A quantum theory for the classical graviton

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I.

This work address the issue of the quantization of a vacuum, globally hyperbolic, asymptotically-flat spacetime containing no horizons. Such a spacetime will be called a classical graviton. Many years ago it was shown that both at future or past null infinity one can perform a free field quantization of the two degrees of freedom associated to the radiation data[1, 2]. Later, the phase space for classical gravitons was derived together with a complex structure, thus giving a Hilbert space for quantum gravitons[3]. Although recently there have been attempts to obtain a quantum scattering matrix linking the fields at future and past null infinity[4–6], what is missing is a dynamical evolution equation that could link the Hilbert spaces associated with $\mathscr{I}^-$ and $\mathscr{I}^+$ to construct an S-matrix theory for the quantum graviton. Linking the radiative data with the fields inside the spacetime via the NSF equations fulfills this need[8].

In this talk we give a brief review of the NSF equations needed for this work. These equations introduce the free Bondi data, representing incoming gravitational radiation, as a source term for the main variable of NSF. To avoid issues with gravitational tails at future null infinity we assume the free data is given on past null infinity, $\mathscr{I}^-$ and the null cone cuts are formed from the intersection of the past null cones from points on the spacetime with $\mathscr{I}^-$. (Note that this is the time reversed version of all the references of NSF).

We then show that it is always possible to obtain a region on past null infinity where the intersection of the past null cone from a point with $\mathscr{I}^-$ is a closed 2-surface with the topology of a sphere. The NSF equations together with its range of validity are presented and a method to construct observables of the spacetime is given. As an example a perturbation procedure to construct the metricin terms of the asymptotic data is given. Mirroring the procedure for asymtotic data in future and past null infinity yields a classical S-matrix for the theory.

Finally, we review the so called asymptotic quantization to turn the classical free data into quantum operators, define the associated Hilbert space and briefly analyse the role of the BMS group in this quantization scheme in liew of recent results[7]. We also analyse and the range of validity of a quantum theory without black holes[9].

[1] Ashtekar A, *Asymptotic Quantization*, Napoli: Bibliopolis (1987).

[2] Ashtekar A, *Geometry and Physics of Null Infinity*, arXiv:1409.1800 [gr-qc] (2015).

[3] E. Dominguez, C. Kozameh and M. Ludvigsen. *The phase space of radiative spacetimes* Class. Quantum Grav. **14** (1997) 3377 - 3389

[4] A Strominger, *On BMS Invariance of Gravitational Scattering*, JHEP 1407 152, (2014).

[5] A Strominger, *Lectures on the Infrared Structure of Gravity and Gauge Theory* arXiv:1703.05448 (2017).

[6] L. Donnay, A. Puhm, A. Strominger, *Conformally Soft Photons and Gravitons*, JHEP 1901 184 (2019). Published in

[7] S. Pasterski, Shu-Heng Shao, A. Strominger, *Flat Space Amplitudes and Conformal Symmetry of the Celestial Sphere*, Phys.Rev. D96 (2017).

[8] M. Bordcoch, C. Kozameh and T. Rojas, *Asymptotic Structure of NSF and the classical graviton*, Phys.Rev. D **94**, 104051 (2016)

[9] Hawking S., Perry M., Strominger A., "*Soft Hair on Black Holes*" Phys.Rev.Lett. 116 no.23, 231301 (2016).