

Venus' Spectral Profiles and the Potential for Photosynthesis in the Clouds

Rakesh Mogul

California State Polytechnic University, Pomona, USA

km

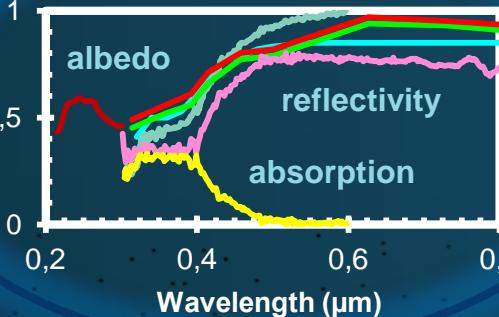
90

70

50

30

10



westward ambient flow

phototrophic
reductive
hv
Vaishampayan
1181-1198 (2018)
gravity wave



bars

10^{-4}

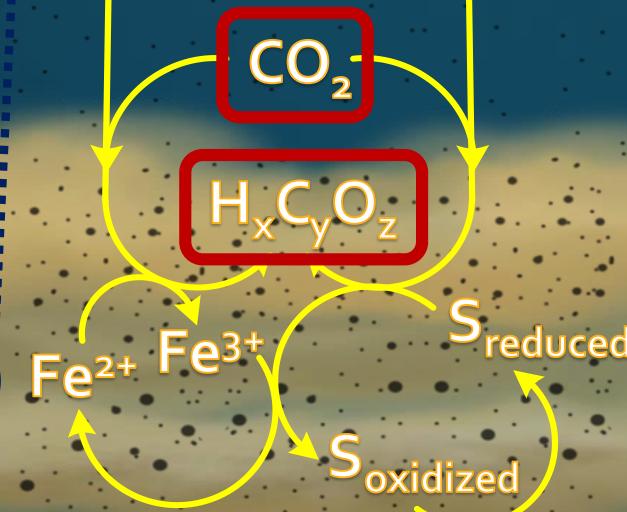
10^{-2}

10^{-1}

1

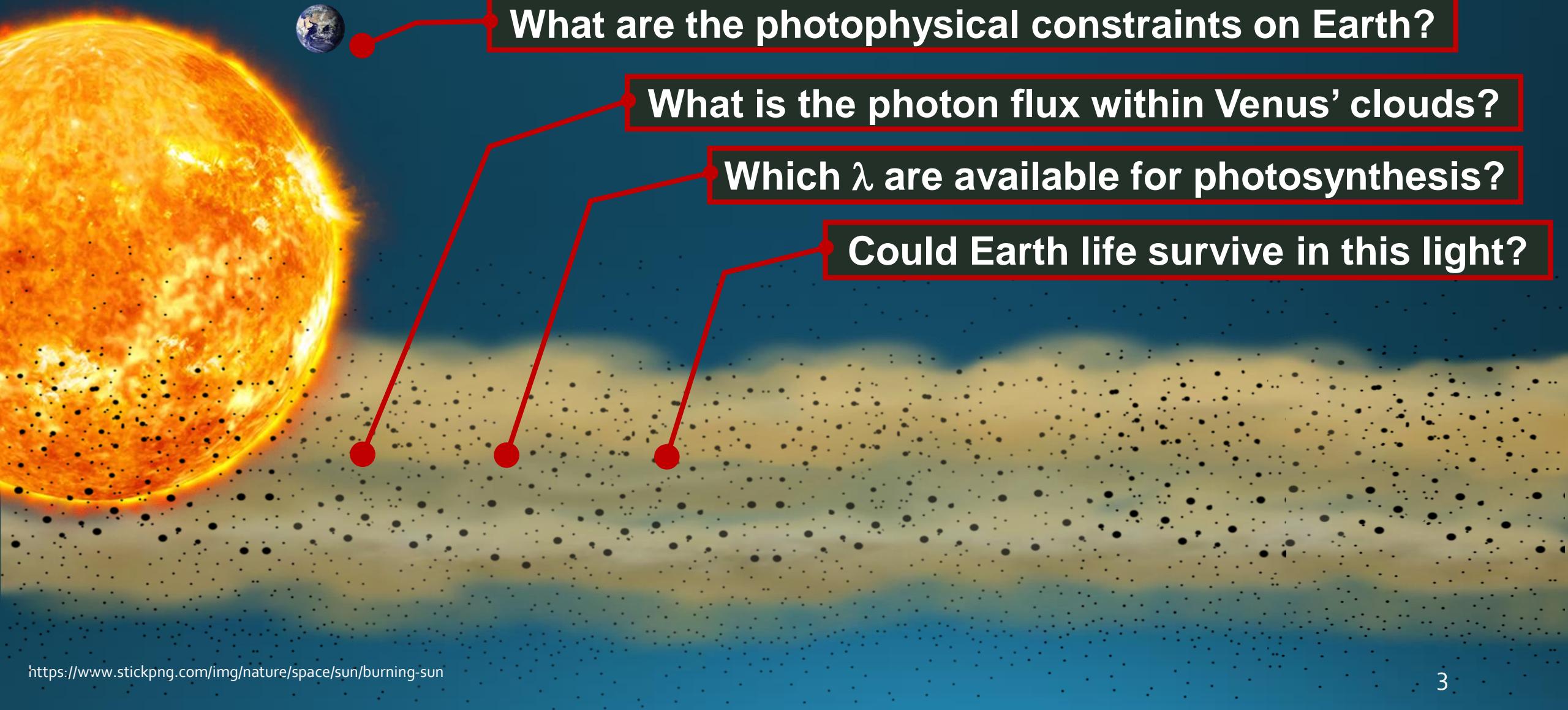
10

100



convective
mixing

Photosynthesis on Venus?



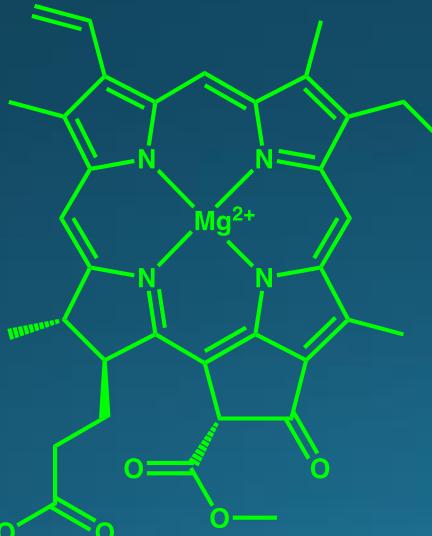
Photosynthesis on Earth

oxygenic photosynthesis



- plants, cyanobacteria, moss, algae...
- pigments: chlorophyll, carotenoids, phycocyanin, etc.

chlorophyll *a*
(Chl *a*)

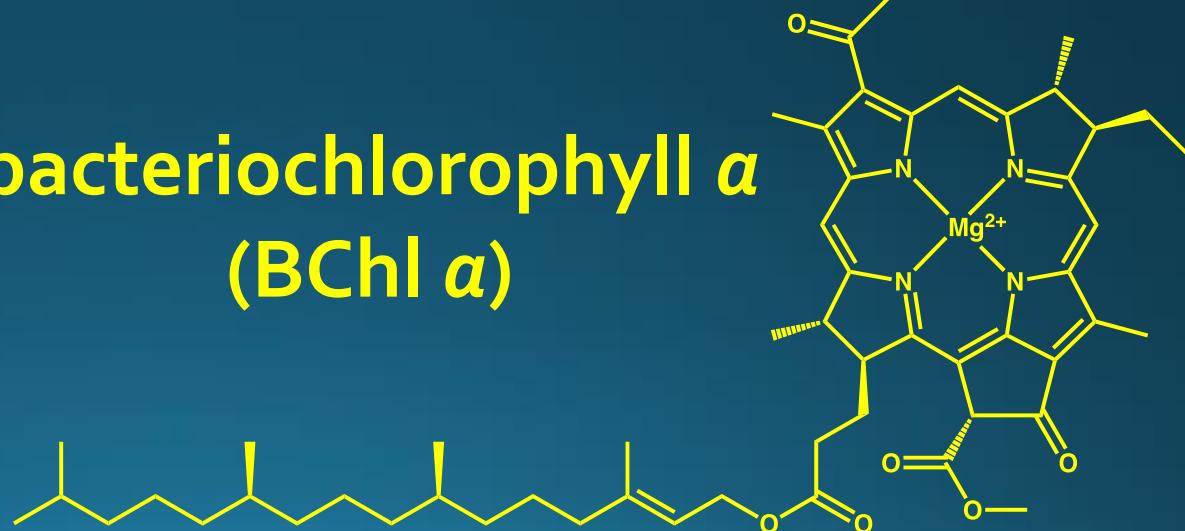


anoxygenic photosynthesis

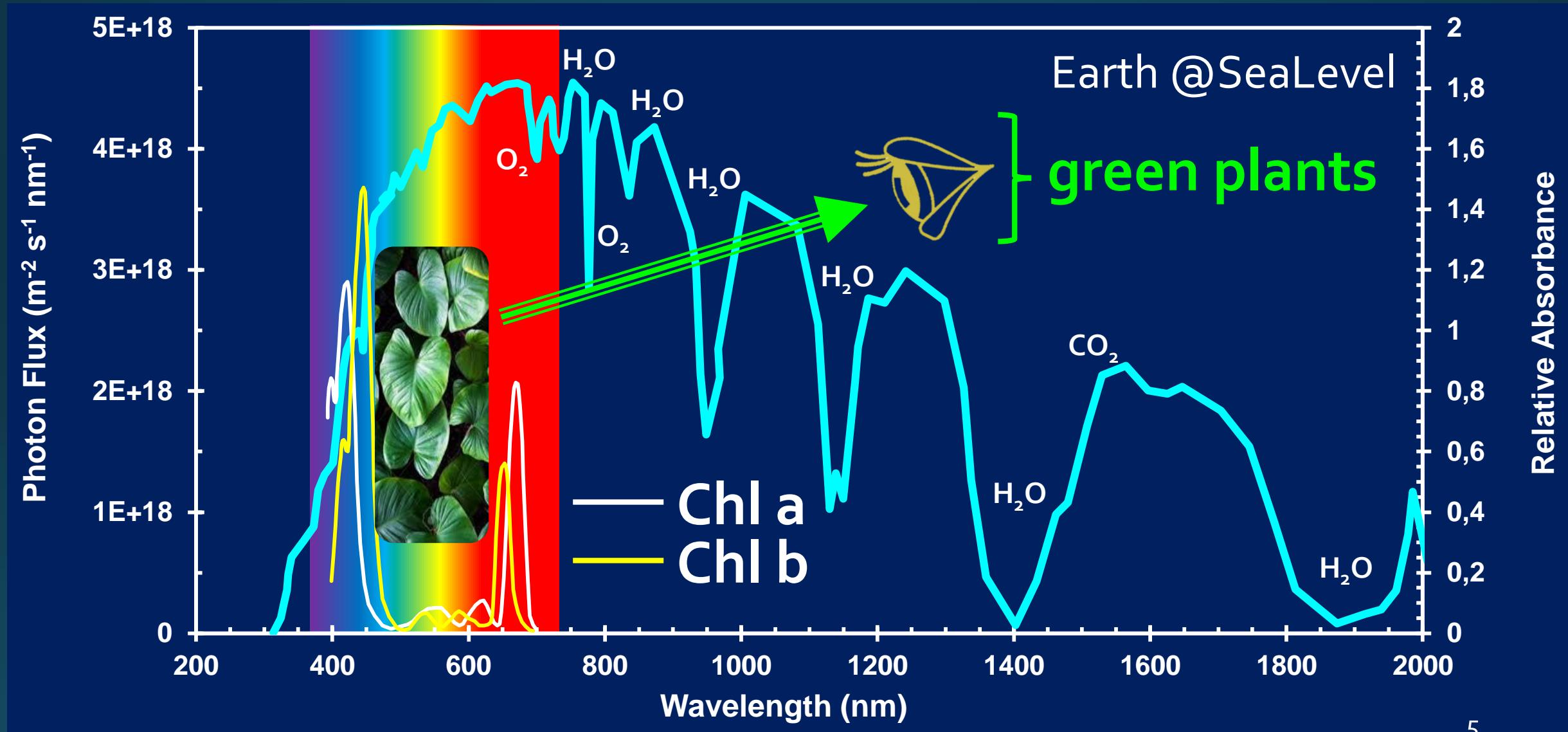


- green sulfur bacteria, purple bacteria...
- pigments: bacteriochlorophyll, carotenoids, etc.

bacteriochlorophyll *a*
(BChl *a*)

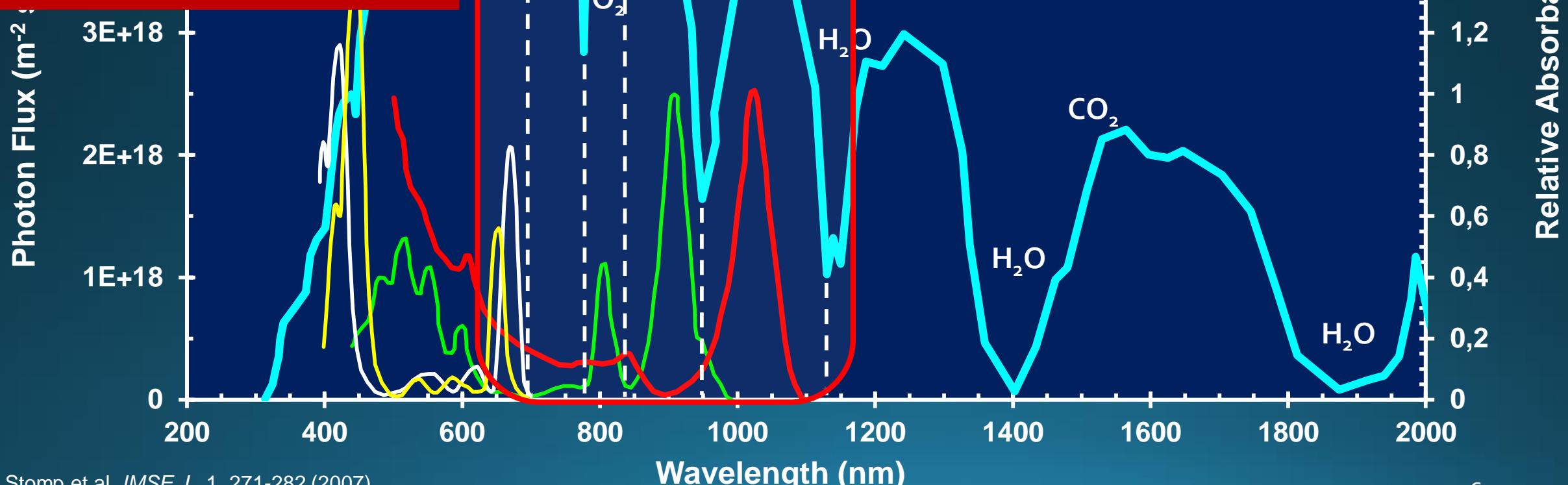


Absorption of Solar Radiation

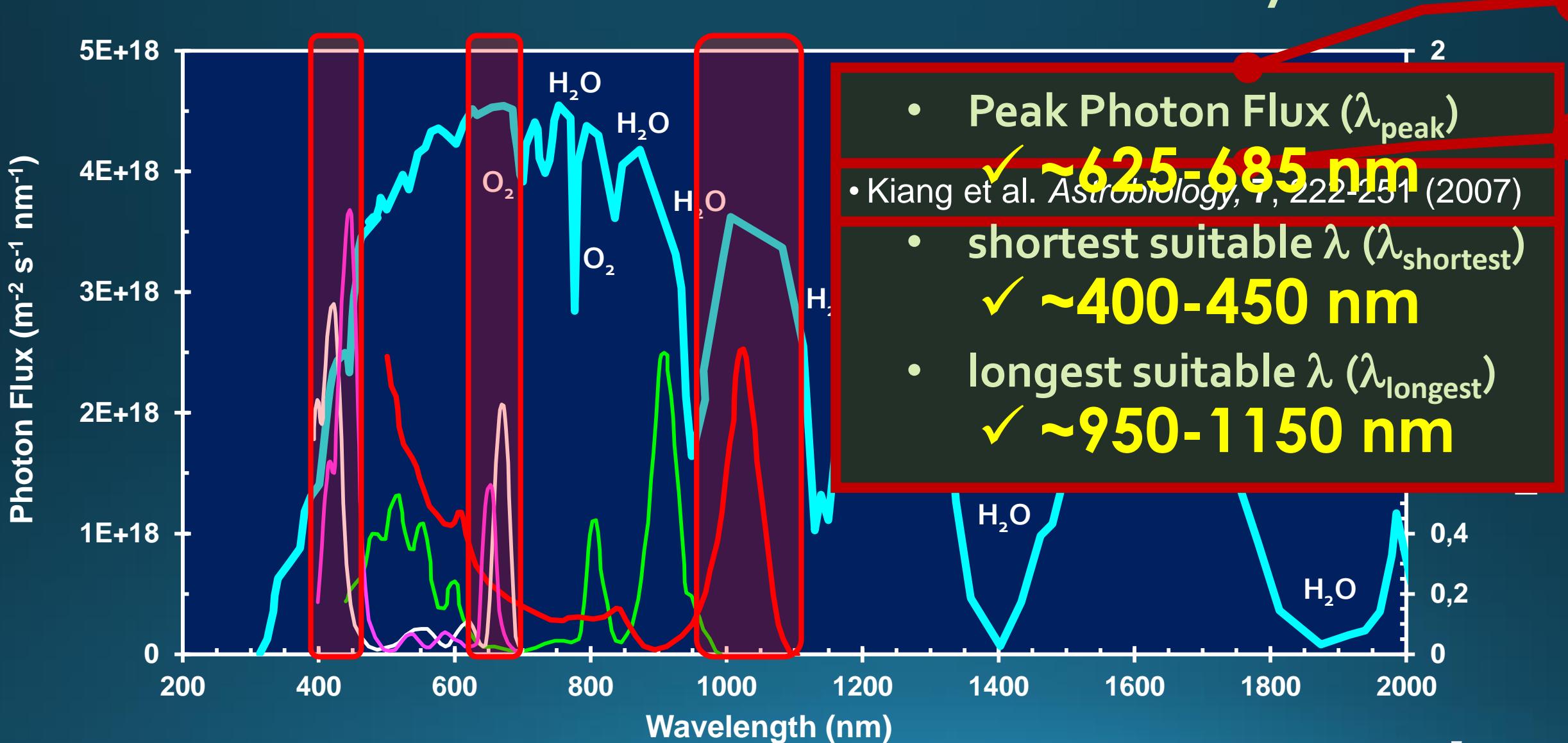


Photosynthetic Windows

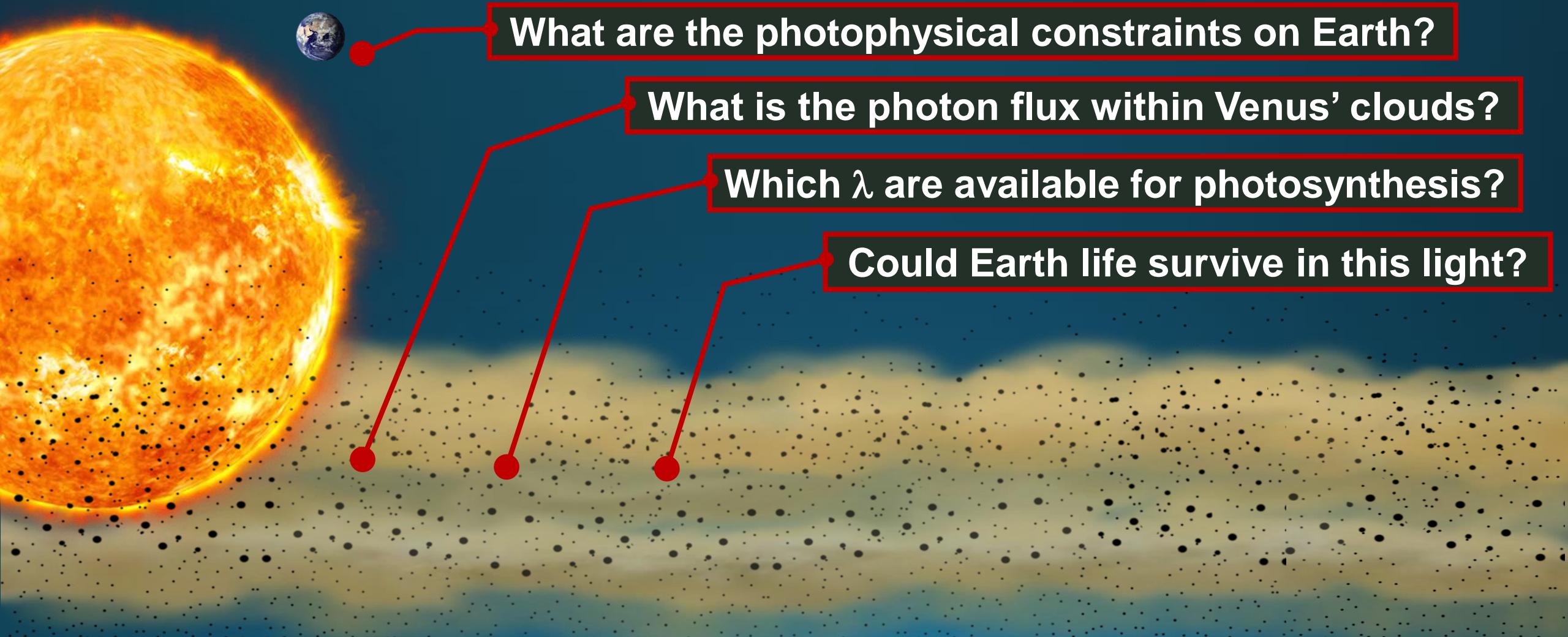
- Photosynthesis occurs between atmospheric absorption bands...



Minimum Determinants of Photosynthesis

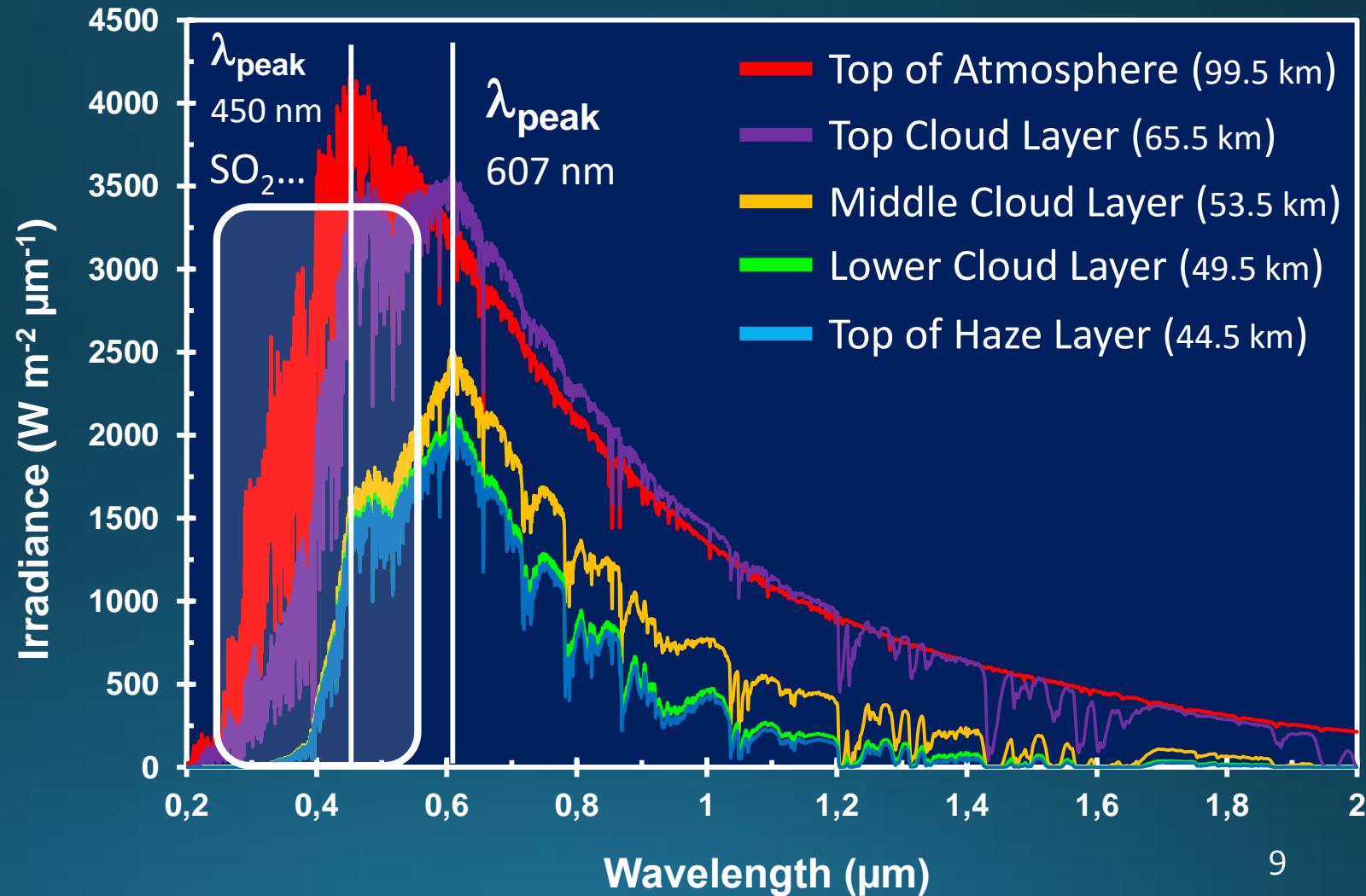


Photosynthesis on Venus?

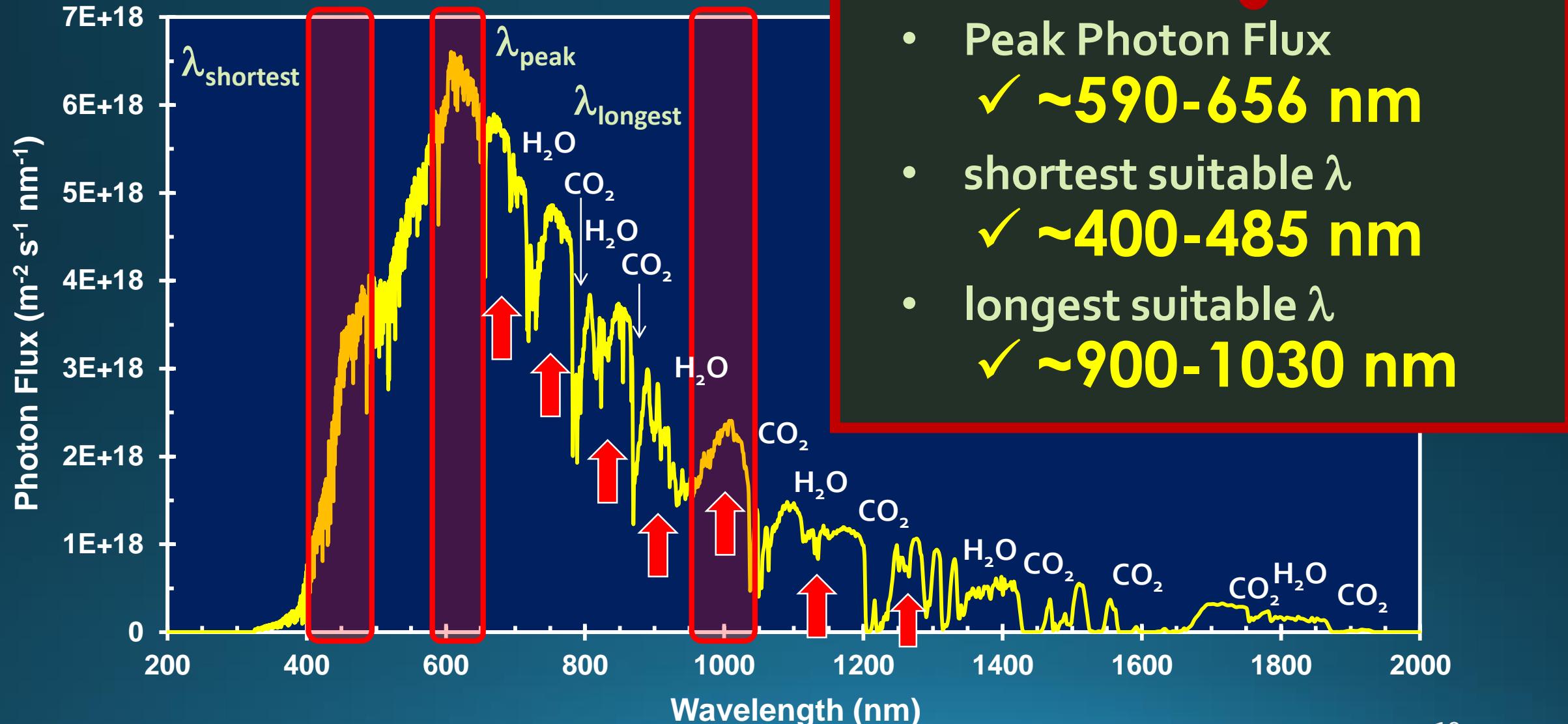


Solar Irradiance in Venus' Clouds

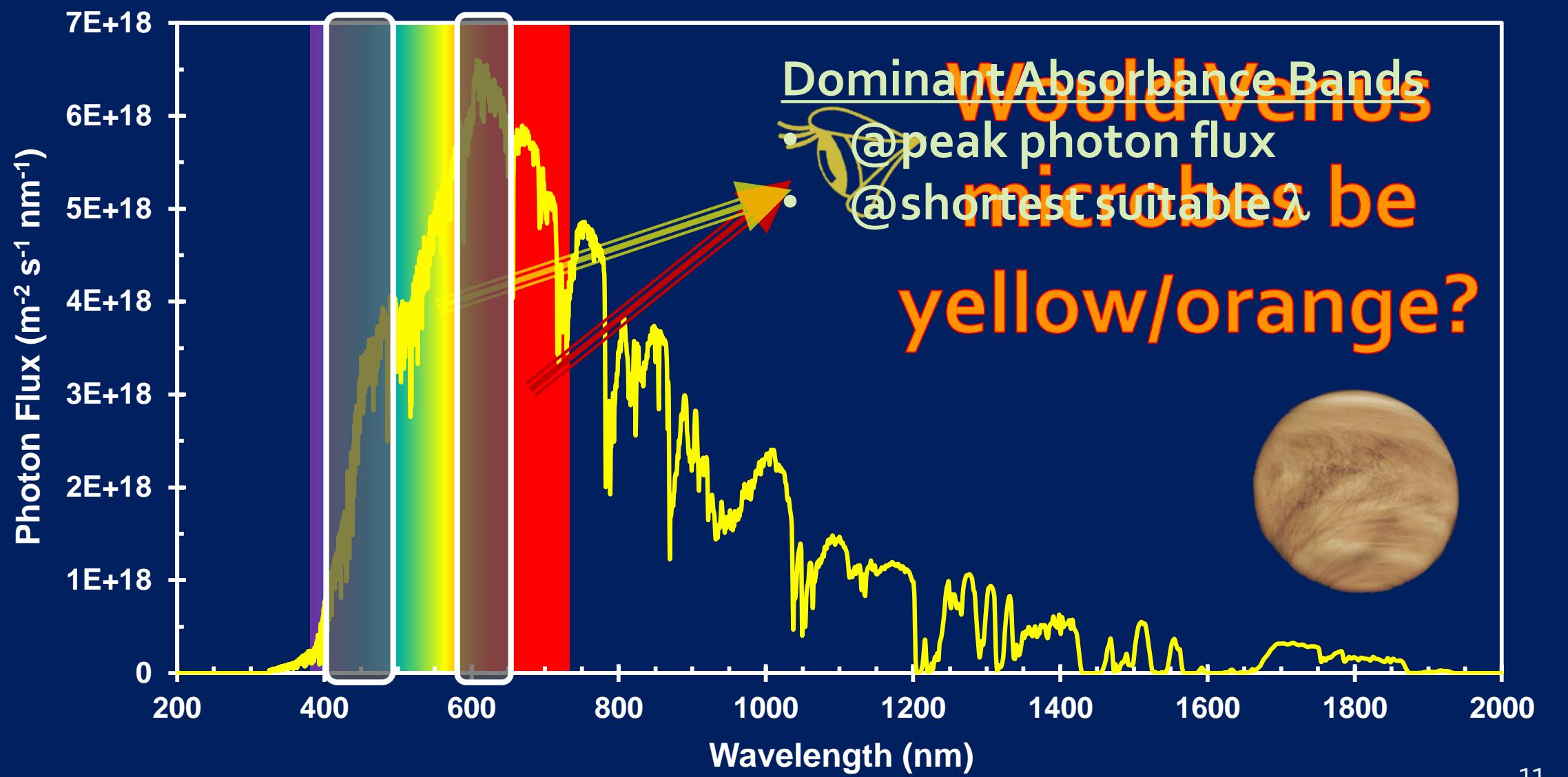
- Yeon Joo Lee
- Lee, et. *Astronom. J.* **158**, 126 (2019)
- local noon time, 15° latitude
- CO₂, H₂O, N₂, SO₂, OCS, HCl, CO, HF, and H₂S
- Rayleigh scattering
- aerosols (modes 1, 2, 2', 3)



Photon Flux in the Lower Clouds



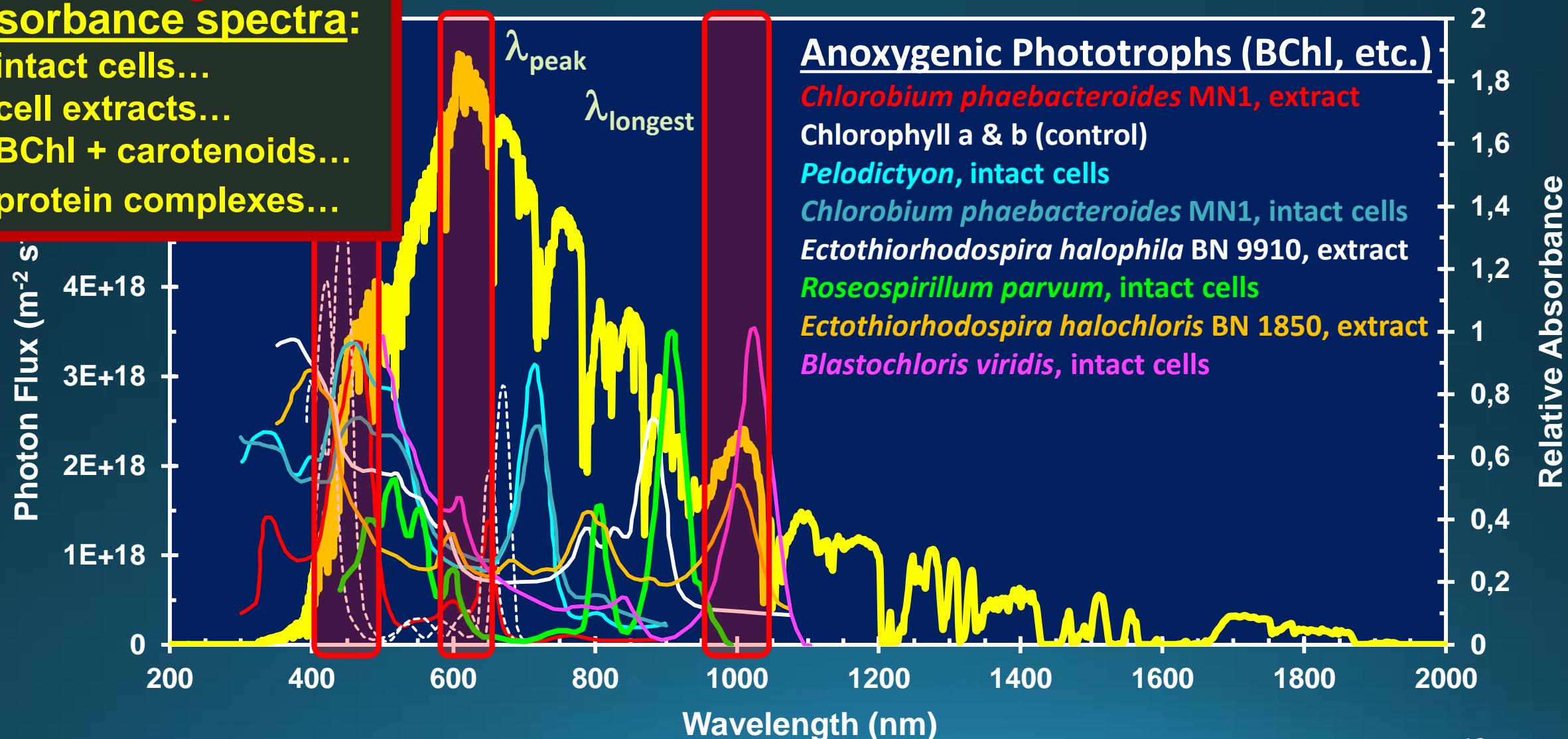
Venus in the Visible



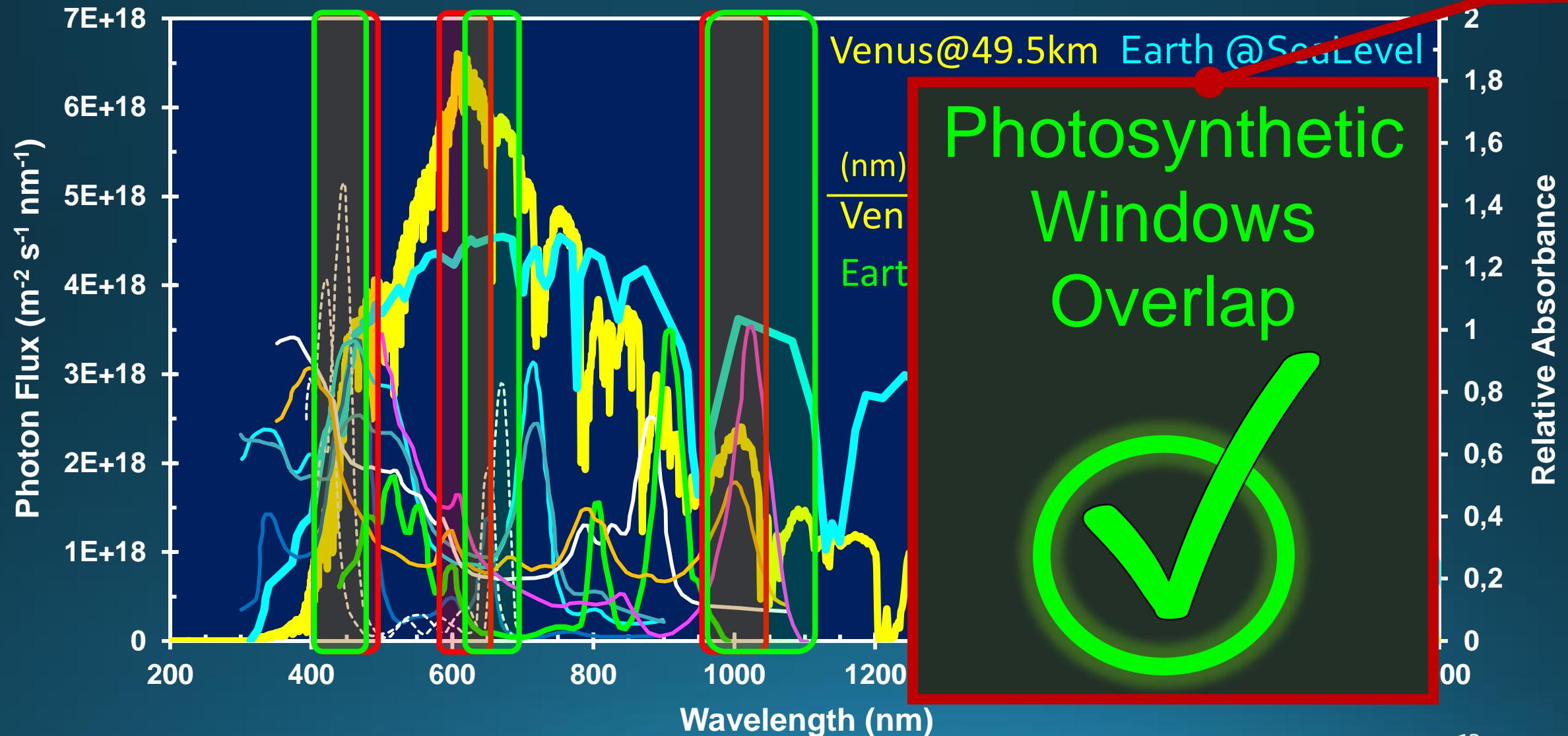
Earth Life in Venus' Light

absorbance spectra:

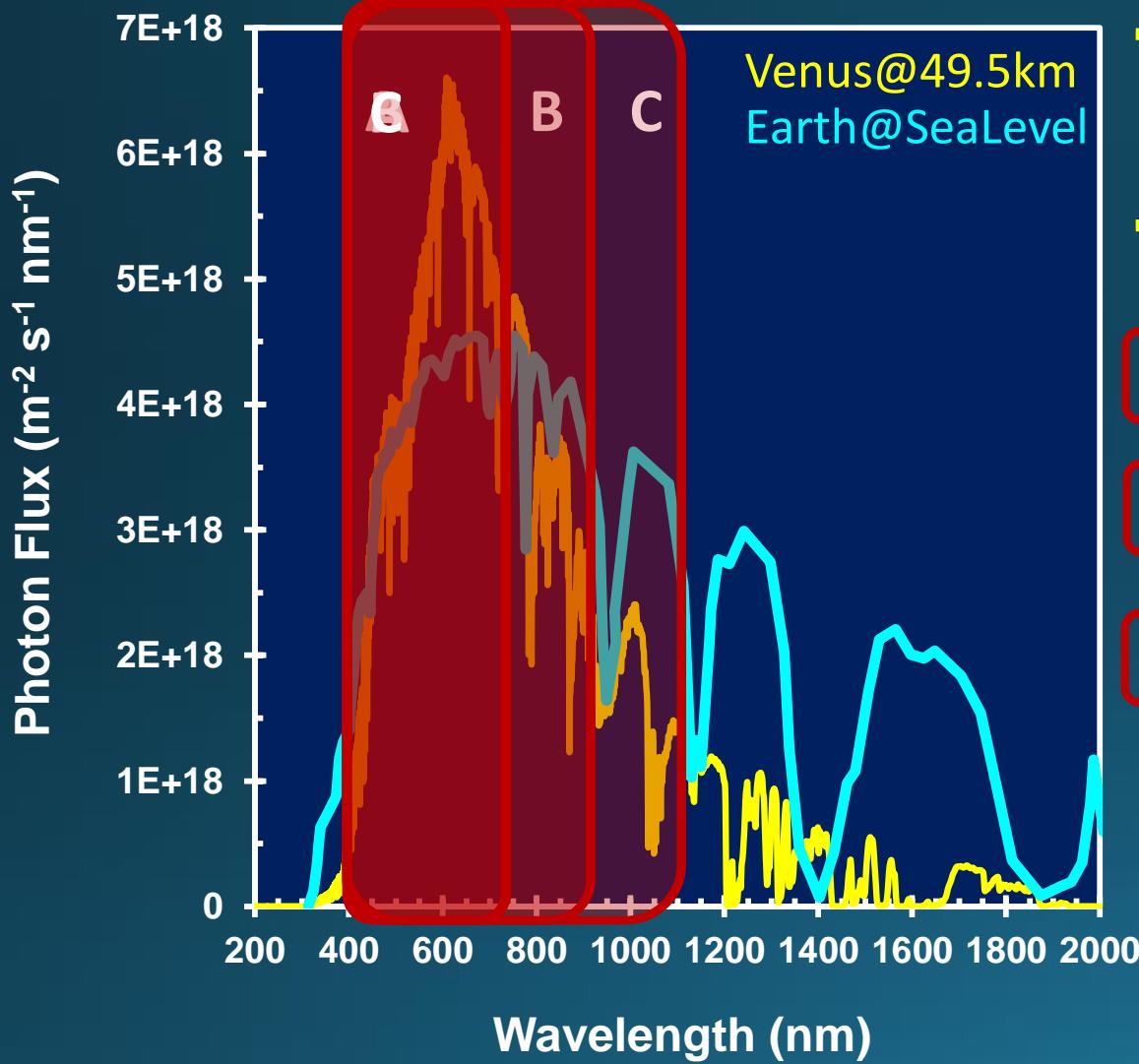
- intact cells...
- cell extracts...
- BChl + carotenoids...
- protein complexes...



Venus' Lower Clouds vs. Earth's Sea Level

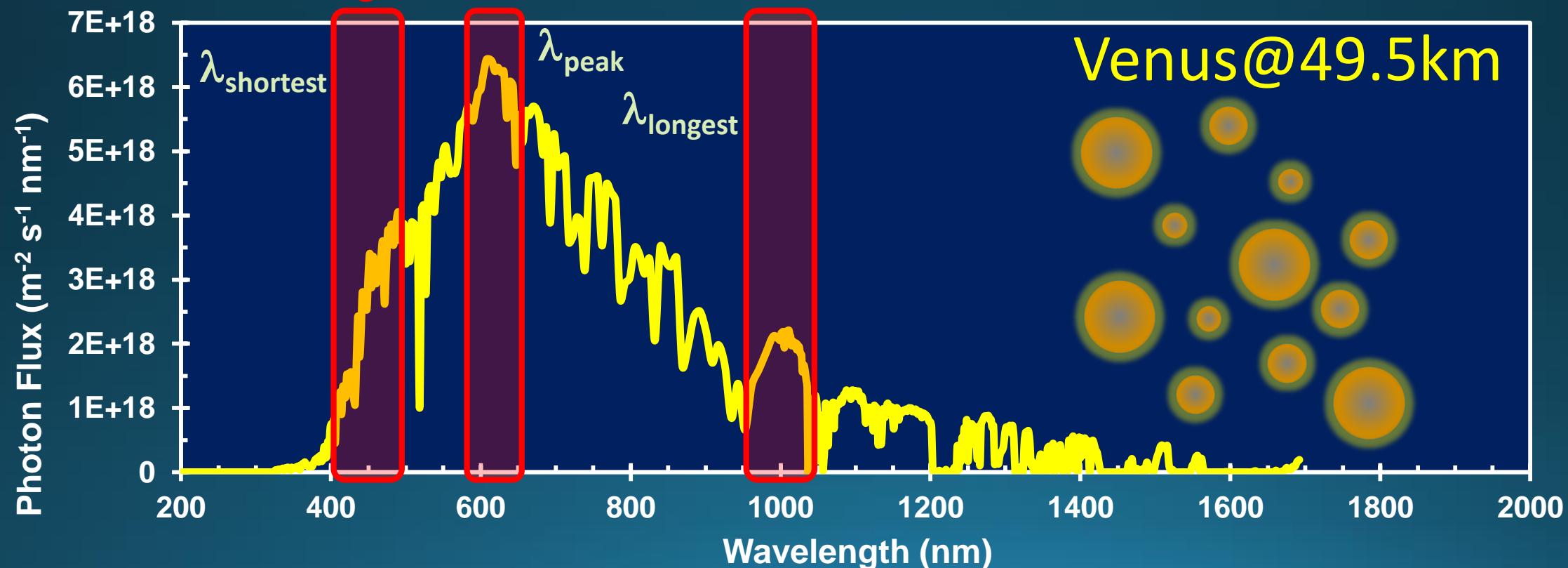


Photosynthetic Active Radiation (PAR)



Windows for Venus Spectrometry

aerosols
(mode 1, 2', 3)



Theoretical Biomass

spherical

spherical

A. ferrooxidans

LCPS
Scanning

=

%
biomass

%
 H_2SO_4

Pioneer Venus: Size particle spectrometer (LCPs)

particle	Radius μm	P D part	Maximum Biomass mg/m³	Venus Mass Loading mg/m³	% Biomass % w/w	% H_2SO_4 % w/w
<i>lower cloud layer</i>						
mode 2'	~1	~50	~4.2	$\sim 4.0 \times 10^8$	0.24	2.0±0.4
mode 3	~4	~50	~270	$\sim 2.6 \times 10^{10}$	16	25±8
<i>middle cloud layer</i>						
mode 2	~1.3	~50	~9.2	$\sim 8.8 \times 10^8$	0.54	1.0±0.3
mode 3	~3.5	~10	~180	$\sim 3.4 \times 10^9$	2.1	3.9±2.1

- Is %Biomass too high?
- Is % H_2SO_4 too high?
- Do spectra of biomass and H_2SO_4 overlap?

Life Detection & Habitability

Raman LIDAR Fluorescence LIDAR Life Detection Microscope

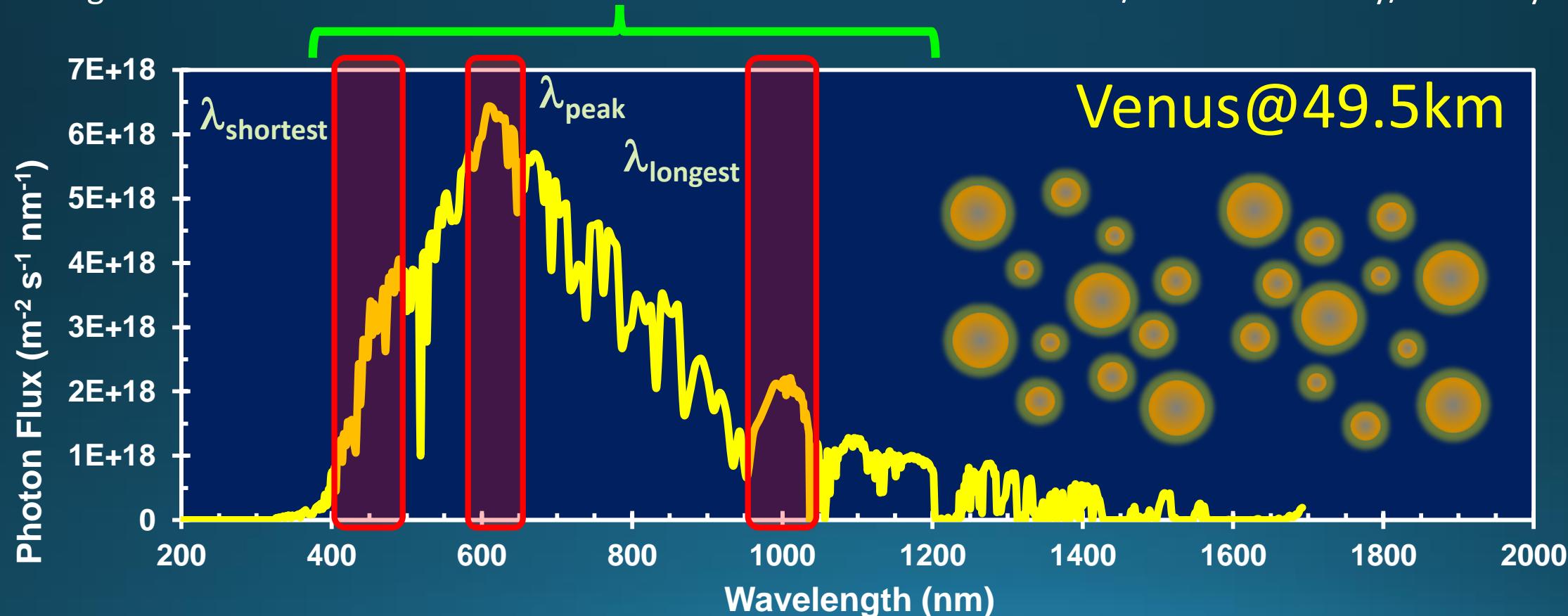
organic functional groups

Inorganic minerals

complex biochemicals/organics

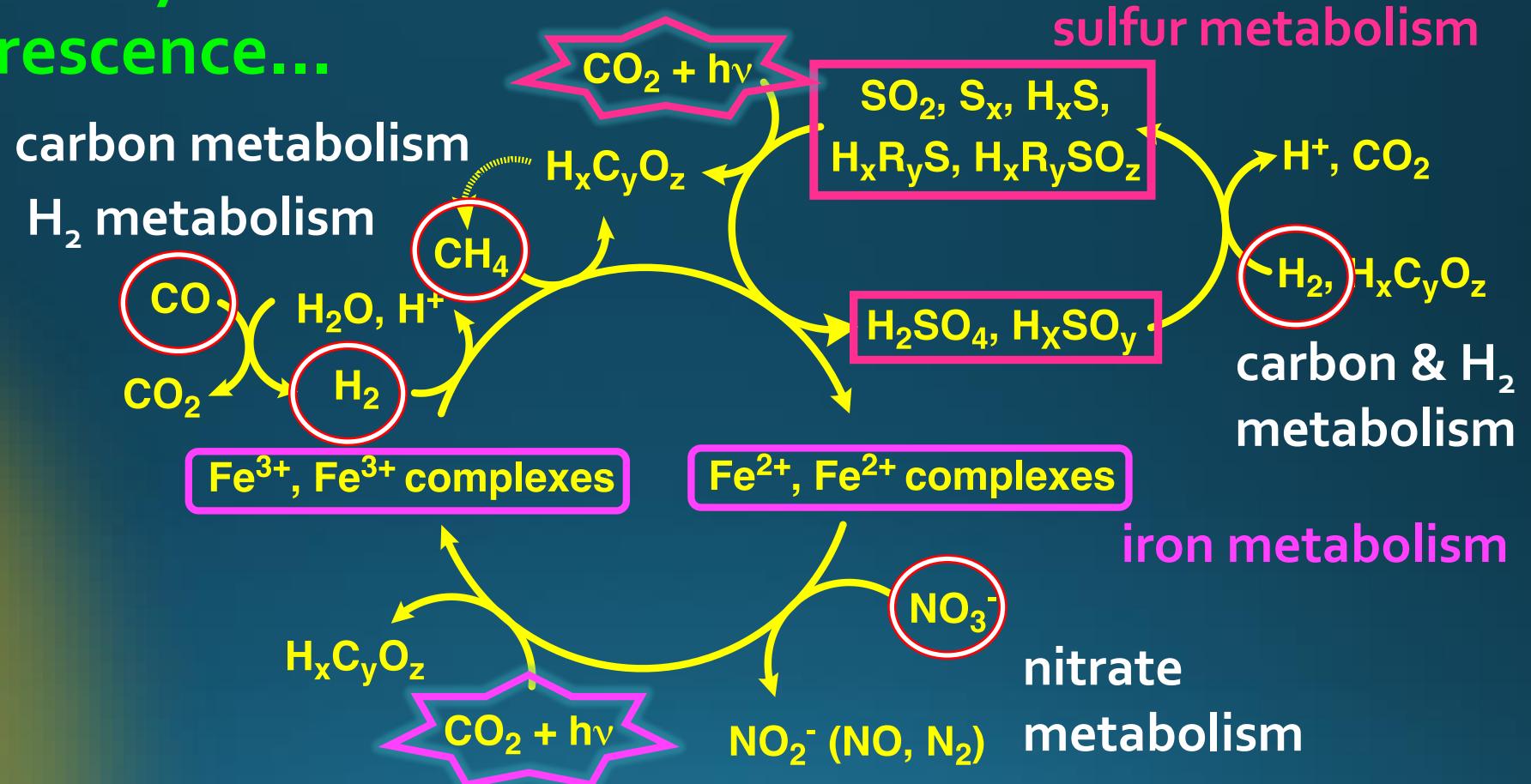
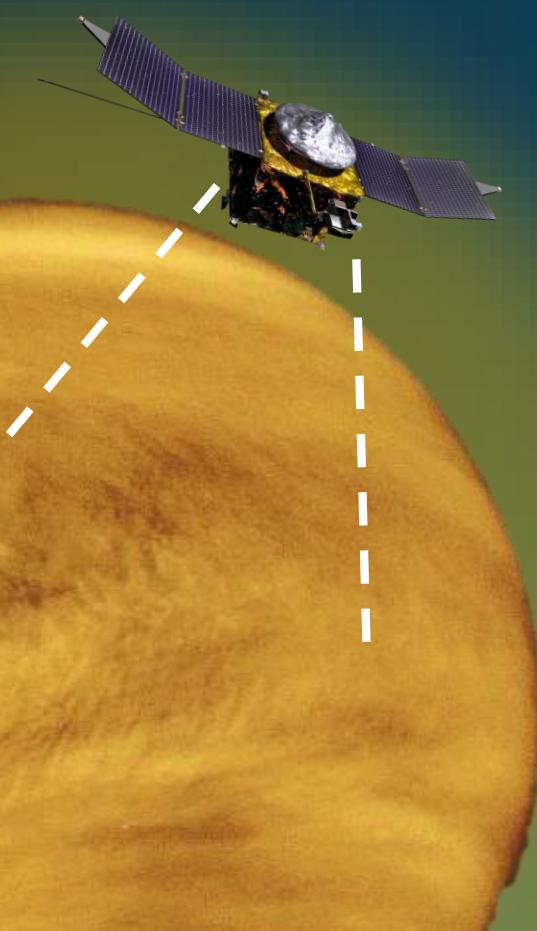
aerosol structure

bio/chemical activity/reactivity



Possible Metabolic Cycles

- ✓ anoxygenic photosynthesis
- ✓ Raman & Fluorescence...



Acknowledgements

Project Collaborators

- Sanjay Limaye (PI)
 - University of Wisconsin, Madison
- Yeon Joo Lee
 - Technical University of Berlin, Germany

Funding Sources

- My Free Time
- NASA
 - NNX09AE85G & NNX16AC79G

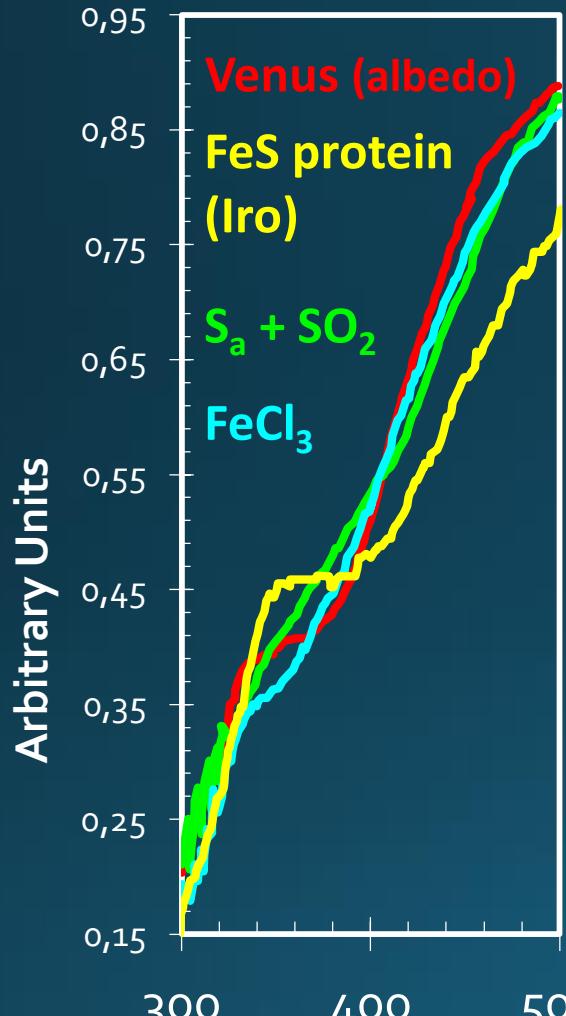
Key References

- Kiang, N.Y., Siefert, J., Govindjee, G., Blankenship, R.E. (2007) *Astrobiology*, **7**, 222-251.
- Stomp, M., Huisman, J., Stal, L.J., Matthijs, H.C.P. (2007) *IMSE J.*, **1**, 271-282.
- Knollenberg, R. G., & Hunten, D. M. (1980). *J. Geophys. Res.*, **85**, 8039-8058.
- Knollenberg, R., Travis, L., Tomasko, M., Smith, P., Ragent, B., Esposito, L., et al. (1980). *J. Geophys. Res.*, **85**, 8059-8081.
- James, E.P., Toon, O.B., Schubert, G. (1997) *Icarus*, **129**, 147-171.
- Krasnopolksy, V.A. (2015) *Icarus*, **252**, 327-333.

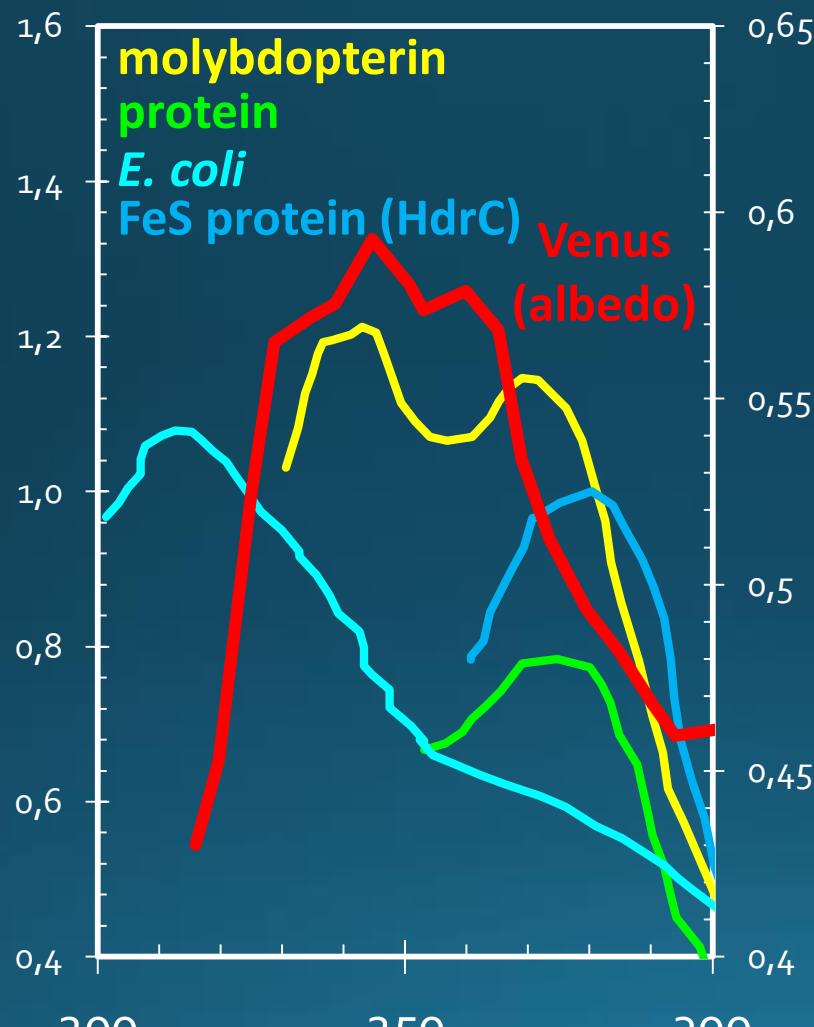


Can Biomolecules Spectrally Contribute?

Albedo/Transmision: 300-500 nm



Biomolecule Absorbance: 200-300 nm



Biomolecule Absorbance: 300-500 nm

