Expectations from GRB Afterglows

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A discussion based largely on:

Levinson et al., 2002

Afterglow Model

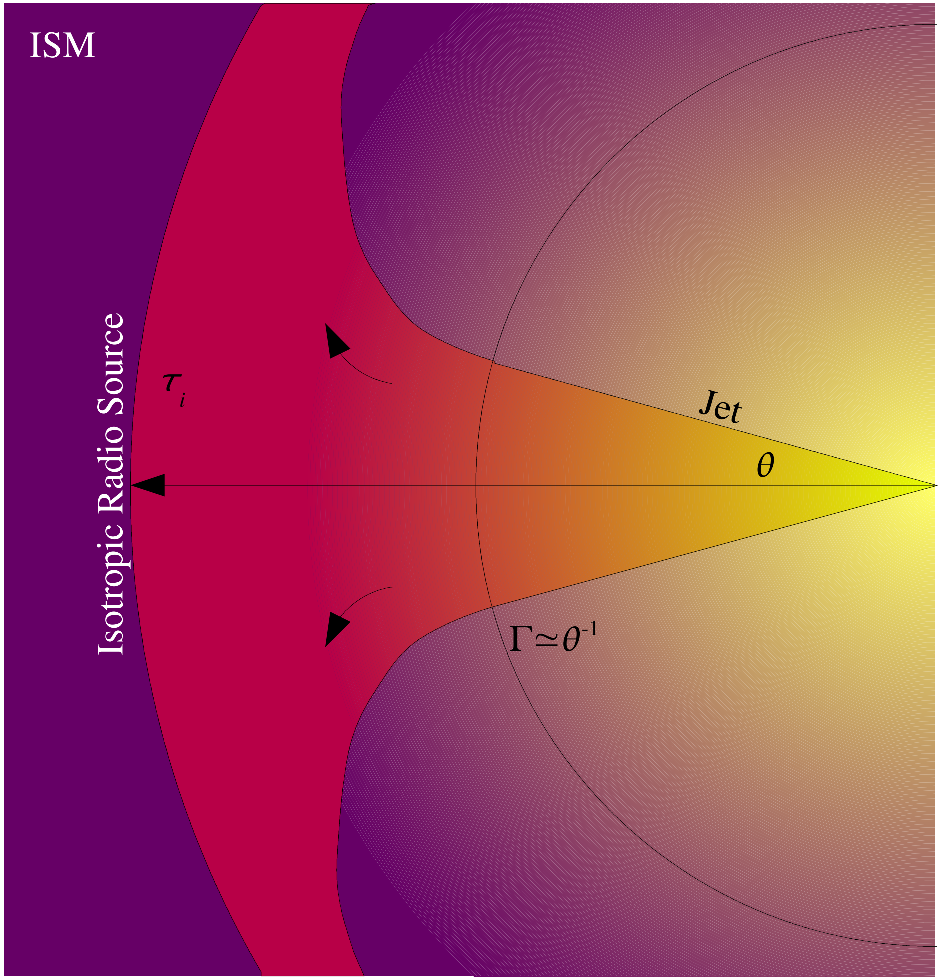
The Basics

- "Ultrarelativistic, jetlike ejecta propagating into an ambient medium..."
- Non-relativistic once $\Gamma \simeq \theta^{-1}$
- Source becomes isotropic

$$\tau_i \simeq 3$$

$$t \equiv \tau t_{\mathrm{SNT}}(1+z)$$

$$t_{\mathrm{SNT}} \simeq 6 \times 10^6 (E_{51}/n_0)^{1/3} \mathrm{s}$$



Afterglow Model

Radio Emission

- After the transition to a non-relativistic jet, the power is dominated by synchrotron emission.
  - Peak synchrotron frequency,

$$\nu_\star \approx 1 \left(\frac{1+z}{2}\right)^{-1} \left(\frac{\xi_e}{0.3}\right)^2 \left(\frac{\xi_B}{0.3}\right)^{1/2} n_0^{1/2}\,\mathrm{GHz}$$

  - Observed flux above $\nu_\star$,

$$f_\nu \approx 2h^2 \left(\frac{1+z}{2}\right)^{1/2} \left(\frac{\xi_e}{0.3}\right) \left(\frac{\xi_B}{0.3}\right)^{3/4} \left(\frac{d_L}{R_0}\right)^{-2} n_0^{3/4} E_{51} \nu_9^{-1/2} \tau^{-9/10}\,\mathrm{mJy}$$

- GRB 970508 (Frail et al. 2000), $n_0 \approx 1, \xi_e \sim \xi_B \sim \frac{1}{3}$

Afterglow Model

Observation Rate

- Age at which flux drops below detection limit,

$$\tau_m = \eta(1+z)^{5/9}(d_L/R_0)^{-20/9}$$

$$\eta = h^{20/9}\left(\frac{f_{\nu,\mathrm{min}}}{1\,\mathrm{mJy}}\right)^{-10/9}\left(\frac{\xi_e}{0.3}\right)^{10/9}\left(\frac{\xi_B}{0.3}\right)^{10/12}\left(\frac{2}{\nu_9}\right)^{5/9} n_0^{10/12}E_{51}^{10/9}$$

- Number of detectable radio afterglows,

$$\frac{dN_R}{dz} = N_0 d_L^2 \frac{dl}{dz}(\tau_m - \tau_i)\Phi(z) \qquad N_0 = f_b^{-1}4\pi R_0^3 \dot{n} t_{\mathrm{SNT}}$$

- Given necessary constants and a cosmological model, we can calculate N_R by integrating over z!

Afterglow Model

A Example Case

- As an example, take,

$$f_{\nu,\min} = 5\,\mathrm{mJy}, \tau_i = 3, h = 0.75, \dot{n} = .5$$

- So then, $d_{L,\max} \simeq 0.2R_0 = 0.8\,\mathrm{Gpc},\ z_{\max} \simeq 0.2$
- Thus we can neglect cosmological effects and we analytically integrate from z=0 to z=$z_{\max}$ to find,

$$N_R \simeq 18(500 f_b)^{-1} \left(\frac{\dot{n}}{0.5}\right) \left(\frac{f_{\nu,\min}}{5\,\mathrm{mJy}}\right)^{-3/2} \left(\frac{\xi_e}{0.3}\right)^{3/2} \left(\frac{\xi_B}{0.03}\right)^{9/8} \left(\frac{\tau_i}{3}\right)^{-7/20} n_{-1}^{19/24} E_{51}^{11/6} \nu_9^{-3/4}$$

Afterglow Model

Comments on this Example

$$N_R \simeq 18(500 f_b)^{-1} \left(\frac{\dot{n}}{0.5}\right) \left(\frac{f_{\nu,\mathrm{min}}}{5\,\mathrm{mJy}}\right)^{-3/2} \left(\frac{\xi_e}{0.3}\right)^{3/2} \left(\frac{\xi_B}{0.03}\right)^{9/8} \left(\frac{\tau_i}{3}\right)^{-7/20} n_{-1}^{19/24} E_{51}^{11/6} \nu_9^{-3/4}$$

- Weak dependence on τ_i
- N_R decrease with increasing beam factor (θ)
- Observations show that ξ_B=0.03, n_0=0.1, $\dot{n}$=0.5 are conservative estimates
- No need to account for beamed sources

Afterglow Model

Numerical Results

- For deeper surveys, one must solve numerically,

$$h = 0.75,\ \Phi(z) = (1 + z)^3$$