

Planetary Atmospheres

Structure

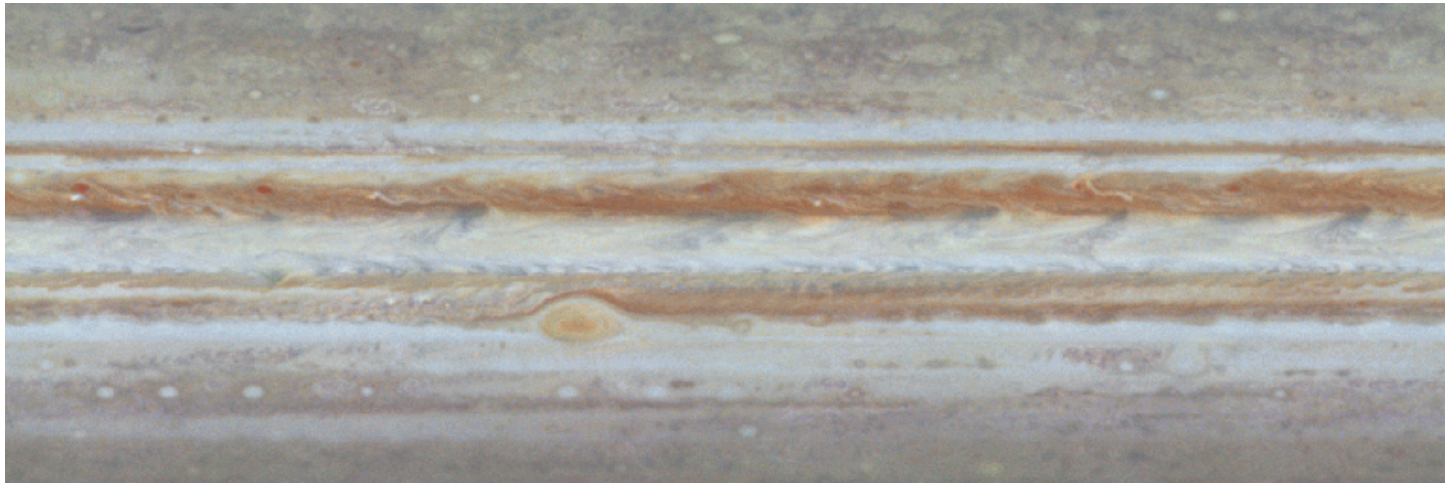
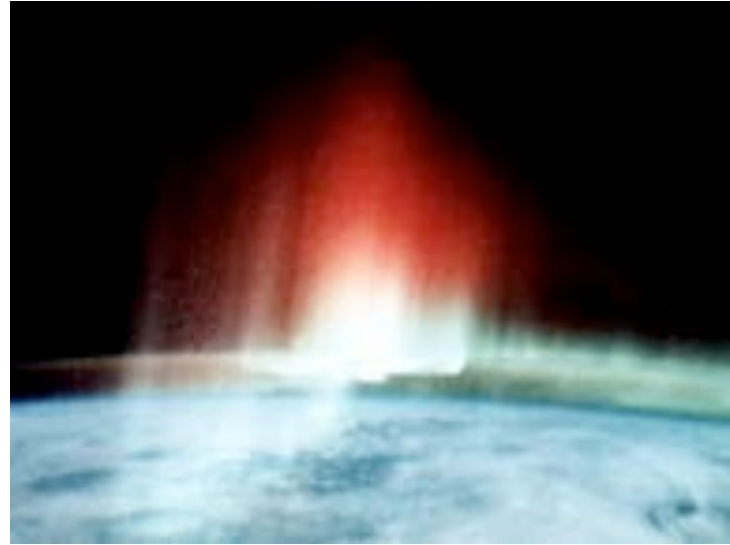
Composition

Clouds

Photochemistry

Meteorology

Atmospheric Escape

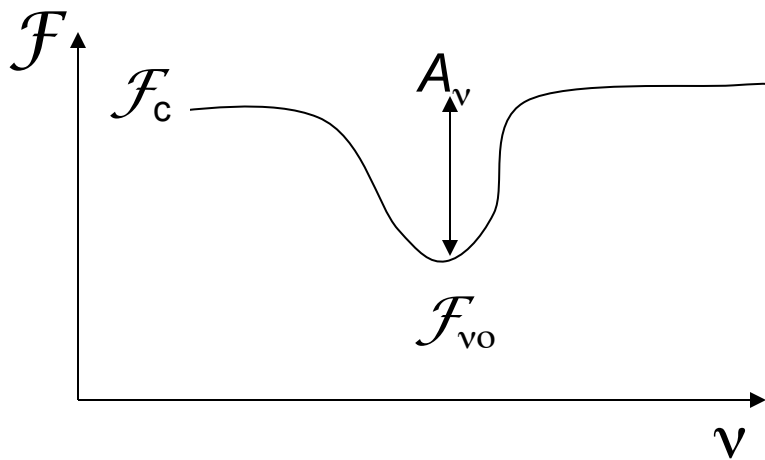


Spectra: Line Profiles

Spectral lines have a finite shape that tells about various properties in the planetary atmosphere we are observing.

Note that the absorption features are often not 'blacked out' lines in the spectrum, but decreases in intensity with a measurable depth and width.

Absorption Depth:



$$A_v \equiv \frac{\mathcal{F}_c - \mathcal{F}_{v_0}}{\mathcal{F}_c}$$

$$A_v = 1 - e^{-\tau_v}$$

Spectra: Line Profiles

Absorption Width: Equivalent Width

$$EW = \int_0^{\infty} A_{\nu} d\nu = \int_0^{\infty} (1 - e^{-\tau_{\nu}}) d\nu$$

The optical depth at the center of the line is determined by the extinction coefficient and the column density (N_c):

$$\tau_{\nu_0} = \int_0^L N \alpha_{\nu_0} dl = N_c \alpha_{\nu_0}$$

Therefore, for $\tau_{\nu} \ll 1$:

$$EW \approx \int_0^{\infty} \tau_{\nu} d\nu = N_c \alpha_{\nu_0} \int_0^{\infty} \Phi_{\nu} d\nu$$

Where the line shape:

$$\Phi_{\nu} \equiv \frac{\alpha_{\nu}}{\alpha_{\nu_0}}$$

Spectra: Line Profiles

Equivalent Width

$$EW \approx N_c \alpha_{\nu_0} \int_0^{\infty} \Phi_{\nu} d\nu$$

Increases linearly with N_c while $\tau_{\nu} \ll 1$, but as τ_{ν} increases the line profile saturates, causing the EW to become proportional to $(N_c)^{1/2}$

If this behavior (the “curve of growth”) is understood, then the abundance of a gas can be determined from the observed EW.

Spectra: Line Profiles

What controls the line shape?

Lorentz Line Shape: Shape due to finite lifetime of excited states

Doppler Broadening: Due to relative motion along the line of sight. Can be used to infer atmospheric wind speeds as well as temperature based on the Maxwellian distribution function.

Pressure/Collisional Broadening: Due to collisions between molecules slightly perturbing the energy levels of electron states (I.e. photons with $\lambda_{ul} \pm \delta\lambda$ can cause excitation/de-excitation)

* Remember that τ_v will determine what altitude you are 'probing' for a given wavelength (or frequency).

Compositions of Terrestrial Atmospheres

	Earth	Venus	Mars	Titan
Pressure	1 bar	92 bar	0.006 bar	1.5 bar
N ₂	77%	3.5%	2.7%	98.4%
O ₂	21%	-	-	-
H ₂ O	1%	0.01%	0.006%	-
Ar	0.93%	0.007%	1.6%	0.004%
CO ₂	0.040%	96%	95%	~1ppb
CH ₄	1.7ppm	-	?	1.6%
⁴⁰ Ar	6.6x10 ¹⁶ kg	1.4x10 ¹⁶ kg	4.5x10 ¹⁴ kg	3.5x10 ¹⁴ kg
H/D	3000	63	1100	3600
¹⁴ N/ ¹⁵ N	272	273	170	183

Isotopes are useful for inferring outgassing and atmos. loss

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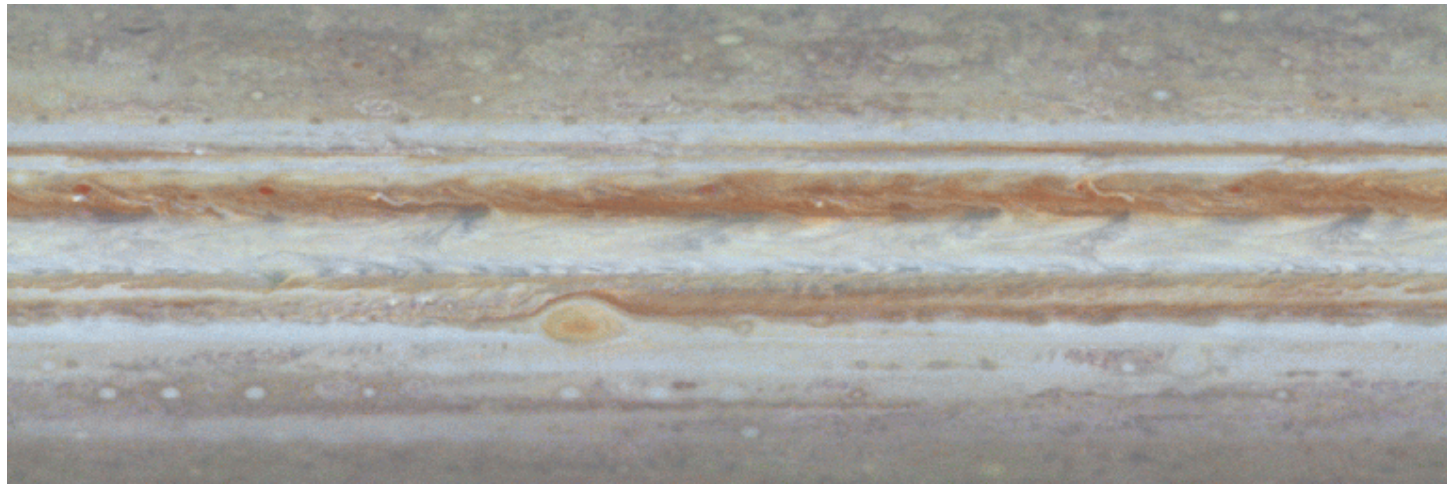
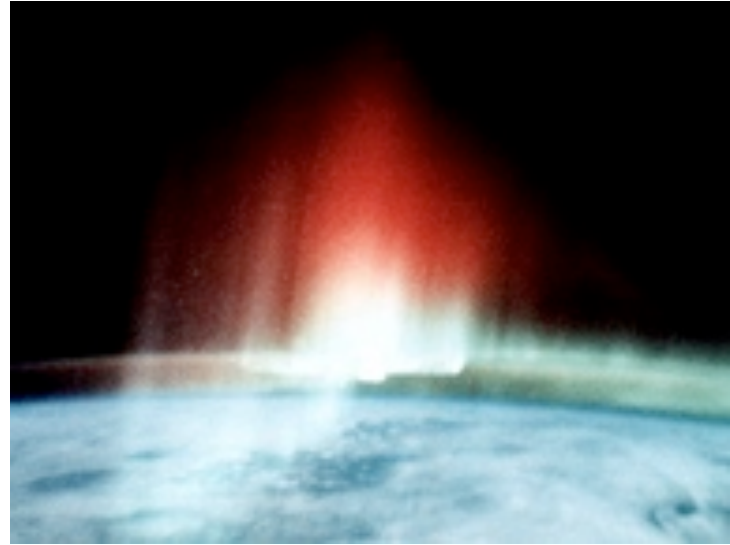
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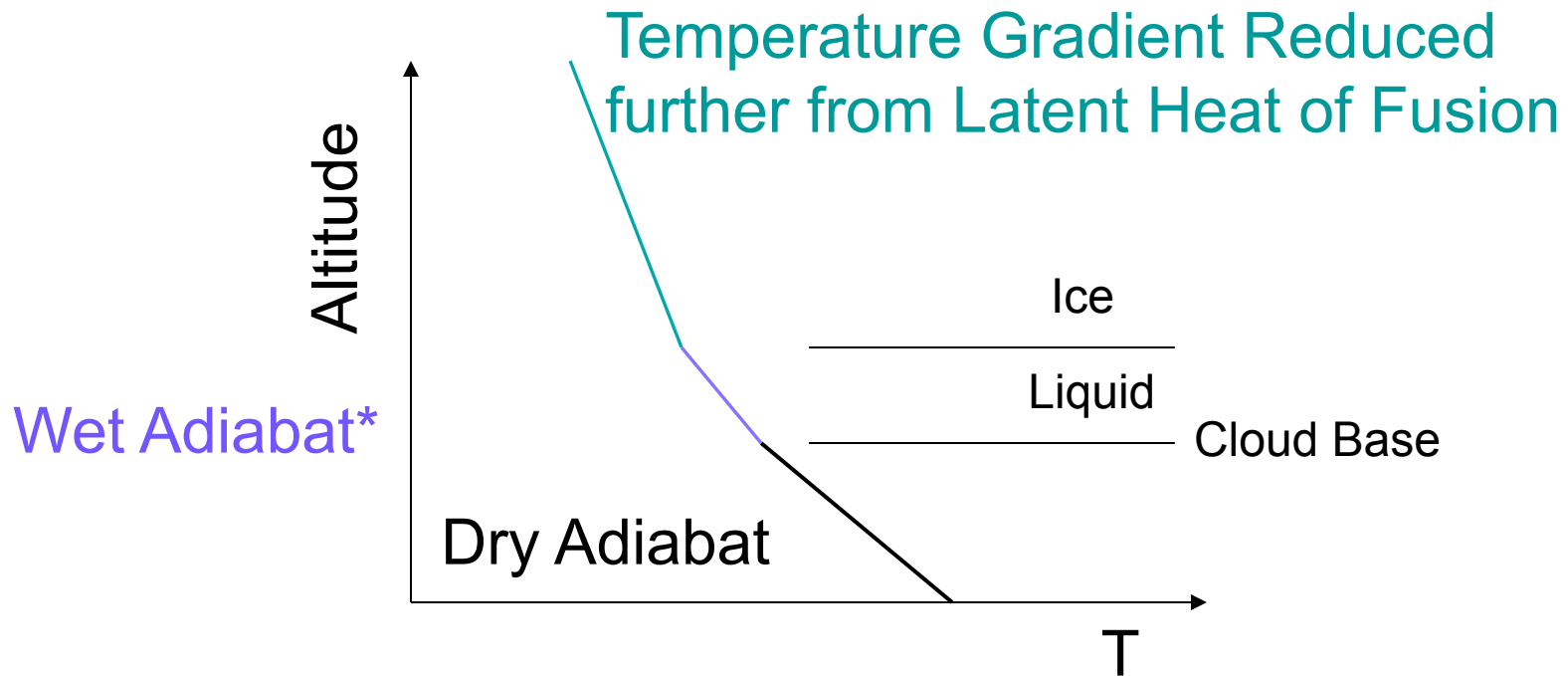
Clouds

Clouds modify the surface/atmospheric temperature of a planet in the following ways --

1. Decrease amount of incoming sunlight due to Albedo (reflectivity)
2. Heat immediate environment by absorbing solar radiation, thus changing the lapse rate
3. Block outgoing IR radiation can lead to greenhouse warming near the surface
4. Reduce the lapse rate via latent heat release during cloud formation

Cloud formation

The phase change of water has an effect on the temperature structure of the atmosphere as well:



*Thermal gradient reduced due to Latent Heat of Condensation

Cloud formation

Saturated Vapor Pressure: Maximum amount of water vapor partial pressure

