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Impact of Dark Matter spikes on the merger rates of Primordial Black Holes

Primordial Black Holes (PBHs) may form in the early Universe by formation mechanisms such as large density fluctuations, bubble collisions, collapse of domain walls or collapse of cosmic strings. PBHs are considered as one of the possible candidates for dark matter. A huge amount of work has been done on PBHs because it is considered that the merger of PBHs binaries can also lead to the origin of gravitational waves seen by LIGO/VIRGO/KAGRA (LVK) Scientific Collaboration. We study the current merger rate of PBHs binaries based on the assumption that PBHs are non-particle candidates of dark matter having a spike of non-annihilating cold dark matter particles such as axions around them. For that we extend the previous calculations of the merger rate of PBH binaries for extended PBH mass functions. Using analytical and numerical approaches, we calculate the current merger rates of PBH binaries with DM spikes assuming that either the DM spikes are completely thrown out of the binaries or they remain static during the merger. We found that the presence of DM spikes alters the distribution of final merger time and size of binaries in such a way that it can lead to either increase or decrease in the merger rate of PBH binaries, in comparison to the PBH binaries without DM spikes. Also, the binary black hole mergers seen in third Gravitational-Wave Transient Catalog (GWTC - 3) of LVK Collaboration can be very well explained by the mergers of PBH binaries with and without DM spikes for Lognormal and Power Law mass function (MF) in PBH mass range $5\,\mathrm{M}_\odot \leq m_{\mathrm{pbh}} \leq 100\,\mathrm{M}_\odot$ and $10^{-2}\,\mathrm{M}_\odot \leq m_{\mathrm{pbh}} \leq 100\,\mathrm{M}_\odot$ respectively, leading to $f_{\mathrm{pbh}} \leq \mathcal{O}(10^{-5} - 10^{-3})$ which is consistent with the previous results. As per our assumptions about the presence of DM spikes around PBHs, this work applies very well to the binaries having either comparable PBH masses or highly assymetric PBH masses, but a general formalism can be developed in future which can apply to binaries having PBHs in any mass ratios.

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