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Some Neglected Possibilities: a Reply to Teitel

Caspar Jacobs*

The Hole Argument presents a formidable challenge against spacetime substantivalism.¹ The doctrine of substantivalism, roughly, holds that spacetime exists independently from matter. In the theory of General Relativity (GR), fields are represented as functions $f(x)$ over a base manifold M , so $f(p)$ represents the value of f at point p . In vacuum GR, the sole field is the metric $g(x)$.

The Hole Argument is this: consider a four-dimensional region H of M , the ‘hole’. Let d denote a diffeomorphism (i.e. a smooth bijection) of the points within H . We then define $d^*g(x) := g(d(x))$; this is called the *push-forward* of d . Because of the diffeomorphism-invariance of GR, $g(x)$ is a solution iff $d^*g(x)$ is; so if the former represents a physically possible field, so does the latter (note that it is incorrect to say, as is sometimes done, that these possibilities are related by a diffeomorphism; rather, they are related by the push-forward of a diffeomorphism). These functions seem to represent distinct fields. Suppose that $g(p)$ is different from $g(d(p))$. Then $g(x)$ assigns a different value of the metric to p than does $d^*g(x)$. But since the difference is confined to the hole, $g(x)$ and $d^*g(x)$ are identical outside H . Given a distribution of the field at some time t in the past of H , then, different distributions of the field after t are compatible with it.² This spoils the determinism of GR!

Moreover, this form of indeterminism is suspicious. Because d ‘drags along’ the metric, it is an isomorphism. The solutions $g(x)$ and $d^*g(x)$ thus represent qualitatively identical states of affairs: they only disagree over which point has which metrical properties. The determinism-spoiling futures in the Hole Argument are therefore observationally equivalent. Indeed, GR is deterministic ‘up to isomorphism’.

Defenders of substantivalism have developed several responses to the Hole Argument. The most popular are *metric essentialism* and *sophisticated substantivalism*. It is not an exaggeration to say that the vast majority of substantivalists subscribes to one of these positions.³ However, Trevor Teitel has recently published a pair of papers in this journal [Journal of Philosophy] which criticise both (Teitel 2019, 2021).⁴ Teitel offers alternative positions – called *sufficiency metric essentialism* and *plenitudinous substantivalism* respectively – but he rejects these as also ultimately unsatisfactory. I will therefore not consider them, but only address Teitel’s challenges to essentialism and sophisticated substantivalism.

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¹ Earman and Norton (1987) sparked the modern debate; for a recent overview, see Pooley (2021).

² By a time in the past of H , I mean a Cauchy surface (a space-like hypersurface) in the causal past of H . Note that not all solutions of GR admit of a Cauchy surface; a necessary and sufficient condition for their existence is that the spacetime in question is globally hyperbolic (Geroch 1970). I will assume this in what follows.

³ Maudlin (1988) has defended essentialism; Brighouse (1994), Hoefer (1996) and Pooley (2006) are some advocates of sophisticated substantivalism. This is not to say that substantivalism is the majority position. Other possibilities are some form of relationism (Huggett 2006; Barbour and Bertotti 1977), structuralism (Esfeld and Lam 2006; Dorato 2000) or functionalism (Knox 2013). Or perhaps spacetime is not even part of the world’s fundamental ontology at all (Dasgupta 2011; Huggett and Wüthrich 2013).

⁴ Teitel defines substantivalism as the thesis that spacetime *exists*, rather than (as is more common in the contemporary literature) the claim that spacetime exists *independently from matter*. This means that even some versions of relationism, structuralism or functionalism count as substantivalist by Teitel’s lights. I doubt whether his ‘revised Hole Argument’ also apply to such forms of ‘substantivalism’ – the original Hole Argument does not – although I lack the space to discuss this point in more detail.

Both of Teitel's papers assume a particular conception of possibilities, on which we can simply stipulate that certain spacetime points (co-)occur in certain possibilities. For example, Teitel writes of "possibilities that differ over which spacetime points there are only inside some region" (2019, 370). I believe that the force of Teitel's challenges derives from this conception of possibilities. But it is not the only conception of possibilities. David Lewis's (1986) modal realism is more restrictive. For Lewis, possibilities are represented by possible *worlds*. Individuals are *world-bound*, so no distinct worlds contain numerically the same point. Nevertheless, the same world can represent multiple possibilities involving different individuals, depending on the *counterpart relation* that is used. On some versions of counterpart theory, this relation is constrained to track qualitative similarity. This imposes a restriction on the total space of possibilities. Unfortunately, Teitel barely engages with Lewis on this point. I will argue that on Lewis's view, Teitel's challenges to substantivalism have no force. This means that one way for an advocate of substantivalism to avoid these challenges is to adopt Lewis's view of individuals as world-bound (which need not come with a commitment to modal realism).

I will proceed as follows. In §1, I state metric essentialism and sophisticated substantivalism. In §2, I present Teitel's challenges: the *revised Hole Argument*, *modal arbitrariness*, and *cheap determinism*. In §3, I briefly present some elements of Lewis's view of modality relevant to the Hole Argument. In §4, I show that the Lewisian approach avoids Teitel's challenges. Finally, in §5, I discuss whether is a version of essentialism and/or anti-haecceitism.

I should note that I very closely follow Butterfield's (1989) response to the Hole Argument; I essentially wish to claim that the Lewis-Butterfield line is invulnerable to Teitel's challenges. Teitel does not discuss Butterfield's seminal paper, despite their shared concerns. More generally, he seems dismissive of much of the literature on the Hole Argument on the basis that it is too concerned with mathematical models rather than possible worlds (2021, §2). But that is not true in the case of Butterfield, who writes: "Of course, some are suspicious of possible worlds, and will deny that we should cast determinism in terms of them. Determinism is to be simply a feature of the class of models, in logicians' sense, of a precise formulation of a spacetime theory [...] I cannot endorse this strategy, since I do not share its austerity about possibility" (1989, 11). The Lewis-Butterfield view is a neglected possibility in Teitel's papers.⁵

1. Essentialism and Anti-Haecceitism

In this section I will state metric essentialism and sophisticated substantivalism, staying close to Teitel's formulations.

1.1. Metric Essentialism

Metric essentialism is the view that spacetime points have their metrical properties and relations essentially. I won't discuss the notion of essence here. What matters is that essentialism entails the following modal claim:

Essentialism: For any possibility w and any spacetime point p within w , p could not have had different metrical properties and relations from the ones it has in w .

If the metrical properties and relations include only *qualitative* relations, such as that of being five metres away from some point, then the resulting position is what Teitel calls *qualitative metric essentialism*; if they in addition include *non-qualitative relations*, such as being five

⁵ Teitel (2012, §6) does discuss some closely related views, but does not cite Butterfield.

metres away from point p , then the resulting position is what Teitel calls *non-qualitative metric essentialism*. Teitel's revised Hole Argument only concerns the former version.

Essentialism avoids the Hole Argument, since the same point p within the hole cannot possibly have the metrical profile represented by g and also possibly have the metrical profile represented by d^*g . If $g(p)$ represents a possible field distribution for p , then $d^*g(p)$ represents an impossible field distribution for p (unless g is highly symmetric). The Hole Argument does not establish that there are distinct possible futures for a given past, so the substantivalist has no reason to doubt that determinism holds in GR.

1.2 *Sophisticated Substantivalism*

Sophisticated substantivalism is the conjunction of substantivalism and the doctrine of *anti-haecceitism*:

Anti-Haecceitism: If possibilities w and w' are distinct, then they differ over the truth-value of some qualitative proposition.

Put differently, anti-haecceitism says that there are no distinct yet qualitatively identical possibilities.⁶

Sophisticated substantivalism avoids the Hole Argument, since $g(x)$ and $d^*g(x)$ represent qualitatively identical fields. The only difference between them lies in which point has which qualitative profile. From anti-haecceitism it follows that these functions must represent the same possibility. Again, the Hole Argument does not establish that there are distinct possible futures for a given past, so the substantivalist has no reason to doubt that determinism holds in GR.

2. Teitel's Three Challenges

In this section, I present Teitel's challenges to these views. The first is directed at qualitative essentialism (Teitel 2019, §5); the latter two at sophisticated substantivalism (Teitel 2021, §3).

2.1 *The Revised Hole Argument*

Even if essentialism is true, one can formulate a revised Hole Argument. Qualitative metrical profiles being essential to spacetime points rules out the possibility of the *same* point having had a different qualitative metrical profile. But essentialism does not rule out that distinct points have the same qualitative metrical profile. This leads to the revised Hole Argument, as follows.

Consider again a region H of possibility w . H contains certain spacetime points: p , q , r , etc. Suppose that w' is a possibility identical to w except that H contains different spacetime points: p' , q' , r' , etc. The point p' has the same qualitative metrical profile as p , q' has the same qualitative metrical profile as q , etc. Consider now a time t to the past of H . From the diffeomorphism-invariance of GR, it follows that both w and w' are physically possible futures for the history of the world up to t . Moreover, metric essentialism does not rule out either of these futures: both p , q , r and p' , q' , r' may very well have their metrical profile essentially. Therefore, GR is indeterministic after all.

Notice that the revised Hole Argument relies on a particular view of modality according to which points 'freely recombine' across possibilities. For the revised Hole Argument to work, there must be pairs of possibilities related by the push-forward of a diffeomorphism that contain

⁶ Lewis (1986, §4.4) espouses a version of anti-haecceitism, but it is different from the one presupposed by sophisticated substantivalism. For further discussion, see Skow (2008) and Teitel (2021, fn. 34).

some, but not all, of the same spacetime points. This is not the case on Lewis's view of modality, as we will see below.

2.2 *Modal Arbitrariness*

The second and third objection are directed at sophisticated substantivalism. The problem of modal arbitrariness is that anti-haecceitism arbitrarily excludes certain possibilities. Consider the counterfactual possibility in which everything is as it actually is, except that I am standing. Suppose that actually the tip of my nose is now located at point p . Is my nose located at p in the counterfactual possibility? If anti-haecceitism is true, then there is only one possibility with this qualitative profile, and it is one in which either the tip of my nose is located at p or not. But either option is arbitrary, so anti-haecceitism entails modal arbitrariness.

Teitel's challenge is not that modal arbitrariness is itself problematic, but rather that we cannot satisfactorily explain where the arbitrariness comes from. Teitel (2021, §4) considers the suggestion that modal arbitrariness is a consequence of modal indeterminacy due to counterpart theory. I will discuss this suggestion in §4.2 in more detail.

Again, Teitel's argument relies on a view of individuals as freely recombinable across possibilities. On the haecceitist view Teitel prefers, there is a possibility in which the same point p is occupied by the tip of my nose, one in which it is occupied by my belly button, and so on. But if this view isn't available, then the argument fails.

2.3 *Cheap Determinism*

The final challenge is the one Teitel presents as most serious: it is directed at a modification of sophisticated substantivalism as well as non-qualitative metric essentialism. First, in response to the problem of modal arbitrariness Teitel (2021) modifies sophisticated substantivalism with the following claim:

Demanding-Modal-Essences: Necessarily, for any spacetime point p , necessarily if p exists then p stands in the spatiotemporal relations it in fact stands in *to the particular spacetime points it in fact stands in those relations to*.

This claim in effect renders spacetime points in GR world-bound. Notice the contrast with classical mechanics, for which the spacetimes of different solutions are isometric and hence there is a sense in which fields are painted onto the *same* canvas; not so for the dynamical spacetime of GR.

There is a sense in which this modification avoids the problem of modal arbitrariness: if my nose is actually at p then it would not be at p if I were standing, since distinct possibilities contain wholly different points. Unfortunately, demanding sophisticated substantivalism faces a worse issue, namely the problem of cheap determinism. Let's start with Teitel's definition of determinism for GR:

Determinism (Teitel): For all possibilities w and w' where GR is true, if there is a time t at both w and w' such that t has the same intrinsic properties at both w and w' , then w and w' agree on the truth value of every proposition.

The problem is this. Since each GR-possibility contains different spacetime points, for any time t in w , the intrinsic properties of t will include properties such as 'contains point p '. But such properties are only true for the unique possibility which contains p . Therefore, there exists no pair of possibilities that agree on *all* intrinsic properties at some time t . Consequently,

determinism is vacuously true for GR. But this is just the opposite of the Hole Argument's conclusion that determinism is vacuously *false* for GR. And if, as Earman and Norton claim, determinism cannot *fail* for reasons of metaphysics, then also, says Teitel, it shouldn't *hold* for reasons of metaphysics.

Once more, Teitel's definition of determinism presupposes a conception of individuals as freely recombinable across possibilities. If points don't recombine then determinism is vacuously true, as the problem of cheap determinism shows. But we will see below that there is a different conception of determinism which is compatible with more restrictive views of possibility.

3. Modality à la Lewis

In this section I will briefly present Lewis's (1986) view of modality, on which possibilities are represented by possible worlds under some counterpart relation. I emphasise that I neither assume nor defend modal realism. The components I set out below are compatible with alternative views, although I will not discuss these in detail.

I am not the first to appeal to Lewis in discussing the Hole Argument. Butterfield's seminal paper 'The Hole Truth' (1989) draws heavily on Lewis. Since I cannot summarise the relevant facts any better than Butterfield himself, I will quote:

Lewis is the great denier of transworld identity: that is, [(1)] he holds that no object occurs in any two worlds. He of course accepts that possible worlds provide the truth-conditions of modal discourse. So [(2)] he offers counterpart theory for treating *de re* modal sentences, e.g. 'Hubert Humphrey might have won the election': in some world there is a counterpart of Hubert Humphrey who wins. That is, it is this counterpart's winning that makes true the sentence, i.e. constitutes the actual Humphrey's modal property. [(3)] Counterparts are picked out by similarity. What properties make for similarity varies from case to case, depending on the meaning of the sentence, so that there are many counterpart relations. In general, counterparts need not be exactly similar in any respect, and often the relevant respects are mostly extrinsic to the objects. [...] Also, what counts as a relevant property is often vague, since the meaning of *de re* modal sentences is often vague. (Butterfield 1989, 22-23)

Butterfield adds to this that the notion of *duplication* – perfect qualitative similarity – provides a privileged counterpart relation. For any point p in world W : if some world W' contains a (unique) point p' that is a duplicate of p , then p' is the (unique) counterpart of p in W' . Crucially, the image of any point p under a diffeomorphism in the Hole Argument is a duplicate of p , because the diffeomorphism 'drags along' the metric field.⁷

It immediately follows that there are no hole-related possibilities, that is, it would not have been possible for the world to be as it actually is yet for the points within H to have had different qualitative metrical profiles. For the diffeomorphism d that generates such possibilities maps points onto duplicate points, so insofar as the privileged counterpart relation tracks perfect qualitative similarity the counterpart of any actual point p within H under a diffeomorphism d has the very same qualitative metrical profile as p actually has.

In what follows I will use lowercase w for possibilities and uppercase W for possible worlds.

⁷ This counterpart relation may require some modification for cases in which distinct points in the same world are qualitatively identical. I will set such complications aside here.

4. Responses to the Challenges

In this section I show how the Lewis-Butterfield view presented above avoids Teitel's challenges. Notice that this doesn't mean that Teitel's challenges aren't successful against their intended targets. I only claim that there is another view which does not succumb to them.

4.1 *The Revised Hole Argument*

It is easy to see that the revised Hole Argument has no traction once we reject transworld identity of points. The situation Teitel envisages, in which a pair of possibilities disagrees *only* over the identity of the set of points located within *H*, cannot occur. For such a situation to occur *de re*, it would need to have been possible for different points from any actual ones to be located within *H*. For that to be true, there has to be a possible world *W'* in which the points located within the counterpart of *H* are not counterparts of the points which are actually located within *H*. There are then two cases: either *W'* is isomorphic to the actual world, or it is not. If it is, then the points within the counterpart of *H* in *W'* are qualitatively identical to the points actually within *H*, and so they are counterparts after all. If it is not, then either *W'* disagrees with the actual world at some time *t* before *H*, in which case there is no threat to the determinism of GR; or it agrees with the actual world at any time *t* before *H* and only diverges thereafter, but in such a way that there is no isomorphism. In the latter case, *W'* is not a world in which the laws of GR are true, since GR is deterministic up to isomorphisms – so there is no threat to the theory's determinism in that case either.

4.2 *Modal Arbitrariness*

The problem of modal arbitrariness is also avoided once we deny transworld identity. Suppose that in the actual world I am sitting and the tip of my nose is located at *p*. We can assess this counterfactual scenario *de dicto* or *de re*. If we assess the counterfactual *de dicto*, then if I were standing neither the tip of my nose nor the centre of my belly button nor any other object would be located at *p*, since *p* only exists in the actual world. There is no need for an arbitrary choice as to which object would occupy *p* in this counterfactual scenario, because *p* would not exist.

Alternatively, we can assess the counterfactual *de re* using counterpart-theory. In that case, the answer depends on the counterpart relation. Perhaps the counterpart of *p* in the possible world in which I am standing is a point somewhere above my desk, since that point stands in the same metrical relations to most matter in the universe as *p* actually stands in. In that case my belly button would be located at *p* if I were standing. This result is non-arbitrary since it follows from the counterpart relation in question. Or it could be that *p* has no privileged counterpart in the possible world in which I am standing; perhaps by some measure of similarity *p*'s counterpart is the location of the tip of my nose, but by another measure it is the location of the Earth's centre of mass. In that case, the counterfactual is indeterminate. But this also avoids an arbitrary choice between possibilities.

Teitel does discuss the latter option; it is the only place in which he specifically addresses Lewis's metaphysics. Teitel objects to *de re* indeterminacy on the basis that one can obtain a more natural notion of possibility if one supervalue over *all* counterpart relations. Thus, the sentence "possibly, I am standing with my nose located at *p*" is true iff there is *some* counterpart relation such that the point at which my standing counterpart's nose is located is a counterpart of *p* under that relation. Since *de re* possibility is then determinate after all, Teitel claims that the Lewisian response fails. But this objection is mistaken. Firstly, it fails to distinguish between *de re* possibility and *de re* counterfactuals. Even if it is *possible* for my nose to be located at *p*, this does not mean that my nose *would* be located at *p* if I were standing. Teitel's response establishes that possibility is determinate, but this does not entail that counterfactuals are. Secondly, even if *de re* possibility is determinate, the problem of modal arbitrariness does not

occur. If it is possible for my nose to be located at p but also for my belly button to be located at p , then there is no arbitrary choice between possibilities.

4.3 Cheap Determinism

It may seem that Lewis' account of modality faces the full force of Teitel's cheap determinism challenge: if spacetime points are world-bound, and if it is an intrinsic property of a time t that it contains a point p , then no possible worlds will agree on all of the intrinsic properties at any time – so determinism is vacuously true. Notice that this version of the challenge uses a definition of determinism in terms of possible worlds rather than possibilities; this is not Teitel's definition! But since Lewis allows possibilities to come apart from possible worlds, adopting Teitel's definition of determinism can only work in Lewis's favour!

The Lewisian response consists of an alternative conception of determinism based on his general doctrine of objective resemblance (Lewis 1983). We first introduce some concepts. Firstly, the *natural* properties are special properties which 'carve nature at the joints'; they are the properties that physics is concerned with. Secondly, *intrinsic properties* are properties that an individual has in and of itself. The intrinsic properties are not all natural; the intrinsic property of being grue, for instance, is not. Lewis claims that the intrinsic properties supervene on the natural properties. Finally, *duplicates* are individuals that share all their natural – hence all their intrinsic – properties. Much has been written on this "tight little circle of interdefinability" (Lewis 1983, 355), but I will note just one salient consequence: non-qualitative properties, such as the property of being p , are not intrinsic. For if they were no duplicates would exist, since each individual has the unique property of being identical to itself. This may seem an unnatural consequence. Surely, nothing is more intrinsic to an individual than the fact that it is *that* individual? So much the worse for intuition; intrinsicity is a thorny enough concept that we cannot rely on it here.⁸

Lewis's (1983, 360) definition of determinism then is similar to (but distinct from) Teitel's:

Determinism (Lewis): For all possible worlds W and W' where GR is true, if there are times t and t' within W and W' respectively such that t and t' are duplicates, then W and W' are duplicates.

The antecedent is almost the same as in Teitel's definition, except that Lewis' definition refers to possible worlds rather than possibilities. But the consequent is much weaker: duplicate world need not agree on *all* propositions, but only on qualitative ones.

On this definition, GR is a deterministic theory.⁹ Consider the diffeomorphic worlds W and W' . Clearly, these worlds are duplicates at some time t before H , since d acts as the identity outside of H . And they are also duplicates entirely, since d maps points within W to points within W' which share the same qualitative features; it is an isomorphism. But GR's determinism is not cheap: the antecedent of Lewis's definition of determinism is not vacuously false. The problem of cheap determinism is avoided.¹⁰

⁸ If one remains wedded to non-qualitative intrinsic properties, then one could also revise the definition of duplicates to apply only to qualitative intrinsic properties – so nothing hangs on this issue.

⁹ For a proof of this claim, see Butterfield (1989, §6). I will not rehearse the details here.

¹⁰ Lewis's definition of determinism as applied to GR remains somewhat controversial. For further discussion, see Belot (1995), Melia (1999), and Brighouse (2020).

The difference between Teitel's and Lewis's definition of determinism is non-trivial. Which is the correct one? If it is Teitel's, then determinism comes cheaply after all. Butterfield addresses this objection; I quote his response at length:

An objection: You said that the basic idea of determinism is that a single physically possible world is specified by the facts on a certain region of spacetime. But your counterpart theory makes determinism something else: a matter of global similarity of worlds, under a certain mode of comparison, being induced by similarity of regions. Moreover, these modes of comparison can be chosen very freely: any diffeomorphism will provide one.

I reply: I agree that this is a disadvantage of my proposal. But I think it is a small one. Because as mentioned above, counterpart theory for all kinds of objects is plausible. And counterpart theory together with substantivalism imply that the basic idea above is automatically true, in a trivial way. For if no object inhabits two worlds, then picking out just one object suffices to specify a possible world. And for a substantivalist, the spacetime points are among the objects, and any physical fact on a region of spacetime involves picking out a spacetime point. Thus the basic idea of determinism is trivially true, whatever the details of one's spacetime theory. Thus if determinism is to be non-trivial, it should be formulated in other terms: comparison and matching are the obvious terms to use. (Butterfield 1989, 26)

Does Butterfield's response beg the question? Agreed, one can always 'turn the modus ponens into a modus tollens', that is, one can say that because the denial of transworld identity 'rules in' determinism in Teitel's sense, we ought to reject the denial. But why stick with Teitel's definition? The correct definition of determinism is not an isolated question; it should fit within our overall metaphysical framework. Lewis's definition does just that, while conforming to our intuitions as to which theories are deterministic and without trivialising the notion of determinism altogether. In a Quinean spirit, we should accept or reject metaphysical pictures and their associated definitions of determinism "as a corporate body". The advantages of Lewis's picture are clear.

5. Close: Essentialism or Anti-Haecceitism?

The Lewisian view of modality clearly delivers: it renders GR deterministic, but not on the cheap. It is not susceptible to the revised Hole Argument, nor does it entail modal arbitrariness. It has not been my aim to defend this view, but only to show that it stands up against Teitel's challenges to metric essentialism and sophisticated substantivalism. This raises the question: is Butterfield's view a version of the former, of the latter, or neither? I will argue that it is neither, and this reveals a potential shortcoming of the view.

On the one hand, it may seem as if the Lewis-Butterfield view is a version of essentialism. Since points are world-bound, there is a sense in which any point has its metrical profile essentially: necessarily, if point p exists, then it has the metrical profile it in fact has. In this vein, Kaplan (1975, 722-3) called Lewis's picture "an unusually rigid brand of metaphysical determinism". I dispute this characterisation. If Lewisian modality is a version of essentialism, then by definition no point could have had different metrical properties from the ones it actually has. We ought to assess such a counterfactual using counterpart theory. If we do, we see that it is false. Had I been heavier than I actually am, the region of spacetime I occupy would have had a different curvature: this because the counterpart of that region has a different curvature in the possible world in which *my* counterpart is heavier. The litmus test for essentialism fails.

But neither is the view a version of sophisticated substantivalism. While the denial of transworld identity has sometimes been called ‘anti-haecceitism’, it should be distinguished from our doctrine by that name, namely that there are no numerically distinct yet qualitatively identical possibilities (see fn. 6). Lewis’s view of modality does not entail this doctrine, since the same world may represent numerically distinct yet qualitatively identical possibilities. This is true in particular for certain symmetric worlds, that is, worlds that contain pairs of qualitatively identical individuals (‘twins’). When such twins are each other’s counterparts, the same possible world represents distinct possibilities. In such cases, anti-haecceitism fails.

Therefore, the Butterfield-Lewis view is neither a version of metric essentialism nor a version of sophisticated substantivalism, but a *tertium quid*. Whether it is an overall satisfactory response to the Hole Argument remains an open question, but it can withstand Teitel’s recent challenges.

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