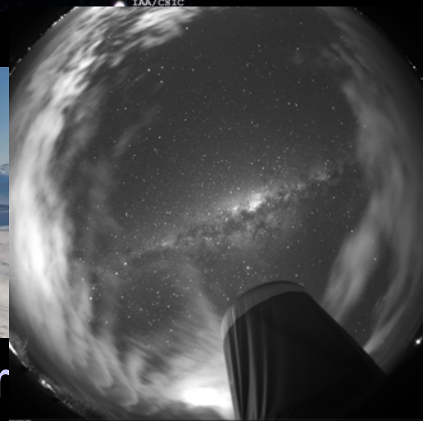
Multiwavelength observations of GRB afterglows

Lomonosov
/ UFFO-p

10.4m GTC

PdB Interferometer



0.6m BOOTES-3

Alberto J. Castro-Tirado
(IAA-CSIC Granada)

IAU Symp 279 – Death of massive stars
Nikko, 13 Mar 2012

Outline

1. Brief Introduction: The Afterglow and historical afterglows

2. Afterglow science in long-duration GRBs

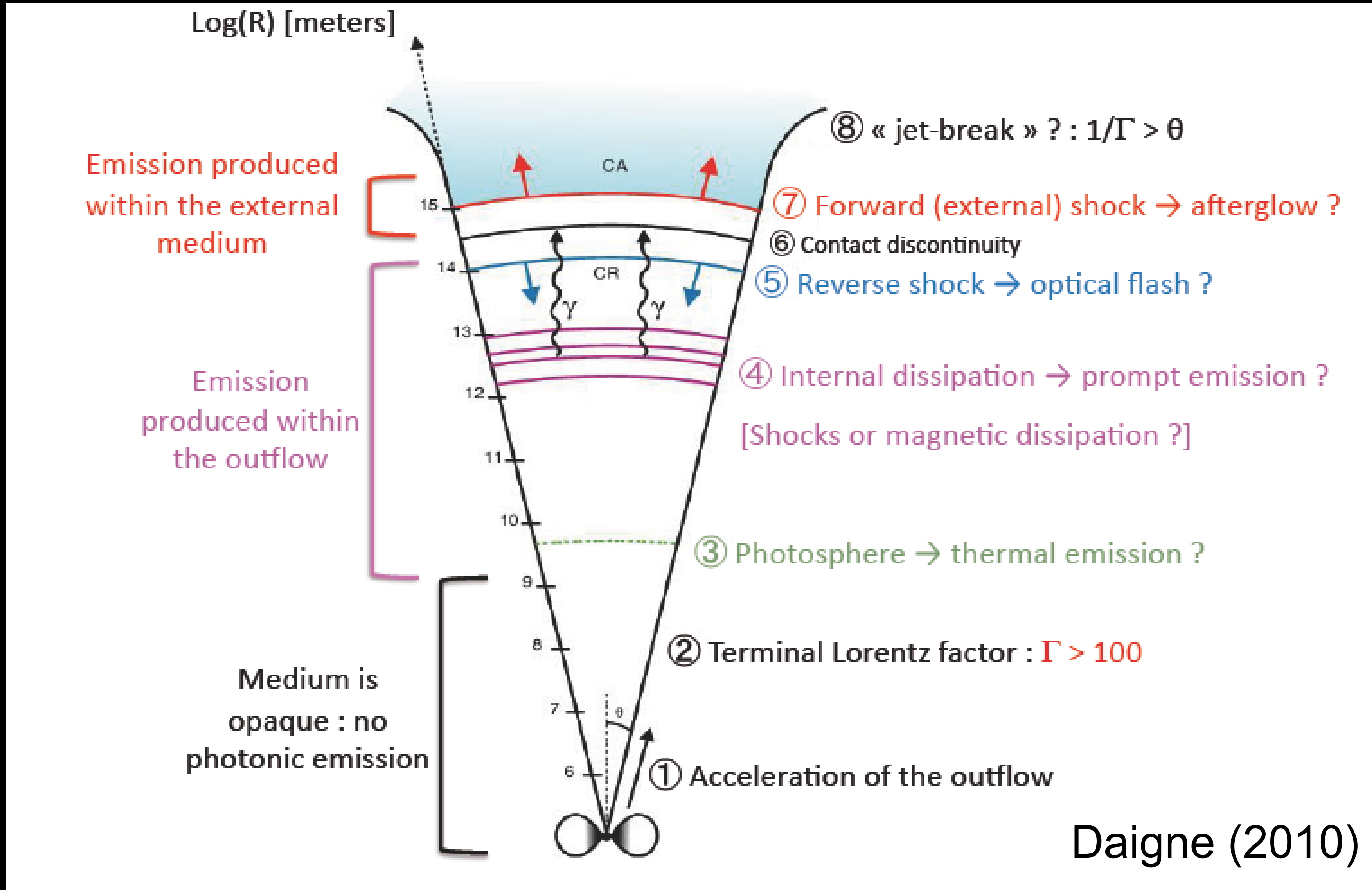
3. Automated and Robotic Telescopes for GRB follow-ups

4. UFFO-p onboard *Lomonosov*

Summary

1. The Afterglow and Historical afterglows

1. The afterglow



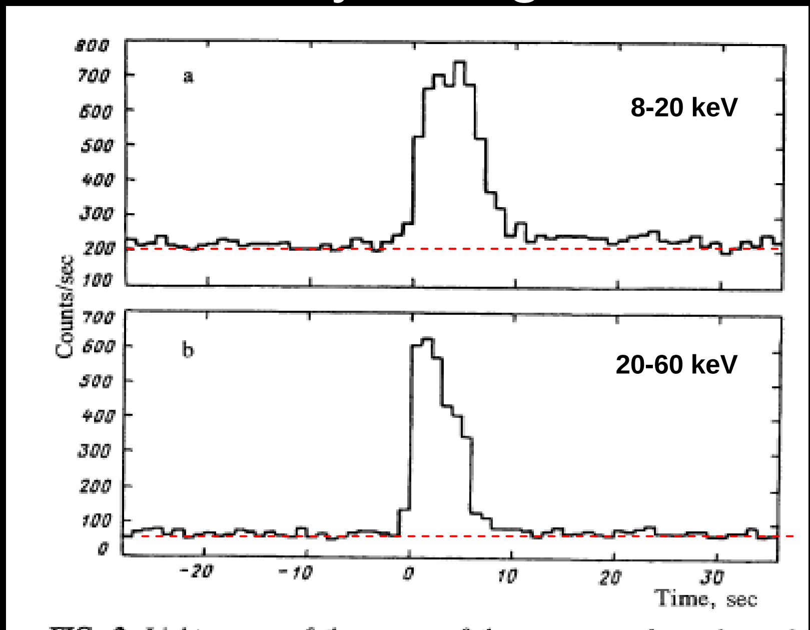
We always refer to '*the Afterglow era*' to the period starting in 1997, following the big *BSAX* discovery of X-ray afterglows (Costa et al. 1997) followed by counterparts at other λλλ.

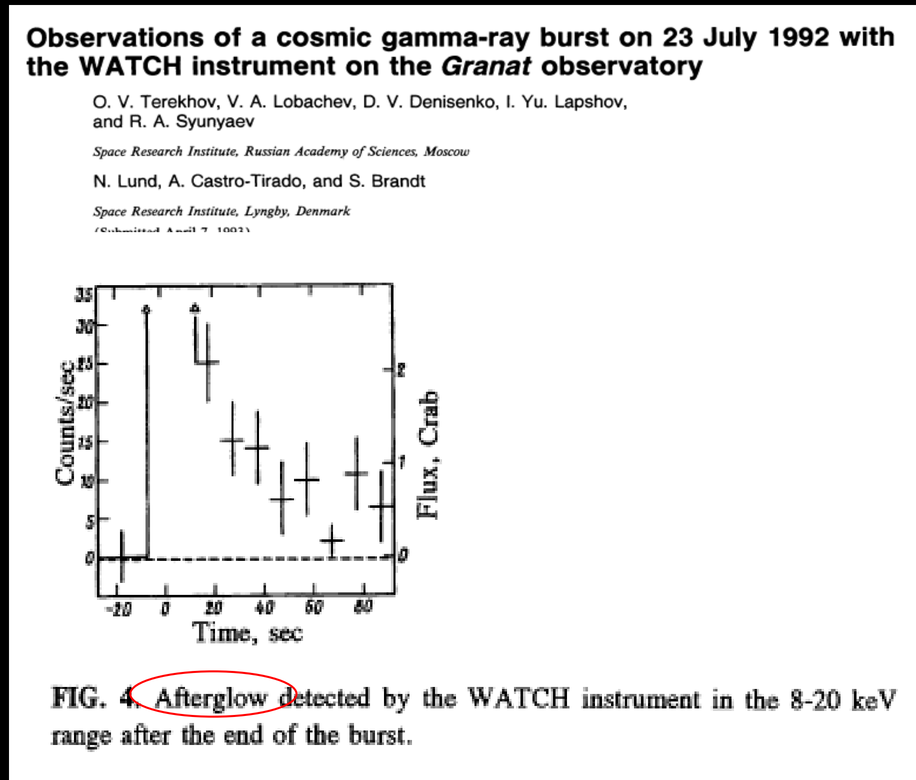
But were out there afterglows prior to 1997?

1. Historical Afterglows (1)

An X-ray afterglow (?) was pinpointed 5 yr before the *BeppoSAX* detection of GRB 970228.

GRB 920723B: evidences for an X-ray afterglow?





Observations of a cosmic gamma-ray burst on 23 July 1992 with the WATCH instrument on the *Granat* observatory

O. V. Terekhov, V. A. Lobachev, D. V. Denisenko, I. Yu. Lapshov, and R. A. Syunyaev

Space Research Institute, Russian Academy of Sciences, Moscow

N. Lund, A. Castro-Tirado, and S. Brandt

Space Research Institute, Lyngby, Denmark

FIG. 4. Afterglow detected by the WATCH instrument in the 8-20 keV range after the end of the burst.

C-T (1994), PhD Thesis

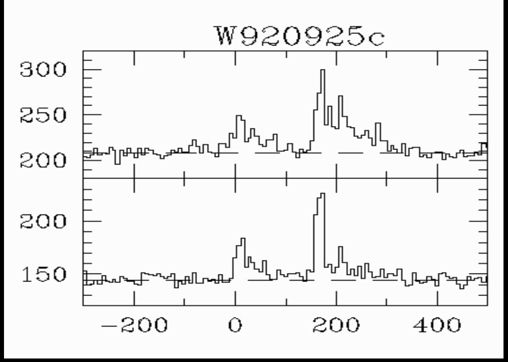
Terekhov et al. (1993), Pis`ma Astron. Zh. 19, 686

1. Historical Afterglows (2)

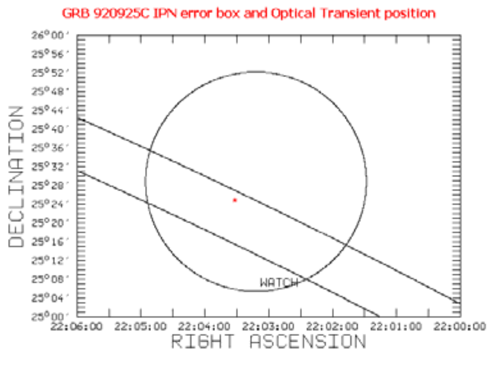
The first optical afterglow was already serendipitously imaged in 1992.

GRB 920925C was reported 4.5 yr prior to the famous GRB 970228, yet its OA needed 10 yr to be discovered! (and reported).

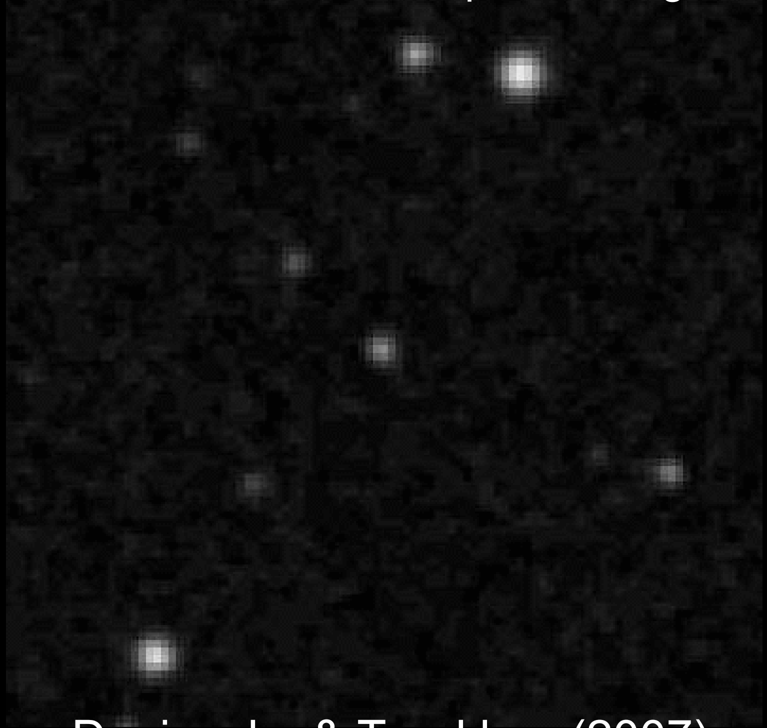
C-T (1994), PhD Thesis



Hurley et al. (2000)



GRB 920925c: the first optical afterglow

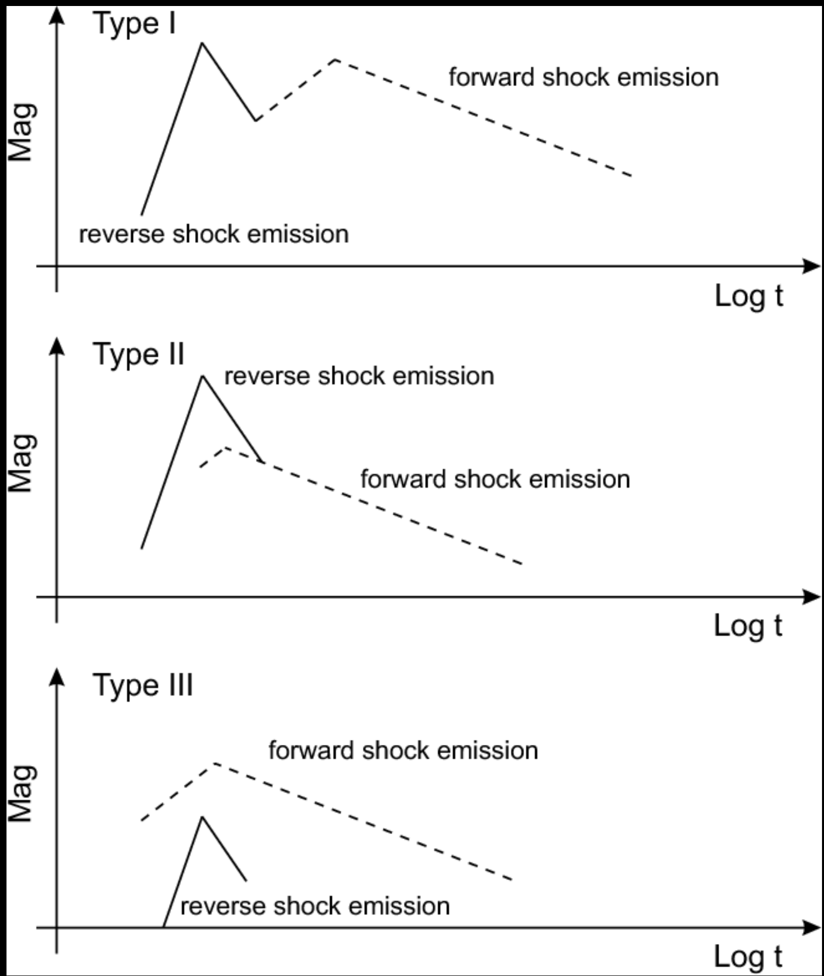


Denisenko & Terekhov (2007)

2. Afterglow science in long-duration GRBs

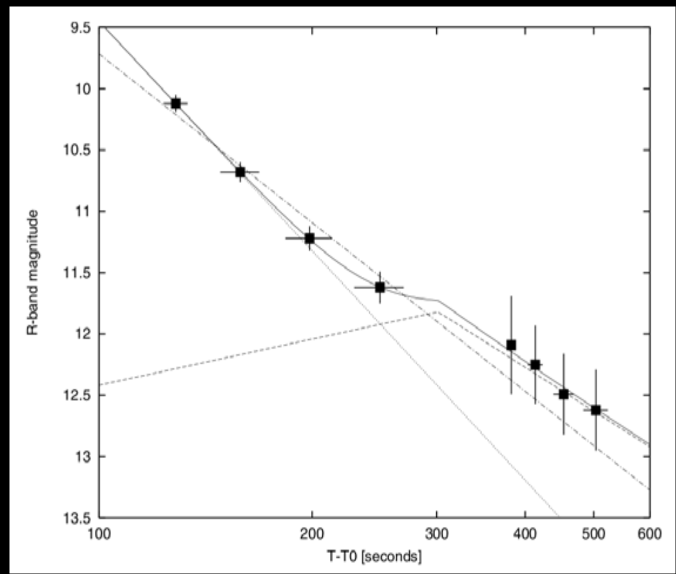
2. Afterglow science in long-duration GRBs (1)

Reverse and Forward Shocks



Zhang Kobayashi Meszaros (2003);
Gomboc et al. (2009)

Strength of RS depends on magnetization content of the ejecta



GRB 060117
(Jelínek et al, 2006)

2. *Afterglow science in long-duration GRBs (2)*

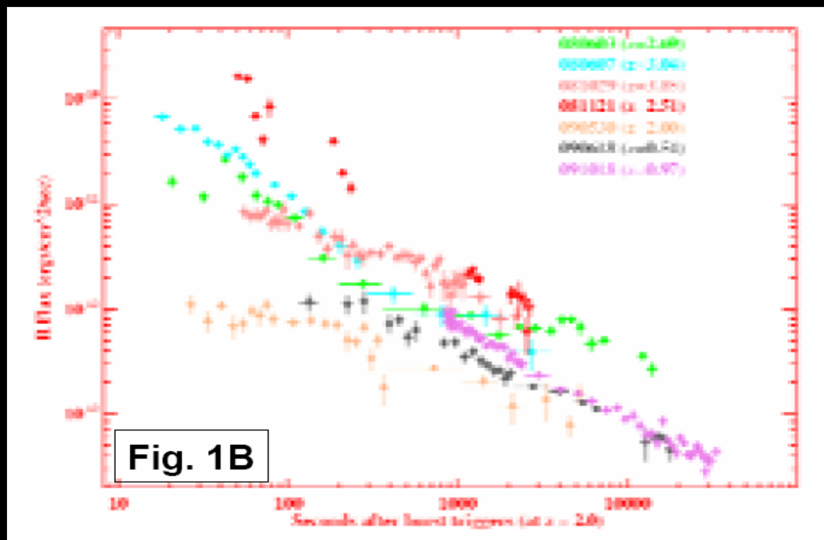
Forward Shock (Afterglow) Emission (1)

Peak time of the rising OA lightcurves → initial Lorenz factor Γ_0 (Molinari et al. 2007).

The rising lightcurves are also important to understand the onset of the afterglow (Sari et al. 1999) : α~2 ($\nu_c < \nu_{optical}$) or α~3 ($\nu_c > \nu_{optical}$) in the case of ISM or α~0.5 for a WIND density profile.

And to constrain off-axis and structured jet models (Painatescu et al. 1998).

$F(t) = At^{\alpha}$

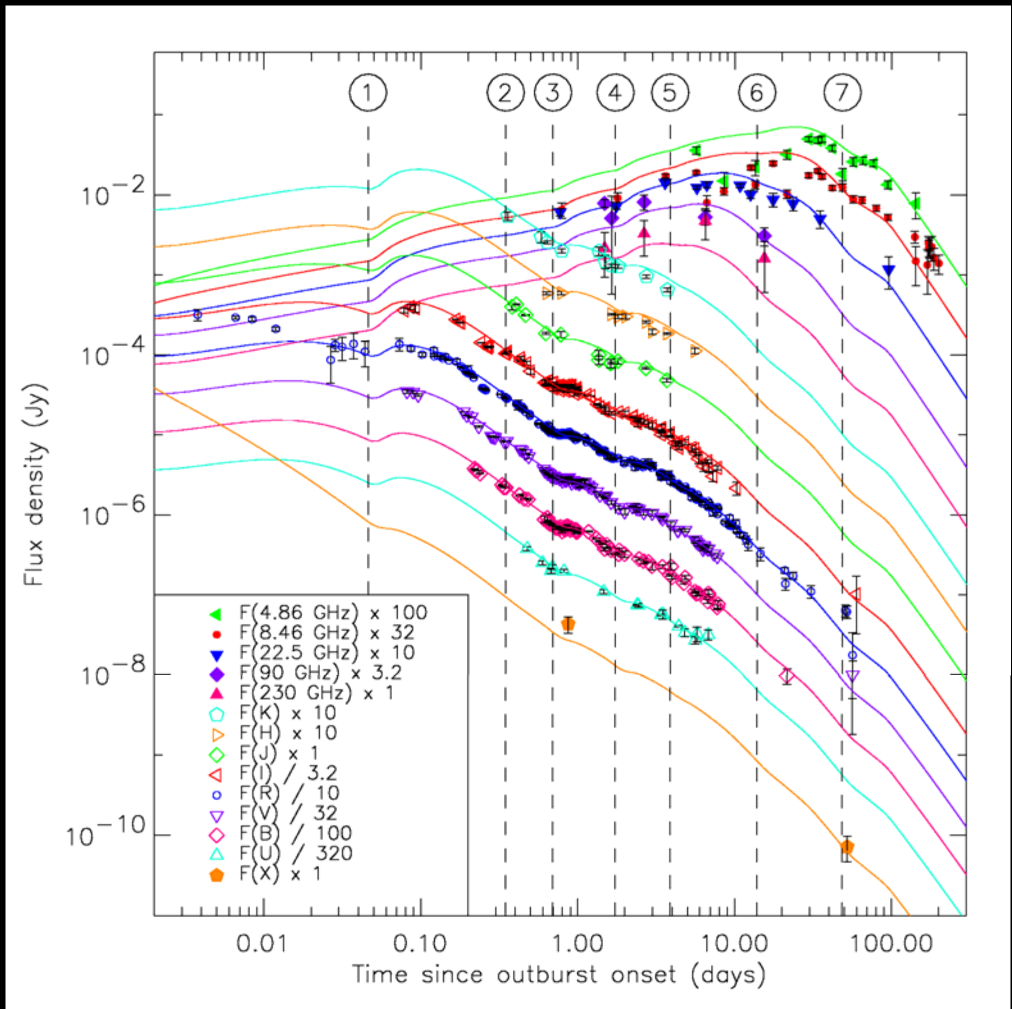


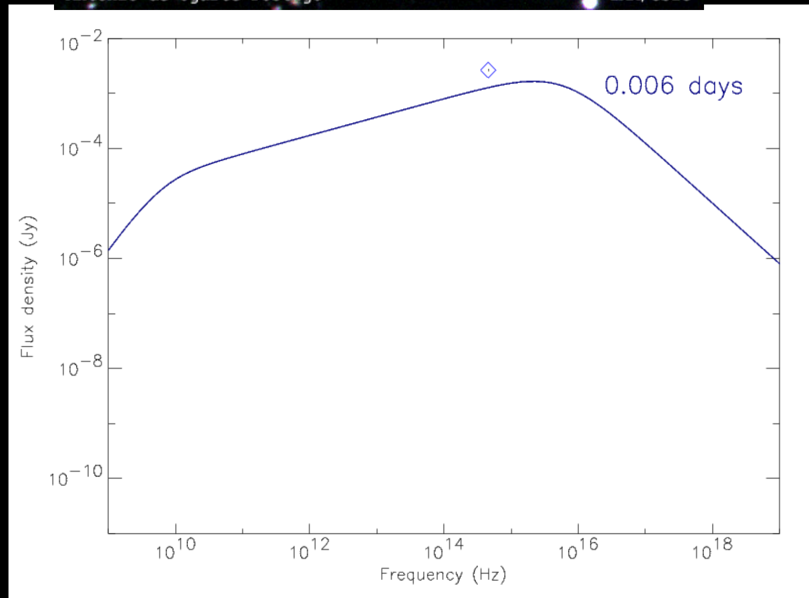
(Pandey et al. 2011)

2. Afterglow science in long-duration GRBs (3)

Forward Shock (Afterglow) Emission (2)

GRB 021004: Multi-λλλ modelling
(de Ugarte Postigo et al. 2006)





2. Afterglow science in long-duration GRBs (4)

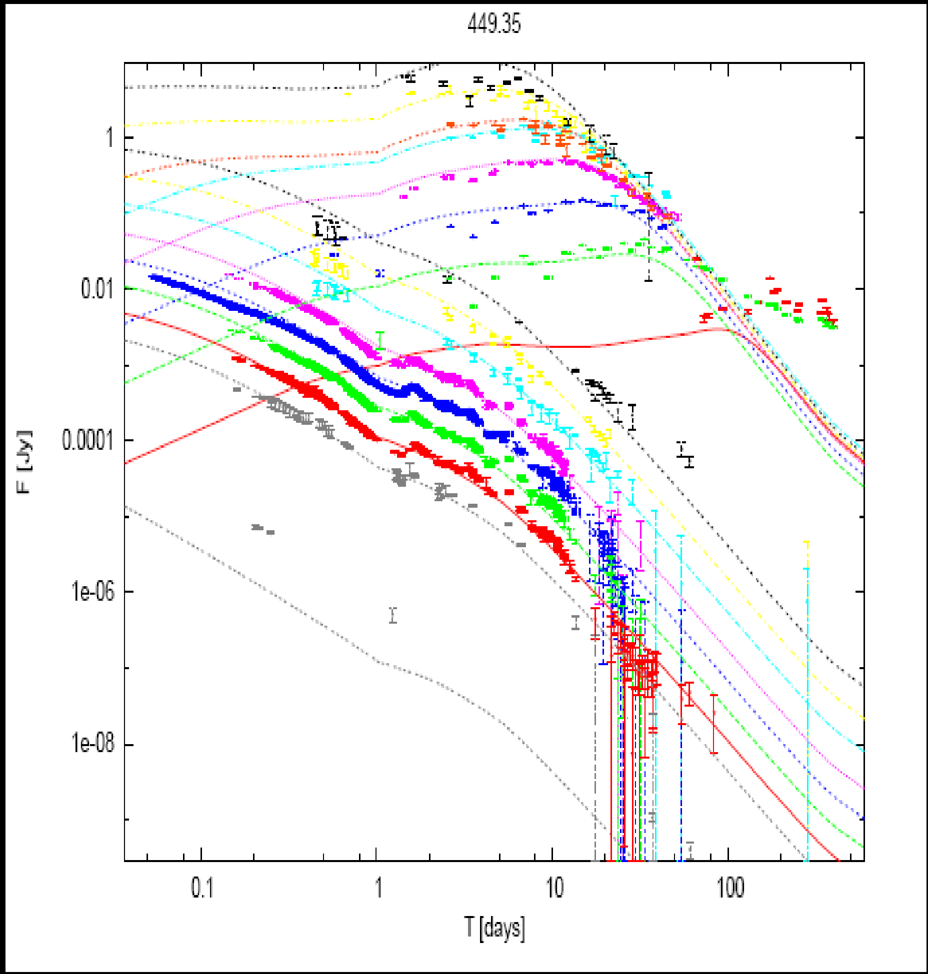
Forward Shock (Afterglow) Emission (3)

(Energy injections everywhere)

GRB 021004 (z = 2.33): modeled by multiple energy injections (de Ugarte Postigo et al. 2005 A&A 443, 841)

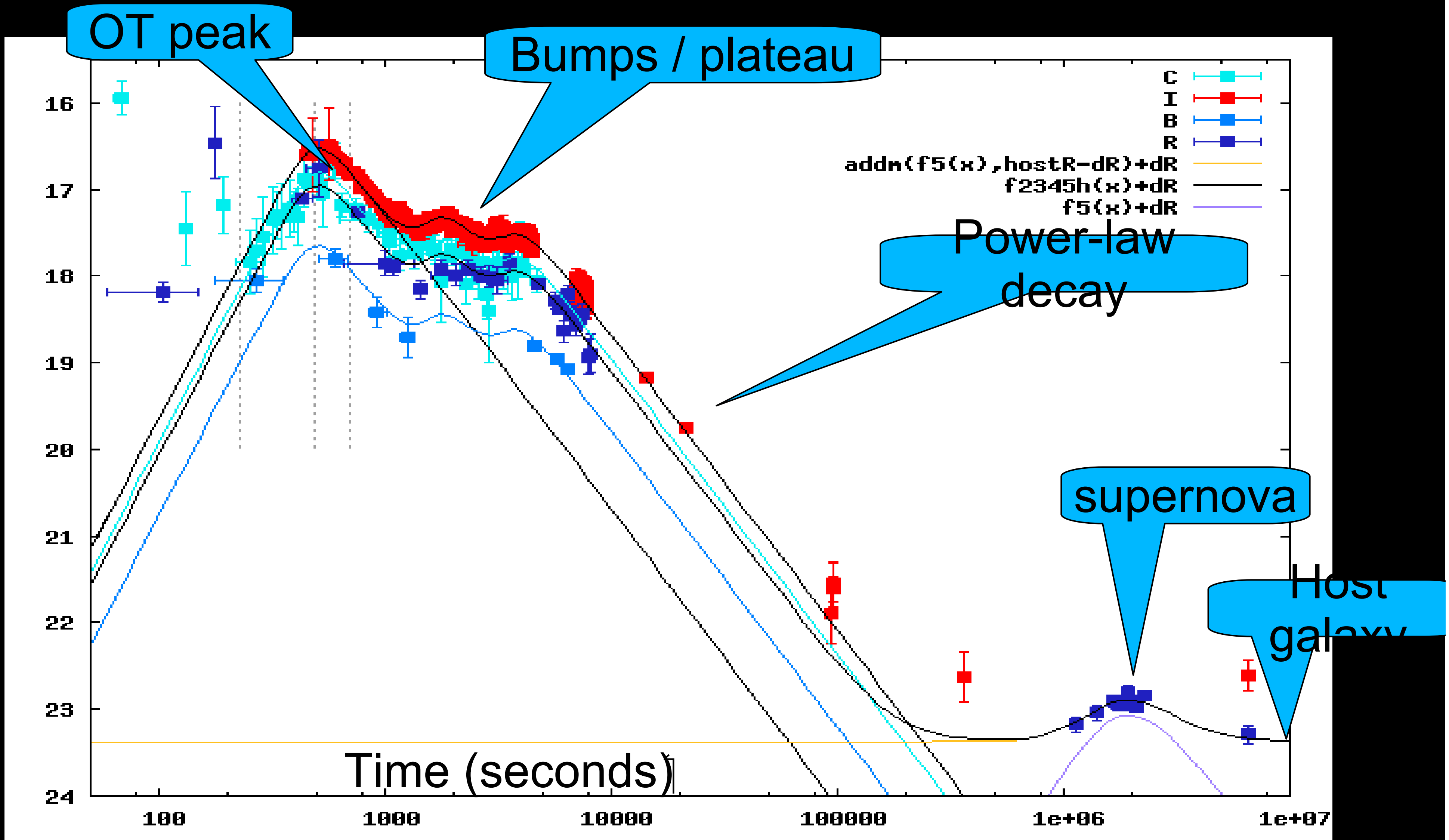
GRB 050730 (z = 3.97) & 051028 (unknown-z): twins peaks? (Castro-Tirado et al. 2005 A&A 459, 763)

GRB 030329 / SN 2003dh (z = 0.168): modeled by multiple energy injections but the initial phase cannot be properly modeled (Guziy et al. 2012, in prep)



2. Afterglow science in long-duration GRBs (5)

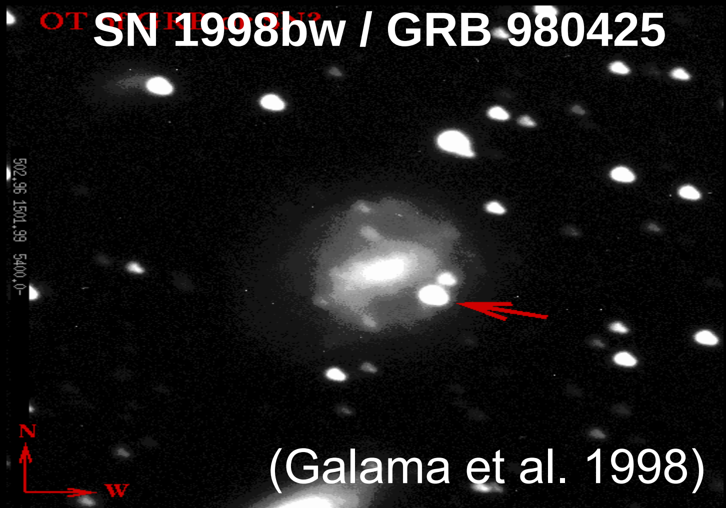
Forward Shock (Afterglow) Emission (4)



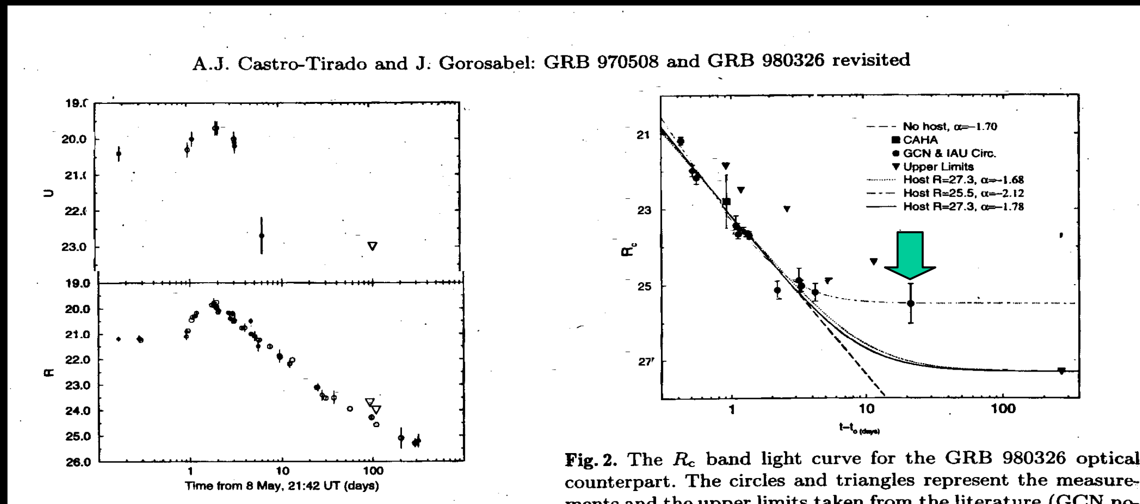
GRB 060904B: displaying all features on its light-curve (Jelinek et al. 2012)

2. Afterglow science in long-duration GRBs (6)

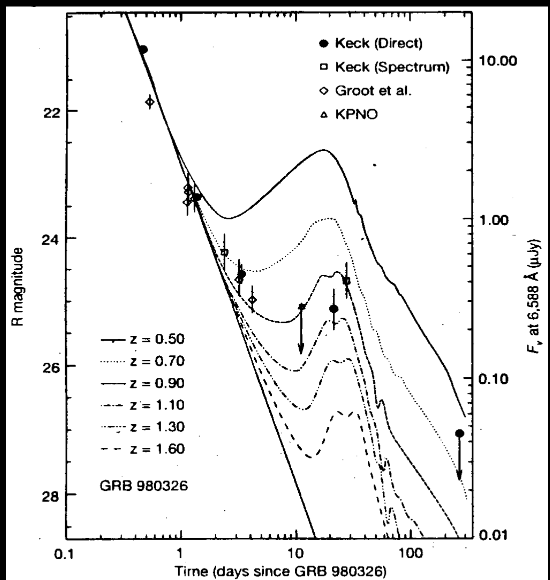
The energetic SN-GRB relationship (1)



Initial evidence for SN 1998bw/GRB 980425 (Galama et al. 1998, Pian et al.)



An underlying SN proposed for GRB 980326 (Castro-Tirado and Gorosabel 1999, A&AS 138, 449)

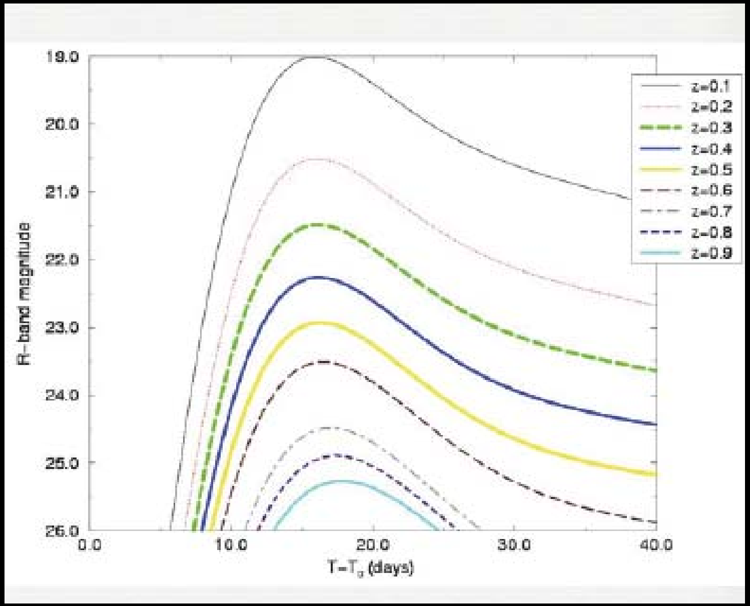


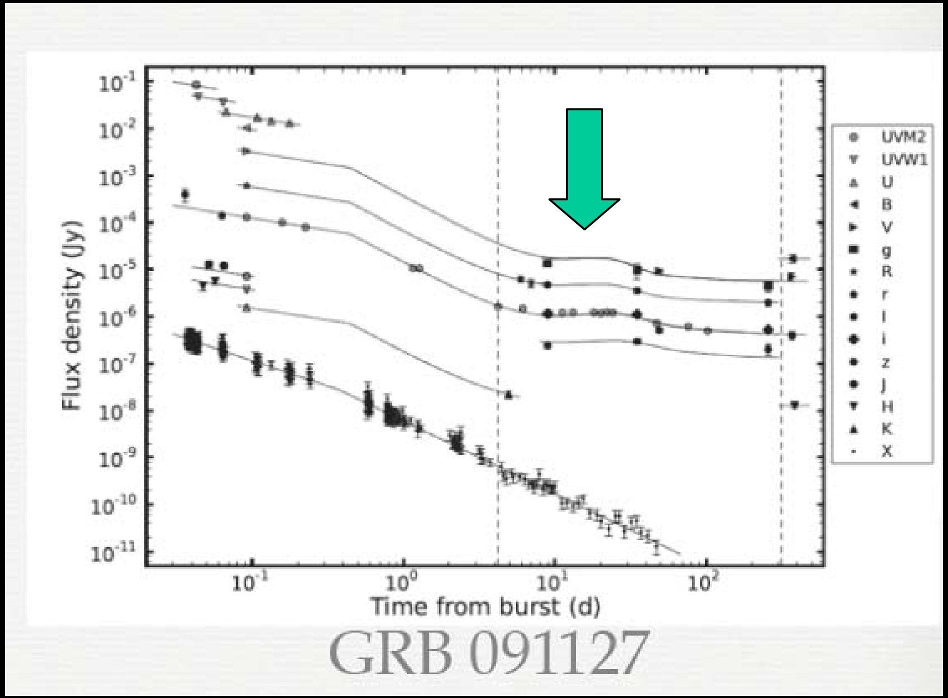
An underlying SN modeled for GRB 980326 (also independently proposed) (Bloom et al. 1999, Nat)

2. Afterglow science in long-duration GRBs (7)

The energetic SN-GRB relationship (2)

SNe/GRB reachable with GTC up to z ~ 1





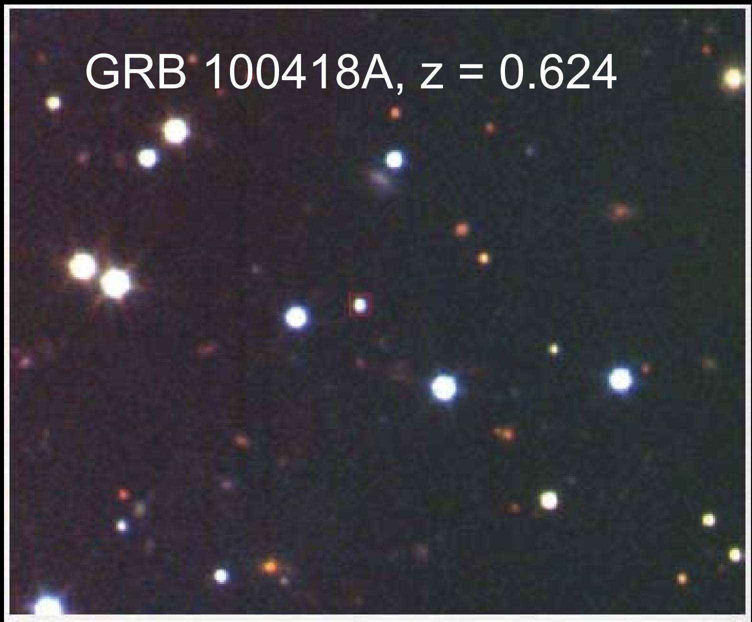
GRB 091127 / SN 2009nz

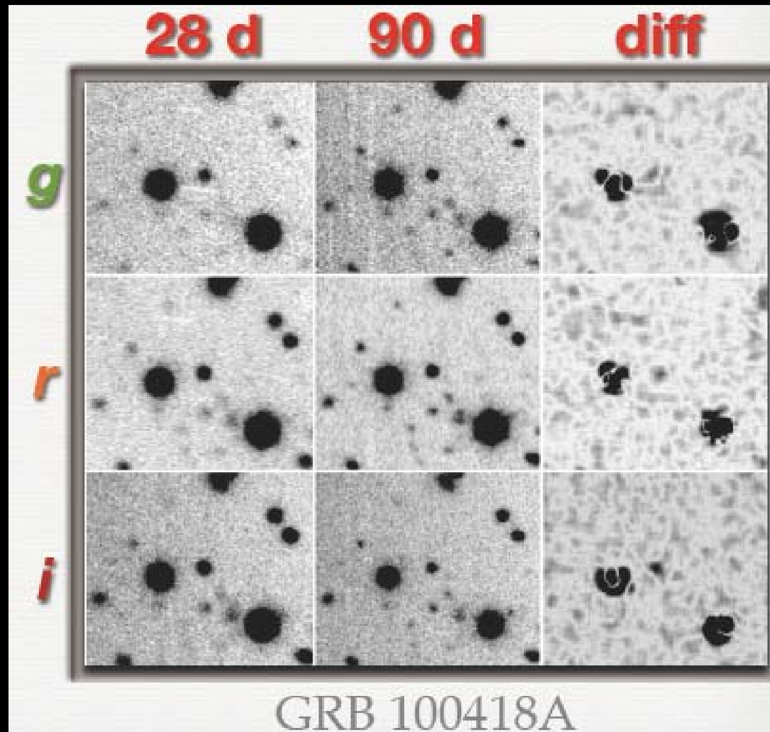
at z = 0.490 (Vergani et al. 2011, A&A 535, A127). See also Cobb et al. (2010), Berger et al. (2011)

2. Afterglow science in long-duration GRBs (8)

The energetic SN-GRB relationship (3)

SNe components give us clues on the nature of the GRB progenitors



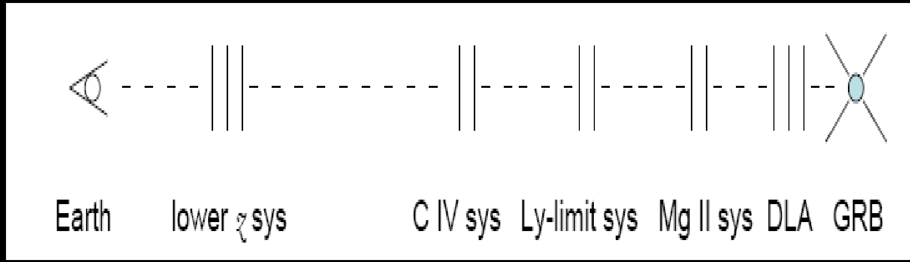


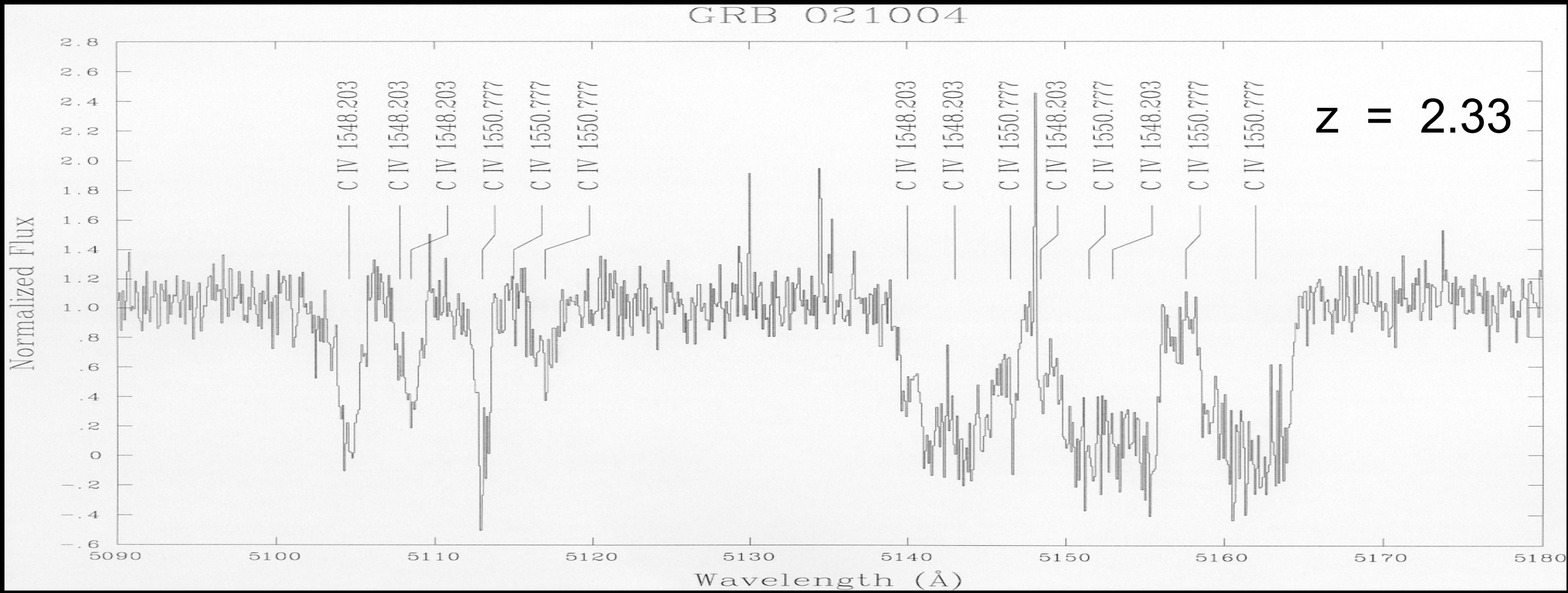
GRB 100418A / SN component (de Ugarte Postigo et al. 2012, in prep)

2. Afterglow science in long-duration GRBs (9)

Spectroscopic observations of GRB afterglows (1)

Besides determining the distance scale, opt/nIR spectroscopy is most essential for understanding the GRB environment (abundances, metallicities, etc).





(Salamanca et al. 2003, Castro-Tirado et al. 2010, Vergani et al. 2011)

GRB 021004: High resolution spectroscopy revealed several high velocity systems in the range 200-3000 km/s.

2. Afterglow science in long-duration GRBs (10)

Spectroscopic observations of GRB afterglows (2)

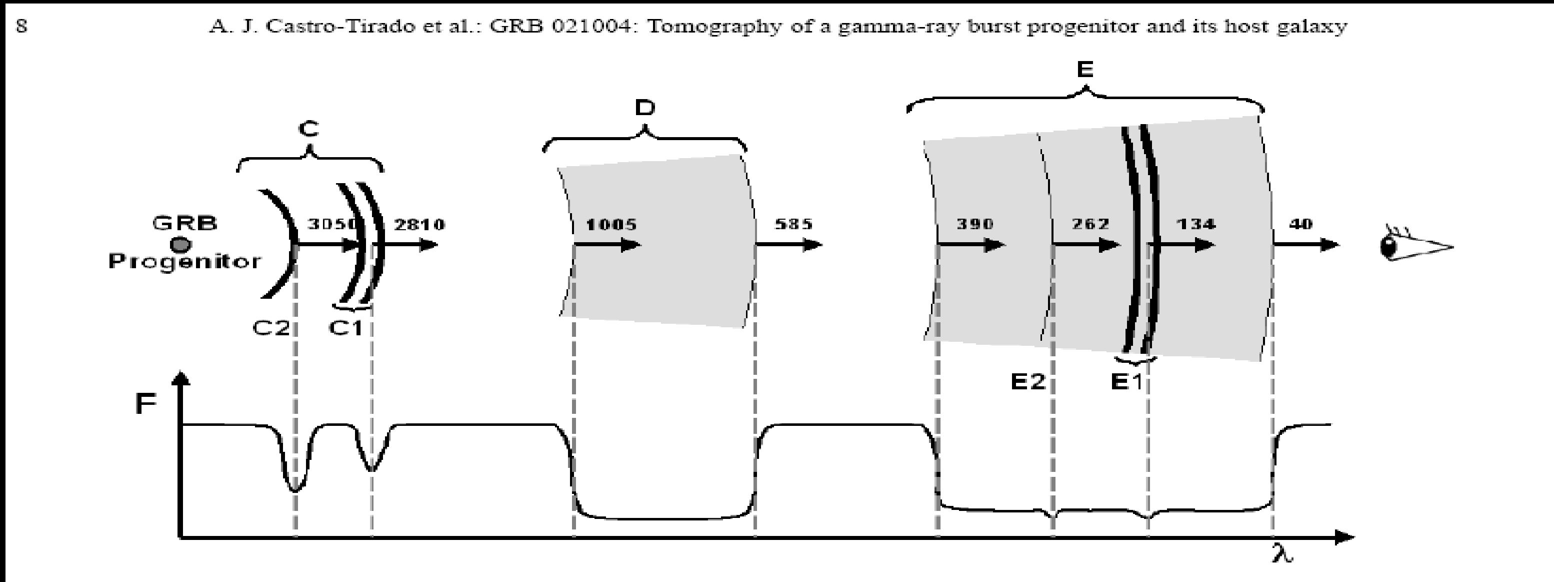


Fig. 5. A sketch showing the absorption line complexes C, D and E in the line of sight to GRB 021004, not drawn to scale.

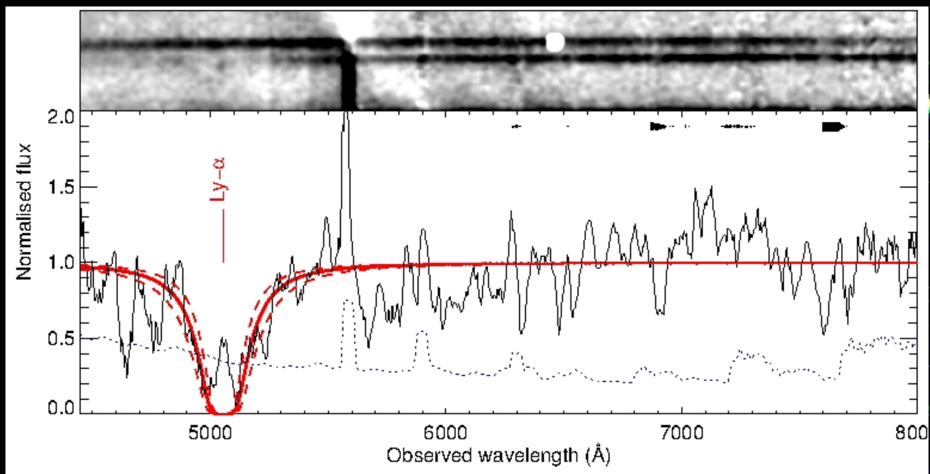
In GRB 021004 (z = 2.33), the C1, C2 and D systems naturally explained by multiple shell formed by stellar winds of a WR progenitor after passing through a LBV phase after reaching the Eddington limit. A ~60 Mo ZAMS progenitor is suggested: O → LBV → WR → SN (Castro-Tirado et al. 2010, A&A 517, A 61).

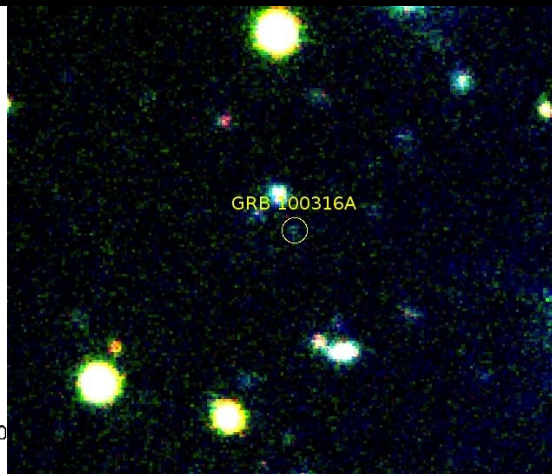
2. Afterglow science in long-duration GRBs (11)

Spectroscopic observations of GRB afterglows (3)

Important role of the 10.4m GTC

Redshifts determination for GRB 100316A, 110503, 110801A and 110918A. Redshift confirmation for 100816, 110422A and 110918A.





(Sánchez-Ramírez et al. 2012, in prep)

GRB 100316A: redshift determination by GTC ($z = 3.2$)

2. Afterglow science in long-duration GRBs (12)

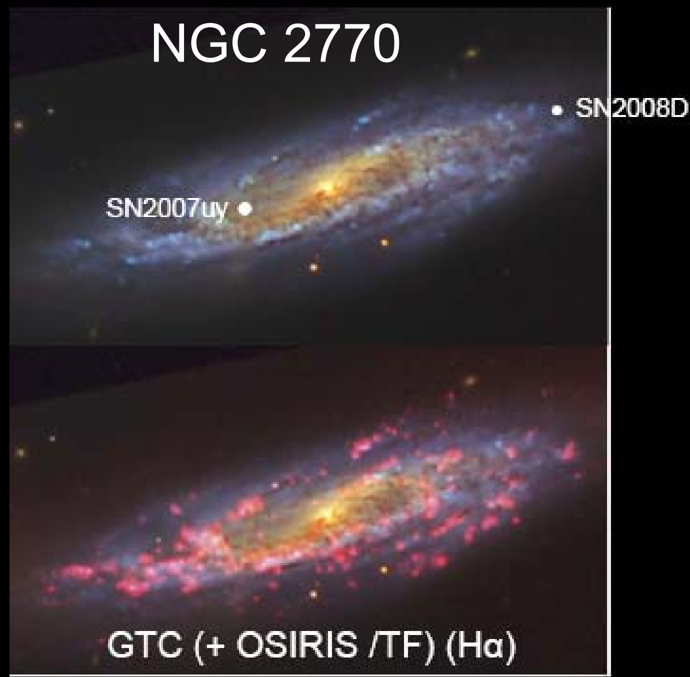
Polarimetric observations of different GRB afterglows

They show the varying level of polarized emission in the jet and the geometry

-Detected on a few “classical” GRBs, usually P = 1-2% (e.g. Gorosabel et al. 2004, A&A 422, 113) and rarely up to 10 % (Steele et al. 2009, Nat 462, 767) . ~1.5% for SN 2003dh / GRB 030329 (Greiner et a. 2003).

-SN 2006aj (Ic) / XRF 060218A: eviden-ce for aspherical expansion. P = 4% to 1.4% plus a 100º P. A. rotation (Gorosa-bel et al. 2006, A&A 459, L33).

-SN 2008d / XRT 080109 in NGC 2270: evidence for aspherical expan-sion. P = 1% (Gorosabel et al. 2010, A&A 522, A14).

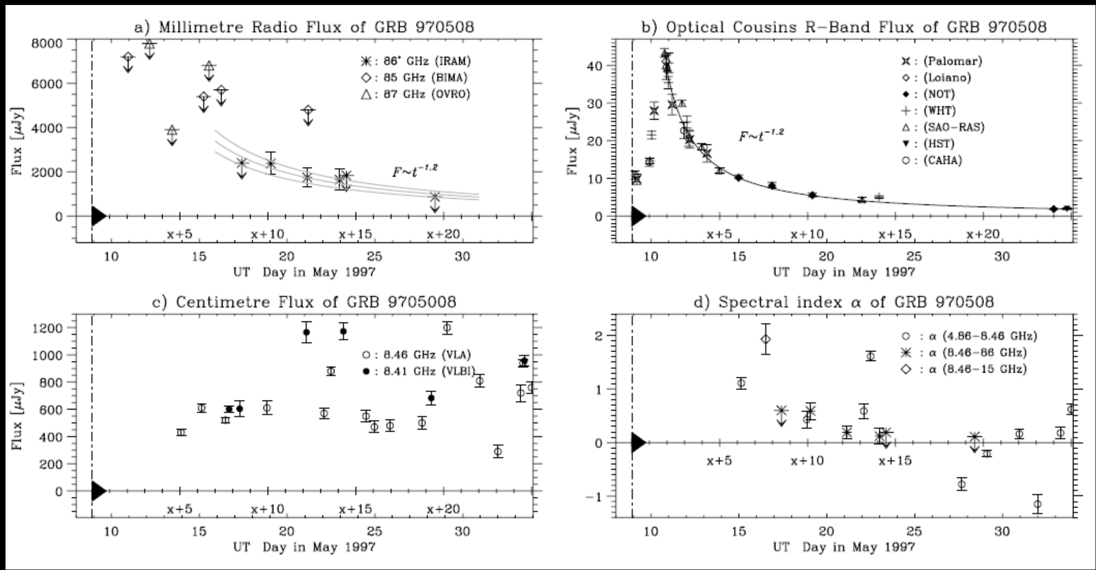


Not associated to any given giant H-II region in NGC 2770

2. Afterglow science in long-duration GRBs (13)

Afterglows at mm and sub-mm wavelengths (1)

As soon as the first X-ray afterglow was discovered by *BSAX* in Feb 1997, we attempted Plateau de Bure Interferometer (PdBI) observations for the second event (May 1997). They led to the first detection ever of an afterglow at mm wavelengths!

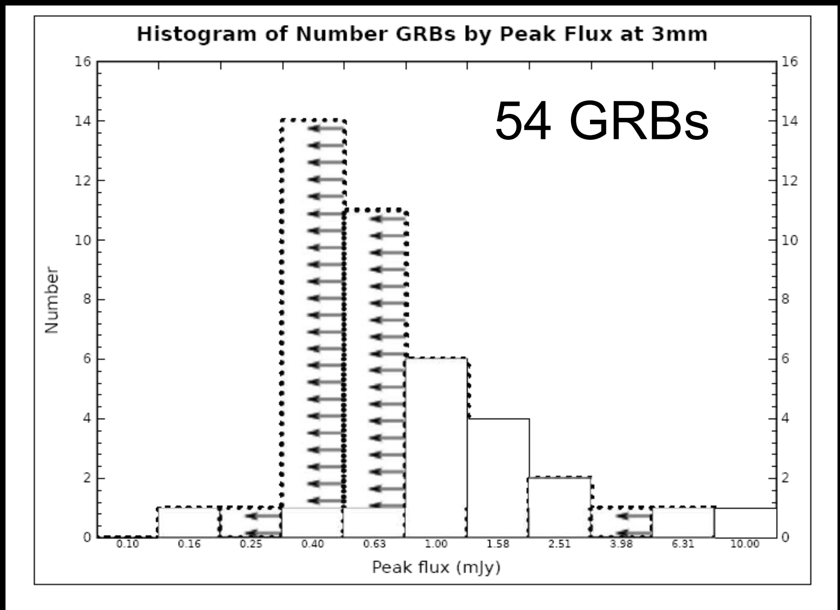


GRB 970508 at z = 0.805 (Bremer et al. 1998, A&A 332, L13)

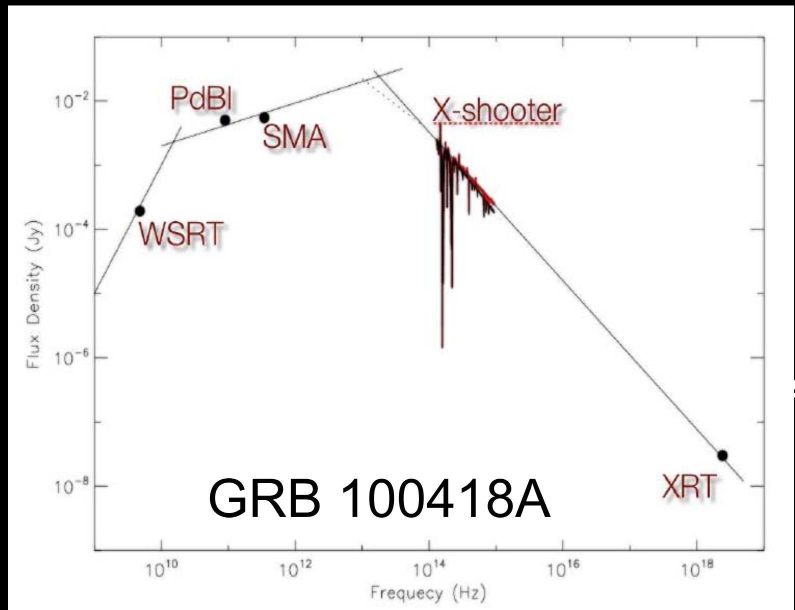
2. Afterglow science in long-duration GRBs (14)

Afterglows at mm wavelenghts (2)

The PdBI GRB legacy survey (Castro-Tirado et al. 2012, A&A, partly published in de Ugarte Postigo et al. 2012, A&A 538, A44, including also sub-mm data): 54 GRBs have been observed at 90 GHz in 1997-2011, with a 37% success in the detection rate.



Castro-Tirado et al. 2012

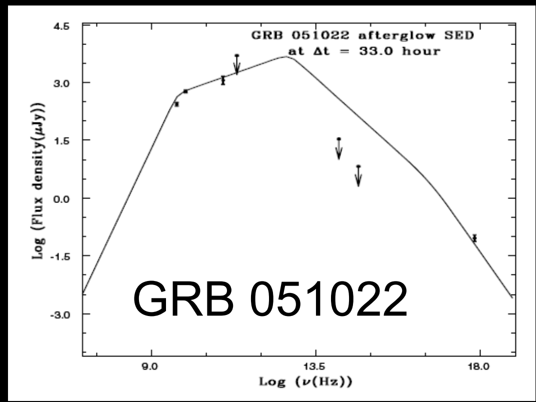


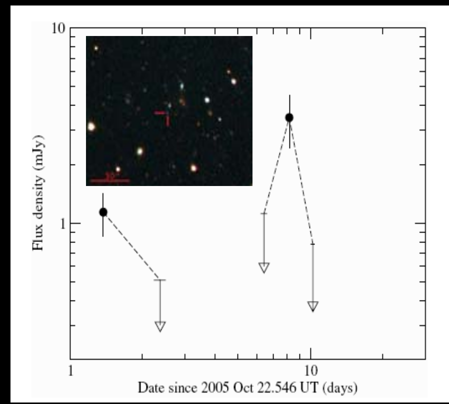
See Poster #10 by de Ugarte Postigo

2. Afterglow science in long-duration GRBs (15)

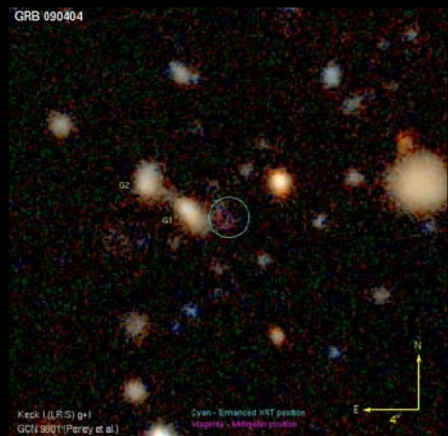
Dark GRBs at mm and sub-mm wavelenghts

GRB 051022 : A dark burst, with the host galaxy (z = 0.809) identified thanks to the mm flares and afterglow detected at Bure (Bremer et al. 2005, GCNC 4157). A powerful sub-mm emitter galaxy? (C-T et al. 2007, A&A 475, 101).





GRB 090404: VLA and PdBI detection of the afterglow for this dark GRB (C-T et al. 2012). No evident host galaxy.



Success rate of attempted dark GRBs at PdBI (bias-selected) : 3/6 (50%)

2. Afterglow science in long-duration GRBs (16)

The SN / GRBs at mm wavelengths

Object ID	Flux Density
GRB 030329 / SN 2003dh	58 mJy
XRF 060218 / SN 2006aj	< 2 mJy
XRT 080109 / SN 2008d	0.65 mJy

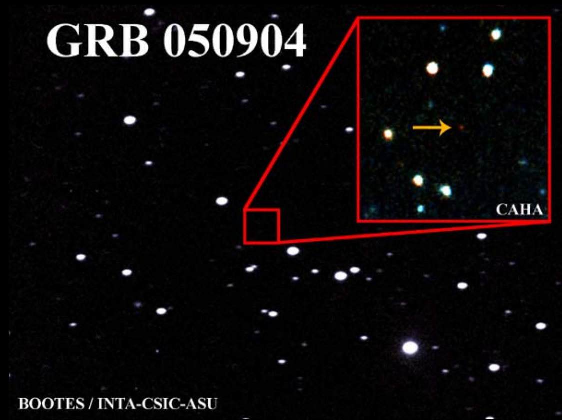
2. Afterglow science in long-duration GRBs (17)

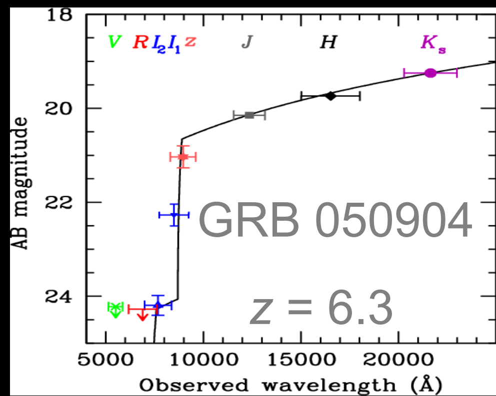
Ultra-high redshift GRBs at mm wavelengths (1)

GRB 050904 (z = 6.29, Kawai et al. 2006): 1.3 mJy @ 90 GHz.

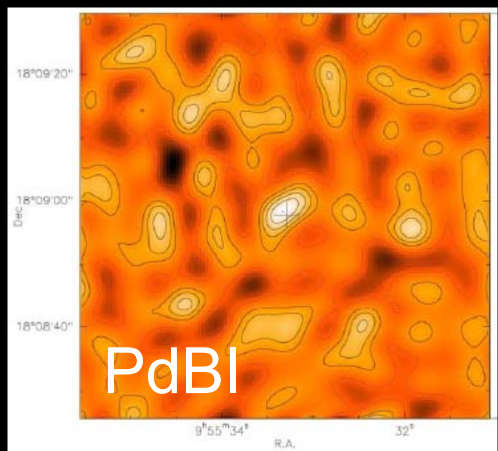
GRB 080913 (z = 6.7): < 0.4 mJy @ 90 GHz (Pérez-Ramírez et al. 2010, A&A 510, A105).

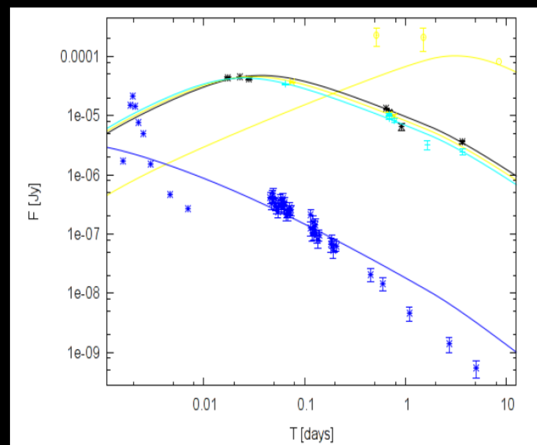
GRB 090423 (z = 8.2): 0.26 mJy (5.1σ), modelled as a RS (C-T et al. 2012).





Detected 2 (out of 3) ultra-high z events !





(Chandra et al. 2010)

3. Automated and Robotic Telescopes and their usage for GRB follow-ups

3. Automated and Robotic Telescopes (1)

Advantages for GRB afterglow follow-ups

<u>Automatization</u> of existing instruments (eg. PAIRITEL in the US or the 1.23 m CAHA tel in Spain)

Early detection of GRB 120311A ~200 s after the GRB (Kubánek et al. 2012, GCNC 13036)

*Fast reaction times (~120-200s for ATs vs 5-30 s for RTs)

*Independent operation

The MITSUME <u>robotic telescopes</u> in Japan

3. *Automated and Robotic Telescopes (2)*

The BOOTES Network of RTs in several continents

BOOTES (Burst **O**bserver and **O**ptical **T**ransient **E**xploring **S**ystem**)**, is becoming a worldwide network (3 so far) of 0.6m Ø identical robotic telescopes, EMCCD cameras and filters (clear and g'r'i'ZY) should help rapidly pointing to these events as soon as they go off. The last station (BOO-4) will be officially opened next week in China.

bootes.iaa.es

3. Automated and Robotic Telescopes (3)

Advantages for GRB afterglow follow-ups

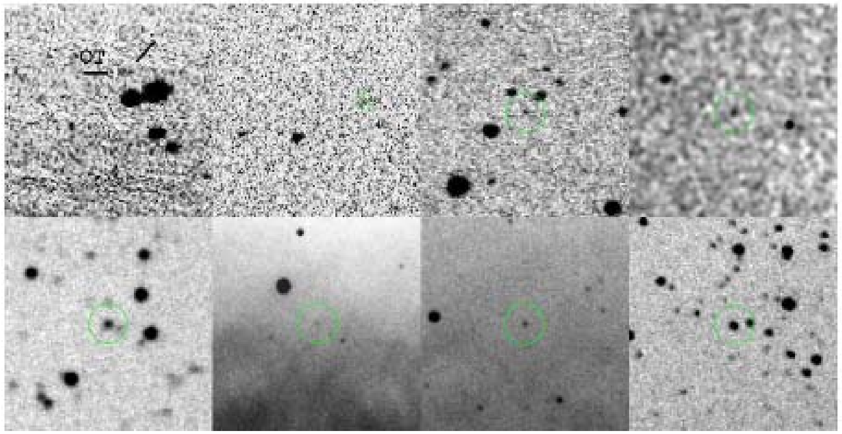
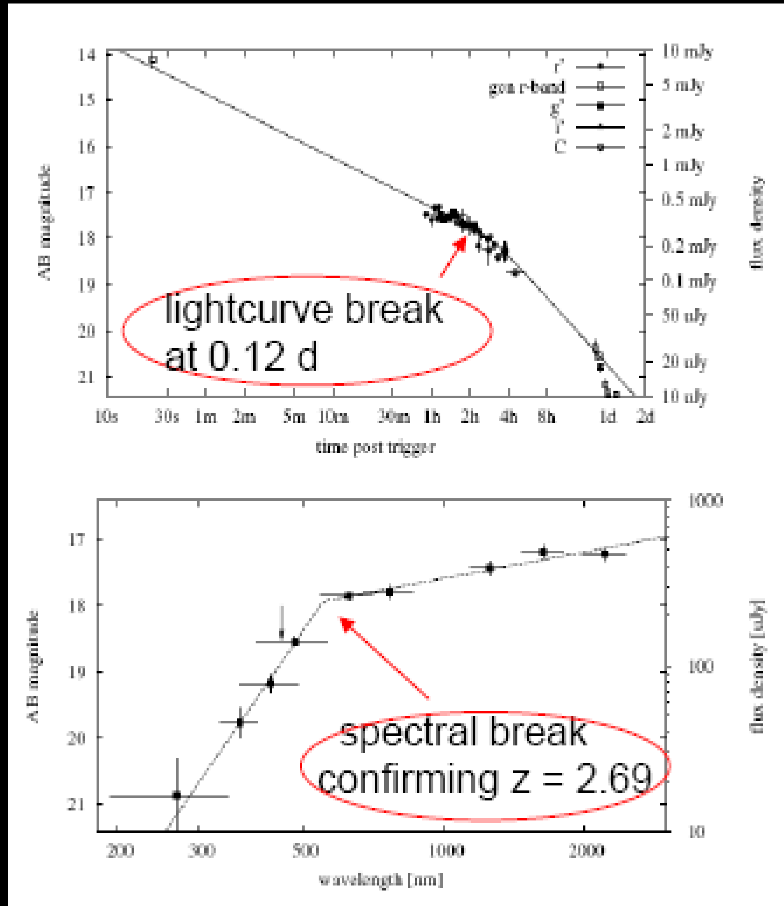


Fig. 3. GRB optical transient detections by BOOTES-1B: first row: GRB 050824, GRB 050922C, GRB 051109A, GRB 080330. Second row: GRB 080413B, GRB 080430, GRB 080602B, GRB 080605.

Jelínek et al. (2010)

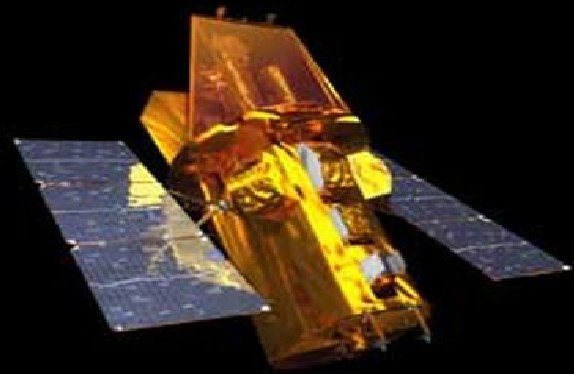


GRB 080603B (Jelínek et al. 2012)

(BOOTES-1 & -2 data)

4. UFFO-p onboard Lomonosov

4. UFFO-p onboard Lomonosov (1)



GRB afterglows can be also monitored by doing the follow-up using the triggering satellite itself besides sending the position to the Earth *(BeppoSAX* in 6-8 hr, *Swift* in 1 min).

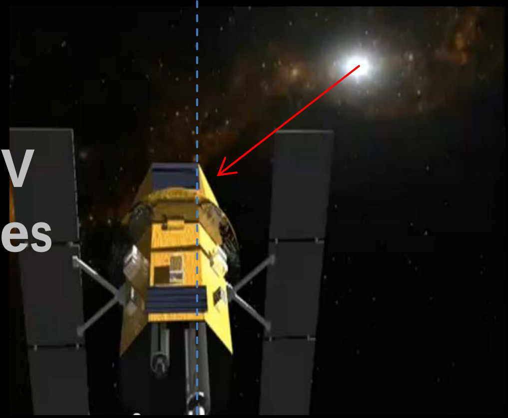
Early follow-up (within ~1 hr) only available to *Swift* so far (even very early sometimes with response of ~1 min) due to the slewing time of the *entire* spacecraft.

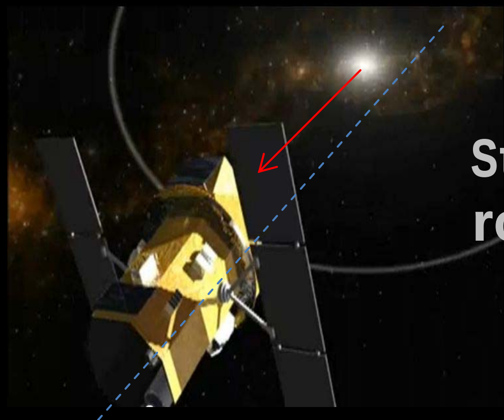
Is it possible to beat this 1 min barrier FROM SPACE?

4. UFFO-p onboard Lomonosov (2)

Concept of Fast Slewing

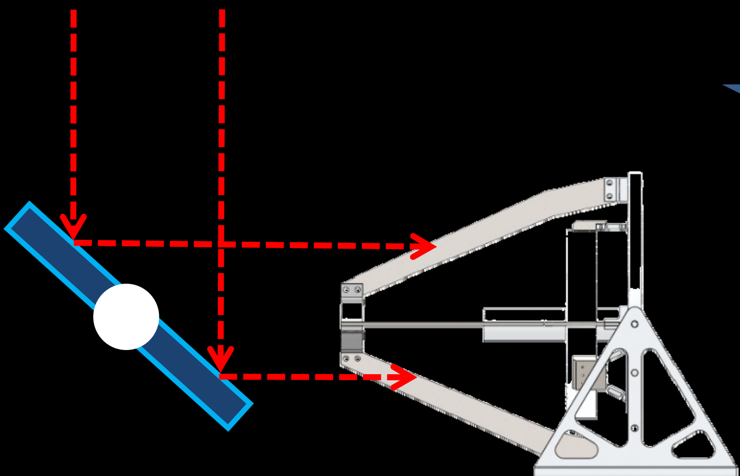
Step 1: wide FOV X/γ camera locates GRB

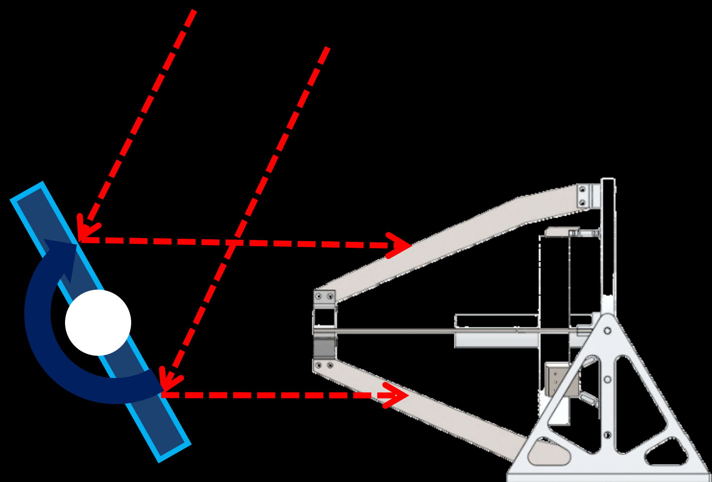




Step 2: Spacecraft rotates to point at GRB

SWIFT rotates entire spacecraft to point UVOT and XRT

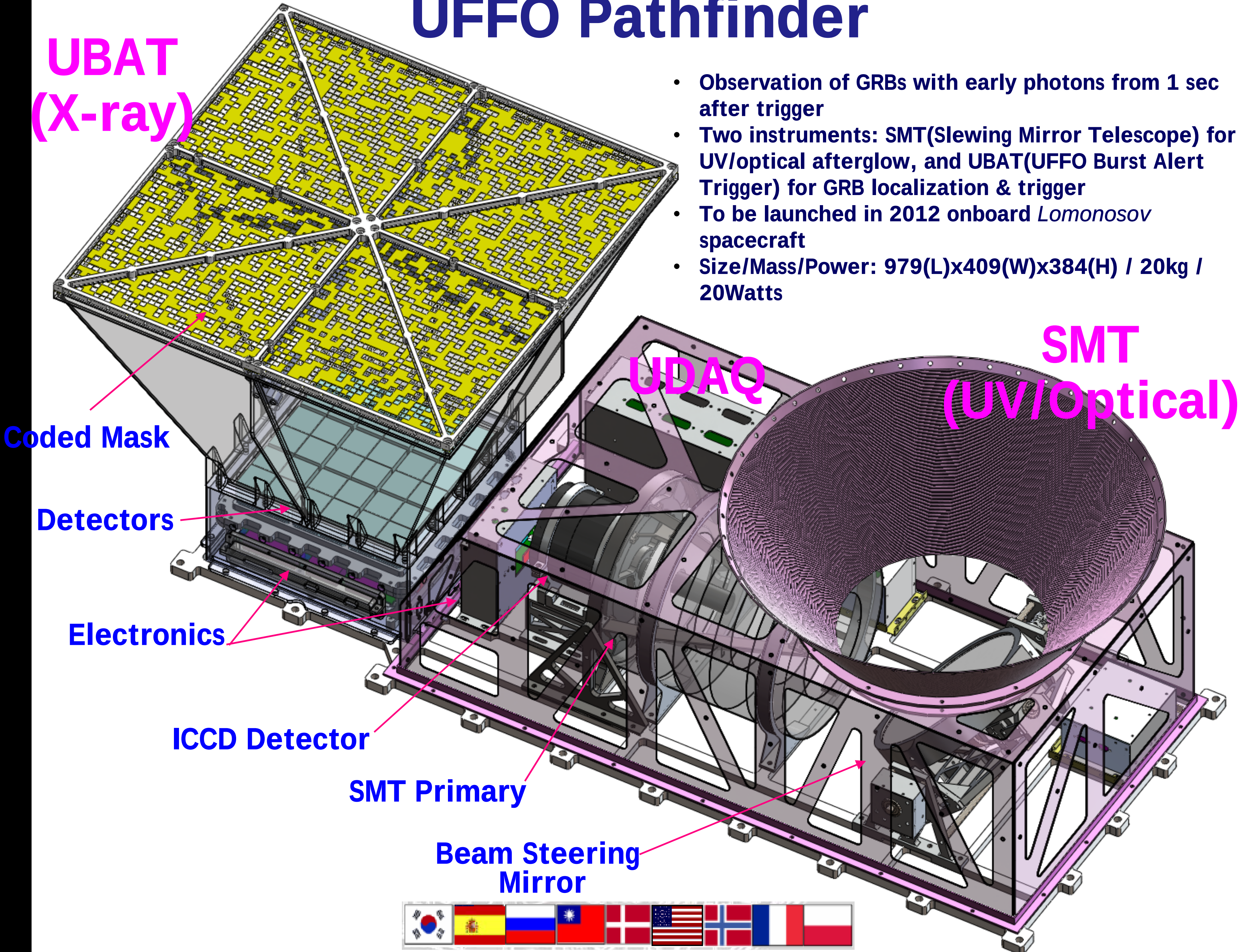




In UFFO-p, we move the optical path, not the spacecraft with fast slewing mirror system → much faster (NEW Concept)

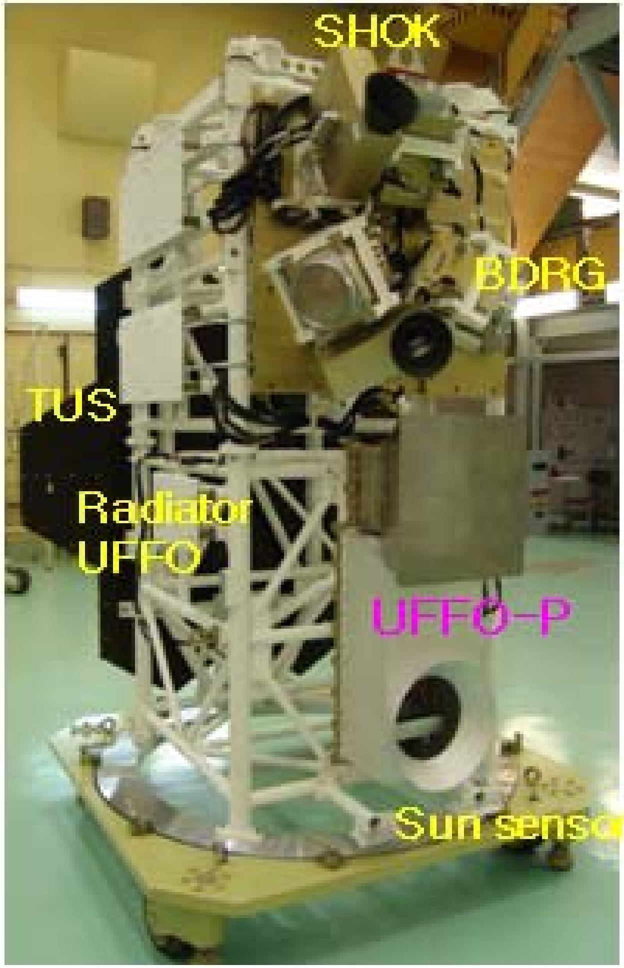
UFFO Pathfinder

- Observation of GRBs with early photons from 1 sec after trigger
- Two instruments: SMT(Slewing Mirror Telescope) for UV/optical afterglow, and UBAT(UFFO Burst Alert Trigger) for GRB localization & trigger
- To be launched in 2012 onboard *Lomonosov* spacecraft
- Size/Mass/Power: 979(L)x409(W)x384(H) / 20kg / 20Watts



4. UFFO-p onboard Lomonosov (4)

UFFO-pathfinder at NIIEM-Russia (Oct 2011)

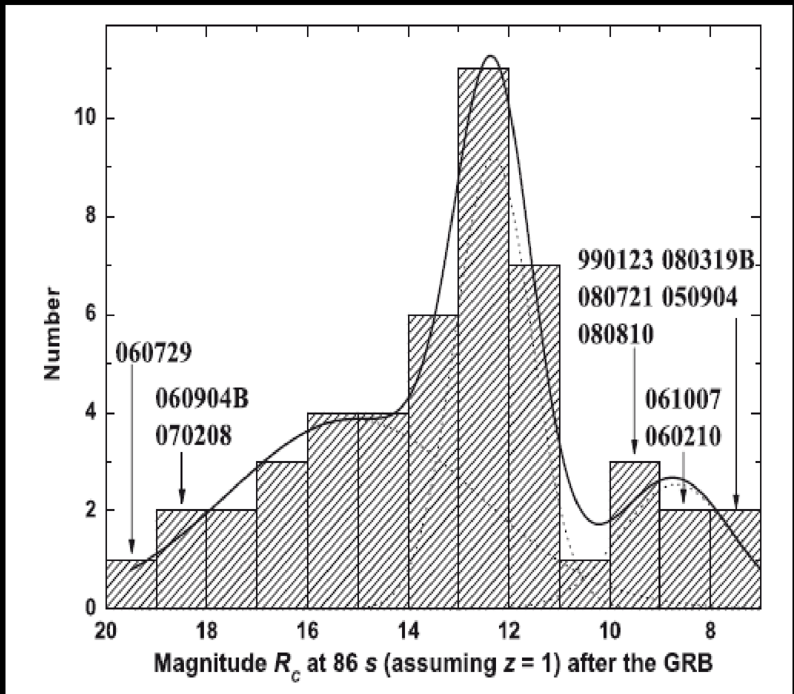


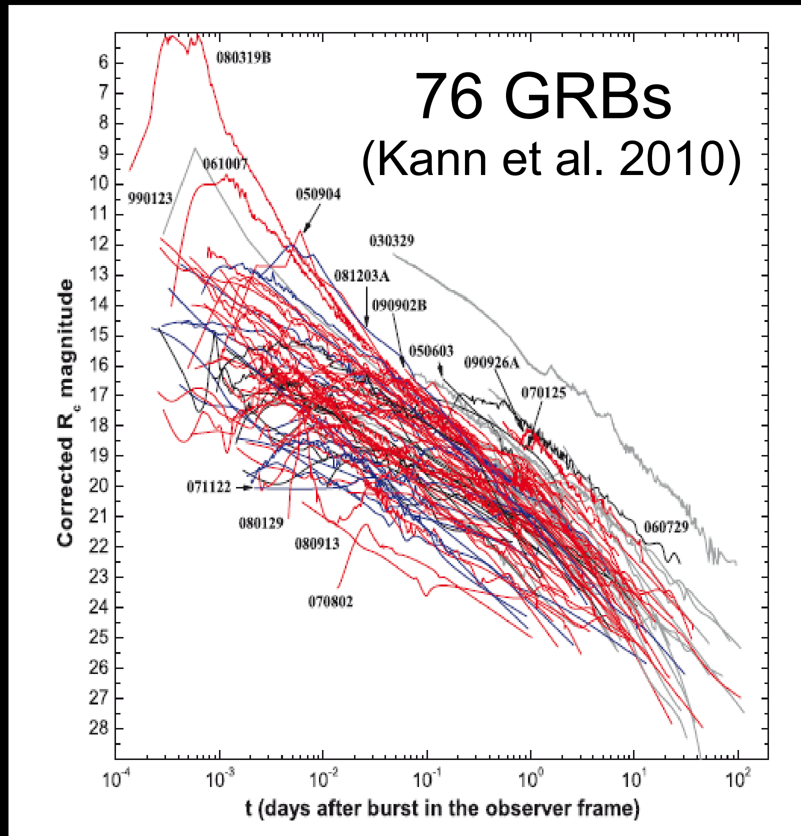
4. UFFO-p onboard Lomonosov (6)

UFFO-p Capabilities

UFFO-p should detect all long-duration GRBs unless they are extinguished by dust in their host galaxies or at high z (> 5).

See poster # 28
by Heujin Lim





5. Summary

Summary

1. Afterglow emission can be detected in all the electromagnetic range, in all timescales from seconds to months (the later in some cases). A variety of features can be studied by different techniques (photometry, spectroscopy, polarimetry) to gain insight into the progenitors, environments, abundances, metallicities, host galaxies... Multi-messenger information also highly valuable.

2. Automated and robotic telescopes are very useful to study the early phases starting seconds after the trigger.

3. *Lomonosov*/UFFO-p is well suited for studying GRB optical emission in the first few seconds (to be launched this year).

4. We are *missing* an X-ray all-sky monitor being able to detect X-ray flashes following the SNe breakouts to record many more XRT 080109-like events. Super-WATCH? LOBSTER?

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