Dissertation Abstract: Mass and Motion

James Owen Weatherall
University of California, Irvine

There is a long tradition, going back at least to Aristotle, of philosophers interested in the origins of unforced motion. How do bodies move in the absence of any external influence, and why? The modern answer to the "how" half of this question originates with Galileo and Descartes, who observed the possibility of uniform, non-accelerating "inertial" motion. Inertial motion is the subject of Newton's first law of motion, which states that in the absence of any external forces, a body traverses a straight line at constant velocity. Newton's first law, however, at least in its ordinary formulation, does not provide an answer to the "why" half of the question. Many physicists and philosophers of physics, Einstein included, have held that this question cannot be answered until one moves to general relativity. Indeed, some have taken general relativity to be distinctive in the history of spacetime theories precisely because it appears to "explain" the nature of unforced motion, in the sense that the geodesic principle—the geometrical version of Newton's first law—can be proved as a theorem. In my dissertation, I argue that Newtonian gravitation provides an explanation of inertial motion almost identical to that of general relativity.

The starting point for this work is a seminal result due to Bob Geroch and Pong-Soo Jang that clarifies the precise sense in which the geodesic principle can be construed as a theorem of relativity theory. The first chapter of the dissertation ["A Brief Remark on Energy Conditions and the Geroch-Jang Theorem." Forthcoming from *Foundations of Physics*] addresses a technical issue that arises in conjunction with this theorem, concerning a complicating assumption used in its proof. I show that the assumption stated in the original Geroch-Jang theorem not only cannot be weakened, but must be strengthened slightly to avoid an explicit counterexample. In the second chapter ["The Motion of a Body in Newtonian Theories." *Journal of Mathematical Physics* **52**(3), (2011)], I show that, in the context of a geometrical reformulation of Newtonian gravitation, one can prove a result that is almost identical (mathematically) to the Geroch-Jang theorem. The third chapter ["On the Status of the Geodesic Principle in Newtonian and Relativistic Physics." Forthcoming from *Studies in History and Philosophy of Modern Physics*] draws on these two results to argue that, *contra* received wisdom, the status of inertial motion in these theories is strikingly similar.

The final chapter of the thesis ["On (Some) Explanations in Physics." *Philosophy of Science* **78**(3), 421–447 (2011)] addresses a slightly different topic. In standard Newtonian gravitation, there are two distinct notions of mass: "inertial mass" and "(passive) gravitational mass". Yet it is an empirical fact that for any body, the values of these masses are always equal. Historically, many physicists have taken this fact to call for explanation. A natural place to look for an explanation of the coincidence of inertial and gravitational mass would be general relativity. In general relativity, however, there is no coherent notion of gravitational mass. This chapter shows how it is that gravitational mass arises as a distinct property of matter in the Newtonian limit of general relativity, and moreover, shows that in any model of standard Newtonian gravitation that approximates a model of relativity theory (in the sense of being a limit of a sequence of relativistic spacetimes), inertial and gravitational mass must be equal. This explanation, I argue, reveals something important about how explanatory demands are made, and can be met, across theories.