Assignment #10: due Thursday, Dec. 18

Theoretical Astrophysics

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Ralf Klessen, ZAH/ITA, Albert-Ueberle-Str. 2, 69120 Heidelberg

1. **Mean free path of gas particles and photons** 20 pt

   (a) Calculate the mean free path of the nitrogen molecules you are currently breathing in and out. Take the radius of N_2 to be 1 Å and assume a (room) temperature of 20 °C. What is the average time between collisions?

   (b) Calculate how far you could see if the atmosphere here in Heidelberg had the opacity of the solar photosphere. Use the simple value for electron scattering, $\kappa \approx 0.2\,\mathrm{cm^2\,g^{-1}}$.

   (c) What is the average mean free path of a photon in Sun if we assume a mean density of $1.4\,\mathrm{g\,cm^{-3}}$ and again take only electron scattering into account?

   (d) How long does it take a photon released at the center of the Sun to escape through the surface? Assume the photons "diffuse" outwards, so that the succession of collisions (actually, absorption and reemission events) can be described as a random walk.

2. **Thermal radiation** 30 pt

   A spherical gas cloud of radius R and temperature T emits thermal radiation at a rate $P(\nu)$ (power per unit volume and frequency range). Its distance from the Earth is d ($d \gg R$).

   (a) First assume the cloud is optically *thin*. What is the brightness of the cloud measured on Earth? Assume the cloud is viewed along a parallel ray which has a distance b from the cloud centre.

   (b) What is the effective temperature of the cloud?

   (c) What is the flux F_ν measured at the Earth coming from the entire cloud?

   (d) How does the measured brightness temperature compare with the cloud's temperature? The brightness temperature T_b is defined by the equation

   $$I_\nu = B_\nu(T_b) \tag{1}$$

   where B_ν is the black body spectrum.

   (e) What are the above answers for an optically *thick* cloud?