

# 伽玛射线暴前身星与中心机制

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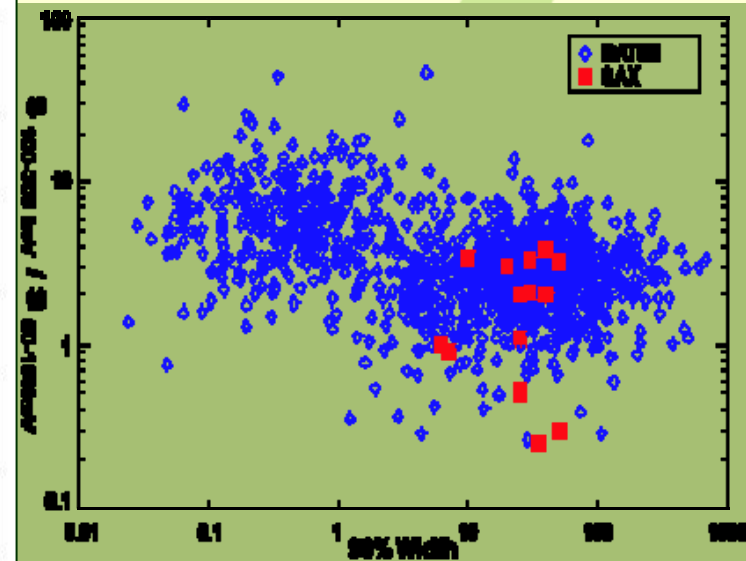
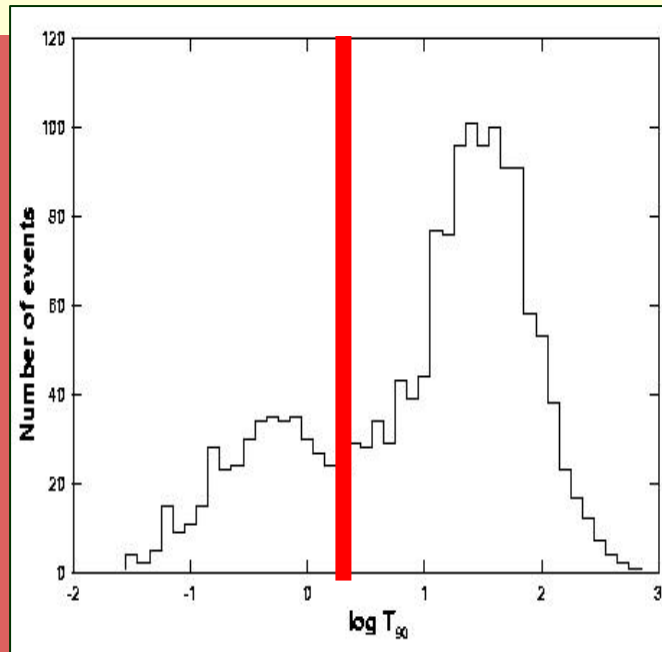
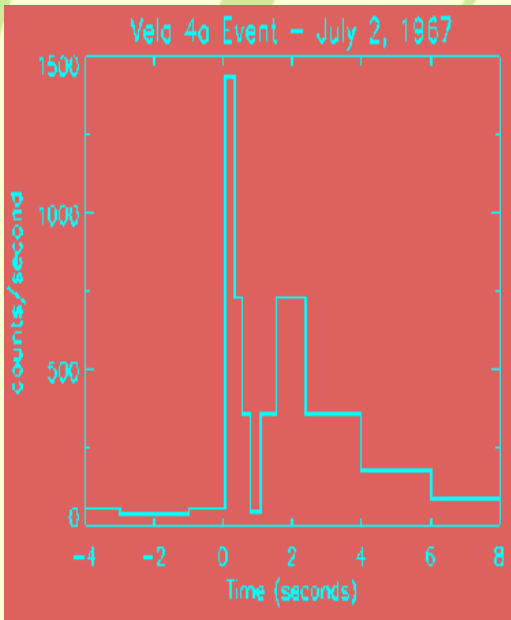


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# 伽玛射线暴 (GRB)

- 能量高  $10^{53}$  ergs
- 时变快 0.01-1000s



Kouveliotou, C., et al. 1993

# 前身星和中心机制

- 前身星

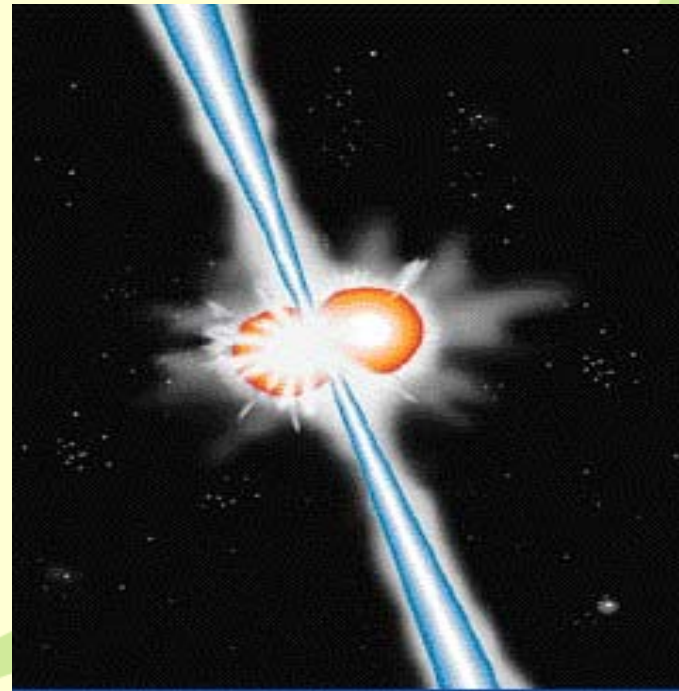
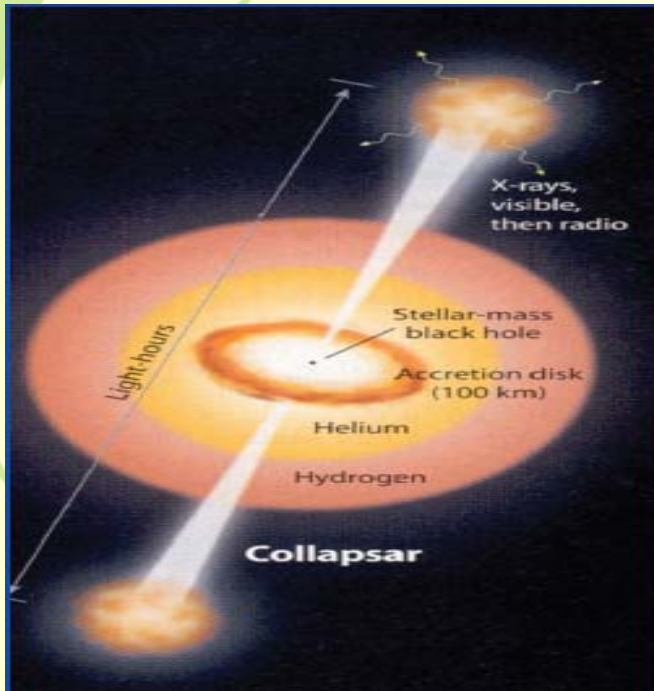
  - 长暴：塌缩 (collapsars)

  - 短暴：合并 (Mergers)

- 中心机制：一个旋转致密星驱动喷流

观测依据

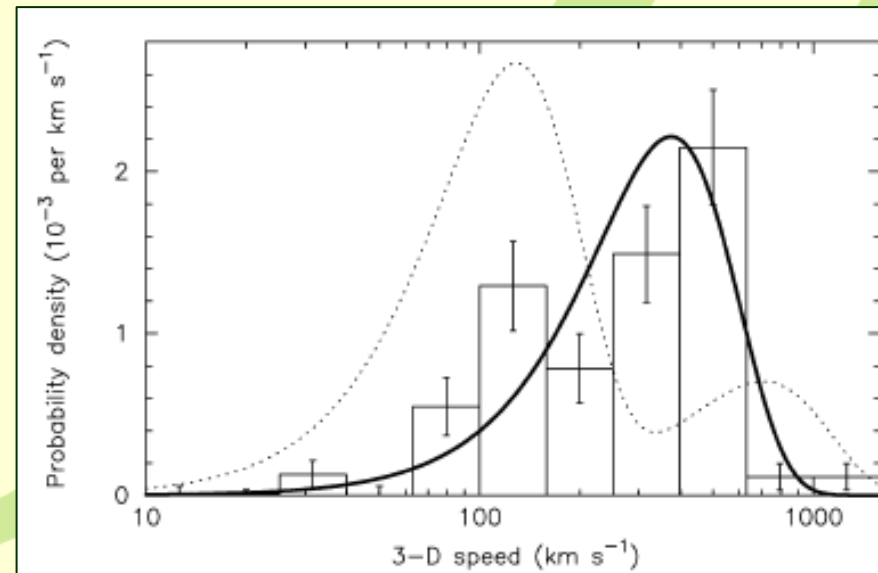
SN



不对称塌缩？

# GRB与脉冲星踢速度

- 中子星的踢速度（预言）
  - “ Any small **asymmetry** during the explosion can result in a substantial 'kick' velocity to the NS” (Lyne & Lorimer 1994)
  - Kick from the relativistic jet of compact jet (Dar & Plaga 1999)
- 脉冲星踢速度（观测）
  - Bimodel  
(Arzoumanian et al. 2003)
  - One component  
(Hobbs et al. 2005)



# 估算

$$P \sim 10^{50} / c \sim 10^{30} \text{ g cm/s};$$

$$v \sim P / 1M_{\text{sun}} \sim 10^7 \text{ cm/s} = 100 \text{ km/s}$$

# 数据

- 137 pulsar kick velocity ( $V = \mu_{\text{tot}} D$ )
- 66 GRBs with known redshifts and fluence

# GRB 模型

- $E_{\text{iso}} = E_{\gamma} (1 - \cos \theta),$   
 $\theta_{\text{max}} = 25 \text{ degrees (GGL04)}$

- The calculation of total energy :

$$E_{\text{iso}} = \frac{4\pi D_L^2 k S_{\gamma}}{1+z}$$

- The 2D velocity in celestial sphere

$$V_{2D} = V_{3D} \sin \phi$$

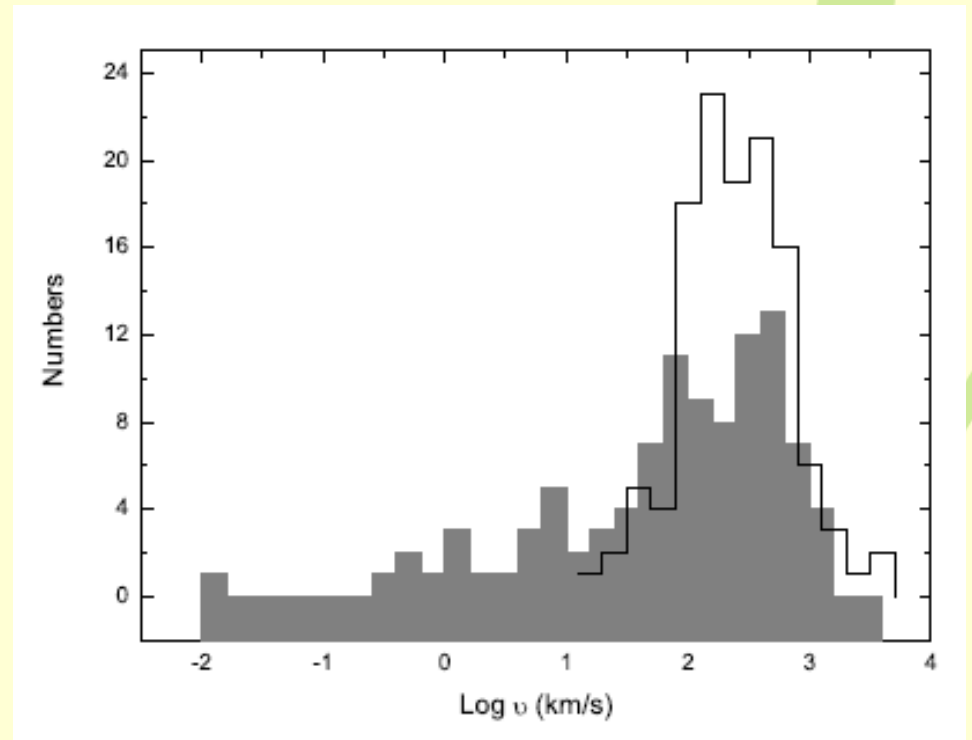
$\phi$  : randomly select in celestial sphere



# 结果

- GRBs (66) with known redshifts and fluences
- PSR (137)

$P_{\text{ks}}=0.36$  with  $p=0.14$



# 小结

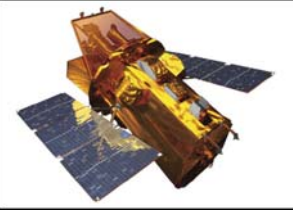
- 同一母体分布
- GRB非对称塌缩为脉冲星踢速度的一个来源

# 讨论

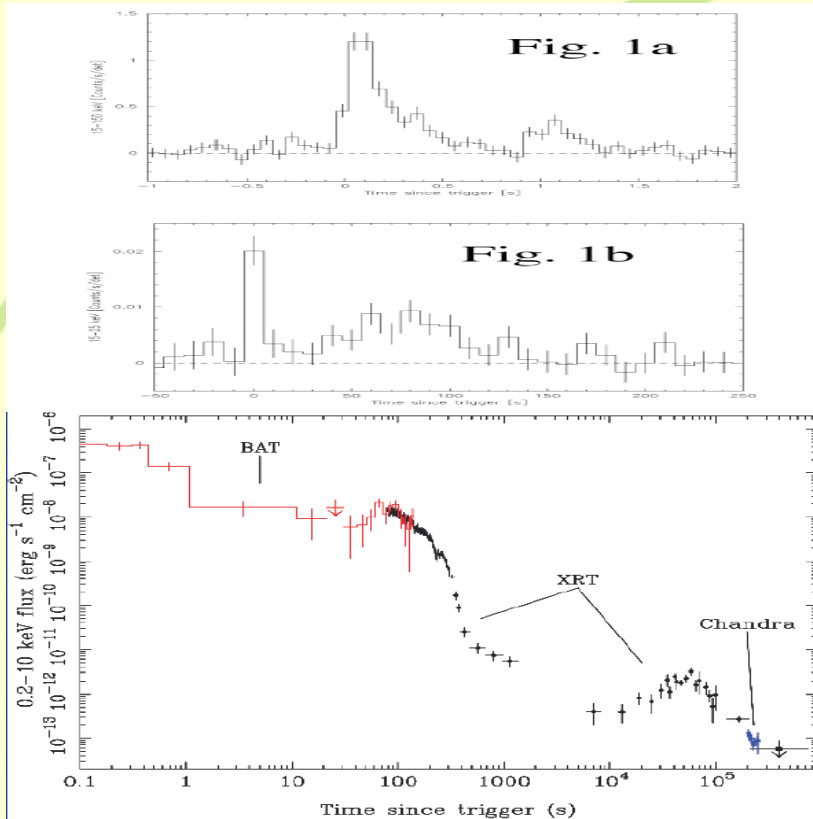
$P_{KS}$

Sample	<i>MSP14</i>	<i>NP107</i>	<i>Young44</i>	<i>old73</i>
<i>GRB66</i>	0.33 (0.43)	0.38 (0.15)	0.13 (0.89)	0.24 (0.69)

结果不随脉冲星周期和年龄而变 (Hansen & Phinney 1997), 这说明 GRB 与脉冲星或许就是本质一样



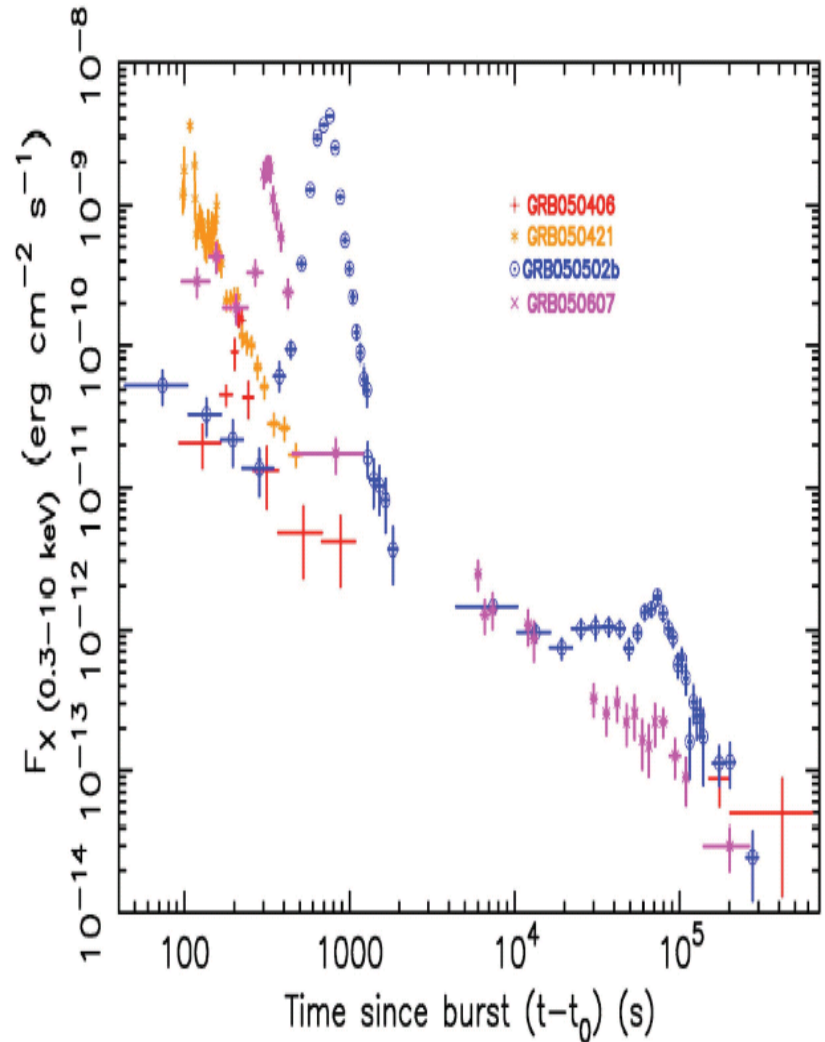
# Swift



Short GRB 050724  
EE+flares

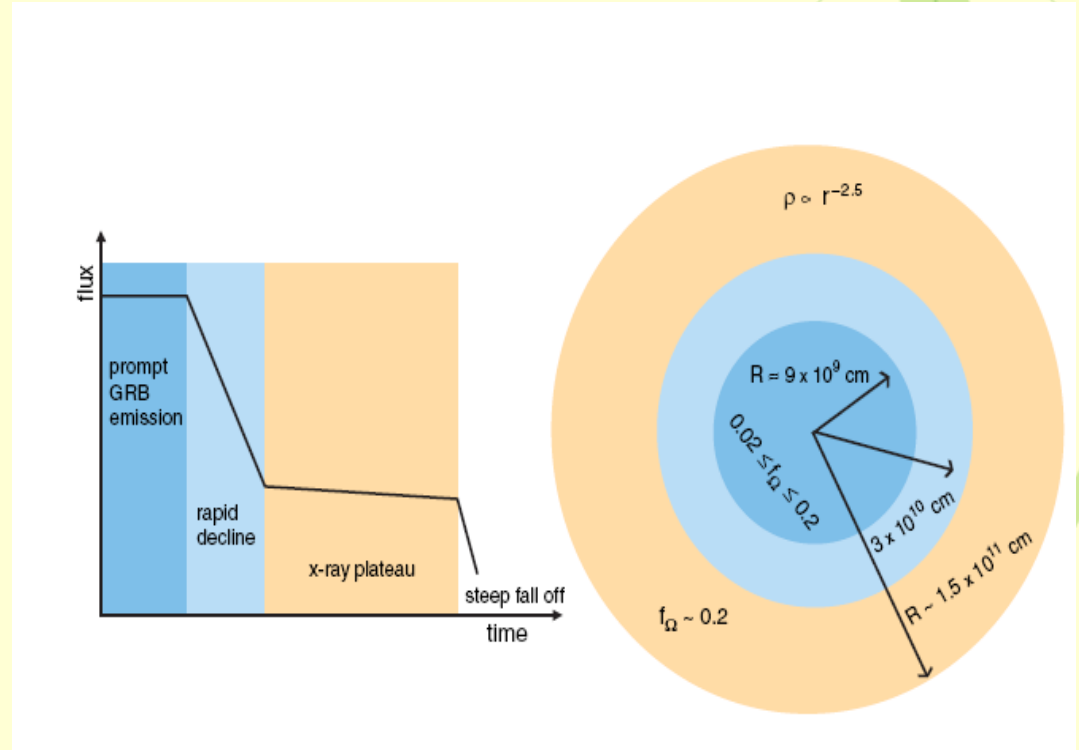
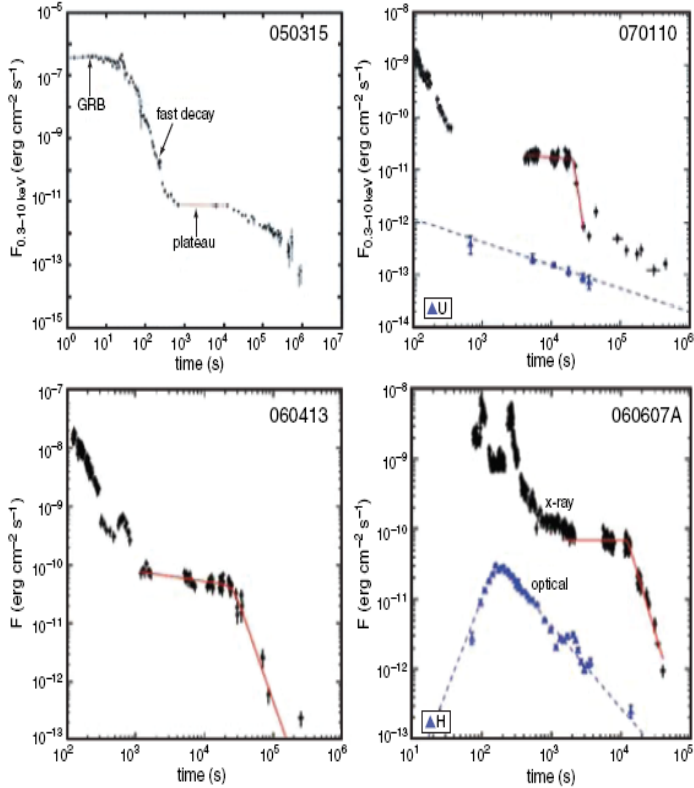
Barthelmy et al. 2005, nature

## X-ray Flares



Nosek et al. 2006

# 塌缩模型



Liang et al. 2007

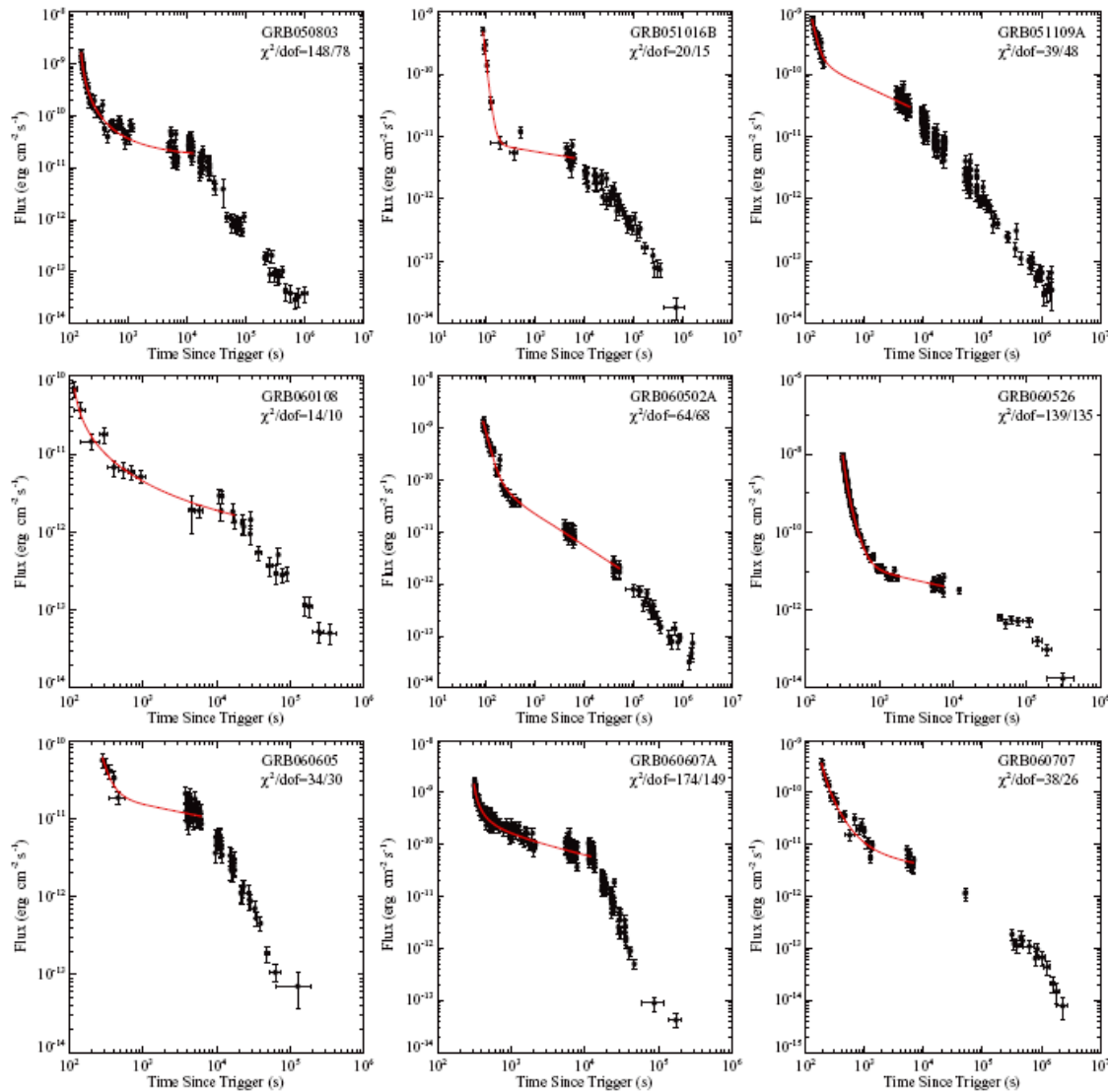
Kumar, P., Narayan, R. & Johnson, J  
 Sci, 2008, 321, 376  
 MNRAS, 2008, 388, 1729

# 基本想法

- X-ray data → 前身星参数和性质 (core, envelope,  $M^*$ ,  $R^*$ )
- 数据:  $z$ , with steep decay and shallow decay
- 参数分布
- 与爆发期间参数的关系

# 光变曲线拟合

$$F = F_0 \left[ \left( \frac{t - t_1}{t_1} \right)^{-\alpha_1} + \left( \frac{t_2 - t_1}{t_1} \right)^{-\alpha_1} \times \left( \frac{t}{t_2} \right)^{-\alpha_2} \right]$$

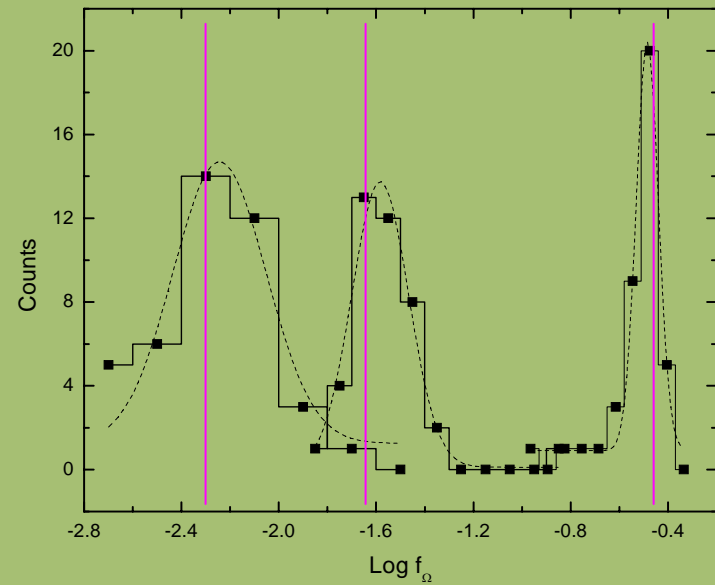
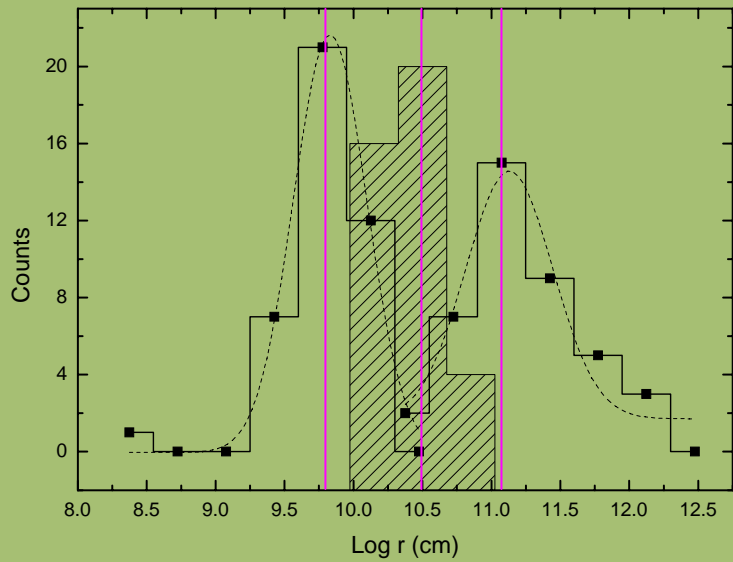


GRB	$S_x^a$ ( $10^{-7}$ erg $\text{cm}^{-2}$ )	$\Gamma_x^b$	$t_1^c$ (s)	$t_2^d$ (s)	$t_3$ (ks)	$\alpha_2^e$	$E_{\text{iso},X}$ ( $10^{50}$ erg)	$L_{X,t_2}$ ( $10^{47}$ erg $\text{s}^{-1}$ )
050416A	$0.62 \pm 0.38$	2.15	$\sim 79$	$\sim 87$	1.74	0.70	$0.7 \pm 0.4$	3.7
050803	$5.96 \pm 0.51$	1.88	$104 \pm 5$	$263 \pm 11$	13.71	0.36	$2.6 \pm 0.2$	0.8
050908	$0.13 \pm 0.11$	3.90	$120 \pm 50$	$684 \pm 82$	8.00	1.01	$2.9 \pm 2.4$	1.4
051016B	$2.18 \pm 1.10$	2.82	$50 \pm 5$	$157 \pm 12$	6.64	0.14	$4.9 \pm 2.5$	0.6
051109A	$3.46 \pm 0.75$	2.33	$62 \pm 23$	$173 \pm 33$	7.30	0.42	$42.9 \pm 9.3$	109.3
060108	$0.53 \pm 0.17$	1.91	$40 \pm 30$	$186 \pm 31$	22.08	0.39	$5.1 \pm 1.6$	5.4
060210	$4.86 \pm 0.69$	1.93	$298 \pm 8$	$452 \pm 11$	7.00	0.80	$141.0 \pm 20.0$	721.2
060418	$1.38 \pm 0.66$	2.04	$81 \pm 2$	$309 \pm 4$	1.00	$\sim 0$	$7.6 \pm 3.6$	51.6
060502A	$5.09 \pm 1.19$	2.43	$12 \pm 6$	$190 \pm 13$	72.57	0.59	$28.6 \pm 6.7$	16.9
060510B	$0.28 \pm 0.27$	1.42	$310 \pm 2$	$\sim 3205$	170.00	$\sim 0$	$11.4 \pm 10.9$	0.7
060522	$0.12 \pm 0.20$	1.97	$117 \pm 15$	$248 \pm 16$	0.73	$\sim 0$	$5.2 \pm 8.6$	114.7
060526	$0.46 \pm 0.26$	1.80	$266 \pm 1$	$1023 \pm 18$	10.00	$\sim 0$	$9.6 \pm 5.4$	9.2
060605	$0.82 \pm 0.52$	1.60	$59 \pm 74$	$455 \pm 42$	7.00	$\sim 0$	$22.8 \pm 14.5$	29.3
060607A	$8.45 \pm 0.17$	1.79	$214 \pm 12$	$384 \pm 10$	12.34	0.44	$166.0 \pm 3.3$	408.0
060707	$0.55 \pm 0.26$	2.00	$56 \pm 22$	$505 \pm 76$	10.00	0.39	$12.8 \pm 6.0$	12.5
060708	$0.96 \pm 1.06$	2.51	$20 \pm 2$	$231 \pm 19$	6.66	0.39	$11.5 \pm 12.7$	16.8
060714	$1.48 \pm 0.46$	2.02	$145 \pm 4$	$311 \pm 15$	3.70	0.02	$23.5 \pm 7.3$	33.1
060729	$19.58 \pm 0.83$	2.71	$120 \pm 2$	$425 \pm 8$	72.97	0.27	$14.3 \pm 0.6$	1.0
060814	$6.93 \pm 0.87$	1.84	$81 \pm 13$	$967 \pm 74$	17.45	0.15	$12.5 \pm 1.6$	1.4
060906	$0.96 \pm 0.29$	2.44	$85 \pm 26$	$222 \pm 21$	13.66	0.33	$25.2 \pm 7.6$	20.7
061121	$19.89 \pm 6.14$	1.62	$103 \pm 2$	$176 \pm 3$	2.43	0.25	$85.4 \pm 26.4$	60.5
070110	$3.59 \pm 0.23$	2.11	$61 \pm 3$	$522 \pm 19$	20.40	0.17	$44.7 \pm 2.9$	17.2
070306	$2.53 \pm 0.94$	2.29	$110 \pm 2$	$542 \pm 8$	15.00	$\sim 0$	$14.0 \pm 5.2$	4.6
070318	$0.79 \pm 1.45$	1.40	$86 \pm 12$	$809 \pm 47$	2.00	$\sim 0$	$1.4 \pm 2.6$	3.2
070721B	$1.80 \pm 1.38$	1.48	$289 \pm 9$	$450 \pm 28$	7.50	0.62	$46.2 \pm 35.4$	192.2
071021	$0.24 \pm 0.39$	2.12	$175 \pm 3$	$558 \pm 74$	20.00	0.37	$10.1 \pm 16.6$	15.6
080310	$1.19 \pm 0.53$	1.45	$504 \pm 1$	$\sim 1313$	20.00	0.33	$15.7 \pm 7.0$	9.1
080430	$0.82 \pm 0.23$	2.42	$0 \pm 5$	$165 \pm 12$	8.80	0.52	$1.2 \pm 0.3$	2.2
080607	$2.85 \pm 0.81$	1.81	$100 \pm 2$	$238 \pm 7$	1.50	1.03	$54.7 \pm 15.5$	954.8
080707	$0.24 \pm 0.13$	2.10	$34 \pm 8$	$192 \pm 28$	7.60	0.16	$0.9 \pm 0.5$	8.4
080905B	$3.50 \pm 2.34$	1.49	$62 \pm 5$	$179 \pm 7$	6.50	$\sim 0$	$44.4 \pm 29.7$	104.4
081007	$0.96 \pm 0.31$	3.00	$\sim 35$	$188 \pm 5$	40.00	0.69	$0.7 \pm 0.2$	1.4
081008	$1.59 \pm 0.52$	1.91	$232 \pm 3$	$484 \pm 15$	20.00	0.73	$14.5 \pm 4.7$	35.0



GRB	$r_c^a$ ( $10^9$ cm)	$r_f^a$ ( $10^{10}$ cm)	$r_e^a$ ( $10^{11}$ cm)	$f_{\Omega,c}^b$	$f_{\Omega,e,low}^c$ ( $10^{-3}$ )	$\delta^d$	$M_c^e$ $M_\odot$	$M_e^f$ $0.1 M_\odot$
050416A	9.14	0.98	0.72	[0.21 0.02]	7.85	2.56	0.02	$0.04 \pm 0.02$
050803	$2.15 \pm 1.57$	$2.26 \pm 0.27$	3.16	[0.34 0.02]	3.75	2.04	$0.09 \pm 0.01$	$0.14 \pm 0.01$
050908	$6.34 \pm 3.53$	$2.03 \pm 0.49$	1.05	[0.19 0.03]	6.52	3.02	$0.61 \pm 0.06$	$0.16 \pm 0.13$
051016B	$6.05 \pm 1.30$	$1.30 \pm 0.23$	7.34	[0.29 0.03]	2.46	1.71	$0.02 \pm 0.01$	$0.27 \pm 0.14$
051109A	$4.86 \pm 2.50$	$0.97 \pm 0.32$	1.17	[0.33 0.03]	6.16	2.13	$0.18 \pm 0.03$	$2.38 \pm 0.51$
060108	$3.87 \pm 3.23$	$1.08 \pm 0.33$	2.62	[0.34 0.03]	4.12	2.09	$0.20 \pm 0.02$	$0.28 \pm 0.09$
060210	$10.74 \pm 0.93$	$1.42 \pm 0.12$	0.88	[0.30 0.02]	7.10	2.70	$12.29 \pm 0.66$	$7.81 \pm 1.11$
060418	$7.09 \pm 0.50$	$1.73 \pm 0.10$	0.38	[0.33 0.03]	10.83	1.50	$2.53 \pm 0.08$	$0.42 \pm 0.20$
060502A	$2.01 \pm 1.29$	$1.25 \pm 0.21$	6.56	[0.24 0.05]	2.60	2.39	$0.69 \pm 0.03$	$1.59 \pm 0.37$
060510B	$9.76 \pm 0.32$	4.64	6.54	[0.38 0.02]	2.61	1.50	$9.27 \pm 0.40$	$0.63 \pm 0.60$
060522	$4.98 \pm 1.28$	$0.82 \pm 0.13$	0.17	[0.33 0.03]	16.26	1.50	$2.77 \pm 0.27$	$0.29 \pm 0.47$
060526	$11.04 \pm 0.30$	$2.71 \pm 0.18$	1.24	[0.35 0.02]	5.99	1.50	$1.47 \pm 0.19$	$0.53 \pm 0.30$
060605	$3.70 \pm 4.30$	$1.45 \pm 0.30$	0.90	[0.36 0.03]	7.05	1.50	$1.07 \pm 0.14$	$1.26 \pm 0.80$
060607A	$9.76 \pm 1.46$	$1.44 \pm 0.13$	1.46	[0.34 0.02]	5.53	2.15	$2.84 \pm 0.11$	$9.23 \pm 0.19$
060707	$3.76 \pm 2.02$	$1.64 \pm 0.46$	1.20	[0.31 0.03]	6.09	2.09	$2.08 \pm 0.20$	$0.71 \pm 0.33$
060708	$2.33 \pm 0.57$	$1.18 \pm 0.23$	1.11	[0.24 0.04]	6.32	2.09	$0.33 \pm 0.03$	$0.64 \pm 0.71$
060714	$8.01 \pm 0.76$	$1.33 \pm 0.18$	0.69	[0.33 0.02]	8.00	1.53	$2.65 \pm 0.18$	$1.31 \pm 0.41$
060729	$12.71 \pm 0.91$	$2.95 \pm 0.20$	9.12	[0.29 0.02]	2.21	1.91	$0.11 \pm 0.01$	$0.79 \pm 0.03$
060814	$8.68 \pm 2.55$	$4.53 \pm 0.82$	3.12	[0.32 0.02]	3.78	1.72	$1.50 \pm 0.02$	$0.69 \pm 0.09$
060906	$4.80 \pm 2.21$	$0.91 \pm 0.19$	1.42	[0.31 0.03]	5.59	1.99	$3.22 \pm 0.20$	$1.40 \pm 0.42$
061121	$8.77 \pm 0.61$	$1.25 \pm 0.09$	3.34	[0.33 0.02]	3.65	1.88	$3.27 \pm 0.05$	$4.75 \pm 1.47$
070110	$4.82 \pm 0.58$	$2.02 \pm 0.22$	2.32	[0.30 0.03]	4.38	1.75	$1.11 \pm 0.07$	$2.48 \pm 0.16$
070306	$8.67 \pm 0.54$	$2.51 \pm 0.15$	2.30	[0.31 0.02]	4.40	1.50	$1.65 \pm 0.09$	$0.78 \pm 0.29$
070318	$9.03 \pm 2.41$	$4.03 \pm 0.61$	0.74	[0.39 0.02]	7.77	1.50	$0.25 \pm 0.01$	$0.08 \pm 0.01$
070721B	$10.95 \pm 1.08$	$1.47 \pm 0.23$	0.96	[0.32 0.02]	6.80	2.43	$5.13 \pm 0.28$	$2.57 \pm 1.96$
071021	$6.61 \pm 0.42$	$1.43 \pm 0.37$	1.55	[0.33 0.03]	5.35	2.06	$3.05 \pm 0.47$	$0.56 \pm 0.09$
080310	$19.39 \pm 0.39$	3.67	2.26	[0.37 0.02]	4.44	2.00	$1.68 \pm 0.15$	$0.87 \pm 0.39$
080430	$0.25 \pm 1.45$	$1.43 \pm 0.25$	2.03	[0.11 0.03]	4.68	2.28	$0.10 \pm 0.01$	$0.07 \pm 0.02$
080607	$5.92 \pm 0.38$	$1.05 \pm 0.10$	0.36	[0.34 0.03]	11.12	3.05	25.60	$3.04 \pm 0.86$
080707	$4.27 \pm 1.60$	$1.36 \pm 0.37$	1.58	[0.32 0.03]	5.31	1.74	$0.11 \pm 0.01$	$0.05 \pm 0.03$
080905B	$4.84 \pm 0.96$	$0.98 \pm 0.11$	0.78	[0.37 0.03]	7.55	1.50	$1.27 \pm 0.14$	$2.47 \pm 1.65$
081007	5.61	$1.72 \pm 0.15$	2.43	[0.25 0.03]	4.27	2.54	$0.03 \pm 0.01$	$0.04 \pm 0.01$
081008	$12.74 \pm 0.70$	$2.08 \pm 0.21$	1.56	[0.33 0.02]	5.33	2.60	$2.18 \pm 0.10$	$0.81 \pm 0.26$

# 参数分布

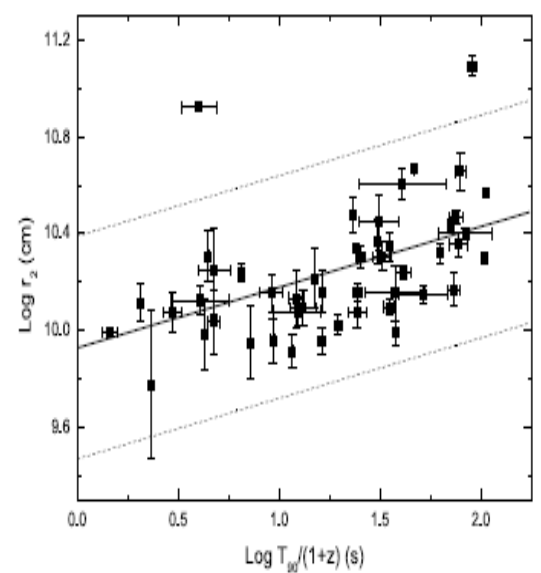
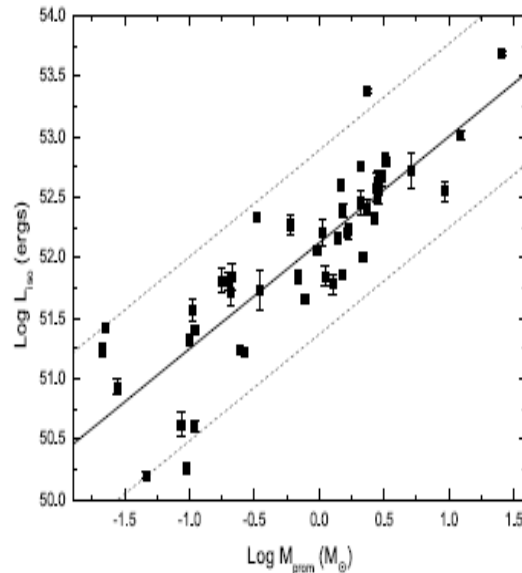
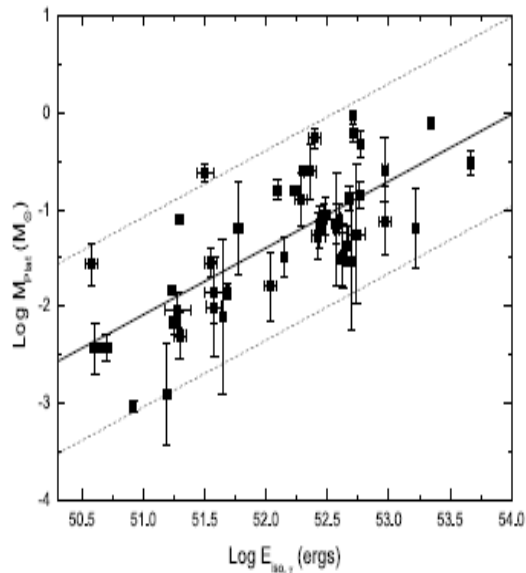


$$\log r_1/\text{cm} =$$

$$9.79 \pm 0.38, \log r_2/\text{cm} = 10.19 \pm 0.20, \log f_{\Omega,1,up} = -0.49 \pm 0.05, \log f_{\Omega,1,low} = -1.56 \pm 0.12,$$

$$\log f_{\Omega,2,low} = -2.20 \pm 0.10$$

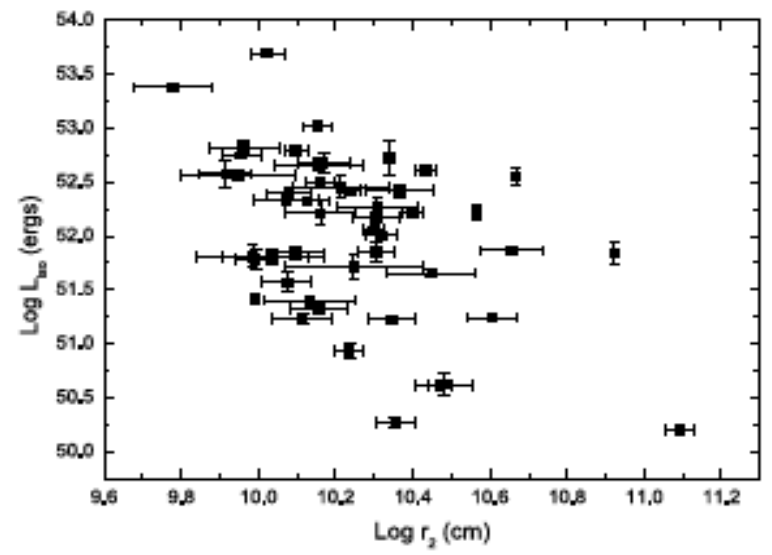
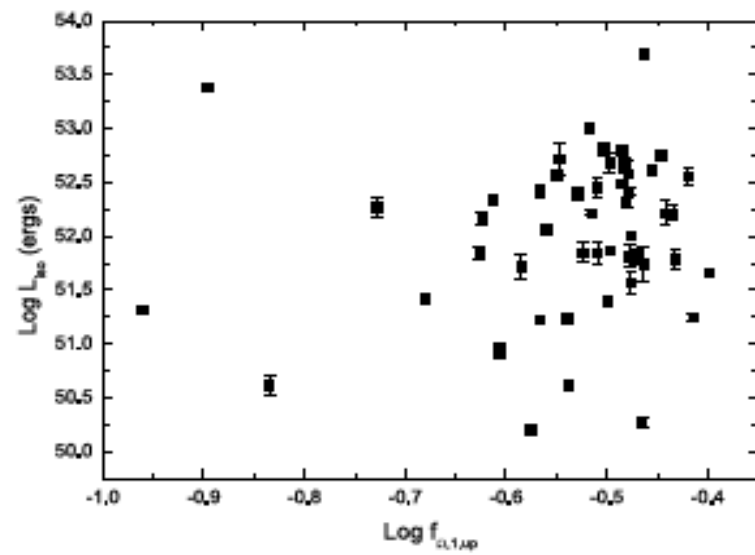
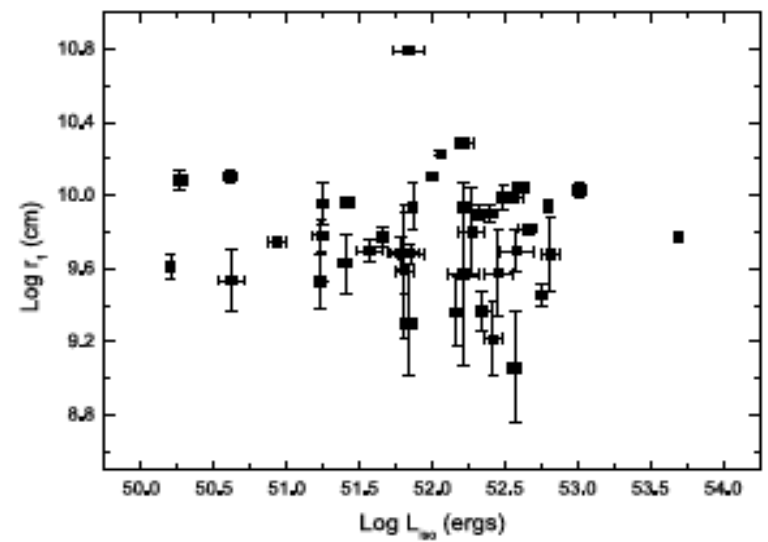
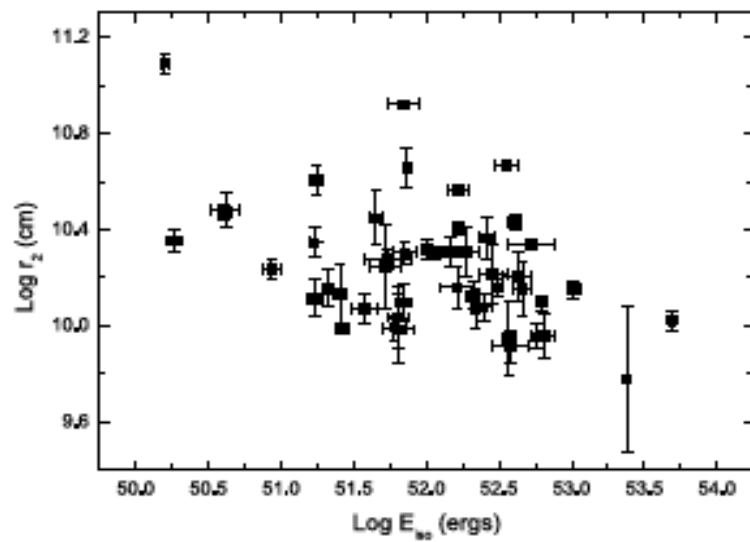
# 相关性分析



$$\log M_{plat} = -(37.25 \pm 5.01) + (0.69 \pm 0.10) \log E_{iso,\gamma} \quad R = 0.73 \quad p < 1e-4 \text{ for } N = 48$$

$$\log L_{iso} = (52.13 \pm 0.05) + (0.88 \pm 0.07) \log M_{prom} \text{ with } R = 0.86 \text{ in } p < 1e-4 \text{ for } N = 48$$

$$\log r_2 = (9.93 \pm 0.09) + (0.25 \pm 0.07) \log T_{(90)}/(1+z) \text{ with } R = 0.49 \text{ and } p = 3.96e-4$$

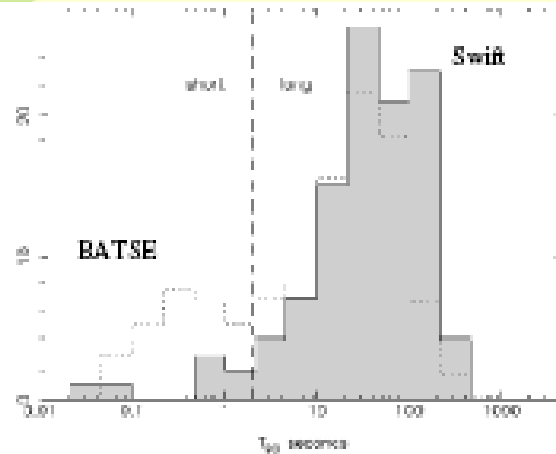
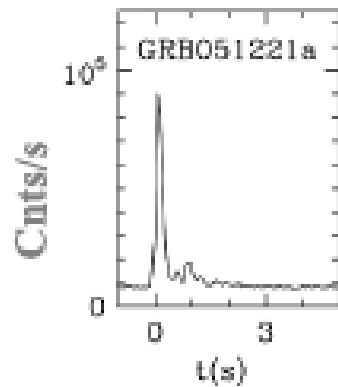


# 小结

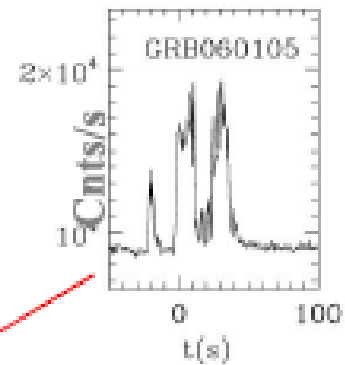
1. 参数对数正态 (lognormal) 分布
2. 在爆发阶段和余辉阶段回落的质量与 $E_{\text{iso}}$ 和 $L_{\text{iso}}$ 相关

# GRB 在寄主星系中位置

## Short GRB



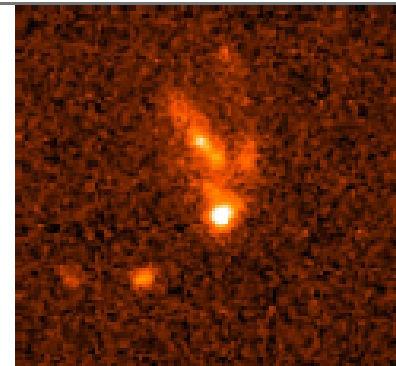
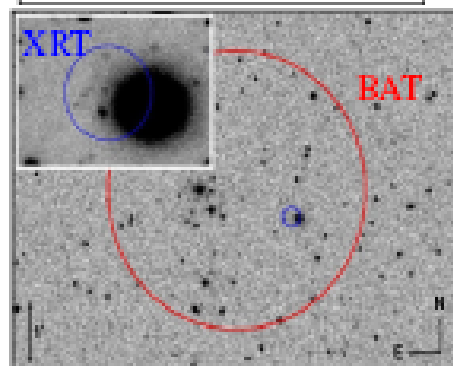
## Long GRB



GRB 050509B - Swift  
VLT Image

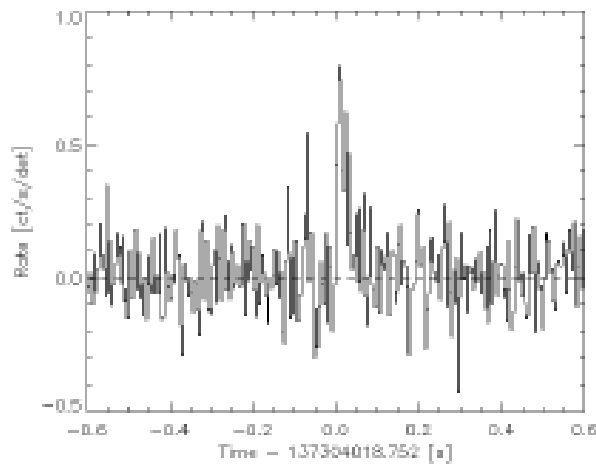
GRB 990123 - BeppoSAX  
HST Image

Short GRBs  
in low-SF  
galaxies  
**Binary mergers**



Long GRBs  
in high-SF  
Galaxies  
**Collapsars**

# 第一个定位的短暴 GRB050509B (Gehrels et al. 2005)



## BAT

- 30 ms duration
- spectrum is medium hard
- very weak,  $2 \times 10^{-8}$  erg/cm<sup>2</sup>

Spacecraft slew in 52 sec

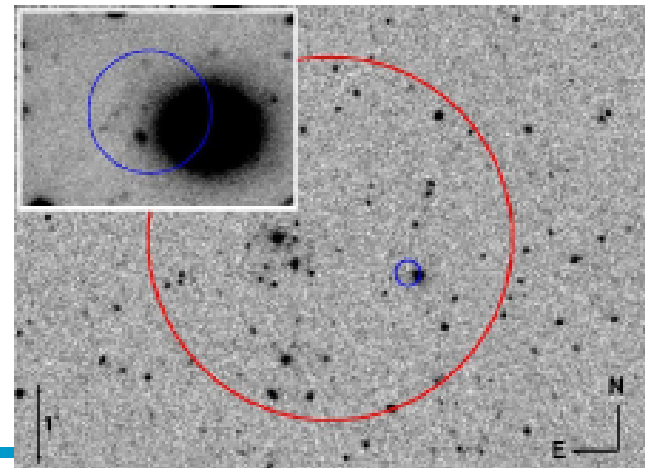
## XRT

- faint source, fading
- 11 cts =  $1 \times 10^{-12}$  erg/cm<sup>2</sup>/s

## Proposed host:

- cD Elliptical
- $K = 14.1$
- $L = 3 L^*$
- $z = 0.225$
- $\text{SFR} < 0.2 M_{\odot} \text{ yr}^{-1}$
- No SNe to faint limits

VLT image  
Hjorth et al.



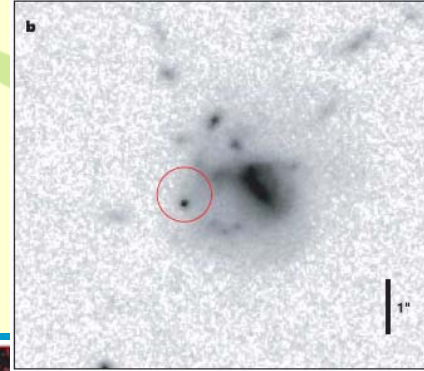
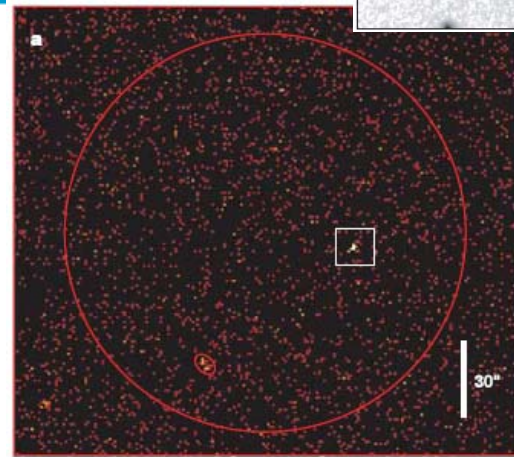
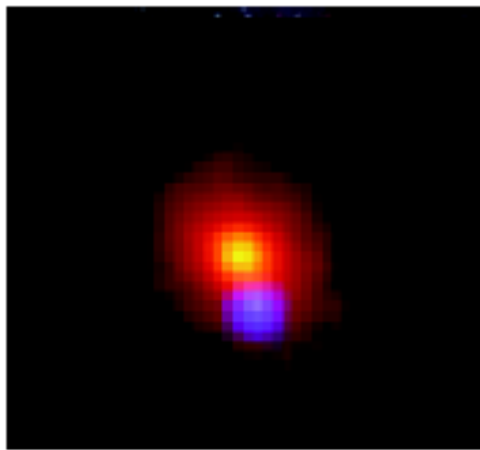
# 另外的早期观测

**GRB 050709** (*Fox+05, Villasenor+05, Hjorth+05*) triggered by HETE-II

optical afterglow: subarcsec localization

SF galaxy at  $z=0.161$

$SFR \sim 3 M_{\text{sun}} \text{ yr}^{-1} L_{\star}^{-1}$ , age  $\sim 0.4 \text{ Gyr}$



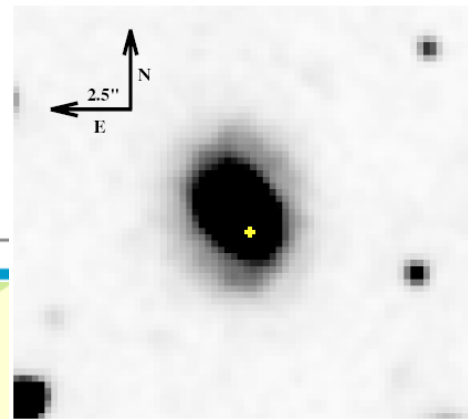
**GRB 050724** (*Malesani+07, Berger+05*)

Optical, NIR and radio afterglow

Elliptical galaxy at  $z=0.258$

$SFR < 0.14 M_{\odot} \text{ yr}^{-1} L_{\star}^{-1} \ll SFR_{\text{long}}$

age  $\sim 2.6 \text{ Gyr}$





# GRB 050724

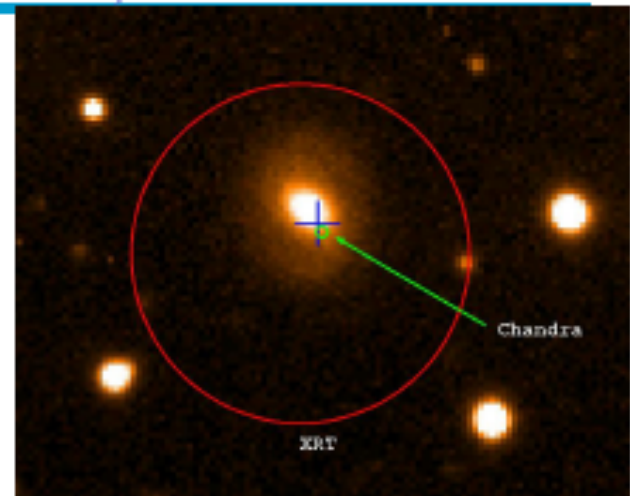
## Barthelmy et al. (2005)

### BAT

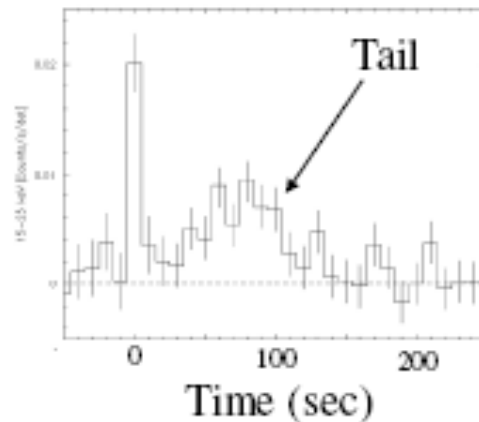
- 250 ms hard spike + softer long tail
- $6 \times 10^{-7}$  erg/cm<sup>2</sup> fluence

### Afterglow

- bright fading x-ray afterglow with flares
- detected by Chandra days after GRB
- optical & IR detections
- radio VLA detection at 12 hours



### GRB 050724



### Host:

- Elliptical
- $K = 15.3$
- $L = 1.7 L^*$
- $z = 0.258$
- $SFR < 0.02 M_{\odot} \text{ yr}^{-1}$

# GRB 060614

$T_{90} = 103$  s,  $z=0.125$ , No SNe  
(Gherels et al, Gal-Yam et al.,  
Fynbo et al., Della Valle et al. 2006)

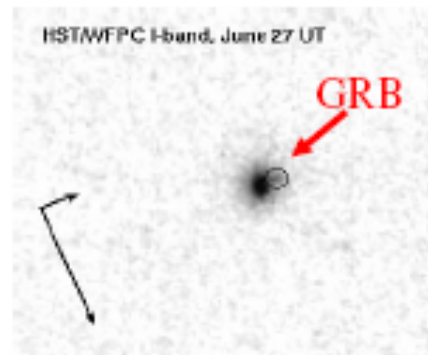
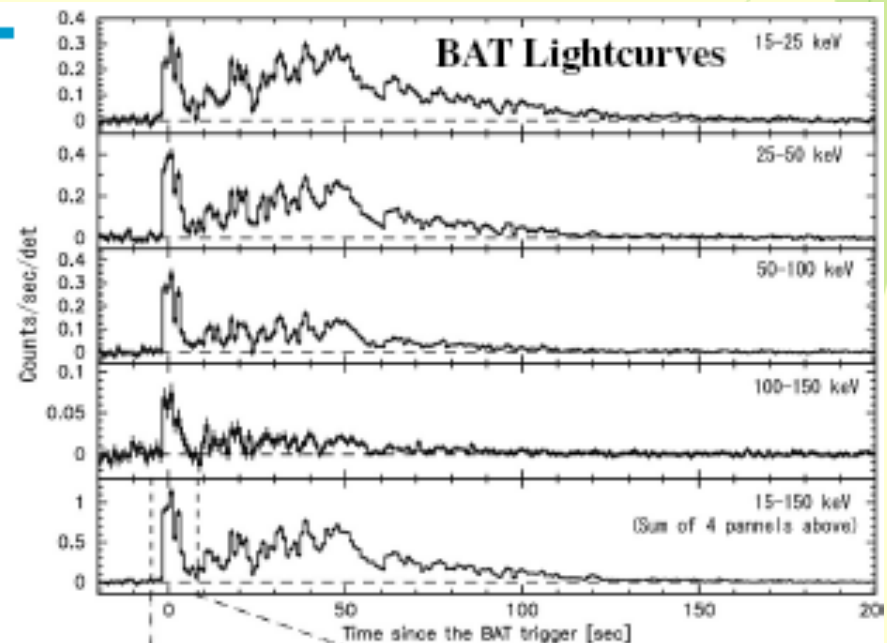
Short ID Pluses:

- Hard short episode followed by long softer hump
- Short spectral "lag" (Norris & Bonnell 2006)

Short ID Minuses:

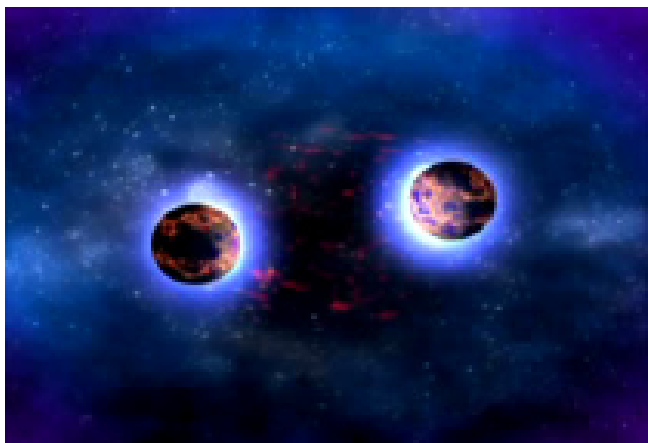
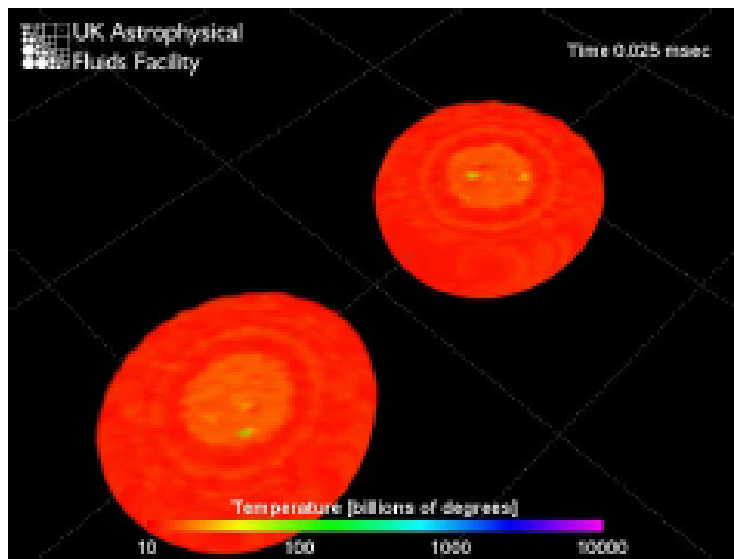
- 5 s duration of hard episode
- Brighter & more variable hump emission than others

Could GRB060614 be a member of a new class – the long shorts?



GRB 060614  
Tiny galaxy  
 $SFR \sim 0.014 M_{\odot} \text{ yr}^{-1}$   
( $S-SFR \sim 3$ )

# 短暴模型 — 双中子星合并



- NS-NS merger is fast (msec)  $\Rightarrow$  BH (some may make magnetars, briefly)
- Can occur in any type of galaxy – should see a variety of “hosts”
- Dynamical “kick” can move NS from original location so final merger can be in a low density environment  $\Rightarrow$  very weak X-rays possible



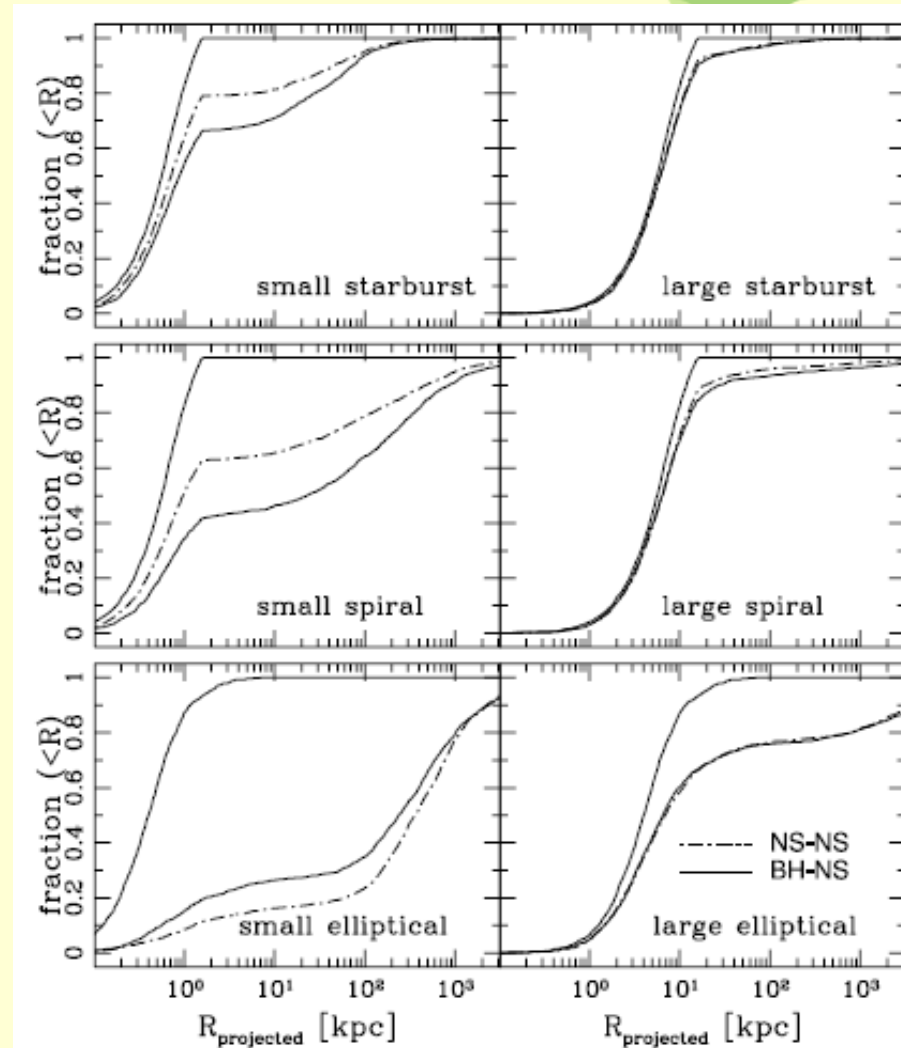
# 数据

GRB	$T_{90}$ (s)	redshift	$R_{\text{projected}}$ (kpc)	$R_{\text{projected}}/R_e$	Type.....
(1)	(2)	(3)	(4)	(5)	(6)
050509B	0.04	0.225	$54.25 \pm 12.05$	$2.59 \pm 0.58$	E
050709*	0.07	0.161	$3.7 \pm 0.03$	$2.04 \pm 0.02$	S
050724*	3	0.258	$2.69 \pm 0.07$	$1.28 \pm 0.05$	E
051210	1.27	<1.4	$30.3 \pm 19.5$	$5.66 \pm 3.65$	0
051221A	1.4	0.546	$2.05 \pm 0.19$	$0.88 \pm 0.08$	S
051227*	110	...	$0.7 \pm 0$	...	0
060121	1.97	>1.7	$0.96 \pm 0.37$	$0.18 \pm 0.07$	Faint
060313	0.7	<1.1	$2.57 \pm 0.53$	$1.66 \pm 0.32$	Faint
060502B	0.09	0.287	$70 \pm 16$	$6.66 \pm 1.52$	E
060505	4	0.089	$7.45 \pm 0.53$	...	S
060614*	103	0.125	$1.1 \pm 0$	...	LSF
060801	0.5	1.131	$19.7 \pm 19.8$	...	0
061006*	0.42	0.438	$1.37 \pm 0.27$	$0.41 \pm 0.09$	LSF
061201	0.8	0.111	$33.9 \pm 0.4$	...	SF
061210*	0.19	0.41	$10.7 \pm 9.7$	...	SF
061217	0.21	0.827	$55 \pm 28$	...	SF
070429B	0.5	0.9023	16.99	...	Faint
070714B*	3	0.9225	11.64	...	S
070724A	0.4	0.457	$4.8 \pm 0.1$	...	SF
070809	1.3	0.2187	20	...	S
071227	1.8	0.381	$15 \pm 2.2$	...	S
090426	1.2	2.609	0.8	...	SF
090510	0.3	0.903	5.5	...	Field

# 方法

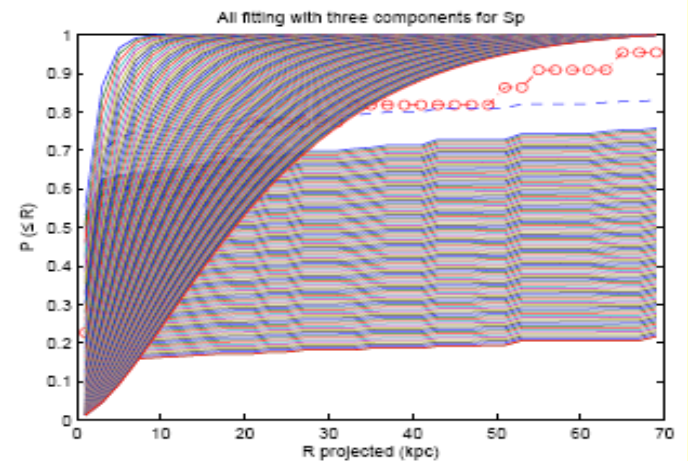
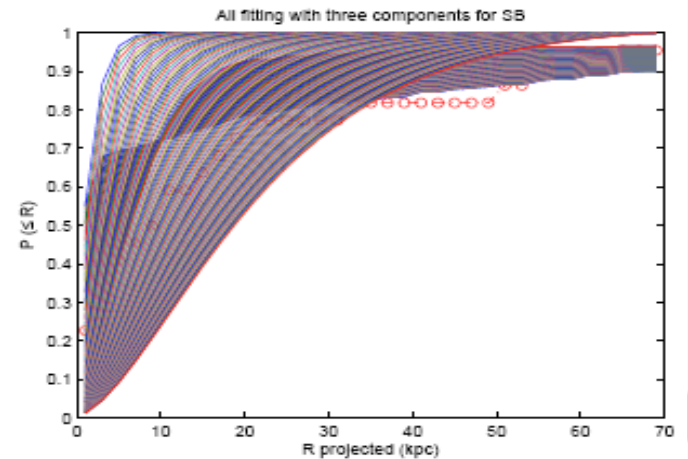
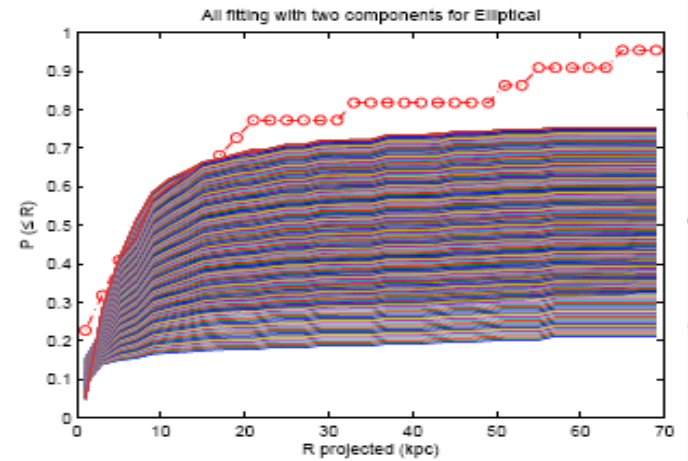
- Belczynski et al. (2006): NS-NS, NS-BH merger location in three types of HG, cumulative probability distribution from PS method
- Bloom et al. (2002): Massive star model from the observations of star distribution in galaxy

$$N(r)dr \propto r \exp(-1.67r) dr,$$



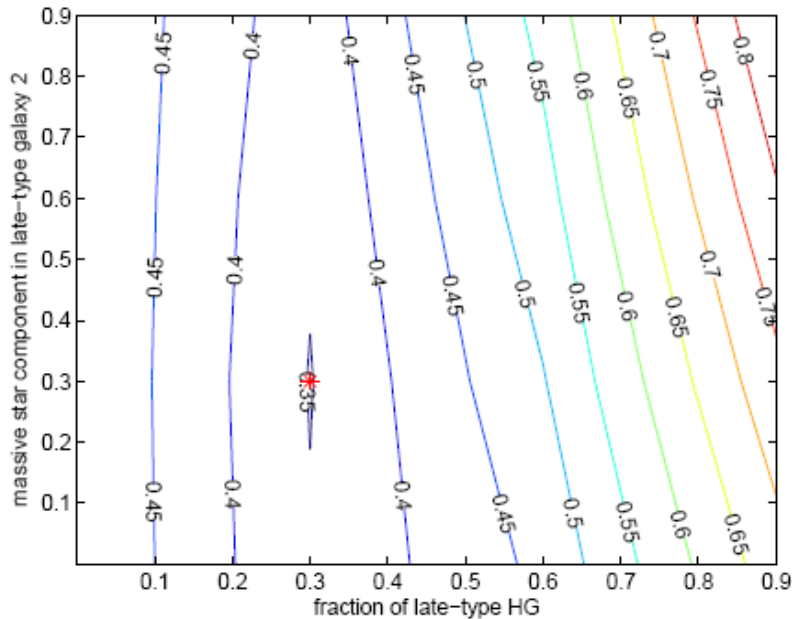
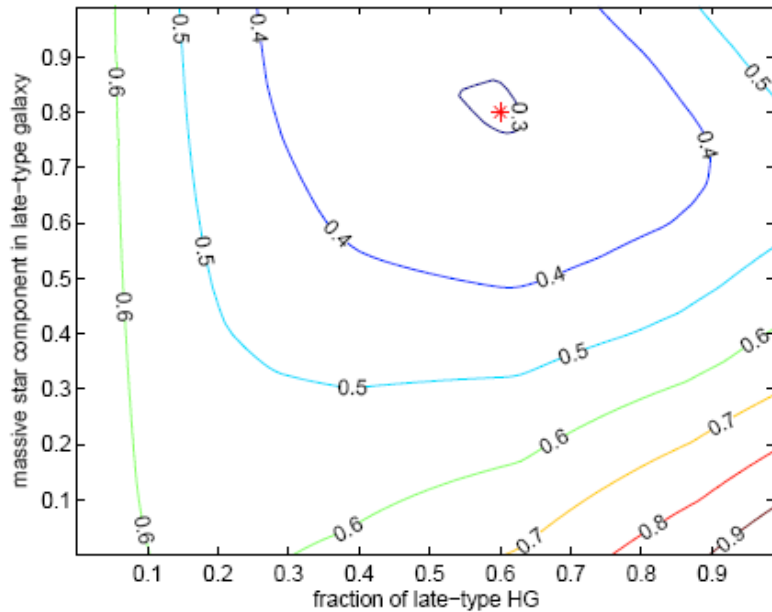
# 步骤

- 生成理论曲线
- 合并模型，拟合
- 最小二乘法

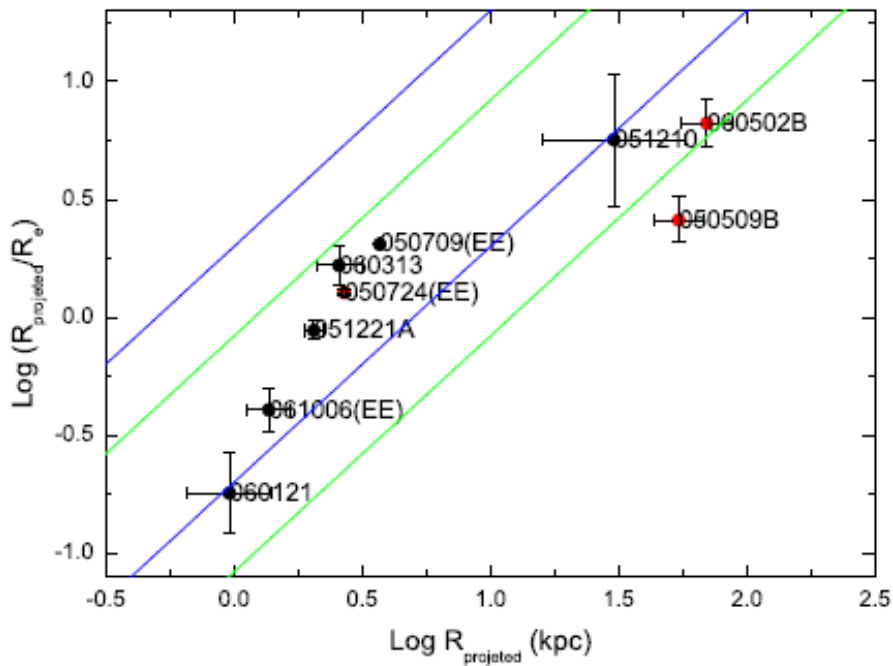


# 最小二乘法

- 不同星系比例
- 不同成分在同一星系中比例



# 相关性



- 预言包括了几乎所有的观测数据
- 早型和晚型星系遵循不同的轨迹：线性相关系数  $R \approx 0.99$ ，置信度  $p < 0.0001$



## 小结

(1) 一种类型的寄主星系不可以

(2) 至少两种类型的寄主星系能拟合观测数据，  
并与观测早型与晚型星系的比例相一致

(3)  $R_{\text{off}} - R_{\text{off}}/R_e$  关系

# 总结

- GRB介绍
- GRB与脉冲星踢速度
- 从Swift观测数据中探究GRB的前身星
- 寄主星系中位置暗示的GRB起源

## 问题

- 研一期间是否应该进入科研，课程与科研任务哪个更重要？如何平衡？
- 读文献时，遇到自己不懂的知识如何寻找相关的资料来补充可以更省时间。（读引文还是请教师兄，等等）
- 学过的东西很多、遗忘很快，有没有更有效的方法来及时的总结吸收所学知识。

# 科研心得

- 读大师的文章
- 多参加讨论
- 及时总结经验与教训
- 大胆想问题，并没有绝对的事情

大爆炸

0,000,001

元素形成  
元形

1

100,000

宇宙微波背景辐射

大爆炸 (年)

1,000,000

1,000,000,000

黑暗带

第一代恒星

今天

15,000,000,000

# 膨胀的宇宙

最遥远星系

$10^{30}$  m

银河系

$10^{20}$  m

邻近恒星

$10^{10}$  m

太阳

地球

人类

$10^0$  m

细胞

原子

$10^{-10}$  m

质子

$10^{-15}$  m

集天地之灵气，纳日月之精华  
与时空之交接，在宇宙之豁达

谢谢！

