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SYMMETRIES AND ASYMMETRIES IN PHYSICS

How is the asymmetry between the open future and the fixed past to be characterized?

Vincent Grandjean[1]

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Abstract
A basic intuition we have regarding the nature of time is that the future is open whereas the past is fixed. For example, whereas we think that there are things we can do to affect how the future will unfold (e.g. acting in an environmentally responsible manner), we think that there are not things we can do to affect how the past unfolded ("what is done is done"). However, although this intuition is largely shared, it is not a straightforward matter to determine the nature of the asymmetry it reflects. So, in this paper, I survey various philosophical ways of characterizing the asymmetry between the 'open future' and the 'fixed past' in order to account for our intuition. In particular, I wonder whether the asymmetry is to be characterized in semantic, epistemic, metaphysical or ontological terms. I conclude that, although many of these characterizations may contribute to a global understanding of the phenomenon, an ontological characterization of the asymmetry is to be preferred, since it is superior to the alternatives in explanatory power, intelligibility, and in how it coheres with interesting senses of openness.

Keywords Open future · Indeterminism · Future contingents · Bivalence

1 Introduction

A basic intuition we have regarding the nature of time is that there is a difference between the future and the past: the former appears to be open and the latter appears to be fixed (or closed). This intuition manifests itself in various ways. First, whereas we think of the future as *partially unsettled* (e.g. it is settled that I will die someday, but it is unsettled whether the first astronaut to go to Mars will be a woman), we think of the past as *fully settled* (e.g. it is settled that Napoleon lost at Waterloo, that dinosaurs are extinct animals). Secondly, whereas we think that there are things we can do to affect how the future will unfold (e.g. making a significant donation to an

✉ Vincent Grandjean
vincent.grandjean@unine.ch

[1] University of Neuchâtel, Espace Louis-Agassiz 1, 2000 Neuchâtel, Switzerland

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NGO, acting in an environmentally responsible manner), we think that there are not things we can do to affect how the past unfolded ("what is done is done"). Thirdly, and perhaps more radically, whereas we may only wonder *how* the past unfolded (e.g. "what happened to John Kennedy?"), we may wonder *whether* the future will unfold (e.g. "will reality continue beyond tonight?").

However, although the intuition of an open future and a fixed past is largely shared, it is not a straightforward matter to determine the nature of the asymmetry it reflects. So, in this paper, I survey various philosophical ways of characterizing the asymmetry in order to account for our intuition. In particular, I discuss the question whether the asymmetry is to be characterized as *alethic* (the principle of bivalence applies to statements about the past but not to future contingents), *epistemic* (we can know much more about the past than we can know about the future), *metaphysical* (the world is fully decided about how the past turned out, but partially undecided about how the future will turn out) or *ontological* (there being facts of the matter about what did happen, but not about what will happen). I conclude that, although many of these characterizations may contribute to a global understanding of the phenomenon, an ontological characterization of the asymmetry is to be preferred, since it is superior to the alternatives in explanatory power, intelligibility, and in how it coheres with interesting senses of openness.

2 The failure of bivalence

It has become increasingly popular to claim that the asymmetry in openness between the future and the past is an asymmetry with respect to whether some statements[1] about the future and the past have a classical truth-value, i.e. are either true or false.[2] Arguably, this claim is originally to be found in Aristotle's *De Interpretatione*, chap. 9. In this book, Aristotle seems to capture the asymmetry between the open future and the fixed past by a semantic claim: future contingents (i.e. statements about the future that, even if they should be either true or false *now*, their present truth-value would anyway not be *predetermined* by the present or the past)[3] are neither true nor false, whereas statements about the past are either true or false. In other words, it might be argued that, for Aristotle, the openness of the future amounts to the failure of Bivalence (which states that all meaningful statements are either true or false) when applied to future contingents. Aristotle writes:

> In the case of that which is or which has taken place, propositions, whether positive or negative, must be true or false. Again, in the case of a pair of con-

[1] Following Strawson (1950), I define 'statements' as 'uses of sentences'. It is sentences which have meaning, but statements which have truth-values and between which logical relations hold.

[2] Cf. Markosian (1995), Tooley (1997), MacFarlane (2003), Diekemper (2004), and Curtis and Robson (2016).

[3] In that sense, even if some future contingents should presently be true (or false), their present truth-value would anyway "not be made inevitable" by facts that are, strictly speaking, facts about what goes on in the present or what went on in the past (cf. Correia and Rosenkranz 2018, p. 110).

> tradictories, either when the subject is universal and the propositions are of a universal character, or when it is individual, as has been said, one of the two must be true and the other false; whereas when the subject is universal, but the propositions are not of a universal character, there is no such necessity. […] *When the subject, however, is individual, and that which is predicated of it relates to the future, the case is altered* (Aristotle 2014, p. 31 [my emphasis]).

As an example, Aristotle famously considers the case of a sea-battle, which has since served as the focal point for most of the philosophical discussions concerning the open future. In Aristotle's picture, a sea-battle "[…] must either take place to-morrow or not, but it is not necessary that it should take place to-morrow, neither is it necessary that it should not take place, yet it is necessary that it either should or should not take place to-morrow." Now assuming that Bivalence holds unrestrictedly and, therefore, that future contingents, such as ⌜There will be a sea-battle tomorrow⌝, are either true or false at the time they are asserted, it seems, as Aristotle puts it, that "[…] everything takes place of necessity and is fixed". In particular, assuming that the statement ⌜There will be a sea-battle tomorrow⌝ is true *now*, it seems that tomorrow cannot be peaceful, because "[…] that of which someone has said truly that it will be, cannot fail to take place; and of that which takes place, it was always true to say that it would be" (Aristotle 2014, pp. 31–32).

Although there are different interpretations of Aristotle's writing on this and other issues, most commentators[4] agree that this Aristotelian argument—commonly referred to as 'the fatalist argument'—can be reconstructed as follows:

(1) Either it is true that there will be a sea-battle tomorrow or it is false that there will be a sea-battle tomorrow.
(2) If it is true that there will be a sea-battle tomorrow, then it is true *now* that there will be a sea-battle tomorrow, and likewise, if it is false that there will be a sea-battle tomorrow, then it is false *now* that there will be a sea-battle tomorrow.
(3) If it is true *now* that there will be a sea-battle tomorrow, or false *now* that there will be a sea-battle tomorrow, then how tomorrow is (at least with respect to sea-battles) is settled by how the present is.
(4) Therefore, how tomorrow is (at least with respect to sea-battles) is settled by how the present is.
(5) Since we were dealing with an arbitrary event at an arbitrary future time, how the future is in all respects is settled by how the present is.

Given that (5) is the denial of the claim that the future is open in any respect whatsoever, the fatalist argument leads Aristotle to conclude that the openness of the future cannot be preserved without excluding future contingents from the scope of Bivalence, i.e. without denying (1). That is presumably why some philosophers[5] go a

[4] Cf. Haack (1974, p. 74), Markosian (1995), Barnes and Cameron (2009, p. 146), Besson and Hattiangadi (2013, p. 3), Le Poidevin (2013, p. 536) and Curtis and Robson (2016, p. 119).
[5] Cf. Markosian (1995), MacFarlane (2003), Diekemper (2004), Curtis and Robson (2016).

step further by *identifying* the 'open future' view with the claim that Bivalence does not hold for future contingents. In this sense, these philosophers do not consider the failure of Bivalence as *merely implied* by the openness of the future (if the future is open, then future contingents are neither true nor false), but pretend that the openness of the future *is nothing but* the non-bivalence of future contingents (the future is open iff future contingents are neither true nor false).[6] Here is, for example, what Markosian writes about the open future:

> Let us agree on some terminology. To say, with regard to some time, t, that the future is open at t is to say that there are some propositions about the future relative to t that are, at t, neither true nor false. To say that the future is closed at t is to deny this, i.e., to say that every proposition about the future relative to t is, at t, either true or else false (Markosian 1995, p. 96).

So, according to Markosian, tomorrow is open (at least with respect to sea-battles) iff (i) it is not true *now* that there will be a sea-battle tomorrow and (ii) it is not false *now* that there will be a sea-battle tomorrow. And, of course, since the openness of the future is not confined to potential sea-battles, those who adopt Markosian's terminology will typically claim that *all* future contingents (at least as defined above) are neither true nor false. For example, as I write these lines, it may be claimed that it is neither true nor false that the first astronaut to go to Mars will be a woman, a cure for cancer will be discovered by the year 2115, and Federer's grandson will also become a famous tennis player. Of course, everyone is free to define the openness of the future as they want, especially in such a way that it is analytic that the future is only open if future contingents are non-bivalent. But such a definition might appear unsatisfying for at least three reasons that I present now.

First of all, the claim that the future is open is meant to capture some basic intuitions we have regarding the nature of time (partial unsettledness of the future, power over what will happen, etc.), and if we identify the 'open future' view with the claim that Bivalence does not hold for future contingents then we risk simply missing the point. The non-bivalence of future contingents has indeed nothing to do with the way we commonly think of time. That may in particular be revealed by our pragmatic assessments concerning the correctness and the incorrectness of statements about how things would turn out. As a first example, consider our current assertions of future contingents; it seems natural to regard some of them as correct. There would, for instance, be nothing *prima facie* problematic in someone's asserting that ⌜I will brush my teeth tonight⌝. However, it is generally taken to be a necessary condition of an assertion's being correct that it is true; so that if an assertion of a proposition is believed to be not true, it will not be assessed as correct (cf. Grice 1989). Given this, Markosian seems compelled to conclude either that the future is fixed (at least with respect to assertions of future contingents that are assessed as correct),

[6] Of course, the fatalist argument—even if it is accepted—does not force us to adopt Markosian's terminology, i.e. to define the openness of the future as the failure of bivalence, *but the converse is not true*. The rejection of the fatalist argument, especially of step (3), undermines Markosian's terminology.

or that we are massively mistaken when we feel pragmatically justified in asserting future contingents. Neither of these options is acceptable.[7]

As a second example, consider our past predictions about how things would turn out; it seems natural to regard some of them as correct *retrospectively*. For instance, while we may think that it is *now* open whether or not there will be a sea-battle tomorrow, once tomorrow comes and there is indeed a sea-battle, we are not only inclined to think that it is true *now* that there is a sea-battle, but we are also inclined to think that this reveals that yesterday's prediction that there would be a sea-battle *was* correct. However, it is hard for anyone who takes openness to consist in (or even to imply) the non-bivalence of future contingents to agree with this. In particular, when Markosian considers predictions made in the past about how things would be at a time that is now the present, he seems forced into saying that they were neither true nor false and—given the orthodox account of assertion—that they could not have been correct. After all, assuming that the openness of the future consists in the failure of Bivalence for future contingents, it must be concluded that while there is *now* a sea-battle, yesterday's prediction that there would be a sea-battle today was not correct, because it was open how things would turn out (cf. MacFarlane 2003, pp. 324–325). That is unacceptable; as Ryle writes: "[i]t is an unquestionable and very dull truth that for anything that happens, if anyone had at any previous time made the guess that it would happen, his guess would have turned out correct" (1953, p. 19).

A second reason why we might think that identifying the 'open future' view with the failure of Bivalence for future contingents is unsatisfying has to do with the fatalist argument. Although this argument seems to be valid, some of its steps—especially (3)—can be disputed. It is not clear whether the bivalence of future contingents rules out the openness of the future. Many philosophers[8] defend the view that the openness of the future is compatible with the bivalence of future contingents and, therefore, that the statement ⌜There will be a sea-battle tomorrow⌝ can be either true or false *now* without settling how the future will be. For example, Barnes and Cameron (2009, 2011) reject step (3) of the fatalist argument. They claim that the move from 'if it is true *now* (or false *now*) that *p*' to 'it is *now* settled that *p*' relies on a mistaken assumption, namely that if a statement has a truth-value then it is settled that it has *that* truth-value. For Barnes and Cameron, it can be settled that a statement has a truth-value (either truth or falsity), without it being settled which truth-value this statement has. Typically, it is settled that ⌜There will be a sea-battle tomorrow⌝ is either true or false, but it is neither settled that this statement is true nor that it is false. This claim leads Barnes and Cameron to conclude that the

[7] This problem is commonly known as "the assertion problem" (cf. Belnap and Green 1994). It should be acknowledged that branching theories of time offer various ways to solve it. For instance, Belnap and Green (1994, p. 382) argue that "[…] it makes sense to assert *A* when *A*'s truth value is no settled at the moment of assertion", since that assertion is an act that has *implications* (in terms of credit and discredit) for the speaker no matter how things eventuate.

[8] E.g. Von Wright and George (1979), Greenough (2008), Prawitz (2009), Barnes and Cameron (2009, 2011), Torre (2011), Besson and Hattiangadi (2013), Cameron (2015), Todd (2016), Correia and Rosenkranz (2018).

bivalence of future contingents can be reconciled with a peculiar kind of open future (expressed in terms of *metaphysical indeterminacy*) and, therefore, that the fatalist argument must be rejected.

Likewise, Correia and Rosenkranz (2018) reject step (3) of the fatalist argument. They argue that it rests on too strong a conception of the so-called 'grounding requirement on tensed truths' (i.e. the requirement according to which tensed truths do not "float free", but are grounded in reality). Their idea is that, although the truth-value of a future contingent must be grounded in reality (i.e. in what exists and how things that exist are), it does not need to be grounded in how things located in the present or past (of now) are or have been. In particular, "[…] the present truth of a statement about how, at some future time, things will be, might well be said to be, at that future time, going to be grounded by things being that way" (2018, p. 108). For instance, supposing that ⌜There will be a sea-battle tomorrow⌝ is true *now*, there will be a sea-battle tomorrow such that it will explain *why*, one day before, the statement ⌜There will be a sea-battle tomorrow⌝ was true. Now, since tomorrow's sea-battle is not *predetermined* (nothing there is or was, in conjunction with how it is or was makes it inevitable), Correia and Rosenkranz conclude that future contingents can *now* have a truth-value without the future being bound to be a certain way; so they reject the fatalist argument.

Finally, a third reason why Markosian's attempt to define the openness of the future seems flawed relates to the important costs generated by the denial of Bivalence. In particular, future contingents cannot be presented as counterexamples to Bivalence without specifying what logic and semantics one ought to assume when reasoning about the open future. Two options are generally retained to model truth-value gaps: (i) assuming a three-valued treatment of truth-functional connectives, (ii) assuming supervaluationism.

However, both of these options have well-known drawbacks. For example, on either Kleene's or Łukasiewicz's three-valued logics, $F\varphi \vee \neg F\varphi$ is neither true nor false when $F\varphi$ is a future contingent; which is clearly undesirable: even if it may be *now* unsettled whether or not there will be a sea-battle tomorrow, it should anyway be settled that either there will be, or there will not be a sea-battle tomorrow (cf. Aristotle 2014, p. 32). In general, it does not seem possible to solve this problem in terms of three-valued semantics if the logic is truth-functional, i.e. if the truth-value of any proposition used in the logic is determined by the truth-values of its parts. As has been argued by Prior (1953, p. 326), it will not help to change the truth-tables to something different from Łukasiewicz's model. As long as the model is truth-functional, it is obvious that the two disjunctions $F\varphi \vee \neg F\varphi$ and $F\varphi \vee F\varphi$ will have the same truth-value. This is not satisfactory, since $F\varphi \vee \neg F\varphi$ is clearly true, whereas $F\varphi \vee F\varphi$ is undetermined, given that $F\varphi$ is undetermined.

With supervaluationism no comparable problem arises; the non-bivalent semantics it affords underwrites all theorems of classical logic, including every instance of $F\varphi \vee \neg F\varphi$. According to this theory, a statement is true at a time t just in case it is supertrue at t, i.e. just in case it is true at t on all histories that include t, and likewise, a statement is false at t just in case it is superfalse at t, i.e. just in case it is false at t on all histories that include t. In all other cases, a statement is neither true nor false. In particular, future contingents—that are true on some future histories, false

on others—are neither true nor false, where this must be understood not in the sense that future contingents have a third truth-value (as in Kleene's or Łukasiewicz's logics), but that they *lack* a truth-value. It is thus common to define future contingents as "gappy" because supervaluationism, contrary to Kleene's or Łukasiewicz's three-valued logics, allows for truth-value gaps. However, since supervaluationism retains the Excluded-middle while it rejects Bivalence, it has to abandon the Tarski biconditional ('φ' is true iff φ)[9] and, therefore, the disquotational property of truth; which could turn out to be unacceptable. Williamson, for instance, writes that "[h]ow much more there is to the concept of truth than the disquotational property is far from clear, but in most contexts truth is assumed to be at least disquotational, whatever else it is or is not" (1994, p. 162).[10]

Moreover, as Williamson (1994, p. 151) points out, the following *rules* of inference are classically valid, yet they may fail in a language with a supervaluational semantics[11]:

[1]	From $\Sigma, \varphi \vDash \psi$ infer $\Sigma \vDash \varphi \rightarrow \psi$	*Conditional proof*
[2]	From $\Sigma, \varphi \vDash \psi$ infer $\Sigma, \neg\psi \vDash \neg\varphi$	*Contraposition*
[3]	From $\Sigma, \varphi \vDash \psi \wedge \neg\psi$ infer $\Sigma \vDash \neg\varphi$	*Indirect proof*
[4]	From $\Sigma, \varphi \vDash \sigma$ and $\Sigma, \psi \vDash \sigma$ infer $\Sigma, \varphi \vee \psi \vDash \sigma$)	*Proof by cases*

It might therefore be argued that, since classical logic and semantics are vastly superior to the alternatives required by the denial of bivalence in "[…] simplicity, power, past success and integration with theories in other domains" (Williamson 1994, p. 186), they should as far as possible be preserved, and so should Markosian's characterization of the asymmetry—which leads to non-classicality—be rejected.

In a nutshell, since we aim (i) to capture some basic intuitions about the nature of time, (ii) to question the fatalist argument, and (iii) to possibly retain classical logic and semantics, it seems wrong to begin with the supposition that the 'open future' view amounts to the failure of Bivalence for future contingents. Rather, we should ask how best to understand our basic intuitions regarding the nature of time, while leaving open the possibility that the failure of Bivalence may end up being a non-logical *consequence* of the 'open future' view. In other words, it seems that the costly rejection of Bivalence is not *definitional* of the open future and, if needed, should only be motivated by our best understanding of our intuitions about time. For these reasons, it seems preferable to look for another, presumably non-semantic, way of characterizing the asymmetry, and ultimately assess whether it might be reconciled with an unrestricted application of Bivalence.

[9] For example, such a proof has been provided by Haack (1974, p. 67).

[10] A possible solution to this objection would be to say, as Thomason (1970, p. 273) does, that Tarski biconditional holds only as a consequence ($\varphi \models$ true 'φ') and not as an implication (so that for some φ, $\not\vDash \varphi \rightarrow$ true 'φ'). However, this solution violates the deduction theorem and, therefore, leads to non-classicality.

[11] The failure of [2] and [3] is already noted in Fine (1975) and Machina (1976), respectively.

3 A reflection of our ignorance

It is often assumed, especially in regard to some results of contemporary physics, that the asymmetry between the future and the past is *merely* an epistemic phenomenon: we can know much more about the past than we can know about the future. For example, if we want to know who won the Nobel Prize for literature last year, or whether John Kennedy was killed on a Tuesday, we can consult our memory or look it up in a book. After all, we find ourselves in a world with plenty of information about the past. By contrast, we have no records of who will win the Nobel Prize for literature next year, no books in which we can look up whether the first astronaut to go to Mars will be a woman. Of course, we can make guesses about how the future will be, but our guesses are "spotty" and "provisional" (Ismael 2016, p. 140). In this sense, the asymmetry between the future and the past is not among the "fundamental features" of reality. It only reflects the fact that whereas we are in a position to gain a wide knowledge of the past, the future remains largely unknowable to us.

At first sight, this understanding of the asymmetry as an epistemic and therefore non-fundamental feature of reality accords well with important results of contemporary physics. For example, the Theory of Relativity seems to imply a 'block universe' view of time,[12] in which the asymmetry does not arise. According to this view, the block universe extends from the Big Bang to the end of time if there is one, or indefinitely, if there is not. It represents all times as equal parts of reality, i.e. without making any fundamental asymmetric distinction between them. Just as spatial places (e.g. Greenwich Village, Plaça de Catalunya) exist, despite not being *here* (in Switzerland), so too past and future times exist, despite not being *now* (in 2019). In other words, the spatio-temporal model favored by contemporary physics does not seem to reflect any difference between space and time that somehow accounts for the fact that there is no here-there space-asymmetry in the same way as there is a past-future time asymmetry.

Likewise, the fundamental laws of physics, which are time-reversal invariant (insofar as the positions of particles are concerned),[13] do not underpin any asymmetry regarding the nature of time. For example, the laws of classical electrodynamics—since they entail that whatever motions particles can execute, they can execute backward—fail to capture the asymmetry: "[…] the unbreaking of glass can be no less in accord with the laws of Maxwellian electrodynamics than the breaking of glass is, and the spontaneous heating of soup can be no less in accord with Maxwellian electrodynamics than its spontaneous cooling is, and the coming of youth can be no less in accord with Maxwellian electrodynamics than its passing is" (Albert 2000, p. 15). After all, for a glass to break, or for a soup to be spontaneously heated is just for their constitutive particles to assume certain particular sequences

[12] Williams (1951) and Putnam (1967) are classic statements of the point. For a more recent discussion see Zimmerman (2011).

[13] There are physical processes (e.g. neutral kaon decay) that are sensitive to the past-future orientation, but these processes are too "infrequent" and "exotic" to lead to strong conclusions (cf. Maudlin 2007, p. 117).

of positions. And, since every sequence of positions $S_1 \ldots S_F$ (which is in accord with the laws of classical electrodynamics) admits the inverse sequence of time-reversed positions $S_{F'} \ldots S_{1'}$ (which is also in accord with these laws), it turns out that classical electrodynamics (as well as most post-Newtonian theories, such as Einstein's relativistic gravity, and quantum mechanics devised by Heisenberg, Schrödinger, and Dirac) makes no significant difference between the future and the past (at least with respect to their fundamental laws).

Of course, one might emphasize that there are exceptions. In particular, one might claim that classical thermodynamics is *partially* governed by its Second Law, which states that the total entropy of an isolated system tends to increase with time, and therefore indicates the irreversibility of natural processes. However, there is an important reason why this claim seems flawed: even if thermodynamics could yield the desired asymmetry, which is doubtful (cf. Uffink 2001; Brown and Uffink 2001), this would not provide a *fundamental* explanation as to why the past appears to be fixed and the future open. Classical thermodynamics postulates both physical magnitudes—such as temperature, pressure, volume, entropy and heat—and laws stated in terms of these magnitudes, such as the Second Law; but these features are not believed to be *fundamental*. Many of them arise at a macroscopic level from the collective behavior of many microscopic entities. In general, quantum mechanics deals with the behavior of such microscopic entities, while its laws are—at least on the standard views—time-reversal invariant. So, even assuming that thermodynamics encodes a time asymmetry, it seems that this would at best postpone the problem: what then grounds the thermodynamic asymmetry in time?

It might therefore be tempting for philosophers of physics to conclude that the asymmetry between the future and the past is some sort of non-fundamental phenomenon, especially an epistemic phenomenon (perhaps an artifact of the peculiar way our minds interact with the world). The main virtue of such a conclusion is a dialectical one: it explains away the awkward fact that the asymmetry has not yet been captured by our best physical theories and, therefore, preserves the reach of our understanding. This dialectical move is, by the way, pretty common in philosophy. There is indeed a fine tradition of dismissing awkward facts as non-fundamental features of reality. Kant (1787), for example, argues that the Euclidean structure of space and time is not among the fundamental features of reality, but arises from the interaction of our sensory apparatus with the things in themselves. This idealist thesis has been explicitly developed to protect our knowledge of geometric truths from Hume's arguments that highlighted the fallibility of our epistemic devices. In brief, assuming that Euclidean geometry does not exist independently of us and, therefore, is not inferred from our ordinary inductive exploration of the world, it does not fall under Hume's skepticism.

Another example is given by the Everett, or "many-worlds", interpretation of quantum mechanics. Many-worlds theorists protect the possibility of some superpositions of systems at the macroscopic level by claiming that the most basic fact of laboratory experience—that experiments have unique outcomes—is an illusion. According to them, every time a quantum experiment with different possible outcomes is performed, all outcomes are obtained, each in a different world. For instance, many-worlds theorists affirm that Schrödinger's cat is both dead and alive,

even before the box is opened. But since we do not see this macroscopic superposition—the cat is just dead, say, when we check—they conclude that there is another "alive" cat we cannot see, so that the definiteness of its death is an illusion. Here again, this theory requires us to dismiss some fact of experience as an illusion: we are actually deceived when we see just a dead cat. This dialectical move allows preserving the linearity of quantum mechanics (which states that objects can evolve into superpositions) without admitting that observation puts an end to this linearity (cf. Norton 2010, p. 31).

However, it might seem that failing to capture particular phenomena, facts or entities is not sufficient grounds to doubt their fundamentality. For centuries, we failed to identify quarks; but that did not prevent some ancient philosophers (e.g. Leucippus, Democritus, Epicurus) from rightly defending (supposing that it is right)[14] the view that the world is fundamentally composed of elementary particles. When, impressed by the tremendous results obtained by physics through the last century, we get used to the idea that our best theories of space and time are telling us all that can be said about the nature of time, we just start to invert the reasoning. If a phenomenon has all the marks of a fundamental and therefore non-epistemic one (like elementary particles in constitution processes), then it can legitimately be expected that physics must somehow characterize it.

Moreover, assuming that the asymmetry is merely an epistemic phenomenon, the mechanism through which this phenomenon arises must be identified. In particular, there is a need to explain *why*—though the asymmetry has allegedly nothing to do with the nature of time—we have privileged epistemic access to the past rather than to the future. But such an explanation is rarely found in the literature. Most of the time, philosophers of science simply avoid the problem by claiming that potential solutions to this issue are to be found outside their field of expertise. For example, Carnap invokes here the role of psychology: "[…] all that occurs objectively can be described in science; on the one hand the temporal sequence of events is described in physics; and, on the other hand, the peculiarities of man's experiences with respect to time, including his different attitude towards past, present, and future, can be described and (in principle) explained in psychology" (1963, pp. 37–38). These kinds of buck-passing answers are, however, clearly unsatisfying. The issue raised by the *causes* of our intuitions regarding the nature of time cannot be skipped under the pretense that it could hypothetically be solved by psychologists (or other scientists).

To be fair, I have to mention that there are projects that aim to explain the epistemic difference between the future and the past in certain physical facts (cf. Reichenbach 1956, Butterfield 1984, Horwich 1987, Craig 2001, Callender 2008). Apart from the details, all these projects involve the notion of causation, by appealing either to the *unidirectionality* of causation, or to the *causal (in)dependence* of the past and the future to the present. However, although I admit that it is natural to associate the idea of an open future and a fixed past with the idea that everything

[14] Of course, the thesis that the world is fundamentally composed of elementary particles is controversial (see e.g. "wave function realism").

that can *now* happen can only have effects on the future (there is no backwards causation), I am skeptical about whether causation can be the key to the explanation of our intuition. In particular, unidirectional causation and causal (in)dependence appear neither necessary nor sufficient for fixity and openness.

First, reflection on fatalistic thinking suggests that causal independence is not necessary for fixity—or, to put it another way: the fixity is compatible with causal dependence. By killing Archduke Franz Ferdinand of Austria, Gavrilo Princip—we may suppose—leaded to the outbreak of World War I: the latter bloody event was causally dependent on the former. Yet (to the extent that this story can occur in a fatalistic context), it seems that we can accept that causal claim, without doubting that World War I could not have failed to take place. Moreover, it seems that causal independence is not sufficient for fixity. A future that is a completely random continuation of the present is surely a future that is causally independent of the present. Yet such a 'random' future, far from being a 'fixed' future, would seem to be "[…] a paradigm of one type of openness (even if it represents a type of openness that brings with it no prospect of control over the course of events)" (Mackie 2014, p. 415).

Secondly, the unidirectionality of causation is not sufficient for openness. Consider the Gödel spacetime that admits closed time-like curves: "[…] if P, Q are any two points on a world line of matter, and P precedes Q on this line, there exists a time-like line connecting P and Q on which Q precedes P" (Gödel 1949, p. 447).[15] In such a theoretical option, the future is clearly fixed (the sequence is closed and composed of a finite numbers of events), in spite of causation being unidirectional. The planting of a seed leads to the growing of a tree which leads to the shading of a bench; events causally related continue in the same way they would do in linear time. Of course, since the sequence of events is circular, one could theoretically plant a tree tomorrow in order to provide shade for a bench yesterday. But this is clearly not a case of backwards causation, since the shading at t_2 continues from the planting at t_4 in the forward direction, i.e. not through t_3, but through t_5, t_6, … t_1 (cf. Diekemper 2005, p. 232). The question of causation thus appears largely independent of the question of fixity and openness.

Finally, and perhaps more generally, the characterization of the asymmetry as a merely epistemic phenomenon betrays our basic intuitions. Although everybody agrees that we can know much more about the past than we can know about the future, *it cannot be the whole story*. We think of the open future and the fixed past in a much stronger sense. In particular, unlike the spatial parts of which we have no memories and only few records (e.g. a distant planet, the center of the Earth), we do not think of the future as *out there*, waiting to be experienced. We think of it, rather, as *partially unsettled* until it has been made available to experience. That may in particular be revealed by ordinary language: if I say that it is open whether my favorite football team will win the match tomorrow, I do not mean that, though settled, I have to wait until tomorrow to know what the score of the match is. I rather

[15] This possibility of closed timelike curves results from Gödel's exact solution of the Einstein Field Equations.

mean that everything about tomorrow's match is still possible: perhaps my favorite team will win, or perhaps it will not. Our intuitions of openness seem thus to relate to worldly unsettledness regarding the future, rather than to our lack of epistemic access to what will happen.

Of course, proponents of the epistemic approach might reply that although their characterization of the asymmetry betrays our intuitions, this is of no consequence, since scientists have shown on many occasions that our intuitions about time are misleading. For example, it seems to us that "our" present extends throughout the world, while this intuition requires an objective notion of absolute simultaneity that has been rejected by Special relativity (cf. Bourne 2006). In other words, proponents of the epistemic approach might claim that our intuition that the future is genuinely open is just part of the wrongheaded family of intuitions we have about time, and therefore that it is not surprising that their characterization of the asymmetry, though correct, does not respect it. To that, I have two objections to make.

First, all our intuitions are not equally important. Admittedly, our intuition of a common present has been denied by science, but this intuition has come very late in the human history. For centuries—as long as travel was on horseback, on foot, or in carriages—every village had its own peculiar time based on natural phenomena; there was then no reason to synchronize clocks between one place and another. It is only in the 19th century—with the development of the rail network—that the problem arose of properly synchronized clocks between different cities, and that the intuition of a universal "now" emerged (cf. Stephens 1989). By contrast, the intuition of a fixed past and an open future has always been part of our manifest image of the world. At least, as long as we have viewed ourselves as agents capable of influencing the world in various ways, we have *presupposed* that the future was open. Therefore, it may not be as easy to deny the intuition of an open future than the intuition of a universal "now", since these two intuitions play roles of varying levels of importance in our relationship to the world.

Secondly, I would like proponents of the epistemic approach to become aware of the huge consequences of their claim: the potential undermining of our society's foundations. To illustrate this point, it is worth reflecting on the idea of *responsibility*. Suppose a young man is on trial for an assault and robbery in which his victim was beaten to death. And let us say that the young man is sentenced to life imprisonment. The reason *why* this sentence might appear to be *fair* is that we think of the young man as being (at least partially) *responsible* for the victim's death—he could have acted otherwise, after all. In other words, the sentence might seem to be appropriated, since both of the two options—to kill, or not to kill—were open to the young man while he was deliberating; he could have chosen either one. Now, assuming that the openness of the future is merely an epistemic phenomenon, this sentence appears to be *totally unfair*. Indeed, in this perspective, to kill or not to kill merely represent epistemic possibilities for the young man, such that he could not have done otherwise than what he actually did, and therefore cannot be held responsible for his crime (cf. Van Inwagen 1983, p. 16).[16] The epistemic approach to the asymmetry

[16] A possible answer might be inspired from the compatibilist strategy for solving the classical problem of freedom and determinism: talking about what persons "can (or cannot) do" is ambiguous; many compatibilists claim that "you can (or you have the power) to do something" must be interpreted as "if you

thus leads to a major threat to our common notion of responsibility which is at the core of our social organization: assuming that the future is *merely* epistemically open (we simply do not know how the future will unfold), it seems that nobody can be held responsible of anything.

Thus, though the asymmetry between what we can know about the past and what we can know about the future may, here again, end up being a *consequence* of the nature of time, it seems wrong to reduce the issue to its epistemic aspect. First, there are no good grounds for dismissing the asymmetry as an epistemic phenomenon (but mainly dialectical grounds). Secondly, there are no (or very few) satisfying attempts to identify the mechanism through which the epistemic asymmetry arises (if not grounded in the nature of time). And, finally, such an epistemic account betrays our basic intuitions that relate to the world itself (and not to the limits of our knowledge). For these reasons, it seems preferable to look for a more fundamental way of characterizing the asymmetry, which may ultimately explain *why* our knowledge of the future is not as vast as our knowledge of the past.

4 Metaphysical indeterminacy

A position which is in the minority, perhaps, but deserves ever greater attention is the claim that the fixity of the past and the openness of the future must be characterized in terms of metaphysical determinacy and indeterminacy, respectively. The main idea is that whereas it is *fully determinate* how the past did turn out, it is *partially indeterminate* how the future will turn out. The way in which how the future will turn out fails to be *fully determinate* is to be understood as a brute fact: sometimes it is simply unsettled how the world is at its most fundamental level. At this point, it is worth noting that among the various phenomena that may be thought of as types of worldly unsettledness, the one we are concerned with here is a matter of the world being poised between various determinate states. In that sense, there are multiple determinate (precise) states between which the world is unsettled, such that it fails to specify which one obtains. For instance, Cameron (2015, p. 196) argues that the openness of the future consists in such brute unsettledness. He claims that if we think that the future is open with respect to whether or not there will be a sea-battle tomorrow, we ought to think that this is a matter of the world being unsettled as to which relevant state obtains.

From a semantic point of view, it is determinately the case that either a future contingent or its negation is true, but it is indeterminate *which* (where this indeterminacy is a brute unsettledness between ways the world could be); so that future contingents are said to be metaphysically indeterminate in truth-value (cf. Barnes and Cameron 2009, p. 294). This is not to say that the worldly conditions required

Footnote 16 (continued)
wanted (or tried) to do it, you would do it". In this perspective, the young man can still be held responsible for his crime (even if the world's history is fully fixed), since 'to not kill someone' is something that he is capable of doing (cf. Kane 2007, pp. 10–13).

for the truth (or the falsity) of future contingents are absent, but rather that there is a "lack of specificity" concerning *what* worldly conditions obtain. As an analogy, Barnes and Cameron take the borderline case of being bald: it might be indeterminate whether this person is bald or not; but it is determinate that *either* he is bald *or* he is not. Thus, as in the case of future contingents, it is determinate that the statement ⌜This person is bald⌝ is *either* true *or* false (those are the only two options), but it is indeterminate which of the two options is in fact the case (cf. Barnes and Cameron 2009, p. 294).

The immediate benefit of such a characterization of the asymmetry is that it allows us to accept Bivalence without restriction and, therefore, to resist the non-classical logic and semantics introduced in §2 (three-valued treatment of truth-functional connectives, supervaluationism). Indeed, assuming that the indeterminacy in truth-value of future contingents results from the world being unsettled in this respect (one way or another, there is a fact of the matter), the world always speaks to the truth or falsity of any claim about how things will be. This allows us, for example, to assess as correct (or incorrect) some of our current and past assertions of statements about how things would turn out (assuming the orthodox account of assertion, §2).[17] Moreover, since this characterization provides a robust understanding of the asymmetry as a genuine feature of how the world is, it avoids the main pitfalls encountered by the theories addressed so far. For example, it provides an explanation as to *why* our knowledge of the future is not as vast as our knowledge of the past: we cannot know more about the future than what determinately will be the case.

However, despite the non-negligible benefits this characterization offers, there are some reasons to complain. First, this characterization faces difficulties in interpretation which render it less than metaphysically illuminating. It is unclear, for example, how metaphysical indeterminacy might involve an indeterminate degree of obtaining: whether or not a state obtains seems to be an all-or-nothing situation; either a state obtains or it does not. In particular, if the future is genuinely open, then intuitively, *none* of the relevant states "obtain"—the future has not yet happened, after all.[18] Likewise, whereas it is clear what it means for human beings to be *undecided*

[17] For example, suppose on Monday I make the prediction that there will be a sea-battle tomorrow. My assertion lacks a determinate truth-value. But come Tuesday, when the sea is fortunately peaceful, I can look back and say that my prediction was not correct. If it had been correct, a sea-battle would now be raging over the sea. It is not the case, so it was not correct. So, since it is determinate that no sea-battle is now raging, I can say that, determinately, my prediction that there would be a sea-battle was not correct. But I cannot say that it was determinately incorrect: it was not, because the future was open with respect to whether things would turn out as predicted (cf. Barnes and Cameron, 2011, p. 4).

[18] To clarify further, the 'metaphysical indeterminacy' account, since it analyses the openness of the future in terms of the world being "stuck" between various states, *presupposes* that these states exist; while it is clear that all of them cannot share the same ontological status. After all, even assuming that both tomorrow's sea-battle and its peaceful alternative exist, only one of these states will be actualized. There must therefore be a difference between these two states: one must "less obtains" than the other. As Barnes (2016, p. 123) admits, the indeterminate degree of obtaining to which her account is committed covers two possibility: "[…] perhaps the state of an object *indeterminately instantiating* a familiar property, or perhaps the state of an object instantiating the *non-familiar* property of *being indeterminately F*." In other words, either the indeterminate degree of obtaining concerns the instantiation of the property, or

between various possibilities (e.g. to go, or not to go to the cinema), it is unclear what it would mean for the world to be *undecided* about, for example, what will happen tomorrow (e.g. there will be, or there will not be a sea-battle). There have been valiant attempts to make sense of this claim—as reflecting, e.g. that it may be "indeterminate which world is actualized" (Barnes and Cameron 2011), or that there may be multiple "actual worlds" (Williams 2008). But even if such attempts are coherent, they occupy, as Wilson says, "[…] a metaphysically tenuous region of logical space" (Wilson 2013, p. 364).

Moreover, there are cases of future contingents lacking determinate truth-value which are not cases of the future being open. According to Barnes (2010), the conditions of being bald are such that there can be people for whom it is unsettled whether they are bald or not. If so, the future contingent ⌜This person will be bald tomorrow⌝ might *now* be metaphysically indeterminate in truth-value. But this does not necessarily seem like a case of the future being open. After all, what is going to happen could be perfectly settled. Perhaps the person in question will undergo a chemotherapy session tomorrow, which has been scheduled for months and which will inevitably make him lose a lot of hair (to such an extent that it will be unsettled whether he is bald or not). There are not different ways the future might develop here; there is only one settled future, but it is unsettled whether it will include an additional bald head. The analysis of the openness of the future as metaphysical indeterminacy might thus appear insufficient, since it fails to delineate cases of open future indeterminacy from other cases (e.g. cases of ontic vagueness).[19]

Nonetheless, Barnes and Cameron (2011, p. 3) outline a solution to this second problem. They claim that there is a clear delineation between cases of open future indeterminacy and other cases: the former cases will be resolved as time passes, while the latter will never be resolved. For example, while it might *now* be open whether or not there will be a sea-battle tomorrow, once tomorrow comes the situation will be resolved: depending on how the future unfolds, it will be determinate that there is a sea-battle or that there is not. By contrast, if it is *now* indeterminate whether or not this person will be bald tomorrow (assuming that the future is perfectly settled), once tomorrow comes it will *still* be indeterminate whether or not this person is bald. Indeed, assuming that it is indeterminate whether a person who has, say, 1000 hairs on his head is bald or not, the passage of time does not help clear up the matter: tomorrow and the following days, it will *still* be indeterminate whether having 1000 hairs is to be bald or not.

This solution may not, however, appear very seductive, since it includes exceptions: (i) there are cases of open future indeterminacy that are never resolved; (ii)

Footnote 18 (continued)
the property itself. However, both the notions of indeterminate instantiation and indeterminate property are mysterious.

[19] Of course, this objection could be prevented by denying that openness and vagueness are two phenomena of the same kind. After all, perhaps vagueness is merely a semantic deficiency of language that can be treated with, for example, a supervaluationist account of truth and validity (Fine 1975, Keefe 2000). In other words, this objection does not rule out the possibility that Barnes and Cameron (2009, 2011) might be wrong about vagueness, but right about the openness of the future.

there are cases of other sorts of indeterminacy that will be resolved. As a first example, consider the prediction ⌜Jesus will return someday⌝ and suppose for the sake of argument that it is open whether he will. Suppose further that this prediction is uttered in a world where time never ends, and where, at any given moment, Jesus has not yet shown up. If time does in fact unfold this way then, it seems that the indeterminacy in 'Jesus will return' will never be resolved: for at all times, there will still be a future in which he might still return. After all, we could wait for the return of Jesus forever! According to Wilson (2013, p. 381), this kind of possibility is not straightforwardly handled on Barnes and Cameron's account, since in supposing that openness consists in the matter of the world being unsettled as to which relevant state obtains, it is presupposed that the future gets settled, one way or another.

As a second example, consider the prediction ⌜Schrödinger's cat will be alive⌝ and suppose that it is uttered five minutes before opening the box; this prediction is *now* indeterminate in truth-value (the world fails to settle a unique determinate of the cat's life status). But, five minutes hence, when opening the box, ⌜Schrödinger's cat is alive⌝ will be determinately true or determinately false. This case will thus be resolved as time passes. However, this is clearly not a case of the future being open. This indeterminacy is indeed to be explained by the weirdness of quantum mechanics, not by the passage of time. After all, one can easily imagine an alternative case in which, five minutes hence, the box will remain closed; so that the indeterminacy will not be resolved as time passes. Since this second case, which has nothing to do with the openness of the future, is of the same nature as the first one, it seems that the first case has nothing to do with the openness of the future either. It therefore appears that Barnes and Cameron fail to provide an absolute criterion to separate cases of the future being open from other cases and, therefore, that their account of openness in terms of metaphysical indeterminacy is insufficient.

Finally, there is an important sense in which the future may be said to be open but that the 'metaphysical indeterminacy' account fails to capture: time could come to an end, with no ontological commitment to future things standing in the way (cf. Correia and Rosenkranz 2018, p. 99). After all, taking seriously the 'doomsday scenario' as it is described, for instance, in the eschatologies of the three major monotheisms (Judaism, Christianism, Islam),[20] it could be that time does not go on indefinitely and, possibly, that there will be a last moment of time. In other words, it seems possible that the future is open not simply in terms of *how* it will unfold, but also in terms of *whether* it will unfold. However, Barnes and Cameron's account, in taking openness to be unsettledness between determinate states, presupposes that there are determinate states, and so cannot accommodate the possibility of radical openness, where more determinate states are simply not available because time has ended. In other words, to say that time could come to an end is to say that there could be no more determinate states for the world to be in; so that if the future may

[20] It is worth noting that this cosmological scenario is also taken seriously by physics. For example, the "Big Crunch" refers to one possible scenario for the ultimate fate of the universe, in which the expansion of the universe will slow to a halt, reverse into contraction, and implode back to a state of infinite (or near infinite) density, pressure, temperature, and curvature (cf. Misner et al. 1973, p. 771).

be said to be open in this radical sense, then Barnes and Cameron's account—which presupposes that there are determinate states—cannot accommodate it. In presupposing that, one way or another, the future gets fixed, Barnes and Cameron exclude the possibility of radical openness.[21]

Nonetheless, it might be argued that, although these latter objections are disconcerting, they only concern Barnes and Cameron's account and not all attempts to characterize the openness of the future in terms of worldly unsettledness. In particular, it might seem that another type of worldly unsettledness that is not expressed in terms of the world being indeterminate whether something is the case, but rather in terms of there being *no fact of the matter* whether something is the case, is better equipped to respond to the above objections. In the next section, I will thus argue that the asymmetry between the open future and the fixed past is to be characterized in such ontological terms: there being facts of the matter about what did happen, but not about what will happen. Such an ontological characterization of the asymmetry seems indeed to be required to fully account for the various ways in which our intuition that the future is open and the past fixed may be expressed. For instance, the radical sense of openness in which time could come to an end can only be captured by an account that presupposes a gap in ontology. The reason why I speak of the 'no fact of the matter' account as an "ontological" account (as opposed to Barnes and Cameron's "metaphysical" account) is that the former takes unsettledness to be a matter of *existence* (there are no facts about what will happen), whereas the latter merely takes unsettledness to be a matter of *which precise way things are* (it is indeterminate which existing things obtain).

5 A non-existent future in a non-deterministic world

When Johnny Rotten from the Sex Pistols chanted "No future!" (in the closing refrain of the controversial song "God Save the Queen"), what he probably intended to say is that, assuming that the future exists, it will certainly be unfair for the English working class. Nonetheless, this slogan (which has since become emblematic of the punk rock movement) might be interpreted in a more literal and, therefore, radical sense: the future is simply nothing at all. This is precisely what C.D. Broad defended, long before the advent of punk rock music. According to his doctrine, "[n]othing has happened to the present by becoming past except that fresh slices of

[21] Setting Barnes and Cameron's account aside, it is possible to characterize the openness of the future in terms of metaphysical indeterminacy without being committed to the existence of any future state. For example, one could hold that while there is no future ontology, there are brute facts about what will happen, and that it is metaphysically indeterminate which of these brute facts obtain. However, although this option can allow for the radical sense in which the future may be said to be open, it is unattractive, since it leads to a *dilemma*. Either the past exists or the past does not exist. If the past does not exist, then it has to be treated as equally open (the asymmetry collapses). If the past does exist, then this option treats the fixity of the past and the openness of the future as being sensitive to different kinds of features of the world in a way that is ad hoc. Indeed, if the fixity of the past is, in some way or other, to be explained by the past ontology, then, due to considerations of parity, the openness of the future should be explained by the future ontology in just the same way.

existence have been added to the total history of the world. The past is thus as real as the present. On the other hand, the essence of a present event is, not that it precedes future events, but that there is quite literally *nothing* to which it has the relation of precedence. The sum total of existence is always increasing, and it is this which gives the time-series a sense as well as an order" (1923, pp. 66–67). On Broad's view, the present is thus a kind of "ontological gateway" through which events have to pass on their way to become real and always remain so (cf. Grey 1997, p. 216).

Although going beyond Broad's view is surprisingly difficult, his intuitions may provide decisive insights into the temporal asymmetry we are concerned with. Indeed, perhaps the asymmetry between the open future and the fixed past is to be characterized by an ontological difference: the past and the present exist, while the future does not exist. In that sense, the openness of the future (as a kind of unsettledness) should perhaps not be regarded as a matter of the world being poised between various determinate states (as Barnes and Cameron suggest), but rather as there being no state that the world is in with respect to what will happen. For example, if we think the future is open with respect to whether or not there will be a sea-battle tomorrow, we ought to think that reality simply lacks the relevant ontology: there is no fact of the matter whether a sea-battle will take place tomorrow. Besides metaphysical indeterminacy, there is thus another way in which reality may fail to settle some future facts: there may be *no fact of the matter* whether these facts obtain.[22]

These two types of worldly unsettledness seem to be very different *by nature*: the first type is a case of *overdetermination* (there are too many states, such that the world is unsettled as to which one obtains), while the second type is a case of *underdetermination* (there is no state, such that the world is unsettled as to whether something obtains). As an analogy, consider two teenage girls—one rich, the other poor—getting ready for a party. In front of their closet, they might both be "unsettled" as to what to wear for the evening: the rich girl because she is spoiled for choice (e.g. she has too many dresses suitable for the occasion), and the poor girl because she has nothing to wear. In such a case, although the two girls are equally unsettled as to what to wear for the party, it clearly appears that this reflects two different phenomena.

This second kind of unsettledness, by the way, is commonly invoked in many different contexts. In the philosophy of quantum physics, for example, the superposition of states as a source of metaphysical indeterminacy can successfully be accommodated by a so-called determinable-based account, which treats certain sources via a gappy implementation. For example, as has already been explained, Calosi and Wilson (2018) argue that the case of Schrödinger's cat suggests a metaphysical indeterminacy that must be seen as involving that there is *no (determinate) fact of the matter* whether the cat is or not alive. Specifically, there is no fact such that the property of *having a certain life status* of Schrödinger's cat has a unique determinate

[22] Of course, someone who denies the existence of the future is not forced to accept the 'no fact of the matter' account of openness. He is not even forced to say that the future is open in any sense whatsoever: he could hold, for example, that while there is no future ontology, there are brute facts about what will happen (cf. Cameron 2015, pp. 194–195).

(*being alive* or *being dead*). Thus, as in the case of the open future, the determinable-based account of quantum indeterminacy does not involve that it is indeterminate which of various determinate facts obtain (*metaphysical indeterminacy*), but rather that it is determinate that no determinate fact obtains (*no fact of the matter*).

Of course, this account may appear *insufficient* to accommodate the open future, since the future is intuitively fixed in a fully deterministic world (where the state of the world at a time nomologically necessitates the state of the world at any later time). Indeed, if it is *necessary*, given the facts about how things are up to a time *t* and what laws obtain, that the world will be a certain way at any later time, then it seems *settled* that it will be that way; which is just to say that the future is *fully settled* at *t* and, therefore, that the future is fixed. However, assuming that *all* that will happen is not made inevitable by how the world currently is (together with the laws of nature)—which sounds quite plausible in light of important results of contemporary physics—the 'no fact of the matter' account provides a powerful characterization of the openness of the future, understood as a kind of unsettledness.

From a semantic point of view, it is not that there is a "lack of specificity" concerning *which* worldly conditions for future contingents obtain, but rather that worldly conditions are absent: there is no fact that speaks to the truth or falsity of ⌜There will be a sea-battle tomorrow⌝. This kind of unsettledness might thus seem to be incompatible with Bivalence. This is, at least, what Broad himself contends when he claims that future contingents are without exception neither true nor false (cf. 1923, pp. 70–73). After all, if there is no fact of the matter as to whether Fφ, i.e. if nothing worldly answers to whether or not Fφ, it might seem that Fφ should be neither true nor false. In particular, Fφ should not be true, because the worldly conditions required for its truth are absent, but nor should it be false, because the worldly conditions required for its falsity are also absent. It might thus be concluded that if there are some statements concerning which there is no fact of the matter, Bivalence must be rejected (cf. Cameron, 2015, p. 181).

This conclusion is clearly problematic. As has already been said, most philosophers believe that "[…] classical semantics and logic are vastly superior to the alternatives in simplicity, power, past success, and integration with theories in other domains" (Williamson 1994, p. 186). However, it is not clear that this has to be accepted. According to Correia and Rosenkranz (2018), this conclusion is driven by too strong a conception of the "grounding requirement on tensed truths" (i.e. the requirement according to which tensed truths do not "float free", but are grounded in reality).[23] They argue that the present truth of a given statement does not require it to be grounded in how things located in the present are, but it might well be grounded, at some future time, by things whose future existence and future ways of being are such as the statement claims. For example, the statement ⌜There will be a sea-battle

[23] The grounding requirement on tensed truths, mentioned by Correia and Rosenkranz, is a stronger principle than the one accepted so far: for p to be truth, the worldly conditions for p's truth would have to obtain; and for p to be false, the worldly conditions for p's falsity would have to obtain. However, this plays no essential role in the debate.

tomorrow⌝ might well be true *now*, provided that, one day hence, there will be a sea-battle whose existence will explain *why*, one day before, the statement was true.

This theoretical option allows Correia and Rosenkranz to affirm that future contingents are not exceptions to Bivalence—they *now* have a classical truth-value—while keeping the future open. Indeed, assuming that there will be things whose existence is not rendered inevitable by how things located in the present or past of now are or were, the present truth of a statement that will be grounded by how matters are going to stand does not undermine its status as a future contingent. In other words, the bivalence of statements about the future that will be grounded by what there will be and how it will be, does not threaten the open future as long as "[…] nothing there is or was, in conjunction with how it is or was, makes it inevitable that, in the future, there will be such grounds" (2018, p. 110). Thus, through a weaker and more plausible conception of the grounding requirement on tensed truths ("[t]he truth of a given tensed statement at most requires that it *sometimes* be grounded in what then is something and a certain way" (2018, p. 108)), Correia and Rosenkranz's option allows us to reconcile the bivalence of future contingents with the 'no fact of the matter' account of openness: the future may be said to be open in the sense that there is no fact of the matter regarding the truth-value of future contingents, without future contingents lacking a classical truth-value.

This final characterization of the asymmetry in ontological terms seems to be appropriate for explaining for our intuition of an open future and a fixed past. As it has been argued, it enables us to assume a classical logic, and in particular a bivalent semantics, even for future contingents. In the light of Correia and Rosenkranz's relaxed conception of the grounding requirement on tensed truths, it also enables us to "[…] draw a systematic distinction between being determinate in truth-value and being predetermined to be true or false" (2018, 112): even if there is no fact of the matter whether a sea-battle will take place tomorrow, the statement ⌜There will be a sea-battle tomorrow⌝ is determinate in truth-value (since, one day hence, there will be things whose existence will explain *why* this statement is true *now* (or false *now*)), but is nonetheless not *predetermined* to be true or to be false (since its truth-value is not made inevitable by what there is or was, in conjunction with how it is or was).

However, so far it has only been shown that the 'no fact of the matter' account of openness does as well as the 'metaphysical indeterminacy' account. No reason for privileging one account over the other has yet been provided. For instance, it is not clear that this new account is more successful in delineating cases of open future indeterminacy from cases of other sorts of indeterminacy (especially cases of quantum metaphysical indeterminacy). After all, a statement like ⌜Schrödinger's cat will be alive⌝ may also be said to be determinate in truth-value (since, when opening the box, there will be a cat whose life status will explain *why* this statement is true *now* (or false *now*)), while it is not *predetermined* to be true or to be false (since its truth-value is not made inevitable by what there is or was, in conjunction with how it is or was).[24] This may invite an answer to the following question: is there any reason for

[24] However, there might still be a way to delineate open future indeterminacy (conceived as there being no fact of the matter) from other sorts of indeterminacy (especially quantum metaphysical indeterminacy): whereas open future indeterminacy involves that there is no relevant ontology at all (there is sim-

preferring the 'no fact of the matter' account to the 'metaphysical indeterminacy' account? I think that the answer is 'yes'; there are at least two reasons that put the former in a better position than the latter: (i) the 'no fact of the matter' account is more metaphysically illuminating; (ii) the 'no fact of the matter' account is more powerful in capturing interesting senses of openness. I develop these two reasons now.

First, whereas the 'metaphysical indeterminacy' account accommodates the openness of the future by introducing an obscure indeterminate degree of obtaining (openness involves indeterminacy about which determinate state obtains), the 'no fact of the matter' account accommodates it by simply denying that any future state obtains. Not only does this second option appear to be decidedly clearer (how should indeterminacy in obtaining be interpreted?), it also seems to be closer to the commonsense view. Indeed, the commonsense view according to which the future is open seems to be naturally read as characterizing relevant states as *determinately failing* to obtain, not as being such that it is indeterminate which relevant determinate states obtain. In particular, if the future options are genuinely open, then intuitively, *neither* tomorrow's sea-battle *nor* its peaceful alternative obtains—the future has not yet happened, after all. It thus seems that the 'no fact of the matter' account is superior to its rival not only in intelligibility, but also in how it tallies with the way we commonly think of the future.

Secondly, as we have seen, there is a sense in which the future may be said to be open that the 'metaphysical indeterminacy' account fails to capture (since it presupposes that the future gets settled, one way or another): time could come to an end, with no ontological commitment to future things standing in the way (cf. Correia and Rosenkranz 2018, p. 99). Yet, there are good reasons to think that the 'no fact of the matter' account is better positioned for capturing this radical sense of openness. Indeed, given that this account presupposes a gap in ontology (i.e. there is no future), it seems that, assuming physical indeterminism (i.e. the doctrine that the future history of the world is not nomologically necessitated by its current history), it can allow for such a doomsday scenario. After all, the possibility that time could come to an end is no more than a possible interpretation of what a strong form of physical indeterminism can lead to. Considering the world's history up to t (especially all the entities actually existing at t, or at any time earlier than t), it might be that any time later than t never exists. Supposing that the future may be said to be open in this sense, it clearly appears that only an account of openness that does not presuppose that there are times later than t can allow for it. It therefore seems that there is at least one sense in which the future may be said to be open which coheres with the 'no fact of the matter' account, but is unavailable to the 'metaphysical indeterminacy' account. It might thus be concluded that the 'no fact of the

Footnote 24 (continued)

ply no future), quantum indeterminacy merely involves that there is no *determinate* ontology (there are states of affairs whose constitutive entities have determinable properties but no unique determinate of these properties). The openness of the future might thus be singled out as being the only sort of indeterminacy that presupposes a *real lack* in the ontology.

matter' account of openness is more powerful than its rivals and, therefore, that the asymmetry reflected by our intuition of an open future and a fixed past is to be characterized in ontological terms.

6 Conclusion

In this paper, I have shown that there are various ways in which the asymmetry reflected by our intuition of an open future and a fixed past can be characterized. I have argued that the substantial characterizations of the asymmetry (the asymmetry reflects how the world truly is) are more promising than the non-substantial characterizations (the asymmetry merely reflects how we speak of the world, or what we can know about it). In particular, I have argued that the openness of the future is to be characterized as a kind of worldly unsettledness. In this respect, I have presented two very different accounts of how reality may fail to fully settle what will happen: (i) although there are facts about what will happen, it is indeterminate which of these facts obtain (*metaphysical indeterminacy*), (ii) there is simply no fact of the matter about what will happen (*no fact of the matter*). Following Correia and Rosenkranz (2018), I have argued that this second account can be reconciled with the bivalence of future contingents (without settling how the future will be), provided there is an appropriately relaxed conception of the grounding requirement on tensed truths. Finally, assuming physical indeterminism, I have claimed that the 'no fact of the matter' account of openness should be preferred, since (i) it is more metaphysically illuminating and (ii) it coheres with a radical sense in which the future may be said to be open that is unavailable to the 'metaphysical indeterminacy' account. Although there is an abundant literature on the question of the past-future time asymmetry (both in metaphysics and in the philosophy of physics), a critical overview of the competing theories is rarely found. I hope that this paper, by combining linguistic, epistemic, physical and metaphysical concerns, helps fill this gap, and that it lays some foundations for the upcoming discussions.

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