Fifteen months of *Swift* What have we learnt?

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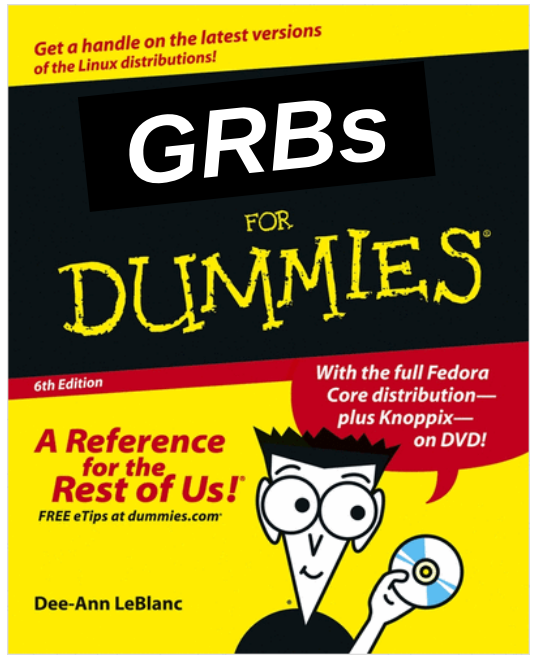
Outline

1. A short introduction to GRBs

2. *Swift*: an overall description

3. Fifteen months of *Swift*
   (a.k.a. how to survive it?)

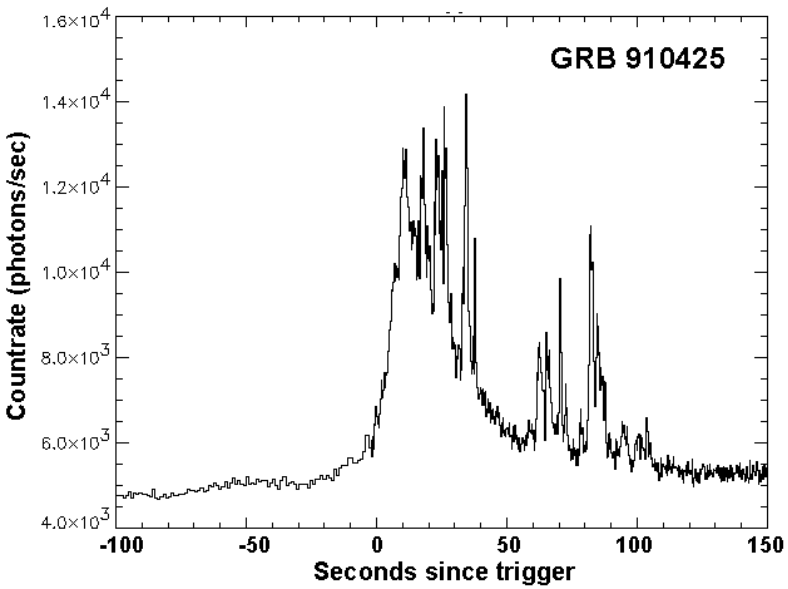
   * Short gamma-ray bursts
   * Surprises in GRB physics
   * Using GRBs to explore the Unverse
   * A new supernova/GRB connection

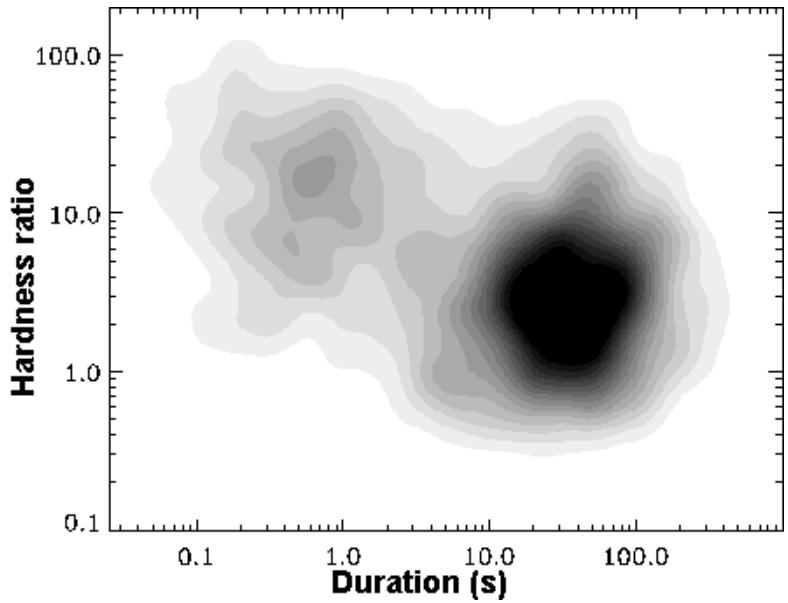


Gamma-ray bursts – basic facts

Brief, sudden, intense flash of gamma-ray radiation

Duration: **< 100 s**
Frequency: **10 keV – 1 MeV**
Fluence: **~10^{-6} erg cm^{-2}**
Flux: **~10^{-7} erg cm^{-2} s^{-1}**





Short (**< 2 s**) vs **long** (**>2 s**)

Complex, variable light curves

Afterglows

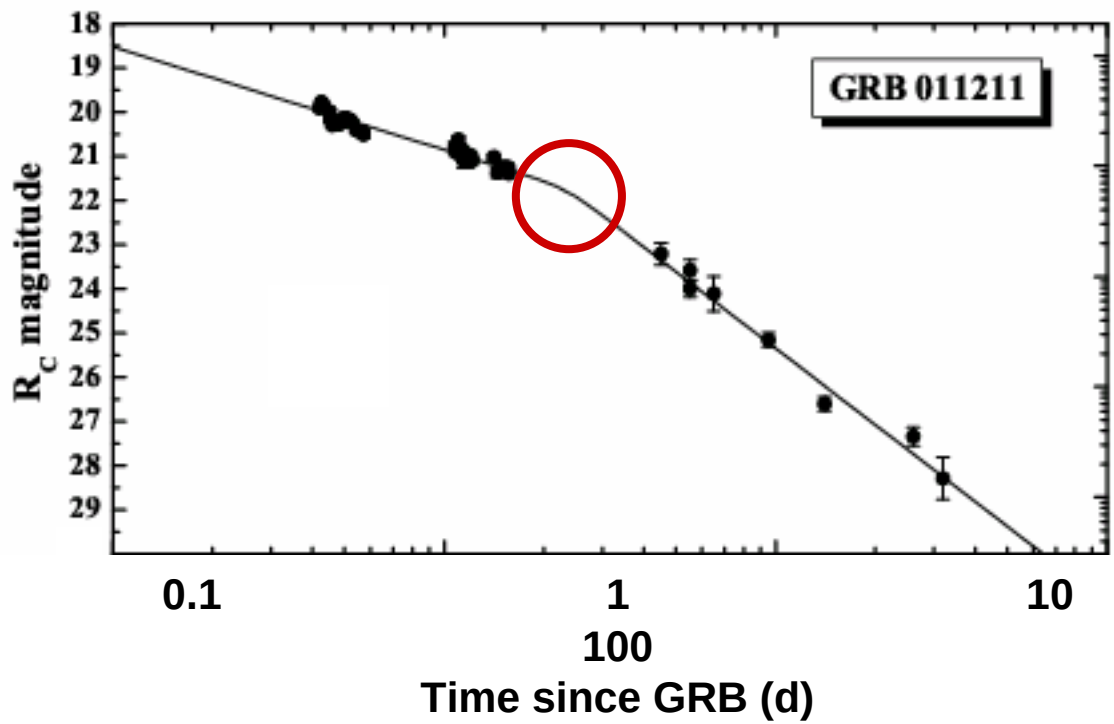
Long-lasting (**days** to **weeks**) multiwavelength counterparts in the **X-ray**, **optical** and **radio** band

Decaying light curve

Power law: $F(t) \propto t^{-\alpha}$
"Logarithmic" time

Steepening of the decay:

collimated emission



Very bright soon after GRB: $R \sim 15–18$, $F_X \sim 10^{-10}$ erg s^{-1} cm^{-2}

What are GRBs?

Afterglows $\Rightarrow$ redshift $\Rightarrow$ **distance & energetics**

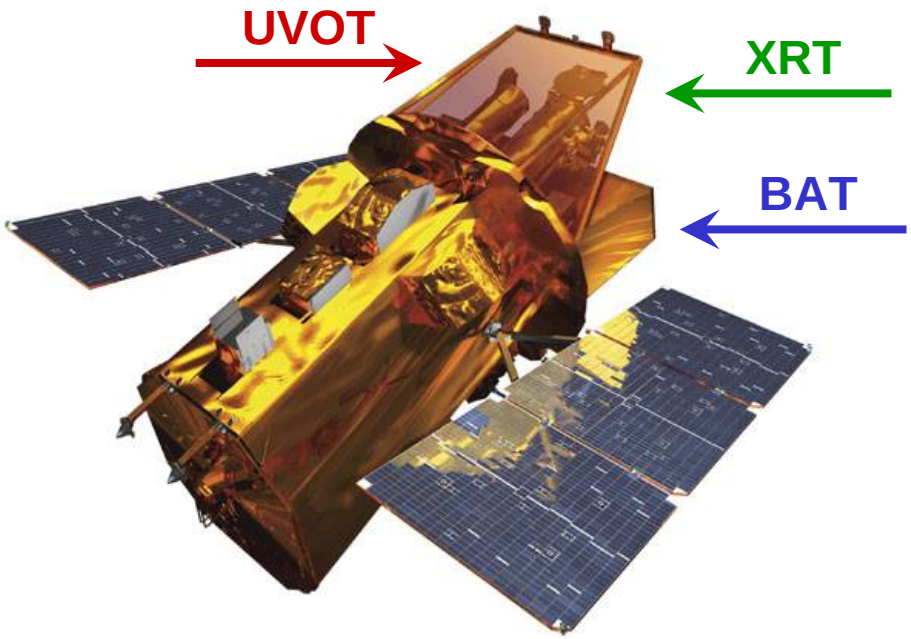
Cosmological events: $\langle z \rangle = 1$

GRBs energies: $\mathbf{10^{51} - 10^{54}}$ **erg** $\Rightarrow$ $\mathbf{10^{51}}$ **erg** if collimated

Very rare in the Universe (**~1/100** of SNe)

LONG GRBs	**SHORT GRBs**
* Association with **core-collapse SNe**	* **Not** associated with recent star formation
* Star-forming host galaxies	* Differentiated host galaxies
* Connection with **cosmic star formation**	* Binary compact object binary mergers**?**

The *Swift* satellite



BURST ALERT TELESCOPE

* Imaging: **15-150 keV**
* Precision: **2-3 arcmin**
* Field of view: **1/6 of sky**

UV/OPTICAL TELESCOPE

* Imaging: **1700 – 6500 Å**
* Precision: **0.5 arcsec**
* Sensitivity: ***V*** **= 20**

X-RAY TELESCOPE

* Imaging in **0.2–10 keV**
* Precision: **3 arcsec**
* Sensitivity: **2×10^{-14} cgs**

Swift aims

* To quickly (~1–2 min) repoint XRT and UVOT: study of the **early afterglows**
* To observe GRBs across a **large spectral band**
* To collect a **large sample** of GRBs and afterglows
* To study **short gamma-ray bursts**
* To trigger **ground-based follow-up** (spectroscopy)

In other words...

* *To boldly go where no man has gone before*

The *Swift* GRB sample

Launch: 2004 November 20 (15 months operations)

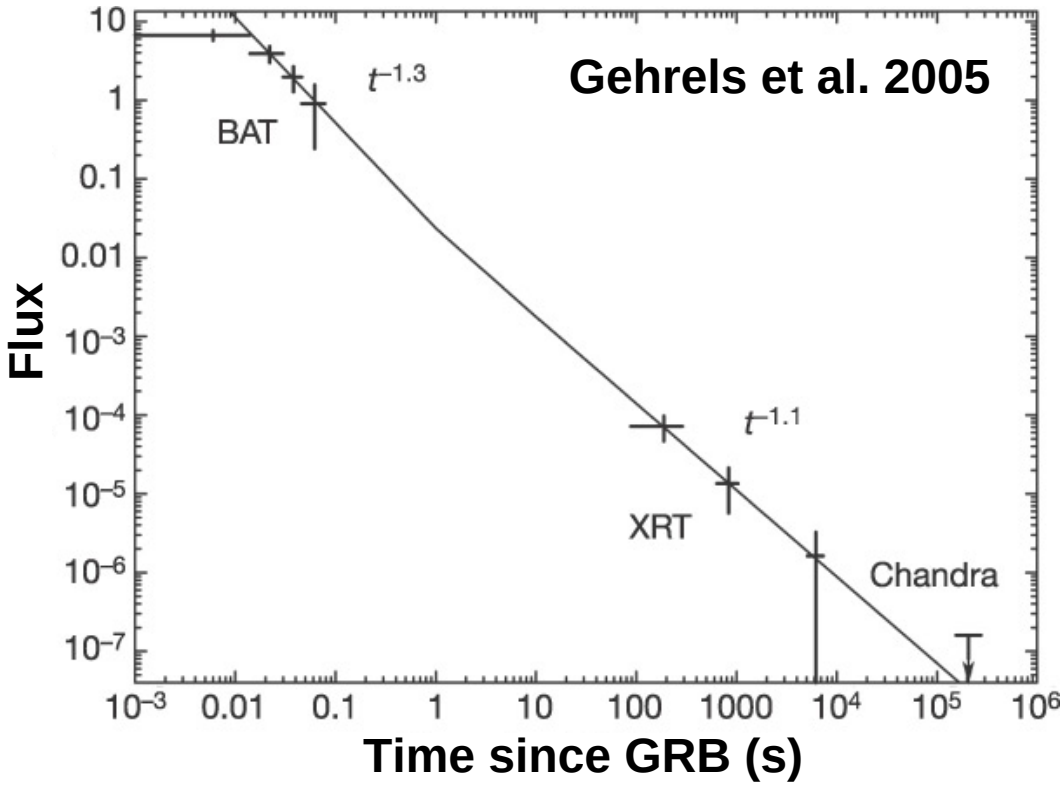
2005 Feb – 2006 Jan:

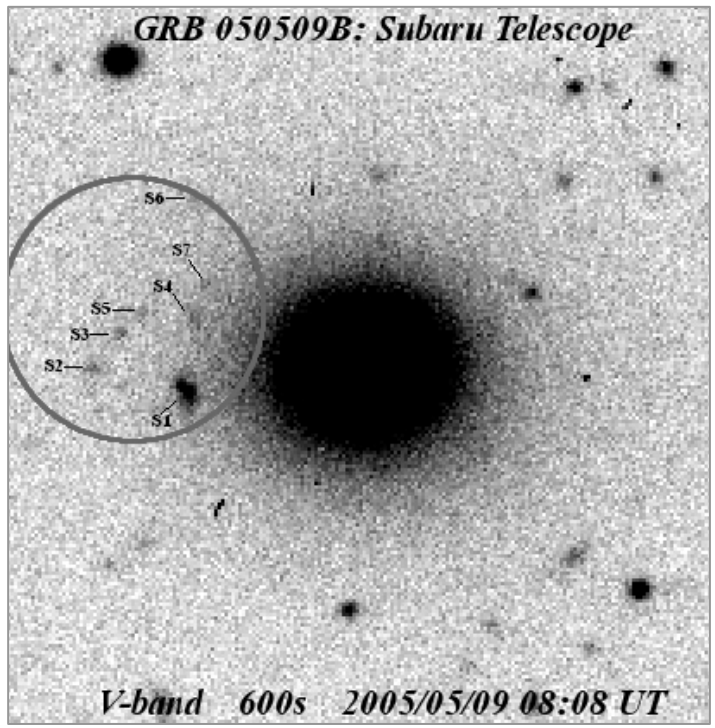
	Total	Long	Short
GRBs	**96**	85	11
X-ray AG	81	75	6
Optical AG	43	40	3
Redshift	**29**	27	2

Afterglows for short GRBs! (I)

No arcsec position for a short GRB before Swift

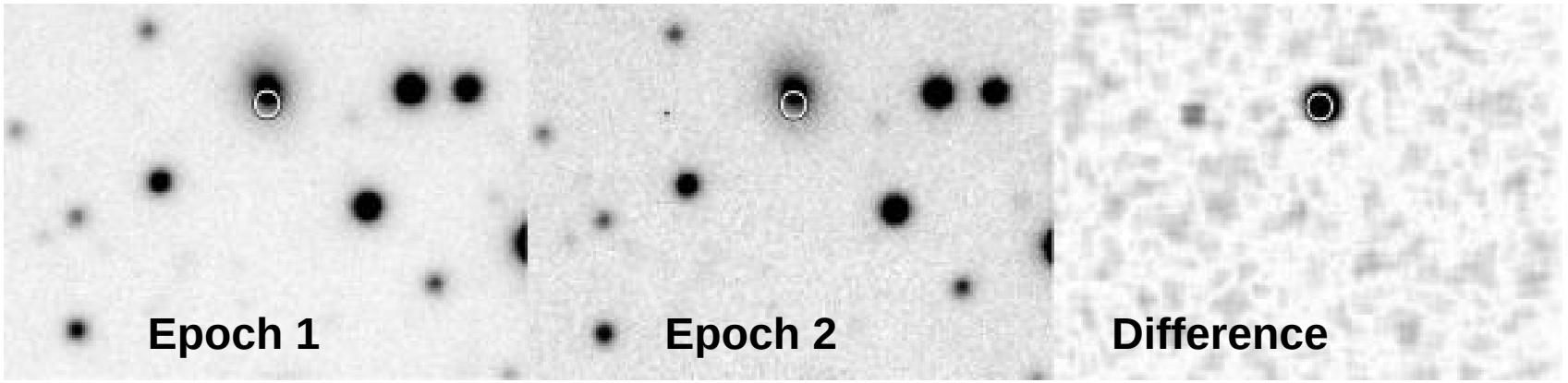
GRB 050509B – first short GRB X-ray afterglow – very faint!





Afterglows for short GRBs! (II)

GRB 050724 – the bright one: optical + X-ray – $z = 0.258$



Malesani et al. 2024
Berger et al. 2005

GRB 051221 – $z = 0.5459$

Soderberg et al. 2006

Clues to short GRB progenitors

Host galaxies: both **early and late type**

No associated supernova

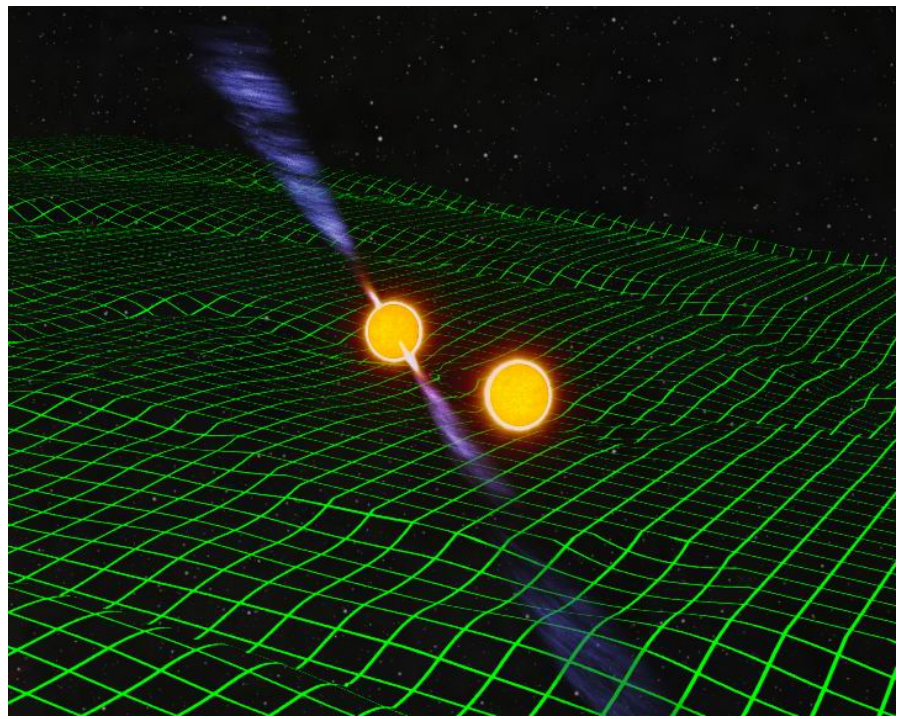
Low redhisft distribution (***z*** **~ 0.2**)

“Low” energy (**10^{50} erg**)

Coalescence of a **binary compact object** system

NS + NS or NS + BH?

Key parameter: **merging time**



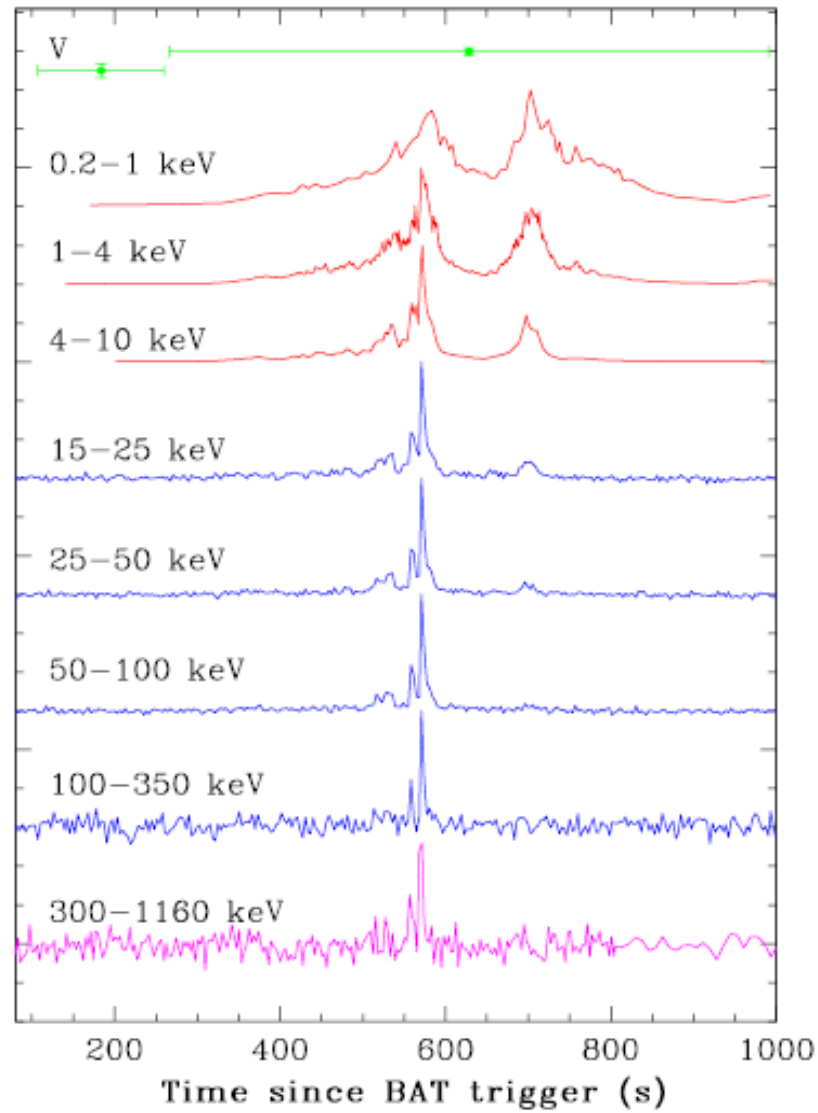
A GRB caught in action

Rapid slewing:

the gamma burst
at non-gamma energies

GRB 060124

* Simultaneous optical emission uncorrelated with the gamma-ray one
* XRT sensitivity ⇒ fine analysis of prompt emission

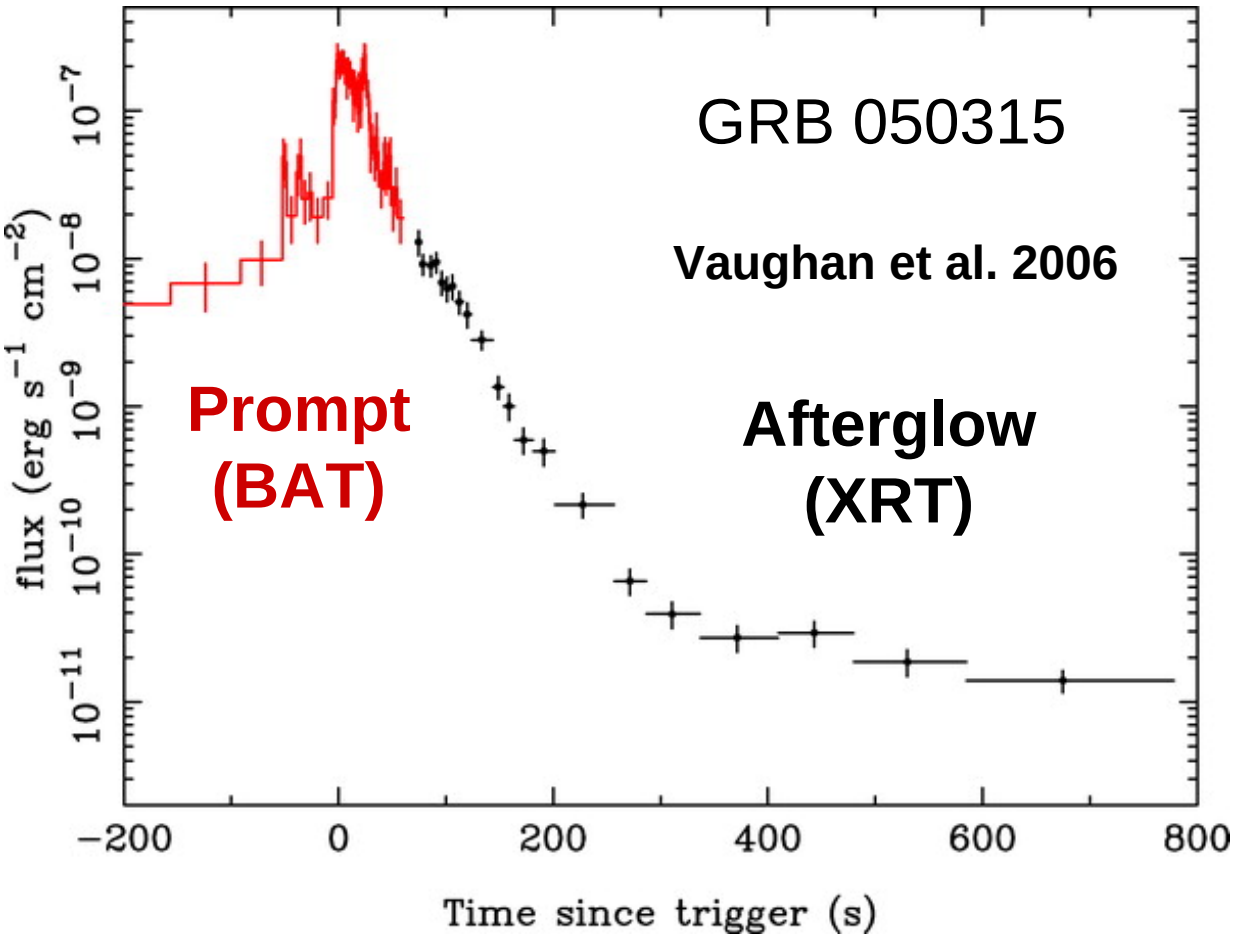


Romano et al. 2006

The GRB/afterglow transition

Filling the gap between the prompt and afterglow phases

* The afterglow **smoothly joins** to the prompt emission
* There is a **steep decay** after the GRB



Tagliaferri et al. 2005

The "canonical" light curve

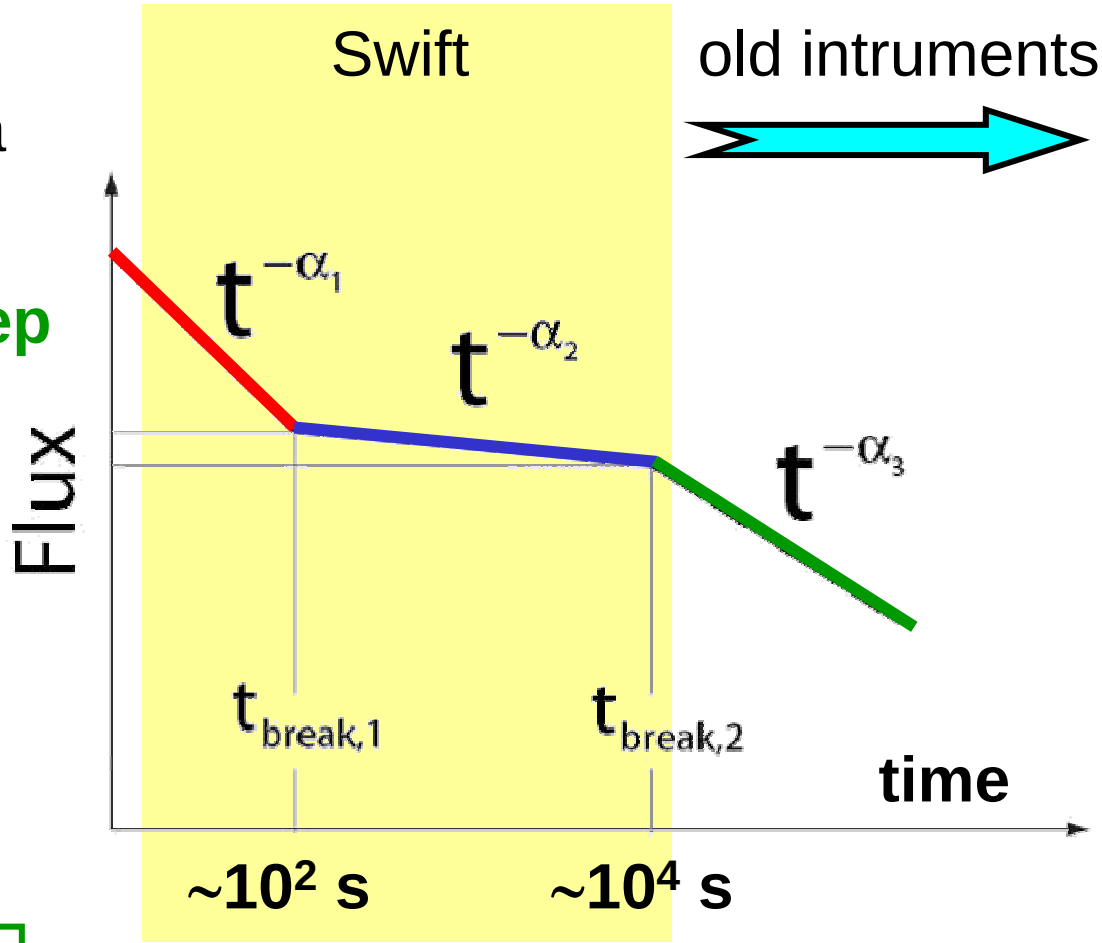
Many afterglows have a typical pattern

Steep – flat – steep

GRB tail

Long-lasting engine activity

"Normal" afterglow



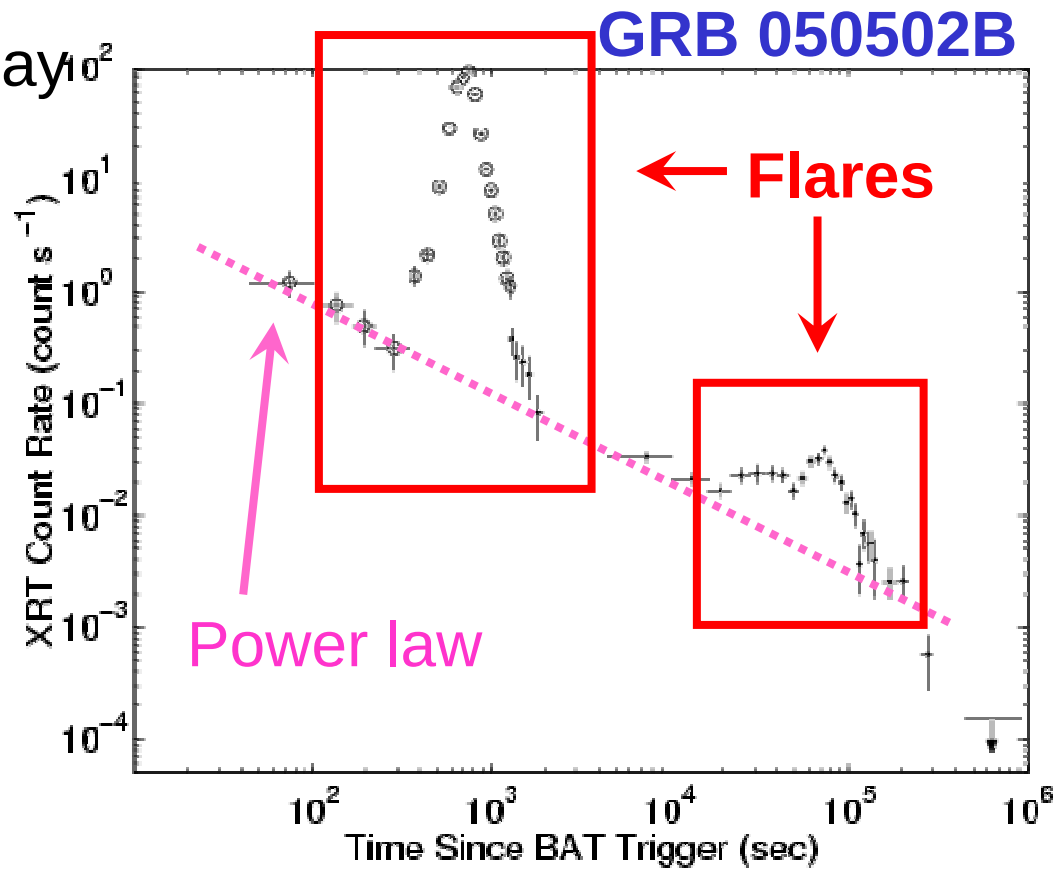
Nousek et al. 2005
Chincarini et al. 2005
O'Brien et al. 2005

A sleepless engine: the flares

Strong **flares** in the X-ray light curves: **10^2 – 10^4 s**

Over the power-law decay

Sometimes large energy in the flare



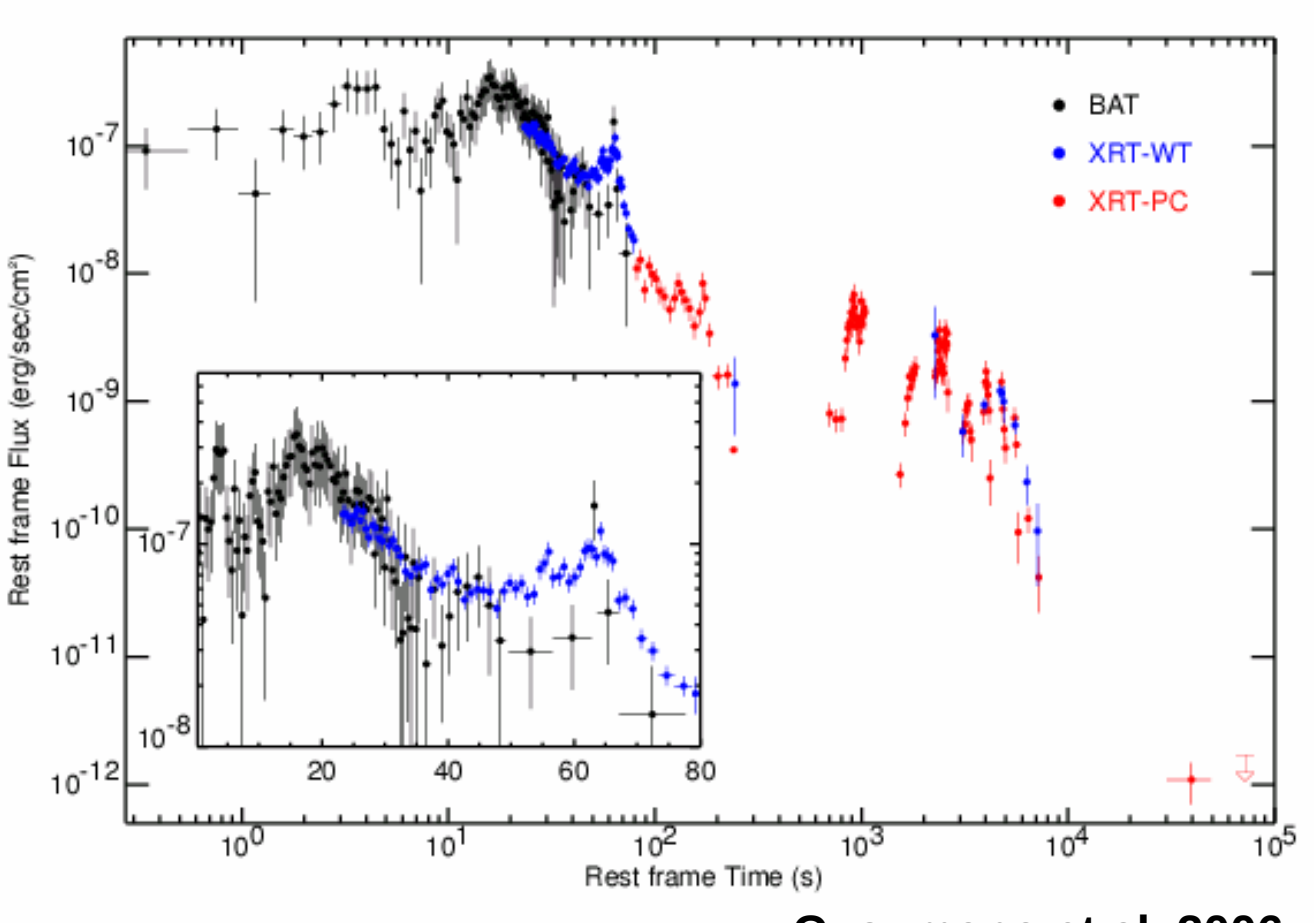
The GRB engine has to keep active for a **very long time**

Falcone et al. 2006

More and more flares

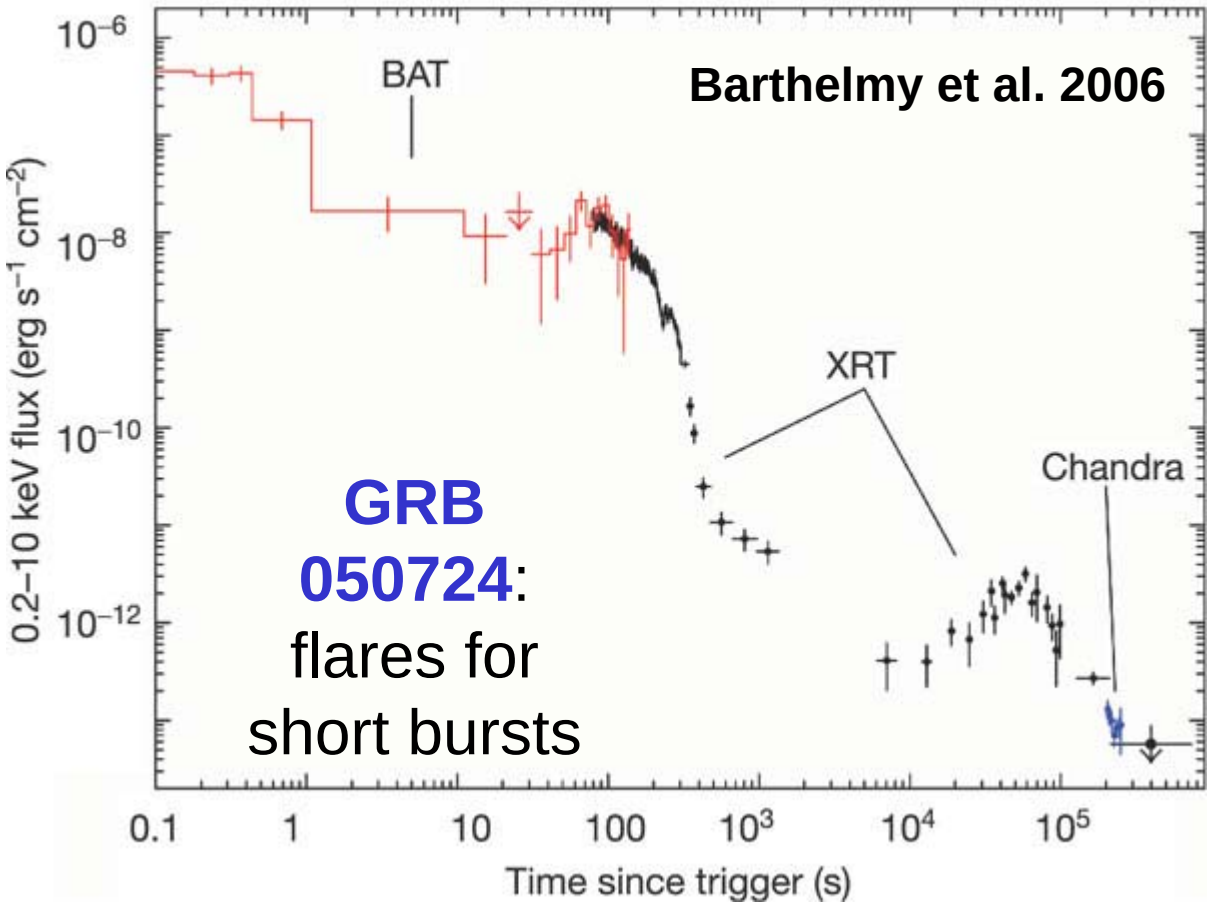
GRB 050904...

Only flares!



Cusumano et al. 2006

More and more flares

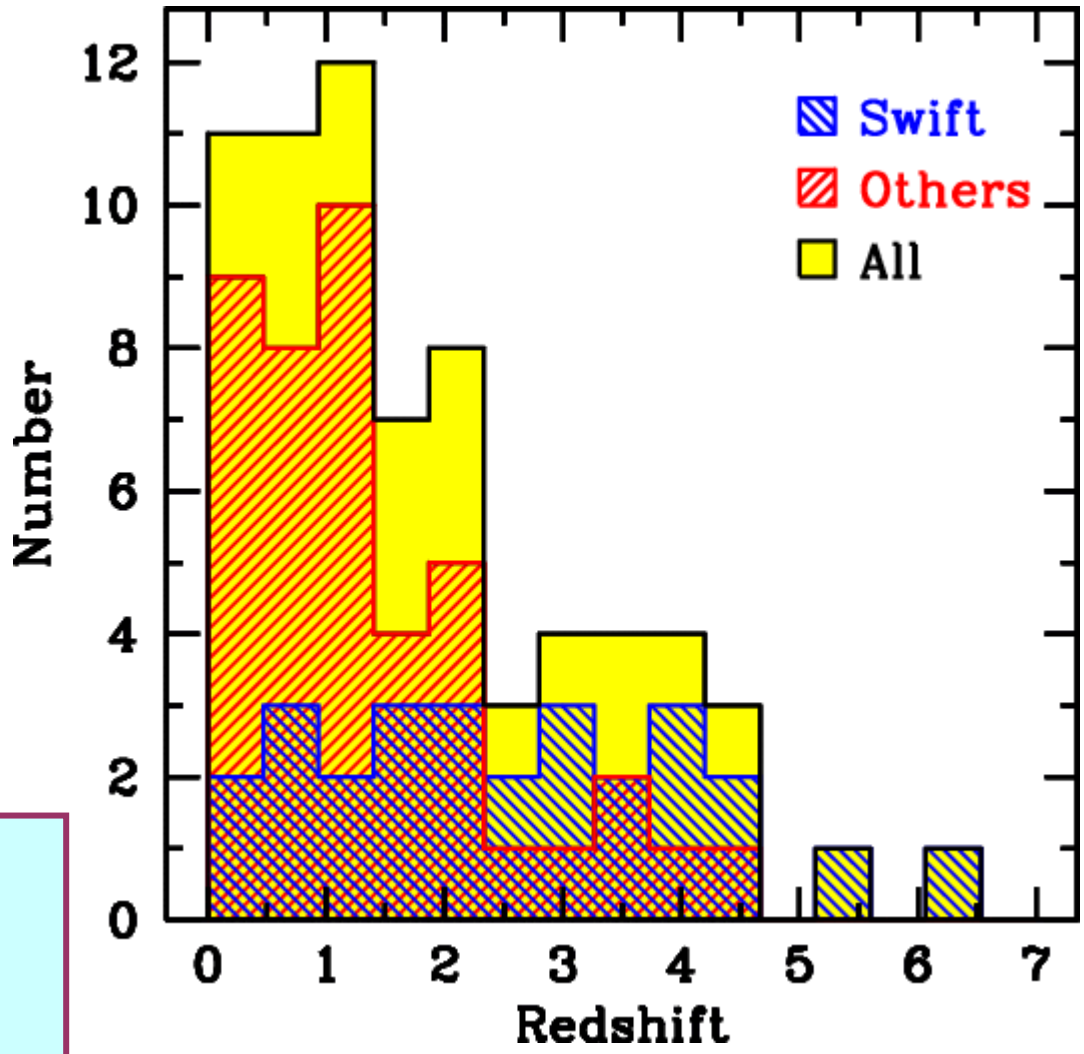


The (long) GRB redshift distribution

Swift afterglows are **faint**

Significantly **larger redshift** than previous missions

$\langle z \rangle = 2.8$ vs $\langle z \rangle = 1.6$

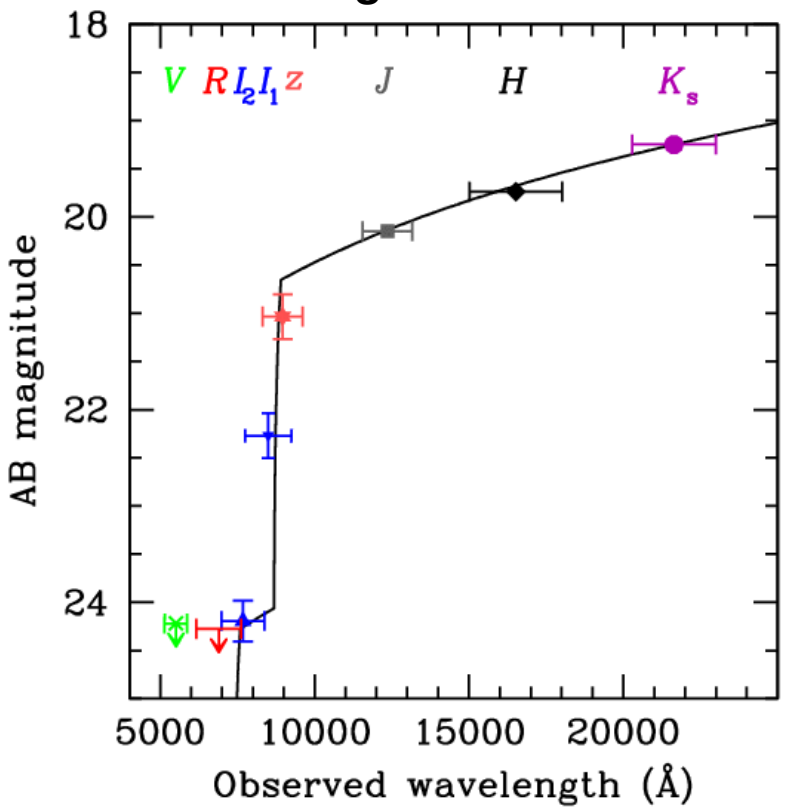


GRBs are thus ideal **probes** of the high-redshift Universe

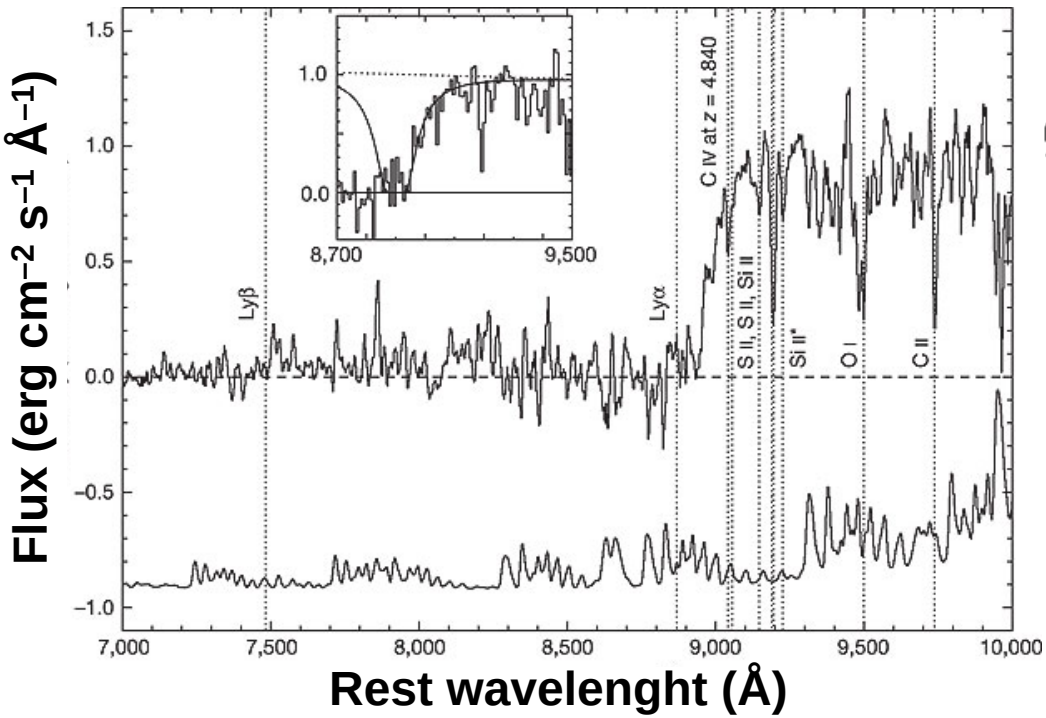
The record! GRB 050904

The record: $z = 6.29$

Tagliaferri et al. 2005



Lyα dropout suppressing optical emission



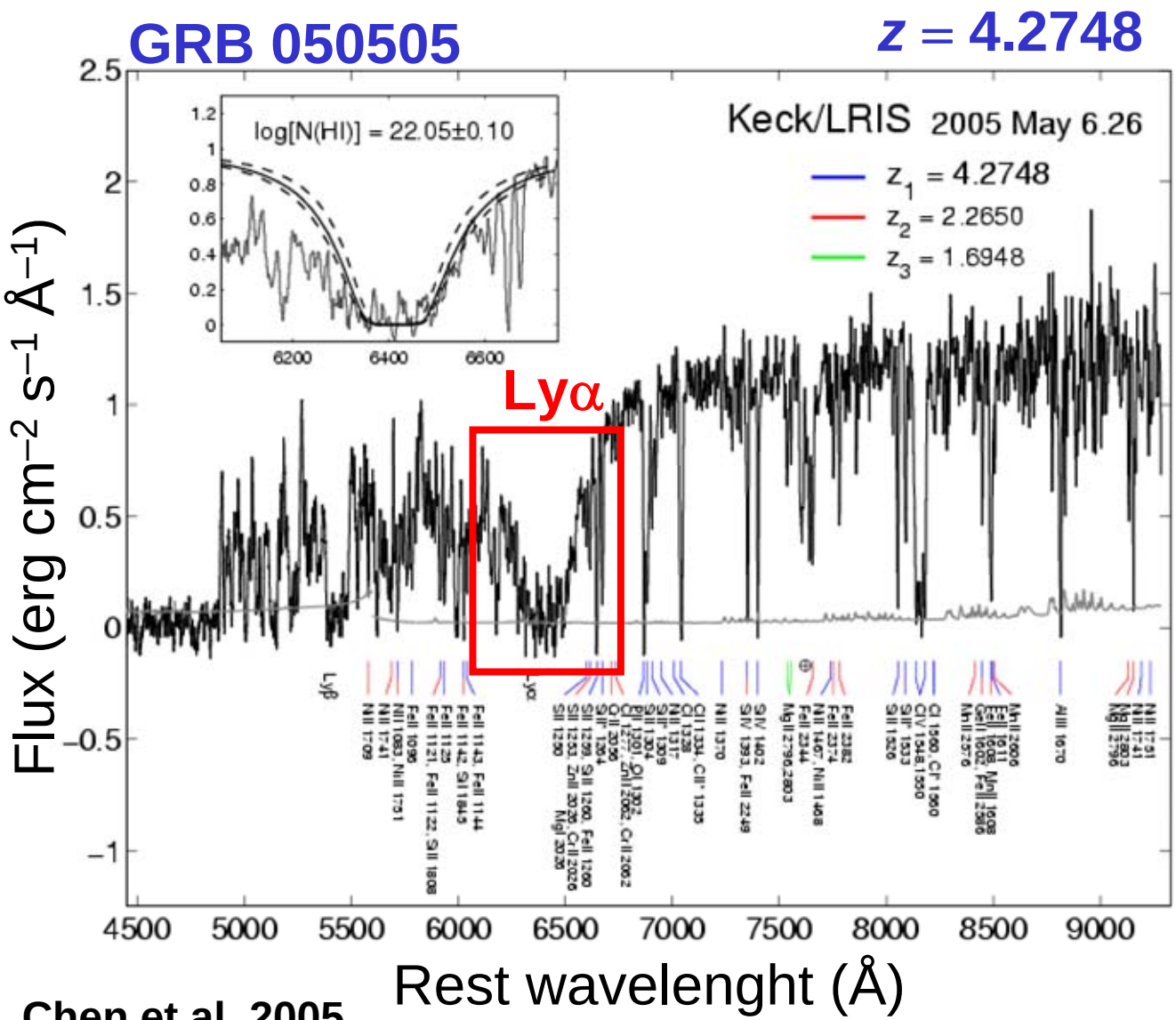
Spectroscopic confirmation!

Kawai et al. 2006

GRB afterglow spectroscopy

GRBs as **cosmic beacons**

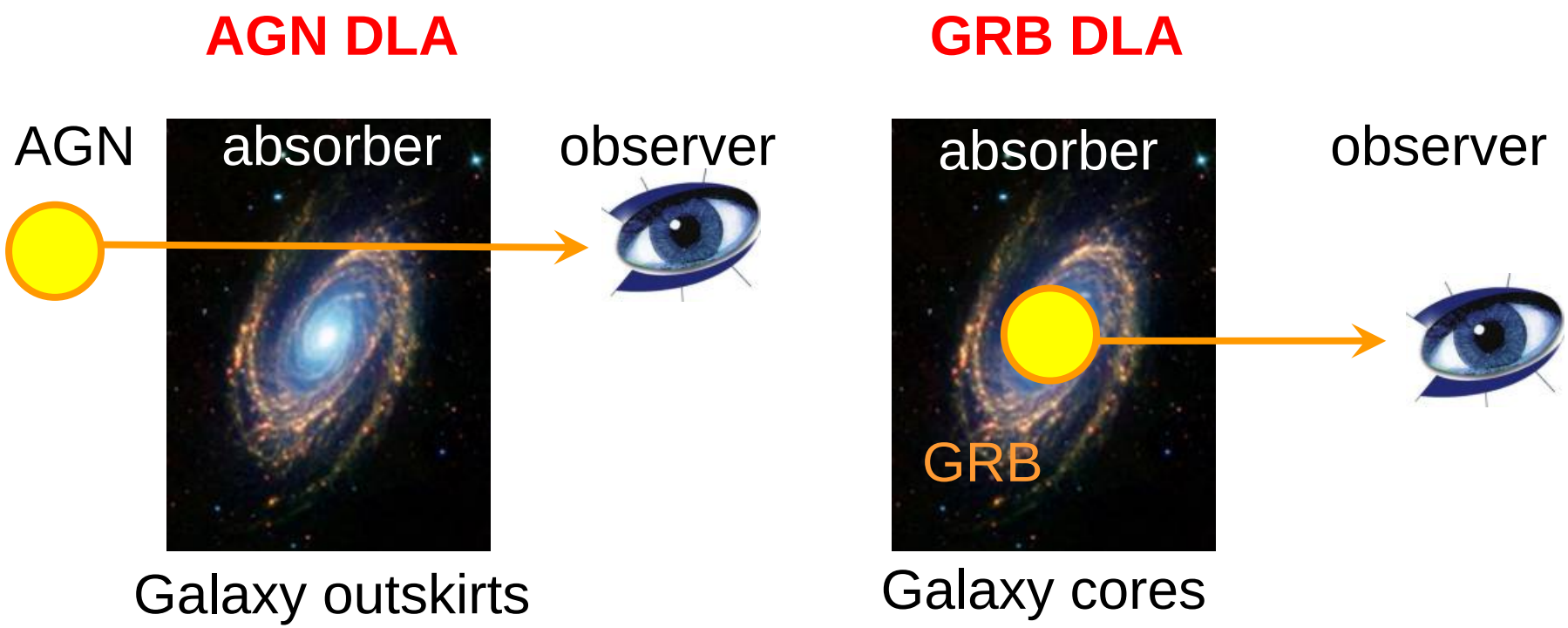
Bright afterglows allow high-quality spectroscopy



Penprase et al. 2005, Chen et al. 2005

The ISM of star-forming galaxies

GRBs probe the very regions where star formation is active



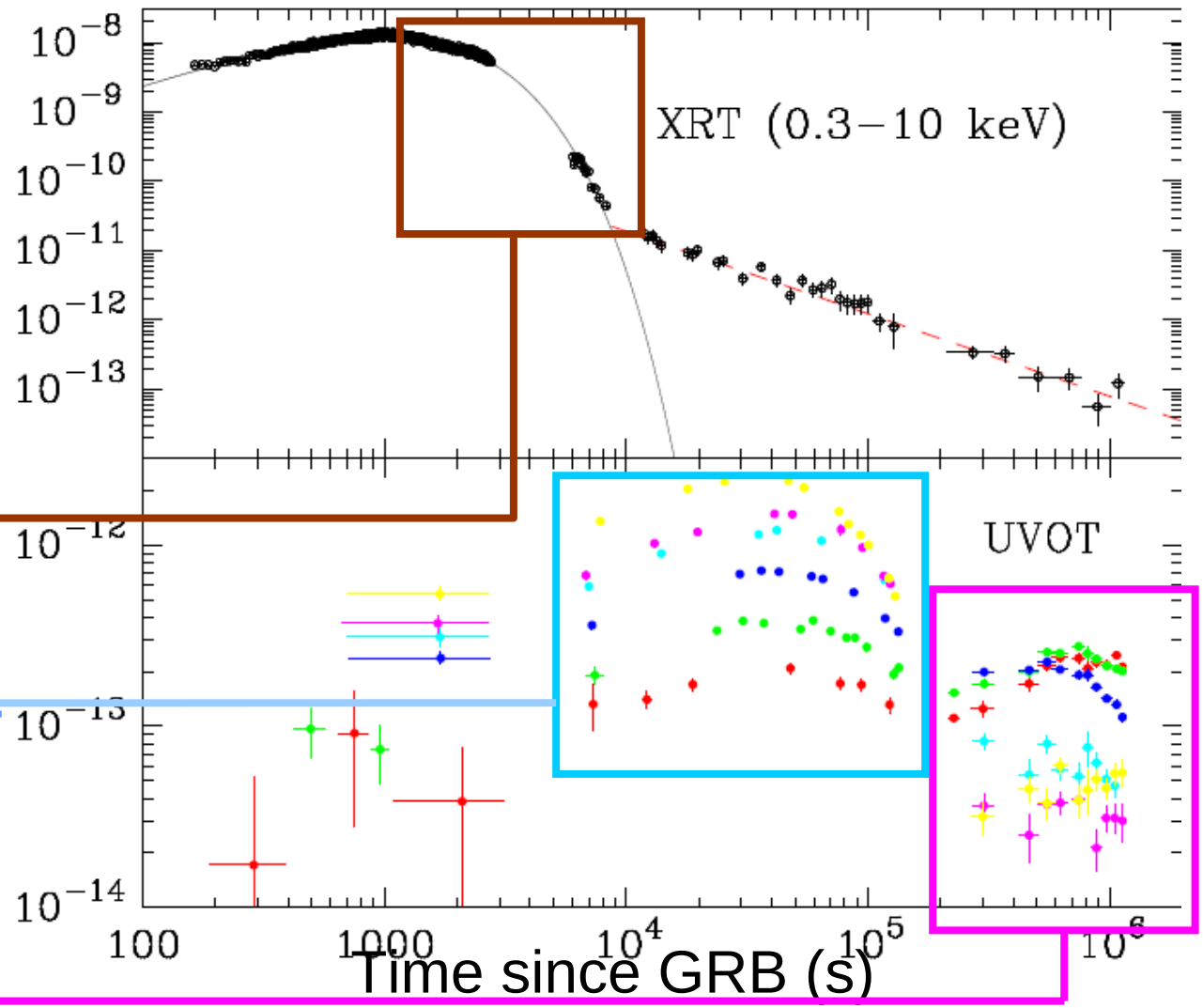
Direct measurements of gas properties in star forming regions

The GRB/SN connection

$z = 0.03352$

GRB 060218
(the second closest GRB)

Campana et al. 2005

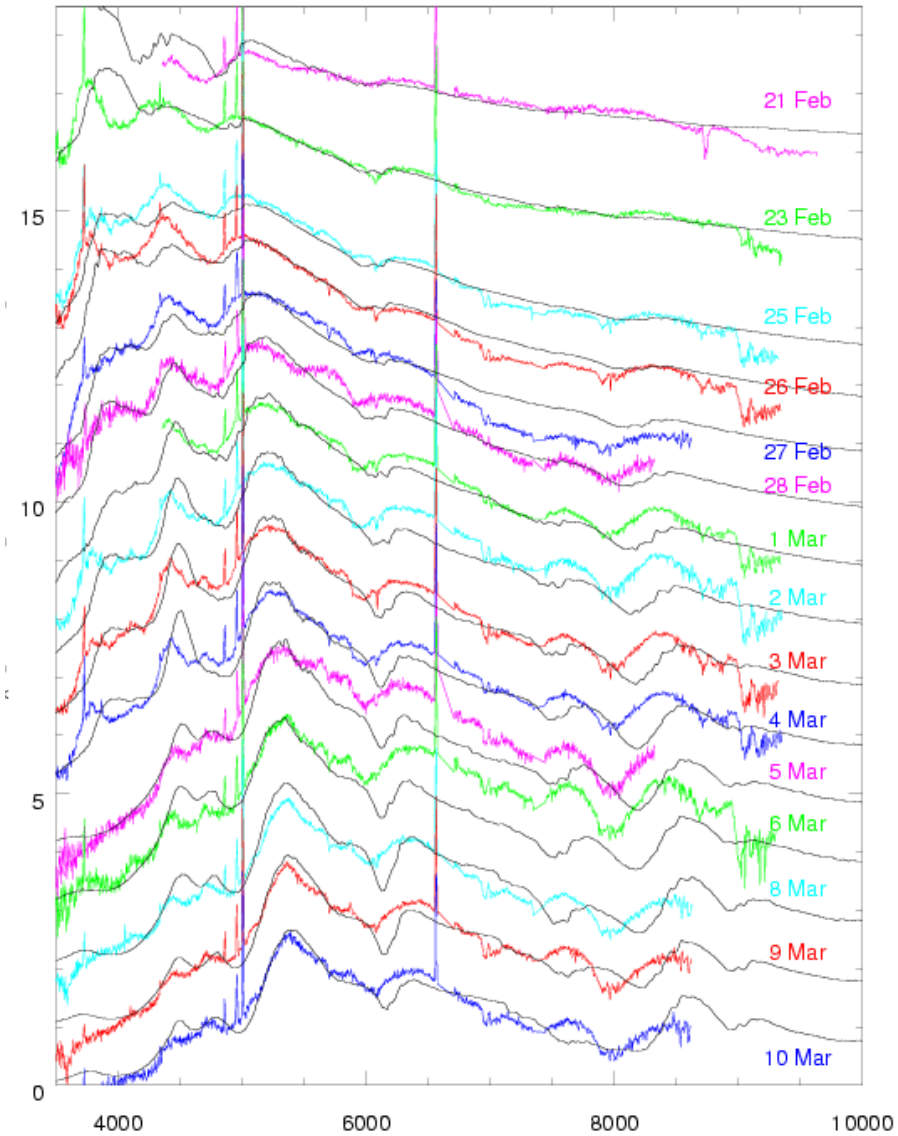


THERMAL SPECTRUM

SHOCK BREAKOUT

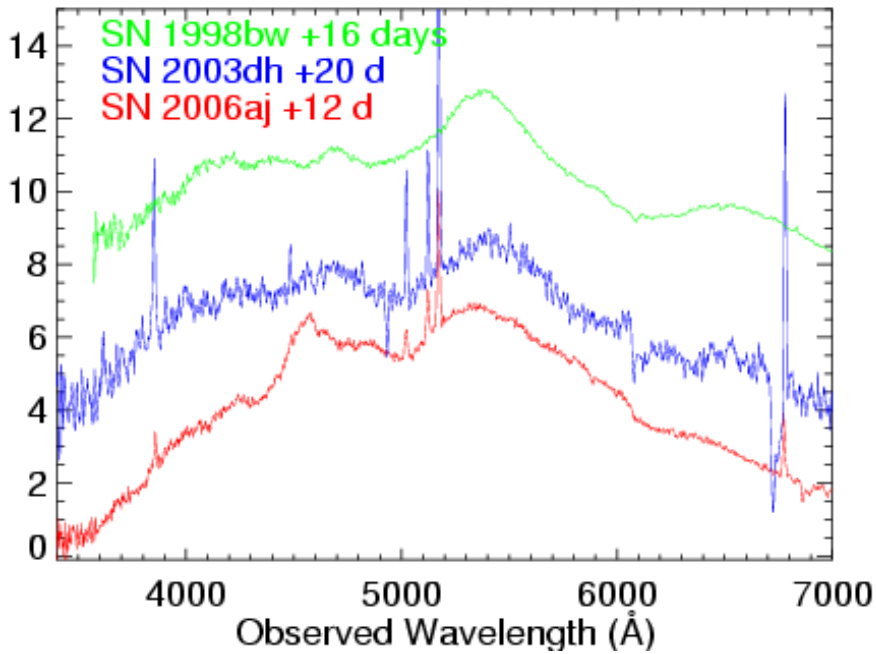
SUPERNOVA

SN 2006aj – another hypernova



Detailed spectroscopic monitoring

Broad-lined "**hypernova**"



Pian et al. 2005, Sollerman et al. 2005

More...

Coming soon

(The end for now)