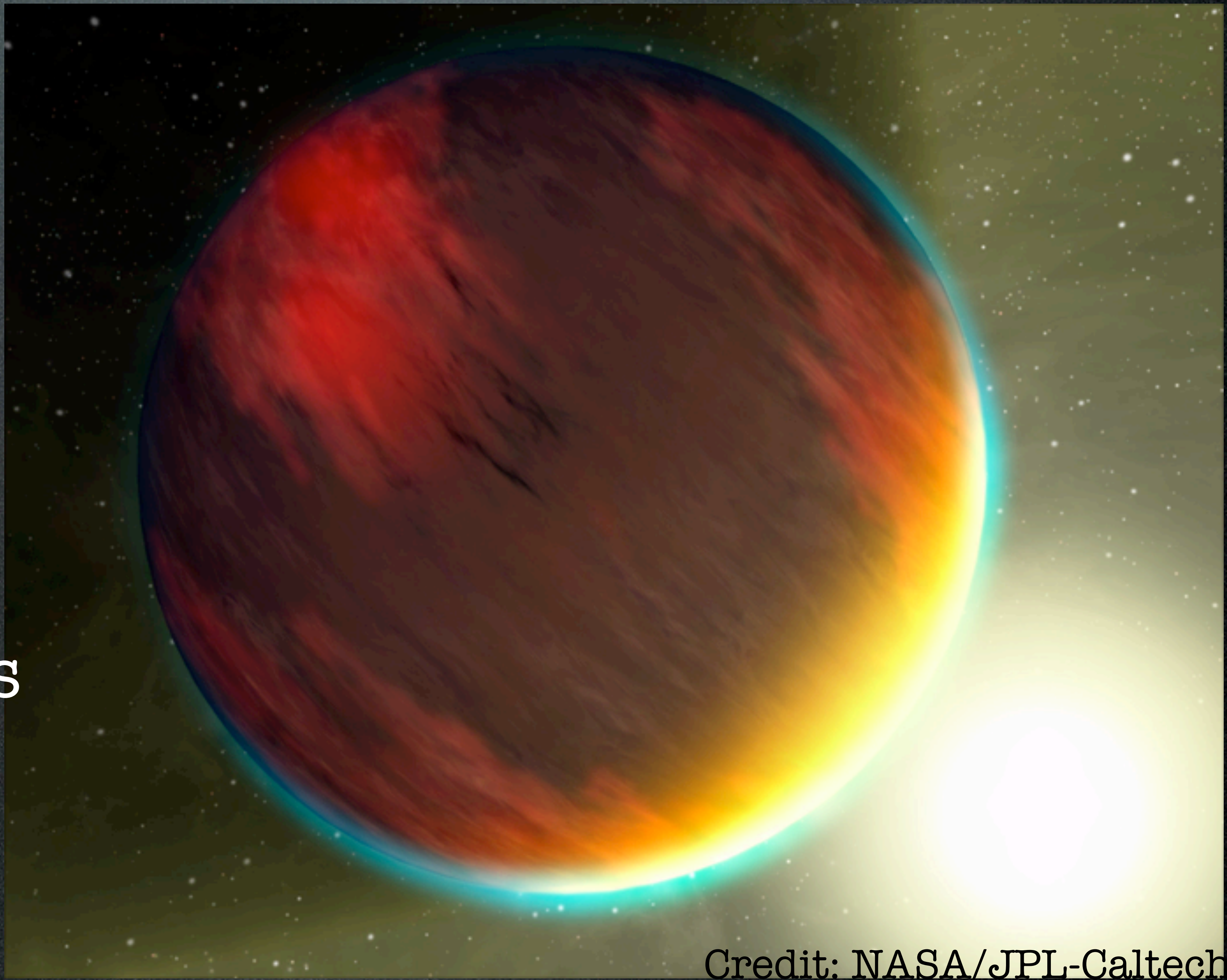
Irradiated Atmospheres:

Hot and Very Hot Jupiters



Based on: *Fortney '08*.

Patricio Cubillos

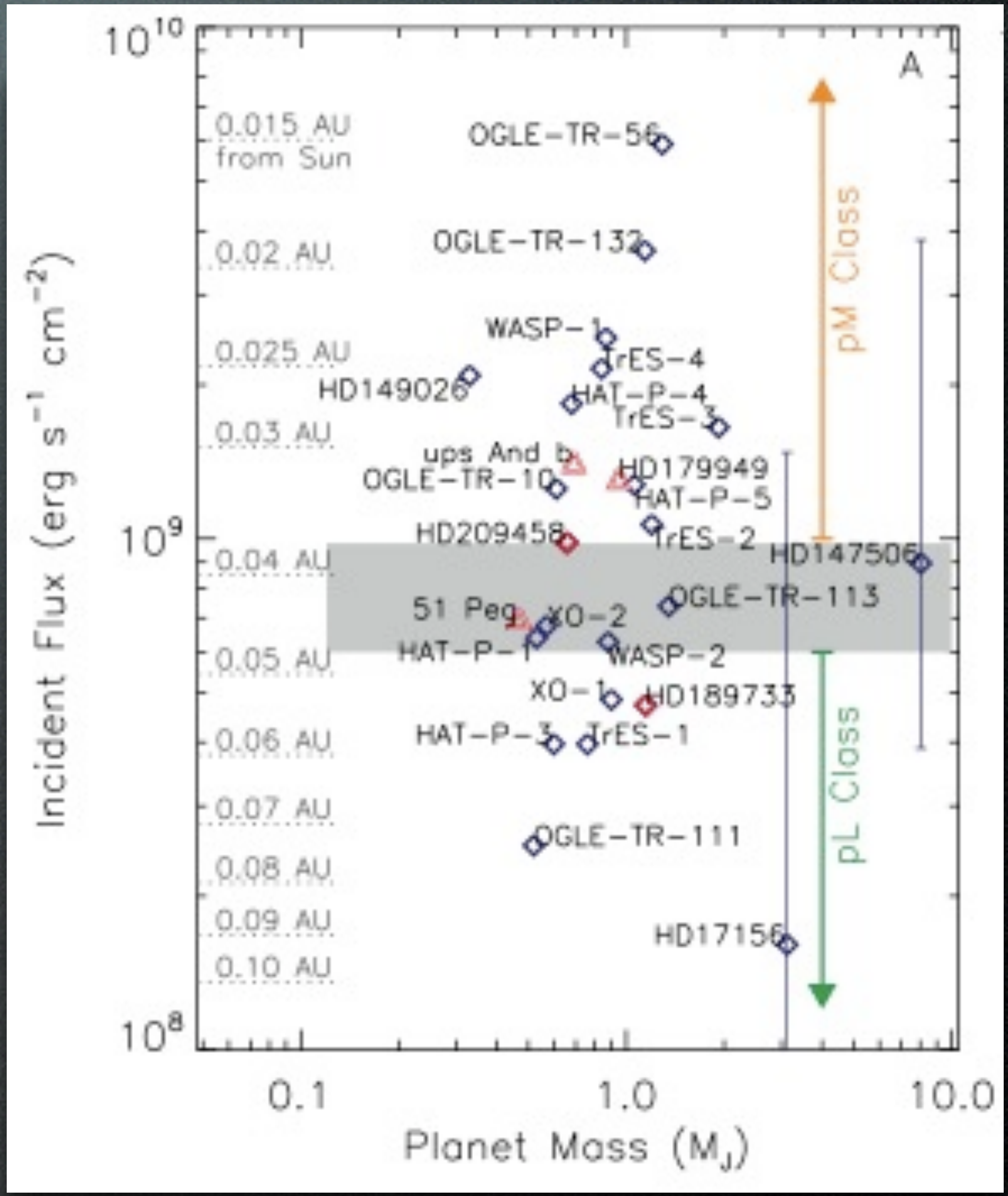
Planetary Atmospheres
April 20th, 2010.

Hot Jupiters:

Two classes of planets emerge.

Irradiation is one of the main factor that determines the atmospheric properties.

Other factors can be important, e.g. metallicity, eccentricity.



The Cold Trap:

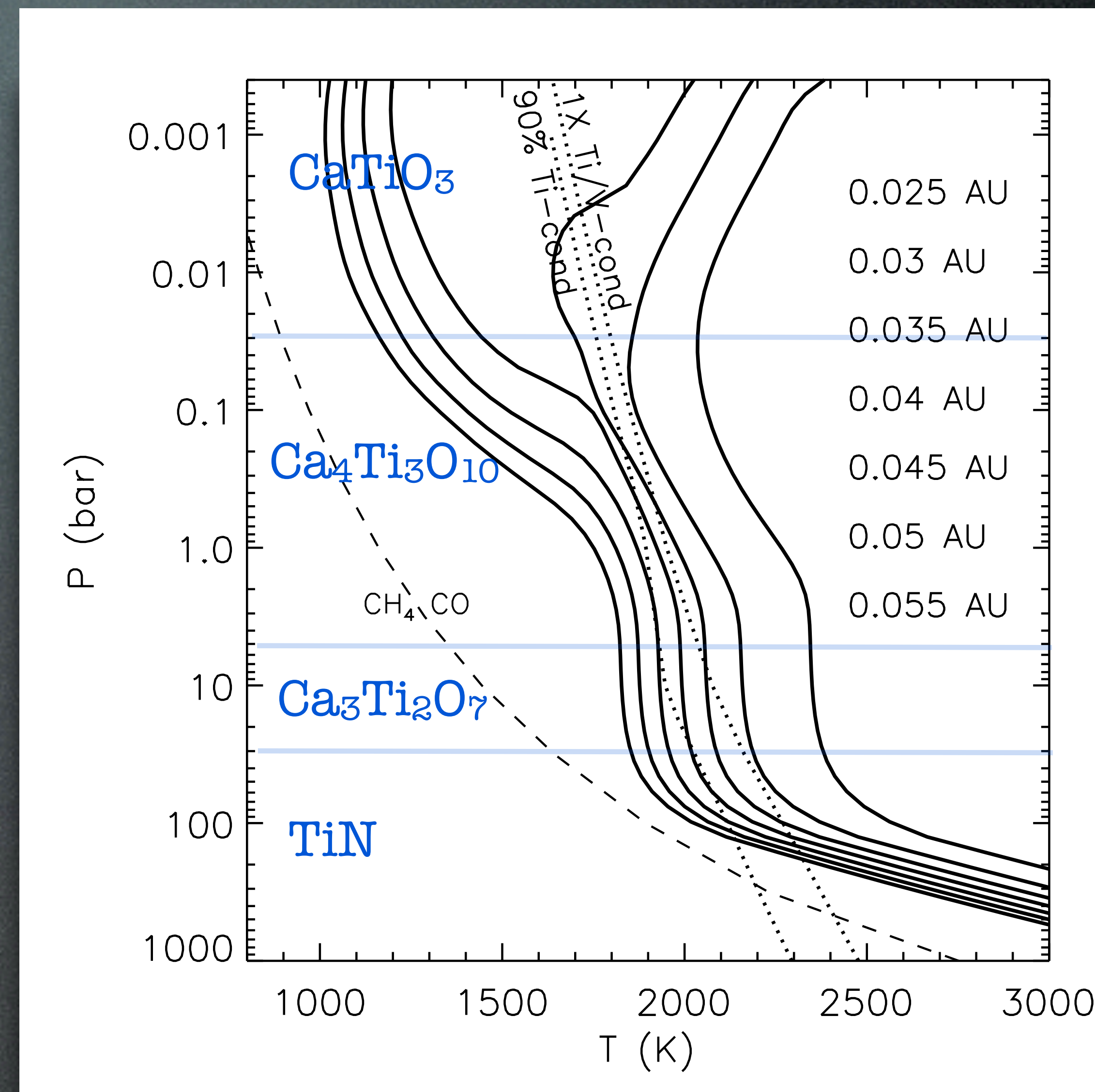
If P-T profile crosses a condensation curve, the species mix down to highest pressure.

Two classes of Hot Jupiters:

Analogous to the star classification: OBAFGKM(LTY)

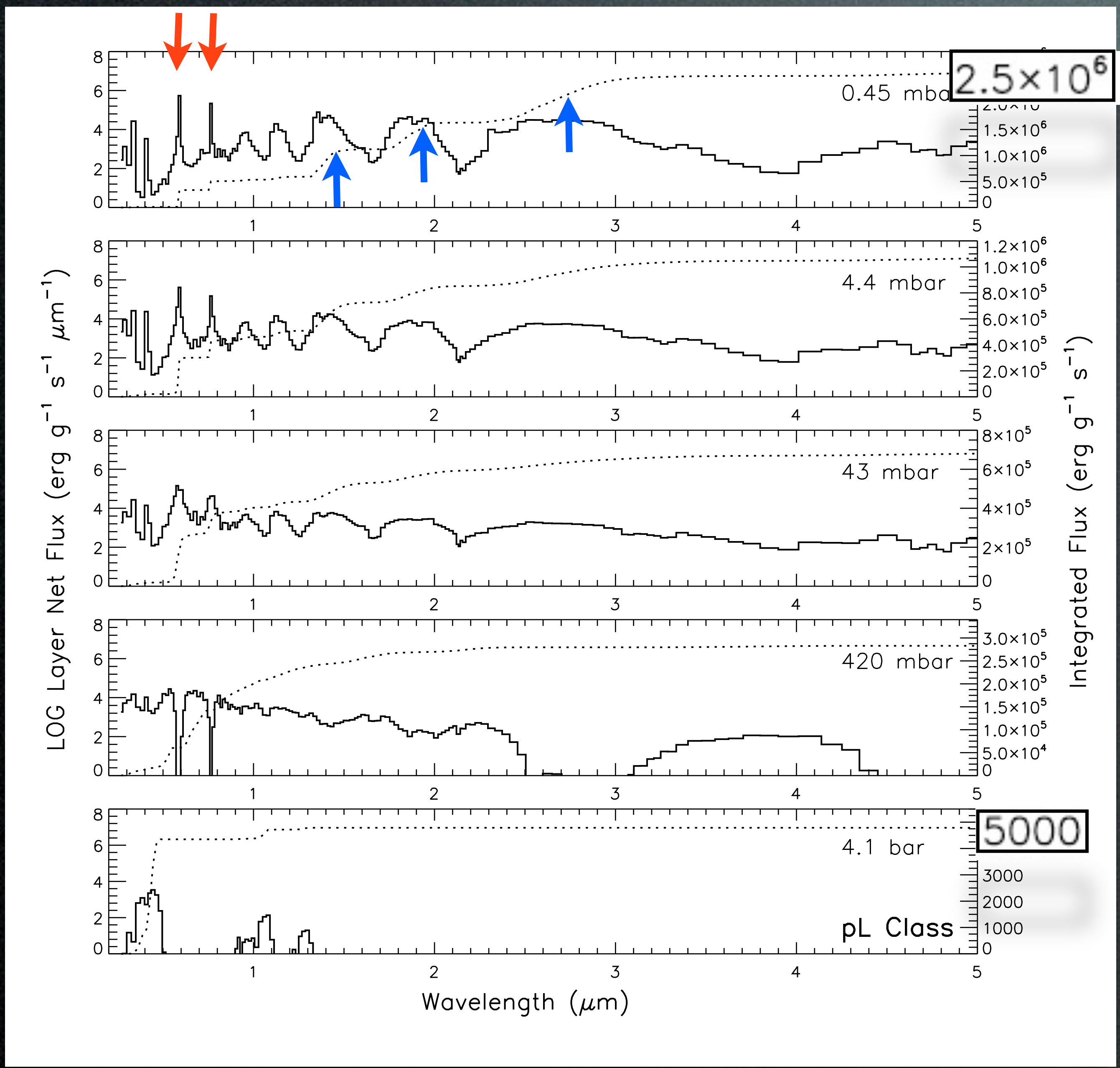
Planets with an inversion layer:
· pM class
Those without:
· pL class

Relevant species TiO/VO (*Hubeny '03*).



The chemistry is complex (*Lodders & Fegley '06*).

Absorption
as a function of Pressure:



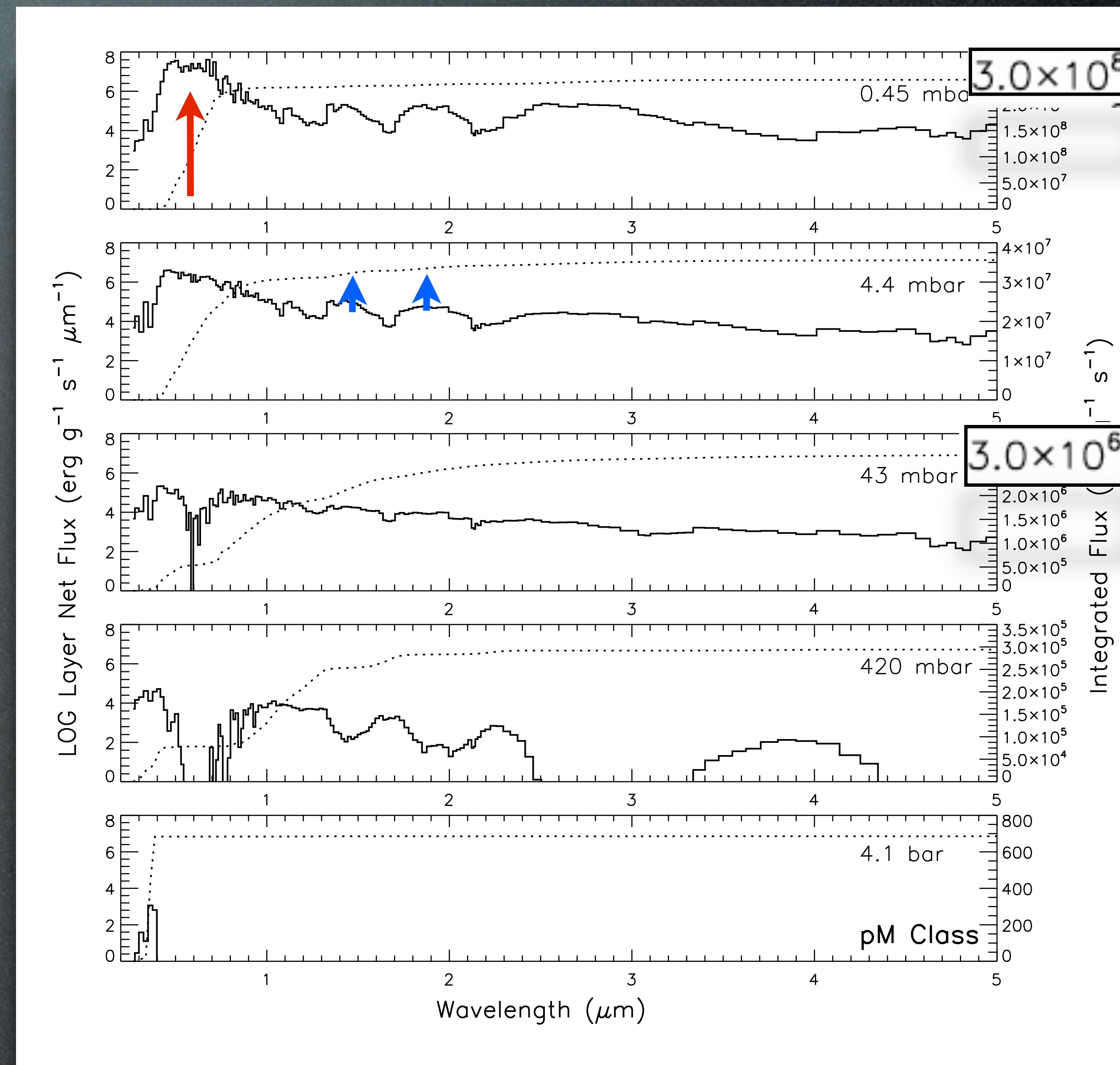
pL class atmospheres:

- Na & K absorption lines.
- H_2O is the major absorber.
- At 4.1 bar, about 10^3 less flux is absorbed than at 0.45 mbar

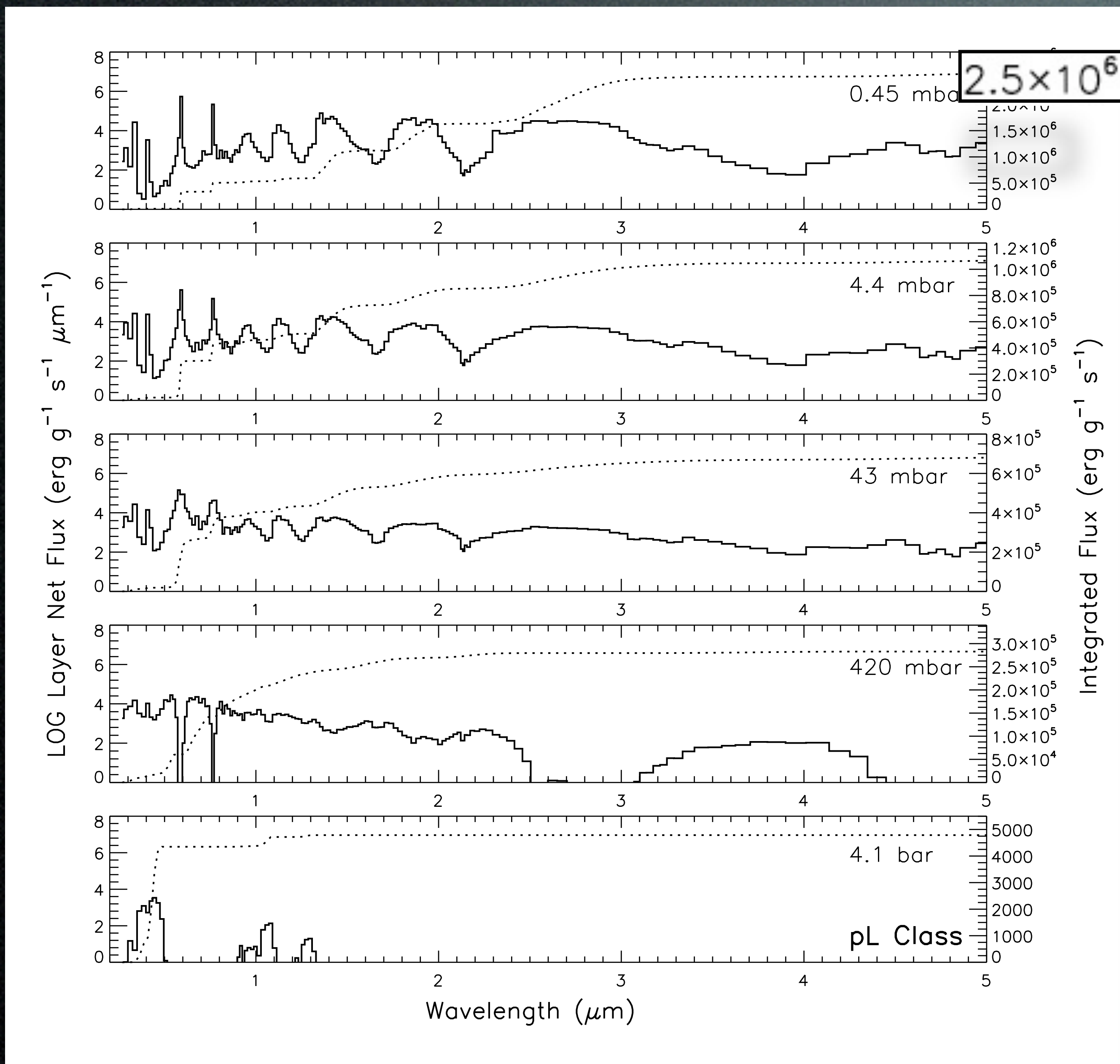
Absorption
as a function of Pressure:

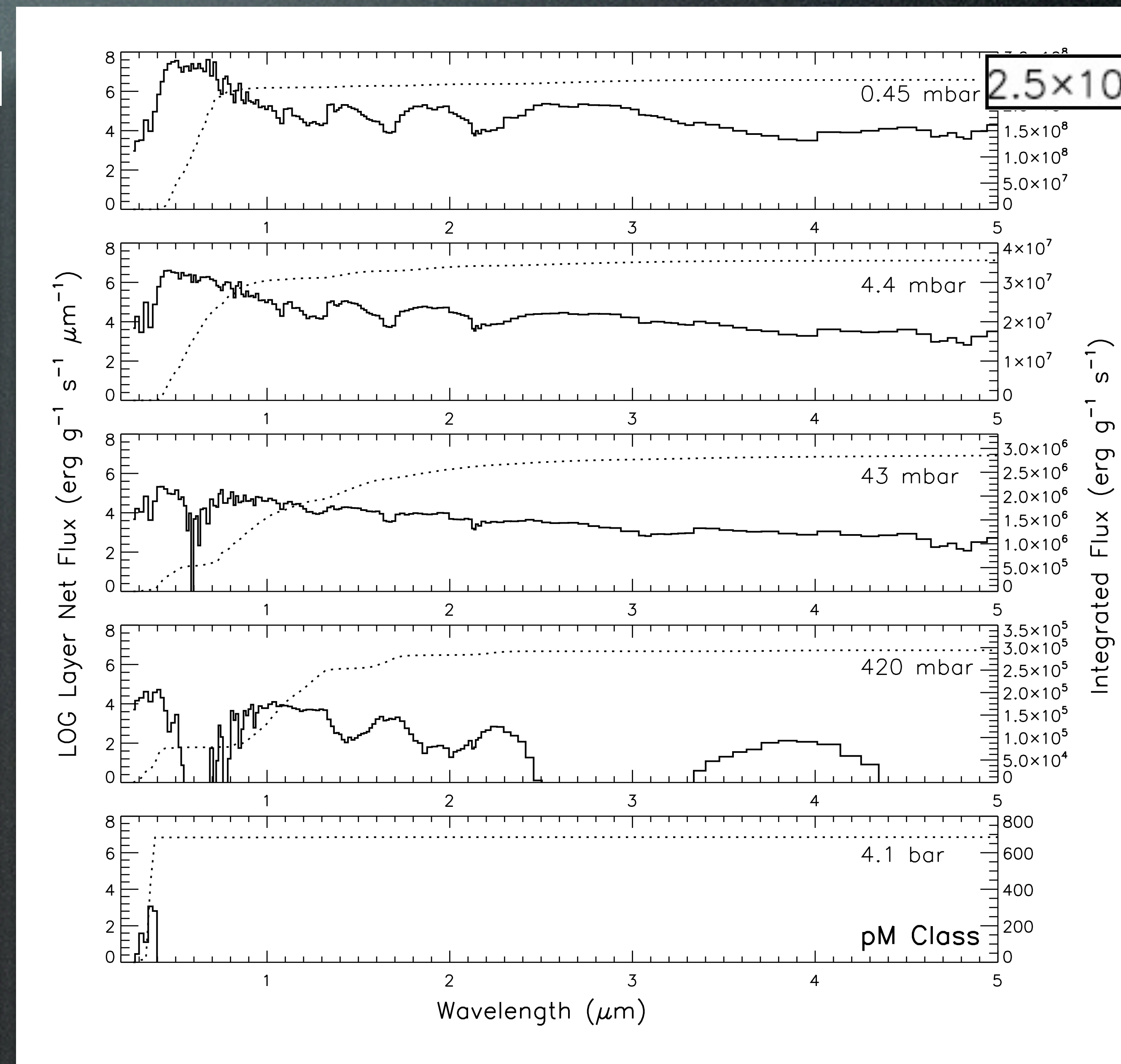
pM class atmospheres:

- TiO & VO bands absorption in optical.
- Some H_2O absorption.
- by 43 mbar almost all incident radiation has been absorbed.



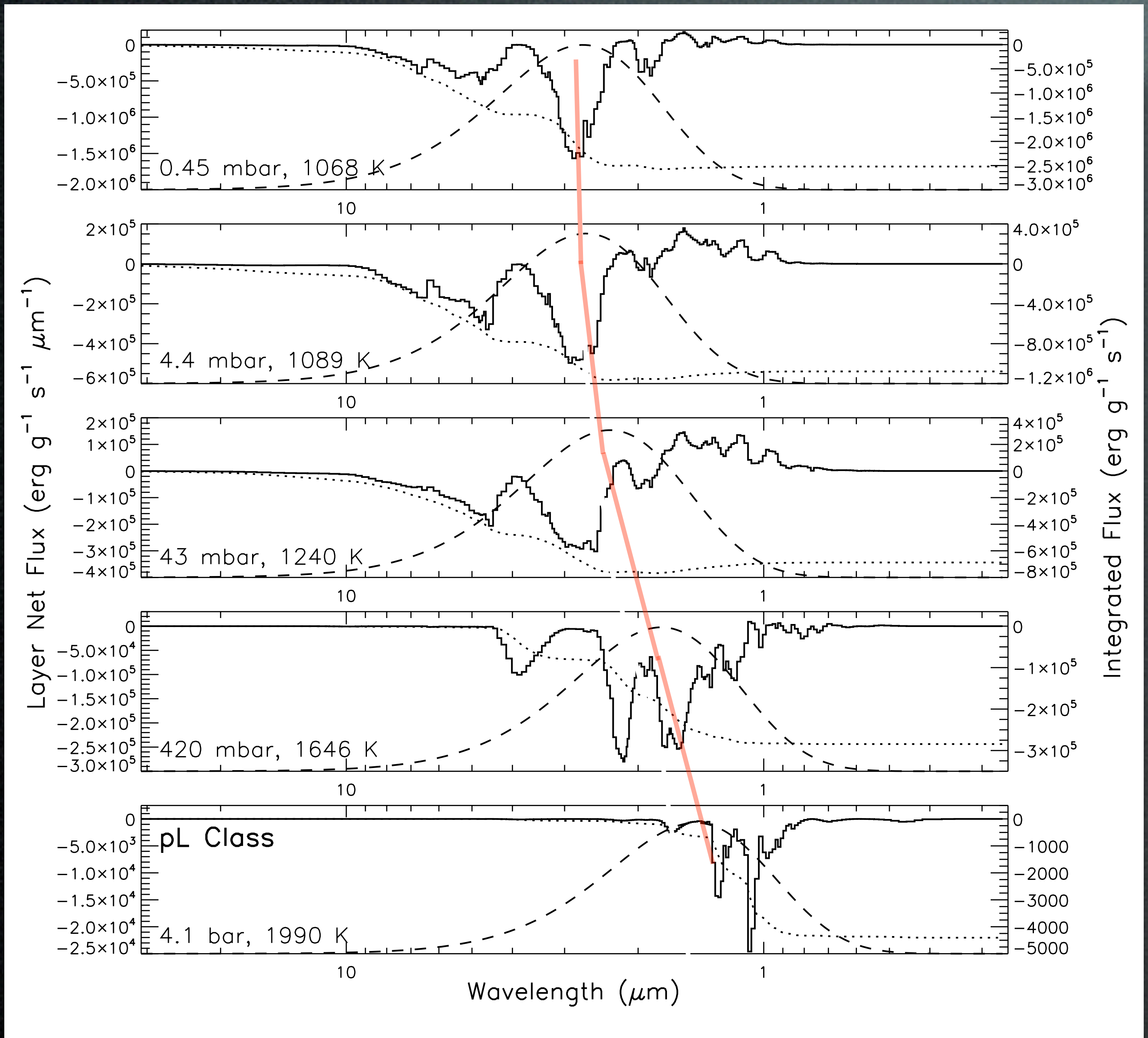
Absorption
as a function of Pressure:





- pM class have much greater incident stellar flux than pL.
- Deposited mainly in higher layer.

Thermal Emission
as a function of Pressure:



pL class atmospheres:

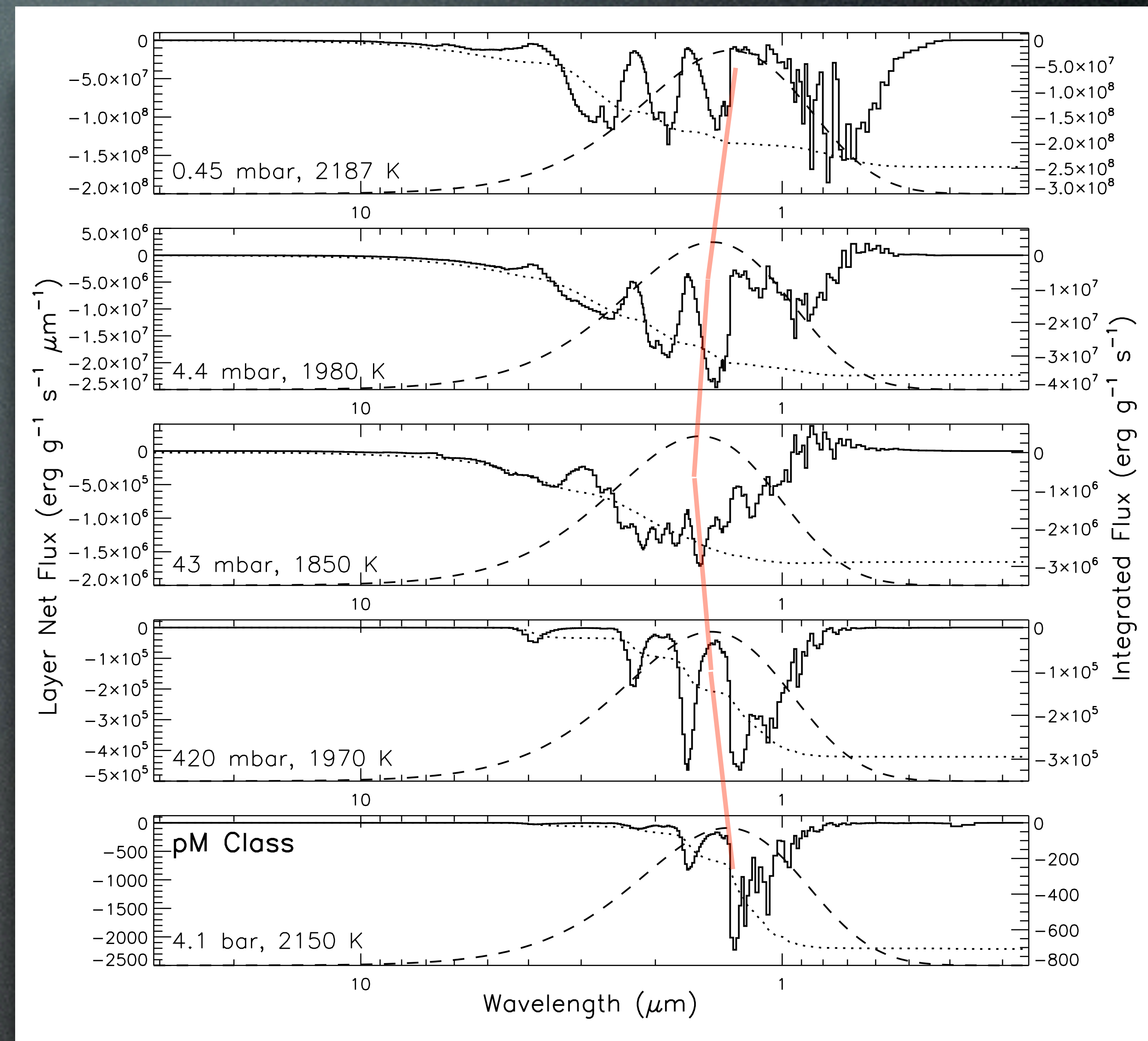
· NIR & MIR H_2O bands cool the atmosphere above 43 mbar.

· Deeper, emission of water bands at shorter wavelengths.

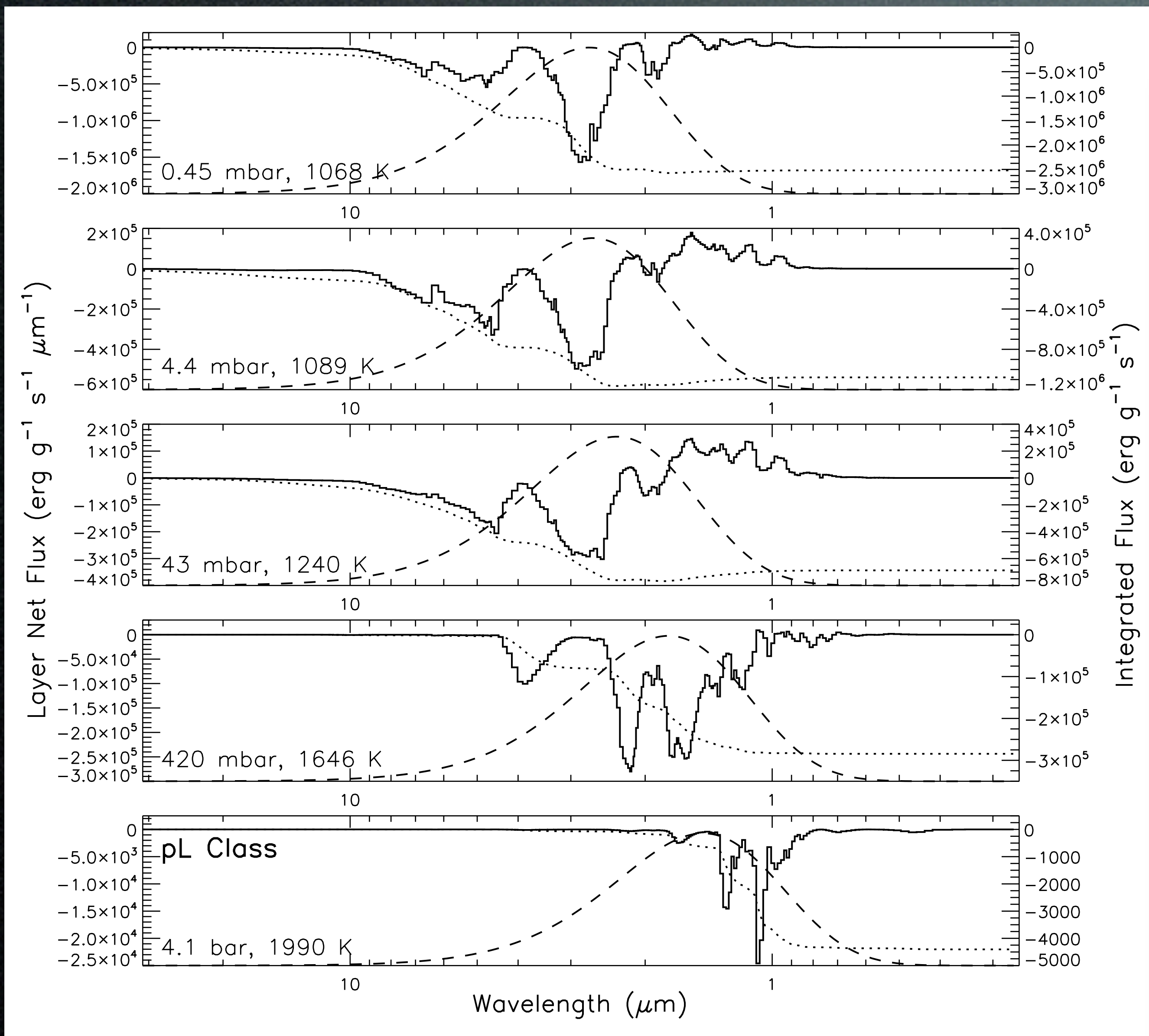
Thermal Emission as a function of Pressure:

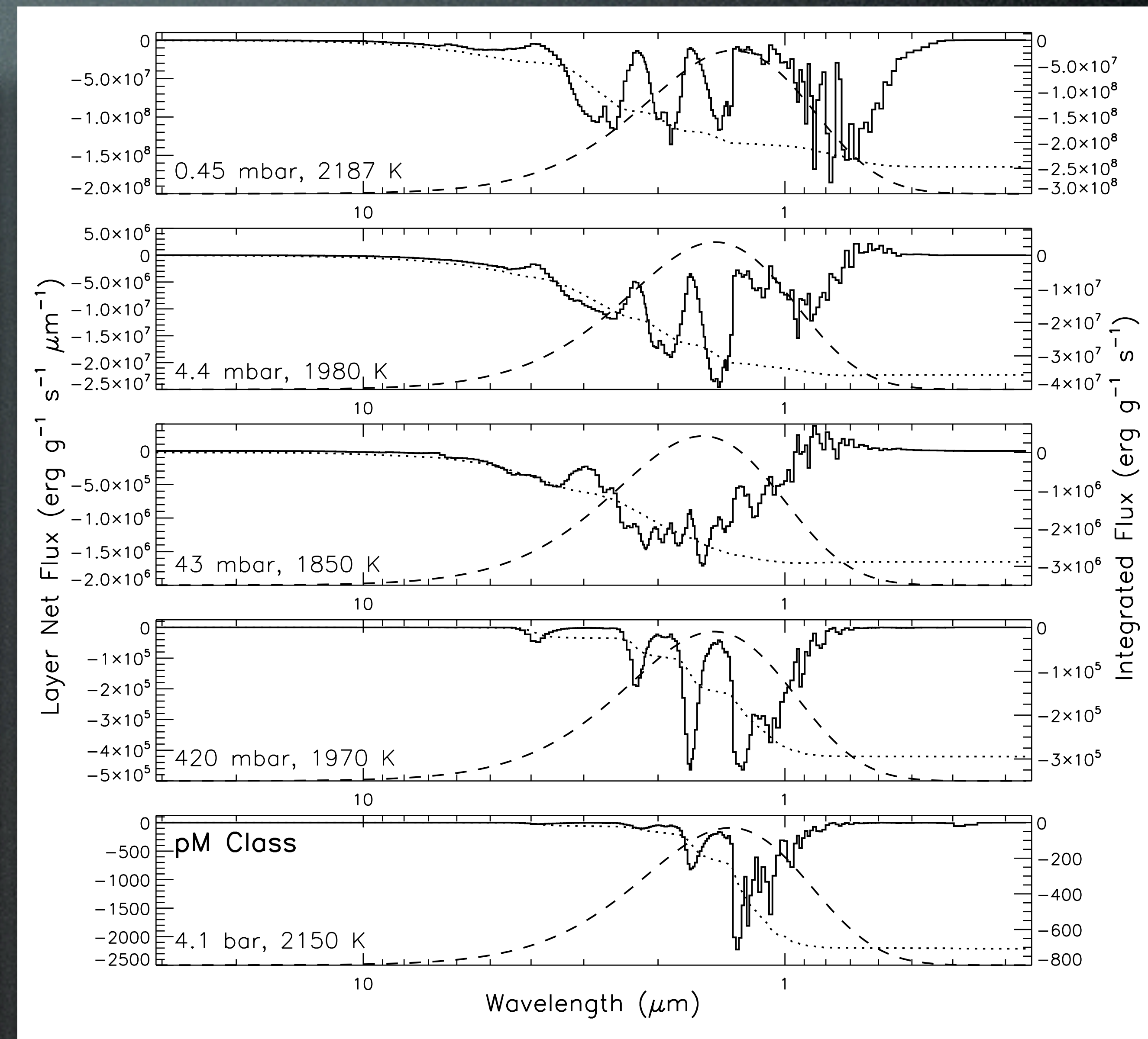
pM class atmospheres:

- Top: much higher temp. to radiate the absorbed energy.
- H_2O and TiO/VO bands emission.
- At 420 mbar, the temp. rises again.



Thermal Emission as a function of Pressure:





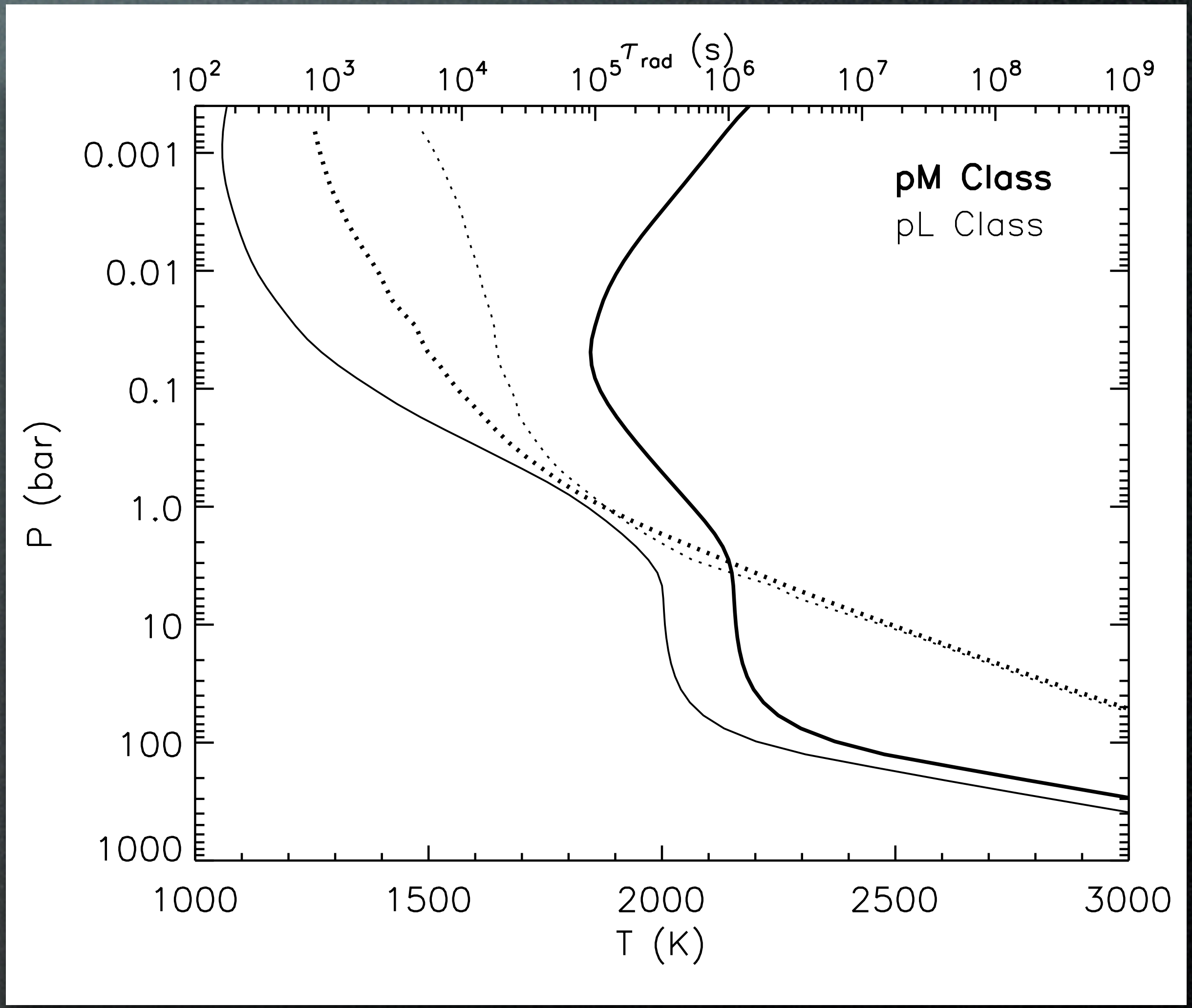
- In general the emission in pL occurs in pressures 1 order of magnitude greater than in pM.

Radiative Time:

A disturbance in temperature returns to equilibrium in a characteristic time (*Showman & Guillot '02*):

$$\tau_{\rm rad} \sim \frac{P}{g}\frac{c_P}{4\sigma T^3}$$

For pL and pM planets, differs in the thiner (observed) upper atmosphere.

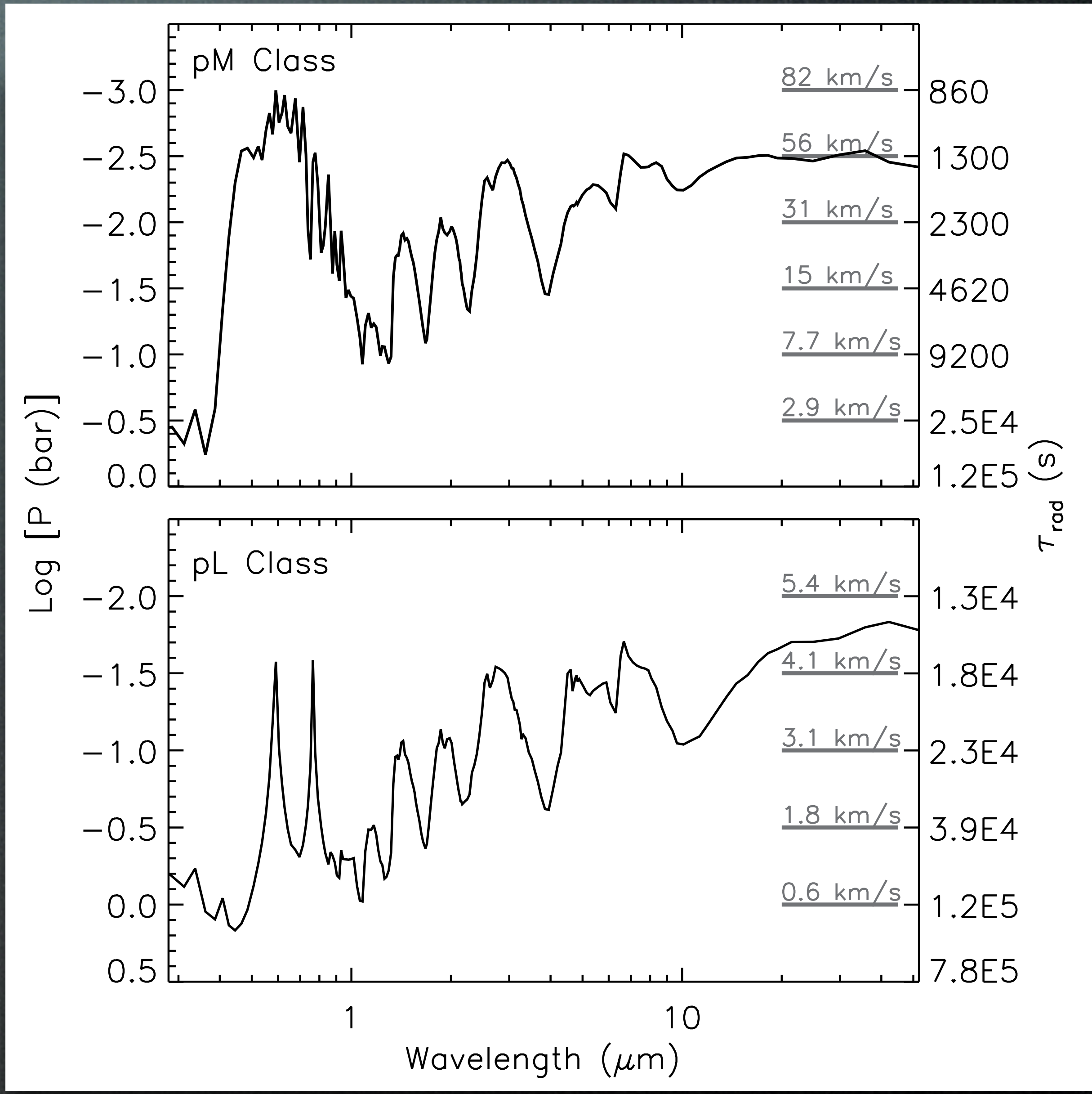


P-T profiles allow to calculate $\tau_{\rm rad}$ along the atmosphere (dotted lines).

Energy Redistribution:

Defining an advective timescale
(*Showman & Guillot '02*):

$$\tau_{\text{advec}} = \frac{R_p}{U}$$



Estimate winds necessary to redistribute energy on the planet ($\tau_{\text{adv}} = \tau_{\text{rad}}$).

Predicts:

· Hottest part at substellar point in pM.

· Higher day/night-side temperature contrasts for pM than pL.

Does all this really work?

- ups And b have large day/night-side temperature contrasts *(Harrington '06)*.
- As well as HD 179949 b *(Cowan '07)*.
- HD 189733 b show small contrast ~240 K *(Knutson '07)*.
- HD 149026 b have bright secondary eclipses *(Harrington '07)*.
- Also HD 209458 b *(Knutson '08)*.
- TrES-1 is no more than 20% brighter than T_{eq} *(Deming '05)*.