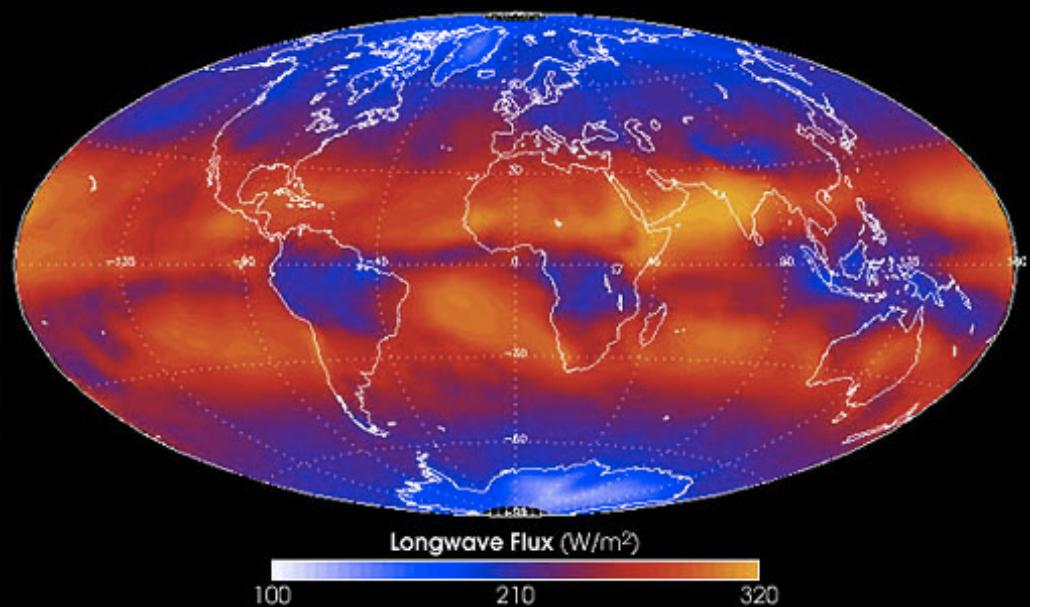
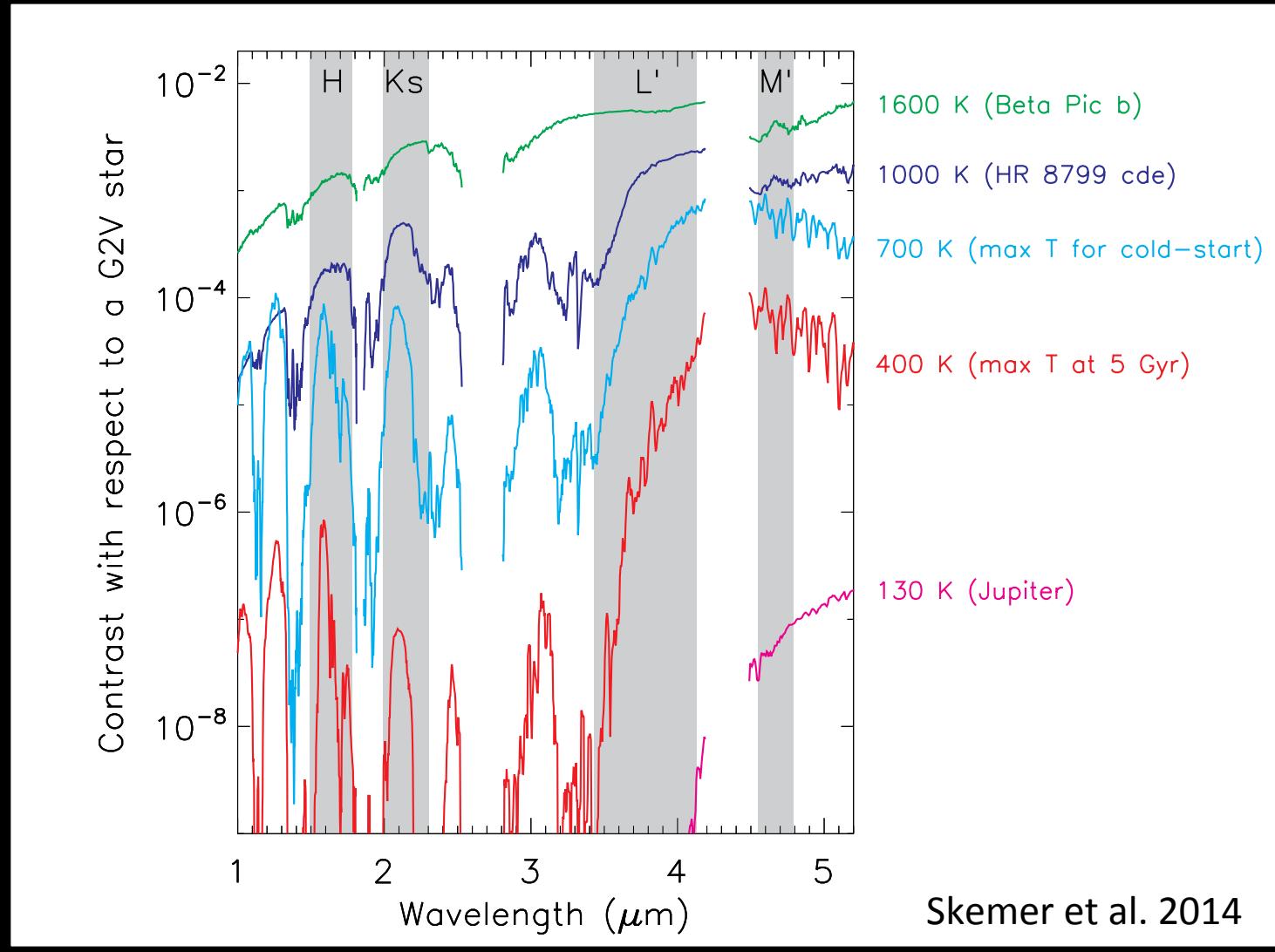


# Thermal Imaging of Gas Giants and Rocky Planets with TMT

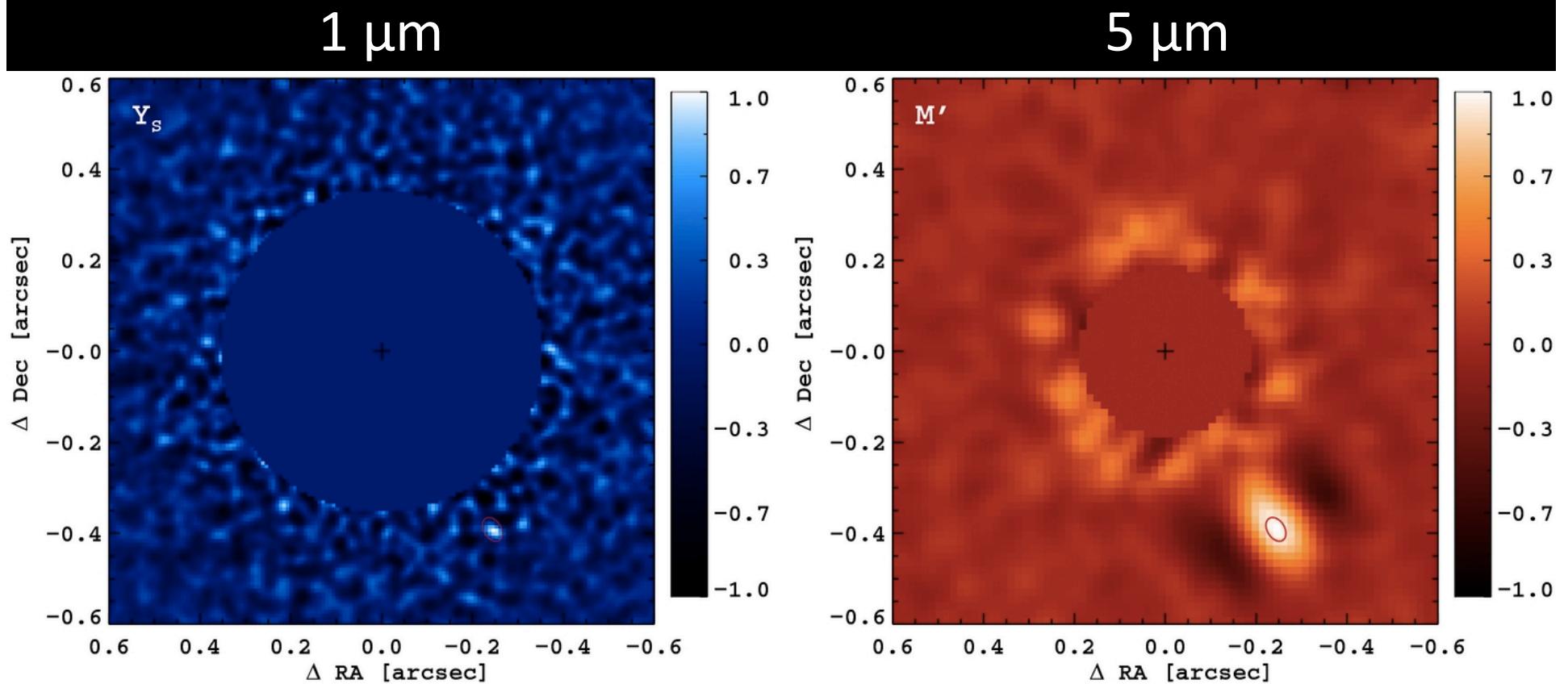


Andy Skemer (UC Santa Cruz)

# Self-Luminous Planets are Easier to Detect in the Thermal Infrared

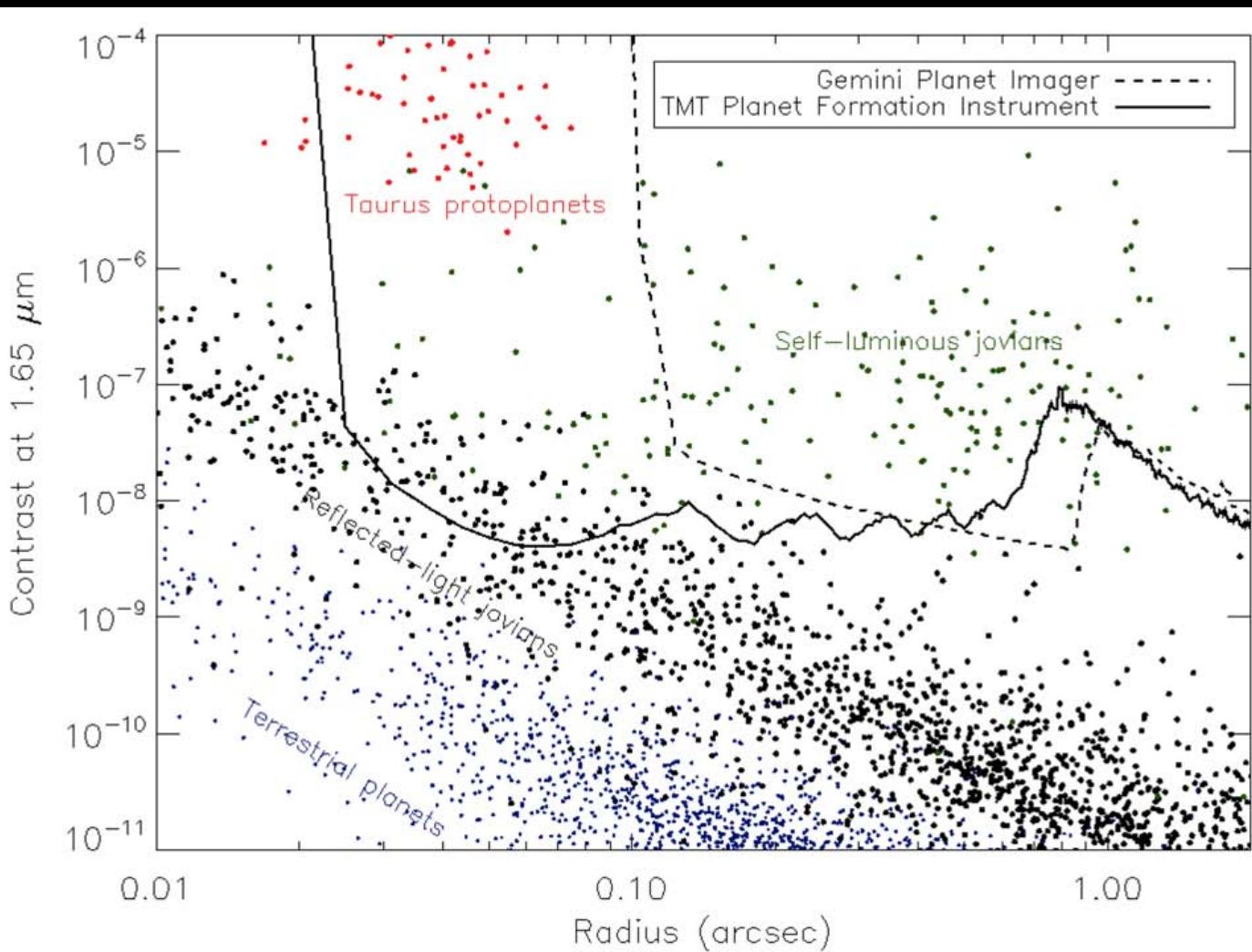


# Example: Beta Pic b

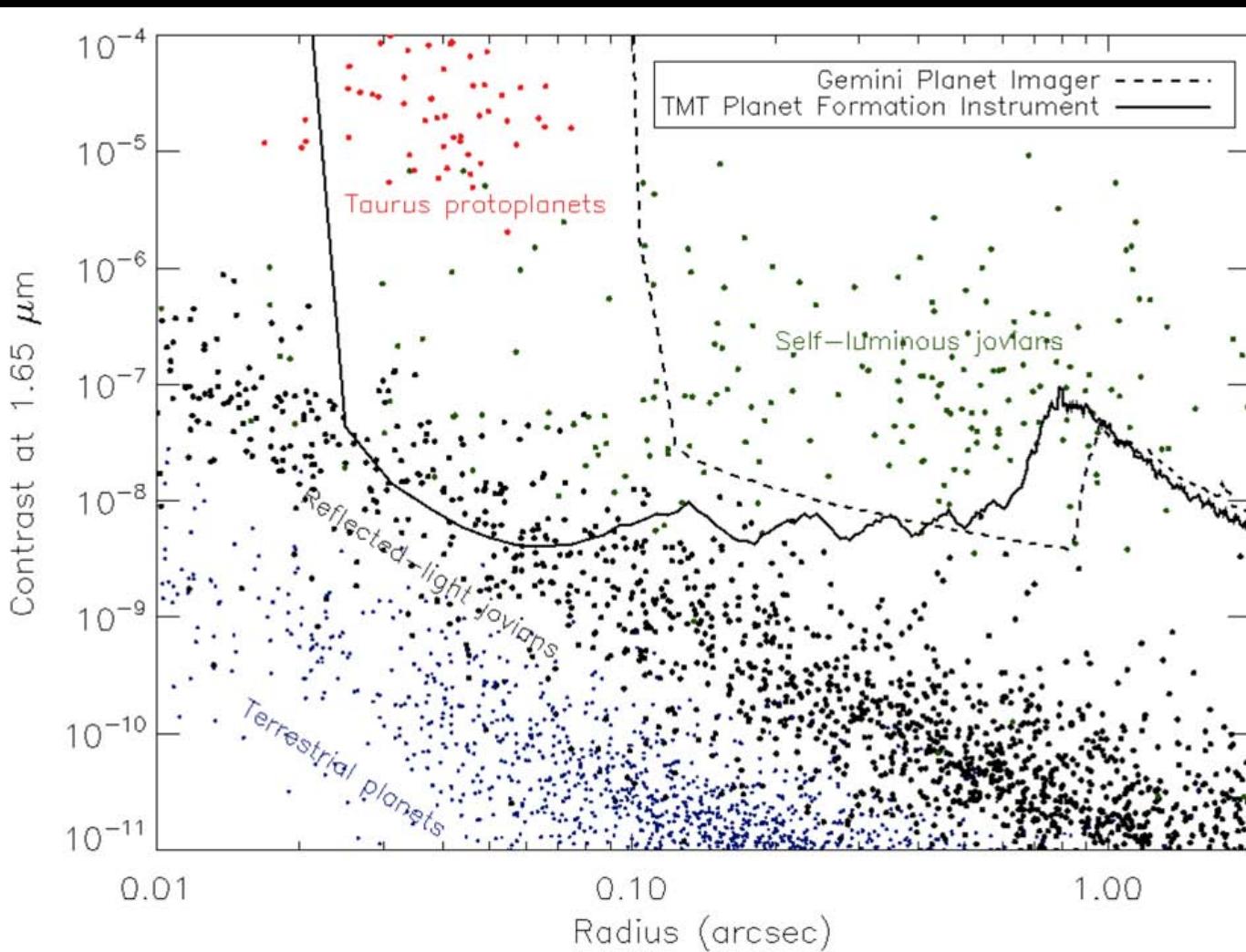


Males et al. 2014

# We haven't found as many gas-giants as we had hoped



# We haven't found as many gas-giants as we had hoped

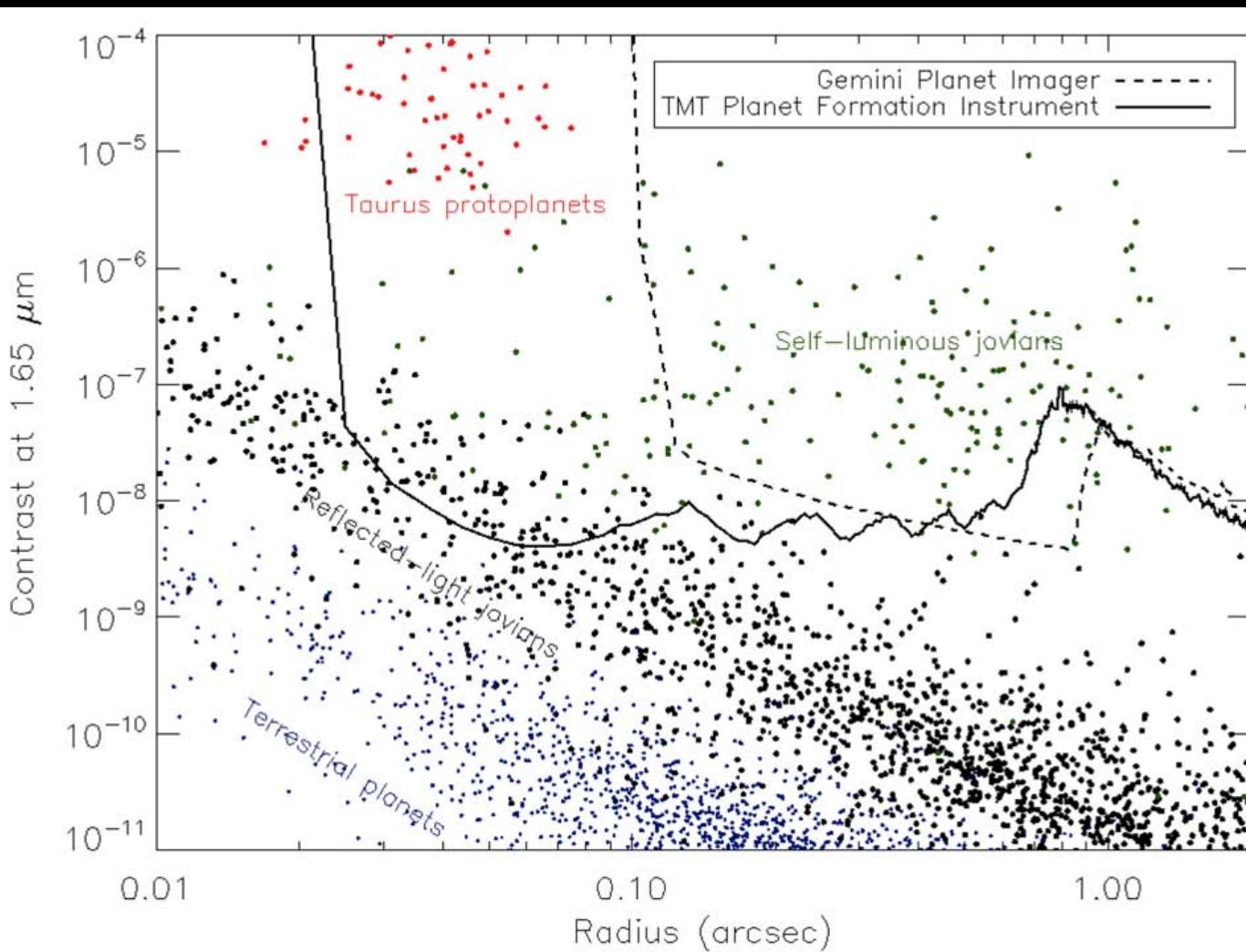


## Two Possibilities

There aren't as many planets at wide separations as we thought

TMT can look where we *know* there are exoplanets

# We haven't found as many gas-giants as we had hoped

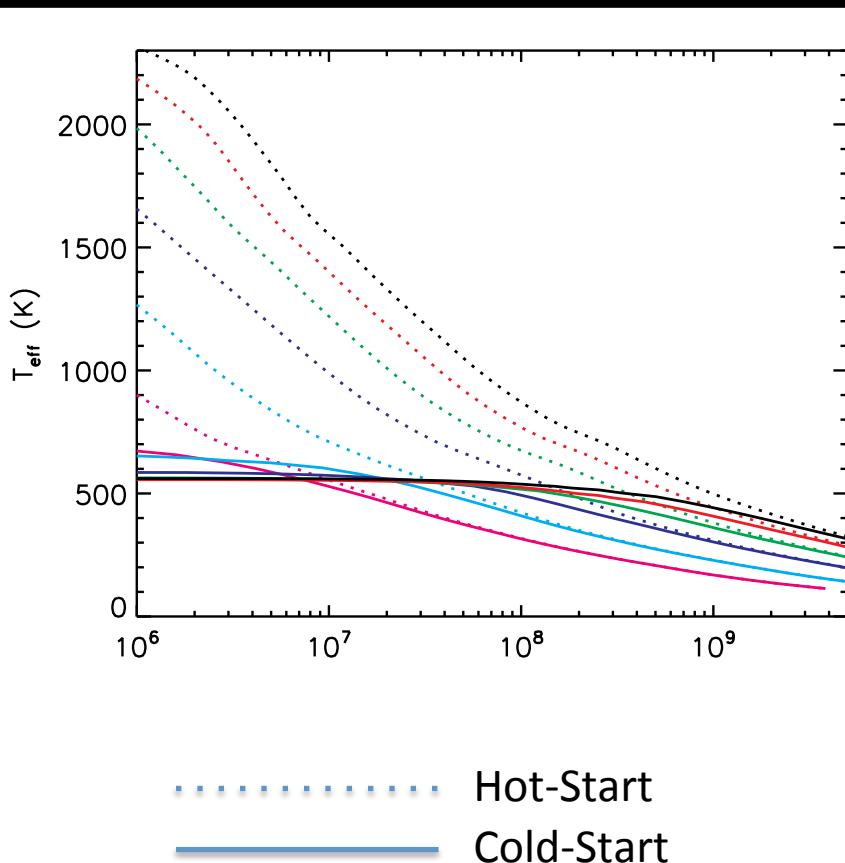
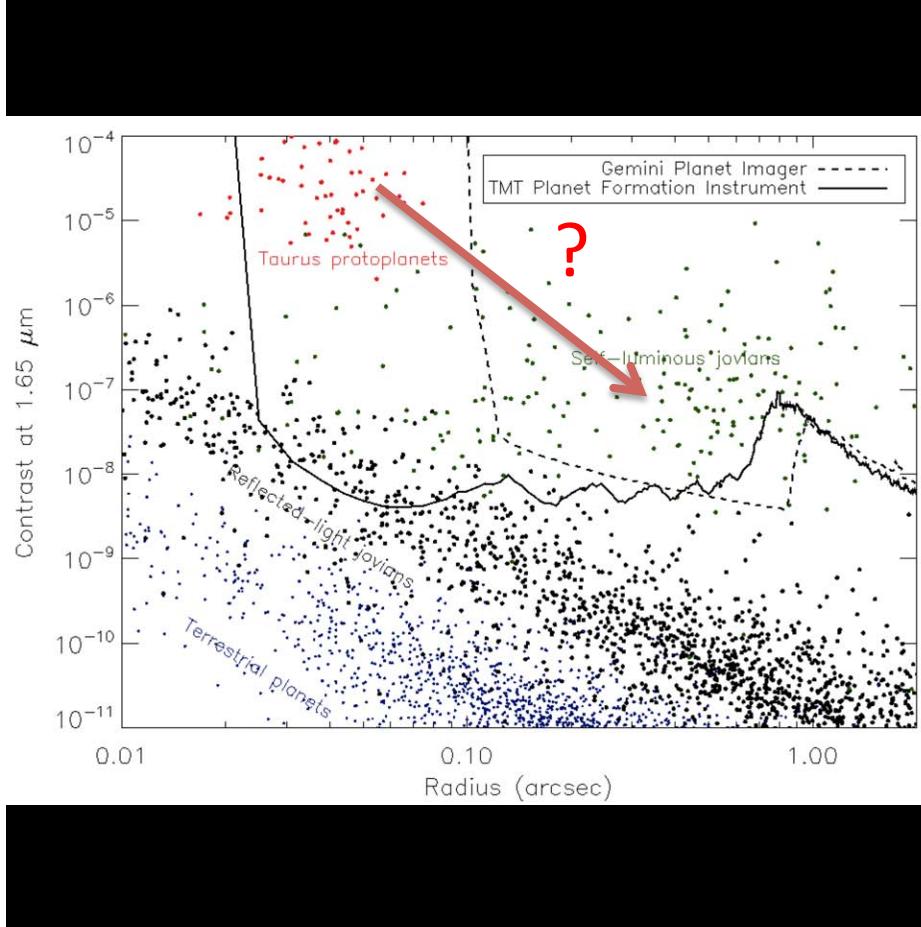


## Two Possibilities

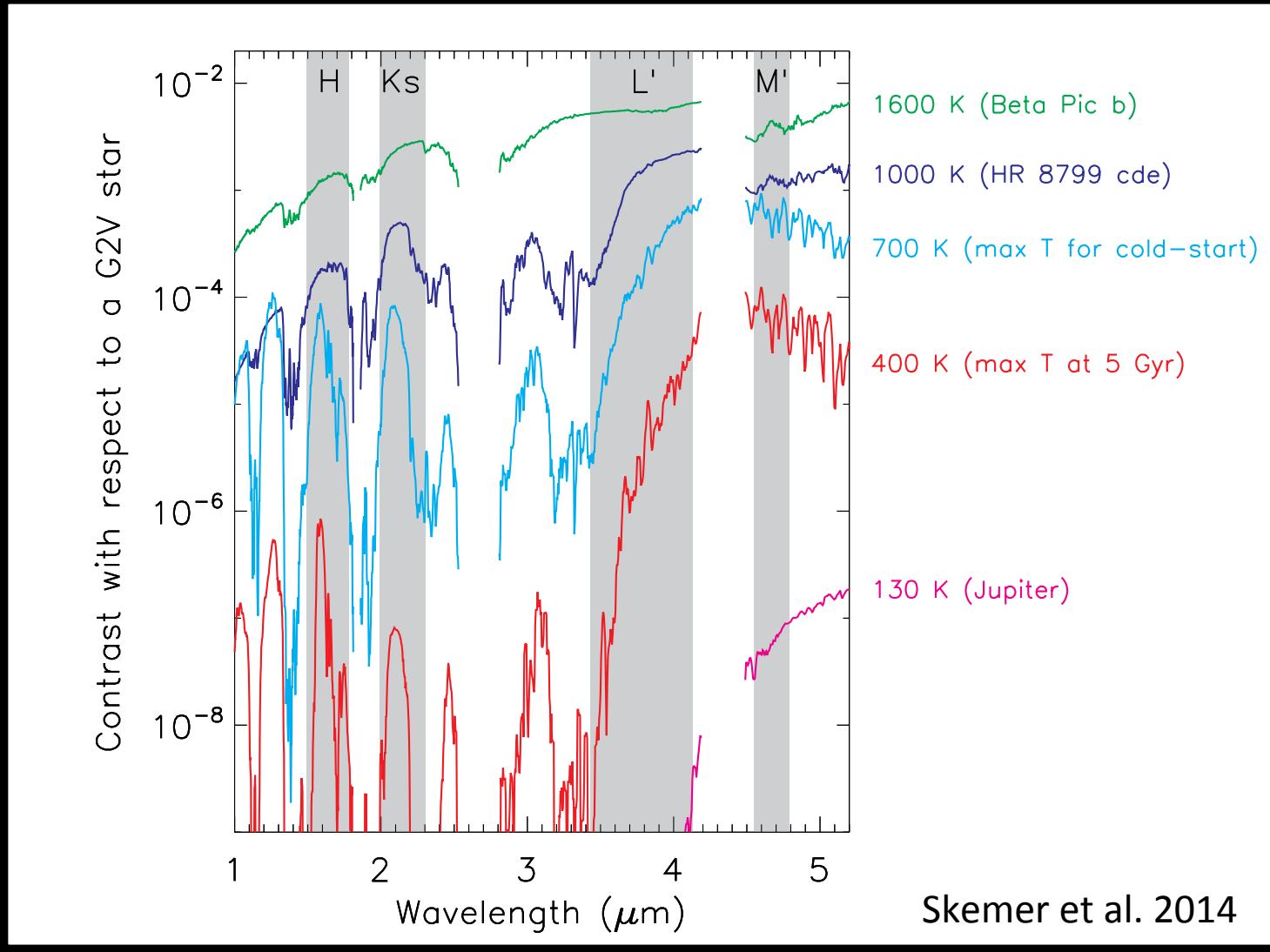
Planets are Colder than we thought

In the thermal infrared,  
TMT can detect cold-  
start planets out to the  
nearest star formation  
regions

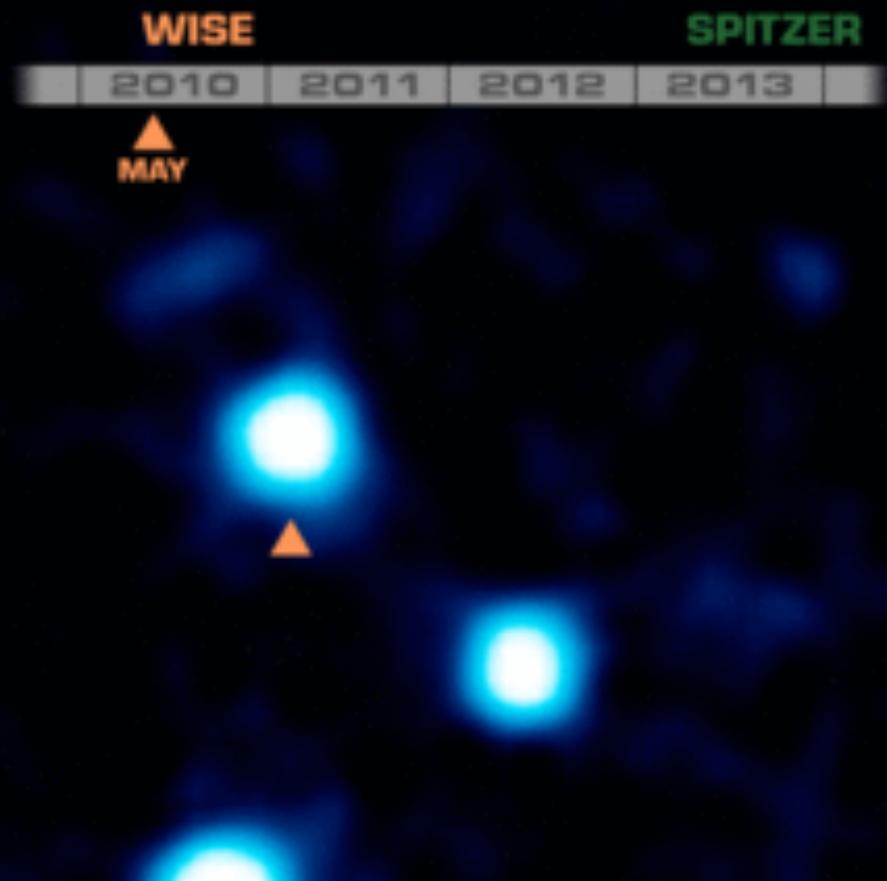
# How do Planets Form and Evolve



# Characterizing Cold Exoplanets

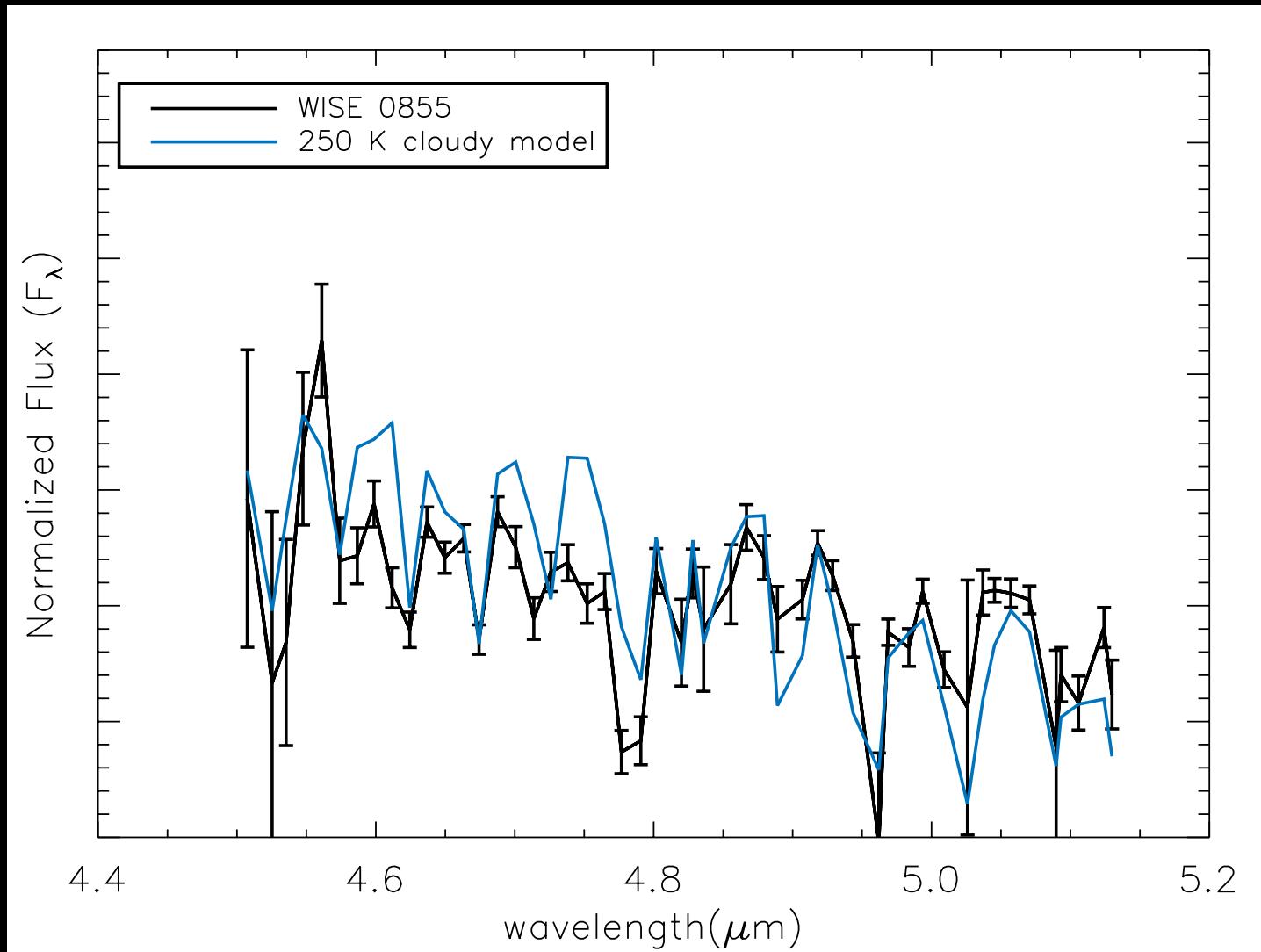


# WISE 0855—A 250 K Free-Floating Planet

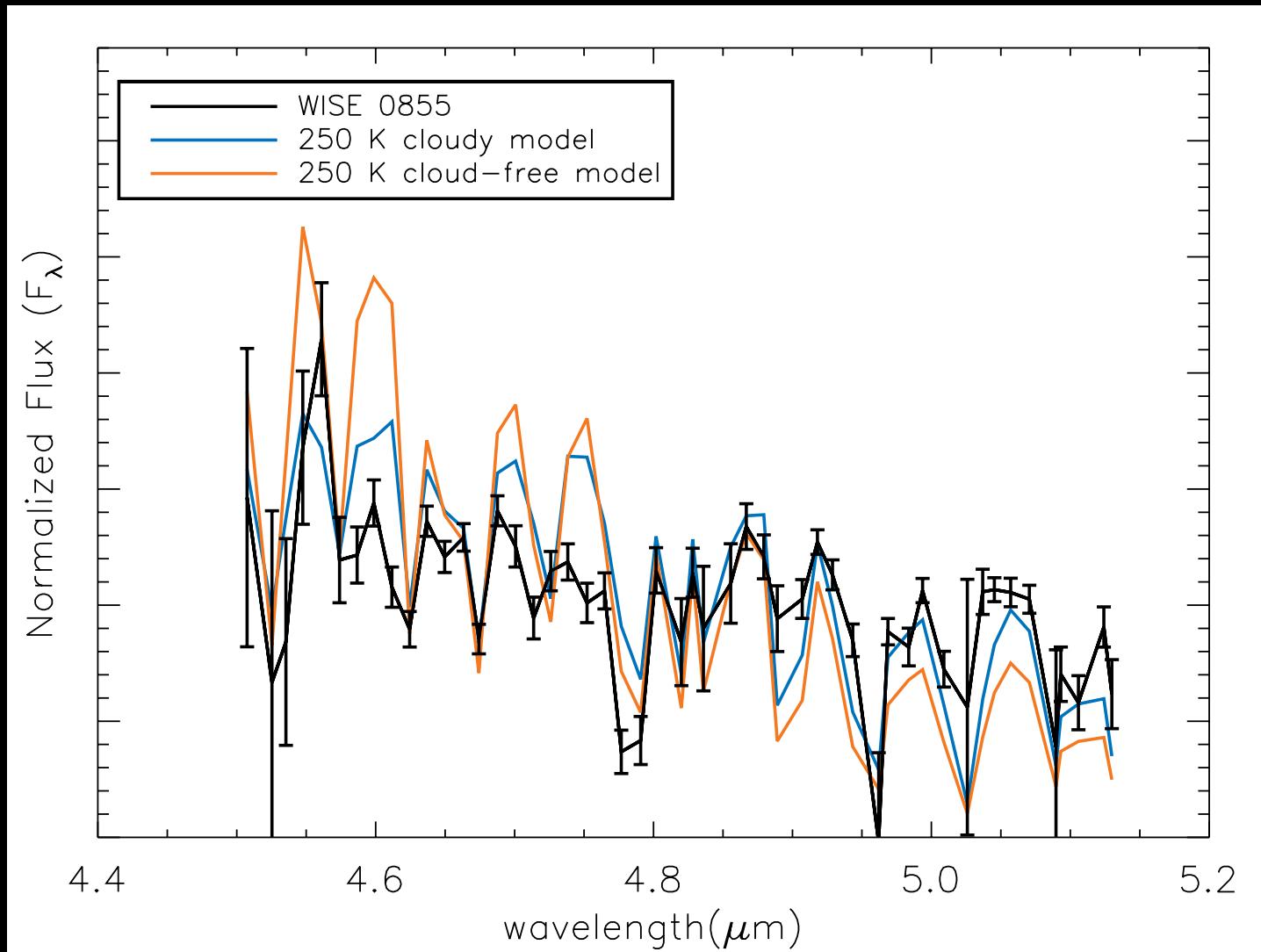


- 5 Jupiter masses
- 2 pc from the Sun
- Coldest compact object outside of our Solar System
- First object outside of our Solar System likely to have water clouds in its visible atmosphere.

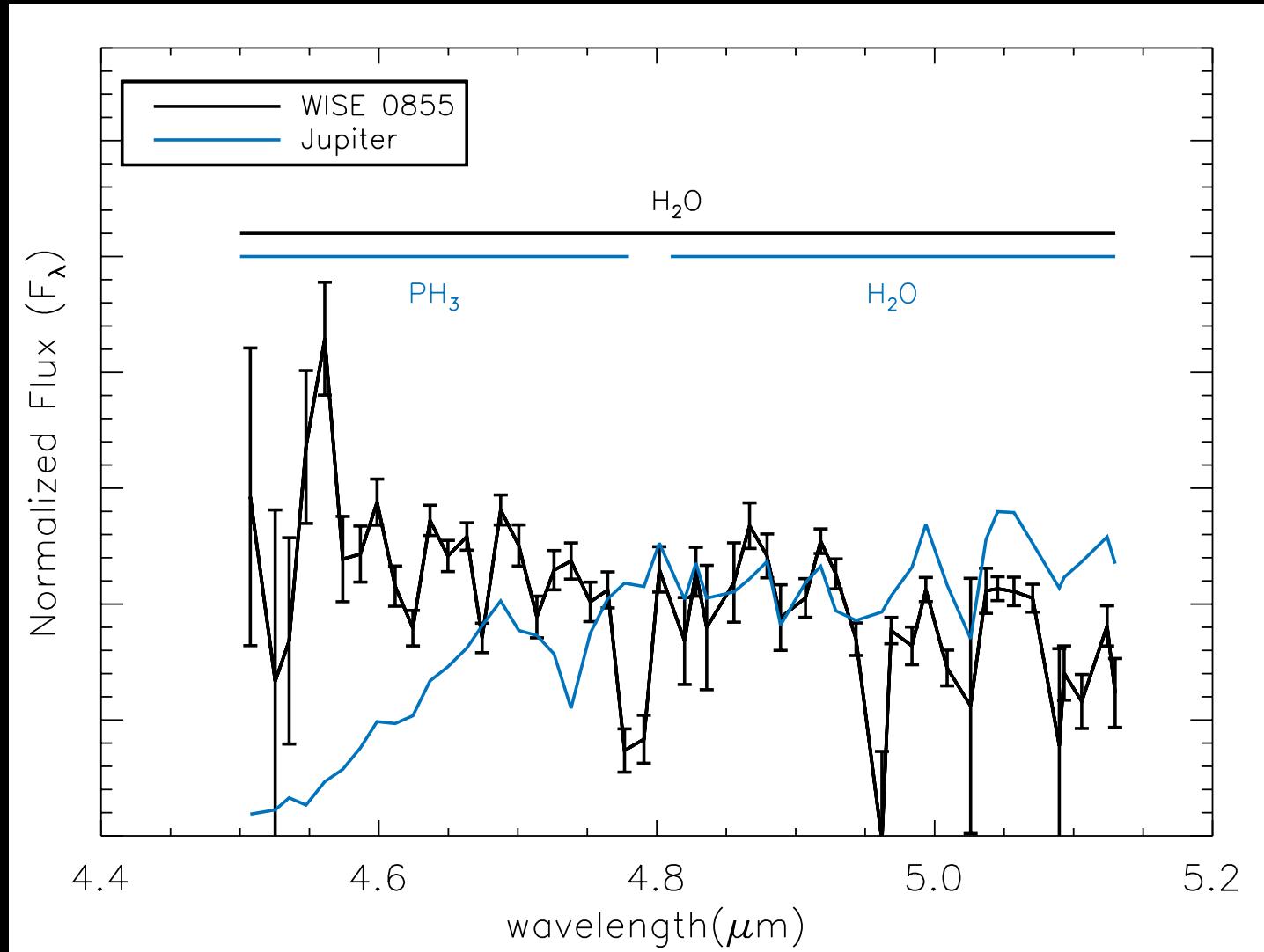
# WISE 0855—A 250 K Free-Floating Planet



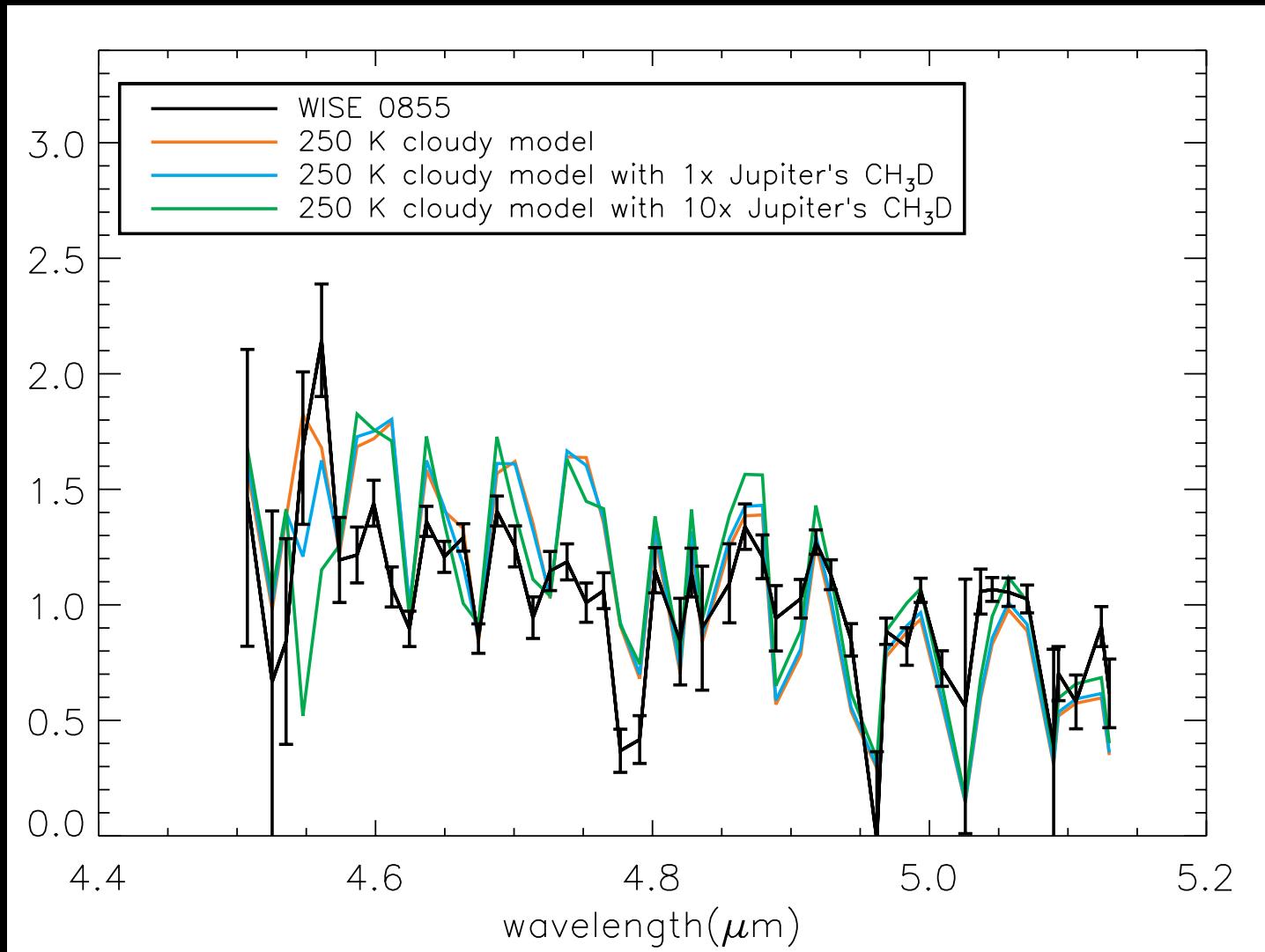
# WISE 0855—A 250 K Free-Floating Planet



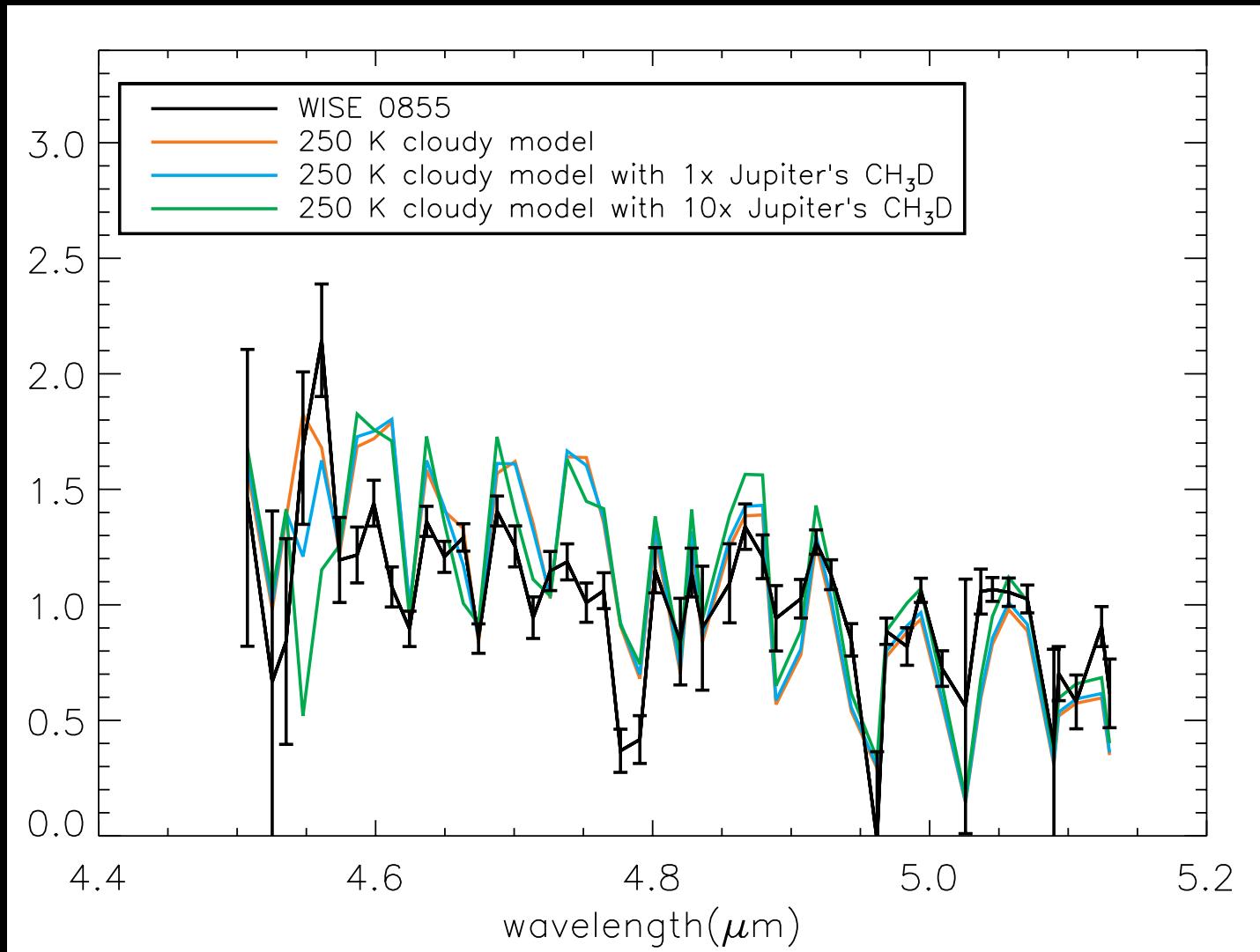
# WISE 0855—A 250 K Free-Floating Planet



# WISE 0855—A 250 K Free-Floating Planet

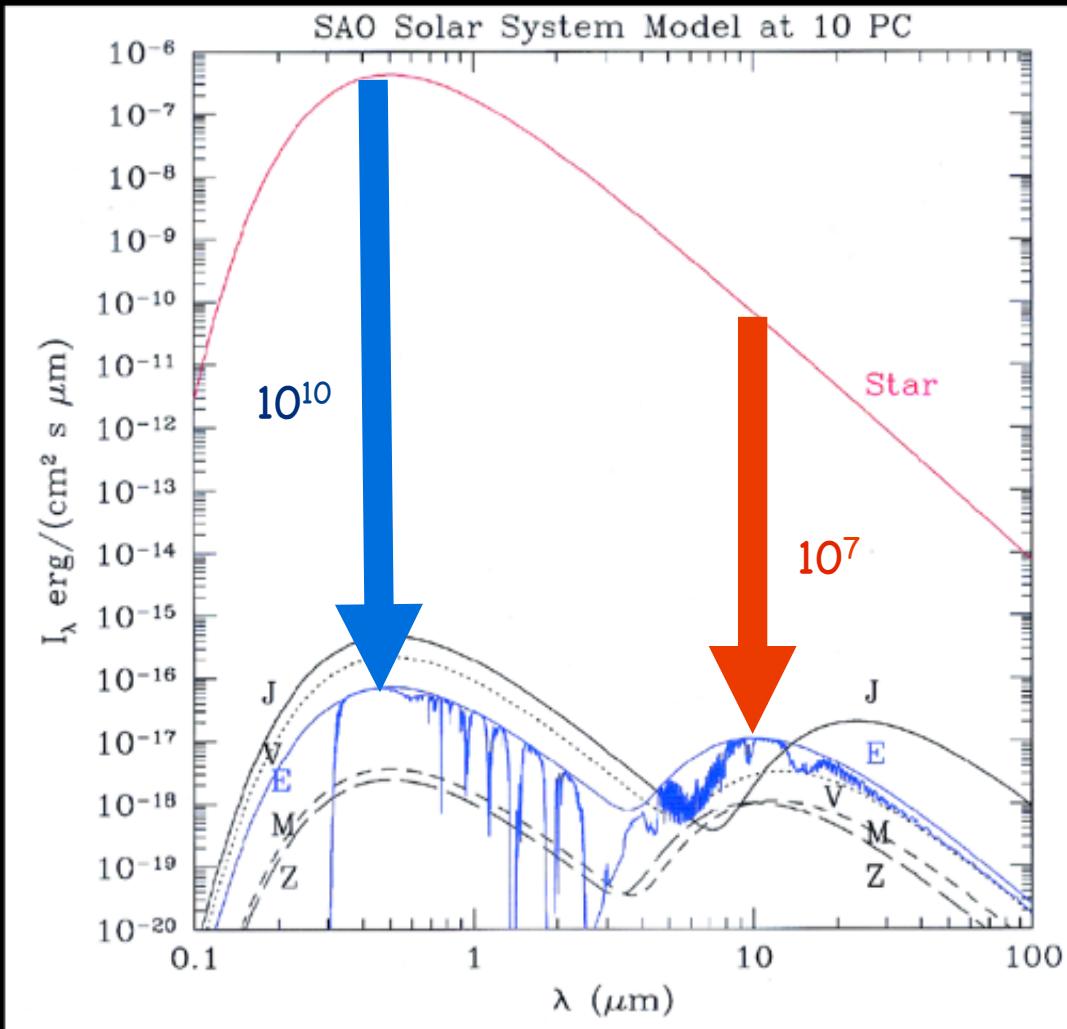


# WISE 0855—A 250 K Free-Floating Planet



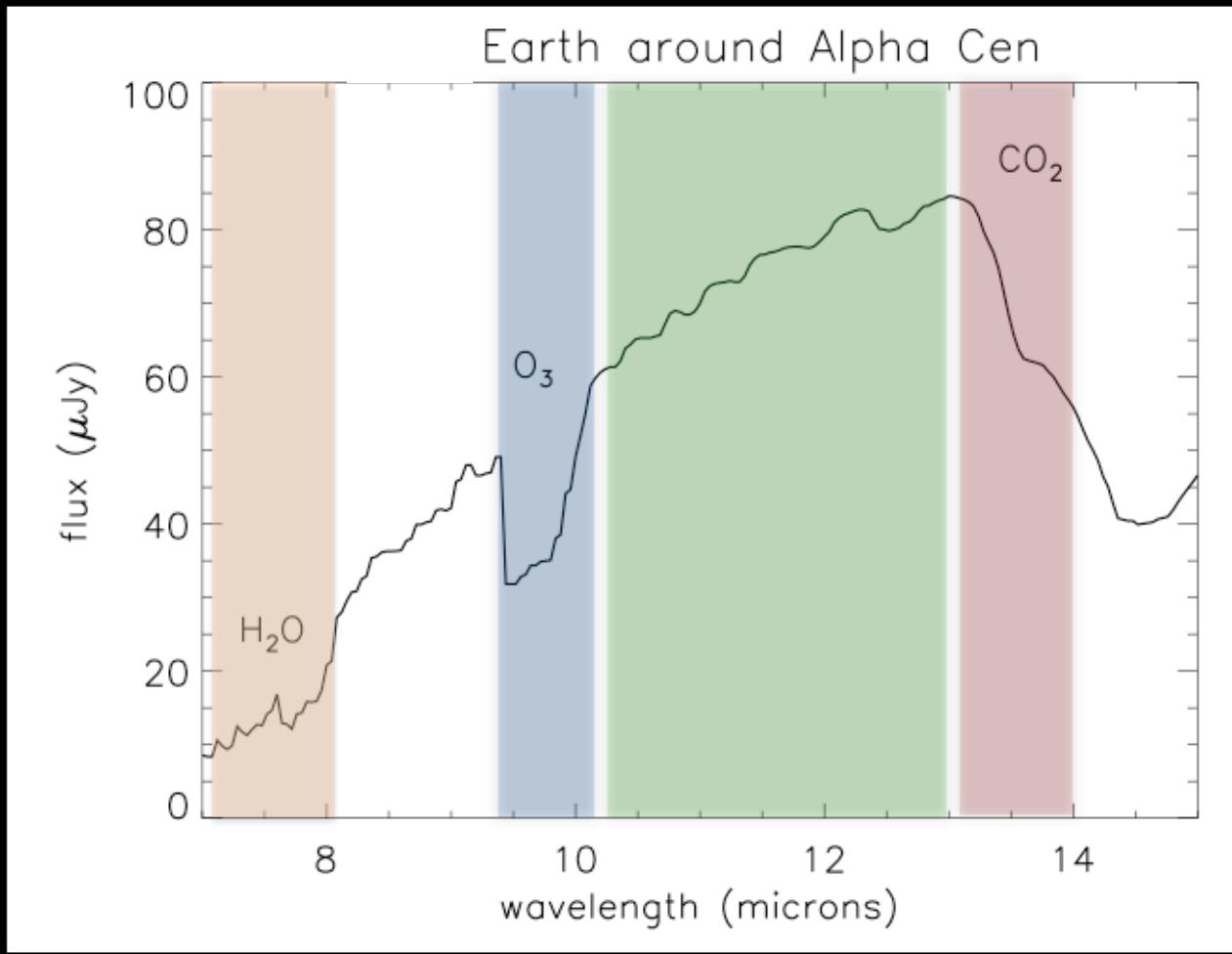
...can do this for planetary systems out to  $\sim$ 10 pc

# Contrast Required to Image Earth



Des Marais et al. 2002

# Sensitivity Required to Detect Earth



TMT MICHI  
(5 sigma)

150 hours

20 hours

2 hours

100 hours

~2 hours for a detection

~100 hours for a low-res spectrum

# Reflected Light + Thermal Light

- Surface Temperature
- Weather
- Energy Budget
- Molecules/biomarkers
- Redundancy!

# Summary: Why the Thermal Infrared?

- Characterization—this is how we study planets in our own Solar System
- Unfinished business with the self-luminous gas-giants—no other telescope will do this first
- Complimentary Earth-Imaging technology

# Summary: Why the Thermal Infrared?

## Easier than reflected light

- Will work at much lower contrasts
- Will work in less than amazing seeing
- No technology development—just need a relatively simple instrument on a big telescope