

# The chromospheric activity of FGK stars in the solar neighborhood as an estimation of the radial velocity jitter

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## Abstract

We present here some of the results of our ongoing long-term high resolution spectroscopic study of nearby ( $d < 25$  pc) FGK stars which aim is to characterize the local properties of the Galaxy, in particular the star-formation history. The level of chromospheric activity of these stars have been determined using different activity indicators, such as H $\alpha$ , Ca II H&K lines or Ca II IRT lines. The chromospheric contribution has been determined using the spectral subtraction technique. The  $R'_{HK}$  index determined from the Ca II H&K fluxes determined in this way has been compared with the traditional  $R'_{HK}$  index (derive from the Mount Wilson  $S$  index) and calibrated with the  $R'_{H\alpha}$  and  $R'_{CaII\ IRT}$  derived from our spectra. We have used these chromospheric activity indexes to estimate the range of expected radial velocity jitter ( $\sigma_{rv}$ ) of these stars using empirical relationships, given by others authors, between  $\sigma_{rv}$  and  $R'_{HK}$ . These values provide an estimation of the activity related noise one should expect for a star, and thus to set the minimum detectable mass for a planet orbiting the star or determine the minimal amplitude variation that could be suspected to be a planet. Following this idea the data presents an enormous potential in terms of target selection for exoplanet searches surveys.

## Stellar Sample

Our team leads a high resolution echelle spectroscopic program with the aim of achieve a fair picture of the local star formation history by characterizing the FGK local population ( $d < 25$  pc) in terms of the kinematics and chromospheric activity/age/rotation/stellar parameters relationships in groups of stars with different ages. Until now we have analysed 322 cool stars (3 A, 50 F, 101 G, 165 K and 3 M type stars).

These stars are potential targets of future projects aiming at detecting Earth-like planets or exo-zodics. In this way, most of our stars will be observed in the framework of DUNES (DUst around NEArby Stars) an approved Herschel Open Time Key Project with the aim of detecting cool faint dusty disks, at flux levels as low as the Solar EKB.

Some stars of the sample (12 of the total sample of 322) have confirmed exoplanets orbiting around them (<http://exoplanet.eu>).

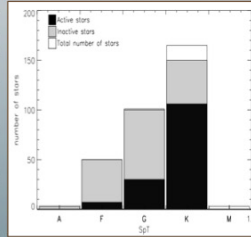


Fig. 1 Distribution fo active and inactive stars

## Observations

To carry out the this study, we used high resolution ( $R = 45000 - 50000$ ) optical spectra with a spectral coverage including the fundamental chromospheric activity indicators (Ca II H&K lines, Balmer lines and Ca II IRT), Lithium line ( $\lambda 6707.8 \text{ \AA}$ ) and the resonant doublet of sodium. The spectra analysed until now were taken by our team between 2005 and 2007 by using the FOCES spectrograph at the 2.2 m telescope of the Calar Alto Observatory and the SARG spectrograph at the Telescopio Nazionale Galileo (3.56 m) in La Palma Observatory. Additional spectra for other stars have been obtained in public archives and libraries like S4N (Allende Prieto et al., 2004).

## Chromospheric Activity

Chromospheric activity produce both photometric and spectroscopic variations that can be mistaken as planets. Large spots crossing the stellar disc can produce planet-like periodic variations in the light curve of a star. Moreover, spots clearly affect the spectral line profiles. Such perturbations will in turn affect the line centroids creating a radial velocity jitter that might "contaminate" the variations induced by a planet. Precise chromospheric activity measurements are needed to estimate the activity induced noise that should be expected for a given star.

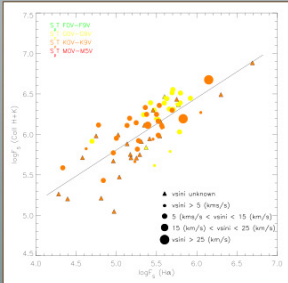


Fig. 2

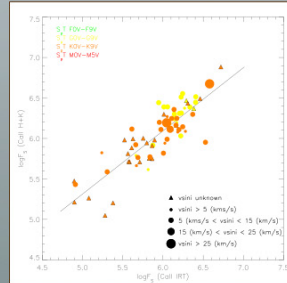


Fig. 3

The chromospheric contribution in the different activity indicators, such as H $\alpha$ , Ca II H & K or Ca II IRT lines (see Fig. 4) has been determined using the spectral subtraction technique described in detail by Montes et al. (1995, 2000). The synthesized spectrum was constructed using the program STARMOD developed at Penn State (Barden 1985). The inactive stars used as reference stars in the spectral subtraction were observed during the same observing run as the active stars. Surface fluxes,  $F_s$  (see Table 2), were determined from the measured excess emission equivalent widths using the continuum flux determined with the empirical relationships given by Hall (1996). Figs. 2 & 3, shown the relationships between  $F_s(\text{Ca II H + K})$  and  $F_s(\text{H}\alpha)$  and  $F_s(\text{Ca II IRT})$ , for more details Martínez-Arnáiz et al. (2009, in preparation).

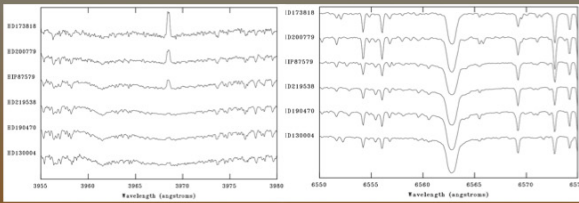


Fig. 4 Stars with different activity levels are shown by different intensities of the Ca II H line (left) H $\alpha$  line (right).

Table 2. Excess emission in different chromospheric activity indicators for the active stars in the sample.

HIP	Spectrograph	MJD (days)	$\log F_s$ (erg cm <sup>-2</sup> s <sup>-1</sup> ) in the subtracted spectrum			$\log R'_{HK}$			
			Ca II H	Ca II IRT	H $\alpha$				
544	McDonald	52031.3248	5.78 ± 0.03	5.68 ± 0.04	5.79 ± 0.14	5.69 ± 0.06	5.69 ± 0.02	-4.67	
544	SARG	54780.9561	...	...	5.47 ± 0.12	5.95 ± 0.12	5.95 ± 0.21	5.95 ± 0.16	-4.61
1803	SARG	54777.9856	...	...	5.94 ± 0.04	5.87 ± 0.20	5.87 ± 0.13	...	-4.39
3093	FOCES	53577.1854	5.32 ± 0.03	...	...	...	...	...	...
3418	FOCES	53580.1213	...	5.03 ± 0.77	...	...	...	...	...
3765	FOCES	53747.7686	5.00 ± 0.37	5.96 ± 0.03	4.13 ± 1.38	...	...	...	-5.33
3765	McDonald	52164.3977	4.95 ± 0.08	4.81 ± 0.12	4.55 ± 1.18	4.76 ± 0.22	4.76 ± 0.04	4.76 ± 0.12	-5.41
4845	SARG	54778.9878	...	...	5.12 ± 0.10	4.97 ± 0.17	4.97 ± 0.60	4.97 ± 0.60	-4.52

## Rotation (v sin i)

The determination of rotational velocities ( $v \sin i$ ) when handling precise radial velocity ( $RV$ ) measurements is crucial. Given that  $RV$  is determined by measuring the position of the centre of the spectral lines, the processes that produce a modification of their shape will have an effect on the measured values. Obtaining  $v \sin i$  of the star is thus essential to test whether detected  $RV$  variations have a stellar or a planetary origin.

We have determined the  $v \sin i$  for all the star of the sample using a method based in the information provided by the cross-correlation function (CCF), for details see Martínez-Arnáiz et al. (2009, in preparation).

Table 1. Stellar parameters of the stars in the sample.

HIP	Spectrograph	MJD (days)	RA (J2000)	DEC (J2000)	B - V (mag)	SpT	$v \sin i$ (km s <sup>-1</sup> )	ACTIVE
171	McDonald	52164.3858	00 02 09.65	+27 05 04.2	0.690	G5Vb	≤ 4.07	Not Active
544	SARG	54780.9561	00 06 36.53	+29 01 19.0	0.749	G8V	8.07	Active
544	McDonald	52031.3248	00 06 36.53	+29 01 19.0	0.749	G8V	5.72	Active
910	SARG	54777.8430	00 11 15.91	-15 28 02.4	0.489	F5V	4.88	Not Active
1499	FOCES	53578.1286	00 18 41.62	-08 03 09.5	0.680	G1.5V	4.18	Not Active
1532	FOCES	54089.7731	00 19 05.58	-09 57 50.8	1.305	K5V	≤ 0.53	Not Active
1598	FOCES	53576.1488	00 20 00.51	+38 13 41.0	0.625	G0V	3.74	Not Active
1803	SARG	54777.9856	00 22 51.55	-12 12 34.5	0.675	G3V	9.94	Active

## Activity ( $R'_{HK}$ ) - radial velocity jitter ( $\sigma_{rv}$ )

The traditional activity index,  $R'_{HK}$ , defined as the ratio of the emission from the chromosphere in the cores of the Ca II H&K to the total bolometric emission of the star can be determined as the ratio of our chromospheric excess flux,  $F_s(\text{Ca II H+K})$ , and  $\sigma_{T_{\text{eff}}^4}$ .

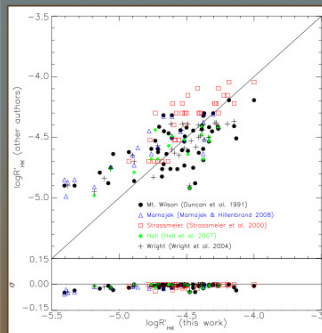


Fig. 5 Comparison of  $R'_{HK}$  of this work with other authors

In order to test whether our  $R'_{HK}$  is consistent with those values of  $R'_{HK}$  computed using photometry (or a technique to mimic photometric results using spectroscopic data) we have compared our data to that obtained by Duncan et al. (1991), Strassmeier et al. (2000), Wright et al. (2004), Hall et al. (2007) and Mamajek & Hillenbrand (2008). Fig. 5 shows that the discrepancies are larger for less active stars but a systematic difference must be discarded.

$R'_{HK}$  can be used as a proxy of the stellar activity to infer the expected  $RV$  noise a star might present ( $\sigma_{rv}$  or jitter).

Table 3. Predicted radial velocity jitter

HIP	Spectrograph	MJD (days)	SpT	$\log R'_{HK}$ (m s <sup>-1</sup> )	$\sigma_{rv}^1$ (m s <sup>-1</sup> )	$\sigma_{rv}^2$
544	McDonald	52031.3248	G8V	-4.67	5 - 15	7 - 18
544	SARG	54780.9561	G8V	-4.61	5 - 18	8 - 19
1803	SARG	54777.9856	G3V	-4.39	10 - 32	11 - 25
3765	FOCES	53747.7686	K2V	-5.33	0 - 2	4 - 10
3765	McDonald	52164.3977	K2V	-5.41	0 - 2	4 - 10
4845	SARG	54778.9878	K7V	-4.52	7 - 23	5 - 13
5286	FOCES	53576.1601	K3V	-4.57	6 - 20	5 - 13

In Table 3 we give the expected  $\sigma_{rv}$  values (within 1  $\sigma$ ) obtained with the empirical relationships derived by Saar et al. (1998)<sup>1</sup> and Santos et al. (2000)<sup>2</sup>. When the Ca II H&K lines are not available in our spectra we derived  $R'_{HK}$  from H $\alpha$  or Ca II IRT lines, see Figs. 2 & 3 and Martínez-Arnáiz et al. (2009, in preparation).

## Acknowledgments:

This work was supported by Universidad Complutense de Madrid (UCM), the Spanish Ministerio de Ciencia e Innovación (MICINN) under grants AYA2008-00695 and AYA2008-01727, and "The Comunidad de Madrid" under PRICIT projects S-0505/ESP-0237 (ASTROCAM) and S-0505/ESP/000361 (ASTRID).

