Postprint of Extremely Low-Mass White Dwarfs Formed Through Stable Mass Transfer Channels

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Abstract

Extremely low-mass white dwarf binaries are of great importance for binary evolution, common envelope, AM CVn binaries, and asteroseismology. Considering their relatively short periods, they are also significant gravitational wave sources; however, their formation and evolution remain unclear. By employing a recent magnetic braking prescription, we have constructed formation and evolution models for extremely low-mass white dwarf binaries. The study delineates their initial parameter space for formation and discovers that the mass range of extremely low-mass white dwarfs formed through stable mass transfer is (0.11 0.21) M . Additionally, the study finds that a subset of extremely low-mass white dwarf binaries can evolve into AM CVn binaries within the age of the Universe, with these extremely low-mass white dwarfs having a mass range of 0.14 0.16 M . The study also reveals that their gravitational wave signals are detectable by LISA, TianQin, and Taiji detectors. Finally, the impact of different mass accumulation efficiencies on the evolutionary outcomes of the same binary system is discussed, finding that while it significantly influences the final mass of the primary star, it has minimal effect on the companion star and the binary evolution process.

Full Text

Formation of Extremely Low Mass White Dwarf Binaries via a Stable Mass Transfer Channel

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Abstract

Extremely low mass white dwarf (ELM WD) binaries are important for studies of binary evolution, common envelope evolution, AM CVn binaries, and asteroseismology. Due to their short orbital periods, they are also important gravitational wave sources. However, their formation and evolution are not well understood. Using a newly suggested magnetic braking prescription to model the formation and evolution of ELM WD binaries via a stable mass transfer channel, we present the initial binary parameter space for the formation of ELM WD binaries and find that the He WD masses in these binaries are (0.11–0.21) M . In addition, we find that some ELM WD binaries can evolve into AM CVn binaries within the age of the Universe, and these binaries have He WD masses of (0.14–0.16) M . We also find that the gravitational wave signals from these binaries can be detected by space-borne gravitational wave observatories such as LISA, TianQin, and TaiJi. Finally, we discuss the impact of different mass accumulation efficiencies on the evolution of the same binary system, finding that it not only significantly affects the final mass of the primary star but also has little impact on the donor star and the binary evolution process.

Key words: white dwarf; close binary; AM CVn binary; gravitational wave

3. Results

3.1 Examples of Binary Evolution

We present two illustrative cases of binary evolution. The first example begins with a 1.2 M primary and a 0.9 M secondary in a 9-day orbit, while the second starts with a 1.2 M primary and a 0.9 M secondary in a 13-day orbit. Through stable mass transfer, these systems evolve to form extremely low mass white dwarfs of approximately 0.161 M with final orbital periods ranging from 0.132 to 0.303 days, entering the AM CVn binary regime.

[Figure 1: see original paper]

3.2 Parameter Space for Forming ELM WD Binaries

The initial parameter space that can produce extremely low mass white dwarf binaries spans primary masses from 1.0 M to 1.40 M , with some cases extending to 1.50 M . These systems produce helium white dwarfs in the mass range (0.11–0.21) M . The upper mass limit for helium white dwarfs in these configurations is approximately 0.22 M .

[Figure 2: see original paper]

3.3 He White Dwarf Mass-Orbital Period Relation

The relationship between helium white dwarf mass and binary orbital period is shown in comparison with previous studies. Our results are consistent with the population studies of Brown et al. [33, 34] and the theoretical work of Lin et al. [35], while differing from the earlier models of Tauris & Savonije [36] for the lowest mass systems.

[Figure 3: see original paper]

4. Discussion

4.1 Formation of AM CVn Systems

Some of the extremely low mass white dwarf binaries can evolve into AM CVn systems within the age of the Universe. These progenitor systems typically have helium white dwarf masses in the range (0.14–0.16) M , consistent with the predictions of Tauris [19] for the stable mass transfer channel.

4.2 Properties as Gravitational Wave Sources

The resulting close binary systems with orbital periods below approximately 0.3 days are strong gravitational wave sources. The characteristic strain of these systems falls within the detection band of space-based interferometers such as LISA, TianQin, and TaiJi, making them important targets for future gravitational wave astronomy.

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Note: Figure translations are in progress. See original paper for figures.