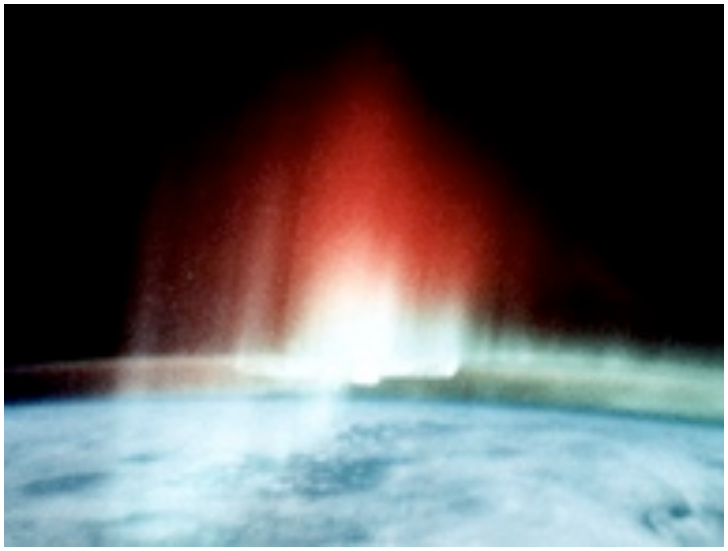
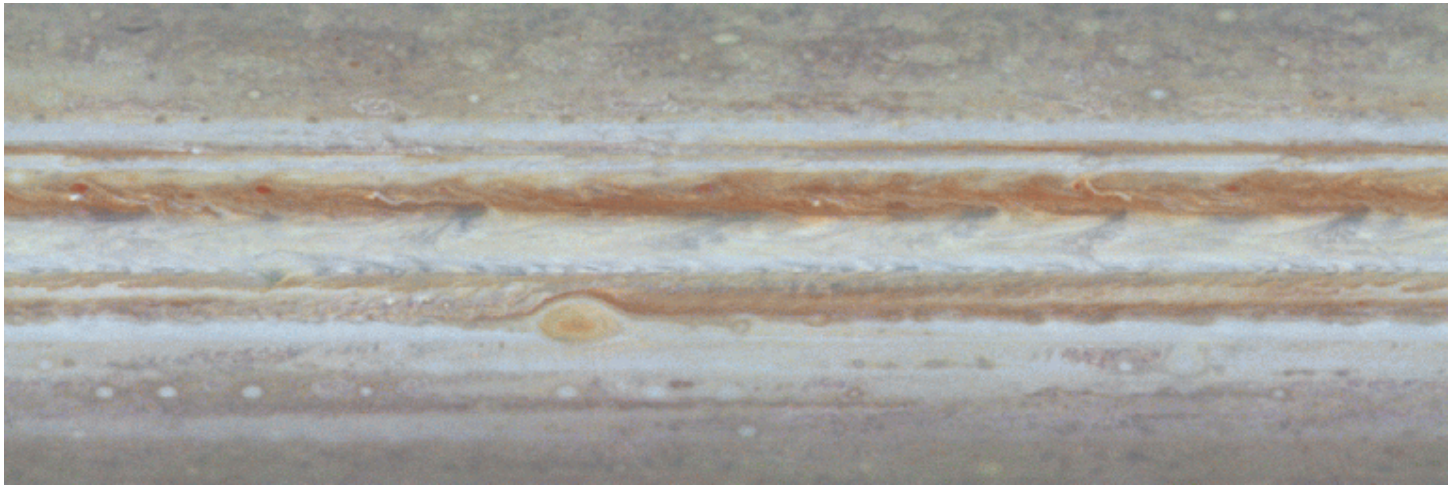
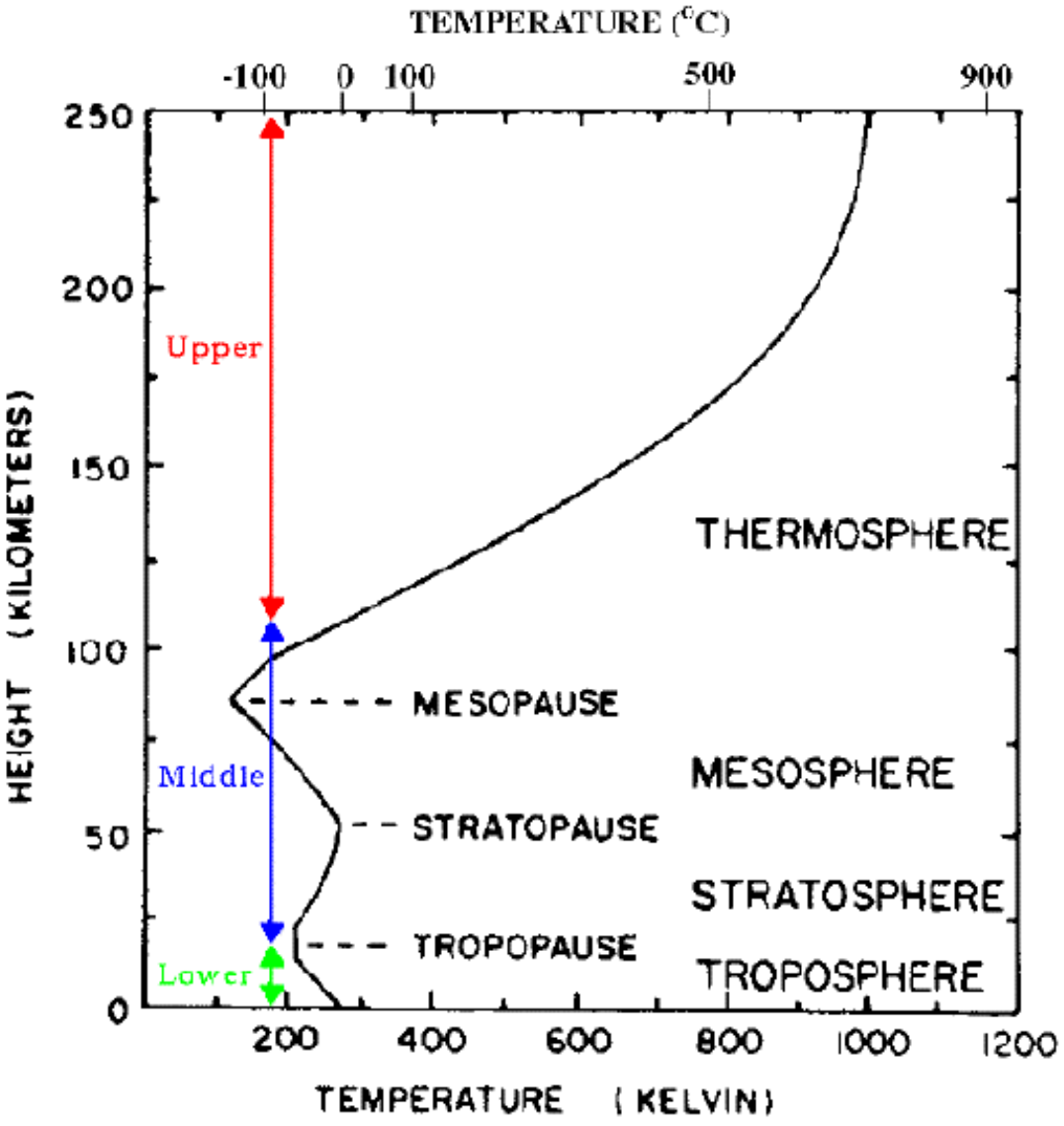
Planetary Atmospheres

Structure
Composition
Clouds
Photochemistry
Meteorology
Atmospheric Escape





Atmospheric Thermal Structure



Troposphere: Where condensable gases form clouds. $dT/dz < 0$

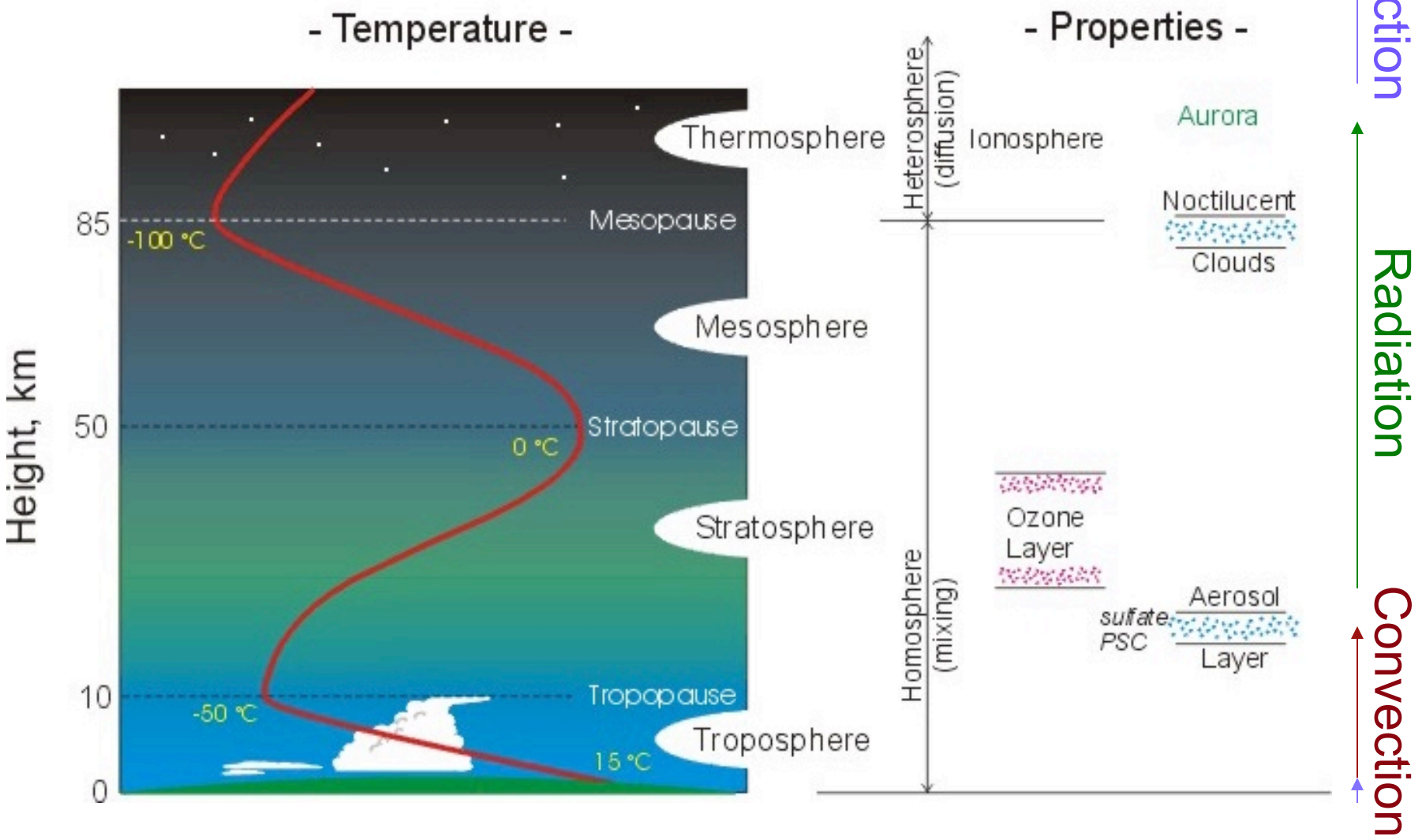
Stratosphere: $dT/dz > 0$

Mesosphere: $dT/dz < 0$

Thermosphere: $dT/dz > 0$

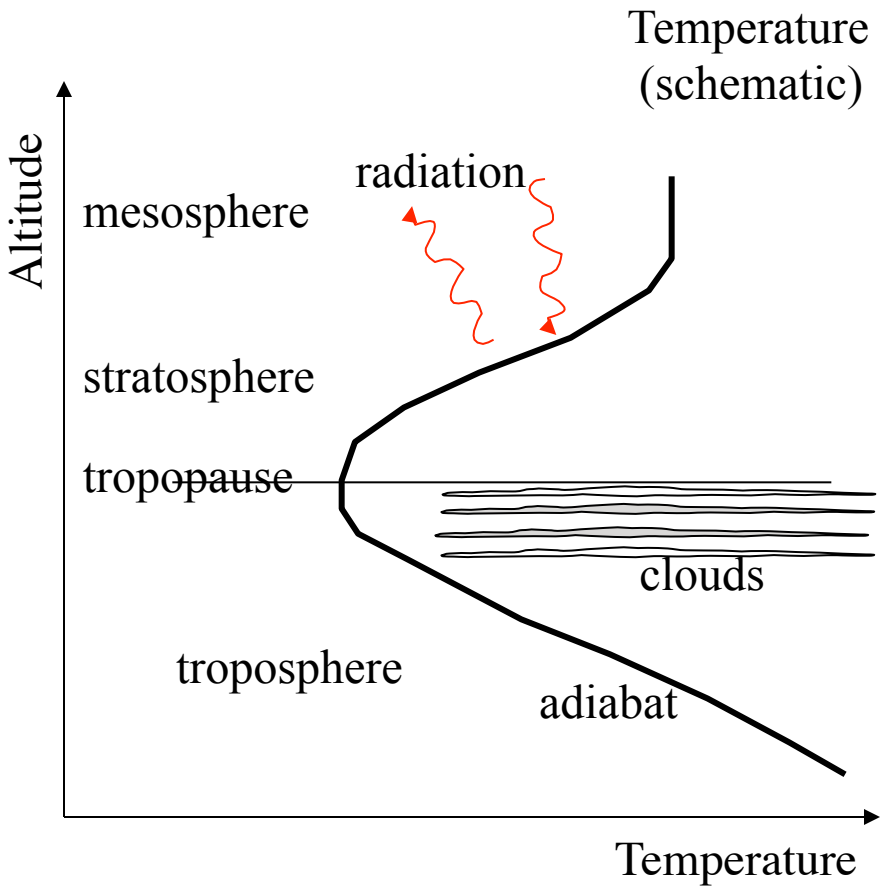
Exosphere: Roughly Isothermal

Atmospheric Thermal Structure

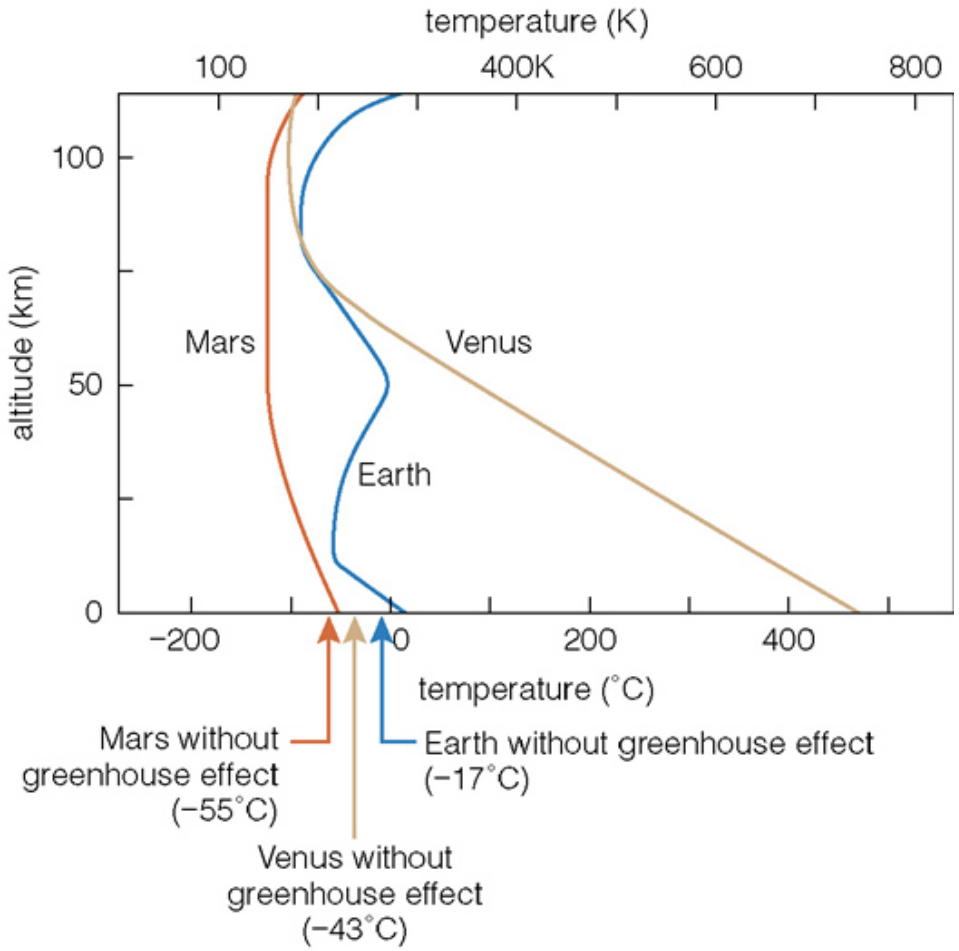


Atmospheric Thermal Structure

- Lower atmosphere (opaque) is dominantly heated from below and will be conductive or convective (adiabatic)
- Upper atmosphere intercepts solar radiation and re-radiates it
- There will be a temperature minimum where radiative cooling is most efficient (the tropopause)



Terrestrial Planets Atmospheric Thermal Structure



Mars, Venus, Earth all

- have warm tropospheres (and greenhouse gases)
- have warm thermospheres which absorb Solar X rays

Only Earth has

- a warm stratosphere
- an UV-absorbing gas (O_3)

All three planets have warmer surface temps due to greenhouse effect

Titan's Atmospheric Thermal Profile

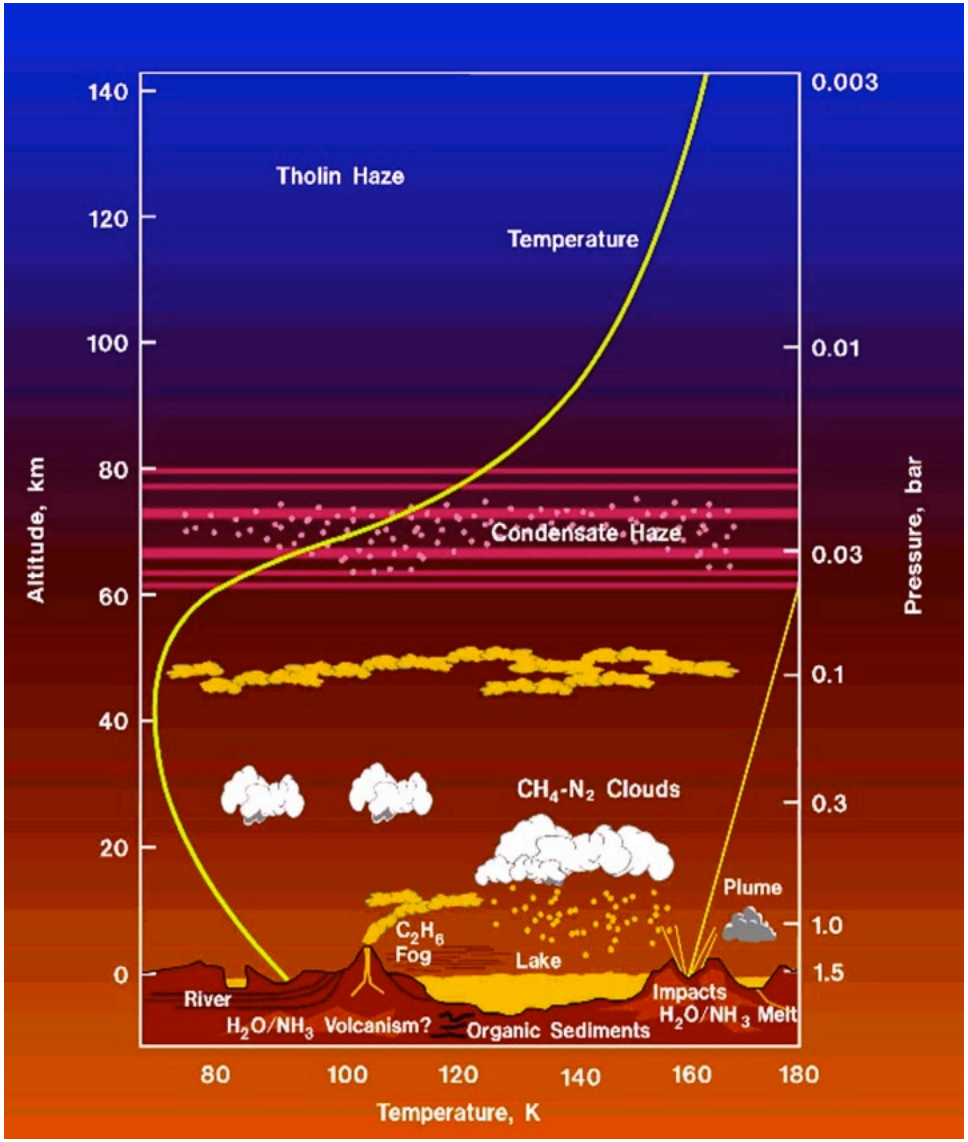
Balance between greenhouse and anti-green house effects:

Greenhouse effects cause +21 K increase in surface temperature over T_{eq}

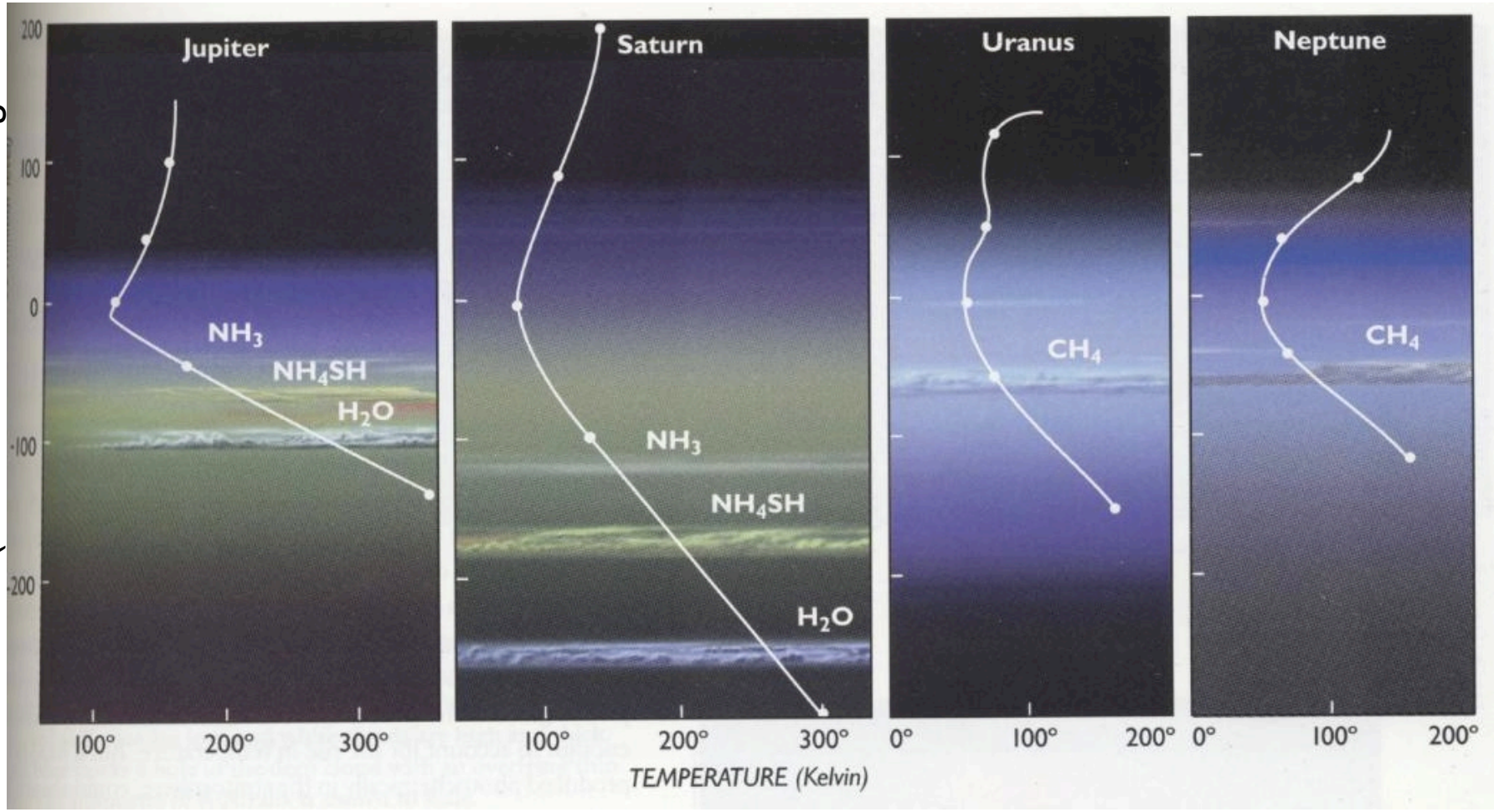
Anti-greenhouse from haze layer absorption of sunlight is responsible for -9 K difference

Net ~12 K increase over T_{eq}

Stratopause at ~250 km (organic-trapped radiation)



Giant Planet Atmospheric Structure



Note position and order/composition of cloud decks

Atmospheric Thermal Structure

Radiation interactions are responsible for the structure we see:

- Troposphere
  - absorbs IR photons from the surface
  - temperature drops with altitude
  - hot air rises and high gas density causes storms (convection)
- Stratosphere
  - lies above the greenhouse gases (no IR absorption)
  - absorbs heat via Solar UV photons which dissociate ozone (O_3)
  - UV penetrates only top layer; hotter air is above colder air
  - no convection or weather; the atmosphere is stably stratified
- Thermosphere
  - absorbs heat via Solar X-rays which ionize all gases
  - contains ionosphere, which reflects back human radio signals
- Exosphere
  - hottest layer; gas extremely rarified; provides noticeable drag on satellites

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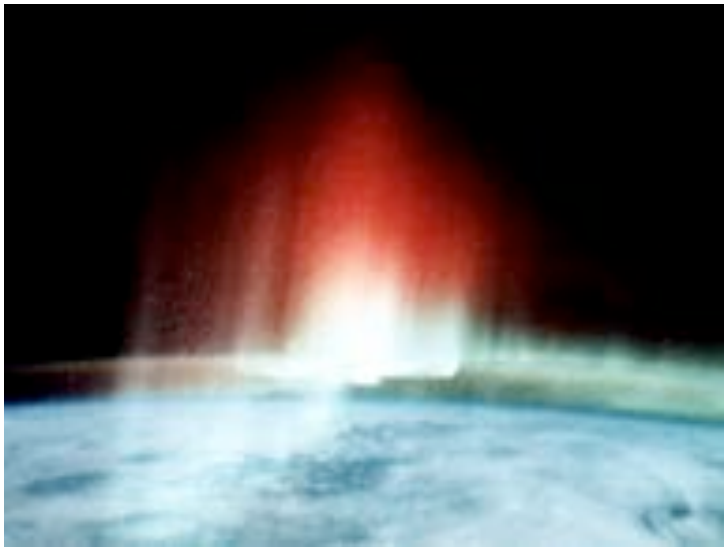
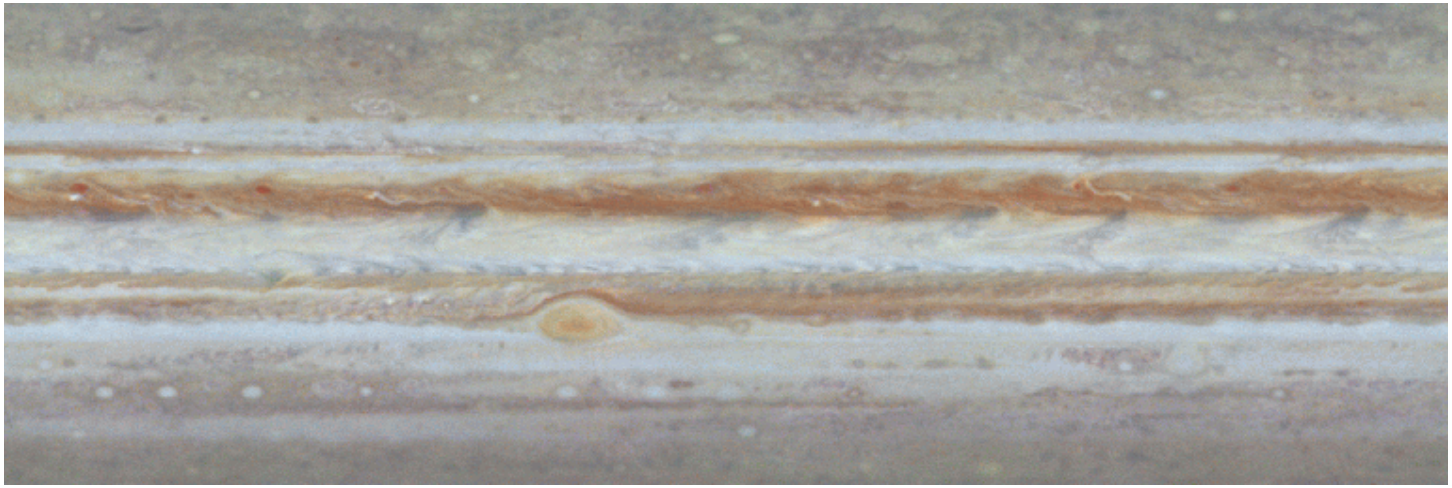




Spectra: Observing the Atmosphere

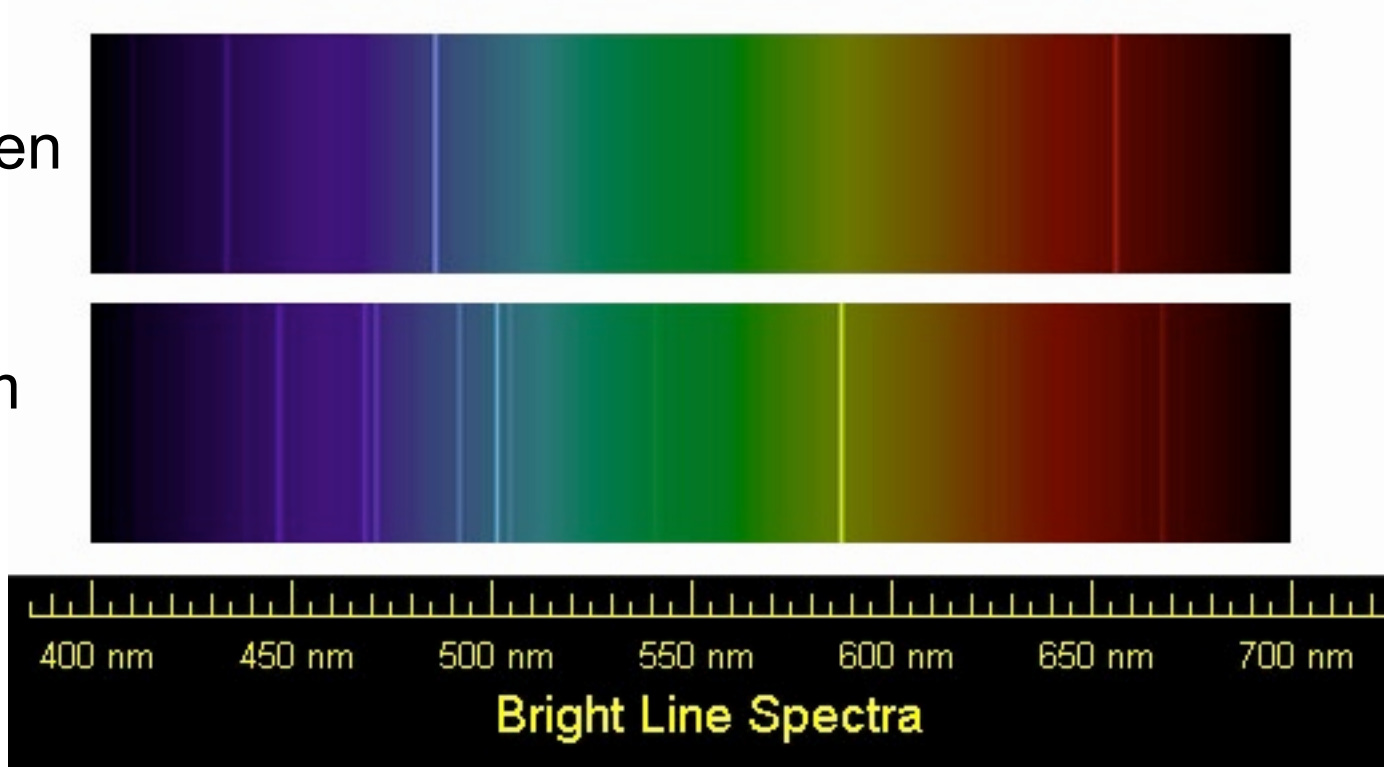
Continuous Spectrum

Absorption Spectrum

Emission Spectrum

Light emitted from a perfect black body generates a continuous spectrum. However, as radiation emitted from the Sun passes through its cooler photosphere, wavelengths of light are absorbed, resulting in absorption lines or a 'Fraunhofer absorption spectrum' in solar radiation.

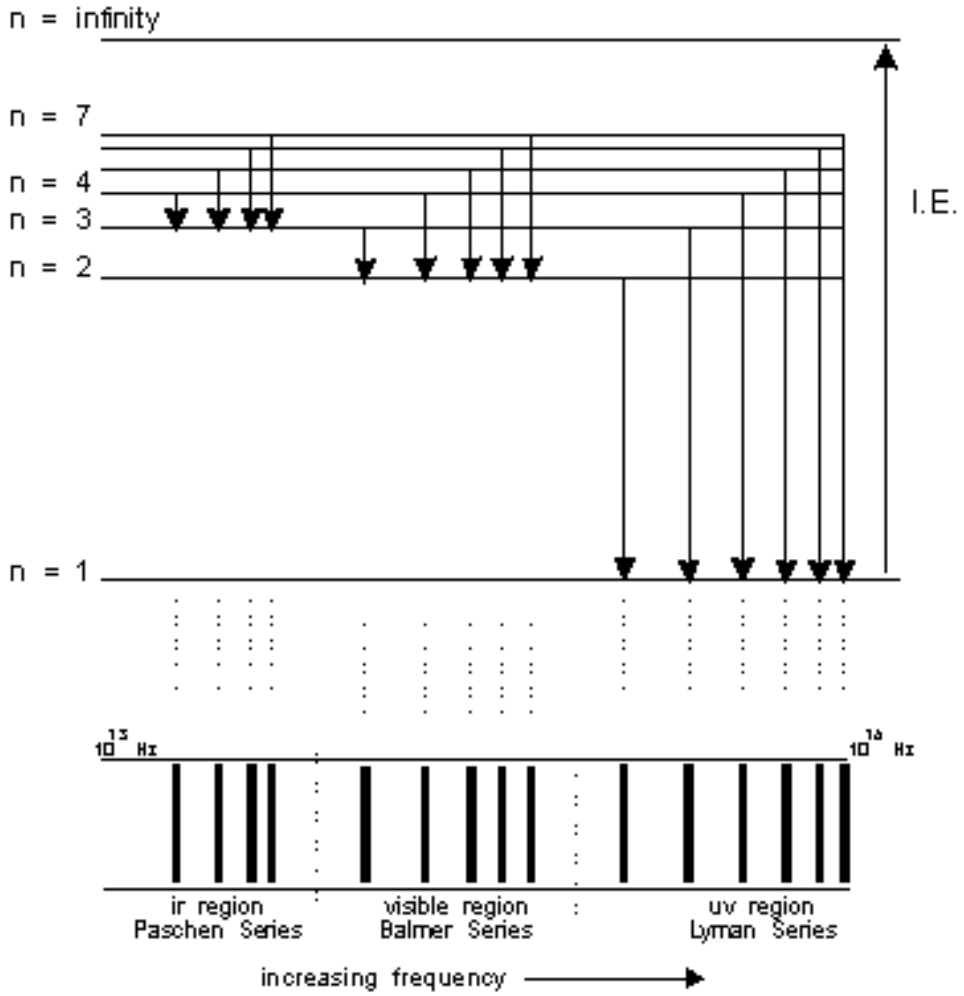
Spectra



Each element/molecule has its own spectral ‘fingerprint’ that can be observed in either emission or absorption depending on its temperature relative to the light source.

Cooler $\Rightarrow$ Then wavelengths will be absorbed and appear dark in the spectrum.

Spectra



Just a reminder:
These wavelengths of emission/absorption are uniquely and directly determined by the quantized energy transitions of electrons in a given atom/ molecule.

$E_{ul} = h\nu = hc / \lambda$

Spectra: Sources

In observing spectral emission/absorption features in a planetary atmosphere, one must consider the primary sources of the continuum spectra.

Reflected sunlight:

Generally in the UV, visible and near-infrared wavelengths

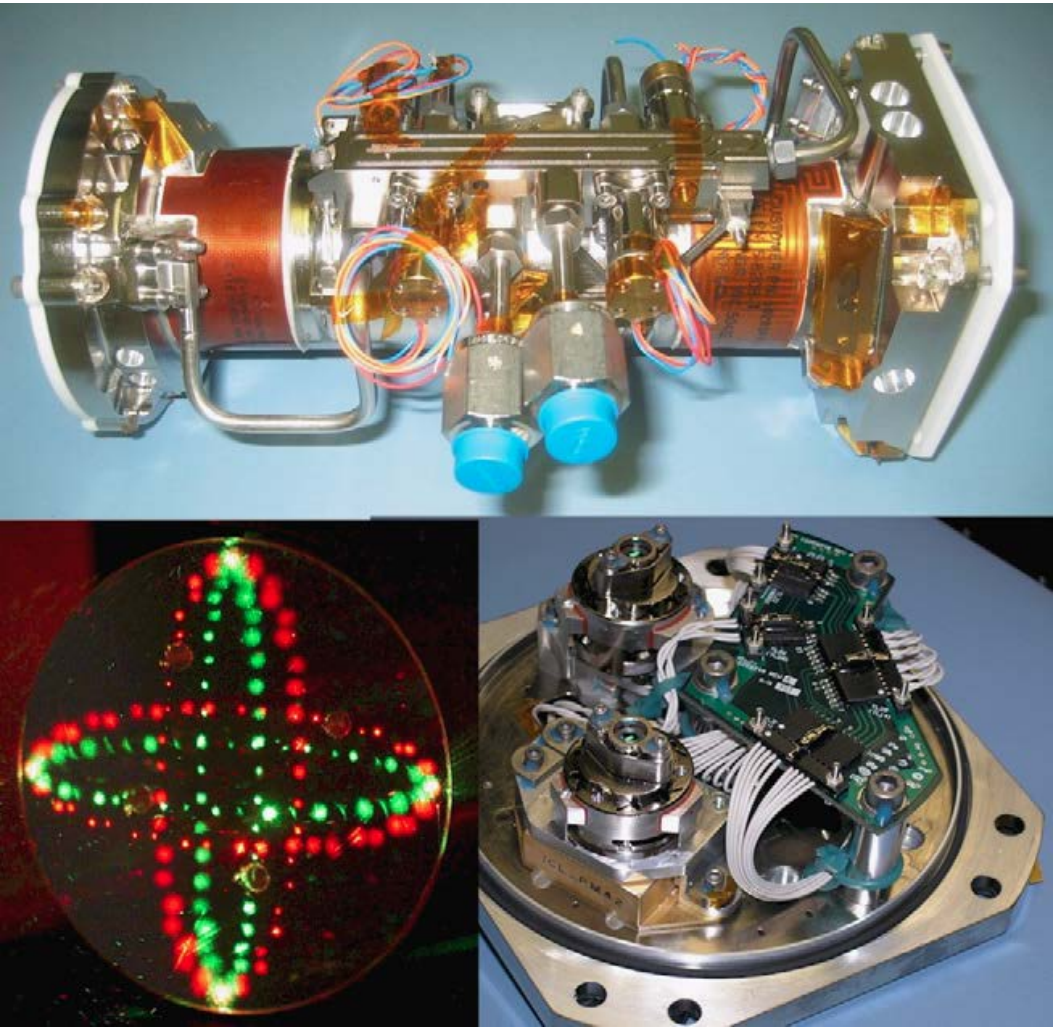
Example: Uranus and Neptune appear green/blue due to the presence of methane in their atmospheres. Methane absorbs the red part of the visible spectrum, causing mostly green/blue light to be reflected.

Thermal radiation:

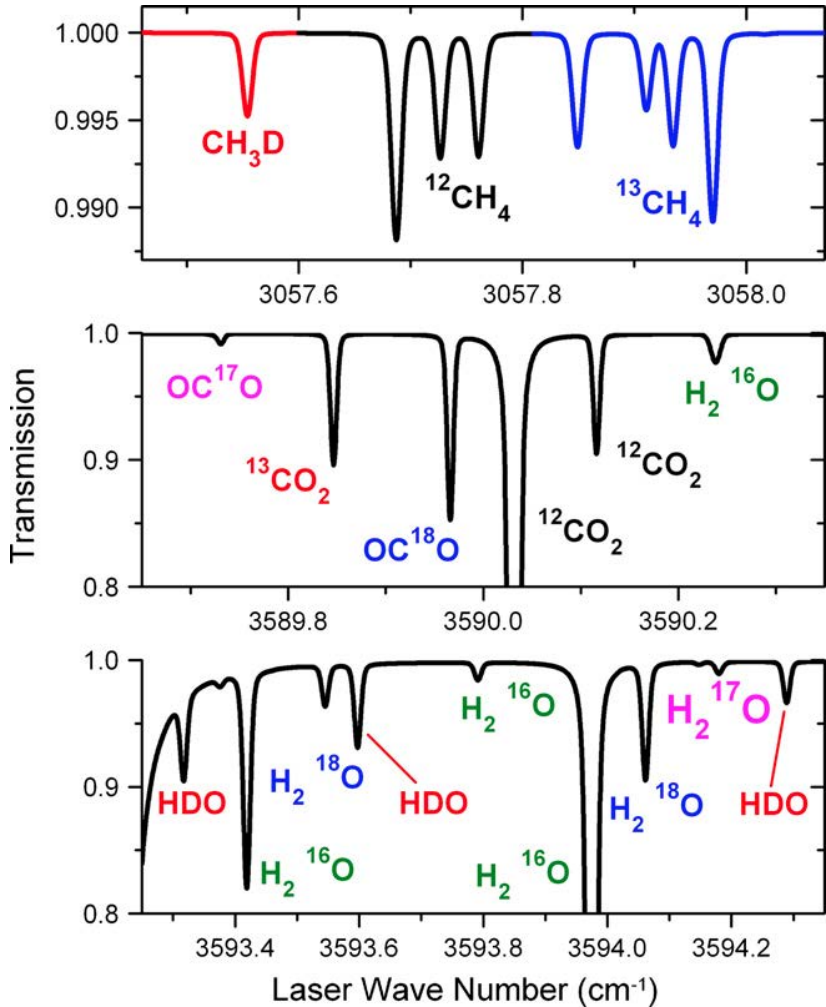
From the ‘surface’ or deeper atmospheric layers of the planet, generally peaks in the infrared and radio wavelengths due to the temperature of the ‘surface’ generating a black body radiation curve.

Ground-based spectra: Fraunhofer + Planetary + Telluric

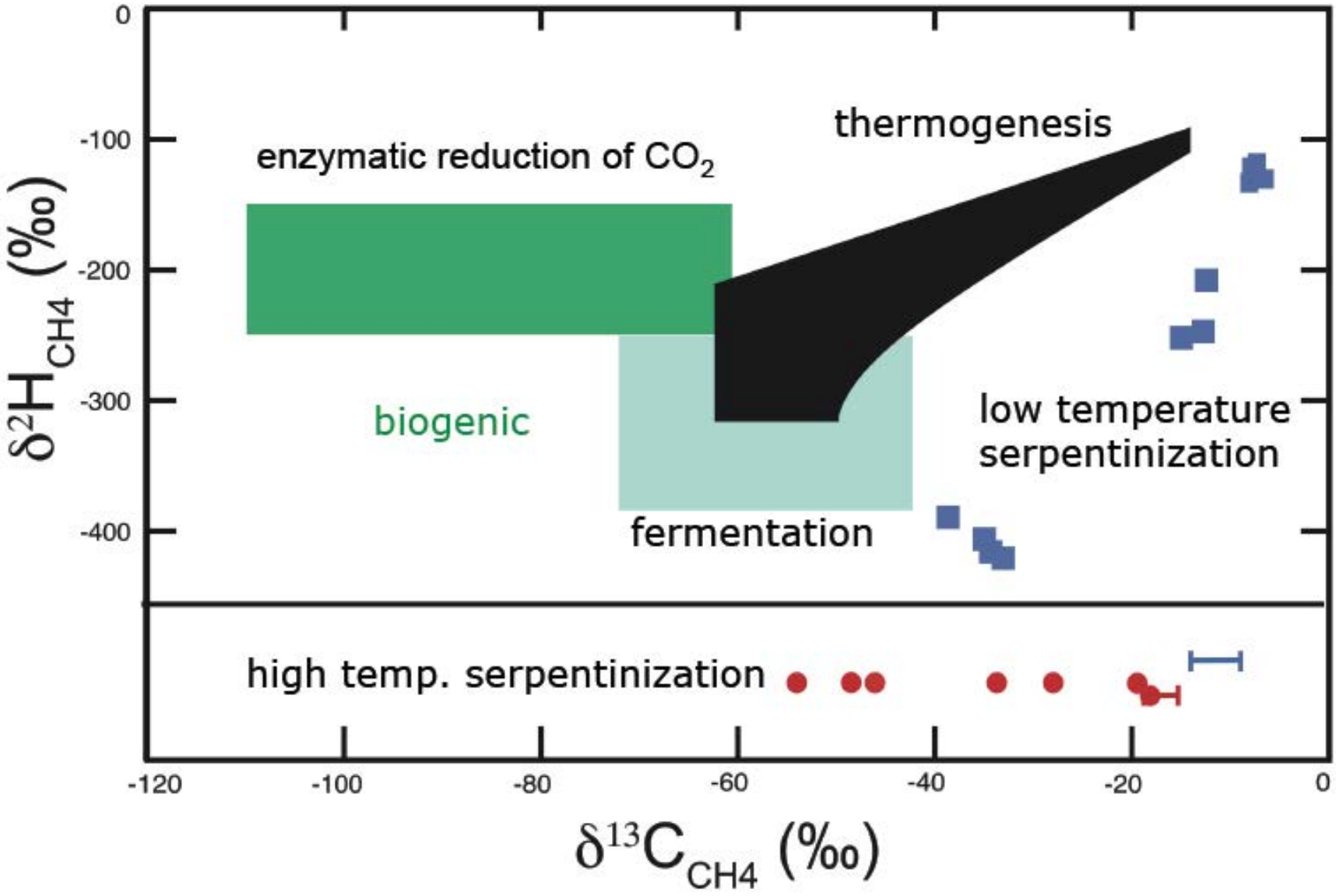
…or just take your own light source and instrument to the planet!
(Curiosity's Tunable Laser Spectrometer, SAM instrument suite)



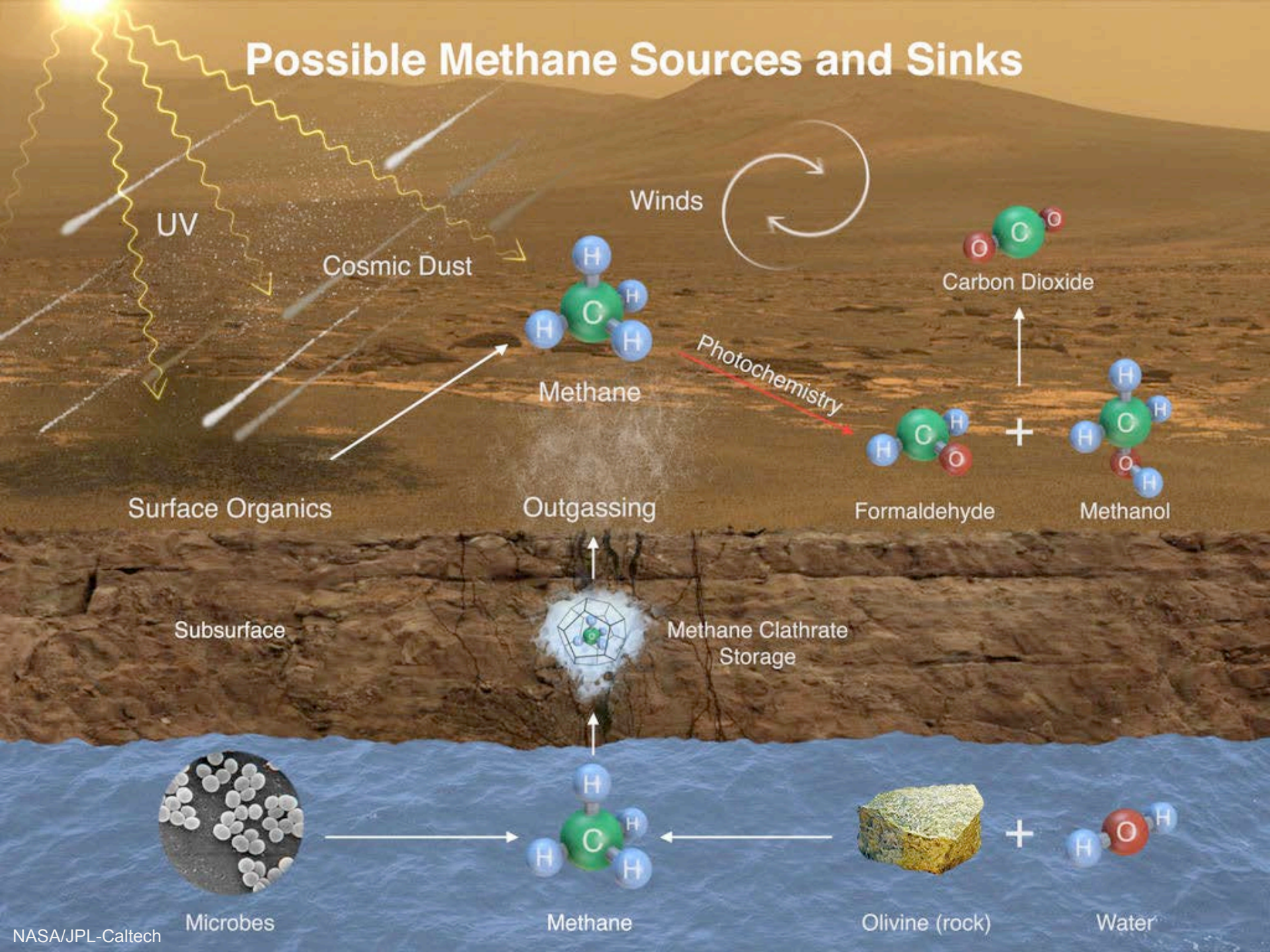
Webster & Mahaffy (2011)



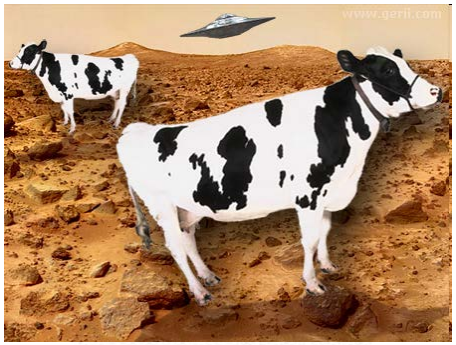
Distinguishing CH_4 sources via isotopes



Atreya et al. (Mars Methane Workshop)


Possible Methane Sources and Sinks
UV
Cosmic Dust
Winds
Carbon Dioxide
Methane
Photochemistry
Surface Organics
Outgassing
Formaldehyde
Methanol
Subsurface
Methane Clathrate
Storage
Microbes
Methane
Olivine (rock)
Water
NASA/JPL-Caltech

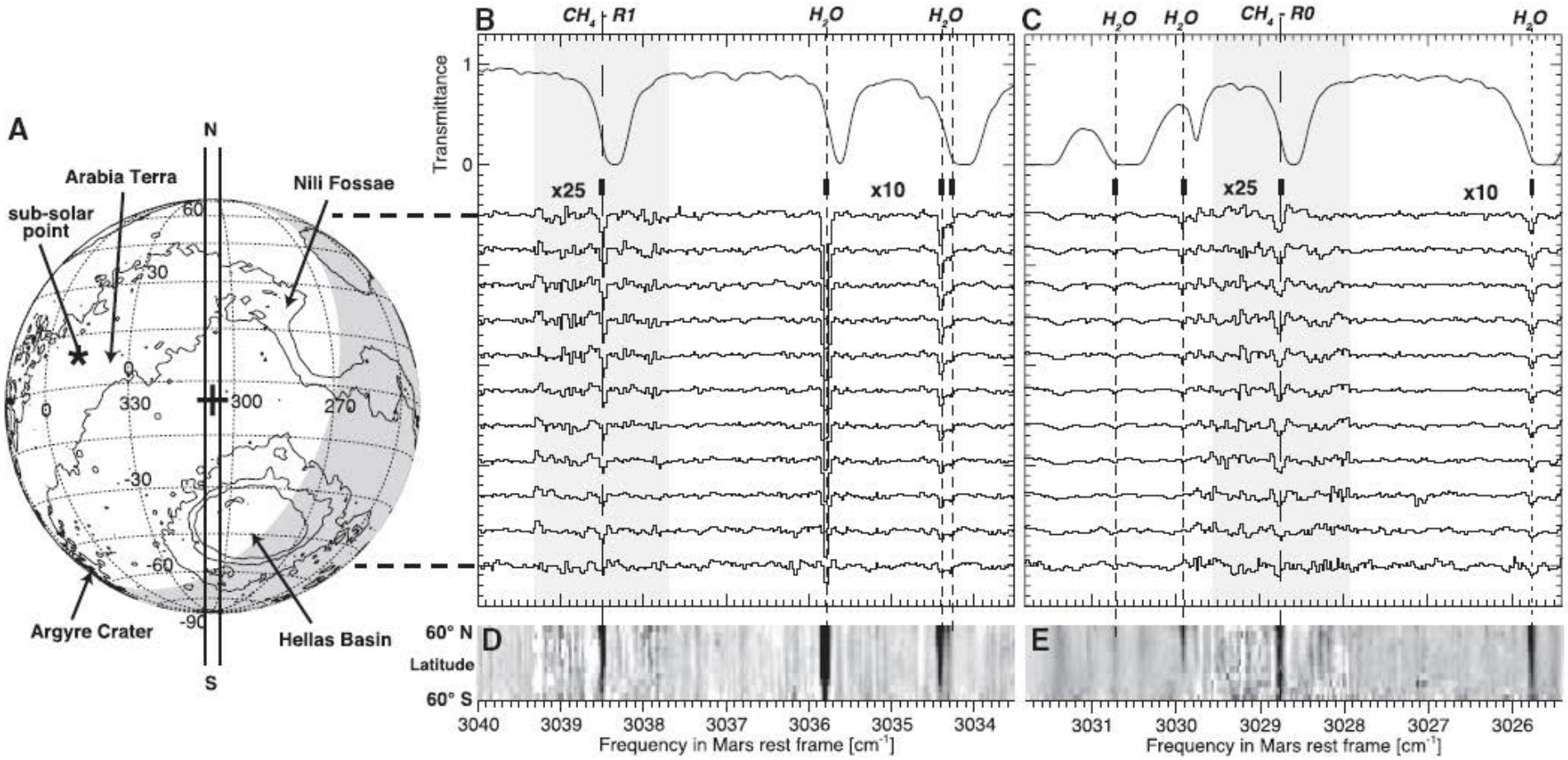
Methane on Earth – mainly biogenic…



20%

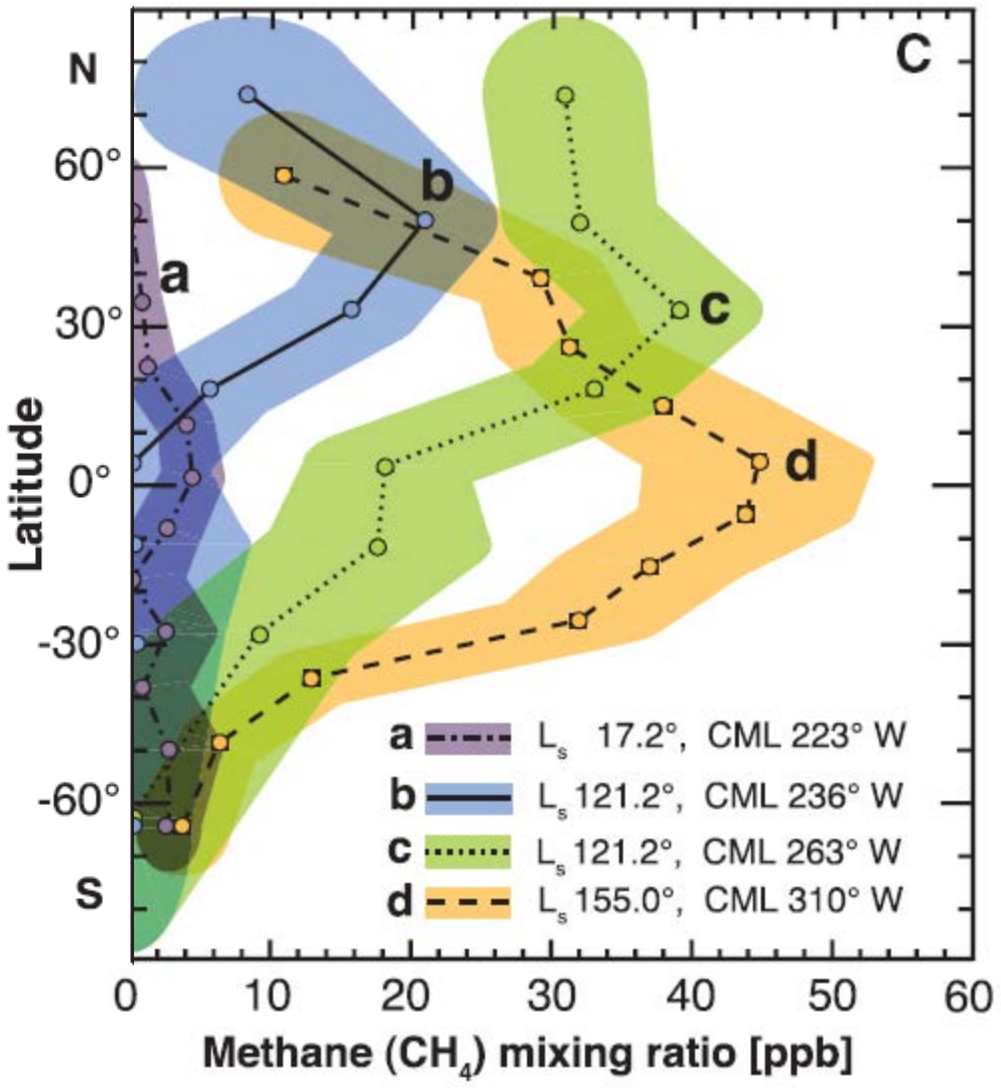
Atreya et al. (2007)

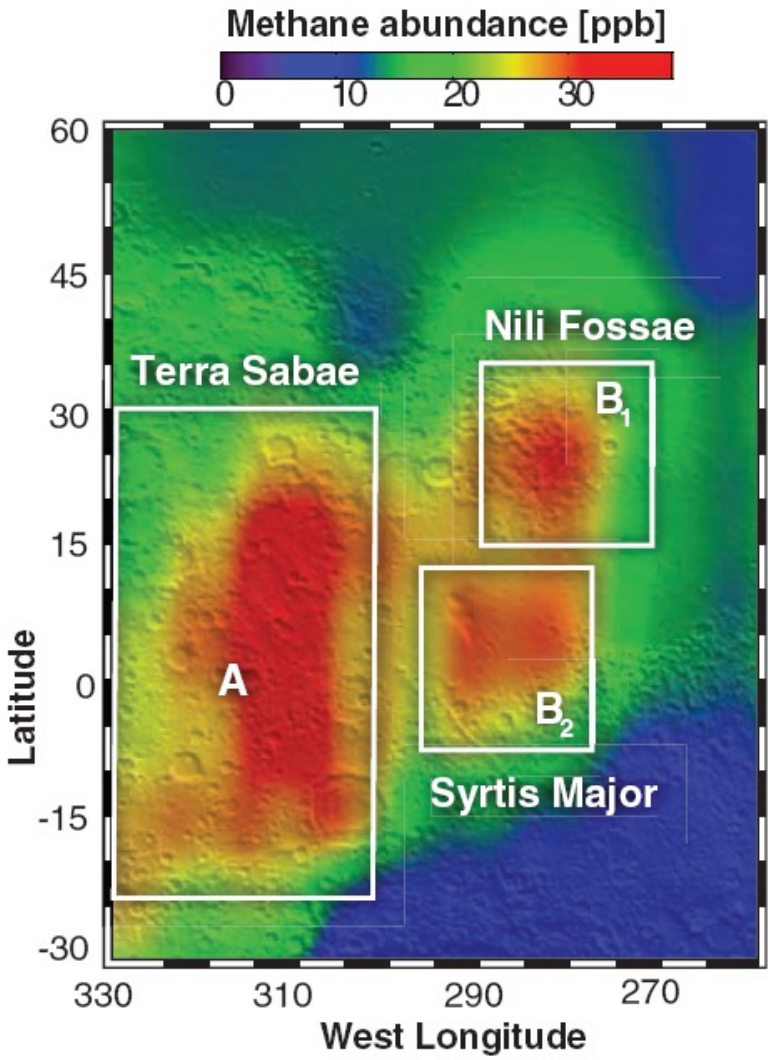
Mumma et al. (2009) – from telescopes on Earth

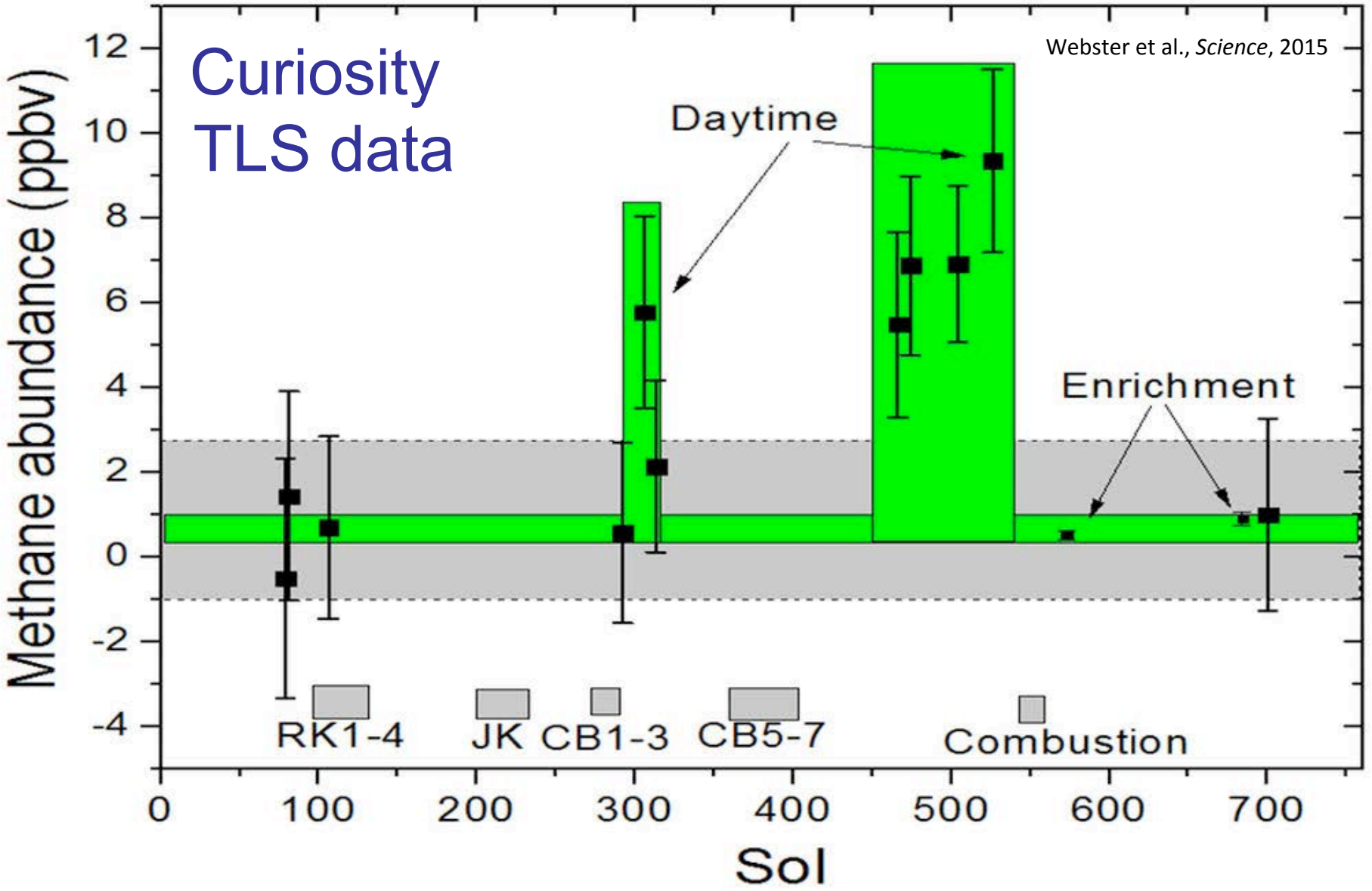


Three lines resolved; no unidentified spectral features

Mumma et al. (2009): seasonal, spatial variations







- Daytime highs + southerly winds at night ➔ source to the north??
- No clear correlation with T, P, humidity, radiation, bedrock composition
- Possible anticorrelation with atmospheric O_2?