Boutiques and Experiments 2015

CUTIE: Cubesat Ultraviolet Transient Imaging Experiment

S. Bradley Cenko, Dominic Benford, and the CUTIE team
CUTIE Overview

- **Science**: UV transients/variables (CCSNe, TDEs, AGN, variable stars, etc.)
- **Instrument**: 8 cm refractive optics, 121 deg$^2$ FOV, 19 mag (AB) per exposure
- **Spacecraft**: 6U cubesat in Low-Earth Orbit
- **Operations**: 1700 deg$^2$ every 95 min orbit for ~1 month (then switch fields)
- **Status**: “In development”
Science I: Core-Collapse SNe Progenitors

- First EM signal from SN explosion is *shock breakout* (subsequent *shock cooling*).
- Luminosity, temperature, and duration of signal sensitive diagnostic of progenitor radius (possibly others).
- For core-collapse SNe, relevant time scales ~ hours to days.

Adapted from Nakar & Sari 2010
Science II: Tidal Disruption Events

- Star disrupted during close approach to SMBH, remnant debris accretes and radiates
- Probes of SMBH in *quiescent* galaxies, as well as accretion process itself
- Peak of SED at soft X-ray/UV wavelengths
- Time scales ~ weeks to months

Gezari *et al.* 2012
Science III: Active Galactic Nuclei

- Power density spectra (e.g., *Kepler*) reveal characteristic size scales in AGN accretion disks
- Reverberation mapping (i.e., time lags) can yield structure *as a function of wavelength*
- High-cadence UV monitoring of large samples missing to date
- ~100 sufficiently bright AGN per CUTIE FOV

Edelson et al. 2015
Science IV: Gamma-Ray Bursts

- GRBs thought to be *highly collimated* explosions
- As a result, ~ 100 events viewed outside the narrow jet for every on-axis GRB
- Off-axis *orphan* afterglows detectable when jet spreads laterally into line of sight
- Such a “smoking gun” signature never yet detected
- UV not ideal wavelength (dust, SED shape), but still possible

Nakar & Piran 2003
Cubesat Overview

- From Wikipedia: “a type of miniaturized satellite for space research that usually has a volume of exactly one liter (10 cm cube), has a mass of no more than 1.33 kilograms, and typically uses commercial off-the-shelf components for its electronics.”
Cubesats for Time-Domain Astronomy

- Standardized ⇒ “Cheap”
- NASA CubeSat Launch Initiative ⇒ free launch
- Fast turn-around time (~ several years)
- Wide FOV + small aperture

but … “fail cheaply”?
CUTIE: Instrument Design

- Multi-Petzval lens (7 optics) refractive system
- e2V UV-optimized 2k x 4k (frame transfer) CCD with QE ~ 50% over bandpass
- Asahi UVB (260-320 nm) filter
- 121 deg² FOV; PSF <~ 2 pixels (38’’) over entire FOV
- Effective area comparable to (30 cm) Swift-UVOT
- Limiting mag: ~ 19 (AB) 5σ
CUTIE: Spacecraft Design

Commercial components: solar panels, battery, computer, power supply, attitude control, and communications (S-band radio)
Low-Earth orbit, ISS-like (or lower) inclination

Observations while in Earth shadow (low background); communication and charge solar panels while on day side

14 x 165 s exposures each orbit

Return to same fields every (95 min) orbit for ~ 1 month

Fields selected for commensal observing and nearby galaxies

Data downlink ~ 3-4x per day (notifications within ~ 12 hr)
CUTIE Science Yield

\[ N_{\text{det}} \approx \frac{\Delta \Omega}{4\pi} \times \rho \times \frac{4\pi d_{\text{max}}^3}{3} \times \tau \times N_{\text{obs}} \]  

where \( \Delta \Omega \) is the FOV, \( \rho \) is the volumetric rate, \( d_{\text{max}} \) is the maximum distance, \( \tau \) is the duration, and \( N_{\text{obs}} \) is the number of (independent) images. The results are summarized in Table 4.

<table>
<thead>
<tr>
<th>Source Class</th>
<th>Absolute Magnitude</th>
<th>( d_{\text{max}} ) (Mpc)</th>
<th>( \rho ) (Mpc(^{-3}) yr(^{-1}))</th>
<th>( \tau ) (d)</th>
<th>( N_{\text{obs}} )</th>
<th>( N_{\text{det}} )</th>
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<tbody>
<tr>
<td>CCSN</td>
<td></td>
<td></td>
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<tr>
<td>RSG Shock Breakout</td>
<td>-17.8 [17]</td>
<td>250</td>
<td>0.31 \times 10^{-4} [68]</td>
<td>0.02 [17]</td>
<td>6300</td>
<td>2</td>
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<tr>
<td>RSG Shock Cooling</td>
<td>-16.0 [17]</td>
<td>200</td>
<td>0.31 \times 10^{-4} [68]</td>
<td>2.0 [17]</td>
<td>420</td>
<td>7</td>
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<tr>
<td>BSG Shock Cooling</td>
<td>-14.9 [17]</td>
<td>65</td>
<td>8.9 \times 10^{-6} [68]</td>
<td>0.6 [17]</td>
<td>6300</td>
<td>0.3</td>
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<tr>
<td>WR Shock Cooling</td>
<td>-13.3 [17]</td>
<td>30</td>
<td>0.26 \times 10^{-4} [68]</td>
<td>0.2 [17]</td>
<td>6300</td>
<td>0.03</td>
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<td><strong>TDE</strong></td>
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<tr>
<td>Observations</td>
<td>-20.0 [41]</td>
<td>1300</td>
<td>6 \times 10^{-8} [69]</td>
<td>60 [41]</td>
<td>14</td>
<td>4</td>
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<tr>
<td>Theory</td>
<td>-20.0 [41]</td>
<td>1300</td>
<td>4 \times 10^{-7} [70]</td>
<td>60 [41]</td>
<td>14</td>
<td>25</td>
</tr>
</tbody>
</table>

AGN: \( \sim 3400 \) per month; Orphan Afterglows: 0.5 per month
CUTIE Status

- Proposed for 2014 NASA AstroPhysics Research & Analysis program (APRA; high-altitude balloons, sounding rockets, etc.) in March 2015
- Rejection notice received 18 August 2015
- Seeking additional sources of funding and/or will re-propose
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