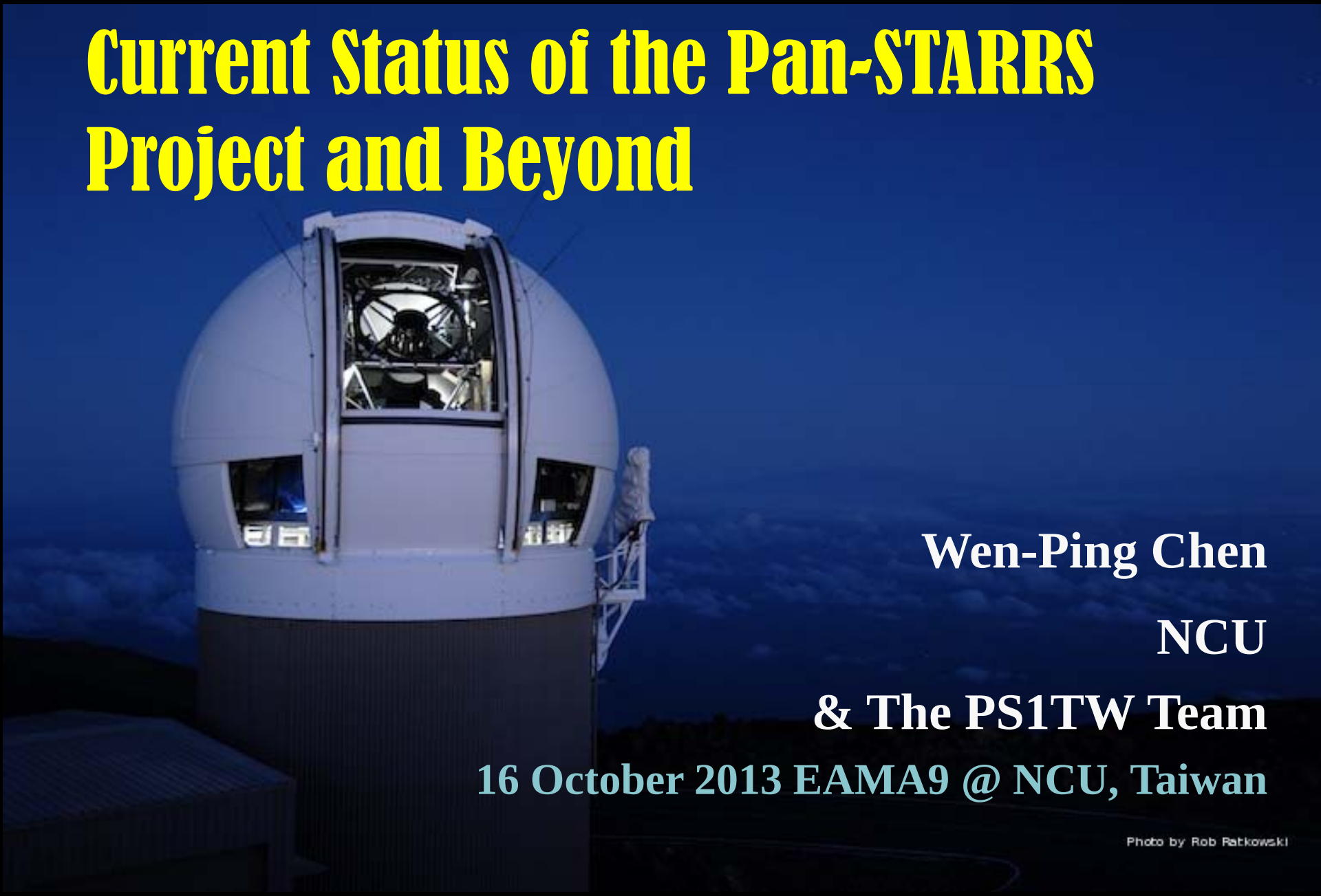
Current Status of the Pan-STARRS Project and Beyond



Wen-Ping Chen

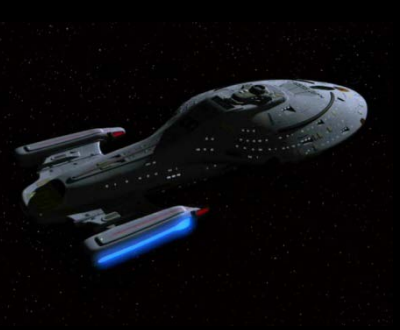
NCU

& The PS1TW Team

16 October 2013 EAMA9 @ NCU, Taiwan

Photo by Rob Ratkowski

Time --- the final frontier …



Astronomy and Astrophysics Decadal Survey

New Worlds, New Horizons, 2010

- Wide-Field Infrared Survey Telescope (WFIRST)
- Large Synoptic Survey Telescope (LSST)
- New Worlds Technology Development Program
  to study earth-like exoplanets
- Cerro Chajnantor Atacama Telescope (CCAT)
  MM/SMM to study young dusty stars and galaxies
- … Laser Interferometer Space Array, X-ray telescope

Panoramic Survey Telescope And Rapid Response System

Pan-STARRS
PS1 Science Consortium

泛星

PS1 consortium members

University of Hawai'i · UH Institute for Astronomy · Max Planck Institute for Extraterrestrial Physics · Max Planck Institute for Astronomy · JOHNS HOPKINS UNIVERSITY Department of Physics and Astronomy · Harvard-Smithsonian Center for Astrophysics · Queen's University Belfast · University of Edinburgh · Durham University Institute for Computational Cosmology · National Central University, Taiwan · Las Cumbres Observatory Global Telescope Network

- To patrol the entire observable sky (3π) several times a month
- An array of 4 telescopes, located in Hawaii, each of D=1.8 m, equipped with a 1.4 gigapixel camera of an Orthogonal Transfer Array CCD detector (= 40 cm square focal plane)
  ➔ 7 square-degree FOV with 0.26" pixels **Prototype PS1**
- Detection of moving, transient, and variable celestial objects down to faint limits
- Very deep cumulative sky images
- Wide-Field Imaging
- Short Duty Cycle
- Efficient Operations

Hawaii, USA


PS4– Mauna Kea, Hawaii

Institute for Astronomy
University of Hawai'i at Mānoa

22 N
20 N
156 W

NI'IHAU
KAUA'I
O'AHU
MOLOKA'I
LĀNA'I
KAHO'OLAWE
MAUI
HAWAI'I

Honolulu International Airport
Waikiki
Honolulu
Kahului Airport

Haleakalā Observatory

Mauna Kea Observatories
Astronomers' Mid-level Facility & Visitor Information Station

Institute for Astronomy
University of Hawai'i at Hilo

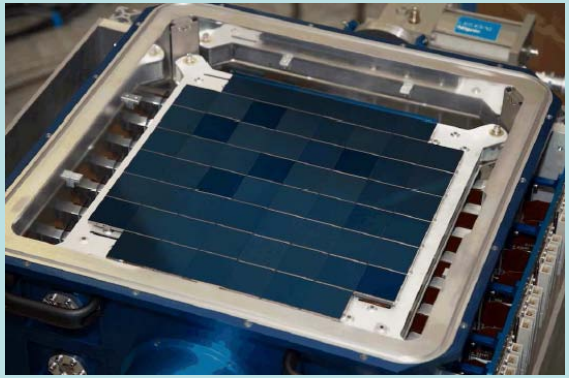
Kona
Hilo
Mauna Loa
Hilo International Airport

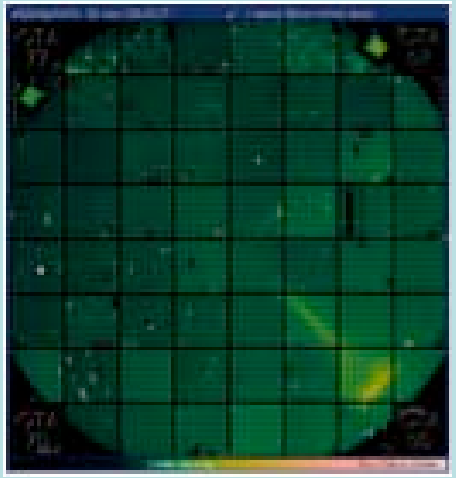
Kaua'i County
City and County of Honolulu
Maui County

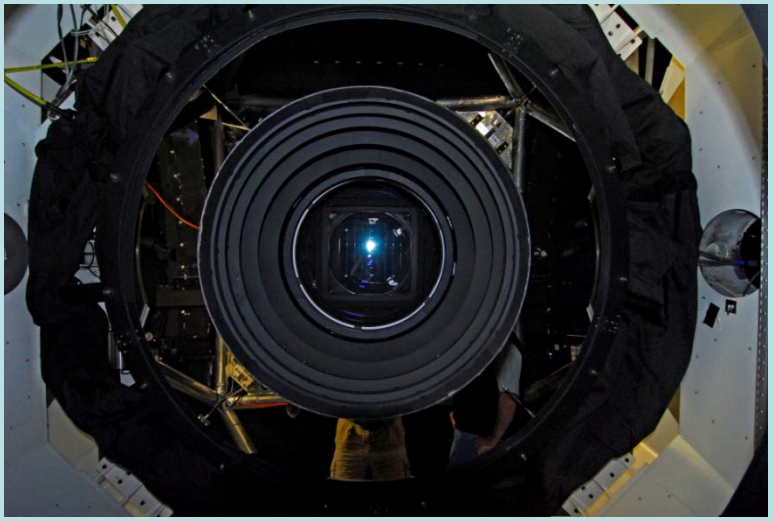


PS1– Haleakala, Maui

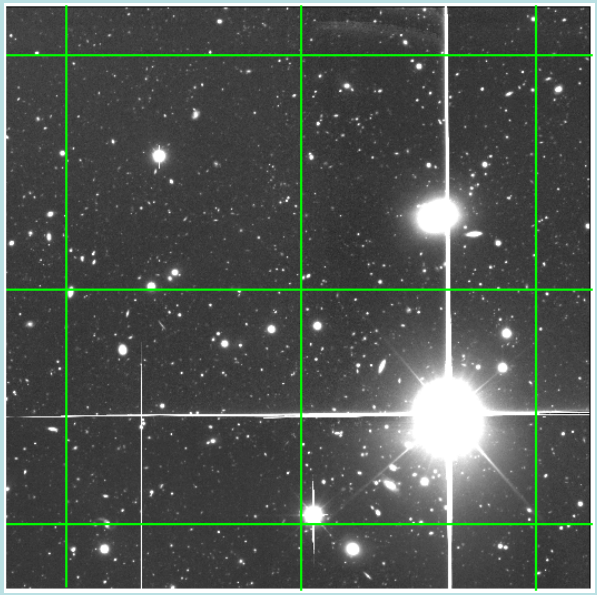
Wide-Field Optics

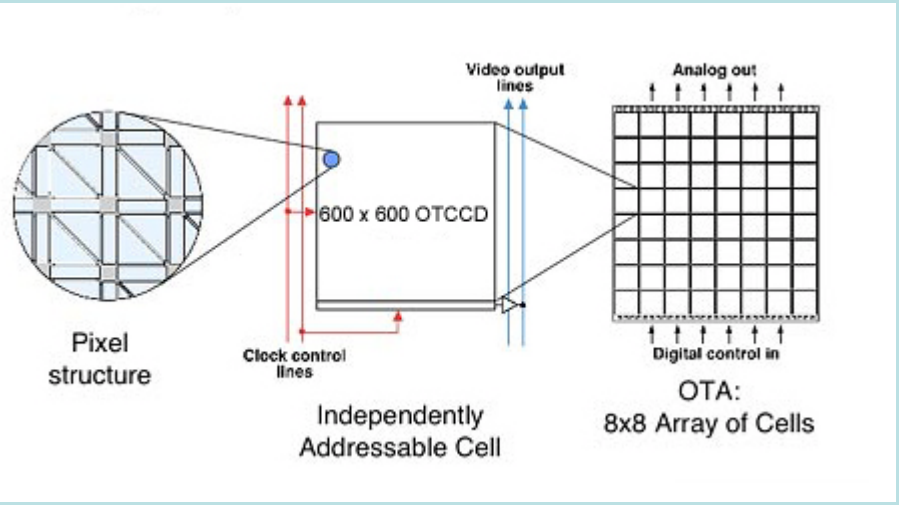




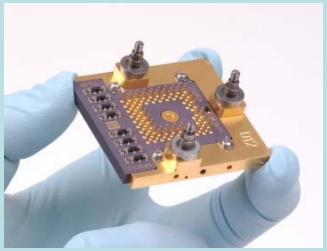


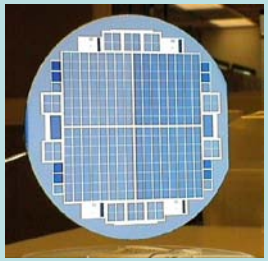
Detector Technology

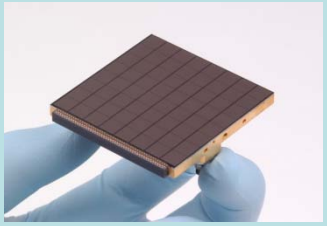


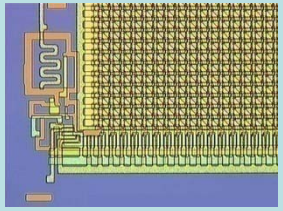


MIT Lincoln Laboratory









Independently addressable orthogonal transfer array (OTA) CCDs (cells)

- Reducing cost by increasing yield
- Fast readout: Gigapixels in 2 s
- On-Chip guiding
- Minimizing effects of bright stars
- Compensating for image motion
- 1.4 giga pixels

Several TBs/night

Science Consortium

- Supports science operations (observations, data servers)
- Annual operations cost ~$4.5M/year

University of Hawaii (UH)

Max Planck Institute for Astronomy in Heidelberg, the Max Planck Institute for Extraterrestrial Physics in Garching

Harvard-Smithsonian Center for Astrophysics /The Las Cumbres Observatory

Johns Hopkins University

Durham University/University of Edinburgh/Queen's University Belfast

Taiwan (NCU, NTHU, ASIAA, NTNU)

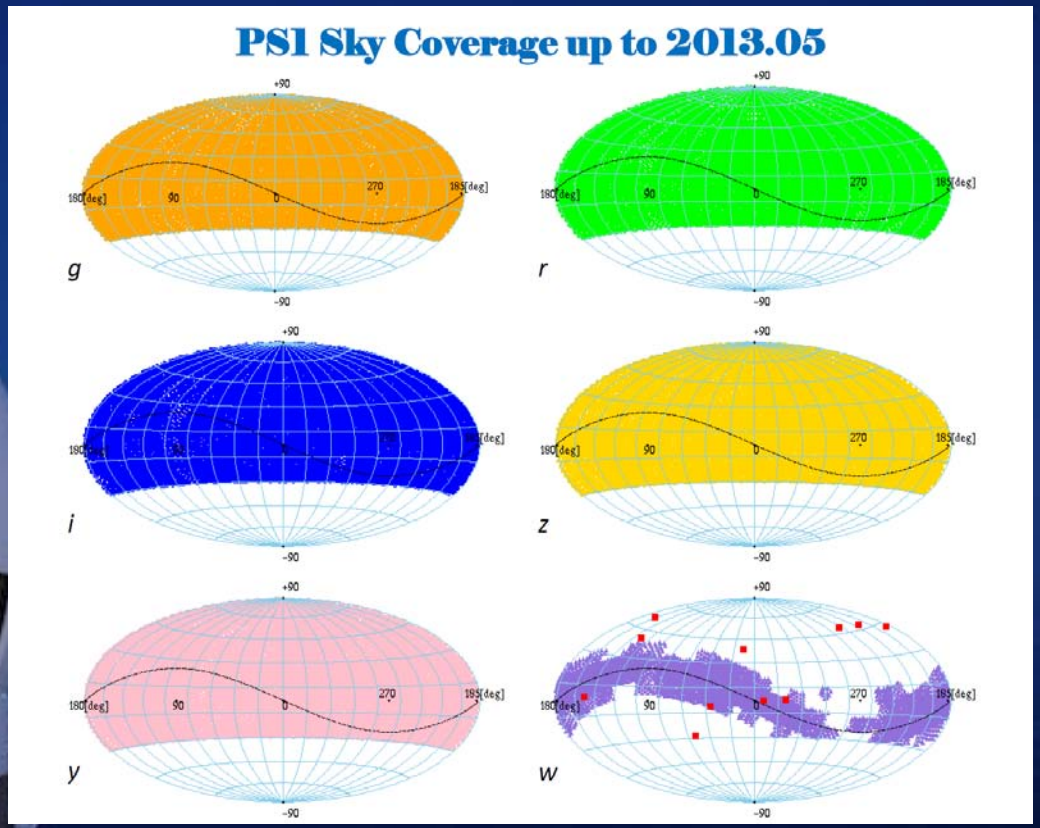
IT Challenges

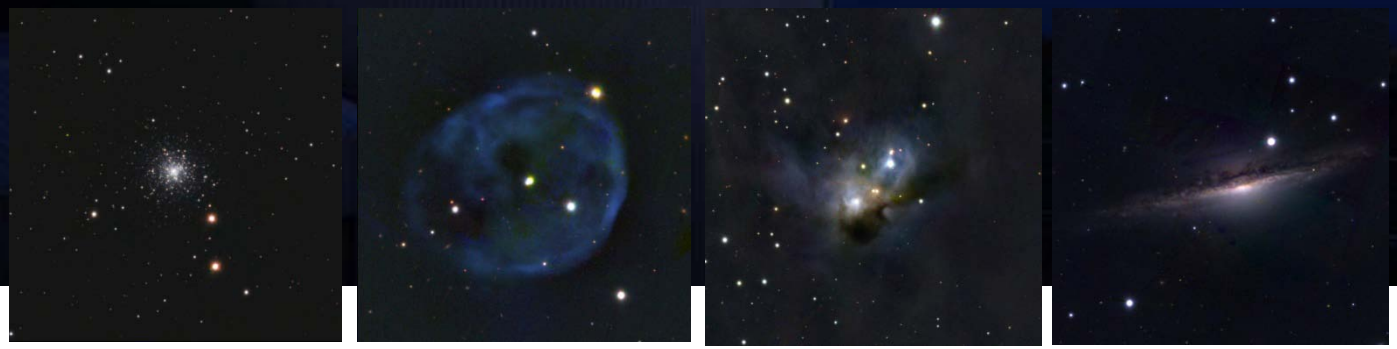
Each raw **image** from a **single** Pan-STARRS camera will contain **2 Gbytes** (2 bytes per pixel).

In the full survey mode, a typical exposure takes **30 seconds**, so the raw data rate is **several terabytes per night** for the full telescope.

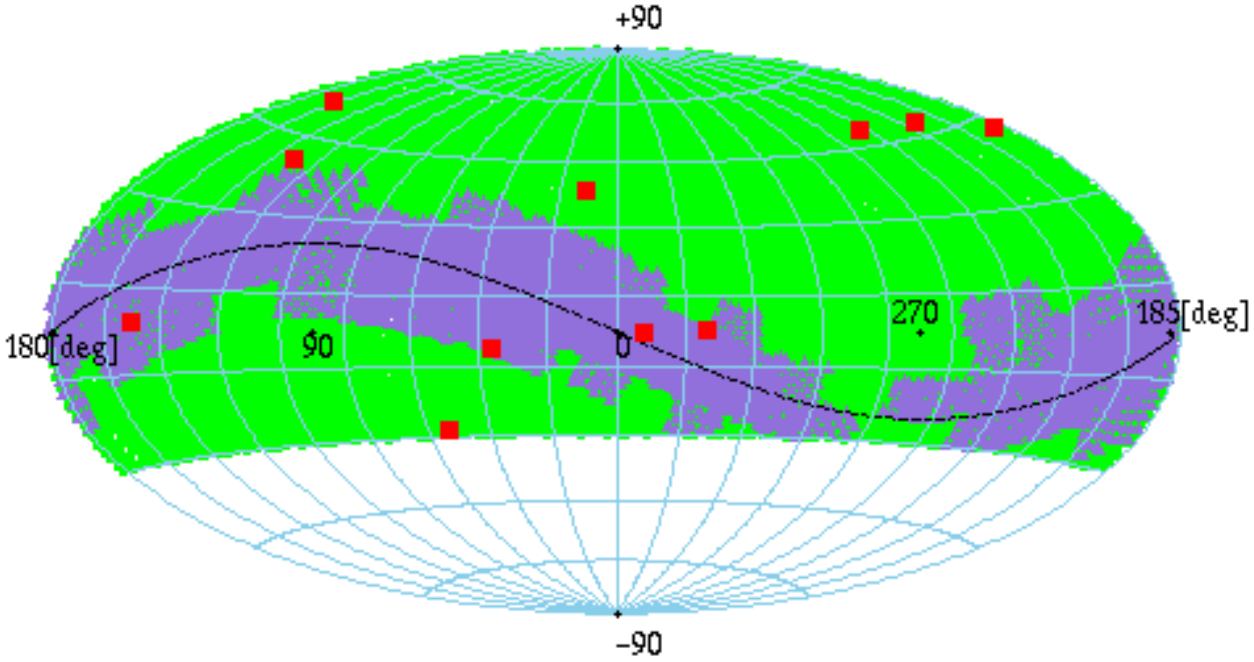
Tremendous **challenges in information technology** to store, process, distribute, and archive the huge amount of data (and metadata, etc)

PS1 has been finding peculiar phenomena.





Green … 3-pi
Red …... MD
Indigo … Sweet spots
Black: Ecliptic

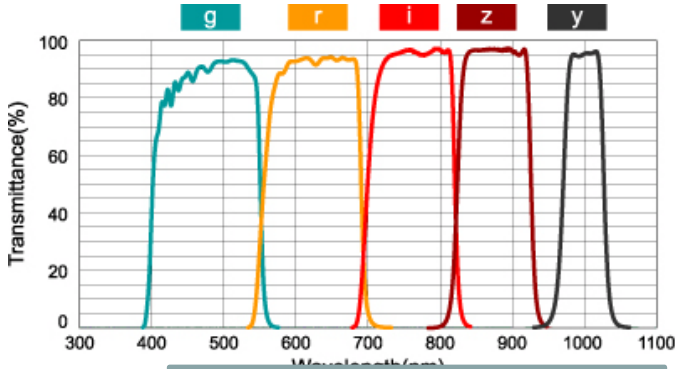


Sky Coverage of all PS1 Data (up to Jan 2013)

grizy bands --- on average 50-60 epochs, ~10 visits per filter

Mission Definition

filter	band (nm)	zero mag (mag)	sky (mag/"^{2})	exp (sec)	limit (mag)
		5σ sensitivity			
g'	405-550	24.90	21.90	60	23.24
r'	552-689	25.15	20.86	38	22.71
i'	691-815	25.00	20.15	60	22.63
z'	815-915	24.63	19.26	30	21.59
y	967-1024	23.03	17.98	30	20.13

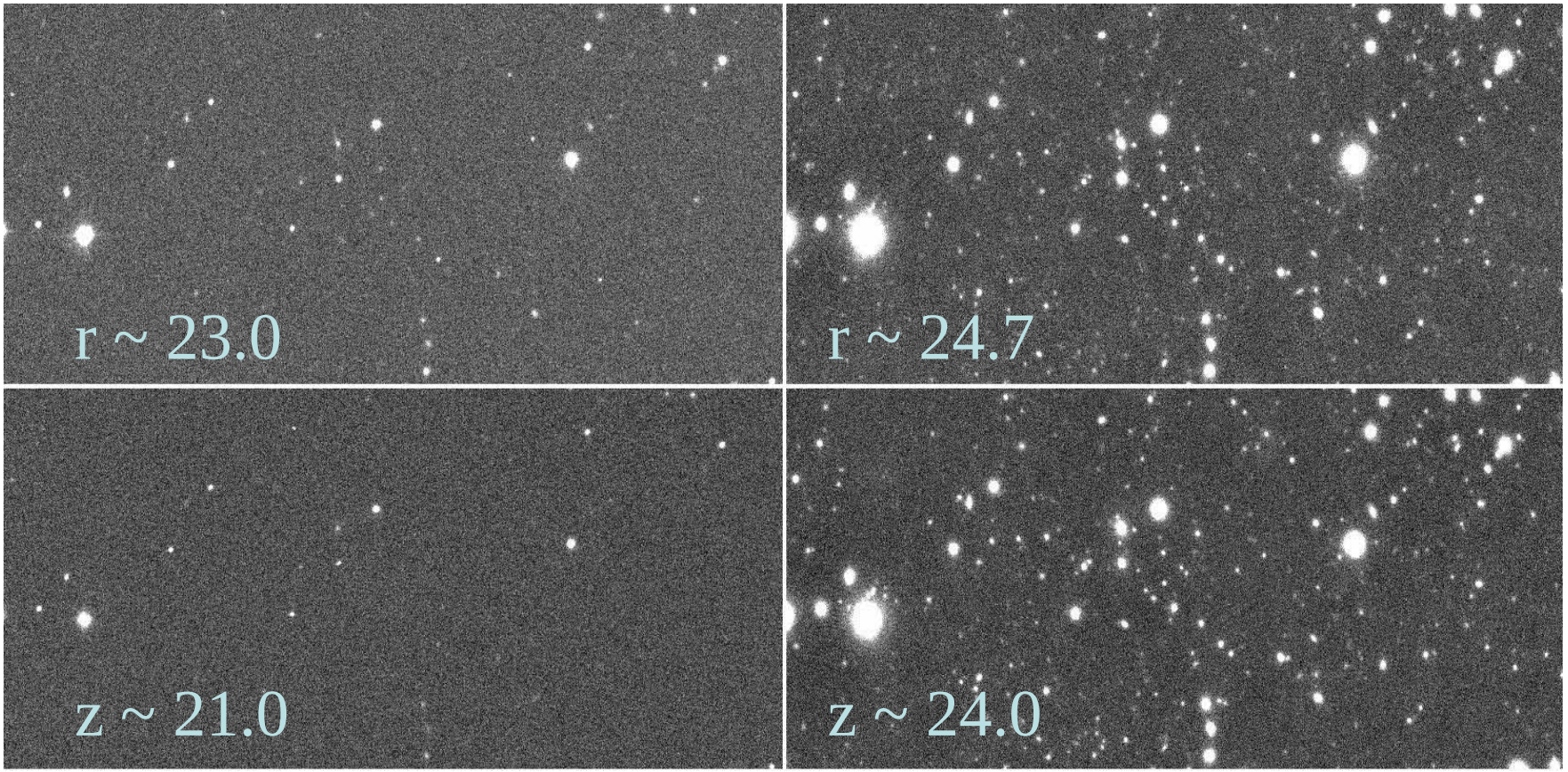


surveys	filters	time given
3π Steradian Survey	g', r', i', z', y	56%
Medium Deep Survey	g', r', i', z', y	25%
Solar System Sweet Spot Survey	r'	5%
Stellar Transit Survey	i'	4%
Deep Survey of M31	g', r', i', z', y	2%
Calibration Fields	g', r', i', z', y	2%
PI Discretionary Time		6%

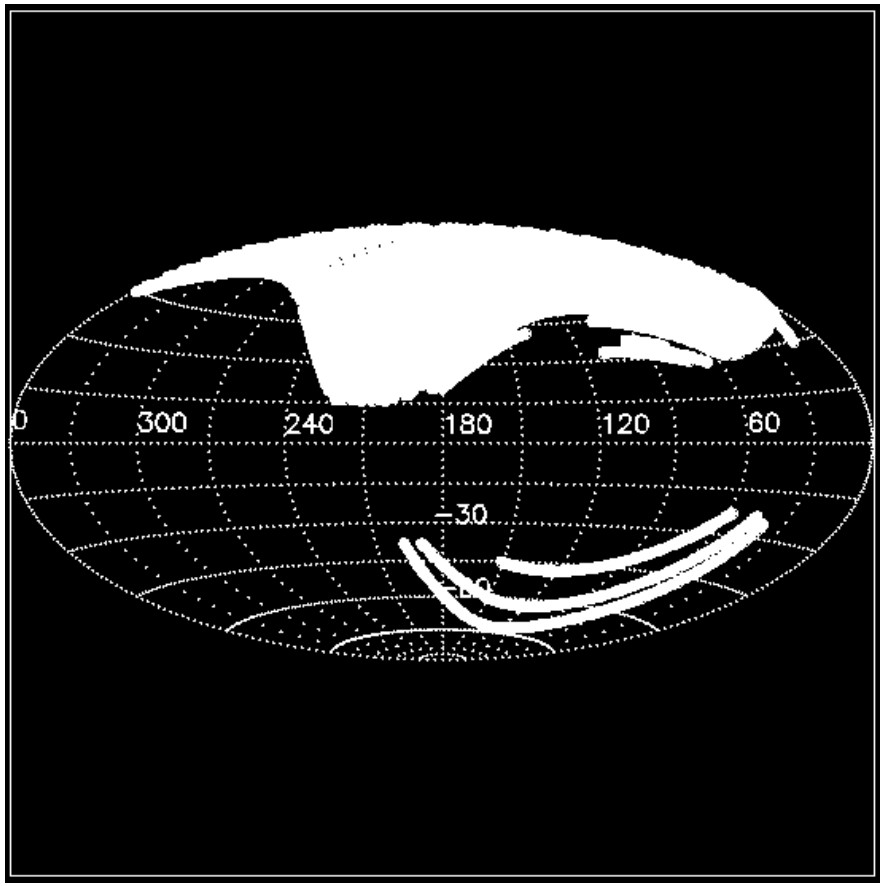
7200 s x 80 epochs
12 fields = 84 sq deg
g → 27.6
r → 27.0
i → 25.9
z → 25.4
y → 24.2

PS1/Medium Deep 1.5 years

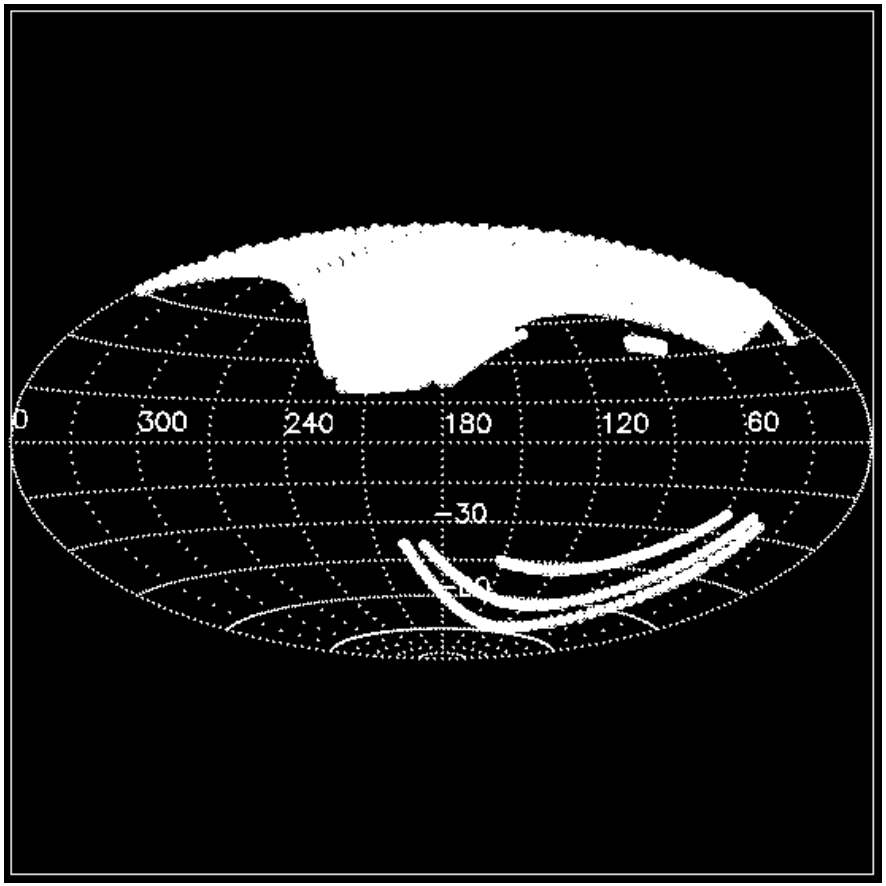
NTNU/ASIAA Stacking



Compare to SDSS --- sky coverage



Imaging



Spectroscopy

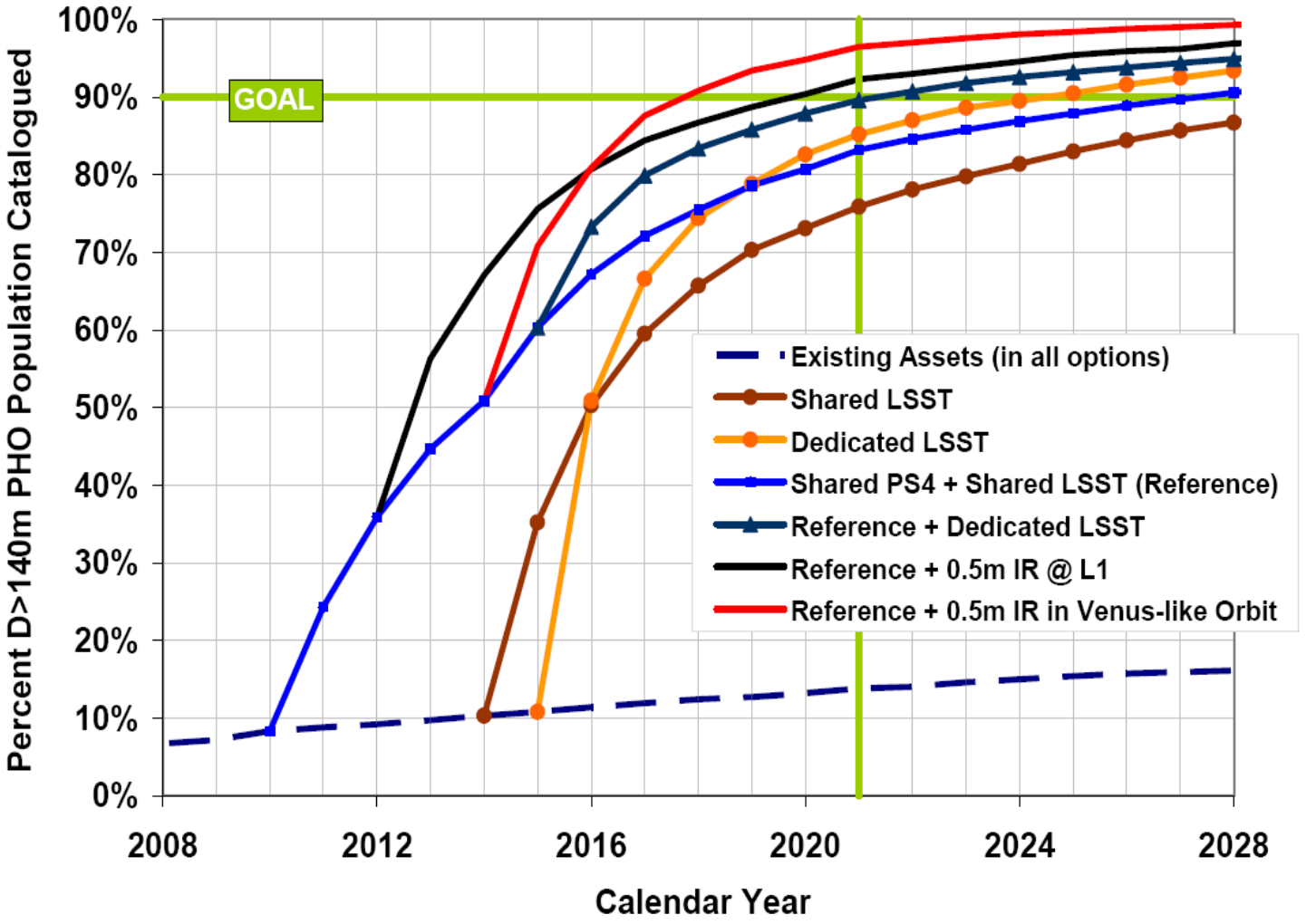
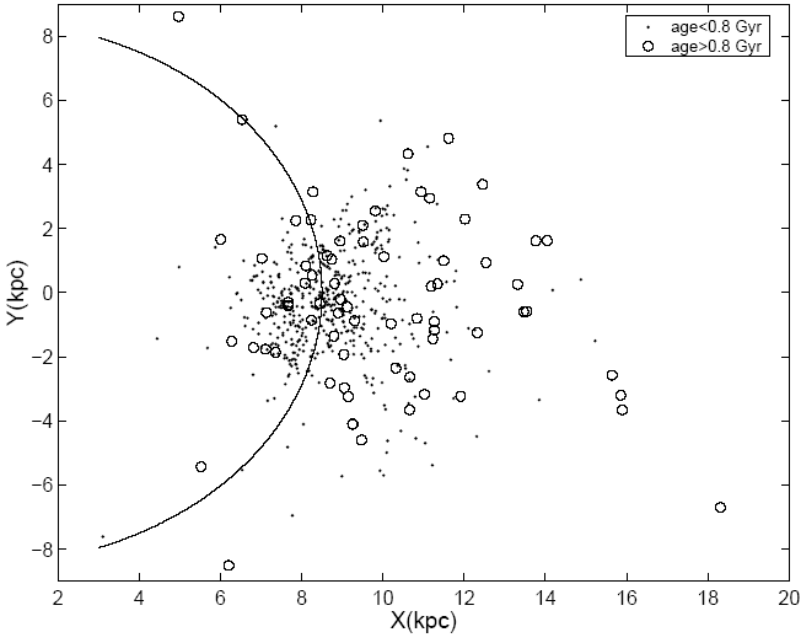
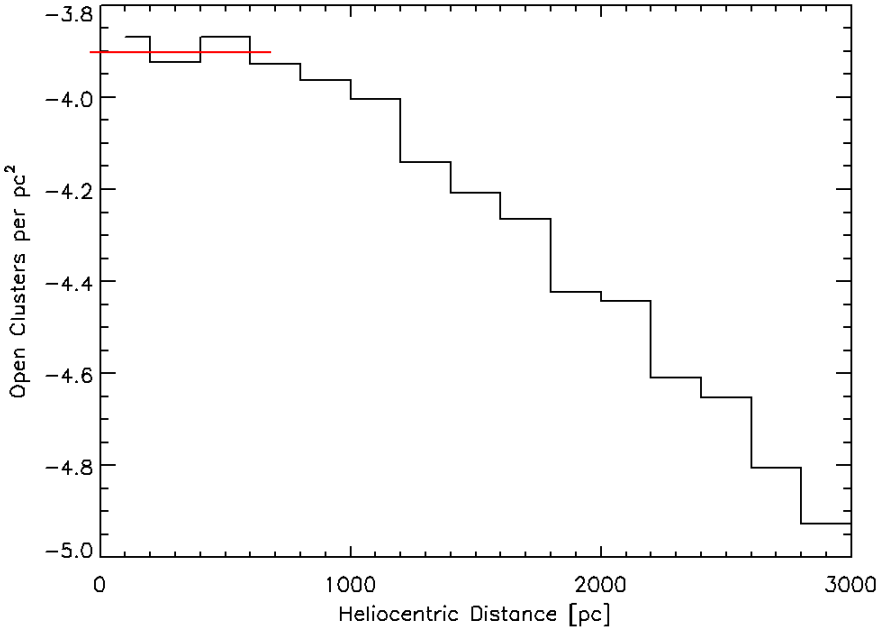


Figure 3. Survey Performance for Selected Alternative Systems

PS1 is the most powerful machine to identify killer asteroids.

PS1 photometry and astrometry: Open Clusters





Chen, L. et al. (2003)

The Galactic OC sample is highly incomplete beyond ~600 pc.

Surface density $= 1.2 \cdot 10^{-4}$ /pc^2

➔ a few 10^3 catalogued vs 10^5 expected

To Search for Uncataloged Star Clusters

G144.9+0.4 is an OC candidate

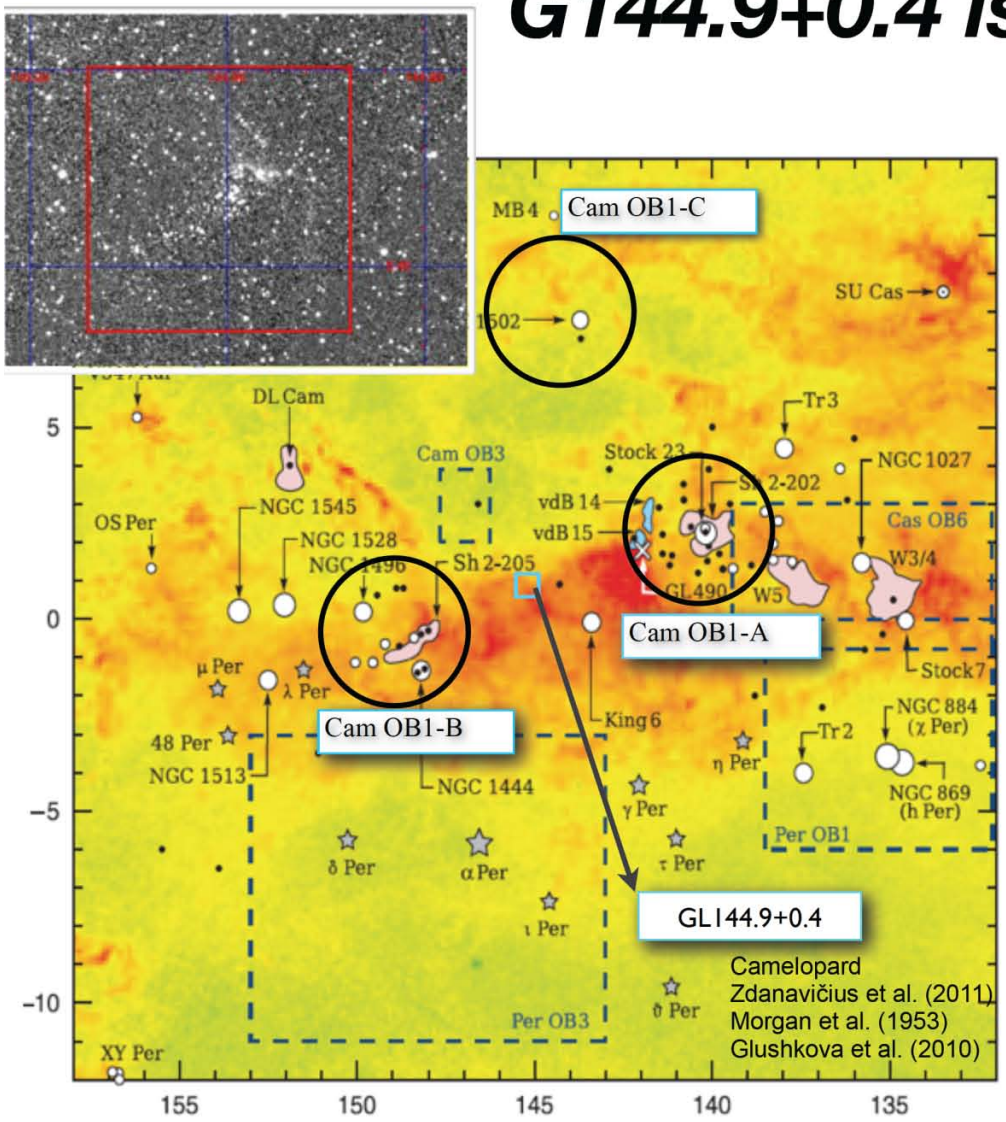


Figure 1. Dust clouds in Camelopardalis and the nearby regions taken by Straizys & Laugalys (2007)

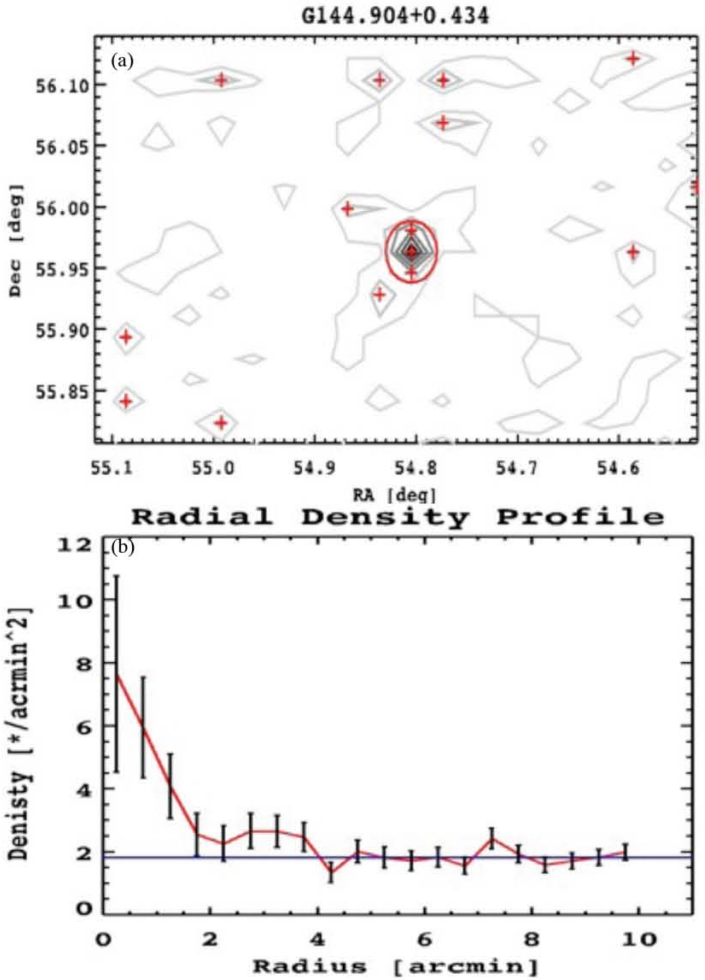
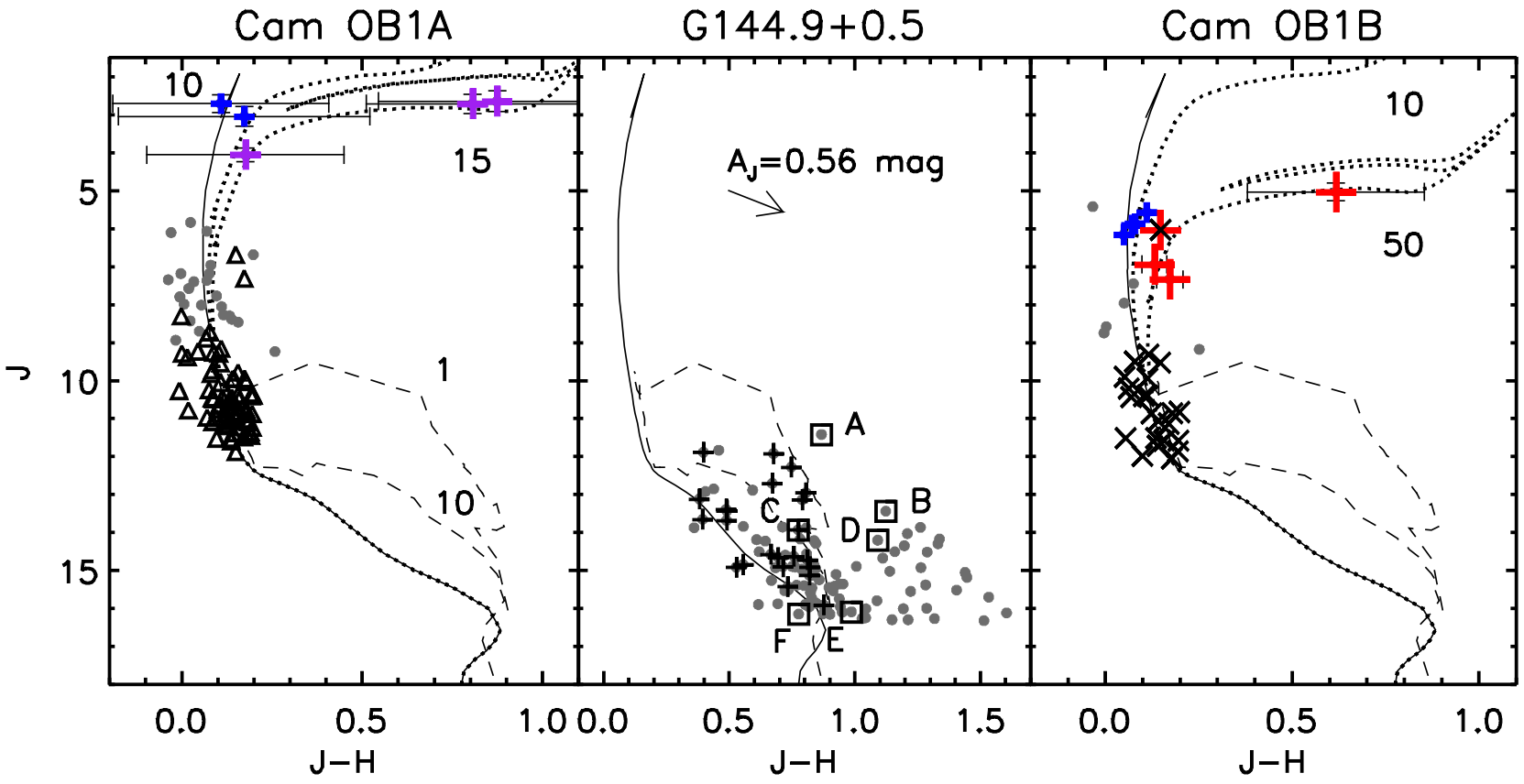


Figure 2. (a) The density map. (b) The radial density profile.

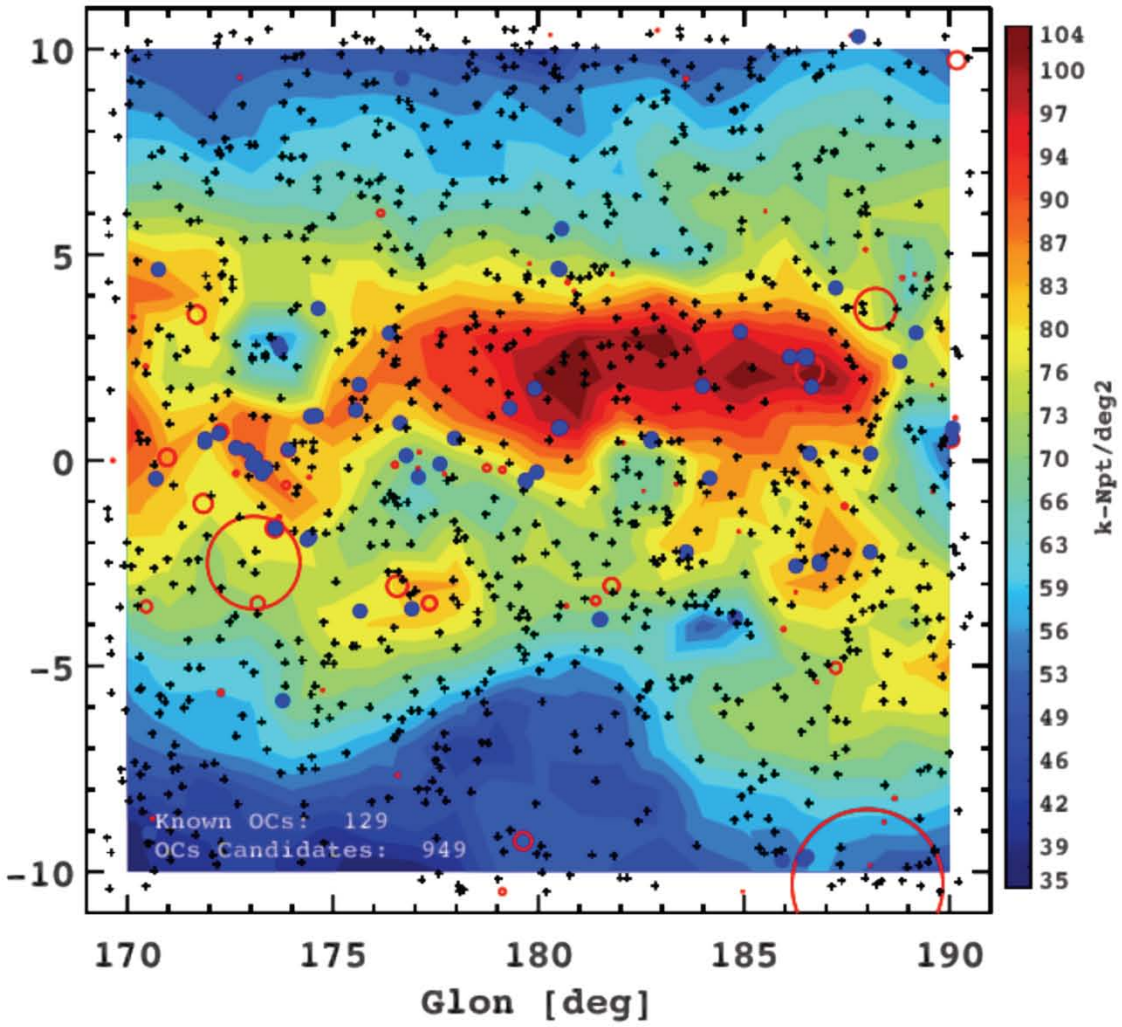
Lin+13



A total of 23 member candidates found; additional 91 OB candidates identified (43 known) ➔ latest SF scenario

Lin+13

Search for Star Clusters with PS1



bands	comp.	std
g	22.10	0.08
r	21.98	0.14
i	21.41	0.12
z	20.76	0.20
y	19.84	0.12

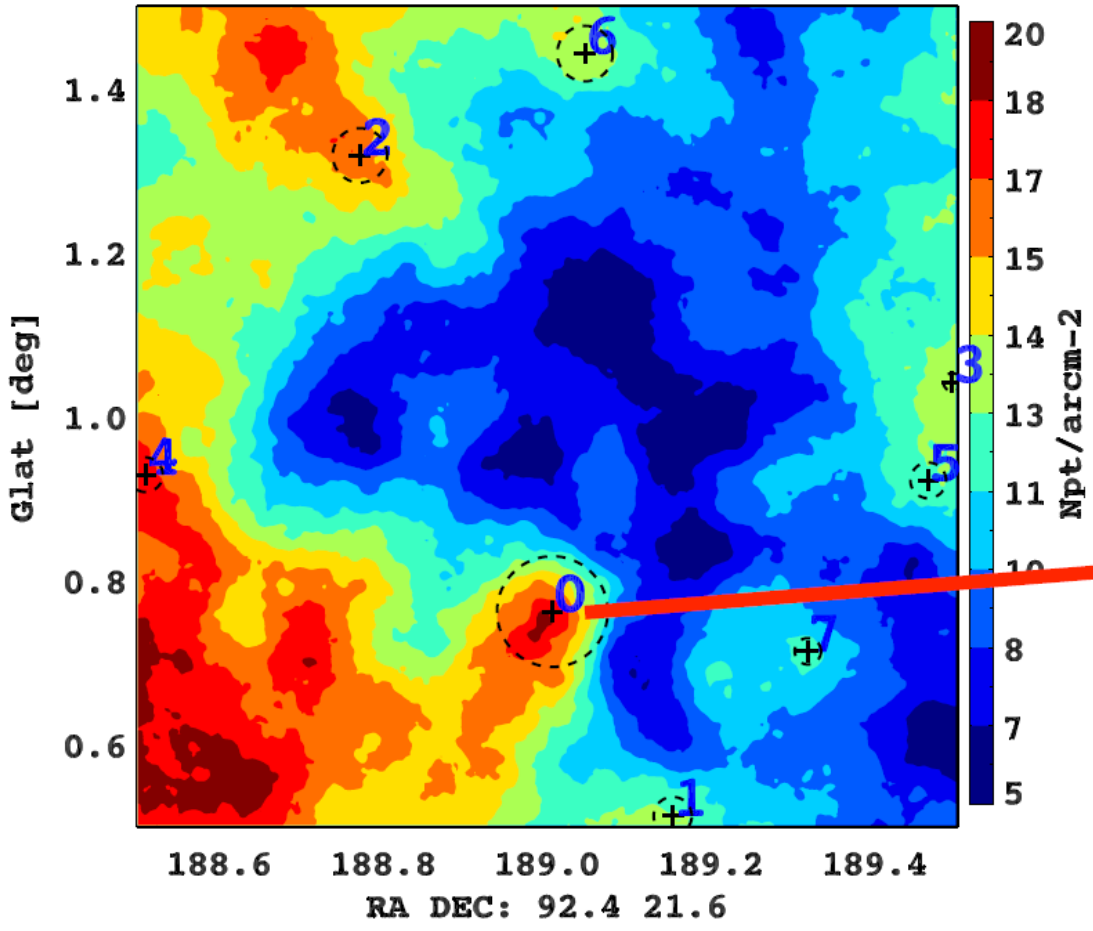
Known OCs : 79/129

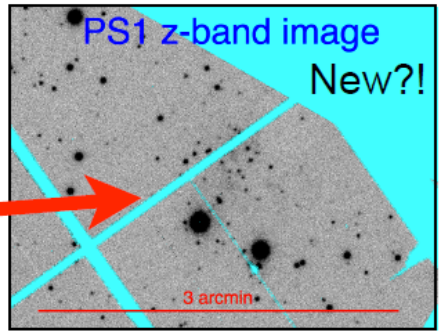
```
 0: Bica et al. 2003a
 9: Bica et al. 2003b
39: Bukowieck et a. 2011
91: Dias et al. 2012
 0: Dutra et al. 2003
61: Froebrich et al. 2007
12: Froebrich et al. 2010
35: Glushkova et al. 2009
57: Kharchenko et al. 2012
11: Loktin et al. 2003
```

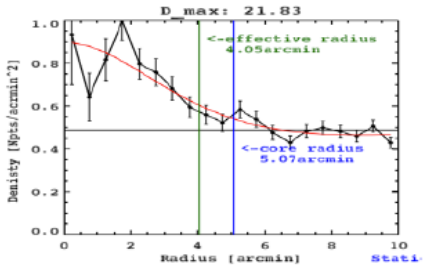
20x20 deg^2 Density Map toward Galactic Anti-Center

189+1.fits
N candidate: 8

glon	glat	mem	reff
189.006	0.761	259	4.05
189.153	0.512	21	1.39
188.771	1.318	33	1.99
189.494	1.041	-7	0.65
188.510	0.928	-5	1.27
189.465	0.921	10	1.31
189.046	1.442	46	2.03
189.318	0.713	11	0.96

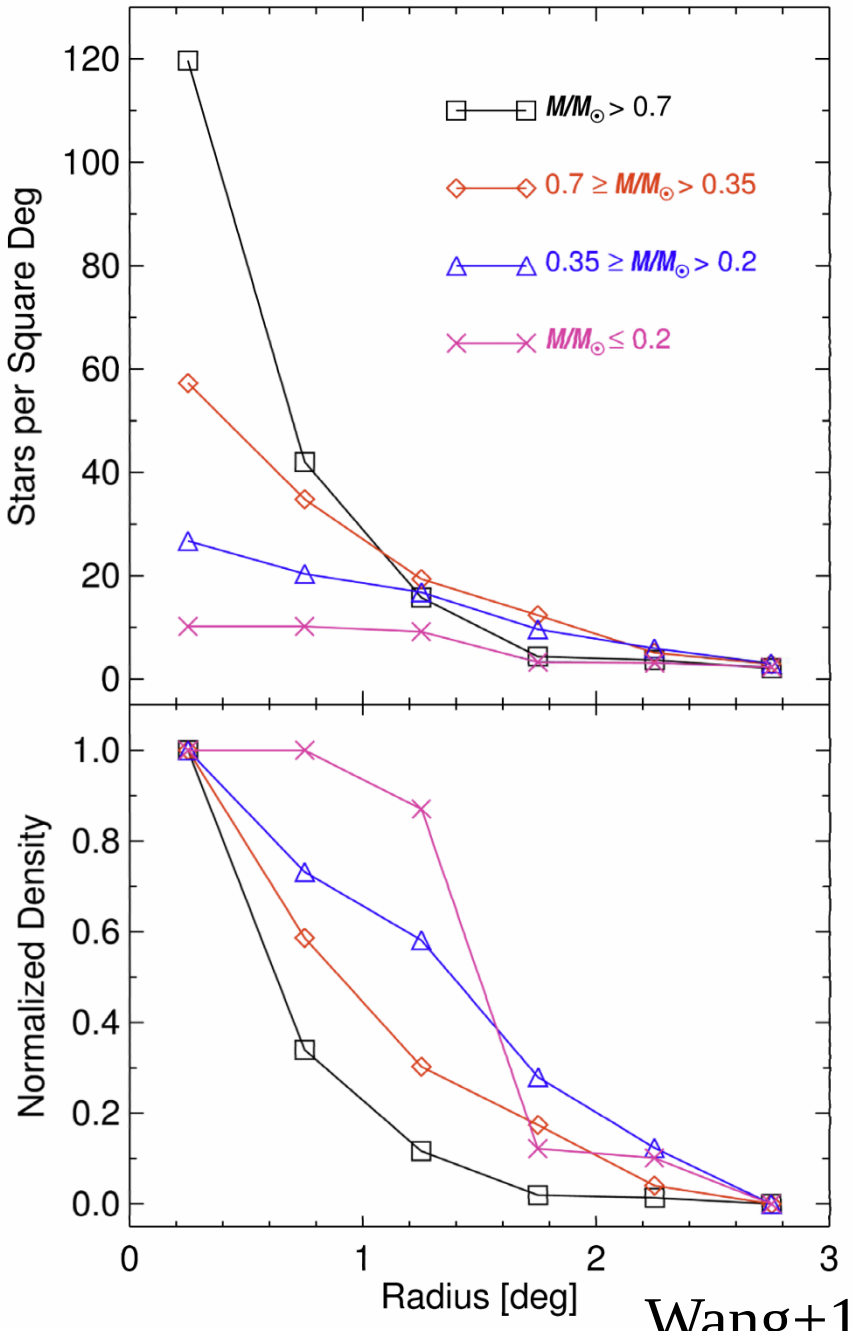






One Example : Over-densities of G189+1

M44 ---Mass Segregation & Stellar Evaporation



Age of Praesepe = 890 Myr ➔ being relaxed with the lowest-mass stars being evaporated

Wang+13

Status of the PS1

- Consortium started 1 Jan 2009
- Members (astronomer and computer scientists) in TW: NCU, ASIAA, NTHU, NTNU
- Commissioning started mid-March 2009
- **Full survey started May 2010**, for duration of 2.5 yrs, now extending to 3.5 yr. **Current funding (PS1SC) ends Jan, 2014**.
- The data server getting ready
- Final uber/hber and re-reduction; **database attributes by July 2014**
- STScI to host PS1 data by Dec 31, 2014

Beyond PS1

- The world gets the data 1 year afterwards.
- PS1.5 (NASA on NEOs) continues with *w* band; NCU will be involved in science.
- PS2 shaping up --- a new consortium
- PS1 + PS2 or PS 1+2
- NCU data store will keep operational, funding permitting.
- Synergies with other datasets, e.g., high-energy compact objects; RVs by LAMOST on star clusters; UKIDSS on lowest-mass stars

Pan-STARRS
pan-starrs.ifa.hawaii.edu

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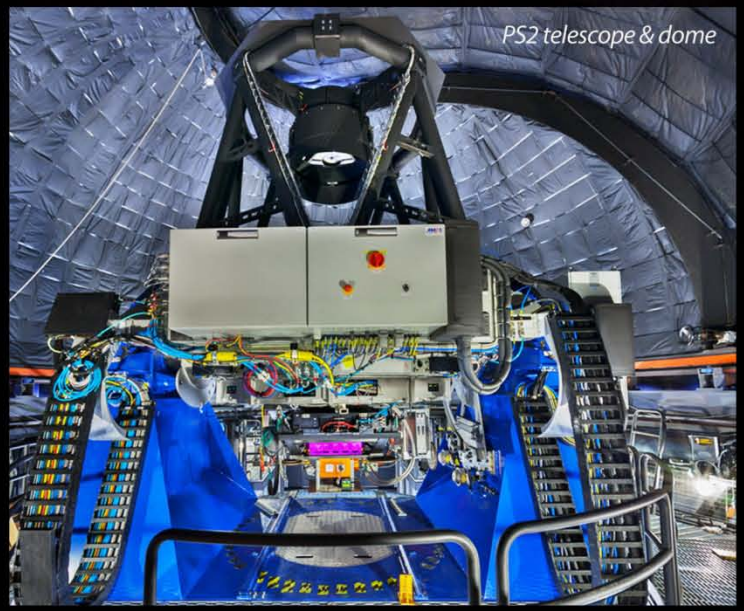
UNIVERSITY OF HAWAII
www.ifa.hawaii.edu

PS2 sees the 1st light.

Telescope photos by Tropical Light

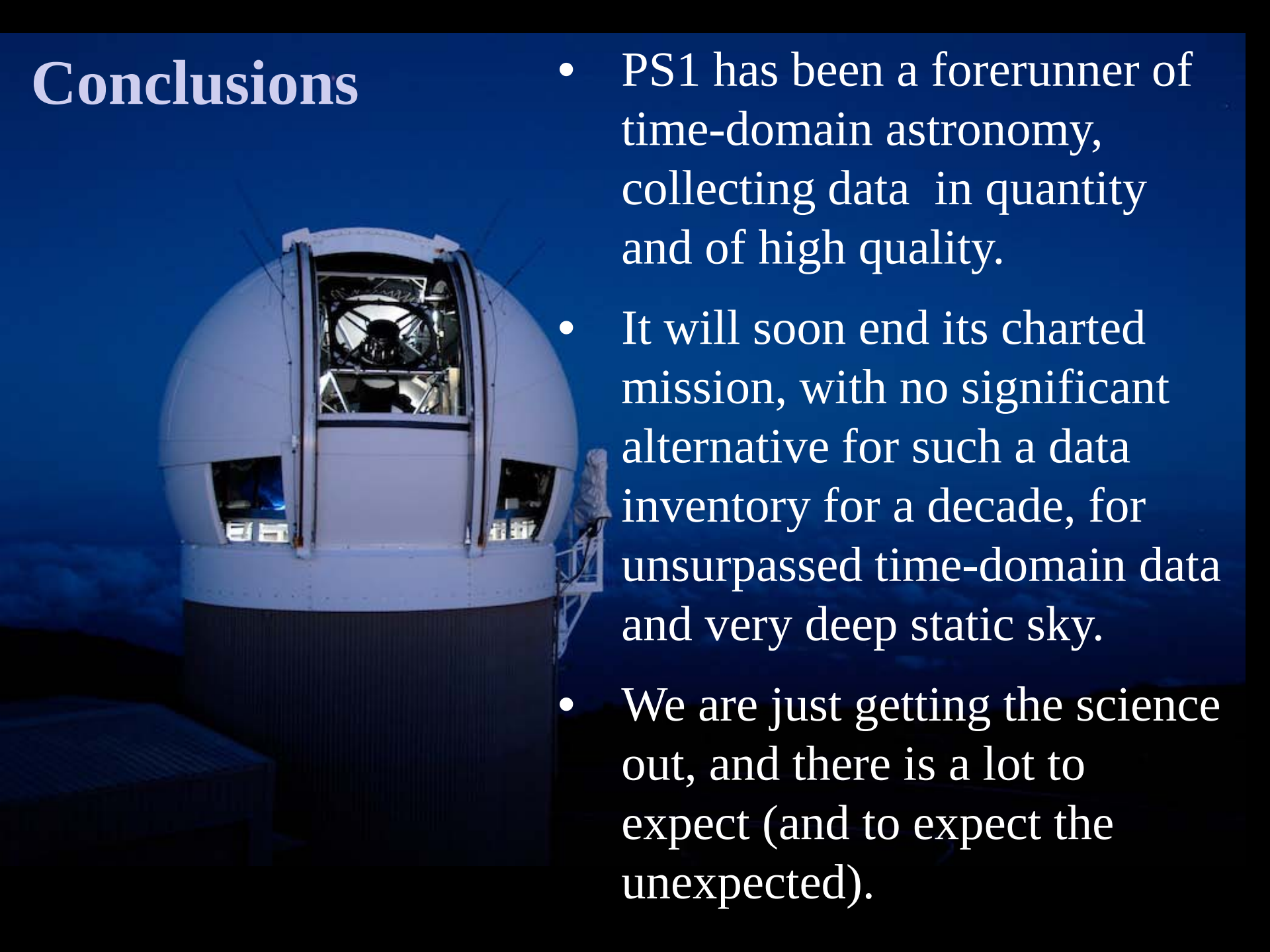

PS2 telescope & dome


TC3 test camera


M17, Omega Nebula
processed by E. Magnier

The Pan-STARRS Observatory on Haleakala (Maui) with the dome of the new telescope, PS2 (foreground), next to the PS1 dome. The 360 Megapixel test camera (TC3) is being used for PS2 testing until the second 1.4 Gigapixel camera (GPC2) is completed. Though only one-fourth the size of GPC2, TC3 still places more pixels on the sky than most cameras now in use. The central portions of M17 were imaged only a few days after PS2's first light in July 2013. PS2 should join PS1 in full science operations in 2014 to make PS1+2 the world's most powerful survey system in terms of simultaneous wide field, high resolution, and depth.

Conclusions



- PS1 has been a forerunner of time-domain astronomy, collecting data in quantity and of high quality.
- It will soon end its charted mission, with no significant alternative for such a data inventory for a decade, for unsurpassed time-domain data and very deep static sky.
- We are just getting the science out, and there is a lot to expect (and to expect the unexpected).