Measuring H_0 with gravitational waves and gamma-ray absorption

Isabela Matos (ICTP-SAIFR) & Katrin Streil (ECAP)

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Multi-messenger gravitational wave (GW) events are very interesting for a broad range of scientific questions, from binary population studies to measurements of the expansion of the Universe. For cosmology, these so-called bright standard sirens are very useful since they allow a reconstruction of the luminosity distance-redshift relation $D(z) = (1+z)\int_0^z dz'/H(z')$, that is sensitive to the expansion history of the Universe and to features of dark energy models.

GWs are distance indicators but they do not provide the information of the redshift, which has to be determined from electromagnetic counterparts. The main point we want to explore here is that, additionally to the redshift, these counterparts, specially the gamma rays, provide extra cosmological information due to their absorption properties while travelling across large distances. With a model for the intrinsic spectrum of the source, by measuring its spectrum one can fit jointly the extra-galactic background light (EBL) and the cosmological parameters. The idea is basically to fit these two with both the information of the spectrum, redshift and distance. After writing down such joint likelihood, the main pieces that have to be put together are the following:

- We need a simulated catalog of sources from which we can detect both the GW signal and γ-rays. Two possibilities are: (i) GWs from binary neutron star mergers with the Einstein Telescope and γ-ray bursts [Belgacem et al. (2019)]; and (ii) massive black hole binaries with active galactic nuclei (AGN), considering the LISA mission [Mangiagli et al. (2022)].
- Get the distance estimates from the simulated detectable GW waveforms, get the spectrum from the hypothetical γ-ray detections with Fermi, H.E.S.S. or CTA and get the redshifts via other electromagnetic observations (e.g. when we can identify the host galaxy, get the galaxy redshift from a catalog). Another option is to not require a measurement of the redshift and fit it as well.

Finally, we would fit all parameters, most importantly the Hubble constant, and check how the inclusion of the absorption information helped the GW test on reducing the errors on H_0. This is feasible considering we have expertise both on GW simulations and parameter estimation and on measurements of the spectrum with γ-rays. Furthermore, this project addresses a main problem of current spatial sciences, which is related to the measurement of the expansion rate of the Universe today, using actual multi-messenger astrophysics techniques.