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A cautionary case of casual causality & UV graviton scattering from IR singularities

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In recent years, causality has become a popular criterion to distinguish between EFTs arising from physical and unphysical high-energy theories. A direct way to ensure a given EFT is causal is to demand a lower bound on scattering time delays, which essentially bounds the propagation speed averaged over the entire trajectory. In flat space, this is unambiguously dictated by the Minkowski light cones, but the situation is much more subtle on curved backgrounds. I will make the case that the relevant notion is the so-called infrared causality. I will then apply this notion of causality to the EFT of gravity on spherically symmetric black hole backgrounds. Careful consideration of the regime of validity shows that time delays are never resolvable (in the geometric optics sense), and therefore there is never any observable violation of infrared causality.

This talk is based on arXiv:2112.05031 in collaboration with C. de Rham, A. Margalit, and A. Tolley.

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Scattering amplitudes mediated by graviton exchange display IR singularities in the forward limit. This obstructs standard application of positivity bounds based on twice subtracted dispersion relations. Such divergences can be cancelled only if the UV limit of the scattering amplitude behaves in a specific way, which implies a very non-trivial connection between the UV and IR behaviors of the amplitude. We show that this relation can be expressed in terms of an integral transform, obtaining analytic results when t log s ->0. Carefully applying this limit to dispersion relations, we find that infinite arc integrals, which are usually taken to vanish, can give a non-trivial contribution in the presence of gravity, unlike in the case of finite negative t. This implies that gravitational positivity bounds cannot be trusted unless the size of this contribution is estimated in some way, which implies assumptions on the UV completion of gravitational interactions. We discuss the relevance of these findings in the particular case of QED coupled to gravity.

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