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Grünbaum Did Not Solve Zeno's Measure Paradox*

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This paper discusses problems with Current Metaphysical Accounts of Matter and Space used by Scientists and Philosophers, and Arguments for Stenger's Particle Reality. It argues that relations or connections between any non-collocated spatial entities do not exist. If my reasoning is correct, it would challenge the basic concepts of the topological accounts of space and of material extension, such as those developed by Adolf Grünbaum, in his alleged solution of Zeno's Measure Paradox, since an extended continuum consists of interrelated non-collocated points. I argue that relations or connections between any non-collocated spatial entities do not exist because it can be shown that they are describable by contraction. Since relativity theory, and much of the theoretical explanation of quantum theory, makes use of such relations, my arguments would indicate that the *theoretical* accounts of these theories needs revision. To my knowledge, my conclusions do not conflict in any way with *empirical* findings of physics. My arguments would also provide evidence for what Stenger calls a 'particle reality', where only particles exist, and there are no metaphysical items connecting them together.

* Forwarded to NPA from GED

1. Introduction: Metaphysical Items in Physics

In this article I will discuss how philosophers, physicists, and mathematicians ubiquitously interpret space and time and the items of quantum world by way of *metaphysical* items—namely *invisible metaphysical relations* of various sorts between particles, between topological religions and spacetime points, and between other sorts of mathematical idealizations of physics. To illustrate my point, consider a passage from a recent article on quantum mechanics by Jenann Ismael, a philosopher:

The heart and soul of quantum mechanics is contained in the Hilbert spaces that represent the state-spaces of quantum mechanical systems. The internal relations among states and quantities, and everything this entails about the ways quantum mechanical systems behave, are all woven into the structure of these spaces, embodied in the relations among the mathematical objects which represent them. [i]

Considering an example from relativity, the description of nature as a field as an interconnected/interrelated network of spatial events is found in Einstein's work. In a passage where "metric" denotes a metaphysical relation, Stenger writes:

So general relativity does away with the need to introduce the gravitational field. However, in its place another field is introduced: the metric field of space-time... [T]his metric field was not the same form at every point in space-time, but varied from point-to-point... Thus the metric of space-time is a field, denoting the geometry of each point in space and time. [ii]

It has often been asserted that the spacetime points of Einstein's relativity, and the point-particles of various theories of quantum reality (quantum field theory, *etc.*), compose the macroscopic physical world, which is a world of extended magnitudes and temporal durations. *How* points give rise to dimension has allegedly been explained by A. Grünbaum and those mathematicians he built his work upon. Grünbaum comes to his alleged solution by postulating the existence of topological relations between spatial and material points, or between temporal points. If Grünbaum is correct, then topological fields and the topology of spacetime can coherently be describable in terms of points giving rise to magnitudes.

Relationships are very often (though of course not always) alleged to be real building blocks of nature, and not just the ways physicists, philosophers, and mathematicians conceptualize the details and the items of physics. In this article I will find that these metaphysical relations, when analyzed carefully, can be shown to be impossible, and for that reason, they do not exist. This would indicate that such metaphysical items are elements of imagination, rather than of reality independent of imagination. The metaphysical interpretations of science which posits that metaphysical relations that hold spacetime and the quantum world together of course only do so by inventing the metaphysical items from the experimental findings of physics, and no empirical observation of anything other than particles and matter has ever occurred.

My goal in this article is to argue that the standard *theoretical* accounts of space and matter given to us by contemporary Western philosophers (especially metaphysicians and philosophers of physics), by physicists (the theoretical accounts, rather than experimental accounts of relativity theorists and quantum physicists), and by mathematicians (especially topologists and applied mathematicians, such A. Grünbaum and those in dimension theory that he built his work from) are useful and pragmatic, but they do not tell us that nature is composed of metaphysical items holding particles and spacetime points and other items of physics together. Physicists only know the empirical particles; the metaphysical relationships are not empirical. This is not enough to conclude that the metaphysical relations do not exist—unless it can be argued that they lead to contradiction, as I will argue in Section 3.

What is leftover, then, if the metaphysical relationships are cleared away from physics, is what Victor Stenger refers to as a "particle reality":

The standard model offers a picture of elementary quarks and leptons, interacting by the exchange of a set of elementary bosons… In this work I am making the unremarkable suggestion that the quarks, leptons, and bosons of the standard model can be safely regarded as elements—perhaps the only elements—of an objective physical reality… The alternative ontology in which continuous fields are "more real" than particles was discussed in the previous chapter. First, we saw that a dual ontology of fields and particles, as existed in the nineteenth century [physics], contradicts the one-to-one correspondence between particle and field in modern quantum field theory. We can have either a reality of fields or a realty of particles (or other localized objects). We cannot have both without asserting some new physics not described by relativistic quantum mechanics. Such an assertion is uneconomical—not required by the data… Second, we saw that any viable field ontology based on relativistic quantum fields necessarily entails a Platonistic view of reality. [iii]

My conclusions are not in disagreement with the *experimental* findings of quantum physics. It is the *metaphysical concepts*, rather than the empirical data, that I attack in this article. If my arguments are correct, they will show that metaphysical relationships do not come out of the data of empirical studies in relativity and quantum experimental physics, and placing them in our theories about that experimental data is an unwarranted philosophical leap. (In another article [iv] I discuss how these metaphysical concepts also lead to the so-called paradoxes of quantum physics, such as wave-particle duality, and thus there is nothing in scientific *observation* that justifies them.)

Much of the metaphysical language comes from mathematics, which ultimately is about metaphysical relations between mathematical objects. (For example, the number 2 gets its distinctiveness being in relationships with other numbers, where these relationships define where 2 is on the number line: 2 is *greater than* 1, *less than* 3, *etc.* [italicized words denote relations that platonists allege are external to the mind].) Topological accounts of space and matter appear to be most copiously filled with reference to metaphysical relations. Consider the following passage from Alexanderoff:

> …[O]ne of the most important and at the same time most general concepts of the whole of modern topology [is] the concept of *topological space*. A topological space is nothing other than a set of arbitrary elements (called "points" of space) in which a concept of continuity is defined. Now this concept of continuity is based on the existence of relations, which may be defined as local or neighborhood relations… [A] topological space is a set in which certain subsets are defined and are associated to the points of the space as their neighborhoods. [v] (Underlining added.)

Although my arguments in this article attack any sort of spatial relation between non-collocated spatial or temporal items, in this article I will however be primarily concerned with topological relations since those are the metaphysical items so widely discussed as being real constituents of spacetime and the quantum world—as Ismeal's passage at the beginning of this article reveals. For reasons discussed in this introductory Section, I am specifically concerned with the *interconnectedness* of points in the continuum of space and the continuum of time, and the *interconnectedness* of matter points in the topological account of material extension. [vi] No point in a continuum of points is immediately next to any other point, and accordingly, the *interconnectivity* discussed by topologists and topologically oriented philosophers that is between points is a *relation*, or a *relatedness*, between or among the *non-collocated* points.

Adolf Grünbaum [vii], in his solution to Zeno's Measure Paradox (*unextended* points make up an *extended* magnitude), is often cited as discussing the interrelatedness of un-extended points in an extended continuum in such a way that solves the Paradox. Edgar writes: "Grünbaum proposes to solve the Measure Paradox by arguing that extended space must be conceived as a *relation* among uncountably many unextended elements." [viii] (Emphasis added.) Grünbaum's famous solution requires the coherence of the *relation*, or the *relatedness*, between or among points in topological descriptions of the extended continuum of space, and topological accounts of material extension, which are also given in terms of an extended continuum of interconnected matter points. I will show in Section 3 of this paper that the *relations* required for Grünbaum's alleged solution are *impossible*, and thus Grünbaum's solution fails. My arguments may show that *any* sort of ontological interrelatedness or connection between or among any non-collocated spatial or temporal entities (such as non-identical spatial, temporal, or matter points) are impossible. If my reasoning is correct, not only would Grünbaum's solution apparently be incorrect, but the very topological *interconnectedness* (*connectivity*) alleged by many physicists, mathematicians, and philosophers to exist among points in a spatial, temporal, or spatiotemporal continuum, and in the topological account of material extension, would also be incorrect. [ix] I will give my argument against ontological relations between or among non-collocated spatial entities and between or among any non-identical spatial points in Section 3. Section 2 is about Grünbaum's work.

2. Grünbaum's Solution of Zeno's Measure Paradox

Zeno's Measure Paradox is: An extended continuum is an aggregate of un-extended points. This Paradox is also called the Geometric Paradox [x], or Zeno's Paradox of Plurality [xi]; it is not one Zeno's famous Paradoxes. Pyle writes:

> The name Zeno of Elea is commonly associated with the four notorious paradoxes of motion, which have bewildered and bedeviled philosophers and mathematicians through the ages… There is, however, another paradox, less well known perhaps, that is both logically prior to… and conceptually more profound than that fearsome quartet. Aptly characterized by Grünbaum as 'Zeno's metrical paradox of extension'… it concerns the very nature of extended magnitude as such, and is therefore of wide scope and applicability. [xii]

Before Grünbaum, the Paradox often evoked to the question: If the basic constituents of an extended line, plane, volume are infinitely-many un-extended points, then how can the *aggregate* [xiii] of the unextended constituents not *also* be un-extended? If the basic un-extended parts give rise to an extended whole, does this not imply that (0+0+0…) ≥1, since the unextended entities give rise to an extension?

For over two thousand years, some philosophers have had reservations about how a line, or a geometric entity of one or more dimension, can be extended if it is an aggregate of *unextended* parts. But in recent decades, philosophers often appear at ease with the Paradox, due to the clarity and precision of the work of Adolf Grünbaum, in his alleged solution of the Paradox, and his discussion of the interconnectedness (called the set-theoretic union), of the points in a manifold. The convincingness and simplicity of Grünbaum's argumentation is so apparent that there has been little debate in the literature about Grünbaum's alleged solution. When discussing the Paradox, philosophers often merely inform their readers that Grünbaum has solved the paradox, and no further explanation follows. An example of this lack of discussion is Dean Zimmerman's interesting article, "Could Extended Objects Be Made Out of Simple Parts? An Argument for 'Atomless Gunk'", where Grünbaum is merely mentioned at the beginning of the article as likely having solved the Paradox, but no further discussion ensues:

Adlof Grünbaum has shown that these paradoxes are significantly defused by Cantor's discovery of the distinction between denumerably and non-denumerably infinite numbers. If Grünbaum is right, the traditional reasons for doubting the consistency of "conceiving of an extended continuum as an aggregate of unextended elements" have been laid to rest. [xiv]

When reading through Grünbaum's solution, its simplicity and clarity are evident, but in this paper I will discuss that there could be a problem to do with one aspect of Grünbaum's solution: the ontological coherence of the very *interrelatedness* of the points. As with Grünbaum, it is standard for mathematical philosophers and topologists to discuss the interrelatedness between points in a continuum, but not to give a detailed account of the *specific* ontological nature of that *interrelatedness* among points in a continuum. I am not suggesting that there is little analysis of *interconnected points*. What I am suggesting is there is little analysis of the *interconnection* itself. I suspect that this is the case because non-complex [xv] relations, such as topological *connectivity*, are widely held to be primitive and un-analyzable. Consider what Edgar writes: "[T]he point-sets of the continuum are not constructed; they simply exist. *The union [interrelatedness] of these sets is not a construction; it simply exists.*" [xvi] (Emphasis added.)

Even though relations, such as relations between non-collocated spatial entities, are typically held to be primitive and unanalyzable, slight analysis of them does exist in the literature, such as when relations are discussed as being platonistic (spatially unlocated), physicalistic (located in space), and so on. But in general, non-complex relations between non-collocated spatial entities not analyzed in detail greater than this, and there is very little analysis in the literature of the *precise* nature of the topological *connectivity* of the points in the material or spatial continuum that goes further than this. A fascinating debate among topologically oriented philosophers has occurred over the past ten years, including insightful work from philosophers such as Zimmerman [xvii], Hudson [xviii], Casati and Varzi [xix], Barry Smith [xx], Markosian [xxi], and several others. Although these discussions are obviously productive and original, nearly no discussion is included in these debates about the precise ontological nature of the interconnectivity of the points in a continuum (or the precise ontological nature of any relation between non-collocated spatial entities), since it is standard to believe that no such analysis can be carried out.

Considering point-sets as *connected* (related) in *neighborhoods* or *unions* (some topologists might denote this interrelatedness with the words, "nearness" [xxii], "closeness", or "connectivity") is standard among topologists, since topology is concerned with structures that are composed of points and relations between point sets. Alexanderoff, in his classic text, writes:

The concept of topological space is only one link in the chain of abstract space constructions that forms an indispensable part of all modern geometric thought. All of these constructions are based on a common conception of space which amounts to considering one or more systems of objects—points, lines, etc.—together with systems of axioms describing the relations between these objects. Moreover, this idea of a space depends only on these relations and not on the nature of the respective objects. [xxiii]

It is these *relations* that Alexanderoff mentions between points that I question this paper, and the precise ontological nature that I assert is rarely discussed. If there were a problem with such relations, there would be a problem with the topological position that space is an interconnected continuum of spatial points, and that material extension consists of an interconnected continuum of matter points.

Since points in a continuum are un-extended and do not directly contact one another (they are not immediately next to one another), there is no other way to account for extension of the continuum of space, or the extension of a continuum of matter points, except by recognizing the existence of a *different* item in the makeup of the continuum, an item *other* than the points. Grünbaum writes that un-extended points are not the only ingredients in the line interval, but are merely included in the line. [xxiv] The other item philosophers and mathematicians typically refer to is the *relation*, or *relatedness*, among the points: what I have been calling the *interconnectivity*.

Zeno's mistake, according to Grünbaum (and others), was that he neglected to recognize that there is more to the continuum than mere points. In discussing Grünbaum's alleged solution and Zeno's Measure Paradox, Pyle writes: "a mere mathematical point adds nothing to the extension of a line; however many points one adds, one does not generate a magnitude... Hence no continuum is compounded of mathematical points..." [xxv] Points cannot be added together (they do not sum to anything greater than a point), and thus addition is not defined for unextended (degenerate) sets.

In Grünbaum's alleged solution to the Paradox, and in basic topology, the two constituents of a line (or a plane or volume [xxvi]) are, in more precise terms, the points, and certain *set conditions* [xxvii] (such as the *set-theoretic union*). For reasons just discussed, Grünbaum tells us that properties such as length apply not to points but to a point-set [xxviii], where the magnitude of the continuum has nothing to do with the unextended points; magnitude comes from the set theoretic union of degenerate sets. Grünbaum's solution, which uses measure theory [xxix], and Cantor's work on infinities, brought about a change of thought from considering a line as a *sum* of points, as Zeno did, to instead considering a line as a set-theoretic union of individual degenerate set intervals of which a single point is a member. Grünbaum's solution depends on set conditions [xxx], and thereby his solution is about *sets*, rather than about set *elements* [xxxi]. Rather than points *aggregating* in some way, point *sets* exist in a *union* (set-theoretic union), and Grünbaum's solution is not about points at all.

Rucker comments on this other constituent of the continuum using another term, "scaffolding" in place of "interconnectedness":

> This view of space has been held by several philosophers since Zeno, notably C.S. Peirce and, perhaps, Kurt Gödel. Gödel distinguishes between the set of points described in set theoretic analysis and the continuous of line of space intuition [then Rucker cites Wang, **From Mathematics To Philosophy**, p. 86 (Humanities Press, New York, 1974): "According to this intuitive concept, summing up all the points, we still do not get the line; rather the points form some kind of scaffold on the line." [xxxii] (Underlining added.)

Analysis of Grünbaum's solution is important because philosophers have often applied Grünbaum's abstract topological conclusions to describe physical space and material objects [xxxiii], as if material points, or unextended physical simples [xxxiv] are basic unextended parts of the ordinary extended objects of everyday experience, and they can be coherently considered to constitute an *extended* continuum. I next argue that any relation or relatedness between points in a continuum is impossible. I do this by merely arguing that any relation or connection between any non-collocated spatial, material, or temporal entities are contradictory.

3. The Impossibility of Relations between Non-collocated Spacetime Points

I will only consider *partless* metaphysical relations between any non-collocated spatial, material, or temporal entities, since that is the way they are typically considered by the philosophers who specifically research such metaphysical items. (For accounts of problems with complex relations—alleged metaphysical relations with parts—see Grupp 2005a, 2005b, and 2005c). If a relation, R, between any points of matter (point particles), between any points of space, time, or spacetime (hereafter I will refer to this points at p_1 and p_3) is partless (noncomplex), it is a *single* entity. [xxxv] If R is describable by a statement, since it is partless then the *entirety* of R is describable by the statement. For example, if R is located at (at least) two topological locations, such as p_1 and p_3, R would be entirely describable by each of the following individual statements, "located at p_1", "located at p_3", and "located at scattered topological region $p_1 - p_3$". (By "scattered topological region" I mean that, as with a flock of birds that involves unconnected birds that occupy a topological region, there are regions of space or time that consist of unconnected topological regions. My argument in this Section works for both scattered and non-scattered topological regions.) This however leads to a contradiction, since this reveals that R is entirely located at one point (such as p_1), but also located at two points (scattered topological region $p_1 - p_3$), this shows us that the relation is both entirely located at a point (p_1) and entirely located at a non-point (scattered region $p_1 - p_3$)—which is a contradiction At the instant in time and space that R does it relating between p_1 and p_3, R would be both a point and not a point. Or, another way to put it would be to maintain that at instant t, R is only located at a point and is only located at *more than* a point. This is however impossible, and it would be analogous to maintaining, for example, that the relation R is both x and not- x ($x \wedge \neg x$), which is the most familiar logical impossibilities known to students of formal logic. For these reasons, I see no other option than to deny that there are partless relations between p_1 and p_3, and this indicates that there are no relations between non-collocated, non-coinciding items, and thus Grünbaum's alleged solution is incorrect since it relies on such relations.

4. Conclusion: Particle Reality

If my preceding arguments are sound, there are no connections of any sort in nature between material, temporal, or spatial points, Grünbaum's alleged solution to Zeno's Measure Paradox is incorrect, and Zeno's puzzle about matter and space is still unsolved—in other words, Zeno's Measure Paradox is, as far as anybody can tell, *not* a paradox at all. Relations and any sort of cannot be part of the ontology or topology of an extended continuum. The only interrelating that would not be affected by the attacks in Section 3 would be interrelatedness that involves the interrelating of entities in a point-sized region. [xxxvi] Relations and relatedness between non-point-sized regions are impossible, and there are no relations between non-identical point-sized regions. It appears that if this is the case, then all point-size regions of nature are *unrelated* to one another.

A debate among topologically oriented philosophers has occurred over the past ten years, including insightful work from philosophers such as Zimmerman [xxxvii], Hudson [xxxviii], Casati and Varzi [xxxix], Barry Smith [xl], Markosian [xli], and several others. Although these discussions are obviously productive and original, nearly no discussion is included in these debates about the precise ontological nature of the interconnectivity of the points in a continuum (or the precise ontological nature of any relation between non-collocated spatial entities), since it is standard to believe that no such analysis needs be carried out. The arguments of this article could show this untrue, as any sort of connection or relation between non-collocated spatial items appears problematical.

If metaphysical connections and relations are cleared away from physics, what is left is the particle reality that is argued for by Stenger, and which is observed in our empirical study of the Universe.

Notes

i Ismael 2000, Section 1.
ii Stenger 2000, 76.
Iii Stenger 2000, 253-54. What Stenger means by "a Platonistic view…" is described in detail below.
iv Grupp, forthcoming.
v 1961. 8.

vi The argument I give in Section 3 that shows that these relations and interconnections are impossible also attach accounts of time and space that are do not involve continuous models of time and space, and they are also arguments that are not repeated in any of my other publications against relations.

vii Grünbaum 1952, 1955, 1967.

viii Edgar, 1979, p. 324.

ix I am not the first to question the basic topological account of space and matter; others, such as Zimmerman (1996), have as well.

x This is what Grünbaum calls it, 1955, p. 165.

xi Zimmerman, 1996, 1.

xii Pyle, 1995, p. 1.

xiii Grünbaum tells us that the Zenoic Paradox arises from the Zenoic manner of considering the points *adding* up, *aggregating*, or *summing* up to a magnitude.

xiv Zimmerman, 1996, p. 1.

xv Non-complex relations are not composed of simpler sub-relations, or parts. Non-complex relations make up complex relations, so if there is a problem with non-complex relations, there is a problem with complex relations also. Some, philosophers, such as David Mellor (Mellor, 1991, 1992.), deny that there are any complex n-adic properties. If this were the case, it would not matter to my reasoning in this paper, since I am going to argue that point.

xvi Edgar, 1979, p. 325. One can attempt to consider the continuum and its interrelatedness of topological points, however without "cutting" (Edgar's word) the continuum apart, which is what I do in this paper.

xvii Zimmerman, 1996.

xviii Hudson, 2002.

xix Casati and Varzi, 1999.

xx Smith, 1997.

xxi Markosian, 1998.

xxii Brown, 1988, p. 2.

xxiii Alexanderoff, 1961, p. 9.

xxiv Grünbaum, 1967, p. 181.

xxv Pyle, 1995, pp. 9-10.

xxvi Grünbaum typically only refers to a line when discussing geometric dimension, so I will also throughout this paper.

xxvii Set conditions can be thought of as relations: there are only two types of entities involved in a set: the set *elements*, and the *relations* between them. Stoll discusses this:

The principle of set extension, the principle of abstraction, and the principle of choice,... constitute the working basis of Cantor's theory of sets. It is of interest to note that... neither of these principles nor the third includes a definition of the word "set". Rather, each is merely the assumption *about* sets. The basic concept used to enunciate these principles is *membership*. Consequently, the membership relation for sets, rather than the notion of set itself, assumes the role of the principle concept of set theory. (Stoll, 1961, 8-9) (Quotes added.)

xxviii Grünbaum, 1967, p. 181.

xxix Nerlich points this out in Nerlich, 1994, p. 204. Nerlich further states: "In measure theory, one always measures sets, usually sets of points, of course."

xxx Nerlich, 1994, p. 204.

xxxi Nerlich, 1994, p. 207.

xxxii Rucker, 1995, pp. 81-82.

xxxiii Salmon, 1980, p. 58: "[Grünbaum] findings enable us to shed more light on a major problem... of ascertaining the geometrical structure of physical space."

xxxiv By "material simple" or "unextended physical simples", I am referring to the current dialogue in the literature between such philosophers as, Markosian (1998), Hudson (2001), McDaniel (2003), Zimmerman (1996), and several others. The terms "matter point" and "physical simple" denote the fundamental, partless substances or bundles, which are the ultimate building blocks. Since Peter van Inwagen's book *Material Beings*, the partless entities have been commonly referred to as "physical simples", "material simples", or "mereological simples", or just "simples".

xxxv To repeat in different words something I wrote above, I am discussing my attack against metaphysical relations as being relations between *points*, but my arguments attack relations between *any* non-identical items that do not perfectly coincide (such as non-point items, like *extended* topological regions of time, space, matter, or spacetime, or topological regions composed of non-points, such as the Planck cells discussed in non-commutative geometry), and I only discuss relations between points for the sake of brevity.

xxxvi This sort of relating is attacked, however, in Grupp forthcoming.

xxxvii Zimmerman, 1996.

xxxviii Hudson, 2002.

xxxix Casati and Varzi, 1999.

xl Smith, 1997.

xli Markosian, 1998.

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