Research Statement

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My principal research interests concern topics arising when one studies General Relativity (GR) in conjunction with the geometrized reformulation of Newtonian gravitation (sometimes called Newton-Cartan theory). There are two varieties of project here that I have worked on, and intend to continue working on. The first variety concerns how these theories, taken together, bear on questions in general philosophy of science and in the metaphysics and epistemology of space and time. The second concerns questions of the logical relations between the central principles of these theories, including technical questions that have arisen in working on the first sort of project.

Newtonian gravitation, geometrized Newtonian gravitation, and GR are distinctive in physics because of the precise technical results that connect them to one another. For instance, it is possible to prove a pair of geometrization/degeometrization theorems that systematically and precisely relate Newtonian gravitation with geometrized Newtonian gravitation. Meanwhile, models of geometrized Newtonian gravitation can be recovered in a precise way as the limit of a sequence of models of GR. This makes these theories an ideal setting for studies of intertheoretic relations, including questions of reducibility, commensurability, and synonymy. For instance, I have recently explored a certain kind of cross-theoretical explanation that one can give by studying how certain characteristic relations arise in the two-step limit from GR to standard Newtonian gravitation [“On (Some) Explanations in Physics.” *Philosophy of Science* **78**(3), 421–447 (2011)]. As an explicit example, I offer an explanation of why inertial and (passive) gravitational mass are equal in Newtonian gravitation. I argue that this kind of explanation has been overlooked by the standard philosophical accounts of explanation, but that it is important to the practice of physics because demands for the kind of explanation I describe shape inquiry into future theories. This paper is the fourth chapter of my dissertation.

In related work, I have also studied whether standard Newtonian gravitation and geometrized Newtonian gravitation are in some sense “theoretically equivalent” or “synonymous” [“Are Newtonian gravitation and geometrized Newtonian gravitation theoretically equivalent?” Unpublished]. Building on classic work by C. Glymour, I argue that the answer to the question depends on how one construes the relations between models of standard Newtonian gravitation. In particular, I argue that if one construes the gravitational potential as a “gauge quantity,” then there is a precise sense in which the two theories *are* equivalent. (If one construes the gravitational potential differently, however, Glymour’s conclusion that they are inequivalent stands.) One philosophically interesting consequence of this work is that certain apparently essential features of standard Newtonian gravitation, such as the flatness of spacetime, are not preserved under a natural theoretical equivalence relation. In the paper, I explore how this result bears on debates concerning the epistemology of geometry; in a future paper, I plan to consider how this work on theoretical equivalence and my earlier work on cross-theoretical explanation bear on the realism/instrumentalism debate.

My work on theoretical equivalence has also led me to pursue a more general question, concerning how to represent a scientific theory abstractly or “as a whole” for the purposes of studying certain relations between theories. This is a difficult question that surely does not admit a single, canonical answer. Nonetheless, it seems to me that one can develop a set of mathematical tools that would be useful in this regard, at least for a wide variety of cases. In collaboration with H. Halvorson, I have begun to explore what these tools should be, with a particular focus on what additional structure needs to be placed on the collection of models of a theory to properly represent that theory. This work draws heavily on recent results in categorical logic, due to S. Awodey and J. H. Forssell, that generalize the Stone duality theorem to make precise the sense in which there is a "categorical duality" between syntax and semantics in first-order logic.

To take a concrete example of the second class of project: physicists and philosophers have long been interested in the status of inertial motion in GR. Einstein and others (most recently Harvey Brown) have suggested that inertial motion, described by the so-called "geodesic principle," has a special status in GR. This status is derived from the fact that, starting from the spacetime structure and some other central principles of the theory, the geodesic principle can be proved as a theorem. Emphasizing that this status renders GR "special," however, suggests a question: what is the status of the geodesic principle in other theories, such as geometrized Newtonian gravitation? It turns out that there is a precise sense in which there, too, the geodesic principle has the status of a theorem ["The Motion of a Body in Newtonian Theories." *Journal of Mathematical Physics* **52**(3), (2011)]. In fact, the relevant theorems are strikingly similar to one another, *mutatis mutandis* ["On the Status of the Geodesic Principle in Newtonian and Relativistic Physics." Forthcoming from *Studies in History and Philosophy of Modern Physics*]. Part of the richness of this topic is that in *neither* case is the situation as clean as one might have hoped. In particular, in order to prove the geodesic principle as a theorem of GR, one needs to invoke a strong "energy condition". In addition to my work on the status of the geodesic principle in Newtonian gravitation, I have been able to clarify precisely how strong that energy condition needs to be in the relativistic case ["A Brief Remark on Energy Conditions and the Geroch-Jang Theorem." Forthcoming from *Foundations of Physics*]. These papers will be three chapters of my dissertation.

More recently, I have been interested in a number of related questions that have arisen in conjunction with this work. For instance, one of the most striking (apparent) foundational differences between GR and geometrized Newtonian gravitation concerns the status of local conservation of energy/mass-momentum. In the relativistic case, the "conservation condition" is an immediate consequence of Einstein's equation; the corresponding claim in the Newtonian case, however, does not seem to hold. And yet some authors, notably C. Duval, H. P. Künzle, and J. Christian, have claimed that there *is* a sense in which conservation is a consequence of the Newtonian field equation, properly understood. I am particularly interested in further exploring the status of these claims.

In addition to my interests in the foundations of spacetime theories and their consequences for general philosophy of science and the philosophy of space and time, I have also done work on the foundations of quantum mechanics ["The Scope and Generality of Bell-type Theorems." Unpublished]) and on the history of British epistemology ["On G. E. Moore's 'Proof of an External World'." Unpublished]. In this latter regard, I have particular interests in Reid and Austin, as well as in Moore. I also maintain research interests and collaborations in atomic, molecular, and optical physics. More information on my work in physics is available at the research page of my website, http://www.jamesowenweatherall.com/research.