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Exploring formation of ultra-massive carbon-oxygen white dwarfs

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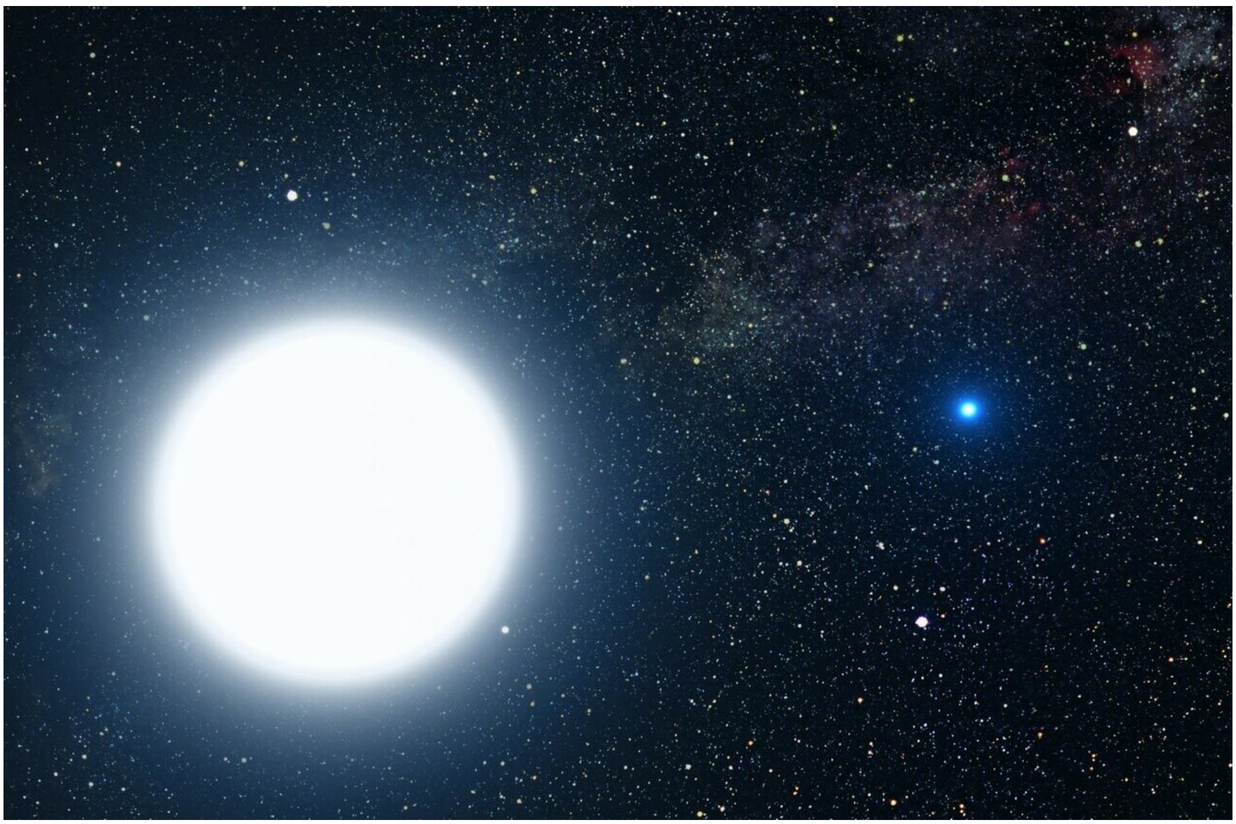

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White dwarf stars (WDs) are the most numerous members of the stellar graveyard. It is widely accepted that more than 97% of the stars in the universe will evolve into WDs. These numerous objects are considered a powerful tool to understand the formation and evolution of stars, the history of our galaxy and stellar populations.

In a study published in *Monthly Notices of the Royal Astronomical Society*, a research group led by Assistant Professor Wu Chengyuan from Yunnan Observatories of the Chinese Academy of Sciences investigated the formation of ultra-massive carbon–oxygen white dwarfs (UMCOWDs).

According to stellar evolution models, WDs with masses lower than about 0.45 $M_\odot$ are helium (He) WDs, and those with masses between 0.45 and 1.05 $M_\odot$ are carbon–oxygen (CO) WDs. WDs with masses larger than 1.05 $M_\odot$ may harbor oxygen–neon (ONe) cores and are usually called ultra-massive WDs (UMWDs).

"The UMWDs play a key role in our understanding of type Ia supernova explosions, the occurrence of physical processes in the asymptotic giant-branch phase, the existence of high-field magnetic WDs and the occurrence of double WD mergers," said Wu.

Recently, Gaia data have revealed an enhancement of UMWDs on the Hertzsprung–Russell diagram, which indicates that an extra cooling delay mechanism such as crystallization and elemental sedimentation may exist in UMWDs. Further studies have suggested that some UMWDs should have experienced fairly long cooling delays, implying that they are CO WDs. However, the formation mechanism of these UMCOWDs is still unclear.

In this study, the researchers investigated whether the mergers of massive CO WDs with He WDs can evolve to UMCOWDs. The results of 3D dynamical simulations on the double WD mergers show that the double WD merger is a very rapid process which can form a hot corona on the primary WD. "In order to construct the initial structures of the merger remnants, we adopted fast accretion method to simulate the merger process in 1D models, and obtained the remnant structures similar to those in 3D models," said Wu.

After constructing the structures of the merger remnants, the researchers found that the post-merger evolution of the remnants is similar to R Coronae Borealis (R CrB) stars. The helium burning of the He shell leads to mass growth of the CO core. The final CO WD mass is influenced by the wind mass-loss rate during the post-merger evolution, and cannot exceed about 1.2 $M_\odot$. Remnants with core masses larger than 1.2 $M_\odot$ will experience surface carbon ignition, which may finally end their lives as ONe WDs.

The current results imply that at least some UMWDs that experience extra-long cooling delays may stem from the merging of CO WDs and He WDs.

More information: Chengyuan Wu et al, Formation of ultra-massive carbon–oxygen white dwarfs from the merger of carbon–oxygen and helium white dwarf pairs, *Monthly Notices of the Royal Astronomical Society* (2022). DOI: 10.1093/mnras/stac273

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