Pan-STARRS and TGBN

Paul Price
Institute for Astronomy
University of Hawaii
Pan-STARRS

- Panoramic Survey Telescope And Rapid Response System
- A fore-runner to the LSST, funded by AFRL
- A dedicated optical survey instrument, 54 m$^2$deg$^2$
- Collaboration between:
  - IfA
  - MHPCC: Data processing
  - SAIC: Databases
  - MITLL: Detectors
- Prototype (PS1) operational in 2006
Optics

- 4 x 1.8m telescopes, f/4, 7 deg$^2$ FoV, ADC option
- $A\Omega = 4 \times 13.5 \text{ m}^2\text{deg}^2$
  - MEGACAM, SuPrimeCam $\sim 8 \text{ m}^2\text{deg}^2$
- Filters: grizy, $w = g+r+i$
Detector News

Front side OTA

Clocking in a 32x32 square

Focal plane scale and controller

Test Camera 1
OT CCDs

M13 I band
300 sec

Telescope guiding only
0.59" FWHM psf

With OT tracking
0.45" FWHM psf
7 Hz frame rate
Image Reduction

- 4 Gpix / 32 sec --> 10 TB raw data per night, 3 PB per year
- Process data in near-real time (30-60 sec each):
  - Bias, flat-field, fringe, sky-subtraction
  - Map individual images to static sky representation
  - Combine individual images from each telescope
  - Subtract static sky and identify transients
  - Add to static sky
- Desire is to create a flexible system that can be used to reduce other mosaic data
Data Products

• Instrumental catalogues
  – Instrumental magnitudes, coordinates
  – For precision astrometry/photometry
  – Postage stamps of bright objects

• Cumulative static sky images
  – Signal + exposure maps
  – Best + working + compressed intermediate saves

• Static sky catalogues
  – Includes time history of object magnitudes

• Difference image detection stream

• Recent (~1 month) source and difference images
Replacement of LURE

MAGNUM Dome
Currently being replaced by University of Tokyo (at increased height)

Service Building
To be Refurbished

LURE Dome - To be Replaced by **IceStorm** Enclosure
housing PS1 Telescope

LURE building
To be Demolished (excavated to rock)
LURE and MAGNUM
Enclosure Overview (Perspective)

- **Level 3**: Observing Floor
- **Level 2**: Floor below
- **Mirror Cart / Camera Cart Rails**
- **Service Balcony**
- **1200mm wide Access Door to Level 1**: Equipment / Rack Room *(door not shown)*
- **Access Stair**
- **Access Balcony**
- **Ground Level**: Storage
PS4 Survey Modes

- 7 deg², 30 sec integrations --> 6000 deg²/night, or visible sky thrice per lunation to R ~ 24 mag

<table>
<thead>
<tr>
<th>Mode</th>
<th>PSY</th>
<th>Area</th>
<th>Cad.</th>
<th>SS</th>
<th>B/g</th>
<th>r</th>
<th>i</th>
<th>z</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS NEO</td>
<td>1.1d</td>
<td>7000</td>
<td>h/d/m</td>
<td>27.5</td>
<td>26.5</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>SS KBO</td>
<td>1.0d</td>
<td>3π</td>
<td>hdmy</td>
<td>26.5</td>
<td>26.5</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Var.</td>
<td>0.8d</td>
<td>133</td>
<td>4 min</td>
<td>29.4</td>
<td>28.8</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>25</td>
</tr>
<tr>
<td>3π</td>
<td>1.3d</td>
<td>3π</td>
<td>14d</td>
<td>26.1</td>
<td>25.8</td>
<td>25</td>
<td>24</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Med. Deep</td>
<td>0.6d</td>
<td>1200</td>
<td>4d</td>
<td>27.3</td>
<td>27.2</td>
<td>27</td>
<td>26</td>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>Ultra Deep</td>
<td>0.5d</td>
<td>28</td>
<td>4d</td>
<td>29.3</td>
<td>29.2</td>
<td>28</td>
<td>27</td>
<td>26</td>
<td>25</td>
</tr>
</tbody>
</table>

**5-σ limit (AB)**

**Total int. (min)**
Rate Estimates (1): Inputs

- \( N_{\text{Trans}} \sim R_{\text{Trans}} \cdot \text{FoV} \cdot t_{\text{proj}} \cdot \epsilon \cdot \mu \)
  - \( R_{\text{trans}} \) is the rate of transients per square degree per day
  - FoV is the field of view
  - \( t_{\text{proj}} \) is the amount of time spent on the project
  - \( \epsilon \) is the observing efficiency
  - \( \mu = \max(1, \min(N_{\text{fields}}, t_{\text{dur}} / t_{\text{exp}})) \) is the temporal multiplex: we don't miss events going off in other fields if the duration of the event (\( t_{\text{dur}} \)) is longer than the time between exposures (\( t_{\text{exp}} \))

- Note: this does not include brightness distribution
Rate Estimates (2): Orphans

- Assume:
  - 2 GRBs/day over $4\pi$ (BATSE)
  - Jet correction of 500 (Frail et al.)
  - Dark burst fraction of 50%
  - 30 sec exposures, 2 sec readout
  - Duration of orphan afterglow brighter than limiting magnitude ($R \sim 24$ mag) is ~ 1 day, so big multiplex
  - Observe each field twice per night (SS survey)

- Expect ~ 20 per night
Rate Estimates (3): DLS Transients

• Assume:
  – \( R_{\text{Trans}} = 1.4 / \text{day} \) (Becker et al.)
  – 30 sec exposures reach sufficient depth (\( R \sim 24 \text{ mag} \))
  – Transient timescale is \( \sim 1000 \text{ sec} \) (Becker et al.) so decent multiplex (~30)

• Expect about 120 per night

• Why haven't we seen any with CFHTLS?
  – FoV (1\(^\circ\) → 7\(^\circ\))
  – Multiplex (1 → 30)
  – Not looking at individual exposures?
Solution: Campaigns

• Not piggy-backing off other surveys, but targeted campaigns designed to detect transients (multiplex!)
• Strong synergy with solar system science, stellar variability
• IfA Variability Survey:
  – CFHT+MegaCam
  – Ecliptic field, galaxy cluster
  – Cycle between four fields over 4 hours
  – 4 runs gives same sky exposure as DLS
Real-time classification?

- Weed out asteroids by proper motion
  - PSF shape
  - Nearby detections in previous images
- Previous variable detections at the same position should give variable stars and AGNs
- Inspect static sky for quiescent source
  - Point source?
  - Colours
- No colour information for transient
- Do we need a slaved follow-up telescope
Looking Ahead

1: Regular detection of transients
   - Would like to have ~ 10 detections by end 2006
     - Light curve taxonomy
     - Measure rate with good precision; luminosity function
     - Search for and study quiescent sources

2: Real-time detection system
   - Feed positions to robotic telescopes
     - Better time resolution of light curves
     - Colours?

3: False positive discrimination
   - Inspection of static sky, real-time feedback?
   - Can start to throw in large telescopes in real time
     - Spectroscopy of the transient