ULTRASAT
Ultraviolet Transient Astronomy Satellite
Eli Waxman, Weizmann Inst. of Science
Feb. 2017
ULTRASAT: Science vision

- It is time for Time-Domain Astronomy.
  - Exciting frontiers, e.g. cosmic explosions, require wide field transient surveys.
  - Enabled by current technology.

- TDA drives observatories in
  Optical (LSST), Radio (LOFAR, SKA),
  X/\gamma-ray (Swift/Fermi/AstroSAT/e-Rosita).

- Missing: UV.
  Will address major open questions:
  - Deaths of massive stars,
  - Counterparts of Gravitational wave sources,
  - Ia SN progenitors,
  - Tidal disruption events (100/yr),
  - Variability from min to month time scale for
    Active galactic nuclei (>10^3),
    Variable/flaring stars (>10^5),
  - Star-planet connection
  - ...

ULTRASAT will revolutionize our understanding of the transient UV universe.

<table>
<thead>
<tr>
<th>Field of View</th>
<th>210 deg^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band</td>
<td>220-280 nm</td>
</tr>
<tr>
<td>Cadence</td>
<td>900 s</td>
</tr>
<tr>
<td>Limiting mag</td>
<td>21.9 (5\sigma, 900s)</td>
</tr>
<tr>
<td>PSF, pixel #</td>
<td>20&quot;, 40Mpxl</td>
</tr>
<tr>
<td>Alert distribution</td>
<td>&lt;20 min</td>
</tr>
<tr>
<td>ToO</td>
<td>50% of sky in &lt;5min for &gt;2.5hr</td>
</tr>
<tr>
<td>(2\pi) Galactic survey</td>
<td>30mag/arcsec^2</td>
</tr>
<tr>
<td>Extra-Galactic deep drills</td>
<td>33mag/arcsec^2</td>
</tr>
</tbody>
</table>

- 300 times the survey capacity of GALEX.
- Drive vigorous ground-based follow-up programs.
ULTRASAT: Science vision

- ULTRASAT's survey reach is comparable to LSST, but it opens a new band (NUV) and a new temporal cadence (minutes) not accessible to any other survey.

- For hot sources (e.g. young supernovae) ULTRASAT's sensitivity is competitive even with LSST, the deepest wide-field survey planned.
## ULTRASAT: Science highlights

<table>
<thead>
<tr>
<th>Source Type</th>
<th># Events</th>
<th>Science Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supernovae</strong></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Shock break-out and Early (shock cooling) of core collapse SNe</td>
<td>&gt;30 &gt;400</td>
<td>Understand the explosive death of massive stars</td>
</tr>
<tr>
<td>Superluminous SNe</td>
<td>&gt;200</td>
<td>Early evolution, shock cooling emission</td>
</tr>
<tr>
<td>Type Ia SNe</td>
<td>&gt;30</td>
<td>Discriminate between SD and DD progenitors</td>
</tr>
<tr>
<td><strong>Compact Object Transients</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emission from Gravitational Wave events: NS-NS and NS-BH</td>
<td>~20</td>
<td>Constrain the physics of the sources of gravitational waves</td>
</tr>
<tr>
<td>Cataclysmic variables</td>
<td>&gt;20</td>
<td>Accretion and outburst physics</td>
</tr>
<tr>
<td>Tidal disruption of stars by black holes</td>
<td>&gt;200</td>
<td>Accretion physics, black hole demographics</td>
</tr>
<tr>
<td><strong>Quasars and Active Galactic Nuclei</strong></td>
<td></td>
<td></td>
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<tr>
<td>Continuous UV lightcurves</td>
<td>&gt;6000</td>
<td>Accretion physics, BLR Reverberation mapping</td>
</tr>
<tr>
<td><strong>Stars</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M star flares</td>
<td>&gt;3\times 10^5</td>
<td>Planet habitability, magnetospheres</td>
</tr>
<tr>
<td>RR Lyrae</td>
<td>&gt;800</td>
<td>Pulsation physics</td>
</tr>
<tr>
<td>Nonradial hot pulsators, e.g., a Cyg, δ Scuti, SX Phe, β Cep etc. types</td>
<td>&gt;200</td>
<td>Asteroseismology</td>
</tr>
<tr>
<td>Eclipsing binaries</td>
<td>&gt;300</td>
<td>Chromosphere and eclipse mapping</td>
</tr>
<tr>
<td><strong>Galaxies and Clusters</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sky Survey - galaxies</td>
<td>&gt;10^8</td>
<td>Galaxy Evolution, star formation rate</td>
</tr>
</tbody>
</table>
Science goal I: Deaths of Massive stars

- Supernova mechanism not understood.
- Key to progress:
  - Identify the “initial conditions”,
    which stars explode as which SNe?
  - So far- a handful of associations
    (pre- vs post- explosion high-res. host galaxy images).
- An alternative- Early, <1d, UV emission carries unique signatures of the progenitor
  (“erased” at later time):
  Progenitor type (size, envelope composition),
  Explosion properties,
  Pre-explosion evolution.
Science goal I: Deaths of Massive stars

- Early UV/opt.: status.
  - A handful of (late, low-quality) Red-Super Giant explosion detections.
  - Space UV (lucky) detection of 1 SN Ib: R=10^{11}\text{cm}; \text{He + C/O envelope; E/M}
    → Mixed He Wolf-Rayet; Explosion energy.
  - Handful of type Ia non detections: R_* < 4\times 10^9\text{cm} → White Dwarfs.

- Current data
  - Validate models,
  - Direct constraints on compact progenitors,
  - Demonstrate potential.

- ULTRASAT:
  - >100/yr, <1d, high quality UV,
    Map all (including rare) SN types.
  - Rapid alerts for follow-ups.
Science goal I: ULTRASAT’s uniqueness

ULTRASAT is an order of magnitude more powerful discovery machine than any other survey

ULTRASAT will map all (including rare) SN types

Why UV?

\[ t \ (T=1 \text{ eV}) \rightarrow R_* \]

Recombination at \( T < 1 \text{ eV} \)
\( \rightarrow \) no optical peak, structure degeneracy

[Rubin et al. 16]
Science goal II: Gravitational wave sources

- LIGO detected BH-BH merger GWs.
- GWs from NS-NS mergers expected. 100 deg$^2$ error box, d<200Mpc.
- EM detection: localization, distance, phys.
  - X-rays: likely 1:100 (beamed).
  - Radio: ~1yr delay, requires CSM.
  - IR: challenging (wide field inst.).
  - Optical: more difficult than UV.

Radio to gamma-ray “Afterglow”
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- ULTRASAT
  - Instantaneous >50% of sky
    (8 times better than ground based),
    in <5 min for >2.5hr.
  - GW error box in a single image.
  - Sensitive out to 200 Mpc to early
    UV signals predicted in common models.

ULTRASAT’s ToO access

Some NS-NS merger model predictions

Free neutrons
\(L \sim 10^{42} \text{erg/s}\)
\(T \sim 1 \text{ eV}\)
\(t \sim 1 \text{ hr}\)

\(L \sim 10^{42} \text{erg/s}\)
\(2450 \text{ K}\)
\(t \sim 6 \text{ hr}\)

\(6500 \text{ K}\)
dynamical ejecta
\(\nu\) irradiated wind

[Metzger et al. 15]

[Metzger et al. 15]
ULTRASAT: Implementation

ISA committed (>50%),
NASA MOO proposal- Dec 2016.

Hosted Launch to GEO+300km (Graveyard) orbit.

Dimenions: 1.2 X 1.2 X 0.6 (m³)
Power: 150 W
Mass: 160 kg
Cost (incl. Launch & Operation): $100M
ULTRASAT: UV detectors

![Graph showing quantum efficiency (% QE) vs. wavelength (nm) for different detector types. The graph includes data for ULTRASAT Detector, Previously published delta-doped, AR-coated detector, Baseline Requirement, and Threshold Requirement. The data was taken from JPL-Nikzad et al. 16.]
Outlook: The importance of an ISRAELI lead breakthrough science mission

- ULTRASAT: breakthrough science with agile, low cost satellite mission.
- Attract talent to science & technology.
- First large scale collaboration of Israeli space industry with NASA.
- Lead the way to future missions, with Israeli industry at an advantage point.