Electromagnetic Signatures of Black Hole Binary Systems

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Abstract: The NASA–ESA Laser Interferometer Space Antenna (LISA) mission, launching in 2035, will detect gravitational waves from black hole binaries (BHBs) and provide sufficiently precise merger-time predictions and sky localization to enable electromagnetic (EM) observatories to pre-point toward the system, offering an opportunity for multi-messenger astronomy (MMA). BHBs will cast a hierarchy of shadows on the image due to extreme gravitational lensing and multiple lensing; the shapes and sizes of these shadows should be able to constrain system parameters such as the black holes' masses, spins, and separation. This work uses the ray-tracing code BOTHROS on a BHB spacetime to measure the shapes and sizes of primary, secondary, and tertiary shadows, including "Einstein shadows," cast by the BHB in the image. Binary phase and inclination angle are sampled efficiently using a novel curvilinear adaptive mesh refinement technique with a braid-group model that we call the Venus FlyTrap method (VFT). VFT allows us to quickly locate and compute arbitrarily obscure BHB shadows in preparation for future explorations of other BHB systems.