Gravitational Wave Astrophysics with MAGIS

progenitors and pre-merger localizations of Advanced LIGO/Virgo binary-merger events

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Gravitational wave observations in the ~30 mHz to 3 Hz range (mid-band) provide degree-scale localizations and binary system parameters prior to their merger detections with LIGO/Virgo. MAGIS, the Mid-band Atomic Gravitational Wave Interferometric Sensor [1], a proposed NASA probe-class space mission concept, will be capable of such measurements.

Summary

- The Mid-band Atomic Gravitational-wave Interferometric Sensor (MAGIS) is a probe-class space-mission concept [1], using an atom-based gravitational wave (GW) detector. MAGIS will provide all-sky strain sensitivities of ~10^{-17}/Hz and better (1-year) in the GW-frequency mid-band (~30 mHz to 3 Hz) between LISA/L3 (~2034 launch) and ground-based Advanced LIGO/Virgo interferometers.
- Joint GW-observations with MAGIS and Advanced LIGO/Virgo offer a path to determining binary system parameters and progenitors by covering all stages of binary coalescence, from inspiral to merger. The GW-degree-scale localizations and distance measurements will be powerful paired with galaxy catalogs, to enable unique galaxy counterpart identifications. Because most neutron star (NS) binary systems (BH-NS, NS-NS) will not have favorable system geometries, and black hole (BH) binary mergers are likely absent of detectable electromagnetic counterparts, GW mid-band observations will uniquely provide information on galaxy demographics of these systems.

Binary black hole progenitors

- The progenitors of the binary black hole systems discovered at higher-frequencies by LIGO/Virgo remains an open problem. They can be formed in isolated or dense environments, leading to different ensemble eccentric distributions [2, 3]. Eccentricities are best-measured in the mid-band – these binaries circularize before they reach the LIGO/Virgo band and the most eccentric binaries are missed by LISA.

- Moreover, triple systems that tend to form in dense environments, are distinguishable in the mid-band by MAGIS, and can result in successive GW merger events observable by LIGO/Virgo within years timescales [4, 5].

Pre-Merger Localizations

- Binary systems last for 100’s days in the mid-band, providing advanced (pre-merger) degree-scale localizations, distances (redshifts), and predicted merger epochs, ~weeks prior to their merger-detections with LIGO/Virgo. The observations will distinguish between neutron star (< 2.8 M⊙) and black hole systems, constrain binary system parameters including orientations, that will facilitate different follow-up strategies. Importantly, the full sequence of events unfold within PhD-timescales.
- These gravitational wave source forecasts make possible, previously unimaginable electromagnetic observations of GW sources, including: (i) searches for precursor emission (possible orbital- or disk-modulated X-ray/UV emission), (ii) progenitor identification (optical/IR galaxy survey within GW-localized volume), & (iii) unique characterization of prompt post-merger transient emission (optical-to-γ-ray polarization of SGRBs, γ-ray line spectroscopy of kilonovae emission, VLBI jet structures).

References & Acknowledgments

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