

The Strange World We Call Home

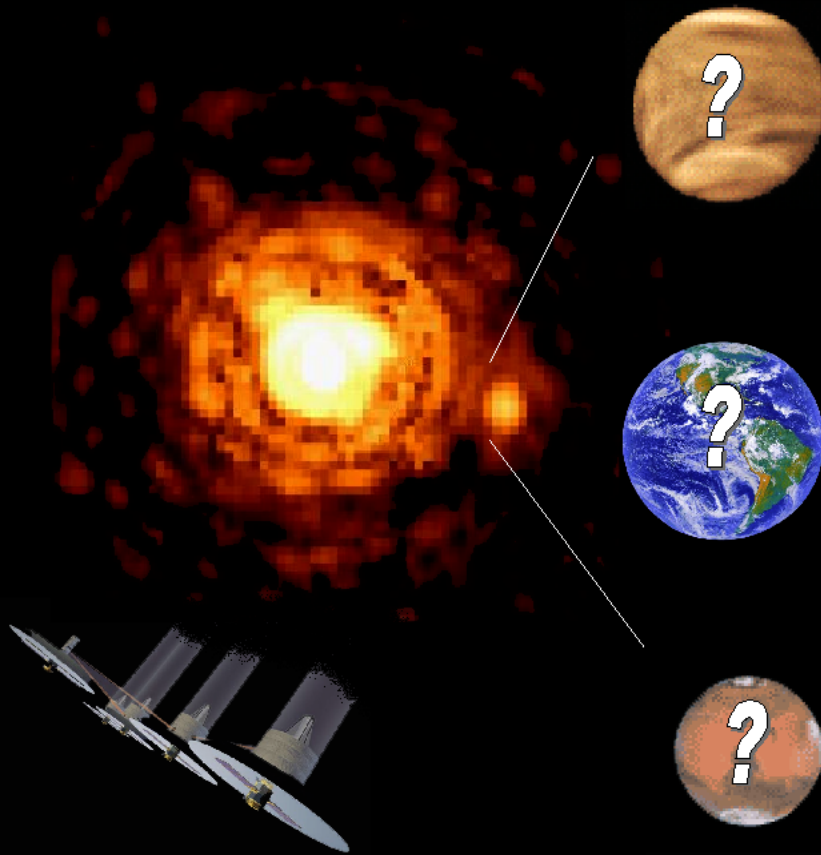
Earth in the Context of an Exoplanet

Tyler D. Robinson^{1,2},
V. S. Meadows^{1,2}, and E. Agol²



¹ NAI Virtual Planetary Laboratory @ the University of Washington

² University of Washington Astronomy Department and Astrobiology Program

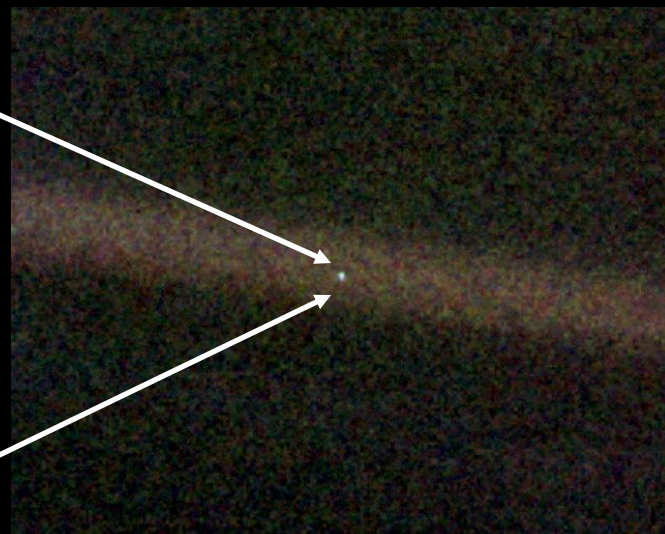
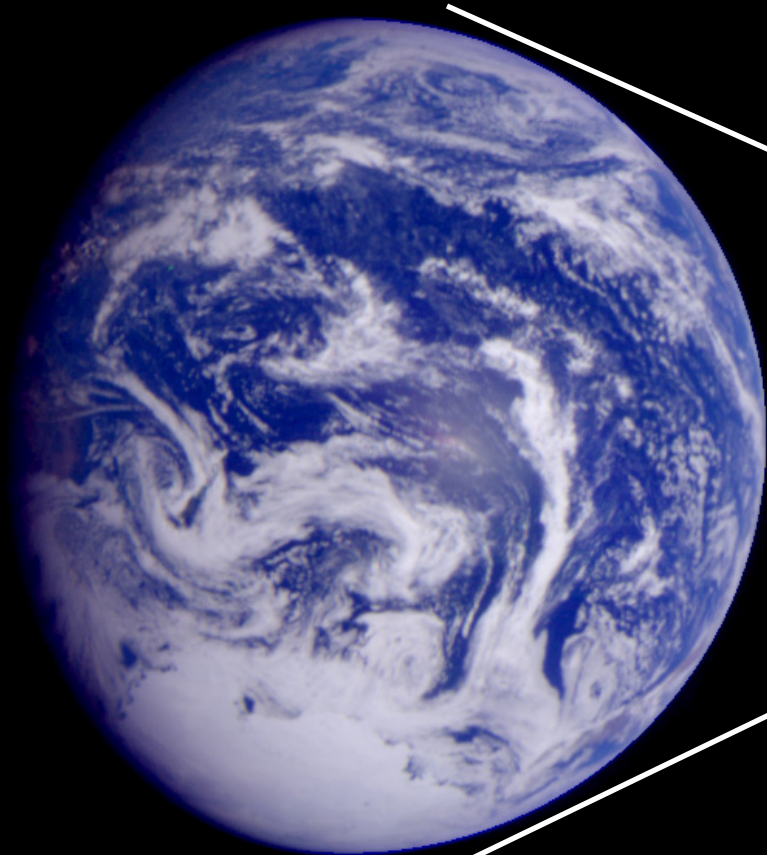


- **Is it habitable?**

- detect surface liquid water
- surface pressure & temperature
 - (see Habitability.06)

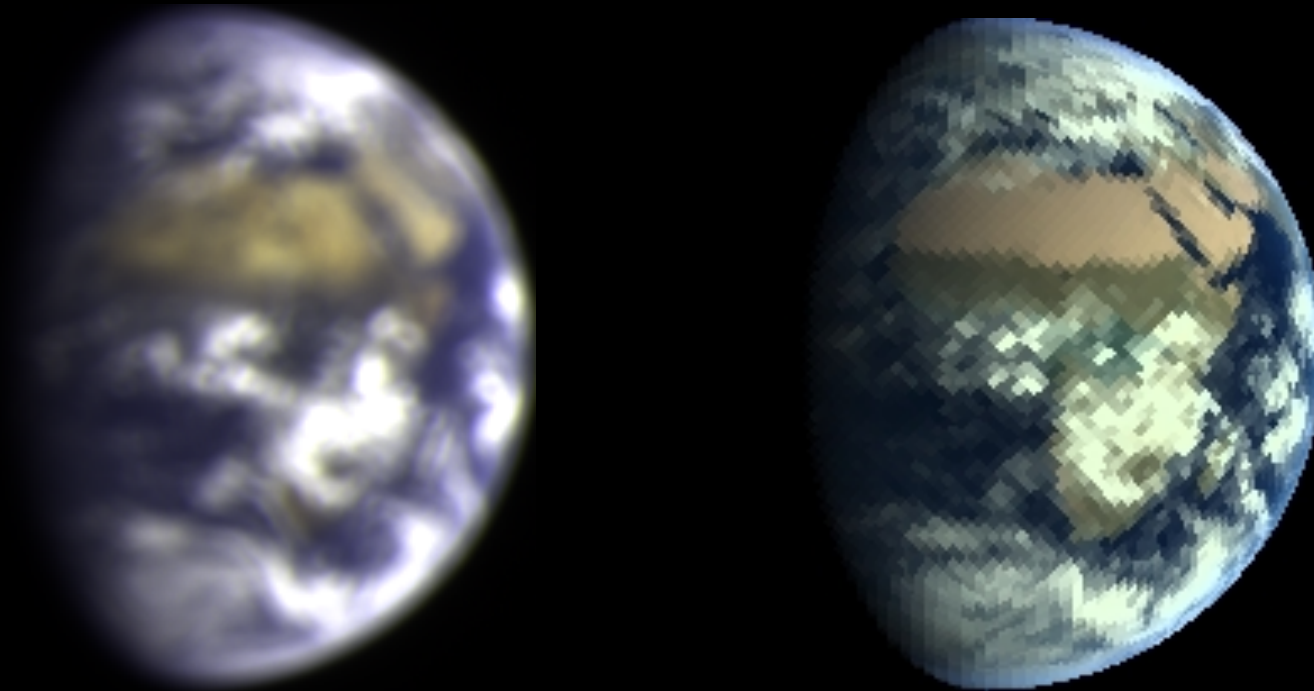
- **Climate stability?**

- presence of large moon



ISS/Voyager 1

Virtual Planetary Laboratory 3-D Spectral Earth Model*



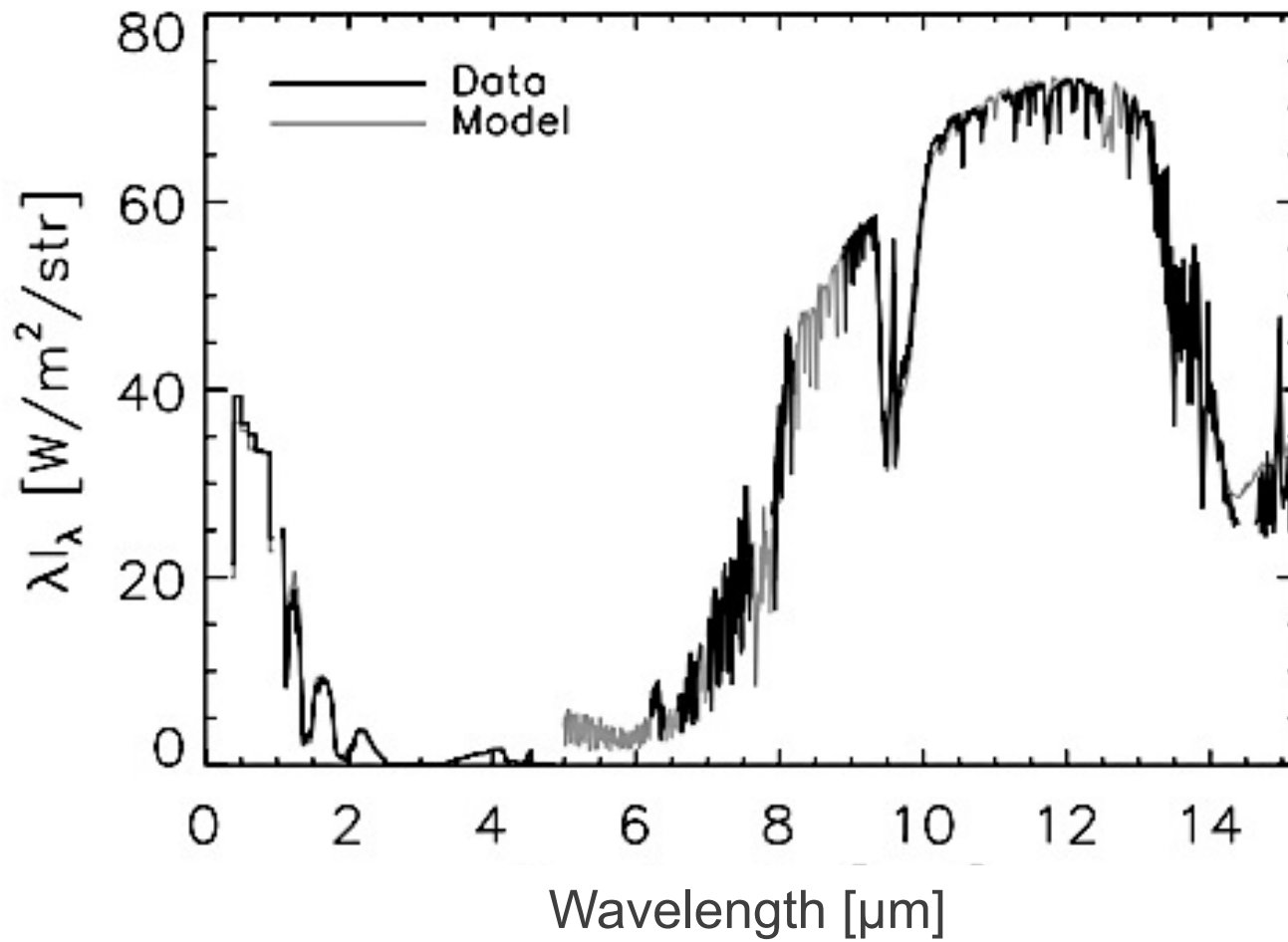
The model:

- produces spatially and temporally resolved spectra of Earth
- includes absorption, emission and scattering from atmosphere, clouds and surface

*Tinetti *et al.* (2006); Robinson *et al.* (in press)

Image Credit (left): NASA/EPOXI

VPL Earth Model Validation

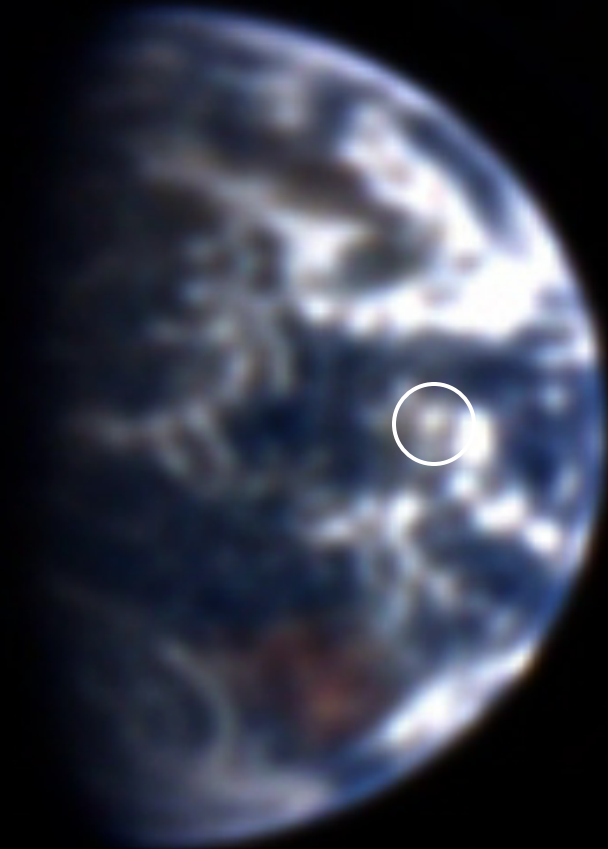


see Robinson et al. (in press)



Image Credit NASA

“... that the surface of the seas would appear darker, and that of the land brighter.” Galileo Galilei (1632)



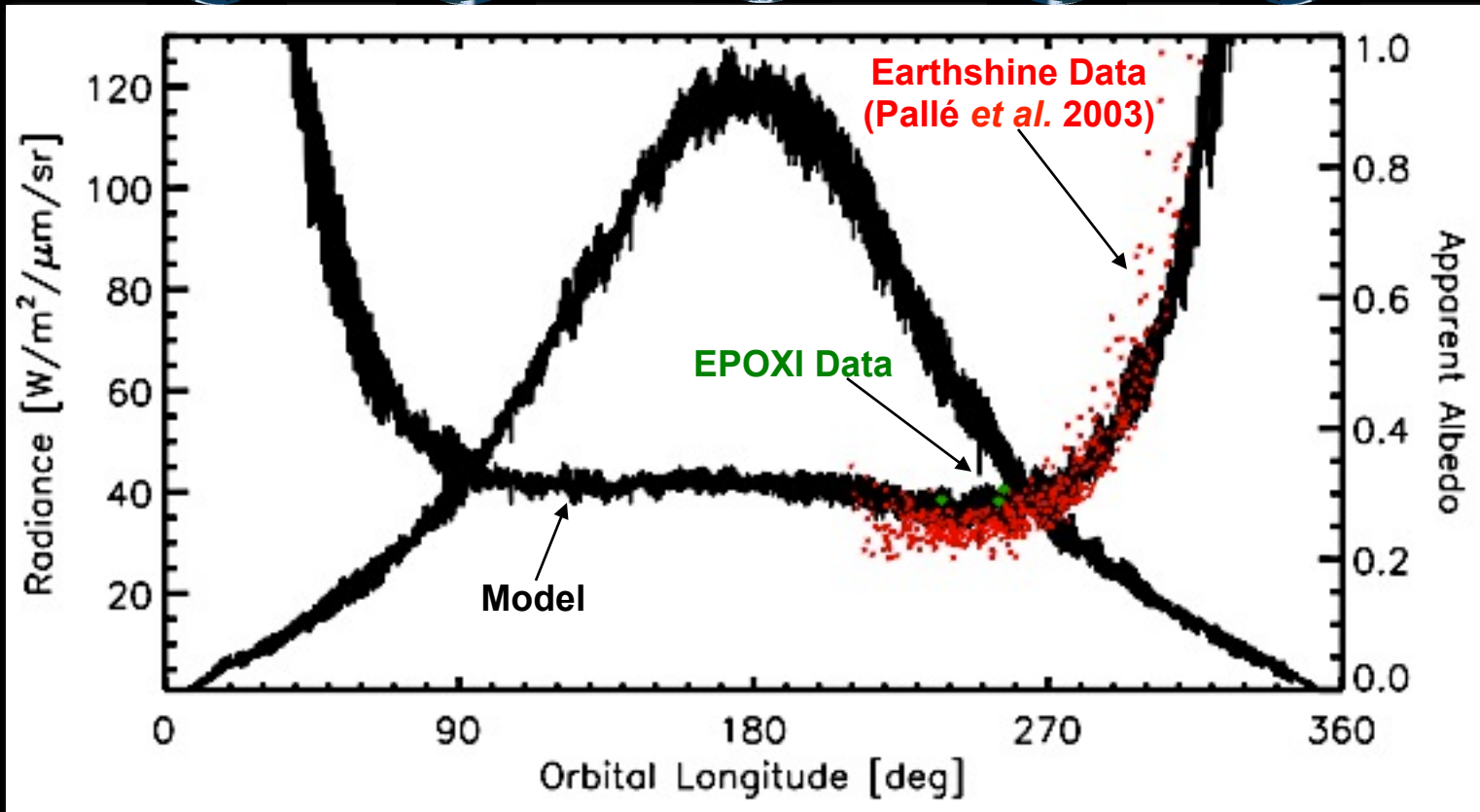
NASA/EPOXI



NASA/Messenger

$i = 90^\circ$ (edge on)
 $\lambda = 400\text{-}700\text{ nm}$
 $\Delta t = 4\text{ hrs}$

Earth Through a Year



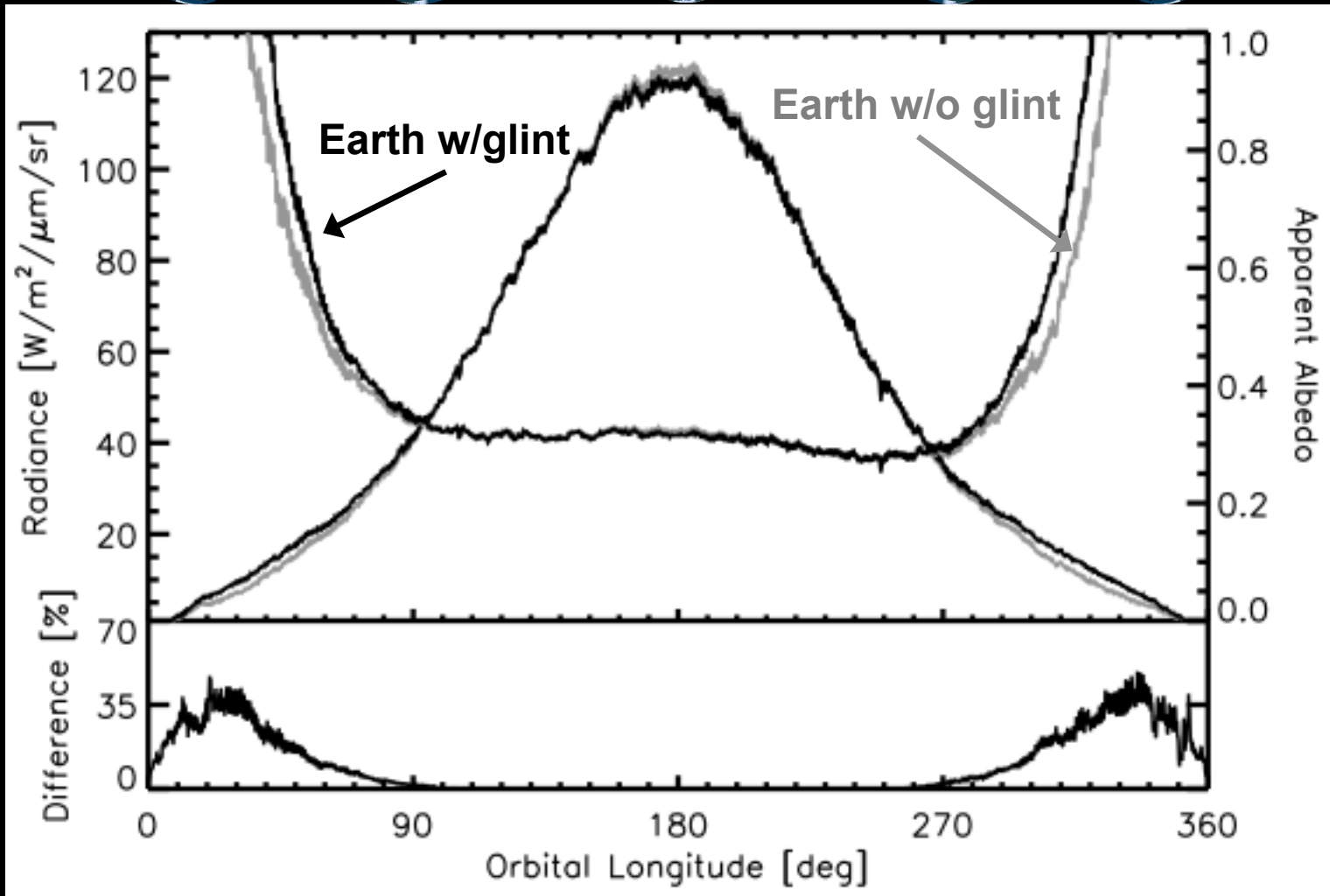
see Robinson, Meadows, & Crisp (2010)

Earthshine data courtesy E. Pallé

Earth images from <http://www.fourmilab.ch/earthview/>, see Walker (1994)

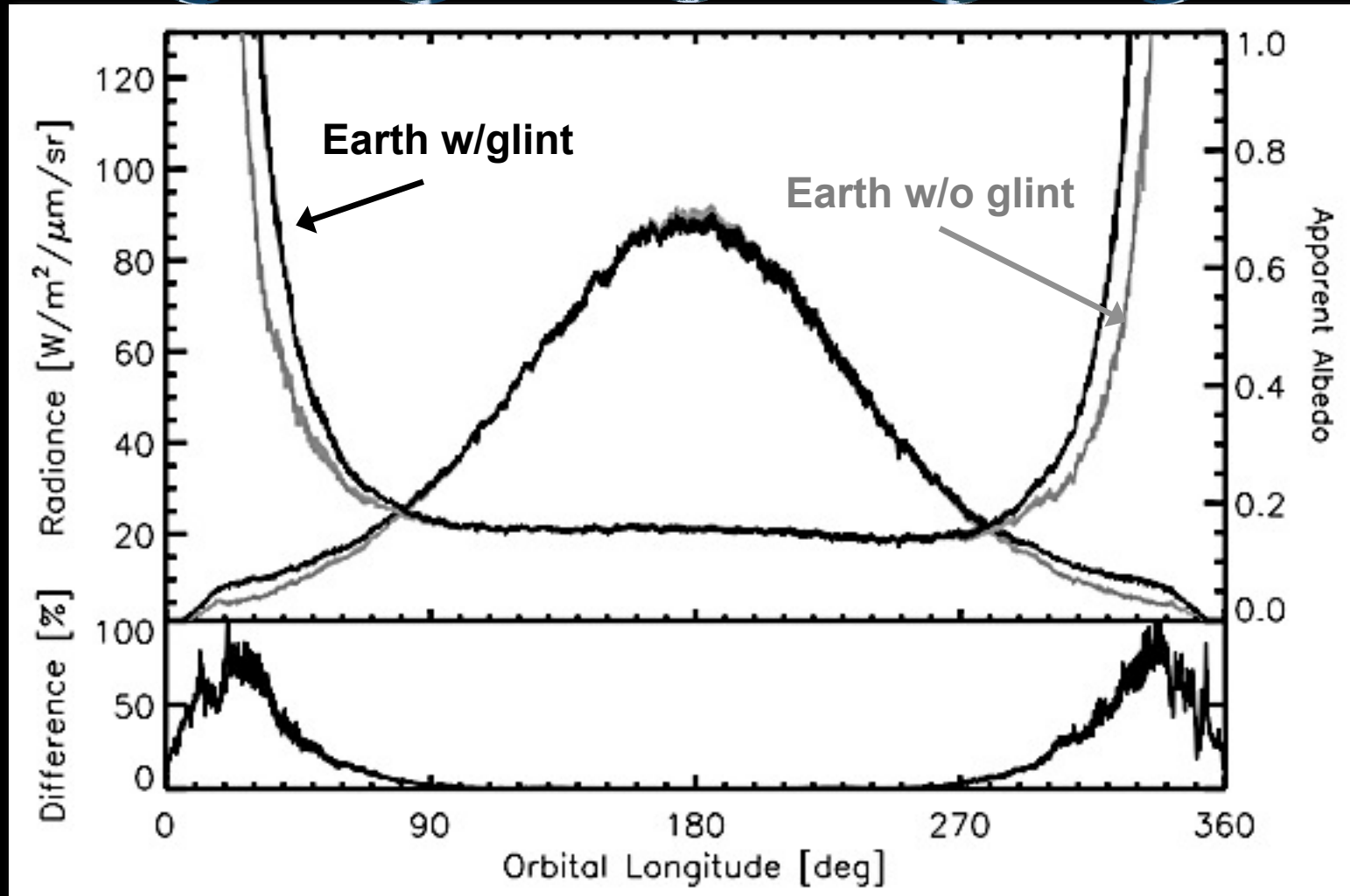
$i = 90^\circ$ (edge on)
= 400-700 nm
 $\Delta t = 4$ hrs

Earth with and without Glint I

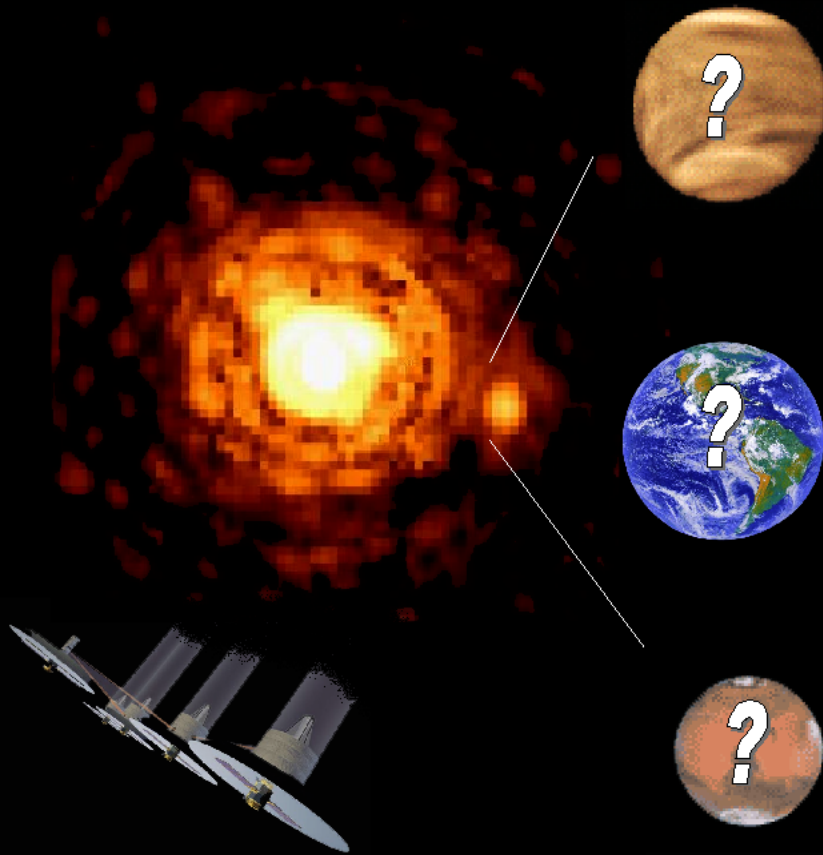


$i = 90^\circ$ (edge on)
 $\lambda = 600\text{-}800\text{ nm}$
 $\Delta t = 4\text{ hrs}$

Earth with and without Glint II



see Robinson, Meadows, & Crisp (2010)

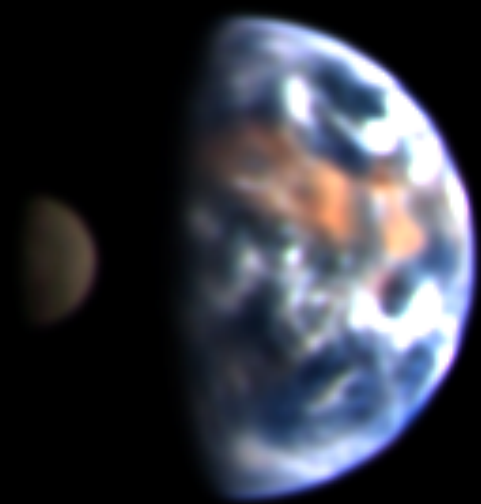


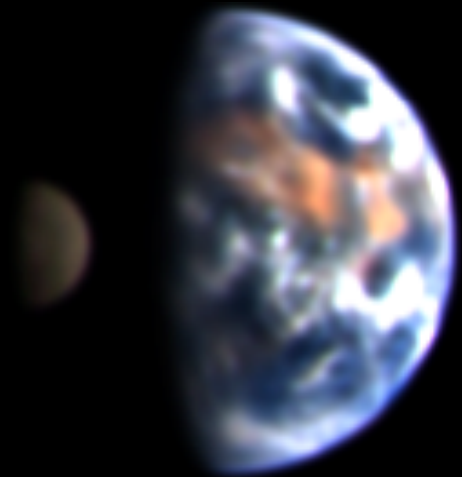
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- surface liquid water
- surface pressure & temperature
 - (see Habitability.06)

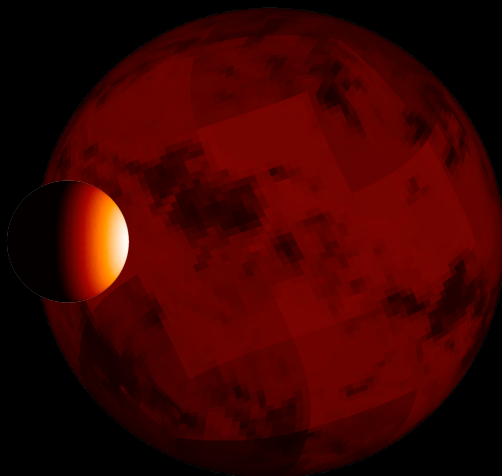
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- presence of large moon

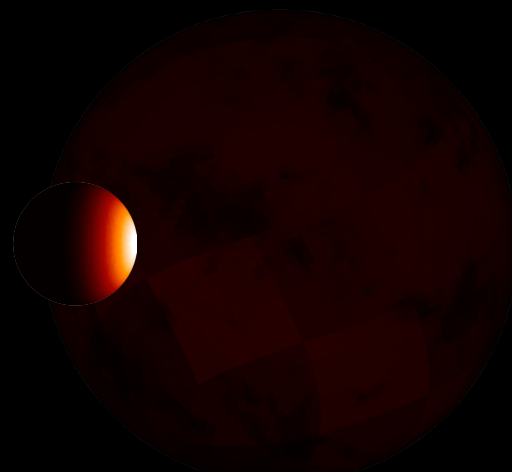




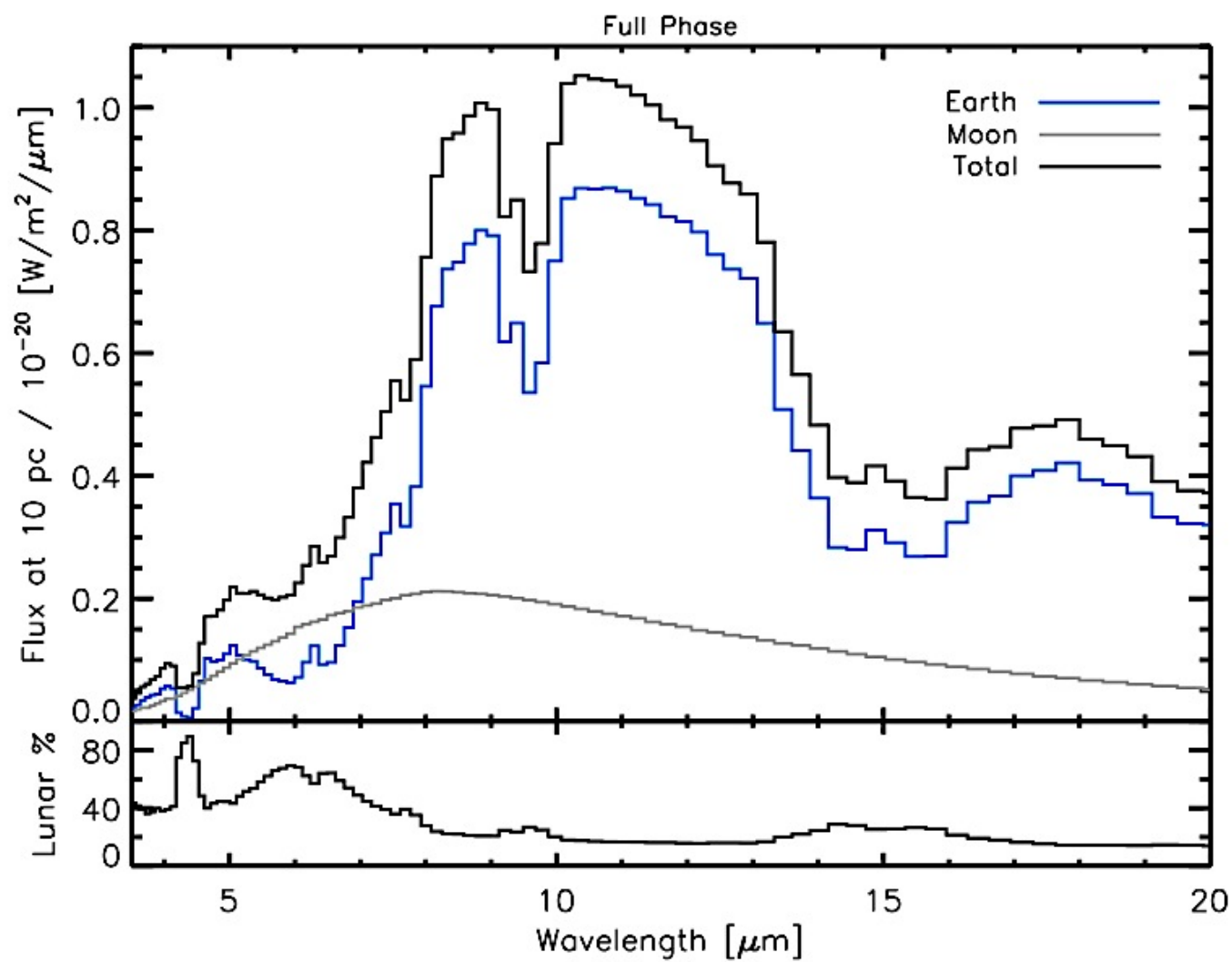
visible



10 μm
(window)



4.3 μm
(CO₂ band)



from Robinson (submitted)

Conclusions

- **Habitability can be established by:**
 - direct observation of surface liquid water via glint
 - direct observation of surface temperature and pressure
 - see Habitability.06 (Meadows & Robinson)
- **Detecting exoMoons:**
 - companions affect observations of host
 - phase-dependent variability can indicate the presence of a moon

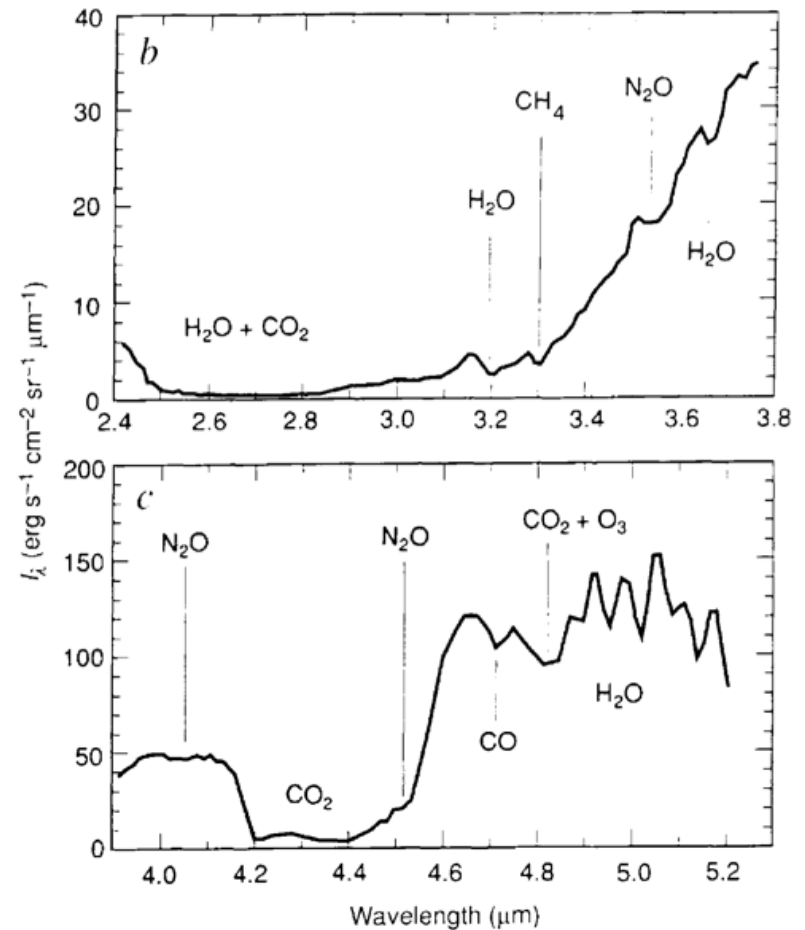
The End

A search for life on Earth from the Galileo spacecraft

Carl Sagan¹, W. Reid Thompson², Robert Carlson³, Donald Gurnett²
& Charles Hord⁵

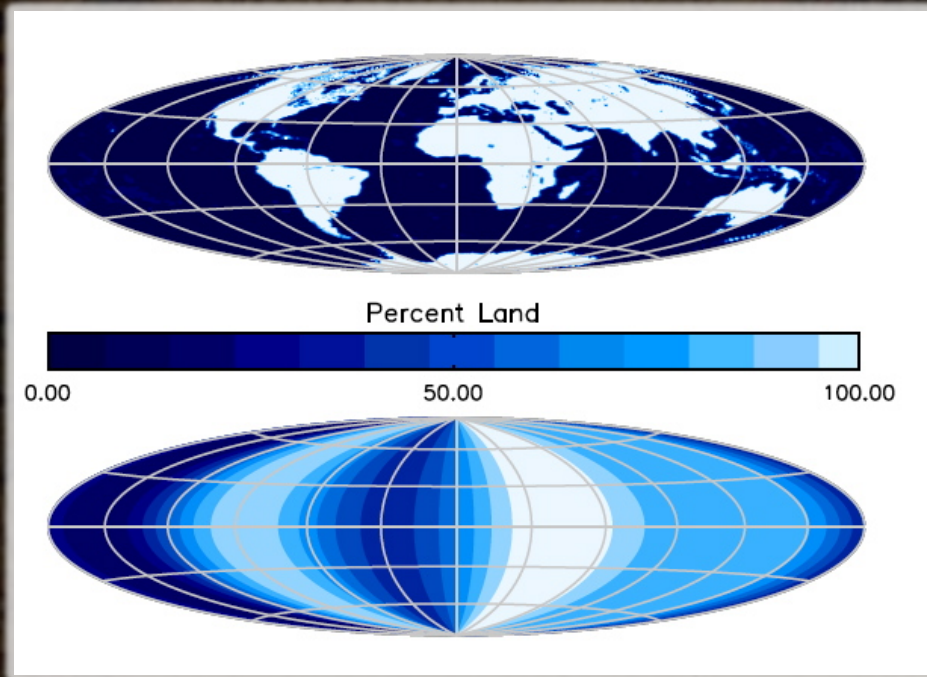


SSI/Galileo

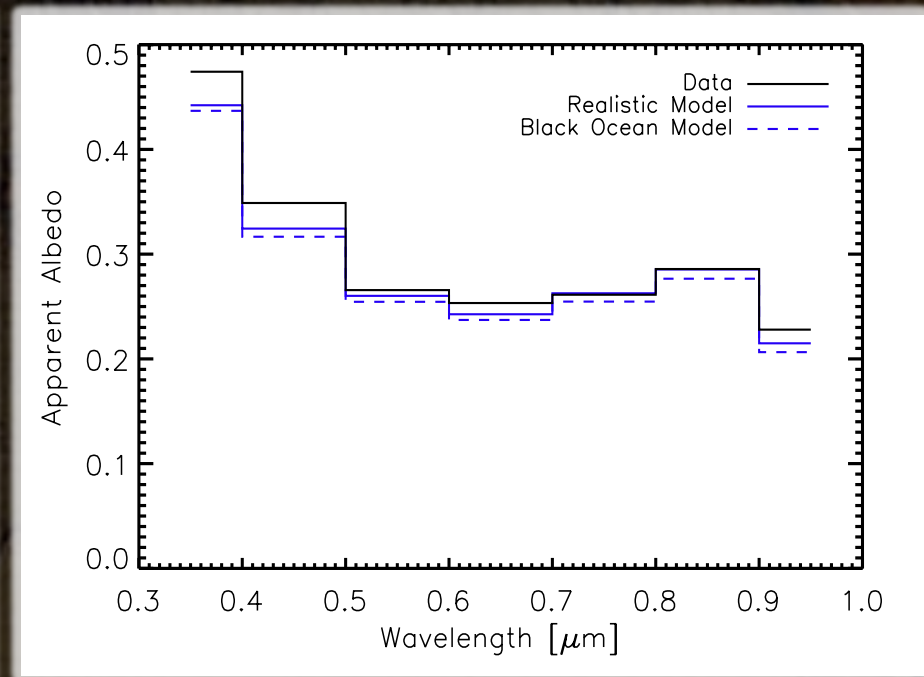


NIMS/Galileo

EPOXI Lightcurve Principle Component Analysis

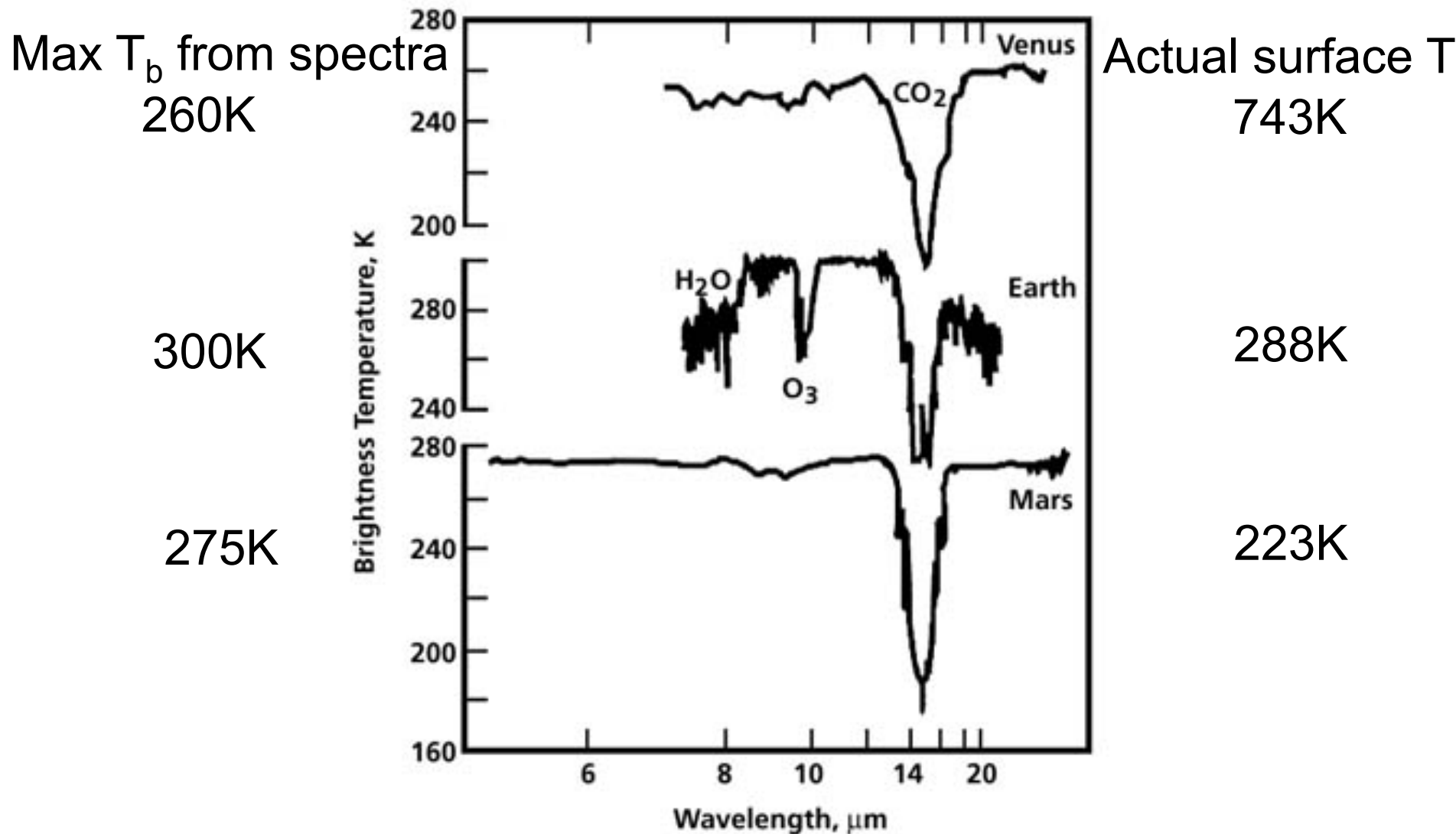


from Cowan *et al.* (2009)

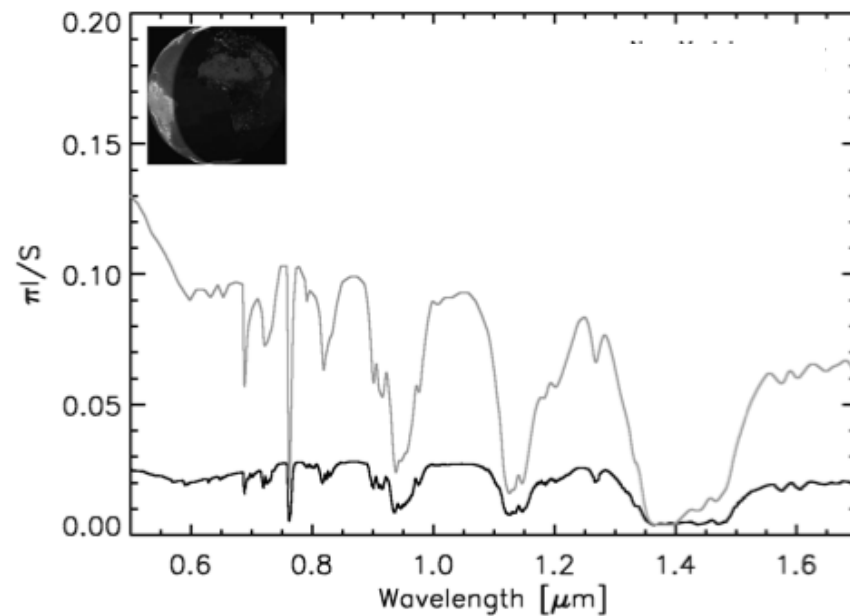
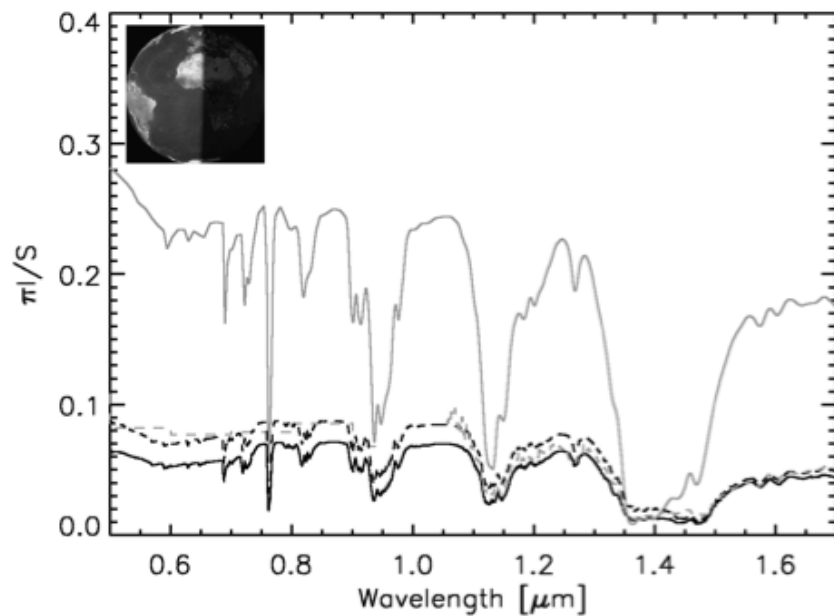
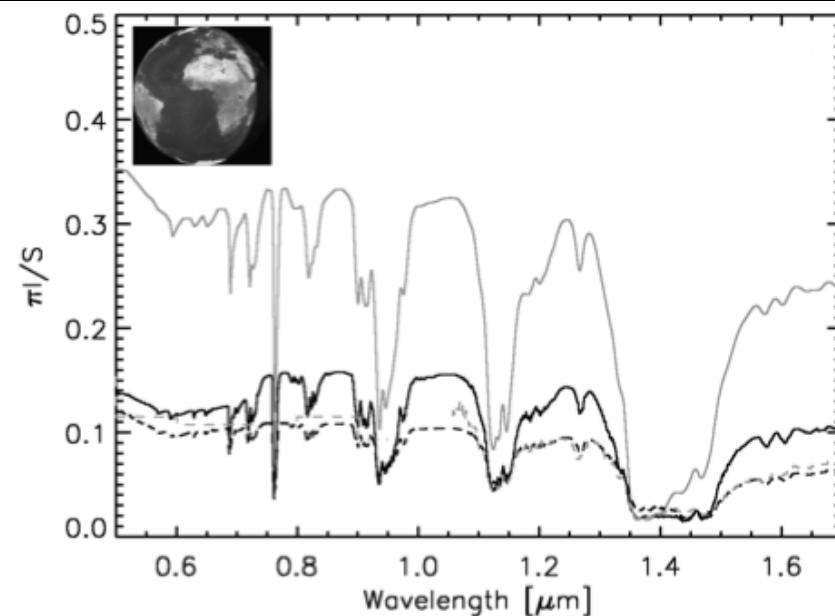
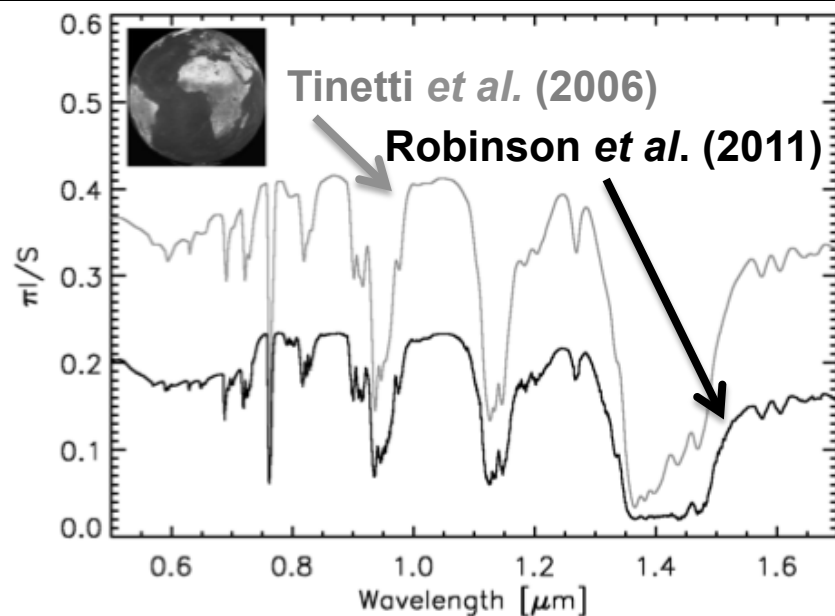


see Cowan, Robinson *et al.* (2011)

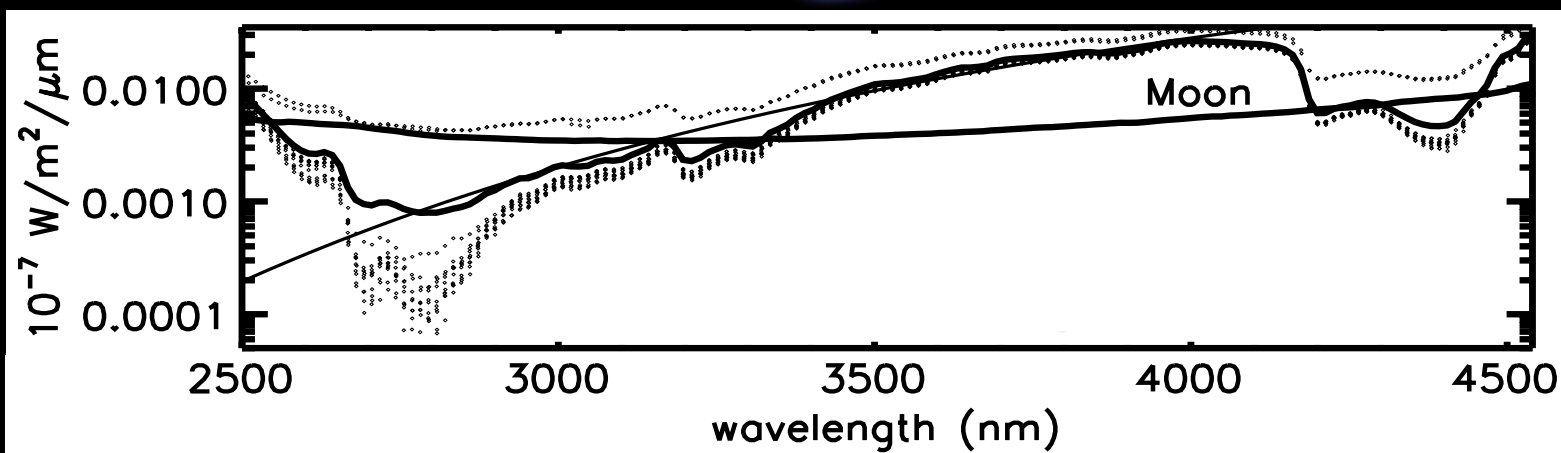
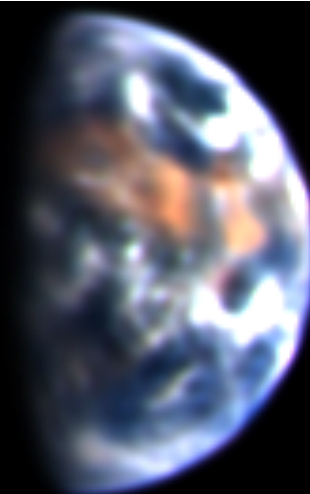
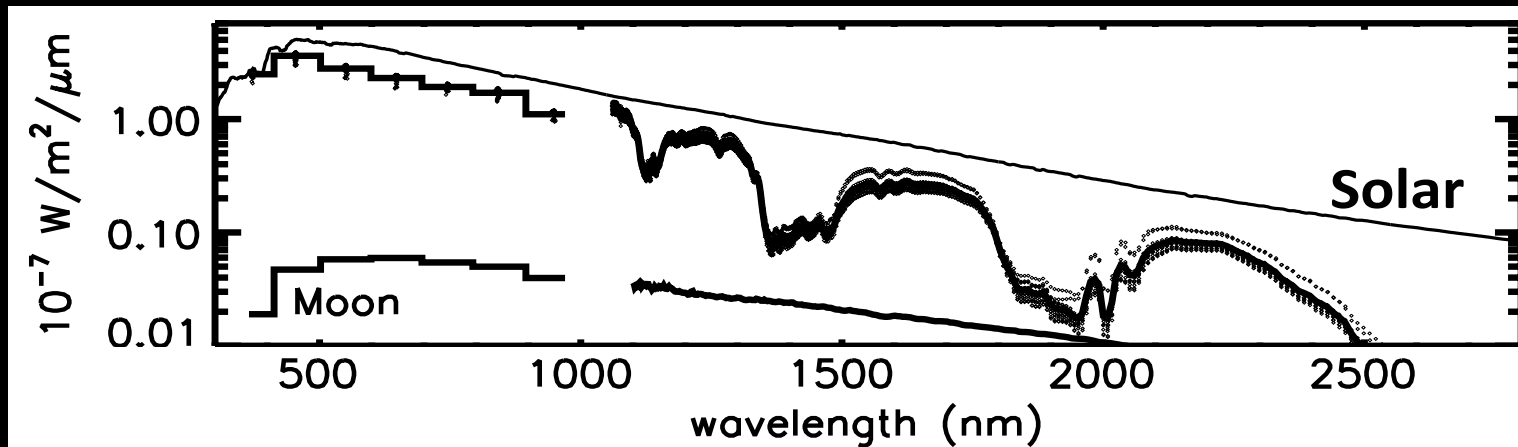
Brightness vs. Surface Temperatures

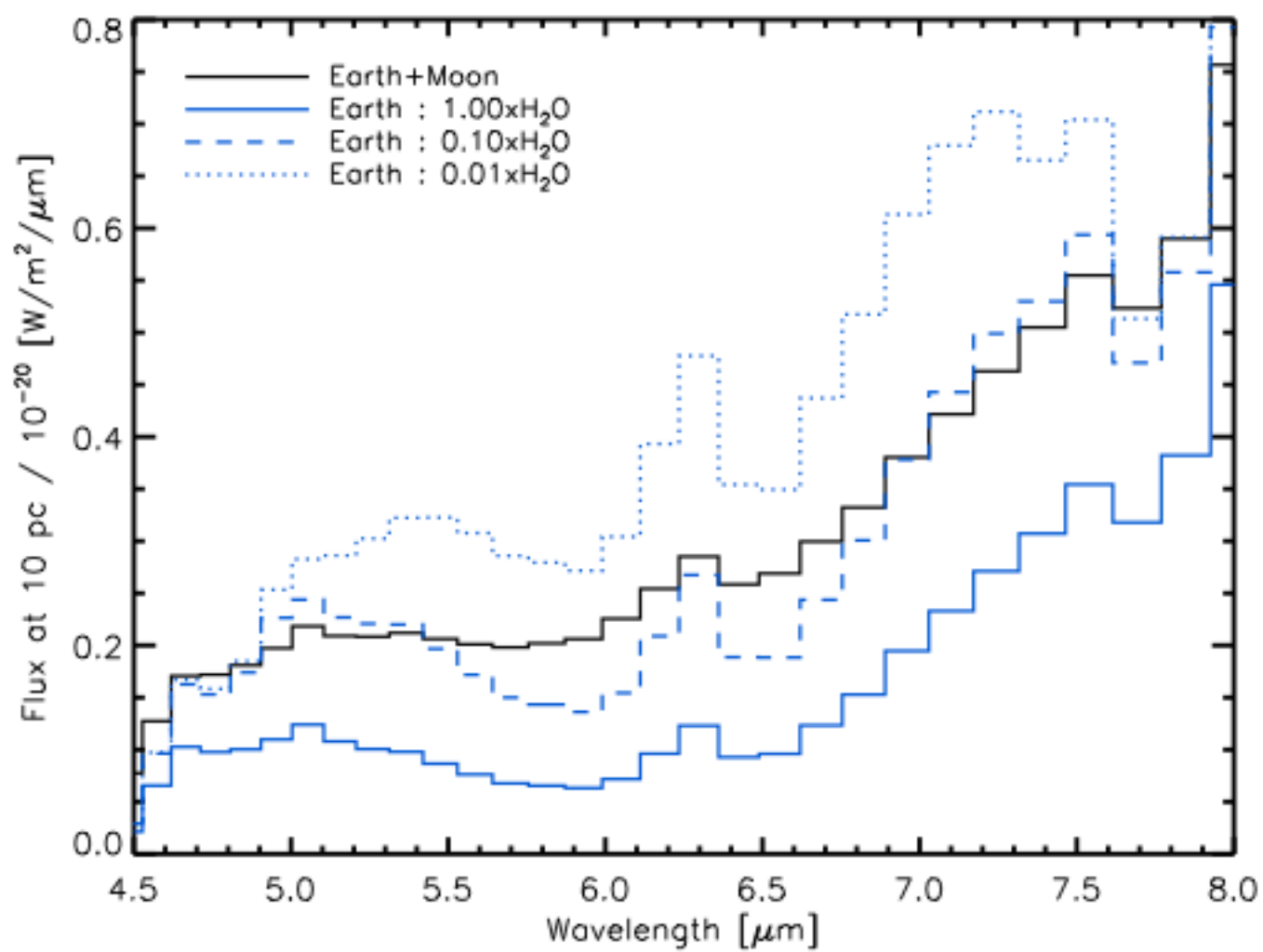


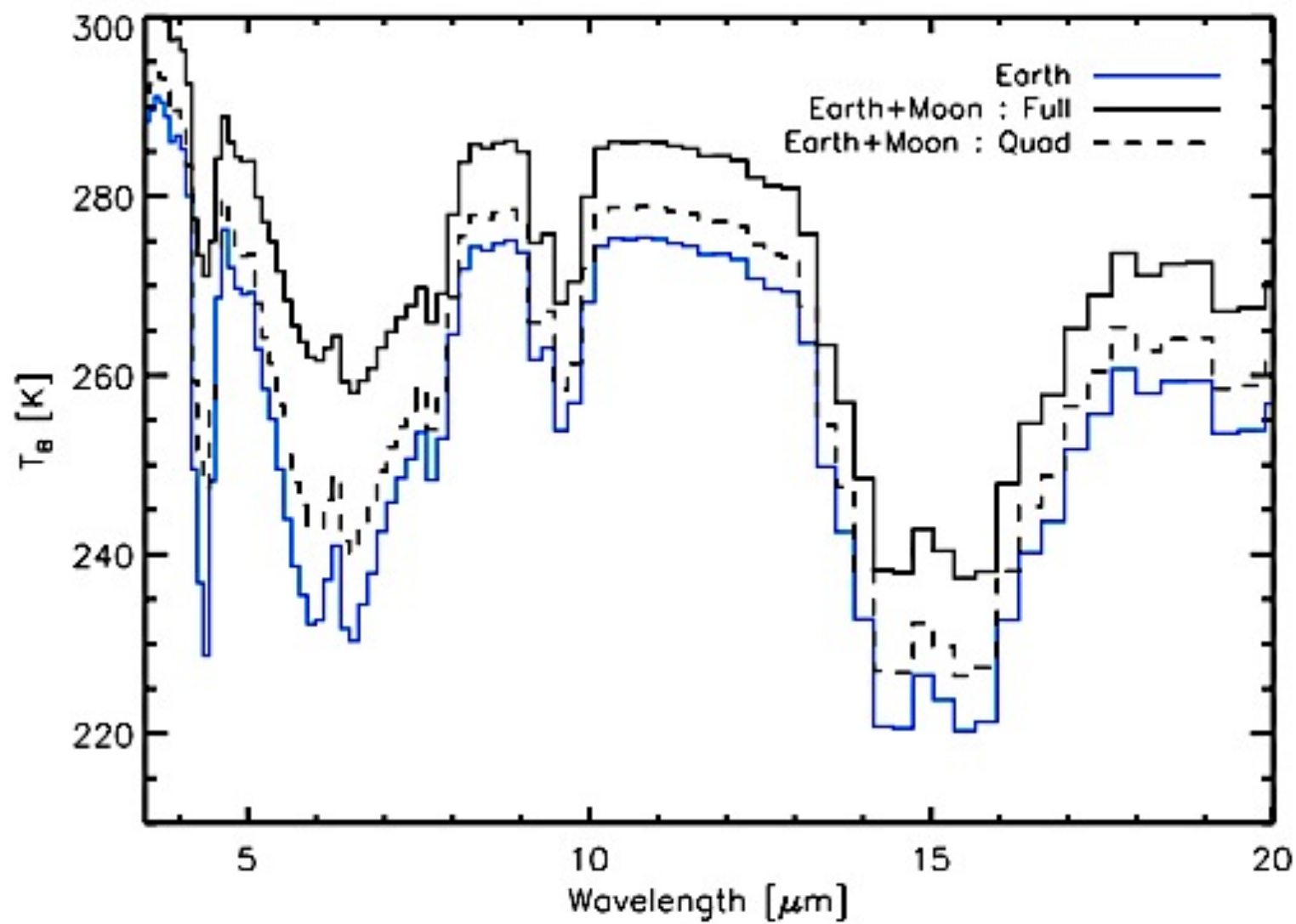
Venus from Venera 15 (Moroz et al. 1986); Earth from Nimbus 4 (Hanel et al., 1972c)
Mars from Mariner 9, (Hanel et al., 1972a)

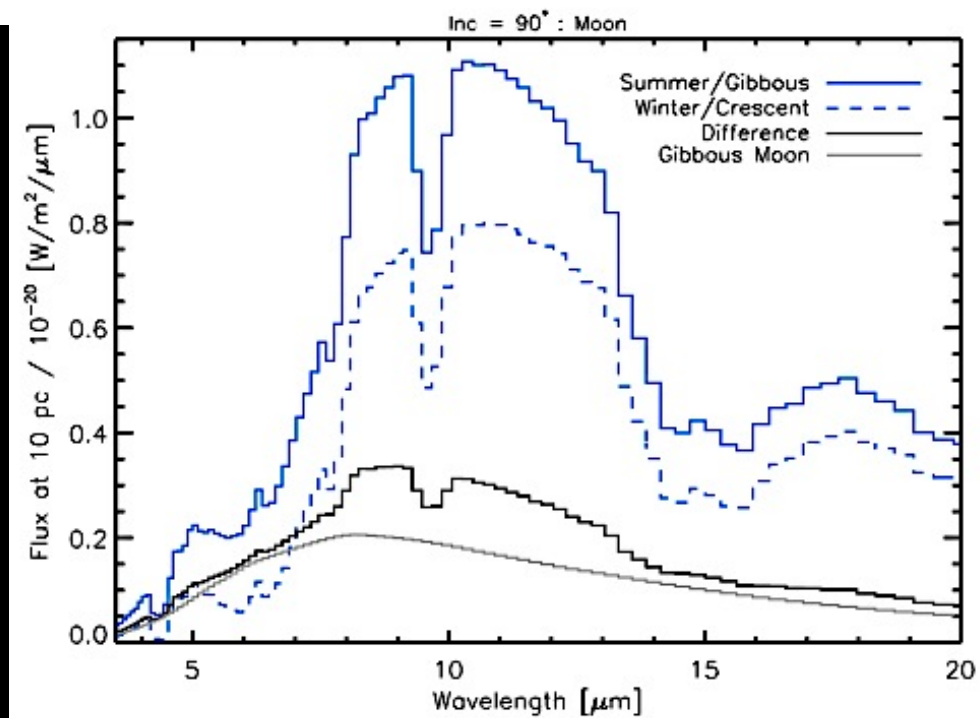
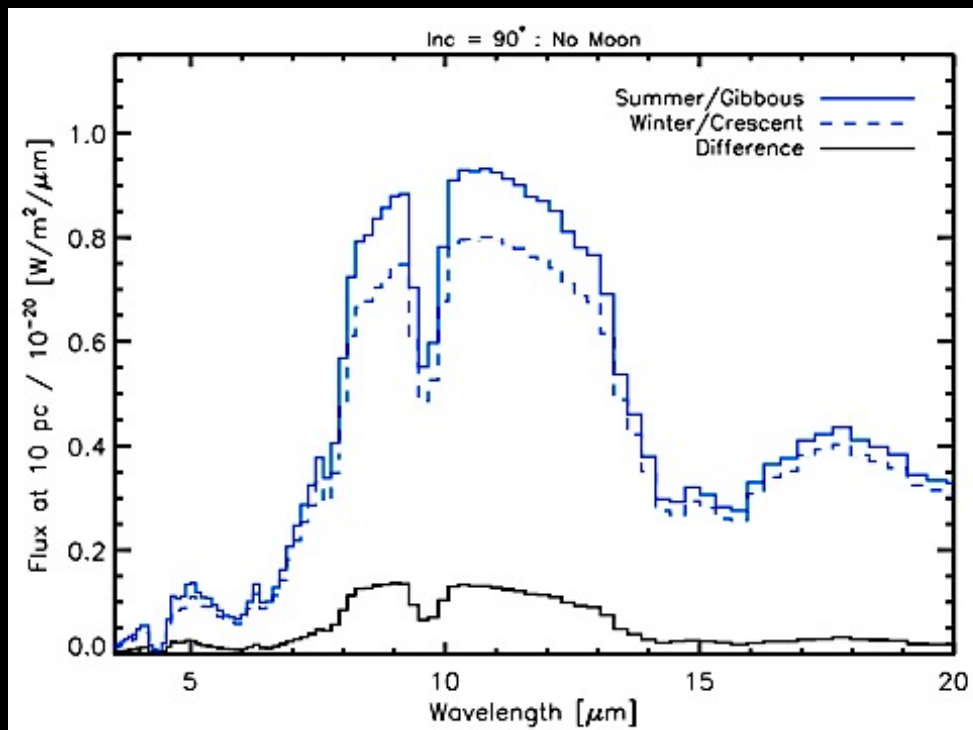


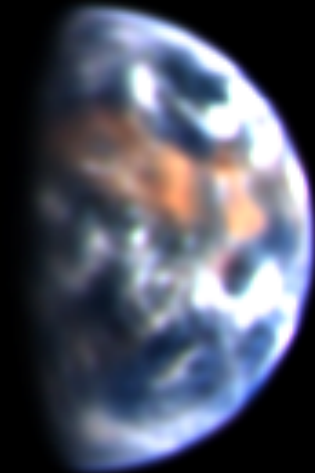
from Robinson *et al.* (2011)



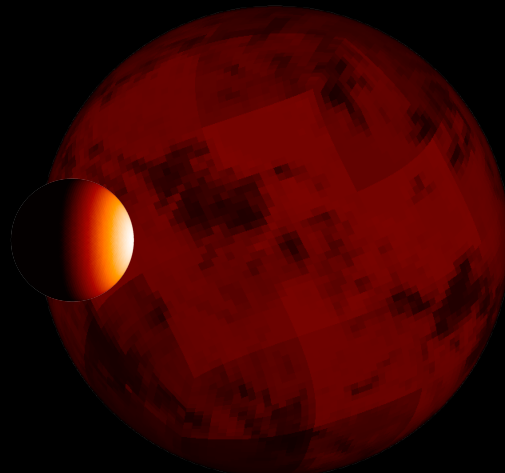




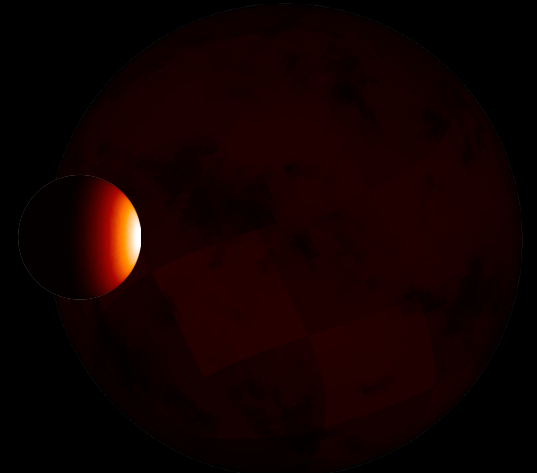




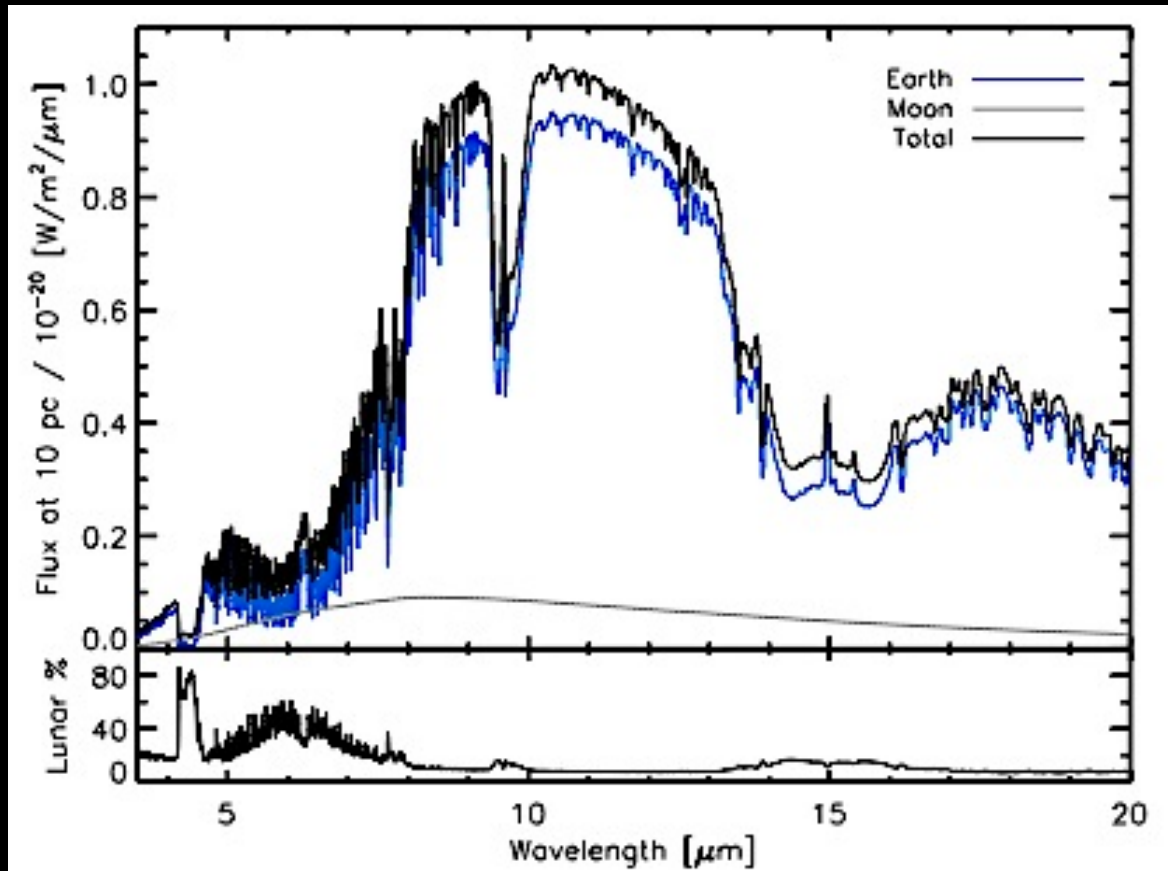
visible



10 μm

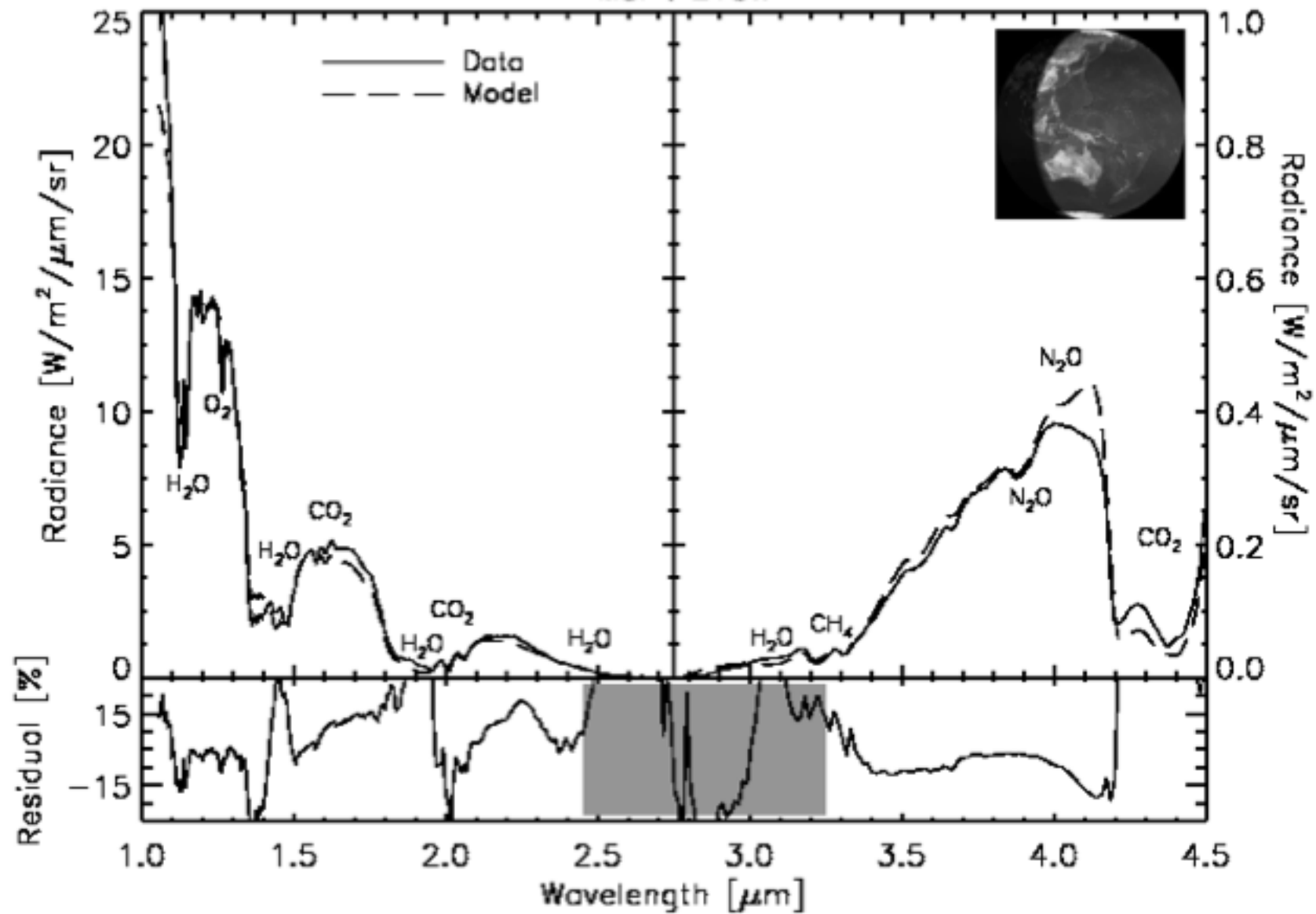


4.3 μm

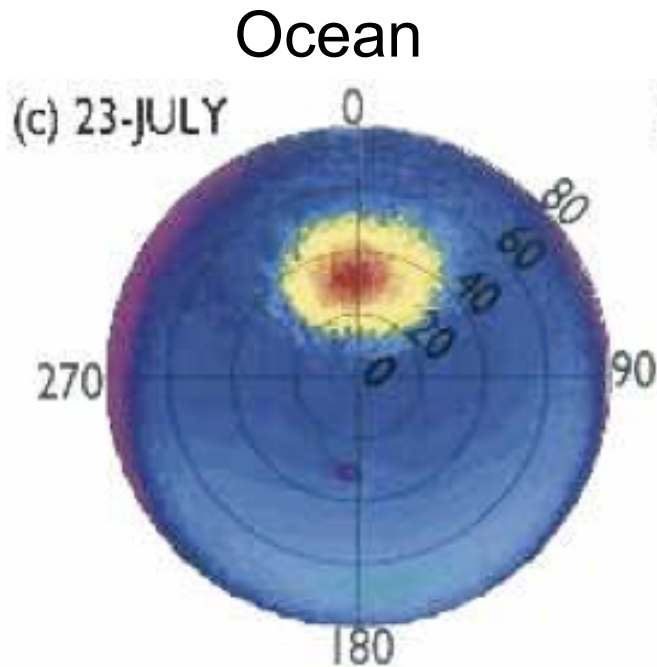
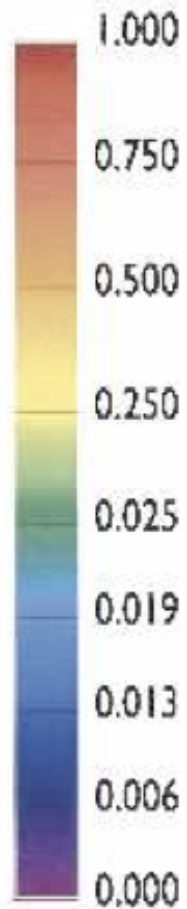


from Robinson (submitted)

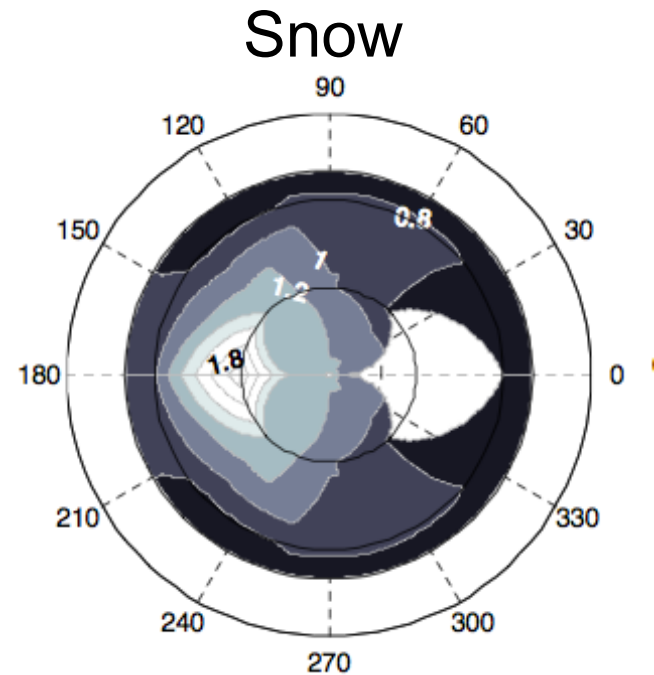
Mar : 210W



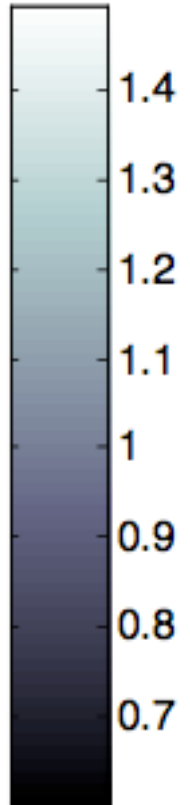
Ocean Glint vs. Snow Glint



from Gatebe *et al.* (2005)



from Dumont *et al.* (2010)





350 nm



450



550



650



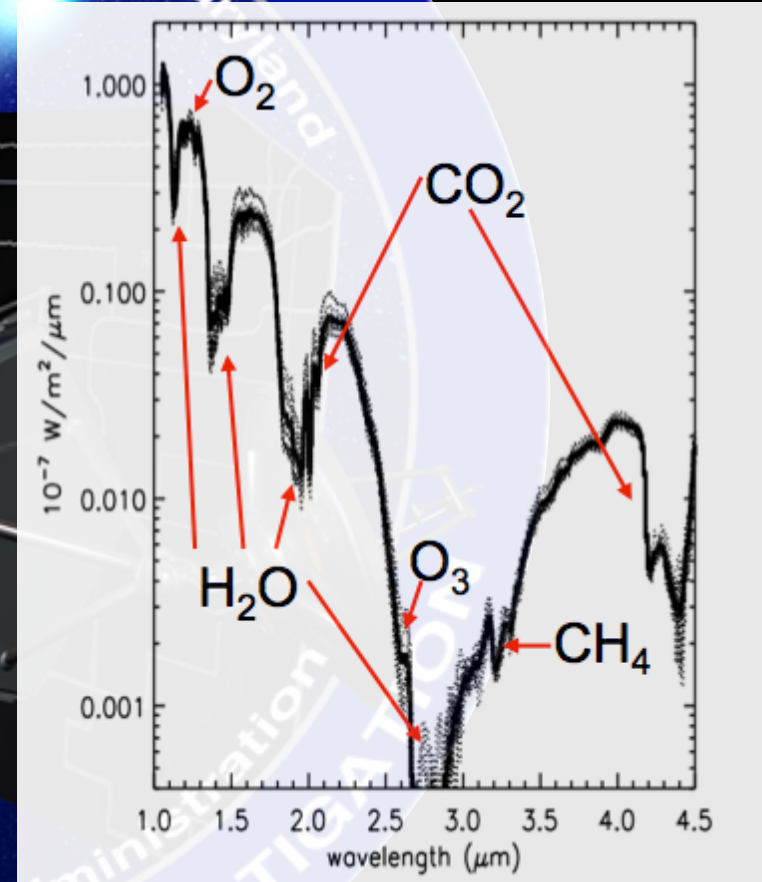
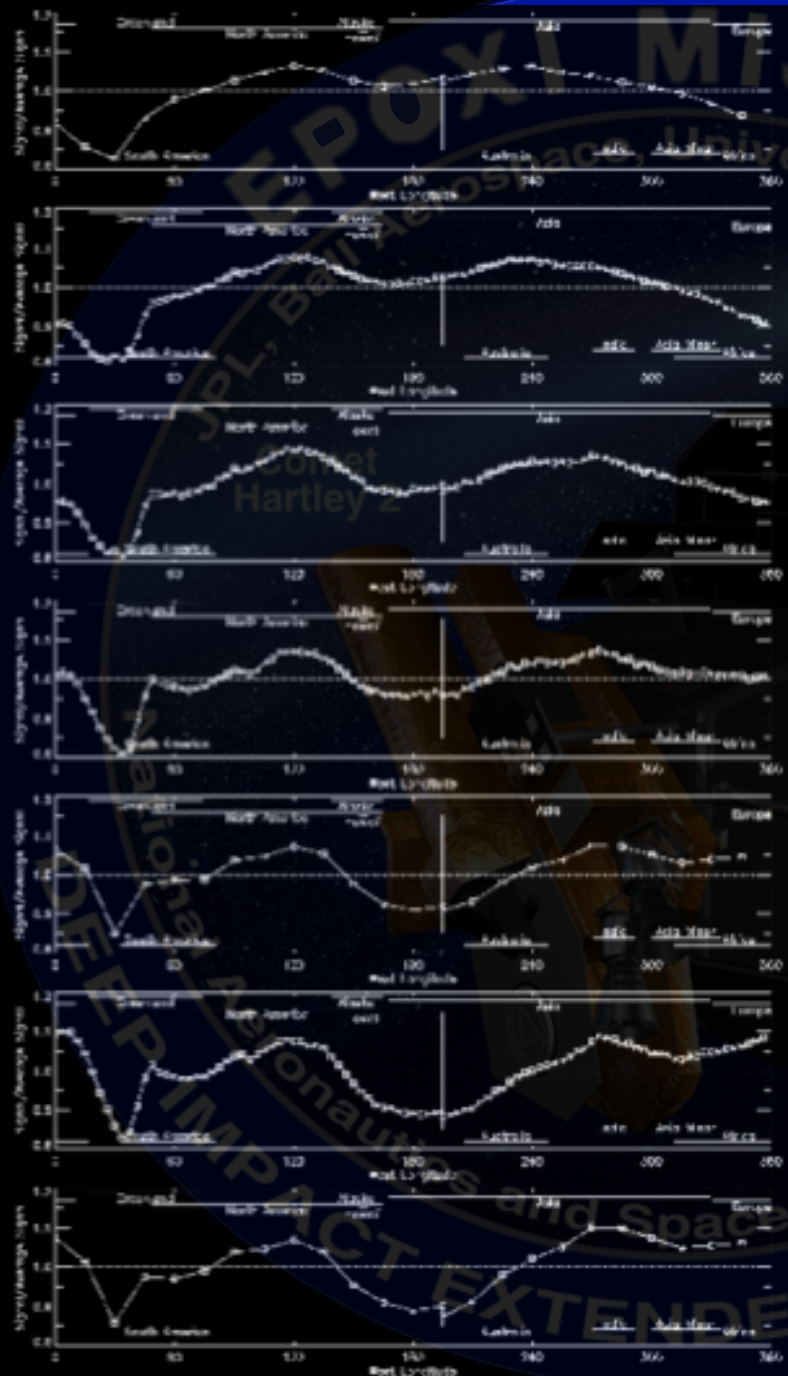
750



850



950



courtesy T. Livengood