FORMATION OF A PLANETARY NEBULA BY CONTINUOUS MASS LOSS

A. Harpaz, A. Kovetz
Tel Aviv University

The evolution of a 1.2M⊙ star along the asymptotic branch with continuous mass loss is presented, showing that this mass loss leads to the formation of a PN with a typical central star in its center.

A former investigation (Harpaz and Kovetz, 1980) has shown that mechanisms for PN creation based on sudden violent processes are not likely to work in the envelope of a red giant star. On the other hand, significant mass loss from red giants was observed as a general phenomenon.

We have followed the evolution of a 1.2M⊙ star along the asymptotic branch, including in the evolutionary calculations a mass loss according to Reimers' empirical formula. It was found that towards the end of this stage, the mass loss rate was about 2.7×10^{-6} M⊙/y, which is consistent with the formation of a typical PN within 30,000 years. When the mass content of the hydrogen rich envelope dropped to 1.5×10^{-3} M⊙, the star began to contract rapidly, forming a typical central star of 0.6M⊙.

REFERENCE :

Harpaz, A., Kovetz, A.: 1980, submitted to Astronomy and Astrophysics.

DISCUSSION

PERINOTTO: Would you please comment on the different morphology we observe in planetary nebulae, say, uniform objects with no central hole, single shell or multiple shell planetary nebulae, in terms of the mechanisms you have discussed?

KOVETZ : The form of the nebula cannot be determined on the basis of the evolutionary calculation I have described. It is just mass lost to the star. There is, e.g. the possibility that $\dot{M}$ will decrease fol-

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lowing a shell flash (because L may decrease), which may lead to multiple shell nebulae, but I cannot advocate this seriously.

RENZINI: The time required by your model to evolve from the AGB to the PN region is extremely different compared to that obtained by Schönberner (1979, A.A. 73, 108). Could you comment on this point? In particular, which was the envelope mass of your model at t= 0 along the post-AGB track?

KOVETZ: So long as the stars evolves along the AGB the mass loss rate goes up, because L does. Our model reached $L \simeq 6400\ L_\odot$ with $\dot{M} = 2.7 \times 10^{-6}\ M_\odot/y$ and envelope $m = 0.0015\ M_\odot$. This was the tip of the AGB for our model, and when this was reached, it moved quickly to the left. There was no slow horizontal evolution. I have not been able to compare notes with Schönberner.

NUSSBAUMER: In answer to Perinotto: The observed double shell planetary nebulae are not necessary in contradiction to the possibility of planetary nebula formation by prolonged mass loss as opposed to a sudden ejection. With our present knowledge or ignorance, we cannot exclude the possibility that a high mass loss rate is for a while reduced before being increased again; this could lead to multiple shells.

KOVETZ: I agree. This is essentially the answer I have given to Perinotto's question.

MENDEZ: From your calculations, would you say that the remnant central star must necessarily retain a H-rich envelope, or is it theoretically possible to eject the H-rich envelope completely?

KOVETZ: Our calculations have used Reimers' $\dot{M}$ formula. According to this, $\dot{M}$ decreases sharply along the post- AGB track (both R and L go down), so some H-rich envelope remains. This need not be realistic. There is no reason to suppose that Reimers' law applies to NPN. Whether another kind of mass loss operates, I do not know.