KIDS compared to PanSTARRS: specs and status

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The **Pan**oramic **S**urvey **T**elescope and **R**apid **R**esponse **S**ystem

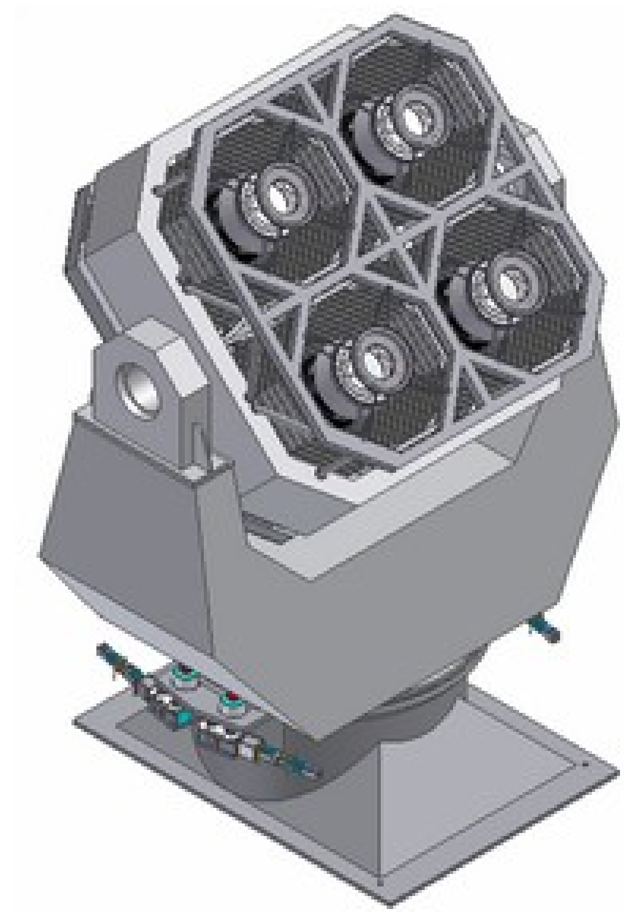
- Background and project history
- Hardware
- Software
- Science Projects
- Status and perspective

Leiden, 31.3.2008

General information: Where, who, why, what?

- Pan-STARRS is developed by the University of Hawaii, partially funded by the US Airforce
- One day Pan-STARRS will be a system of four 1.8m telescopes that will survey the entire visible sky (3π) in five filters every five nights
- New technology wide-field camera, FOV is 7 sqdeg with 0.3” pixels, tip-tilt correction on the chip!

Possible telescope design



Pan-STARRS1: The prototype

- One 1.8m telescope
- Built on Haleakala (on Maui, Hawaii)
- PS1 will allow us to test all the technology that is being developed for Pan-STARRS, including the telescope design, the cameras and the data reduction software.
- PS1 will be used to make a full-sky survey

Pan-STARRS

PS1 Science Consortium

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

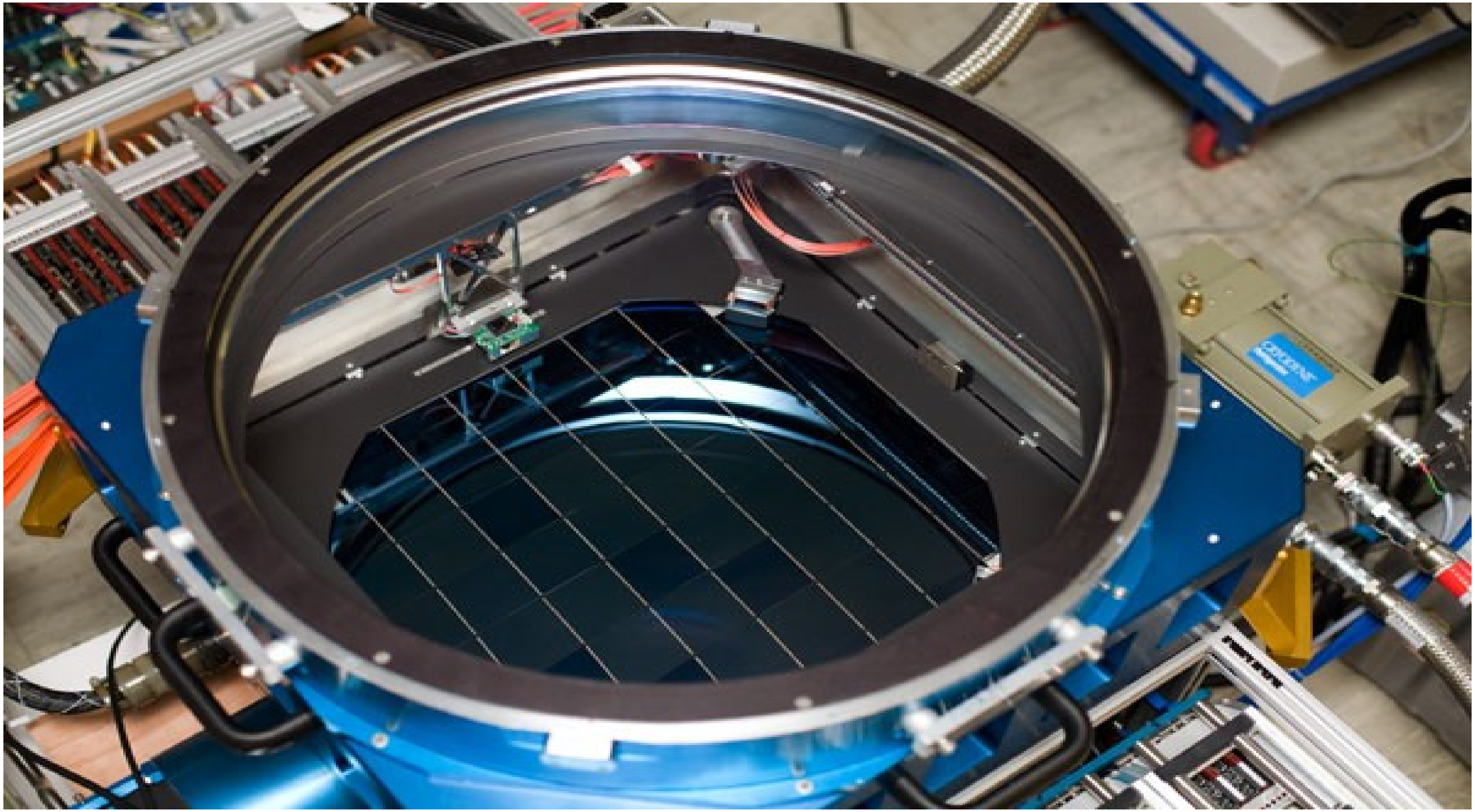
National Central University, Taiwan

Las Cumbres Observatory Global Telescope Network

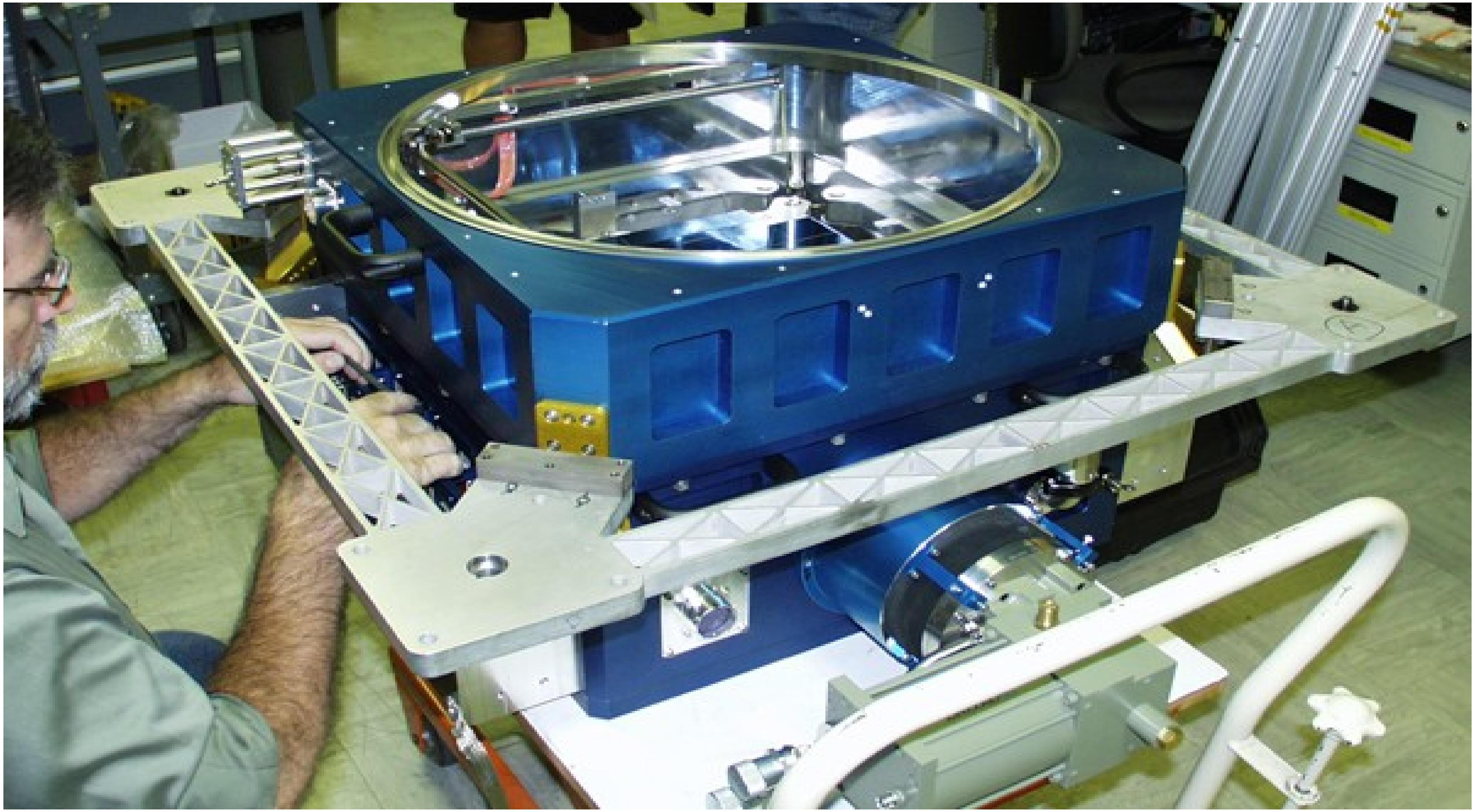
The camera

- Consists of an array of 64x64 CCDs
- Each CCD has 600x600 pixels
- A total of 1.4 Gigapixels spread over 40x40 centimeters
- Orthogonal transfer allows for a shift of the image during the observation -> tip-tilt correction on the chip
- Expected data flow: 50Tbytes/month

The camera



The camera

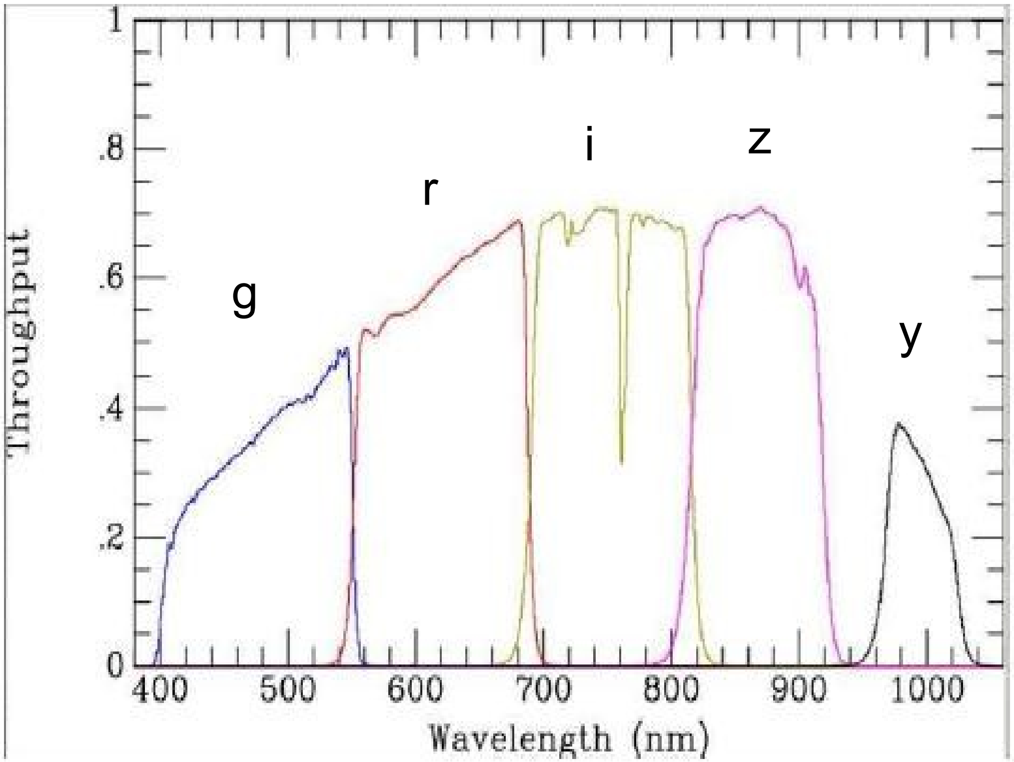


First light on 22nd of August 2007!

PS1SC

The famous Bonn-Shutter

The filter system: grizy



- Pan-STARRS will be a very red survey
- Good photometric redshifts only for red galaxies (LRGS -> similar to SLOAN)
- For studies of galaxy properties have to combine with other surveys

PS1SC

The PS Pipeline

- Completely automatized data reduction pipeline on the mountain
- Satellite tracks detected and deleted from raw data: only censored data will be given to the astronomical community
- Photometrically and astrometrically calibrated single frames
- Evolving coadded frames, difference images
- Static and time-dependent object catalogues, secondary catalogues (photometric redshifts, spectral classification, light-curve fitting, etc.) accessible through a centralized database
- Galaxy photometry performed „a‘ la SLOAN“: PSF-convolved model fitting

Our further plans

- Copy reduced frames to our PanSTARRs Beowulf cluster (through the net or cassettes)
- Ingest frames in AstroWise
- Perform PSF equalization across colors
- Reassess object detection, photometry and photometric redshifts
- Perform difference imaging and light curve analysis for microlensing search in M31 and transit planet light curves

The PS1 Surveys

- 3π steradian Survey
- Medium Deep Survey
- Solar System Sweet Spot Survey
- Stellar Transit Survey
- Deep Survey of M31

The 3π Survey

- Survey the entire visible sky (from Hawaii)

➡ *Earth-bound all-sky survey*

- In five filters
- 56% of total observing time
- Every field will be visited 4 times in each band pass every year, 3.5 years long
- Median redshift: z~0.7

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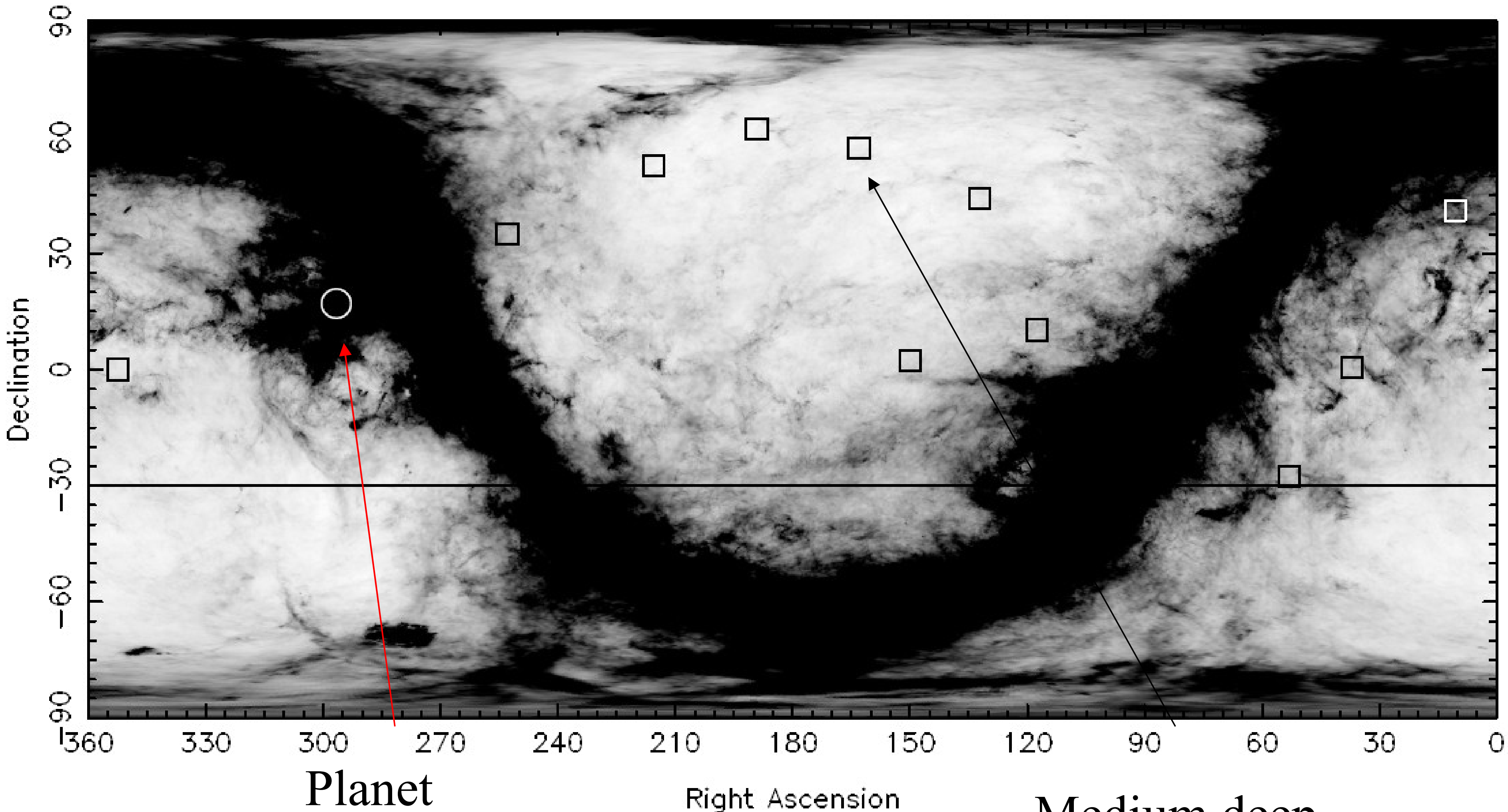
The 3 survey

Starting end 2008 to mid of 2012



Planet Transits

Medium deep fields

Limiting magnitudes

Table 3: *Estimated PS1 sensitivities for single exposures in the 3π survey. The tabulated numbers use the above equations and assume 75 micron chips, aluminum coating, effective loss of 0.35 area from secondary mirror blockage and diffraction from baffles and secondary mirror support structure. The average sky brightness μ at Haleakala assumes the Wainscoat light pollution factor in g and r band, and an average air mass of 1.4 is assumed. The FWHM is taken to be* 0.78 *arcsec, or three pixels assuming OTA improvement. A read noise of 5 electrons rms is assumed, and zero contribution from RFI.*

Filter	Bandpass (nm)	m_1 AB mag	μ AB mag/asec^2	exposure time/visit sec	5σ trailed NEO/visit	5σ pt. source per vist	visits in one night	visits per year	visits per 3 yrs	5σ pt. source in 3 yrs
g	405–550	24.90	21.90	60	23.06	23.24	2	4	12	24.59
r	552–689	25.15	20.85	38	22.62	22.70	2	4	12	24.05
i	691–815	25.00	20.15	30	22.48	22.59	2	4	12	23.94
z	815–915	24.63	19.26	30	21.53	21.59	2	4	12	22.94
y	967-1024	23.03	17.98	30	210.07	20.12	2	4	12	21.47

Lensing!

Medium deep survey, 84 sq. deg.:

Filter	Bandpass (nm)	m_1 AB mag	μ AB mag/asec^2	exp time sec	5σ point source in 4 nts	5σ point source in 1 yr	5σ point source in 3 yrs
g	405–550	24.90	21.90	3×240	24.76	26.68	27.27
r	552–689	25.15	20.85	3×240	24.43	26.34	26.93
i	691–815	25.00	20.15	6×240	25.43	27.34	27.93
z	815–915	24.63	19.26	6×240	23.76	25.67	26.26
y	967-1024	23.03	17.98	6×240	22.32	24.23	24.82

The Medium Deep Survey

- 10 GPC1 footprints distributed uniformly across the sky (optimized for SnIa studies)
- Nightly depth chosen to detect SnIa at z=0.8
- Stacks constitute 84 square degrees
- Facilitates detection of L* galaxies at z=1.8

Key science projects

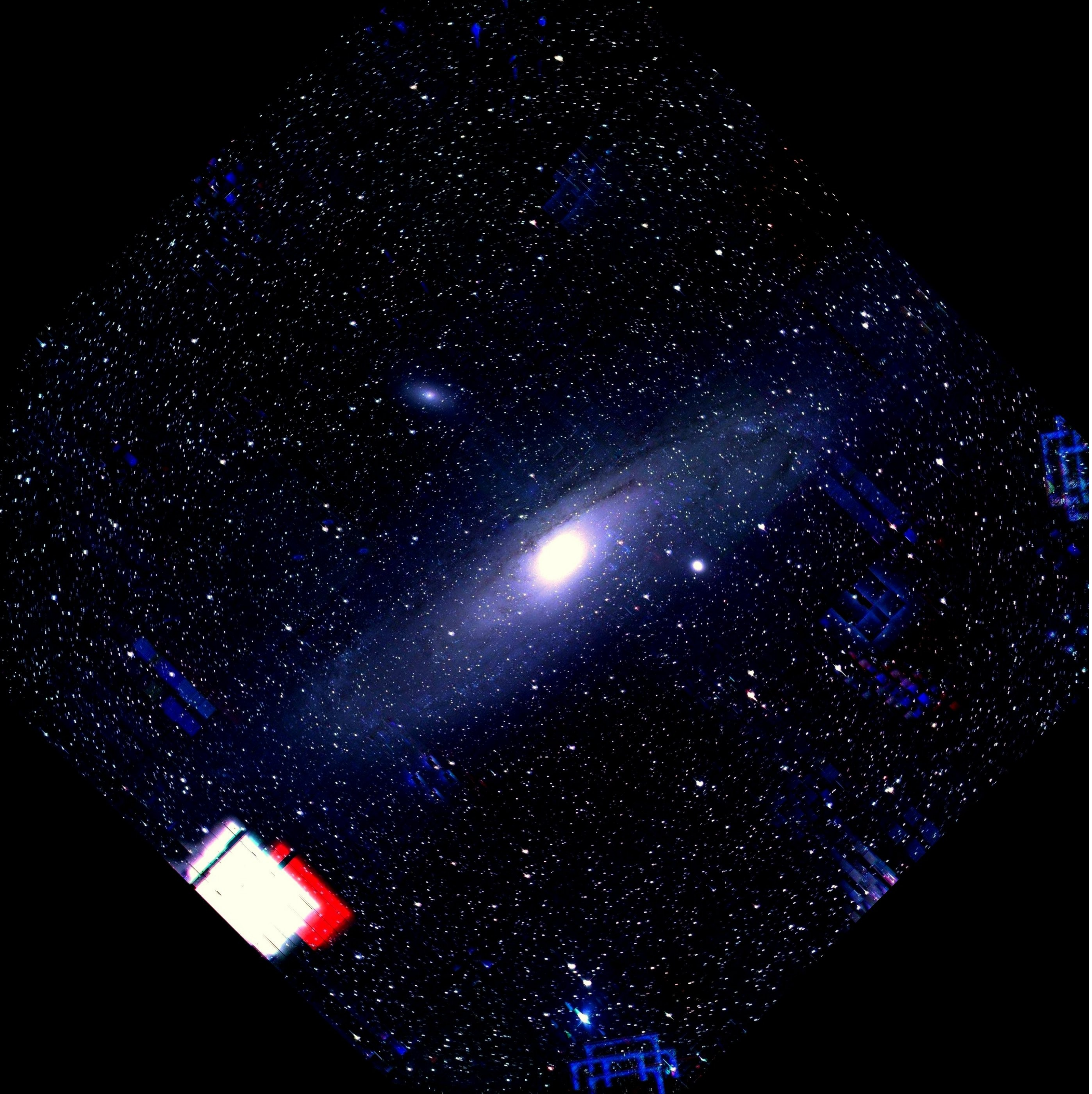
- Populations of objects in the Inner Solar System
- Populations of objects in the Outer Solar System (Beyond Jupiter)
- Populations in the Local Solar Neighborhood, the Low Mass IMF, and Young Stellar Objects
- Search for Exo-Planets by dedicated Stellar Transit Surveys
- Structure of the Milky Way and the Local Group
- A dedicated deep survey of M31
- Massive Stars and Supernovae Progenitors
- Transients
- Galaxies and galaxy evolution in the local universe
- Active Galactic Nuclei and High Redshift Quasars
- Cosmological lensing
- Large Scale Structure

PS1SC

Status and Perspectives

- Optical alignment of the primary+secondary+camera lens system optimized using a novel technique, image quality improving steadily
- Problems with mirror support under investigation
- Electronics performances improving as the tele- and radio-transmission towers are moved away from the telescope
- Overall optical transmission efficiency under assessment
- Pipeline well developed, still work to be done on satellite tracks elimination (outsourced to Boeing...)

Aimed start of science operations: Fall 2008



M31

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PS1SC

Key project 12: Large Scale Structure

(PIs: S. Cole and S. Phleps)

- Input:
  - Redshift catalogues
  - realistic Pan-STARRS mocks
- Science projects:
  - BAOs and cosmological parameters
  - Clustering as a function of X
  - Higher Order Statistics
  - Galaxy Clusters
  - CMB foregrounds

Redshift catalogues
(Coordinated by R. Saglia and D. Wilman)

- Accurate multiband seeing-matched photometry
- Photometric redshifts (goal: σ_z<3% for LRGs)
  - Supplementing Pan-STARRS grizy with other wavelength information (where available)
  - Calibrate photometric redshifts with spectroscopic redshifts (over full range of Galactic extinction)
- Surface photometry
- Completeness maps (depth and coverage as function of coordinates)

Saglia, Wilman, Bender, Meneux, Drory, Lerchster, Seitz, Szalay, Metcalfe, ….

Realistic mocks

(Coordinated by F. van den Bosch and C. Frenk)

- Different mock catalogues:
  - A 7 square degree PS1 footprint synthetic sky
    - Redshifts, apparent magnitudes, structure parameters, but no clustering
  - Timeslize galaxy catalogues (realistic clustering at fixed redshifts)
  - Galaxy lightcones (with evolution of clustering along the line of sight)

LSS and BAOs
(Coordinated by S. Cole, S. Phleps and A. Szalay)

- Use the acoustic oscillations in the galaxy distribution as a standard ruler to measure the equation of state of dark energy with
  - Projected correlation functions
  - Angular correlation functions in z slizes
  - Power spectra (spherical harmonics decomposition)
- Compare with models/theoretical predictions and infer w

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Requirements (from the ESA/ESO Cosmology Report)

- 1% error in distance gives 5% error in *w*
- For a spectroscopic survey minimum volume is 5 h^{-3} Gpc^3
- Typical number of galaxies: N = $2*10^6$
- Blake and Bridle 2005: for photometric redshifts need a factor of 10 more (to make up for redshift smearing)

Measuring the acoustic peak in Pan-STARRS

- We have area! -> 3π =30000 sq.deg
- In order to calculate clustering statistics we need good redshifts ($\sigma_z/(1+z)<0.03$) -> select luminous red galaxies (LRGs)
- Expect to find about 10000000 LRGs with I<23, 0.2<z<1

➡ **We will be able to measure *w* to 3-5%**

Potential difficulties

- 10000000 LRGs is a huge number of galaxies -> computationally challenging
  - run the codes in parallel on the Beowulf cluster
  - additionally use a tree code or adaptive grid
- Have to understand systematics:
  - Influence of redshift errors and varying depth across the sky on measurements
  - nonlinear biasing on large scales
  - shift of acoustic peak (see Smith et al. 2007, astro-ph/0703620
  - very large angles -> distant observer approximation not valid any more

Clustering as a function of X

(Coordinated by F. van den Bosch, S. Phleps)

- Analyse clustering statistics as a function of
  - Luminosity
  - Colour
  - Stellar mass
  - Star formation rate
- Compare with models based on
  - Halo occupation distribution
  - Conditional luminosity function
  - Semi-analytics

Clustering as a function of X

(Coordinated by F. van den Bosch, S. Phleps)

- And learn something about
  - How galaxies trace the underlying dark matter density field (biasing)
  - How the environment (the local overdensity) influences the galaxies' properties

Higher order statistics

(Coordinated by I. Szapudi)

- Complementary information from
  - Three-point correlation function
  - Bi-spectrum
  - Scaling indices
  - Minkowsky functionals
  - Count-in-cells
  - Void probability function
- Put constraints on non-Gaussianity of distribution and initial conditions as well as (non-linear) biasing and
- Put constraints on cosmological parameters (e.g. σ_8)

CMB foregrounds

(Coordinated by J. Peacock and C. Frenk)

- Integrated Sachs-Wolfe effect
- Rees-Sciama
- Sunyaev-Zeldovich
- Lensing

Galaxy clusters

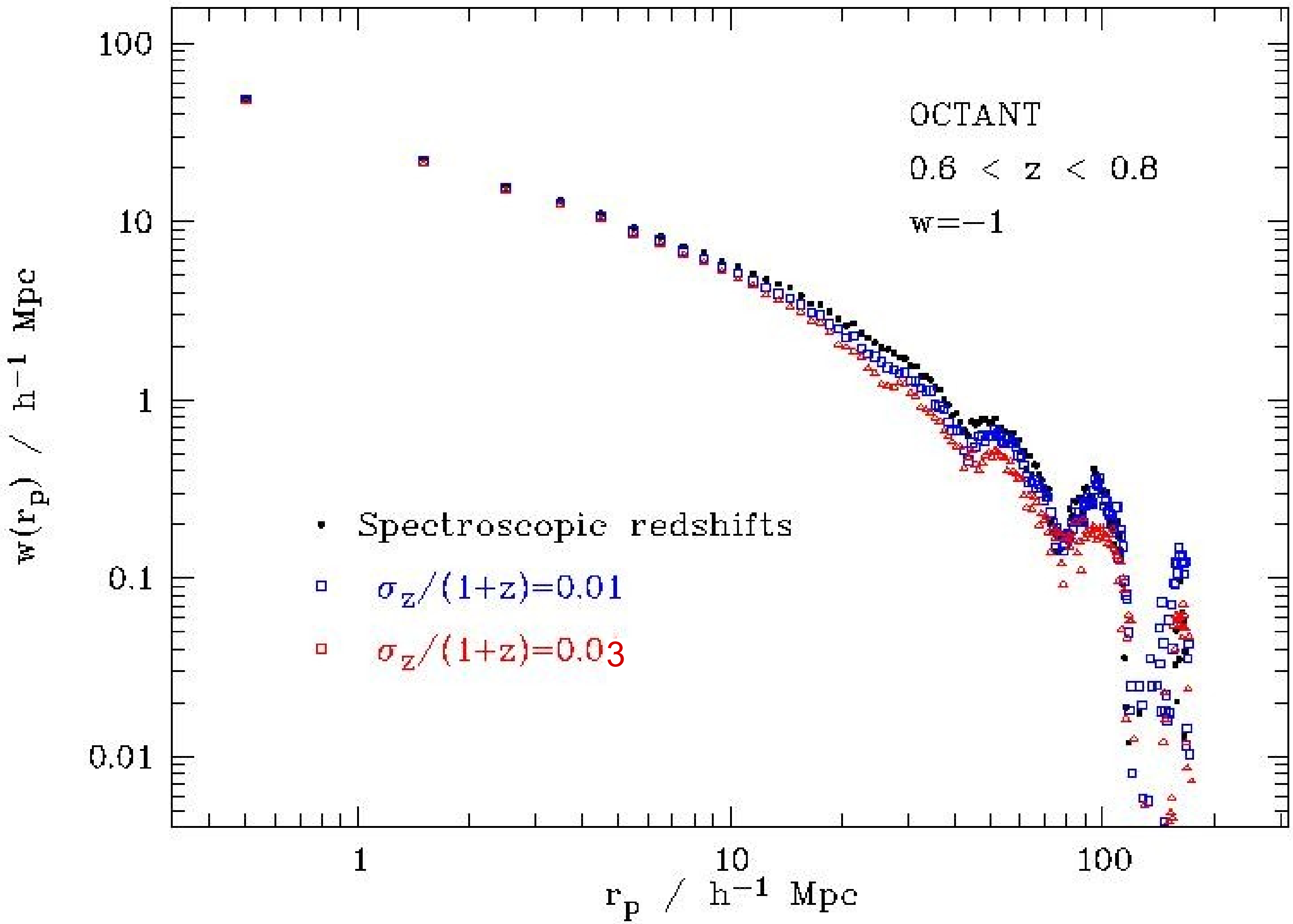
(Coordinated by R. Bower and H. Böhringer)

- Cluster catalogue (using a matched filter technique)
- Measurement of LSS and constraints on cosmological parameters
- Constraints on galaxy formation theories and role of environment on galaxy properties
- Probe thermodynamics and metal enrichment history of intracluster/group medium
- Lensing: provide a source list of gravitational telescopes for constraining cosmological distance scale and properties of background objects

Summary

- Pan-STARRS 1 will survey 3π of the sky in five filters for 3.5 years
- Expect about 10^7 LRGs up to z=1 with redshift accuracy of ~3%
- Huge number of science applications
- Particularly interesting for cosmology: LSS and BAOs: will be able to measure w with 3% accuracy

The acoustic peak: a first simulation



$N_{particles}$ ~ 3 Million, 45 degrees x 45 degrees