THE SPECTROSCOPY OF THE PULSATING CARBON STAR R Lep

L. Začs, O. Alksnis

Institute of Atomic Physics and Spectroscopy, University of Latvia
19 Rainis blvd., Riga, LV-1586, Latvia, *zacs@latnet.lv*

ABSTRACT. The first results of detailed spectroscopy are presented for carbon Mira R Leporis. This long-period variable is undergoing deep fadings, apparently caused by dust formation around the star. High-resolution CCD spectra were observed for two seasons. The heliocentric photospheric radial velocity was found to be +32.6 and +38.4 km s^{-1}, respectively. Blueshifted emissions from the circumstellar gas are seen.

Key words: Stars: carbon; stars: oscillations; (stars:) circumstellar matter; stars: individual: R Lep

1. Introduction

Carbon-rich variable stars are thought to be near the end of the asymptotic giant branch evolution just prior to planetary nebula formation. Many of them are losing mass. Mira variables have visual light amplitudes more than 2.5 mag, emission lines in their spectra at certain phases, and periods in the 80 to 1000 days range. The variability characteristics of carbon stars differ greatly from one to another. There is a group of stars (R For, R Lep and R Vol, etc.) which lose mass in an apparently erratic way.

R Lep is a bright carbon Mira. It has a late spectral type of C 7,6e and a pulsation period of 432 days. From the extensive visual observations available for this star, Mattei & Foster (2000) find that its period of pulsation is slowly increasing. Whitelock et al. (1997) reproduced the light curve of R Lep with a sum of a 20,000 days sinewave and its first harmonics, plus a 438 d sinewave plus the first harmonic. They presented evidence that carbon-rich dust ejection occurs in a preferred direction, possibly from the equator and noted some similarity with R Coronae Borealis stars. Polarimetric observations clearly established the intrinsic polarization and its variability in R Lep (Raveendran 2002). Careful analysis is required to study this phenomenon in detail.

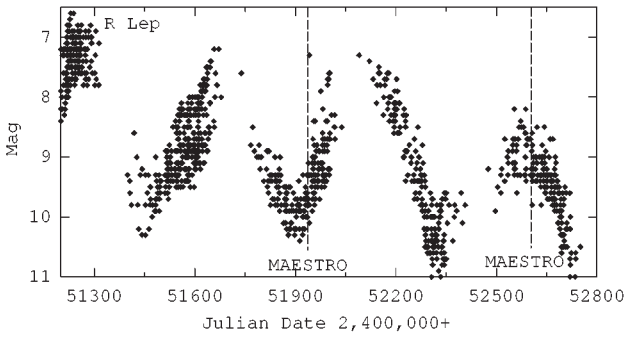

Figure 1: Light variations of R Lep according to the AAVSO data. The moments of high-resolution spectroscopic observations are indicated by the dashed lines.

2. Observations and results

High-resolution spectra for R Lep and the comparison star U Hya (C 7,3) were obtained with the coude echelle spectrometer MAESTRO fed by the 2-m telescope at the Observatory on the Terskol Peak in Northern Caucasus equipped with a CCD detector with a resolving power of 45,000. Two spectra were observed by F.Musaev on 26 January 2001 (JD2451936) and on 26 November 2002 (JD2452604) near the minima and maxima of periodic light pulsations (see Fig. 1). The spectra covered region from about 3600 to 10,200 Å in 85 wavelength bands overlapping shortward of H_α. Each region spanned from 50 to 140 Å. The reduction of spectra were performed with the standard DECH20T routines. The basic data for both stars from literature are provided in Table 1.

An inspection of the high-resolution spectra of R Lep shows that a large number of strong C_2 and CN lines dominate over all the analyzed spectrum, blending significantly with the atomic absorption lines. However, a limited number of relatively uncontaminated atomic (molecular) lines were selected to measure radial velocity and check metallicity. Our analysis shows that the lines of the iron-peak elements in R Lep are of similar strength with those in U Hya. The radial velocity

Table 1: The basic data for R Lep and the comparison star U Hya.

Star	R Lep	U Hya
l,b (deg)	214, -31	260, +38
Sp.type	C 7,6e	C 7,3
Var.type, P	M, 432 d	SRb, 450 d
M_{bol}	-4.79 (-3.6)	-4.0
T_{eff}	2390 K	2825
$[Fe/H]$	+0.2	-0.1
C/O	1.03	1.04
$^{12}C/^{13}C$	62	32

(RV) for R Lep was measured using about 30 relatively clean and symmetric atomic absorption lines selected over the whole spectral region in both spectra. In addition about 30 uncontaminated CN lines were selected for RV measurements. No significant difference was found in the velocity derived from atomic or molecular lines. The heliocentric correction was calculated to be -19.7 and $+2.9$ km s^{-1}, respectively. Thus the mean heliocentric stellar $RV_{\odot}$ was found to be +32.6 (2001) and +38.4 km s^{-1} with a standard deviation of the mean value of about 0.4 km s^{-1}. The difference between the photospheric radial velocities derived for two seasons seems to be significant. The change could be the result of pulsations in this Mira variable.

The resulting spectra for the region around Na I D12 lines along with that for the typical carbon star U Hya are presented in Fig. 2. Most significant changes between two seasons in this region are seen in the sodium lines. While on January 2001 typical absorption lines of D12 are visible, on November 2002 the overlap of emission(?) and sharp absorption appeared near to the line cores. These sharp absorption features are blueshifted with an averaged D1&D2 velocity of -25.6 km s^{-1} relative to the photospheric velocity. It is clear that such features are formed in the circumstellar matter ejected by R Lep. Significant changes between two seasons were found also in another strong (resonance) lines: the Balmer H_{α} & H_{β}, K I at 7698 Å, Ca II at 8542 (see Fig. 3) atomic, and C_2 molecular lines.

Acknowledgements. This research has been supported by grant 05.1863 from the Latvian Council of Science. We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.

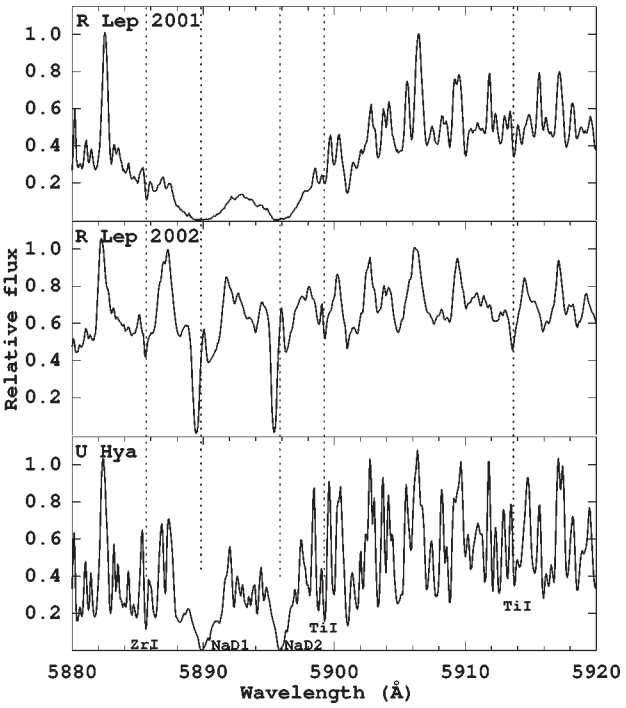

Figure 2: The observed spectra of R Lep around the Na I D12 lines for two different seasons, January 2001 (top panel) and November 2002 (middle panel), near the minima and maxima of light pulsations. Also shown is the spectrum for a comparison star U Hya. All spectra have been shifted in wavelengths to correct for the stellar radial velocities. Complicated profiles of sodium lines are visible in the spectrum of R Lep observed on November 2002.

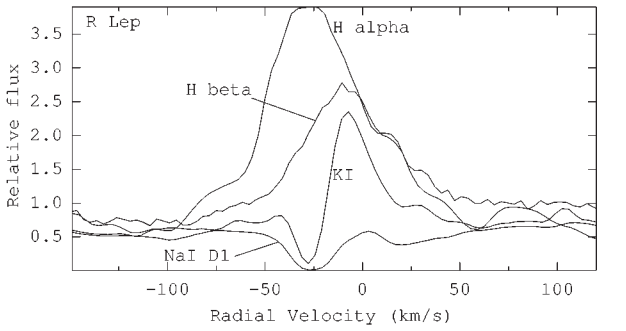

Figure 3: The emission features of Balmer H_{α} & H_{β}, K I at 7698 Å, and Na I D1 lines in the spectrum of R Lep observed on November 2002 in the radial velocity scale relative to the photospheric velocity of +38.4 km s^{-1}.

References

Mattei J.A., Foster G.: 2000, *in Wing R.F., ed., Proc. IAU Symp.177, The carbon Star Phenomenon*, Kluwer, Dordrecht, p. 155.

Raveendran A.V.: 2002, *MNRAS*, **336**, 992.

Whitelock P.A., Feast M.W., Marang F., Overbeek M.D.: 1997, *MNRAS*, **288**, 512.