Relational Primitivism about the Direction of Time

Personal information

Authors: Cristian Lopez and Michael Esfeld

Affiliations: Université de Lausanne, Switzerland ; Université de Lausanne, Switzerland

E-mail addresses: cristian.lopez@unil.ch ; Michael.esfeld@unil.ch

Abstract

Primitivism about the direction of time is the thesis that the direction of time does not call for an explanation because it is a primitive posit in one's ontology. In the literature, primitivism has in general come along with a substantival view of time according to which time is an independent substance. In this paper, we defend a new primitivist approach to the direction of time –*relational primitivism*. According to it, time is primitively directed because change is primitive. By relying on Leibnizian relationalism, we argue that a relational ontology of time must be able to distinguish between spatial relations and temporal relations to make sense of the distinction between variation and change. This distinction, however, requires the assumption of a primitive directionality of change, which ushers in the direction of time. Relational primitivism is an attractive view for those who want to avoid substantivalism about time but retain a primitive direction of time in a more parsimonious ontology.

Word count: 8,008

1. Introduction

Primitivism about the direction of time holds that the direction of time does not call for an explanation because it is a primitive posit in one's ontology. The aim of this paper is to defend this thesis, but on a relational basis. To do so, we introduce a new member in the family of primitivist views –*relational primitivism*. This may look strange at first glance since primitivism about the direction of time has commonly been associated with temporal substantivalism suggesting that the former entails the latter. We believe this association is just contingent, and that relational primitivism is not only metaphysically coherent, but also attractive.

The structure of the argument is the following. Relationalism puts forward a monist ontology in which there is just one kind of substance, matter, that engages in spatial and temporal relations. Space and time are therefore not independent substances, but they are derived from matter and the spatial and temporal relations it is engaged in. Spatial relations are the first type of world-making relations. Spatial relations thus glue together substances in a configuration of matter. Yet, the configuration of matter is static if it does not change, but change cannot be obtained from purely spatial relations. Then, it needs to be imposed as additional structure. If the configuration of matter changes, then matter also engages in a second type of world-making relations, *temporal* relations. A changing (or dynamical) configuration of matter engages in both spatial *and* temporal relations. The nature of these relations must be different as the nature of space and time is different. We argue that what is special about temporal relations is that they are directed. Therefore, the direction of change must be primitive, with it, the direction of time.

Relational primitivism, we submit, has two attractive features in the metaphysical landscape of the philosophy of time. It enjoys the explanatory advantages of primitivism about the direction of time, avoiding the issues of reductionist approaches. It also remains parsimonious in the ontology without adding any temporal structure over and above matter and temporal relations, avoiding the issues of temporal substantivalism.

2. The Problem of the Direction of Time: Reductionism and Primitivism

In an influential paper, John Earman writes that "it seems not a very great exaggeration to say that the main problem with "the problem of the direction of time" is to figure out exactly what the problem is or is supposed to be" (Earman 1974, 15). Fifty years later, it is not yet clear what the problem is really about. Frequently, the problem seems to be about what *justifies* our temporally asymmetric experiences (see Price 2011). More specifically, the problem is frequently formulated in terms of entropy-increasing phenomena and a seemingly contradiction between thermodynamics (irreversible processes given by the Second Law) and classical statistical mechanics (reversible processes and time-reversal invariance) (see Reichenbach 1956, Callender 1997, Albert 2000, Loewer 2012). Subsidiarily, the problem ultimately boils down to whether the so-called "Past Hypothesis" (Albert 2000) can be justified (Price 1996; for criticisms see Earman 2006).

These are undoubtedly crucial problems in the explanation of our experience of a temporally asymmetric world and the foundations of thermodynamics. The connection with the problem of the direction of time is however not so straightforward. To begin, if we think that the problem of the direction of time *is* the problem of justifying the thermodynamical arrow, then we assume that the direction of time can somehow be *reduced* to the Second Law of thermodynamics and entropy-increasing phenomena. As Lawrence Sklar (1974) and John Earman (1974) argue, this is far from obvious. Other similar views that reduce the direction of time to some physical asymmetry as the increasing of complexity in the universe (Barbour 2020), the asymmetry of radiation in classical electromagnetism (Zeh 1999), etc., also assume that the direction of time reduces to a non-temporal asymmetry.

A more general formulation can nonetheless be given. For it, it is necessary to abstract some common theses. To begin, the problem of the direction of time is not the problem of whether *there* *exists* a direction of time; it is not an *existence* question. Any physical theory and most philosophical approaches to the direction of time want to recover it at some level. Putting aside few eliminativist views that deemed time (and, in consequence, the direction of time) as a plain illusion, most views take the direction of time to exist. The problem is rather about *how* the direction of time exists, that is, whether the direction of time is primitive (i.e., irreducible) or derivative (i.e., reducible, emergent, or supervenient).

When approached in this way, two views on the direction of time naturally arise: *primitivism* and (conservative) *reductionism*.[1] Reductionist views start off by assuming that the direction of time calls for an explanation. To explain the direction of time, conservative reductionism holds, anything temporal (e.g., the fact that "A comes before B") must be reduced to a *non-temporal* physical asymmetry (which could in turn be a "de facto" asymmetry or a "nomological" asymmetry). There are different ways to achieve this reduction, but one of the most typical is in terms of correlative definitions (see Reichenbach 1956, Sklar 1974): the direction of time *is* the direction in which the magnitude x increases its value. The increasing of x's value is a matter of physics and, prima facie, a non-temporal fact. In this way, those who hold a reductionist view seek *to explain* the direction of time in terms of the directionality in which non-temporal facts exhibit an increase in the value of some magnitude of interest.

Since the work of Ludwig Boltzmann (1896), the best candidate to reduce the direction of time to a physical asymmetry has been thermodynamics through entropy and the Second Law. Even though the fundamental theory (in this case, classical statistical mechanics) does not single out a direction of time because Newton's laws are time-reversal invariant, the imposition of a very low entropy macro-state of the universe as initial condition allows explaining the thermodynamic asymmetry (and the direction of time consequently). This assumption is the Past Hypothesis (as mentioned earlier) and it allows not only explaining the thermodynamical direction of time, but various temporally asymmetric phenomena. The most prominent contemporary account in this vein is the one of Albert (2000, ch. 4) and Barry Loewer (2012), which is known as "the Mentaculus", which among its ingredients there is the assumption of a very low entropy initial macro-state of the universe (the Past Hypothesis). Though this one-asymmetry model (Price 200) is very attractive and economical, it ultimately relies on justifying the Past Hypothesis. This is what has been called the "hard problem" of the direction of time (Goldstein 2001). Even though it can be dissolved by assuming that the Past Hypothesis is a law of nature (as Albert and Loewer do by adopting the Best System Approach to laws), some voices have been raised against its necessity (see Earman 2006, Barbour 2020, Lazarovici and Reichert 2020).

Primitivism about the direction of time starts off from a completely different place. It holds that the direction of time does not call for any explanation since it is primitive. On the contrary, it is the direction of time which explains temporally asymmetric phenomena or why the value of a physical magnitude of interest *increases*. For primitivism, there is no way we can make sense of

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[1] Any argument against conservative reductionism is also an argument against eliminativist reductionism, so we focus on the former.

temporally asymmetric predicates as the "expansion" of the universe or the "increasing" of entropy without assuming a direction of time (for a similar argument, see Maudlin 2002, Mozersky 2015). Thus, the ultimate reason for postulating the direction of time as primitive is the same reason for postulating any structure at all—to explain phenomena. It can therefore not be reduced to a non-temporal material asymmetry because our explanation of those non-temporal material asymmetries needs a primitive (or fundamental) direction of time to work as intended. In other words, primitivism holds that the direction of time is not the *explanandum*, but the *explanans* of a myriad of phenomena throughout physics.

Although reductionist views on the direction of time have been much more popular in the field, primitivist views on the direction of time have been defended on different grounds. The locus classicus for primitivism is Isaac Newton's Scholium in the *Principia Mathematica*: "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without any relation to anything external". More contemporarily, John Earman (1974), Tim Maudlin (2002), Mario Castagnino and Olimpia Lombardi (2009) and Joshua Mozersky (2015) have defended primitivism about the direction of time on the basis of the *structure* of space-time. Maudlin, for instance, says:

> My ultimate aim is to defend a simple proposition: time passes. To be more precise, I want to defend the claim that the passage of time is an intrinsic asymmetry in the structure of space-time itself, an asymmetry that has no spatial counterpart and is metaphysically independent of the material contents of space-time. (Maudlin 2000, 259)

In a more general framework, Joshua Mozersky (2015) also endorses primitivism when saying that:

> My suggestion is that it is an *irreducible* and *built in* feature of the world that it is objectively directed along its temporal dimension. In other words, the direction toward what we call the future truly is *later* and not just later in relation to us (Mozersky 2015, 173)

But his primitivism about the direction of time, as Maudlin's and Castagnino and Lombardi's, is based on the fact that "*each point in time* –space-time, ultimately, of course– comes with a built-in orientation, which we might think of as like a vector" (Mozersky 2015, 174. Italics added), which has a substantivalist flavor.

So, it is fair to say that, at least historically, primitivism about the direction of time has gone hand-in-hand with temporal substantivalism. According to it, time is a substance independent from matter. *Manifold* substantivalism holds that instants ('points' of time) are enough to characterize time as a substance (Earman 1989); *metric* substantivalism adds that a metric is intrinsic to it and necessary to account for time as a substance (Maudlin 1989; see also Hoefer 1996). Temporal substantivalists are thus in general committed to a dualist ontology, where time (or space-time) exists independently from matter. It follows from this that the properties of time (whether it is directed or not) are properties of an independent substance and are independent from the behavior of matter.

It is easy to see why primitivism about the direction of time goes with temporal substantivalism: the direction of time, as such, is an intrinsic property of time as a substance ("each point in time … comes with a built-in orientation" as Mozersky says), so it does not depend on properties of the behavior of matter. There is hence a clear sense in which time has a primitive direction despite the behavior of matter being reversible –the latter does not determine the properties of the former. For instance, John Earman's 'Time Direction Heresy' assumes this view when claiming that "if it exists, a temporal orientation is an intrinsic feature of space-time which does not need to be and cannot be reduced to nontemporal features" (Earman 1974, 20).

So, primitivism about the direction of time has historically entailed temporal substantivalism. Besides the reasons to reject primitivism about the direction of time, this history-grounded inference may suggest that the rejection of substantivalism about time is, by Modus Tollens, the rejection of primitivism about the direction of time. For instance, parsimony has been one of the leading arguments against temporal substantivalism as it multiplies the kinds of substances that exist. Thus, the literature seems to suggest that whoever worried about keeping the ontology parsimonious by endorsing, for instance, a relational view of time is *ipso facto* committed to reject primitivism about the direction of time.[2] In what follows we argue that this is just a historical contingency –primitivism about the direction of time does not imply substantivalism about time. The view we endorse, primitive relationalism, seeks to make a case for a primitive direction of time in a relational framework, inspired mainly by Leibnizian relationalism.

3. Primitive Relationalism: Primitive Change and Leibnizian Relationalism

Primitive relationalism is meant to be not only a logical coherent view, but also metaphysically attractive. It benefits from the explanatory advantages of primitivism about the direction of time, but without overloading the ontology by assuming that time is also a substance. Other things being equal, a relational ontology of time or space-time that does without any commitment to substantival time is much more parsimonious and should thereby be preferred. If primitive relationalism can be defended, then it is, we submit, an attractive metaphysical proposal.

But why is temporal relationalism to be preferred? Since the debate between Leibniz and Clark between 1715 and 1716 (Alexander 1956), relationalists have argued that substantivalism is committed to unobservable and unnecessary structure. Substantivalists have replied by arguing that the additional structure posited by substantivalism is not unnecessary since it allows formulating successful empirical theories. Therefore, substantivalism's Modus Ponens has been

[2] An exception to the historical association of primitivism with substantivalism is Matias Slavov's new book *Relational Passage of Time* (2023). Our proposal is very much in line with Slavov's, but we do not argue in favor of a relational *passage*, which seems to require further temporal structure than a relational *direction*. In that sense, our account of time is more parsimonious as it requires less structure. Also, our project seeks to provide a metaphysically detailed Leibnizian account of the direction of time, in which temporal relations enter the ontology as primitive world-making relations in a changing world. In this sense, our view is more specific than Slavov's, although we share to a great extent the spirit of his proposal. We thank an anonymous reviewer for drawing our attention to this new book.

relationalists' Modus Tollens. Notwithstanding this seeming impasse, substantivalism has enjoyed the apparent advantage of being at the basis of successful physical theories, from Newtonian classical mechanics to General Relativity. Relationalism has then the burden of proof –to show that successful physical theories can be reformulated in a relational vein.

Even though the debate between relationalism and substantivalism is still open, Barbour and collaborators have made since the 1970s a big effort to show how a relational ontology can accommodate our physics by developing shape dynamics as a general framework for physics (e.g., Barbour 2012, Mercati 2018). This includes proposals of how general relativity (e.g., Gomes and Koslowski 2013) and quantum mechanics can be formulated in this relational framework (e.g., Dürr et al. 2019). Suppose for the sake of the argument that shape dynamics or something similar can work, in the sense of matching today's physics. As physical theories, the resulting relational theories will be more complicated than standard classical mechanics, Einsteinian special and general relativity, or quantum mechanics (that are all formulated in terms of absolute time or space-time, at least originally). But simplicity in representation is one thing, and simplicity in ontology another one. The two should not be conflated. The mere possibility of a reformulation is already an argument against substantivalism.

Since we are mostly interested in the metaphysical coherence and viability of relational primitivism, we simply take for granted that relationalism is overall compatible with our best physical theories or empirically adequate formulations thereof. Although there may be different ways to support temporal relationalism, relational primitivism about the direction of time as we defend it here is mainly inspired by Leibnizian relationalism. We believe that Leibnizian relationalism offers the main ingredients for a metaphysically appealing relational framework, even though we do not fully endorse a full-fledged Leibnizian metaphysics, as it will be clear later on. For instance, it has been suggested that Leibnizian relationalism entails modal relationalism (Belot 2011); but our arguments are independent from whether modal relationalism is true or not, we remain non-committed in that respect. Our claim is thus much more circumscribed and exclusively related to temporality and its directedness. That said, a primitive direction of time is not only perfectly compatible with Leibnizian relationalism, but it is also required by any empirical adequate application of it. The upshot is that within Leibnizian relationalism on time, if the basic ontology engages in temporal relations (and consequently change), then a primitive direction of time must be assumed too. So, we submit that the following conditional holds: if Leibnizian relationalism on time is true, then relational primitivism about the direction of time must also be true. If we succeed in showing this, then we not only open up a new family of logically coherent views on the direction of time, but also free primitivism from the charge of being committed to substantival time and thus to a non-parsimonious ontology.

As it was mentioned in passing before, *primitivism* is simply the thesis that some entity, property, or relation in the basic ontology is left unexplained because it is taken to be irreducible. When it is said that the direction of time is primitive, it is said that the direction of time is unanalyzable in non-temporal terms. Or, similarly, that it is irreducible to non-temporal entities, properties, or relations. But this does not per se imply that if the direction of time is primitive, time itself must be a substance: something else in the ontology can be temporal and primitively directed. The main argument in favor of primitivism about x is to show that x plays a paramount explanatory role. By the same token, the main argument against primitivism about x is to show that x is superfluous in the explanation and can be obtained from more fundamental posits.

Leibnizian relationalism about the direction of time holds that any statement or fact about the direction of time is nothing but a fact or a statement about *temporal relations* that matter (as primitive substance) is engaged in. Thus, time (and space) are regarded as ideal, not as independent substances. This is clear in Leibniz's metaphysics, where space and time are regarded as "beings of reason" (*entia rationis*). In a three-layer metaphysics composed of fundamental substances (the monads, *substantiae*), well-founded phenomena (matter, *quasi-substantiae*) and ideal beings (numbers as well as space and time, *entia rationis*), there is nothing like space and time in the "metaphysical ground floor", but they are obtained through abstraction at a higher level (the ideal level). This is not the place to dig into Leibniz's metaphysics, but this is so primordially because space and time are wholes that express indeterminate, continuous possibilities (in coextension and duration, respectively; see Leibniz 1875, VII, 562). In virtue of this, they can only be abstract and ideal since substances are concrete. Yet, as Leibniz repeatedly emphasizes, the ideality of space and time does not make them mere fictions, but they do represent truths about well-founded phenomena, and secondarily, about the fundamental substances (see Hartz and Cover 1988, 512). Once again, it is not necessary to subscribe to Leibniz's metaphysics completely to endorse this specific point –space and time are ideal because they are not substances, nor properties of substances, but abstract entities that do express truths about the ontology, in particular, about the *relations* among relata in the ontology.

It is important to stress two things. First, as matter engages in temporal relations, there is something primitively temporal in the ontology. But this does not mean that what is temporal in the ontology is an independent substance. Hence, Leibnizian relationalism, as we take it, postulates temporal *relations* as primitive, but not time. This amounts to reductionism about time, but not reductionism about the *direction* of time since it can be identified with the direction of temporal relations. Second, if relativistic theories are considered, temporal relationalism will become *space-time relationalism*, since the theoretical structure of those theories assumes that time and space are dimensions of the same structure, the space-time. Nonetheless, we have preferred to make our point for space *and* time rather than for space-time for simplicity in the representation and argumentation. The core of our argument can be straightforwardly extended to space-time, since the temporal dimension is not equivalent to the spatial dimensions (the former, for instance, sets the causal structure of the theory, while the latter do not).

So, be that as it may, space and time are nonetheless different (be different substances, relations, or dimensions of the same structure). Leibnizian relationalism upholds the difference by distinguishing between space as the "order of possible coexistence" and time as the "order of succession". In this sense, the ideality of space and time *reduces* to the relations among relata that deliver, on the one hand, an order of coexistence and, on the other, an order of succession. The crucial point here is that they are different orders because matter engages in different *types* of relations in each case. We call the order of coexistence “configuration of matter”. A configuration of matter is *maximal* when it comprehends the totality of basic entities, their properties (if any), and a complete class of world-making relations that glues everything together. A class of world-making relations is necessary to speak of *one* configuration of matter, as a unity, to which all the basic entities in the ontology belong. This idea traces back to David Lewis’ metaphysics, when he says that a world is unified by spatiotemporal interrelation of its parts (worldmates) (Lewis 1986, 71).

Following partially the Lewisian tradition, we take for granted that a configuration of matter requires *spatial* relations as world-making relations. This means that the basic entities in the ontology are glued together because they engage in spatial relations among each other. When all the basic entities, their properties (if any), and the class of all the spatial relations (relative distances among the basic entities) are taken into account, we have a *maximal configuration of matter* (**MCM**), which we can represent as a set:

(1) $\mathbf{MCM} = \{e_1 \dots e_n, P_i \dots P_k, < R_j >\}$

Where $e_1 \dots e_n$ refers to the set of all basic entities, $P_i \dots P_k$ to the possible properties that can be instantiated, and $< R_j >$ to all spatial relations (i.e., the relative distances among the basic entities). Note that a **MCM** at an instant is just a complete basic ontology. The key aspect of relationalism is that all facts and statements about space *reduces* to distance relations among relata: the basic ontology does not include anything like space as an additional item, but only *spatial* relations. Space is in this sense an ideality (abstraction) that takes all the relata and their distance relations as a whole, but it is not a “container” or independent substance in which the basic entities are located, or the fundamental properties instantiated.

A **MCM** can be asymmetric, in the sense that the spatial distribution of the basic entities is not uniform. For instance, if the basic ontology is composed of individual substances, some of them may maintain closer spatial relationships with some, while maintaining more distant spatial relationships with others. It can then be said that the configuration of matter exhibits *variation*, that is, the distance relations among relata are not symmetrical. For the sake of simplicity, consider a billiard table: some billiards balls may be concentrated around one of the billiard pockets, while others may be at a more distance. If the billiard table is regarded as a maximal configuration, then it displays variation in the sense that the distance relations among billiard balls are not symmetrical.

MCM

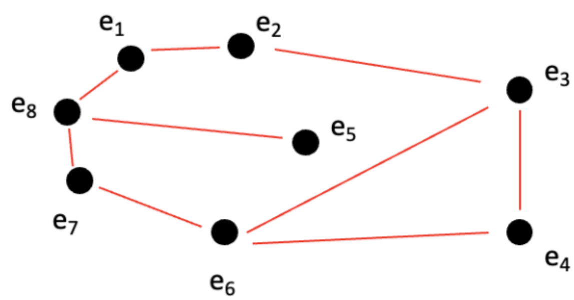

Figure 1. A configuration of matter where variation within the configuration is given by difference in the relative distance relations among the basic entities (e_n)

A **MCM** can then display variation *within* the configuration. But it is of course possible that a **MCM** was different because it exhibits a different pattern in the distance relations or the instantiated non-relational properties (if any). When two different **MCM**s are so conceived, there are at least two possible connections between them. One of them is *modal*: two **MCM**s are just two possible ways in which distance relations or basic entities' properties vary. Thus, $\mathbf{MCM}^{\star}$ may be one configuration of matter and $\mathbf{MCM}^{\dagger}$ another possibility:

(2) $\mathbf{MCM}^{\star} = \{e_1 \dots e_n, P_i \dots P_k, < R_j >\}$
$\mathbf{MCM}^{\dagger} = \{e_1 \dots e_n, P'_i \dots P'_k, < R_i >\}$

To emphasize, $\mathbf{MCM}^{\star}$ and $\mathbf{MCM}^{\dagger}$ are different **MCM**s since variation within them exhibits different patterns (in the instantiation of their properties or in the distance relations among relata). In so far as the connection between $\mathbf{MCM}^{\star}$ and $\mathbf{MCM}^{\dagger}$ expresses two different **MCM**s as *possibilities*, the connection between them is exclusively modal. This does not per se implies the existence of *possibilia* (or modal relationalism in the sense of Belot 2011), but simply the fact that it is possible to conceive alternative configurations of matter. To come back to the billiard table example, billiards balls can be concentrated around one of the pockets, but they might be spread out throughout the table; or they might be symmetrically distributed around pockets. All of them merely represent different possibilities that display different patterns in the variation within the configuration.

But there is another way to connect two different **MCM**s: *temporal*. When the connection between, say, $\mathbf{MCM}^{\star}$ and $\mathbf{MCM}^{\dagger}$ is temporal, we talk about one *changing* **MCM**, where each of the **MCM**s, as $\mathbf{MCM}^{\star}$ and $\mathbf{MCM}^{\dagger}$, become instants in a temporal series. What connects different **MCM**s in one changing **MCM** is a *new relation* that is irreflexive, asymmetric and transitive. In this way, different **MCM**s are once again glued together through a second type of world-making relation, which renders a unified *changing* **MCM**: temporal relations are a type of world-making relation because they entitle us to talk about *one* changing **MCM**, and not simply about two possible different configurations of matter. While within a **MCM** there may be, e.g., spatial variation, between different **MCM**s that belong to a changing **MCM** there is *change*. We said previously that a **MCM** is equal to a temporal instant:

(3) $\mathbf{MCM}^{\star} = t^{\star}$

If $\mathbf{MCM}^{\star} \neq \mathbf{MCM}^{\dagger}$ and there is a temporal relation between them, then $\mathbf{MCM}^{\star} = t^{\star}$ and $\mathbf{MCM}^{\dagger} = t^{\dagger}$, where $t^{\star} \neq t^{\dagger}$. It is possible now to define a *changing* **MCM** as follows.[3]

(4) $changing\ \mathbf{MCM} = \{\mathbf{MCM}^{\star} \ldots \mathbf{MCM}^{\dagger}, < T_k >, \}$

Informally, a changing **MCM** is a series of **MCM**s at different instants, glued together by temporal relations ($< T_k >$).

Two points are in order. First, in a relational ontology, a **MCM** is *identical* to a temporal instant (t) (see (3)). So, it is not the case that a **MCM** "occupies" a temporal instant, as it would be the case in a substantivalist ontology. For the sake of simplification, the series of temporal instants could be eliminated in the definition of a relational changing **MCM** (4). Second, why is there change at all? Or differently, what does justify passing from a static **MCM** to a changing **MCM**? Once again, it is matter of explanatory resources. If a **MCM** did not change, then the entire ontology we have is the **MCM** and its supervenient elements *at an instant*, where the distance relations and the properties instantiated by the basic ontology (if any) remain the same. This is clearly a simple picture of reality, but with a serious drawback: everything in the ontology (in the basic and the derivative) is static. The experienced temporal becoming, and the temporal relations themselves, would be mere illusions, remaining unexplained. If the metaphysical project was about explaining why there seems to be temporal becoming, a direction of time, or even temporal relations, a static **MCM** cannot be the answer: such a metaphysical framework lacks the conceptual tools to explain why the world seems to be temporal at all. Since a changing world cannot arise out of a static world, change must enter the picture as a primitive for explanatory reasons. The transition from a **MCM** to a changing **MCM** is then postulated. Therefore, the burden of proof is on those who want to dispense with the change in the fundamental ontology: they must explain why the change is redundant in the explanation of why the world seems to change.

Having accepted that change enters the picture as a primitive, the nature of change holds the key to the direction of time and why it is also primitive. In imposing that a **MCM** changes, it is possible to conceive a changing **MCM** where different ***MCMs*** are ordered and glued together by temporal relations. But what is the difference between temporal relations and spatial relations? We

[3] $t^{\star}$ in this case works as an index and does not represent anything in the ontology besides a **MCM**.

said previously that differences in spatial relations or instantiated non-relational properties deliver variation within a **MCM**. We now say that differences in spatial relations or instantiated non-relational properties between different **MCM**s deliver change, given by temporal relations gluing together the different **MCM**s at different instants. Thus, in imposing change, temporal relations are ipso facto imposed in the ontology. But temporal relations are fundamentally dyadic two-term relations that are asymmetric, irreflexive, and transitive. A **MCM** that changes are therefore two **MCM**s at different instants related by a dyadic two-term relation

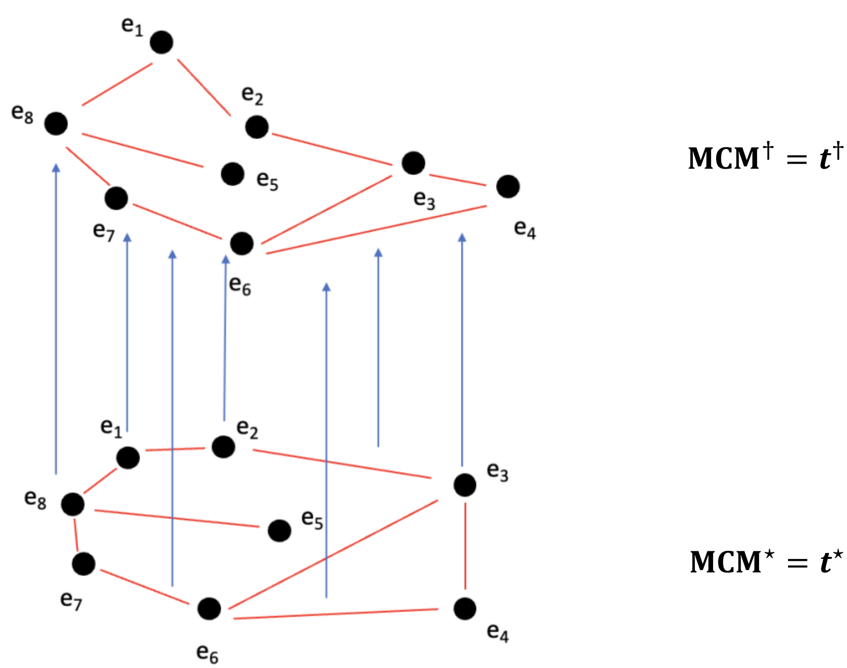

Figure 2. Change between two different configurations of matter. Blue lines represent temporal relations, while red lines represent spatial relations. Basic entities (e_n) then change their position relative to each other.

That they are related by a temporal relation tells us that one of them is earlier than the other. *First* comes $\mathbf{MCM}^{\star}$ and *then* $\mathbf{MCM}^{\dagger}$. This is what being in a temporal relation means. It is because different **MCM**s are engaged in temporal relations that they are not just merely alternative possibilities, but *one changing* **MCM**. In that sense, temporal relations are also world-making relations. What is then special about temporal relations as world-making relations different from spatial relations is that the former is *intrinsically* directed, while the latter is not. That is, temporal relations establish earlier/later relations between different **MCM**s. It is easy to see that spatial relations lack the structure to do so since a series of points in a spatial series does not have any intrinsic direction: no point comes earlier than another one, but it is just "in between" two other points. This is clearly stated by C.D. Broad:

> In the temporal series there are two intrinsically opposite directions, earlier-to-later and later-to-earlier. In the linear spatial series, there is no intrinsic direction. If direction is to be introduced, this must be done extrinsically, either by reference to motion along the line (and therefore to time) or by reference to the right and left hands of an external observer, or in some other way (Broad 1937, 69)

This distinction between spatial and temporal relations implies a distinction between variation and change. If temporal relations are intrinsically directed, then change must also be intrinsically directed. After all, change is just to be engaged in temporal relations. An analogous distinction can be traced back to Leibniz himself. In analyzing phenomenal change, he distinguishes between points and instants. In a letter to Louis Bourguet, dated 5th of August 1715, Leibniz says

> I admit however that there is this difference between instants and points – one point of the universe has no advantage of priority over another, while a preceding instant always has the advantage of priority, not merely in time but in nature over the following instants. (Leibniz 1989: 664; translated from Leibniz 1887, 581-582)

This passage is crucial to understand the primitiveness of the direction of change in Leibnizian relationalism as we endorse it. For Leibniz, an *instant* is a momentary state of the world of successive phenomena (see Anapolitanos 1999, 136), what we have called a **MCM** that belongs to a changing **MCM**. The distinctive feature of instants is hence an in-built priority (or directedness), a metaphysical difference that distinguishes them from points–instants stand always in a later/earlier relation; if they did not, they would not be instants, but points in mere variation. They acquire this essence because they are generated by the change of the basic ontology. It is in this way that **MCM**s (instants) can then be seen as momentary states of the basic ontology that result from the primitive change of the basic ontology as it unfolds. The Leibnizian understanding of change and temporality has indeed a Lewisian resemblance in this respect: change is nothing but just one single instant following another, and this constitutes the unfolding or evolution of the basic ontology. This unfolding is *intrinsically* ordered and directed because it is not made of points, but results in instants (see Arthur 1985, 277). Undirected change is then meaningless, because being directed is a distinctive feature of what change *is*.

In philosophy of time, that change is primitive in this sense delivers the structure of a B-series of time, where any temporal predicate can be reduced to temporal relations. It is then not necessary to rely on an A-structure to have genuine change or a direction of time: all there is to change is that the different **MCM**s are engaged in dyadic, asymmetric temporal relations. It is also important to note that in our view these temporal relations are also primitive if change is primitive (see Oaklander 1998). Of course, the basic ontology might be changeless, and therefore, it might lack of temporal relations. But once change is postulated as primitive, temporal relations are also primitive as well. This means that it is not necessary to reduce temporal relations in terms of, for instance, causal relations (as Leibniz did; see also Grünbaum 1963 and Mellor 1998).

Once change is introduced as primitive and explained in terms of temporal relations, the primitive nature of the direction of time in Leibnizian relationalism follows almost immediately. If change is intrinsically directed, then temporal relations are so, too. But time is *nothing but* an ideality that derives from temporal relations and their relata when conceived as a whole. Therefore, in the ontology time is identical with change, and if change is directed, time must also be primitively directed: the direction of time is *nothing but* the direction of change, that is, the directed unfolding of a changing $\mathbf{MCM}$. To explain it differently: $\mathbf{MCM}^{\star}$ changes to $\mathbf{MCM}^{\dagger}$ as a primitive fact. But change between different **MCM**s is different from variation within a **MCM**. The difference boils down to the sort of relations that hold in each case. Change entails temporal relations, which are dyadic relations that are intrinsically directed and asymmetric, while variation does not. Temporal relations therefore impose a direction as they express the temporal fact that one maximal configuration of matter (say $\mathbf{MCM}^{\star}$) is earlier than another one (say $\mathbf{MCM}^{\dagger}$). This is what it means that there was change between $\mathbf{MCM}^{\star}$ and $\mathbf{MCM}^{\dagger}$. But all there is for the direction of time in Leibnizian relationalism boils down to the primitive directness of the temporal relations and of change. If change (and temporal relations) were not primitively directed, then the distinction between variation and change would blur, and with it, the distinction between spatial and temporal relations would disappear. If this were so, then the basic ontology could not change since it could only engage in spatial relations. The drawback is the explanatory limitations that were mentioned before. Therefore, it is metaphysical coherence and empirical adequacy which call for a distinction between variation and change. The distinction is that change is directed, and so is time.

Parsimony is one of the main virtues that guided relational primitivism as an alternative to temporal substantivalism. Our view is compatible with other metaphysical projects that also champion parsimony as the norm. For instance, Michael Esfeld and Dirk-André Deckert (2017) have put forward a minimal, parsimonious ontology where the primitive ontology consists in matter points that are individuated by distance relations. But matters points are propertyless, so change can only be change in distance relations (and not in a difference in the instantiated properties at different instants). In this case, therefore, a more parsimonious **MCM** (**PMCM**) will be given by:

(5) $\mathbf{PMCM} = \{e_1 \dots e_n , < R_j >\}$

Since distance relations individuate the matter points, they alone may yield variation (i.e., the configuration of matter points is not globally symmetrical). Standing in distance relations is all there is to the matter points. Thus, as they lack basic intrinsic properties, there cannot be an intrinsic change of the matter points. Consequently, in so far as the matter points are concerned, the basic ontology is changeless. However, this view could not account for phenomena if the distance relations among matter points did not change. Hence, change must primitively come into the picture, which brings temporal relations in the ontology: the **PMCM** also changes, engaging in temporal relations consequently. Supposing that the matter points are permanent, the variation in the distance relations constitutes a plurality of distinct matter points and thus a configuration of them, whereas change in the matter points consists in a change of the distances between them. Here, again, there is change only if it is directed as a primitive matter of fact, because otherwise it would just be mere variation in distance relations within a **PMCM**. And if this were so, we would not be able to distinguish between a relation that constitutes *different* matter points and a change in the *same* matter points.

It is easy to see how relational primitivism so conceived can make sense of basic physics. For the sake of illustration, it is worth giving some concrete examples. First, consider a field ontology in which the field is represented by an electromagnetic field and its behavior by Maxwell's equations. Mathematically, we can describe such a field as vector fields, namely the electric and magnetic fields, having a value defined at every point of space and time, $\boldsymbol{E}(x, y, z, t)$ and $\boldsymbol{B}(x, y, z, t)$. Let us focus on the electric field ($\boldsymbol{E}$) and suppose that it is inhomogeneous as its magnitude and direction vary as we move along a space region. An easy example is given by placing a charged metal ball in some spatial region, which generates a field that is inhomogeneous. Insofar as the magnitude of the electric field is concerned, it varies as we come closer to (or move away from) the center of the charged metal ball. This illustrates variation within a **MCM**: the values of ***E*** and ***B*** vary *spatially* along the field**.** And we can make sense of variation by relying on spatial relations.

Take now the same inhomogeneous field with a certain configuration at some temporal instant. We know that the $\boldsymbol{E}(x, y, z, t_1)$ varies as we move along the spatial region. Suppose now that we move the charged ball throughout the spatial region, but we only focus on what happens at one point. Insofar as different temporal instants are now considered, the values of ***E*** at one point will now *change*. If we could see the electric field from outside as time passes by, what we probably would see is a wavy variation, where each point will have different ***E*** values depending on how close it is from the moving charged metal ball. But it is clear now that the change in the value of ***E*** at one point requires a different relation, namely, a temporal relation. This relation tells us which was the earlier state of that point in the field at an instant, and what it is the state at a later instant. The change from one to the other is directed.

As another example, consider the contrast between a poker *being* hot at one end and cold at the other one. If we conceive of the poker as a whole configuration of matter, then it can be regarded as a **MCM**. The difference in temperature between one extreme and the other then displays variation within a given configuration. But the poker as a **MCM** could change from cold to hot (Geach 1965, 323). Now, different instants of the poker as a *changing* **MCM** are related by temporal relations. Variation in the former scenario is grounded in *spatial* relations, while change in the latter case is given in terms of *temporal* relations. It is clear that change involves variation, but variation is not enough to account for change.

It is worth asking whether relational primitivism entails a single direction of time for the whole universe or rather multiple frame-relative directionalities.[4] If the physical world were a classical relational world (that is, a relational formulation of a Newtonian world), it is clear that the direction of change (i.e., the direction of time) would span across all universe's events. In that case, the direction of change would be unique and absolute. Yet, our world is more likely relativist.

[4] We thank an anonymous reviewer for raising this concern.

Katherine Fazekas (2016) argues for multiple B-series in a Minkowskian space-time, delivering "multiple invariant temporal orderings" (Fazekas 2016, 216). Her argument is that special relativity can only establish genuine invariant temporal orders of time-like separated events; but for those events that are space-like separated, alternative reference frames might order events differently. It would follow from this that there cannot be a universal temporal order for *all* events, that is, there can only be multiple invariant temporal orderings. Would relational primitivism also entail that in a relativistic world there should be multiple B-series, as Fazekas argues?

Not necessarily. One of the assumptions in Fazekas' argument is that "if a B-series is defined as a temporal order of time-like related events, that B-series is part of the *intrinsic structure of space-time*" (Fazekas 2016, 217. Italics added). It means that Fazeka's multiple B-series depend on a subtantivalist-like view of space-time. Clearly, primitivism relationalism is at odds with this assumption and would explain relativity phenomena differently. Two alternatives can be proposed. One of them is to conceive B-series as a frame-relative global order of events: all events (time-like and space-like separated) can be temporally ordered from a specific reference frame. The order would then be global, but frame relative. A second alternative, closer to Fazekas but that does it without equipping space-time with an intrinsic structure, is to claim that only causally related events (time-like separated) can be meaningfully temporally ordered because they do engage in temporal relations. Non-causally related events (space-time separated) cannot be temporally ordered whatsoever because they are not engaged in temporal relations with respect to a given reference frame. It is not that temporal ordering can vary; there is no temporal ordering whatsoever, in the same sense as there is no spatial order. Under relational primitivism this view makes sense since what it makes time up is temporal relations and change.

Before concluding, let us mention two possible objections to our view. First, it may be argued that change cannot genuinely impose a direction because change can be reversed: it is possible that $\mathbf{MCM}^{\star}$ changes to $\mathbf{MCM}^{\dagger}$, or that $\mathbf{MCM}^{\dagger}$ changes to $\mathbf{MCM}^{\star}$. If the direction of change can be reversed, then the direction of time, too. And two directions of time are not a direction at all. Two comments are in order here. To begin, let us call the change from $\mathbf{MCM}^{\star}$ to $\mathbf{MCM}^{\dagger}$ the changing maximal configuration $\mathbf{CMCM}$, and the change from $\mathbf{MCM}^{\dagger}$ to $\mathbf{MCM}^{\star}$, the changing maximal configuration $\mathbf{CMCM^{T}}$, where the latter is the time-reversed of the former. Since in Leibnizian relationalism time reduces to temporal relations and change, $\mathbf{CMCM}$ and $\mathbf{CMCM^{T}}$ represent *different* changes: there are facts about the properties and/or the distance relations among relata that are connected by different temporal relations in each case. Going from $\mathbf{MCM}^{\star}$ to $\mathbf{MCM}^{\dagger}$ is different from going from $\mathbf{MCM}^{\dagger}$ to $\mathbf{MCM}^{\star}$ because the direction is different, and they therefore imply a different way to connect temporal instants. In other words, both changes could be possible, but they are different because they differ in the direction. It is an empirical question whether $\mathbf{CMCM}$ and $\mathbf{CMCM^{T}}$ are physically equivalent, or whether only one of them genuinely represents the phenomena of the real world. If they were physically equivalent in the sense that our best physical theories could not tell a physical difference between them, then this fact could reveal that the directionality of change is redundant for all physical purposes. And this could well motivate to also eliminate the distinction metaphysically. But the argument to go through requires further assumptions. For instance, that there is an effective way to represent the time-reversed version of **CMCM** within physics, which can be challenged. After all, the symmetry of time reversal is a property of highly idealized dynamical equations that aims to reverse motion, and it is not clear if it amounts to a reversion of the temporal relations in the ontology (see Lopez and Esfeld 2023 for a similar argument within Humeanism). One may furthermore hold that it is also not obvious that physical symmetries in our representation of phenomena are suitable guides to metaphysics (see Lopez 2023).

Second, it can be argued that there is no fundamental distinction between space and time, between variation and change, as the metaphysical tradition has had it. The argument could run as follows. Our assumption was based on explanatory necessity: to account for phenomena and temporal evolution in physics, change must be primitive in the metaphysics. The metaphysical assumption of a primitive change plays therefore an explanatory role since it explains why the world seems to change. If we endorse the view that the world seems to change but it is fundamentally changeless at the fundamental level because there is no distinction between variation and change, then there is a gap in the explanation: how is a seemingly changing world obtained from a changeless basic ontology? But such a gap is justified on physical grounds: cutting-edge physics (as some theories of quantum gravity propose) entails that reality is changeless at bottom (see Huggett, Vistarini and Wüthrich 2013). A deference to physics puts our assumption into question: if any of the proposals to quantify gravity is successful, and it implies that physical reality is changeless at bottom, then relational primitivism must be false. Two comments on this. First, deference to physics should be taken with a grain of salt: deference is never absolute because physics frequently introduces elements in the theories that are meant to play only a representational role. Also, different formulations of the same theory introduce different elements, leading to metaphysical underdetermination that cannot be overcome by deference to physics. But even accepting complete deference, the argument is not conclusive as things stand now: theories of quantum gravity remain speculative proposals without empirical confirmation for the time being. Our initial claim was that we take relational primitivism to be a metaphysically coherent and attractive view that does not conflict with *empirically adequate* physics as it stands.

4. Final Remarks

In this paper, we have introduced a new member in the family of primitivism about the direction of time –relational primitivism. According to it, time reduces to change, and the direction of changes ushers in the direction of time. The difference between change and variation follows from distinguishing between spatial and temporal relations. Relational primitivism holds that the crucial difference between spatial and temporal relations is that the latter are primitively directed, while the former are not. The rejection of this assumption brings about the collapse between spatial and temporal relations, rendering the ontology changeless. Our arguments in favor of relational primitivism also show that it is not true that primitivism about the direction of time entails temporal substantivalism. It is then possible to defend a minimalist view of time, but to endorse primitivism about the direction of time. It enjoys the best of two worlds –the strong explanatory advantages of primitivism to explain temporally directed phenomena and the ontological parsimony of temporal relationalism.

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