

Stellar variability: impact on the detection of low-mass planets

I. Boisse¹, X. Dumusque^{1,2}, N.C. Santos¹, J. Gomes da Silva¹, X. Bonfils³, A.F. Lanza⁴

¹ Centro de Astrofísica da Universidade do Porto, rua das Estrelas, 4150-762, Porto, Portugal

² Observatoire de Genève, Université de Genève, 51 Ch. des Maillettes, 1290 Sauverny, Switzerland

³ Université Joseph Fourier -- Grenoble 1 / CNRS, Laboratoire d'Astrophysique de Grenoble (UMR 5571), BP 53, 38041 Grenoble Cedex 9, France

⁴ INAF – Osservatorio Astrofisico di Catania, via S. Sofia, 78, 95123, Catania, Italy

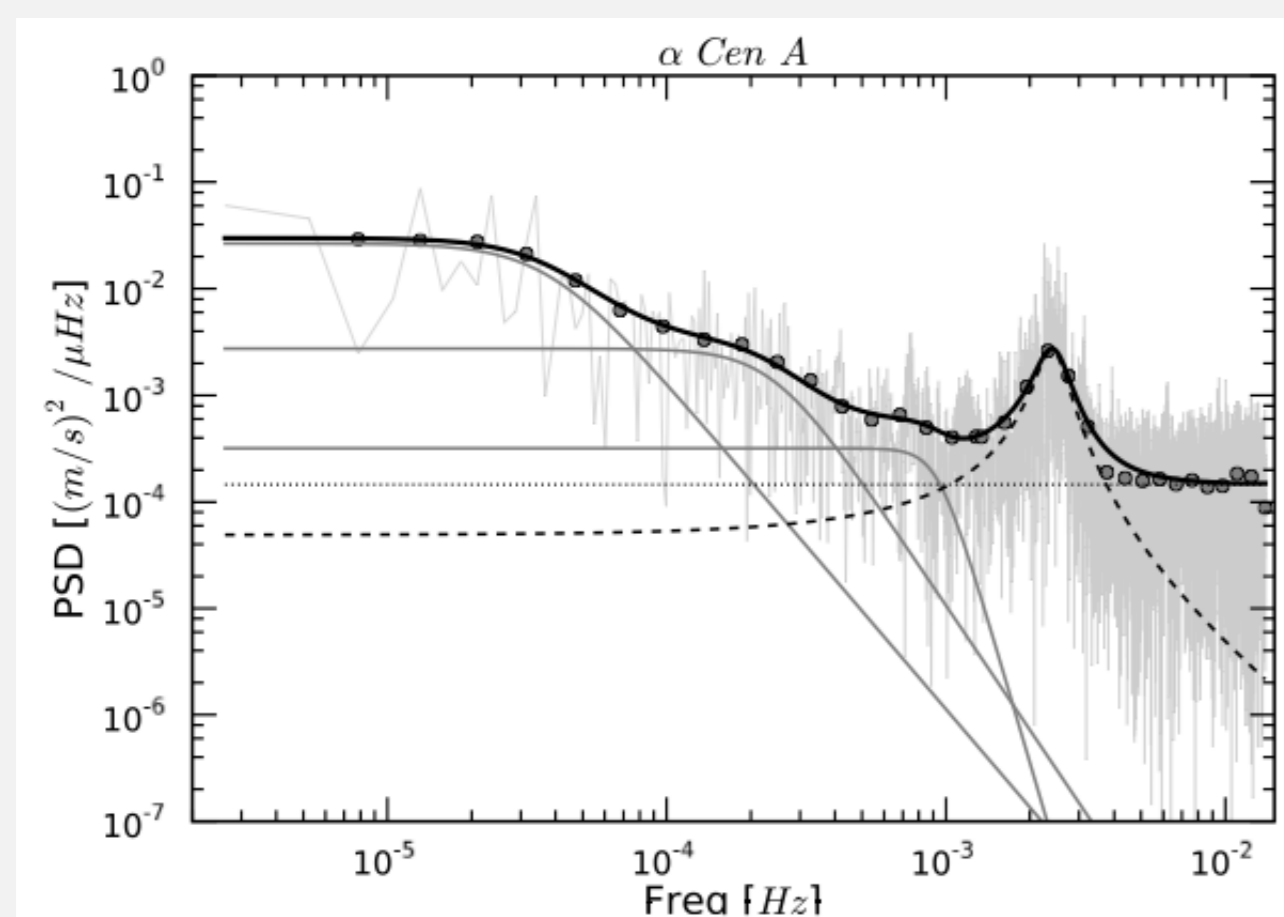


Although many methods are currently being used to search for planets orbiting other stars, the radial-velocity (RV) technique remains the most prolific. Moreover, **transit surveys need RV follow-up** to establish the planetary nature of their candidates and to measure their masses. This mass measurement, combined with the radius one via the transit light-curve, is crucial to have an estimation of exoplanets density. **Ground-based RV measurements are then critical to explore the physical characterization of exoplanets.**

Although extremely efficient, the RV technique is, however, an indirect method (as well as photometric transit detection or astrometry). One of the problems with this is the fact that periodic RV variations can in some cases be caused by some other mechanisms, not related to the presence of low-mass companions. **Phenomena such as stellar pulsation, inhomogeneous convection, spots or magnetic cycles can prevent us from finding planets**, they might degrade the parameters estimation, or give us false candidate, if they produce a stable periodic signal.

We consider the different kind of «noise» that are generated by stars, as well as the methods proposed and used to overcome this issue. The impact for the detection of other earths using high-precision RV instruments, like HARPS or ESPRESSO is considered.

Granulation / Pulsation



Velocity power spectrum density from HARPS asteroseismology measurements of α Cen A. The contribution of oscillation mode (dashed line) and granulation phenomena (super, meso and granulation from left to right in light grey lines) are fitted. Simulations are then derived from these observations to determine the best observational strategy. **Dumusque et al., A&A 2010**

Pressure waves (p-modes) propagate at the surface of solar-type stars leading to a dilatation and contraction of external envelopes over time scales of a few minutes (5 to 15 minutes for the Sun). The RV signature of these modes is typically varying between 0.1 and 4 m/s.

The phenomena of granulation due to convective nature of solar-type stars also affect RV with amplitude similar to the ones observed for p-modes and timescales of minutes to hours.

1 measurement of 15 mins per night
→ reduce stellar oscillation noise

3 measurements per night, 10 mins each 2 hours
→ detection limits 30% better because reduce the effect of stellar granulation

Stellar activity

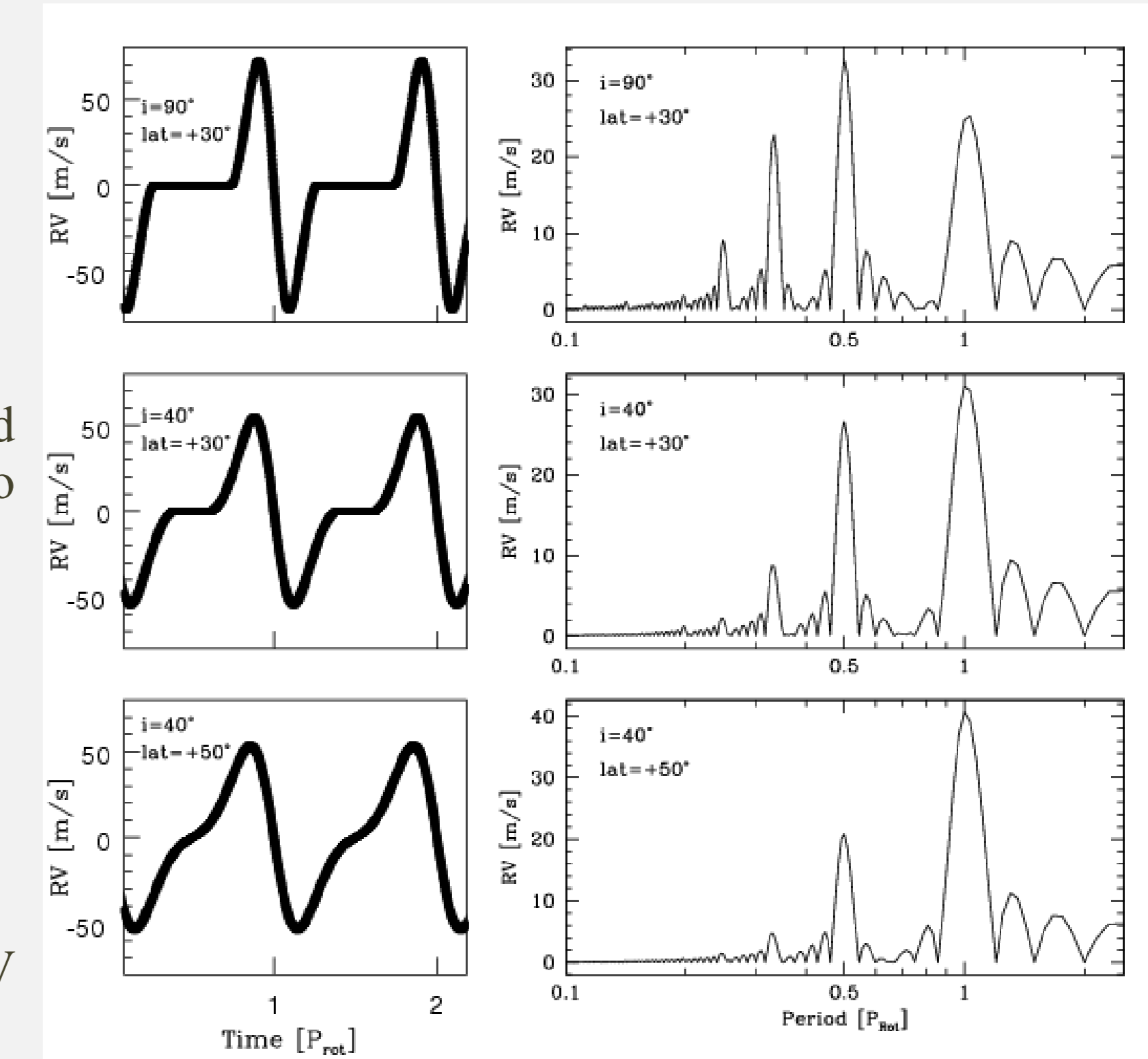
Magnetic activity is related to the appearance of dark spot and bright plages on the stellar photosphere, breaking the flux balance between the red and blue-shifted halves of the star, producing an apparent Doppler shift as the star rotates.

The timescale of the effect is similar to the rotational period of the star. The amplitude is varying from several cm/s to several m/s as a function of the age and the vsini of the star.

Stellar activity might be followed by several spectroscopic indicators (bisector of the lines and flux variations in active lines: H α , HeI, CaII H&K) and also by photometric measurements. These indicators might be used to correct the RV from the active signals. **Boisse et al. A&A, 2009**

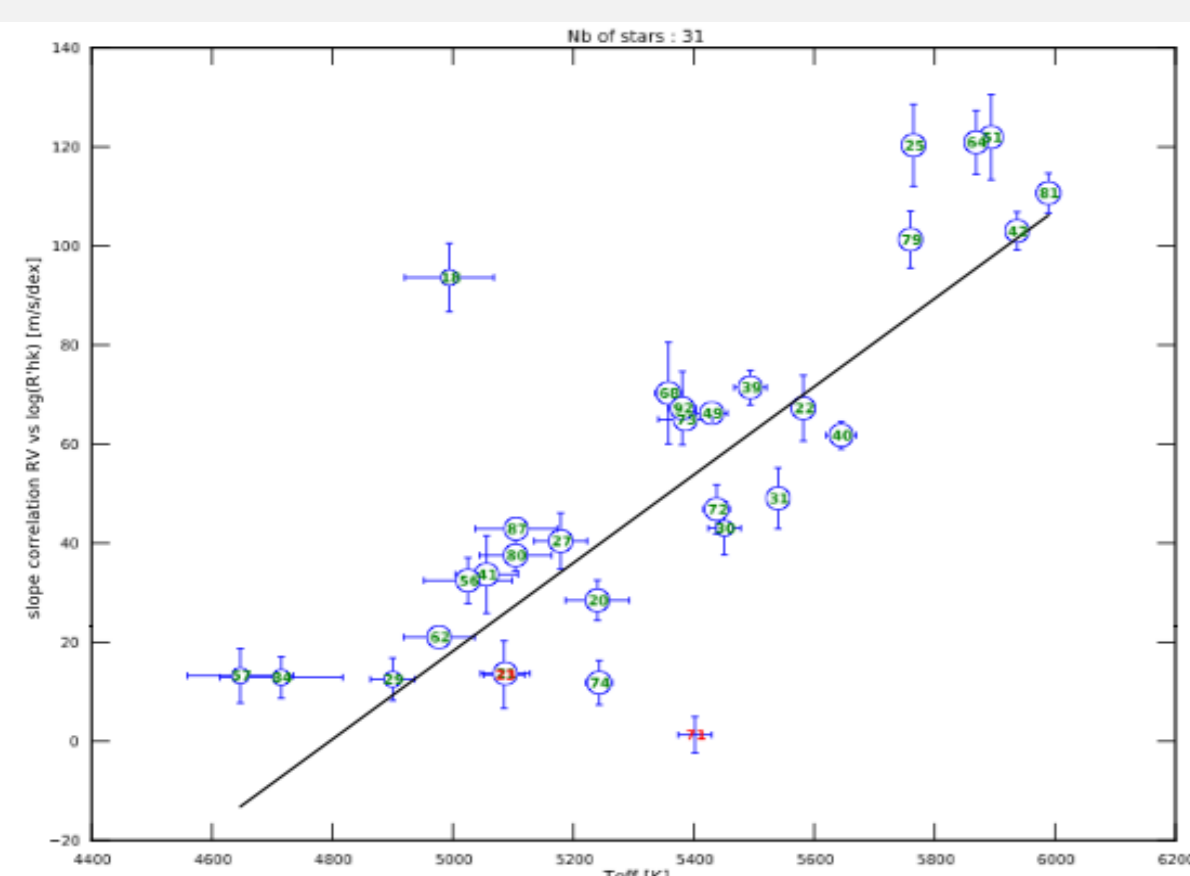
SOAP is a tool that simulate the stellar spots effects on RV and photometry **Boisse, Bonfils & Santos, in prep.**

Using these simulations, we showed that **three sinusoids fixed at the rotational period of the star, Prot, and its two-first harmonics allow to remove about 90% of the jitter amplitude.** This allow to fit simultaneously the effect of activity and that of one (or several) planet(s). These results have been validated on HARPS measurements of active planet-host stars. **This method is particularly adapted to RV follow-up of transit surveys.** **Boisse et al. A&A, 2011**



Left: RV modulations due to one spot as a function of time (expressed in rotational period unit). At $t=0$, the dark spot of 1% of the visible stellar surface is in front of the line of sight. The shape of the signal changes with the inclination i of the star and the latitude lat of the spot, labelled in the top left of each panel. Right: Lomb-Scargle periodograms of the three RV modulations showed at the left. The fundamental frequency, Prot, and its first harmonics are detected. **Boisse et al. A&A, 2011**

Stellar cycles

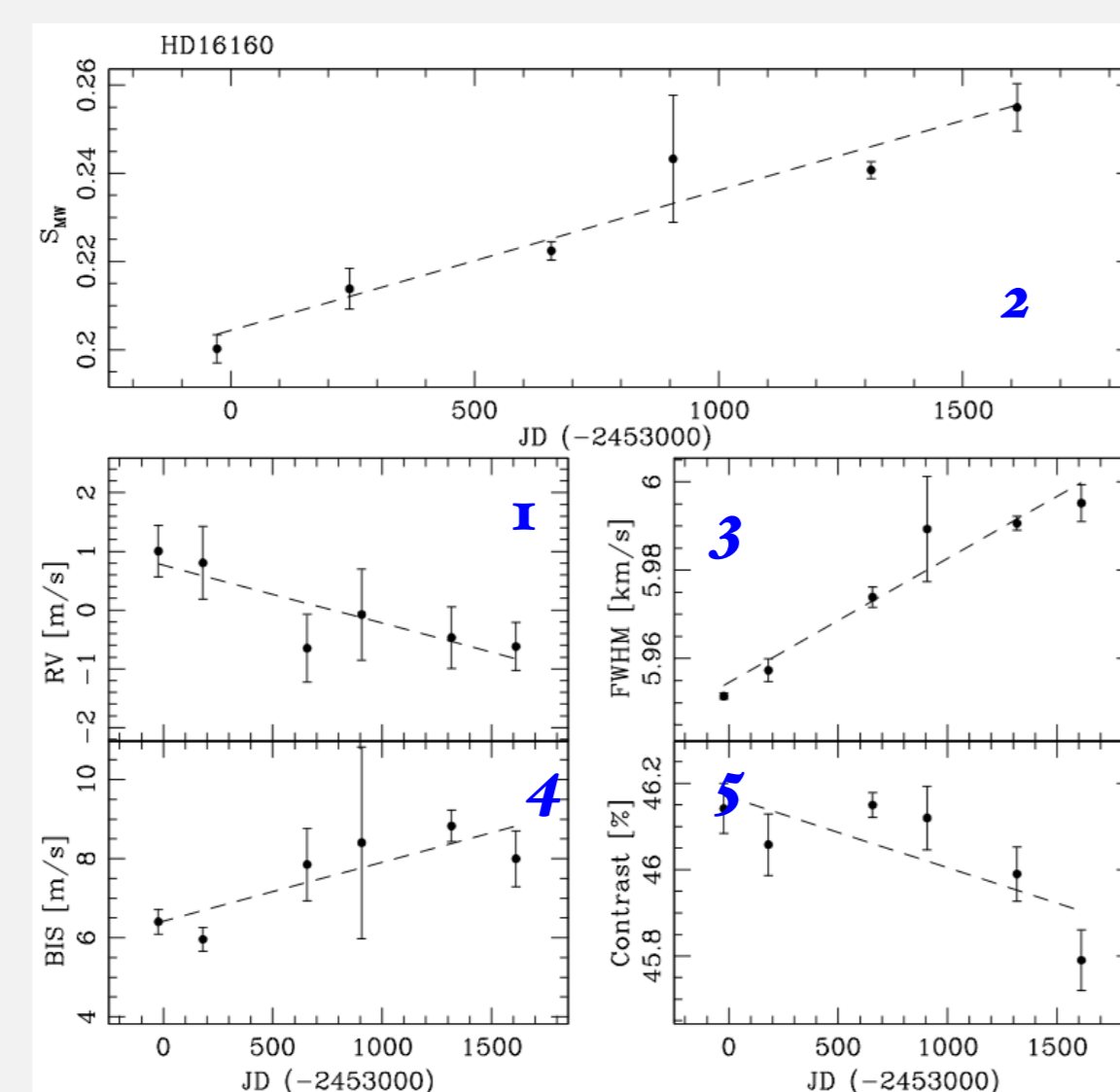


Correlation between the amplitude of the active jitter ($RV\text{-logR}'_{HK}$) and T_{eff} for a sample of stars observed with HARPS **Dumusque et al. 2011**

Long term stellar magnetic cycles change convective pattern and the level of stellar activity.

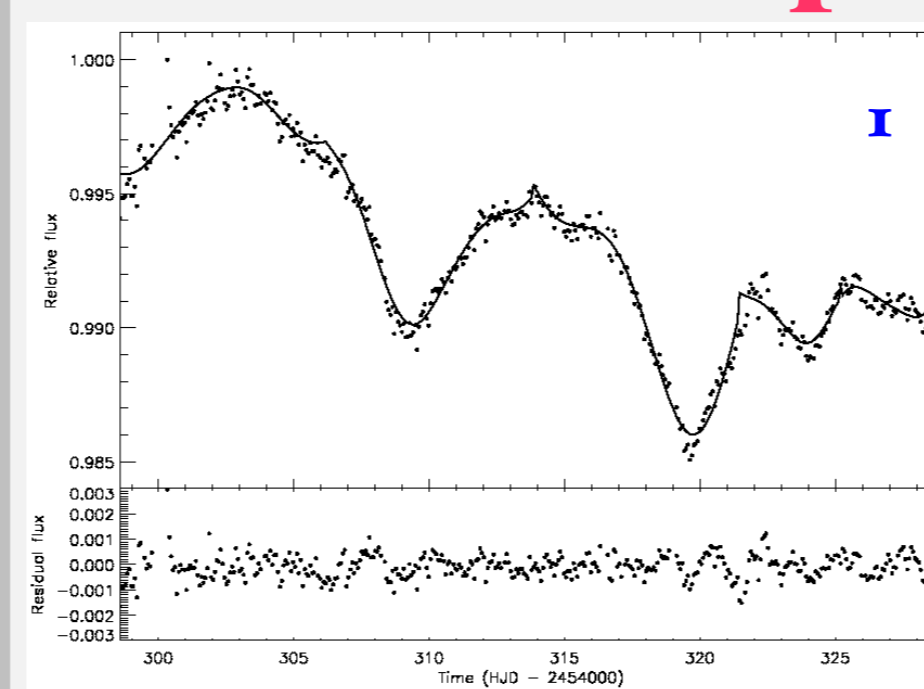
Follow-up of stars with known magnetic cycles measured with HARPS show that for K (**Santos et al. 2010**) and M (**Gomes da Silva et al., in prep.**) dwarfs the effect in RV is small. It may be stronger for earlier spectral types (**Dumusque et al. 2011**). Hopefully, there are different ways to diagnose these signals (bisector of the lines, flux in active lines). Magnetic cycles are then *probably* not a main threat to the detection of long-period and low-mass planets.

On the other hand, simulations of Sun spot group appearance were done to determine the best observational strategy → measurements each 3 nights average out the effect of stellar activity (**Dumusque et al. 2011**).



An example of RV variations (1) that may be induced by stellar cycle (2) for a K dwarf observed with HARPS. Spectroscopic indices (3,4 and 5) seems also to follow the activity and RV variations and allow of a correction. **Santos et al. A&A 2010**

Simultaneous observations in photometry and RV



Simultaneous observations in photometry and RV **permit to constrain models used to derive RV activity jitter from the photometric variations.** These models might be used for RV follow-up of transit candidates around active stars. **Lanza et al. in prep.**

We use simultaneous measurements of the active planet host star, HD189733, with high-precision optical photometry by MOST and high-resolution spectra by SOPHIE. **The synthesized RV show a remarkably good agreement with the observed ones.**

- 1 MOST light curve (**Boisse et al. 2009**) with spot modelling best fit. Lower panel: the residuals.
- 2 Activity-induced RV jitter observed with SOPHIE (filled dots, **Boisse et al. 2009**) and synthesized RV variations from the spot modelling (open diamonds). Lower panel: the residuals.

Resume and perspectives

Significance of the observational strategy

Improving our understanding of stellar variability

Contribution of CoRoT and Kepler missions