THE JET STRUCTURE of 'BAMA-RAY GLAST's

(or HAVING A GLAST IN HUNTSVILLE!)

by

Jay Salmonson

Lawrence Livermore National Lab

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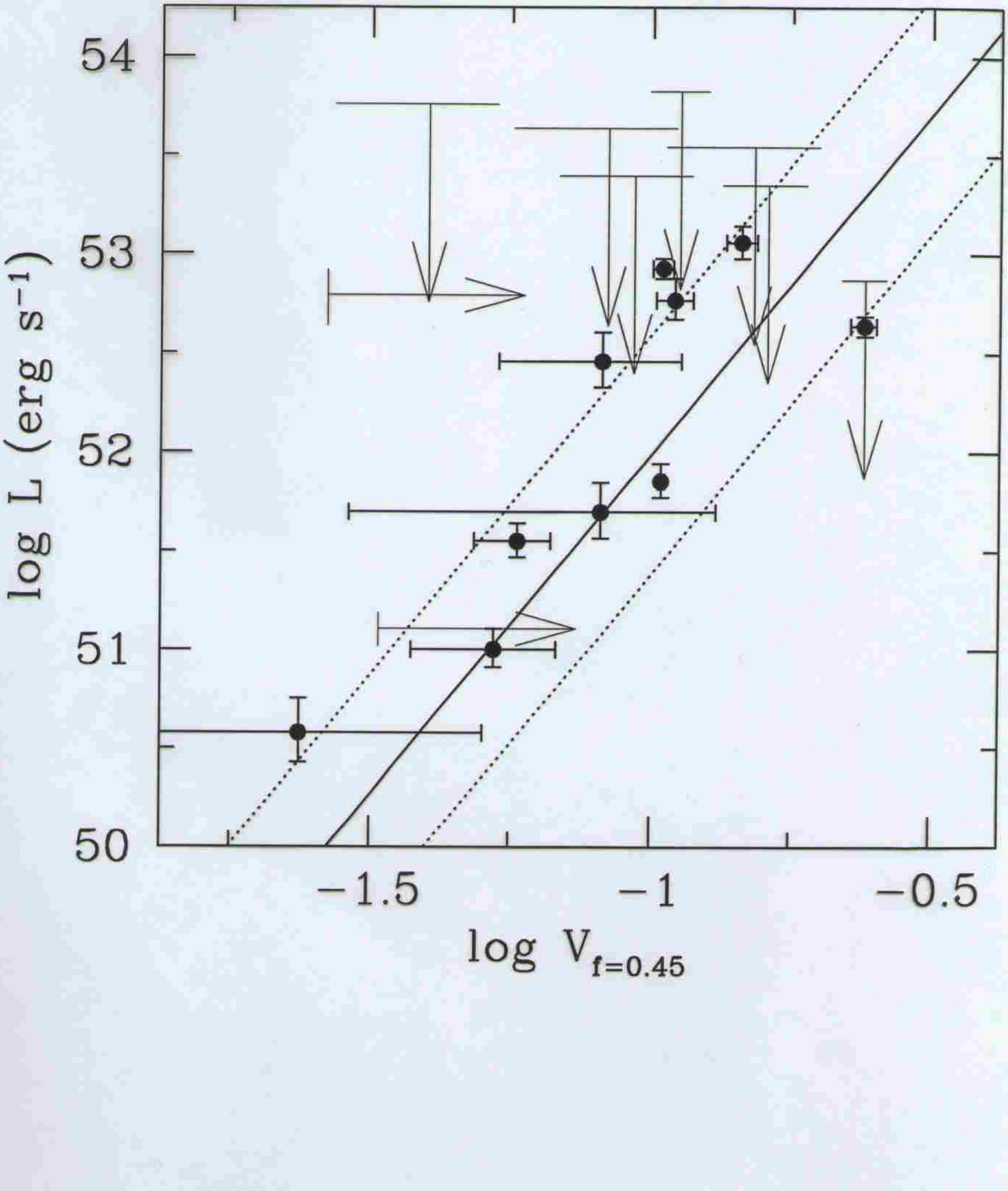
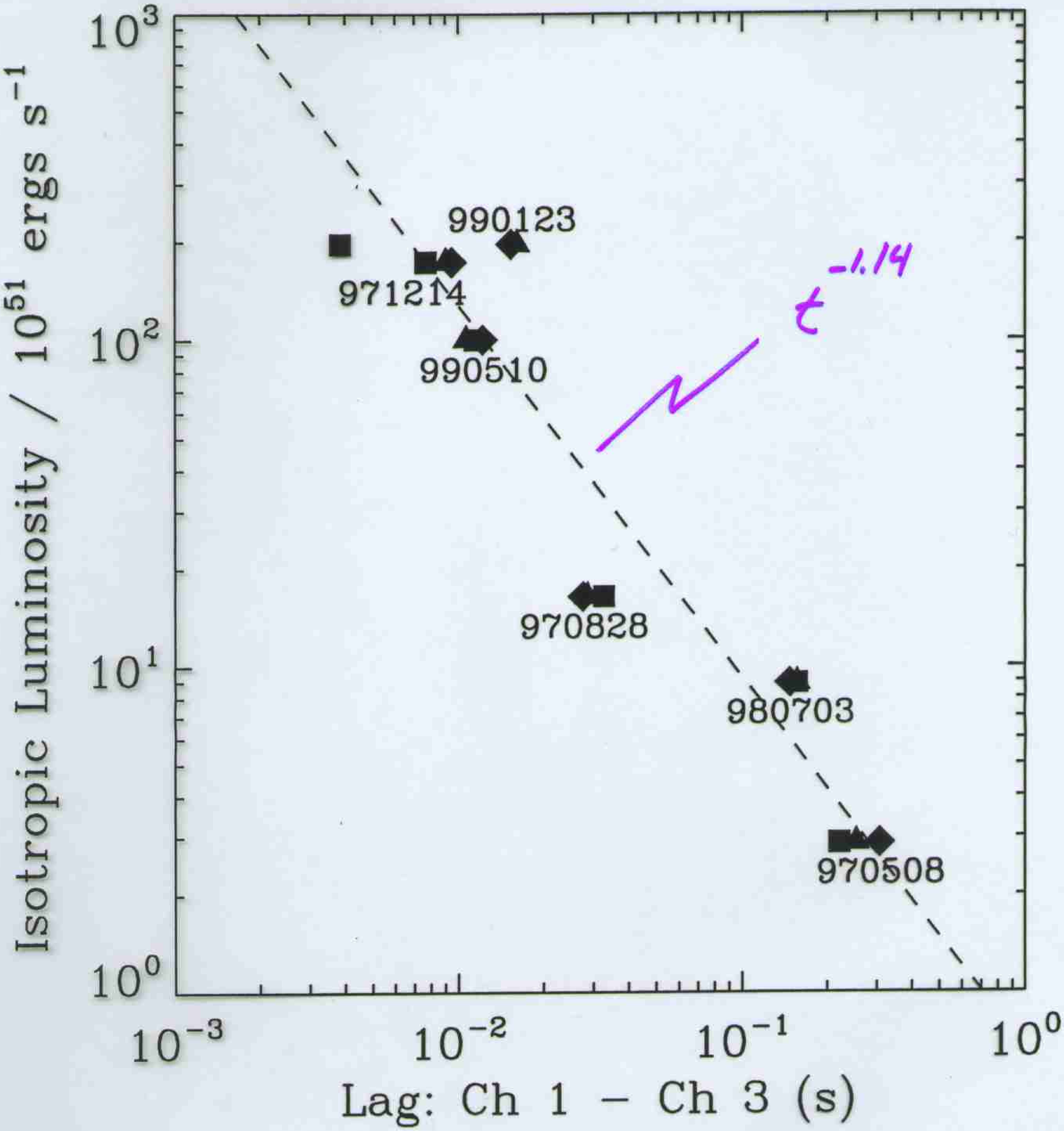
Reichart et al. 2001





Norris, Bonnell & Marani
2000

Lag-Luminosity Relationship (Norris et al.)

$$L_{pk} \sim \frac{1}{\Delta t}$$

Doppler Factor

$$\mathcal{D} \equiv \frac{1}{\gamma(1-\beta\cos\theta)(1+z)} \sim \frac{\gamma}{(1+(\gamma\theta)^2)(1+z)}$$

Spectrum

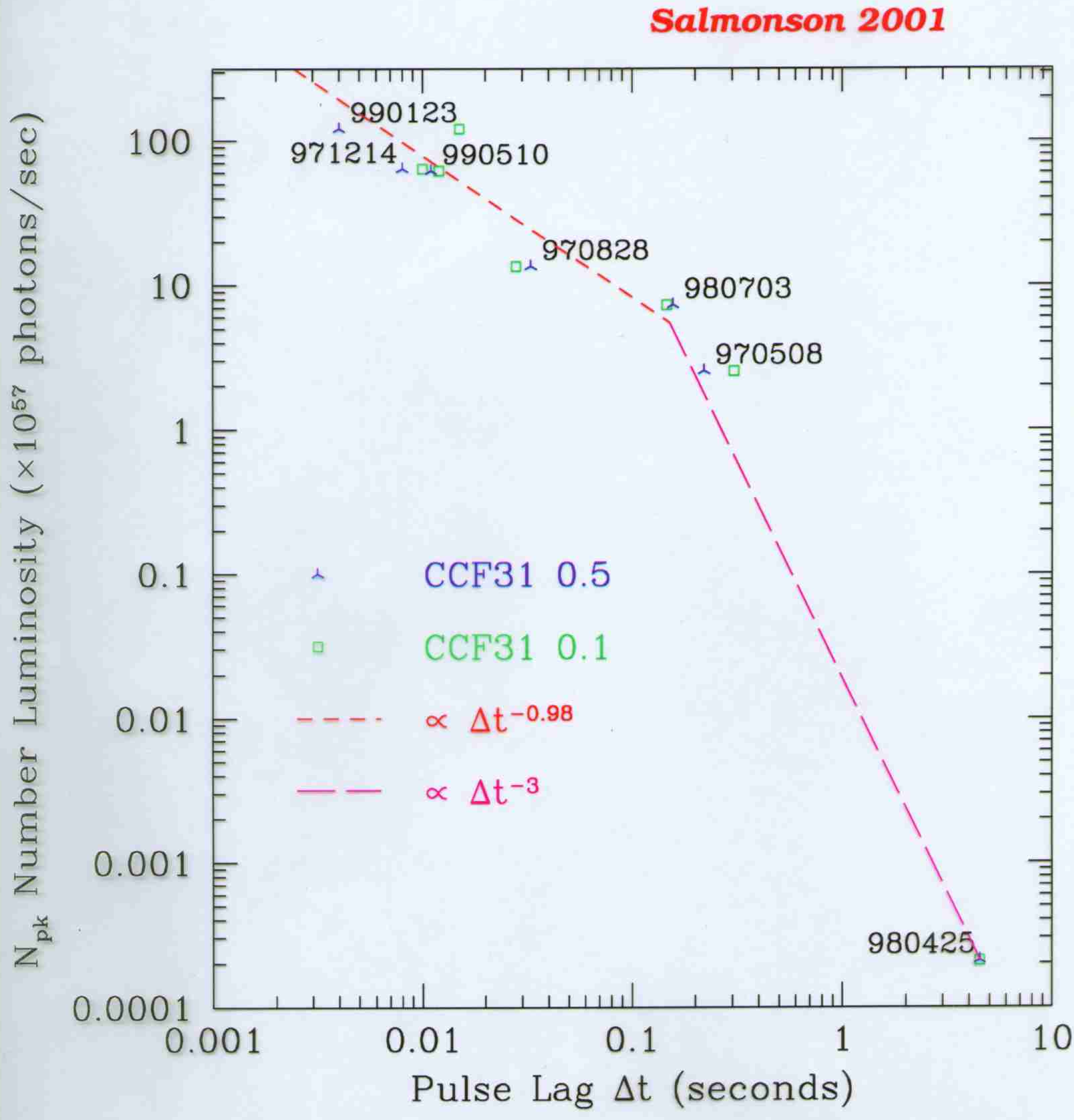
$$\phi(E) \sim \begin{cases} E^{-\alpha}, & E<E_0 \\ E^{-\beta}, & E>E_0 \end{cases} \Rightarrow E^{-\alpha}$$

$$L_{pk} \propto \int_{e_1}^{e_2} E\,\phi\left(\frac{E}{\mathcal{D}}\right) dE \propto \mathcal{D}^{\alpha} \quad (\alpha \approx 1)$$

$$\Delta t \propto \frac{\Delta t'}{\mathcal{D}}$$

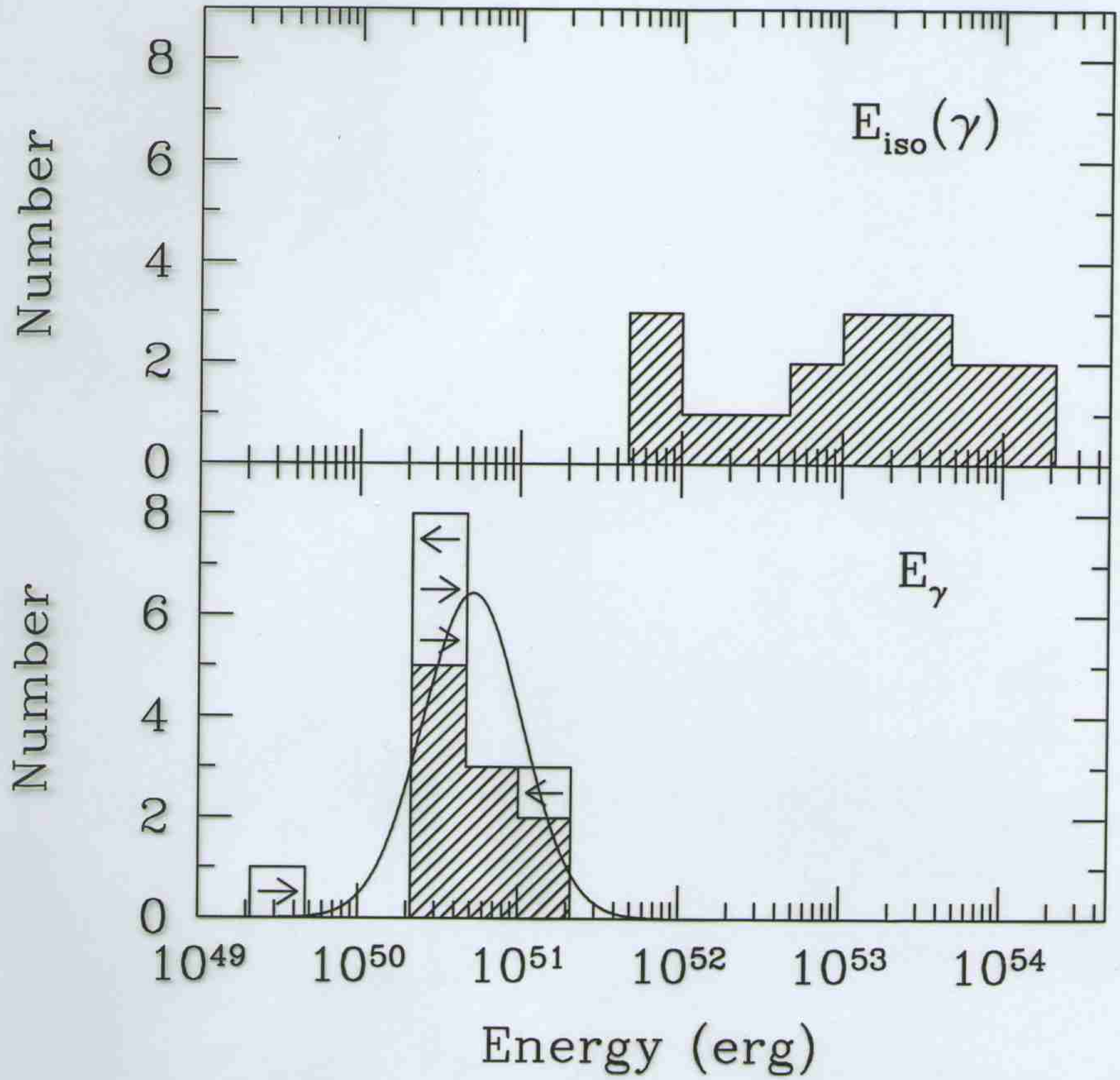
so

$$L_{pk} \propto \left(\frac{1}{\Delta t}\right)^{\alpha} \quad (\alpha \approx 1)$$



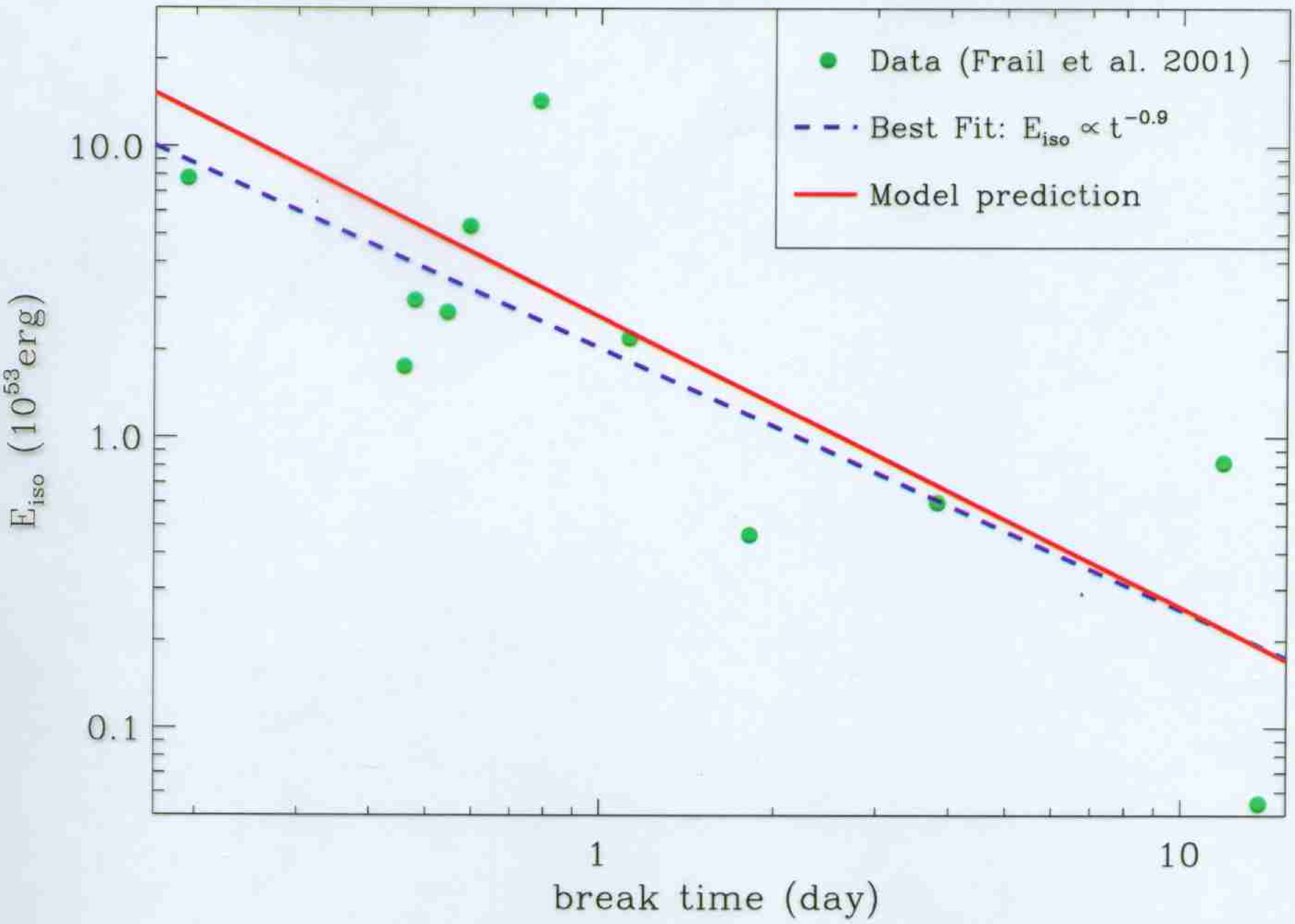
Salmonson 2001
990123
971214
990510
970828
980703
970508
980425
CCF31 0.5
CCF31 0.1
$\propto \Delta t^{-0.98}$
$\propto \Delta t^{-3}$
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1
10
N_{pk} Number Luminosity ($\times 10^{57}$ photons/sec)
Pulse Lag Δt (seconds)

Frail et al. 2001



$E_\gamma \propto \theta^2 E_{iso} \approx$ constant

Rossi, Lazzati & Rees



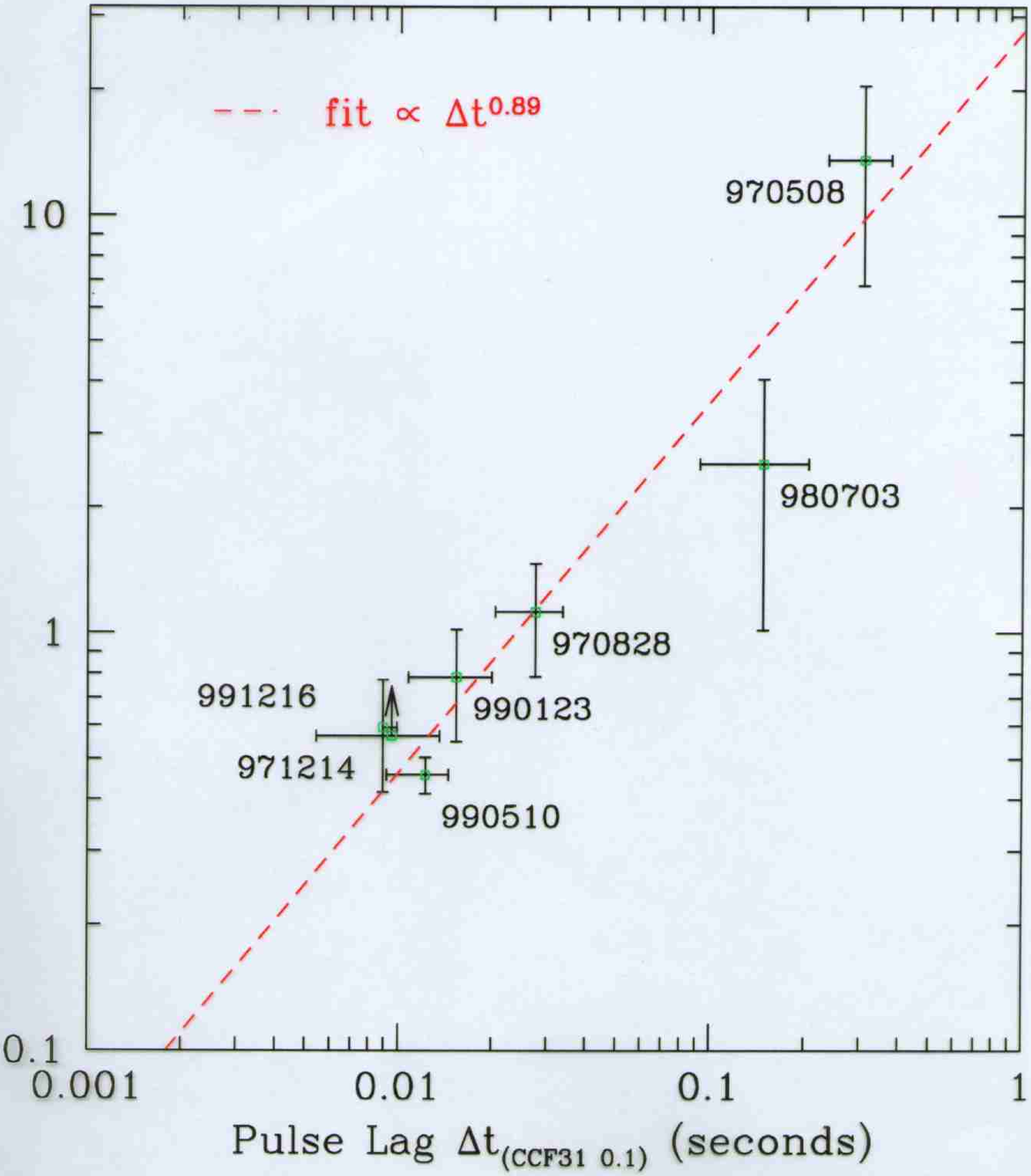
Frail et al. noticed: $E_{iso} \propto t_j^{-1}$

so since $t_j \propto E^{\frac{1}{3}} \Theta^{\frac{8}{3}}$

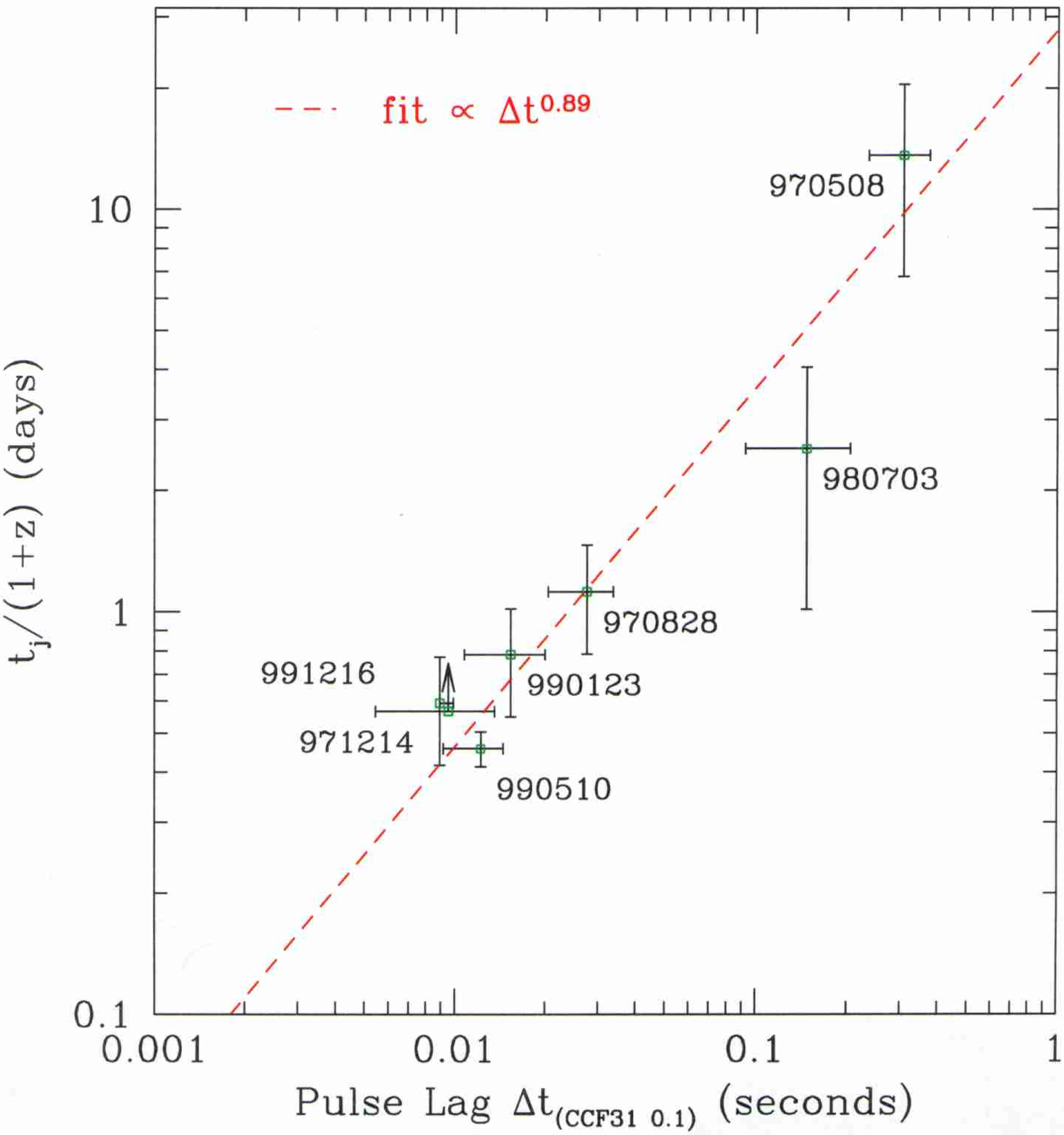
then $E \sim E^{-\frac{1}{3}} \Theta^{-\frac{8}{3}}$

or $E_{iso} \propto \Theta^{-2}$

Salmonson & Galama 2002

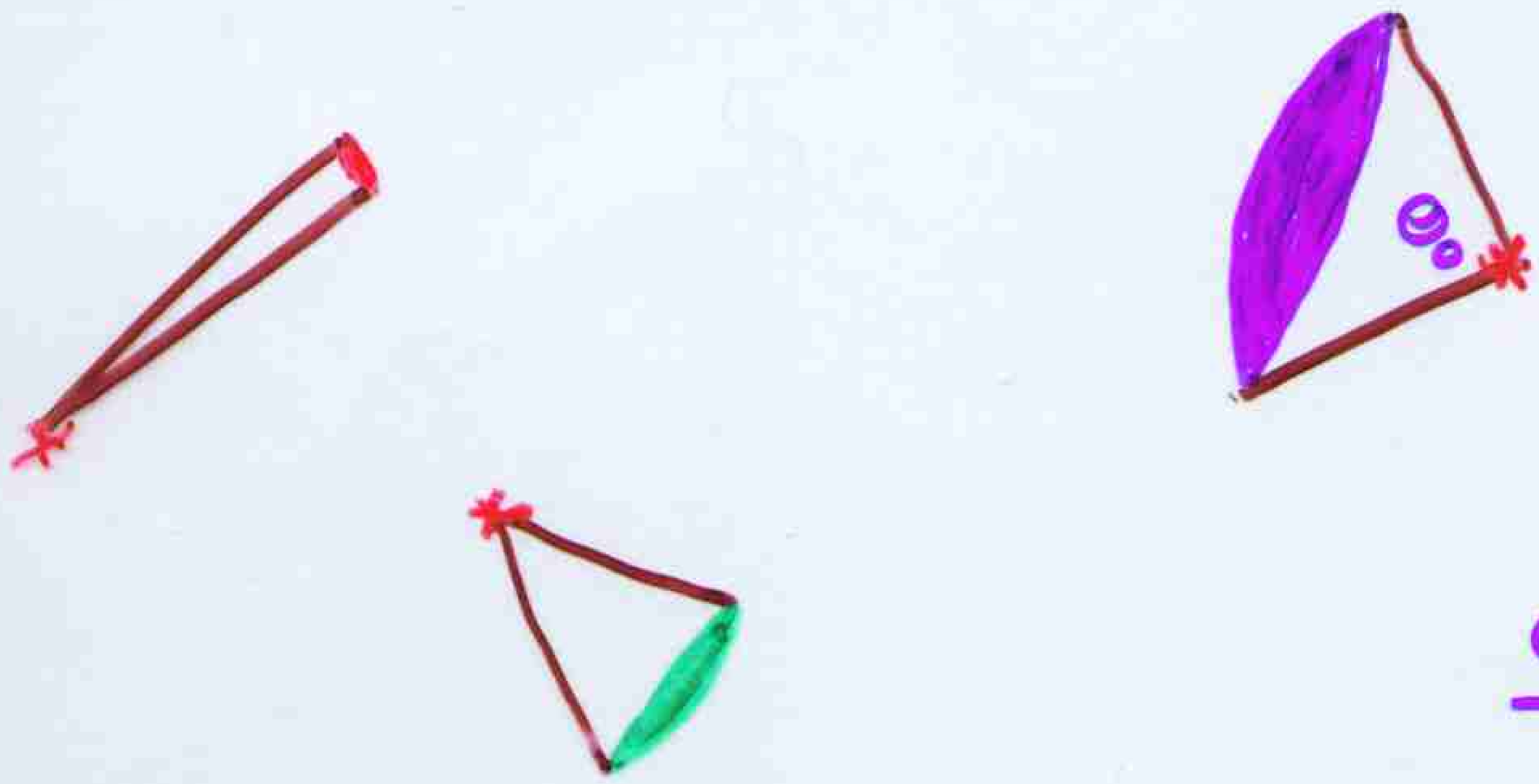


Salmonson & Galama 2002



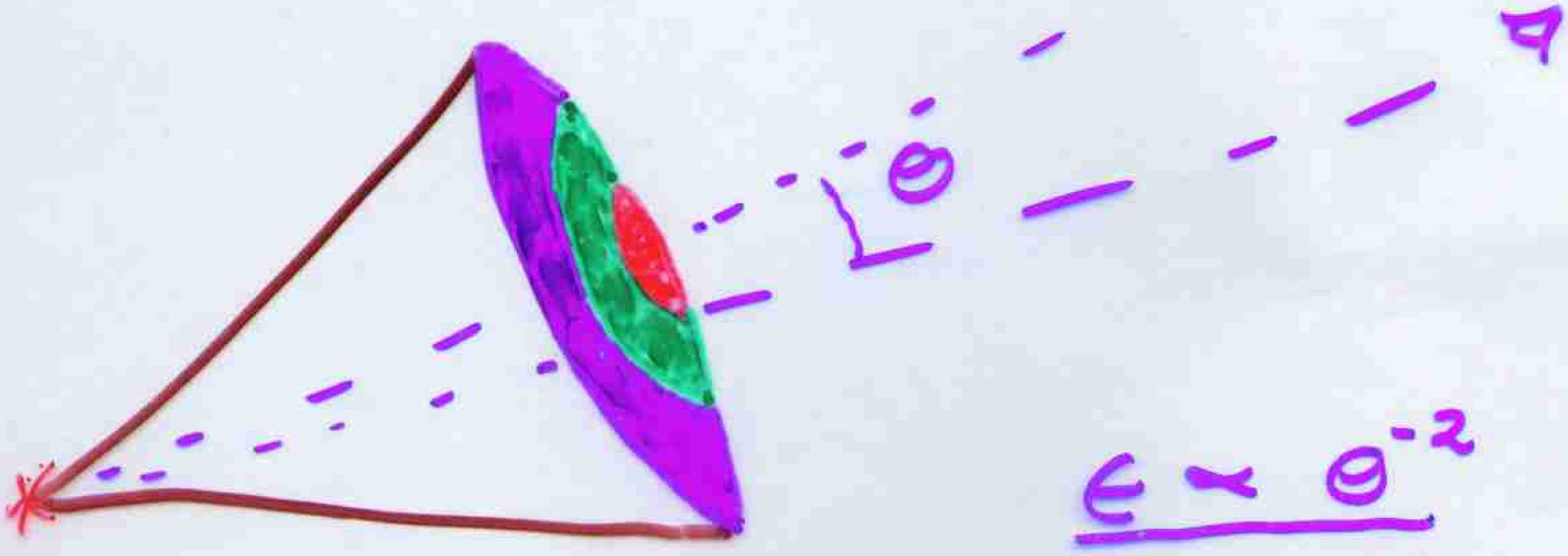
Two Paradigms

Many bursts:



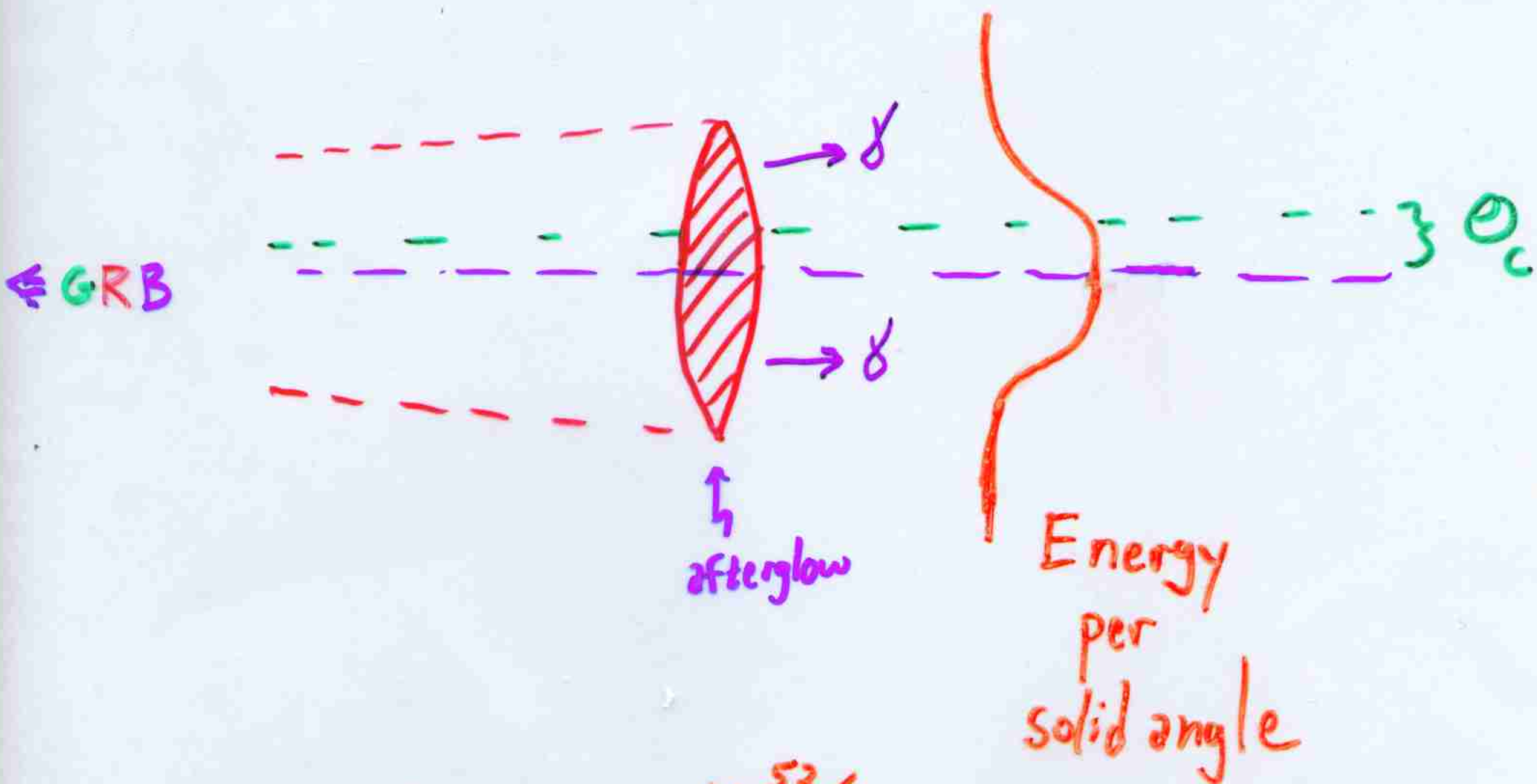
$\epsilon \propto \theta_0^{-2}$

Universal burst:



$\epsilon \propto \theta^{-2}$

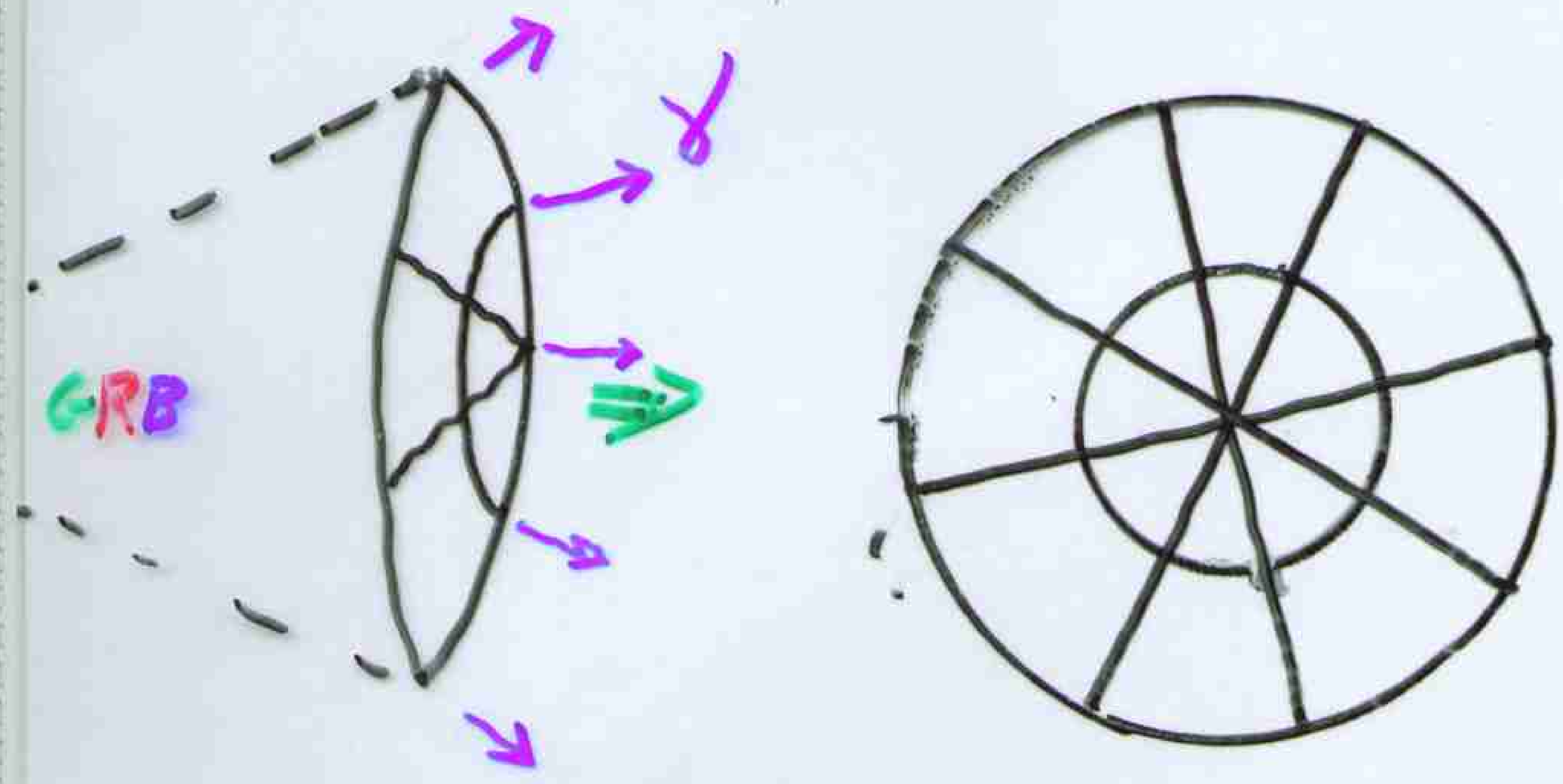
Structured Jet



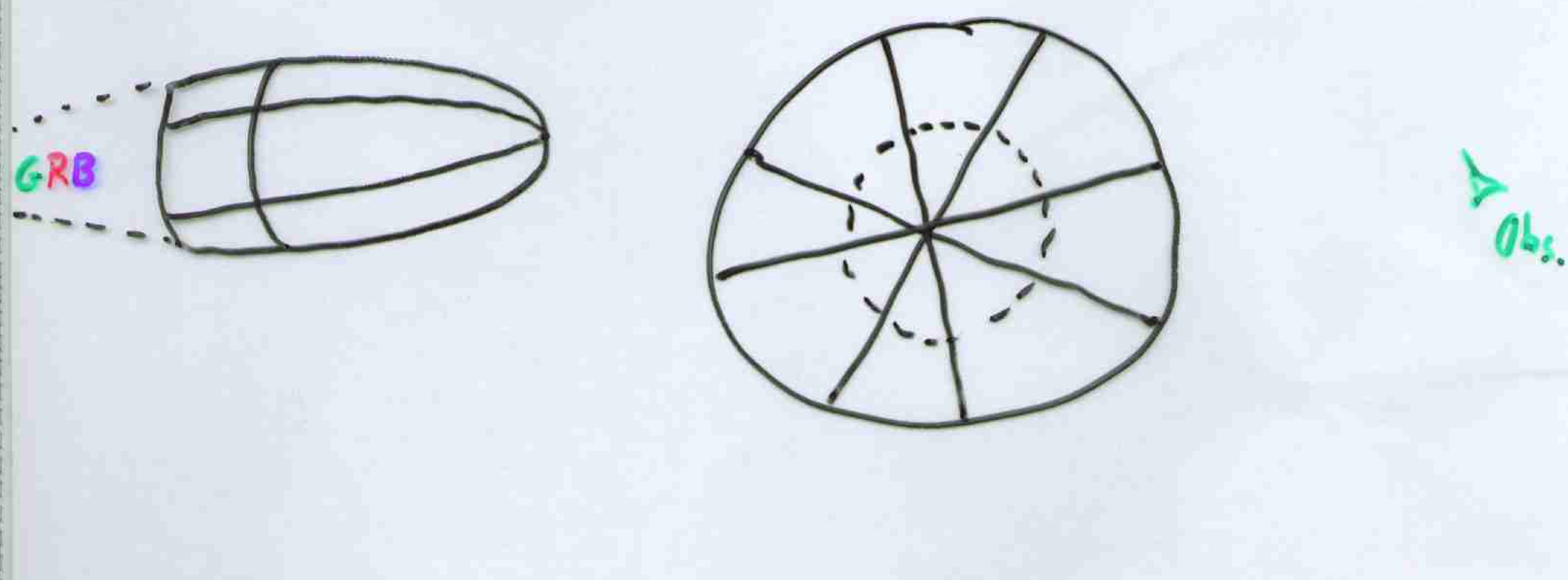
$$\xi(\theta) = \frac{10^{52}/4\pi}{1 + (\theta/\theta_c)^2} \propto \theta^{-2}$$

$$\gamma(\theta) = \Gamma_0 = 100$$

Discretize jet surface in θ&φ:



Stuff moving toward the observer evolves faster than stuff moving at an angle:



Fireball Dynamics

An afterglow of initial mass, M_0, and Lorentz factor, Γ_0, sweeps into the ISM, it decelerates according to conservation of energy and radial momentum which give the following evolution equations (Paczynski & Rhoads '93 ApJ, 418,L6).

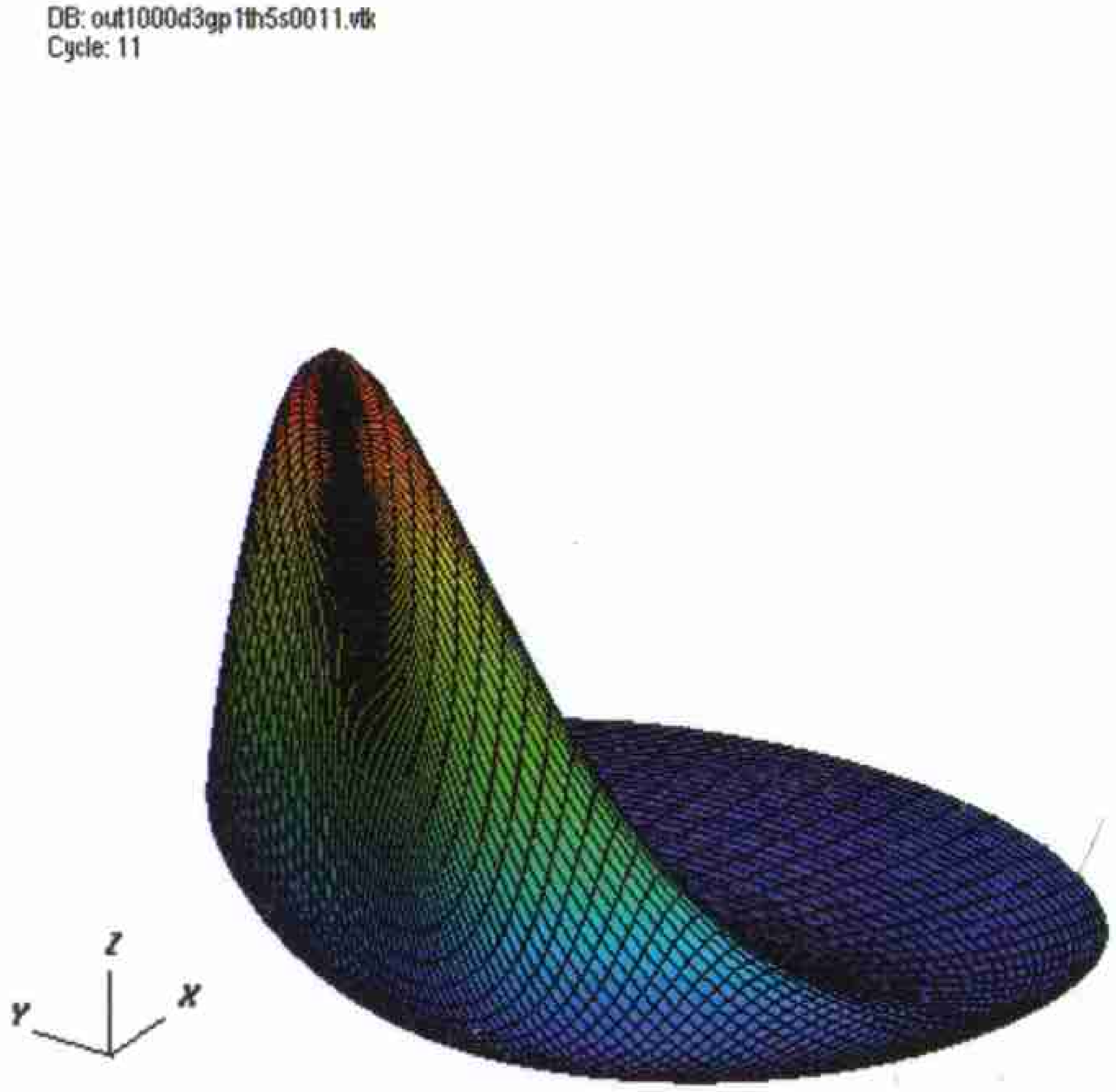
$$f = \frac{M(R)}{M_0} = \frac{1}{M_0}\int_0^R r^2 \Omega_m \rho_{ISM} dr$$ swept up mass fraction

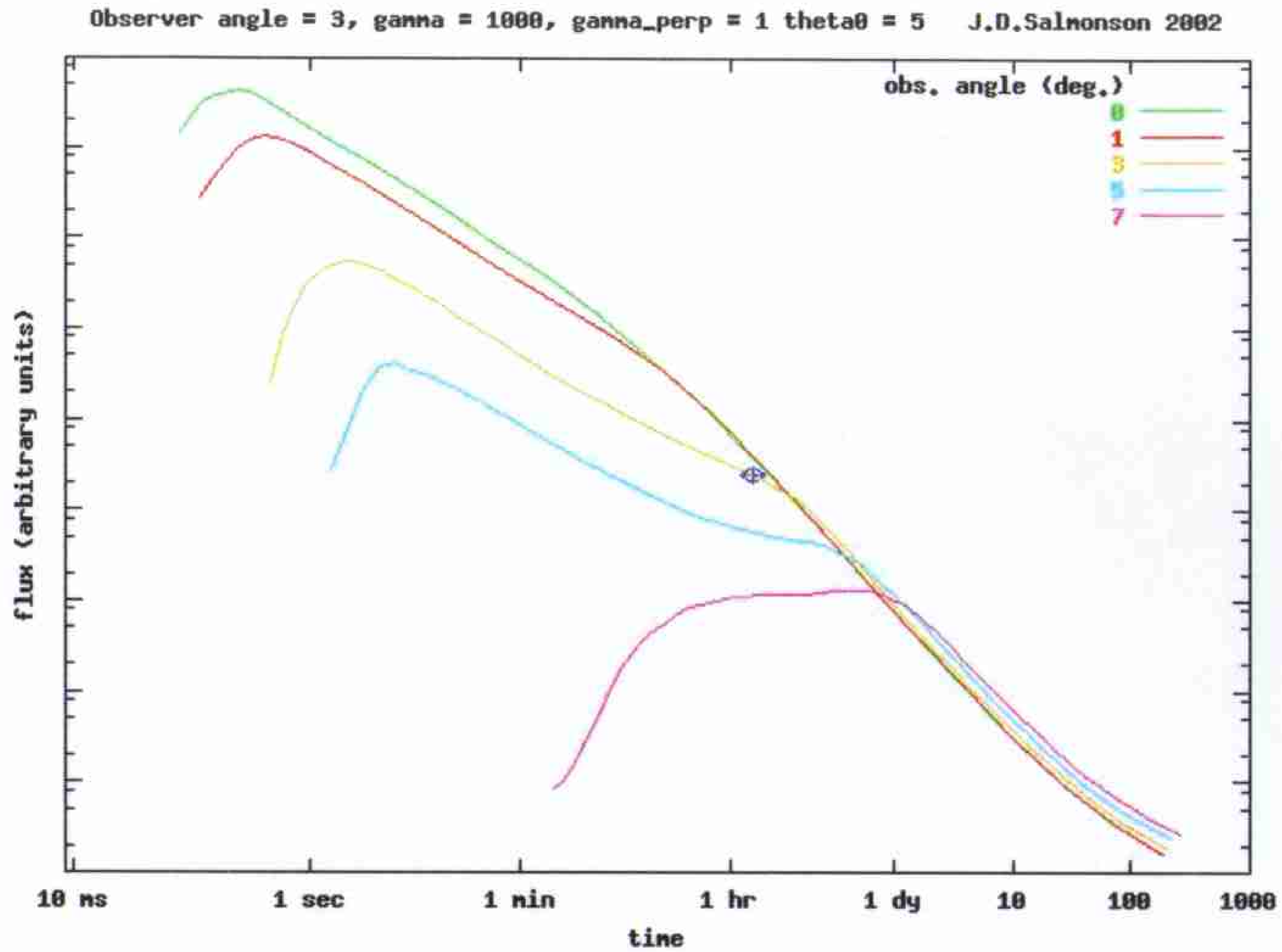
$$\Omega_m = \pi(\theta_0 + v_\perp t'/R)^2$$ jet opening solid angle

$$\beta = \frac{v}{c} = \sqrt{1 - 1/\Gamma^2}$$ velocity

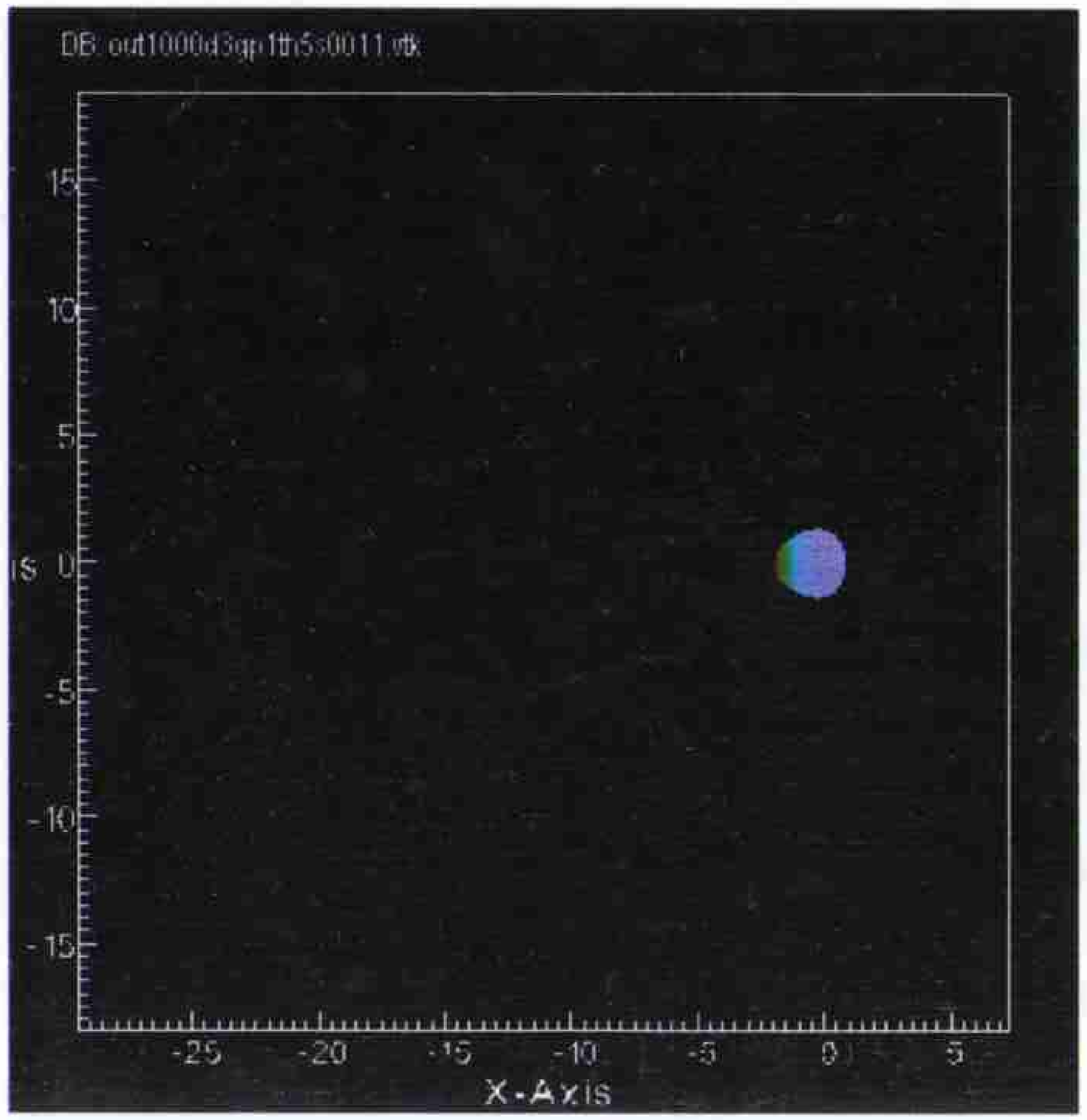
$$\Gamma = \frac{\Gamma_0 + f}{\sqrt{1 + 2\Gamma_0 f + f^2}}$$ Lorentz factor

$$t' = \int_0^R \frac{dr}{\Gamma\beta c} = \int_0^R \frac{dr}{U}$$ proper time

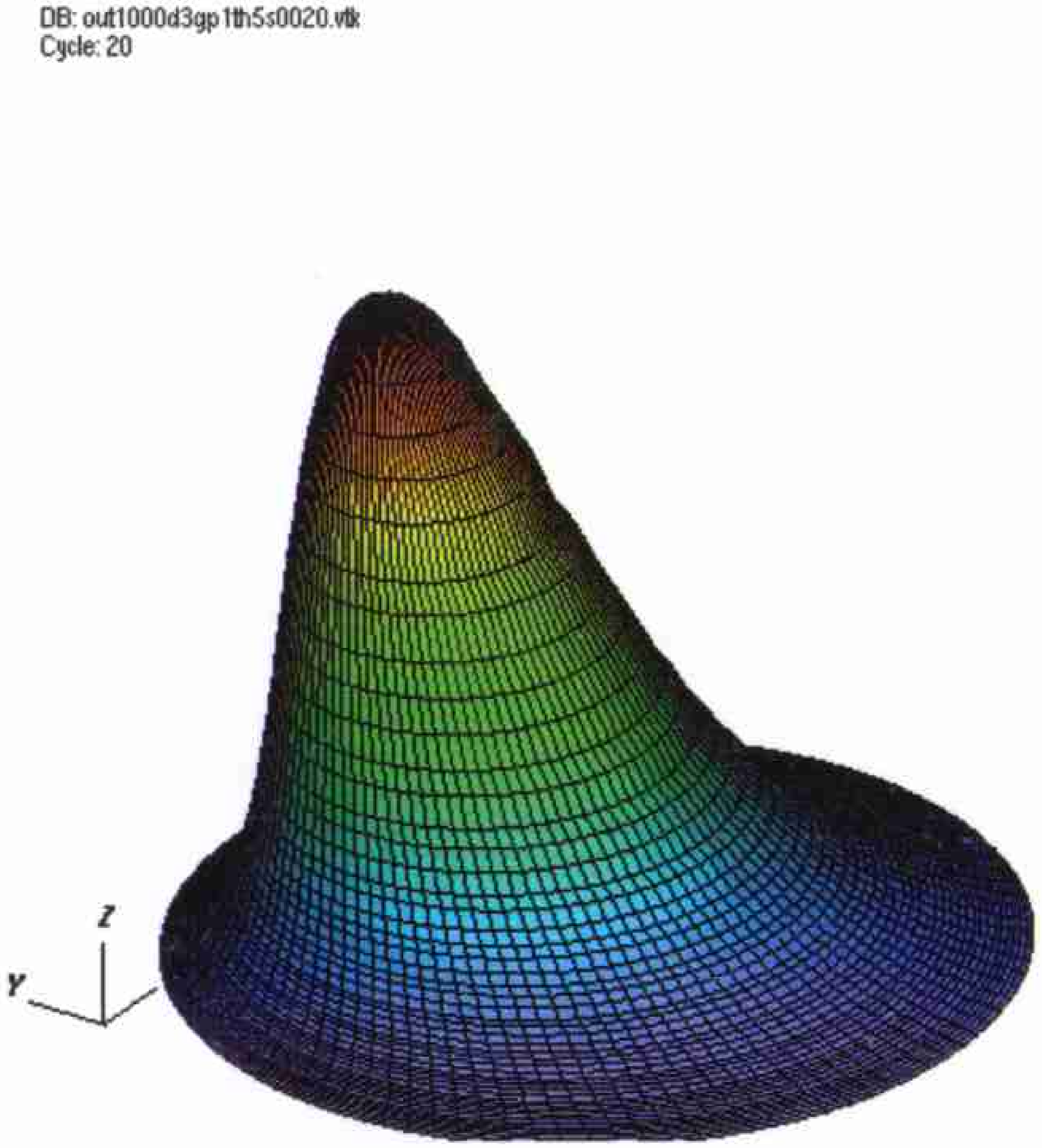


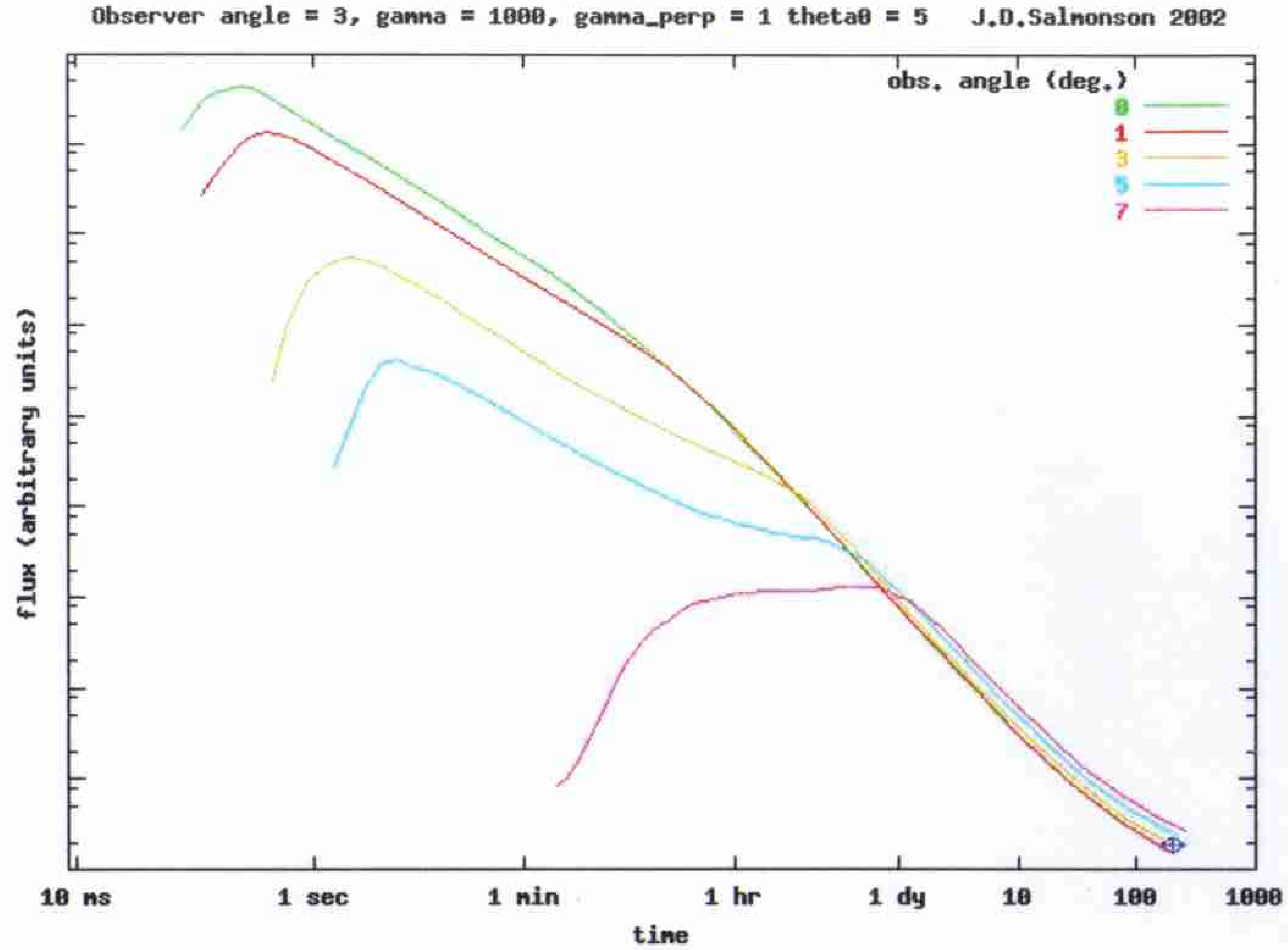


Above: the pole of the jet is almost aligned with the flux peak. Once the peak passes by the pole, the jet will break (upper right).

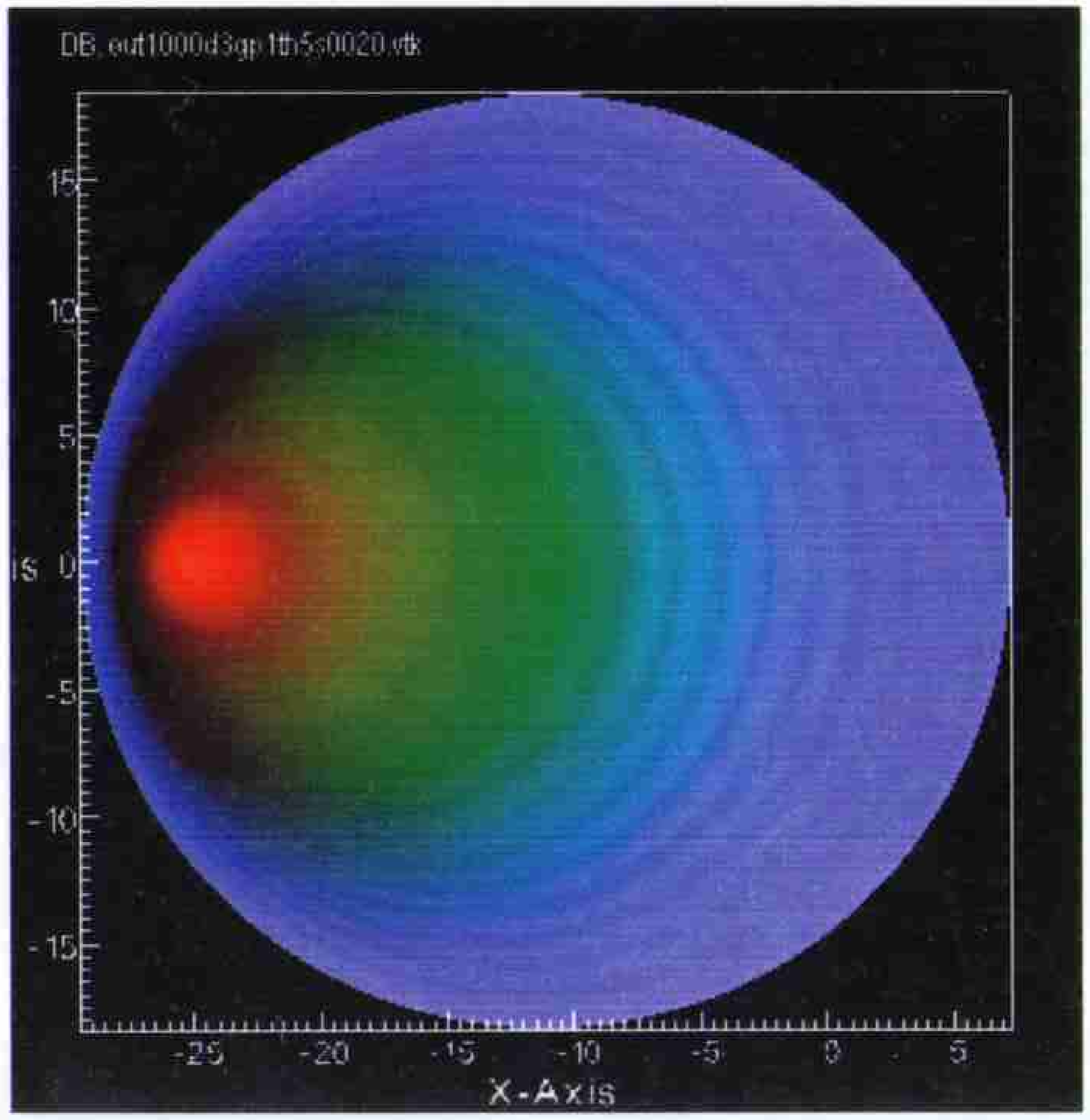


Left: a "view" of what the afterglow would look like at this time. X–Y scale is in light–days.



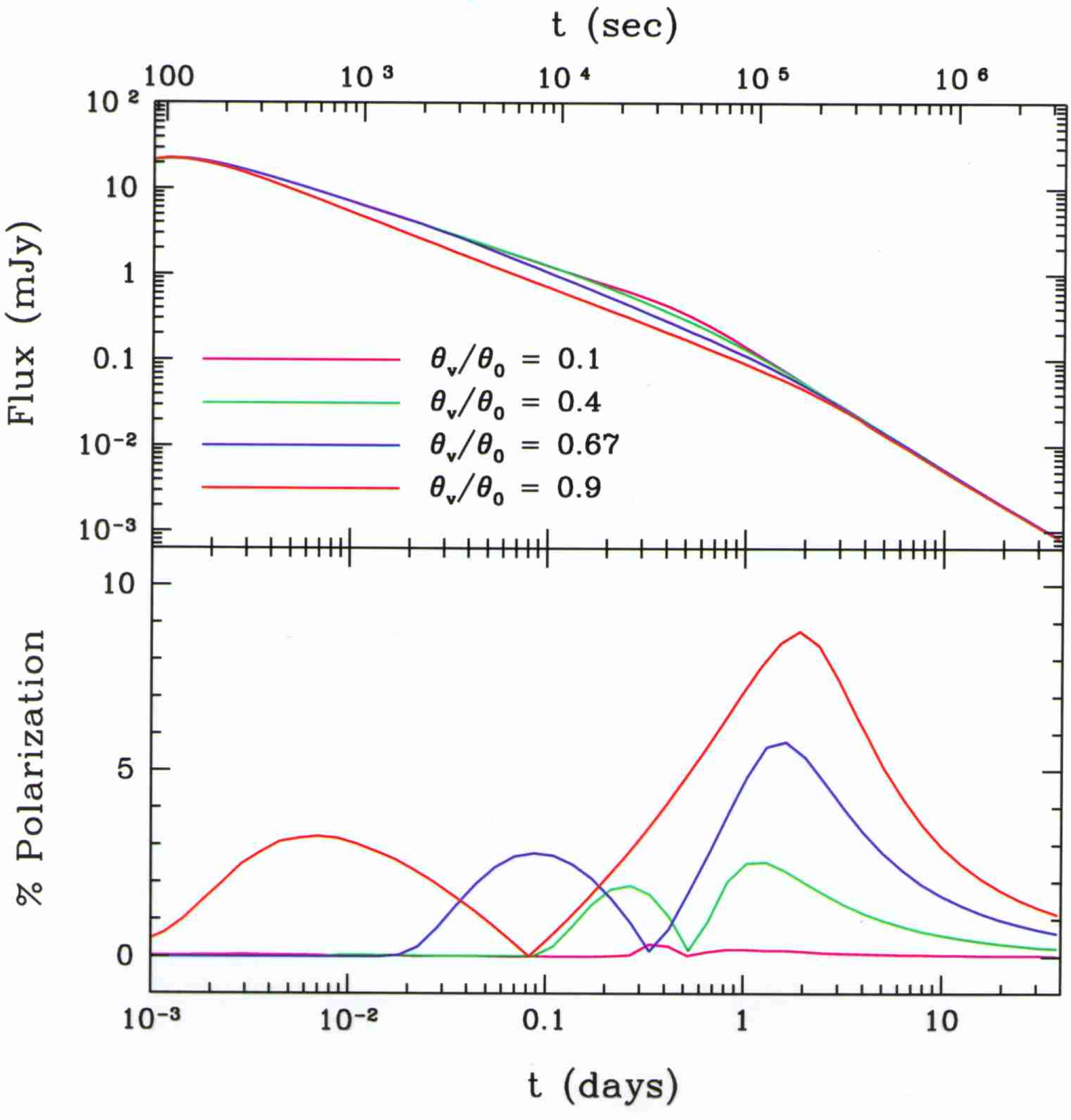


Above: the "sombrero" shape of the structured jet is apparent as the Lorentz factor has decreased to almost unity.



Left: a "view" of what the afterglow would look like at this time. X–Y scale is in light–days.

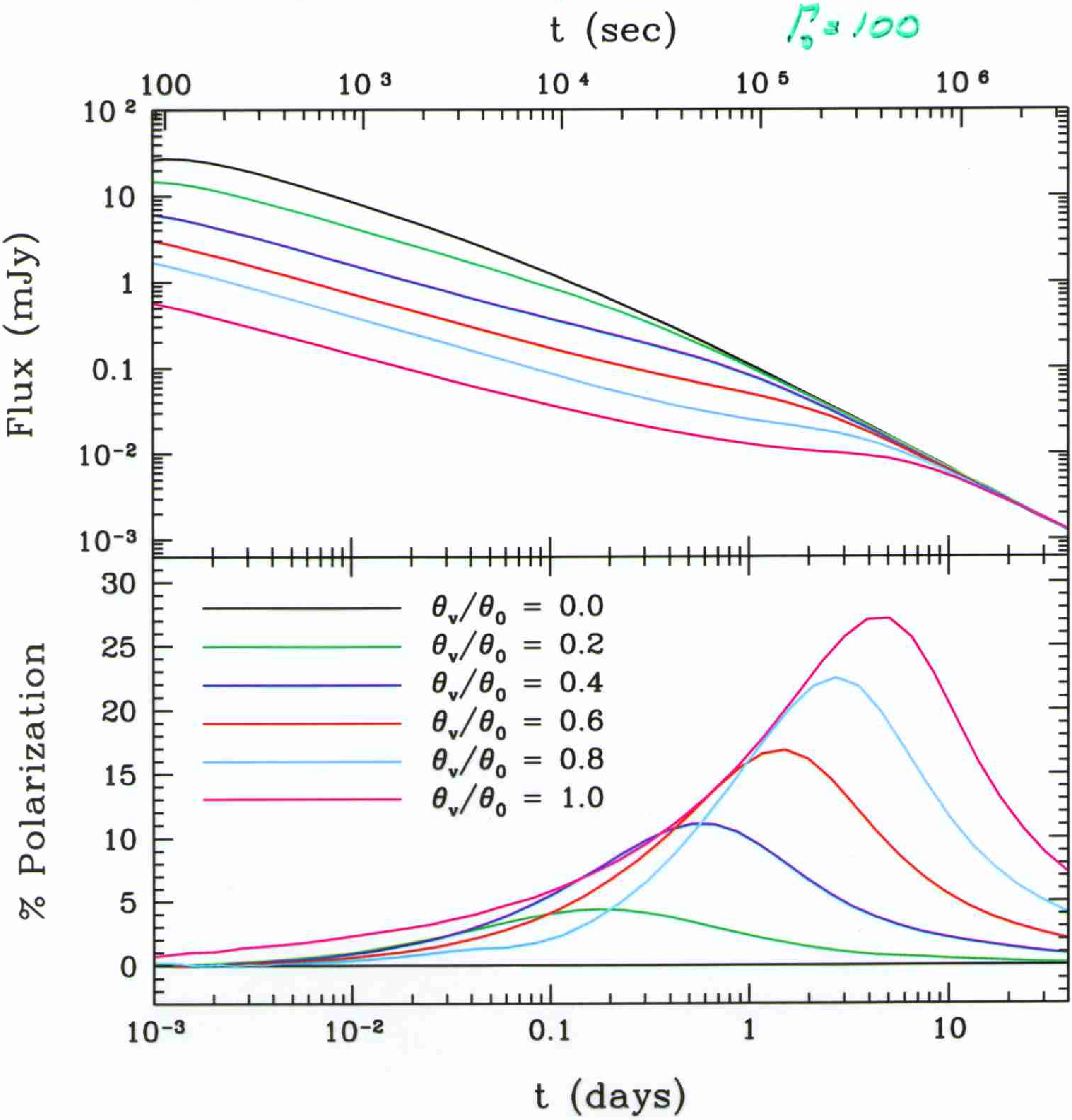
Homogeneous, $\mathcal{E} = 10^{52}$ ergs, $\theta_0 = 5°$, $\Gamma_0 = 100$



$R_K = 0$

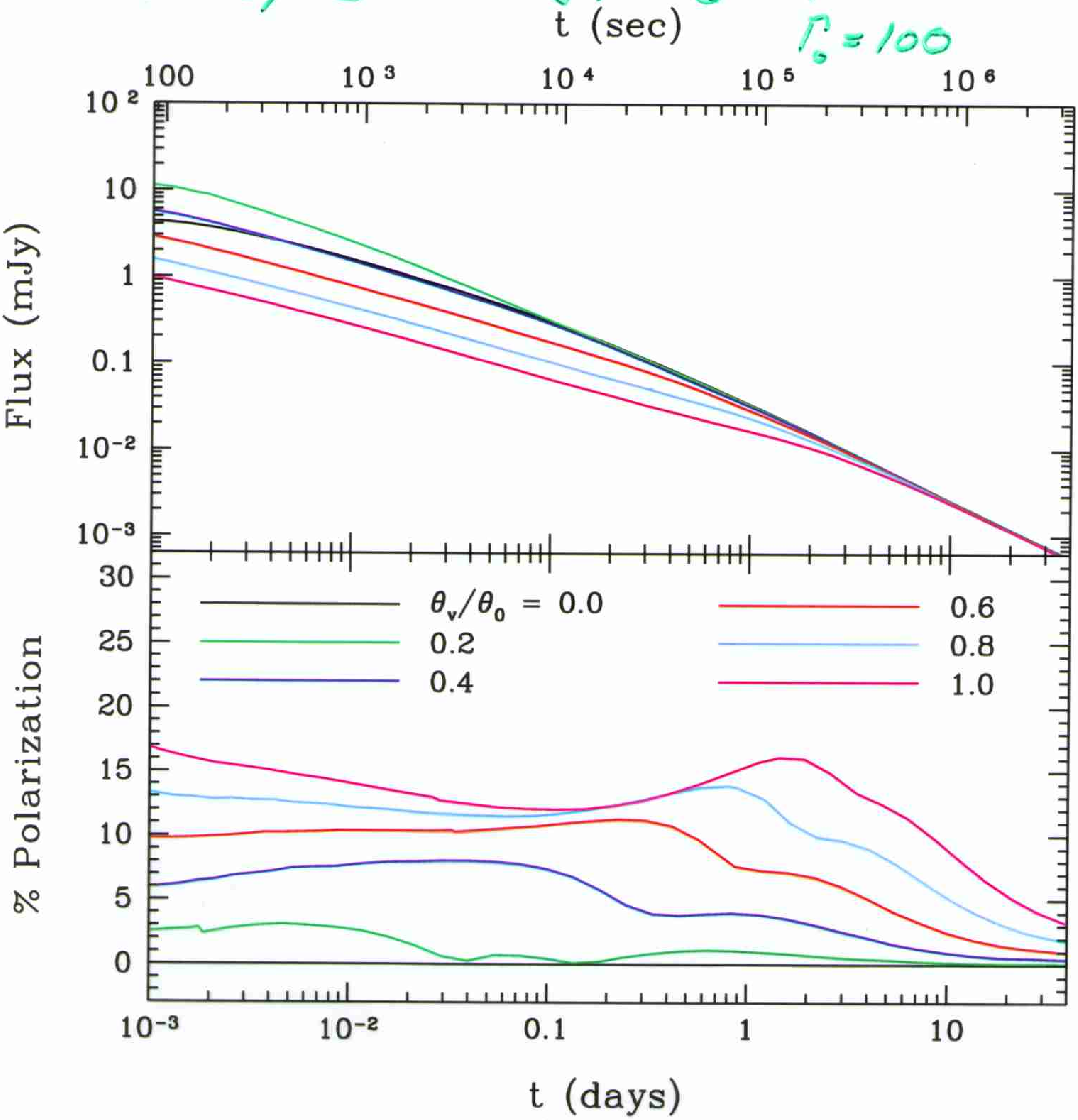
Structured, $\mathcal{E} = 10^{52}$ ergs, $\theta_c = 3°$, $\theta_0 = 15°$

$\Gamma_0 = 100$

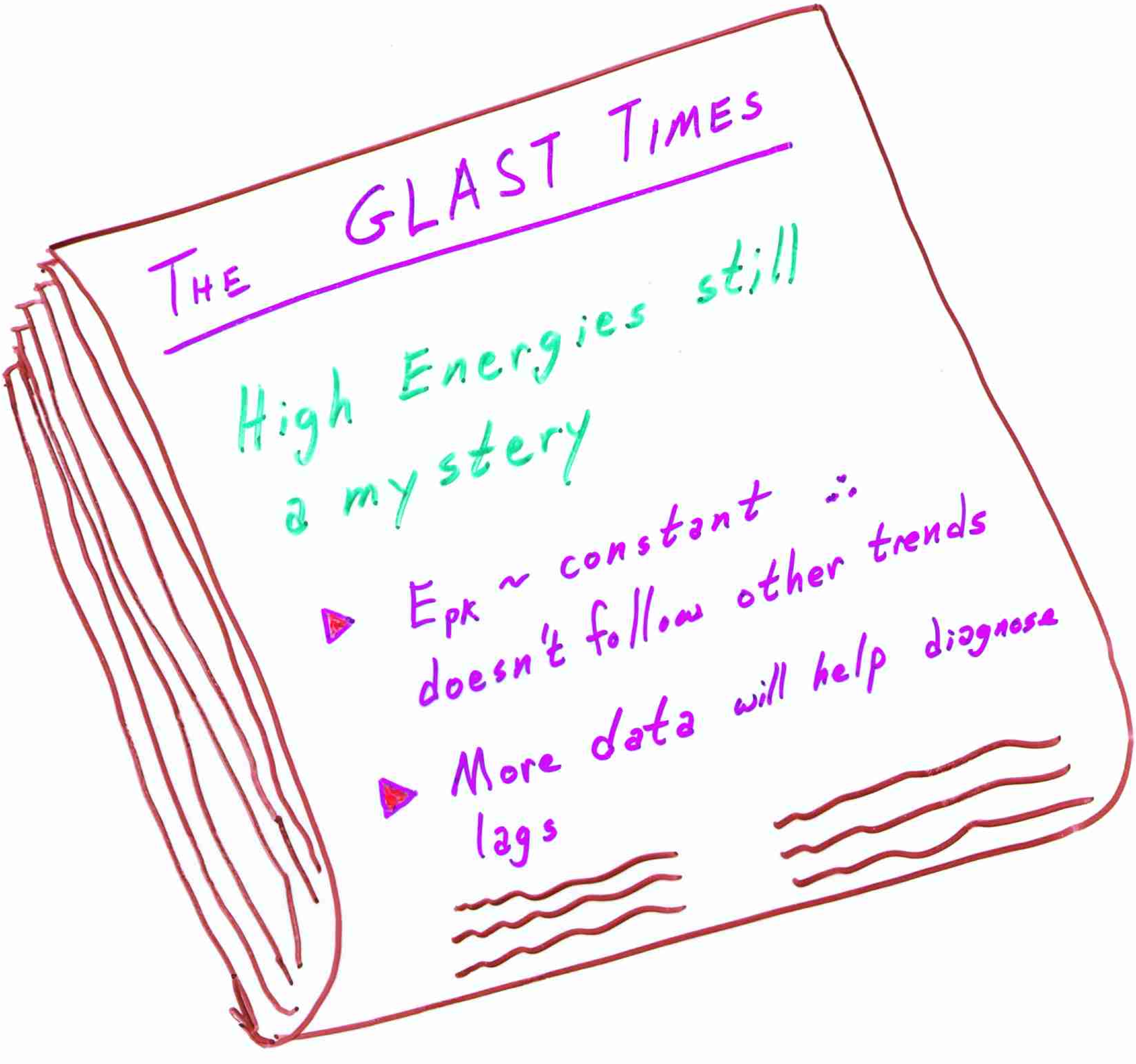


$R_K = 0$

Structured, E = 10^53 ergs, θ_c = 3°, θ_0 = 15°, Γ_0 = 100



$R_K = 0.1$


THE GLAST TIMES
High Energies still a mystery
Epk ~ constant ∴ doesn't follow other trends
More data will help diagnose lags