

ガンマ線バースト 最初の三時間

井岡 邦仁（京大理）

当真 賢二（京大理）

山崎 了（広大理）

中村 卓史（京大理）

astro-ph/0509159

astro-ph/0511718

astro-ph/0511749

去年11月20日以降の進展

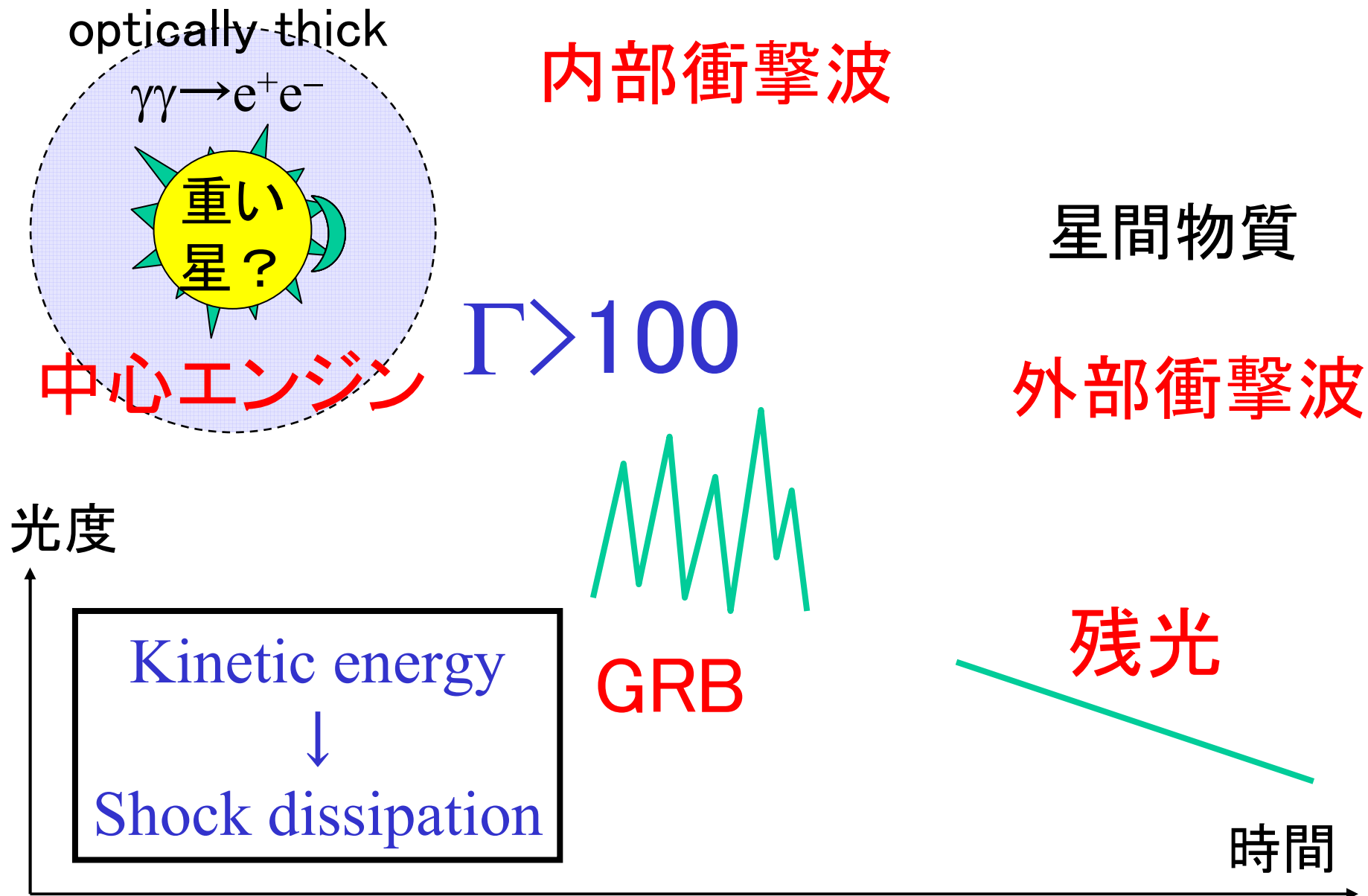


GRB専用衛星
Swiftの打ち上げ

1. 予想外の初期X線残光
2. X線フレア
3. Short GRBの残光、 z
4. GRB050904 @ $z \sim 6.3$
5. Prompt optical/IR flash
6. Dark GRB (Dim RS)
7. Dec 27 SGR giant flare

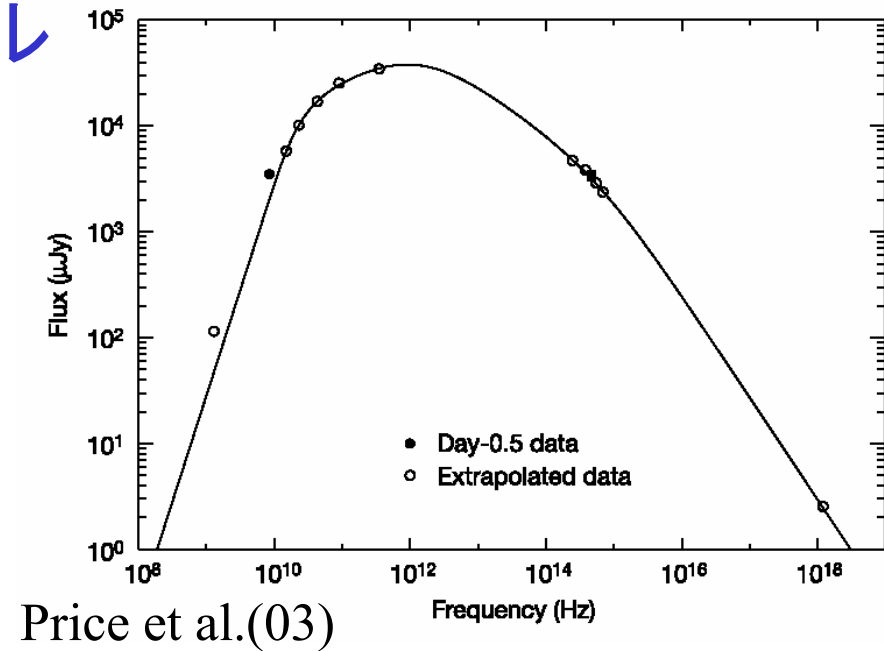
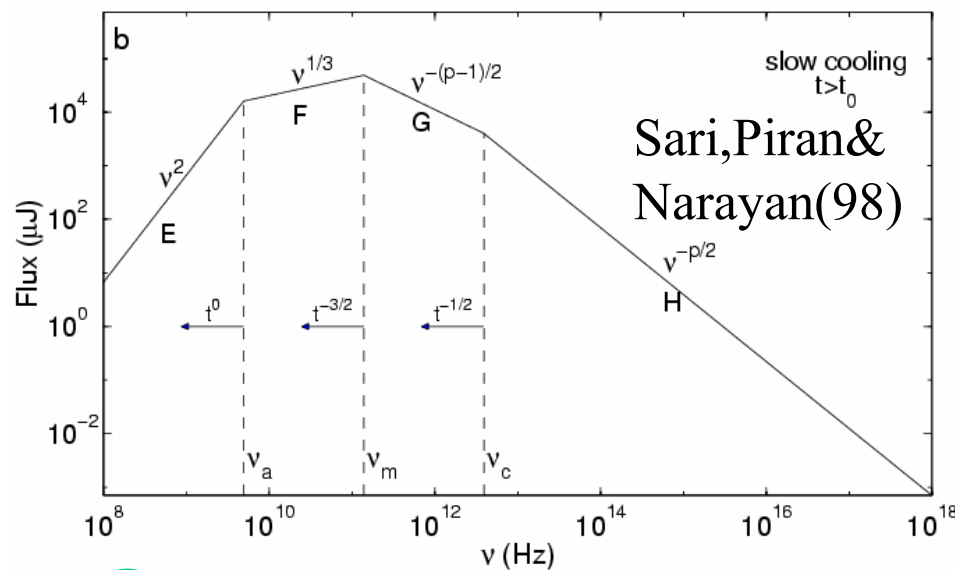
、、、多分まだ出る

標準モデル



残光モデルの成功

シンクロトロン衝撃波モデル



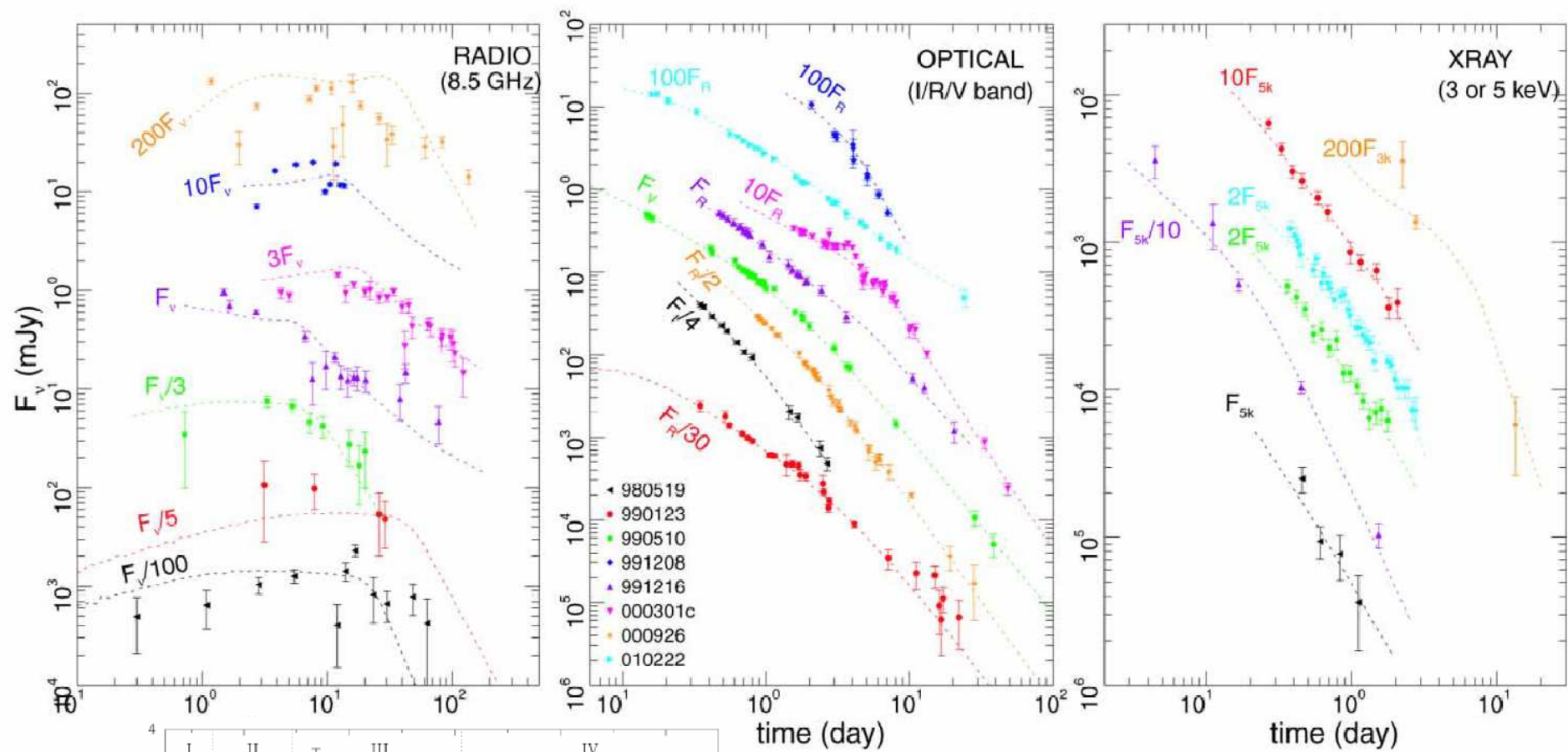
- ① 電子の加速
 - ② 磁場の生成
- ⇒ シンクロトロン放射
- 数個のパラメータしかない
- E , n , ε_e , ε_B , p

Fitting: $E \approx 10^{51-54} \text{ erg}$

$n \approx 0.01 - 100 \text{ cm}^{-3}$

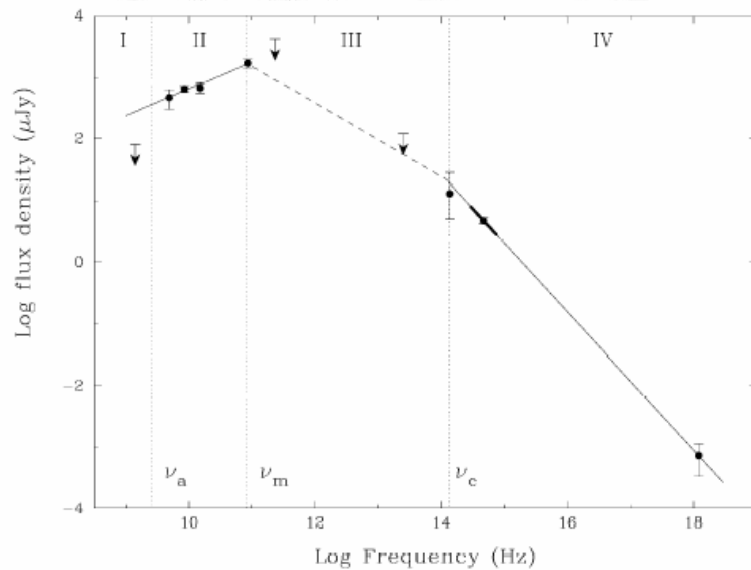
$\varepsilon_e \approx 0.1$

$\varepsilon_B \approx 0.01$



Panaiteescu&Kumar(00)

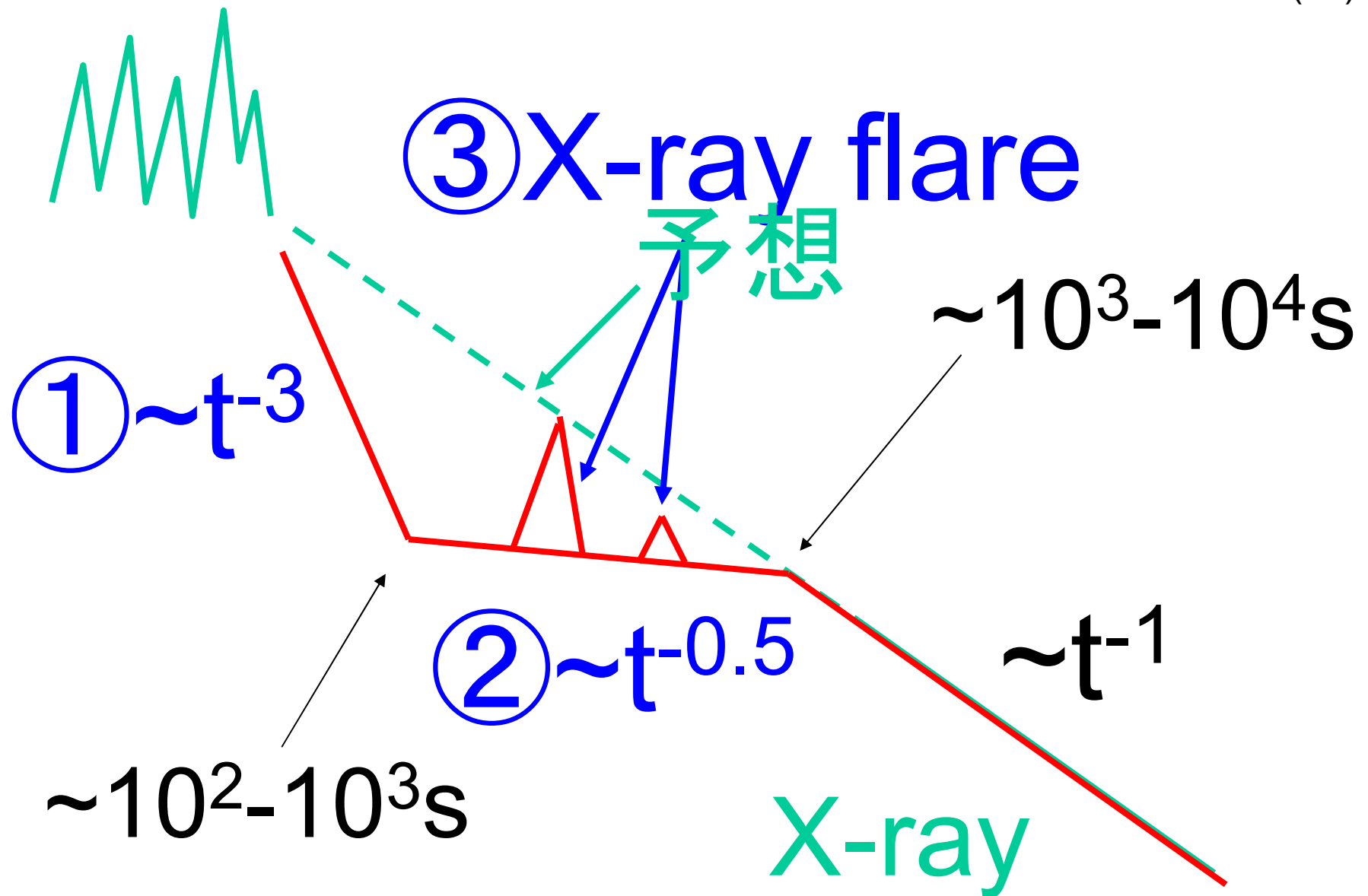
~1日後では
かなりよく合う

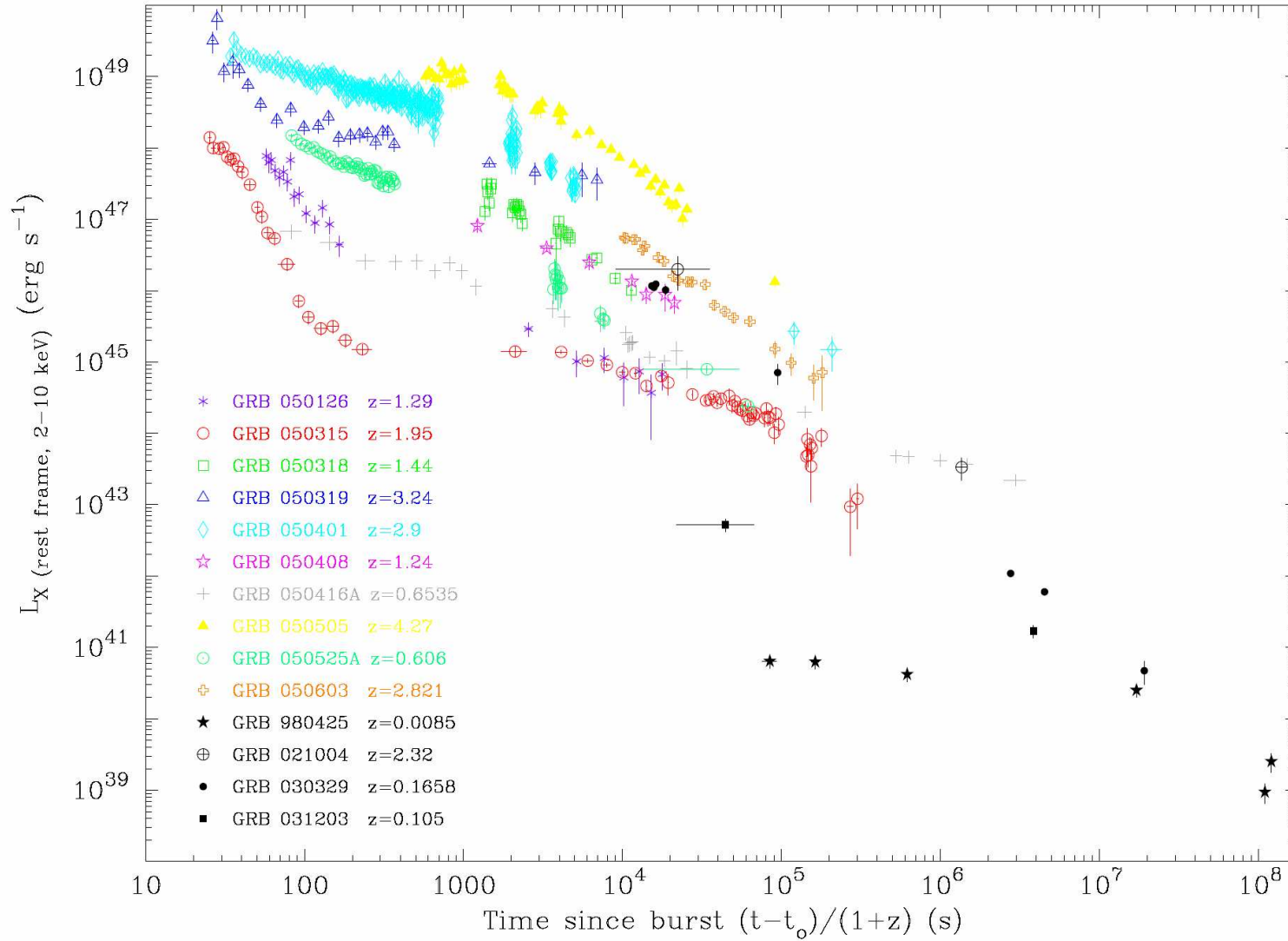


Galama et al.(98)

最初の三時間

Nousek et al.(05)
Zhang et al.(05)
Burrows et al.(05)





Nousek et al.(05) a-ph/0508332

Fig. 1.— The X-ray luminosity in the range 2–10 keV as a function of time (both measured in the cosmological rest frame of the GRB) for *Swift* GRBs with established redshifts (coloured symbols), plotted together with selected earlier events (all in black symbols) from Figure 3 in Kouveliotou et al. (2004).

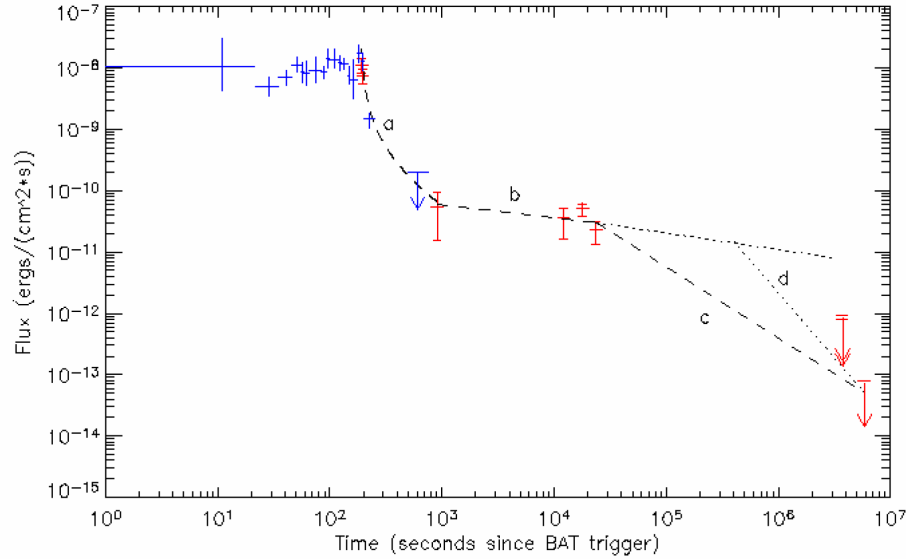


Fig. 5.— GRB 050117 lightcurve (absorbed fluxes): The BAT (blue) lightcurve using the spectral fits for each time bin and extrapolating the 15–100 keV flux into the 0.5–10 keV band (the flux and upper limit for the time intervals $t = 204 - 250$ seconds and $t = 300 - 913$ seconds were calculated using the photon index from $t = 190 - 204$ seconds) and the XRT (red) lightcurve (0.5–10 keV), showing the upper limits for the observations at more than 43 days after the burst; a) A power law fit assuming high latitude emission from the internal shock where $t_{shock} = 187$ seconds, $\alpha < -1.2$; b) A power law fit to the afterglow decay with energy input from refreshed shocks assuming a $t_0 = triggertime$, $\alpha = -0.2 \pm 0.2$; c) Continuation of the afterglow decay assuming a break in the lightcurve at $t = 6.6$ hours, $t_0 = triggertime$, $\alpha = -1.2$; d) Extrapolation of $\alpha = -2$ from $t = 43$ days, showing the latest expected time of the break in the lightcurve at ~ 4.5 days ($t_0 = triggertime$).

Hill et al.
a-ph/0510008

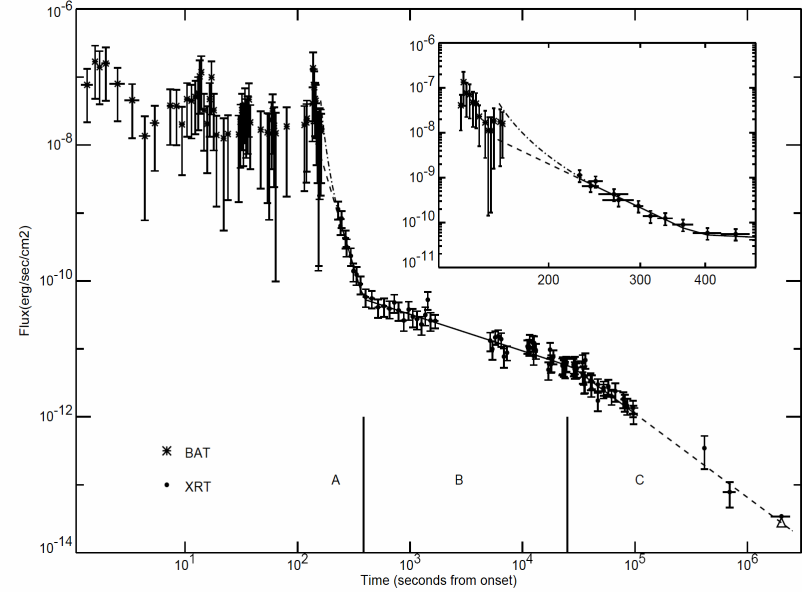


Fig. 2.— XRT light curve decay of GRB 050319. The XRT count rate (0.2–10 keV) was converted into flux units by applying a conversion factor derived from the spectral analysis of each correspondent phase (see section 3.3). The solid line represents the best fit model, the dashed line is the extrapolation of this model prior to the first XRT observation. The dot-dashed line represents the extrapolation back to the end of the prompt emission of the best fit obtained using the double broken power law model with times referred to the peak time of last spike of the prompt emission ($T = 137$ s after the burst onset). The last point after 10^6 s is a 3σ upper limit. The gaps in the XRT light curve in the first observation are due to blind observing periods during the spacecraft orbit. The BAT light curve was extrapolated into the XRT energy band by converting the BAT count rate with the factor derived from the BAT spectral parameters. The gaps in the BAT light curve corresponds to time intervals where the GRB count rate level was consistent with zero. The inset shows the time interval including the last peak of the GRB and the phase A of the afterglow.

Cusumano et al.
a-ph/0509689

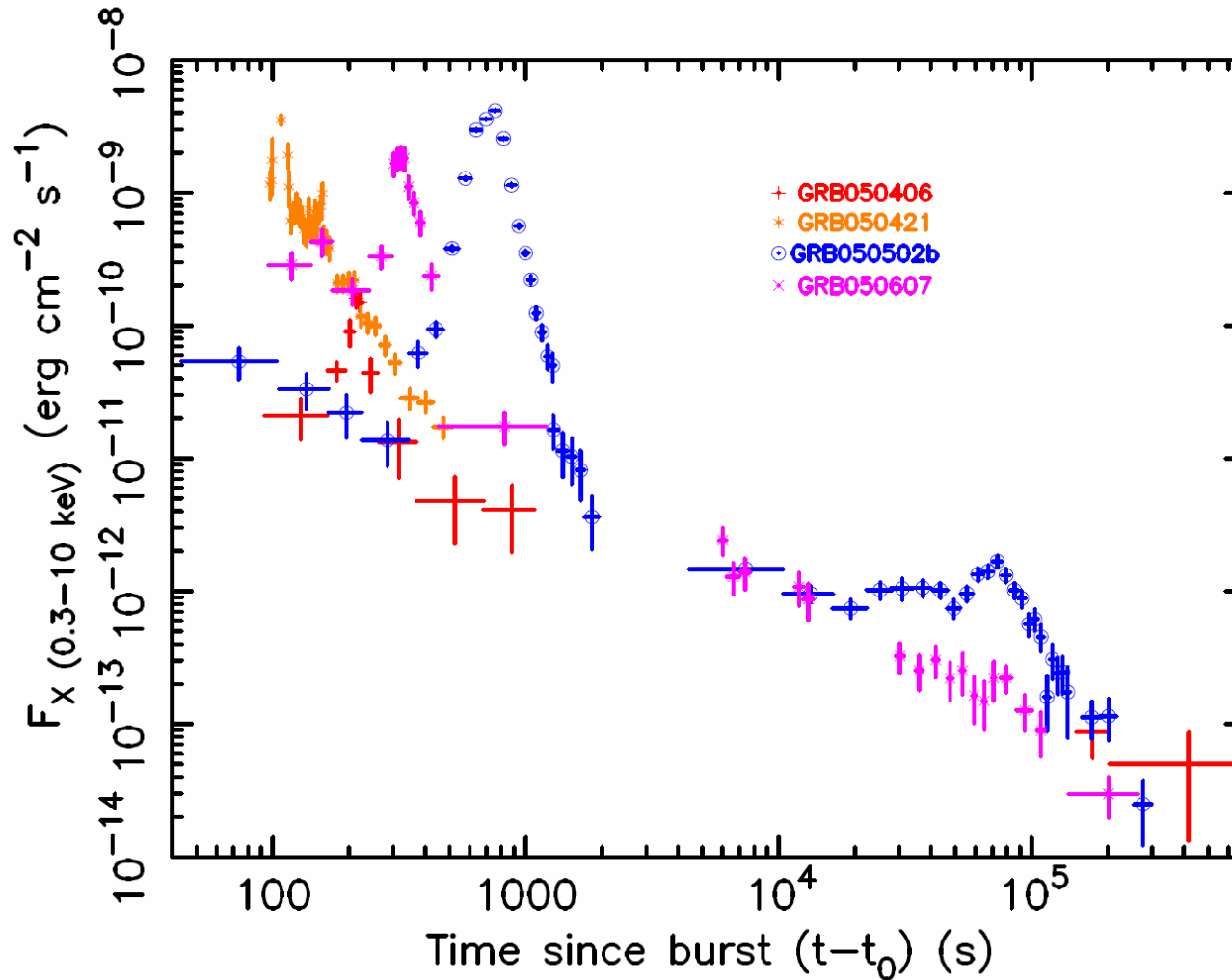
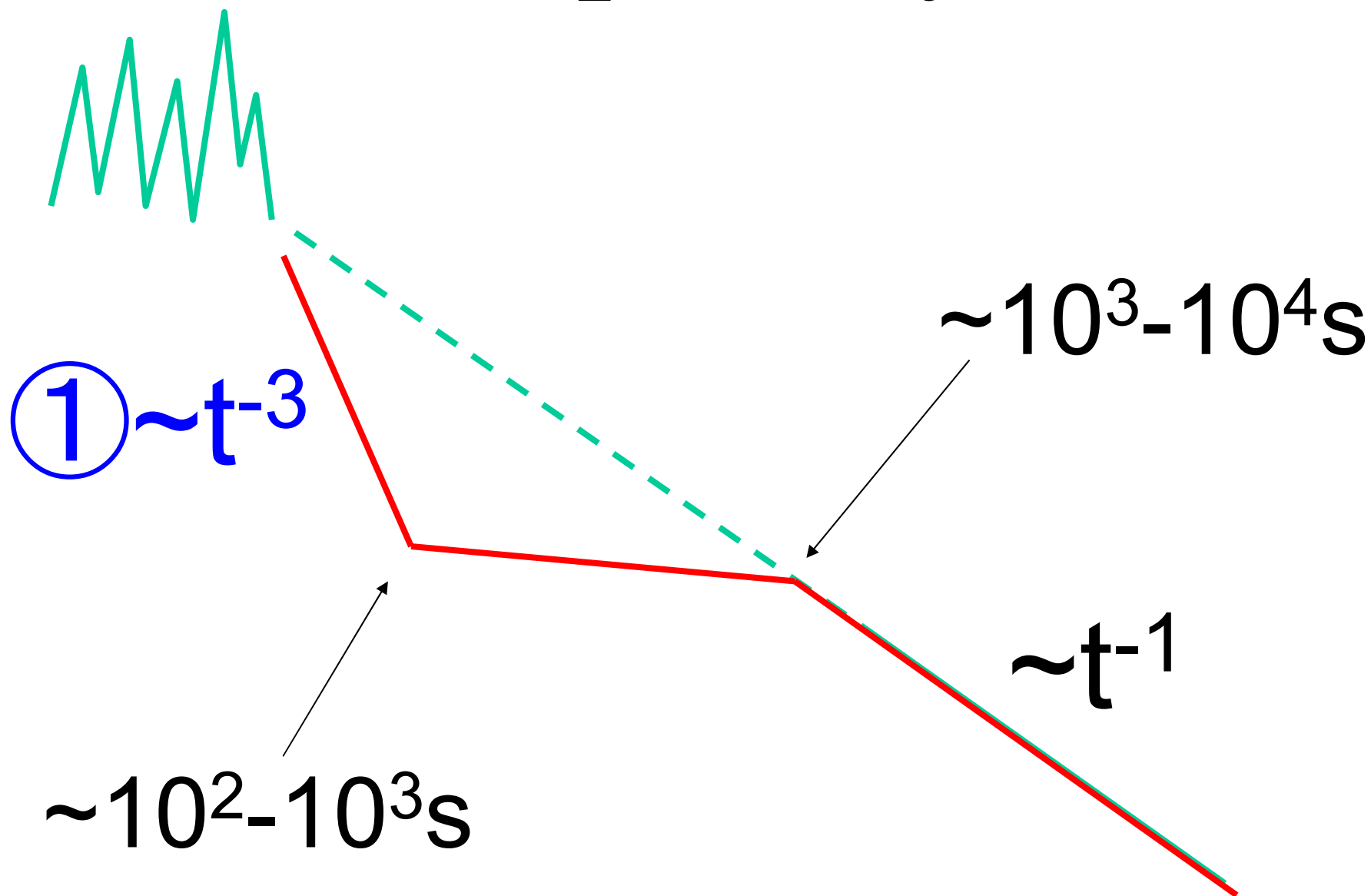


Fig. 2.— The X-ray flux (0.3 – 10 keV in the observer frame) as a function of the observed time, for all *Swift* GRBs without known redshifts, with (*upper panel*) and without (*lower panel*) X-ray flares.

X-ray flare

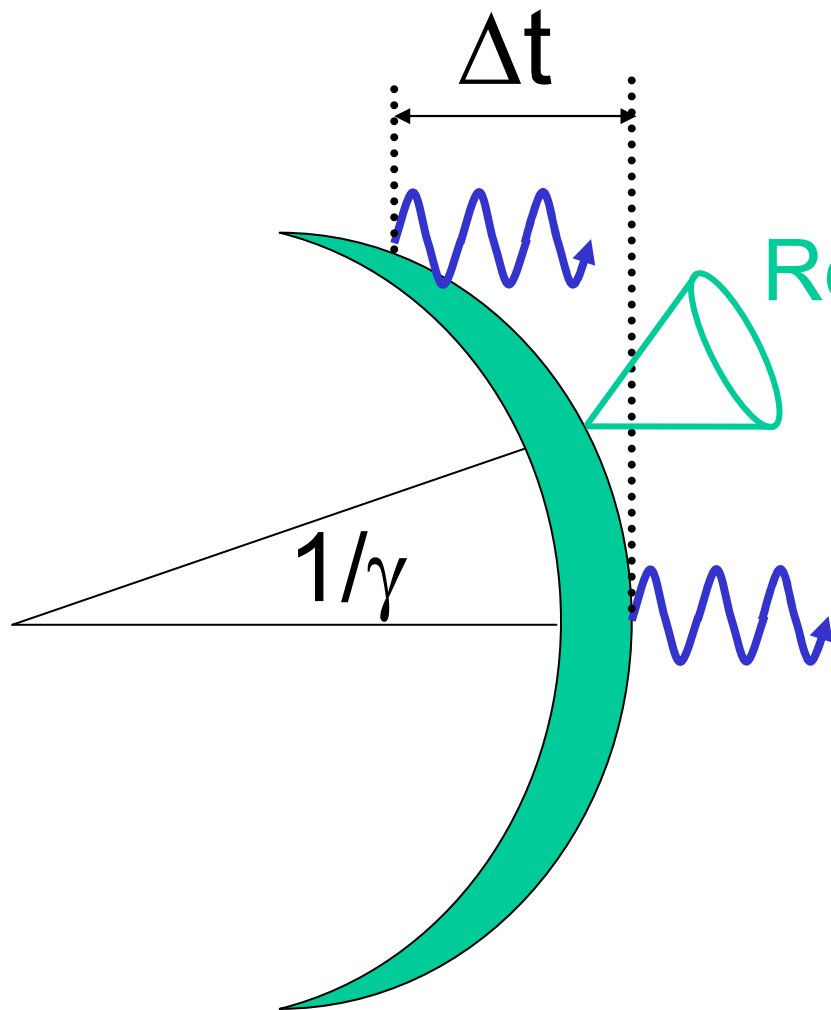
Nousek et al.(05)
Burrows et al.(05)
Piro et al.(05)

Steep decay



Steep decay

Off-axis high-latitude emission

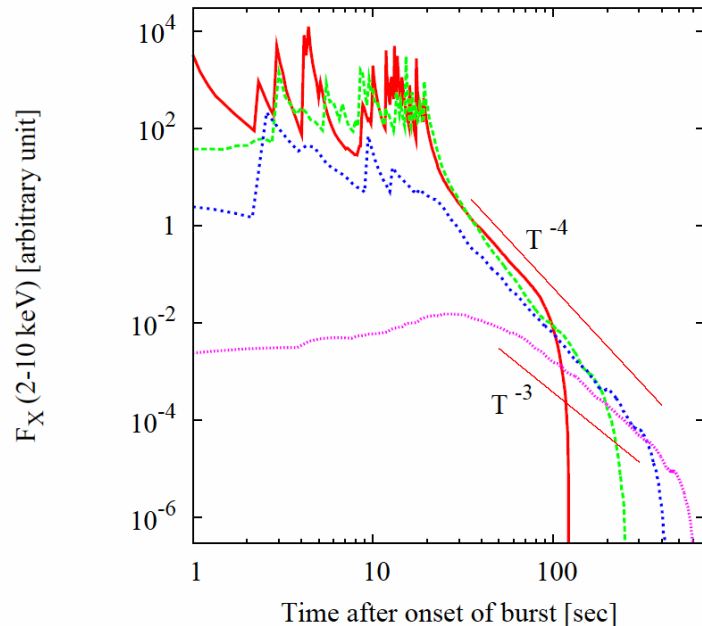
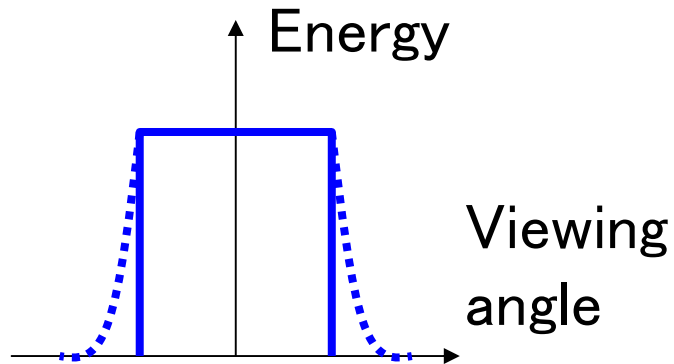


Relativistic beaming

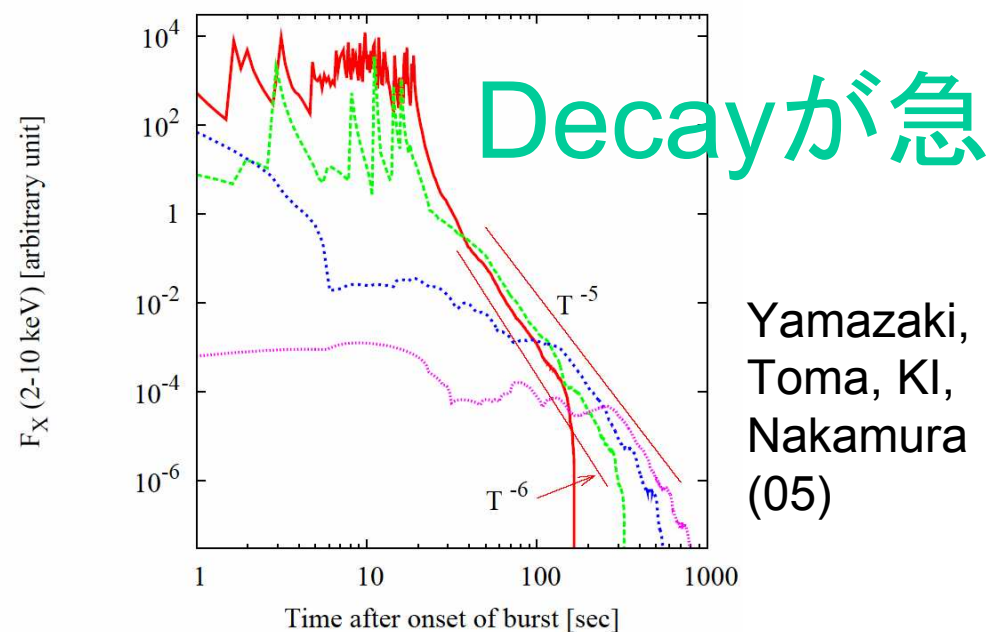
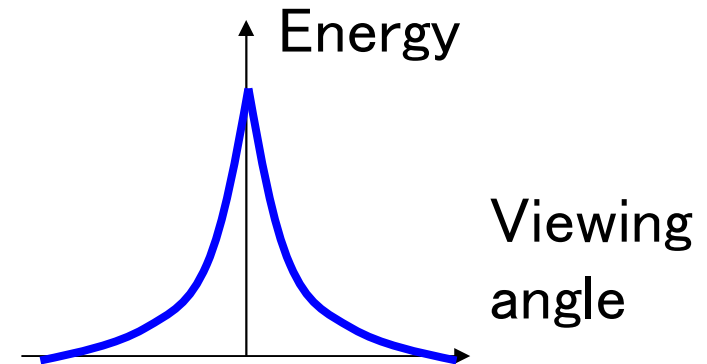
$$\begin{aligned} F_{\nu} &\sim (t-t_0)^{-\alpha} \nu^{-\beta} \\ &\sim (t-t_0)^{-2-\beta} \nu^{-\beta} \\ &\sim t^{-3} \end{aligned}$$

Jet構造の診断

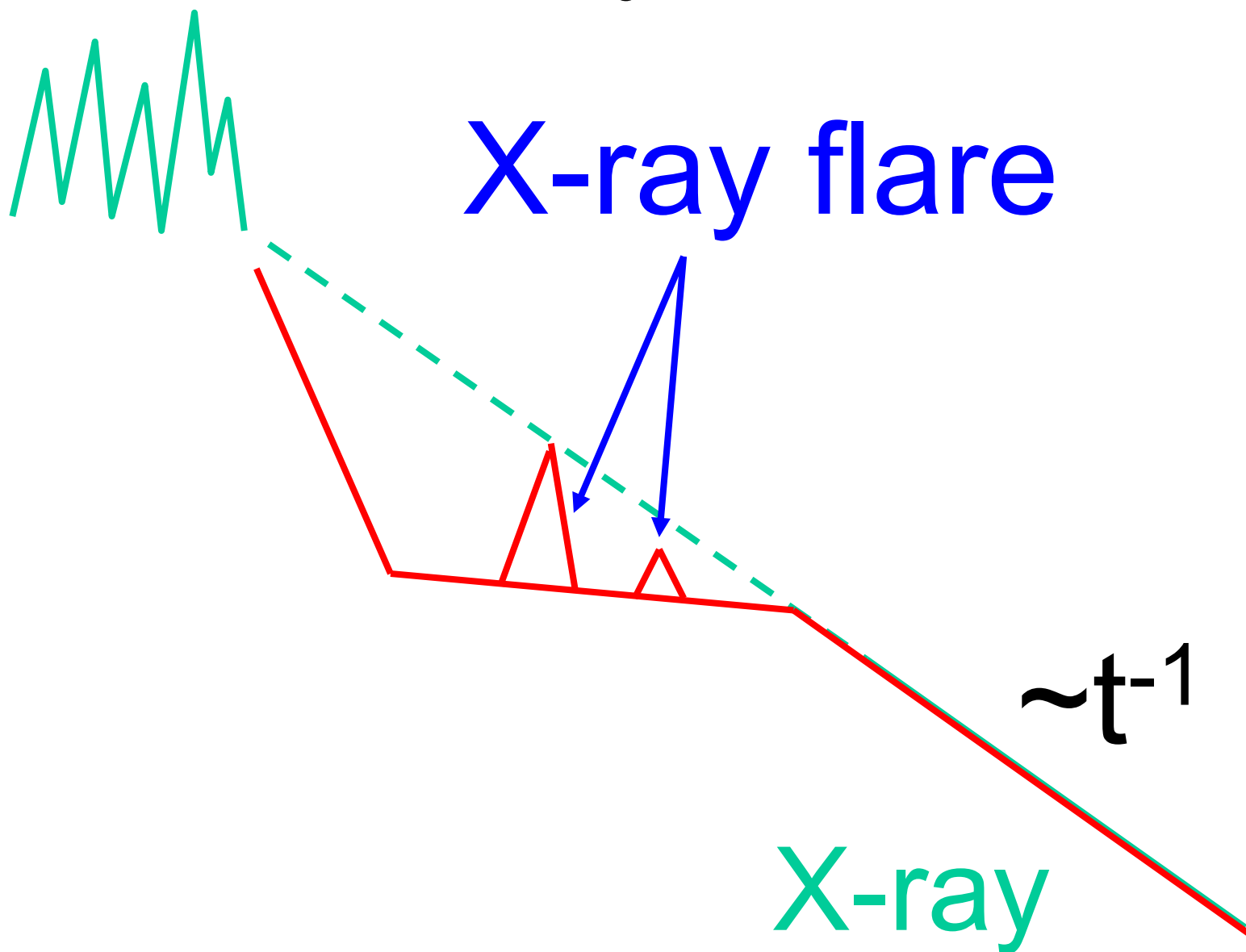
Uniform jet



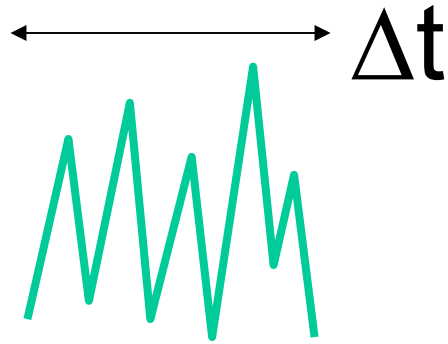
Power law jet



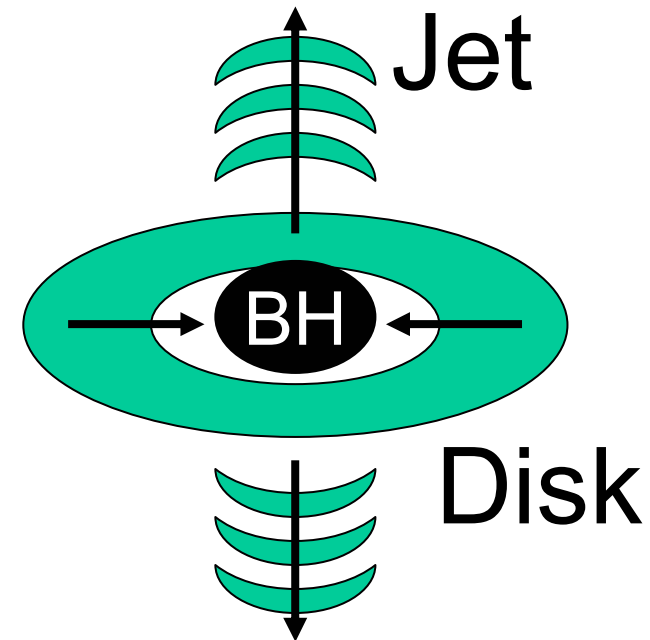
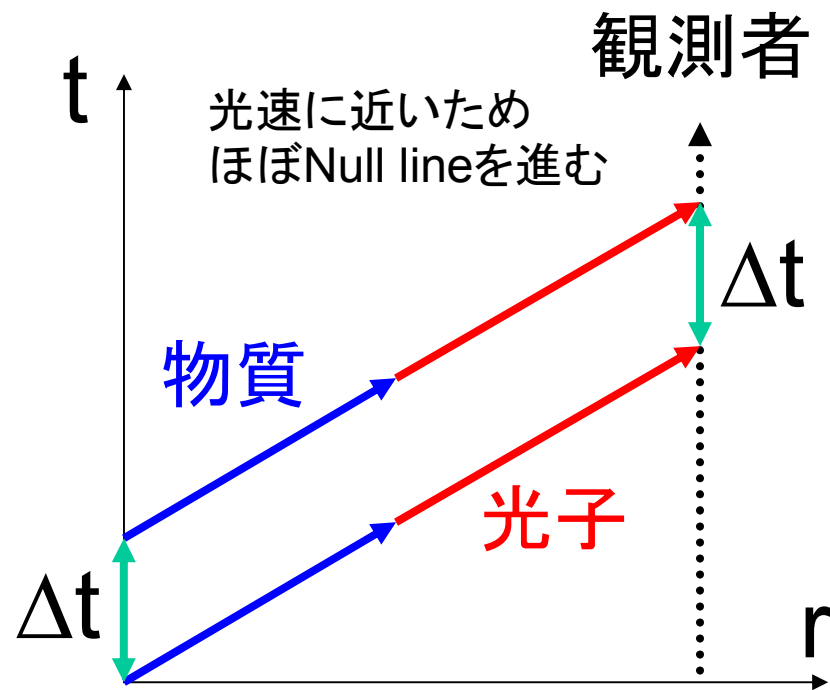
X-ray flare



Duration



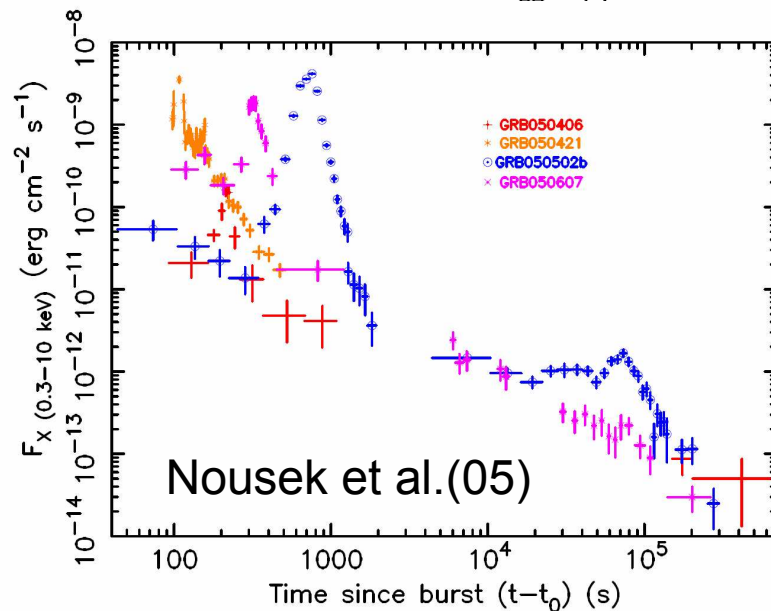
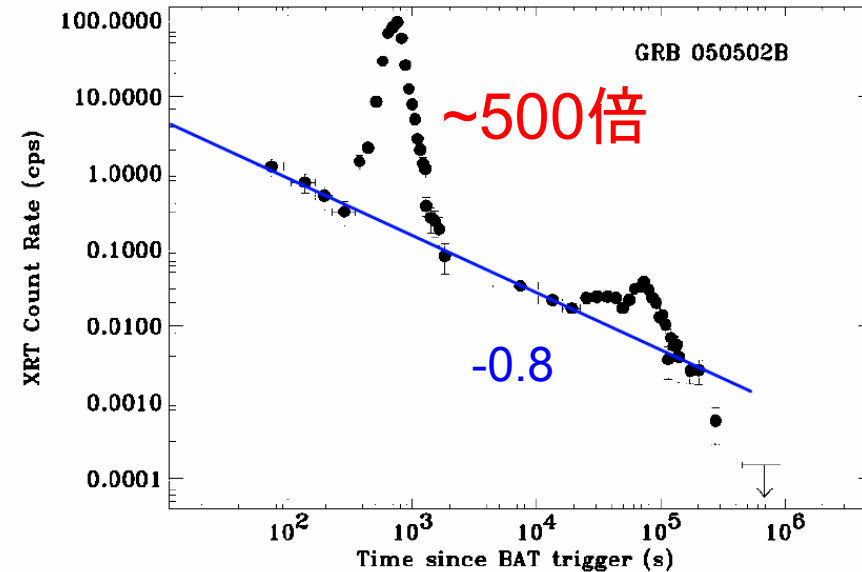
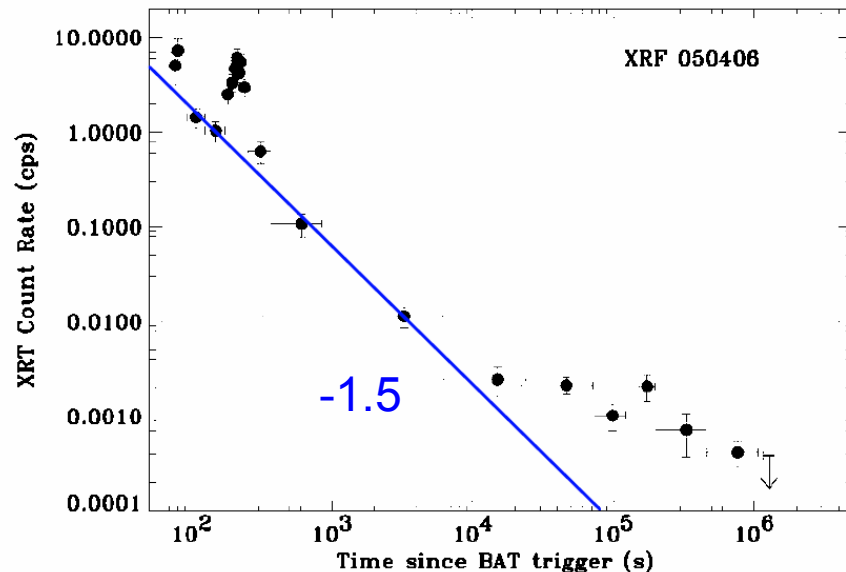
GRBの継続時間 Δt
= エンジンの継続時間



$\Delta t \sim$ 降着時間 $\sim 100\text{s}$

X-ray flare

Burrows et al.(05)



結論：中心エンジンは
1時間から1日も
活動している！！

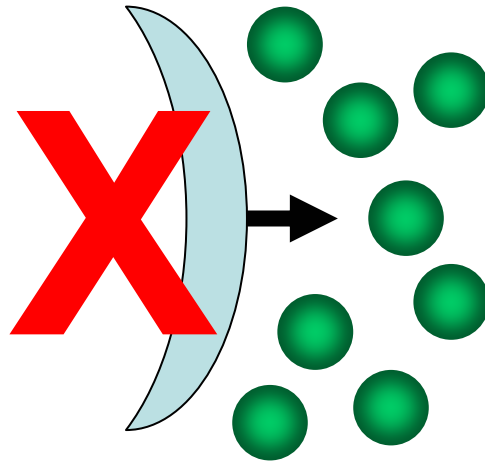
周囲の密度変化では説明できない

変動の主なモデル

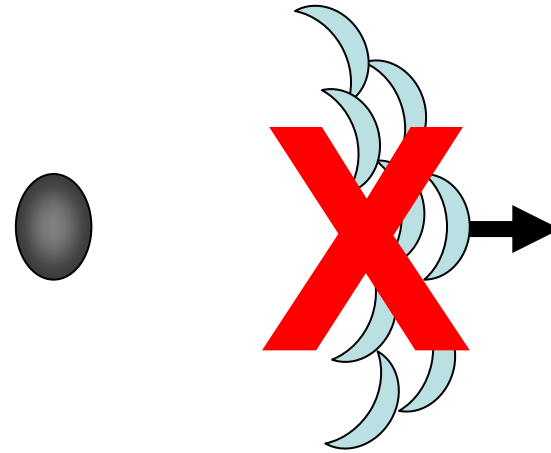
密度変化

外部衝撃波

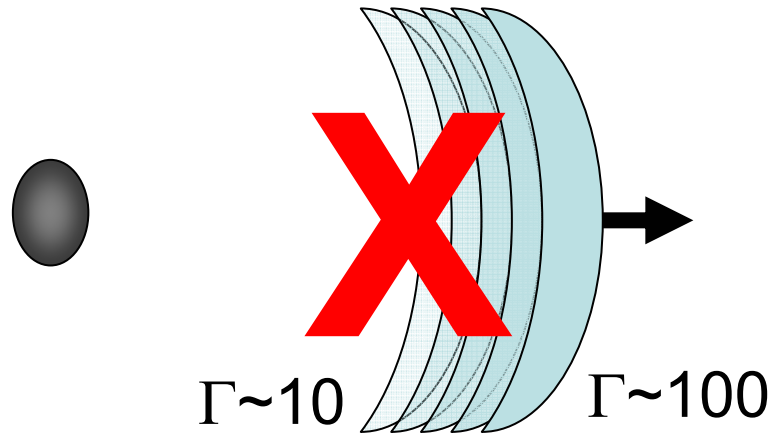
中心エンジン



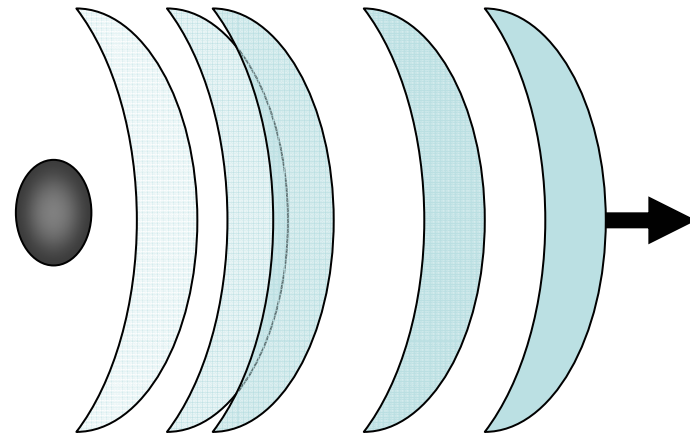
非一様ジェット



遅いものが追いつく



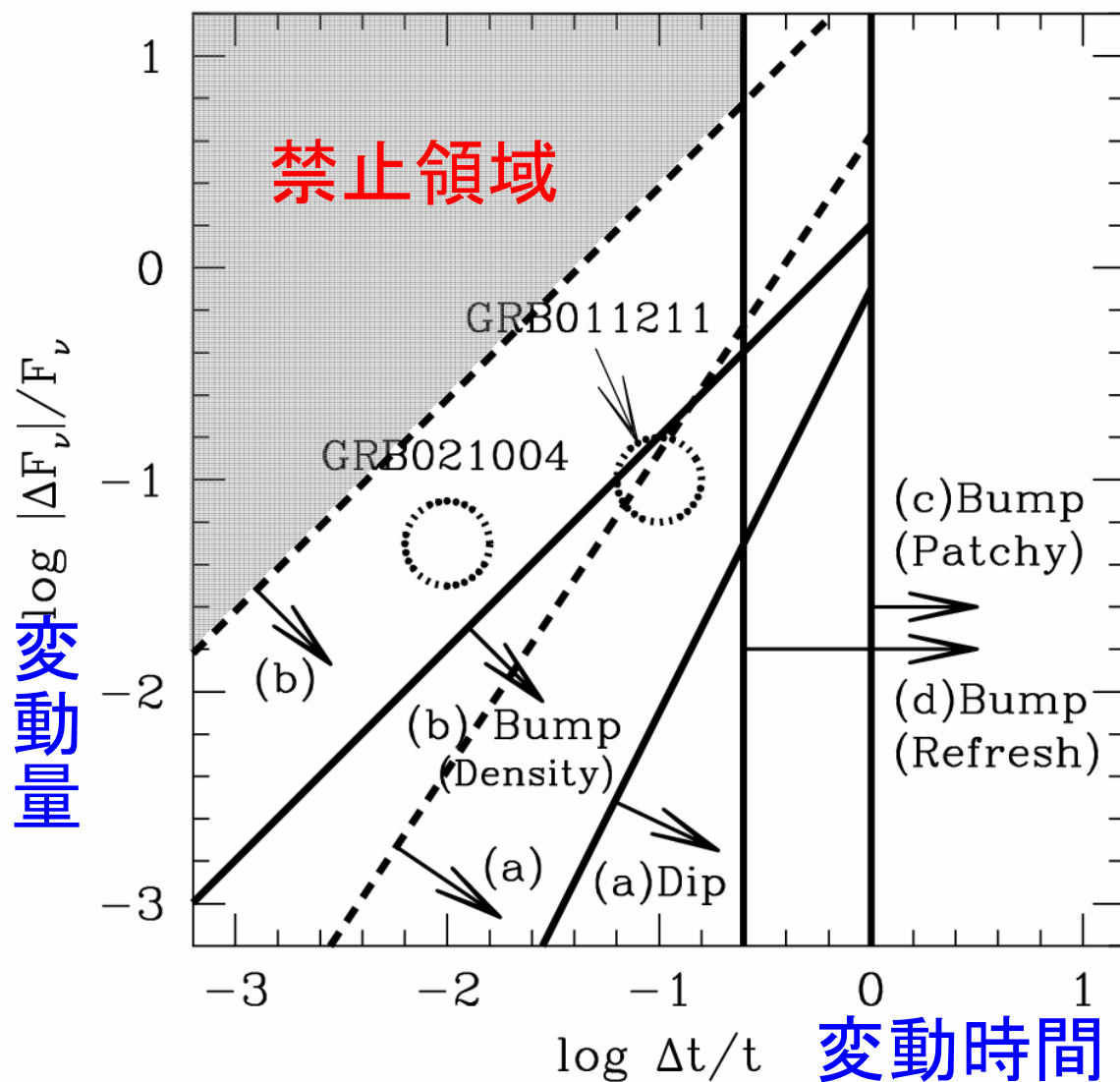
長寿命な中心エンジン



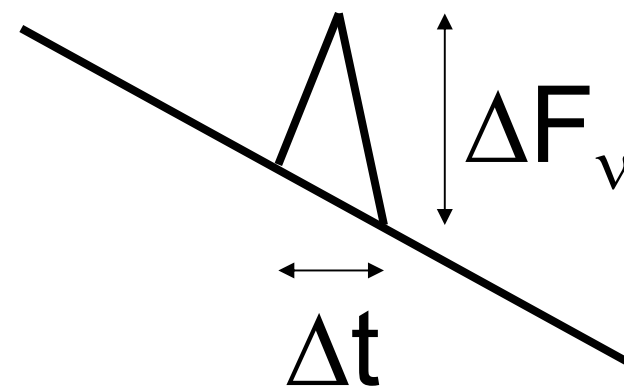
力学的制限



KI, Kobayashi&Zhang(05)



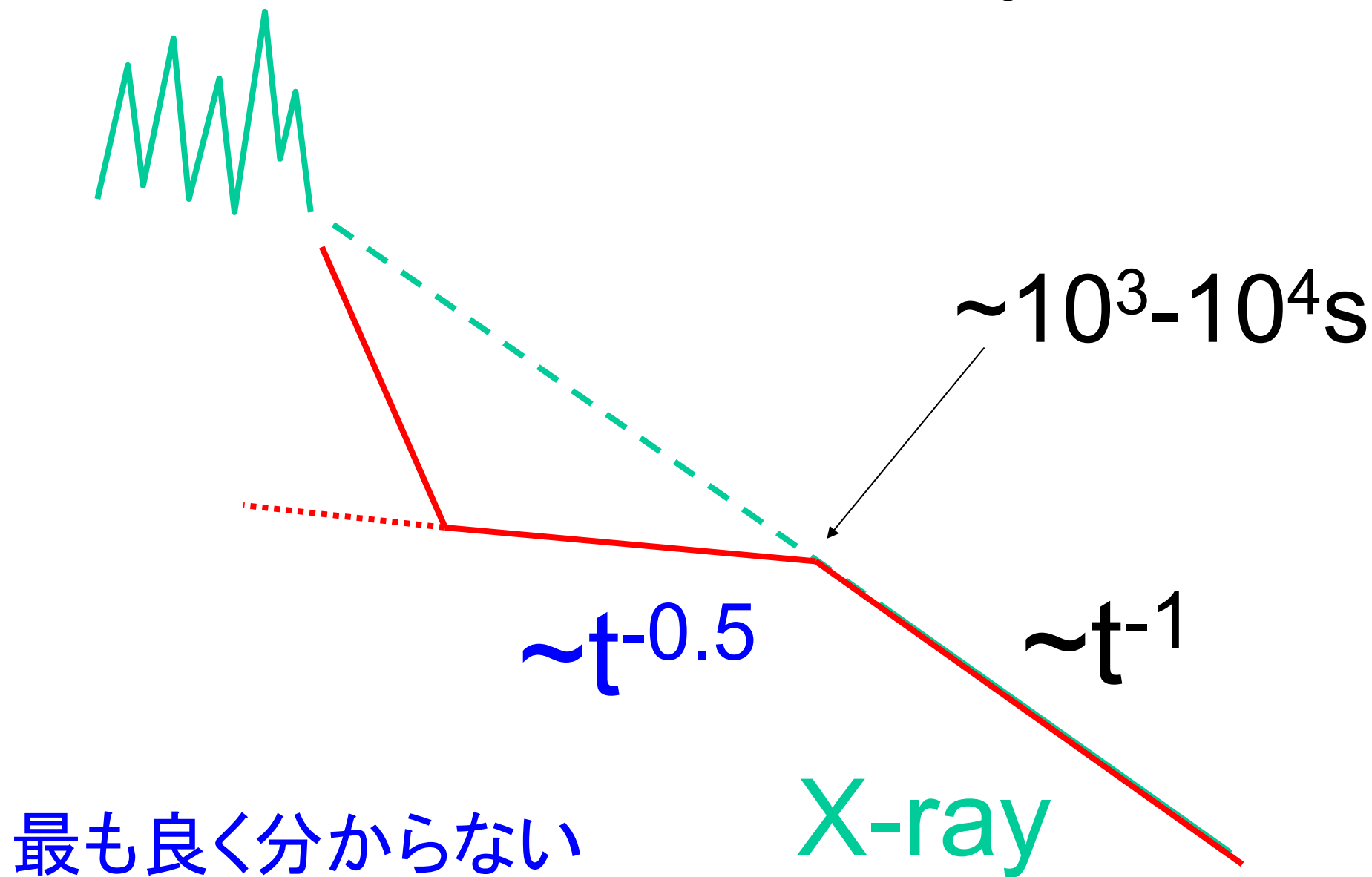
密度変化などでは
短く大きな残光変動
は作りにくい



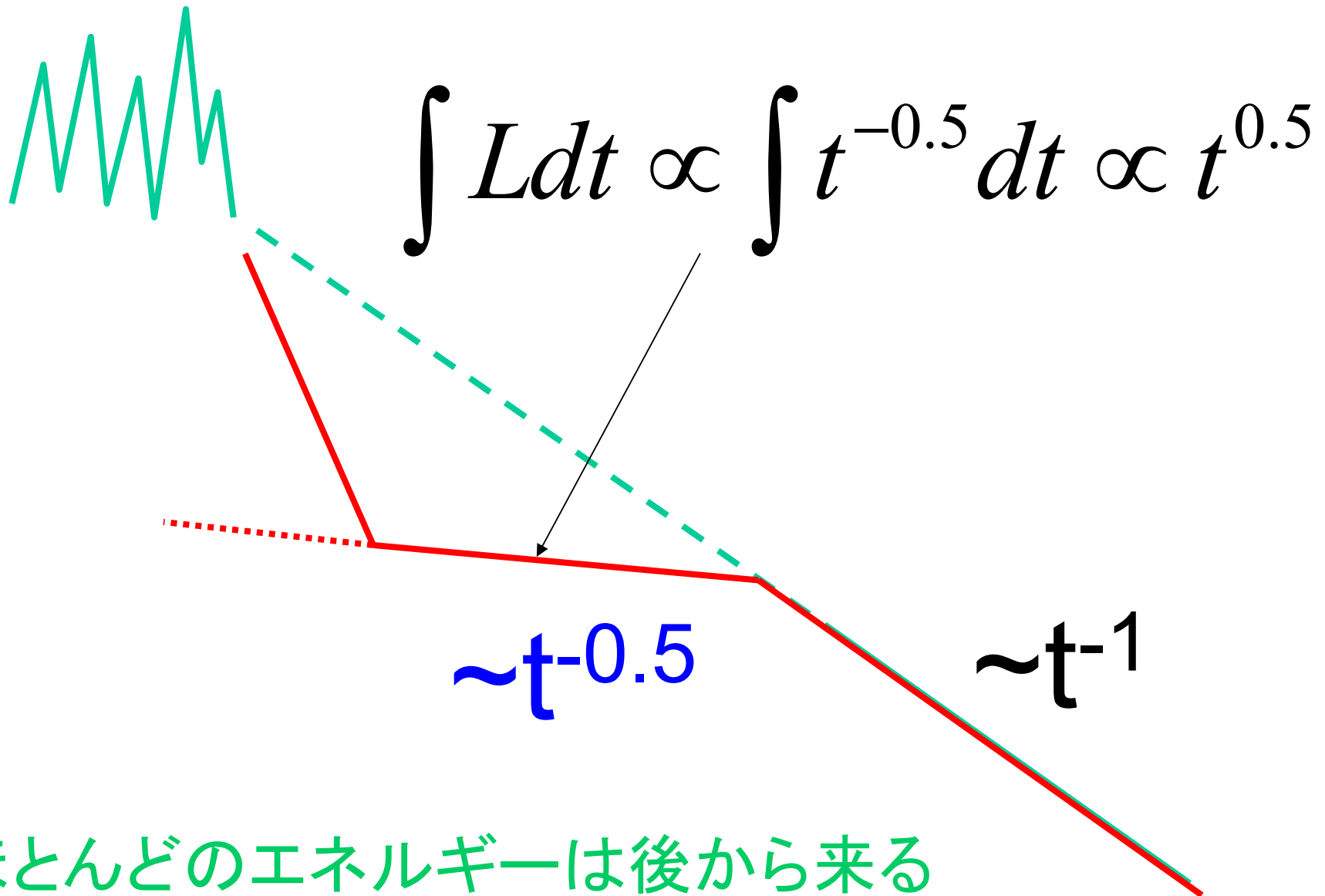
残光変動ではない
⇒ エンジン起源

降着が長すぎる？

Shallow decay

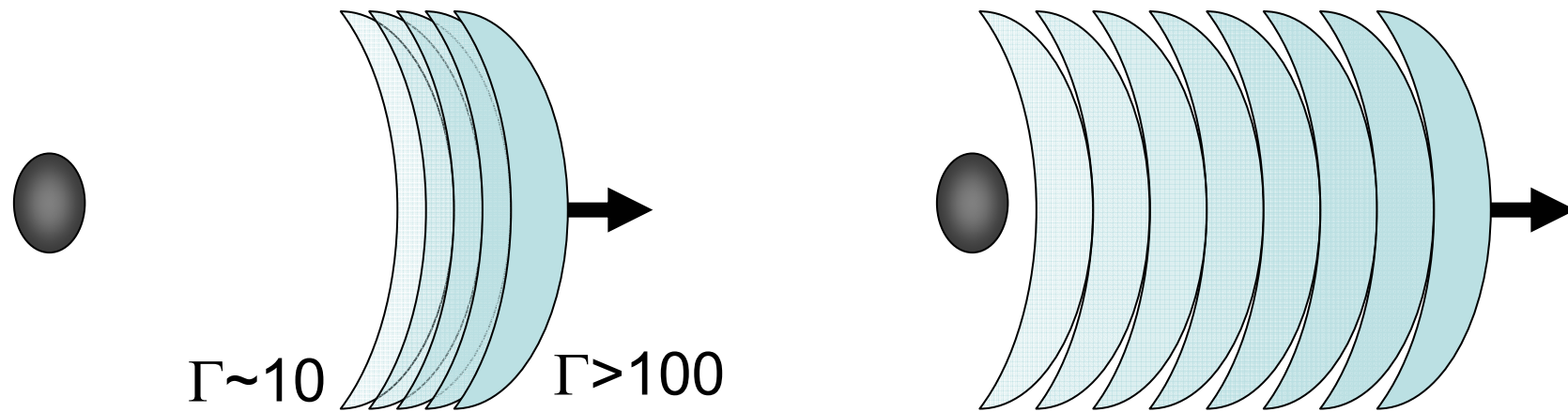


積分エネルギーは増加



① Energy injection

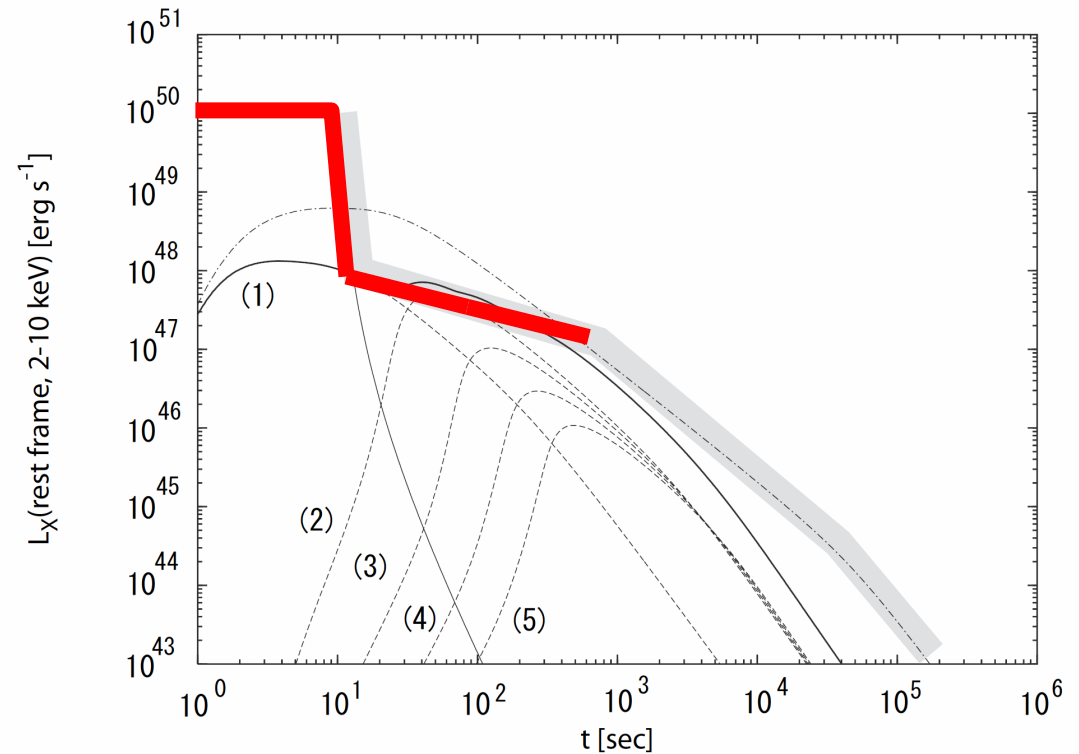
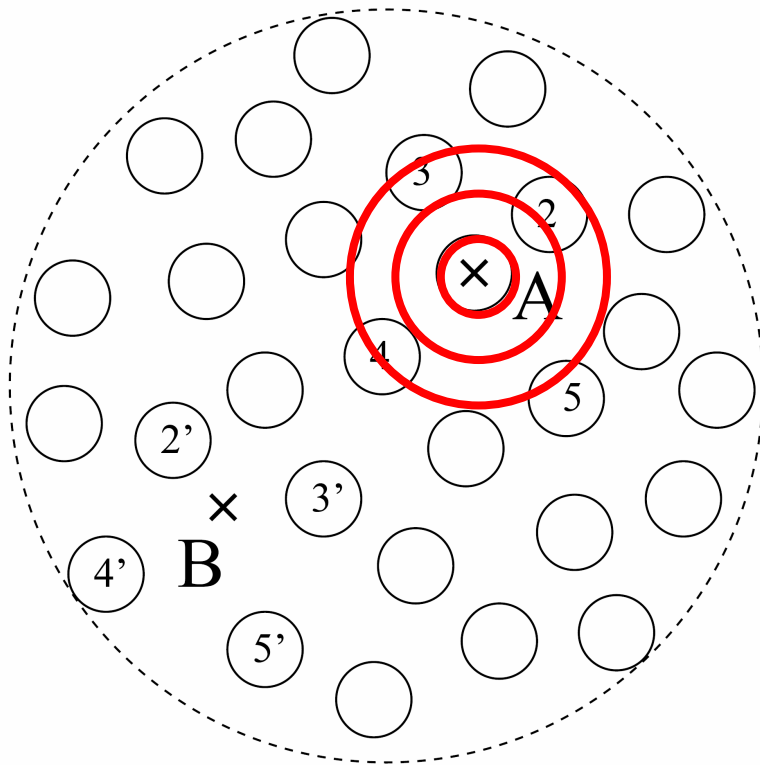
遅いものが追いつく 長寿命な中心エンジン



後から来るflowが多くエネルギーを持つ

Nousek et al.(05)
Zhang et al.(05)

② 非一様ジェット



1/ Γ が減速すると大きくなる
⇒ 周りが見えてくる

Toma et al. a-ph/0511718
Eichler&Granot a-ph/0509857

Efficiency crisis

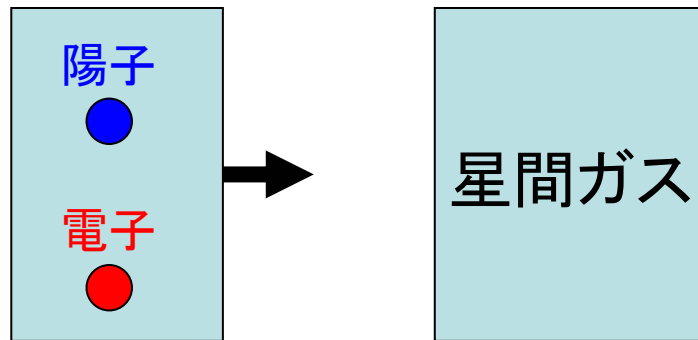
①、②ではガンマ線の放射効率が異常に高い必要がある(>70-90%)

今まで $E_{\text{GRB}} \sim E_{\text{残光}}$

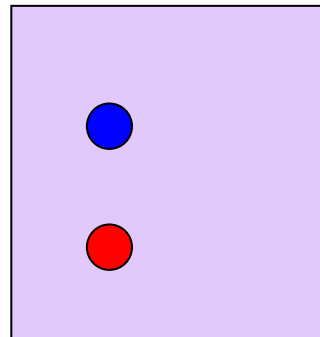
実は $E_{\text{GRB}} \gg E_{\text{残光}}$

標準モデル(内部衝撃波)で説明するのは難しいかも

③ 時間変化するMicrophysics



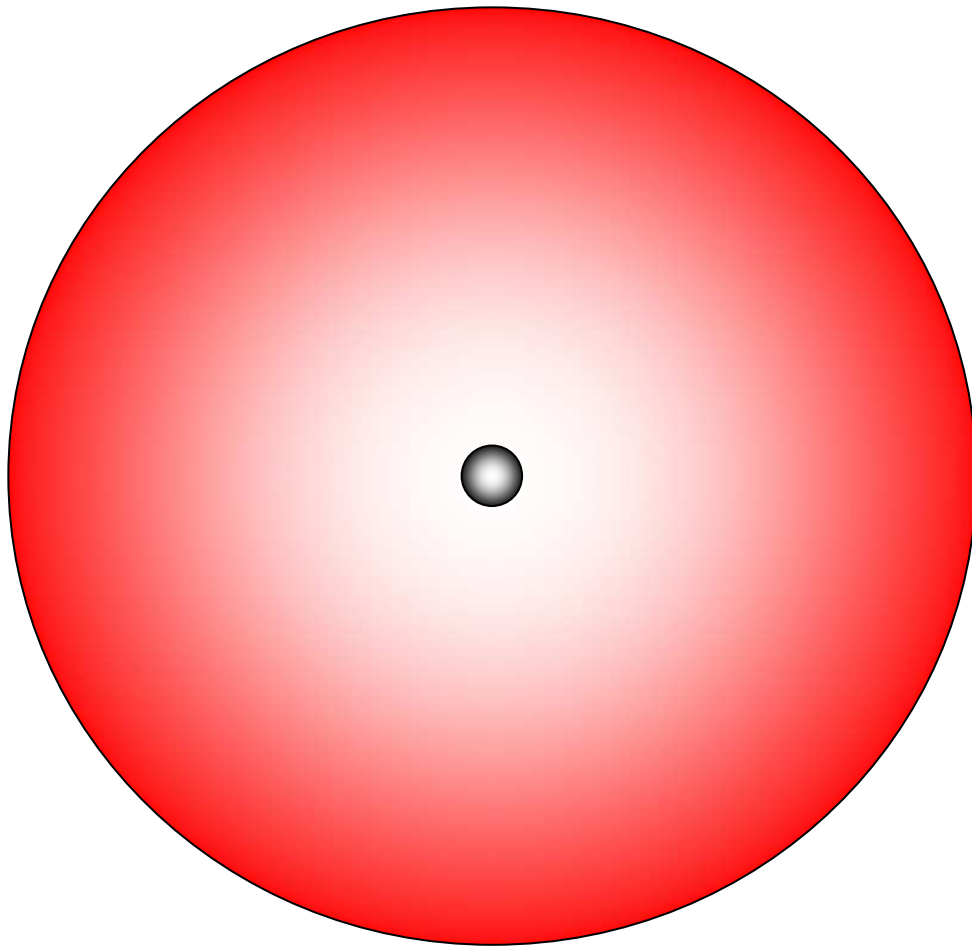
最初は $E_{\text{陽子}} \sim 2000 E_{\text{電子}}$



標準モデルでは
 $E_{\text{陽子}} \sim 10 E_{\text{電子}}$ を仮定
 \Rightarrow 電子が放射

最初の三時間、 $E_{\text{電子}}$ が少ない \Rightarrow 平坦残光
つまり非効率残光

④ Prior activity



事前に小さな爆発
⇒まわりの物質は
外側に速度を持つ
⇒逃げながら衝突
されるので暗くなる

$$E_{\text{prior}} \ll E_{\text{main}}$$

Precursorを予言

まとめ

最初の三時間は標準モデルからずれる

Steep decay

Off-axis放射 ⇒ Jet構造の診断

Shallow decay

- ① Energy injection
- ② 非一様ジェット
- ③ 時間変化するmicrophysics
- ④ Prior activity ⇒ 多波長観測で区別

X線フレア

中心エンジンが長寿命