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# RADIATION PROCESSES – AST1440F

## Review Questions for Section 8

1. In what frequency range does the bremsstrahlung continuum dominate the recombination continuum? And vice-versa?
2. What are the basic mechanisms for exciting the hydrogen Balmer lines and the forbidden lines in gaseous nebulae?
3. In computing the Balmer decrement in nebulae, statistical equilibrium does not require the solution of an infinite set of simultaneous equations. What approximation and what circumstances allow us to simplify the problem?
4. Why are the *relative* intensities of the Balmer lines independent of density and temperature?
5. How does $D_n \equiv j_{n2}/j_{42}$ depend on $n$, roughly speaking? Can you explain why $D_n$ decreases with increasing $n$?
6. In the first table on p127, Model C has a steeper Balmer decrement. Why?
7. What reasons can you give for explaining why $\langle\sigma^{(\mathrm{exc})}\rangle \gg \langle\sigma^{(\mathrm{rec})}\rangle$?
8. Why is it not surprising that the forbidden lines in nebulae are in general *stronger* than the permitted lines?
9. Why are forbidden lines associated with heavy atoms and not with light ones like H and He?
10. How does the forbidden line intensity depend on density and the transition coefficient, $A_{21}$, in both the low density ($N_e < N_c$) and the high density regimes?
11. At high densities ($N_e > N_c$), we say that the states are "thermalized". What does this mean exactly?
12. Under what conditions can high-$A_{21}$ lines be *less* intense than low-$A_{21}$ ones?
13. What kind of transitions are needed as probes of (i) $T_{\mathrm{kin}}$, and (ii) density ($N_e$ or $N_{\mathrm{H}}$)?
14. We considered a case study of fine structure transitions in atomic C and O and saw how the density $n_{\mathrm{H}}$ might be determined from observed line ratios. What about the kinetic temperature $T_e$? Could it be determined from the same observations?
15. Molecular lines (such as those belonging to CO) can be used as probes of density and temperature in cool clouds just as atomic lines can be used to probe (relatively) hot gaseous nebulae. Why is the first problem more difficult to analyze than the second? Give *two* reasons.
16. What are the basic modelling steps that one has to go through in analyzing molecular line data?

17. Why is this a *coupled* radiative transfer, statistical equilibrium problem? Why does the problem have to be solved *by iteration*?
18. What is the basic principle behind the "Large Velocity Gradient" method?
19. What if the velocity gradient in the molecular line source were zero? Would the line intensities give us any information on the gas densities? The gas temperatures?
20. After a model fit using the LVG method, one gets basic info on the gas densities of (for example) CO *and* $n(H_2)$. Why is the molecular hydrogen density related to the CO line intensity?
21. In the example considered in class (DR21), no mention was made of the kinetic temperature of the gas. Can you see how $T_{\rm kin}$ might be determined as well as the densities?
22. How can interstellar absorption lines be distinguished from stellar ones?
23. Why is it much easier to predict the degree of excitation of interstellar atoms and ions than the degree of ionization?
24. Explain why interstellar lines exhibit only a Doppler core with very little wing structure.
25. Why does the equivalent width of weak lines depend only on $\tilde{N}f$, the absorbing power of the relevant atom and not on the Doppler broadening?
26. For strong lines, however, the equivalent width depends on both the absorbing power and the Doppler broadening. Why? How do we separate the two effects?
27. What are the limitations of the Doublet Ratio Method? Can we get around them?
28. How do we infer the *total* abundance of an atomic species, knowing only the abundance of one of its ions?
29. Ionization equilibrium calculations require a knowledge of the electron density. How do we get this quantity?
30. Why are higher stages of ionization favored in H I regions where the density is low?
31. How do you explain the fact that the measured abundances of many heavy elements in the ISM are much lower than corresponding abundances in stars? The fact that the *most* under-abundant elements have the *highest* condensation temperatures is a useful clue that points to a possible answer to this question.