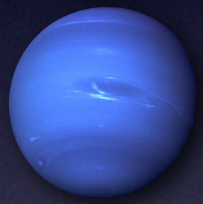
Spectra of Cool Giants

Mark Marley & Kerri Cahoy
(NASA Ames)

Classes of Targets

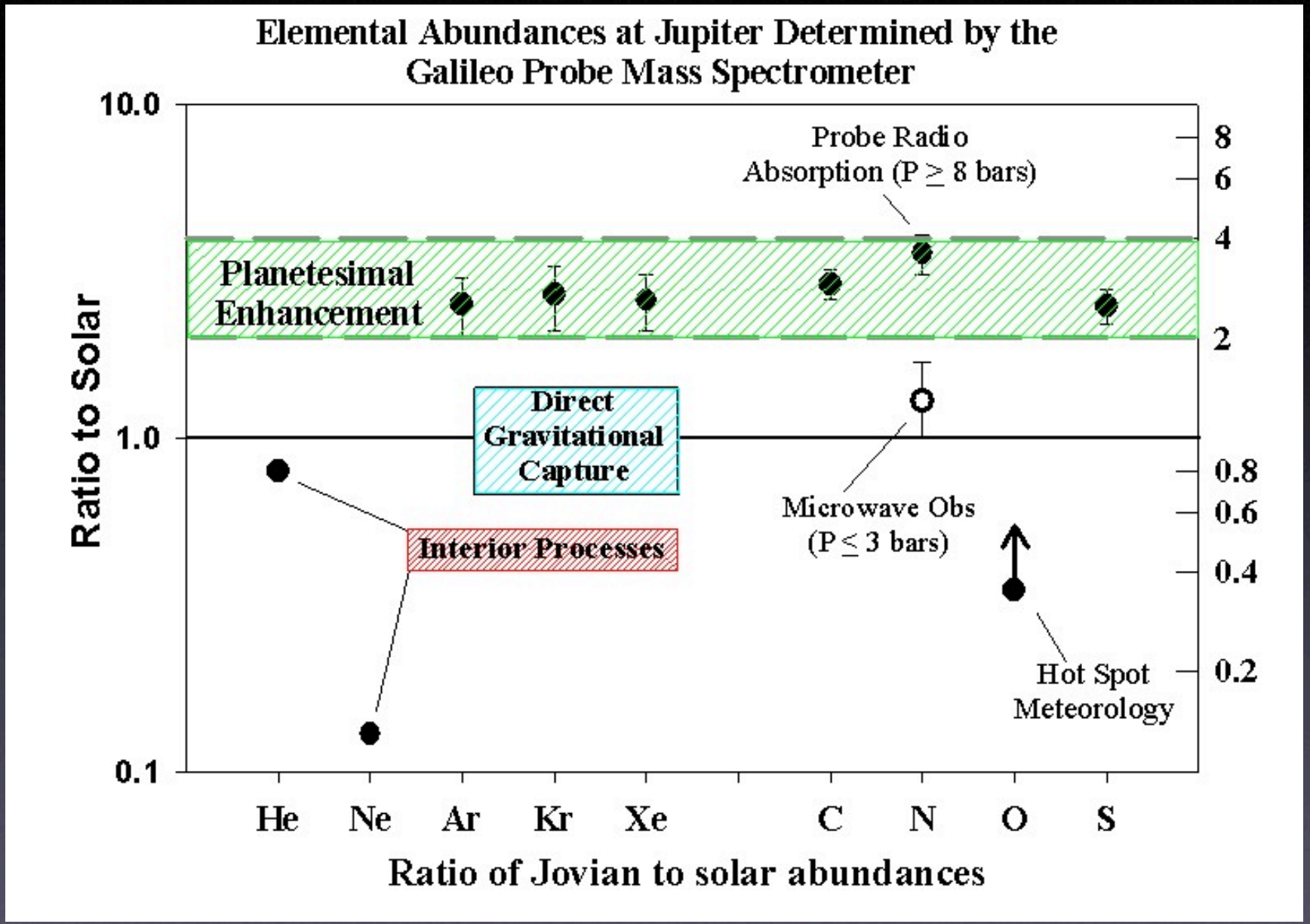
- Giants
  - gas - Jupiter
  - "ice" - Neptune
  - transition to brown dwarfs - 55 Cnc d



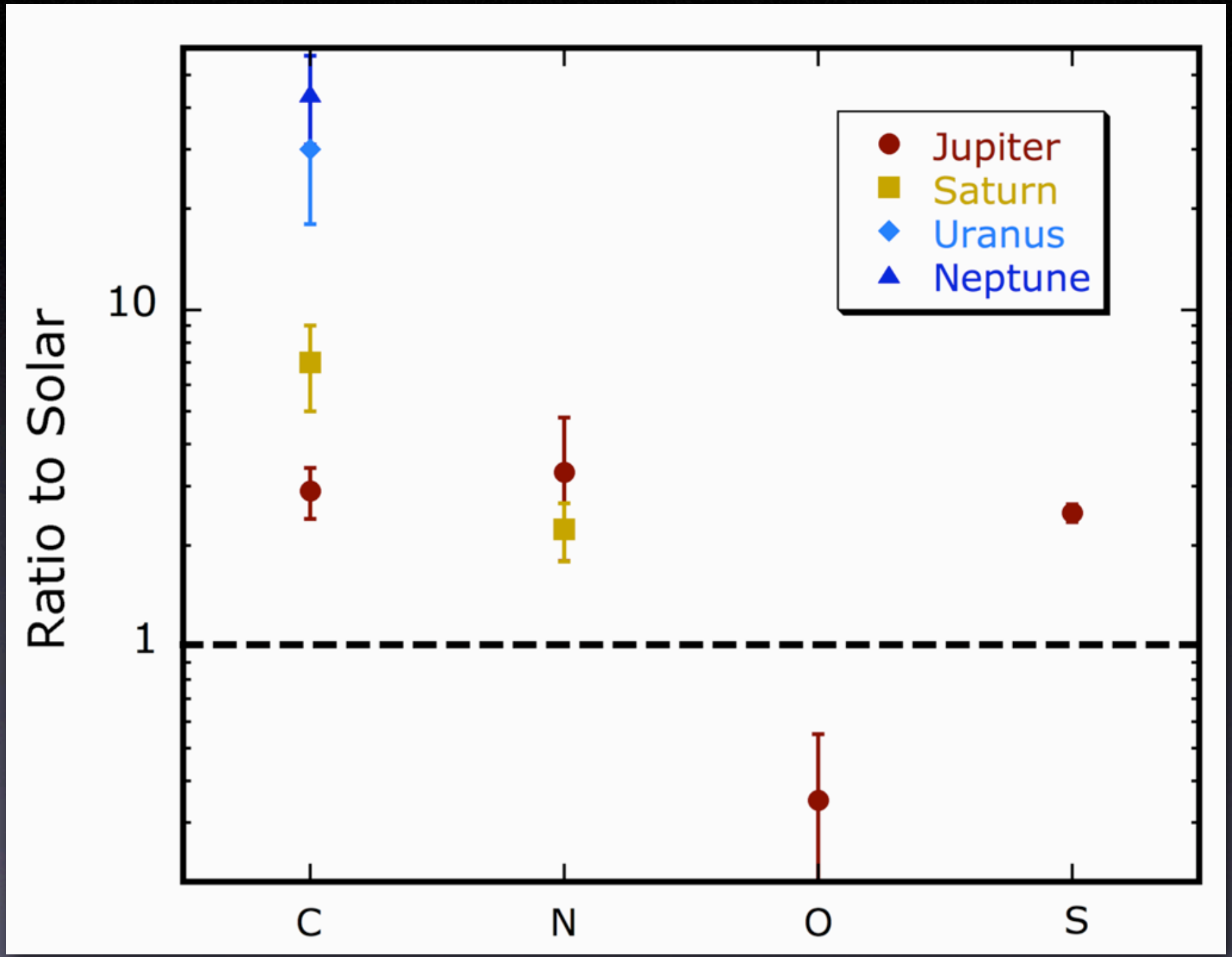
- What can we learn from low resolution spectra or colors?

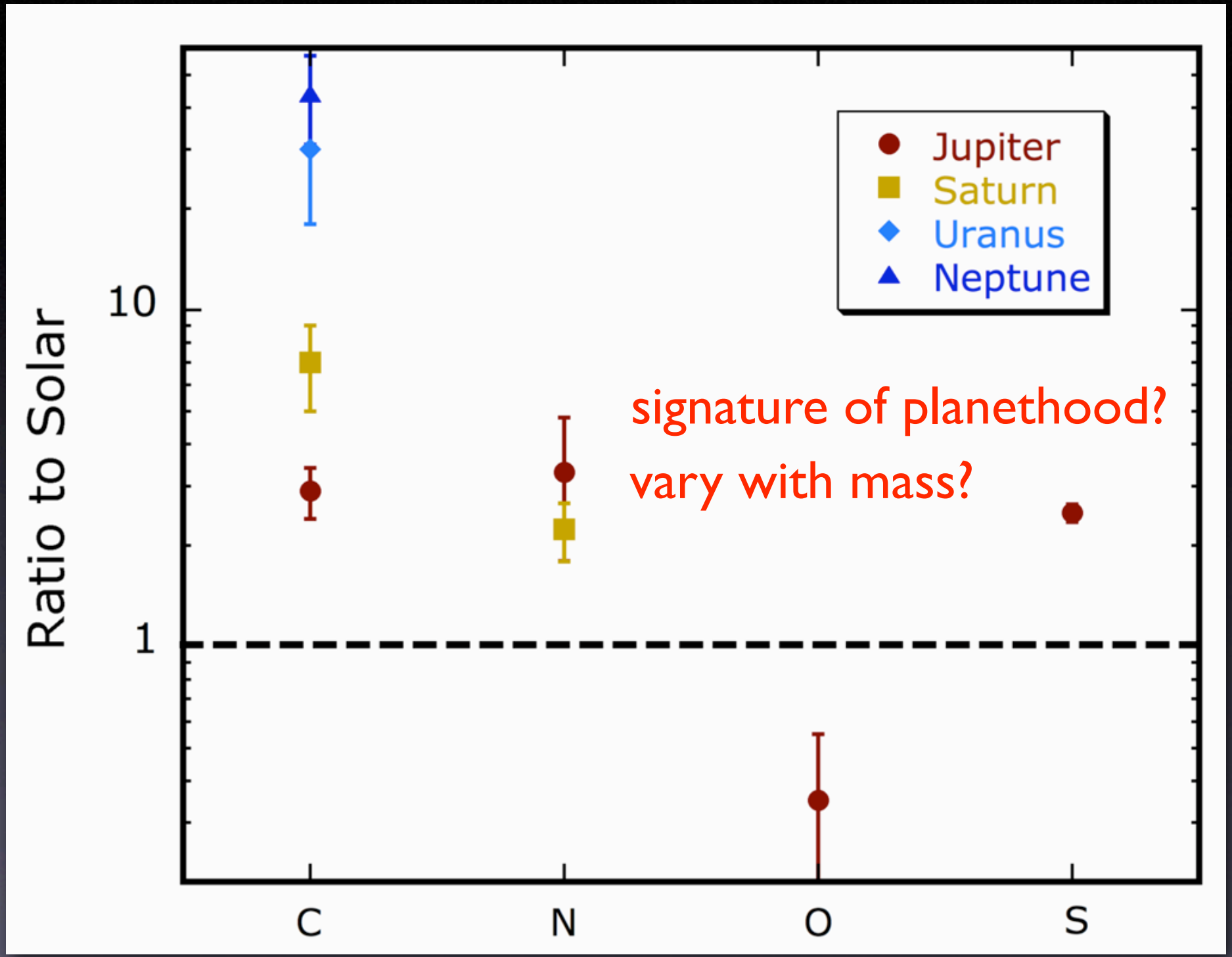
Reflection Spectra

- Composition
- Clouds
- Phase dependence



Owen et al. (1999)


Ratio to Solar
10
1
C
N
O
S
Jupiter
Saturn
Uranus
Neptune


Ratio to Solar
10
1
C
N
O
S
Jupiter
Saturn
Uranus
Neptune
signature of planethood?
vary with mass?

Clouds

Color and albedo are functions of type and depth of clouds.

Clouds depend on BOTH internal heat flow (mass, age) and incident flux.

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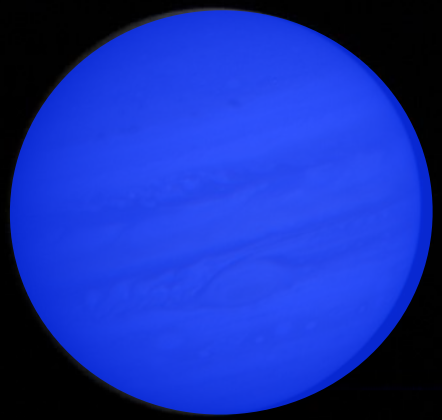

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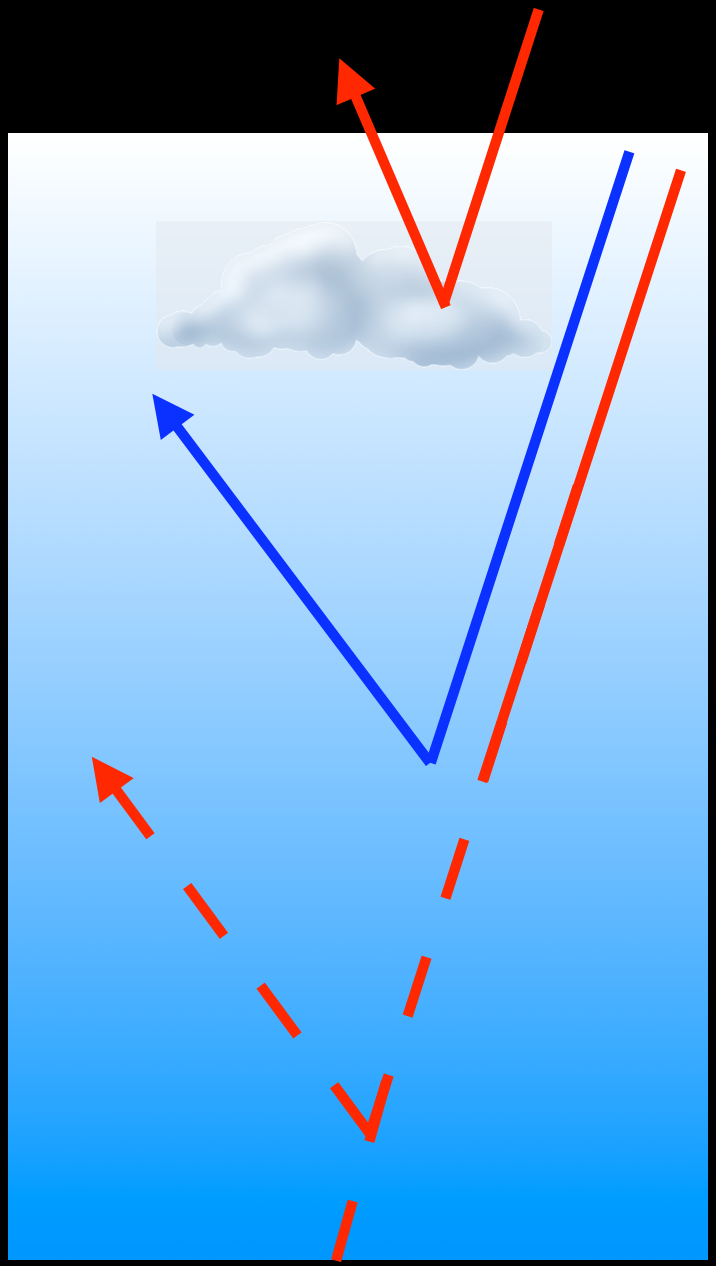
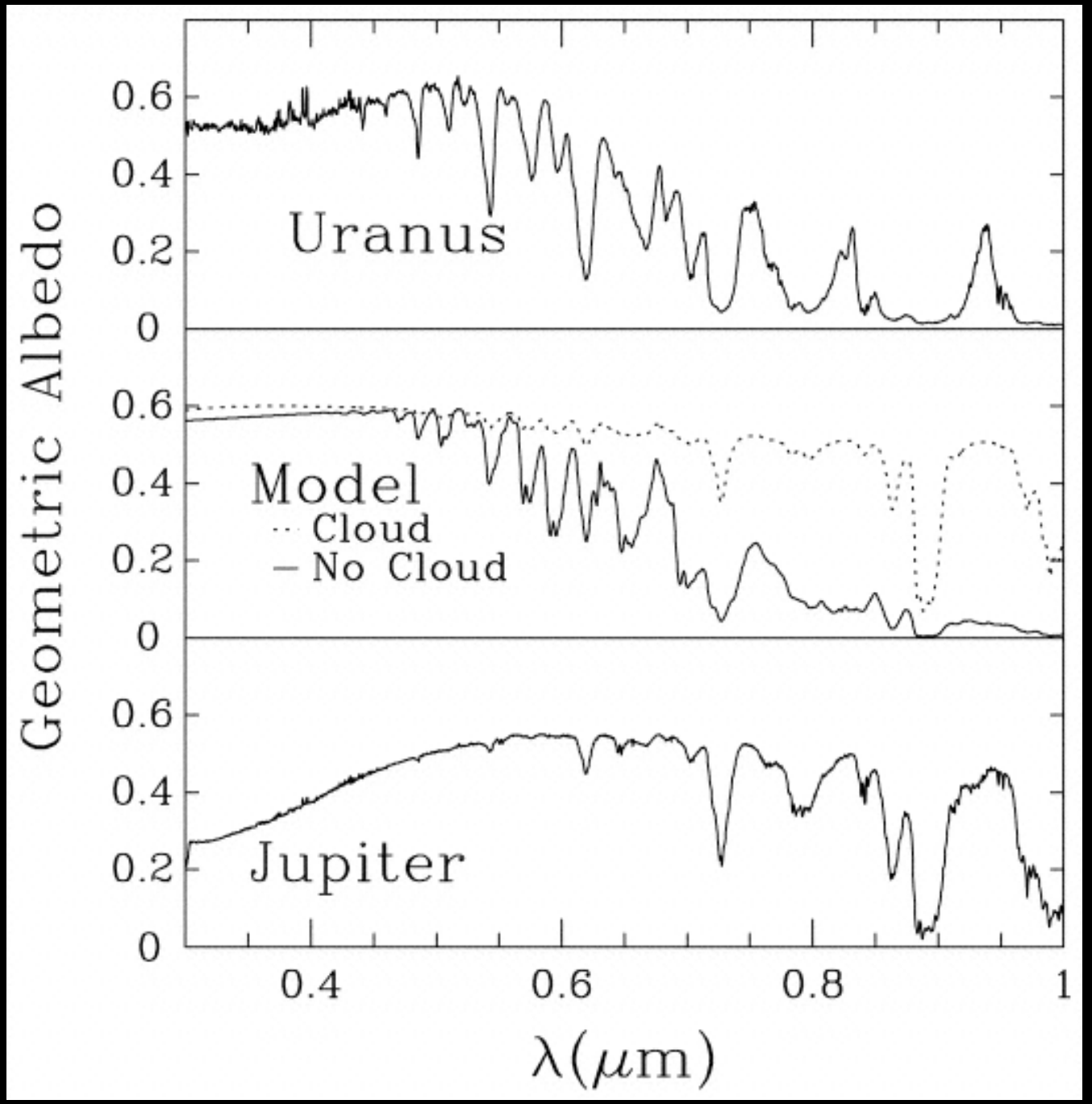
photochemistry

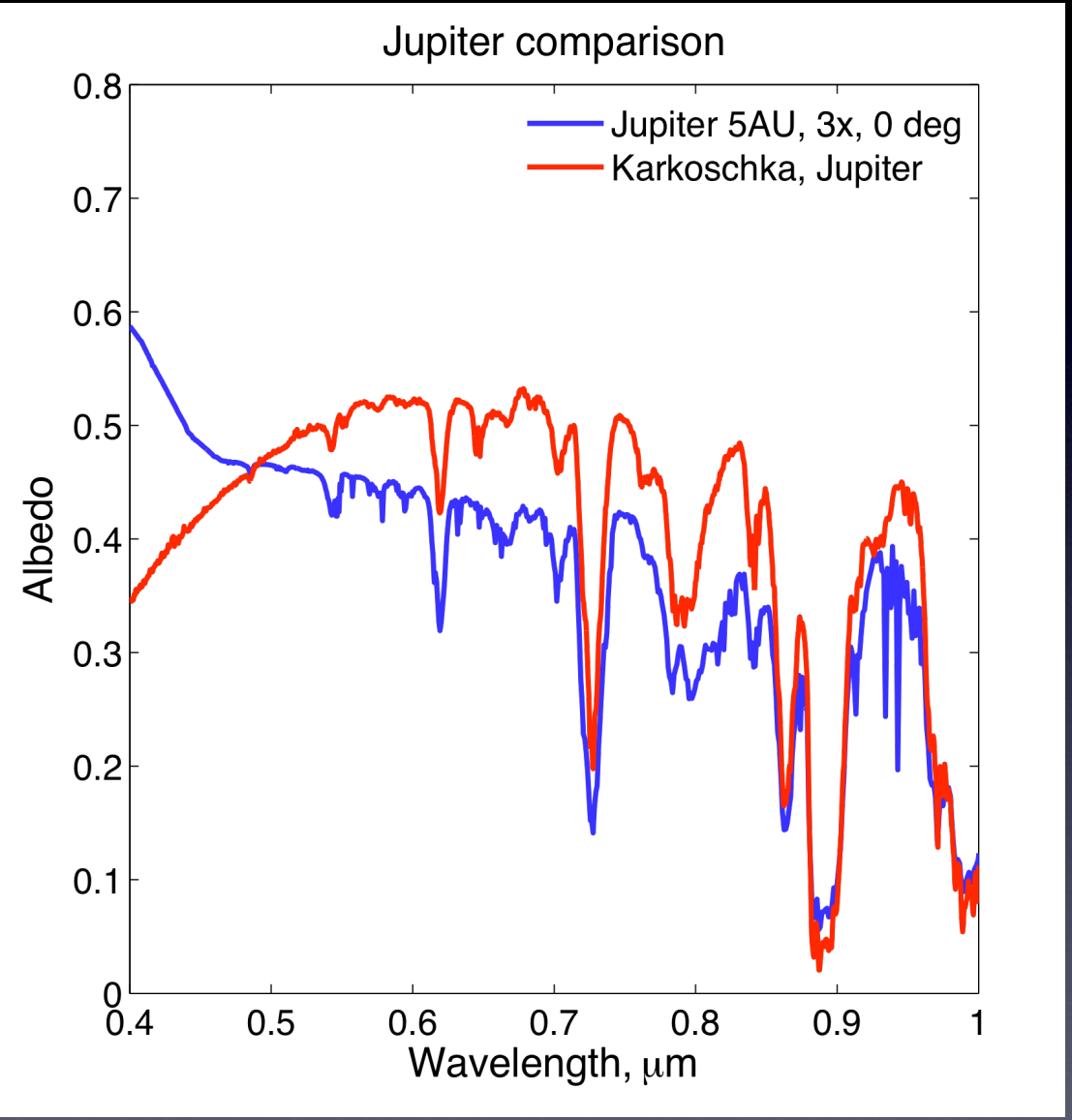




Marley et al. (1999)

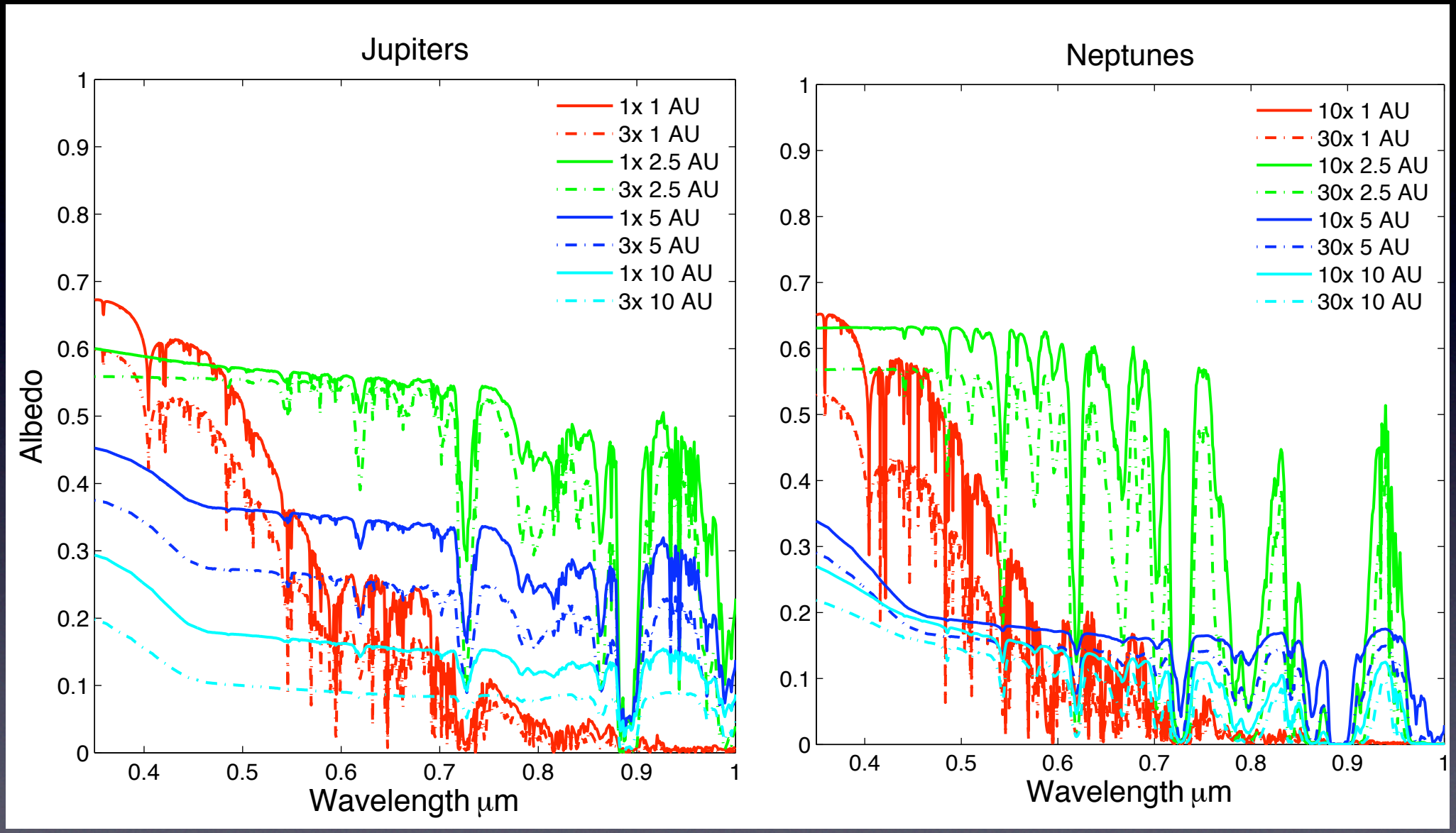
Model Albedo Spectra

- Comparison of output albedo spectra with measured spectra from Karkoschka (1994)
  - *Untuned* model
  - Real Jupiter has a haze layer that absorbs well in the blue
  - Model does not include UV gaseous absorbers like C_2H_2
  - Clouds too low in this model
  - Could be mistaken for metallicity



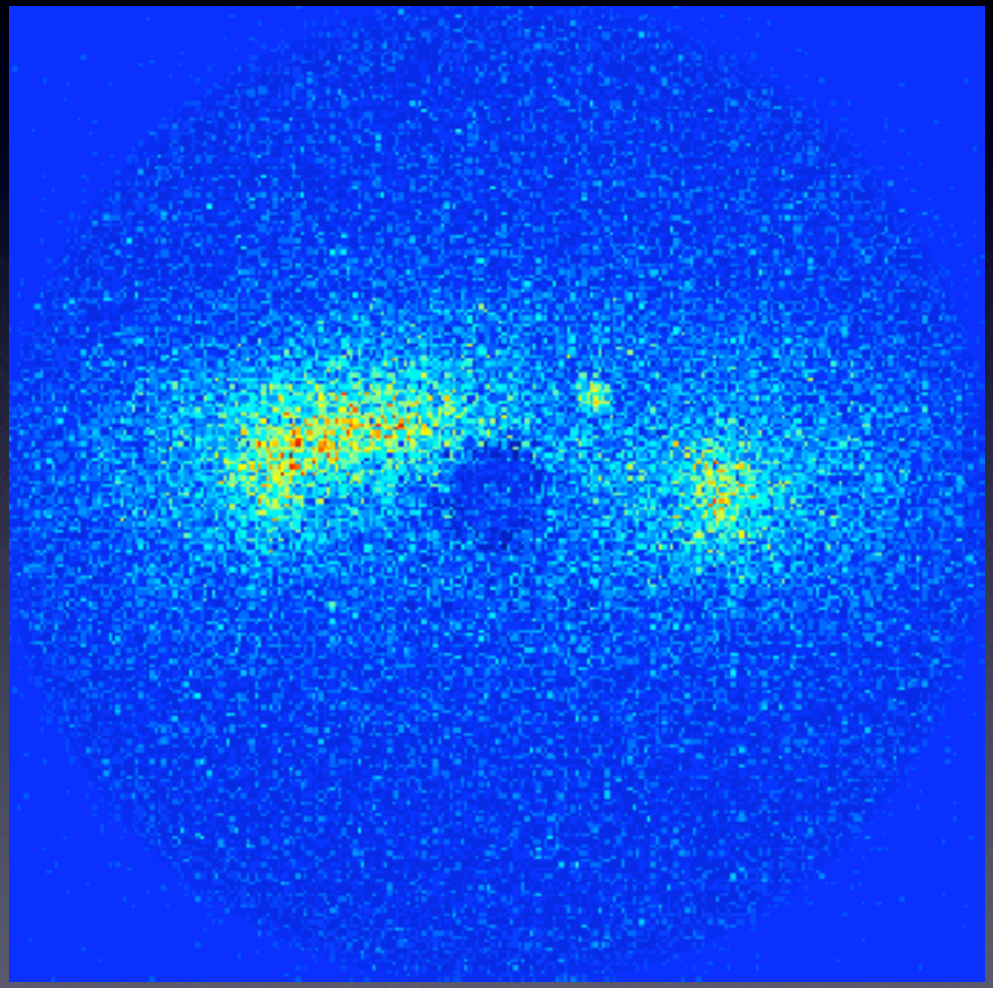
Cahoy, Marley & Fortney (in prep)

Diversity of Spectra



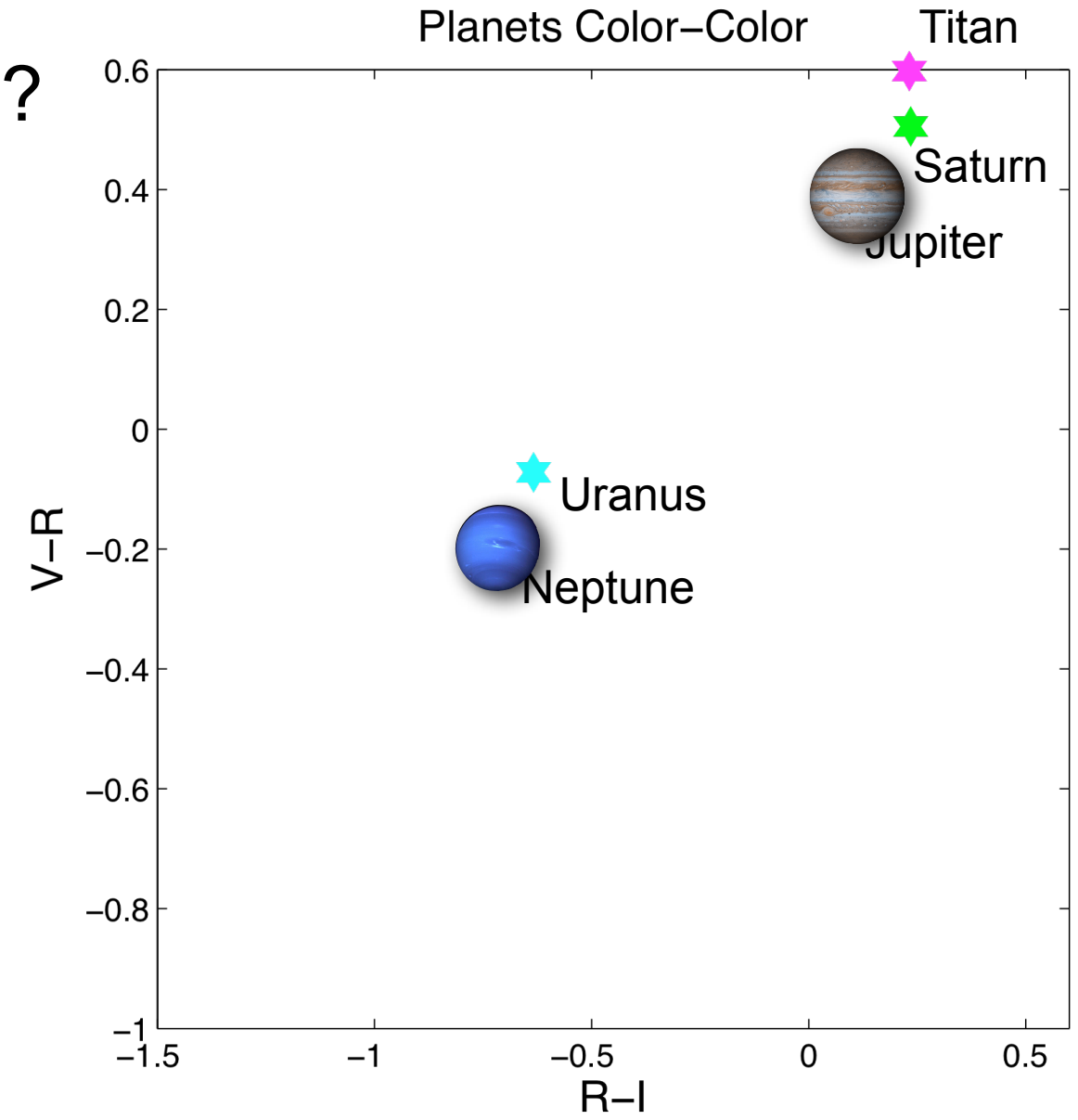
Cahoy, Marley & Fortney (in prep)

Few Band Photometry?



Diversity of Colors

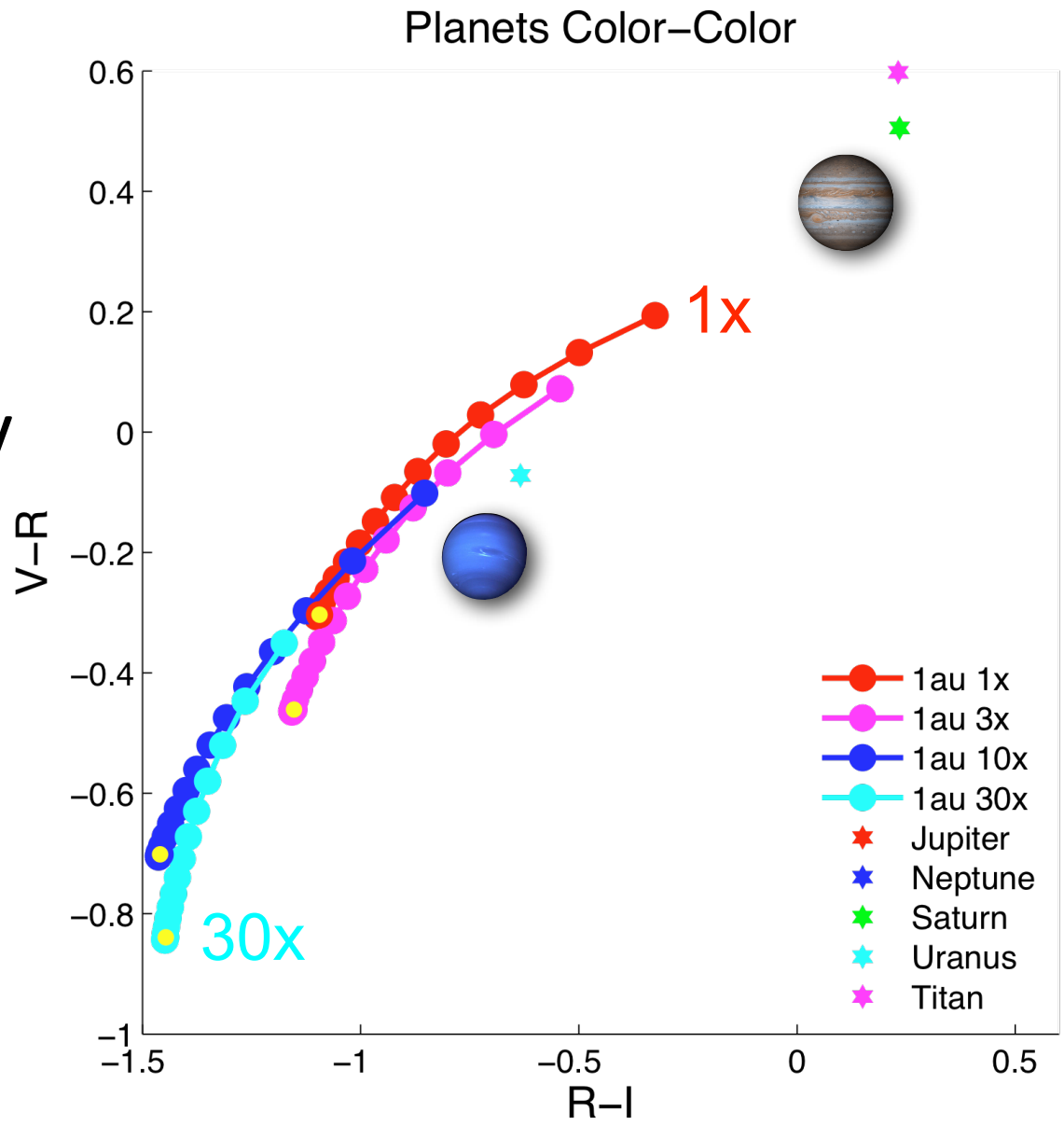
Do colors ID planets?



Cahoy, Marley & Fortney (in prep)

Diversity of Colors

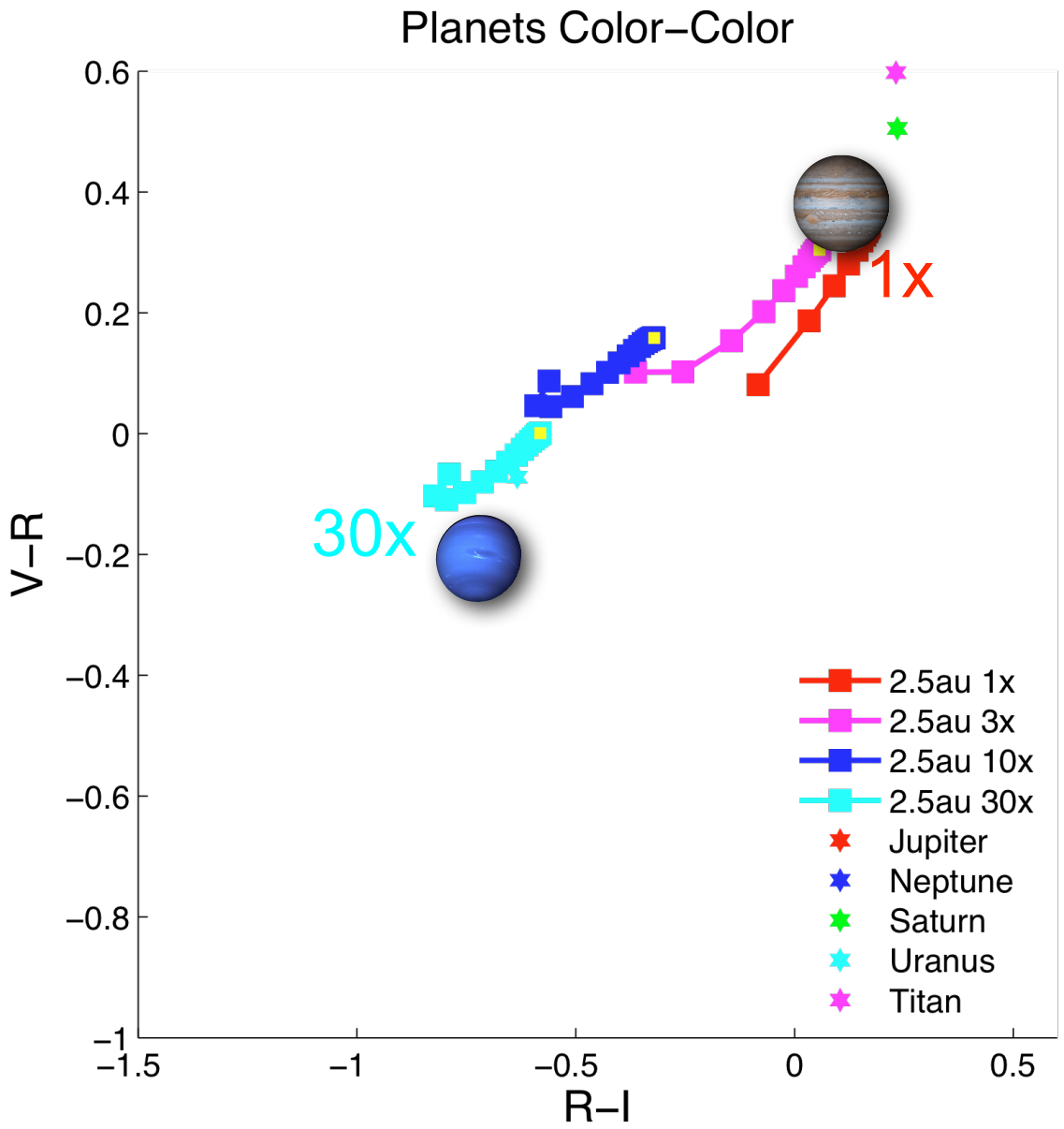
- 1 AU
- color sensitive to metallicity
- phase angle is very important



Cahoy, Marley & Fortney (in prep)

Diversity of Colors

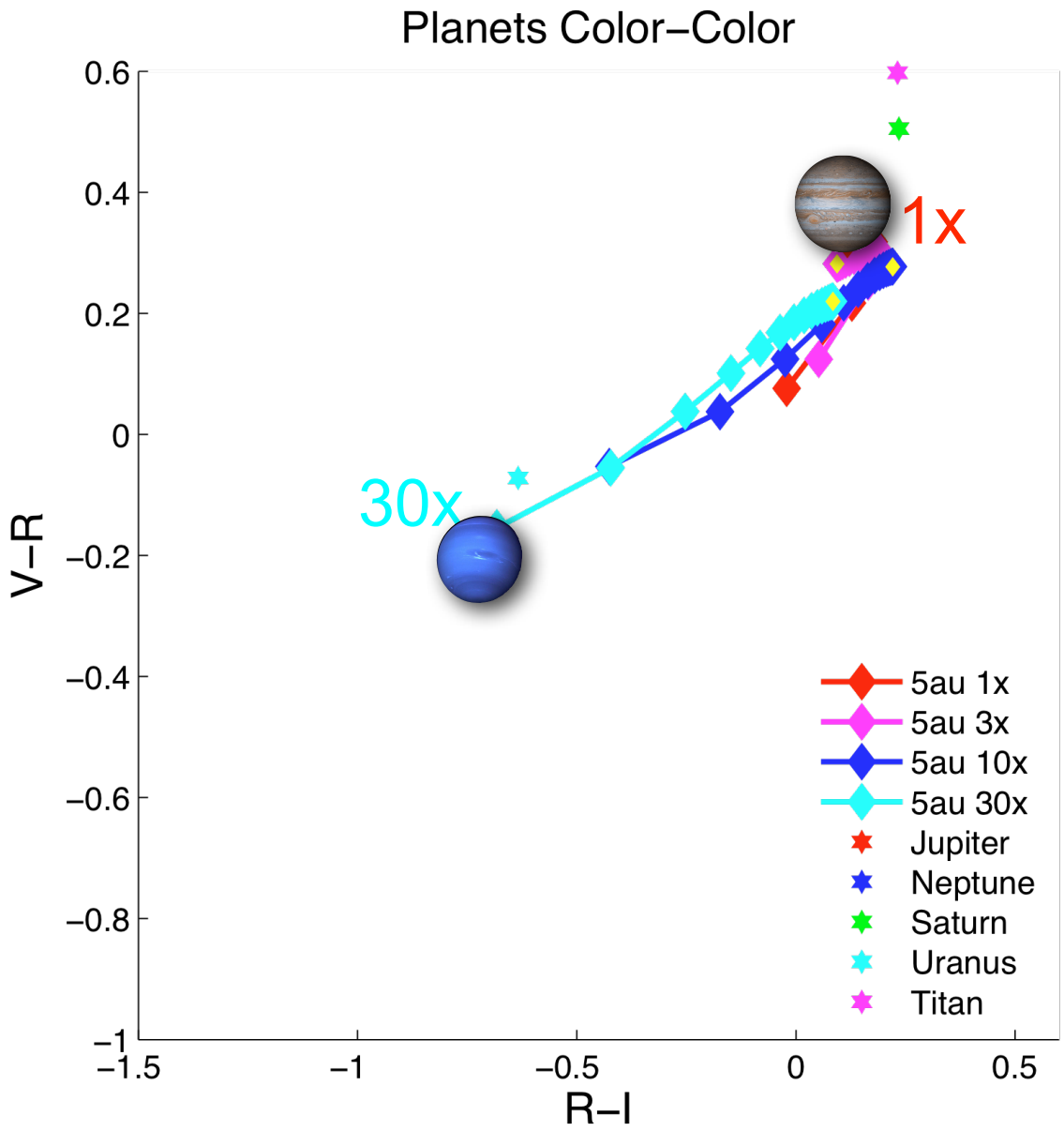
- 2.5 AU



Cahoy, Marley & Fortney (in prep)

Diversity of Colors

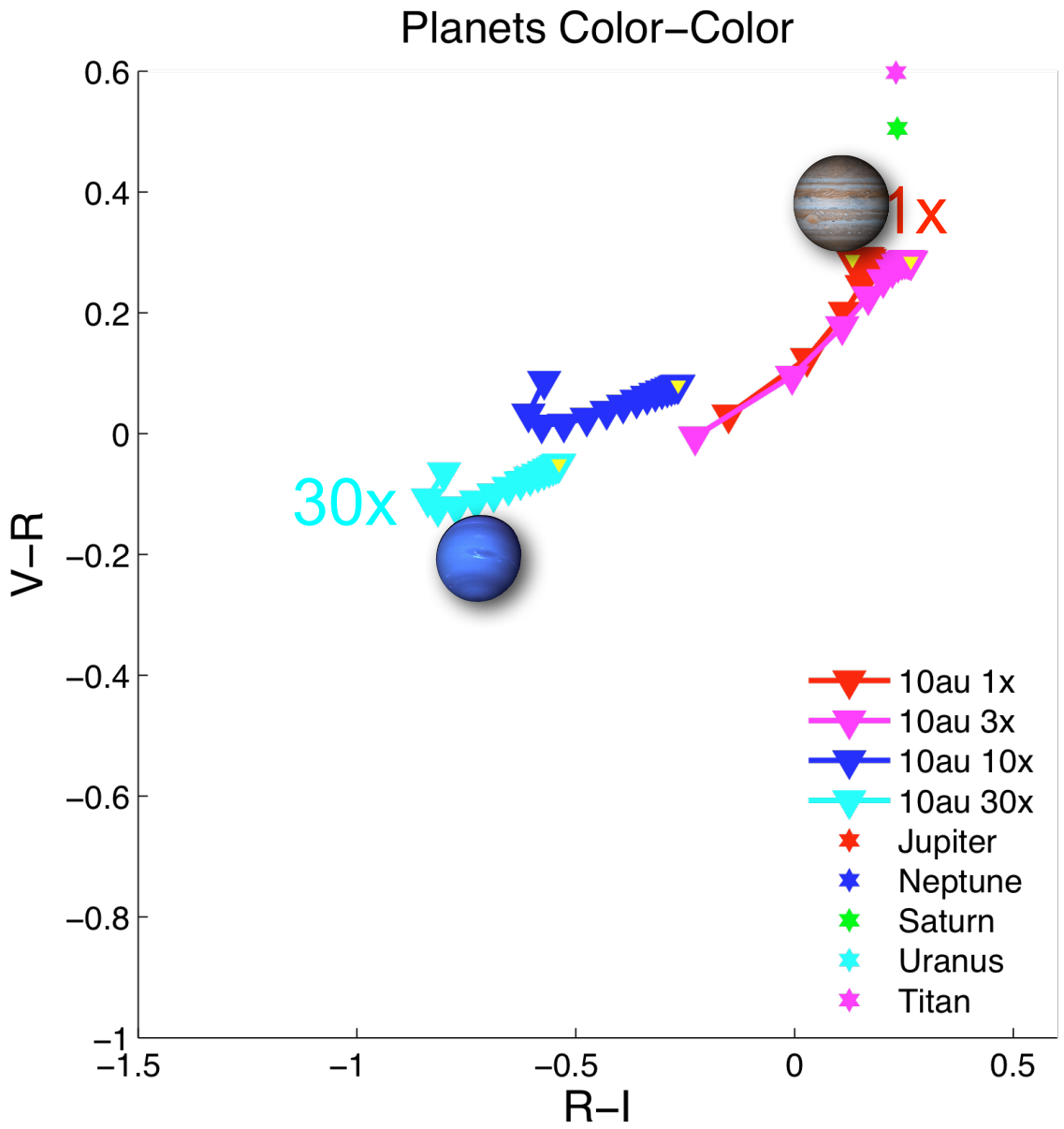
- 5 AU



Cahoy, Marley & Fortney (in prep)

Diversity of Colors

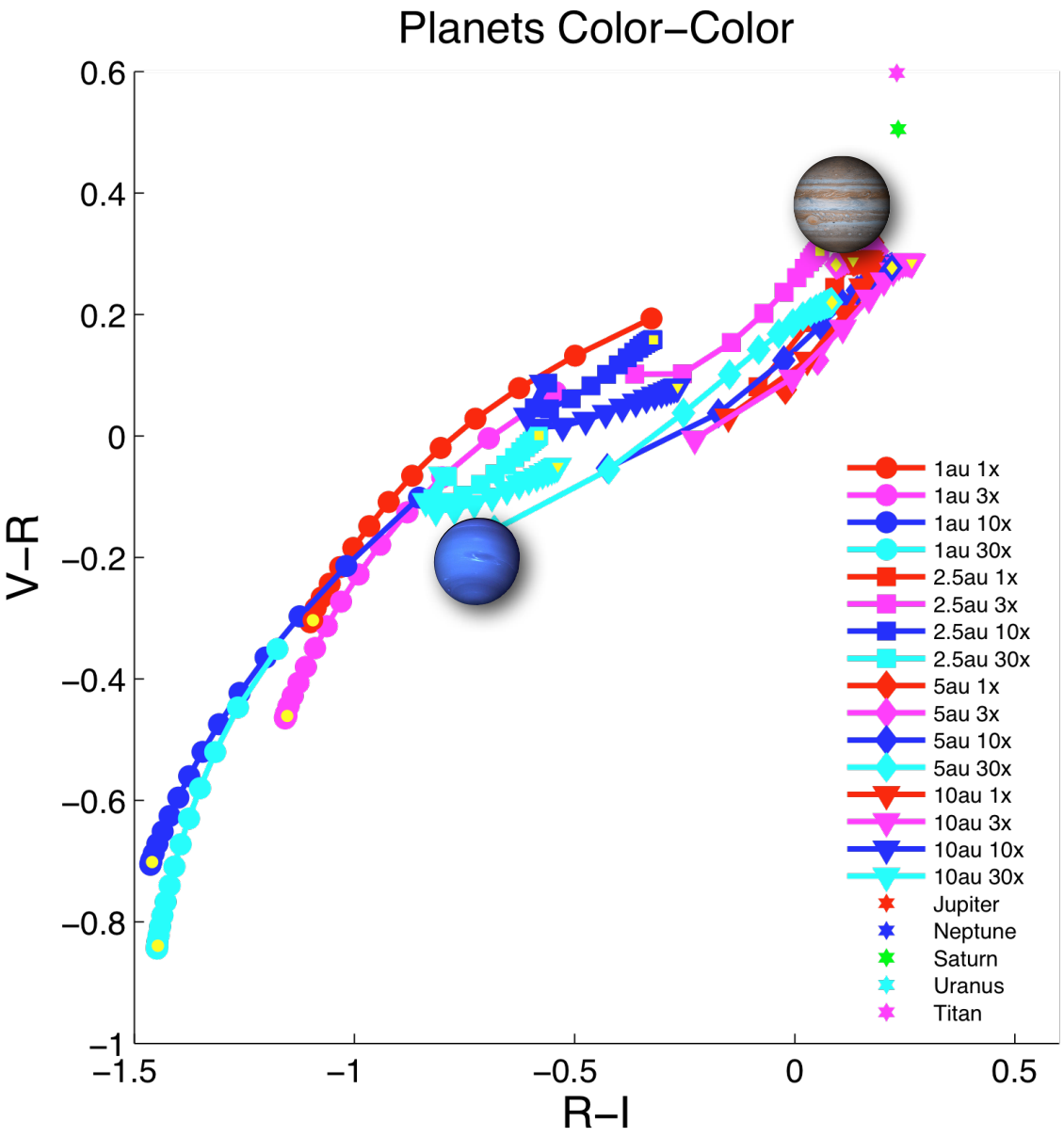
- 10 AU



Cahoy, Marley & Fortney (in prep)

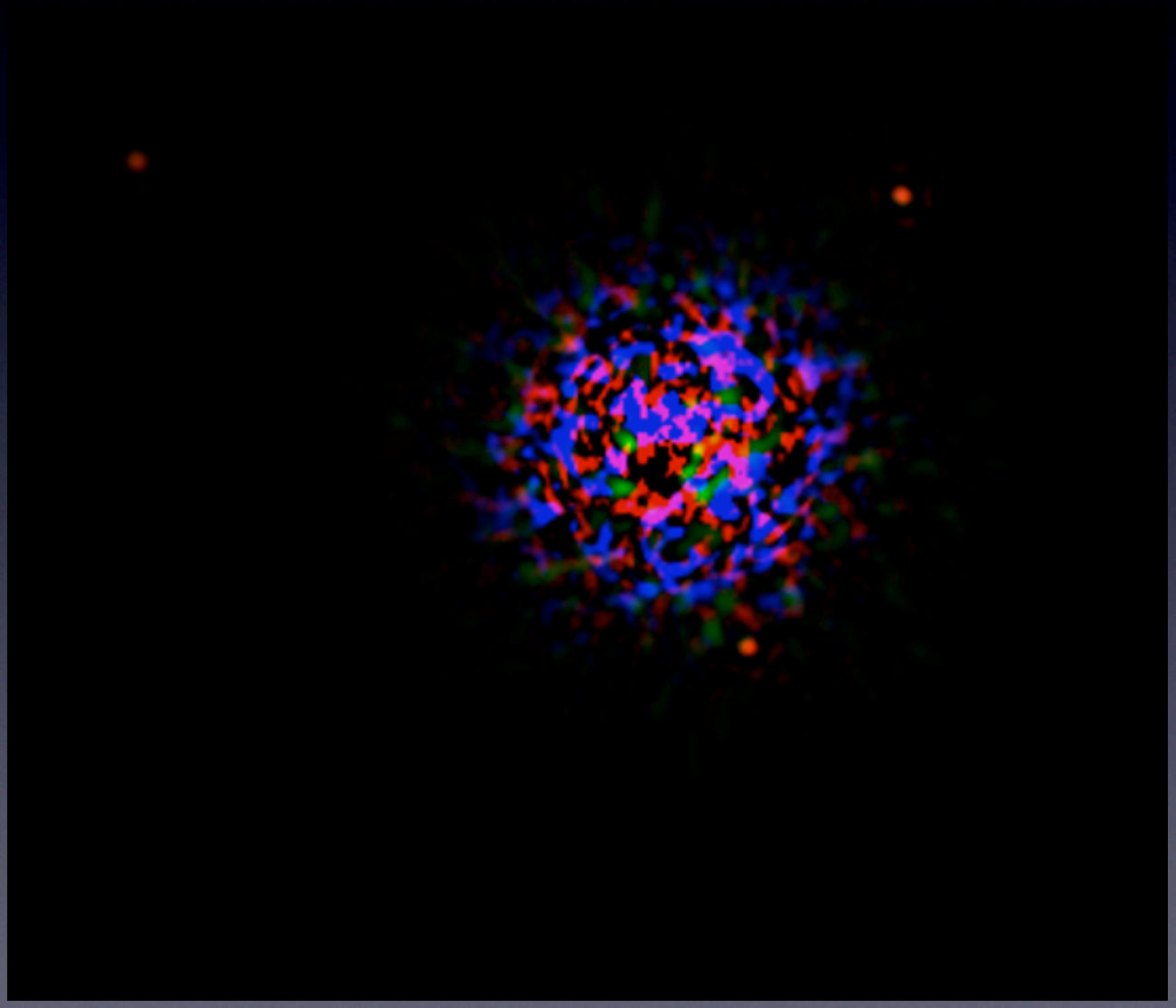
Diversity of Colors

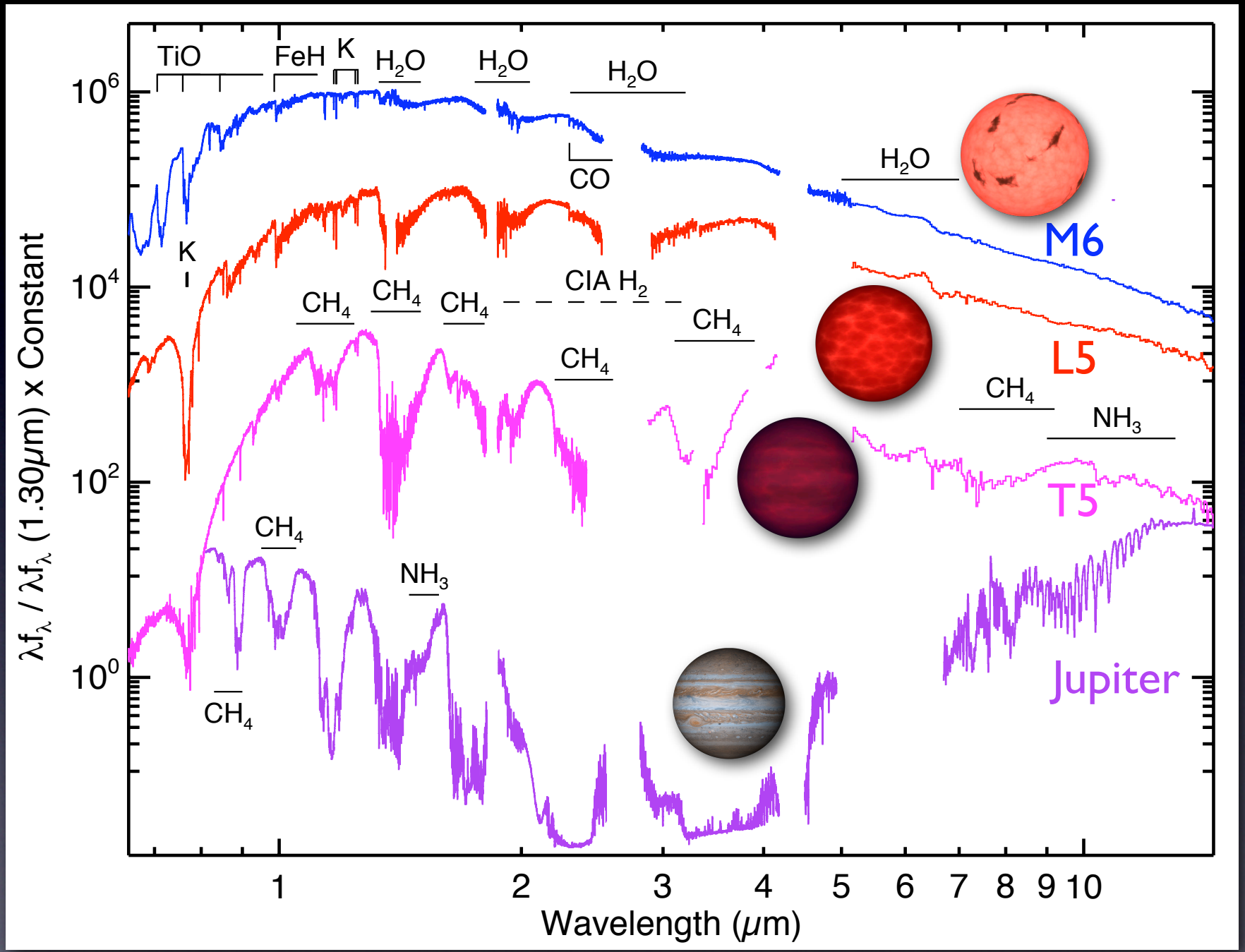
- Colors are a first characterization step
- Need to know observed phase in order to properly interpret spectra and colors
- Trivial if RV or astrometric detection, otherwise less so



Cahoy, Marley & Fortney (in prep)

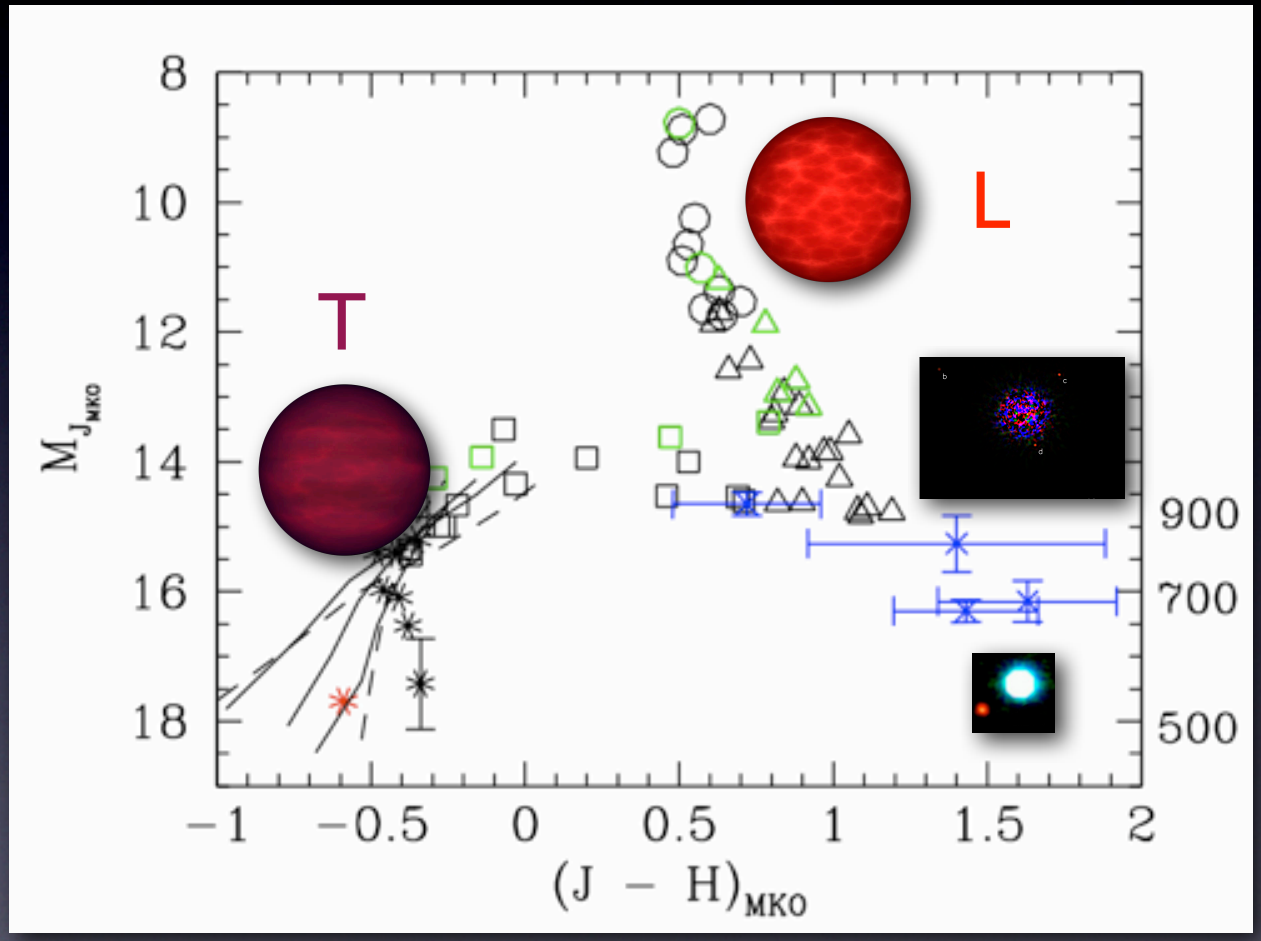
Thermal Emission



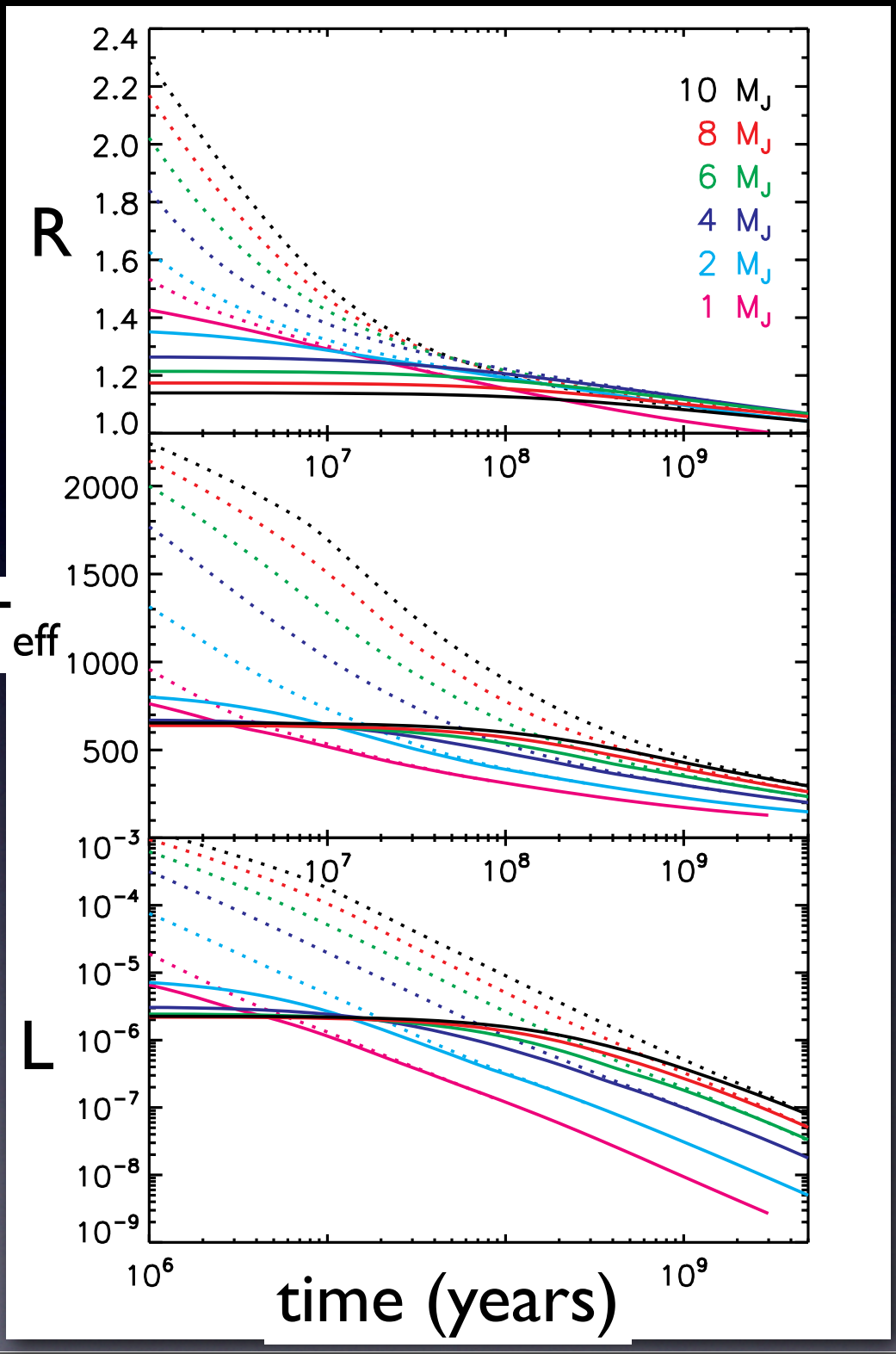


Marley & Leggett (2009)

HR 8799 Planets Look Cloudy



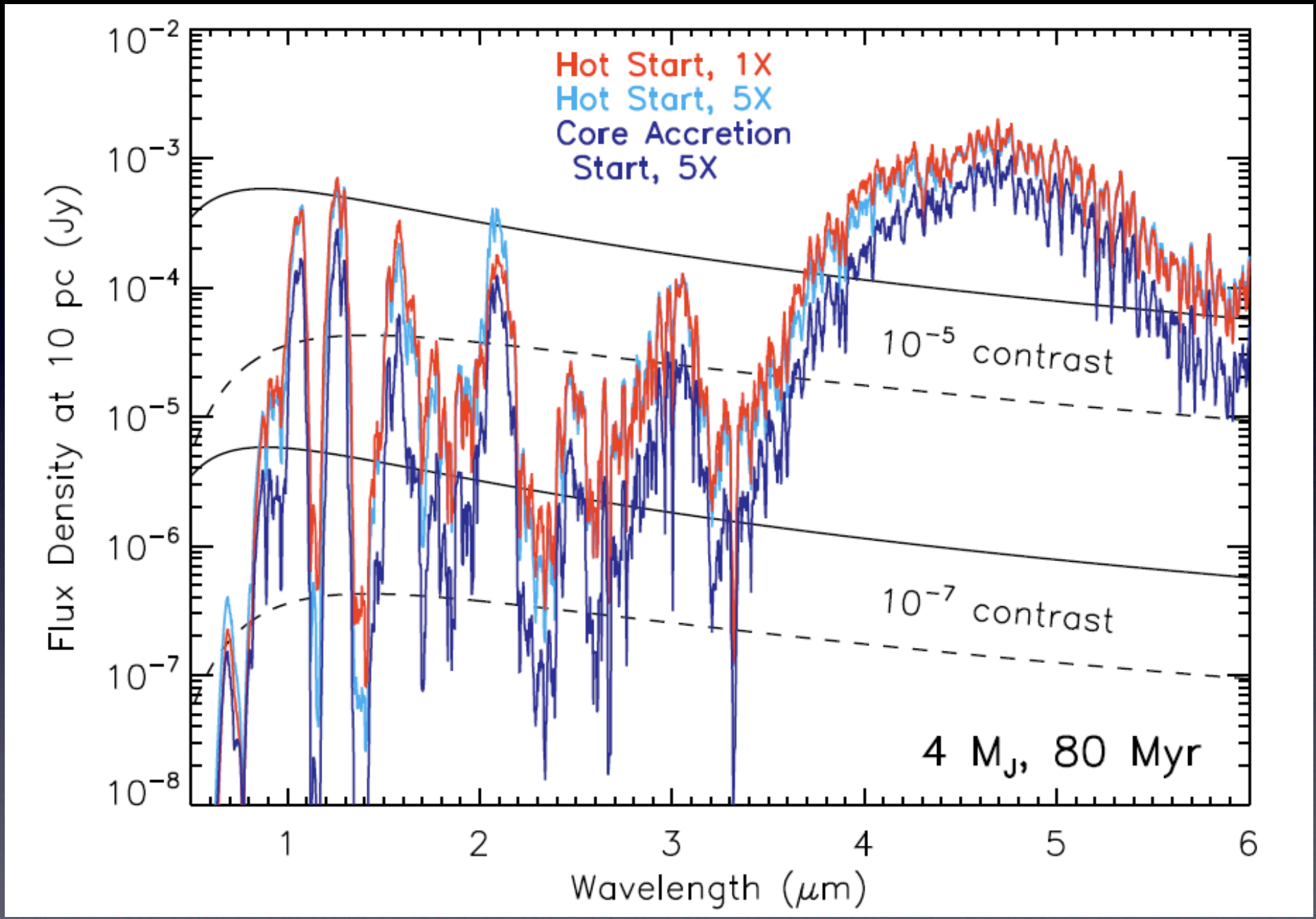
- HR 8799 b,c,d and 2M1207B look like extensions of L sequence
- Cloudy & low Teff
- Need to understand clouds to interpret their spectra



Thermal Emission

Mass
Age
Formation Mechanism
Composition

Marley et al. (2007)

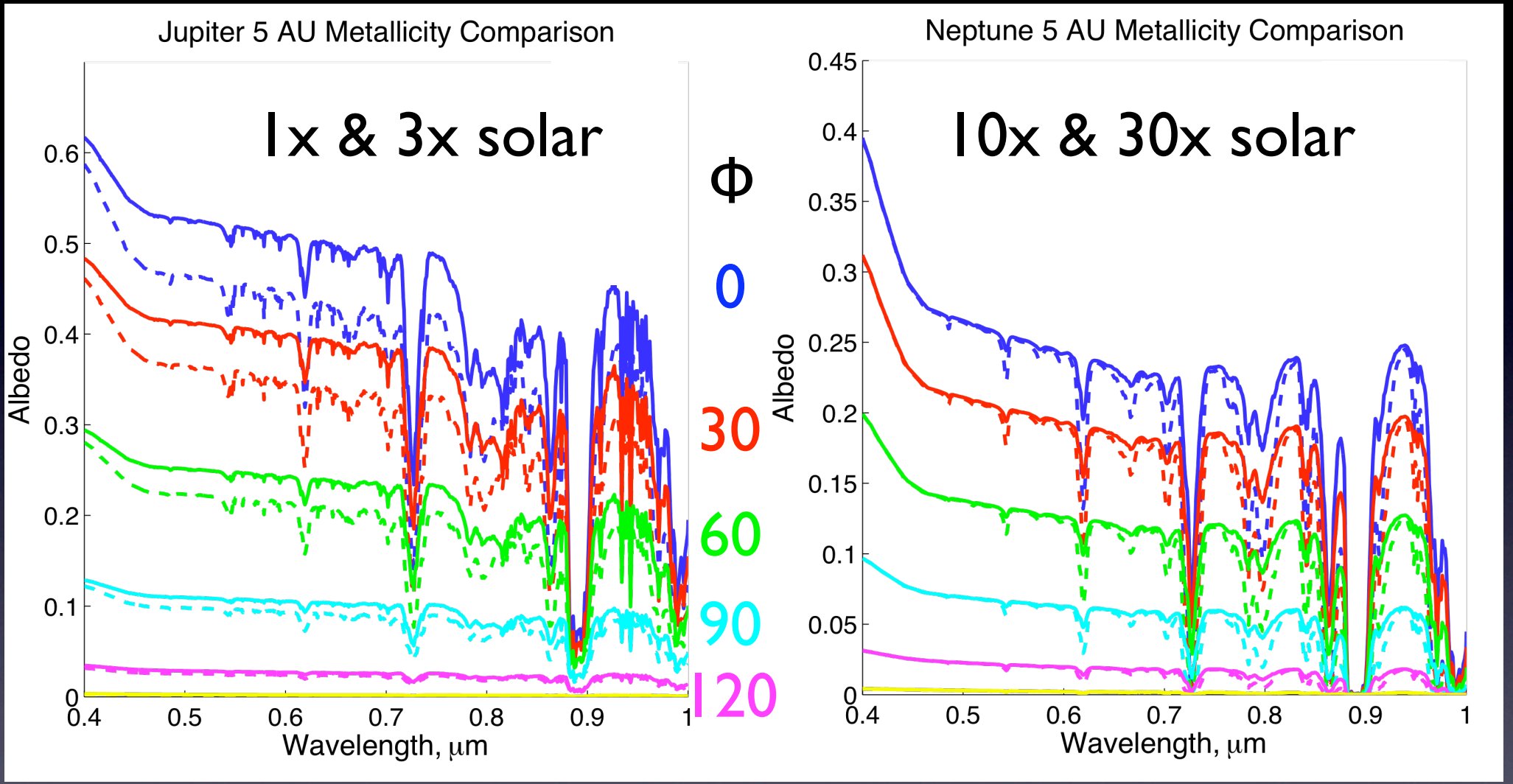

Hot Start, 1X
Hot Start, 5X
Core Accretion
Start, 5X
10^{-5} contrast
10^{-7} contrast
4 M_J, 80 Myr
Flux Density at 10 pc (Jy)
Wavelength (μm)
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1
2
3
4
5
6

Cool Jupiters

- Science goals:
  - Composition
  - Clouds
  - Atmospheric structure
  - Mass (difficult from spectra alone)
- Constraining observed phase angle is important for proper visible light characterization
- Happy to share models for detection studies
  - MM gone remainder of week, but see Kerri Cahoy

Backup

Effect of Metallicity at 5 AU



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