Time Domain Astronomy: Gamma-ray Bursts and DECam

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Many exciting astronomy discoveries currently happening in the time domain:
- Supernovae
- Gamma-ray Bursts
- Extrasolar Planets
- Tidal Disruption Flares
- Cataclysmic Variables
- AGN
- Microlensing, etc.

Need availability of Target of Opportunity observations (ToO), with clear guidelines and procedures

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

$\Rightarrow$ Accreting Black Hole
GRB Photon Production:

Short-Duration
- < 2 seconds
- Compact object mergers

Long-Duration
- > 2 seconds
- Type Ic SNe
Current Status of GRB Research

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

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

GRB 090423 @ z = 8.2

(Tanvir et al. 2009)
GRB Satellites:

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

DSS “before” image

GRB 050730
~ 3 hrs

~ 28 hrs

~ 10 days

Observed by the SMARTS 1.3m telescope at CTIO in Chile

(pre-burst)
GRB AG Example: Jet Opening Angles

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

\[ E_\gamma = (1 - \cos \theta_j) \ E_{\text{iso}}(\gamma) \]
Serendipitous Observations

• Extremely early time afterglow? (Coincident with gamma-rays?)
• Pre-gamma-ray optical emission?
• Orphan afterglow?
→ Low probability, but high interest/reward!

Interest in GRB behavior at very early times post-burst
GRB-Related SNe:

GRB 980425
SN 1998bw
(z=0.0085)

GRB 060218
SN 2006lw
(z=0.033)

(Fynbo et al. 2000)

(Galama et al. 1998)

(Cobb et al. 2006)
GRB 091127/SN 2009nz

$z = 0.49$

Gemini-South Observations
(Cobb et al. 2010)
GRB 091127/SN 2009nz

$\alpha = 0.5$

$\alpha = 1.3$

(Cobb et al. 2010)
GRB Host Galaxies

Keck observations of “dark bursts”

Few dark bursts are at high redshift!

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

⇒ Instead, dark bursts are due to dust.

⇒ BUT… hosts generally do not appear highly extincted!

Where is the dust?
Local to the GRB progenitor? Unevenly distributed in host?

(Perley et al. 2009)
**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 **non-active** 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
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.