

A sunset over the ocean with a person standing in the water. The sun is low on the horizon, casting a golden glow across the sky and water. The sky is filled with scattered clouds, some of which are illuminated by the setting sun. The water is dark blue, and a person in a red dress is standing in the shallow surf on the right side of the frame.

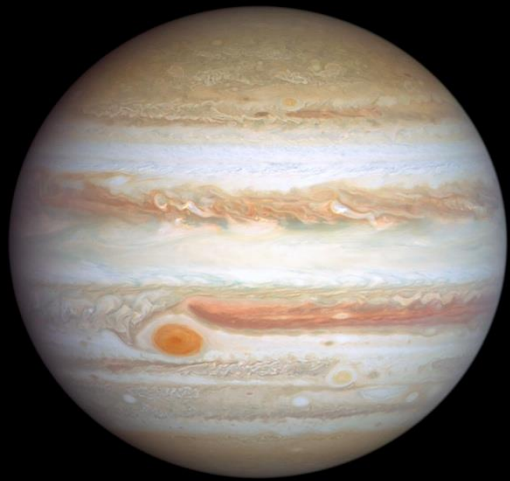
Building on JWST

Linking elements of planets and disks with IR high-res spectroscopy

Klaus Pontoppidan, Jet Propulsion Laboratory/California Institute of Technology

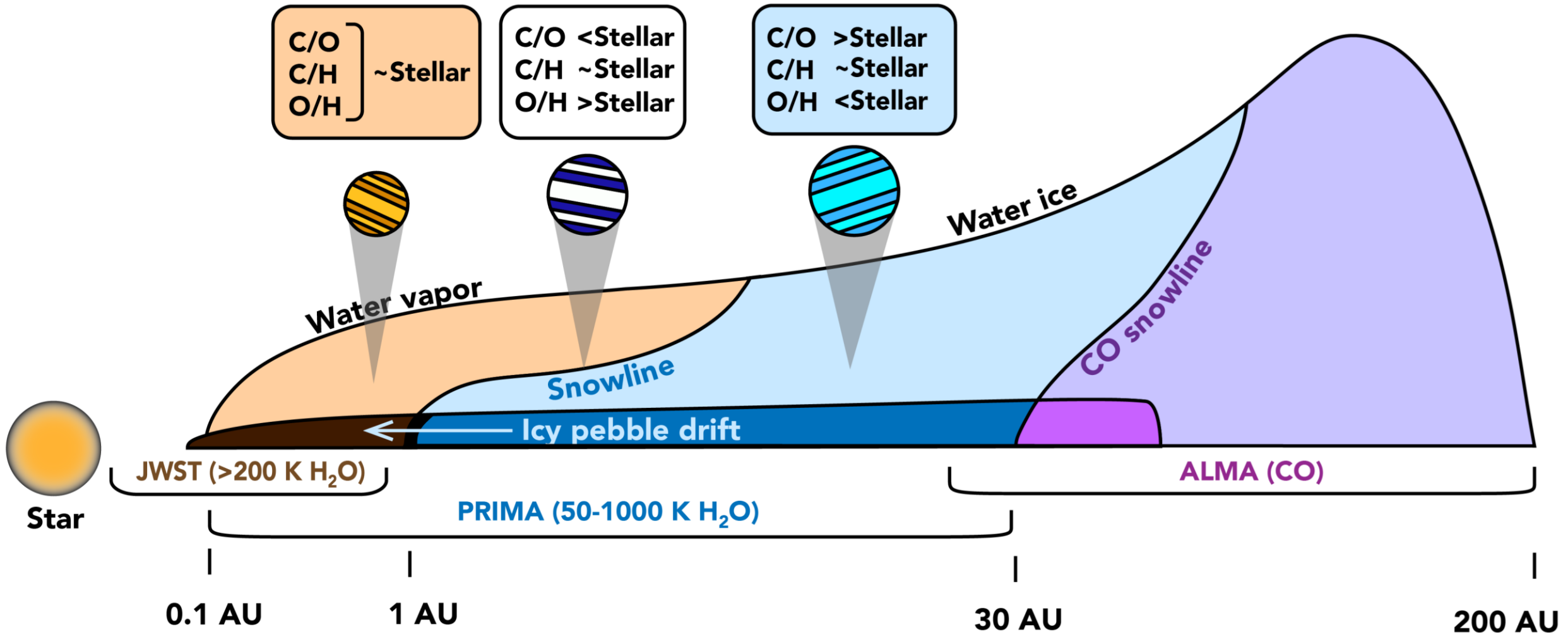
Tiffany Kataria (JPL), Geoffrey A. Blake (Caltech), Gregory Mace (UT Austin)

Giant planets represent the integral over the disk solids first (core) and gas second (primary atmosphere)



$$= \int_{t=0}^{\sim 1 \text{ Myr}} \text{Solids } dr dt + \int_{t \sim 1 \text{ Myr}}^{t \sim 10 \text{ Myr}} \text{Gas } dr dt$$

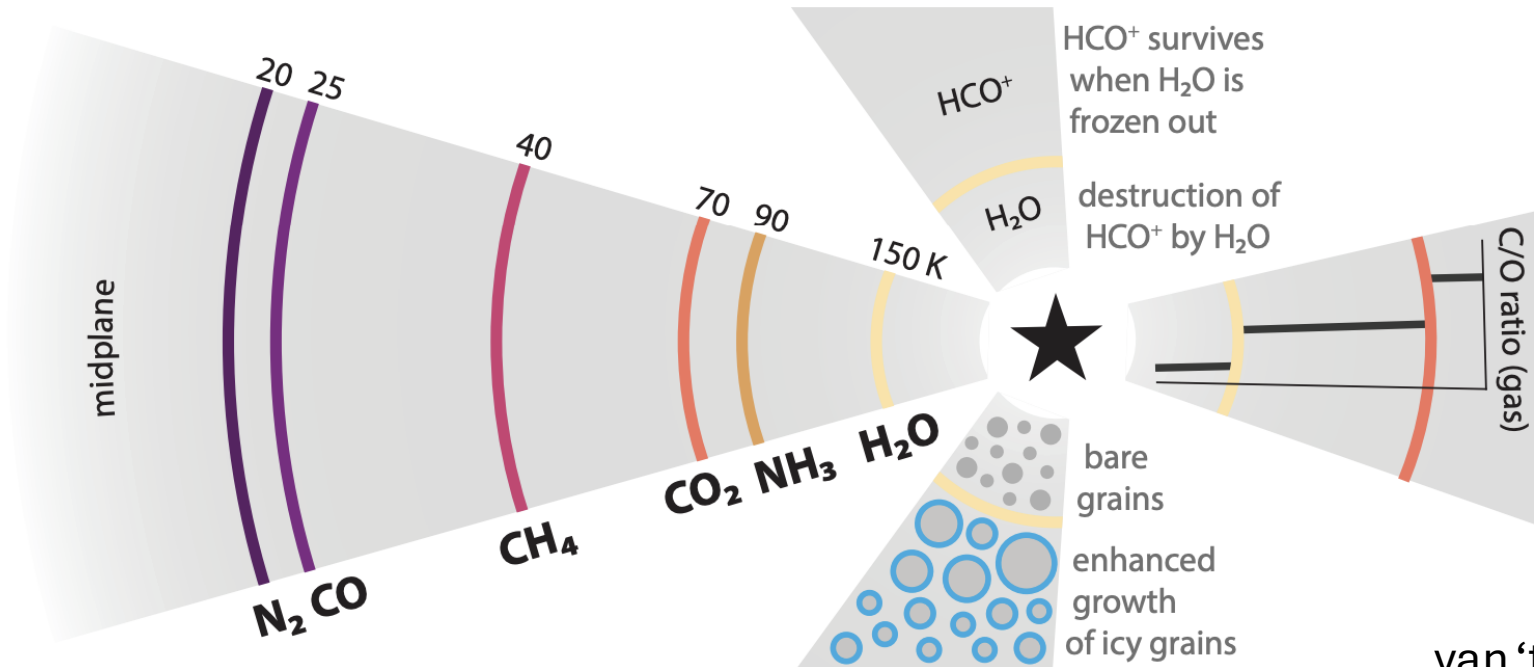
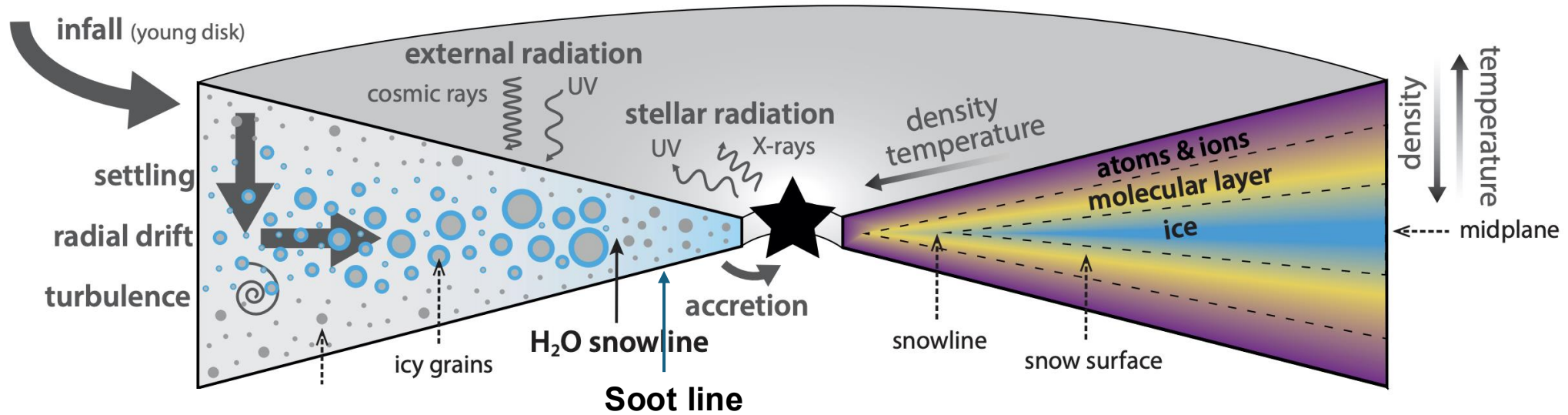
Exoplanet composition depends on the C/H, O/H, and C/O composition in the first ~1 Myr



Need **precise** measurements of C/H and O/H in:

- 1) Protoplanetary disks at all disk radii within ~10 au.
- 2) Giant exoplanet atmospheres representative of feeding zones within ~10 au.

Disk elemental composition depends on ice lines, soot lines, and powerful transport processes

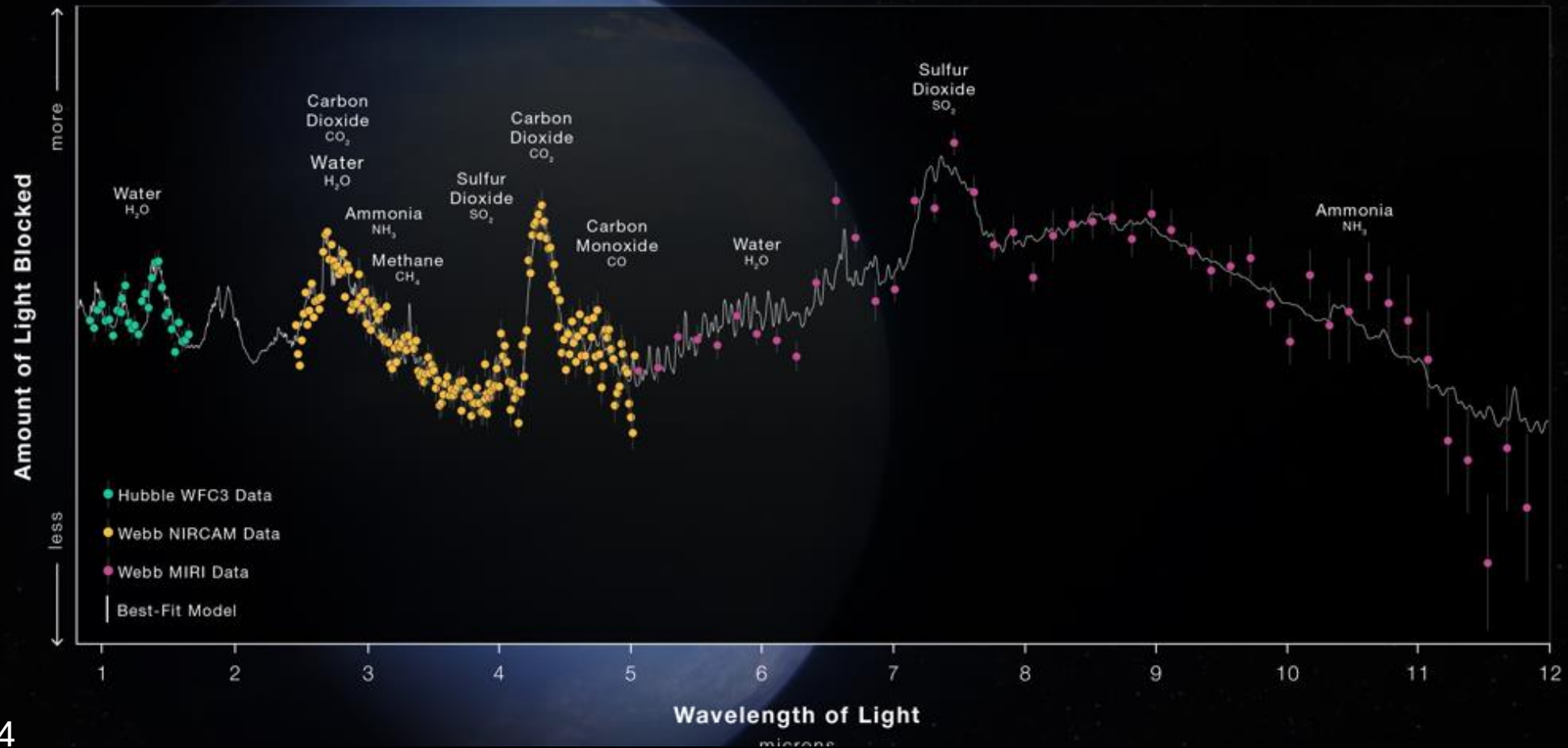


Some information on exoplanetary C/O ratios are available from low-resolution spectra, but with limited precision

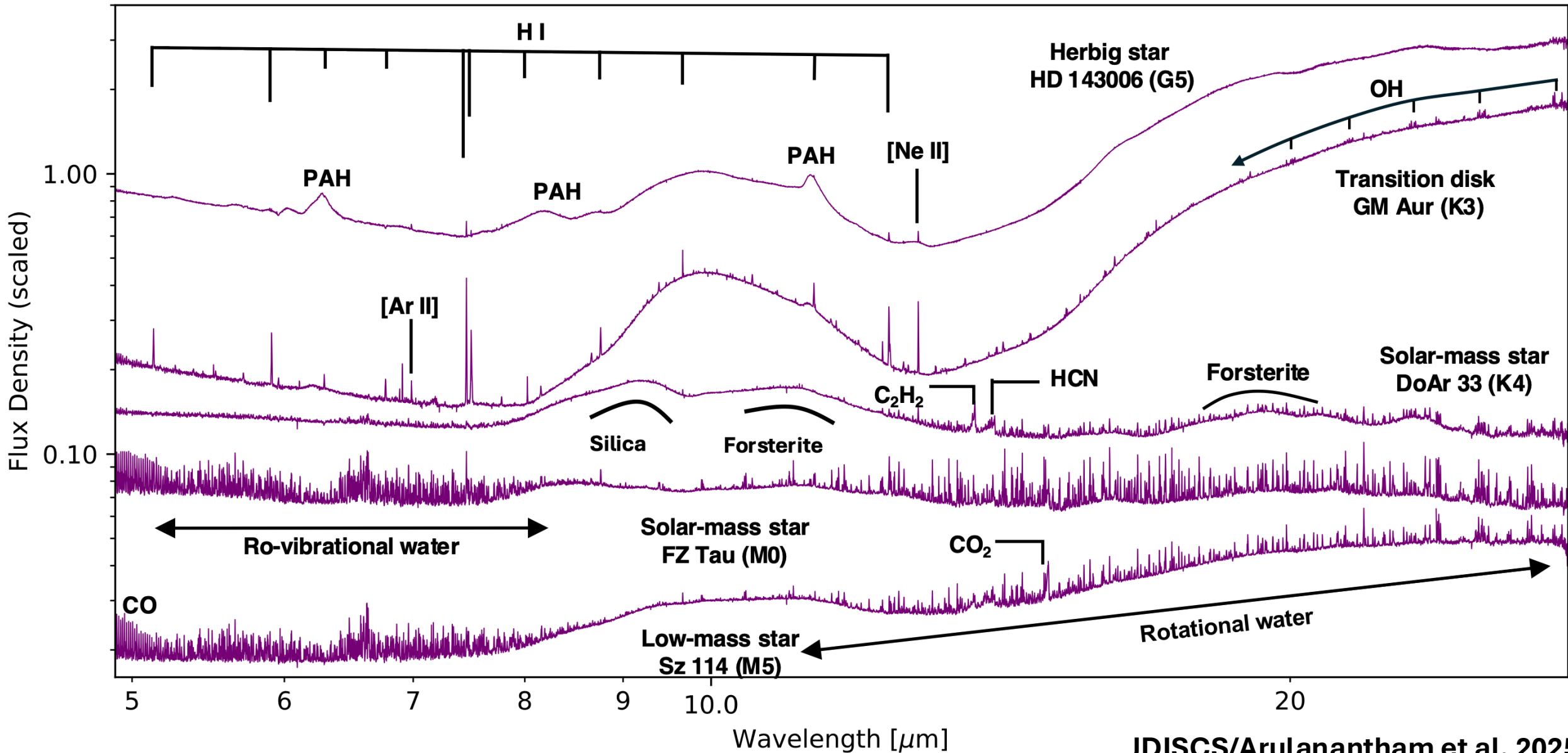
GAS-GIANT EXOPLANET WASP-107 b

TRANSMISSION SPECTRUM

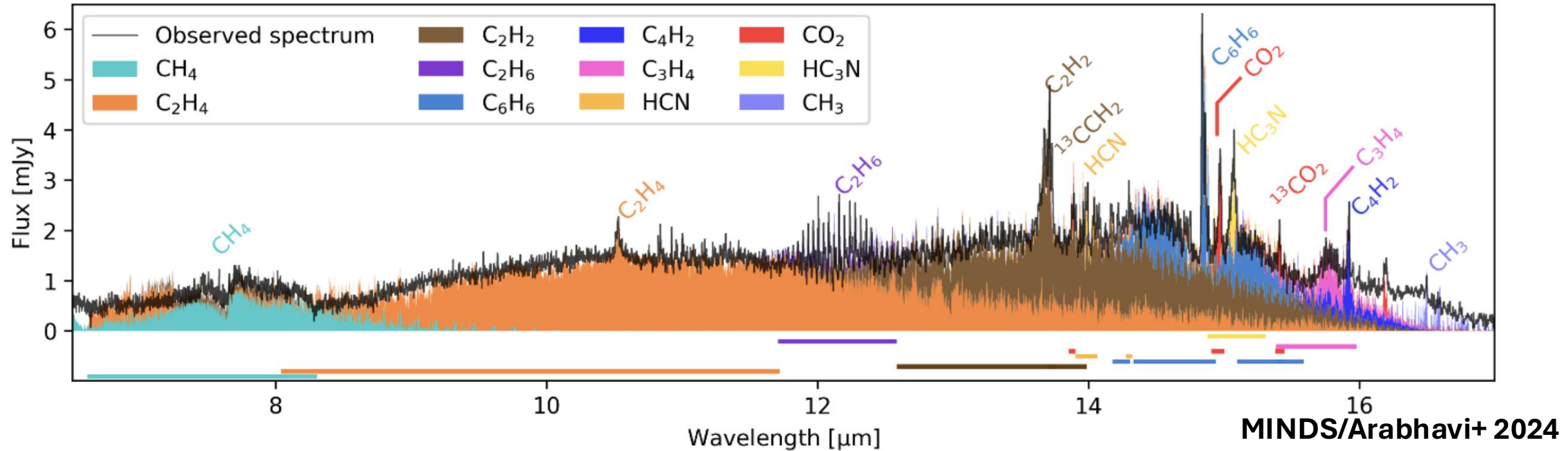
Hubble WFC3	Grism Spectroscopy
Webb NIRCam	Grism Spectroscopy
Webb MIRI	Low-Resolution Spectroscopy



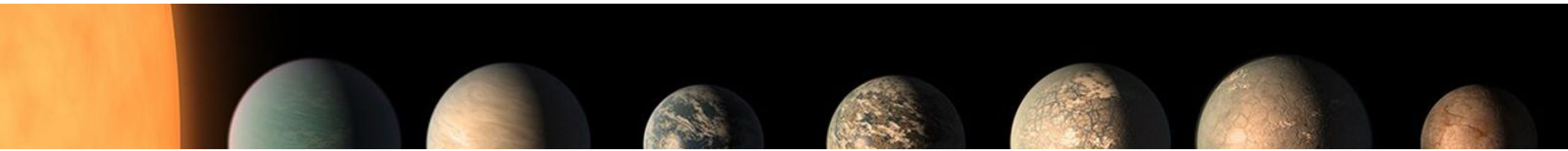
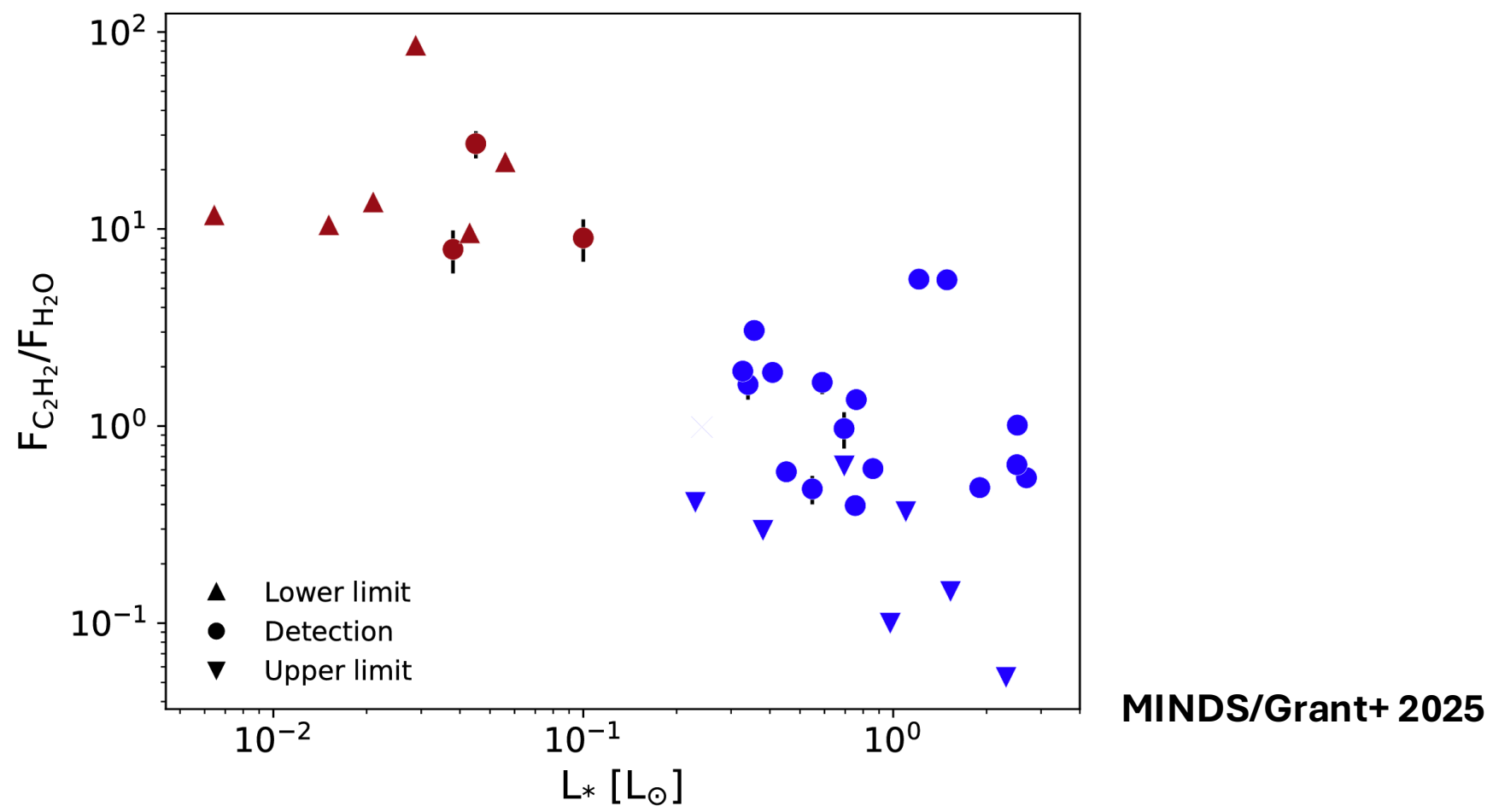
JWST observations of ~400 protoplanetary disks show incredible diversity



There is a radically different carbon-chemistry in low-mass and older disks

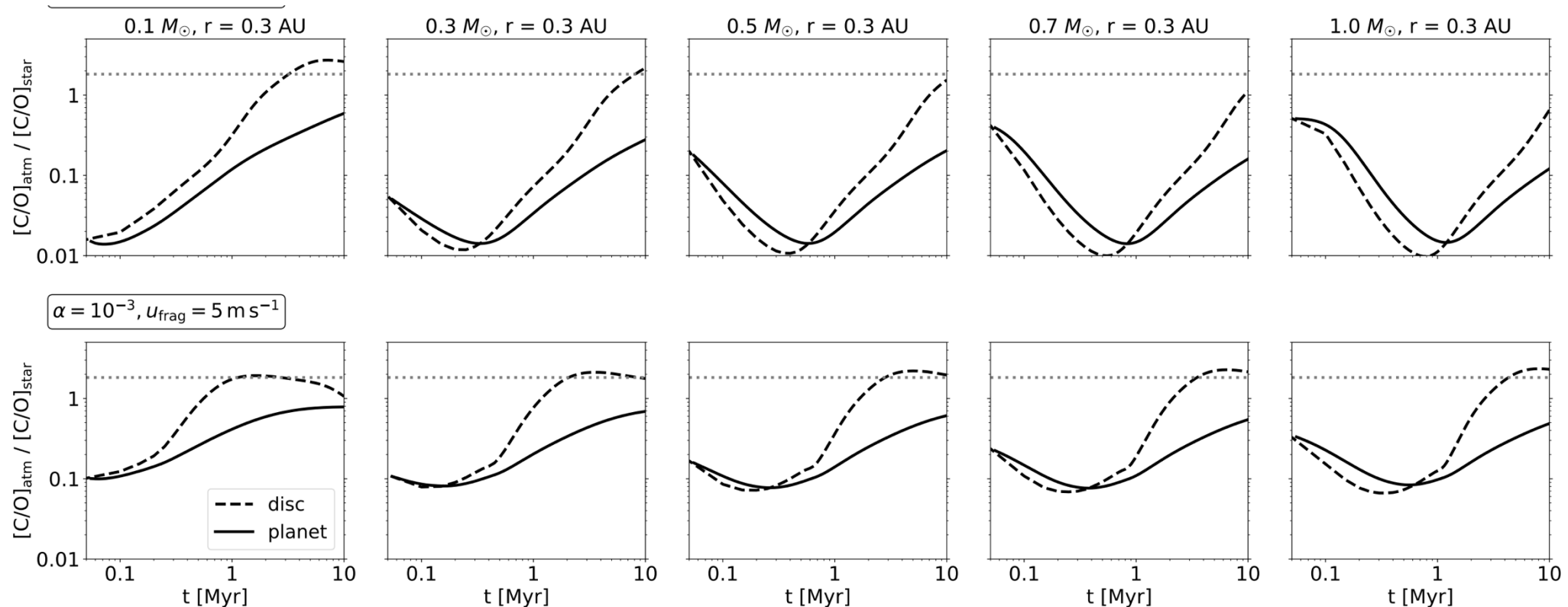


The C/O ratio evolves, predicting strong dependence of planet composition on stellar mass and disk age

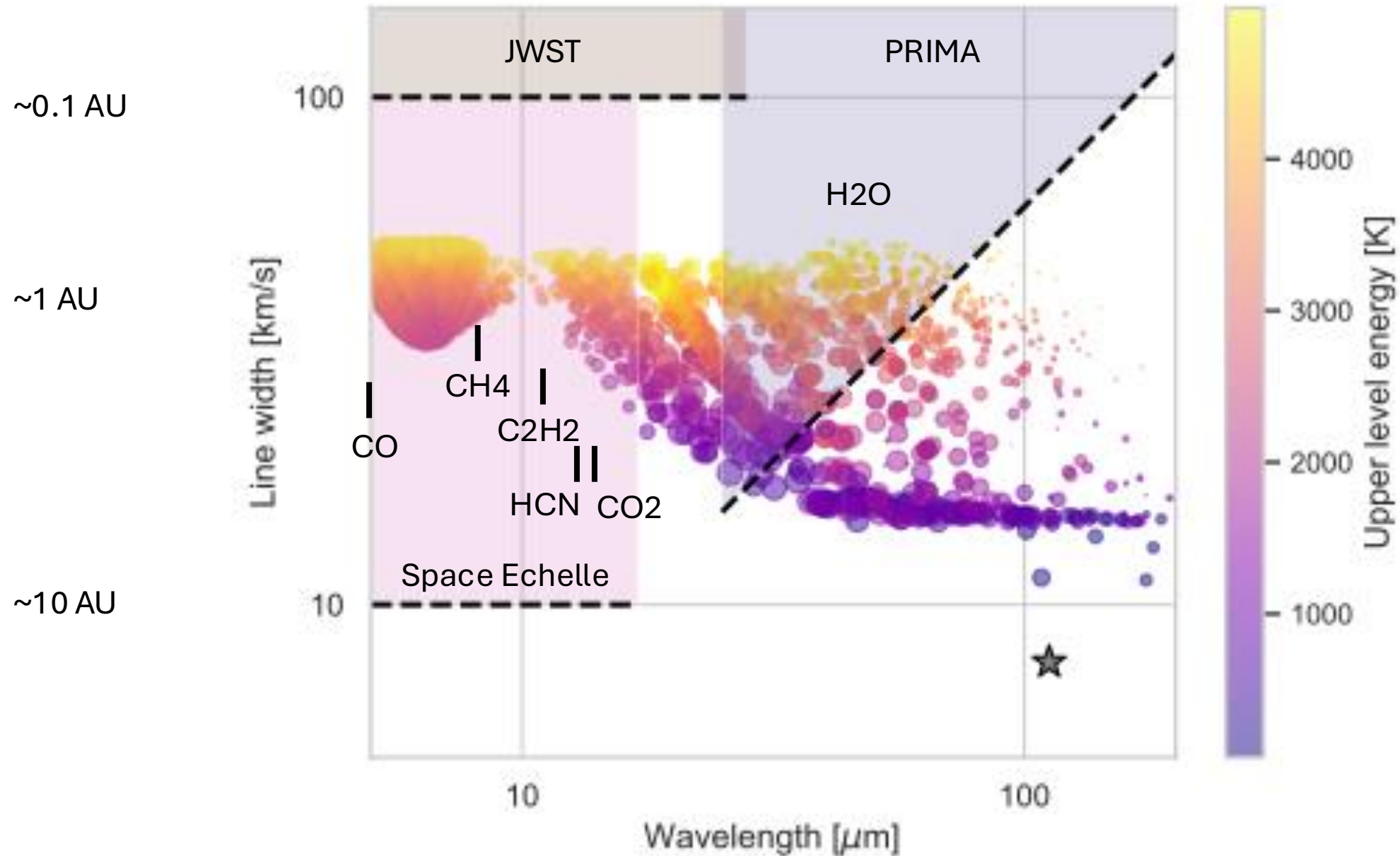


There are multiple competing explanations for the evolving C/O ratios

- 1) Rapid early drift of O-rich icy pebbles, followed by slow advection of C-rich gas from outside the snowline (Mah+ 2023).
- 2) Slow erosion of C-rich grains into the gas-phase (Colmenares+ 2024).
- 3) Decreasing dust opacity leading to line tracers probing deeper layers in the disk (Arabhavi+ 2025).

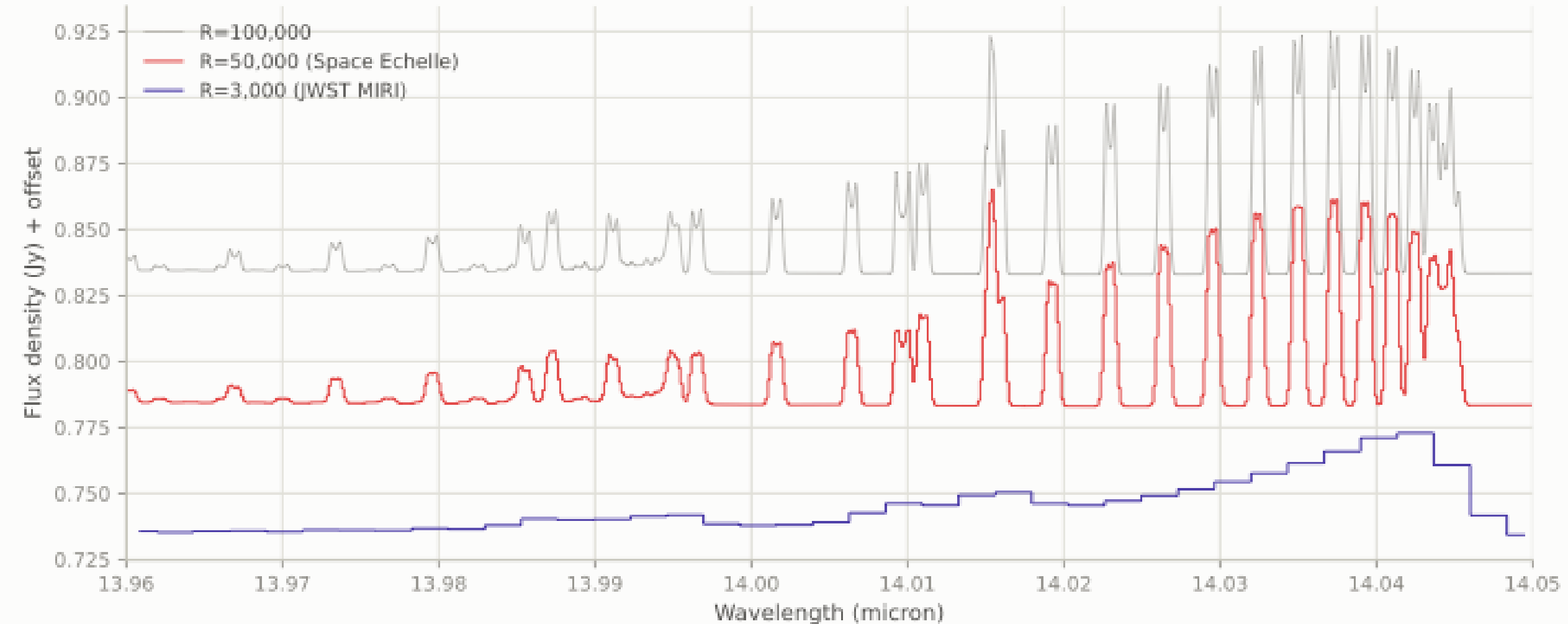


No existing or planned instrument is capable of kinematically resolving hydrocarbon lines in the planet-forming region



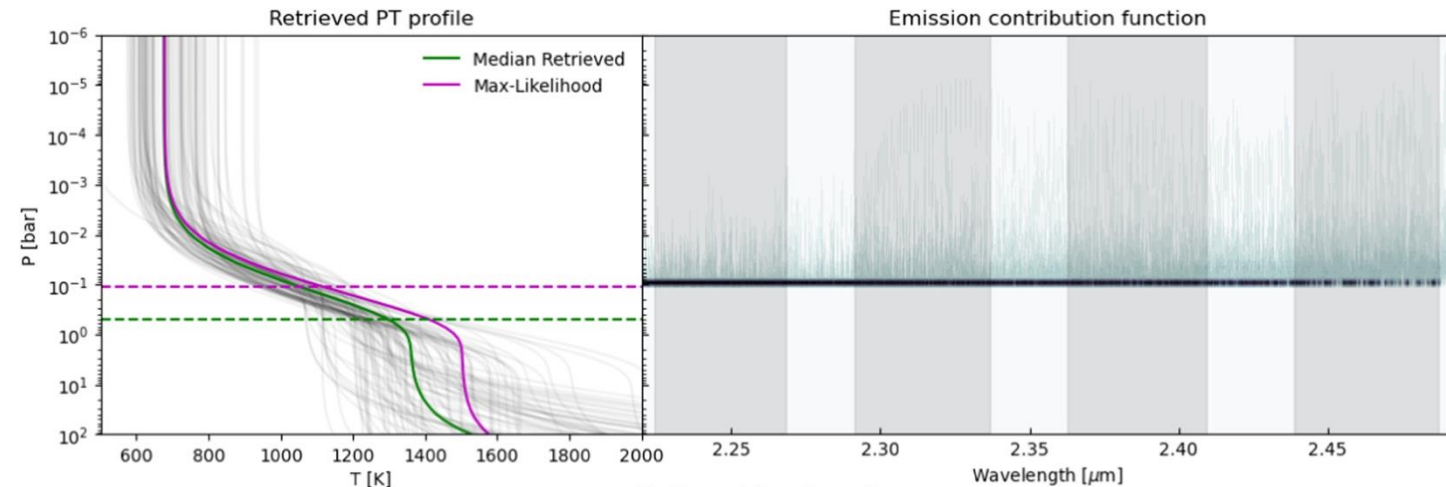
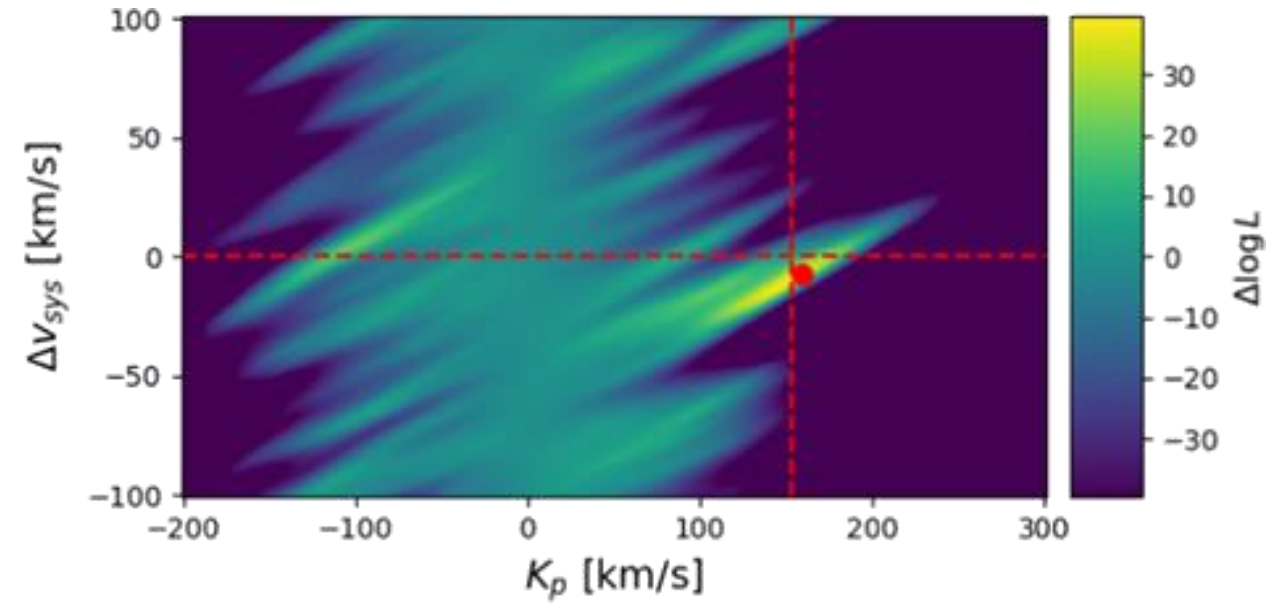
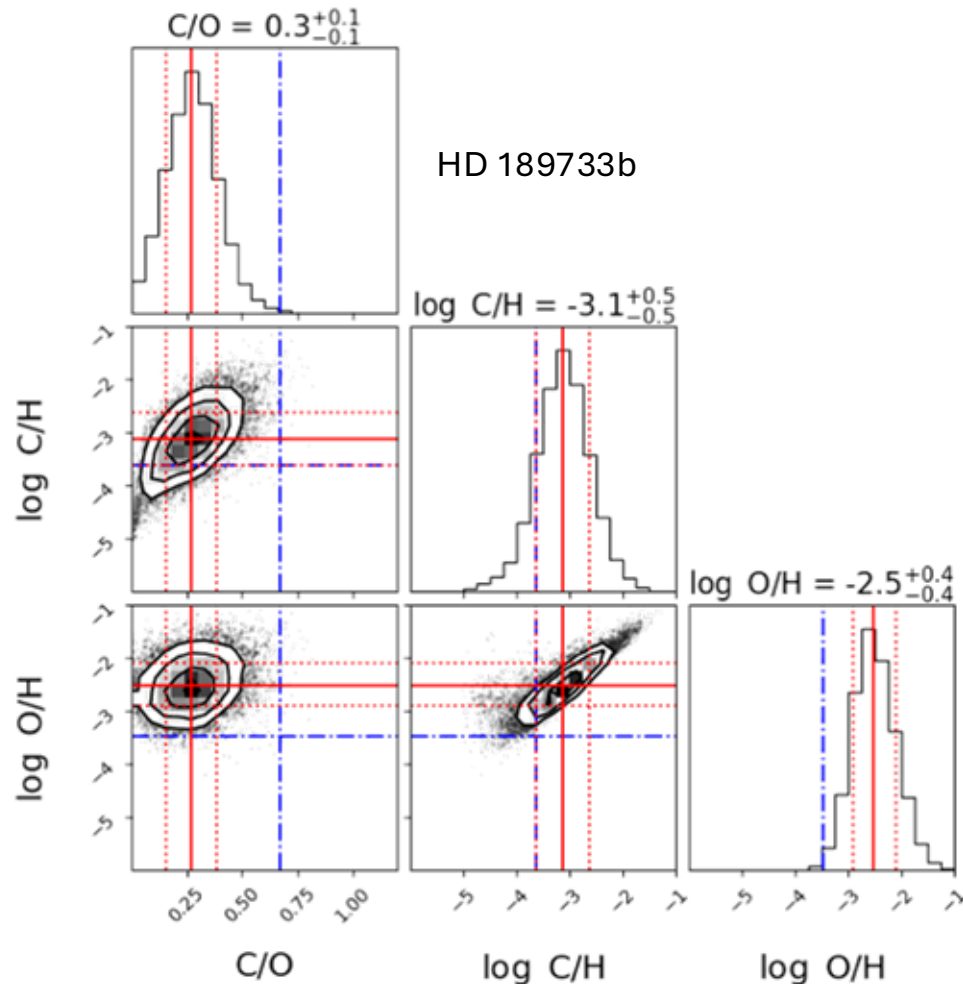
$R > 30,000$ kinematically resolves key mid-infrared molecular lines in disks and planets.

HCN Q-branch: spectral resolution comparison



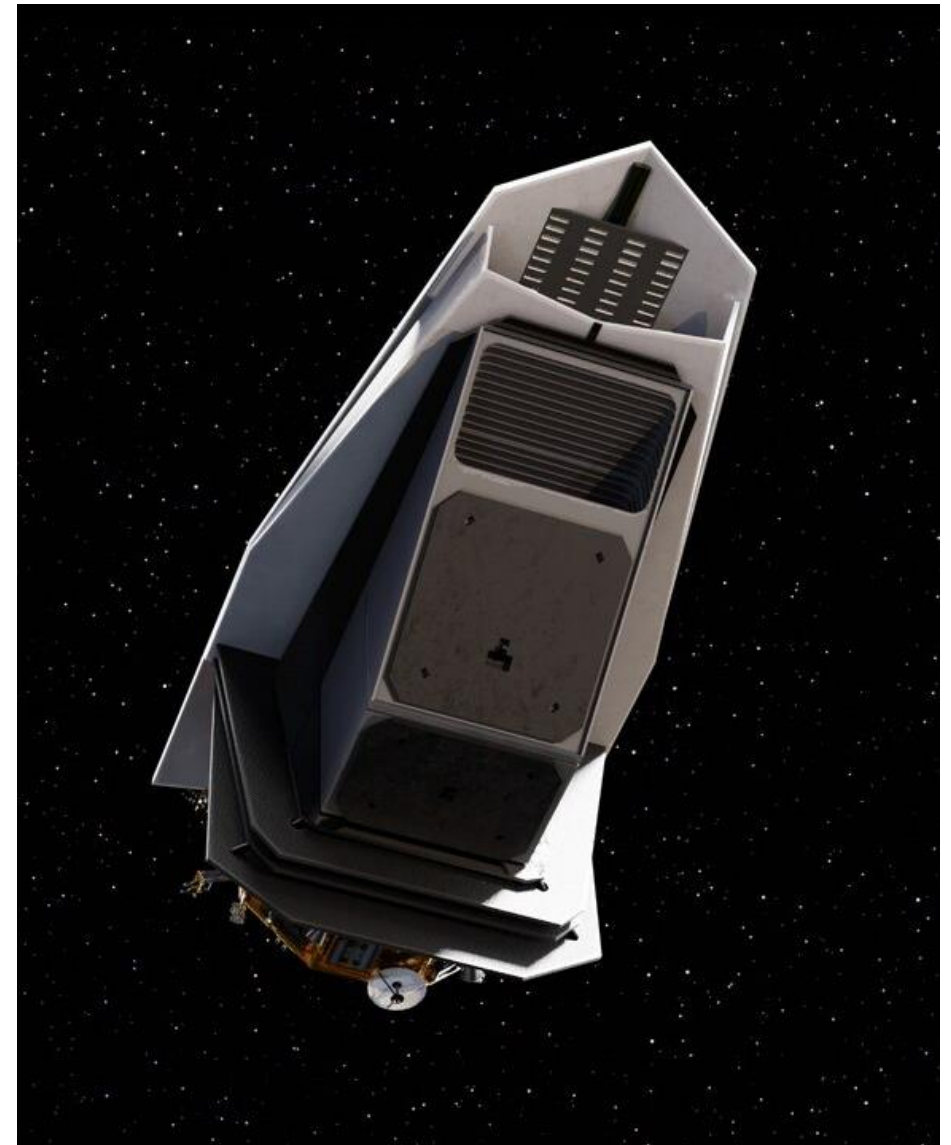
High-resolution ($R > 30,000$) spectroscopy of hot jupiters to mini-neptunes precisely retrieve metallicities and pressure profiles

Cross-correlation Doppler analysis of high-res ($R \sim 35,000$) spectra of exoplanets constrains **both** metallicities and pressure profiles (from the Keck Planet Imager and Characterizer - KPIC).



A “Space Echelle” is required to make progress in connecting exoplanets to disk chemistry beyond JWST

- **Same instrument** targets the C/O/H ratios in both protoplanetary **disks** and giant **exoplanets**.
- **Telescope/SC:** Sufficient sensitivity provided by ~1.0-1.5 m primary aperture, passively cooled to ~50 K at L2.
- **Instrument:** Cross-dispersed immersion Si+Ge gratings with multiple sequential or simultaneous channels allowing broad-band spectral coverage from 3-15 micron at $R > 30,000$. System throughput $> 20\%$
- **Measurements:** Bands of CH_4 , C_xH_x hydrocarbons, HCN, CO_2 , H_2O , CO, H_2 , OH, and a wide range of atomic lines.
 - Sensitivity: Disks to 30 mJy in 1 hour (100σ); detect Jupiter-mass planet atmospheres to $V \sim 10$ mag with cross-correlation Doppler techniques.
- **Heritage:**
 - NEOSurveyor, SPHEREx heritage
 - Operational ground-based immersion gratings
 - Compact design without moving parts
 - HgCdTe detectors with long-wave cutoff
- **Community:** Core exoplanet and disk science cases, but with potential for extensive General Observer program.
- **Technology challenges:** Long-wave detector cutoff to 14 micron with 100 Mpx FP, efficient cross-dispersed optical design.



Neosurveyor