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Maximally Contiguous Simples

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by

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ABSTRACT

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Much of the recent work done in mereology has been focused on answers to Ned Markosian's Simple Question: What are the necessary and jointly sufficient conditions for an object's being a simple i.e. a thing with no parts? In this paper, I analyze Markosian's own answer, The Maximally Continuous View (MaxCon), and highlight a few of the strongest objections against that answer. I then argue that the objections only arise because Markosian assumes problematic conceptions of spacetime and matter. After updating each assumption with our best physics, I arrive at my own view, which I call the Maximally Contiguous View of Simples. I show that my view accommodates the intuitions that motivated MaxCon while also avoiding the issues that plagued it. I conclude by interacting with a couple possible objections to my view.

To

Johanna, my love,

for reading this paper too many times to count

and my parents

for supporting me through the process

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None of this would be possible without the unfailing love and support from my parents, Carol and Rick. I offer my deepest gratitude to them and to the rest of my family for all they have done for me these many years.

To posit a substantive and informed ontology, metaphysics must be informed by other fields, especially fundamental physics. In this paper, I apply this insight at length to the field of mereology (which concerns the relations between parts and wholes). Section 1 of this paper introduces Ned Markosian's "Simple Question" and details his answer to the question, a theory he calls the Maximally Continuous View (MaxCon). I then present what I take to be the strongest arguments against MaxCon. In sections 2 and 3 I show that these problems arise from specific assumptions that Markosian makes about the nature of spacetime and of matter. For each assumption, I offer another option informed by our best understanding of physics. In section 4, I present my own answer to the Simple Question, the Maximally Contiguous View. Contrary to most contemporary theories, my view attempts to preserve the spirit of MaxCon while updating the scientific assumptions. I show how updating each of Markosian's assumptions with our best physics ameliorates the problems that plagued MaxCon. By so doing, my view is able to preserve the core intuitive draw behind MaxCon without any of its drawbacks. Finally, in section 5, I engage with an argument by Joshua Spencer from the possibility of time travel against spatial occupancy accounts of simplicity and in response extend my view to incorporate spacetime occupancy.

1. MaxCon

Ned Markosian shifted the landscape of the field of mereology when he published his paper "Simples."[1] Where the field was mostly concerned with questions of composition, Markosian asked

[1] Ned Markosian, "Simples," *Australasian Journal of Philosophy* Vol. 76, No 2 (1998): 213-228.

The Simple Question: What are the necessary and jointly sufficient conditions for an object's being a simple?[2]

By stipulation, a material simple is an object with no proper parts. However, such a definition does not help us locate the simples or give any illumination on other mereological categories such as parthood. Thus, we want an answer to the Simple Question that does not make reference to parthood or any other mereological term. After surveying a few intuitive answers to the question, Markosian posits the following:

The Maximally Continuous View of Simples (MaxCon): Necessarily, *x* is a simple iff *x* is a maximally continuous object.[3]

Where:

x is a maximally continuous object $=_{df}$ *x* is a spatially continuous object and there is no continuous region of space, R, such that (i) the region occupied by *x* is a proper subset of R, and (ii) every point in R falls within some object or other.[4]

Despite the unintuitive verbiage, MaxCon is conceptually straightforward. To find a simple, you must first isolate some region of space that is continuous and entirely filled with matter.[5] Then, you must determine whether that region is a proper sub-region of another region that is also continuous and matter-filled. This process continues until no such greater region can be found, at which point the matter in that region constitutes a simple.[6] Loosely, something is a simple just in case it is separate from anything else and has

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[2] Ibid. Note: the majority of people working on simplicity are concerned with material simplicity in particular. In general, it is thought that if there is a mereology of e.g. concepts or non-physical concreta, then those principles will be distinct from material mereology. At least, this will be an assumption of this paper.
[3] Markosian, "Simples."
[4] Ibid. Markosian borrows his topological definitions from Richard Cartwright's "Scattered Objects" (1975).
[5] Talk of "matter" is introduced in Ned Markosian, "Simples, Stuff, and Simple People," *The Monist* 87 (2004): 1-3.
[6] Talk of "constitution" is introduced in Ibid., 3-4.

no portion that is separate from the rest. Finally, it may help to note the inverse of the view, namely that composite objects must occupy disjoint regions of space.

This core intuition is strong, and ought to be upheld if possible. However, things quickly break down when we push on the theory to test its limits. First, this view gives no reason to think that there could not be a very large mereological simple, say, a maximally continuous, life-sized statue of Joe Montana. All that this would require is enough matter arranged continuously. However, such a simple would fly in the face of our usual assumptions about simples (e.g. that they are small). Additionally, we lack any evidence that would lead us to believe that such an object would be as feasible as MaxCon makes it out to be. In particular, while such large simples may be physically difficult to construct, there is nothing in an ideal theory that would disallow arbitrary amalgams of matter to be made into simples. A second, more damning, objection was formulated by Markosian himself and further developed by Kris McDaniel.[7] This objection involves the possibility of perfect contact between non-identical objects. However, to explain the argument will require a short detour into the field of topology.

Topology is a sub-discipline of mathematics which is concerned with the geometric properties of space "that are preserved through deformations, twistings, and stretchings of objects."[8] One of the central distinctions drawn in topology is between open and closed regions of space. These terms are best understood by analogy with the number line. If a number is "less than or equal to 1," there is a greatest number that it can be—a determinate upper bound to its value—1. If something is merely "less than 1," this fact does

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[7] Kris McDaniel, "Against MaxCon Simples," *Australasian Journal of Philosophy* Vol. 81, No. 2 (2003): 265-275.
[8] Eric W. Weisstein, "Topology," from MathWorld—A Wolfram Web Resource.

not obtain—no matter how close a number is to 1, there will always be another number that is closer to the boundary. The same can be said of regions. A region is topologically closed just in case it has a determinate outer bound (a final point along its surface or edges), and topologically open just in case such a bound does not exist. Some regions can act as receptacles for objects, and the view that any kind of region can be a receptacle is called a liberal theory of receptacles.[9] We then define an object's topological features derivatively from the region it exactly occupies: open if it occupies an open region, closed if it occupies a closed region, and perhaps mixed if the region is partially open and partially closed.

For truly perfect contact between two objects, it is theorized that one of the objects would need to be closed (to supply that final bound), and the other open (to accept that final bound). With this in mind, if we have two objects, A and B, one of which is at least partially topologically open and the other at least partially topologically closed, we can imagine the two coming closer together until they come into perfect contact with one another, thus occupying a continuous region of space. If MaxCon is true and we have a liberal view of receptacles, then in the instant that we would expect A and B to touch, we would instead witness either the annihilation of A, the annihilation of B, or the annihilation of both A and B and the spontaneous appearance of a new thing, C, *viz.* the simple occupying the relevant maximally continuous region. However, our intuitions generally lead us to believe that all we see is two distinct objects coming into contact. The intuition can be strengthened if we imagine the two 'bouncing' off one another, which would require

[9] Gabriel Uzquiano, "Receptacles," *Philosophical Perspectives* vol. 20 (2006): 427-451.

the annihilation and spontaneous appearance of a number of objects over a very short span of time.

The oddity of this conclusion has been further highlighted by McDaniel who poses the Simple People Problem, in which we conceive of all of a person's simple constituents coming into perfect contact, perhaps by threading a simple length of string through all of the simples in that person's body, thus making a single, large simple: a simple person. Then, we can conceive of two such people coming into contact and forming a single material object. However, intuitively both persons persist, despite there being only one material object. Assuming that persons are material objects, this spells trouble for MaxCon.[10] These bizarre outcomes are more than enough to turn many away from MaxCon.

2. Theoretical Foundations of MaxCon: *Space*

Many of the issues with MaxCon stem from assumptions that Markosian makes about the way the world functions. One such wide-spread assumption is that space is classical. We say a space is classical when it is dense and continuous. A space is dense just in case "between any two atomic regions there is a third atomic region."[11] It will again be useful to consider a number line to understand this concept. Take any two numbers, say 1 and 2. Between these two numbers will be another: 1.5. But between 1 and 1.5 will be another number: 1.05. With some reflection, we can see that this process can be repeated ad infinitum. So too with points in space. A space is continuous just in case for any finite, extended portion of space, that portion is constituted by an uncountably infinite number of points such that any perfect cut in that space will necessarily leave half of the space along

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[10] McDaniel, "Against MaxCon Simples," footnote 15, 270. For a more thorough version of the argument, see Joshua Spencer, "A Simple Paper."
[11] Joshua Spencer, "Material Objects in a Tile Space-Time" (Ph.D. thesis, University of Rochester, 2008), 1.

the cut topologically open and half topologically closed. Returning to the number line, there are uncountably infinite numbers between 1 and 2. Furthermore we can make a perfect cut (called a Dedekind cut) in those numbers at 1.5 by isolating just those numbers that are greater than 1.5, forming an open boundary. However, this necessarily creates a closed boundary on the other side since 1.5 is not included in the former category and thus constitutes the upper bound of that set of numbers. And again, we can apply this insight to space. Thus, in more approachable terms, classical space assumes that space is fundamentally like a 3-dimensional Cartesian grid with points in space exactly corresponding to an ordered triplet of real numbers.[12]

While classical space seems to be the default belief held by most people, it comes with a host of paradoxes that give us good reason to be suspicious of it. To be clear, the following is a cumulative-case argument meant to weaken the intuitive support for classical space. None of the arguments are meant to be knock-down defeaters of that conception of space, and indeed classical space remains by far the more popular option. However, it is my impression that that consensus is waning, in no small part because of the considerations I raise. First, classical space allows for topologically open and closed regions, which, paired with the possibility of extended objects and a liberal view of receptacles, implies the possibility of topologically open and closed objects. Above, we employed these concepts to allow for perfect contact, but we can also use them to disallow contact. Take two topologically closed objects. As we move them closer together, we can track just the

[12] Because of special relativity, it will turn out that space will correspond to a Minkowski spacetime rather than Cartesian space, and general relativity will further deform the space. However, the relationship to the real numbers remains fixed in both.

location of their closest points (where they would inevitably touch). However, because classical space is dense, there will always be an uncountable infinity of points between these two points. No matter how close they get, they can never actually touch.[13] Note too, that this is not because of any external force or from their collision. No physical impediment exists, but still no matter how much we try to move the objects together, by definition they cannot meet. The situation is similarly odd when both objects are topologically closed. The objects are able to move together until there is zero distance between them and still fail to touch, and were they to collide they would mysteriously repel without ever coming into contact. Again, note that this is not because of any forces like the electromagnetic repulsion we find in reality, but is rather the result of their geometry alone.

Classical space also gives rise to some of Zeno's paradoxes of motion. For example, the Paradox of the Dichotomy says that to reach some point, you must first get halfway there, but to get halfway you would first have to get halfway to the halfway point (one quarter the way), and so on.[14] In the end, you end up having to complete an infinite number of tasks in a finite time to reach the original target point. The standard response to the paradox is to highlight that the requisite time in question is also being reduced down toward 1/infinity. Thus, for any distance traveled, the time required to cross that distance will reduce concomitantly; crossing each of two regions takes half as much time as crossing the whole distance, crossing each of one billion regions takes one billionth as much time as crossing the whole region, and so forth. This is roughly the way that calculus interprets

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[13] Dean Zimmerman, "Could Extended Object Be Made Out of Simple Parts? An Argument for 'Atomless Gunk'" *Philosophy and Phenomenological Research*, Vol. 56, No 1 (1996): 11-19.
[14] Nick Huggett, "Zeno's Paradoxes," *The Stanford Encyclopedia of Philosophy* (2018).

continuous rates of change. However, this leads to its own problems, such as the fact that all distances end up containing the same amount of points (a one inch line and the entire observable universe contain the same cardinality of infinity of points). Additionally, it is the resultant infinities that allow for the Banach-Tarski paradox, which says it is possible to take an object in classical space and cut it into up to five distinct pieces, all of which are the same size and mass as the original.[15] While it is not feasible to instantiate this paradox (as it requires infinitely complex cuts using the Axiom of Choice), the metaphysical possibility would persist, which is enough to weaken our trust in classical space.

The most prominent alternative to classical space is discrete space. We say a space is discrete just in case it is not dense, i.e. there are spatial atoms between which there are no other spatial atoms. Given some plausible restrictions, such as space being uniform in each direction and not changing drastically across different regions, discrete space also yields a space that is non-continuous and thus contains a finite number of spatial atoms in each finite region. I follow Spencer's terminology and will call extended, discrete spatial atoms "tiles," and any space or spacetime composed entirely of tiles a "tile space." One important upshot of choosing a tile space is that it leads to spatial atoms that tessellate, fitting together in a way that does not allow of gaps. There are many ways of specifying different sorts of tile spaces, but these basic tenants are enough for the view I ultimately plump for.

While the possibility of tile space may be initially suspect, it is not without precedent. Scientists have long searched for a theory of quantum gravity that would unite general relativity and quantum mechanics. Such a theory would fully embrace Einstein's

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[15] Eric W. Weisstein, "Banach-Tarski Paradox," from MathWorld—A Wolfram Web Resource.

insight—that there is no absolute space—by positing a gravitational field which describes the geometric quantities of length, area, and volume.[16] One of the most promising avenues for such a theory is that of loop quantum gravity. Loop quantum gravity attempts to bring Einstein's gravity field fully under quantum field theory, which would necessitate the gravitational field to be quantized, i.e. for the geometric quantities of length, area, and volume to come in discrete packets.[17]

Furthermore, there is already a length at which our understanding of physics and our concept of distance fail: the Planck length ($1.6X10^{-35}$ m). In the remainder of this section, I will offer a cumulative-case argument for approximately Planck length-sized tiles. As with my arguments against classical space, none of the following arguments on their own offer proof of tile space, but together give some reason to think that space may be composed of tiles. One way to visualize this breakdown is by thinking of a quantum version of Zeno's Tortoise thought experiment. We can imagine one stationary (or relatively slow moving) particle, which we will call Tortoise, and one moving (or relatively faster) particle, which we will call Achilles. At time t_1 we can tell that Achilles is behind Tortoise, whereas at time t_2 we can tell that Achilles is in front of Tortoise.[18] If we assume a classical, continuous spacetime, then there will be some time t_n at which Achilles is less than one Planck length

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[16] Carlo Rovelli, "Quantum spacetime: What do we Know?" in *Physics Meets Philosophy at the Planck Scale: Contemporary Theories in Quantum Gravity*, eds. Craig Callender and Nick Huggett (Cambridge: Cambridge University Press, 2001), 110-111.
[17] Lee Smolin, *Three Roads to Quantum Gravity*. (New York: Basic Books, 2000), 95-105.
[18] To minimize the indeterminacy introduced by the possibility of quantum tunneling, we can imagine that at t_1 Achilles is trapped using an ideal, infinite-potential barrier on one side of a perfect vacuum chamber while Tortoise is held somewhere in the middle. At some time, we release Achilles and accelerate it toward the opposite end of the chamber, causing it to pass Tortoise, and at exactly t_2 Achilles strikes a sensor attached to the opposite wall. The general point I am making does not seem targetable by other technical concerns though.

behind Tortoise. However, at this scale, spacetime is wholly dominated by quantum phenomena (which will be touched upon below), which make it impossible to differentiate between the two locations.[19] Thus, to say that Achilles is one-tenth of a Planck length behind Tortoise is a metaphysically indistinguishable state of affairs from Achilles being one-tenth of a Planck length in front of Tortoise. Thus, while we may be able to conceive of distances below this threshold, they, in reality, do not exist.

Another reason to think that the Planck length is fundamental has to do with the entropy of black holes. Entropy, roughly, is the measure of the disorder in a system, and is tied to the statistical likelihood of certain sets of micro-states that macroscopically "appear" the same.[20] One may then wonder about the entropy inside of a black hole. Because black holes are the densest possible configuration of matter, they will also have the highest entropy since any arrangement of matter within their event horizon will yield an identical-appearing black hole.[21] Surprisingly, it has been shown that the entropy inside of a black hole is determined by the number of Planck lengths squared needed to tile the surface area of the black hole's event horizon.[22] Since black holes will have the greatest possible entropy, and the entropy of black holes comes in discrete units of Planck squares,

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[19] For those with some knowledge of quantum mechanics: the way we define location is using an object's de Broglie wavelength, but the de Broglie wavelength does not differentiate between locations at the Planck scale.

[20] This sense of appearance is vague but intuitive enough. If I drop some cream into my coffee, there are many configurations that make the cup appear fully mixed together and homogenous, while there are relatively very few configurations which appear the same as all the cream pooling in one corner.

[21] Brandon Carter, "Axisymmetric Black Hole Has Only Two Degrees of Freedom," *Physical Review Letters* vol. 26 no. 6 (1971): 331.

[22] Jacob D. Bekenstein, "Black Holes and Entropy," *Physical Review D* vol. 7 no. 8 (1972): 2334. For a more approachable discussion, see also Brian Greene, *The Fabric of the Cosmos: Space, Time, and the Texture of Reality*, (London: Penguin Books, 2004), 151-156.

it would appear that the Planck square is the fundamental unit of space.[23] To see why, assume for *reductio* that there were smaller regions. Then we could conceivably recombine the matter in those smaller areas and thus increase entropy. But this contradicts the scientific posit that black holes have maximal entropy. Thus, science would seem to suggest that Planck units are fundamental.[24]

Finally, the Planck length operates as an observational barrier. When investigating subatomic space, we cannot directly observe any phenomena because it is too small. However, we are able to circumvent this problem by packing incredible amounts of energy into those areas and observing the results (this is the basic principle on which particle accelerators and colliders are built). But this solution only works to a point. Eventually, just the energy being packed into the area will create enough gravitational force to form an energy-based black hole, called a kugelblitz. The limit below which we cannot probe without forming a kugelblitz just so happens to be the Planck length.[25]

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[23] This interpretation is not without its own controversies. There are some reasons to think that perhaps these measurements are the result of intense gravitational effects. Additionally, there is an even more remarkable theory that, assuming a 3+1 dimensional analog of AdS-CFT duality, allows for the universe to be one infinitely large hologram, which would explain the relationship between black hole entropy and surface area (See Juan M. Maldecena, "The Large N Limit of Superconformal Field Theories and Super Gravity," *International Journal of Theoretical Physics* vol. 38 no. 4 (1999): 1113-1133). However, this theory has yet to receive a determinate mathematical model. Regardless, the above interpretation seems to be fairly standard.

[24] Alternately, we can approach the problem as an answer to the quantum information paradox. We begin with the fact that black holes have maximum information (given similar reasoning as is supplied in the main text for their maximum entropy, as entropy and information are importantly linked). The only properties had by black holes are mass, spin, and charge, so it would seem that information about what fell into the black hole is destroyed. However, this violates the conservation of information. Thus, we might posit that that information is stored on the event horizon of the black hole and eventually yielded back into the universe via Hawking radiation. But then, since entropy is related to Planck squares on the surface of the black hole, were there more information than could be stored in those squares, then black holes would not have maximal density of information. But they do have maximal information. Thus, quantum information must come in packets regarding Planck squares at the fundamental level.

[25] I recognize that this point is far from definitive on the matter; just because we cannot see that far down does not mean that those distances do not exist. However, it is interesting that the barrier exists at just that place where our ideas of distance break down.

While neither the prospect of quantum gravity, the break-down of our concept of space on smaller distances, the seemingly discrete nature of entropy in black holes, nor the observation barrier give us an absolute reason to affirm discrete space, all of these facts hint that our world is fundamentally discrete. Additionally, given the metaphysical and mathematical conundrums that arise from classical, continuous space, we have good reason to favor a discrete model.

3. Theoretical Foundations of MaxCon: *Matter*

With the above theory of tiles, we are able to avoid the problems with classical space. However, Markosian still runs afoul with his understanding of matter. In particular, he assumes that micro-scale objects act classically. When I interact with a medium-scale object, say, a beach ball, it has familiar properties like the ability to move approximately according to Newton's laws, as well as having determinate location and momentum values. However, these properties only arise at this medium size. Our best understanding of particle physics, Quantum Field Theory, says that objects at the sub-atomic scale exist in different ways, which we dub particle-wave dualities.

One crucial upshot of this fact is the Heisenberg Uncertainty Principle, which states that every particle has both indeterminate position and momentum until one is measured. Importantly, this indeterminacy is metaphysical, not epistemic, so in some sense the particle is located in each possible location—a state called superposition.[26] At the moment of measurement, the indeterminacy of one of the values, say location, probabilistically

[26] For the purposes of this paper, I assume we are using any of the leading theories besides Bohmian pilot-wave theory. Most of what I say will be more closely in line with the Copenhagen interpretation and the von Neumann-Dirac collapse notation. However, it is easy enough to translate for those inclined toward GRW or Everett's pure wave mechanics.

snaps to one exact value—called an eigenvalue—while the other value, in this case the momentum, becomes wholly indeterminate. In essence, particles can only have precision in one domain at the expense of indeterminacy in another. The probability of finding a particle in a given location can be coded in a mathematical entity called a wave function. These wave functions evolve over time according to the Schrödinger equation, and we call the operation that snaps an indeterminate value, say of its location, to an eigenvalue, "collapsing" the wave function. Thus, we can conceive of an infinite set of ordered pairs of vectors, $|x\rangle|p\rangle$, that, for any given particle, give the possibility space for its eigenvalues of position and momentum, respectively. Then, when a measurement is made, the possibility space collapses to a determinate value, e.g. for location in three dimensions $|2, 5.1, 3.7\rangle$.[27]

This causes issues for MaxCon because we cannot say whether an object is maximally continuous or not when it, other objects, and even sub-portions of those objects, could exist in superpositions of locations. For example, take two electrons that are close to one another. If no measurement is made, the electrons exist in a superposition of states, some of which are continuous with one another and some of which are discontinuous. MaxCon gives us no way to evaluate this situation. Furthermore, since the majority of matter in the universe goes unobserved, MaxCon will fail to describe all but a very small

[27] This is not to say that vagueness sneaks in or that classical logic breaks down. Similar to the way that space and time are relative and undergo Lorentz transformations from our perspective but spacetime coordinates are Lorentz invariant, superpositions appear as if they are indeterminate but we can describe their state in a Hilbert space wherein we can see that the super position is the particle determinately having values of less than 1 in numerous orthogonal bases that describe location in the infinite-dimensional manifold. For an approachable introduction to this material, see David Albert, *Quantum Mechanics and Experience*.

subset of the matter in the universe, and only in the instant of measurement.[28] Such a limited theory cannot be what we are looking for.

4. Maximally Contiguous Simples

For all that is wrong with MaxCon, I believe that its basic intuition (that simples should not allow of gaps) should be preserved. In this section, armed with the above scientific theories, I will offer an updated version of MaxCon which is better suited to respond to the usual objections.

While MaxCon relies on the concept of continuity, this is a topological term that only applies to classical, point-based spaces.[29] Therefore, we will need a version of this concept that works on tile spaces and can do the same theoretical work. However, since we cannot refer to sub-regions of the tile when defining this concept (since the tiles have no sub-regions), we will have to define this perfectly-next-to relation in a somewhat roundabout way. I offer the following as a possibility:

> **Contiguity**: A set of tiles, S, is contiguous iff either S contains only one tile, or for any subregions of S, j and k, there is a path connecting them, all of whose members are members of S.

Where

> a path is an ordered series of regions, $m_1 - m_n$, such that for any member of the series, m_Φ, if there are members immediately preceding or following it, $m_{\Phi-1}$ or $m_{\Phi+1}$ respectively, then there is no region whatsoever between m_Φ and $m_{\Phi-1}$ or $m_{\Phi+1}$.[30]

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[28] This articulation of the argument strongly assumes the Copenhagen interpretation. However, other interpretations will have versions that fit their understandings. GRW will have collapses spontaneously, but even so, there will almost certainly be more matter in the universe in superpositions than in eigenstates of location. Everettian pure wave mechanics will have no collapse mechanics, only foliations of the wave function. These will yield similar results and can likewise ground the distinctness of particles.

[29] More accurately, continuity and related topological terms like "open" and "closed" apply only to spaces that are divisible an unaccountably infinite number of times.

[30] Thank you to Joshua Spencer for leading me both to this issue and to this style of response.

Furthermore, I will call an object "internally contiguous" just in case all of the tiles occupied by that object are contiguous with one another via a path all of whose tiles are occupied by that object. With these definitions, we can easily switch from Markosian's maximal continuity to maximal contiguity without appeal to classical space:

> **Maximal Contiguity**: An object *o* is maximally contiguous $=_{df.}$ *o* is internally contiguous, and there is no occupied tile *t* such that *o* does not occupy *t* and any tile in *o* is contiguous with *t* via a path that is occupied by something or other at each of its members.

With tile space, contiguity, and some quantum mechanics at our disposal, we can finally posit a fully developed theory. However, we must be careful in the formulation of the view. It would be tempting to claim an object is a simple just in case all of its possible eigenstates of position are maximally contiguous. However, this is much too strong. Take the case of photons in a laser. We may wish to claim photons are simples, but when they are in a laser's beam, they are packed so tightly that they overlap one another in a way that would make many of their possible eigenstates contiguous with one another. For a more nuanced approach, I offer the following.

> **The Maximally Contiguous View of Simples**: An object *x* is a simple iff all of *x*'s possible eigenstates of position are internally contiguous, and there is no object *p* such that all of *p*'s possible eigenstates of position are contiguous with *x* via a path that is occupied by something or other at each of its members.

Note that maximal contiguity never appears in the view explicitly, but any eigenstate of a simple that collapses away from any other object will be maximally contiguous. This solves the problem with photons in lasers from above. Roughly, simples are the maximal things that always collapse together.

The influence of MaxCon on this view is quite clear, but it is its similarity to another view, the Indivisibility View of Simples, that helps it avoid the problem of perfect contact.

The Indivisibility View states that an object is a simple just in case none of its portions can be separated (either physically or metaphysically) from any other portion.[31] Thus, while it is certainly the case that two simples will have possible, contiguous eigenstates, it will never be the case that they are necessarily contiguous if they are indeed separate simples.

To illustrate, we can assume that the fundamental particles of the standard model are simples, i.e. for each other thing in the universe *x*, there will be some possible eigenstate of the particle in question on which the particle is non-contiguous with eigenstates of *x*. So, I might wonder whether a meson is a simple or not. I make a measurement and find that the matter in the meson collapses into two disjoint internally-contiguous regions (perhaps corresponding to a bottom and an anti-bottom quark). I can then determinately say that the meson is not a simple, but the quarks could be. However, if I made a measurement with the strange result that there was only one contiguous region, this would not be sufficient to prove that the meson is a simple since there could have been other possible collapses for the constituents that were non-contiguous.

We are now in a position to respond to the problems that I originally raised for MaxCon. First, a life-sized, simple statue of Joe Montana on MaxCon merely requires that we glom together enough matter in a continuous region. On my view, while it may be broadly metaphysically possible for all that matter to accumulate in such a way, the laws of nature dictate that the individually collapsing entities are all much smaller than such a statue (which is grounded in facts about the stability of certain states in quantum fields). Thus, barring a radical rewriting of the laws of nature, the simple statue is ruled out. As for the Simple People Problem, the Maximally Contiguous View allows for the perfect contact

[31] Markosian, "Simples," 11-13.

of distinct simples so long as there were other possible eigenstates of position for each of the particles in question. Therefore, one could never create a state of affairs such that at time t_1 there are two simples, but at time t_2 there is only one simple that is constituted of the same matter, and so the problem of perfect contact is averted.

One worry that is sure to arise is that I rely on scientific theories that are contentious in the scientific community. Both tile space and the interpretations of quantum mechanics compatible with my view lack anything resembling unanimous agreement among scientists. Even if one believes that the laws of nature are necessary, we lack knowledge of which laws are true. This is hardly a unique problem for science though. There is disagreement surrounding almost every proposition in philosophy, whether it be a grand theory or the most fundamental assumption. In the face of such disagreement, we must take a stance on the more fundamental propositions and theory-build from there. True, there will be those who disagree on the fundamentals, but they can build their own theories that best fit their assumptions. In the event that science progresses to a point where it can arbitrate between the fundamental facts, we will already have theories that accommodate that outcome. On the other hand, if the best mereological theories all end up assuming e.g. loop quantum gravity, we end up with some evidence that that theory may be correct rather than a competing theory. Thus, I am free to avail myself of a few controversial theories, granted I am forthcoming about that fact.

5. Time Travel and Spacetime Occupancy

Spencer raises an objection that targets all accounts of simplicity that are based on the region that the supposed simple occupies.[32] Roughly, the argument imagines a particle

[32] Spencer, "Material Objects in a Tile Space", Ph.D. diss., University of Rochester (2008):61-88.

that travels backward through time to occupy a space disjoint from its earlier self. Spencer then notes that any occupancy account of simplicity, my own included, will give the conclusion that the two matter-filled regions are two distinct objects. However, we know that there is merely one, time traveling object. Thus, occupancy accounts of simplicity must be wrong.

This argument makes an assumption about location that is fairly natural given Markosian's formulation of MaxCon: namely that location is a merely spatial property. For the argument to work, we must only be looking at the distribution of matter in space for a given time. However, we can easily extend the view to encompass temporal occupancy. In fact, given the unity of spacetime, it makes more sense to flesh out the view in terms of contiguous spacetime tiles, with the concept of a path including tiles next to one another in the temporal dimension.[33]

To appreciate the primary difficulty with this move will require another short digression into quantum mechanics. As noted above, quantum particles are described using wave mechanics on a probability wave function until they are measured, and then collapse mechanics dictate how they snap into an eigenstate. However, after the collapse, they immediately return to being spread out along their wavefunction.[34] Thus, a simple will only be in an eigenstate of location for one instant and then will immediately enter a superposition of numerous states, so defining contiguity can be difficult. However, the

[33] My view above is not fleshed out in these terms so as to be neutral with respect to temporal ontology. The following exposition will assume 4-dimensionalism/eternalism about time. I believe there is a way that this could be fleshed out in terms that would be agreeable to a presentist using tense operators, but the specifics elude me.
[34] This is because the particle's momentum value is very indeterminate. Each possible momentum will take the particle in a different direction at a different speed, leading quickly to a spread-out superposition of locations.

wave dynamics used to describe the particle are well defined and deterministic, so we can track simples from their collapse to their subsequent states. This allows simples to continue being simples when they again enter superposition since all possible collapses at each instant will be contiguous with those at the last instant. Another way to visualize what is happening is that the particle takes all possible paths after its collapse to an eigenstate of position and its superposition is a kind of aggregate of all these possible paths (called a path integral). Since each of these paths are contiguous, we can still claim that the particle is simple.[35]

Favoring a spacetime account of location not only can give us a clean understanding of the persistence of simples, but also can explain the phenomenon of time-reversal. Quantum field theory predicts the existence of anti-particles for every particle of the standard model: electrons have positrons, top quarks have anti-top quarks, etc. One leading theory about these anti-particles is that they are time-reversed versions of the standard particles. So, from our perspective we might view an electron and positron colliding, annihilating one another, and emitting a photon, but from a timeless perspective, the same interaction could be viewed as an electron spontaneously emitting a photon and as a result heading back in time. A purely spatial view of location will struggle to describe this situation as a single object since at each time there appear to be two particles. With my view, however, we can track the particle through spacetime and determine if it is contiguous along some dimension at each point. If it is, then we can say that the electron and positron are actually one object.

[35] Using Hilbert space notation makes this tracking even clearer, since the particle is always denoted by a single, length-1 vector. See footnote 24 above.

In order for Spencer's argument against location-based views to apply to my view, he would have to assume the use of disjoint time travel. Fictional time machines often utilize this sort of time travel, jumping suddenly to their new temporal location without following a contiguous spacetime path. However, all physically viable time travel options we are aware of rely on either time-reversal or radical curvatures of spacetime, both of which allow for clear, contiguous paths from the future to the past. Thus, time travel itself does not undermine my position. This does raise questions about teletransporter cases, wherein an object is suddenly and disjointly sent to some remote location. A couple thoughts on these cases: First, because quantum mechanics is already appealed to in my definition of material simplicity, teletransporters that rely on quantum entanglement will be non-starters as objections. Since these are our best candidates for teletransporters, I do not think that this worry holds up. Second, even if there were truly disjoint teletransporters and one decided to bite the bullet and agree that a simple sent through such a machine would come out a distinct object, this does not necessarily entail that any objects composed of those simples must also be annihilated upon entering the machine.

Finally, my view does yield the result that at any given moment it is unclear how many distinct simples there are in existence. I take this oddity as a strength though. Take the single-electron universe hypothesis raised by John Wheeler.[36] It notes that, since electrons can propagate backwards through time, it seems possible that there is only one electron in the universe that goes back and forth through time to each moment that we observe an electron. This hypothesis is very likely wrong, but this is an empirical fact that

[36] R.P. Feynman, "Space-Time Approach to Non-Relativistic Quantum Mechanics," *Reviews of Modern Physics* vol. 20, no. 2 (1948): 367-387.

we ought not assume is false in our theory of simplicity. My view can make sense of such a possibility, which I take to be a strength.

Conclusion

While Ned Markosian's MaxCon fails as it was originally stated, updating the scientific assumptions at play was enough to develop a far more robust and informative theory. By favoring a tile space, we avoided problems that surround concepts like topologically open and closed, as well as oddities like the Banach-Tarski paradox. Framing the theory using quantum mechanics not only makes the theory meaningful from a particle physics perspective, but also solves the most damning objections to MaxCon that arise from the possibility of perfect contact. Finally, by expanding contiguity to the temporal dimension, my view is able to accommodate multiple phenomena surrounding time travel and overcome Spencer's argument against occupancy accounts of simplicity. The benefits of consulting our best physics are particularly striking in the field of mereological simplicity because MaxCon is so widely maligned, but the insight—and the resultant benefits—generalize to other areas of metaphysics. Thus, I hope to have both supplied a new theory of simplicity and highlighted a way forward for the field broadly.

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