C1: Atomic Physics and the ISM Problem Set 2

Michaelmas Term 2013

---

1. A hot star is embedded in a dusty region. Silicate dust grains have a radius of 0.1μm and have an efficiency $Q_\nu \propto \nu$, such that the efficiency ratio $<Q_{IR}> / <Q_{UV}> = 2\times10^{-2} a T_{gr}$, while carbon grains have a radius of 0.01μm and have an efficiency $Q_\nu \propto \nu^2$, such that the efficiency ratio $<Q_{IR}> / <Q_{UV}> = 4\times10^{-4} a^2 T_{gr}^2$, where a is in μm. Calculate the temperatures that these grains will attain at a distance of 20 AU from the central star of a planetary nebulae with a temperature of 40 000 K and a luminosity of 10^4 $L_\odot$. Comment on these temperatures and the possible behaviour as a function of distance from the star in this object.

Observations in the mid-infrared at $\lambda = 10\mu$m show emission extending to distances of 0.01pc from the central star. What is the likely explanation for this emission. [10]

2. Describe the main sources of opacity at visible wavelengths in the photospheres of hot (B-type) stars, solar-type stars and cool stars. Explain the physical conditions that give rise to the different opacity sources. [8]

Estimate the temperature at which the number of hydrogen atoms in the first excited state is equal to the number in the ground state for a thermal distribution. Is this level population likely to be realised in practice? [7]

Without detailed derivation, justify the following expression for a grey atmosphere, defining all terms used and stating any assumptions made:

$$S(\tau) = \frac{3}{4\pi}\left(\tau + \frac{2}{3}\right)F$$

Adopting a grey atmosphere approximation, estimate the temperature ranges which may be investigated by measurements at the limb and at the centre of the solar disk. [10]

3. Observations of a HII region in a galaxy at a distance of 3Mpc give the following values for the intensities of Hydrogen recombination lines:

Line	Wavelength (μm)	Observed Intensity I_ν (10^{-18} Wm^{-2})	Relative Intrinsic Intensity
H(Gamma)	0.434	0.0119	47
H(Beta)	0.486	0.0455	100
H(alpha)	0.656	0.702	285

Theoretical line intensities relative to $H_\beta = 100$ calculated by Hummer & Storey are also listed.

The extinction expressed in magnitudes relative to an extinction of A(V)= 1 magnitude in the optical can be approximated by:

$$A(x) = 1.0 + 0.826(x-1.83) - 0.320(x-1.83)^2$$

where x is the inverse wavelength $1/\lambda$ in units of μm^{-1}.

What is the extinction, expressed as magnitudes of visual extinction A(V) towards the emitting region? [8]

What information can be obtained from the extinction-corrected hydrogen line fluxes, and how might the calculated value of the extinction be checked?

Give an estimate of the total number of ionizing photons emitted by the stars, and estimate the size of the resulting HII region, assuming an electron density $n_e \sim 10^{10} m^{-3}$. [7]

The hydrogen recombination coefficient $\alpha = 2.6 \times 10^{-19} m^3 s^{-1}$

4. Rest-frame ultraviolet absorption lines from the ground state of C II have been detected towards the QSO 0347 - 3819 at a redshift of 3.025. The ground state of the C^+ ion consists of two levels $2s^2 2p\ 2P^0_{1/2,3/2}$ with an energy separation of $\Delta E = 63.42\ cm^{-1}$.

Assuming thermal equilibrium, obtain an expression for the level population of the ground and excited fine structure levels within the ground state, and estimate the excitation temperature using the column densities in the two levels and the other information below. Comment on the value of T_{ex} found. [10]

The column densities estimated from the transitions from the ground and excited levels within the ground state are $5.05 \pm 0.28 \times 10^{15}\ cm^{-2}$ and $1.92 \pm 0.1 \times 10^{13}\ cm^{-2}$ respectively. For the ground level J=1/2 and for the excited level J=3/2.