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The Nebula Surrounding the B[e] Supergiant R4

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Abstract. New, NTT observations of the B[e] supergiant RMC4 in the Small Magellanic Cloud show that the star is embedded in a circumstellar nebula, whose velocity structure is typical of a bipolar outflow. The nebula is kinematically associated with RMC4 and expanding at 100 km/s on average. Its diameter as computed from the spatial extension of its spectral lines is of 8.6″ which corresponds to a linear size of 2.4 pc and gives a dynamical age of 12500 yr. The line ratio [NII]λ6584/[SII]λ6717 indicates that the nebula is nitrogen enriched as it is expected for ejected nebulae. This is the first bipolar outflow detected around a well-established B[e] supergiant which also belongs to a binary system. The nebular morphology and chemistry are consistent with the picture of a binary merger in which RMC4 was composed by a close pair and a third star (the observed companion). The close pair merged into a single star (the present B[e] supergiant) and produced a circumstellar nebula to be later shaped by the ensuing B star wind (cf. Langer & Heger 1998).

1. Introduction

RMC4 has been classified as a B[e] supergiant by Zickgraf et al. (1986). B[e] supergiants are characterized by the simultaneous presence of strong Balmer emission lines and narrow, permitted and forbidden lines of heavy elements such as iron. Moreover, they display an infrared excess which is usually attributed to dust emission. Zickgraf et al. (1985) have explained these properties through a

two-component wind, where the polar and hot wind produces the high excitation lines observed in the UV and the equatorial and cool wind (probably in the shape of a disk) is responsible for the narrow lines. These objects are mostly identified in the Magellanic Clouds because of their known distance and very few galactic candidates have been suggested so far. Few B[e] supergiants exhibit properties typical of Luminous Blue Variables (LBVs): for example, S22 shows an intrinsic polarization of 0.52% in similarity with the galactic LBV HR Carinae, probably due to an aspherical stellar wind (Schulte-Ladbeck & Clayton 1993; Clampin et al. 1995). Moreover, S22 has been found to vary by a factor of 2 in the UV flux (Shore 1990); the amplitude of its UV variability well compares with what observed for LBVs (Pasquali & Nota 1999).
Do these data mean that B[e] supergiants and LBVs are evolutionary linked? The answer is still not clear. One way to investigate the occurrence of the LBV phase during the evolution of massive B stars is to detect the presence of circumstellar nebulae around B[e] supergiants and determine whether their properties are those of LBV nebulae. RMC4 has been the first target to be observed in this framework. Zickgraf et al. (1996) have shown that RMC4 is a binary system (a = 23 A.U.) composed by a B[e] supergiant with a LBV-like variability and an evolved A type companion which is 10 times less luminous.

2. Observations

We have observed RMC4 with EMMI mounted on the NTT telescope on the nights of July 27 - 30, 1998. We have acquired longslit spectra in the wavelength range 6240 Å - 6870 Å at three different positions: on the star, at 3″ North and 3″ South. The spectra have been reduced, wavelength-calibrated with the IRAF LONGSLIT package. The achieved spectral resolution is of 25 km/s at the Hα line and the wavelength calibration is certain at $\pm$ 10 km/s.

3. The nebular kinematics

All the acquired spectra are characterized by extended nebular emissions of [NII] $\lambda\lambda$6548, 6584 and [SII] $\lambda\lambda$6717, 6731. They define a nebular size of 8.6″ which corresponds to a diameter of 2.4 pc at the SMC distance of 57.5 kpc (van den Bergh 1989).
We have binned the spectra by a factor of 2 along the spatial axis (i.e. a step of 0.54″) and measured the peak wavelengths of the [NII] λ6584 line for each bin in order to obtain the radial velocities distribution as a function of distance from the star. At 3″ North the nebula is redshifted by 84 km/s with respect to the star whose systemic velocity is of 147 km/s (Zickgraf et al. 1996), while at 3″ South it is blueshifted by 118 km/s. We then conclude that the nebula is kinematically associated with the star. In particular, the velocity map at 3″ North displays two local maxima at $V \sim 130$ km/s at 2.5″ E and 1.5″ W and at these same positions the 3″ map shows two local minima around $V \sim -140$ km/s. The data thus indicate that the nebular expansion is symmetrical not only along the N-S axis but also in the E-W direction. This symmetry puts strong constraints on the morphology of the nebula, which can not be either a shell or a strictly bipolar outflow; we believe that the nebula may be constituted

by two bipolar outflows giving rise to a "cloverleaf" morphology. Future high resolution imaging will be devoted to confirm whether this speculation is correct.

4. Discussion

The longslit spectra collected for RMC4 clearly show that the star is surrounded by a bipolar nebula which is kinematically associated with the star, chemically enriched and with a dynamical age of ~ 12500 yr. Therefore, it is likely an ejected nebula whose properties are, moreover, comparable with the LBV nebulae (cf. Nota et al. 1995).

This is the first nebula detected so far around a well-established B[e] supergiant. Yet, RMC4 is a quite peculiar B[e] supergiant, since it belongs to a binary system where the companion is an evolved A-type star 10 times less bright (Zickgraf et al. 1996). Here is then the puzzle: in the time required for the companion to evolve into an A star, the progenitor of the B[e] supergiant would have gone through the supernova phase, while we still observe it as a B supergiant. Langer & Heger (1998) have thus suggested that RMC4 was originally a system comprising a close pair and a third star, the present A star. The close pair merged into one single star with a "disk" stellar wind (responsible for the B[e] spectral morphology) and the merger process produced a circumstellar nebula to be later shaped by the B star wind.

Our findings are all consistent with this scenario, therefore they make RMC4 the strongest observational evidence for merger of massive binaries. Futhermore, the similarity of the RMC4 nebula with LBV nebulae in terms of morphology, kinematics and chemistry implies that a number of LBV outbursts and nebulae may be due to the merging process of two massive stars.

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