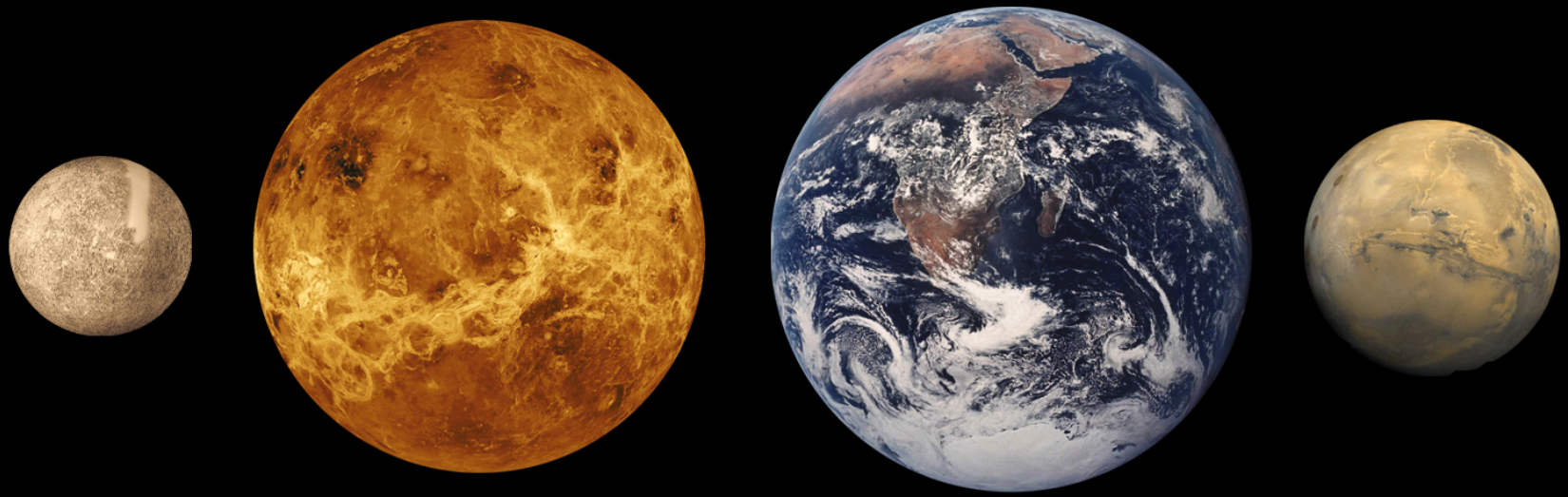
Seeing Through the Clouds of Venus

Giada Arney

ESS 495

5/2/13



Sister Planets?

Similar size (95%), mass (82%) and density (95%)

Venus is a terrible place

96% CO_2
3.5% N_2
T_s = 740K = 872°F
P_s = 93 atm
H_2SO_4 clouds

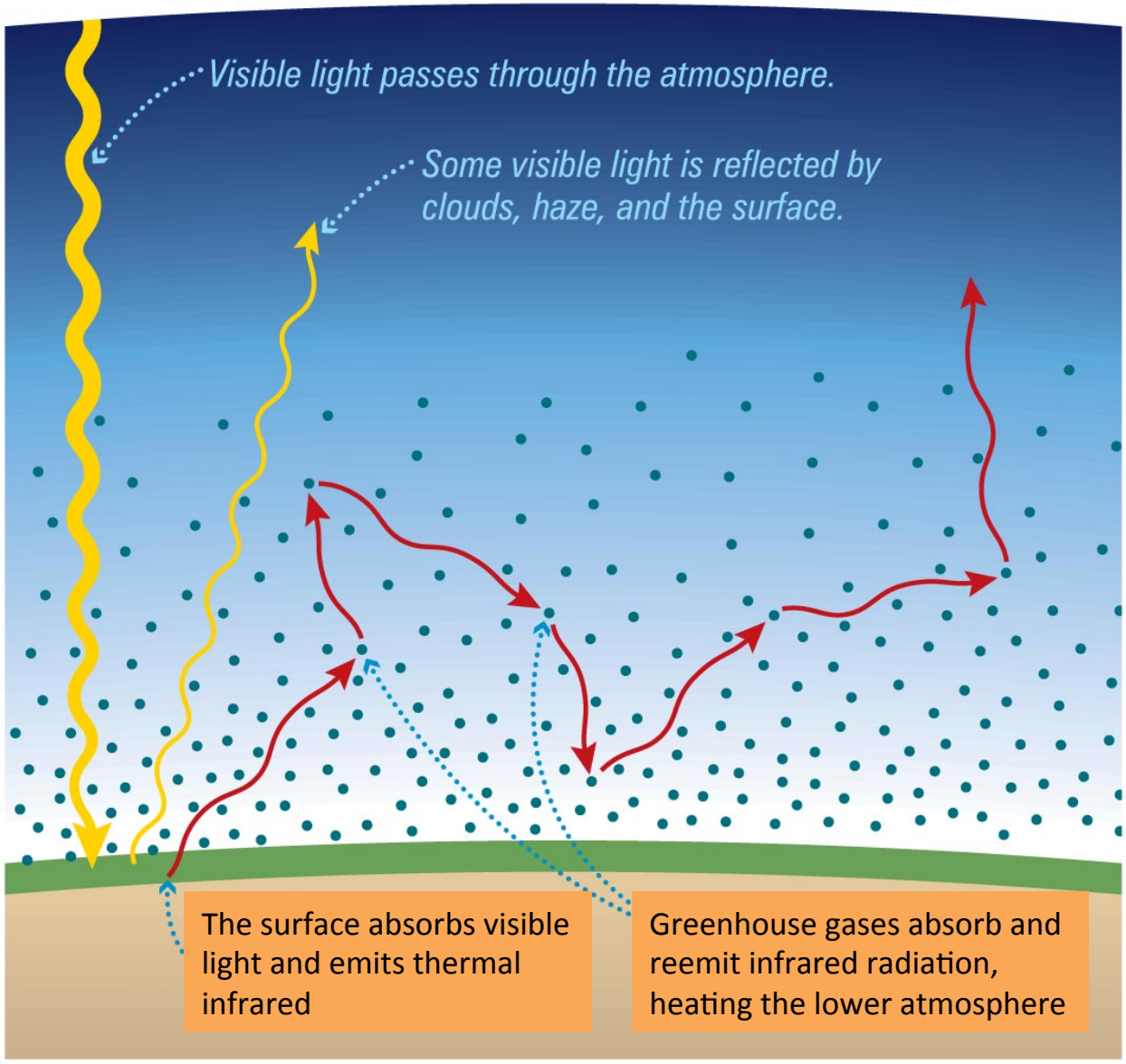
78% N_2
21% O_2
T_s = 288K
P_s = 1 atm
H_2O clouds

J. Whatmore

Slide courtesy of Vikki Meadows

www.mondoart.net

The Greenhouse Effect



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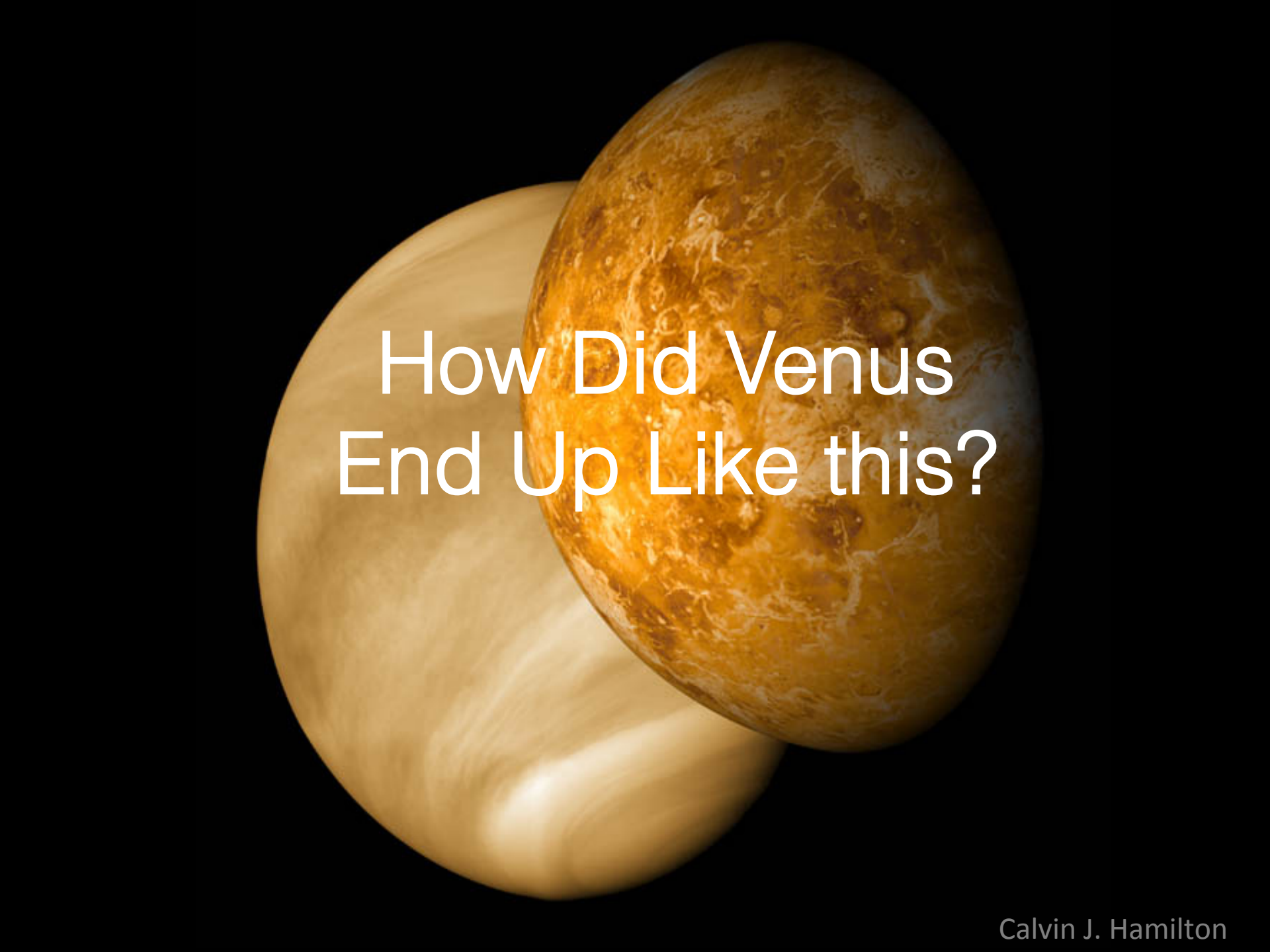
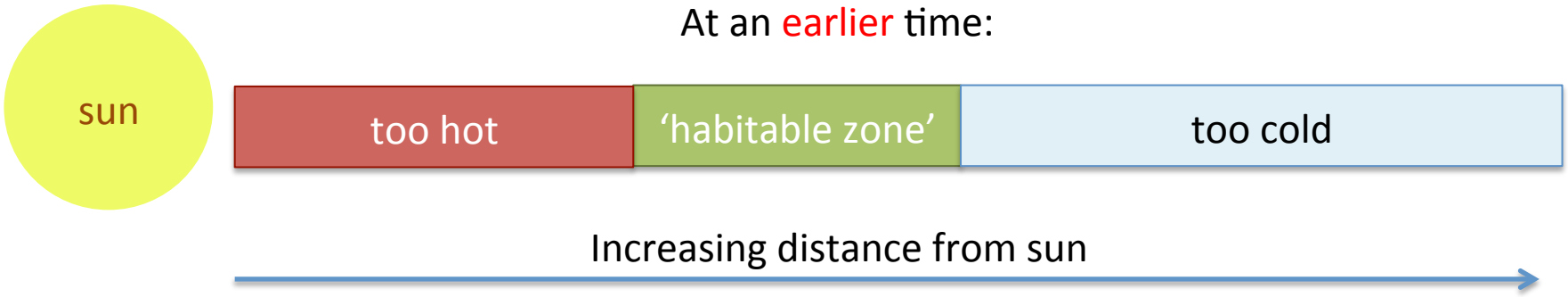


Calvin J. Hamilton

A couple of things to know…

- The sun gets ~6% more luminous every 1 billion years
- As the sun gets brighter (hotter) with time, the region around the star where habitable planetary temperatures are possible gets pushed outward



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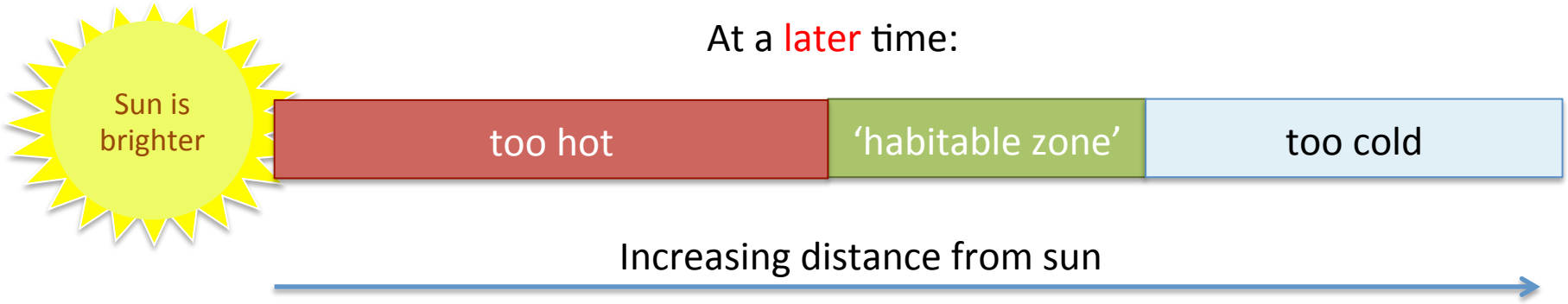
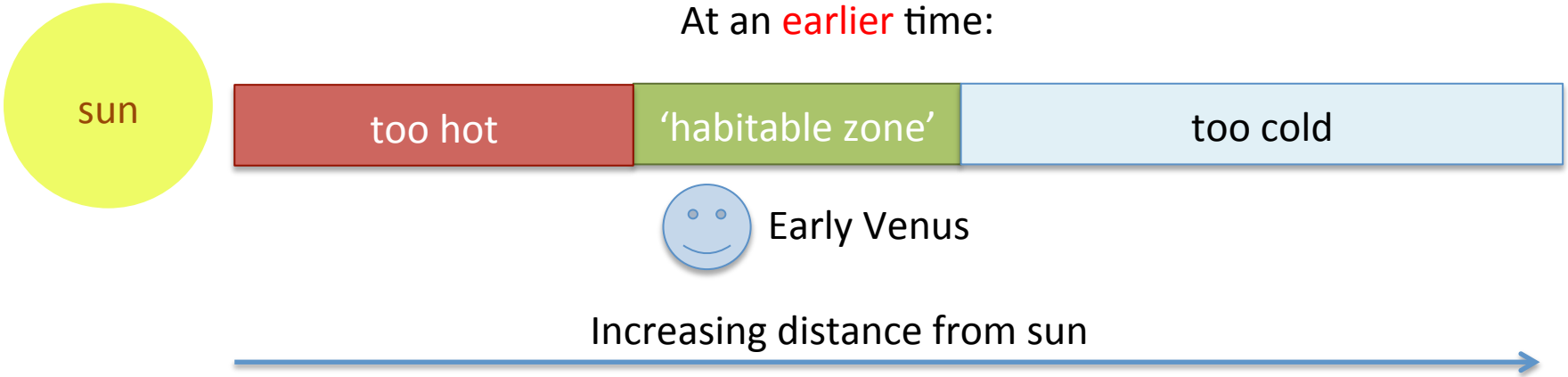


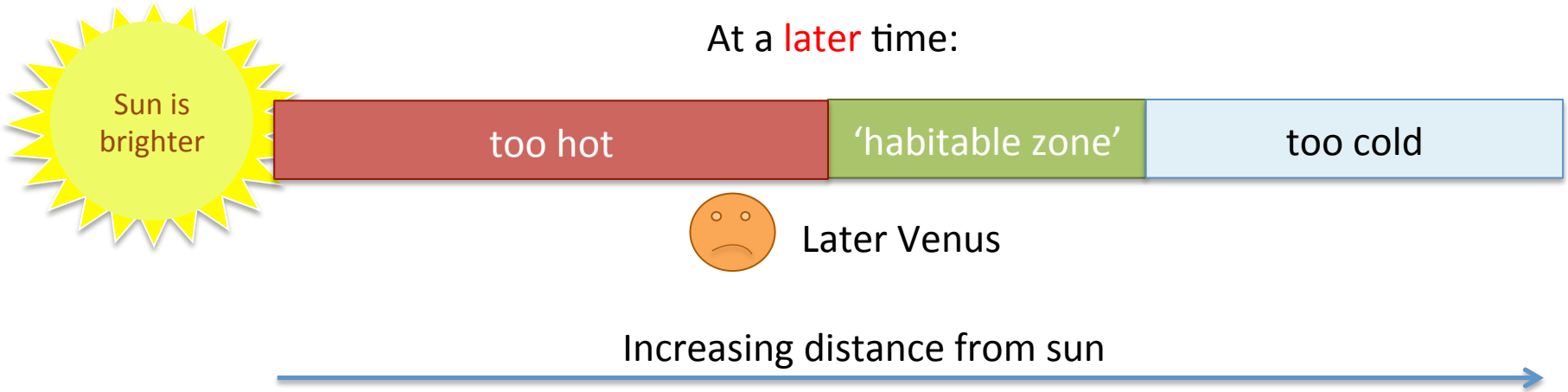
So…

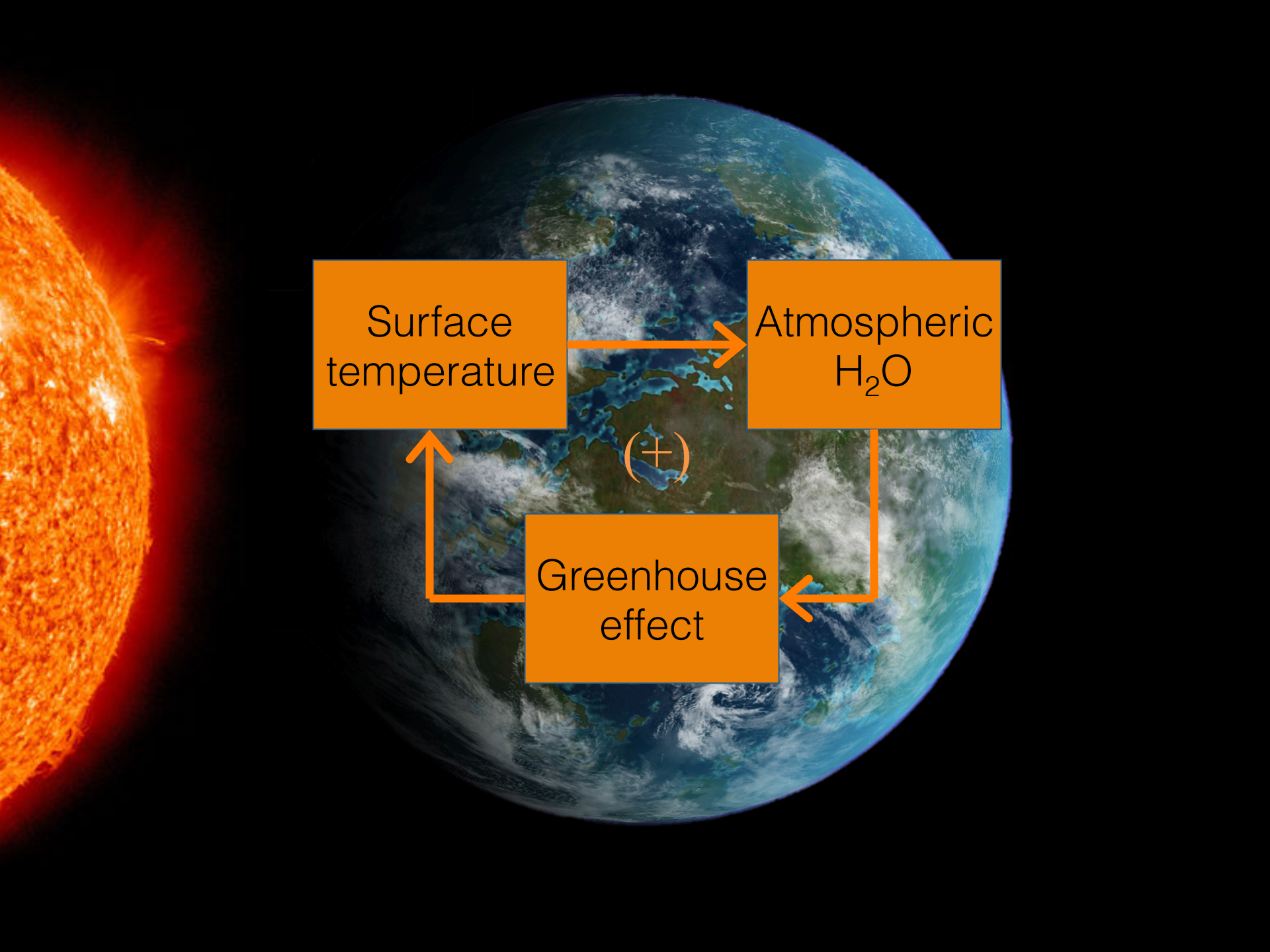
- The heat received by a planet from the sun continually increases with time.
- The ‘habitable zone’ moves farther away from the star with time.
- A planet that was once in the habitable zone at one time may become too hot later

This may have happened to Venus

The Fate of Venus






Surface temperature
Atmospheric H_2O
(+)
Greenhouse effect

The Fate of Earth?

Today:

sun

too hot | 'habitable zone' | too cold

Present Earth

Increasing distance from sun

At a later time:

Sun is brighter

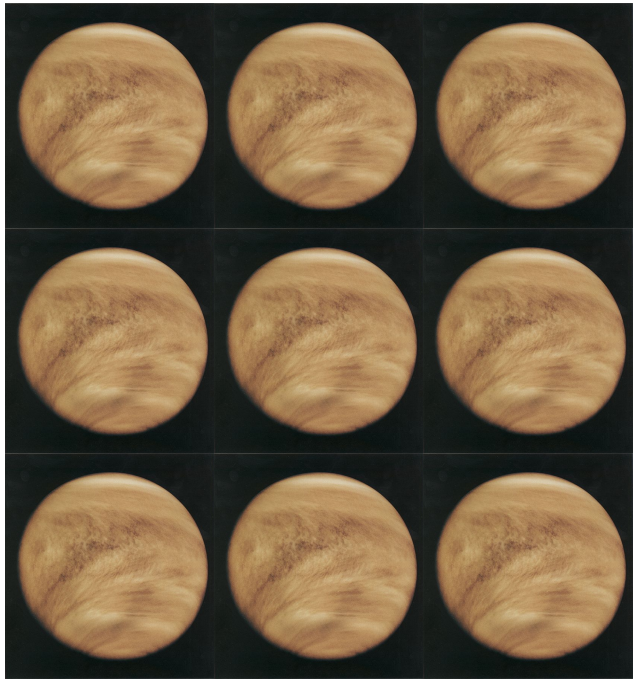
too hot | 'habitable zone' | too cold

Future Earth?

Increasing distance from sun

Exoplanet population

- Are Venus-like planets common?
  - The migration of the habitable zone outward may leave Venuses in its wake
  - There may be large number of Venus-like worlds in the exoplanet population
  - “end state” of Earthlike planets?



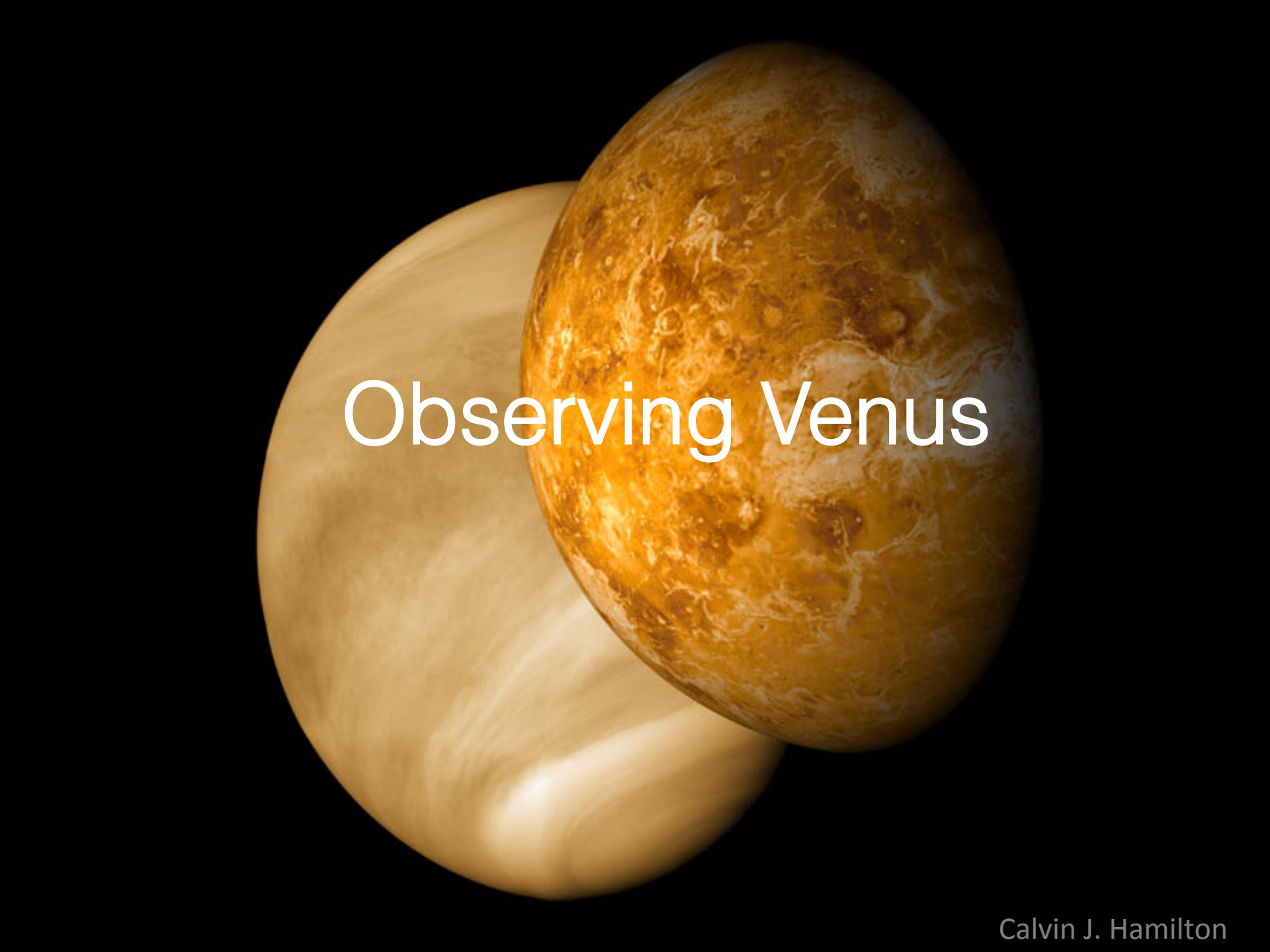
Mercury

Venus

Earth

Mars

Jupiter

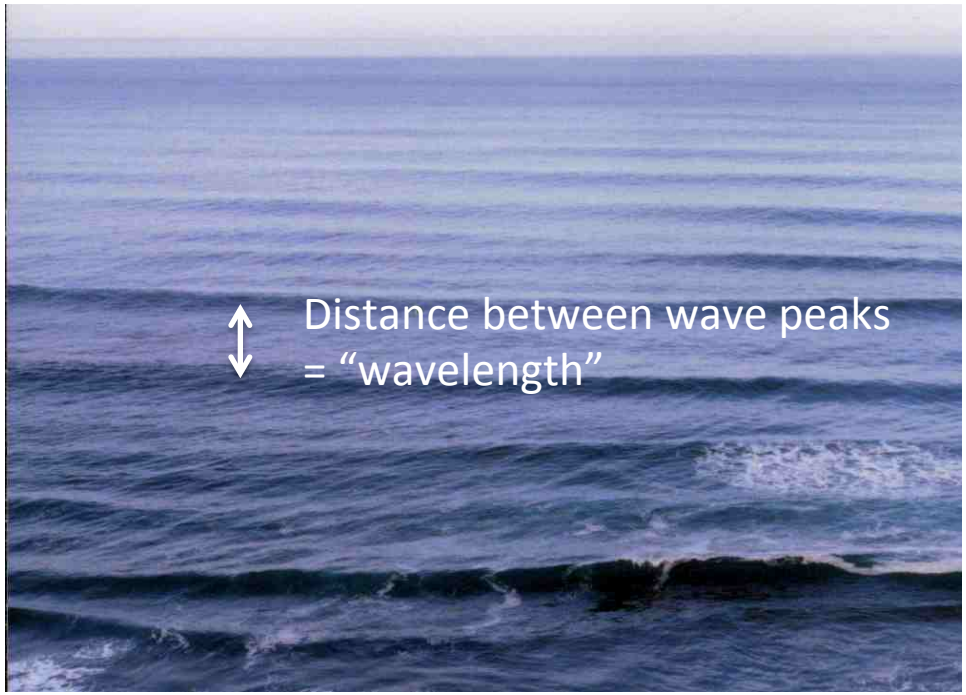


Observing Venus

Calvin J. Hamilton

We need to talk…about light

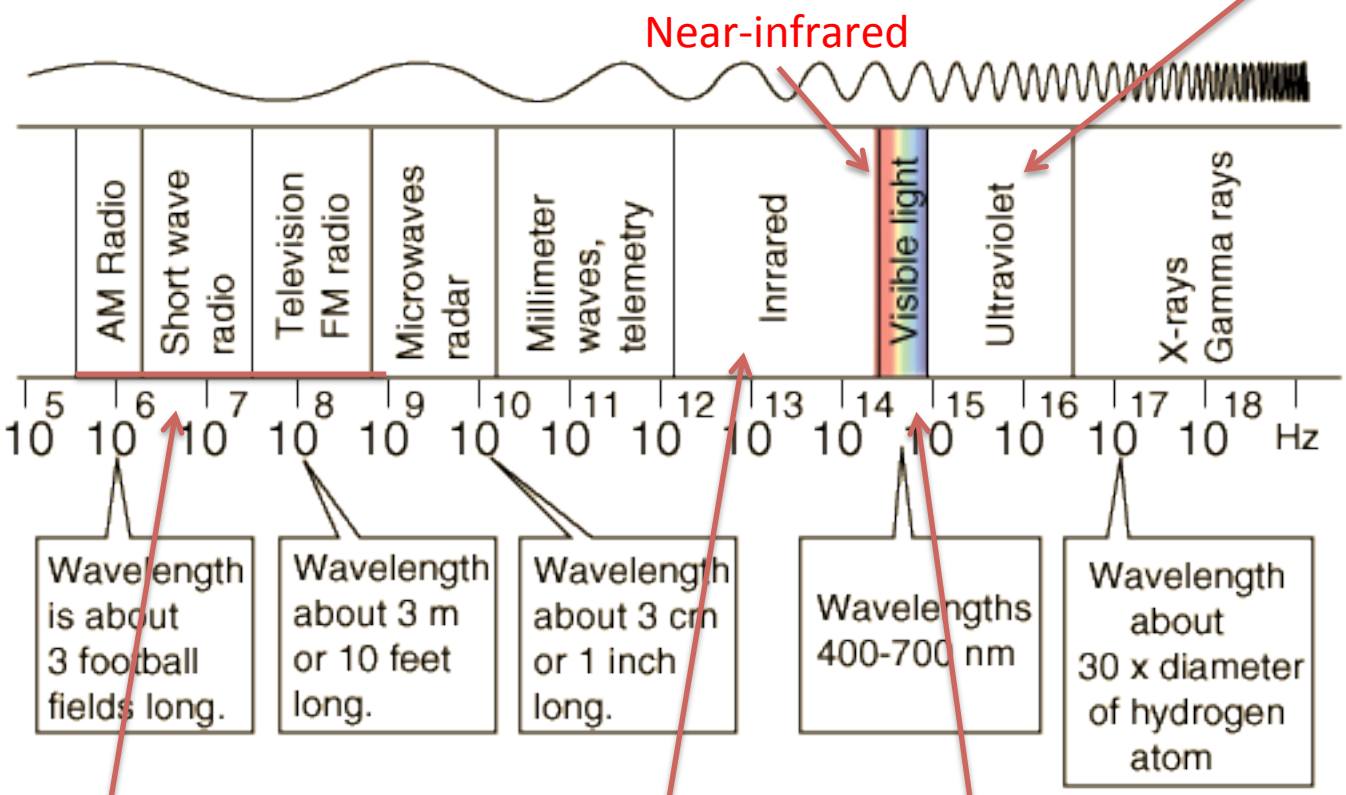
- Think of light "particles" (aka photons) as little wave packets of oscillating electric + magnetic fields traveling through space



Different "wavelengths" = different types of light

Spectrum of Light

Gives you sunburns ☹



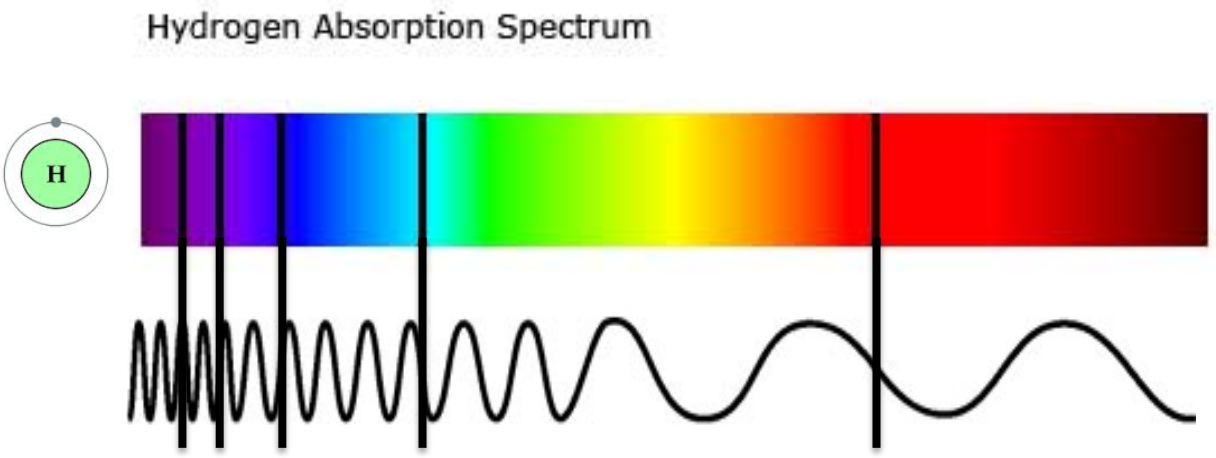
Used for broadcasting & communication

Your body feels infrared wavelengths as heat

These wavelengths register in your eyes and brains as different colors

Spectroscopy

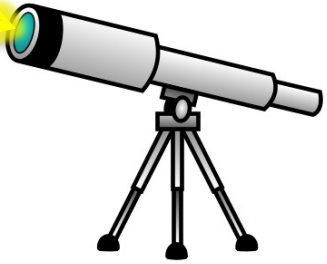
- Spectroscopy studies interactions between light and matter
- Different atoms and molecules emit and absorb light at different characteristic wavelengths



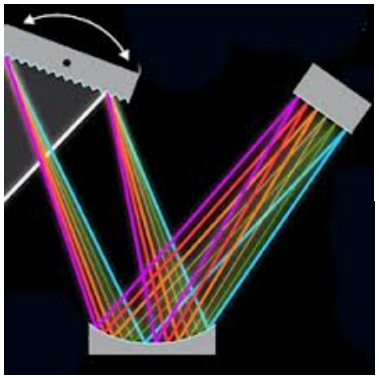
Hydrogen absorbs these wavelengths of light, so they cannot be seen in the spectrum

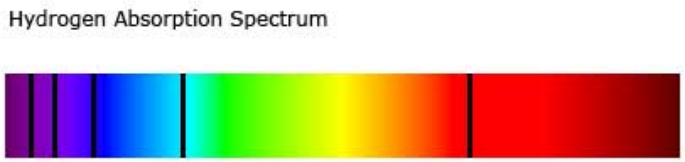
Spectroscopy is useful!!

Planet

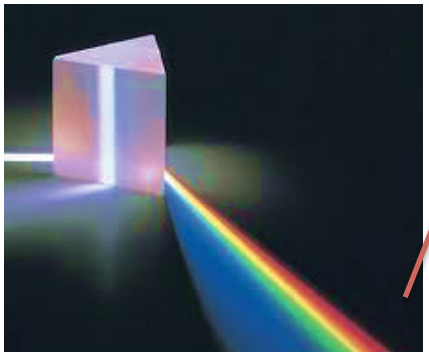


Telescope + spectrograph





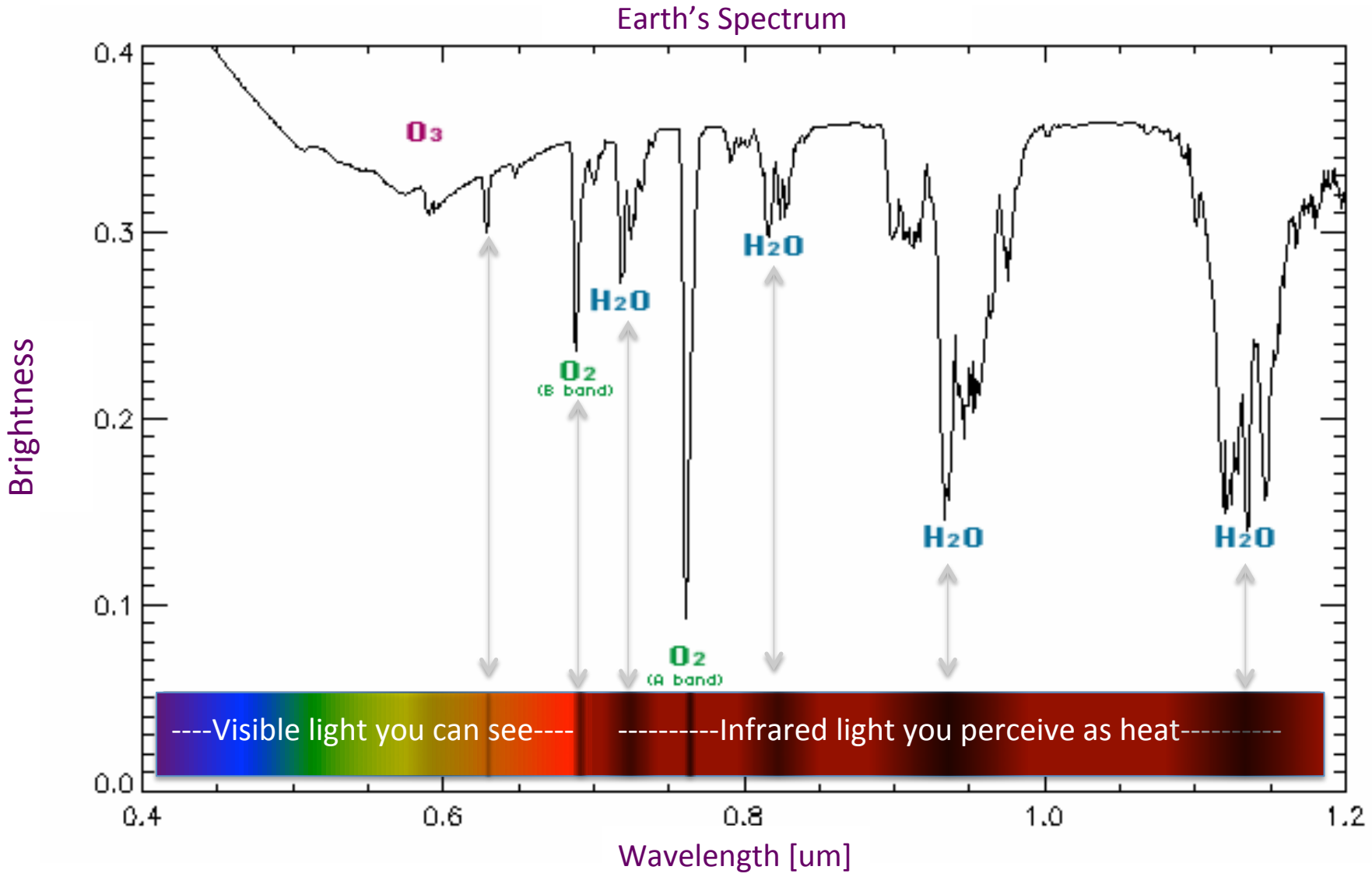
If you see hydrogen there, then you can say…

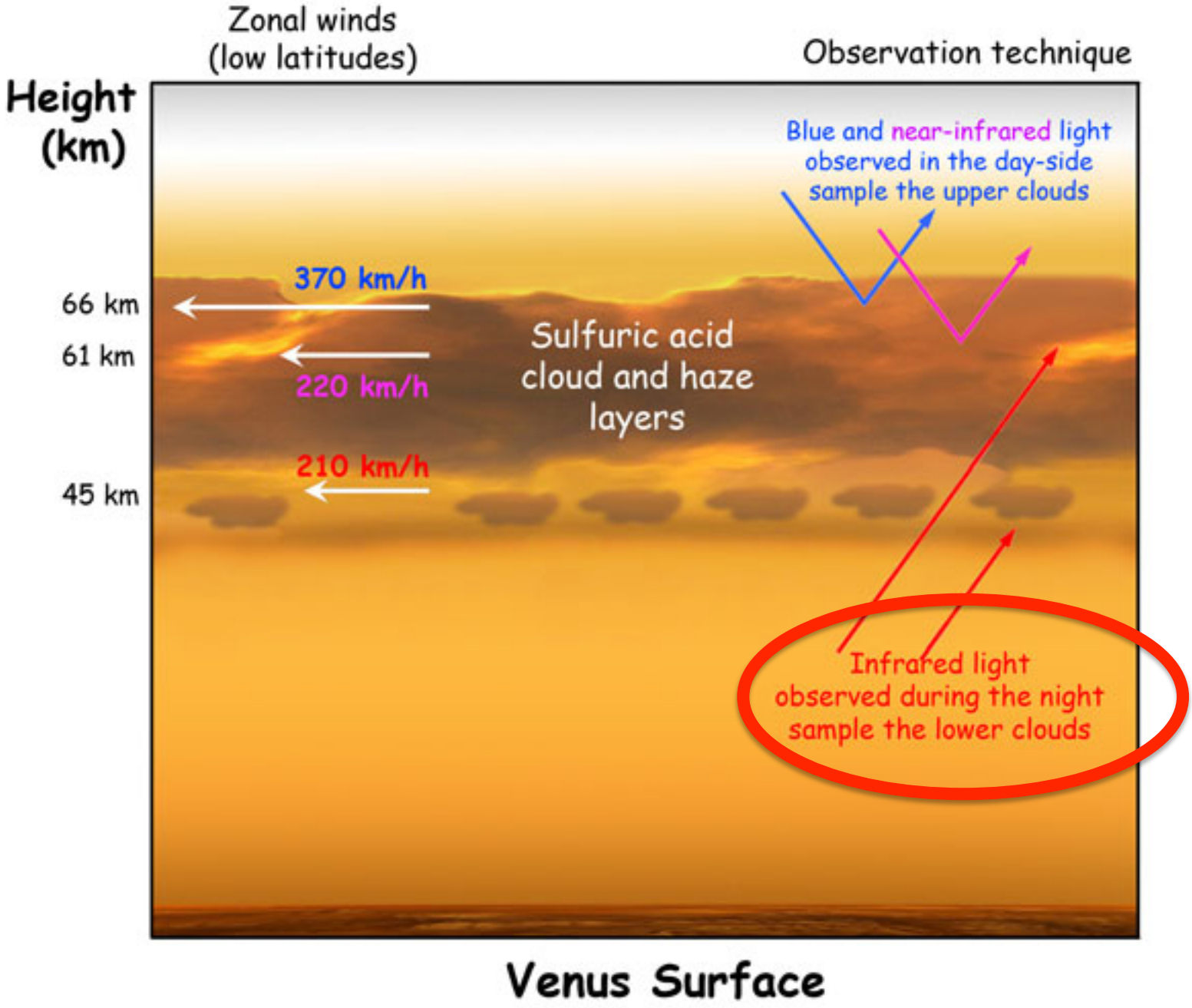


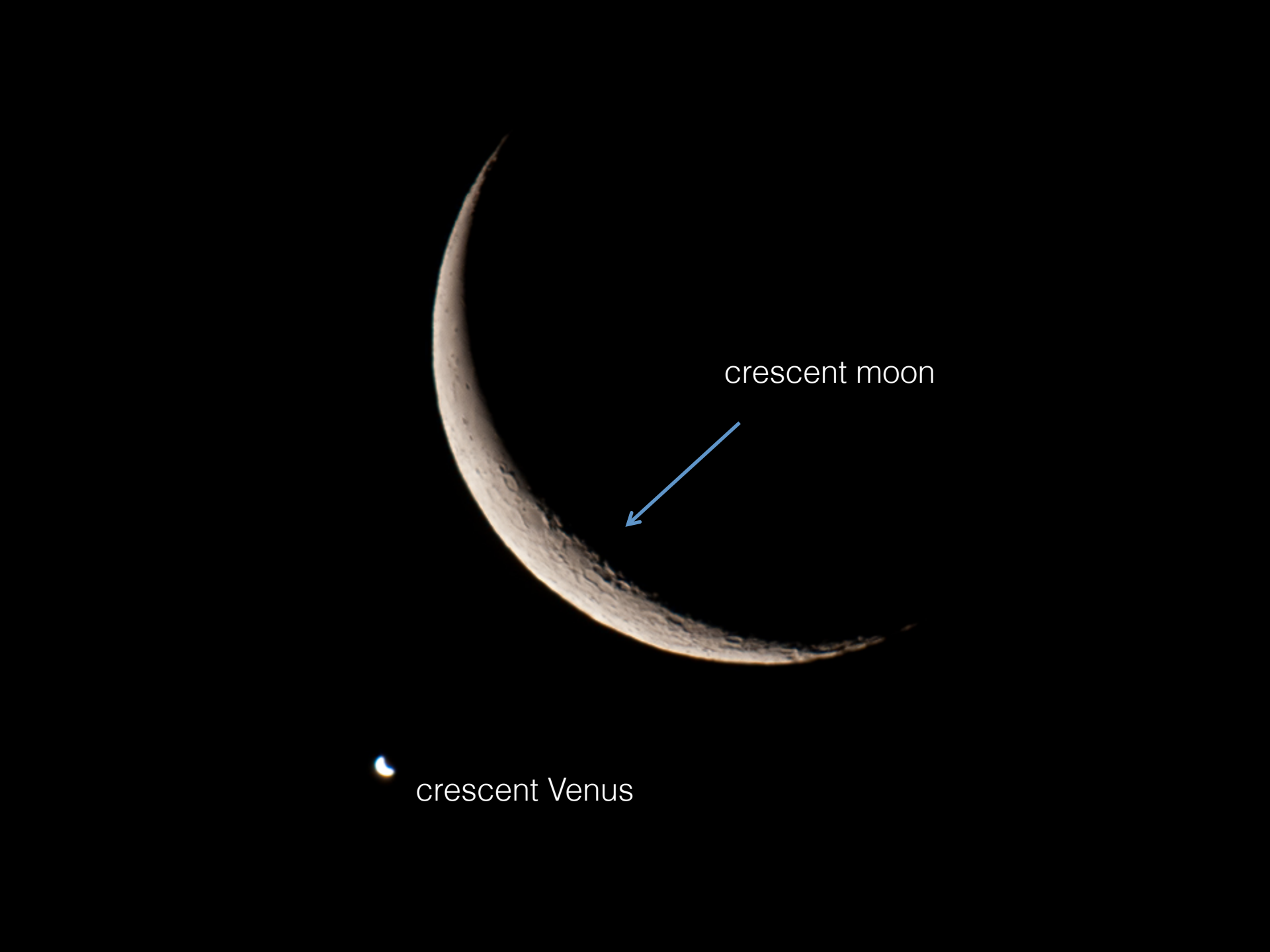
(basically a complicated prism)

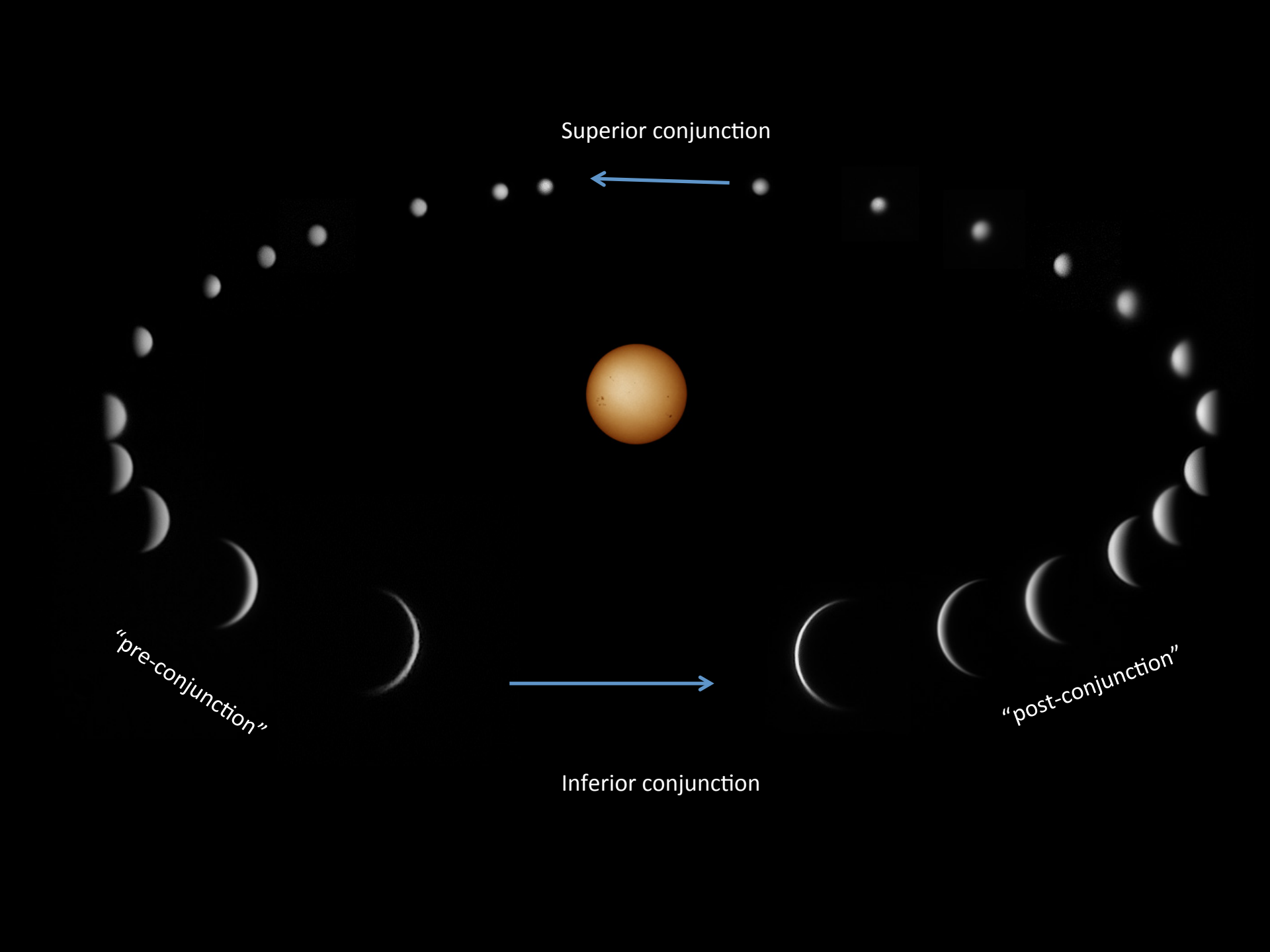
Aha! This planet has hydrogen in its atmosphere!

Example spectrum



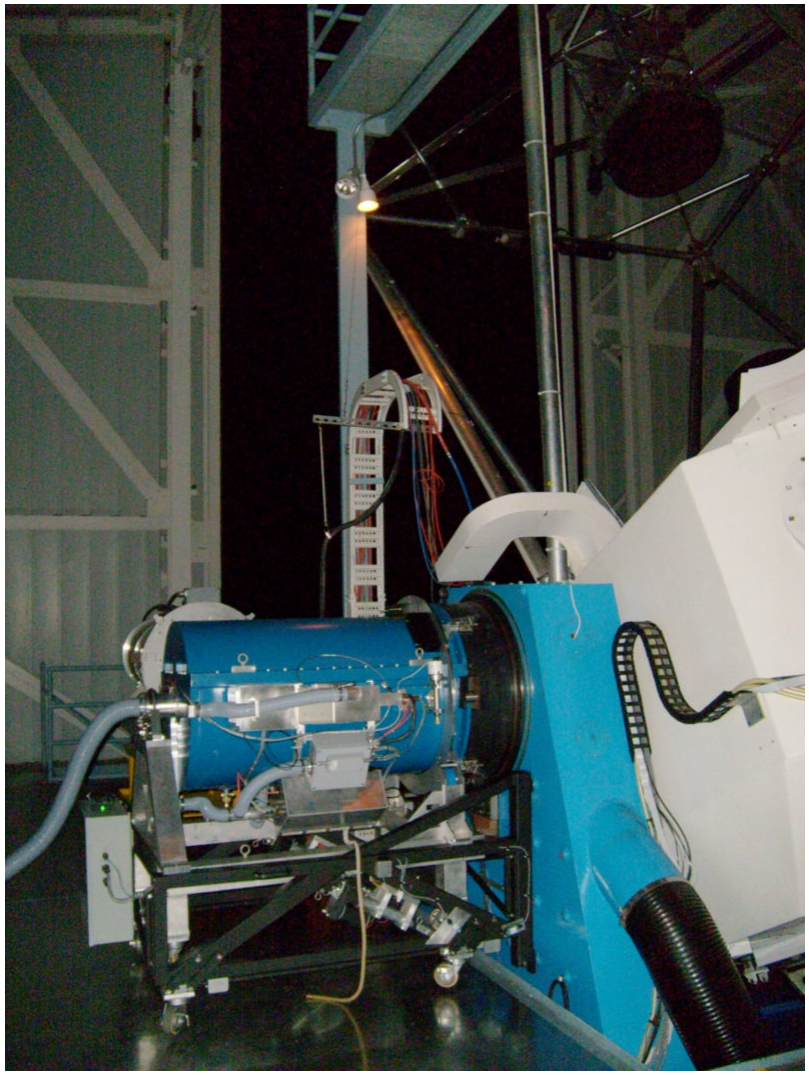

Zonal winds
(low latitudes)
Observation technique
Height
(km)
Blue and near-infrared light
observed in the day-side
sample the upper clouds
370 km/h
66 km
61 km
220 km/h
Sulfuric acid
cloud and haze
layers
210 km/h
45 km
Infrared light
observed during the night
sample the lower clouds
Venus Surface


crescent moon
crescent Venus


Superior conjunction
"pre-conjunction"
"post-conjunction"
Inferior conjunction

Our observations

- Six nights in late November & early December 2010 "post-conjunction"
- Apache Point Observatory 3.5m telescope Triple Spec instrument



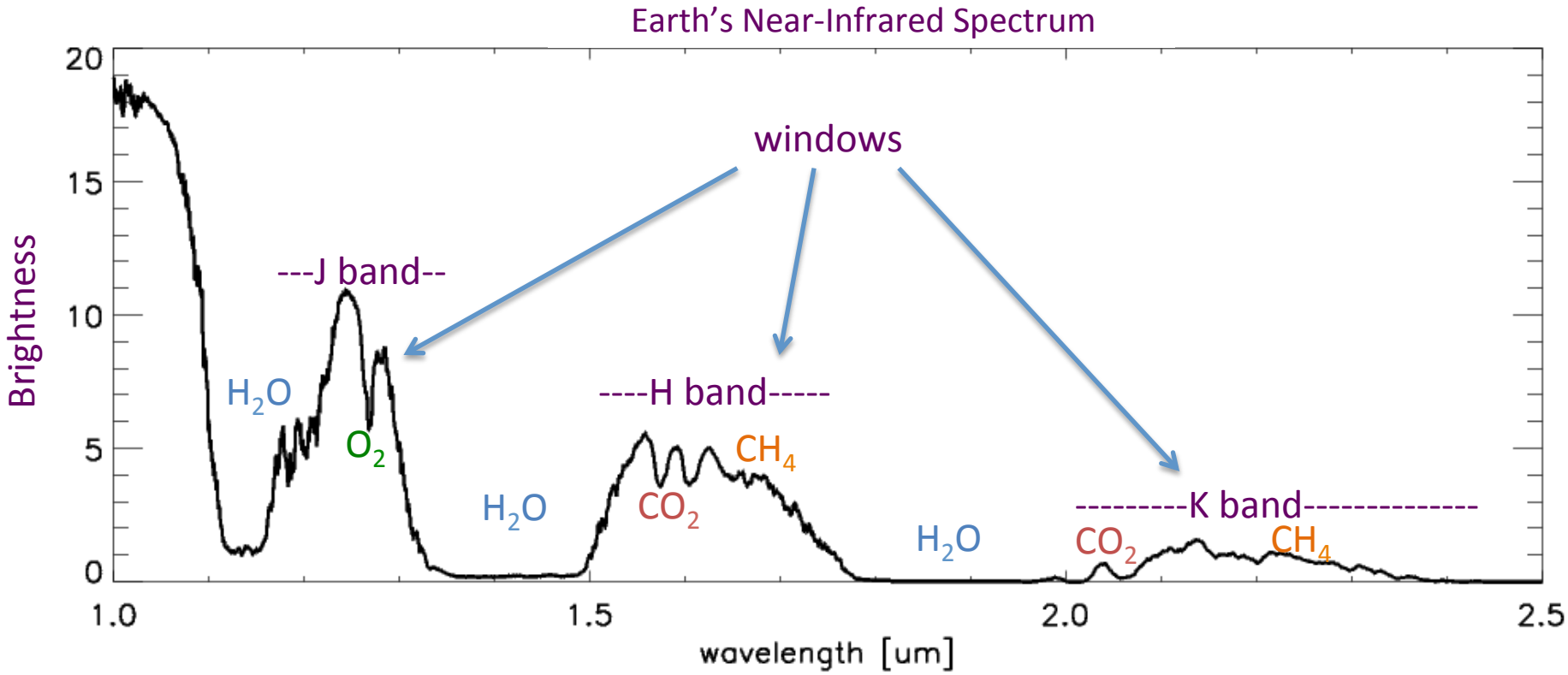
Why are we doing this?

- What do we want to learn?
  - What's in Venus' atmosphere and where is it? This will help us better understand the Venus greenhouse
  - Is there current volcanism?

- How can we learn these things?
  - Spectroscopy of Venus' atmosphere
  - Imaging the surface of Venus

Near Infrared Atmospheric Windows

Earth's atmospheric windows: J, H, K bands
This spectrum is of Earth's DAYSIDE



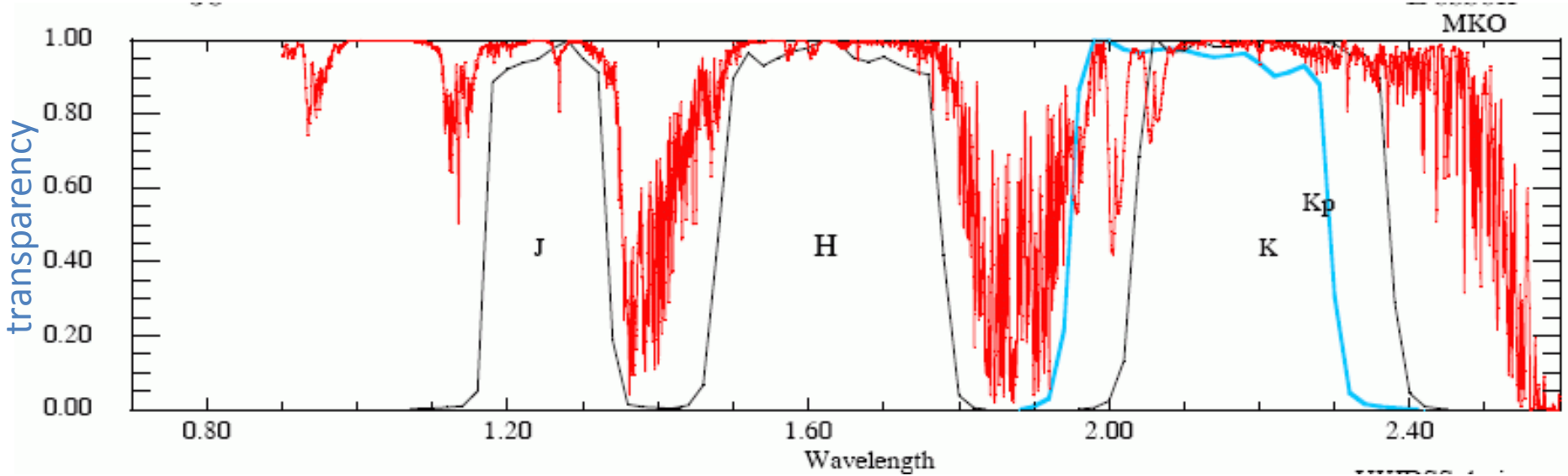
----------Infrared light you perceive as heat----------

Near IR Atmospheric Windows

Think of windows as places where the atmosphere is relatively transparent.

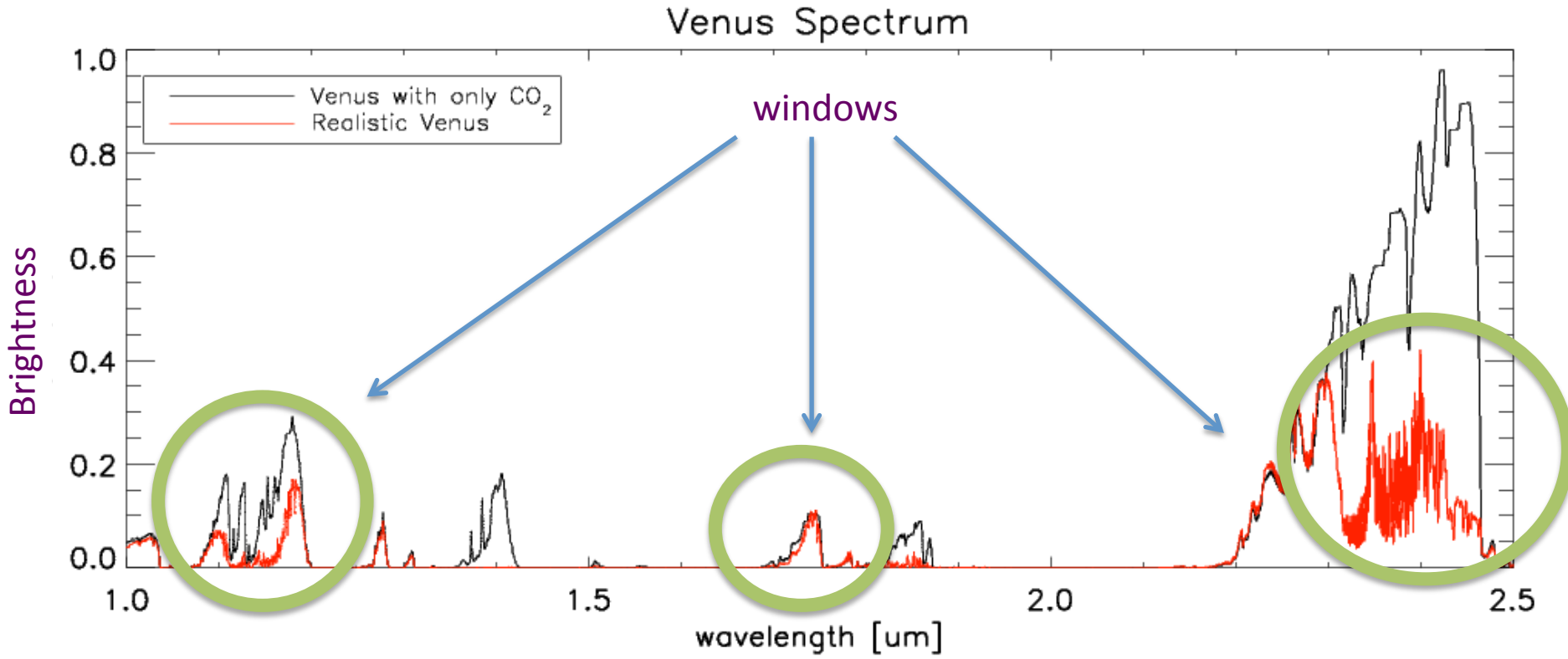
- Good wavelength regions to look into space if you're on the surface (or to look at the planet's surface if you're in space).

Earth's NIR atmospheric transparency



Near IR Atmospheric Windows

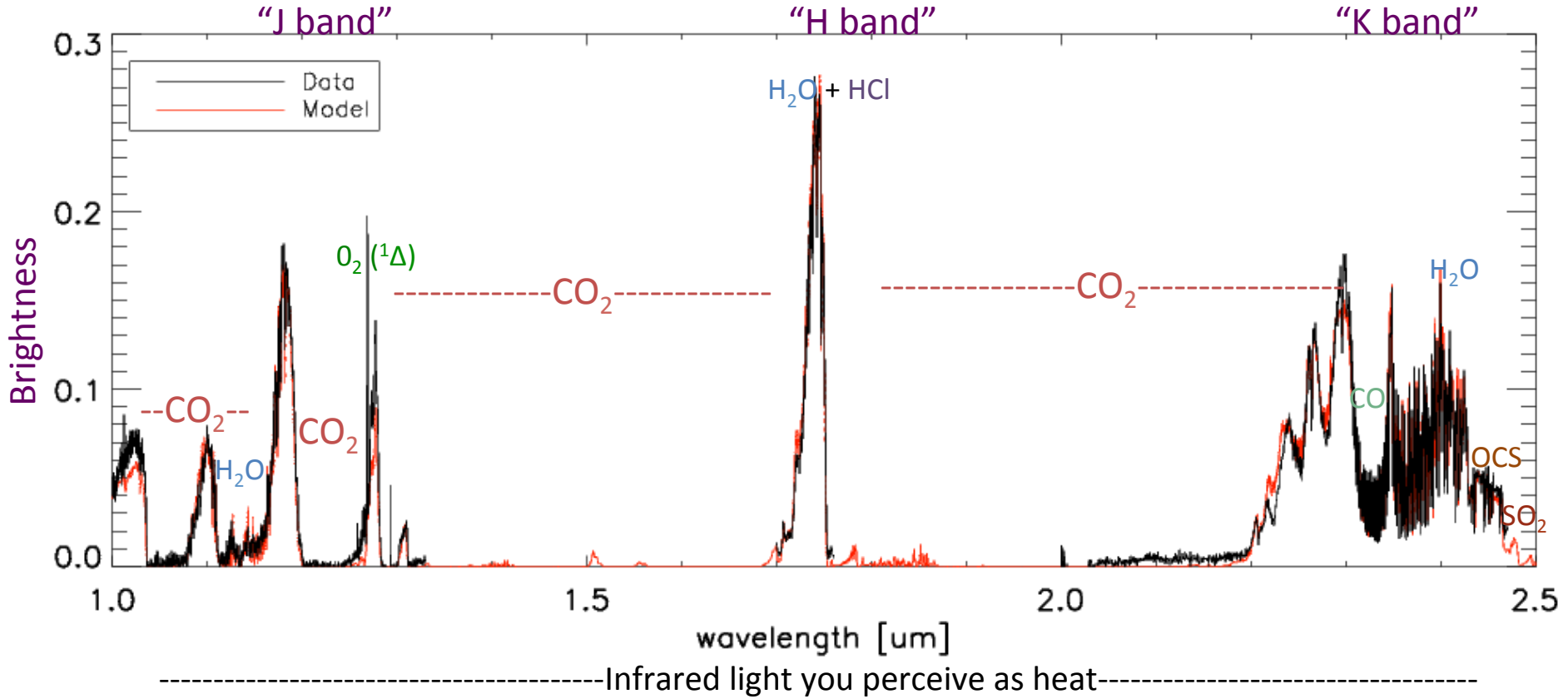
We can use Venus' atmospheric windows to probe the surface and lower atmosphere.
These spectra are of Venus' NIGHTSIDE



----------Infrared light you perceive as heat----------

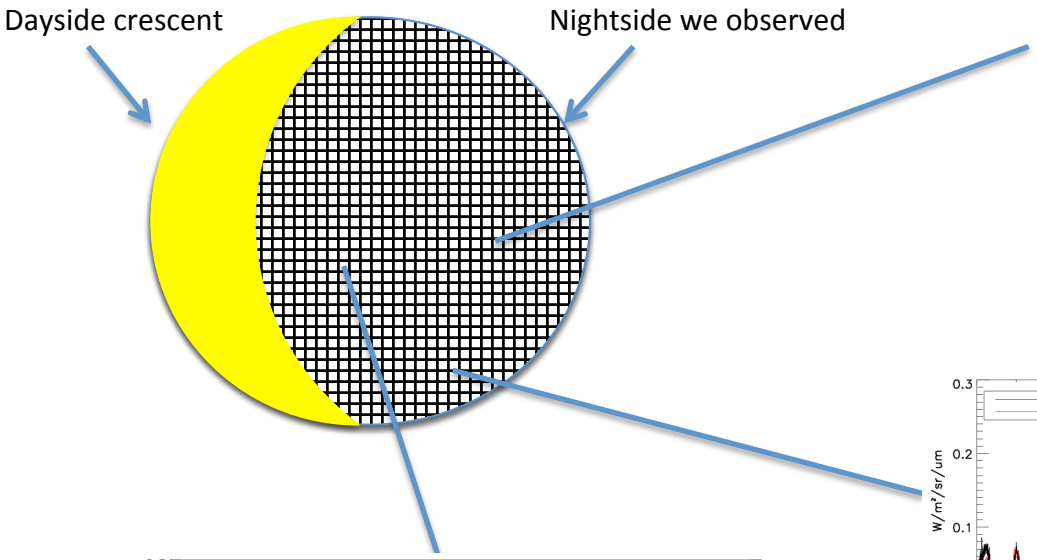
Near IR Atmospheric Windows

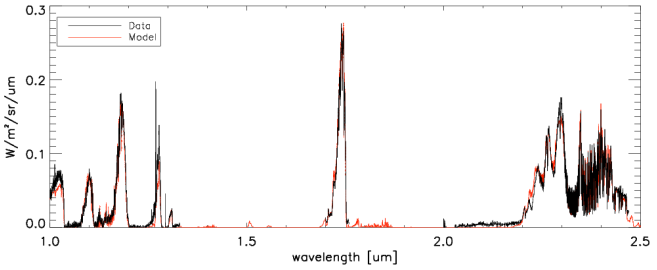
Venus atmospheric windows can measure minor species, can tell us about cloud properties, and can measure surface thermal variations



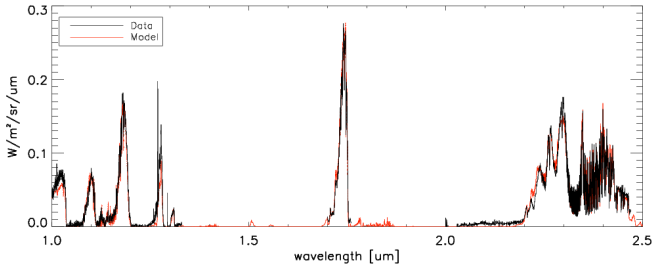
The data we have

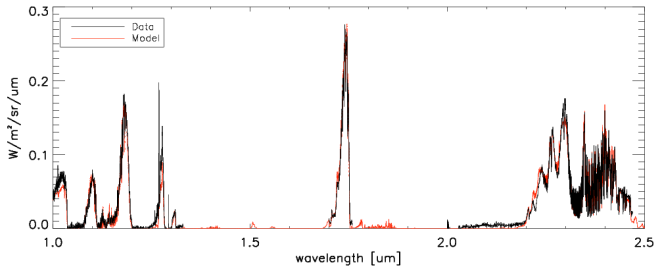
- 6 nights of data





Each pixel has an associated 1-2.5µm spectrum

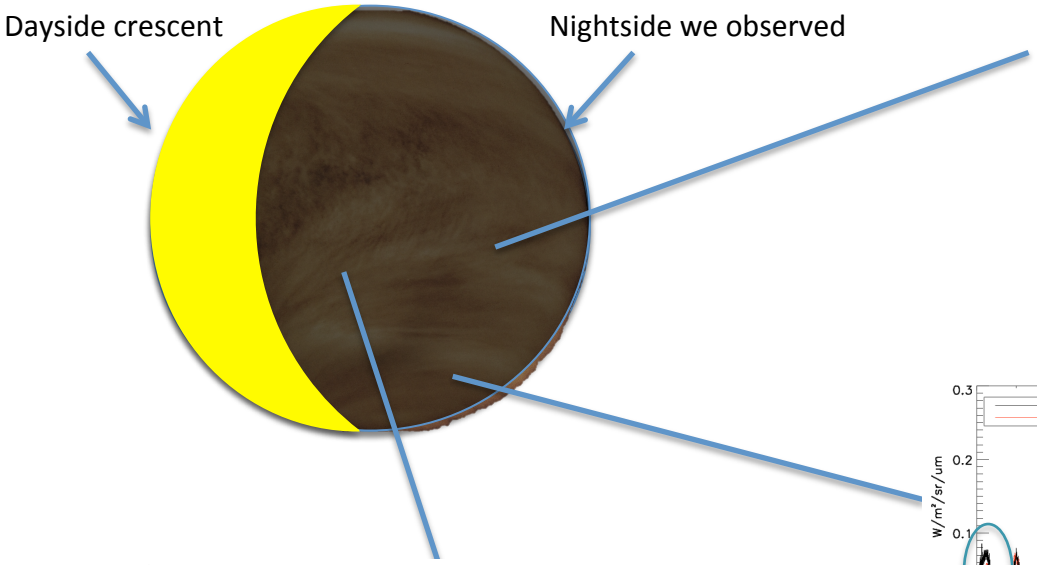


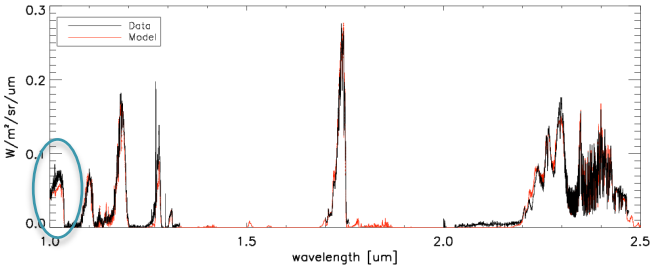


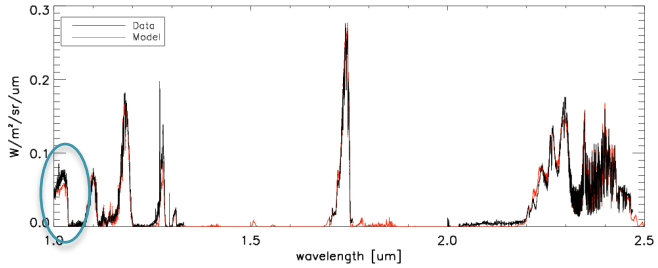
Spatial, temporal, and spectral information ☺

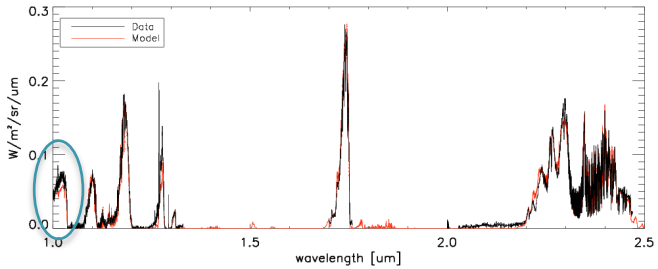
Imaging the surface

1.0um window is 96% surface thermal emission



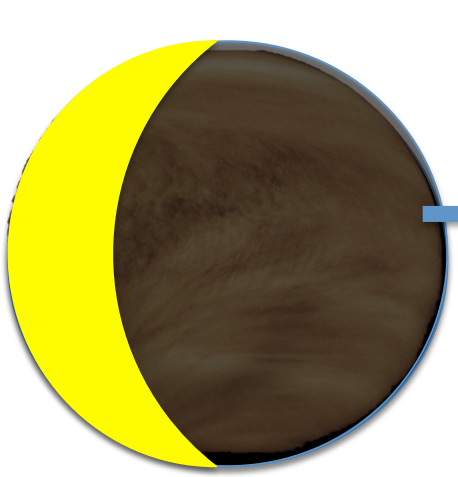




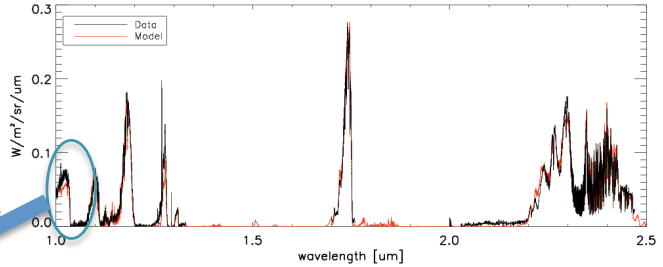


Imaging the surface

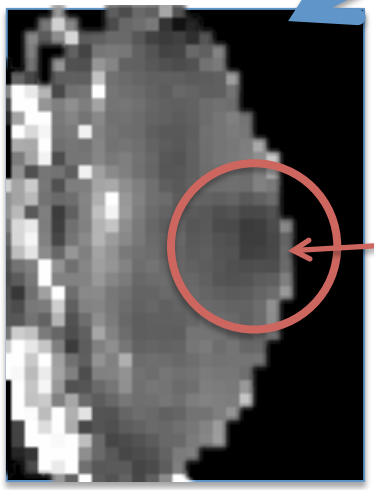
How do you do it?



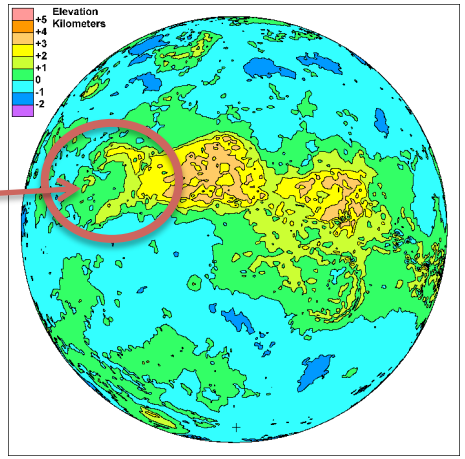
Measure 1um brightness in each pixel



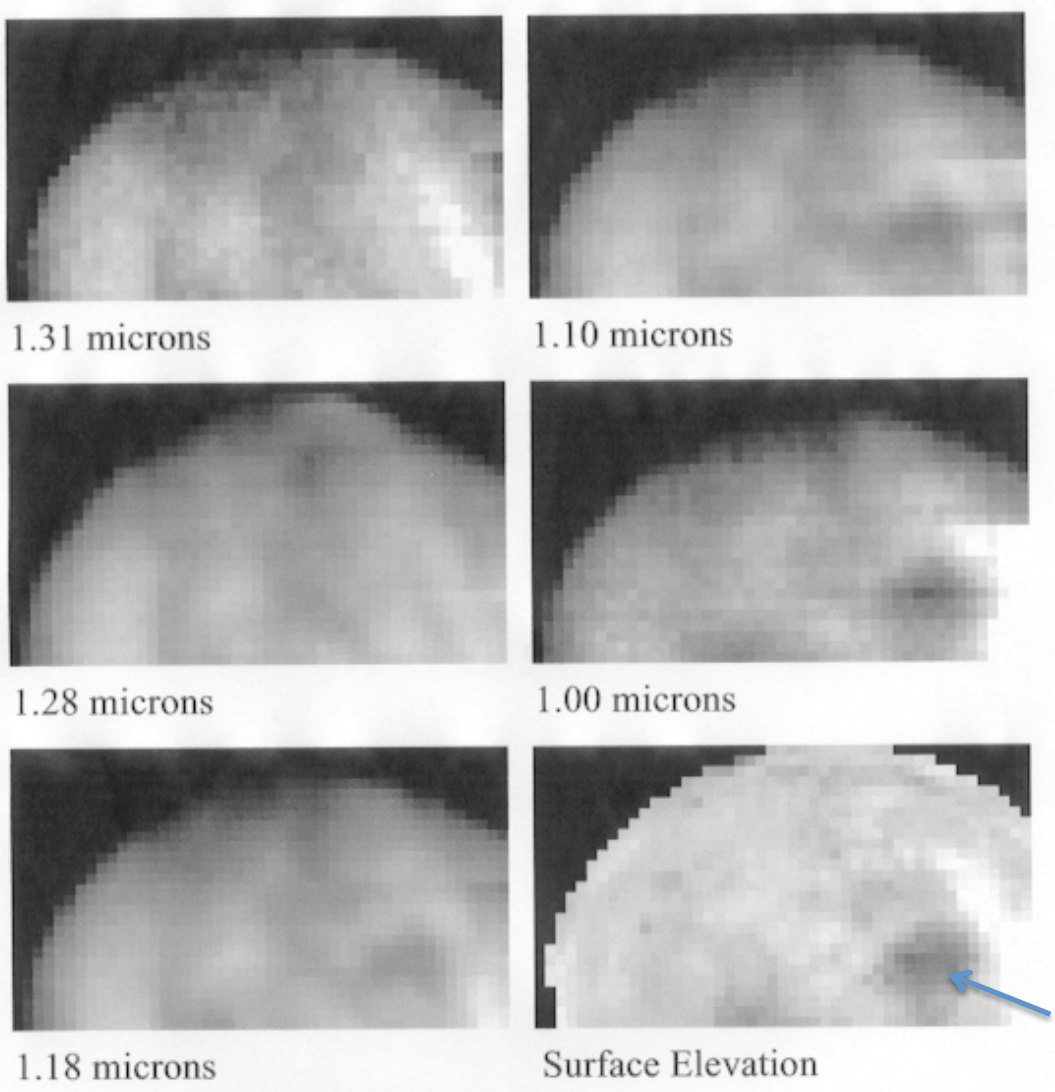
Build up map of brightness variations



Aphrodite Terra

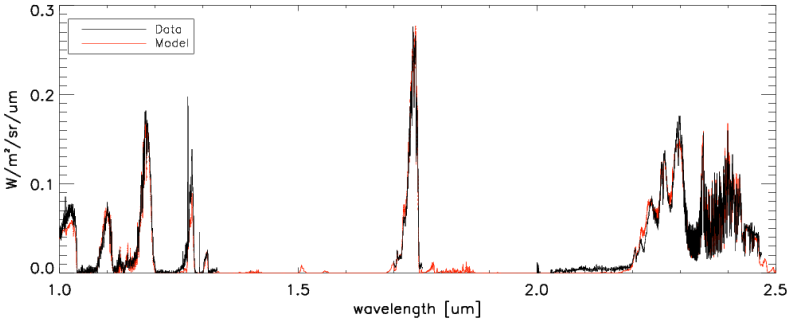


Images in the Windows



Meadows and Crisp, 1996, JGR-Planets, 101, 4595.

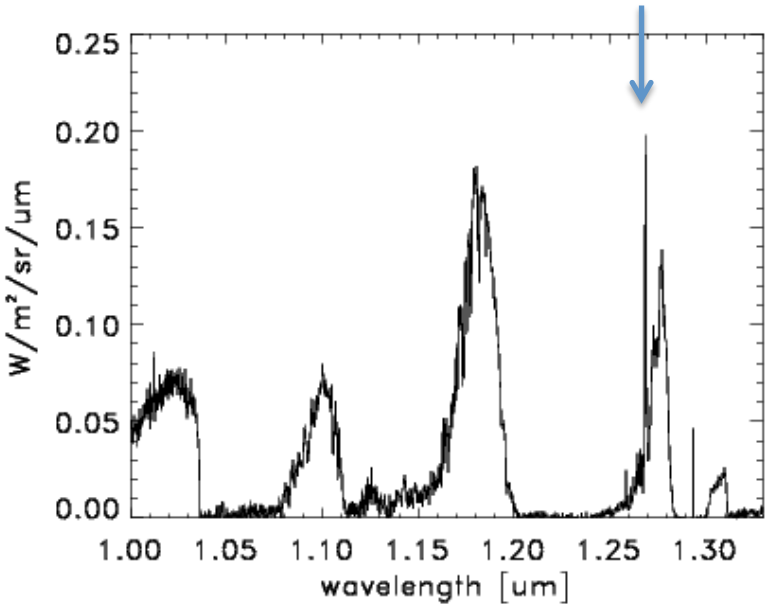
The windows probe to different altitudes, so we see different patterns at different wavelengths.

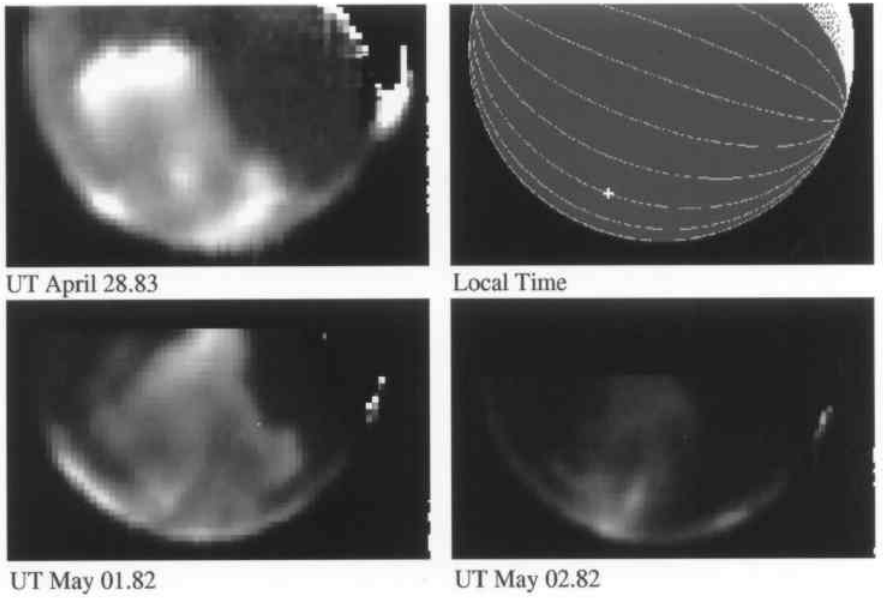


Beta Regio

Oxygen Airglow

- CO_2 is broken apart high in the atmosphere on the dayside. O_2 recombines in mesosphere on the nightside and releases light at ~1.27um

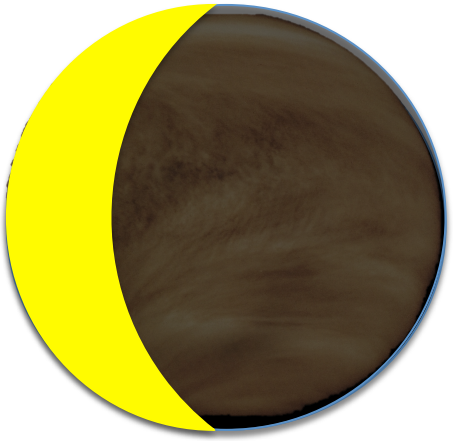




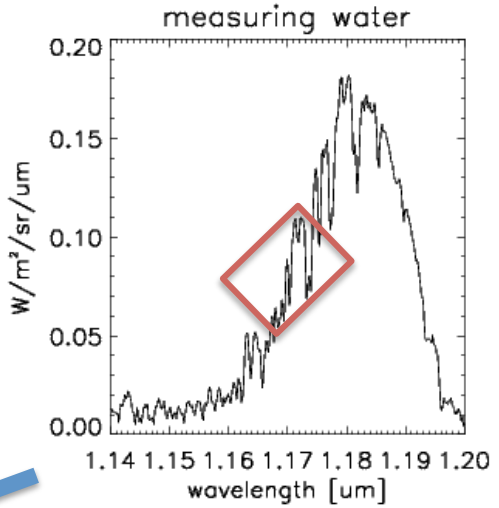
AAT IRIS Data, 1993, Meadows, Allen and Crisp

Measuring Atmospheric Species

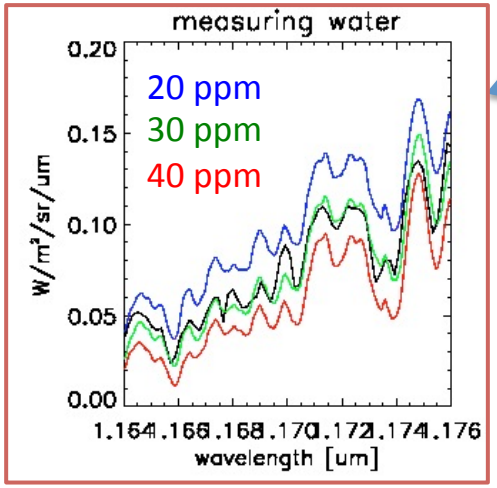
The general idea is:



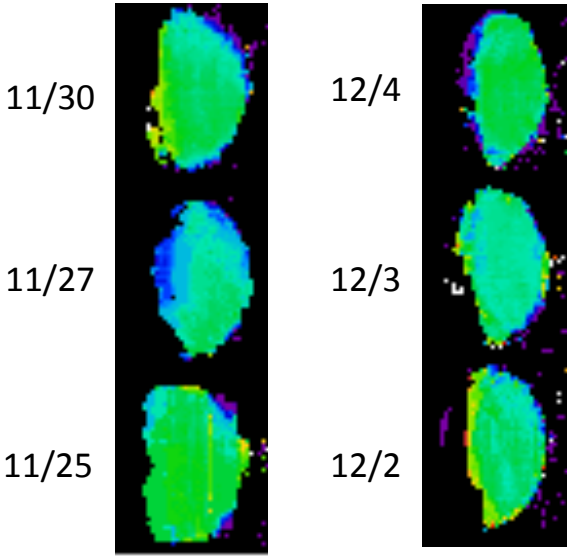
Measure spectral range of interest in each in each pixel

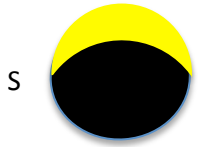


Compare models to data in spectral region



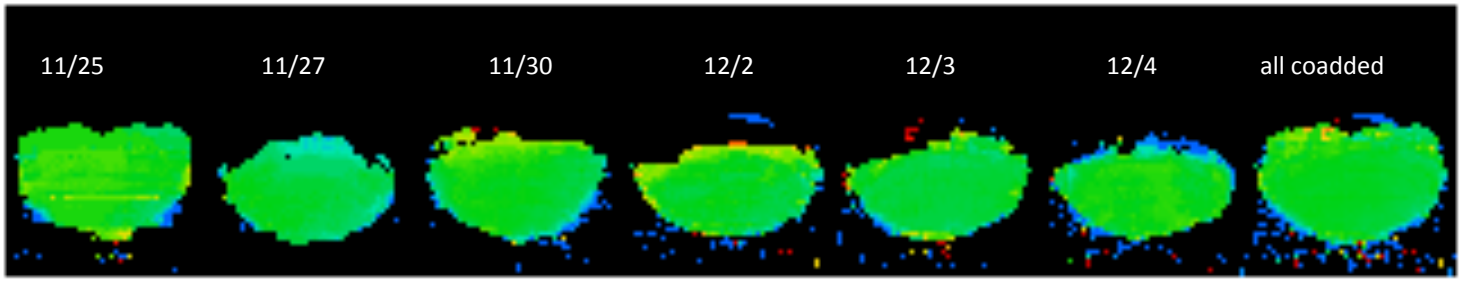
Determine best fit model for each pixel
to build up abundance maps on each night

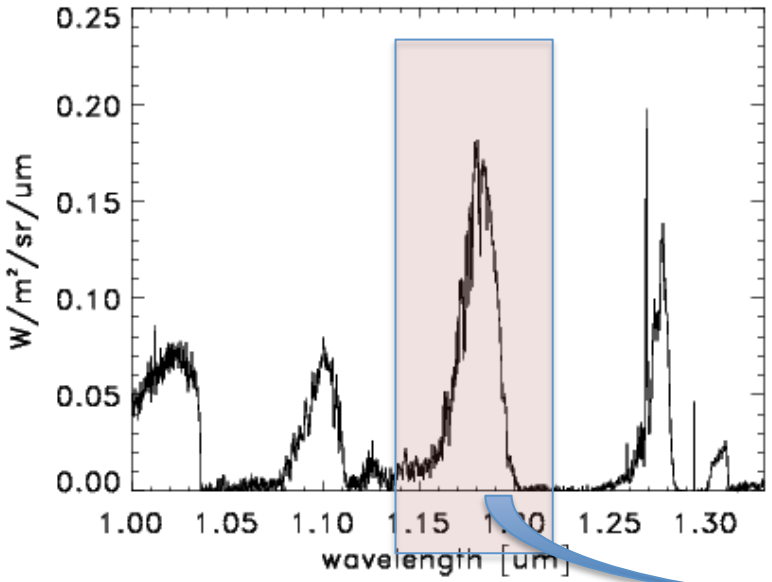


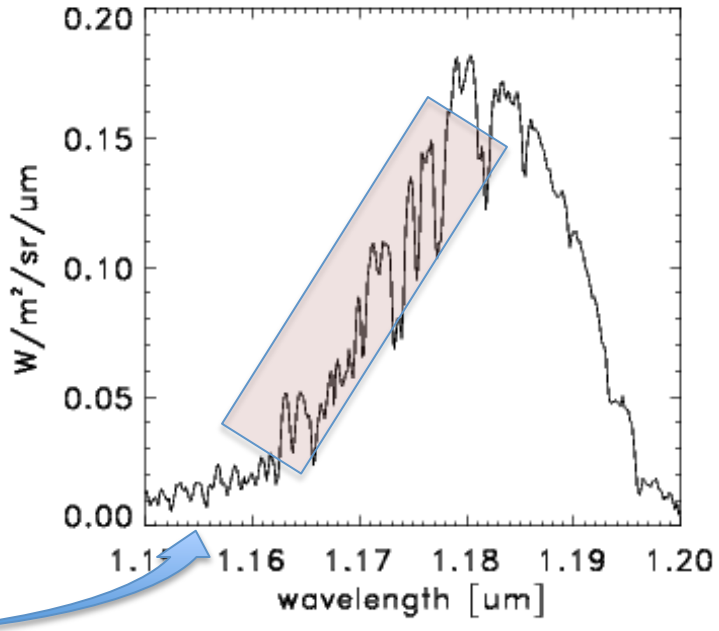


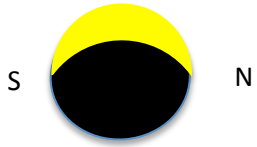
Water Maps

1.18µm window: below 16 km



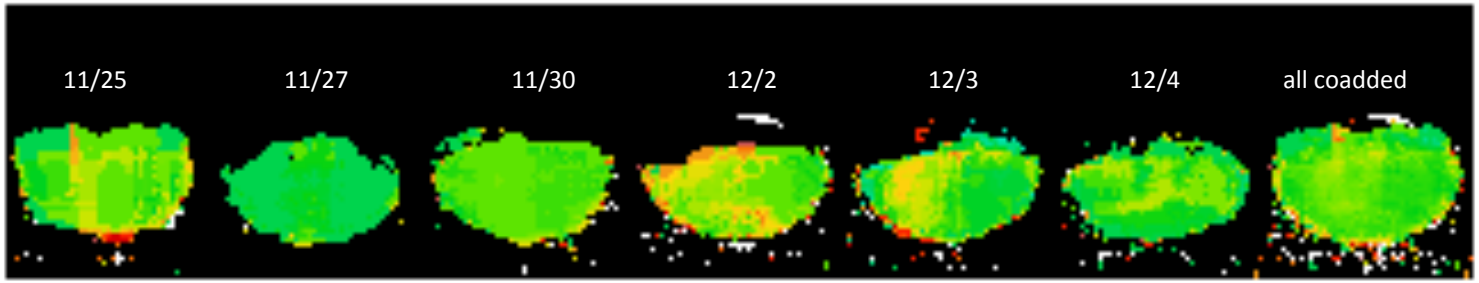


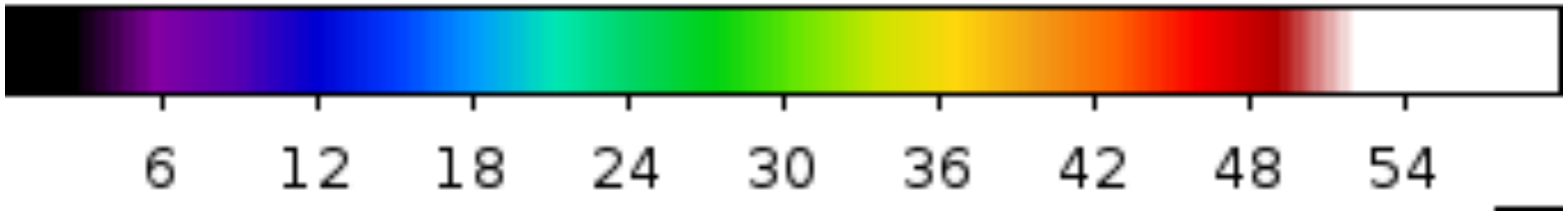


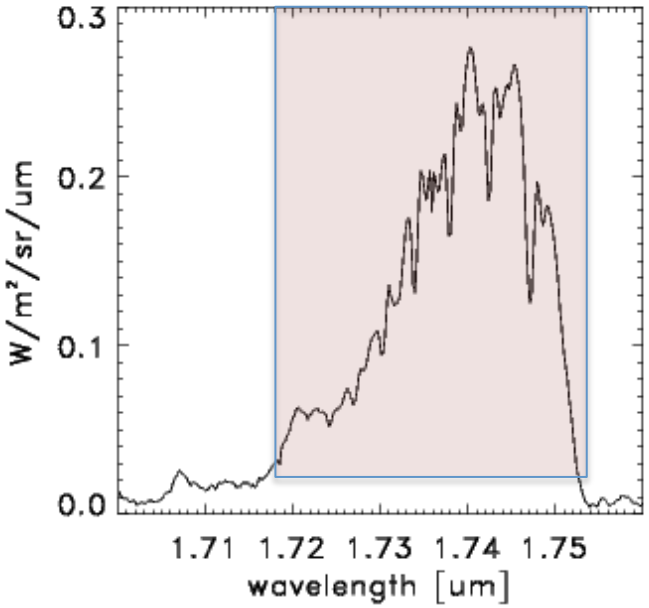


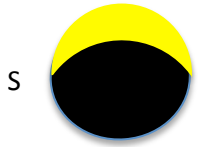
Water Maps

1.74µm window: 16-30 km



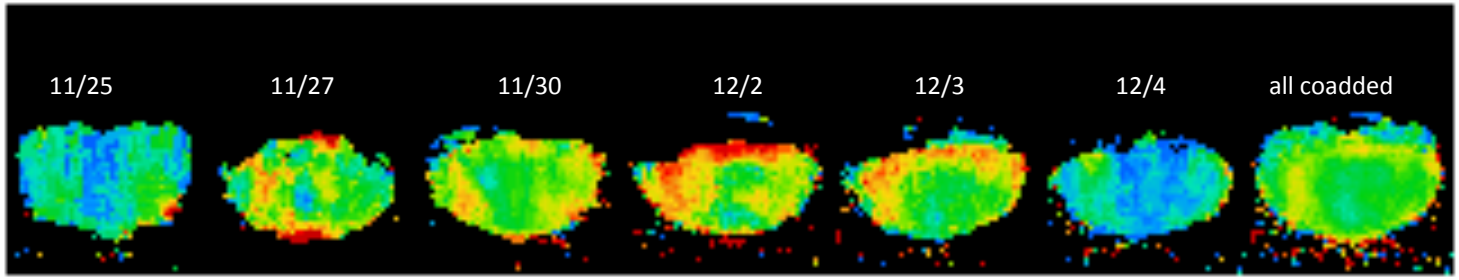


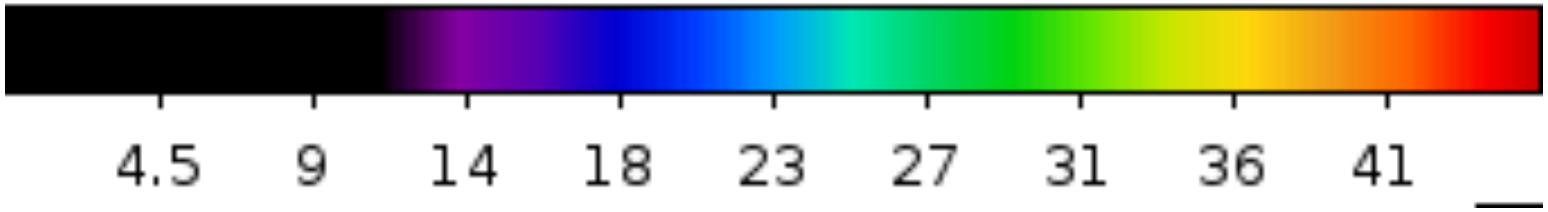


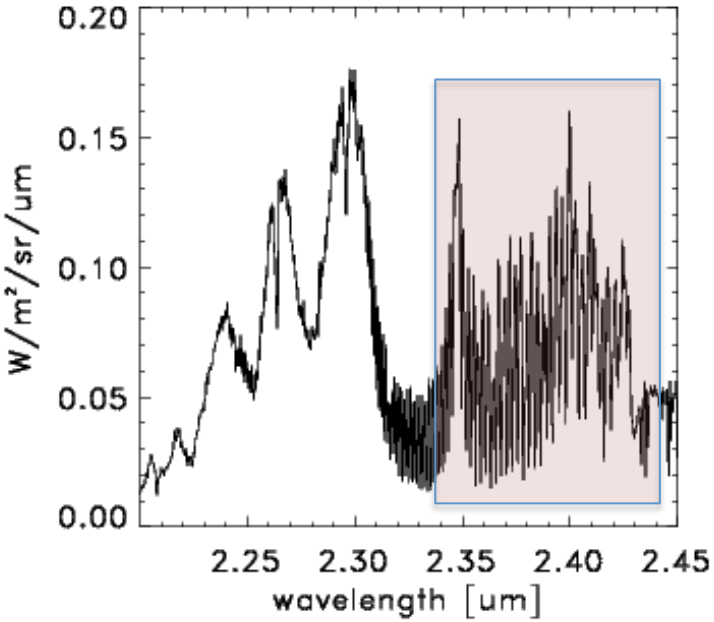


Water Maps

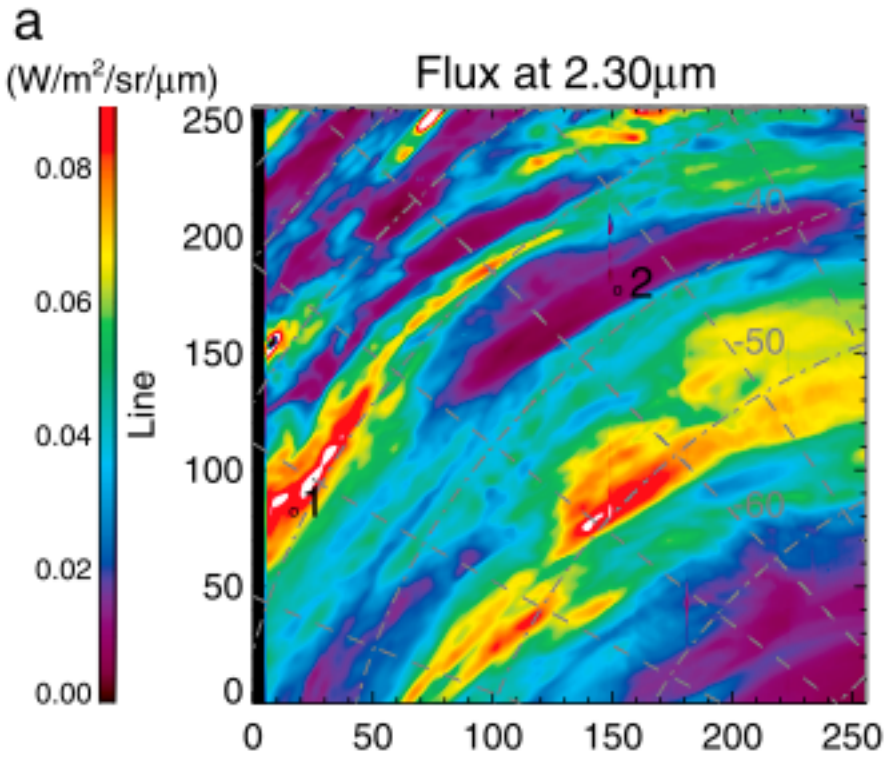
2.3µm window: 30-45 km

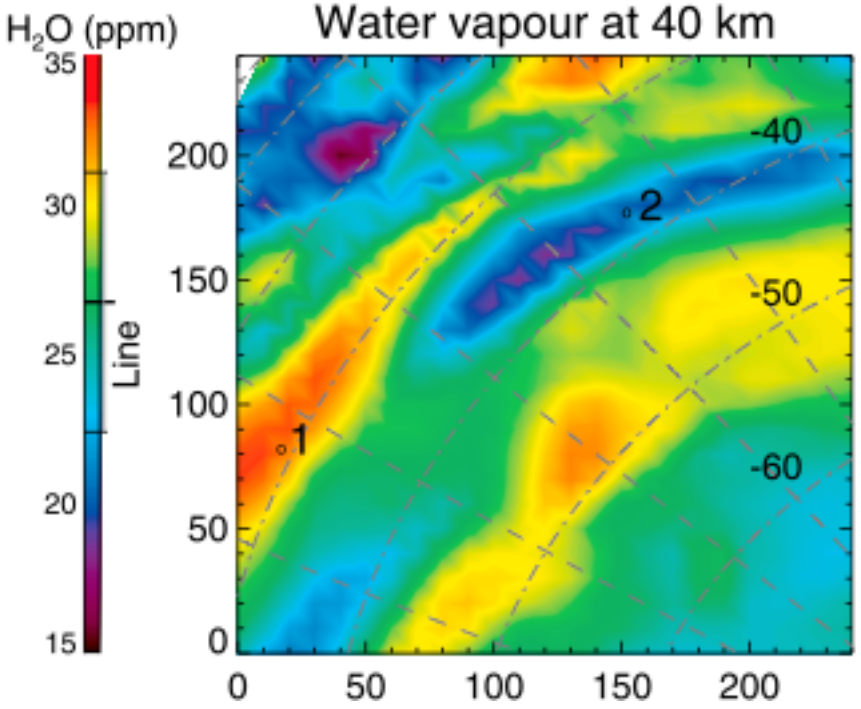






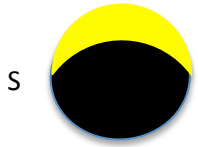
Water & Clouds





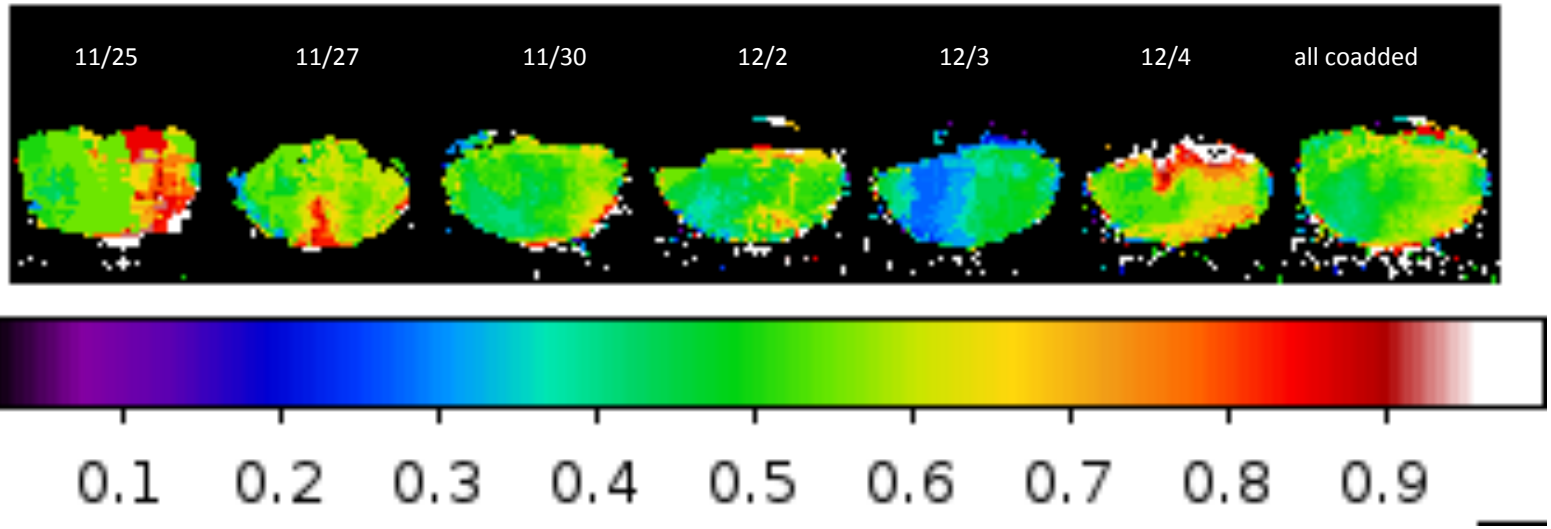
Tsang et al 2010

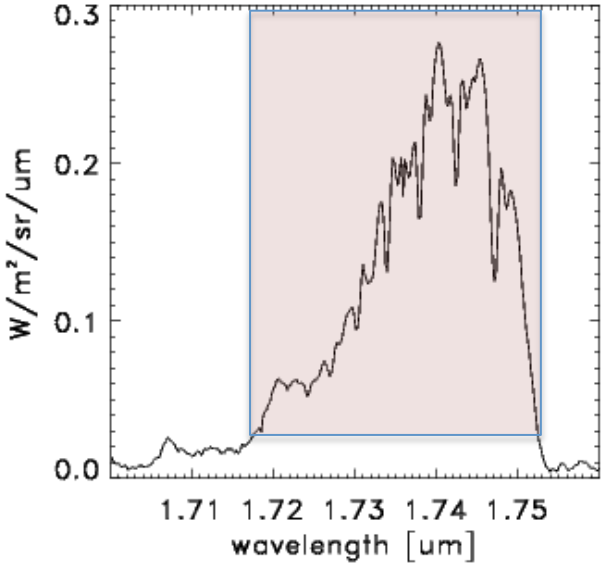
Venus Express

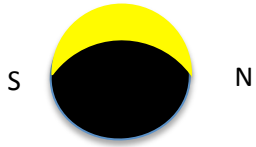


HCl Maps

1.74µm window: 16-30 km

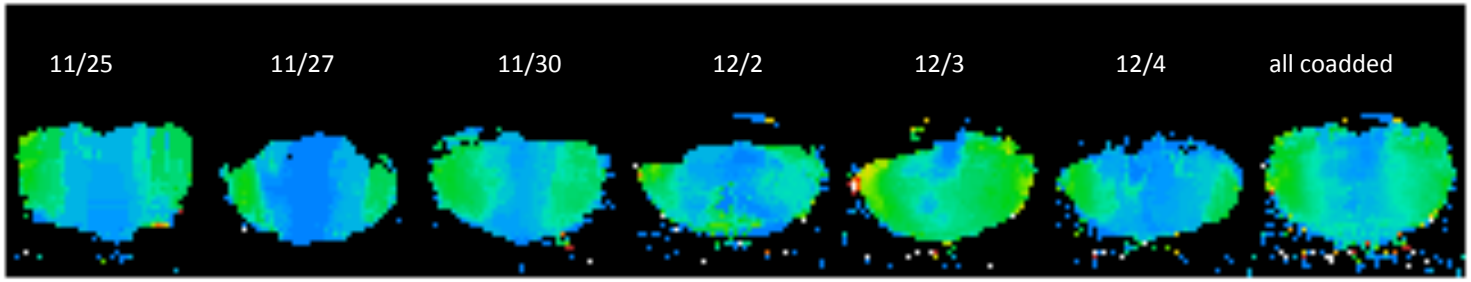


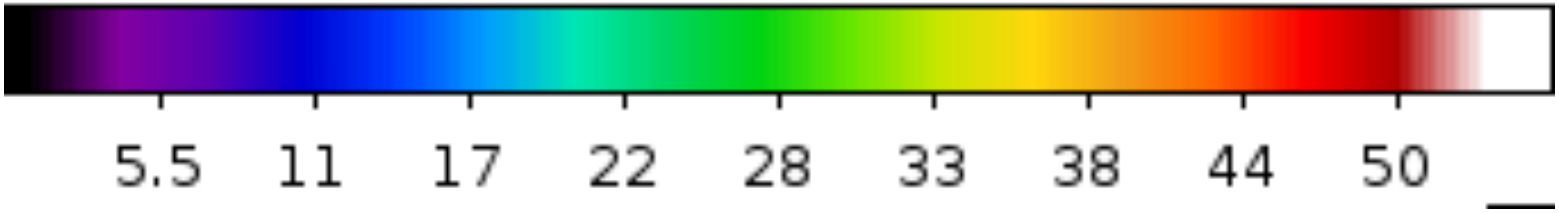


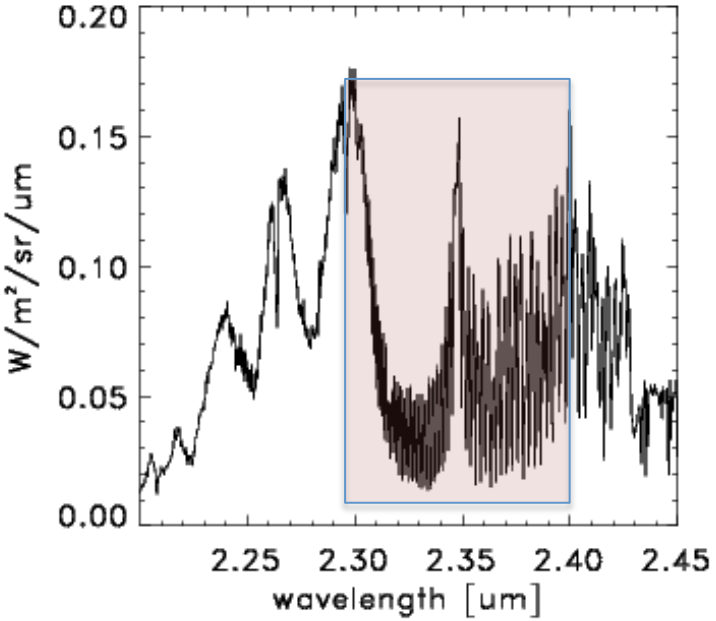


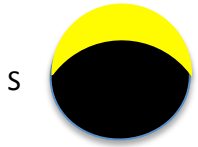
CO Maps

2.3µm window: 30-45 km



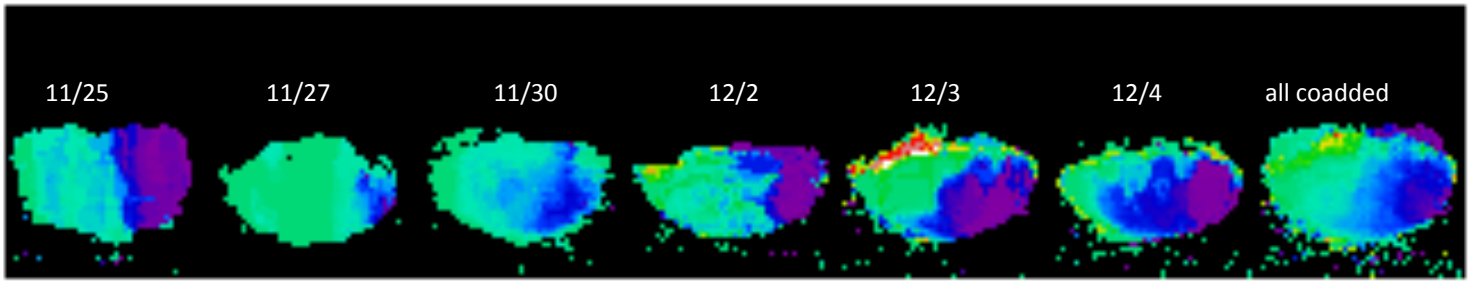


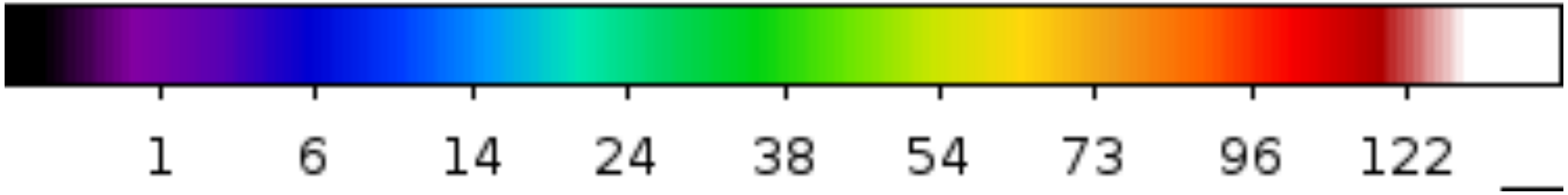


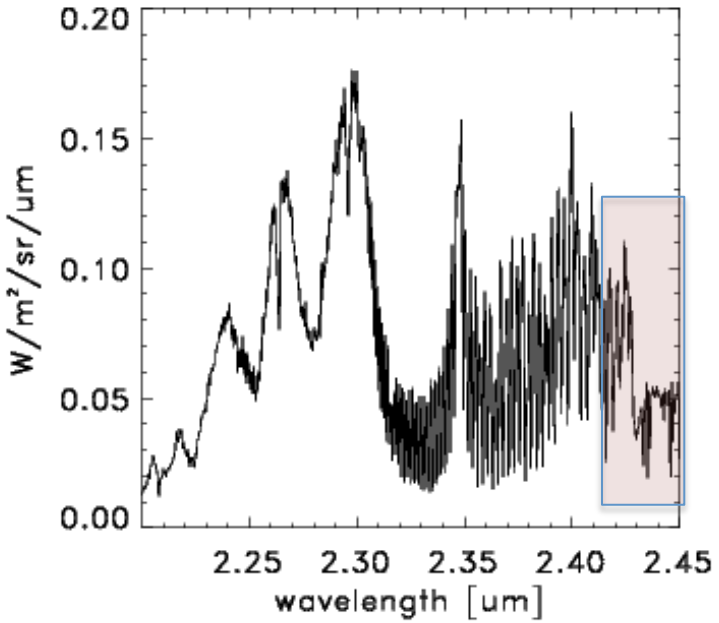


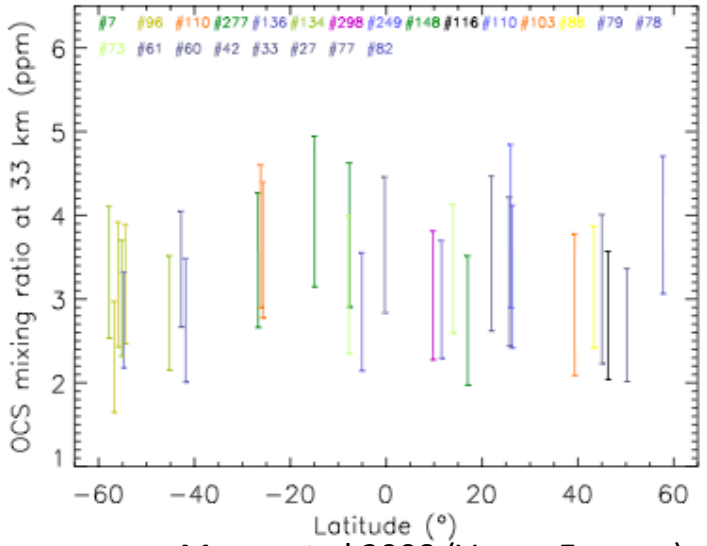
OCS Maps

2.3µm window: 30-45 km

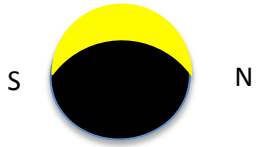








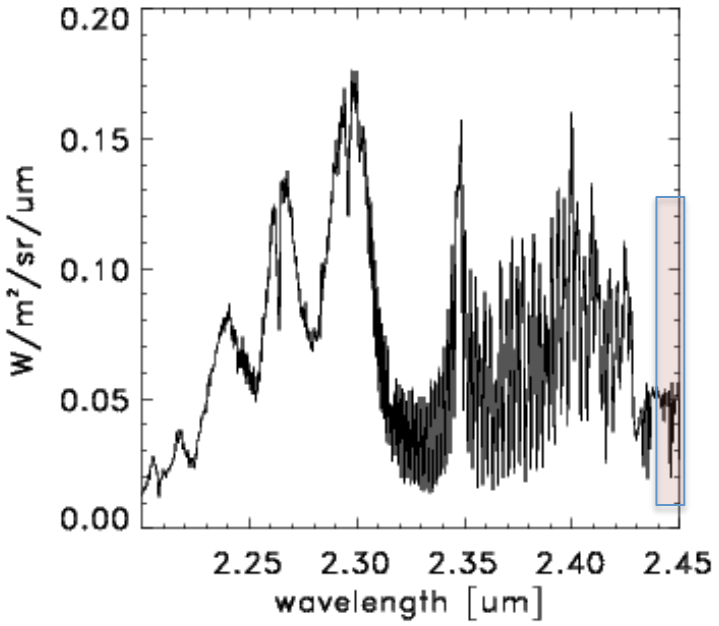
Marcq et al 2008 (Venus Express)

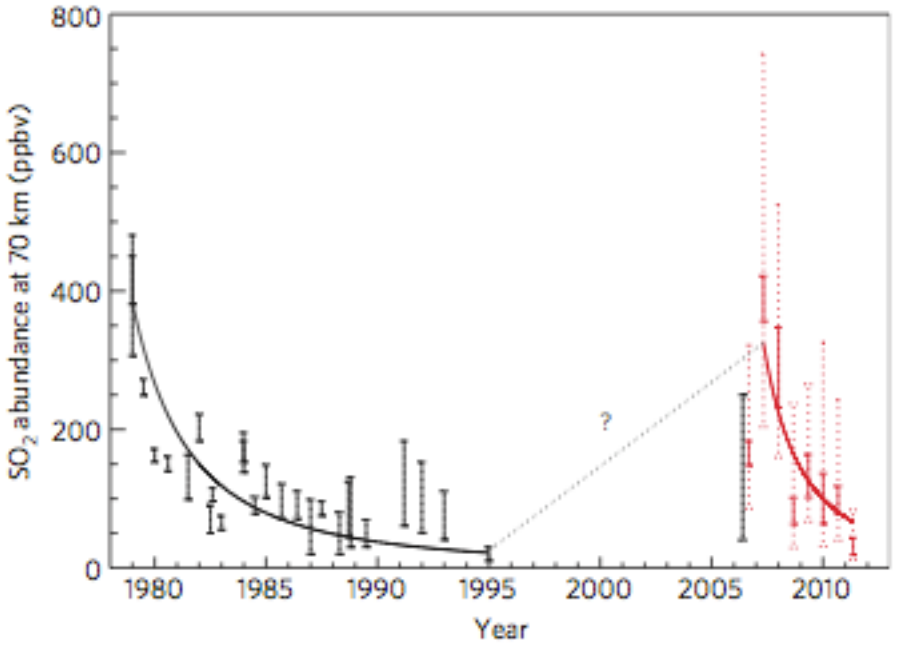


SO_2 Maps

2.3µm window: 30-45 km

TBD…





Marcq et al 2012 (Venus Express)

Calvin J. Hamilton