Future Observations of Exoplanet Atmospheres

Dr. Aki Roberge

NASA Goddard Space Flight Center

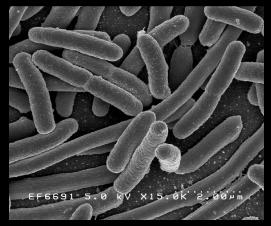
Exoplanets & Stellar Astrophysics Lab

Does Life Exist Outside the Earth?

Animals

Plants

Fungi



Bacteria

Protists

- Minimum requirements for life?
  1. Solid surface ➔ terrestrial planet
  2. Liquid water ➔ particular surface T, atmosphere
  3. Plate tectonics ? ➔ particular planet mass ?
- Habitable zone for an Earth-twin
  - Roughly, just beyond Venus to Mars
  - $a_{inner,\ outer} = (0.7 - 1.5)\ AU \times (L_{star}/L_{sun})^{1/2}$

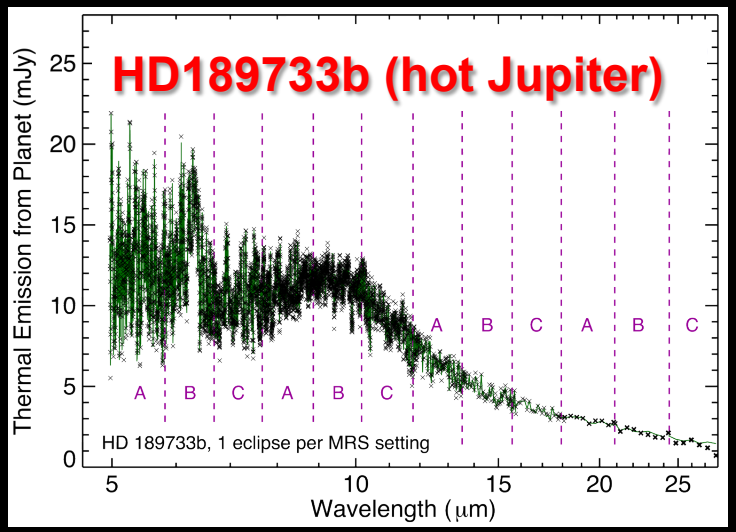
James Webb Space Telescope

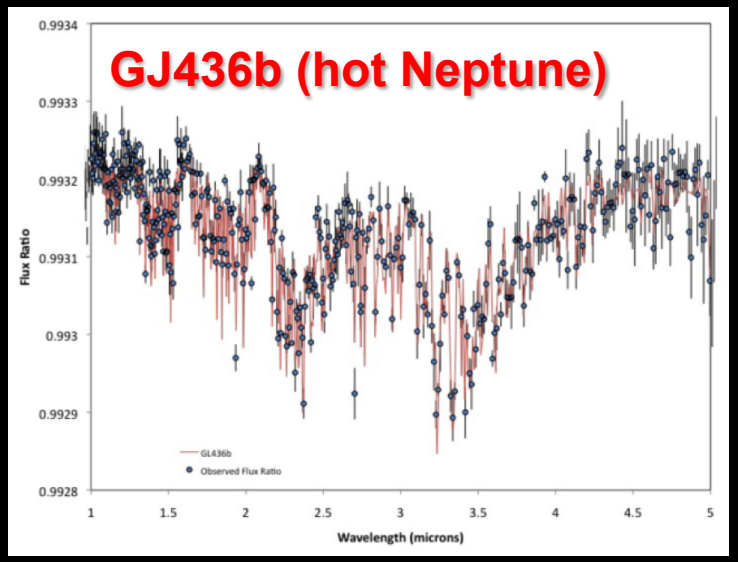
- 6.5 meter diameter mirror, 4 instruments
  - NIRCam
    - Imaging from 0.6 – 5 microns
  - NIRISS
    - Imaging & low-resolution spectroscopy from 0.6 – 3 microns
  - NIRSpec
    - Medium-resolution spectroscopy (R ~ 3000) from 1 – 5 microns
  - MIRI
    - Imaging & medium-resolution spectroscopy (R ~ 3000) from 5 – 28.3 microns

JWST Planet Characterization

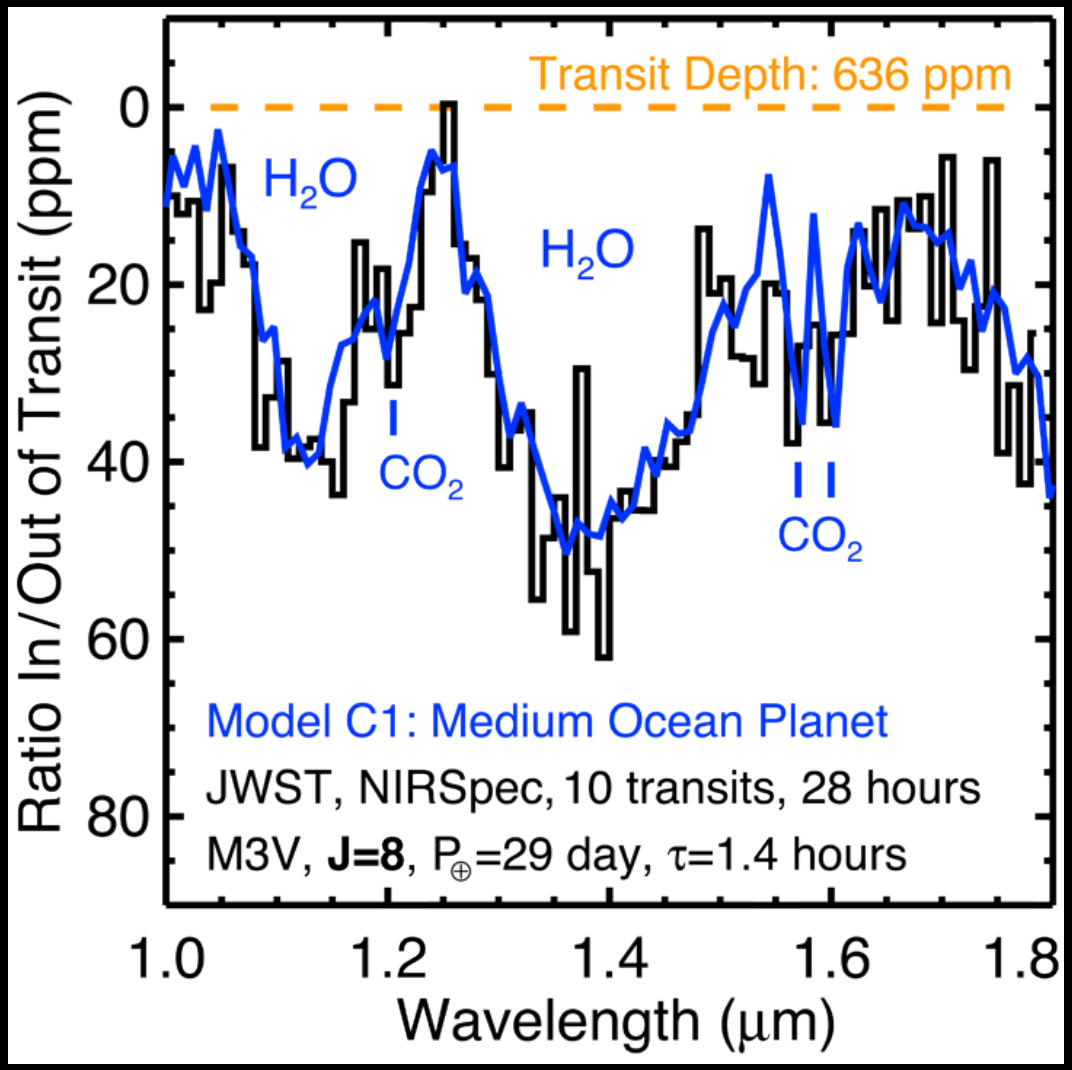
Sources: M. Clampin (GSFC), J. Valenti (STScI), T. Greene (Ames)

- Spectroscopy of hot & cold gas giants
  - In both transit & eclipse
  - High S/N and good resolution (R = 100 – 3000)
- Transit spectroscopy of Neptunes & super-Earths around low-mass stars
  - Small stellar radi = larger transit signal





Transit Spectrum of Habitable "Ocean Planet"

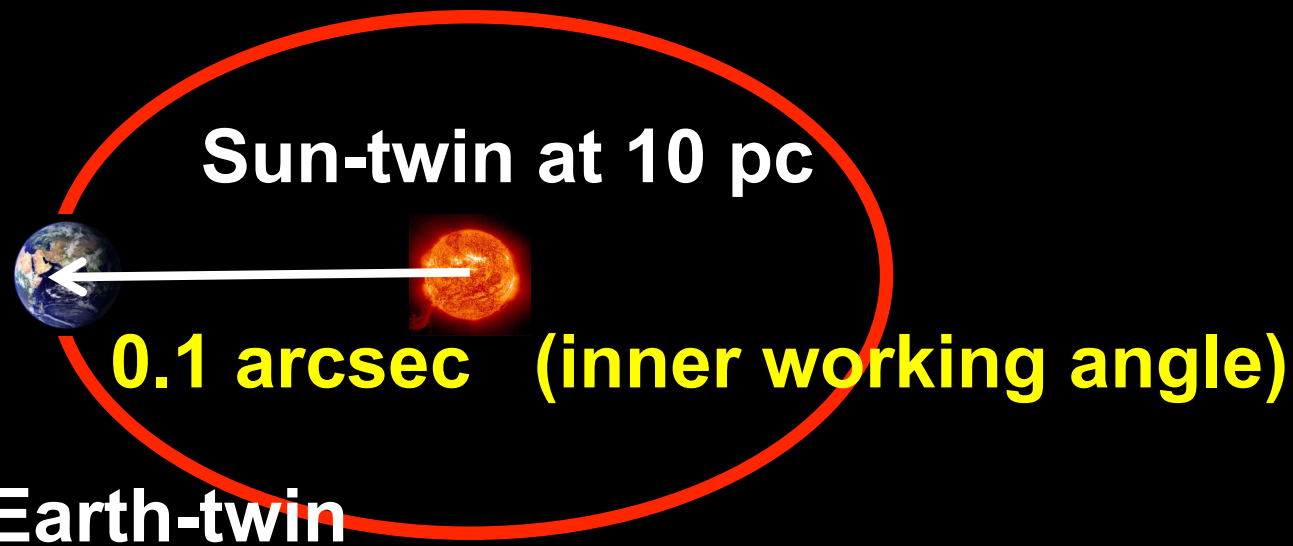


Simulation by J. Valenti (STScI)

- Host star
  - Mass = 0.3 solar masses
  - Radius = 0.5 solar radii
- But JWST can't do true Earth-analogs

ExoEarths: The Technical Challenge

- To get a direct image of a habitable planet around a nearby Sun-like star …

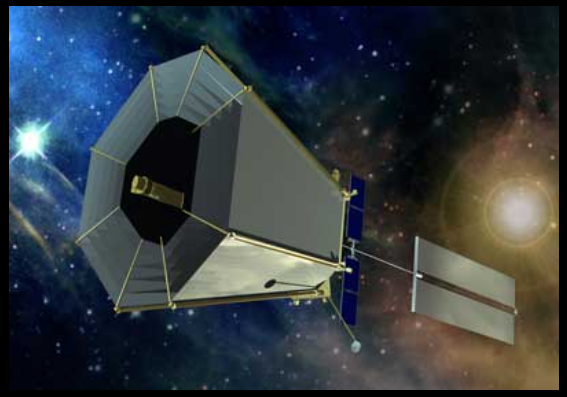


Earth-twin

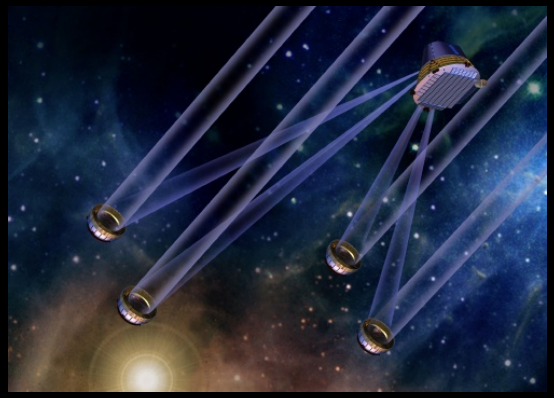
$F_{planet} / F_{star} = 1.155 \times 10^{-10}$ **(contrast)**

Like a picture of a firefly 1 meter from a searchlight 2000 km away

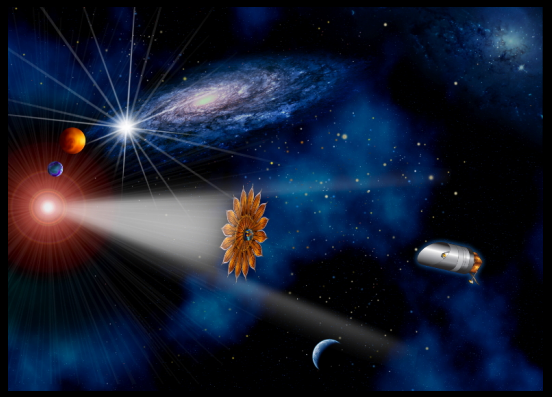
Starlight Suppression



Internal Coronagraph
(visible wavelengths)
aka. Terrestrial Planet Finder



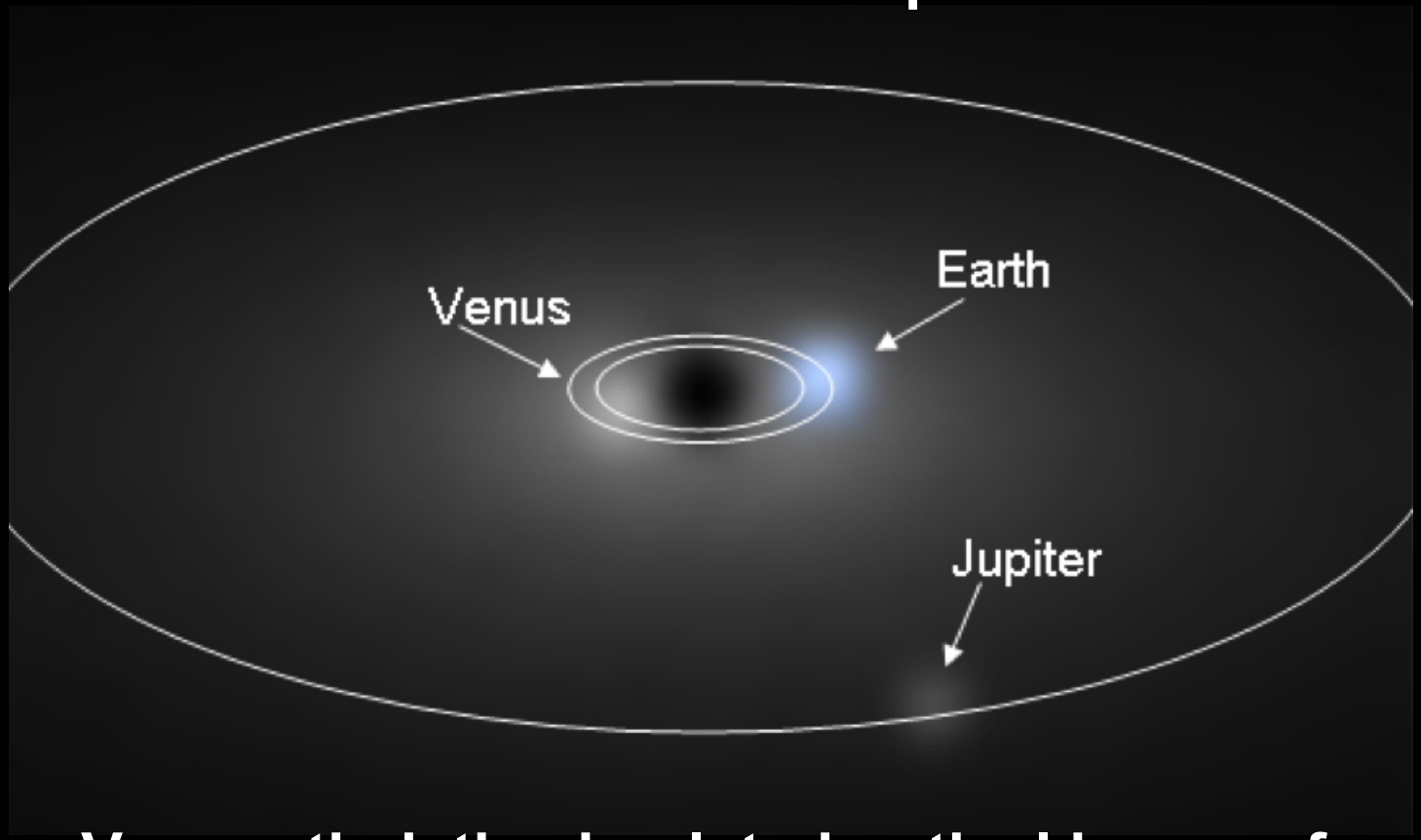
Nulling Interferometer
(infrared wavelengths)
aka. Darwin



External Occulter
(visible wavelengths)
aka. New Worlds Observer

What Will We See?

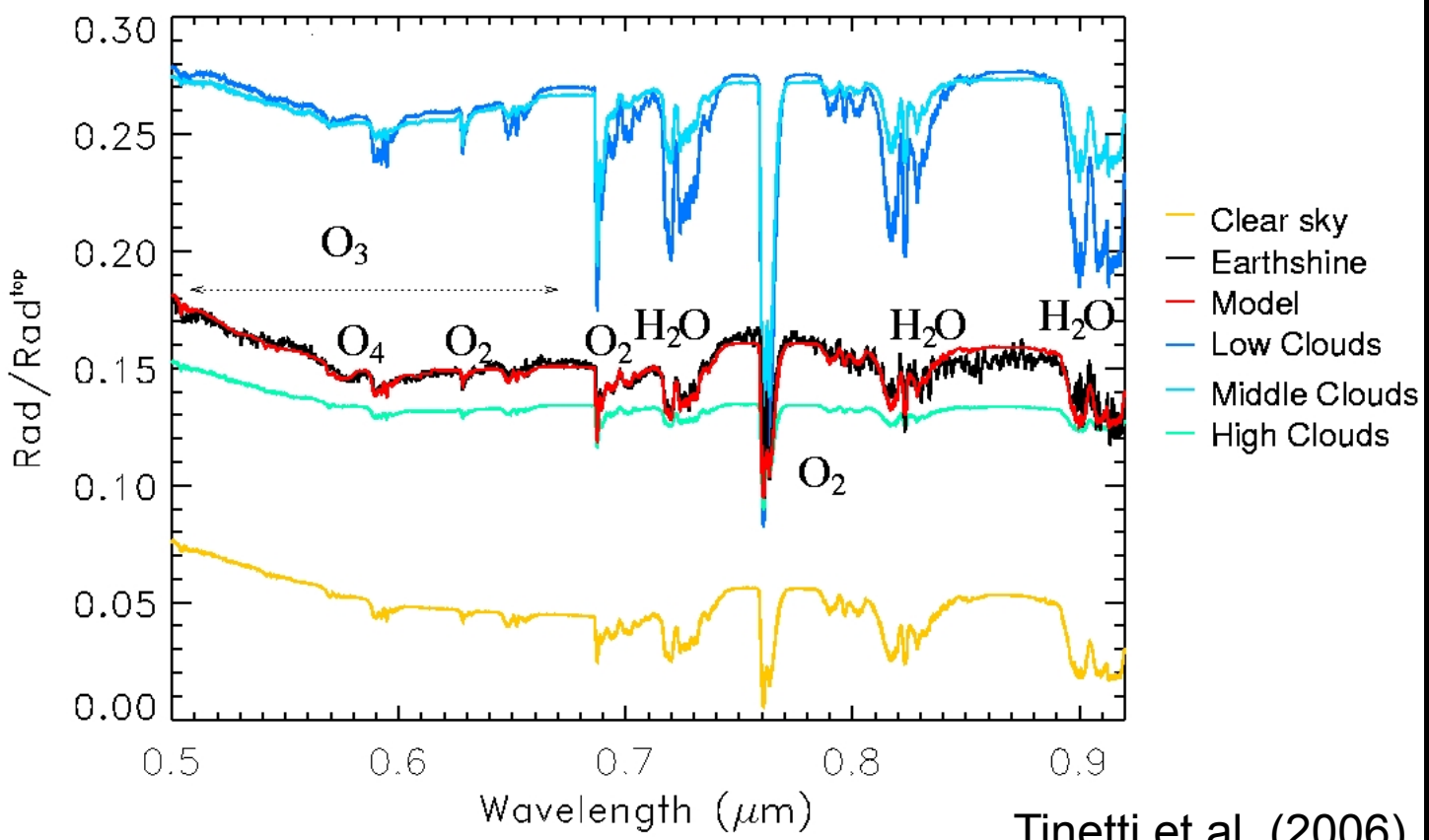
Unresolved image = integrated light from whole illuminated area of planet



Very optimistic simulated optical image of the Solar System at 10 pc

Model Disk-Averaged Earth Spectra

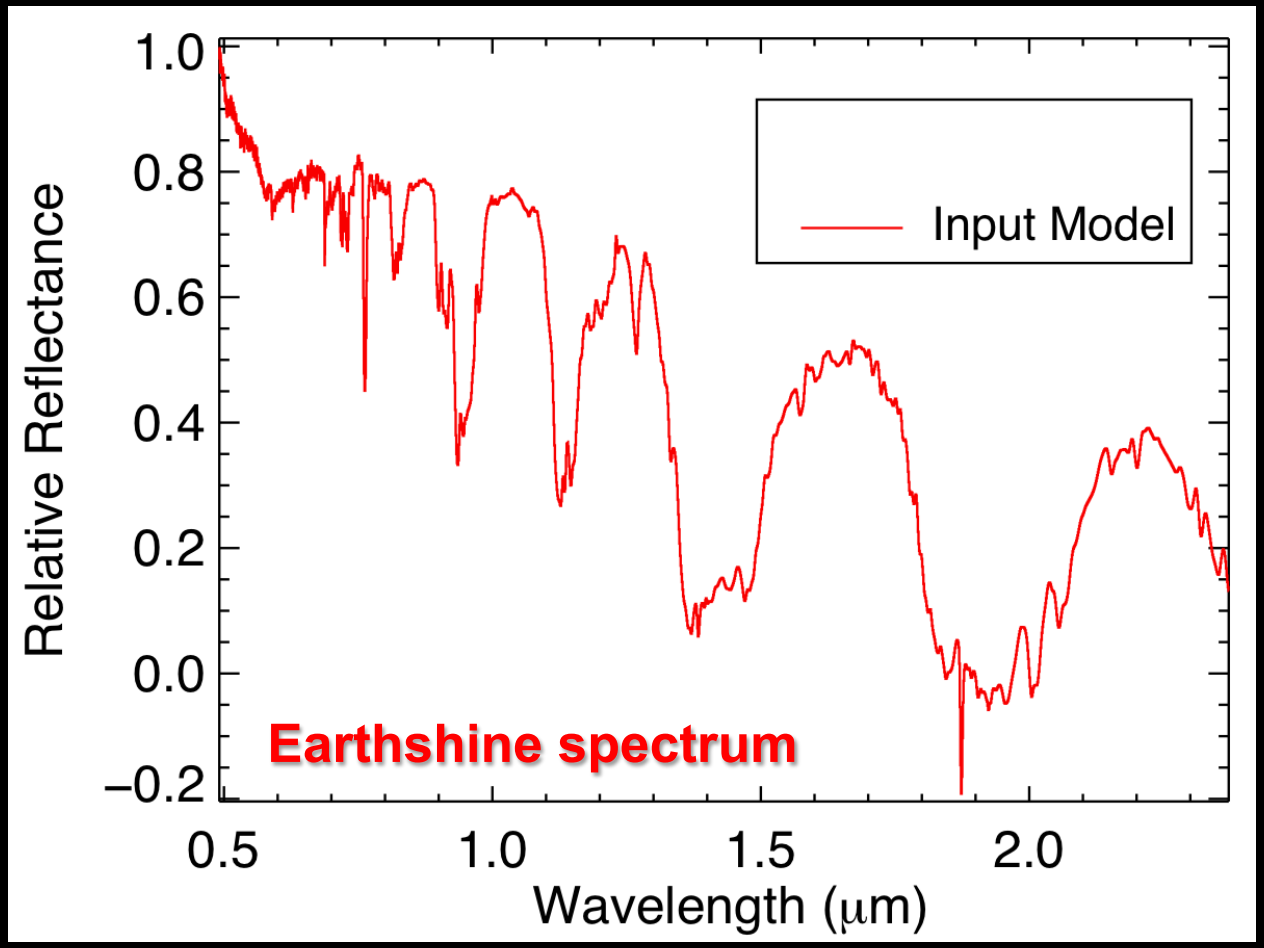
- Optical spectra of Earth shows mostly reflected sunlight, then clouds and atmospheric constituents



Tinetti et al. (2006)

Simulated Spectra

- Low spectral resolution (R ~ 100), modest S/N



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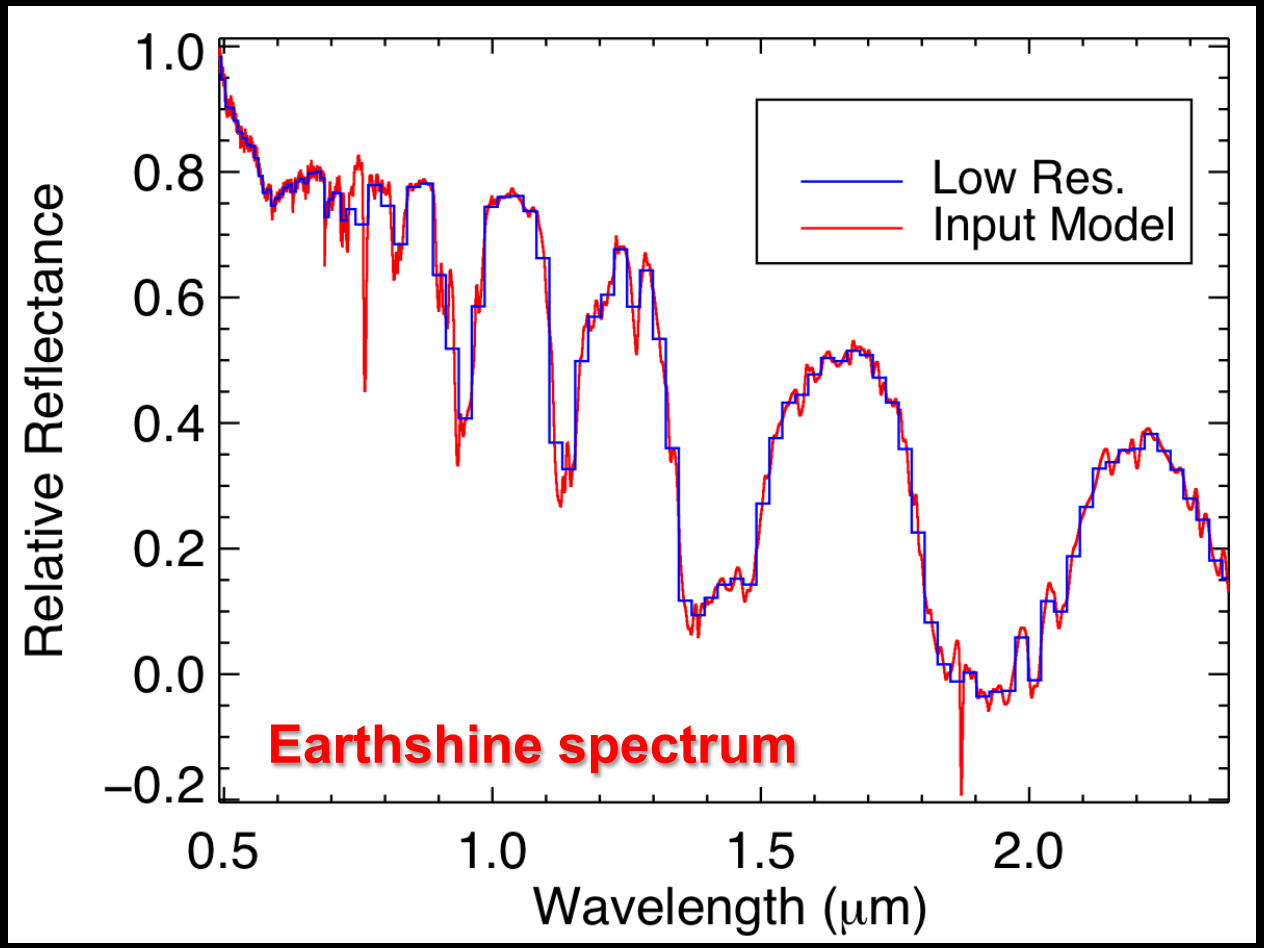

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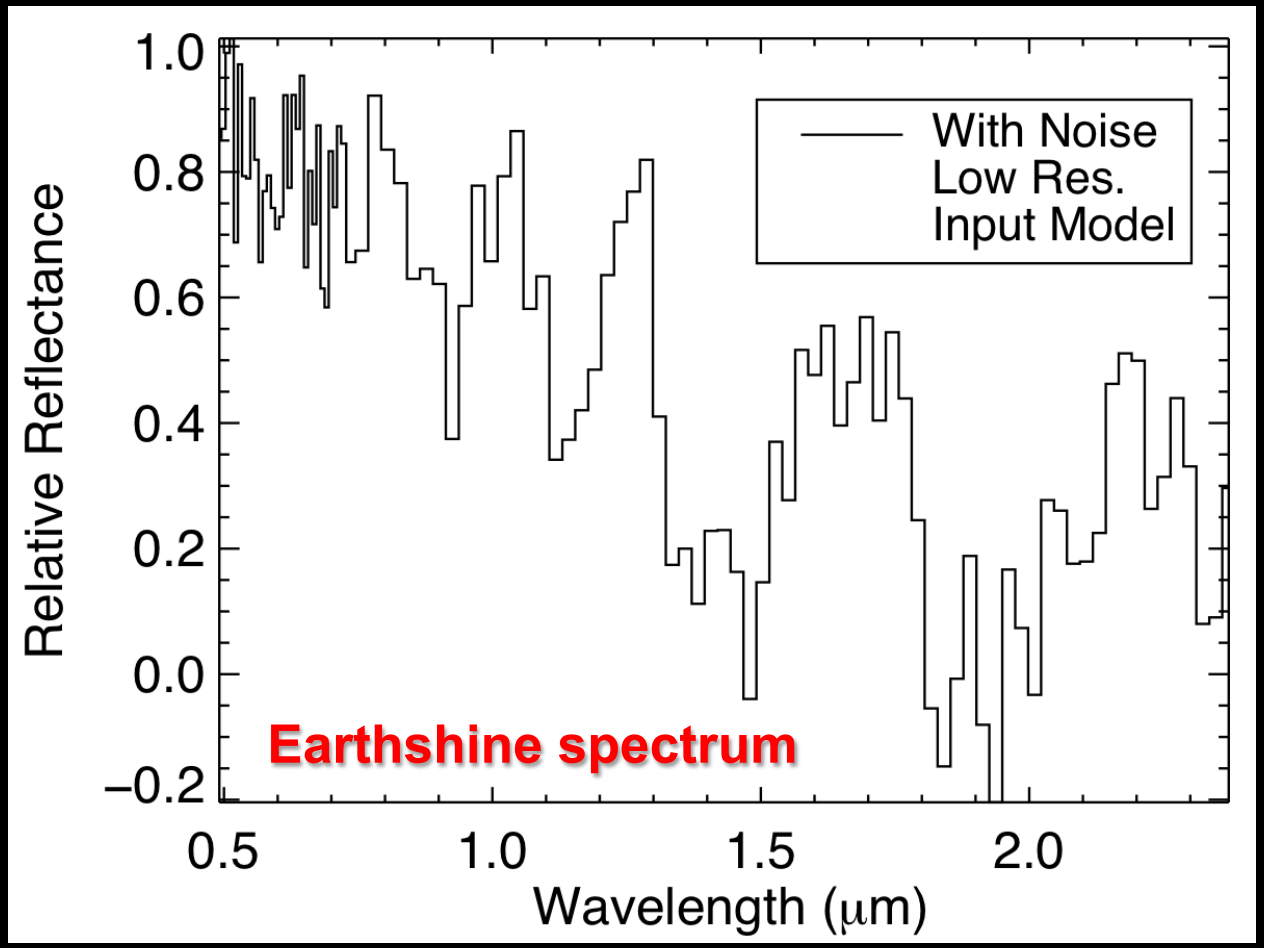

Issues Needing Study

- Variations from Earth model …
  - Atmosphere composition
  - Photochemistry (different stellar input spectrum)
  - Gravity (in particular, more massive planets)
  - Orbital distance, seasonal insolation changes