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Detecting the Motion of Gravitational Wave Sources

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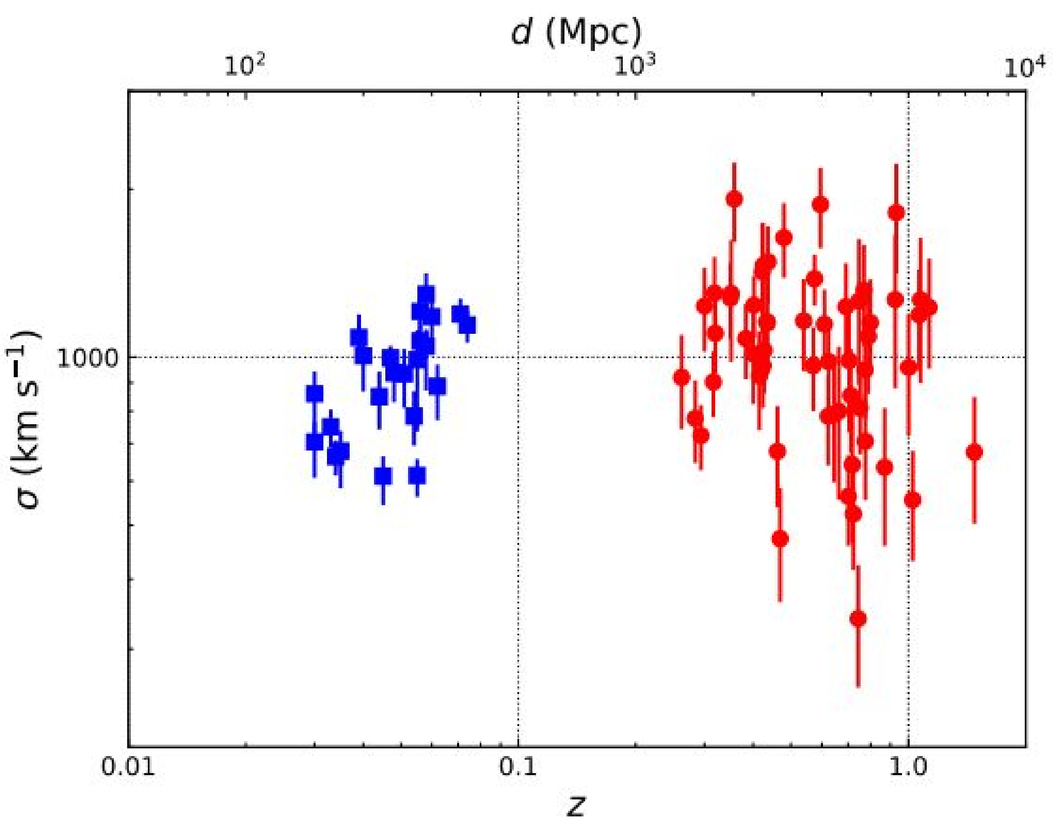
Based on: Torres-Orjuela et al., Phys. Rev. Lett 127 (2021) & Torres-Orjuela et al., arXiv:2010.15856 (2020)

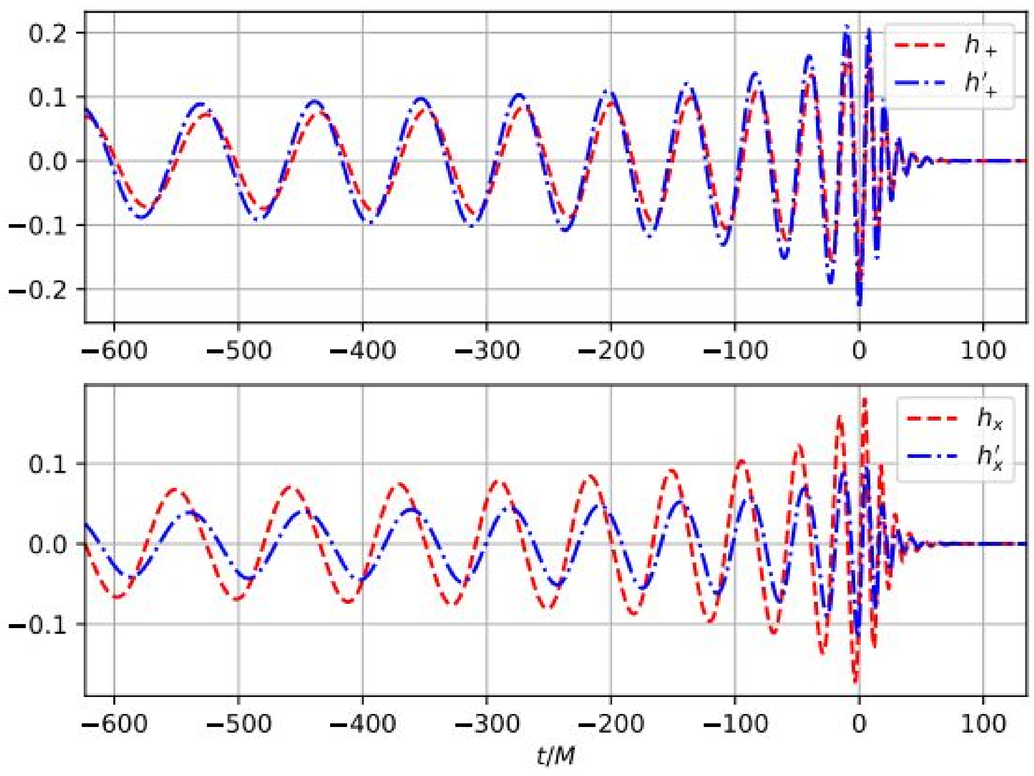
Summary: Considering the spherical modes of gravitational waves (GWs) and how a constant center-of-mass velocity acts on them, the motion of the source can be detected by only using gravitational waves. Thus, not only breaking the well known mass-redshift degeneracy of gravitational waves, that appears when only considering the effect of velocity on the frequency of the wave, but also providing a way to obtain information about the source and its environment. For an extreme mass-ratio inspiral moving due to the peculiar velocity of its host galaxy, the velocity can be detected for a signal-to-noise ratio (SNR) of only 20. For an SNR of 100 the velocity of the source can be measured to a precision of a few percent.

Motivation:



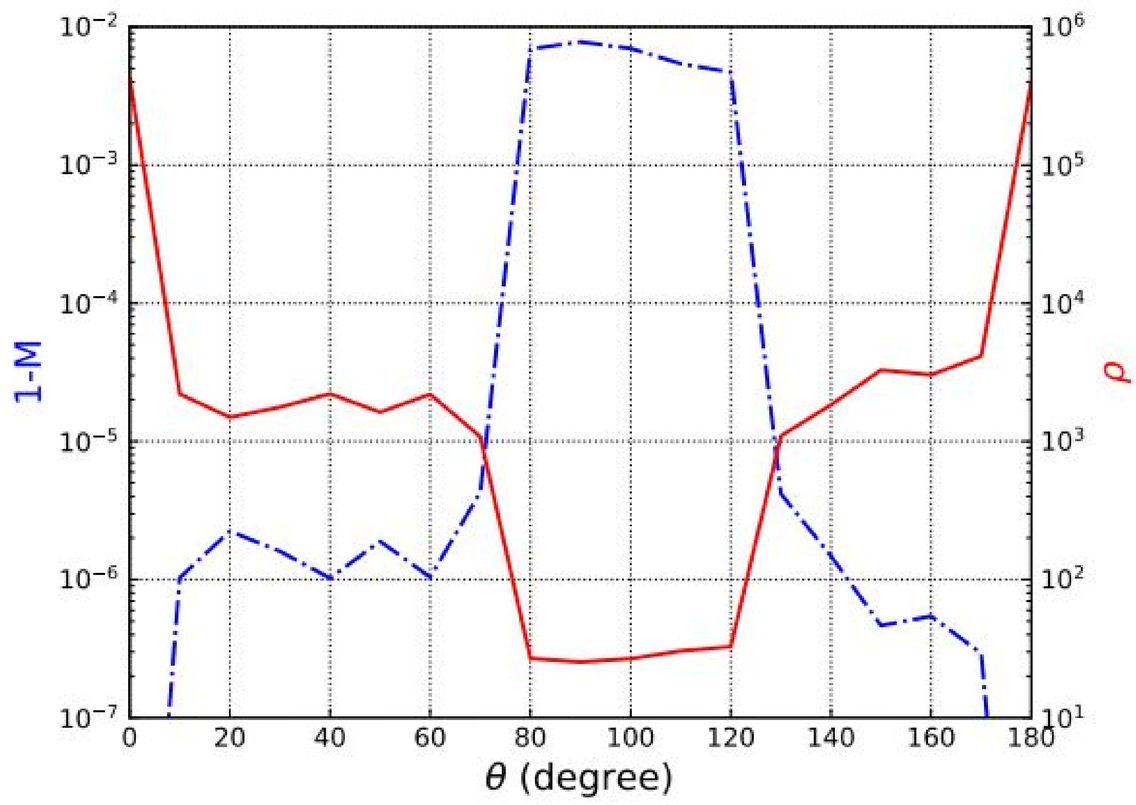
A motion of a GW source can be induced by different mechanisms and is often related to the environment of the source. Such a mechanism is, e.g., the peculiar velocity of the host galaxy that induces a motion of in average 1000 km/s.

Excitation of modes:

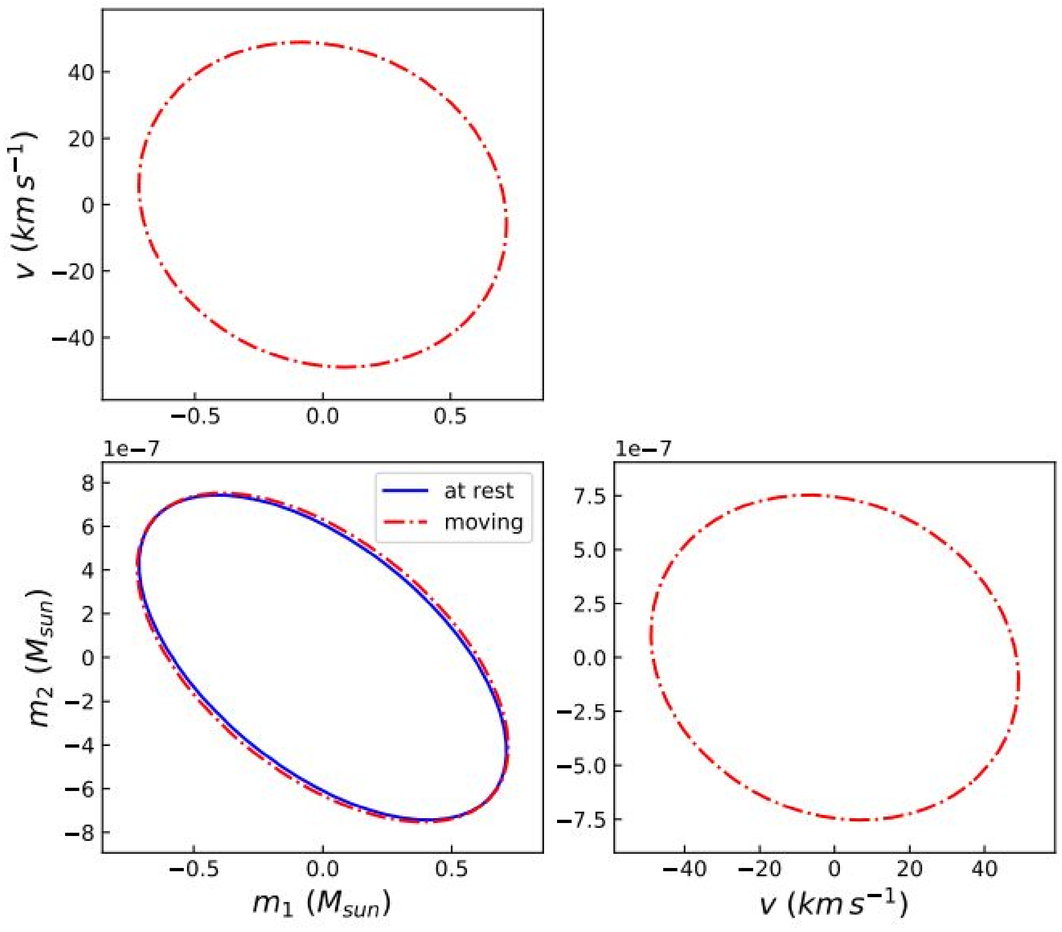


The motion of the source affects its radiation pattern, thus changing the modes excited. This excitation of additional modes will make the signal from a moving source, h‘, differ from one at rest, h.

Results:



A velocity of 1000 km/s leads to a mismatch big enough to be detected for an SNR of only 20 in favourable cases. For around a third of the sources an SNR of O(100) is enough to detect the same velocity.



For an SNR of 100 the velocity can be detected with an accuracy of only 4 %. The detection of other parameters is not significantly affected but could be biased when ignoring the effect of velocity on them, i.e., the mass due to redshift.

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