



# INSIGHTS ON THE SPECTRAL SIGNATURES OF STELLAR JITTER FROM PCA

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#### Radial velocity history



## Radial velocity technique

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- Spectral lines indicate red/blueshift of spectrum
  IDEALLY, the measured shift is due to Keplerian motion

$$\frac{\lambda - \lambda_0}{\lambda} = \frac{\Delta \lambda}{\lambda} = \frac{v}{c}$$



## Activity creates spurious RVs

- Flux effect
  - Darker/brighter regions create flux imbalance as star rotates
  - Dominant for spots on fast rotators



Spots: dark, cool

Faculae: bright, hot

### Activity correction



- CCF washes out detail of individual spectral lines vary
- Chromospheric indicators imperfectly correlated with photospheric velocities that cause jitter



## Modeling activity with SOAP 2.0

- Assign solar spectrum to grid points across star
- Alter spectra if spot or facula is present
- Create 9 sets of
  25 time-series spectra:
  Spot: S = 0.1, 1, 5%
  Facula: S = 0.1, 1, 5%
  Planet: K = 1, 10, 50 m/s



Dumusque et al. 2014

#### PCA w/ Singular Value Decomposition

#### $\square$ n = 25; p $\approx$ 500,000



## Principal component analysis



http://setosa.io/ev/principal-component-analysis/

... throw out the rest

## Fraction of variance

- 9
- □ 99.99% of variance in PC 1 in all sets
- Active regions have more var. in higher PCs
  esp. larger ARs



### Wavelength dependence of activity

Individual lines respond differently to activity
 Temp-sensitive lines like Ti I show large PC 1 signal



Davis et al. 2017 (submitted)

## Principal component analysis



# **score**: projection of the dataset onto a PC direction

Where does each spectrum fall along a PC?

http://setosa.io/ev/principal-component-analysis/

## Noisy spectra

- 12
- Compare noisy, low res. spectra to ideal spectra
- N<sub>PC</sub> is the number of PC scores whose structure is maintained



Davis et al. 2017 (submitted)

## High resolution is valuable

Doppler shift has at most 1 signif. PC  $\square$  N<sub>PC</sub> grows faster with resolution than S/N for activity

$$S/N \sim R^{-0.5}$$

Davis et al. 2017 (submitted)



## Conclusions

- The information that distinguishes planets and activity is embedded in spectra
- Future high-resolution instruments will be better able to access this information

- □ Future work:
  - Applying PCA to non-solar spectra
  - Exploring other promising techniques including:
    - Sparse functional PCA
    - Dictionary learning