EuJAP | Vol. 8 | No. 2 | 2012
UDK 1:53
530.1:140.8

IS THERE A (COMPELLING) GAUGE-THEORETIC ARGUMENT AGAINST THE INTRINSICALITY OF FUNDAMENTAL PROPERTIES?

VASSILIOS LIVANIOS
University of Athens

ABSTRACT

In this paper I critically examine the most recent gauge-theoretic argument against the intrinsicality of fundamental properties formulated by French and McKenzie (2012). I show that it cannot achieve its intended goal (which is to undermine Lewis's neo-Humean metaphysical project) but it can have a significant influence to dispositional essentialists that hold that the fundamental physical properties are intrinsic features of their bearers.

Keywords: intrinsic properties, gauge theory, local symmetries, gauge bosons

In the recent philosophical literature one can find several arguments against the intrinsicality of (fundamental) properties as physical science describes them. These arguments range from 'global' ones, concerning the totality of scientific properties as *all* physical theories present them, to more 'local' ones, concerning the fundamental properties as *specific* contemporary theories describe them.[1] In this short paper I concentrate on an argument of the second category. More precisely, I examine the most recent *gauge-theoretic* argument against the view that all fundamental properties are intrinsic which appears in Steven French and Kerry McKenzie (2012). The argument focuses on charges (especially the electric one) and its declared aim is to defeat Lewis's Humean metaphysical project which is largely based on the assumption of the intrinsicality of *all* fundamental properties that serve as the minimal Humean supervenience base. As far as I can see, though, it is not just an

1 According to one 'global' argument, properties of science fail to be intrinsic because we only come to know or think about them via their causal/structural profiles (for a discussion, see, for instance, Jackson (1998, 23-24)). The most discussed 'local' argument is based on the phenomenon of quantum mechanical entanglement. See, for instance, Ney (2010) for details and discussion.

argument against Lewis's metaphysical worldview but it has important implications in other areas of metaphysics. For instance, if it is sound, it undermines the almost unanimous view of dispositionalists that the fundamental dispositional properties such as mass, spin *and charge* are all intrinsic features of their bearers.[2] It can also have a considerable impact on the ontic structuralistic project which inter alia aims to eliminate the intrinsic fundamental properties in favour of the relational (or structural) ones.

In what follows, I begin by presenting the premises of the gauge-theoretic argument explicitly.

Premise 1. The current best candidates for the fundamental laws of physics are formulated as local gauge theories.

Premise 2. According to local gauge theories, the equations governing particle interactions should be generated from the interaction-free equations by demanding that those equations are invariant under a local gauge transformation.

Premise 3. In order to *generate* the properties of particles through which they undergo fundamental interactions (such as the colours of quarks and the charges of electrons) one *must* apply the appropriate gauge transformation to their interaction-free equation.

Premise 4. The application of local gauge transformations *implies* the existence of gauge bosons.

Premise 5. From premises 1 to 4, it looks as we have no choice but to say that the properties such as electric charge and colour are not the sort of properties that lone objects can have.

Premise 6. If a property P is intrinsic, then whether or not an object is P should not depend on whether or not it is lonely (Langton and Lewis 1998). So for P to be intrinsic[3] *all* the following four cases should be possible: a) There exists a lonely P. b) There exists a lonely non-P. c) There exists an accompanied P. d) There exists an accompanied non-P.

Conclusion. From premise 5, we see that the first of the four cases mentioned in premise 6 is not possible as far as the properties under consideration is concerned. Hence, at least some of the fundamental properties of the actual world are not intrinsic.

The point of the present paper is brief and concerns whether we have conclusive reasons to believe that premise 5 is *unconditionally* true. My answer is clearly no; but before showing that, I have some comments for the other premises of the argument.

2 Among the dispositionalists who explicitly endorse the intrinsicness thesis are Molnar (2003) and Bird (2007).

3 Actually, it is the *basic* intrinsic properties (upon which all other intrinsic properties supervene) that must satisfy these conditions. Yet, *fundamental* properties such as charge, if they are intrinsic, cannot but be basic intrinsic in Lewis and Langton's sense.

Premise 1, as it is here presented, is not indisputably true given that whether the General Theory of Relativity (the best current theory describing gravitation) can be construed as a local gauge theory is a highly controversial issue. Nevertheless, I take it that what French and McKenzie mean is that the current best candidates for the laws of interactions related to the *specific* properties (electric charge, colour) are formulated as local gauge theories; and *that* is, to a certain extent, uncontroversial. Premise 2 is undeniably true because it only describes what a local gauge theory of interaction *is*.

Two points need to be said for premise 3; first, French and McKenzie should have made clear the sense in which properties are *generated* by the application of a local gauge transformation to an interaction-free equation. Even under an ontological interpretation of local gauge symmetries[4] (which is highly controversial and for most philosophers improbable) at least a brief story must be said about the metaphysics of this alleged 'generation'. In absence of such a story, and for the sake of the argument, I shall regard this problematic claim as a kind of *explanatory* claim concerning the theoretical explanation of one of the roles that charges actually have and not as an ontological claim concerning the conditions of their existence. The second point concerns the kind of necessity that accompanies the word "must" appeared in the premise under consideration. As far as I can see, it cannot be metaphysical necessity, because French and McKenzie provide no extra argument to exclude the possibility of worlds that possess charges and, nevertheless, are not characterized by the local gauge symmetries that characterize the actual world. There is no argument offered even for the more moderate claim that in all metaphysically possible situations we are at least justified to explain the interaction-role of charges by appeal to the demands of local gauge invariance. Hence, I construe the "must" under consideration as expressing a kind of 'contingent necessitation' related only to those worlds in which we are at least justified to follow the gauge-theoretic explanatory route. But crucially this leaves room for possible worlds in which charges exist and either there is no theoretical explanation of their interaction-role or there is one which is, however, independent from gauge theoretic considerations. I shall return to that point soon when I shall examine the premise 5.

In the spirit of the above remarks regarding the claims of premise 3, I also bypass the plausible question concerning whether there is an *ontological* sense in which the application of local gauge theories *implies* the existence of gauge bosons. So, sidestepping once again the ontological implications, I construe the claim of premise 4 as a kind of theoretical explanation of the (conditions of) existence of gauge bosons.

Finally, and for the sake of the argument, I assume that Lewis and Langton's definition presented in premise 6 is adequate in capturing the notion of intrinsicality at least for the case of the natural fundamental properties of our world.

4 According to the ontological interpretation, symmetries represent properties characterizing objects, or laws of nature or the structure of the physical world. Under the rival, epistemic, interpretation, symmetries are related either to conditions on the possibility of knowledge or to limits inherent in the human way of describing the physical world.

Let me now come to the core of my objection to the gauge-theoretic argument. In premise 5, French and McKenzie claim that we have no choice but to say that charges are not the sort of properties that lone objects can have. This seems an almost unavoidable conclusion given the truth (under my charitable interpretations) of premises 1 to 4. But let us look more carefully on this issue. French and McKenzie think that they strongly support their conclusion because they are convinced that premises 1 to 4 prove that we have no option but to accept the necessary co-existence of charges and gauge bosons.[5] But is that latter claim true? Recall that they refrain from providing any ontological explanations and, if I am right, confine their discussion to the most plausible contemporary theoretical explanations of the roles that charges (can) play. But what are those roles? Following their strategy, we seek them in what the contemporary physical theories suggest; and what we find is that fundamental charges have a dual role. They measure the strength with which a particle possessing them interacts with the appropriate fields *and* are fundamental conserved quantities. For instance, electric charge is the coupling measuring the strength with which a charged particle interacts with electromagnetic fields and is also a fundamental conserved quantity. The interesting point is that only the first aspect of the role that charges play in the actual world is 'necessarily' related to the invariance under the action of local gauge symmetry transformations. The second aspect, the one concerning their conservation, can be captured by demanding invariance under the action of *global* gauge transformations *which, crucially, does not imply the existence of gauge bosons*.[6]

Let us now focus on electric charge and consider a charged particle in the actual world. Its total Lagrangian L_{tot} (describing, inter alia, particle's interaction with the electromagnetic field) is (partially)[7] constructed by the demand of local U(1) invariance of the Lagrangian of the free from interactions particle. It can be shown that the application of Noether's *first* theorem to the global U(1) subgroup of the full (local) gauge group of L_{tot} yields the conserved current and, by the appropriate integration, the conserved charge.[8] Assume now that the *only* essential feature of the property of electric charge is the invariance of the Lagrangian describing its bearer under global U(1) internal symmetry. In other words, assume that the conservation aspect related to the invariance under the global U(1) is what determines the transworld identity of electric charge. Under that assumption, the dynamical aspect (which concerns the interactions) is a *contingent* feature of charge. Hence, there are

5 Necessary co-existence is enough for their purposes. I think that any claim about existential dependence between charges and bosons would be unwarranted given only the premises of their argument.

6 The connection between conservation and invariance under the global symmetry is secured by Noether's first theorem. Consider the Lagrangian density L of a physical system and the action S related to it. According to Noether's first theorem, if the action is invariant under a continuous group of transformations depending smoothly on independent constant parameters, then, given that the equations of motion of the system are satisfied, there are continuity equations for currents associated with each parameter on which the symmetry group depends. Given appropriate boundary conditions, each continuity equation corresponds to a conserved quantity. For the technical details, see, for instance, Ryder (1996, 90-92).

7 One of the terms of L_{tot} is introduced by hand.

8 Conservation of charge can be construed as dependent upon the satisfaction of the equation for the matter fields in any possible world characterized either by global or by local U(1) invariance. But especially in worlds characterized by local U(1) invariance can be *also* construed as a consequence of a) the lack of independence of the matter and the gauge field and b) the satisfaction of the field equation of the gauge field independently of whether the matter field equations are satisfied. For details, see Brading (2002).

possible worlds in which a *free* Lagrangian describes a charged particle. In those worlds charged particles do not interact and there is no law of their interaction. Some philosophers (most probably French and McKenzie included) may protest that there are no metaphysically possible worlds in which charges exist and do not interact. Even if the *actual* law of charge interaction ('emerging' from the local U(1) invariance of the Lagrangian) is a contingent feature of electric charge, there *must* (in the metaphysical sense) be *some* law of interaction in each world in which charges exist. I grant this to the protesters. But the assumed metaphysical contingency of the dynamical aspect of charge also implies that there are possible worlds in which the Lagrangian of a charged particle, though describes the interaction between charged particles, is one that it cannot be constructed through the demand of local U(1) invariance of the corresponding free Lagrangian. (Recall my comment on premise 3 of the argument.) And one of these worlds is all that I need to ground the following objection to premise 5.

I invite the reader to consider one of the aforementioned worlds that contains a lone particle and is characterized[9] by the *global* U(1) internal symmetry but not the local version of it. This world is metaphysically possible because, in absence of the local U(1) symmetry, we have no reason to assume that gauge bosons are present.[10] The law of interaction of the lone particle of that impoverished world has (obviously) nothing to do with the local U(1) symmetry, whereas the particle itself is characterized by a property which can be identified as a conserved quantity simply by demanding the invariance of its Lagrangian under the action of global U(1) symmetry. *Granted that this property is the electric charge*, I am entitled to conclude that the latter *is* the sort of property that lone particles can have. Therefore, premise 5 is not true and the gauge-theoretic argument is not sound. French and McKenzie do not have any claims for other natural fundamental properties besides charges (such as mass[11] and spin) and so it seems that their attempt to undermine the view that all fundamental properties are intrinsic fails.

This conclusion can be challenged in a number of ways. Yet, as I'll try to show in the sequel, the most controversial assumption that supports it concerns the metaphysical contingency of the dynamical aspect of charge's role. Indeed, in what follows, I'll argue that the gauge-theoretic argument under scrutiny (given the presented charitable interpretations of its premises) can achieve its goal, but only provided that its defender rejects the above assumption.[12] In other words, the gauge-theoretic argument against the intrinsicality of the fundamental properties is compelling only under the proviso that fundamental properties such as charge are characterized by

9 A word of caution; my objection does not presuppose the ontological interpretation of U(1) symmetry and the reality of the gauge transformations related to it. We may easily rephrase the assumption of my argument saying that in the suggested world we have strong theoretical reasons to appeal to the global U(1) symmetry (but not to the local version of it) in order to provide adequate explanations of the behaviour of particles (recall my comments on premises 3 and 4). I want to thank an anonymous referee for pressing me this important point.

10 Soon I'll examine other reasons that may challenge the metaphysical possibility of the suggested world.

11 But see Bauer's (2011) argument for the extrinsicness of mass.

12 As we will see, by rejecting this assumption, the defender of the gauge-theoretic argument also rejects the claim that the property characterizing the lone particle in my suggested world is electric charge.

essential interaction-nomic roles.[13]

Let me start by examining a number of objections challenging the metaphysical possibility of the suggested world. According to a first objection, there are conclusive reasons to deny *in general* the possibility of worlds where particles (charged or not) can exist unaccompanied. Some of the reasons are metaphysical (either 'pure' or scientifically-based), while others are related directly to the conclusions of the best current physical theories. As far as the former is concerned, I do not think that French and McKenzie want to appeal to 'pure' metaphysical reasons to reject the metaphysical possibility of the world of my scenario. After all, their argument aims to show that there is a scientifically-based reason to conclude that some fundamental properties are not intrinsic. Hence an appeal to 'pure' metaphysical reasons that have nothing to do with science would betray the spirit of the whole attempt. (Incidentally, in fn.13 of their paper, French and McKenzie believe that they present a 'pure' metaphysical reason to reject the possibility of lone-worlds. It is the case of an advocate of Armstrongian immanent realism of universals who thinks that fundamental charges are universals and so they cannot exist uninstantiated. The case against loneliness, however, presupposes *multiple* instantiation of universals and Armstrong's theory does not demand that. For more 'pure' metaphysical reasons against lone-worlds, see Cameron 2008). Furthermore, the appeal to certain extra metaphysical theses, even if the latter are (in a broad sense) scientifically-based, would most probably reduce the power of the argument since it has to beg the question against the rival views. Consider, for instance, the possibility of appealing to substantivalism about spacetime as a necessary truth. In that case every object that is not a region of spacetime is necessarily accompanied by some spacetime (ibid.). Though this reason is (in a broad sense) scientifically-based I do not think that French and McKenzie want to appeal to it. For, they most probably do not want to defend the conclusion of their argument in a way that begs the question against relationism about spacetime.

Leaving behind all the metaphysical considerations, French and McKenzie seem to believe that there are conclusions of the best current theory describing some of the fundamental interactions (the Standard Model) that exclude the possibility of lonely worlds.[14] Though I agree that the Standard Model is currently the best candidate for an adequate theory of fundamental laws of some of the interactions, I cannot see how its *actual* theoretical results can ground conclusions about the *metaphysical* impossibility of lonely worlds. This is not because I deny that contemporary science should inform metaphysics; it is rather because I believe that we should not in general conflate nomic (im)possibility (based on actual laws and symmetries) with metaphysical (im)possibility. According to my view, scientific results should guide our search for (at least the fundamental) metaphysical truths as long as we acknowledge that the latter are metaphysically contingent. Acknowledging the metaphysical

13 As we will see, this conclusion presupposes that the defender of the argument exercises a kind of scientifically-informed metaphysics. But this is not an unreasonable assumption given the premises of the argument.

14 Here are two examples from the list they present: there cannot be a lone-massive-particle world in the absence of Higgs field and there cannot be a lone-charged-particle world in the absence of photons. As we have already seen, the latter scientific fact is the ground of French and McKenzie's argument.

contingency of the fundamental truths that we reach in a scientifically-informed metaphysical context does not confine the metaphysical discussion to the actual world or to worlds sharing with the actual our laws and symmetries. For, there are possible worlds with different from the actual laws and/or symmetries for which physical science can provide useful modal information (an example of those worlds is the one of my scenario)[15].

There is plenty of room for disagreement about the above remarks concerning the relationships between science, metaphysics and modality. But fortunately we do not need to reach a consensus on these matters in order to show that the first objection cannot support the gauge-theoretic argument. The reason is that following it renders the gauge-theoretic argument either unsound or redundant. Assuming that Lewis's analysis of intrinsicality is true, the argument is redundant, because, according to the objection(s), no objects can exist unaccompanied, and a fortiori no charged objects can be lonely. So we do not need the argument to prove that charges cannot be intrinsic. If, on the other hand, we assume that Lewis's account of intrinsicality is false, the argument is not sound, because in such a case premise 6 is false as well.

A second possible objection challenges the metaphysical possibility of my suggested world by questioning the assumption that the invariance under global U(1) can be the *only* essential feature of electric charge. Given that that invariance is related to charge's conservation which is one of the aspects of charge's role, the challenge may appear in three versions. Either both aspects are essential, or the dynamical aspect is the only essential, or none of the aspects are essential. The first two versions of the objection are related to the essentialist projects and will be examined soon. As far as I can see, the third version has a consequence that (most probably) French and McKenzie should be reluctant to accept. For, given that the above aspects are most probably the only relevant features that are based on current science, it implies that there are no scientifically-based features that determine charge's transworld identity. So, following this version, French and McKenzie should accept that charge's transworld identity is grounded on scientifically suspect ('pure' metaphysical) entities such as quiddities. Of course, as French and McKenzie themselves correctly point out, a scientifically-informed metaphysician (like them) may find it extremely useful to appeal to extant 'pure' metaphysical views in order to develop her claims. But, as they also insist, the above metaphysician must hold that science circumscribes our conceptions of the metaphysical possible. And it is at least not clear whether a scientifically-grounded metaphysical possibility can 'allow' the possible existence of quiddities, especially in those cases (like the one under consideration) where other scientifically 'decent' entities can play the same metaphysical role.

According to a third objection, my suggested world is metaphysically impossible because there is no possible world that is characterized by global U(1) invariance unaccompanied by its local version. In order to support a plausible objection, this

15 Of course, if we assume that all the actual laws (and symmetries) are metaphysically necessary, the distinction between nomic and metaphysical possibility collapses. But this assumption needs extra arguments; it cannot be taken for granted.

claim cannot be a *brute* modal assumption. Yet, I cannot see what arguments can support it. Under an ontological interpretation of symmetries, the claim presupposes a highly speculative kind of metaphysical interdependence of global and local U(1) symmetries. And even refraining from ontological commitments, we are not entitled to say that in all metaphysically possible situations we *have* to theoretically explain charge's role by appeal to *both* global and local gauge invariance.

I conclude by addressing a final worry; is the property in the possible world of my scenario the electric charge, or a different property (call it charge*) that happens to play one aspect of the role that actual charge plays? If it is the latter, my argument is not sound because the suggested possible world does not contain a lone particle possessing electric charge. The claim that the property under consideration is charge* (rather than charge) can be defended in two different ways. According to the first, the property of the lone particle is not charge because it does not play both aspects of charge's actual roles. Whereas according to the second, it is not charge because it does not play the actual dynamical aspect. Both versions of the objection are related to the question concerning which features of electric charge are relevant to its transworld identity. As far as the first version is concerned, my response is that the objector must give us a reason to believe that *all* actual features related to both aspects of the role of charge are relevant to its transworld identity. And the most plausible reason I can see is that they are *essential* features of charge. No property in any possible world can be charge (or counterpart of charge) unless it is conserved and characterized by the actual specific law of interaction. Similarly, and as far as the second version is concerned, the objector most plausibly must assume that the dynamical aspect of the role of charge is essential to it. Believing, however, that the law of interaction is an essential feature of electric charge is tantamount to believing that in any world in which charge exists the law holds. In other words, the law is metaphysically necessary. Hence the objector cannot make her case unless she begs the question against all those that hold that *all* fundamental laws of nature are metaphysically contingent (and of course Lewis is among them). I conclude that there is no cogent objection to the critic based on my suggested scenario which is consistent with Lewis's nomic contingentism. Consequently, French and McKenzie's argument has no force against its intended target. Yet, under the essentialist assumption about charge's causal/nomic role, the gauge-theoretic argument succeeds in showing that charges are not intrinsic properties. This conclusion can have a considerable impact especially on dispositional essentialists who claim that properties such as electric charge are intrinsic and have dispositional essences related to their causal/nomic roles.[16, 17]

16 Some global symmetries (such as the global SU(3)) have been construed as classificatory of the elementary particles. An extra worry might be raised then that no possible world can instantiate them and fail to contain tokens of *all* the particle-types that fill the gaps in the relevant symmetry pattern. This is not the case, however, with global U(1) that holds in the possible world of my scenario.

17 Interestingly enough, French and McKenzie themselves contemplate the possibility of a contingent association of gauge bosons with charges. They also point out that this possibility is related to a denial of nomic essentialism. Yet, surprisingly, they do not think that denying this possibility begs the question against Lewis. They rather insist that Lewis should provide an argument against nomic essentialism. They also do not think that the conclusion of their argument, *given the truth of nomic essentialism,* creates a difficulty for some philosophers (dispositional essentialists) who endorse the latter view.

REFERENCES

Bauer, W.A. 2011. An Argument for the Extrinsic Grounding of Mass. *Erkenntnis* 74: 81-9.

Bird, A. 2007. *Nature's metaphysics: Laws and properties*. Oxford: Oxford University Press.

Brading, K. 2002. Which Symmetry? Noether, Weyl and conservation of electric charge. *Studies in History and Philosophy of Modern Physics* Vol.33, Is.1: 3-22.

Cameron, R. 2009. Intrinsic and Extrinsic Properties. In *Routledge Companion to Metaphysics*, eds. Le Poidevin, R., Simons, P., Mc Gonigal, A. and Cameron, R., 265-75, Routledge.

French, S. and K. McKenzie 2012. Thinking Outside the (Tool)Box: Towards a More Productive Engagement Between Metaphysics and Philosophy of Physics. *European Journal of Analytic Philosophy* 8: 43-60.

Jackson, Frank. 1998. *From Metaphysics to Ethics: A Defence of Conceptual Analysis*. Oxford: Oxford University Press.

Langton, R. and Lewis, D. 1998. Defining Intrinsic. *Philosophy and Phenomenological Research* Vol. LVIII, No. 2: 333-45.

Molnar, G. 2003. *Powers: A study in metaphysics*. Oxford: Oxford University Press.

Ney, A. 2010. Are There Fundamental Intrinsic Properties?. In *New Waves in Metaphysics*, ed. Allan Hazlett, 219-39, Palgrave Macmillan.

Ryder, L. 1996. *Quantum Field Theory*. Second Edition: Cambridge University Press, ch.3.3

Received: February 21, 2012
Accepted: July, 1, 2012

Department of Philosophy and History of Science
University of Athens
University Campus, 15771 Athens
Greece
vlivan@phs.uoa.gr