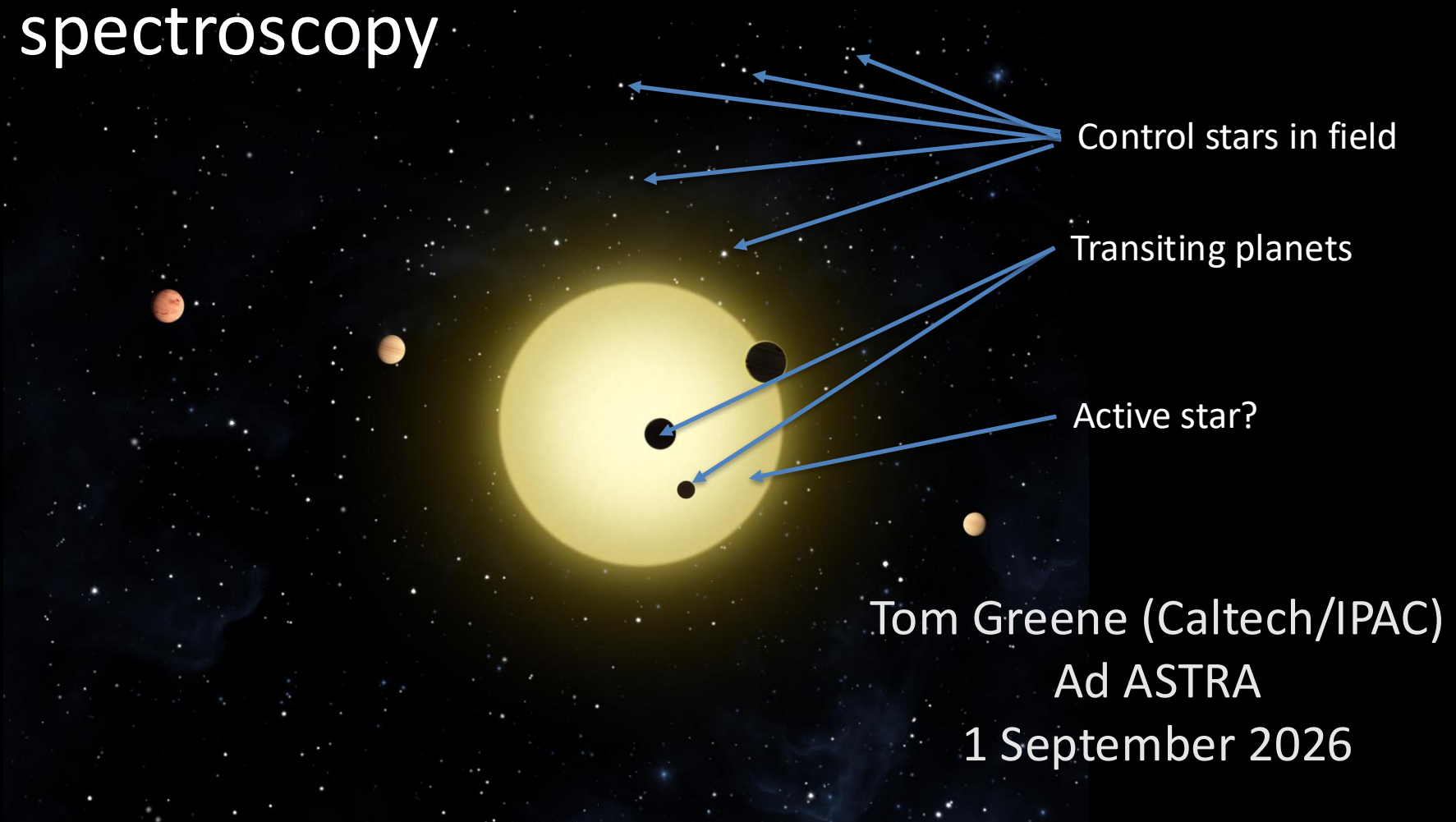
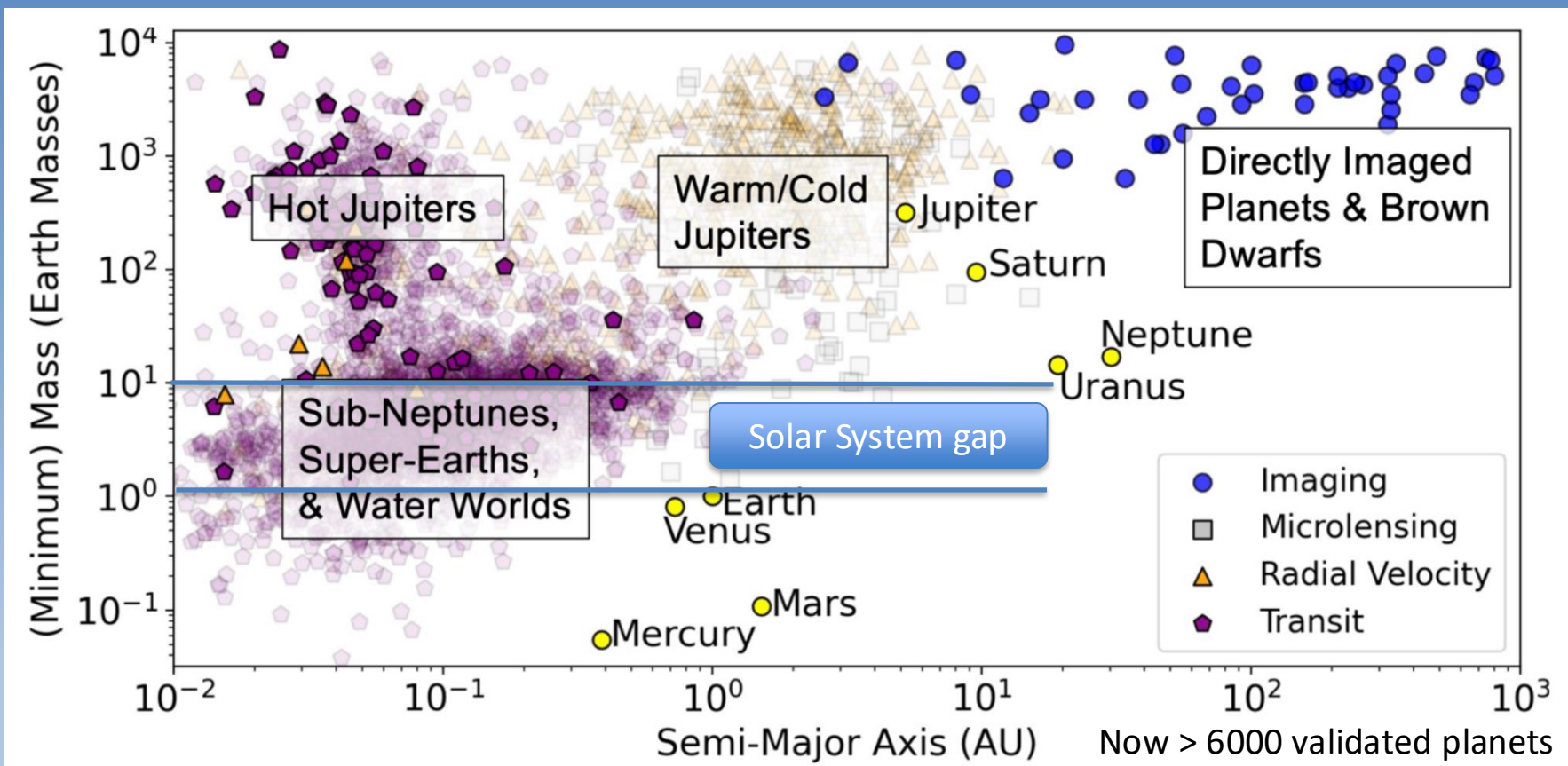


CHROMOS for transiting exoplanet spectroscopy



Current exoplanet census

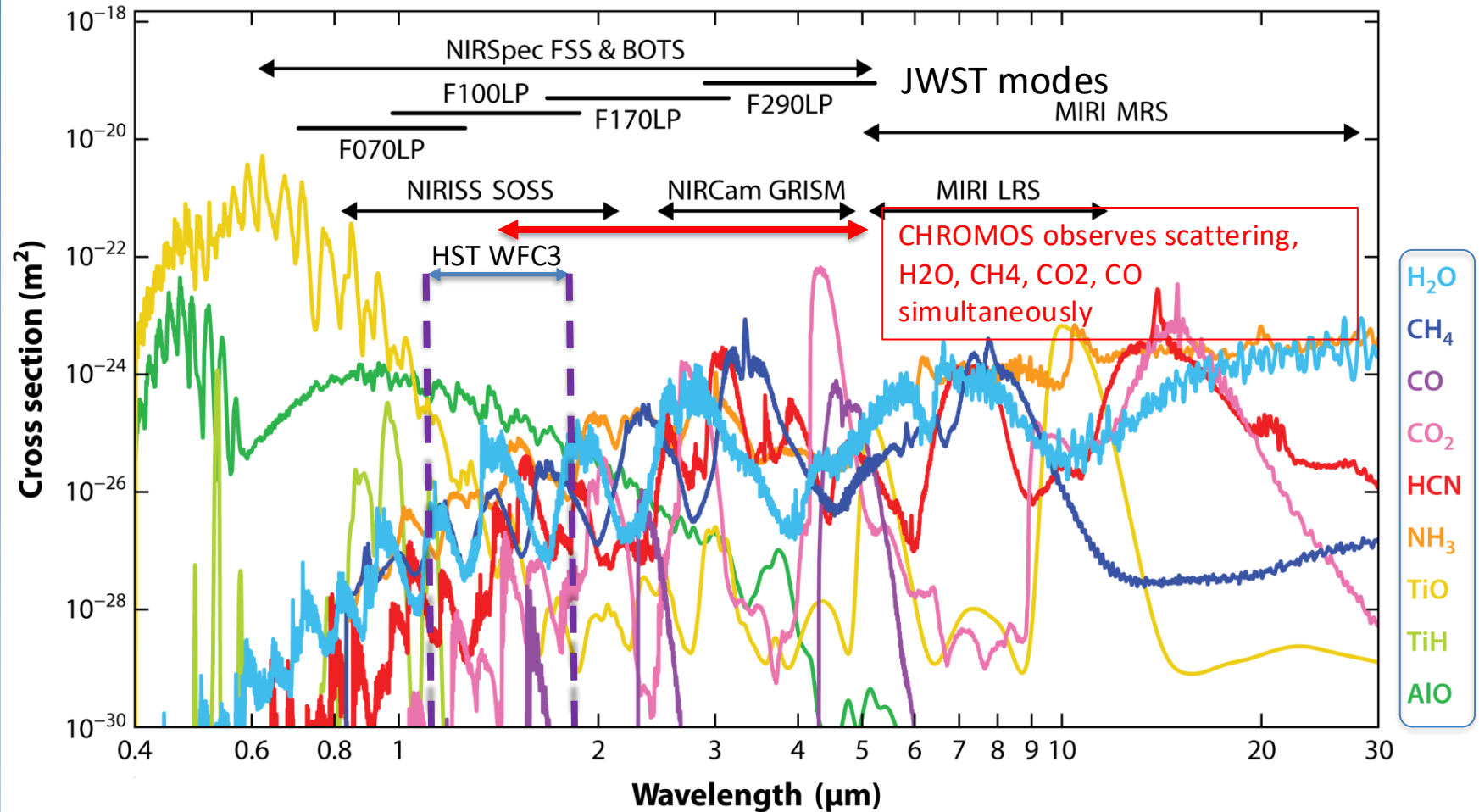


Kempton & Knutson (2024)

Exoplanet Atmosphere Characterization 2030+

- **Need to study large samples to relate compositions to formation processes**
 - JWST will have characterized atmospheres of ~500 planets
 - High quality spectra but are subject to systematic biases due to stellar heterogeneity
 - Expensive in time because multiple modes and transits are usually needed
- **Ariel will launch in 2031**
 - Dedicated exoplanet characterization machine but limited 1-m aperture
 - Will observe ~1000 transits at SNR and precision of ~1/6 JWST
 - Also subject to systematic errors produced by stellar heterogeneity
- **We will have a good sample (~1000 planets) by ~2035, but understanding their compositions will be limited by stellar heterogeneity and modest SNR**
- **We will still need to answer:**
 - *What are the compositions of sub-Saturn planets, and how did they form?*

JWST spectral coverage of molecular features

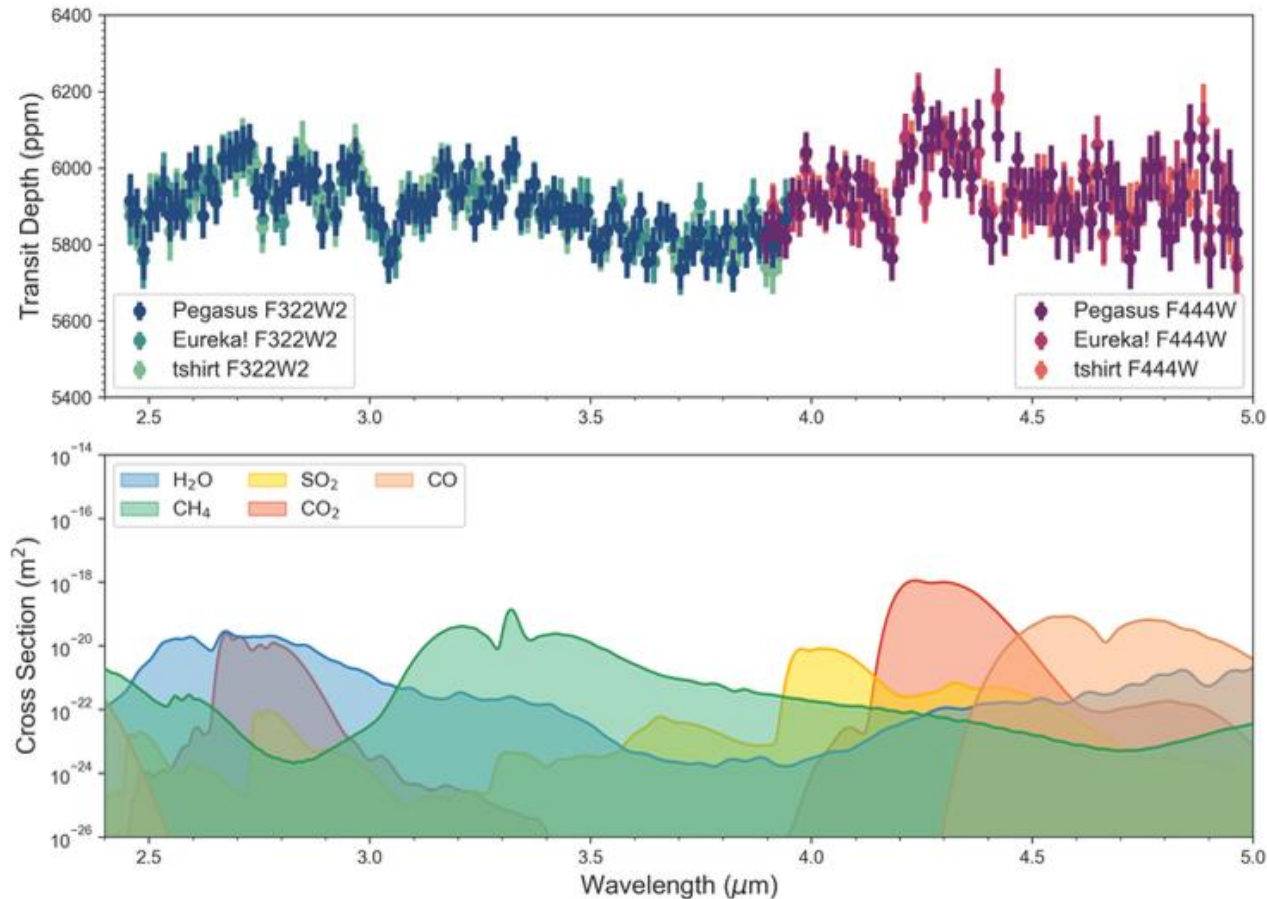


Composition of GJ 3470 b sub-Neptune

Most common planets in the galaxy but unlike any in our Solar System



Thomas
Beatty+ 2024
MANATEE GTO



Before JWST we only knew of H_2O – now we have carbon and sulfur molecules (5 total)

Composition of GJ 3470 b sub-Neptune

$M/H \sim 125$ Solar and $C/O \sim 0.35$ (subsolar); C/S & O/S cons. w/pebble accretion



Thomas Beatty+ 2024
MANATEE GTO

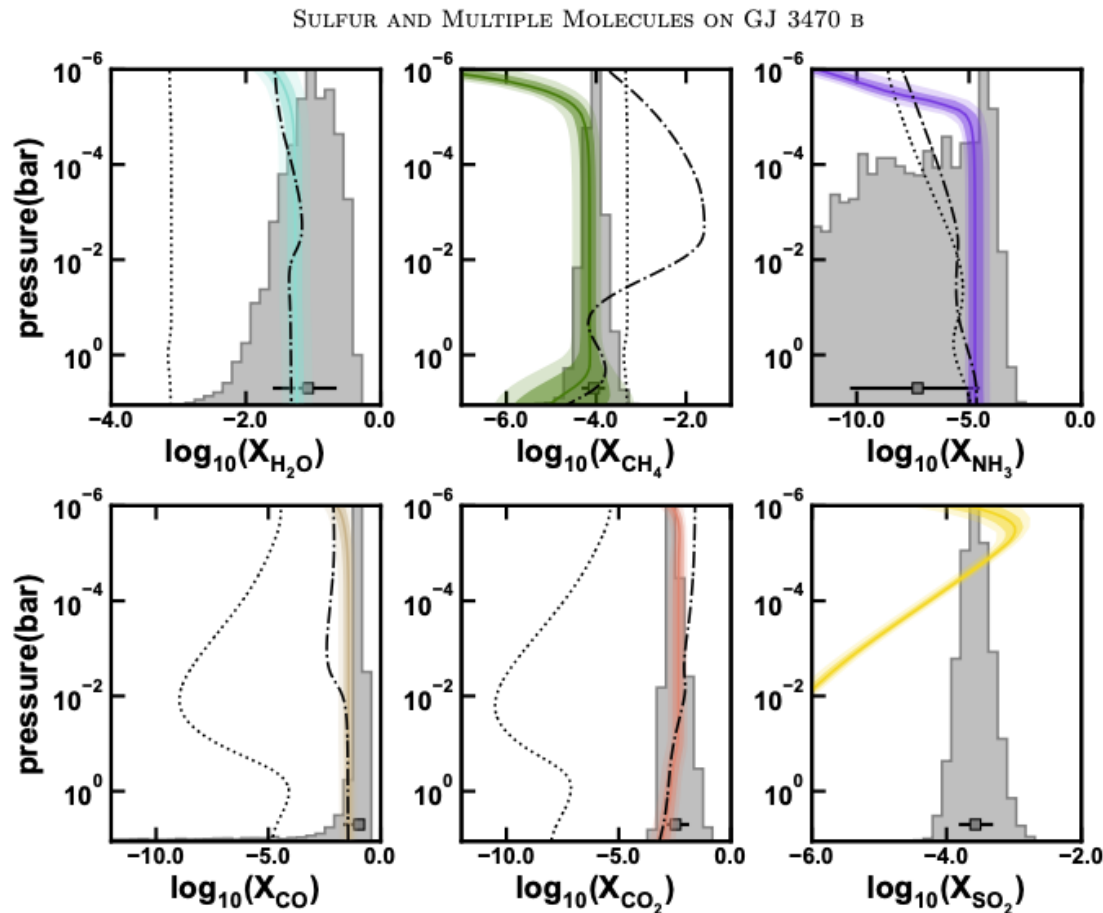
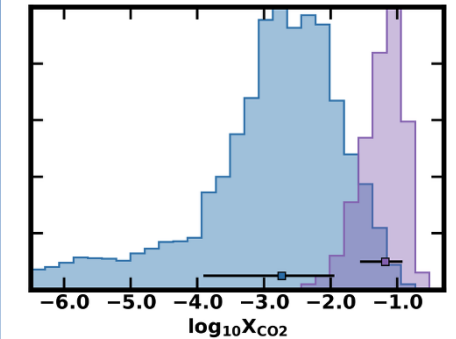
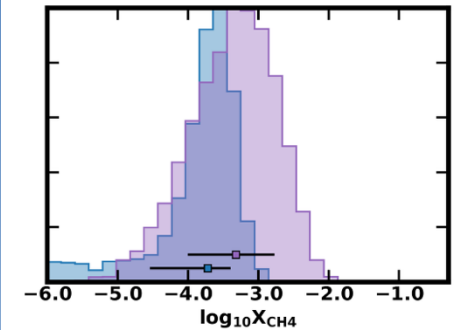
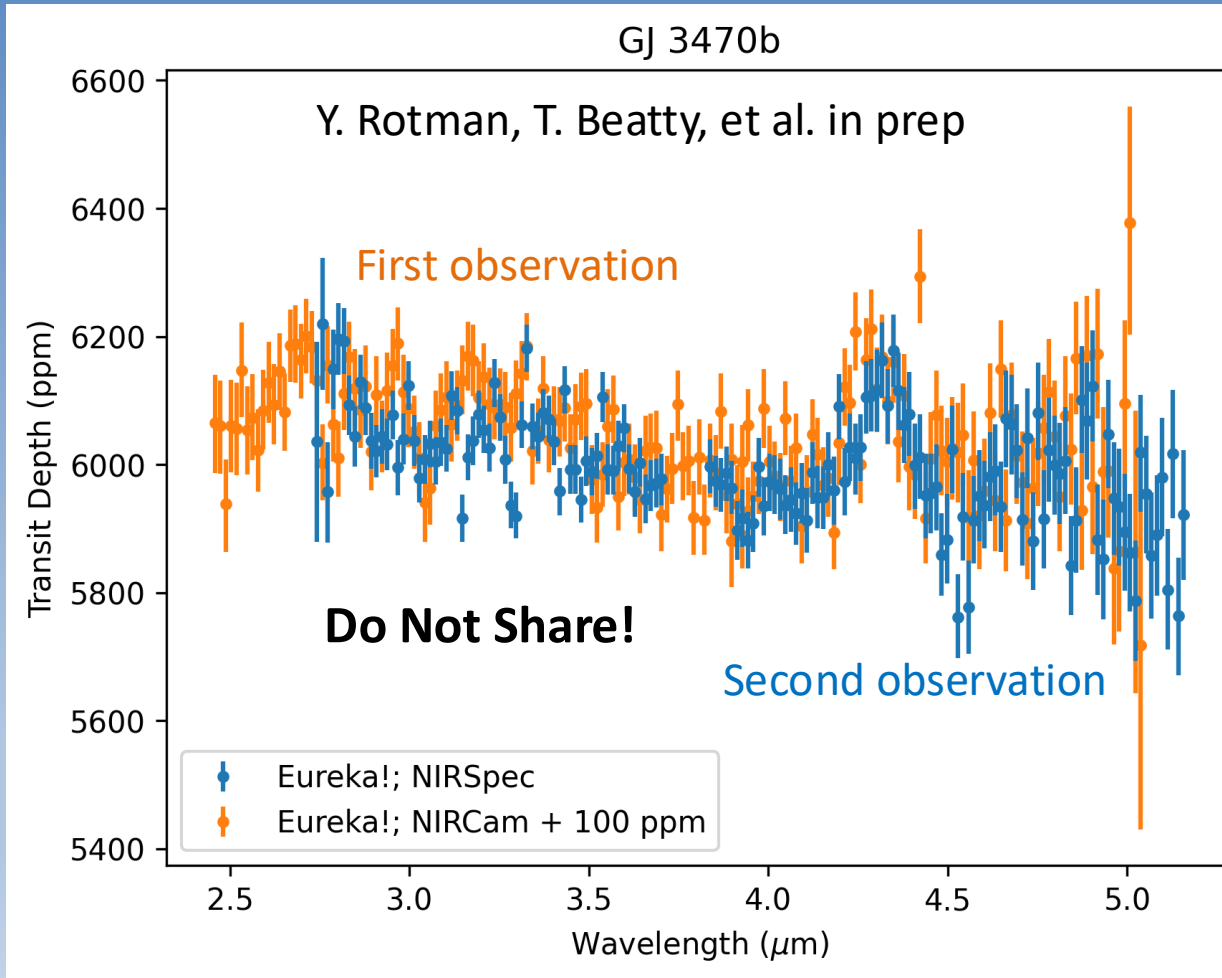


Figure 4. A comparison of the results from the 1D-RCPE and the free-retrieval atmospheric modeling, demonstrating their

- Disagreement between the rad-conv thermo-chemical equilibrium models (colored distributions) and free retrievals (gray distributions) for CH_4 and SO_2 is due to photochemistry
- Lowest T planet with S photochemistry

GJ 3470 b: all was good until we re-observed it!

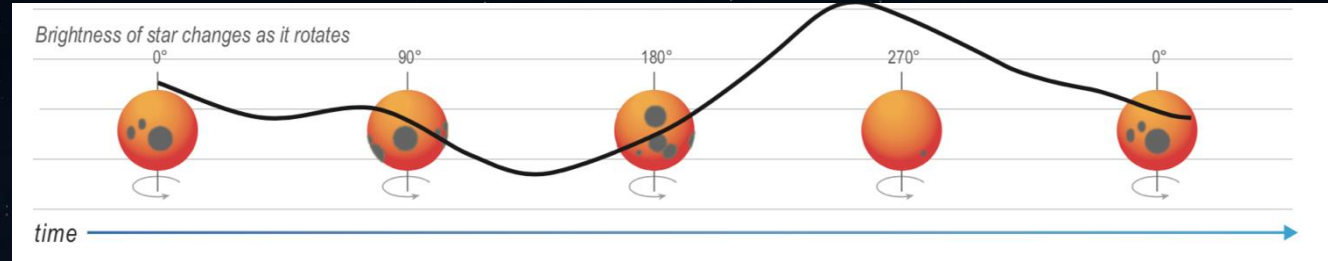


The two observations were made over a year apart, and they disagree. Why???

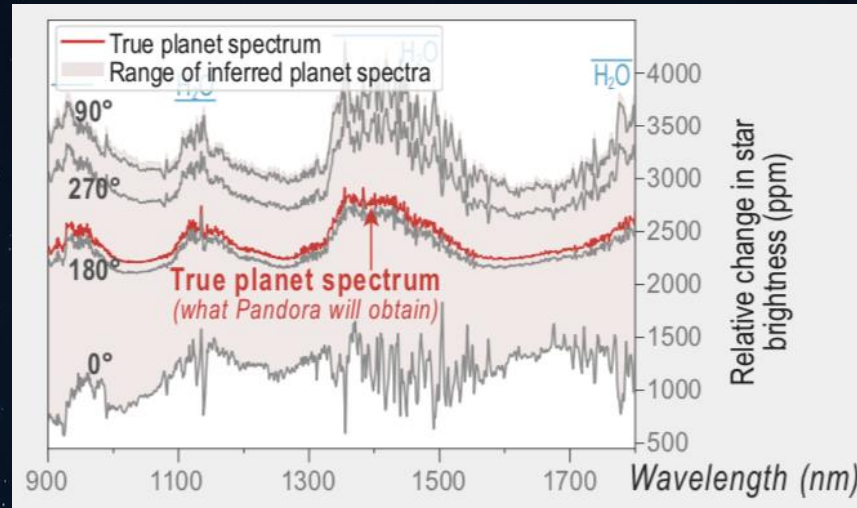
Planet vs. stellar differences (Pandora mission)

Visible photometry

(380-750nm) captures stellar brightness over time



Simultaneous NIR spectroscopy (870-1630nm) captures variations in spectra over time (NIRCam SV flight spare detector)

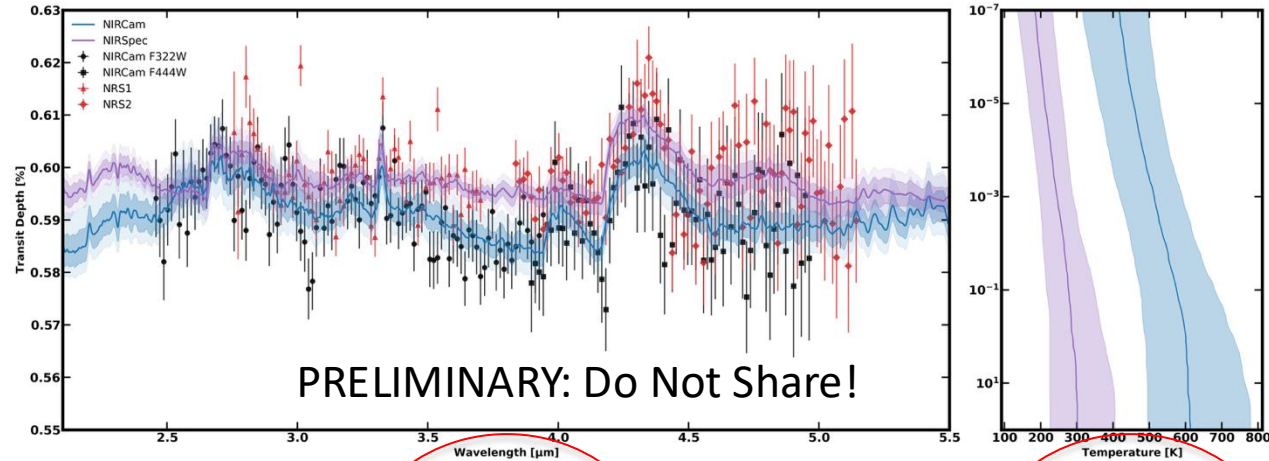


Together, the visible photometry + spectroscopy provides constraints on star spot coverage, which is needed to disentangle the star and planet spectra, **enabling robust measurements of the planet's true atmospheric makeup**

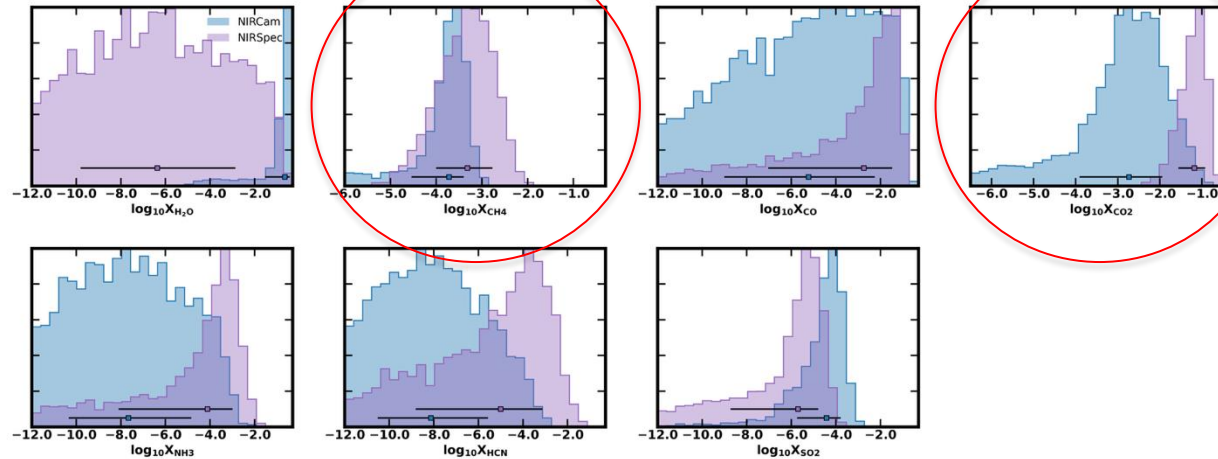
GJ 3470 b: NCam vs NSpec retrievals



Y. Rotman retrievals: without stellar contamination



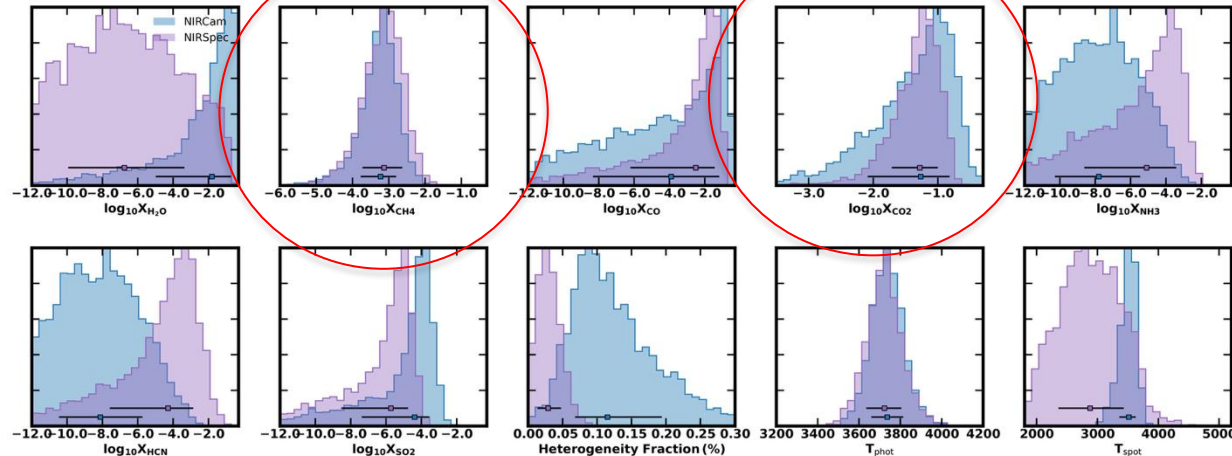
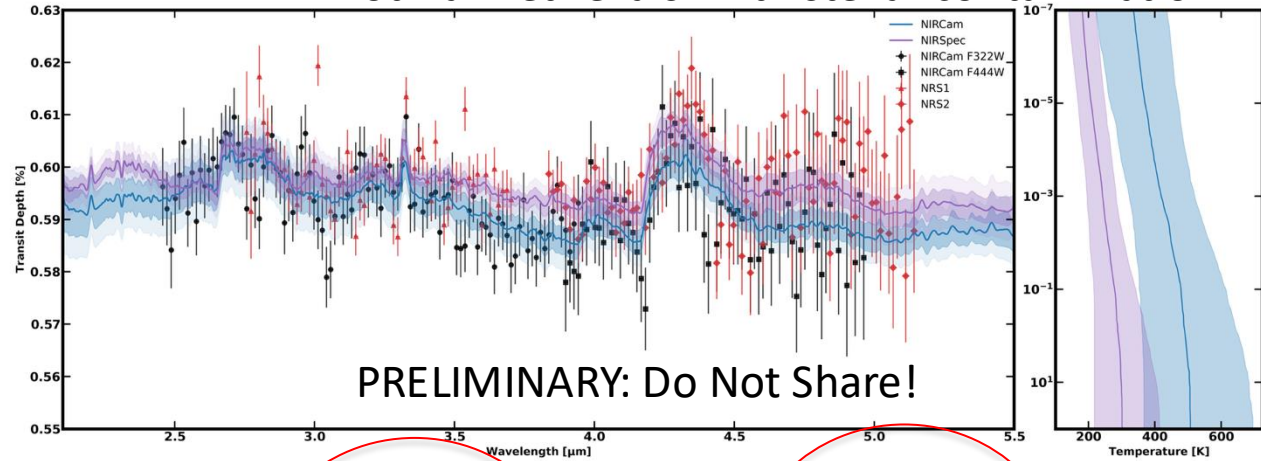
PRELIMINARY: Do Not Share!



GJ 3470 b: NCam vs NSpec retrievals



Y. Rotman retrievals: with stellar contamination

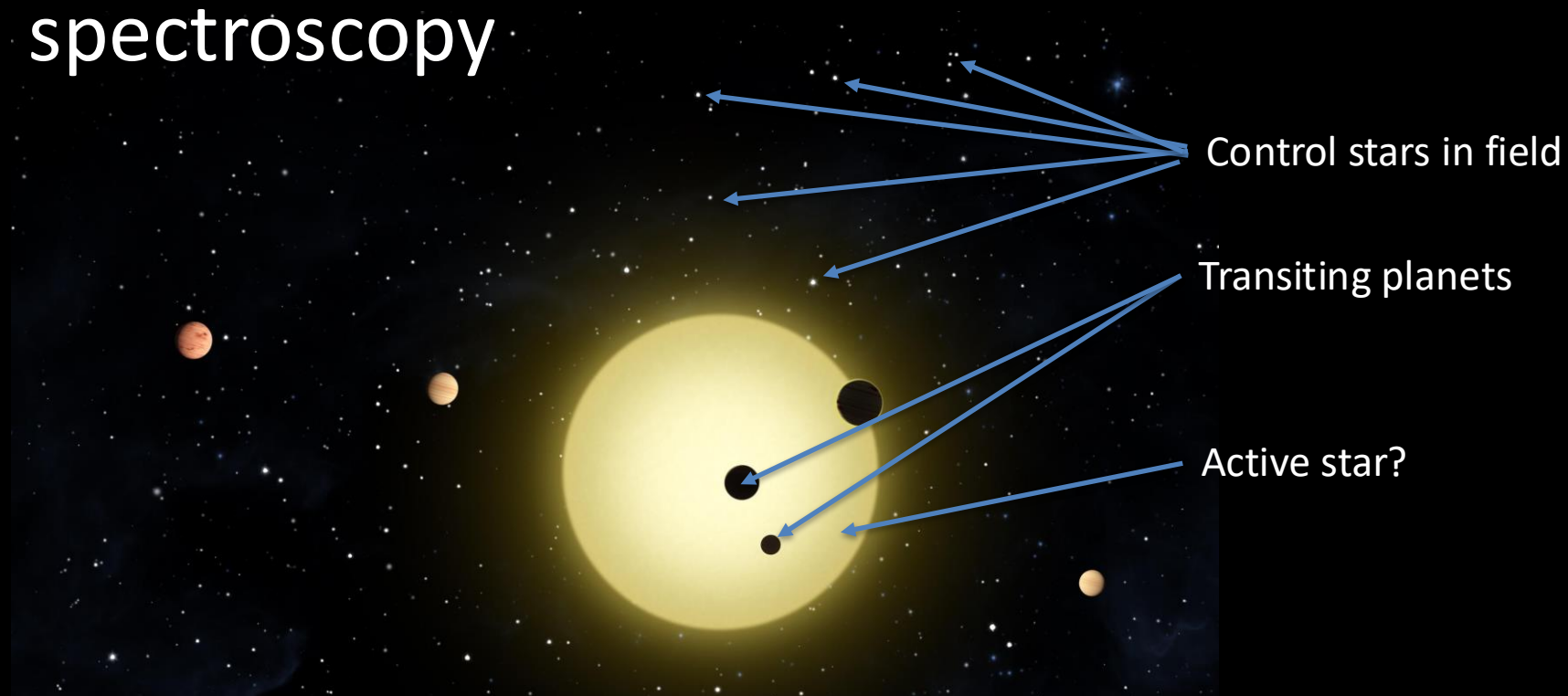


CHROMOS Mission Concept

(from team Confluence site)

- Telescope aperture: 2m diameter
- FoV: 0.463 deg²
- Wavelength range: 1.25–5μm
- Total throughput: ~ 0.25
- 4 identical spectrographs 1.25–5μm (blue channel 1.25–2.5μm, red channel 2.5–5μm)
- 8 H4RG detectors (2 per spectrograph)
- 1 imager (guiding/calibration)
- Spectroscopic resolution: $R = 1000$ (cleanly separate H α & NII)
- Spectroscopic multiplex: > 16,000 (30 micron pixel next-generation Digital Micro-mirror Device)
- DMD micro-mirror scale: 0.75"×0.75", Detector pixel scale: 0.375"
- Pointing stability: < 0.02" RMS (exoplanet science driven)
- Orbit: L2
- Cost: ~\$1.2B (scaling 1.5m ATLAS Probe to 2m)

CHROMOS for transiting exoplanet spectroscopy



- Expect ~ 70 stars with $V \leq 12$ mag per sq deg ($b = 30^\circ$ and average)
- Therefore ~ 32 suitable stars per CHROMOS FOV
- Compare mean time-series variations of background stars to transited one to assess and reduce astrophysical noise (and remove common-mode noise)

CHROMOS transit survey

- *Observing 1000 transits (equals Ariel) requires ~1 year with 70% efficiency assuming 6 hours observing dwell time per transit*
- *2-m aperture yields photon-limited precision about 1/3 of JWST (2 X Ariel), suitable for Neptune-sized planets*
 - *Reduced impact of stellar activity/heterogeneity*
 - *Covers 1.25 – 5 microns in a single transit: 2x faster than JWST for 1/3 the precision (1/2 precision) with less temporal variation*
 - *Can co-add multiple transits for higher precision*
- **Ad ASTRA CHROMOS talks**
 - *CHROMOS Mission: Gregory Wirth, Sep 2, 1:42 pm*
 - *CHROMOS Cosmology: Yun Wang, Sep 1, 11:45 am*
 - *CHROMOS Galaxies: Andreas Faisst, Sep 1, 2:15 pm*
 - *CHROMOS Inner Galaxy: Lynne Hillenbrand, poster*

Thank you