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Differential Interferometric Signatures of Close Binaries of Supermassive Black Holes in Active Galactic Nuclei

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Pairs of supermassive black holes (SMBHs) at different stages are the natural results of galaxy mergers in the hierarchical framework of galaxy formation and evolution. However, identification of close binaries of SMBHs (CB-SMBHs) with sub-parsec separations in observations are still elusive. Recently, unprecedented spatial resolutions achieved by GRAVITY/GRAVITY+ on board the Very Large Telescope Interferometer through spectroastrometry (SA) provide new opportunities to resolve CB-SMBHs. Differential phase curves of CB-SMBHs with two independent broad-line regions (BLRs) are found to have distinguished characteristic structures from a single BLR. Once the CB-SMBH evolves to the stage where BLRs merge to form a circumbinary BLR, it will hopefully be resolved by the pulsar timing array in the near future as sources of nanohertz gravitational waves. In this work, we use a parameterized model for circumbinary BLRs to calculate line profiles and differential phase curves for SA observations. We show that both profiles and phase curves exhibit asymmetries caused by the Doppler boosting effect of accretion disks around individual black holes, depending on the orbital parameters of the binary and geometries of the BLR. We also generate mock SA data using the model and then recover orbital parameters by fitting the mock data. Degeneracies between parameters contribute greatly to uncertainties of parameters but can be eased through joint analysis of multiple-epoch SA observations and reverberation mappings.

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