# PROJECT FOR POST-DOCTORAL FELLOWSHIP

**Project Title**

Modeling spectroscopic signatures of stellar activity

**Supervisor: Jorge Meléndez**

**Summary**

This postdoctoral project aims to better understand stellar activity through characterization of lines with chromospheric contribution, such as the Ca II H and K lines. We also intend to model the effect of stellar activity on radial velocities, which is key in our quest to characterize exoplanets, especially small planets such as super-Earths and in the future Earth analogs.

**Description of goals**

Stellar activity can have an important impact on radial velocities. Convection is suppressed in active regions, thus depending on their extent and geometrical distribution (that depends on stellar cycles, appearance and disappearance of active regions, and modulations by stellar rotation), we can have changes on the line profiles, introducing apparent changes in radial velocities (RV). The effects can be of the order of 10 m $s^{-1}$ for young solar twins, and of the order of 1 m $s^{-1}$ for solar-age stars, so that stellar activity must be taken into account when modeling RV data for exoplanet detections (e.g., Haywood et al. 2014; Bedell et al. 2015; López-Morales et al. 2016; Yu et al. 2017).

Even for stars like the Sun, stellar activity cycles (like the pseudo periodic 11-year sunspot cycle) are still not well established, due to lack of observations, only partial coverage of stellar cycles, or because the measurements did not achieve enough precision. Indeed, previous large surveys did not include many solar twins (which started to be discovered in large number only about a decade ago), so that the behavior of stellar cycles with stellar ages is still an open issue. We know that magnetic activity decays with stellar age (e.g. Skumanich 1972; Mamajek & Hillenbrand 2008; Lorenzo-Oliveira et al. 2018), but although the long-term decay is more or less understood, the exact behavior of stellar activity cycles is not well understood, both from the observational point of view and on theoretical

grounds (e.g., Strugarek et al. 2017). The main goal will be to try to model different signatures of stellar activity (including their impact on radial velocities), in different timescales, from day-to-day modulations due to changing active regions modulated by stellar rotation, to month-year variations due to stellar activity cycles.

**Work plan**

Measurements of chromospheric activity from high-resolution spectra are straightforward, using different activity indexes such as the H$\alpha$ line, the CaII H and K lines, or He features. The measurements are performed in the line core and compared to the flux in continuum regions, and calibrated to a given system (see for example Wright et al. 2004, for measurements of stellar activity based on the CaII H and K lines, and calibrated to the Mount Wilson system).

The postdoctoral scholar will measure stellar activity in our sample of solar-type stars, in particular in solar twins, using the HARPS spectra that we have been obtaining over the years, together with HARPS spectra from other programs, and new spectra that we plan to obtain. The postdoc could also implement the measurements and calibrations for other spectrographs, such as the STELES spectrograph at the 4m SOAR telescope, which is currently undergoing commissioning in Chile, and our proposed small spectroscopic facility (high-resolution spectrograph + 1m telescope) to study stellar activity in a large sample (> 60) of solar twins, sampling thus the evolution of a star like the Sun (one-solar-mass solar-metallicity star) at different ages.

Besides the implementation of stellar activity measurements, the most challenging part will be on the modeling of stellar activity itself. The main difficulty is that magnetic activity is not strictly periodic, and activity cycles can be as long as a decade. Over the years we have been collecting HARPS spectra, and together with data from other programs, we have a precious dataset of precise stellar activity observations that could be employed to study activity cycles. More data is needed, as many stars have only partial information on stellar cycles. It is also important to model short-term variations in stellar activity, due to the appearance and disappearance of active regions, and the modulations introduced by stellar rotation. We plan to use the existing data, as well as to perform intensive observing campaigns to help track short-term variations of stellar activity for stars of different ages, which depending on their evolutionary stage could be more dominated by spots or plages. The postdoc will use data from the spectroscopic facility that we are proposing, or also spectra from other observatories, such as the

HARPS spectra that we recently got for two young solar twins, mapping their activity variations and impact on radial velocities, over almost two rotation periods. We plan to tackle this problem first using existing tools such as SOAP 2.0 (Dumusque et al. 2014), but also trying other techniques such as a Gaussian process (e.g., Haywood et al. 2014), that is starting to be implemented already in Prof. Meléndez' group.

The work on modeling the different manifestations of stellar activity (both chromosperic activity indexes and radial velocities) is key to detect and characterize exoplanets, specially small ones, as the keplerian signal could be of the same order of magnitude, or even smaller, than the spurious variations in radial velocity introduced by changes in magnetic activity.

**Schedule**

Month 1: Familiarize with the HARPS data and tools already developed at the group
Month 2 - 4: Write proposals for more data, download existing data, process the data and compare with previous measurements
Month 5 – 10: Analysis of the data using existing tools (such as SOAP 2.0) and new tools being developed at the group
Month 11: Write paper with the first results from the analysis
Month 12 - 19: Obtain new observations, calibrate other spectrographs based on newly acquired data (including our own new facility), write new observing proposals.
Month 20 – 22: Analysis of the data with the tools already developed
Month 23: Write paper with the new results
Month 24: Write FAPESP report.

**How the postdoc fellowship fulfill the goals of the FAPESP postdoctoral fellowships**

We intend to attract a promising young scientist, who has obtained its doctorate degree no earlier than seven years ago, thus fulfilling the goals and rules of FAPESP. We will conduct an internationally selection process, by advertising on international journals and job newsletters, as well as in the national newsletters and job databases.

Our request fits perfectly within our proposed FAPESP *Temático* project because the research plan

deals with the study of stellar activity, hence it is important to have the postdoctoral grant approved along with the *Temático* project.

Following the recommendations of FAPESP, we will select preferably a scientist who has not done its PhD at the host Institution (either IAG/USP or Mackenzie), unless no suitable candidates from other institutions are found. Nevertheless, the proposed FAPESP *Temático* certainly has the potential to attract young talents from different institutions.

**Bibliography**


- Bedell, M., Meléndez, J., Bean, J. L. et al. 2015, A&A, 581, A34
- Dumusque, X. et al. 2014, ApJ, 796, 132
- Haywood, R. et al. 2014, MNRAS, 443, 2517
- López-Morales, M. et al. 2016, AJ, 152, 204
- Lorenzo-Oliveira, D. et al. 2018, A&A, 619, A73
- Skumanich, A. 1972, ApJ, 171, 565
- Strugarek, A., et al. 2017, Science, 6347, 185
- Wright, J. T. et al. 2004, ApJS, 152, 261
- Yu, L. et al. 2017, MNRAS 467, 1342