

Recent Scientific Highlights of HETE-2 Mission

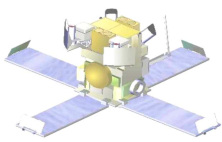
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and the HETE Science Team

Warsaw, Poland
4 October 2006

<http://space.mit.edu/HETE>



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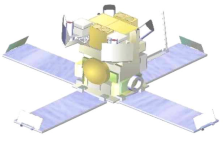
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Stanford E. Woosley

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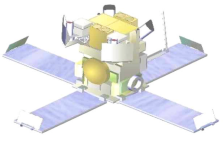
F. Rick Harnden
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Outline of Talk



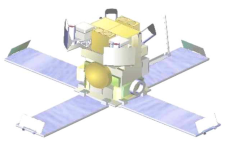
- HETE-2 Mission Status
- Science Highlights of the HETE-2 mission
 - X-ray Flashes
 - GRB-SN Connection
 - Short GRBs
 - Optically Dark GRBs
- Summary



HETE-2 Mission Statistics



- HETE-2 **localized 95 GRBs** in 5 yrs of operation
- **34** of these localizations have led to the detection of X-ray, optical, or radio **afterglows**
- As of today, **redshifts** have been established for **22** of these afterglows
- HETE-2 localized **26 XRFs**
- HETE-2 has observed >250 bursts from SGRs 1806-20 and 1900+14 in the summers of 2001-2004
- HETE-2 has observed ~ 1000 XRBs

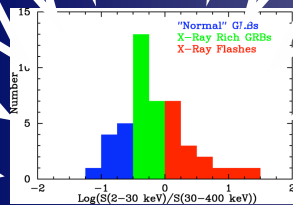


HETE-2 Gamma-Ray Bursts: Six Major Scientific Insights



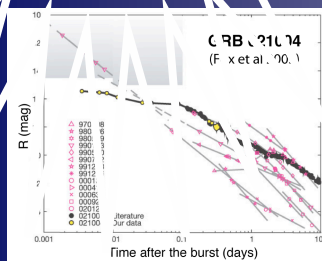
GRB020531:

First detection of short GRB with prompt optical/X-ray followup



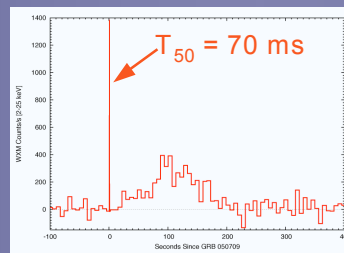
GRB020903:

Elucidation of
"X-ray Flashes"



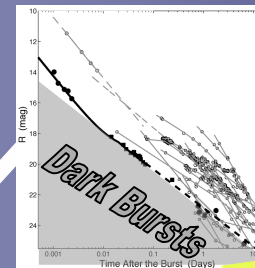
GRB021004:

Refreshed shock
or inhomogeneous jet
(NASA SSU)



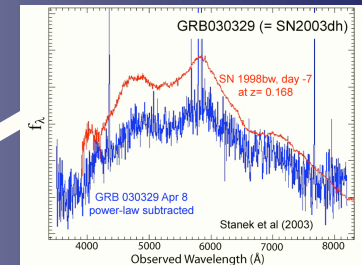
GRB050709:

Short-hard GRB
identified (z=0.16)



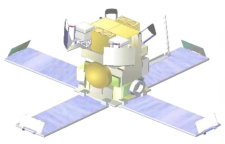
GRB021211:

Insight into "Optically
Dark" GRB Mystery

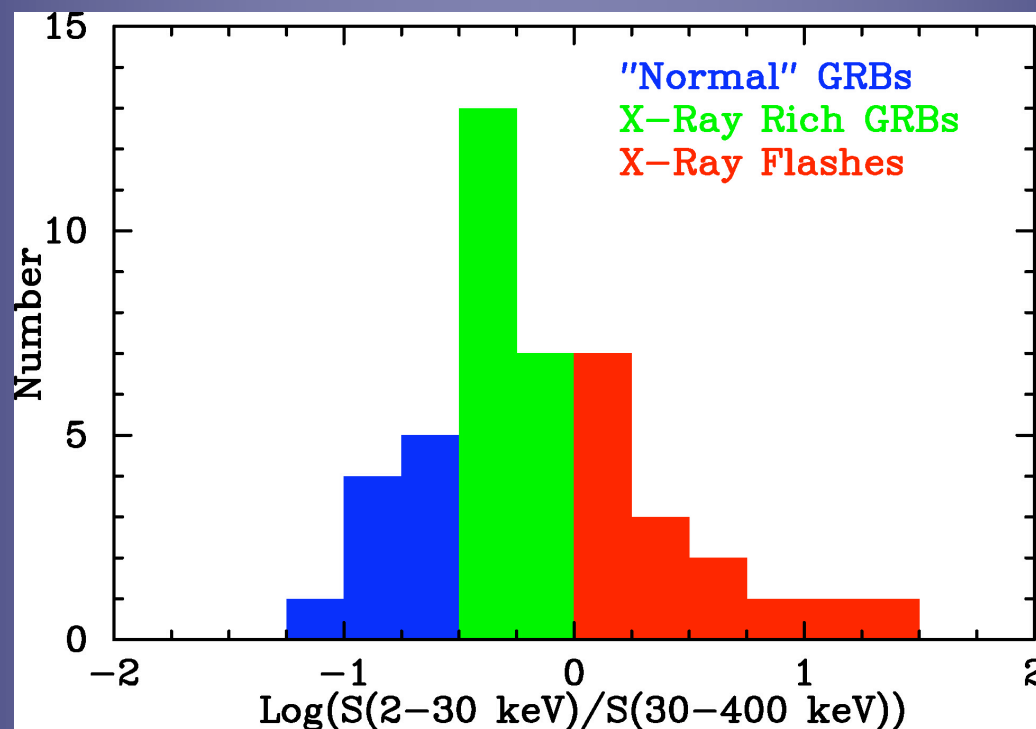


GRB030329:

GRB-SN Connection
(SN2003dh; z=0.168)



X-Ray Flashes Localized by HETE-2

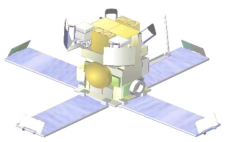


- Of the HETE-2 bursts

- 3/9 XRFs
- 4/9 "X-ray-rich" GRBs
- 2/9 "classical" GRBs

- Nature of XRFs is still largely unknown

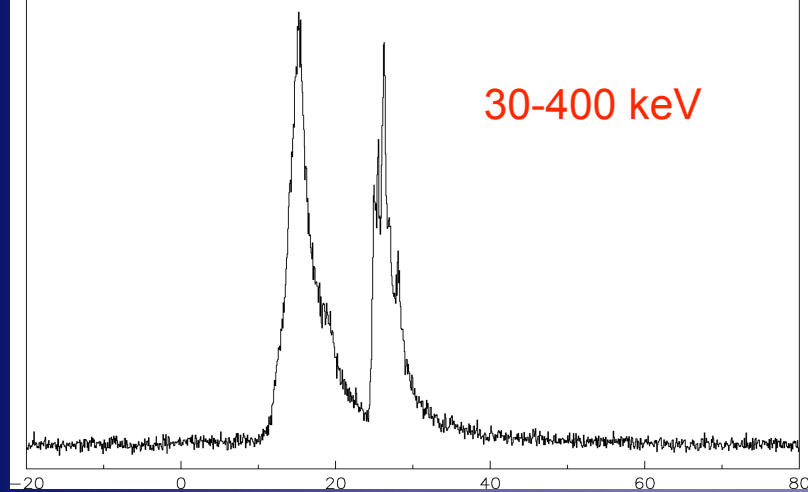
- XRFs are providing unique insights into:
 - Structure of GRB jets
 - GRB rate
 - Nature of Type Ic supernovae



GRB030329: HETE-2 “Hits a Home Run”

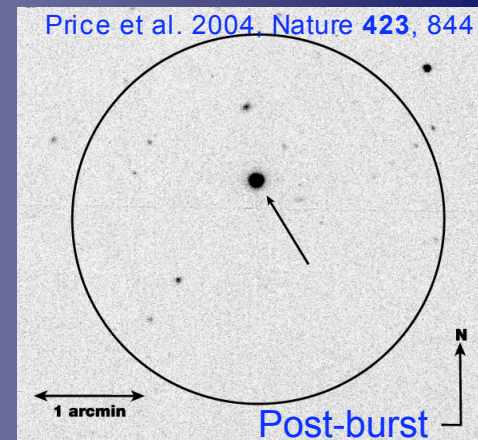
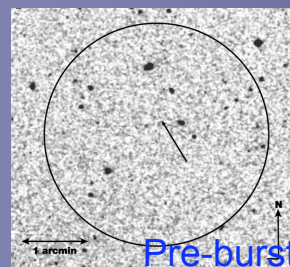


Vanderspek et al. 2004, Ap. J. **617**, 1251

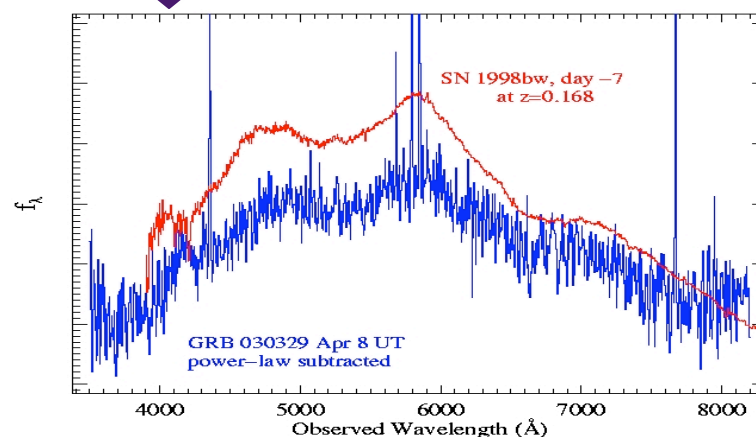


Exceptionally High Fluence
(Top 1%; 1.5×10^{-4} ergs cm^{-2})

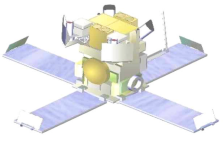
Brighter than R=13 an hour after the burst



$z = 0.1675 \Leftrightarrow$ probability of detecting a *bright GRB* this close by is $\sim 1/5000$
 \Rightarrow unlikely that HETE-2 or *Swift* will see another such event



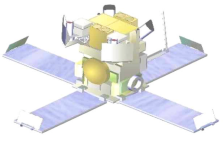
Stanek et al. (2003; also Fynbo et al. 2003)



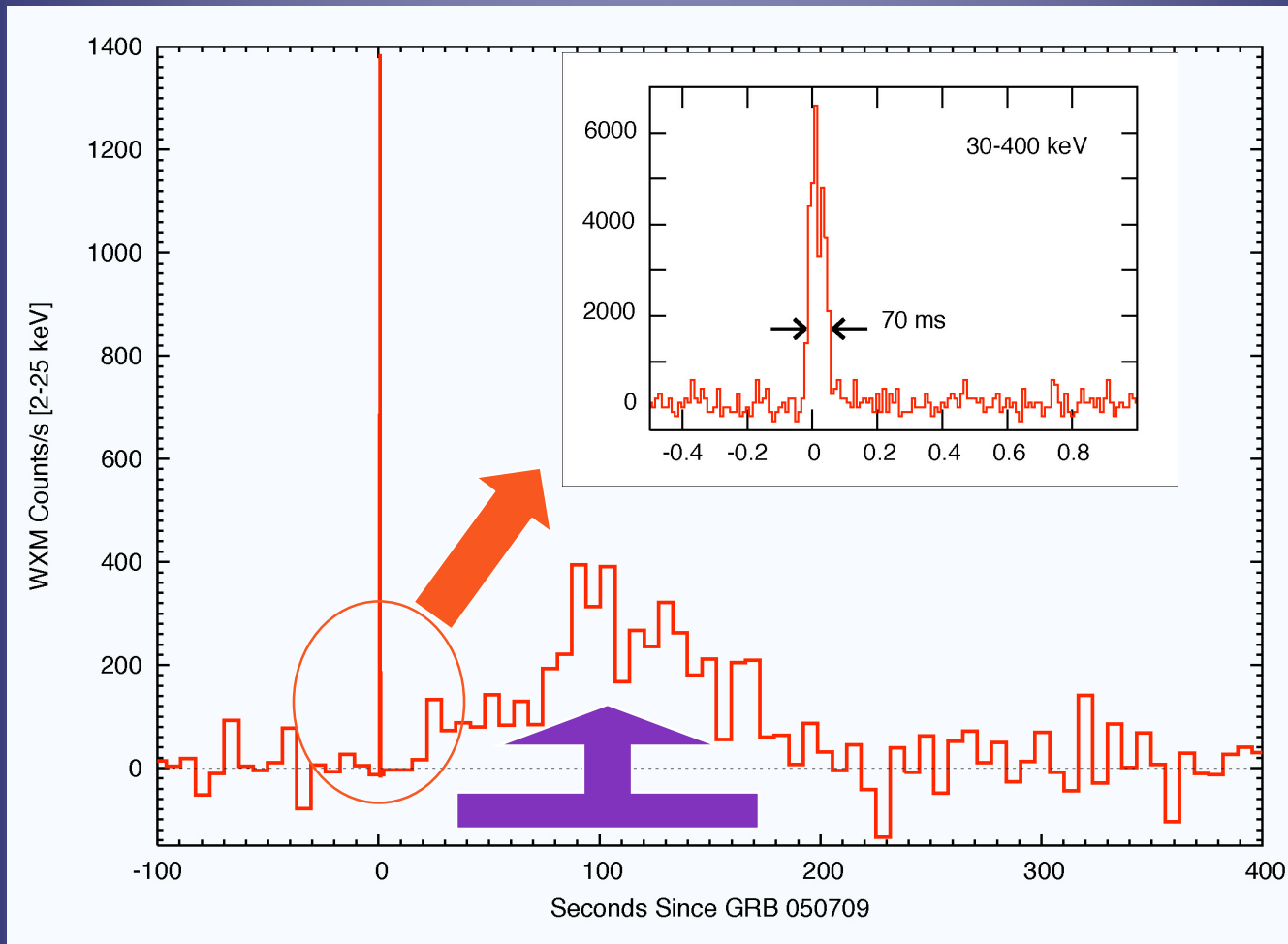
GRB030329: Implications



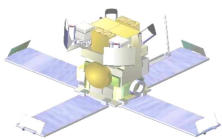
- HETE-2—localized burst GRB030329/SN 2003dh fully establishes the GRB - SN connection
- Result strengthens the expectation that GRBs occur out to $z \sim 20$, and are therefore *a potential probe of first light and reionization*



GRB 050709: “Solid Gold” Short-Population GRB



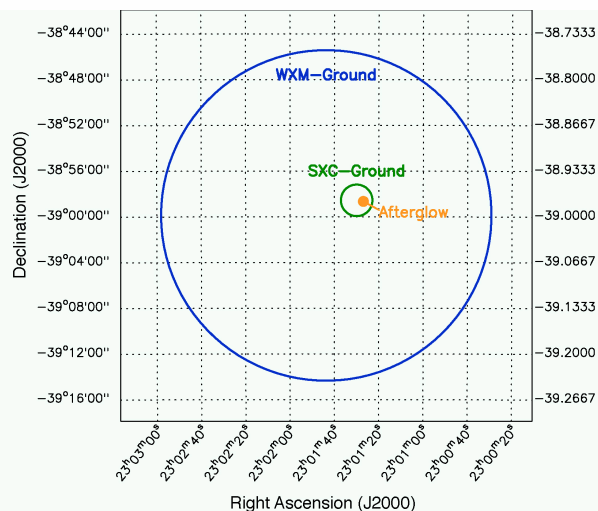
- Short Spike : ~70 ms Hard Burst at $t = 0$ s
- Long Bump : Classic Afterglow spectrum at ~100 s



GRB 050709: HETE-2 Localizes & HST Images



HETE-2 Error Circle



Villasenor et al., Nature (6 October 2005)

- HETE-2: Light Curve & Localization

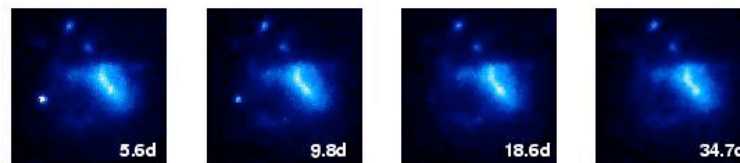
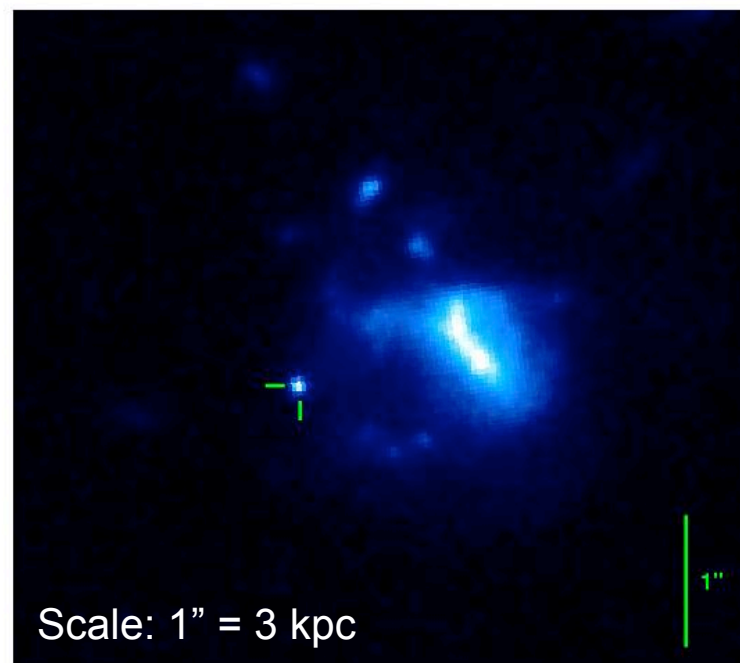


- Chandra: X-ray Error Circle



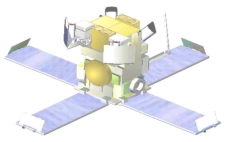
- Hubble: Fading Optical Counterpart

HST Images at 4 Epochs



Fox et al., Nature (6 October 2005)

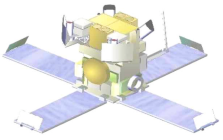
Redshift $z=0.160$



Short GRB Mystery Largely Solved



- GRB 050709, a classic short GRB, played a key role in solution (as did the Swift bursts GRB 050509B & GRB 050724)
- GRB 050709 occurred in outskirts of host galaxy - not in star-forming region - unlike all long GRBs
- L and E_{iso} is 1000 times smaller than those of long GRBs
- Delay of ~ 100 s in peak of afterglow seen by HETE-2 implies burst occurred in low-density environment - unlike long GRBs
- All of these properties are exactly those expected for merging compact binaries

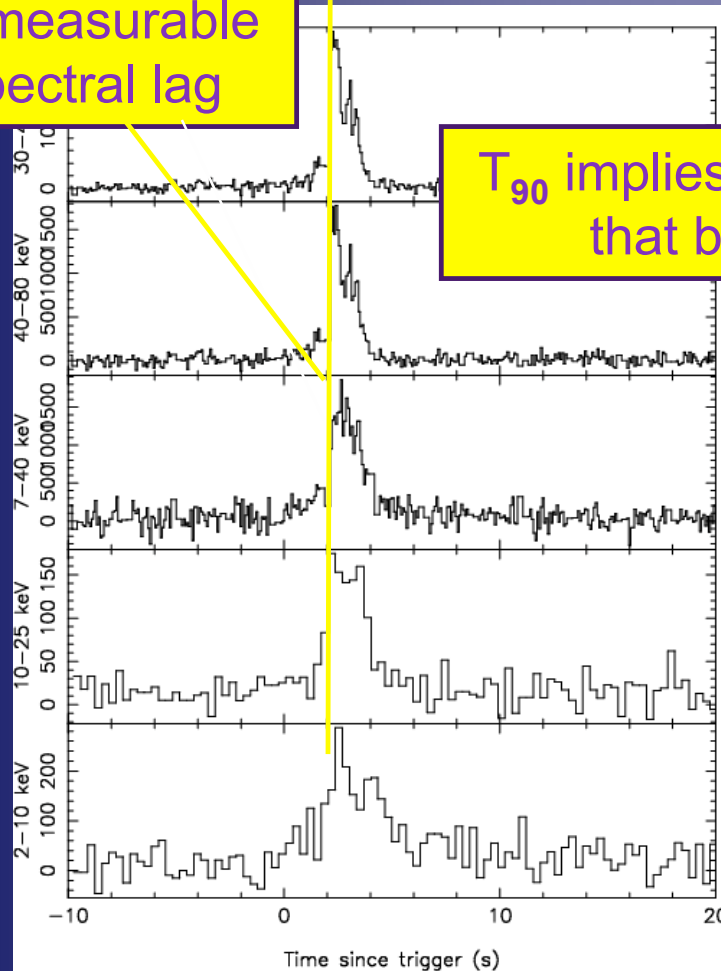


HETE-2 Short Burst GRB 060121

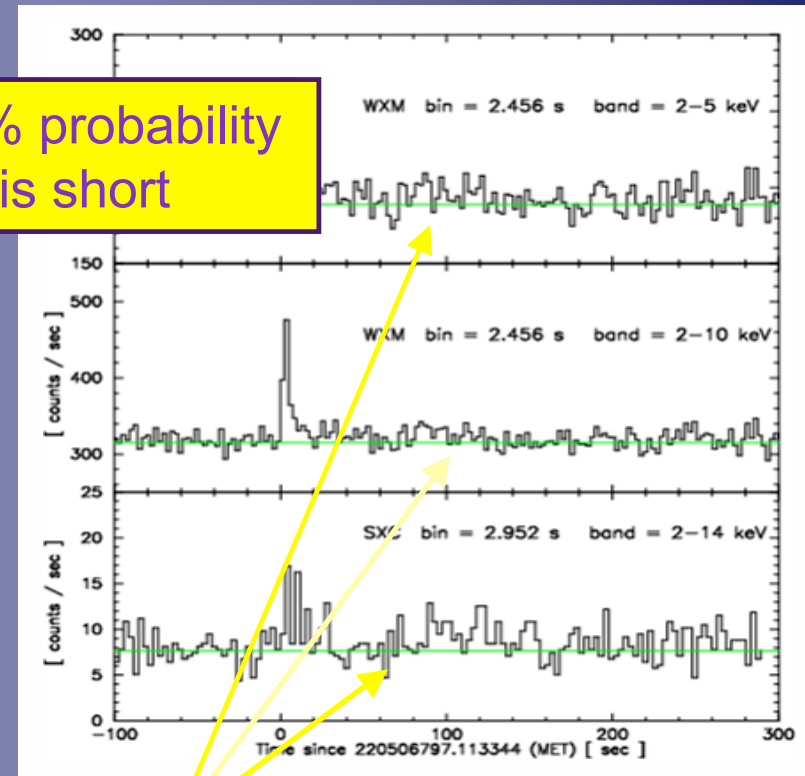


Donaghy, Lamb, Sakamoto, Norris, et al. (2006)

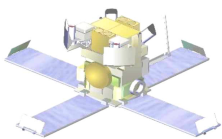
No measurable
spectral lag



T_{90} implies 95% probability
that burst is short



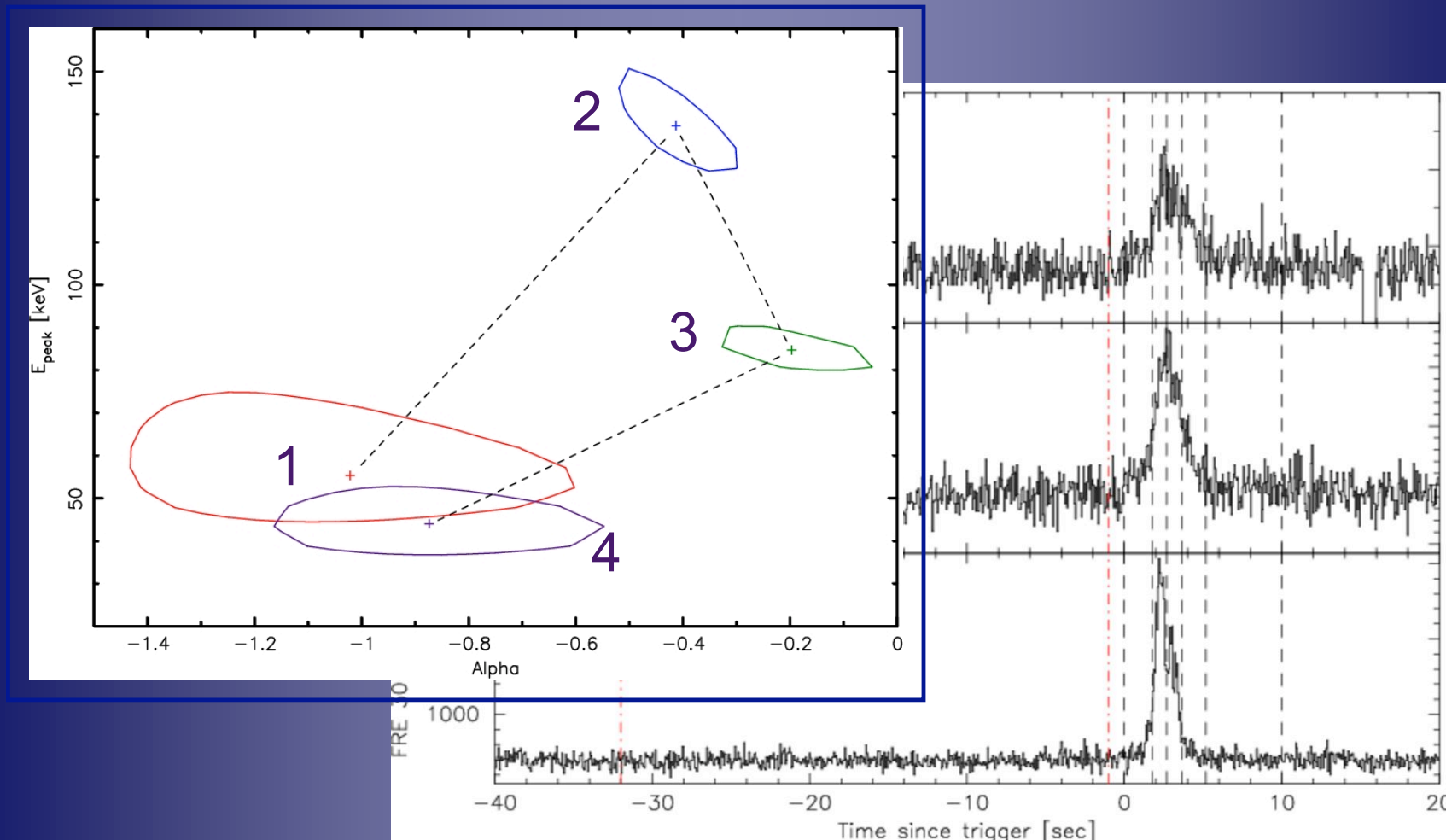
Long, soft bump

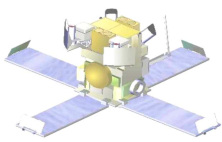


HETE-2 Short Burst GRB 060121: Time-Resolved Spectroscopy



Donaghy, Lamb, Sakamoto, Norris, et al. (2006)

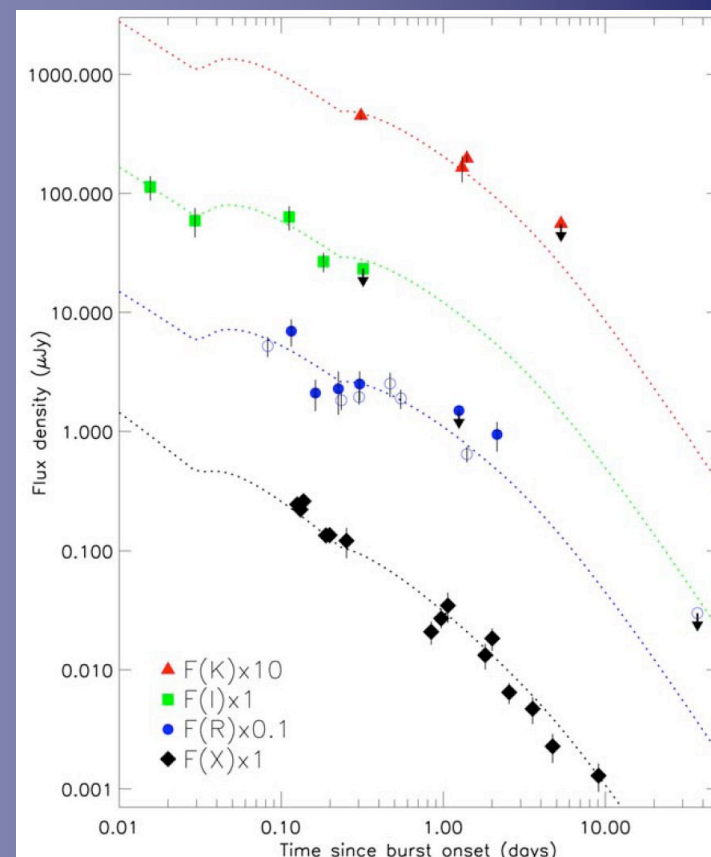
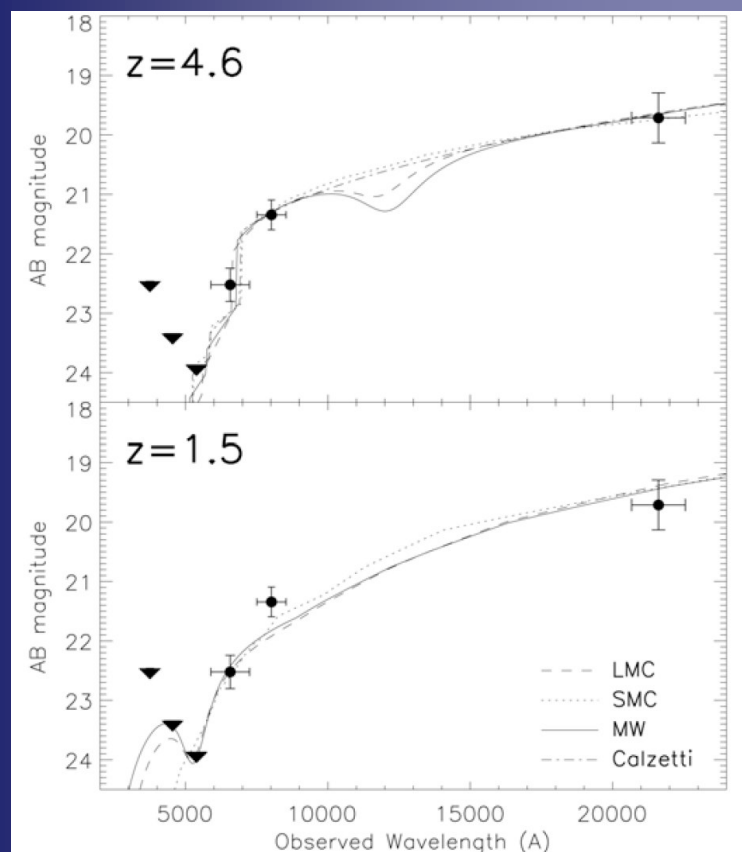


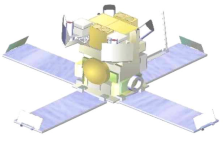


HETE-2 Short Burst GRB 060121: Photometric Redshift



Ugarte de Postigo et al. (2006)

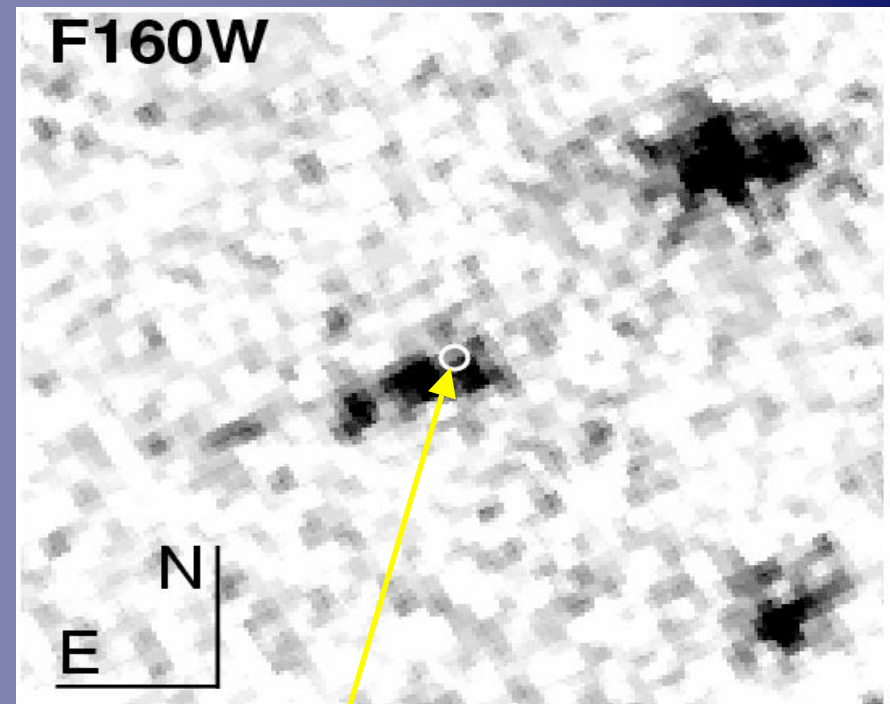
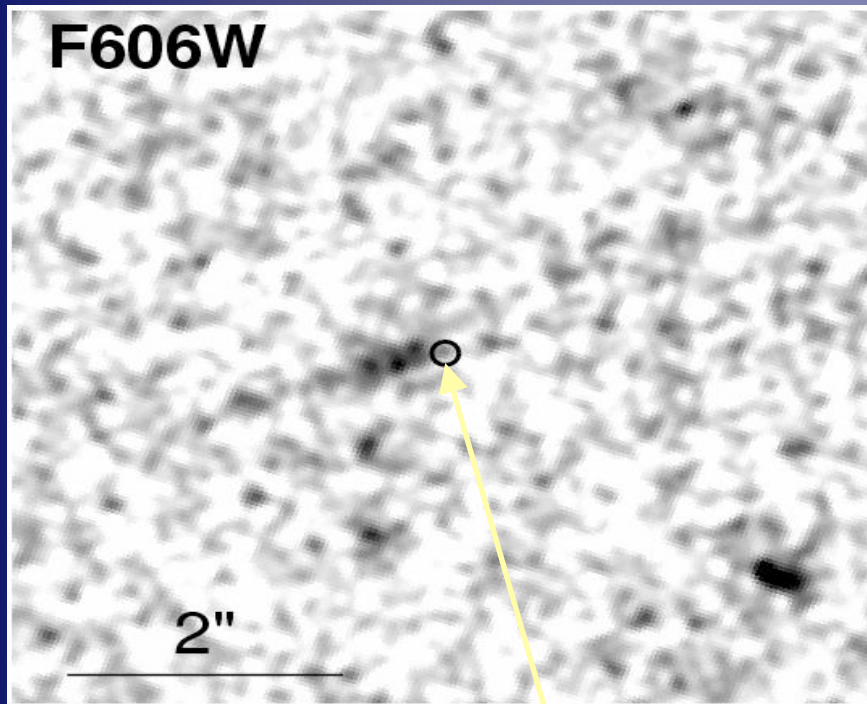




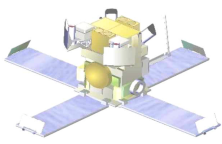
HETE-2 Short Burst GRB 060121: Host Galaxy



Levan et al. (2006)



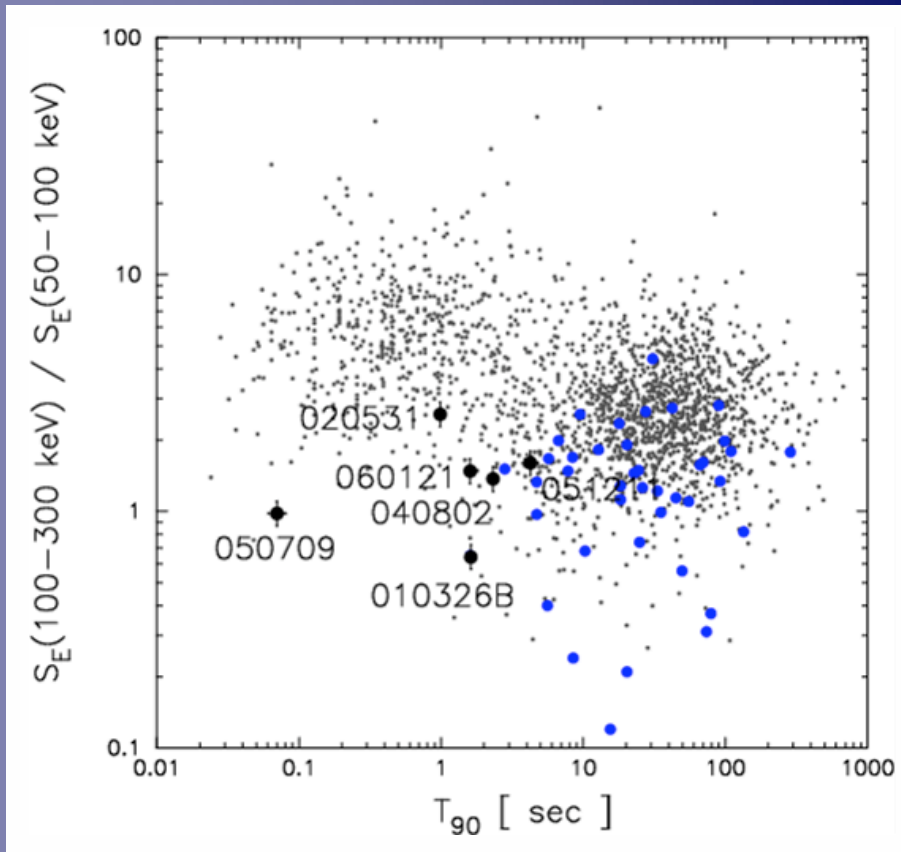
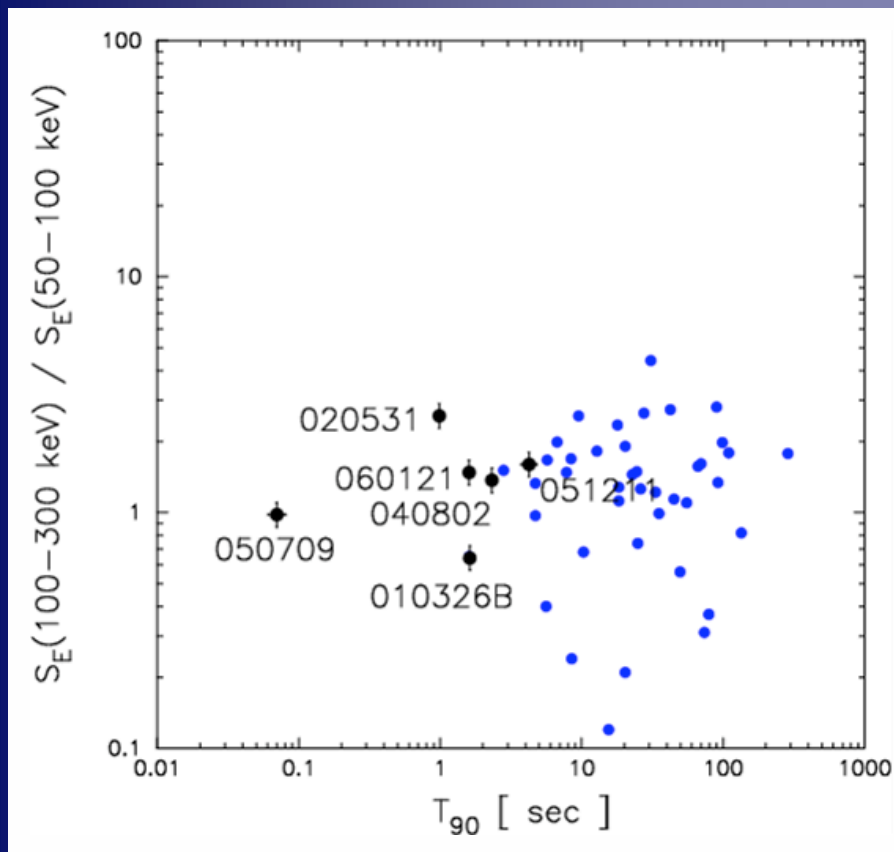
Burst occurred outside bright star-forming regions

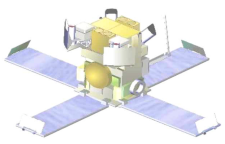


Locations of HETE-2 Short- and Long-Duration Bursts in (T_{90}, S_E) -Plane

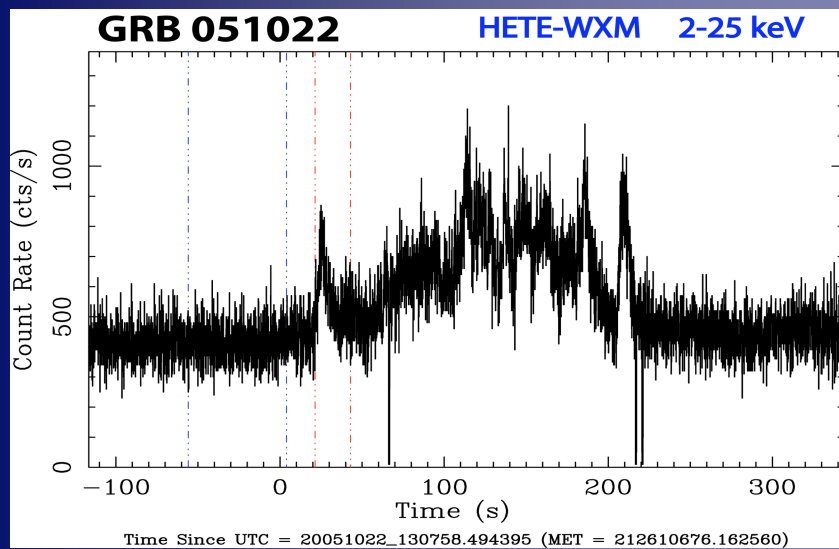


Donaghy, Lamb, Sakamoto, Norris, et al. (2006)

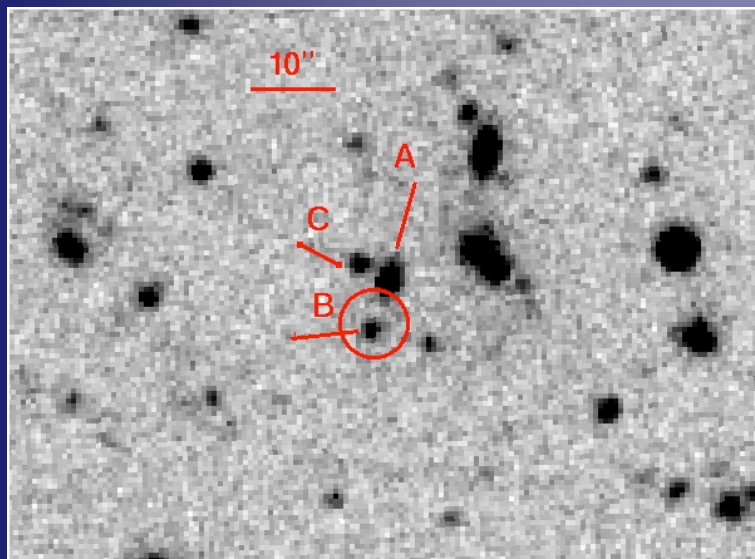




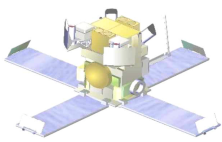
GRB 051022: “Darkest of Dark Bursts”



[Cool, GCN4149]



- HETE-2 SXC prompt localization
 - Highest Fluence GRB in 5 years
 - ⇒ $1.6 \times 10^{-4} \text{ ergs cm}^{-2}$
 - Large column density:
 - ⇒ $n_H \sim 1.5 \times 10^{22} \text{ cm}^{-2}$
 - ⇒ Swift XRT follow-up in 3.5 hrs
- Chandra TOO
- Optical/IR Counterpart
 - J, Ks (GCN4133)
 - R~21.5 host
- Bright Radio Counterpart
 - 0.6 mJy
 - Redshift $z = 0.8$
- High extinction ($A_v \sim 41 \text{ mag !}$)



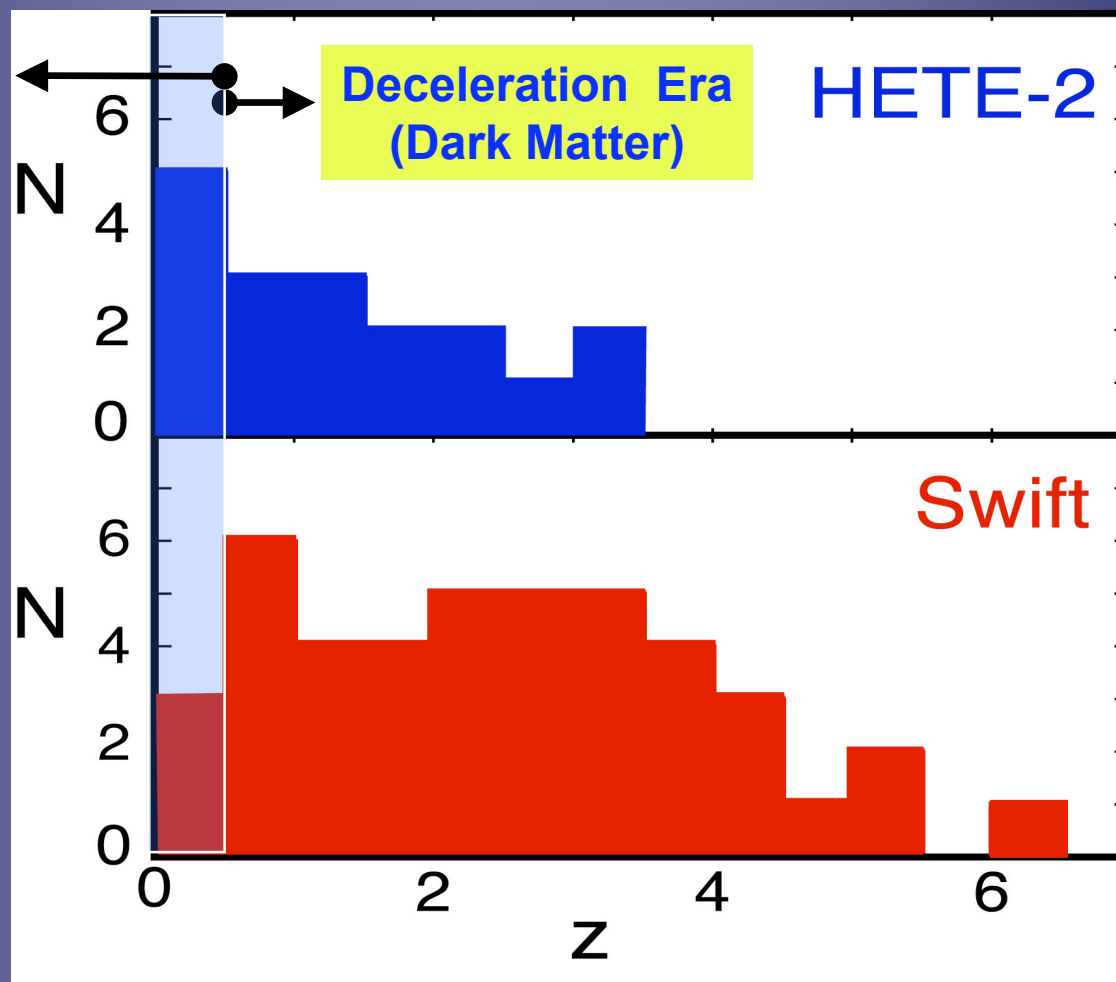
Redshift Distributions: HETE and Swift Long GRBs



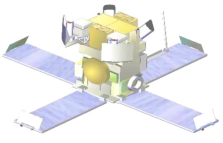
Acceleration Era
(Dark Energy)

Deceleration Era
(Dark Matter)

HETE-2



Current $z < 0.5$ GRBs: 3 of 43 from Swift BAT; 5 of 18 from HETE



Summary



- HETE-2 **localized 95 GRBs** in 5 yrs of operation, including **26 XRFs**
- **34** of these localizations have led to the detection of X-ray, optical, or radio **afterglows**
- **Redshifts** have been established for **22** of these so far
- HETE-2 solved nature of XRFs (same phenomenon as hard GRBs; progenitors are Type Ic SNe at modest redshifts)
- HETE-2 decisively confirmed GRB-Type Ic SN connection
- HETE-2 made key contribution to solving mystery of short GRBs
- HETE-2 GRB catalog will be released soon