

Introduction

Physics and Metaphysics

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1. PHYSICS AND METAPHYSICS. AN OVERVIEW

It is notoriously difficult to define Metaphysics¹, its content, its method, its language, its scope. Thus I will not even try an attempt here. I will rest content to point out some widely held characterizations. A long and highly influential tradition maintains that Metaphysics is the study of being qua being. It is concerned with what there is, what kind of things are the things that there are, what properties do they have, how they are related. In this sense Metaphysics deals with the more general features of reality, the most fundamental categories of being. Call this tradition *General Metaphysics*.

It is well known that empiricism of any sort² has always been very skeptical of the very possibility of such an enterprise, at least one it considered an enterprise that should be carried out a-priori. Kant's transcendentalism somehow endorsed this skepticism about General Metaphysics yet it did not dispense with Metaphysics in general. Metaphysics, according to this Kantian standpoint, is nothing but the clarification of the most general structures at work in our knowledge of the world. Call this *Transcendental Metaphysics*. Strawson (1959) famously introduced a distinction between *Descriptive* and revisionary, or *Prescriptive Metaphysics*. Descriptive Metaphysics aims to describe the most general features of our conceptual scheme. Prescriptive Metaphysics, on the other hand, attempts to revise our ordinary way of thinking and our ordinary conceptual scheme in order to provide an intellectually and morally preferred picture of the world. It could be argued, though this might turn out to be a controversial claim, that in some sense Descriptive

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¹ See for example discussion in Loux 1998 and van Inwagen 2007. There is whole industry now in the analytical community that deals specifically with such questions. It is called Meta-metaphysics.

² Both classical Empiricism of Locke and Hume and logical Empiricism of Carnap, Reichenbach, Ayer.

Metaphysics is the continuation, or a contemporary variant, of Transcendental Metaphysics and that Revisionary Metaphysics is a continuation, or a contemporary variant of General Metaphysics. It remains the fact that both traditions are alive in contemporary analytical philosophy.³

Physics on the other hand might at first seem easier to define, at least since the publication of Galileo's *Discourses and Mathematical Demonstrations relating Two New Sciences* in 1638, that can as well serve as the birthmark of modern mathematical physics. A very rough characterization of it will probably mention the study of matter and motions of matter through spacetime. In a broader sense Physics deals with the general analysis of nature, the world and their components.⁴

It is immediately clear, even from these very sketchy presentations how wide and deep is the area of overlap between these two disciplines. For clearly, matter, space, time and so on do seem, at least at first sight, good candidates for the alleged general categories of being or general categories of human understanding. Another, I believe straightforward, empirical argument in favor of the existence of such a deep and wide overlap, comes from a look at contemporary introductions to Metaphysics, even if it is a brief and quick look.⁵ They almost invariably contain materials on space, time, causation, constitution of material objects, identity, determinism and free will and so on. But these are the very notions Physics is supposed to be about.⁶

If my argument is sound then this overlap immediately raises deep issues about the relationship between Physics and Metaphysics. There is almost an infinite variant of positions one might hold. I cannot do justice to them here.⁷ So I will rest content at rehearsing some of those. It seems to me that the two extreme positions one might maintain can be labeled *Metaphysical*

³ I invite to read this claim not as a militant claim but rather as a pragmatic one. It just serves to purpose of delimiting boundaries that, even if artificial, are sometimes useful if not implicitly sustained.

⁴ I use these terms in a very loose way. Thus I do not want to suggest that there is a difference between the world and nature or that components should be understood as parts or participants for example. Mine is a claim of humility. An introduction is not the place to settle discussions that have shaped the very course of Western Thought.

⁵ See for example again Loux 1998 and references therein.

⁶ Probably free will will not be explicitly mentioned in any physics textbook. However in contemporary metaphysics the issue of free will is deeply connected to the issue of determinism, and this is surely a topic physics deals with.

⁷ I refer the reader to the excellent Dorato (this volume).

Foundationalism (MF) and *Physical Eliminativism* (PE).⁸ According to MF, Metaphysics is the study of the most general feature of reality independently of any particular science. Metaphysics provides the general framework in which any empirical considerations, physics included, become meaningful.⁹ Thus Metaphysics is the foundation of every empirical science, Physics included. I doubt that anyone would endorse such an extreme version of foundationalism nowadays, although it could be argued that formal ontology is precisely a contemporary variant of such attitude.¹⁰

On the other hand PE maintains that there are no genuine metaphysical problems. There are only the empirical questions asked by Physics. Suppose for sake of argument that Physics could solve all of its problems. Then there will be no problems left to solve.

Between these two extremes there is a wide range of options. One might uphold a sort of *Naturalistic Attitude* (NA). Proponents of NA do not deny that there are genuine metaphysical questions about, for example the nature of existence, but they do deny that those questions can be solved or even formulated or even arise¹¹ independently of any physical considerations.¹² According to such an attitude whether God exist is not a genuine problem after all¹³. But it is a genuine metaphysical problem whether the electromagnetic field exists and whether it supervenes or not on charged particles. But naturally this question does somehow depend on physical considerations, mainly

⁸ Here and in what follows I will not make any attempt to decide whether any particular philosopher would endorse any particular thesis.

⁹ I am perfectly aware that strictly speaking this claim does not follow from the previous one. But I am not attempting to give a rigorous definition of Metaphysical Foundationalism here.

¹⁰ One of the authors in the volume, Vincenzo Fano, has suggested me a different taxonomy of the possible relationships between Physics and Metaphysics. Here I briefly sum up his argument. i) Genuine metaphysical problems are just foundational problems of physics, or foundational problems of natural science in general. It would be interesting to assess whether this is my NA. ii) There are genuine metaphysical problems but they have to be formulated keeping in mind the technical resources used by physical sciences. Again, it is interesting whether this is an instance of my NA again. iii) Metaphysical problems are independent from physics in their formulation but they might be solved by physics. iv) Physics has no relevance whatsoever for metaphysics. This seems to be a stronger variant of my IT. v) There are no metaphysical problems. It is probably a strong variant of my PE. Thanks to Vincenzo Fano for helpful comments on a previous draft of this work.

¹¹ Depending probably on the strength of such naturalistic attitude.

¹² Or broadly speaking independently of any considerations drawn from natural sciences in general.

¹³ Though this might be a strong controversial claim even for those who have naturalistic inclinations. Some of them will probably argue that Physics do have something to say about that question. And some would go probably as far as saying that Physics does settle that question.

classical electromagnetism and quantum electrodynamics.

Another possibility would be to hold an *Independence Thesis* (IT). IT would probably claim that Physics and Metaphysics are two independent disciplines with their own language, their own methodological and theoretical components. Sometimes they do overlap. And when they do they are both best understood as incomplete descriptions of the same portion of reality.

Someone willing to accept the distinction in Strawson 1959 that I have mentioned above might want to argue that Physics and Metaphysics are both independent and distinct and that the only viable Revisionary Metaphysics is Physics and that the only viable Metaphysics is Descriptive Metaphysics. I leave it to the reader to explore whether this option is just a variant of NA, IT or a combination of both.

It is clear however, or, at least it should be clear, that whatever thesis one might hold about the relationship between Physics and Metaphysics this calls for substantive argument.¹⁴

I am personally inclined to think that Metaphysics without Physics is blind and physics without metaphysics is crippled. This claim should be understood tentatively along the following lines. Our metaphysical theories should be informed by our best, experimentally successful physical theories. I would probably go as far as claiming that a contradiction with a well confirmed physical theory should be a reason good enough to seriously consider the possibility that a certain metaphysical theory is simply false... But it is also the case, I believe, that our best physical theories are not metaphysically transparent. To read off a particular metaphysics from a physical theory sometimes, if not always, requires substantive work that is not and cannot be done by the physical theory itself. I would probably go as far as claiming that there are genuine metaphysical questions for which physics by itself does not have the answer. This conviction was what first motivated me to embark in the present work. It follows from this conviction that an interaction between Physics¹⁵ and Metaphysics is necessary and should be welcome. In what follows I will provide what I take to be an interesting case of fruitful interaction between those two.

¹⁴ Again, see Dorato (this volume) and references therein.

¹⁵ And naturally philosophy of physics.

2. PHYSICS AND METAPHYSICS. AN EXAMPLE

My arguments in section 1 notwithstanding, it is a widely recognized fact that Metaphysics and Physics have been rather self isolated enterprises, even in the analytical community. On one hand, metaphysical issues about identity, location, persistence through time, material composition, causation and so on have rarely been discussed within the framework of physical theories. On the other hand, Physics and philosophers of physics have somehow endorsed a form of skepticism along the lines I have sketched in section 1 about the possibility for Metaphysics to provide a consistent and valuable view of how the world is. In recent years however there has been a tendency to bridge the gap between the two. Considerations drawn from physical theories have played a major role in metaphysical disputes like the ontology of time, nature of persistence, theory of identity and even mereology, to name just a few. This section explores one particular case in which considerations drawn from Physics and philosophy of Physics have been fruitfully used to deepen, clarify, and arguably, solve classical metaphysical issues.¹⁶ The case I have in mind is Special Theory of Relativity¹⁷, and its consequences for Metaphysics of Time and Metaphysics of Persistence. I am choosing this example for different reasons. First of all providing a general and compelling argument about the relationship between Physics and Metaphysics is far beyond my possibilities. I leave this problem to better hands than mine.¹⁸ Second this example is what I am mostly concerned with. And finally it is briefly mentioned in various works in the present volume¹⁹ yet not directly addressed by any of those. So hopefully this will not affect any reading of the papers, which are the main strength and should be the main focus of the present issue. These seem to me good enough reasons.

¹⁶ Again, I leave it to the reader to judge if my own take of the problems is an instance of NA or not.

¹⁷ STR from now on.

¹⁸ And again here, see Dorato (this volume).

¹⁹ See in particular Norton, Barons, Evans and Miller, Weinert, Torrenge and Dorato (this volume).

2.1 SPECIAL THEORY OF RELATIVITY AND METAPHYSICS OF TIME²⁰

There are famously three different Metaphysical theories about Time²¹, namely Presentism, Possibilism and Eternalism. They can be roughly defined along the following lines:

- (1) Presentism i) Only the Present exist, the Past and the Future do not, and²² ii) Only Present Objects exist.²³
- (2) Possibilism i) Only the Present and the Past exist, the Future does not, and ii) Only Present and Past Objects exist.²⁴
- (3) Eternalism i) Past, Present, Future, they all exist, and ii) Past, Present and Future Objects they all exist.

It is widely held that STR provides one of the most compelling arguments against Presentism. If this is indeed the case²⁵ then this is a clear example in which considerations drawn from a specific physical theory are used to solve traditional metaphysical problems. It should be noted however that physical considerations play a much subtler role than it is usually recognized. For they do not enter only in the solution of the metaphysical problem. They enter, or better, I think they should enter, even in the formulation of it. Claims (1)-(3) are cast in temporal language. It is however controversial whether there is time at all in a relativistic world.²⁶ Startling as it might be this claim has authoritative defenders.²⁷ Even if someone is not willing to go as far as denying the existence of time in a relativist world one might still worry about the fact that STR is best

²⁰ This section is not supposed to be an exhaustive treatment of such issues. It should give the reader a flavor, so to say, of how a fruitful interaction between Physics and Metaphysics might work. For a careful analysis see Calosi (unpublished).

²¹ I am taking for granted that these debates are genuine metaphysical debates and not just semantic debates in disguise. Those who are inclined to endorse such a semantical skepticism should read my claims counterfactually.

²² The justification for this conjunction is based upon some implicit technical assumptions about reducibility of objects to spacetime regions. It should be noted that the presentism eternalism debate is not to be confused with another classical debate in philosophy of time, namely the debate between A-theory of time and B-theory of time.

²³ I am personally inclined to read this claim within the framework of a formal theory of location. Such a theory is a formal theory in the logic sense. It is a set of definitions, axioms and theorems in the language of the first order calculus. See again Calosi (unpublished).

²⁴ In what follows I focus on Presentism. Most of the arguments will apply to Possibilism too so there is no need to distinguish here.

²⁵ As I maintain it is.

²⁶ See the excellent Barons, Evans and Miller (this volume).

²⁷ Most notably Barbour, Pooley and Stein.

understood as a spacetime theory that attributes a particular geometric structure on the world, namely that of Minkowski spacetime.²⁸ And Minkowski spacetime is not *just* space and time.²⁹ Thus one might endorse some sort of Supervenience thesis according to which temporal facts supervene on spatiotemporal facts. If so, my formulation in (1)-(3) is, if not mistaken, at least misleading. Fortunately enough it is not difficult to find a formulation of such a debate that is more relativistic friendly. It can be reconstructed along the following lines:

- (4) Relativistic Presentism: i) There exists only one particular subregion of Minkowski spacetime that is called the Present, and ii) there exist only those objects that are located at that subregion of Minkowski spacetime that is mentioned in i).³⁰
- (5) Relativistic Eternalism: i) There is no ontological distinction between different subregions of Minkowski Spacetime, and ii) objects do not lose or acquire any particular ontological status just by be merely located at them.

There are at least two main relativistic arguments against Presentism, both as defined as in (1) or (4). I label them *The Relativity of Simultaneity Argument* and the *No Spatially Extended Present Argument*. Here is a brief reconstruction of both, starting with the *Relativity of Simultaneity Argument*:

- (6) STR is true.
- (7) If STR is true there is no absolute, i.e., frame independent, relation of simultaneity.³¹
- (8) If Presentism is true than there is absolute simultaneity.
- (9) Hence Presentism is false (by (6), (7), (8)).

The *No Spatially Extended Present Argument* instead runs roughly as follows:

²⁸ That is a n-dimensional metric affine space with signature (1, 1-n) where n = 4.

²⁹ The reader should grant that for sake of argument, namely the fact that time is not *just* the timelike submanifold of Minkowski spacetime and space is not *just* the spacelike submanifold orthogonal to it. Again, to see how an argument towards this conclusion can be constructed, see Barons, Evans and Miller (this volume).

³⁰ Even this formulation is not satisfactory in many ways. I cannot enter into these subtleties here.

³¹ This follows from the following facts about Minkowski Spacetime. Simultaneity is represented geometrically by Minkowskian orthogonality, i.e., two events p and q are simultaneous relative to a timelike line L iff $\langle pq, u \rangle = 0$ where u is an arbitrary timelike vector that spans L. Vectors are written in bold characters. But different timelike lines will single out different spacelike submanifolds orthogonal to them and so different events could count as simultaneous relative to different lines.

- (10) If STR is true there is no spatially extended present.³²
- (11) If Presentism is true then there is a spatially extended present.
- (12) Hence, Presentism is false (by (6), (10), (11)).

A careful and detailed analysis of such arguments is beyond the scope of this introduction. But it is important to note something about them. They seem³³ to assume implicitly the following premise, where event should be taken to be, loosely speaking, as the content of a spacetime point.

- (13) The Present of an event e_1 is the region of spacetime that contains all and only those events that are absolutely simultaneous with e_1 .

Then, given (13) it is possible to derive the geometry of such a region from the geometry of Minkowski spacetime and go on to argue as in (7)-(9) and (10)-(12). But (13) is not supported by STR itself. It is rather a metaphysical claim that could be resisted on metaphysical grounds. Thus anyone who is willing to question (13) should be able to resist both the arguments I have presented. If I am right this is a very nice example of how much subtler and deeper the interrelations between physical and metaphysical considerations are. I should note here that I do believe that a new, more compelling and more sophisticated relativistic argument can be given against Presentism. Here I can only give a brief sketch of it.³⁴

- (14) If Presentism is true, on pain of contradiction, every event should belong to just one privileged subregion of Minkowski spacetime that is suitable to represent geometrically the Present.
- (15) If so the relation of belonging to such a subregion is an equivalence relation (by (14)).
- (16) There are no equivalence relations that are definable in terms of the geometric structure of Minkowski spacetime³⁵ beside the identity relation and the universal relation (by the geometric structure of Minkowski spacetime).

³² This claim is allegedly based upon the causal structure of Minkowski Spacetime.

³³ Though I know that this might be, again, a controversial claim.

³⁴ For a detailed presentation see Calosi (unpublished).

³⁵ This is due to facts about signature and facts about causal isomorphisms of Minkowski spacetime, i.e., maps of the form $\varphi: A \rightarrow A$ where A is the underlying affine space that preserves the causal structure. Formally if pKq stands for p is causally connectible with q then invariance under causal isomorphism can be written as $pKq \rightarrow \varphi(p)K\varphi(q)$.

- (17) If the relation in question is taken to be the identity relation then Presentism implies that there exists only one spacetime point. (by (1) or (4) and (16)).
- (18) It does not exist only one spacetime point.
- (19) Thus the relation in question is the Universal Relation (by (16), (17) and (18)).
- (20) If the relation in question is the Universal relation it follows that every spacetime point is in the present of every spacetime point. And so every spacetime point is real. Thus Eternalism follows.

It is not possible to assess whether this argument is successful here.

2.2 SPECIAL THEORY OF RELATIVITY AND METAPHYSICS OF PERSISTENCE

While observations drawn from STR have played a considerable role in Metaphysics of Time at least since the seminal Gödel (1949) and Putnam (1967), they have been almost absent from another metaphysical debate, namely the one concerning Metaphysics of Persistence, until fairly recently.³⁶ Things persist through time. This much seems uncontroversial. The controversy is how they do so. Famously there are two main Metaphysics of Persistence³⁷, namely three and four-dimensionalism. Let me start by giving a rough definition of a three and a four-dimensional object.

- (21) x is a 3D object =_{df} x is a persisting object that persist through time by being wholly present at each time of its existence, thus not having any temporal parts.
- (22) X is a 4D object =_{df} x is a persisting object that persists through time by having a different temporal part at each time of its existence.

Then three and four-dimensionalism can be stated as

- (23) 3D = every material object is a 3D object.
- (24) 4D = every material object is a 4D object.

³⁶ Yuri Balashov is the one who first suggested a detailed relativistic argument in favor of a particular metaphysics of persistence, namely four-dimensionalism. This argument is improved in his Balashov (forthcoming). See the beautiful Del Savio's review in this volume.

³⁷ I am leaving the possibility of stage theory or exdurantism aside. From a strict ontological point of view this theory can be seen as a variant of four-dimensionalism. From the metaphysical point of view there is however, I believe, room for disagreement.

It is clear that this formulation of the debate over the Metaphysics of Persistence is centered about the existence of temporal parts. Call this way of formulating the problem Mereological Persistence. Even in this case STR has played a considerable role even in the formulation of the problem. As it turns out the task of giving a precise formulation of the central notions in the debate over Mereological Persistence, namely the notion of temporal part and the notion of being wholly present, is very far from trivial. This difficulty has raised a considerable amount of skepticism over those notions and thus over the entire debate. STR itself proves a substantive argument in favor of a reformulation of the debate. The central notions are in fact again cast in purely temporal terms and thus they fall short of the Supervenience argument of the previous section. But STR itself, and more generally, spatiotemporal theories have proved to be fruitful instruments to recast the debate in different terms. An alternative formulation of the debate centers around the notion of location, in particular the notion of exact location.³⁸ The driving intuition behind the notion of the exact location is that an object and its exact location share all the relevant geometrical properties. Thus the exact location of my hand will be a hand shaped region, the exact location of a square with the side of one inch will be a square spacetime region whose sides do measure one inch and so on. Let me introduce some terminology. I will write³⁹

- (25) $\text{ExL}(x, R)$ for x is exactly located at spacetime region $R =_{\text{df}} x$ and R do have the same geometrical properties.
- (26) $\text{OvF}(x, R) =$ for x overfills $R =_{\text{df}} \text{ExL}(x, R_1) \wedge (R \ll^{40} R_1) =$ there is no part of R which is free of x .
- (27) $\text{Path}(x) =_{\text{df}} \cup_i R_i$ $\text{ExL}(x, R_i) = \text{Path}(x)$ is the union of all and only those regions⁴¹ x is exactly located at.⁴²

Then the distinction between a 3D and a 4D object can be made precise in locational terms, along those lines. A three-dimensional object is an object that

³⁸ I cannot enter into the details of different formal theories of location. I will therefore stick to the theory that is almost invariably used, as it is found in Gilmore 2007 or Balashov (forthcoming). I have personally some reservations about those theories of location.

³⁹ Notation and definitions are taken from Calosi (unpublished).

⁴⁰ \ll stands for the mereological notion of proper parthood. The mereological system presupposed in what follows is Minimal mereology. For those and other mereological details see Varzi (2009).

⁴¹ If there is just one such a region than it follows that $\text{ExL}(x, \text{Path}(x))$.

⁴² Index i ranges over spacetime regions.

is multiply exactly located at different non overlapping temporally unextended⁴³ spacetime regions while a four-object is an object that is singly exactly located at a temporally extended spacetime regions. These claims actually capture the powerful intuition according to which three and four-dimensional objects do have different geometrical properties. The last piece of notation is grounded in the geometric structure of Minkowski spacetime. I will write

$$(28) \quad \text{Achr} (R) \text{ for } R \text{ is an achronal region of Minkowski spacetime} \\ =_{\text{df}} (\forall p) (\forall q) (p \in R \wedge q \in R) \rightarrow pq \text{ is spacelike.}^{44}$$

Then a persisting object x is defined via

$$(29) \quad \text{Pers} (x) \text{ for } x \text{ is a persisting object} =_{\text{df}} \sim \text{Achr} (\text{Path} (x))$$

and three and four-dimensional objects can be given the following precise definitions:

$$(30) \quad x \text{ is a 3D object} =_{\text{df}} \text{Pers} (x) \wedge (\exists R_1) (\exists R_2) (R_1 \neq R_2 \wedge \text{ExL} (x, R_1) \\ \wedge \text{ExL} (x, R_2) \wedge \text{Achr} (R_1) \wedge \text{Achr} (R_2) \wedge \sim \text{Achrn} (R_1 \cup R_2)).^{45}$$

$$(31) \quad x \text{ is a 4D object} =_{\text{df}} \text{Pers} (x) \wedge \text{ExL} (x, \text{Path} (x)) \wedge (\text{ExL} (x, R) \rightarrow R \\ = \text{Path} (x)).$$

Informally definitions (31) and (32) say that a 3D object is an object that is multiply exactly located at different achronal subregions, while a 4D object is an object that is exactly located at a single non achronal subregion, namely its path.

Then three-dimensionalism and four-dimensionalism can be formulated again via (23) and (24). Call the present formulation of the debate Locational Persistence.⁴⁶ This long formulation of Locational Persistence is again a fine example of a case in which physical considerations have proved fruitful in reformulating a typical metaphysical problem.

Within the background of locational persistence different relativistic arguments against three-dimensionalism have been put forward. In what

⁴³ The relativistic counterpart of this notion is achronality. See later on.

⁴⁴ Where pq is spacelike iff $\langle pq, pq \rangle < 0$.

⁴⁵ Note that $\text{Pers} (x)$ is redundant here. This definition of a 3D object can indeed be improved upon, but I cannot refine it here.

⁴⁶ I cannot enter here into the subtleties about the relationships between Mereological Persistence and Locational Persistence.

follows I briefly rehearse two of them, the *Explanatory Argument* due to Yuri Balashov⁴⁷ and the *Location Argument* due to Cody Gilmore⁴⁸, before addressing one of my own relativistic arguments the Relativistic Argument from Change.

The *Explanatory Argument* is a typical inference to the best explanation arguments. It follows from STR and thesis about Locational persistence that the same object will have different 3D shapes relative to different frames. Three-dimensionalism will not have any explanation of why different and loose 3D shapes form a remarkable unity and come together to form a smooth four-dimensional volume. Four-dimensionalism on the other hand has a ready and simple explanation. This is due to the fact that different 3D shapes are just cross section of a four-dimensional object.⁴⁹

The *Location Argument* maintains that three-dimensionalism cannot answer the so called Location question. Here's the location question. Let x be a material object. What subregions of Path (x) does x exactly occupy? Four-dimensionalism has a ready answer. Since x is a 4D object it will exactly occupy the only proper subregion of Path (x), namely Path (x) itself. But if x is a 3D object it exactly occupies just achronal slices of Path (x). But which ones? Gilmore suggests different answers to this problem and discard them all using arguments based on relativistic consideration. And this again suggests that four-dimensionalism is somehow favored by STR.

To conclude the section I will briefly sketch one of my own relativistic arguments. I can only give a rough presentation of it. I have labeled it elsewhere the *Relativistic Argument from Change*. Think for a moment to the classical case. Suppose x is a 3D object that changes from having the property F at time t_1 to having the property $\sim F$ at time t_2 . On pain of contradiction x cannot have two incompatible properties. Traditional three-dimensionalist solution to this problem maintains that properties should be somehow relativized to times. Let me write $F\text{-at-}t_1(x)$ for x has the property F at t_1 . Then $F\text{-at-}t_1$ and $F\text{-at-}t_2$ are not incompatible properties and the problem from change vanishes. Given Locational Persistence this strategy will involve that 3D

⁴⁷ See his Balashov (forthcoming) reviewed in this volume. This work contains at least another influential relativistic argument in favor of four-dimensionalism, namely the so called coexistence argument.

⁴⁸ See his Gilmore 2007 for a detailed presentation.

⁴⁹ This argument has been challenged many times. The interested reader should read Balashov's own discussion in Balashov (forthcoming).

objects have properties relativized to spacetime regions they occupy. I will write

$$(32) \quad F\text{-at-}R_1(x) \text{ for } x \text{ has property } F \text{ at spacetime region } R_1.$$

Now suppose x is a 3D object that is exactly located at two different overlapping achronal subregions of Minkowski spacetime R_1 and R_2 . The fact that x can be exactly multi-located at R_1 and R_2 follows directly from the definition of a 3D object. The fact that those regions can overlap comes from the fact that the best answer to the Location Question presented above a three-dimensionalist has is that x exactly occupies every achronal slice of $\text{Path}(x)$.⁵⁰ Then possibility of change implies that x can have incompatible properties at R_1 and R_2 . Consider now the following property, being uniformly F , defined via

$$(33) \quad \text{Un}F\text{-at-}R(x) \rightarrow (\forall R_1) (\text{Ov}F(x, R_1) \rightarrow F\text{-at-}R_1(x)).$$

Claim (33) just says that if x is Uniformly F at one of its exact locations it is F at every subregion of that exact location. It follows from definition of Overfill that every region x does overfill is a subregion of its exact location. Now everything is in place for the new relativistic argument. I am presenting it in a shortened version.

$$(34) \quad \text{Un}F\text{-at-}R_1(x) \text{ (assumption).}$$

$$(35) \quad \text{Un}\sim F\text{-at-}R_2(x) \text{ (from possibility of change).}$$

$$(36) \quad (\exists R) (R \ll R_1 \wedge R \ll R_2) \text{ (by definition of Overlap}^{51}\text{).}$$

$$(37) \quad \text{Un}F\text{-at-}R_1(x) \rightarrow (\forall R) (\text{Ov}F(x, R) \rightarrow F\text{-at-}R(x)) \text{ (definition of Un}F \text{ and (34)).}$$

$$(38) \quad \text{Un}\sim F\text{-at-}R_2(x) \rightarrow (\forall R) (\text{Ov}F(x, R) \rightarrow \sim F\text{-at-}R(x)) \text{ (definition of Un}\sim F \text{ and (35)).}$$

$$(39) \quad F\text{-at-}R(x) \text{ (by (34), (36) and modus ponens).}$$

$$(40) \quad \sim F\text{-at-}R(x) \text{ (by (35), (36) and modus ponens).}$$

Thus the conjunction of three-dimensionalism and possibility of change entails a contradiction. Note that this argument crucially depends on the geometric

⁵⁰ This claim calls for substantive argument. I think that Gilmore (2007) gives reasons enough to believe that this is the only viable answer to the location Question for a three-dimensionalist. I have also a different more general argument for this claim. Given Locational Persistence the every slice answer to the location question is the only answer that can account for basic relativistic phenomena such as length contraction.

⁵¹ Again, see Varzi 2009.

structure of Minkowski spacetime. In a classical spacetime a 3D object will in fact never be exactly multiply located at different but overlapping regions. There are ways to resist the argument but I contend that they all fail. It is not my intention to defend conclusively this argument of mine here. I just wanted to give it as an example of interaction between physical and metaphysical considerations.

3. PHYSICS AND METAPHYSICS. STRUCTURE

The present volume of *Humana.Mente* embodies perfectly the spirit of the first two sections. It tries to bridge the gap between Physics and Metaphysics, both in an historical⁵² and in a more theoretical perspective. It offers examples of the interaction between Physics and Metaphysics at their very best. The volume contains discussion of various physical theories ranging from Relativity Theory (Norton, Barons, Evans and Miller, Lam, Macchia), to Quantum Mechanics (Carola and Sozzo, Angelucci and Fano), from Thermodynamics (Weinert), to Quantum Field Theory (Lupher), from Electromagnetism (Angelucci and Fano) to Quantum Gravity (Barons, Evans, Miller) to String Theory (Veneziano). Considerations drawn from these physical theories are used to clarify and solve traditional metaphysical issues. Among those who are explicitly addresses in the volume we find the question of realism (Carola and Sozzo), metaphysics of time (Norton, Barons, Evans and Miller, Weinert), causation (Lam), questions about cosmology (Macchia) and fundamental ontological questions regarding fields, particles and the spacetime structure (Lupher and Macchia respectively). Commentaries provide new takes on classical texts on Physics and Metaphysics. They provide new challenging arguments on classical questions such as the relations between physical theories and phenomenology of experience (Barrett), the relations between composition, strict metaphysical language and loose common sense language (Nolan), the relations between physics, mathematics and experience (Weatherall) and paradoxes of time travel (Torrengo). The volume also contains review of recent works that I am confident will provide a fundamental contribution to the discussion in the field for many years to come. These works include authors such as Maudlin, Rovelli, French and Balashov.

⁵² See mainly Angelucci and Fano (this volume).

Finally this issue has the privilege to have an interview with A. Grünbaum, that many will probably regard as one of the highest vertex when it comes to the philosophical enquiry on Physics and Metaphysics. And with this I leave the reader to the volume.

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