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Magnetic Activities of Late-type Stars

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Abstract. We present a brief overview for magnetic activities of late type stars in optical wavelength. Then, we introduce our ongoing project about magnetic activities of late-type stars. In the end, we listed our preliminary results, as follow. We revised orbital parameters and obtained new starspot parameters of a RS CVn eclipsing binary of V404 And and a low-mass eclipsing binary of NSVS 02502726. More interesting, we found new flare events on DV Psc. By analyzing the light curves, we found several Kepler eclipsing binaries show magnetic cycle. We also present chromospheric activities of late-type stars based on stellar spectrum survey of LAMOST (also called GuoShou-Jing telescope) in 2010-2013. Using the equivalent widths of the Hα line (larger than 1 Å), we have found 6391 active stars from 99741 M samples and revised the fraction of active as a function spectral type. The samples of M0-M3 of Lamost are larger than all previous samples, and the fractions are a bit larger than before. By comparing the TiO 5 and Ca H 1 2 3 molecular bands, there are many subdwarf candidates.

1. Introduction

Late-type stars (spectral type : From F to L, and evolution stages from the pre-main sequence to giant) with thick convective zones and rapid rotation exhibit magnetic activity phenomena, such as starspot, plage, flare, magnetic cycle, and active rotational modulation ... (Baliunas et. al., 1995; Güdel 2002, 2004; Berdyugina 2005; Hall 2008; Strassmeier 2009; Lanza 2010; etc). However, in many such kinds of stars, the details of the active phenomena are not well understood. In order to have a better understanding of the stellar magnetic activity, herein we plan to study the magnetic activities of late-type stars of the different stellar parameters by multi-color CCD photometry, and low, medium and high-resolution spectroscopy, and investigated the properties of the detailed magnetic activity in the photosphere, chromosphere and corona, and the relations of the magnetic activity and stellar parameters. These reveal the structure of magnetic fields and provide valuable constraints for solar and stellar dynamo theory.

Photometry remain the most common technique for study stellar activity. The corresponding methods are a light curve synthesis to obtain orbital parameter and starspot parameters (longitude, latitude, radius, and temperature) (Wilson & Devinney 1971, Budding & Zeilik 1987; Ribarik et al. 2003; Wilson & Van Hammer 2004; etc), light curve inversion to obtain starspot structure (Berdyugina et al. 2002), eclipse mapping to obtain some part of surface map during eclipse (Collier Cameron 1997). Continuous photometric data allow to reveal long-term evolution and find new flare events.

Chromospheric activity produces filled-in or emission in some strong photospheric lines (Fig.1 left). Sometimes flare was detected on some chromospheric active stars, such as HR 1099 (Fig.1 right). The equivalent widths (EWs) of Hα emission of HR 1099 increase by almost a factor of 4 (García-Alvarez et al 2003). Usually, we use these lines as chromospheric activity indicators (Montes et al. 2004; Zhang 2011; etc). These indicators are summarized as follows: the Na I D_1, D_2 lines and Mg I b triplet lines (formed in the upper photosphere and lower chromosphere.), the Ca II infrared triplet (IRT) lines (in the lower chromosphere), the Hα and other Balmer lines, the Ca II H & K lines (in the middle chromosphere), the He I D_3 lines (in the upper chromosphere) (Montes et al. 1995; Gunn & Doyle 1997; Montes 2004; Zhang & Gu 2010, Zhang 2011; etc.). By analyzing the chromospheric activity variation with orbital phase, astronomers have found some stars show rotational modulation phenomena (Frasca et al. 2008). Here we give an example of SZ Psc (Zhang & Gu 2008), which the

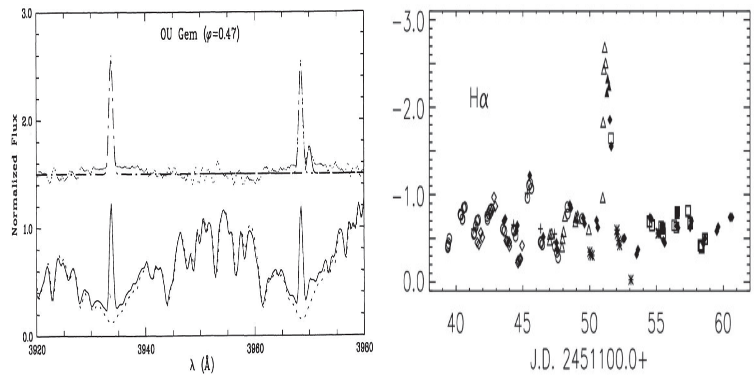

Figure 1. The left is the Ca II H&K observed and subtracted spectra of OU Gem (Montes et al. 1995), and the right is flare of HR 1099 (García-Alvarez et al 2003).

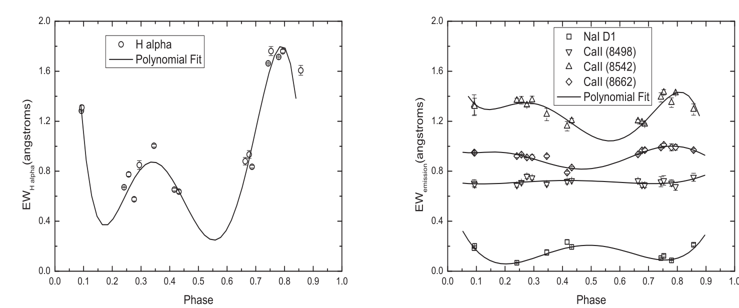

Figure 2. The EWs of the excess emissions vs. orbital phase for Na I D, Ca II IRT (left) and Hα (right) lines. The solid line refers to a polynomial fit to the data.

chromospheric emissions of SZ Psc are stronger around two quadratures of the system (phases 0.25 and 0.75) in the Hα and Ca II IRT lines (Figure 2).

From long-term monitoring of photospheric starspot, chromospheric emission, and magnetic field, astronomer obtained that many cool stars show different activity cycles (Wilson 1978; Baliunas et al. 1995; Radick 2000; Pi et al., 2012; etc).

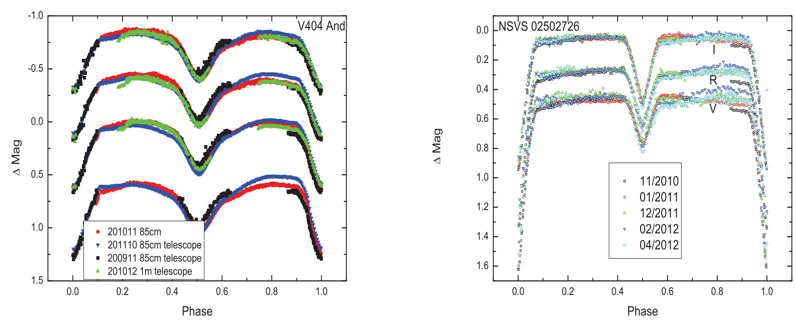

Figure 3. BVRI light curves of the RS Cvn binary of V404 And (left), and the low mass eclipsing binary of NSVS 02502726 (right) in different observational seasons.

2. Observation and objects

We aim to study magnetic activity by using photometry and spectroscopy. For photometric study, our instruments are 1.0 m telescope with a 2048 × 2048 pixel CCD (Qian et al. 2012) of Yunnan Observatory, and 85 cm telescope with a 1024 × 1024 pixel CCD and the standard Johnson-Cousin-Bessell BVRI filters (Zhou et al. 2009) at Xinglong station, NAOC. Our photometric objects are eclipsing binaries including some RS CVn eclipsing binaries and low-mass eclipsing binaries. For the RS CVn eclipsing binaries, there are RT And (Zhang & Gu 2008), DV Psc (Zhang et al. 2010a), V1034 Her (Zhang 2012), V404 And .... For the low mass eclipsing binaries, there are NSVS 02502726, NSVS 07453183, NSVS 11868841 (Zhang et al. 2012a). We plan to obtain their orbital parameters, and starspot evolution by analyzing the light curves using WD2004 program. If we are lucky, some flare events might be found on these binaries.

Spectroscopy is one of the main tools of modern astrophysics. For research by the high-resolution spectroscopy, the telescope is 2.16 meter telescope with echelle spectrograph at Xinglong station, NAOC (Zhao & Li 2001). The wavelength of echelle spectrograph are 3800 – 9000 Å with resolution 37, 000. Our objects are some chromospheric active stars, such SZ Psc (Zhang & Gu 2008), and V368 Cep, V383 Lac, DX Leo, EP Eri (Zhang 2011), and LQ Hya. The method we used is the spectral subtraction technique and the code is starmod developed by Barden (Barden 1985). We determined the behaviour of chromospheric active indicators and their chromospheric active strength. For low- resolution spectroscopy, our telescope is Guoshoujing Telescope (also named LAMOST), Xinglong station, NAOC (Zhao et al 2012; Cui et al. 2012). The wavelength region is 3800 – 9200 Å and the resolution is about 1800 (Luo et al. 2012). Our object is to discuss the magnetic activities of late-type stars based on stellar spectral survey of Guoshoujing Telescope (Zhang et al. 2012b; Pi et al. 2013).

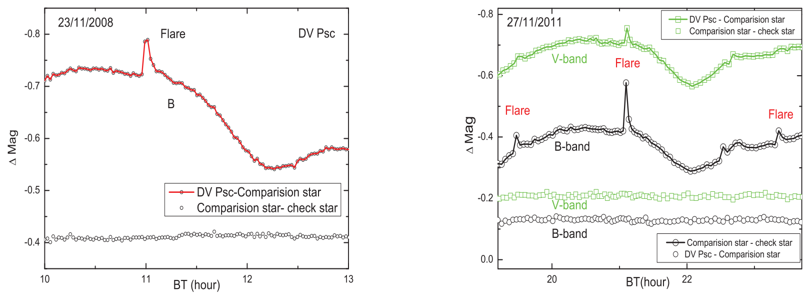

Figure 4. The flare events of DV Psc using the 85 cm telescope at xinglong station, NAOC.

3. Result

In the section, we listed our results of magnetic activities of the late-type stars.

3.1. Starspot evolution

For V404 and, it is a short period RS CVn binary with a Period of 0.68 days (Robb 1998). By analyzing the light curves (Figure 3 left), we found that starspots are variable on both a short and long time scale, especially the short-term variation. For NSVS 02502726, it is a low eclipsing binary with a period of 0.56 days (Çakirli et al. 2009; Coughlin & Show 2007; Lee et al. 2013). By analyzing the light curves (Figure 3 right), we found that the starspots are variable on both a short and long time scale.

3.2. Flare

DV Psc is a short period RS CVn eclipsing binary with a period 0.309 days, mass 0.7 $M\odot$ +0.49 $M\odot$, and spectral type K4 + M1 V (Robb 1999; Zhang & Zhang 2007; Zhang et al. 2010a). During our observations, several flare-like events might be detected on DV Psc in Figure 4 (Zhang et al. 2010a; Pi et al. 2012) using 85 cm telescope, NAOC.

3.3. Chromospheric activity

LQ Hya (P_{rot} = 1.6 days) is a young, rapidly-rotating single K2-dwarf and was classified as BY Dra type spotted star (Frasca et al. 2008; etc). By means of the spectral subtraction technique, we analyze our spectroscopic observations including several optical chromospheric activity indicators (the Hα, and Ca II IRT lines). For the Ca II IRT lines and the Hα lines (Figure 5 left and middle), it seems that there are also a rotation modulation of chromospheric activity for our data (Figure 5 right) and the previous data

(Frasca et al. 2008; Alekseev & Kozlova 2002; López-Santiago et al. 2010).

Guo Shou Jing Telescope provides a wonderful chance to study chromospheric

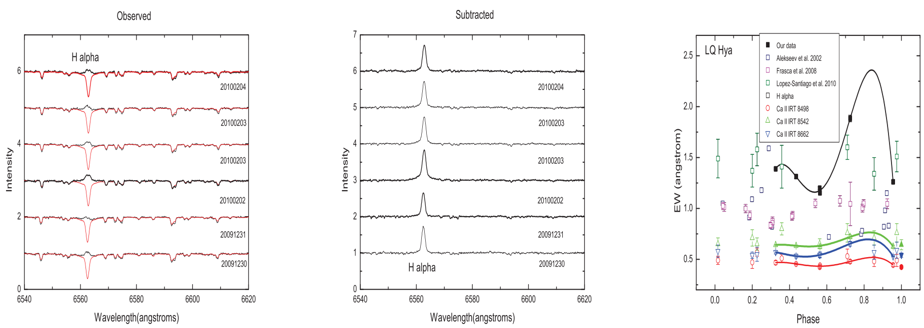

Figure 5. The left panel is the observed (black) and synthetic spectra (red) in the Hα line. The middle panel is the corresponding subtracted spectra. The right panel is the EWs of the excess emissions vs. orbital phase for the Hα and Ca II IRT lines.

activity of late type stars. We have reduced the stellar spectrum of M candidates of LAMOST in 2010-2013. We measured the chromospheric EWs of Hα line using the Hammer program and visually inspected all candidates and manually assigned spectral types (Hawley et al. 2002; West et al. 2004; Zhang et al. 2012b). The criteria to classify active stars are that the EW of the Hα line is larger than 1 Å, and its error, and the center height of the Hα emission must be 3 times its noise. These are similar to the criteria of West et al. (2011) and Zhang et al. 2012. We found 6391 active stars from 99741 M samples. Figure. 6 shows the LAMOST spectra of active M0 - M9 stars (left) and the fraction of stars that are active as a function of spectral types (right). By comparing the TiO 5 and Ca H 1 2 3 molecular bands (Figure 7), there are many subdwarf candidates.

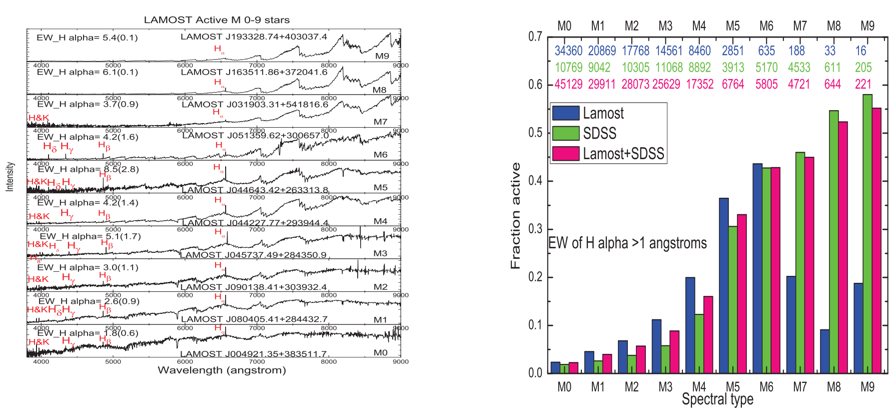

Figure 6. The LAMOST active spectra (left) and fraction of active stars as a function of spectral type (right). The upper numbers represent the total numbers of stars.