Even a tiny cosmological constant casts a long shadow

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— Aruna Kesavan is a graduate student at the Pennsylvania State University

How safe is it to ignore the cosmological constant in the study of isolated systems and gravitational waves?

Analysis of isolated systems, such as stars, black holes and compact binaries, has dominated gravitational science, spanning diverse areas that include geometric analysis, computational relativity, gravitational waves, relativistic astrophysics and quantum black-holes. For example, over the past four decades, powerful positive energy theorems were proved, a theory of gravitational radiation in exact general relativity was developed, computational simulations were carried out to extract energy-momentum emitted during binary mergers, and evaporation of black holes was analyzed using appropriate Hilbert spaces of asymptotic states.

These advances are based on the Bondi-Penrose framework for zero cosmological constant Λ. But by now observations have led to a consensus that Λ is positive. However, since its observed value is so small, one's first expectation would be that only a small extension of the Bondi-Penrose framework is needed to incorporate it.

— Béatrice Bonga is a graduate student at the Pennsylvania State University.

However, this is *not* the case. No matter how small Λ is, we lose almost every central result that has led to physical advances in the non-linear regime. We no longer have the notion of `Bondi news'; there is no longer a gauge-invariant notion of gravitational waves in exact general relativity. Because the asymptotic symmetries are all space-like near $\mathcal{I}$, energy, as it is normally defined, cannot be positive-definite even for test fields, let alone in non-linear gravity. So far, there is no conceptually satisfactory method of wave extraction that numerical simulations can use, nor asymptotic Hilbert spaces in space-times describing stellar collapse to a black hole.

— Abhay Ashtekar is the Eberly Professor of Physics at the Pennsylvania State University

Our CQG paper shows why. Basically, if we just use Penrose's conformal completion at $\mathcal{I}$, the structure is too weak to pick out translations from the asymptotic symmetries, or to introduce the notion of `Bondi news'. Consequently, we no longer have access even to basic notions such as the Bondi energy-momentum. This situation led researchers to strengthen boundary conditions so as to reduce the asymptotic symmetry group to the de Sitter group. One can then introduce the analog of Bondi energy-momentum. But these quantities are now absolutely conserved. The strengthening is so strong that *gravitational waves cannot carry any energy-momentum*! Thus, as matters stand, one either has too little asymptotic structure or has too strong asymptotic conditions.

In subsequent papers in this series we develop a framework to overcome this conceptual impasse. We also hope to introduce approximation schemes to estimate the errors one makes in analytical and numerical analysis of gravitational waves beyond the linear approximation.

Read the full article in Classical and Quantum Gravity:
Asymptotics with a positive cosmological constant: I. Basic framework
Abhay Ashtekar, Béatrice Bonga and Aruna Kesavan
2015 Class. Quantum Grav. 32 025004

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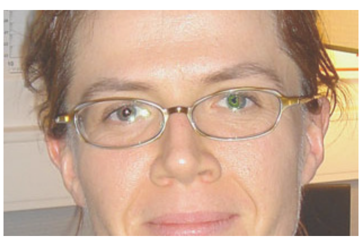

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