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THE CARBON CONTENT IN GALACTIC RING NEBULAE: CNO NUCLEOSYNTHESIS IN MASSIVE STARS

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We have determined C abundances in two Galactic ring nebulae. The C enrichment patterns are really puzzling, showing C overabundances that do not fit the predictions of stellar evolution models.

An interesting group of ring nebulae is that presenting chemical traces of processed stellar material, which today are thought to be blown by the stellar progenitors of long-duration γ-ray burst (e.g. Gräfener et al. 2012). Observational studies have shown these ring nebulae have overabundances of He and N, and a deficiency of O (e.g. Esteban et al. 1990, Stock et al. 2011). This enrichment pattern is consistent with the CNO cycle, the main nuclear reactions working in massive stars along the main sequence (MS). However, the lack of reliable determinations of C abundances in any ring nebulae has hindered for decades the full knowledge of the CNO cycle trace.

We present observations of the ring nebulae NGC 6888 (Mesa-Delgado et al. 2013) and NGC 7635 (Mesa-Delgado & Esteban 2010). The C II 4267 Å recombination line was detected (Fig. 1), allowing us to investigate the C/H ratio in both objects. The results show C abundances of about 0.4 dex higher than the expected from the Galactic C gradient. Stellar evolution models do not predict a C enhancement in the evolution phase of the central stars when the nebular material was ejected. NGC 7635 is an interstellar bubble blown by the massive MS star BD+60^o 2522 (O6.5 IIIef; Dawanas et al. 2005) and thus a pollution of C processed by this star is very unlikely. In contrast, NGC 6888 represents material ejected in the post-MS stages of the WN6 star WR136 (van der Hucht 2001). The only way to understand the strong C enrichment in the outer layers of the stellar progenitor of NGC 6888 is that a rotational-induced dredge-up of processed C took place earlier in the evolution of the central star, even before starting the WR phase. Another possible explanation may be the destruction of carbon-rich dust by the shocks associated with the expanding wind-blown bubble (Moore et al. 2002). Further investigation is required making use of the state-of-the-art spectrographs in 10 m telescopes and space-borne observatories.

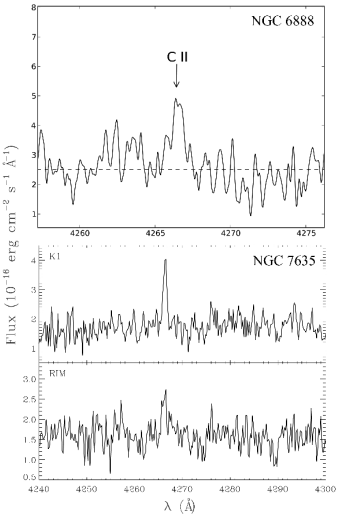

Fig. 1. Detections of the C II 4267 Å recombination line in NGC 6888 and NGC 7635. The dashed line corresponds to the average local continuum used to measure this line in NGC 6888. In NGC 7635, the line was detected in the knots to the west of the central star (K1) and the rim of the bubble (RIM).

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