Atmospheric structure of brown dwarfs from spectral variability measurements

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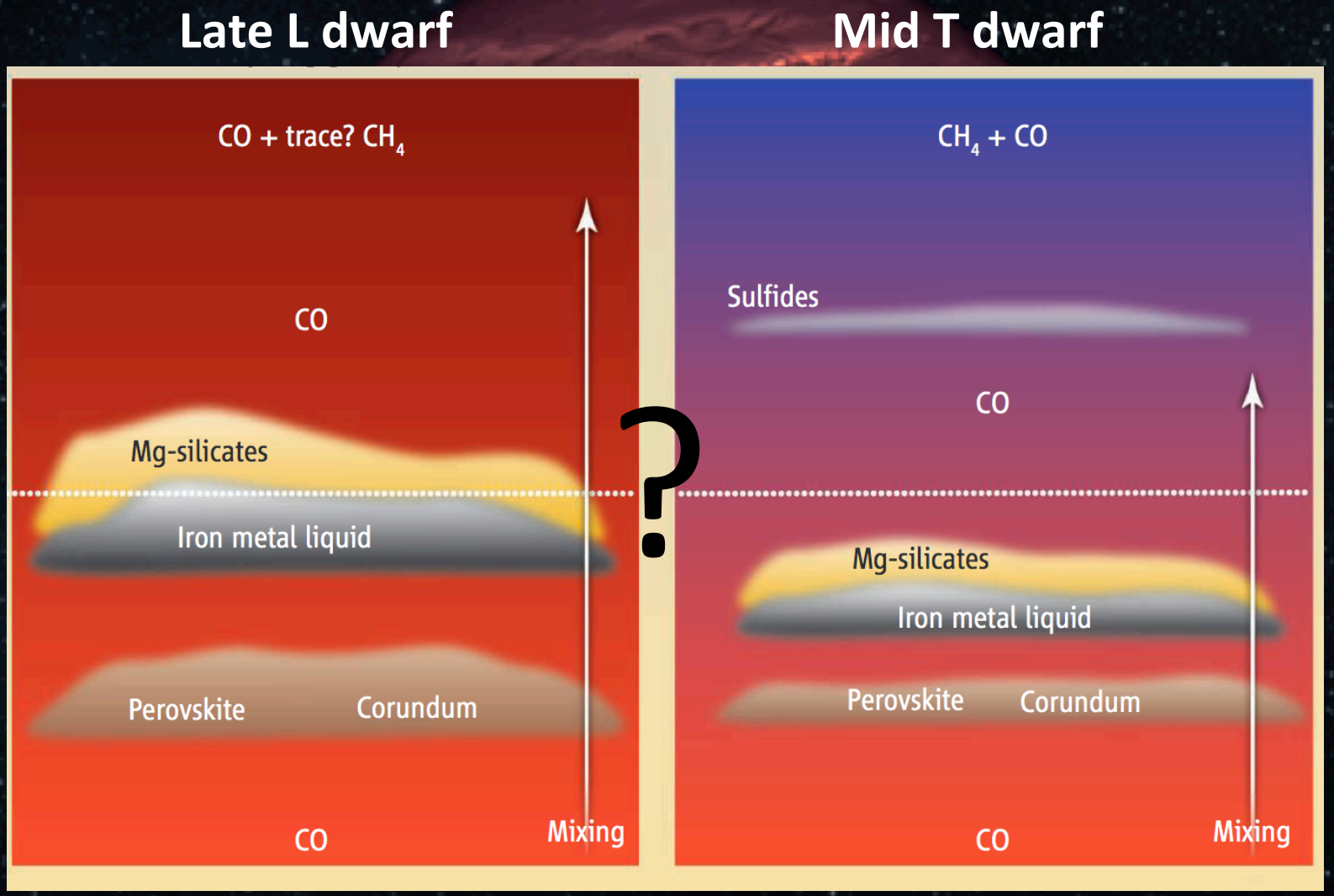
Gaia and the unseen workshop, March 25 2014

Background image:
Artist impression of a variable T6 dwarf, NASA/JPL

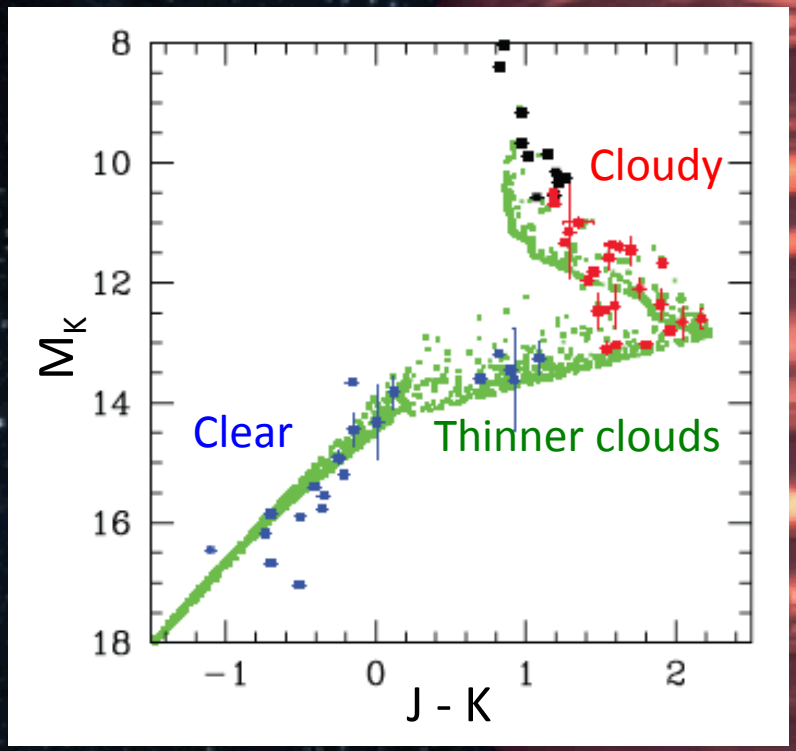
Cloud Evolution



Marley 2013

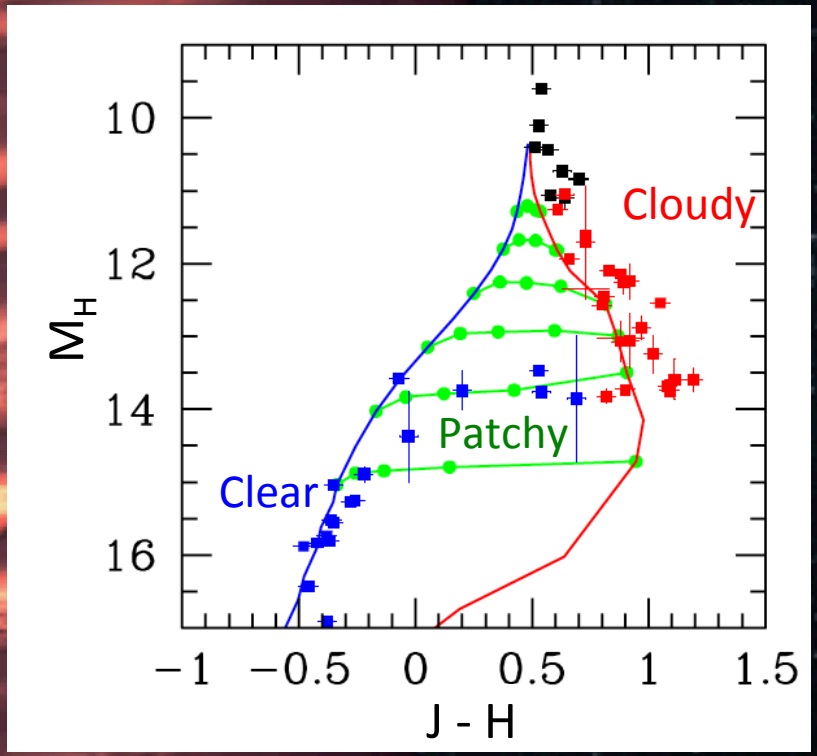
L/T transition models

Increased sedimentation efficiency



Saumon & Marley 2008

Increased cloud patchiness

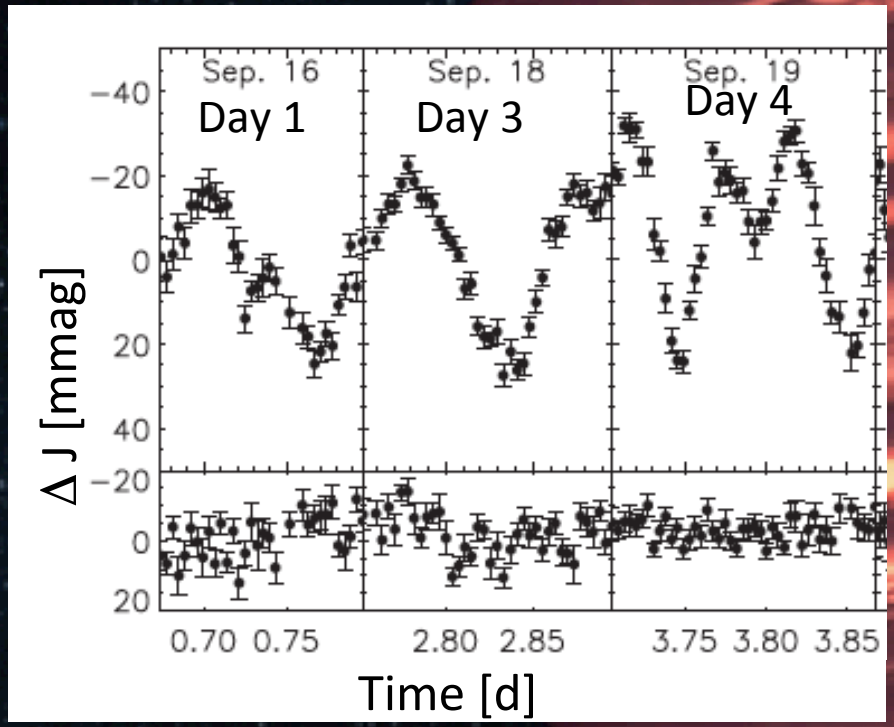


Marley et al. 2010

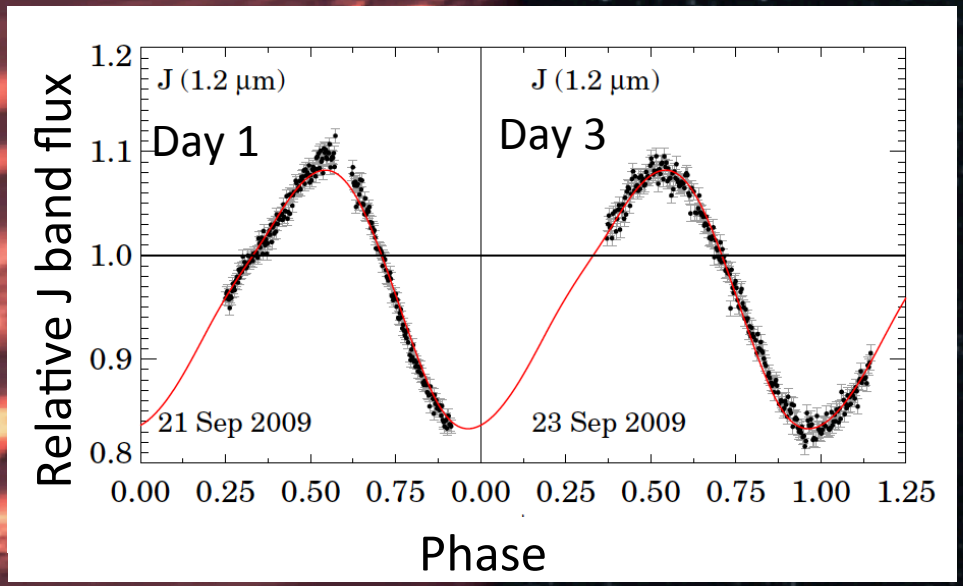
Patchy clouds → Variability

Variable L/T transition dwarfs

SIMPJ013656.5+093347



2MASSJ21392676+0220226

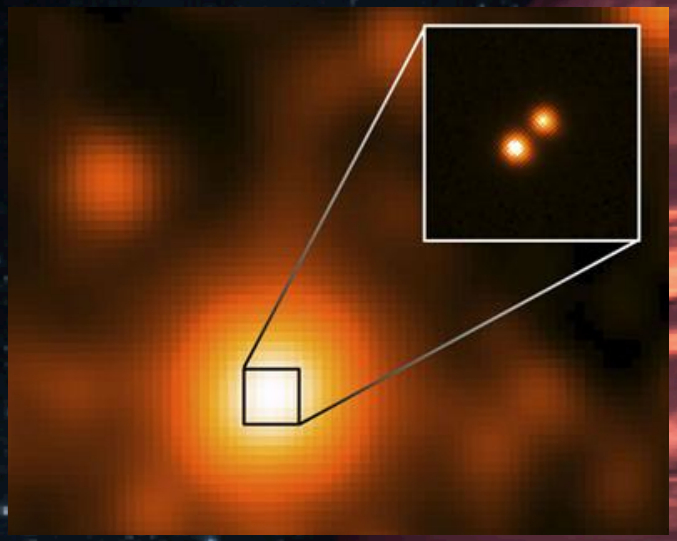


Artigau et al. 2009
T2.5 dwarf, 5% variability in J
2.4 h period

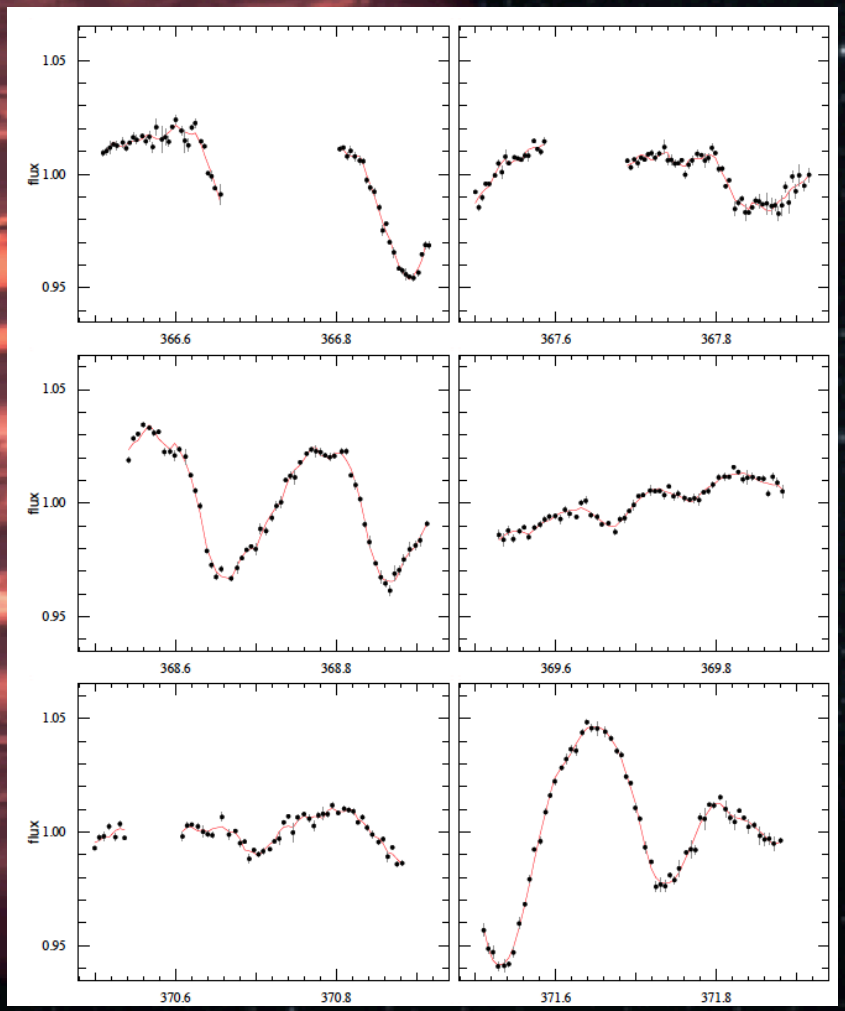
Radigan et al. 2012:
T1.5 dwarf, 26% variability in J
7.8 h period

Light curves can evolve dramatically

WISE J104915.57-531906.1 aka Luhman 16



L7.5 / T0.5 binary
Distance: 2 pc (!)
B is variable:
Period = 4.87±0.01 h
Max. Amplitude = 11%



TRAPPIST 60 cm telescope, I+z filter (750-1100 nm), Gillon et al. 2013

Spectroscopic variability with HST

WFC3/IR G141 slitless spectroscopy

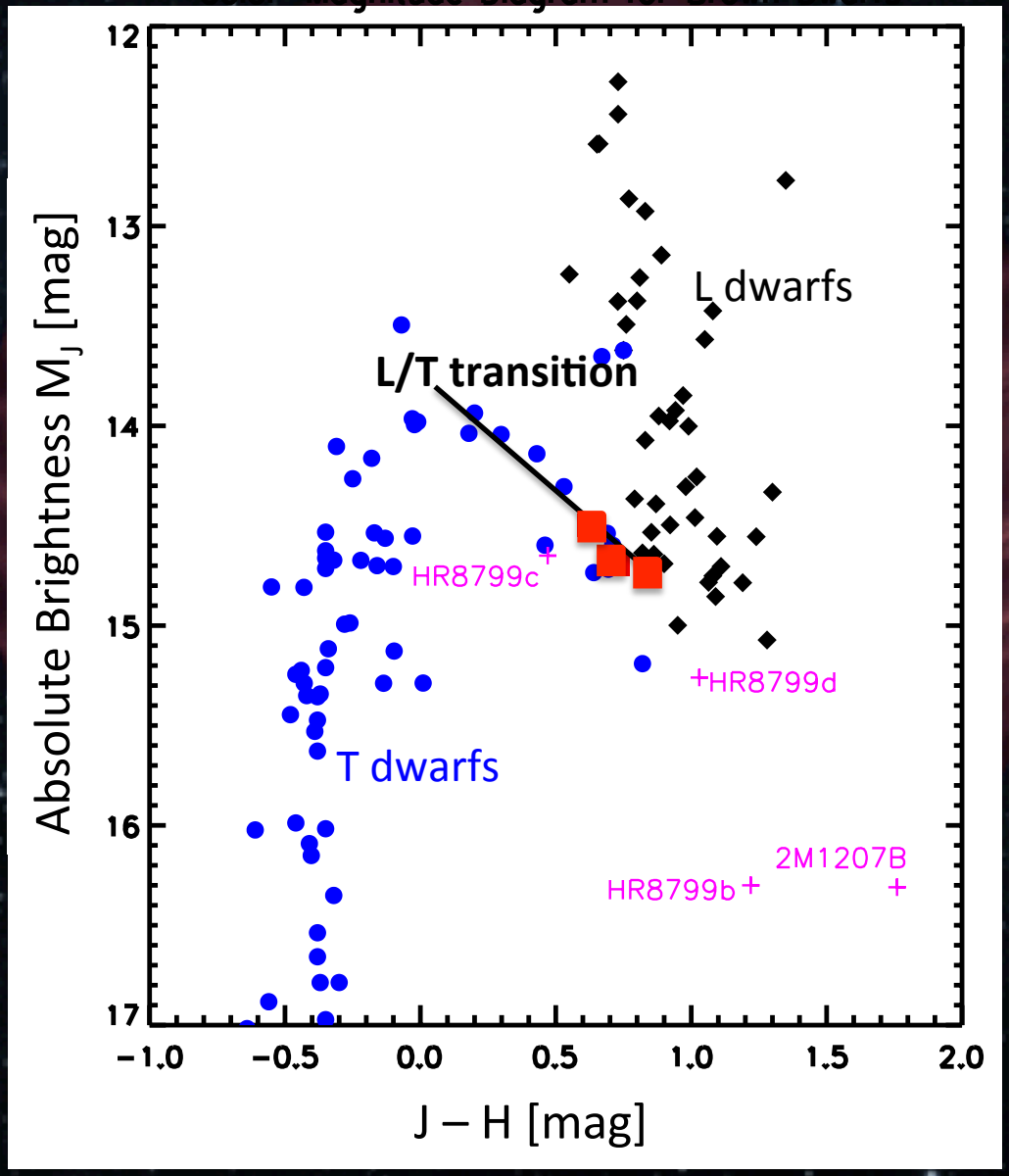
1.1 – 1.7 μm with 9 nm spectral resolution, R~130

Precision on the ~0.1-0.5% level at few min cadence

Need several orbits per target to cover full rotation, gaps…

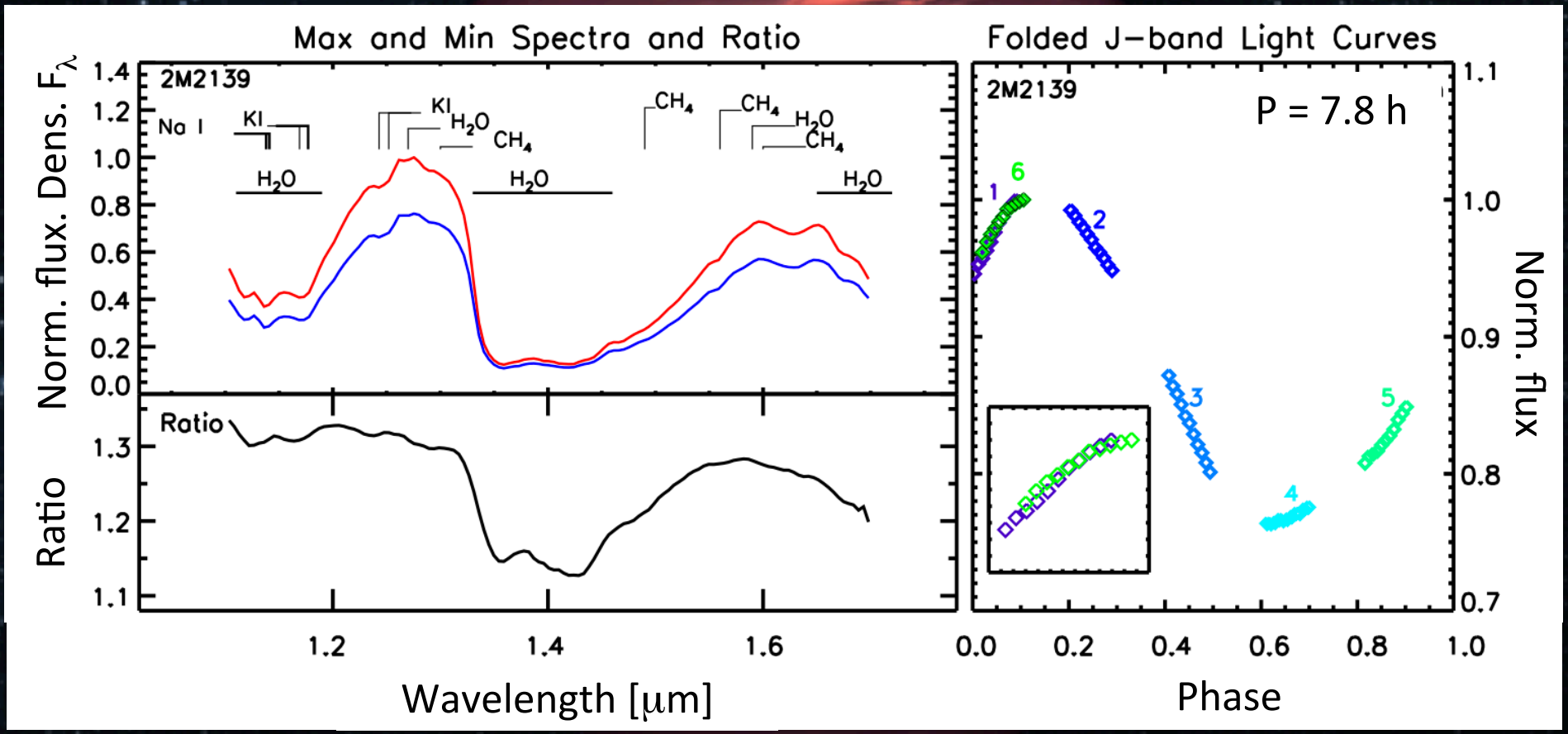

Variable L/T transition dwarfs:
Are they partly cloudy?

L/T transition dwarfs



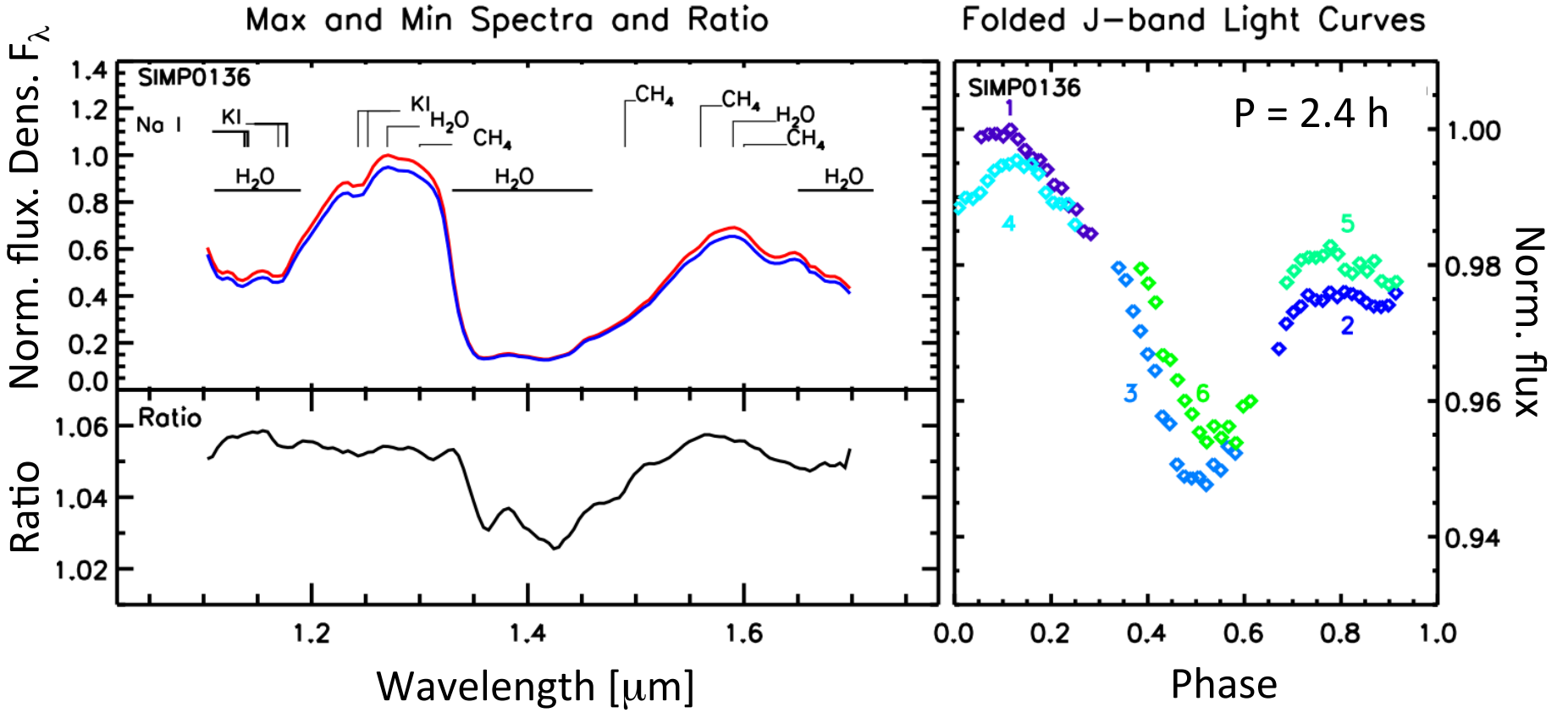
Data from database of ultracool parallaxes maintained by T. Dupuy

T1.5 dwarf 2M2139



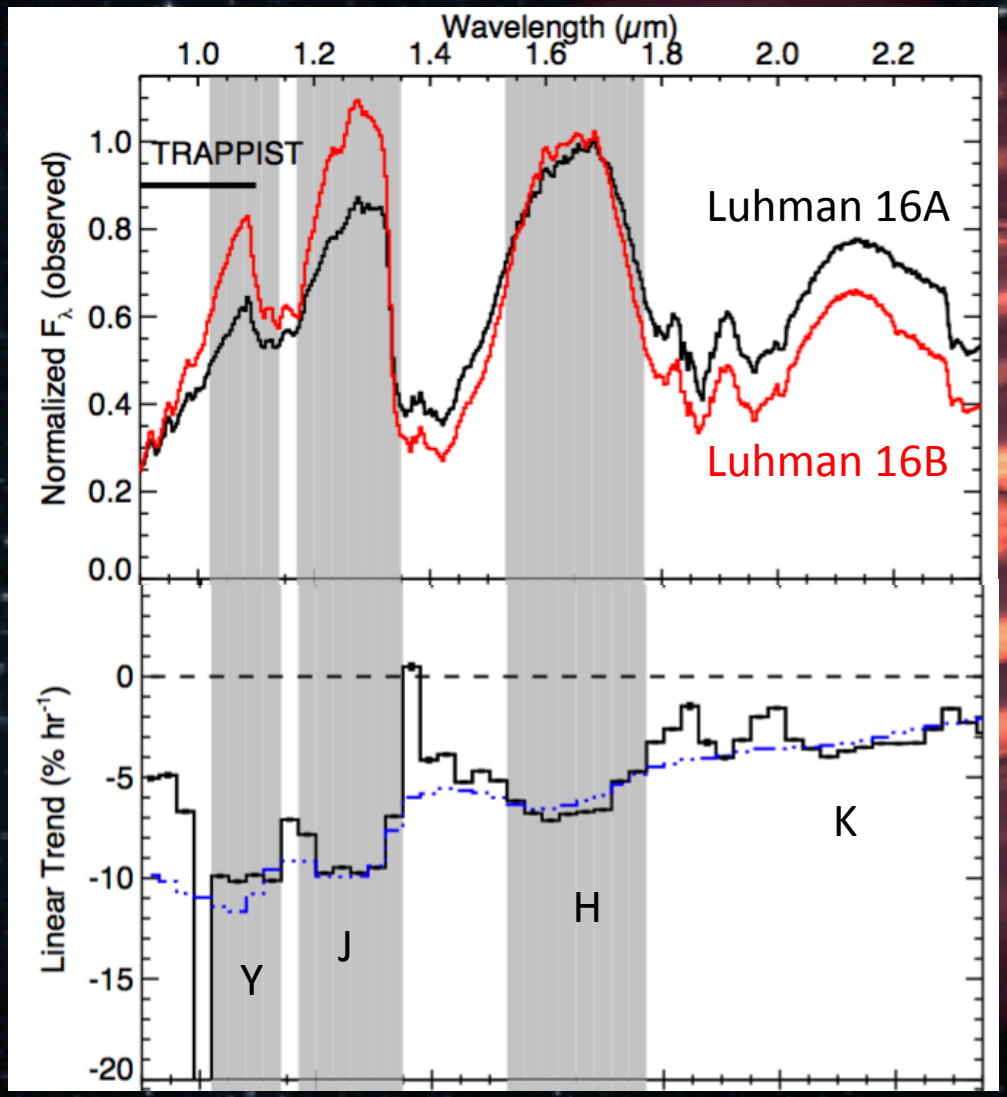
Apai, Radigan, Buenzli et al. 2013

T2.5 dwarf SIMP0136



Apai, Radigan, Buenzli et al. 2013

Ground based spectroscopy of Luhman 16B

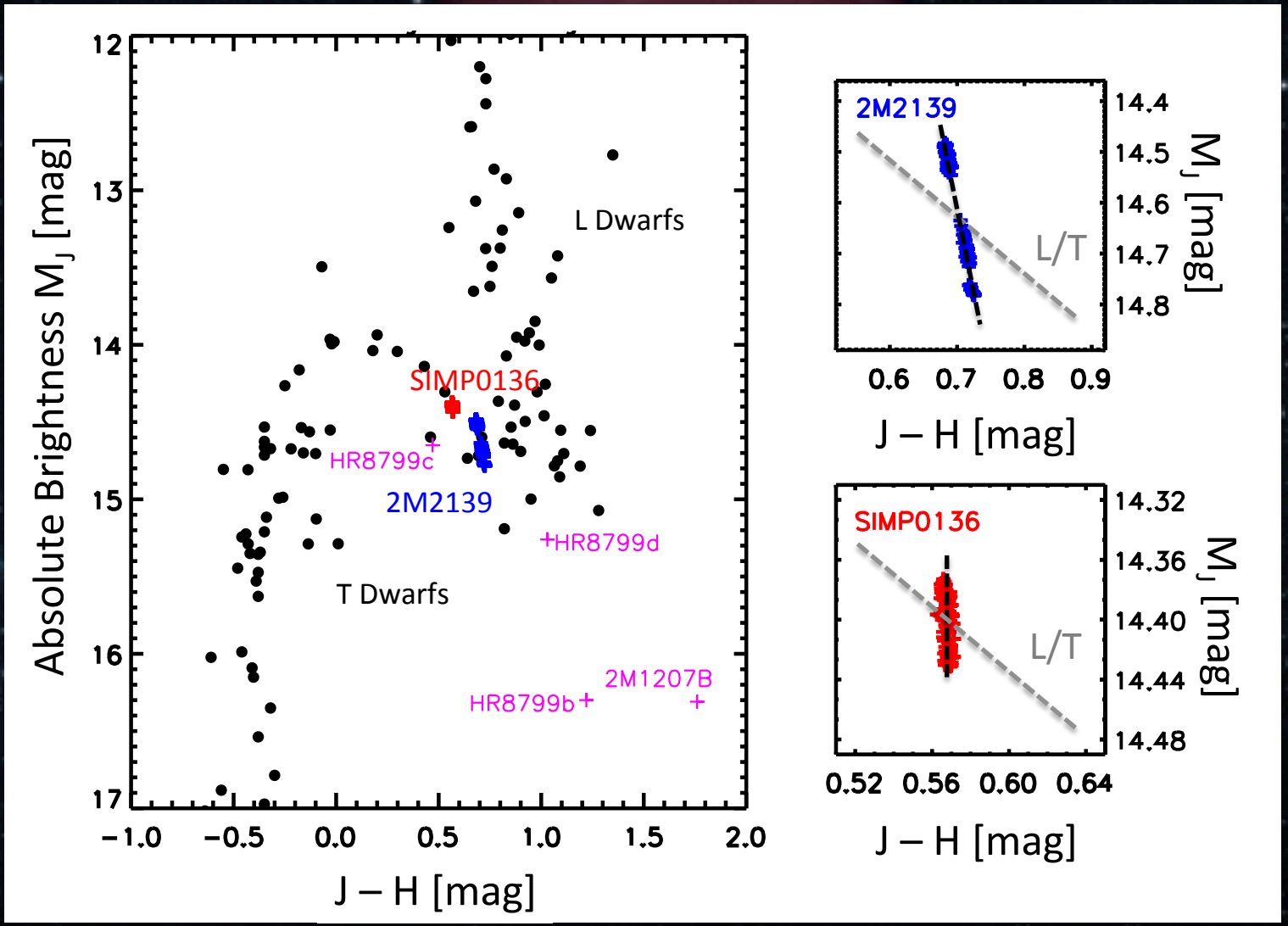


Chromatic + achromatic variability components

No differences in smaller spectral bins

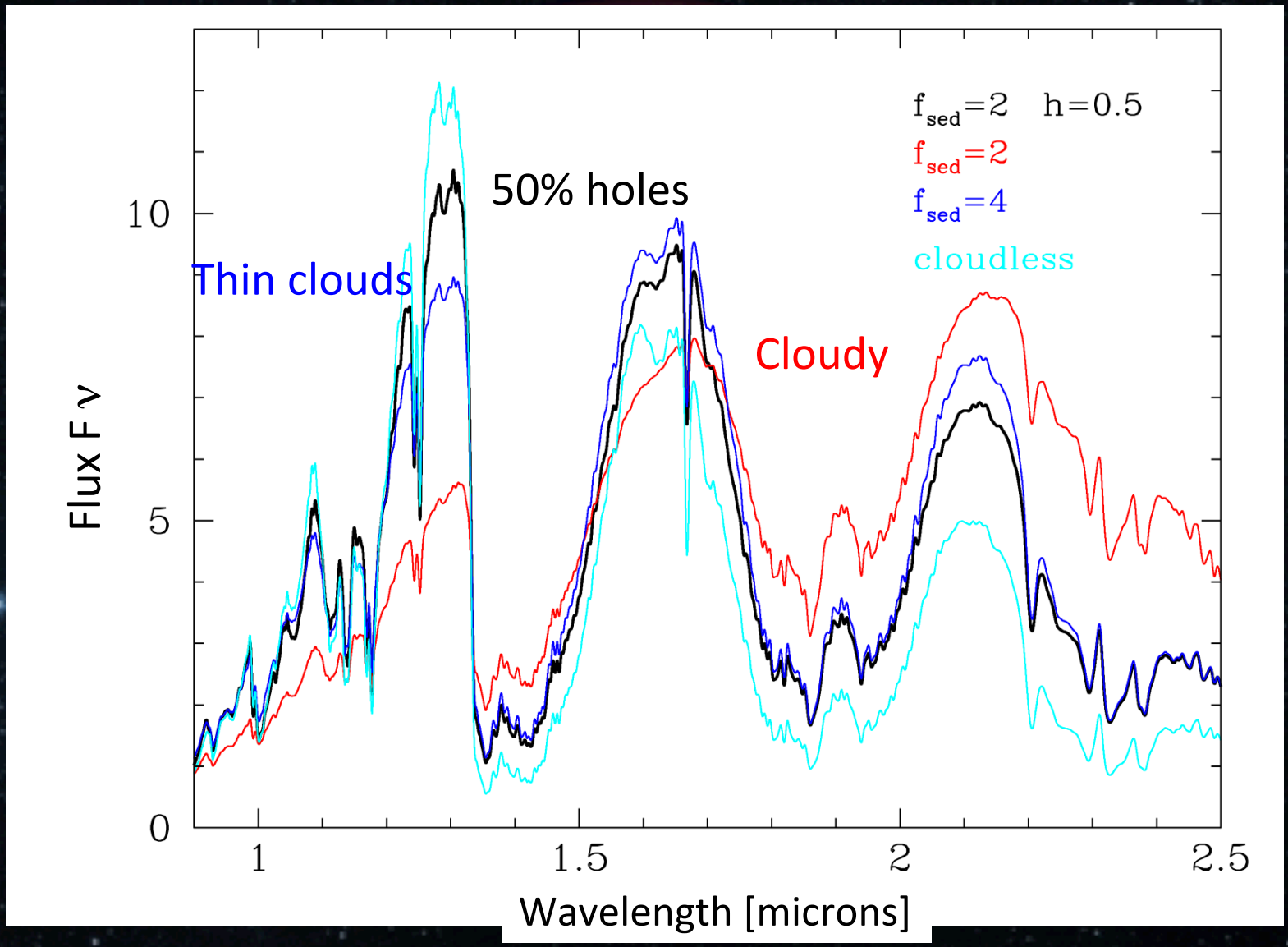
Burgasser et al. 2014

Variability does not follow L/T transition



Apai, Radigan, Buenzli et al. 2013

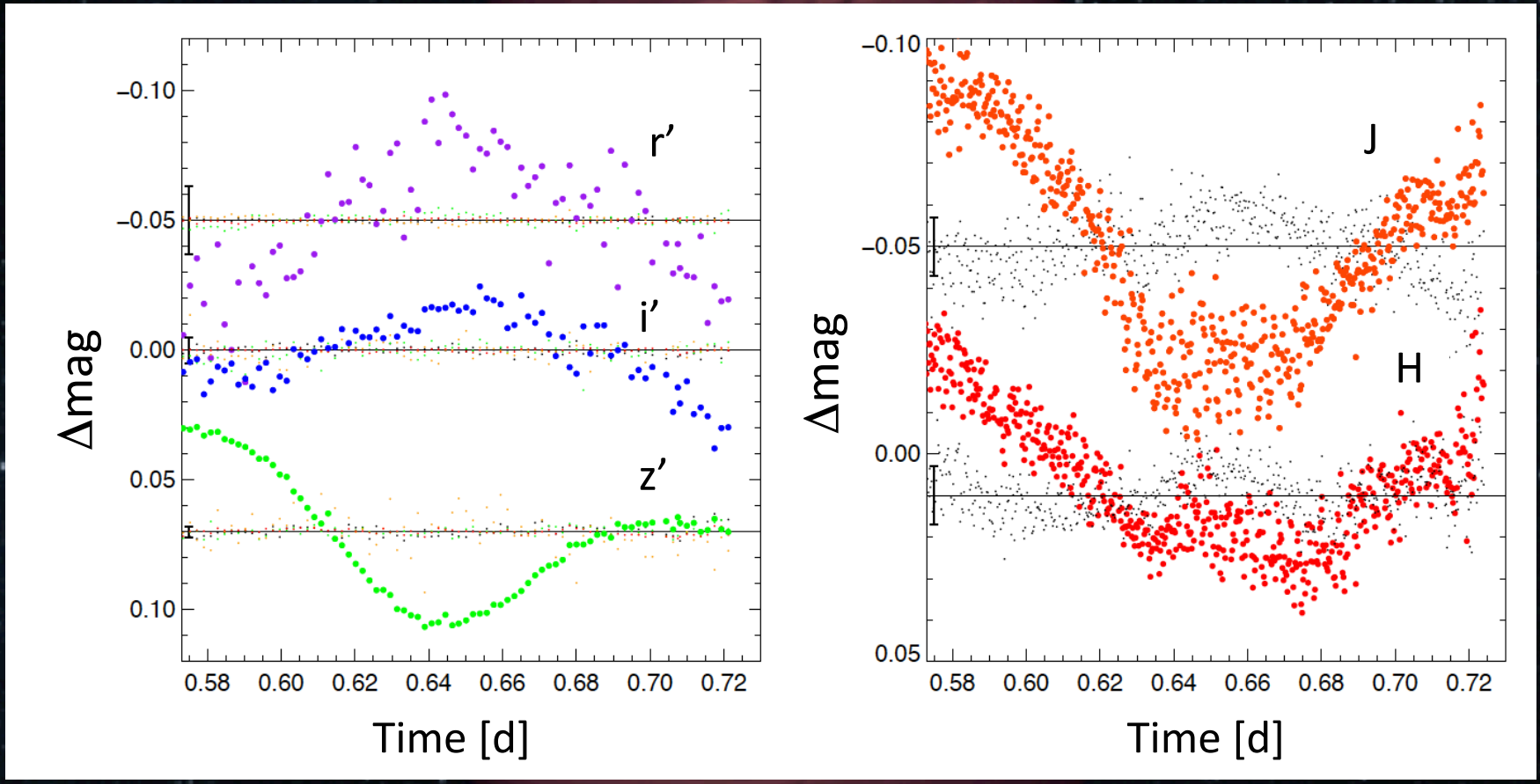
Cloudy vs clear



Marley et al. 2010

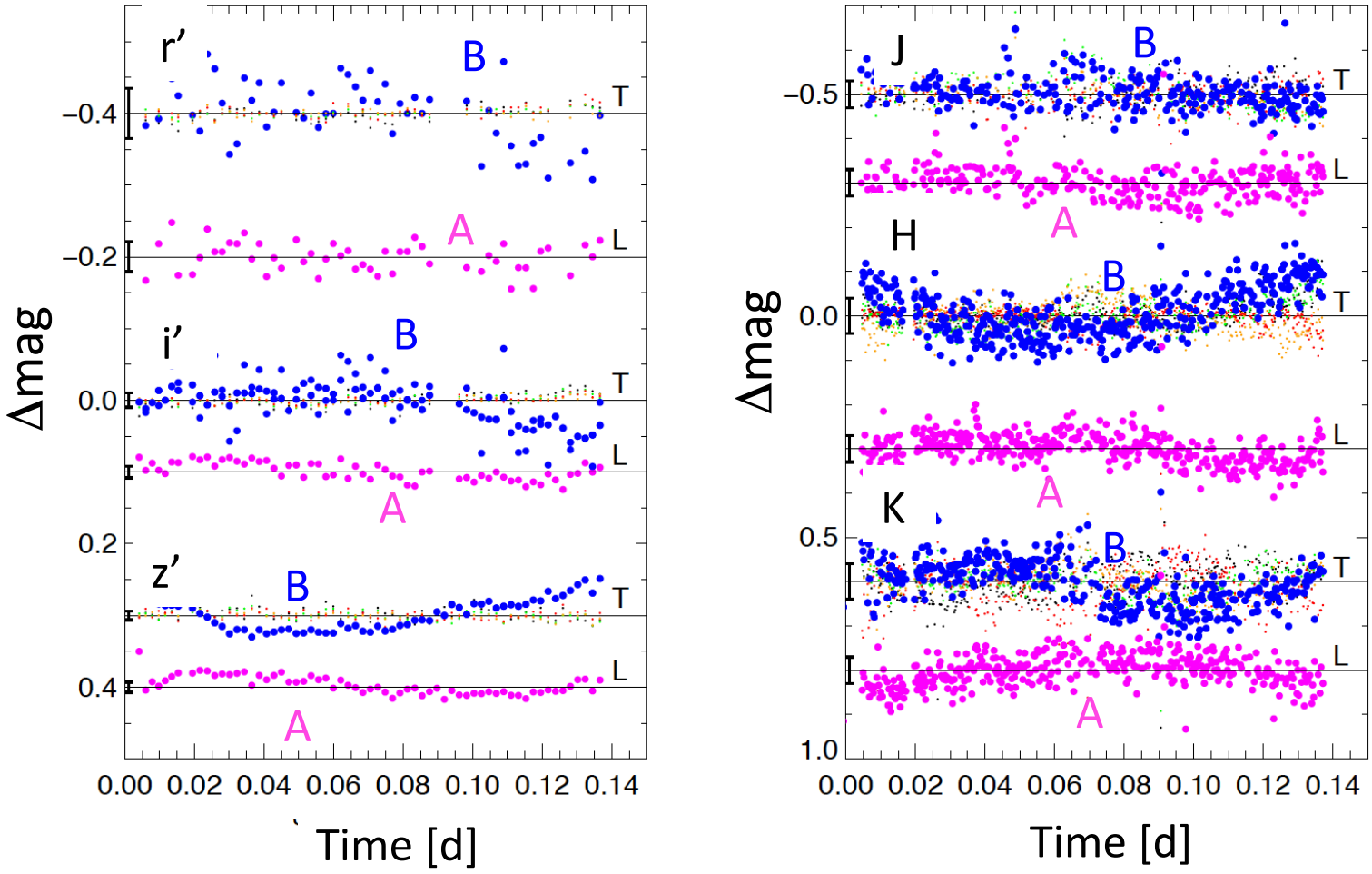
Cloud/clearing models don't work...

The curious case of Luhman 16B



GROND (2.2 m) unresolved photometry, Biller et al. 2013

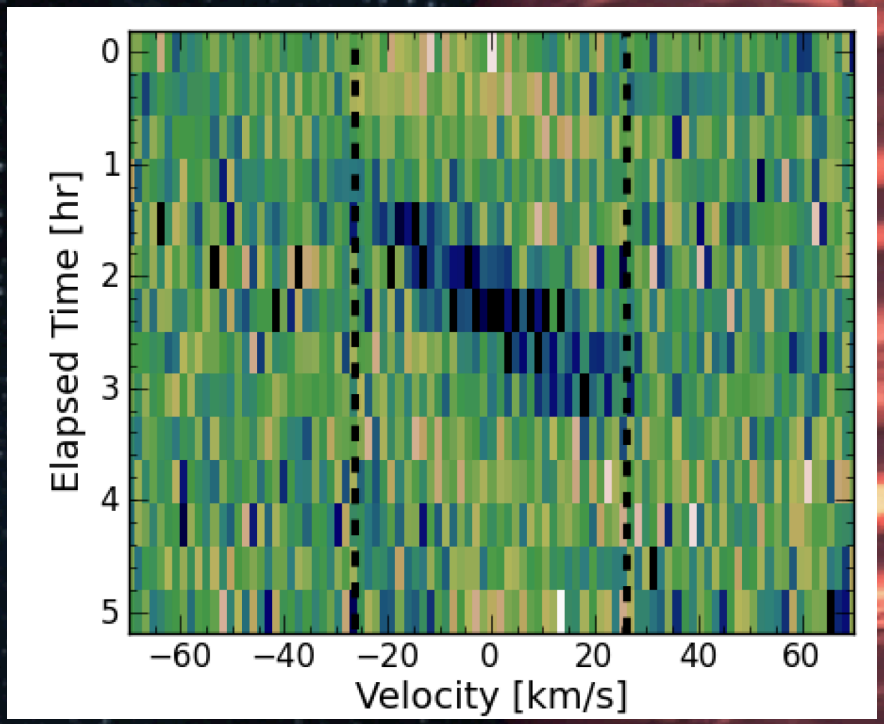
The curious case of Luhman 16B

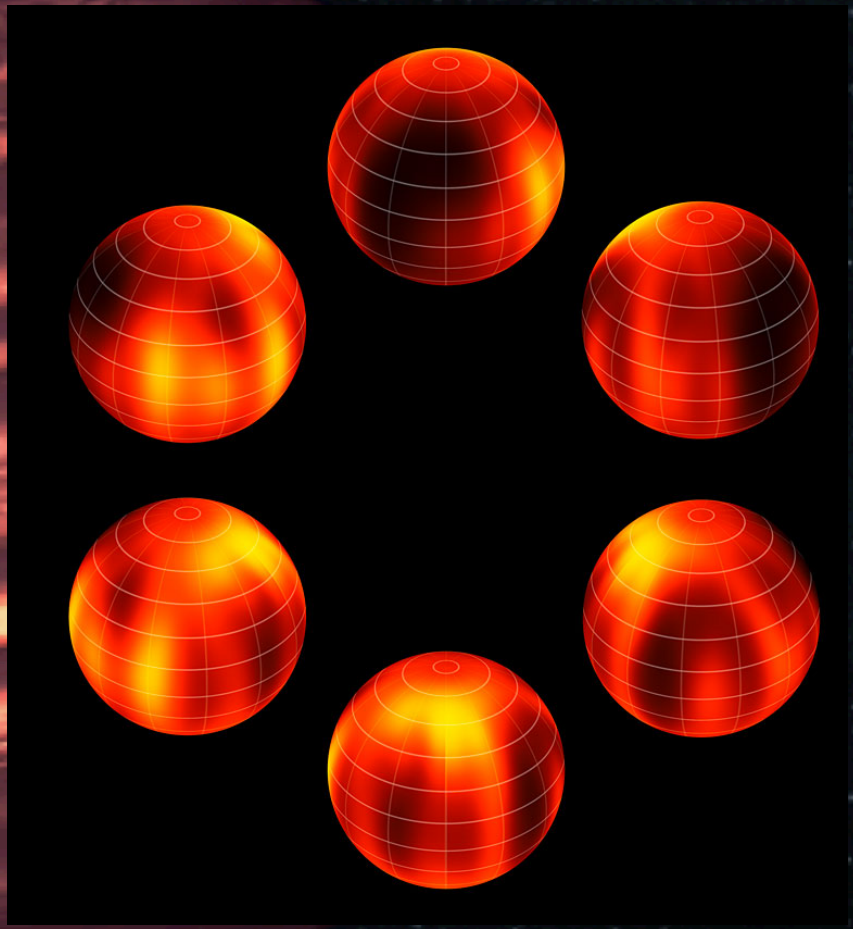


GROND (2.2 m) resolved photometry, Biller et al. 2013

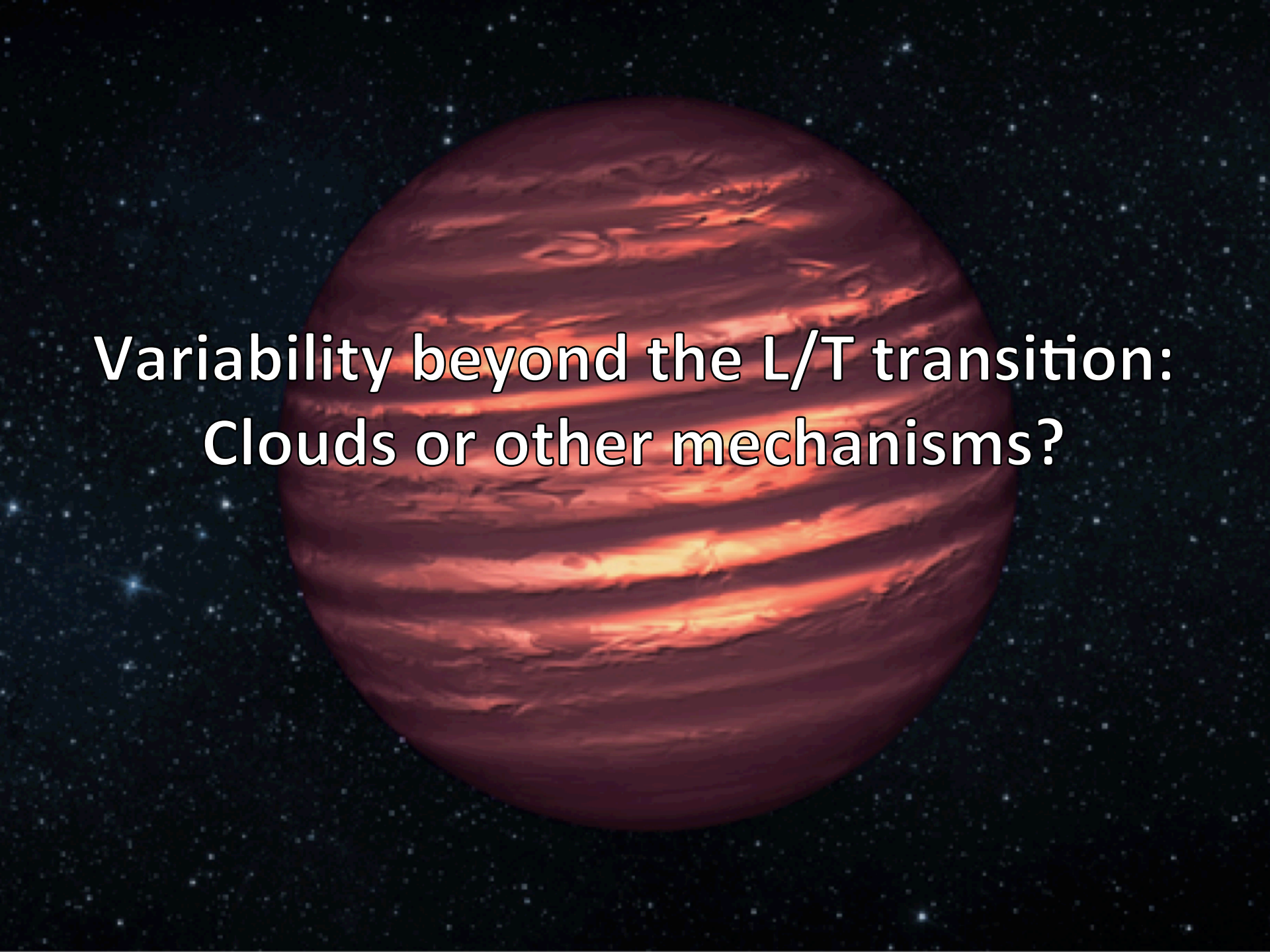
The first 2D map of a brown dwarf

Doppler imaging, VLT/CRIRES

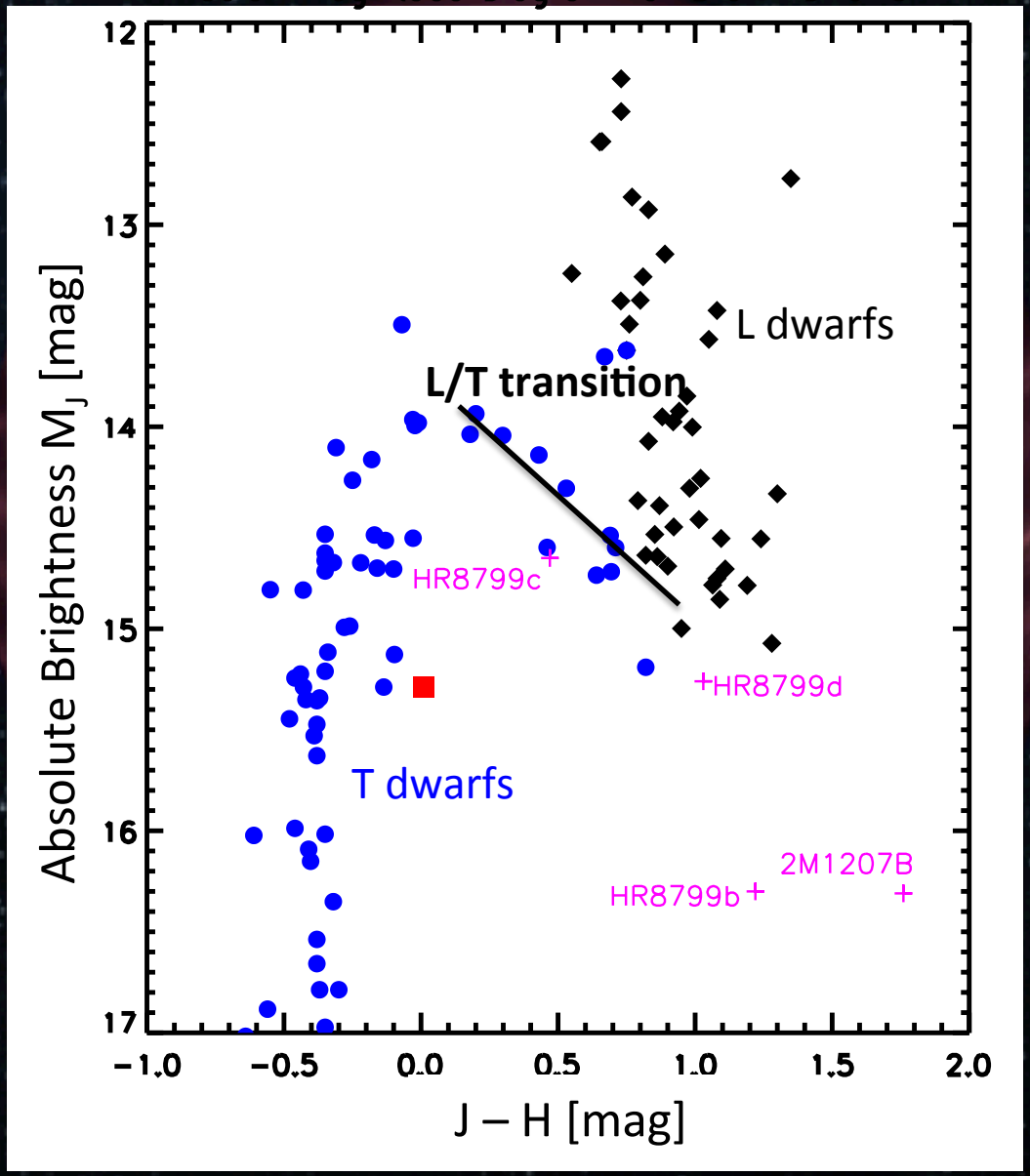




Crossfield et al. 2014, Nature


Variability beyond the L/T transition:
Clouds or other mechanisms?

Variability beyond the L/T transition



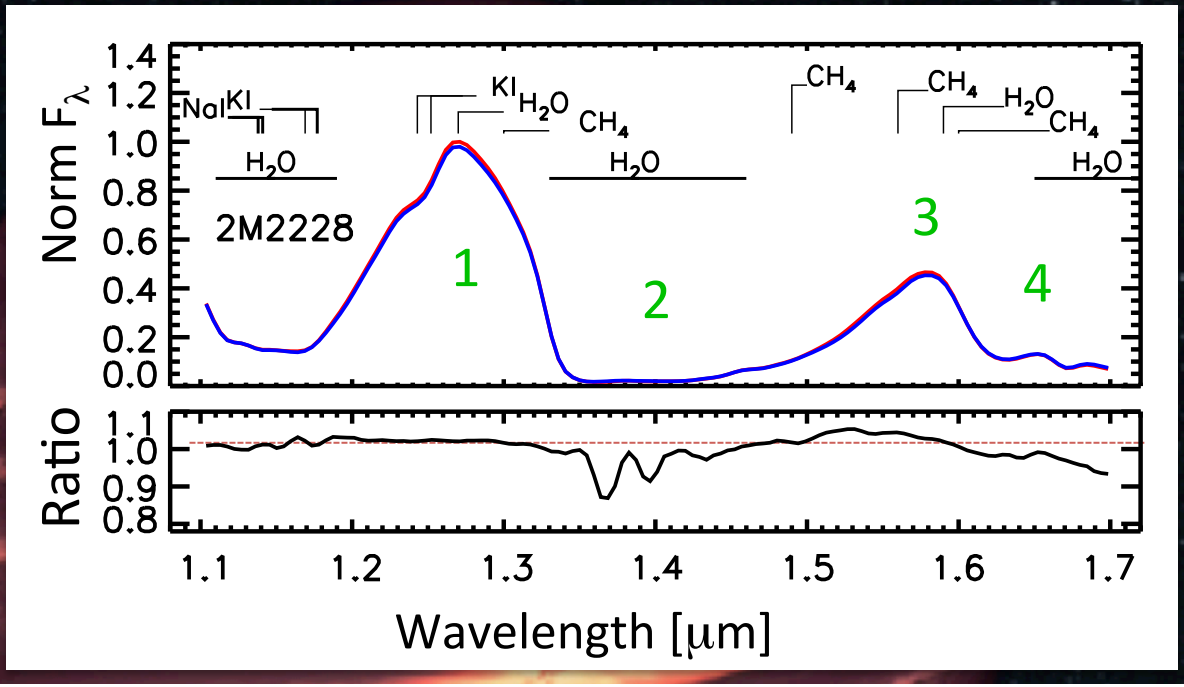
Data from database of ultracool parallaxes maintained by T. Dupuy

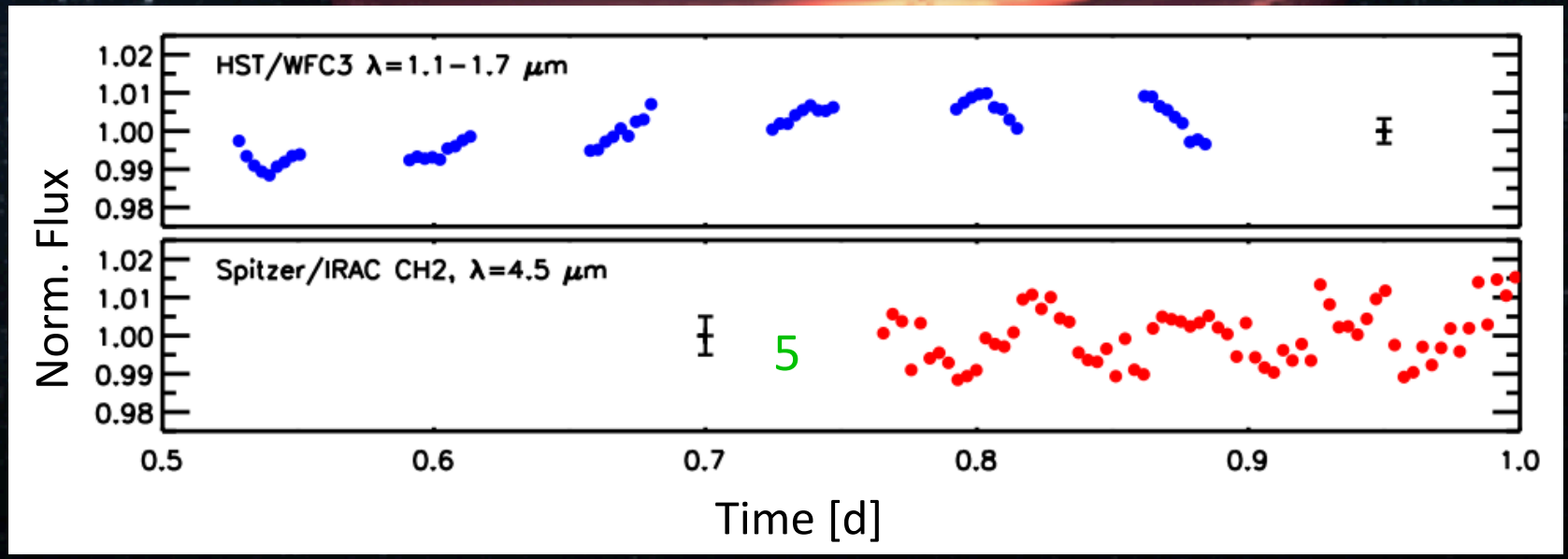
T6.5 dwarf 2M2228

Min. and Max. Spectra

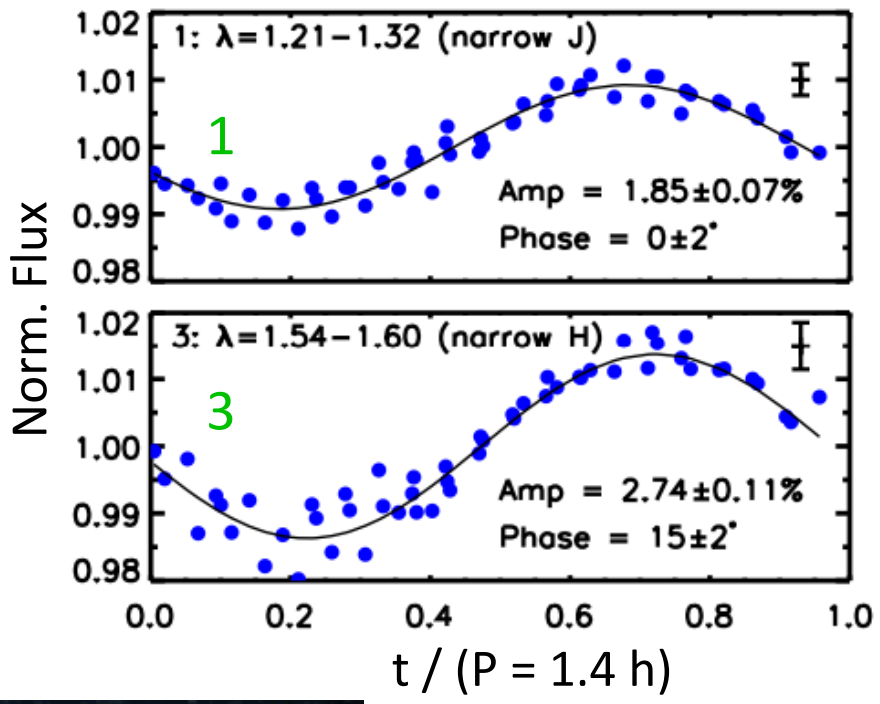
Ratio

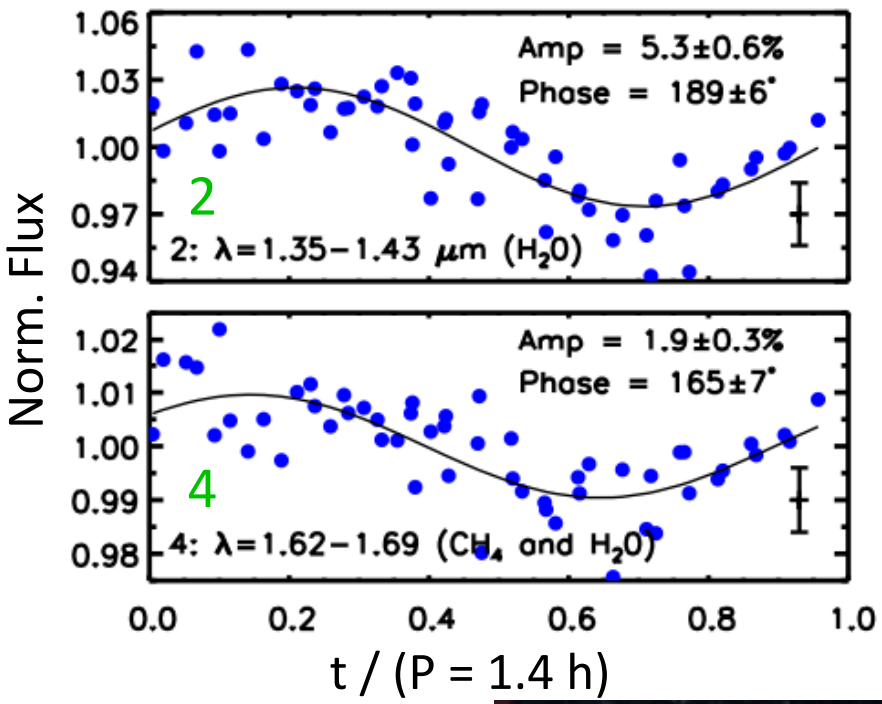
Buenzli et al. 2012

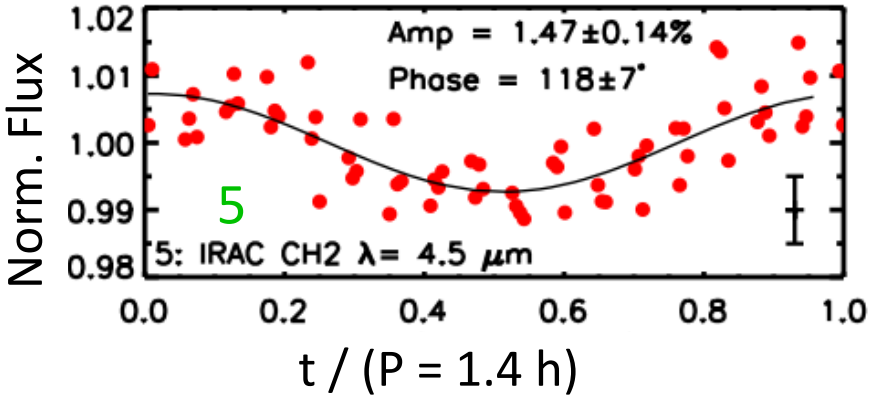




T6.5 dwarf 2M2228



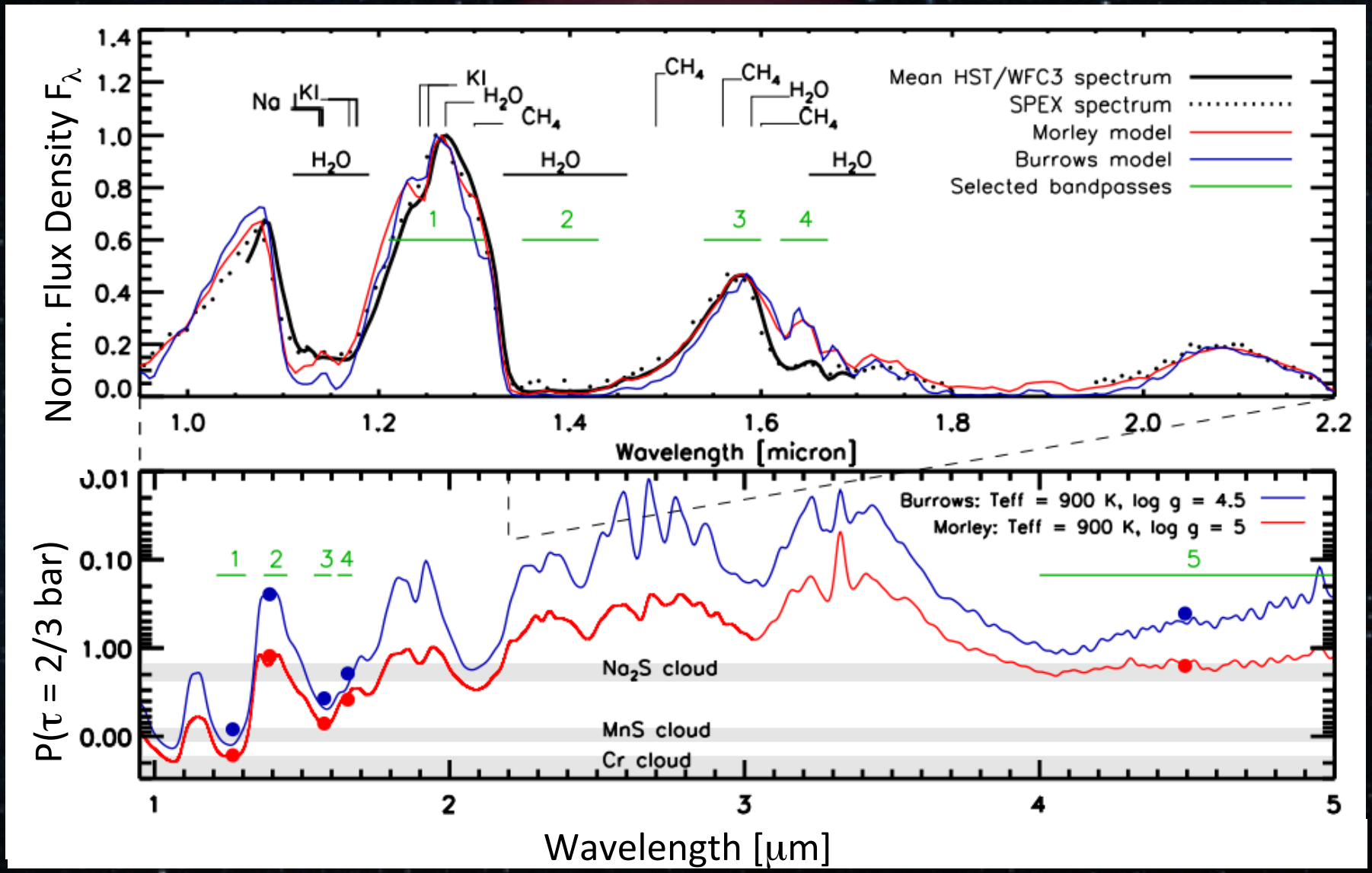




Buenzli et al. 2012

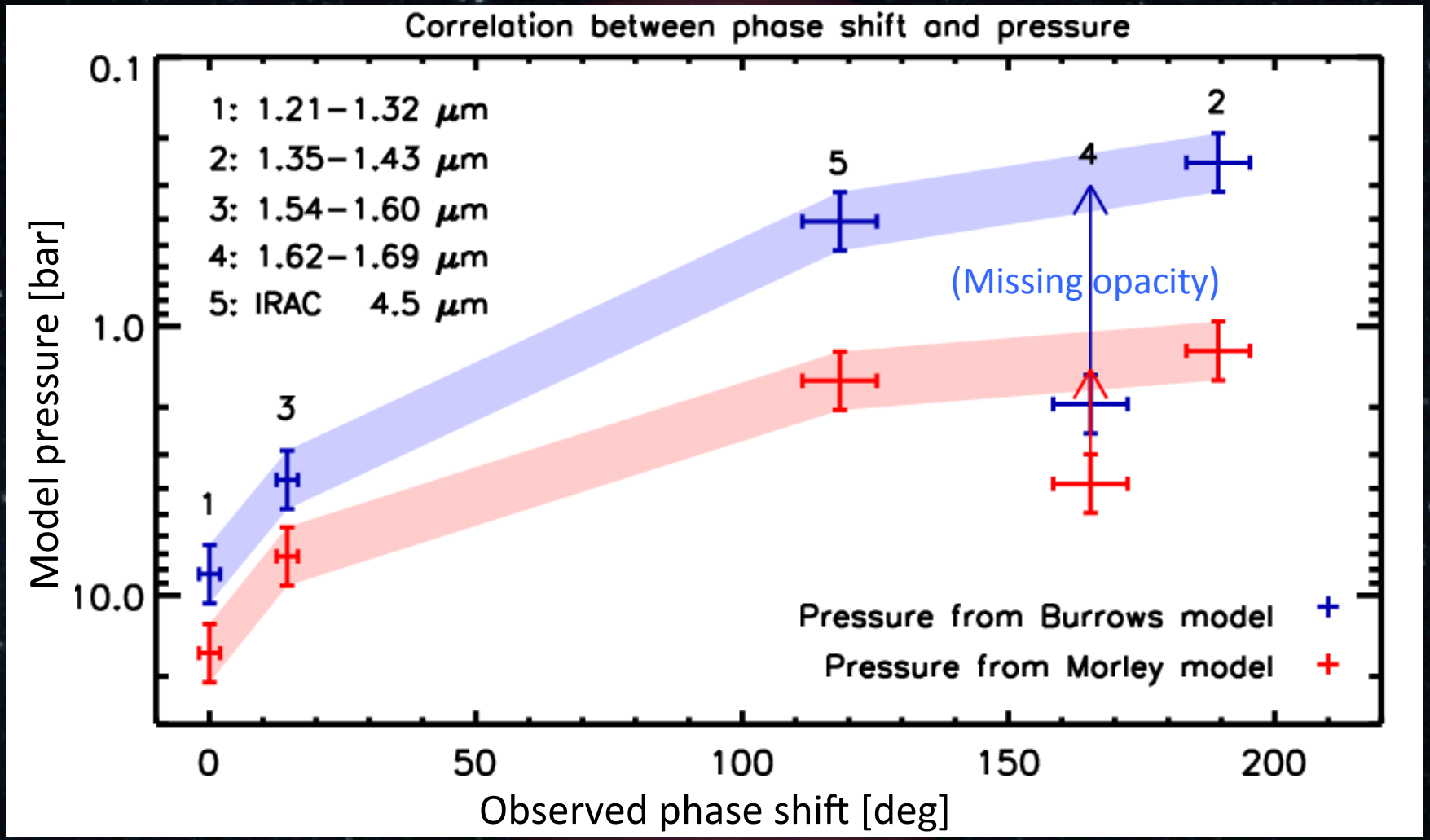
→ The phase is shifted significantly for different wavelengths!

Spectral modeling



Buenzli et al. 2012

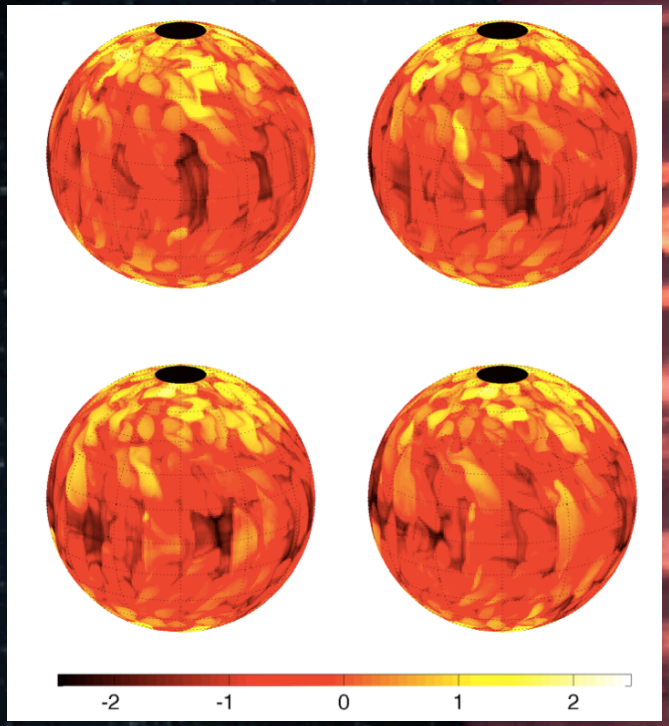
Phase shift vs Pressure



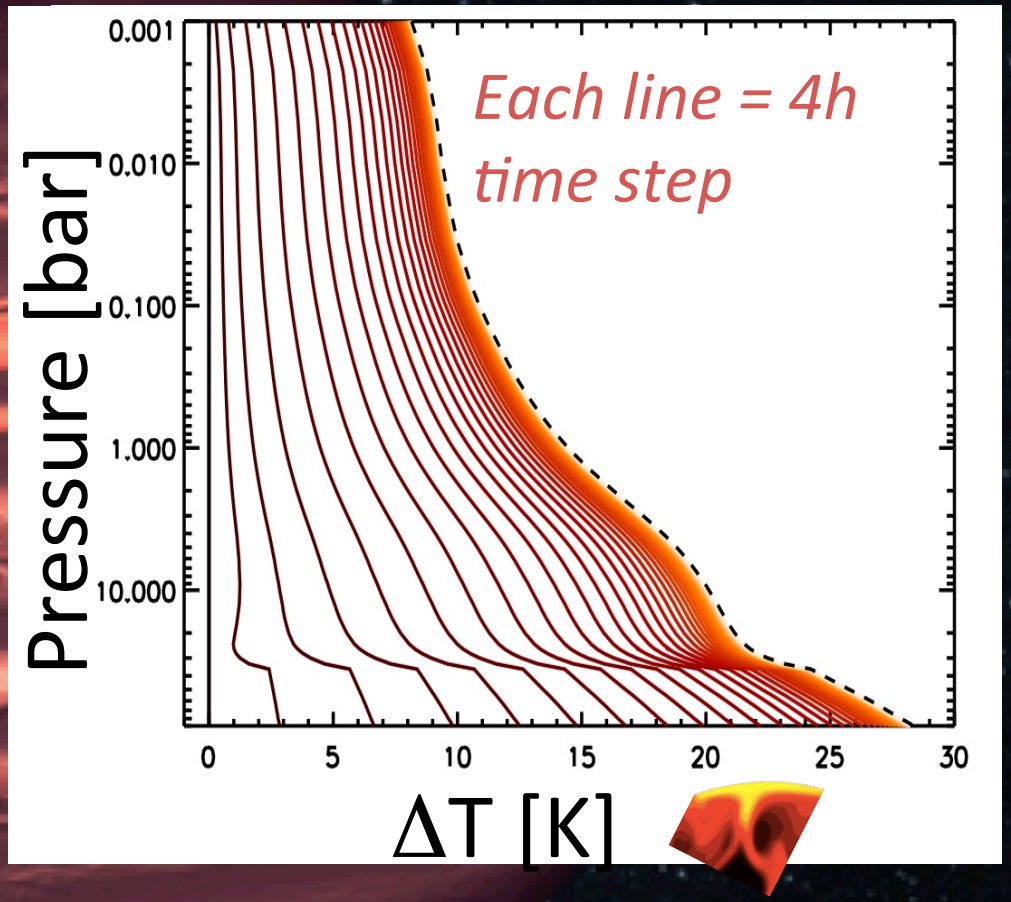
Buenzli et al. 2012

Temperature perturbations?

From Dynamics

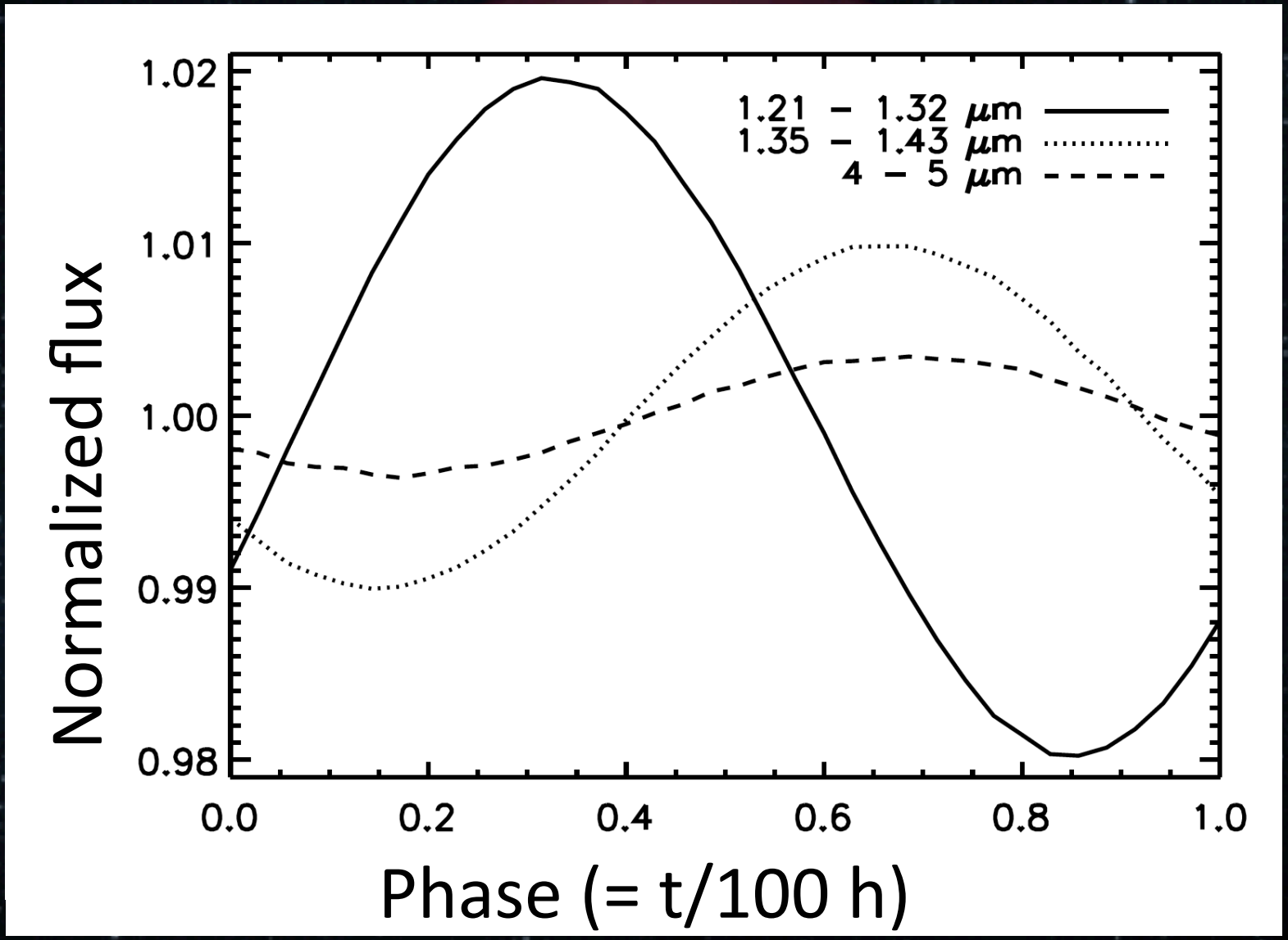


Showman & Kaspi 2013

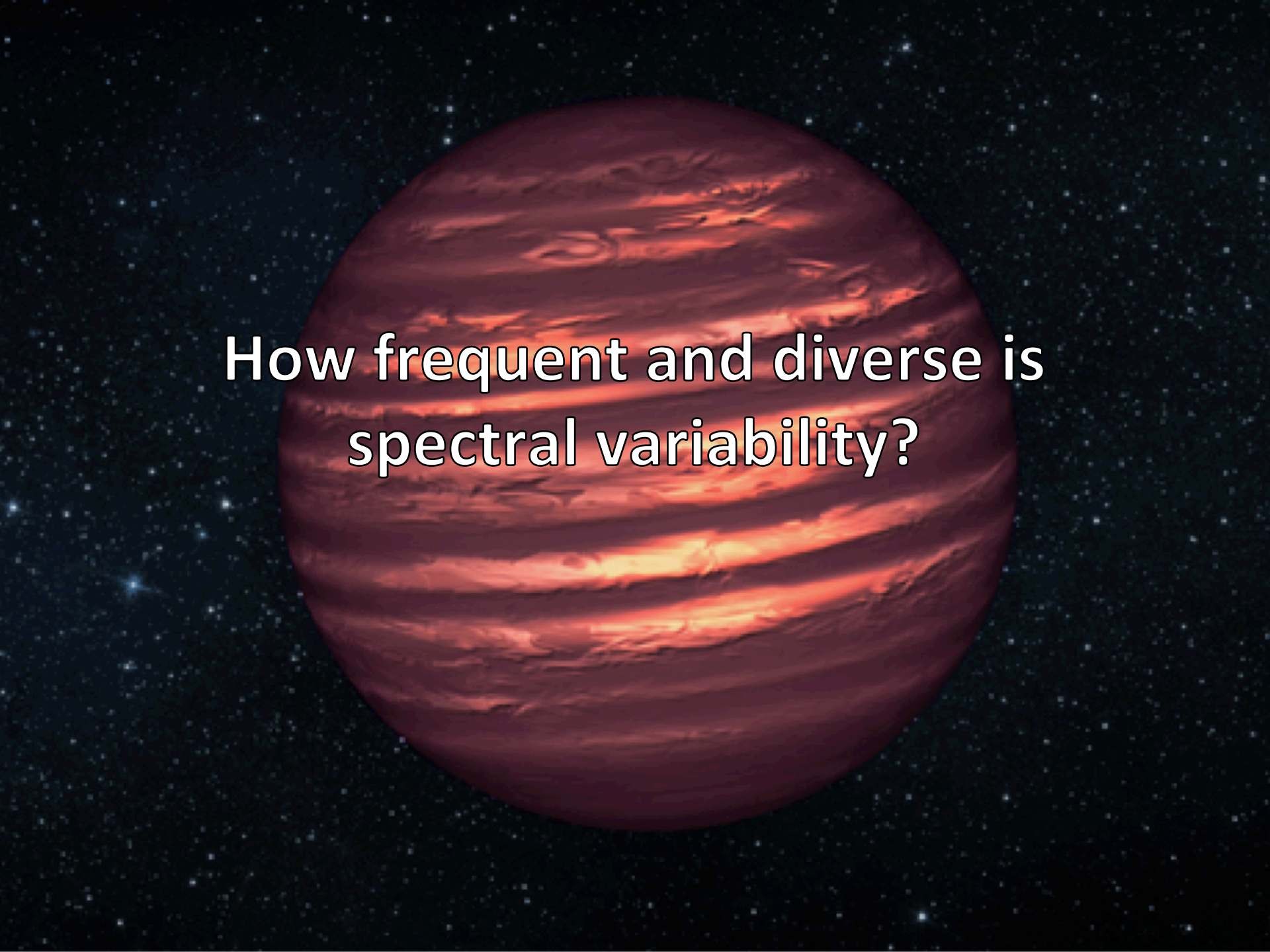


Robinson & Marley 2014

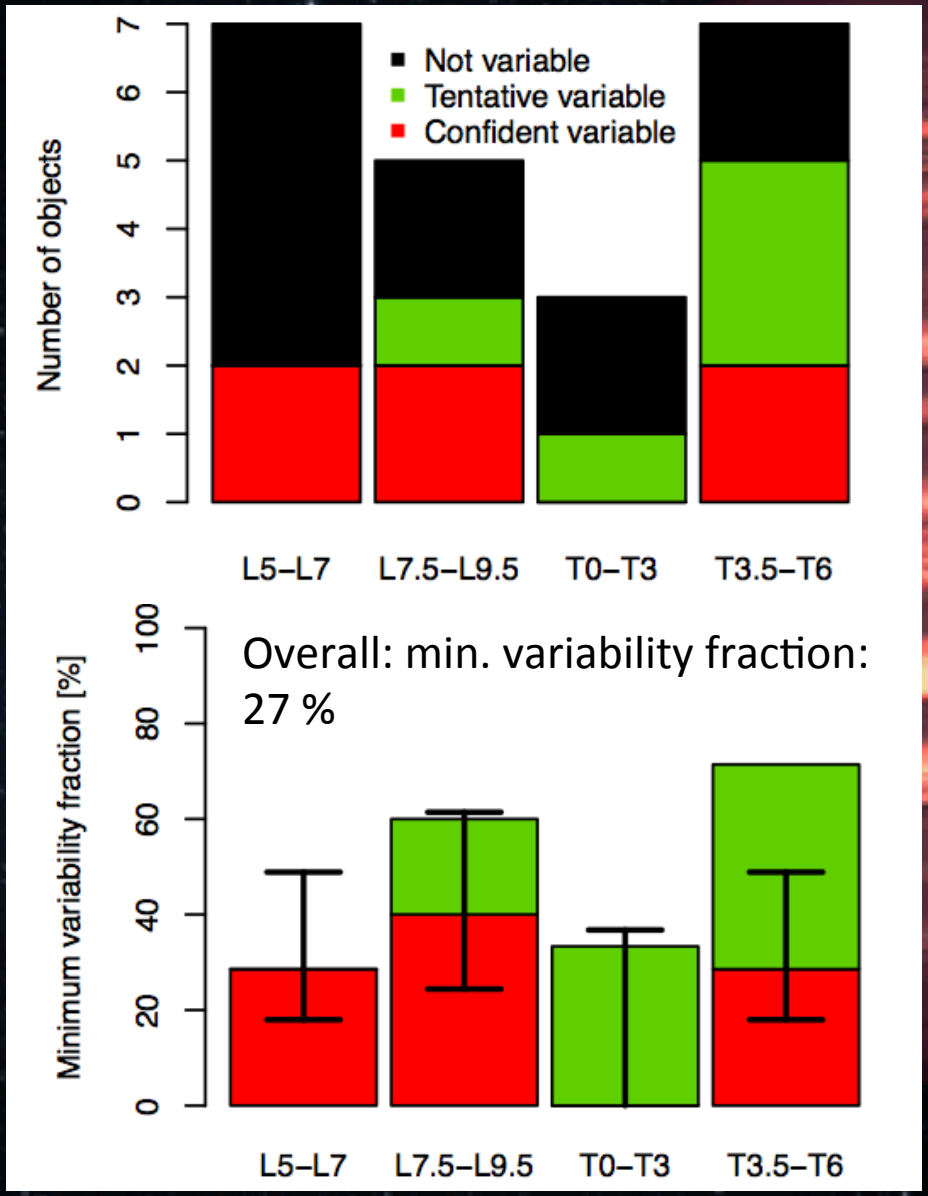
Temperature perturbations?



Robinson & Marley 2014


How frequent and diverse is spectral variability?

Variability frequency?



Overall: min. variability fraction: 27 %

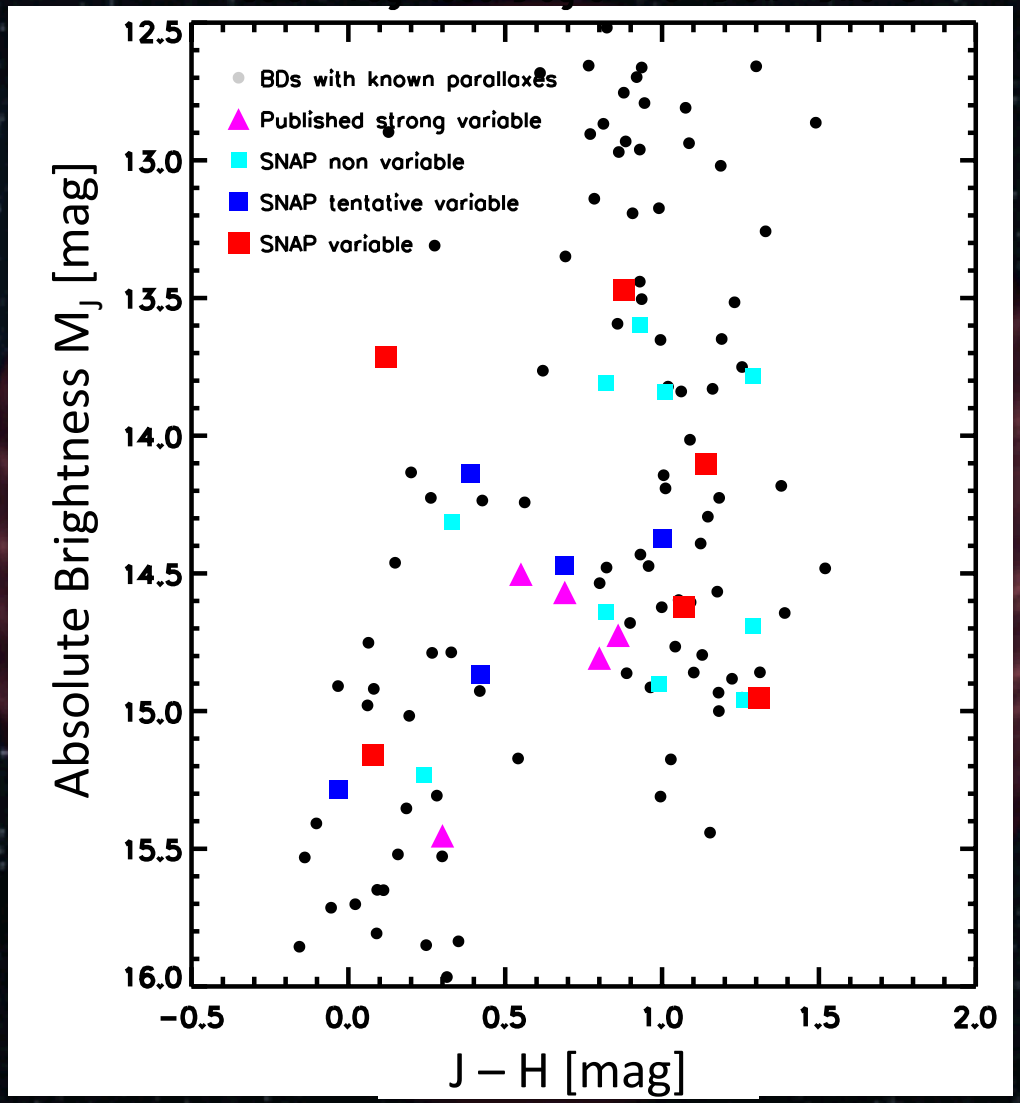
HST "Snapshot" survey

Variability trends within 40 min for 22 objects, L5 – T6

→ Primarily low-level variability: ~ 1% in ~40 min

Buenzli et al. 2014

Variability everywhere?



Buenzli et al. 2014

Low-level variability is common, but multiple percent variability is rare and only occurs in the L/T transition?

Summary

- Cloudy/clear models fail at L/T transition,
  fast evolving weather
- Temperature perturbations (+clouds?) for mid T dwarfs
- Low-level variability is frequent (>30 %) from mid L to mid T,
  but strong broad-band variability only at L/T transition?
- Luhman 16 is a unique test case for the L/T transition,
  observable with Gaia

→ Models need to account for 2D and 3D heterogeneities