First Results of the TIGRE Chromospheric Activity Survey

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Abstract. We present the first results of the stellar activity survey with TIGRE (Telescopio Internacional de Guanajuato, Robótico-Espectroscópico). This long term program was started in August 2013 with the monitoring of a larger number of stars. We aim at measuring the short- and long-term variability of stellar activity for stars of different spectral types and luminosity classes, using indicators of different spectral lines (mainly Ca II S-Index, Ca II IR triplet, H_α and sodium D). A transformation equation of the TIGRE S-Index into the Mount Wilson S-index was derived in order to compare our results to the vast body of existing S-index measurements. Furthermore, the correlation between the S-index and the lines of the Ca II IR triplet has been studied, based on strictly simultaneous observations.

1. Introduction

Ca II H+K line emission is a very sensitive indicator of stellar activity. Therefore, this resonance line doublet at 3934 and 3968 Å has become the work horse for investigating the chromospheric stellar activity of cool stars. However, this spectral region is difficult to observe for stars of very late spectral type, since it is quite faint in the spectra of late K and M type stars. From that practical point of view, it is much more efficient to use some other stronger lines at longer wavelengths. One possibility is offered by the Ca II IR triplet, since it is known that the Ca II IRT line depths are indeed correlated with the Ca II H+K emission, (Busà et al. 2007; Martínez-Arnáiz et al. 2011).

In our study we started with investigating the question, how good and how sensitive are the Ca II IRT lines as a stellar activity indicator. For such studies the TIGRE instrumentation and its double-channel (red & blue) spectrograph is ideally suited, because both the Ca II H+K and IRT lines are observed strictly simultaneously (Schmitt et al. 2014).

Table .1: This set of calibration stars was used to derive the transformation of the TIGRE S-index onto the Mount Wilson S-index.

Objects and references: (0) Interpolate from time series from Baliunas et al. (1995), (1) Baliunas et al. (1995), (2) Hall (private communication)				
HD 6920[1]	HD 23249[1]	HD 42807[2]	HD 100563[1]	HD 129333[1]
HD 10307[2]	HD 25998[1]	HD 45067[1]	HD 101501[1]	HD 131156A[1]
HD 10700[1]	HD 26923[1]	HD 61421[1]	HD 106516[1]	HD 137107[1]
HD 13421[1]	HD 30495[1]	HD 72905[1]	HD 142373[1]	HD 142373[1]
HD 16673[1]	HD 32923[2]	HD 75332[1]	HD 115043[1]	HD 158614[1]
HD 17925[1]	HD 35296[2]	HD 75528[2]	HD 115383[1]	HD 201091[0]
HD 19373[2]	HD 37394[1]	HD 89744[1]	HD 115617[1]	HD 207978[1]
HD 22049[1]	HD 39587[2]	HD 95735[1]	HD 124570[1]	HD 216385[1]
HD 22072[1]	HD 41330[2]	HD 97334[1]	HD 124850[1]	HD 217014[1]

2. Transformation from the TIGRE S-index into the Mount Wilson S-index

The Mount Wilson S-index (hereafter S_{MWO}-index) is the most commonly used and most important activity index in the optical spectral range, thanks to the decades-long efforts of the "Mount Wilson HK-Project". This project was a long-term monitoring effort to search for chromospheric variations in solar-type stars (Wilson 1978; Duncan et al. 1991; Baliunas et al. 1995). Basically, the S_{MWO}-index is defined as the ratio of the sum (i) of the counts in the Ca II H+K line centre in a triangular bandpasses with a FWHM of 1.09 Å over (ii) two 20 Å pseudo-continuum bandpasses centred at 3901.07 Å and 4001.07 Å(Vaughan et al. 1978; Duncan et al. 1991).

The TIGRE S-index (hereafter S_{TIGRE}-index) is calculated from the blaze-normalised and echelle-order-merged spectra. Here a rectangular 1.0 Å bandpass is used to represent the flux in the Ca II H+K line centres (instead of the classical triangular bandpass with a FWHM of 1.09 Å; cf. Vaughan et al. (1978)).

In general, any type of S-index measured with an instrumentation other than the original instrument has to be transformed to the Mount Wilson scale by measuring the original set of calibration stars to allow a direct comparison. This calibration procedure and the linear least-square correlation between our and the original S-index measurements results in a linear equation which then transforms any S_{TIGRE}-index measurement into the respective S_{MWO}-index values. The calibration stars with very well known S_{MWO} values were selected from Baliunas et al. (1995) and Hall et al. (2007). More importantly, these stars are known to be relatively constant in their activity levels and do not show any periodic activity behaviour either (with the only exception of HD 201091 (see Tab. .1).

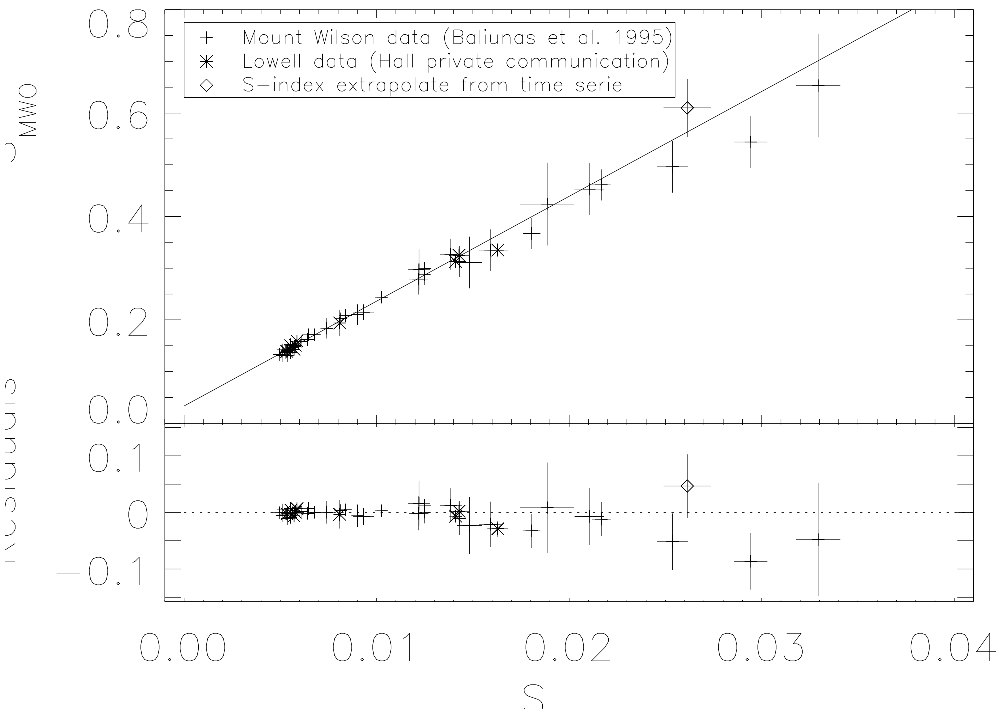

Figure .1: S_{MWO}-index vs. S_{TIGRE}-index. Upper panel: S_{MWO}-index vs. S_{TIGRE}-index, the solid line shows the best linear fit to convert the $\mathrm{S_{TIGRE}}$-index into $\mathrm{S_{MWO}}$-index. Lower panel: Fit residuals.

All calibration stars have been observed more than ten times with TIGRE to obtain a robust average $\mathrm{S_{TIGRE}}$ value. In Fig. .1, $\mathrm{S_{MWO}}$-index values are plotted vs. the respective $\mathrm{S_{TIGRE}}$-index measurements. A tight, linear correlation between S_{MWO} and $\mathrm{S_{TIGRE}}$ is evident. The least-square fit is represented by the solid line, which defines the transformation:

$$S_{\mathrm{MWO}} \quad = \quad (0.033 \pm 0.003) + (20.3 \pm 0.4) S_{\mathrm{TIGRE}}. \tag{1}$$

The standard deviation of the residuals is very small (0.02) and the mean scatter of the residuals between the transformed $\mathrm{S_{TIGRE}}$-index and the corresponding reference S_{MWO}-index is 3.6%.

3. Correlation between the $\mathrm{S_{MWO}}$-index and the Ca II IRT 8542 line of HD 131977

To investigate the correlation between the $\mathrm{S_{MWO}}$-index and the Ca II IRT lines, suitable activity indicator must first be defined for the Ca II IRT lines. For this purpose, the same definition is used as for the $\mathrm{S_{MWO}}$. Consequently, we again use "S" as the name for this indicator, but with the index "IRT 8542" for the Ca II IRT 8542 line. $\mathrm{S_{IRT8542}}$ is defined as the ratio of the counts in a 1 Å bandpass centred on the line core over a 20 Å continuum bandpass centred at 8580 Å. In Fig. 2, the $\mathrm{S_{IRT8542}}$-index values are plotted over the respective $\mathrm{S_{MWO}}$-index measurements and a clear correlation between both indicators is evident. However,

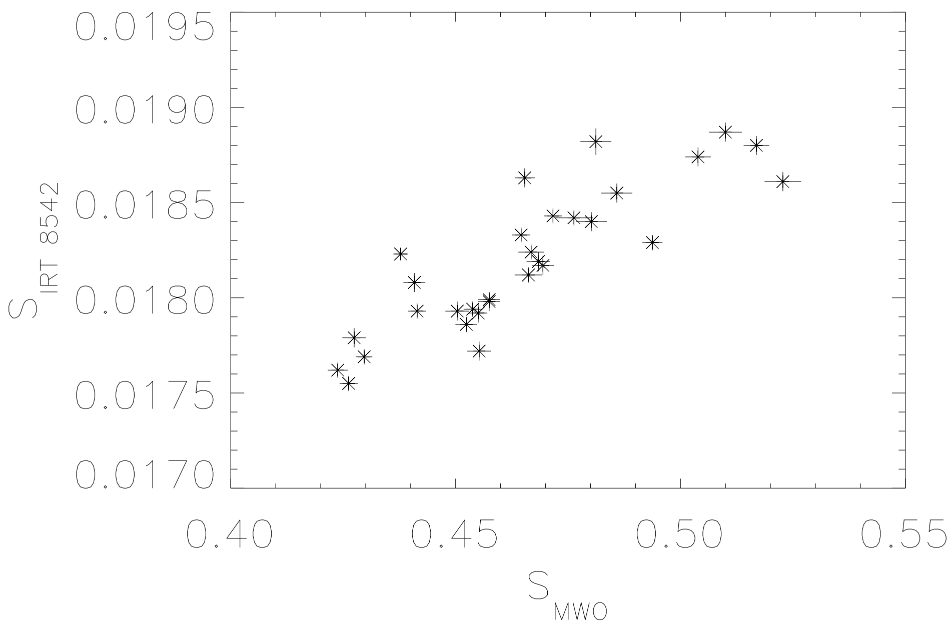

Figure .2: Correlation between the $S_{IRT8542}$-index vs. S_{MWO}-index.

this graph also illustrates the fact that the Ca II IRT 8542 line is not as sensitive as the Ca II H&K lines, since it varies by about a factor of 2 less.

4. Variation in the S_{MWO}-index and the Ca II IRT 8542 line time series of HD 131977

In Fig. 3a, a time series of TIGRE S_{MWO}-index vaoues is shown for HD 131977. The time series was detrended and a Fourier analysis has been performed using the Lomb-Scargle periodogram. As a result, a periodic variation of 33.0 ± 0.4 days was found, (see Fig. 3b). In Fig. 3c, the detrended time series is plotted phase-folded with that period. We interpret the main peak as the rotation period of that star.

The same investigation was performed for the Ca II IRT 8542 line S-index, see Fig. 4a. In Fig. 4b, the periodogram is shown and again we find a clear peak at the period of 33.3 ± 0.5 days, showing that these two activity indicators vary with the same period.

5. Summary and conclusions

In the first year of TIGRE observations at La Luz Observatory La Luz we were able to take the first time series for a stellar sample of more than 100 stars. This sample includes ≈ 90% of the stars listed in Baliunas et al. (1995). One result of this initial observing season is the calibrated equation to transform our S_{TIGRE}-index measurements into S_{MWO}-index values.

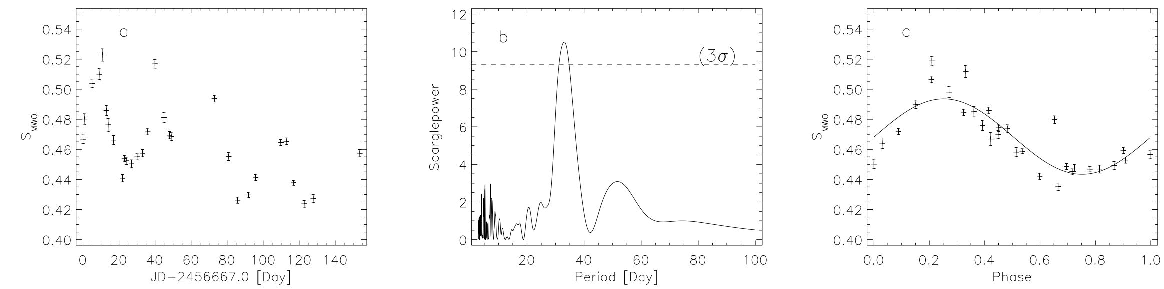

Figure .3: Left panel: S_{MWO}-index time series. Medium panel: Periodogram of the detrended time series. Right panel: Phase folded detrended time series.

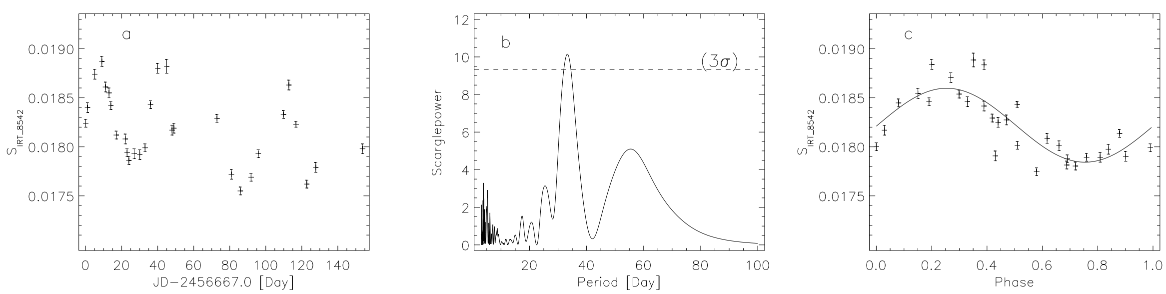

Figure .4: Left panel: $S_{IRT8542}$-index time series. Medium panel: Periodogram of the detrended time series. Right panel: Phase folded detrended time series.

With this transformation onto the Mount Wilson scale, it is possible to compare our results with data covering a time-span of several decades and several thousands of stars.

Furthermore, we have investigated the correlation between the S_{MWO}-index and the Ca II IRT lines and show that the rotation periods measured in the S_{MWO}-index series and in the Ca II IRT lines is the same for the case of HD 131977. Thus we can estimate how the sensitivity of the Ca II IRT lines to stellar activity compares with that of the Ca II H+K based S_{MWO}-index. Furthermore, we find that the sensitivity of $S_{IRT8542}$-index compared to S_{MWO} is a factor of $\approx$2 lower, nevertheless, Ca II IRT lines are usable to measure rotation periods. Through this possibility, a new observation window can be open to measure the rotation period of very late type stars (late K and M type stars) since these objects are much easier to observe in the near IR.

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