

Breakthrough Listen and the Automated Planet Finder

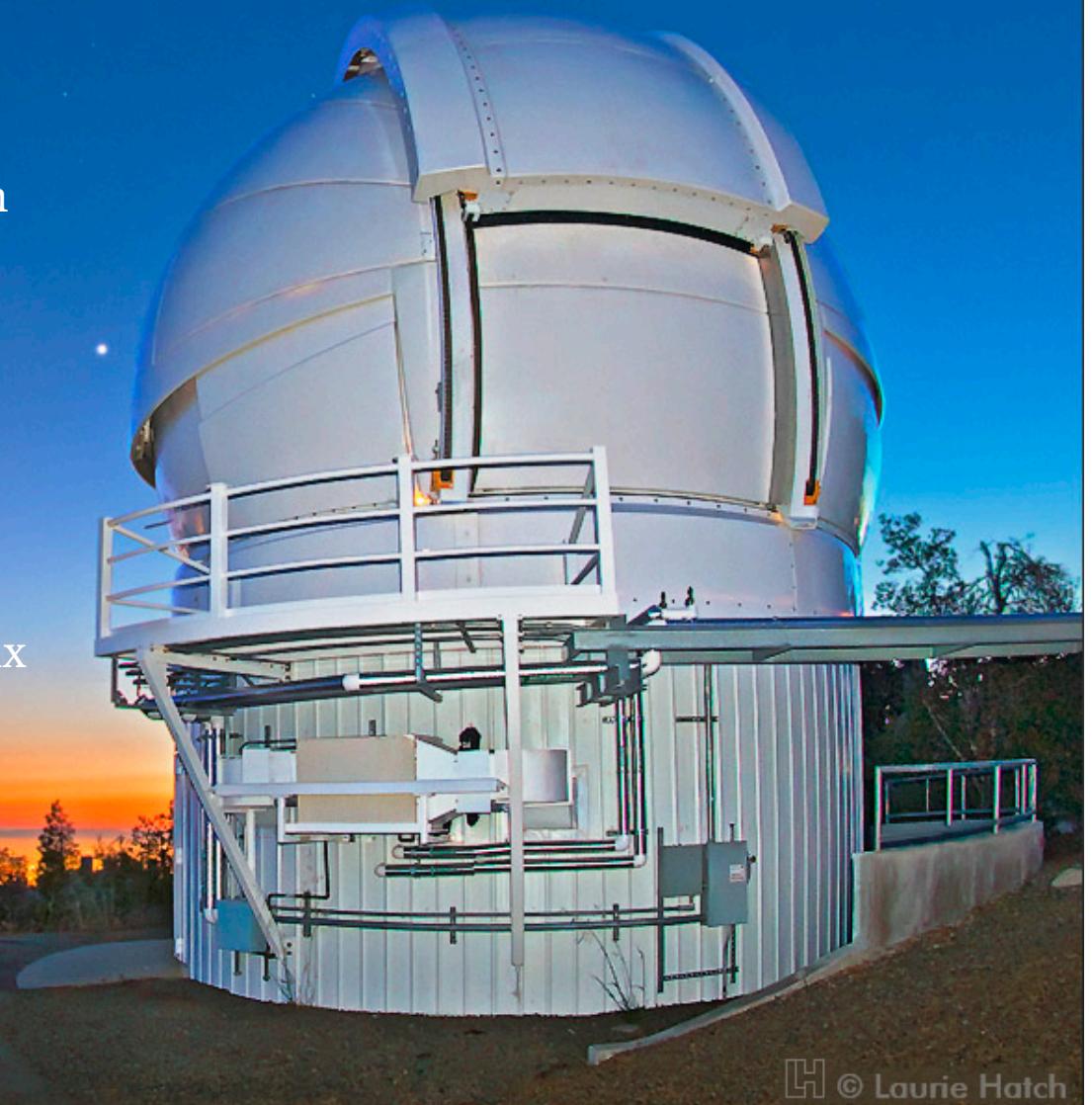
Howard Isaacson
Breakthrough Listen Machine Learning seminar/workshop/hackathon
2 June 2016

APF Telescope on Mt. Hamilton, CA

Primary Mirror: 2.4m

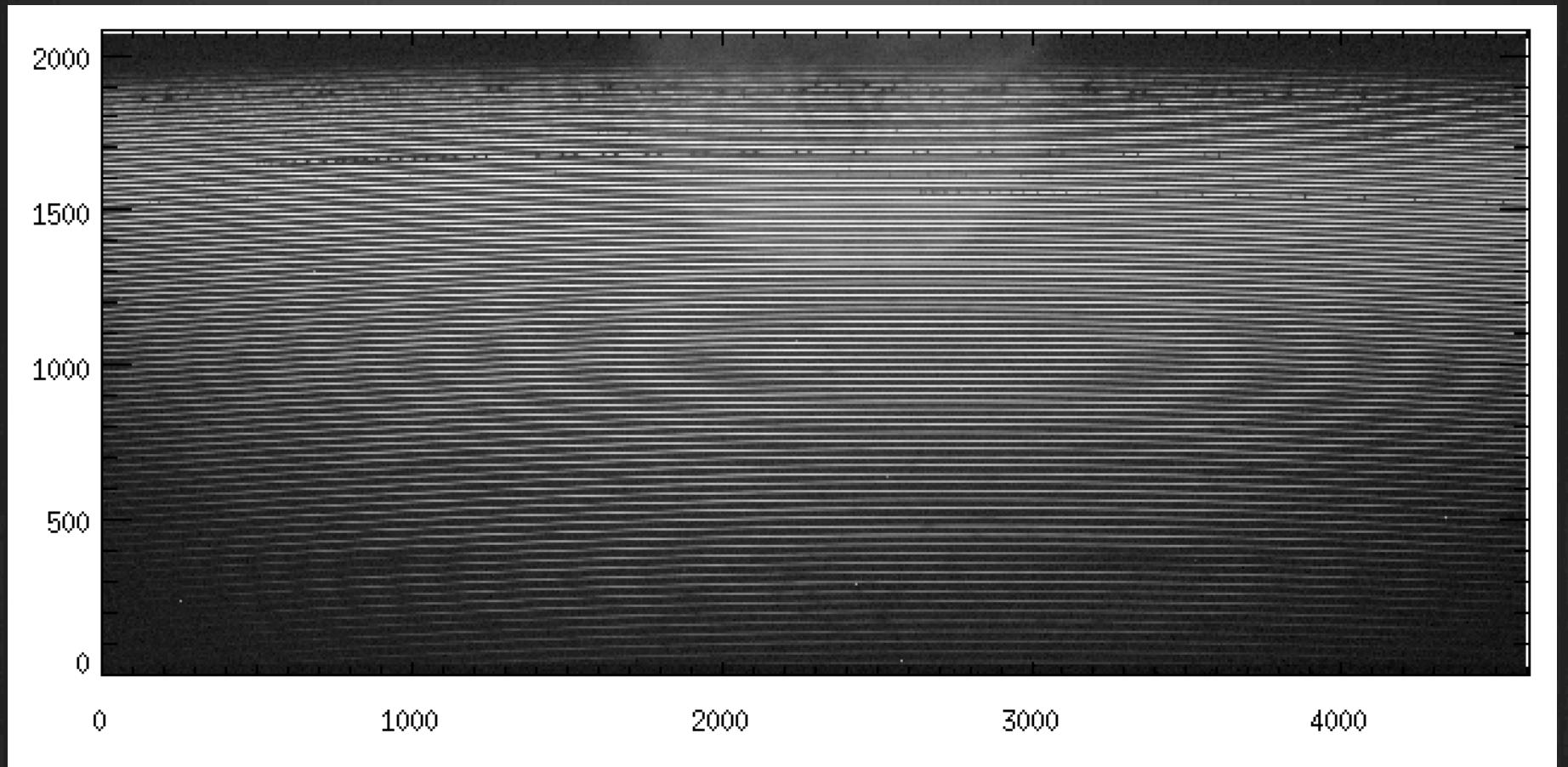
Instrument: Levy Spectrometer

- High Resolution Echelle
- $R_{\max} = 100,000$
- Wavelength Range: 370nm-900nm
- Visual magnitude limit: 13
- BL has 20% of total time
- Shared risk collaboration with UCB/UH planet hunting team
- Typical exposure time for BL:
5-20 minutes.
- ~200 nearby stars observed so far.
- Raw file size: 19MB: 2080x4808pix



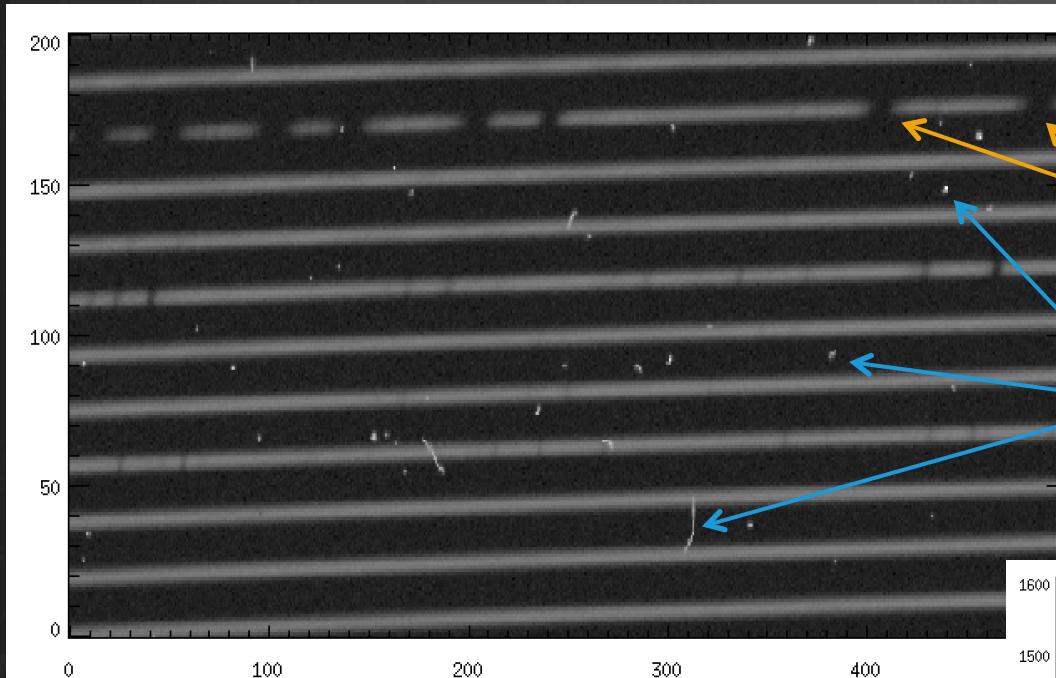
Data Format: raw image

2080 x 4808pix, 79 Echelle orders



Data Format: raw image

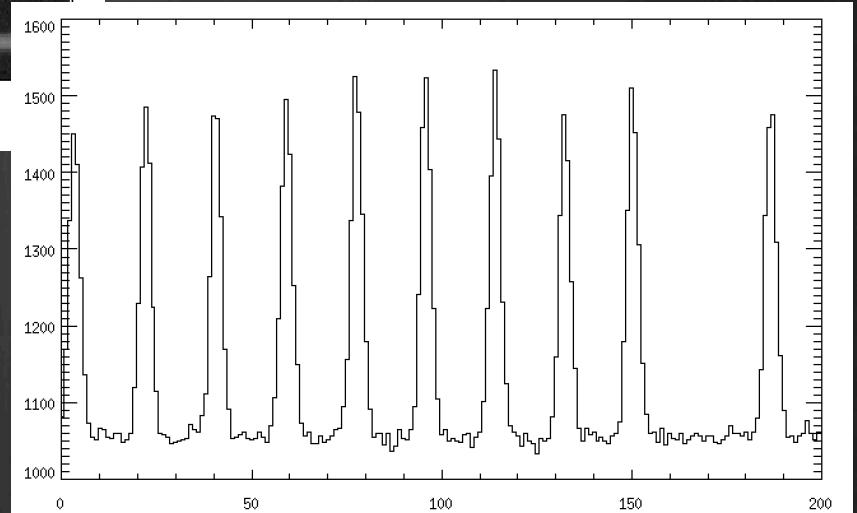
2080 x 4808pix, 79 Echelle orders



500 x 200 pix sub plot
-Note the absorption features

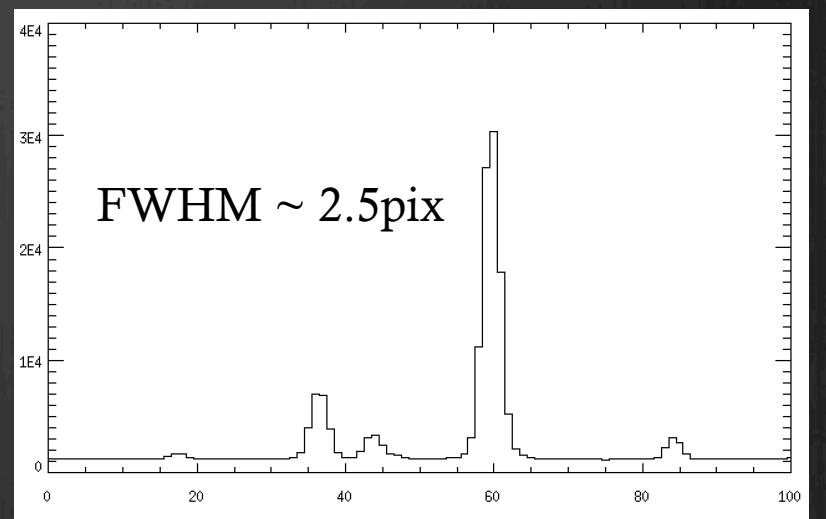
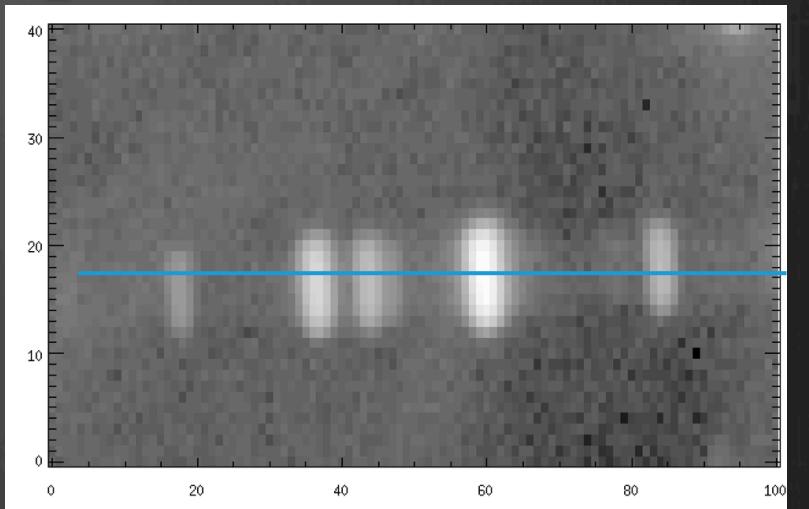
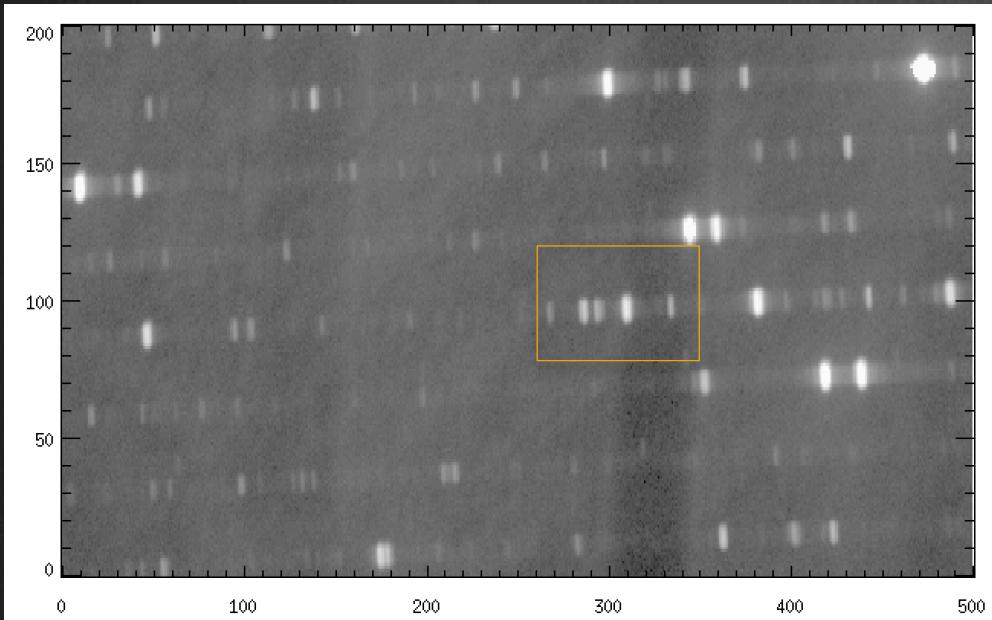
Note the cosmic rays.

Column cut showing vertical profile



Data Format: Thorium-Argon lamp calibration

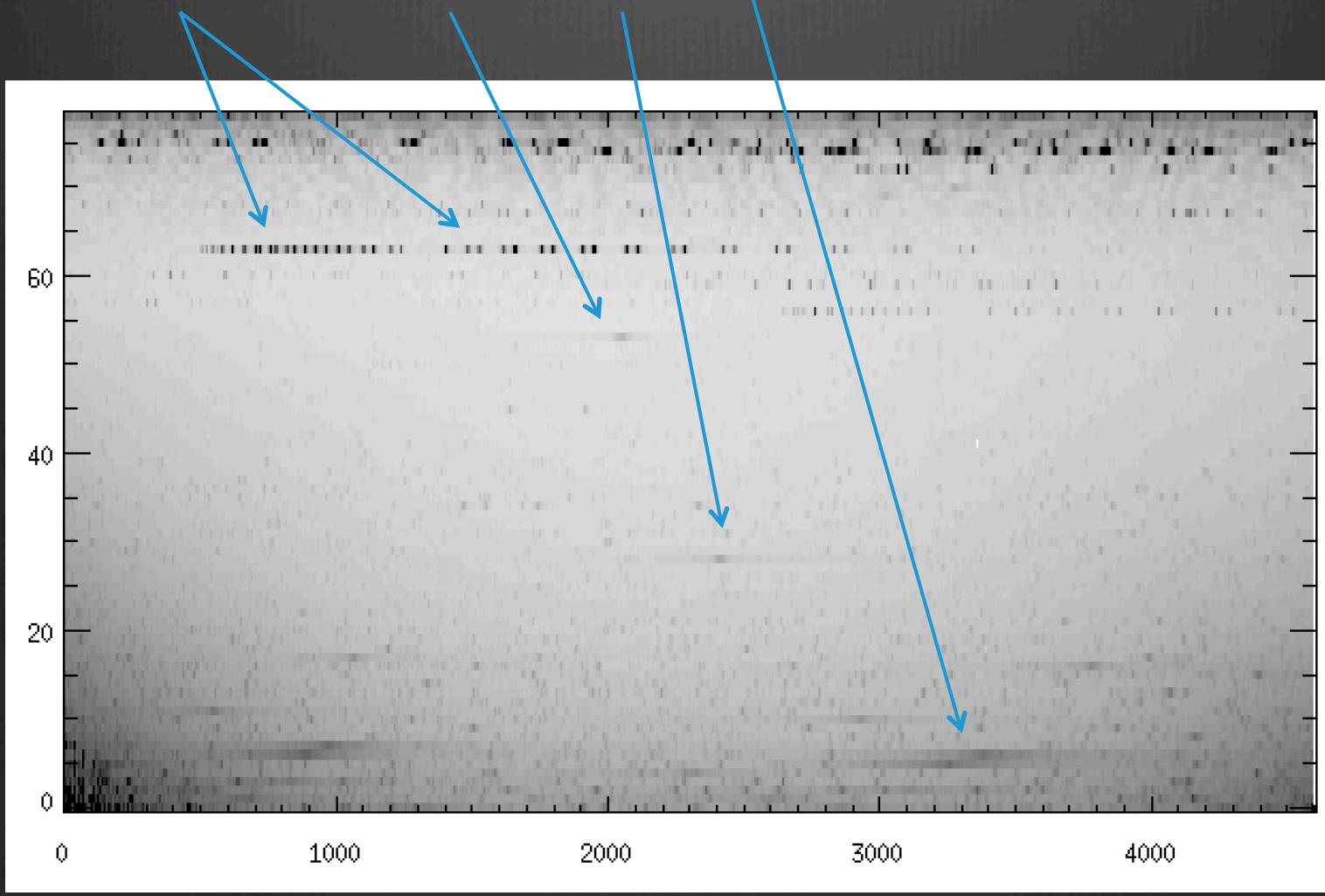
Emission line lamps help
determine the intrinsic point
spread function of the instrument



Data Format: Reduced Image

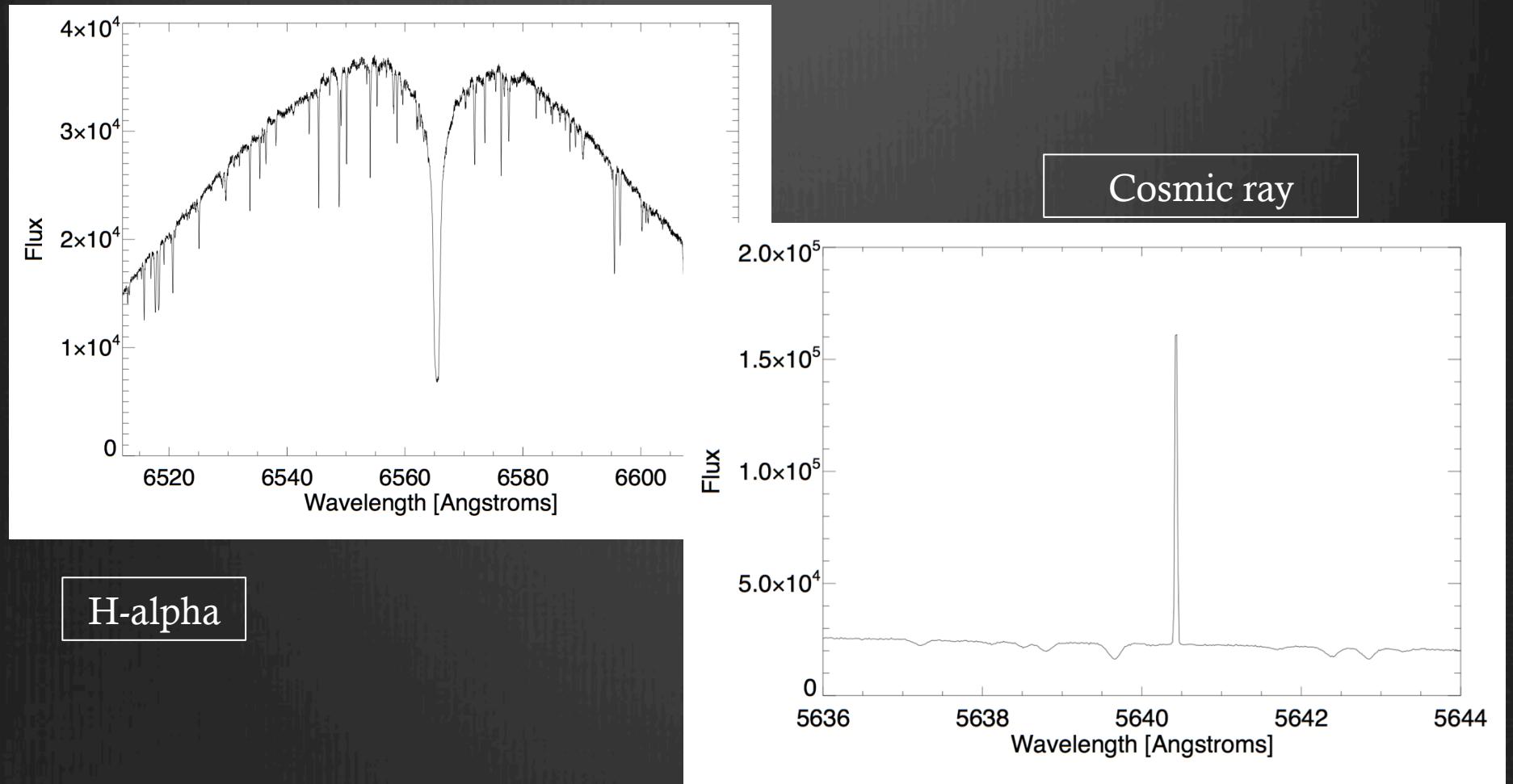
79 orders x 4808 pix

Telluric features, H-alpha, H-beta, Ca H&K are visible to the trained eye.



Data Format: Reduced Image

79 orders x 4808 pix



Previous Searches for Laser Lines in Keck/HIRES spectra

- ⦿ Tellis & Marcy(2015) searched ~2800 high resolution spectra for laser lines that fit the shape of the instrumental PSF.
- ⦿ The PSF was modeled as a Gaussian in the dispersion and cross dispersion direction. A χ^2 metric was used to determine goodness of fit.
- ⦿ Injection and recovery was used to test method robustness.
- ⦿ Consideration must be taken for cosmic rays, night sky emission lines and scattered light features, which can mimic laser lines.

Previous Searches for Laser Lines in Keck/HIRES spectra

- ⦿ Only ‘sky’ pixels between spectral orders were searched. Extra solar laser lines from nearby the target star would be superimposed on the stellar spectrum, over a narrow wavelength range.
- ⦿ Signals with $\text{SNR} \geq 10$ were analyzed by eye.
- ⦿ Claimed sensitivity: 150 photons/signal ($0.4 \text{ m}^{-2} \text{ sec}^{-1}$)
 - ⦿ 1.0kW laser could be detected out to distances of 1000 light years.
- ⦿ Follow-up paper will examine laser lines that are coincident with the stellar profile. In this scenario, only a 1D fit is needed but a higher SNR is also required.