SF2A 2007
J. Bouvier, A. Chalabaev, C. Charbonnel (eds)

STELLAR METALLICITY AND ACTIVITY STUDY FOR EXOPLANETS SEARCHES WITH THE SOPHIE SPECTROGRAPH.

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Abstract. The spectrograph SOPHIE (1.93-m OHP) has been opened to the scientific community since November 2006. In order to increase the scientific return of the instrument, we develop automatic tools for characterizing targets. The use of cross-correlation technique for radial velocity measurements allows a direct estimation of the star metallicity [Fe/H] with a good approximation (± 0.1 dex). Such an estimation may help in the strategy of exoplanet search considering that a host planetary system is mostly found around metal-rich star. Stellar activity may be characterized by the relative flux in the emission lines of CaII H and K which can be scaled to the activity index R'_{HK}. Such index may help in the estimation of the radial velocity jitter due to the stellar activity and the discrimation between Doppler motion and radial-velocity noise due to stellar spots. We present here these calibrations, which will be soon available in the SOPHIE automatic data reduction pipeline, and discuss how these estimations of metallicity and activity are used in the large program of exoplanets search.

1 Introduction

After the discovery in 1995 of the first confirmed extra-solar planet around solar-type star by M. Mayor and D. Queloz, nowadays more than 250 exoplanets are known, mostly detected *via* radial velocimetry. The increase of stability of all the spectrographs built (ELODIE, CORALIE, HARPS, FLAMES) allows high precision measurements and increase the number of targets followed. The new spectrograph SOPHIE (1.93-m Haute Provence Observatory), principaly dedicated to exoplanets search, has been opened to the scientific community since November 2006 (Le Coroller et al. these proceedings). The objective of the work presented in this paper is to develop tools in order to increase the scientific return of the instrument and to optimize the observation strategy of the consortium Exoplanets SOPHIE (Bouchy et al. these proceedings). The first tool is an automatic determination of the observed star metallicity in order to follow metal-rich stars given that Hot-Jupiters are mostly found around them. The second one is the characterization of the star activity in order to distinguish radial velocity variations induced by activity phenomena at the stellar surface from those due to a planetary compagnon. These tools had been already studied and showed their efficiency for other spectrographs (Santos et al. 2000, 2002) and we now develop them for SOPHIE.

In section 2, we present the calibration of stellar metallicity. Section 3 contains the calibration of stellar activity and we focus on the study of the relation between radial-velocity jitter and chromospheric activity index in section 4.

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2 Stellar metallicity

The radial velocity of a star is measured by the cross-correlation function (CCF) between the stellar spectra and a binary mask. This CCF should be considered as an averaged spectral line and can be used to estimated the metallicity index [Fe/H]. Masks used for SOPHIE are mainly built out of a set of weak neutral spectral lines. Since most of them are iron lines, we can expect that the surface (i.e. the Equivalent Width) of the CCF is well related to the [Fe/H] of a star. In Fig. 1, the CCF surface depends on the metallicity for a given B-V index (well correlated with temperature) and it is independant of the $v \sin i$ of the star.
We observed a set of stars with SOPHIE whose metallicity were determined by one of us (A.E.) from a careful spectral analysis of the stellar lines using ARES tool (Sousa et al. 2007). We fit a relation of calibration between the surface, B-V and [Fe/H] index (Fig. 2). There seems to be no special systematics with B-V in Fig. 2 as well as with [Fe/H] and *log g*. We can thus use this calibration to estimate values of [Fe/H] index with an incertitude of ± 0.1 *dex* for the stars with $0.430 \leq B - V \leq 0.980$ observed with SOPHIE without any spectroscopic analysis. This calibration can be used for stars observed in High Efficient and High Resolution mode with a $S/N \geq 20$ for an observation in *Obj_AB* and a $S/N \geq 150$ in *Th_Simult*.

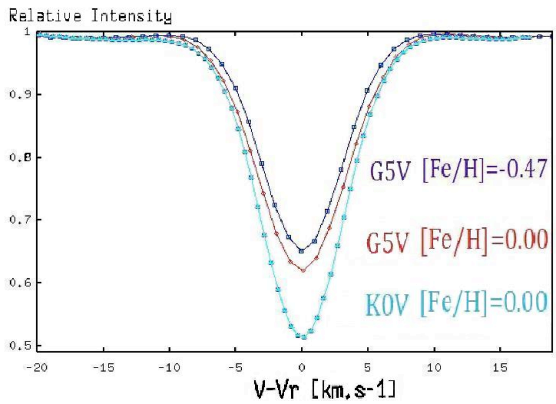

Fig. 1. *Illustration of the CCF dependance with spectral type (well correlated with B-V index) and metallicity.*

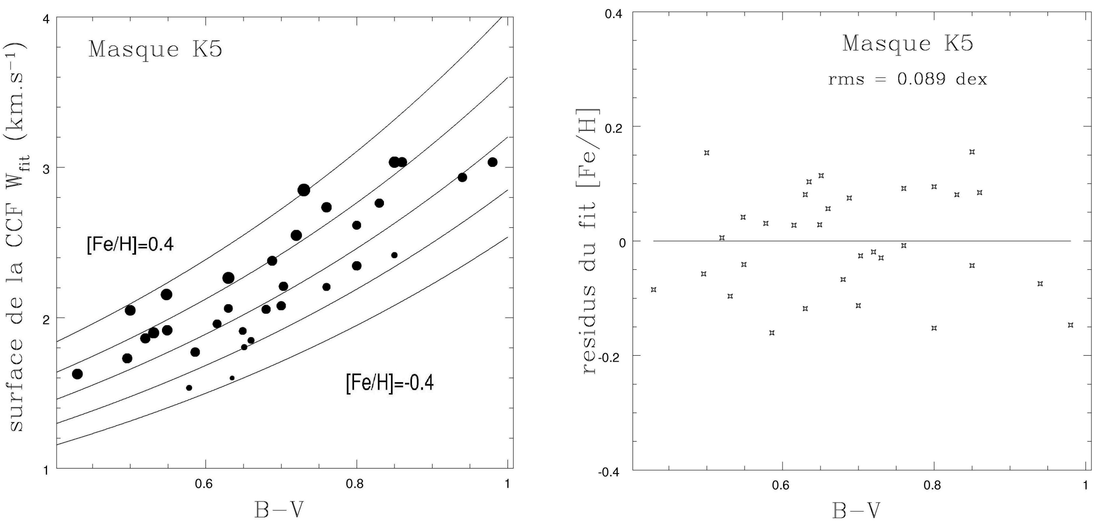

Fig. 2. *(Left) Calibration of the dependance between CCF surface W_{fit}, metallicity and B-V. W_{fit} is defined as $\sqrt{2\pi}.\sigma_{fit}.A_{fit}$, where σ_{fit} and A_{fit} are the gaussian width and depth of the measured CCF. The points width are correlated with the spectroscopic metallicity. The curves indicate the relation for constant [Fe/H]. (Right) The residuals of the calibration ($Fe_{spectro} - Fe_{fitted}$) as a function of B-V index. There is no dependance between the parameters. The uncertainty of the metallicity estimation is ± 0.1 dex given the uncertainty of the CCF surface's measurement.*

3 Stellar activity

The SOPHIE spectra, with a bandpass from about 3900 Å to 6800 Å, include the two Calcium II H and K resonant lines centered at 3968.49 Å and 3933.68 Å respectively. In Fig. 3, we can see two high S/N SOPHIE spectra of the Ca II lines central region. The left spectrum correponds to a chromospherically active star and the right one to a rather low activity star. The stellar activity is parametrized by an index created by Wilson (1968) defined by the ratio between the emitted flux in the center of the rays and the continuum flux. We measure a chromospheric index S_{SOPHIE} that is calibrated in $S_{Mont\ Wilson}$ by observing calibration stars (Fig 4) in mode HE and HR. With this index, we can calculate the litterature's index corrected from photospheric emission, R'_{HK} (Noyes et al. 1984). This measure is available only for F,G and K dwarfs observed in *obj_AB* mode.

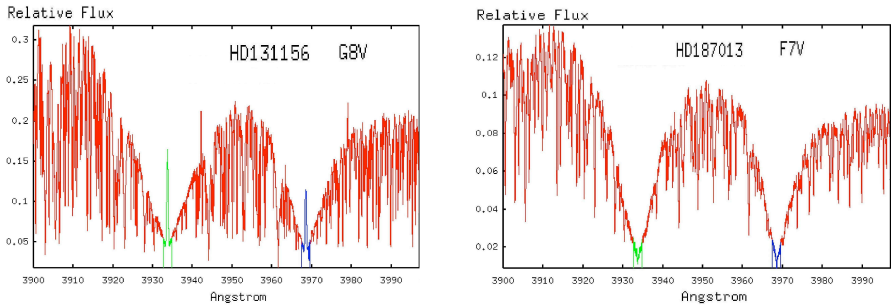

Fig. 3. *Two SOPHIE spectra of the region of the CaII H and K lines between 3900 and 4000 Å. In green and blue, the emission region of the spectra used to compute the activity index. (Left) Active star. (Right) Non active star.*

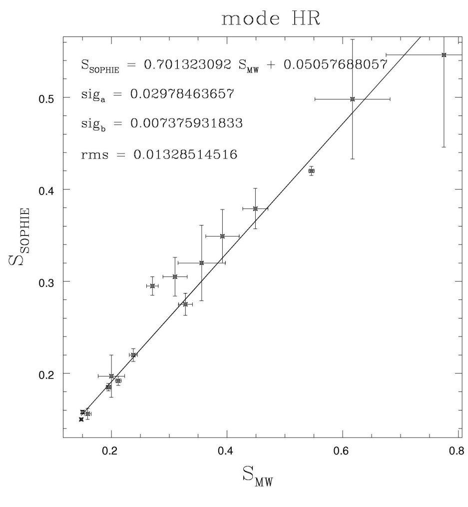

Fig. 4. S_{SOPHIE} *as function of* S_{MW} *for a set of 16 calibrations stars (Duncan et al. 1991) in High Resolution mode. The solid line represent the best least-square linear fit.*

4 Study with the chromospheric activity index and perspectives

The activity index gives us the possibility of checking the activity of the stars of the SOPHIE consortium extra-solar planet search program. The radial velocity dispersion σ_{RV} as a function of stellar activity index (Santos et al. 2002) is calibrated for the F stars. With this kind of plot (Fig. 5), we can remark the planetary candidates upper of the dashed lines and between them if the dispersion measure can be induced only by activity. To this end, we can study the estimation of the slope of the CCF bissector, the span (Fig. 6) to disentangle the causes of the radial velocity jitter. For example, HD90905, an active F star whose spectra present emission flux in the CaII rays, is located in red in the Fig. 5. The activity index and span bissector jitters as functions of radial velocity are anticorrelated that shows that the dispersion of radial velocity measurements are principaly due to activity (Fig. 6).

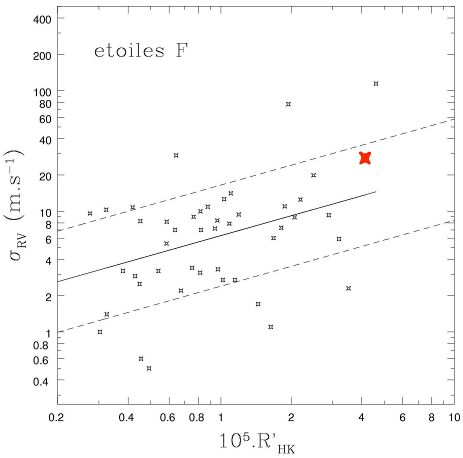

Fig. 5. *Dispersion of radial velocity σ_{RV} as a function of the activity index R'_{HK} for dwarf stars F observed with SOPHIE. The solid line represents the best fit by χ^2 while the rms of the fit is represented by the dashed line. The active star HD90905 is over-plotted in red.*

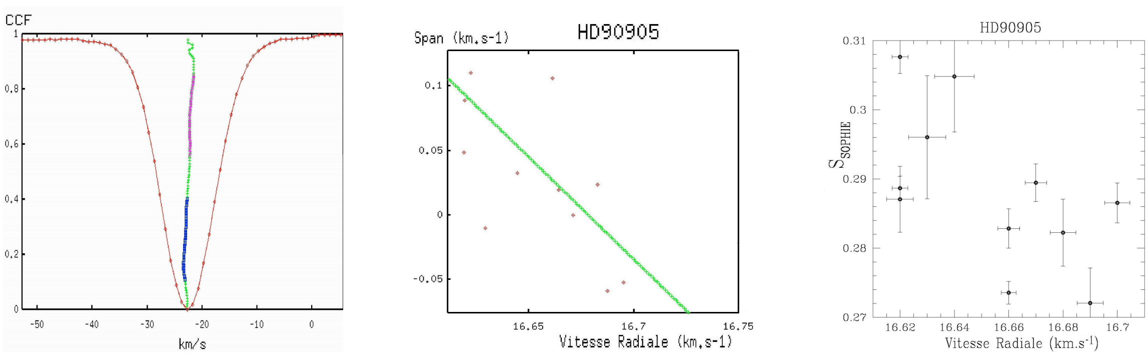

Fig. 6. *(Left) The bissector is plotted inside the CCF with a velocity scale 10 times larger. The span (estimation of the slope) is calculated with the regions located in pink and blue. (Center) Span bissector as a function of radial velocity for HD90905. The anticorrelation of the parameters shows that radial velocity jitter is principaly due to activity. (Right) Activity index S_{SOPHIE} as a function of radial velocity for the same star. We note an anticorrelation of the parameters.*

5 Conclusion

The calibration of star metallicity and activity will be soon available in the SOPHIE automatic data reduction pipeline and will allow a better observation strategy for exoplanets search program as well as for other programs of stellar physics.

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