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Very Special Linear Gravity: A Gauge Invariant Graviton Mass

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In 2006, A. Cohen and S. Glashow presented for the first time the idea of Very Special Relativity (VSR), where they imagined to restrict space-time invariance to a subgroup of the full Lorentz group, usually the subgroup $SIM(2)$. The advantage of this theory is that, while it does not affect the classical prediction of Special Relativity, it can explain the existence of neutrino masses without the addition of new exotic particles or tiny twisted space dimensions, which until now have not been observed in experiments.

The addition of either P, CP, or T invariance to $SIM(2)$ symmetry enlarges the entire symmetry group again to the whole Lorentz group. That implies the absence of VSR effects in theories where one of the above three discrete transformations is conserved.

Since we know thanks to Sakharov conditions that these discrete symmetries must be broken in cosmology, the effects of VSR in this framework become worthy of being studied. With our work, we managed to construct a $SIM(2)$-invariant version of linearized gravity, describing the dynamics of the space-time perturbation field $h_{\mu\nu}$. Such a theory may be used as a starting point for the study of VSR consequencies in the propagation of gravitational waves in a Lorentz breaking background.

In the end, our analysis will correspond to a massive graviton model. That could be of great interest due to the various recent applications that are being explored for massive gravity, from dark matter to cosmology, despite the strong boundaries we already have on the graviton mass.

Until now, massive gravity models were usually constructed as Lorentz invariant. Nevertheless, as in the case of Electromagnetism and the Proca Theory, there is no way of trivially preserving both Lorentz and Gauge invariance when giving mass to the graviton.

Giving up on the Gauge invariance directly leads to the appearance of three additional degrees of freedom (D.o.F.) respect to the ones of General Relativity (GR), which are responsible for different pathologies of these theories, like the vDVZ discontinuity and ghost modes (i.e. the Boulware-Deser ghost). Many of these problems have already been solved with the Vainshtein Mechanism and the fine-tuned dRGT action to avoid ghosts, making dRGT massive gravity a good candidate to solve the cosmological constant problem. Even so, dealing with cosmology brings up new problems and instabilities which have not already been solved.

Giving up on Lorentz invariance, that is what we considered in our work by implementing VSR, is the other viable possibility for massive gravity. Experience with VSR Electrodynamics and VSR massive Neutrinos tell us that VSR extensions avoid the introduction of ghosts in the spectrum: in fact, as we will see, gauge invariance of our formulation does not allow for new additional D.o.F. other than the usual two of the massless graviton, getting round most of the problems cited above, like the Boulware-Deser ghost. Nevertheless, these advantages come at the price of considering new non-local terms in the theory and assuming a preferred space-time null direction, represented by the lightlike four-vector n^{μ}.

Finally, through the geodesic deviation equation, we have confronted some results for classic gravitational waves (GW) with the VSR ones: we see that the ratios between VSR effects and classical ones are proportional to $(m_g/E)^2$, E being the energy of a graviton in the GW. For GW detectable by the interferometers LIGO and VIRGO this ratio is at most 10^{-20}. However, for GW in the lower frequency range of future detectors, like LISA, the ratio increases signficantly to 10^{-10}, that combined with the anisotropic nature of VSR phenomena may lead to observable effects.

In-person participation

Yes

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