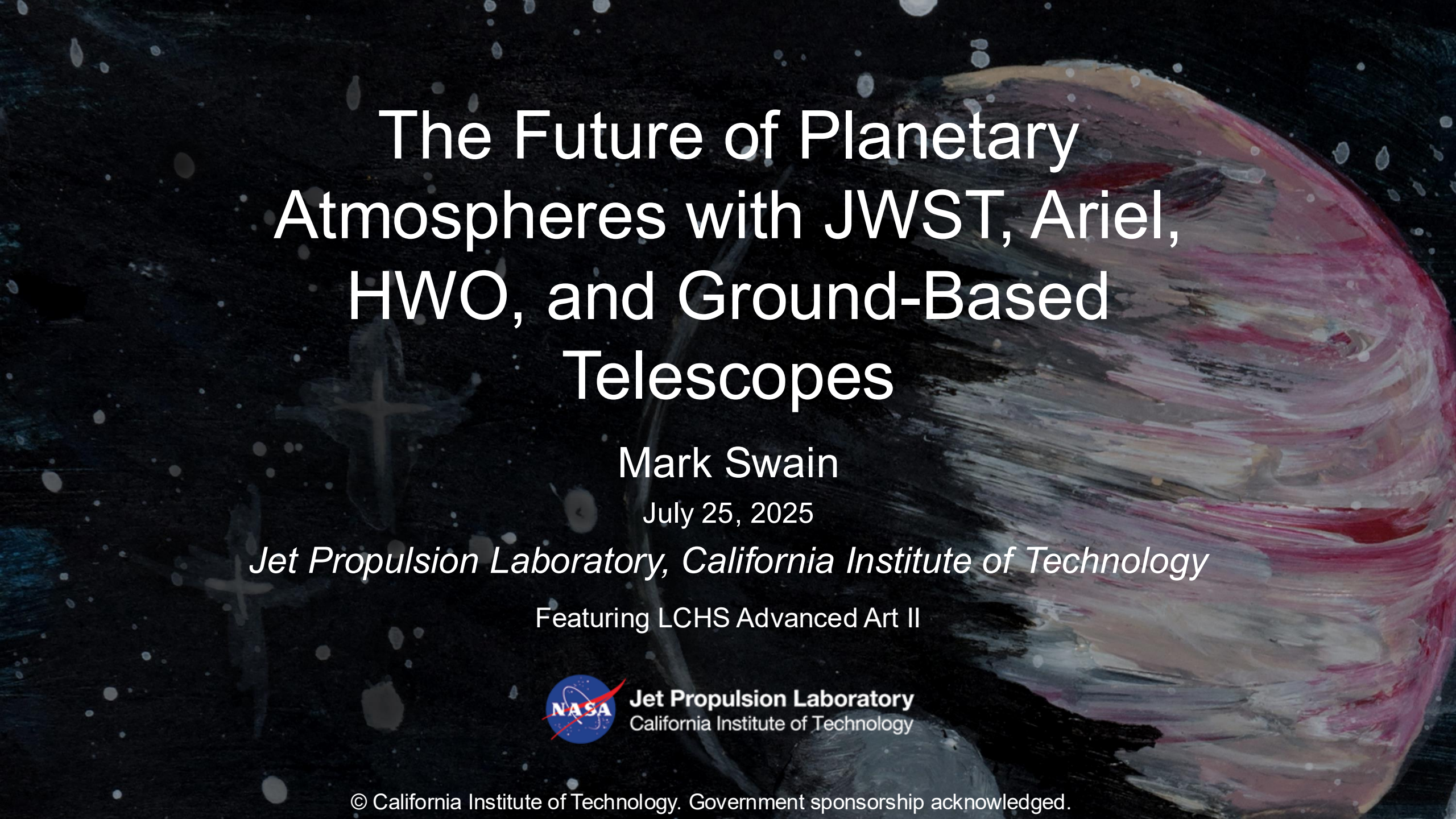

The Future of Planetary Atmospheres with JWST, Ariel, HWO, and Ground-Based Telescopes

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July 25, 2025

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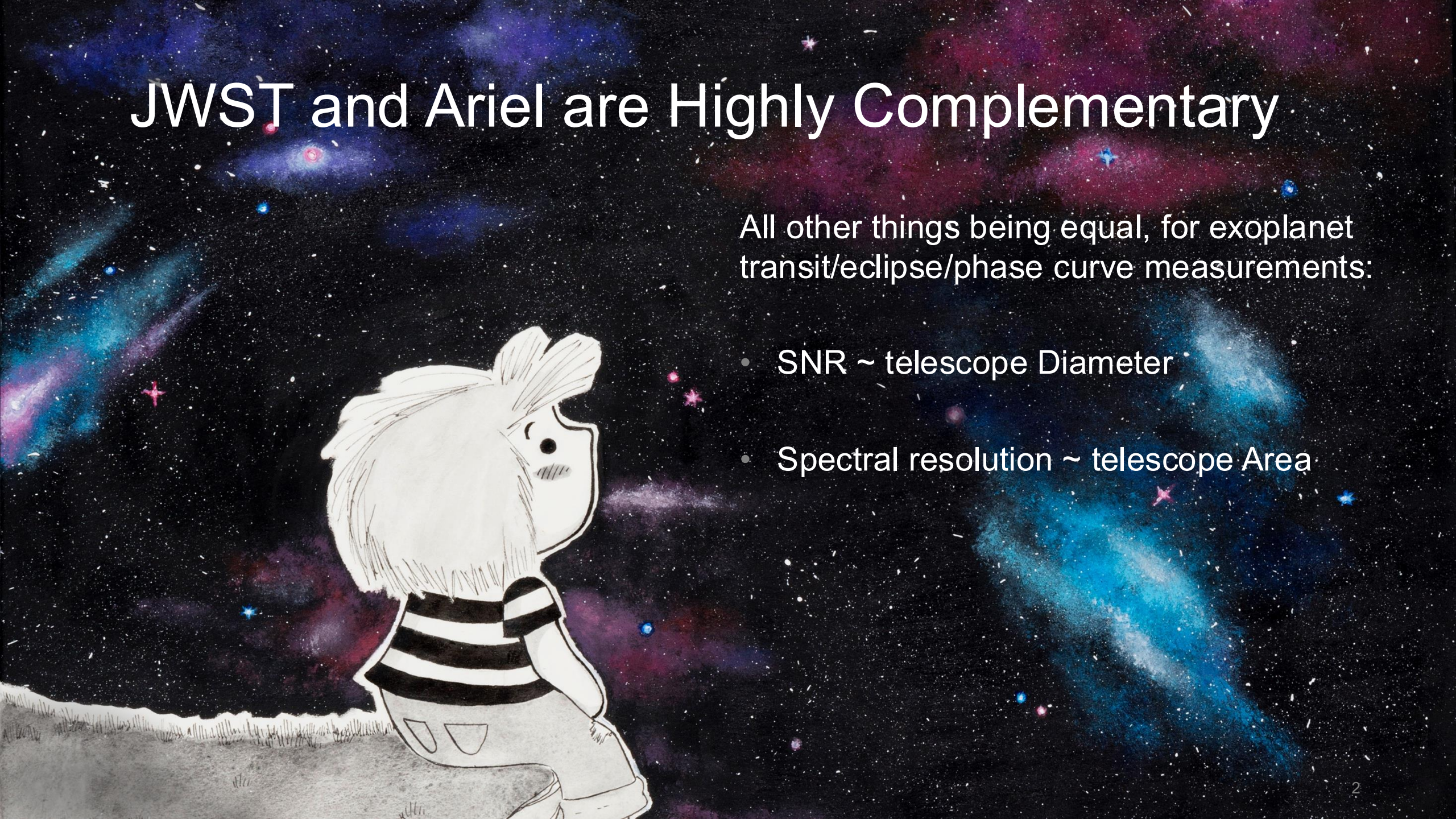
Featuring LCHS Advanced Art II

Jet Propulsion Laboratory
California Institute of Technology

JWST and Ariel are Highly Complementary

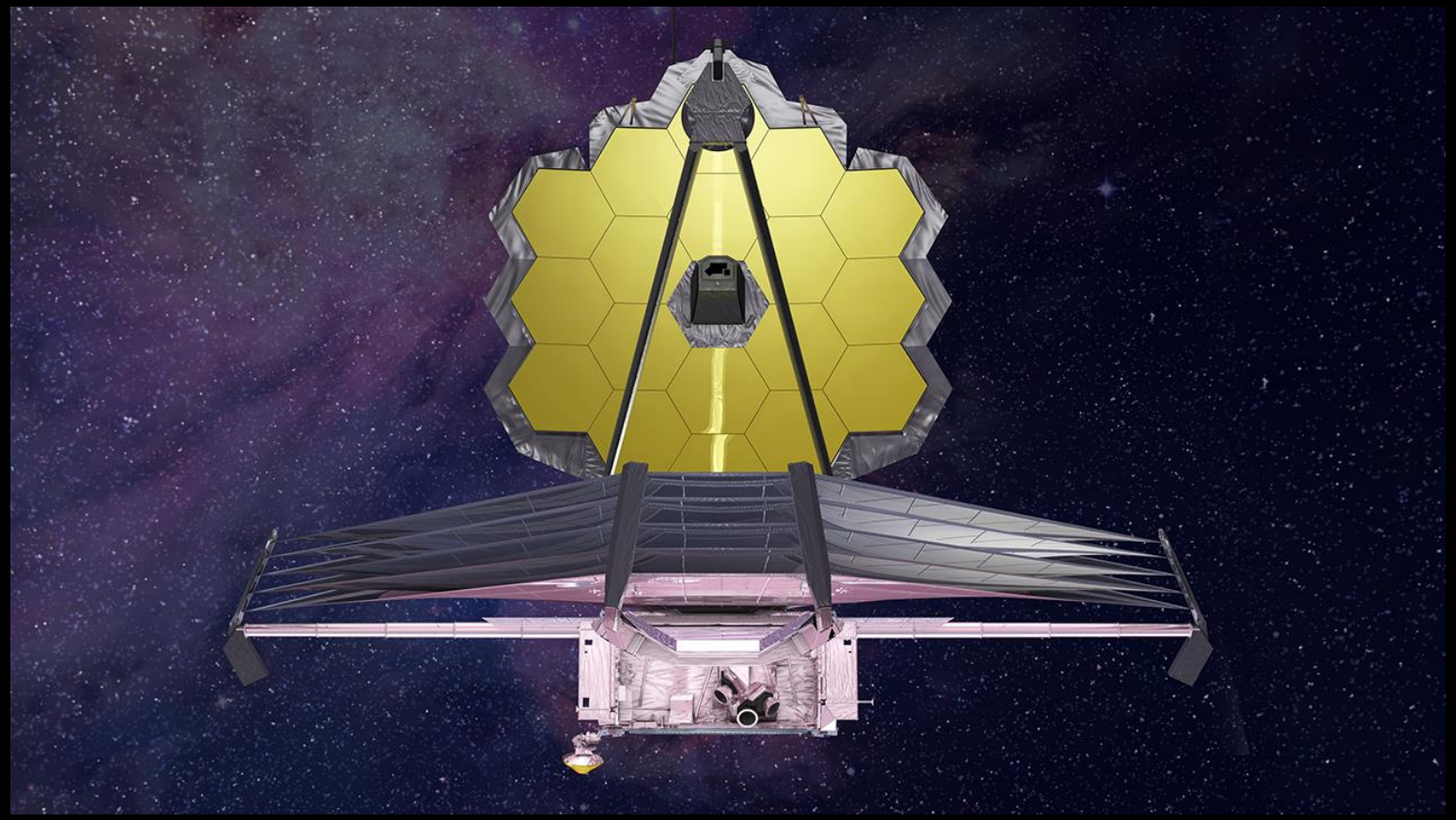


All other things being equal, for exoplanet transit/eclipse/phase curve measurements:

- SNR ~ telescope Diameter
- Spectral resolution ~ telescope Area

JWST

- Sensitivity & spectral resolution
- Multiple instruments and instrument modes
  - Various spectral resolutions available
  - Wavelength coverage options from visible to 28 μm
- Shared observatory



Ariel

- Broad instantaneous spectral coverage
  - 0.5-7.8 μm
- Uniform observations
  - Single instrument configuration
- Dedicated to surveying exoplanet atmospheres

Comparing JWST and Ariel

JWST

- Optimal for detailed investigation of specific planets
- Ability to tailor observations to the science question
- Excellent tool for investigations of small planets

Ariel

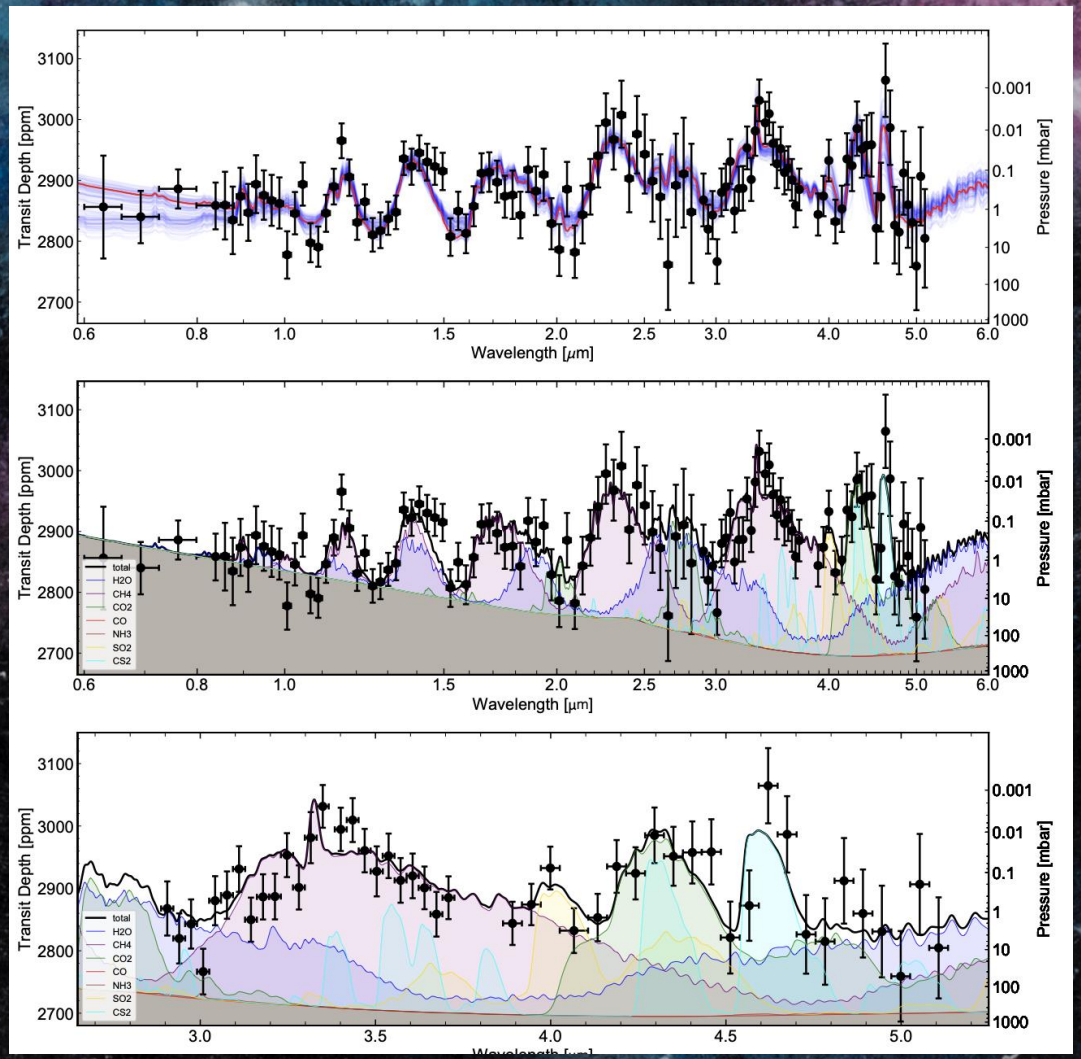
- Optimal for unform survey of exoplanet atmospheres
- Single observation configuration with broad instantaneous spectral coverage
- Excellent tool for statistical comparative planetology

Selected Highlights Anticipating Future

- JWST measurements of small planets
- Ariel population studies
- HWO observations of exoearths
- Large telescope observations of atomic species

JWST: subNeptune TOI-270 d

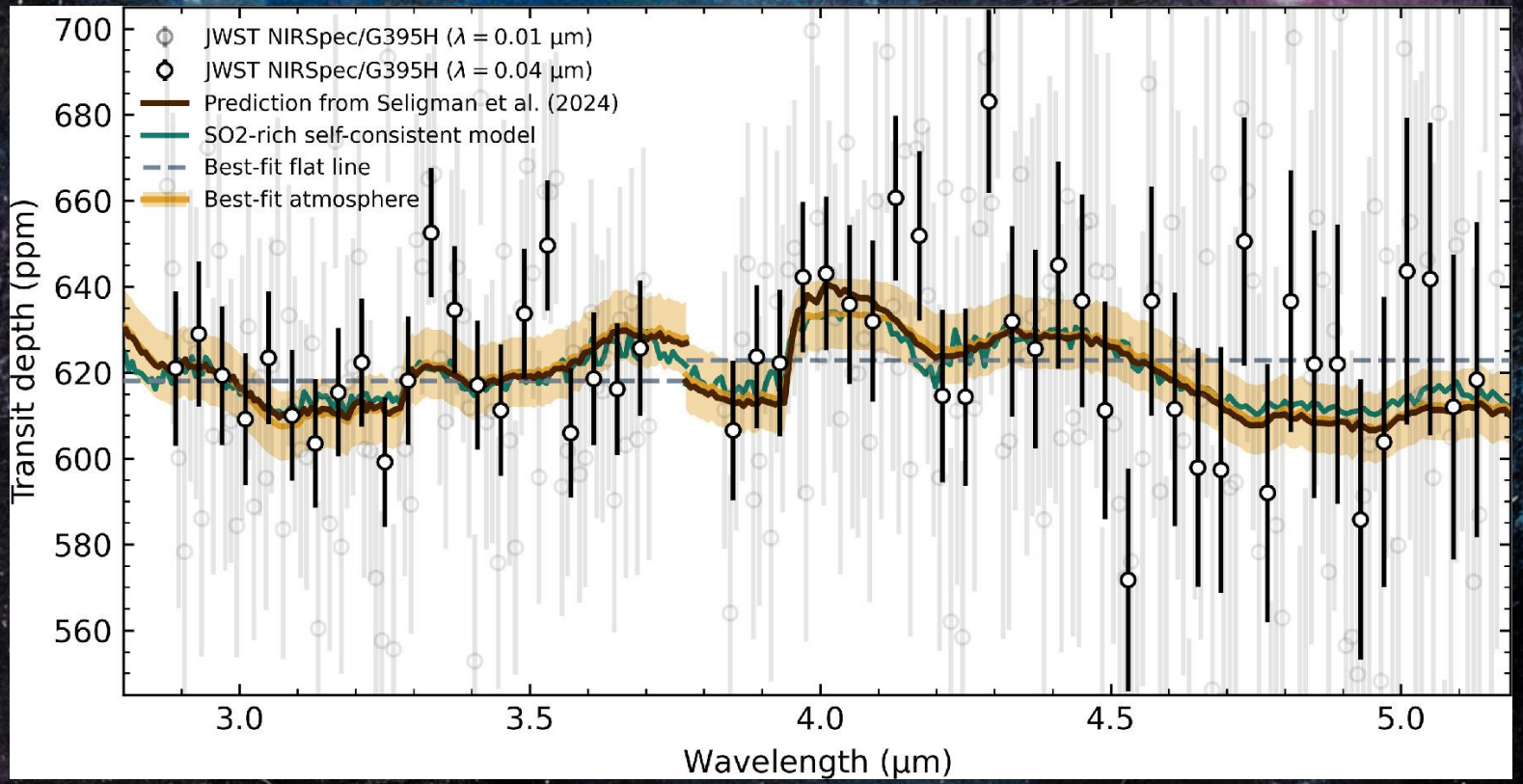
- Mp=4.78 Me, Rp=2.13 Re, P=11.4 days, Teq=387 K, M3 V (Van Eylen+2021)
- High metallicity atmosphere
- Authors suggest a new planet class “miscible-envelope sub-Neptune”



Benneke et al. 2024

JWST: terrestrial planet L 98-59 b

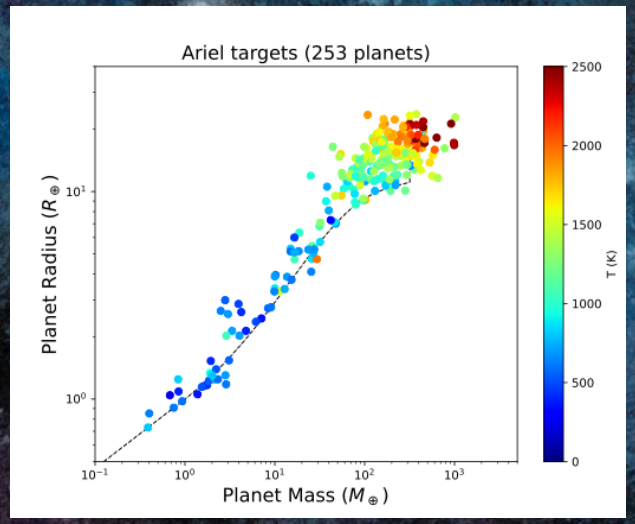
- Mp=0.40 Me, Rp=0.85Re, Period=2.2 days, Teq 627 K orbiting a M3 V star (Demangeon_2021)
- Spectrum interpreted as evidence for a volcanic atmosphere

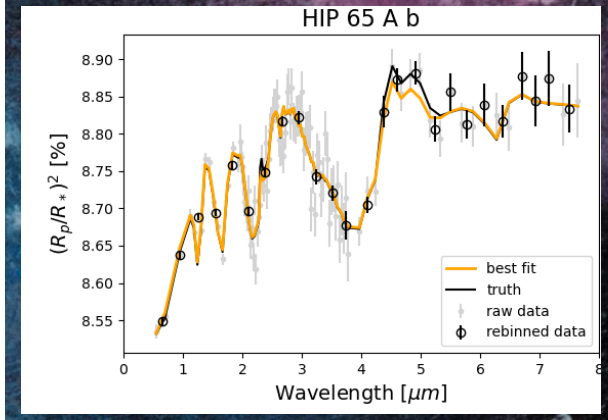


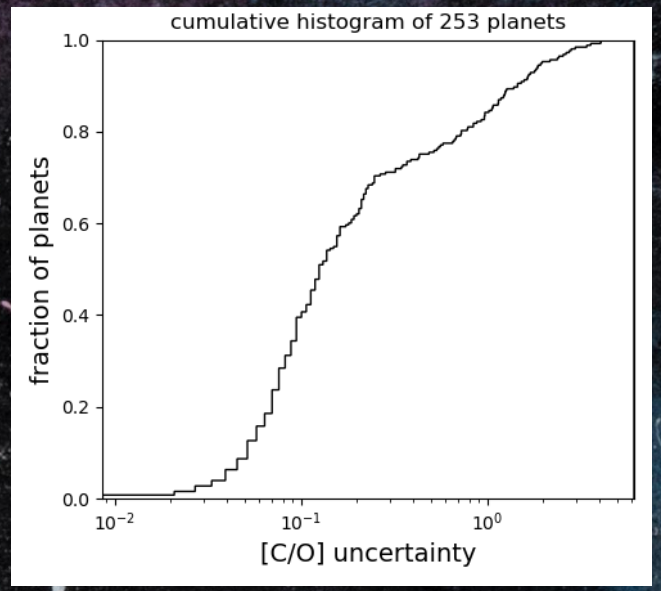
Bello-Arufe et al. 2025

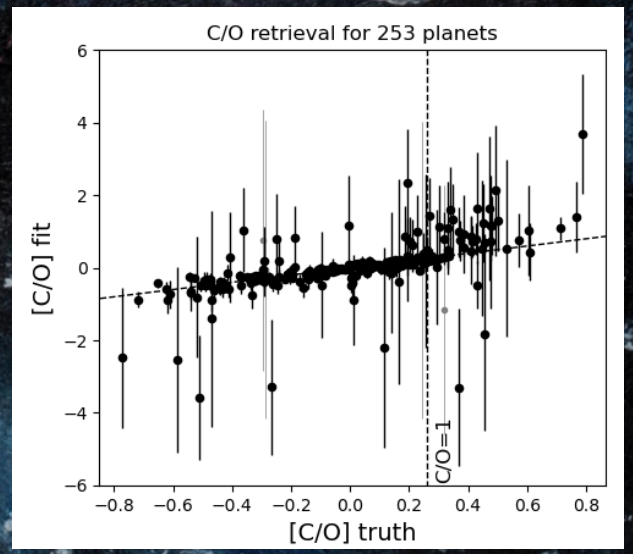
Ariel: C/O Population Study

- C/O potentially traces location of planet formation (eg Oberg+2011, Bergin+2023)
- Simulated Ariel Tier 2 survey assuming TEC and known targets
- Median C/O uncertainty ~0.1 dex



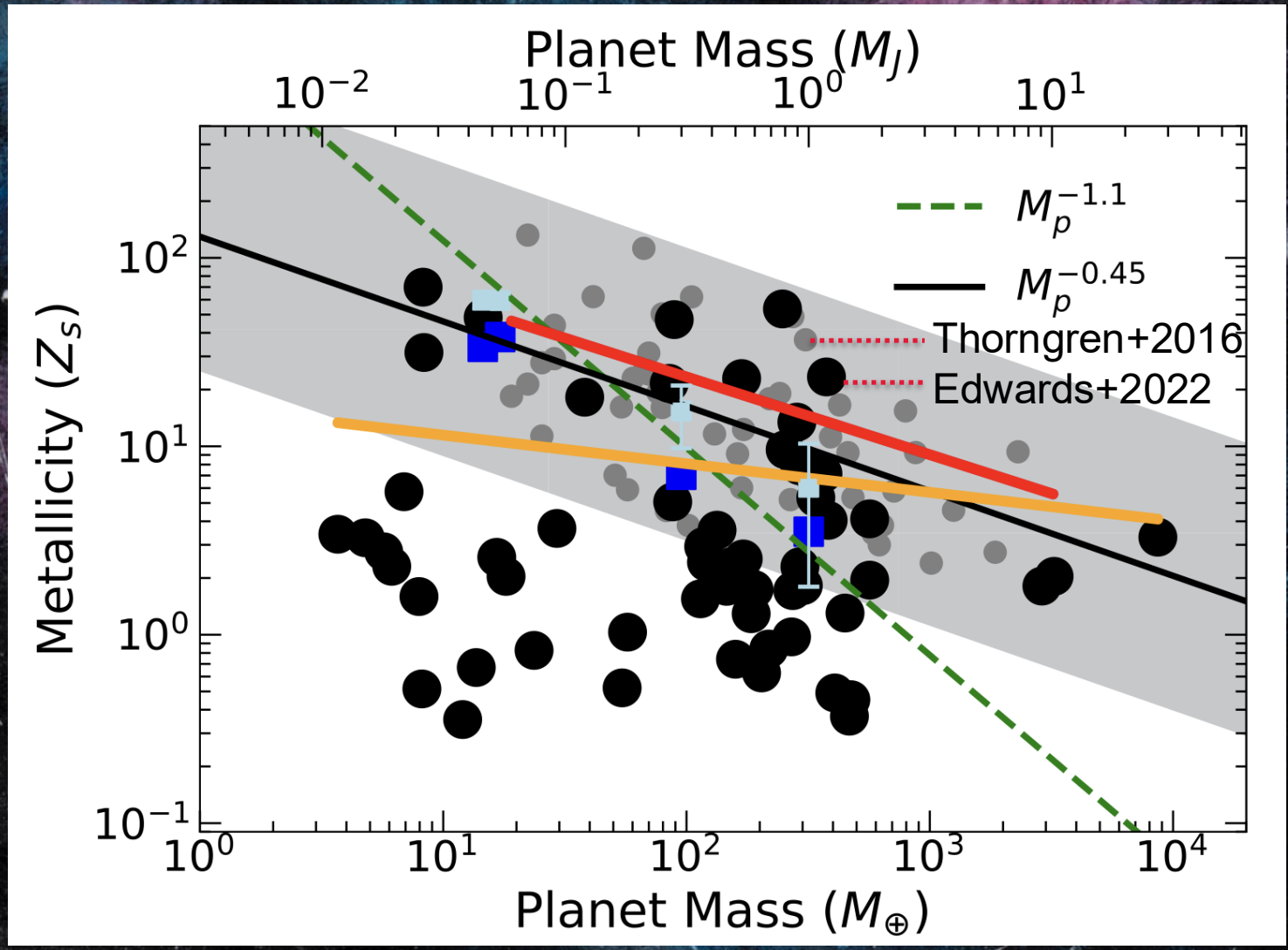






Ariel: Mass-Metallicity Trends

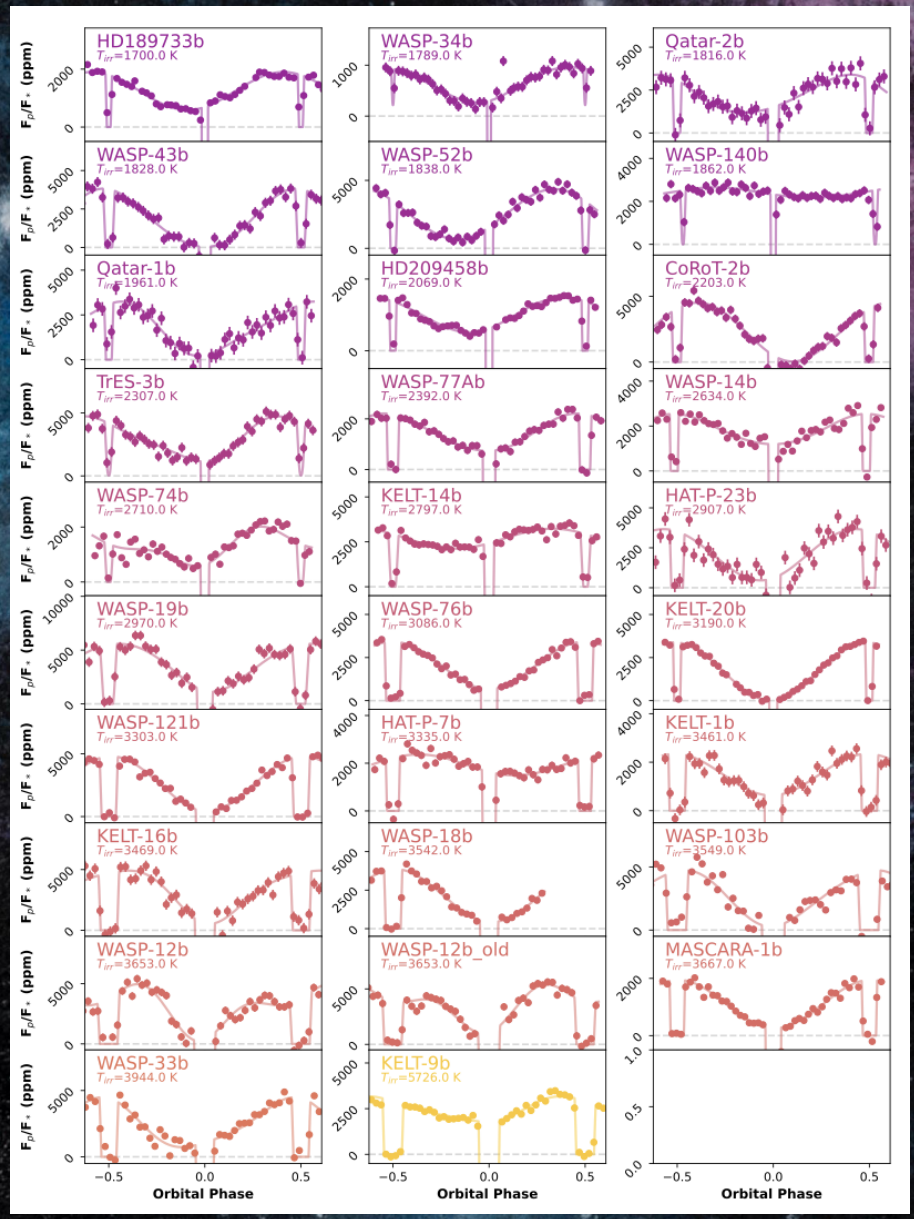
- Metallicity estimated by both bulk density and transit spectroscopy.
- Transit measurements sample outer layers of envelope.
- Comparing bulk density and transit metallicity estimates can reveal interior structure.



Swain et al 2024

Ariel: Phase Curves

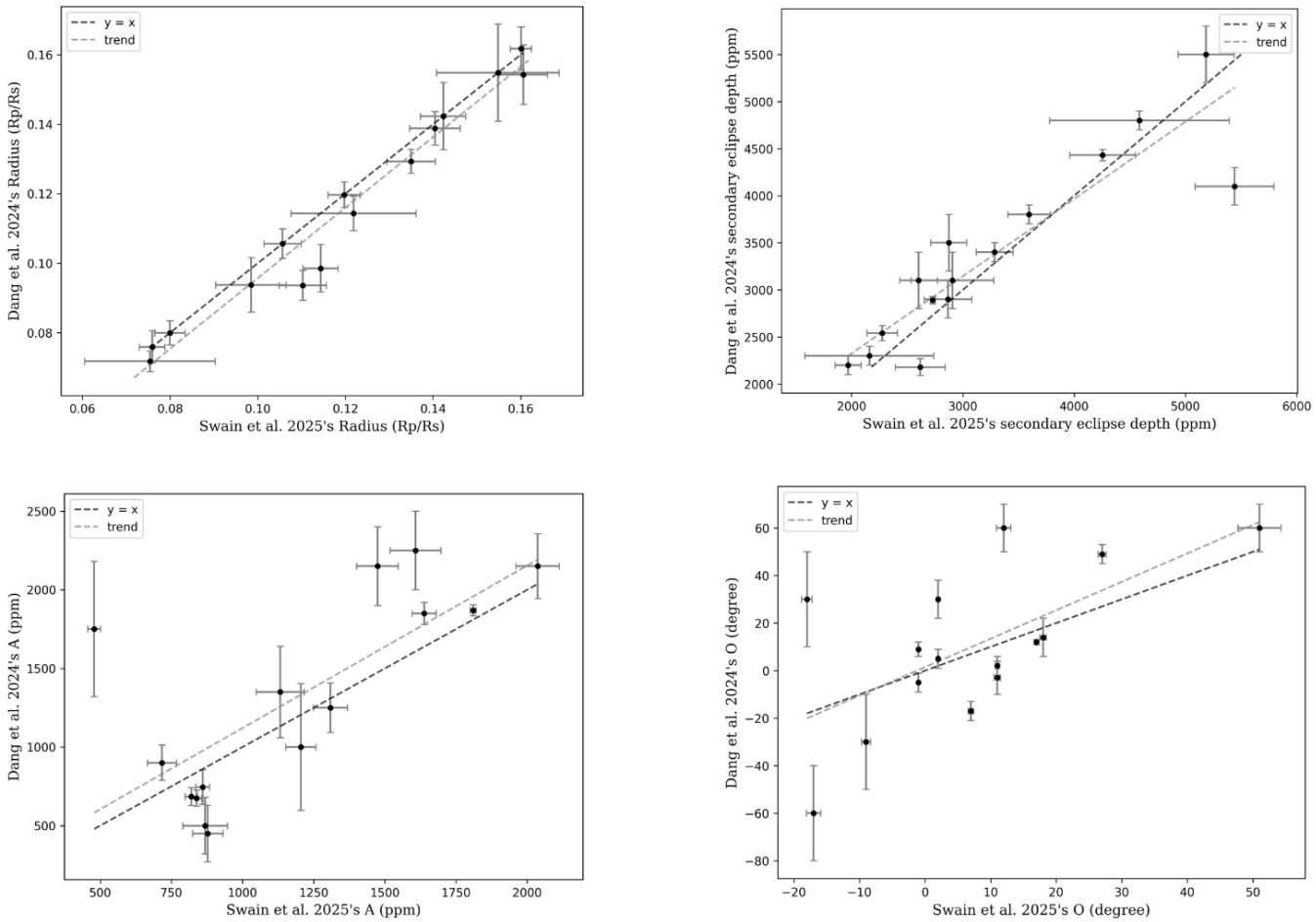
- Recent phase curve catalogs
  - 29 planets, 4.5 μm, Dang+2025
  - 34 planets, 3.6 & 4.5 μm, Swain+2025
  - corresponds to >125 days Spitzer observing
  - 3.6 & 4.5 μm phase curves for 16 planets probe the pressure dependence of heat transport
- Tremendous scope for Ariel
  - Spectroscopic phase curve survey
  - Ariel phase curves address numerous science questions
  - ~180 days of Ariel observing would provide a completely unique catalog



Dang et al 2025

Ariel: Catalog Comparison

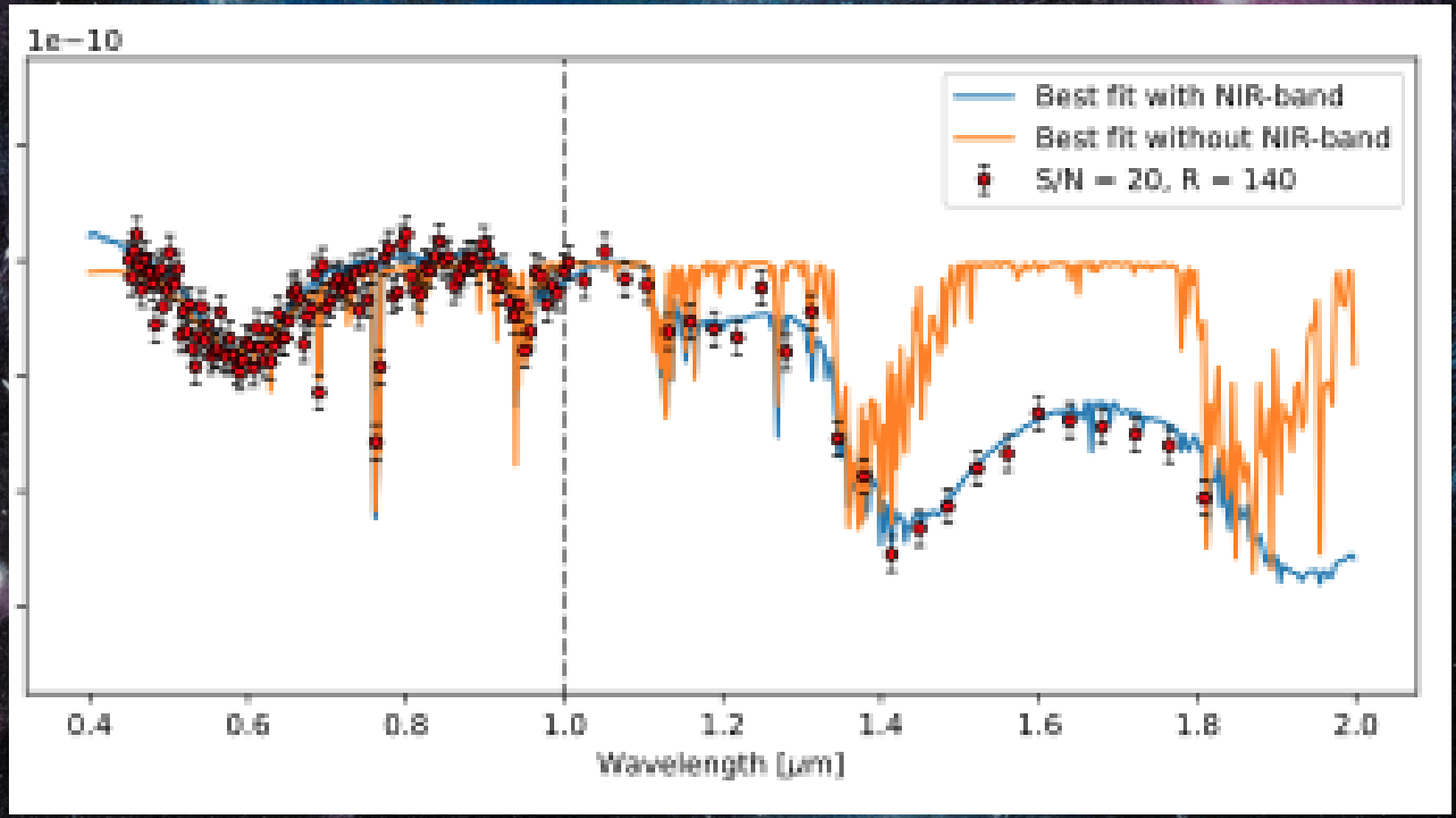
- Need to comparison of catalog processing to understand potential processing biases (Mugnai+2024)
- Catalog comparison for Dang+25 and Swain+25 Spitzer results in preparation
- Similar comparison studies will be essential for Ariel



Decocq et al. submitted

HWO: Terrestrial Atmospheres

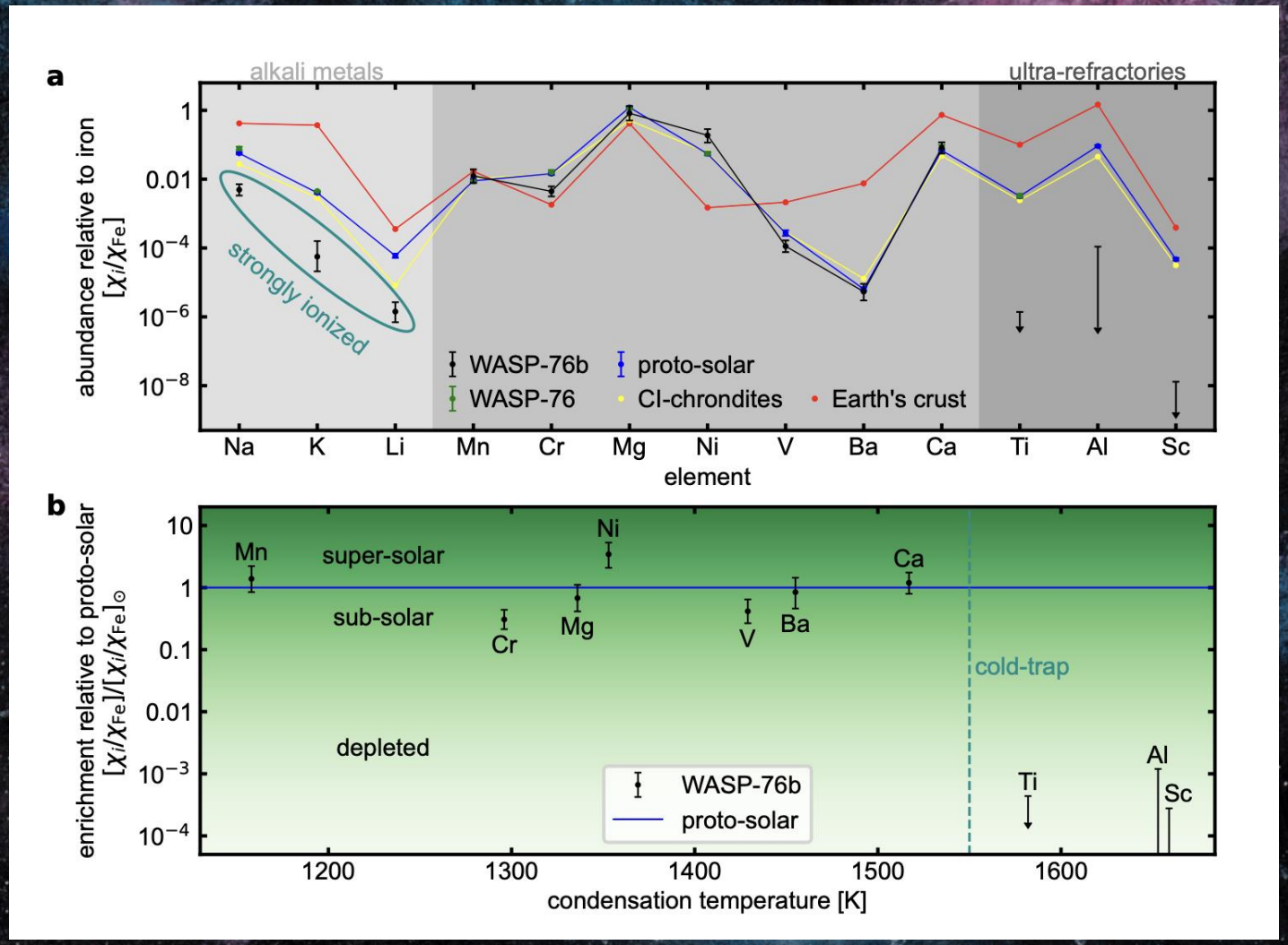
- HWO will likely include high-contrast capability
- Key goal will be the study of Earth-like planets around Solar type stars
- Simulations of reflection spectra from an Earth-like planet highlight the importance of the near-infrared wavelengths.



Damiano & Hu 2022

High Resolution Ground Based Results

- R~100,000 measurements of the hot Jupiter WASP-76 b (Period=1.8 days)
- 7 metals follow the X/Fe ratio of CI-chondrites (volatile rich and believed to form beyond the Solar system's snow line >4 AU)



Pelletier et al. 2023

Expectations for 2045

- Ground-based cross-correlation surveys of atomic species probing the dynamics and thermal structure of hot-Jupiter atmospheres
- Detailed characterization of numerous small planet atmospheres with JWST, including a few potentially habitable planets
- Statistical characterization of trends for large segments of the exoplanet population with Ariel including probing interior structure
- HWO atmospheric reflection spectra of small temperate worlds orbiting nearby stars


Invent
the
Future