Activities of Antigone M. Nounou

April 2009 –September 2010

Conferences & Invited Talks

"Scientific models and the Aharonov-Bohm effect", Seminar of the Advanced Study Group, Max Planck Institute for the Physics of Complex Systems, July 23, 2010.

"Understanding with and without Explanation", Workshop on Scientific Understanding and the Aims of Science, Leiden, May 31-June 4, 2010.

"From Objects to Structures and Back", EPSA Conference. Amsterdam, October 21-24, 2009.

"A Story about Gauge Potentials, Holonomies and Time". 6th Elati Meeting, Elati, July 14-17, 2009.

"Holonomies and Time: The Clash between Holonomy Interpretation and Relativistic Locality ". SPSP Second Biennial Meeting. Minneapolis, June 20, 2009.

For programs, see attachments

Publications

- "Scientific Understanding and Colorful Quarks", *Les Archives International d' Histoire de Science* (June 2010).
- "Holonomy Interpretation and Time: an Incompatible Match?", *Erkenntnis* **72**(3): 387-409 (2010).
- Contribution to Review Symposium "A new perspective on objectivity and conventionalism". *Metascience* **19**(1): 3 (2010).

Abstracts

Scientific Understanding and Colorful Quarks

Abstract: Scientific understanding comes in different kinds, and each kind comes in degrees. Two of these kinds are revealed by the examination of a recent episode from the history of physics: the making of the theory of strong interactions. The first of these kinds of understanding is associated with the realization that some mathematical formalism or theory may have a fruitful application to physical phenomena. This is what I call prior understanding. Yet another kind is associated with the development of the mathematical formalism into a physical theory that purports to be mathematically consistent and empirically complete –at least in the domain of its applicability. This second kind I call internal understanding. None of these two kinds is conferred by explanations; both are associated with what some authors have called genuine or scientific understanding; and both are epistemically relevant in that they are required for the achievement of some of science's epistemic aims.

Holonomy Interpretation and Time: an Incompatible Match?

Abstract: I argue that the Holonomy Interpretation, at least as it has been presented in Richard Healey's Gauging Whatís Real, faces serious problems. These problems are revealed when certain approximations and idealizations that are innate in the original formulation of the Aharonov-Bohm effect are thrust aside; in particular, when the temporal dimension is taken into account. There are two ways in which time re-appears in the picture: by considering complete solutions to the original problem, where the magnetic áux is static, and by examining the effects of time dependent magnetic fluxes. Both cases expose explanatory gaps in the Interpretation, as well as conflicts between it and customary ideas about relativistic locality and local action on which the Interpretation depends.

Review Symposium

Objectivity, Invariance and Convention:

Symmetry in Physical Science

Talal A. Debs & Michael L. G. Redhead
Cambridge Massachusetts: Harvard University Press, 2007.

Pp. ix + 194.
£24.95, €34.00, $39.35.[1]

The main theme in Debs' and Redhead's book *Objectivity, Invariance and Convention* revolves around the question 'How do symmetries displayed by different media relate to the notion of objective scientific representation?' In a few words, their answer could be summarized as follows. Invariantism, the position stating that invariance under symmetry transformations is both necessary and sufficient for objectivity, is unattainable. Yet, in cases where only spatiotemporal symmetries are involved, symmetry transformations may be interpreted as changes of perspective. In such cases, invariance becomes synonymous with multi-subjective agreement and, consequently, it can provide necessary and sufficient conditions for objectivity. On the other hand, since invariance is associated with formal ambiguity and conventional choice, it turns out that invariance has to do with convention as much as it does with objectivity.

I am very sympathetic to the authors' view. In fact, I am impressed by both the modesty with which they approach the subject and the depth of their analysis. Yet I am also sceptical about one of their contentions. Specifically, I am not entirely convinced that the relation between objectivity and convention is as close as they claim it is. But let me first outline their argument before I turn to its appraisal.

I

Arguably, scientific representations of the world are two-dimensional and implicate structures. One dimension is social, in that it involves social mediation of scientific knowledge, whereas the other is formal, as it is concerned with formal relations among structures. A structure is "*an entity (or object) comprised of other sub-entities that bear specific relationships to one another*" (pp. 16-7).

The discussion in the book revolves around three structures (a system *W* in the world, an original idealized conceptual model *O* of *W*, and the mathematical representation or model *M* of *O*) and the relations between them. The relationship between *W* and *O* is an isomorphism, usually partial, and concerns the world and entities therein. *O* and *M* constitute the formal chain of media through which scientific representations are actually effected, and their relationship is twofold. On the one hand the two are structurally similar (or isomorphic), and on the other *M* is considered to be the representation of *O*. All three relations are logical, but the representational involves an irreducibly social element: since formally *M* is a representation of *O* as much as *O* is of *M*, the representational direction is

[1] Forthcoming (2010) in *Metascience*.

decided upon by social agents, the scientists. This fact constitutes an indication that the two dimensions of scientific representation, the formal and the social, interact.

As far as objectivity is concerned, the authors' opinion is that scientific representations of the world may be considered to be objective in one of two senses. They may be objective in the sense that all different observers agree upon them, in which case objectivity is closely related to what we might call intersubjective agreement; or they may be objective in the sense that they represent the true ontology of the world, which exists independently of our minds. The first sense of objectivity has a certain constructivist zest. But constructivists focus solely on the social dimension, on relations involved in the path of transmission of information, and tend to ignore the formal. The second sense concerns the relation between *W* and *O*, and it is associated with the difficult question of scientific realism. But scientific realists tend to overlook the social dimension and restrict their discussion to the formal. Yet, the former kind of objectivity is a prerequisite for the latter, the authors argue, and this is yet another indication of the interaction between the formal and the social. The fact that the two dimensions interact indicates that the social should be an indispensable element in any accurate account of objectivity.

The authors promise not only to do better than either the realists or the constructivists, but also to bridge the gap between the two. Taking an admittedly Latourian turn, they bracket out of their discussion the *W-O* relation, and along with it the issues concerning scientific realism. Instead, they focus on objectivity as a genre of intersubjective agreement that does not exclude the possibility for theories to be direct extensions of the world; and they avoid a merely constructivist account by concentrating on the relations that are involved in the social path of transmission but manifest within the formal chain. Their aim can be achieved, they argue, if one considers the relations between symmetry, invariance, formal ambiguity, objectivity, and convention as they transpire inside and between the relevant structures *O* and *M*.

The symmetry operations of interest in the present context are isomorphic mappings from a structure to itself that leave the structure invariant. They are called automorphisms and are characterized by their respective groups. Given the isomorphic relation between *O* and *M*, if *O* is subject to automorphisms, so is *M*. In mathematical structures like *M*, automorphisms are understood as mappings from one mathematical model of *O* to another. But since all these models are equally good representations of *O*, there is no fact-of-the-matter that could distinguish one from another. The authors claim that this characteristic of physical representation, known as formal ambiguity, calls for social resolution; that is, for conventional choice of which mathematical model represents the idealized original.

The kind of conventionalism required is absolute, they assert. As opposed to relational conventionalism, which "*has to do explicitly with physical systems*" (p. 49) and their relations to models, absolute conventionalism is unconstrained because the choices involved cannot be determined by the physical systems concerned; thus it is internal to the theory and the structures *O* and *M* involved. But unlike trivial conventionalism, which depends on semantic conventions and has no physical content, absolute conventionalism has physical content that must be sought in the fact that "*there is no fact-of-the-matter that distinguishes one possible choice* [of a mathematical representation of *O*] *from another*" (p. 49).

Finally, because spatiotemporal symmetry transformations portray change of perspective from one (inertial) observer to another, invariance of models and relations under such transformations implies that all observers attribute to them the same characteristics. Thus invariance may be interpreted as intersubjective agreement and used for determining what is objective**.** It is worth noting that given the fact that invariance entails symmetry and vice versa, the two are dual to each other and neither can be considered to be more fundamental or explanatorily prior. But in physics one typically begins with symmetries and subsequently identifies the invariants –otherwise the use of invariance in determining objectivity would be tautologous.

II

The view advocated by Debs and Redhead replaces invariantism, the pretty-much standard approach to the relation between invariance and objectivity, which is espoused by a number of scientists and philosophers alike (e.g. Weyl, Klein, Auyang, and Nozick). For invariantists, the physical significance of symmetries lies in the fact that invariance, in general, provides criteria for objectivity. Debs and Redhead argue however, and rightly so in my view, that this idea is misleading.

The main claim of invariantism that remains invariant through all its variants is that invariance under symmetry transformations is both necessary and sufficient for objectivity. Invariantists associate this condition with the unquestionable heuristic power of symmetries and with ideas about universality, where the latter refers to the putative existence of a universal theory of physical phenomena. Yet, in the authors' view, no argument as to why invariance is both necessary and sufficient for objectivity has been provided.

Focusing on the invariantist positions of Weyl and Nozick, Debs and Redhead propose a sufficient condition that should satisfy both: "*If a feature of O is invariant under its automorphism group, then it is objective*" (p. 65). Nonetheless, they argue, turning this sufficient condition into a necessary one is impossible unless further assumptions are made. To justify necessity, invariantists typically appeal to heuristic power and fruitfulness of symmetries. For, this heuristic fertility is not a generic characteristic of all the symmetries appearing in physical representations, and even when certain symmetries have earned the heuristic characterization deservedly, there is no guarantee that they are necessary, or universal.

The example that advances their criticism is from the physics of the weak interactions and concerns violation of the symmetry of spatial reflections, also known as parity. Parity is an undeniable symmetry of nature; thus invariantists would expect all objective features of an idealization, *O*, of interacting physical systems to be parity invariant. Weak interactions, on the other hand, occur in nature and should constitute an objective part of *O*, but they violate parity. Obviously, one must dispute either the objectivity of weak interactions, or the idea that invariance under general symmetry transformations is necessary for objectivity. Debs and Redhead opt of course for the latter, and propose a limited form of invariantism, called perspectival invariantism (PI henceforth).

III

PI is aptly restricted to spatiotemporal symmetries. Like many other symmetries in physics, they have proved their heuristic power and generalizability. But unlike the rest, only they are amenable to an interpretation as change of perspective. Since the focus is on objectivity as intersubjective agreement, it follows that only invariance under these transformations might provide both a sufficient and a necessary condition for objectivity; and it does.

The sufficient condition remains the same as before, if the automorphisms are thought to be spatiotemporal. But it also turns into a necessary one because only the features that 'look' the same from every perspective can be dubbed objective. Thus, once the spatiotemporal automorphism group of an idealization *O*, and therefore of its corresponding representations *M*, has been decided upon (on the basis of its admittedly limited, yet undisputable generalizablity and heuristic fruitfulness), invariance under this group is both necessary and sufficient for objectivity. This kind of objectivity they call (Obj_p).

Aside from the achievement of a definition for objectivity, there is an additional aim in the analysis of Debs and Redhead. Invariance under spatiotemporal automorphisms should illuminate the relation between objectivity and convention, they anticipate.

Despite the authors' success in showing that invariance under spatiotemporal symmetry transformations is both necessary and sufficient for objectivity, I have some reservations as regards their second aim. Three case studies aim to illustrate PI and the relation between symmetry, objectivity and convention: simultaneity and the twin paradox in special relativity, and particles and localization in relativistic quantum theory. First I will consider the twin paradox, because in my view it demonstrates the success of their account in the best possible way. Then I will turn to the other two and, through them, I will lay out my misgivings.

IV

Debs and Redhead assert that the various resolutions of the twin paradox in the literature employ specific inertial frames, and relations that are not invariant under the theory's symmetry group, the Poincaré. Consequently, if one considers invariance under this group to be one's objectivity criterion, all these accounts fail to be (Obj_p). But they all "*share the invariant representational relationship between elapsed time,* t_c*, on a moving clock* [which is part of *O* and invariant under its automorphisms] *and proper time* τ [which belongs to *M* and is also invariant]" (p. 99).

Using this invariant relation alone, the authors recast the twin paradox in accordance with PI requirements, and they show that the differential age of the two twins (the earthbound and the space-traveller) is independent not only of particular frames, but also of the simultaneity convention one may adopt: the earthbound twin ages more than the space-traveller. Since all the structures and relations involved in their discussion are invariant under the symmetry group of the theory, namely the Poincaré, the account they offer is objective (Obj_p), and as a result it provides a better resolution of the paradox, they claim.

But there is an additional benefit from their PI analysis. The insistence on invariant objects and relations allows one to realize the extent to which "*there is no objective fact-of-the-matter to distinguish any story of the twins that does violate the invariance requirement*" (p. 132). Thus invariance delineates the *scope* for conventional choice in the representation of an original idealization *O* by *M*.

The other two case studies aim to endorse this conclusion.

V

The question whether simultaneity in special relativity is not merely relative but also conventional is almost as old as the theory itself. Its relativity is unassailable. The Poincaré symmetry of the theory entails that synchrony between events, formally described by hyperplanes of simultaneity, is not objective. Put differently, since hyperplanes of simultaneity are observer-dependent, there is no universal agreement among inertial observers upon which events are synchronous. Relative simultaneity exemplifies absolute conventionalism because "*there is no factual way to distinguish* [simultaneity with respect to one inertial frame] *from* [simultaneity with respect to] *another*" (p. 92).

Then again, this relativity is implicated in the question whether simultaneity of distant events is, in the end, conventional. Its relativity aside, simultaneity is determined formally by the relation

$$t_2 = t_1 + \varepsilon(t_3 - t_1),$$

where ε is a parameter ranging over [0, 1]. Proponents of the conventionality view insist that no facts can distinguish the value ε =½ (corresponding to Einstein's simultaneity criterion) from any other in the interval [0, 1]. Therefore, simultaneity is absolutely conventional, they conclude.

Non-conventionalists assert otherwise. They maintain that given an inertial frame, Einstein's simultaneity criterion is uniquely definable in terms of the causal structure of Minkowski space-time. Therefore, unique definability leaves no room for conventional choice.

The authors' contention, however, is that the fact that unique definability depends on a *single* inertial frame (or model) "*brings back into consideration all the implications of the conventionality thesis*" (p. 87) for the following reason. Each frame employed is merely one among infinitely many we may conventionally choose from; any other frame, resulting from a Lorentz transformation of the chosen one, would also do. But the representational relation between simultaneity in *O* and simultaneity as it is expressed in *M* should be invariant under the symmetry transformations of special relativity, or else it would not be objective (Obj_p). Since simultaneity in *M* is uniquely definable only relative to a frame, it is not Lorentz invariant. Thus, given that Lorentz transformations are an integral part of the symmetry group of the theory (i.e. the Poincaré group), failure to define simultaneity in *M* in a Lorentz invariant way entails failure of the representational relation to be Lorentz invariant, and this, in turn, entails failure of objectivity (Obj_p).

Does this mean that there is no objective account of simultaneity available? Hardly, they assert. The representational relation is not objective (Obj_p) only if one requires invariance under the Poincaré group. If one chose to drop Lorentz transformations, one would get a representational relation for simultaneity that is objective (Obj_p), albeit with reference to a particular frame.

Thus, the authors conclude, the issue of conventionality of simultaneity is amenable to PI analysis. But they also claim that "*since the objectivity of the synchrony relation depends on this choice of invariance criterion, one can see that for the perspectival invariantist, invariance has at least as much to do with convention as it does with objectivity*" (p. 97).

VI

A word about my concerns is in order. The PI analysis of simultaneity reveals that there are two occasions where choice may be called for: choice of inertial frame (or model) and choice of invariance criterion. The first choice is conventional; the second, I contend, is not. To see why, let us take a closer look at absolute conventionalism and its role in special relativity.

Poincaré symmetry entails formal ambiguity. In other words, it entails that there is a plethora of mathematical models in *M* that represent *O* equally well and whose choice can only be conventional. This conventionality is absolute because it is unconstrained by physical systems *W* in the world: there is no fact-of-the-matter that would allow one to distinguish the description of phenomena in one frame from their description in another.

Poincaré symmetry also involves invariance, which, by and large, serves a dual purpose according to PI. It determines the characteristics of models and relations that are objective (by singling out the invariants), and it delineates the scope available for conventional choice. To see why, and where exactly, the latter is problematic, consider the following.

Assume that, for some purpose or other, we choose (conventionally) one inertial frame (or model) from the infinitely many in *M*. Once a frame is chosen, the original symmetry of *O* is hidden or broken in it, and the model's symmetry appears to be different. This, however, is only an appearance, because so long as the choice of model is absolutely conventional, the overall structure of *M*, and therefore of *O*, remains invariant under the original symmetry–*O* and *M* being isomorphic. This means that when the symmetries present in the formal chain of media remain intact, we are still within the boundaries of the aforementioned scope available for conventional choice.

Things, however, change when invariance criteria are contested. To see this, consider that, while in a particular frame, the need arises to appeal to invariance criteria. Granted, we could use any criterion allowed for by PI, which decrees that any generalizable and heuristically fruitful symmetry would do. But by choosing a criterion entailed *not* by the original symmetry of *O* (and therefore of *M*) but by the specific model's apparent symmetry, we would as good as change the actual symmetry of the model to its apparent symmetry. Change in the symmetry of a particular model would precipitate change in the symmetry of *M* and, accordingly, of *O*. Change in *O*'s symmetry, however, indicates that with this move, with this choice, we stepped outside the scope available for conventional choice, because the symmetries of *O* are not unconstrained by *W*. For, despite the authors' decision to bracket out the *W*-*O* relation, the symmetries of *O* are ultimately dictated by physical facts. Consequently, what exactly the appropriate symmetries of a model of *M* are will also be dictated by physical facts that are external to the formal chain of media. As a result, the choice of appropriate invariance criteria for *M* is non-conventional and cannot decided upon from within the formal chain of media.

The PI analysis of the representation of point-particles in relativistic quantum mechanics faces similar challenges.

VII

Non-locality is not unheard of in quantum physics, but it takes a different gloss when relativity is involved. The representational relation of interest here is between idealized relativistic point particles (idealized objects in *O*) and their quantum mechanical representations by state vectors (mathematical entities in *M*). Being in the domain of special relativity, this relation should be invariant under the complete Poincaré group, but it is not under Lorentz transformations, because although the original relation is between point-particles and state vectors, the Lorentz-transformed vectors correspond to particles that are no longer localized. The authors claim that two possibilities open if one insists on objective (Obj_p) representations. First, one may forego localized particles altogether and opt for a relativistic theory of quantum fields. Thus one may alter both *O* (extended objects for point-particles) and *M* (fields for particles), but maintain Poincaré invariance of the representation. Or else, one may retain the original structures *O* and *M*, but choose to change the invariance criterion by excluding from it invariance under Lorentz transformations.

In my view, however, the choice called for in the first proposal is not entirely unconstrained by the world: experiments and observations will ultimately dictate whether the ontology of *W*, and *O*, is particle-like or field-like. Hence the choice of ontology is non-conventional. As for the second proposal, it implicates choice of appropriate invariance criteria, and, as I argued before, this choice is also non-conventional. Therefore, as in the simultaneity case, here too, maintaining objectivity (Obj_p) involves non-conventional changes either in the ontology of *O* or in its symmetry. Granted, both alterations result in objective (Obj_p) representations, and this demonstrates how wide-ranging PI is. But if I am right in that both choices fall outside the scope available for conventional choice, then these examples also delimit the power of PI to account for objectivity from within the formal chain of media.