Bumps, Burps & Booms in the Skies

Source: APOD, NASA
The Palomar Observatory
Fritz Zwicky (1889-1974)
A Star Dies: A Supernova is born

Astronomy Picture of the Day (NASA)
“Metals”=Stellar Ashes
II. GO AND FIND NEW AND WEIRD STUFF ("PHASE SPACE EXPLORATION")
“Phase Space”
III. FRONTIER AREAS OF ASTRONOMY & PHYSICS
Frontier Area: Energetic Particles
Frontier Area: Gravitational Waves
The Palomar Transient Factory
(Systematic Exploration of the Skies)
Paul Wellman

Wayne Rosing at Las Cumbres Observatory Global Telescope Network.

Google Mastermind Turns to the Stars
Hardware

The PTF camera field of view

92 MPix
1.0 arcsec sampling
R=21 in 60 seconds
Gray-ware
Supernova, good!

Subtraction artifacts, bad!

Time from exposure to candidates in the subtraction database: **20 - 40 minutes**

Software, software & more software
IPAC images & catalogue pipeline

Lead by J. Surace

Data products:

- Reduced images
  - \( \sim 100 \text{TB per year} \)
- Catalogue
  - \( \sim 10^{12} \) sources per year (10 TB)
An Explosion of Explosions
PTF haul (to date)

2234
Super-Luminous Supernovae (Hydrogen)
Superluminal Supernovae (no Hydrogen)
Double White Dwarfs (AM CVn)
Weird Outcomes: Carbon Stars, Calcium Ashes, Thermonuclear Explosions
A sequence of $\text{H} \rightarrow \text{He}$ TDF DE Candidates

Arcavi et al. (submitted)

PS1-10jh
Gezari et al.
ON TO LOW LATENCY
(SAME NIGHT)
Rapid Response: PTF10vdI (dry run)

Led by A. Gal-Yam
PTF11kly: A nearby Ia Explosion (Rosetta Stone)

Nugent et al
Li et al.
A Supernova

Source: PTF Collaboration
What next?

S. R. Kulkarni
Short timescale is terra incognito
DEMONSTRATION: HOW TO FIND A NEEDLE IN THE HAYSTACK?
Figure 1. P48 imaging of GRB 130702A and discovery of iPTF13bx1. The left panel illustrates the γ-ray localizations (red circle: 1-σ GBM; green circle: LAT).
UT 2013 July 2

- 00:05 Fermi GBM trigger (394416326)
- 01:05 position refined by human (GBM group)
- 03:08 Sun sets at Palomar
- 04:17 PTF starts observations
  - (10 fields, 2x60-s per field; 72 square degrees)
- RB2>0.1 yielded 4214 "candidates"
  - 44 were known asteroids
  - 1744 were coincident with stars (r<21)
  - Insisting on 2 frame detection, nix on hot pixels, columns
  - led to 43 viable candidates
  - Human inspection reduced this to 7 excellent candidates
    - iPTF13bxh core of a bright galaxy
    - iPTF13bxu "
    - iPTF13bxr known quasar (SDSS J145359.72+091543.3)
    - iPTF13bxt was close to a star in SDSS
  - LEAVING
    - iPTFbxj (RB2=0.49), iPTFbxl(RB2=0.86) and iPTFbvk (RB2=0.83)
  - SUN ROSE in California
UT 2013 July 3

• 00:50 Swift observations for iPTF13bxl requested
  – X-ray source detected
• 04:10 Robotic observations of these candidates at P60
  – iPTFbxl showed decline relative to first P48 observation (!)
• 04:24 Spectral observations on the Palomar 200-inch
  – Spectrum is featureless (!!)
• 08:24 Announced iPTF13bxl as afterglow (ATEL, GCN)
• 17:34 LAT localization (3.2 square degrees)
• 19:03 IPN announces annulus of width 0.9 degrees
• 23:17 Magellan observations led to $z=0.145$
Not a fluke!

M. M. Kasliwal (Carnegie Observatories/Princeton), L. P. Singer (Caltech) and S. B. Cenko (NASA/GSFC) report on behalf of the intermediate Palomar Transient Factory (iPTF) collaboration:

Starting 2013-10-12 05:26 UT, we imaged about 70 deg^2 in the vicinity of the localization of the Fermi-GBM trigger 403206457 with the Palomar 48-inch Oschin telescope (P48). Sifting through 10,816 candidate variable sources in the GBM error circle using standard iPTF vetting procedures including Palomar 60-inch follow-up, we identify iPTF13dsw as a possible optical afterglow candidate:

RA(J2000) = 02h 10m 06.38s
DEC(J2000) = -04d 24' 40.3"

Light Curve: R=19.7mag @ 05:26 UT (P48), R=20.2mag @ 08:07 UT (P60)
Automating the discovery of the Universe

S. R. Kulkarni
Caltech Optical Observatories
Zwicky Transient Facility
Plano-convex window

Frames for Field Flatteners

CCDs faceted on spherical surface with ~9m radius

Aluminum mount, integrated flexures

Vacuum interface board trapped between two O-rings

TechApps flexible thermal straps

Activated Carbon getter

1mW/K Kapton flex circuits to CCD

Connect to Vacuum Interface Board

Connectors to COTS cables

Polycold Joule-Thomson coolers (2)
The SED Machine

PI: Nick Konidaris, PS: Robert Quimby
In collaboration with NCU-Taiwan

30 arcsec

7 arcminute
Robo-AO

January 22nd, 2013  3:05 - 7:37 UTC
Tools in development

• Robotic spectroscopy
  – “Spectrum on demand” [hardware]
  – Machine Learning (ML) classification of spectra

• Continued improvement of ML classification of transient candidates

• Development of automated “alert” system
ULTRASAT addresses NASA Strategic Goals:

<table>
<thead>
<tr>
<th>NASA Important Questions</th>
<th>ULTRASAT Compelling Science Objectives</th>
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<tbody>
<tr>
<td>SSE-3: How do the lives of massive stars end?</td>
<td>Massive Stellar Death (SSE-3*)—Early UV photometry of a sample of ~300 new supernovae will determine the radii and surface composition of their progenitor stars, and thus the deceased progenitor star pre-explosion nature: cool red supergiant (~500 Sun Radius $R_\odot$), hot blue supergiant (~50 $R_\odot$), or a compact Wolf-Rayet star (~5 $R_\odot$). ULTRASAT will identify mass-loss signatures to constrain pre-explosion evolution.</td>
</tr>
<tr>
<td>GCT-3: How do black holes grow, radiate, and influence their surroundings?</td>
<td>Tidal Disruption Events (TDEs)—ULTRASAT will achieve the first robust measurement of the TDE rate, probing galactic structure models (spherical vs. triaxial) and studying TDE physics, by identifying &gt;100 TDEs per year.</td>
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<tr>
<td>What mechanisms are at work when SNe produce GRBs?</td>
<td>Gamma Ray Burst Afterglows (GRBAs)—ULTRASAT will identify ~10 GRB UV afterglows per year and an expected similar number of orphan GRB afterglows. Detection of even a single orphan GRB will confirm the GRB jet model; the normal/orphan ratio will constrain jet structure and thus true GRB energy.</td>
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ULTRASAT Instrument
Four wide-field UV imaging telescope array

Single Telescope Exploded View

Science Payload Key Facts

<table>
<thead>
<tr>
<th>Payload type</th>
<th>4 telescopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (kg)</td>
<td>91</td>
</tr>
<tr>
<td>Field of View</td>
<td>&gt; 484 deg²</td>
</tr>
<tr>
<td>Band of Operation</td>
<td>200 – 240 nm</td>
</tr>
<tr>
<td>Sensor type</td>
<td>Fully depleted p-channel CCD</td>
</tr>
<tr>
<td>Sensor format</td>
<td>4128 x 4114 pixels, binned</td>
</tr>
<tr>
<td>Readout Noise</td>
<td>&lt; 5 e⁻ rms</td>
</tr>
<tr>
<td>Net Throughput (Optics, CCD)</td>
<td>&gt; 30 %</td>
</tr>
<tr>
<td>Pixel Scale</td>
<td>19.3''</td>
</tr>
<tr>
<td>Point Source Detection</td>
<td>21 mag (AB), 5 σ</td>
</tr>
<tr>
<td>Data / day (compressed)</td>
<td>&lt; 2 GB</td>
</tr>
<tr>
<td>Young SNe</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Transient alerts distribution</td>
<td>&lt; 30 min</td>
</tr>
</tbody>
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Field of View = 121 deg²
ZTF Grayware

Iair Arcavi
Eric Bellm
Yi Cao
Alessandra Corsi
Mansi Kasliwal

David Levitan
Gina Duggan
Branimir Sesar
Daniel Perley
Adam Waszczak
http://www.ptf.caltech.edu/