# GRB Afterglows with eXTP


Xuefeng Wu

MiXiang Lan

*Purple Mountain Observatory*


eXTP Meeting, Roma, Italy, Feb. 6-8, 2017

# Outline

- Introduction

  1. picture of GRB
  2. Polarization models for GRB
  3. magnetic field configuration and central engine

- X-ray observations in GRBs and its polarization

  1. X-ray flares
  2. X-ray plateau

- Summary

# Outline

- Introduction

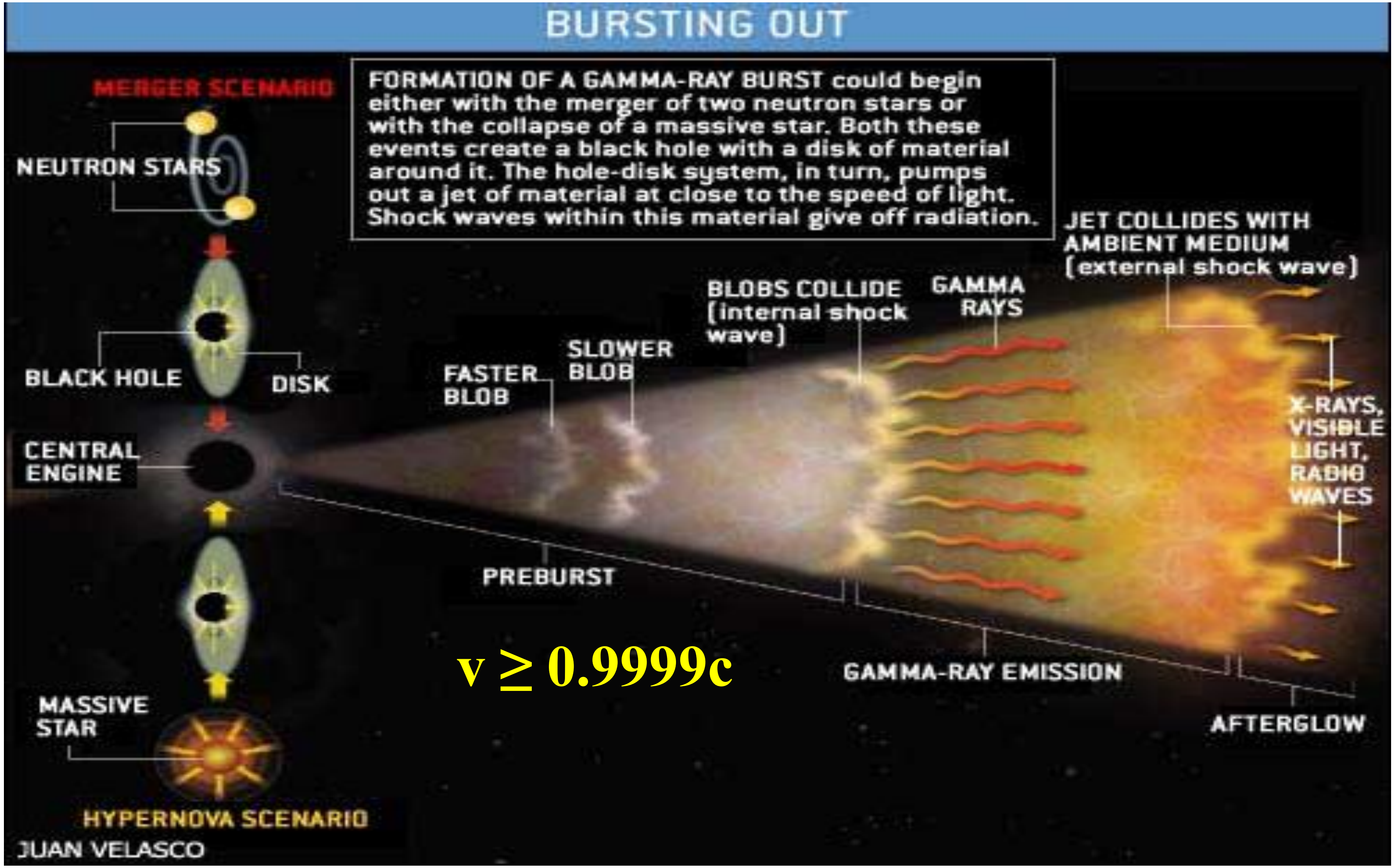
  1. picture of GRB
  2. Polarization models for GRB
  3. magnetic field configuration and central engine

- X-ray observations in GRBs and its polarization

  1. X-ray flares
  2. X-ray plateau

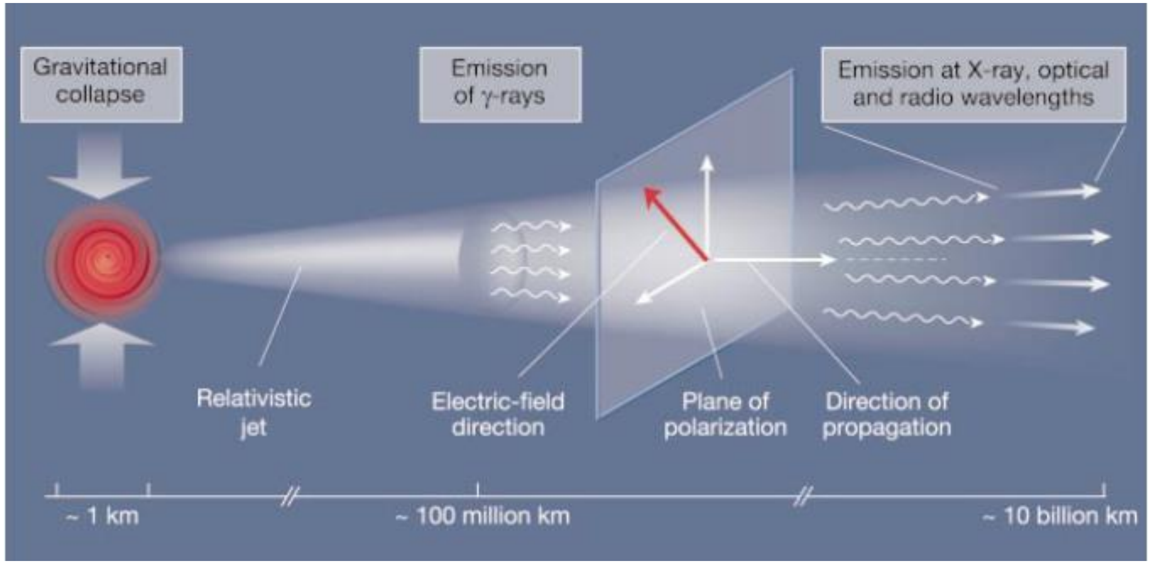
- Summary

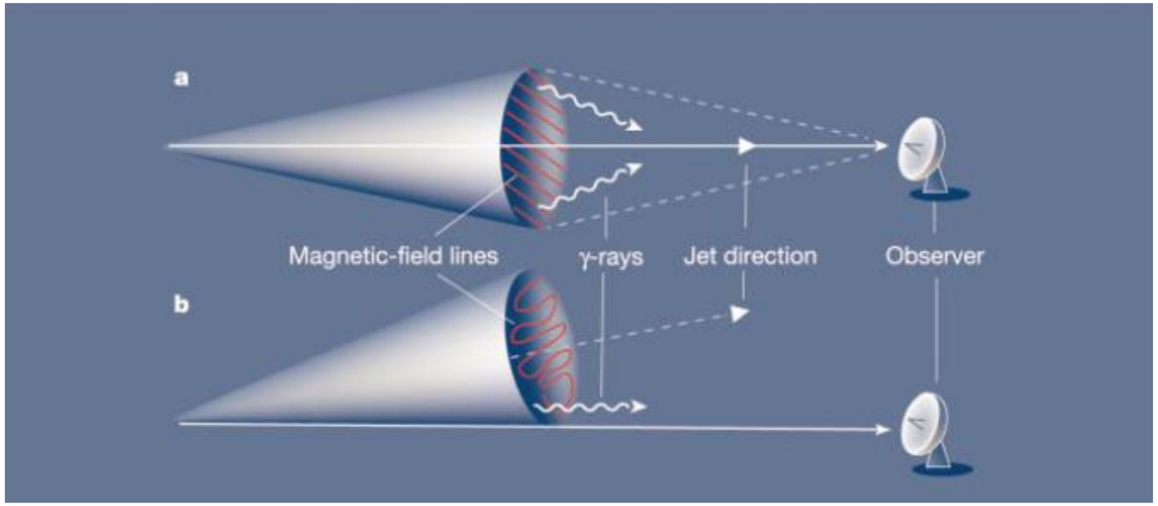
# Physical Picture of Gamma-Ray Bursts




Gehrels et al., 2002, Scientific American

# Models on GRB polarization




Waxman, 2003, Nature, **423**, 388

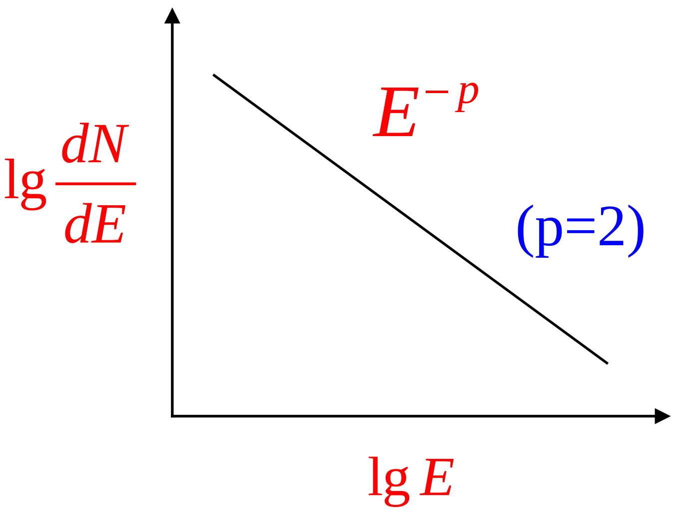
Nonthermal emission:

- synchrotron
- (inverse-) Compton

large-scale B and syn:

$P_L=(p+1)/(p+7/3)\sim70\%$

Shock accelerated electrons




Large-scale B-field may exist in

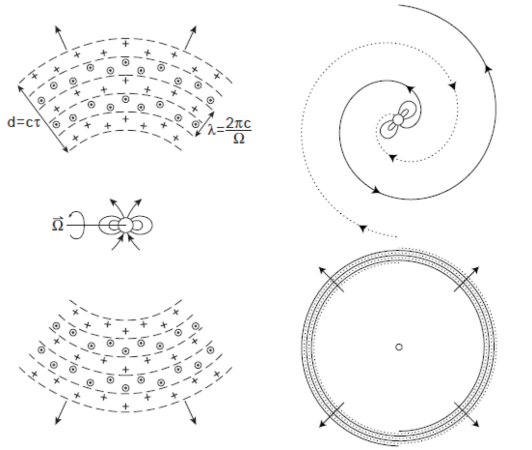
(1) Prompt GRB emission;

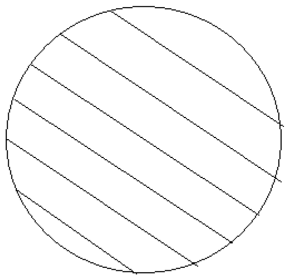
(2) Early afterglows (reverse shock)

(3) X-ray flares

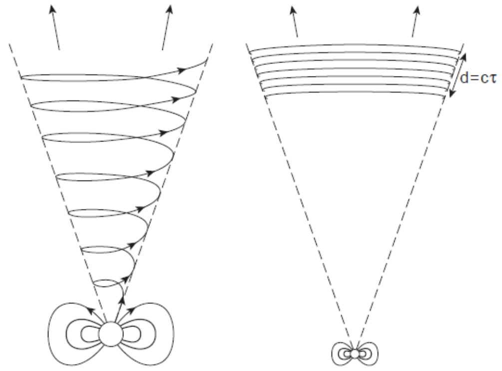
(4) X-ray plateaus

# Magnetic field configurations and Corresponding central engines

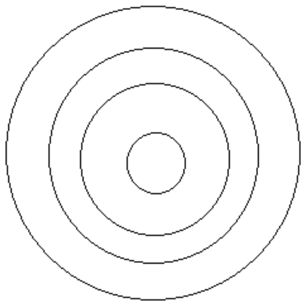


magnetar



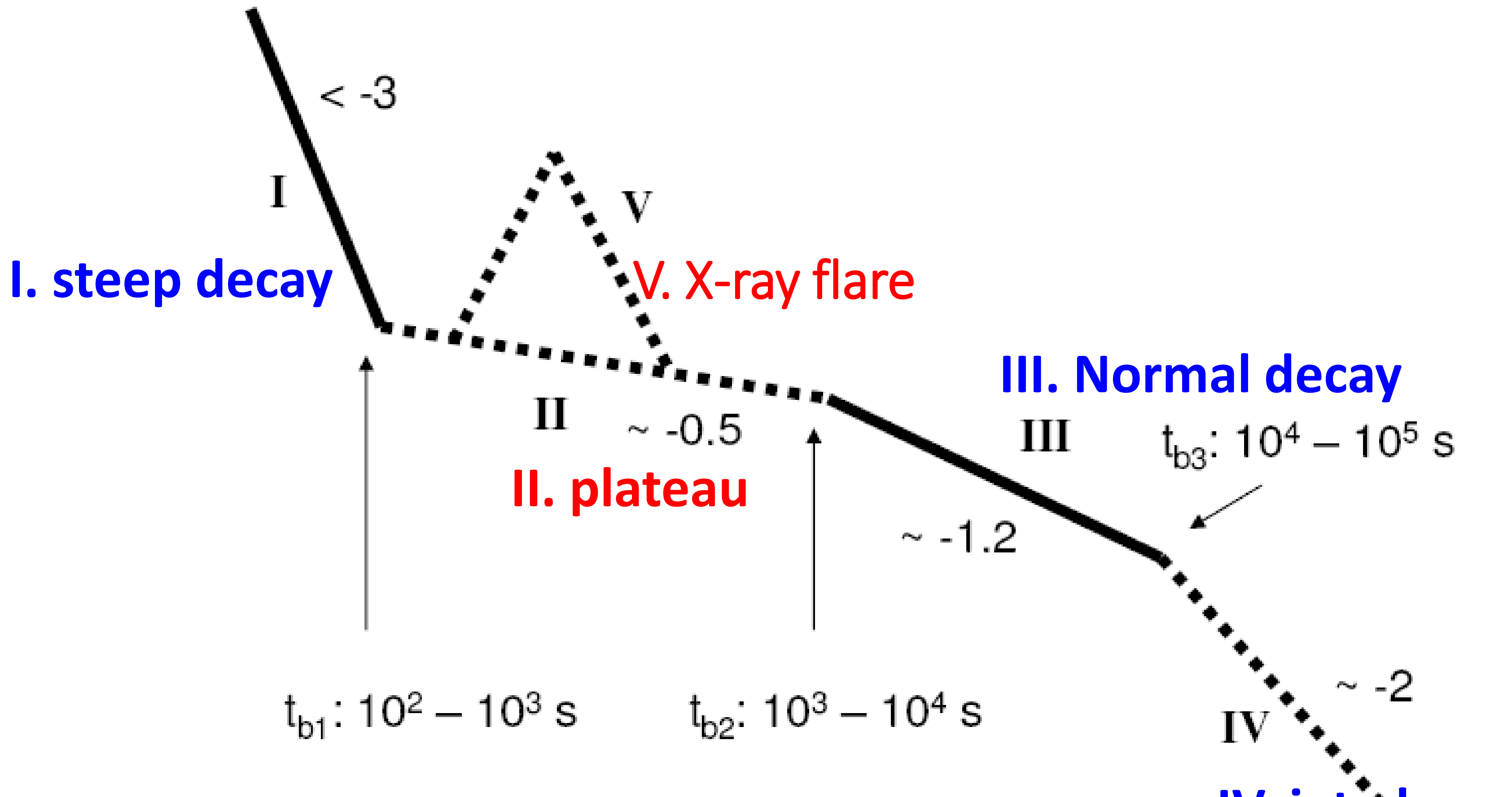

Spruit et al. 2001



Black hole

# Swift Canonical X-ray lightcurve

X-ray polarimeter – a new era for GRBs !




Zhang, Fan, Dyks et al. 2006, ApJ, 642, 354

# Outline

- Introduction
  1. picture of GRB
  2. Polarization models for GRB
  3. magnetic field configuration and central engine

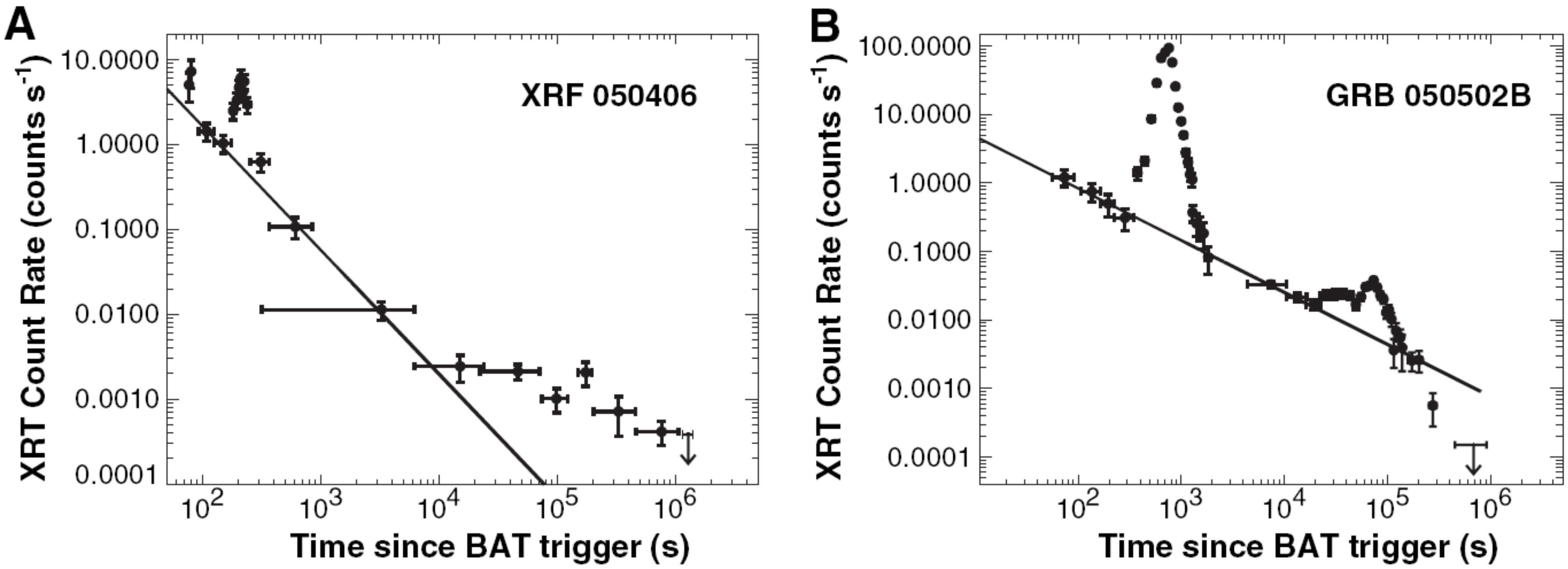
- X-ray observations in GRBs and its polarization
  1. X-ray flares
  2. X-ray plateau

- Summary

# X-ray flares

fast rise + steep decay

Burrows et al. 2005, Science, 309, 1833

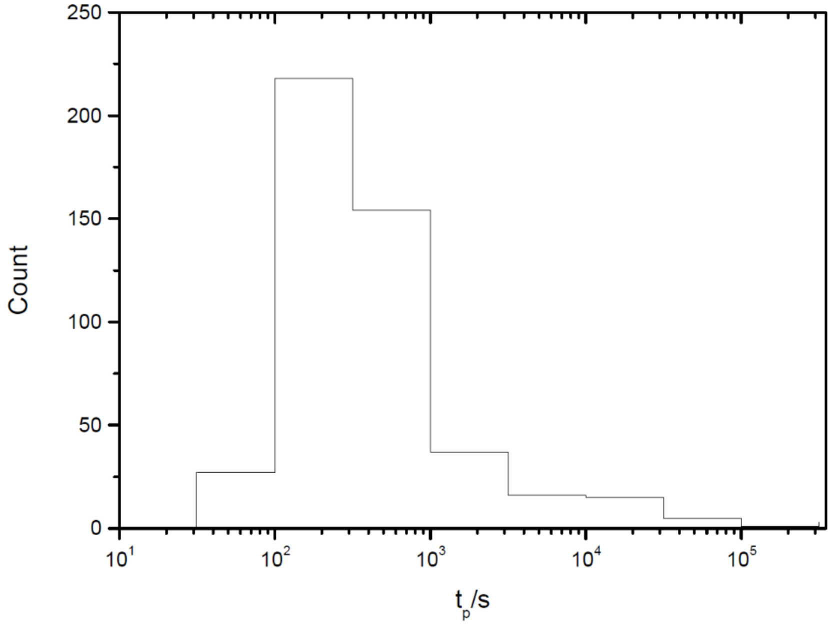



**Explanation:** late internal shocks (Burrows et al. 2005; Fan & Wei 2005; Zhang et al. 2006; Wu, Dai, Wang et al. 2005),

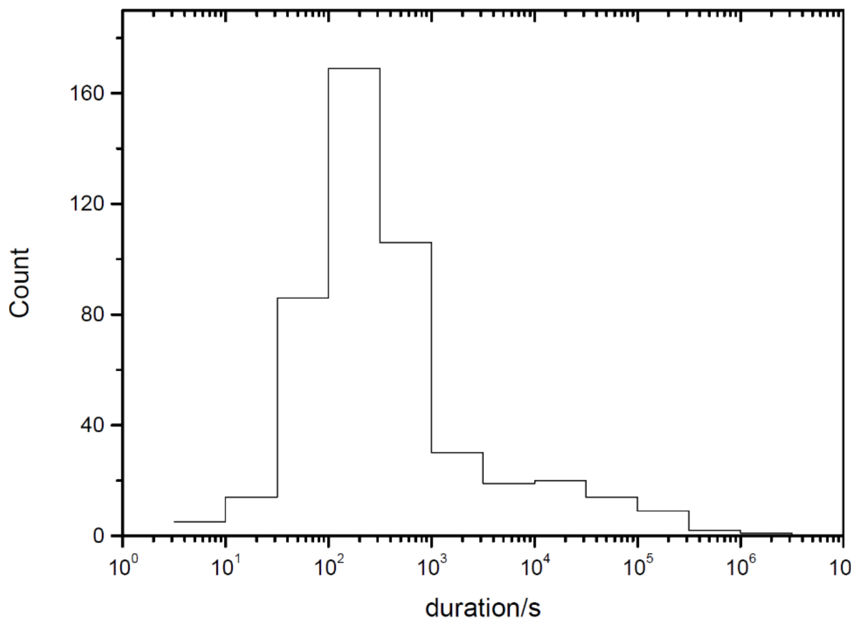
implying a long-lasting central engine.

# X-ray flare sample

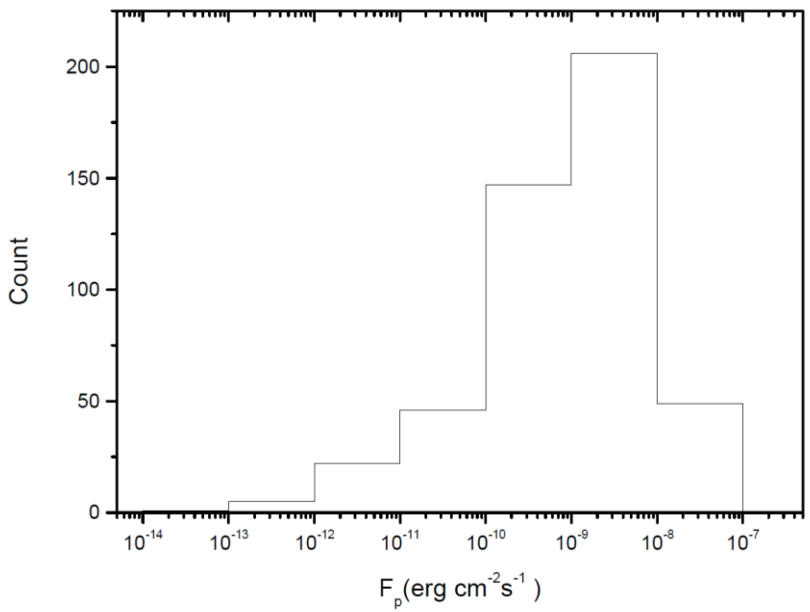
Swift XRT observations (May 1 2005 – April 30 2015)
476 flares in 201 GRBs (1/5 Swift triggered GRBs in 10 years)




Peak time centered at ~300 s

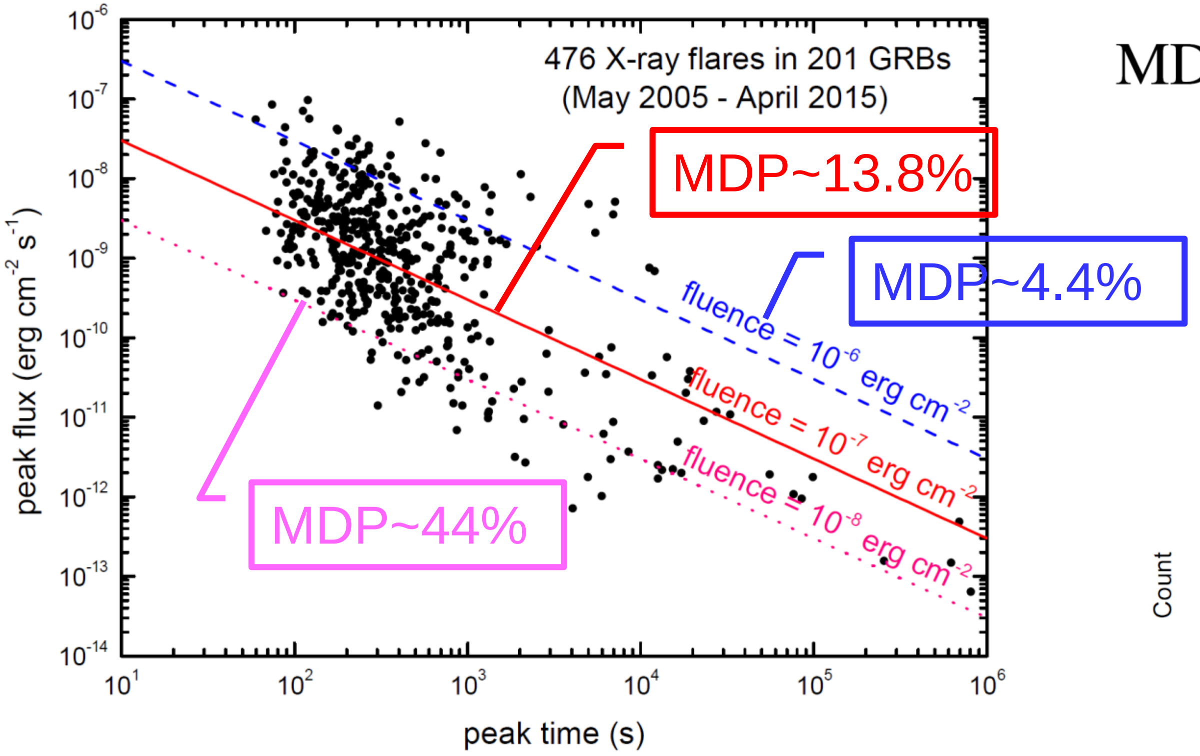



duration time centered at ~300 s




Peak flux centered at ~3e-9 erg/cm^2/s

# fluence distribution of X-ray flares



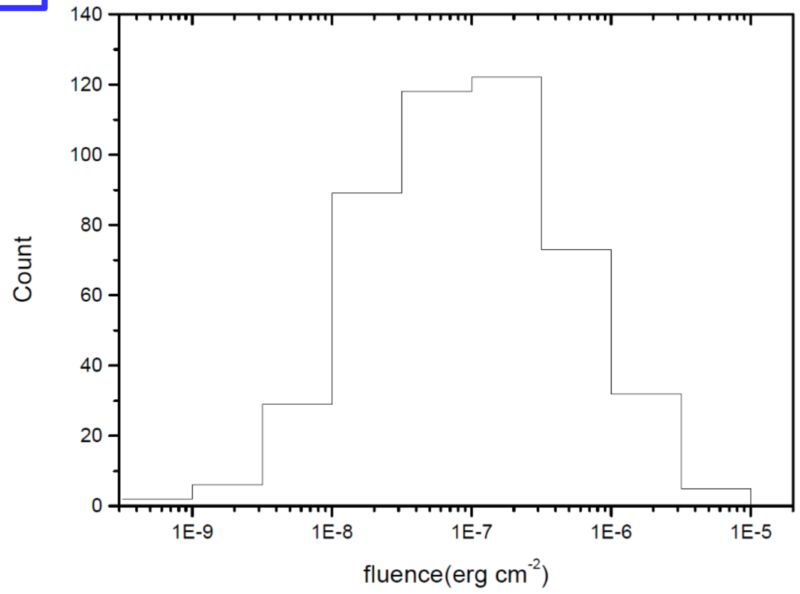

XTP can do polarization detection for bright X-ray flares if it slews to the GRB within ~1 ks after the trigger!

Minimum Detectable Polarization:

$$\mathrm{MDP} = \frac{4.29}{\mu R_s}\sqrt{\frac{R_s + R_b}{t}}$$

**~ (fluence*S) ^-0.5**

**S=200 cm^2**




fluence ~ Fp*Tp/3

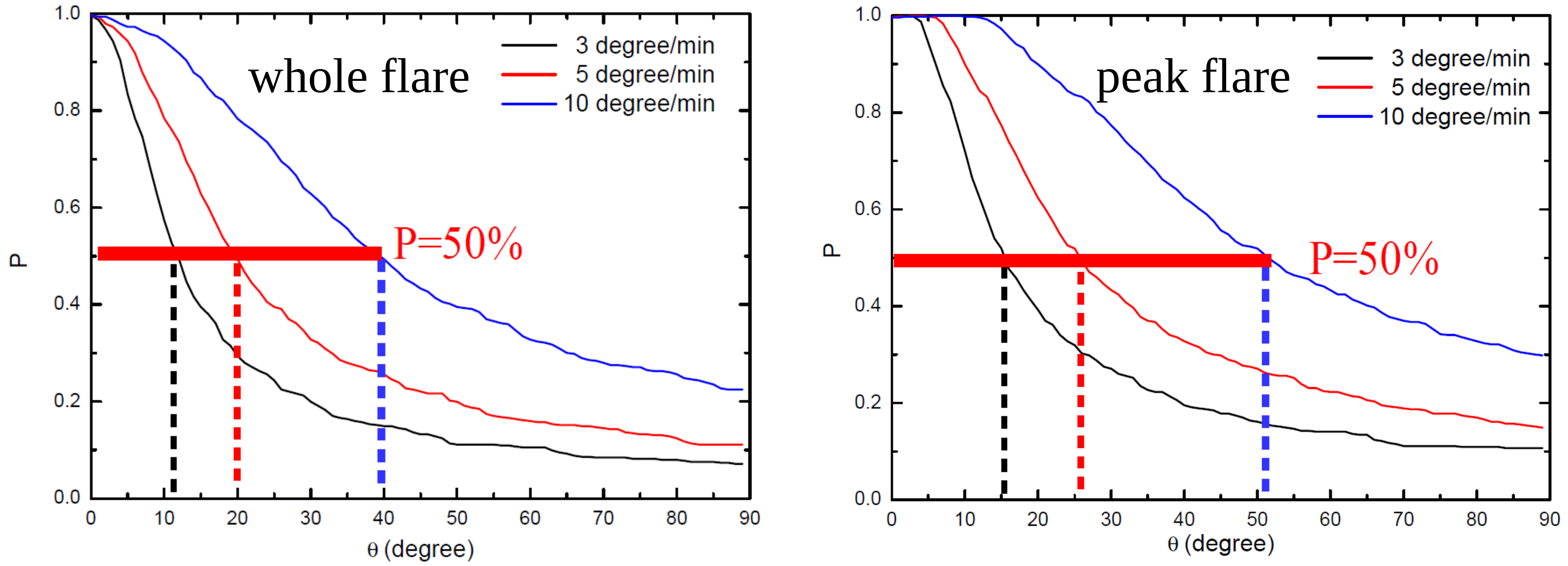
peaked at 1e-7 erg/cm^2

# X-ray flare sample: expected eXTP detection possibility

Swift XRT observations (May 1 2005 – April 30 2015)
476 flares in 201 GRBs (1/5 Swift triggered GRBs in 10 years)

Assume

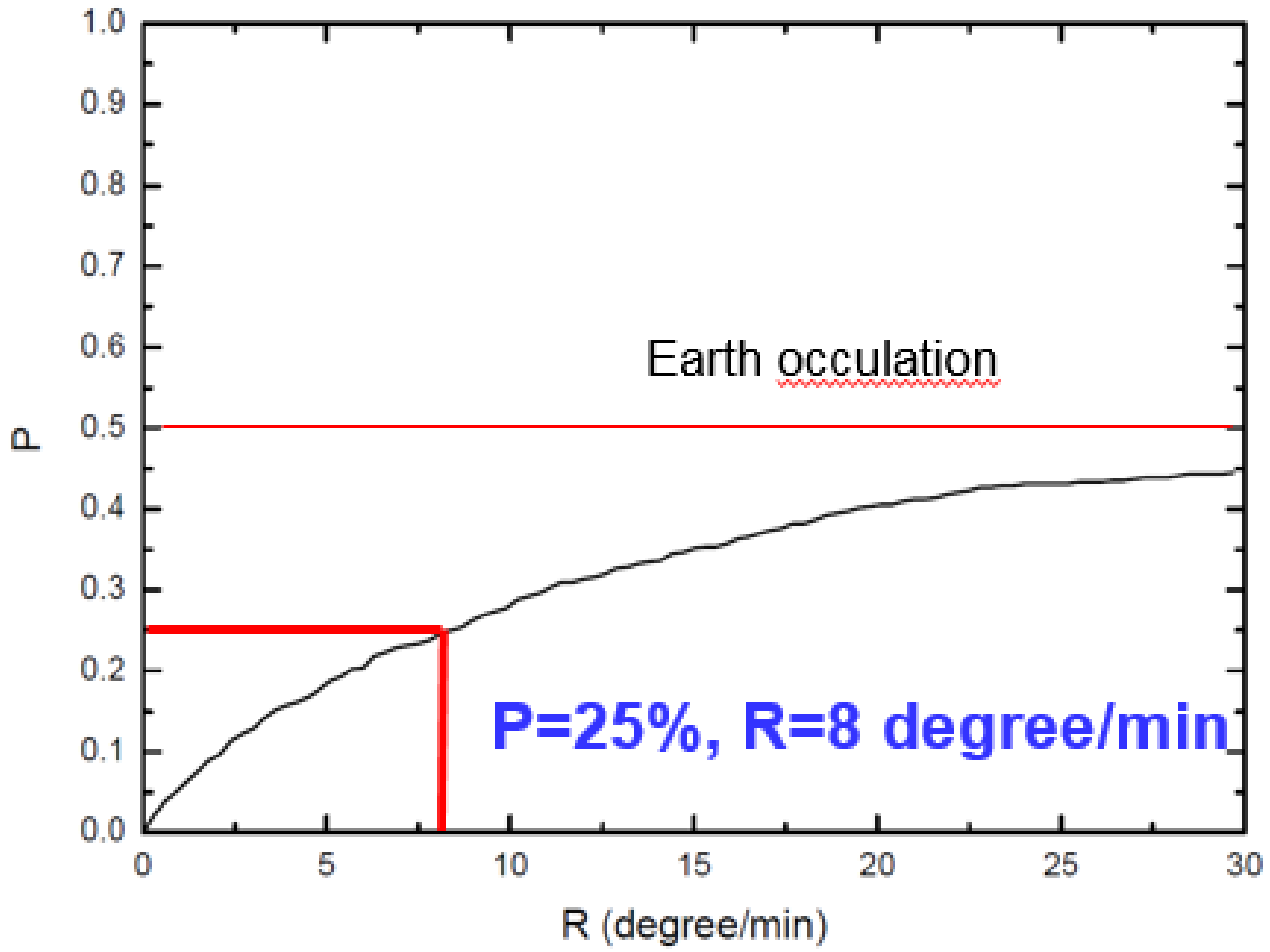
(1) XTP flux sensitivity = 4.4e-15 (t/10^4 s)^(-1/2) erg/cm^2/s
(2) XTP slewing speed = (3 – 10) degrees per minute




(angle between the GRB and XTP boresight)

# X-ray flare sample: expected eXTP detection possibility

Swift XRT observations (May 1 2005 – April 30 2015)
476 flares in 201 GRBs (1/5 Swift triggered GRBs in 10 years)



# Outline

- Introduction

  1. picture of GRB

  2. Polarization models for GRB

  3. magnetic field configuration and central engine

- X-ray observations in GRBs and its polarization

  1. X-ray flares

  2. X-ray plateau

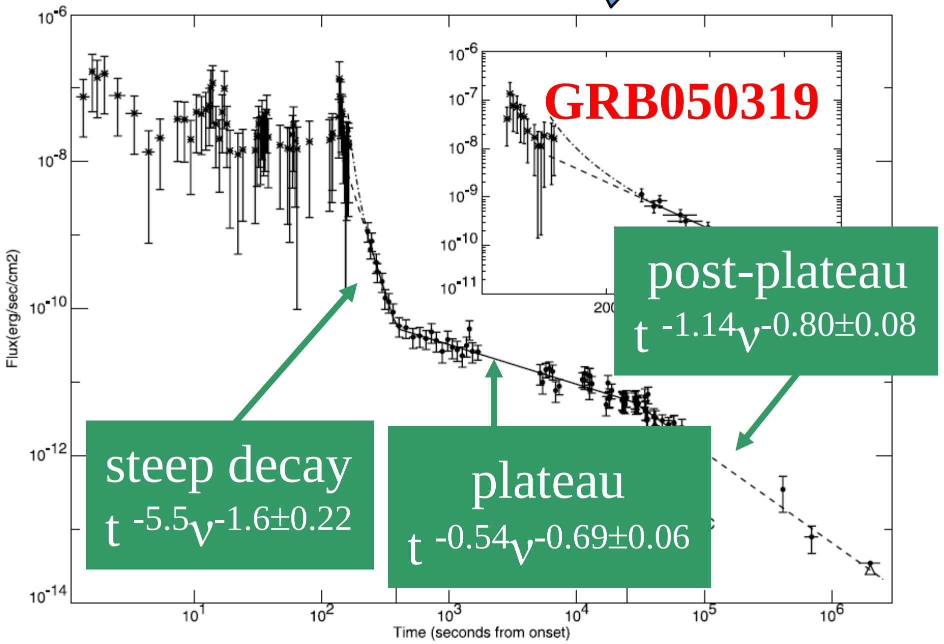
- Summary

# X-ray Plateaus

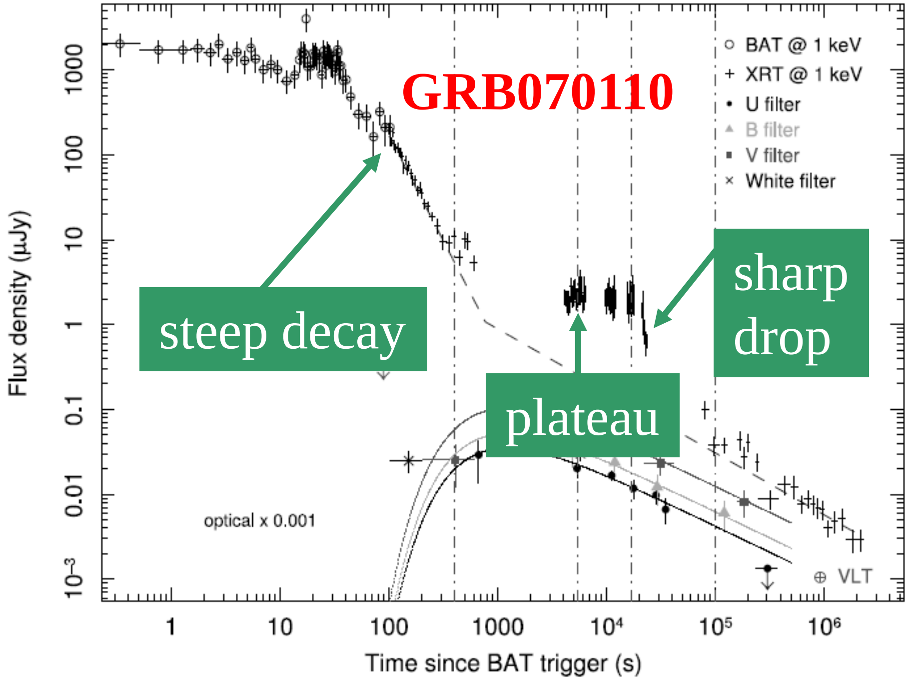
## - Swift discovery and hydrodynamic origin

external plateau by energy injection:
matter-dominated？ -> low poln
Poynting flux – domianted ？ -> high poln

Internal plateau
magnetic dissipative process？ -> high poln



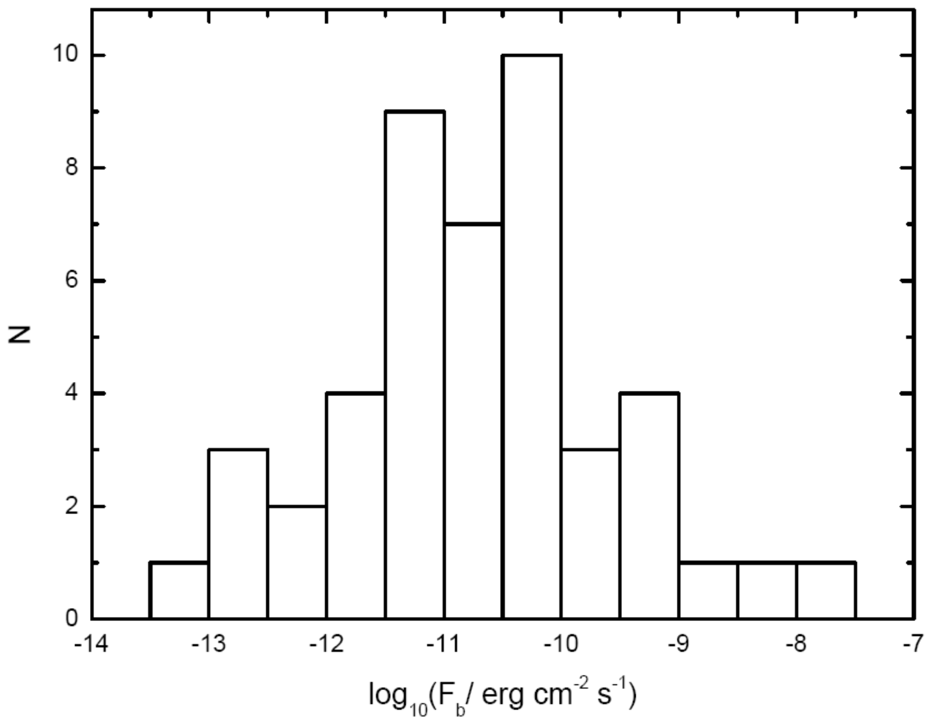

Cusumano et al., 2006, ApJ, 639, 316



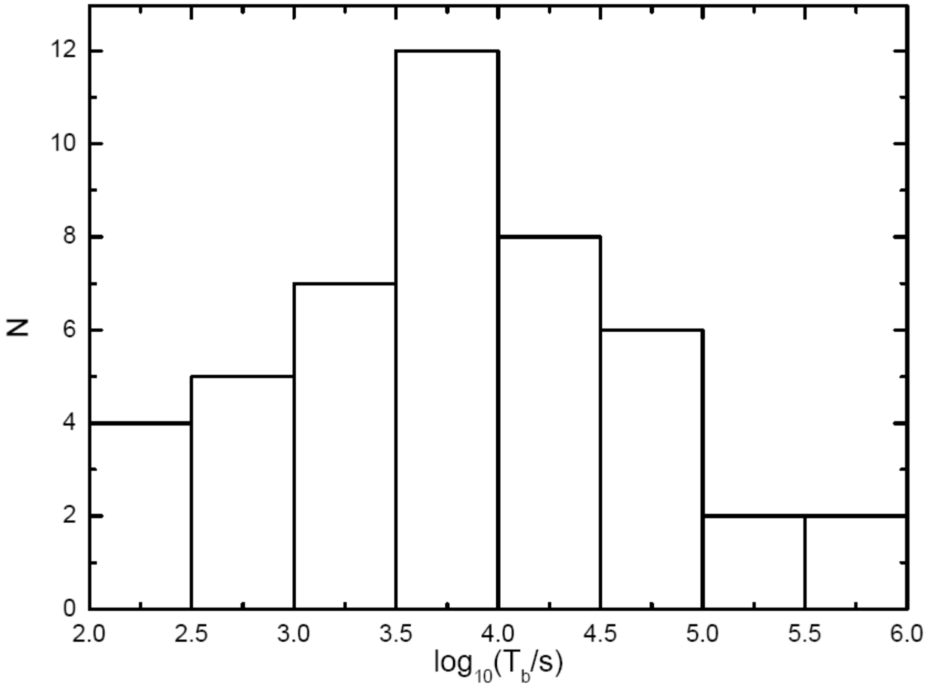

Troja et al., 2007, ApJ, 665, 599

# X-ray plateau sample

Swift XRT observations (March 2005 - October 2010)
46 X-ray plateaus (1/10 Swift triggered GRBs in 5 years)

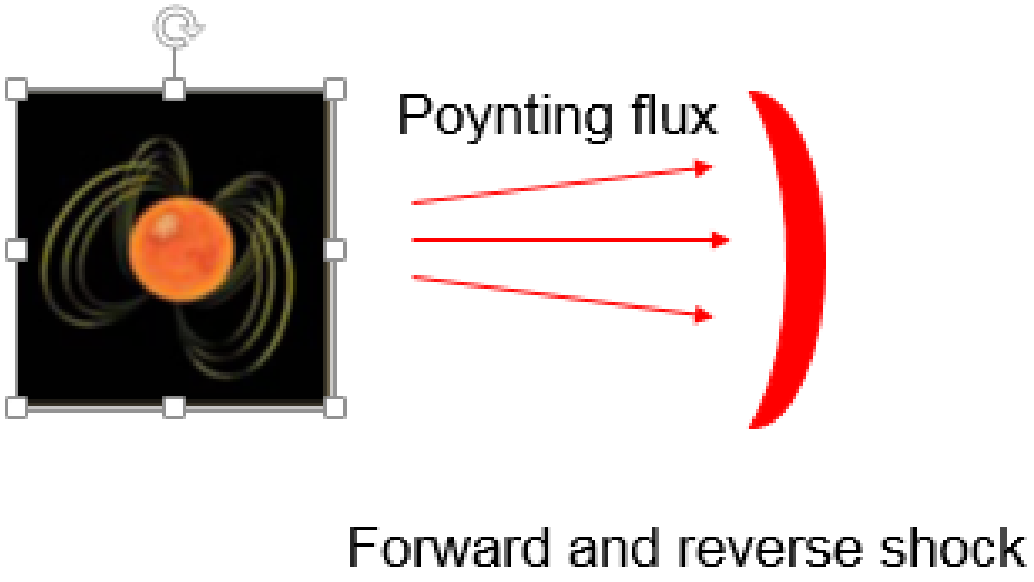



flux centered at 1e-11 erg/cm^2/s

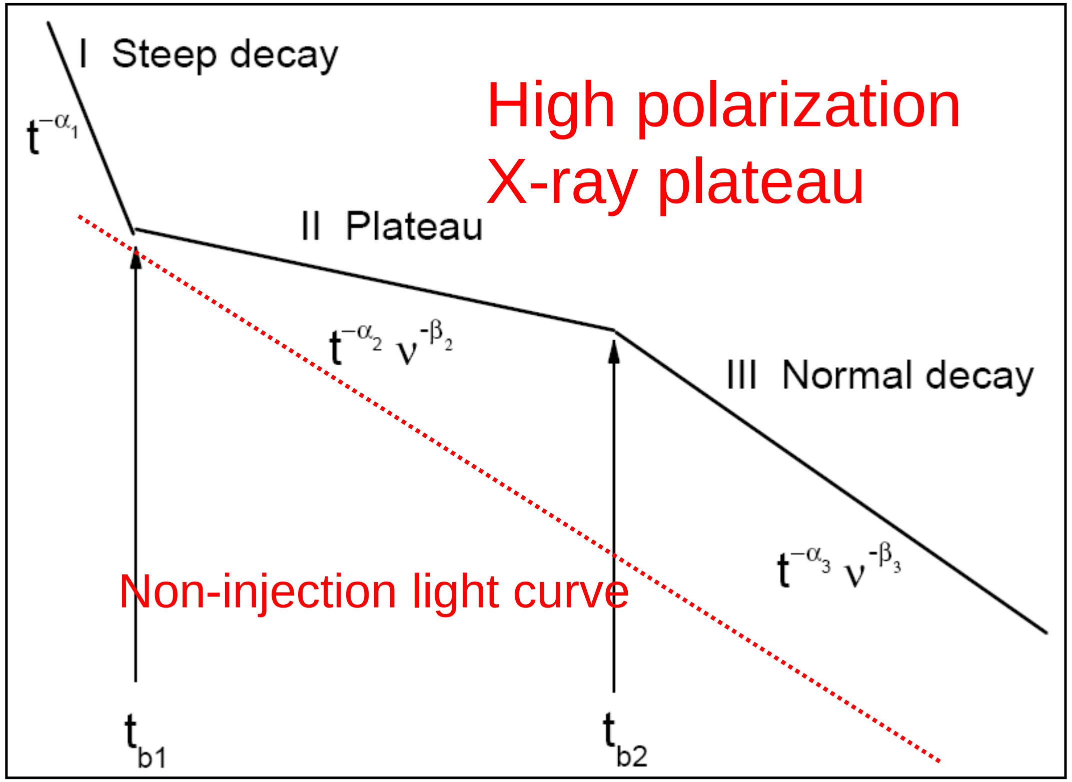



duration ~ 1 – 100 ks, typically ~10 ks

# RWB model with the Poynting flux injection

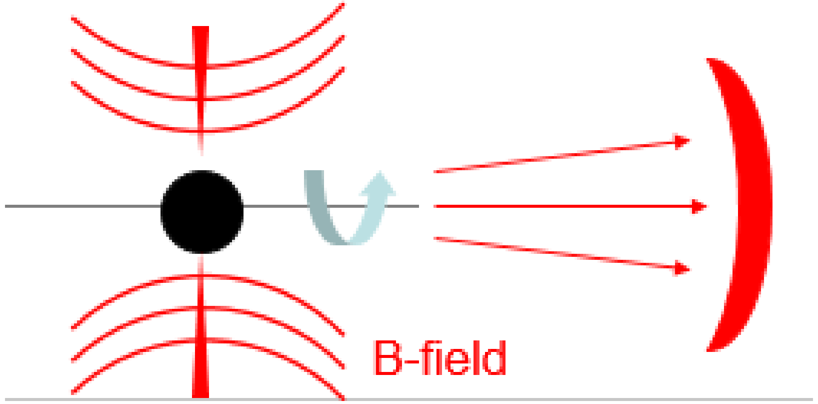



Magnetar

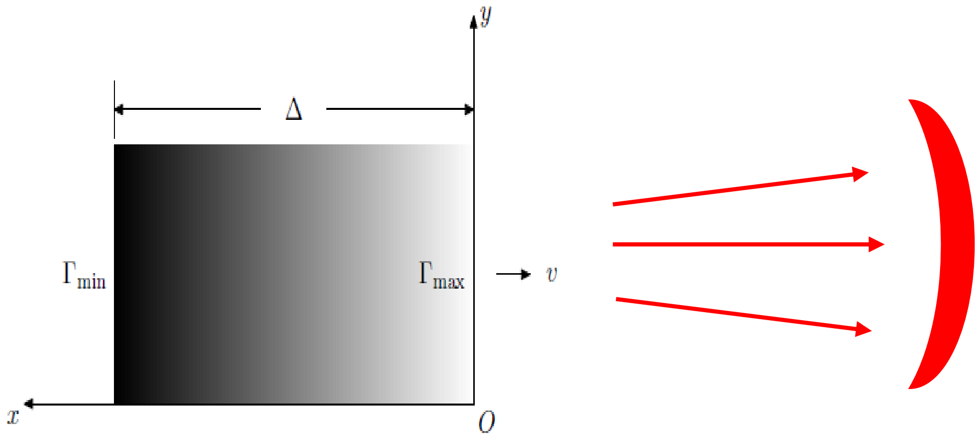


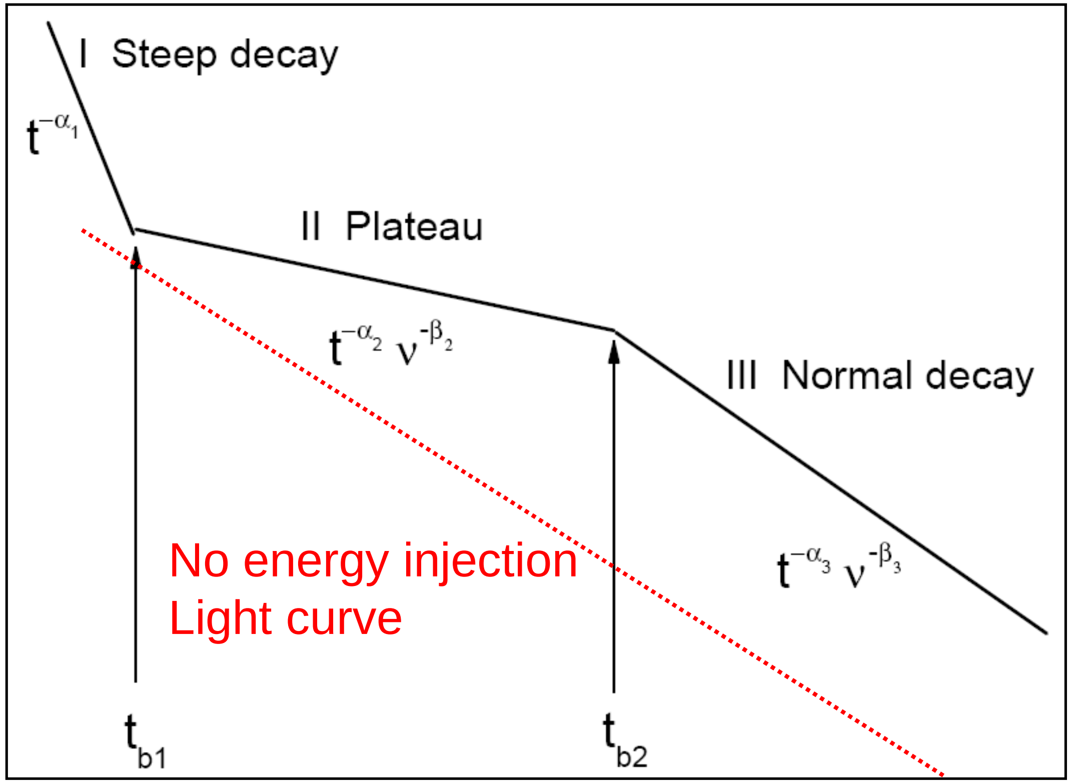

Dai & Lu 1998

# Structured ejecta model




Black hole

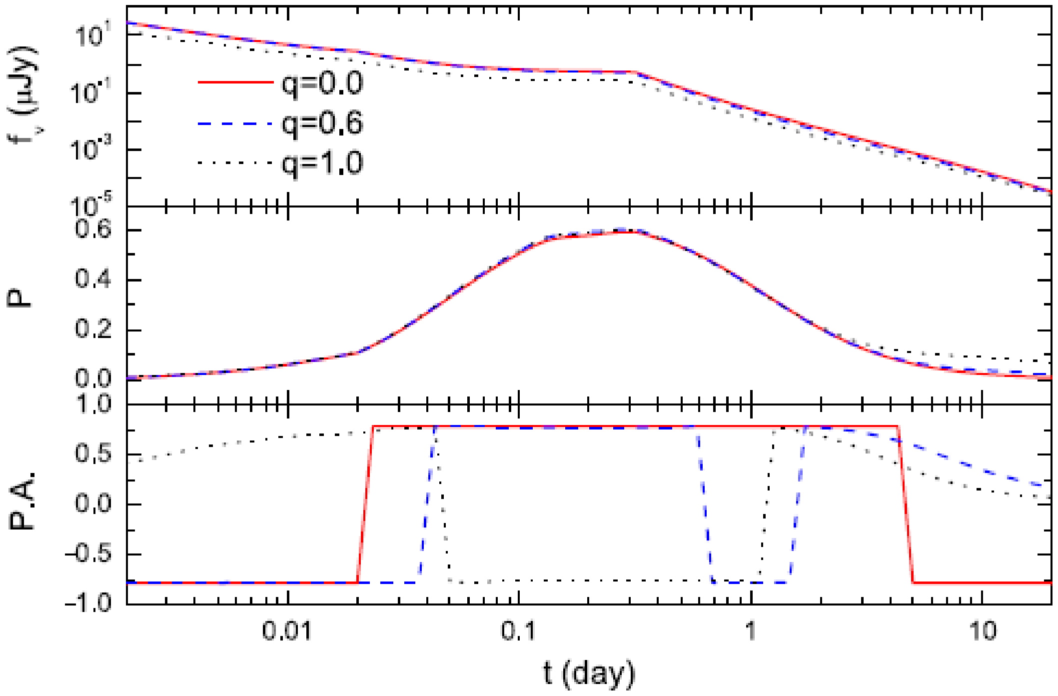


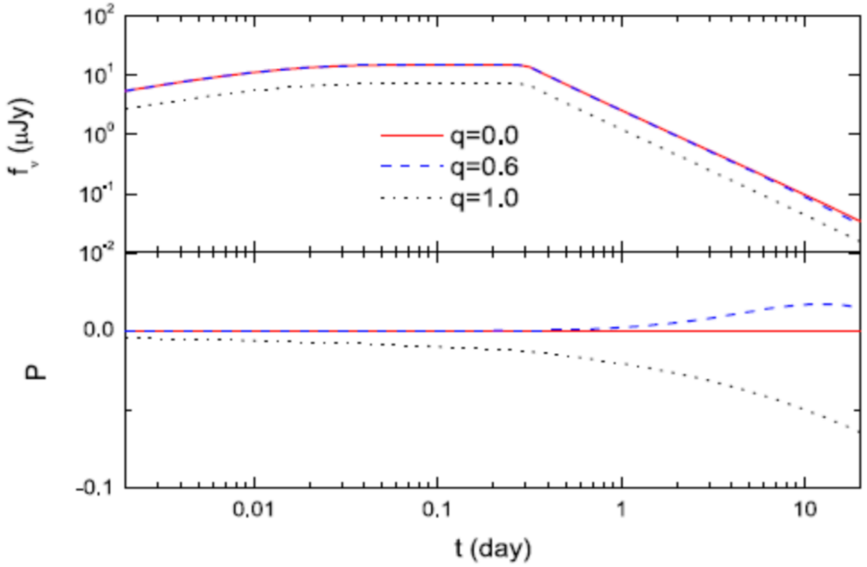

Lorentz factor distribution (Rees & Meszaros 1992):

$$M \propto \Gamma^{-s}$$

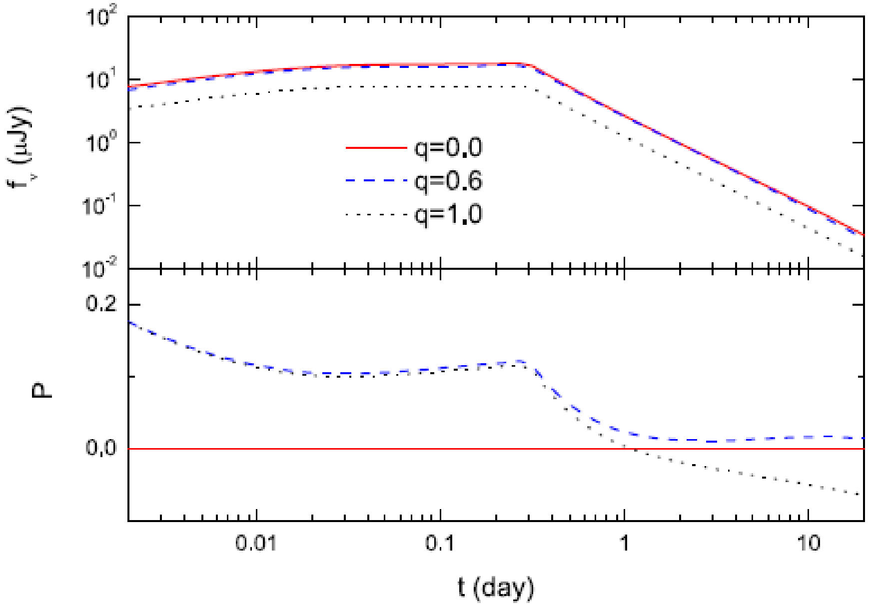
# Testing models using polarization in the X-ray plateau phase




RWB model in 2 keV




random




toroidal

Structured ejecta model in 2 keV

Lan, Wu & Dai 2016 ApJ

# Outline

- Introduction

  1. picture of GRB

  2. Polarization models for GRB

  3. magnetic field configuration and central engine

- X-ray observations in GRBs and its polarization

  1. X-ray flares

  2. X-ray plateau

- Summary

# GRB Afterglows with eXTP: Summary

- **Polarization of GRB X-ray emission**

  **most GRBs have X-ray flares or plateaus**

  **large-scale B-field & physical origins**

  **magnetic field configuration & central engine**

# Input of X-ray flare simulation

(reference to Toma et al. 2009, ApJ )

1. **GRB rate (redshift distribution)**

$$\dot{\rho}_{\mathrm{GRB}}(z) = k_{\mathrm{GRB}} R_{\mathrm{SF}}(z) f(z)$$

2. **GRB jet half-opening angle distribution**

$$f(\theta_j)d\theta_j \propto \begin{cases} \theta_j^{q_1} d\theta_j, & \text{for } 0.001 \leqslant \theta_j \leqslant 0.02, \\ \theta_j^{q_2} d\theta_j, & \text{for } 0.02 \leqslant \theta_j \leqslant 0.2, \end{cases}$$

3. **X-ray flare energies (analogue to Frail relation)**

$$E_{\mathrm{iso}} \theta_j^2 / 2 = 10^{50} \xi_1 \ \mathrm{erg}$$

$$\Pi_0 = \Pi_0^{syn} \equiv \begin{cases} (\alpha+1)/(\alpha+\frac{5}{3}), & for\ x \le \beta-\alpha \\ (\beta+1)/(\beta+\frac{5}{3}), & for\ x \ge \beta-\alpha \end{cases}$$

4. **Viewing angle distribution**

$$p(\theta_v)\, d\theta_v = \sin\theta_v\, d\theta_v$$

5. **Amati relation and Band Function**

$$E_p = 80\xi_2 (E_{\mathrm{iso}}/10^{52}\ \mathrm{erg})^{1/2}\ \mathrm{keV}$$