W39a Formation and evolution of compact object binaries in AGN disks

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The astrophysical origin of gravitational wave (GW) events discovered by LIGO/VIRGO remains an outstanding puzzle. In active galactic nuclei (AGN), compact-object binaries form, evolve, and interact with a dense star cluster and a gas disk. An important question is whether and how binaries merge in these environments. To address this question, we have performed one-dimensional N-body simulations combined with a semi-analytical model which includes the formation, disruption, and evolution of binaries self-consistently. We point out that binaries can form in single-single interactions by the dissipation of kinetic energy in a gaseous medium. This "gas capture" binary formation channel contributes up to 97 % of gas-driven mergers and leads to a high merger rate in AGN disks even without pre-existing binaries. We find that the distribution of $\chi_{\rm eff}$ predicted by our AGN model is similar to the distribution observed during LIGO/Virgo O1 and O2. We further suggest that high binary masses and the positive correlation between binary mass and the standard deviation of $\chi_{\rm eff}$ for chirp masses up to $\approx 20\,M_{\rm sun}$, can be possible signatures for mergers originating in AGN disks. Finally, hierarchical mergers in AGN disks naturally produce properties of the recent GW event GW190412, including a low mass ratio, a high primary black hole spin, and a significant spin component in the orbital plane.