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TWO RINGS BUT NO FELLOWSHIP: LOTR 1 AND ITS RELATION TO PLANETARY NEBULAE POSSESSING BARIUM CENTRAL STARS

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LoTr 1 is a planetary nebula thought to contain an intermediate-period binary central star system (orbital period, P ∼ 100–1500 days). The system shows the signature of a K-type, rapidly rotating giant, and most likely constitutes an accretion-induced post-mass transfer system similar to other PNe such as LoTr 5, WeBo 1 and A70.

Such systems represent rare opportunities to further the investigation into the formation of barium stars and intermediate period post-AGB systems – a process still far from being understood. Here, we present the first detailed analyses of both the central star system and the surrounding nebula of LoTr 1 using a combination of spectra obtained with VLT-FORS2, AAT-UCLES and NTT-EMMI, as well as SuperWASP photometry.

From the study presented here, we have been able to show that LoTr 1 possesses a double-shelled, slightly elliptical morphology of age of 35,000±7,000 years for the outer shell, and 17,000±5,500 years for the inner. We have been able to infer the presence of a K1 III-type giant ($t_{\rm eff} \sim 4500$ K) and hot white dwarf ($t_{\rm eff} \sim 123$ kK, R = 0.017 $R_\odot$) binary system at its core. The cool star has been shown to be kinematically associated with the nebula, and to have a rotation period of 6.4 days. Although it was not possible to accurately determine the [Ba/Fe] value for the central star system, we were able to say with confidence that LoTr 1 does *not* show any evidence for an over-abundance of Ba II.

Unlike LoTr 1, the PNe A70 and WeBo 1 have both been previously confirmed to contain a Ba II-enriched central star system at their core (Miszalski et al. 2012; Bond et al. 2003). The two nebulae are also shown here to display morphologies distinct to that of LoTr 1, with both possessing ring-like waists and possible extended lobes. The similar morphologies and chemical enrichment strongly imply that the two have undergone very similar evolutionary or mass-loss processes. It is possible that the wind-accretion process involved in the formation of Ba II stars is also responsible for the formation of these ring-like morphologies. Although the CSPN of LoTr 1 does share some common traits with those of A70 and WeBo 1 – namely binarity with a hot- and cool-components, and rapid rotation of the secondary – both the lack of a significant over-abundance of Ba II and the marked difference in nebular morphology would imply a difference in the evolution of this system. The lack of Ba II enhancement could be explained by a difference in progenitor mass, metallicity, or simply quantity of mass transferred via the same wind-accretion process (the amount of material accreted is strongly dependent on orbital separation – Boffin & Jorissen 1988). However, as shown by Boffin & Zacs (1994) only a small amount of matter is needed to be accreted to make a star appear as a barium star and some mass must have been transferred as it is required in order to spin up the secondary to its rapid rotator state. The most obvious explanation, therefore, is that the mass was transferred at an earlier stage in the evolution of the primary, i.e. before the thermally-pulsing AGB phase, when the s-process elements are created and brought to the surface. This would allow us to infer that the AGB evolution of the primary was cut short by this mass-transfer episode, signs of which should be detectable in the properties of the WD. We strongly encourage follow-up observations of the system in order to confirm this hypothesis, and in particular it would be crucial to determine the orbital period of these systems.

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