Surveying hot Jupiter atmospheres with Keck/KPIC

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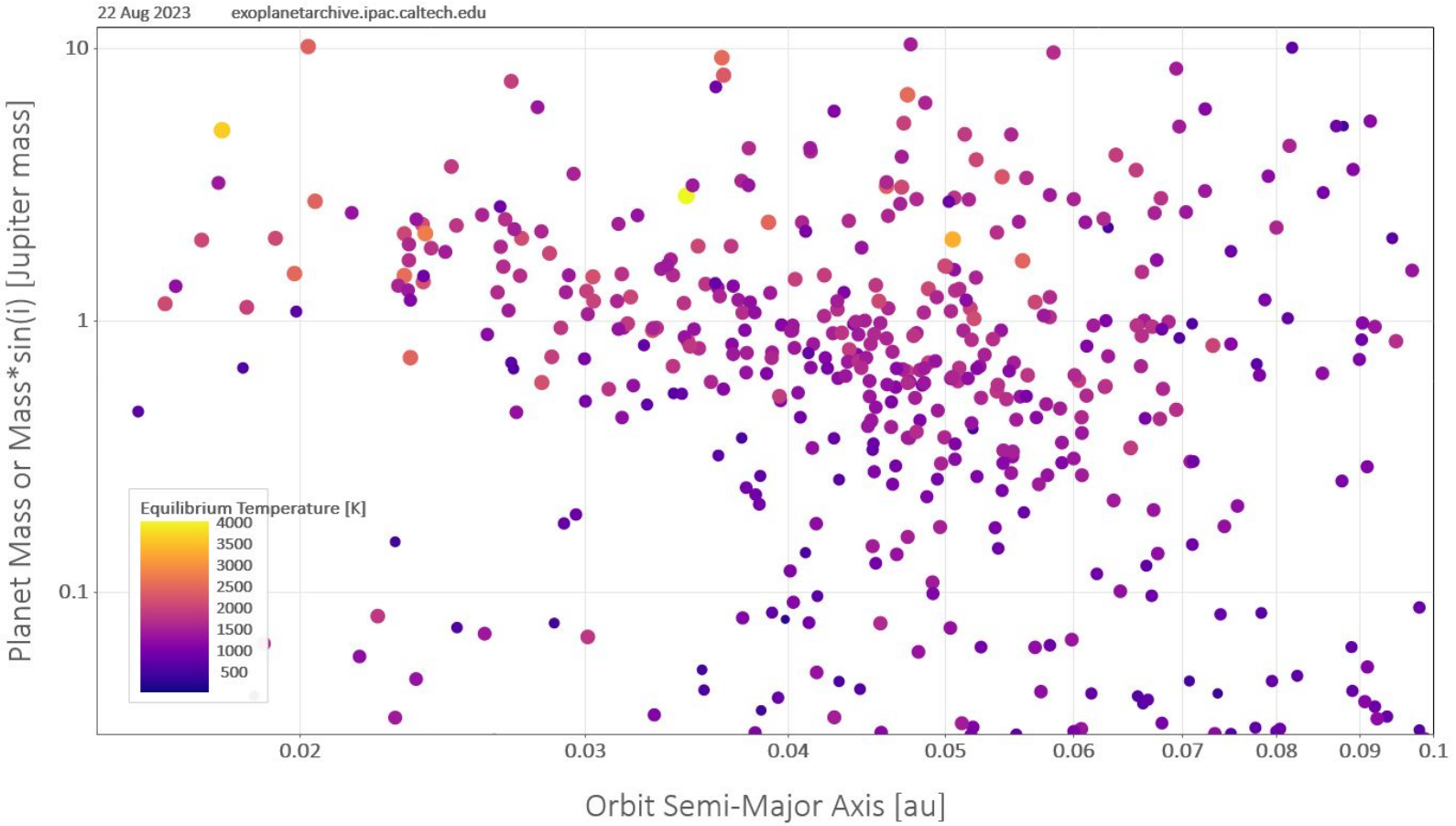


Hot Jupiters in context

Formation pathways

Core Accretion

- Solid core becomes large enough to undergo runaway gas accretion
- Requires initial solid core
- Atmospheric composition depends on location with respect to snow lines, solid:gas accretion ratio
- Accretion and disk lifetime limit mass

Direct collapse

- Portion of protoplanetary disk becomes gravitationally unstable and collapses
- Requires instability conditions
- Composition similar to stellar
- Can produce very high masses very quickly

Formation pathways

Disk migration

- Giant planet migrates inwards due to interactions with disk
- Continues accreting during migration
- Aligned with host star
- Migration stops at/before inner edge of disk

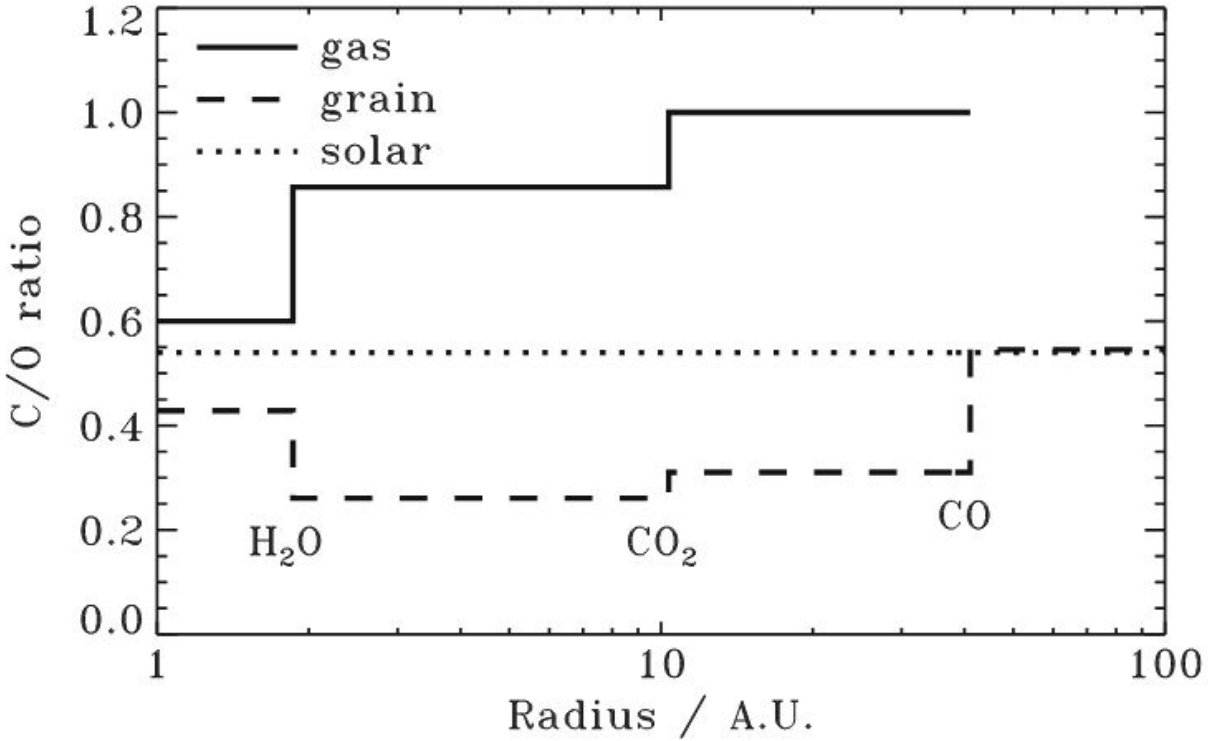
High-eccentricity migration

- Giant planet migrates inwards due to scattering with another companion
- Disk dissipated prior to migration, no continued accretion
- Misaligned final orbits
- Tidal circularization requires very small periapsis

In/near-Situ

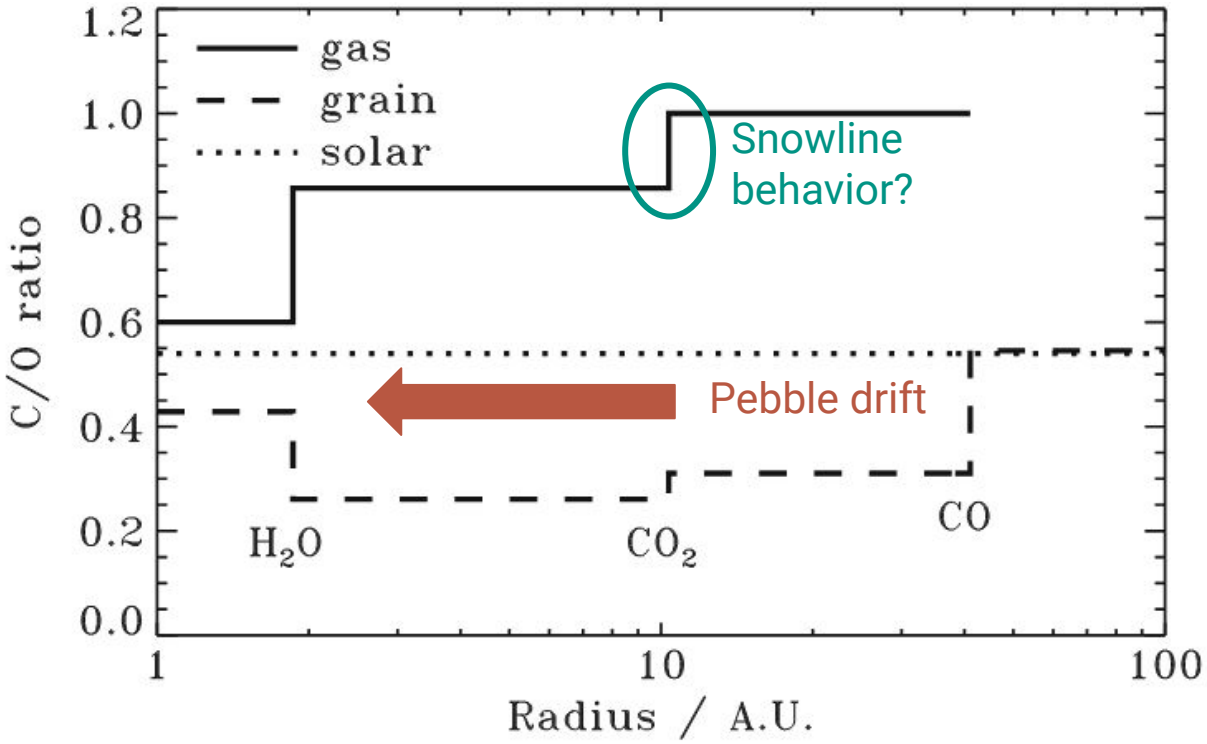
- Can massive planets form inside water ice line?
- Massive disks?
- Aligned orbits
- Beyond inner edge of disk (absent later migration)

Chemical tracers of formation



Oberg, Clay, & Bergin (2011)

Chemical tracers of formation



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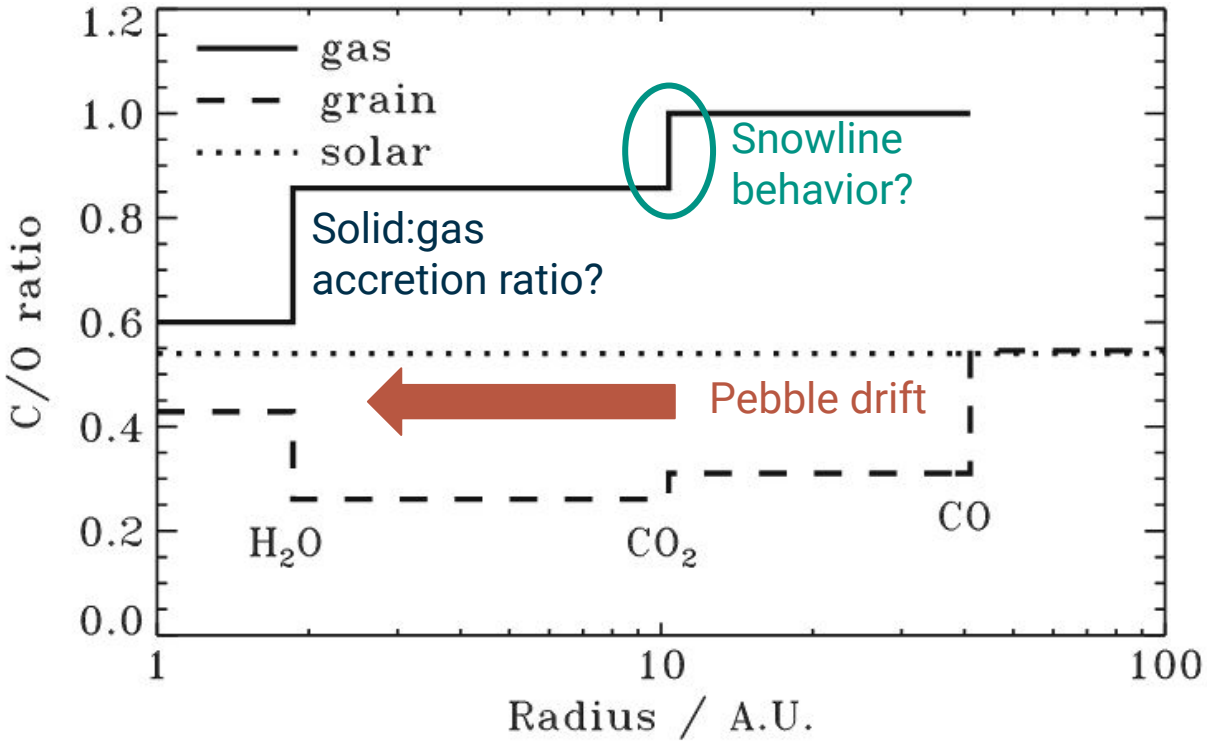

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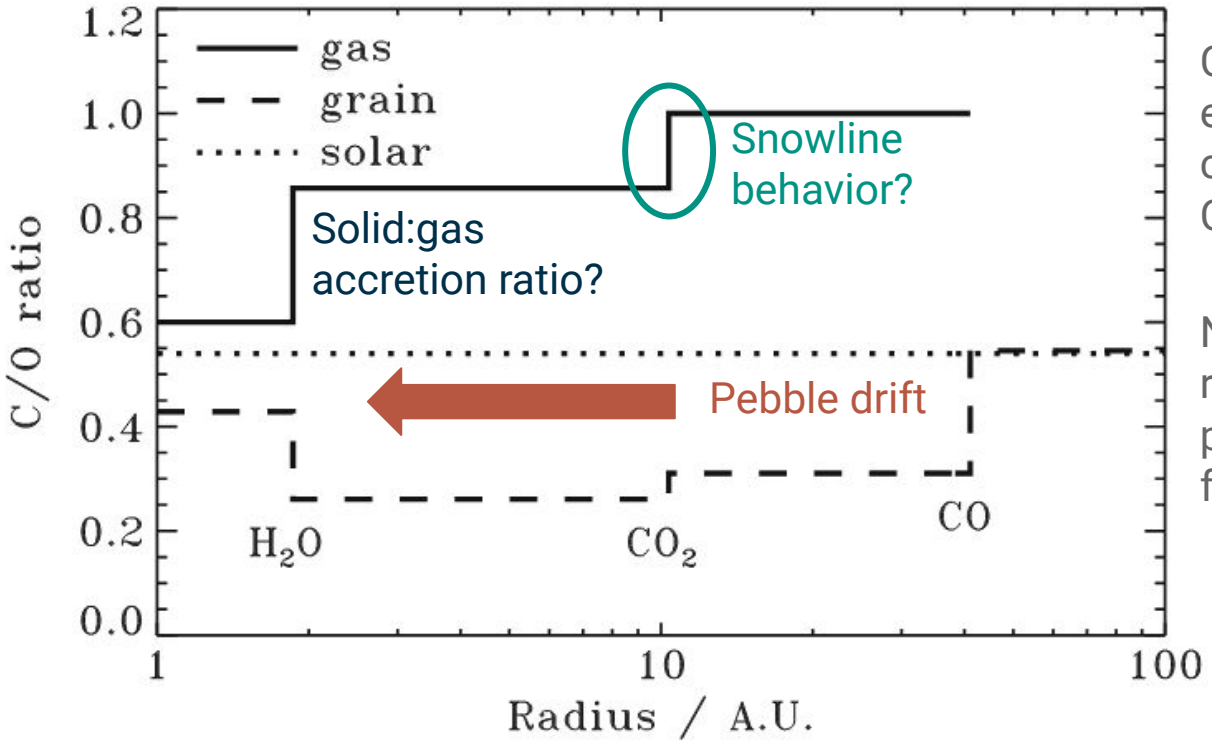
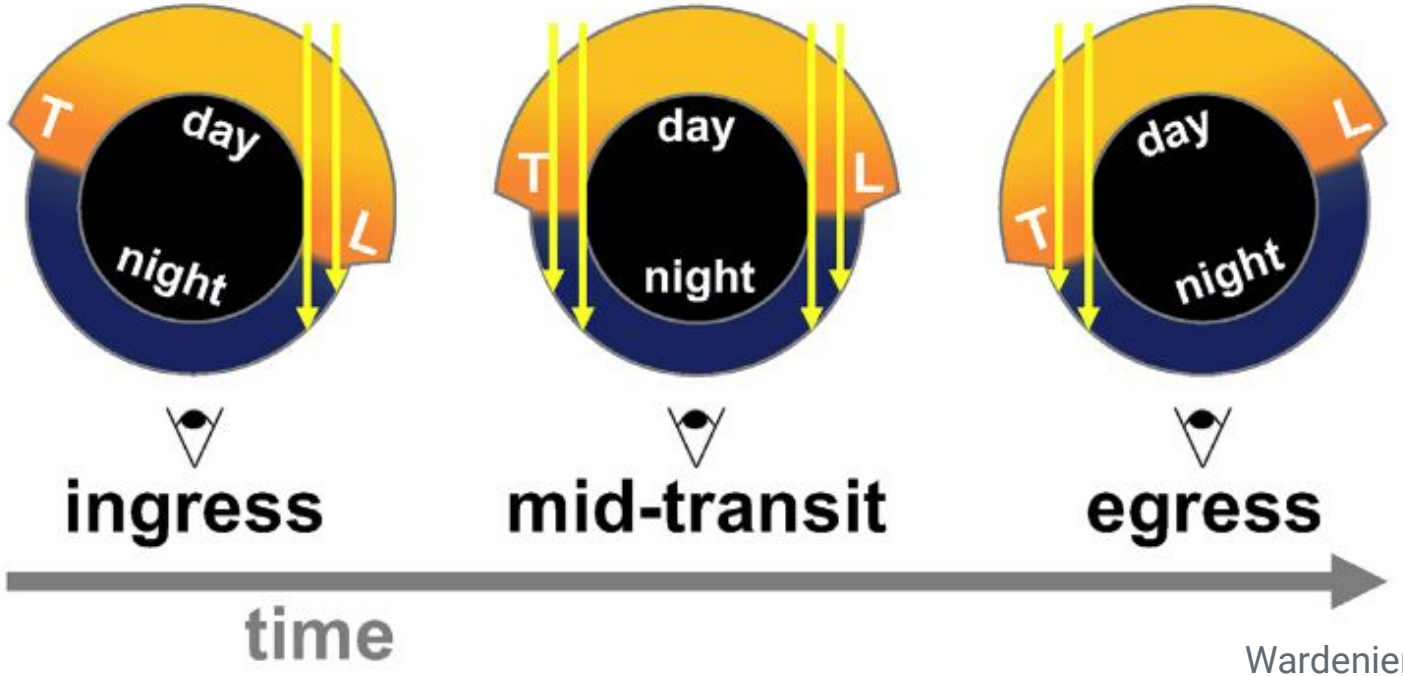


Core accretion: expect inverse correlation between C/O and C/H

N/O, Si/C, $^{12}C/^{13}C$, refractory/volatile all potentially interesting formation indicators

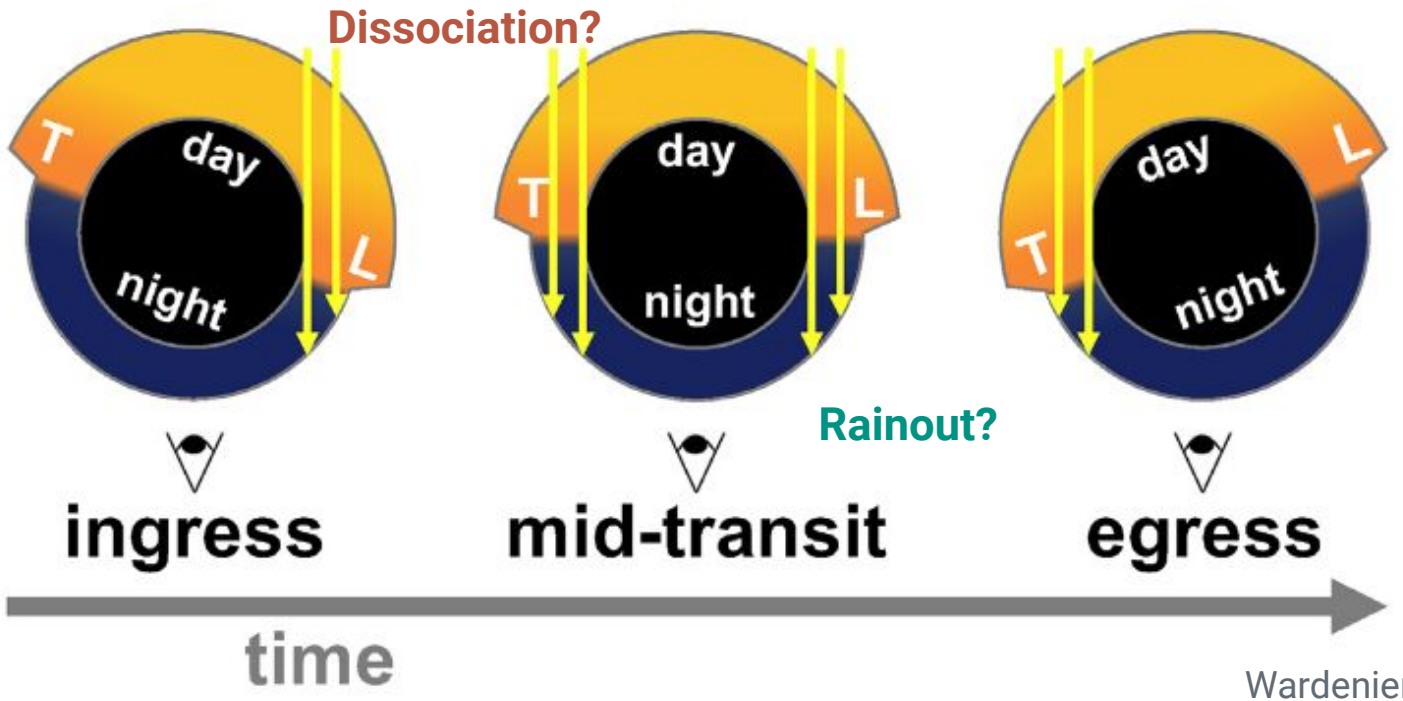
Oberg, Clay, & Bergin (2011)

Challenges to characterization



Wardenier et al (2021)

Challenges to characterization



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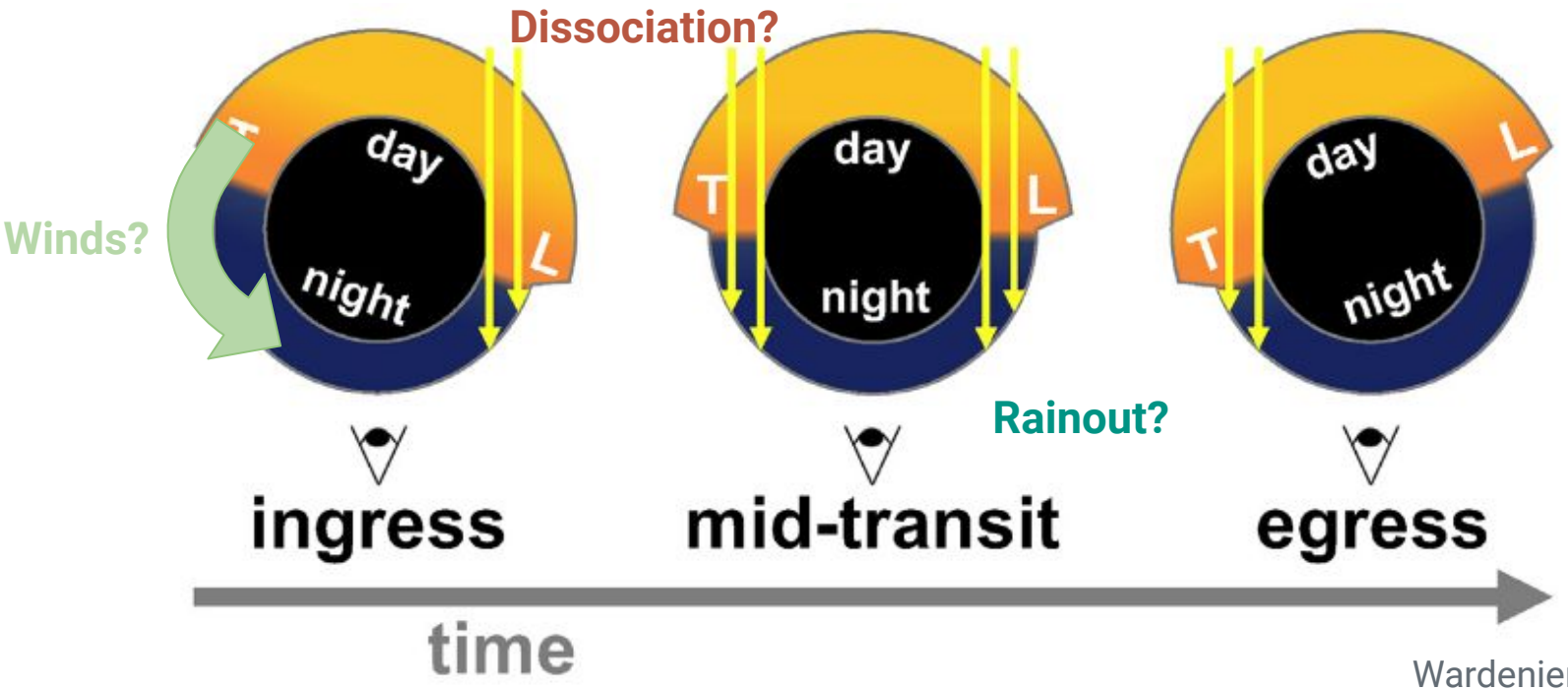
Challenges to characterization



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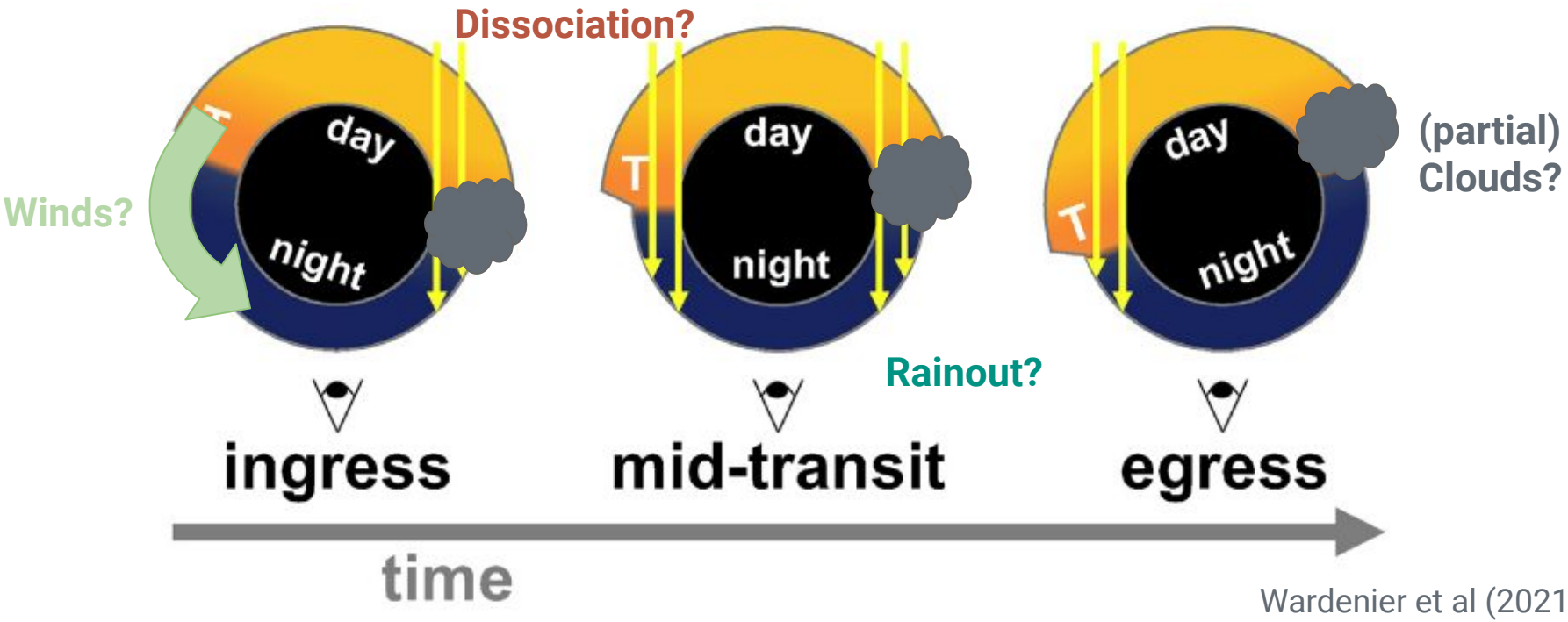

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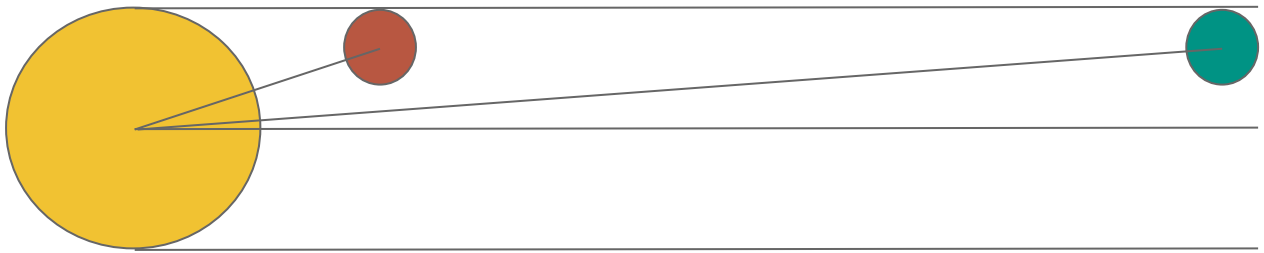


Only 1/10 hot Jupiters transit their host star

Only 1/200 planets at 1 AU transit their host star

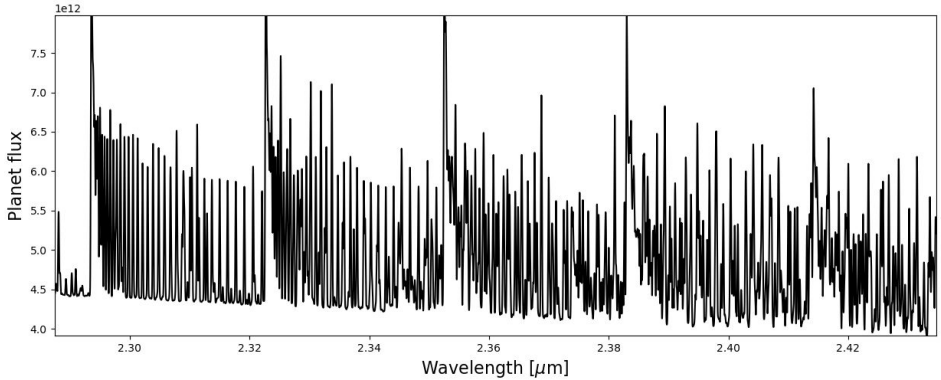
Transiting planets are rare, and dimmer on average. How do we characterize the rest?

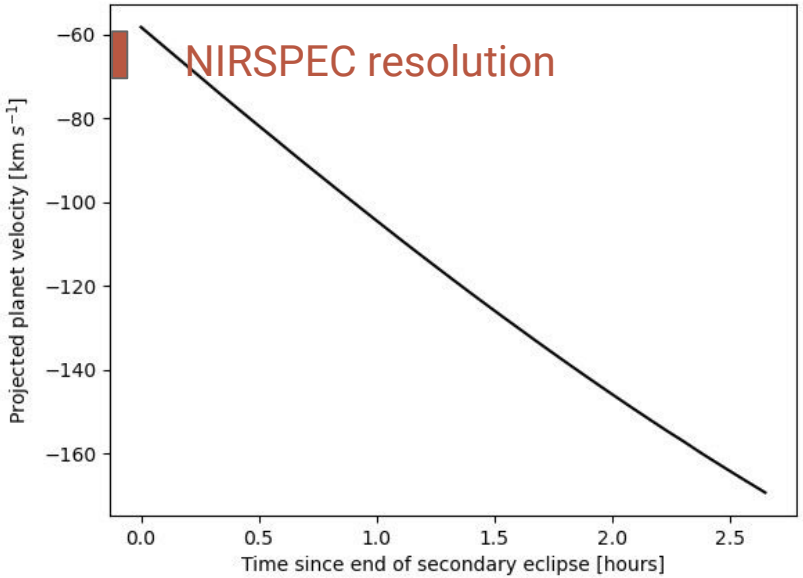
Hot Jupiters as binaries

- Hot Jupiters have star/planet contrasts of ~few x 10^{-4} in near-infrared

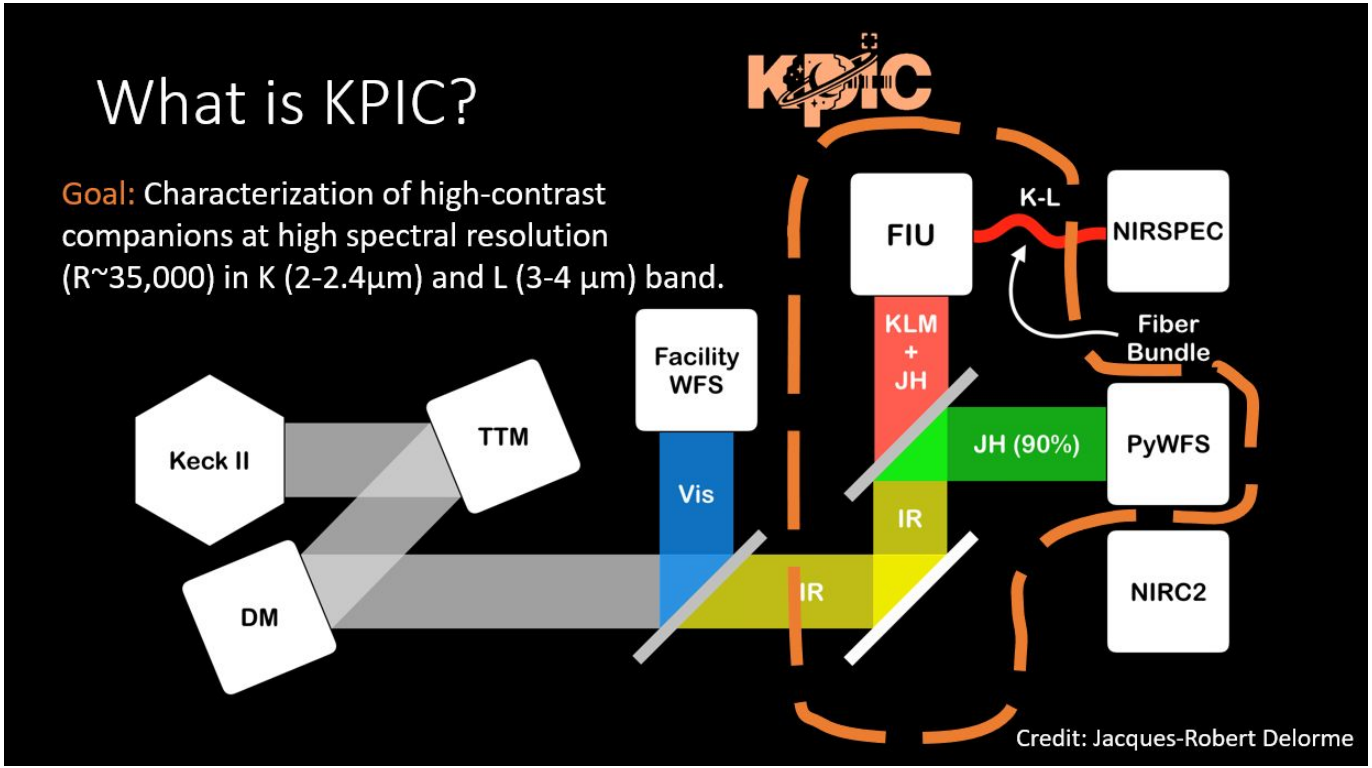
Hot Jupiters as binaries

- Hot Jupiters have star/planet contrasts of ~few x 10^{-4} in near-infrared
- High resolution spectrographs resolve many planet lines
- Planet lines shift in wavelength

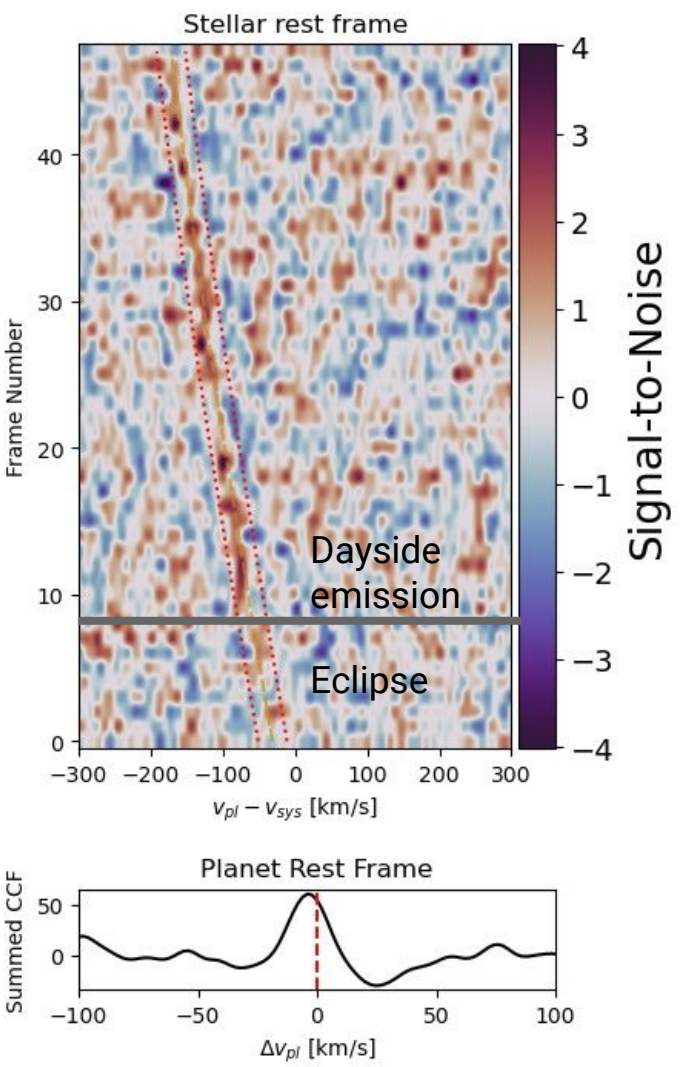




Keck/KPIC

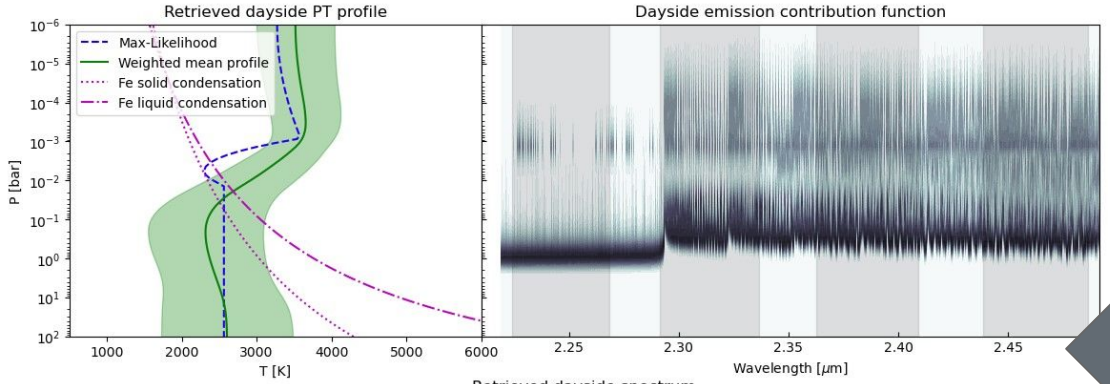

What is KPIC?
Goal: Characterization of high-contrast companions at high spectral resolution (R~35,000) in K (2-2.4μm) and L (3-4 μm) band.
KPIC
FIU
K-L
NIRSPEC
Fiber Bundle
KLM + JH
Facility WFS
Keck II
TTM
DM
Vis
IR
IR
JH (90%)
PyWFS
NIRC2
Credit: Jacques-Robert Delorme

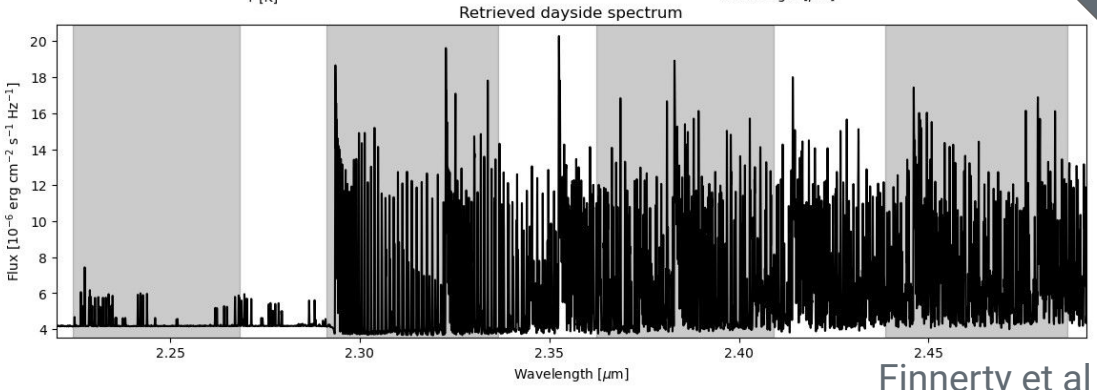
Hot Jupiters with Keck/KPIC

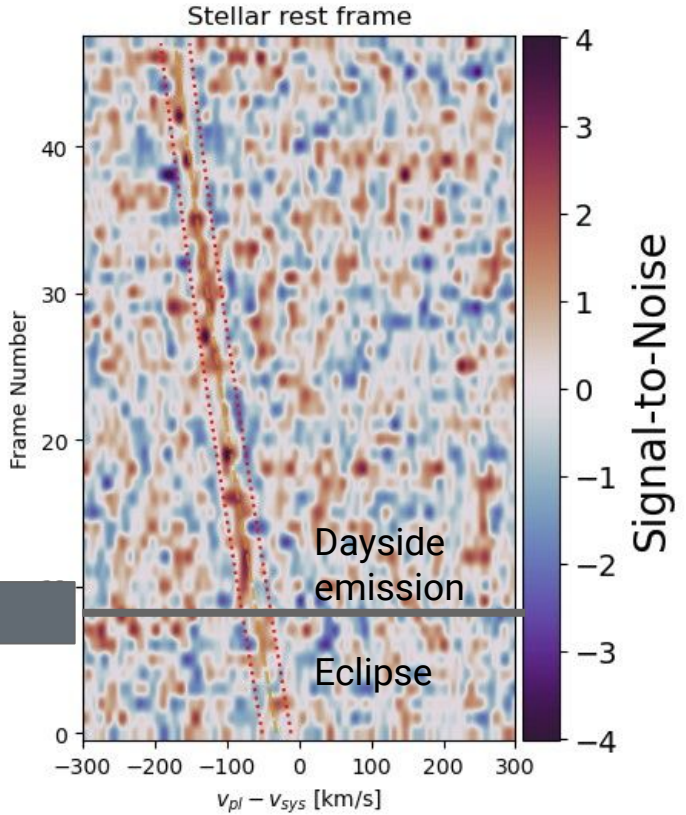


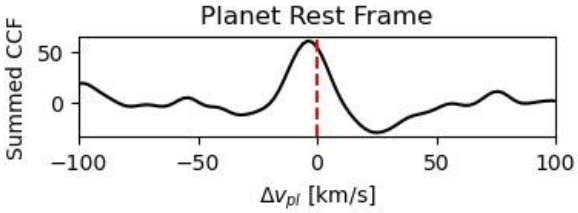
Finnerty et al (2023)

Hot Jupiters with Keck/KPIC





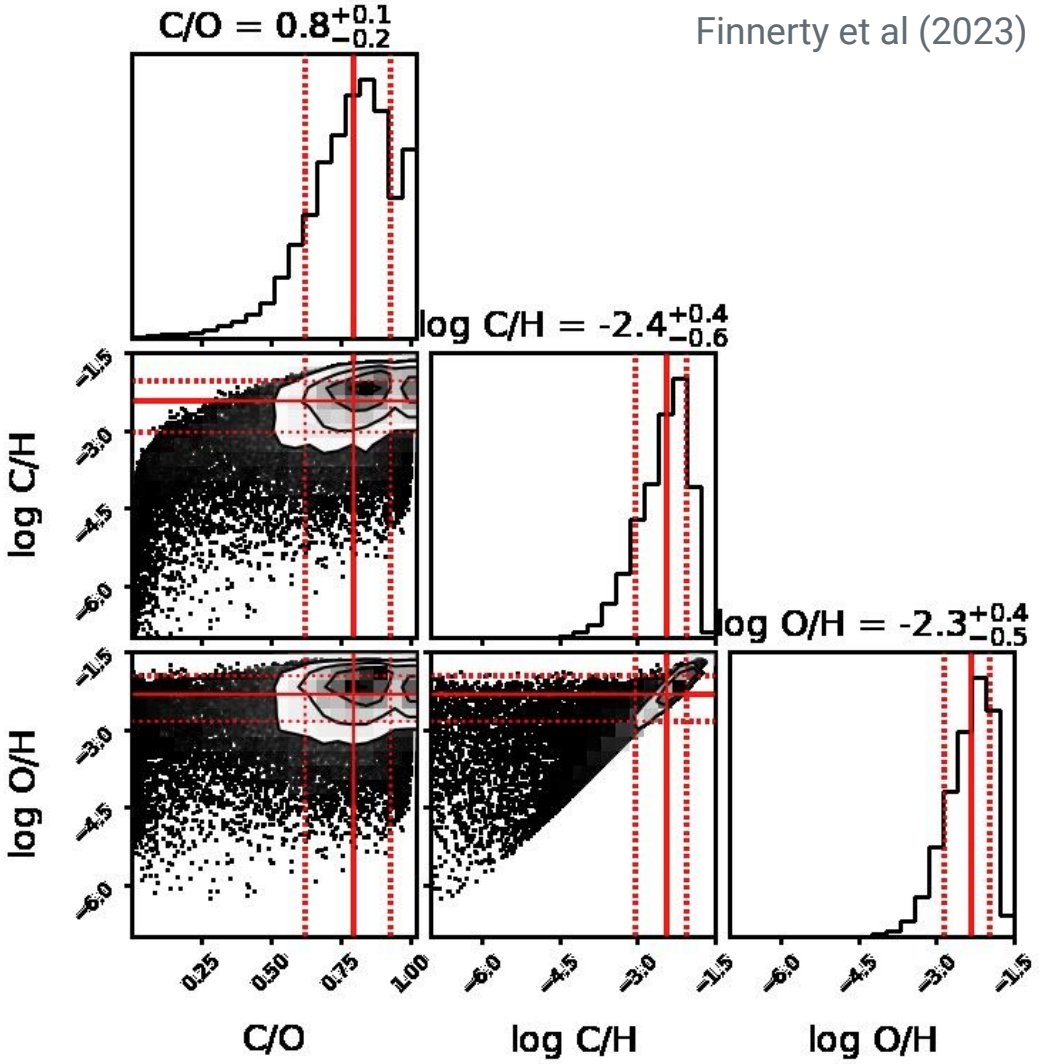




Finnerty et al (2023)

WASP-33 b

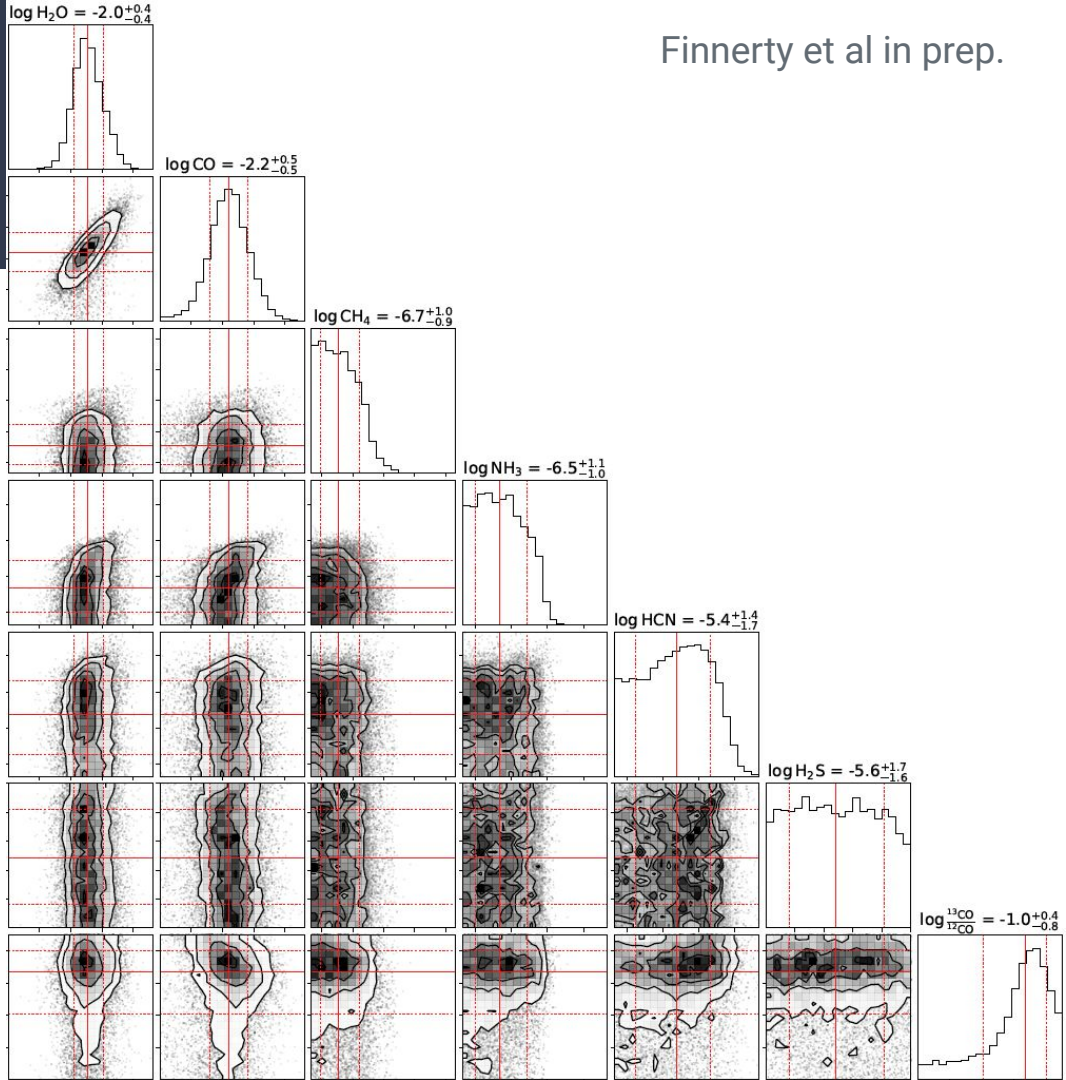
- Retrieved composition is high-C/O, high-metallicity
- WASP-189 b shows similar composition
- Retrieval improvements to address possible dissociation biases



Finnerty et al (2023)

HD 189733 b

Finnerty et al in prep.



HD 189733 b

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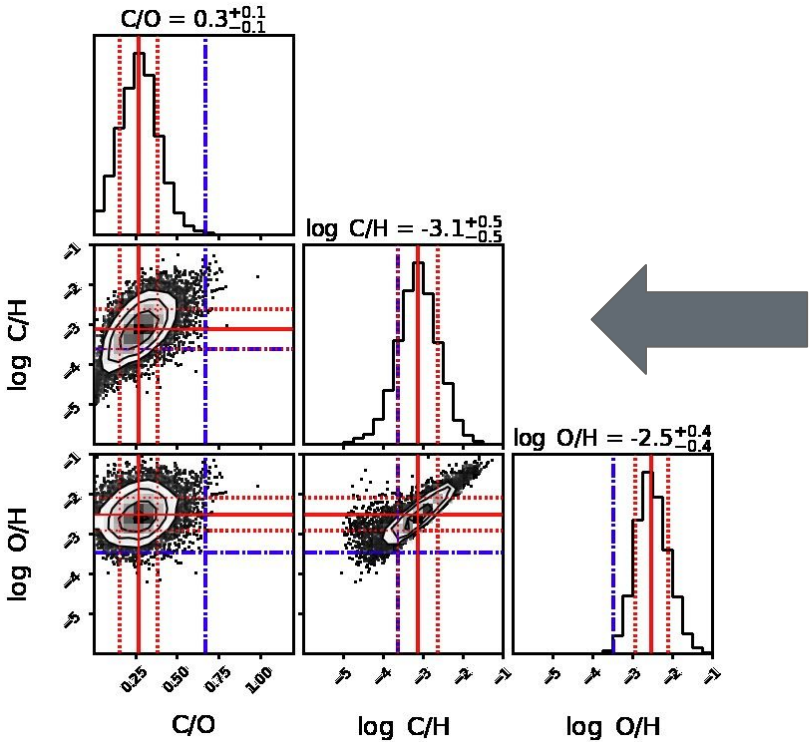

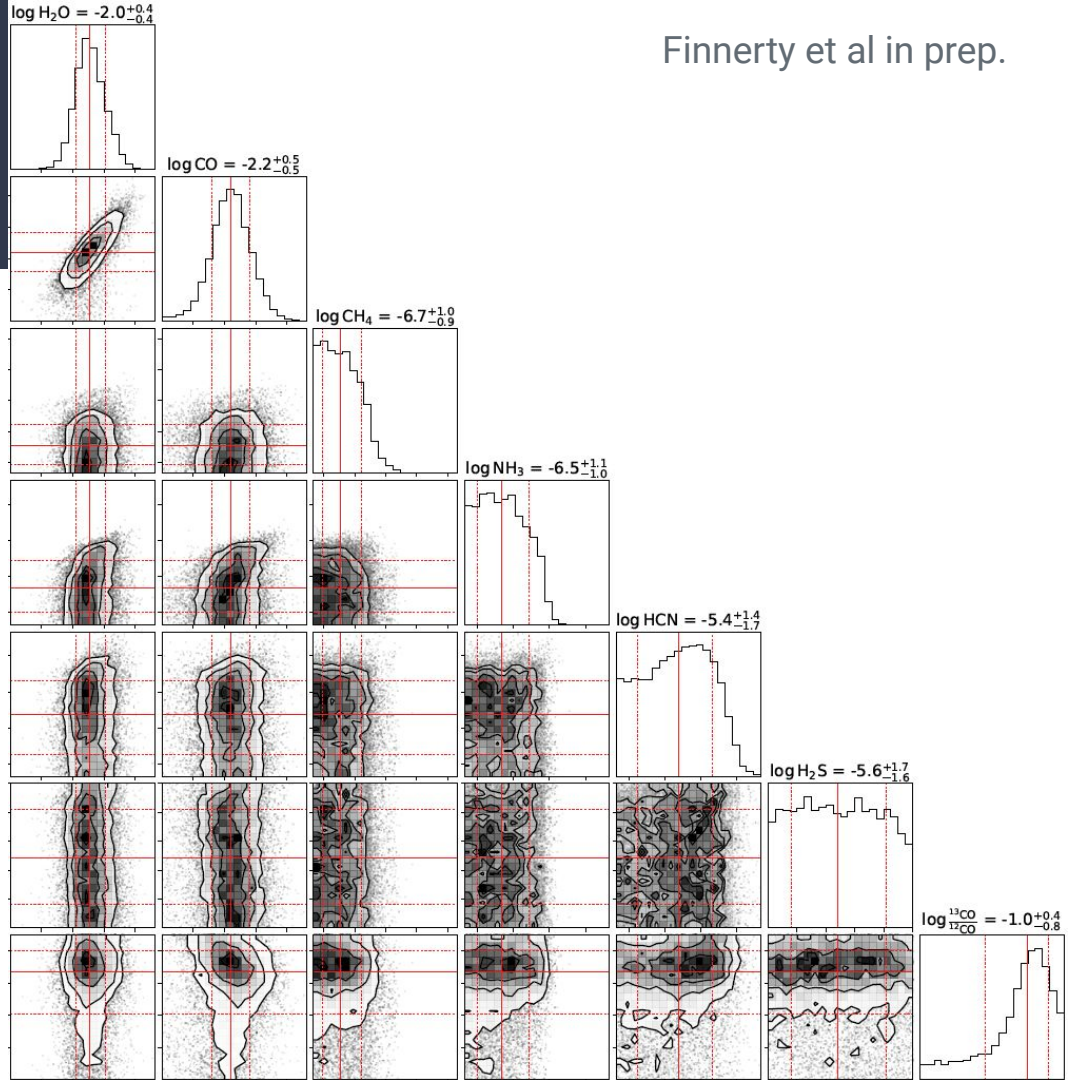

HD 189733 b

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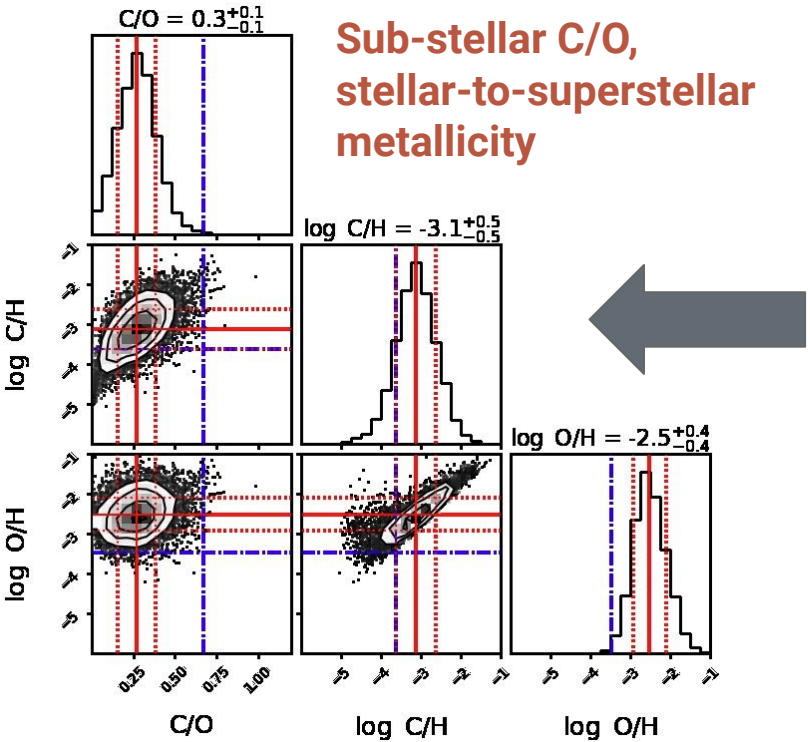
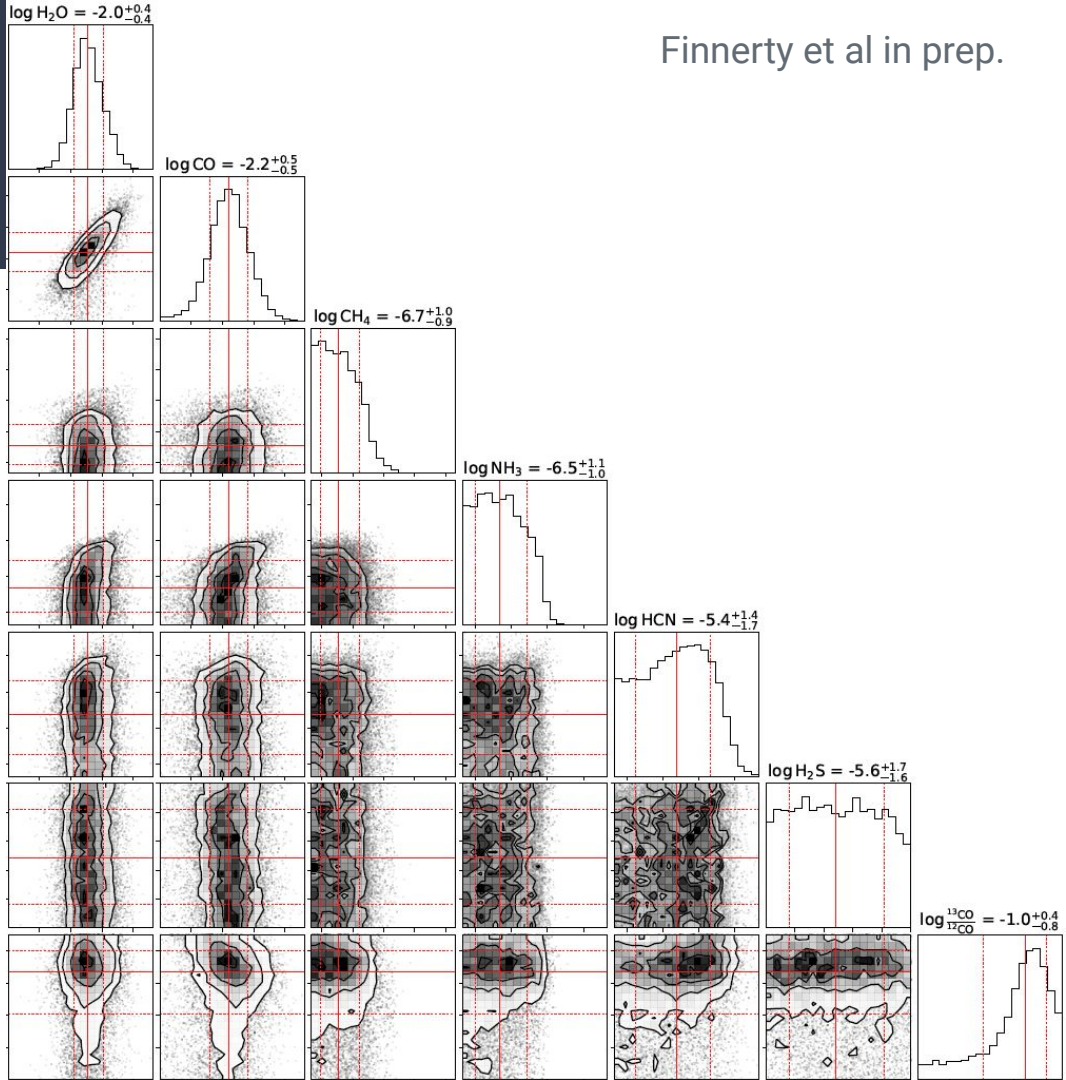
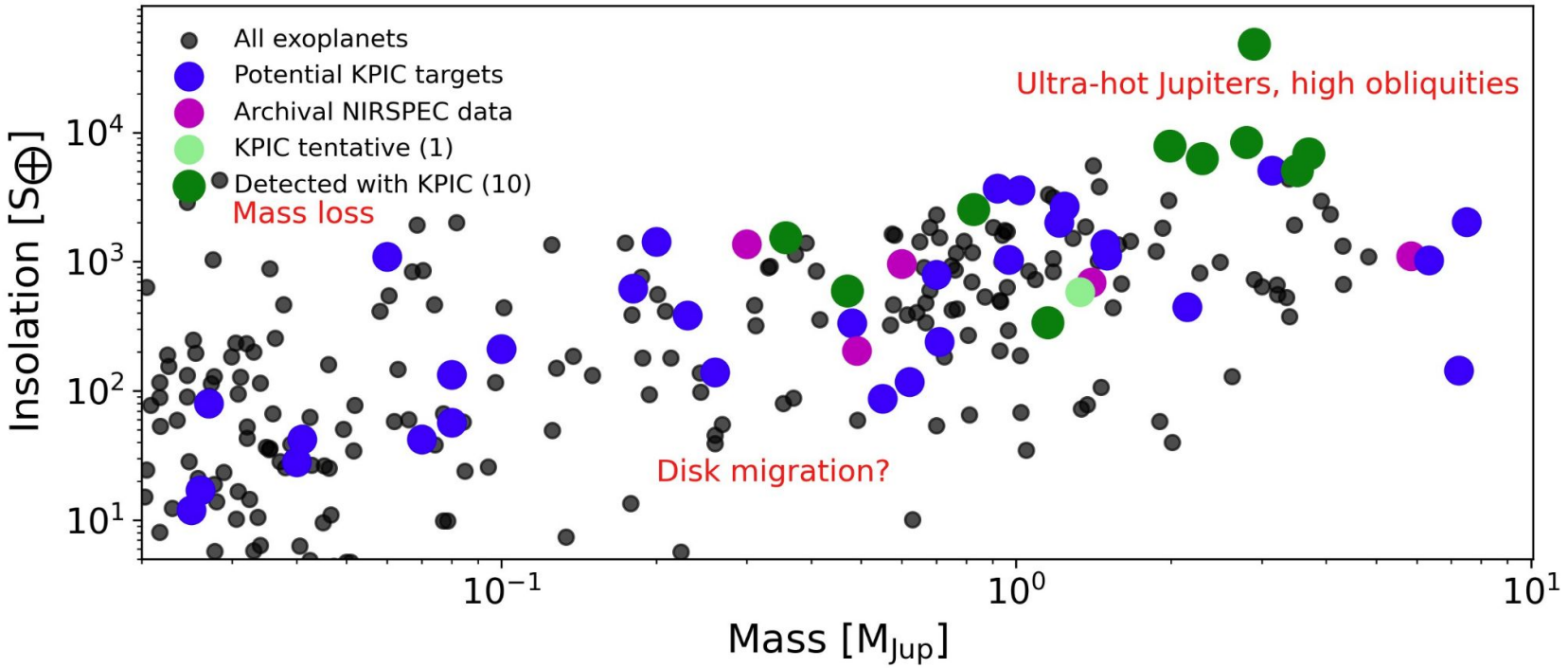
Sub-stellar C/O, stellar-to-superstellar metallicity

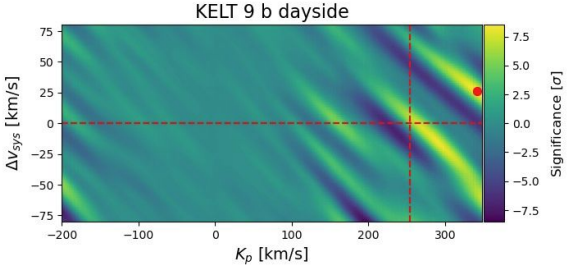


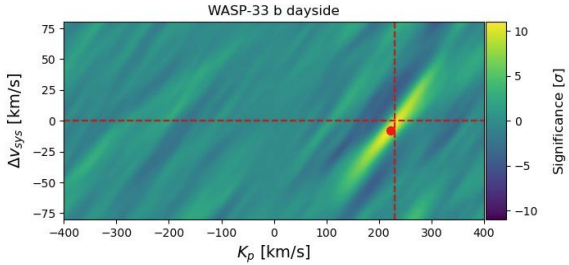


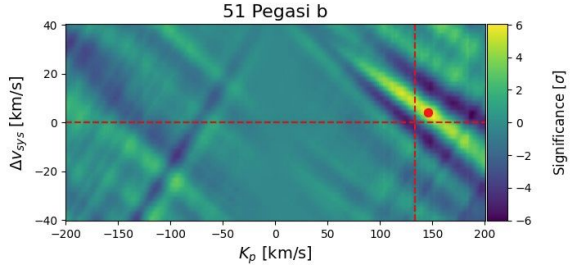
Survey status

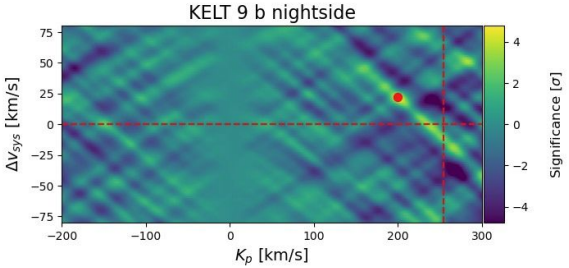


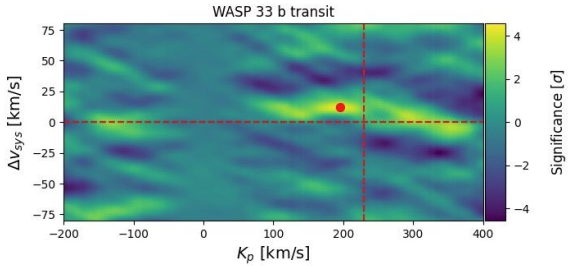
Pre-2023A KPIC hot Jupiter detections

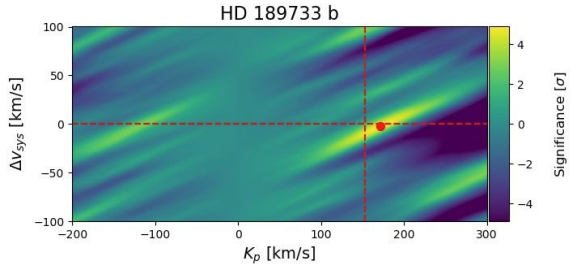




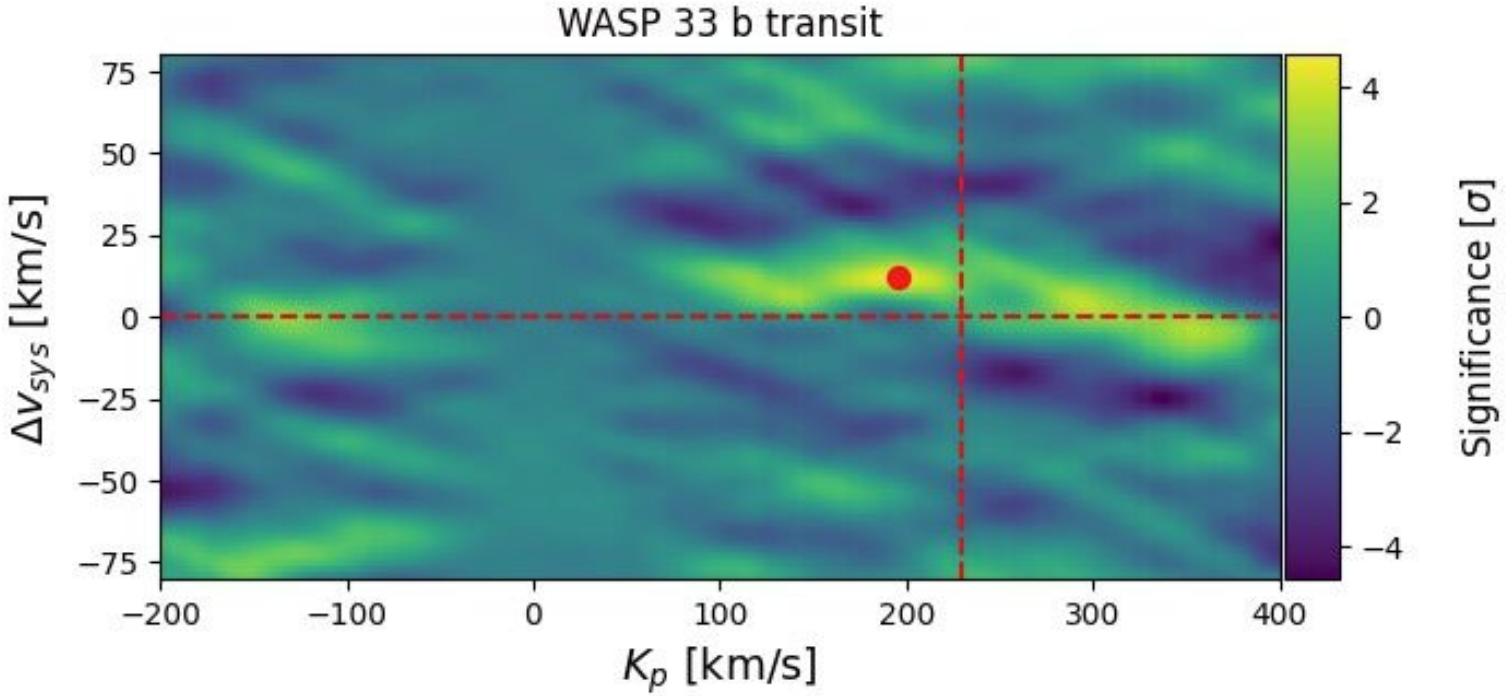




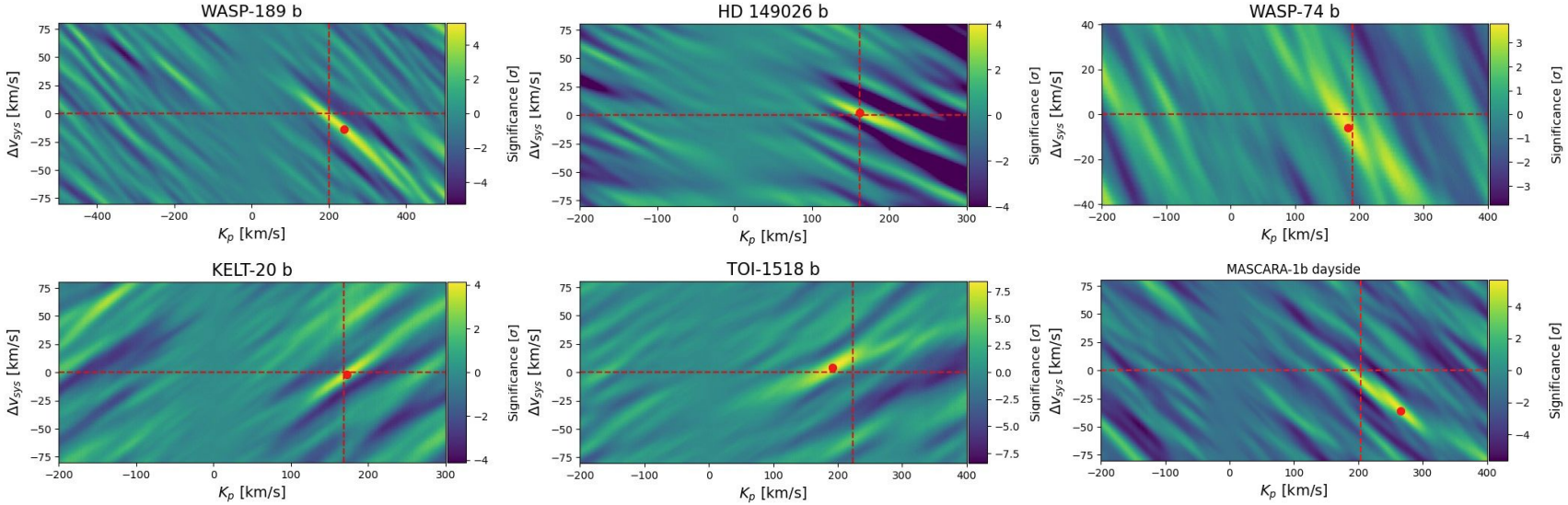




KPIC transmission spectroscopy

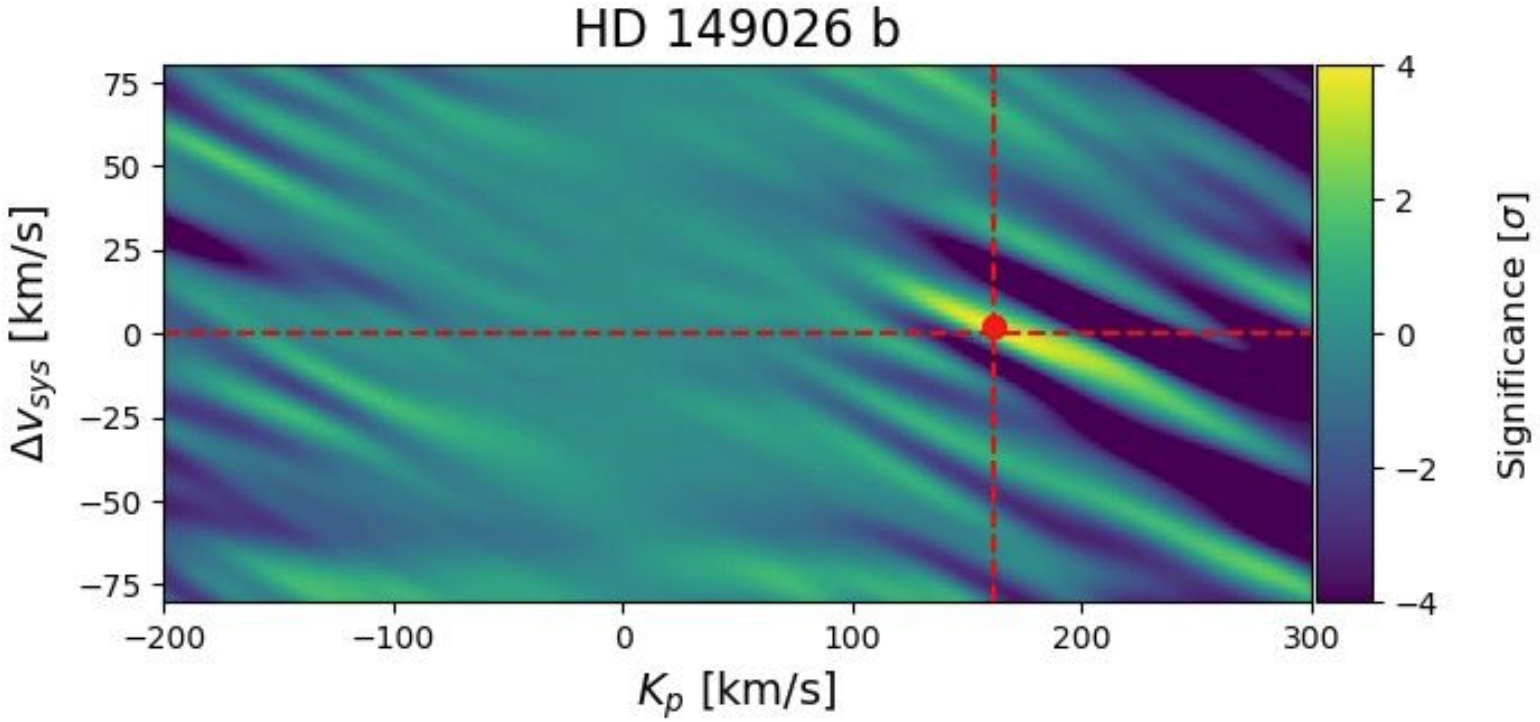


New 2023A KPIC hot Jupiter detections

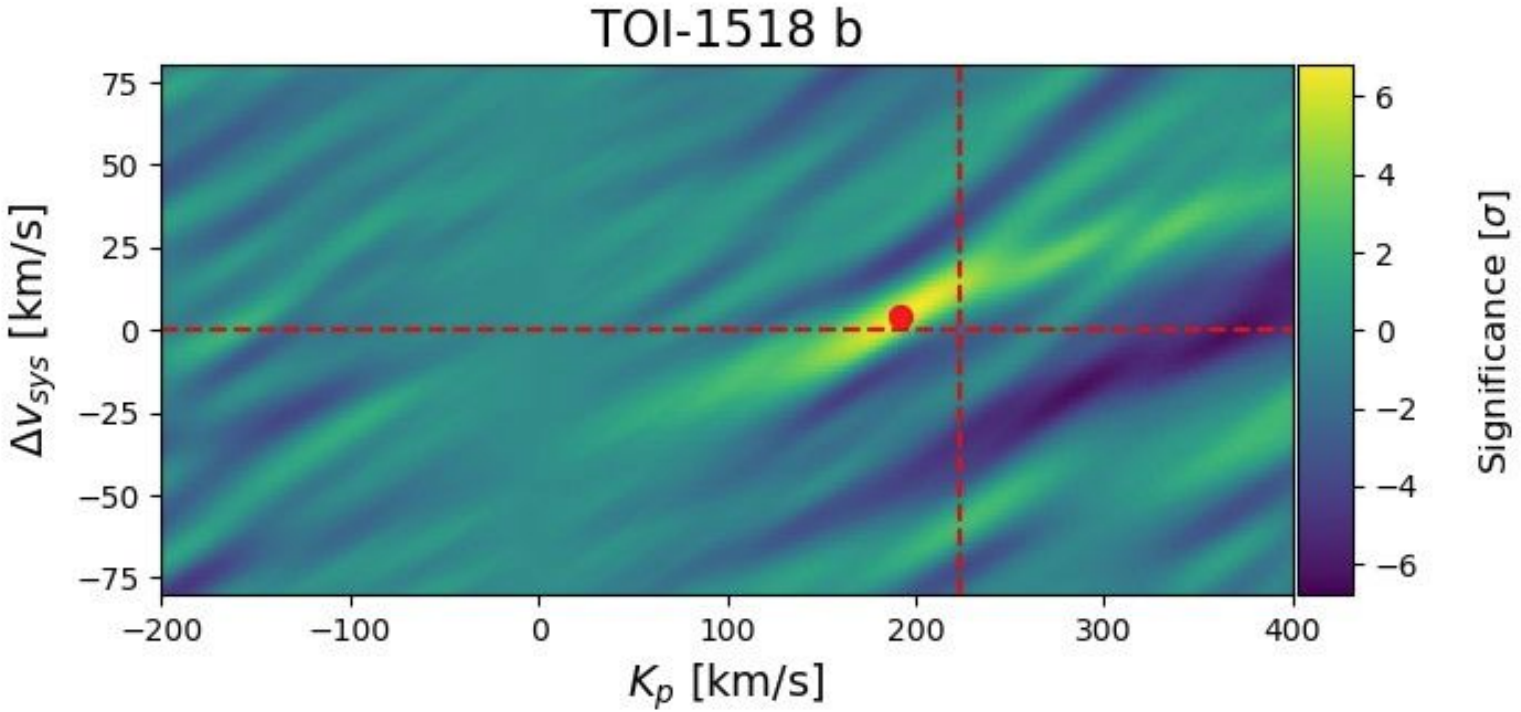


+1 more in progress

200x Solar metallicity?

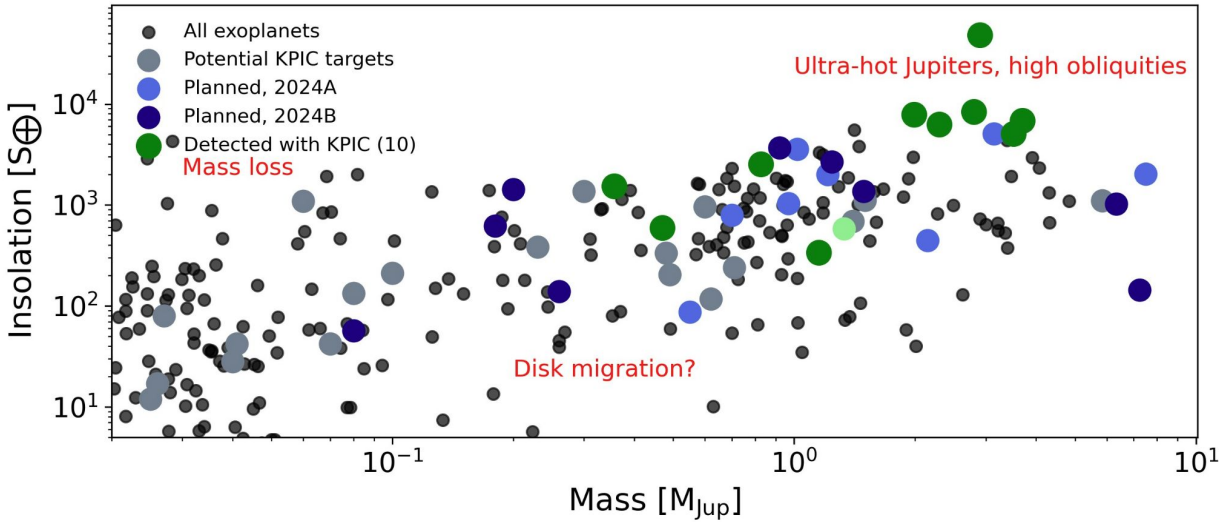


Near-real time quicklook



Towards a population-level understanding

- Underlying distribution of C/O and metallicity constrain formation channel(s)
- Sample achievable by 2024B after 2023B shutdown
- Winds, photochemistry, $^{13}C/^{12}C$ also constrained
- Ongoing improvements to atmospheric retrieval frameworks are easing/speeding analysis



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