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Deriving the Manifestly Qualitative World from a Pure-Power Base: Light-like Networks

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Résumé : Dans la perspective de construire le monde manifestement qualitatif des objets et des entités sans recours à une base ni catégorique ni qualitative, nous présentons une description possible de la manière dont des propriétés catégoriques d'ordre supérieur et des objets peuvent émerger d'un substrat de pures puissances. Nous explorons la possibilité de l'existence de champs, dont les fluctuations sont les entités transportant les interactions, et qui se sont différenciés de la topologie microscopique d'un espace de dimensions spatiales compactifiées. Puisque les trajectoires spatio-temporelles des bosons de jauge ne possèdent pas d'extension spatiale ni temporelle, nous soutenons que leur accorder le statut d'entités fondamentales conforte une ontologie de pures puissances. De telles entités, circulant à l'intérieur d'un réseau micro-topologique auto-suffisant, entretiennent des configurations spatiales de grandeurs physiques conservées, notamment l'énergie et l'impulsion. Perçues comme de type temporel et massif, elles représentent les entités fermioniques et donnent naissance au monde manifeste.

Abstract: Seeking to derive the manifestly qualitative world of objects and entities without recourse to fundamental categoricity or qualitativity, I offer an account of how higher-order categorical properties and objects may emerge from a pure-power base. I explore the possibility of 'fields' whose fluctuations are force-carrying entities, differentiated with respect to a microtopology of curled-up spatial dimensions. Since the spacetime paths of gauge bosons have zero 'spacetime interval' and no time-like extension, I argue that according them the status of fundamental entities would support a pure-power ontology. Such entities, circulating within self-sustaining microtopological 'networks', feasibly maintain definite spatial configurations of conserved physical quantities, including energy-momentum. Perceived as time-like and massy, and representing fermionic entities, they give rise to the manifest world.

This paper rises to the challenge of providing a sustainable account of the manifestly qualitative world without drawing upon fundamental categorical properties or particulars. It does so by conjecturing that the ostensible spatial priority of the world might obtain by virtue of powerful microtopological networks giving rise to massy and persistent ‘entities’, such networks comprised of circulating gauge bosons which travel at the speed of light, possess no spatiotemporal extension, and lack rest mass. I describe how spacetime, locations, fermions, and the categorical-dispositional distinction, may all arise at higher levels. The challenge for this Light-like Network Account (LNA) is to describe how we get from the fundamental to these higher levels.

1 Primitives

I begin with the idea that field fluctuations—light-like processes with a spacetime interval of zero—are suitable candidates for fundamental ‘entities’. I also refer to them as ‘Neo-Parmenidean Individuals’ in deference to Rom Harré and Edward H. Madden [Harré 1970], [Harré & Madden 1975]. Harré and Madden propose a field-theoretic view in which the underlying ‘Parmenidean’ primitives are unchanging, immutable, pure-power entities that give rise to higher-order, qualitatively-describable and changeable ‘Aristotelian’ individuals, which then constitute complex, manifest objects.

A key difference between Parmenidean Individuals and the Neo-Parmenidean Individuals put forward in this paper concerns spatiotemporal extension. From the perspective of an independent coordinate frame of reference, an object can be considered to be ‘extended in space’ if, at any one time, it occupies more than one spatial location or point. The same idea can be used with respect to extension in time. An object can be considered to be ‘extended in time’ if, at any one spatial location, it occupies more than one temporal location or moment. As discussed in Section 3 of this paper, being extended in time corresponds to a thing having rest mass, whereby its velocity is restricted to less than the speed of light. While Harré’s Parmenidean Individuals are not extended in space, they have the time-like extension of persisting singularities. I view Harré’s treatment, however, as not being even-handed with respect to space and time. If Parmenidean Individuals—as pure power—should have no extension in space, then why should they be assigned extension in time? To correct for this bias, Neo-Parmenidean entities correspond to gauge fields and to the gauge particulars that represent these fields in the case of emission and absorption events. In keeping with the naming convention used by Charis Anastopoulos [Anastopoulos 2008, 316], I refer to these entities variously as ‘gauge particles’, ‘mediators of force’, ‘field fluctuations’, or—as they are often referred to in physics literature—‘gauge bosons’. These part company with their Parmenidean cousins in their having neither extension in space nor extension in time, indicating that they never ‘sit still’

in, nor ‘ever purely occupy’, either space or time. Throughout this paper, in referring to ‘individuals’, ‘entities’ and ‘particles’, I qualify my use of these terms by noting that I take their referents to be underdetermined at fundamental levels in line with discussions by Michael Redhead [Redhead 1975], [Redhead 1982, 70–80].

There are considerable metaphysical repercussions that arise from the level—classical versus quantum—at which field theories are considered. Classical physics is relevant to the macroscopic level, describes physical quantities of the ‘actual’ world, and treats spacetime, processes and symmetries as continuous. Leon M. Lederman and Christopher T. Hill describe this as an ‘averaging effect’ due to the interactive complexity of the macroworld [Lederman & Hill 2008, 204–205]. Andrew Watson notes that much of the structure of gauge theory, such as gauge transformations that come about due to changes in the electric and magnetic potentials, is classical. In contrast, Quantum Field Theory focuses upon ‘numbers of particles’ which are quantised and identified with some conserved quantity, such as ‘charge’ [Watson 2004, 101]. Thus, quantum gauge theories are applied to discussions of gauge ‘particles’ and other micro-level entities, and to the quantum mechanical effects that apply at the microscopic level.

In classical gauge theory, the electric and magnetic fields arise from a point source: a moving charge becomes a current. Whereas in quantum theory, the converse holds: if an electron is accelerated the gauge field is emitted as a quantum particle in the form of a photon [Watson 2004, 183], [Lederman & Hill 2008, 246]. These differing perspectives can be understood, however, to be different ways of considering a unified whole, in the sense that the classical and the quantum systems coexist—it is only at the level where concrete measurements are made that quantum mechanics can be applied. Consequently, quantum objects must be associated with classical ones for there to exist any empirical quantum-mechanical investigation [Anastopoulos 2008, 207], [Lederman & Hill 2008]. (In keeping with the co-existence of the classical and quantum frameworks, throughout this paper I will switch between one and the other, and where it is not already clear, will indicate which I am using.)

As a preliminary comment, I explicitly recognise that gauge bosons are not philosophically unproblematic. For example, the interdependence of the classical and quantum theoretical systems arguably reside at the heart of well-known concerns that neither classical nor quantum theories can independently provide us with an adequate account of processes that appear to involve non-localised, properties (see, for example, the Aharonov-Bohm effect,¹ and the Einstein-Podolsky-Rosen correlations). Richard Healey further points out that classi-

1. The Aharonov-Bohm effect is shown by an electron two-slit study, which reveals that the results of the experiment do not depend upon the local values of the electric and magnetic fields, but on some other influence. See [Anastopoulos 2008, 210–211], [Watson 2004, 92–94].

cal field theoretical accounts either involve action-at-a-distance phenomena, or failing that, a holistic approach that is empirically impoverished [Healey 2007]; but that contemporary quantum gauge theories also inherit the measurement problem already noted. The interpretation of any fundamental theory cannot be supplied independently of some ontology of particles which is assumed for empirical purposes [Healey 2007, 222–225]. Interpretative models standardly rely upon similarity relations between the model and ‘actual’ things that are being modelled. This is available at the classical level, since such a relation can be given by assuming the existence of actual things and then providing independent characterisations of them. Interpretation in this way may work for non-fundamental questions. However, concerning fundamental spacetime, the objects assumed to exist are themselves derivative of the model being proposed, and thus are not independently available. Other questions raised by Healey involve renormalisation, and the dependence of gauge theories upon locally defined gauge potentials which are not represented by, nor correspond to, anything in the classical world.

Notwithstanding these concerns, the quantized gauge theories of the Standard Model are, as Healey notes, currently our ‘most fundamental, empirically confirmed, theories of this domain’ [Healey 2007, 221]. In this paper, then, I will draw upon the Standard Model, as well as upon certain aspects of classical accounts, with the caveat that the paper presents only a toy model, which while drawing upon physics for its legitimacy, is primarily a metaphysical model used to show that one can feasibly derive the manifestly qualitative world from a pure-power base. I conceptualise a world where only gauge bosons, together with a spatiotemporal topological structure, exist at the fundamental levels. These I consider to be the Neo-Parmenidean Individuals representative in the Harréan sense of pure power. I take the liberty, though, of considering Harré’s notion of ‘unchanging’ in terms of the contemporary notion of symmetry principles.

The Standard Model of particle physics describes four types of gauge bosons; the elementary carriers of the ‘four’² fundamental forces. Photons carry the electromagnetic force. *W* and *Z* bosons carry the weak interaction involved in quark flavour changing. Gluons carry the strong interaction involved in the cohesion between quarks, antiquarks and colour gluons, within protons and neutrons. Gravitons—whose existence is supported by Quantum Mechanics, although not directly confirmed—carry gravity.

2. The status of the electroweak force is still incomplete. Electrical and magnetic forces were united under the auspices of a single electric charge. However, the electroweak force has to be explained in terms of different ‘charges’ or ‘coupling constants’, which involves the hypothesised Higgs field [Anastopoulos 2008, 322]. Further unification of the strong force, and indeed of all four forces, is still an outstanding issue in physics.

W and Z bosons, and photons within superconductors, have rest mass. However photons (in nature) and colour gluons are ‘light-like’ entities (i.e. their motion occurs at the speed of light) and are thus massless. (As a ‘massy’ object accelerates, its mass/energy increases such that this would be infinite at the speed of light. Hence, only things without rest mass can travel at the speed of light.) Light-like processes, or events with a light-like separation, have a spacetime interval of zero by the formula: $Q^2 = c^2\Delta t^2 - \Delta s^2$, where Q represents the spacetime interval, c is the speed of light, and Δt and Δs represent changes in time and space coordinates, respectively. Providing the speed of light is defined as $c = 1$, two events are separated by zero spacetime interval when the space between them exactly matches the time between them. Since the worldlines of these force mediators correspond to a spacetime interval of zero, they are neither continuously space filling nor persistent. That is to say, in no coordinate frame of reference do they possess either purely spatial extension or purely temporal extension.

Gauge particles are associated with gauge fields, and photons can be thought of as ‘moving disturbances in electric and magnetic fields’ [Wilczek 2008, 95]. Inside a superconductor, a photon’s presence results in a ‘vigorous’ effort by electrons to restore equilibrium by ‘exerting a drag’ upon the photon’s motion. Slower than light-speed motion is then represented in the form of mass, and the photon becomes ‘heavy’. Frank Wilczek proposes this as a model for what occurs with W and Z bosons in nature. W and Z bosons do resemble photons *in nature* in certain, very important respects. For example, just as photons can be considered electromagnetic field disturbances, W and Z bosons arise as disturbances in the fields responsible for the weak interaction. Like photons, they have integer spin, a degree of freedom corresponding to a physical magnitude analogous to self-rotation but one that is also applicable to ostensibly point-like entities [Anastopoulos 2008, 205–206]. Unlike photons in nature, however, W and Z bosons move at less than light-speed (are massy). Wilczek notes that this behaviour of W and Z bosons resembles that of photons *inside superconductors*. Since the electromagnetic and weak forces are seen in quantum theory to be a single force, there is a heavy investment in this analogy between the W and Z bosons in nature and photons within a superconductor. Accordingly, spacetime itself can be thought of metaphorically as a ‘kind of superconductor’ for W^+ , W^- and Z^0 bosons [Anastopoulos 2008, 213].

Chen-Ning Yang and Robert L. Mills proposed an extension of the gauge symmetry of electromagnetism to the other forces by way of a mediating field [Yang & Mills 1954]—now called the Higgs field—that interacts with certain gauge fields, and it is thought to be this interaction which results in the W and Z bosons being massy. Although a detailed discussion of this phenomenon is not within the scope of this paper, analysis of the Higgs field suggests that its properties include a non-unique vacuum state, corresponding to particles

that have zero spin [Anastopoulos 2008, 314–316]. In quantum theory, when a gauge field interacts with a Higgs field, the resulting ‘mixed’ field involves gauge bosons with three spin degrees of freedom (one of which is zero), and which are ‘massy’ in that their motion is less than light-speed. In this case, the Higgs field is said to have been ‘absorbed’ by the gauge field. A similar story is also thought to apply to fermions, whereby they would be massless but for their coupling with the Higgs field [Anastopoulos 2008, 216–217], [Lederman & Hill 2008]. Gauge bosons that remain massless are thought not to interact with the Higgs field. This paper offers an account whereby the mechanism of the Higgs field corresponds to the mechanism provided by a microtopology of compacted dimensions. Thus, in addition to the gauge fields, we may regard spacetime’s dimensional topology (incorporating length, breadth, height, time and how they interconnect) as a further primitive. A ‘dimension’ in some physical set up is the number of variables, or quantities subject to change, which are required to describe it [Stewart 2007, 226]. In our everyday experience, each spatial dimension represents an arbitrarily orthogonal direction of displacement, and the existence of more dimensions would simply mean the availability of further orthogonalities.

Extending early efforts by Gunnar Nordström [Ravndal 2003] and Joseph Larmor [Larmor 1919], [Wuensch 2003, 354], Theodore Kaluza put forward a five-dimensional theory of spacetime using the Riemannian metric, which employs a vector space capable of describing positively curved spacetime [Kaluza 1921], [Stewart 2007, 224–227]. Successful in accounting for charge in terms of a compacted, tightly ‘curled-up’ dimension, this theory resulted in a unification of the electromagnetic and gravitational forces, if charge is regarded as corresponding to motion within such a dimension. As Daniela Wuensch notes, the appearance of two separate interactions in four dimensions shows up in Kaluza’s theory as one ‘gravitation-like’ interaction in five dimensional space [Kaluza 1921, 971], [Wuensch 2003, 527]. Ian Stewart describes Kaluza’s theory as a demonstration that if Einstein’s four-dimensional theory were embedded in a five-dimensional spacetime, then in addition to the ten standard equations that fall out of Einstein’s theory, five extra equations would accompany the five-dimensional theory. Four of these would describe Maxwell’s equations for the electromagnetic field, and the extra equation would describe light as a vibration in an extra curled-up dimension [Stewart 2007, 225].

Extending Kaluza from a classical to a quantum model, Oskar Klein’s research resulted in the ensuing Kaluza-Klein model whereby an extra, finite dimension of space is curled up at every spacetime location [Klein 1926], [Krauss 2005], [van Dongen 2002]. This compacted dimension is periodic such that motion in the curled up direction returns again and again to the starting place. The overwhelming 1930s focus on Quantum Mechanics resulted in very little follow-up research on unobservable dimensions, until the concept was reinvigorated with the advent of String Theory [Aitchison 1991], [Weingard 1991]. Higher-dimensional frameworks are presently being re-examined and

‘Kaluza-Klein Theory’ now generally refers to the geometrical representation of fields in more than four dimensions [Gribbin 2007, 162]. In this paper I revisit the notion of compacted dimensions to consider how gauge bosons might circulate in networks that give rise to fermions and the manifest substantial world.

2 Circulation Networks

The toy model being put forward in this paper is not intended as a scientific theory or model of the physical world, since that is the work of scientists. Rather, it merely constitutes a mental gymnasium for answering a metaphysical question: How could we plausibly explain the existence of the manifest world and its ostensible objects while starting from a pure-power base? Because the account describes a scenario in which the fundamental entities are light-like processes that form networks, for efficiency I refer to what follows as the Light-like Network Account (LNA).

The principle of symmetry figures prominently in modern physics. A symmetry is the invariance of an object or system to a transformation. The term ‘invariance’ is used here to mean the sameness or constancy of the system in form, appearance, composition, arrangement, and so on; and a transformation can be understood as an abstract action that we apply to a system, which carries it from one state into another equivalent one [Lederman & Hill 2008, 15]. For example, if a vase is symmetrical in form and shape, when rotated about a vertical symmetry axis it looks identical before and after the rotation and is thus said to be ‘invariant’ under such a transformation.

Certain features of both gauge bosons and fermions represent conserved quantities which remain invariant in closed systems. Examples include: charge, isotopic spin and energy-momentum. Global symmetries apply to whole systems, but where only part of a system changes we get local symmetry transformations. The disturbance of any local symmetry generates a compensatory force, and each respective force can be described in relation to some gauge boson [Icke 1995, 176–185]. Such a quantity is ‘gauge invariant’ if the system undergoes a transformation that leaves the measure of that quantity unchanged. In classical theory, for example, the symmetry of gauge invariance described by Emmy Noether leads to the conservation of electric charge; one gauge field can be transformed into another without changing the values of the electric and magnetic field [Lederman & Hill 2008, 240]. For the electromagnetic field, the associated gauge boson is the photon, and in nature symmetry is restored following the movement of a photon in an electric field by the presentation of a counteracting magnetic field [Gribbin 2007, 104–106]. A similar story can be postulated in terms of the other three primary forces.

LNA presents an alternative, broadly compatible interpretation of symmetry at the fundamental level. Local symmetry transformations tell us that conserved quantities are tied inextricably to fundamental force-fields, which can be described in terms of the gauge bosons associated with these fields. An important question is raised: where do the conserved quantities come from? LNA suggests understanding conserved quantities in terms of *networks* of circulating gauge bosons giving rise to fermions and hence the manifestly substantial world. Without speculating on how many, LNA views *some* extra, curled up spatial dimensions residing at every ‘spacetime point’. In extrapolating from the Kaluza-Klein attempt to account for electromagnetic charge in terms of one compacted dimension, LNA conjectures that a similar story might be applied to all conserved physical quantities. This portrays each form of gauge boson as circulating in Kaluza-Klein fashion, and each forming ‘circulation networks’, reflecting Gribbin’s speculative picture of a photon as a ‘ripple’ in the fifth dimension, a W boson as a ripple in the 6th, a Z boson in the 7th and so on, including combinations [Gribbin 2007, 105–106]. In the example of an electron, the networks themselves may be thought to comprise the gauge invariant conserved quantity of charge. An electron can be thought of as a charged area surrounded by a ‘sea of virtual photons’ or ‘messenger bosons’ [Davies & Gribbin 1992, 230–231].

A ‘barber pole effect’ illustrates how such networks offer an explanation for massiness, despite the constituent gauge bosons lacking rest mass. Figure 1 is a schematic Minkowskian representation of a gauge boson circulating within one compacted dimension. The effect can be likened to moving in a spiral up a barber pole, consecutively returning to the spatial starting place although at successively later times. A cross-section of the barber pole is just a circle (or ellipse), the simplest compact space orthogonal to everyday 3-space. In a 3+1 dimensional universe, the 45° light-like process in Figure 1 applies. However, if compacted dimensions are involved, then while a gauge boson travels at the speed of light—maintaining a spacetime interval of zero in a ‘five-plus’ dimensional spacetime—it may circulate as part of some network whose displacement entails velocity less than c .

Figure 2 schematically shows how the velocity indicated by the lean of the barber pole varies depending upon how, relative to a frame of reference, gauge bosons travel through the compacted orthogonal spaces. Barber pole A represents the path of a gauge boson as a network that is persisting through time with zero velocity; B and C represent the same thing at successively greater velocities; and for D the overall path is light-like. The velocity of the network (the barber pole) itself differs from case to case, although the circulating gauge bosons comprising the networks always have light speed, indicated by 45°.

If each 'network' is representative of a fermion, this makes sense of the emission and absorption of gauge bosons by fermions, for example, photons by electrons. As Icke notes:

the old problem: if an atom drops to a lower energy state and emits a photon, where was the photon before that? The answer... the photon was in another world, another “abstract space”, and has become apparent at the juncture between the space(s) containing the single electron. [Icke 1995, 182]

LNA sees this ‘other space’ as the compacted dimensions in which gauge bosons circulate. In this view, virtual gauge bosons are neither created nor annihilated, since this would be inconsistent with postulating them as basic, ‘Neo-Parmenidean’ entities. Rather, just as an excited electromagnetic field will ‘produce’ a photon, LNA speculates that gauge bosons enter and exit—in being absorbed and emitted—the respective circulation networks. The requisite *change in trajectory* to do so involves the exchange of energy and quantum states, corresponding to the causal efficacy of gauge bosons as ‘messengers’ and force carriers.

Gauge bosons, then, can be pictured as being constantly emitted from and absorbed by the circulation networks. In the case of a photon, when it is circulating in the compacted dimensions, its motion is at the speed of light. When emitted into open- or 3-space, it also moves at the speed of light and is thus massless. Quantum theory describes photons as being Abelian entities which remain massless in accord with their non-interaction with other photons or with the Higgs field. In terms of LNA, this equates to photons traveling either purely within the compacted dimensions (and at the speed of light) or else in 3-space, having been emitted from the compacted dimensions (or electron) upon excitation of the respective electron. LNA posits that in the case of a W or Z boson, however, the emission from compacted space is never complete—that a component of the trajectory necessarily somehow remains in the direction of the one or more compacted dimensions. The correlative principle in quantum theory would be the ‘coupling’ of the W or Z boson to the Higgs field. LNA speculates, nonetheless, that W and Z bosons may circulate through networks (corresponding to relevant fermions) fully within the compacted dimensions. At these times, like photons, their motion would be at the speed of light, as demanded by a gauge theory were the Higgs mechanism not operative. But when the W and Z bosons appear in 3-space, they accordingly appear as massy.

Because W and Z bosons resemble photons in enough respects (e.g. spin) to be counted as gauge bosons, an account of their difference from photons with respect to their Higgs field coupling should be offered. The original Yang-Mills Theory initially faltered because it ‘failed to make contact with reality’ in that it required *all* particles to be massless [Anastopoulos 2008, 312]. LNA suggests that the light-speed and masslessness of photons also holds for W and Z bosons *at the microtopological level*, while allowing for the massiness of W and Z bosons in relation to 3-space. Moreover, if the networks that appear at the interface of the compacted dimensions and 3-space represent

the fundamental fermionic particles (where a network of circulating photons represents an electron, and a combination of networks of W and Z bosons and gluons represent the families of quarks and leptons, and so on), then LNA may also account for the massiness of fermions, positing that they occur only as permanent couplings to the compacted dimensions. This mechanism again parallels the role of the Higgs mechanism in quantum gauge theory. I emphasise again that LNA does not pretend to model physical reality, but in attempting to establish consistency among metaphysical considerations of reality, it echoes certain prominent contemporary scientific research, which lends credence to its premises.

LNA views a change in a fermion occurring within the compacted spaces where field fluctuations circulate, which then results in a gauge boson either entering or exiting the network. For example, the excitation of an electron results in the emission of a photon from the circulating network. This requires that fermions are ‘made of’ gauge bosons; and this sets a challenge for LNA: the proposed microtopology somehow must account for bosonic whole-integer spin (or single-loop phase path), as opposed to fermionic half-integer spin (or double-loop phase path). This calls for some topological development whereby extra dimensions are made available beyond the 3+1 dimensions of everyday spacetime. As Icke explains, this is needed because given

The right to step out into another direction, we can twist and untwist the phase paths of bosons and fermions... to change angular momentum by *half* a unit. [Icke 1995, 279]

This possibility is explored by Supersymmetry (SUSY) Theorists in modern physics. The extra dimensions supplied by Supersymmetry models allow—by proposing the extra dimensions to be themselves fermionic—for a photon to be transformed into a ‘photino’ with a half-integer spin [Lederman & Hill 2008, 285]. We can see, however, that if fermions could be explained in terms of the effectively permanent outcome of a topological field fluctuation, as accommodated by LNA, then it would be natural to regard them as networks of gauge bosons in disguise. A note of supporting evidence comes from the fact that when a fermion meets its antimatter (chiral) counterpart, which is presumably of opposite ‘twist’, their mutual annihilation results in nothing but gauge bosons.

To summarise LNA: first, field fluctuations would otherwise travel along geodesic paths in 3-space, but the compacted, tangent spaces allow them to circulate through a multi-dimensional microtopology whose local structure is influenced by the ‘original’ field fluctuation, forming specific circulation patterns. The resulting networks are gauge boson absorbers and emitters. Second, any given network (e.g. charged region in a sea of virtual photons; *a.k.a.* electron) as a whole moves slower than the speed of light; representing a concentration of energy-momentum with associated rest mass, identifiable by type. A consequence of LNA is that, from the frame of reference of any network,

other networks appear ‘massy’—persisting as the fermionic constituents of qualitative objects.³ In this light, fundamental levels may be devoid of rest mass, while at supervening levels the appearance of networks gives rise to the manifest world.

3 The semblance of the categorical

LNA posits that when gauge bosons are absorbed or emitted, it is a dynamic matter; that they enter or exit, not nothingness, but extra-dimensional ‘circulation paths’. This means that they would be neither destroyed nor created, but merely change trajectory, and that the physical quantities corresponding to any field fluctuation are thereby conserved. Gauge bosons may enter or exit circulation networks of ‘sibling’ gauge bosons, and in accordance with quantum theory, this action may involve quantisation for geometric reasons. But the idea of the ‘quantum’ need not be tied to that of ‘particularity’, and should not lead us to suppose that quantization of gauge bosons renders them somehow discrete in the sense of their natures being exhausted, self-contained or categorical in a metaphysical sense.

In terms of the stated aims of this paper, LNA unifies conserved quantities, their associated gauge bosons and the interplay between them. If an electron—representative of a fermion—were just a set of conserved quantities constituted of field fluctuations, this could be without recourse to anything categorical. ‘Categoricity’ and/or ‘qualitativity’ in metaphysics, is often tied to the concept of *individuation* by means of haecceity and/or by quiddity. In line with Robert Black’s [Black 2000] and Stephen Mumford’s [Mumford 2004] descriptions of the term, a ‘quiddity’ can be thought of as whatever there is to a property apart from the power that it bestows on its bearer. The essential nature of power can be viewed within a context of causation; as that which enables effect. Quiddities are those properties or features of properties that do not contribute to the causal role of the objects that possess them. Following David Armstrong’s usage, ‘haecceity’ refers to fundamental particularity or primitive thisness; that which individuates one particular from another, but which is over and above the properties borne by such particulars [Armstrong 1997, 109]. The claim that I defend in this paper is that quiddity concerning properties, and haecceity concerning particulars, are superfluous at fundamental levels, and that a pure-power account—one that denies categoricity at fundamental levels—is adequate to explain the higher-order manifest objects and structures of the world.

3. Whereas photons would circulate among the microtopological paths that we identify as electrons, gluons would do the same for quarks. Of course, while photons do not interact with each other, gluons do so. We can speculate that the difference derives from their being fluctuations of distinct combinations of compacted dimensions.

Categorical properties (e.g. size, shape, solidity) are said to involve spatial extension or space-occupation, to exist independently of behaviour, are multi-dimensional (i.e. spatial), structural and non-dispositional [Ellis 2002, 68–70, 117]. They are non-powerful, epiphenomenal quiddities [Mumford 2004, 180–191], and as Ullin Place notes, properties that epitomize ‘actuality’ [Armstrong, Place, Martin *et al.* 1996]. Armstrong’s description includes ‘completeness’, their natures being ‘exhausted’ in their instantiation by particulars [Armstrong 1989, 118], [Armstrong 1997, 41, 69, 245]. Charlie Martin describes his version of categorical properties—qualitative properties—as those needed for things to be perceived [Martin 1997], and John Heil describes them as what individuates or differentiates powers [Heil 2006], [Heil 2007, 84]. Although many inter-theoretical differences exist in defining what it means to be a categorical property, I think a fair, overall summary would be to say that such properties do not actively contribute to the powers of the objects that possess them. Whereas the identity of dispositions and/or powers is given—at least in many metaphysical power theories—in terms of their causal role.

Whether categoricity exists at fundamental levels, is a question of considerable importance in metaphysics. Arguments for the existence of categorical properties include those put forward by Richard Swinburne [Swinburne 1980a], [Swinburne 1980b]. Charles Martin [Armstrong, Place, Martin *et al.* 1996], [Martin 1997], John Heil [Heil 2003], David Armstrong [Armstrong 1997, 80], [Armstrong 2000, 13–14], [Armstrong 2004, 138–139], and Brian Ellis [Ellis 2001], [Ellis 2002], [Ellis 2008]. These all have in common the conclusion that categorical properties are needed for the grounding of powers and/or dispositional properties. Most of these arguments exist only within a classical framework, and often involve giving an epistemological account of the world in addition to ontological considerations. These types of arguments mostly boil down to the claim that qualitative and/or categorical properties supply the matter or substance of the world, and also enable the perception or detection of this ‘substance’. Heil, for example, claims that without qualitative properties, substantial nature dissolves and we are bereft of a coherent conception of material bodies because a non-qualitative world has insufficient resources to allow differentiation between empty and occupied space [Heil 2003, 99–107].

The arguments for fundamental categoricity rely upon the intuitive context of temporal extension—it is the persisting presence of categorical and/or qualitative properties or their features which permit their bearers (also persisting entities) to be ‘detectable’. What we mean when we talk about a persisting ‘object’ or a ‘thing’ is that it is something that is re-identifiable over successive occasions. Redhead refers to objects or particulars being thought of as ‘continuants’, and also notes their familiar description as entities that can be re-identified across different times by virtue of ‘transcendental individuality’ [Redhead 1982, 88]. But re-identification presupposes temporal extension, whereby something persists or endures through time, affording epistemic access

to it. But there is also a close association between being temporally extended and having rest mass, detailed as follows: Things that persist through time are temporally extended, or time-like. Light-like processes—such as those represented by photons in nature—have, by the formula $Q^2 = c^2\Delta t^2 - \Delta s^2$, a spacetime interval (Q^2) of zero. In contrast, time-like processes have a spacetime interval greater than zero. From Special Relativity, we can present the familiar $E = Mc^2$ more precisely:

$$E = \frac{M_0 c^2}{\sqrt{1 - (v/c)^2}}$$

where E is energy, M_0 is rest mass, v is velocity and c denotes the speed of light. As the velocity of a massy entity approaches the speed of light, its energy approaches infinity. Since infinite energy is not viable, only entities without rest mass can travel at the speed of light. A rearrangement of the above formula yields:

$$E \cdot \sqrt{1 - (v/c)^2} = M_0 c^2$$

Thus, given velocity less than c , the term designated by $1 - (v/c)^2$ will be positive. The presence of a positive value of energy, E , therefore implies non-zero rest mass.

Through the co-occurrence of temporal extension and rest mass, it is understandable that entities with motion less than the speed of light have been thought to possess categorical properties, given that these are the properties most readily associated with observability, solidity, size, shape and so on—properties traditionally associated with ‘matter’. A cohesive spatial arrangement of time-like, persisting entities, mutually at rest (or thereabouts) and engaged in the ongoing exchange of force carriers, amounts to the space-occupancy and observability traditionally associated with categoricity in the metaphysics literature. However, if the basic elements of the universe are, as suggested in this paper, light-like rather than time-like, then categoricity can be denied at the fundamental level, even though it appears as a higher-order, supervenient, phenomenon at the fermionic level, or in Ellis’s terminology, ‘the object level’ [Ellis 2010, 135].

4 Powerful structure

I now turn to the question of whether spacetime structure should be considered categorical, or whether we can justify the claim that it is powerful. Alexander Bird observes that classical accounts, in which spacetime is treated as ‘background’, have contributed to the assumption that spacetime structure is categorical. He argues that spacetime’s ostensible lack of agency (its causal impotence) is only an artefact of conventionalisms about spacetime, such as

those put forward by Mach, Poincaré, Schlick and Duhem which view choice of geometry and metric as ‘conventional’ rather than reflecting any ‘real structure’ of spacetime [Bird 2005, 458], [Bird 2007, 161–168]. In virtue of this lack of agency, distance and duration have been considered categorical rather than powerful. Others point out that spatiotemporal background dependence leads to an assumption of a fixed theoretical structure [Kribs & Markopoulou 2005, 4], and this has been traditionally interpreted as categorical. However, seen from a classical view, Carlo Rovelli argues that the distinction between background and dynamic properties collapses in General Relativity, whereby the metric-gravitational field carries energy and momentum, engages in causal interactions and is equivalent in terms of effect to forces such as electromagnetism [Rovelli 1997, 193, 209].

Since LNA treats dimensionality as fundamental, it is important to the argument that compacted dimensions are not viewed as categorical in the sense of ‘bordering off’, ‘directing’ or ‘containing’ power in the way that qualitative structure is often portrayed. Everyday dimensions, for instance, do not border off motion. I may walk indefinitely in an arbitrary direction or orthogonally in two others, in accord with local spacetime curvature. Motion among compacted dimensions would be likewise unbounded. The overall idea is that the motion of gauge bosons emerges interdependently with spacetime curvature, both in macroscopic 3-space and throughout the microtopology. While it is initially useful to separate talk of field fluctuations from discussion of the dimensional topology, they can be regarded as not strictly distinct. Rather, the dimensional orthogonalities together with gauge bosons could be considered interdependent while dynamically overlapping, as each force carrier induces curvature, modifying the range of orthogonalities ‘available’ to itself and others. That is, gauge bosons—as primitive effects—could conceivably change the geometry and even the topology in terms of independent orthogonalities in which they affect and are affected. In the classical framework, consider, for example, the convergence of photons that increases the energy density in some spacetime region. The consequently greater gravitational curvature changes how photons may be absorbed and emitted by that region. Just so, in LNA spacetime structure is conceived as being interdependent and to some degree interchangeable with gauge-boson activity. That is to say, the underlying field structure of intrinsic orthogonalities and the field fluctuations (gauge bosons) need not represent distinct metaphysical categories. If this is the case, then the microtopological dimensions are causally active, and should be therefore treated as powerful rather than categorical.

I visit one final concern, namely that of location. LNA focuses on the microtopology of the compacted dimensions and the field fluctuations or ‘forces’, which invariably entail motion at the speed of light. In this respect, they could be construed as interactions between ‘temporality’ and ‘spatiality’. Because the motion of field fluctuations ‘detours’ among the compacted dimensions,

it generates the appearance of sub-luminal motion in the form of fermionic matter. This immediately permits frames of reference and the ability to establish coordinate systems from which ‘location’ emerges. Prior to frames of reference, spacetime’s geometry cannot be defined. However, any apparent sub-luminal motion is *not* that of any *particular*. All of spacetime has some presence of ‘field’ (some potential gradient involving force; some curvature or geodesic). LNA proposes that sub-luminal motion is essentially just a relation between certain geodesics of ‘open’ spacetime and certain geodesics of the microtopology, all of which are comprised by the metaphorical ‘Great Field’ of Rom Harré’s literary invention. These relations are powerful.

The importance of the above is that there is no transparent reason for viewing the spacetime structure represented by the dimensional topology as ‘categorical’ in the sense of being passive, non-powerful, space-filling, space-occupying, or representing some individualising mechanism. Neither should we regard it as supplying the ‘grounding’ for ‘active’ participants—the agents that underpin causation. There is, however, one sense that is often applied to things that are categorical, and which also applies to LNA’s microtopology—the notion of ‘actuality’ or ‘ontological robustness’. Traditionally in metaphysics, a thing that is ‘actual’ is assumed to have been replete with all the descriptors of a passive, concrete, self-contained entity. These descriptors contrast with ‘dispositional’ or ‘powerful’ properties by casting the latter in contradistinction—‘mere possibilities’, capacities, which are otherwise dependent upon some grounding categorical substrate for their existence. LNA’s conjectured microtopology denies this demarcation, instead viewing spacetime topology as both ontologically-robust and powerful, evoking Mumford’s distinction between ‘potencies’ and ‘mere possibilities’: potencies as ‘real and substantial’ rather than mere possibilities that only become real when they manifest or act [Mumford 2009, 100]. LNA is a claim for the cogency of a powerful fundamental structure—one that conforms neither to descriptions of the categorical nor the ‘merely’ dispositional.

This distinction between the categorical and dispositional is viewed as emerging at higher levels only. LNA describes how the fermions that give rise to the manifest world might emerge from a pure power basis, and with these entities we get the possibility of differentiation (although not strict distinction) between ‘objects’, or more precisely ‘clumps of fluctuations in the field’. Such differentiation allows for the attribution of approximate relative location, size, shape and other properties that are viewed as qualitative, as well as the emergence of higher-order powerful properties. Hence, at this level—and only at this level—does the dispositional-categorical dichotomy come about, along with the appearance of contingency and possibility. Nonetheless, it does not follow that our perceptual and conceptual familiarity with these at higher levels requires them to be fundamental, ontologically-robust features of the world.

5 Summary and conclusions

This paper defends a pure-power view of spacetime and its structure. I put forward the Light-like Network Account (LNA) as a toy model of how the manifest world and its objects can plausibly emerge from a pure-power base. In Section 1, I have described gauge bosons and a dimensional topology, consisting of both open and curled-up Kaluza-Klein dimensions, as suitable primitives for a pure power ontology. Drawing on the principle of symmetry, I posit that gauge bosons circulate within curled-up dimensions and that the consequent networks may account for the conserved physical quantities that feature in the world. I further explore the idea that the entry and exit of gauge bosons to and from the networks correspond to the absorption and emission events described by physics. If the networks themselves comprise the conservation of physical constants, and if these networks are comprised of circulating gauge bosons, it is natural to regard such constants as gauge bosons in disguise.

I describe the metaphysical debate concerning the existence and role of categoricity, which is primarily to account for the observability of the world. This debate occurs at the classical level, yet claims for fundamental categoricity must involve quantum theoretical considerations. I argue that the higher-level, appearance of certain features of spacetime, such as mass, location, and discreteness between objects, need not appear at the fundamental level; and that at the quantum level, the physical world can be explained without recourse to anything fundamentally categorical. The fermionic entities that are the building blocks of the manifest world can be viewed as, themselves, manifestations of an underlying powerful field comprised of gauge bosons and the associated topological dimensions.

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