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GALACTIC TWINS OF THE RING NEBULA AROUND SN1987A AND A POSSIBLE LBV-LIKE PHASE FOR SK-69 202

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RESUMEN

Algunas supernovas de colapso de núcleo muestran señales evidentes de interacción asimétrica con el material circunestelar denso. Las nebulosas circunestelares alrededor de progenitores de supernova proveen información acerca del origen de dicha falta de simetría en la evolución inmediata de la pre-supernova. En esta contribución discutiré las preguntas sobresalientes respecto a la formación de la nebulosa anular alrededor de SN1987A y las implicaciones de la presencia de nebulosas anulares similares alrededor de supergigantes B de nuestra Galaxia. Varios indicios sugieren que la nebulosa de SN1987A puede haber sido eyectada en un evento de tipo LBV en vez de a través de vientos interactuantes en una transición de supergigante roja a supergigante azul.

ABSTRACT

Some core-collapse supernovae show clear signs of interaction with dense circumstellar material that often appears to be non-spherical. Circumstellar nebulae around supernova progenitors provide clues to the origin of that asymmetry in immediate pre-supernova evolution. Here I discuss outstanding questions about the formation of the ring nebula around SN1987A and some implications of similar ring nebulae around Galactic B supergiants. Several clues hint that SN1987A's nebula may have been ejected in an LBV-like event, rather than through interacting winds in a transition from a red supergiant to a blue supergiant.

Key Words: circumstellar matter — stars: evolution — stars: winds, outflows — supernovae: individual (SN1987A)

It is commonly assumed that bipolar nebulae consist of slow ambient material that is swept-up by the faster wind of the hot supergiant. To create the bipolar shape, the surrounding slow wind must have an equatorial density enhancement (i.e. a disk); the consequent mass loading near the equator slows the expansion and gives rise to a pinched waist and bipolar structure. However, it's unclear how the required pre-existing disk could have been formed. One does not normally expect RSG or AGB stars to rotate rapidly, so a disk-shedding scenario probably requires the tidal influence of a companion during prior evolutionary phases in order to add sufficient angular momentum. In the case of SN 1987A, a binary merger would be required for this particular scenario to work (Collins et al. 1999). However, there are reasons to question this binary merger scenario for the formation of SN1987A's nebula:

1. A merger model followed by a transition from a RSG to BSG requires that these two events be synchronized with the supernova event itself, requiring that the best observed supernova in history also happens to be a very rare event. One could easily argue, though, that the merger and the blue loop scenario might not have been invented if SN1987A had occurred in a much more distant galaxy where it would not have been so well-observed (i.e. we wouldn't know about the bipolar nebula or its BSG progenitor).

2. After the RSG swallowed a companion star and then contracted to become a BSG, it should have been rotating at or near its critical breakup velocity. Even though pre-explosion spectra (Walborn et al. 1989) do not have sufficient resolution to measure line profiles, Sk–69°202 showed no evidence of rapid rotation (e.g., like a B[e] star spectrum).

3. Particularly troublesome is that this merger and RSG/BSG transition would need to occur twice. From an analysis of light echoes for up to 16 yr after the supernova, Sugerman et al. (2005) have identified a much larger bipolar nebula with the same axis orientation as the more famous inner triple ring nebula. If a merger and RSG/BSG transition are to blame for the bipolarity in the triple-ring nebula, then what caused it in the older one?

Perhaps a more natural explanation would be that Sk–69°202 suffered a few episodic mass ejections analogous to LBV eruptions in its BSG phase (see Smith 2007). The B[e] star R4 in the Small Magellanic Cloud may offer a precedent at the same luminosity as the progenitor of SN1987A; R4 is con-

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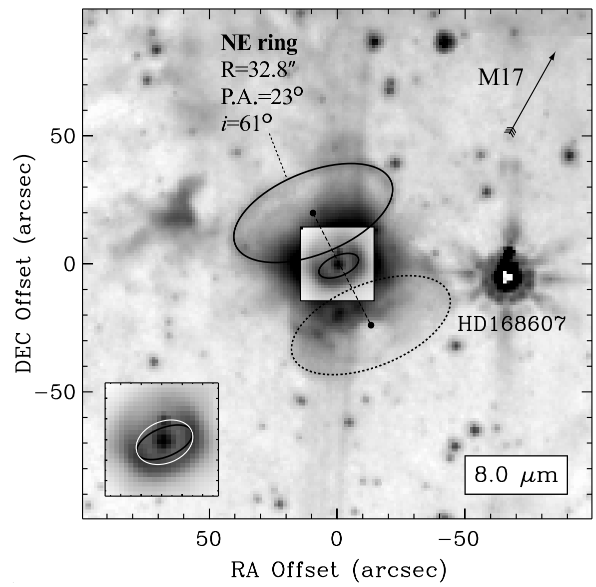

Fig. 1. An 8 μm Spitzer/IRAC image of the LBV candidate HD168625 from Smith (2007). It shows a nebula with a geometry very much like that around SN1987A, but in this case the bipolar shape probably originated in the ejection by the central LBV star and not from interacting winds.

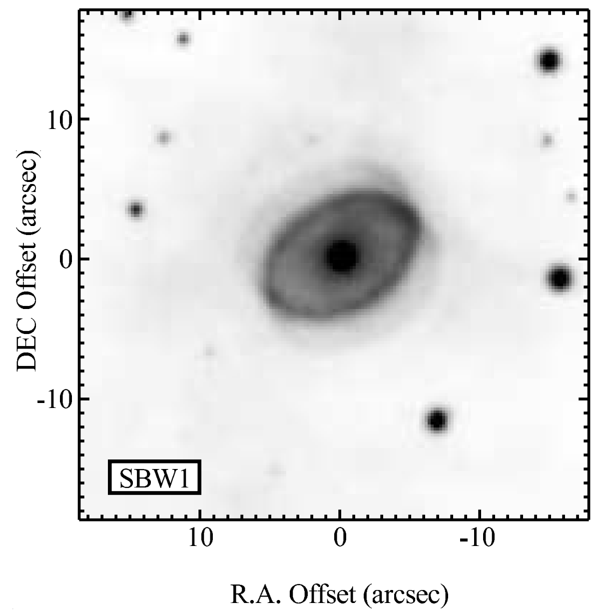

Fig. 2. An Hα image of the ring nebula SBW1 in the Carina Nebula, surrounding a B1.5 Iab supergiant. It has the same radius as the ring around SN1987A and the star has the same luminosity as the progenitor of SN1987A, but it has solar N abundance, indicating that it has not yet been a RSG.

sistent with a 20 $M_\odot$ evolutionary track, and it experienced an LBV outburst in the late 1980's (Zickgraf et al. 1996). R4 also has elevated nitrogen abundances comparable to the nebula around SN 1987A.

We can gain further insight to the formation of SN1987A's ring nebula and its pre-SN evolutionary state by studying analogs of it around massive stars in our own Galaxy. Three close analogs in the Milky Way are currently known:

Sher 25 in NGC3603: HST images of this B1.5 supergiant show a remarkable equatorial ring with the same radius as the one around SN1987A, plus bipolar ejecta (Brandner et al. 1997). Although the nebula has moderate N-enrichment, Smartt et al. (2002) find that the N abundance is too low to be the result of post-RSG evolution. In fact, the stellar luminosity is above the limit where no RSGs are seen. Thus, the nebula around Sher 25 did not form from interacting winds during a RSG-BSG transition.

HD168625 near M17: This LBV candidate has a luminosity closer to the progenitor of SN1987A than Sher 25. Its nebula has an equatorial ring, and it is the only object known so far to also show polar rings like SN1987A (Figure 1; see Smith 2007). It is therefore our Galaxy's closest analog to the progenitor of SN1987A. Its LBV status is interesting, since LBVs are known to have eruptive episodes of high mass loss (e.g., Smith & Owocki 2006) and are often surrounded by bipolar nebulae. Based on the properties of the nebula, I have argued (Smith 2007) that the nebula was probaby ejected as an LBV.

SBW1 in the Carina Nebula: This equatorial ring nebula (Figure 2) also has the same 0.2pc radius as the one around SN1987A, and the central B1.5 supergiant has essentially the same luminosity as Sk-69°202. It is seen in the Carina Nebula, but it is probably more distant, at ~7kpc (Smith et al. 2007). Its nebula shows no evidence for N-enrichment; the N abundance is roughly solar (Smith et al. 2007). Thus, the star has never been a RSG either.

Of the three examples of ring nebulae around BSGs that are our Galaxy's closest known analogs to the nebula around the progenitor of SN1987A, two could not have been red supergiants because of their chemical abundances, and one was ejected as an LBV. Thus, of the three examples known, *none* were formed by interacting winds during a RSG to BSG transition. This proves that there must be some other physical mechanism that can eject equatorial rings and bipolar nebulae. The best candidate is an intrinsically bipolar ejection by a rotating LBV, or an episodic mass ejection analogous to LBV outbursts. The star does not necessarily need to have a high angular velocity, as the effects of rotational shaping can be enhanced in a star with even moderate angular speed if it is near the Eddington limit. This also hints that SN1987A and other type II SNe with circumstellar material did not necessarily transition recently from the RSG phase; instead, they may have been in an LBV-like phase before explosion. If LBVs can be SN progenitors, it puts a rather embarassing spotlight on our current lack of an explanation for the LBV instability.

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DISCUSSION

R. Barbá - A question and a comment. In the SW part of the Carina Nebula (where a cavity-like structure is observed) several [SII] tiny filaments appear. Could they be related to previous SNe?

N. Smith: Well, there are some hints about that. First, Carina has bright extended soft X-ray emission over a large part at the nebula, and there are indications that the abundances may be peculiar. Second, there are some high-velocity absorption components seen in high resolution spectra of stars across much of the nebula, which Nolan has worked on. So it could be the case that there has already been a SN in Carina (but the star would have had a larger initial mass than Eta Car, presumably).

Elena enjoying a break after lunch.