A311, 2005-10-14

1. We know that the gas in both the BLR and NLR of AGN is largely confined to discreet clouds rather than being smoothly spread throughout the region. In this problem, you will estimate the *filling factor* (that is, what fraction of the volume is occupied by the clouds) of the NLR.

Suppose you are looking at a Seyfert galaxy which is at a distance of 40 Mpc. The NLR is observed to extend in a cone of length 1 kpc with width at the end of 200 pc. You measure, among many others, the following line narrow fluxes:

line	λ	**flux** ($\mathrm{erg\,cm^{-2}\,s^{-1}}$)
[OIII]	4959Å	22.7×10^{-13}
[OIII]	5007Å	7.3×10^{-13}
[SII]	6716Å	3.9×10^{-13}
[SII]	6736Å	3.7×10^{-13}

Assume you've measured that the NLR has an electron temperature of $T = 10^4\,\mathrm{K}$. ASsume that the gas as solar abundances ($n_{\mathrm{He}} = 0.1 n_{\mathrm{H}}$, $n_{\mathrm{O}} = 7 \times 10^{-4} n_{\mathrm{H}}$), that the H and He in the NLR-emitting gas is all fully ionized, and that the O in the NLR-emitting gas is doubly-ionized.

(a) What is the electron density in the NLR-emitting gas?

(b) What is the total volume of the NLR-emitting gas?

(c) What is the filling factor of the NLR?

2. Planetary nebulae are gas clouds found around very hot, very compact stars. The gas is the ejected envelope from a very evolved giant star of $M < 8M_\odot$. The hot, compact star is the exposed core, and is either a hot new white dwarf, or something that will very soon be that. What you end up with is diffuse gas around a source of ultraviolet radiation capable of ionizing Hydrogen— similar to what you have in HII regions (where the ultraviolet source is massive hout *young* stars, rather than left-over remnants of stars). Hence, you see a similar spectrum from the regions of ionized gas.

The [OIII]/Hβ flux ratio from planetary nebulae tends to be higher than that from HII regions. Assume that the recombination cross-section (which gives rise to the Hβ line) has a similar dependence on electron density and temperature as the collisional excitation cross-section. Given that, suggest two different reasons why the [OIII]/Hβ flux ratio might be higher in one nebula as compared to another (i.e. a planetary nebula as compared to an HII region).

Fun Numbers

$$h = 6.626 \times 10^{-27}\ \mathrm{erg\ s} \qquad \frac{hc}{4363\text{Å}} = 4.56 \times 10^{-12}\ \mathrm{erg}$$

$$\hbar = 1.055 \times 10^{-27}\ \mathrm{erg\ s} \qquad 1\,\mathrm{pc} = 3.086 \times 10^{18}\,\mathrm{cm}$$

$$k = 1.381 \times 10^{-16}\ \mathrm{erg\,K^{-1}} \qquad \frac{hc}{5000\text{Å}} = 4.0 \times 10^{-12}\ \mathrm{erg}$$

$$m_e = 9.109 \times 10^{-28}\ \mathrm{g} \qquad \Omega(^3P,^1D) = 2.17 \text{ for [OIII]}$$

$$m_p = 1.673 \times 10^{-24}\ \mathrm{g} \qquad \Omega(^3P,^1S) = 0.28 \text{ for [OIII]}$$

$$1\,\mathrm{amu} = 1.66 \times 10^{-24}\,\mathrm{g} \qquad \Omega(^1D,^1S) = 0.62 \text{ for [OIII]}$$

OIII Transition	λ **(Å)**	$\mathbf{A_{21}}$ $\mathbf{s^{-1}}$
$^1D_2 - ^1S_0$	4363	1.8
$^3P_2 - ^1S_0$	2331	7.8×10^{-4}
$^3P_1 - ^1S_0$	2321	2.2×10^{-1}
$^3P_2 - ^1D_2$	5007	2.0×10^{-2}
$^3P_1 - ^1D_2$	4959	6.7×10^{-3}
$^3P_0 - ^1D_2$	4931	2.7×10^{-6}