Contribution ID: **107** Type: **Oral**

Gear-up for the Action Replay: Leveraging Lensing for Enhanced Gravitational-Wave Early-Warning

Pre-merger gravitational-wave (GW) sky-localisation of binary neutron star (BNS) and neutron star black hole (NSBH) coalescence events, would enable telescopes to capture precursors and electromagnetic (EM) emissions around the time of the merger. We propose an astrophysical scenario that could provide early-warning times of hours to days before coalescence with sub-arcsecond localisation, provided that these events are gravitationally lensed. The key idea is that if the BNS/NSBH is lensed, then so must the host galaxy identified via the EM counterpart. From the angular separation of the lensed host galaxy images, as well as its redshift and the (foreground) lens redshift, we demonstrate that, \response{for galaxy-scale lenses}, we can predict the {\bf time delays/arrival time differences} assuming a standard lens model. We further assess the feasibility and benefits {\bf of lensing as a tool for early-warning} in various GW observing runs of the LIGO-Virgo-Kagra network, including Voyager, and the third generation network. To that end, we study the effect of limited angular resolution of the telescopes on our ability to predict the time delays. We find that with an angular resolution of $0.05''$, we can predict time delays of > 1 day with 1σ error-bar of $\mathcal{O}$(hours) at best. We also construct realistic time delay distributions of detectable lensed BNSs/NSBHs to forecast the early-warning times we might expect in the observing scenarios we consider.

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Session Classification: Gravitational Waves

Track Classification: Gravitational Waves