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Photometry of LO Pegasi in B, V, R colors

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Abstract
Variable magnetic activity manifested by starspot distribution is investigated on the single K5-K7 dwarf LO Peg, using one month long photometric observations. We supposed three circular spots for light curve solution. We find variable spot temperature, whose average is 3960 K. The sizes of spots were stable for two spots and one spot showed a significant decrease. Different migration periods on two spots indicate differential rotation, the magnitude of the migration is slow. During the measured 90 stellar rotations (38.5 days) the location of the activity remained on the same hemisphere of the star.
Keywords: *starspots – stars:activity – stars:atmospheres – stars:late-type – stars:imaging – stars:individual:LO Peg*

1 Introduction

LO Peg (BD+22^o 4409) is among the least massive stars of the young rapid rotators in the solar neighbourhood. It was detected by the ROSAT Wide Field Camera (WFC) extreme ultraviolet (EUV) all sky survey as the source RE J2131+23, and by the Extrem Ultraviolet Explorer survey as the source EUVE J2131+23.3 (Malina et al., 1994). Jeffries & Jewell (1993) identified LO Peg as a member of the Local Association on the basis of its galactic space motions and a large EUV to bolometric flux ratio. LO Peg was first studied in detail

by Jeffries et al. (1994) who determined an axial rotation period of 0.42375 d from V-band photometric observations. Photometry yielded a visual magnitude of V=9.19±0.05 and colours (B−V) = 1.08±0.02, (V−R) = 0.59±0.02. Jeffries et al. (1994) also obtained a model fit to the spectrum of LO Peg, and found a spectral type of K5-K7 and an age slightly over 30 Myr. At this spectral type, the radiative core decreases in size as the star approaches the fully convective regime at spectral type early to mid-M. If a solar like interface dynamo is at work, according to Schüssler et al. (1994) and Granzer et al. (2000) we may expect only intermediate to high latitude eruption of magnetic flux. The K5V-K7V spectral type makes LO Pegasi an important object because not very much single stars of this late spectral type have been studied.

2 Observations and data reduction

CCD photometric observations of LO Peg were obtained at the Baja Astronomical Observatory using a 0.5-m Ritchey-Chrétien telescope on twenty-one night in Summer 2005. The detectors were an Apogee Alta U16 camera (Kodak chip, 4096x4096 pixels, field of view $\sim$ 30'x30') and an Apogee AP7 camera (SiTe Si-502A chip, 512x512 pixels, field of view $\sim$ 10'x10'). All photometric reductions (image processing, digital photometry) were done with the corresponding IRAF tasks. TYC 2188-1288-1 was used as comparison star and GSC 02188-00700 was used as check star. The magnitude differences between the comparison star and check star was constant during the time of the measurements (Figure 1, left side, lower panel). The determined calibrated differential magnitudes of the comparison and check stars are $\triangle$B=−0.090±0.001, $\triangle$V=−0.988±0.001 and $\triangle$R=−1.474±0.001. For both cameras photometric calibration were made. LO Peg was also observed for photometric calibration using PG 2213-006 (Landolt, 1992) and EF Peg (Henden) standard fields on 2005 July 15 and July 29 in the B,V and R bands. The determined transformation constants are given in Table 1.

Table 1: *Determined transformation constans for B−V (μ), V−R (ν), V (ϵ).*

Camera	μ	ν	ϵ
Apogee Alta U16	1.143±0.025	0.976±0.039	−0.052±0.012
Apogee AP7	1.018±0.082	1.002±0.109	−0.023±0.052

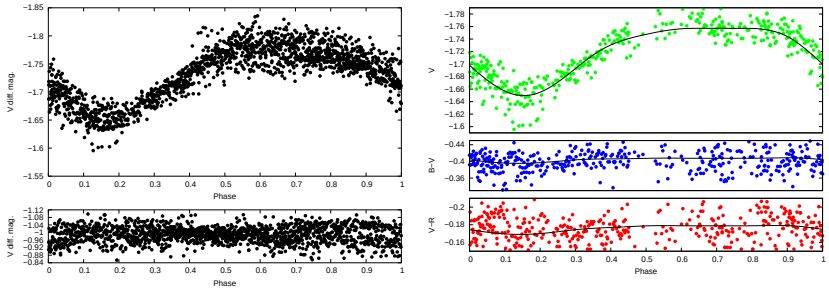

Figure 1: *(left) V light curve of the variable (upper panel) and the corresponding comparison-check data (lower panel); and example fit to the data observed between 53576 HJD - 53582 HJD (right).*

3 Modelling

For starspot modelling we used the SpotModeL program (Ribárik et al., 2003). Table 2. shows the fixed parameters and the starting values of the free parameters. As unspotted brightness, in lack of long-term data, the maximum measured values were used. We supposed three circular spots for the light curve solutions. One spot was fixed on the pole of the star on the basis of Doppler Imaging results (Barnes et al., 2004). The other two spots were fixed at $+10^o$ latitude to ensure, that spots do not overlap each other during the modelling. The spot coordinates and temperatures were simultaneously fitted in two different bandpasses (B,V and V,R). Figure 1 (right panel) shows the result of such a fit.

Table 2: *Starting values of spot parameters.*

	1. spot	2. spot	3. spot
α	30^o free	130^o free	360^o fix
β	10^o fix	10^o fix	90^o fix
γ	20^o free	20^o free	20^o free

Table 3: *Wavelength dependent fixed parameters.*

	B band	V band	R band
Limb darkening (van Hamme, 1993)	0.906	0.763	0.658
Unspotted brightness (mag)	−2.255	−1.840	−1.655

Table 4: *Fixed parameters of LO Peg.*

T_{eff} (K)	4750 ± 250	(Pandey et al., 2005)
log g	4.5 ± 0.5	(Pandey et al., 2005)
Axial inclination (deg)	45.0 ± 2.5	(Barnes et al., 2004)
P (d)	0.423229 ± 0.000048	(Barnes et al., 2004)
Epocha (HJD)	2 453 540	

4 Results

The folded light curves for the data observed between 53545 and 53576 shows, that the maxima are at phases 0.6 and 0.8. Comparing this to the phased light curve obtained between 53582.5 and 53585 it is well seen (Figure 2), that the spot maxima are shifted to phases 0.4 and 0.6 while the light curve minima did not change much. This indicates, that the spots/spot groups moved or the sizes of spots/spot groups decreased and other spots/spot groups increased or emerged.

Figure 3, left panel, shows the results of spot temperature variations. At the beginning of the observations, higher brightness and hotter spot temperature is found, which indicates more hotter plages and less dark spots. The spot temperature relaxed to a constant value by the end of the measurements. The average spot temperature is about 3960 K, which is 790 K cooler than the effective temperature of the star. From the B−V and V−R color indicies the values of the derived spot temperatures agree within the errorbars except two points.

Figure 3, right panel, shows the variation of spot's sizes and the spot coverage. Spot 1 and spot 3 showed stable spot sizes, while spot 2 showed a significant decrease.

Figure 4 displays the time behaviour of the spot's longitudes. Slow migration is observed in the longitude positions of the two low-latitude spots as 0.96±0.26 ^{o}/days and 1.74±0.49 ^{o}/days. The calculeted migration periods are about 374 days and 205 days for the two spots. This indicates the presence of differential rotation and that the spots are at different latitudes.

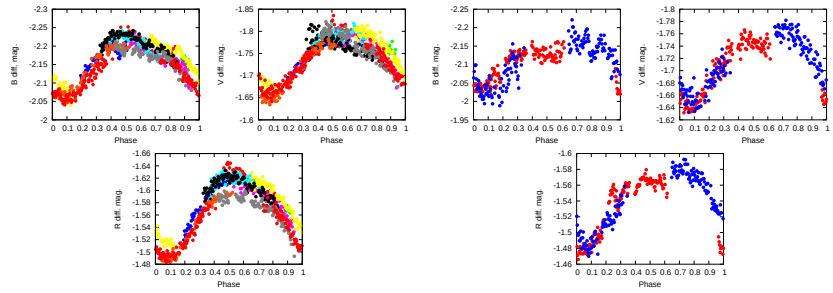

Figure 2: *Light curves observed between 53545 HJD - 53576 HJD (left) and 53582.5 HJD - 53585 HJD (right) of LO Peg. Different colors mark observations obtained on different nights.*

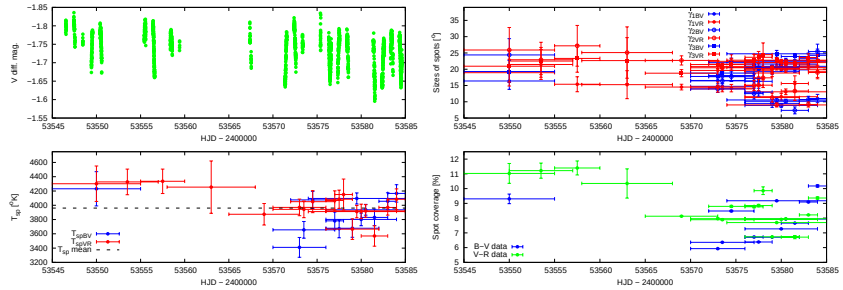

Figure 3: *V observations and variations of spot the temperature (left) and variation of spot sizes and spot coverage (right). Vertical bars give the errors of the results, horizontal bars show the time intervals of the observations that were used together for the modelled, folded light curves.*

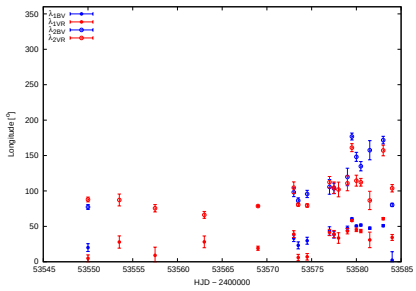

Figure 4: *Time behavior of spot's longitudes.*

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