Multi-messenger synergies with massive black hole binary mergers in the LISA era

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In ∼2034 the Laser Interferometer Space Antenna (LISA) will detect the coalescence of massive black hole binaries (MBHBs) from 10^5 to 10^7 $M_\odot$ up to $z \sim 10$. The gravitational wave (GW) signal is expected to be accompanied by a powerful electromagnetic (EM) counterpart, from radio to X-ray, generated by the gas accreting on the binary.

If LISA locates the MBHB merger within an error box $< 10\,\mathrm{deg}^2$, EM telescopes can be pointed in the same portion of the sky to detect the emission from the last stages of the MBHB orbits or the very onset of the nuclear activity, paving the way to test the nature of gas in a rapidly changing space-time. Moreover, an EM counterpart will allow independent measurements of the source redshift which, combined with the luminosity distance estimate from the GW signal, will lead to exquisite tests on the expansion of the Universe as well as on the velocity propagation of GWs. In this talk, I present some recent results on the expected rates of MBHBs counterparts detectable jointly by LISA and EM facilities such as LSST, SKA, ELT and Athena. We combine state-of-the-art models for the galaxy formation and evolution, Bayesian tools to perform the parameter estimation of the GW event and analytical expressions to simulate the EM emission.

We explore three different astrophysical scenarios employing different seed formation (light or heavy seeds) and delay-time models, in order to have realistic predictions on the expected number of events. We estimate the detectability of the sources in terms of its signal-to-noise ratio in LISA and perform parameter estimation, focusing especially on the sky localization of the source. Exploiting the additional information from the astrophysical models, such as the amount of accreted gas and BH spins, we model the expected EM counterpart to the GW signal in soft X-ray, optical and radio. In our standard scenario, we predict ∼ 14 standard

sirens (stsi) with detectable counterparts over 4 yr of LISA time mission and ∼6 (∼20) in the pessimistic (optimistic) one. For the Athena case, we investigate the trade-off between sky position accuracy and limiting flux: if we increase the sky localization threshold and reduce the limiting flux , the rates decrease by ∼ 20%.

We also explore the impact of absorption from the surrounding gas both for optical and X-ray emission: assuming typical hydrogen and metal column density distribution, we estimate only ∼3 stsi in 4 yr in the standard scenario.

Finally we combined the redshift and luminosity distance information to estimate cosmological parameters: we find that H_0 can be constrained to ∼few percent precision thanks to few sources whose redshift is measured spectroscopically.