Adaptive Mesh Refinement Simulation of the Common-Envelope Phase of Binary Star Evolution

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Using the FLASH adaptive mesh refinement simulation code, we study the hydrodynamic evolution of a low-mass binary star system consisting of a 1.05 solar-mass red giant and a 0.6 solar-mass companion through five orbits of its common-envelope evolution.

During the rapid inspiral phase, the interaction of the companion with the red giant's extended atmosphere causes about 25% of the common envelope to be ejected from the system, with mass continuing to be lost at the end of the simulation at a rate of about two solar masses per year. The resulting loss of angular momentum and energy reduces the orbital separation by a factor of 7. After this inspiral phase the eccentricity of the orbit rapidly decreases with time. The gravitational drag dominates hydrodynamic drag at all times in the evolution, and the commonly used Bondi-Hoyle-Lyttleton prescription for estimating the accretion rate onto the companion significantly overestimates the true rate.

On scales comparable to the orbital separation, the gas flow in the orbital plane in the vicinity of the two cores is subsonic, with the gas nearly corotating with the red giant core and circulating about the red giant companion. On larger scales, 90% of the outflow is contained within 30 degrees of the orbital plane, and the spiral shocks in this material leave an imprint on the density and velocity structure. Of the energy released by the inspiral of the cores, only about 25% goes toward ejection of the envelope.