



Detecting Life on Extrasolar Planets with Future Telescopes

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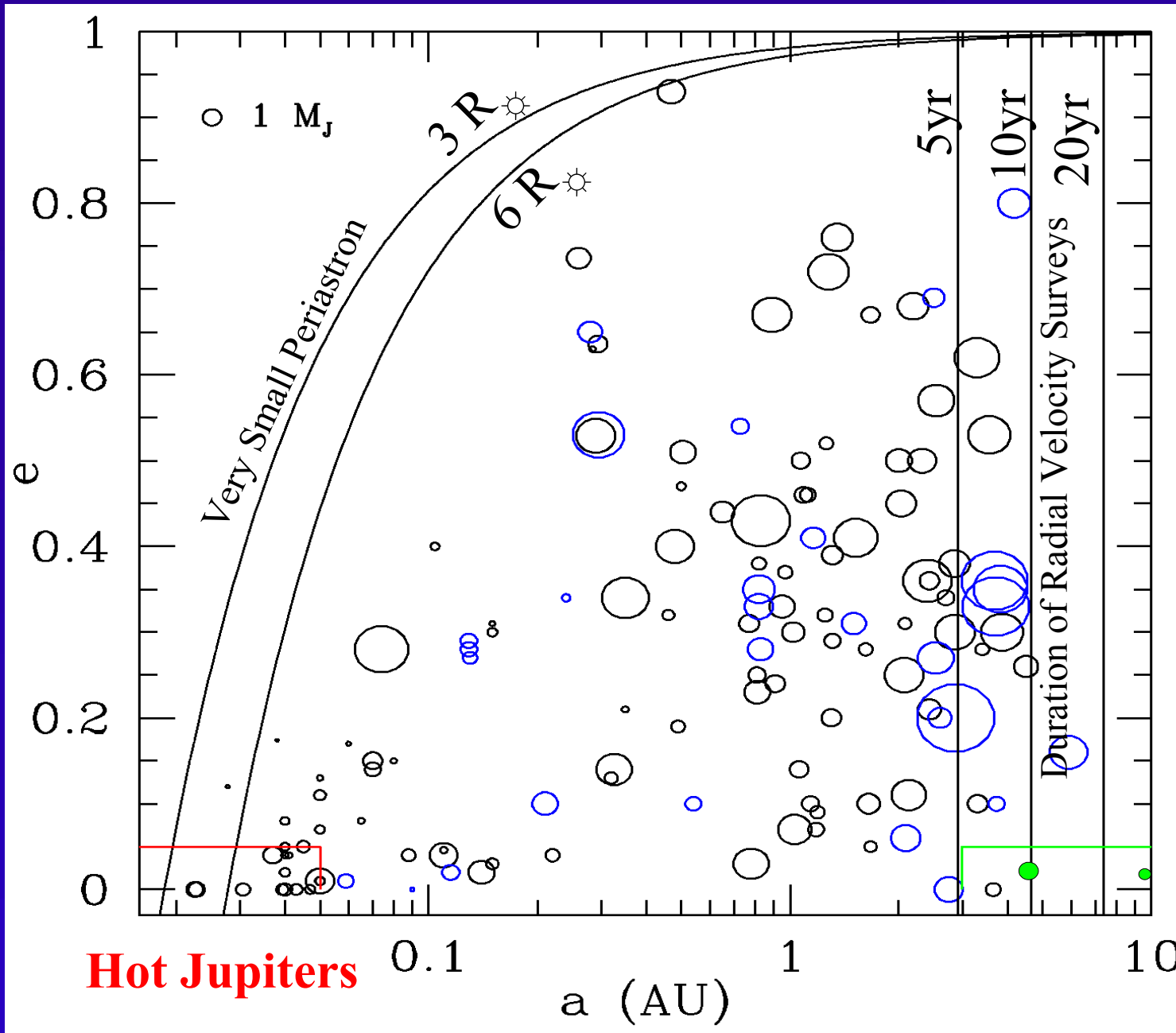
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Northwestern Astrobiology Workshop

Collaborators: Debra Fischer, Geoff Marcy, Fred Rasio, Scott
Tremaine, Sara Seager, Justin Schaefer, Wes Traub, Ed Turner

Motivation

- Understand Formation of Planetary Systems & Life
- Are planetary systems like our own common/rare?
 - Are Giant Planets in circular orbits at 5 AU common?
 - Are Terrestrial Planets common?
 - In the Habitable Zone?
 - With Favourable Climates?
 - With Chemistry suitable for life?
- Do nearby stars have planets that harbour life?
- Rapid & dramatic increase in observational data

Diversity of Extrasolar Planets



Eccentric Planets

Multiple Planet Systems

Solar System Giant Planets

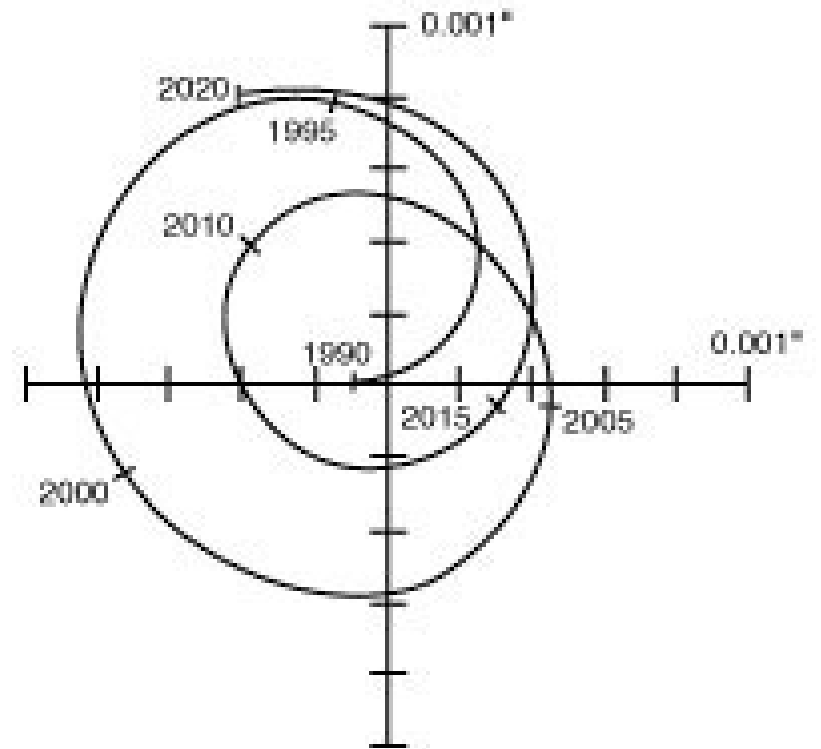
Future of Extrasolar Planet Observations

- **Radial Velocity Surveys:**
 - **Systems with Multiple Giant Planets**
 - **Giant Planets with Long Orbital Periods**
 - **Terrestrial Planets in Short-Period Orbits**
- **Transit Searches**
 - **Frequency of Terrestrial Planets in Habitable Zone**
- **Astrometry: Space Interferometry Mission – Planetquest**
 - **Orbits of Terrestrial Planets in Habitable Zone**
- **Direct Detection**
 - **Ground-based**
 - **Terrestrial Planet Finder – Coronagraph**
 - **Terrestrial Planet Finder – Interferometer**

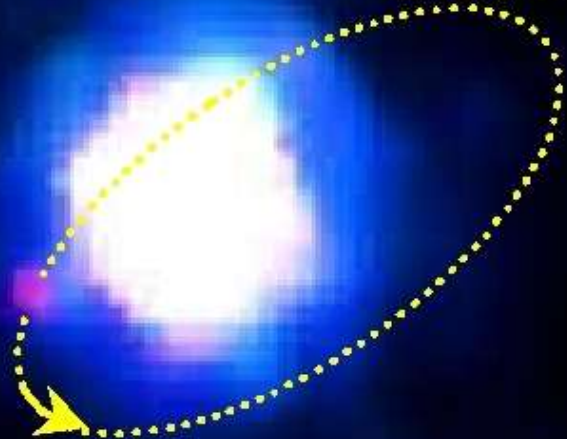
Astrometry: Space Interferometry Mission - Planetquest



NASA



Orbit of AB Dor C



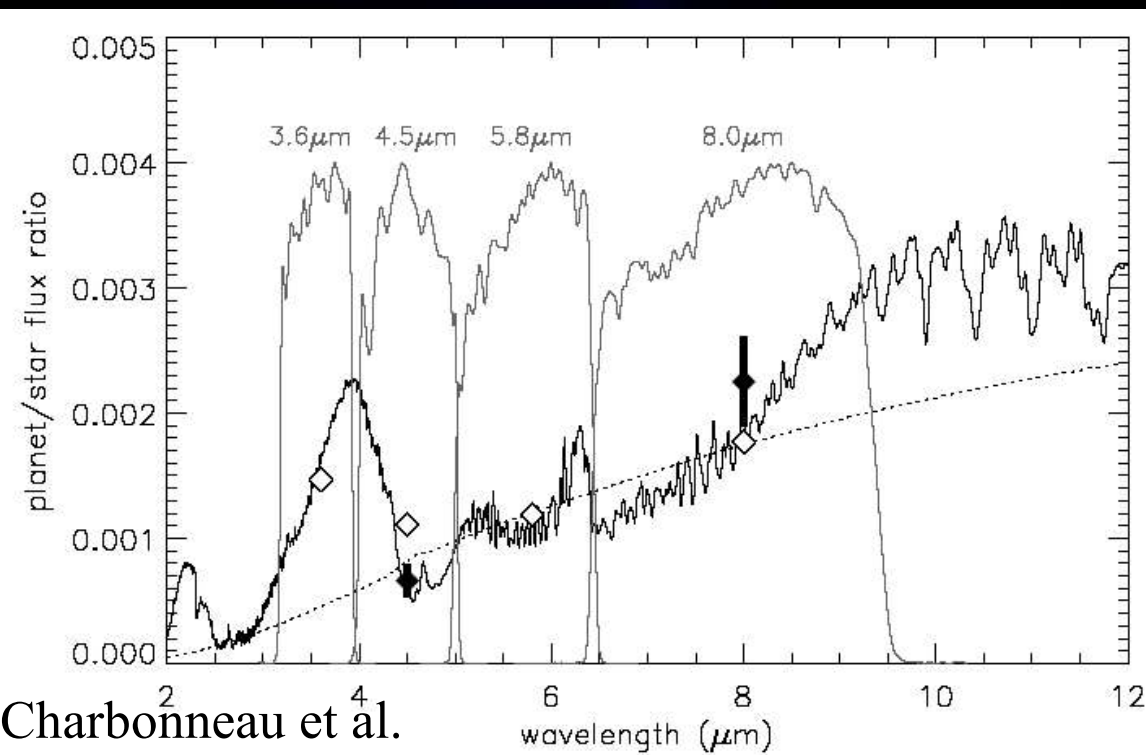
Close et al.

Direct Detection



778 mas
55 AU at 70 pc

Chauvin et al.



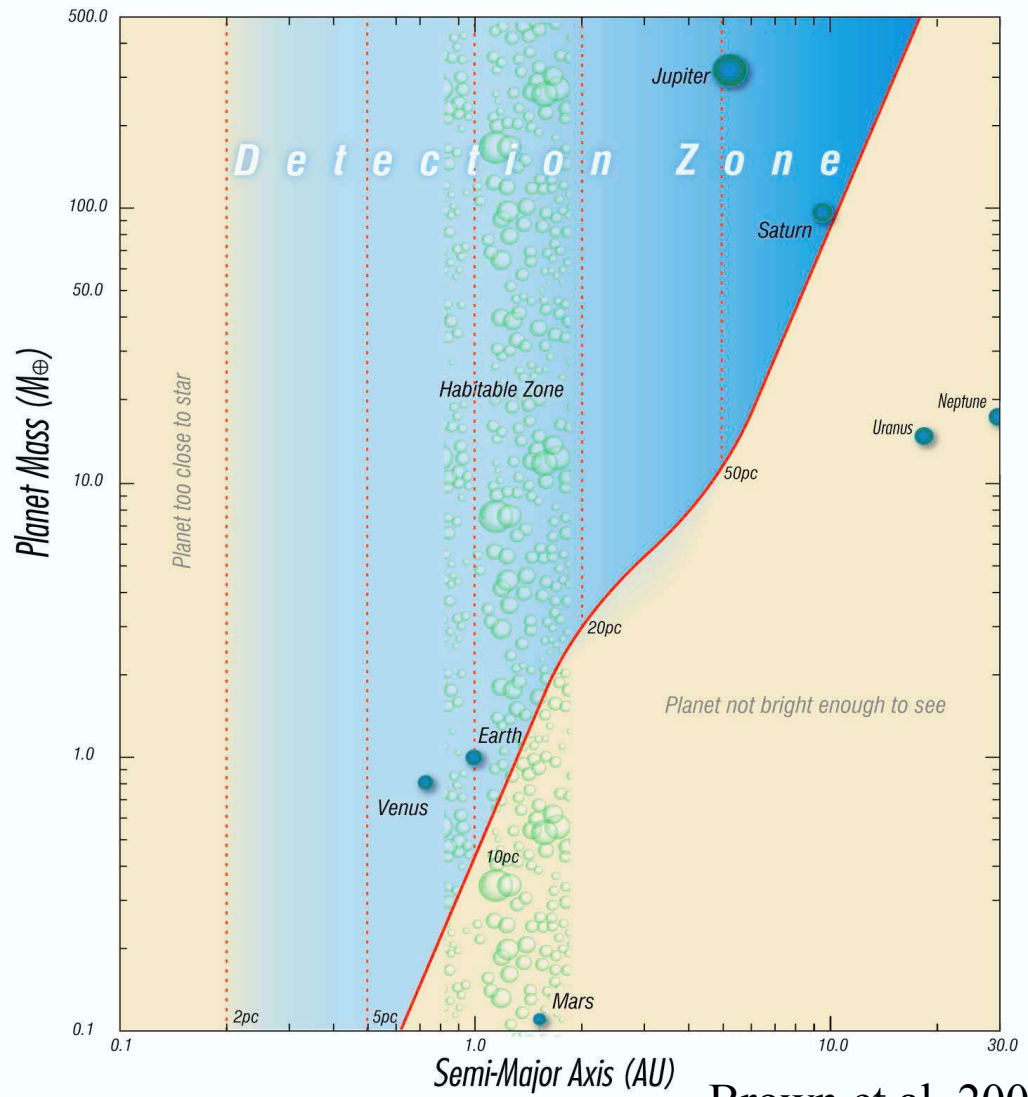
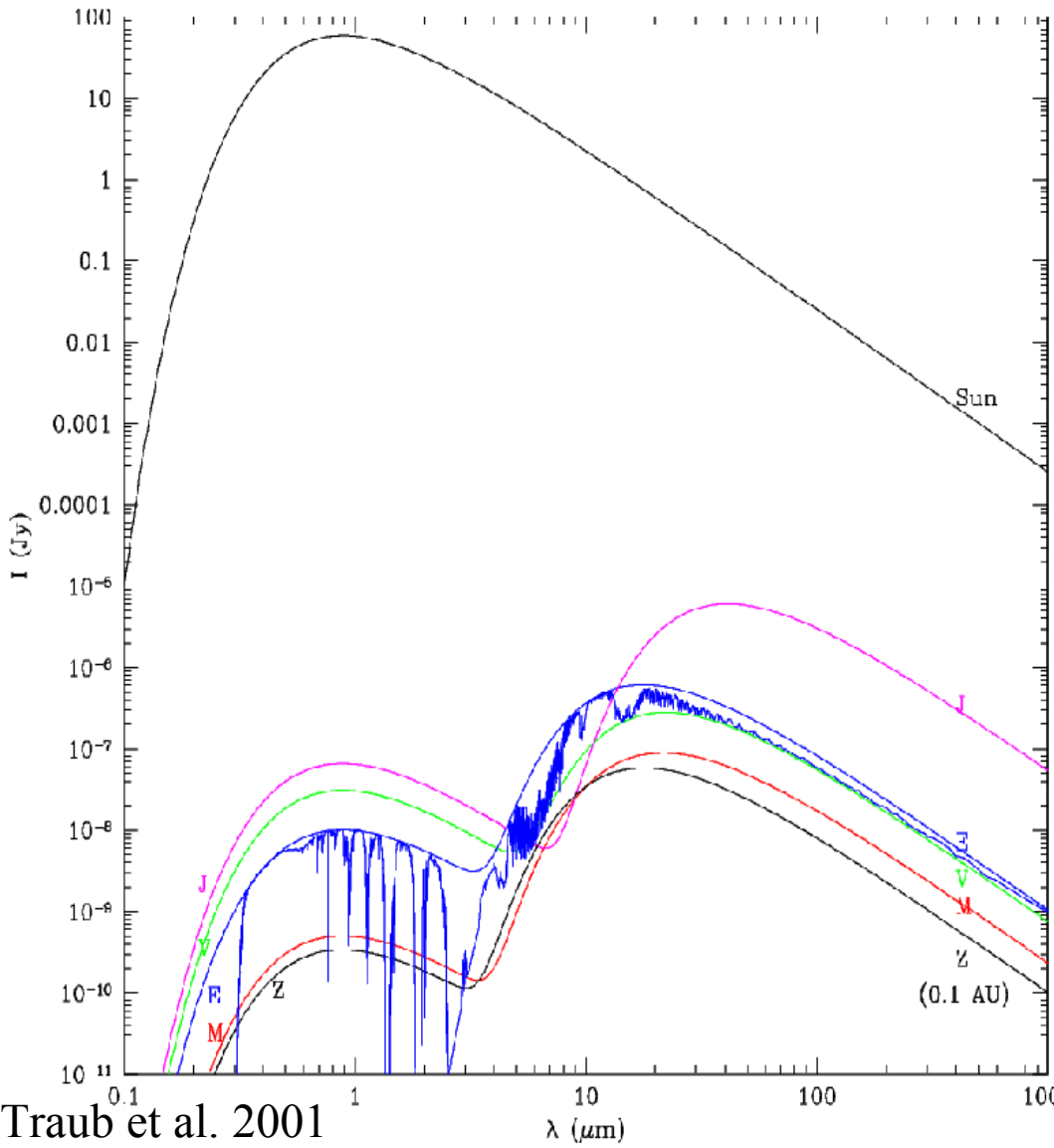
Charbonneau et al.

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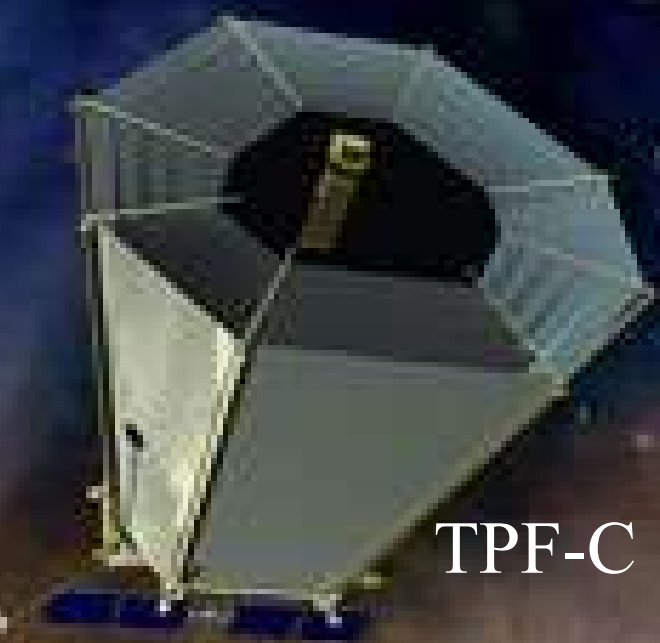


Neuhauser et al.

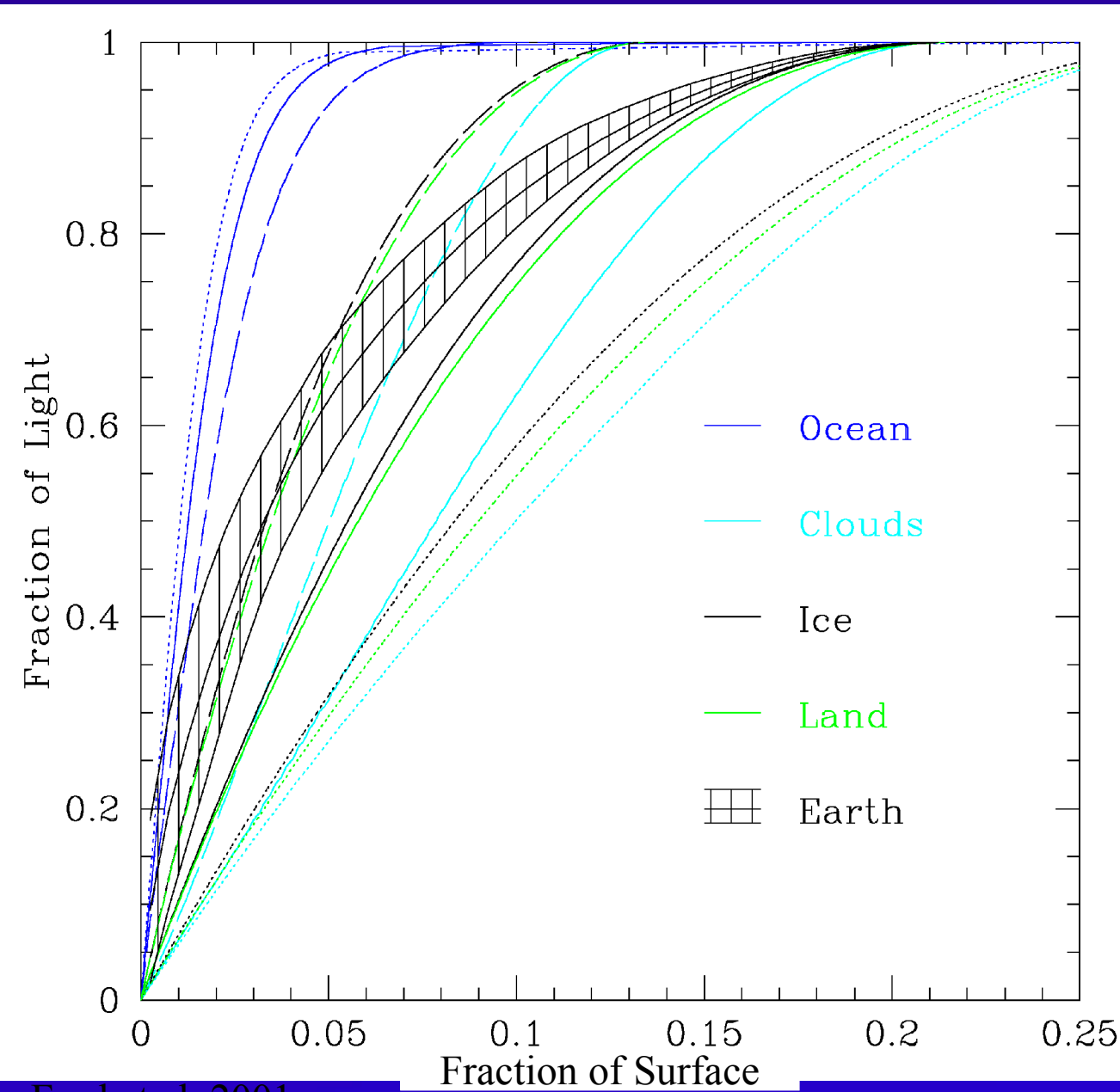
Terrestrial Planets: What Wavelength?



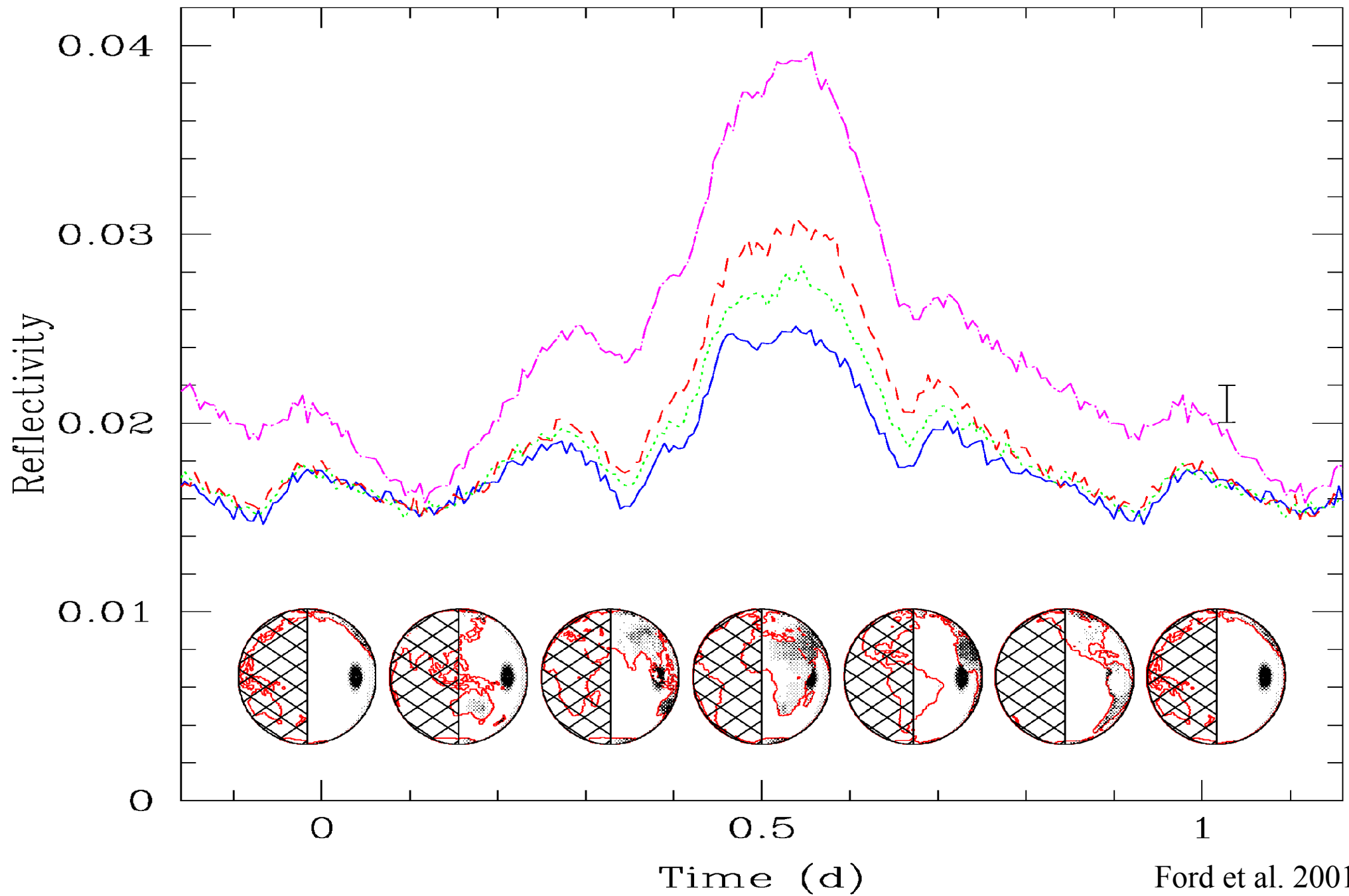
Direct Detection: Terrestrial Planet Finder



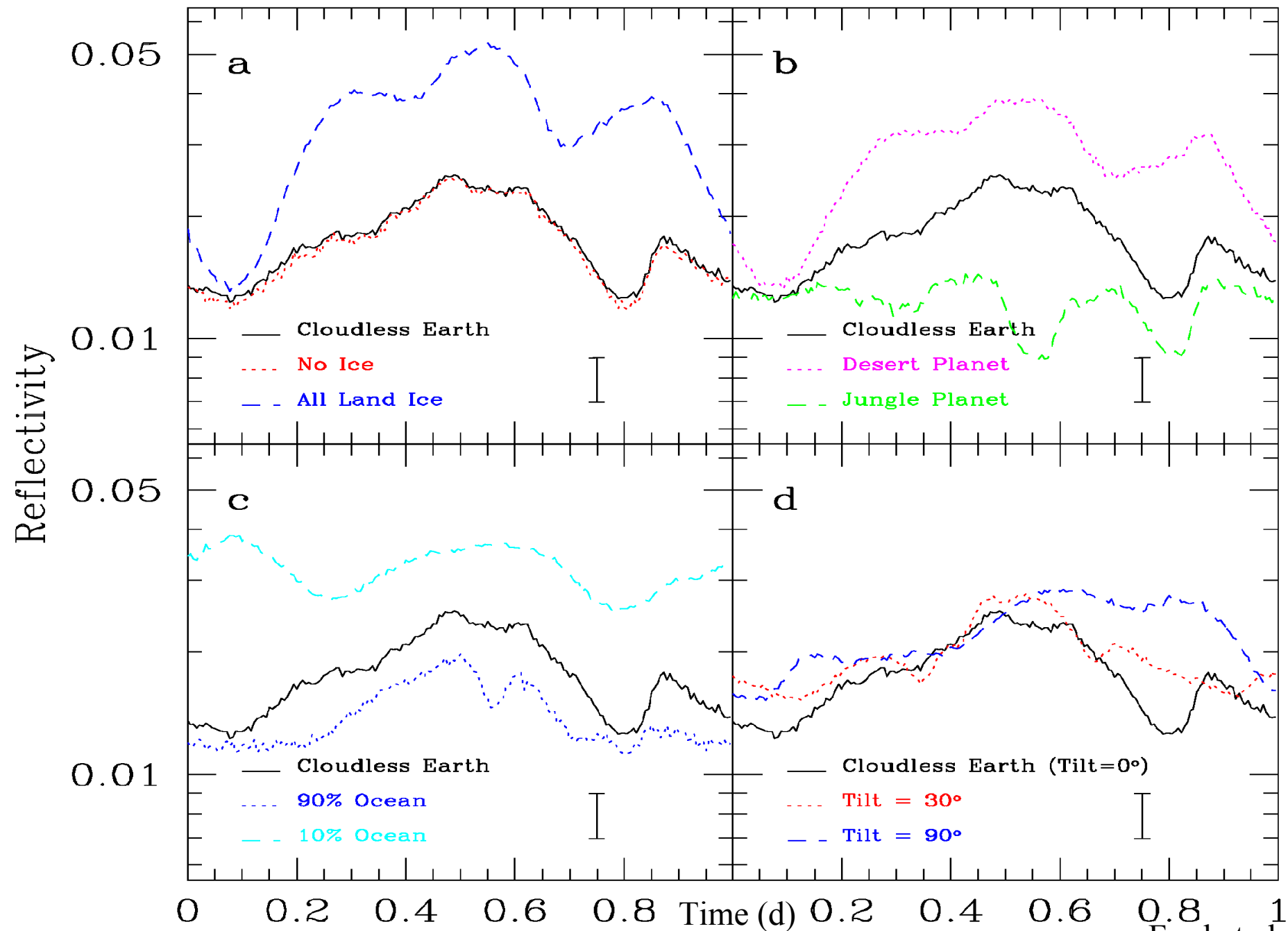
Direct Detection: Variability



Light curve for cloudless Earth

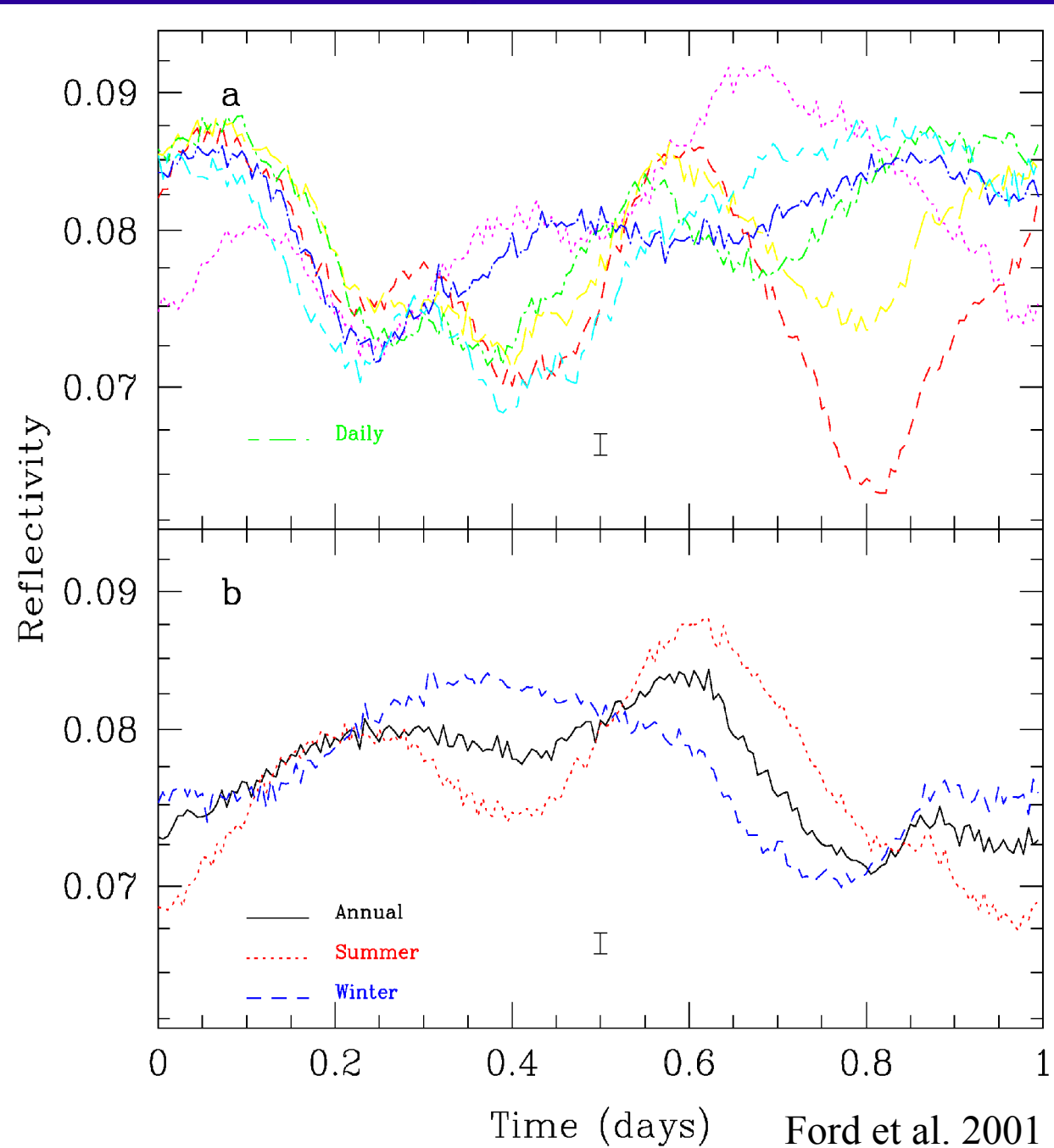


Variability of Other Worlds

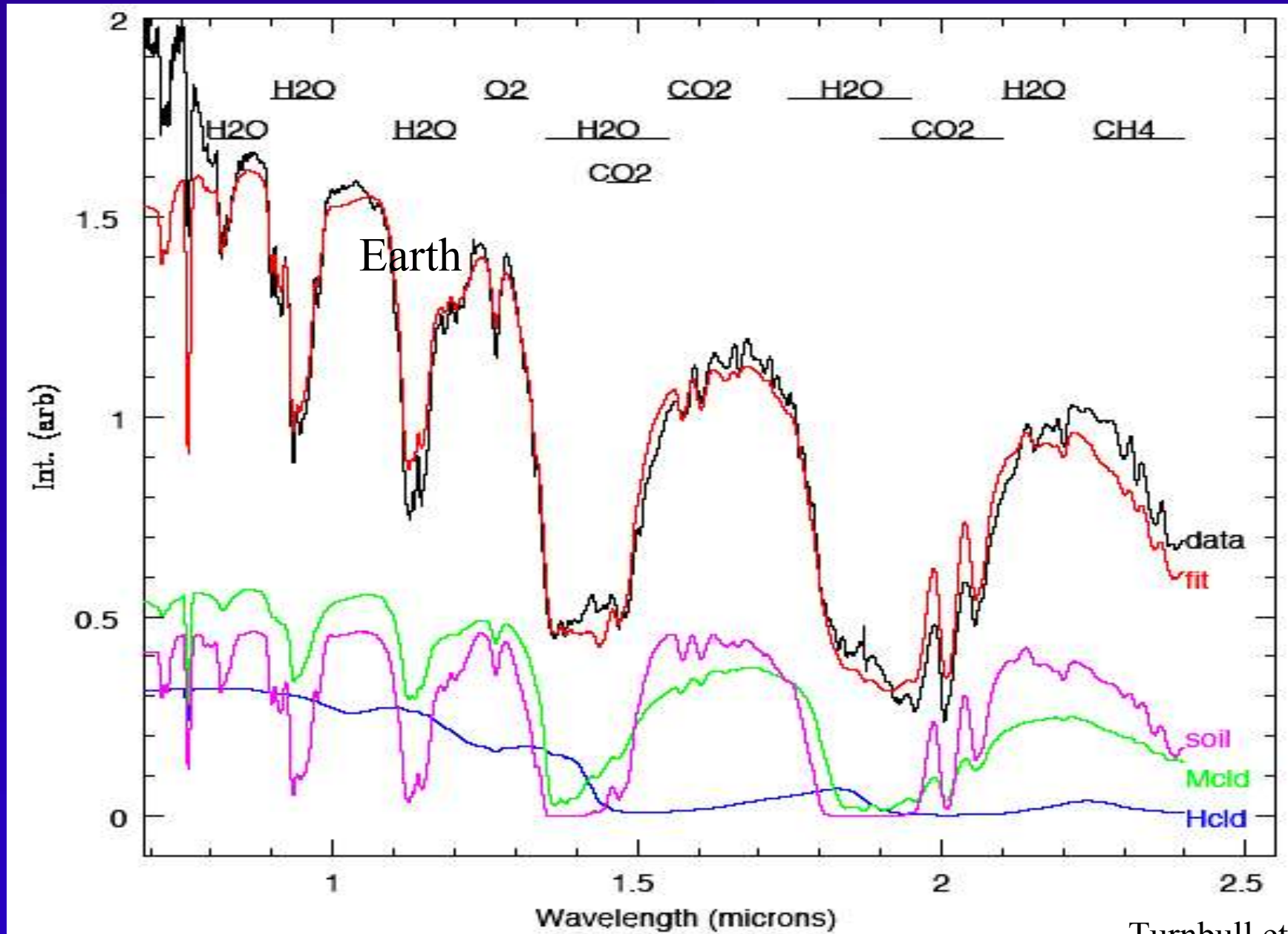


Earth Model with Clouds

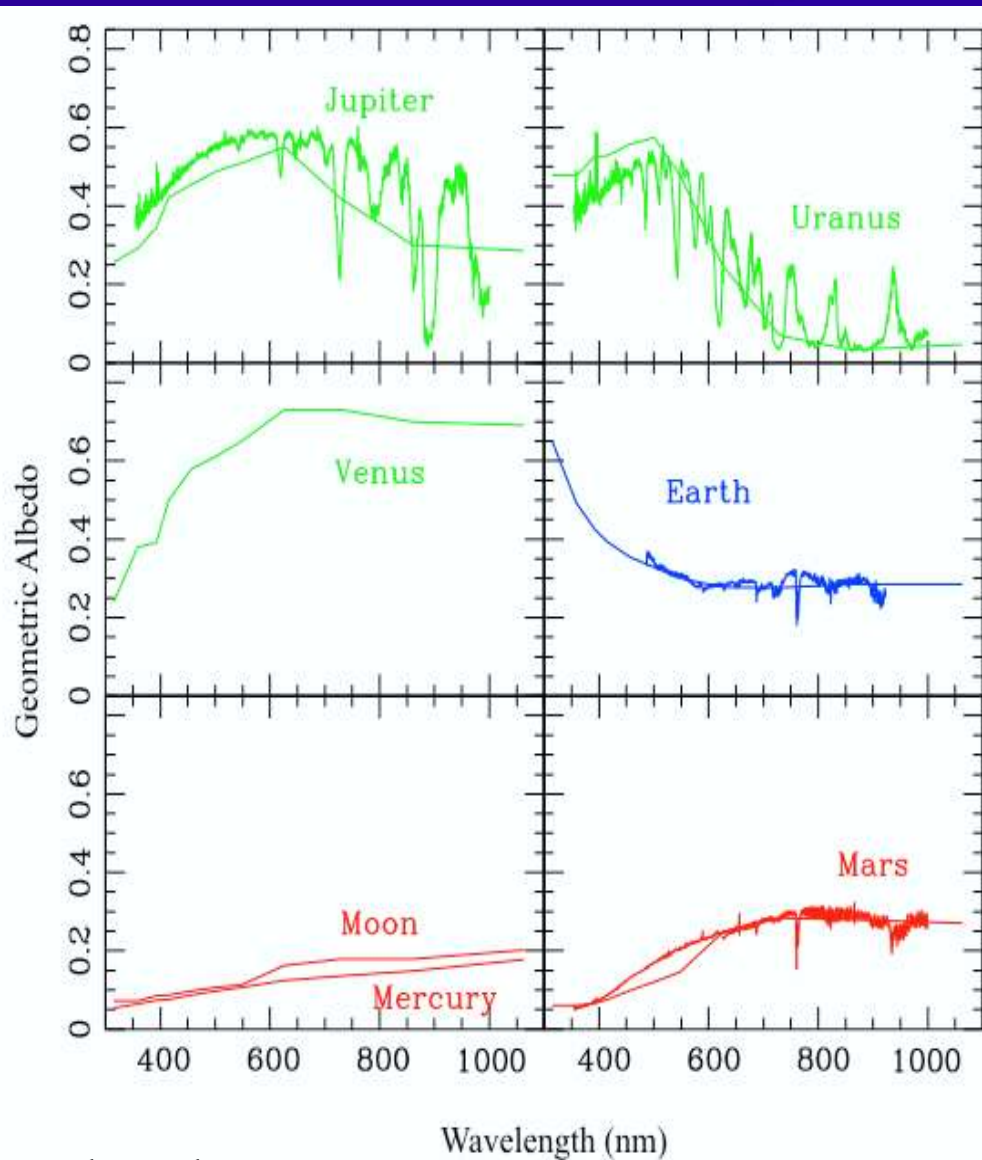
- Clouds increase Earth's albedo
- Clouds reduce Earth's fractional variability due to surface features
- Weather patterns cause additional variability
- Seasonal Effects



IR Spectra & Biomarkers

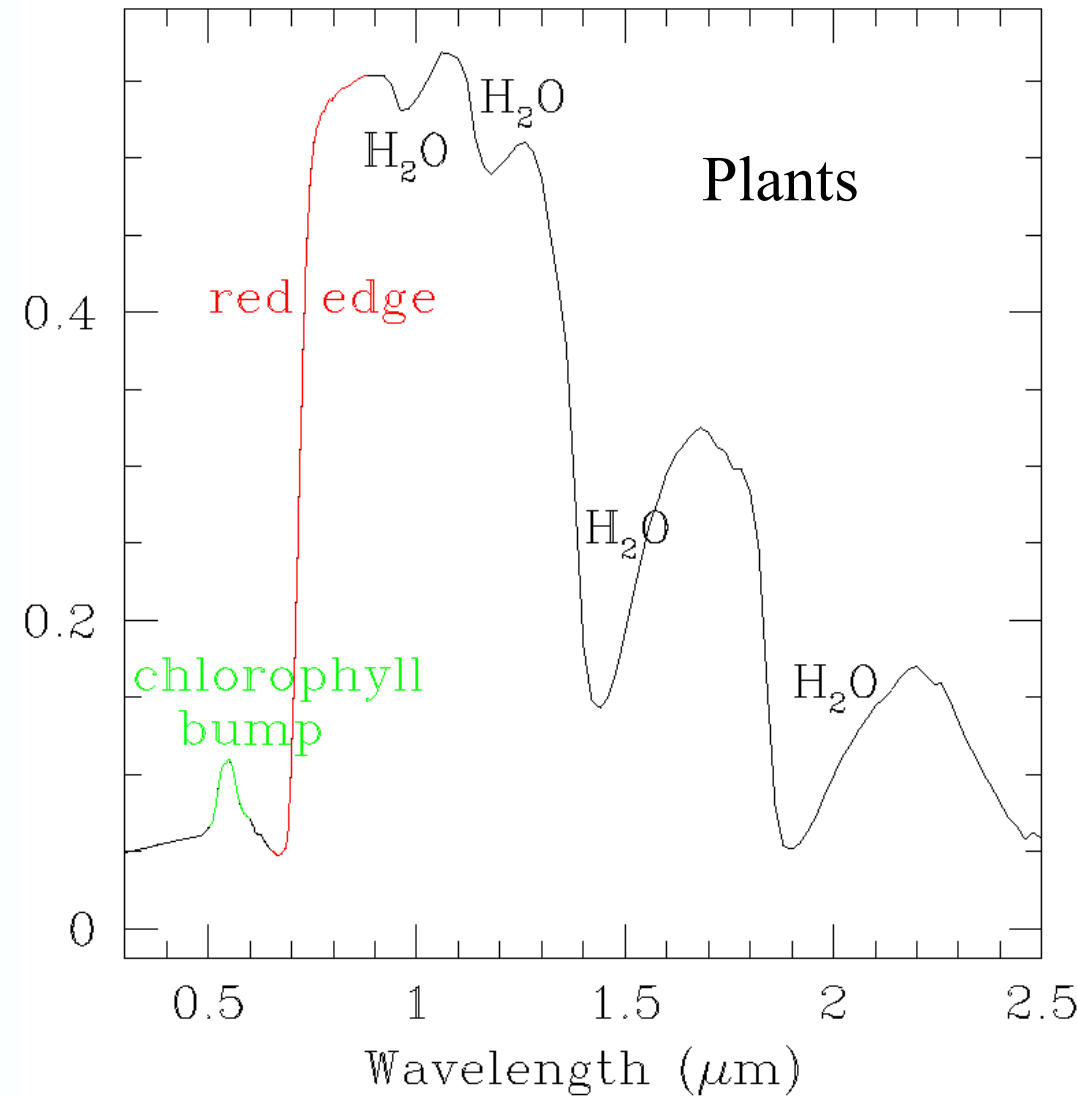
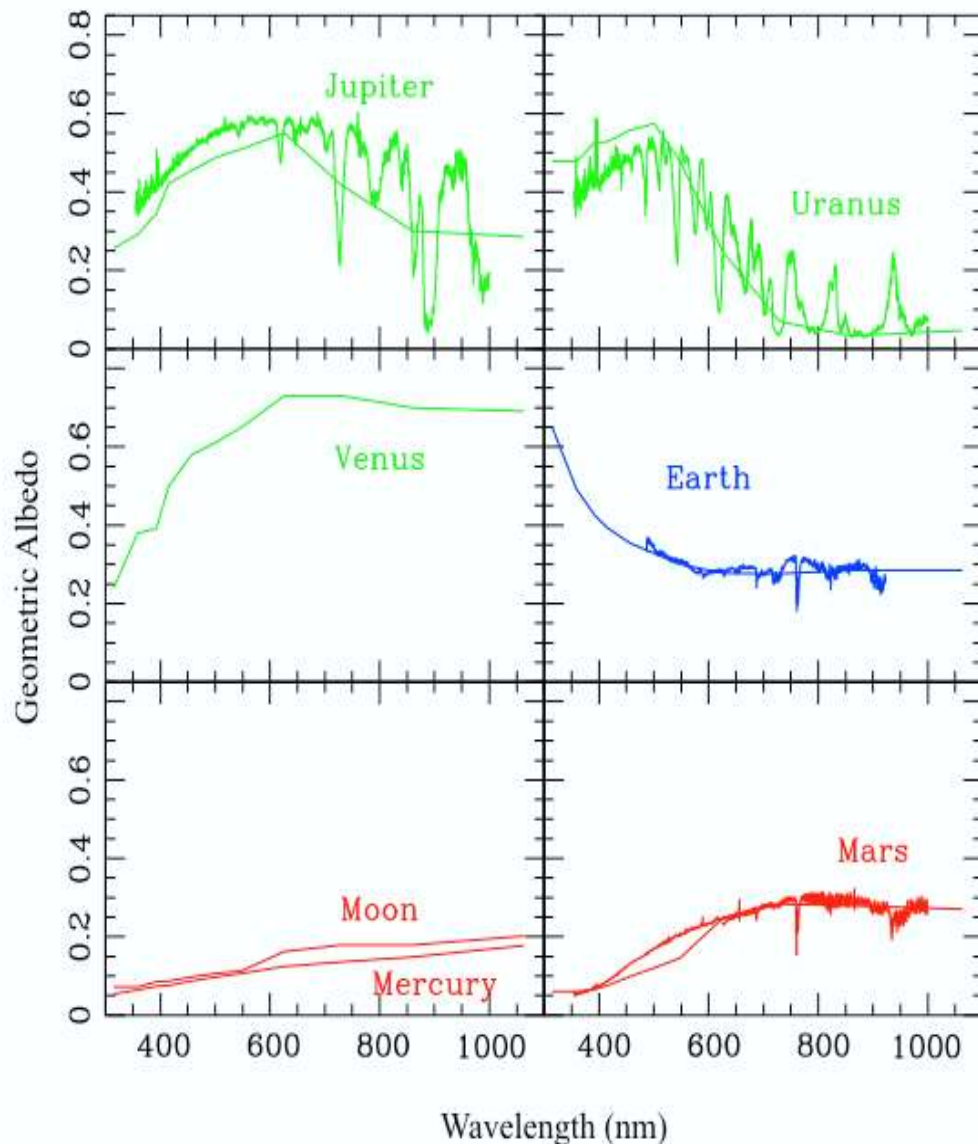


Optical Spectra & Biomarkers



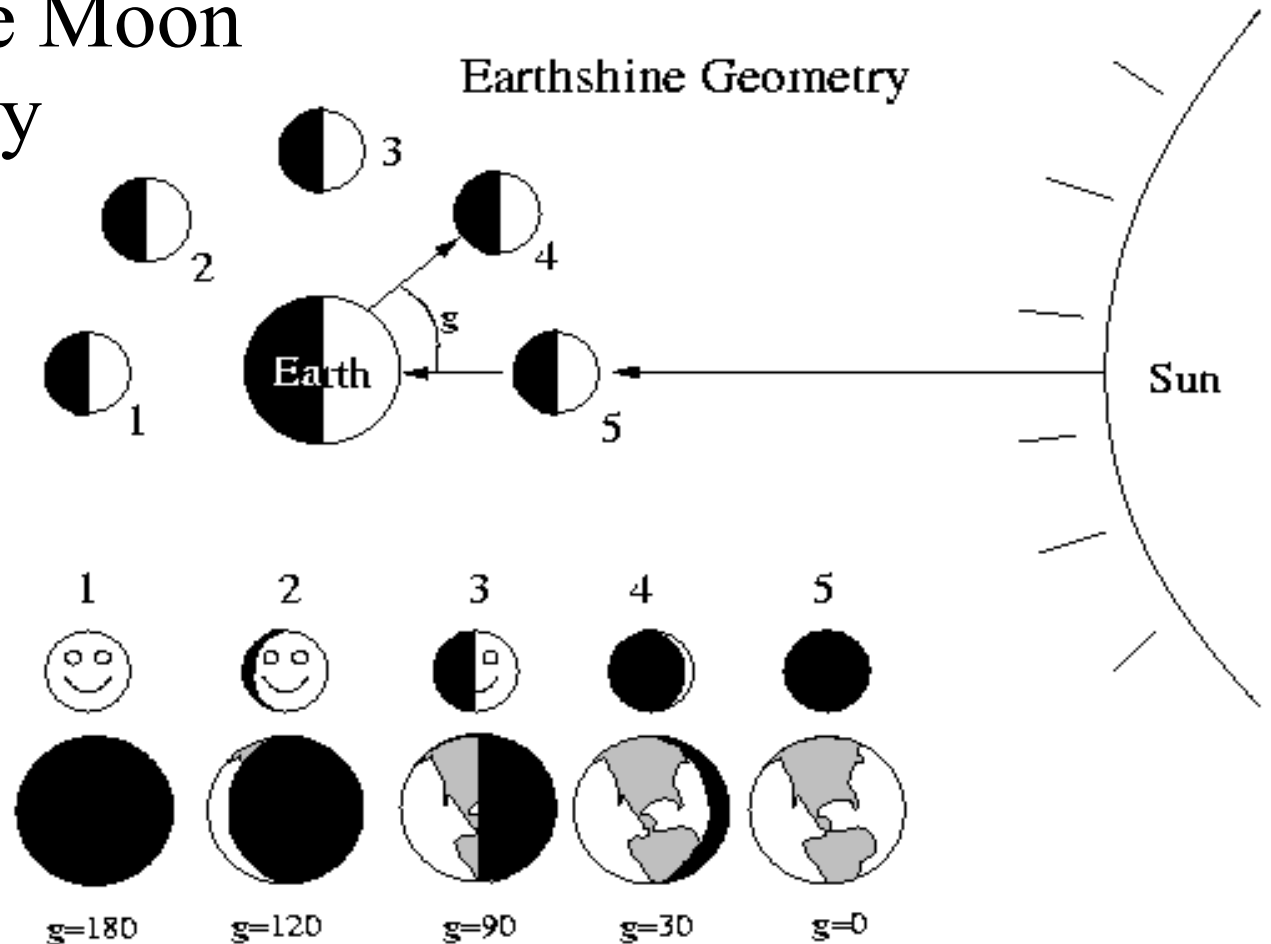
- **Planet mass & radius** (albedo)
- **Atmospheric mass** (Rayleigh)
- **O₂** (760nm A-band)
- **O₃** (580, 320nm)
- **H₂O** (940, 820, 720nm)
- **CO₂** (1050nm, if abundant)
- **CH₄** (890, 790nm, if abundant)
- **Chlorophyll** (~720nm)

Optical Spectra & Biomarkers

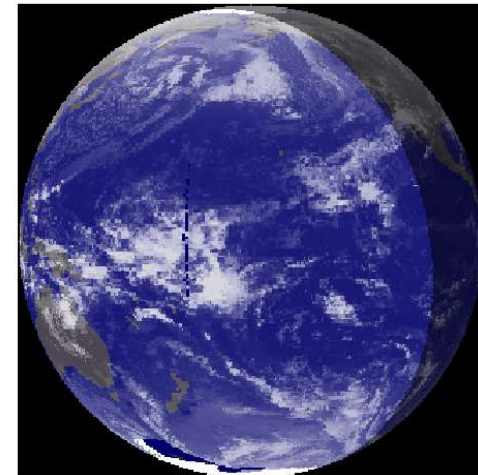
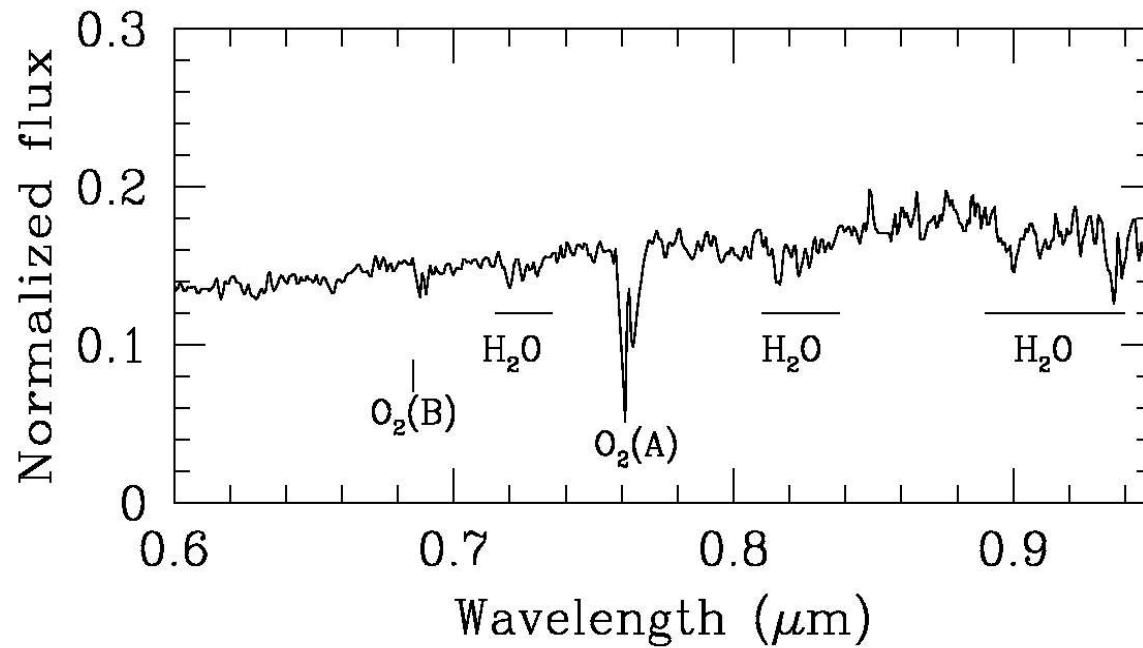
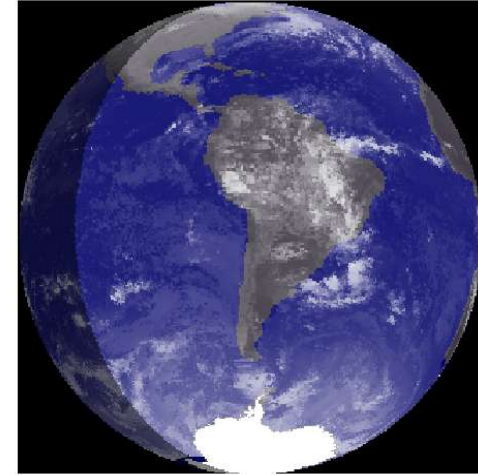
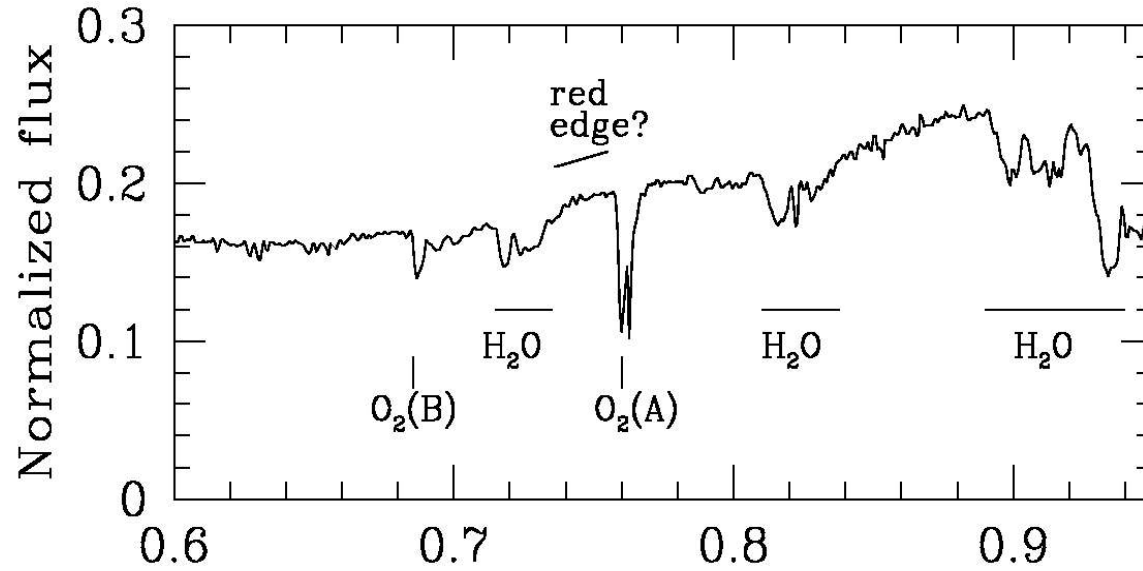


Earthshine Observations

Dark side of the Moon
is illuminated by
Earthshine



Earthshine Spectra



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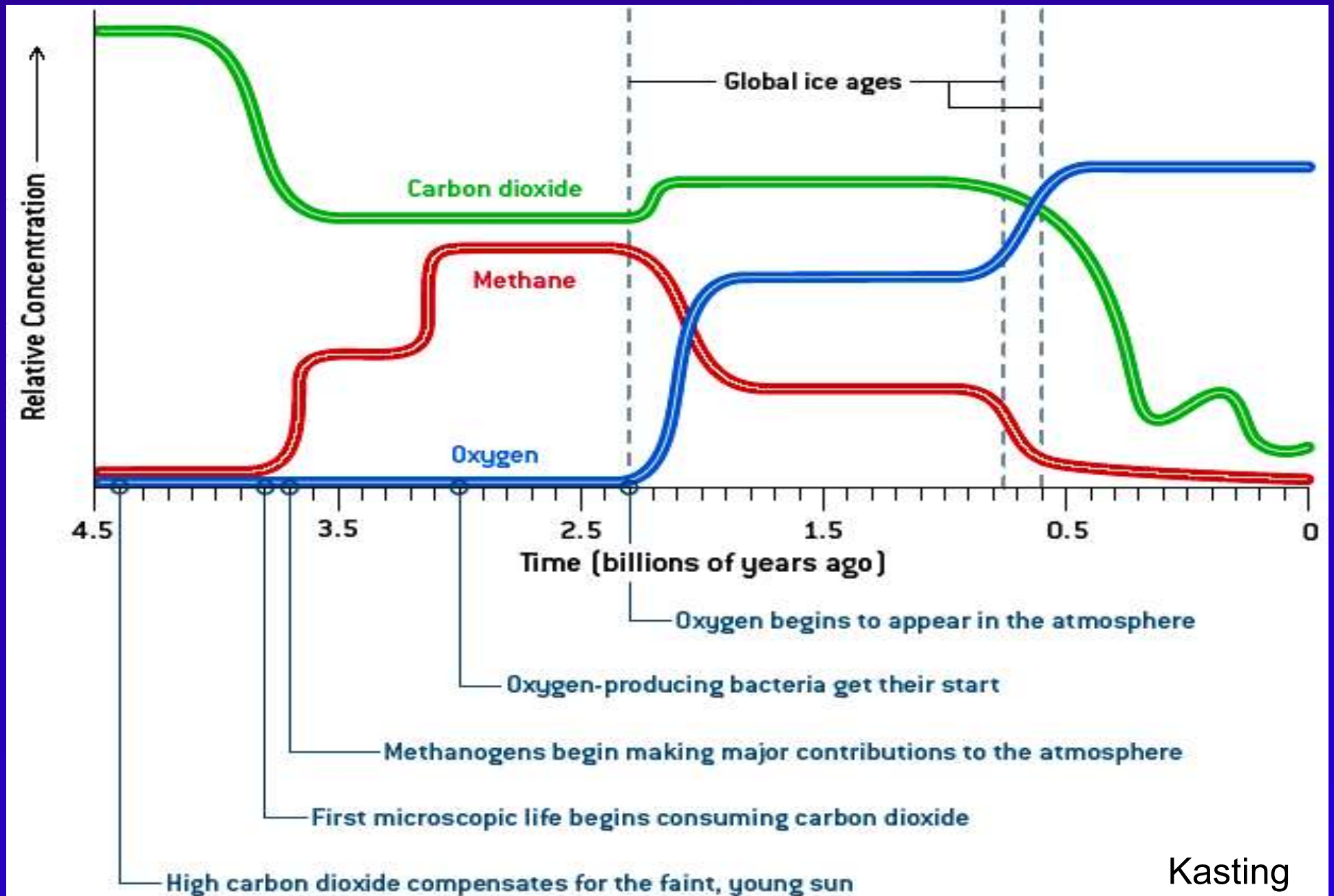
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Diversity of Life

Evolving Earth



Questions?

