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White Dwarf merger simulations and detonations using the moving-mesh code AREPO

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The merging of degenerate dead stars (compact stars) have been of interest to astrophysicists for several decades. White dwarfs (WDs), in particular, are important not only as a macroscopic demonstration of quantum degeneracy and stellar astrophysics but also vitally important to investigate the nature of many violent astrophysical phenomena, such as Type Ia supernovae, routinely used to study the accelerating expansion of the universe, gamma-ray bursts, and possibly also Fast Radio Bursts, which are the most mysterious and luminous objects in the universe.

This work discusses the application of the 3D MHD code AREPO to mergers of WDs and discusses some of the early results of these simulations [1]. Prior work by, e.g., Schwab et al., Schneider et al., and Zhu et al [2-4] rely on simplified assumptions of reduced dimensionality, use unrealistic WD chemical structures or neglect to fully account for magnetic effects. Several prior studies including Zhu found strong magnification of magnetic fields as a result of the Magnetorotational Instability (MRI), though these observations are generally not factored into an analysis of plasma fusion during the merger [2].

Here we show results of simulations which include more accurate WD internal structures generated using the White Dwarf Evolution Code (WDEC) [5]. We also discuss future work relating the stellar masses and mass ratios have on the production of ultra-strong magnetic fields (100-10^{11} Tesla) observed in white dwarfs and neutron stars, which may trigger thermonuclear runaway explosions. Figure 1 shows a merger example where the primary has a CO core and He shell while the companion is a pure helium star. In this simulation the primary's mass is 0.75 $M_\odot$ and the secondary 0.35 $M_\odot$.

Finally, we highlight the physical limitations of the simulation framework, which include numerical accuracy and restrictions on the WD chemical composition. Such limitations, in turn, have downstream effects on chemical abundances in the Galaxy and on simulations of Type Ia supernovae.

References

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Figure 1: 3D MHD simulations of WDs produced with AREPO. The left image shows matter being accreted onto a high-mass COHe WD from a low-mass He companion. The right image shows an example of the variable nuclear composition of the high mass WD, with the proportion of carbon in each cell represented in the range [0, 1].