Outline
• PS1 overview
• Status
• First Science
• Future
Survey Figure of Merit (FOM)

Each generation of astronomical survey hardware is providing a substantial increase in $A\Omega \varepsilon$ product.

Still on steep part of FOM vs. cost curve.
Number of objects detected per unit time, to given SNR.
The Pan-STARRS project
Panoramic Survey Telescope and Rapid Response System

PI: N. Kaiser
Project Manager: W. Burgett
Camera Lead: J. Tonry
Telescope Lead: J. Morgan
IPP Lead: G. Magnier
PSPS: J. Heasley

- Univ. of Hawaii project: USAF funded, technology demonstrator – sky surveys
- Construction of prototype PS1 and 1.4Gigapix camera (GPC1)
- Now moving to PS2 and PS4 construction
• PS1SC is funding a 3.5 yr science mission with PS1 2009-2012
• PS1 data products release to the consortium – full public release 1yr after survey finishes
• PS1SC have “long term lease”
PS-1 Telescope and GPC1 Camera

- 1.8m telescope on Haleakala (Maui)
- 1.4 gigapixel camera (GPC1)
- 40x40 cm focal plane
- 7 sq. deg. FOV, 0.26" pixels
- 8x8 chips, 8x8 cells per chip, 584x591 pixels
Orthogonal Transfer CCDs

Normal guiding (0.73")

OT tracking (0.50")
OTA Quantum Efficiency

- Red sensitivity!
SDSS and Pan-STARRS bandpasses
PS1: surveys

- 3pi survey
  - 3 years: 12 epochs in grizy
  - 30 sec, 2 x grizy in 15 days, then another epoch one month later
  - 24000 SNe per year

- Medium-Deep Fields (MDFs)
  - gr=8x120 sec
  - iz=8x240 sec
  - Repeats every 4 days
  - ~1000-2000 SNe in 1 year
  - Limiting magnitudes:
    - g, r, i, z = 23.6, 23.3, 23.3, 22.3

Courtesy of Steve Rodney
PS1: surveys

- **Solar System Sweet Spot Survey**
  - 2 rectangles ~500 deg. at opposition region +/- 30 deg.
  - w(gri) TTI, 3 nights in 15 days.
  - MOPS software ready!

- **Deep M31 survey**
  - r=2x360s, i=360s nightly
  - g=360s dark time,
  - z=300s, y=60s bright time
  - Limiting mag after 3 years: gri=27th mag
  - Microlensing, Novae, LBV’s, Cepheids, Eclipsing binaries

- **Stellar Transit Survey (STS)**
  - Search for Exoplanets
  - One 7deg² field: 400,000 dwarfs
  - ~1h per night
Key Projects

1) ISS - Populations of objects in the Inner Solar System [Jedicke]
2) OSS - Populations of objects in the Outer Solar System (beyond Jupiter) [Holman]
3) LMS - Low-Mass Stars, Brown Dwarfs, and Young Stellar Objects [Magnier, Brandner]
4) STS - Search for Exo-Planets by dedicated Stellar Transit Surveys [Afonso, Henning]
5) MW - Structure of the Milky Way and Local Group [Bell, Rix]
6) M31 - Dedicated Deep Survey of M31 [Seitz, Bender]
7) MSSP - Massive stars and supernova progenitors [Smartt, Bresolin]
8) CIVET - Cosmology Investigations with Variables & Explosive Transients [Tonry, Riess, Stubbs]
9) GAL - Galaxy Properties [Heckman, Meurer, Ferguson]
10) AGNHZQ - Active Galactic Nuclei and High Redshift Quasars [Chambers, Walker]
11) CL - Cosmological Lensing [Heavens, Kaiser, Taylor]
12) LSS - Large Scale Structure [Cole, Phleps, Bender]
PS1: status

- First real stream of images of MDFs in summer 2009
- Growing pains
  - CCD artifacts
  - Software not quite ready to deal with all the data
  - System PSF still significant
  - Magic
- First set of SN and transients in June+ 2009
  - 50 SN-like lightcurves
  - 13 spectr. confirmed SN, z<0.4
  - Boticella et al., arXiv:1001.5427
- Setback in fall 2009: 6 week shutdown to fix secondary
PS1: status

BUT: turned the corner in the last 2 month!

- Transient search very succesful!
  - Harvard/JHU
    - IPP stacks
    - ESSENCE diffim pipeline & alert system
    - 200-300 SNe in 2 month in MD fields
    - End2end system
  - QUB
    - IPP End2end
    - Classification!
    - 60 SNe in 1 month

SN Ia @ z=0.03
PS1: status

BUT: turned the corner in the last 2 month!

- Transient search very succesful!

SN Ia @ z=0.03
PS1: MDF transients

- Good lightcurves
- Early discovery!
  - In January: 2 SN Ia 6 days before max

SN Ia @ z=0.31
PS1: MDF transients

- Faint!
  - Good lightcurves at $z=0.6$!
  - Great lightcurves in the red!
- 25 spectr. Confirmed Sne in Jan/Feb
SNe Ia in MD

- >1000 SN Ia per year
- Select SN to minimize systematics!
  - Host galaxy
  - Distance to host
  - Lightcurve coverage
  - ...
- Unprecedented range in redshift!
- Spectroscopy for all not possible!
  - Lightcurve-only
  - SNACC filter (Riess, Scolnic,

Preliminary!

17 PS1 SN Ia, spec. confirmed in Jan 2010, SALT lightcurve fitting

Even the PanSTARRS Universe is still accelerating....
Alerts pages

- Lightcurves automatically updated
- Organize follow up
- Finders etc
Cosmic Rays

Icicles

Burns

Xtalk

Diffim Artifact
Variable Objects

- RR Lyrae
- LBVs
- AGN
- QSO
Lead by Suvi Gezari

Initial results: UV-luminous Type II-P SN at z=0.18 (Boticella et al., arXiv:1001.5427)

Potentially detectable (with no extinction) by PS1 at z=2.5!
PS1 + GALEX Time Domain Survey

- Initial results: Early UV light curve of Type IIP SN at z=0.086 (Gezari et al., in prep)
During PS1 “Demo Month” in February, GALEX TDS monitored the MD04 field every 2 days.

Detected:
- 32 variable stars
- 29 QSOs
- 23 AGNs
- 1 SN

Goal: tidal disruption events
3pi survey

- 30 sec, 2 visits per night (TTI pair)
- grizy in 15 days, then another epoch one month later
- Challenges:
  - Need follow-up!
  - Cadence: How can we find the interesting objects?
  - Next year: better templates
- Incredible amount of transients!
Light Echoes

Rest et al., 2008, ApJL, 681
Light Echoes

Rest et al., 2008, ApJL, 681
Next Steps

- Image reduction and transient identification works
- Huge amount of data!
- Full classification not yet ready
- Archive/Public Release
- 3pi biggest challenge
- Moving objects on track
- M31, STS just starting…

<table>
<thead>
<tr>
<th>Standard Reduction</th>
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<tbody>
<tr>
<td>Difference Imaging</td>
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<tr>
<td>Diffim Photometry</td>
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</table>

**Events**
- cluster detections into objects
- get postage stamps
- forced photometry
- automatic update of lightcurves
- Association with outside catalogs/ancilliary info

**Classification tools**
- Lightcurve fitting
- Fourier analysis
- PCA analysis

**Alerts**
- Extracting subset of transients
- Collect all info about object
- Organizing follow-up
Summary

- Lots of data in last months!
  - PS1 inching towards survey mode
- Lots of hard work by telescope/camera/pipeline teams
- Camera, data analysis push current technology
- MDF Transients: turned the corner in depth, stability, latency, false-positives
  - SNe: driver
  - End2end system
  - 100s of transients in just a couple of month
  - Good lightcurves
  - First papers
- Tip of the iceberg! Incredible data set.
Event Identification Break-out session:

- Saturday, 9am!
- Please come and bring ideas!
Moving objects

- MOPS software ready to go!
- Currently finishing up processing
Haleakalā Observatory, Maui
Haleakala Observatory, Maui

Map of the Hawaiian Islands showing Maui and other islands.
## General Survey Cadences

<table>
<thead>
<tr>
<th>Survey</th>
<th>Visit/night</th>
<th>Intra-night</th>
<th>Inter-night</th>
<th>Visit/mth</th>
<th>Visit/yr</th>
<th>Visit/3 yr</th>
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<tbody>
<tr>
<td>3PI</td>
<td>2</td>
<td>TTI</td>
<td>4,5 d</td>
<td>2x3-4 band</td>
<td>4x5 band</td>
<td>12x5 band</td>
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<td>1</td>
<td>8</td>
<td>1</td>
<td>30</td>
<td>8x30</td>
<td>24x30</td>
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<tr>
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<td>TTI</td>
<td>4,5 d</td>
<td>3x1 band</td>
<td>3x1 band</td>
<td>18x1 band</td>
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<tr>
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<td>4 min</td>
<td>4,5 d</td>
<td>5x30</td>
<td>150</td>
<td></td>
</tr>
<tr>
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<td>0-5 hr</td>
<td>1</td>
<td>30-60</td>
<td>45x5</td>
<td>675</td>
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<tr>
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<td>2</td>
<td>1-2xTTI</td>
<td>var</td>
<td>var</td>
<td>180/band</td>
<td>540/band</td>
</tr>
</tbody>
</table>
The **PS1 System**

**Status**

**April 14, 2008**

- **PS1 Telescope**
  - photons
  - commands and feedback

- **Gigapixel Camera**
  - raw images

- **Observatory, Telescope, & Instrument Software - OTIS metadata**

- **Image Processing Pipeline - IPP**
  - detections
  - static sky images
  - detections, metadata

- **Published Science Products System - PSPS**
  - static sky images
  - reduced data products
  - detections, metadata

- **Science Analysis Servers**
  - detections, metadata

- **Moving Object Processing System - MOPS**
  - orbits
  - identifications
  - detections, metadata

- **Solar System Community**

- **PS1 Science Consortium Members**
  - reduced data products

*Ken Chambers*

PS1SC Heidelberg, Apr 2008