Comparativist theories or conspiracy theories?
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COMPARATIVIST THEORIES OR CONSPIRACY THEORIES?*

Many of our most successful physical theories posit the existence of absolute quantities. Newtonian mechanics, for instance, is an empirically adequate theory of medium-mass, low-velocity phenomena that seems to posit the existence of both absolute positions and absolute masses. However, such absolute quantities are often said to be undetectable because they vary under the theory's symmetries.[1] For example, absolute position varies under boosts, and absolute mass (arguably) varies under uniform scalings.[2] This is

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[1] See John T. Roberts, "A Puzzle about Laws, Symmetries and Measurability," *The British Journal for the Philosophy of Science*, LIX, 2 (2008): 143–68; or Shamik Dasgupta, "Symmetry as an Epistemic Notion (Twice Over)," *The British Journal for the Philosophy of Science*, LXVII, 3 (2016): 837–78. For dissent, see David Wallace, "Observability, Redundancy, and Modality for Dynamical Symmetry Transformations," in James Read and Nicholas J. Teh, eds., *The Philosophy and Physics of Noether's Theorems: A Centenary Volume* (Cambridge, UK: Cambridge University Press, 2022), pp. 322–53; and Ben Middleton and Sebastián Murgueitio Ramírez, "Measuring Absolute Velocity," *Australasian Journal of Philosophy*, XCIX, 4 (2021): 806–16. However, for a response to the latter, see Caspar Jacobs, "Absolute Velocities Are Unmeasurable: Response to Middleton and Murgueitio Ramírez," *Australasian Journal of Philosophy*, C, 1 (2022): 202–06. The case of mass is discussed in Niels C. M. Martens, "The (Un)detectability of Absolute Newtonian Masses," *Synthese*, CXCVIII, 3 (2021): 2511–50.

[2] Whether uniform mass scalings are symmetries of Newtonian mechanics is controversial. See Shamik Dasgupta, "Absolutism vs Comparativism about Quantity," in Karen Bennett and Dean W. Zimmerman, eds., *Oxford Studies in Metaphysics, Volume 8* (Oxford: Oxford University Press, 2013), pp. 105–48; John T. Roberts, "A Case for Comparativism about Physical Quantities" (unpublished manuscript, 2016); Martens, "The (Un)detectability of Absolute Newtonian Masses," *op. cit.*; Niels C. M. Martens, "Machian Comparativism about Mass," *The British Journal for the Philosophy of Science*, LXXIII, 2 (2022): 325–49; David J. Baker, "Some Consequences of Physics for the Comparative Metaphysics of Quantity," in Karen Bennett and Dean W. Zimmerman, eds., *Oxford Studies*

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one of the puzzles that motivates a view called *comparativism*, which aims to reformulate our theories in terms of comparative quantities that do not vary under symmetries, such as distances or mass ratios. The absolutism/comparativism debate (or, in the context of discussions of space and time, the substantivalism/relationism debate) dates back to the Leibniz–Clarke correspondence. There, Leibniz argued that space could not be a real substance in which bodies were located, since this implied the possibility of worlds that are qualitatively indiscernible yet differ by a uniform shift of all material bodies. More recently, there has been significant debate over whether mass properties or mass relations are fundamental (see references in fn. 2), and over whether quantities that vary under gauge symmetries are fundamental.[3] In both debates, absolutism is opposed to comparativism.

If the comparativist is to succeed, her theory must "save the phenomena," for even if there are *in fact* only distances and mass ratios, the predictive success of absolutist theories means that the world looks just *as if* there are absolute positions and masses. In this paper, I argue that if comparativism is true, there is a sense in which it is a "cosmic conspiracy" that the world looks just as if there are absolute quantities. The comparativist cannot satisfactorily explain why it is that our absolutist theories are empirically adequate if they are in fact false. The argument is structurally similar to the well-known No Miracles Argument for scientific realism, which reasons that the success of science is a cosmic coincidence if theories are not in fact (approximately) true.[4] Just as anti-realism cannot explain the empirical adequacy of our theories in general, so comparativism cannot explain the empirical adequacy of absolutist theories in particular. For this reason, I call

in Metaphysics, Volume 12 (Oxford: Oxford University Press, 2020), pp. 75–112; Shamik Dasgupta, "How to Be a Relationalist," in Bennett and Zimmerman, eds., *Oxford Studies in Metaphysics, Volume 12, op. cit.*, pp. 113–63; and Caspar Jacobs, "The Nature of a Constant of Nature," *Philosophy of Science*, XC, 4 (2023): 797–816.

[3] Richard Healey, *Gauging What's Real: The Conceptual Foundations of Contemporary Gauge Theories* (Oxford: Oxford University Press, 2007); Frank Arntzenius, *Space, Time, and Stuff* (Oxford: Oxford University Press, 2012); Carlo Rovelli, "Why Gauge?," *Foundations of Physics*, XLIV, 1 (2014): 91–104; and Neil Dewar, "Sophistication about Symmetries," *The British Journal for the Philosophy of Science*, LXX, 2 (2019): 485–521. Healey's holonomy approach is understood as a form of 'gauge relationism' (Arntzenius, *Space, Time, and Stuff, op. cit.*, p. 194); see section III.5 below.

[4] The *locus classicus* is Hilary Putnam, *Mathematics, Matter and Method: Philosophical Papers, Volume 1* (Cambridge, UK: Cambridge University Press, 1975); see also Richard Boyd, "On the Current Status of Scientific Realism," in Richard Boyd, Philip Gasper, and John D. Trout, eds., *The Philosophy of Science* (Cambridge, MA: MIT Press, 1991), pp. 195–222; and Stathos Psillos, *Scientific Realism: How Science Tracks Truth* (London: Routledge, 1999). The phrase 'cosmic coincidences' is due to J. J. C. Smart, *Philosophy and Scientific Realism* (London: Routledge, 1963).

the argument presented in this paper the *No Miracles Argument against comparativism*.

The paper proceeds as follows. In section I, I characterize absolutism and comparativism. As the difference between these positions turns on what kind of quantities are *fundamental*, section II offers an analysis of what it means for a quantity to be fundamental: namely, that it satisfies a principle of free recombination. In section III, I present a series of examples of comparativist conspiracies, putting this style of argument in its historical context. This will reveal that many different arguments for absolutism share a common structure. In section IV, I consider and refute an objection, namely that such "conspiracies" are just laws of a comparativist theory. In section V, I return to the relevance of *symmetries*: I outline a proof that the presence of symmetries is, under certain assumptions, a sufficient condition for the occurrence of cosmic conspiracies. Section VI concludes with a discussion of absolutism vis-à-vis underdetermination.

I. ABSOLUTISM AND COMPARATIVISM

Quantities are the fundamental building blocks of physics. They are similar to ordinary properties and relations, except that quantities can have a range of values. The quantity 'mass', for example, is not just the property of being massive, which a particle either has or does not have. Rather, the mass of a particle is of a particular *magnitude*, such as five kilograms. This feature is often expressed in terms of a distinction between *determinable* and *determinate* properties. In the case of mass, the property of having a mass of (say) five kilograms is a determinate of the determinable property of being massive.[5]

The answer to the question of what quantities *are*—whether they are universals, or tropes, or whether nominalism applies to them—does not matter for my purposes, so I will not discuss it here.[6] I will assume that quantities are represented by functions from a theory's domain into some *value space*. For my purposes, a value space is a structure in the sense of Bourbaki: a set over which certain functions and relations are defined.[7] The value space itself represents a determinable quan-

[5] For more on the distinction between determinables and determinates, see Jessica Wilson, "Determinables and Determinates," in Edward N. Zalta and Uri Nodelman, eds., *The Stanford Encyclopedia of Philosophy* (Spring 2023 Edition), https://plato.stanford.edu/archives/spr2023/entries/determinate-determinables/.

[6] For more on the metaphysics of quantities, see Maya Eddon, "Quantitative Properties," *Philosophy Compass*, VIII, 7 (2013): 633–45, and references therein.

[7] Nicolas Bourbaki, *Theory of Sets* (London, Ontario: Addison-Wesley, 1968). The idea of a structured 'value space' for physical quantities is found, in various forms, in Bas C. van Fraassen, "Meaning Relations among Predicates," *Noûs*, I, 2 (1967): 161–79;

tity, whereas the elements of the value space represent determinate magnitudes. For example, the mass quantity in Newtonian mechanics is represented by a function $m(i)$ from the domain of particles into a value space whose elements represent mass magnitudes. The structure of this value space encodes relations between mass determinates, such as the fact that 6 kg is three times as much as 2 kg. Likewise, we can represent 'position' as a function from particles into a value space with a metric structure, for instance, Euclidean space.[8] The value space typically has a *representation* in terms of the real numbers: we can assign each mass value a positive real number that amounts to a choice of unit. But the value space itself does not have the structure of the real numbers, since many different mappings from the mass values into the real numbers represent the former equally well.[9]

Both absolutism and comparativism are views about what type of quantities are fundamental within a particular class, such as the class of mass quantities (I will say more about what 'fundamental' means in the next section). X-absolutism is the view that the fundamental quantities within class X are *non-comparative*, whereas X-comparativism is the view that the fundamental quantities within class X *are* comparative. The notion of comparativeness is one which I will not define but only characterize by means of example. The relation *x*-loves-*y*-more-than-*x*-loves-*z* (Amir loves Blake more than he loves Carmen) is comparative: it tells us how the love of *x* for *y* compares to the love of *x* for *z*. On the other hand, the relation of loving *simpliciter* (Amir loves Blake) is non-comparative: it tells us that someone loves someone else but makes no comparison. Or, to choose an example closer to the topic of this paper, absolute mass values are non-comparative. To say that a particle's mass is 5 kg is to say something about that particle but not to compare it to any other particle. On the other hand, to say that a particle is five times as massive as another is to compare these parti-

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Robert Stalnaker, "Anti-Essentialism," *Midwest Studies in Philosophy*, IV, 1 (1979): 343–55; Peter Gärdenfors, *Conceptual Spaces: The Geometry of Thought* (Cambridge, MA: MIT Press, 2000); David A. Denby, "Determinable Nominalism," *Philosophical Studies*, CII, 3 (2001): 297–327; Eric Funkhouser, "The Determinable-Determinate Relation," *Noûs*, XL, 3 (2006): 548–69; Adam Caulton, "The Role of Symmetry in the Interpretation of Physical Theories," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, LII (2015): 153–62; and Caspar Jacobs, "Invariance or Equivalence: A Tale of Two Principles," *Synthese*, CXCIX, 3 (2021): 9337–57.

[8] I leave open whether this means that space(-time) is a quantity, as argued in Paul Teller, "Space-Time as a Physical Quantity," in Robert Kargon and Peter Achinstein, eds., *Kelvin's Baltimore Lectures and Modern Theoretical Physics* (Cambridge, MA: MIT Press, 1987), pp. 425–48.

[9] For more on the numerical representation of quantities, see J. E. Wolff, *The Metaphysics of Quantities* (Oxford: Oxford University Press, 2020), and references therein.

cles *qua* mass, so mass ratios are comparative. (For the comparativist, the locution 'is 5 kg in mass' is a comparison in disguise.) There are also borderline cases. I suggested above that distance is a comparative relation. The idea is that distances compare objects *qua* their position in space, in the same way that mass ratios compare objects *qua* their mass. However, Dasgupta seems to think of distance as an absolute quantity: it is just a relation that pairs of objects enter into.[10] The comparative spatial quantities for Dasgupta are qualitative relations between distances, such as the relation of London being farther away from Edinburgh than from Paris. I will not aim to settle this dispute here. If distances are not comparative quantities then the argument in this paper concerns a certain generalization of comparativism that includes distance relations, but for simplicity I will continue to use the term 'comparativism'.[11] Finally, let me contrast this characterization of comparativism with those of Dasgupta and Martens.[12] Dasgupta claims that absolute quantities are *intrinsic* while comparative quantities are not, where a quantity is intrinsic just in case the values that one or more objects instantiate are purely a matter of how the objects are in themselves and (in the case of relational quantities) among each other.[13] But intrinsicality is neither necessary nor sufficient for absoluteness. Firstly, it is not necessary: Martens points out that on a certain view called 'regularity comparativism', absolute masses are grounded in the totality of qualitative relations between particles, which means they are extrinsic. Secondly, it is not sufficient: a comparative relation such as x-loves-y-more-than-x-loves-z *is* intrinsic, since whether this relation obtains is purely a matter of how these individuals relate to each other. For these reasons, Martens proposes that absolute quantities are monadic whereas comparative quantities are dyadic. Yet this definition is also inadequate, since, as we have just seen, a dyadic relation such as x-loves-y is non-comparative. Moreover, there are comparative monadic properties: the property of being taller than Carmen, for instance. These examples show that a quantity's adicity is not the central issue.

[10] Dasgupta, "Absolutism vs Comparativism about Quantity," *op. cit.*

[11] Ratios of distances, unlike distances themselves, are *dimensionless*. Baker argues that the comparativist ought to consider only dimensionless quantities as *fundamental*. See Baker, "Some Consequences of Physics for the Comparative Metaphysics of Quantity," *op. cit.* But that normative claim does not entail that only dimensionless quantities are *comparative*.

[12] Dasgupta, "Absolutism vs Comparativism about Quantity," *op. cit.*; and Martens, "The (Un)detectability of Absolute Newtonian Masses," *op. cit.*

[13] See David Lewis, "Extrinsic Properties," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, XLIV, 2 (1983): 197–200. On this definition, both properties and relations can be either intrinsic or extrinsic.

II. FUNDAMENTALITY AND COMMON GROUND

I have defined absolutism and comparativism in terms of what sort of quantities are fundamental—but what does it mean for a quantity to *be* fundamental? Contemporary discussions of absolutism versus comparativism have put the issue in terms of *ground*.[14] We can think of ground as a "vertical" relation between fundamental and nonfundamental entities; I will discuss this account of fundamentality in section III.1. But one can also consider "horizontal" relations *between* fundamental entities. Here, the idea that fundamental quantities are "modally free" has proven attractive; I discuss this in section III.2. These accounts of fundamentality are not in competition, but exist side by side.[15] Section III.3 puts the vertical and horizontal accounts of fundamentality together to formulate a criterion for what counts as *evidence* of fundamentality, namely the so-called *common-ground inference*. The possibility of common-ground inferences is what drives the No Miracles Argument against comparativism.

II.1. Vertical Fundamentality. I follow Dasgupta in assuming that some class of quantities is less fundamental than another class of quantities iff any fact about the former class of quantities is (partially) grounded in some facts about the latter class of quantities. Here, *grounding* is a relation (between facts or objects—I will remain neutral on the details) which expresses a concept of 'metaphysical because'.[16] For example, the fact that my bicycle is solid is grounded in the dynamical behavior of the particles that constitute it; the fact that it is currently raining is grounded in the fact that small drops of water produced by clouds are currently falling from the sky. Grounding is not a causal relation: the fact that drops of water are falling from the sky is not what

[14] Dasgupta, "Absolutism vs Comparativism about Quantity," *op. cit.*; Jill North, "A New Approach to the Relational–Substantival Debate," in Karen Bennett and Dean W. Zimmerman, eds., *Oxford Studies in Metaphysics, Volume 11* (Oxford: Oxford University Press, 2018), pp. 3–43; and Martens, "The (Un)detectability of Absolute Newtonian Masses," *op. cit.*

[15] In terms of the discussion of Lewisian naturalness in Cian Dorr and John Hawthorne, "Naturalness," in Bennett and Zimmerman, eds., *Oxford Studies in Metaphysics, Volume 8*, *op. cit.*, pp. 2–77, the vertical relation concerns (something close to) 'Supervenience', while the horizontal relation concerns (something close to) 'Independence'.

[16] For more on the metaphysics of grounding, see Kit Fine, "Guide to Ground," in Fabrice Correia and Benjamin Schnieder, eds., *Metaphysical Grounding* (Cambridge, UK: Cambridge University Press, 2012), pp. 37–80; Gideon Rosen, "Metaphysical Dependence: Grounding and Reduction," in Bob Hale and Aviv Hoffman, eds., *Modality: Metaphysics, Logic, and Epistemology* (Oxford: Oxford University Press, 2010), pp. 109–36; and Jonathan Schaffer, "On What Grounds What," in David Manley, David J. Chalmers, and Ryan Wasserman, eds., *Metametaphysics: New Essays on the Foundations of Ontology* (Oxford: Oxford University Press, 2009), pp. 347–83, as well as references therein.

causes it to rain but what makes it the case *that* it is raining. Instead, grounding is a relation of constitutive explanation.

The debate between absolutism and comparativism is a debate about ground. In particular, X-absolutism claims that comparative quantities of class X are less fundamental than absolute quantities of the same class: any fact about the comparative quantities is (partially) grounded in some facts about the absolute quantities. The X-comparativist claims the contrary: some facts about the comparative quantities of class X are not grounded in any facts about the absolute quantities of the same class.[17]

Put in these terms, the debate is about *relative* fundamentality, for even if the facts about (for example) mass magnitudes ground the facts about mass relations, it may still be the case that facts about mass magnitudes are themselves grounded in some even more fundamental facts. There is good reason for this, since we know that the theories in question are not fundamental. Newtonian mechanics is a highly accurate theory within the domain of medium-mass, low-velocity phenomena, but it does not describe nature at the most fundamental level. Therefore, there is little reason to believe that the fundamental quantities of Newtonian mechanics are truly fundamental. However, for convenience I will usually discuss these positions *as if* they concern the most fundamental quantities in nature. This means that a quantity is fundamental iff facts about that quantity are ungrounded. In what follows, I will simply say that absolutism states that non-comparative quantities are fundamental but comparative quantities are not, whereas comparativism states that comparative quantities are (also) fundamental.[18] It is always understood that 'fundamental' here means: most fundamental with respect to the quantities posited by the theory in question. I will remain silent on the further question of whether the most fundamental quantities within a particular theory are truly fundamental.

II.2. Horizontal Fundamentality. So much for the "vertical" relations between fundamental and non-fundamental quantities. What are the "horizontal" relations *between* fundamental quantities? The guiding idea is that fundamental quantities are "modally free": since facts about fundamental quantities are ungrounded, any way those quanti-

[17] On this definition, comparativism is consistent with the claim that both absolute and comparative quantities are equally fundamental. However, most (if not all) contemporary comparativists have made the stronger claim that comparative quantities are more fundamental than absolute quantities. The difference between these positions does not matter for our purposes.

[18] Martens calls these positions 'Strong Absolutism' and 'Strong Comparativism', respectively. See Martens, "The (Un)detectability of Absolute Newtonian Masses," *op. cit.*

ties could logically hang together is a way in which they possibly *can* hang together. This idea is often seen as a consequence of Hume's Dictum, which Wilson expresses as follows:[19]

> *Hume's Dictum*: There are no metaphysically necessary connections between wholly distinct entities.

The relevant point for our purposes is this: Hume's Dictum implies that if x and y are wholly distinct entities and m is a certain quantity, then the values of $m(x)$ and $m(y)$ are mutually independent. I will assume that entities are wholly distinct iff the entities neither ground each other nor possess a common ground.[20]

So, if there is some possible world in which $m(x) = a$, and some possible world in which $m(y) = b$, then there is a possible world in which both $m(x) = a$ *and* $m(y) = b$. If such a world is not possible, then there is a necessary connection between the values of $m(x)$ and $m(y)$. Wang calls this consequence of Hume's Dictum the 'Fundamentality Entails Modal Freedom' (FEMF) principle, which she summarizes as follows: "[The set of fundamental properties and relations] is modally free iff any pattern of instantiation of the properties or relations in [this set] is possible."[21] So, Hume's Dictum implies that a necessary condition on fundamentality is that fundamental quantities are *freely recombinable*.

The above statement of FEMF explicitly mentions both properties and relations, and I intend to use the principle in the same way. However, Hume's Dictum is usually taken to apply only to monadic quantities. For instance, David Lewis famously synthesized a principle of recombination with the thesis of *Humean supervenience*, which sees the world as "a vast mosaic of local matters of particular fact. . . .all else supervenes on that."[22] On Lewis's picture, Hume's Dictum only applies to monadic quantities because only monadic quantities are fundamental. But this restriction to non-relational quantities is a historical accident. Some decades before Lewis, Carnap formulated a syntactic principle of free recombination that applied to relations as much as to

[19] Jessica Wilson, "What Is Hume's Dictum, and Why Believe It?," *Philosophy and Phenomenological Research*, LXXX, 3 (2010): 595–637.

[20] In Jenann Ismael and Jonathan Schaffer, "Quantum Holism: Nonseparability as Common Ground," *Synthese*, CXCVII, 10 (2020): 4131–60, it is suggested that this is the notion of 'wholly distinct' Hume himself may have had in mind.

[21] Jennifer Wang, "Fundamentality and Modal Freedom," *Philosophical Perspectives*, XXX, 1 (2016): 397–418, at p. 401.

[22] David Lewis, *Philosophical Papers, Volume II* (Oxford: Oxford University Press, 1986), p. ix.

properties.[23] For Carnap, possible worlds are represented by state descriptions: classes of sentences of a language L which, for each atomic sentence ϕ of L, contain either ϕ or $\neg\phi$—and nothing else. If the set of primitive predicates (which are taken to denote fundamental properties and relations) of L contains relations, then there is a state description for any of their possible patterns of instantiation.

Like Carnap, I believe that the intuition behind Hume's Dictum applies to relations as much as to properties. In what follows, I will therefore assume that any fundamental quantity is modally free, whether monadic or relational. I should mention that not everyone believes that fundamental quantities *are* modally free. For example, *nomic essentialism*—the view that properties are individuated by their nomic features—is incompatible with free recombination.[24] The argument in this paper does not apply to such views. But as many find FEMF a compelling principle, I will assume it in what follows.

II.3. Common Ground. I will now put the vertical and horizontal accounts of fundamentality together. From the claim that fundamental quantities are modally free, it follows by contraposition that quantities that are not modally free are not fundamental. Moreover, from the claim that quantities are fundamental iff facts about such quantities are not grounded in any further facts, it follows that facts about non-fundamental quantities *are* grounded in some further facts. Therefore, if some quantity does not seem to be modally free, we have reason to believe that that quantity is grounded in some more fundamental quantity. This is the principle Ismael and Schaffer call 'Grounding Inference':[25]

> *Grounding Inference*: If non-identical entities a and b are modally connected, then either (i) a grounds b, or (ii) b grounds a, or (iii) a and b are joint results of some common ground c.

The 'entities' in question may include (the values of) certain quantities. When the values of a quantity are modally connected, that quantity is not modally free. We are interested specifically in cases of type (iii), which Ismael and Schaffer call 'common-ground inferences'. The idea of a common-ground inference is analogous to Reichenbach's common-cause principle, by which we infer a common cause

[23] Rudolf Carnap, *Logical Foundations of Probability* (Chicago: University of Chicago Press, 1950), section 118.

[24] For one recent view of this kind, see Marco Dees, "Physical Magnitudes," *Pacific Philosophical Quarterly*, XCIX, 4 (2018): 817–41.

[25] Jenann Ismael and Jonathan Schaffer, "Quantum Holism: Nonseparability as Common Ground," *Synthese*, CXCVII, 10 (2020): 4131–60.

from correlations between simultaneous events.[26] Principles of this kind are common in the history of science. Janssen coins the term 'common-origin stories' for a form of inference to the best explanation which mirrors common-ground inferences, and uses this form of inference to conclude that spacetime structure underlies the dynamical symmetries of relativistic theories.[27] In a similar spirit, Caulton has recently formulated the thought of "Hume's Dictum as a guide to what there is," which he traces back to Hume, Carnap, and the early Wittgenstein.[28] I will not offer a defense of Grounding Inference here, but simply assume the principle in what follows.

In order to clarify the idea of common-ground inferences, consider the following example, borrowed from Ismael and Schaffer. The ideal gas law states that $pV = nRT$: for a given volume V, the pressure p of a gas is proportional to the temperature, T. This is a modal connection between pressure and temperature: the ideal gas law tells us that if the pressure of a gas were to increase, its temperature would also increase. From Grounding Inference, it follows that these facts should have a common ground. This is indeed the case: kinetic theory tells us that both the pressure and the temperature of a gas supervene on the motion of the molecules that constitute it. Therefore, facts about molecular motion are a common ground for facts about both pressure and temperature. The example thus illustrates a successful common-ground inference.

Our evidence for the existence of such modal connections is just the kind of evidence we have for counterfactual behavior more broadly: a balance of introspection and experiment. For example, we know that there is a modal connection between the pressure and temperature of a gas since we have repeatedly observed that whenever we increase the pressure of a gas, its temperature also increases. Such evidence is defeasible: it always remains possible that what *seems* to be a modal connection is in fact just an accidental coincidence. But this does not pose a problem: the same situation occurs for the common-cause principle, as it is always possible (indeed, expected!) that some correlations are spurious. Ismael and Schaffer put this as follows: "Grounding Inference simply says that all else being equal, in the kind

[26] Hans Reichenbach, *The Direction of Time* (Berkeley: University of California Press, 1956).

[27] Michel Janssen, "COI Stories: Explanation and Evidence in the History of Science," *Perspectives on Science*, x, 4 (2002): 457–522; and Michel Janssen, "Drawing the Line between Kinematics and Dynamics in Special Relativity," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, xl, 1 (2009): 26–52.

[28] Adam Caulton, "A Humean Alternative on What There Is," presentation (PERSP, Universitat Autonoma de Barcelona, 2013).

of epistemic setting in which we have no direct access to the grounding substructure of a collection of objects, a theory that explains constraints on their modal covariation by reference to a common ground is better than one that regards it as a brute modal connection between distinct existences. . . . Grounding Inference expresses a preference for theories that trace modal connections to common grounds over ones that don't."[29] Grounding Inference is not intended as an *a priori* truth but as a regulative principle.

Grounding Inference does entail that we have a *prima facie* reason to be suspicious of apparent modal connections. If the observable phenomena are such that distinct existents appear modally connected when in fact they are not, then this is a "cosmic conspiracy." Suppose, for example, that temperature and pressure were *not* grounded in molecular motion but were independent properties of a gas. Their connection would be a cosmic coincidence which makes it seem just *as if* both properties have a common explanation. While it is possible that the world is rigged in this way—that the temperatures and pressures of gases just happen to line up—a common-ground explanation of this harmony is, all else being equal, more satisfactory.

III. COMPARATIVIST CONSPIRACIES: SOME EXAMPLES

In this section, I place the No Miracles Argument against comparativism in historical context by way of a number of examples of "cosmic conspiracies" in comparativist theories.[30] While none of these examples are entirely new, this is the first paper to show that they possess a common structure exemplified by the common-ground inference.[31] Moreover, the history of this style of argument dates back further than contemporary discussions would lead one to believe: I present examples from figures such as Bertrand Russell and Rudolf Carnap below. Together, this indicates that cosmic conspiracies are a pervasive feature of comparativist theories, rather than an isolated accident. This insight constitutes the No Miracles Argument against comparativism.

[29] Ismael and Schaffer, "Quantum Holism," *op. cit.*, p. 4139.

[30] There are more examples than I have space to discuss: Dewar (Dewar, "Sophistication about Symmetries," *op. cit.*) shows that relationism cannot explain that handedness partitions bodies into equivalence classes; Dewar (*ibid.*) and Roberts (Roberts, "A Case for Comparativism about Physical Quantities," *op. cit.*) both argue that comparativism about potentials fails to account for the fact that certain forces are conservative; and Leeds (Stephen Leeds, "Gauges: Aharonov, Bohm, Yang, Healey," *Philosophy of Science*, LXVI, 4 (1999): 606–27) believes that only absolutism about the vector potential can explain the form of the momentum operator.

[31] Dewar mentions some of the examples below in his discussion of reduction. However, Dewar does not relate the conspiracies to comparativism. See Dewar, "Sophistication about Symmetries," *op. cit.*

III.1. Equality of Quantity. The first example dates back to 1903, in Russell's *The Principles of Mathematics.*[32] Russell asks: in virtue of what are pairs of quantities equal? He discusses two views. On the *relative view of quantity*, "equal, greater and less are all direct relations between quantities," while the *absolute view of quantity* holds that "equality is not a direct relation, but is to be analyzed into possession of a common magnitude."[33] Consider equality of mass. On the former view, it is a brute fact whether two particles *a* and *b* have the same mass. On the latter, it is not: *a* and *b* have the same mass iff the mass of *a* is numerically identical to the mass of *b*. Here, the phrase 'the mass of *a*' refers to a magnitude, and *a* and *b* are equally massive whenever the magnitude denoted by 'the mass of *a*' is numerically identical to the magnitude denoted by 'the mass of *b*'.

Russell then notes that equality of mass is an equivalence relation: it is reflexive, transitive, and symmetric. On the absolute view, this is no surprise. Since equality of mass is grounded in identity of magnitude, and since it is in the very concept of identity that this is an equivalence relation, it follows immediately that equality of mass is also an equivalence relation. But on the relative view, equality of mass is fundamental. Hence, there is nothing which explains that it is an equivalence relation. Russell finds this suspicious: "For it may be laid down that the only unanalyzable symmetrical and transitive relation which a term can have to itself is identity, if this be indeed a relation. Hence the relation of equality should be analyzable."[34] The absolute view *does* offer such an analysis, so it is preferable.

To put the point in our terms, Russell notes that the fact that equality of quantity is an equivalence relation makes it look just *as if* this relation is grounded in an identity claim. There is a modal connection between the equality relations of distinct pairs of objects. If equality of quantity is fundamental, and if we believe that fundamental properties and relations are modally free, then this is a cosmic conspiracy. Grounding Inference suggests that equality relations possess a common ground. And if equality of quantity is grounded in identity of magnitude, we can explain the cosmic conspiracy by a common-ground inference. Therefore, Grounding Inference supports the absolute theory of quantity.

[32] Bertrand Russell, *The Principles of Mathematics* (Cambridge, UK: Cambridge University Press, 1903).

[33] *Ibid.*, p. 209.

[34] *Ibid.*, p. 253.

III.2. Transitivity of 'Warmer Than'. A second example of a cosmic conspiracy is found in an objection that Yehoshua Bar-Hillel leveled against Carnap's syntactic principle of free recombination.[35] Recall that Carnap required that all primitive predicates and relations are logically independent from each other. For example, the properties of being blue and of not being blue cannot both be primitive, since this allows for a state description in which some object is simultaneously blue and not blue. But as Bar-Hillel pointed out, it is not enough to require that all primitive relations are logically independent *from each other*, since some relations also seem to have an intrinsic logical structure. For example, the relation 'warmer than' (Wxy) is transitive, and so there is no system in which Wab, Wbc, and Wca are all true. This is the case even if W is the language's sole predicate, so the requirement of logical independence is trivially satisfied. Bar-Hillel's objection to Carnap's theory of state descriptions, then, is that it implies that if the relational predicate 'warmer than' is primitive, it must be possible for a to be warmer than b, b warmer than c, yet c warmer than a—which it clearly is not. In the terminology of the previous section, Bar-Hillel points out that the modal connections in the pattern of instantiation of W suggests that W is not a fundamental relation.

Carnap responded that in a sufficiently strong language, qualitative relations such as 'warmer than' are defined in terms of the numerical values of absolute quantities.[36] For instance, let $T(x)$ denote the temperature of x with a real number and stipulate that Wxy iff $T(x) > T(y)$. In that case, 'warmer than' *must* be transitive, since there is no triple of real numbers such that $T_1 > T_2$ and $T_2 > T_3$ yet $T_3 > T_1$. Carnap realized that the transitivity of 'warmer than' can only be guaranteed if the relation is not fundamental but depends on some absolute quantity. We can recognize a common-ground inference in Carnap's response: the modal connection between temperature comparisons is explained by the fact that such comparisons are grounded in claims about absolute temperatures.

The overall pattern is the same as in the previous example: comparativist quantities seem to bear certain modal connections to each other, but if they are truly fundamental—and if the fundamental is modally free—then such connections are a cosmic coincidence. However, if the comparativist quantities are grounded in absolute quantities, then the modal connections are fully explained. Therefore, Grounding Inference favors temperature absolutism.

[35] Yehoshua Bar-Hillel, "A Note on State-Descriptions," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, II, 5 (1951): 72–75.

[36] Rudolf Carnap, "The Problem of Relations in Inductive Logic," *Philosophical Studies: An International Journal for Philosophy in the Analytic Tradition*, II, 5 (1951): 75–80.

III.3. The Triangle Inequality. The remaining examples draw more explicitly on mathematical physics. This next example concerns relationism in the traditional sense: the view that there is no substantival space in which bodies have an absolute location, but that the distances between bodies are fundamental. Maudlin argues that relationism cannot guarantee that the *triangle inequality* is satisfied.[37] The triangle inequality states that, for any three particles *i*, *j*, and *k*, the distance between *i* and *j* added to the distance between *j* and *k* must equal or exceed the distance between *i* and *k*. It is essential for any empirically adequate relationist theory to satisfy the triangle inequality, since it holds true in the actual world. But if distance relations are fundamental, then it follows from FEMF that pairs of bodies can bear *any* fundamental distance relation to each other, whether they satisfy the triangle inequality or not. The triangle inequality is a modal connection between distances that demands explanation in terms of a common ground.

Maudlin argues that one can explain the triangle inequality if one assumes that distances are grounded in the lengths of paths in space. If the distance between *i* and *j* is defined as the length of the shortest path between particles *i* and *j*—which, in Riemannian geometry, is determined by the metric tensor—and if it is assumed that the length of the concatenation of a path from *i* to *j* and a path from *j* to *k* is just the sum of their individual lengths, then the triangle inequality is a mathematical theorem.[38] For the concatenation of the shortest path from *i* to *j* and the shortest path from *j* to *k* *is* a path from *i* to *k*, so the distance between *i* and *k*—the length of the shortest path between them—cannot exceed the sum of the distance between *i* and *j* and the distance between *j* and *k*. If particles are assumed to occupy a position in absolute space, the triangle inequality could not have failed to hold.

The triangle inequality is a modal connection between distances which makes it seem *as if* they depend on positions. If distances are fundamental, and if the fundamental is modally free, then this is a cosmic conspiracy. But if distances are in fact grounded in properties of absolute space, the triangle inequality is explained away. Therefore, Grounding Inference supports absolutism over relationism.

[37] Tim Maudlin, "Suggestions from Physics for Deep Metaphysics," in *The Metaphysics within Physics* (Oxford: Oxford University Press, 2007).

[38] On the (il)legitimacy of this latter assumption, see Marco Dees, "Maudlin on the Triangle Inequality," *Thought: A Journal of Philosophy*, IV, 2 (2015): 124–30.

III.4. Ratio Multiplication Principle. This example concerns particle mass in Newtonian mechanics. Recall that if mass is absolute, each particle i is assigned a fundamental mass magnitude which is represented by a function $m(i)$. The mass relations are grounded in these absolute magnitudes. But according to comparativism about mass, the mass relations themselves are fundamental. These mass relations are represented by functions $r(i, j)$ from pairs of particles into some value space of mass ratios.

The comparativist's mass relations must obey the following constraint:

$$(1)\quad r(i, k) = r(i, j) \cdot r(j, k)$$

Roberts, who discusses this example in some detail, calls (1) the *ratio multiplication principle* (RMP).[39] This states that the mass ratio between i and j times the mass ratio between j and k is equal to the mass ratio between i and k. For example, if Amir is twice as massive as Blake, and Blake is three times as massive as Carmen, then Amir must be six times as massive as Carmen. In effect, mass relations are *transitive.* Any comparativist theory must satisfy RMP in order to remain empirically adequate. But if mass relations are fundamental, then it follows from FEMF that pairs of bodies can bear *any* fundamental mass relation to each other, whether RMP is satisfied or not.

Therefore, just like the triangle inequality, RMP is a modal connection between the values of r for distinct pairs of particles that demands explanation in terms of a common ground. Martens calls it the 'conspiracy of mass relations'.[40] On the other hand, if mass relations are grounded in absolute masses then RMP becomes a mathematical theorem. For in that case:

$$(2)\quad r(i, k) = \frac{m(i)}{m(k)} = \frac{m(i)}{m(j)} \cdot \frac{m(j)}{m(k)} = r(i, j) \cdot r(j, k)$$

Equation (2) holds for whatever values we assign to $m(i)$, $m(j)$, and $m(k)$. Therefore, the existence of absolute masses in which mass relations are grounded allows us to explain (away) the conspiracy of mass relations.

The transitivity of mass relations is a modal connection between mass relations which makes it seem *as if* they depend on absolute masses. If mass relations are fundamental, and if the fundamental is

[39] Roberts, "A Case for Comparativism about Physical Quantities," *op. cit.*

[40] Martens, "Machian Comparativism about Mass," *op. cit.*; see also Niels C. M. Martens, "Against Laplacian Reduction of Newtonian Mass to Spatiotemporal Quantities," *Foundations of Physics*, XLVIII, 5 (2018): 591–609.

modally free, then this is a cosmic conspiracy. But if mass relations are in fact grounded in absolute masses, the conspiracy is explained away. Therefore, Grounding Inference supports absolutism over comparativism about mass.

III.5. Composite Loop Multiplication. The final example concerns the ontology of electrodynamics. Because the example is somewhat technically involved, I will be brief here.[41]

On a literal reading of electrodynamics, the vector potential **A** is a real vector field: it assigns a three-dimensional vector to each spacetime point. For any open path γ, this field defines a line integral $\mathbf{A}(\gamma) = \int_\gamma \mathbf{A} d\mathbf{x}$. The vector potential is a gauge quantity, which means that it varies under the theory's (local) gauge symmetries. For this reason, **A** is traditionally seen as a mathematical artifact which does not represent a real field. But the discovery of the Aharonov–Bohm effect, in which **A** seems to play a causal role, has led many physicists—most notably Feynman[42]—to consider **A** as physically real. Call this view 'gauge absolutism'.

However, the fact that **A** is variant means that its values are unmeasurable. In response to this objection, Healey proposes that not the field itself but its *holonomies* are fundamental: functions of integrals of **A** around closed paths, or "loops," in spacetime.[43] The holonomy of a loop l is defined as $H(l) = e^{iq \oint_l \mathbf{A} d\mathbf{x}}$, where q is a fixed unit of charge. Unlike the vector field itself, holonomies are invariant under gauge symmetries. Since any loop l is composed of a pair of open paths γ_1 and γ_2, we can consider holonomies as comparative relations between those pairs of paths: for any pair of open paths that jointly form a closed loop, $H(\gamma_1, \gamma_2)$ is their 'holonomy relation'. For this reason, Arntzenius dubs Healey's view 'gauge relationism'.

Arntzenius also points out that, in order for gauge relationism to remain empirically adequate, holonomies must satisfy the relation of *composite loop multiplication* (CLM):

(3) $H(l_1 \circ l_2) = H(l_1)\, H(l_2)$,

where $l_1 \circ l_2$ denotes the concatenation of l_1 and l_2, that is, the path that results from first going around l_1 and then going around l_2. It will come as no surprise that in this case, too, the relationist cannot

[41] For details, see Arntzenius, *Space, Time, and Stuff, op. cit.*, chapter 6; and Caspar Jacobs, "The Metaphysics of Fibre Bundles," *Studies in History and Philosophy of Science*, XCVII (2023): 34–43.

[42] Richard Feynman, Robert B. Leighton, and Matthew Sands, *The Feynman Lectures on Physics*, vol. 3 (Reading: Addison-Wesley, 1964).

[43] Healey, *Gauging What's Real, op. cit.*

explain why CLM holds: if holonomies are fundamental then it follows from FEMF that $H(l_1 \circ l_2)$ could have any value no matter what the values of $H(l_1)$ and $H(l_2)$ are. The fact that CLM holds in the actual world is a comparativist conspiracy.

But if holonomies are grounded in integrals of **A** along open paths, then CLM reduces to a mathematical theorem:

$$\begin{aligned}(4)\quad H(l_1)\,H(l_2) &= \exp[iq\oint_{l_1}\mathbf{A}d\mathbf{x}]\cdot\exp[iq\oint_{l_2}\mathbf{A}d\mathbf{x}]\\ &= \exp[iq\oint_{l_1\circ l_2}\mathbf{A}d\mathbf{x}]\\ &= H(l_1\circ l_2)\end{aligned}$$

As Arntzenius puts it, "a fairly obvious explanation of why [CLM] hold[s] is that the map H is, roughly speaking, the integration of [**A**] around a loop."[44]

In sum, composite loop multiplication makes it seem *as if* holonomies depend on local field values. If holonomies are fundamental, and if the fundamental is modally free, then this is a cosmic conspiracy. But if holonomies are in fact grounded in local field values, composite loop multiplication is explained away. Therefore, Grounding Inference supports gauge absolutism over gauge relationism.

IV. CONSPIRACIES OR LAWS?

I anticipate the following objection, using the triangle inequality as a representative example:[45] the claim that positions are fundamental does not entail the triangle inequality any more than the claim that distances are fundamental does. After all, the triangle inequality is only satisfied if physical space has the structure of a *metric space*, such as Euclidean space. But this is a substantive assumption about the distances between points of space themselves. If the absolutist is allowed such an assumption about distances between points, then why isn't the comparativist allowed a similar assumption about distances between particles? The absolutist simply replaces one miracle with another! But we cannot explain miracles with miracles, so comparativism is no worse off than absolutism.

The same objection can be made *mutatis mutandis* for quantities such as mass. The RMP is guaranteed by the fact that we can represent mass magnitudes with positive real numbers, which in turn fol-

[44] Arntzenius, *Space, Time, and Stuff, op. cit.*, p. 195.

[45] Compare Dees's (Dees, "Maudlin on the Triangle Inequality," *op. cit.*) response to Maudlin (Maudlin, "Suggestions from Physics for Deep Metaphysics," *op. cit.*).

lows from the fact that mass value space has an *additive structure*.[46] But, the objection goes, mass value space could have had a different structure for which mass multiplication is not transitive. If this objection succeeds, then absolutism cannot explain modal connections such as the triangle inequality or the transitivity of mass ratios after all.

I will concede the central contention: absolutism *does* require an additional posit, for instance, that space has a metric structure or mass value space has an additive structure. But I do not believe that this poses a challenge to the No Miracles Argument against comparativism, because there remains an asymmetry between absolutism and comparativism. While the modal connections between comparative quantities can be explained by a common-ground inference, the reverse is not the case. Therefore, we ought to prefer absolutism over comparativism.[47]

Recall from section II.3 that it is not always possible to explain a modal connection between distinct existents via a common-ground inference, in the same way that it is not always possible to explain a correlation between simultaneous events in terms of a common cause. Grounding Inference tells us that all else being equal, a common-ground explanation of such modal connections is preferred. But if no such explanation is on offer, then we will simply have to accept the appearance of brute modal connections. This is the situation we are in. On the one hand, we have seen that modal connections between comparative quantities—such as the triangle inequality or RMP—are adequately explained if we assume that such quantities are grounded in absolute quantities. On the other hand, the modal connections between absolute quantities—for instance, the fact that path-lengths are additive—have *no* explanation in terms of comparative quantities. That is, while one can show that the triangle inequality must hold for particles if it holds for paths of the space within which these particles are located, one cannot conversely show that the triangle inequality must hold for paths between points in space if it holds for the particles which occupy some of these points. This asymmetry means that the "miracles" that the absolutist is committed to are not suspicious in the same way that comparative conspiracies are. For while compara-

[46] Roughly, this means that order and addition are well-defined. For more on additive structures, see David H. Krantz, Patrick Suppes, and R. Duncan Luce, *Foundations of Measurement I: Additive and Polynomial Representations* (New York: Academic Press, 1971), chapter 3; or J. E. Wolff, *The Metaphysics of Quantities* (Oxford: Oxford University Press, 2020), section 5.2.

[47] I thank Jenann Ismael for an insightful exchange of ideas on this point.

tive conspiracies have a preferred explanation in terms of a common ground, absolutist conspiracies do not.

It is instructive to see *why* the structure of space cannot be grounded in facts about distances between particles. The reason is that particles in different worlds occupy different points of space.[48] Consider a class of models of Newtonian mechanics, each of which represents a finite number of particles positioned within a Euclidean affine space. The relationist may argue that in any particular world, the distance between a pair of occupied points supervenes on the distance between their occupants. But this leaves us without any ground for the distances between *un*occupied points. Moreover, it is unclear how one could ground distances between unoccupied points in facts about actual particles. But the particles across these worlds are all positioned within the same Euclidean space (up to isomorphism). We can thus reduce facts about the distances between particles in different possible worlds to the same set of facts about the actual structure of space.[49]

[48] These obstacles to relationism are well known. See, for instance, Hartry Field, *Science without Numbers: A Defense of Nominalism* (Princeton, NJ: Princeton University Press, 1980), chapter 6; Gordon Belot, *Geometric Possibility* (Oxford: Oxford University Press, 2011), chapter 2; and Frank Arntzenius and Cian Dorr, "Calculus as Geometry," in Frank Arntzenius, ed., *Space, Time, and Stuff* (Oxford: Oxford University Press, 2012), pp. 213–68. In response, relationists have attempted to supplement their accounts of the structure of space. I lack the space to discuss these attempts, but in this footnote let me briefly mention two approaches. The first approach is to include, in addition to facts about the distances between *actual* particles, facts about the distances between *possible particles*. But this approach—called *modal relationism*—has come in for substantial criticism; see, for instance, Hartry Field, "Can We Dispense with Space-Time?," *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* (1984): 33–90; Jeremy Butterfield, "Relationism and Possible Worlds," *The British Journal for the Philosophy of Science*, XXXV, 2 (1984): 101–13; and Belot, *Geometric Possibility*, *op. cit.* In particular, it seems that such modal relationism has little appeal for empiricists. The second approach is to quantify over *representations* of spacetime, rather than spacetime itself. Huggett's *regularity relationism* is an example of such an approach (Nick Huggett, "The Regularity Account of Relational Spacetime," *Mind*, CXV, 457 (2006): 41–73). However, regularity views run the risk of collapsing into *eliminativism*, the view which holds that there are no fundamental quantities, whether absolute or comparative (Oliver Pooley, "Substantivalist and Relationalist Approaches to Spacetime," in Robert Batterman, ed., *The Oxford Handbook of Philosophy of Physics* (Oxford: Oxford University Press, 2013), pp. 522–86, section 6.3.1). Martens develops an analogous criticism of regularity comparativism about mass (Niels C. M. Martens, "Regularity Comparativism about Mass in Newtonian Gravity," *Philosophy of Science*, LXXXIV, 5 (2017): 1226–38).

[49] Of course, if matter forms a plenum *in every physically possible world*, then one can offer an account of the structure of space in terms of the distances between matter points. But as Field (Field, "Can We Dispense with Space-Time?," *op. cit.*) notes, this move essentially gives up the spirit of relationism. Moreover, the assumption of a plenum is hardly tenable for non-spatiotemporal quantities, such as mass. The analogue position is that in *each* physically possible world, *every* mass value is instantiated by some matter point. But this is not the case even for those field theories which seem most amenable to a treatment of matter as a plenum.

This explains the sense in which the triangle inequality for particles is a conspiracy. On the one hand, if distances between particles satisfy the triangle inequality, it looks just *as if* they are grounded in distances between points of space. If this were not the case, then it is a cosmic coincidence that the distances between particles just happen to line up in this way. On the other hand, if the distances between points of space satisfy the triangle inequality, then this does *not* make it look as if those distances are grounded in distances between particles. The metric structure of space is not a cosmic coincidence; it is just the way things are.

These considerations apply *mutatis mutandis* to quantities such as mass or field strength. While one can ground facts about mass relations in facts about monadic mass properties, for instance, the reverse is not the case. This is a consequence of the fact that particles across worlds instantiate a mass value from the same value space (up to isomorphism), whereas the particles in distinct worlds collectively instantiate different mass values. So, while the fact that mass relations are transitive makes it seem just *as if* they are grounded in absolute masses, the fact that absolute masses themselves have an additive structure does *not* make it seem as if they are grounded in mass relations. Therefore, the modal connections between mass values too are not cosmic conspiracies in the way that modal connections between mass relations are.

V. SYMMETRIES AND CONSPIRACIES

I hinted in the introduction at a connection between the absolutism/comparativism debate and the occurrence of *symmetries* in physics. In this section I discuss this connection. The variance of absolute quantities under symmetries is often used to motivate comparativism. It thus seems that the near-universal presence of symmetries in physics supports comparativism. I aim to reverse this contention: symmetries are a problem for comparativism. The reason is that the *in*variance of comparative quantities under symmetries, given certain conditions, is a sufficient condition for a cosmic conspiracy to occur. The widespread presence of symmetries therefore really supports absolutism rather than comparativism.

Comparativism is often motivated by the claim that some absolute quantities are variant under a theory's group of symmetry transformations, whereas the relevant comparative quantities are not. For instance, positions—but not distances—vary under so-called static shifts. The variance of absolute quantities under symmetries is said to entail that they are undetectable, which leads to a particularly problematic form of underdetermination. The informal argument goes as follows:[50] suppose that one were to move the entire material universe three meters north. Since this is a symmetry transformation which preserves all distances, the difference is indiscernible. In particular, any putative position-measurement device will display the exact same value before and after such a shift. But this means that the device does not accurately measure absolute position, which varies under shifts. Therefore, absolute position is undetectable; or, to put it more precisely, it is impossible to encode information about (unobservable) absolute positions in information about (observable) distances. The argument holds *mutatis mutandis* for other variant quantities. For this reason, comparativism often goes hand in hand with a view called 'reductionism': the demand for a 'reduced' theory formulated solely in terms of new, invariant quantities.[51] The comparativist follows the following recipe to obtain a reduced theory: (i) start with the theory's absolute quantities, m, which vary under some symmetry; (ii) construct new, comparative quantities r from the old quantities m that are invariant under the same symmetries; (iii) formulate a reduced theory in terms of these new quantities. For an example, consider the absolute quantities $m(i)$ and $m(j)$, which represent the masses of some particles i and j. Suppose that $m(i)$ and $m(j)$ vary under the theory's symmetries, but that their ratio $m(i)/m(j)$ does not. The comparativist can then postulate a new, comparative quantity $r(i,j)$ as fundamental, where by definition $r(i,j) \equiv m(i)/m(j)$. We can think of $r(i,j)$ as the mass ratio between i and j, but since the comparativist renounces the (fundamental) reality of absolute masses this is true only metaphorically. As Roberts puts it: "there is nothing for them to be ratios *of*."[52] The comparativist claim is rather that ratios between absolute quantities merely represent the fundamental comparative quantities in a redundant way.

In principle, reductionism and comparativism can come apart: it is possible to construct theories with invariant but non-comparative quantities, and conversely one can formulate theories with variant comparative quantities.[53] But the combination of comparativism and reduction is a natural one, since the same worry about superfluous

[50] For more details, see the references in fn. 1.

[51] For more on reductionism, see Dewar, "Sophistication about Symmetries," *op. cit.*; Niels C. M. Martens and James Read, "Sophistry about Symmetries?," *Synthese*, CXCIX (2021): 315–44; and Caspar Jacobs, "Invariance, Intrinsicality and Perspicuity," *Synthese*, CC, 135 (2022).

[52] Roberts, "A Case for Comparativism about Physical Quantities," *op. cit.*, p. 6.

[53] Newton–Cartan Theory is an example of non-comparative reduction; a theory in which all positions are expressed in terms of their distance to a privileged point of the manifold is an example of comparativism without reduction.

symmetry-variant structure motivates both views. Both historical and contemporary defenses of comparativism have drawn the connection with symmetries, hence reduction has often taken the form of a move from some set of absolute variant quantities to another set of comparative invariant quantities.

In appendix A, however, I present a formal proof that under a fairly general set of assumptions, almost any form of comparativism whose fundamental quantities are symmetry-invariant involves cosmic conspiracies. In the remainder of this section I offer an informal outline of the proof and its limitations. The upshot of the result is that symmetries are a sufficient condition for the comparativist conspiracies discussed in this paper to occur, and thereby support the No Miracles Argument *against* comparativism.

The essential observation is that comparative quantities are usually not postulated *de novo* but rather defined in terms of the old, absolute quantities. As we have seen, this is awkward because (for example) fundamental mass ratios are not really ratios *of* anything. However, it also entails that comparative quantities are constrained, since it is not the case that any arbitrary pattern of instantiation of, for example, mass relations is consistent with some assignment of masses. If the pattern of mass relations fails to satisfy the RMP, then it is not consistent with any assignment of absolute mass magnitudes.

In more detail, it can be proven that if the comparative quantity r is invariant under a symmetry group G which acts on the absolute quantity's value space $\mathcal{A}$, then the value space $\mathcal{R}$ of the comparative quantity r "inherits" the mathematical structure of G. Therefore, *each value of the comparative quantity itself represents a symmetry transformation.* For example, each displacement vector between a pair of bodies can act on Euclidean space to effect a uniform translation. Similarly, each mass ratio—which is expressed as a positive real number α—corresponds to a uniform scaling of all masses by a factor α. This connection between symmetries and relations is expressed in the following theorem (see appendix A for the proof):

> *Theorem.* If r is invariant under a regular group action of G on $\mathcal{A}$, then there exists a bijection between G and $\mathcal{R}$ which endows $\mathcal{R}$ with a canonical group structure.

From this theorem, the occurrence of cosmic conspiracies follows as a corollary. The intuitive idea is that symmetry transformations must compose in certain ways. For example, the result of one symmetry transformation after another is itself a symmetry transformation. In the case of mass scalings, this means that the result of the successive application of one scaling after another is also a scaling. Since there is a correspondence between symmetry transformations and values of r, these composition rules also apply to the latter. Therefore, we can always define the "composite" of a pair of comparative values. In the case of mass scalings, the composite of the mass relation represented by the real number α and the mass relation represented by the real number β is the mass relation represented by the product $\alpha \cdot \beta$. Generally:

Corollary (Cosmic Conspiracy). For any $i, j, k \in \mathcal{D}$,

(5) $r(i,j) \circ r(j,k) \circ r(k,i) = I$

where $\circ$ denotes the composition operation and I is the identity element: the unique relation that each object bears to itself.

In the case of mass ratios the identity element is 1, since any object is equally massive as itself—so the corollary says that the product of the mass ratios of any three objects equals 1, which is the RMP. Similarly, the sum of the vectors between any triple of points in a Euclidean space is the zero vector: the vector that points from any location to itself. The corollary thus says that the values of r for any triple of objects have to "add up" to the identity. The result immediately implies that comparative quantities violate the principle of free recombination. If the fundamental is modally free, it follows that comparative quantities are not fundamental.

Let me mention some limitations of this result. Firstly, as noted at the outset, it is assumed that the comparative quantities are invariant under the theory's symmetries. Given that symmetry-variant quantities are undetectable, this is a reasonable desideratum. Nevertheless, not all examples of cosmic conspiracies are motivated by the presence of symmetries. Maudlin's discussion of the triangle inequality, for instance, holds for spacetimes with arbitrary curvature—many of which display no symmetries at all.[54] It follows that distances are not invariant under any non-trivial class of symmetries, so the theorem does not apply in this case. Of course, this does not mean that the theorem is incorrect, only that it is limited in scope. The exclusion of certain examples is consistent with the main claim that symmetries are a sufficient condition for cosmic conspiracies. For those cases in which comparativists *have* tried to motivative their view by appeal to symmetry considerations, the theorem provides a potent antidote.

Secondly, the proof assumes that the group G of symmetry transformations has a free and transitive action on the absolute value space:

[54] I thank an anonymous referee for stressing this point to me.

for any pair of values of the absolute quantity, there is a unique symmetry transformation which takes one to the other. In the case of mass, there is a unique scaling transformation between any pair of mass values. But as noted in the appendix, not all symmetries satisfy these requirements. Distance, for instance, is invariant under reflections, translations, and rotations; but the action of the latter on Euclidean space is not free, since non-trivial rotations act as the identity on the axis of rotation. It is therefore not possible to derive the triangle inequality from the theorem even within the highly symmetric context of Euclidean space. The class of quantities to which the theorem does apply is nevertheless sufficiently broad to include some of the examples from this paper, namely mass relations and holonomies (see appendix B for some worked examples).[55] This illustrates the point made before: although (one class of) symmetries are a sufficient condition for comparativist conspiracies, not all such conspiracies are motivated by symmetries. This suffices to show that the symmetry-driven environment of contemporary physics is inhospitable to comparativism.

VI. CONCLUSION

The No Miracles Argument against comparativism is *ipso facto* an argument in favor of absolutism, since the latter can explain comparativist conspiracies via common-ground inferences. But note that I have used a "thin" definition of absolutism, namely as a commitment to non-comparative quantities. The term 'absolutism' is often used in a much stronger sense. For instance, a belief in absolute positions is normally understood to entail that worlds related by static shifts—uniform translations of the entire material universe—are physically distinct. This leads to the well-known worry that absolutist theories with non-trivial symmetries are committed to a harmful form of underdetermination. My definition of absolutism does not have this consequence. Absolutism in the thin sense is perfectly consistent with anti-haecceitism, the thesis that there are no numerically distinct yet qualitatively identical worlds. Since shift-related worlds *are* qualitatively identical, anti-haecceitism implies that models related by a shift represent the same possibility: shifts are "distinctions without a difference." The conjunction of substantivalism and anti-haecceitism is called 'sophisticated substantivalism'. Importantly, sophisticated substantivalism is still a form of absolutism in the thin sense, since it is committed to the fact that objects possess some position in space: that

[55] I should also note that it is still an open question whether the theorem can be generalized to include a broader class of symmetries, such as rotations.

is what makes it a form of substantivalism. Therefore, sophisticated substantivalism can explain the triangle inequality, which is simply a consequence of the fact that objects are located on a Riemannian manifold, without underdetermination.

A similar stratagem exists for non-spatiotemporal quantities such as mass. The analogue of anti-haecceitism here is anti-quidditism, the thesis that determinate values are qualitatively individuated.[56] For example, suppose that mass scalings leave all qualitative mass facts the same (that is, all mass facts except for those about *which* mass values are instantiated). In that case, anti-quidditism implies that objects in mass-scaled worlds in fact have the *same* mass. This view was held by Teller, who writes:

> What is it to be the property of having a mass of five grams? Perhaps it is no more and no less than bearing certain mass relations to other masses, or possibly to other exemplified masses. On this account we still take there to be individual mass properties, but we take the principle of individuation of an individual mass to be its mass relations to other masses, so that the mass relations between masses become essential to all of them.[57]

Just like static shifts, scalings are then revealed to be distinctions without a difference. Dewar has recently explored the application of sophistication to internal quantities in more detail.[58]

In conclusion, sophistication offers a "third way" position. Of course, there is much more to be said. For the purposes of this paper, the crucial point is that sophisticated absolutism does not result in underdetermination. Since this is the chief case against absolutism, it can be concluded that the No Miracles Argument against comparativism shows that we should prefer absolutism over comparativism. Absolutism can explain the cosmic coincidences that are conspiracies for the comparativist, so all else being equal, the former is preferable to the latter. Moreover, on a "sophisticated" interpretation ab-

[56] Black defined quidditism in terms of *determinable* quantities; anti-quidditism then implies that there are no distinct worlds in which, for instance, mass and charge are swapped. See Robert Black, "Against Quidditism," *Australasian Journal of Philosophy*, LXXVIII, 1 (2000): 87–104. However, I will use the term in a slightly different sense, namely to cover the determinate *values* of physical quantities. The idea is that, for instance, mass magnitudes have no primitive identities, but are qualitatively identified via their pattern of instantiation. For further discussion, see Martens and Read, "Sophistry about Symmetries?," *op. cit.*, p. 332.

[57] Paul Teller, "Substance, Relations, and Arguments about the Nature of Space-Time," *The Philosophical Review*, C, 3 (1991): 363–97, at p. 393.

[58] Dewar, "Sophistication about Symmetries," *op. cit.*; see also Jacobs, "Metaphysics of Fibre Bundles," *op. cit.*

solutism does not entail underdetermination, so all else *is* equal. To paraphrase Putnam: absolutism is the only philosophy that does not make the success of our theories a miracle.[59]

APPENDIX A. PROOF OF THEOREM

Suppose that $m : \mathcal{D} \to \mathcal{A}$ is a function from a certain domain $\mathcal{D}$ into a value space $\mathcal{A}$. Call m the *absolute quantity*.[60] Let $\bar{r} : \mathcal{D}^2 \to \mathcal{R}$ be a function from ordered pairs of objects in $\mathcal{D}$ into a different value space $\mathcal{R}$. Call $\bar{r}$ the *comparative quantity*. We assume that $\bar{r}(i, j) \equiv r(m(i), m(j))$, where r is a surjective function from $\mathcal{A} \times \mathcal{A}$ onto $\mathcal{R}$. We require that r is surjective so each comparative value corresponds to some pair of absolute values. If this were not the case, then the comparative value space would contain superfluous elements which are empirically inaccessible given the theory's dynamics.

In order to account for the invariance of r under some relevant symmetry group G, we first suppose that G has an action ψ on $\mathcal{A}$. For ease of expression, instead of $\psi_g(x)$ we will simply write gx for the result of acting with g on x. We will use e to denote G's identity, and assume that the action of G is *regular*; that is, it is both *free* (if $gx = x$ then $g = e$) and *transitive* (for any x, y, there exists a g such that $y = gx$). To be sure, this is not the case for all symmetries. For instance, rotations of an affine space are not free since they have a fixed point. Conversely, charge conjugation is not transitive, since it is not the case that any pair of charges is related by a conjugation. Whether a similar result holds for these symmetries is an open question.[61]

We can then define the invariance of r as follows:

Invariance. The comparative quantity r is invariant under G's action on $\mathcal{A}$ iff for any $x, y, x', y' \in \mathcal{A}$,

$$r(x, y) = r(x', y') \text{ iff } y' = gy \text{ and } x' = gx \text{ for some } g \in G.$$

Invariance says that symmetry transformations—and *only* symmetry transformations—leave the values of r invariant.

We will prove that when r is an invariant relation, the values of $r(x, y)$ and $r(y, z)$ constrain the value of $r(x, z)$. If that is the case, the

[59] Putnam, *Mathematics, Matter and Method, op. cit.*, p. 73.

[60] $\mathcal{D}$ could also consist of tuples of objects to allow for cases of higher-order comparativism.

[61] As it turns out, the quantities which are invariant under these symmetries—distances and charge ratios, respectively—*are* involved in cosmic conspiracies. For distances, it is a cosmic coincidence that they satisfy the triangle inequality. And for charge ratios, it is a cosmic coincidence that whenever the ratio between c_1 and c_2 has the same sign as the ratio between c_2 and c_3, then the ratio between c_1 and c_3 also has the same sign. So, I am optimistic that a generalization of the present proof is possible.

comparative quantities are not mutually independent: a cosmic conspiracy. In order to show this, we first prove an important Theorem:

Theorem. If r is invariant under a regular group action of G on $\mathcal{A}$, then there exists a bijection between G and $\mathcal{R}$ which endows $\mathcal{R}$ with a canonical group structure.

Proof. Define $k_x : \mathcal{R} \to G$ such that $k_x(r(gx, hx)) = g^{-1}h$. We first show that k_x is well-defined. Since r is surjective, for any $v \in \mathcal{R}$ there exist $y, z \in \mathcal{A}$ such that $v = r(y, z)$; and since G acts freely and transitively on $\mathcal{A}$, there exist $g, h \in G$ such that $y = gx$ and $h = hx$. The product $g^{-1}h$ is unique: from Invariance, $r(gx, hx) = r(g'x, h'x)$ iff $g' = jg$ and $h' = jh$ for some $j \in G$, iff $g'^{-1}h' = g^{-1}j^{-1}jh = g^{-1}h$.

Next, we show that k_x is a bijection. From Invariance, it follows that k_x is injective. For let $g' = jg$ and $h' = j'h$. Then $g'^{-1}h' = g^{-1}j^{-1}j'h = g^{-1}h$ iff $j = j'$. But from Invariance, $r(gx, hx) = r(jgx, jhx)$, so $r(gx, hx) = r(g'x, h'x)$. Furthermore k_x is clearly surjective, since for any $g \in G$, $k_x(r(x, gx)) = g$. Therefore, k_x is a bijection.

It immediately follows that $\mathcal{R}$ inherits G's group structure. Define $v_g := k_x^{-1}(g)$. Then the identity is v_e and group composition is defined such that $v_g \circ v_h = v_{gh}$. This structure is canonical; that is, it does not depend on the choice of x. For consider an arbitrary $y \in \mathcal{A}$ such that $y = kx$. We can then define a map $u : k_x^{-1}(g) \to k_y^{-1}(g)$, which is such that $u(v_g) = v_{k^{-1}gk}$. (Note that if G is Abelian, this is just the identity map.) We then see that $u(v_e) = v_e$, since $k^{-1}ek = e$. Moreover, $u(v_g) \circ u(v_h) = u(v_{gh})$, since $k^{-1}gkk^{-1}hk = k^{-1}ghk$. Therefore, u preserves both the identity and group composition. □

From the Theorem it follows that comparative quantities are involved in cosmic conspiracies. We will abbreviate $\bar{r}(i, j) =: v_{ij}$. The claim then is that:

Corollary (Cosmic Conspiracy). For any $i, j, k \in \mathcal{D}$,

(6) $v_{ij} \circ v_{jk} \circ v_{ki} = v_e$

Proof. From the definition of $\bar{r}(i, j)$, it follows that $v_{ij} = r(m(i), m(j))$. For arbitrary x, let $m(i) = g_i x$; and likewise for j, k. Then $v_{ij} = r(g_i x, g_j x) = v_{g_i^{-1}g_j}$. Therefore,

$$
\begin{aligned}
(v_{ij} \circ v_{jk} \circ v_{ki}) &= (v_{g_i^{-1}g_j} \circ v_{g_j^{-1}g_k}) \circ v_{g_k^{-1}g_i} \\
&= v_{g_i^{-1}g_j g_j^{-1}g_k} \circ v_{g_k^{-1}g_i} \\
&= v_{g_i^{-1}g_j g_j^{-1}g_k g_k^{-1}g_i} \\
&= v_e
\end{aligned}
$$

where we have used the associativity $\circ$. Hence, $v_{ki} = (v_{ij} \circ v_{jk})^{-1}$. Since inverses are unique, the values of v_{ij} and v_{jk} thus uniquely constrain the value of v_{ki}. This proves the corollary. □

APPENDIX B. WORKED EXAMPLES

Vector Relationism. We assume that:

1. $x(i) : \mathcal{D} \to A$, where $\mathbb{A}$ is a set of points;
2. $\vec{d}(i,j) : \mathcal{D}^2 \to \mathbb{V}$, where $\mathbb{V}$ is a vector space;
3. $\vec{d}(i,j) \equiv x(j) - x(i)$, for some binary function '$-$';
4. $\vec{d}(i,j)$ is invariant under T, the group of translations of $\mathbb{A}$.

From the Theorem, it follows that the inverse of $\vec{d}$ is a free and transitive action of $\mathbb{V}$ on $\mathbb{A}$. Since $\mathbb{V}$ is a vector space, this means that $\mathbb{A}$ is *affine space*: $y - x$ yields the displacement vector from x to y. The Cosmic Conspiracy corollary follows straightforwardly (where we abbreviate $\vec{d}(i,j)$ to $\overrightarrow{ij}$):

$$x(i) + (\overrightarrow{ij} + \overrightarrow{jk} + \overrightarrow{ki}) = (x(i) + \overrightarrow{ij}) + (\overrightarrow{jk} + \overrightarrow{ki}) \tag{7}$$

$$= x(j) + (\overrightarrow{jk} + \overrightarrow{ki}) \tag{8}$$

$$= (x(j) + \overrightarrow{jk}) + \overrightarrow{ki} \tag{9}$$

$$= x(k) + \overrightarrow{ki} \tag{10}$$

$$= x(i) \tag{11}$$

and hence $\overrightarrow{ij} + \overrightarrow{jk} + \overrightarrow{ki} = 0$. In physical terms, this means that for any triple of objects, the displacement vector from i to j plus the displacement vector from j to k is identical to the displacement vector from i to k.

Mass Ratios. We assume that:

1. $m(i) : \mathcal{D} \to \mathcal{V}_m$, where $\mathcal{V}_m$ is a mass value space;
2. $r(i,j) : \mathcal{D}^2 \to \mathbb{R}^+$, where $\mathbb{R}^+$ is the group of positive real numbers under multiplication;
3. $r(i,j) \equiv \bar{r}(m(i), m(j))$, for some binary function $\bar{r}$;
4. $r(i,j)$ is invariant under S, the group of scalings of $\mathcal{V}_m$.

From the theorem, it follows that $\mathcal{V}_m$ is a principal homogeneous space for $\mathbb{R}^+$, such that $\bar{r}(m(i), m(j)) := m(i)/m(j)$. We can then easily prove the existence of Cosmic Conspiracies:

$$r(i,j) \cdot r(j,k) \cdot r(k,i) = \frac{m(i)}{m(j)} \cdot \frac{m(j)}{m(k)} \cdot \frac{m(k)}{m(i)} \tag{12}$$

$$= 1 \tag{13}$$

In physical terms, this means that the mass ratio between i and j times the mass ratio between j and k is identical to the mass ratio between i and k.

Holonomies. Let P_G be a principal G-bundle over a manifold M. We assume that:

1. $A(\gamma) : \Gamma \to h$, where Γ is the set of open paths $\gamma[a, b]$ on M, and h is the set of all homomorphisms between the fiber above a and the fiber above b;
2. $H(l_a) : L \to G$, where L is the set of all closed paths l_a with base point a on M, and G is the set of functions from the fiber above a to itself (which is isomorphic to G);
3. $H(\gamma_1 \circ \gamma_2) \equiv r(A(\gamma_1), A(\gamma_2))$, for some binary function r, whenever the concatenation of γ_1 and γ_2 forms a loop;
4. $H(\gamma_1 \circ \gamma_2)$ is invariant under G, the structure group of P_G.

From the theorem, it follows that h is a principal homogeneous space for G such that $H(\gamma_1 \circ \gamma_2) = A(\gamma_1) \circ A(\gamma_2)$, where the right-hand side denotes a composition of homomorphisms. We can then prove the cosmic conspiracy as follows. Let $l_1 = \gamma_1 \circ \gamma_2$, and $l_2 = \gamma_2^{-1} \circ \gamma_3$. Then:

$$H(l_1)H(l_2) = (A(\gamma_1) \circ A(\gamma_2))(A(\gamma_2^{-1}) \circ A(\gamma_3)) \tag{14}$$

$$= A(\gamma_1) \circ A(\gamma_3) \tag{15}$$

$$= H(l_1 \circ l_2) \tag{16}$$

In physical terms, this means that the homomorphisms $H(l_1)$ and $H(l_2)$ compose to the isomorphism $H(l_1 \circ l_2)$, which is induced by an element of G.

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