Research Proposal

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1 Introduction

Radial velocity observations have been widely used, and highly successful, in the search for exoplanets. They trace the spectral Doppler shift resulting from the barycentric reflex motion of a star with gravitationally bound companions (e.g. planets). However, surface inhomogeneities on a star (e.g. arising from stellar activity) can modify the shape of a spectral line-profile, and if those changes are asymmetric, they will introduce an apparent radial velocity shift. This "noise" variability can be on timescales and amplitudes similar to those of planetary signals, hindering the detection of exoplanets.

2 Research Aims

This thesis will investigate how line-profile deformation caused by stellar variability can impact radial velocity detections of exoplanets. We aim to develop robust techniques to parametrize spectral line shapes (and especially line asymmetries) and their variation, so as to quantify and remove the Doppler impact of stellar activity and other surface inhomogeneities from radial velocity planet search data.

3 Research Plan

To start with, we will construct high signal-to-noise stellar spectral line-profiles from observed planet search data on an epoch-by-epoch basis, utilizing either cross-correlation or least squares deconvolution (LSD – [1], [3]) techniques. We will also use the Spot Oscillation And Planet 2.0 (SOAP 2.0, [2]) code to generate simulated line-profiles that include the effects of both dark spots and bright plages, and then test line-profile quantification metrics using these simulated data.

We will then explore the quantification of the resulting profiles (both real and simulated) using suitable sets of orthogonal basis functions (e.g. the Gauss-Hermite series). Robust quantification of line shape variation should give us a means to correct planet search data for the component of apparent Doppler shifts produced by intrinsic stellar variability in a manner never previously explored.

Once suitable metrics are identified, they will be tested using aditional sets of archival data (e.g. from the substantial on-line archive of HARPS spectra), to see whether these metrics can be used to "clean up" the Doppler time series data for active and inactive stars, and so search for lower amplitude planets currently hidden by the noise of stellar variability.

References

[1] J.-F. Donati, M. Semel, B. D. Carter, D. E. Rees, and A. Collier Cameron. Spectropolarimetric observations of active stars. *mnras*, 291:658, November 1997.

[2] X. Dumusque, I. Boisse, and N. C. Santos. Soap 2.0: A tool to estimate the photometric and radial velocity variations induced by stellar spots and plages. *The Astrophysical Journal*, 796(2):132, 2014.

[3] Kochukhov, O., Makaganiuk, V., and Piskunov, N. Least-squares deconvolution of the stellar intensity and polarization spectra. *A&A*, 524:A5, 2010.