Chromospheric activity of FGK stars in the solar vicinity

An estimation of the radial velocity jitter

R.M. Martínez-Arnáiz[1], J. Maldonado[2], D. Montes[1], C. Eiroa[2] and B. Montesinos[3]

[1] Universidad Complutense de Madrid, Dpto. de Astrofísica, Fac. C.C. Físicas, Madrid, Spain,
[2] Universidad Autónoma de Madrid, Dpto de Física Teórica C-XI, Fac. de Ciencias, Madrid, Spain
[3] LAEX, CAB (CSIC-INTA), ESAC Campus, P.O. BOX 73, 28691 Villanueva de la Cañada, Madrid, Spain

Sociedad Española de Astronomía
IX Reunión Científica
Campus Central del CSIC, Madrid
Del 13 al 17 de Septiembre, 2010

ABSTRACT

Chromospheric activity produces 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. These spots clearly affect the spectral line profiles and their perturbations alter 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. We obtain precise chromospheric activity measurements and projected rotational velocities for nearby (d < 25 pc) cool (spectral types F to K) stars, to estimate their expected activity-related jitter. As a complementary objective, we attempt to obtain relationships between fluxes in different activity indicator lines, that permit a transformation of traditional activity indicators, i.e, Ca II H & K lines, to others that hold noteworthy advantages. We used high resolution (~50000) echelle optical spectra. To determine the chromospheric emission of the stars in the sample, we used the spectral subtraction technique. Rotational velocities were determined using the cross-correlation technique. To infer activity-related radial velocity (RV) jitter, we used empirical relationships between this jitter and the R'_{HK} index. We measured chromospheric activity, as given by different indicators throughout the optical spectra, and projected rotational velocities for 371 nearby cool stars. We have built empirical relationships among the most important chromospheric emission lines. Finally, we used the measured chromospheric activity to estimate the expected RV jitter for the active stars in the sample.

Observations

To carry out 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 (λ6707.8 Å) 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).

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 cromospheric activity/age/rotation/stellar parameters relationships in groups of stars with different ages. Until now we have analysed **371** cool stars (56 **F**, 126 **G**, 186 **K** and 3 M type stars).

These stars are potential targets of future projects aiming at detecting Earth-like planets or exo-zodies. 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 (15 of the total sample of 371) have confirmed **exoplanets** orbiting around them (http://exoplanet.eu).

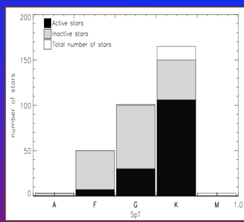

Fig. 1: Distribution fo active and inactive stars

Chromospheric Activity

Chromospheric activity produces 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.

The **chromospheric contribution** in the different activity indicators, such as Hα, 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). Fig. 2 shows the relationships between F_S **(Ca II H + K)** and F_S**(Hα)** and F_S**(Ca II IRT)**, see Martínez-Arnáiz et al. (2010) for more details.

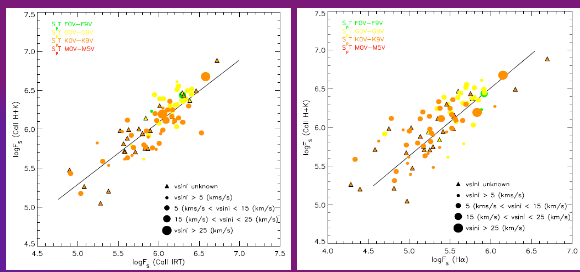

Fig. 2: Flux-flux relationships between Ca II (H+K) and Ca II IRT (left panel) and Ca II (H+K) and Hα (right panel).

Activity (R'_{HK}) - radial velocity jitter (σ_{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 (Ca II H+K), and σT_{eff}^4.

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. 3 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 (**σ_{rv} or jitter**).

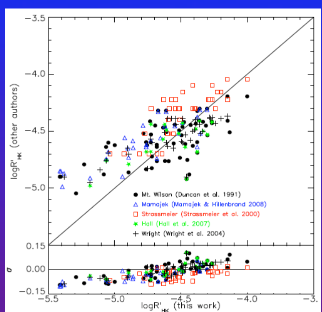

Fig. 3: Comparison of R'_{HK} of this work with other authos

HIP	Spectrograph	MJD (days)	SpT	$\log R'_{HK}$ ($m\,s^{-1}$)	σ_{rv}^{1} ($m\,s^{-1}$)	σ_{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 σ_{rv} values (within 1 σ) obtained with the empirical relationships derived by Saar et al. (1998)[1] and Santos et al. (2000)[2]. When the Ca II H&K lines are not available in our spectra we derived R'_{HK} from **Hα** or **Ca II IRT** lines, see Fig.2 and Martínez-Arnáiz et al. (2010).

Rotation (vsini)

The determination of **rotational velocities (vsini)** 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 *vsini* of the star is thus essential to test whether detected *RV* variations have a stellar or a planetary origin.

We have determined the ***vsini*** 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. (2010).

References

Allende Prieto et al., 2004, , A&A, 420, 183
Barden 1985, ApJ, 295, 162
Duncan et al. 1991, ApJ Suppl., 76, 383
Hall et al. 1996, Publications of the ASP, 108, 313
Hall et al. 2007, AJ, 133, 862
Mamajek & Hillenbrand 2008, ApJ, 687, 1264
Martínez-Arnáiz et al. 2010, A&A, 520, A79
Montes et al. 1995, A&A Suppl., 114, 287
Montes et al. 2000, A&A Suppl., 146, 103
Saar et al. 1998, ApJ, 498, L153
Santos et al. 2000, A&A, 361, 265
Strassmeier et al. 2000, A&AS, 142, 275
Wright et al. 2004, ApJS, 152, 261

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 project S2009/ESP-1496 (AstroMadrid).