Physics of the Diffuse Universe

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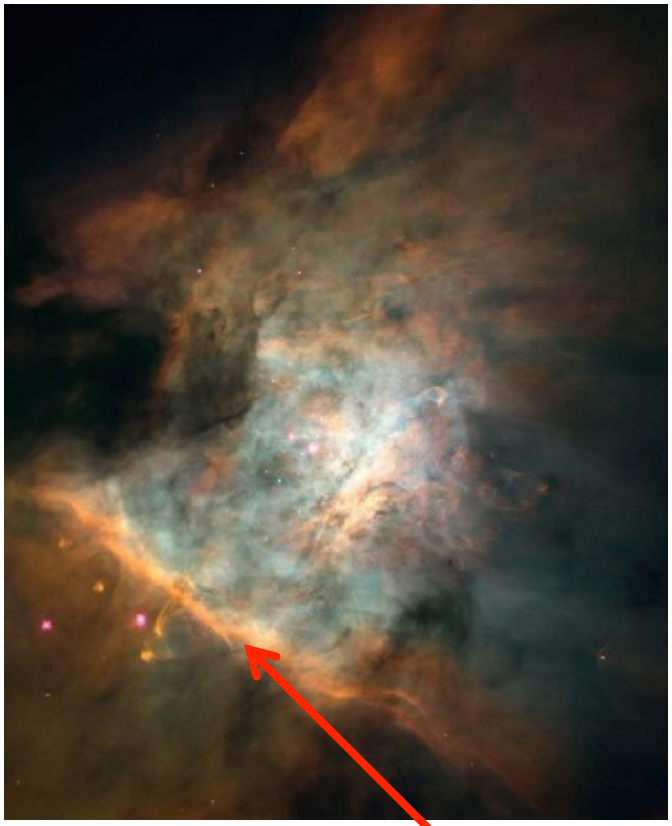
Outline for HII Regions

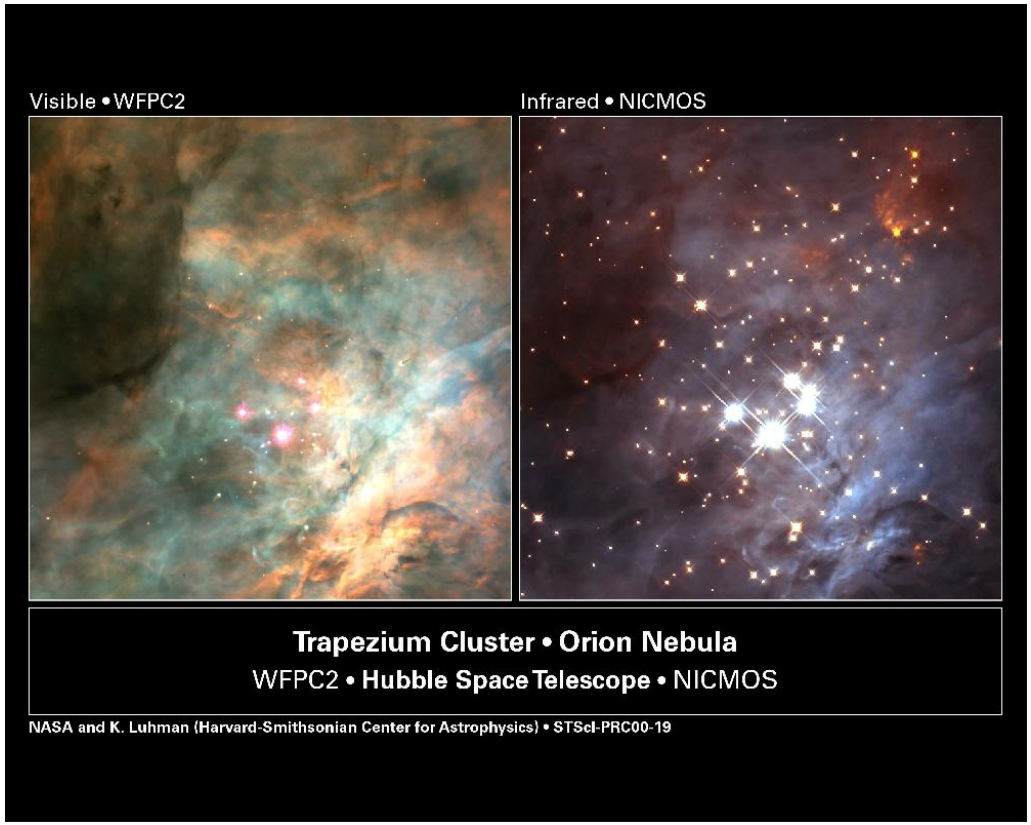
- Thermal Equilibrium
- Stromgren Sphere
- Recombination Line Spectrum

Resources

- Draine ch 27, 15, 14
- Osterbrock
  - Astrophysics of Gaseous Nebulae and AGN
  - Ch 2, 3, 4
- Dopita & Sutherland
  - Ch 9, 10

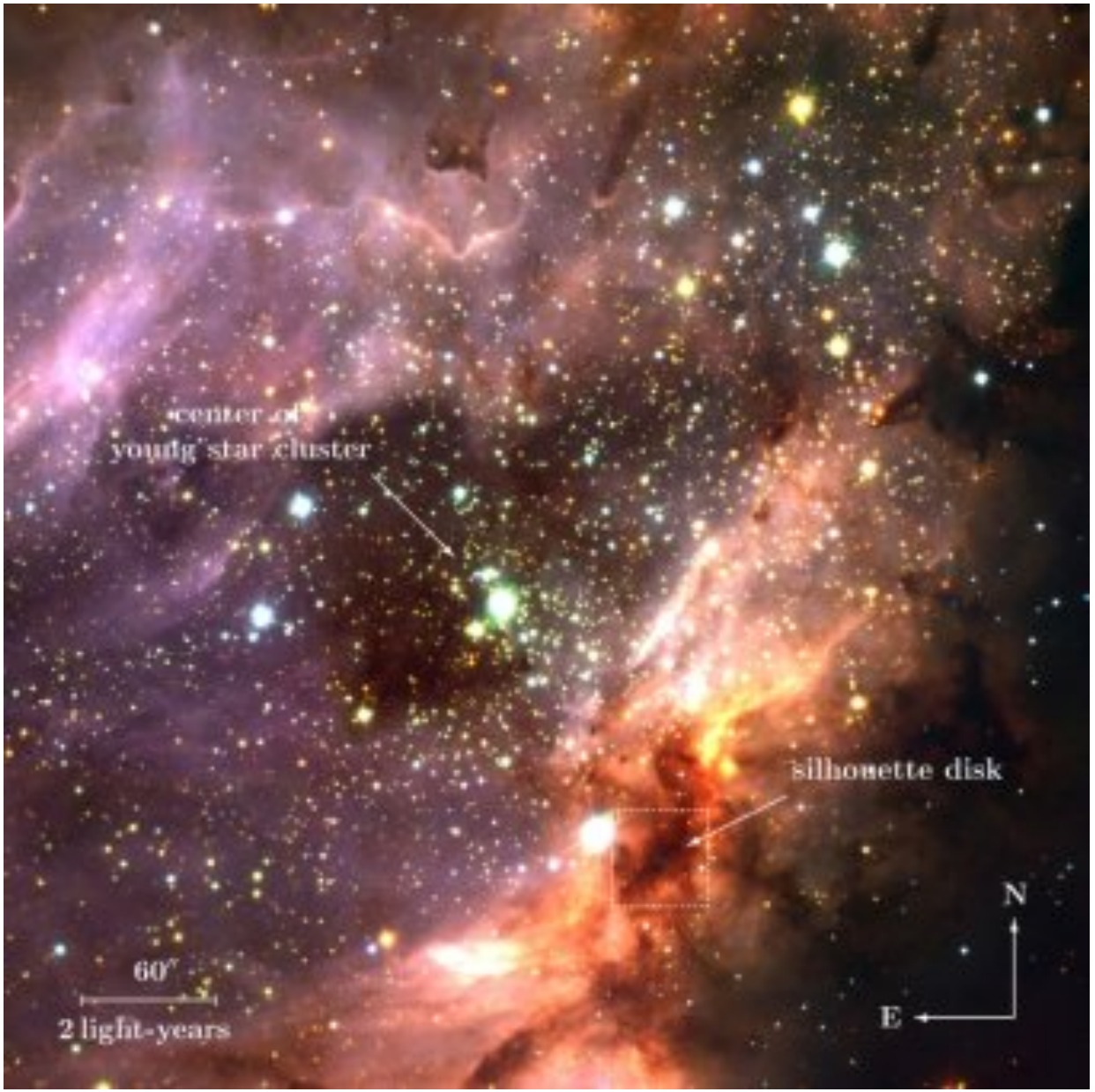
Nestled in the center of M42 is a group of stars, known as the Trapezium, which have formed from the gas in the nebula.The stars of the Trapezium are young blue stars. It is their energy which makes the nebula glow.



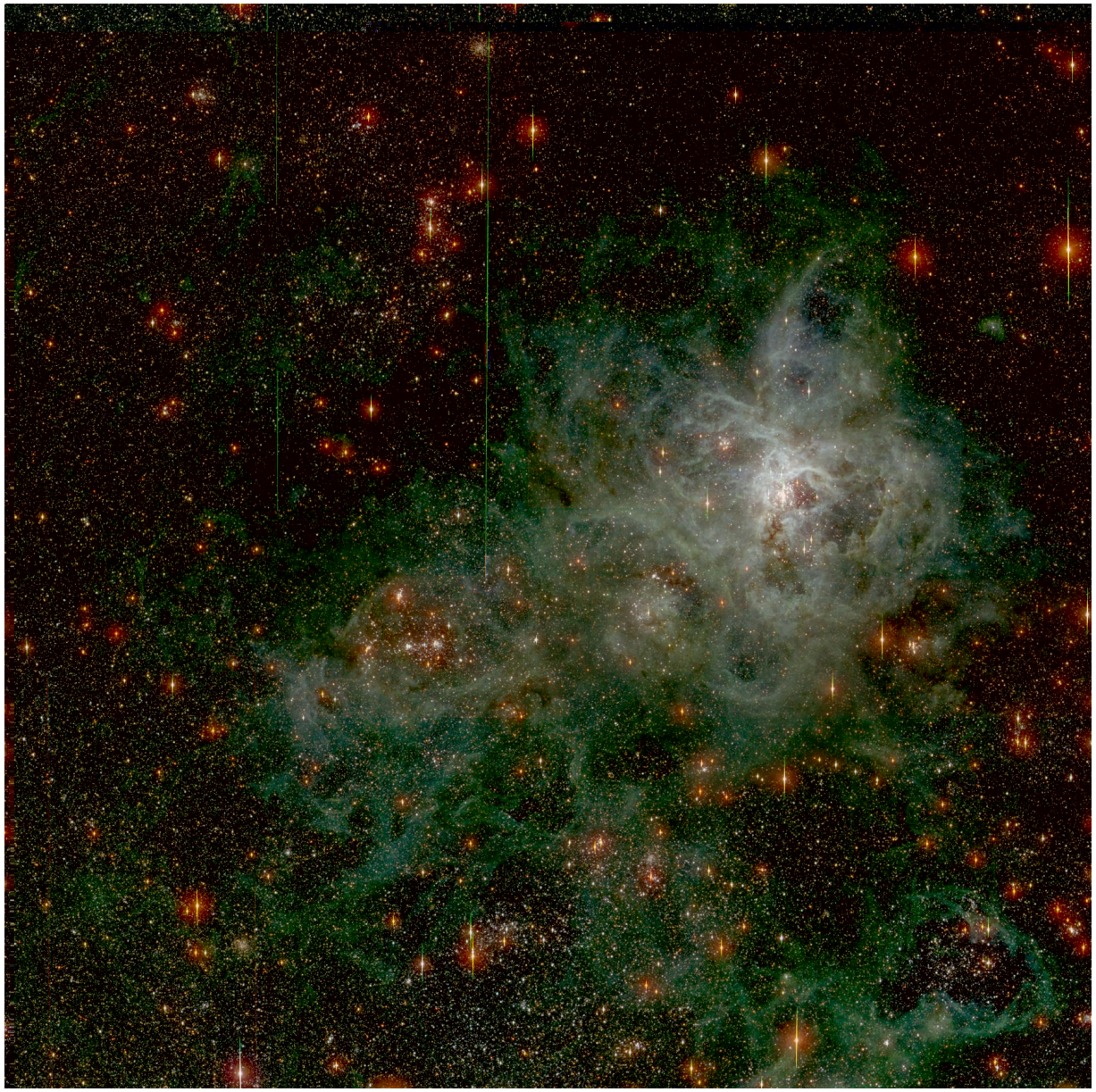


Winter 2016

Orion Bar (Photodissociation Region, or PDR)


center of
young star cluster
silhouette disk
60″
2 light-years
N
E

30 Doradus



Thermal Equilibrium

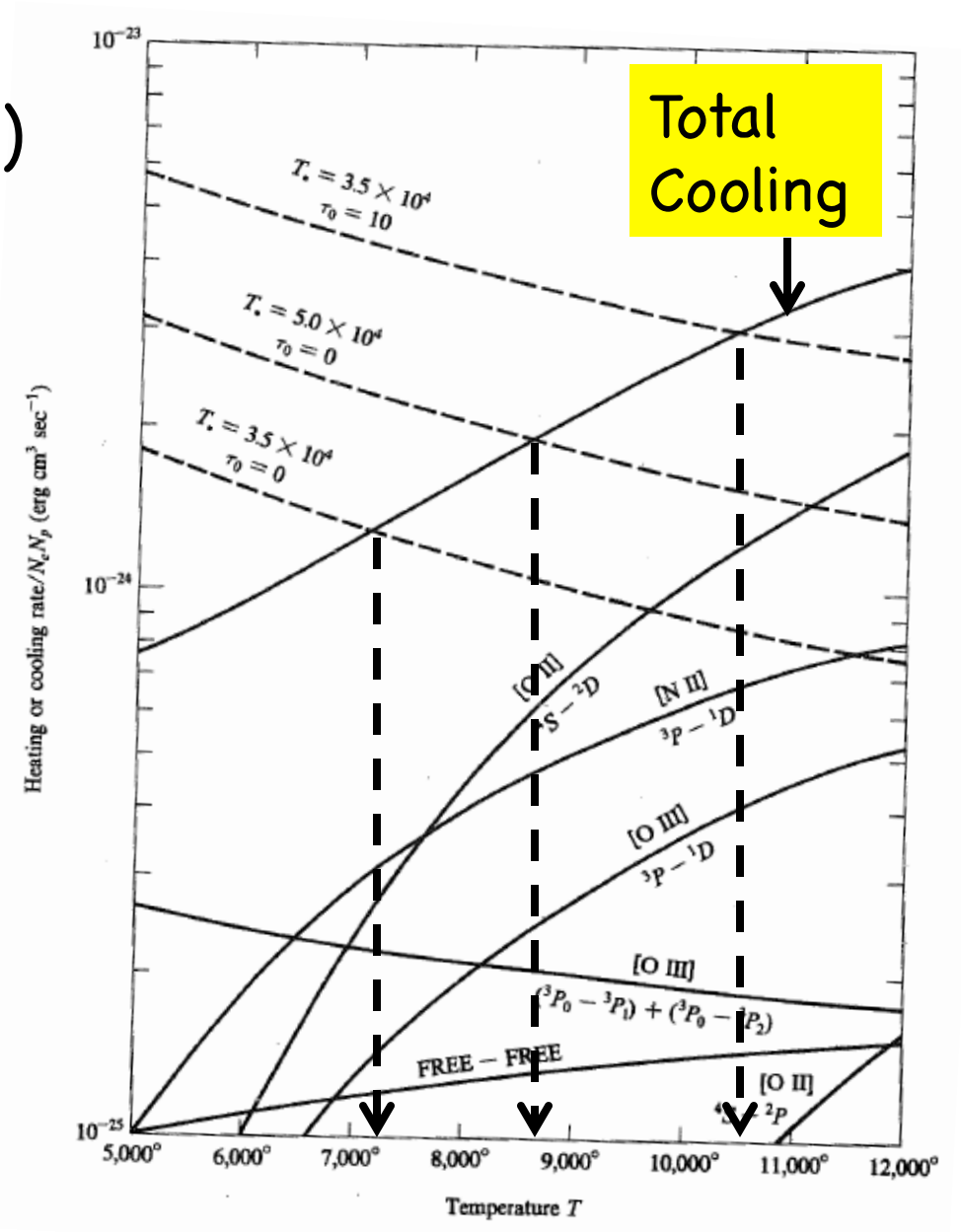
- Mean energy of a photoelectron is kT*
- Depends only on the shape of the Spectral Energy Distribution (SED)
- The rate of photoelectron production depends on the strength of the radiation field.
- Mean energy of a recombining e- is kT_e
- $\alpha_{Rec} \sim \sigma_{Rec} v \sim \nu^{-1} \sim T^{-1/2}$
- $\sigma_{Phot} \sim \nu^{-3}$
- SED hardens with increasing distance from a star

Thermal Equilibrium of HII Regions

- Plot heating rate and cooling rate vs. temperature
- The intersection of these functions gives the equilbrium temperature
- The rapid increase in cooling rate with T, and the decrease in heating rate with T, acts as a 'thermostat' to regulate the HII region T to a narrow range (roughly 8000 K to 20,000 K) over a very wide range of heating rates (MS stars, PNe, AGN, etc.)

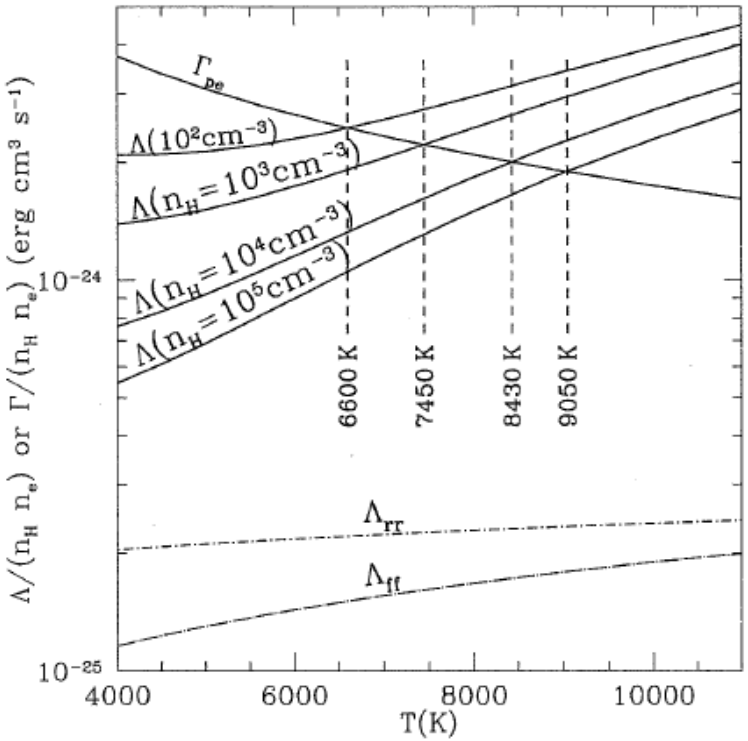
Heating and Cooling Rates / $N_e N_p$ (erg/ cm^3 s^{-1})

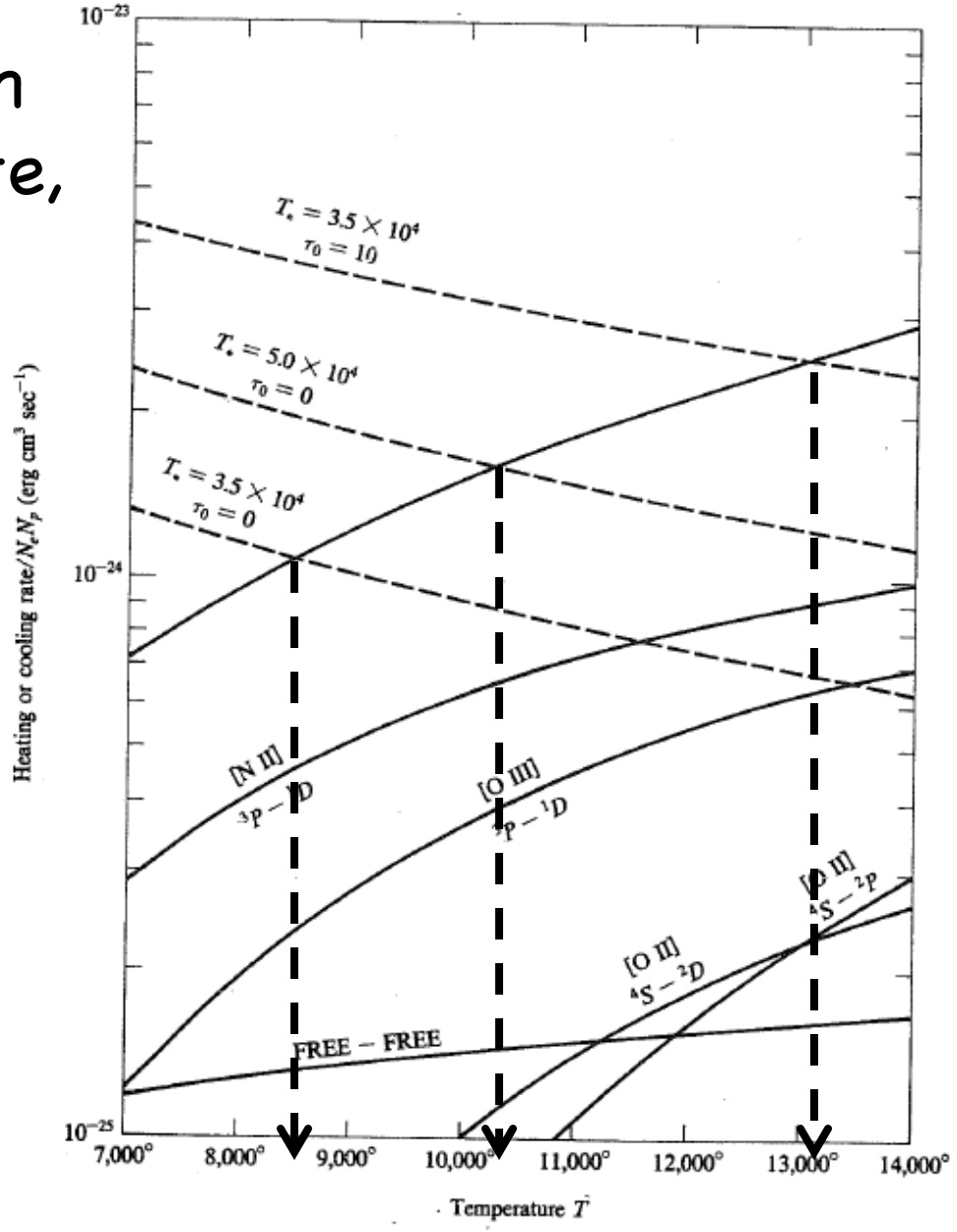
- What are the main contributors to the total radiative cooling rate?
- How does increasing the stellar temperature change the equilibrium temperature?
- How does changing the optical depth change the equilibrium temperature?
- How would including collisional de-excitation change the equilibrium temperature?



T_{EQ} = 7200, 8700, 10500 K

Collisional de-excitation reduces the cooling rate, so the equilibrium T is higher at higher n.

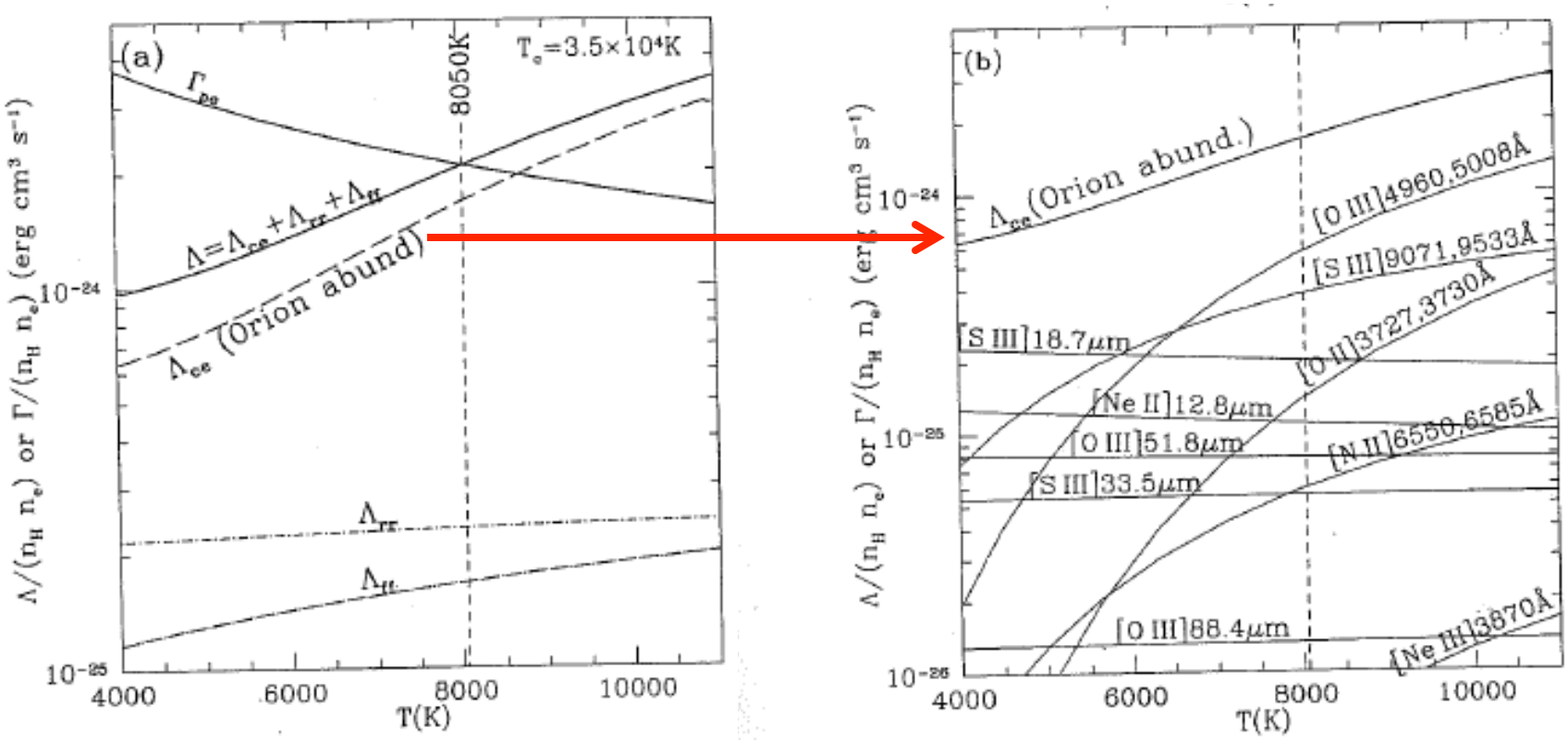




T_{EQ} = 8600, 10300, 13200 K

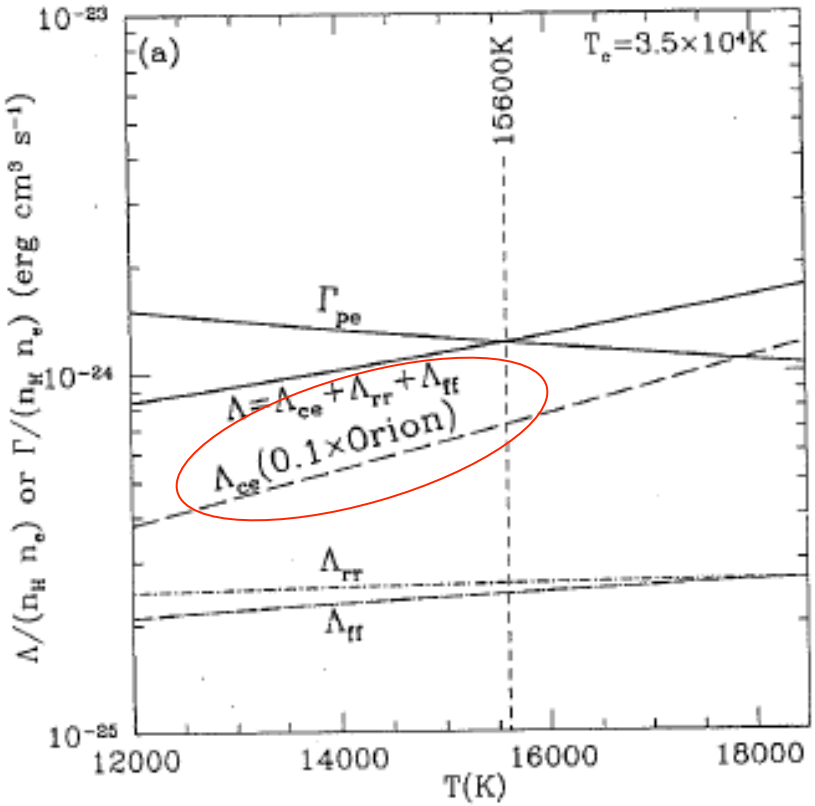
Temperature of Orion Nebula

- Orion-like abundances and n_H=4000 cm^{-3}
- How will the T change if Z = $0.1Z_0$? Or, Z = $3Z_0$?

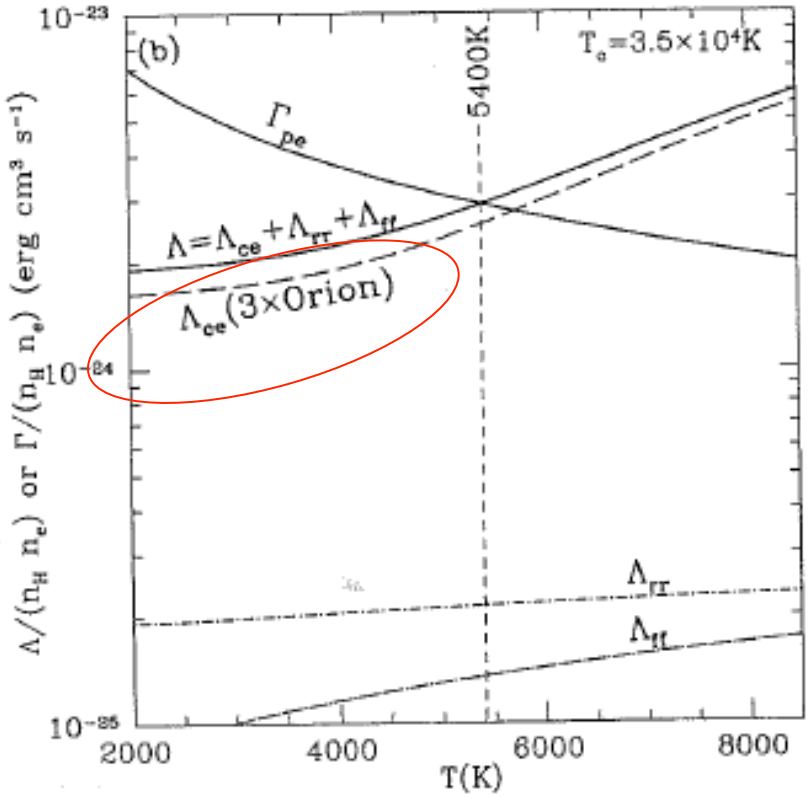


Heating and Cooling Rates / $N_e N_p$ (erg/ cm^3 s^{-1})

Hotter



Cooler



End Lecture 9

- Read
  - D: ch 27
  - Osterbrock: ch 3
- Supplemental
  - DS: ch 9