Gravitational Energy and Substantivalism
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In principle a burst of gravitational radiation could shatter the rock of Gibraltar, to borrow an example used by Carlo Rovelli. Rovelli uses the example to motivate the claim that the metric field should be understood as on par with matter fields. A burst of electromagnetic radiation could similarly shatter the rock, and Rovelli argues that an ontological distinction between the two cases is "ill-founded." It is also tempting to appeal to energy-momentum transfer by gravitational waves in an argument for substantivalism: the metric field should qualify as a substance because it carries energy and momentum from the source of the gravitational wave to the rock of Gibraltar, through regions of otherwise empty space.

Both claims are subject to objections based on a feature of GTR spelled out clearly in Hoefer (2000): the covariant "energy conservation" principle in GTR, $\nabla^a T_{ab} = 0$, cannot be given an integral formulation except in spacetimes possessing time translation symmetries. Hoefer argues that as a result the energy-momentum carried by the gravitational field should not be treated as "genuine energy." It is represented by a coordinate dependent pseudo-tensor t_{ab} rather than a true tensor T_{ab}, and the covariant conservation principle does not underwrite the claim that "gravitational energy" is transferred locally from gravitational waves to matter or vice versa. Careful consideration of the status of the covariant conservation principle thus establishes a distinction between matter fields and the metric field, and it undermines a substantivalists' claim to have an advantage over the relationalist in accounting for the "gravitational energy" of otherwise empty space.

But as Hoefer acknowledges there is a loophole: gravitational energy can be defined globally for some spacetimes, and there have been various proposals for a quasi-local (i.e., associated with open subsets of spacetime with compact closure) defintions of energy. Hoefer's argument appears to require that "genuine energy" is localizable, and gravitational energy clearly fails this test. However, the debates regarding different definitions of quasi-local energy proposed in the physics literature revolve around what it is reasonable to demand for an energy concept in GTR. There are still active debates regarding various proposed definitions of quasi-local energy. I will argue that these debates reveal that there is much more than simply localizability at stake; none of the available definitions satisfy a list of fairly natural requirements one might demand for a definition of quasi-local energy, and many physicists expect that no definition could satisfy them all. By looking at this debate in some detail I hope to clarify the options available for the substantivalist, who will be forced to abandon some plausible requirements on the energy concept in order to appeal to the "gravitational energy" of empty space.