Gamma-Ray Bursts: A Population Study

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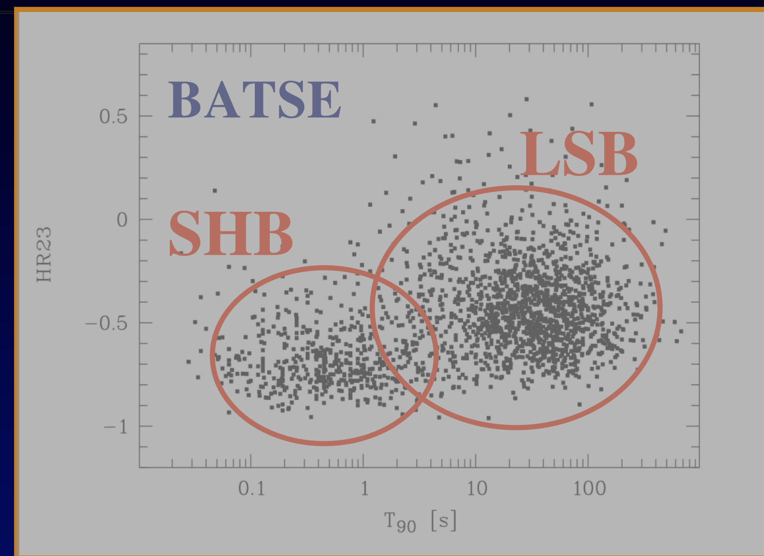
[Jan 25 2006]

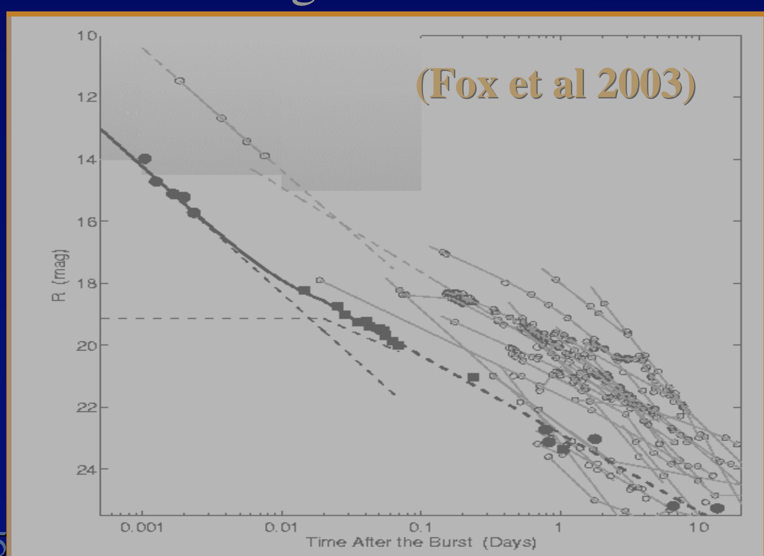
GRBs in a nutshell

Discovery by Vela 4

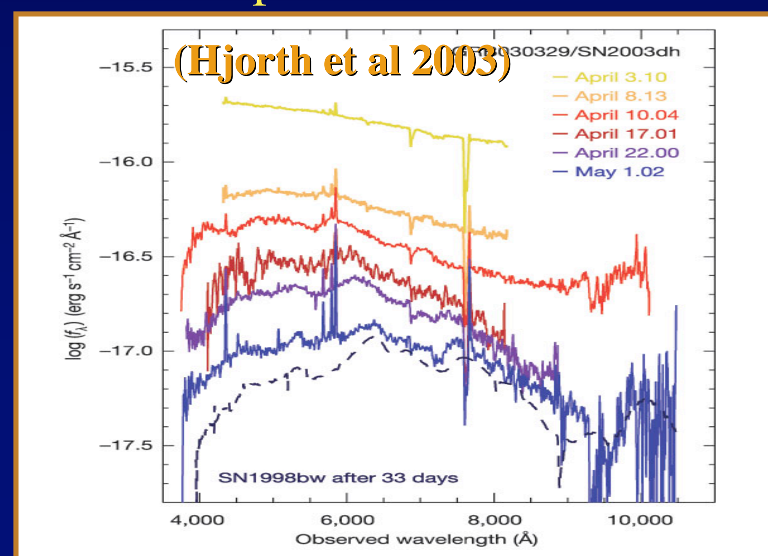
Two populations



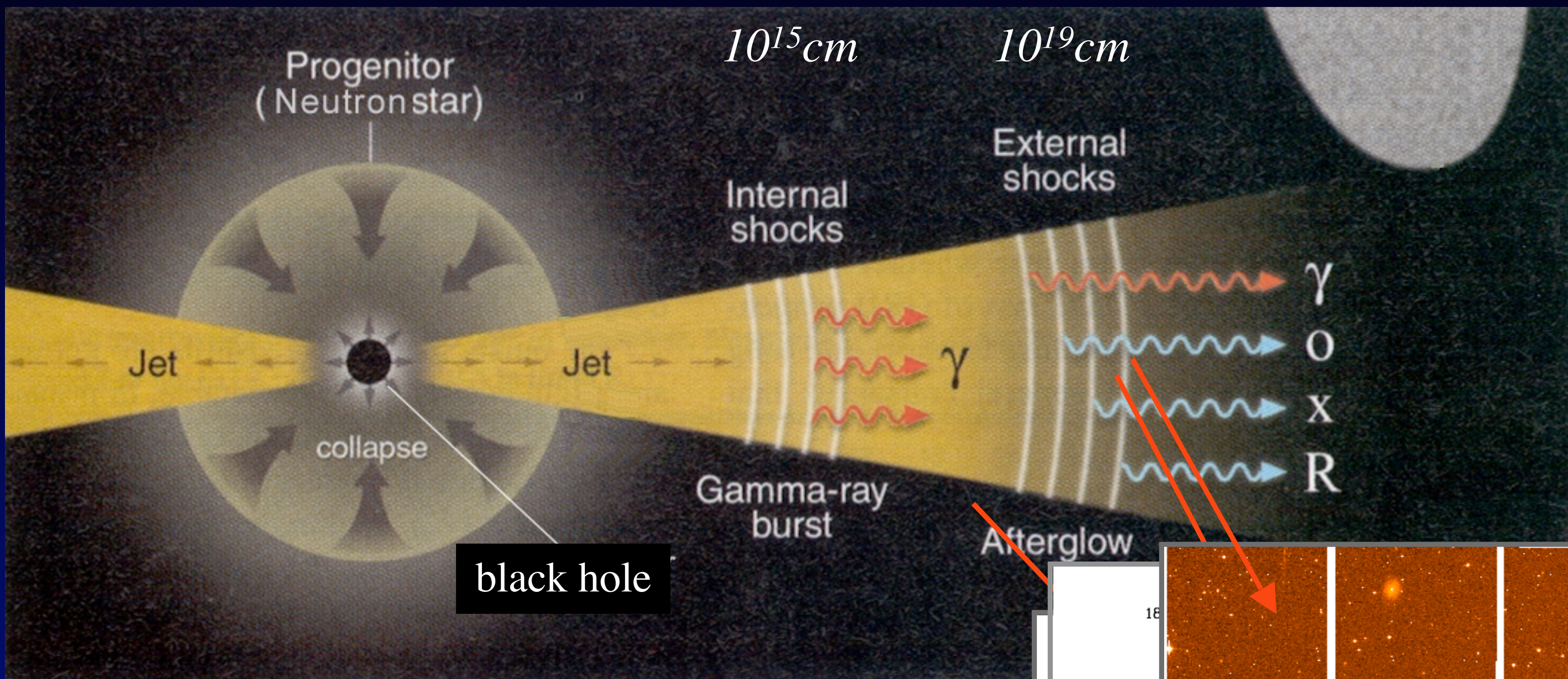
Afterglow emission

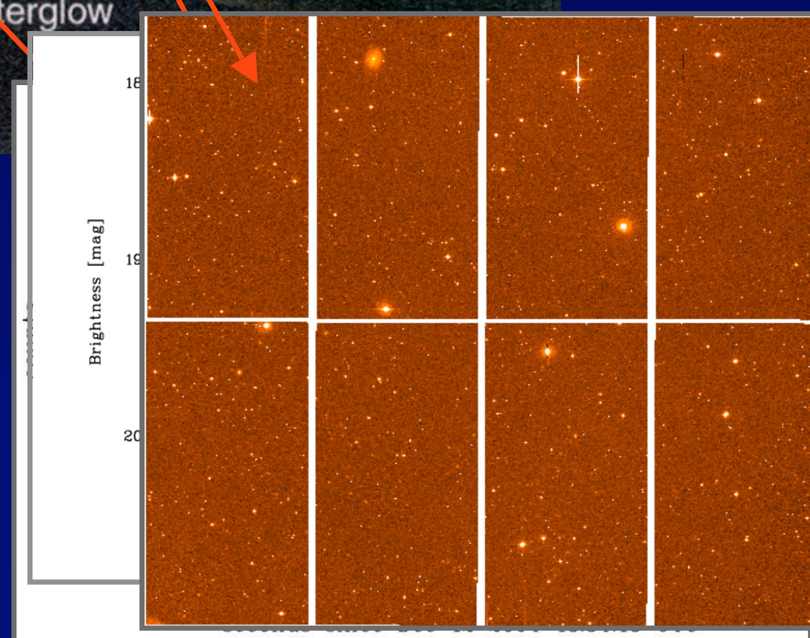


Supernova connection



Thesis/talk overview





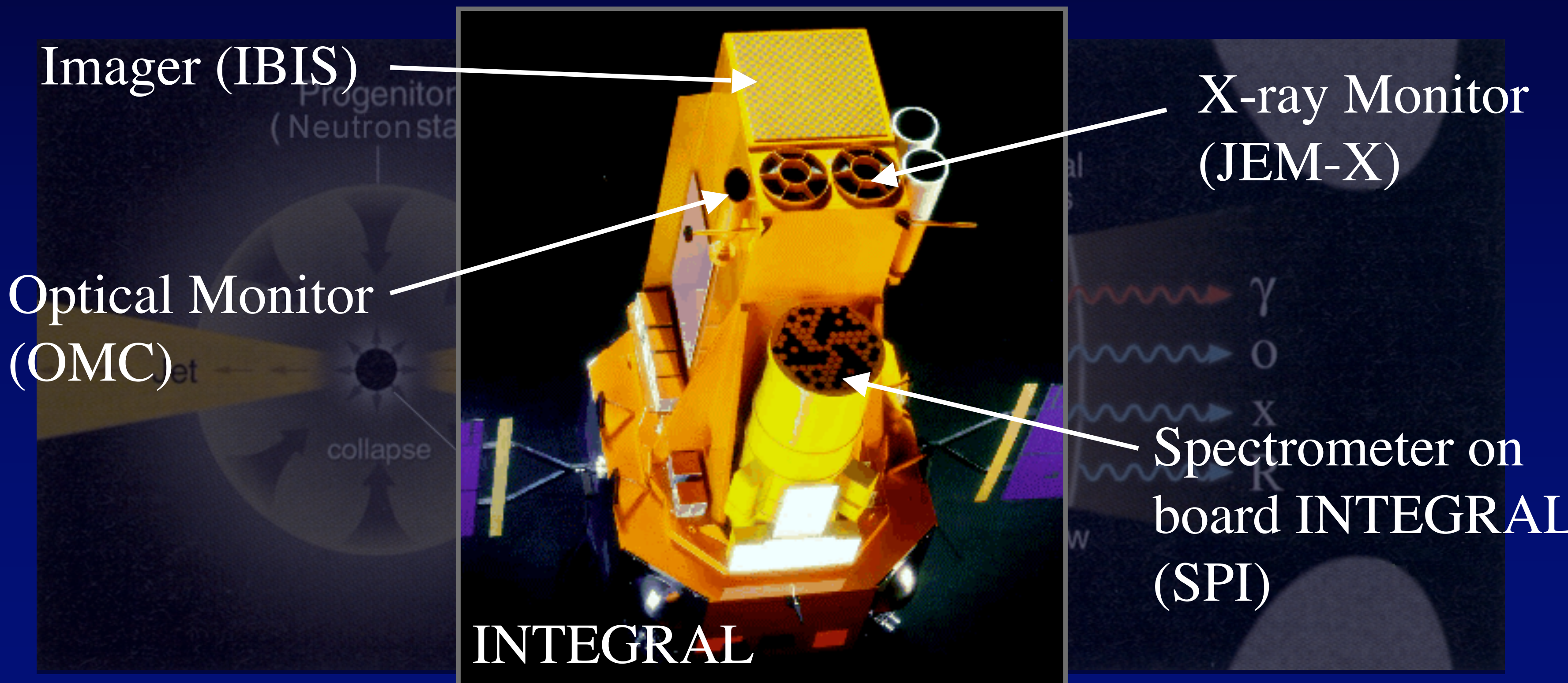
1) GRBs with INTEGRAL SPI-ACS
2) GRB/XRF 030528
3) Orphan afterglow survey

[Jan 25 2006]

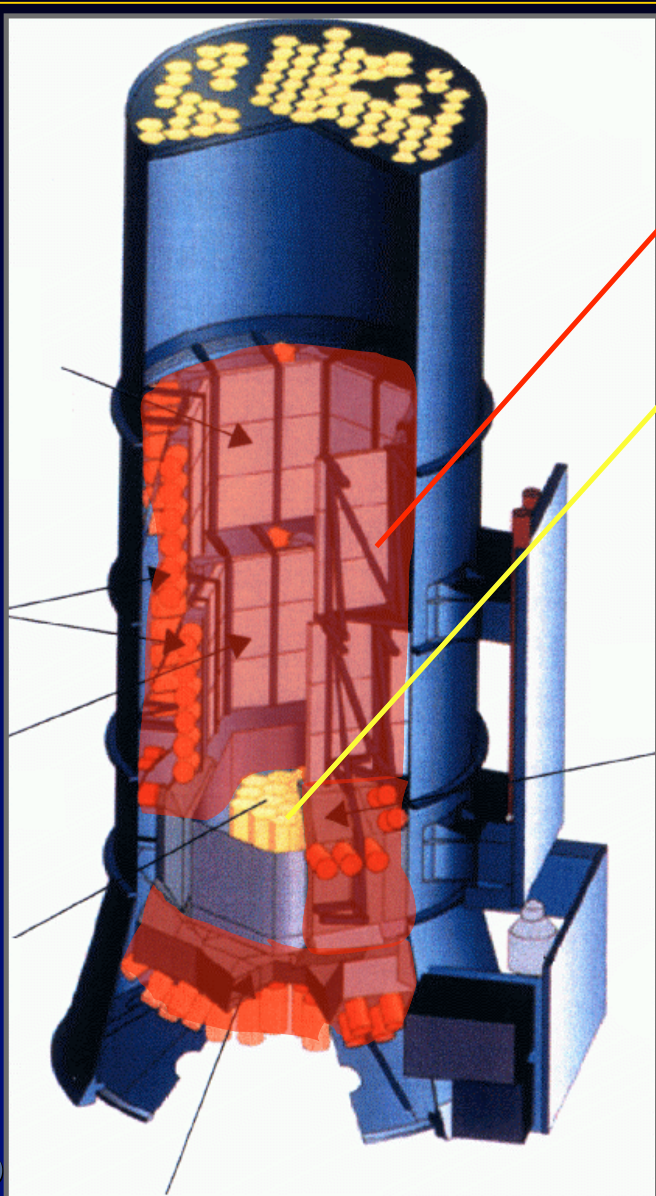
Population 1:

GRBs with the Anti-Coincidence Shield SPI-ACS

[AR, von Kienlin, Hurley & Lichti, A&A, 438, 1175 (2005)]



SPI-ACS as GRB Detector



91 $Bi_{12}GeO_{20}$ (BGO) crystals

19 SPI-Ge detectors

- omnidirectional FoV
- ~80keV - 10MeV
- 50ms time resolution
- no spectral/spatial resolution
- localization via triangulation

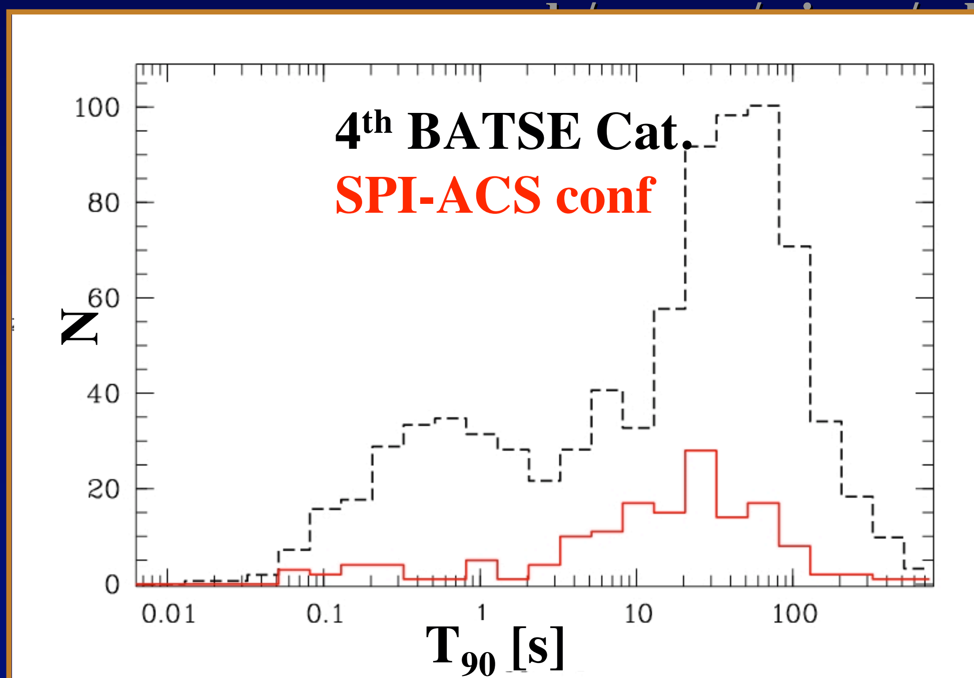
The sample of candidate GRBs

(Oct 2002 - Jan 2005)

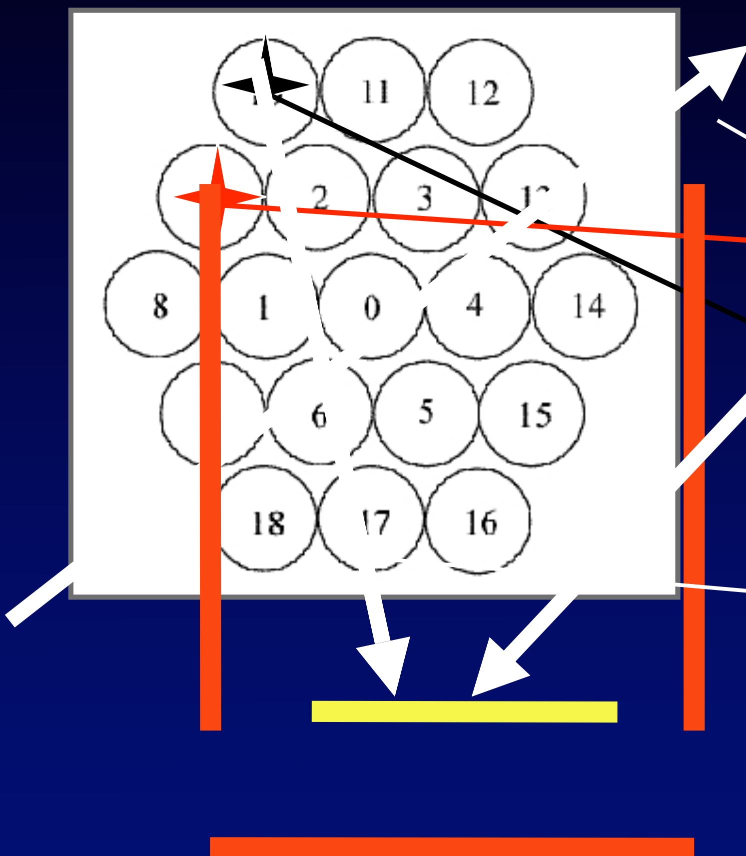
SPI-ACS Gamma-Ray Bursts: January 2003

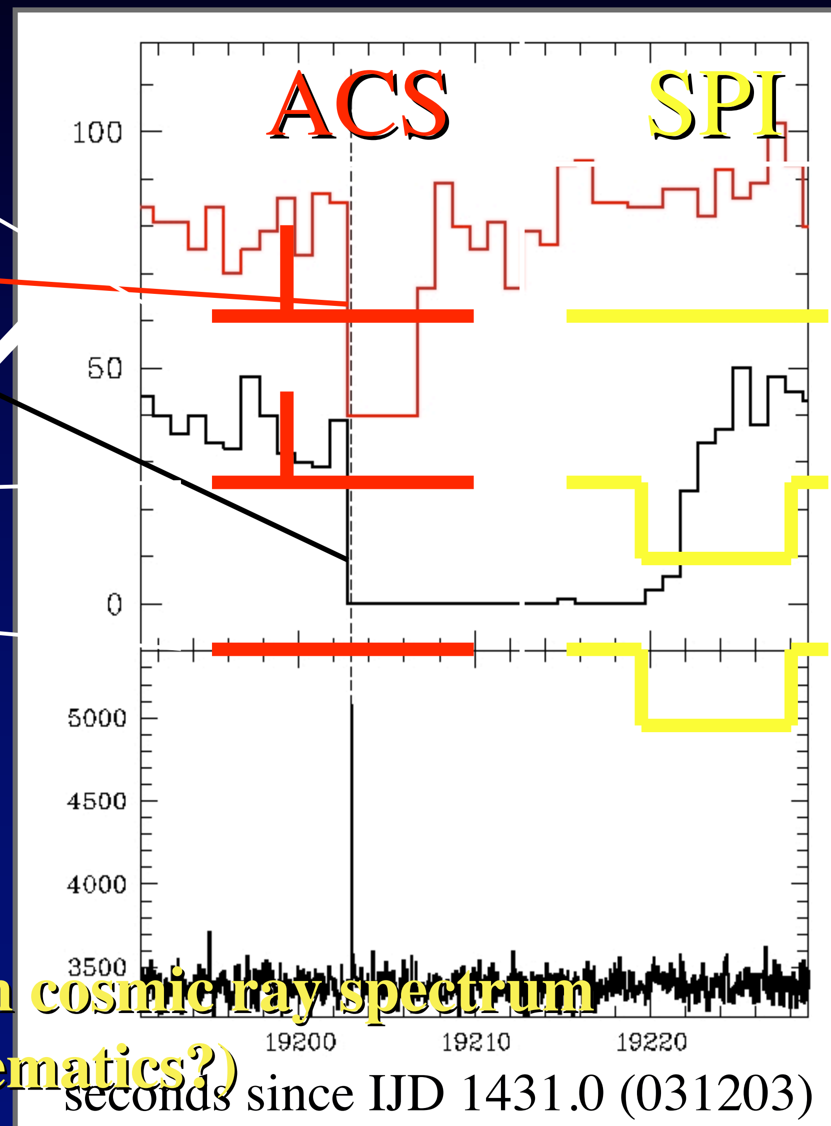
#	DATE	TIME UTC	SIGMA	T_{90} [s]	T_{50} [s]	C_{INT} [kcnts]	C_{MAX} [kcnts]	V/V_{MAX}	VAR	CONF.			COMMENT
18	2003-01-01	20-43-32	42	0.65±0.05	0.25±0.05	16±0.7	8.2±0.2	0.15	0.01±0.01	UKH	JPEG	ASCII	
19	2003-01-02	15-47-43	25	7.3±0.4	4.4±0.5	32±2	3±0.2	0.33	0.18±0.01		JPEG	ASCII	
20	2003-01-02	23-18-59	36	12±0.8	2.9±0.1	46±3	4.6±0.2	0.19	0.23±0.01	UKR	JPEG	ASCII	
21	2003-01-05	14-34-06	72	0.9±0.05	0.3±0.05	30±0.9	12±0.2	0.07	0.07±0.01	MKR	JPEG	ASCII	
22	2003-01-07	08-59-41	28	0.15±0.05	0.05±0.05	5.6±0.3	5.4±0.2	0.28			JPEG	ASCII	
23	2003-01-09	09-37-37	28	0.7±0.5	0.05±0.1	5.3±0.5	4.8±0.2	0.28		U	JPEG	ASCII	
24	2003-01-10	09-39-28	18	0.05±0.1	0.05±0.05	2.6±0.2	2.7±0.2	0.54		K	JPEG	ASCII	
25	2003-01-15	06-24-29	50	66±6	33±2	190±10	2.5±0.2	0.12	0.31±0.01	UMKHR	JPEG	ASCII	

...b/1ACSburst.html



Origin of events with T_{90} < 0.25s



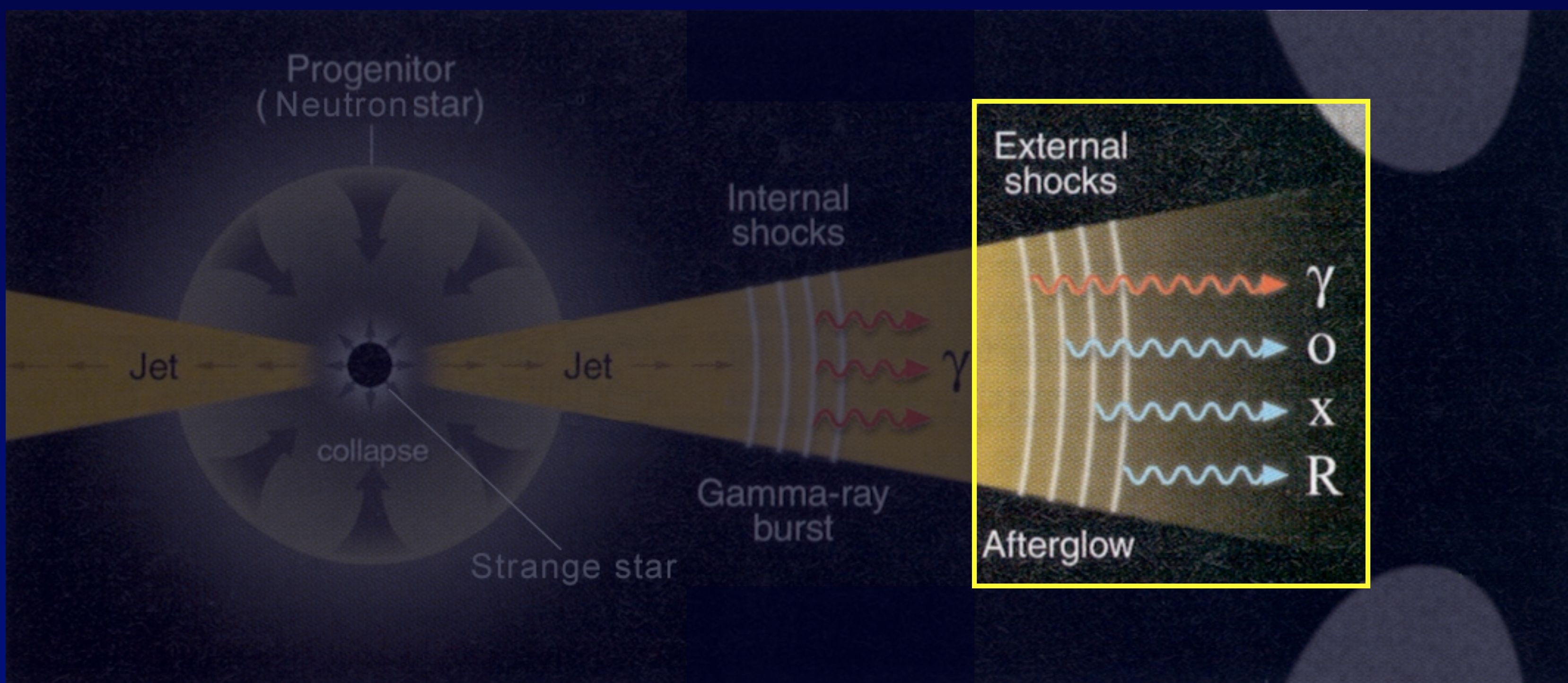


- short events consistent with cosmic ray spectrum
- deficit of short GRBs (systematics?)

Population 2:

Afterglows and Hosts: GRB 030528

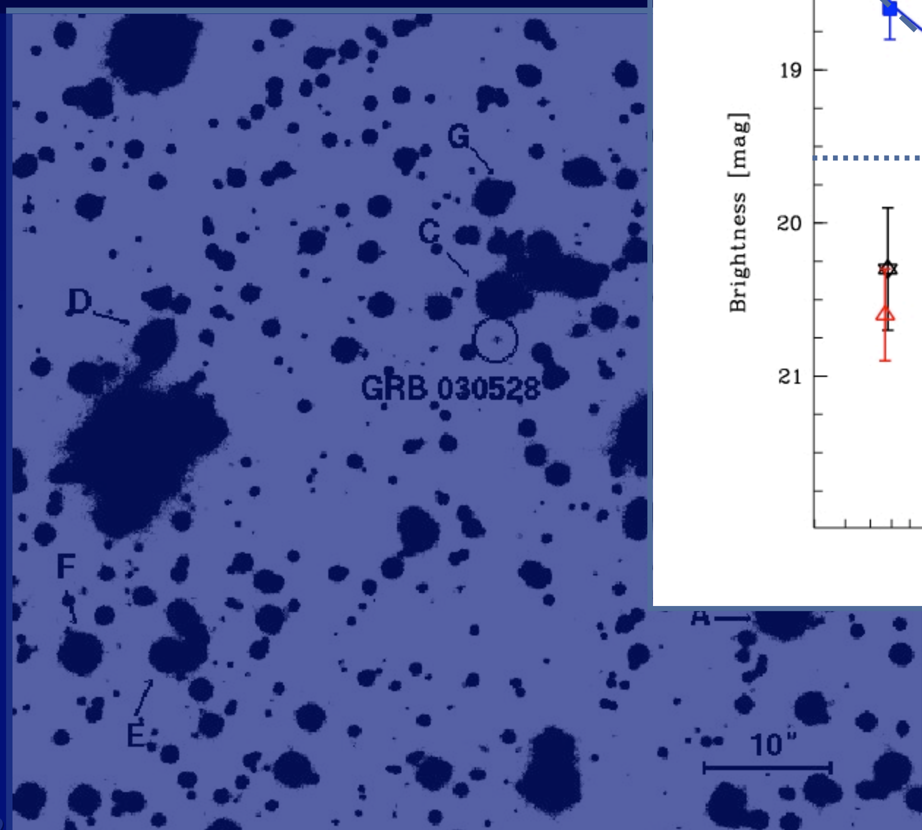
[AR, Greiner, Klose & GRACE, A&A, 427, 815 (2004)
AR, Salvato & Greiner, A&A, 444, 425, (2005)]

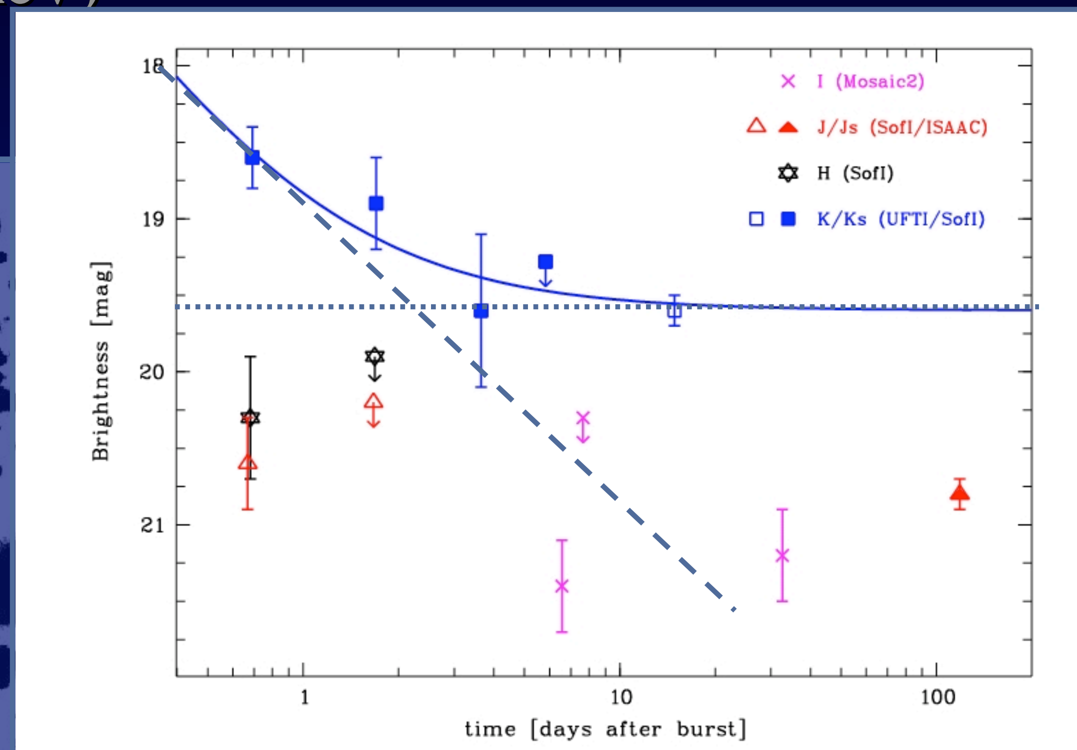


Afterglow discovery

- HETE-2 detection
- $T_{90} = 49.1$s (30-400 keV)

intrinsic $A_V = 2$ mag





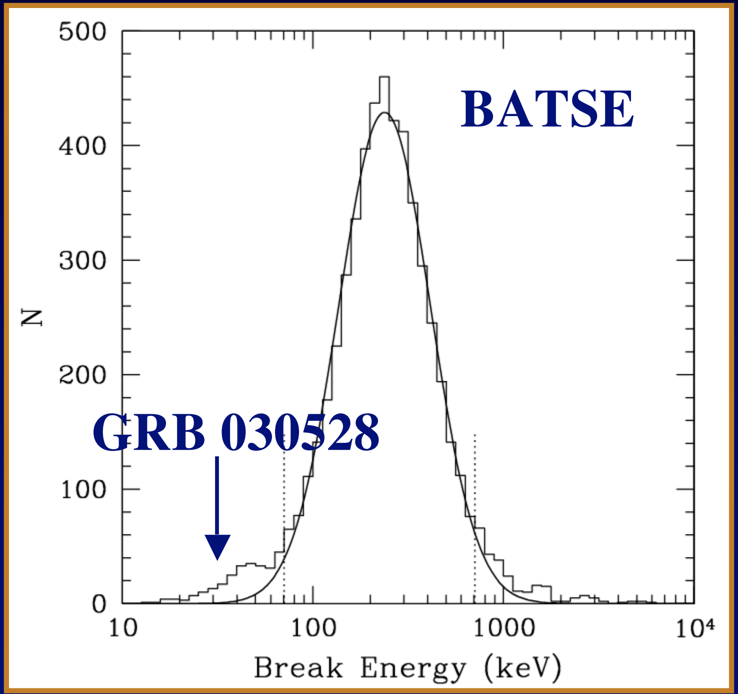
VLT/ISAAC
J_s-band

GRB 030528 - an X-ray Flash

$E_{peak,obs}$ = 32±5 keV → X-ray Flash (XRF)

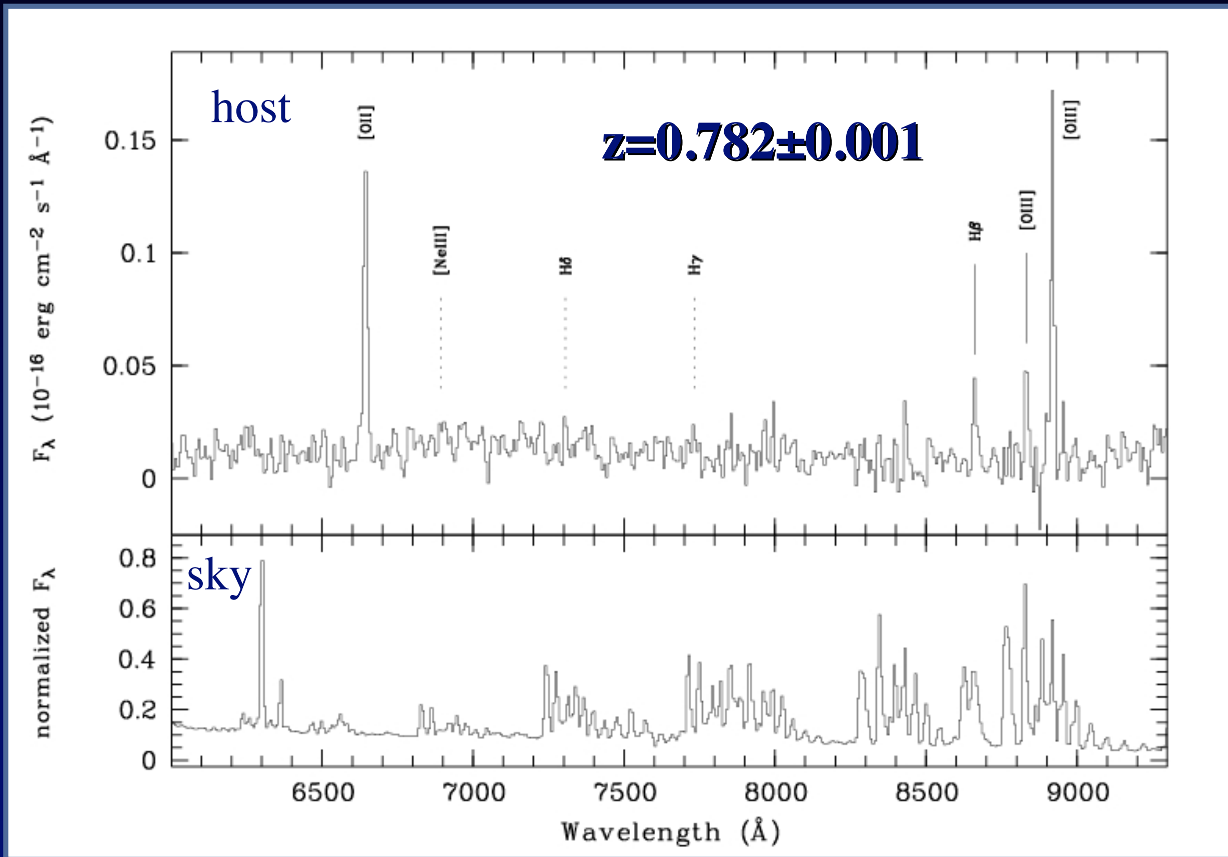
XRFs similar to LGRBs except lower peak energy

Models:
(e.g. high baryon loading,
wide opening angle jet,
off-axis bursts,
high redshift)



distance scale important, but only two XRFs with redshift (z=0.251, z=2.66)

Host spectroscopy with VLT/FORS2

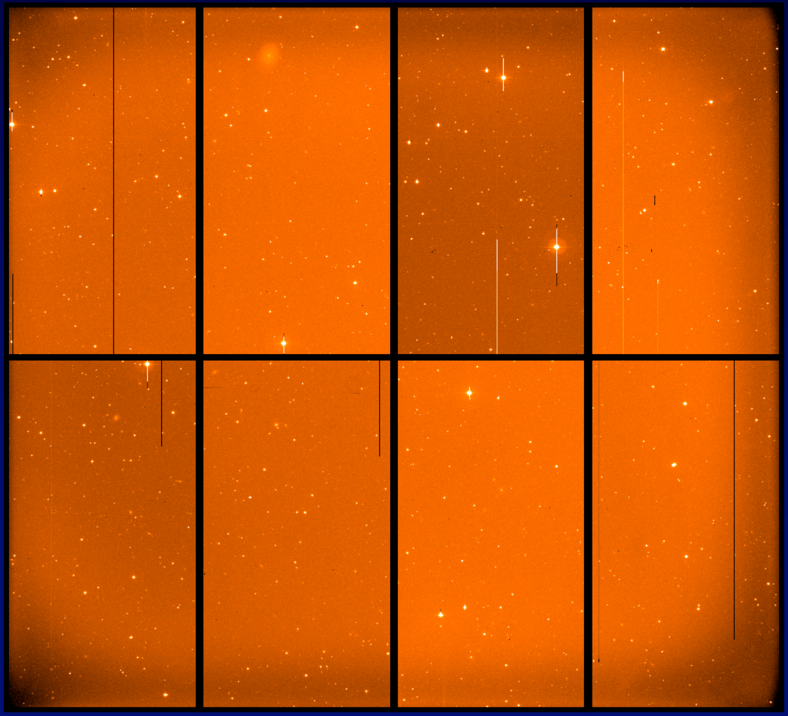


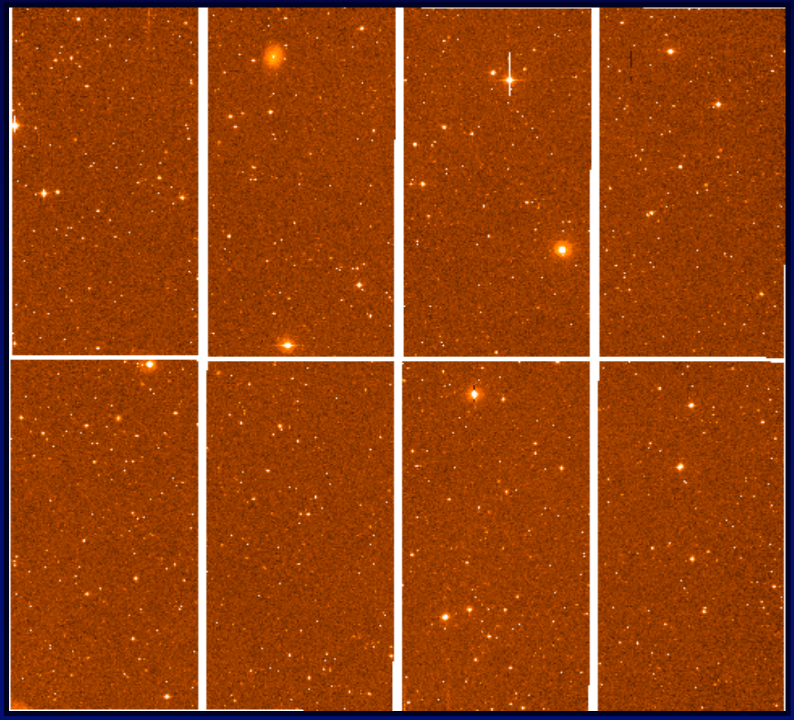
- $E_{peak,rest}$ = 60 keV
- actively star forming galaxy (20 $M_\odot$ yr^{-1})
- Z=10-60% $Z_\odot$
- mass: 2×10^{10} $M_\odot$

Population 3:

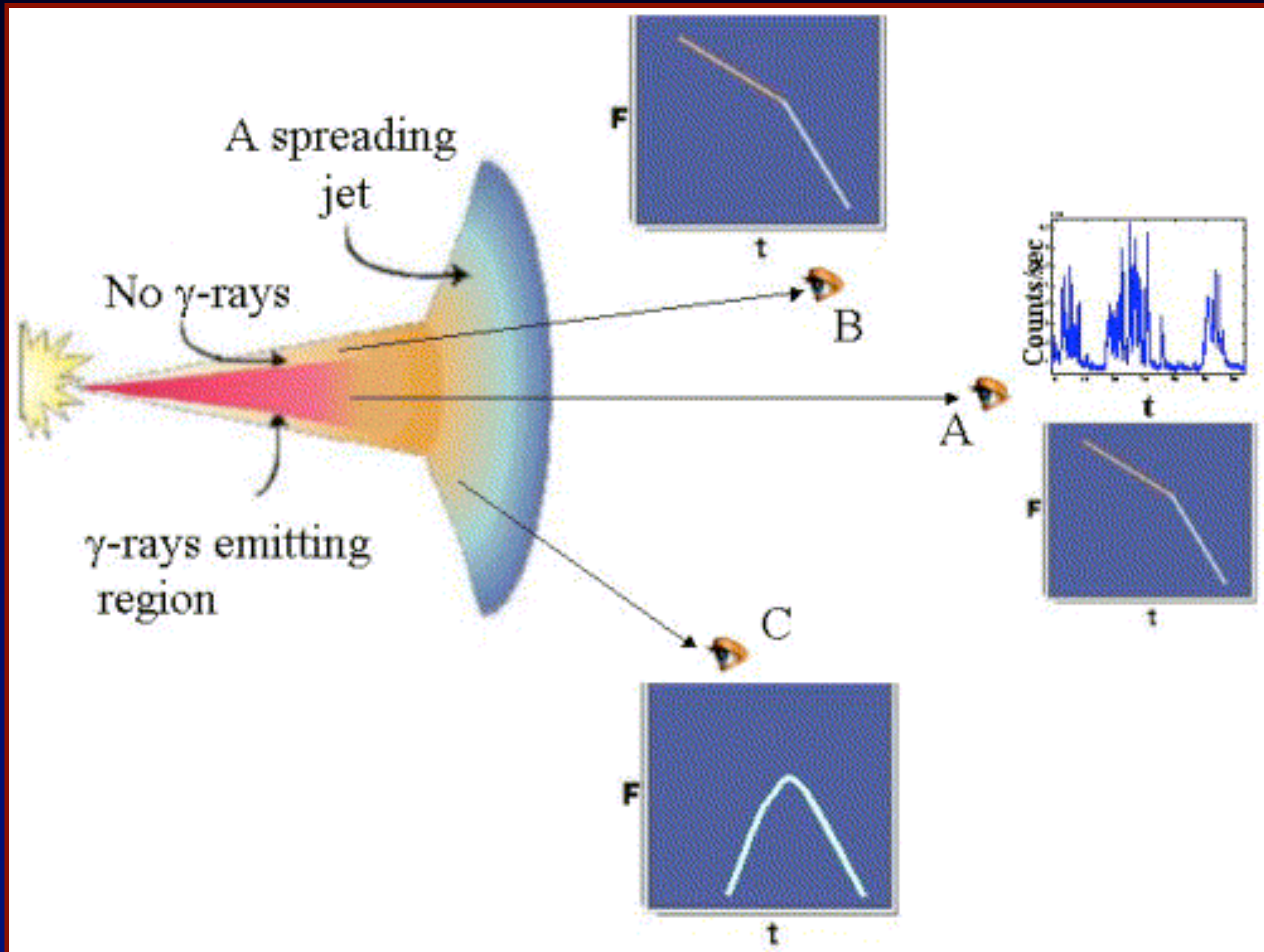
Orphan Afterglows with WFI

[AR, Greiner & Schwarz, A&A in press (2006)]



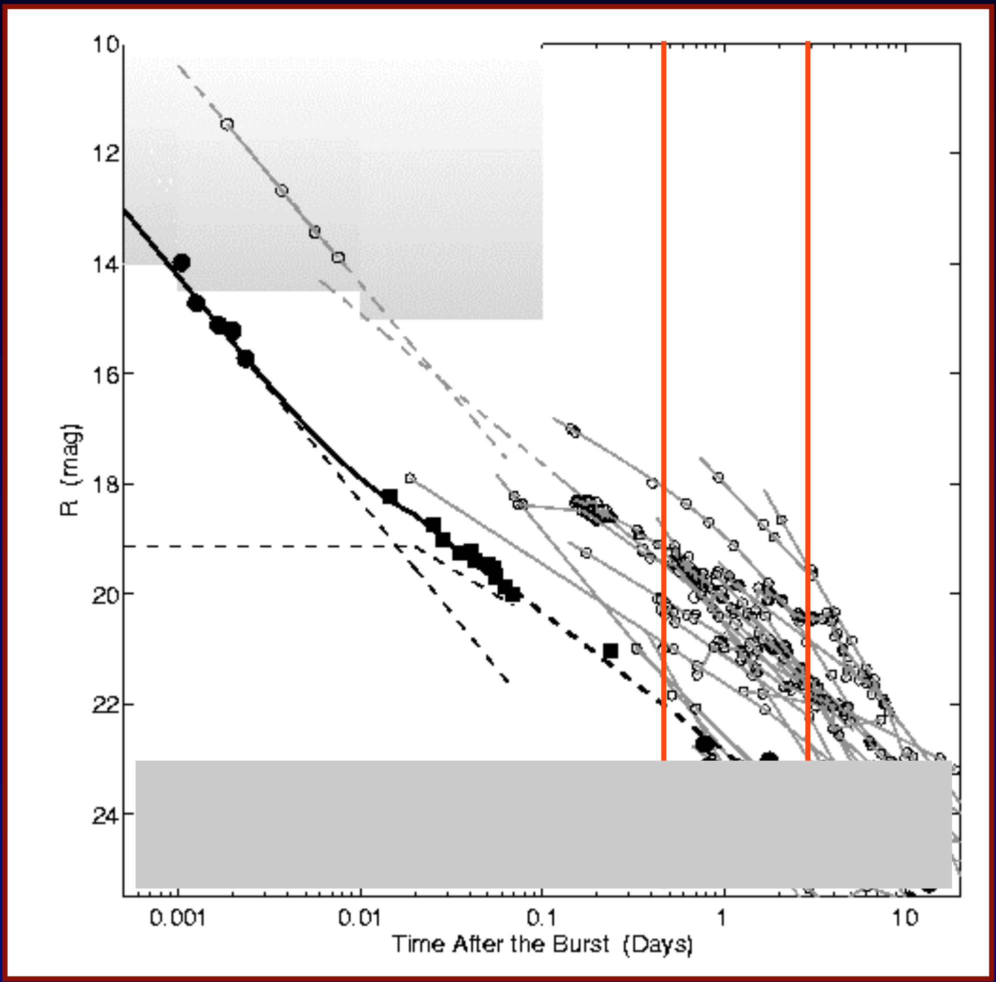


On-axis and off-axis orphan afterglows



(Nakar & Piran 2003)

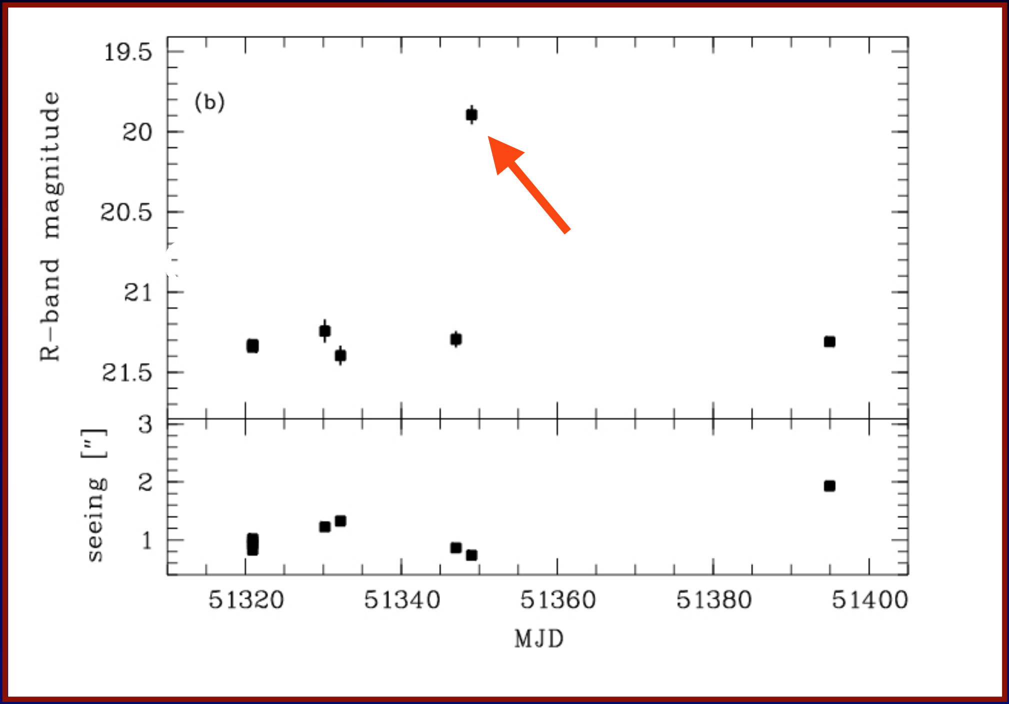
Strategy, Instrumentation

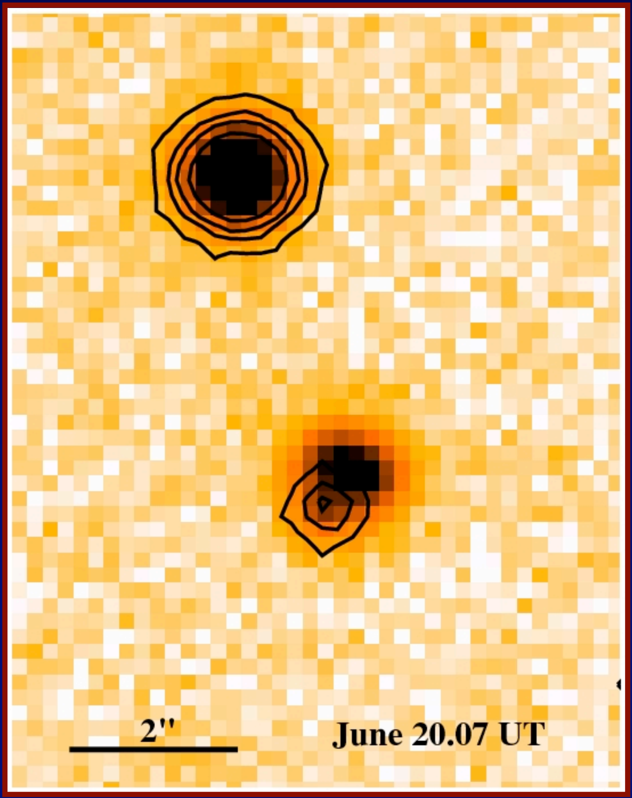


(Fox et al 2003)

- WFI MPG/ESO 2.2m
- 12 deg^2 in up to 25 nights (700 images, 420s)
- R<23 (10σ)
- IRAF/WIFIX pipeline
- Differential photometry (ΔR>0.75 mag)
- 12000 candidates ⇒ 4 transient sources

Candidate transients - #1





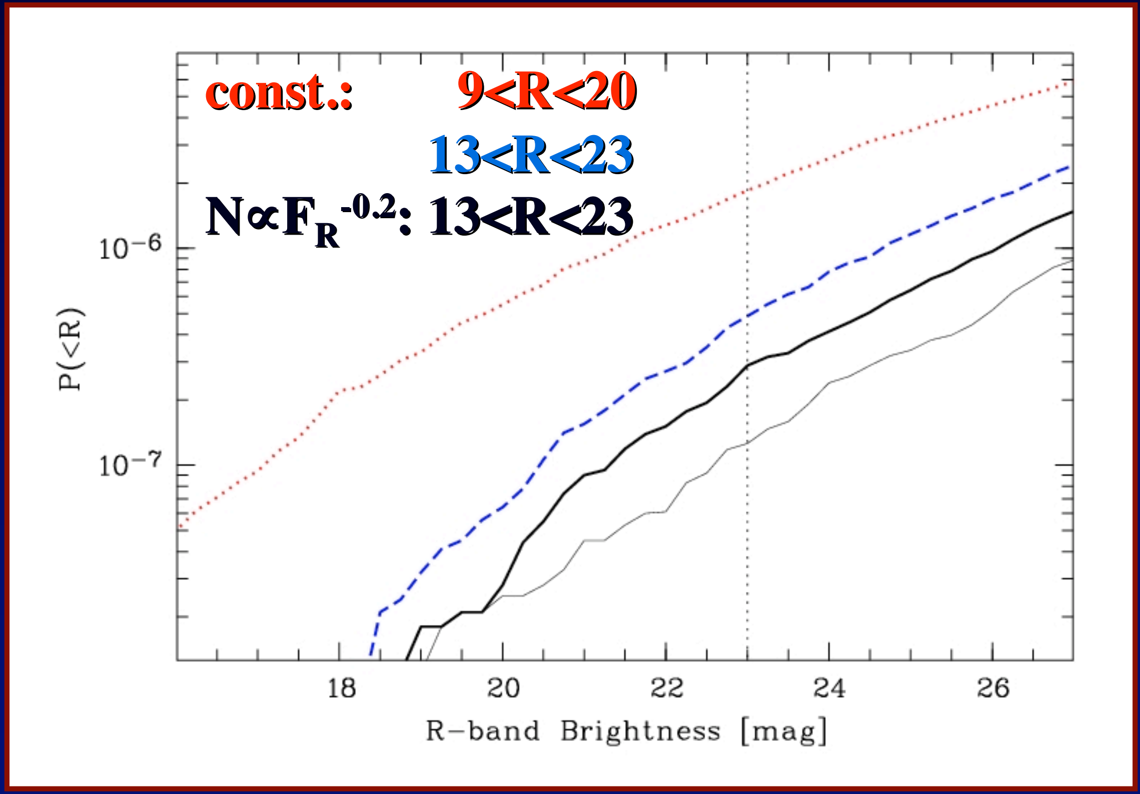
- ΔR~1.5 mag in 2 days
- flare star, supernova, afterglow ?
- not associated with a triggered burst

[Jan 25 2006]

Afterglow detection efficiency

$F_R \propto t^{-\alpha 1}$: $t \leq t_b$ $0.4<\alpha_1<1.8$; 0.4 days$<t_b<$4 days

$\propto t^{-\alpha 2}$: $t > t_b$ $1.4<\alpha_2<2.8$ (Zeh et al. 2005)



$N_{MC} \propto P^{-1}$ ~10^7 (R_{lim}=23)

Collimation

$f_c = N_A / N_\gamma < N_{MC} / N_\gamma < N_{MC} / (N_{\gamma,obs} \cdot f_\gamma \cdot f_D \cdot f_S) < 12500$

$f_c < f_B < 75 \ldots 500$ **(Guetta et al. 2005; Frail et al. 2001)**

f_c : ratio of optically to γ-ray emitting area

N_A : rate of detectable on-axis OTs

N_γ : LGRBs with detectable OT

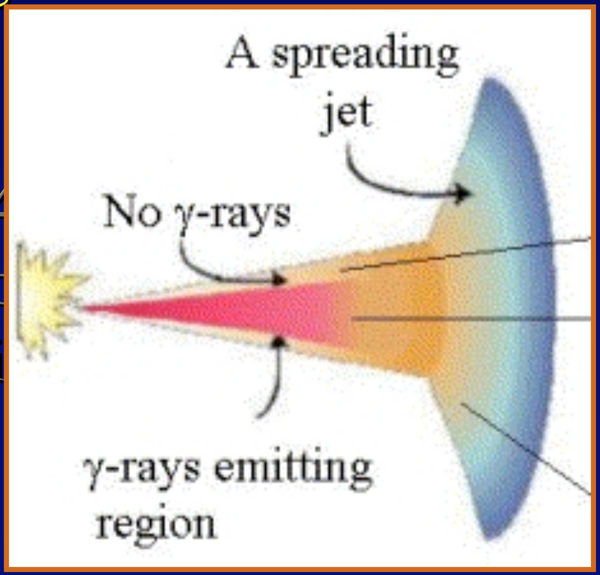
$N_{\gamma,obs}$: observed LGRB rate (BATSE: 44

f_γ : prompt emission completeness co

f_D : optically dim/dark bursts correcti

f_S : OTs of short bursts (~1)

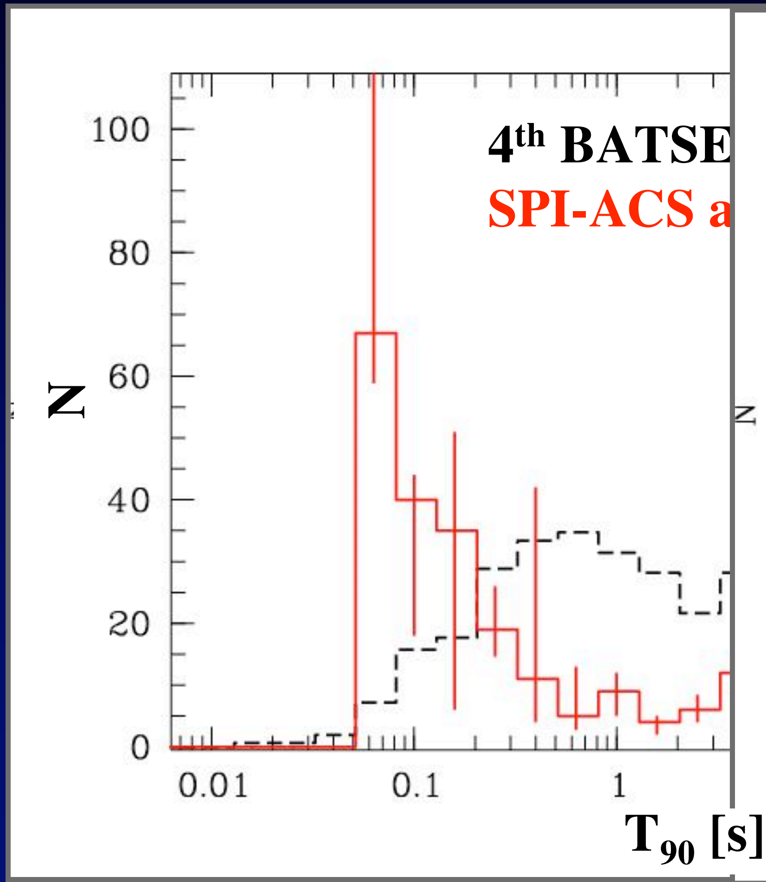
f_B : γ-ray beaming correction

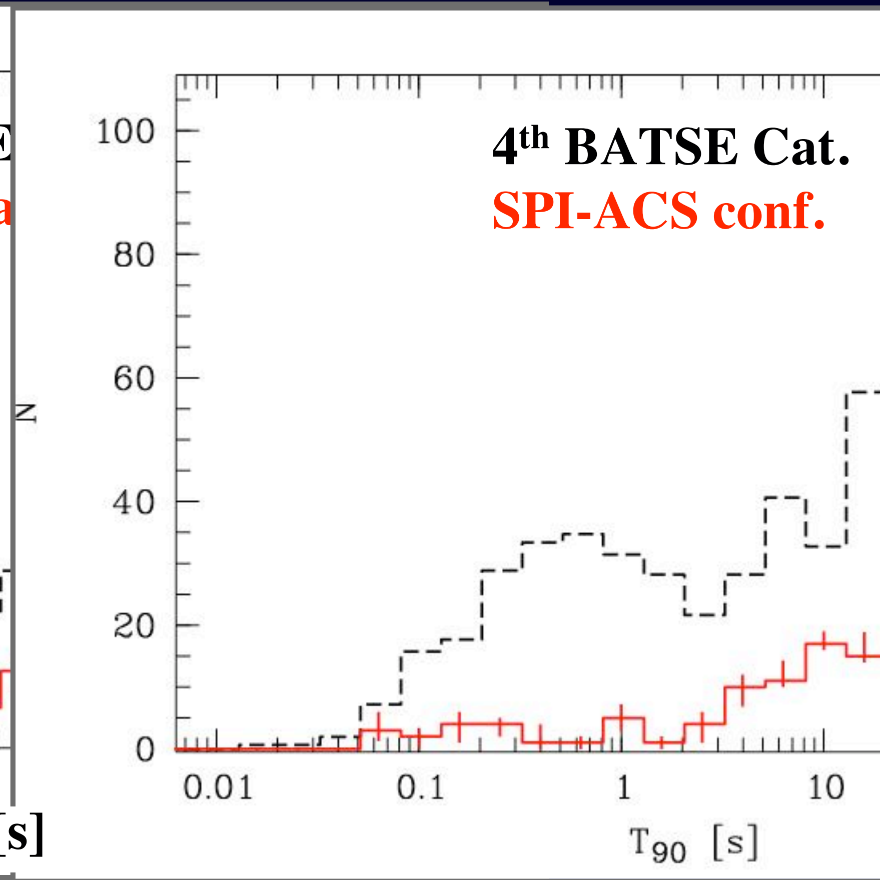


Summary

prompt γ-emission: INTEGRAL SPI-ACS	• burst trigger pipeline • web- and catalogue maintenance • analysis and interpretation	• very short events from cosmic ray interaction • deficit of SHB • *AR et al. 2005a*
afterglows and host galaxies: GRB 030528	• PI ESO/VLT proposal • imaging & spectroscopy data reduction • analysis and interpretation	• afterglow discovery • redshift and host properties • *AR et al. 2004, 2005b*
orphan afterglows: Wide-Field Imaging Survey	• pipeline for data reduction and analysis • interpretation and Monte Carlo simulations	• pilot survey • 4 transient sources • *AR et al. 2006* • Hubble/Chandra fellow application

T_{90} Distribution vs BATSE

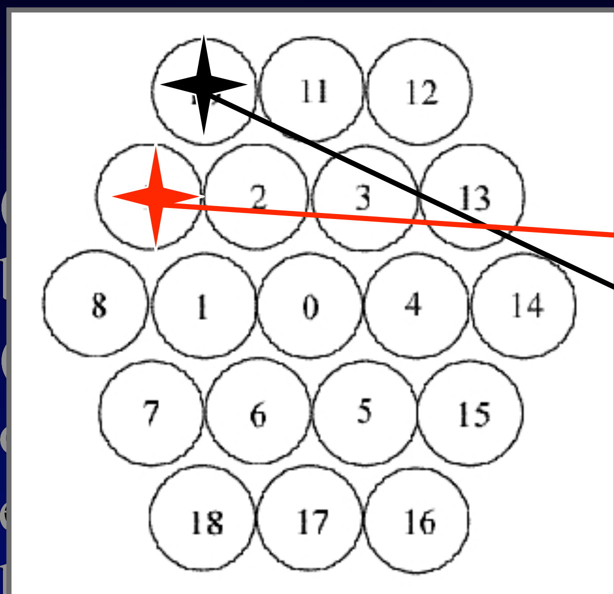


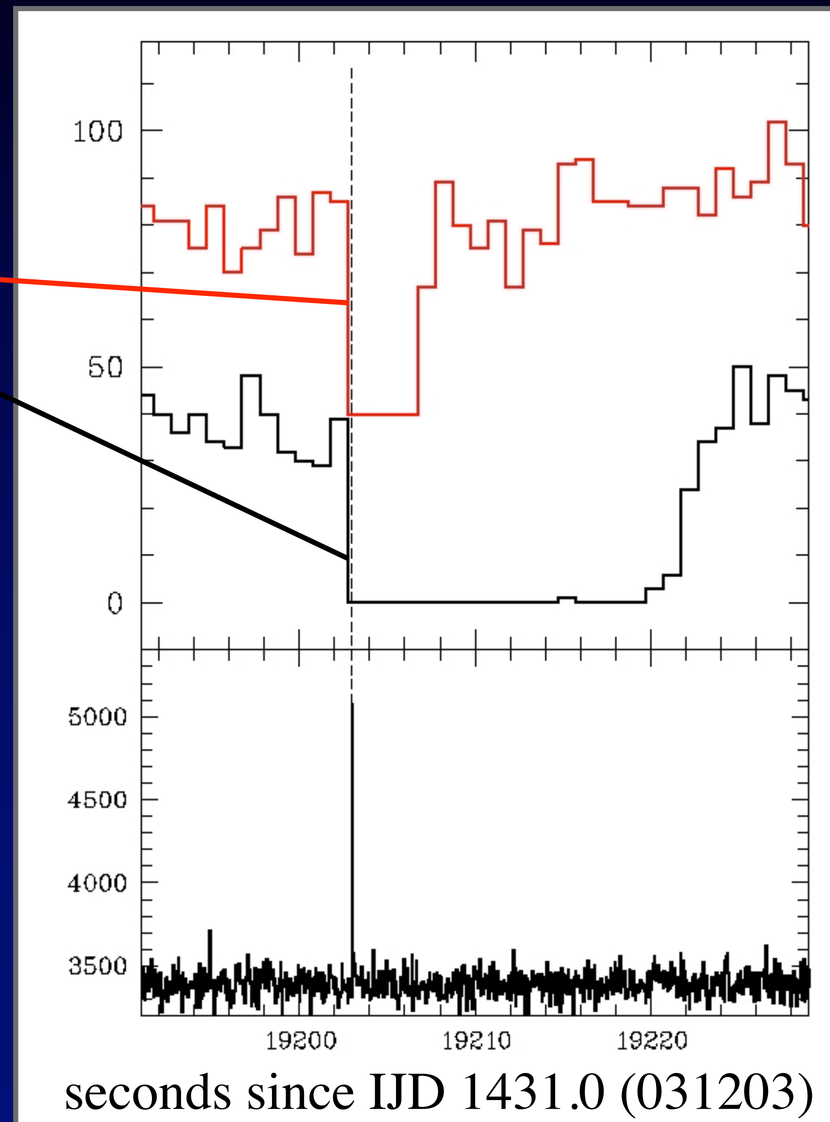


confirmed: ~1/10

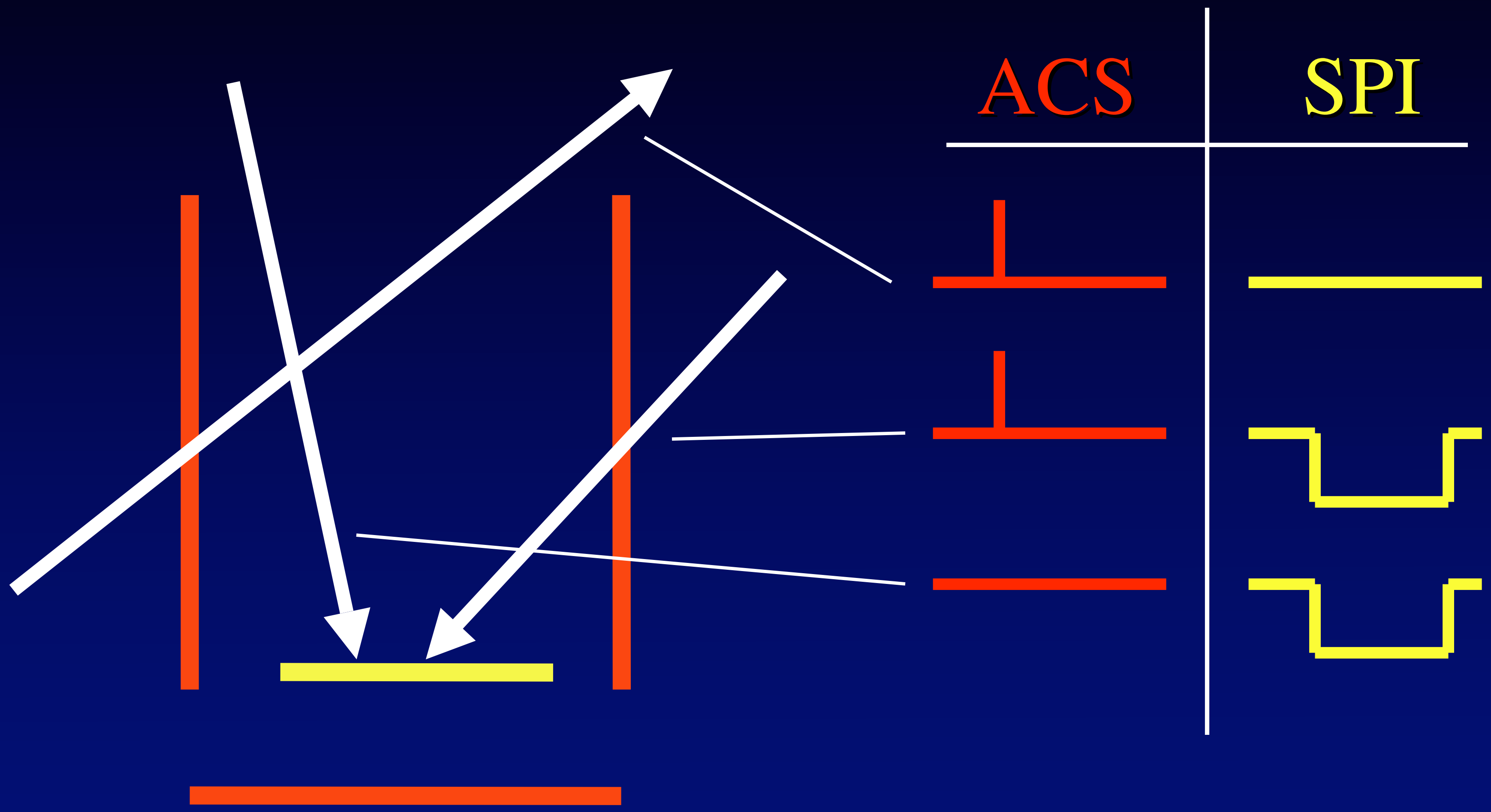
Origin of events with T_{90} < 0.25s

1. ... ort
2. ...
3. ... al
   Hawking radiation ?
4. instrumental effects or cosmic ray interactions ?



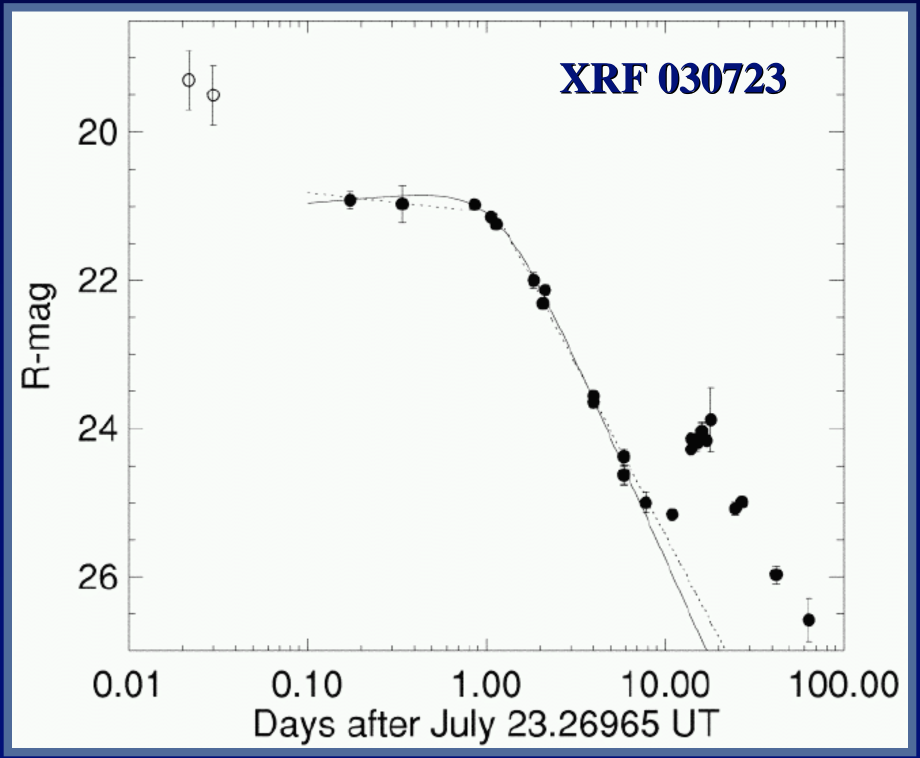


Scenario: cosmic ray interactions



X-ray Flashes - late

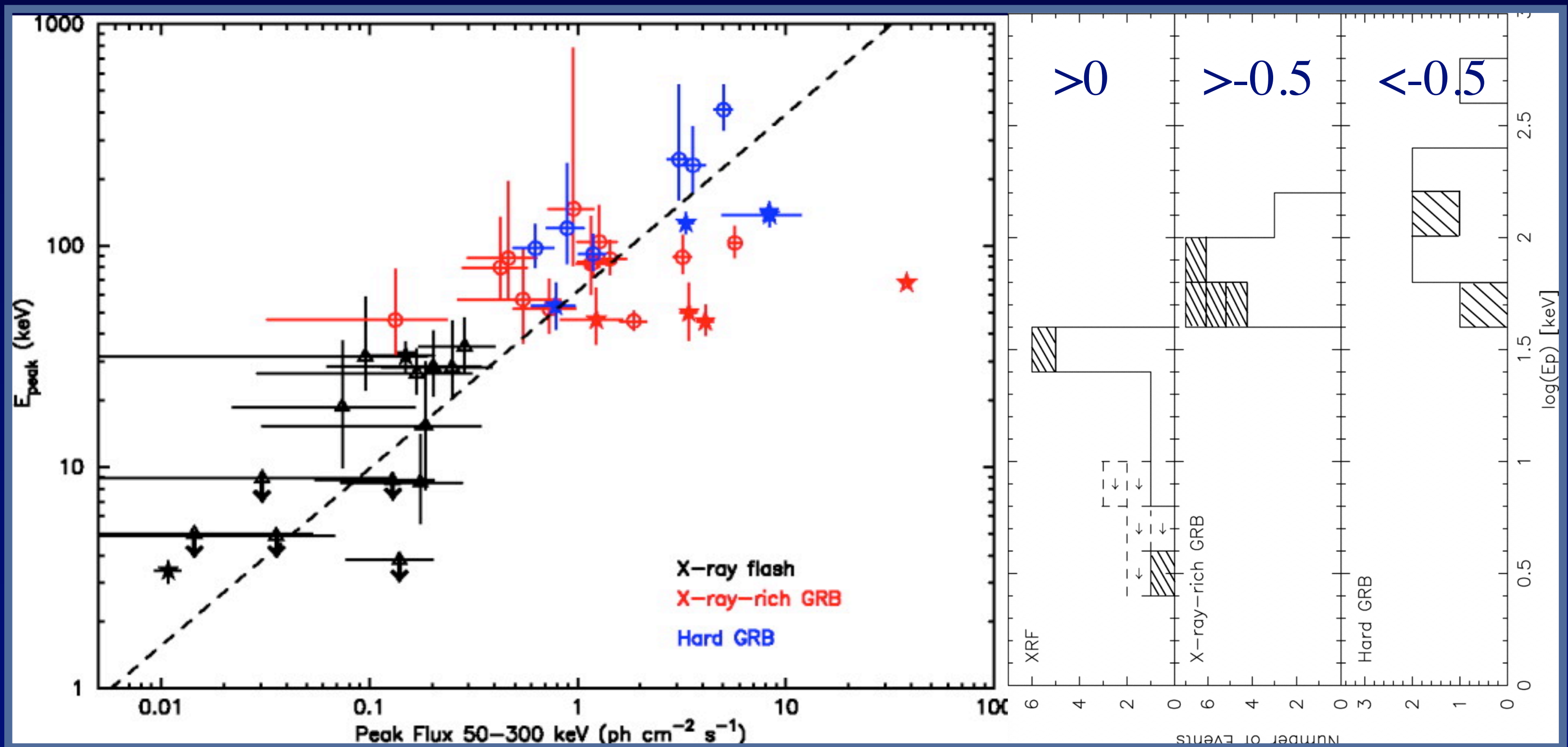
- XRFs/XRRs/LGRBs form continuum
- X-ray, optical, radio afterglows
- underlying supernova (Fynbo et al. 2003, Soderberg et al. 2005)
- late type host galaxies (e.g. Bloom et al. 2003)



(Fynbo et al. 2003)

X-ray Flashes - prompt

- BeppoSAX WFC (Heise et al. 2001)
- similar to LGRBs except E_{peak}
- HETE-2 observer frame classification:
  $\log(S_x(2\text{-}30\ \text{keV}) / S_\gamma(30\text{-}400\ \text{keV}))$ (Sakamoto et al. 2004)



(Sakamoto et al. 2005)

X-ray Flashes - models

- high baryon loading in the ejecta (e.g. Dermer et al. 1999)
- wide opening angle jet
- low contrast between the bulk Lorentz factors of colliding relativistic shells (Barraud et al. 2005)
- off-axis bursts (e.g. Yamazaki et al. 2002)
- high redshift (e.g. Heise et al. 2001)

Distance Scale is important:

XRF 020903: z=0.251 (Soderberg et al. 2004)
XRF 030429: z=2.66 (Jakobsson et al. 2005)

ESO proposal for spectroscopy of host of XRF 030528 written and accepted

030528 in the rest frame

030528:	$E_{peak,obs} = 32\pm5$ keV	$\Rightarrow$	$E_{peak,rest} = 57\pm9$ keV
	$\log(S_x/S_\gamma)_{obs} = 0.04$	$\Rightarrow$	$\log(S_x/S_\gamma)_{rest} = -0.17$
	XRF_{obs}	$\Rightarrow$	XRR_{rest}
030429:	XRF_{obs}	$\Rightarrow$	XRR/GRB_{rest}
020903:	XRF_{obs}	$\Rightarrow$	XRF_{rest}

⇒Do we need the XRF/XRR/GRB classification ?

⇒ if yes: then in the rest frame !

⇒ What about short XRFs ?

Summary

SPI-ACS:

- trigger software development
- T_{90}<0.25s population ⇒ cosmic ray interactions
- 236 GRBs (T_{90}≥0.25s) ⇒ 1 every 3 days
- defizit of short duration GRBs

GRB/XRF 030528:

- discovery of near-IR afterglow and host galaxy
- ESO/VLT proposal for host study written+accepted
- spectroscopic redshift (z=0.782)

Hier tabelle!!

Host Properties

- metallicity from emission lines: $R_{23}=\log(([OIII]+[OII])/H_\beta)$
  $0.1<Z<0.6$
- absolute magnitudes

	M_{AB} [mag]	L/L_*
U	-20.5 ± 0.1	1.2 ± 0.2
B	-20.7 ± 0.1	0.5 ± 0.1
R	-21.1 ± 0.1	0.35 ± 0.05
J	-21.4 ± 0.1	0.25 ± 0.05
K_s	-21.6 ± 0.1	0.17 ± 0.05

- stellar mass: $9\cdot10^9\ M_{sun}$ (Brinchman & Ellis 2000) to
  $2\cdot10^{10}\ M_{sun}$ (Bell et al. 2005)
- size: ~11 kpc

Summary - 3

- R-band survey for orphan afterglows ($12\ deg^2$ in up to 25 nights, R<23)
- 4 candidate transients (1x CV, 1x flare star, 1x dwarf nova, 1?)
- "ideal" survey: every two nights over 150 nights of $50\ deg^2$ (330, 2500) $\Rightarrow f_c < 500$ (75, 10)

Summary - 2

- discovery of near-IR afterglow and host galaxy of GRB/XRF 030528
- z=0.782
- observer frame XRF ⇒ rest frame XRR
- rest frame classification scheme required (if at all)
- Do we expect also short XRFs ?

Summary

- R-band survey for orphan afterglows (12 deg^2 in up to 25 nights, R<23)

- 4 candidate transients (1x CV, 1x flare star, 1x dwarf nova, 1?)

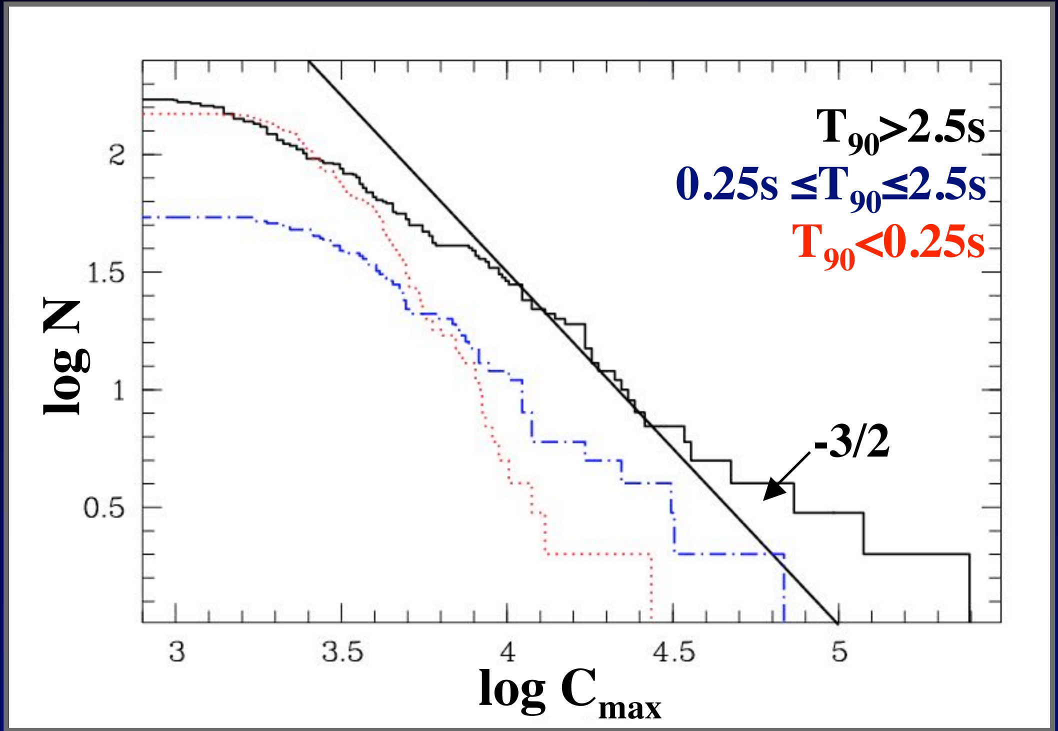
- "ideal" survey: every two nights over 150 nights of 50 deg^2 (330, 2500) $\Rightarrow f_c < 500$ (75, 10)

- 236 GRBs ($T_{90} \geq 0.25$s) $\Rightarrow$ 1 every 3 days (179 IPN confirmed)

- $T_{90} < 0.25$s population with different origin than $T_{90} \geq 0.25$s population $\Rightarrow$ cosmic ray interactions

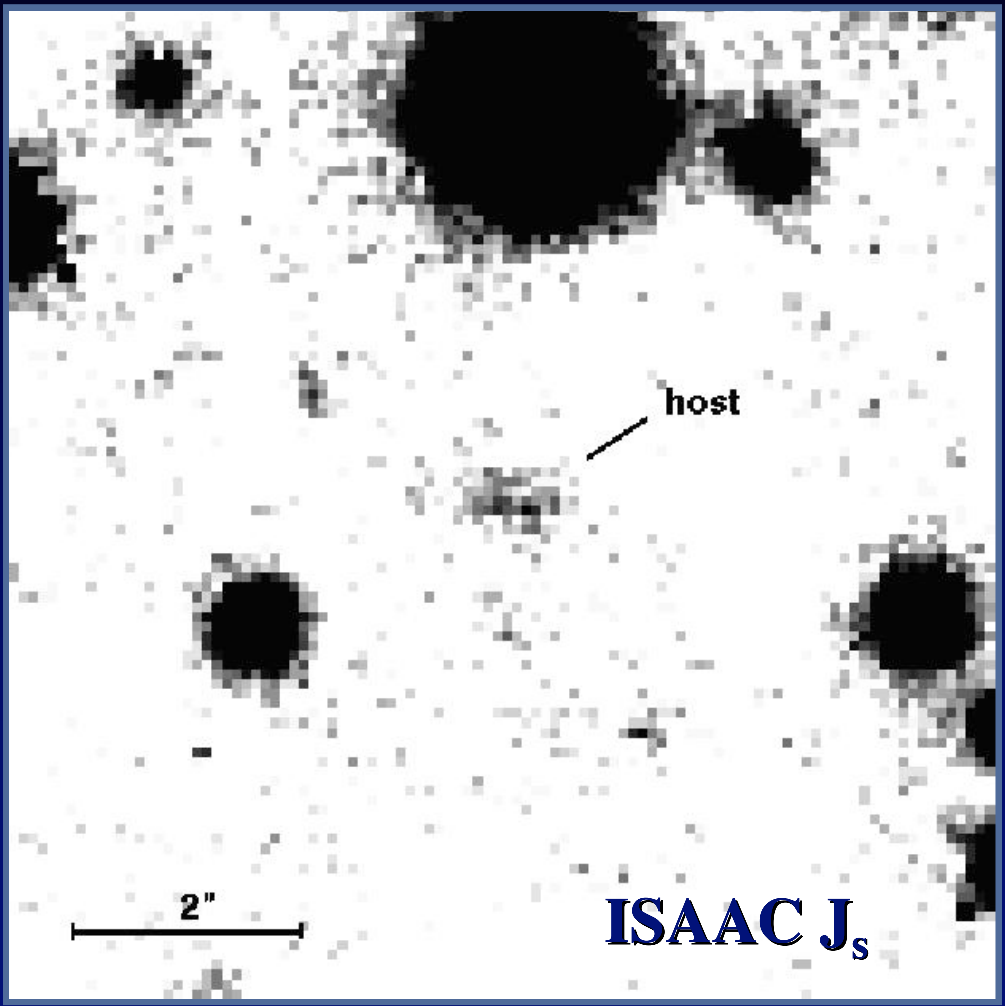
- discovery of near-IR afterglow and host galaxy of GRB/XRF 030528 at z=0.782

Intensity Distribution



	logN - logP	<V/V_max>
BATSE	(Fishman et al. 1994)	0.34
$T_{90}>2.5$s	-1.1	0.26
$0.25\text{s}\leq T_{90}\leq 2.5$s	-1.1	0.31
$T_{90}<0.25$s	-2.3	0.48

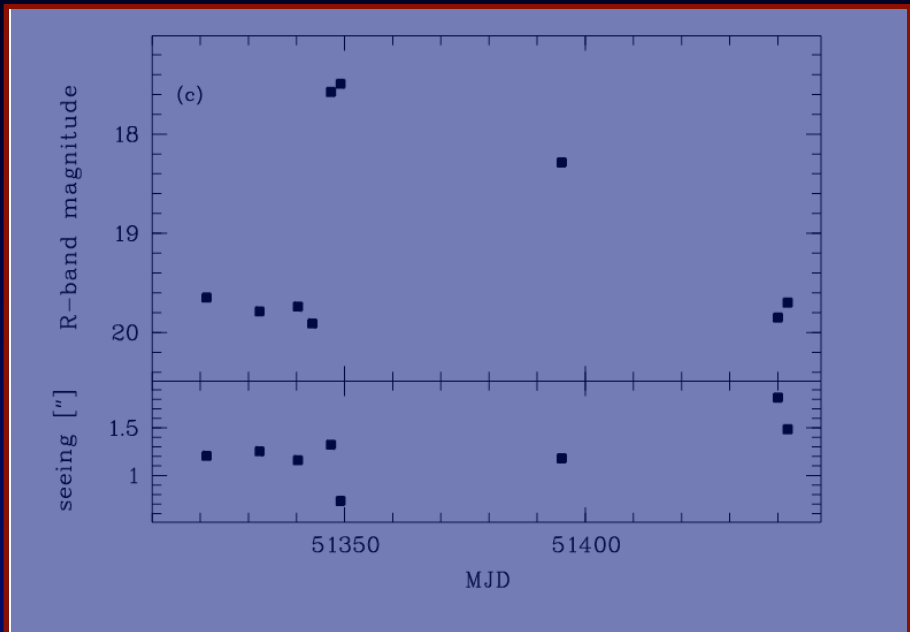
Host Galaxy - Photometry



$V = 21.9 \pm 0.2$
$R = 22.0 \pm 0.2$
$I = 21.3 \pm 0.3$
$J = 20.8 \pm 0.1$
$H < 20.3$
$K = 19.9 \pm 0.7$

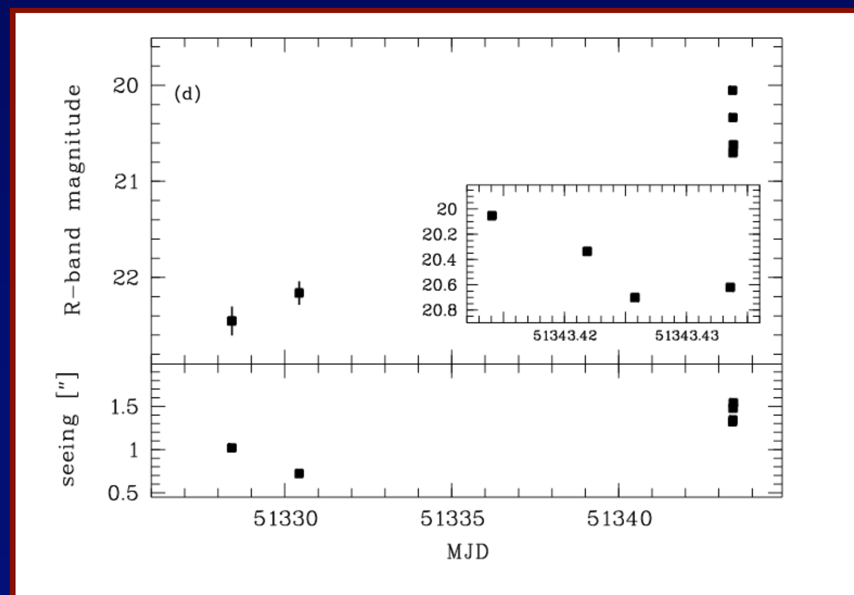
SED consistent with late type galaxy at z<4

Candidate transients - #2

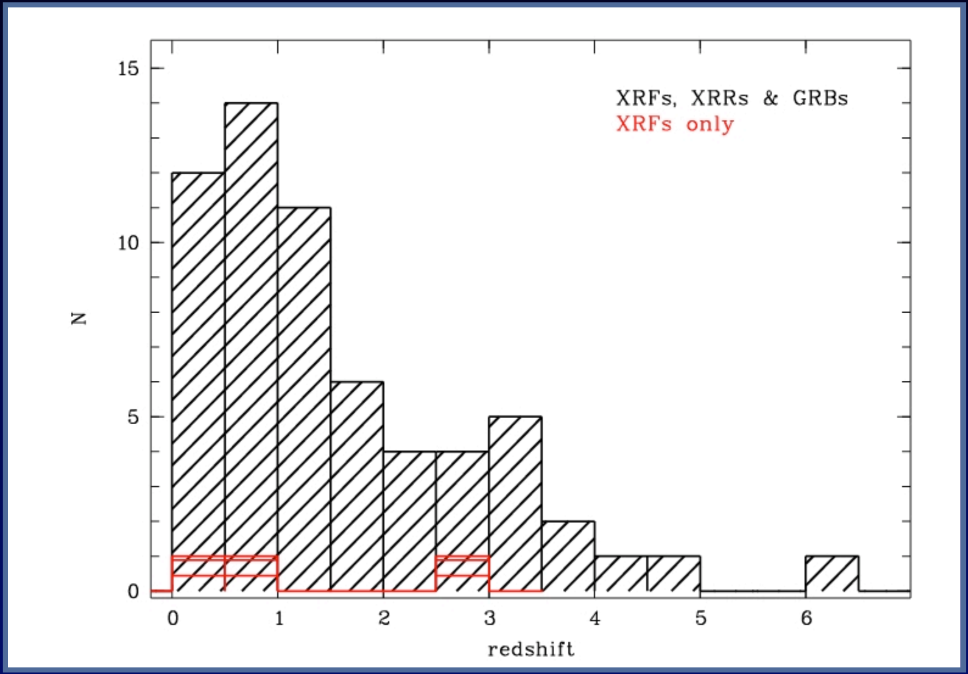


- ΔR=2.4 mag in ~2 days
- faint ROSAT source
- dwarf nova ?

- rise: ΔR=1.9 mag
- decline: ΔR=0.7 mag in 20 min
- flare stare, afterglow ?



030528 in the rest frame



030528: $E_{peak,obs}$ = 32±5 keV ⇒ $E_{peak,rest}$ = 57±9 keV

$\log(S_x/S_\gamma)_{obs} = 0.04$ ⇒ $\log(S_x/S_\gamma)_{rest} = -0.17$

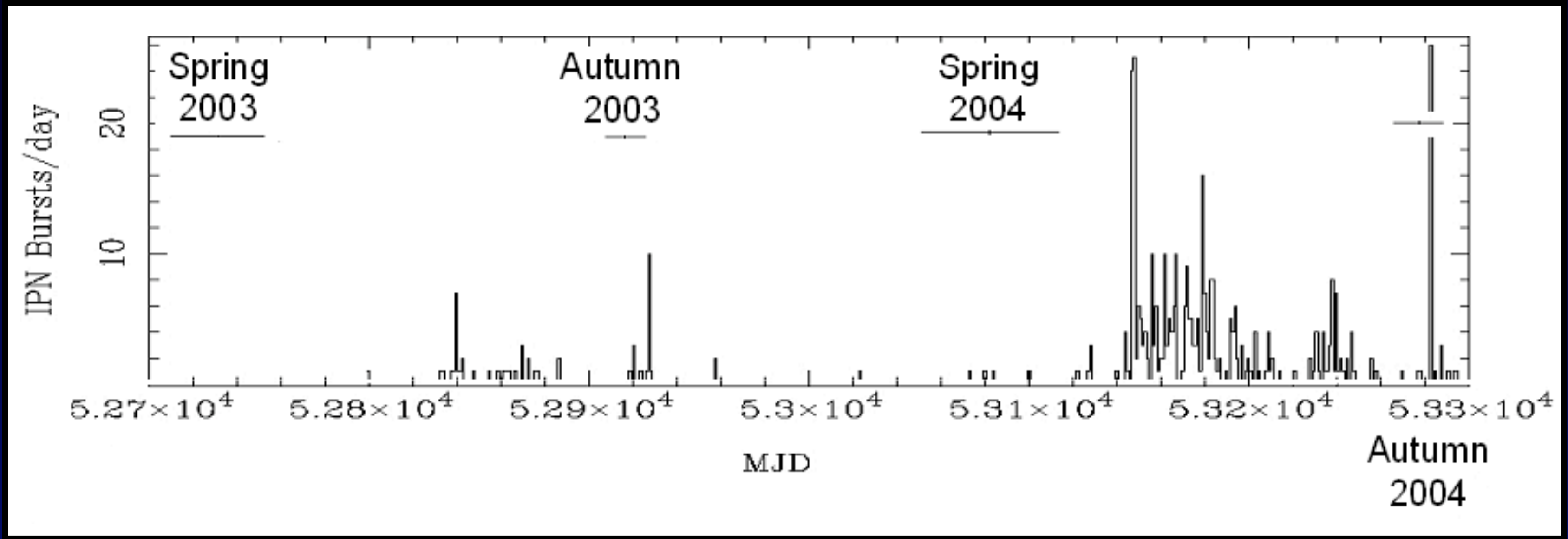
XRF_{obs} ⇒ XRR_{rest}

030429: XRF_{obs} ⇒ XRR/GRB_{rest}

020903: XRF_{obs} ⇒ XRF_{rest}

The giant flare of SGR 1806-20 on Dec 27, 2004

(Mereghetti, Götz, von Kienlin, AR et al. 2005, ApJL in press)

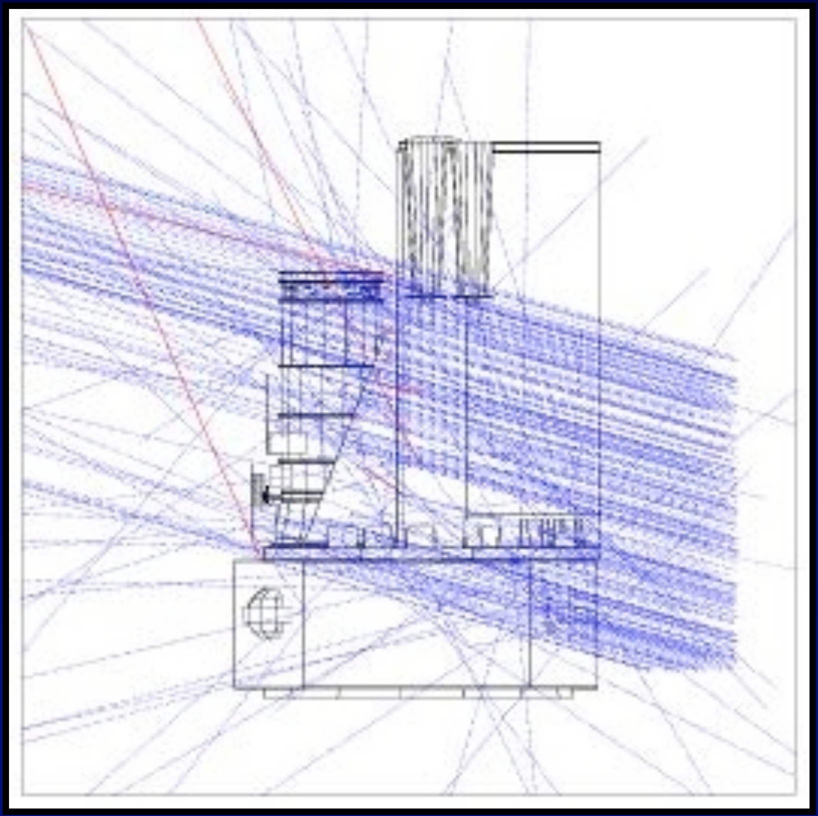


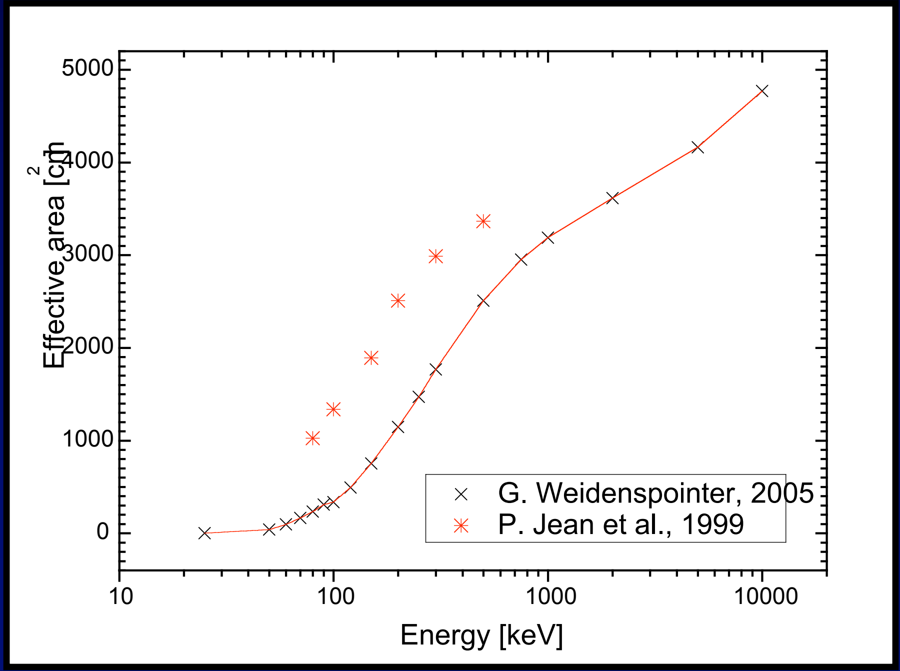
(Mereghetti et al. astro-ph/0411695)

- increasing level of activity
- two strong clusters with 10^{-4} erg cm^{-2} on Oct 5, similar to SGR 1900+14 three months before giant flare in 1998 (Golenetskii et al. 2004)

Effective Area for Dec 27, 2004 flare

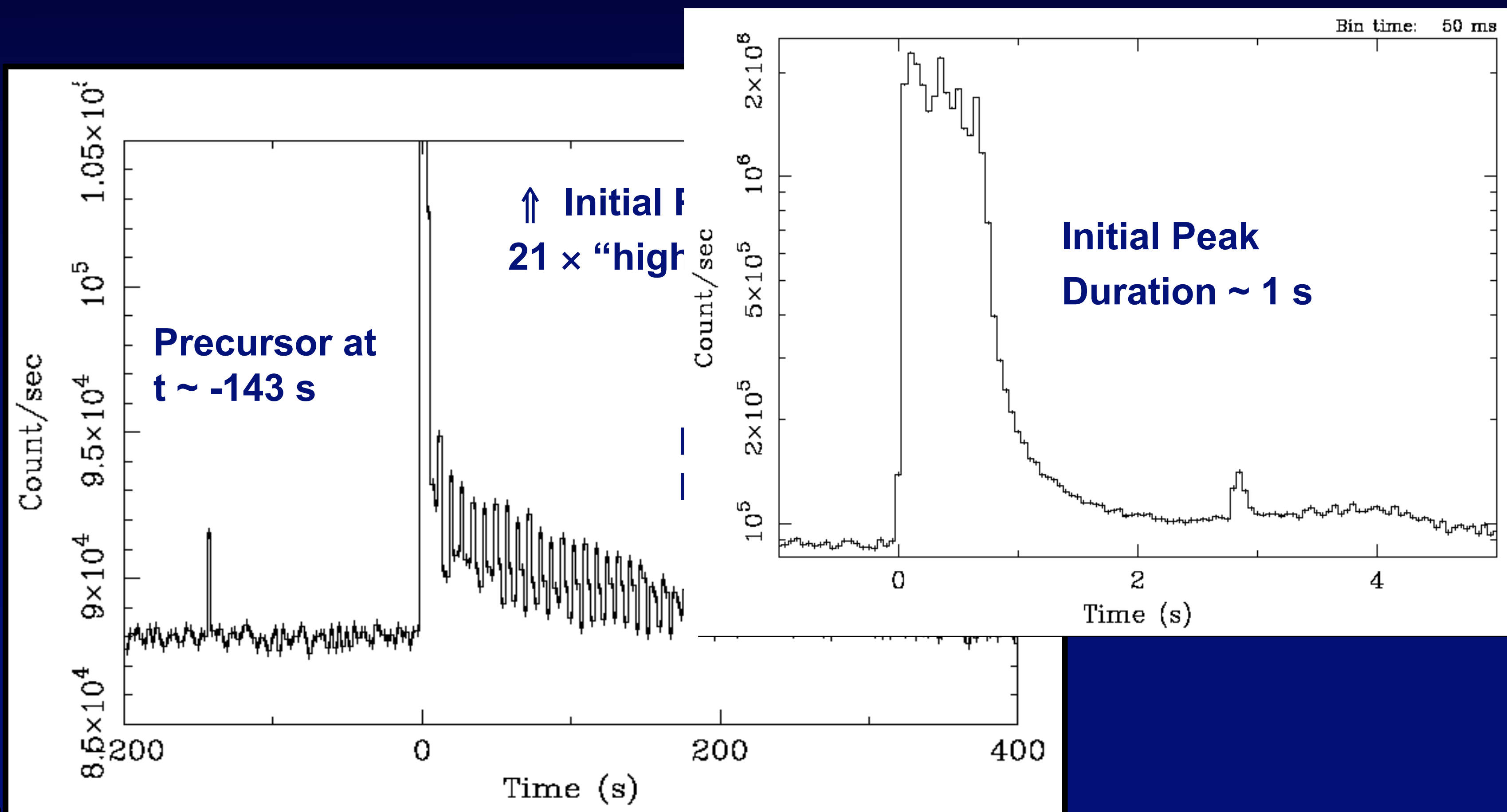
- GEANT simulation (by G. Weidenspointer)
- known spectral shape: conversion factor
  1 SPI-ACS count s^{-1} ~ 4.3×10^{-10} erg cm^{-2} s^{-1} (kT=30keV)





SPI-ACS light curve

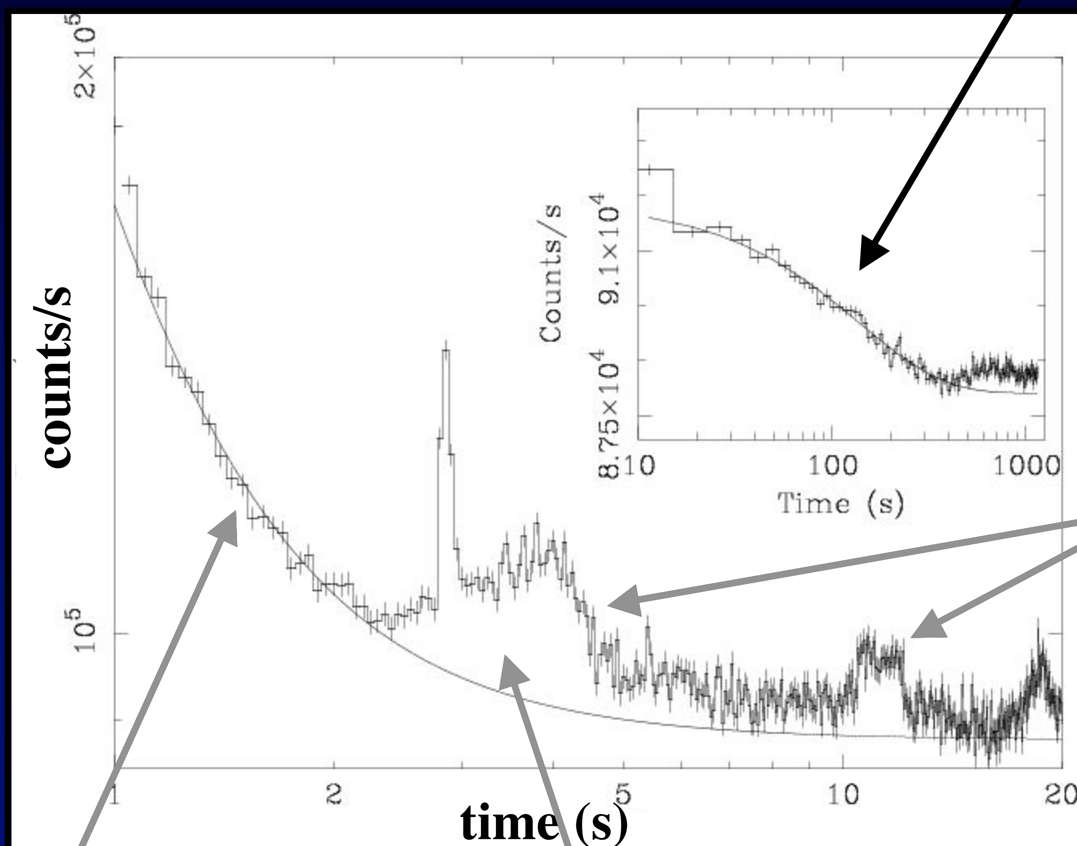
- precursor: S (kT_{br}=15keV, E>80keV) = 4.4×10^{-6} erg cm^{-2}
- initial peak: 99% dead time



Light curve decay

15-400s: $F \propto e^{-t/138s}$

S (kT_{br}=30keV) = 2.6×10^{-4} erg cm^{-2}



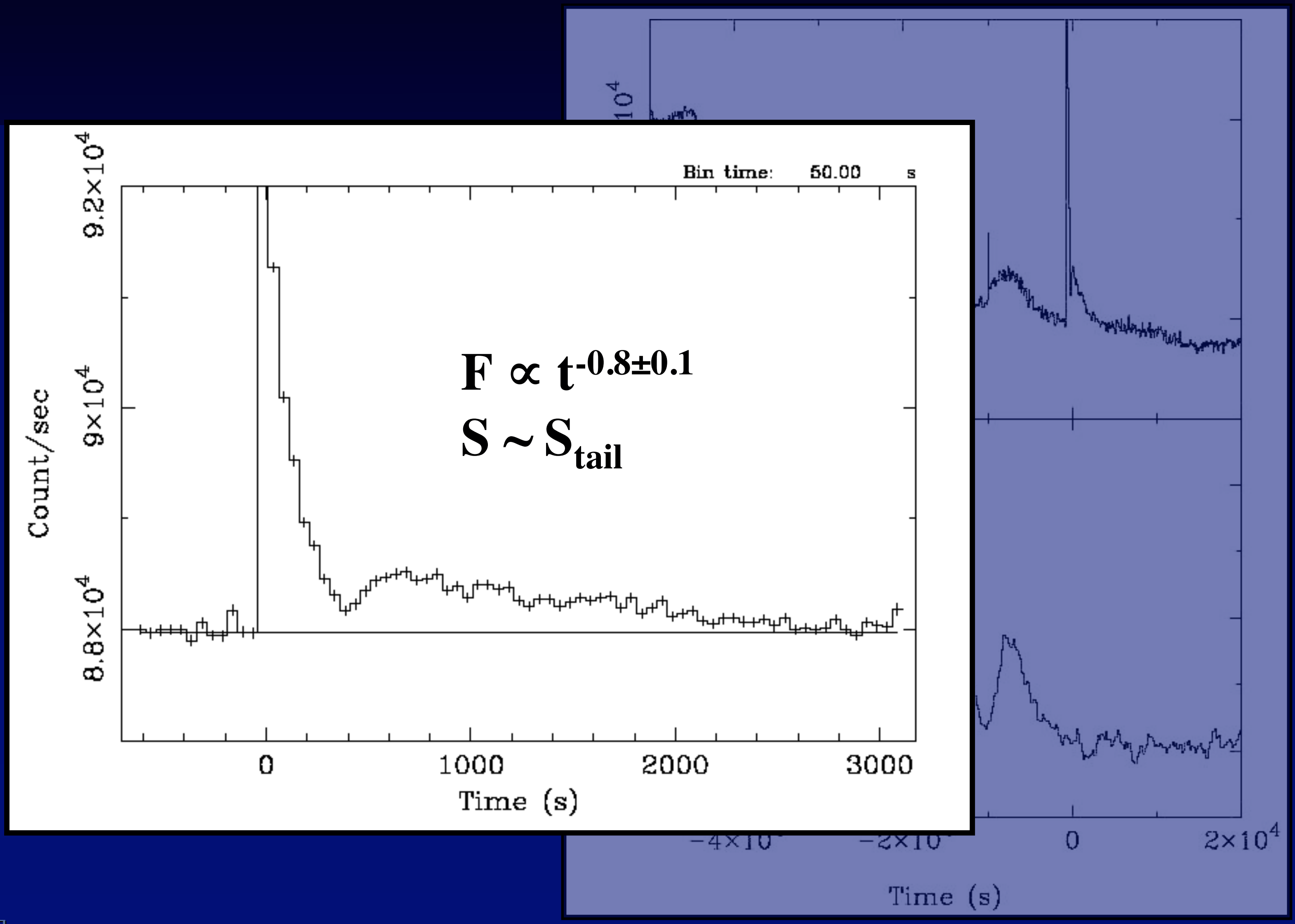
7.56s pulsation

1.2-2.2s: $F \propto t^{-2.1\pm0.1}$

moon reflection

(Helicon-Coronas-F (Mazets et al. 2005))

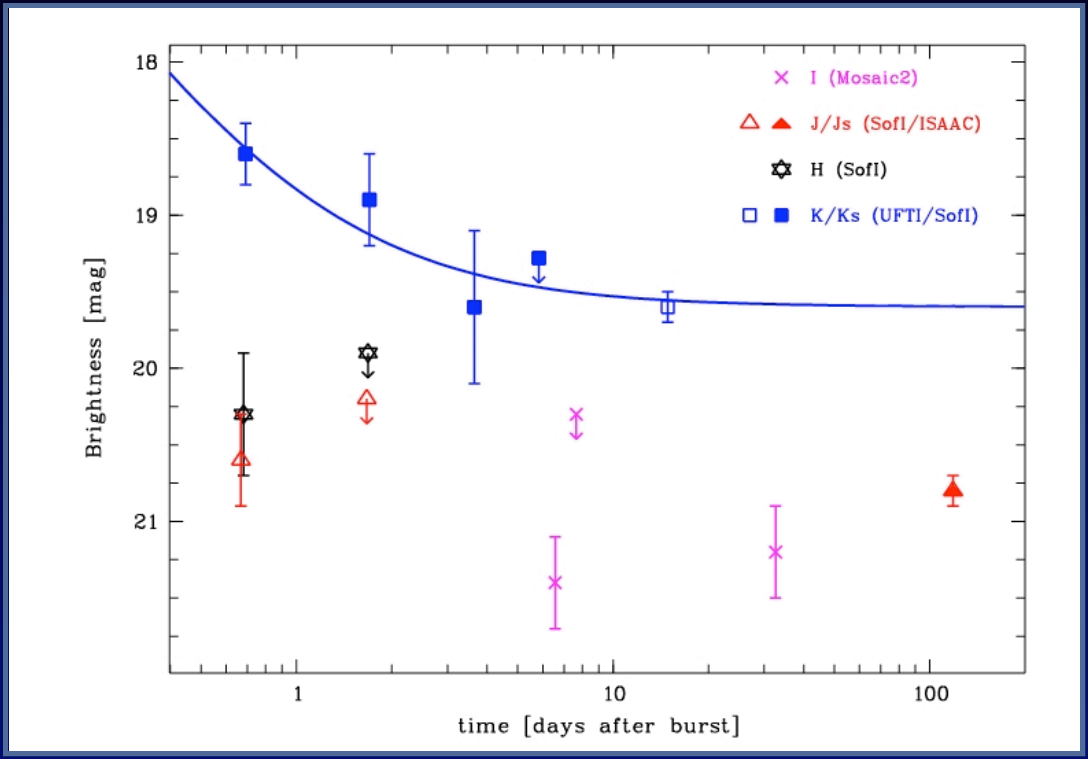
Late time component



$F \propto t^{-0.8\pm0.1}$

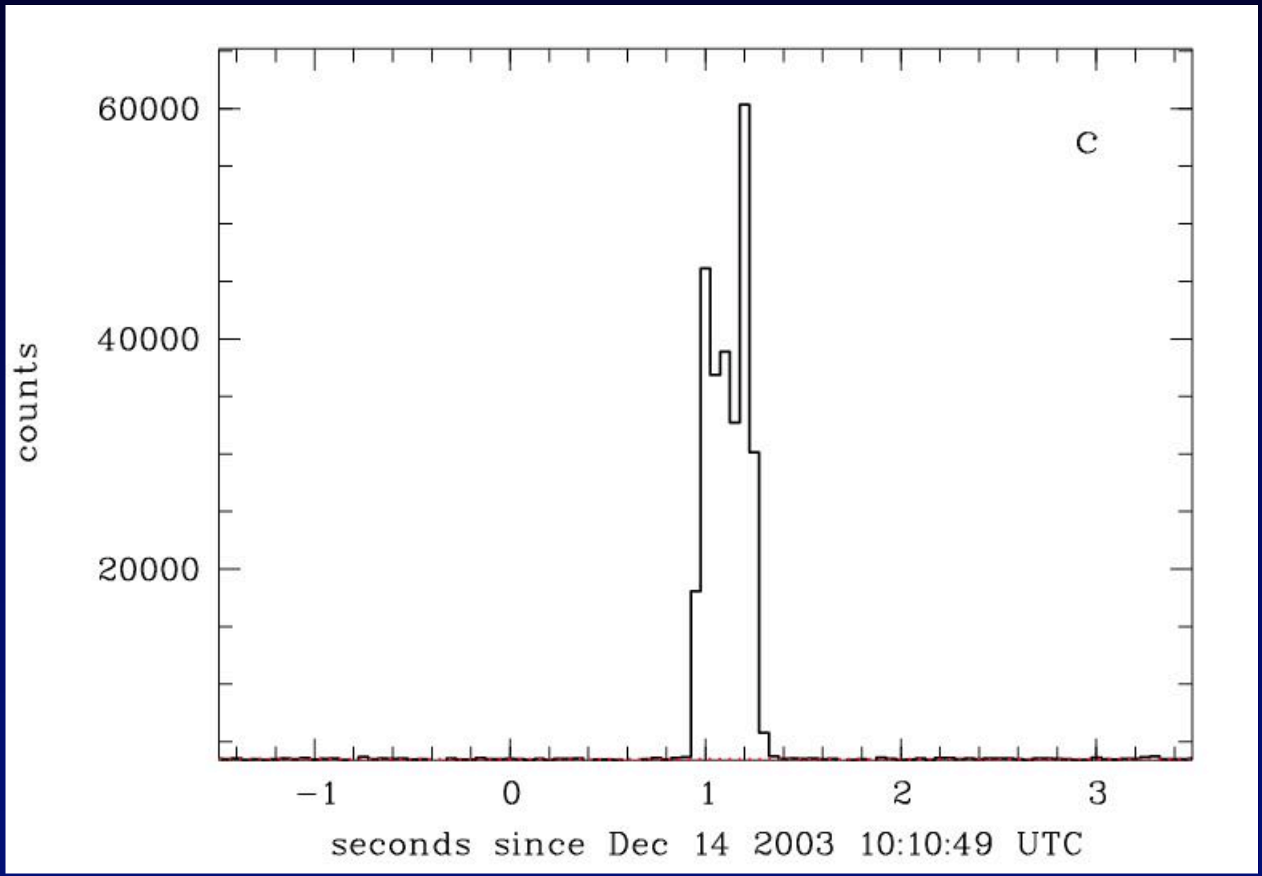
$S \sim S_{tail}$

Afterglow photometry



$F_K \propto t^{-1.2} \bullet \nu^{-(>0.4)}$

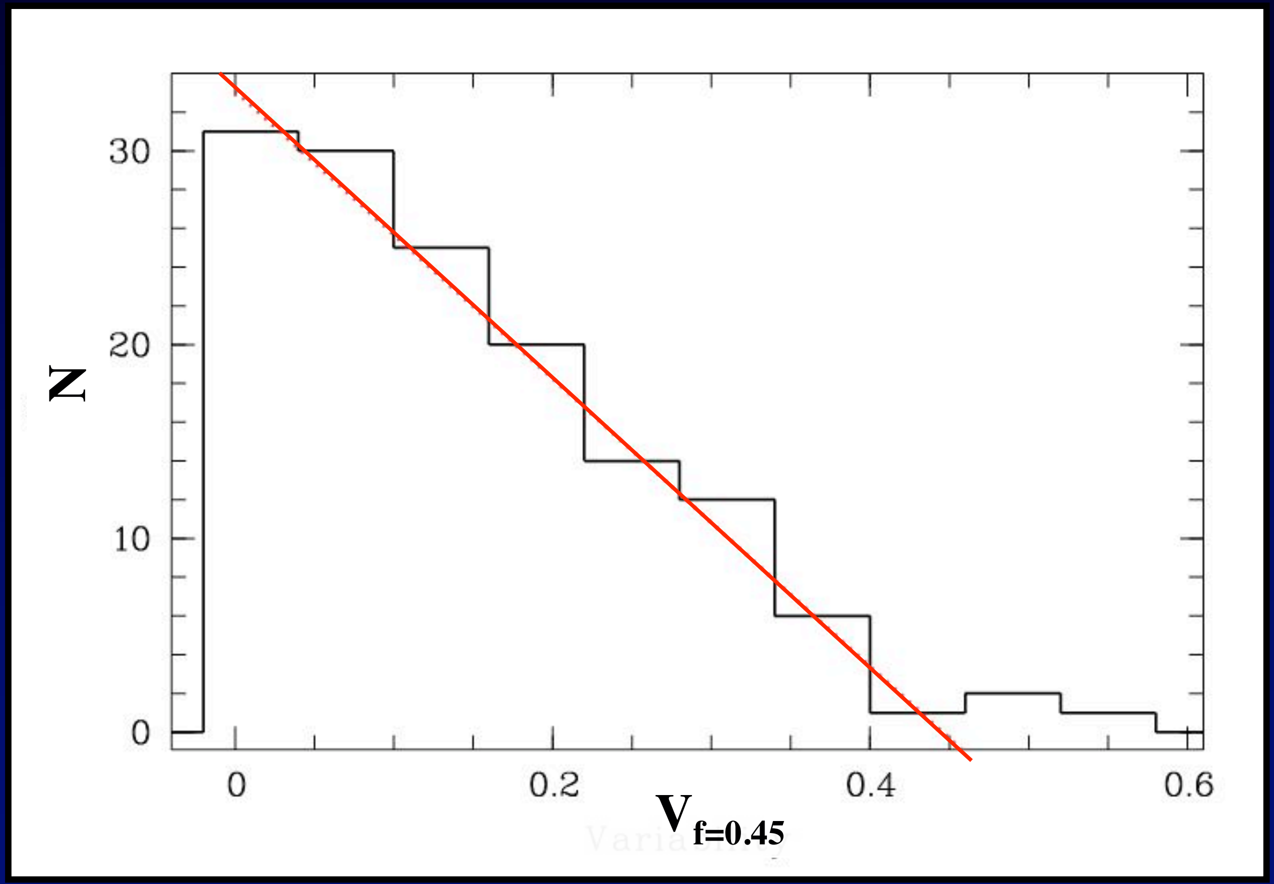
	expected [mag]	observed [mag]	
H	19.5	20.6 ± 0.3	$A_V > 2$ mag
J	20.4	20.3 ± 0.4	



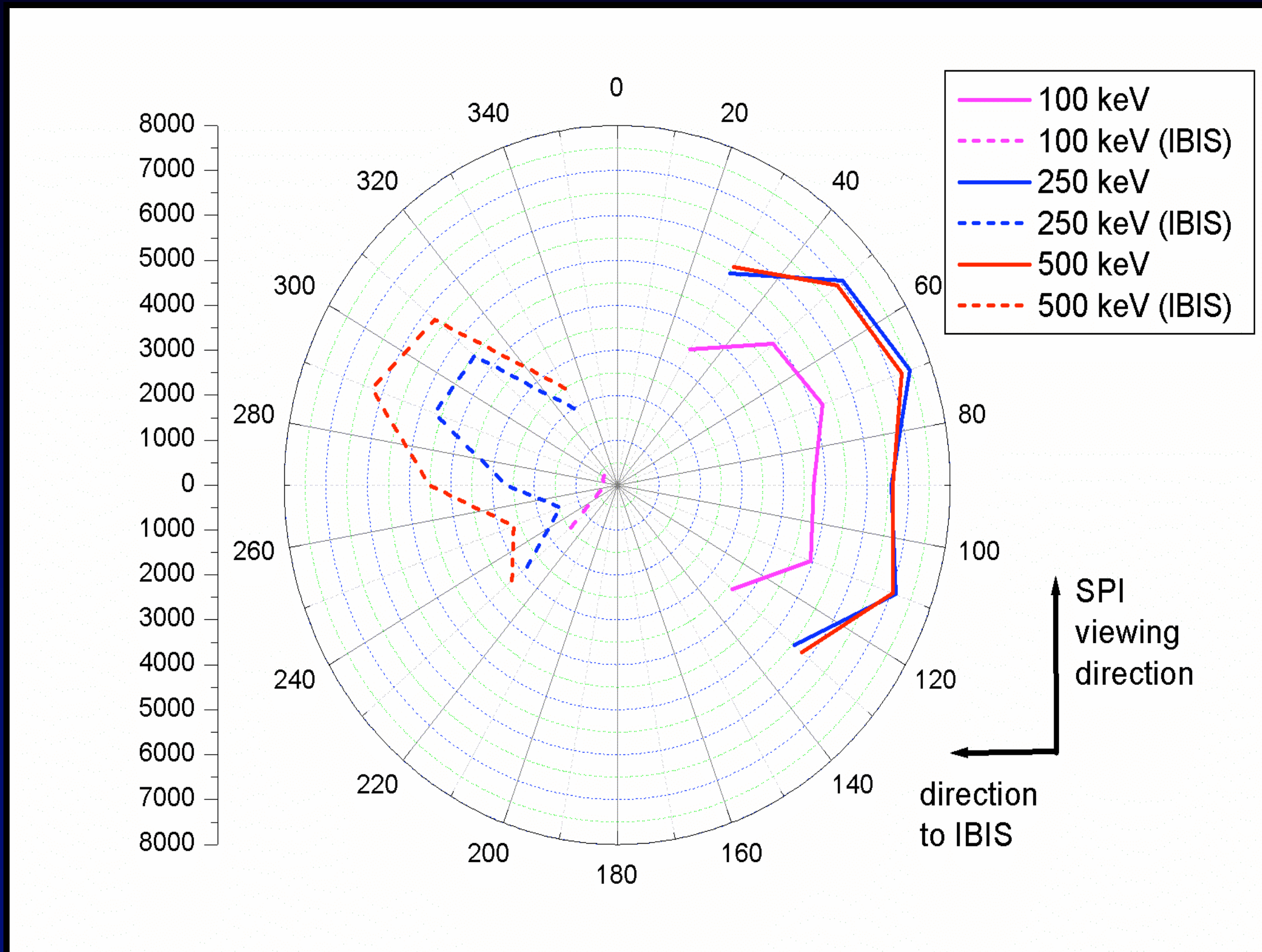
60000
40000
20000
counts
C
−1
0
1
2
3
seconds since Dec 14 2003 10:10:49 UTC

Variability

• formulation of Reichart et al. (2001)

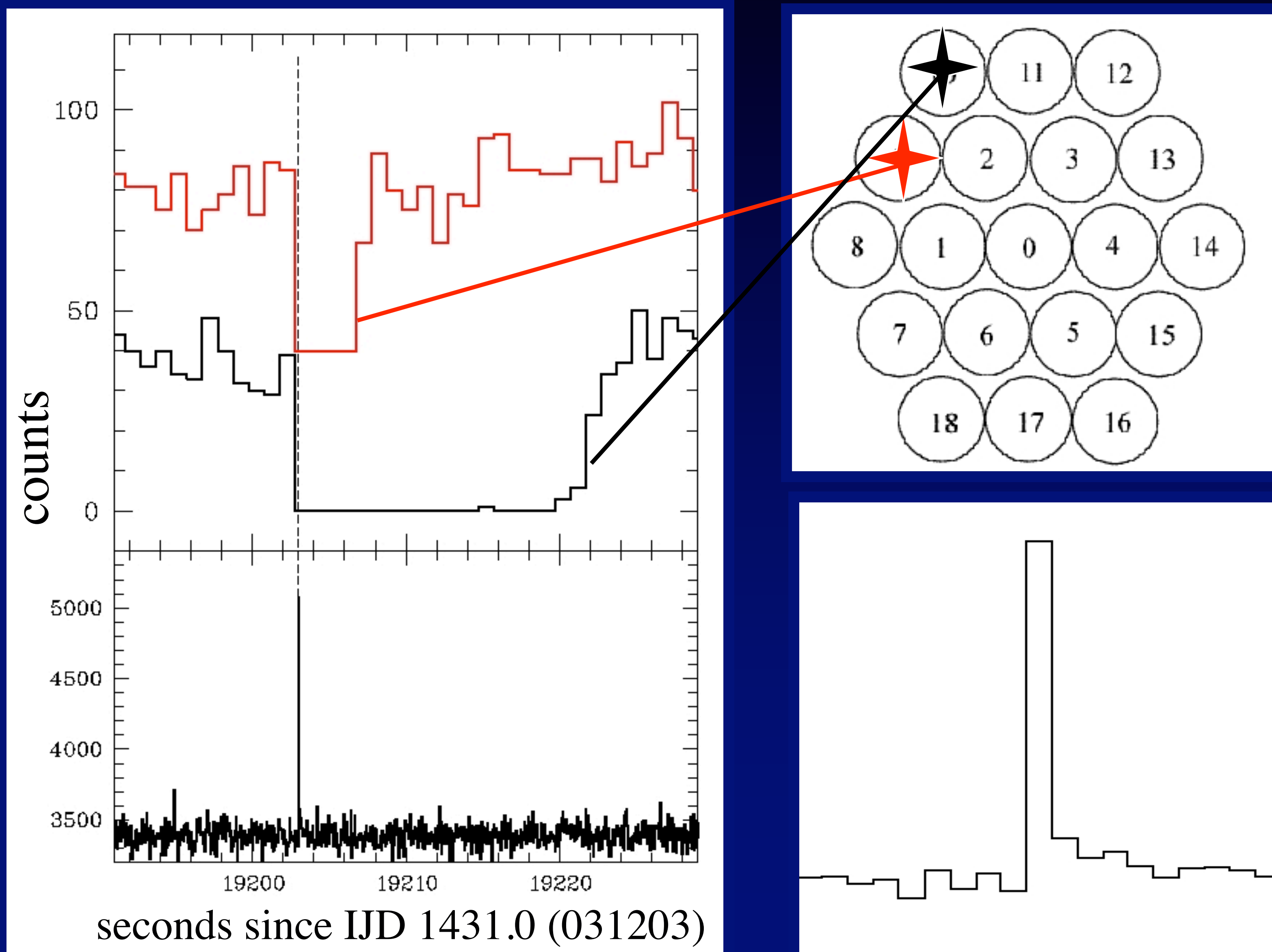


Effective Area

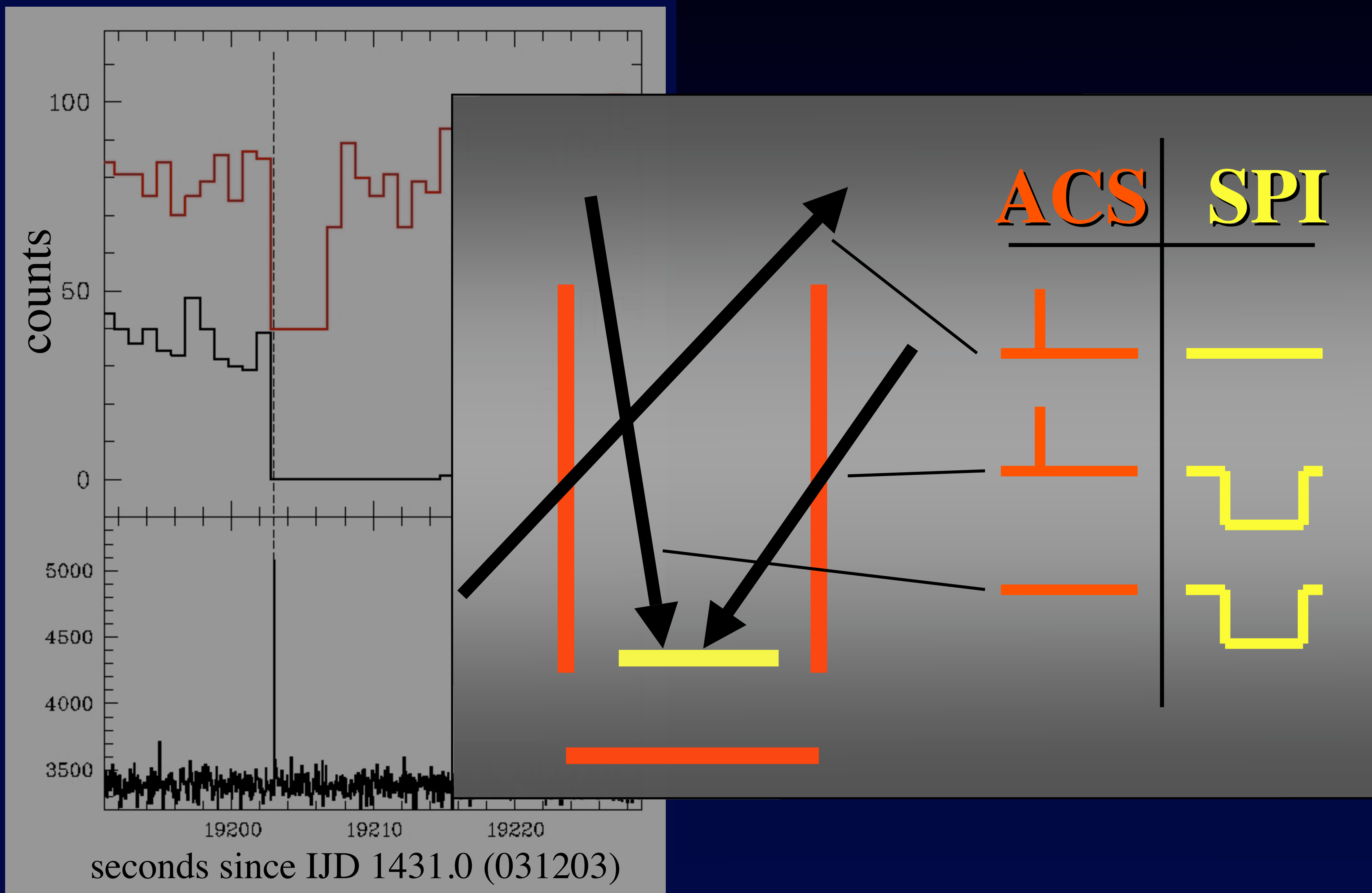


[Simulations by P. Jean]

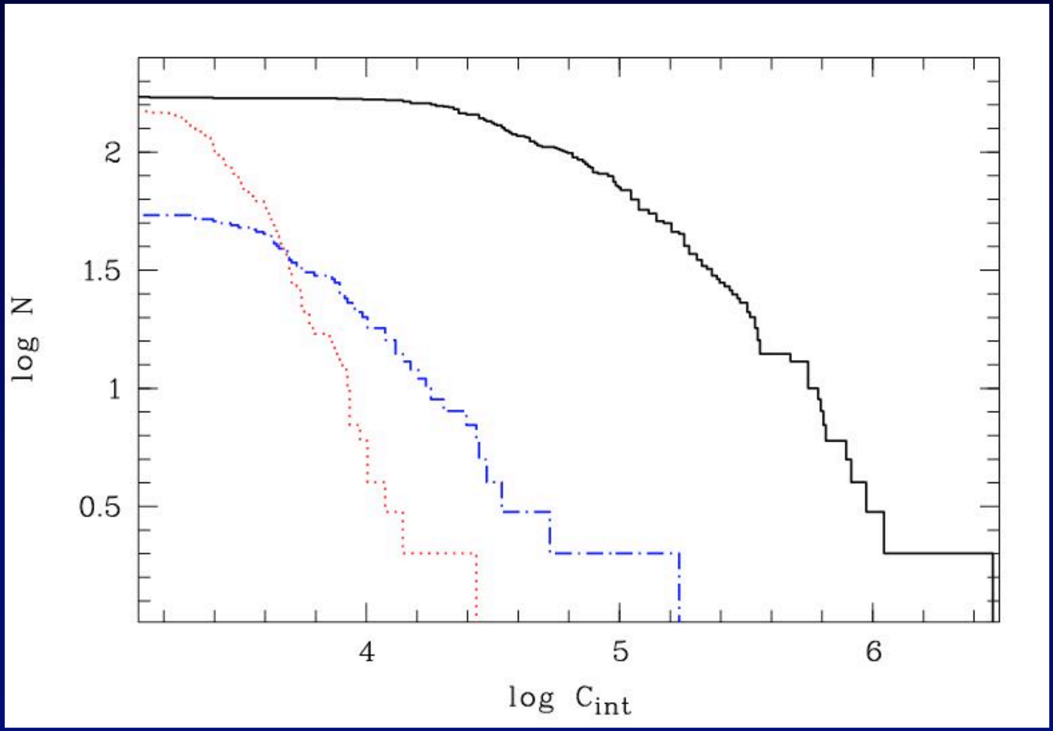
Origin of events with T_{90} < 0.25s

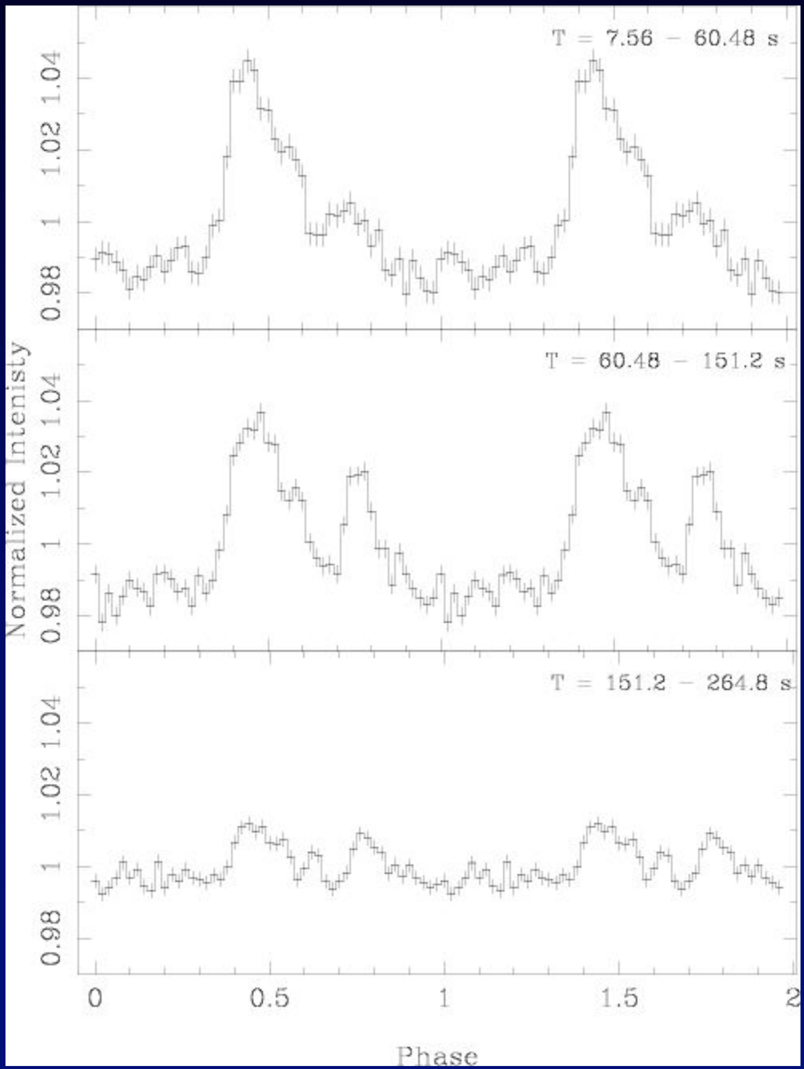


Short Events



[Jan

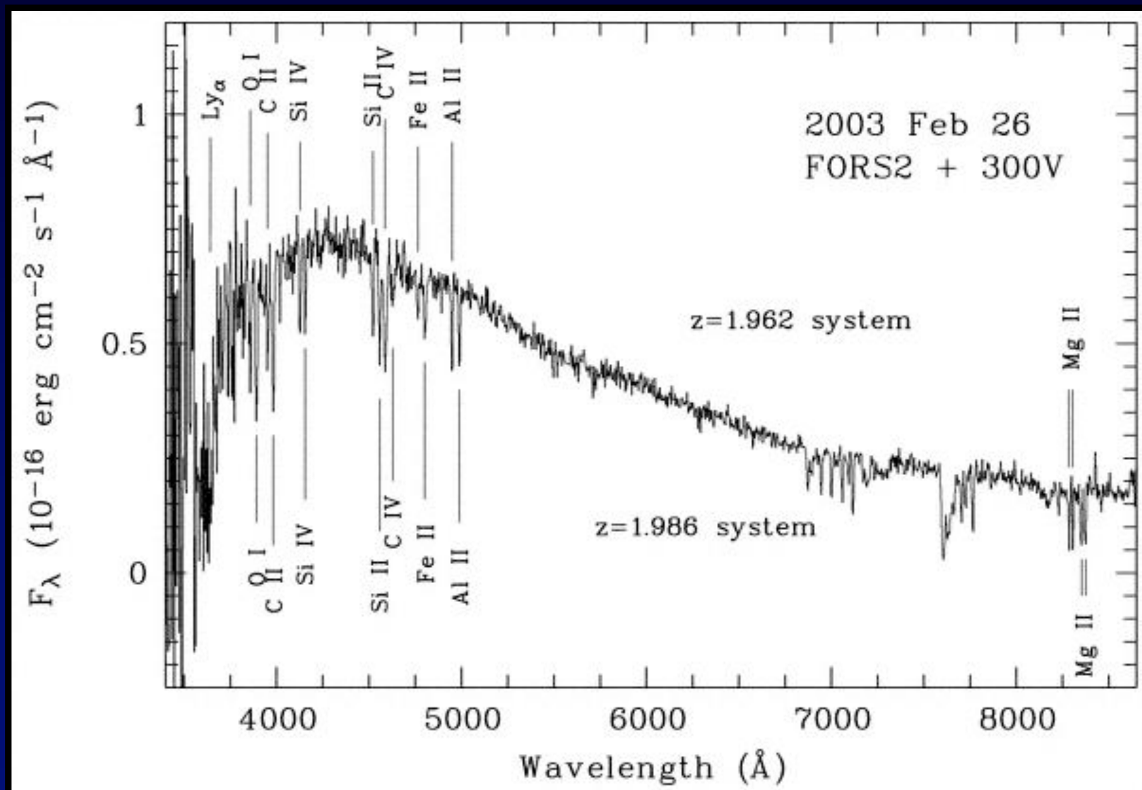

2
1.5
1
0.5
log N
4
5
6
log C_{int}


T = 7.56 – 60.48 s
T = 60.48 – 151.2 s
T = 151.2 – 264.8 s
Normalized Intenisty
0.98
1
1.02
1.04
0
0.5
1
1.5
2
Phase

Optical/near-IR Afterglow Observations

GRB 030226: **VLT/FORS spectroscopy**

(Klose, Greiner, AR et al. 2004, AJ, 128, 1942)



Kinematics: **signatures of absorbing clouds from expanding shells (Δv=2400 km/s) around massive Wolf Rayet Star**

Star Formation

[OII]: $SFR(M_s\ yr^{-1}) = 1.4 \pm 0.4 \cdot 10^{-41} L_{[OII]}$ (Kennicut 1998)

$SFR(M_s\ yr^{-1}) = 8.4 \pm 0.4 \cdot 10^{-41} L_{[OII]}$ (Rosa-Gonzalez 2002)

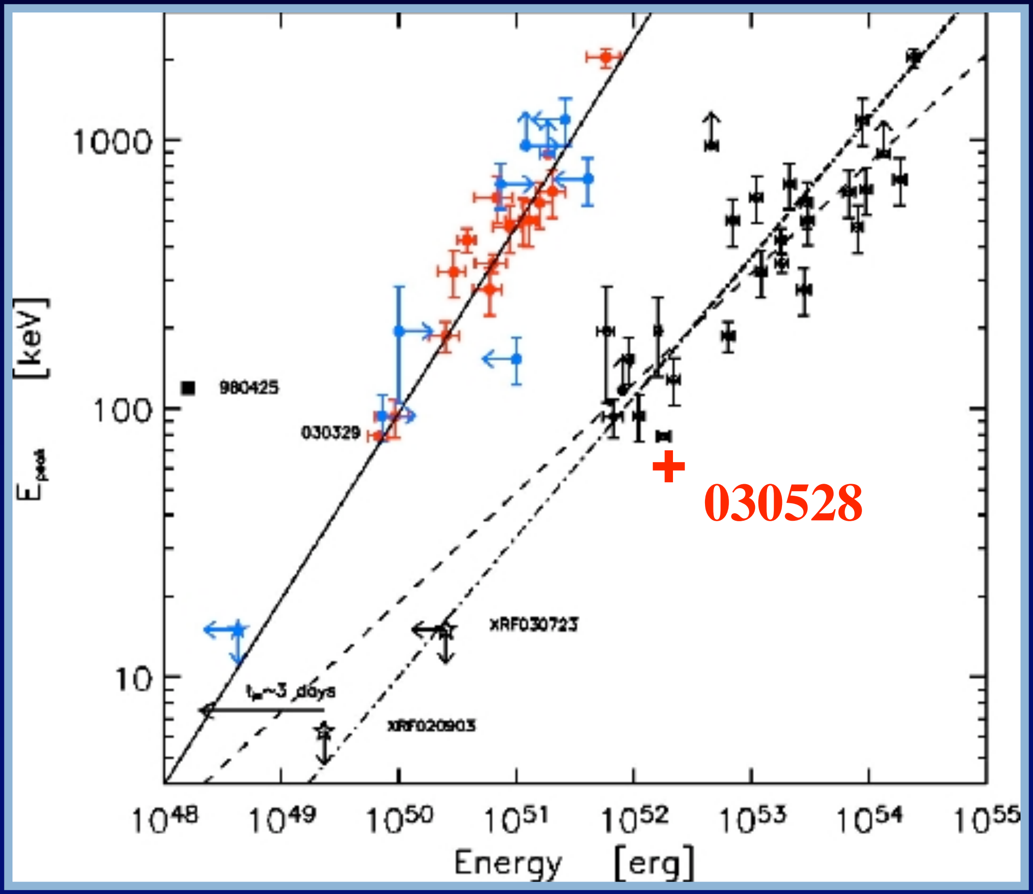
UV: $SFR(M_s\ yr^{-1}) = 1.4 \pm 0.4 \cdot 10^{-28} L_{\nu,UV}$ (Kennicut 1998)

$SFR(M_s\ yr^{-1}) = 6.4 \pm 0.4 \cdot 10^{-28} L_{\nu,UV}$ (Rosa-Gonzalez 2002)

		SFR	SSFR	SFR
		$[M_s\ yr^{-1}]$	$[M_s\ yr^{-1}]$	$[M_s\ yr^{-1}\ M_s^{-1}]$
[OII]	K98	6 ± 2	12 ± 3	$2 \cdot 10^{-10}$
	RG02	37 ± 4	74 ± 6	$12 \cdot 10^{-10}$
UV	K98	4 ± 1	8 ± 2	$1 \cdot 10^{-10}$
	RG02	17 ± 3	34 ± 4	$5 \cdot 10^{-10}$

Energetics

$E_{iso,\gamma} = 2.0\pm0.7\text{x}10^{52}$ erg (2-400keV)

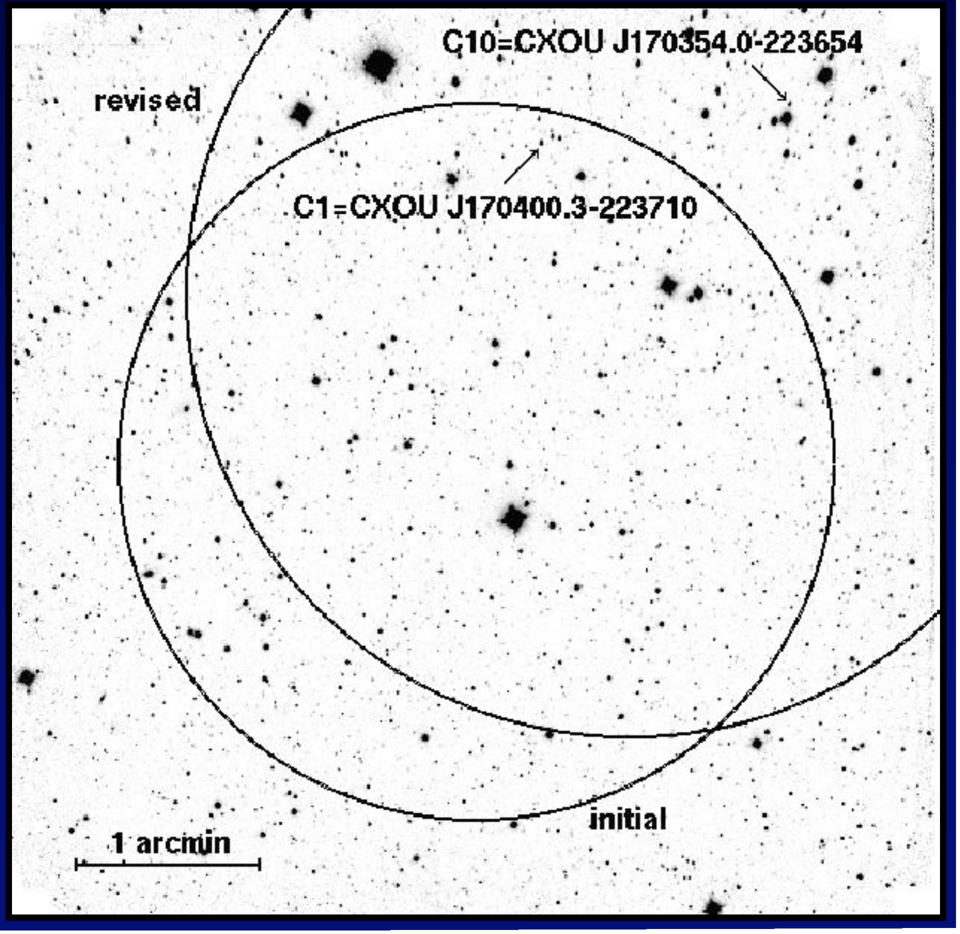


(Ghirlanda et al. 2004)

Near-IR/X-ray Observations

0.67 days: NTT/Sofi J,H,Ks
1.67 days: NTT/Sofi J,H,Ks
3.65 days: NTT/Sofi Ks
6 days: Chandra
4 Sources (Butler et al. 2003a)
12 days: Chandra
C1 fading (Butler et al. 2003b)
14.8 days: UKIRT/UFTI K
120 days: VLT/ISAAC Js

→ **AG candidate**
(Greiner, AR, Klose et al. 2003)



[Jan 25 2006]

What causes this burst to be optically dark ?

Large intrinsic extinction: $A_V > 2$mag

Observational limitations: $R_{obs} > 18.7$ (t=0.097) (Ayani & Yamaoka 2003)

$R_{exp} = 20.1\text{-}23.1$

Burst properties: ??

High redshift: ??

Conclusions

- Discovery of the near-IR afterglow
- Would have been 'dark' burst without near-IR and Chandra observations
- 2nd faintest near-IR detected so far
- 'optical darkness' certainly due to lack of rapid and deep observations

- Discovery of the underlying host galaxy
- among the brightest K-band hosts known
- late type galaxy at $z < 1$

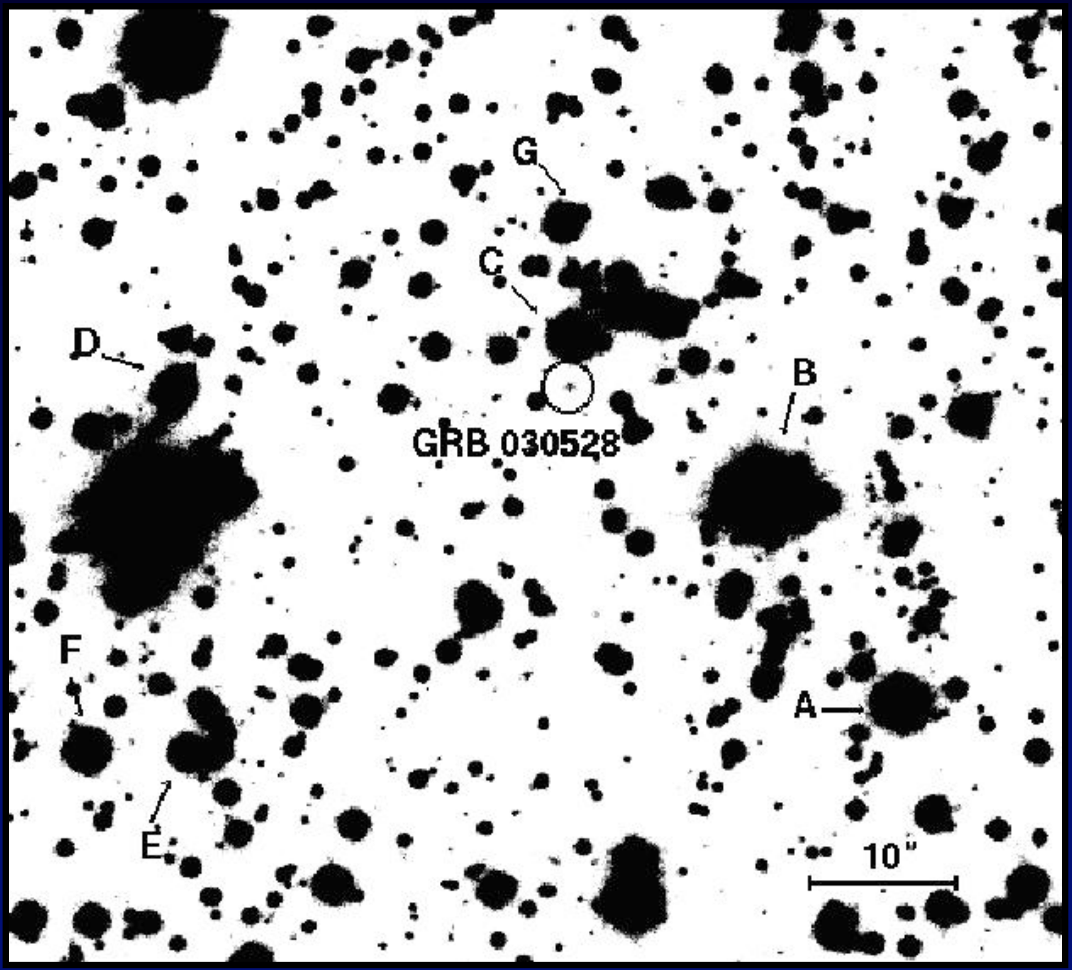
Early Optical Observations

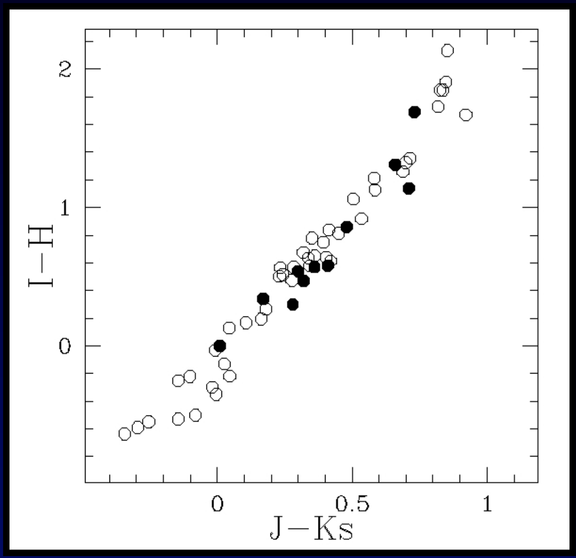
t	filter	mag	ref.
106s	white	>15.8	Torii 2003
152s	white	>16	Uemura et al. 2003
0.097d	R	>18.7	Ayani et al. 2003
0.496d	white	>20.5	Valentini et al. 2003

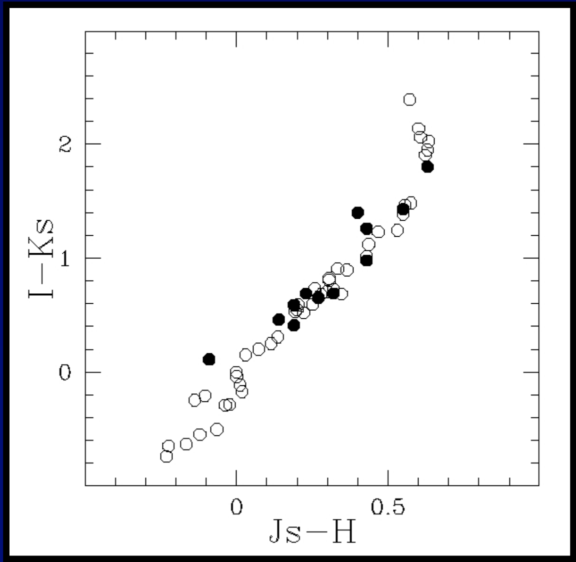
→ **optically dark burst !**

Data Reduction & Calibration

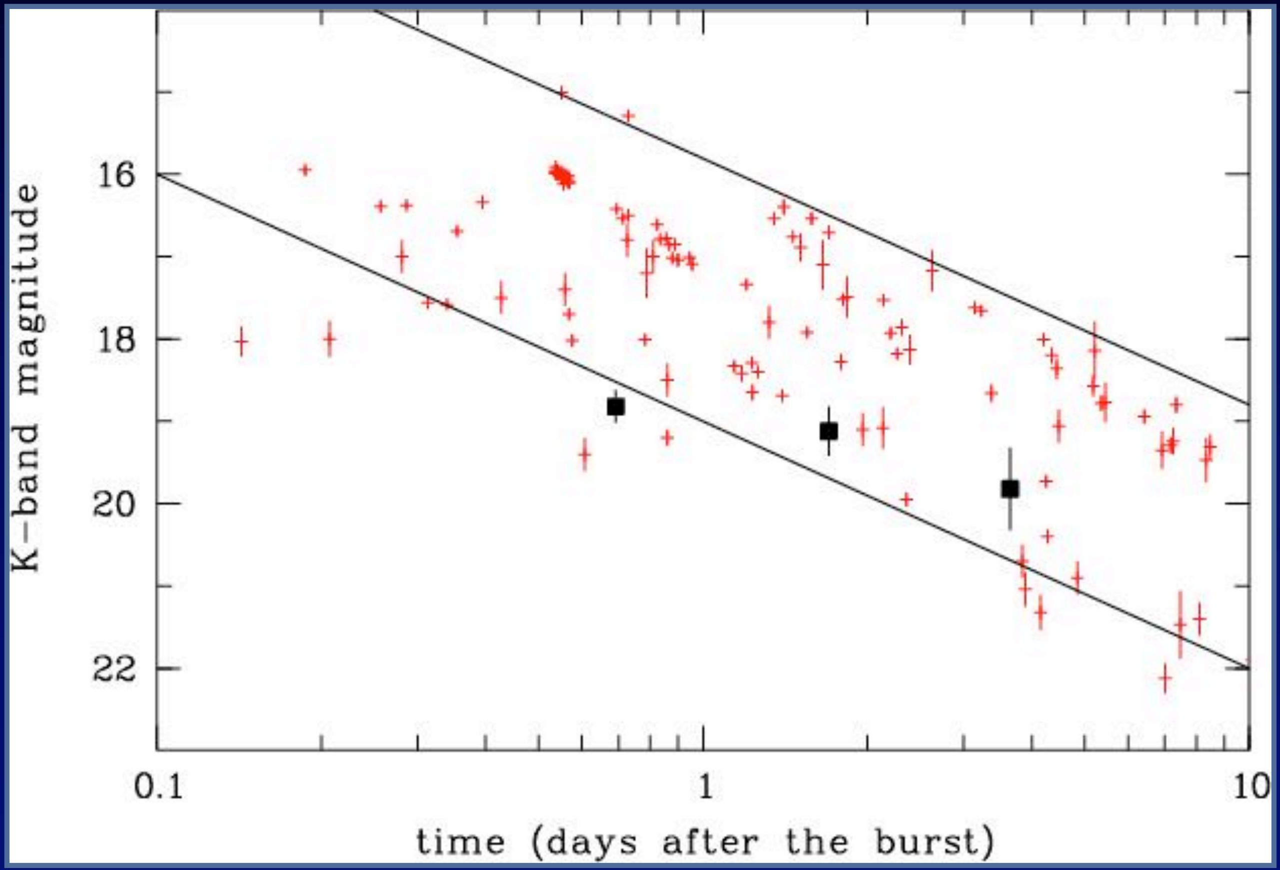
ISAAC Js





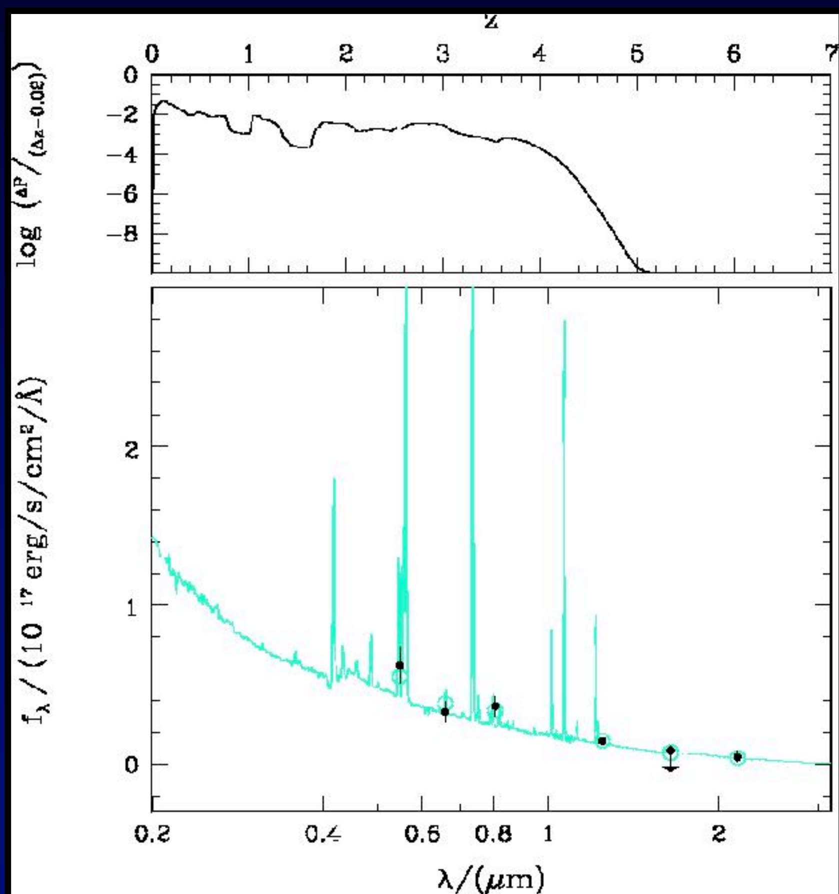


A very faint near-IR afterglow



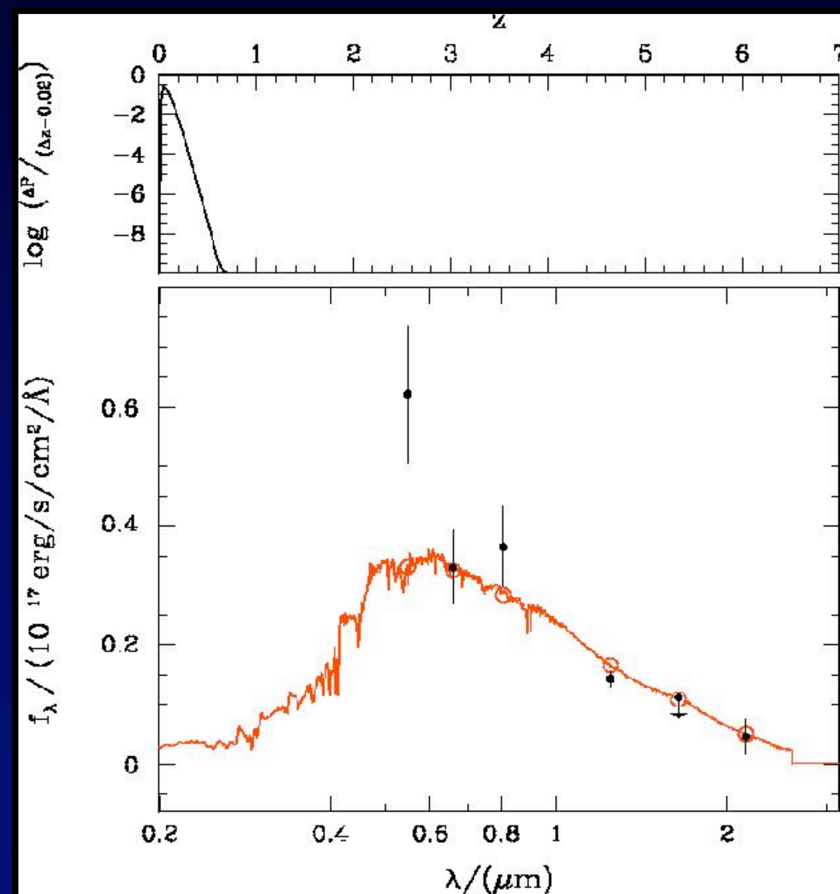
SED fitting - photometric redshift

late type galaxy



reduced $\chi^2 < 1$

early type galaxy



reduced $\chi^2 > 2$

(tools: Bender et al. 2001)