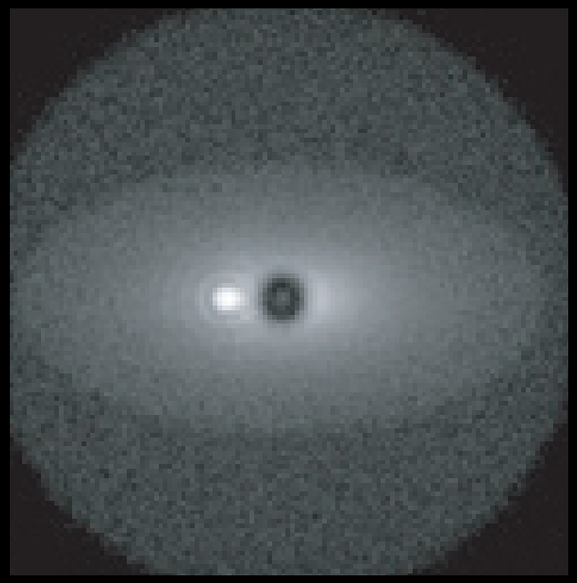
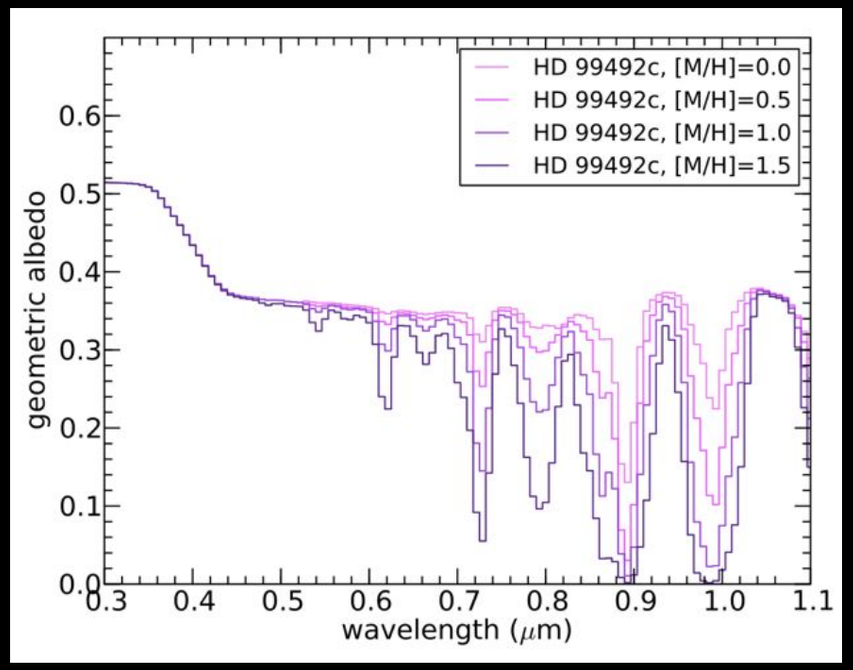
Spectral and Polarimetric Signatures of WFIRST Exoplanet Coronagraphy Targets





Nikole K. Lewis
STScI

WPS Program Team

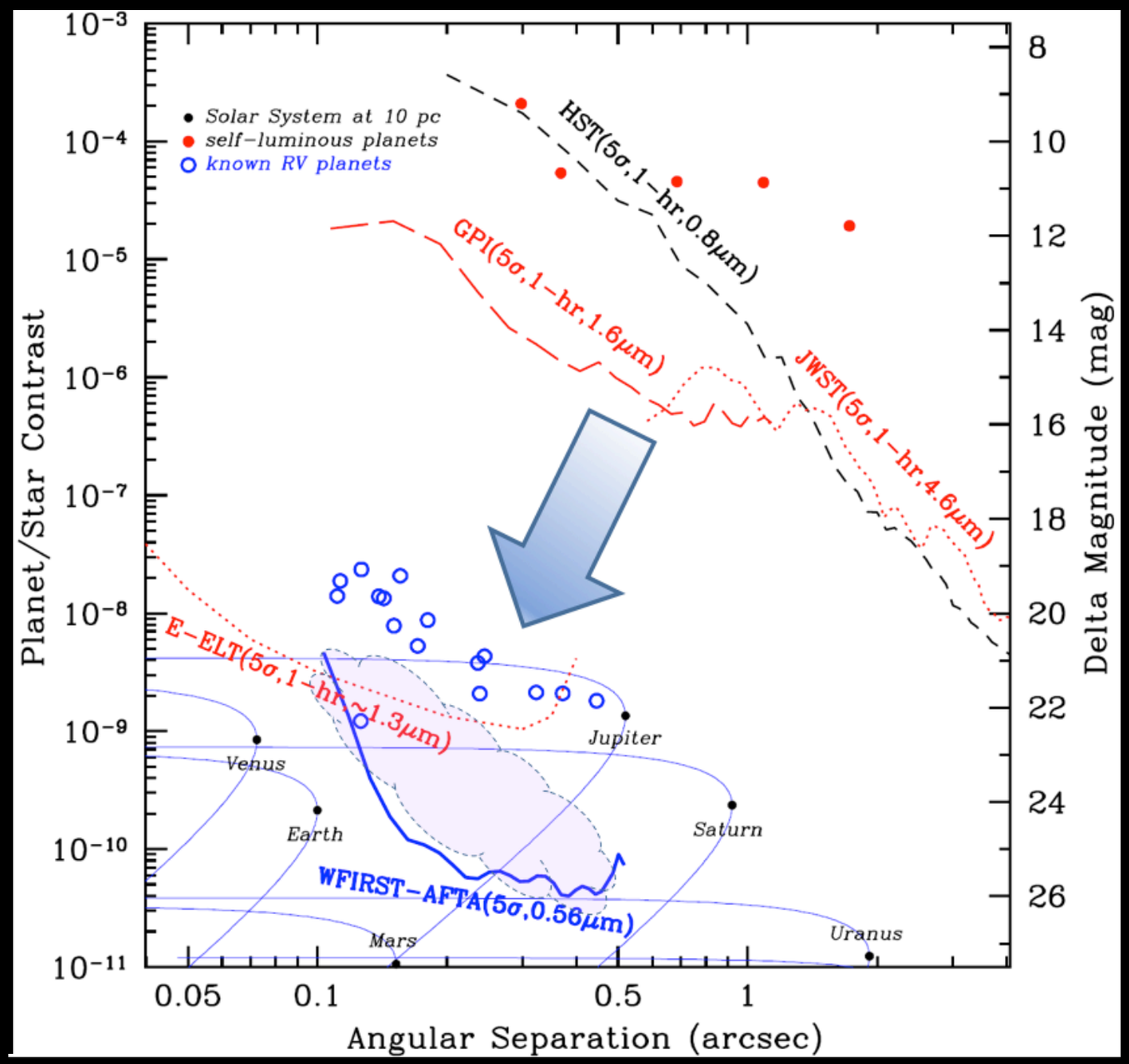
Nikole Lewis, PI (STScI) -> Program Management, Forward Models, Spectral Generation, Result Synthesis

Roxana Lupu (NASA Ames) -> Retrievals (Lead), Atmospheric Opacities
Mark Marley (NASA Ames) -> Retrievals, Polarimetry, Result Synthesis
Laura Mayorga (NMSU) -> Polarimetry

Jonathan Fortney (UCSC) -> Forward Models, Retrievals
Caroline Morley (UCSC) -> Forward Models
Mikey Nayak (UCSC) -> Retrievals
Tyler Robinson (UCSC) -> Instrument Model

Tom Greene (NASA Ames) -> Instrument Model
Wes Traub (JPL) -> Instrument Model
Channon Visscher (Dordt College) -> Atmospheric Chemistry
Richard Freedman (NASA Ames) -> Atmospheric Opacities
Mike Line (UCSC/ASU) -> Retrievals

WFIRST Mission: Coronagraph



- Broadband Imaging (430-970 nm)
- R~70 spectroscopy (600-970 nm)

Spergel et al (2015), WFIRST-AFTA 2015 Report

WFIRST Preparatory Science (WPS) Program

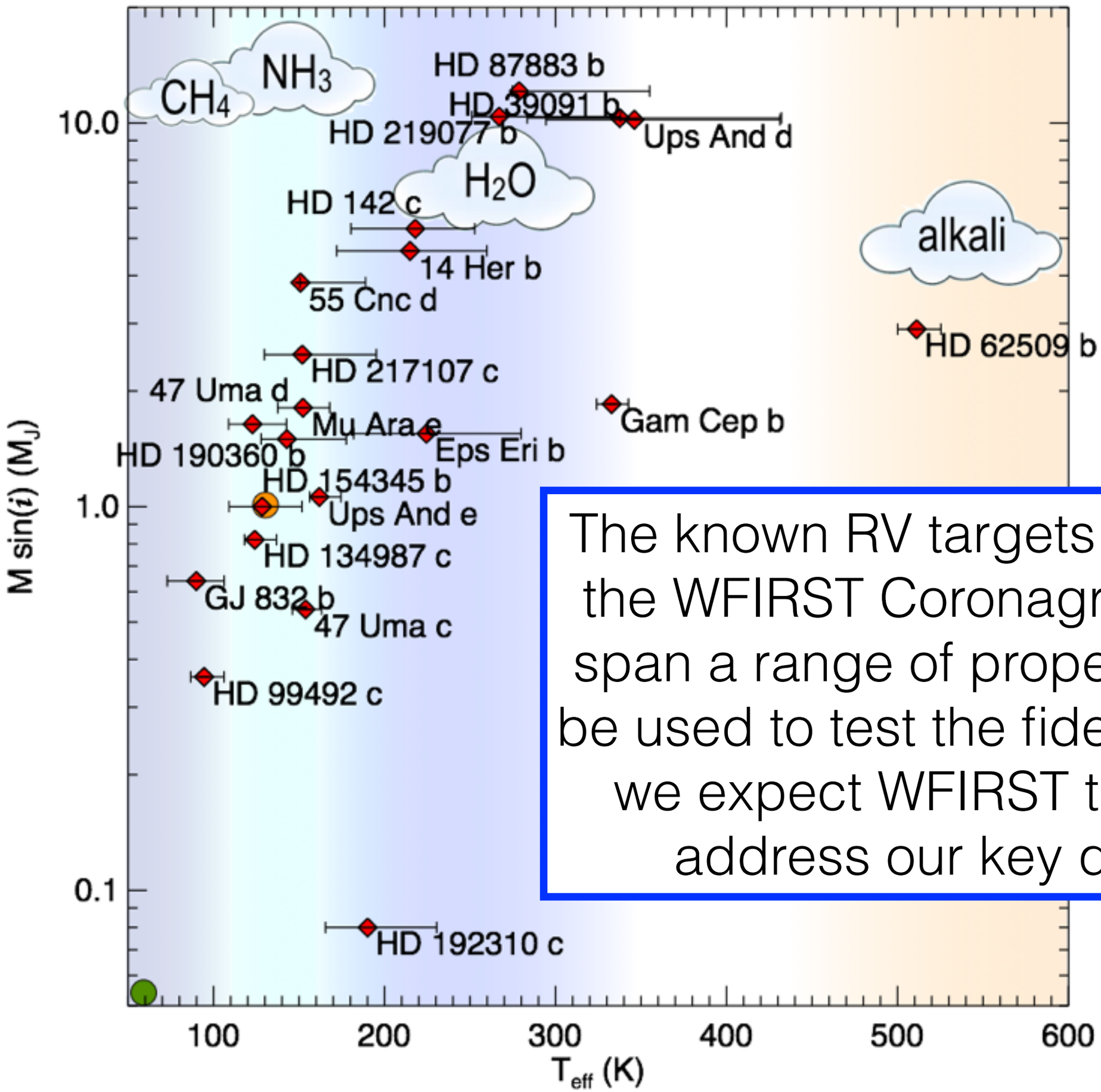
- Goal: Provide constraints on the giant exoplanet science achievable with WFIRST-AFTA under the current (evolving) mission design.

- Key Science Questions:

  1. How does the composition of gas and ice giant planets vary with mass, orbit, and stellar mass and metallicity?

  2. How do clouds affect giant planet atmospheres and vary with atmospheric temperature and other planetary parameters?

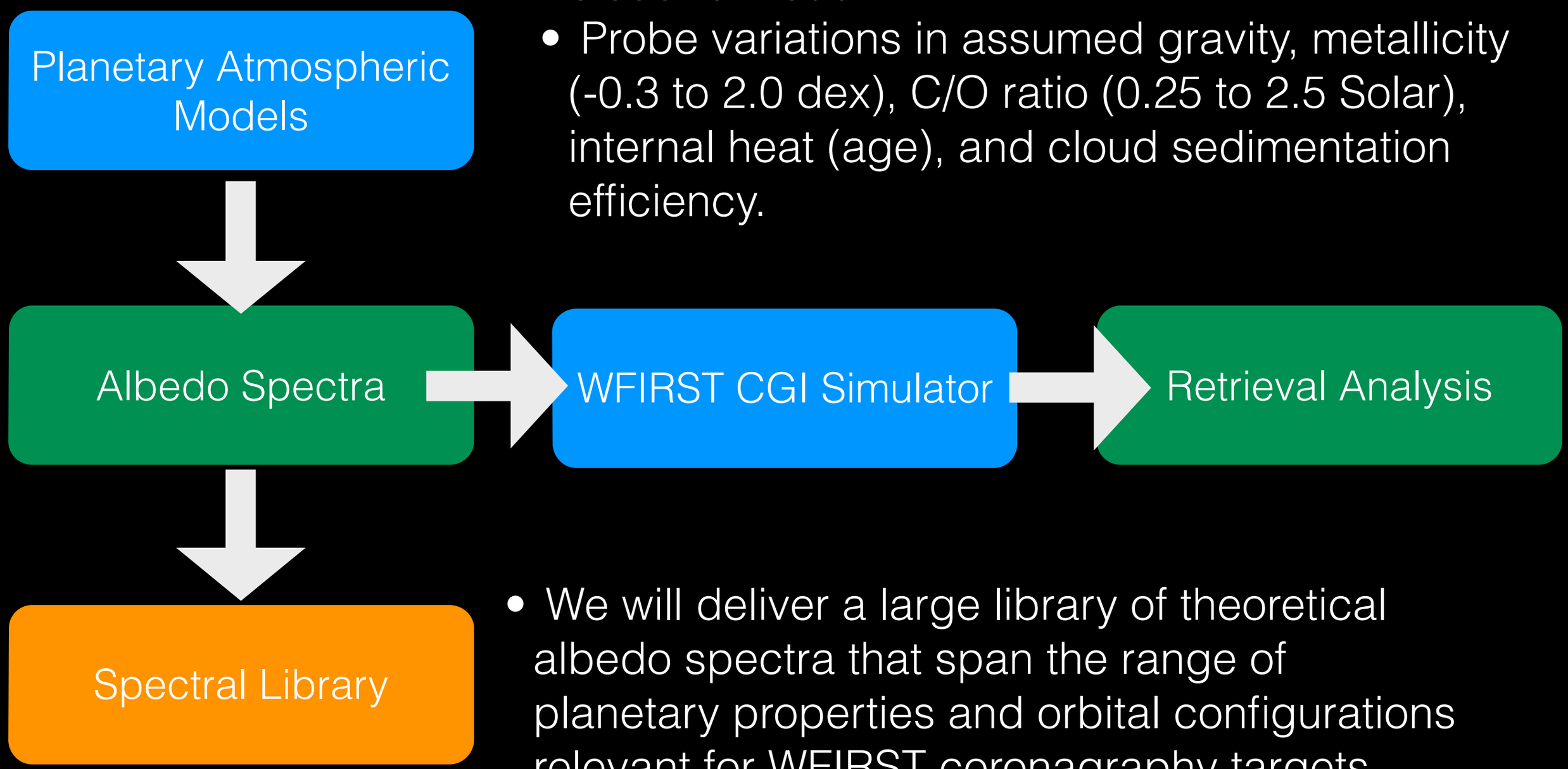
  3. Do planets formed inside and outside the nebular ‘snow line’ have different compositions or C/O ratios?



The known RV targets accessible to the WFIRST Coronagraph naturally span a range of properties and can be used to test the fidelity with which we expect WFIRST to be able to address our key questions.

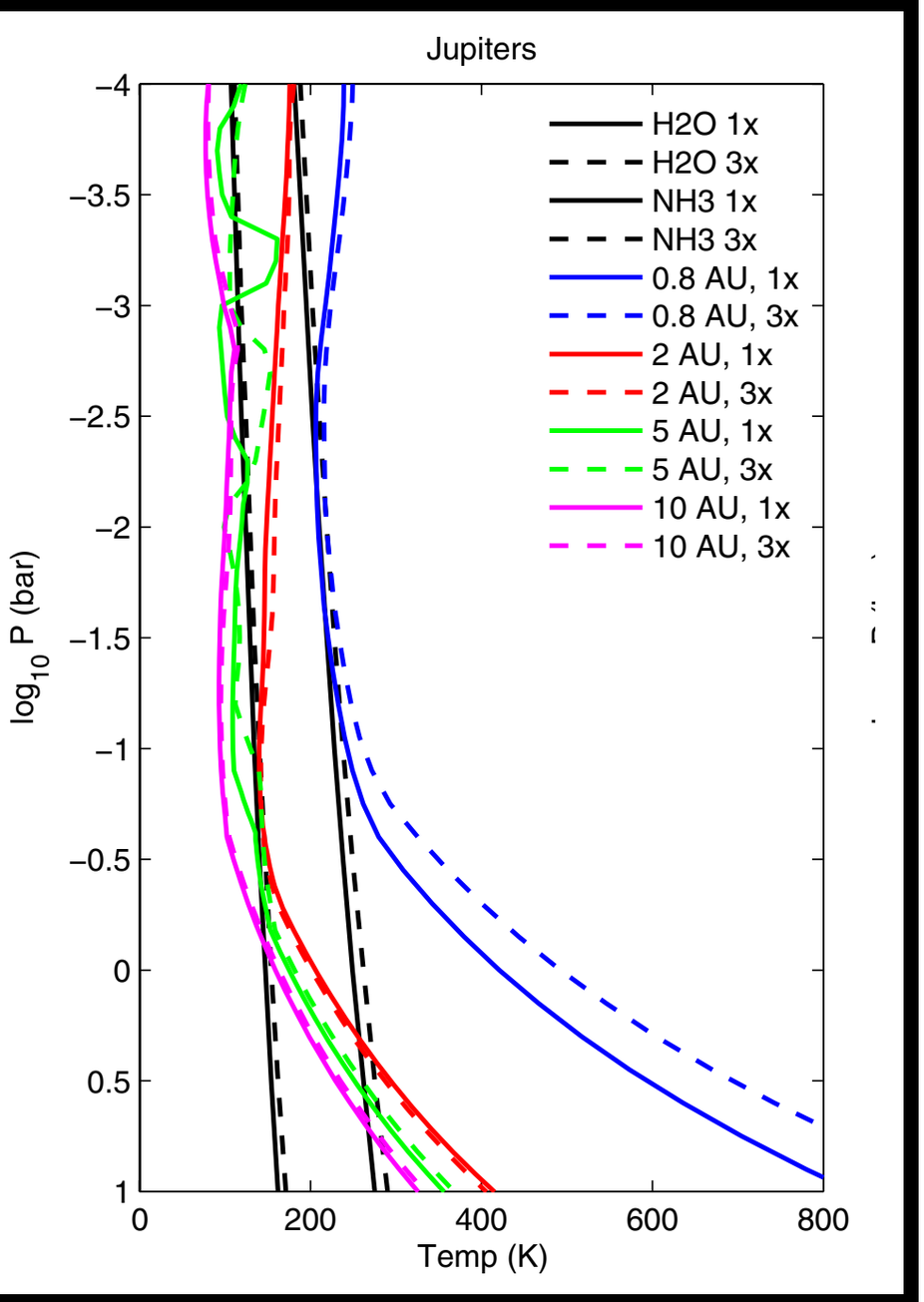
WPS Program Overview

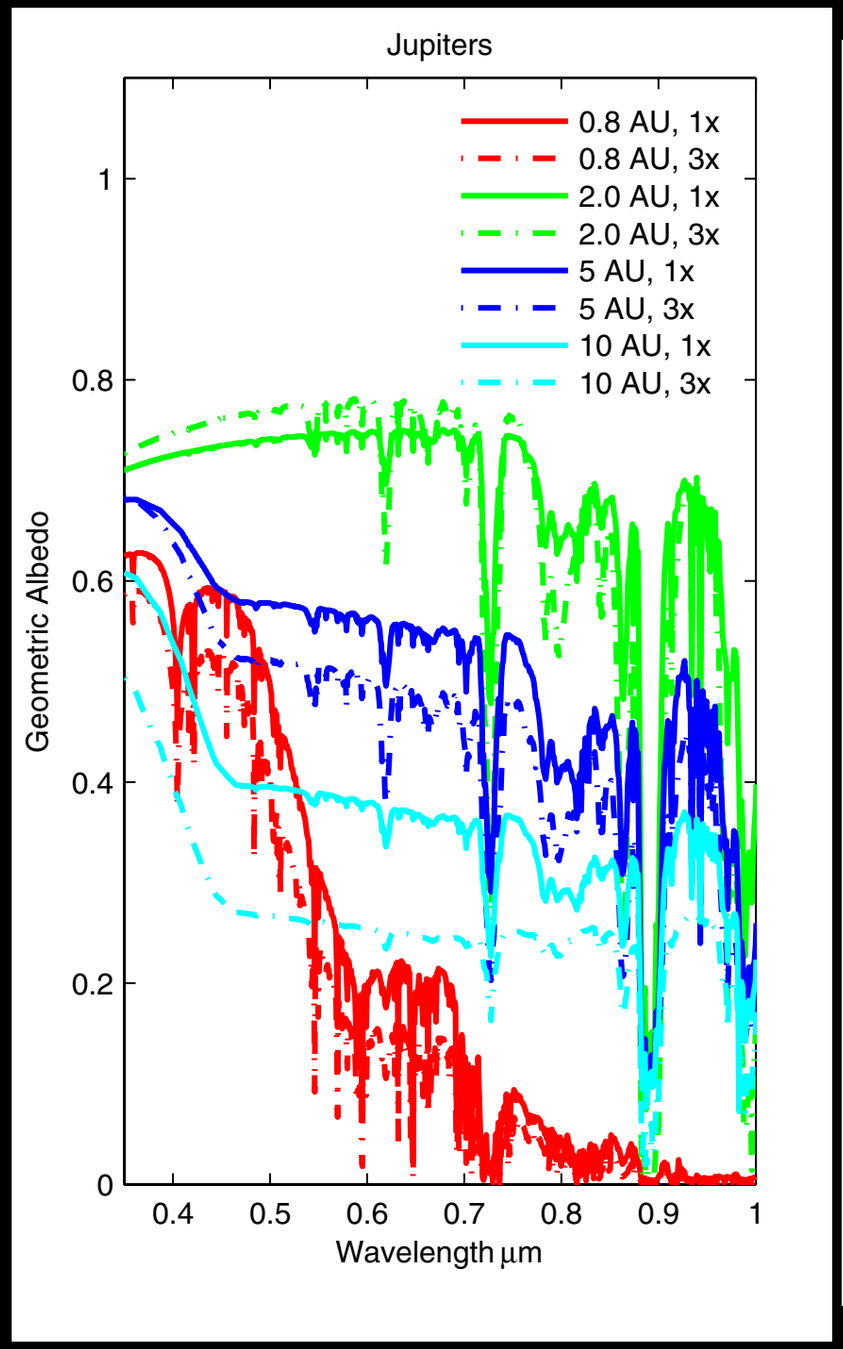
- 1D radiative-convective models that include cloud formation
- Probe variations in assumed gravity, metallicity (-0.3 to 2.0 dex), C/O ratio (0.25 to 2.5 Solar), internal heat (age), and cloud sedimentation efficiency.

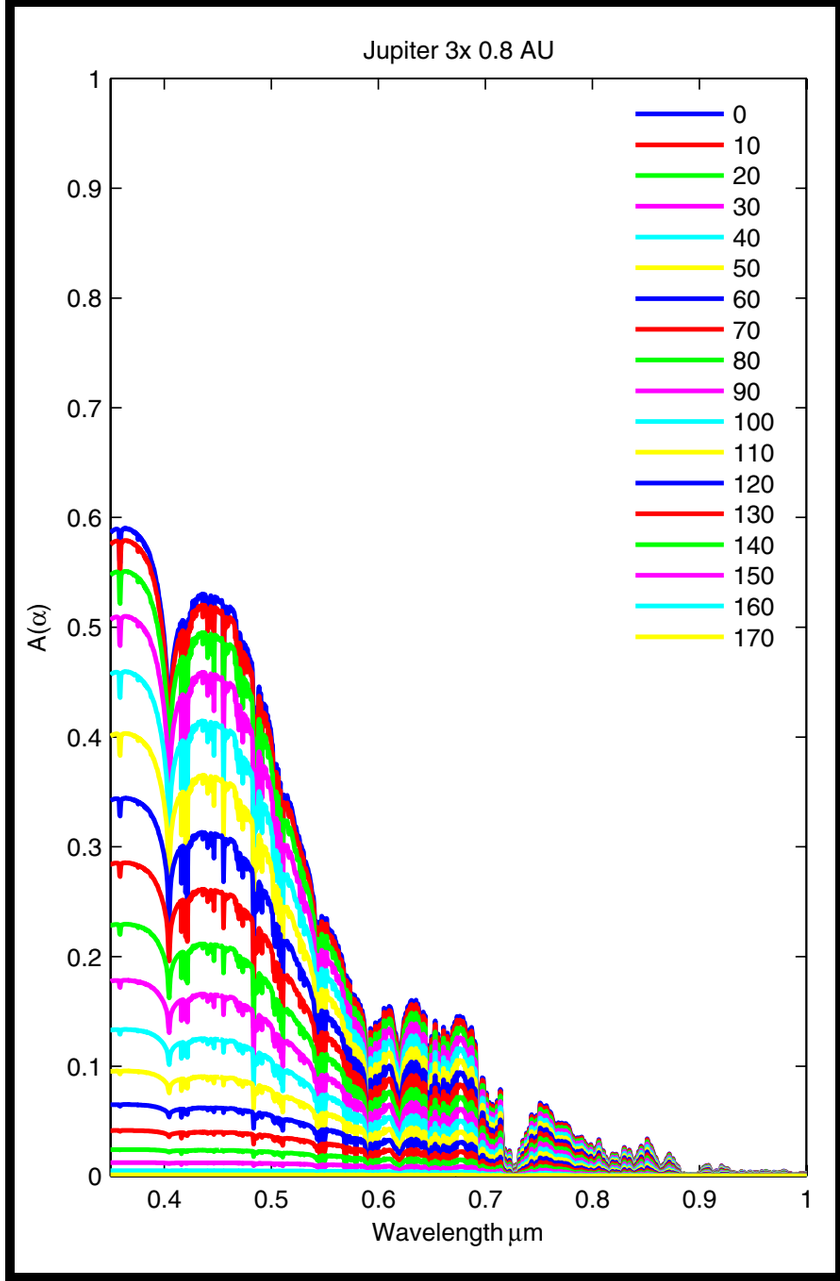


- We will deliver a large library of theoretical albedo spectra that span the range of planetary properties and orbital configurations relevant for WFIRST coronagraphy targets

Planetary Atmospheric Models → Albedo Spectra → Spectral Library

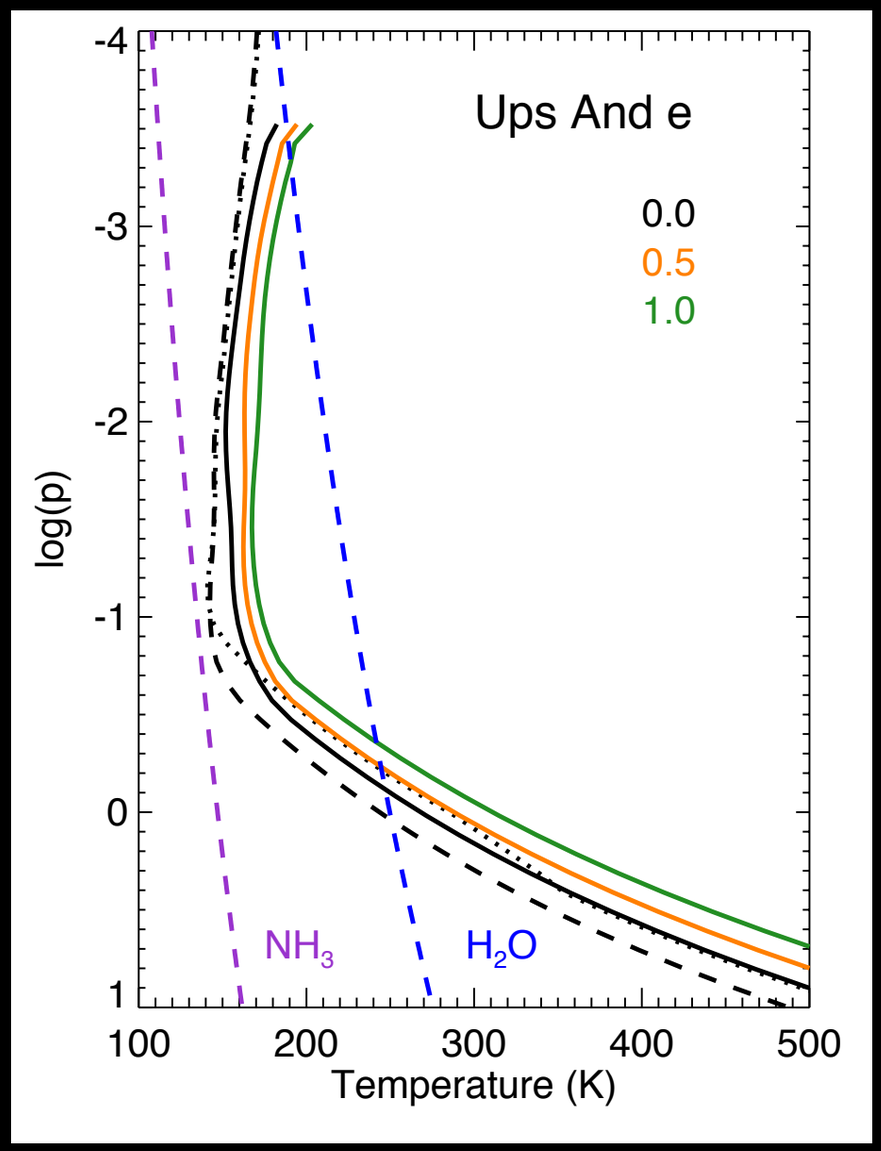


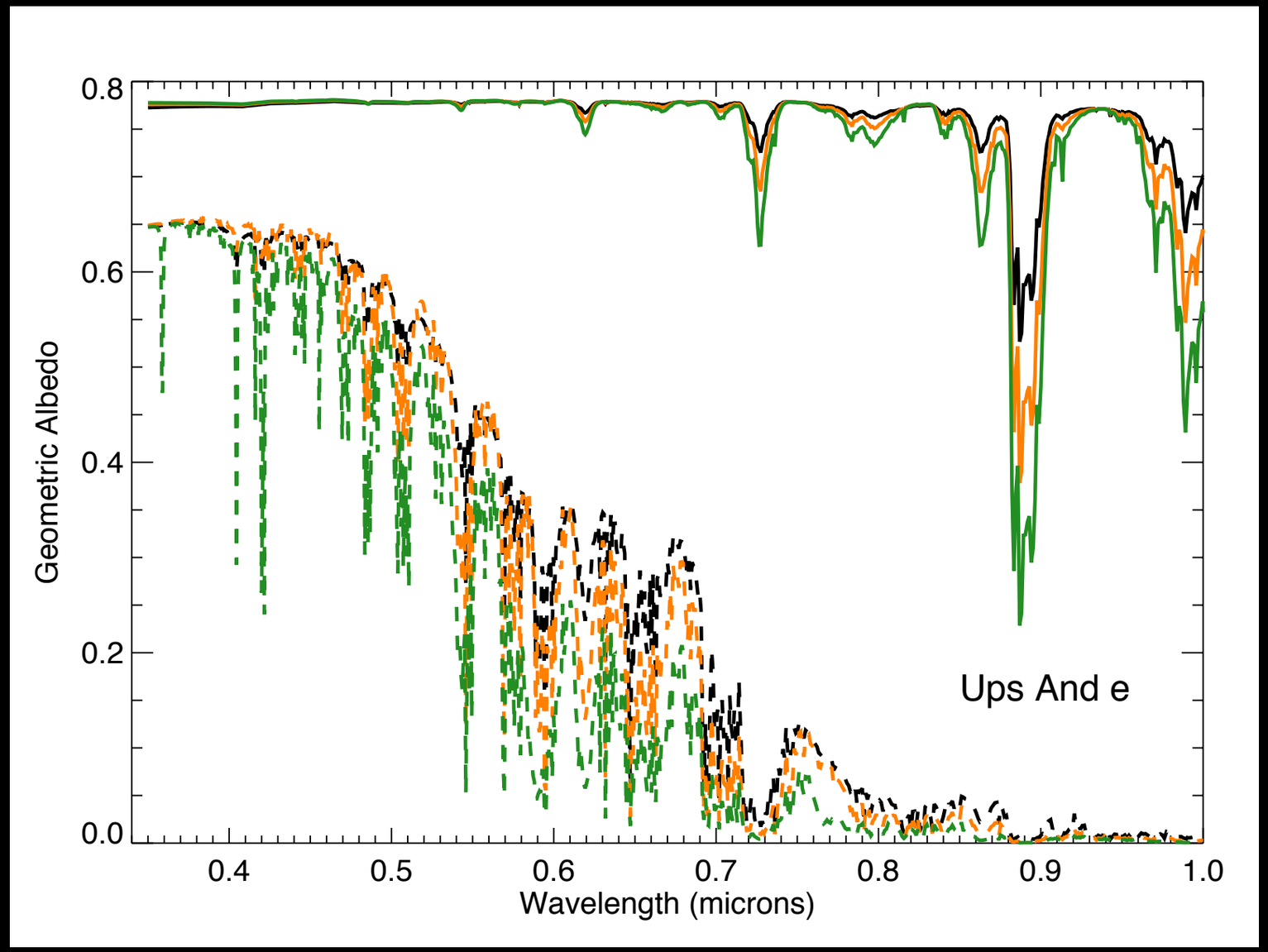




Cahoy et al (2010)

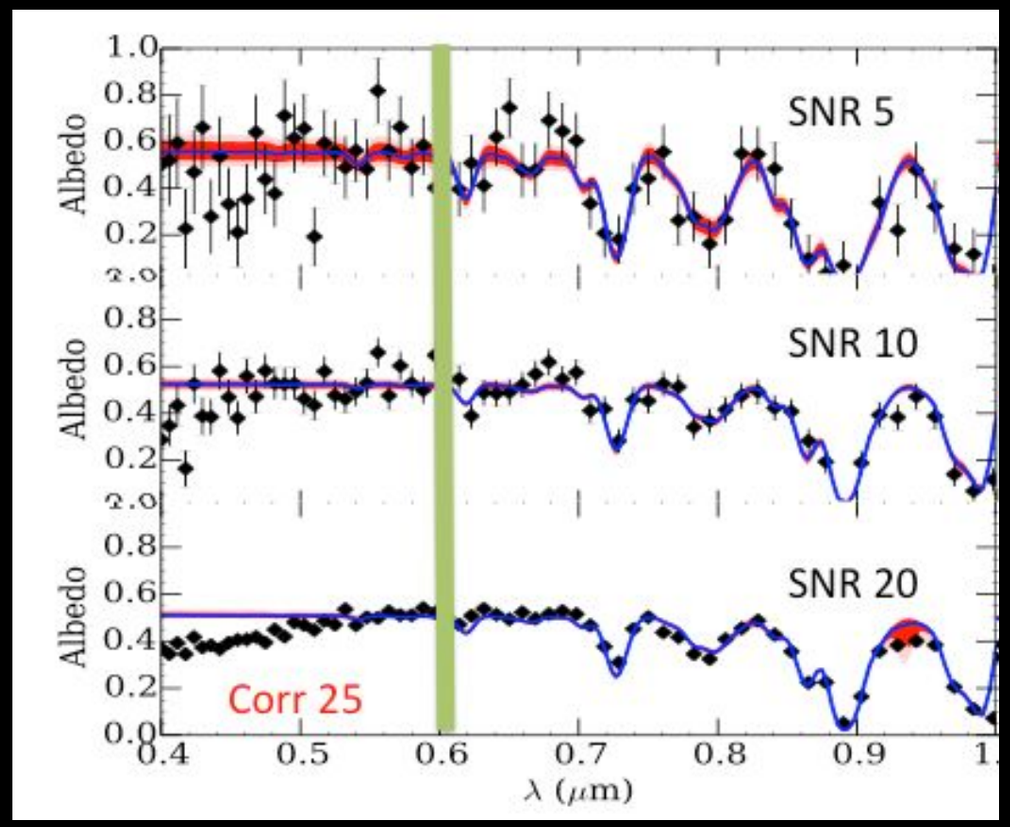
Example Known RV Target

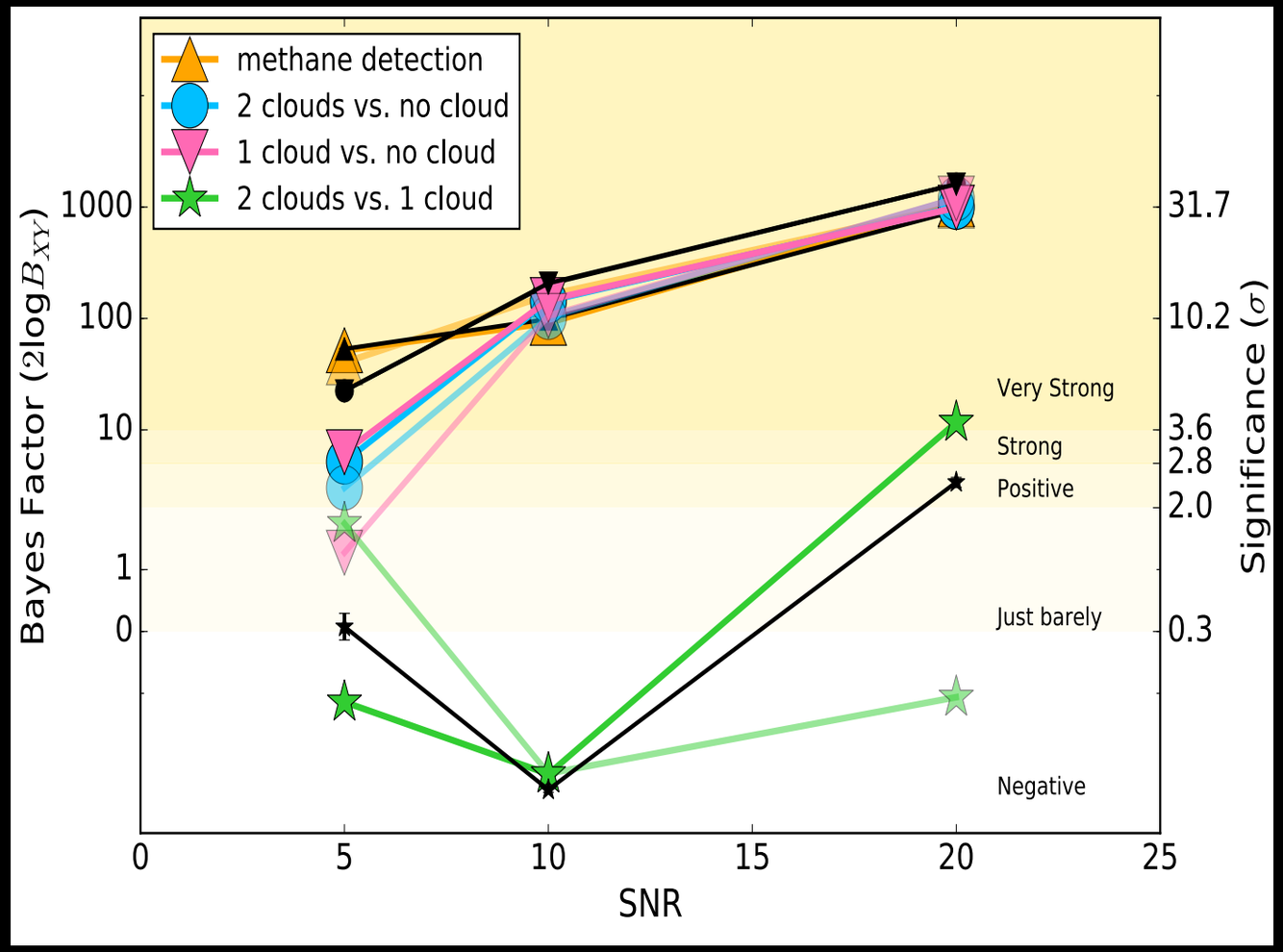


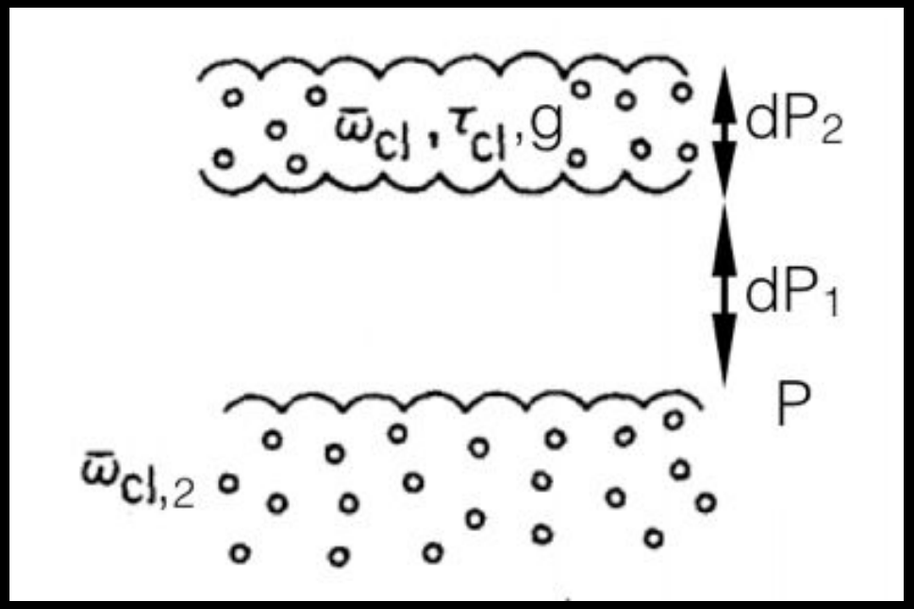


Lewis et al, in prep

Albedo Spectra → WFIRST CGI Simulator → Retrieval Analysis







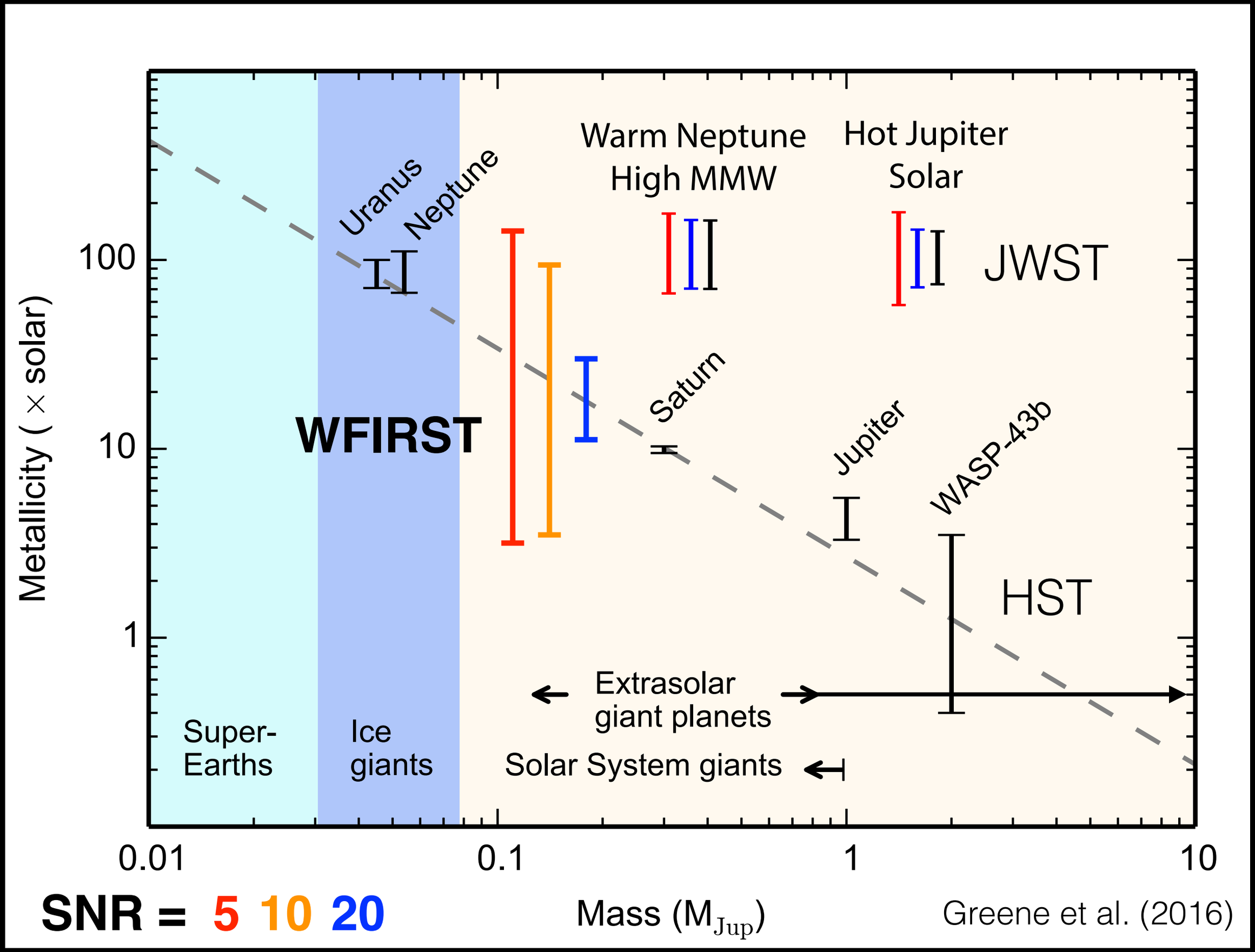
- Methane Abundance (fCH4)
- Surface Gravity (g)
- Cloud Properties
  - Single Scattering Albedo (ϖ)
  - Asymmetry factor (ğ)
  - Optical Depth (τ)
  - Cloud Top Pressure (P)

Lead: R. Lupu

Marley et al (2014)
Lupu et al., in prep

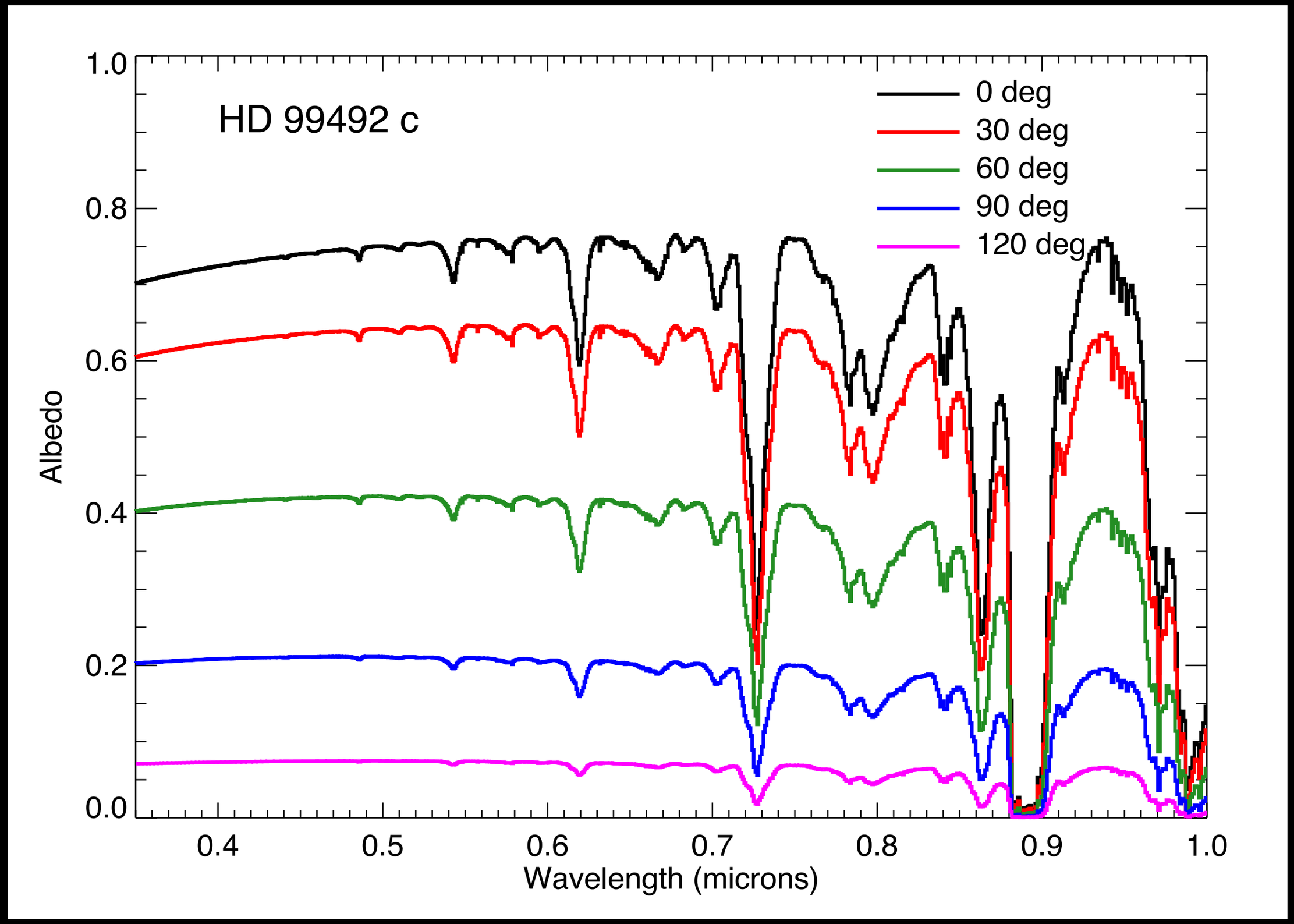
Question #1

How does the composition of gas and ice giant planets vary with mass, orbit, and stellar mass and metallicity?

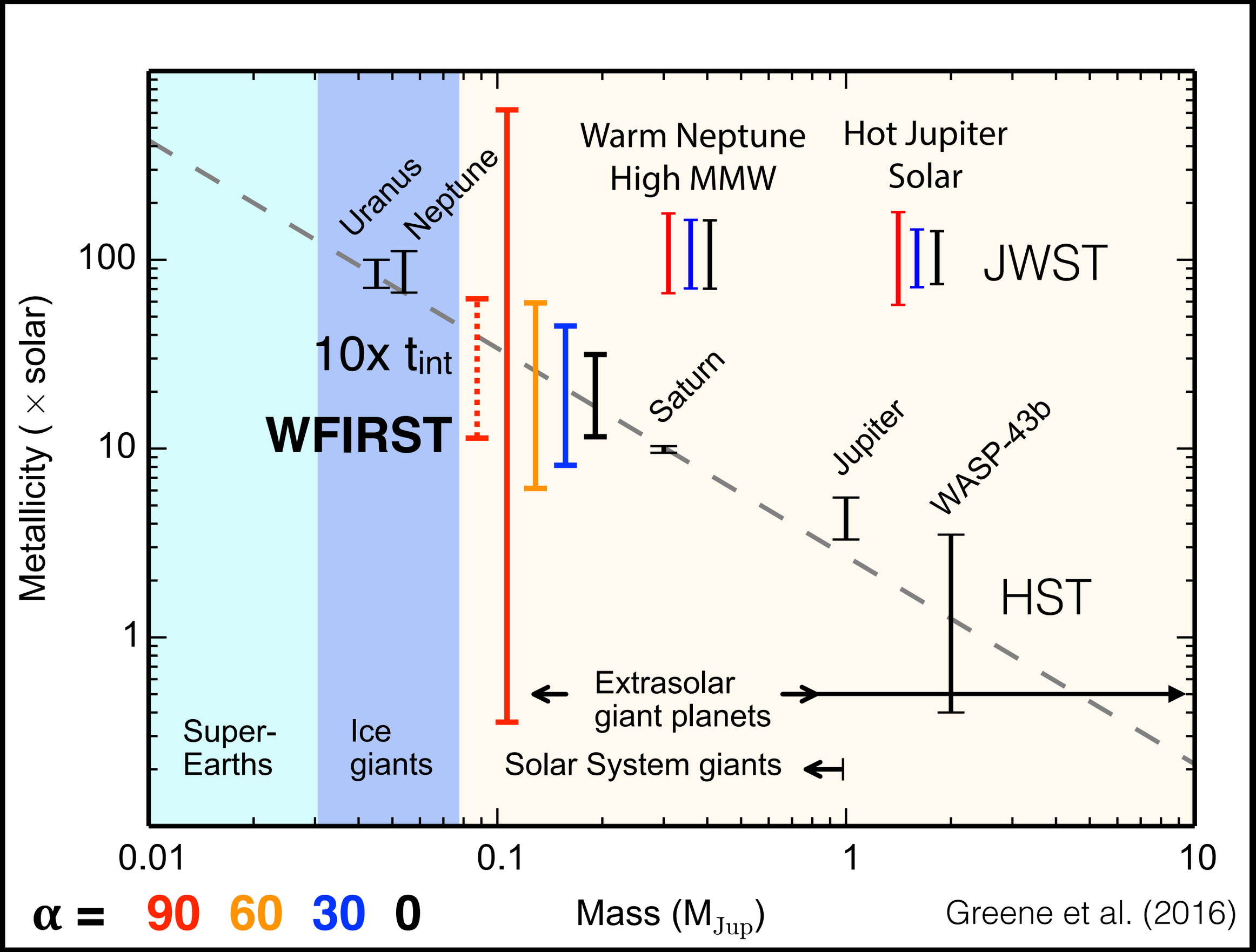


Lupu et al, in prep

Orbital Phase Matters!!!



Lewis et al, in prep

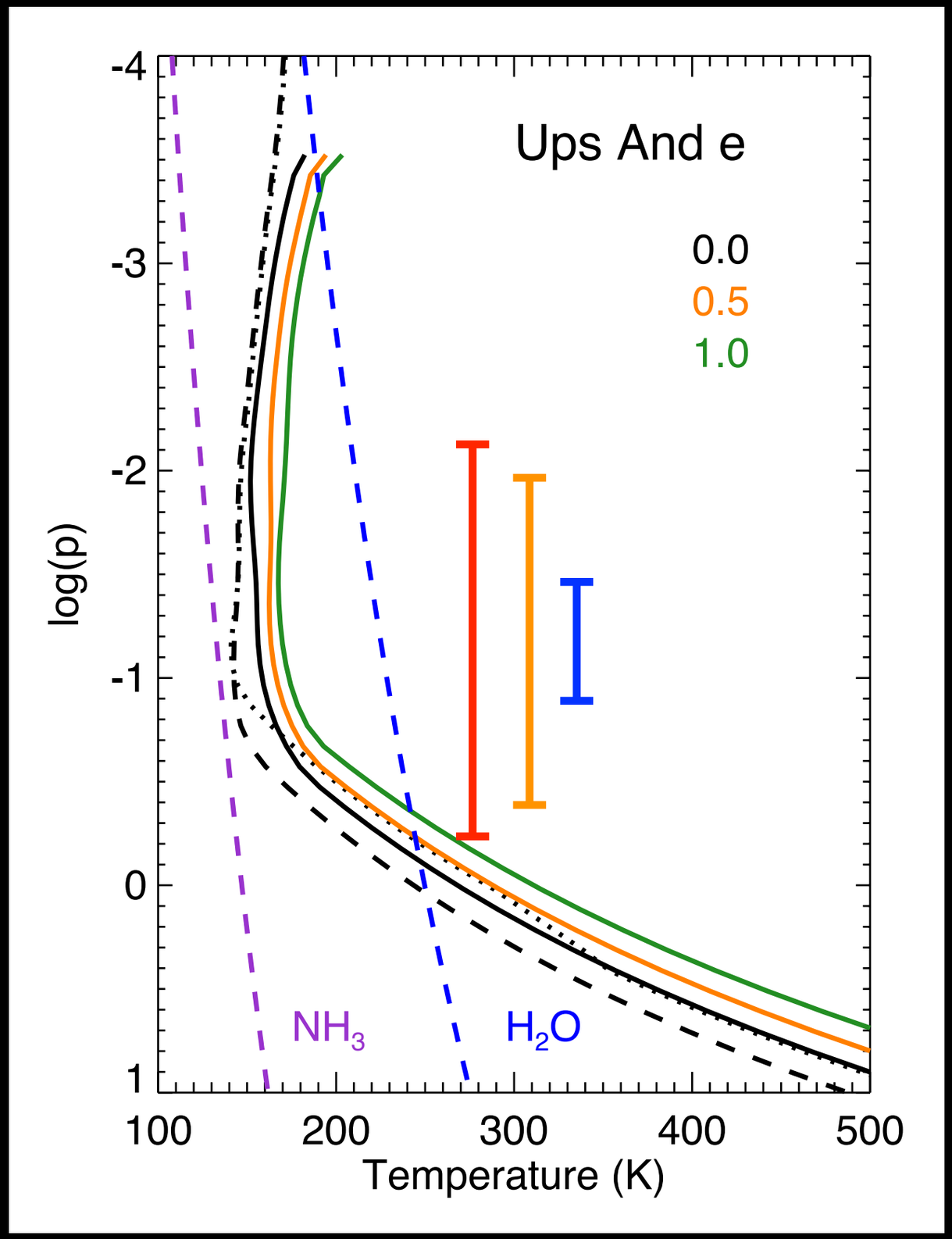


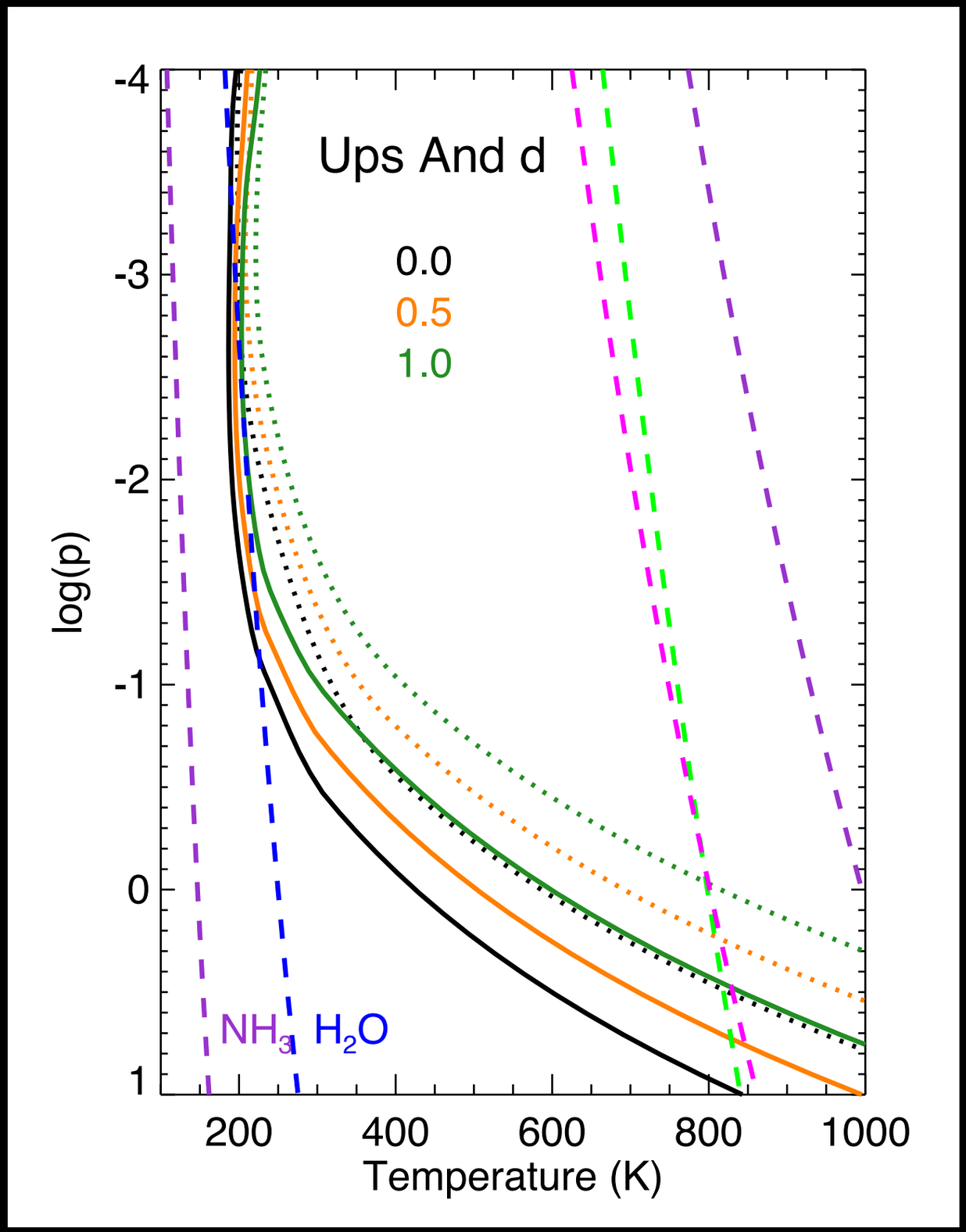
Fixed Integration Time (30 hr)

Nayak et al, in prep

Question #2

How do clouds affect giant planet atmospheres and vary with atmospheric temperature and other planetary parameters?



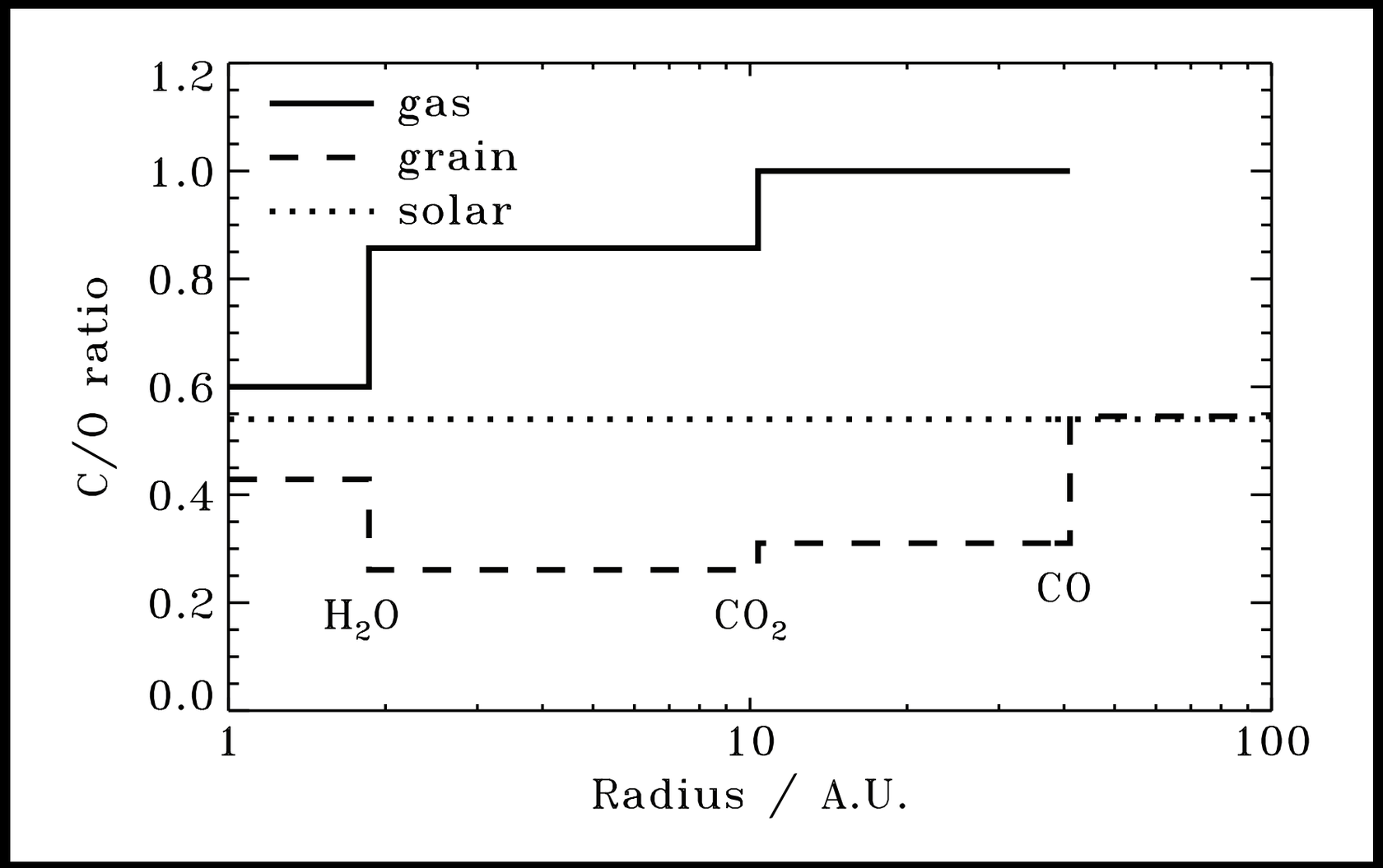


SNR = 5 10 20

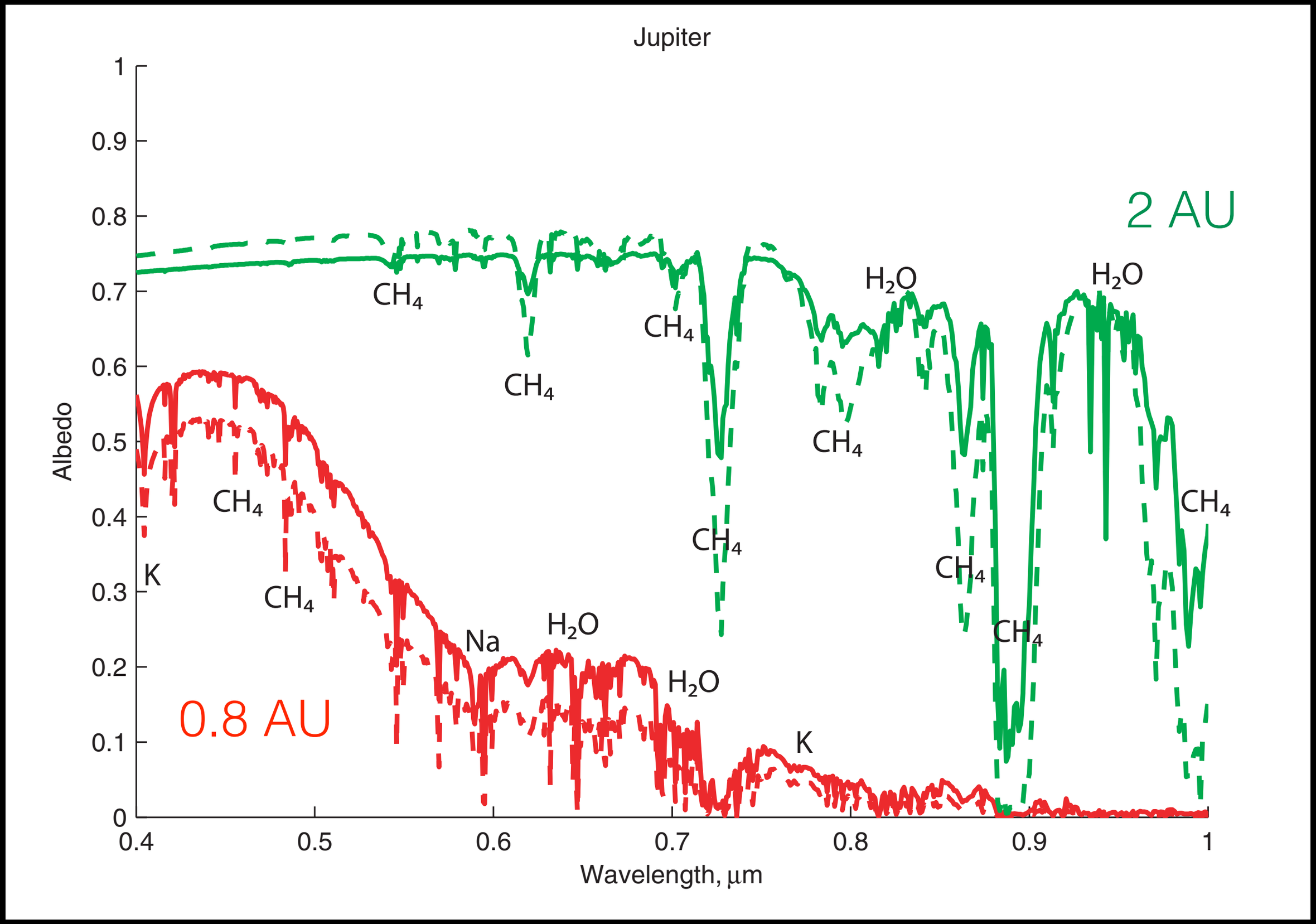
Lupu et al, Lewis et al, in prep

Question #3

Do planets formed inside and outside the nebular ‘snow line’ have different compositions or C/O ratios?

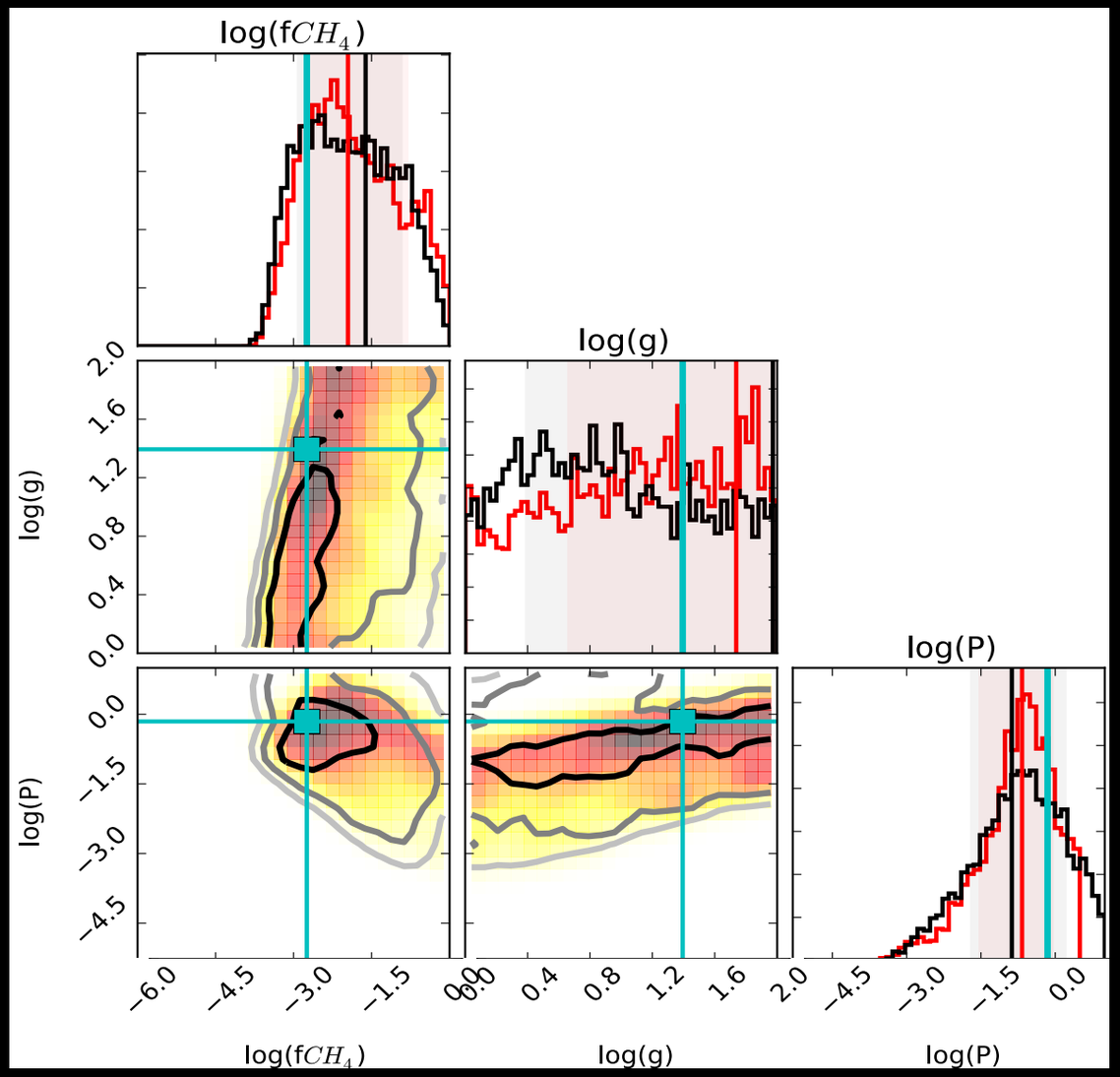


Oberg et al., 2011



Cahoy et al (2010)

Path Forward



Lupu et al, in prep

Degeneracies exist between retrieved parameters, such as methane abundance, gravity, and cloud top/ bottom pressure. Investigating ways of combining outside information (priors) to limits these degeneracies

- g/fCH4 -> Constrain Msini
- cloud height/fCH4 -> photometric Information
- orbital phase/planet size/albedo -> photometric information, M-R relationship

Near Term Goals

- Complete C/O retrieval exercise for RV target in ideal temperature range
- Polarization estimates for known RV targets
- Begin ingesting Super-Earth to Neptune mass theoretical spectra into retrieval exercises
- Public release of spectral library