

An Observer For Asymptotically Flat Spacetimes

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Observers have always played a central role in quantum mechanics, yet their consistent incorporation into quantum gravity remains poorly understood. In asymptotically flat spacetimes, this issue becomes especially acute due to the infrared structure of gravity and the infinite-dimensional BMS symmetry group, which render the definition of observables highly nontrivial. In standard quantum field theory, local observables are required to commute with asymptotic symmetry charges. However, in quantum gravity, any attempt to construct such large-gauge-invariant observables encounters a fundamental obstruction: the observable algebra admits only a single pure state, namely the vacuum, making the formulation of nontrivial physical states seemingly impossible.

In this work, we propose a resolution by introducing an external observer degree of freedom into the boundary algebra of asymptotically flat quantum gravity. Remarkably, dressing the gravitational Fock space with the observer Hilbert space generates an entire sector of gauge-invariant quantum gravity states. A central feature of this construction is that the observer regulates ultraviolet divergences in frequency along I , providing the first systematic avenue for gauging the full BMS supertranslation group. The resulting dressed Hilbert space naturally takes the form of a Faddeev–Kulish-like framework and gives rise to a type II von Neumann algebra of observables, offering a mathematically controlled and UV-finite formulation of the theory.

This approach establishes a precise setting for defining UV-finite gravitational observables and opens a path toward computing nonlinear local charges and entropies at null infinity.

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