XMM-NEWTON OBSERVATIONS OF GAMMA-RAY BURST AFTERGLOWS

Presentation for:
Four Years of Chandra Observations:
A Tribute to Riccardo Giacconi

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- **Overview:**
  - **Constraints and Observations**
  - **Scientific Results**
    - **GRB 030329: X-ray afterglow after 61 days**
    - **GRB 011211 and GRB 030227: X-ray emission lines**
    - **GRB 001025A: the "Dark Bursts"**
  - **Scientific Perspectives**
    - **X-ray emission lines**
    - **Dark Bursts**
    - **Short Bursts**

Constraints and Observations

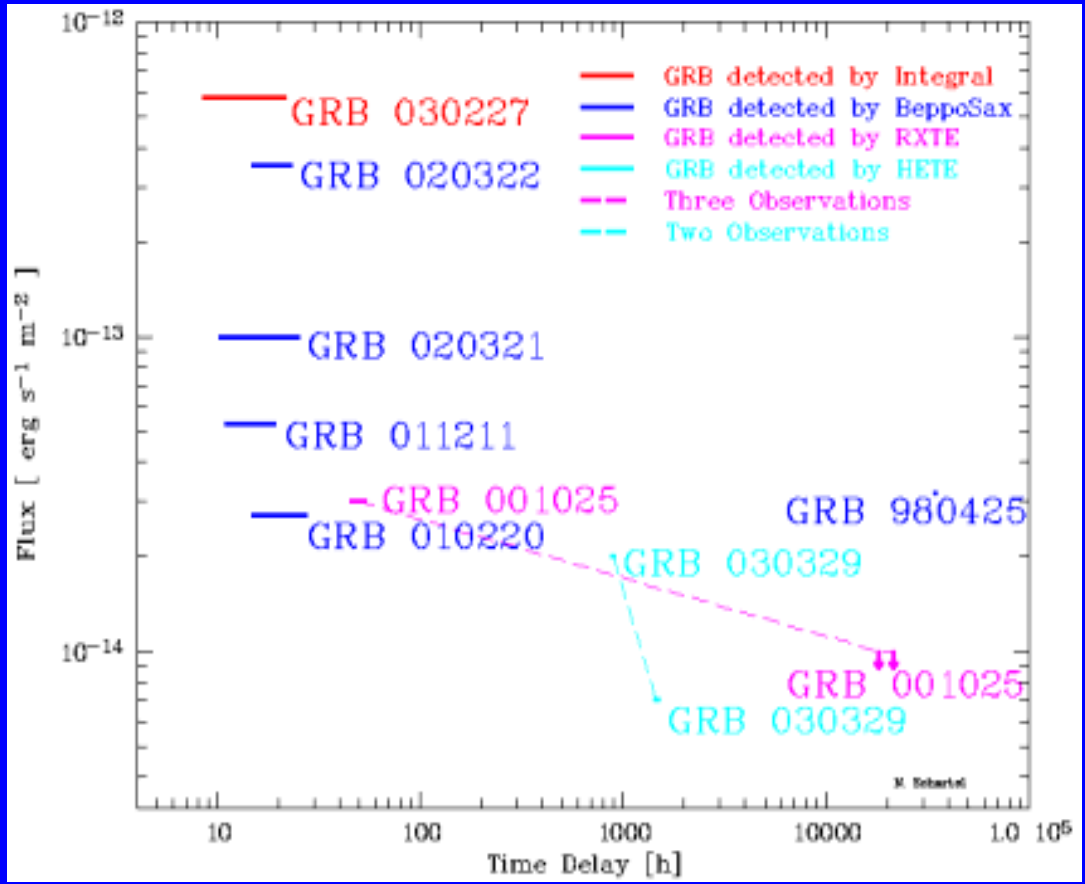
- the majority of GRB afterglows are observed as TOOs based on the detections of other high energy satellites

- time delay with respect to GRB notification:
  - 4.00 hours (evaluation, generation of time line, stop of ongoing observation)
  - 0.50 hours (target acquisition)
  - 0.50 hours (reaction wheel bias)
  - 1.00 hours (calculation of offset-maps for EPIC-pn)
  - ?.?? hours (slew with 90 degrees per hour)
  - ?.?? hours (visibility constraints)

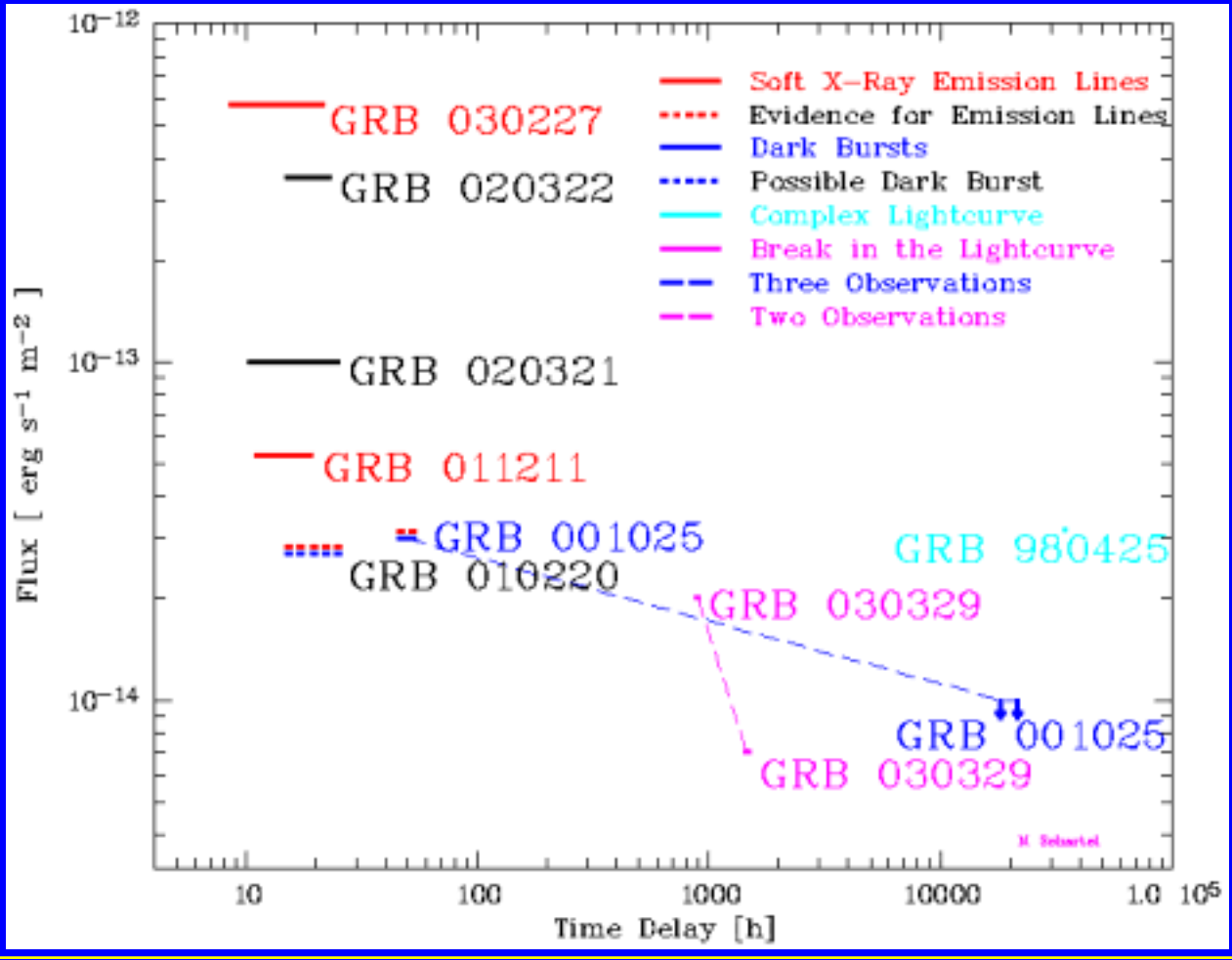
- TOO observations, which are not violating data rights of other observations, are immediately public after standard pipeline processing

Constraints and Observaitons

- **observations:**
  - in total 11 observations in the direction of 8 GRBs
  - 6 observations within 2 days
  - 1 observation started 8.6 hours after the GRB

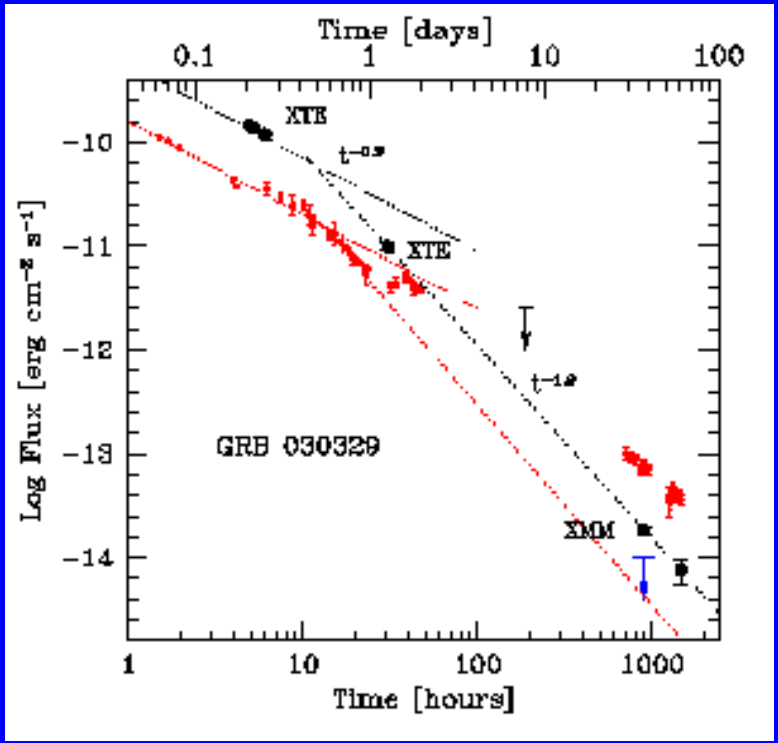


Scientific Results



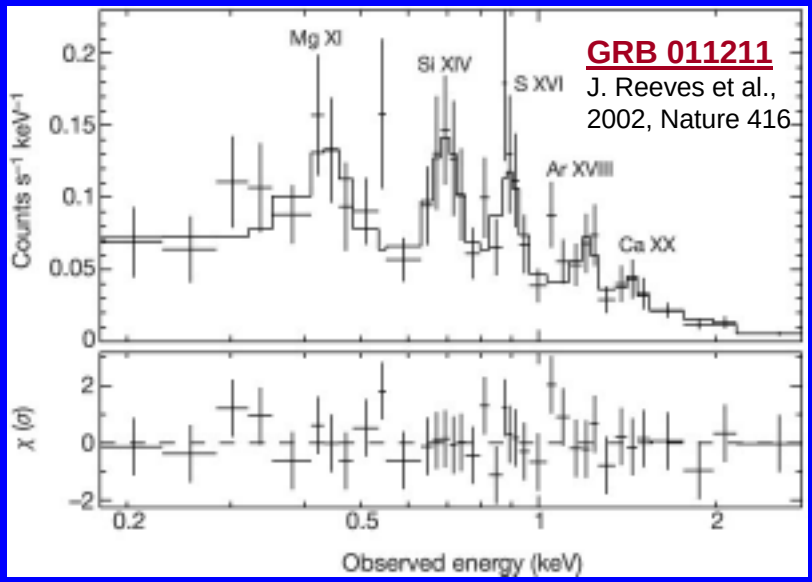
GRB 030329 / an afterglow after 61 days

- detection of X-ray afterglow 37 and 61 days after GRB
- spectra well fitted with power-law, no indication for thermal emission
- ratio of optical to X-ray flux indicates that X-ray flux is not related to SN
- no detection of Fe K_α emission
- in combination with XTE data: break in decay of light curve (index of decay decreases from 0.9 to 1.9)

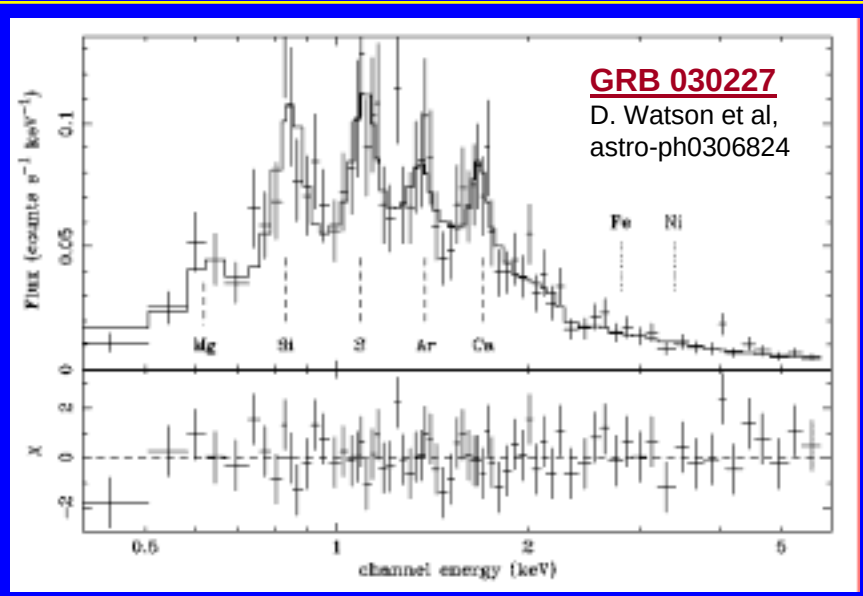


X-ray light curve of GRB 030329 compared with optical data. (A. Tiengo et al. 2003, astro-ph/0305564)

GRB 011211 and GRB 030227: X-ray emission lines



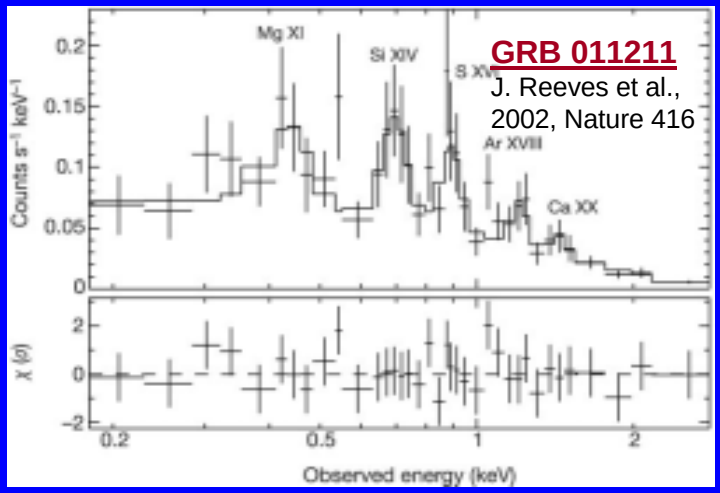
EPIC-pn spectrum taken from J. Reeves et al. (2002; Nature 416, 521)

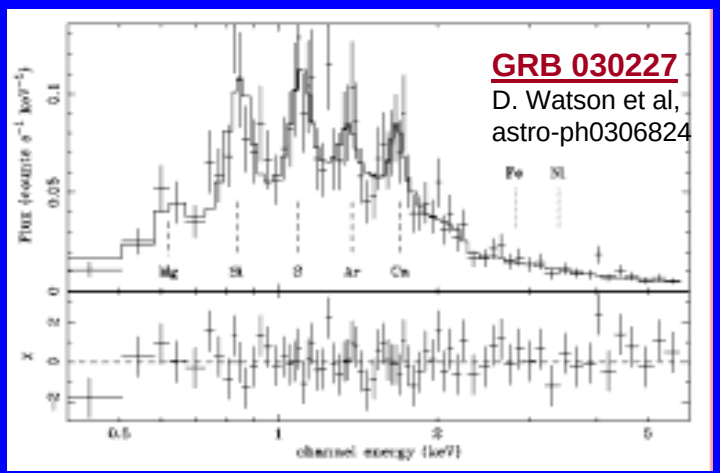


EPIC-pn spectrum taken from D. Watson et al. (astro-ph/0306824)

Both spectra show remarkable similarities

GRB 011211 and GRB 030227: X-ray emission lines





Similarities:

1) lines are blueshifted with with respect to the host galaxy implying an outflow velocity of one-tenth of the speed of light

2) emission lines of lighter elements are dominating:
011211: Mg XI, Si XIV, S XV, Ar XVII, Ca XX
020227: Mg XII, Si XIV, S XVI, Ar XVII, Ca XX

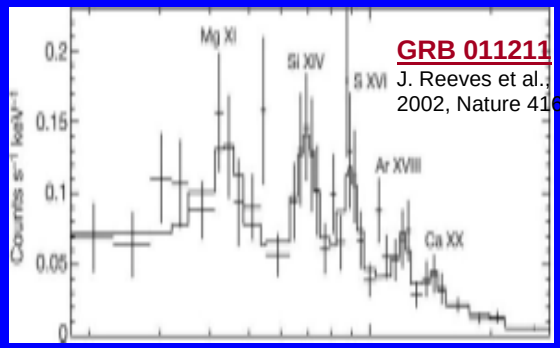
3) emission lines of heavier elements, i.e. Ni and Fe, are not detected or very weak

4) photoionization and reflection models fail to reproduce the spectra as they favour heavier metals such as Fe or Ni

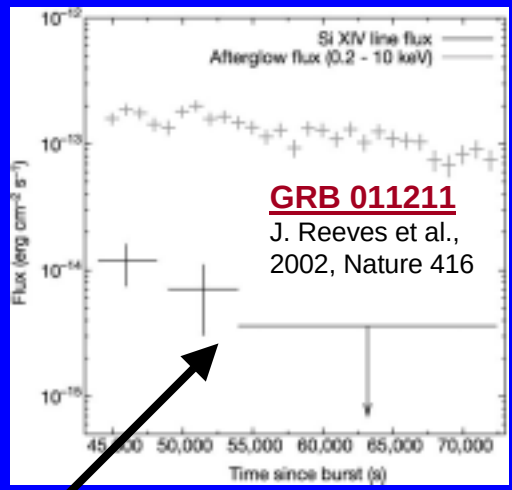
GRB 011211 and GRB 030227: X-ray emission lines

- **Consistent Scenario for GRB 011211 (J. Reeves et al., 2002 Nature):**
  - **emission lines originate in a dense shell of material, the ejecta of a recent supernova, which is heated by the GRB**
    - **merging of compact objects scenario can be excluded for these two GRBs**
    - **shell is expanding at 0.1 c**
    - **illuminated ejecta from outer stellar layers implying the domination of lower-atomic-core-number elements in recent supernova**
    - **(stable) Fe enrichment later via beta-decay within months (Ni→Co→Fe, with reaction half-lives of 6 and 78 days)**
    - **thermal emission, cooling time and measured end of line emission allow to derive the geometric dimension of the system**

The X-ray afterglow of GRB 011211



GRB 011211
J. Reeves et al., 2002, Nature 416



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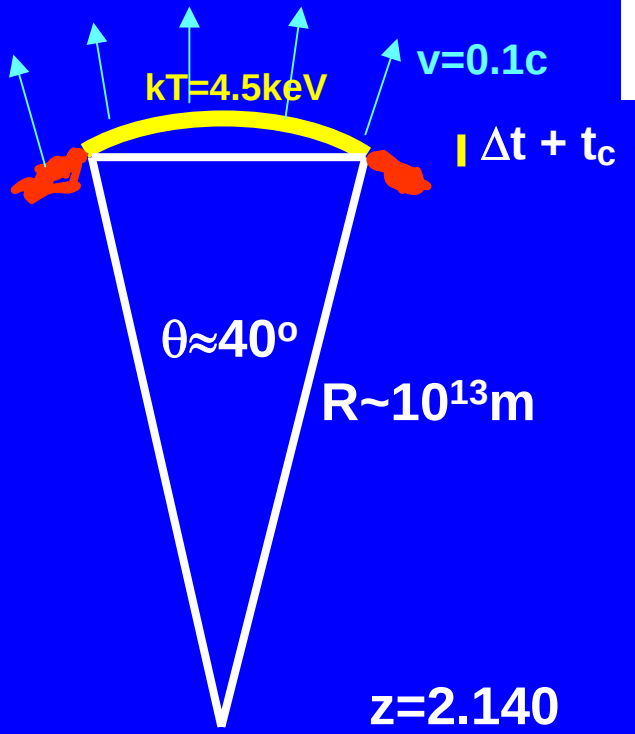
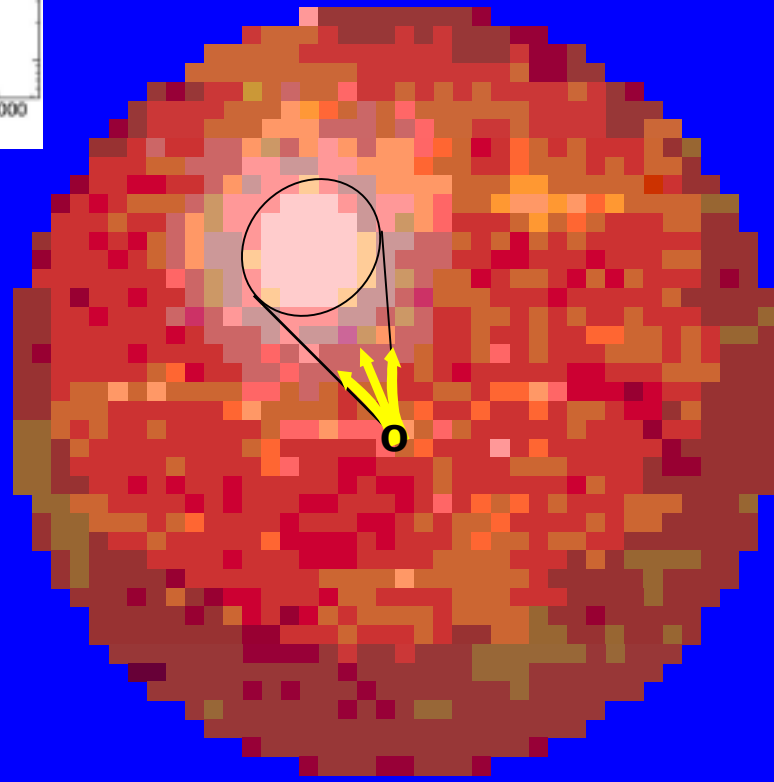


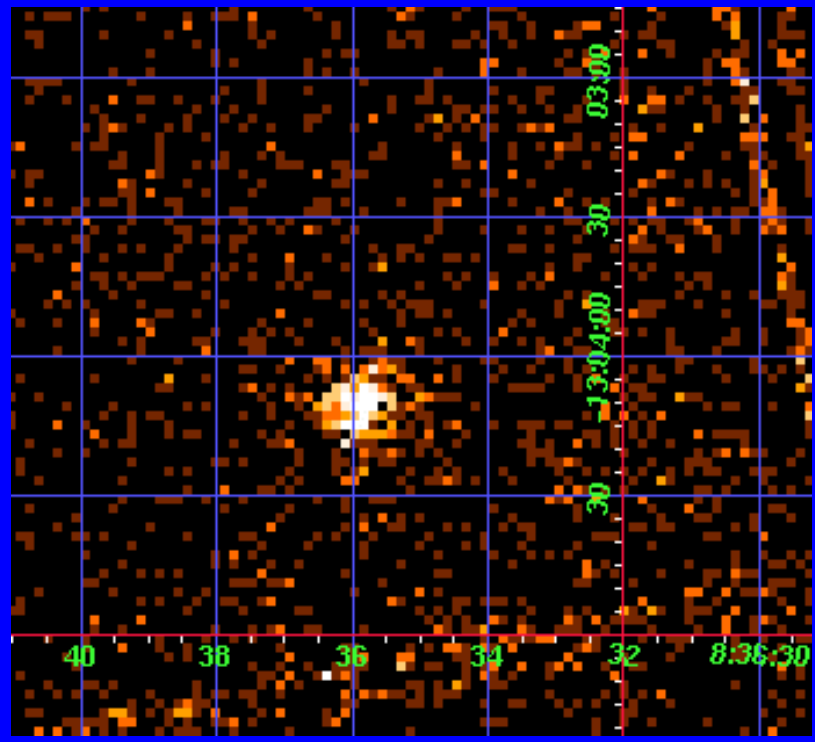
$I\ \Delta t + t_c$



z=2.140

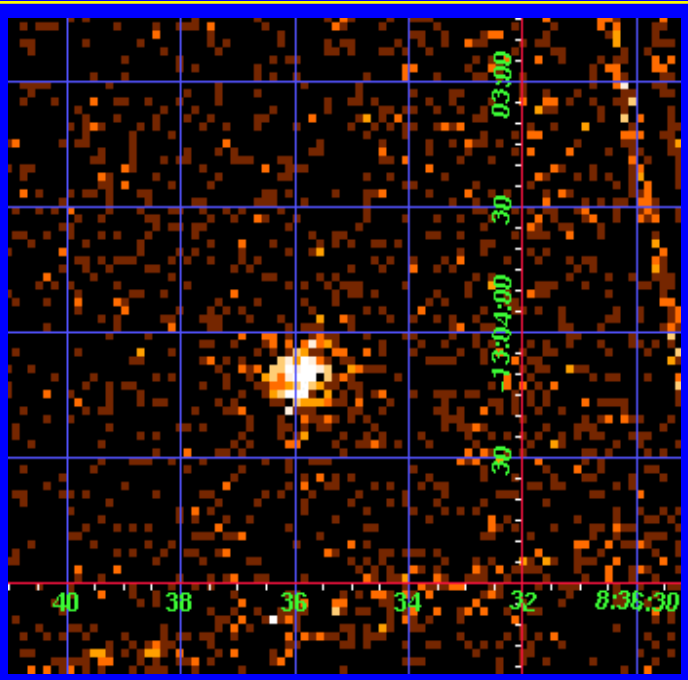
GRB 001025A: the Dark Burst

- Despite several deep optical observations no optical counterpart could be detected for GRB 001025A → Dark Burst
- XMM-Newton found an X-ray source in the error-box, but statistics are too poor to confirm flux decrease with certainty
- X-ray afterglow or AGN?

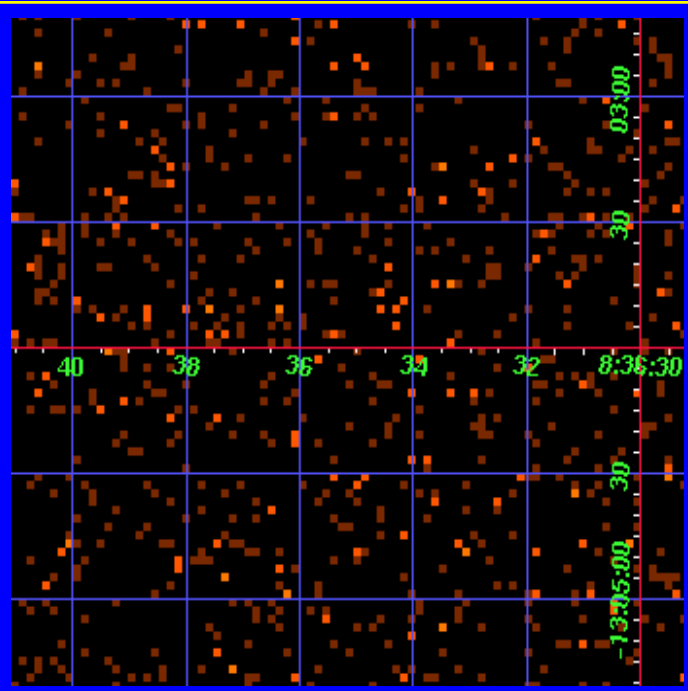


EPIC-pn image of GRB 001025A: first observations

GRB 001025A: the Dark Burst



EPIC-pn image of GRB 001025A: Left: first observations Right: second observations (K. Hurley et al. 2003, in preparation)



The possibility of an X-ray source, like an AGN, is ruled out by the data taken during follow-up observations.

XMM-Newton has observed the afterglow of the Dark Burst GRB 001025A

Scientific Results

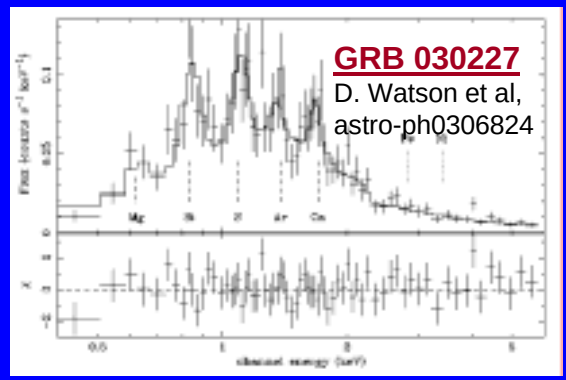
- **Publications (2.9.2003):**
  - **10 circulars**
    - GCN 869, GCN 884, GCN 1192, GCN 1348, GCN 1293,
    - GCN 1901, GCN 2241, GCN 2249, GCN 2285, IAUC 8087
  - **7 publications in refereed journals**
    - A&A, 393L, 41W, 2002; A&A, 395L, 41W 2002;
    - Nature, 416, 512R, 2002; A&A, 403, 463R, 2003;
    - MNRS, 339, 600, 2003; ApJ, 590, 73L, 2003;
    - ApJ, 583L, 57B 2003
  - **5 publications in press**
    - astro-ph/0305564; astro-ph/0305359; astro-ph/0306284;
    - astro-ph/0304521; astro-ph/0307222

Scientific Perspectives

- XMM-Newton can observe GRBs afterglows with a short time delay only as TOO
- this implies that the scientific results cannot be predicted in advance
- but it is possible to estimate the impact of future XMM-Newton observations for actual questions in the field of GRB

X-ray emission lines

- progenitors?
- early supernovae?
- light curves of emission lines?
- outer stellar shells directly after SN explosion?
- abundance of elements?
- Fe and Ni?
- time delay between SN and GRB?
- beam angle of GRB?
- light curve of GRB,- re-heating?



XMM-Newton:

high effective area: up-to 4500 cm² at 1.5 keV

<10 hours reaction time

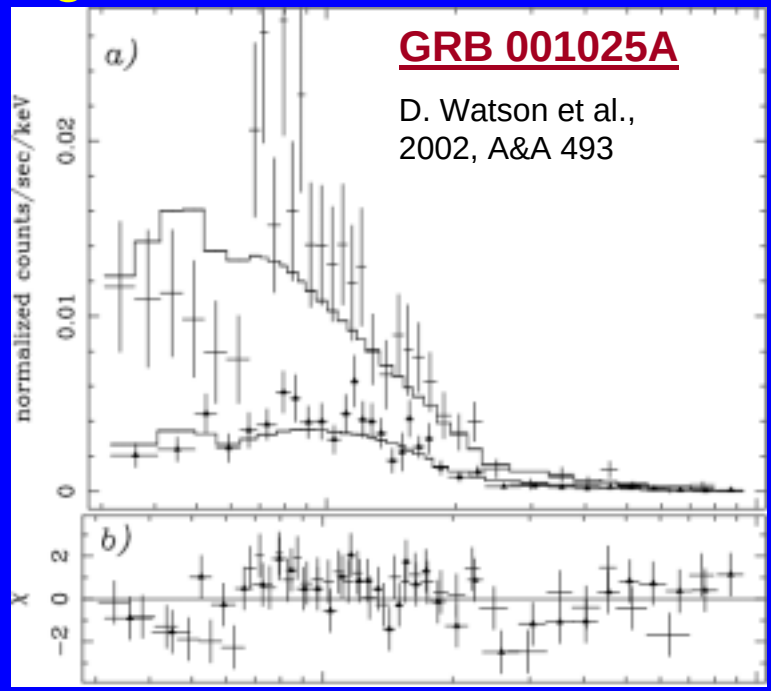
SN at high redshift (observed: z=2.14 and z≈1.6)

Dark Bursts

- available observations suggest that all GRB have an X-ray afterglow
- but 50% do not show a counterpart at optical or radio wavelengths → very restricted knowledge (e.g. distance?)
- they are called “Dark Bursts”
- suggested explanations:
  - burst emitted in region which is highly obscured
  - burst occurs in surrounding where the medium is too tenuous for the forming of an optical afterglow
  - burst is located at very high redshifts

Dark Bursts

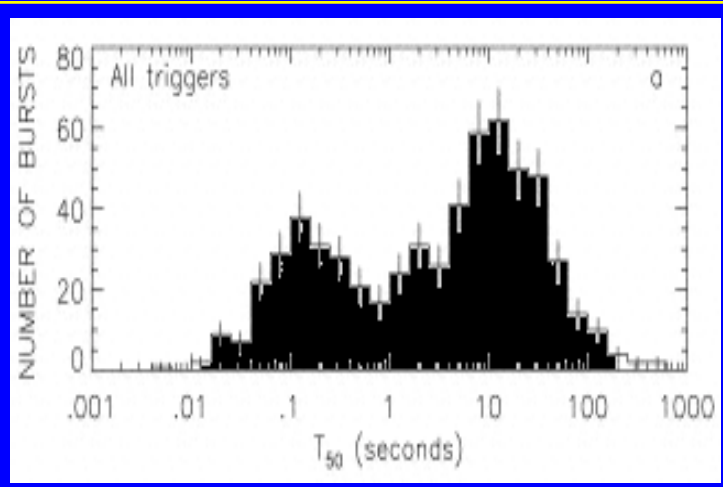
- XMM-Newton observation of the afterglow of Dark Burst GRB 001025A very promising:
  - follow-up observations show that XMM-Newton has really seen the X-ray afterglow (K. Hurley et al., in preparation)
  - despite its poor statistics, the X-ray spectrum is complex and may point to X-ray emission lines (D. Watson et al., A&A 493, 2002)



- future XMM-Newton observations may allow to distinguish between the different scenarios for Dark Bursts

Short GRB

- **GRBs form two distinct populations with respect to the duration of the gamma-ray emission:**
  - Long GRB with $t_{emission}$>1sec
  - Short GRB with $t_{emission}$<1sec
- **up to now not a single afterglow of a Short GRB was detected**
- **but instrumental selection effect!**
- **no strong argument why Short GRB lack afterglows**
- **their detection is a challenge for future XMM-Newton observations**



Duration distribution for GRB in the fourth BATSE Burst Catalog (taken from W. S. Paciesas, ApJS 122, 1999)