A Symmetric Bipolar Nebula Around MWC 922

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The Be star MWC 922 has previously been noted for its spectral features: unusually strong forbidden [Fe II] in emission (*1*) and more recently the dust mineralogy and chemistry of its rich infrared spectrum (*2*). The distance to this object is unknown (it may lie within the Ser OB1 association at 1.7 kpc), as is its evolutionary status (both pre- and postmain sequence have been suggested).

Here, we report high angular resolution observations in the infrared H band made with the adaptive optics system on the 200" Palomar telescope [detailed further in (*3*)]. An image showing the extended Red Square nebula surrounding MWC 922 is given in Fig. 1, together with a highpass filtered image that reveals underlying structural elements and a model describing the key features. The box-shaped X structure necks down into twin opposing hyperbolic bicones separated by 0″.34 at the center, where they are crossed by an equatorial dark band running northeast to southwest. Along the principle axis of symmetry (PA = 46°), a remarkable series of orthogonal linear rungs appear at 1″.77 and 3″.1 arc sec (northwest bicone) and at –1″.44 and –3″.2 arc sec (southeast bicone). Where the rungs meet the bicone surfaces, we find bright vortices that subtend an opening angle of 105° at the origin.

In addition, we have established the presence of a series of radial linear features resembling a comb and appearing to lie along both bicone surfaces between the second bright rung and the outer edge of the nebula. One possibility is that the comb may be the outcome of a projected illumination effect as light from the central regions is blocked by some periodic structure en route to the outer bicones. An example could be shadows cast by "ripples" on the rim of a circumstellar disk, such as those believed to result from gravitational or other excitation of standing-wave modes (*4*), although high azimuthal orders ($l \sim 50$) are required.

Among the most notable properties of this nebula is the extent to which structures are reflection-symmetric about the principle axis. This symmetry and linearity of the rungs implies that the viewing angle onto this system axis is very close to 90°. It seems likely that this appearance depends on this critical alignment, whereas the regularity of form argues against a premain sequence identity. A weaker (although still notable) symmetry exists across the equator between structures in the northwest and southeast bicones, with perhaps the largest departure being the axial displacement of the innermost rung, which appears 20% further out in the northwest than the southeast bicone. This high degree of correspondence between structures in the two bicones argues for common creation in episodic eruptions within the central star system. This result also has implications for other bipolar systems, such as the Red Rectangle, where direct correspondence between pairs of rungs in the two bicones could not be established (*5*), arguing against models with one-sided mass ejections.

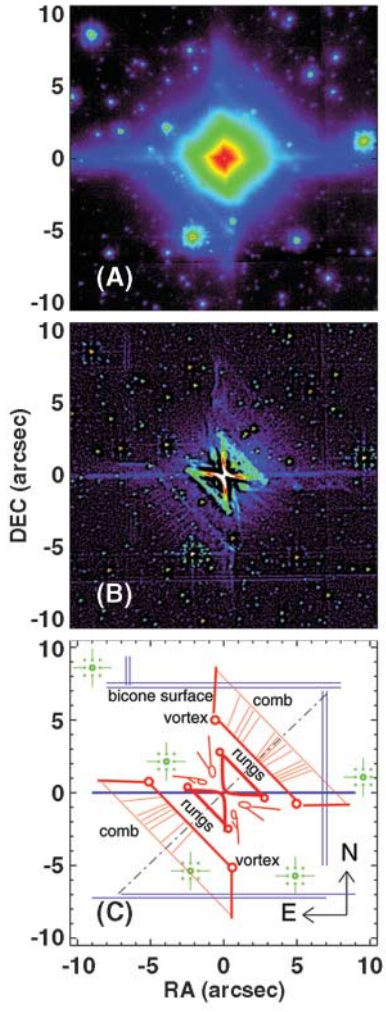

Fig. 1. MWC 922 from Palomar H-band adaptive optics imaging: (**A**) image at a logarithmic color stretch, (**B**) image data after Laplacian filtering to accentuate structure [such as edges; see (*3*) for details], and (**C**) model skeleton structural elements fitted to the Laplacian filtered image. This model also depicts spurious linear features from imperfect mosaicing and charge persistence (blue) and bright neighboring stars (green), whereas real Red Square nebula structures are plotted in red. The system's principal symmetry axis is given as a dot-dashed line, together with a compass rose and annotations labeling key features in black. DEC, declination; RA, right ascension.

Adopting the (speculative) distance of 1.7 kpc, the linear size of the Red Square is twice as large as the Red Rectangle at the same dynamic range in surface brightness. If we further speculate that outflow velocities are not dissimilar [~7 km/s (*5*)], then the dynamical ages of the two major rung systems are ~3000 and 6000 years. However, given the significantly hotter spectrum of MWC 922's central star [B3-B6 (*6*)] as compared with the Red Rectangle [peculiar A supergiant in a 319-day binary (*5*)], basic parameters such as wind speeds may differ substantially. The finding of a cousin to the Red Rectangle, but with differing spectrum and a hotter central star, implies that the conditions of formation for these elegant bipolar ladders may not be so singular and unique as formerly thought.

The clearly demarked narrow rungs reported here places MWC 922 in rare company with only two other known systems [Sher 25 and HD168625 (*7*)] that support ringed bipolar nebulae, structures which make them viable progenitors for polar ring systems like that seen in SN1987A. As the only one of the three to exhibit multiple rings and a wealth of other forms, MWC 922 should make an excellent laboratory for the study of the creation of such structures.

References and Notes

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8. We thank Palomar Observatory and its dedicated staff for help with the observations.

Supporting Online Material

www.sciencemag.org/cgi/content/full/316/5822/247/DC1
Materials and Methods
References

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