HiCannon: Data-driven spectroscopy of cool stars at high spectral resolution

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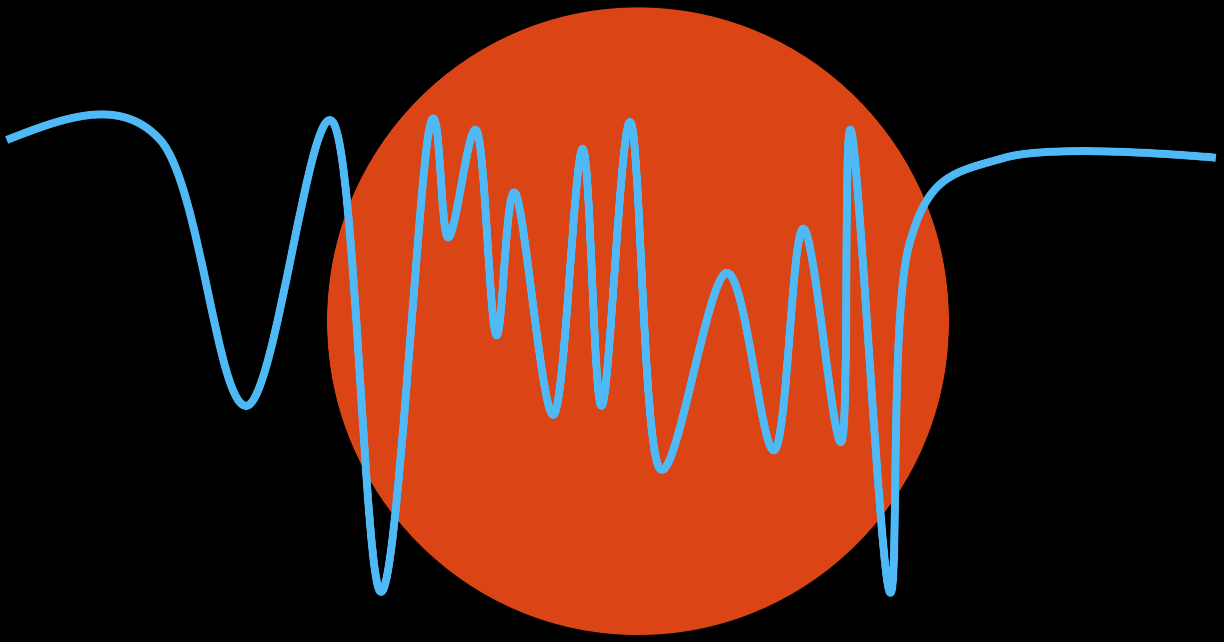
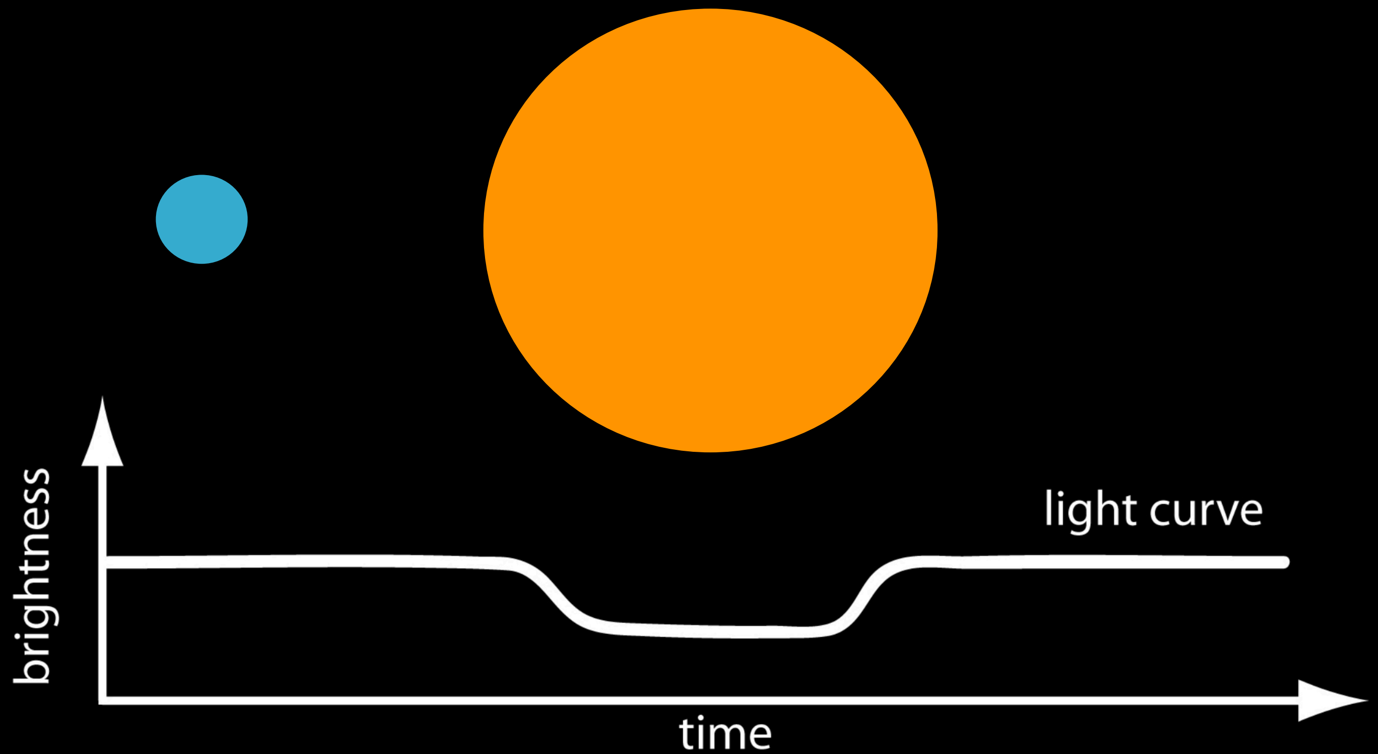


Why is it important to determine stellar parameters / abundances (R_*, M_*, T_{eff}, [Fe/H], etc.)?

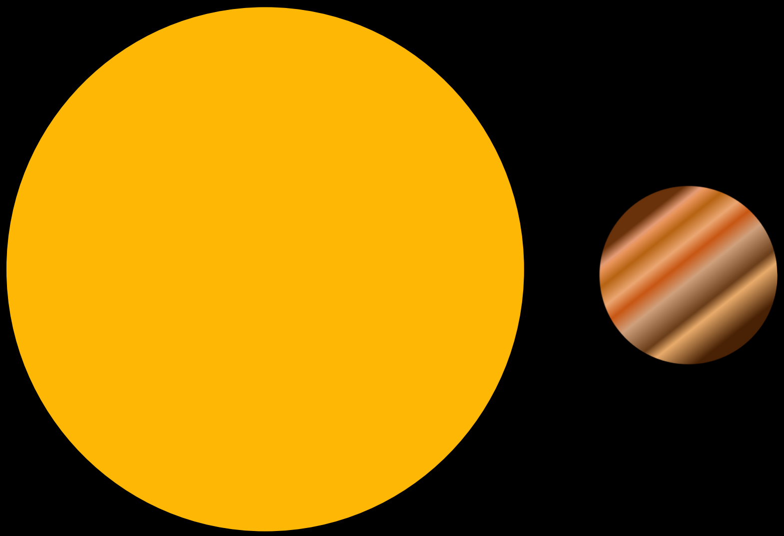
Transit detections of exoplanets

Need R_* to determine planet radius R_p



Why is it important to determine stellar parameters / abundances (R_*, M_*, T_{eff}, $[Fe/H]$, etc.)?

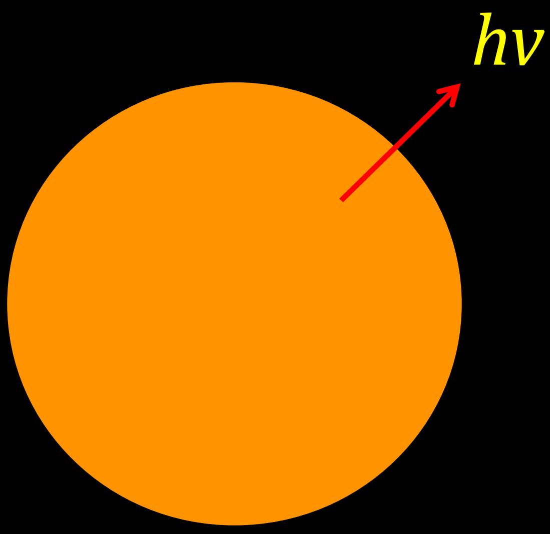
Correlations between stellar abundances planets properties



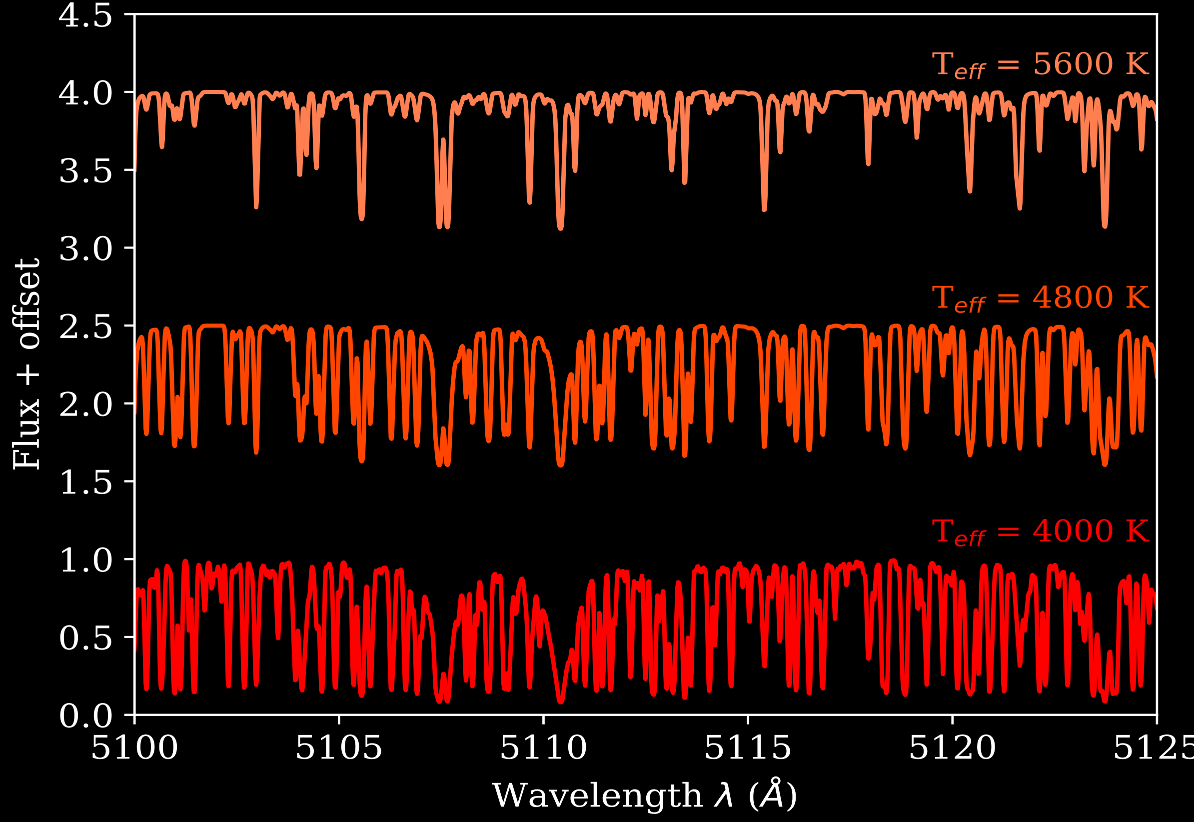
Stars with high $[Fe/H]$ more likely to host giant planets *(Fischer & Valenti + 2005)*

How do we determine stellar parameters / abundances before?

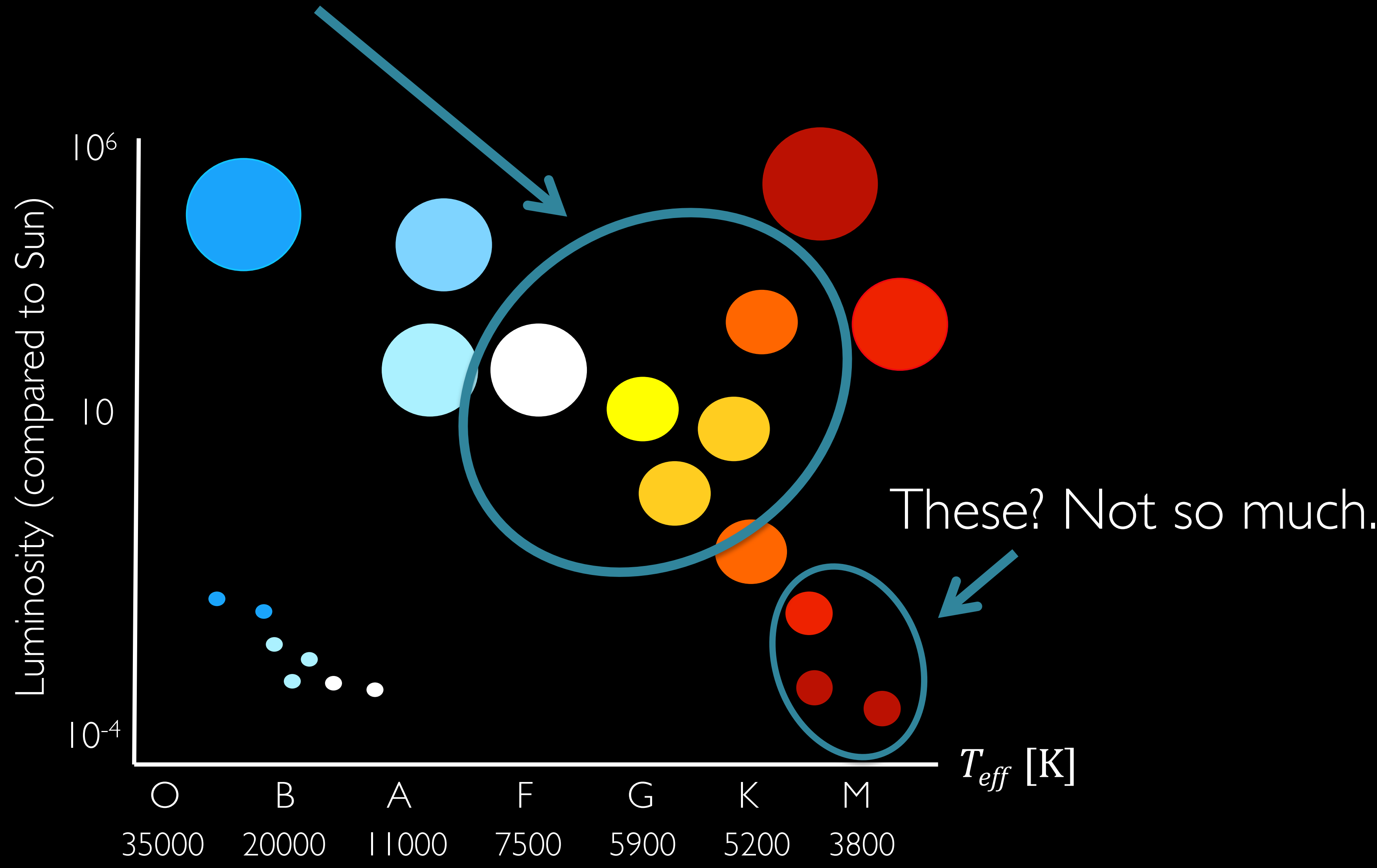
Synthetic spectral libraries



SpecMatch-Syn (Petigura+2015)

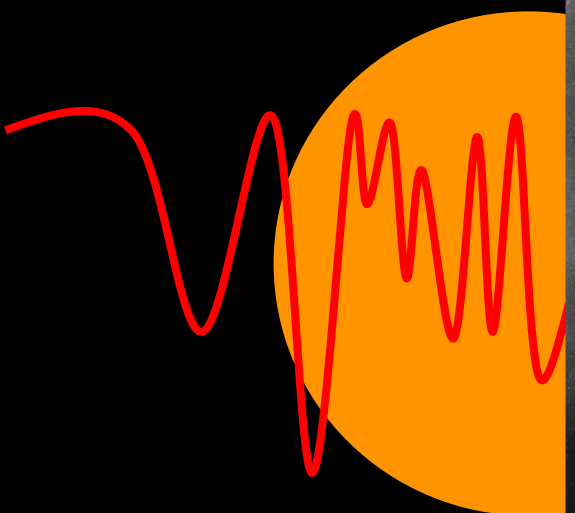


Synthetic spectral libraries make good abundance / parameter predictions for these stars



The Cannon

Data-driven (ML) approach for predicting stellar "labels" (parameters + elemental abundances) from spectra



els:

nperature T_{eff}

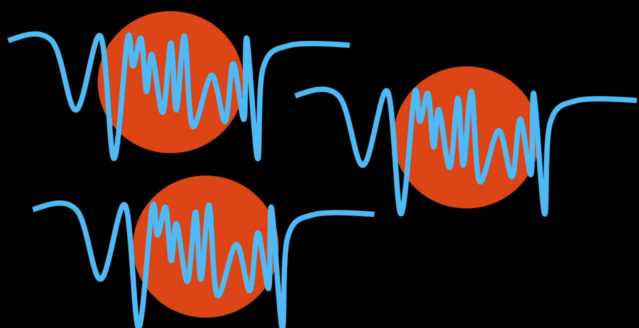
k metallicity *[Fe/H]*

lar radius R_*

The Cannon was developed by Melissa Ness (MPIA), Andy Casey (Monash U.), and Anna Ho (Caltech)

The Cannon

"Training Step"

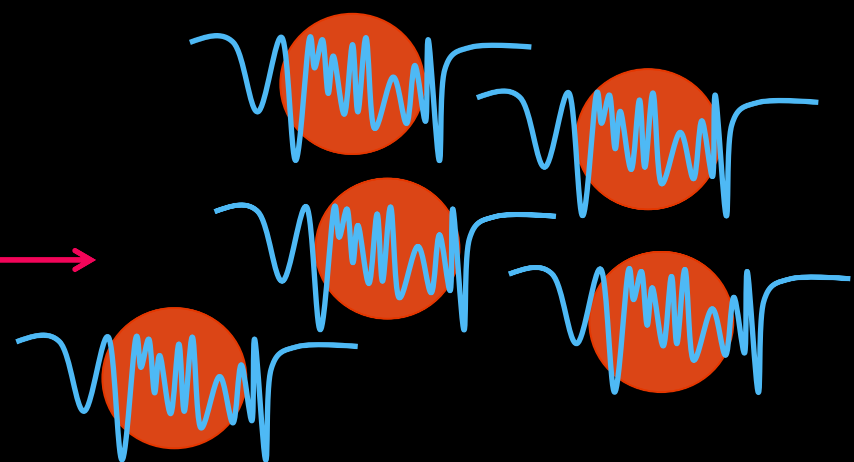


Construct flux model

$f_{jn} = V(\ell_n) \bullet \vartheta_j + noise$

"Test Step"

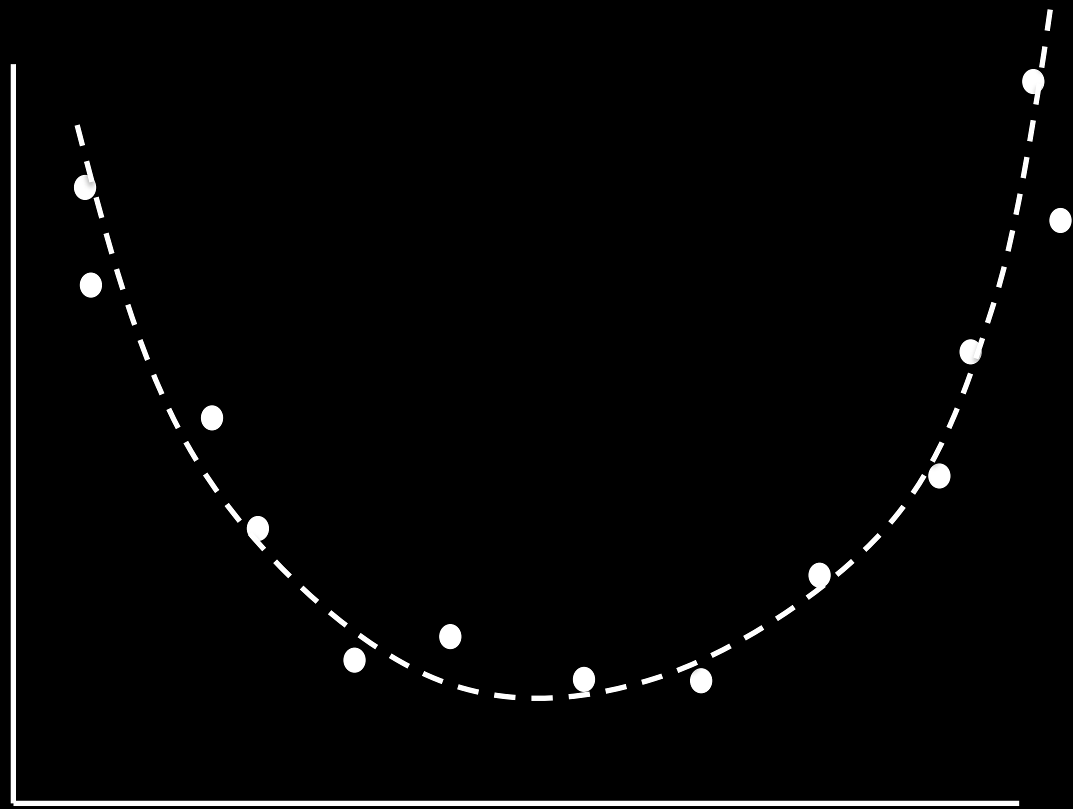
Apply f_{jn} to test set spectra



Cannon flux model fitting:

$$l_n = [\ 1,\ T_{eff},\ R_*,\ [Fe/H]\ \ldots\ ]$$

$f_{jn}\,(l_n\,,\,\vartheta_j\,)$



ϑ_j

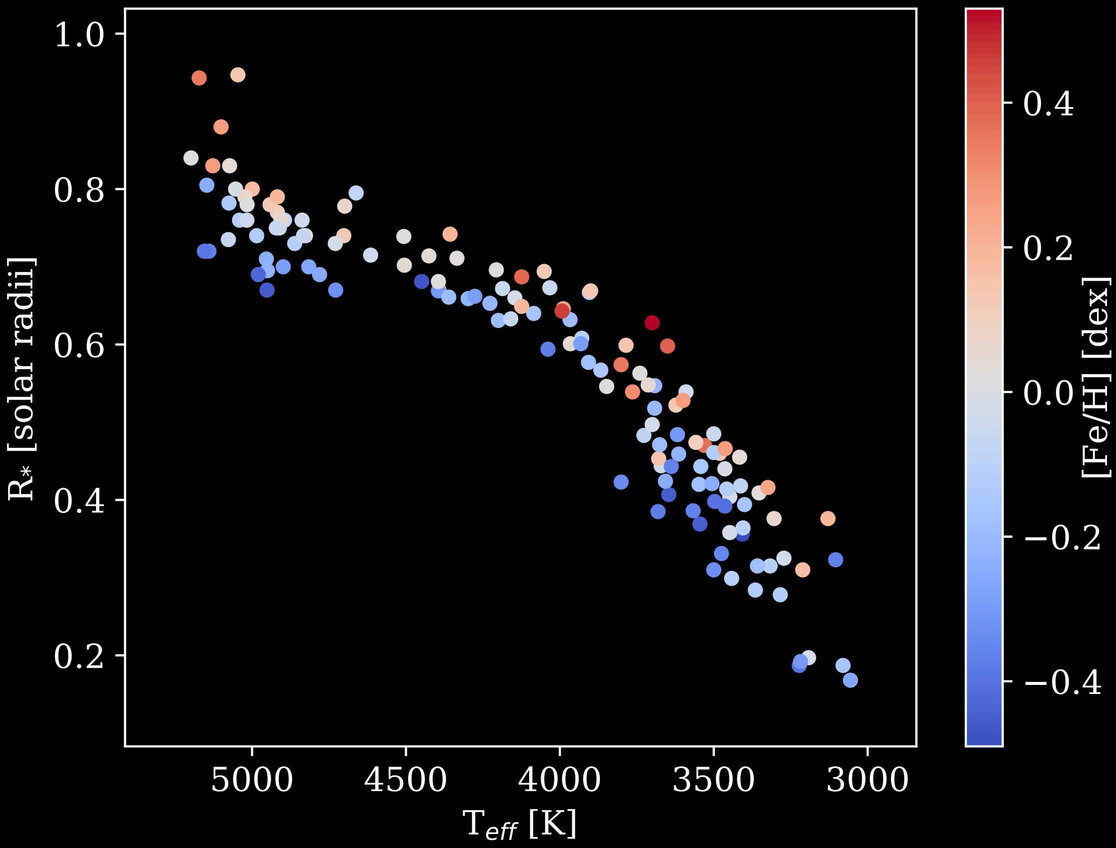
High Resolution Echelle Spectrometer (HIRES) sample

141 stars, K and M dwarfs:

- 3000 K < T_{eff} < 5200 K
- No giants ($R_* < 1\ R_\odot$)

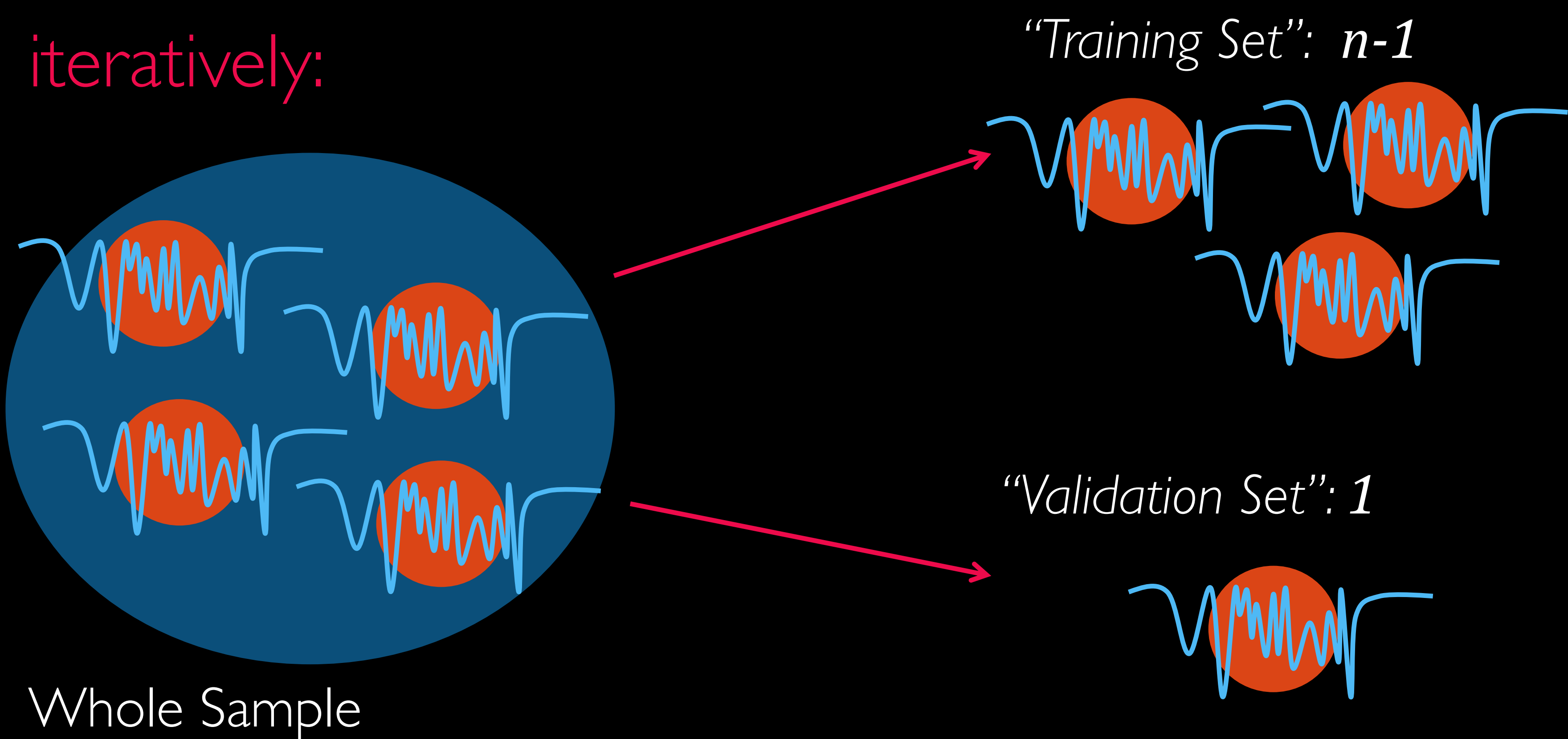
Labels (T_{eff}, R_*, *[Fe/H]*):

- Interferometry
- SED Modeling
- Gaia Parallaxes



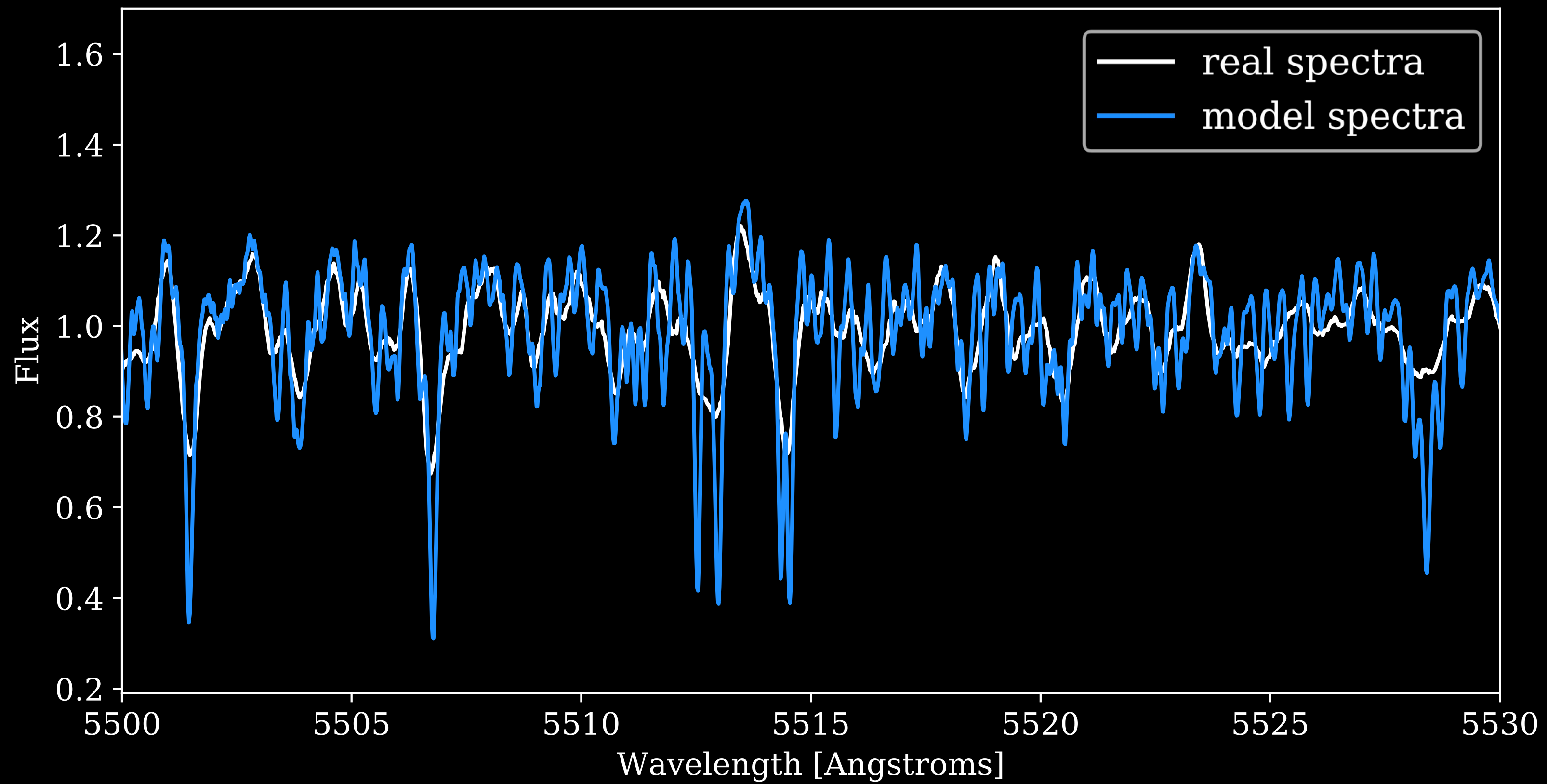
Evaluating *Cannon* performance: Cross-validation bootstrap scheme

iteratively:



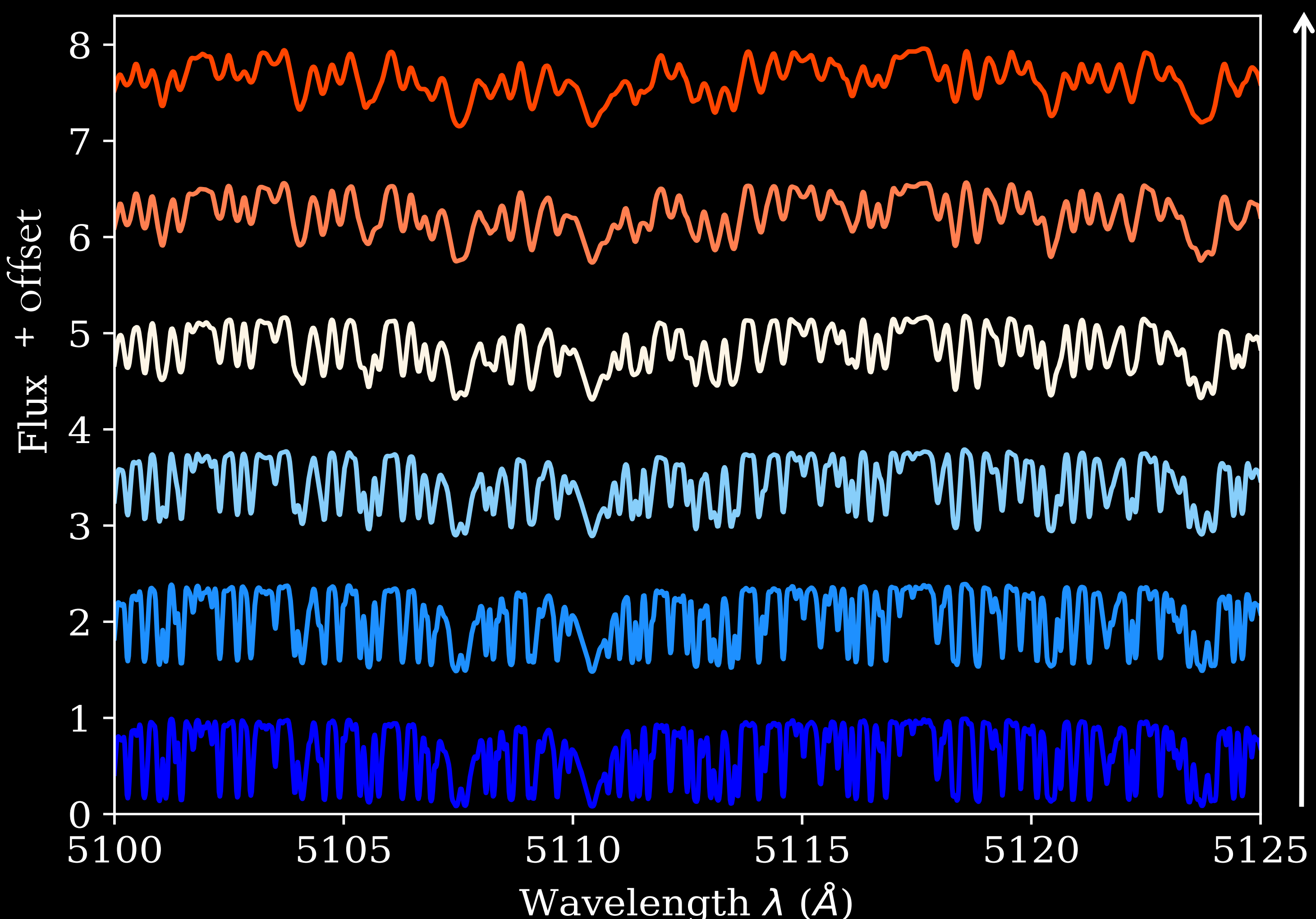
The Cannon cannot make predictions for spectra not well-represented in training set!

GL896A: a fast rotator



…diversify the training set!

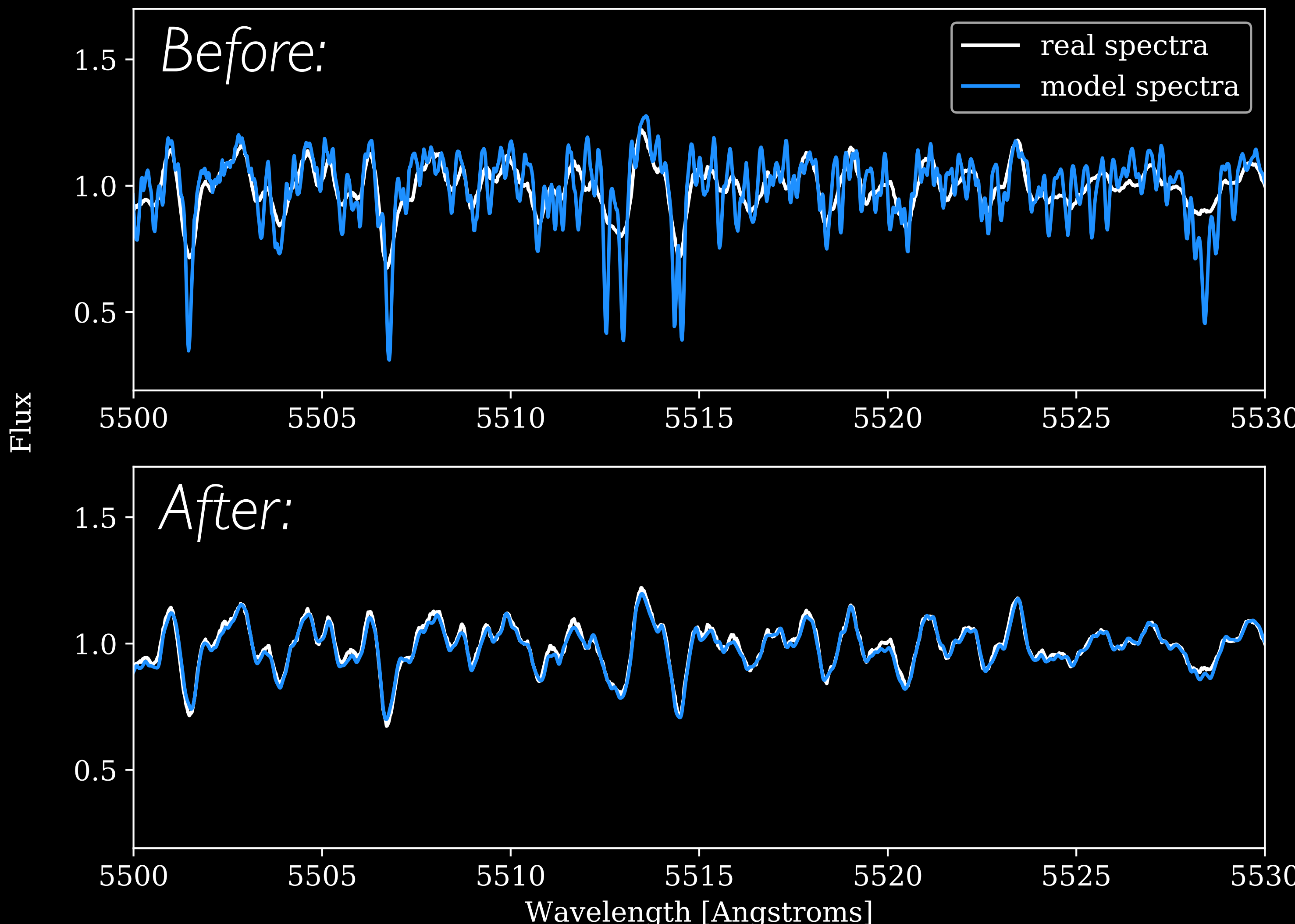
SpecMatch-Syn (Petigura+2015)



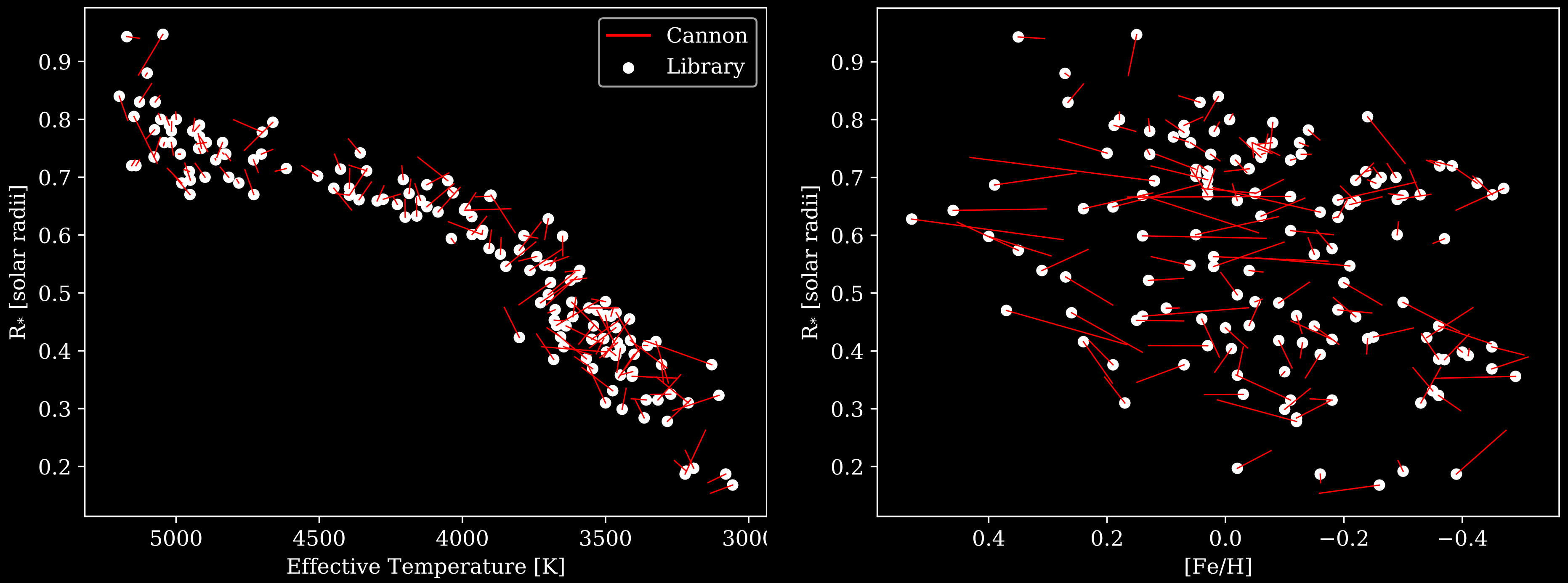
Copy each spectrum in training set and artificially broaden

+0-20 km/s

GL896A


Before:
real spectra
model spectra
After:
Flux
Wavelength [Angstroms]
1.5
1.0
0.5
5500
5505
5510
5515
5520
5525
5530

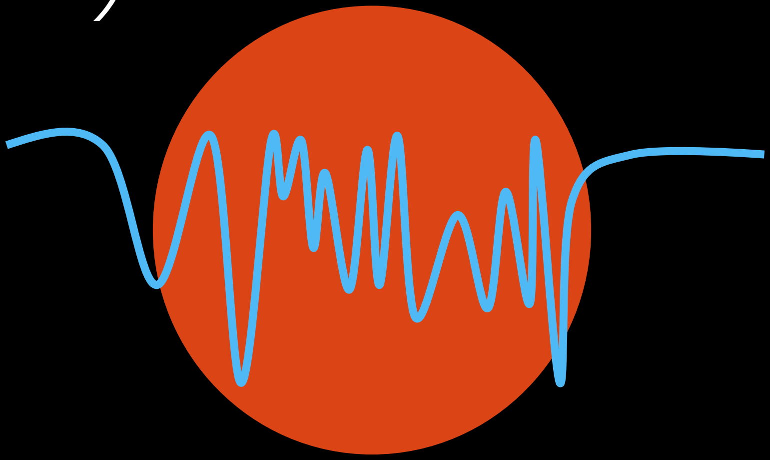
Results



T_{eff}: ~70 K ; R_*: ~5% ; $[Fe/H]$: ~0.08 dex

Conclusion

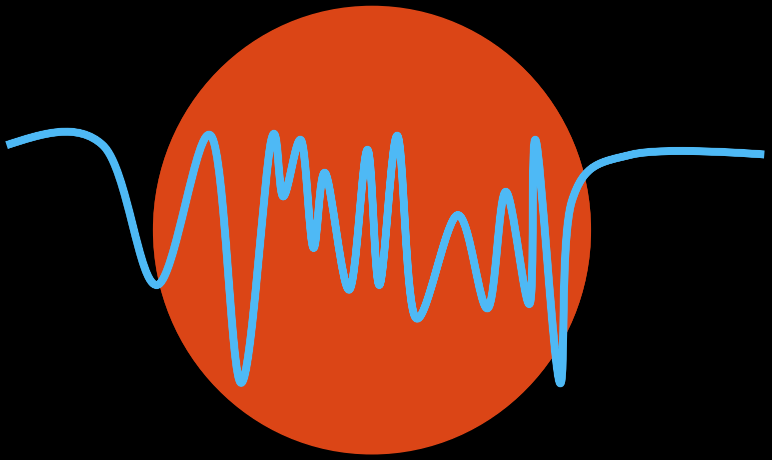
*(with some modifications to the spectral sample), **The Cannon** is able to make label predictions for cool stars comparable to the best alt. methods (but is easier to use – data driven!)*



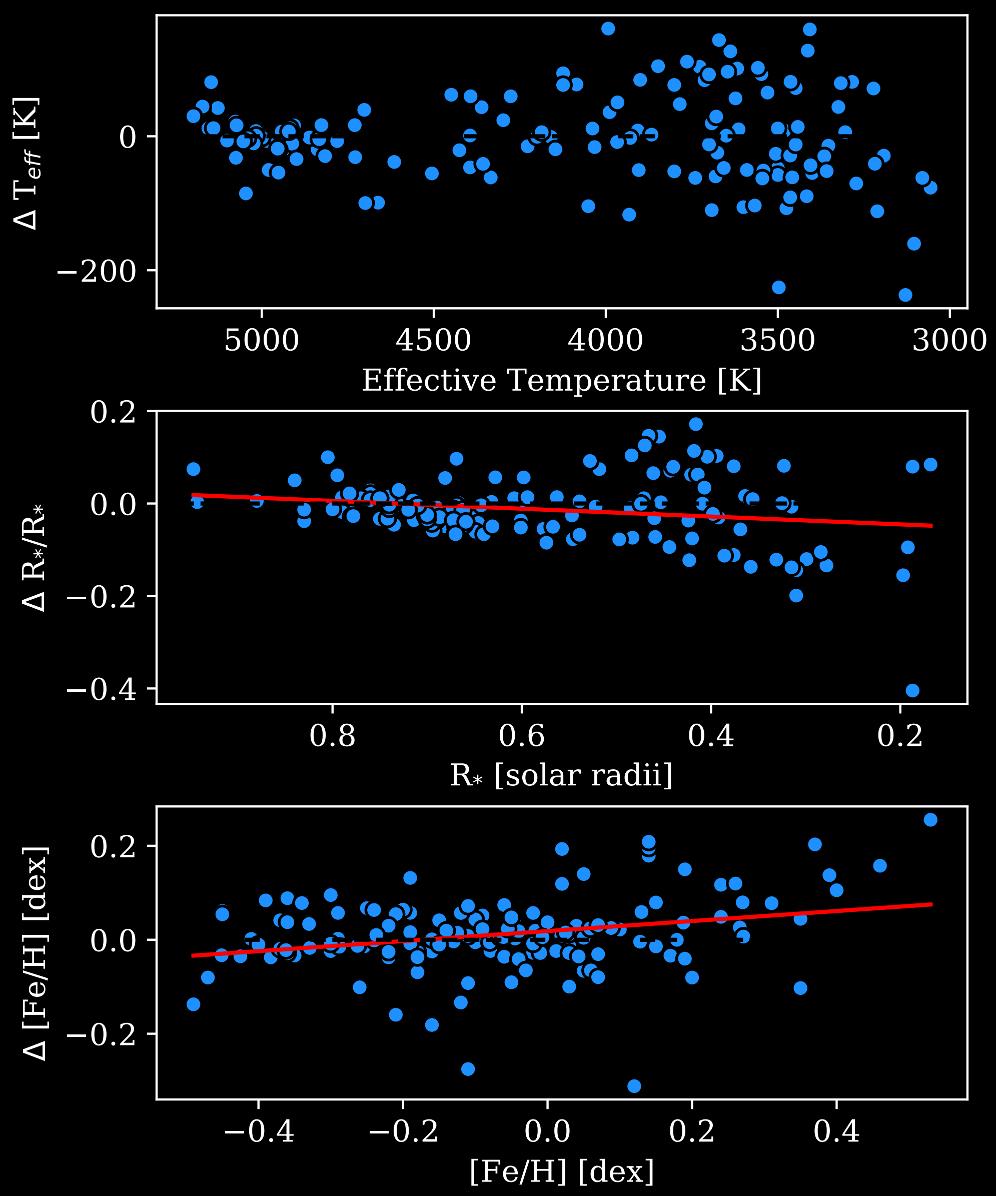
Future work

Consider including prior information (line lists, etc.)

Elemental abundance studies



Prediction residuals



Flux model

"complex vectorizer" function → V ; model coefficients → ϑ_j

$$f_{jn} = V(l_n) \bullet \vartheta_j + noise$$

$$l_n = [\ 1,\ T_{eff},\ R_*,\ [Fe/H]\ \ldots\ ]$$

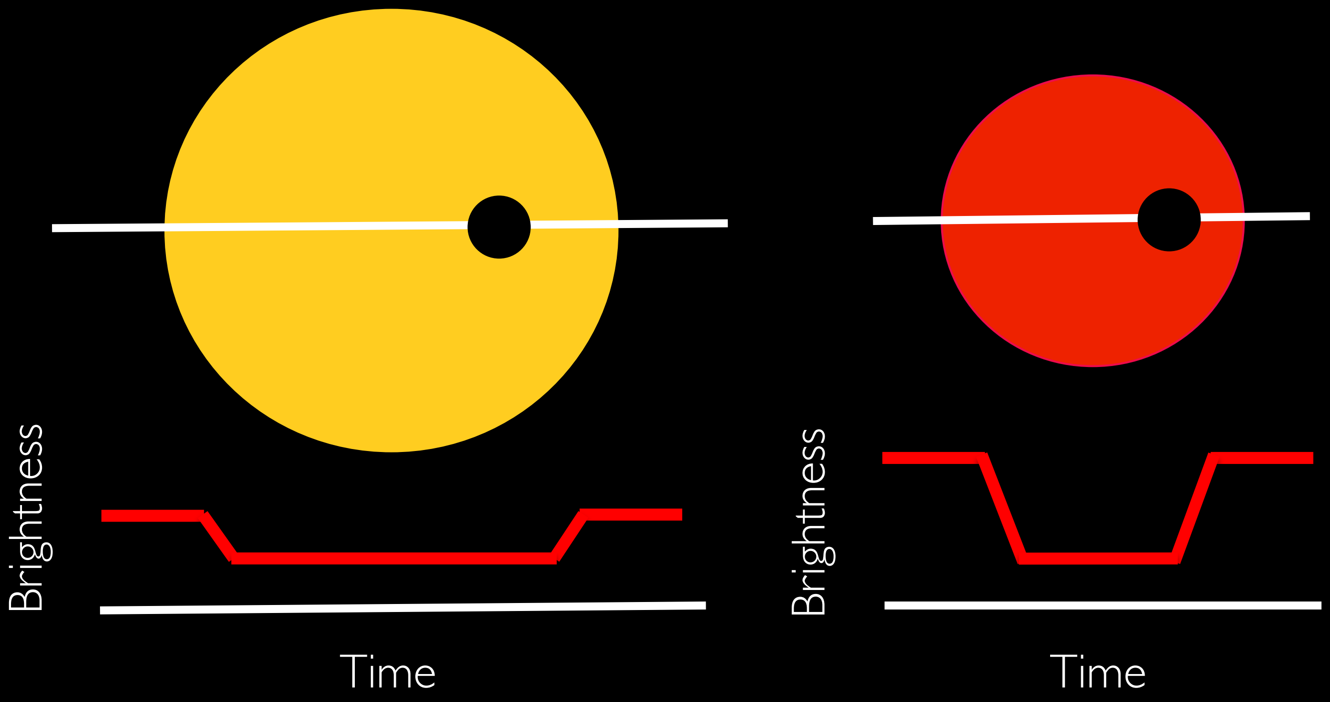
"Training Step" : fit for model coefficients ϑ_j for each flux model

"Test Step" : fit for labels l_n for each star in the validation set that best reproduces empirical flux

Synthetic spectral libraries struggle with small, cool stars…

Too bad! Good for finding small, cool planets

Transit method



Radial velocity method

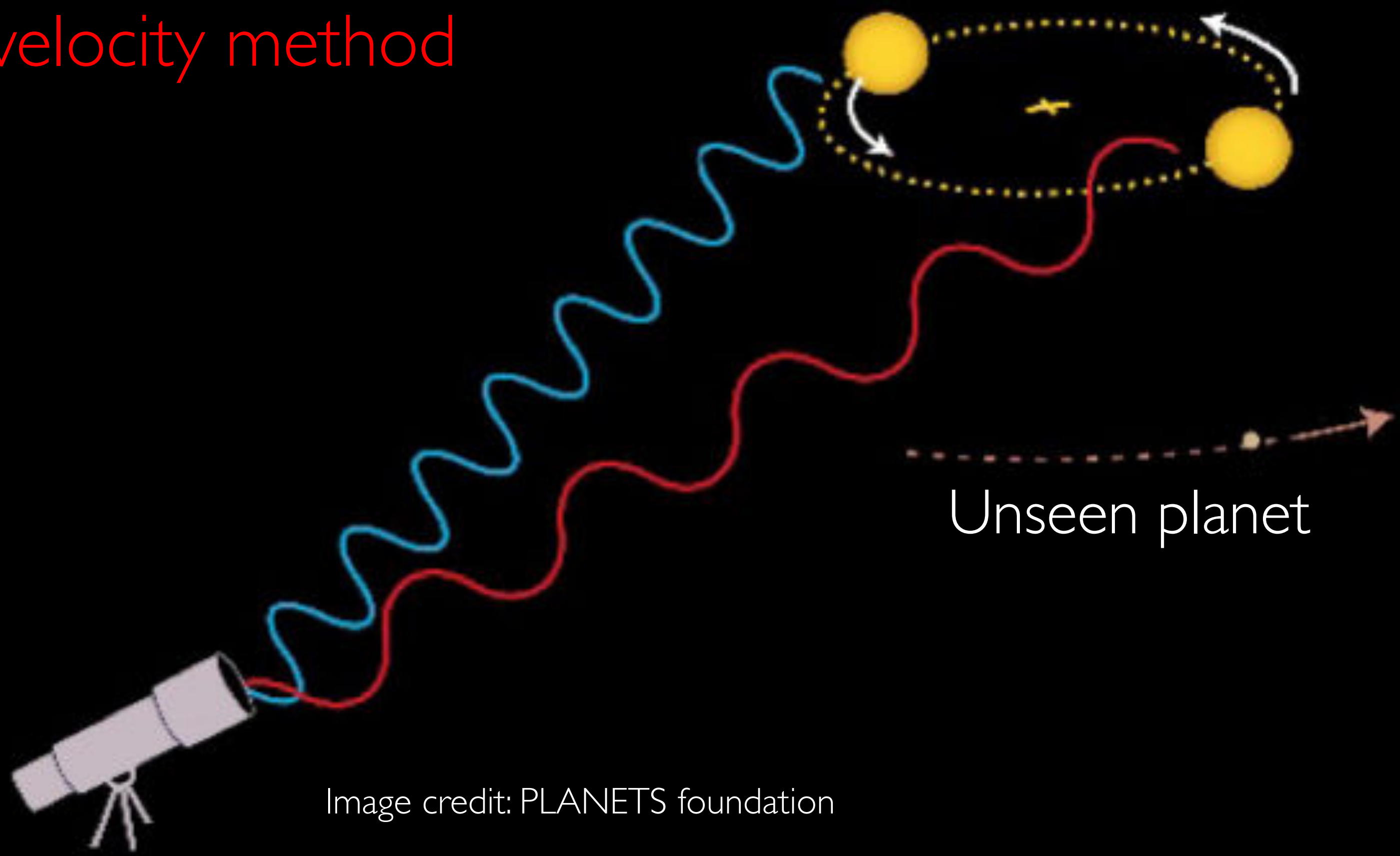
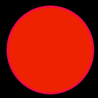


Image credit: PLANETS foundation

…And most common stars in the galaxy



M-dwarfs = ~75% of stars in solar neighborhood!