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Long-term polarimetric behaviour of the carbon Mira R Leporis

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Summary. *BVRI* polarimetry of R Lep obtained during 1984–87 shows large changes in the normalised wavelength dependence of polarisation. We find that both the amount and position angle of polarisation had components which secularly varied since their first measurements in 1966. Circumstantial evidences suggest a possible connection between the largest polarisation observed in 1966 and the faintest ever observed light maximum during 1959–60.

Key words: Mira variables – carbon stars – R Lep – polarisation – circumstellar matter

1. Introduction

The carbon Mira variable R Lep has a period of 432 days and a late spectral type c7, 6e (Kukarkin et al., 1969). The first polarisation measurement of this object was made by Serkowski (1966). Because the observed value ($\sim 2.7\%$ in V band) was much in excess of the expected interstellar polarisation at the galactic latitude ($b = -31°$) of R Lep, he suggested that it is of either stellar or circumstellar origin. Further polarimetric observations were obtained by Kruszewski et al. (1968) in B and V bands on six nights spread over 300 days. Their data did not show any obvious correlation of polarisation with the visual brightness of the star and so to determine the wavelength dependence they combined these observations with that obtained earlier in three other wavelength bands centred at 0.65 μm, 0.84 μm, and 0.95 μm and found that the polarisation decreases towards red but shows a flat wavelength dependence in the yellow-blue region. Spectropolarimetry by Landstreet and Angel (1977) and Boyle et al. (1986) shows that blueward of C_2 band-head at 5160 Å, both polarisation and position angle exhibit variable large amplitude structure. R Lep has been detected at 12 μm, 25 μm, 60 μm, and 100 μm passbands in the far infrared by the Infrared Astronomical Satellite, IRAS (Beichman et al., 1985).

R Lep was observed as part of a programme of multicolour broad band polarimetry of carbon variables to study the wavelength dependence of polarisation. In this paper we present the results of our observations of R Lep and discuss its long-term polarimetric behaviour.

2. Observations

During the period 1984 December – 1987 January, we observed R Lep on 3 nights in *BVRI* bands and one night in *BVR* bands with the 102-cm telescope of Vainu Bappu Observatory, Kavalur. The polarimeter used consists of a halfwave retarder rotated at 10.41 Hz acting as the polariser and a Wollaston prism as the analyser. A microcomputer system built around a Z-80 microprocessor was employed for the acquisition and on-line processing of the data. A detailed description of the polarimeter and the method of calibration are given in Deshpande et al. (1985).

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3. Results

The linear polarisation ($P\%$), position angle ($\theta°$) and the errors in their measurements are given in Table 1 against the corresponding Julian days of observation. Values of $P\%$ and $\theta°$ are plotted in Fig. 1 against the respective inverse of the effective wavelength of filter band. The inset in the figure shows the mean light curve determined from AAVSO observations (Mattei, 1986, private communication). The epochs of polarimetric observations are indicated. It is clear from the figure that polarisation shows significant changes, but apparently, they are not directly linked to the light variation. Within the errors the first three sets of measurements show a weak wavelength dependence with the polarisation decreasing towards red. The last set of observations, obtained on JD 2446826.18 which coincided with a light maximum, shows just the opposite. In the yellow-blue region the wavelength dependence is seen to be nearly flat. The polarisation change is the least in V band.

Position angles in *VRI* bands show significant but only marginal changes. But the position angles in B show a very large scatter. This is consistent with the observations of Serkowski (1971). Spectropolarimetry of R Lep shows that the position angle of polarisation in the blue region exhibits large amplitude structure (Landstreet and Angel, 1977; Boyle et al., 1986). R Lep has a very late spectral type and the flux blueward of 4700 Å is very low. Hence, we feel that the scatter seen in B band is largely due to the slight differences in the effective wavelengths of observation at different epochs.

4. Discussion

4.1. Wavelength dependence of polarisation

In Fig. 2, we have plotted the polarisation normalised to unity at $\lambda^{-1} \approx 2.06\,\mu m^{-1}$ observed at different epochs. Since the differences in the polarisation values are only marginal, the first three sets of observations of R Lep given in Table 1 are averaged and the mean is plotted. Similarly, the polarisation in B and V

Table 1. *BVRI* polarimetry of R Lep

JD 2446000+	*B*		*V*		*R*		*I*	
	P%	$\theta°$	*P*%	$\theta°$	*P*%	$\theta°$	*P*%	$\theta°$
055.19	0.60±0.15	57±7	0.73±0.03	50±1	0.60±0.04	46±2	0.51±0.02	52±1
117.16	0.29±0.24	–	0.54±0.04	41±2	0.52±0.03	49±2	0.44±0.01	52±1
470.11	1.05±0.21	71±6	0.56±0.04	46±2	0.68±0.06	39±2	–	–
826.18	0.48±0.15	179±9	0.59±0.03	39±1	0.93±0.04	51±1	1.37±0.07	48±1

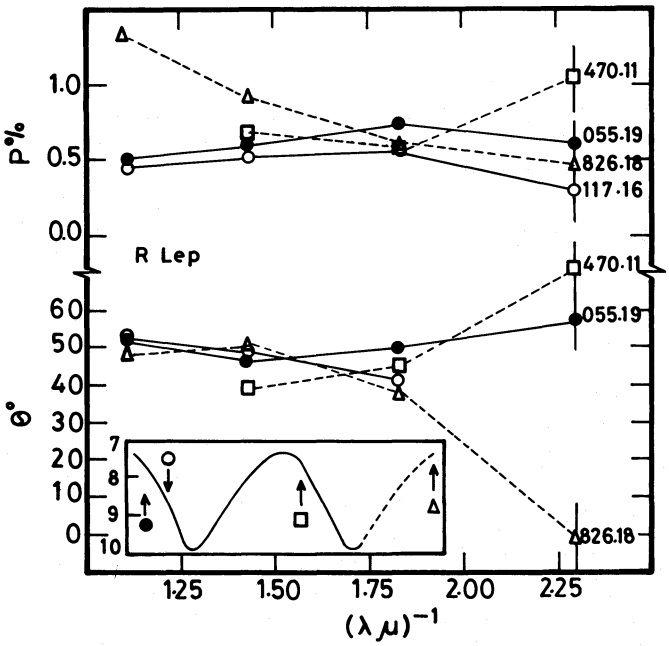

Fig. 1. Plot of linear polarisation (*P*%) and position angle ($\theta°$) of R Lep against the corresponding inverse of the effective wavelength of the filter band. The Julian day of observation is indicated against each curve after leaving out the first 4 digits 2446. The inset shows the mean visual light curve determined from the AAVSO data. The dahsed portion is the expected light curve. The epochs of polarimetric observations are indicated by arrows

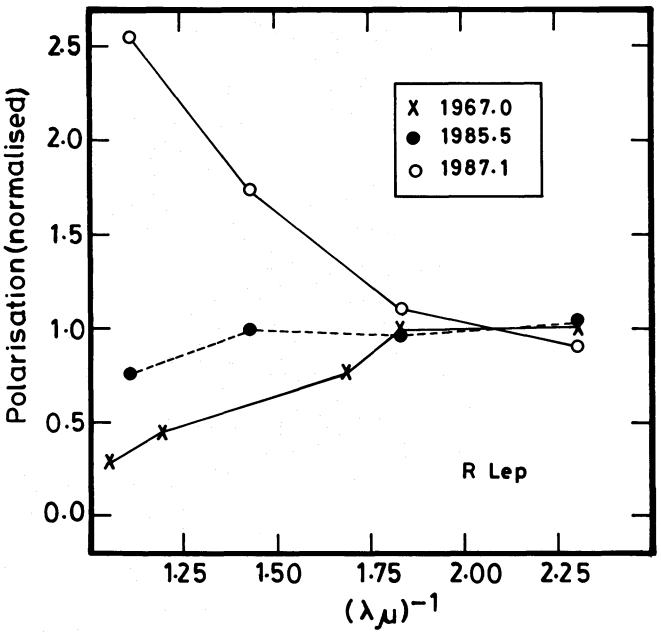

Fig. 2. Plot of normalised wavelength dependence of polarisation observed at different epochs. The mean epochs of observation are identified by different symbols

bands given by Kruszewki et al. (1968) are also averaged and combined with their earlier observations at longer wavelength bands to obtain the normalised wavelength dependence. It is evident from the figure that drastic changes have occurred in the normalised wavelength dependence since its first determination in 1967. The polarisation spectrum in the region 0.5 μm–1.1 μm of R Lep obtained in the later half of 1974 by Landstreet and Angel (1977) shows that polarisation decreases towards red and probably the normalised curve would lie in between that of 1967.0 and 1985.5.

From the available data, it is difficult to conclude whether the variation in wavelength dependence is secular or with a time-scale several times the pulsational period as in the case of the semi-regular variable L_2 Pup (Magalhães et al., 1986). Because the changes in polarisation are not directly linked appreciably to the light variation, the changes in the normalised wavelength dependence are not definitely cyclic with the pulsational period as seen in the case of the oxygen Mira *o* Cet (Shawl, 1975).

4.2. Polarisation and position angle

P% and $\theta°$ measurements of R Lep in the *V* band obtained by Serkowski (1971) and Dyck and Sanford (1971) are plotted in Fig. 3 along with those given in Table 1. The polarisation in the region 5200–5800 Å, estimated from the spectra given by Landstreet and Angel (1977) and Boyle et al. (1986) are also indicated in the figure. The data obtained during 1966–71 period strongly suggests that the narrow dip in the polarisation and the corresponding peak in position angle curves seen during 1968.5–1970.0 are transients that are superposed on more slowly varying components of the respective quantities. However, it is not clear from the data at hand whether the polarisation obtained during 1984–87 is a continuation of the slowly varying component and the comparatively low value observed in the second half of 1974 is part of a transient component or alternatively, the polarisation continued its initial near linear trend and became low (<1.0%) some time in 1973 and remained so since then.

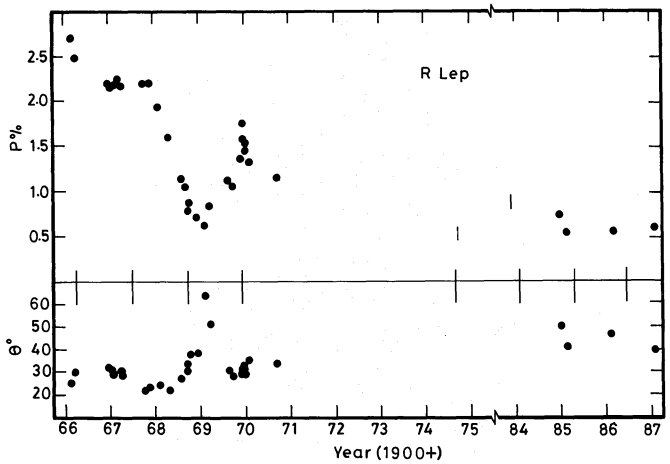

Fig. 3. Plot of polarisation (P%) and position angle (θ°) in the V band against the time of observation. The short vertical lines represent spectropolarimetric observations and the big vertical lines the times of light minima. Note the break in the time axis

4.3. Brightness at the light maximum

The average visual brightness of R Lep at the light curve maximum is ~6.7 mag. But during 1959–60 it was fainter than 9.3 mag (Mayall, 1963). The recovery from the minimum was very rapid and by the middle of 1962, the maximum increased to ~7.5 mag (Mayall, 1970). We propose that most probably the large value of polarisation observed in 1966 is directly related to the faintest light maximum of R Lep ever observed. The trend of the polarisation curve suggests that it had a still higher value before 1966. Unfortunately, no polarimetric data exists for R Lep prior to 1966.

Mayall (1963) has pointed out that the variation of brightness at maximum of light curve probably has a period around 40 years. There are only a few red long period variables which appear to have such large amplitude long period modulation (Mayall, 1963). In the case of the carbon variable V Hya, the existence of an 18-year period is well-established (Mayall, 1965). Wood (1979) has suggested that if the 18-year period corresponds to the fundamental mode pulsation, then V Hya may be on the verge of ejecting a planetary nebula and if it is not, then the long secondary period may be an indication of shell helium flashes occurring in the star.

The mechanism(s) of polarisation in late type variable stars is still not clearly understood. Boyle et al. (1986) have suggested that there are more than one polarigenic mechanism and that both photospheric and circumstellar processes are important. The changes in the normalised wavelength dependence of polarisation in R Lep indicates that at least at wavelengths longward of blue, circumstellar grain scattering is a major contributing factor to the observed polarisation. For a net polarisation to appear in integrated light, there should be an overall departure from spherical symmetry. We feel that the secularly varying component of polarisation seen after 1966 is possibly a result of an episodic asymmetric mass ejection sometime before 1962 and its subsequent dissipation in the circumstellar envelope.

Definitely, R Lep deserves further attention polarimetrically.

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