching-Worms, ordinary-objects, people etc. are coherent. Saunders & Wallace (2008, 298) suggest a personal continuant in only one Branch.

Figure. 31

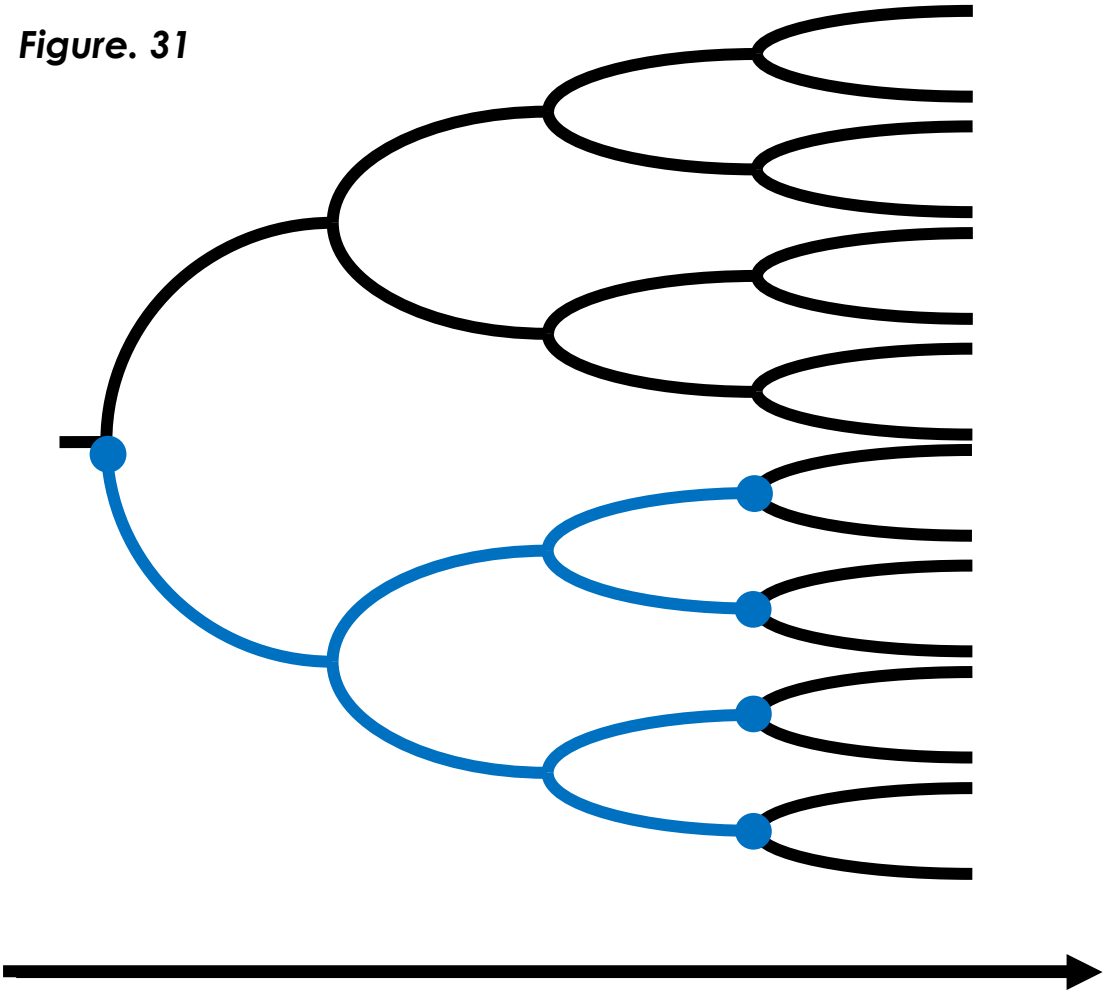
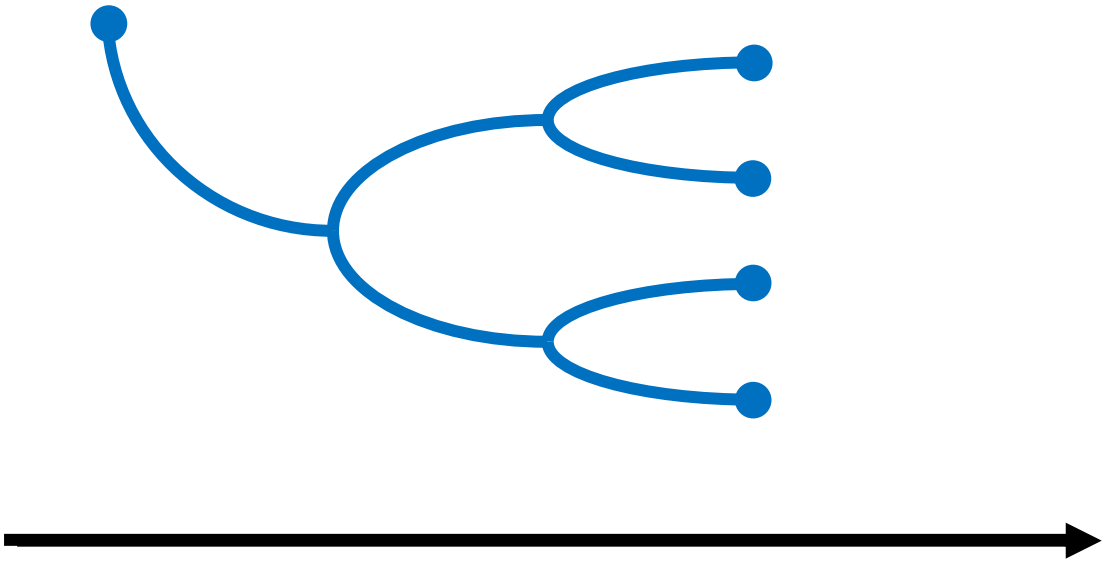


Figure. 32



As Branching-Worms span across different parallel branches, some clarifications need to be made as to the nature of their identity across branches and worlds.

§6.3.1 Identity across branches and worlds

On EQM linear temporally extended (unordinary) objects span across multiple consecutive branches – a Branch – and have 'trans-branch identity': the same object is identified across different branches.[42] Irreducible objects don't have trans-branch identity, they belong only to the branch they're located on.

As outlined in *§2.3.4* a world is a Branch of maximal extent. A branch is an irreducible part of a world and composes a part of multiple worlds – a world set – unless it is the final part of a world.

Even though irreducible objects don't have trans-branch identity, irreducible and temporally extended objects belong to multiple worlds in virtue of

[42] I take 'temporally extended' to mean linearly extended.

belonging to a branch or Branch which is a part of multiple worlds.[43] irreducible or temporally extended parts of an ordinary-object belong to multiple worlds and hence have 'trans-world identity'.[44] As Branching-Worms are ordinary-objects made up from parts, it follows that they have two sorts of trans-world identity.

First, Branching-Worms have some part which belongs to a world set; part *p* of object *o* belongs to world set *w1*. As such object *o* has trans-world identity across the worlds in world set *w1*. This sort of trans-world identity applies to both irreducible and temporally extended objects on EQM.

Second, Branching-Worms have 'trans-parallel-branch identity' in virtue of having parts located on different parallel branches; part *p* of object *o* belongs to world set *w1* and part *q* belongs to world set *w2*, whereby part *p* and *q* exist on parallel branches. So, object *o* has trans-world identity across the worlds in world set *w1* and *w2*. This specific sort of trans-world identity – 'trans-parallel-world identity' – is unique to Branching-Worms given they span across different parallel branches.

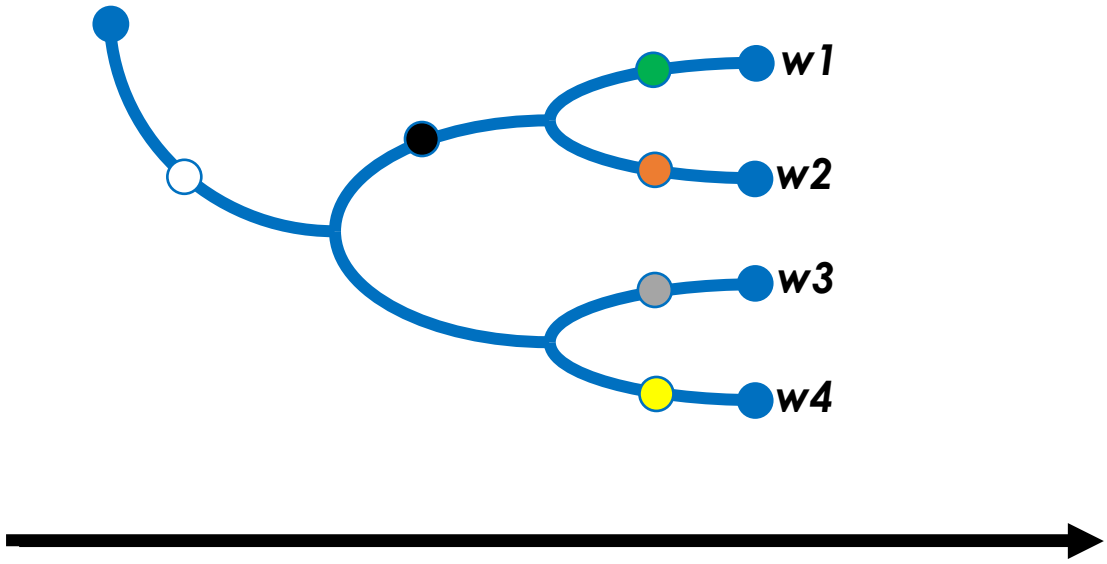
So, ordinary-objects – Branching-Worms – have trans-world identity in virtue of having some part which belongs to multiple worlds and trans-parallel-world identity in virtue of having multiple parts which belong to different parallel world sets. This is illustrated in *figure. 33*.

The Branching-Worm – situated somewhere in the universe – is illustrated by the blue branching structure. The green dot represents a part of the ordinary-object which belongs to world set *w1*. The Branching-Worm has trans-world identity, given it has some part (which belongs to multiple worlds). Trans-parallel-branch identity and trans-parallel-world identity is illustrated by the Branching-Worm having multiple parts – represented by other non-blue dots – which belong to different parallel branches. The orange dot represents part of the Branching-Worm which exists in world set *w2*. The grey dot represents a part belonging to world set *w3*. The yellow dot represents a part belonging to world set *w4*. The black dot represents a part belonging to world set *w1 – w2*. The white dot represents a part belonging to world set *w1 – w4*.

[43] Provided irreducible objects don't belong to the final branch of a world. All the examples and illustrations I provided are whereby parts belong to multiple worlds and don't belong to the final branch of a world.

[44] I don't suggest that ordinary-objects are 'wholly located' in more than one world.

Figure. 33



As Branching-Worms have multiple parts which exist on different parallel branches, they belong to multiple world sets – world set *w1* to *w4* in the example – and have trans-parallel-world identity.

Although ordinary-objects and their individual parts have trans-world identity, as different parts are located on different branches, not all parts belong to the same worlds. Each part has a unique history. Earlier parts of an ordinary-object belong to more worlds than later parts. Branching-Worms have trans-parallel-world identity across all worlds they have parts in.

Even though Branching-Worms have parallel-branch identity and trans-parallel-world identity, I take there to be plausible conditions for when different Branching-Worms are distinct ordinary-objects.

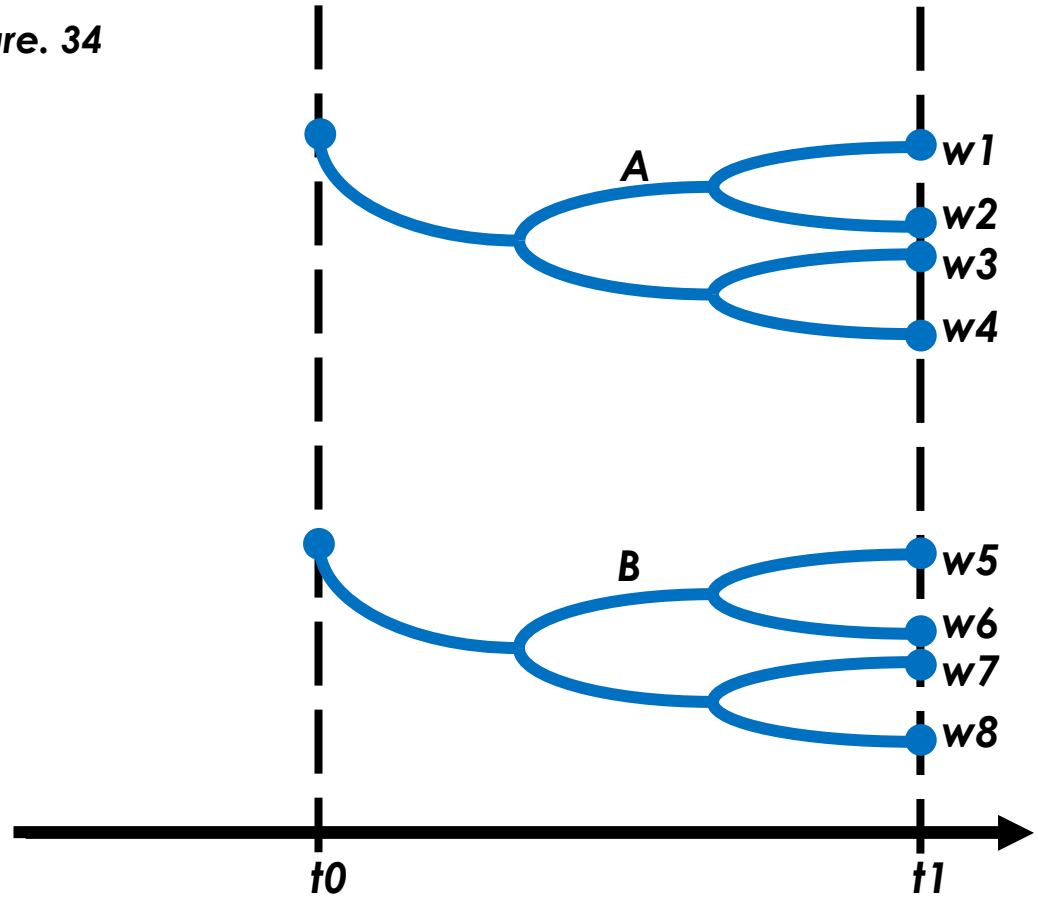
Questions of composition aside, I take two ordinary-objects – Branching-Worms – to be distinct if they have different origins, similar to Kripke's essentiality of origins (Kripke 1980, 114).[45]

[45] Mackie (1998) has noted that the plausibility of essentiality of origins is a symptom of our tendency to think of possibility in terms of a branching model so it fits nicely with

Unlike Kripke, I specify origins as a particular spatiotemporal and branch location. Origins cannot be identified across branches or different spatiotemporal locations. Were two very similar ordinary-objects to originate from different spatiotemporal locations then they have different origins and hence are distinct ordinary-objects. Even if two very similar ordinary-objects originate from the same spatiotemporal coordinates but on different branches, these are different origins and hence distinct ordinary-objects.

This is illustrated in *figure. 34*. *A* and *B* are both cubes, two objects – Branching-Worms – which are qualitatively identical but exist in different worlds. Cube *A* exists across world set *w1 – w4*. Cube *B* exists across world set *w5 – w8*. Both cubes come into existence at *t0* when made by a factory and cease to exist at *t1* when crushed.[46]

Figure. 34

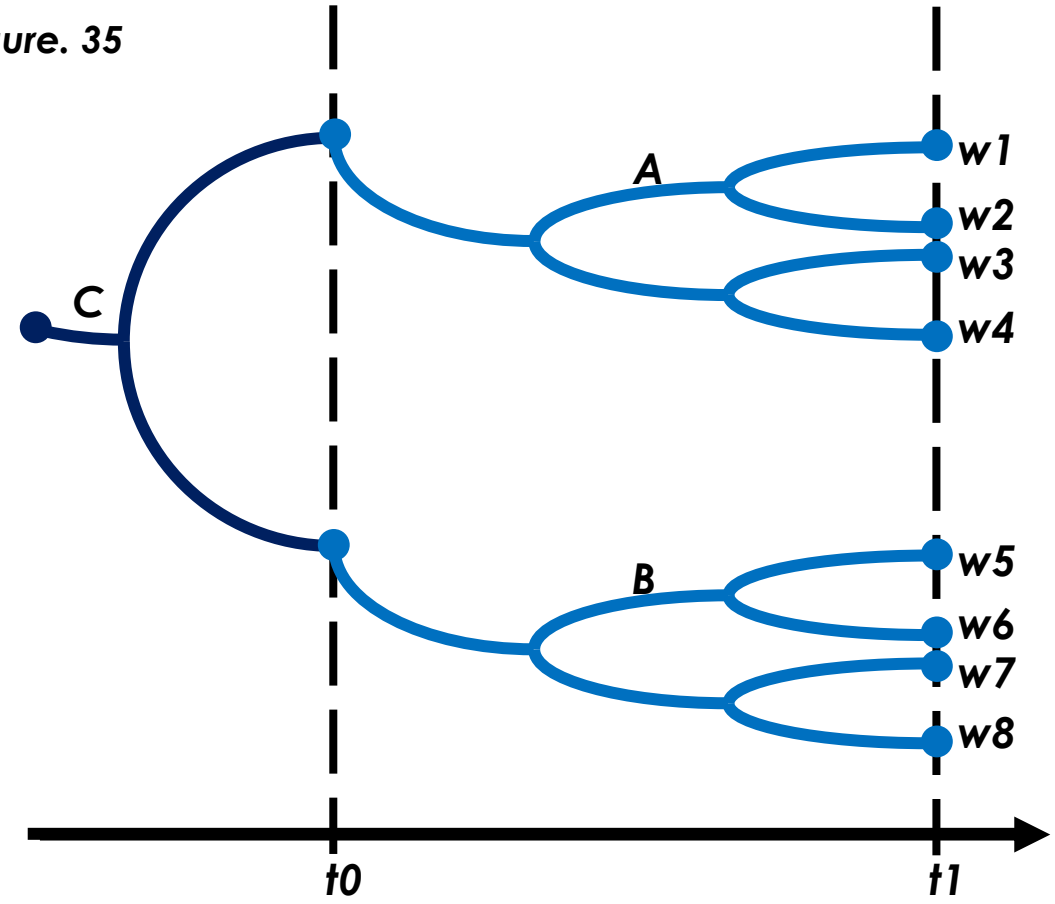


EAM. Although Vetter (2015, 290-1) holds that the essentiality of origins describes a deeply held intuition about the nature of objects, it isn't uncontroversial – alternative criteria are coherent with EAM.

[46] I set aside the question of under what conditions an ordinary-object – or objects generally – come into and out of existence as it is beyond the scope of this thesis.

Before making the cubes, the factory underwent a branching event. After the branching event the factory created *A* on one branch and *B* on another branch. The cubes were created by different temporal parts of the same factory – the same Branching-Worm – at the same spatiotemporal coordinates but on different branches. This is illustrated in *figure. 35* whereby the dark blue Branching-Worm *C* is the factory.

Figure. 35



Although the two cubes are qualitatively identical and created by the same factory at the same spatiotemporal coordinates, the two ordinary-objects are created on different branches so have different origins and are hence two distinct ordinary-objects (assuming a cube is an ordinary-object).

So, although unrestrictive composition holds that *A* and *B* taken together form a larger object *AB*, given their differing origins *AB* isn't an ordinary-object. Ordinary-objects are not just any mereological sum of different parts but have limitations.

Given *A* and *B* are qualitatively identical but aren't numerically identical, were one to opt into counterpart theory then ordinary-objects that are

sufficiently qualitatively similar could be viewed as sharing a counterpart relation. I discuss this further in *§7.2.5.*

Given the essentiality of origins, within the EQM universe Branching-Worms necessarily – or essentially – have their parts and properties. The properties had by some part of a Branching-Worm isn't necessary to it in the sense that it applies to all parts of the Branching-Worm. Rather, all parts taken together are essential to that Branching-Worm. Taken as an atemporal whole, ordinary-objects cannot be other than what they are. This is then a form of mereological essentialism of temporal parts, but as I shall show in §7, this doesn't result in the majority of *de re* possibility claims about material objects being false, as McDaniel claims (McDaniel 2004, 139).

§6.3.2 Seemingly contradictory properties

On classical Worm Theory, contradictory statements about an ordinary-object are explained by the statements being about different temporal parts located at different times (Sider 2001, 4-5 & 92-98).

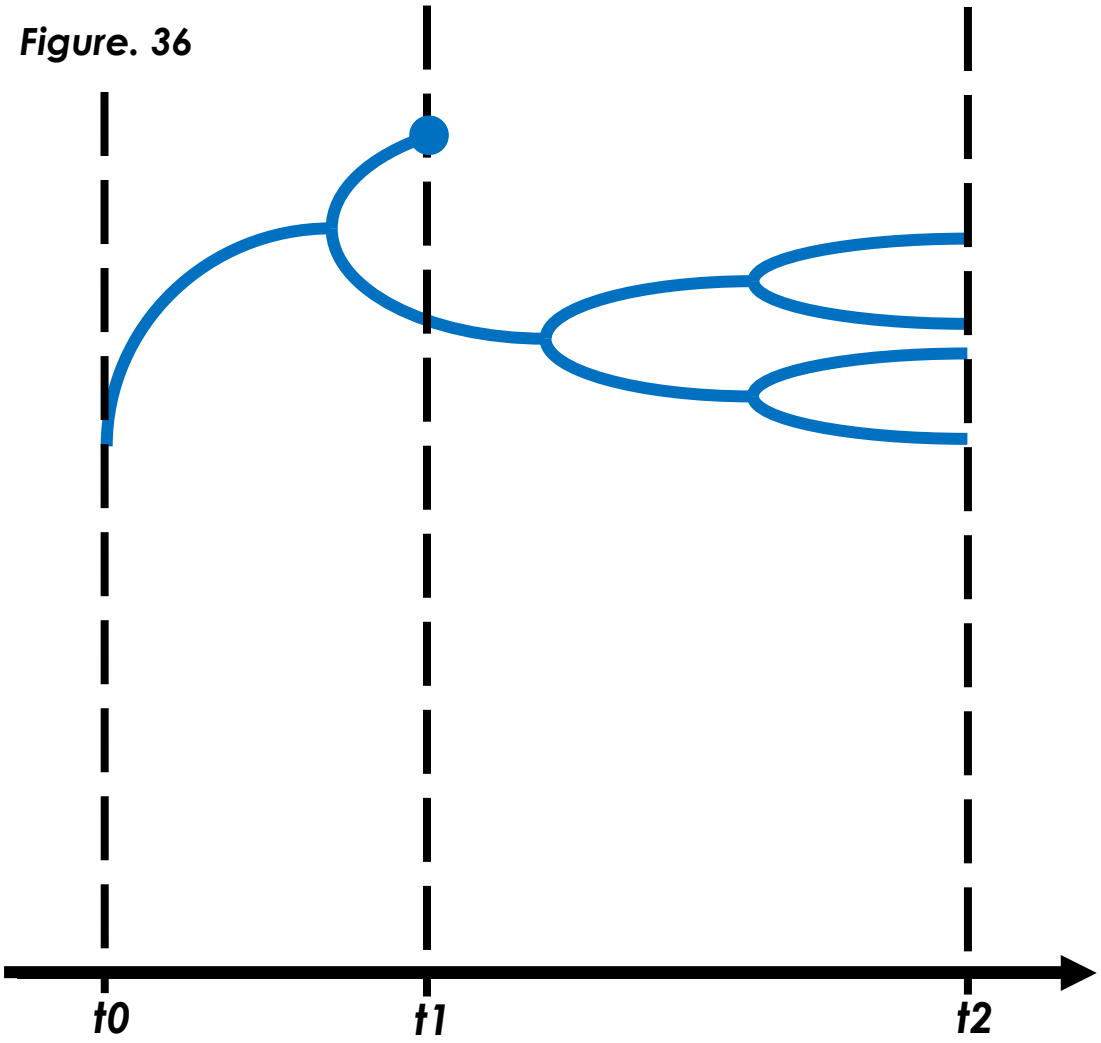
For example, the statement "the houseplant is alive" contradicts the statement "the houseplant is dead". On classical Worm Theory both are true as they're about different temporal parts of the plant. The first statement refers to an earlier part of the Worm houseplant. The second statement refers to the final part of the Worm houseplant.

However, Branching-Worms – unlike classical Worms – appear to have contradictory properties at the same spatiotemporal coordinates. The explanation that contradictory statements are referring to different parts located at different times seems less applicable.

The examples and illustrations of Branching-Worms I have provided so far are whereby the final parts of the Branching-Worm – that exist on different parallel branches – cease to exist at the same time. This is by no means necessary. To explicate how Branching-Worms seemingly have contradictory properties, I focus discussion on contradictory statements about the Branching-Worm's length of persistence as this can be clearly illustrated in the diagrams. However, the point being made applies to any seemingly contradictory properties.

For example, the Branching-Worm in *figure. 36* is a houseplant which comes into existence at *t0*. All parts of the plant at *t1* are located on a shelf at the same spatiotemporal coordinates but on different Branches. Unfortunately, the house plant dies at *t1* on one Branch – represented by the blue dot – but continues to exist until *t2* on the other Branches.

Figure. 36



This appears paradoxical, atemporally speaking the houseplant is both dead and alive on the shelf at *t1*. The houseplant appears to have contradictory properties which can't be explained away by their parts being located at different times. Their parts are at the same spatiotemporal coordinates, on the shelf at *t1*.

However, these aren't really contradictory properties. Although the parts of the Branching-Worm with apparent contradictory properties are located at the same spatiotemporal coordinates, they aren't at one and the same location. Instead, they are different parts located at different parts of the universe.

Lewis objects to trans-world ordinary-objects on the basis of the problem of accidental intrinsics, which Wilson echoes. He states that if an ordinary-object has an intrinsic property in one world but lacks it in another, then it both has and lacks the property. In order to explain this one must relate these

properties to different worlds and intrinsic properties end up being relational properties (Lewis 1986, 198-209 & Wilson 2020, 89).

However, just as temporal parts on classical Worm Theory are parts of an ordinary-object *simpliciter*, different temporal parts of a Branching-Worm are parts of that ordinary-object *simpliciter*. Such properties are intrinsic to different parts of the same Branching-Worm and hence the Branching-Worm itself. Just as seemingly contradictory intrinsic properties on classical Worm Theory are explained by appealing to different temporal parts of that ordinary-object, seemingly contradictory intrinsic properties on Branching-Worm Theory are explained by appealing to different temporal parts of that ordinary-object.

A Branching-Worms properties are no more relations to worlds than temporal parts are relations to times. Just as we need to specify the time at which a part is located at in order to distinguish the apparent contradictory properties on classical Worm Theory, The same applies on Branching-Worm Theory, we need to specify the Branching-Worms spatiotemporal which includes the branch location of the seemingly contradictory parts.[47]

Seemingly contradictory statements like "the houseplant is both alive and dead at the same spatiotemporal coordinates" simply fail to specify which part we are talking about and which branch or world set it belongs to. So, although it may be true that the plant is both dead and alive on the shelf at *t1*, there is a part which is alive and a different part which is dead. These parts just exist at different spatiotemporal locations.

§6.3.3 Summary

In summary, Branching-Worms are massive sprawling ordinary-objects which are exponentially larger – have exponentially more parts – than classical Worms. Given the branching structure of the EQM universe, Branching-Worms uniquely have trans-parallel-world identity. Different Branching-Worms are distinguished by their essentiality of origins.

I henceforth adopt Branching-Worm Theory to further explicate my account. For the sake of simplicity, I assume that just as classical Worms are the

[47] Sider rejects the notion of temporal parts whereby "the temporal part of x at time t is […] defined as the part of x that exists only at t and has the same spatial location as x". He claims that talk of spatial location is problematic as the definition fails for an object without spatial location and for an object sharing spatial location with one of its proper parts e.g. a trope (Sider 2001, 59). As I focus on ordinary-objects with spatial locations and don't appeal to tropes, this definition may be more suitable in order to distinguish contradictory properties.

ordinary-objects we quantify over on a classical universe, Branching-Worms are the ordinary-objects we quantify over on a EQM universe.

§7: Branching-Worms and Modal Statements

In this section I outline how, given their size, Branching-Worms ground the truth of modal and non-modal *de re* statements while meeting desiderata 5). In short, non-modal statements about an ordinary-object are grounded in parts of the Branching-Worm which exist in an utterer's 'actual' Branch. While modal statements about an ordinary-object are grounded in parts of the Branching-Worm which exist in an utterer's 'non-actual' and 'unactual' branches.

First, I apply the semantics of 'actual' to Branching-Worms. Second, I outline in detail the semantics of *de re* modal statements. Third, I briefly outline the semantics of *de dicto* modal statements. Fourth, I comment on counterfactual statements. Fifth, I discuss how we have knowledge of what grounds modal statements. Finally, I summarise.

§7.1 Actuality

In *§5.2* I stated that 'actual' applies to past and present branches – including the objects and events contained within them – which compose the utterers history. 'Non-actual' applies to all past, present and non-stemming future branches – including objects and events within them – which don't compose the utterers history. 'Unactual' applies to future stemming branches, including the objects and events within.

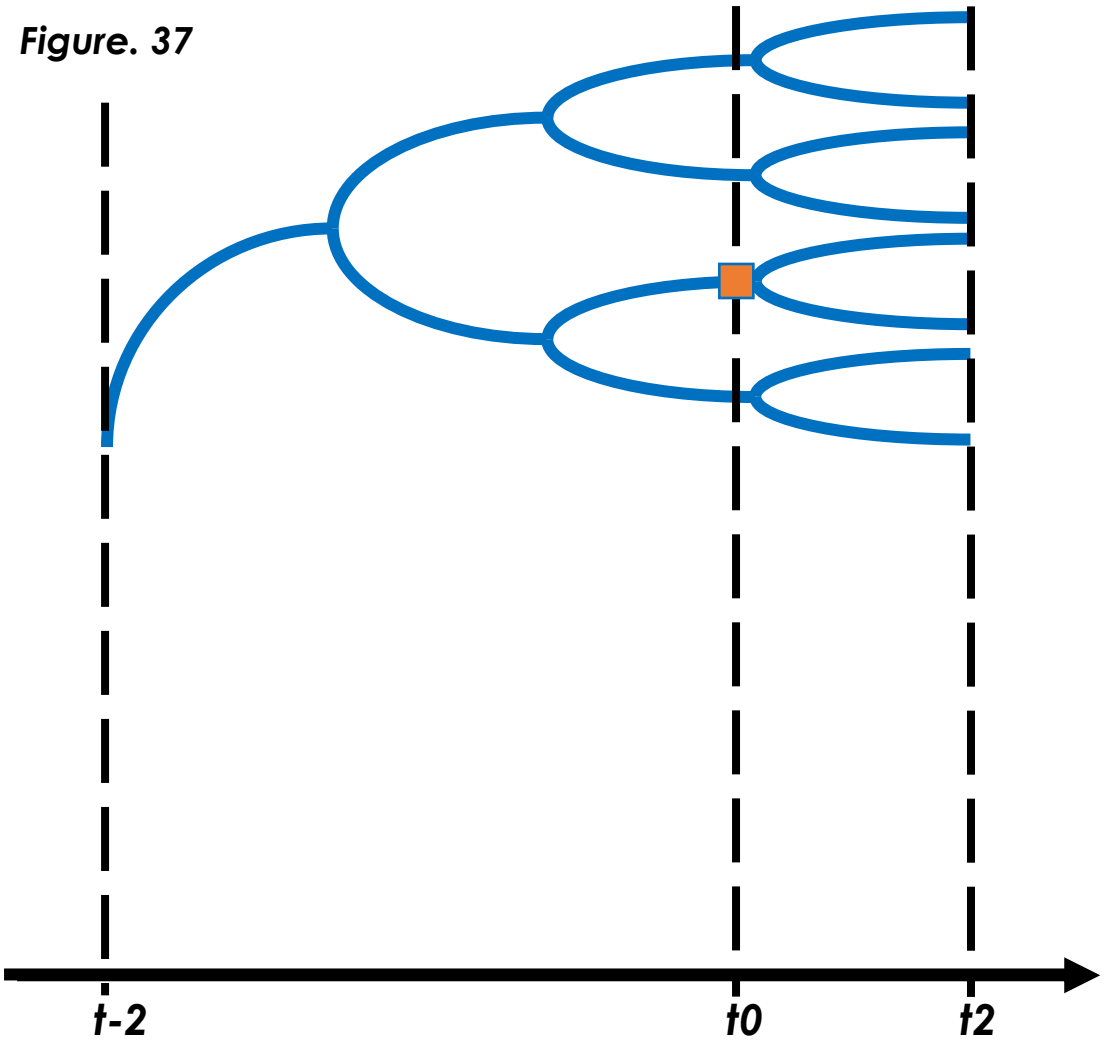
I assume people to be ordinary-objects and hence Branching-Worms. I take an 'utterer' to be a linear temporally extended part of the person – Branching-Worm – which makes the utterance.[48] Each temporal part has a unique history, so when an utterer says 'actual' it applies to the unique history of that temporal part of the Branching-Worm making the utterance, not the Branching-Worm as a whole. Given the indexical nature of the word, what is 'actual' depends on which part is making the utterance.

[48] This means *ex hypothesi*, an utterer is an unordinary object. However, I focus on one linear utterance made by a temporally extended part to simplify things as in reality it is far more complex: utterances bifurcate along with the ordinary-objects making them so there are many coincident linear utterances – with slight differences between them – made along different parallel Branches. In other words, there are multiple temporally extended parallel parts making multiple utterances.

Depending on which part makes the utterance, an utterer regards certain parts of themselves – the Branching-Worm – as 'actual', 'non-actual' and 'unactual'. What parts of the Branching-Worm person are 'actual', 'non-actual' or 'unactual' depends on what part of the Branching-Worm is making the utterance. 'Actual' parts are those which compose the utterer's history and can be thought of as 'actually me' by the utterer. 'Non-actual' parts are those past, parallel present and non-stemming future parts which don't compose an utterer's history. 'Unactual' parts are those which are stemming future parts of the utterer. 'Non-actual' and 'unactual' parts can be thought of as 'not actually me' by the utterer. The different parts – 'actual', 'non-actual' and 'unactual' – taken together still compose the whole Branching-Worm person.

This is illustrated in *figure. 37*. The blue branching structure is a Branching-Worm – a person – called Clare. Clare comes into existence at *t-2* and – although not represented on the diagram – continues to exist and bifurcate after *t2*. The orange square at time *t0* represents utterances made by a temporal part of the Branching-Worm Clare.

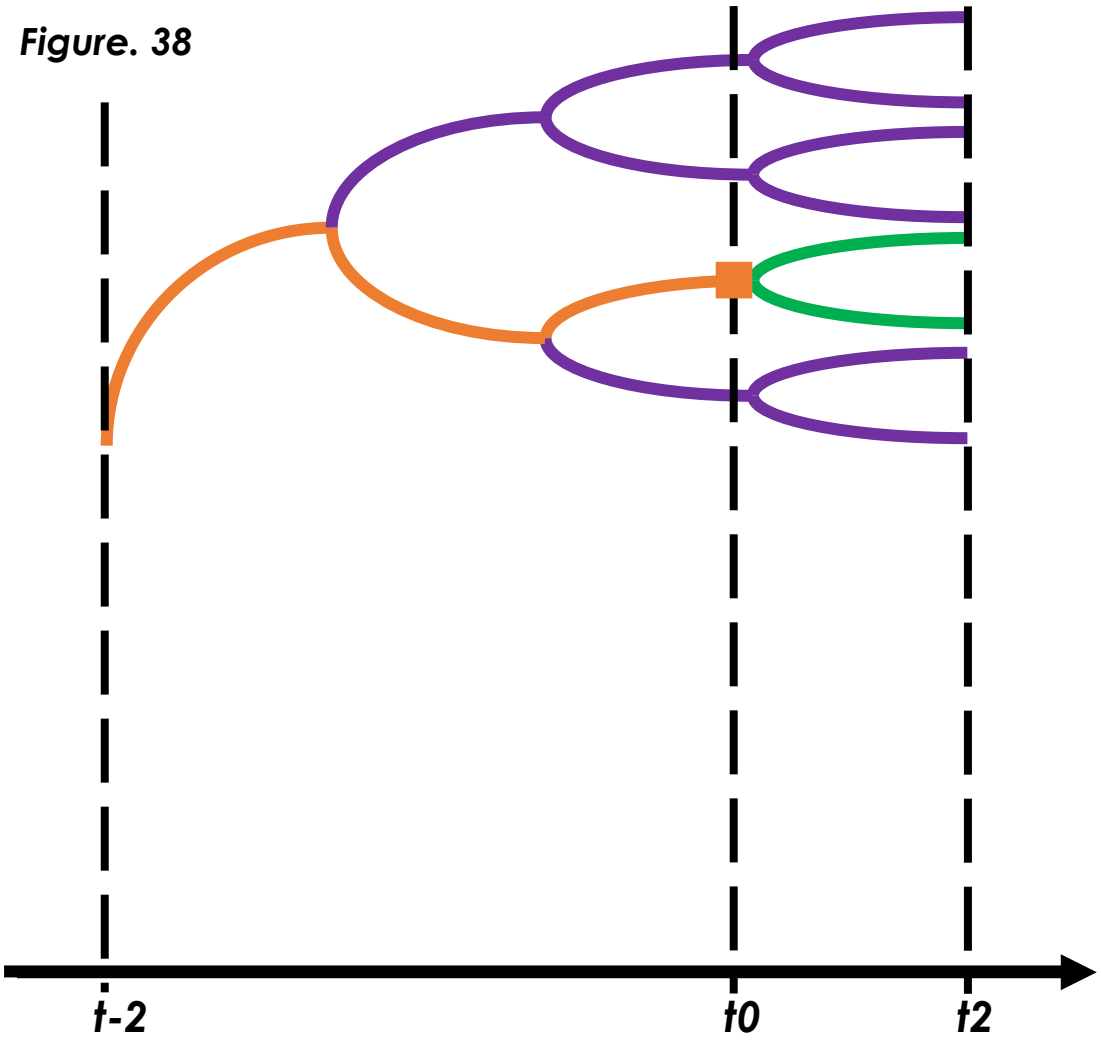
Figure. 37



Even though Clare is one whole ordinary-object, a temporal part of Clare making an utterance doesn't regard all of her other temporal parts as 'actual', just as not all temporal parts of Clare agree on what time 'now' refers to. From the perspective of the part making the utterance, some other parts of the Branching-Worm Clare – namely those that don't compose the utterers history – exist on 'non-actual' and 'unactual' branches.

This is illustrated in *figure. 38*. The parts of Clare which the utterer regards as 'actual' – given they exist in 'actual' branches – are highlighted orange. Parts which are regarded as 'non-actual' – given they exist in 'non-actual' branches – are highlighted purple. Parts which are 'unactual' – given they exist in 'unactual' branches – are highlighted green.

Figure. 38



All temporal parts of Clare will regard a certain Branch as 'actual'. Namely the Branch prior to *t-2* which composes the history of the whole Branching-Worm Clare.

§7.2 De Re Modal Statements

In this section I explicate what grounds the truth of different kinds of *de re* modal statements about a particular ordinary-object on EAM. I use examples of a Branching-Worm making modal utterances about itself as this provides the clearest illustration. The modal statements I focus on are those grounded in parts which the utterer regards as 'unactual' or 'non-actual'. Such examples can then be generalised to other modal statements.

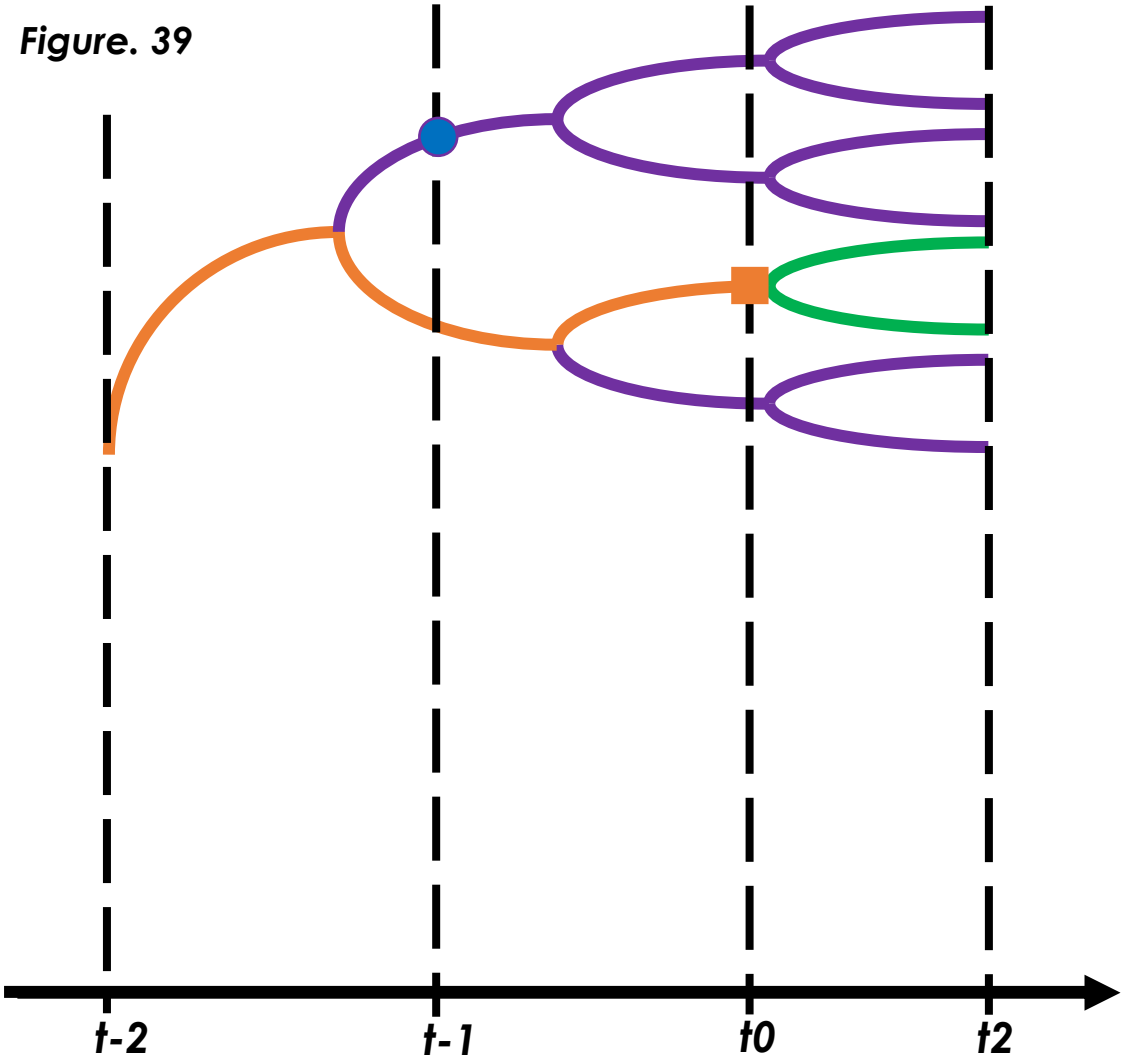
§7.2.1 Past possibilities

Past tensed *de re* possibility statements concern past possibilities of an ordinary-object. Such *de re* statements are true in virtue of the ordinary-object having at least one temporal part which exemplifies properties that

the modal statement asserts of the ordinary-object and is – in relation to the utterance – located in a 'non-actual' past Branch.

For example, in *figure. 39* at time *t0* a temporal part of Clare – represented by the orange square – utters the statement "I could have gone running yesterday [but didn't]". The truth of this past tensed counter-to-fact modal statement is grounded in the Branching-Worm Clare having a past temporal part – represented by the blue dot at *t-1* – located on a past non-actual Branch where that past part goes running a day before the utterance.

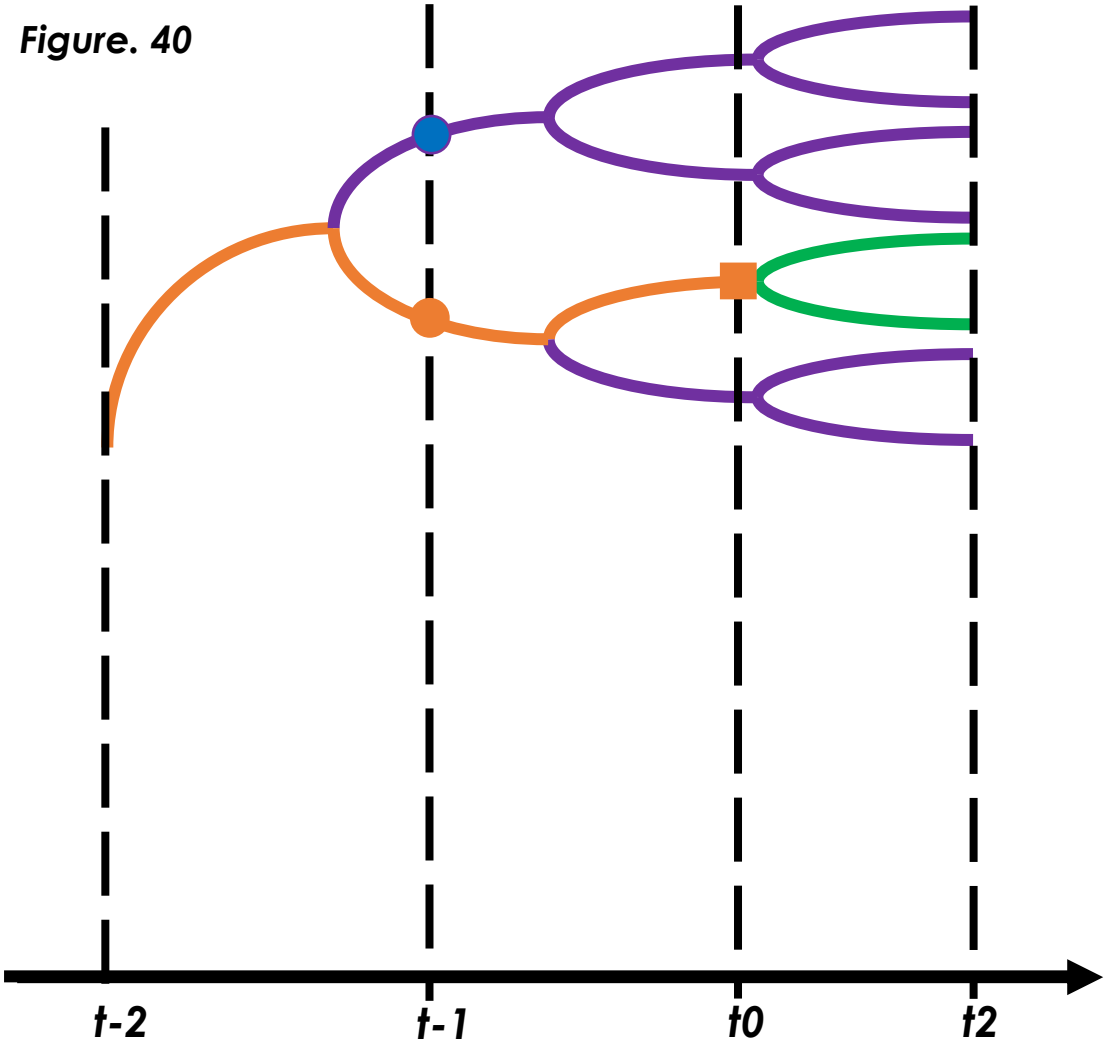
Figure. 39



The "[but didn't]" is an abbreviation of "I didn't go running yesterday". This non-modal statement is grounded in the Branching-Worm Clare having an 'actual' temporal part – represented by the orange dot *t-1* in *figure. 40* – whereby that past 'actual' part didn't go running the day before the utterance. Past tensed non-modal statements are grounded in 'actual' parts

of the Branching-Worm. Past tensed counter-to-fact modal statements are grounded in past 'non-actual' parts of the Branching-Worm.

Figure. 40



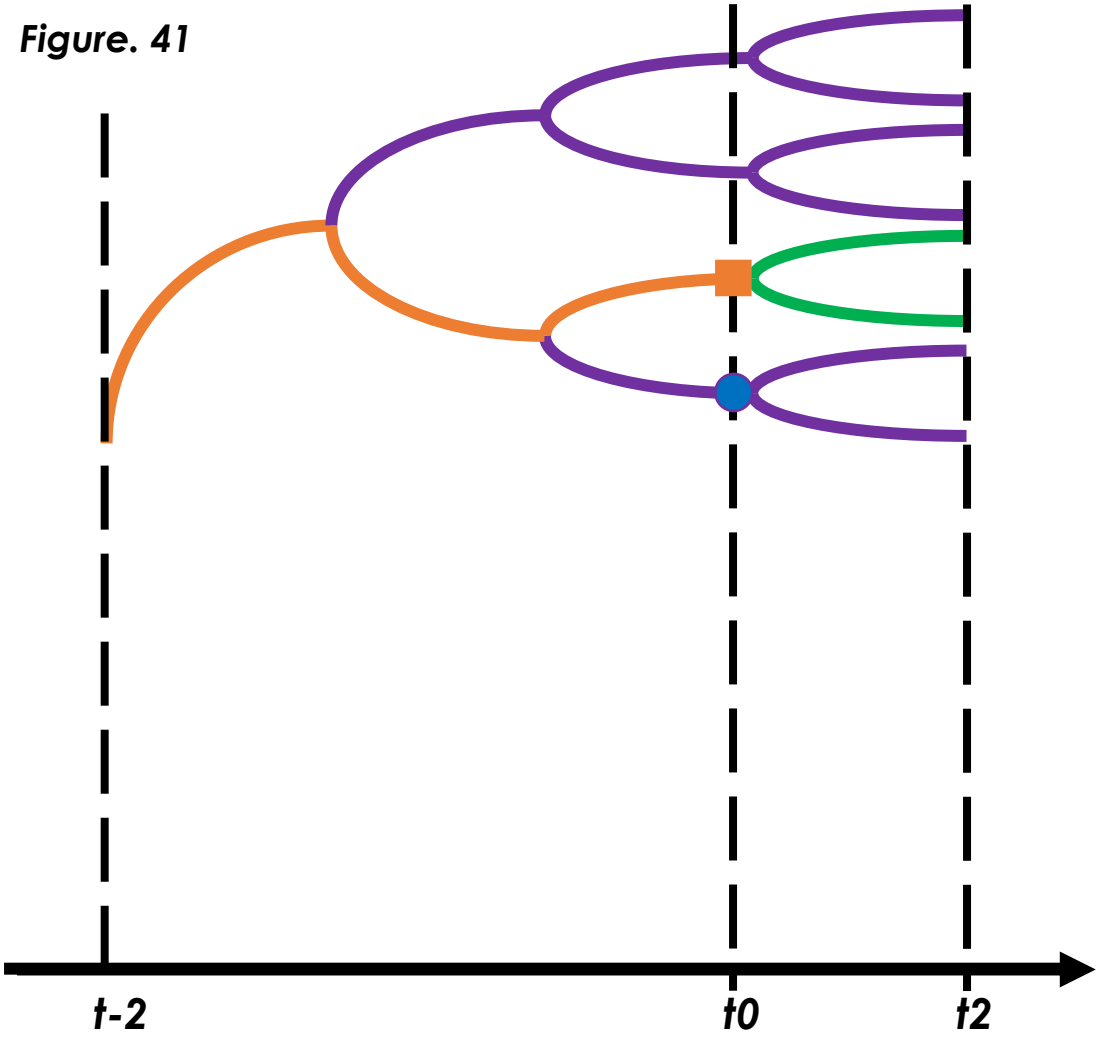
§7.2.2 Present possibilities

Present tensed *de re* possibility statement make an assertion about what is possible for an ordinary-object at the time of utterance. Such *de re* statements are true in virtue of the ordinary-object having at least one temporal part which exemplifies properties that the modal statement asserts of the ordinary-object and is – in relation to the utterance – located in a 'non-actual' parallel present Branch.

For example, in *figure. 41* at time *t0* a temporal part of Clare – represented by the orange square – utters the statement "I could be running right now". The truth of this present tensed modal statement is grounded in the Branching-

Worm Clare having a temporal part – represented by the blue dot at *t0* – located on a 'non-actual' parallel present Branch where that part is running.

Figure. 41



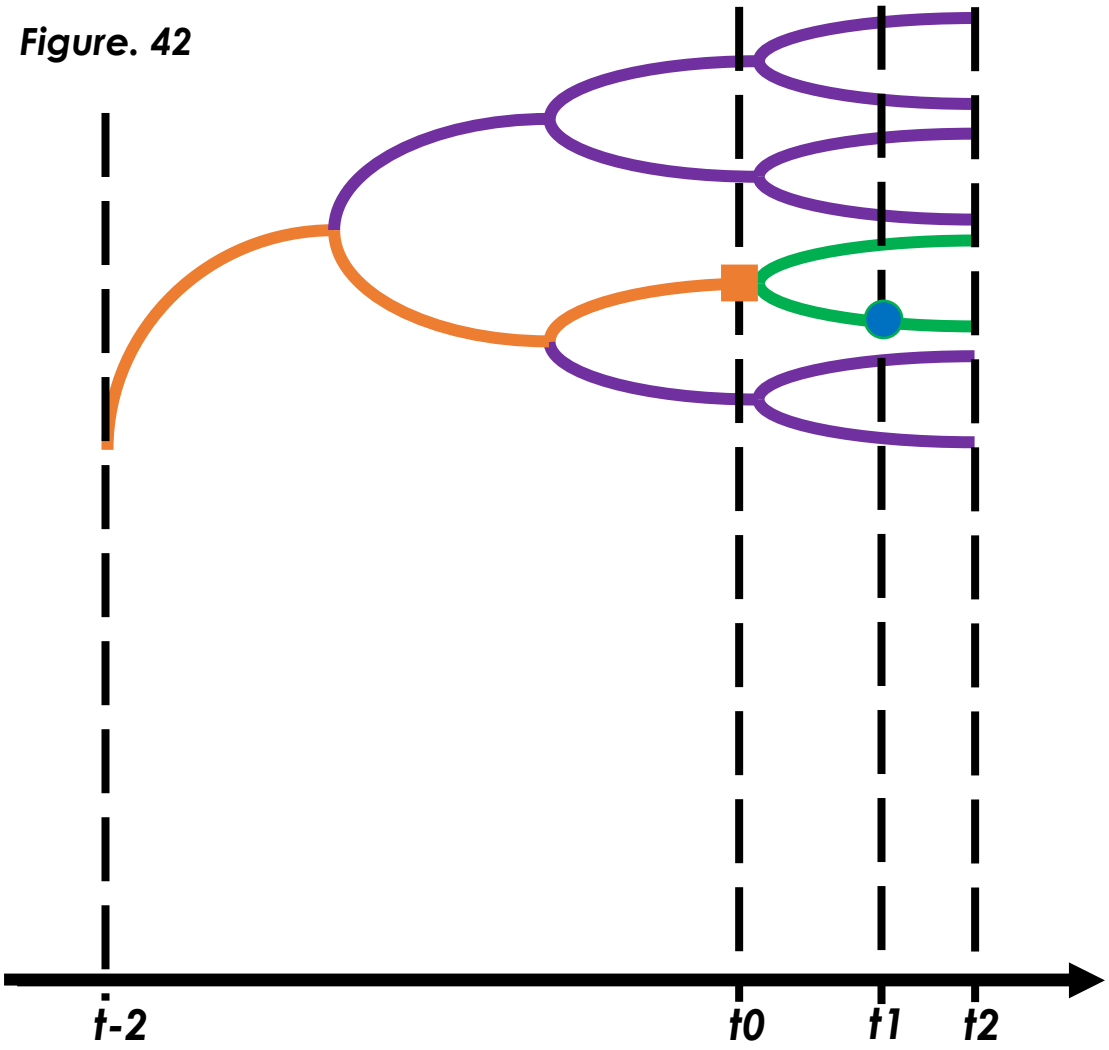
Present tensed non-modal statements are grounded in 'actual' parts of the Branching-Worm. Present tensed counter-to-fact modal statements are grounded in parallel 'non-actual' parts of the Branching-Worm.

§7.2.3 Narrow-future possibilities

Narrow-future tensed *de re* possibility statements concern future possibilities of an ordinary-object given the state of the utterer's history at the time of utterance. Such *de re* statements are true in virtue of the ordinary-object having at least one temporal part which exemplifies properties that the modal statement asserts of the ordinary-object and is – in relation to the utterance – located in a 'unactual' future Branch.

For example, in *figure. 42* at time *t0* a temporal part of Clare – represented by the orange square – utters the statement "I might go running tomorrow".[49] The truth of this narrow-future tensed modal statement is grounded in the Branching-Worm Clare having at least one future temporal part – represented by the blue dot at *t1* – located on a future 'unactual' branch where that part is running a day after the utterance.

Figure. 42



Future tensed non-modal statements are most naturally understood in a narrow sense and have an indeterminate truth value but are still meaningful. Something like "I will go running tomorrow" is an expression of an intention, credence or suchlike. Narrow-future tensed modal statements are grounded in 'unactual' parts of the Branching-Worm.

§7.2.4 Broad-future possibilities

[49] Most naturally read as narrow-future tensed. A broad-future tensed reading is feasible.

Broad-future tensed *de re* possibility statements concern the future possibilities of an ordinary-object *simpliciter* which don't depend on the state of the utterer's history at the time of utterance. Such *de re* statements are true in virtue of the ordinary-object having at least one temporal part which exemplifies properties that the modal statement asserts of the ordinary-object and is – in relation to the utterance – located in a 'non-actual' future Branch.

Natural language examples of broad-future statements aren't obvious, but they are characterised by past tensed locutions even though the statement itself is future tensed. They either appear like a narrow-future statements or a 'might' counterfactual conditional.

For example, in *figure. 43* at time *t0* a temporal part of Clare – represented by the orange square – utters the statement "I could have won the lottery tomorrow". This can be characterised as a broad-future statement even though "could have won" is past tensed.[50] The "could have" implies that the utterer has not actually bought a lottery ticket, but that there was a past point at which – were the utterer to have purchased a ticket – then winning the lottery would be a narrow-future possibility grounded in a stemming future part that wins the lottery.[51]

Assume the utterer of the statement "I could have won the lottery tomorrow" does not have – and is unable to acquire – a ticket. In which case there are no future stemming branches in which the utterer wins the lottery.[52]

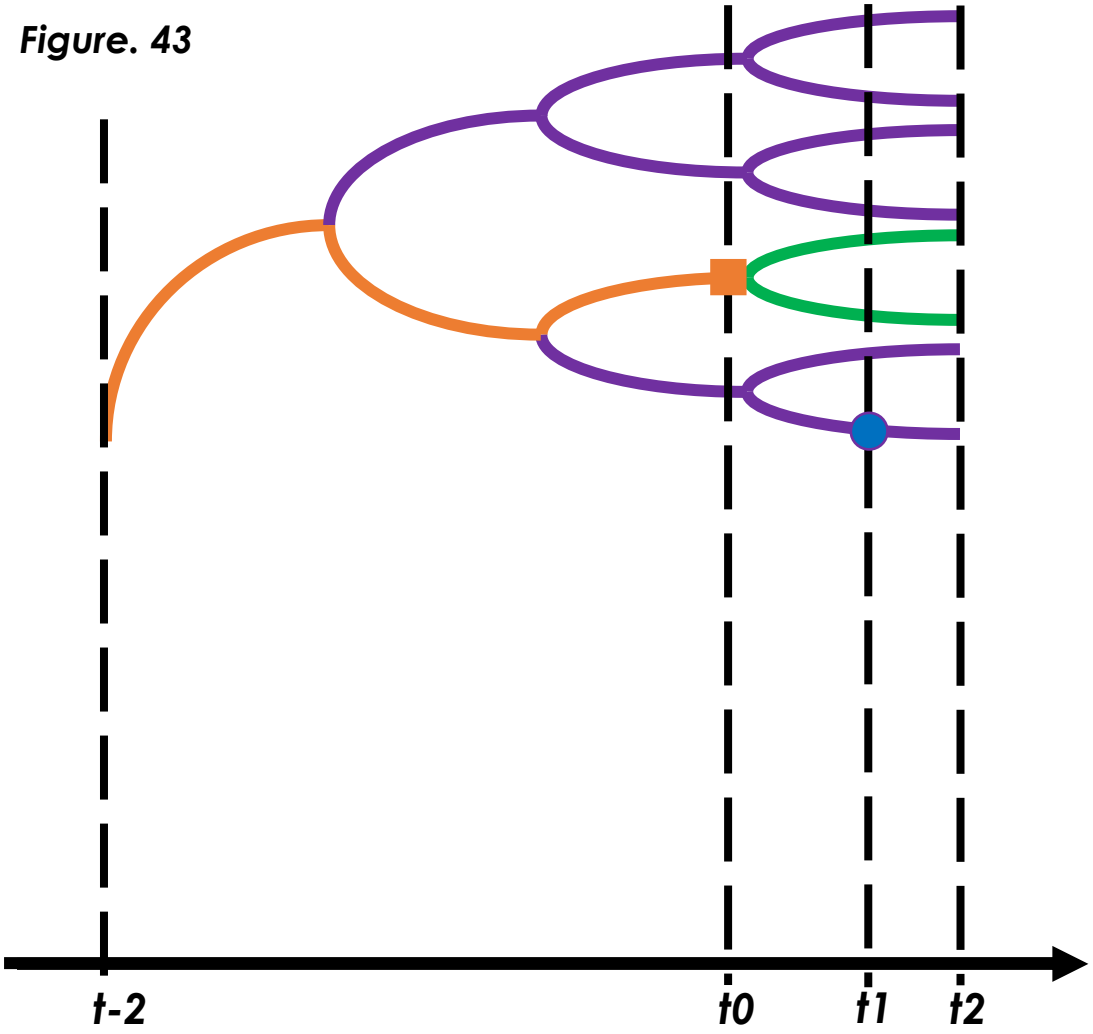
The truth of this broad-future tensed modal statement is grounded in the Branching-Worm Clare having a future temporal part – represented by the blue dot at *t1* – located on a future 'non-actual' Branch where that part wins the lottery.

[50] Described as 'Fake Tense' by Iatridou (2000).

[51] This arguably provides a metaphysical grounding for Condoravdi's Temporal Interpretations of Modals (Condoravdi 2001).

[52] In reality there may well be cases in which they somehow win the lottery without having purchased a ticket. For the sake of explanation set these aside.

Figure. 43



It is not clear what broad-future tensed non-modal statements are, but they too are indeterminate in truth value. Broad-future tensed modal statements are grounded in future 'non-actual' parts of the Branching-Worm.

§7.2.5 Further clarifications[53]

For *de re* modal statements about ordinary-objects other than the utterer, the truth of such statements is also grounded in that ordinary-object having parts – located past, present or future of the utterer – which exemplify properties that the modal statement asserts of the ordinary-object.

[53] Applying BT semantics of Belnap et al. (2001, 220-52) to my terminology, "I could have gone for a run yesterday", "I could be running right now" and "I could have won the lottery tomorrow" are, roughly, true iff there was a past point at which it would have been true to say 'It is possible that I will run/win', i.e., if there was a point prior to the utterance where there is at least one future stemming Branch in which Clare runs/ wins - 'Was:Poss:Will:(Clare runs/wins)'. "I might go running today" is true iff there is a future stemming Branch in which Clare runs - 'Poss:Will:(Clare runs)'.

De re modal utterances about events are grounded in the ordinary-objects involved in that event having parts which exemplify properties that the modal statement asserts of the ordinary-objects.

Tensed *de re* necessity statements are duals of the corresponding possibility statements. For example, "It is necessary that it is/was/will be p" is true iff "it is not possible that it is/was/will be not-p".

Tenseless *de re* possibility statements about an ordinary-object are true if they correspond to some part of the ordinary-object which they are about. Tenseless necessity statements are true if they correspond to all relevant parts of that ordinary-object.

In summary, when one makes a *de re* modal statement about an ordinary-object the truth of that statement is literally grounded in that ordinary-object itself in virtue of it having parts which correspond to the utterance. Therefore, my account meets desiderata 5): the truth of the modal statement and non-modal statements are grounded in the ordinary-object which the modal statement is about, not some distinct object. Given ordinary-objects have parts which ground the truth of modal statements, these parts can be regarded as 'modal parts'.

When outlining the first pass of EAM *§4.1* I noted that modalising involves quantification over all future, past or parallel branches depending on the tense of the statement. However, this isn't required on EAM as quantification can be restricted and localised to the ordinary-object which the *de re* modal statement is about given it has modal parts, just as non-modal *de re* statements about an ordinary-object just quantify over that ordinary-object in virtue of its temporal parts.

There are however cases of *de re* modal utterances about an ordinary-object which don't correspond with any parts of that ordinary-object, so the ordinary-object cannot ground the truth of such statements itself. This is particularly the case for utterances about past possibilities of an ordinary-object which predate the origination of the ordinary-object, given the essentiality of origins.

For example, assume the Branching-Worm Clare was born in June 1996 but a part of Clare makes the modal utterance "I could have been born in 1806". Given that the ordinary-object Clare was born in 1996, she has no temporal parts in 1806 as all of the Branching-Worm's parts originate from 1996. There may be other branching-worms called 'Clare' born from the same Branching-Worm parents earlier or later than 1996 which have the same properties as Clare, but as outline in *§6.2.1* these are distinct Branching-

Worms given their different origins. The *de re* statement "I could have been born in 1806" is then false on EAM, given there are no parts of the Branching-Worm Clare to ground the truth of the statement.

Unaugmented, EAM results in certain *de re* modal statements like the one above being false. However, I don't take this to be a problem. Intuitively such statements seem false even if somehow conceivable. EAM simply aims to meet the desiderata and provide the truth conditions of *de re* modal statements, it doesn't aim to ground the truth of all conceivably modal statement. The fact that some statements come out as false is an unproblematic consequence of EAM which I accept.

§7.3 De Dicto

Unlike *de re* modal statements, *de dicto* modal statements aren't about a particular object but rather concern representative content – what is said – about what is possible or necessary for things in general.

Although the focus of EAM is *de re* modal statements, not *de dicto*, the laws of EQM determine how things in general could have or might be and, in short, *de dicto* statements are true on EAM if the kind of things being described exist somewhere in the EQM universe and exhibit properties that the *de dicto* modal statement asserts of them.[54]

That said, statements like the ones in the previous section which come out as false on a *de re* reading due to the ordinary-object having no parts to ground them could be understood to be about things in general and come out as true on a *de dicto* reading.

For example, "I could have been born in 1806" could be translated as meaning "something which is similar to me in relevant respects was born in 1806". So seemingly *de re* statements could invoke something like counterpart theory in order to ground their truth on a *de dicto* reading. The truth of a *de dicto* reading of such statements are grounded in a distinct counterpart of Clare – Counterpart-Clare – which has a temporally extended part which stems from 1806 and exemplifies properties similar to the 'actual' part of Clare which make the utterance.[55] This would involve quantification over Clare and relevant past 1806 branches.

That said, invoking counterpart theory results in a dual account whereby *de re* modal statements about an ordinary-object are grounded in modal parts

[54] Broadly similar approaches are given by Wilson (2020, 3) and Vetter (2015, 3 & 202).
[55] I leave open whether counterparts have to belong to 'non-actual' or 'unactual' – as opposed to 'actual' – branches in order to be regarded as counterparts.

of an ordinary-object whereas certain seemingly *de re* modal statements are in fact de *dicto* and are grounded in counterparts.[56] Although there is disunity between *de re* and *de dicto* statements, desiderata 5) specifies unity and localisation of *de re* modal statements about ordinary-objects, which has been achieved. Adopting a sort of counterpart theory for certain *de dicto* statements maintains serviceability of EAM that would otherwise be lost without contradicting desiderata 5). However, I cannot address this further so set it aside as an area for further development.

§7.4 Counterfactual Conditionals

In this section I address the much-contested topic of counterfactual conditionals. Counterfactual conditionals are typically about what might or would happen if a certain situation were the case, in a history with conditions different to the utterer's own.

'Might' counterfactual conditionals have the structure 'if x, might *y*'. For example, "if I take the penalty, I might score". They are true on my account iff there is some Branch in which *x* occurs and is followed by *y*. Most 'might' counterfactual conditionals are unproblematically true, provided they don't contradict the laws of QM.

'Would' counterfactual conditionals ('counterfactuals' henceforth) have the structure 'if x, would *y*'. On a classical universe they are typically understood as necessity statements about what 'will' happen following certain circumstances.

As outlined in *§5.2.2*, there aren't clear-cut non-modal future tensed semantics on EQM. I adopted semantics whereby non-modal future tensed statements about what 'will happen' have an indeterminate truth value. For the sake of simplicity, I apply the same semantics to counterfactuals about what 'would' happen. Such statements are indeterminate as they fail to specify the Branch in which *x* is followed by *y*.

That said, as with 'will' semantics there are other options available which I now briefly make note of.

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[56] Uniform semantics could be retained across the board by invoking Stage Theory instead of Branching-Worm Theory. Stage Theory holds that Stages ('irreducible parts' on Worm Theory) are the ordinary-objects that we quantify over and are related to one another via counterpart relations (Sider 2001, 193-6). Were one to invoke Stage Theory, then all modal and non-modal statements could be grounded in Stages and their counterpart relations. However, this would mean that *de re* modal statements aren't grounded in ordinary-objects themselves but in the counterpart relations with distinct ordinary-objects and would fail to meet desiderata 5).

Option one: counterfactuals are false given they fail to denote a certain Branch in which *y* occurs following *x*.

Option two: counterfactuals are true given they denote neither Branch following *x* but the disunited sum, in some of which *y* occurs. 'Would' counterfactuals then have the same truth conditions as 'might' counterfactual conditionals.

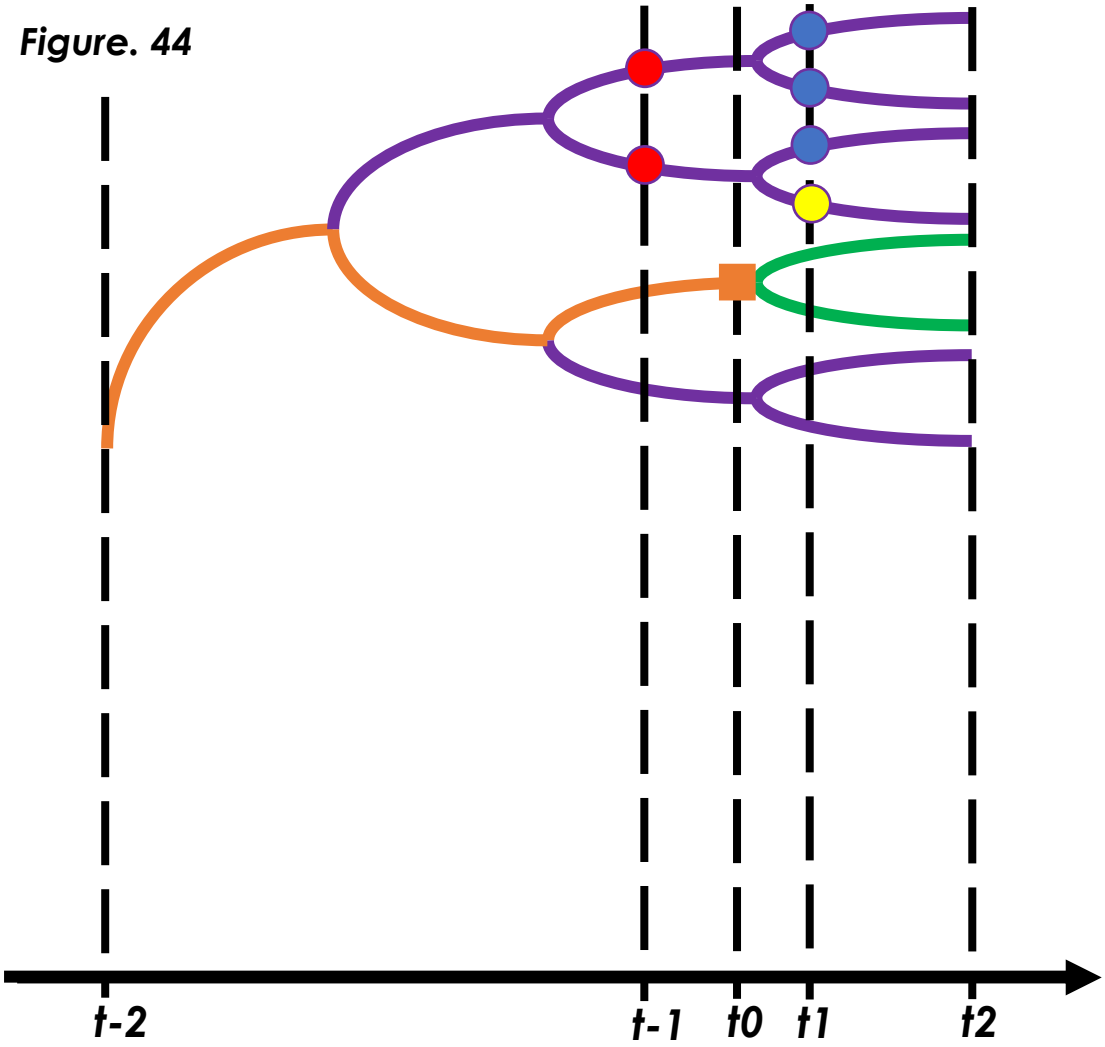
Option three: counterfactuals are true iff in all Branches where *x* occurs, *y* necessarily follows. This is most akin with classical 'will' semantics and counterfactual analysis. On this analysis most counterfactual statements are false. Given the laws of QM, there are Branches in which *x* occurs, but *y* doesn't follow.[57]

For example, in *figure. 44* a temporal part of Clare – represented by the orange square – utterers the statement at *t0* (assume 10am) "if I had gotten up at 8am today instead of 10am, I would have gone running at 11am". The Branches in which temporal parts of Clare get up at 8am – where *x* occurs – are represented by the red dots. Branches in which temporal parts of Clare go running at 11am – where *y* follows – are represented by blue dots. Yet there is at least one Branch in which Clare doesn't go for a run at 11am following getting up at 8am. Instead, Clare goes for a walk, for example, represented by the yellow dot.[58]

[57] Assuming we can specify the antecedent, consequent and counterfactual connective, this provides an additional argument to Hajek's claim that most counterfactuals are false on these semantics, particularly in a deterministic EQM universe (Hajek 2014, 38-47; 2020, 3-4).

[58] In reality things are far more complex but cannot be represented given the sheer number of differing branches.

Figure. 44



Only certain counterfactuals like "if I hadn't slept in, then all electrons would be negative charge now" are true.

Option four: counterfactuals are true iff there is a higher probability of *y* occurring following *x* than other outcomes *z*, whereby far-fetched low probability possibilities that would falsify the counterfactual are suitably ignored. But it's not entirely clear which counterfactuals come out as true, overly complex empirical tests would have to determine the truth of such statements.

Option five: counterfactuals are true iff *y* follows *x* in all the closest Branches. Similar to Lewis' analysis (Lewis 1973, 91-5; 1986, 20-7), the closeness relation is understood as a similarity relation. Counterfactuals are true iff they occur in all the Branches most similar to the utterers Branch. Given the branching structure, an additional closeness relation can be added: spatiotemporal closeness. In other words, Branches which stem from the utterer's history, closer to the spatiotemporal location of the utterance than further away. So, counterfactuals are true iff *y* follows *x* in all the Branches similar to the utterer's

Branch and which are spatiotemporally closest. In the example, it is the parts of Clare which are spatiotemporally and similarity closest to the part making the utterance.[59]

Given space limitations I set these options aside as areas for further development. I maintain that counterfactuals have an indeterminate truth value like the chosen 'will' semantics.

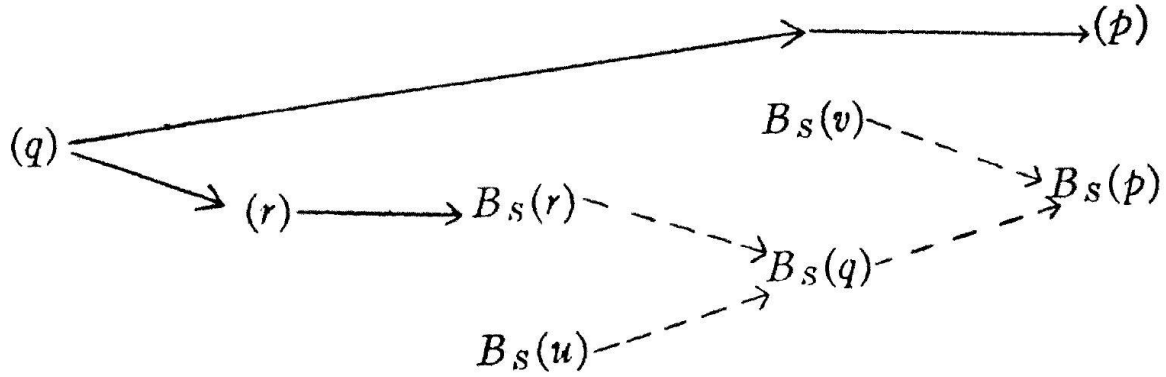
§7.5 Knowledge via Common Cause

The question remains how an utterer has knowledge of what grounds the truth of modal statements. Given the CST-related nature of worlds, EAM can provide a causal modal epistemology. This isn't to say that it is correct or the only suitable ontology, rather it is one which is similar to what I assume our non-modal epistemology to be like, hence going some way to unifying modal and non-modal epistemology.

Parts of ordinary-objects which ground modal statements exist in non-actual and unactual branches, so the utterer cannot know of them via direct causal interaction with them. However, as outlined in *§2.3.6,* branches – including objects and events within them – are CST-related to one another via common cause. An utterer is also CST-related to the ordinary-objects that ground the truth of modal statements via common cause.

An utterer has knowledge of the ordinary-objects that ground the truth of modal statements in the same way we have knowledge from common causation, as outlined by Goldman. Goldman holds that we can empirically come to know something *p* by interacting with *q* which causes *p*, from which we infer our belief that *p*. Interacting with *q* results in both *p* and our knowledge of *p,* even if we never directly interact with *p*. As illustrated in Goldman's 'Pattern 2' diagram below (Goldman 1967, 357-8, 360, 364-6).

[59] For classical counterfactuals Stalnaker notes the problem of backtracking whereby statements like "if I hadn't slept in, Hitler would have won WWII" come out as true in virtue of being the closest (similarity) worlds. On option five, backtracking is avoided given the branching structure and the inclusion of spatiotemporal closeness. The above statement is false given that Hitler lost WWII in the utterer's history. Any Branch in which the utterer didn't sleep in stems from the actual branch at a point close to the utterance.



Although Goldman isn't talking about knowledge in a EQM universe of 'non-actual' and 'unactual' branches. Goldman's epistemology combined with an implicit understanding of how the wavefunction deterministically evolves results in knowledge of what grounds modal statements.

An utterer knows of the objects that ground narrow-future modal statements by having knowledge of their present branch – including the objects and events contained within it – combined with an understanding of how the wavefunction deterministically evolves. From which they infer what kind of objects and events exist in unactual branches.

An utterer knows of objects that ground past, present and broad-future possibilities by having knowledge of their history – including the objects and events contained within – combined with an understanding of how the wavefunction deterministically evolves. From which they infer what kind of objects and events exist in non-actual branches.

So, although an utterer doesn't directly interact with objects and events in non-actual and unactual branches, an utterer is CST-related to such branches via common cause so has empirical knowledge of such ordinary-objects and events. EAM can provide a causal explanation for our modal knowledge which is similar to our non-modal knowledge.

§7.6 Summary

In summary, EAM reductively, uniformly, parsimoniously and locally grounds the truth of *de re* modal statements in CST-related concrete ordinary-objects (contained within an Eternalist branching EQM universe) – Branching-Worms – in virtue of Branching-Worms having CST-related modal parts, which exist in unactual or non-actual branches, and exhibit properties which the utterer attributes to the ordinary-object. Branching-Worms also ground the truth of non-modal *de re* statements in virtue of having CST-related parts – which exist in actual branches – that exemplify properties that the non-modal utterance asserts of the ordinary-object. EAM therefore meets desiderata 1) – 5).

Chapter Three

Comparison with Notable Modal Accounts, Areas for Further Development and Conclusion

§8: Comparison with Notable Modal Accounts

In this section I conduct a brief comparison of EAM outlined in Chapter Two with the accounts assessed in §1. I outline the similarities and differences to show where EAM is situated in relation to contending accounts of modality. Although I offer up some response to potential objections, I don't claim, nor attempt to show, that EAM is preferable to contending accounts.

First, I compare it with Lewisian Modal Realism, second Wilson's QMR, third Meg Wallace's Lump Theory and finally Vetter's Potentialities approach.

As the first three accounts I compare EAM with are modal realist accounts which adopt CST-isolated diverging possible worlds, I won't repeat the points made in the comparison with Lewis's but instead focus the comparison on pertinent similarities and differences which are unique to each account.

§8.1 Lewisian Modal Realism

As outlined in *§1.1*, Lewisian Modal Realism reductively and parsimoniously grounds modal statements – without circular appeal to modal notions – in concrete ordinary-objects in virtue of their fundamentally non-modal properties. Like Lewis', EAM reductively and parsimoniously grounds *de re* modal statements in concrete ordinary-objects.

A significant difference is that EAM utilises CST-related overlapping worlds, whereas Lewis utilises diverging CST-isolated worlds. As such, ordinary-objects on EAM are trans-world Branching-Worms, whereas ordinary-objects are world-bound linearly extended spacetime worms on Lewis's.

Furthermore, on EAM the existence of the plurality of worlds is posited as a result of EQM – an empirical definite theory which is determined by rigorous scientific observation and inference to the best explanation – whereas for Lewis worlds are posited on grounds of semantic serviceability. Therefore, worlds on EAM are posited on a more naturalistic basis.

Furthermore, while Lewis holds non-modal knowledge requires causation, he holds that our modal knowledge – knowledge of CST-isolated possible worlds – is due to our *a priori* mathematical-like knowledge of the recombination principle. On EAM however, given that the possible worlds overlap and are CST-related with one another, there is a causal element to both modal and

non-modal knowledge. As outlined in *§7.5*, we can know what CST-related Everettian worlds are like – as well as the ordinary-objects contained within them – via something like Goldman's common cause epistemology.

Another major difference is that EAM, as outlined so far, isn't as serviceable as Lewis's for a number of reasons. First, EAM doesn't utilise counterpart theory for *de re* modal statements but grounds them ordinary-objects which exist in the 'actual' world but which have modal parts that exist in 'unactual and 'non-actual' branches. Second, EAM so far focuses only on physical or nomic modality, whereas Lewis' accounts for metaphysical modality. I now outline these in more detail.

§8.1.1 Modal parts vs. counterparts

On Lewis' account non-modal statements are grounded in ordinary-objects which exist in our CST-related world, whereas modal statements are grounded in counterpart ordinary-objects which exist in CST-isolated possible worlds.

I aimed to unify modal and non-modal *de re* statements by producing an account where there isn't as much disparity in where these objects are located and how we know of them. On EAM *de re* modal statements are grounded in ordinary-objects – Branching-Worms – in virtue of their parts which exhibit non-modal properties that the modal statements asserts of that very ordinary-object.

As Branching-Worms are distinguished by their essentiality of origins, this results in them having limited parts which ground a more limited set of *de re* modal statements than on Lewis's account which utilises counterpart theory. So given that my account doesn't utilise counterpart theory for *de re* statements like Lewis', less *de re* modal statements are true on EAM than on Lewis'. Therefore, EAM is far less serviceable than Lewis'.

That said, has briefly noted in *§7.3*, such statements could have a *de dicto* reading and utilise some form of counterpart theory to ground the truth of them. However, this requires further development which is beyond the scope of this thesis.

EAM can account for uncontroversial *de dicto* statements by grounding them in the kind of things being described, existing somewhere in the EQM universe and exhibiting properties that the statement asserts of them.

§8.1.2 Metaphysical modality

Everettian worlds aren't as bountiful as Lewisian possible worlds, the initial conditions of the universe plus the laws of QM determine what does and

doesn't exist, hence why EAM focuses on nomic possibility. What exists on Lewis' Modal Realism is far greater: all possible worlds that don't contradict the laws of logic. So, Lewis' account factors in wider metaphysical modality and grounds the truth of far more modal statements. EAM as outlined so far is less serviceable than Lewis's.

However, there are a few viable options regarding metaphysical possibility on my account.

First option is to, like Wilson, regard physical and metaphysical modality as the same thing whereby metaphysical modality just is physical modality: what is possible and necessary *simpliciter* is determined by the laws of QM (Wilson 2020, 26). This option retains a unified semantics for metaphysical and physical modality holistically given they're the same.

A consequence of this option is that certain metaphysical statements that seem conceivably true – like 'the laws of physics could have been different' or 'there might have just been one particle' – are in fact meaningless or false.

On Lewis's account there are possible worlds with different laws of physics so statements like 'the laws of physics could have been different' are true in virtue of some world in which the physical laws that govern it are different to our own world. As such, choosing this option results in significantly reduced serviceability, but I don't take this to be problematic.

I sympathise with Vetter's point that it may be that ideas about what is or isn't metaphysically possible are shaped by the prevalent ways of theorising about metaphysical modality (Vetter 2015, 300). Although such things may be in some way conceivable, they are not in fact possible.

The second option regarding metaphysical modality on EAM is to retain it as a distinct and separate form of modality which isn't reducible to physical modality.

Were there other concrete universe governed by different laws of physics which exist separate from our own branching universe, then one could ground metaphysical modal statements in such concrete entities, like Lewis does. However, EQM doesn't assert such things and cannot be accounted for on the view I have outlined so far. However, as metaphysical modality is about the metaphysical, that which is over and above the physical, I am open to metaphysical modality being grounded in something other than concrete entities such as abstracta, fictions, unanalysable brute facts or something else.

Either way, opting for option one, whereby metaphysical modality equates to physical modality, results in an account which isn't as serviceable as Lewis. Opting for option two, whereby metaphysical modality is distinct from physical modality, results in an account which isn't holistically reductive and uniform like Lewis' but is a disunited dual modal account. Given space limitations I cannot assess this further and remain neutral on which option is preferable, this is an area for further development.

§8.2 Wilson's QMR

EAM is similar to Wilson's QMR as it is reductive, ontological parsimonious and concrete, as well as utilising a EQM framework whereby possible worlds are posited as a result of rigorous science, not on metaphysical speculation and semantic serviceability alone. So EAM, like QMR, provides a naturalistic and scientifically backed Modal Realism.

However, the fundamental difference between EAM and QMR is the structure of worlds. Wilson adopts diverging CST-isolated Everett worlds while EAM adopts overlapping CST-related Everettian worlds. Wilson's account can provide truth conditions for non-modal future tensed statements, whereas mine does not.

Furthermore, while Wilson adopts a common ground epistemology which doesn't rely on CST-relations for modal knowledge, I provide an account which allows for a common cause epistemology.

Like Lewis, Wilson utilises counterpart theory across CST-isolated worlds to ground the truth of *de re* modal statements whereas my account grounds the truth of *de re* modal statements in ordinary-objects and their CST-related parts which exhibit non-modal properties.

Although QMR is less serviceable than Lewis' given it equates nomic and metaphysical modality, EAM is less serviceable than QMR for a number of reasons. As EAM doesn't adopt counterpart theory for *de re* modality it is less flexible as the essentiality of origins limit which *de re* modal statements about an ordinary-object are true.

Furthermore, unlike Lewis' formulation of Modal Realism, QMR readily addresses concerns around advanced modalizing which EAM so far hasn't factored in.

§8.2.1 Advanced modalizing

Advanced modalizing, first characterised by John Divers (1999), are modal claims about the reductive modal base. On EAM and QMR, this would be modal claims about the many-worlds posited by EQM, such as "possibly (or

necessarily), there are many-worlds posited by EQM". EAM so far hasn't providing truth conditions for advanced modal statements.

One option is to take an approach which Dorr (MS) argues is similar to early Lewis (1968), whereby there are two distinct languages: a language about objects within worlds where we can apply modal operators and a language about the plurality of worlds themselves where we cannot apply modal operators to such statements.

On this option, although we can speak non-modally about things within worlds and worlds generally, statements about the plurality of worlds themselves is a class of statements which fall outside of the scope of modal statements. Although such statements sound meaningful, they are in fact meaningless and make as much sense as Escher sentences like "more people have written about modality than I have".

The problem is that it is then neither true nor false that "the multiverse could have been different" or "that it couldn't have been different". Like Wilson, I take it that we want to regard worlds as existing necessarily, both to maintain metaphysical truths are necessary truths and to try retain orthodox S5 modal logic (Wilson 2020, 37).

One way of avoiding this problem is to ground statements about the plurality of worlds in a completely different way to statements about things within worlds. As with an option for metaphysical modality, advanced modal statements could be grounded in something like abstracta, fictions, unanalysable brute facts or something else.

However, this results in a rather significant disunity in how we speak about things within worlds and the plurality of worlds. Even though I set out to achieve unity of *de re* non-modal and modal statements about ordinary-objects in the actual world, this option would no doubt be an unappealing aspect of EAM.

Wilson's QMR however utilises the counterpairings approach taken by Dorr (MS), whereby the claim that there unrestrictedly speaking exists the many worlds, trivialises modal claims about the modal base and results in it being the case that the many-worlds necessarily exist, possibly exist and just exist.

Following Dorr, Wilson outlines that this involves generalising the idea that all modality is explicable in terms of counterpart relations, whereby 'possibly' and 'necessarily' modal operators quantify over generalised 'counterpairings': functions from individuals in the pluriverse (totality of worlds) to other individuals in the pluriverse. Wilson states that counterpairings involve intricate permutations (orderings or arrangements) of all individuals,

permutations of just two individuals that leave all others unchanged, and the identity function. 'Possibly, *a* if *F*' is just to say there exists a counterpairing that maps *a* to something that is *F*. Necessarily, *a* is *F*' says that all counterpairings map *a* to something that is *F*. Counterpairings are global permutations of the whole domain that can then be restricted (Wilson 2020, 38-9).

Furthermore, Wilson outlines that while ordinary modal claims attributes properties to the actual world and involves restricting quantifiers, advanced modal discourse is not attributing any property to the actual world, rather is unrestrictedly making claims about the pluriverse as a whole. As there is just one pluriverse, advanced modal discourse maps counterpairings of the pluriverse to itself and modal operators are redundant. So 'necessarily, there is a pluriverse' is equivalent to 'there is a pluriverse' which is equivalent to 'possibly, there is a pluriverse'. This maintains the orthodox S5 modal logic and avoids having distinct modal and non-modal language for in world claims and advance modalizing claims (Wilson 2020, 38-9)

Were my account to take a similar approach to Wilson's, this would result in a more unified logic and avoid the disparity concerns relating to having two languages, allowing for modal and non-modal talk both in world and about the many-worlds themselves. Adopting Dorr's approach would seemingly involve committing to counterpart theory, but as noted in §7.3, I am open to a dual account whereby statements of a certain class are grounded in parts whereas statements of another class are grounded in counterparts. How Dorr's approach would be applied to EAM is an area for further development.

Were such an approach unsuccessful then one could fall back on the aforementioned options or adopt a BT logic of Balnap's.

What is clear is that while EAM appeals to the localised intuition and focuses on attempting to unify modal and non-modal *de re* semantics, QMR is far more serviceable and readily able to unify different classes of modality.

§8.3 Wallace's Lump Theory

Wallace's Lump Theory adopts Modal Realism with CST-isolated diverging possible worlds and applies unrestrictive mereological composition to arrive at ordinary-objects being trans-world Lumps with modal parts. Wallace intends for modal and temporal parts to be analogous in appropriate ways, whereby any view that is committed to modal parts is parallel in structure to that of temporal parts (Wallace 2014, 358-60).

Wallace's account assumes unrestricted mereological composition and argues that this results in Lump Theory across CST-isolated possible worlds.

Wallace argues that ordinary-objects are trans-world objects which have modal parts that exist in CST-isolated possible worlds and it is ordinary-objects, in virtue of their modal parts, that ground *de re* modal statements about such objects.

EAM also arrives at ordinary-objects having modal parts in a similar attempt to unify what grounds modal and non-modal *de re* statements. On EAM, as with Lump Theory, *de re* modal statements about an ordinary-object is grounded in that ordinary-object itself, in virtue of its modal parts which exhibit properties that the modal statement asserts of the ordinary-object.

Wallace argues that a rich modal profile is integral to ordinary-objects and a part of what they are: how an ordinary-object could or could not be is part of what it is. Ordinary-objects and their persistence conditions are often defined and distinguished by what they can and cannot do. A modal profile plus Leibniz's Law distinguishes coincident entities. Wallace claims that Lump Theory's ability to solve certain metaphysical puzzles is a reason why Lumps are worthy of our attention (Wallace 2014, 360; 2019, 416 & 420-1).

EAM is similarly able to uniformly solve the metaphysical puzzles of constitution, composition and co-location. In short, on EAM, the statue Branching-Worm and lump Branching-Worm share parts which overlap, when the statue is squished it ceases to exist while the lump continues to exist. The statue and lump are distinguished as not all of their parts overlap. The modal difference between the statue and lump is accounted for by the qualitative differences of their modal parts which mirrors the explanation of spatial and temporal coincidence.

However, while both Branching-Worms and Lumps are trans-world ordinary-objects, the main difference between EAM and Wallace's is that Lumps span across CST-isolated diverging worlds whereas Branching-Worms span across CST-related overlapping worlds. In order for Wallace to arrive at Lumps, unrestricted mereological composition across CST-isolated worlds is required, whereas EAM can arrive at Branching-Worms with more restrictive forms of composition, given that worlds overlap and are CST-related.

On EAM modal parts are just CST-related temporal parts of Branching-Worms located in 'non-actual' and 'unactual' branches which are CST-related to the utterer. However, on Lump theory temporal parts of Lumps are CST-related parts which exist in the CST-related actual world, while modal parts are CST-isolated parts which are located in worlds that are CST-isolated from the utterer. The difference between modal and temporal parts is indexical on EAM and Lump theory, but given there are no CST-relations between a Lump

ordinary-object and its modal parts, there are only similarity relations between such parts. On EAM there are both similarity and CST-relations between parts.

So, although Wallace seeks to draw an analogy between modal and temporal parts, as noted in *§1.3* there remains is a disanalogy in where such parts are located, their relation to the ordinary-object and their ability to account for gradual change over time.

On EAM however, given modal parts and temporal parts of Branching-Worms are CST-related and similarity related, there is less of a disanalogy between modal and non-modal parts. For example, gradual change of modal parts is accounted for in just the same way as for temporal parts, by appealing to causal and temporal relations between successive CST-related parts. Therefore, EAM closes the gap in the disparity between modal and temporal parts.[60]

§8.4 Vetter's Potentialities Account

Vetter's Potentialities account is a non-reductive approach which doesn't use the framework of possible worlds but grounds *de re* modal statements about an ordinary-object in that very CST-related concrete ordinary-object, in virtue of the fundamentally modal properties – potentialities – it exhibits. Vetter's account is then localised in the sense that it grounds modal truths about ordinary-objects in those ordinary-objects themselves which exist in the actual world.

Like Vetter's, EAM is localised as it grounds *de re* modal statements about ordinary-objects around us in those very CST-related concrete ordinary-objects which exist in the actual world. Vetter notes that as potentiality is asymmetric with respect to time and that Mackie (1998) has linked asymmetry in an objects temporal career to a branching picture of possibility, the potentiality account is rather similar in spirit, though not quite in letter, to a branching-worlds model of possibility (Vetter 2015, 290).

One fundamental difference between EAM and Vetter's is that Vetter assumes the world is fundamentally dispositional and as such does away with possible worlds, whereas EAM adopts fundamentally non-dispositional Eternalist Everettian worlds and hence can retain some possible world semantics.

[60] Wallace draws attention to problems relating to fission cases (Wallace 2019, 409 & 427) which I cannot adequately address here. In short, Branching-Worms are in no better position to address 'intra-world' fission cases like that described by Parfit (1971) and as expected they give rise to odd consequences. One way of addressing them may be to introduce a more nuanced 'Branching-Worm' to 'person' relation.

Although Vetter's account and EAM ground *de re* modal claims in ordinary-objects that exist in the actual world, on EAM this is due to such objects – Branching-Worms – having modal parts which exhibit fundamentally non-modal properties and exist in 'non-actual' or 'unactual' branches within the Eternalist branching Universe, whereas on Vetter's it is due to ordinary-objects having fundamentally modal properties. EAM therefore reductively grounds *de re* modal statements whereas Vetter's does not.

EAM reductively explains the potentiality of an ordinary-object as follows: an ordinary-object *o* has a potentiality x if there is some branch/Branch in which a part of *o* has the property x. For example, the Golden Gate Bridge (a Branching-Worm) has the potentiality to break as there is some part of the bridge – located on some Branch – where that part breaks. Degrees of possibility can be explained by something like the probability of that thing occurring.

Vetter notes that as potentiality is asymmetric with respect to time, one potential outcome is that manifestations of potentialities concern the future or the present, but only trivially concern the past. For example, past potentialities are possessed iff they are manifested and we cannot accept the possibility that there were never any of the actually existing objects (Vetter 2015, 187 & 290).

While EAM can account for many past possibilities of ordinary-objects, as noted in *§7.2.5,* it cannot account for certain past tensed *de re* modal statements about an ordinary-object that predate the time at which that object comes into existence given the essentiality of origins. Furthermore, despite EAM assuming determinism, it can account for there being Branches in which there aren't any objects that we regard as 'actual', except for those which are shared by all worlds such as events like the Big Bang.

However, I agree with Vetter's sentiment that thinking the universe could have been different to how it in fact is, is not central to our modal intuitions and that the necessity of origins is more so, as is the idea that the beginning of time is modally 'special'. Intuitions that the universe could have been different to how it in fact is, are arguably just based on conceivability of such a state of affairs, but there is good reason to divorce possibility from conceivability (Vetter 2015, 290-1).

§9: Areas for Further Development

Given the scope of this thesis I have made various substantive unargued assumptions and focused on outlining an account for *de re* modality that

meets the desiderata. In this section I make note of such assumptions and note areas of EAM which would benefit from further development.

I make the conditional assumption that if EQM is true, then EAM can follow. The obvious point being that if EQM is false, then EAM loses its grounding. Further justification for adopting EQM would strengthen the validity of EAM.

Furthermore, EAM assumes Eternalist EQM with overlapping worlds. Further justification for adopting Eternalism as well as overlapping worlds, beyond wishing to explore their metaphysical consequences, would strengthen EAM. This would include further outlining suitable future tensed semantics, further justification of modal parts not being relations to worlds and further outlining of objective probability on branching EQM.

Another substantive assumption made was that non-modal statements are grounded in concrete ordinary-objects that are CST-related to the utterer. While this may be more broadly accepted, EAM would benefit from further development of how we are to understand causality, spatiotemporal relations, the nature of concreteness and ordinary-objects, aside from just drawing comparisons. Relatedly, the epistemology of EAM would benefit from further development.

The substantive assumption that the Universe consists of concrete ordinary-objects that are CST-related was made in order to present a unified account of *de re* modal and non-modal statements. Seeking unity in this area was driven by the intuition that modal and non-modal *de re* statements about an ordinary-object should be grounded in that very ordinary-object, not some distinct object. EAM would benefit from further justification of this intuition and aim for unity in this area.

This aim for unity with modal and non-modal *de re* statements results in reduced serviceability, due to the essentiality of origins and significant disunity in other important areas of modality. EAM would benefit from justification of the essentiality of origins, further development of *de dicto* modality, counterfactuals, metaphysical modality and advanced modalizing.

§10: Overall Conclusion

In conclusion, I proposed that if EQM is true then adopting the overlapping Everettian worlds it posits allows for an account of *de re* modality that meets the desiderata set out in *§1.6* following a brief assessment of notable realist accounts of modality. I don't claim that because EAM meets the desiderata

that it is therefore correct or should be accepted, as noted in §9 and throughout there are many areas in need of further development.

Nevertheless, although EAM as it stands isn't an all-encompassing account of modality, it is an account of *de* re modality which has met the desiderata it set out to achieve:

1) EAM is reductive and unified as it explains *de re* modality by invoking entities of the same kind, without invoking modal notions, hence providing a unified *de re* modal semantics.
2) EAM is ontologically parsimonious as it doesn't posit new general kinds which aren't already in our ontology, but invokes apparatus readily available in science and metaphysics: many-worlds with overlap posited by EQM and applies perdurant worm theory.
3) EAM is concrete as the entities that ground modal statements are concrete physical entities.
4) EAM is naturalistic and CST-related as the modal account itself is scientifically backed as it is based on EQM and the entities that ground modal statements are CST-related to the utterer of the modal statements rather than being CST-isolated.
5) EAM is localised and unified as modal (and non-modal) statements about an ordinary-object Branching-Worm are directly grounded in, and identified with, that ordinary-object Branching-Worm itself and the properties it itself exemplifies and not some distinct but similar ordinary-object, hence providing a unified modal and non-modal semantics.

EAM is a unique account which has – like all accounts of modality – appealing aspects as well as concerning drawbacks. However, I hope that EAM has shown some potential to be a plausible contending account of modality which would benefit from further development.

Bibliography

Armstrong, David. (1989). *A Combinatorial Theory of Possibility*. (Cambridge University Press, New York)

Belnap, Nuel. & Green, Mitchell. (1994). 'Indeterminism and the Thin Red Line'. *Philosophical Perspectives*, *8*, 365–388.

Belnap, Nuel. & Müller, Thomas. (2010). 'Branching and Uncertain Semantics: Discussion Note on Saunders and Wallace, "Branching and Uncertainty"', *The British Journal for the Philosophy of Science* 61(3): 681-96

Belnap, Nuel. Perloff, Michael. & Xu, Ming. (2001). *Facing the Future: Agents and Choices in Our Indeterminist World*. (OUP, New York)

Belnap, Nuel. (2002). 'Double Time References: Speech-Act Reports as Modalities in an Indeterminist Setting, in F. Wolter, H. Wansing, M. de Rijke and M. Zakharyaschev (eds), *Advances in Modal Logic*, Volume 3, Singapore: World Scientific, pp. 37–58.

Berkeley, George. (1968). *Locke and Berkeley: a collection of critical essays* ed. Charles Burton Martin and D.M. Armstrong (Macmillan, London)

Borghini, Andrea. & Torrengo, Giuliano. (2013). 'The Metaphysics of the Thin Red Line'. *Around the Tree: Semantic and Metaphysical Issues Concerning Branching and Open Future* (Springer Netherlands, Dordrecht)

Broad, Charlie. (1923). *Scientific Thought.* (Routledge & Kegan Paul, London)

Cameron, Ross. (2012). 'Why Lewis's analysis of modality succeeds in its reductive ambitions.', *Philosophers Imprint*, Vol. 12, No. 8, pp. 1-21 (Michigan Publishing)

Cameron, Ross. (2015). *The Moving Spotlight: An Essay on Time and Ontology*. (OUP, Oxford)

Cariani, Fabrizio. & Santorio, Paolo. (2018). '*Will* done Better: Selection Semantics, Future Credence, and Indeterminacy', *Mind*, Vol. 127, No. 505, pp. 129-65

Carnap, Rudolph. (1947). *Meaning and Necessity* (University of Chicago Press, Chicago)

Carroll, Sean. (2019). *Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime* (Oneworld Publications)

Condoravdi, Cleo. (2001). 'Temporal Interpretation of Modals: Modals for the Present and for the Past', *The Construction of Meaning* (CSLI Publications)

Divers, John. (1999). 'A Genuine Realist Theory of Advanced Modalizing', *Mind* 108 (430): 217-40.

Dorr, Cian. (MS). 'How to Be a Modal Realist'. Available on PhilArchive: https://philarchive.org/archive/DORHTB

Everett, Hugh, et al. (1973). *The Many Worlds Interpretation of Quantum Mechanics* (Princeton University Press)

Hajek, Alan. (2014). 'Most Counterfactuals Are False', *PhilArchive*: https://philarchive.org/archive/HJEMCA

Hajek, Alan. (2020). 'Counterfactual scepticism and antecedent-contextualism' *Sunthese*

Iatridou, Sabine. (2000). 'The Grammatical Ingredients of Counterfactuality.' *Linguistic Inquiry*, Vol. 31, No. 2, pp.231–270.

Ismael, Jenann & Schaffer, Jonathan (2020). Quantum holism: nonseparability as common ground. *Synthese* 197 (10):4131-4160.

Kratzer, Angelika. (2012). *Modals and Conditionals: New and Revised Perspectives* (OUP, Oxford)

Kripke, Saul. (1980). *Naming and Necessity* (Blackwell, Oxford)

Ladyman, James. & Ross, Don. (2007). *Everything Must Go: Metaphysics Naturalized* (OUP, Oxford)

Lewis, David. (1968). 'Counterpart Theory and Quantified Modal Logic', *Journal of Philosophy*, 65, pp. 113-26

Lewis, David. (1973). *Counterfactuals* (Blackwell, Oxford)

Lewis, David. (1983). 'Survival and Identity'. *Philosophical Papers Volume I* (OUP, Oxford)

Lewis, David. (1986). *On the Plurality of Worlds* (Blackwell, Oxford)

Mackie, Penelope. (1998). 'Identity, Time and Necessity.' *Proceedings of the Aristotelian Society* 98:59-78.

Markosian, Ned. (2004). 'A Defense of Presentism'. *Oxford Studies in Metaphysics Vol. 1* (OUP, Oxford)

McCall, Storrs. (1994). *A Model of the Universe: Space-Time, Probability, and Decision* (Clarendon Press, Oxford)

McKenna, Robin. (2015). 'Contextualism in Epistemology.' *Analysis*, Vol. 75, No. 3, pp. 489-503

Mellor, D.H. (1981). *Real Time* (Cambridge University Press, Cambridge)

Müller, Thomas. (2014). *Nuel Belnap on Indeterminism and Free Action*. Ed. Thomas Müller. (Springer International Publishing, Cambridge)

O'Leary-Hawthorne, John. (1996). 'The Epistemology of Possible Worlds: A Guided Tour', *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, Possibilism and Actualism, Vol. 84, No. 2/3, pp. 183-202 (Kluwer Academic Publishers)

Parfit, Derek. (1971). 'Personal Identity', *The Philosophical Review*, Vol. 80, No. 1, pp. 3-27

Plantinga, Alvin. (1974). *The Nature of Necessity* (Clarendon Press, Oxford)

Rosen, Gideon. (1990). 'Modal Fictionalism.', *Mind*, Vol. 99, No. 395, pp. 327-54 (OUP, Mind Association)

Russell, Bertrand. (1994). 'Necessity and Possibility'. In Alasdair Urquhart, (ed.). The Collected Papers of Bertrand Russell. Volume 4: Foundations of Logic, pp. 507-520. (Routledge, London)

Saunders, Simon & Wallace, David. (2008). 'Branching and Uncertainty.' *The British Journal for the Philosophy of Science*, Vol. 59, No. 3, pp. 293-305 (The University of Chicago Press on behalf of The British Society for the Philosophy of Science)

Savitt, Steven. (2000). 'There's No Time like the Present (In Minkowski Spacetime).' *Philosophy of Science*, Vol. 67, pp. S563-74 (The University of Chicago Press, Philosophy of Science Association)

Sider, Theodore. (2001). *Four-Dimensionalism: An ontology of persistence and time* (Clarendon Press, Oxford)

Skow, Bradford. (2015). *Objective Becoming*. (OUP, Oxford)

Skyrms, Brian. (1980). *Causal Necessity*. (New Haven: Yale University Press)

Stalnaker, Robert. (1984). *Inquiry* (MIT Press, Cambridge Massachusetts)

Tooley, Michael. (1997). *Time, Tense, and Causation* (Clarendon Press, Oxford)

Wallace, David. (2003). 'Everettian rationality: defending Deutsch's approach to probability in the Everett interpretation', *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, Vol. 34, No. 3, pp. 415-439

Wallace, David. (2012). *The Emergent Multiverse: Quantum Theory according to the Everett Interpretation* (OUP, Oxford)

Wallace, Meg. (2014). 'The Argument from Vagueness for Modal Parts', *Dialectica*, Vol. 68, No. 3, pp. 355-73

Wallace, Meg. (2019). 'The Lump Sum: A Theory of Modal Parts', *Philosophical Papers*, Vol. 48, No. 3, pp. 403-35

Wang, Jennifer. (2020). 'Potentiality, modality, and time', *Philosophical Inquiries*, Vol. 8, No. 1, pp. 185-98

Wilson, Alastair. (2011). 'Macroscopic Ontology in Everettian Quantum Mechanics', *Philosophical Quarterly*, Vol. 61, No. 243, pp. 363-82

Wilson, Alastair. (2020). *The Nature of Contingency: quantum physics as modal realism* (OUP, Oxford)

Wilson, Alastair. (2021). 'Explanations of and in Time'. In *Philosophy Beyond Spacetimes*, eds. Chris Wüthrich, Baptiste Le Bihan and Nick Huggett (OUP, Oxford)

Wittgenstein, Ludwig. (2014). *Tractatus Logico-Philosophicus with an Introduction by Bertrand Russell*. Trans David Pears and Brian McGuinness. (London: Routledge)

Vetter, Barbara. (2015). *Potentiality: From Dispositions to Modality* (OUP, Oxford)