Saving the Appearances: the Direction of Time and Time-Reversal Invariance

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Abstract

In this paper, I endorse phenomenal conservatism as epistemic theory of justification and I defend that we are justified in believing that the direction of time is primitive because it seems to us to be primitive, unless there were defeaters for having such a belief. This is what I call the "Argument From Appearances". I then analyse one of the most powerful argument against this argument, the "Time-Reversal Argument", and claim that it relies on supplementary premises that can be challenged. Therefore, it is rendered harmless and does not qualify as a solid defeater against the Argument from Appearances.

1. Introduction

My view is that the direction of time is so important for even a minimal understanding of our daily experience and of scientific phenomena that it must be regarded as primitive in any empirically well-based ontology. Isaac Newton and Gottfried Leibniz championed this view in the eighteenth-century, *despite* their disagreement about the nature of time. In the contemporary literature, primitivism has rather been scarcely defended: Tim Maudlin, Michael Esfeld, and I have also defended primitivism recently, though on different grounds (see Maudlin 2002, 2007, Lopez and Esfeld 2024, Lopez 2024b). Typical reasons to uphold some form of primitivism come from explanatory necessity: a direction of time is postulated as a primitive structure of space-time because it is needed for explanation. In Maudlin's view, for instance, it follows from the necessary structure that space-time must have in order to get good working physical theories. Esfeld and Lopez run a more metaphysically oriented argument, defending primitivism as the best way (if not the only) to distinguish spatial and temporal relations in any ontology that involve, at least, change.

In this paper, I defend primitivism about the direction of time on different grounds and in a non-direct, perhaps more winding way (readers are referred to Lopez and Esfeld 2024 and Lopez 2024b for a more direct and positive defense). I do this by, first, suggesting an alternative way to understand the problem at an epistemological level and, second, by arguing that one of the strongest and most persuasive arguments against primitivism (what I call the 'Time-Reversal Argument', **TRA** henceforth) can be rendered harmless. Let me briefly depict the overall argumentation.

To begin, quarrels about the direction of time in physics and philosophy of physics have generally assumed some form of *reliabilism* as a theory of epistemic justification[1] (see Goldman 1979, 1986): to generate justification for beliefs about the direction of time, a reliable, truth-conducive process must be adopted and followed. Without such a process, any positive belief about the direction of time is deemed unjustified. In a naturalistic framework, such a justification has relied on what physics can tell us about the direction of time, following in general a reductionist strategy. This epistemological assumption puts the burden of proof on the defender of a primitive direction of time: she is forced to deliver justification for the belief in a reliable way (i.e., in relying on physics). I do not want to argue that reliabilism as epistemological principle fails in general, but I want to suggest that, by shifting such an epistemological background, the burden of proof can be swapped. Instead of looking for epistemic justification in a reliable method, I adopt the view that all species of appearances are a prima facie source of justification for beliefs. In the epistemological literature this view is known of as *phenomenal conservatism* (see Huemer 2007, Tucker 2013) and gives raise to what I call the "Argument from Appearances": in the absence of defeaters, if the direction of time seems to be primitive to an agent, then there is some degree of justification for such an agent to believe that the direction of time is primitive. That the direction of time seems to be primitive (at least in the sense that it seems to be fundamental for the natural world) follows rather easily from the overwhelming evidence that time does seem to be directed. Note that this epistemological view has swapped the burden of proof –It is now on those who want to show that such a belief is unjustified because there are solid defeaters.

This brings us to the second part of the general argumentation. The fact that most laws of physics are time-reversal invariant has been an all-too-common argument in the literature against a primitive direction of time. This is the **TRA**, and it works as a defeater within phenomenal conservatism: despite the fact that time seems to be directed, any belief in a primitive direction of time is left unjustified because there is a solid defeater[2]. Yet, I argue that the **TRA** is actually harmless and thereby fails to be a solid defeater. In particular, I cast a series of doubts on the **TRA** that puts into question its strength and persuasive force, at least as it stands now. I divide my objections in three groups:

- Those that relate to which are the laws of interest
- Those that relate to what is the right concept of time reversal
- Those that relate to what is the role of symmetries in physics.

All these points against **TRA** play the role of showing that it is not really a solid defeater. Therefore, since phenomenal conservatism simply accept that assuming things are the way they

[1] Reliabilism is an externalist theory of justification since the factors that justify a belief are not necessarily conscious experiences or within one's own first-person perspective. It opposes to internalist theories of justification, according to which the factors that justify a belief must be within one's first-person sphere (e.g., conscious experience). *Evidentialism* as an internalist theory usually contraposes to reliabilism. Other views are the acquaintance theory, skepticism, phenomenal conservatism, among others.

[2] It is technically a *rebutting defeater*: time seems to be directed, but it is a false belief because there would be solid arguments in physics that teach us that it is fundamentally directionless.

appear to us is the rational default position, the absence of defeaters is enough to uphold that the belief in the direction of time as primitive is justified.

The article is structured as following. In Section 2, I introduce in a general fashion the problem of the direction of time along with two epistemic views: *reliabilism* and *phenomenal conservatism*. In Section 3, I provide a careful reconstruction of the **TRA** and its main assumptions. In Section 4, I argue against some of the premises of the **TRA**, showing that it needs to be, at least, supplemented by additional premises. I also argue that such supplementary premises can be put into question, rendering the argument harmless. In conclusion, in the absence of solid defeaters, that time seems to be primitively directed to us is enough rational ground to have justification for believing that time is primitively directed.

2. What's at Stake? The Problem of the Direction of Time and an Epistemological Shift

2.1. The General Problem of the Direction of Time

The problem of the direction of time has largely been associated with problems in the foundations of thermodynamics and statistical mechanics (see Boltzmann 1872, 1964, Reichenbach 1956, Price 1996, Callender 1997, Albert 2000, Loewer 2012). In a classical book, Hans Reichenbach has famously introduced the problem of the direction of time as following:

> "The elementary processes of statistical thermodynamics, the motions and collisions of molecules, are supposed to be controlled by the laws of classical mechanics and are therefore reversible. The macro-processes are irreversible, as we know. How can this irreversibility of macro-processes be reconciled with the reversibility of micro-processes? It is this paradox which the physicist has to solve when he wishes to account for the direction of thermodynamical processes and for the *direction of time*" (Reichenbach 1956: 109. Italics mine)

More contemporarily, Craig Callender has said:

> "Concisely put, the problem is that given a non-equilibrium state at t_2, it is overwhelmingly likely that (a) the non-equilibrium state at t_2 will evolve to one closer to equilibrium at t_3, but that due to the reversibility of the dynamics it is also overwhelmingly likely that (b) the non-equilibrium state at t_2 has evolved from closer to equilibrium at t_1" (Callender 1997: S225)

There is of course a deep and philosophically rich problem in the foundations of thermodynamics about the seeming contradiction between temporally directed macroprocesses and temporally undirected microprocesses (see Price 1996, Goldstein 2001). I however think that the philosophical debate over the direction of time greatly exceeds the more circumscribed issues around the foundations of thermodynamics, or of any other physical theory. In other words, I think this is a too narrow formulation of the problem of the direction of time, as if it were exclusively exhausted by the problem of the thermodynamical arrow of time (the same goes for the cosmological arrow of time, see Hawking 1985, Penrose 1989, 2004; the electromagnetic arrow of time, see Frisch

2000, Rohrlich 2005, Earman 2011; and the quantum-mechanical arrow of time, see Penrose 1989, Callender 2000, Hartle 2013). In consequence, I believe that the problem should be introduced in a more general way.

Let me then pursue a broader formulation. To begin, it is worth distinguishing the problem of the direction of time from related, but different issues. That time instantiates the problem of having a direction does not per se imply that time is dynamics, or that there is an objective becoming (Markosian 2004, Bourne 2006; see Price 2011 for a similar clarification). In metaphysics, it is common to distinguish between dynamical and static theories of time (Baron 2015); or, in John McTaggart's vocabulary, between A- and B-theories (McTaggart 1908, Gale 1966). While A-theories hold that time objectively flows (it is dynamic), B-theories deny it. Strictly, time is directed in both structures, regardless of whether time is dynamic or not. In other words, if time is directed, then it is *at least* B-structured. Some philosophers have argued that time may also be C-structured, in the sense that time is ordered, but directionless (see mainly Price 1996, Farr 2012, 2020). According to them, time may exist without a direction[3]. So, whether time is directed or not is not a problem about whether time has a A- or B-structure (i.e., whether it is dynamics or not), but about whether it has a B- or C-structure.

The second point is that, from a broad perspective, the problem of the direction of time is not about whether the direction of time is real (or whether it exists). That is, it does not hinge upon an "existence" question. Most explanations of the direction of time (even the most reductionist ones) try to recover it at some level, which implicitly implies that it must be taken as part of the ontology. A more metaphysics-oriented formulation of the problem would focus on *how* the direction of time exists, i.e., about whether it is *primitive* (fundamental) or *derivative* (reducible to something else). In accordance with this, philosophical attitudes towards the direction of time can then be divided into *primitivism* and *reductionism*. In turn, reductionism comprehends two alternative views: *conservative* and *eliminativist* reductionism (see Esfeld and Sachse 2011). While primitivism takes the direction of time to be an irreducible, fundamental property of time, reductionism takes it to be reducible. It is now clear why existence questions are not at stake: reductionism does not mean per se that the direction of time is unreal, but that it is not primitive. Conservative reductionism will, for instance, endow time with a non-fundamental reality, as part of the secondary (or derivative) ontology. Primitivists and conservative reductionists do not then debate over the reality of the direction of time, but over whether it is part of the basic (or fundamental) ontology. In this sense, they are *realist* views of the direction of time. Eliminativist reductionism does defend that the direction of time is unreal, an illusion, nor being even part of the secondary ontology. In this way, only eliminativist reductionism (a scarcely defended view) holds that the problem of the direction is about its existence, in opposition to both primitivism and conservative reductionism.

To sum up, my view is that the problem of the direction of time is, first and foremost, the problem of whether time instantiates the property of having a direction or not. This basically means

[3] I disagree with the view since I think that C-theories of time are not actually theories of time at all, but theories of something else.

that if one direction obtains (say, from "past-to-future"), then the other does not (say, from "future-to-past")[4]. Second, it is about whether such a property is primitive in one's ontology (because, e.g., it plays a paramount role in explaining temporal asymmetries) or derivative (i.e., reducible to some material—*de facto* or *de iure*—asymmetry). The problem of the thermodynamical arrow of time, the cosmological arrow of time, the quantum-mechanical arrow of time, etc., are sub-problems (or more specific problems) that presuppose that the direction of time is real but not primitive, calling for an explanation in terms of a non-temporal asymmetry.

2.2. An epistemological shift

Epistemological aspects have been barely discussed in the literature on the direction of time. It seems to me that most approaches to the problem of the direction of time have not only taken a reductionist attitude, but also implicitly adopted as epistemological principle some form of *reliabilism* for epistemic justification. This is an externalist account of epistemic justification which emphasize that the *type of methodology* employed to form beliefs is what confers justification (see Goldman 1979, 1986, 1994). From this perspective, the epistemic problem is about whether we have *justified beliefs* about the direction of time as primitive (or not) by following a reliable belief-generating processes. More precisely, reliabilists state that the property of being the outcome of a reliable belief-forming method is what confers justification for a given belief: the belief that time has a primitive direction can only be justified if it is the outcome of a reliable belief-forming method (in this case, if it is an outcome of physics, see Goldman 1994). Otherwise, our belief is rendered unjustified. The introduction of epistemological considerations is not trivial since they command the necessary criteria to ultimately have knowledge of something (although these criteria might be not sufficient). Unjustified beliefs perform very poorly in the competence of having knowledge of the world since knowledge will at least be formed by justified beliefs.

I do not want to argue that reliabilism is false (see Huemer 2007). My aim here is just to shift the epistemological principle at work in the debate to swap the burden of proof. If reliabilism (or something close to it) is assumed as an overarching theory of epistemic justification in the discussion, then the burden of proof is on whom must show how a given belief is the outcome of a reliable process (e.g., physics). But this could be different under an alternative theory of epistemic justification. To make my point, I adopt here what it has been called *phenomenal conservatism* (Huemer 2001, 2007, Tucker 2013). It basically states that if it seems to an agent that *p*, then, in the absence of defeaters, such an agent thereby has at least some degree of justification for believing that *p*. In terms of the topic of this article, phenomenal conservatism would imply that if it seems to an agent that the direction of time is primitive (e.g., by observation, by sensorial experience, by introspection, by explanatory necessity, or by paying attention to

[4] The labels 'future' and 'past' are conventional, so the direction of time does not hinge upon which direction is really the future and which really the past. The point is that if it is possible to fix a direction (which can conventionally be baptized as the 'past-to-future', or the 'positive', direction), then the opposite direction is a *different* direction (it might even be metaphysically or physically impossible).

common ordinary and scientific explanations, etc.) then, in the absence of defeaters, such an agent has at least some degree of justification for believing that the direction of time is primitive.

Of course, further metaphysical arguments can be given to support the belief (e.g., explanatory power, simplicity in the basic ontology, etc., see Maudlin 2002, Lopez and Esfeld 2024, and Lopez 2024b), but phenomenal conservatism, as a theory of epistemic justification, already sets the default rational position differently, swapping the burden of proof. In order for us to have justified beliefs on the direction of time we should now keep an eye on rebutting the defeaters, rather than positively defending why we are entitled to have some beliefs rather than others. Appearances (understood in a broad sense) already confer some degree of justification for believing that the direction of time is primitive (or at least that it is central in the explanation of our daily experiences and scientific processes), so the burden of proof is now placed on the power of the defeaters. From phenomenal conservatism, an "Argument from Appearances" can be sketched as follows:

The Argument from Appearances

> 1. In the absence of defeaters, if time seems to us to be primitively directed, then there is a prima facie justification for believing that time is primitively directed.
>
> 2. It is true that time *seems* to us to be primitively directed.
>
> 3. There is no defeaters.
>
> C. Therefore, there is a prima face justification for believing that time is primitively directed.

P1 just states phenomenal conservatism applied to the problem of the direction of time. I will not argue in favor of P2, so I will just take it for granted[5]. Proviso that P3 holds, conclusion follows by Modus Ponens. So, everything in this argument gravitates around P3. So, in the next section I introduce one of the main reasons to object to this argument: the **TRA**. To be clear, if the **TRA** holds, then the Argument from Appearances does not. In Section 4, I argue that the **TRA** does not hold (as least as it stands), cleaning the way for the Argument from Appearances to go through.

3. The Defeater: The Time-Reversal Argument

In the last years, philosophers of physics and metaphysicians alike have been growingly drawing their attention to physical symmetries to address various philosophical issues, such as the nature of space-time, the nature of natural properties and of the fundamental interactions, etc. The basic idea is that at least some physical symmetries would allow us to infer features or structures of the world (see, for instance, Baker 2010, North 2008, 2021). Shamik Dasgupta (2016) refers to this inferential mechanism as "the symmetry-to-reality inference". The **TRA** as I interpret it, can be viewed of as an instance of a symmetry-to-reality inference, where the symmetry of interest is time

[5] It can be argued that time does not appear to us to be *primitively* directed, but just merely directed. This is true. But if we take this as the ending point of the discussion, we are not yet debating the problem of the direction of time as I have introduced it in Section 2. Once we enter the debate, we must endorse either reductionism or primitivism. In this context, I hold that primitivism is the standard rational position giving the paramount role that a directionality of time has in any explanation. In this sense, time appears to us as primitively directed.

reversal, and the aspect of reality is the direction of time. One of the questions is whether the inference can be justified: Why are we entitled to draw metaphysical conclusions from physics or mathematics? (See Lopez 2023b for a critical assessment). More particularly, why are we entitled to draw metaphysical conclusions about the direction of time from time-reversal invariance? (See Lopez and Esfeld 2023 for a critical stance on this).

Another question is if the inference is really about what is real. I am a bit hesitant to take the argument in terms of what's real and what's not: even if all laws of physics come out time-reversal invariant, the direction of time would still be real! So, I take the inference as referring to what's primitive (or fundamental). In this line, the **TRA** states that because laws of nature are time-reversal invariant, the direction of time is not primitive. This can very well be explained because physical symmetries would be symptomatic of redundant or superfluous structure, so it is epistemically advisable going with the most parsimonious structure, "slicing away superfluous structure" (Earman 1989: 46). So, in a general form, the "Symmetry-to-Primitive Argument" can be posed as follows:

The Symmetry-to-Primitive Argument

1. Take the laws of physics L

2. There is a property P in the laws whose value can vary freely while keeping the laws true.

3. Then, if P2 is true, P is redundant/superfluous/non-objective, etc.

4. We shouldn't accept redundant/superfluous/non-objective properties as part of our primitives (Ochkam's Razor)

C. Therefore, P cannot be part of our primitives (i.e., it is part of the derivative ontology).

There would be various points to discuss here, but I do not have enough room for providing a detail discussion. It is just noteworthy that P3 is crucial, since it provides a more robust, narrow concept of what a physical symmetry is. In P2, the notion of symmetry is too abstract to be conceptually useful; thus, it requires some additional content to have physical and conceptual meaning (see, for instance, Belot 2013, Dasgupta 2016). This is what P3 delivers. There have been many ways to characterize such an additional content, but some of these narrowed concepts of symmetries have been related to the concept of objectivity (Weyl 1952, Nozick 2001), to undetectable properties (Robert 2008, Dasgupta 2016), to unmeasurable quantities (Ismael and van Fraassen 2003), or to physical equivalence (Saunders 2003). Others have been skeptic that the enterprise can be successfully achieved at all (Belot 2013, Wallace 2022).

I say that the **TRA** is an instance of the Symmetry-to-Primitive Argument. It relies on the fact that most of our fundamental laws of nature have the property of being time-reversal invariant. What is meant by 'time reversal' has been extensively discussed in the literature (see Sachs 1987, Albert 2000, Callender 2000, Earman 2002, Malament 2004, North 2008, Peterson 2015, Lopez 2021a-b, Lopez 2023a , Roberts 2022, Allori 2019, 2024 among others), but it is enough for my purposes here to say that time reversal is a formal operation acting upon states, magnitudes and parameters in a dynamical equation that transforms them in such a way that represents an inversion

of motion plus a re-parametrization of the time coordinate (see Wigner 1932: 325, Gibson and Pollard 1976: 177; Sachs 1987: 6). If time-reversal invariance holds, then the space of solutions of the dynamical equation is preserved (i.e., time reversal maps solution to solutions and non-solution to non-solutions). More informally, it is said that time-reversal invariance "preserves" the truth of the laws of nature; or that it in principle means that laws of nature are "blind to", or "do not care about", the direction of time.[6]

If time-reversal invariance is a pervasive feature of dynamical equations in physics, why do we need a direction of time after all? At least at first glance, *if* our metaphysical beliefs ought to be tailored by our best physics, then it seems that the **TRA** suggests otherwise. In one way or another, a primitive a direction of time seems unnecessary, superfluous. Why postulate it then?

The Time-Reversal Argument

P1. If the dynamical laws are time-reversal invariant, then a primitive direction of time is metaphysically unnecessary [assumption]

P2. We shouldn't posit unnecessary structures [parsimony]

P3. It happens that (most) dynamical laws are time-reversal invariant [empirical premise]

P4. A primitive direction of time is then unnecessary [MP with P1]

C. We shouldn't posit a primitive direction of time [from P4 and P2].

The argument is of course valid. Whether it is true depends on the premises. Many in the literature on the direction of time have taken the argument as containing true premises, which undermines primitivism about the direction of time. According to the epistemological principle I have adopted in Section 2, if the **TRA** is true, then it is a solid defeater in the Argument from Appearances. If this is so, then any belief that time is primitively directed because it seems to be so is just unjustified. In the following section, I examine in detail the **TRA** and argue that it is not a solid defeater.

4. Defeating the Defeater

The **TRA** (or something very close to it) has had a huge influence in the philosophy of time and of physics. It puts into question a deep intuition about what the natural world is like. Yet, I believe the argument resorts on some premises that need thorough examination. I do not claim that the **TRA** is incorrect or incoherent; nor that it cannot be accepted under any circumstance. What I claim is that the truth of some of its premises depends on additional premises for them to preserve its persuasive force. Otherwise, the argument is much less convincing that it seems at first glance.

[6] This is just an instrumental and very general definition of time-reversal invariance. The details vary across theories and contexts, and many subtleties should be mentioned. However, for my purposes here, this definition is good enough to introduce **TRA** as it is frequently introduced. It can be also argued that this definition of time-reversal invariance is too liberal and must be constrained. This is an important point to which I will come back in Section 4.

I focus on two premises that I think are particularly troublesome –**P1** and **P3**. In a nutshell, my caveats, which I unfold in the next subsections, can be grouped in three questions:

- Which types of *laws* are time-reversal invariant?
- What is *time reversal*?
- What is the role of *symmetries* in physical theories?

None of these questions can get definite answers. They can rather be replied in different ways. But more crucially, the replies require supplementary premises. The problem is that there are good reasons to reject these supplementary premises. If they are rejected, then the **TRA** is rendered harmless or, at least, much less persuasive than originally thought. This would show that one of the strongest defeaters of the Argument from Appearances is ineffective.

4.1. Which types of laws are time-reversal invariant?

To begin, it is not strictly true that *all* laws of physics are time-reversal invariant. This has been already argued for in different ways, but it is worth emphasizing its importance for the debate. If it is not the case that *all* laws are time-reversal invariant, then **P3** in the time-reversal argument is just false. For instance, some have argued that the decay of neutral kaons or B-mesons in weak interactions are solid enough examples of time-reversal violation. In quantum field theories, the **CPT** theorem states that for any local relativistic quantum theory in Minkowski space-time, the combined combination of charge conjugation (**C**), parity transformation (**P**), and time reversal (**T**) is a symmetry (for more details, see Greaves and Thomas 2014). In 1964, Christenson, Cronin, Fitch, and Turlay carried out an experiment at the Brookhaven Alternating Gradient Synchroton (AGS) in which they discovered that neutral kaons violated **CP**, thereby violating **T**.[7] In particular, they found that long-life neutral kaons (K_L^0) decay asymmetrically violating **CP**, and whereby, **T** (for further details, see Sachs 1987, Sozzi 2008, Bigi and Sanda 2009). Therefore, there is a fundamental violation of time reversal.[8]

Another way to argue against **P3** along the same line is by relying on quantum theories that explicitly introduce a time-asymmetric evolution for quantum systems. Theories of objective collapses (e.g., GRW, CSL) modify the Schrödinger equation in such a way that quantum states spontaneously and stochastically undergo collapses that localize them in space-time (see Ghirardi, Rimini and Weber 1985, 1986; Ghirardi, Pearle and Rimini 1990). Due to the stochastic nature of the spontaneous collapses, these theories are not time-reversal invariant (see Arntzenius 1997, Esfeld and Sachse 2011, North 2011). So, if these theories are accepted as good ways to solve the

[7] First experiments shown an *indirect* violation of **T**. But new experiments (see Angelopoulos et al. 1998) shown *direct* violations of **T**.

[8] There has been some discussion about whether this experimental result is relevant enough to conclude that there is a direction of time (see, for instance, Horwich 1987, Penrose 2004; also, Maudlin 2007, North 2011). Nonetheless, I am not interested here in showing that the experimental violation of **CP** is relevant for the direction of time debate, but that *within* the framework of the **TRA** it is evidence against **P3.**

measurement problem, then **P3** no longer holds. Of course, the downside of this argument is that it heavily depends on endorsing some version of the theories of objective collapse as an attractive way to solve the measurement problem, which can be contested. Be that as it may, it is enough to introduce some qualification in stating **P3**.

There is a third, much more interesting way to show that **P3** could be untrue. **P3** implicitly assumes that only *the simplest and fundamental expressions of a dynamical law* are the relevant ones to assess time-reversal invariance. Philosophers of science have referred to them as "the general laws" or "covering laws" (Dray 1957, Hempel 1965, Cartwright 1983), arguing that such laws capture the general, highly idealized behavior of physical systems under unrealistic circumstances (see Lopez 2024a and Lopez 2024c). Yet, a vast number of instantiations of the covering laws (what is usually called *phenomenological laws*) will *not* be time-reversal invariant. Why is it then insisted that laws of physics are time-reversal invariant? The underlying assumption (which I call the *Fundamentality* assumption) is that only general and simple expressions of the dynamical laws are fundamental, meaning that they should be taken as ontologically privileged (latching on to reality at bottom, so to speak), while phenomenological laws (their more specific instantiations) are rather derivative. Craig Callender (1995) says:

> "[in classical mechanics] we disregard 'phenomenal' forces and focus on the 'fundamental ones when we decide whether a theory and the systems it describes are TRI. When asking if the universe is TRI [time-reversal invariant], we desire to know whether it is *at bottom* time-reversal invariant. We make an ontological assumption" (Callender 1995: 333)

And then he continues: "classically, there are really only particles in motion and interparticulate (distance-dependent) forces" (Callender 1995: 333). All this means that **P3** actually requires an additional premise to do the job it intends to do: Only fundamental laws (in the sense of general or covering laws) are taken as relevant to assess time-reversal invariance.

There could be good motivations to adopt this premise, but I believe that it is matter of one's underlying ontology after all. For instance, whoever endorses an ontology of capacities in science or a dispositional ontology as fundamental (see, for instance, Cartwright 1989, Mumford and Anjam 2011) would be more reluctant to accept that covering laws are fundamental in any sense. After all, won't laws of nature be redundant? Won't laws of nature be instrumental? If this is so, which are the reasons to take covering laws as ontologically fundamental under an alternative ontological framework? Under such a dispositional ontology, the situation seems to be in reality the other way around –more realistic, less idealized models (e.g., those that contain non-conservative forces) are likely to be ontologically more fundamental than the abstract covering laws! An analogous argument can be run from what has recently been called 'the open systems view' (Cuffaro and Hartmann 2023). According to the traditional view, closed systems are conceived of as fundamental. When assessing whether a dynamical law (or a model) is time-reversal invariant, it is also customary to focus on isolated systems, which goes in the same line as the **TRA**. Cuffaro and Hartmann, however, propose an alternative view in which systems interacting with their environment (i.e., open systems) are considered of as fundamental.

Remarkably, if an open system view is taken to assess time-reversal invariance, then *most* fundamental, now open-system models will be non-time-reversal invariant (for instance, many of them will involve non-conservative forces, see Lopez 2024b for an argument on this line).

I do not mean that dispositionalism or the open systems view are correct. What I want to point to is that the Fundamentality Assumption is crucial to run the **TRA** and alternative views may have good reasons to not accept it. Without something close to the Fundamentality Assumption, **P3** is left unwarranted.

4.2. What is time reversal?

Putting aside the question about which types of laws are to be considered as relevant to assess time-reversal invariance, another pressing question is about the concept of time reversal itself. There has been some debate about what time reversal is in different theoretical frameworks in the last years. I will not get into much detail here (see Sachs 1987, Albert 2000, Callender 2000, Earman 2002, Malament 2004, North 2008, Peterson 2015, Lopez 2021a-b, Lopez 2023a, Roberts 2022, among others), but I will circumscribe myself to show how this debate might affect the **TRA**, casting doubts on the scope of **P3**.

When it is claimed that time-reversal invariance holds, it is claimed that there is a formal operation that preserves some structure. It must be also assumed that there are good reasons to call such a formal operation 'time reversal'. A symmetry transformation is just a series of operations acting upon observables, states, and parameters in a specific way. The symmetry transformation *is* such operations. Of course, such operations are meant to represent something physical, as reflecting states in space, rotating systems by a certain angle, or reversing the motion of physical systems. It can be argued that the series of operations that are usually taken as formally implementing time reversal are actually representing something different (see Callender 2000, Lopez 2019). Let us call the formal operations '**T**'. Prima facie, **T** could stand for anything –e.g., it could be a trivial transformation without physical meaning. **P3** must not only state that **T** is a symmetry of most physical theories, but also that **T** fairly represents the *concept* of time reversal**.** This observation does not merely show that there might be a failure in the formal implementation of the symmetry transformation (i.e., that **T** should be replaced by another set of operations, say **M**), but that there might also be a failure in the association of a symmetry transformation with the *concept* it intends to formally implement. So, the argument against **P3** is that there exists a symmetry under **T**, but that it fails to fairly capture the notion of time reversal. In other words, the symmetry transformation should be rather associated with a different concept since it is not actually reversing time (see Callender 2000, Lopez 2019)

I know that this is a non-standard argument, but I think it has some grip. In physics textbooks, the presentation of time-reversal invariance is often accompanied by the following clarification:

> "In this approach we see that no metaphysical notion of reversal of the direction of the flow of time is involved. We are led to consider time reversed processes but not reversal time itself.

> Although motion reversal and motion reversal invariance would be better names, we shall adhere to the accepted, if imprecise, usage" (Gibson and Pollard 1976: 177)

Eugene Wigner (1932: 325) and Leslie Ballentine (1998: 377) also qualify time reversal along the same line –the physical meaning of the time-reversal transformation is completely exhausted by an inversion of motion plus a re-parametrization of the time coordinate. Although there can be very good physical reasons to adopt this definition (see Roberts 2017, Lopez 2021b for arguments in favor of it in non-relativistic quantum mechanics), it is not free of assumptions. To begin, the association of time reversal with motion reversal at least rejects that motion (or change) can be independent from time. Temporal substantivalism, for instance, would defend that time is independent from matter in motion. More technically, that genuine temporal relations (e.g., instant-to-instant relations) are independent from temporal relations between matter (e.g., event-to-event relations). So, in the framework of temporal substantivalism would not be natural to suppose that the inversion of motion *means* the inversion of time (for an argument in this line, see Lopez 2019). Or to put it differently, it is not obvious that the inversion of event-to-event relations (motion) is equivalent to the inversion of instant-to-instant relations (time). A reliable time-reversal transformation should then be one in which **T** transforms instant-to-instant relations, upon which the inversion of event-to-event relation might supervene. The canonical implementation of time reversal, the argument goes, fails to implement time reversal properly. If the **TRA** is about the direction of time, **P3** is irrelevant (as space rotation would be also irrelevant).[9]

Besides whether this argument succeeds or not (it depends on whether temporal substantivalism is tenable or not; whether it can come up with a formal implementation that captures physicists' practice, etc.), it tells us that time reversal (and thereby, time-reversal invariance) can be conceived of differently. This gives rise to an "Argument from Underdetermination" (see Lopez 2023a), according to which the implementation of time reversal is not unique, but it depends on various metaphysical and epistemic theses about time. Once again, this forces us to put the **TRA** into perspective: **P3** turns out true *if* time reversal is implemented in a specific way, but it might turn out to be false *if* time reversal is implemented differently. One's underlying metaphysics of time can thus influence our conceptualization and implementation of time reversal. And it is clear that there is no guarantee that some dynamical equation will turn out to be time-reversal invariant if the formal implementation of time reversal is to be different (see Albert 2000, Callender 2000, Lopez 2019). So, in the end, this Argument from Underdetermination recommends another qualification in the time-reversal argument, now concerning the meaning of time reversal and the right way to implement it.

The Argument from Underdetermination concludes that canonical implementations of time reversal (**P3**) might fail to capture the concept of time reversal. But here is another argument that rather states that canonical implementations already assume that the direction of time cannot be

[9] Jill North (2008) says: "what is a time-reversal transformation? Just a flipping of the direction of time! That is all there is to a transformation that changes how things are with respect to time: change the direction of time itself" (North 2009: 212)

primitive (or fundamental). Hence, this new argument runs, **P3** should be rejected in the **TRA** because it begs the question against primitivism, and it cannot then be used non-trivially against it.

There is some consensus that time reversal not only reverses the order of a temporal series:

$$\boldsymbol{T}[A \to B \to C \to D] = D \to C \to B \to A$$

but also, the states themselves

$$\boldsymbol{T}: X \to TX = X';$$

What gives

$$T[A \to B \to C \to D] = TD \to TC \to TB \to TA = D' \to C' \to B' \to A'.$$

For instance, in Hamiltonian classical mechanics, time reversal is expected to transform the states by inverting the sign of conjugated momentum ($T: p \to -p$) but keeping the generalized positions unaltered ($T: q \to q$). In classical electromagnetism, time reversal transforms the states by changing the sign of the magnetic field ($T: \mathbf{B} \to -\mathbf{B}$) and the current ($T: \mathbf{j} \to -\mathbf{j}$) but keeping the electric field ($T: \mathbf{E} \to \mathbf{E}$) and the electromagnetic force ($T: \mathbf{F} \to \mathbf{F}$) (see Albert 2000, Malament 2004, Arntzenius and Greaves 2009 for discussion).

But what are the reasons to suppose that the time-reversed states are *physically possible* states? It can be argued that the direction of time is so crucial for the states to be even possible that the inversion of the direction of time will make them impossible. In other words, the assumption that time-reversed states are *physically possible* states is equivalent to assume that the inversion of the direction of time is not important enough to affect the possibility of such states. But this indeed looks like an assumption that many primitivists about the direction of time can very well reject. If this is so, it follows that the canonical implementation of time reversal, in assuming that time-reversed states must be possible states, begs the question against primitivism: to properly assess whether time-reversal invariance holds, the possibility of physical states must not be presupposed. Therefore, **P3** should not be endorsed as it stands. Let me give an example.

Imagine a photon emitting device (the emitter) and a photocell (the absorber). Now consider the following series in one temporal direction (say, '+'). First, the emitter radiates a photon at t_1 (event *E*) that a photocell absorbs at t_2 (event *A*). In the middle, the photon travels through space a distance $\Delta x = x_n - x_m$ for $\Delta t = t_2 - t_1$ (event *T*). It yields the following sequence of events:

$$+\boldsymbol{SEQ} \qquad E \to T \to A$$

The **TRA** requires us to time reverse the temporal series, that is, to transform $+\boldsymbol{SEQ}$ into its time reversed, $-\boldsymbol{SEQ}$. In accordance with the canonical implementation of time reversal, the order of the series must be transformed along with its elements (in this case, the events themselves). The time-reversed series would then look like the following:

$$-\boldsymbol{SEQ} \qquad \boldsymbol{T}(E \to T \to A) = \mathbf{T}A \to \mathbf{T}T \to \mathbf{T}E = A' \to T' \to E'$$

If **T** is a symmetry, then there is some relation of equivalence between $+\boldsymbol{SEQ}$ and $-\boldsymbol{SEQ}$ plus some preservation of structure or observational content. Therefore, the **TRA** concludes that positing a primitive direction of time that makes both sequences distinct is positing unnecessary structure or unobservable content. Since this should be avoided, a primitive direction of time is unwarranted.

Yet, one can wonder, what are A' and E'? It is clear what A and E are in the ordinary ('+') direction of time, but what is the time-reversed version of an emitter *emitting* a photon and a photocell *absorbing* a photon? Are they even physically possible events? Take the event E'. A plausible assumption is that E' is a time-reversed emitter that behaves like an absorber. But is an emitter the *kind* of thing that may absorb anything? An emitter can be defined by the role it performs. But it seems meaningless to talk about emitters that absorb photons in the opposite direction of time since it would not be an emitter any longer! It can in consequence be argued that if E' means a time-reversed emitter that absorbs photons (it would allegedly be the time-reversed process of emitting), then the event is not only impossible, but also meaningless. Even stronger, the very role of the object was destroyed under time reversal. Therefore, it seems that we are not entitled to even conceive of a time-reversed version of E without begging the question against primitivism, which presumes that to fix a direction of time is essential to explain what an emitter is and what it does.

But this construal of E' can be wrong. It can alternatively be said that E' is not a time-reversed emitter that absorbs photons, but that a time-reversed emitter *is* a photocell in the reversed direction of time ('$-$'). Naturally, photocells are indeed the right kind of things that absorb photons, so the previous argument is blocked. Nevertheless, this is even worse because the time-reversal transformation becomes trivial. If E' is to be construed as a photocell that absorbs photons in the negative direction of time, then the time-reversal transformation becomes merely a relabeling: $+\boldsymbol{SEQ}$ and $-\boldsymbol{SEQ}$ are rendered symmetrical because time reversal *only* changes the labels of the events and the sign of the time coordinate. To say it differently, time reversal becomes the transformation that transforms, for instance, the '$+t$' into '$-t$' and that *names* '$+\boldsymbol{SEQ}$' as '$-\boldsymbol{SEQ}$'. But if this is so, then it is legitimate to not take the **TRA** seriously: while the question about the direction of time was a metaphysical question, **P3** in the **TRA** is just merely stating a trivial linguistic feature, namely, that a change of labels should not change the physics.

To sum up, all these caveats call for a revision of the scope and limits of **P3**. As it stands, it is either underdetermined or unspecific. Any determination and specification require supplementary premises, which must be assessed separately. Be that as it may, the **TRA** is weakened.

4.3. Going Deflationary: The Role of Symmetries in Physics.

Let us suppose that problems 4.1 and 4.2 can be overcome. And let us now focus on **P1**, rather than on **P3**. As it was said previously, **P1**'s role is mainly to connect time-reversal invariance with the direction of time (that is, the formal apparatus of a physical theory with what the world is like fundamentally). But why, and how, is this inference justified? A way to resist the **TRA** could be

to deflate the meaning of time-reversal symmetry in **P1.** That is, the overall argument erroneously supposes that time-reversal invariance as a formal property can shed light on the direction of time as a metaphysical issue. But a metaphysical conclusion requires metaphysical premises somewhere. It can hence be argued that **TRA** fails to properly bridge this gap between the theory and the world without additional assumptions. Since a complete exposition would lead us too far in the investigation of the role of symmetries in metaphysics, I circumscribe myself here to giving a hint of a response.

Some have held that symmetries are real or, even stronger, fundamental (see Weinberg 1987, 1993, French 2014, Schroeren 2020). If such a philosophical position is adopted, then it is straightforward to connect time-reversal symmetry with a metaphysical conclusion about the direction of time. After all, symmetries are located in the basic ontology to begin with. Others, less clearly, have had it that some symmetries entitle us to draw metaphysical conclusions (see North 2009, 2021; see Lopez 2023b for arguments against). Nevertheless, others have taken symmetries (or some of them) as "epistemic virtues" or, more radically, mere conventions (see Martin 2002, Guay 2004, Bird 2007, Lopez 2024c). These epistemic readings of symmetries (or, at least, of some symmetries) would deflate the metaphysical status of time-reversal symmetry. After all, that time-reversal symmetry holds just exhibits an "epistemic" virtue of physical theories, not a feature of what the world is like. To say it differently, whether a physical theory is time-reversal invariant or not is a theoretical problem about the formulation of physical theories; whether the direction of time is primitive or not is a metaphysical issue (see Lopez and Esfeld 2023).

To briefly illustrate this point, let me show an epistemic version of time-reversal symmetry. Suppose the best system approach to laws of nature in a Humean framework. Laws of nature then supervene on the Human Mosaic, but they are axioms (or theorems) in the best system, striving for simplicity and informativeness (Lewis 1986, Loewer 1996). In some sense, the laws of nature are assessed epistemically at the same time that they objectively describe the regularities in the Mosaic, but without fixing its content. What the basic ontology (the Humean Mosaic) is like will be a metaphysical issue, on which the laws of nature do not play any role. What about time-reversal invariance? It can mean two different things. Time-reversal invariance as a property of the laws of nature is a formal property of the axioms of the best system. Time-reversal invariance is thus involved in the epistemic assessments of the axioms in terms of its simplicity and informativeness. It may happen that axioms that have the property of being invariant under time reversal are simpler than axioms that have not. Under this construal, the property of being invariant under time reversal have no take in assessing the content of the Humean Mosaic (for instance, whether it contains a primitive direction of time). This Humean interpretation of time reversal cannot accept **P1** as it stands, which undermines the **TRA** (for a more complete exposition of what Humean time-reversal symmetry would look like see Lopez and Esfeld 2023)

It can be said that this reading of time-reversal invariance is too weak. According to a second reading, time-reversal invariance is actually a property of the Humean Mosaic; that is, it temporally reverses the patterns in the Humean Mosaic, transforming its temporal relations and states into

their time-reversed counterparts. Then, time-reversal invariance holds when both Mosaics are equivalent in some respects (e.g., their supervenient observational content is preserved). This "metaphysical" reading of time reversal is stronger than the previous one, but it is not so clear to me that the canonical implementations of time reversal are compatible with it. I find this approach highly problematic by various reasons. First, since laws supervene on the Humean Mosaic there is no reason to suppose that equivalent laws are to obtain in a time-reversed Mosaic, however we have got to it. We should have independent means to time reverse the Humean Mosaic, without going through the laws. Second, even if we can guarantee equivalent laws, there is no reason to assume that properties of the laws that supervene on certain regularities of a Mosaic are to be preserved in a hypothetical time-reversed mosaic. And third, which reasons independent from the laws of nature can we have to suppose that a time-reversed Mosaic exists to begin with? Those reasons may run in begging-question arguments as pointed to in 4.2.

The main aim of this deflationary argument is to point out that the **TRA** must presume some way to bridge the gap between a symmetry (as a formal features of a physical theory) and a metaphysical claim, which in turn seems to demand a metaphysically stronger view of time-reversal symmetry. It is this stronger view which would entitle us to take time-reversal symmetry metaphysically seriously. So, in order for the **TRA** to work as intended, **P1** should be complemented by another premise stating that **P1** is true only if a "realist" view of symmetries (and of time-reversal symmetry) is also true. As I argued, this supplementary premise can be rejected by endorsing a more deflationary view of time-reversal symmetry. But are there independent reasons to adopt a deflationary view? Let me just give one reason that could suggest that we should go deflationary when thinking of time-reversal invariance (and of symmetries in general).

In a 2009 paper, Frank Artzenius and Hillary Greaves say that the implementation of time-reversal invariance in classical electromagnetism follows what they call 'the textbook account':

> "Next let us consider the electric and magnetic fields. How do they transform under time reversal? Well, the standard procedure is simply *to assume* that classical electromagnetism is invariant under time reversal. From this assumption of time reversal invariance of the theory (…) it is inferred that the electric field E is invariant under time reversal (…)" (Arntzenius and Greaves 2009: 6. Italics mine)

The procedure is also recommended in a more general fashion by Detlef Dürr and Stephan Teufel (2009) when introducing the fundamentals of Bohmian Mechanics:

> "A symmetry can be a priori, i.e., the physical law is built in such a way that it respects that particular symmetry by construction. This is exemplified by spacetime symmetries, because spacetime is the theater in which the physical law acts (as long as spacetime is not subject to a law itself, as in general relativity, which we exclude from our considerations here), and must therefore respect the rules of the theater". (Dürr and Teufel 2009: 43-44)

In a nutshell, the idea is that dynamical equation of motion *must* respect some symmetries as constraints (in that sense, they can be regarded of as "a priori". See Redhead 1975). They must thus be assumed in order to write down the dynamical equations in the right way. This suggests a 'by-stipulation' view of some symmetries at least: they seem to play the role of constraining the dynamics as they are part of the set of necessary assumptions that are required to formulate a physical theory (see Lopez 2024c for the difference between by-stipulation and by-discovery views). For instance, in non-relativistic quantum mechanics, Robert Sachs (1987) says that

> "In order to express explicitly the independence between the kinematics and the nature of the forces, we *require* that the transformations leave the equations of motion invariant when all forces or interactions vanish" (Sachs 1987: 7. Italics mine)

So, in order to set up the kinematics and dynamics of non-relativistic quantum mechanics, it is stipulated that the time-reversal transformation must keep the equations of motion invariant in some circumstances, which amounts to stipulating that time-reversal symmetry holds under some circumstances. This is not per se an argument for a deflationary view of time-reversal symmetry (and other symmetries, more generally), but I do think it emphasizes the architectonic aspect that time-reversal symmetry plays in physical theories. In other words, it seems to be part of some of the necessary assumptions that help physicists build acceptable and good physical theories, as it were part of the virtues that an acceptable physical theory must exhibit. The reasons can vary, but it is widely accepted that symmetries in general, and time-reversal symmetry is not an exception, play a role in simplifying the formal structure of a physical theory and in identifying superfluous structure (see Dewar 2019). This strong theoretical-epistemic role points toward the deflationary camp, rather than towards the realist one.

4. Final Remarks

The aim of this paper was to defend that it is justified to believe that the direction of time is real and primitive because it *seems* so. I began by shifting the epistemological background of the discussion. By endorsing phenomenal conservatism, the epistemic starting point is to assume that if things appear to us in a specific way, then we have justified beliefs that they are in such a way, if there are no reasons to believe otherwise (i.e., if there are no defeaters). In terms of the problem of the direction of time, phenomenal conservatism implies that if the direction of time seems to us to be primitive (or fundamental), then we have justified beliefs that it is so, if there are no defeaters. The main argument was:

The Argument from Appearances

1. In the absence of defeaters, if time seems to us to be primitively directed, then there is a prima facie justification for believing that time is primitively directed.

2. It is true that time *seems* to us to be primitively directed.

3. There is no defeaters.

C. Therefore, there is a prima face justification for believing that time is primitively directed.

As I pointed out, phenomenal conservatism as epistemological background swaps the burden of proof: it is not necessary to justify a belief by going beyond how things appear to us (as a reliabilist epistemology would recommend us), but to argue against the potential defeaters that can be brought up. In the debate about the direction of time, the *par excellence* defeater is what I have called the Time-Reversal Argument (**TRA**) as presented in Section 3. This argument directly attacks P3 in the Argument from Appearances, making the conclusion untenable.

The Time-Reversal Argument

P1. If the dynamical laws are time-reversal invariant, then a primitive direction of time is metaphysically unnecessary [assumption]

P2. We shouldn't posit unnecessary structures [parsimony]

P3. It happens that (most) dynamical laws are time-reversal invariant [empirical premise]

P4. A primitive direction of time is then unnecessary [MP with P1]

C. We shouldn't posit a primitive direction of time [from P4 and P2].

Notwithstanding its persuasive force, I have argued in Section 4 that the argument must be substantially qualified to work as intended, which amounts to adopting additional premises with respect to laws of nature, time reversal and the role of symmetries:

- To begin, I have focused on **P3** arguing that it is not true that all laws of nature are time-reversal invariant and that the premise also presumes that only so-called covering (or general) laws are ontologically relevant to assess time-reversal invariance. This Fundamentality Assumption can be nonetheless challenged by adopting alternative ontological frameworks.
- Next, I have centered in the concept of time reversal arguing that it suffers from underdetermination (the Argument from Underdetermination): Not only can time reversal be understood differently (bringing about different formal implementations), but its canonical implementations can also be challenged. To a large extent, **P3** either is underdetermined or begs the question.
- Finally, I have focused on **P1**, assessing the role of symmetries in physics. **P1**, I have argued, presupposes a realist interpretation of symmetries, which can be challenged. By adopting a deflationary view, it is harder to justify why we are entitled to move from a feature of physical theories (time-reversal invariance) to an aspect of the world (the direction of time). By challenging **P1**, the whole **TRA** is rendered harmless.

I haven't argued that phenomenal conservatism is true, and that it is enough to endorse primitivism with respect to the direction of time. Nor have I argued that the Argument from Appearances is necessary to uphold primitivism. My thesis is conditional: if an alternative epistemological background is adopted, then the Argument from the Appearances has some grip, and the burden

of proof is rather on the defeaters. Since I find the main defeater unconvincing, phenomenal conservatism can be employed to claim that we are justified in believing that the world is fundamentally time directed.

Primitivists about the direction of time can well be in need of a more positive defense of primitivism. They could also reject phenomenal conservatism as epistemic theory of justification. Nonetheless, by removing the main argument against primitivism, a prima facie epistemic justification for it can be offered. In the end, I fully endorse Charles Peirce's words: "let us not pretend to doubt in philosophy what we do not doubt in our hearts.

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