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Possible trends in expansion velocities of planetary nebulae evolved from common envelope binary systems

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1. Introduction

Planetary Nebulae (PNe) are the shells of gas ejected from intermediate mass stars during their late stages of evolution. The nebular ejection takes place through a 'superwind' in the case of a progenitor AGB star evolving as a single entity or in a detached binary system. For an AGB star in an interacting binary system of separation $\leq 1500\ R_{\odot}$, however, the nebular ejection occurs through the Common Envelope (CE) which forms when the giant star engulfs its main sequence companion by expanding beyond its Roche lobe. In the latter case the orbital energy of the secondary is deposited in the common envelope surrounding the binary which causes the ejection of the envelope bringing the cores closer. From hydrodynamical calculations done earlier (Volk & Kwok 1985), it can be seen that the nebular expansion velocity (V_{exp}) depends critically on the mass-loss rates. We examine here the difference in mass- loss rates in the two cases and find out if such a difference leads in turn to a substantial difference in V_{exp}.

2. Expansion velocity in PNe formed from close binaries

The life-time of the superwind phase in an isolated AGB star is approximately a few thousand years during which the star loses $\simeq 0.1\ M_{\odot}$ only, whereas, the CE ejection event causes the removal of a considerable fraction of the progenitor mass during the same duration causing a larger mass - loss rate than the superwind. Hydrodynamical calculations show that the higher the progenitor mass-loss rate the lower would be the nebular expansion, assuming that all other conditions are identical. Here we compare these theoretical predictions with the observed values of V_{exp} of PNe with central stars which are confirmed/suspected binary systems. Table 1 shows observed V_{exp} of PNe with close binary, spectroscopic binary and detached binary nuclei which are listed in the ESO catalogue of galactic PNe (Acker et al. 1992). The samples given in the Table 1 are complete as listed in the catalogue. The binarity nature of A 78, NGC 1360, NGC 1514, NGC 3132, NGC 6543, He 1 - 5, IC 418, IC 4406 are taken from Livio (1982). Fig 1 shows a histogram of expansion velocities for the PNe evolving from CB (lower panel) and the detached binaries (upper panel). The doubtful cases were shown as shaded regions. The figure shows a tendency of lower V_{exp} for PNe with CB nuclei than those with SB/VB systems.

Table 1. Expansion velocities of some selected PNe having binary nuclei

Close Binary		Spectroscopic Binary		Visual Binary	
Nebulae	V_{exp}(km/s)	Nebulae	V_{exp}(km/s)	Nebulae	V_{exp}(km/s)
HFG 1	13	Vy 1-1 ?	10	A 24	14
HaTr 4	13	A 36	36	A 30	40
LoTr 5	27	NGC 4361?	32	A 33	32
A 35	4	NGC 6826?	11	NGC 246	39
A 65	11	Hu 1-1 ?	16	NGC 650 - 1	39
A 78?	27			NGC 3132?	15
NGC 1360?	28			NGC 6853	15
NGC 1514?	25			IC 4406?	6
NGC 2346	8				
NGC 6543?	20				
He 1-5?	34				
SP 1	29				
IC 418?	6				

(PNe marked with '?' are having as-yet-unconfirmed close binary / spectroscopic binary / detached binary nuclei)

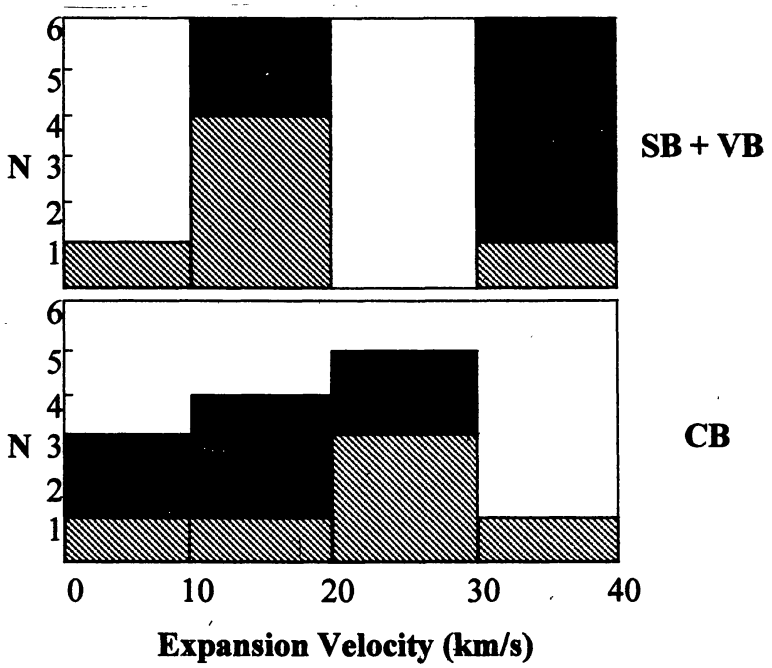

Figure 1. A histogram of the number (N) of planetary nebulae (PNe) having different V_{exp}. CB stands for the PNe with close binary nuclei and SB+VB stands for those with spectroscopic / visual binary nuclei.

As shown in the table, PNe with confirmed close binary have V_{exp} not more than $\simeq$ 30 km/s. It can also be seen from the table that PNe with detached binary core have V_{exp} upto 40 km/s, and those with confirmed/suspected spectroscopic binary nuclei (which may either be close binaries or detached binaries) and suspected close binary nuclei are more oriented towards lower expansion. In comparison, the PNe with single core have expansion velocities upto $\simeq$ 55 km/s. We must note here that the observed V_{exp} values are line-of-sight averaged and further that there may be considerable uncertainty regarding the age and the distance of the PNe.

Of all the 1820 true or probable or possible PNe appearing in the ESO catalogue, only about 60 objects can be separated out to have either confirmed or suspected binary nuclei. Of these 60 objects, the V_{exp} is measured only for 28 objects, which are presented here. This underscores the necessity for continued efforts towards the expansion velocity measurements of PNe. Eventhough the sample may not have enough statistical significance, there is certainly a trend in the V_{exp} data that goes in support of the theoretical expectation.

Further, in an attempt to explain the morphologies of PNe with a unified approach, Yungelson et al. (1993) argued that all the PNe could in principle evolve from binary systems. Even in such a case, the mass-loss leading to the formation of PN in detached binaries is by superwind mechanism (like in the case of a single star) and is significantly lower than those in close binaries (CE ejection events), and hence should lead to a higher V_{exp}.

3. Conclusions

PNe formed out of close binary systems seem to show a tendency for lower values of V_{exp} from the survey of limited but complete sample of PNe having confirmed or suspected binary nuclei. However, this requires to be substantiated from further V_{exp} observations. This observational trend can be understood from the fact that in these systems the mass-loss rate during the CE phase is much higher than the superwind mass-loss rates in the case of single stars. The present study, if confirmed, shows that V_{exp} may be used as a handle to discriminate between the two classes of progenitors of PNe.

References

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