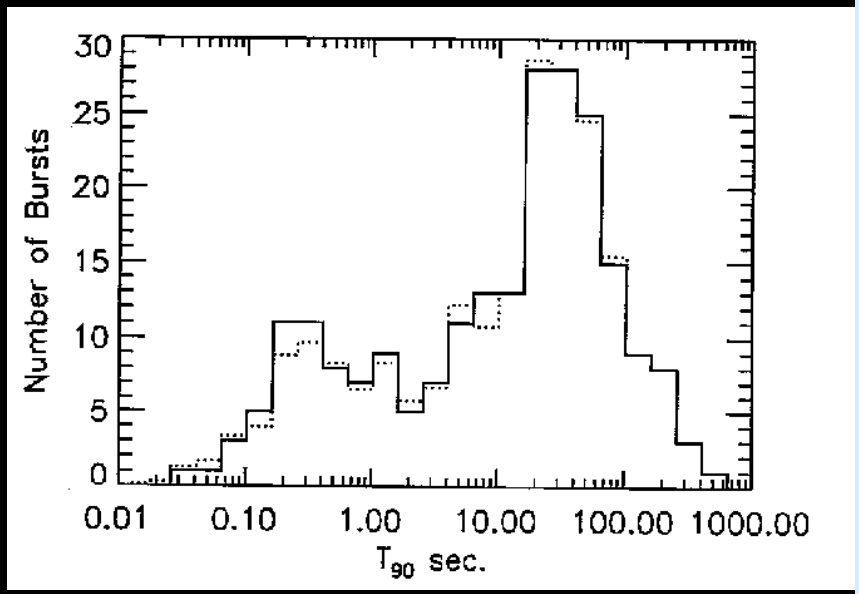
The Late-Time Light Curves of GRB Afterglows with Chandra

Dirk Grupe

Dave Burrows, Gordon Garmire

Pennsylvania State University

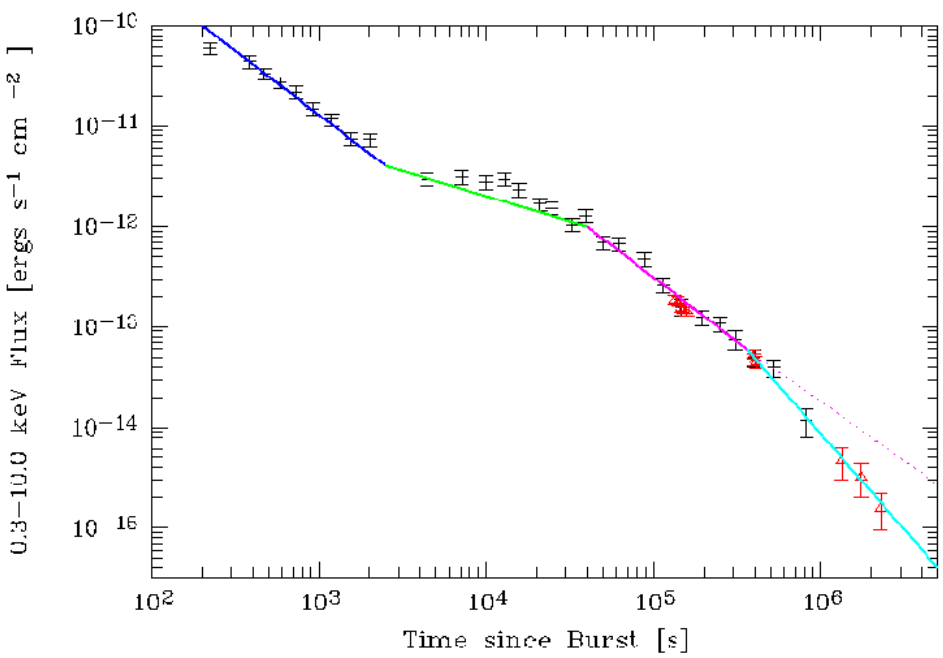
Gamma Ray Bursts (GRBs)



Kouveliotou et al. 1993, ApJ, 413, L101

- Most energetic explosions in the Universe
- isotropic energy release~e51-e54 ergs
- Formation of a black hole
- Two types of GRBs: short hard and long soft bursts
- Short bursts:
  - T90 < 2s
  - Neutron star mergers
  - Associated with elliptical galaxies
- Long bursts:
  - T90 > 2s
  - Explosions of massive stars
  - Hypernova

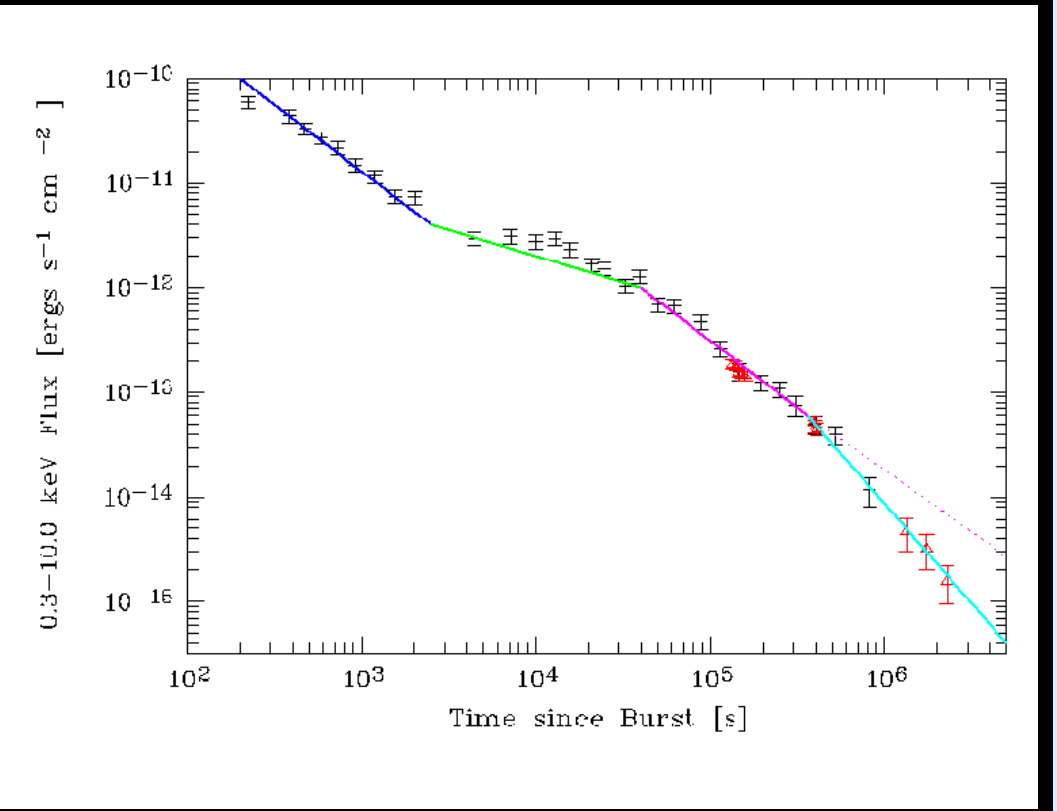
Energy problem in GRBs and solution



Most X-ray afterglows follow canonical light curve (Nousek et al. 2006, Zhang et al., 2006)

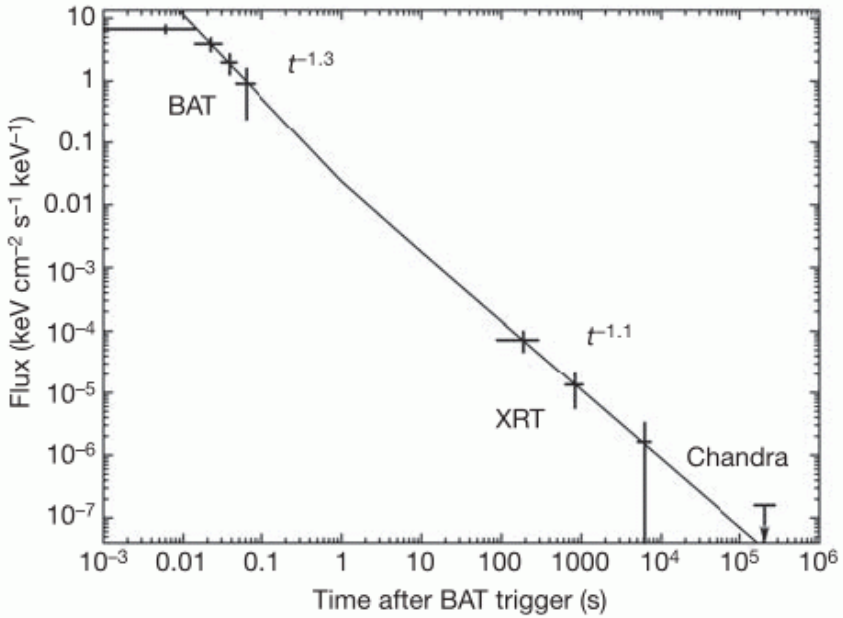
- Isotropic Energy e51- e54 ergs
- What is energy is beamed?
- `Fireball model' predicts a jet
- Collimated light → smaller energy release
- Jet interacts with surrounding matter → jet decelerates
- Faster decay in flux light curve
- Visible as an **achromatic** `jet break'
- Typical decay slope ~ 2.0 after the break
- Jet breaks are seen in the Optical and in Radio
- Typically seen a few days after the break
- Relation between jet break time and jet opening angle

Another problem: no jet breaks by Swift



- Relation between break time and jet opening angle: given by Frail et al. (2001) and Sari et al. (1999):
- theta ~ T_break^(3/8)
- → Break time has information on GRB energetics
- Problem: Swift does not see jet breaks in X-ray light curves of most GRBs!
- Solution: Jet breaks occur after the flux of the X-ray afterglow is below the Swift XRT detection limit
- **Extent light curves of bright bursts with Chandra** (PI: D. Burrows at PSU with Gordon Garmire)

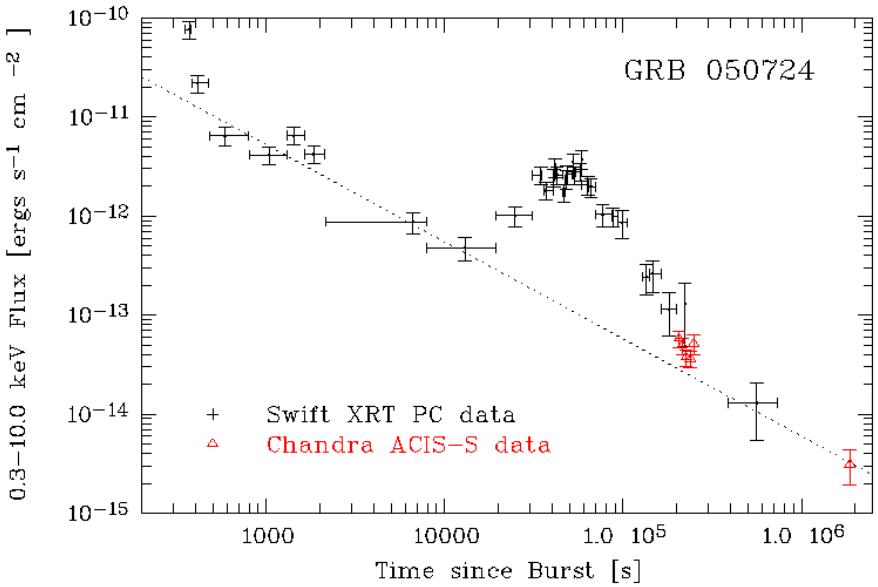
Short GRB 050509B



Gehrels et al. (2005)

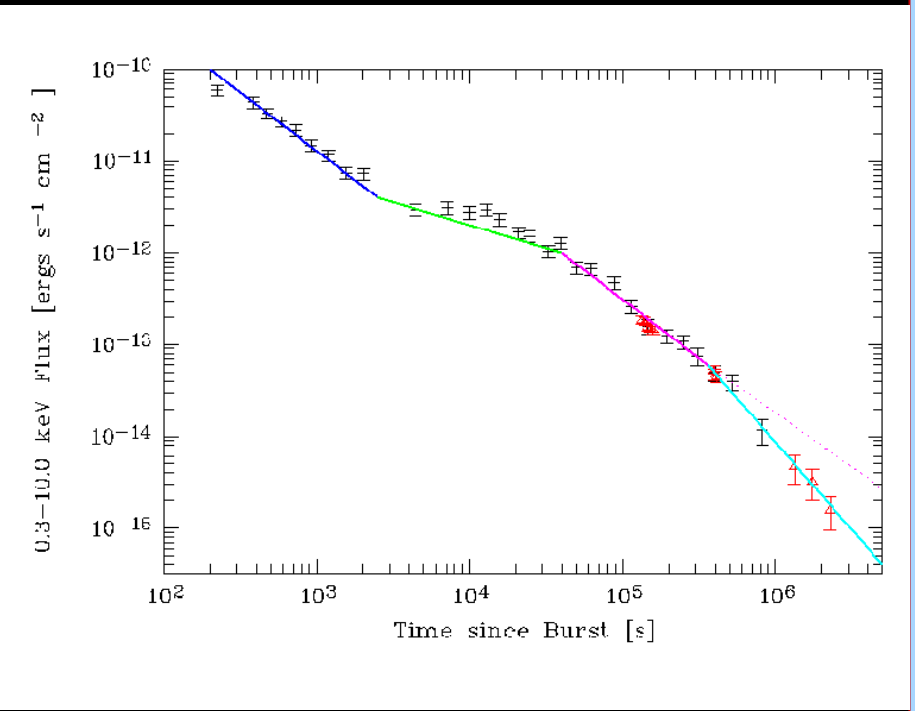
- First detection of an X-ray afterglow of a short GRB (Gehrels et al. 2005, Nature, 437, 851)
- Chandra Observation 48 hours after the burst
- 50 ks observation
- No detection!
- Short GRBs fade fast!

Short GRB 050724



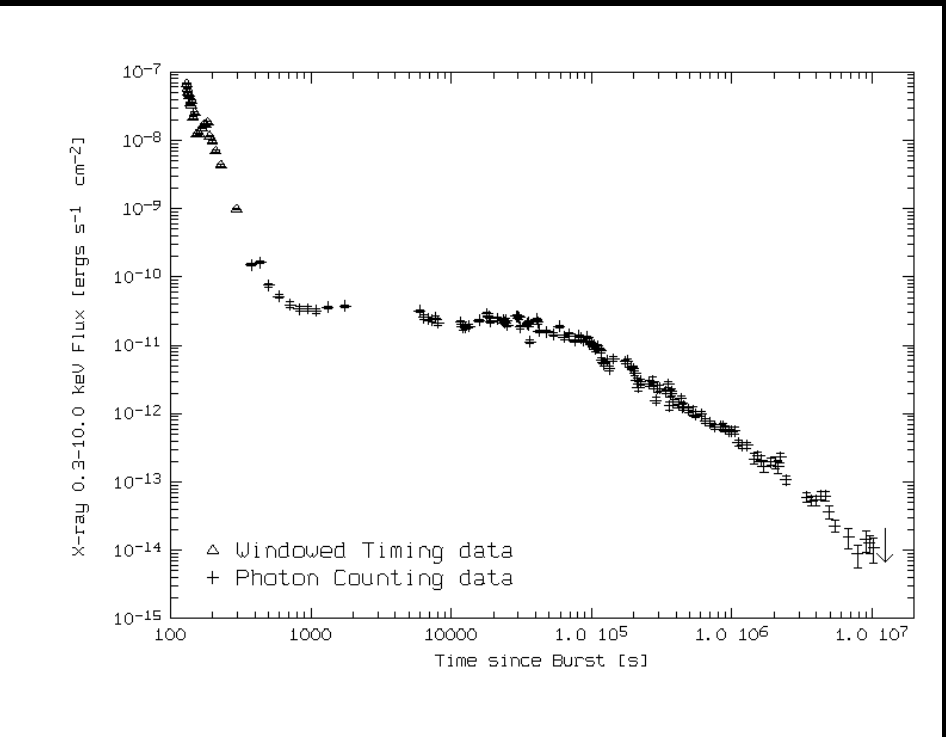
- **GRB 050724**: bright short GRB
- Strong late time flare
- Chandra Observations about 2 and 21 days after the burst
- Exposure times 49 and 45 ks
- Clear detections of the X-ray afterglow
- No jet break (Grupe et al. 2006, ApJ, 653, 462)
- Opening angle > 25 degrees
- Energy at least 4e49 ergs

Short GRB 051221A



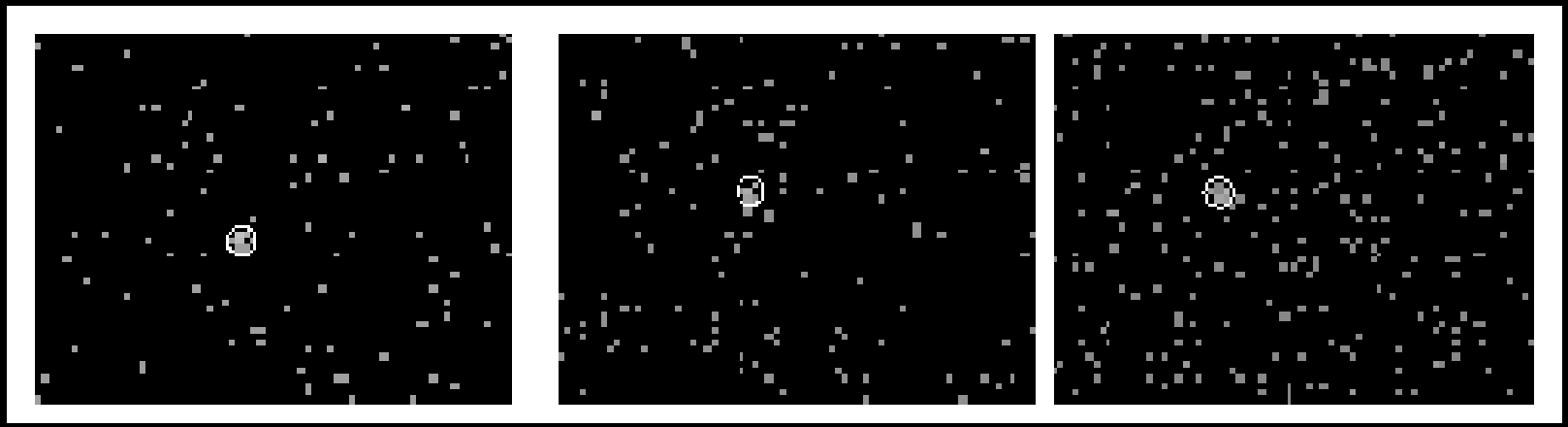
- **GRB 051221A**: bright short GRB
- Light curve follows canonical GRB afterglow light curve (Nousek et al. 2006, Zhang et al. 2006)
- 5 Chandra observations from starting 1 day up to 26 days after the burst
- Jet break at ~4 days after the burst (Burrows et al., 2006, ApJ, 453, 468)
- Opening angle ~4-8 degrees
- Comparable with break times and opening angles typically seen in optical and radio afterglows
- Energy release (1-5)e49 ergs

GRB 060729: Latest detection of an X-ray afterglow ever



- Long extremely bright burst in X-rays
- E-iso 1.6e52 ergs
- Very long plateau phase
- Redshift z=0.54
- Swift could detect X-ray afterglow up to 125 days after the burst (Grupe et al. 2007)
- No jet break!
- No break in any of the UVOT filters either up to 31 days after the burst (in W1)
- Initiated Chandra follow-up through PSU GTO program (Gordon Garmire)

GRB 060729: Chandra observations

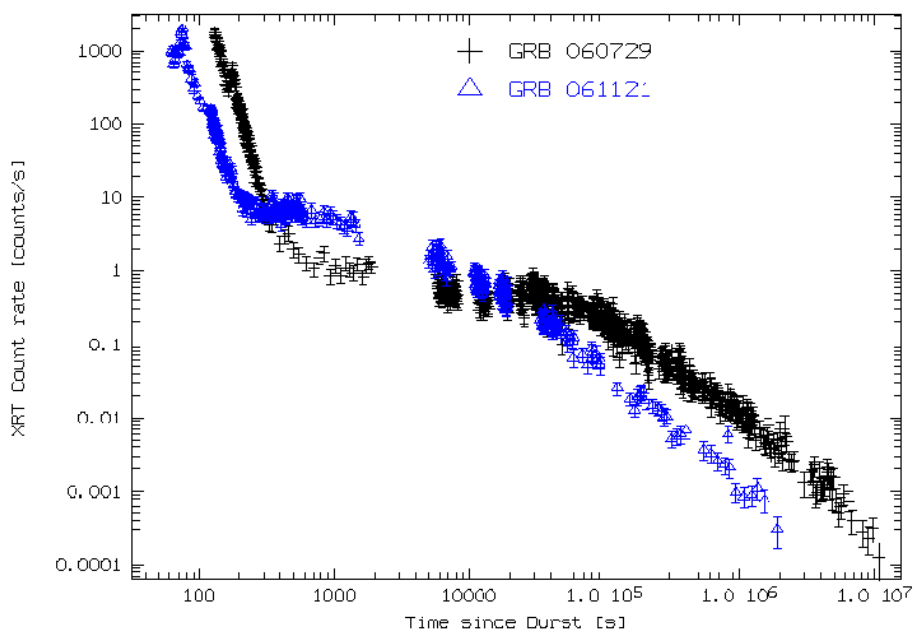


- Three Chandra observations in 2007, March to June
- X-ray afterglow detected in all three observations
- Latest detection is 330 days after the burst
- Latest detection of an X-ray afterglow ever

GRB 060729: X-ray light curve

- New Chandra data points may suggest break at about 5 – 6 month after the burst.
- Jet opening angle ~ 30d
- E ~ 2e51 ergs
- Not exclusive, light curve is very bumpy and can still be fitted by single power law decay
- Paper in preparation
- Two more Chandra observations next year for 80 and 120 ks (at beginning and end of AO9)

GRB 060729 vs GRB 061121



- **GRB 061121:** Brightest X-ray afterglow seen by Swift
- Chandra observation 2 months after the burst through PSU GTO program
- No detection in 33 ks
- Why is GRB 060729 still visible?
  - Bright and long-lasting plateau phase
  - Decay slope after the plateau phase ~ 1.3
  - Longer energy injection than typically in GRBs
  - Fluence in the 0.3-10 keV band during plateau phase is about 1/3 of the 15-150 keV fluence during the prompt emission
  - Possible scenario is magnetar
- **GRB 060729 will be still detectable by Chandra next year**
- **2 more observations next year**

Late-time Chandra observations are crucial for our understanding of GRB energetics