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Unified Insights in Gravity Theories: Asymptotic Symmetries and Celestial Holography

The Infrared (IR) triangle, famously portrayed by Strominger, highlights the unity between soft theorems, infinite-dimensional asymptotic symmetries, and Memory Effects within a single framework. In the realm of Gravity, this is known as BMS symmetry, with a corner relating to measurable classical Gravitational Memory Effects. The revolutionary detection of gravitational waves sets the stage for profound insights into Gravitational Wave Astronomy. Memory effect bridges classical observables with quantum phenomena, such as soft theorems and asymptotic symmetries, and is of particular importance.

The study engages quantum gravitational scattering to unveil the fundamental forces operating at lower energies. Employing Celestial Holography, this work explores scattering amplitudes and symmetries of asymptotically flat spacetimes, effectively translating intricate gravitational dynamics in higher dimensions into behaviors in lower dimensions at their boundaries. Here, the boundary in question is a null hypersurface that represents the celestial sphere of the gravitational system. This study delves into the exploration of asymptotic symmetries in gravity and supergravity theories, departing from conventional methods to embrace Celestial Holography. Recent developments have suggested the Operator Product Expansions (OPEs) of relevant celestial amplitudes to ascertain asymptotic symmetries in four-dimensional asymptotically flat pure gravity and $N = 1$ supergravity. Extending this approach, we apply it to four-dimensional Einstein-Yang-Mills and Einstein-Maxwell theories, revealing their asymptotic symmetry algebras [1]. This method serves as a consistency validation for known algebras in the existing literature. Along with this, we explored the asymptotic symmetries in the case of maximally supersymmetric $N = 8$ supergravity theory [3], which is new in the literature. Moreover, these insights facilitate a deeper exploration of the Celestial Conformal Field Theory (CCFT) technique and its effective application in unraveling symmetries across diverse theories.

Further investigation employs the Double Copy (DC) formalism in the soft and collinear sectors of Gravitational Scattering amplitudes, yielding significant applications in modern gravitational physics. The DC technique, a multiplicative bilinear operation, finds application in diverse fields like string theory, particle physics, and gravitational physics. We focus on the soft and collinear sectors of both gravity and gauge theory, and the N=8 supergravity to $N = 4$ super Yang-Mills (SYM) duality is explored through the DC relation. Applying this formalism unveils the interplay between the two theories and facilitates calculations in the soft and collinear sectors of $N = 8$ supergravity via known results in $N = 4$ SYM [2].

As our understanding of gravitational wave physics advances, the expansion of our knowledge regarding soft limits, such as classical spins, highlights the remarkable potential of the field. By delving into scattering amplitudes in perturbative quantum gravity, classical interactions of massive objects within gravitational fields are effectively deciphered, guided by the newfound insights in Gravitational Wave Astronomy.

References:
[1] "Asymptotic symmetry of four-dimensional Einstein-Yang-Mills and Einstein-Maxwell theory", JHEP 01, 033 (2022), [arXiv:2110.15657].
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