The Design and Construction of Henrietta, a high-precision low resolution near-infrared spectrograph to explore exoatmospheres

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Photo Credit: Ashwin Choudhary

Talk Outline

- **Surveying the instrument landscape**
- **Introduction to Henrietta**
- **Roadblocks to achieving high-precision spectrophotometry**
- **Results and Outcomes**

HUBBLE 25

James Webb Space Telescope

JWST

NASA • ESA • CSA

ARIEL

Pandora

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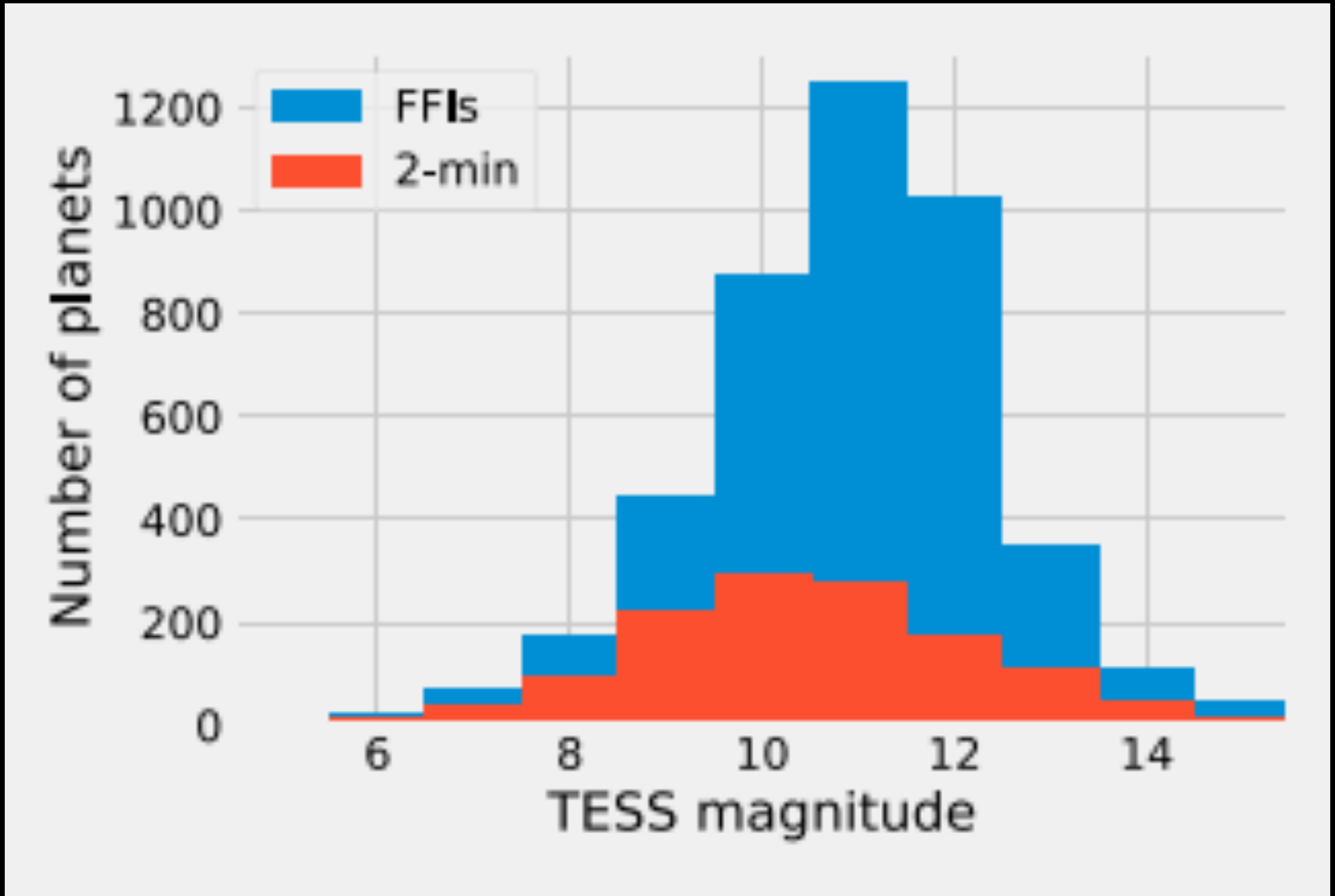
Introducing Henrietta

- A near-infrared (NIR) spectrograph to be deployed at the 1-m Swope Telescope at Las Campanas Observatory
- To survey the molecular content of exoplanet atmospheres using transmission/emission spectroscopy at near photon-limited precision.
- First light in August of 2022

Why a 1-meter telescope?



Barclay et. al 2018

Henrietta Swope

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Instrument Co-Lead/Lead PI

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Instrument Lead/Co-PI

Tyson Hare
Senior Engineer @ Carnegie Obs.
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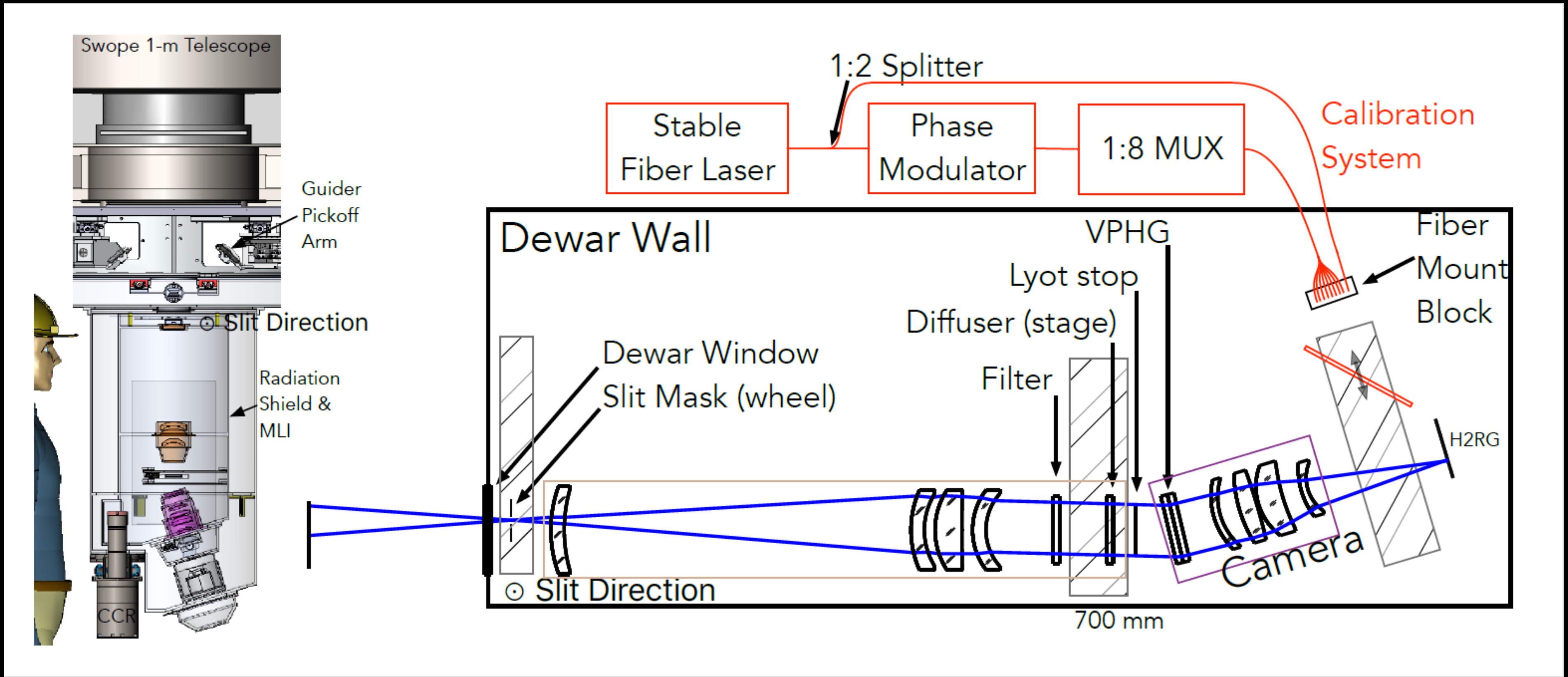
Staff Scientist @ Carnegie EPL
Co-PI

Instrument Layout and Specs

- Field of view: 25’ x 3’ , long-slit and multi-object
- Wavelength range: .6 – 1.2um or 1.2 – 2.4um via interchangeable grism
- Resolution: ~ 200 at center of both spectrums



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SLIT LOSS

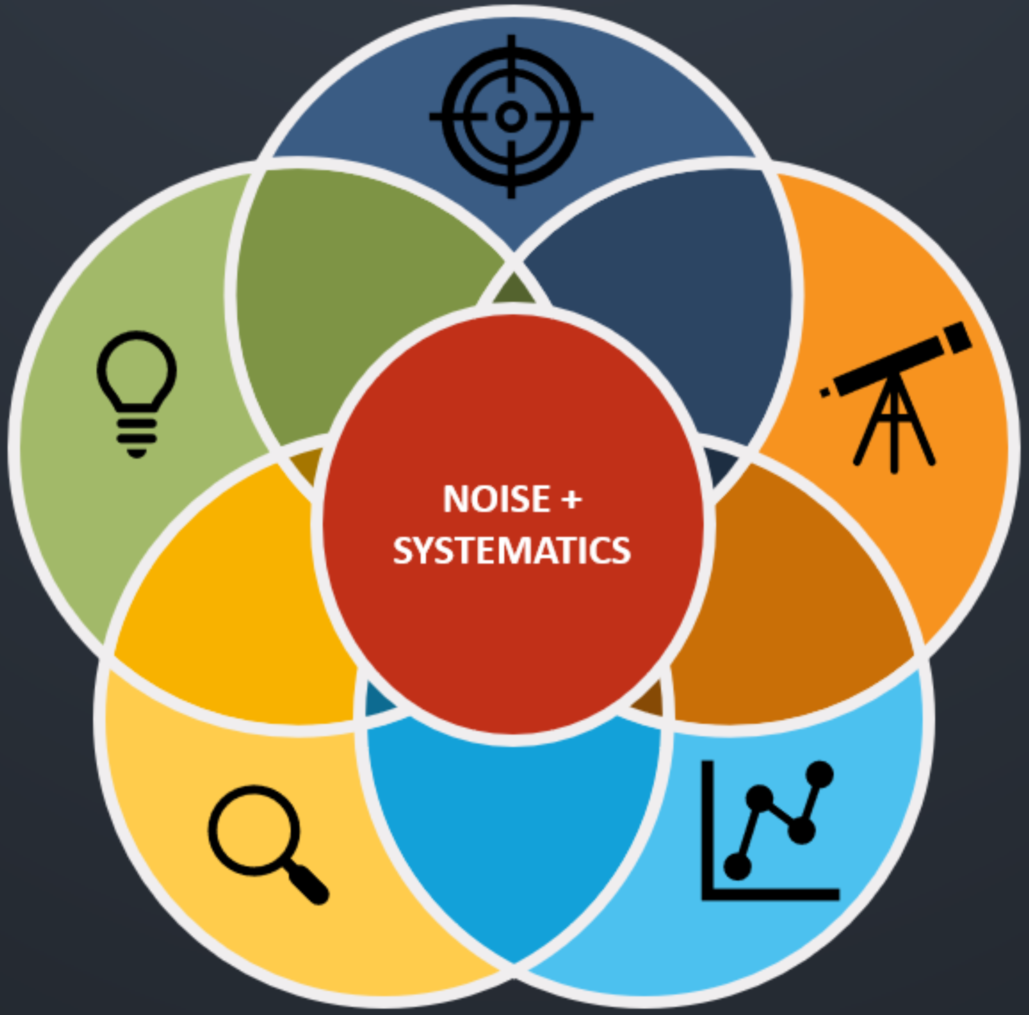
Atmospheric seeing and atmospheric refraction causes the amount of light across the slit to vary throughout the night, which appears as noise.

NIR SKY EMISSION

Spatio-temporal variations in the near-infrared sky emission couple to scattered light within the instrument, appearing as noise.

DIFFERENTIAL EXTINCTION

To second-order, atmospheric absorption depends on the color index. Therefore, wavelength dependent systematics can occur if target star and comparison star have different spectral types.



SCINTILLATION

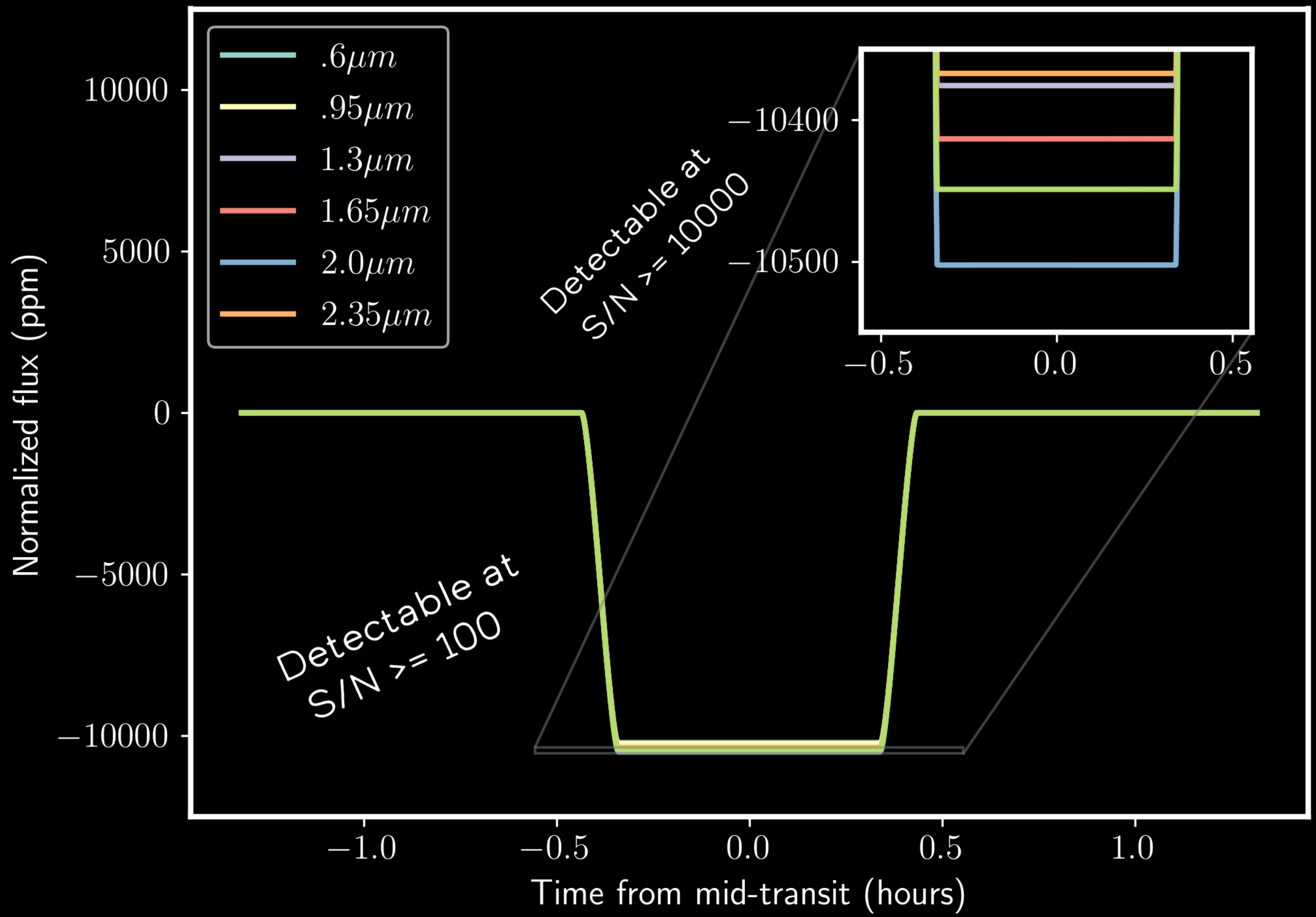
Scintillation occurs because turbulence in our atmosphere deflects light in to and out of our telescope randomly.

INTRA-PIXEL QE VARIATION

HAWAII-2RG (H2RG) infrared detectors have quantum efficiency variations down to 1/32nd of a pixel. This can't be removed by a flat-field and when it couples to telescope jitter it causes a time-dependent noise.

Template Credit: PresentationGo

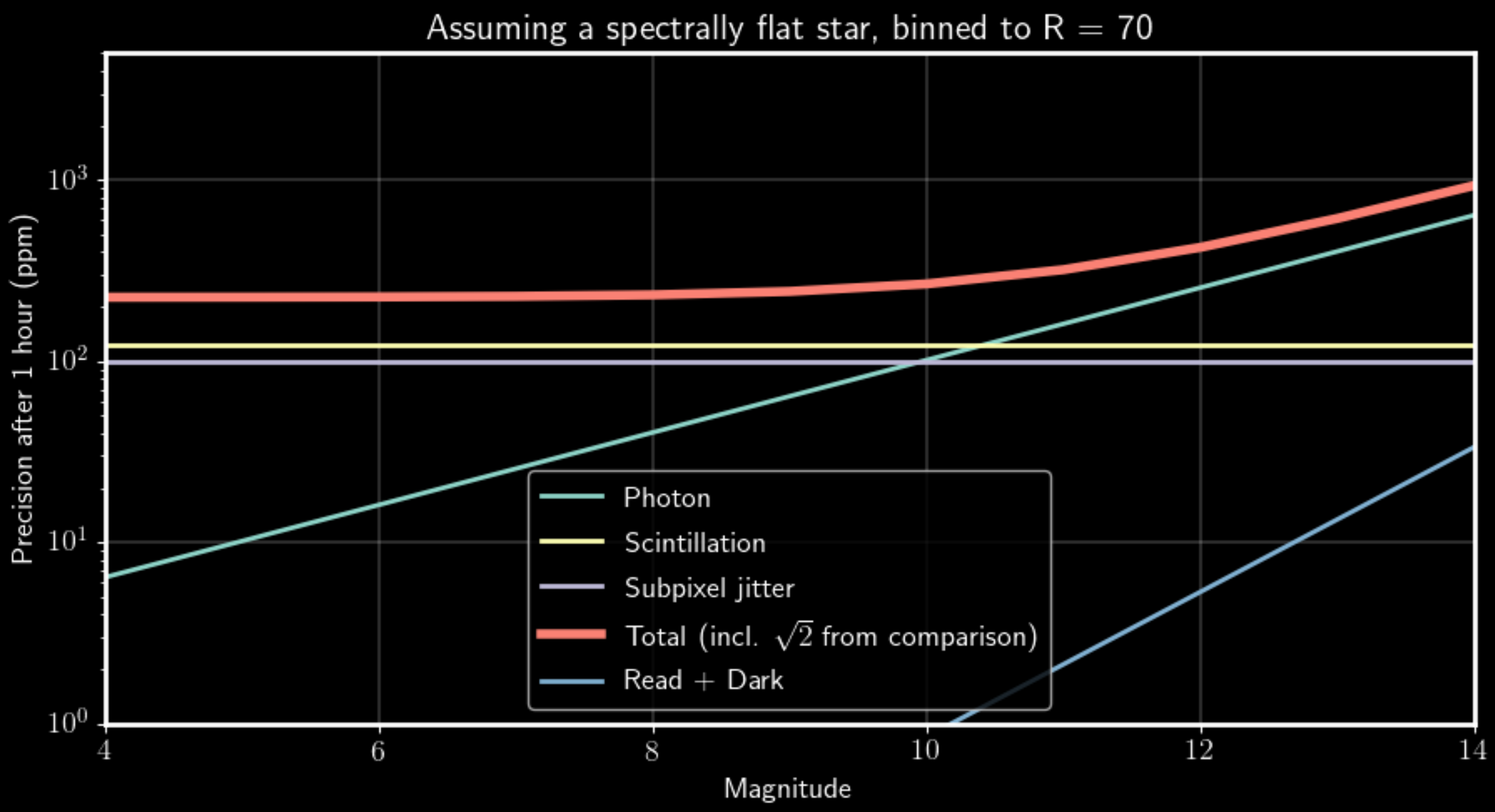
Exoatmosphere observations require high S/N



Strategies to increase SNR

- **Remove Noise**
- **Add more photons:**
  - Time binning
  - Spectral binning
  - Combining transits
- **Remove systematics**

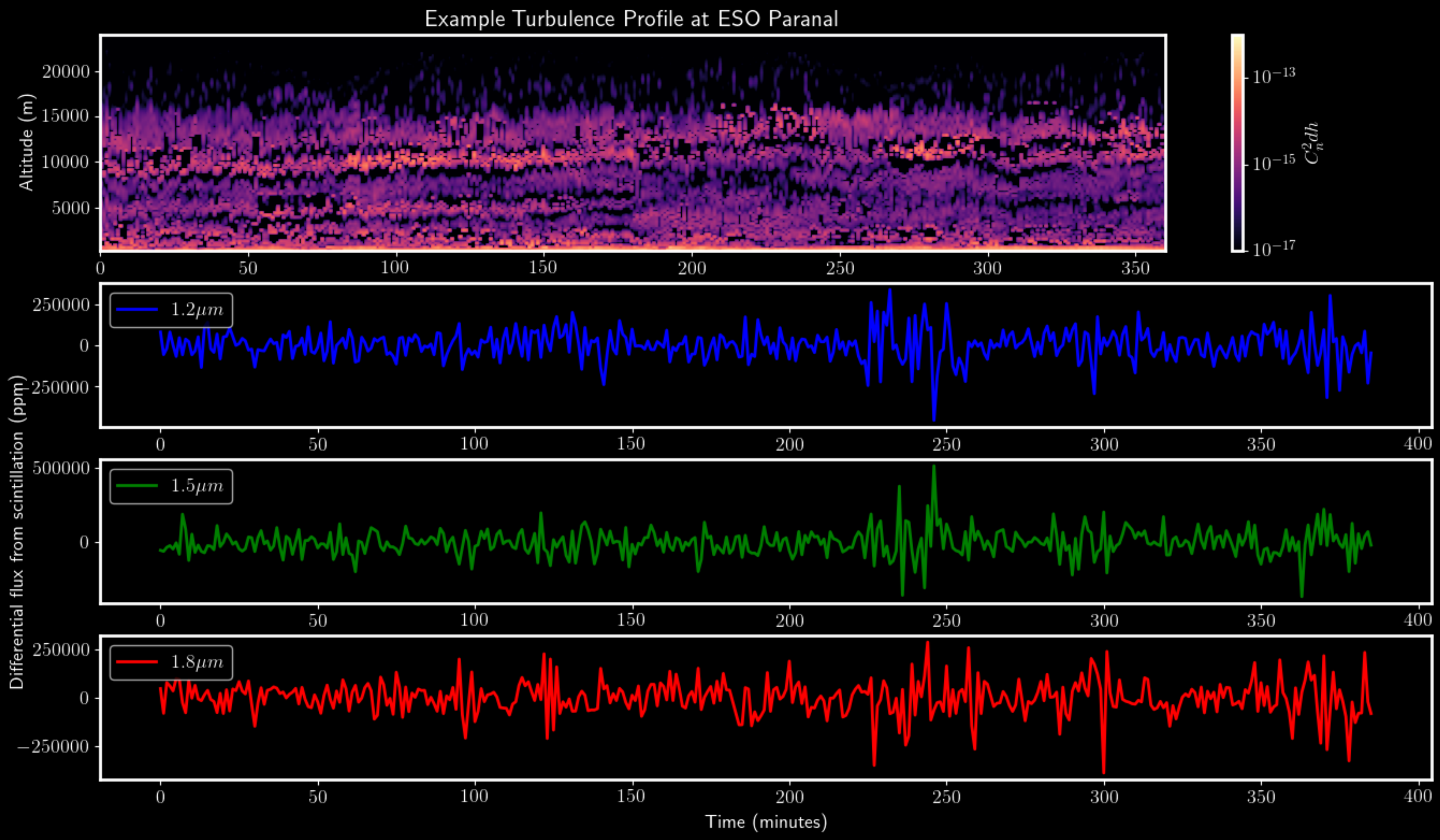
Noise budget



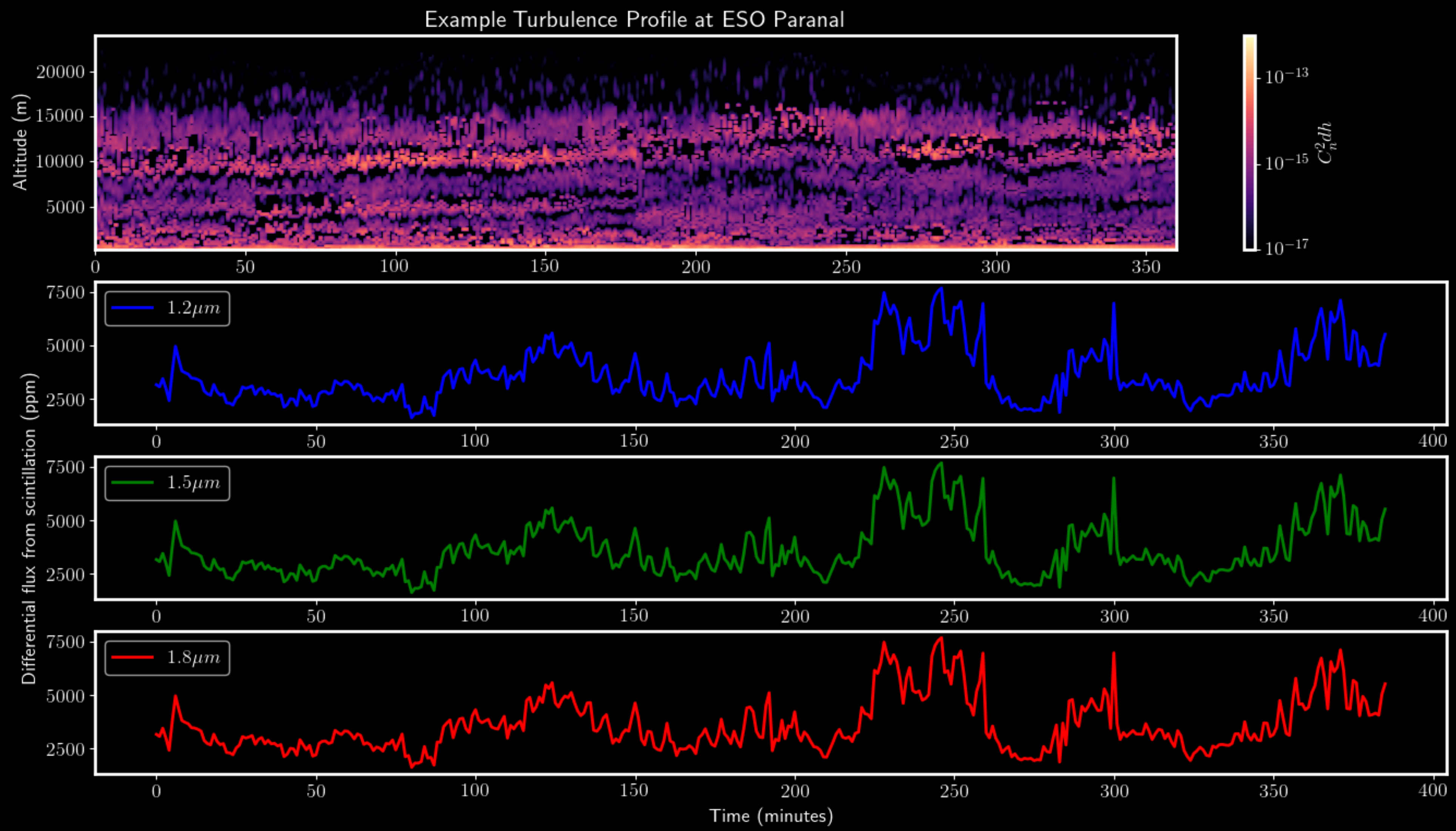
Scintillation is responsible for the 'twinkling' effect we see every night.

Vid credit:
Youtube.com/FlattermanIsland

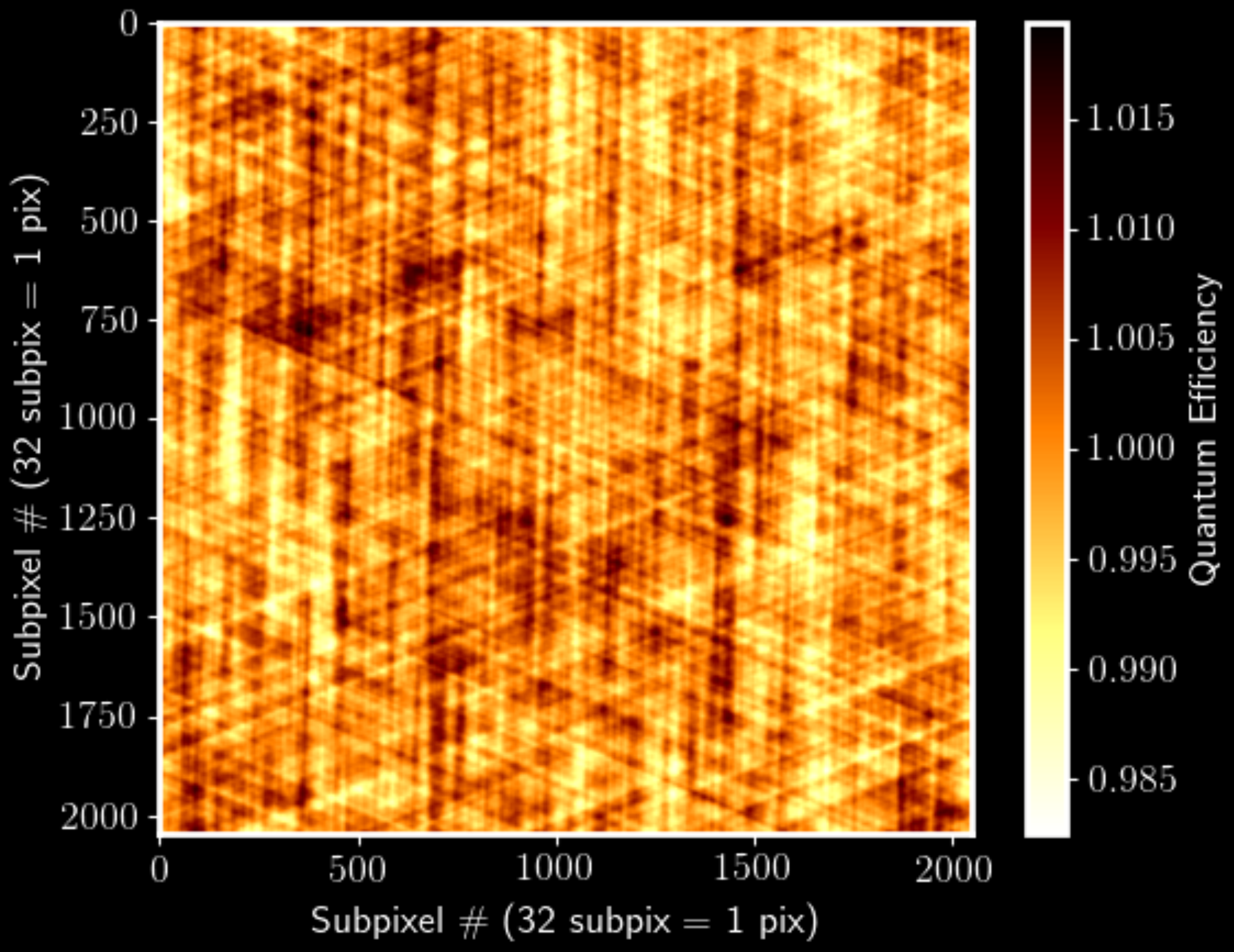
For small apertures, scintillation is wavelength dependent!



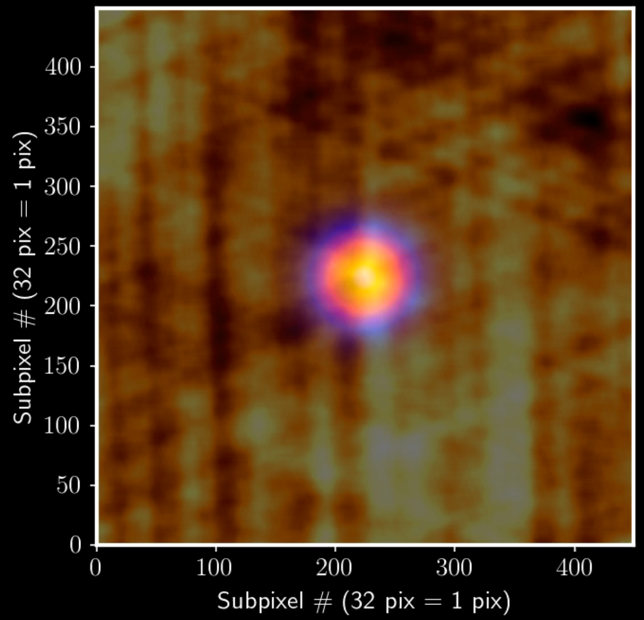
On large telescopes, scintillation noise decreases and becomes achromatic

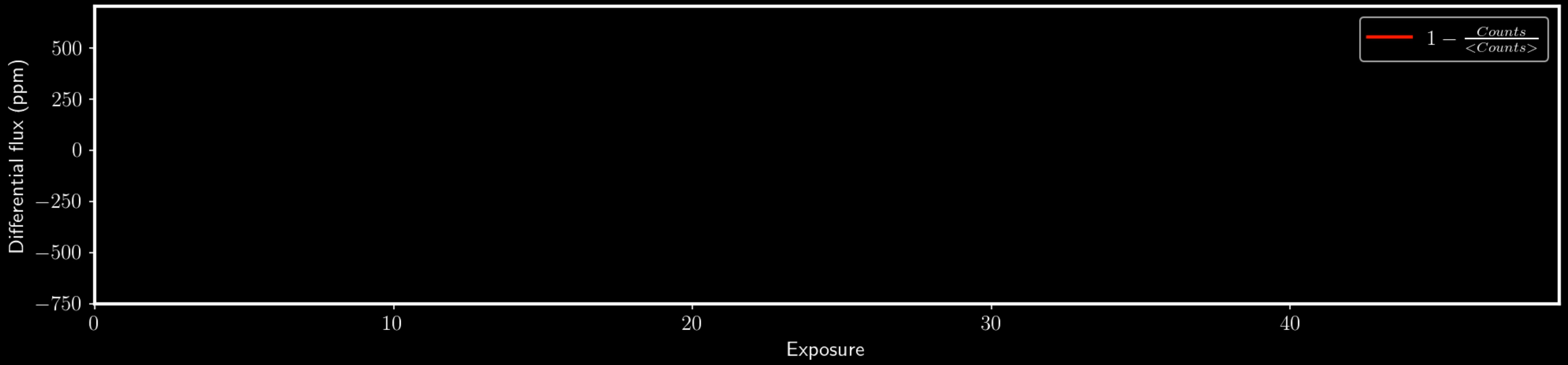


HAWAII-2RG detectors have intra (sub) pixel sensitivity that can’t be removed by flat-fielding

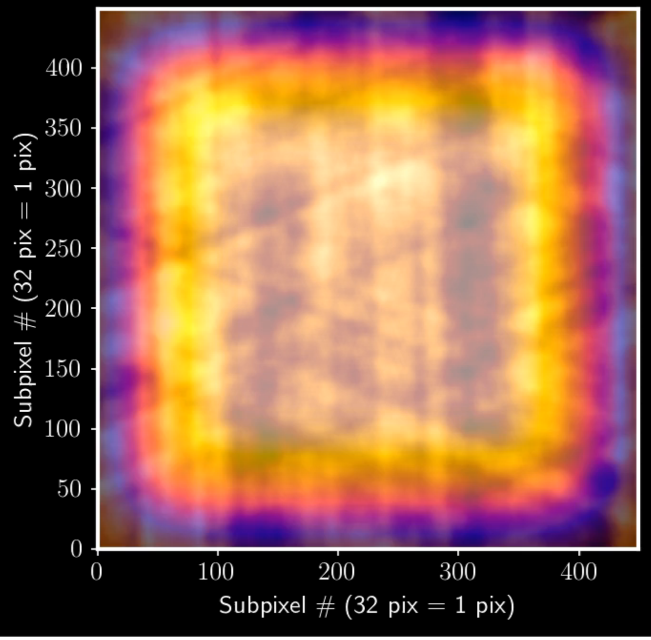


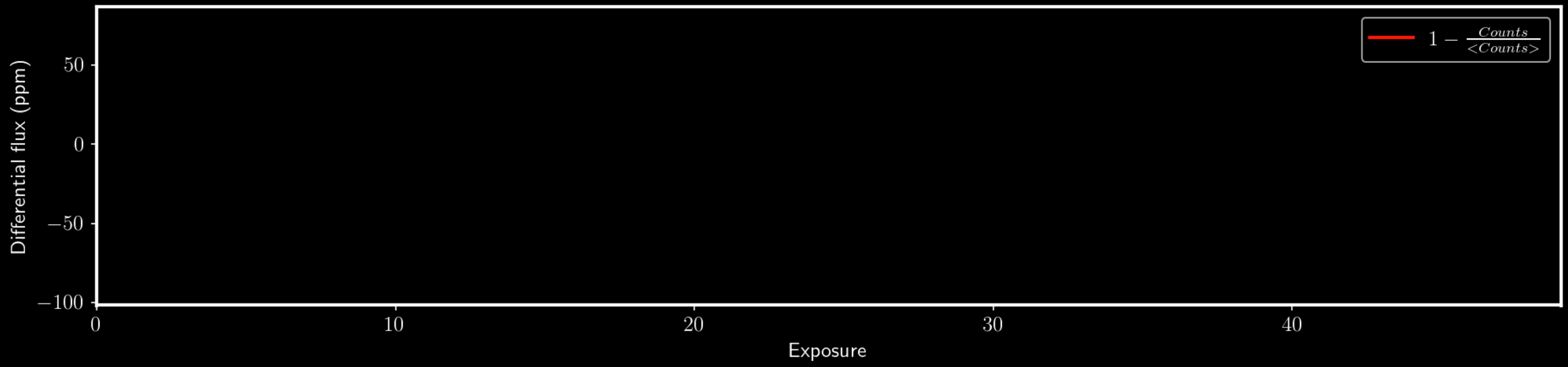
An in-focused PSF, when coupled with telescope pointing jitter, creates time-varying noise.



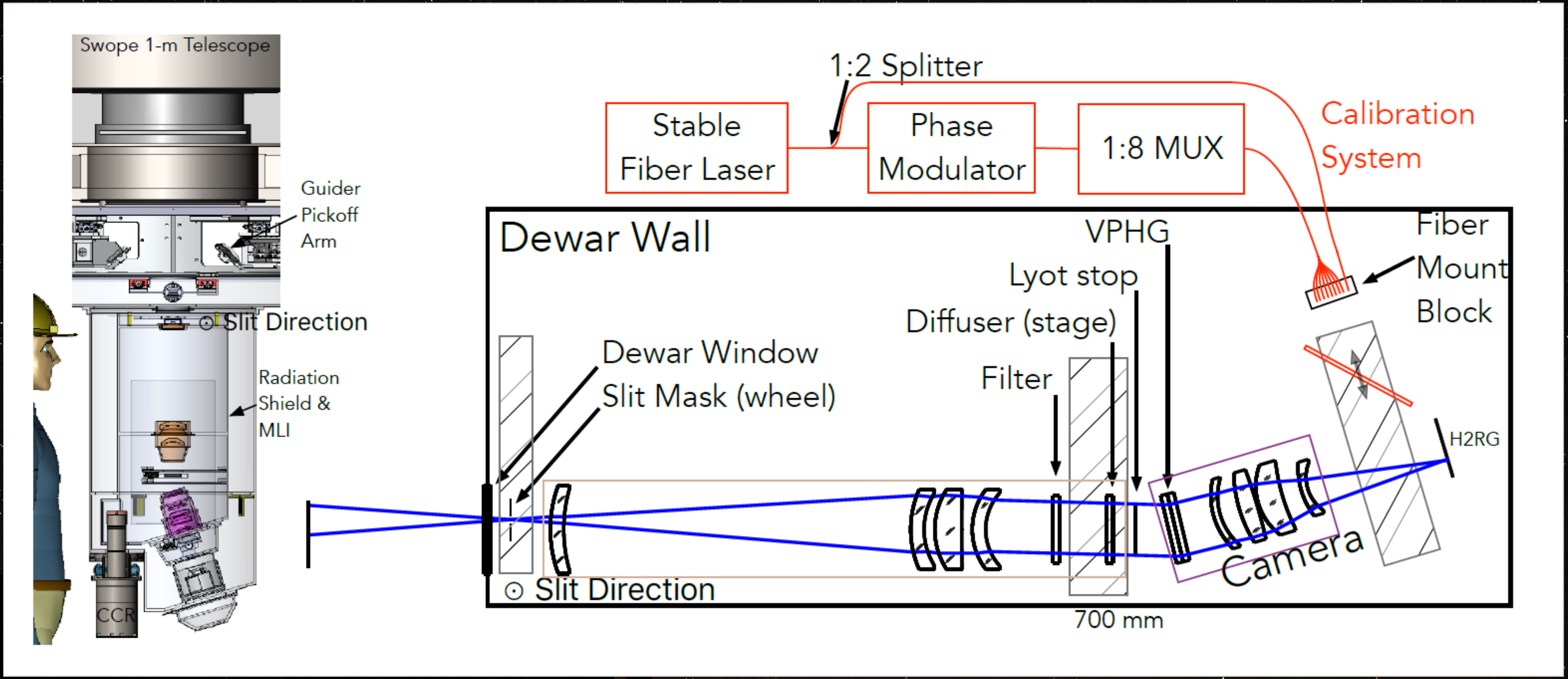


Solution 1: Diffuse the point spread function

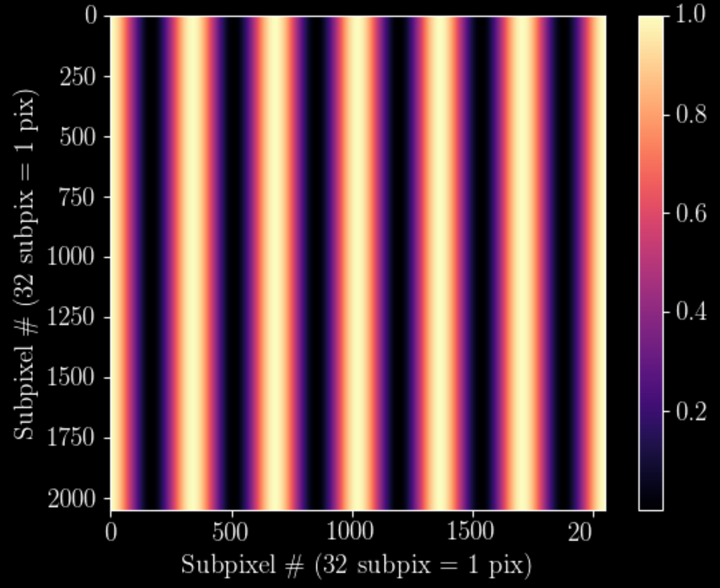




Solution 2: Characterize the detector

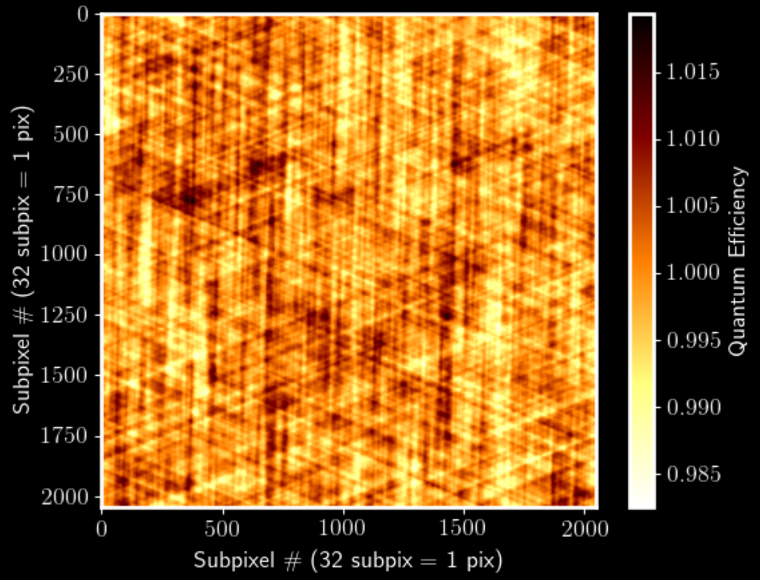


A

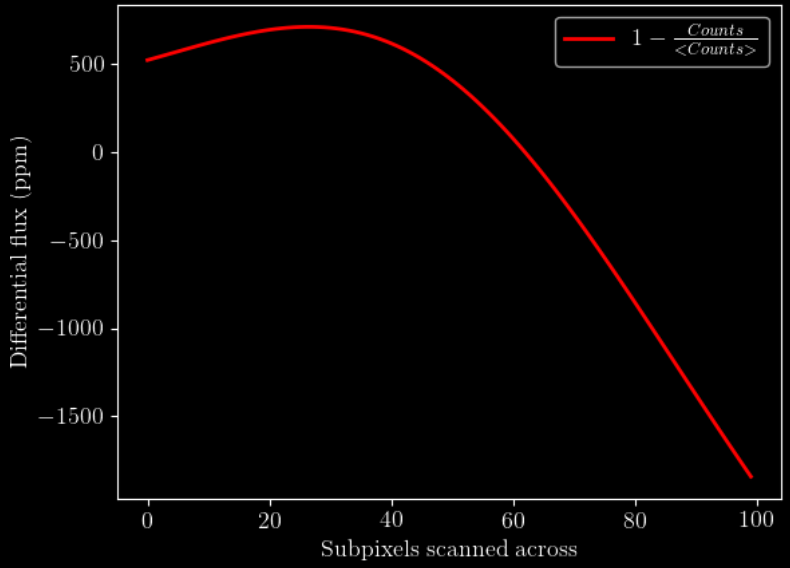


$*$

$\vec{x}$



$\vec{b}$



$$A^{-1}\vec{b} = \vec{x}$$

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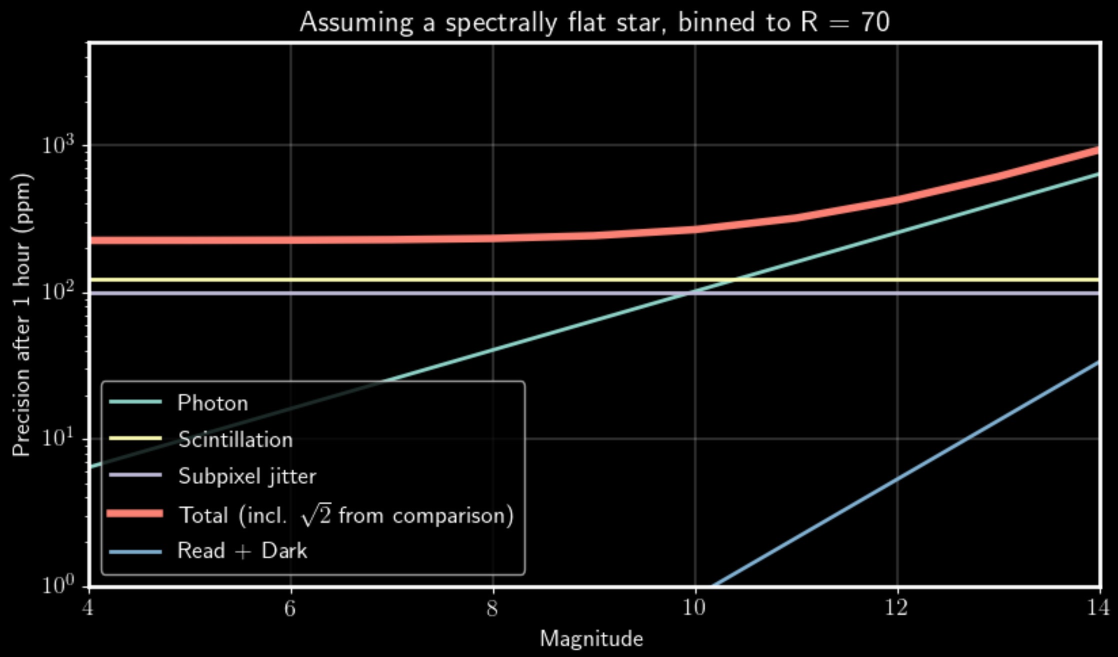
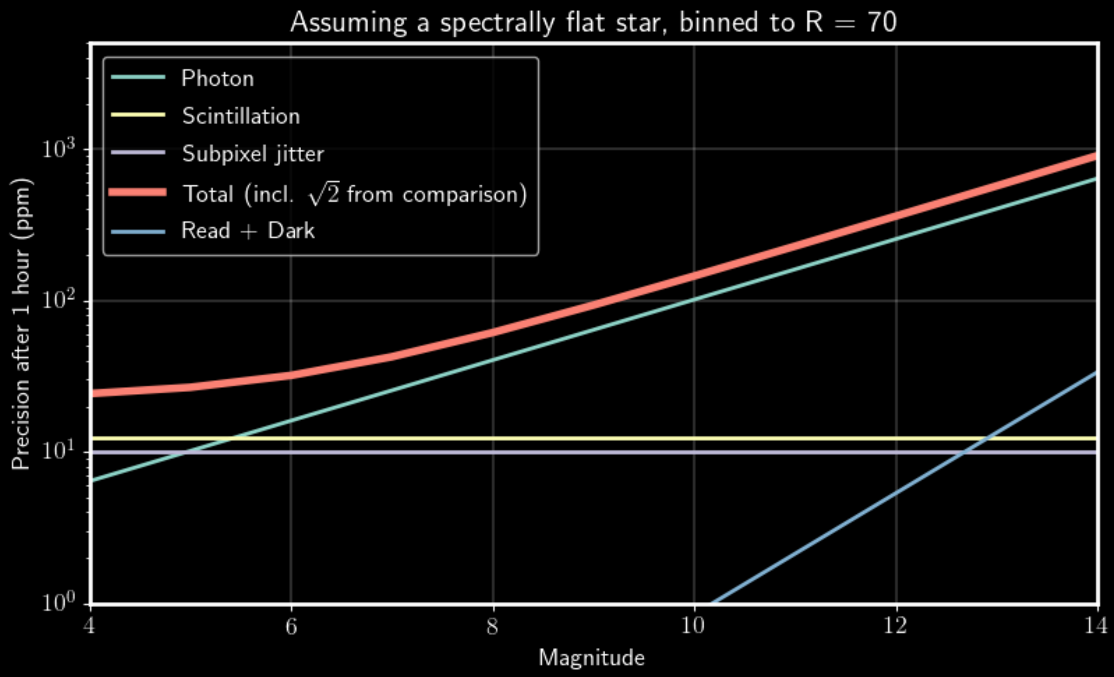
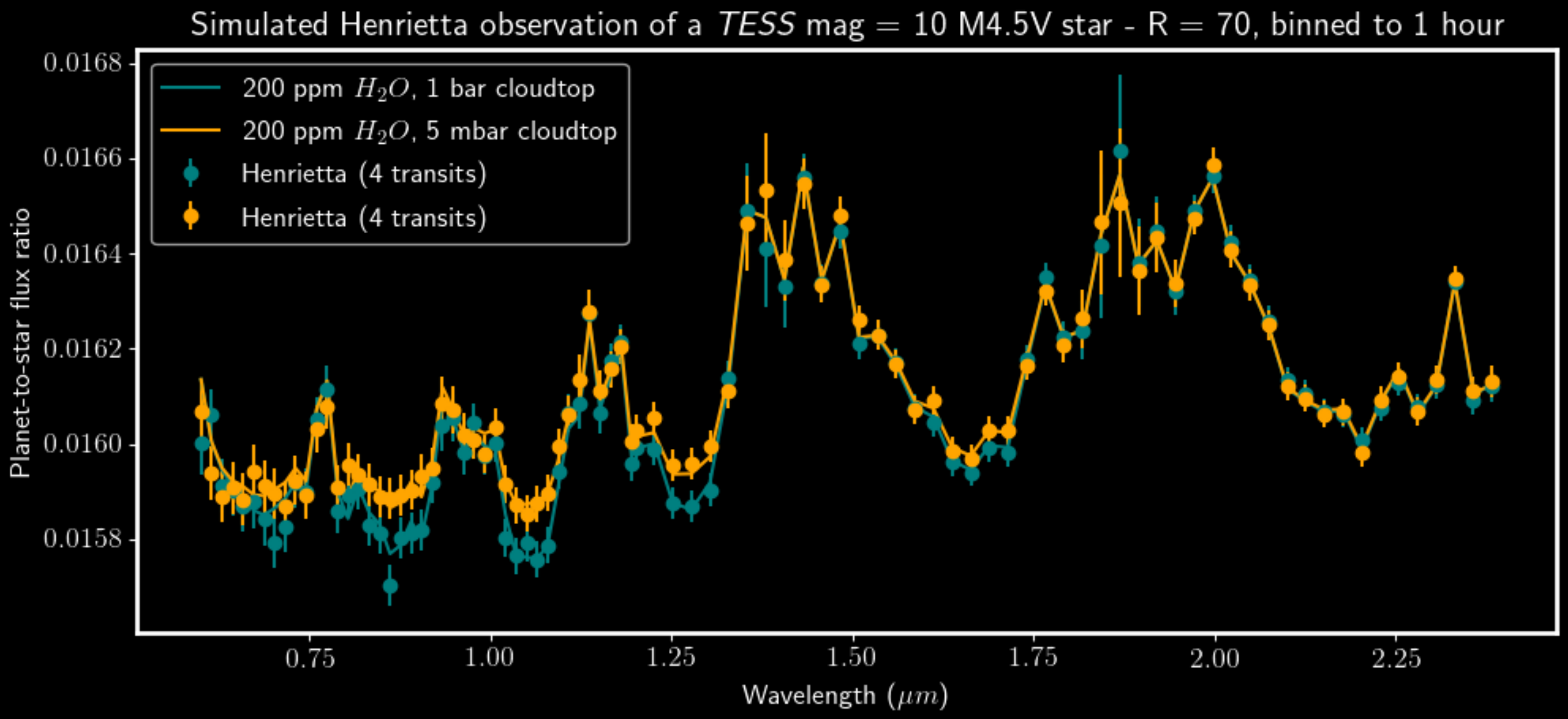
BEFORE

AFTER

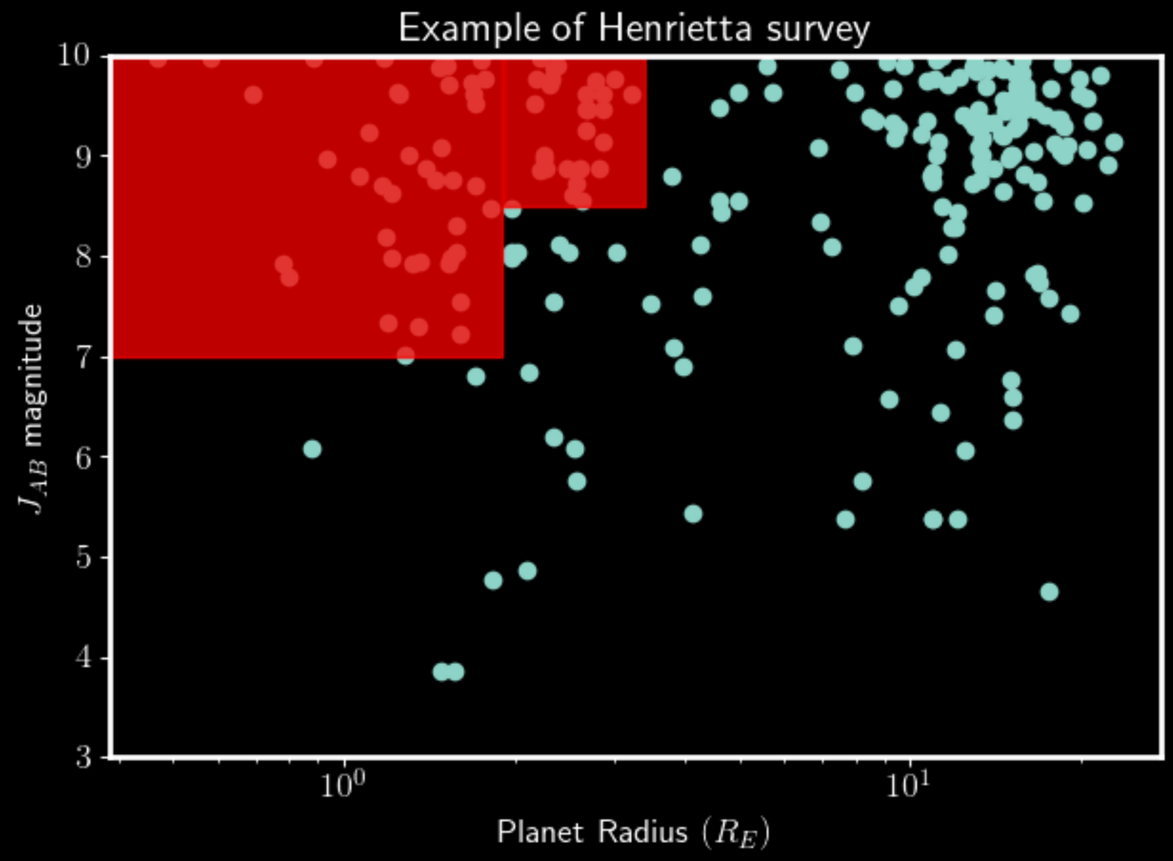




If we achieve our goal, Henrietta be a scientifically productive in its own right.

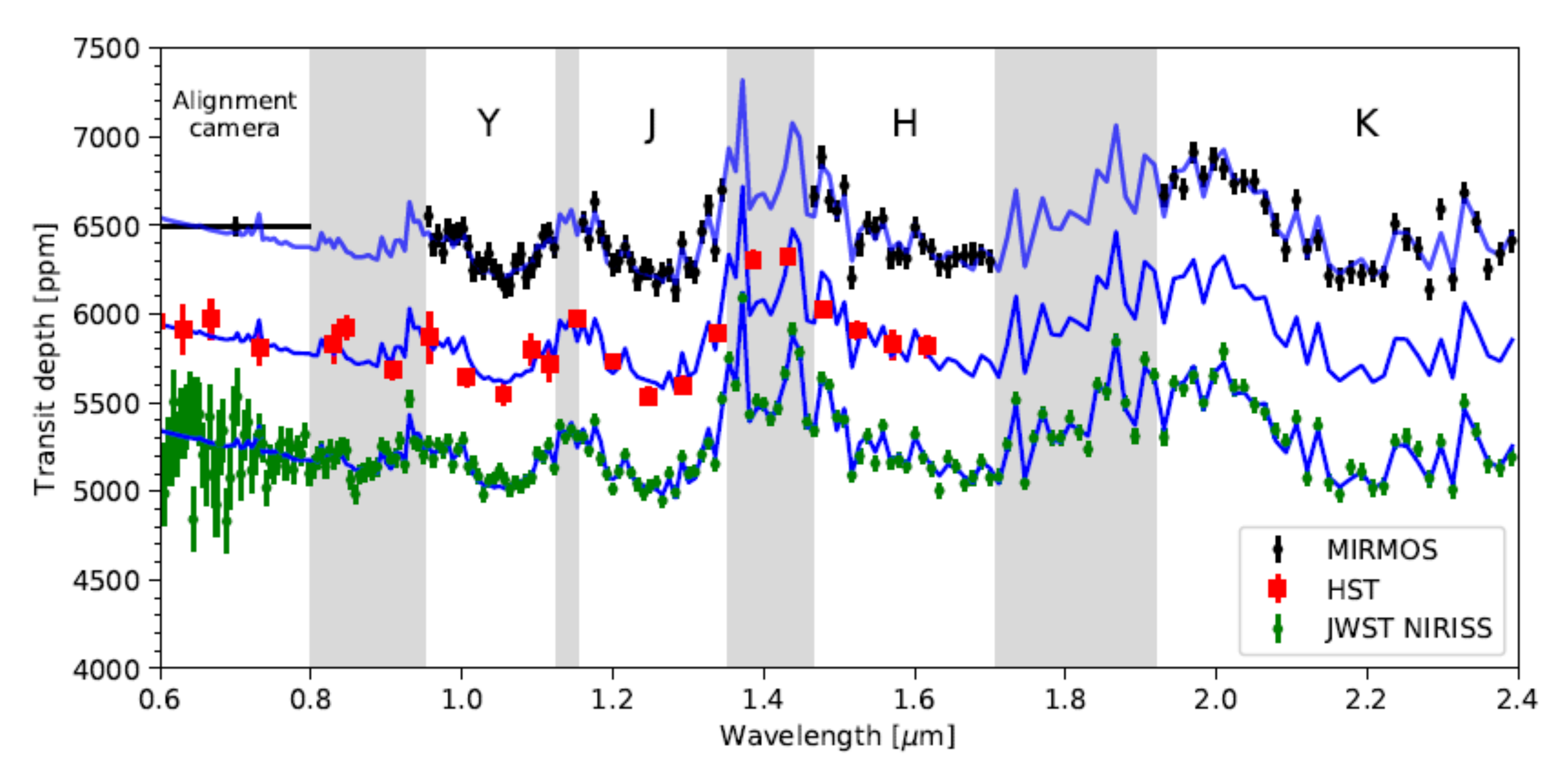


Henrietta can complete a survey of ~ 100 exoatmospheres in a year, with most 'unique' targets sent to JWST for detailed followup.



Data from Open Exoplanet Catalogue

Henrietta will ultimately serve as a testbed for future ground-based exoatmosphere instruments.



Progress

Order Parts (April 2021)

Lab Integration and Testing (September 2021)

Commissioning (August 2022)

Conclusion

- There are currently no dedicated exoatmosphere instruments to help prioritize targets for JWST.
- Henrietta is designed to have high spectrophotometric precision and will help prioritize targets for JWST.
- If we achieve our goal of near-photon noise limited precision, Henrietta will be scientifically productive on its own.
- Henrietta will ultimately serve as a testbed for future IR exoatmosphere instruments.