THE ONE-WAY VELOCITY OF LIGHT AND THE ONTOLOGY OF TIME

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ABSTRACT: Some philosophers have attempted to show that the thesis according to which the one-way velocity of light cannot be empirically determined (a thesis referred to in this paper as the **IOV**) opens a possibility for defending some A-theoretic ontologies of time in the context of relativistic physics, for, as they suggest, it can make a crucial contribution to developing an argument in favor of the definability of *absolute simultaneity*. Other authors, however, have taken the same thesis, i.e., the **IOV**, as pointing to the conclusion that some form of B-theory is the true metaphysical view of reality. In this paper, I first attempt to show how these two lines of reasoning can be traced back to two different assumptions regarding the **IOV**—construing this indeterminacy as either an *epistemic* or an *ontic* restriction—and I suggest that as long as each side takes one of these *assumptions* for granted, without providing further justification for their respective position, no decisive metaphysical conclusion can be reached. I then argue that a more promising avenue emerges when we consider a reverse line of reasoning. Rather than *deducing* a metaphysical view of time given a preferred assumption regarding the **IOV**, one can consider defending an assumption regarding the **IOV** given a preferred metaphysical view of time. This route can be expressed in terms of inference to the best explanation. Finally, I argue that the B-theory offers a better explanation of the **IOV**.

KEYWORDS: one-way velocity of light, conventionality thesis, absolute simultaneity, metaphysics of time, A-theory, B-theory

1. Introduction

Much work in the literature on the philosophy of time has been devoted to an assumption made by Einstein in giving his *operational definition of simultaneity*,[1] namely, his assumption concerning the isotropy of the velocity of light. Without appealing to an assumption concerning the one-way velocity of light, it has been argued that any attempt to synchronize clocks using a light signal would face a circularity, since in order to synchronize the clocks, the one-way velocity of light is needed, but in order to measure this one-way velocity, two distant synchronized clocks are needed. As a consequence of this circularity, it has been argued that it is *impossible* to empirically determine the value of the one-way velocity of light (a

[1] The definition will be provided in the following section.

thesis which we call hereafter the *in-principle* indeterminacy of the one-way velocity of light, or the **IOV**).

The conventionality thesis about simultaneity (developed by Reichenbach (1958, 123–35) and Grünbaum (1973, 342–68)) stresses the circularity mentioned above and avoids committing to Einstein's assumption concerning the one-way velocity of light via Reichenbach's *generalization* of the definition of simultaneity, famously called *ε-Synchronization*.

The literature on the **IOV** contains two general strands. First, there have been attempts either to refute it by presenting some physical methods for measuring the one-way velocity of light (for example, Ellis and Bowman 1967; Greaves, Rodríguez, and Ruiz-Camacho 2009), or to prove that the equality of the speed of light in all directions is the only possibility in Minkowski space-time (Malament 1977). However, many philosophers insist that these attempts leave the **IOV** untouched (for some criticism of the use of physical methods for measuring the one-way velocity of light see, for example, Salmon 1977, Janis 1983, and Norton 1986; and for criticism of Malamet's attempt see Grünbaum 2010; see also Rynasiewicz 2012 for a discussion. Janis 2018 contains an excellent discussion of these attempts and their associated problems. For a discussion of the conventionality thesis, see Jammer 2006).

Second, there has also been work—although remarkably little—on the *ontological implications* of the **IOV**, that is, the possible consequences that the **IOV** might have for the debate over metaphysical views in the philosophy of time, and especially for debates concerning the reality of an absolute relation of simultaneity between events and its consequences for debates over alternative ontologies of time. It is this second strand that concerns us in this paper.

Numerous ontological theses have been proposed in the philosophy of time, differing both in terms of which class of events—past, present, or future—they regard as real, and in whether they recognize a privileged present.[2] However, for reasons that will be clarified in this paper, what suffices for our purposes here is a broader classification of views into two general types: absolutism and non-absolutism. Let us call 'absolutism' the view that simultaneity is an absolute objective physical relation between events that partitions reality into equivalence classes of *simultaneity planes*, in contrast to 'non-absolutism' which simply is the denial of

[2] For example, according to presentism, only the present exists; according to the block universe view, all times—past, present, and future—equally exist and there is no privileged present; according to the moving spotlight view, although all events (past, present, and future) exist, there is nevertheless a privileged present; and according to the growing block theory, only the past and present exist.

absolutism. This partitioning is absolute, according to absolutism, in the sense that it remains invariant under transformations between inertial frames of reference. Thus, in this paper, what we will primarily set in opposition as two rival metaphysical views of time is not A-theory and B-theory,[3] but rather what we refer to as 'absolutism' and 'non-absolutism.' Although A-theory is often associated with absolutism, it is not necessarily an absolutist view. Some philosophers have defended certain forms of A-theoretic views within the context of Minkowski spacetime, which is non-absolutist. Conversely, some absolutist spacetimes, such as the Newtonian or Galilean, are entirely consistent with eternalism, which represents a B-theoretic ontology of time.

There are two general ways in which the IOV has been addressed in the context of the discussion of the metaphysical views of time. Ben-Yami (2015) argued that this indeterminacy would undermine the famous Putnam–Rietdijk argument for eternalism (Putnam 1967; Rietdijk 1966).[4] Tooley (1997) and more recently Cohen (2016) have attempted to show that the IOV opens a *possibility* for defending an A-theoretic model of temporal reality, for it can be used to argue for the *definability* of absolute simultaneity and therefore absolutism in the context of relativistic physics. (This argument will be examined in more detail in section 4.) This possibility, which the IOV might open up, amounts to revising the standard formulation of Special Relativity. On the contrary, Weingard (1972) and Petkov (1989 and 2008) argued that the IOV not only refutes absolutist A-theoretic models of temporal reality but has the ontology of (non-absolutist) eternalism as its only consequence (for a more detailed taxonomy of positions, see Thyssen 2019).

At first sight, it seems strange that there should be two lines of argument, beginning *prima facie* with the same premise, yet resulting in *radically different* metaphysical conclusions concerning temporal reality. However, as we will see, these two lines of reasoning can be traced back to two radically different assumptions regarding the IOV. One can construe this indeterminacy as either an *epistemic* or an *ontic* restriction, and as long as each side takes one of these assumptions for

[3] The debate between the A-theory and the B-theory centers on whether reality is fundamentally structured by a dynamic, objective 'now' (A-theory) or by static temporal relations (B-theory). Roughly, the A-theory holds that time essentially involves an objective distinction between past, present, and future, and that there is a genuine temporal becoming or passage. According to the B-theory, there is no objective distinction between past, present, and future, and all times and events are equally real, embodying temporal being rather than becoming. (For an articulation of positions, see Dyke 2021.)

[4] For a recent discussion of the Putnam–Rietdijk argument, see Peterson and Silberstein 2010 and Amiriara 2021.

granted, without providing further justification for their respective position, no decisive metaphysical conclusion can be reached.

After setting the stage by introducing the conventionality thesis (section 2), I attempt to show that the two lines of reasoning mentioned above implicitly adopt assumptions regarding the IOV without clearly or adequately discussing them (section 3). As we shall see, the structure of their arguments reflects this: they begin with the phenomenon of IOV and proceed toward evaluating its consistency or inconsistency with absolutism or non-absolutism. Tooley and Cohen argue that IOV is *consistent* with absolutism (section 4), whereas Petkov contends that it is not (section 5). It should be noted here that although Petkov's claim of inconsistency seems to rest on a deduction of non-absolutism from the IOV, Tooley and Cohen's notion of consistency does not involve any such deduction of absolutism.[5]

Finally, in section 6, I first attempt to make the point that leaving the distinction unaddressed risks begging the question against the opposing view. I then propose a new approach: namely, to frame the two assumptions as competing *explanatory* proposals, in the sense that one might argue that one of them offers greater explanatory power with respect to the IOV. That is, rather than simply assuming a particular view of the IOV and drawing metaphysical implications from it, we can ask which assumption might better explain the IOV—namely, which metaphysical framework offers the more adequate account of the phenomenon. Thus, one can consider defending an assumption regarding the IOV on the basis of the *explanatory power* that its associated metaphysical view of temporal reality provides in explaining the IOV itself. This route can be expressed in terms of inference to the best explanation. I argue that the metaphysical content of non-absolutist eternalism has such an *explanatory power*. I also seek to show that some elements of this line of reasoning can be found—albeit implicitly and, in my view, problematically—in the works of Petkov and Tooley. I conclude by offering a critique of the likely responses from Tooley and Bourne.

2. The Conventionality Thesis

Roughly speaking, according to the conventionality thesis, the determination of the simultaneity relation between two events, as well as the determination of the one-way velocity of a signal, in an inertial frame of reference, is not a matter of *knowledge* but is *conventional*. This proposal differs from the thesis of the "relativity

[5] Nevertheless, I believe this difference is not important to the overall argument of this paper, as it does not depend on absolutism being *derived* from the IOV. As we shall see (in section 4), the mere claim of consistency is sufficient to indicate a commitment to an assumption regarding the IOV, and the argument can proceed on that basis.

of simultaneity," according to which two inertial frames, having a velocity relative to each other, would determine different sets of events as the simultaneity sets (or simultaneity hyper-planes). The conventionality thesis, instead, is claimed to hold even within a single frame of reference. The thesis stresses the above-mentioned seemingly vicious circle, which manifests itself in the *operational definition of simultaneity* using the synchronization method of distant clocks that are stationary relative to the same inertial frame of reference. In this procedure, known as *Einstein's standard synchrony*, a light signal is used to synchronize two clocks located at A and B, leaving A at time t_A (according to a clock fixed at A). This light signal then arrives at B at time t_B (according to a clock fixed at B) and is then reflected, arriving back at A at time t'_A. These two clocks, it can be said, are in sync iff:

$$t_B = t_A + \tfrac{1}{2}(t'_A - t_A) \qquad (1)$$

However, the above definition rests, as Einstein puts it, on a "by definition" assumption (Einstein 1952), that is, the isotropy assumption according to which the speed of light (in a vacuum) is the same in *any direction*.

There are two ways to avoid this assumption: either to determine the one-way velocity of the signal, or to generalize (1) such that it would not depend on the isotropy assumption. The first way appears to be blocked since, to determine the one-way velocity of the signal, we need two clocks synchronized *beforehand*. However, the second way remains open, for we can generalize the *standard synchronization* to reach *ε-Synchronization*, as Reichenbach has suggested:

> Two clocks placed in spatially separated positions A and B (both fixed relative to an inertial frame of reference K) are in sync iff:
>
> $$t_B = t_A + \varepsilon\,(t'_A - t_A) \qquad (2)$$

What links ε-Synchronization to the conventionality thesis is the admissibility of choosing *any* number between 0 and 1 for the value of ε. Although the choice of ½ for ε *might seem* more intuitive, the conventionalist is motivated by the apparent underdetermination of simultaneity by the physical facts alone, leading to the conclusion that a choice (a convention) is necessary to define it for spatially separated events. This is significant for the conventionalist, as it appears to reveal a crucial conventional—and, for Reichenbach, unverifiable—element at the core of the special theory of relativity. The *only* limitation on choosing a number for ε in (2), it has been claimed, is due to the necessity of preserving the causal ordering. That is, should ε be more than 1, then the return of the signal to A would be earlier than its arrival at B. Moreover, should ε be less than 0, the arrival of the signal at B would be earlier than its departure from A, both of which Reichenbach finds

impossible. Nevertheless, any number between 0 and 1 for the value of ε is admissible, and it will be a matter of *convention* which value is chosen. With the ε-formulation of synchronization and the conventionality of the value of ε, it can be seen how the determination of the one-way velocity of the signal would also be a matter of convention. Suppose that the average velocity of the signal, from its departure from A to its return to A, is C. And C_{AB} and C_{BA} are one-way velocities of that signal from A to B, and B to A, respectively. Then:

$$C_{AB} = C / 2\varepsilon \qquad (3)$$

$$C_{BA} = C / 2(1 - \varepsilon) \qquad (4)^{6}$$

So the conventionality of simultaneity and conventionality in determining the value for the one-way velocity of the signal are inseparable (Jammer 2006, 180).

3. Epistemic vs. Ontic Assumptions Regarding the IOV

As mentioned above, there is a long history of attempts to empirically determine the one-way speed of light in an inertial frame and so to refute the **IOV**. Here we will not focus on these attempts. Instead, let us grant that the **IOV** holds true. One who endorses the truth of **IOV**, when pressed on the grounds of its truth, may articulate one of two distinct justificatory strategies—each reflecting a fundamentally different philosophical stance on the nature of **IOV** itself. First, one can respond that the **IOV** holds because statements concerning the exact magnitude of the one-way speed of light in an arbitrary direction are just cases of *epistemically unverifiable* statements. Second, one can respond that these statements express *ontologically non-factual* states of affairs, that is, states of affairs that lack any ontological counterpart in the external world or posit conditions or structures with no real-world instantiation. An important point to mention here is that it is better to take the first position as one which allows *unverifiable factual* statements, since the requirement that unverifiable statements are *meaningless*, and thus not even eligible to be considered

[6] Given that:

(i) $C_{AB} = AB/(t_B - t_A)$

(ii) $C_{BA} = AB/(t'_A - t_B)$

(iii) $(t'_A - t_A) = 2AB/c$

(iv) $t_B = t_A + \varepsilon(t'_A - t_A)$

the equation (3) follows directly from (i), (iii), and (iv); the equation (4) follows directly from (ii), (iii), and (iv).

As can be seen from these equations, different values of the one-way speeds in the forward and backward directions accord with different values of ε. For instance, if the speed of light from A to B is twice that from B to A, then the value of ε (which is one-half in the standard synchronization equation) becomes one-third.

as factual, stands on a positivistic dogma, i.e., the verification theory of meaning, which today finds little support. Thus, in this paper, we also avoid the dogma that unverifiability implies meaninglessness.[7]

The first option then expresses an *epistemic* restriction, while the second option expresses an *ontic* restriction. That is, the **IOV** is true, under the first position, in virtue of an in-principle epistemic inability *to measure an actual* process in the world; and it is true, under the second position, in virtue of the absence of any corresponding state of affairs in the fundamental structure of reality—that is, there is no fact of the matter regarding the **IOV**.

This recognition of the epistemic/ontic distinction and its relation to the conventionality argument is not new; it figures in a recent paper by Pieter Thyssen (2019); nevertheless, it can be seen as far back as a 1977 paper by Michel Friedman.

In his discussion of the difference between Reichenbach's and Grünbaum's accounts of conventionality, Friedman recognized that

> Reichenbach argues from an *epistemological* point of view; he argues that certain statements are conventional as opposed to "factual" because they are *unverifiable* in principle. Grünbaum argues from an *ontological* point of view; he argues that certain statements are conventional because there is a sense in which the properties and relations with which they purportedly deal do not really exist, *they are not really part of the objective physical world*. Thus, Reichenbach's and Grünbaum's arguments depend on two different characterizations of the difference between conventional and "factual" statements. According to Reichenbach, the "factual"/conventional distinction is just the verifiable/unverifiable distinction. According to Grünbaum, the "factual"/conventional distinction rests on a prior distinction between properties and relations that are objective constituents of the physical world and those that are not. (Friedman 1977, 426; my italics)[8]

[7] Note that the position could be formulated solely in terms of epistemic inaccessibility. For three reasons, however, I prefer to frame it in terms of unverifiability: first, to highlight the historical connection with the positivist tradition and to clarify the issue in relation to that background; second, to make the later quotation from Friedman more concrete; and third, to emphasize that the position in question does not equate unverifiability with meaninglessness.

[8] One might wonder whether Grünbaum is claiming that certain statements—such as those asserting the existence of particular facts—are simply *false* because the relevant facts do not obtain, much like statements found in fictional works such as *Harry Potter*. It is important to clarify that the conventions discussed by Grünbaum (e.g., selecting a standard of congruence or a definition of simultaneity) pertain to *the formulation of a framework* for describing physical reality. Once such a convention is adopted, empirical statements within that framework can be meaningfully formulated and subjected to testing. For instance, the choice of a specific rod as a standard of congruence enables us to empirically determine the geometry of a surface or the lengths of other objects. The conventionality lies in the initial choice of the standard or the definition, or in

The conventionality claim regarding the value of ε—and, consequently, the one-way speed of light and simultaneity—can then be cashed out, borrowing from Friedman, in two *characterizations* of the "convention": non-factual (ontic) and unverifiable (epistemic).[9] Both positions agree that any choice of ε (within the interval [0, 1]) results in empirically equivalent theories; that is, no differences arise with respect to empirical consequences. According to the first position, there is no physical or empirical fact that could privilege one choice over another—the world is such that no particular selection is superior. The second position, as intended in *our* discussion, by contrast, holds that the world does privilege one specific choice, but that choice is epistemically inaccessible.

Before proceeding, a note on terminology is in order. Friedman's characterization of the distinction might suggest that the difference is semantic in nature—that is, a matter of how to interpret the notion of "convention." However, the distinction I aim to explore in this paper primarily concerns the **IOV** itself, rather than the conventionality associated with it. Moreover, the distinction I have in mind pertains to the different answers that parties might offer to the question "Why is the **IOV** true?" In this context, when I am using "assumptions" regarding the **IOV**, I do not intend to refer to a *semantic* disagreement.[10] Rather, I presuppose semantic stability with regard to the **IOV** and argue that the disagreement arises only subsequently.

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attributing certain relations in contexts where there is no intrinsic physical basis for a unique choice—not in the idea that the *entire framework* is fictional or devoid of factual content.

[9] Again, in our discussion, we avoid the dogma that unverifiability implies meaninglessness (see note 7).

[10] It is worth noting why I use the term "assumption regarding the **IOV**" rather than simply referring to a distinction between two "explanations of the **IOV**." I believe that "assumption" is a more fitting term in this context, as it better reflects the role these views play in the structure of the arguments for absolutism/non-absolutism. These are rather background commitments or starting points that shape how each party approaches the **IOV**. Given that, "explanation" may imply a level of explicit consensus or intentional articulation among the parties involved—something I do not believe can be clearly established in this case. Although Friedman did clarify two distinct "points of view" on conventionality (which in this paper is attributed to the **IOV**), it is not evident that the parties under discussion in this paper held clearly defined or consciously articulated explanatory positions regarding the matter. Indeed, one of the main aims of the paper is to explore the debate over absolutism and non-absolutism through the lens of the epistemic/ontic distinction. Referring to these positions as "explanations" of the **IOV** risks suggesting that the parties themselves explicitly offered such explanations. I therefore find "assumption" to be a more suitable term: it implies that these views are *being assumed as explanations* of the **IOV**.

As mentioned before, this epistemic/ontic distinction is not novel. Indeed, Friedman recognized this distinction long before the figures under discussion (Petkov, Tooley, and Cohen) published their contributions. However, none of these authors cites Friedman's work. (Nor even does the more recent study by Thyssen (2019), which directly addresses the epistemic/ontic distinction regarding *conventionality*, make any reference to Friedman either.) This silence I think suggests that the distinction was not consciously thematized in their debates. Clarifying this point is, in fact, the central aim of the next two sections: to explore the role of these underlying assumptions in arguments that appeared many years after the distinction had already been made—at least by Friedman.

4. Absolutism *from* the IOV

Michel Tooley is known for exploiting themes from the conventionality literature to argue in favor of a particular A-theoretic model of temporal ontology that requires an absolute notion of simultaneity (i.e., the growing block ontology).[11] His basic idea is as follows. He argues for the *definability* of the concept of absolute simultaneity in the relativistic setting of the special theory of relativity (hereafter the **STR)**. Of course, it is clear that this concept is not definable in *the standard formulation* of the **STR**. He therefore goes on to *modify* the standard formulation so that the resulting theory permits such an absolute concept. This is where he makes dramatic use of the *ε-Lorentz transformations* developed by John Winnie (1970a, 1970b), with the *ε-formulation* of simultaneity as its core.[12] Specifically, the crucial step here is dropping the isotropy assumption "in favor of the weaker assumption that the average round-trip speed of light is the same in all inertial systems" (Tooley 1997, 339), as well as providing a substantivalist account of space as an enduring entity.

[11] Note that here we restrict ourselves to a debate over the *absoluteness of the relation of simultaneity*. So, the differences between alternative ontologies concerning past, present, and future events will be ignored.

[12] Let K and K′ be two inertial frames in constant relative motion (along the x-axis), with ε and ε′ denoting the synchronization parameters chosen in K and K′, respectively. If the relative speed of K′ to K is v_ε, the ε-Lorentz transformations are given by:

$$x' = \frac{(x - v_\varepsilon t)}{\alpha}$$

$$t' = \frac{\left\{\left(\frac{2v_\varepsilon}{c}\right)(1 - \varepsilon - \varepsilon') + 1\right\}t - x\left\{\frac{2c(\varepsilon - \varepsilon') + 4v_\varepsilon(\varepsilon)(1 - \varepsilon)}{c^2}\right\}}{\alpha}$$

Where,

$$\alpha = \sqrt{\frac{\left(c - v_\varepsilon(2\varepsilon - 1)\right)^2 - {v_\varepsilon}^2}{c^2}}$$

(Winnie 1970b, 234)

We need not go further into his metaphysics of substantivalist space; it suffices for our purposes to grant that a consistent notion of such an entity that he calls *absolute space* can be provided.

Granting this substantial enduring absolute space, Tooley can define absolute simultaneity simply as follows: "E and F are simultaneous relative to some frame of reference that is at rest with respect to absolute space" (Tooley 1997, 343–44). The ε-formulation (see formulas 3 and 4) permits light to have *different* one-way speeds in *different* inertial frames but a constant speed in all directions in the *privileged* frame, i.e., the frame in absolute rest relative to the absolute space. This constancy Tooley calls the "Principle of the Constancy of the Speed of Light Relative to Absolute Space" (1997, 346). This, in turn, entails "The Round-Trip Light Principle," according to which

> the average round-trip speed of any light-signal propagated (*in vacuo*) in a closed path is equal to a constant *c* in all inertial frames of reference. (Tooley 1997, 350)

So, *starting with the assumption that the* **IOV** *holds*, Tooley cooks up a modified version of the **STR**, formulated in terms of ε-formulation, with a consistent statement of the notion of absolute simultaneity.

In another but a very similar line of argument, Yehiel Cohen exploits the **IOV** to *defend* an A-theoretic view of reality. In his article "Why Presentism Cannot Be Refuted by Special Relativity" (2016), he argues for the definability of "an absolute spatially extended simultaneity relation even in a relativistic setting" (2016, 49). Like Tooley, Cohen also exploits the **IOV** to defend an ontological view. His main idea is that in assuming the ε-formulation of the **STR**, the value of ε in each frame of reference can be independently chosen in such a way that all frames agree on the same simultaneous set of events. In this way, an absolute simultaneity relation is definable, he says,

> by employing an appropriate distribution of ε values. This result follows directly from the interesting fact that simultaneity defined by $\varepsilon = 1/2$ in a given inertial frame corresponds to $\varepsilon \neq 1/2$ in another. Hence, to define an absolute simultaneity relation, we simply need to fix $\varepsilon = 1/2$ in an arbitrary inertial frame and then adjust the ε values in the remaining inertial frames such that they will lead to the same result. (Cohen 2016, 49)

Cohen also points out that this possibility of distributing ε values among frames of reference can be clearly stated by Winnie's formulation of the ε-Lorentz transformation. Given this formal possibility, the next step is to grant all this a metaphysical meaning—that is, to hold that among those appropriate distributions of ε values with which the relation of absolute simultaneity is definable, one of them

may correspond to *the actual state of affairs*; that is, that ε could take on an appropriate *objective* value in each frame of reference. As Cohen says:

> Interestingly, some distributions yield an absolute spatially extended simultaneity relation, and it is physically possible that one of them should coincide with reality. (2016, 49)

However, as Cohen admits, because of the inherent circularity in determining the one-way velocity of light, these objective values cannot be discerned. Now it is rather clear that the main idea both in Tooley and Cohen is the same: to exploit the *unverifiability* of the one-way speed of light as grounds for modifying the standard **STR** and, by that means, to make their favored ontology of events (growing block ontology for Tooley and presentism for Cohen) empirically sufficient. It should also be clear, though, that their argument stands crucially on the *epistemic assumption* regarding the **IOV**. Their argument cannot get off the ground under the supposition that the ontic assumption is true. This is because, as Cohen puts it, for one of the distributions that yield absolute simultaneity to be physically possible, it must be assumed that the one-way speed of light has an objective value in different frames of reference—that is, that ε has a privileged and objective value (albeit epistemically inaccessible) in each frame. In other words, that a particular ε-distribution is metaphysically privileged. If the ontic assumption is correct, however, then none of these distributions would be metaphysically privileged. Similarly, when Tooley speaks of the constancy of the speed of light in the preferred absolute frame, he assumes that the value of ε in that preferred frame is a privileged one (namely, ½), and that its value in other frames is determined in accordance with the relative velocity of those frames. As will be discussed in section 6, he then attempts to explain why these values are epistemically inaccessible.

This can provide a line of objection against these arguments. Why, after all, should one prefer the epistemic over the ontic assumption? Let us put aside this problem for the moment and first see another line of argument that exploits the **IOV** to deduce non-absolutist eternalism.

5. Non-Absolutism *from* the IOV

Appealing to the **IOV**, in at least two articles Vesselin Petkov (1989, 2008) attempts to refute what he calls the "three-dimensionality of the world" and, thus, refute presentism as well as defend eternalism. (Weingard (1972) also made a similar point.) His appeal to the **IOV** is evident at the outset since he regards this refutation of "three-dimensional reality" as "the message of the vicious circle involved in any

attempt to determine any[13] one-way velocity and simultaneity of distant events" (Petkov 2008, 180). It should be noted that by a three-dimensional reality, what Petkov has in mind is "a set of simultaneous events at the present moment" (1989, 74), i.e., as expressed in his later work, "the class of events that are absolutely simultaneous at the present moment" (2008, 181). This class is a pre-relativistic reality in which the relation of simultaneity is absolute in the sense that all events are partitioned into equivalence classes of simultaneous events. *Each* of these classes represents a three-dimensional world, a world of events that are absolutely simultaneous with each other and spread over a three-dimensional space. Note that this is equivalent to what we refer to as 'absolutism.' Indeed, his way of discussion in terms of *dimensionality* may be somewhat misleading. First, the debate over three-dimensionality versus four-dimensionality is more commonly understood in the literature as a discussion about *persistence* over time, rather than a direct confrontation between presentism and eternalism, although these two debates are related. Second, as previously mentioned, some versions of four-dimensional metaphysics can be entirely consistent with absolutist spacetimes, such as Newtonian or Galilean frameworks. Therefore, referring to "the class of events that are absolutely simultaneous at the present moment" as a "three-dimensional reality" could lead to misunderstandings regarding these concepts.

With this caveat in mind, let us examine Petkov's argument. He wants to draw an undesirable conclusion from the premise that the world is 'three-dimensional'. The undesirable conclusion, he holds, is *the conventionality of reality*; according to it, whether something is real or not is a matter of convention. More precisely, his argument has *two* premises, namely, "the three-dimensionality of reality" *and* "the conventionality of simultaneity." From the premises, an "unacceptable conclusion" follows: the conventionality of what exists or is real. This unacceptable conclusion, he continues, "can be avoided if we give up one of the premises"; however, it is "the premise of the three-dimensionality of the world that should be abandoned" since the conventionality thesis is impossible to refute (Petkov 1989, 75).

The same line of reasoning also figures in his second paper, where Petkov (2008) claims that if the conventionality thesis is true, then the definition of simultaneous sets of events is not a matter of objective fact but is conventional. We are entirely *free* to choose a value for ε between 0 and 1, as such choices do not affect

[13] Note that Petkov generalizes this circularity problem concerning the one-way velocity from light to any other physical entity. He thinks that not only the one-way velocity of the signal but also the one-way velocity of any other physical object fails to refer to anything real in the world since what has been said about the **IOV** can be said about any other physical entity (Petkov 2008, 177).

empirical adequacy. So if this thesis is true and reality is 'three-dimensional,' then it is a matter of convention what simultaneity set of events we assume as reality, which is, Petkov thinks, "clearly unacceptable" (2008, 180).[14]

Is Petkov's argument convincing? There seem to be three ways one can object to this argument. One might question: (1) the 'three-dimensionality of the world [absolutism]' as the unique option for a non-eternalist ontology (given that he is trying to defend eternalism); (2) the truth of the conventionality of simultaneity; and (3) the conventionality of reality as an *unacceptable* conclusion. For the purposes of this paper, let us grant (1) and (3) and focus just on (2).[15]

As seen above, an essential step in Petkov's argument is that, since it is not admissible for reality to be conventional, then either the conventionality thesis is false or reality is not 'three-dimensional.' He then appeals to "the impossibility of refuting the conventionality thesis of simultaneity" (1989, 75). By the impossibility of refuting the conventionality thesis, he means "the impossibility of demonstrating by means of a physical experiment the privileged state (existence) of only one set of events which are to be considered as *simultaneous* at the present moment" (1989, 75). This impossibility is due to the in-principle impossibility of determining the one-way velocity of light, i.e., the **IOV**. So, the **IOV** is the *primary source* of Petkov's argument in favor of (non-absolutist) 'four-dimensionalism.'

However, this is where an implicit *petitio principii* in Petkov's argument manifests. As we saw in Tooley's defense of the definability of absolute simultaneity, the **IOV**, as such and without embedding any metaphysical assumption to it, cannot be used as a working premise in Petkov's argument. The *petitio principii* reveals itself most evidently by considering the above epistemic/ontic assumptions regarding the **IOV**. Petkov explicitly holds an ontic assumption: "the velocities of these signals and bodies are determined by convention since they do not represent anything real" (2008, 184). So, the indeterminacy concerning the one-way velocity

[14] Note that the same story can be told with the standard formulation of simultaneity in **STR**, i.e., with $\varepsilon = 1/2$. Having the resulting relativity of simultaneity premise (i.e., substituting the intrasystemic with intersystemic relativity) coupled with the 'three-dimensionality premise,' the *relativity of reality* would follow. (For a discusstion, see Amiriara 2021.)

[15] As for (1), we should keep in mind that not all A-theoretic ontologies of time are committed to three-dimensionality. For example, point presentism which takes only here-now as the present (Stein 1968), Bowtie Presentism which takes only the absolute elsewhere of here-now as the present (for discussion, see Gilmore, Costa, and Calosi 2016), and cone presentism (Hinchliff 2000) all have been introduced as ways to make presentism compatible with the special theory of relativity. (3) has been offered as an option by some philosophers (for example, Sklar 1977; Hinchliff 1996) but is often regarded as a highly unintuitive option (for a taxonomy of positions, see Thyssen 2019).

of light is conceived as a consequence of an ontological fact: the fact that the concept of velocity has no counterpart in reality.[16] In other words, there is an *ontological restriction* concerning the determination of the one-way velocity of light in reality: reality contains nothing corresponding to these concepts. Nevertheless, it seems that this supposition would beg the question against the defender of the 'three-dimensional' or, better, absolutist view of reality who would claim that the **IOV** only shows an *epistemological restriction* concerning the determination of the one-way velocity of light: the concept of velocity may really refer to something objective in the world, though it is beyond our *knowledge*, or, to put it differently, it seems reasonable to speak of three-dimensional objects that are *moving* within a three-dimensional world—and this appears to conflict with Petkov's conclusion.

6. The Epistemic vs. Ontic Quarrel

So far, I have introduced two arguments that defend two radically different ontologies despite apparently having a crucial premise in common (the **IOV**). However, as we have seen, the conflict can be traced back to two different assumptions concerning the **IOV**. This reveals the reason why drawing an ontological conclusion from the **IOV** concerning the simultaneity relation (i.e., absolutism/non-absolutism) depends crucially on which assumption regarding it one would take as true. The **IOV** can be exploited for developing an argument in defense of absolutism as long as one takes it as an *epistemic* restriction. Absolutism cannot be defended on an *ontic* assumption regarding **IOV**. However, given that nothing seems to necessitate or give a sufficient reason for preferring either an epistemic or

[16] On this, Petkov says:

> An obvious question is "If *in reality* the velocity of light in one direction has an objective value, how can it depend on human choices and be a matter of definition (convention)?" Obviously, this question is based on the assumption that the concept of velocity, and therefore the one-way velocity of light as well, has a counterpart in the objective world. (2008, 177)

Also, in a footnote on the same page, he explicitly states that "'Velocity' in this paper means what is meant in the context of the conventionality thesis—'three-dimensional velocity', not the 'four-dimensional velocity' of special relativity." Petkov's view here seems to be closely tied to his four-dimensionalism. According to him, there is no such thing as a *three-dimensional object moving* through space with a certain velocity; rather, what exists are four-dimensional worldlines and worms. Accordingly, talk of the velocity of an object can be replaced by talk of the geometric properties of worldlines and worms. For example, the constancy of the speed of light can be rephrased in terms of the geometric property of light's worldline—the light cone—in Minkowski geometry.

an ontic assumption regarding **IOV**, have we then reached a stalemate? I answer: no, as long as further argument(s) can be presented in defense of one of those assumptions. In this section, I argue that at least one such argument can be presented.

Before that, let us distinguish two argumentative directions concerning the relation between the **IOV** and reality. First, one might argue, like Petkov, Cohen, and Tooley, that it is the **IOV** that can be exploited to form an argument in defense of the absolutist/non-absolutist view of the world. However, one can imagine a converse relationship between the **IOV** and one's view of reality. This could be seen as the second argumentative direction, in which it is absolutism/non-absolutism that can be exploited as a basis for evaluating *explanations* of the **IOV**. In other words, this involves viewing absolutism and non-absolutism not as some thesis inferred of the **IOV**, but as offering alternative explanations of it that are to be evaluated in light of the **IOV**. The argumentative direction of deriving or dismissing an ontology *from* the **IOV** is based on presupposing the validity of one view of the **IOV** while dismissing the other as mistaken. This indicates that such reasoning is susceptible to the *petitio principii*. The approach I defend, in contrast, does not consist in inferring an ontology from the **IOV**; rather, it involves offering reasons for preferring one view over the other.

In what follows, I aim to argue that this way of reasoning is a viable option. Specifically, I support the view that the ontology associated with the ontic assumption has greater *explanatory power* than that of its alternative. Thus, one may defend such a position through an *inference to the best explanation*—namely, that non-absolutism offers the best explanation of the **IOV**.

In both of his papers, Petkov thinks not only that (non-absolutist) 'four-dimensionality'[17] *follows* from the conventionality thesis, but that it also *explains* its motivation, i.e., the apparent circularity in determining the one-way velocity of light:

> It can now be said that the logical circle obtained in an attempt to imagine an experiment enabling us to define which events are simultaneous at a given moment of time, or to establish the one-way velocity of light, convincingly shows that we have tried, on the basis of an *erroneous* view of the dimensionality of the world to discover the *objective* content of concepts (as simultaneity and velocity), for which it appears that they have no such content according to a more adequate view of reality. *This explains why* [my italics] the conventionality of simultaneity does not presuppose some kind of 'agreements' concerning physical magnitudes as to which we have been

[17] As mentioned at the beginning of section 5, talk of *dimensionality* can be misleading. It is important to note that 'four-dimensionality' here is meant as a non-absolutist view of reality.

> intuitively convinced that they have an exactly defined *objective* content. (1989, 75–76)

The same point also figures in his later work (remember that according to equations (3) and (4), assuming the ε-formulation of simultaneity, the value of the one-way velocity of the signal depends on ε):

> There are no three-dimensional objects in spacetime and no motion of such objects. *That is why* the concept of velocity does not have an ontological counterpart. For this reason we are indeed free to choose the value of velocity when we describe Minkowski spacetime in terms of our three-dimensional language. (Petkov 2008, 183; my italics)

This passage seems to suggest that Petkov thinks (non-absolutist) four-dimensionality *explains* the **IOV**. This shows that there appears to be a complication in Petkov's line of reasoning since, evidently, it is one thing to say that four-dimensionality *follows* from **IOV** and something different to say that four-dimensionality *explains* the **IOV**. As we argued before, four-dimensionality cannot be a straightforward consequence of the **IOV**; it can be said, however, that four-dimensionality *explains* (or *best explains*) the **IOV**, and this might form an independent argument in favor of four-dimensionality, even though Petkov did not carefully separate them. That being said, it seems reasonable to conclude that *there is* a straightforward explanation of the **IOV** in the ontic assumption.

The critical question now is whether there is an explanation of the **IOV** in the epistemic assumption and whether it is better than the explanation given in the ontic assumption. As we saw, adopting the epistemic assumption regarding the **IOV** is crucial for Tooley and Cohen to argue for the possibility of their absolutism: in each frame, light has a determinate value for its one-way speed, though this value varies with frames, each having a determinate ε value between 0 and 1. However, since the **IOV** holds, this value cannot be determined. What, then, is the explanation of this indeterminacy within their account? Cohen provides no answer. However, we can find some statements in Tooley's account which can be read as addressing this question. These statements figure in his response to a possible objection to his theory, which he thinks is "the most forceful that can be mounted against any theory that entails the existence of absolute rest" (Tooley 1997, 365): the *conspiracy-of-silence* objection.

According to this objection, which was raised initially by Zahar (1983, 39), while the existence of some privileged frame is not an *impossibility*, it is unlikely that nature systematically conceals the *privileged* frame. In other words, the defender of such a privileged frame should feel an urge to explain such a silence, an urge Tooley also feels and tries to address. Tooley's response, however, is again based on the **IOV**. He thinks that the conspiracy appears

> only because, and precisely because, the Special Theory of Relativity itself entails that there is, in nature, a conspiracy of silence with respect to a certain matter—namely, the one-way speed of light. (1997, 365)

So, according to Tooley, both the standard formulation of the **STR** and his own modified version of it, with its absolute enduring space, contain such a conspiracy. In other words, if it were possible to determine empirically the one-way speed of light, then it would be possible to determine the absolute frame empirically.[18] This means that, as Tooley says, the conspiracy concerning the privileged frame and the conspiracy concerning the one-way speed of light are *related*, that is, are two sides of the same thing (1997, 366–67). Thus, Tooley argues, this *conspiracy-of-silence* objection is not a good reason for rejecting the modified theory, since either it is possible to determine the one-way speed of light or it is not. If possible, the choice between the standard **STR** and its modified version can be settled empirically. If, on the other hand, as the long history of failed attempts suggests, it is not possible, then "both the modified theory and all versions of the Special Theory of Relativity involve the acceptance of what is essentially the same conspiracy of silence within nature" (1997, 367).

However, this is precisely where the ontic assumption regarding the **IOV** can show its force. According to the ontic assumption, what is silent about the **IOV** *is* Tooley's modified theory, not *nature* nor the standard **STR** nor even the *ε-formulation* of **STR**. The main reason this kind of conspiracy arises is the presupposition that *there is such a privileged reference*. It is precisely this presupposition that makes the nature of the **STR** a systematic conspirator. Without such an existential assumption, there simply is no conspiracy. Not only would the presupposition that there is a physically detectable privileged frame of reference violate the principle of relativity, but also, as we have seen, on the ontic assumption, there is a perfectly straightforward explanation why such a privileged frame is not detectable: there is no such thing as a privileged frame, nor some objective (even intrasystemic) relation of simultaneity.[19]

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[18] That is, if an experiment were possible that allowed one to measure the one-way speed of light, and the result of such an experiment showed variations in the one-way speed of light depending on direction or inertial frame, these variations would accord with the modified theory's account of motion relative to absolute space. Measuring how the one-way speed of light varied would make it possible to determine the velocity of that inertial frame relative to absolute space. This empirical determination of velocity relative to absolute space is precisely what is meant by empirically identifying the absolute frame. Thus, the empirical measurability of the one-way speed of light is directly linked to the empirical detectability of the absolute frame.

[19] That is, according to the ontic view, since the claim that the one-way speed of light is the same in all directions has no factual basis in reality, the standard simultaneity plane associated with it

This is where, in my view, Craig Bourne, another defender of an A-theoretic model of ontology, also went wrong in his analysis of the conspiracy objection:

> In order for Einstein's definition of simultaneity to work, ONE-WAY is essential. But ONE-WAY rests on the assumption of the constancy of the one-way speed of light, something that nature conspires to keep us from testing, whereas, in order for the presentist's definition to work, there has to be a privileged frame of reference, something, again, that nature conspires to keep us from detecting. Put this way, it seems that there is very little to choose between these two 'conspiracies'. So at this stage we are left in a stalemate situation which can only be resolved by appeal to principles of good theory construction. (Bourne 2006, 181)

To see what went wrong with his analysis, it is useful to see how Bourne sets the stage for his defense of presentism. He concedes that, given the conventionality assumption in Einstein's definition of simultaneity, a conspiracy objection *arises*: nature seems to conspire systematically to prevent us from testing the one-way speed of light. However, this alleged "conspiracy" related to the one-way speed of light is used by Bourne as a counterpoint to the "conspiracy of silence" objection that might be raised against presentism. According to that objection, if there were an absolutely privileged frame—as presentism (or more generally, absolutist A-theory, in our context) appears to require—then nature would conspire to make it empirically undetectable. Bourne notes, however, that this is not a good argument against presentism, since although "ONE-WAY is essential" to Einstein's definition of simultaneity, nature similarly conspires to block any direct test of it. In both cases, then, a form of empirical inaccessibility is at play: the presentist's reliance on an undetectable privileged frame parallels Einstein's reliance on a conventionally defined one-way speed. Bourne takes this apparent stalemate to imply that the choice between these views ultimately turns on broader "principles of good theory construction." Nevertheless, Bourne aims to strengthen the presentist position by accepting that the isometry assumption in Einstein's definition is in fact true (ibid.). That is, he sets aside the ε-formulation of **STR** in order to present *a stronger defense* of presentism that must wrestle with the conspiracy challenge. By setting the stage in this way, he ventures to argue, "the presentist can argue that there are good *metaphysical* reasons for invoking privileged frames" (2006, 182).

However, this is not the right way of setting the stage since, as we have seen, there is no conspiracy challenge even for the *ε-formulation* of **STR** as long as one adopts the ontic assumption regarding the **IOV**. The conspiracy problem arises only *after* one postulates a privileged frame, that is, when one assumes the epistemic assumption. This point can be inferred from the way Zahar states the conspiracy

(i.e., ε = 1/2) also lacks any counterpart in reality—even relative to frames of reference.

objection, although he does not frame it in terms of the ontic/epistemic assumption regarding the **IOV**:

> *If* one postulates, or philosophically defines, an absolute frame of reference, *then* one has simultaneously to accept … a huge "conspiracy of silence". (1983, 39; my italics)

The point thus becomes particularly clear when one considers the conditional form of the conspiracy objection. Put in terms of the ontic/epistemic assumption regarding the **IOV**, this objection arises only when one adopts the epistemic, not the ontic, assumption.

7. Conclusion

As an effective way of surviving in the face of the **STR**, various A-theorists have attempted to argue for (at least the possibility of) the *existence* of a privileged frame that makes the notion of absolute present compatible with relativistic physics. In this regard, as we have seen, some A-theorists have attempted to do so by appealing to both the **IOV** and the *ε-formulation* of **STR**.

I argued that taking the **IOV** itself as a starting point, or as a premise, in an argument for a metaphysical view of temporal reality would appear to lead nowhere. However, by taking some metaphysical view, which is reflected in an assumption regarding the **IOV**, as a starting point, we can construct an argument, in the form of inference to the best explanation, to settle the issue. Absolutist A-theory not only lacks a satisfactory explanation of the **IOV** but also appears to render **STR**—one of our best physical theories—and nature itself systematic conspirators: *there is* something, that is, an absolute present, whose existence cannot be known *in principle*. Non-absolutist B-theory, on the other hand, gives a better and more straightforward explanation of the **IOV**: There simply is nothing in reality that corresponds to, or can be known as, the objective velocity of light *in motion*.[20]

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