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AGAINST MAGNITUDE REALISM

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SUMMARY: In recent work, Christopher Peacocke has argued for a kind of realism (or anti-reductionism) about magnitudes such as temperature and spatial distance. Peacocke's argument is that magnitudes are an ineliminable commitment of scientific and everyday explanations (including high-level explanations), and that they are the natural candidates for semantic values of our ordinary magnitude talk, and for contents of our mental states. I critique these arguments, in particular focusing on whether the realist has a satisfactory account of how high-level magnitude facts are grounded in lower-level facts. I argue that a less realist (i.e., more reductionist approach) is preferable, or at least viable. I also aim to substantially clarify what is at stake in the debate.

KEY WORDS: magnitudes, grounding, reductionism, realism, relationism

RESUMEN: En trabajos recientes, Christopher Peacocke ha defendido una especie de realismo (o antirreduccionismo) sobre magnitudes como la temperatura y la distancia espacial. El argumento de Peacocke es que las magnitudes son un compromiso ineliminable de las explicaciones científicas y cotidianas (incluidas las explicaciones de alto nivel), y que son las candidatas naturales para los valores semánticos de nuestro discurso ordinario sobre magnitudes y para los contenidos de nuestros estados mentales. Critico estos argumentos, centrándome en particular en si el realista tiene una explicación satisfactoria de cómo los hechos de magnitud de alto nivel están fundamentados en hechos de más bajo nivel. Argumento que es preferible, o al menos viable, un enfoque menos realista (es decir, más reduccionista). También pretendo aclarar sustancialmente lo que está en juego en el debate.

PALABRAS CLAVE: magnitudes, fundamentación, reduccionismo, realismo, relacionismo

Ordinary experience, thought and talk predicates families of properties to objects that are commonly known as magnitudes or quantities. Familiar examples include spatial distance, duration, weight, volume, and temperature. My topic here is a kind of realism (or *anti-reductionism*) about these magnitudes that has been argued for in recent work by Christopher Peacocke (2014, 2019, ch. 2). In brief, Peacocke's argument for realism about these magnitudes is that they are an ineliminable commitment of scientific and everyday explanation (including high-level explanations), that they are the natural candidates for semantic values of our ordinary magnitude talk (which is hard to give a plausible semantics for without them) and also that they are well-suited to serve a role in constituting the contents of our perceptual experiences and perceptual states (for example, perceptions of spatial distances). I will critique his arguments and suggest that, for all he has said, a less realist (i.e., more reductionist) approach to magnitudes is preferable, or at least viable. I also aim to substantially clarify what is at stake in the debate.

I'm particularly interested in Peacocke's view here for two reasons. First, it's a recent and sophisticated iteration of a "realist" position, building on similar views defended by Mundy (1987), Swoyer (1987) and Eddon (2013). Second, Peacocke's account is deliberately supposed to apply to both fundamental *and* non-fundamental magnitudes, and my interest here is particularly in the latter. I'll argue that the Peacockian realist can't deliver a plausible view of how non-fundamental magnitudes are grounded in fundamental physics. That said, some of the discussion will apply to fundamental magnitudes also (particularly sections 6 and 7).

Since Peacocke does not actually elaborate an account of the grounding of such non-fundamental magnitudes, I'm also going to draw on some important recent work by Schaffer (2017a, 2017b), who I read as holding a realist view of magnitudes similar to Peacocke's, but embedded in a well-developed grounding theory. The overall target is therefore a chimeric hybrid of Peacocke and Schaffer that may not be wholly embraced by either; still, I hope to persuade readers this is a beast worth pursuing.

I proceed as follows: In the first section, I distinguish between lightweight and heavyweight views of magnitudes, and propose that we understand magnitude realism as a heavyweight view. In section 2, I discuss some important general features of magnitudes, as understood on both a heavyweight and a lightweight view. In sections 3–6 I argue and critique the arguments for Realism. In section 7, I briefly consider fundamental magnitudes.

1. *What is Magnitude Realism?: Lightweight and Heavyweight Views*

A magnitude like mass is a family of property-like entities (it's instances), such as 15kg, 5g, 100 tons, etc. Although we inevitably pick out these instances in units, they are typically supposed to be individuated in a unit-free way, so that, for example 15kg is the same instance as 150000g.[1] They are grouped into a magnitude-family in

[1] See section 5.

virtue of standing in certain structural relations; in particular, on Peacocke's account, magnitudes have a ratio-scale structure: that is, they form a strict ordering, and there is an addition function that takes pairs of magnitudes to their sum (more on this below). It's worth commenting at the outset that there are other structures one might want to postulate magnitude-like entities as having, such as ordinal, interval, or multiplicative structure, and it's unclear why we are treating ratio-scaled magnitudes as if they have a special status. I will return to this point below (section 7).

Peacocke's magnitude realism (which, again, is comparable to the views of Mundy (1987), Swoyer (1987) and Eddon (2013)) is strongly reminiscent of the realism about universals one finds in the work of figures like Armstrong, and some of the arguments are strongly parallel. Armstrong (1980) argued for realism about universals on scientific realist grounds: they are apparent commitments of our scientific explanations (for example, they are needed on Armstrong's non-Humean view of laws). Armstrong was not just a realist about the properties predicated in fundamental physics, and similarly, as mentioned, Peacocke very much wants his magnitude realism to extend to the kind of high-level magnitudes that we humans typically think about and appeal to in everyday explanations. Moreover, attempts to paraphrase away apparent commitments to universals in a nominalist friendly manner —for example by treating sets of objects as surrogates for properties— were argued by Armstrong to be inadequate, and Peacocke wields similar arguments against his "reductionist" opponents.

To get clearer on the kind of realism Peacocke believes in, it's important to see that he rejects the view that magnitudes like distance and mass are lightweight or notional, as opposed to what I'll call "heavyweight".[2,3] Once we have some initial magnitudes on the table, we can define other magnitudes as mathematical functions of these primary magnitudes. For example, I can define the average mass of a group of objects, or consider log distance instead of regular distance (see below). Peacocke himself gives the example a magnitude ascribed to each continent (we could call it its "mountcar value"), calculated by taking the sum of the heights of the tallest mountain in each country in the continent recognized by the united nations, divided by the number of cars in that continent. Such magnitudes are

[2] I choose this terminology because it is fairly standard in the recent grounding literature.

[3] See Peacocke 2014, section 5.

notional or lightweight in the sense that we can truly and meaningfully predicate them without committing to anything over and above the primary magnitudes (or other entities) we used to define them. In that sense, they are *metaphysically cheap*. The distinctive claim of the magnitude realist is that many high-level magnitudes, including many of those predicated in every day life, and many of those appealed to in high-level sciences, are *not* merely notional in this sense, but are substantial "heavyweight" metaphysical commitments.[4]

It is clear that if fundamental physics appeals ineliminably to magnitudes, then they cannot be purely notional, because then they would be defined in terms of other magnitudes (or other entities), and so not fundamental. The *fundamental-magnitude realist* believes in such fundamental magnitudes (I do not mean to suggest that this is the only way to avoid treating them as merely notional —perhaps a nominalist (e.g., the ostrich nominalist (Devitt 1980, Quine 1948)) can offer a different view). The distinctive claim of the *high-level-magnitude realist* is that there are magnitudes, which despite being *non*-fundamental, and despite having their instances fully grounded in the fundamental world, are *not* merely notional. By contrast, the *global anti-realist* believes that there are no heavyweight magnitudes, whether fundamental or non-fundamental, and the *high-level anti-realist* believes that there are at most fundamental heavyweight magnitudes, so that *all high-level magnitudes are lightweight*. I'm mostly interested here in the viability of high-level anti-realism, although I will make some brief comments in section 7 about global anti-realism, which I also regard as a view to be taken seriously.

By rejecting high-level anti-realism, Peacocke (as I read him) is taking a stance in a broader metaphysical debate between lightweight and heavyweight theorists about the status of high-level properties and entities of all different kinds. On the lightweight view (exemplified by Lewis (1983), Sider (2012), Jackson (1998) and Chalmers (2012)), the high-level world is nothing beyond fundamental physics in the sense that its existence is a trivial a priori consequence of physics. Imagine a powerful being with full knowledge of physics, and an armory of conceptual devices for abstracting and generalizing. They will be able to spot patterns in the fundamental soup, patterns that they will see as following from physical descriptions

[4] Note that if Peacocke was merely committing to magnitudes in the lightweight sense, then what he would need to do is show that they can be defined or constructed from a fundamental base; but that is not how he proceeds. Furthermore he explicitly rejects such a "reductionist" project, as we will discuss below.

—they can be constructed a priori from them. For example, they can take averages or perform other algebraic or statistical operations on fundamental quantities. They might, for example, track the centers of mass of large objects through space, and note that these often approximately conform to Newton's laws. The lightweight theorist says that the high-level world is no more than can be derived by such a super-being from physics.

The heavy-weight theorist, on the other hand, has a totally different picture (Schaffer 2017a, 2017b, is my model here).[5] Theirs is a "layer-cake" view of reality, in which high-level objects and properties have an existence that goes substantially beyond what we find in physics. To be sure, they are "grounded" in physics, but for the heavyweight theorist, grounding is akin to causation. They picture the existence of "metaphysical laws" that are required to generate high level facts, analogous to the way that dynamical laws generate later facts from earlier facts. On this picture, if all we know is physics, this leaves open many epistemic possibilities for how the high-level world is. For example, Schaffer claims that a "flatworld" is perfectly conceivable, in which only fundamental physics exists, and nothing else. If there is anything else, it must be generated by special laws. For example, it is not trivial that if two hydrogen atoms and an oxygen atom are bonded in a certain way, then a water molecule exists. That would require some thing like a law of fusion, that declares the conditions under which mereologically complex entities exist. And if the molecule has any features, such as a mass determined by the masses of its parts, that also requires a special law —a "property inheritance law"— it doesn't follow trivially from the lower-level facts. As Schaffer explains:

> It cannot be analytic which concrete individuals the world gives out, or whether a conceptual condition happens to satisfied. So it cannot be analytic that, even if the world gives out an H, an H, and an O atom (arranged and bonded in the right ways), it also gives out a further individual —their fusion— satisfying further conditions enabling it to count as an H20 molecule (§2.3). And in general it cannot be analytic

[5] An important historical antecedent to contemporary "layer cake" views is British Emergentism (McLaughlin 1992). See also Wilson (2022) for a taxonomy of Emergentist views, and Armstrong (1980) for a clear example of a heavyweight "layer-cake" view that is an ancestor to Schaffer's. Many theorists who have expressed sympathy with "anti-reductionism" in its many forms are often hard to classify as clearly endorsing a metaphysical thesis as opposed to merely an epistemic form of anti-reductionism, which makes it tricky say who exactly Schaffer et al. keep company with.

> that, if fundamental reality is so, then there are also just so many derivative entities as well, satisfying various further conditions. (2017, p. 23)

Two important points of clarification here. The first is that the lightweight theorist will presumably want to cash out the super-being metaphor in terms of a more rigorous theory of lightweight facts.[6] Here I remain neutral on how to do this, assuming that the notion of "lightweight" fact is in good enough shape to proceed.[7]

Second, it is important that the lightweight theorist (at least as I understand them) is not automatically committed to the stronger kind of "rationalist" position associated with theorists like Chalmers (2012) and Jackson (1998), on which high-level descriptions *stated using our ordinary concepts* are (to a first approximation) derivable a priori from the fundamental facts. The lightweight picture is rather more like this: there is a set of concepts that an omniscient super-being might use to derive a priori a high-level description of the world from their knowledge of the fundamental distribution. Every state of affairs that we describe using *our* concepts is *also* a state of affairs that they can describe using *their* concepts. So, to take a particularly fraught example, a lightweight materialist about consciousness might say that there is a truth of the following form:

(X) What it is for Geoff to feel pain is for P to obtain[8]

where "P" is a statement in the language of our omniscient super-being. For example, P might be something like:

(P) Object O has functional property F

[6] See Chalmers 2012.

[7] I take it that particular kinds of lightweight constructions can be introduced in a rigorous way that allow us to define sub-classes of "lightweight facts", and that for many applications this is all we really need. For example, a class of mathematical functions on fundamental magnitudes can allow us define a class of lightweight facts involving notional magnitudes. Or we can introduce lightweight constructions (e.g., lightweight mereology) on fundamental particulars that defines a class of lightweight facts about lightweight composite objects, without committing in any substantive way to more than the fundamental particulars. I take it that what is probably more controversial is a *complete* domain of lightweight facts because that involves the idea of a complete set of such modes of lightweight construction. It might be better to think in terms of an indefinitely extensible class of lightweight facts rather than a definite totality. This is a way in which the super-being metaphor might be both helpful (because it encourages us to think as inclusively as possible about lightweight facts) but also misleading.

[8] See Dorr (2016) for an account of "what it is for X to obtain is Y" statements.

where (P) is derivable a priori from the fundamental facts. Statement (X) itself, if we could contemplate it, need not be a priori, nor need it be a priori derivable from complete knowledge of the fundamental facts (i.e., rationalism need not be true). It is *P* that is derivable a priori from the fundamental facts. On the other hand, I take it that the distinctive claim of the heavyweight theorist, applied to an example like pain, is that there is no truth of the form (X), because Geoff feeling pain is not a lightweight fact such as P (putting it this way also has the advantage of making it clear that lightweight and heavyweight views are the only options). Furthermore, if their metaphysical ideology allows them to *directly* mark facts as both heavyweight and non-fundamental (e.g., because they appeal to a primitive concept of "heavyweight" or some related notion), then they may want to say that what explains the lack of lightweight analysis is that the target fact (e.g., Geoff is in pain) is heavyweight.[9]

I would therefore similarly propose to treat the magnitude realist as saying that what it is for an object to instantiate a magnitude can *not* be given the following treatment:

> *Lightweightism*: What it is for object x to instantiate magnitude M of Type T is for Q to obtain

Where Q is stated in the lightweight concepts of our omniscient super-being (e.g., it might state some condition on the fundamental properties and relations of the parts of x, such as a functional condition). Note that Lightweightism is not an "anti-realist" view of M in the sense of denying that anything instantiates M. It's really a way of spelling out a kind of *reductionism* about M; and reductionism is of course not the same as eliminativism. Furthermore, I take this to be a good explication of the "reductionism" that Peacocke rejects, and so read him as a "heavyweight" theorist at least in the *negative* sense of denying lightweightism. As mentioned, there is also a

[9] The disadvantage of a purely negative classification of heavyweight high-level facts as those lacking a lightweight analysis, is that this involves quantifying over an alleged complete domain of lightweight facts, and it's unclear how well-defined this is. For this reason (and maybe others), a view that positively marks them as heavyweight in an independent sense could be preferable. Two possible disadvantages of this latter approach are that requires an ideology that allows non-fundamental facts to be directly marked as heavyweight (although if we already have some such machinery for marking fundamental facts as heavyweight, this may not be a cost), and that it's not totally obvious why all facts must either have a lightweight analysis or be positively heavyweight! Could there be a "third realm" of facts? I leave that issue for another time. (Thanks to Shamik Dasgupta for discussion here.)

"positive" version of the heavyweight view on which we recognize a primitive concept of "heavyweight", and then claim that what *explains* the lack of lightweight analysis is that M, or facts about M, are independently characterizable as "heavyweight". Regardless, my intention here is to be as neutral as possible consistently with taking the lightweight/heavyweight distinction seriously, and hence I hope that my characterization does not read commitments into the realist position that Peacocke would find unacceptable. (If it does, of course it would be interesting to learn why.)

2. *Magnitudes: General Features*

Having clarified the *realist* component of magnitude realism, I now discuss some important general points about the metaphysics of magnitudes, specifically through the lens of the lightweight/heavyweight distinction.

2.1. Magnitudes as Extensive Systems

Peacocke follows Scott (1963) in treating magnitudes as an "extensive system", defined as a system of entities with an ordering relation R and an addition function + that satisfy Hölder's (1901) axioms, which collectively define a ratio-scale structure. The most important thing to bear in mind here is that in a ratio-scale, the addition function defined on pairs of entities allows us to also define rational-valued *ratios*. With addition in hand, we can multiply each magnitude by a whole number scalar m by adding it to itself m times. The ratio of magnitude x to magnitude y is m:n just if mx = ny.[10,11] Note that although ratios are well-defined in a ratio scale, multiplication of one magnitude by another is *not* well-defined —for that we need a privileged *unit* magnitude (a point to be born in mind when considering the idea of functions on fundamental magnitudes). Also note that ratio comparisons across magnitudes *are* well-defined —e.g., the ratio of two spatial distances can be the same as the ratio of two durations.

In classic "extensional" approaches to magnitudes (e.g., Suppes and Zinnes 1963, Field 1980) the entities to which R and + apply

[10] Ratios of magnitudes as defined are therefore rational numbers. Can there be irrational ratios? If needed, they could be handled in a standard way in terms of converging series of increasingly accurate rational approximations.

[11] As Peacocke (2019, p. 45) notes, Scott's formulation is equivalent to the formulation in Definition 5 of Book V of Euclid's *Elements*, attributed to Eudoxus (Euclid 1956).

are particular material objects —objects we would typically think of as in the *extensions* of magnitudes. So for example, a stick of 2 meters can be "added" to a stick of 1 meter to give us a stick of 3 meters. One distinctive feature of a realist approach is that it is the property-like magnitude instances themselves that are taken to form an extensive system —so for example "2 meters" can be added to "3 meters" to give us "5 meters" (although again the units are inessential here). A possible motivation for the extensional approach, of course, is a nominalist's aversion to such abstract entities, but there could be other motivations, such as a relationist's desire to eliminate unnecessary structure at the fundamental level.

The latter point is important. Since the magnitude realist is committed to rejecting extensional approaches, prima facie they are committed to rejecting *relationist* approaches to magnitudes, and therefore hold a kind of absolutist view. On a relationist approach to, say, *mass*, the fundamental facts about mass involve mass-relations between particulars, such as a two-place mass congruence relation and a 3-place mass additivity relation (Field 1980, Dasgupta 2013). This is an "extensional approach" because what forms an extensive system here is, if anything, sets of equi-massive objects, not "real magnitudes". Peacocke, admittedly, tries to back away from the prima facie absolutist character of magnitude realism, but it's unclear this is viable —I return to this below.

Now, it's important to note that lightweight magnitudes can *also* be understood as forming extensive systems. For example, suppose we consider log distance. Presumably most theorists would agree that to treat log distance as a separate ontological commitment beyond a commitment to distance would be very weird. Log distance is a purely notional magnitude, one that we might find it convenient to consider for pragmatic purposes (e.g., because it converts ratios into differences which may be easier to compute with). Also, although log distance is technically an interval scale, not a ratio scale (since it converts ratios to differences and does not have a well-defined zero point), it can easily be treated for convenience as a ratio-scale by selecting an arbitrary zero point (this corresponds to selecting a unit of length). Such a log scale is an extensive system in a clear sense, even though the truth-conditions for statements about e.g., the addition of its magnitudes (log distances) are entirely parasitic on the truth-conditions for the addition of distances. Or to take another example, consider again Peacocke's mountcar magnitude. This (presumably) purely notional magnitude also, in a clear sense, forms an extensive system, even though, again, this is parasitic on distance forming an extensive system.

Note that these parasitic, lightweight extensive systems could be grounded in different ways at the fundamental level. They could be grounded in fundamental realist magnitudes, or they could be grounded in an extensive system of material objects standing in magnitude relations, or one could conceive of other kinds of hosts —e.g., structures at the level of fundamental physics that are not ratio-scaled magnitude structures at all—, a point to which I return in section 7. However they are grounded, the point is that such a parasitic status could hold for *all* the high-level magnitudes that are the subject of ordinary talk and high-level explanations. This is the high-level anti-realist view.

2.2. Extensive vs Intensive Magnitudes

Another important preliminary to consider is the traditional distinction between extensive and "intensive" magnitudes. In a way that I worry invites confusion, Peacocke defines an extensive magnitude as simply any magnitude that forms an extensive system —that is, it has additive structure. However, the traditional notion of "extensive" magnitude applies to only a subset of such magnitudes, those that are additive in a stronger mereological sense. Moreover, magnitudes traditionally classified as *in*tensive, such as temperature or speed, turn out to be extensive in Peacocke's sense; they are magnitudes with additive structure, but not in the stronger mereological sense.

A magnitude is mereologically extensive if it applies to mereologically complex entities, and the value of the magnitude for the whole is the sum of the values of its parts (in the sense of a set of disjoint proper parts whose mereological sum coincides with the whole (and which may in some cases need to meet further conditions)). For example, the mass of a complex object is the sum of masses of any set of disjoint parts which sum to the whole. The length of a line is the sum of the lengths of any set of disjoint segments of it which sum to the whole. The volume of a 3D object is similar. The length of a 3D object along a certain direction is mereologically extensive in rather more complex way —the decomposition has to involve slicing the object up along the relevant spatial direction (hence the "further condition" clause for some cases).

Peacocke cites Kant as a precedent for the notion of extensive magnitude he is interested in. However, consider how Kant defines the notion:

> I call an extensive magnitude that in which the representation of the parts makes possible the representation of the whole (and therefore necessarily precedes the latter). I cannot represent to myself any line, no matter how small it may be, without drawing it in thought, i.e., successively generating all its parts from one point. (p. 287, Guyer and Wood edition of *Critique*.)

Kant's notion is more like the mereological notion I just defined, although he gives it a more epistemic/representational spin (and that is another typical connotation that it is important to bear in mind in interpreting uses of the term).

Importantly, some so-called "intensive" magnitudes are not additive in the mereological sense. The absolute temperature of the mereological sum of two disjoint objects is not the sum of their absolute temperatures. The speed of the sum of two objects is not the sum of their speeds. Notice, however, that it would be a mistake to conclude from this that temperature and speed are not magnitudes with additive structure. Since absolute temperature has a zero point and differences in temperature are well-defined, it follows that ratios and sums of temperature also are well-defined (although of course one has to be careful about their physical interpretation, given that temperature is not mereologically extensive). According to at least one historian of science (Michell 2003), the idea that some non-mereologically-extensive magnitudes can nonetheless have additive structure was an important insight of pre-enlightenment scholastic figures such as Duns Scotus and the "Oxford Calculators", an insight that laid an important part of the foundation for mathematization of nature that later occurred in the scientific revolution. It is also notable that thinkers have often found such quantities difficult to understand: for example, Fechner's idea that conscious experience involves phenomenal magnitudes like pain intensity that have additive structure, was frequently questioned in the 19th century and beyond on the grounds that an intense pain is not the sum of many less intense pains (Michell 1999). Without further explanation, this can reasonably be dismissed as making the mistake of thinking that a magnitude can only be additive if it is mereologically additive.

Ironically, although many of the paradigm magnitudes that we are intuitively familiar with (and which Peacocke treats in a realist way) are mereologically extensive, arguably mereological extensivity is in itself a good motivation for treating a magnitude in a lightweight way, so that the fundamental additive magnitudes (if there are such) are all *in*tensive. The reasons have to do with the status of the axiom governing mereological additivity. Take mass, for example. On a lightweight approach to complex mass, we start with a mass magnitude that applies only to atomic parts (here I assume a decomposition into finitely many atomic parts —in the continuous case, we would use mass-density instead). The "mass" of a complex object is then simply *defined up* as satisfying the axiom of additivity, which is therefore a trivial definitional truth. What is non-trivial is that this is a *useful* magnitude to define up. For example, in a Newtonian setting, a reason this is useful is that Newton's laws imply that the behavior of a complex object will approximate the behavior of a point particle with the "same mass" located at its center of mass.[12]

Now, it is sometimes observed that "it is an empirical discovery that mass is additive". This is true in the sense that it is non-trivial that additive composite mass plays a functional role analogous to atomic mass. In some settings this fails: for example, in special relativity if we want a notion of composite mass that has the right dynamics (it measures a composite object's resistance to acceleration), we need to define composite mass in a non-additive way.[13] Importantly, it would be a mistake to think that the empirical status of mass additivity *in this sense* impunes the triviality of mass-additivity advocated by the lightweightist, and instead supports a "realist" heavyweight approach to complex mass. On the heavyweight view, the axiom of additivity is instead a *synthetic* necessary truth governing the nature of mass qua magnitude, a magnitude that can apply both to atomic and complex objects. The lightweightist should argue that this extra commitment to heavyweight composite mass is unjustified and unhelpful. Consider again the special relativity case. Note that regular additive mass can still be defined in this context, it just won't have the "right" dynamics (i.e., it won't play the "resistance to acceleration" role). So what we are really discovering is that in a SR setting we need to define composite mass a certain way in order for it to have certain (derivative) properties.[14] That does not mean that a statement of the definition itself isn't analytic.[15]

[12] See McQueen (2015) for elaboration and also concerns about the kind of explanation gestured at here.

[13] See Lange 2002 (ch. 8) for helpful discussion.

[14] Also note that a further sense in which we have an empirical issue here could be that we have a pre-theoretical notion of mass (p-mass), and it could a posteriori (or even deeply a posteriori) that "p-mass is a-mass" where a-mass is a lightweight additive (or non-additive!) mass property.

[15] Another possible benefit of the lightweight approach is that the dynamics

In general, the lightweightist can hold that if the laws of nature can be formulated in a way that only appeals to atomic intensive magnitudes, talk of mereologically extensive composite magnitudes can and should be given a derivative (and relatively a priori) justification in terms of what the laws entail about the behavior of complex wholes. Even in cases like spatial distance and duration this reductive move is available in many physical theories; for example, in a continuous relativistic space-time, space-time distance results from integrating (= the continuous analog of addition) the values of a distance-metric tensor field defined at each space-time point, and therefore distance is naturally treated as a derivative quantity *defined* in terms of the integration function, rather than a fundamental one that is governed by certain synthetic axioms linking it to the values of the distance-metric tensor field.[16]

Extensive magnitudes are therefore one example where, despite a prima facie argument to the contrary, the role of the magnitude in causal explanation is better understood on a lightweight approach. I now turn to that general issue.

3. *The Role of Magnitudes in Causal Explanation*

What are the pros and cons of the realist position? Let us first note that lightweight anti-realism has an obvious benefit in its slenderer commitments. So as I see it, the burden is on the realist to demonstrate the theoretical indispensability of their additional commitments. Peacocke has two main arguments along these lines. First, that magnitudes are indispensable in scientific and everyday causal explanations. Second, that "reductionist" attempts to construe such explanations as not really committed to magnitudes are bound to fail. I start by considering the former line of argument, which as we will see, will also involve revealing some further flaws in the realist position. I then develop another line of attack against the realist in section 4. In section 5 I then respond to Peacocke's critique of

governing atomic mass (or whatever other magnitude) do not need to be assumed to *exactly* apply to composite mass (e.g., if we approximate an object as a point particle at its center of mass); relatedly, we can allow there may not be a single optimal way of defining composite mass. If atomic mass and composite mass are just the same heavyweight magnitude, governed by a hegemonic synthetic grounding principle, it's not clear that we have this flexibility.

[16] Perry (2015) argues that such spatio-temporal magnitudes differ from other extensive magnitudes like mass, in that their status as additive *doesn't* depend on the dynamics, but rather follows directly from their connection to the mereological structure of an object —they are "properly extensive".

reductionist alternatives, which will also shed some interesting light on how one might develop the anti-realist alternative.

On Peacocke's view, the signature of a real magnitude as opposed to a merely notional one is that it is appealed to in causal explanation. Presumably this is supposed to be the key difference between the mountcar magnitude, and a magnitude such as temperature. However, it is very unclear why notional magnitudes are less fit for causal explanation. Take the elements of your favorite theory of (high-level) causation: counterfactual dependence, probabilistic difference-making, subsumption under high-level laws, the underpinning of causal processes by lower-level causal mechanisms. None of these elements seem to depend in any way on whether magnitudes in question are heavyweight or lightweight. Or to put it another way, suppose a metaphysical seer visits us and informs us that the high-level world is entirely lightweight. It is hard to see why that would in any way justify altering our practice of giving causal explanations. Or imagine that most of the magnitudes we talk about in every day life are heavyweight, but that it turns out that, say, temperature, is a lonely exception. That wouldn't stop temperature from being a highly explanatory magnitude.[17]

For the same reasons, I think we should be sceptical about whether we need heavyweight as opposed to lightweight magnitudes to serve as semantic values for our talk, thought, or other mental representations. For example, Peacocke (e.g., 1993) has emphasized the role that externally individuated mental contents can play in explaining externally individuated actions —e.g., my reaching for a certain place in space to pick up an object can be explained by my having a mental representation of the object having a certain spatial relation to me. It's hard to see why the motivation for this should depend on treating this represented spatial relation in a heavyweight way.

Having said this, I actually think there *is* an interesting argument for the heavyweight view that appeals to causal considerations, due to Shoemaker (1988). I believe this is the strongest argument for the view, but because I discuss it in detail in other work (Lee (manuscript)) I will just briefly summarize some key points here.

[17] Peacocke (2014, p. 31) appeals to the example of Spearman's G, a psychological measure in the field of intelligence studies whose explanatory utility has been contested, to illustrate the notional/real magnitude distinction. But there's no reason why the lightweight theorist can't draw a distinction between genuinely explanatory and non-explanatory lightweight magnitudes. G is explanatory if it stands in the right counterfactual relations to other psychological quantities, and meets other relevant criteria.

On a lightweight view, composite objects and non-fundamental properties and relations (including magnitudes) are abundant and metaphysically cheap. Almost all of this is "metaphysical junk" that we ignore both in everyday life and in scientific taxonomies. Shoemaker's concern was that if we also have a lightweight view of high-level causation, on which it amounts to no more than certain kinds of correlations occurring between events across modal space, then there is a risk that junk events involving junk properties of junk objects might count as genuinely causally explanatory in the same way that ordinary events (e.g., a brick hitting a window) are (e.g., they stand in the appropriate counterfactual relations). In particular, he proposed a method of taking the contents of a merely possible situation (for example, a situation where something like the plot of the show *Game of Thrones* is playing out), and projecting a (prima facie) functionally isomorphic situation into the actual world (details discussed in Lee (manuscript)). In this way, the actual world arguably contains "ghost" systems whose patterning across modal space mimics a system of real physical events.[18]

Let's assume that a construction along these lines is possible[19,20] Shoemaker understandably considered it intolerable to grant the same kind of reality to these ghost systems as we would to the systems of macroscopic objects and properties that we ordinarily interact with and think about. And a solution he takes seriously is to say that the ghost systems are merely notional constructs, whereas the ordinary systems have a kind of robust reality that the ghost systems lack. Let's interpret this as a "sparse" heavyweight view on which ordinary systems but not ghost systems involve heavyweight objects and properties.

Now of course, if we take the view that everything except fundamental physics is "merely notional" in the relevant sense, then this heavyweight response isn't available. We're just as "notional" as

[18] We should note the close similarity here with triviality arguments against functionalism (e.g., Putnam 1988, Sprevak 2018). For the purpose of thinking through the lightweight/heavyweight issue I find Shoemaker's discussion a more helpful route into the issues.

[19] See Lee (manuscript) for details and discussion.

[20] Note that if the lightweight theorist grants that there exists a (lightweight) object for every function from worlds to space-time regions, and that there exists lightweight properties/relations/magnitudes for every arbitrary function from worlds to lightweight objects (or for relations/magnitudes, to n-tuples of objects, or to object/number pairs), then the lightweight universe is so densely populated that it's very plausible that one can construct ghost systems where at least some of the counterfactual dependencies characteristic of causation obtain.

our ghost counterparts. This raises the concern that the lightweight theorist has no way of dismissing the ghost systems as in any sense less real or robust as regular macroscopic systems. Can the sparse heavyweight view come to the rescue?

The problem is that their view has its own unattractive features. The most serious issue that they are (arguably) committed to drawing the nice/junk distinction in a sharp all-or-nothing way, which leads to the worry that it will be a completely arbitrary distinction.[21] By contrast, if we bracket concerns about ghost systems, it looks like the theoretically important distinctions between nice and junk properties/objects are causal-explanatory distinctions that *come in degrees and are multi-dimensional*. For example, we typically focus on composite objects whose spatial parts are stuck together and whose temporal parts form an analogous causal unity. But such relations of causal unity come in degrees, and plausibly there is a plurality of related kinds of causal unity that matter to us. Arguably a similar point applies to properties too. Counterfactual and probabilistic difference making are not all-or-nothing but come in degrees; and it's very implausible that there is a single sharply defined relation that is THE CAUSAL RELATION, rather than a family of related notions that are more or less useful in different contexts. This suggests that the sparse heavyweight theorist can't use a causally motivated account of the nice-junk distinction to motivate their sharp, simplistic line-drawing. Instead, it will be a kind of *emergency measure* to avoid granting equal status to the ghost systems; but like many emergency measures, it will be crude and poorly targeted.

Of course, this raises the question whether the lightweight theorist can do any better here. I hold out hope that they might be able to show that ghost-systems don't, after all, really count as genuine causal networks, because of the wayward way in which they are grounded at the fundamental level —but that's a story for another time. I do think that it's completely intolerable to embrace a pessimistic view on which, from a cosmic perspective there is no deep difference between us and the ghosts.[22] So if a lightweight response to the

[21] See e.g., Lewis (1986) and Sider (1997) on unrestricted composition and the non-vagueness of existence and parthood. The basic thought here is vagueness is not a feature of the mind-independent world, it's a feature of our language or mental representations. The heavyweight view is a proposal about the mind-independent metaphysics of the world, and therefore presumably there is a precise fact of the matter about what the heavyweight facts are.

[22] For example, if the ghosts are functionally like us, then they may have mental lives like ours. We get a preposterous kind of mental explosion, a universe

problem can't be pulled off, we may need the sparse heavyweight theorist's emergency solution. For this reason, I retain an open but skeptical mind towards the view.

Of course, I have yet to explain all my reasons for this skepticism. The issues with the causal motivation for realism are not the only problems, as I will now explain.

4. *The Role of Magnitudes in Dynamical and Metaphysical Laws*

As Peacocke discusses, magnitudes have historically been appealed to in fundamental physical laws, the most famous case being Newton's law F=MA. It will pay to pause for a second and consider what this law is actually telling us. On a naïve reading, it tells us that the acceleration of a body can be calculated by dividing the force applied to it (which has a direction and magnitude) by the mass of the body (a magnitude). However, on reflection, things can't be so simple. As stated, this makes no sense, because (as mentioned earlier) distinct ratio-scaled quantities cannot meaningfully be multiplied or divided by each other. The reason we don't notice this in practice is that we make the calculation *relative to a choice of units*. And in so doing, we are really implicitly leaning on the fact that *ratios of magnitudes* of different types *are* comparable, and can be multiplied and divided by each other. So, as Peacocke notes, a more perspicuous way of representing what F=MA is actually saying is that it is telling us about a connection between ratios of magnitudes. If we are concerned with the force F1 applied to a certain object, and its relation to the object's mass M1 and acceleration A1, we must also introduce a distinct force F2, mass M2 and acceleration A2 as reference points, and apply the law "F1/F2 = (M1/M2) * (A1/A2)". Intuitively, what this is saying is that alterations in the mass of the object or in the force applied to it, produce proportional changes in the acceleration of the object, holding fixed our reference magnitudes M2, F2 and A2.

So far so good, but now there is another important problem which Peacocke does *not* take note of. For Newton's law to be a deterministic law that actually tells us what will happen, we must conceive of it as a kind of machine that takes forces and masses as inputs and delivers accelerations as outputs. However, the law stated in the previous paragraph emphatically does not do this. It is merely a *constraint* on how such a machine works. All it tells us is that however that

densely populated by ghost minds! And if we accept that, we must ask: how can we then know that we aren't ghosts? If we don't know that, there is much else we don't know.

machine works, it had better be that proportional changes in forces or masses as inputs result in proportional changes in accelerations as outputs. If we start with a machine that satisfies this and change its output function by any arbitrary scalar, it will still satisfy this constraint. This is not a huge deal in practice. It can be dealt with by supposing that there is an *arbitrary constant* in the law, which would take a particular numerical value relative to a choice of units for all three quantities, but which in practice is "absorbed" by setting our units so that it takes value 1. But it's important metaphysically, because it means that there is some unattractive "excess structure" here, illustrated by the fact that we could, at least notionally, consider "shifted" worlds where, say, all the masses of items are multiplied by a certain constant, but everything plays out in *exactly the same way*, because our arbitrary constant is also shifted to accommodate this.

My main concern is not whether this excess structure at the fundamental level is an unacceptable cost. If we don't like it, the obvious stereotypical move to make is to try go *relationist* about, say, mass, so that there is no intelligible way to shift all the masses by a constant value (although this raises its own issues vis a vis determinism (Baker 2020, Dasgupta (forthcoming))). That is, it might be said that the problem results from the fact that we were naively treating these magnitudes in an absolutist way. But whether this response works doesn't matter here. I introduce the problem because I think it has an analog in the case of the laws or principles governing the *grounding* of high-level magnitudes by lower-level ones.

As mentioned earlier, if we reject the lightweight view, then we reject a picture on which the high-level world is a trivial a priori consequence of the fundamental distribution. Instead —at least on the alternative view developed by Schaffer (2017a, 2017b)— the high-level distribution is a significant further fact, which can be thought of as systematically linked to the fundamental distribution by a metaphysical analog of dynamical laws. These will be conditional principles that tell us that if a certain fundamental distribution obtains, then a certain high-level fact obtains —for example, we might have the principle that if two hydrogen atoms and an oxygen atom are bonded in a certain way, then a water molecule exists. Again, for Schaffer, the existence of this molecule given the bonded atoms is *not* just trivial. It's a substantial further state of affairs; according to him, it's intelligible that the atoms could be bonded in this way, and a water molecule *not* exist, because it is intelligible that there is no composite object that has these atoms as parts.

The metaphysical laws themselves can be understood in different ways that parallel different views of dynamical laws. On a non-Humean approach, these laws are substantial entities in their own right, which somehow play a metaphysical role in "generating" the high-level world. On a Humean view, they are more like a convenient summary of the *correlations* between high-level and low-level facts, and play an explanatory role in a more purely epistemic sense; they are thus not a substantial further postulate beyond the heavyweight high-level facts themselves.

Which view the heavyweight theorist takes of these laws won't matter here. What matters is that a magnitude realist is presumably committed to a view of grounding along these lines (I assume this is particularly clear if we are leaving the Humean view on the table —then we are not committing our realist to robust metaphysical laws). Take the example of temperature. It's trivial that the individual molecules in a gas are moving around in a certain way, then the gas has a certain *lightweight* temperature, which is temperature just defined in the normal way in terms of average kinetic energy. But if we are treating temperature as a substantial ontological commitment beyond the low-level features on which it depends, as the heavyweight approach would recommend, then it is merely grounded in these features, in virtue of a substantial non-trivial law linking the features together.

I want to highlight two serious problems with this picture, both highlighting ways in which it gives us "too much structure". The first exactly parallels the issue with F=MA discussed above. If we treat temperature as a separate magnitude from the low-level magnitudes that ground it, then the principle that it scales proportionally with, say, mean kinetic energy, is really telling us about the connection between temperature *ratios* and mean kinetic energy *ratios*, and does not fully pin down which *particular* temperature value we get given a complete specification the low-level facts. We can deal with this by supposing that there is an arbitrary constant in our metaphysical grounding law. But the cost is that in this setting, one could at least notionally conceive of a world where all the temperature values are rescaled by a certain amount, and everything else is held constant. Admittedly, Schaffer would not allow that such temperature shifted worlds are metaphysically possible, because for him the metaphysical laws could not be different from what they are —and they actually have a particular value for the arbitrary constant. But it's hard to see that spoiling the point. The point is that the mere intelligibility of such shifts, and the idea that we *need* to postulate such a constant, suggests we have the wrong picture of how temperature depends on low level facts. On the lightweight view, the closest we can get to making sense of such "temperature shifts" is that we can understand changing the *units* that we use to *describe* temperature. But that's fine —that's a change in our representational scheme, not a change in the facts themselves. It is as if on the heavyweight view we are projecting a legitimate representational device onto the world itself —a theme I will come back to.

Call this the *scaling* problem. Could the problem be avoided by treating high-level temperature in a less absolutist way, perhaps instead postulating a relationist scheme of heavyweight temperature relations between objects instead? Yes, I think so. But the point for present purposes is that Peacocke is explicitly committed to rejecting this kind of view —it's a version of the "reductionist" position that he contrasts his own realist view. He offers a different kind of retreat that I discuss below. But this does mean that the scaling argument only works against one flavor of heavyweight view of high-level magnitudes. Another theorist (e.g., Schaffer), could retreat to a heavyweight *relationist* position. This is a kind of "magnitude realism" that is "realist" because it retains the heavyweight part of Peacocke's view, but is "reductionist" because it takes the relationist path. In this way the view is preferable, but it still faces the other objection I want to raise.

This other (related) problem is what I'll call the *horizontal dependence* problem. This arises when we have a situation where there is more than one equally good way of describing a system in a high-level way, and the different descriptions mutually entail one another. An example might be describing a system in cartesian coordinates and then switching to a description in polar coordinates. Or, to highlight an example that Peacocke explicitly considers, one can consider a description of a system in a particular relativistic frame of reference, and then switch to a description in a different frame of reference. The problem now is that there appear to be only three interpretations of a situation like this:

(1) Double heavyweight: both descriptions carve the situation in a way that corresponds to heavyweight structure.

(2) Asymmetrical single heavyweight: exactly one of the descriptions carves the situation in a way that corresponds to heavyweight structure.

(3) Double lightweight: Neither description carves the situation in a way that corresponds to heavyweight structure.

Let's run this through the relativistic frame example. The problem with "double heavyweight" is that the connection between one set of heavyweight facts and the other cannot be trivial and a priori. So on this view, it turns out to be a substantial non-a priori fact that if we have certain facts obtaining in one frame, then when we perform a certain Lorenz transformation we get these *other* facts obtaining in the *other* frame. The correspondence will probably be explained by the different ways in which these facts depend on the fundamental distribution,[23] but such an explanation appeals to substantial non-trivial grounding laws. But surely these connections actually *are* a priori.[24] That's already bad, and as a bonus we seem to also get a weird ontological explosion on this view. For every frame of reference there's a completely different set of heavyweight facts!!

The problem with "single heavyweight" is that it postulates an asymmetry where there appears to be none. Perhaps such an asymmetry can be motivated in some cases. For example, if you think there is a natural spatial metric to use on macroscopic space, then you might be tempted to treat transformations and rescalings of this as giving us "merely notional" structure that asymmetrically depends on the privileged metric. But why think it's always like that? The relativistic case very much does not look like it should be treated this way. That would be to suppose that there is a single privileged frame that gives us how the world "really" is, and every Lorenz transformation of that gives us a merely notional redescription of the true and one reality. That's a clear case of more "excess structure" that is very unattractive.

The only option left on the table is "double lightweight" which is also just obviously the natural view. It is the only view that postulates

[23] One could also contemplate postulating asymmetrical grounding relations between the facts in different frames, but that gets us into the same kind of trouble discussed for single heavyweight option.

[24] We need to be careful here about the kind of spatial descriptions we are dealing with. Ordinary spatial descriptions of the kind that might be given by a person completely ignorant of the Minkowski structure of space-time might still be true on in a frame-relative way, without the connection between different frame-relative descriptions being a priori or transparent to the ignorant thinker. What I mean here is that spatio-temporal descriptions that explicitly make the Minkowski structure of space-time apparent are such that it a priori what an alternate spatio-temporal description would be in a different frame. The connection between such a "transparent" spatial description and an ordinary spatial-description is a posteriori.

no asymmetry between the facts in different frames, and allows that the transformation between them is trivial and a priori. The point is that these are surely just *the same facts described in different ways*, and this is the only view that allows for this without postulating an asymmetry between the different descriptions.

Now let's return to Peacocke. He is not unaware that the frame-relativity of some of his favorite magnitudes could cause problems for him. His response is simply to put relativity to a frame (and time) into a canonical statement of what it is for a magnitude to be instantiated:

(1) x has magnitude M of type T, at time t, relative to frame r.

However the appeal to *relative instantiation* here is to be understood, it doesn't appear to address the horizontal dependence problem. Consider the result of Lorenz transforming the state of affairs described in (1):

(2) x has magnitude M* of type T, at time t*, relative to frame r*.

Again, how can there be mutual a priori entailment and metaphysical symmetry between (1) and (2) unless they are given a lightweight interpretation?

It's also notable here that a frame is being invoked in the instantiation condition for M, because a frame is (arguably) an abstract object that is playing a similar role here to the assignment of numbers in a scheme of units. It's an assignment of a coordinate scheme to the points in space-time, similar to the assignment of a cartesian coordinate scheme with an origin an axis to a Euclidean space. If Peacocke is clear that instantiating 5kg does not really involve the number 5, why be happy with an abstract object like a frame of reference being involved?

I'll return to this kind of point below, as the role of abstract objects in individuating magnitudes will be important for understanding the anti-realist's response to Peacocke's positive criticisms of "reductionist" alternatives. In the next section, I will argue that there are lightweight approaches to magnitudes that are recognizably "reductionist" but which escape his arguments.

To sum up: the commitment to heavyweight high-level magnitudes commits us to theoretically unattractive excess structure in a ways that I have tried to dramatize with scaling and horizontal dependence problems. No doubt more could be said here, but for present purposes I move on to consider some other important issues.

5. *Extensional and Relationist Theories vs Notional Theories, and the Role of Abstracta in Individuating Magnitudes*

Notably, Peacocke takes the main "reductionist" alternatives to realism to be the kinds of extensional approaches that treat material bodies rather than real magnitudes as forming the extensive systems that are the subject of our magnitude talk (so e.g., "5 kg" is just the set of all things that are 5 kg). Peacocke thinks that this commits these theorists to implausible views of how explanations involving these magnitudes work, and of the meaning of ordinary talk about magnitudes.

As noted earlier, what Peacocke calls "extensional" views are actually a version of *relationist* views; that is, views that reject such properties as absolute spatial distance or absolute mass, and instead see the fundamental structure as relational: e.g., fundamentally, there are only mass-relations between them objects.[25] The case of mass is instructive: the mass-relationist might hold that the fundamental mass-ideology is a relational one, with a two-place mass-ordering relation and a three-place mass addition relation holding between particular objects. And although this view has stereotypically been defended by nominalists like Field (1980), as noted above, one could treat these relations in a heavyweight way —perhaps there are mass-relations lurking in Plato's heaven! One could even hold a heavyweight relationist view of high-level relations like temperature relations. Such a view is clearly a kind of "magnitude realism" (because it is at least a heavyweight view), but is still in Peacocke's cross-hairs.

It's also important for my purposes that not all high-level lightweight views are reductionist (i.e., relationist) in this sense. My lightweight anti-realist could be a magnitude realist about fundamental magnitudes and treat them in an absolutist way. A kind of absolutism could then be derivatively true for the lightweight high-level magnitudes that are grounded in them. For example, maybe atomic particles at the fundamental level have absolute mass in a magnitude realist sense. Mereologically complex objects have mass in only a derivative lightweight sense, but it is *absolute* lightweight mass, derived by summing the masses of atomic parts. Peacocke's

[25] The spatial distance case is very confusing in this regard. What counts as a "relational" view for current purposes would be a view on which in lieu of a 2-place absolute spatial distance relation, we have comparative relations that obtain between pairs of objects, such as a 4-place relation marking that the distance between A and B is equal to the distance between C and D (see Field 1980).

arguments against "reductionist views" simply do not apply to a lightweight view like this.

That said, I do think that relationist views are an important version of anti-realism, and thinking about how they might respond to Peacocke's arguments is very illuminating in general for the anti-realist/lightweight project. The arguments Peacocke offers against "reductionist" views —aka relationist/extensional views— have to do with the allegedly implausible way they handle the meaning of ordinary magnitude talk and high-level explanation. For example, on a mass-relationist view, if I truly say that my bike weighs 5kg, what makes this true can't simply be that the bike has a certain real mass-magnitude. Instead, there must be some relation between the bike and other objects that makes it true. For example, one might naturally try out (and people have tried this out) the idea that a certain relation to a standard kg kept in a vault in Paris is what makes this true. This gets us into trouble. For example, it's not true if the standard kg in Paris had been heavier, then my bike would have weighed more. So, the view seems to get the counterfactuals wrong. And as Peacocke emphasizes, when I explain the bike's behavior in terms of it's mass (e.g., how hard it is to pick it up when I'm carrying it), it's relationship to what is going on in Paris is surely irrelevant to the explanation.

Peacocke clearly thinks these problems will generalize to any relationist reconstruction of our ordinary talk and thinking about magnitudes. But the problem is that if this was right, it would (at least prima facie) give us reasons to be absolutists rather than relationists about, say, mass properties. But surely that only *fundamental* considerations —that is, considerations about what is an adequate ideology for our best fundamental physical theory— could matter for that issue. That is, we should figure out *first* based on fundamental considerations whether relationism or absolutism is true, and then handle the best we can, given the view we have taken, the kind of high-level phenomena to which Peacocke points. I would be the first to agree that relationist views make life more difficult for interpreting ordinary magnitude talk, but I think it's implausible to take this as a cost of these views (and certainly Peacocke who advocates a "metaphysics first" methodology (2019) ought to agree with this).

Now, Peacocke's response to this is that it is possible to be both a magnitude realist but elaborate the view in a way that buys us the benefits of relationism, because his real magnitudes can be individuated in a partly relational way (2014, pp. 9–10). This is supposed to be illustrated by the kind of relative instantiation that he builds into his canonical formulation:

(1) x has magnitude M of type T, at time t, relative to frame r.

However, aside from the problems with this mentioned in the previous section, it's hard to see how he would adapt this for the mass-relationist case. Presumably he doesn't want a formulation like:

(2) x has magnitude M of type T, at time t, relative to the standard kg in Paris.

Now, I do think there might be a principle like (2) in the offing but which builds in relativity to something more like a relativistic frame. But it will instead build in an abstract numerical representation of mass in a way that Peacocke explicitly rejects:

(3) x has magnitude M of type T, at time t, relative to numerical representation of mass n.

One of Peacocke's main principles is the plausible idea that magnitudes do not constitutively involve numbers, which are merely used to represent them. Now, despite the plausibility of this principle, I actually think that relationists (and lightweight theorists more generally) may have reasons to question it, and end up with a view at least in the spirit of (3). Let's see why that is; we can then ask, finally, whether there is an amendment of Peacocke's own view in a similar spirit, somehow combining realism and relationism.

I think it is fair to say that we often talk about the world *as if* it contains absolute magnitudes —e.g., we talk about the "masses" or "lengths" of individual objects and not just mass-relations or length-relations. How should the relationist construe this apparent commitment? In my view, the guiding idea of a relationist here should be the following: the relational structure of the world allows a kind of absolutist *representation* of it, that projects more structure onto it than strictly speaking exists (an interesting contrast with the more familiar case where we abstract *away* from structure that isn't relevant for our descriptive and explanatory purposes). In the mass case, the mass-order relation sorts objects into equivalence classes of "same mass" objects, classes which are then themselves sortable and relatable by ordering and additivity. It's obviously very convenient to deal with this by representing it in terms of a more absolute ratio-structure that assigns a single "mass" to each such equivalence class.

This is much like the way that it's convenient to represent mass in units, even though strictly speaking there is no privileged unit mass.

This suggests a distinction between two relationist approaches to the truth conditions of "X weighs 5kg", a "platonist" approach and a "nominalist" approach. The *Platonist* approach just builds into the truth conditions the existence of a mapping between sets of equimassive concrete objects and an abstract ratio-scaled structure. It says that an object is 5kg if it is mapped onto a particular point in the abstract representational structure:

(4) x has magnitude M of type T iff x is assigned coordinate c in abstract representation n.

Importantly, n could just be a numerical representation, in which case c is just a number.[26] The relationist can explain how different numerical representations in a sense "pick out the same magnitude", by giving an equivalence relation on linearly related abstract representations, rather than taking the realist line that there exists a real magnitude that all these representations represent.

Now, (4) might sound like a weird confusion of representation and representatum, but I think it is motivated. One way to think of it is as parallel to (and a surrogate of) a traditional Platonist view on which these sets stand in relations of *instantiation* to abstract mass-*universals*. Instead of a relation of instantiation, we have a relation of *representation* to elements in an abstract structure that plays a similar, surrogate, role. Or another way to think of it is in fictionalist terms: because we can map these sets onto these representational abstracta, it is *as if* they instantiate platonic mass-universals —these abstracta function as *make-believe* universals.

In general, what we have here is a rather attractive picture on which we are able to describe abstract structures that can serve as useful *models* of the world without being perfectly isomorphic to the fundamental structure. In using these models, we (at least implicitly) set up mappings from the fundamental world onto these abstract structures; furthermore, sometimes it can be helpful to treat our statements as true in virtue of how the world and the abstract model are related, not just how the world is in itself. Moreover, we are

[26] It's true that in order to specify a particular numerical representation, we might need to pick it out using a standard unit, like a standard kilo. But the fact that the standard kilo might play this kind of reference-fixing role doesn't mean that we need to mention it in a truth condition like (4) —this is an advantage of a view like this.

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prone to illicitly *projecting* the model onto the world, in the sense of treating its elements as universals.

The more typical "Nominalist" approach just tries to state the truth-conditions directly in terms of the relations between objects. It is along this path that we end up with the dubious accounts that appeal to standard meter rules and standard kilos. Now admittedly, even if we aren't nominalists, we might be tempted to think that we need not stop with something like (4). Surely, the thought goes, there is something about the state of concrete world —namely *the place that x stands in a system of relations*— that makes a magnitude ascription construed in the Platonist relationist way true. So surely we need not settle with the Platonist view.

Tempting as this is, I suspect that the project of giving nominalist truth-conditions on a relationist view may be doomed to fail. The reasons are beyond the scope of this paper, but they have to do with the way in which an abstract model may project more structure onto the world than actually exists.[27] If we consider a merely possible distribution of, say, mass-relations and ask —"which objects in this distribution weight 5kg?", this may be a question that does not have a completely objective answer— it depends how we extend our abstract model from the actual world. For example, if we describe a possible world with a bunch of non-actual massive objects, it might be a matter of arbitrary stipulation which ones we treat as "5kg". Even if we describe a possible world containing actual objects, arguably it's still a matter of stipulation whether we treat them as having the same mass as in the actual world. If that's right (and more would need to be said to establish it), on a relationist view a term like "5kg" does not really have an objective extension across possible worlds considered independently of the abstract model we put on them; it's only relative to a way of modelling these worlds that the term has an extension.

These comments all assume a relationist base. But I think there's also a reason to be attracted to the Platonist lightweight approach, even without relationism being on the table. Being able to say that high-level statements are about a relation between the fundamental facts and an abstract model of those facts, enables us to fine-grain those facts and give them a subject matter that isn't *just* the fundamental facts, in a way that mimics a more heavyweight approach. To illustrate, consider an example where the horizontal dependence problem holds, such as two frame-relative descriptions of the same

[27] See Dasgupta (forthcoming) for related discussion.

system, or even a very simple case like mass and log mass. Even though in one important sense, facts about mass and facts about log mass are just facts about the same thing, it may be helpful for some purposes to distinguish these facts, because they involve different ways of projecting the base into an abstract model. If that's right, there is an attractive generalization of the lightweight Platonist's way of dealing with the awkward lack of structure we have on a relationist view.

Obviously more could be said here, but I rest content with simply putting these ideas on the table. Could Peacocke adapt them in a way that fits with magnitude realism, as he attempts to with formulation (1)? It's hard to see a compelling view of this kind. In the case of mass-relationism, it's hard to see how he can do better than formulations like (2) and (3) which seem to give us the worst of both realist and lightweight views (and hopefully (1) is now revealed as being in the same boat)! Instead of having a single mass magnitude, an object now has it only relative to either a sample object or a numerical representation. On the lightweight view, these act as surrogates for the absolute mass-magnitude and are therefore motivated; but their use does not combine in a natural or plausible with commitment to realist mass-magnitudes.

6. *Magnitudes in the Theory of Mind*

I won't have space here to consider Peacocke's rich discussion of magnitudes in the theory of mind —for example their role in explaining analog representation. However, let me briefly mention an important connection to what we have just been talking about. For Peacocke, the phenomenal character of perceptual experience is partly constituted by its externally individuated content, which includes representing high-level magnitudes in his realist sense. Against this kind of externalist view, it's natural for the phenomenal internalist to object that perceptual-processing typically involves projecting the space of external physical states of affairs (characterized by magnitudes like spatial distance) in a non-linear, dimensionality-reducing way onto a simplified internal model. For example, in color processing the infinite-dimensional space of surface-reflectance profiles is projected onto (something like) the low-dimensional Munsell color solid. The internalist will say that in general the structure of experience is given by this internal model, not by the structure of the external physical state that it represents. I won't defend this idea here. Suffice to say that this picture pairs nicely with the light-weight

Platonist view just described. The internalist can say that perception does not acquaint us with, or phenomenally represent "real" high-level magnitudes. Rather, it projects the fundamental physical structure of the external world into a simplified abstract model reflected in the (internally determined) structure of experience. We can think of the externally-directed content of experience as the projection of the physical layout onto this abstract model (although a benefit here is that there is no requirement on this picture that a type of experience have a single once-and-for-all content, as opposed to a content that can vary in a flexible way in different contexts, or be indeterminate in various ways). Moreover, what goes for experience could go for other kinds of mental representations, such as iconic representations in perception or cognition.

I should also admit here that conscious experience itself (including the magnitudes that characterize it, such pain intensity) is a difficult case for the view I've been defending. If it's not fundamental, could it be a mere lightweight abstraction from the fundamental? It's very tempting to think it must exist in a more robust sense than this! I won't try to properly answer this objection here save to ask the following question to those who claim to have a direct insight that consciousness must be more "heavyweight" than this. How could we explain the reliability of this insight? I am skeptical that we really have such a faculty of metaphysical perception.

7. *Magnitude Realism at the Fundamental Level*

I've been arguing for high-level anti-realism, but should I at least concede that there are probably magnitudes at the fundamental level? I'm open to this possibility, but there are two reasons why this claim is not obviously true. First, even if the one true ultimate physical theory merrily makes irreducible use of magnitudes in its description of the fundamental world, it's not obvious this must be given a realist interpretation in the sense that these magnitudes are fundamental *ontological* commitments —that they are in the domain of God's quantifiers, as it were. Surely the debate here will just exactly parallel the debate about universals. In that case, one potentially viable alternative is the ostrich nominalist view on which these are taken as ideological but not ontological commitments (Quine 1948, Devitt 1980, Sider 2012) —that is, the fundamental facts may include facts of the form "x has magnitude M of type T", but we don't need to *quantify over* magnitudes to state the fundamental facts. Admittedly, it may be difficult to state dynamical laws without quantifying over values of the fundamental magnitudes, but it's not obvious that dynamical laws are fundamental facts —perhaps a Humean approach is correct. Anyway, I'm not defending magnitude ostrich nominalism. I'm merely pointing out that it is an alternative to be reckoned with.

Admittedly, ostrich nominalism is still a "realist" view in a looser sense, because it is still *ideologically* committed to magnitudes and maybe that's sufficiently in the spirit of the realist view to be enough. But that brings me to my second point. It's not at all obvious that the one true ultimate physical theory *will* ascribe magnitudes. Of course it will involve a complex structure (or structures) that we (hopefully) can mathematically model. But ratio-scaled magnitudes are just one of an entire zoo-ology of mathematical structures one might invoke. For example, Maudlin (2007, ch. 3) considers the fiber-bundle structure of quantum-chromodynamics, on which the object that characterizes the state of the world at a given point is only comparable with the state at another point in a *path-dependent* way. That is, whether it is the same or different state, or what it's similarity relation is, is not absolute, but relative to how we transport the state to make the comparison. Such fiber-bundle states are therefore presumably not magnitudes, which are absolutely and directly comparable across different instantiations. It's also worth pointing out here (again) that a relationist treatment of apparent absolute magnitudes may also be viable at the fundamental level, on which ordering and additive relations really hold between concrete particulars rather than property-like magnitudes.

It therefore seems to me that the state of play is very much that a global anti-realism about magnitudes could be true; that is, there are no magnitudes at the fundamental level, and high-level magnitudes are mere lightweight constructs. Peacocke has done a valuable service in developing the realist position, but more needs to be said before we should be persuaded to sign on.[28]

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[28] This paper developed out of comments I gave on Christopher Peacocke's work on magnitudes at the 2018 magnitudes workshop at York University. Thanks to Chris and participants at the workshop for helpful and inspiring discussion, and to Jonathan Schaffer, Shamik Dasgupta, Chris Peacocke, and two anonymous referees for helpful feedback on the paper.

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