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


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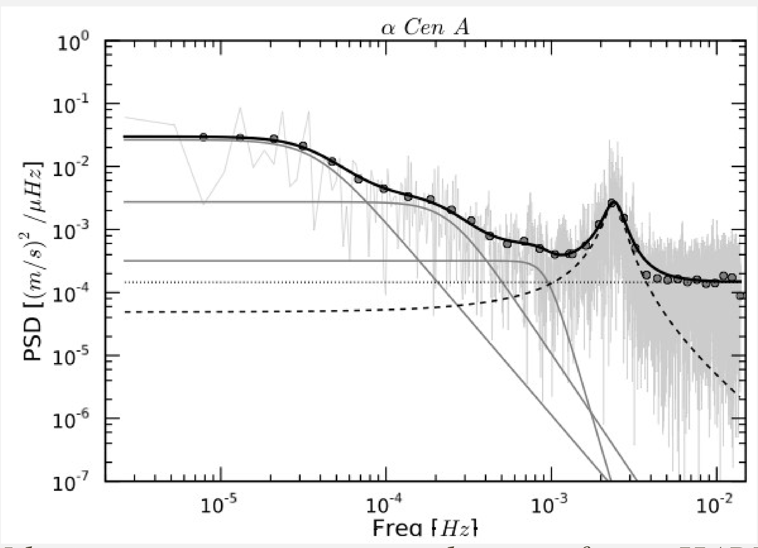
Although many methodes are currently being used to search for planets orbiting other stars, the radial-velocity (RV) technique remains the most prolific. Moreover, **transit surveys need RV follow-up** to establish the planetary nature of their candidates and to measure their masses. This mass measurement, 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

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.



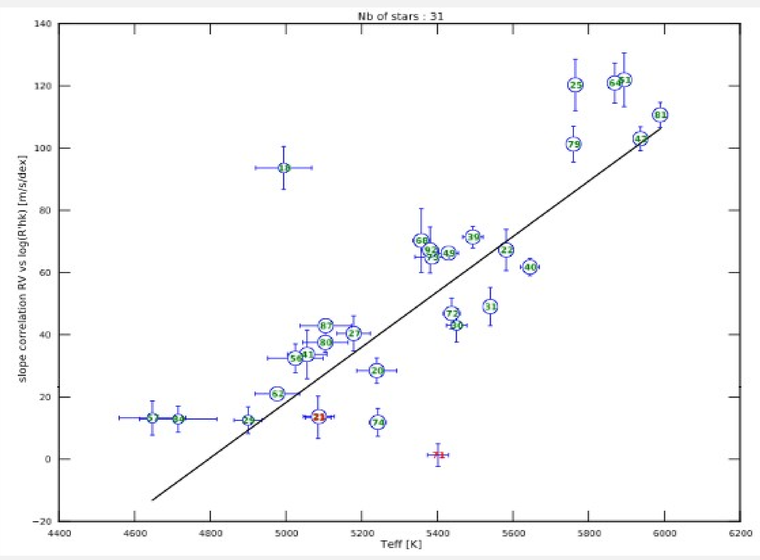

*Velocity power spectrum density from HARPS asteroseismology measurements of α Cen A. The contribution of oscillation mode (dashed line) and granulation phenomena (super, meso and granulation from left to right in light grey lines) are fitted. Simulation are then derived from these observations to determine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

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.

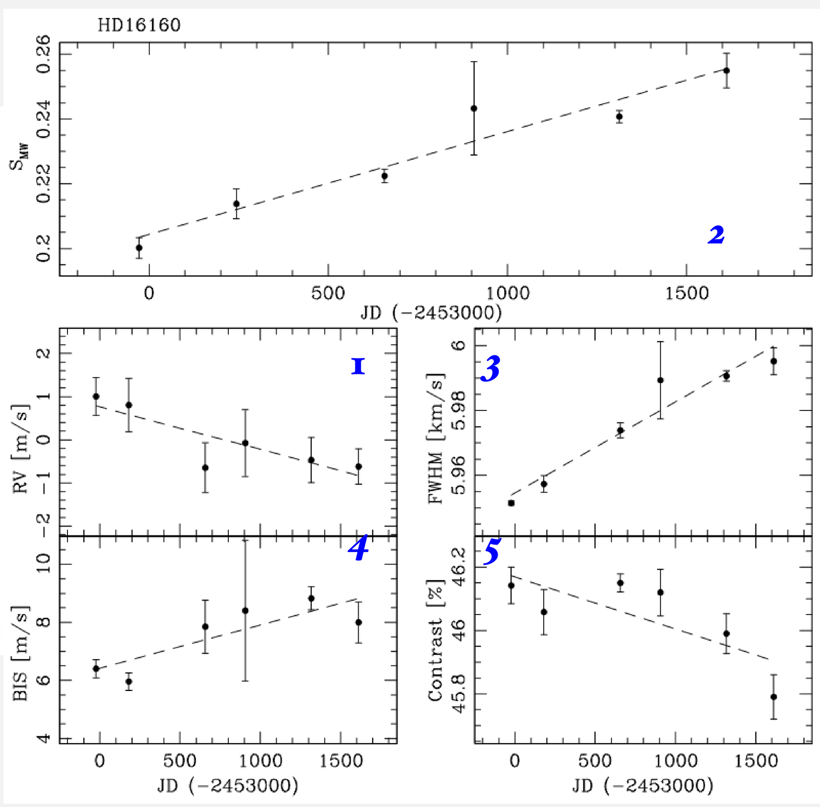
1 measurement of 15 mins per night
→ reduce stellar oscillation noise

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

## Stellar cycles



*Slope of the correlation RV-logR'hk as a function of Teff for a sample of stars observed with HARPS* **Dumusque et al., 2011**




*An exemple 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 et al., A&A 2010**

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 in 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 *propably* 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 obsevational strategy → measurements each 3 nights average out the effect of stellar activity (Dumusque et al. 2011).

## Stellar activity

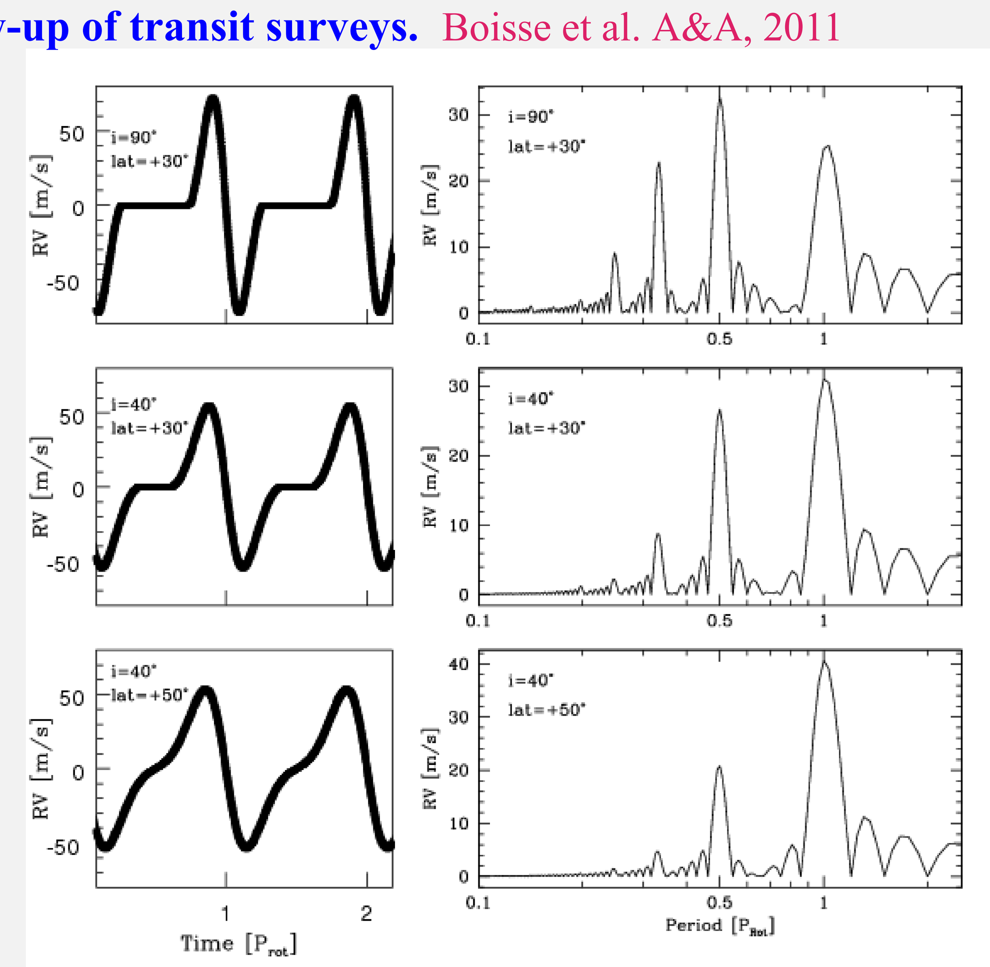
Magnetic activity is related to the appearance of dark spot and bright plages on the stellar photosphere, breaking the flux balance between the red and blue-shifted halves of the star, producing an apparent Doppler shift as the star rotates.

The timescale of the effect is then similar to the rotational period of the star, modulated by the differential rotation. 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 actives lines: Hα, 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

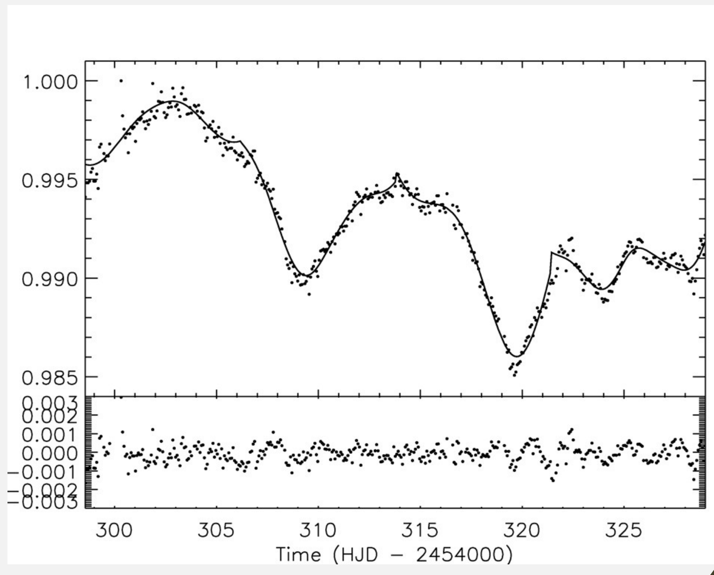
SOAP is a tool that simulate the stellar spots effects on RV and photometry **Boisse, Bonfils & Santos, in prep**.

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 valitated 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

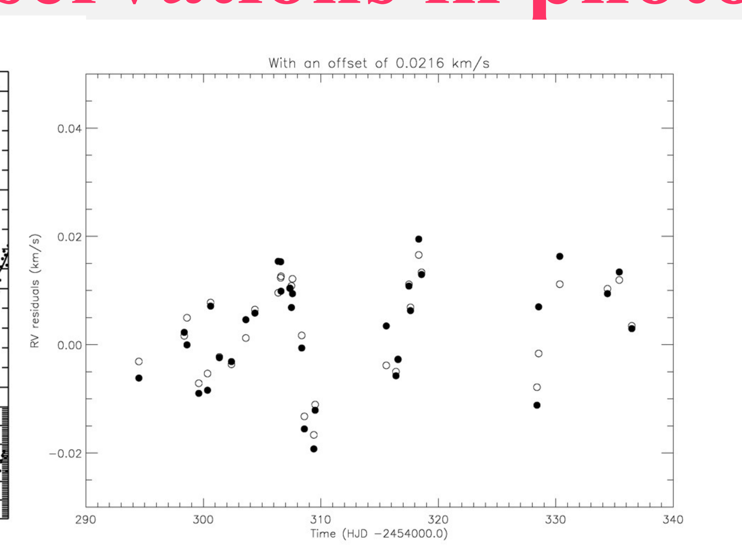


*Left: RV modulations due to one spot as a function of time (expressed in rotational period unit). At t=0, the dark spot of 1% of the visible stellar surface is in front of the line of sight. The shape of the signal changes with the inclination i of the star and thelatitude lat of the spot, labelled 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**

## Simultaneous observations in photometry and RV



*MOST light curve (**Boisse et al. 2009**) with spot modelling best fit. Lower panel: the residuals.*



*Activity-induced RV jitter observed with SOPHIE (**Boisse et al. 2009**) and synthetized RV variations from the spot modelling.*

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, Boisse, Bonomo, Moutou, Bouchy et al., in prep.**

## Resume and perspectives

Significance of the observational strategy

Improving our understanding of stellar variability

Contribution of CoRoT and Kepler missions