CGWAS 2015 Problem Set - Transient Astronomy
(Alessandra Corsi) - SOLUTIONS

EM counterparts of compact binary coalescences

- kilonovae: optical/NIR, want to observe within 1 d post-burst; core-collapse SNe typically observed in optical and take longer (2-3 weeks) to peak; GRBs emit from gamma-rays to radio and the emission peaks at different timescales depending on wavelength (and viewing angle). Gamma-rays are only emitted promptly and are missed if off-axis, X-ray and optical emission span days-to-weeks timescales, radio can peak from a few days to months or even of order a year after the burst depending on off-axis angle.
- Radio, optical, X-ray, and Gamma-ray facilities the students can mention are any of the ones mentioned in the lecture, e.g., VLA, PTF, LSST, Swift, Fermi...

Observing short GRB X-ray afterglows

1. For nearby (redshift $z << 1$) bursts, we can neglect k-corrections and relate the flux observed at time t, $F_X(t)$, corrected for Galactic absorption, to the isotropic X-ray afterglow luminosity $L_X(t)$, as:
$$F_X(t) \approx L_X(t)/(4\pi d_L^2), \tag{1}$$
where d_L is the luminosity distance. Thus, at 200 Mpc (200 Mpc=$200 \times 10^6 \times 3.08 \times 10^{18}$ cm=6.2×10^{26} cm) and 2 d post burst, the observed X-ray flux in cgs units reads:
$$\frac{8.5 \times 10^{43} \mathrm{erg\,s^{-1}}}{4\pi(6.2 \times 10^{26} \mathrm{cm})^2} \times (24\,\mathrm{hr}/11\,\mathrm{hr})^{-1.2} \times (2\,\mathrm{d}/1\,\mathrm{d})^{-2.2} = 1.5 \times 10^{-12} \mathrm{erg\,cm^{-2}s^{-1}} \tag{2}$$
The jet break is the time at which $\gamma(t_{break}) = 1/\theta_j$ where $\gamma(t)$ is the fireball Lorentz factor. At this time, the relativistic beaming angle equals the jet aperture and an on-axis observer starts seeing the edges of the jet.

2. To calculate the *Swift/XRT* count rate corresponding to a given source flux, we use WebPIMMS with settings as shown in Figure 1 and get that 1 cps for *Swift/XRT-PC* corresponds to an unabsorbed source flux of $3.576 \times 10^{-11} \mathrm{erg\,cm^{-2}s^{-1}}$. Thus, considering that for a detection we want 12 source counts collected during T_{exp}, we can write the following equation:
$$F_{X,lim} = 3.576 \times 10^{-11} \mathrm{erg\,cm^{-2}s^{-1}} \times \frac{12}{\mathrm{T_{exp}(s)}} = 4.291 \times 10^{-10} \mathrm{erg\,cm^{-2}s^{-1}} \left(\frac{1\,\mathrm{s}}{\mathrm{T_{exp}}}\right) \tag{3}$$
$$\approx 1.5 \times 10^{-12} \mathrm{erg\,cm^{-2}s^{-1}} \left(\frac{290\,\mathrm{s}}{\mathrm{T_{exp}}}\right) \tag{4}$$

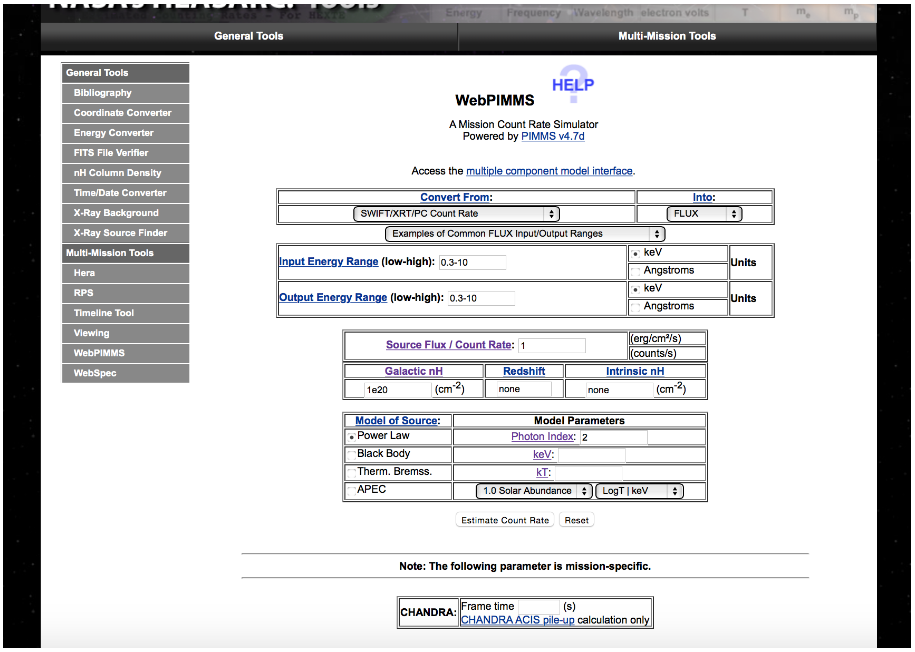

Figure 1: WebPIMMS screenshot.

3. Because $t_{peak} \approx 2t_{break} = 2\,\mathrm{d}$, then the peak flux of the off-axis afterglow is approximately $0.1\times$ the flux we calculated in point 1. above, i.e. $F_X(2\theta_j, t_{peak}) \approx 1.5 \times 10^{-13} \mathrm{erg\,cm^{-2}s^{-1}}$. Thus, we need an exposure time of $T_{exp} = 2.9 \times 10^3\,\mathrm{s}$ for a detection with *Swift/XRT-PC*.

4. The observing time available is $1/3 \times 2 \times 86400\,\mathrm{s}$ and we know that each field needs to be observed for $T_{exp} = 2.9 \times 10^3\,\mathrm{s}$ to detect off-axis afterglows with $\theta_{jobs} = 2\theta_j$. Thus the area A we can cover is:

$$A = \frac{1/3 \times 2 \times 86400\,\mathrm{s}}{2.9 \times 10^3\,\mathrm{s}} \times 0.15\,\mathrm{deg}^2 \approx 3\,\mathrm{deg}^2 \tag{5}$$

which is about 1/10 of the GW error-box.