Contribution ID: **60** Type: **Oral**

Addressing issues in defining the Love numbers for black holes

Among various properties of black holes studied so far, their response to an external tidal field remains an especially interesting topic. In our recent work [arXiv:2306.13627 \[gr-qc\]], we presented an analytic method for calculating the tidal response function of non-rotating and slowly rotating black holes from the Teukolsky equation in the small frequency and the near horizon limit. We pointed out that in the relativistic context, there can be two possible definitions of the tidal Love numbers and the dissipative part that arise from the tidal response function. Our results suggest that both of these definitions predict zero tidal Love numbers for a non-rotating black hole. On the other hand, for a slowly rotating black hole in a generic tidal environment, these two definitions of the tidal Love numbers do not coincide. While one procedure suggests zero tidal Love numbers, the other procedure gives purely imaginary tidal Love numbers. As expected, the dissipative terms differ as well. We emphasize that in our analysis we kept all the terms linear in the frequency, unlike previous works in the literature. Following this, we also discuss a procedure to calculate the tidal response function and hence the Love numbers for an arbitrarily rotating black hole presented in the aforementioned paper.

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Session Classification: Gravitational Waves

Track Classification: Gravitational Waves