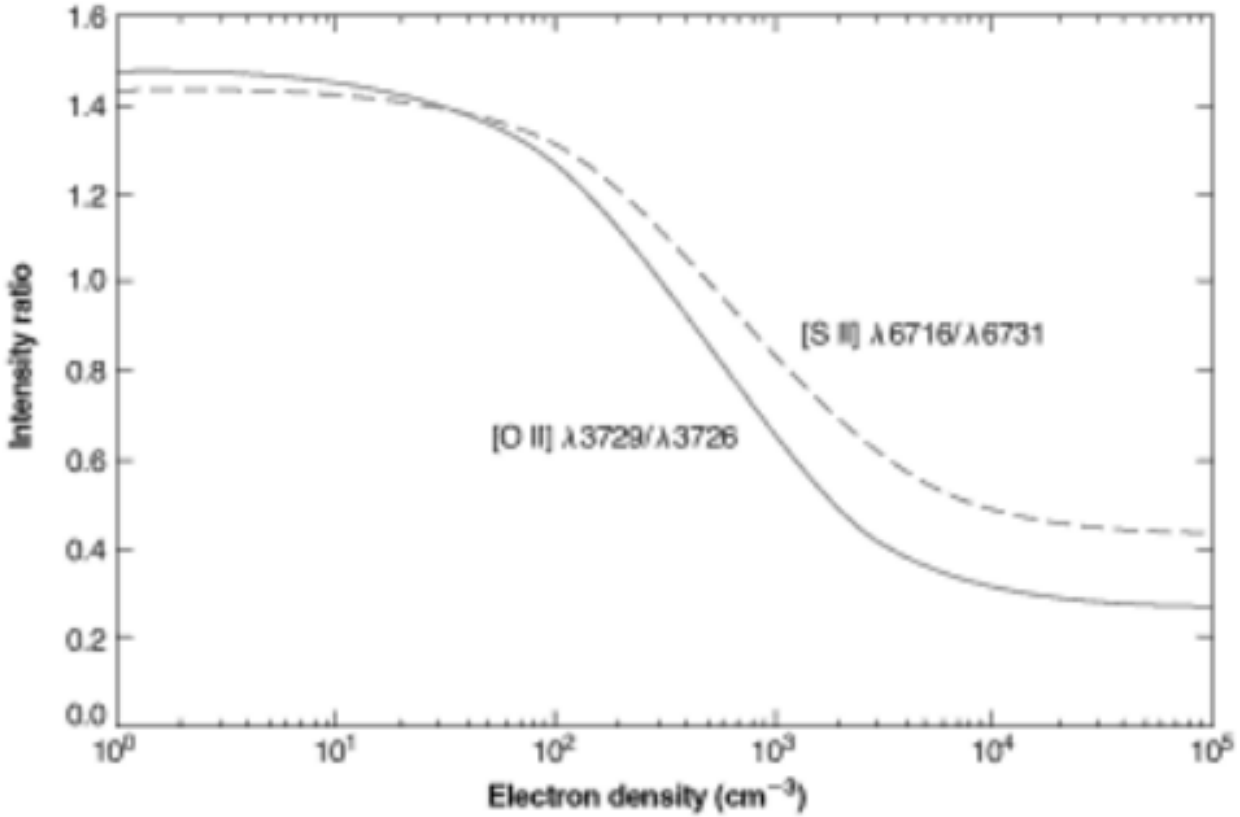
III. Emission Line Diagnostics



Review 2 Level Atom: Critical Density

- Define a **critical density** where the collisional de-excitation rate matches the radiative depopulation rate.

  $n_{crit} = A_{ul}\ g_u\ T^{1/2}\ /\ \beta\ \Omega_{lu}$

- Represents the transition from the LDL to LTE level populations for that transition
- The line emissivity (vs. n) flattens from slope 2 to slope 1 (in log space)
- Compare the critical densities for forbidden, intercombination, and resonance lines.

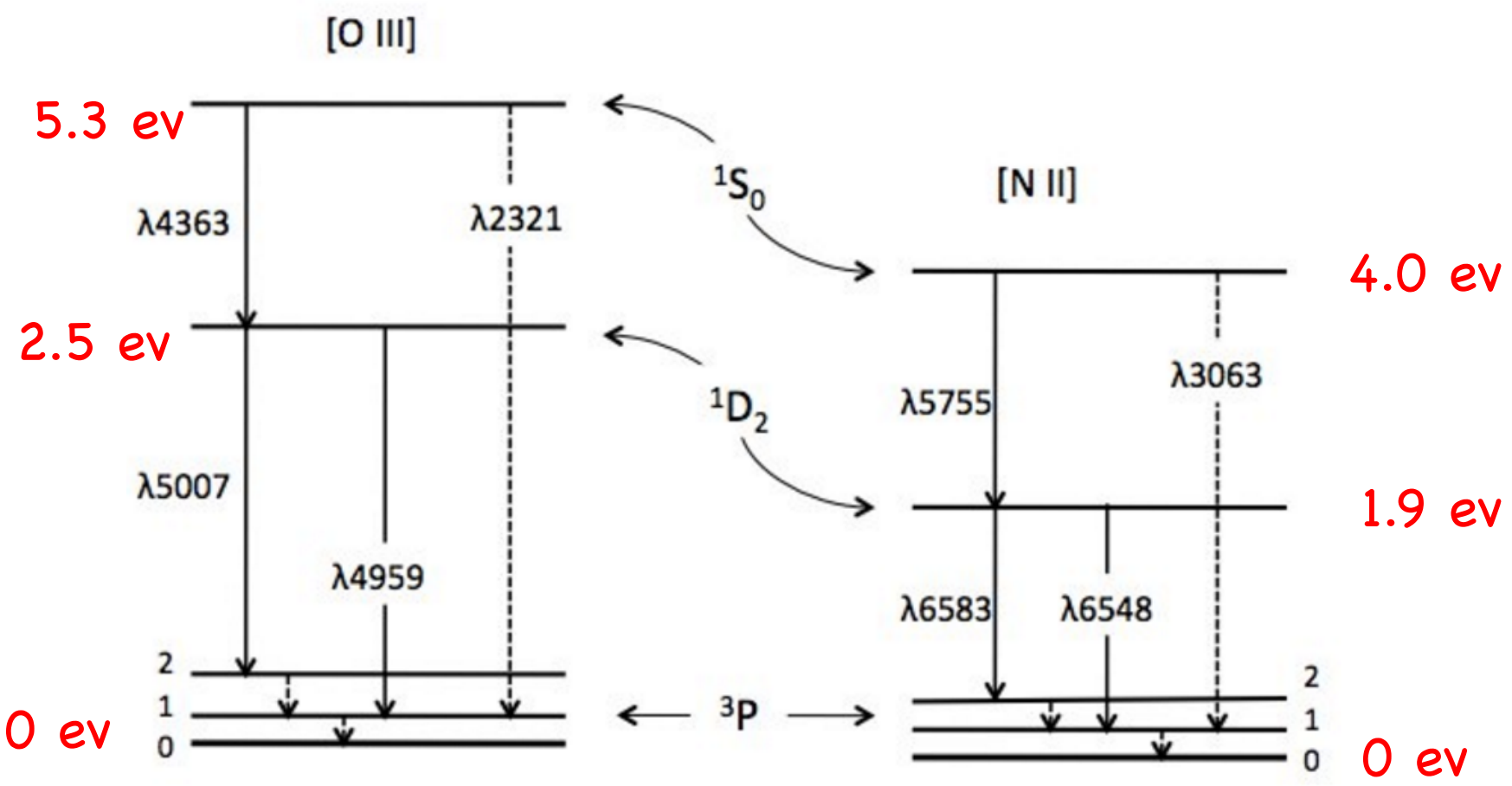
Three Level Atom (Introduction)

- **Three Level Atom** describes many of the strong lines in spectra of ionized nebulae (and late-type galaxies) used to infer physical conditions.
- The states have different spin-orbit interactions but the same principle quantum number, so these are forbidden lines

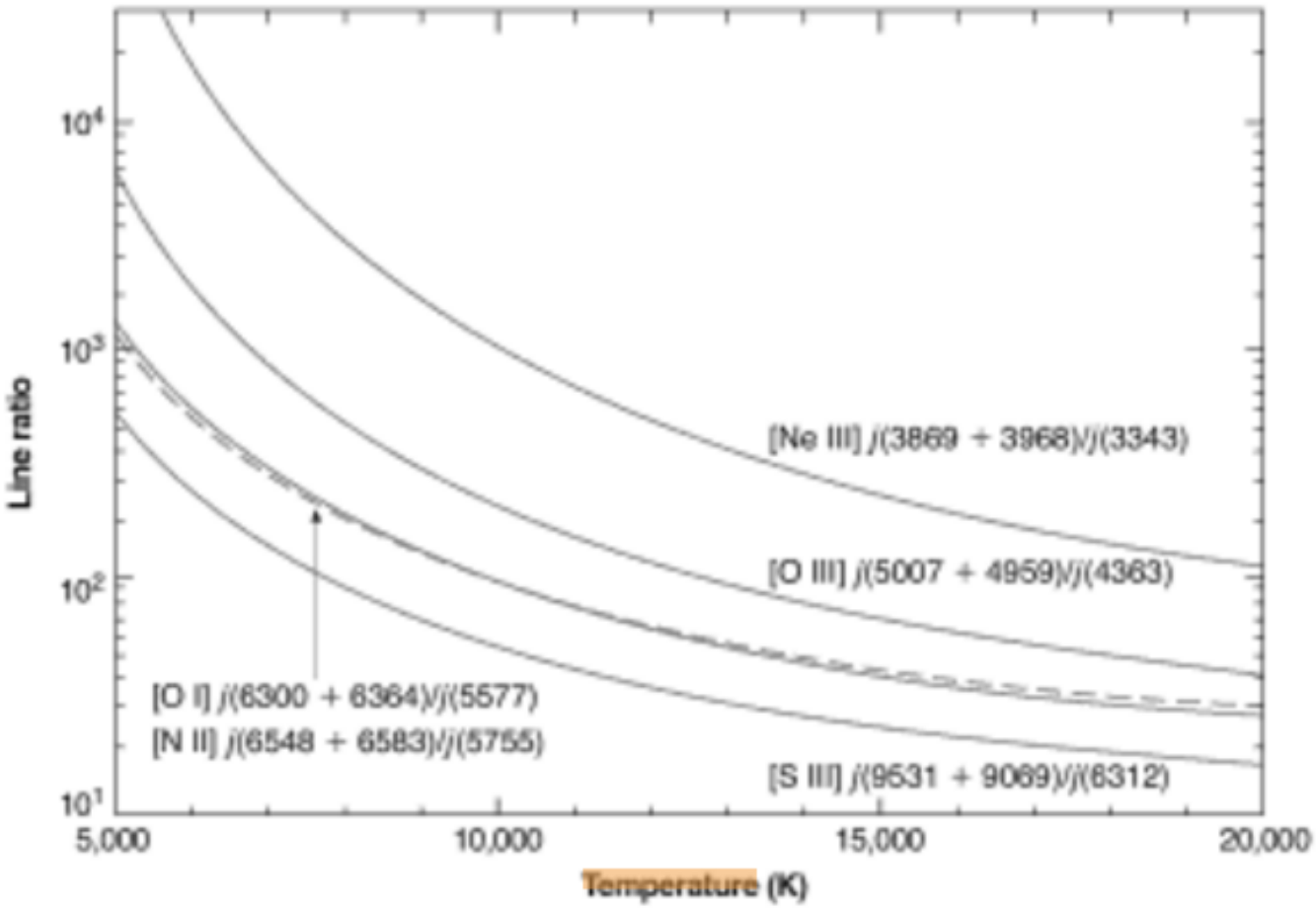
Temperature diagnostics via p^2 and p^4 ions (I)

- Consider intensity ratios of lines from different energy levels of a single ion [BB]
  - $E_{32} \sim E_{21}$
  - $C_{12} >> C_{13}$ (C = collision rate per ion = $n_e \langle \sigma v \rangle$)
  - Low Density Limit
- Levels populated by collisional excitation and depopulated by spontaneous emission.
- Find that the relative intensities depend strongly on T:
- $F_{32}/F_{21} = E_{32}/E_{21} * A_{32}/(A_{32} + A_{31)} * \Omega_{12}/\Omega_{12} * \exp(-E_{32}/kT)$

Temperature diagnostics via p^2 and p^4 ions (II)



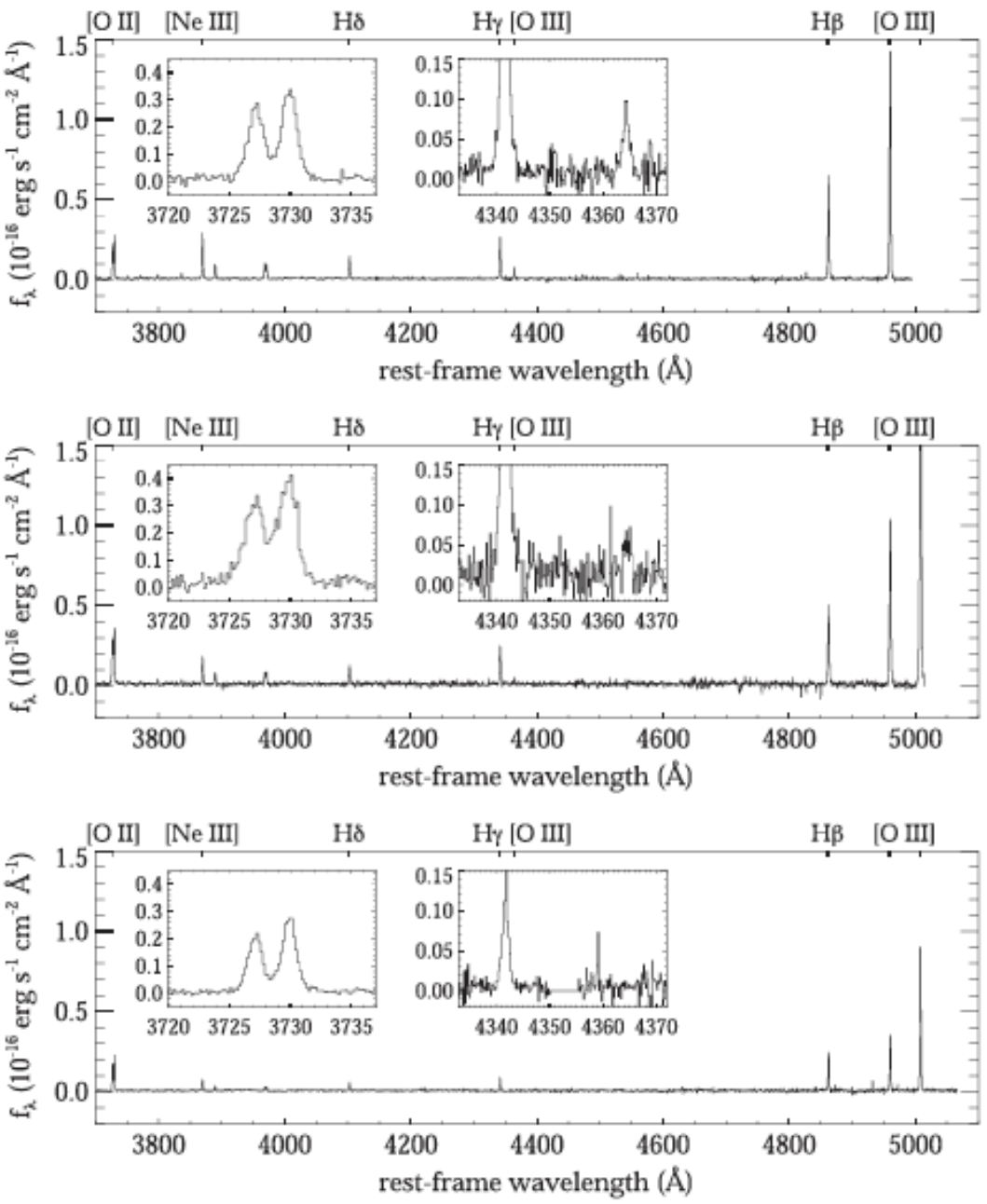
Temperature diagnostics via p^2 and p^4 ions (III)



Temperature diagnostics

- Temperatures of HII regions increase with galactic radius due to metallicity gradient
  - Why does lower Z produce higher T?
- Planetary nebulae generally have higher T than do HII regions.
  - Why?
- [OIII] and [NII] may give slightly different temperatures.
  - Can you think of ways this could this happen?

Application to high redshift galaxies



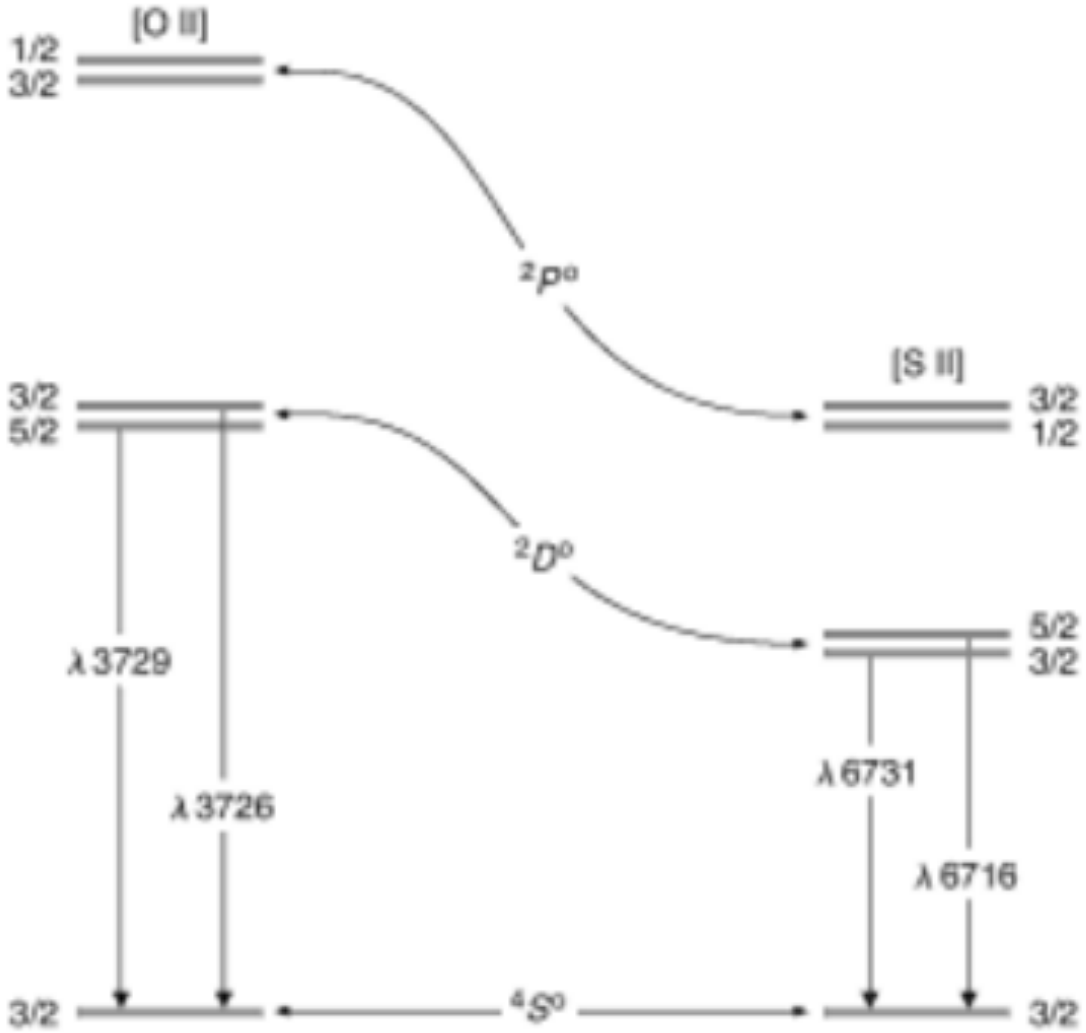
Density diagnostics via p^3 ions

- Consider the relative intensities of lines originating from levels of the same ion with roughly the same energy but different A (and g) values.
  - $E_{32} \ll E_{21}$
  - $A_{32} \ll A_{31}$ and A_{21}

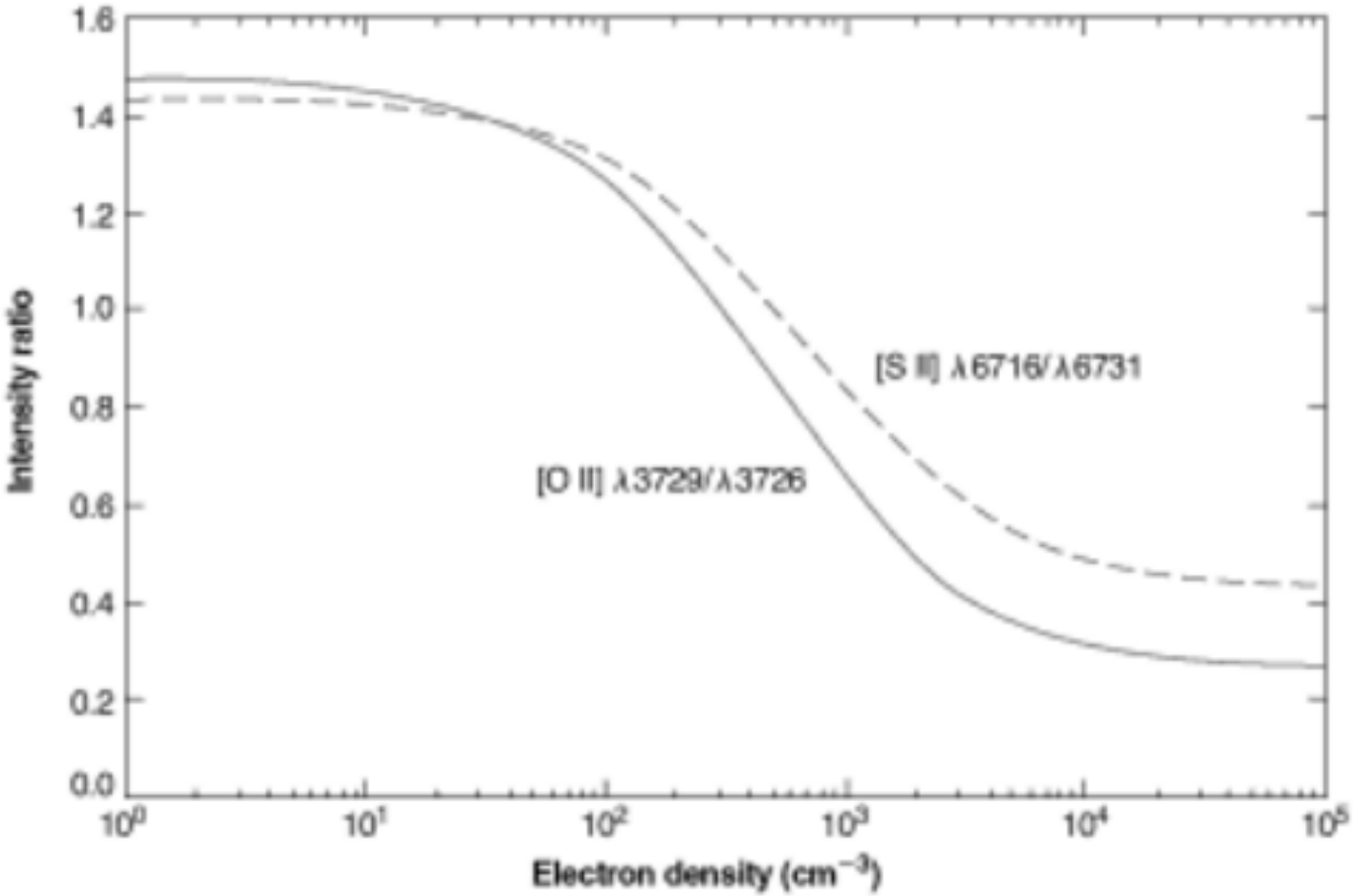
Density diagnostics via p^3 ions

- LDL -- all collisional excitations result in radiative decays
- [BB] $F_{31}/F_{21} = \Omega_{13}/\Omega_{12}$
- See sum rule for collision strengths
- HDL -- Radiative decay rate matters because collision deexcitation may occur
- [BB] $F_{31}/F_{21} = A_{13}/A_{12} * g_3/g$
- At what densities is the line ratio a good indicator of the electron density? [BB]

Density diagnostics via p^3 ions



Density diagnostics via p^3 ions



End of Lecture 3

- Assigned Reading
  - Read D. ch 4 and 18
  - For further references see also D. ch 5, 6.3, and 6.7 and Osterbrock ch. 5