Characterizing Gas-giant Exoplanets in the Thermal-Infrared with LBTI and the Arizona Lenslets for Exoplanet Spectroscopy (ALES)

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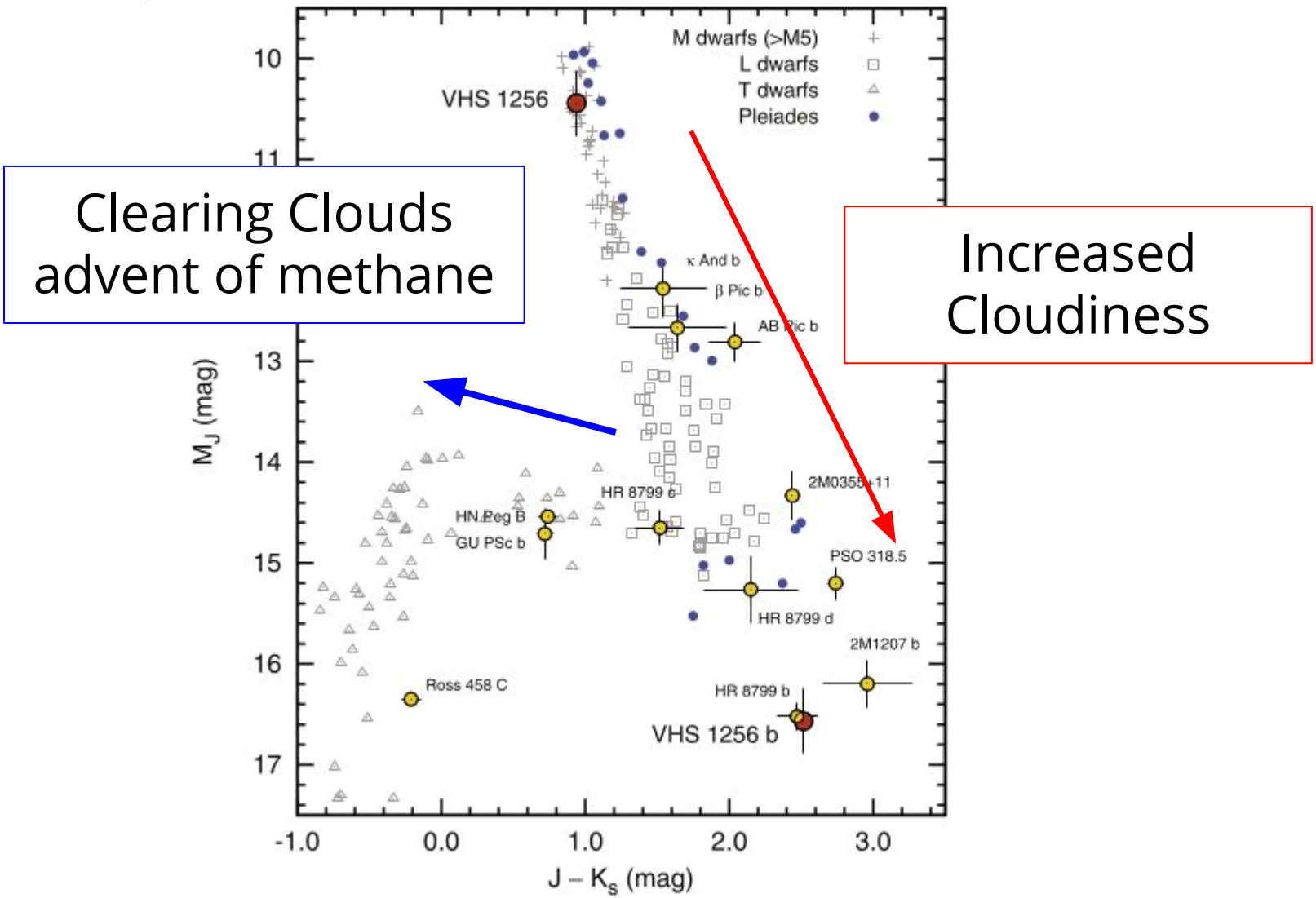
What do we know about gas-giant exoplanet emission spectra?

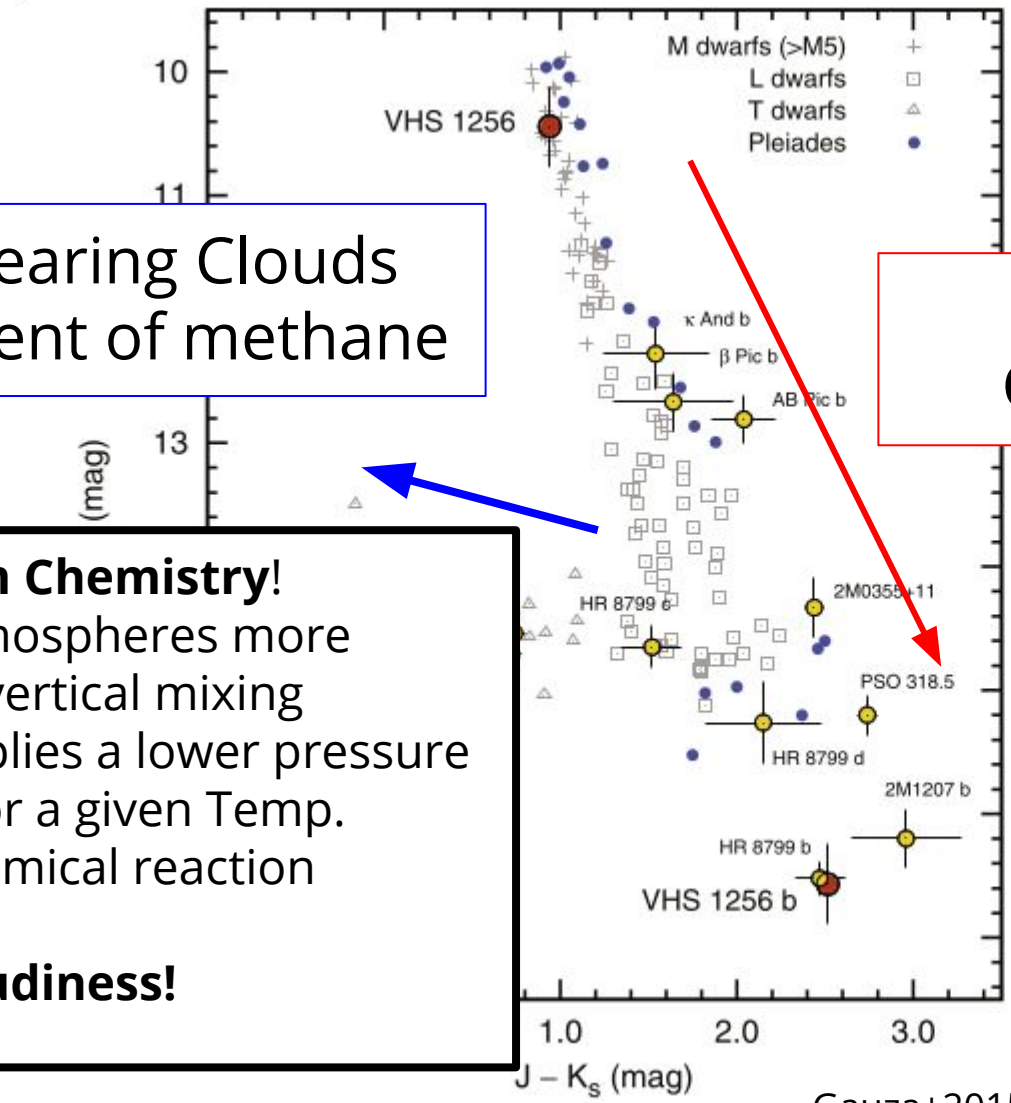
1) Low-gravity atmospheres appear different than the field brown dwarf population, even at the same effective temperatures

1) Low-gravity atmospheres are distinct from brown dwarf sequence



Gauza+2015

1) Low-gravity atmospheres are distinct from brown dwarf sequence



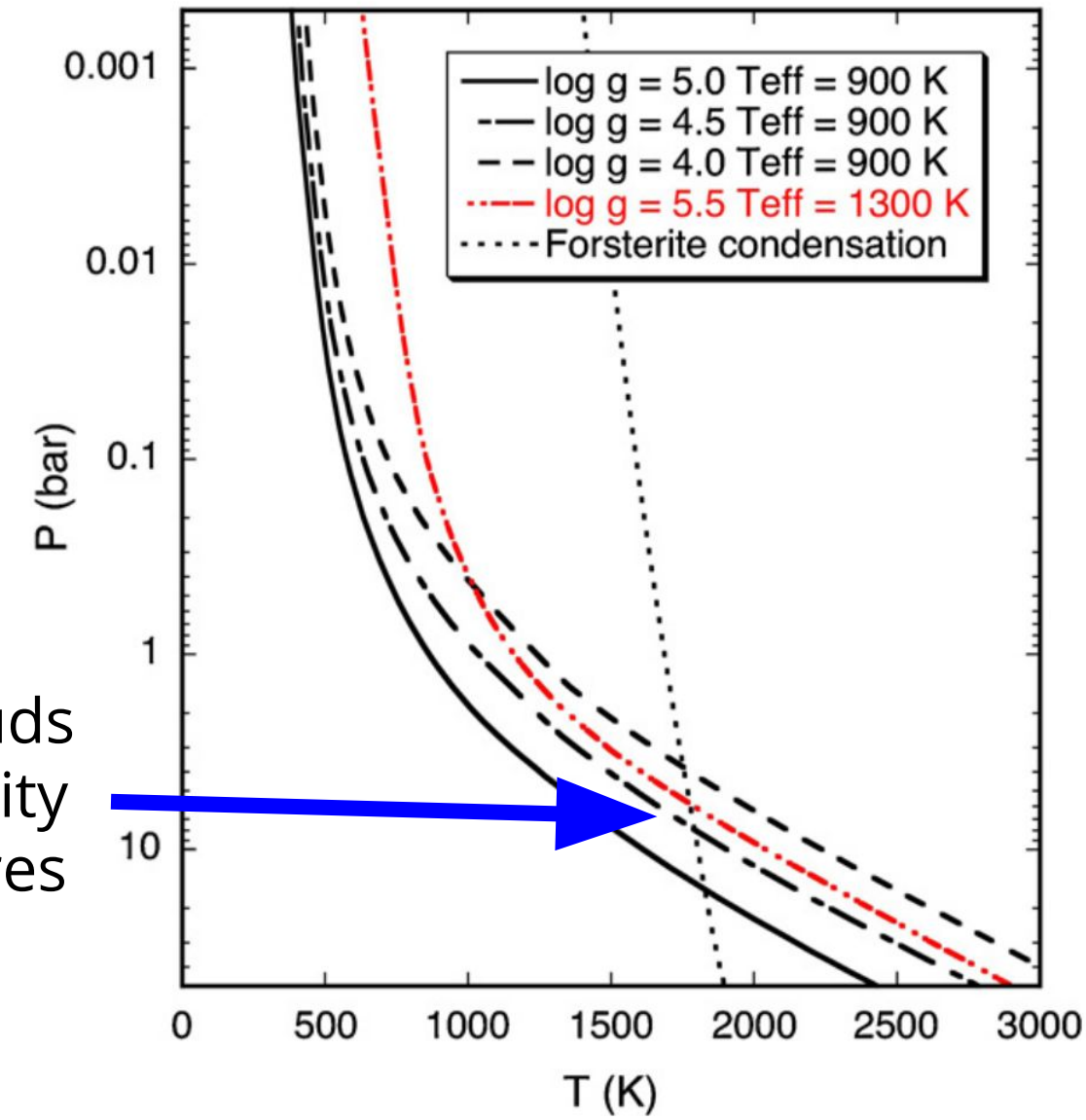
Clearing Clouds advent of methane

Increased Cloudiness

- **Disequilibrium Chemistry**!
- Low gravity atmospheres more susceptible to vertical mixing
- Low gravity implies a lower pressure (and density) for a given Temp.
  - Longer chemical reaction timescales
- **Increased Cloudiness!**

Gauza+2015

1) Low-gravity atmospheres are distinct from brown dwarf sequence



Higher clouds in low-gravity atmospheres

Degeneracies!

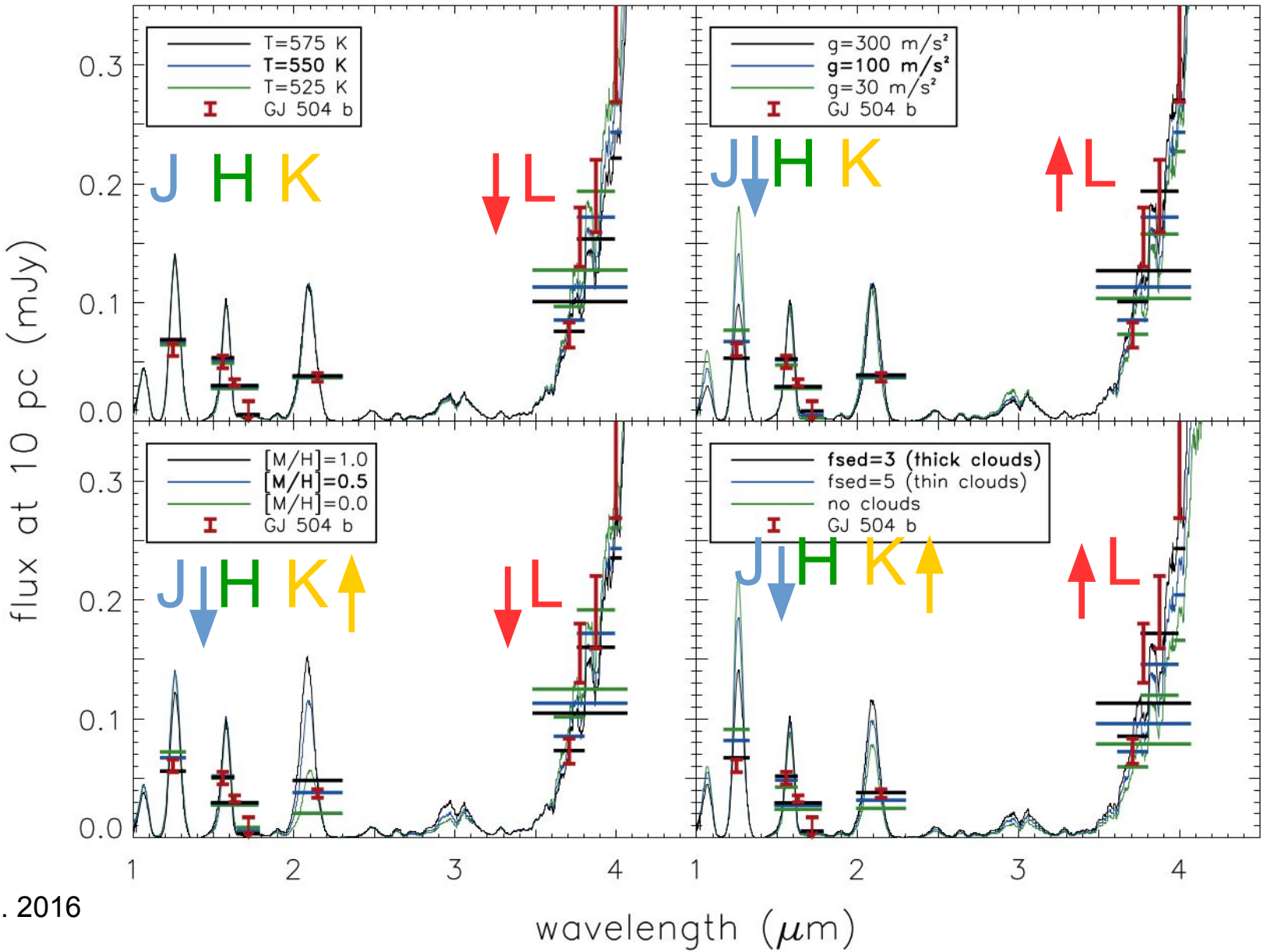
- Teff
- gravity
- chemistry
- cloudiness

Marley+2012

Degeneracies!

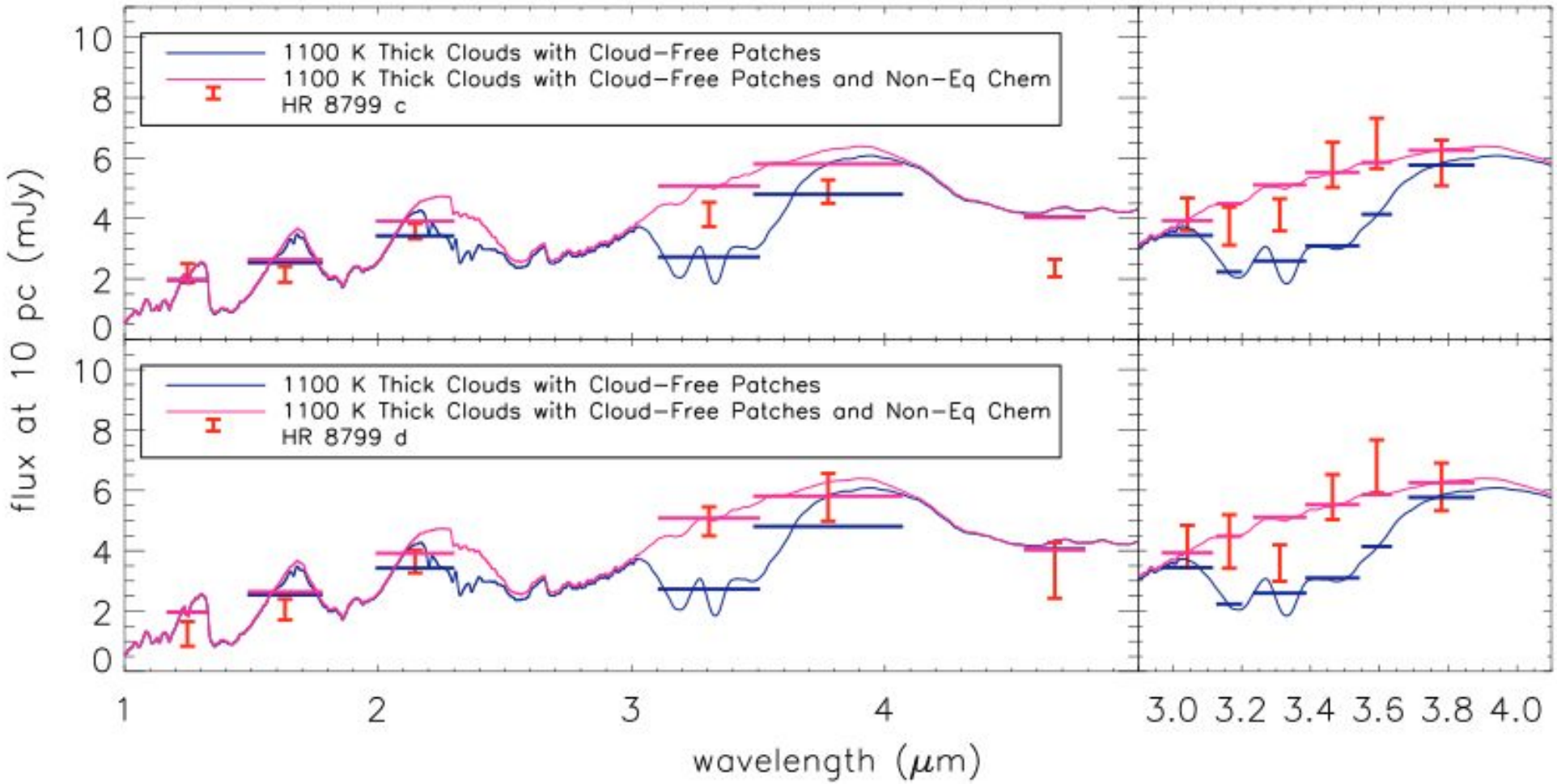
log(g), T_{eff}, chemistry, composition

Thermal-Infrared Constraints can Break Degeneracies



Skemer et al. 2016

LEECH characterization of HR 8799 c,d



L-band **<u>much</u>** more sensitive to changes in cloud structure and chemistry:
Patchy clouds and dis-equilibrium chemistry

Skemer et al. 2014

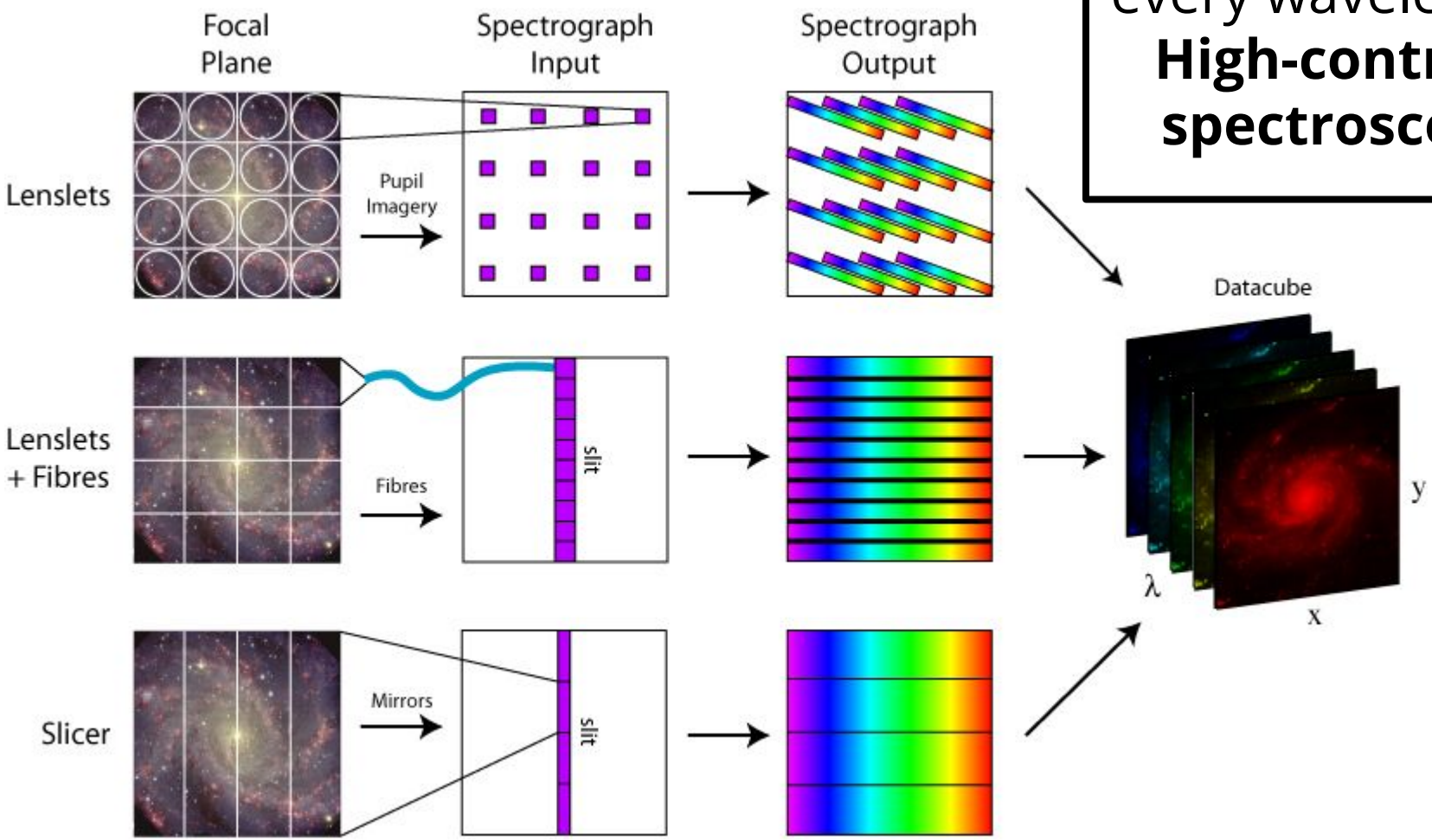
ALES

AO-fed integral field spectrograph built into LBTI

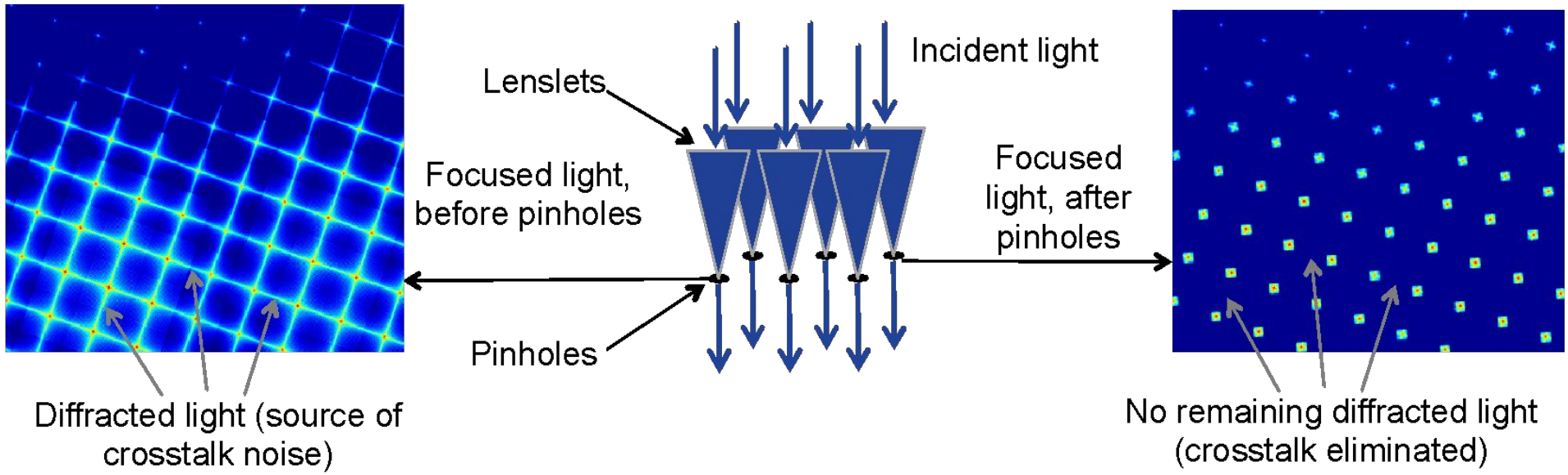
Only IFS operating at 3-5 microns

IFS

High-contrast data processing at every wavelength: **High-contrast spectroscopy**

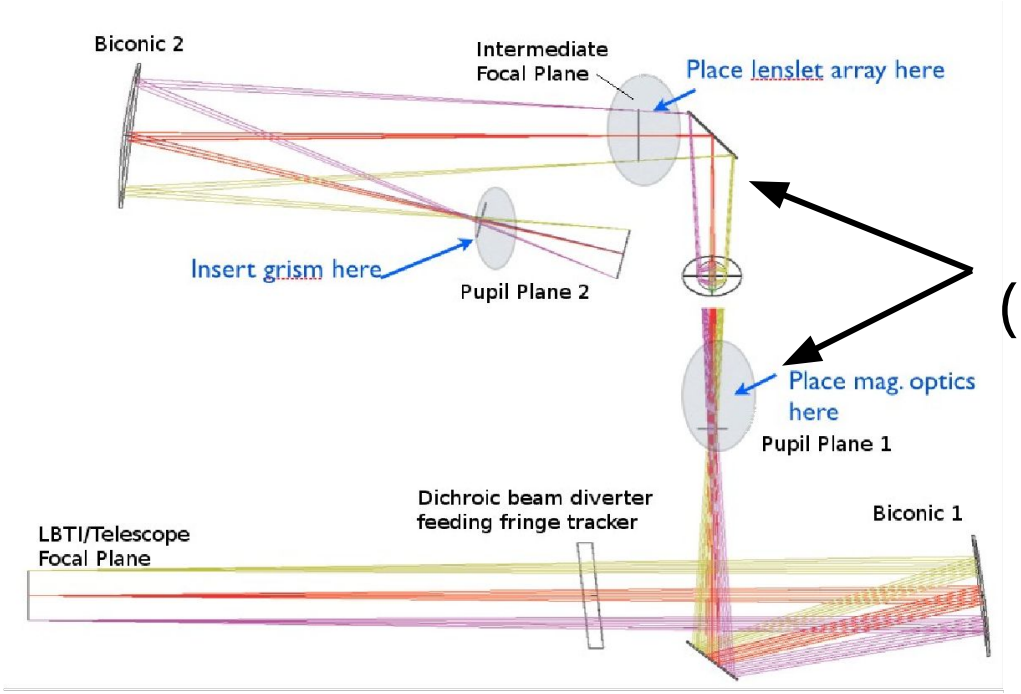


Diffraction Suppression



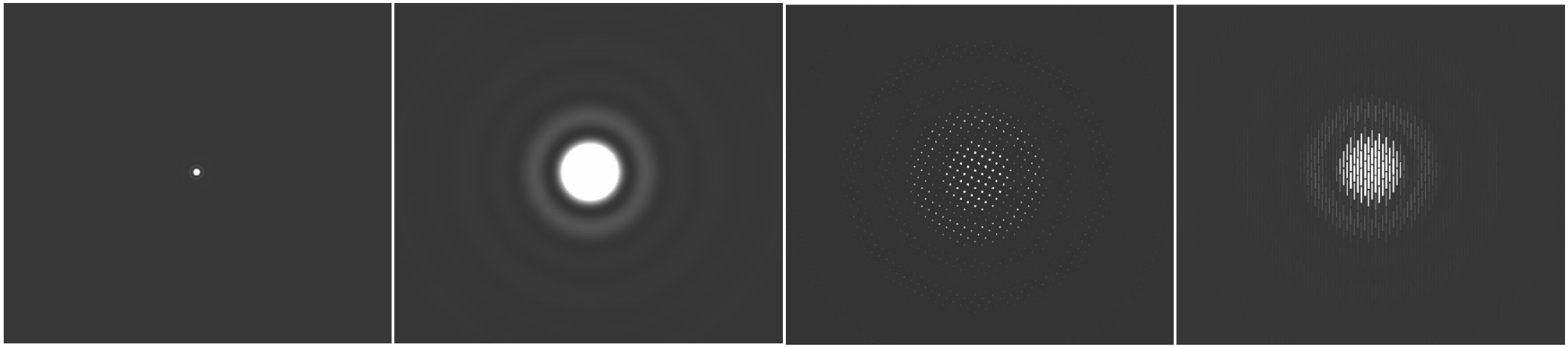
ALES built into LBTI/LMIRCam

LMIRcam ray Trace

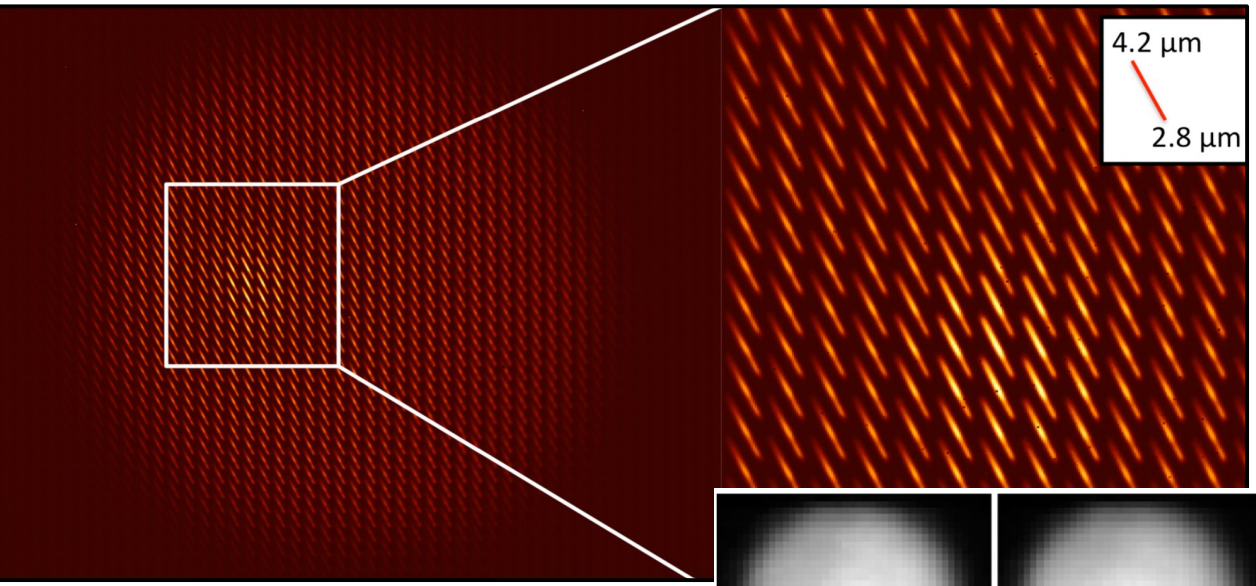


ALES optics:
2 new wheels
(more to come)

Skemer et al 2015

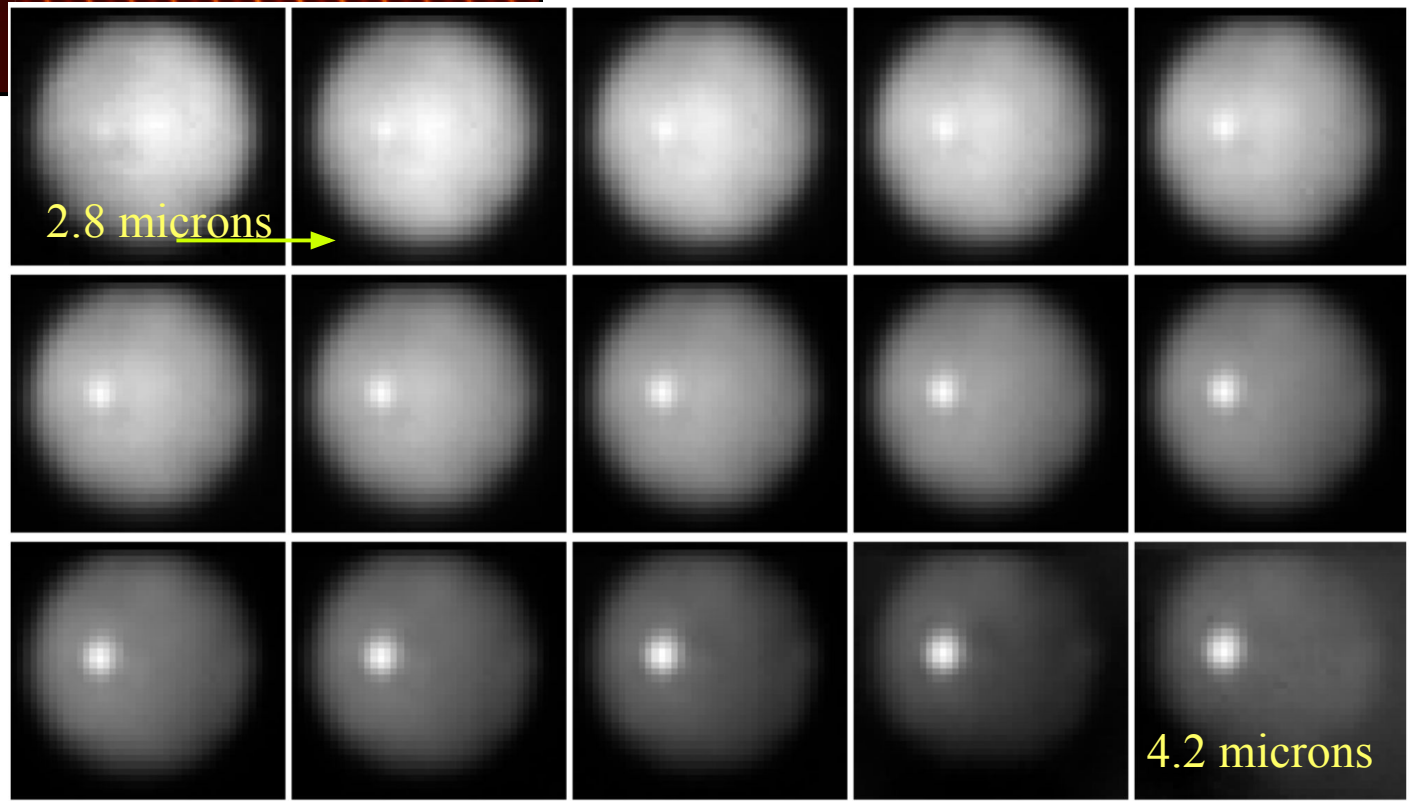


Early ALES observations



Jupiter's moon Io

Skemer+2015

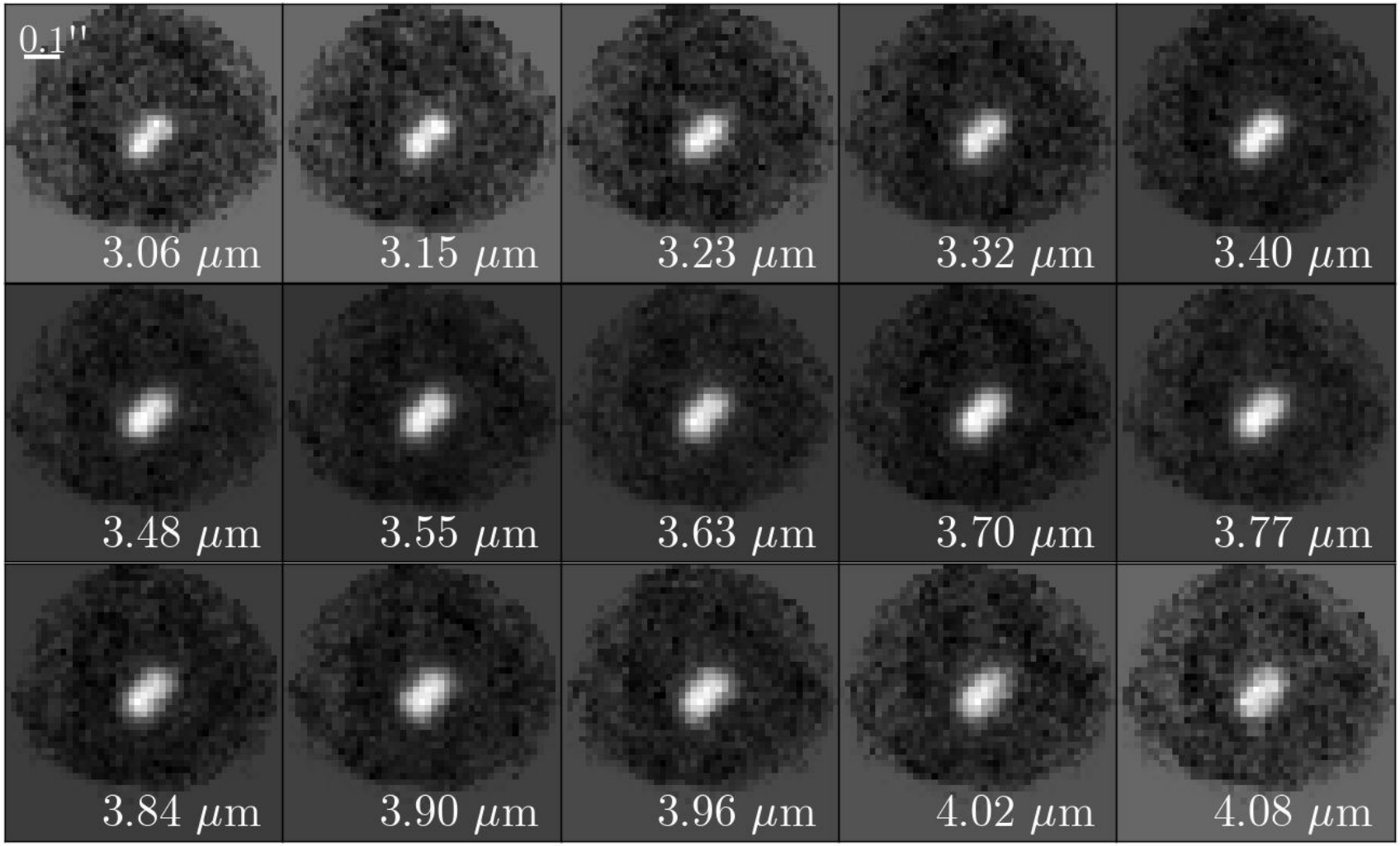


R~20 spectroscopy
from 2.8 to 4.2µm

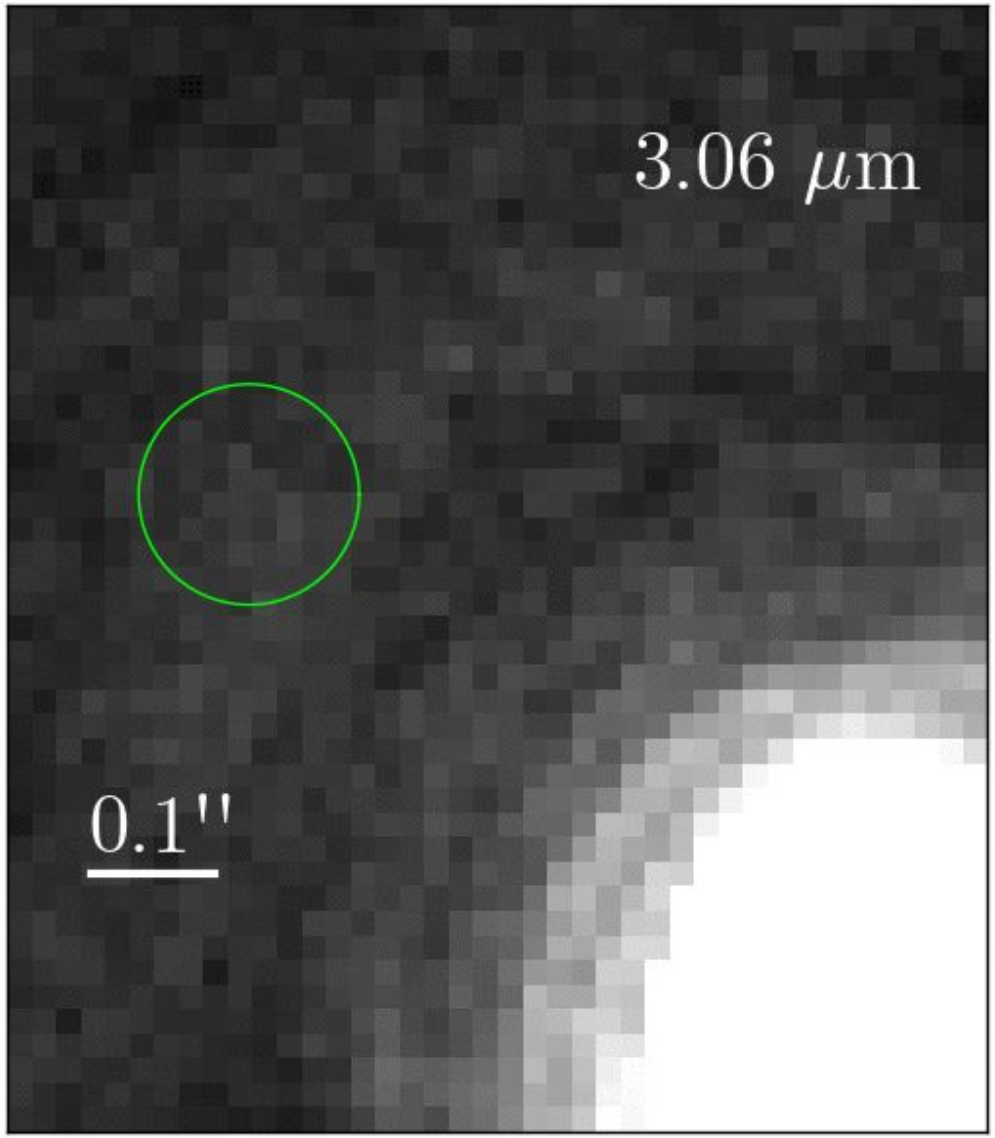
Early ALES observations

The benchmark binary brown dwarf system HP Boo BC
constraining models at the wavelengths where JWST will observe

Breisemeister+in prep



Early ALES observations



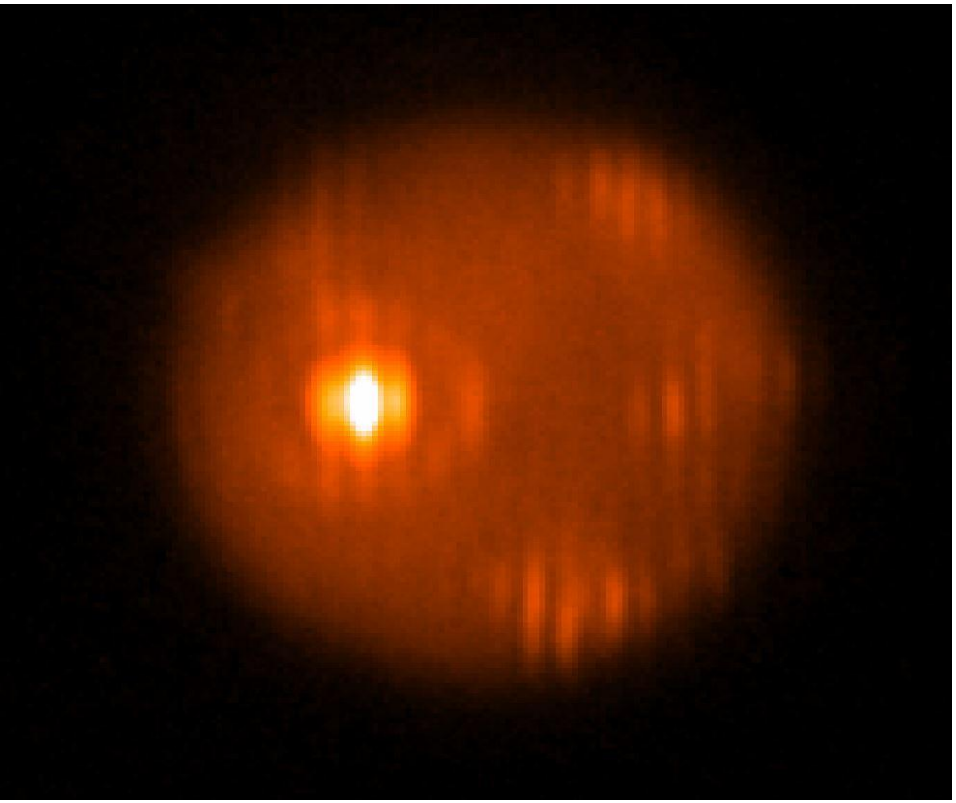
Stone+ in prep

ALES upgrades

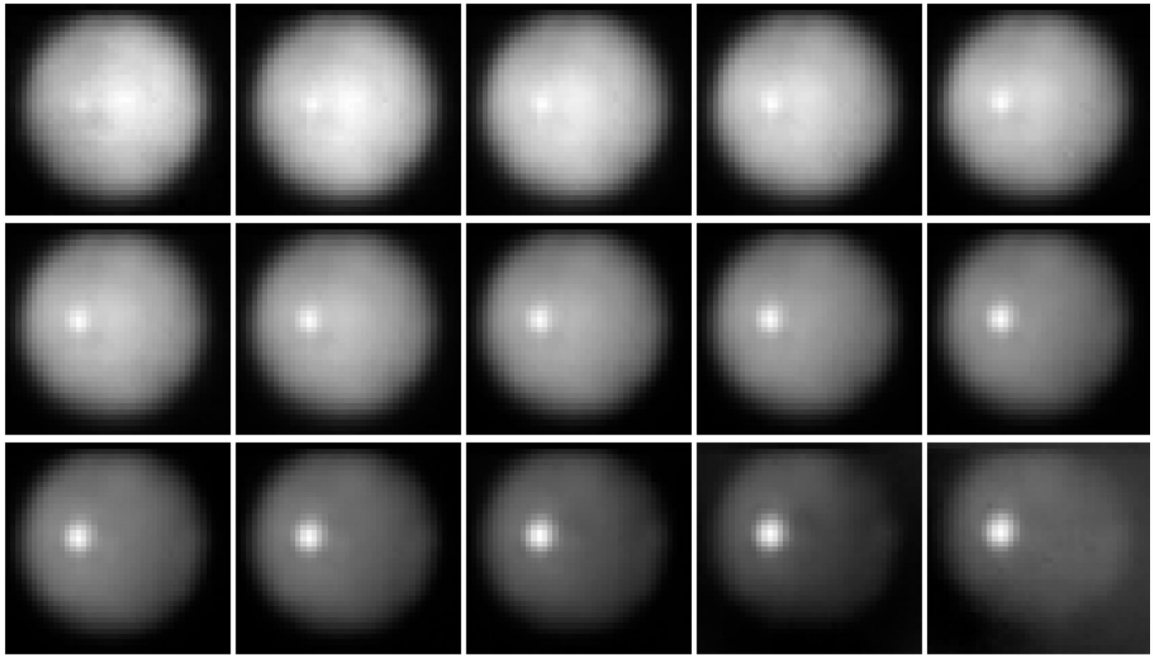
- **<u>First Light:</u>**
- 50x50 spaxels
- Single waveband option:
  - 2.8 – 4.2 microns
  -
  -
  -
  -
- R~20
- Plate scale for single aperture AO –-1.2''x1.2'' FOV

- **<u>2017B:</u>**
- 100x100 spaxels
- multiple waveband options:
  - Br γ (accretion stars/planets)
  - PAH (debris disks)
  - Ice (solar system bodies, disks)
  - Lspec (exoplanet atmospheres)
  - LM (exoplanets, solar system bodies)
- R~10-300
- Multiple plate scales to accommodate single and double sided observations

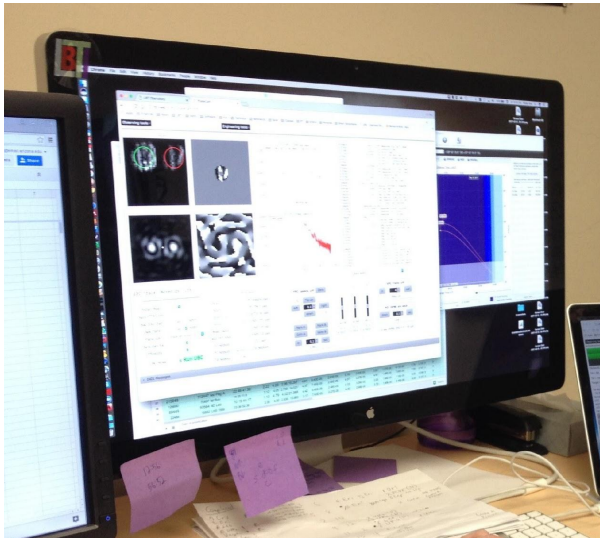
ALES+Interferometry



Conrad+2015



Skemer+2015



Summary

- Thermal – Infrared is an important spectral regime for understanding gas-giant planet atmospheres:
  - clouds/ carbon chemistry/ gravity/ temperature/ composition
- LBTI was specifically designed to provide low-background observations in the thermal-infrared
- ALES:
  - the world's only thermal-infrared IFS is being commissioned
  - will provide the constraints necessary to better understand gas-giant planet atmospheres