Problem Set 5

(assigned November 22$^{\text{nd}}$, due December 6$^{\text{th}}$)

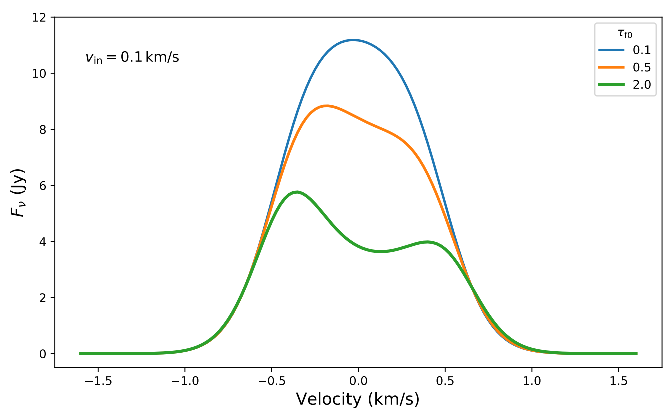
For the final problem set of the class, do questions 1 and 2 and then choose one of questions 3 or 4.

1. Is the Hot Ionized Medium bound to the Milky Way? i.e., compare the sound speed of a proton at $10^6\,$K to the escape speed from the Galaxy (which you can estimate or intuit but explain your reasoning). What about the LMC?

2. The Milky Way will merge with the Andromeda galaxy in about 4.5 Gyr (just as the Sun turns into a white dwarf). Estimate how many stars will undergo a head-on collision? Briefly describe what happens to the ISM.

3. Model a collapsing core as two slabs with relative motion. Write down an expression for the observed specific intensity, I_ν, as a function of the excitation temperature and optical depth of the front and back layers, T_f, T_b, τ_f, τ_b, respectively.

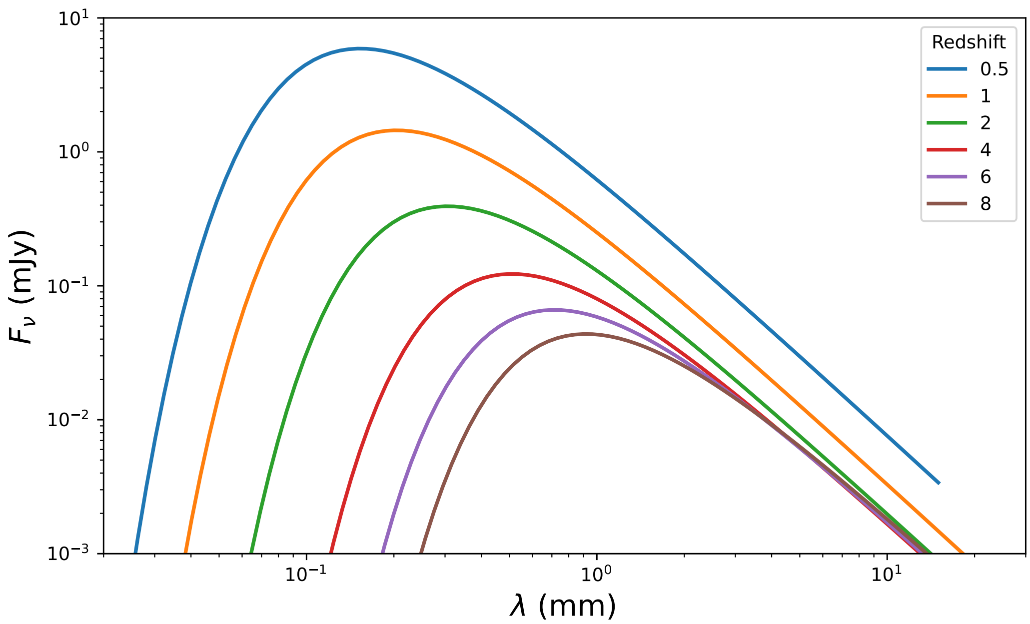
3a. Assume that the optical depth has a Gaussian velocity profile with the same velocity dispersion, σ, and that the front layer is moving toward the back layer with speed, $v_{\rm in}$. Fix parameters $T_f = 5\,$K, $T_b = 20\,$K, $\tau_b = 2$, $\sigma = 0.3\,$km/s, $v_{\rm in} = 0.1\,$km/s, and plot spectra for three values of the forward layer optical depths, $\tau_f = 0.1, 0.5, 2$, assuming observations of the CS $J = 2 - 1$ transition at 97.981 GHz and a core radius of $10''$. My result is attached as a guide.



3b. Now fix parameters $T_f = 5\,$K, $T_b = 20\,$K, $\tau_b = 3$, $\tau_f = 1$, and $\sigma = 0.3\,$km/s, and vary $v_{\rm in} = -0.1, 0, 0.1\,$km/s. Plot your results together in a new figure and briefly interpret.

4a. Model the SED of a dusty starburst galaxy, such as M82 which lies at a distance of 3.5 Mpc and has a bolometric luminosity of $5 \times 10^{10}\, L_\odot$. Use the expression for the luminosity distance in the excellent primer on cosmological distance by Hogg (1999; see website for link) and assume a flat, ΛCDM cosmology with $H_0 = 67\,\mathrm{km\ s^{-1}\ Mpc^{-1}}, \Omega_\mathrm{M} = 0.3, \Omega_\Lambda = 0.7$

As a first step, plot the flux density versus wavelength for a 50 K blackbody and same distance and luminosity as M82 at redshifts $z = 0.5, 1, 2, 4, 6, 8$. My result is attached as a guide. But this is not the SED of a starburst galaxy – why?



4b. Make the same redshifted SEDs for a greybody with a dust optical depth $\tau_\nu = (\nu/\nu_0)^\beta$ where $\nu_0 = 3 \times 10^{12}$ Hz and $\beta = 1.7$ as in the Milky Way. How does the SED differ from the pure blackbody result above and how might you take advantage of this to study dusty star-forming galaxies in the distant Universe?