Statistical Methods for Characterizing Variability in Stellar Spectra

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SAMSI ASTRO Working Group IV  
Astrophysical Populations

WG leaders: Jessi Cisewski, Eric Ford 
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*Contact David if interested in joining group

Some of the group’s goals:

- improve the statistical methodology for interpreting detections of exoplanets, gravitational waves (GW), as well as using those to infer the underlying population of planetary systems and GW sources

- developing techniques to robustly detect and characterize planets in the presence of stellar activity from Doppler Surveys for which we do not have a first-principles model

- detecting gravitational wave sources for which the details of the primary GW signal and/or backgrounds are unknown
Allen B. Davis Poster 425.04 TODAY

*Insights on the spectral signatures of RV jitter from PCA*

425. Extrasolar Planets Late Poster Session
1:00 PM - 2:00 PM
Longhorn D (Gaylord Texan Resort & Convention Center)
Radial Velocity Method

Plots: https://www.youtube.com/watch?v=tUzDKlaTHFM
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Plot: Debra Fischer and http://exoplanets.org

Jessi Cisewski
Figure: Xavier Dumusque (Geneva)
What’s the problem?
What’s the problem?

**Stellar activity**

Spots, plages, faculae, limb darkening, convective blue shift, stellar oscillation and magnetic cycles, ...

Spots
Credit: SDO/HMI/Alex Young, universetoday.com

Granulation
Credit: BBSO/NJIT, http://phys.org

Rotation
Credit: Xavier Dumusque (Geneva)

Limb Darkening
Credit: SDO/HMI
Stellar activity

Figure 1 from Davis et al. (2017) (courtesy of J. Valenti)
Figure: Xavier Dumusque (Geneva)
Figure 7 from Davis et al. (2017)
- SOAP 2.0 spectra (Dumusque et al., 2014)
- Wavelengths: 3925.87 Å to 6661.54 Å (∼500,000 measurements)
- An equatorial **spot/facula** with coverage area of 0.1%, 1%, 5%
- A **planet** in circular orbit with RV semi-amplitude of 1, 10, 50 m/s
- Stellar rotation period of 25 days, 1 spectra/day
Figure 3 from Davis et al. (2017)
Figure 5 from Davis et al. (2017)
- 50 realizations of noise for the 1% spot
- Resolution = 150,000, S/N = 800
1% spot, Res = 150,000, S/N = 800, 50 sets of spectra

$$\sum_{\rho} = \sum_{i=1}^{10} \sum_{j=1}^{50} g(\rho_{ij}) \frac{\rho_{ij}}{50}$$

$$\rho_{ij}$$ = correlation of PC i scores for realization j with PC i scores of high-res, noise-free PC scores

i = PC, j = independent realization of noise, $$g(\rho_{ij}) = 1$$ for small p-value (otherwise = 0)
1% spot, Res = 150,000, S/N = 800, 50 sets of spectra

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Figure 6 from Davis et al. (2017)
Figure 7 from Davis et al. (2017)
Summary

- Radial velocity method is an effective technique for detecting exoplanets
- Signals for less massive planets require accounting for stellar activity
- Stellar activity can mimic planetary signals
- Statistical methods are needed to distinguish Doppler shifts from other variability in the spectra
- The sources of variability appear to have different effects on the spectra

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THANK YOU!!!

Dumusque, X., Boisse, I., and Santos, N. (2014), “SOAP 2.0: A TOOL TO ESTIMATE THE PHOTOMETRIC AND RADIAL VELOCITY VARIATIONS INDUCED BY STELLAR SPOTS AND PLAGES”The tool is available at http://www.astro.up.pt/soap. The work in this paper is based on observations made with the MOST satellite, the HARPS instrument on the ESO 3.6 m telescope at La Silla Observatory (Chile), and the SOPHIE instrument at the Observatoire de Haute Provence (France).” The Astrophysical Journal, 796, 132.