Precise Near-Infrared Radial Velocities with iSHELL

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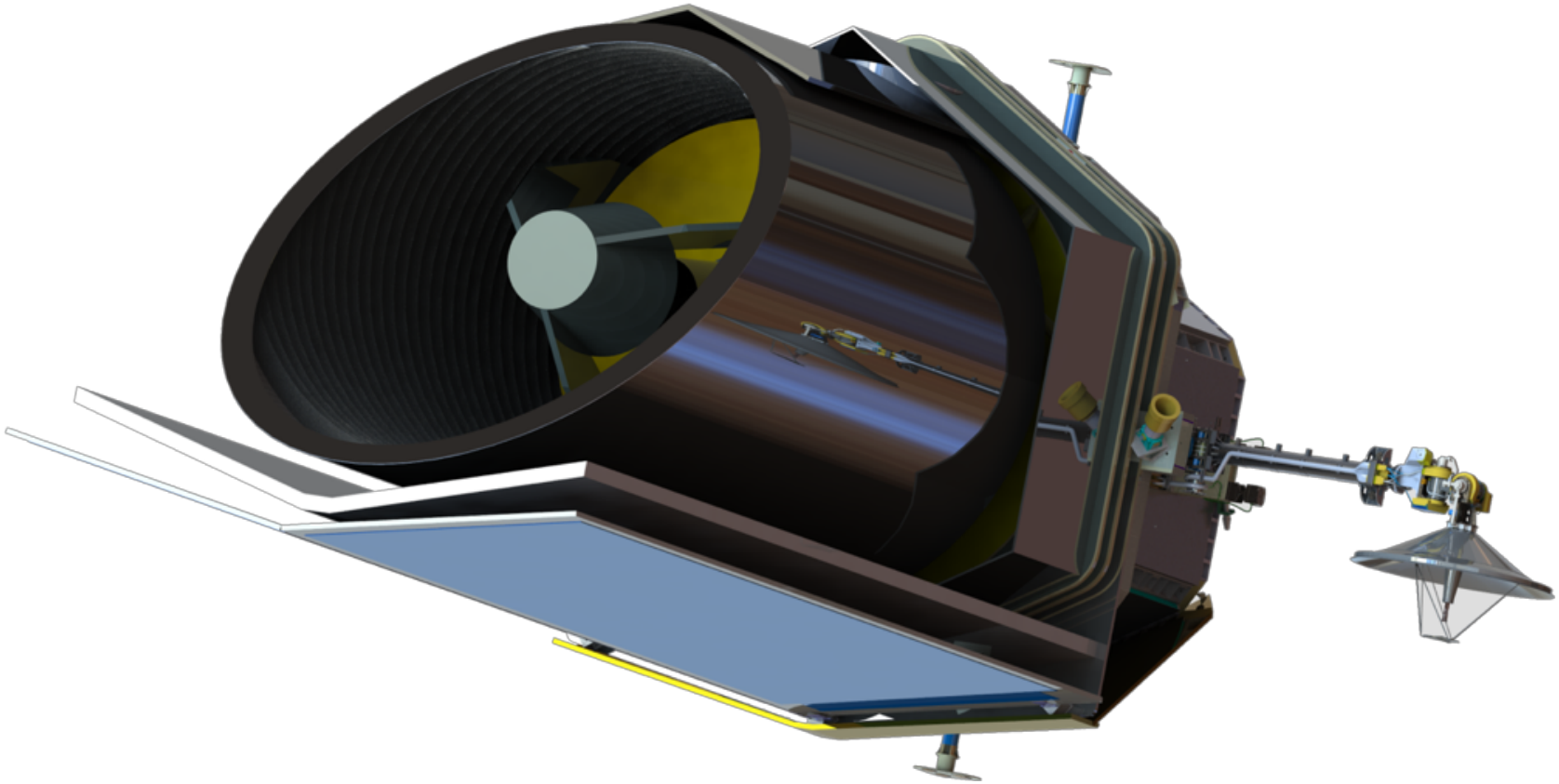
EarthFinder

- **Probe ($1B) Mission Concept Study Report submitted to NASA 3/15**
- **Please see poster by Mason undergrad William Matzko in poster session for summary**

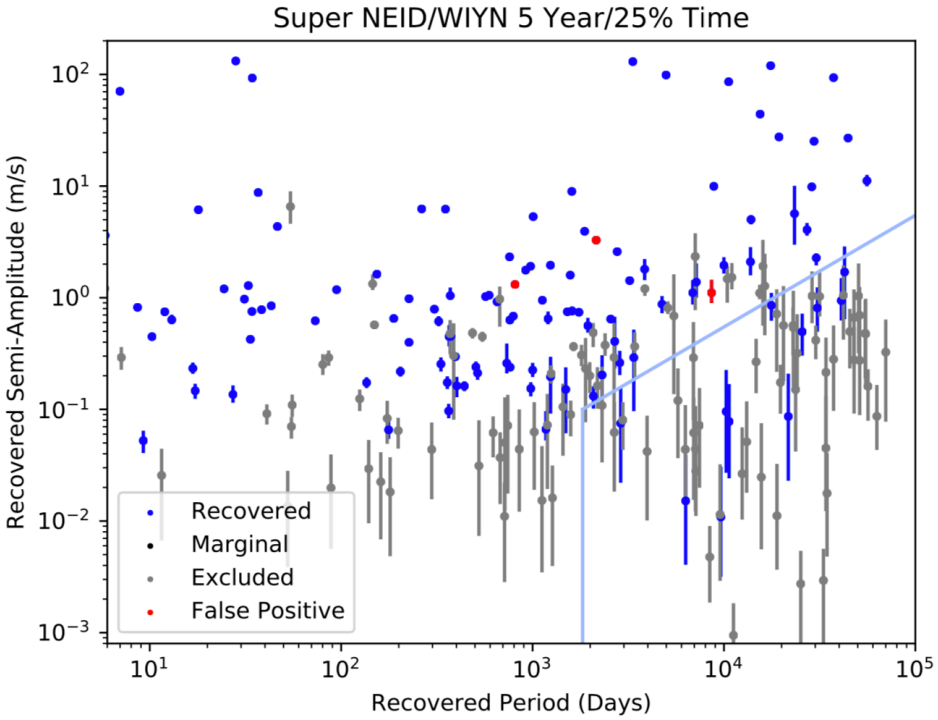


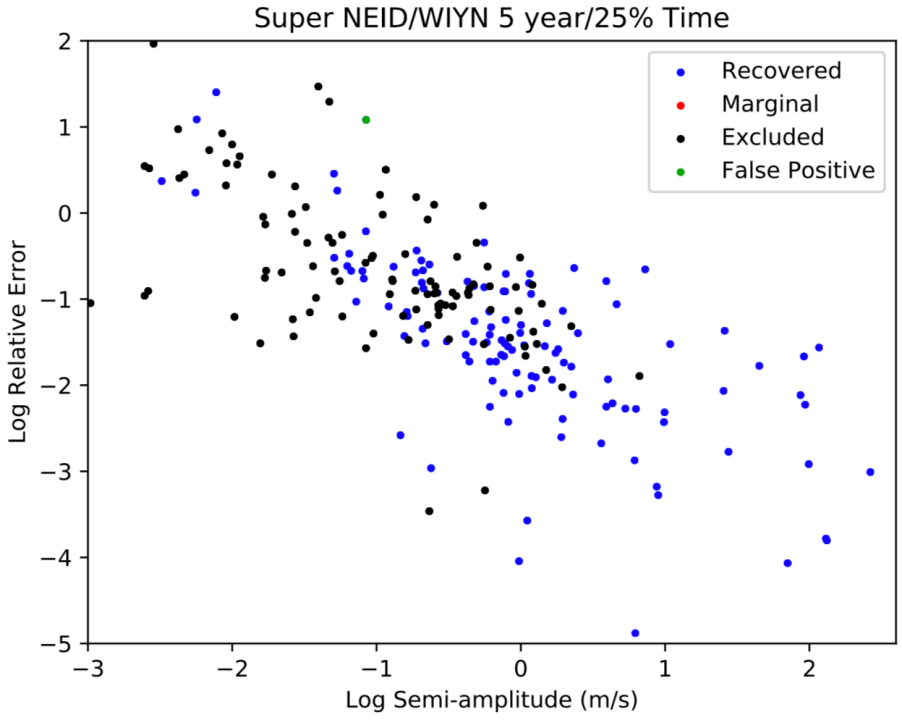
Credit: Ball Aerospace

Radial Velocities … *in space!*

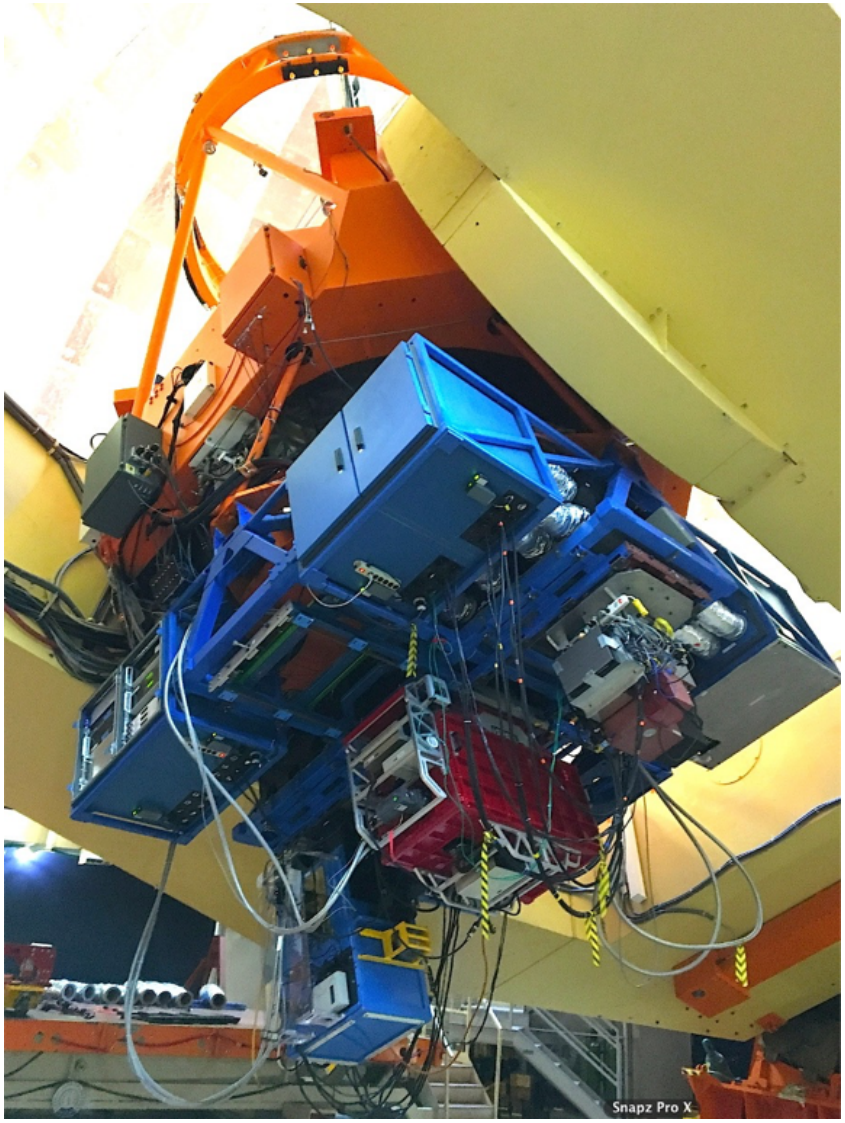
RV Survey Simulations

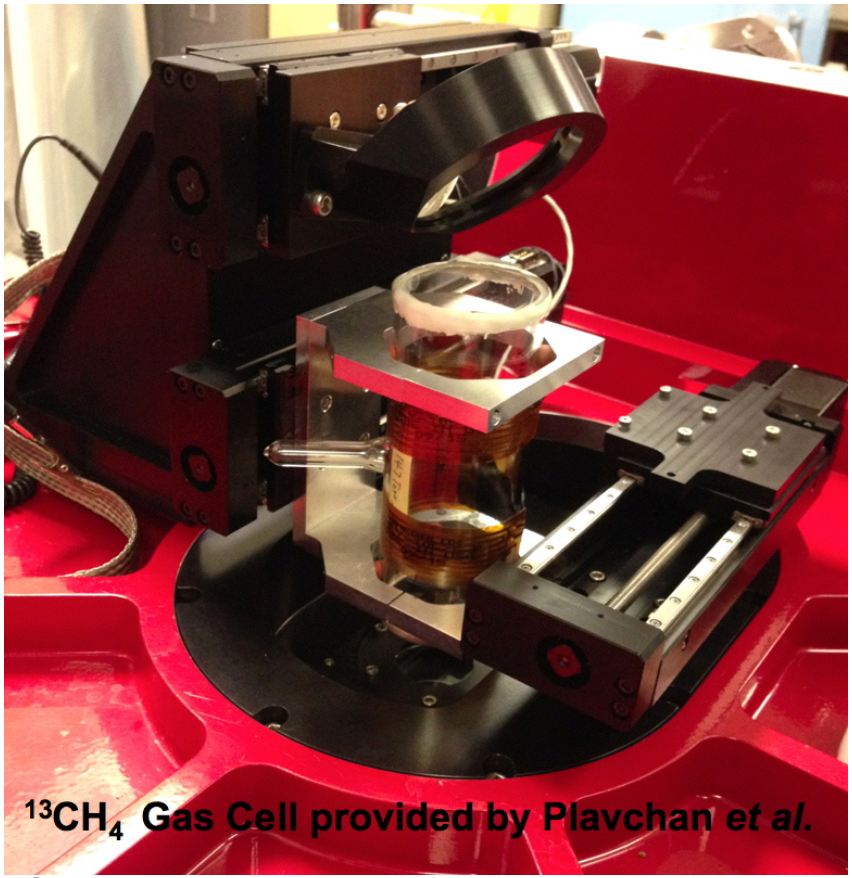
- See poster by Mason PhD student Patrick Newman.





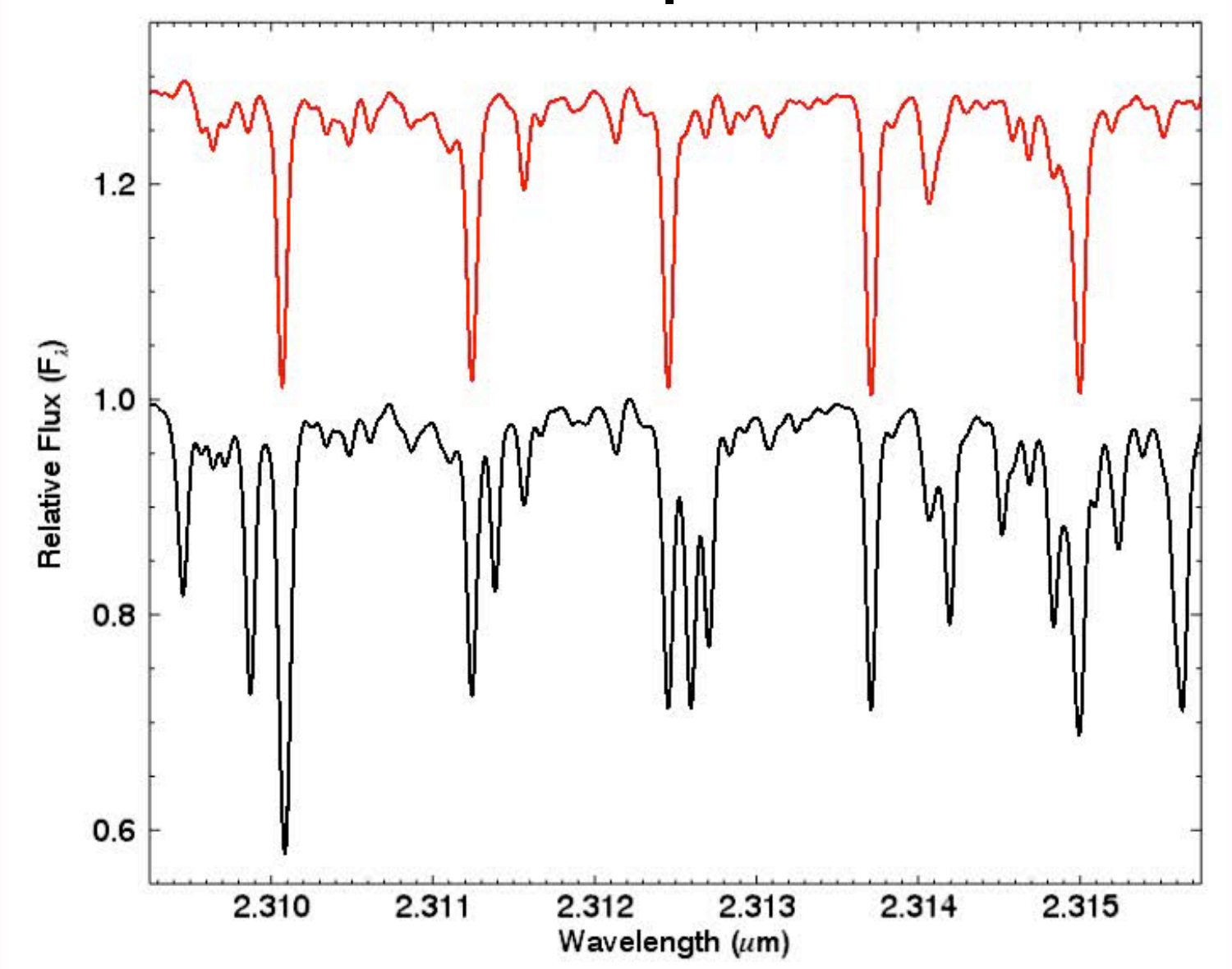
iSHELL



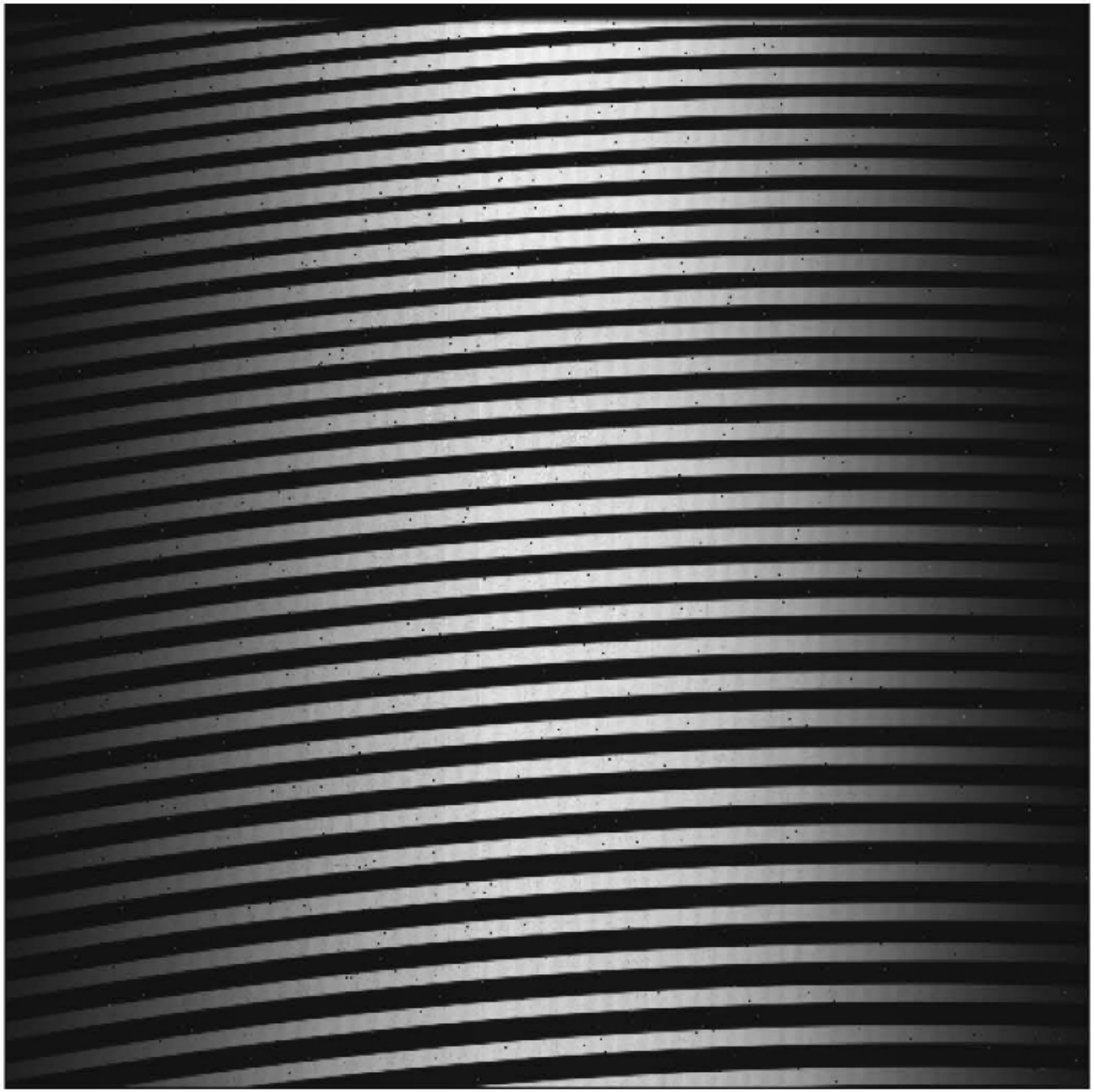


Operational since fall 2017
Facility 1-5 μm instrument at Cass focus

Gas Absorption Cell



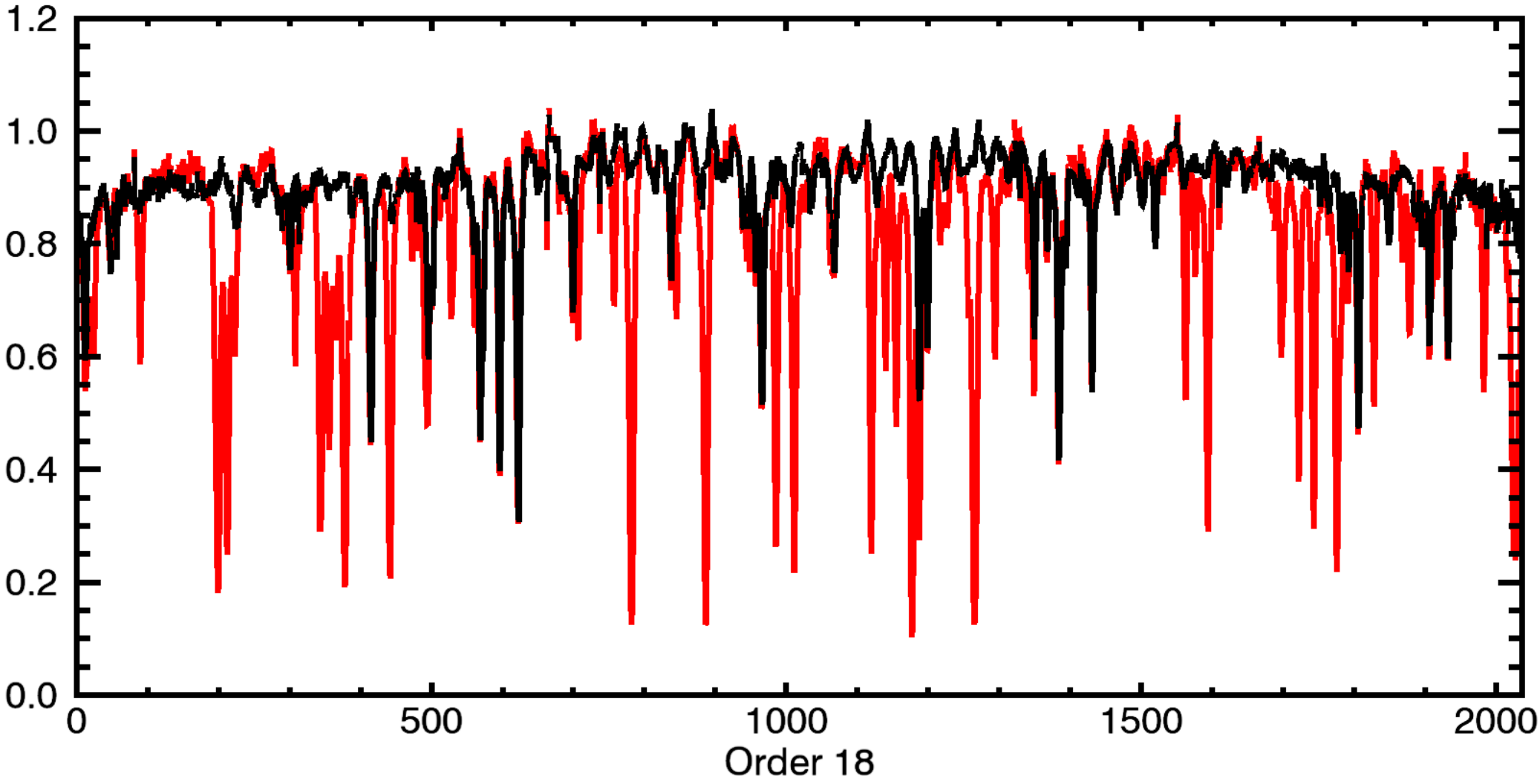
Gas Cell Lines



2.18- 2.47 μm

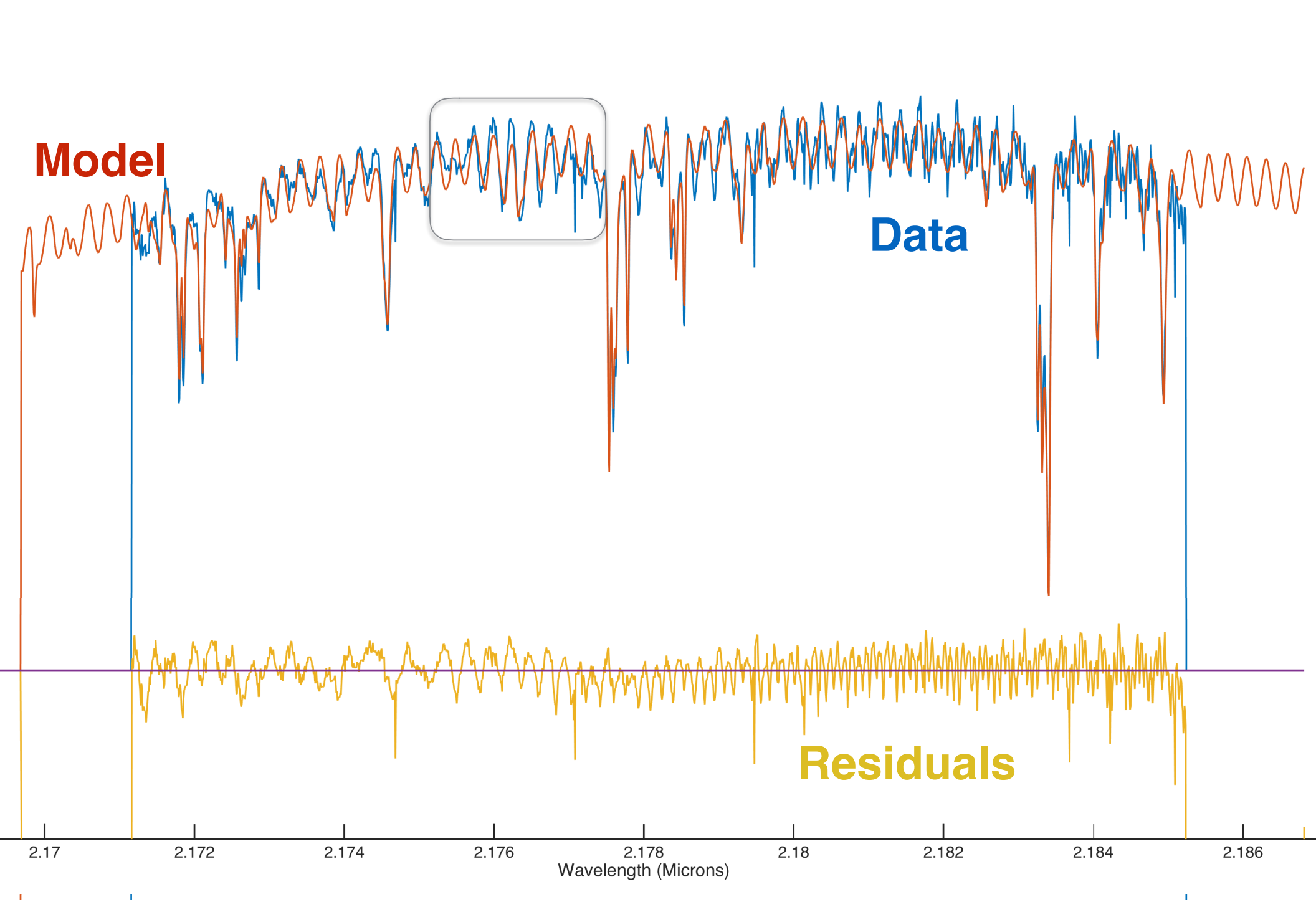
Extracted Data

Vega Single Order

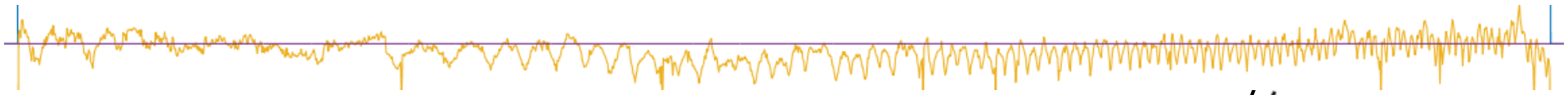


Without gas cell

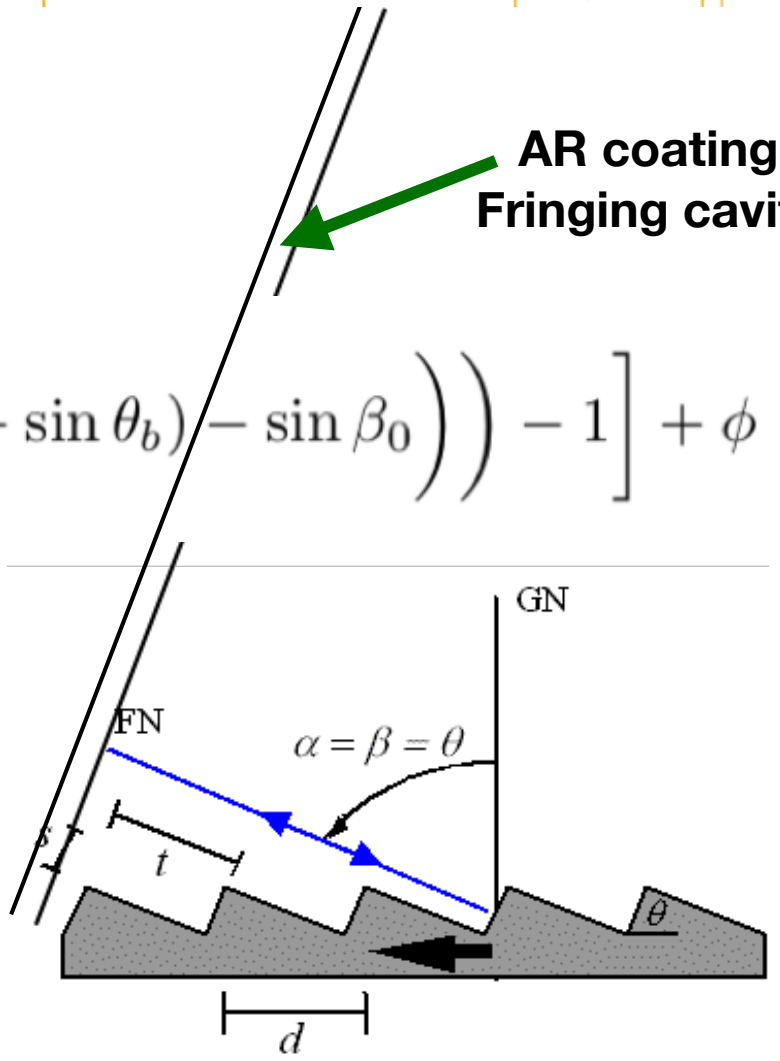
With gas cell


Model
Data
Residuals
2.17
2.172
2.174
2.176
2.178
2.18
2.182
2.184
2.186
Wavelength (Microns)

Silicon Immersion Grating Exit Face Fringing



$$\delta_{AR} = \frac{C_{AR}}{\lambda}\left[\cos\left(\beta_0 - \arcsin\left(\frac{\lambda}{\lambda_0}(\sin\beta_0 + \sin\theta_b) - \sin\beta_0\right)\right) - 1\right] + \phi$$



Spectral Model

$$\delta_{AR} = \frac{C_{AR}}{\lambda}\left[\cos\left(\beta_0 - \arcsin\left(\frac{\lambda}{\lambda_0}(\sin\beta_0 + \sin\theta_b) - \sin\beta_0\right)\right) - 1\right] + \phi$$

$$I_{obs}(\lambda) = LSF(\lambda) * [I_s(\lambda + \Delta\lambda_s)T_g(\lambda + \Delta\lambda_g)T_t(\lambda + \Delta\lambda_t)\Sigma(\lambda)K(\lambda)]$$

Wavelength Solution

Quadratic+Cubic

Line Spread Function

Water, Methane, Nitrous Oxide, Carbon Dioxide

Quadratic+Cubic

$^{13}CH_4$ Spectrum

$$T_t = T_{to}^{\tau_t}$$

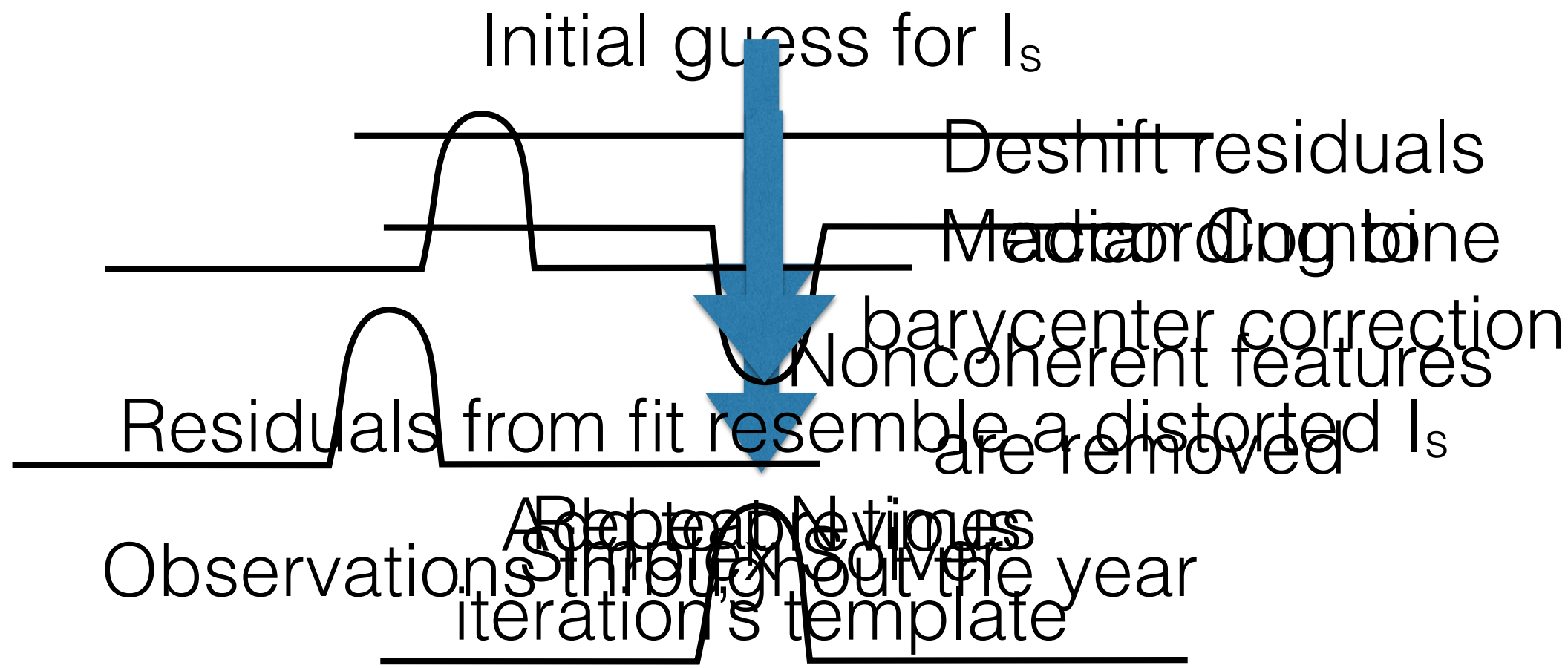
Fringing

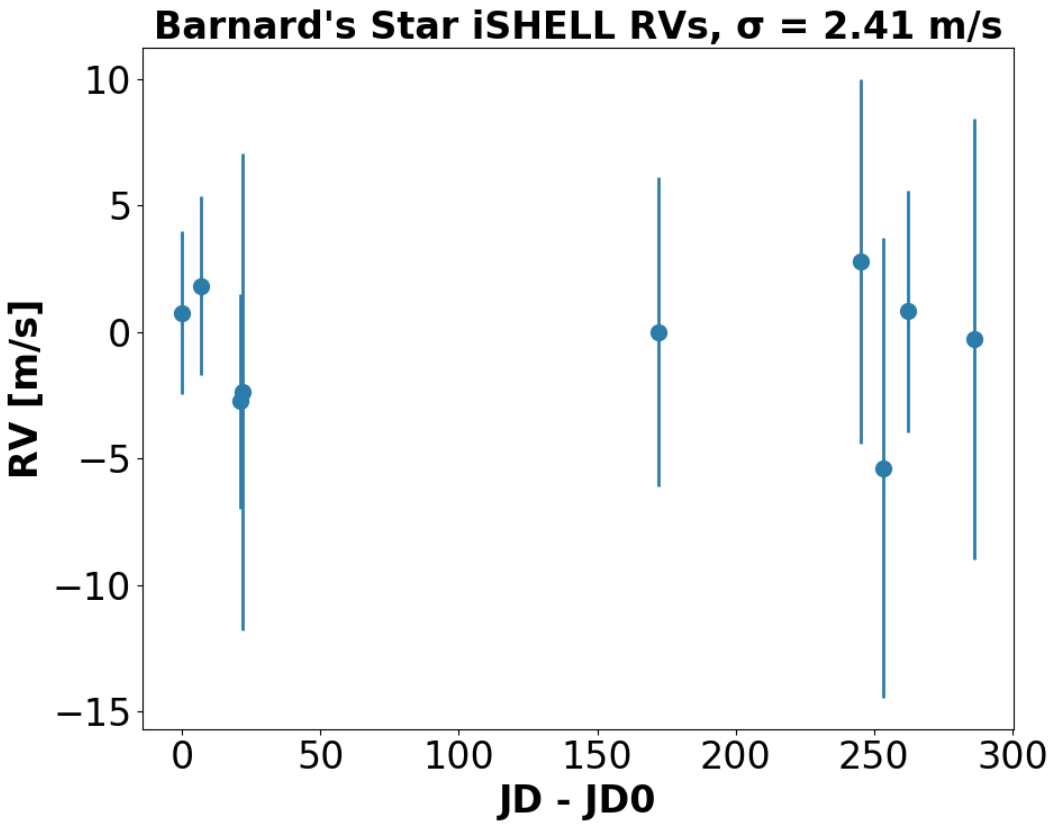
60+ parameters

Solved with a custom downhill simplex algorithm in Python

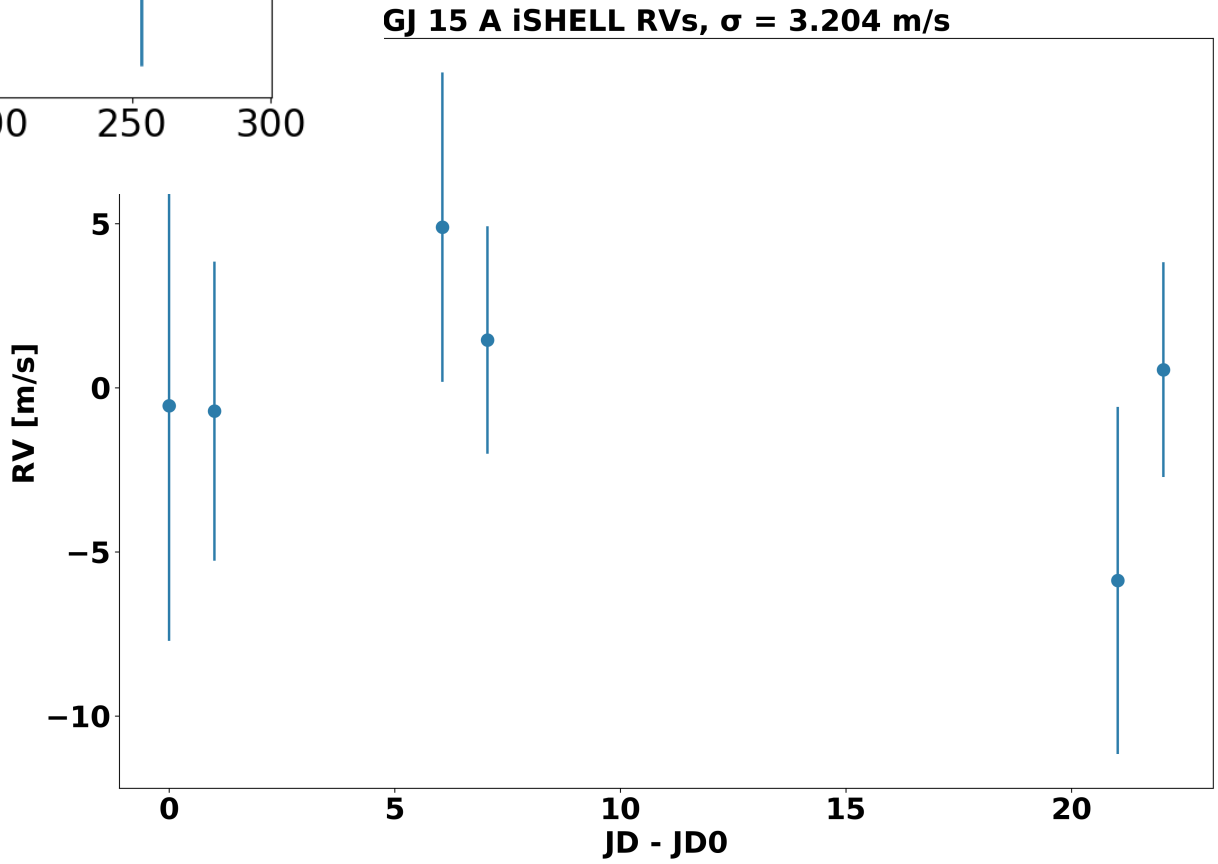
The Grand Solution

(Gao et al. 2016)



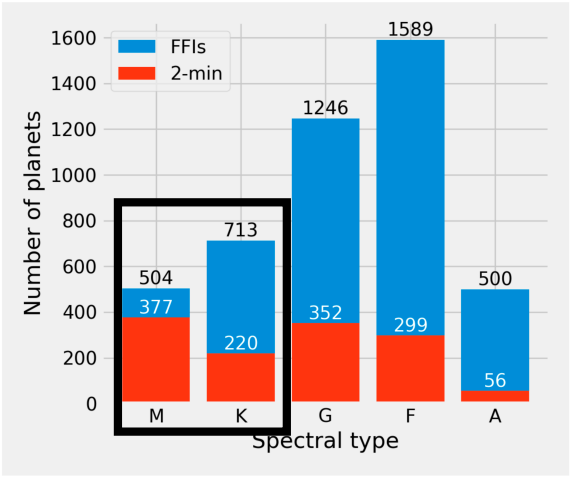


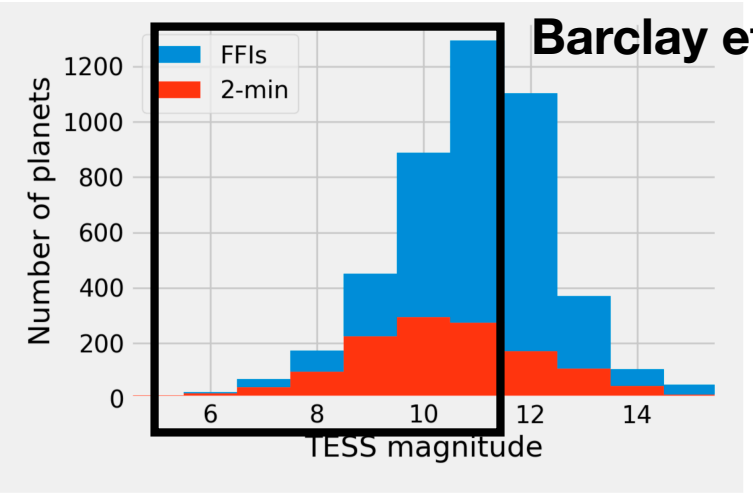
Collected commissioning data for one year on RV standards late G,K,M dwarfs



Analysis works!
Computationally expensive

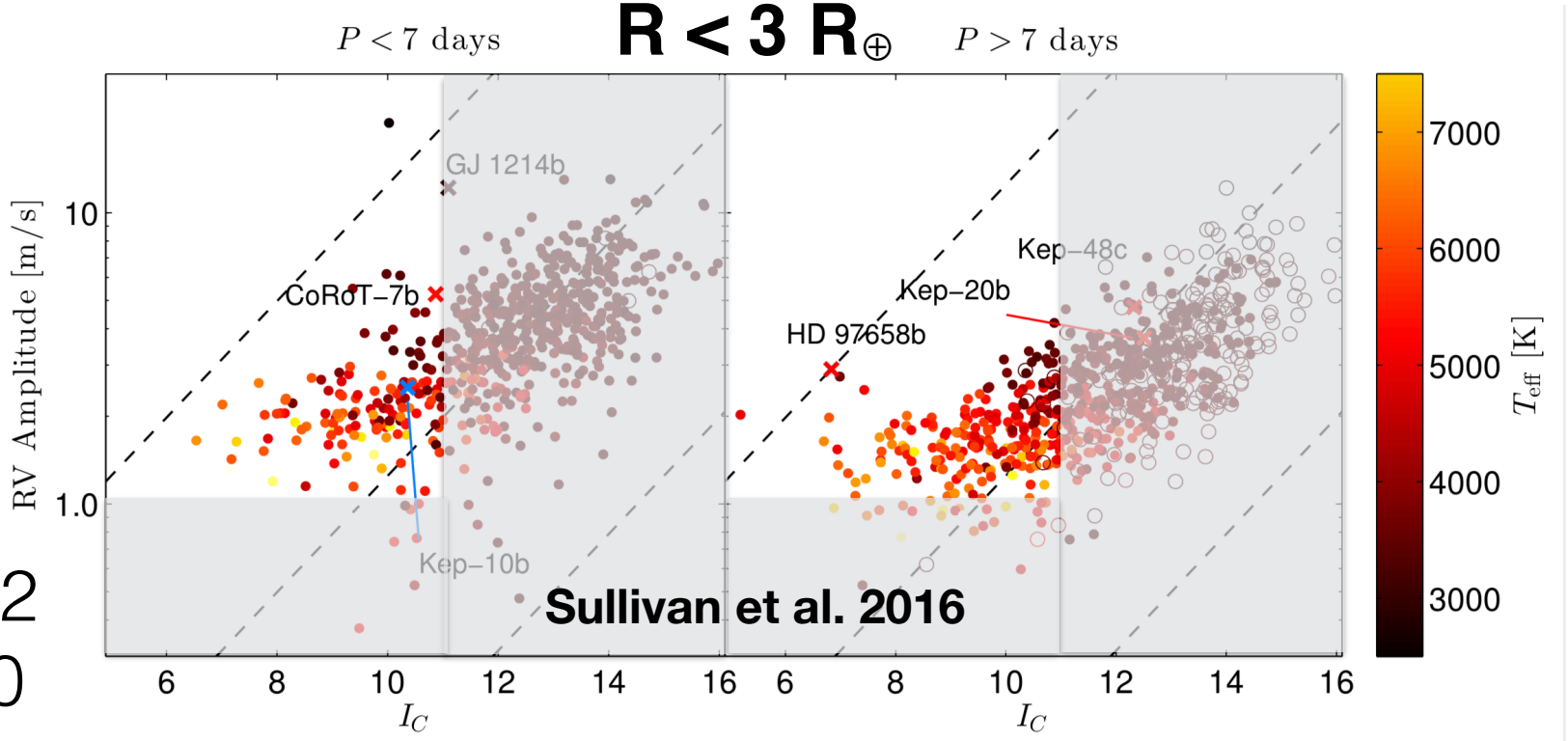
TESS Follow-Up





Barclay et al. 2018

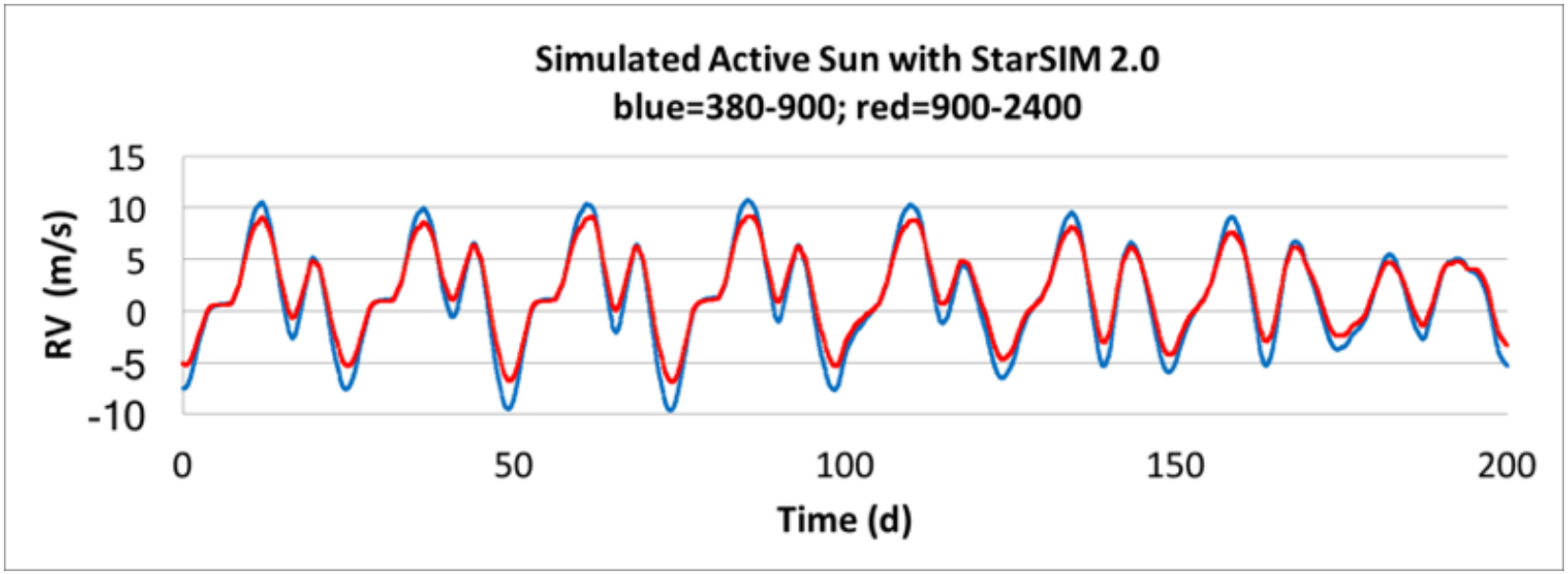
R < 3 R⊕



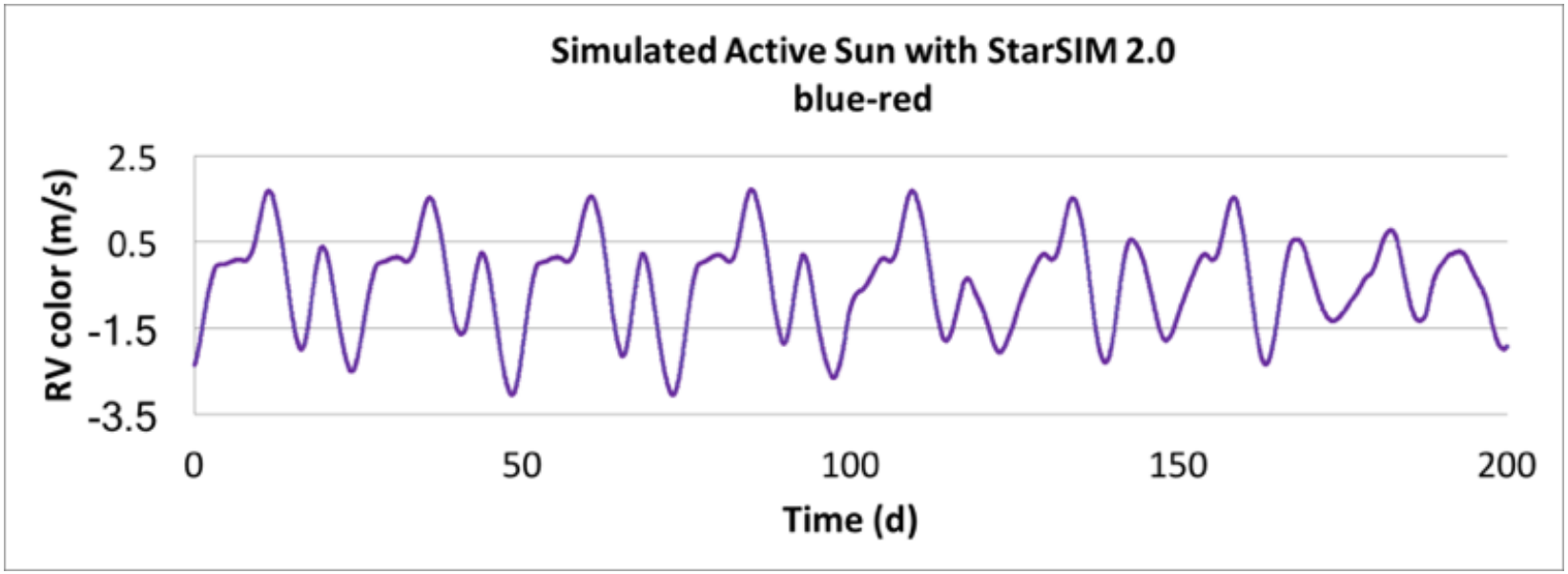
Sullivan et al. 2016

$K_s \sim I_C - 2$ for M0

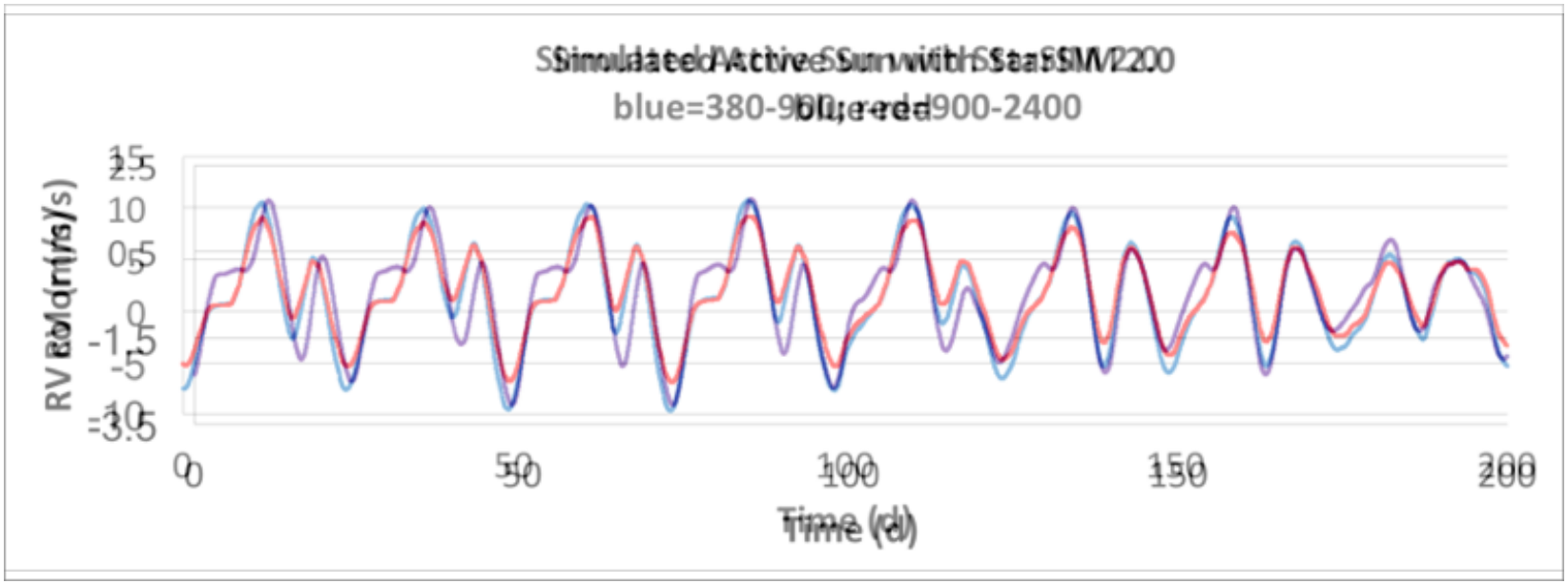
RV Color


Simulated Active Sun with StarSIM 2.0
blue=380-900; red=900-2400
RV (m/s)
15
10
5
0
-5
-10
0
50
100
150
200
Time (d)

RV Color


Simulated Active Sun with StarSIM 2.0
blue-red
RV color (m/s)
2.5
0.5
-1.5
-3.5
0
50
100
150
200
Time (d)

RV Color



Summary

- We have achieved 2.5 m/s long-term precision with iSHELL swinging at Cass focus using a methane isotopologue gas cell. Not sure yet what is limiting our current precision (fringing, tellurics, or otherwise).

- iSHELL RV mode is available to all US PIs for proposing

- Excellent facility for TESS follow-up on a NASA-owned telescope of K<9 (V<13) M dwarfs and active stars late G,K and M stars, and for probing the wavelength dependence of activity with simultaneous RV color

- Thank you to my wonderful group of students, including Patrick Newman, William Matzko & Natasha Latouf here at this meeting, and Bryson Cale whose work on iSHELL I presented; and to Jonathan Gagne, Peter Gao and others who contributed to observing sessions and the software analysis.

- Stay away from fringing from immersion gratings. Please. But it is a solved problem; Cale et al. in prep.