Stellar Feedback and Mergers of Supermassive Black Holes

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Since the late 1970s the hierarchical structure formation theory has been the standard paradigm for structure formation, according to which structure forms in a bottom-up fashion with smaller structures forming the larger ones via clustering and mergers. According to our current understanding, the observable Universe contains approximately 2×10^{12} galaxies, from which most have undergone some degree of mergers during their evolutionary history, within the framework of hierarchical structure formation theory. It has also become a commonly accepted consensus that nearly all massive galaxies harbour a supermassive black hole (SMBH) in their galactic centres with masses exceeding $M_{\mathrm{SMBH}} \gtrsim 10^5 M_{\odot}$. Therefore, when galaxies merge, their central SMBHs merge as well.

The gravitational waves emitted in the mergers of SMBHs are the primary targets of ongoing and future gravitational wave detectors (e.g. Laser Interferometer Space Antenna; LISA), thus it is imperative to provide theoretical predictions for these observational surveys. Numerical simulation studies of massive galaxies have investigated how feedback from active galactic nuclei (AGN) influences the merging time-scales of the central SMBHs in idealised galaxy merger scenarios. However, the influence of galaxy-bound feedback has not yet been studied for lower mass galaxies, in which stellar feedback is dominant over the feedback from AGN.

To explore this problem, this work focuses on understanding the influence of stellar feedback on the SMBH merging time-scales by analysing a series of idealised galaxy merger simulations in which the amount of energy per supernova explosion is systematically varied. In this work, a total of four simulation runs was performed by using the simulation codes GADGET-3 and KETJU. The progenitor galaxies were gas-rich, disc galaxies with a mass ratio of 1 : 1 and stellar masses of $M_* = 4.9 \times 10^9\ M_{\odot}$. The central SMBHs were included in the simulation as non-accreting particles, with masses set to $M_{\mathrm{SMBH}} = 6.55 \times 10^6\ M_{\odot}$. The mergers of SMBHs of this mass represent the kind of mergers that the upcoming LISA mission will be most sensitive to.

The influence of the stellar feedback was evident in all of the obtained results; stronger stellar feedback was seen to efficiently drive and heat the star-forming gas to hot, low-density regions of the phase space, thereupon suppressing star formation and consequently decreasing the number density of stellar particles. Finally, in agreement with similar studies of more massive galaxies, the stronger feedback results in longer SMBH merging time-scales, whereas weaker feedback allows a faster SMBH binary coalescence. The findings of this work have implications on the detectability of the SMBH-SMBH mergers for missions such as LISA, where the merging time-scales play a significant role in determining the amount of time that a binary spends in the detectable mHz gravitational wave band, i.e. at separations of $\sim 0.001 - 1$ parsecs.