An Hα Image of Nova V1500 Cygni Twelve Years After Outburst

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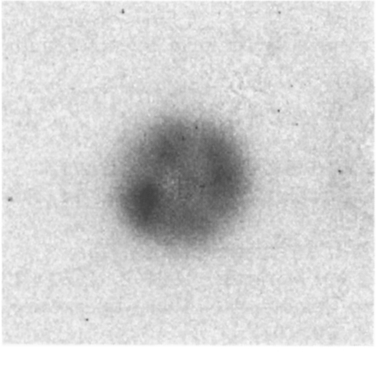
Observations and Analysis

We obtained a narrow band Hα image of V1500 Cyg during an engineering run at the R-C focus of the KPNO 4 m telescope on UT 1987 July 19. Our detector was an 800 × 800 format TI CCD, which yielded a plate scale of 0.1013 arcsec/pixel. The exposure was 2000 sec and was made through a 75 Å wide filter centered at 6563 Å. The seeing was $\sim$ 1.2 arcsec.

Our reductions were accomplished with the DAOPHOT photometry package (Stetson 1987) and IRAF data reduction facility. After performing standard bias level subtraction and flat field division, we used DAOPHOT to find the frame's normalized point spread function (PSF) by summing the images of several field stars. We then scaled the PSF to calculate the instrumental magnitudes of the stars and of V1500 Cyg. This procedure overestimates the brightness of the nova, since the nebula contributes extra light to the central object and modifies the expected intensity distribution. (This is especially true in the narrow Hα bandpass.) Hence, in a frame where the PSF has been used to remove the fitted images, all the stars have satisfactorily small residuals around the mean sky level, except the nova itself. The image of V1500 Cyg shows sky level at the center, but a halo that rises from the center and then falls away.

It is more plausible that the nebula does not fall to zero surface brightness at the center. We therefore arbitrarily adjusted the central star's magnitude until the residual between the scaled PSF and the original image showed a more-or-less flat radial profile. This required an adjustment of 0.15 ± 0.07 mag to the DAOPHOT-derived instrumental magnitude.



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Discussion

The figure shows the image of V1500 Cyg with the central star removed. The sky level is 45 ± 5 counts/pixel. Since the half-power radius of the PSF is between 5.5 and 6 pixels, the radius of the nebula in July 1987 must have been 22 ± 2 pixels, or 2.23 ± 0.2 arcsec. This implies an angular expansion rate of 0.187 ± 0.02 arcsec/year. From a very early photograph made when the nebula was much smaller, Becker and Duerbeck (1980) found an expansion rate of 0.25 arcsec/year.

As can be seen in the figure, the nebula has an asymmetrical brightness distribution inside a roughly circular outline; in the outer envelope, the maximum to minimum contrast above sky level is about a factor of 2. The central position angles of the three most enhanced sectors are $\sim 31°$, 115°, and 287°. This last sector presumably corresponds to the "extension into the NW quadrant" noted by Becker and Duerbeck (1980) from a direct plate taken 1979 August 27. Cohen's (1985) Figure 1 shows knots of increased brightness at position angles of $\sim 45°$, 135°, and 285° (our measurements). Given the small scale of the reproduction in their article, these results are in satisfactory agreement. It is not clear that this brightness pattern represents 'polar blobs' and an 'equatorial ring' as proposed by Boyarchuk and Gershberg (1977) or by Hutchings and McCall (1977) and Hutchings, Bernard and Margetish (1978).

If v(tangential) = v(radial) = 1600 km/s for the expanding gas, as assumed by Becker and Duerbeck (1980), then our observations imply a distance to the nova of 1.80 ± 0.2 kpc, provided no deceleration has occurred in the expanding shell. Lance *et al.* (1988) adopted a distance of 1.2 ± 0.2 kpc from the weighted mean of three methods, but with our angular expansion rate, their distance implies a v(tangential) = 1070 ± 180 km/s. As Becker and Duerbeck (1980) pointed out, v(tangential) and v(radial) need not be the same if only a portion of the nebula's surface is bright, but the presence of emission at all azimuths out to the same radius is difficult to reconcile with this interpretation.

The high signal-to-noise and oversampling rate in our image makes it ideal for image sharpening techniques, such as the maximum-entropy method. This will allow us to better estimate the nebular radius and structure. We will also be able to estimate the total Hα flux in the nebula from the monochromatic magnitudes of the fields stars. But clearly the next observational step is to measure the line-of-sight expansion velocity as a function of angular position in the nebula itself. These measurements will lead to an improved expansion distance and a more direct test of the "blobs and ring" model.

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