Chapter 4

Photometric observations of RS CVn Binaries of Chromospherically Active Stars

“I know the stars are wild as dust and wait for no man’s discipline but as they wheel from sky to sky they make our lives with pins of light.”

Leonard Cohen: ‘Another Night With Telescope’
The BV photoelectric photometric observations of six chromospherically active stars were carried out during the period 2006-2007 using the 0.30m Meade Cassegrain telescope at JES, Jalna. We also included photometric data on the stars from Padmakar et al. (1999) for the period 1996-1998 and Barwey et al. (2005) for the period 1998-2002.

**UX Ari (HD 21242)** is one of the most active RS CVn binary systems. It is a bright binary SB2 system consisting of two components of KO IV and G 5V. The brighter components exhibit strong chromospheric emission in the Ca II H & K lines (discovered in 1939 by Hogg (1939)) and variable emission in the Hα line which correlates with the rotational phase of the star (Carloss and Popper 1971; Bopp & Talcott 1978). UX Ari revealed strong activity in the ultraviolet, X-ray, and radio bands. Photometric observations of UX Ari were begun in the 1970s by Hall et al. (1975). Long series of observations have been made by Raveendran & Mohin (1995), Aarum Ulvas & Henry (2003), and Rodono & Cutsipoto (1992). Vogt & Hatzes (1991) have obtained Doppler images for the brighter component of the system. Observations show that, unlike with other RS CVn systems, the spots on UX Ari lie primarily in the hemisphere opposite to the secondary component (Vogt & Hatzes 1991; Raveendran & Mohin 1995). A correlation has been noted between the spottedness of the star and its flare-induced radio emission (Elias et al. 1995).

Data for a total of 34 nights used for investigating short term variation in the light curve of UX Ari and are shown in Fig 4.2. Existence of two maxima in light curve during epoch 2006-07 separated from each other by 0.4 in phase is also noticed. Differential amplitude continuously increases and reaches maximum (0.24) during 2006-07 and decreases to 0.01 magnitude. Our observations reveal variation in (B-V) color index and
also $\Delta V$ and $\Delta (B-V)$ as reported in the literature (Padmakar et al. (1999) & Barwey et al. (2005)).

**Fig 4.1:** V Band light curve of UX Ari observed during 1996-2002

**Fig 4.2:** V band light curve of UX Ari Observed during 2006-2007
**V711 Tau (HD 22468)** is non-eclipsing binary SB2 system consisting of components with spectral classes K1 IV and G5 V. The brighter, more active component of the star has a strong variable chromospheric emission (Bopp & Fakel 1976), variable lines in the transition region (Rodono et al. 1987, and X-ray emission (Walter 1978). The star is known to be a strong source of variable radio emission (Owen et al. 1976). The first photometric observations of V711 Tau were made by Cousins et al. (1963), and rotational modulation was discovered by Landis & Hall (1976). Periodicity in the photometric activity of the star was discovered using the data for 22 years by Olah et al. (2000). Further, it was found to have active longitudes and differential rotation (Vogt et al. 1999). The light curves for this star vary significantly from season to season. Numerous studies by Doppler Imaging have revealed the presence of high latitude spots on the stellar surface. V711 Tau has been observed at soft and hard X ray (Walter et al. 1978; Agrawal & Vidya 1988; Singh et al., 1995), and at EUV wavelength (Drake et al. 1994). Furthermore V711 Tau is found to be a source of strong radio outburst (Owen et al. 1976; Trigillio et al. 1993; Umana et al. 1995) and the radio emission is highly circularly polarized (Gibson et al. 1978).

The data for investing seasonal variation in V711 Tau include the photometric observation in BV band of V711 Tau carried during December 2006–March 2007. Significant changes in the V band light curves can be seen from **Fig 4.4**. Differential amplitude jumps from 0.05 to 0.15 during epoch 2006. Minimum of light curve also moves from phase 0.7 to 0.3. The B-V colours do not show any significant correlation with the light variation. They appear scattered about their respective mean values.
Fig 4.3: V Band light curve of V711 Tau observed during 1996-2002

Fig 4.4: V band light curve of V711 Tau Observed during 2006-2007
HD 52452 (Vmax = 8.05) is one of the shortest period non-eclipsing chromospherically active binary stars. The spectral type of active components of this star was designated as G 5 V. The photometric rotation period of this star has been found to be ~ 0.42304 days. (Messina1999). The BV photoelectric observations of HD 52452 were carried out during December 2006- March 2007 for 32 nights. We also included data from previous observer Barwey for the two season’s period 2000 and 2001. In order to obtain accurate differential photometry, we used star HD 52071 (K 2 III, V = 7.11, B-V = 1.27) as a comparison star. No significant light variation was detected for the differential magnitudes of the comparison star, which is good measure of the quality of our observation. The uncertainties in ΔV and Δ (B-V) are 0.01 and 0.02 magnitudes respectively. The amplitude of light variation is ~ 0.23 magnitude in V band which is larger compared to the ~ 0.16 magnitude in V band reported by Messina (2001). The present observations suggest that the optical variability in the star HD 52452 is due to the presence of cool spots on the stellar surface.

The comparison of our data with previous observers reported by Messina et al. (2001) & Barwey et al. (2005) shows that there is a variation in amplitude but the phases of the two minima are quite stable during observations. The very short photometric period makes that this star is very interesting for studying the evolution of spots on stellar surface.
Fig 4.5: V band light curves of HD 52452 during December 2006- March 2007

Fig 4.6: V band light curves during Feb- Mar 2000. (From Barwey et al. (2005)
The open triangle denote the observations from Messina et al. (2001)
**HD 61396** (SAO14296, recently given the variable star name FG Cam is an 8th magnitude KO star that received little attention until the 1990’s. The BV photoelectric observations of HD 61396 were carried out during the period February-March 2007 about 14 nights. All observations were made differentially with respect to HD 59033 used as a Comparison star. The differential magnitude measured per night in B & V band; associated colures (B-V) are displayed in Fig. The uncertainties in $\Delta V$ and $\Delta (B-V)$ are 0.02 and 0.03 magnitude respectively.

Although we have only 15 nights of observations for this star, it is evident from phase diagram that the observations cover the entire phase. One can notice a significant variation as well as change in amplitude and shape of light curve from previous reported photometry. The differential amplitude $\Delta V$ turns out to $\sim$0.02 mag while Barwey et al. (2005) reported a value 0.07 magnitude. This indeed further confirms that the star belongs to the class of RS CVn type variables and light variation is due to the presence of starspots on the stellar surface.
Fig 4.7: V band light curve and (B-V), (V-R) colours of HD 61396. (Barwey et al.2005)

Fig 4.8: V band light curves of HD 61396 observed during February-March 2007
**λ And (HD 222107 G8 III-IV)** is a single line spectroscopic binary star classified as RS CVn system. It is among the brightest ($V=3.82$) of all known chromospherically active binaries discovered so far. λ And is a source of strong Ca II H & K, and Hα emission lines which are strongly correlated with the optical light variation i.e., strongest at light minimum (Henry et al. 1995). Evidence of corona in λ And comes from EINSTEIN X-ray observations (Walter et al. 1980) and later confirmed by ROSAT observations. Hall et al. (1991) and Henry et al. (1995a) investigated cyclic behavior of its activity using mean brightness as a tracer of activity and an activity cycle of 11-year which accidentally matches with the solar activity cycle.

The BV photoelectric photometric observations were carried out during November 2006-February 2007 about 34 nights. All observations were made differentials with respect to HD 22304 (Psi And $V = 4.98$, $B-V = 1.084$) as a comparison star. **Fig 4.9** shows light curve of λ And in $V$ band. The nature of photometric variability is not qualitatively different from Padmakar (2000) had reported for the period 1995 and 1998. Previous observation shows a variation in $V$ amplitude between 0.05 to 0.23 magnitudes which in turn implies that our observations λ And was in the stage of moderate activity. Our results do not show any significant variation Δ ($B-V$) color index.
**Fig 4.9:** $V$ light curve of $\lambda$ And obtained during 2006-2007
**IM Peg (HD 216489)** is very active bright member of the long period RS CVn group. The spectral type is K1 IV III P according to Herbst (1973) and only that the star is seen in the spectrum. Strong Ca II H & K emission was observed by Herbst (1973) and Koniges (1977). The spectroscopic orbit of Harper (1993) shows an orbital period of $P(\text{orb}) = 24.649$ days. Photometry in V by Herbst in (1971) show that HD 216489 was variable with amplitude of 0.16 magnitude. The light curve obtained by Eaton et al (1983) and Strassmeier (1989) show remarkable variation in the amplitude (from 0.11 to 0.24 mag) whereas they do not reveal significant variation in the shape.

Our presented photometry is obtained during 2006-2007 in about 10 nights and we obtain accurate differential photometry HD 216635 ($V = 6.61 \ B-V = 0.988$) is taken as the comparison star for IM Peg. The observations are corrected for the atmospheric extinction and transfer into BV standard system. The light curve in V band are shown in Fig 4.12. The uncertainties in $\Delta V$, $\Delta B-V$ are 0.02, 0.05 mag respectively. The shape of light curve however is similar to those of earlier investigators. The wave minima (0.92 phase) closely resembles with observations of Strassmeier et al. (1989) and Padmakar & Pandey et al. (1995).
Fig 4.10: Differential V band light curves of IM Peg (From Padmakar & Pandey 1995)

Fig 4.11: Differential V band light curves of IM Peg during 2006-2007
Fig 4.12: V band light curves of IM Peg during 2006-2007
Chapter 5

Conclusions

“On the mountains of truth you can never climb in vain: either you will reach a point higher up today, or you will be training your powers so that you will be able to climb higher tomorrow”.

Friedrich Wilhelm Nietzsche
5.1 Discussions and Results

In the light curve of variable stars for differential magnitudes using different filters and for different color indices, certain gaps of phase are seen. This happens because of the non availability of the information about the photometer counts due to non observable sky condition on certain nights.

The motivation behind the present work was to use to see the small telescope equipped with state of art backend instrument and to study the short term as well as long term photometric light variation of chromospherically active stars. In this thesis we have presented the photoelectric photometry of 6 RS CVn binaries carried out in observing season during 2006-2007 by using 12” LX200 Meade Schmidt-Cassegrain reflector telescope at JES College Jalna. Our new photometry shows a small variation in the shape as well as amplitude in the light curve of classical RS CVn chromospherically active stars. UX Ari (HD 21242) is a well known non-eclipsing triple-lined system (Duemmler & Aarum 2001) where the two main components constitute a double-lined spectroscopic RS CVn binary system comprising a hot G5 V primary and an active cool K0 IV secondary star (Carlos & Poper 1971).The photometric and spectroscopic observations of UX Ari have been carried out several investigators (Hall et al.1975; Guinan et al. 1981; Nations and Ramsey 1986; Strassmeier et al.1989; Raveendran & Mohin 1995 and references therein). Presence of secondary spot group is distorted or asymmetric light curve is obtained has been found by previous observers (Busso et al. 1986; Strassmeier et al.1989; Raveendran & Mohin 1995). For the observations of UX Ari star existence of two maxima in light curve during epoch 2006-07 separated from each other by 0.4 in phase is also noticed. The differential amplitude continuously increases and reaches maximum (0.24)
during 2006-07 and decreases to 0.01 magnitude. My observations reveal variation in (B-V) colour index and also $\Delta V$ and $\Delta$ (B-V) as reported in the literature (Padmakar et al. (1999) & Barwey et al. (2005).

For the observations of V711 Tau, a survey of the literature on this system shows that the shape of light curve has undergone significant seasonal changes from almost symmetrical and sinusoidal to asymmetric and double peaked, and some times becoming almost flat. Variation in V photometric band has been reported to lie in the range 0.05 mag to 0.24 mag (Mohin and Raveendran 1993). Our observations indicate that the phase for the minimum light lies at 0.01 and the wave amplitude in the V band is 0.2 mag. The brightness of light maximum and minimum are 1.61 and 1.67 mag respectively. The large amplitude and nearly symmetric curve indicates that a large spot is concentrated at the longitude corresponding to 0.2 phase and is at higher latitude. The B-V colours do not show any significant correlation with the light variation.

For HD 52452 star observations no significant light variation was detected for the differential magnitudes of the comparison star, which is good measure of the quality of our observation. The uncertainties in $\Delta V$ and $\Delta$ (B-V) are 0.01 and 0.02 magnitudes. The amplitude of light variation is $\sim 0.23$ magnitude in V band which is larger compared to the $\sim 0.16$ magnitude in V band reported by Messina (2001). The present observations suggest that the optical variability in the star HD 52452 is due to the presence of cool spots on the stellar surface. The comparison of our data with previous observers reported by Messina et al. (2001) & Barwey et al. (2005) shows that there is a variation in amplitude but the phases of the two minima are quite stable during observations. The very short photometric period makes that this star is very interesting for studying the evolution of spots on stellar surface.
For HD 61396 star observations significant variation as well as change in amplitude and shape of light curve from previous reported photometry. The differential amplitude $\Delta V$ turns out to $\sim 0.02$ mag while Barwey et al. (2005) reported a value 0.07 magnitude. This indeed further confirms that the star belongs to the class of RS CVn type variables and light variation is due to the presence of starspots on the stellar surface.

For $\lambda$ And star observations, the nature of photometric variability is not qualitatively different from Padmakar (2000) had reported for the period 1995 and 1998. Previous observations shows a variation in V amplitude between 0.05 to 0.23 magnitudes which in turn implies that our observations $\lambda$ And was in the stage of moderate activity. Our results do not show any significant variation $\Delta$ (B-V) color index.

For IM Peg star observations, the light curve obtained by Eaton et al (1983) and Strassmeier (1989) show remarkable variation in the amplitude (from 0.11 to 0.24 mag) whereas they do not reveal significant variation in the shape. The observations of IM Peg are corrected for the atmospheric extinction and transfer into BV standard system. The uncertainties in $\Delta V$, $\Delta B-V$ are 0.02, 0.05 mag respectively. The shape of light curve however is similar to those of earlier investigators. The wave minima (0.92 phase) closely resembles with observations of Strassmeier et al. (1989) and Padmakar & Pandey et al. (1995).
5. 2 Future Prospects

There has been a remarkable progress in observational facilities and techniques for studying differential magnitude of variable stars. In this thesis I have presented the photoelectric photometry of 6 RS CVn binaries stars having small photometric period carried out in observing season during 2006-2007 by using 12” LX200 Meade Schmidt-Cassegrain reflector telescope at J.E.S. College Jalna. In future I along with my research colleagues may observe the long term photometric variations of RS CVn stars, CCD photometry of RS CVn and other group of stars also study starspots model which would uniquely determine spot parameters. In the next coming days we will have take some projects on occultation. We also participate in AAVSO companion observations of stars like Epsilon Auriga and get satisfactory result.
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