Astronomy 596/496 APA, Fall 2009
Homework #6
Due on Compass: Thursday, Sept. 24

1. *Order-of-Magnitude Astrophysics: Fast Radio Bursts.* Next week's Colloquium Speaker, Jeff Cooke, will speak on searches for rapid transient events across many wavelengths. In particular, he will talk about how radio observations can be combined with UVOIR and high-energy observations.

   One particularly mysterious class of transients he will discuss are *fast radio bursts*, hereafter FRBs. These are brief radio pulses, which apparently do not repeat. These were only recently discovered, and to date there are about 10 FRBs published.

   As always, this problem is wordy but straightforward.

   (a) The "fast" aspect of FRB refers to the signal duration. Typical timescales are a few milliseconds; some have durations short enough that only limits can be placed at $\delta t < 1$ ms.
   We do not know what object is doing the emitting, yet we know the emitting region must be smaller than a size $r \sim c\delta t$. Briefly explain why this limit holds. Evaluate r. What astrophysical objects does this rule in? What are ruled out?

   (b) FRBs are rapid enough that their flux evolution $F(t)$ over time ("light curves") are poorly determined. What is better measured is time time-integrated flux, also called the *fluence* $\mathcal{F} = \int F(t)\ dt$. In fact, what is really measured is the fluence at a particular frequency, i.e., the flux $F_\nu = dF/d\nu$ is integrated to give $\mathcal{F}_\nu = \int F_\nu\ dt$.
   Many bursts are detected at $\nu = 1.3$ GHz, with fluences spanning $\mathcal{F}_\nu \sim (0.8 - 8)$ Jy ms, where the 1 Jy = 1 Jansky = 10^{-26} Watt m^{-2} Hz^{-1}.
   We can estimate the total (frequency-integrated) FRB radio fluence as $\mathcal{F} = \int \mathcal{F}_\nu\ d\nu \sim \nu\mathcal{F}_\nu$. Using this, evaluate a typical $\mathcal{F}$.

   (c) Let D be the distance to the FRB source. Explain the physical significance of the quantity $4\pi D^2 \mathcal{F}$.

   (d) We do not know whether FRBs are Galactic (i.e., come from sources in the Milky Way) or extragalactic, i.e., at cosmological distances.
   Use the fluence from part 1b to estimate the quantity discussed in part 1c for distance values typical for (a) a Galactic objects, and (b) an extragalactic object.
   Finally, the Sun has a flux $F_\nu^\odot \sim 10^4$ Jy at 1.3 GHz; use this to find the Sun's fluence in $\delta t = 1$ ms. Using this, evaluate $4\pi D^2 \mathcal{F}$ for the Sun.

   (e) Comment on the implications of your result from part 1d. Are Galactic sources ruled in or out? Extragalactic sources?

   (f) The FRB event rate is estimated to be $\sim 10^4$ events sky^{-1} day^{-1}, i.e., in one day there would be 10^4 events over the entire sky.
   For a radio telescope with a field of view of 1deg^2, how long must one typically observe one point of the sky to see one FRB? Comment briefly.
   Hint: the entire sky has angular area 4π steradian = 4π radian^2; evaluate this in deg^2.