Time Domain Astronomy: Gamma-ray Bursts and DECam

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The George Washington University
DECam Community Workshop
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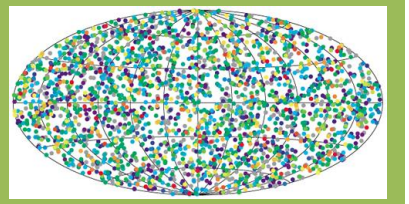


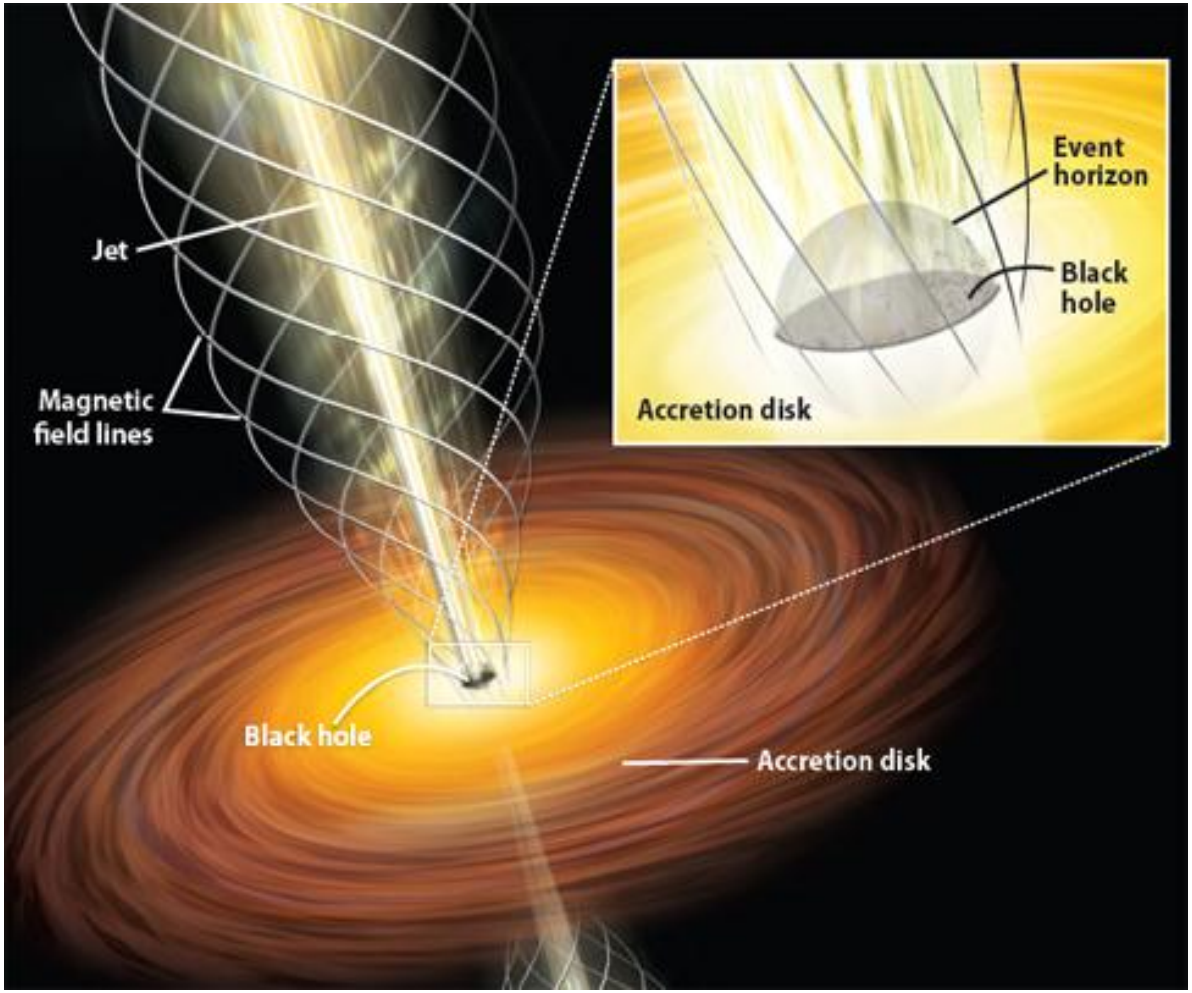
Time Domain Astronomy

- Many exciting astronomy discoveries currently happening in the <u>time domain</u>:
  - Supernovae
  - Gamma-ray Bursts
  - Extrasolar Planets
  - Tidal Disruption Flares
  - Cataclysmic Variables
  - AGN
  - Microlensing, etc.
- Need availability of Target of Opportunity observations (ToO), with <u>clear guidelines and procedures</u>
- Need repeated observations of fields on various timescale (minutes, hours, days, weeks, etc.)
- Need for data access/management including
  1. Real-time (or at least relatively fast) analysis
  2. Fast/easy access to pre-event image archives (online sky atlases, etc.)
  3. Management of large datasets
  4. Quick image differencing / relative photometry

Outline

- Gamma-ray burst (GRB) central engines & progenitors
- GRB afterglows
- GRB-related supernovae
- GRB host galaxies
- Tidal disruption flares

GRB Central Engines:



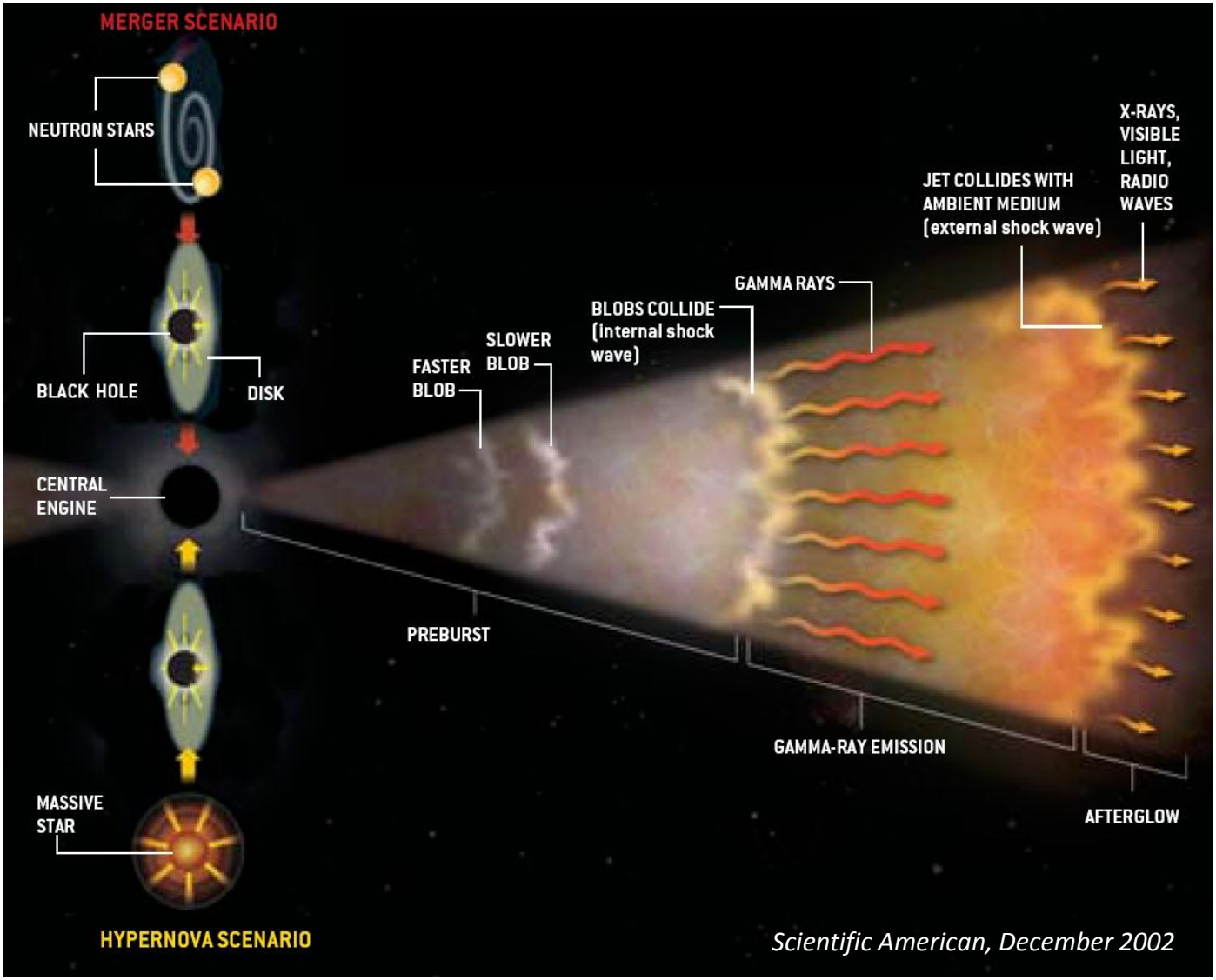
- ✓ Produces ~10^{52} ergs of power in only seconds
- ✓ High temporal variability = small size
- ✓ Rare (~1 per galaxy every 10^6 years)

➔ Accreting Black Hole

GRB Photon Production:

Short-Duration
- < 2 seconds
- Compact object mergers

Long-Duration
- > 2 seconds
- Type Ic SNe



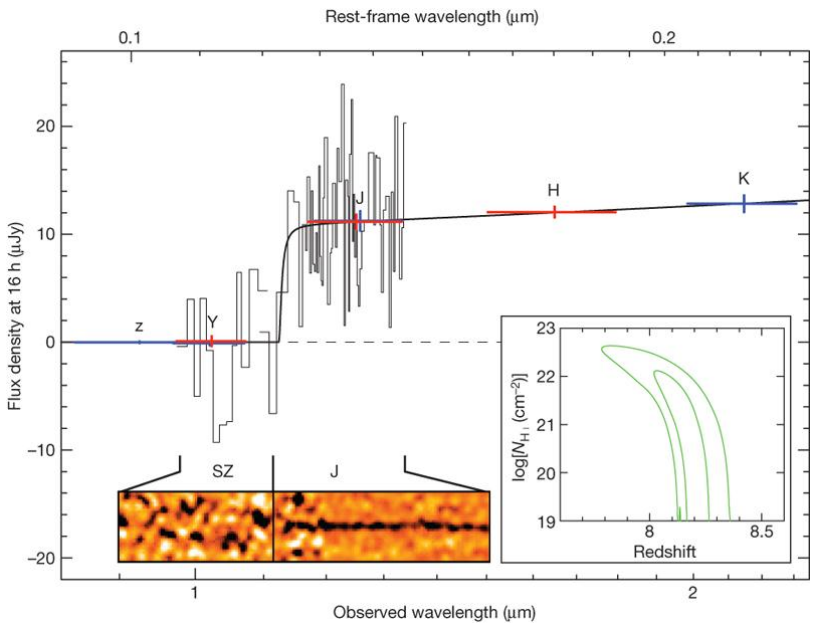
Scientific American, December 2002

Current Status of GRB Research

Open Questions:

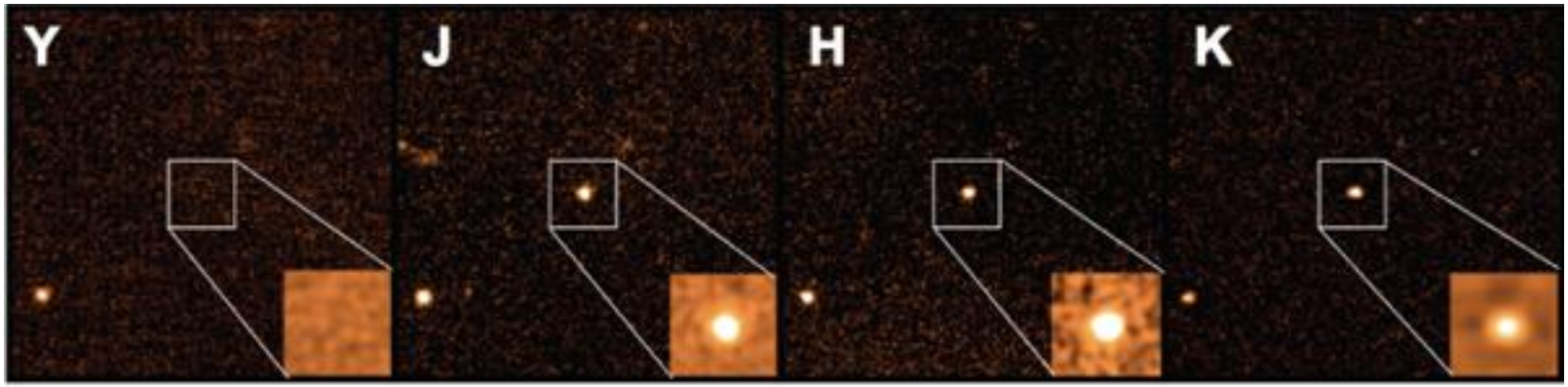
- Short-duration GRB progenitors?
- Long-duration GRBs all from core collapse?
- GRB circumstellar environments/dust?
- Shock details?
- Metallicty?
- Trace obscured star formation?
- Clues to reionization history of the universe?

Understand GRBs as individual events →
Use as cosmological probes… ?



(Tanvir et al. 2009)

GRB 090423 @ z = 8.2



GRB Satellites:

(Credit: NASA/GSFC)

- > 500 GRBs detected since 2004
- Rapid GRB localization via onboard X-ray and UV/Optical telescopes

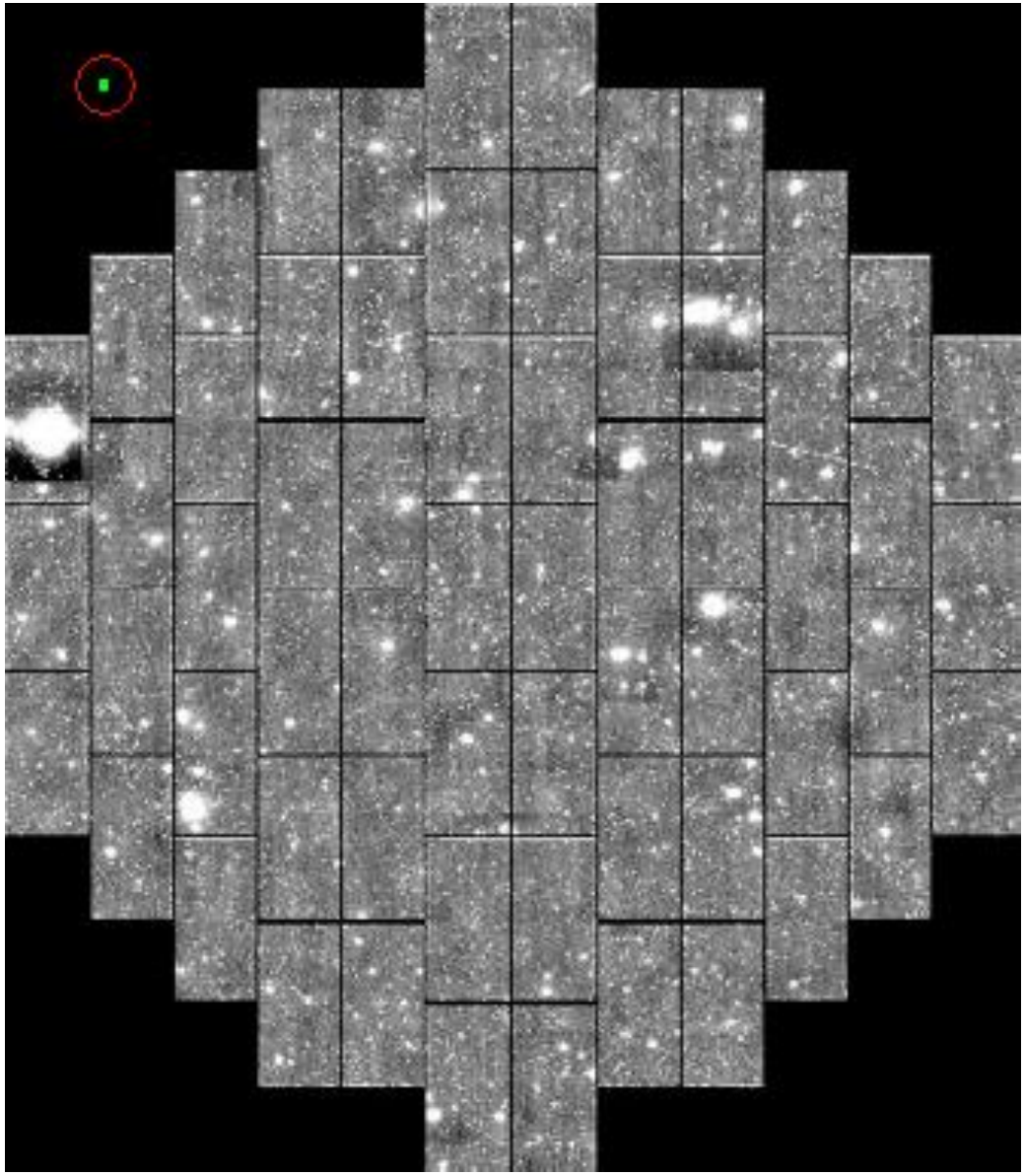
(Credit: General Dynamics C4 Systems)

- Launched in June 2008
- High energy sensitivity for improved gamma-ray spectral coverage
- Generally poor localization (~0.1 - 1 degree radius)

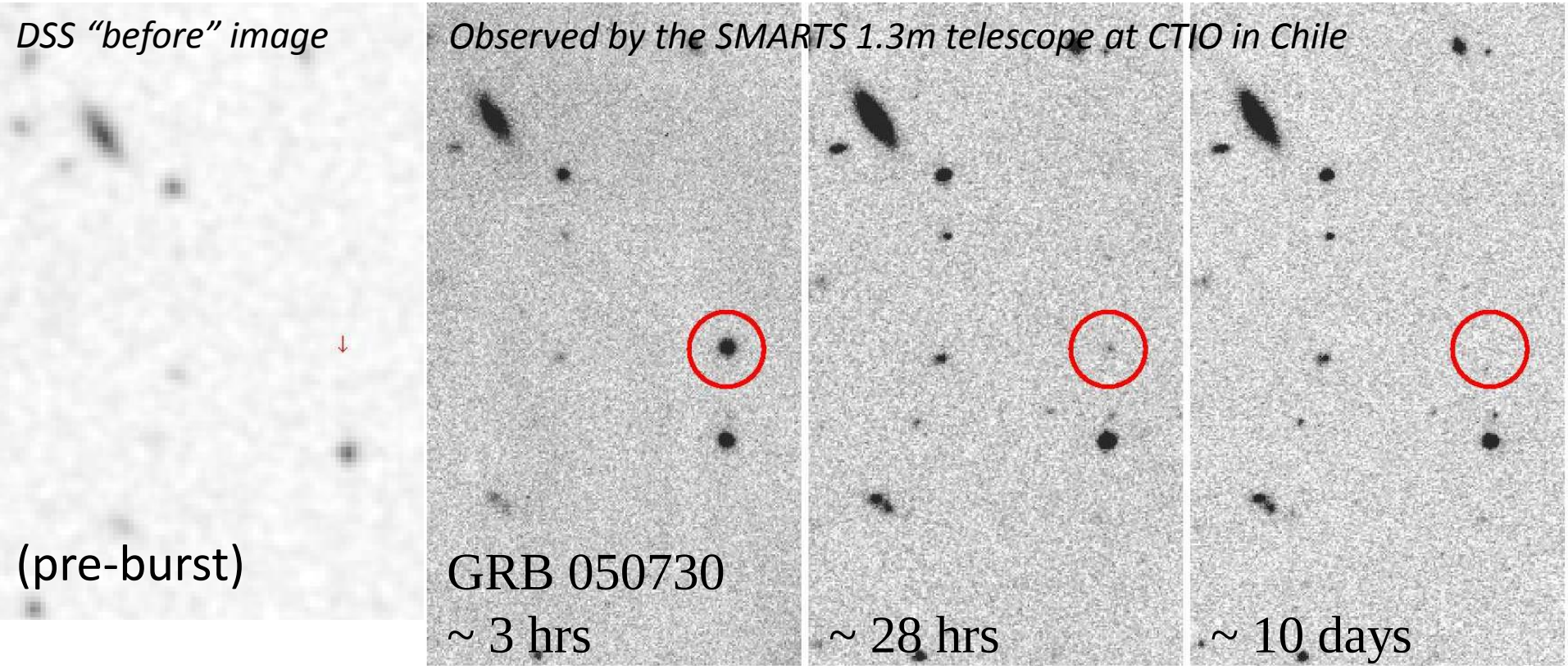
Wide-field Capabilities

Swift won't last forever (*sob!*)

Large area instrumentation required to cover Fermi GRB localizations!

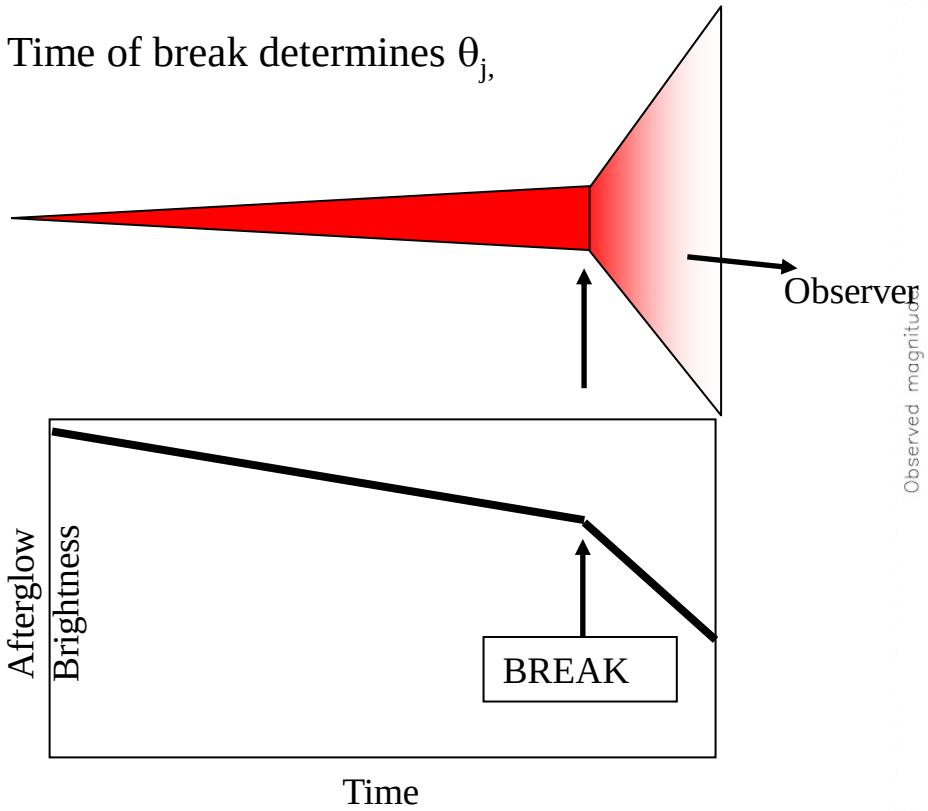


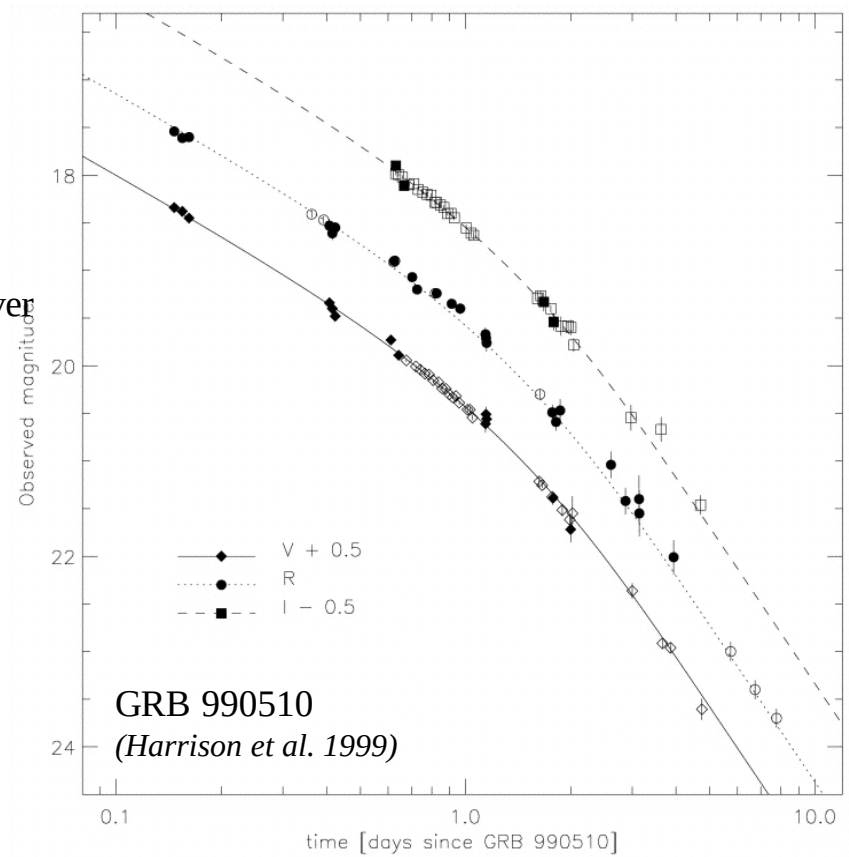
GRB Afterglows:



GRB AG Example: Jet Opening Angles

- Blastwave ($\theta_j >> 1/\Gamma$) to blob ($\theta_j < 1/\Gamma$)
- Time of break determines θ_j,



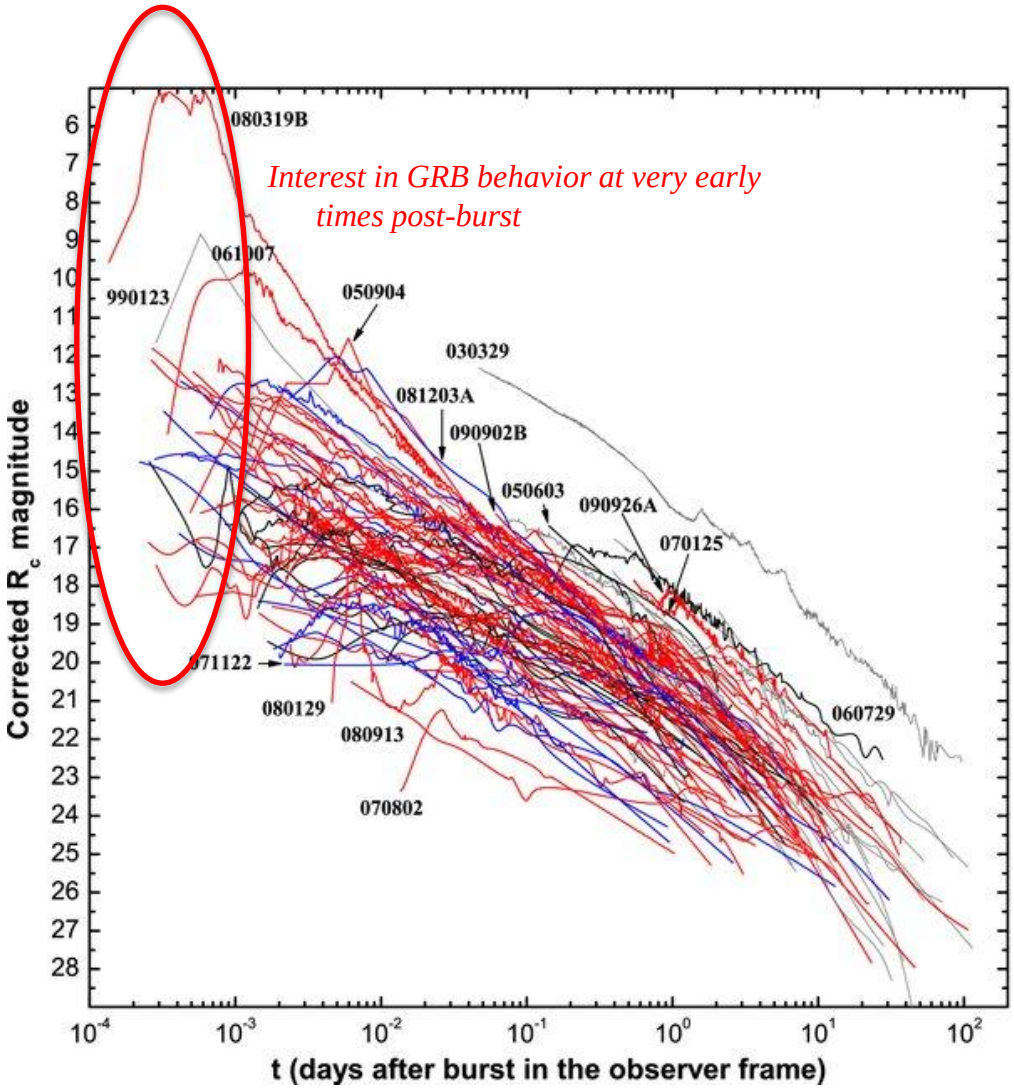


$$E_\gamma = (1 - \cos\theta_j)\, E_{iso}(\gamma)$$

Serendipitous Observations

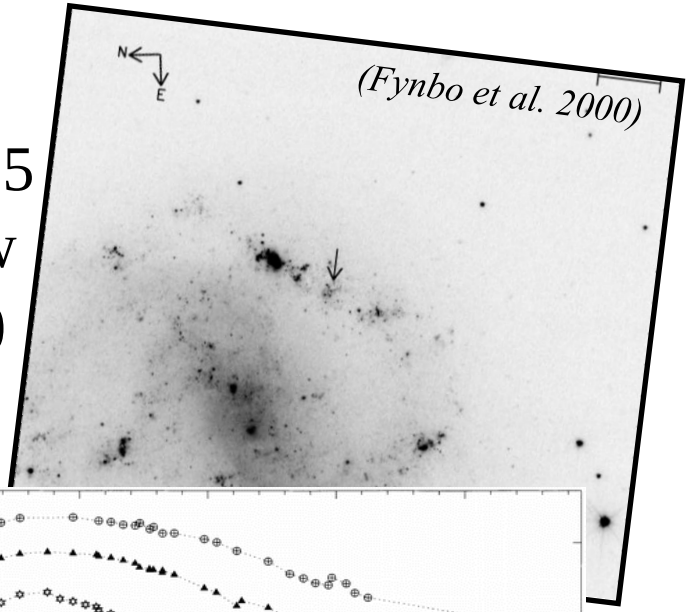
- Extremely early time afterglow? (Coincident with gamma-rays?)
- Pre-gamma-ray optical emission?
- Orphan afterglow?

→ Low probability, but high interest/reward!

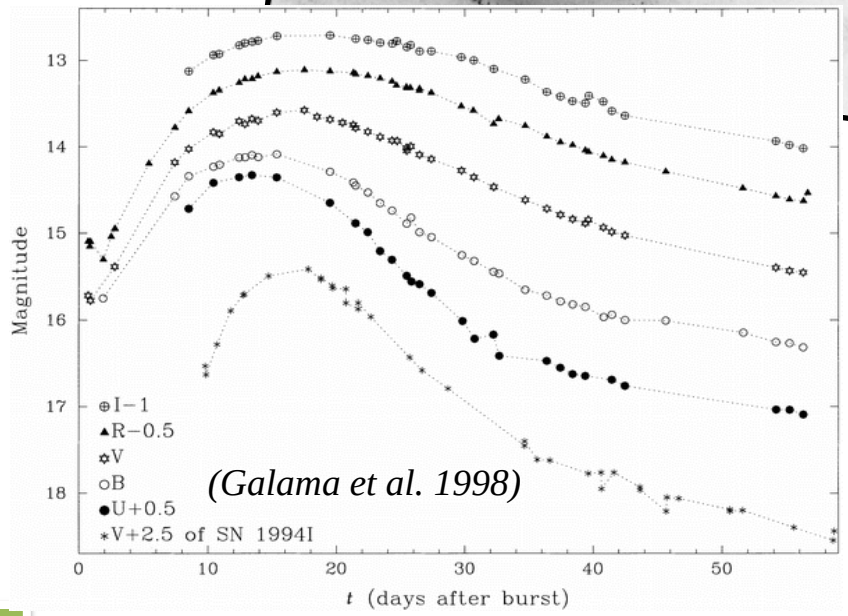


GRB-Related SNe:

GRB 980425
SN 1998bw
(z=0.0085)

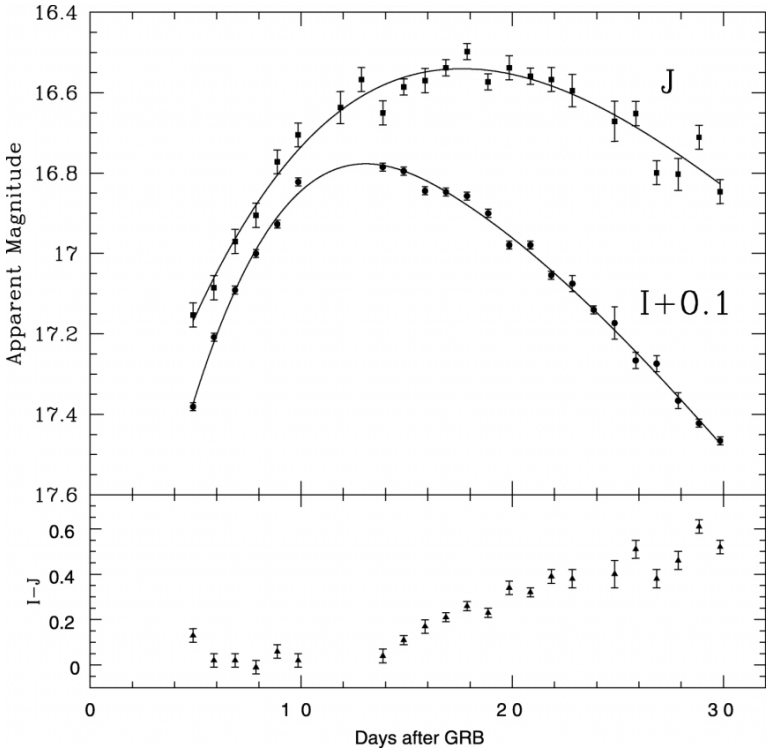


(Fynbo et al. 2000)



(Galama et al. 1998)

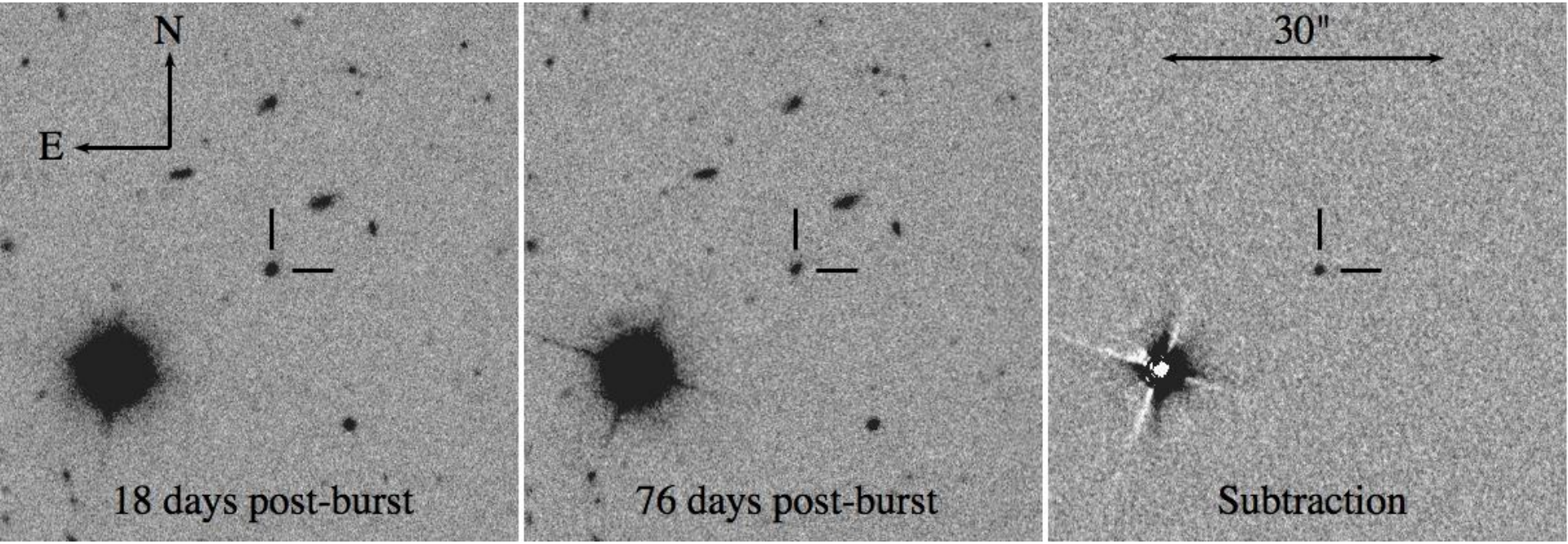
GRB 060218
SN 2006lw
(z=0.033)



(Cobb et al. 2006)

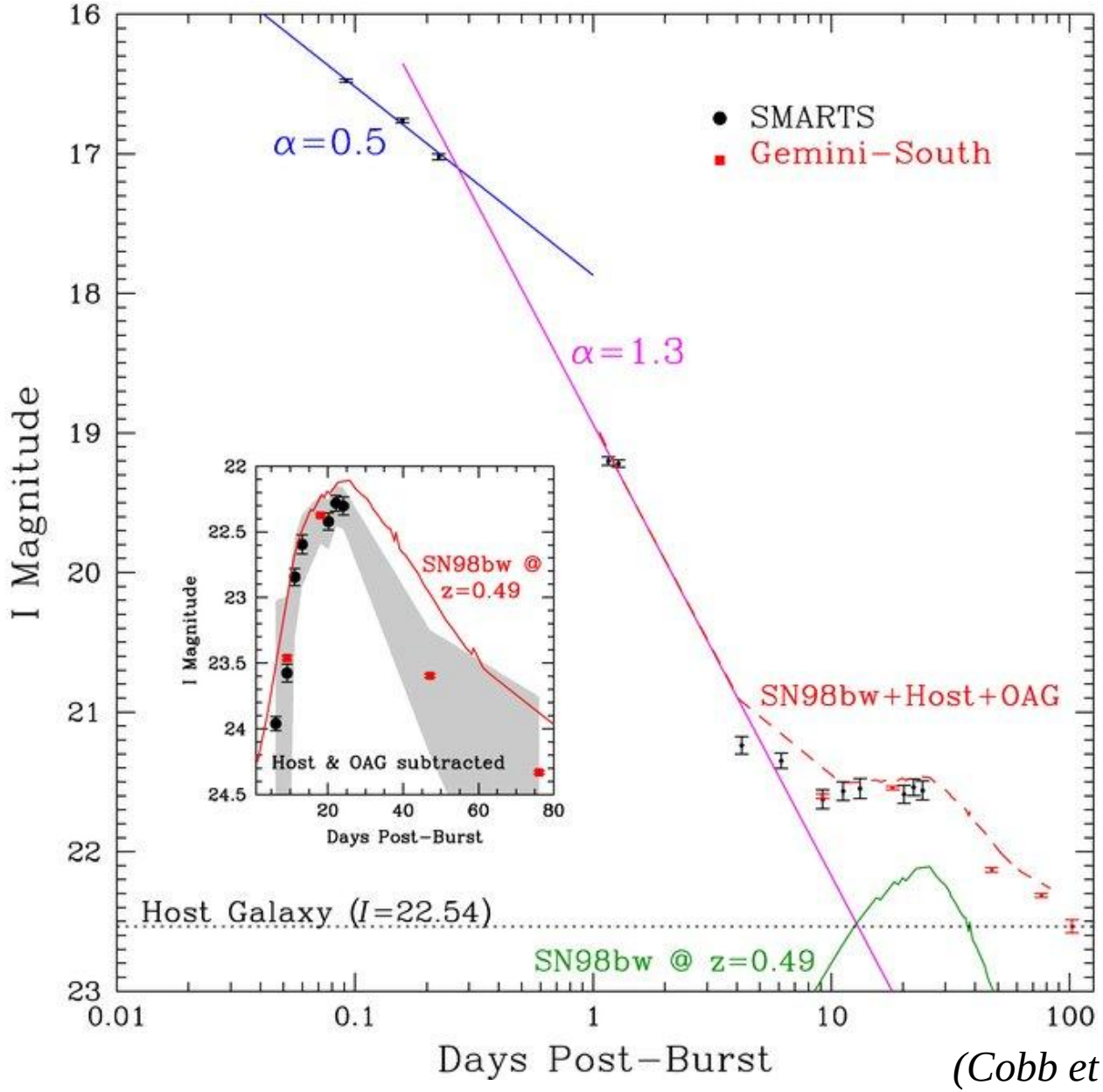
GRB 091127/SN 2009nz

$z = 0.49$



Gemini-South Observations
(Cobb et al. 2010)

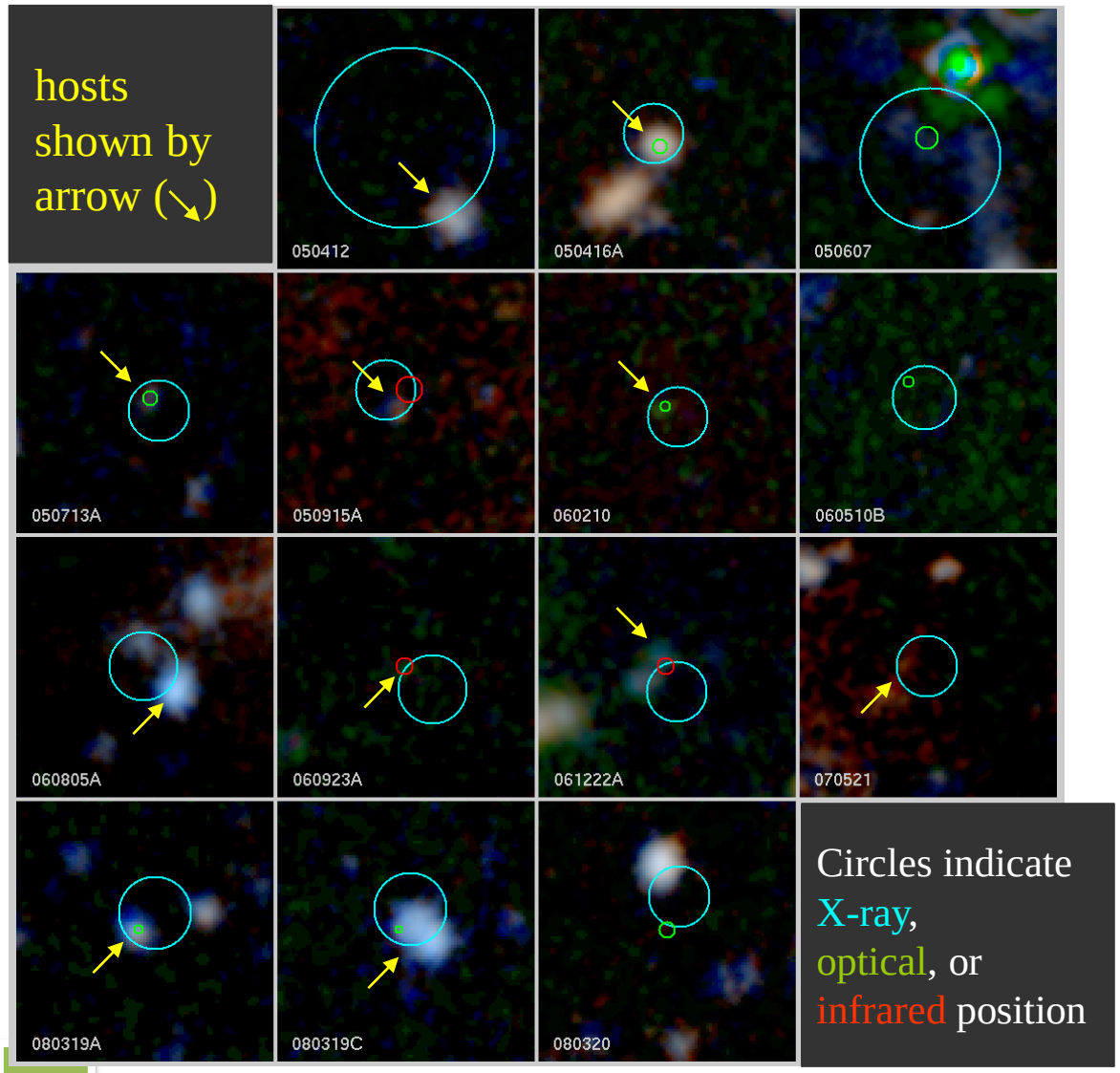
GRB 091127/SN 2009nz



(Cobb et al. 2010)

GRB Host Galaxies

Keck observations of "dark bursts"



(Perley et al. 2009)

Few dark bursts are at high redshift!

< 7% of *Swift* bursts are at z > 7 (90% confidence)

→ Instead, dark bursts are due to <u>dust</u>.

→ BUT… hosts generally do not appear highly extincted!

Where is the dust?

Local to the GRB progenitor?

Unevenly distributed in host?

Tidal Disruption Flares

New class of high energy transients in need of optical follow-up!

GRB 110328A / Swift J164449.3+573451 (@ z= 0.3534)
(*Levan et al. 2011; Burrows et al. 2011; Zauderer et al. 2011, Bloom et al. 2011, etc.*)

Triggered *Swift* like a classic long-GRB…
Then X-rays kept going and going and going…
Coincident with the nucleus of a <u>non-active</u> galaxy…
Conclusion: tidal disruption of a star passing too close to the central black hole!

Other examples?
Swift J2058.4+0516 (@ z=1.1853), etc…
(*Cenko et al. 2011*)

Tidal Disruption Flare Characteristics:
→ Months-long super-Eddington X-ray outbursts
→ Luminous radio counterparts, indicating the presence of relativistic ejecta
→ Relatively faint optical emission

Summary

- Many open questions about GRB progenitors, environments and host galaxies!

- As a sensitive, wide-field imager on a 4-meter class telescope, DECam provides a new instrument capable of significant contributions to our understanding of GRBs, particularly if ToO observations are available and survey data is eventually quickly and easily accessible