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BVR photometry of a newly identified RS CVn binary star HD 61396

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Abstract

BVR photometry of a recently identified RS CVn binary star HD 61396, carried out during 2001, is presented. The new photometry reveal significant evolution in the shape and amplitude of light curve when compared with those reported earlier by Padmakar et al.(2000). The traditional two-starspot model has been used to obtain the spot parameters from the observed light curve. Changes in the spot area and their location on the stellar surface are discernible from the extracted parameters from the new photometry.

Key words: Star:activity; Star:spots; Star:individual:HD 61396; Stars:late-type
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1 Introduction

HD 61396 (SAO 14296,FG Cam) is identified as the likely optical counterpart to the X-ray source 1ES 0738+612 in the Einstein IPC Slew Survey by Elvis et al.(1992). On the basis of this identification, supported by the detection of strong Ca II H & K emission by Schachter et al.(1996), and its association with a 29 mJy source of radio emission (BWE 0738+6117) in Becker, White & Edwards (1991) Catalog of 6-cm sources, Schachter et al.(1996) stated it to be an RS CVn system. Published measurements by the *Hipparcos* Satellite (Perryman et al.1997) have provided the following basic parameters for HD 61396:

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V= 8.024, B-V= 1.23 ± 0.015, V-I= 1.19 ± 0.01, $V_{max} = 7.97$, $V_{min} = 8.11$, variability magnitude (ΔV)= 0.112 ± 0.021,and parallax = 3.89 ± 0.93 miliarcseconds (which implies a distance of 257^{+81}_{-50}pc, and an absolute visual magnitude of ~ 1 indicating that HD 61396 is a luminosity class III star, i. e. , a giant) with photometric period of 35.31 days. Furthermore, in the 74th Special Name-List of Variable stars (Kazarovets et al.1999), the variability type of FG Cam was refined to a semi-regular giant or super-giant variable of F-K spectral type, with a period in the range of 30 to 1100 days. Detailed optical photometric and spectroscopic, X-ray and radio continuum study of HD 61396 by Padmakar et al.(2000) suggest that HD 61396 is a long-period RS CVn binary system with photometric period 31.95 days showing variation of 0.18 magnitude in the Johnson broad band V.

If the suggestion of Schachter et al.(1996) and Padmakar et al.(2000) that HD 61396 is an RS CVn type active binary system is correct, then it would be expected to show significant changes in photometric light variation as well as in amplitude due to dark spots distributed inhomogeneously over the stellar surface of the primary star, similar to behavior noted in other confirmed RS CVn stars, such as σ Gem and λ And. Keeping this objective in mind we further carried out the photometric observation of this star during the year 2001 using the 40-cm Schmidt-Cassegrain Meade LX-200 telescope situated in the campus of Inter University Centre for Astronomy and Astrophysics (IUCAA) in Pune, India and results are presented here.

2 Photometric Observation

The BVR photoelectric photometric observations of HD 61396 were carried out during the observing run during the period February - March, 2001. Because of rather unfavorable sky conditions we could observe this star for a total of 15 nights only. The 40-cm Schmidt-Cassegrain telescope equipped with SSP-3A photoelectric photometer and Johnson standard broad-band BVR filters were used for observation. The detector used in SSP-3A photometer was a silicon PN-photodiode which is not cooled. The response of the B,V and R filters with the detector closely matches the Johnson standard B,V and R response function. In order to obtain accurate differential photometry, we used two nearby stars HD 59033 (K5, V = 6.68, B-V = 0.989) as comparison star and HD 60293 (A0, V = 7.00, B-V = 0.064) as check star. The basic parameters of variable star are given in Table 1. The observation were corrected for atmospheric extinction and transformed into BVR standard system. The mean of four to five independent differential magnitudes measured per night in the V bands, and associated colors (B-V), (V-R) are displayed in figure 1 as a function of Julian Day. The uncertainties in ΔV, Δ(B-V) and Δ(V-R) are 0.015, 0.02 and 0.017 magnitude respectively. We obtained the phase diagram

Table 1
Basic parameters for HD 61396

Star	V	B-V	Sp. Type	T_{phot}	ΔT	i	μ_V	μ_R
HD 61396	8.02	1.23	K2 III	4520 K	836 K	60	0.799	0.655

using the photometric ephemeris $HJD = 2451209.70 + 31.95^d \times E$ as given in Padmakar et al.(2000).

3 Results and Discussion

3.1 Photometric variability

Although we have only 15 nights of observations for this star but it is evident from the phase diagram (figure 2) that the observations cover the entire phase. In the same figure we also plotted the light curve of HD 61396 obtained by Padmakar et al.(2000) for comparison. From figure 2 one can notice a significant light variation as well as change in amplitude of light curve from the previous reported photometry. Present observations do not reveal any significant variation in (B-V) and (V-R)color indices. The differential amplitude ΔV turns out to be $\sim$0.07 magnitude while Padmakar et al.(2000) reported a value of ΔV $\sim$0.18 magnitude. This indeed further confirms that the star belongs to class of RS CVn type variables and the light variation is due to the presence of starspots on the stellar surface.

3.2 Starspot modeling

We have modeled the light curve of HD 61396 in the V band in the frame work of starspot. The details of modeling technique are given in Padmakar & Pandey (1999). To extract geometrical parameter of spots we adopted the analytical formulation given by Dorren (1987). We have taken two circular spots on the stellar surface and another spot permanently located on poles for modeling. To model V band light curve we have taken wavelength-dependent limb-darking coefficients (μ), inclination (i), photospheric temperature (T) and difference between the photospheric and spot temperature (ΔT) as constant (given in Table 1) and the longitude(λ), latitude(β), radius(γ) as free parameters. The final best fit parameters along with their uncertainties are listed in Table 2.

Polar spots or spots uniformly distributed over the stellar surface do not produce any rotational signature in the light output, and therefore, are undetectable by the photometric modeling of the light curve. Our spot modeling

Table 2
Starapot parameters for HD 61396

Spot 1			Spot 2			Polar Spot	Total Spot	χ^2
λ	β	γ	λ	β	γ	Radius	Area (%)	
285.07	35.41	10.26	53.46	-2.37	11.80	38.59	1.86	1.43
± 3.27	±1.08	±0.40	± 0.94	±1.42	± 0.54	± 0.31	± 0.11	

technique for this system indicates that two nearly equal sized spots having radii of 10.26° and 11.80° situated at opposite hemispheres were responsible for the observed light variation. The spots were separated from each other by $\sim 230°$ in longitude, and cover ~ 2 percent of the stellar surface. A comparison of our results with those of Padmakar et al.(2000) shows that there is a substantial variation in the location of the minimum and the shape of the light curve. This behavior in turn reflects that changes in the amplitude are mainly due to the redistribution of spots on the stellar surface rather than overall changes in the level of spottedness.

4 Conclusion

We have presented BVR photometric observations for a newly identified RS CVn type star HD 61396. The light curve show significant variation in the shape as well as amplitude. The differential amplitude in V is ∼0.07 mag which is smaller than the previously reported value. The spot parameters also indicate changes in their location as well as in size, supporting the starspot hypothesis. A comparison from previous observations reported by Padmakar et al.(2000) shows that there is a significant variation in location of the minimum and the shape of the light curve and it is quite conceivable that the observed light variation is due to a change in the position of the major starspot.

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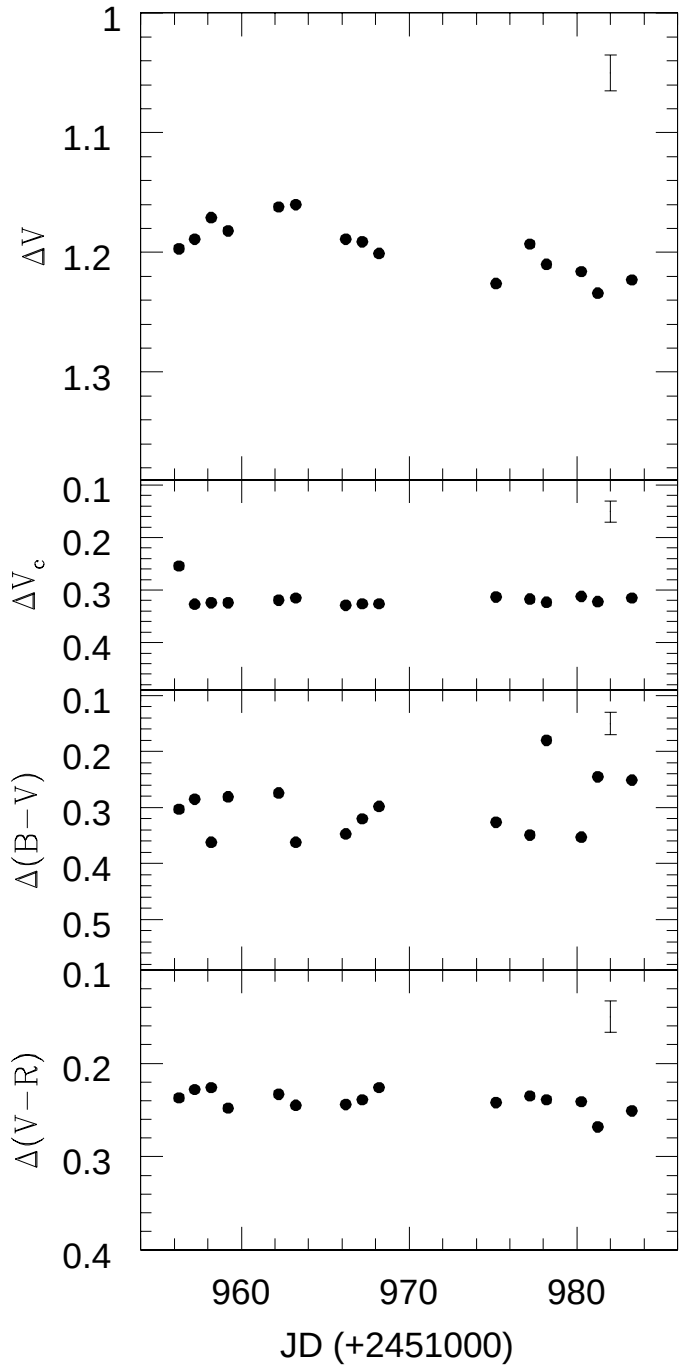

Fig. 1. V band light curve and (B-V) and (V-R) colors of HD 61396 as observed during 2001 using differential photometry plotted against Julian day. V_c is for the check star observed on the same night. Typical error bars are shown in the upper right corner of each light curve.

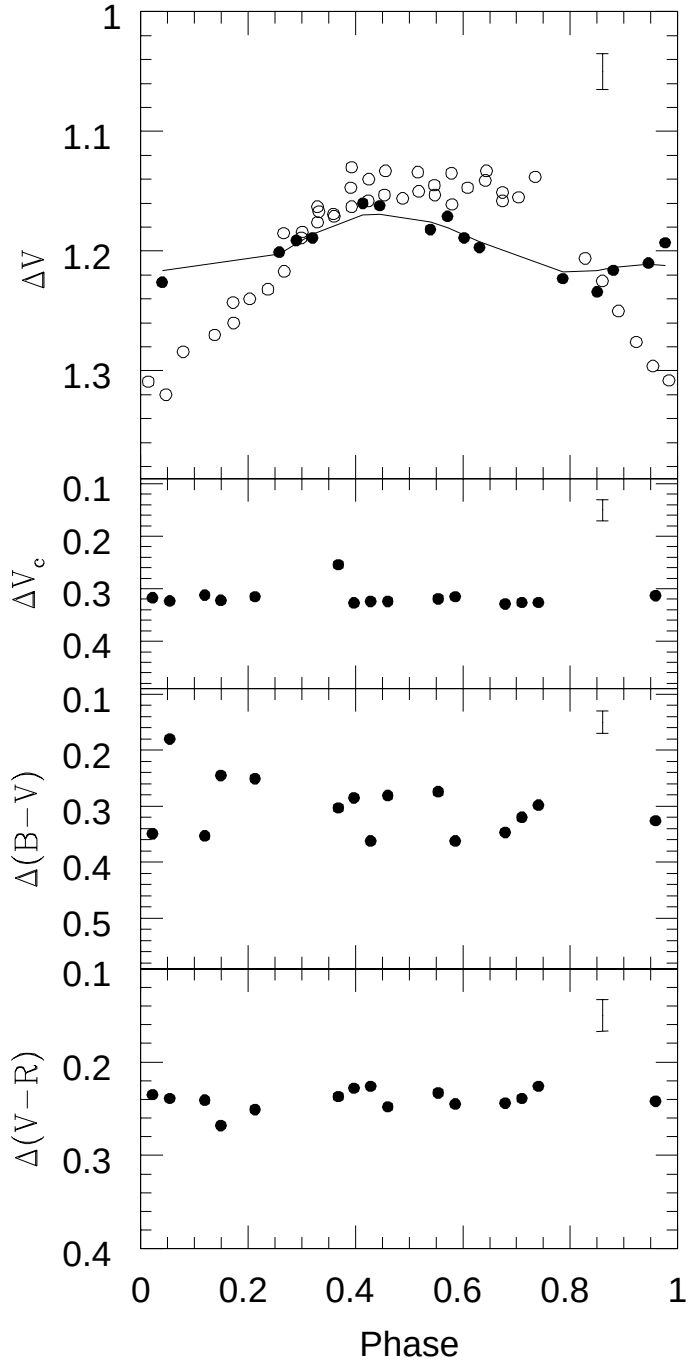

Fig. 2. As in figure 1 observed data points have been folded in phase diagram using the photometric ephemeris *HJD = 2451209.70 + 31.95*$^d \times E$. The curve represent the best-fit two-spot model for V band data. Open circles denote the light curve from Padmakar et al.(2000). Typical error bars are shown in the upper right corner of each light curve.

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