THE CIRCUMSTELLAR ENVIRONMENTS AND VARIABILITY OF RY AND RU LUP

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ABSTRACT. The variability of the two T Tauri stars RY and RU Lup has been monitored between 1980 and 1984 at both optical and infrared wavelengths. We present here a preliminary analysis of the data and suggest possible mechanisms for the observed variability.

1. OBSERVATIONS

Our data were taken at the South African Astronomical Observatory between 1980 and 1984 on the 0.5 and 0.75 m telescopes. We have broadband photometry from U (0.36 μm) to N (10 μm), together with Hβ photometry. The complete set of observations is given in Kilkenny et al. (1985).

2. LIGHT AND COLOUR VARIATIONS

Fig. 1 shows the observed variation of B-V with V for both stars. For RY Lup there is clearly more scatter, and a change in slope, for $V > 11.4$, otherwise the slopes for the two stars are $R = \Delta V/\Delta(B-V) \simeq 3.2$, approximately that expected for variable extinction by interstellar-like grains ($R = 3.1$). The visual lightcurve of RY Lup has several distinct sharp minima (see Fig. 2), which give rise to the change in R for $V \gtrsim 11.4$; at each of these minima the Hβ line goes into nett emission.

In the case of RY Lup two distinct mechanisms could account for the observed deep minima. Large, cool (with respect to T_*) starspot groups on the stellar surface could effectively smother the observable photosphere at minimum light, with the effect of enhancing the chromospheric contribution (in the form of the line emission) to the total light output of the star. Alternatively, occultation of the observed stellar disc by optically thick circumstellar dust aggregations would also give rise to enhanced chromospheric emission by reducing the effective photospheric contribution to the light output (cf. Evans et al. 1982).

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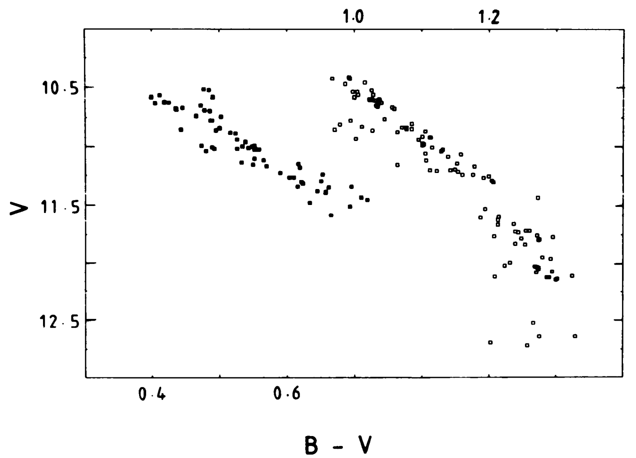

Fig. 1: [V, (B-V)] diagram for RU Lup (filled squares) and RY Lup (open squares). Upper (B-V) scale refers to RY, lower scale to RU.

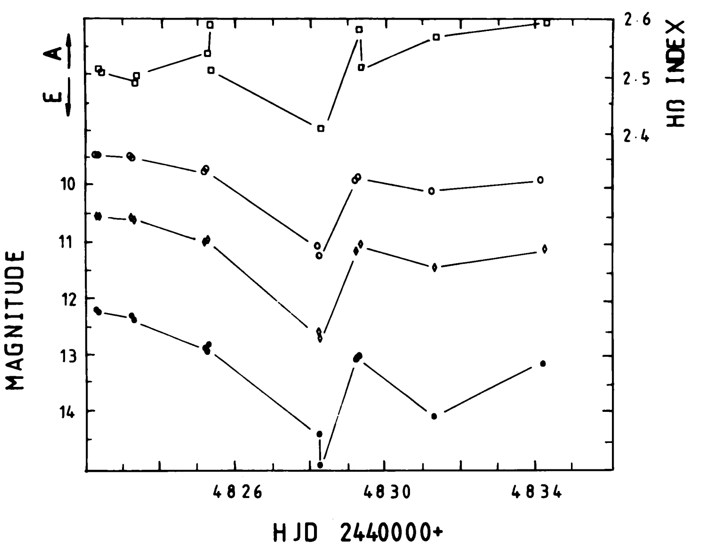

Fig. 2: U (filled circles), V (diamonds), I (open circles) light curves, and Hβ light curve (open squares), for RY Lup. For Hβ, E denotes nett emission, A nett absorption.

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We suggest that smaller starspots and/or flaring are responsible for the small amplitude variations outside deep minima. To investigate the possibility that starspots cause the small amplitude light variations, we attempted to fit sine curves to the lightcurves (cf. Vrba et al. 1986); attempts to fit more complex functions are currently under way. We assumed that the rotation period of RY Lup was 3.7 days (P. Bastien, private communication), which corresponds with a peak in the fourier power spectrum algorithm of Deeming (1975) for each light curve. The rotation period of RU Lup was taken to be 2.9 days, although none of the peaks in our power spectra were particularly dominant. The irregularity of the light variations suggests that large flares may also contribute to the observed flux: in the case of RU Lup this would certainly be consistent with its ultraviolet excess.

Although the lightcurves were irregular, we had some measure of success in fitting sections of the light curve with sine curves having various phases. Such changes in phase would be due to the continual appearance and disappearance of several spot groups as the star rotates. We found that the change of amplitude with wavelength can best be approximated by (Bopp and Noah 1980)

$$\Delta m = 2.5 \log\{1 - f\,[1 - (B_\lambda(T_*)/B_\lambda(T'))]\}$$

for a single spot of characteristic effective temperature T' covering a maximum fraction f of the observed disc. From a non-linear least squares fit we find that $T_* = 6000$ K, f = 0.9 and $T' = 10000$ K for RY Lup, and $T_* = 4400$K, f = 0.6 and $T' = 5150$K, for RU Lup. The fit for RY Lup is clearly not physically realistic and casts doubt on the possibility that all the observed minima are due to variable starspot coverage.

3. STELLAR AND DUST PARAMETERS

From our estimated bolometric luminosity and T_* for RY Lup, we find that $R_* \simeq 2\,R_\odot$. Using the measured rotation velocity $v \sin i = 25 \pm 4$ km s^{-1} (Bouvier et al. 1986), and a rotation period of 3.7 days, we see that the star's rotation axis is close to the plane of the sky.

We can extend our wavelength coverage to 100 μm using the IRAS PSC data (Beichmann et al. 1985). We deredden our data assuming that our (V-I) and (V-R) colours are least affected by reddening, and use the colour excess ratios given by Mendoza (1968). To the resultant flux distributions we have fitted blackbody functions. We find that both stars have infrared excesses which can be modelled by a hot (≃ 1600 K), a tepid (≃ 250 K) and a cool (≃ 50 K) dust shell. Thus the hypothesis that minima in the lightcurve of RY Lup could be caused by optically thick circumstellar "clumps" is tenable, and it remains possible that both stars may have associated protoplanetry discs and expanding shells of dust in which cometry formation may occur. Many pre-main sequence stars (including RY Lup) are also variable polarimetrically (e.g. Bastien 1985); models to account for the polarimetric variability, involving scattering by circumstellar dust clumps, are currently being developed by P. Bastien (private communication).

4. CONCLUSIONS

We find evidence for irregular modulation of the lightcurves of both RY and RU Lup. For RU Lup the modulation is possibly due to starspot activity, and also to flaring activity. A simple starspot interpretation for RY Lup gives unrealistic results, and it is more likely that other processes contribute to the light modulation (e.g. flares and circumstellar extinction). Both stars may be prime candidates to investigate planetary and cometary formation. Further co-ordinated photometric, polarimetric and spectroscopic studies of these stars are highly desirable.

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