On the detemination of spot parameters in active late type stars

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Abstract. Photometric and spectroscopic variability of active late-type stars are frequently interpreted as evidence for magnetic activity analogous to solar activity. In particular cool, dark spots with enhanced photospheric magnetic fields are invoked to explain both photometric and spectroscopic variablity. In one of the diagnostic methods, the features such as TiO and VO in spectra were suggested to detect spots in stellar atmosphere of cool stars. In this contribution we discuss the TiO band technique and its limits using our own spectroscopic material.

1. Introduction

Photometric and spectroscopic variability of late type stars is frequently interpreted as evidence for magnetic activity analogous to solar activity. Techniques to detect spots are basically devided into three: photometry, Doppler imaging and TiO band spectroscopy. Spectral features such as Titanium Oxide (TiO) or Vanadium Oxide (VO) molecular bands (Ramsey & Nations 1980) were suggested as proxies to detect cool spots on the atmospheres of active stars since these molecules can only exist on those parts of the stellar atmosphere cooler than around 3500 K. This spectroscopic method was explored by several authors and applied to a sample of chromospherically active late type stars. In the recent publications (O'Neil et al. 1997) the authors used TiO spectra at the 7055Å and 8860Å spectral regions of late-type stars to examine both spot temperature and areas on a number of chromospherically active stars. We have obtained high signal-to-noise, high resolution spectra of a sample of field K and M dwarfs to study TiO bands, in particular TiO 7055Å and 8860Å bands. In this contribution we examine the calibration of TiO 7055Å band using our own spectroscopic material and take a very preliminary look at the active star EQ Vir as well.

2. Observations

During two nights in June 1994 we observed 9 dwarf stars with spectral types between K0 and M5 using 4.2m WHT in the Canary Islands. The instrument was equipped with the Utrecht Echelle Spectrograph (UES) providing the resolving power ∼30000 and signal-to-noise ∼200 in the continuum near 7055Å region. Table 1 gives some basic characteristics of the programme stars, i.e. spectral

Table 1. Programme stars-WHT94.

Gliese No.	Sp. Type	B-V	R-I	TiO band depth
411	M2V	+1.51	+0.92	15.0
517	K5V	+1.20	+0.54	5.5
569	M0V	+1.48	+0.80	22.0
673	K7V	+1.36	+0.60	4.0
687AB	M3.5V	+1.50	+1.10	28.0
699	M5V	+1.73	+1.25	38.0
702A	K0V	+0.86	+0.26	1.0
820A	K5V	+1.17	+0.47	2.4
896A	M4V	+1.71	+1.28	36.0

type, photometric indices from Gliese & Jehreiss (1991) and our measured TiO band-depth index. The spectra were extracted from the echellograms and routinely reduced. The metallicity for these stars was studied in Zboril & Byrne (1998) and was found not to vary within the individual stars too much, from -0.20 up to -0.30 dex. Another set of observations of relatively high spectral resolution (0.08Å) is available from AAT (observations made in January 1996) and from WHT+UES (June 1996) (resolution 0.08Å). The INT (September 1997) data using MUSICOS spectrograph, on the other hand, are associated with stars known to have very different metallicities and surface gravities but are still being processed and will become available in winter 1998.

3. TiO λ7055 Å index

To define the empirical band-depth index given in Table 1, we have followed Neff et al's procedure, i.e. we measured the difference between pseudo-continuum levels on either side of the bandhead, expressed as a percent of the continuum level to the blue of the bandhead. The exact spectral regions used to determine this ratio were 7043-7048 Åand 7060-7065 Å. To intercompare our results directly we plotted in Figure 1 the dependence of band-depth index with the (R–I) colour index rather than with the effective temperature.

EQ Vir is a young, single, rapidly rotating, flare and variable star. The photometric period is 3.96 days (Bopp & Fekel 1977). It also possesses strong chromospheric and transition emission lines. Saar et al. (1986) derived a value for the mean magnetic field of 2.5 kG, covering 80% (!) of the stellar surface. Figure 2 shows differences in TiO band-depth index and the hydrogen alpha profile within 2 consecutive nights, i.e. phase difference 0.25.

Table 2. Programme stars-AAT96 & WHT96.

HD/Gl No.	Sp. Type	B-V	R-I	TiO depth	phase
HD45184	G2V	0.62	—	1.1	
HD26965	K1V	0.82	0.45	1.1	
HD22049	K2V	0.88	0.47	1.4	
Gl204	K5V	1.11	0.43	2.3	
Gl205	M1.5V	1.49	0.85	19.5	
HD33833	G7III	0.96	—	1.2	
HD29085	G6III	0.98	0.54	1.0	
HD34649	K2.5III	1.28	0.63	1.0	
HD38099	K4III	1.48	—	8.3	
HD147379	M0Vvar	1.41	0.68	9.0	
HD151288	K7.5Ve	1.37	0.57	2.5	
Gl517	K5Ve	1.20	0.54	6.5	0.00[1]
Gl517	K5Ve	1.20	0.54	6.5,7.0	0.25

[1] Note: JD0 adopted equals to JD of the night.

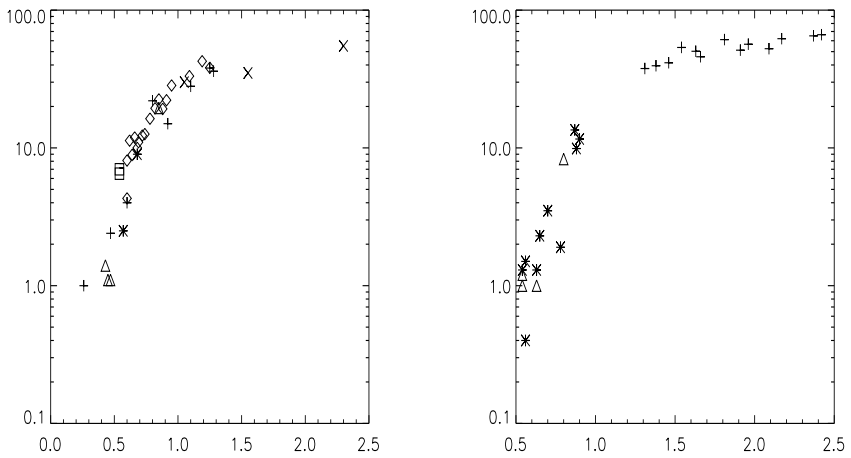

Figure 1. Left figure: TiO 7055 Å band depth index vs. $(R–I)$ for dwarf stars. *Crosses*-WHT94 data, *stars*-WHT96 data, *triangle*-AAT96 data, *diamonds*-Neff & O'Neal (1995), *slantcrosses*-Phoenix data and *squares*-EQ Vir data points. Right figure: The relationship for giant stars. *Crosses*-O'Neal & Neff (1997) data, *stars*-Neff & O'Neal (1995), *triangles*-AAT96 data.

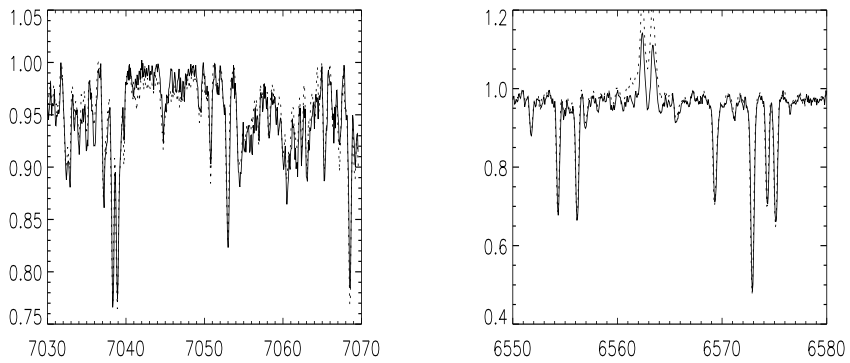

Figure 2. Left figure: TiO 7055 Å index progress for EQ Vir in two consecutive nights. Right figure: hydrogen alpha profile progress.

4. Results

We have evaluated numerically the dependence of the band index upon the (R–I) colour index by making a polynomial fit to the data for both dwarfs and giants.

$$D_{7055}^{dw,giant} = \sum a_i \cdot (\log (R - I))^i \qquad (1)$$

The relationships saturate for very cool stars which means that the error bar on the measured band-depth index will respond in a large error in temperature estimate. The hot stars in the calibration, on the other hand, display a scatter making the calibration less precise as well. Our spectroscopic observations seem to be integrated very well into the previous calibrations. The band-depth indexes for EQ Vir suggest later spectral type while the hydrogen alpha emissions changed dramatically in two consecutive nights covering 0.25 of the photometric phase. A more detailed account of this work will appear in forthcoming paper.

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