FAR INFRARED CIRCUMSTELLAR "DEBRIS" SHELLS: CLUES TO THE EVOLUTION OF MASSIVE STARS?

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ABSTRACT: A survey of the infrared properties of late-type supergiant stars, using the IRAS database, reveals that about 25% of the stars possess resolved, extended circumstellar shells. These shells are typically several arc minutes in apparent size and therefore on the scale of parsecs at the source. Furthermore, among the resolved sources, there is an inverse correlation between physical size of the infrared shell and B–V color, suggesting that these shells are formed while the objects are red supergiants, but continue to expand ballistically, while the star evolves blueward from that extreme. These shells may be the material swept up into ring nebulae when the central star develops a fast wind.

1. Introduction

Despite the comparatively coarse angular resolution of the *Infrared Astronomy Satellite* (IRAS), it is now known that it resolved a number of stellar sources. Perhaps the most extreme example is the peculiar G supergiant variable R CrB, where the 18 arc-minute far infrared shell was estimated to contain between 0.2 and 6 $M_{\odot}$ of material (Gillett et al. 1986).

The survey of the infrared properties of late–type supergiants in the catalog of Humphreys (1978) by Stencel, Pesce and Bauer (1988, 1989) found that many late–type supergiants show evidence for dust in their infrared flux distribution, and that about 25% are resolved at 60μm. More importantly, among the resolved sources, the physical extent of the multi–arc-minute infrared shells appear to be largest among the supergiant stars with smallest B–V color.

2. Discussion

We argue that this observation is significant for understanding the evolution of massive stars, perhaps including the LBV stars, for the following reasons. The LRS data indicate that the dust forming phase is most efficient while the star is at the reddest extreme of its evolutionary track, based on the presence of the 10μm silicate feature. This and the inverse correlation with B–V color suggest that the resolved, infrared shell is the debris of that phase of evolution when dust forming occurred, and the subsequent expansion is simply ballistic. The multi–parsec sized shells among the G and F supergiants require $\sim 10^5$ years

K. Davidson et al. (eds.), Physics of Luminous Blue Variables, 293–294.

to expand at 20 km/sec, the typical red supergiant wind velocity.

As the star continues its blueward evolution, ultimately the radiation field of the star should begin to alter the infrared characteristics of the debris shell, in the sense of first dissociating, then ionizing and shocking the inner material as a function of the surface temperature and stellar wind characteristics of the central star.

Van Buren and McCray (1988) have discussed the infrared shells of various early–type stars, and described several bow wave situations where the wind and stellar motion are subsonic (e.g. δ Per, B5 III) and the resoved infrared shell shows a bow wave shape. An expanded survey of A and F type supergiants may reveal similar structures. At the extreme, the galactic Wolf–Rayet ring nebulae (Chu et al. 1983), which share similarities in physical size and material content with the debris shells of late–type stars, could be the evolutionary consequence of the continued evolution of the central, massive star within such a structure. The analogy with lower mass stars that form planetary nebulae, is difficult to resist.

McGregor et al. (1988) in their study of the infrared emission from the ring surrounding the galactic S Doradus variable AG Car conclude that the ring structure is most likely due to material that was lost by AG Car during a prior evolutionary phase and subsequently swept up bv the present hot superwind phase. Similarly, the optical and ultraviolet light echoes of Supernova 1987A are beginning to reveal the evolutionary history of the stellar wind in that former star. In principle, therefore, a more complete survey of the optical and infrared structures of intermediate spectral type objects may reveal an important evolutionary link between red and blue phases for 30 to 60 $M_{\odot}$ stars, perhaps along the lines of suggestions by Lamers et al. (1983). Such infrared inventories of OB Associations are underway by Stencel, MacConnell and others.

We are grateful for partial support of this research from NASA grants JPL 957632 and NAG5-816 to the University of Colorado.

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