Overview

If an oxygen-neon white dwarf (WD) grows to near the Chandrasekhar mass, electron-capture reactions can trigger a collapse to form a neutron star (NS).

Such a situation can arise in a binary system with a massive ONe white dwarf accreting from a non-degenerate companion (e.g., Nomoto & Kondo 1991). Alternatively, this can occur in the remnant of a super-Chandrasekhar (total mass) WD-WD merger, where the compression is caused by the cooling of the outer layers (e.g., Siao & Nomoto 1985). Electron-capture supernovae from super asymptotic giant branch stars are a closely related phenomenon; there, a degenerate ONe core is formed and then compressed by the deposition of material from exterior shell-burning (e.g., Miyaji & Nomoto 1987).

Accreting ONe WDs: The approach to collapse

The thermal and compositional evolution of accreting ONe WDs is largely driven by weak reactions. We have updated the MESA stellar evolution code with an accurate treatment of electron-capture and beta-decay reaction rates in electron-degenerate conditions and applied these capabilities to studies of accreting WDs.

Our MESA models confirm previous work showing the role that $^{24}$Mg and $^{25}$Na play in reducing the electron fraction and heating the core. We demonstrate the presence of a thermal runaway in the core that launches an oxygen-driven detonation wave from the center of the star. The ability of MESA to perform fine spatial zoning allows the models to reach length-scales that, for the first time, directly connect full-star simulations to MESA's treatment of electron-capture and beta-decay reaction rates in electron-degenerate conditions and applied these capabilities to studies of accreting WDs.

Work covered by this poster (2015-2017)

The evolution of the central temperature and density of an accreting ONe WD. The 2015 line (dashed gray) considers only $^{24}$Na, $^{25}$Na, and $^{27}$Na; the 2017 line (solid black) adds $^{23}$Na and $^{25}$Mg. The labeled dotted lines show the attractor solution (where neutrino cooling balances compositional heating) and a sample adiabat. The accurate inclusion of key weak reactions, which are indicated at the densities where they occur, is essential for understanding the evolution of these objects.

The merger of two CO WDs with a total mass in excess of the Chandrasekhar mass has long been proposed to lead to the formation of an NS (Nomoto & Iben 1985; Saio & Nomoto 1985). Instead of triggering a core ignition, the merger leads to off-center carbon ignition and then an inward-going carbon flame that converts the core to ONe. We have taken results from double WD merger simulations and mapped them into MESA. Our calculations evolve the remnant for longer than previous work and find that because the degenerate core is massive, it subsequently also experiences off-center ONe ignition. If the inward-going neon-oxygen flame reaches the center, this prevents the electron-capture-triggered collapse that occurs in a cold ONe core. Instead, the process likely leads to collapse to a NS reminiscent of that in low-mass Fe core collapse SNe.

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