Scientific Results from the Virgin Islands Center for Space Science at Etelman Observatory

Dr. **Jon Hakkila**, University of Charleston SC at the College of Charleston
Dr. **David Morris**, Director of Etelman Observatory, University of the Virgin Islands
Dr. **Bruce Gendre**, Etelman Observatory, University of the Virgin Islands
Dr. **James E. Neff**, National Science Foundation
Dr. **Timothy Giblin**, United States Air Force Academy
Dr. **N. Brice Orange**, Etelman Observatory, UVI, and OrangeWave Innovative Science, LLC
Dr. **Antonino Cucciara**, University of the Virgin Islands
Dr. **Judy Racusin**, NASA-Goddard Space Flight Center
Dr. **Amy Lien**, University of Maryland at Baltimore County
Jarred A. Hanley, University of the Virgin Islands
Jason Baron, University of the Virgin Islands

NASA EPSCoR grant awarded to SC Space Grant Director Dr. **Cassandra Runyon** at the College of Charleston

Etelman Observatory, USVI

- Location: Saint Thomas, United States Virgin Islands
- Coordinates: Lat 18°21′08.36″N, Long 64°57′24.43″W
- Altitude: 1325 ft.

UVI Telescope

- 0.5 m automated f/10 Cassegrain telescope
- Still in commissioning phase
- Used for research, classes, and public outreach
- Research – fast slewing is perfect for locating gamma-ray burst afterglows, unique longitude location is ideal for international observing campaigns

EPSCoR grant has dramatically improved Etelman operations

- Upgrades to power, encoders, filter wheel, software, etc.
- Building repairs and maintenance (e.g. roofs and gutters)
- New computer infrastructure
- Weather equipment
- Climatized dome
- Upgraded automated rapid response

Education and Outreach at Etelman

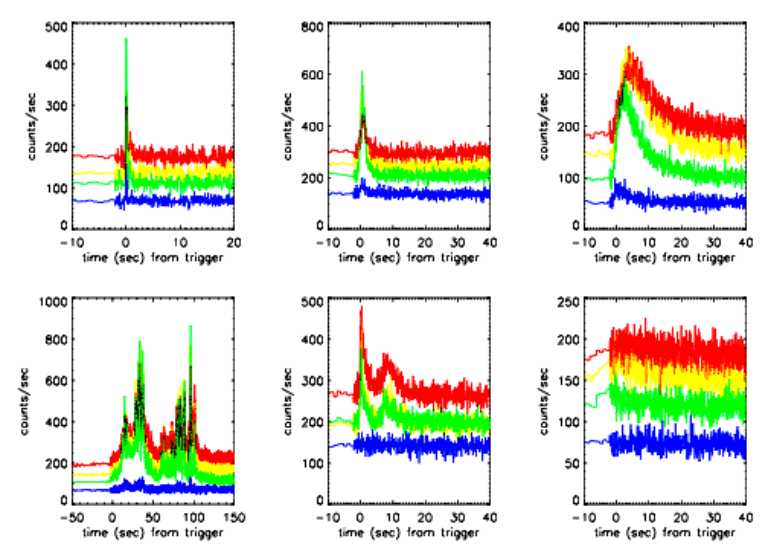
- 11 summer undergraduate research students
- 2 summer undergraduate research students sent to NASA/Goddard
- 2 PhD student visits to UVI
- New astronomy lab course introduced and taught at the observatory
- UVI-NASA-EPSCoR curriculum development grant to expand UVI physics offerings
- 20 very successful public evenings at Etelman

Science – Gamma-Ray Bursts

- This EPSCoR Grant has contributed greatly to our understanding of GRBs (gamma-ray bursts)
- GRBs are the most energetic explosions in the universe, lasting from tens of milliseconds to thousands of seconds and generating energies of around 10^{51} ergs, mostly in the form of gamma-rays and x-rays.
- GRBs originate at cosmological distances (redshifts 1-5) and appear to indicate beamed material with average Lorentz factors around 300.

General Prompt GRB Properties

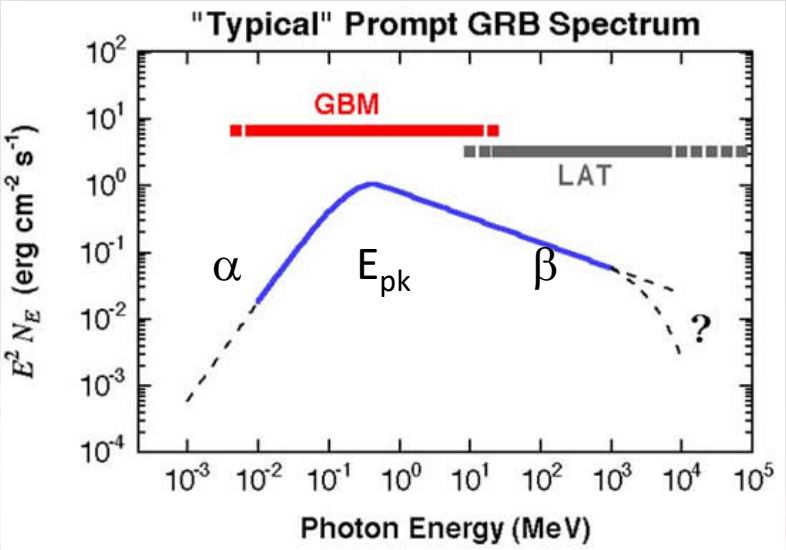
Light Curves

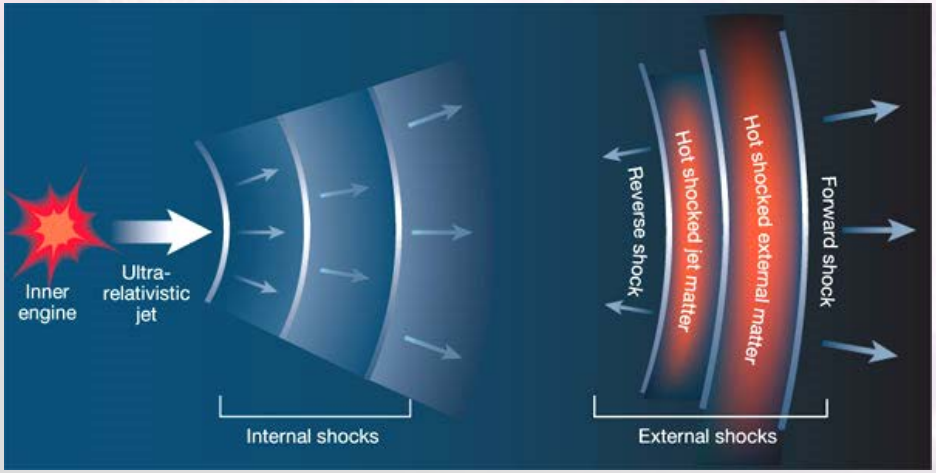


25-50 keV, 50-100 keV,
100-300 keV, 300 keV-1 MeV

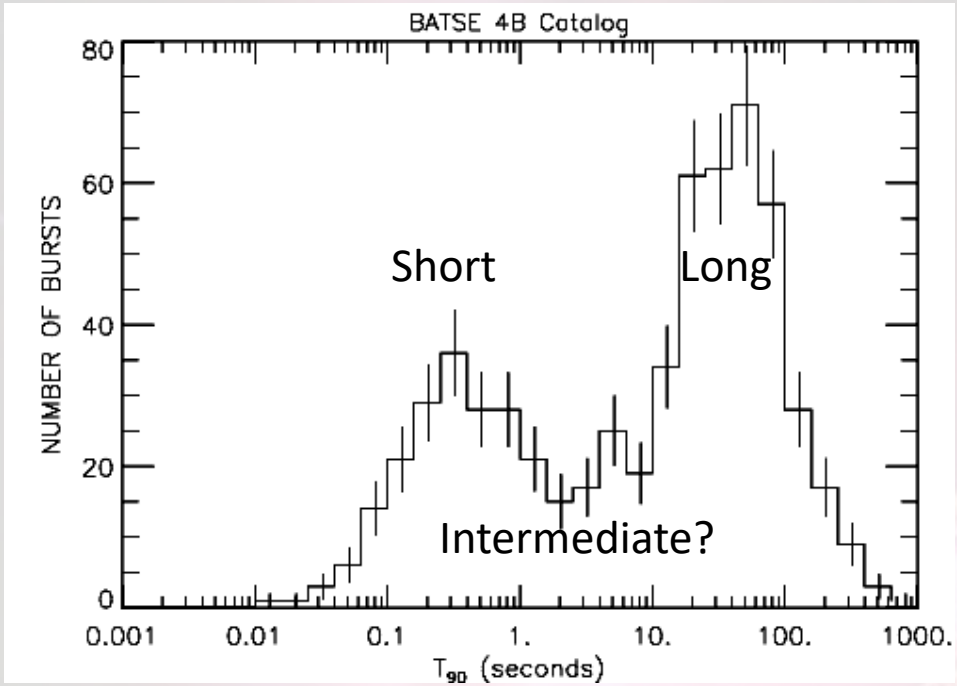
Most luminous sources in the Universe.

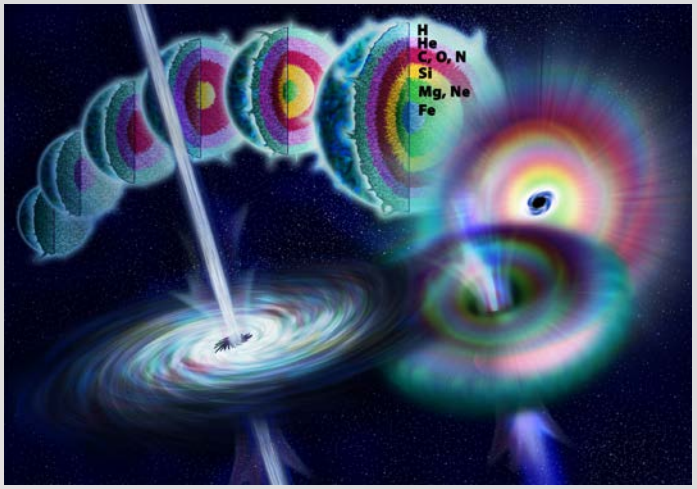
Spectra





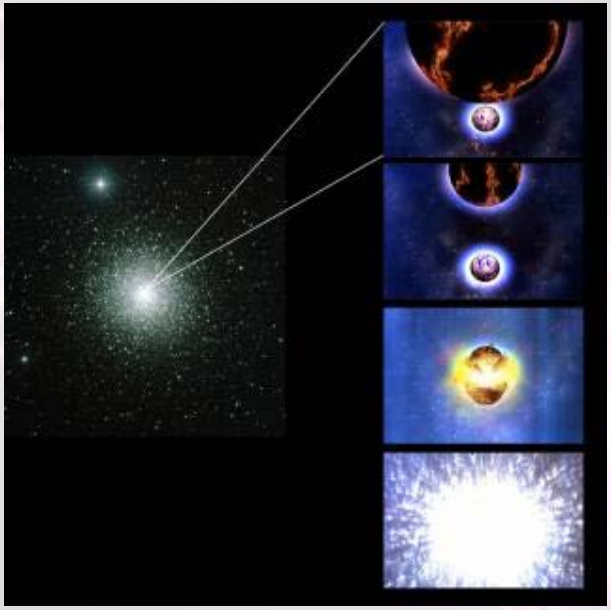
GRB Classes





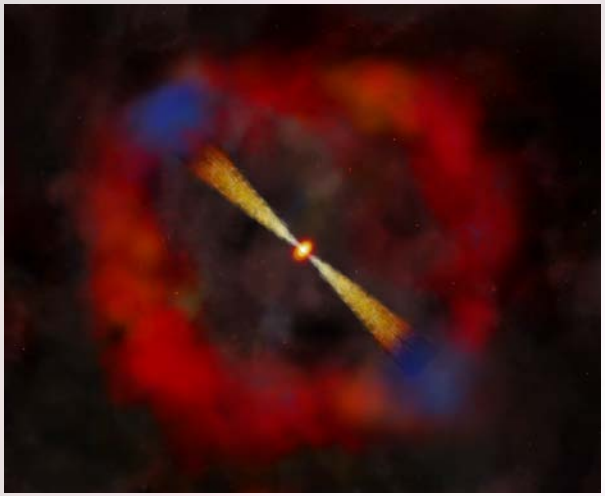
Hypernova Central Engine Model of **Long** GRBs

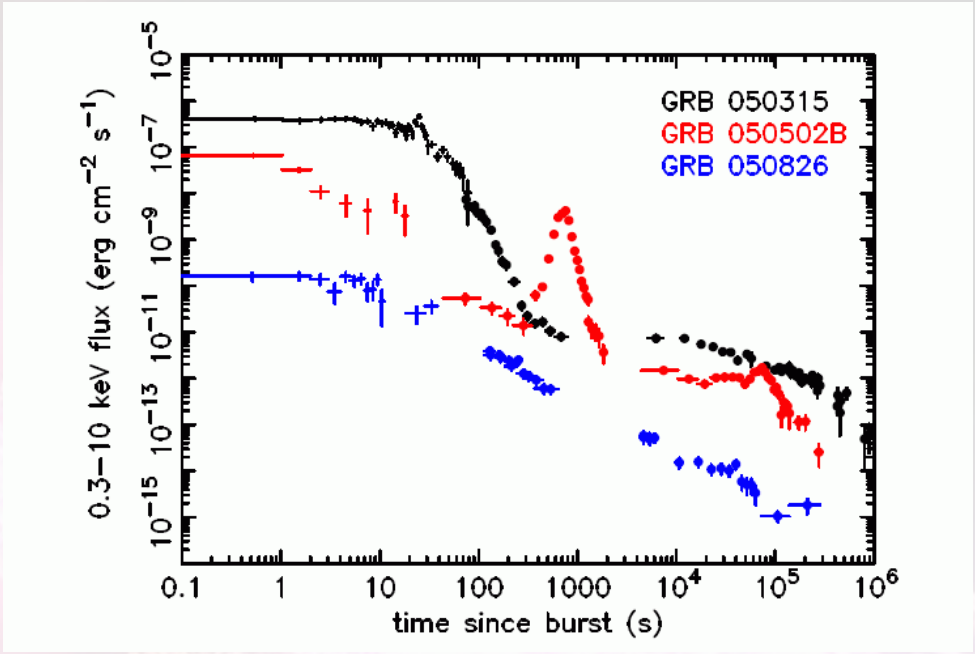
The Intermediate class - statistically identified in BATSE and Swift data, although not unambiguously associated with a separate source population.

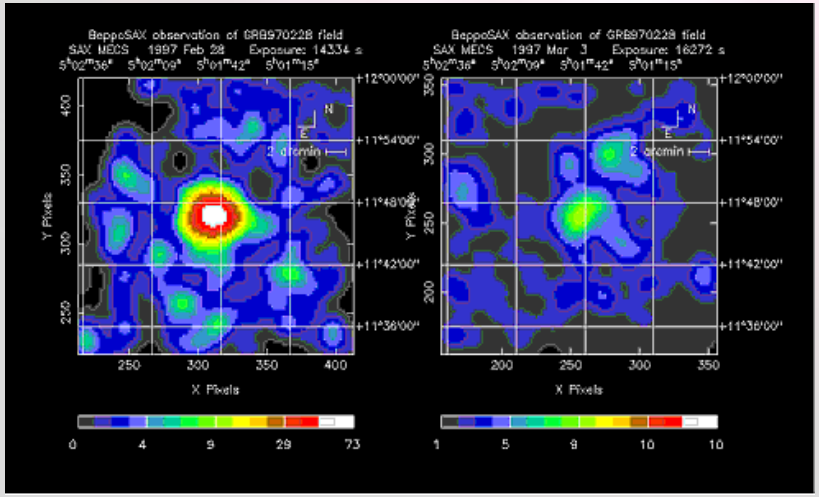


Merging Compact Objects Central Engine Model of **Short** GRBs

GRB Afterglows





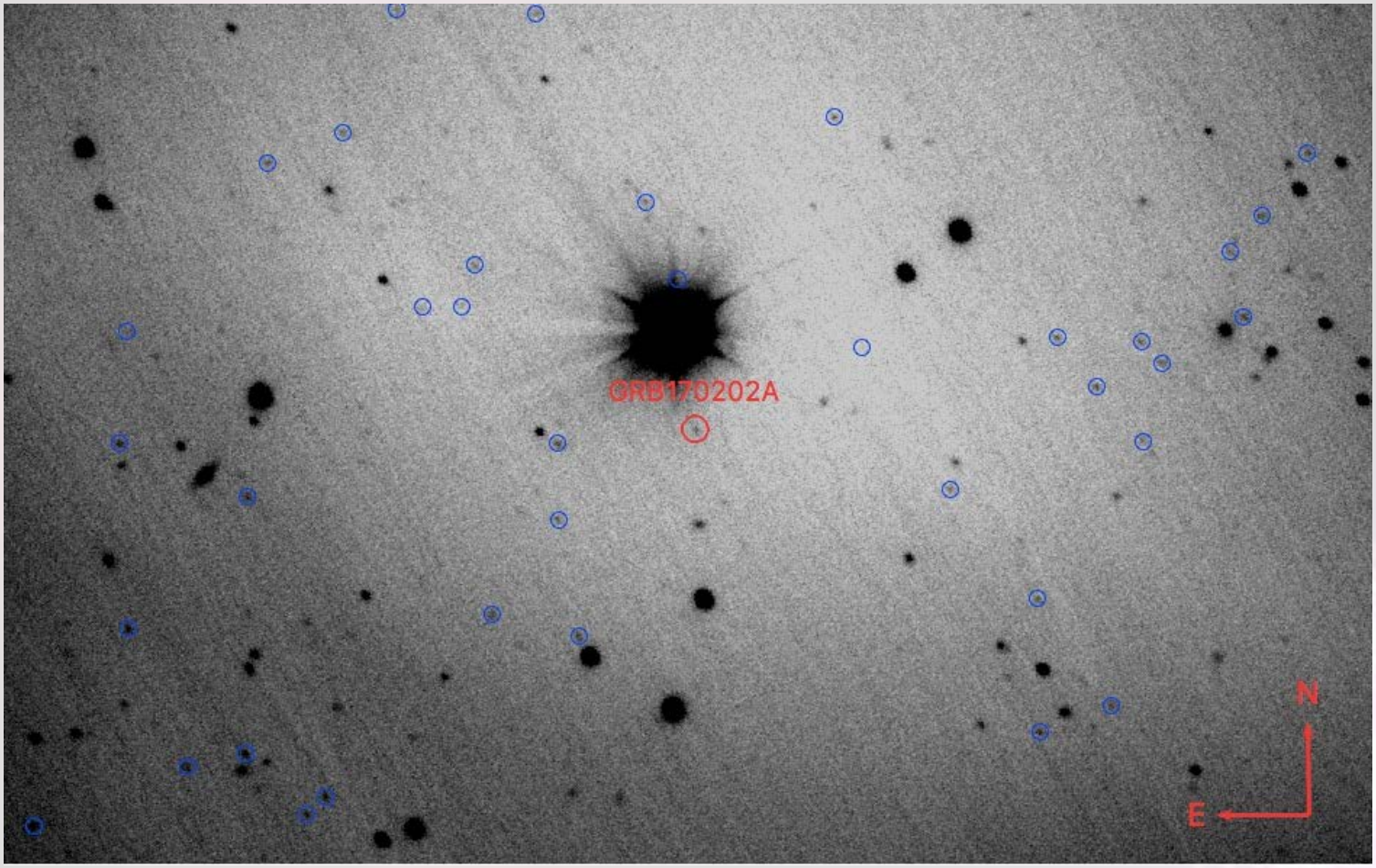


GRB afterglow physics fairly well understood, indicating the deposition of energy into an external medium from relativistic shocks

Although thousands of GRBs have been observed by dozens of different satellites, we still do not understand

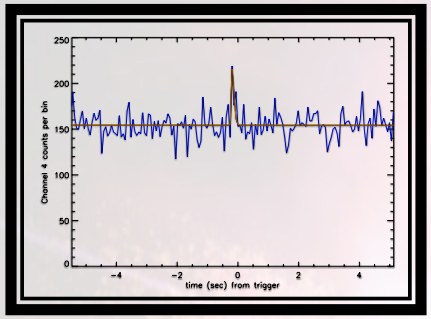
- the radiation mechanism by which they produce their prompt emission
- the physical structure and kinematics of the region producing the prompt emission,
- the exact form of their (invisible) progenitors

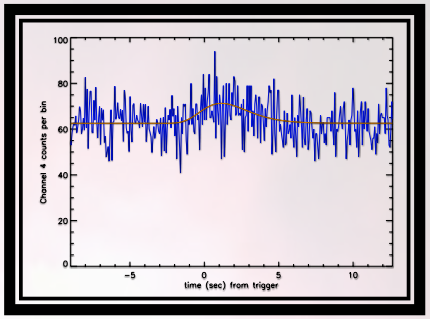
GRB170202A

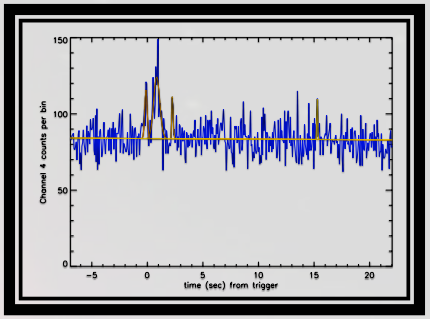


Feb. 3, 2017 from Etelman Observatory: R = 20.8 +/- 0.3, Resulting image from stacking 11 images

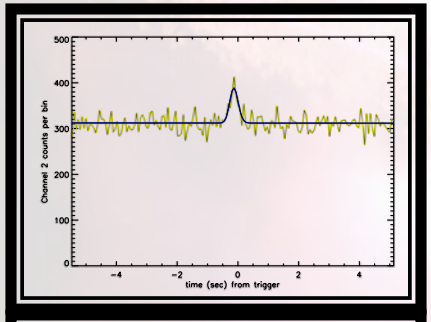
GRB Pulses

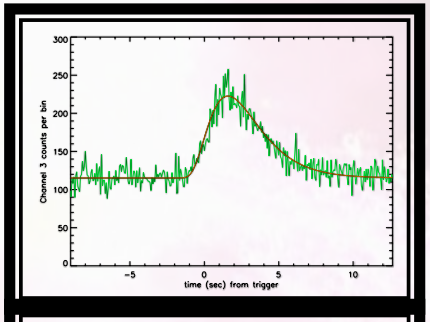


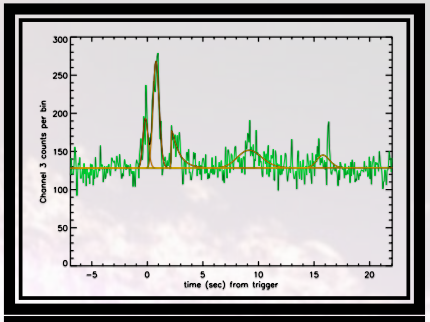




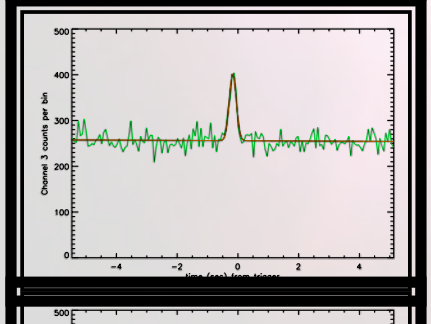
300 keV
to
1 MeV

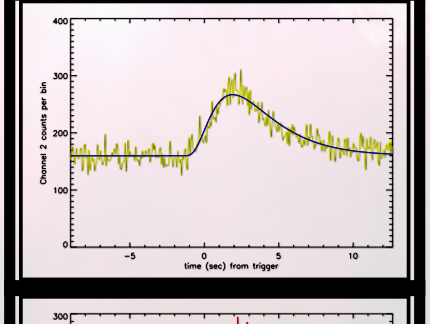


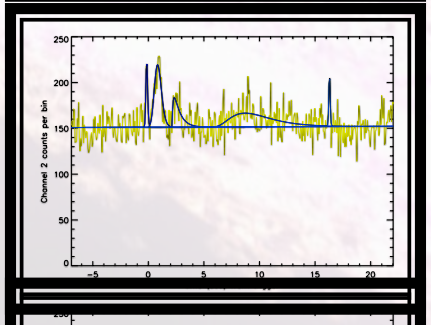




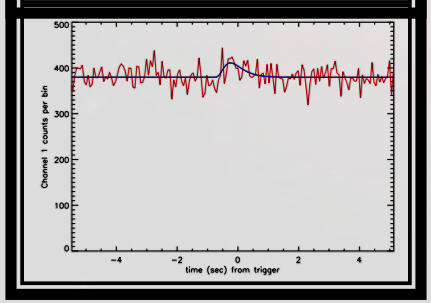
100 keV
To
300 keV

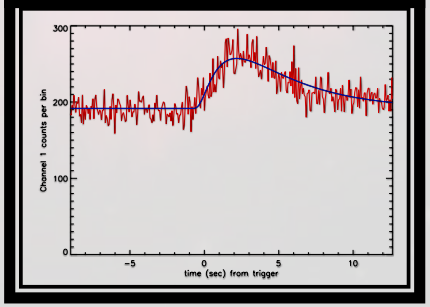


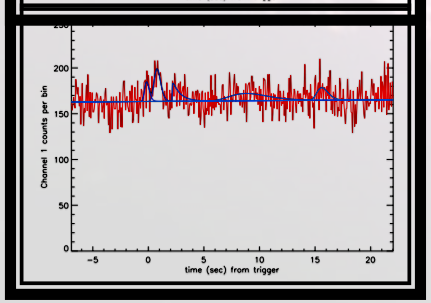




50 keV
To
100 keV

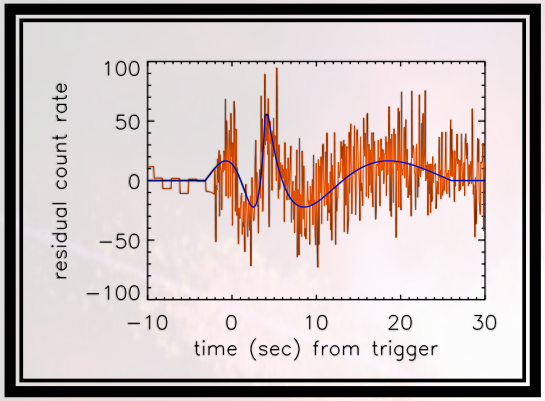


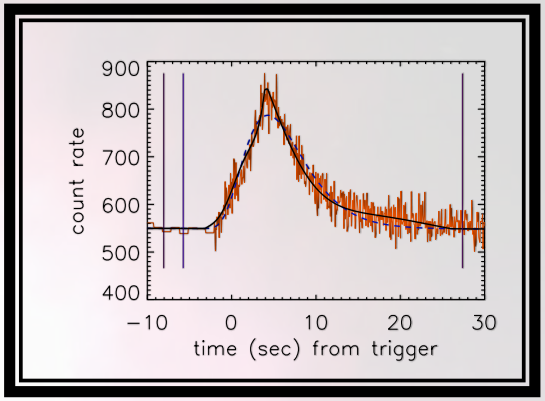


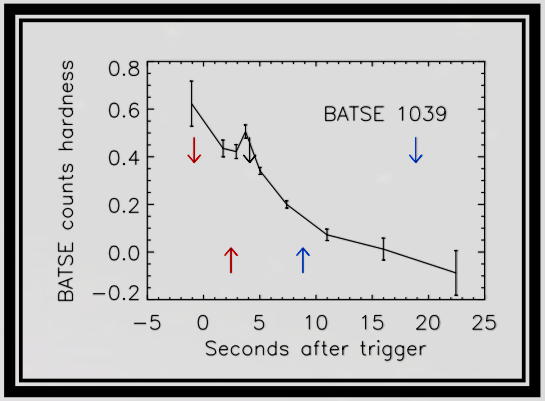


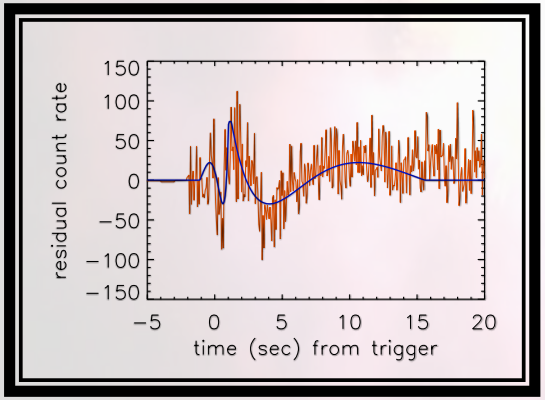
20 keV
To
50 keV

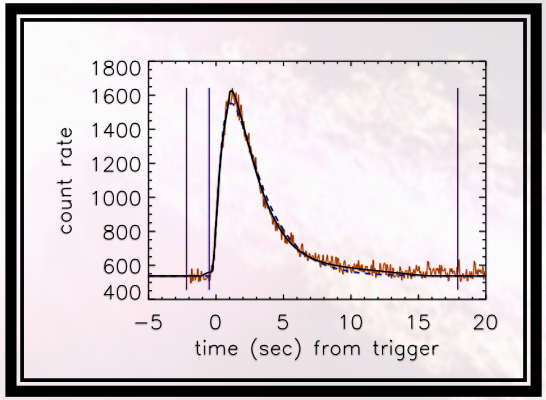
GRB Pulse Residuals and Pulse Structure

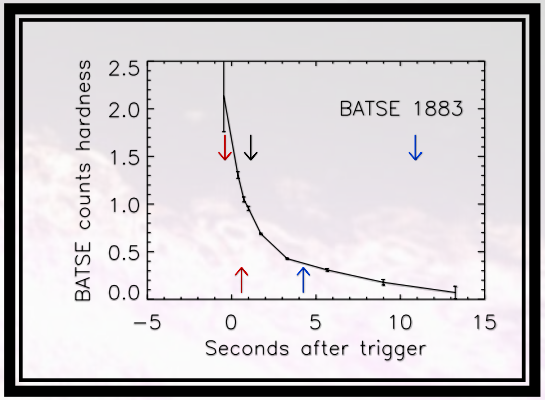


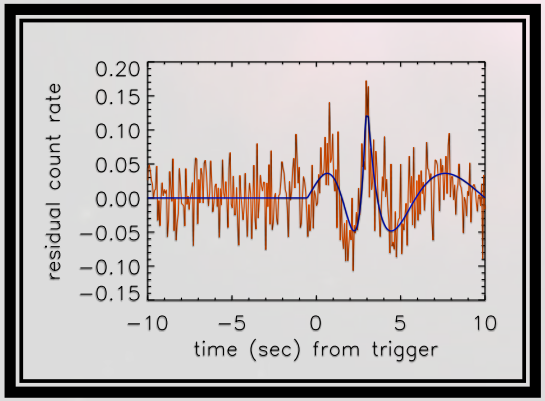


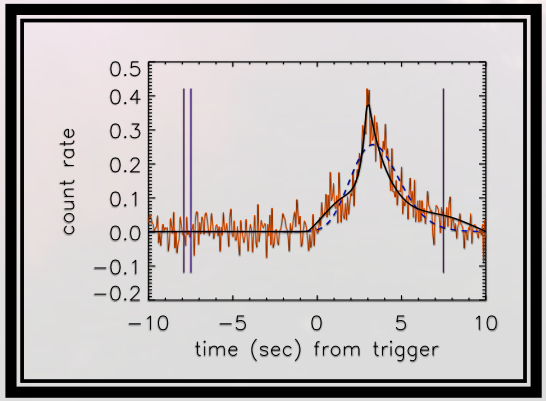


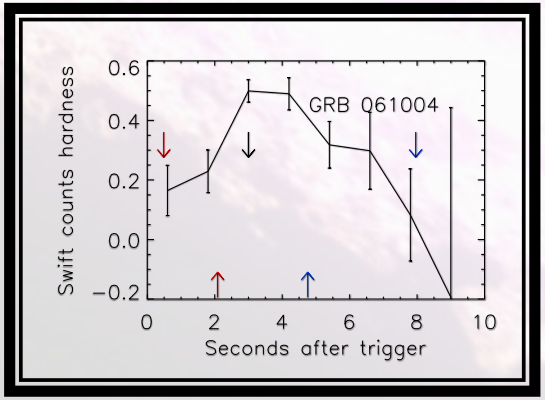




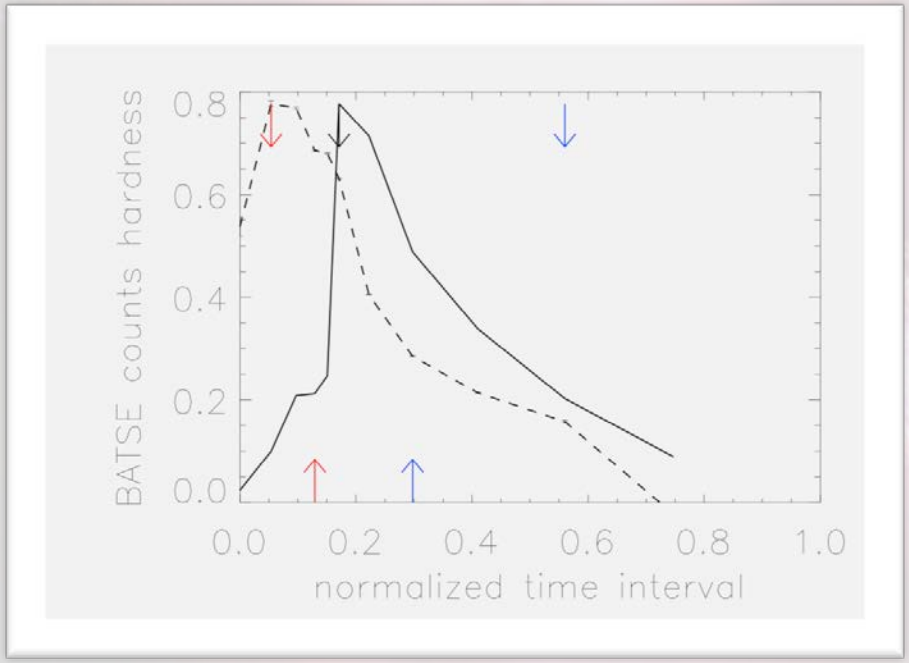




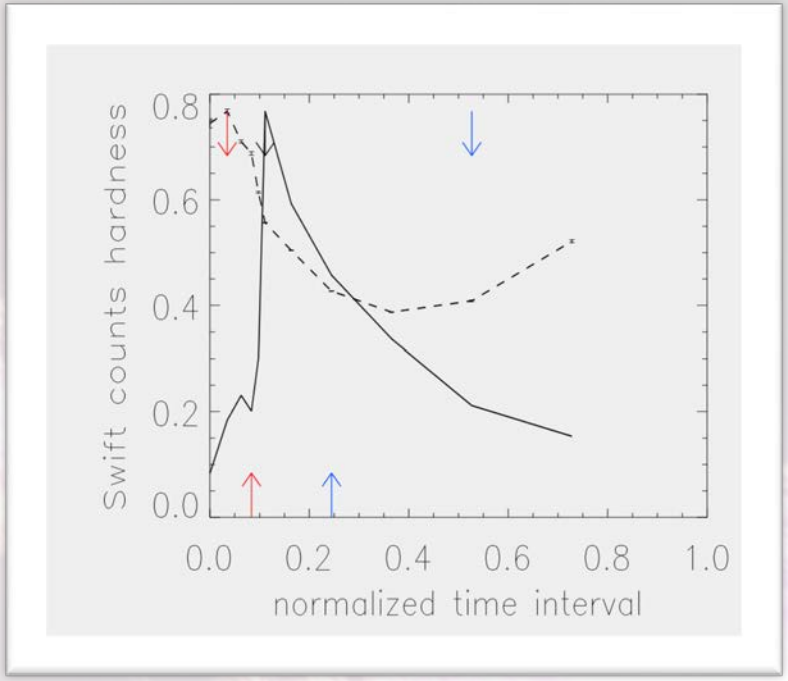




GRB Pulse Profiles

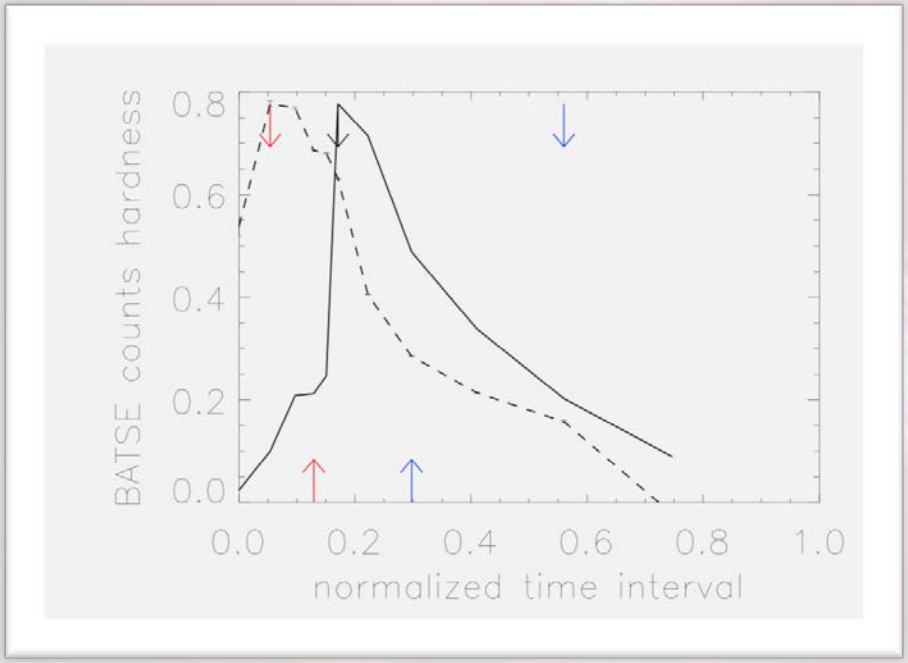


Composite BATSE GRB pulse profile

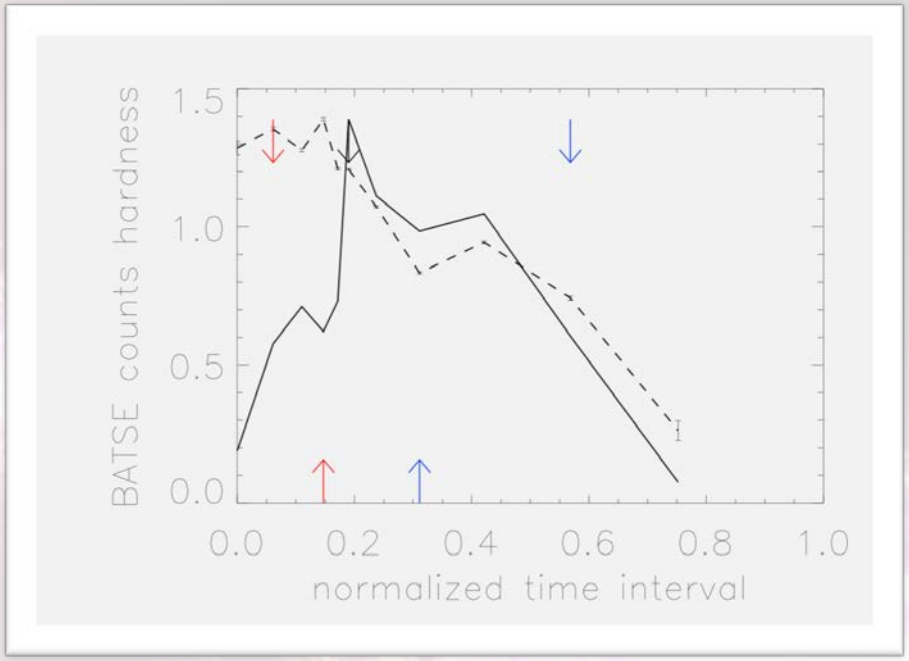


Composite Swift GRB pulse profile

GRB Pulse Profiles

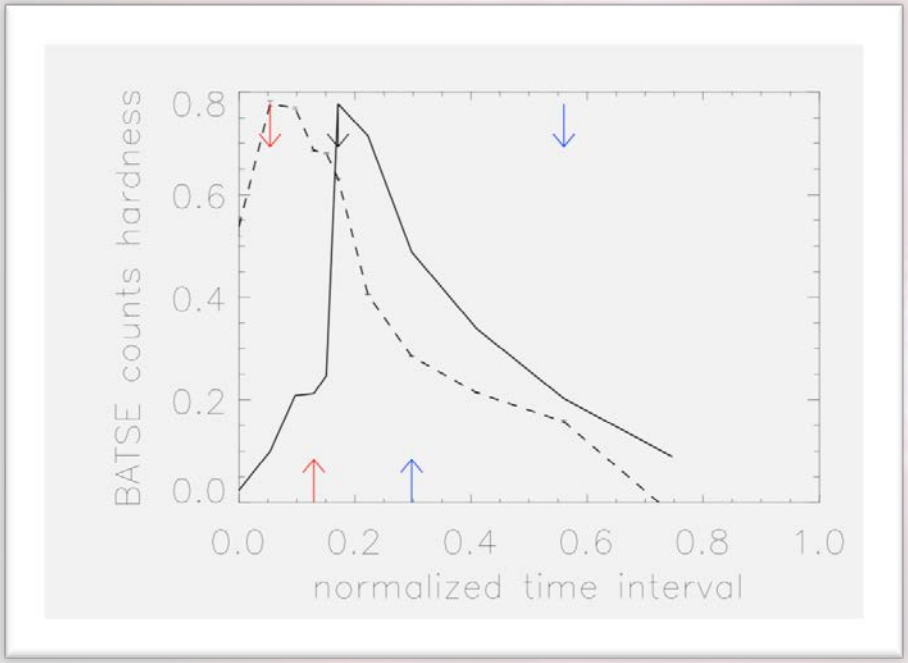


Composite Long BATSE GRB pulse profile

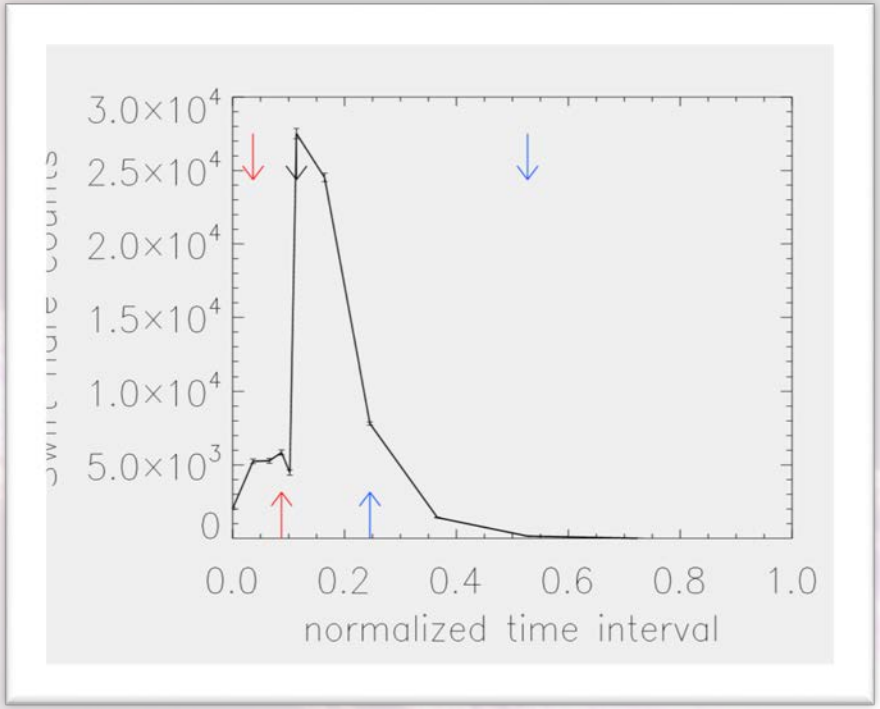


Composite Short BATSE GRB pulse profile

GRB X-ray Flare Profiles

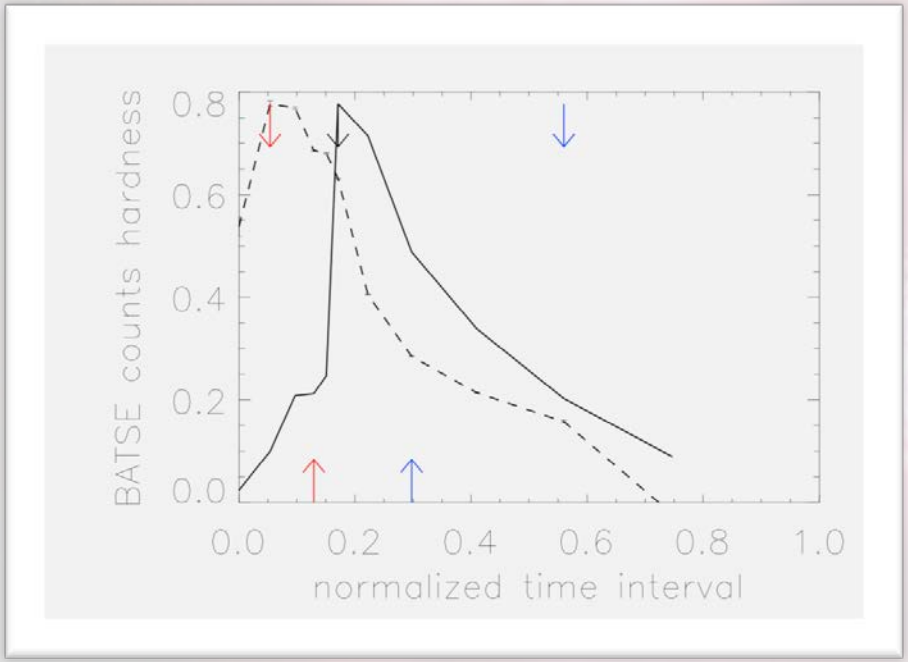


Composite Long BATSE GRB pulse profile



Composite x-ray flare pulse profile

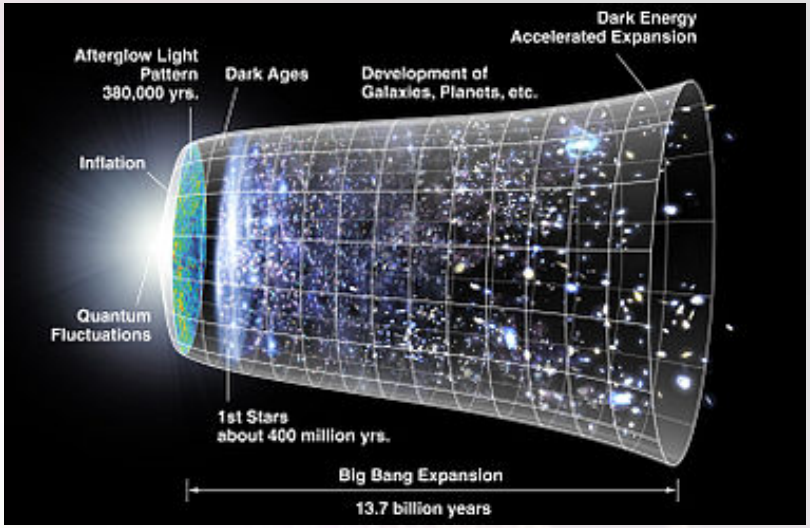
GRB optical flares

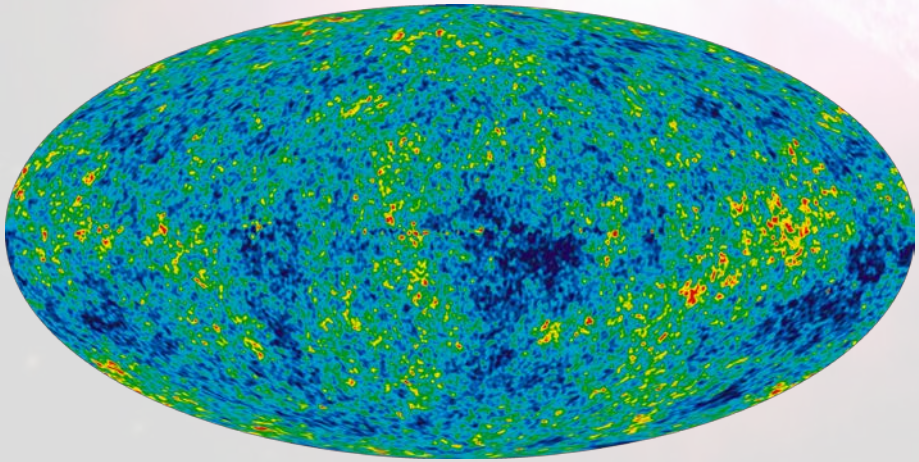


Composite Long BATSE GRB pulse profile

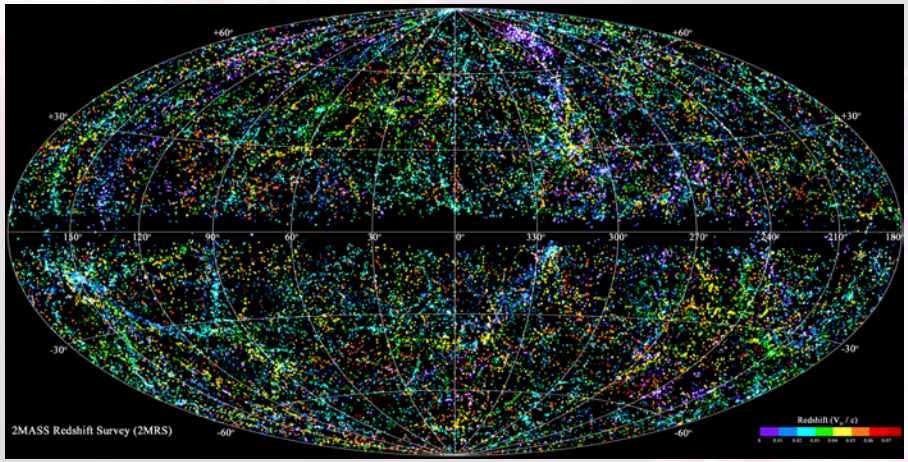
Composite optical flare pulse profile
TBD usingEtelman Observatory

Large-scale universal structure



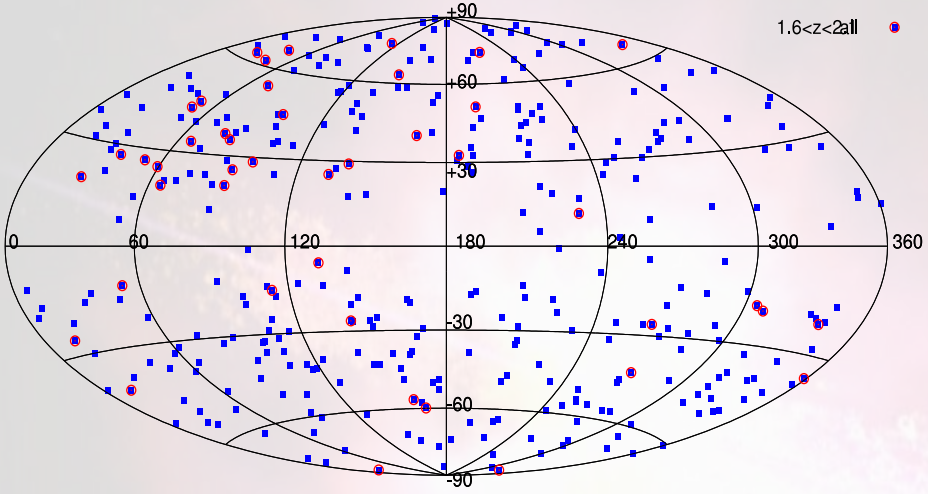


Large scale structure found from Planck data (500,000 years after the Big Bang).

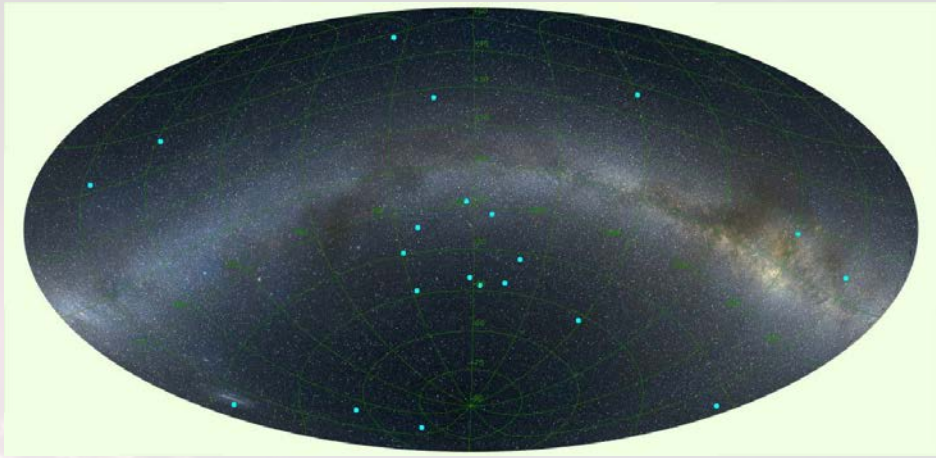


Large scale structure found from 2MASS (out to 180 million years ago).

GRBs as Probes of Large-Scale Structure



Hercules Corona Borealis Great Wall



Giant GRB Ring

Structure	Size	Distance
Sloan Great Wall	1.4 billion ly	1 billion ly
Clowes-Campusano LQG	2 billion ly x 1 billion ly	9.5 billion ly
U1.11 LQG	2.2 billion ly	8.8 billion ly
Huge-LQG	4 billion ly x 2 billion ly	9 billion ly
Hercules-Corona Borealis Great Wall	10 billion ly x 10 billion ly	10 billion ly

Conclusions

- With the help of EPSCoR, UVI's Etelman Observatory has become a powerful tool for observing many astronomical objects, including GRB afterglows
- The basic units of GRB emission are triple-peaked, hard-to-soft evolving pulses
- All GRB classes have pulses exhibiting these non-monotonic behaviors, regardless of the nature of their progenitors
- X-ray flares found in GRB afterglows exhibit behaviors similar to those of GRB pulses
- The unknown physics of GRB pulses must be relatively simple and ubiquitous
- GRBs are luminous and can be used to study large-scale universal structure