Pan-STARRS 1
Panoramic Survey Telescope & Rapid Response System

In anticipation of the public release …

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Chair: Data Reduction, & Analysis Verification Group (DRAVG)

What is Pan-STARRS?

"A major goal of Pan-STARRS is to discover and characterize Earth-approaching objects, both asteroids and comets, that might pose a danger to our planet"

Actually, Pan-STARRS was a University of Hawaii project for four identical telescopes (in the end there were two). A Consortium was put together to run the first one – PS1:

- 1.8m f4.4 Ritchey-Chretien
- 3.2 degree FOV (~ 7 sq. deg.)
- 1.4 gigapixel camera, 0.26" per pixel

Designed to scan the sky from Hawaii 3 times per month

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

Durham University Institute for Computational Cosmology

National Central University, Taiwan

Las Cumbres Observatory Global Telescope Network

NSF

Space Telescope Science Institute

Operated for NASA by AURA

University of Maryland

Los Alamos National Laboratory

Science Consortium

- Not just asteroids – 12 Key Projects were set up covering Solar System science right out to Cosmology, and most things in between!

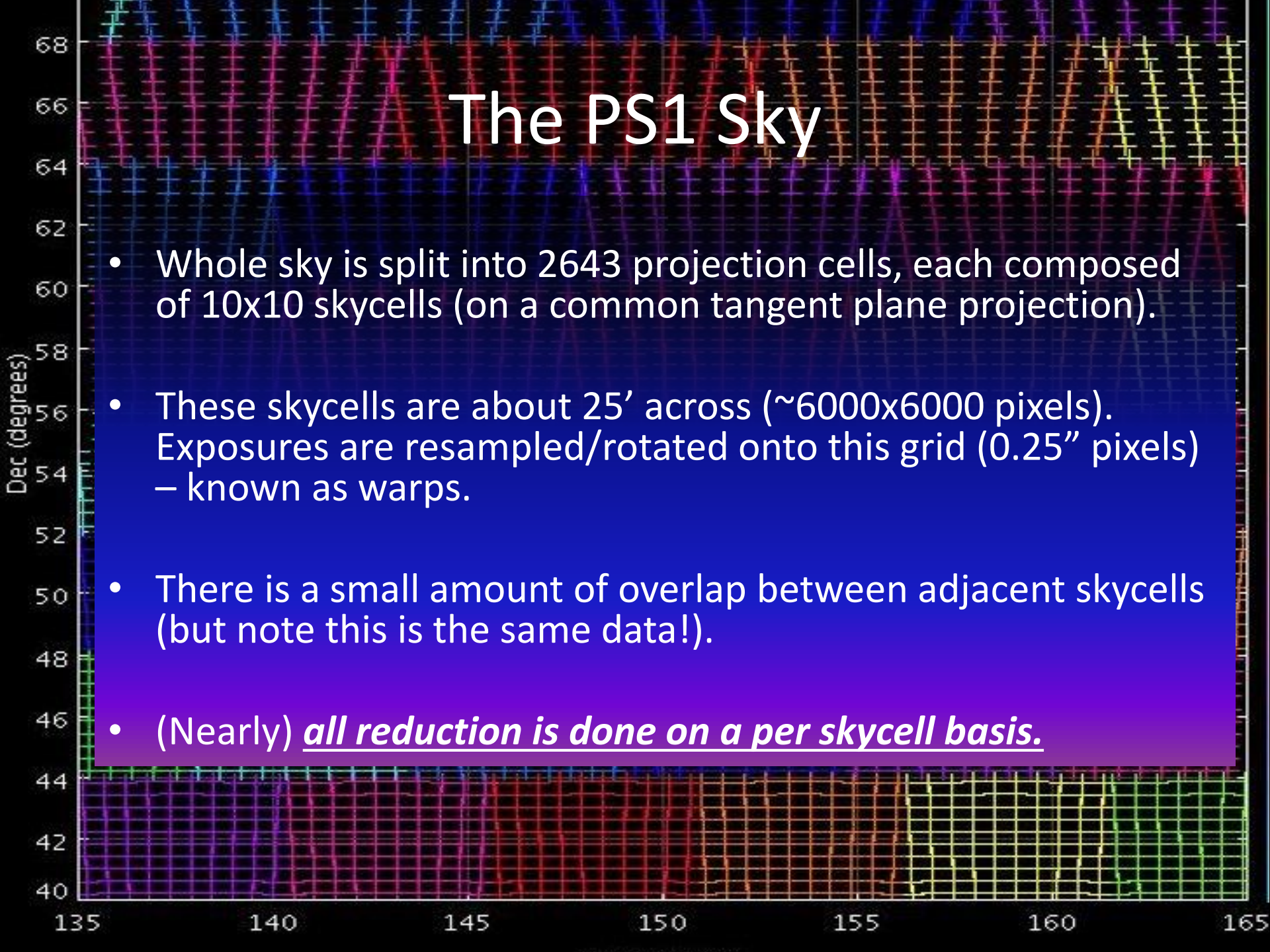
- Plenty of science still to be done …

The PS1 Camera

- 60 OTAs (8x8 with the corners missing) 70”x36” gaps
- Each OTA an array of 8x8 cells (600x600 pixels) 9”x5” gaps
- That is a lot of gaps, and a lot of opportunity for things to go wrong!

- Designed for fast readout (~10 secs), with low read noise (5-6e^-) and to enable charge shuffling (never really switched on)

- Purpose built data reduction/analysis pipeline – Gene Magnier



The PS1 Sky

- Whole sky is split into 2643 projection cells, each composed of 10x10 skycells (on a common tangent plane projection).
- These skycells are about 25’ across (~6000x6000 pixels). Exposures are resampled/rotated onto this grid (0.25” pixels) – known as warps.
- There is a small amount of overlap between adjacent skycells (but note this is the same data!).
- (Nearly) ***all reduction is done on a per skycell basis.***

The PS1 Surveys

Survey	Area (sq.deg.)	Filters	Percent Time	Exposure (secs)
3 π	30,000	g,r,i,z,y	56	43/40/45/30/30
Medium Deep	70	g,r,i,z,y	25	113/113/240/240/240
Solar System	10,000	w	5	45
Stellar Transit	40	i	4	15 or 30
M31	7	r,i	2	60/60

Data collection started early in 2010 and completed in April 2014

Disclaimer!

- Didn’t achieve the expected seeing or depth
- Problems with variable bias lead to cell-scale issues in the background – bad for extended objects

- Ghosting, persistence. bleed trails, cross-talk *mostly* masked
- Leads to quite a high false positive rate *per exposure*
- Background over-subtraction around large objects

Remember – this will be the first release. SDSS are into double figures!

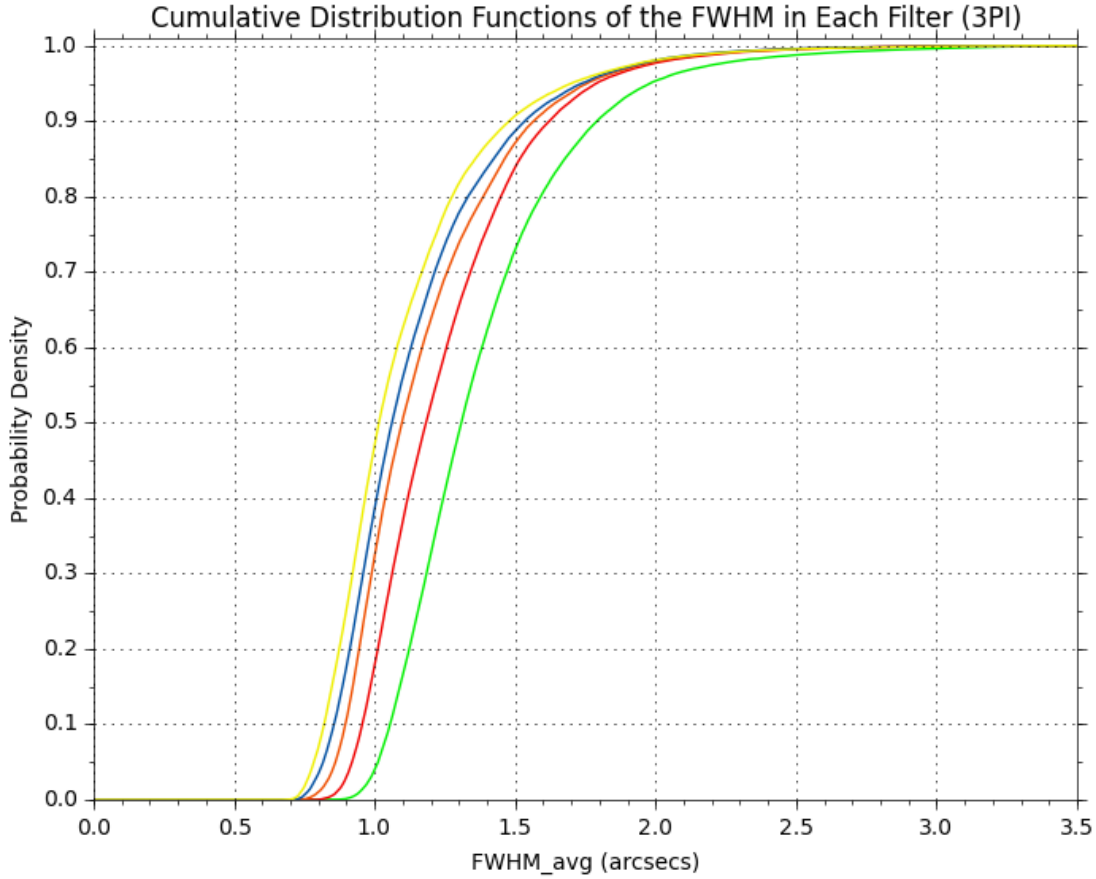
The 3π Survey

- Whole sky north of Dec -30.
- Target was 4 exposures per filter per year, composed of two 15 min pairs (in the same lunation for gri, several months later for zy).
- Ideally, at the end of the survey there should 12 visits per band, with a 6-dither pattern.

Single pointing point source modal depths (AB mags):

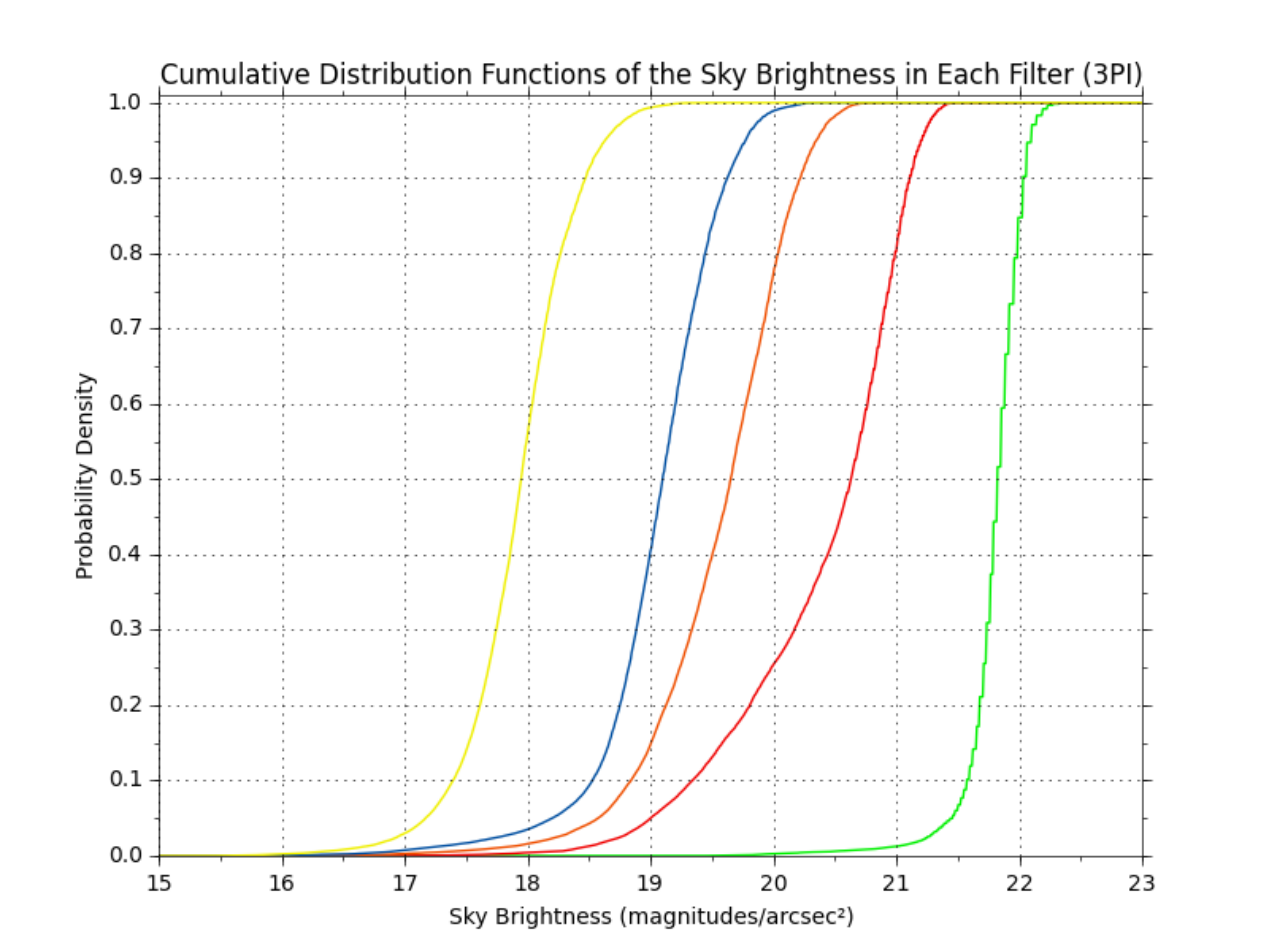
Band	5σ	Bright
g	22.0	14.5
r	21.8	15.0
i	21.5	15.0
z	20.9	14.0
y	19.7	13.0

Seeing Distribution for 3pi



	Mode	Median
g	1.18	1.31
r	1.02	1.19
i	0.96	1.11
z	0.96	1.07
y	0.96	1.02

Sky Brightness for 3π



	Mode	Ave
g	21.86	21.82
r	21.04	20.42
i	19.68	19.58
z	19.22	19.07
y	17.85	17.94

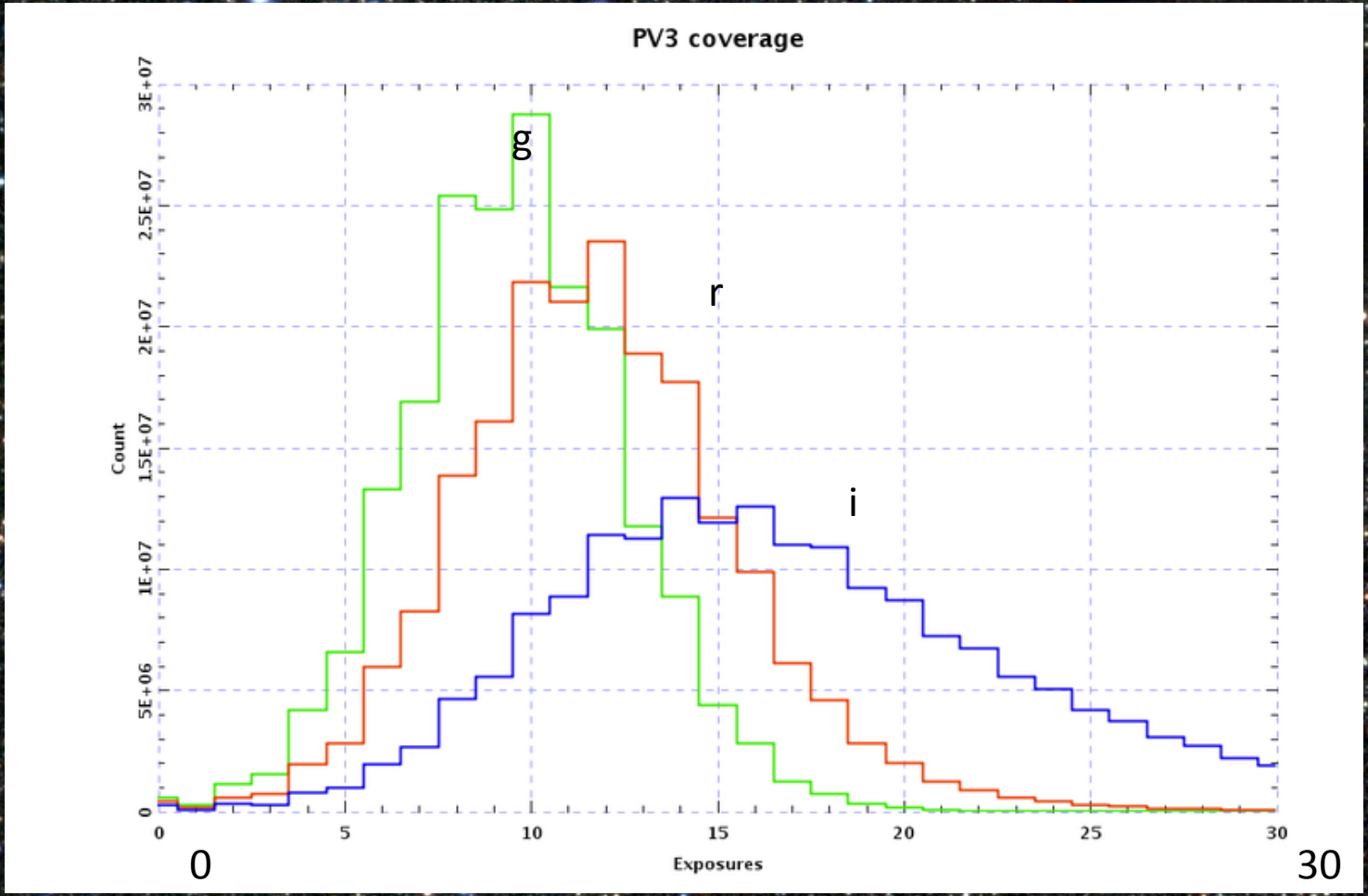
The Three π Survey

Actual coverage per pixel over the sky – the original aim was 12 pointings per filter (excluding masking):

Filter	Visits per pixel
g	9.6 +/- 3.0
r	11.8 +/- 3.8
i	17.4 +/- 6.9
z	11.2 +/- 3.0
y	11.7 +/- 3.2

The Three π Survey

Histogram of g,r,i coverage per pixel over the sky :



The Three π Survey

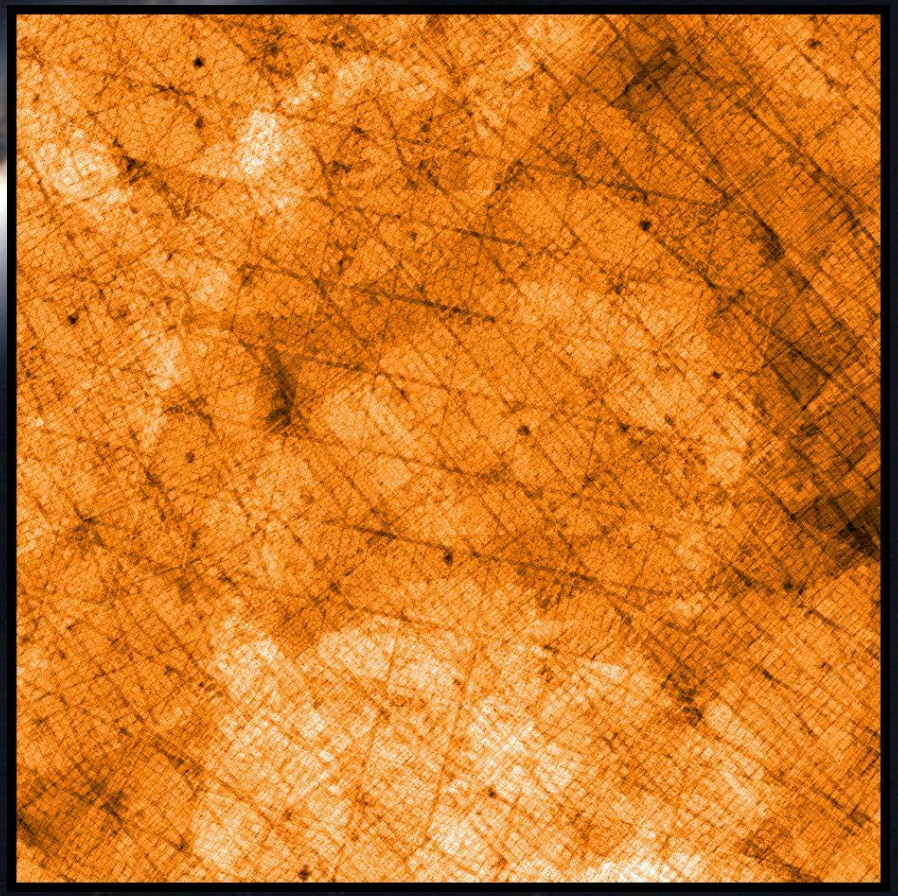
This leads us to the concept of the Static Sky, which is the PS1 weighted, stacked data release.

Filter	5σ stack
g	23.3
r	23.2
i	23.1
z	22.3
y	21.4

Median point source 5σ depth (AB mag) over the whole stacked survey (assuming the median seeing):

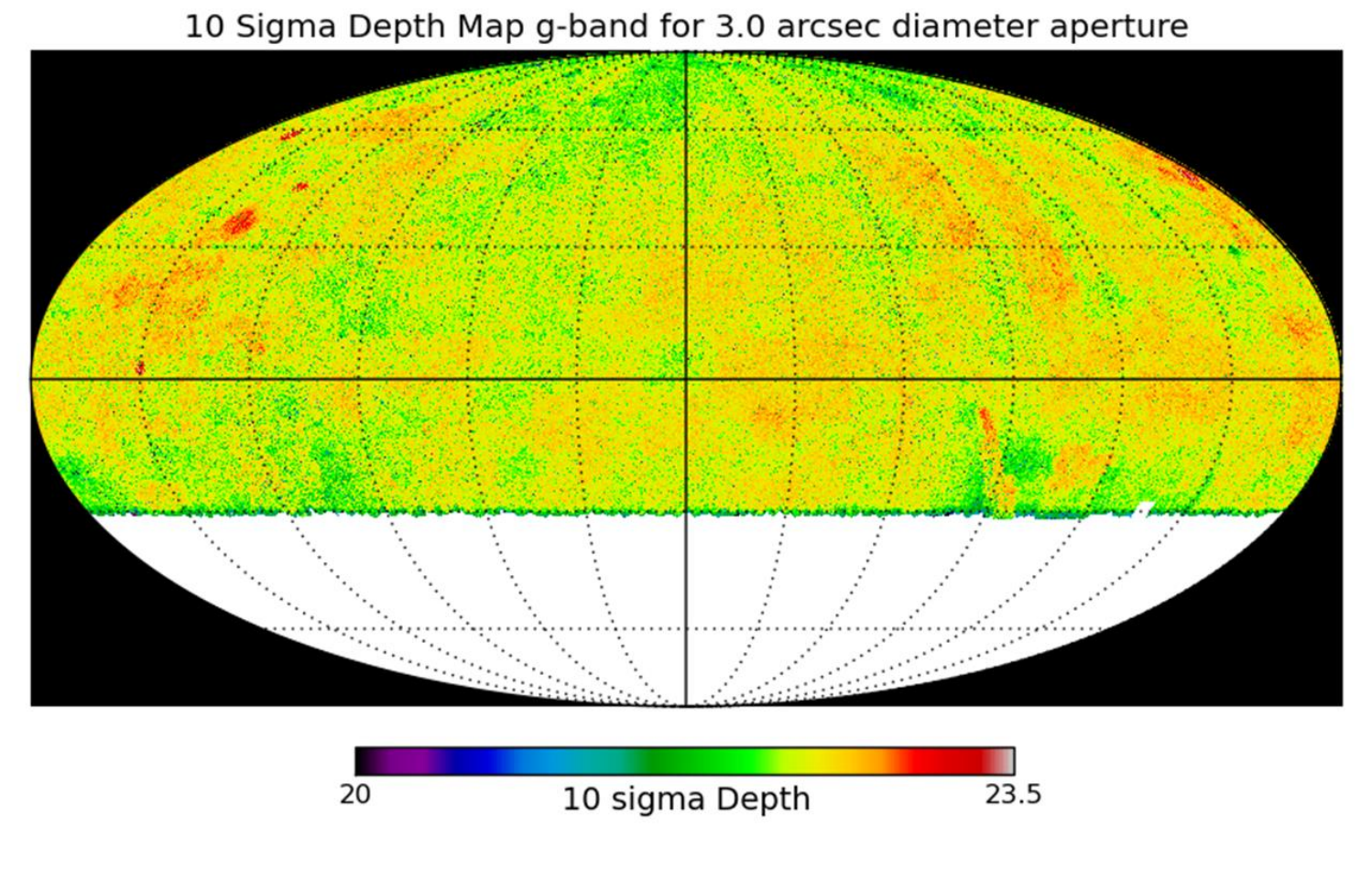
The Three π Survey

The survey coverage is very heterogeneous, especially on small scales. This is the coverage on a typical projection cell (4 deg across)

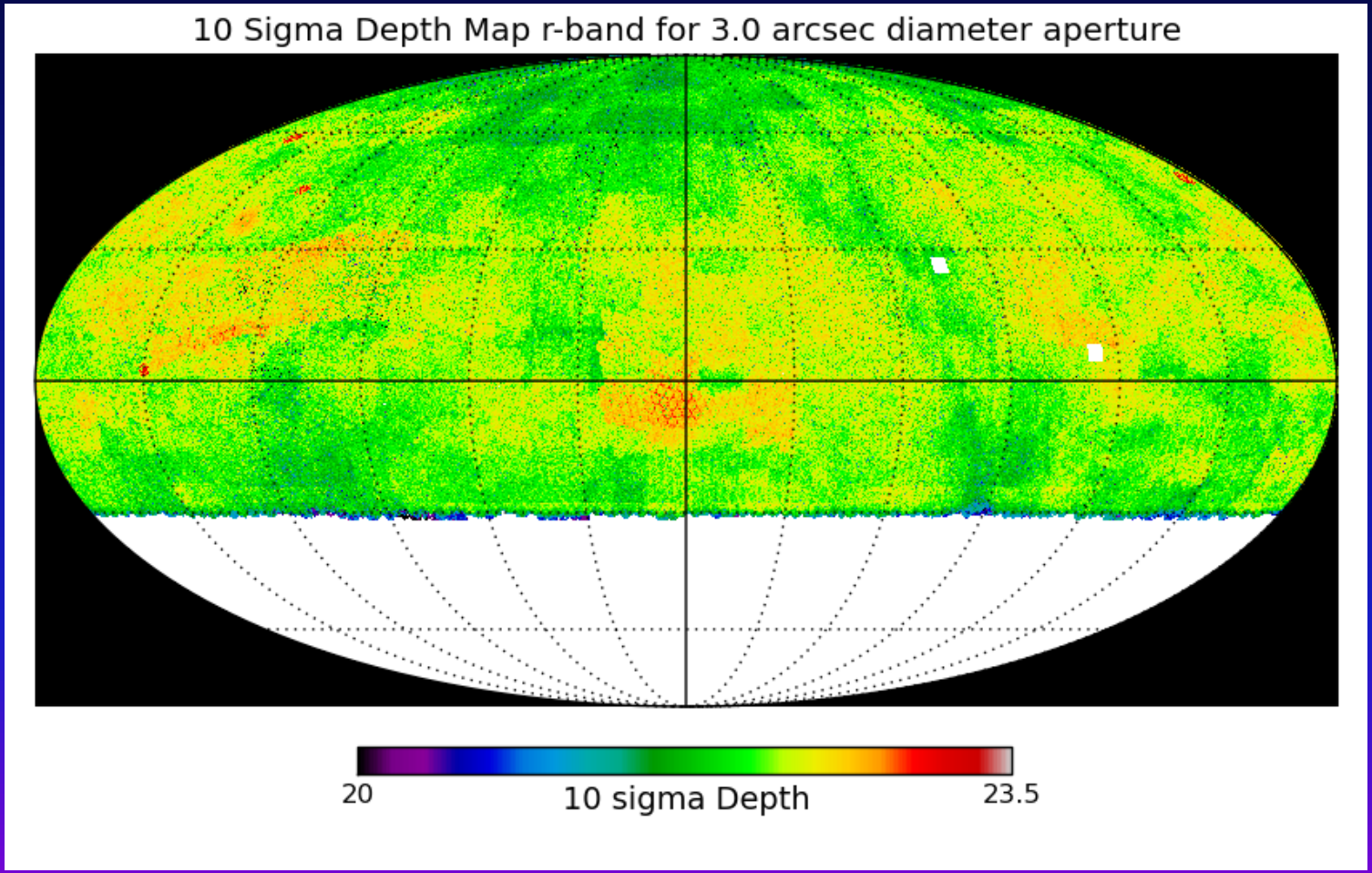


Range is 0-17, black to white

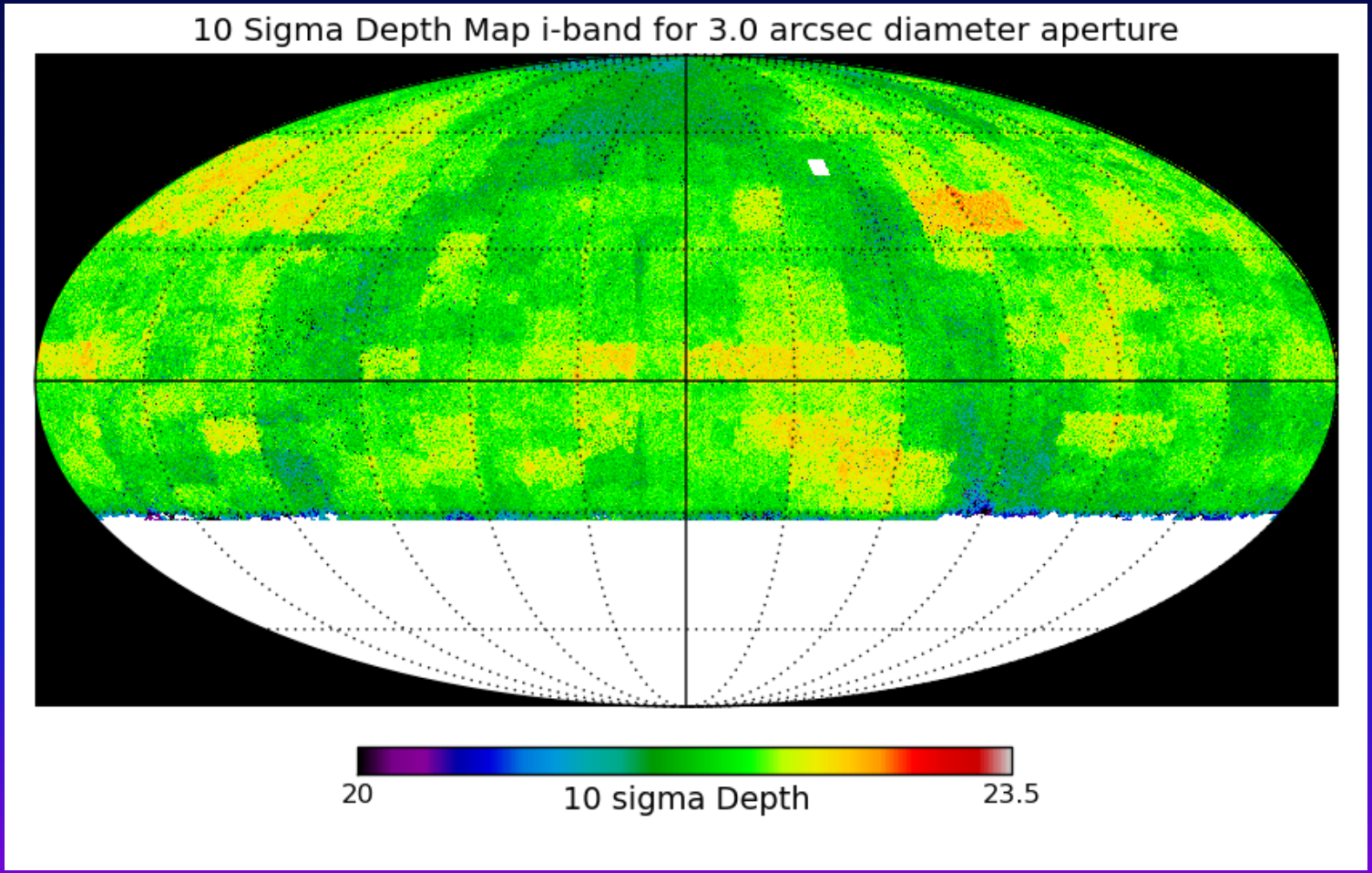
The Three π Survey



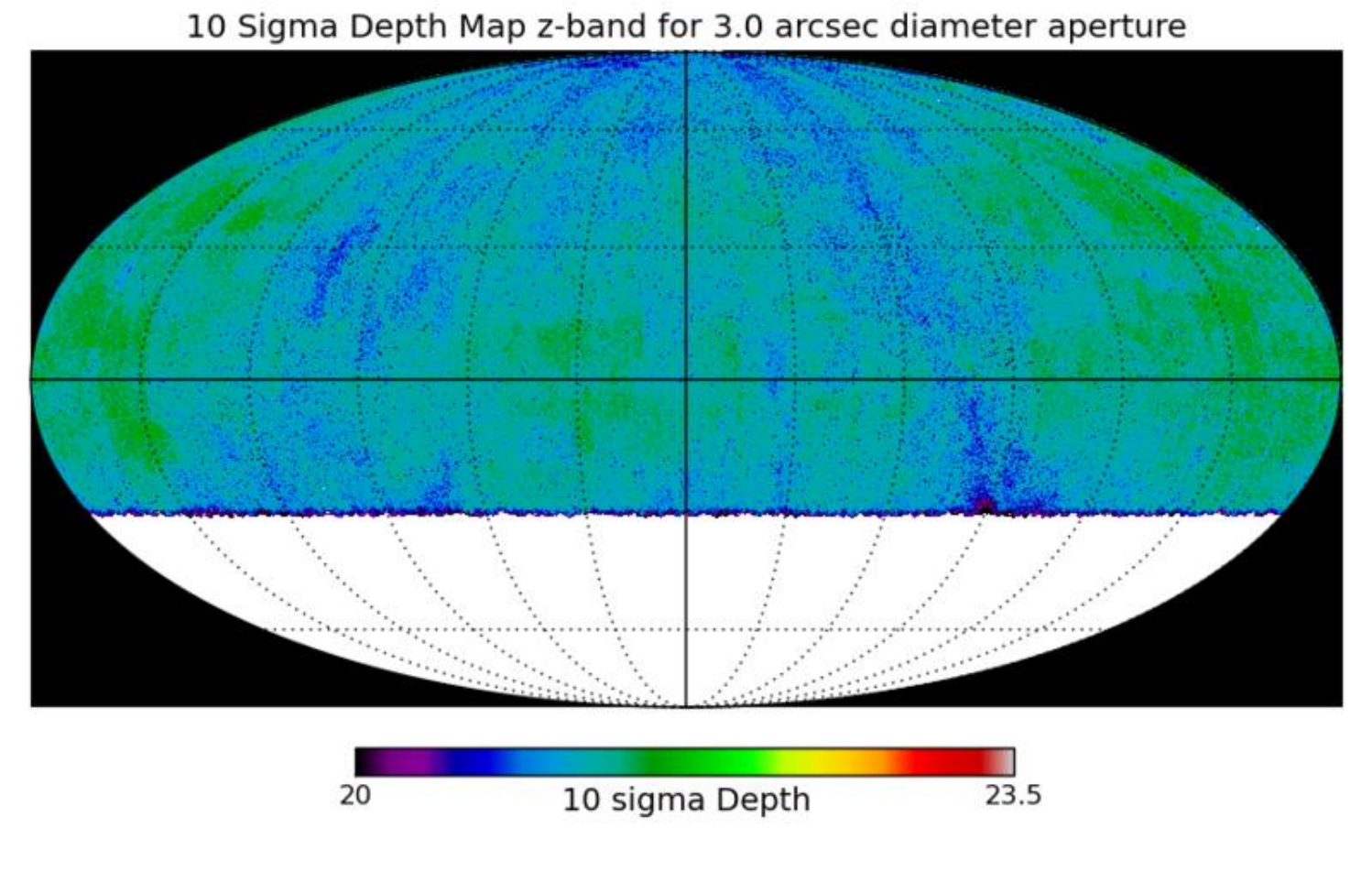
The Three π Survey



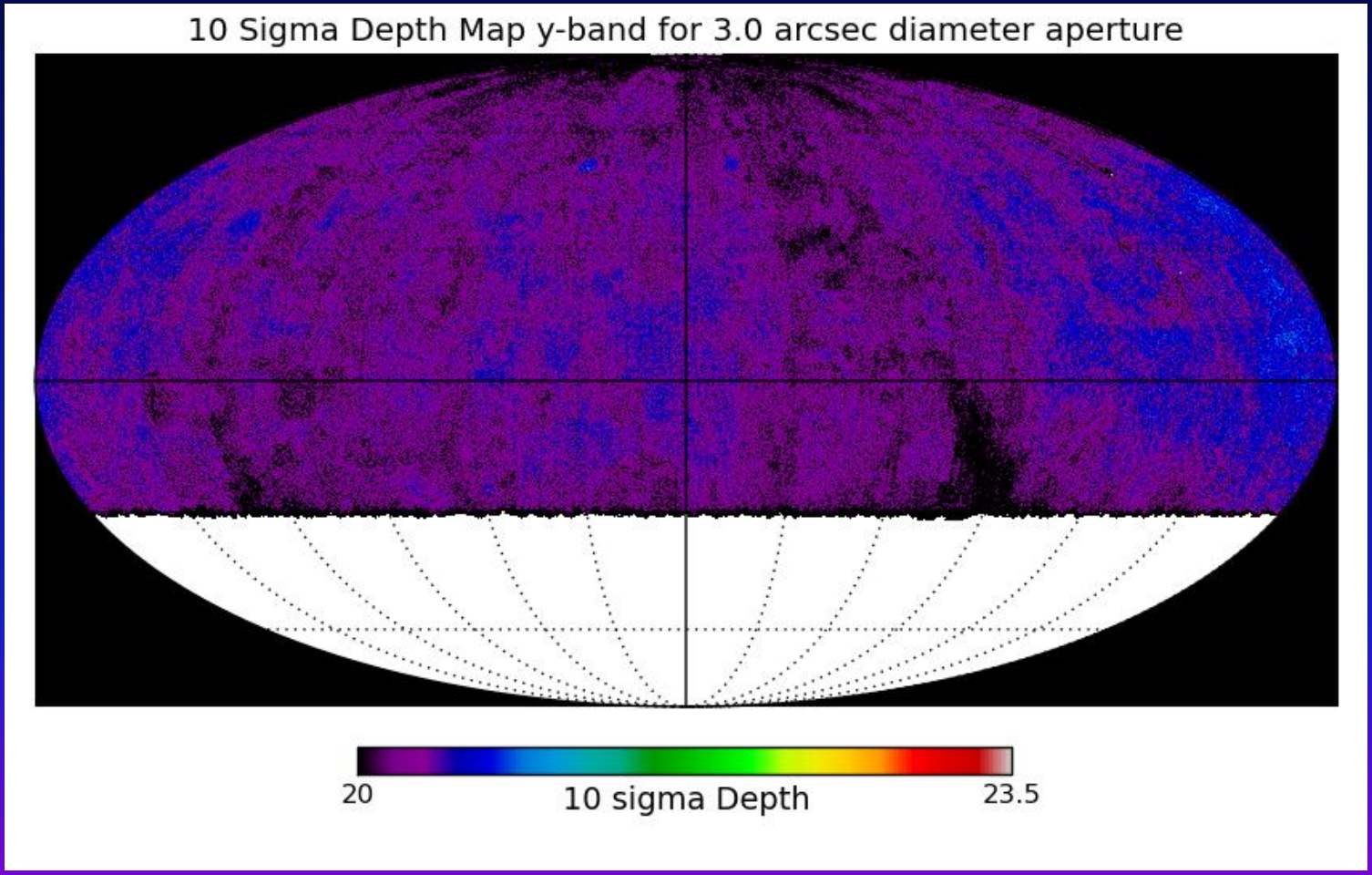
The Three π Survey



The Three π Survey

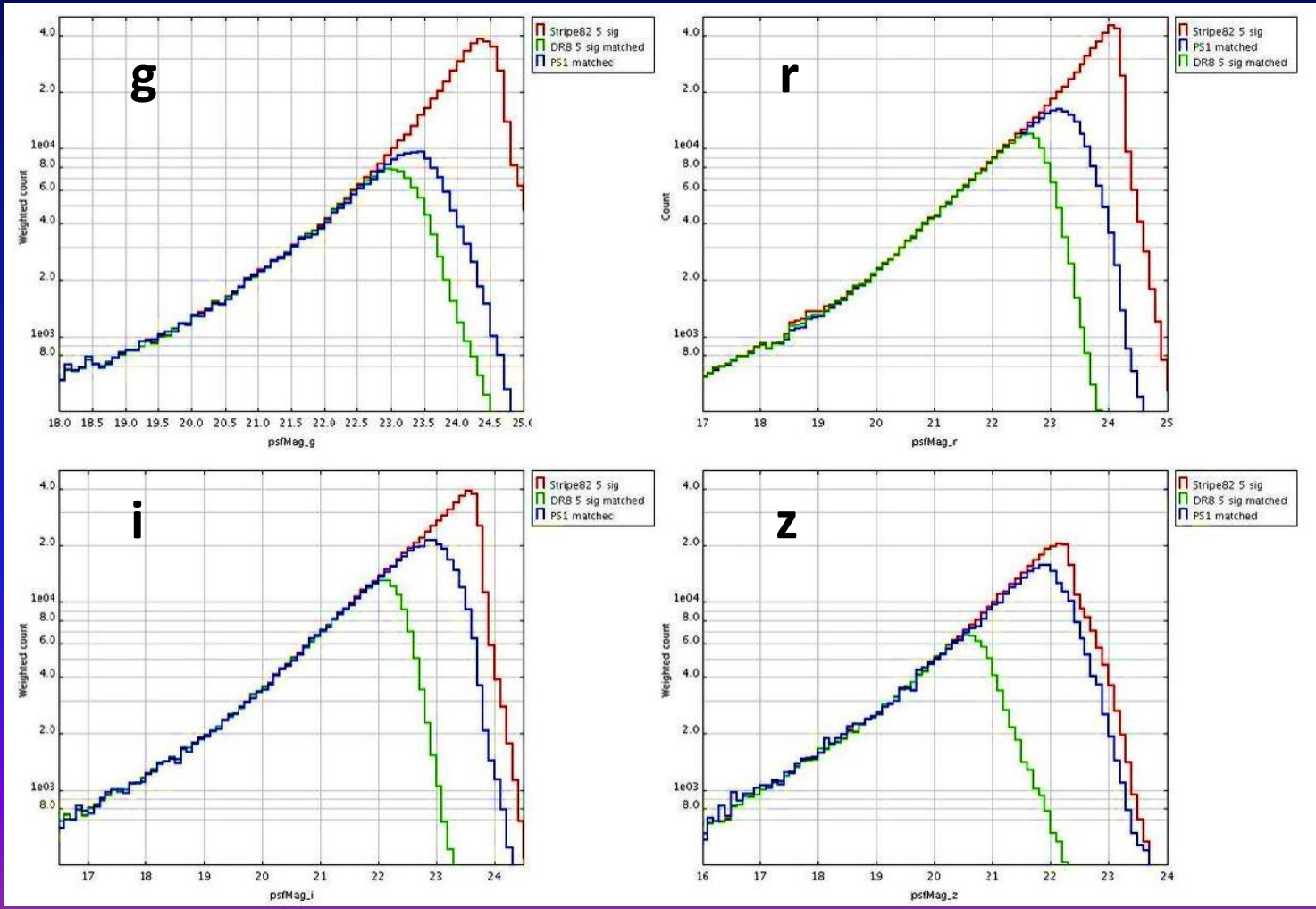


The Three π Survey



3π Depth Relative to SDSS

Note – this is the best case!

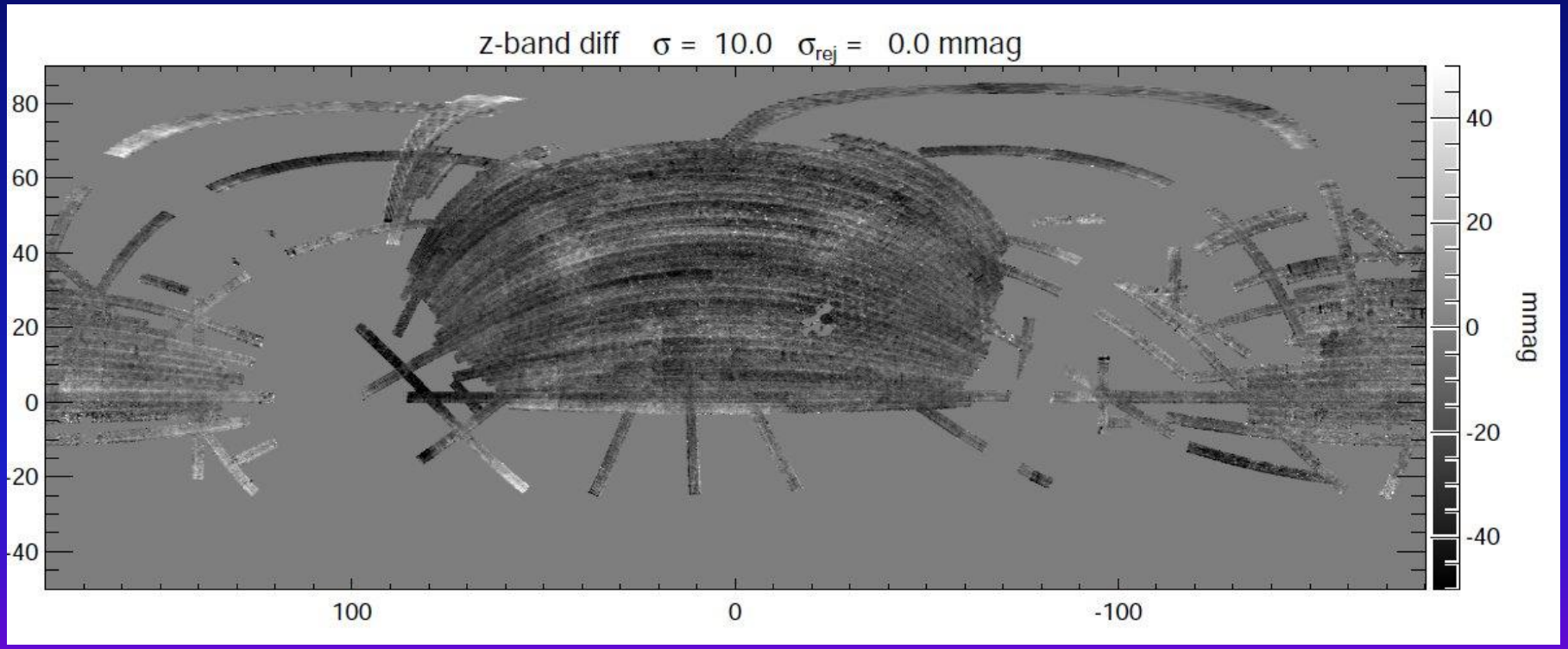


Red –Stripe82
Blue – PS1
Green – DR8

PS1 is a red sensitive instrument

3π Photometry relative to SDSS

Best calibrated optical survey ever? Shows SDSS stripe offsets at the few millimag level …



Eddie Schlafly, Doug Finkbeiner

The Medium Deep Fields

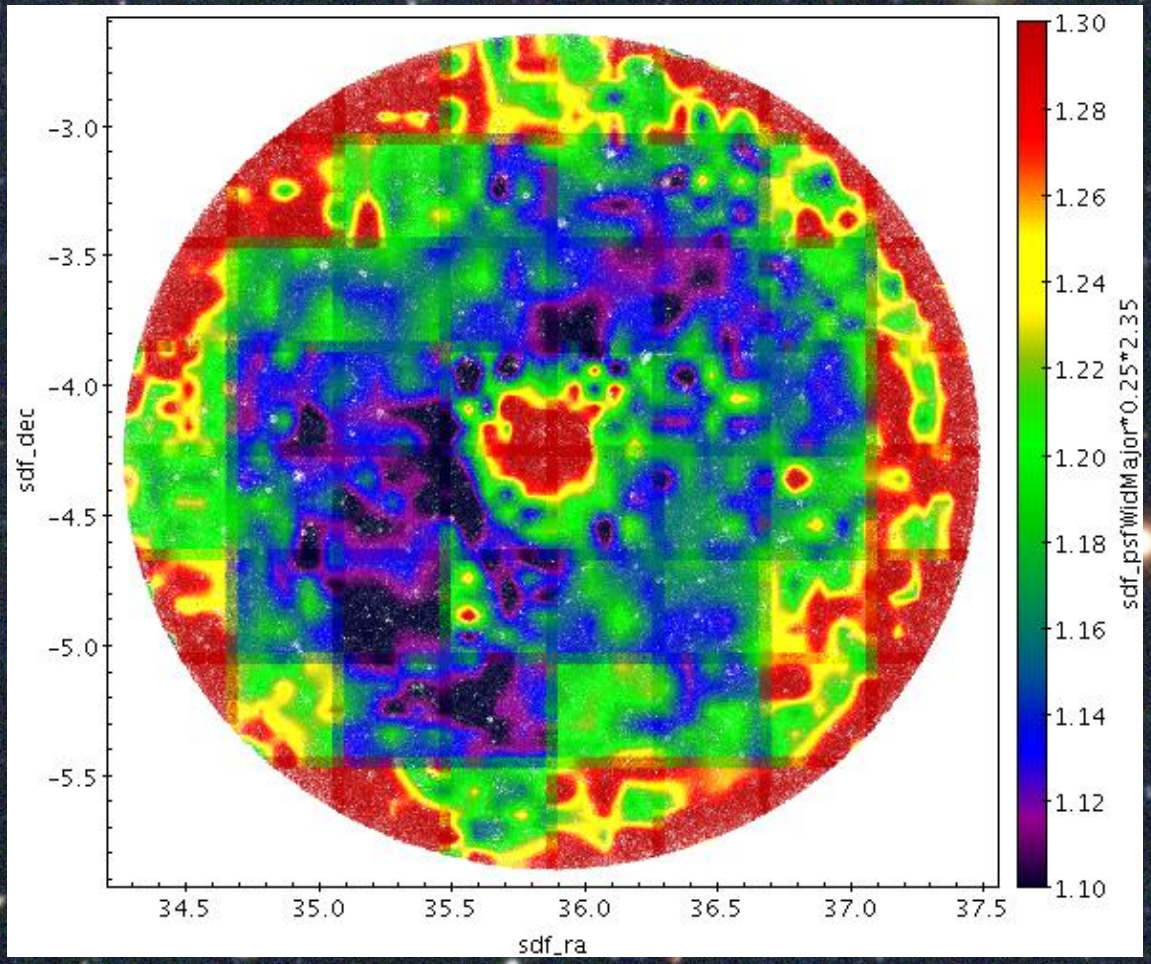
- 10 fields (single pointing) visited 8 times every night in some band , repeating every 4 days (when up – so about 6 months of the year). Result is several hundred exposures per field in each band.
- Total area around 70 sq. deg.
- Good for transients etc, but will also be available as deep stacks.
- Deepstack can be optimised for seeing. FWHM 0.9-1.4”

The Medium Deep Fields

Here are the stacked 5σ depths for the deepest 2014 stacks – public release will be similar:

MD	RA	Dec	g	r	i	z	y
01	02h 23m	-04° 15’	25.9	25.8	26.0	25.6	24.3
02	03h 32m	-27° 48’	25.6	25.4	25.8	25.3	24.1
03	08h 42m	+44° 19’	25.8	25.8	26.0	25.6	24.3
04	10h 00m	+02° 12’	25.8	25.7	25.8	25.4	24.0
05	10h 47m	+58° 05’	25.8	25.7	25.9	25.4	23.9
06	12h 20m	+47° 07’	25.8	25.6	25.9	25.3	23.9
07	14h 14m	+53° 05’	25.8	25.7	25.9	25.4	24.1
08	16h 11m	+54° 57’	25.9	25.8	26.0	25.4	24.2
09	22h 16m	+00° 17’	26.0	25.9	26.1	25.6	24.1
10	23h 29m	-00° 26’	25.9	25.8	26.1	25.6	24.1

Medium Deep Seeing

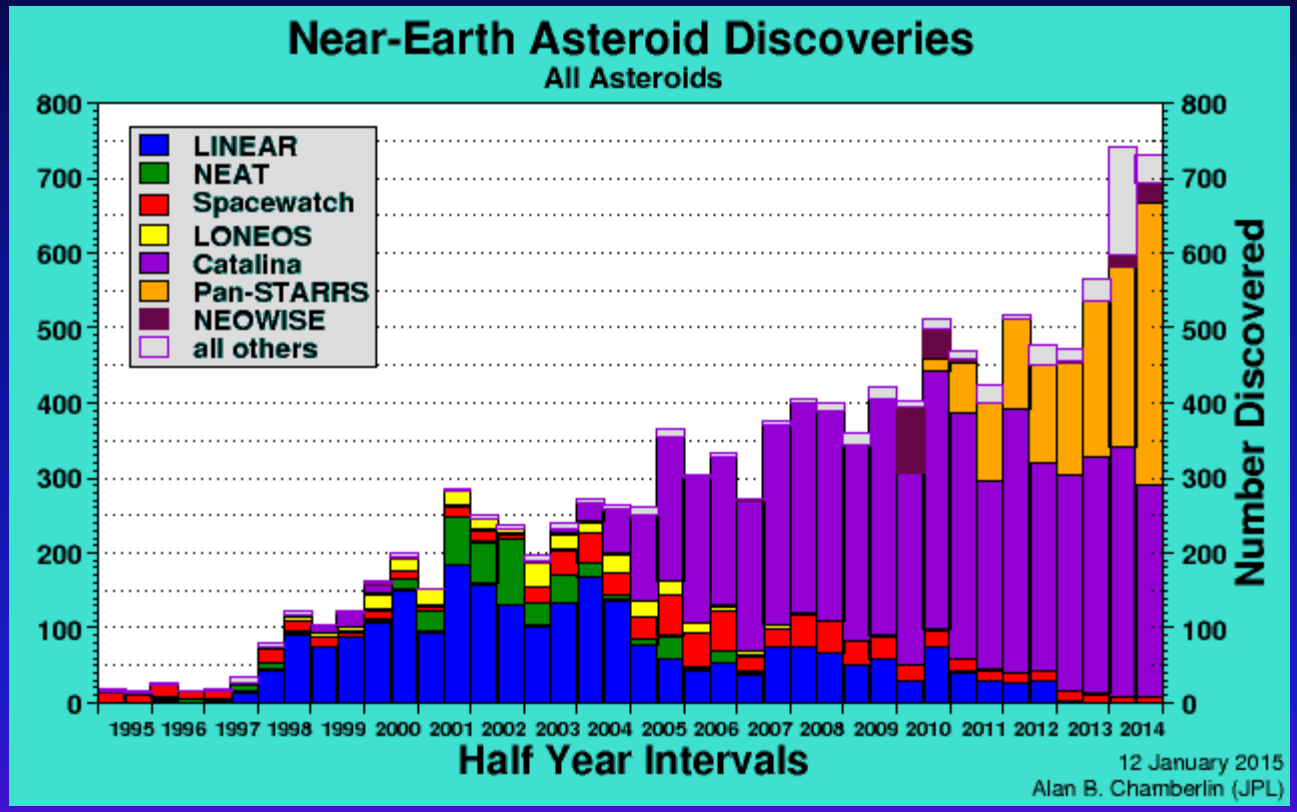


Note the ‘tent’ in the centre.

FWHM also goes off towards the edge.

PS1 successes

- PS1 continues to discover Near Earth Asteroids ….

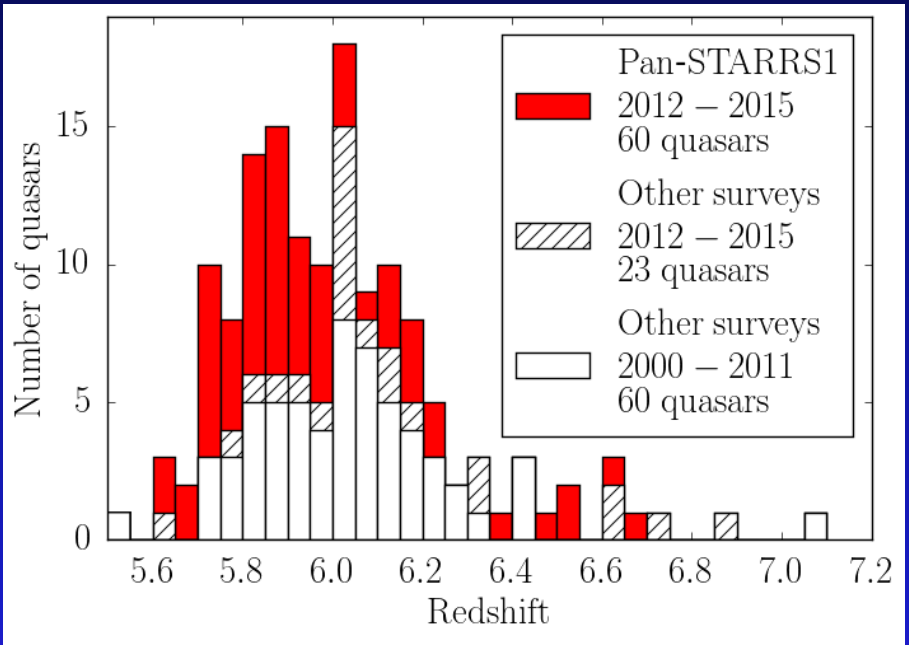


- PS1 has over 50% of the comet discoveries since 2014 (49/94).

Denneau et al. (2013) - MOPS

PS1 successes

- PS1 continues to discover high redshift QSOs:



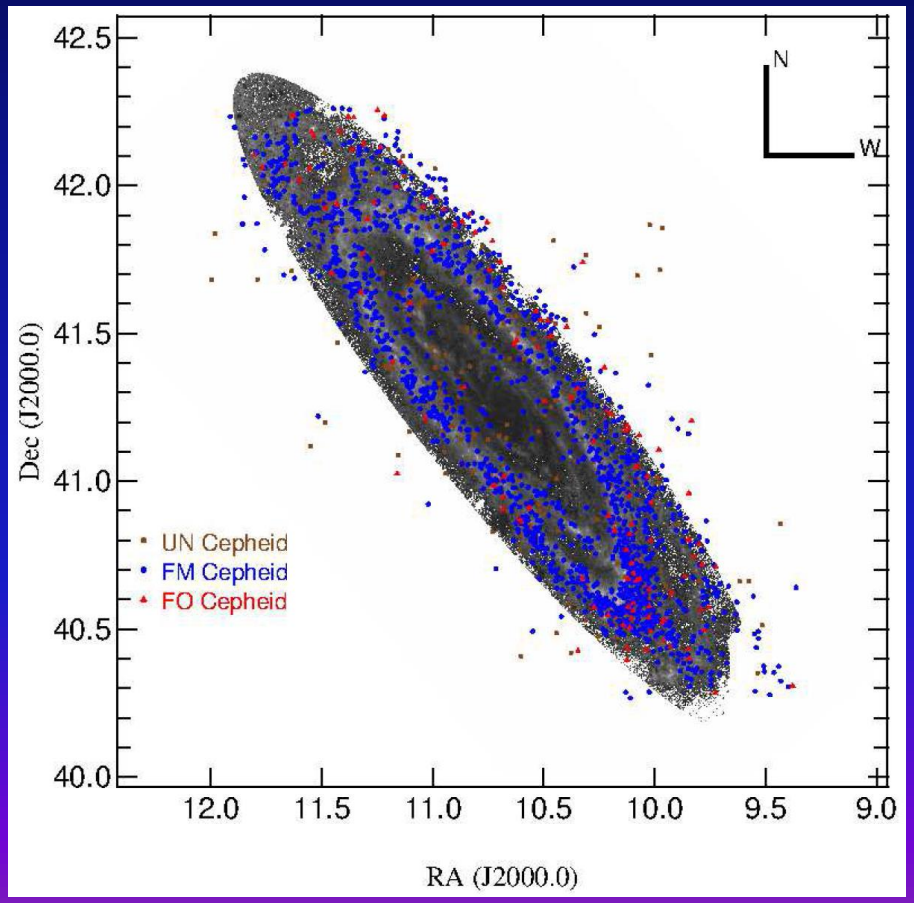
- PS1 has basically doubled the number of such quasars known.

Banados et al (2014)

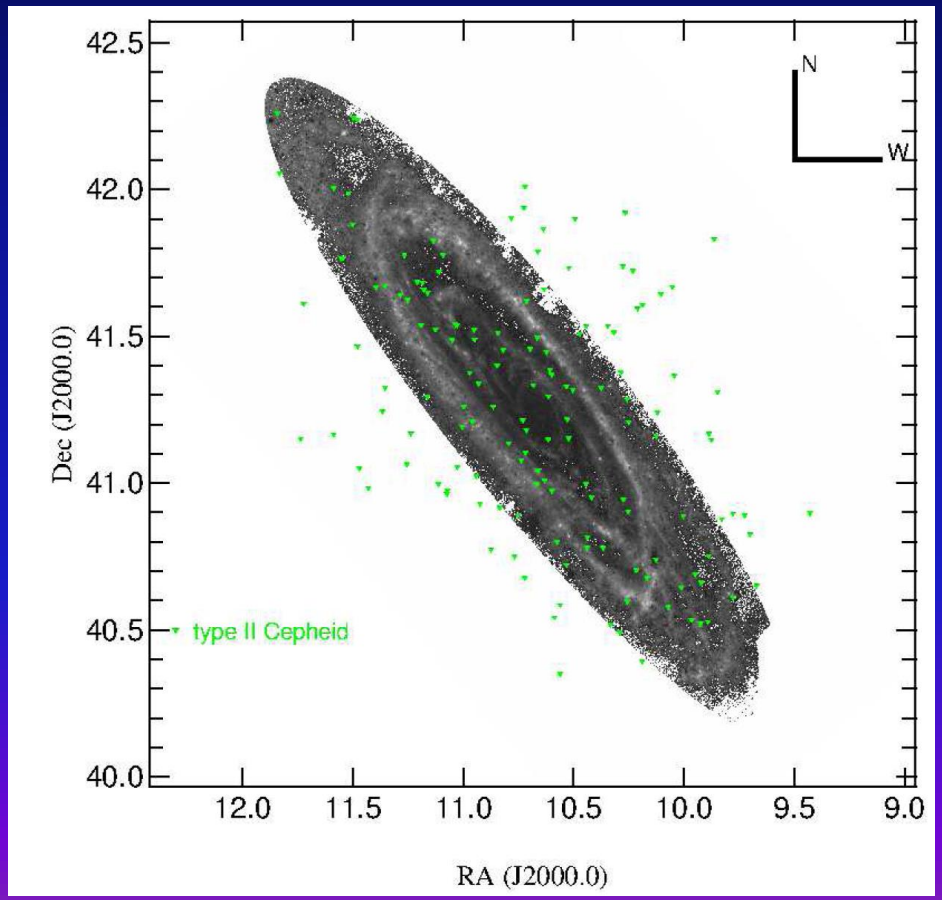
PS1 successes

Nearly 2000 M31 Cepheids – Spatial Distribution

Type I Cepheids trace the spiral arms,



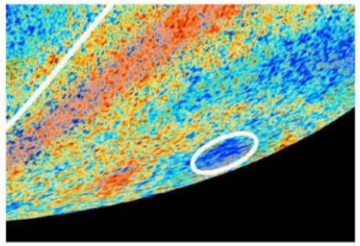
Type II Cepheids trace the halo

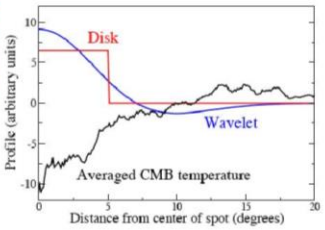


Kodric et al. (2013)

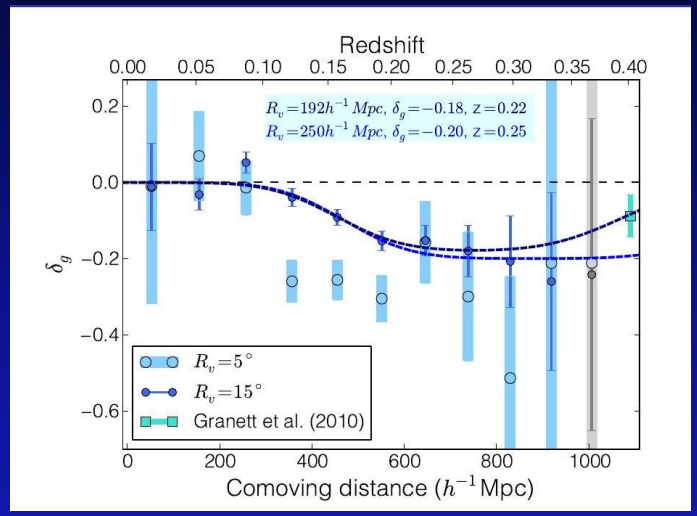
PS1 successes

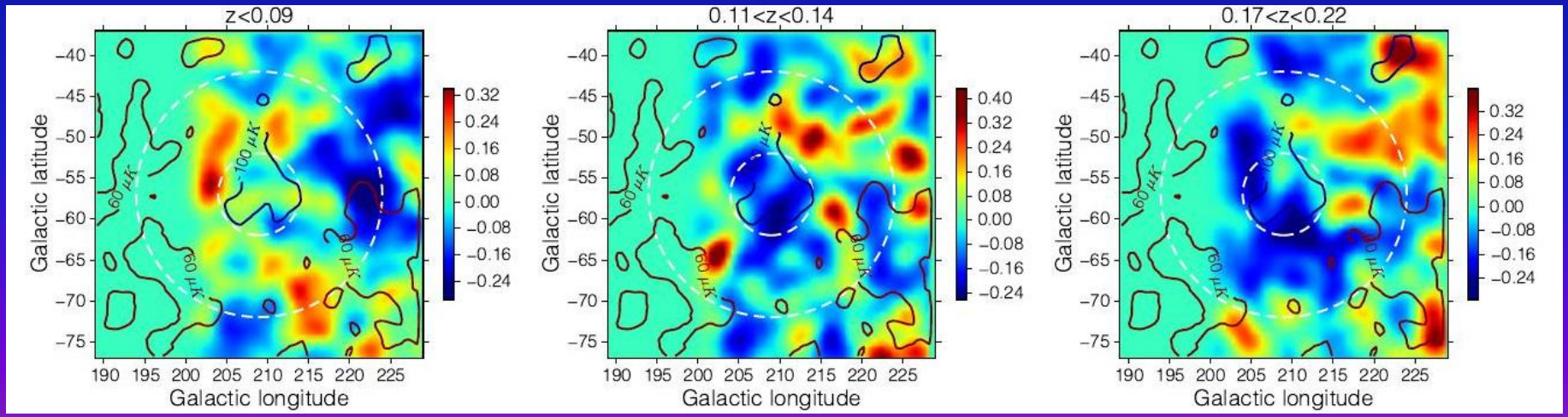
Large scale structure : The CMB cold spot





- Discovered in WMAP data and confirmed by Planck
- Cold Spot 0.5% unlikely (Cruz et al. 2006), $\Delta T \simeq -70\ \mu K$
- extends at least 5°, and up to 15° on the CMB
- explanation ranges from textures to statistical fluke
- Inoue & Silk (2007): $200 h^{-1}\mathrm{Mpc}$ void with $\delta = -0.3$ via linear ISW (at redshift $z \approx 1$)





Kovacs et al. (2014)

Data Products

Catalogues – access via SQL server – PS1 has the concept of detections and objects:

- Individual detections (~3.5 x10^{10}) – grouped into “objects”.
- Stacked objects (~8x10^{9})
- Forced individual detections (for objects found on stack)
- Difference detections

For all you will get:

- PSF magnitude (fit to model PSF)
- Total aperture-based magnitude (better for stars on stacks)
- Kron magnitude
- Assorted radial moments
- Circular radial aperture mags (in SDSS radii, starting at 1”)

Data Products

For a s/n and galactic latitude limited subset of objects you will also get:

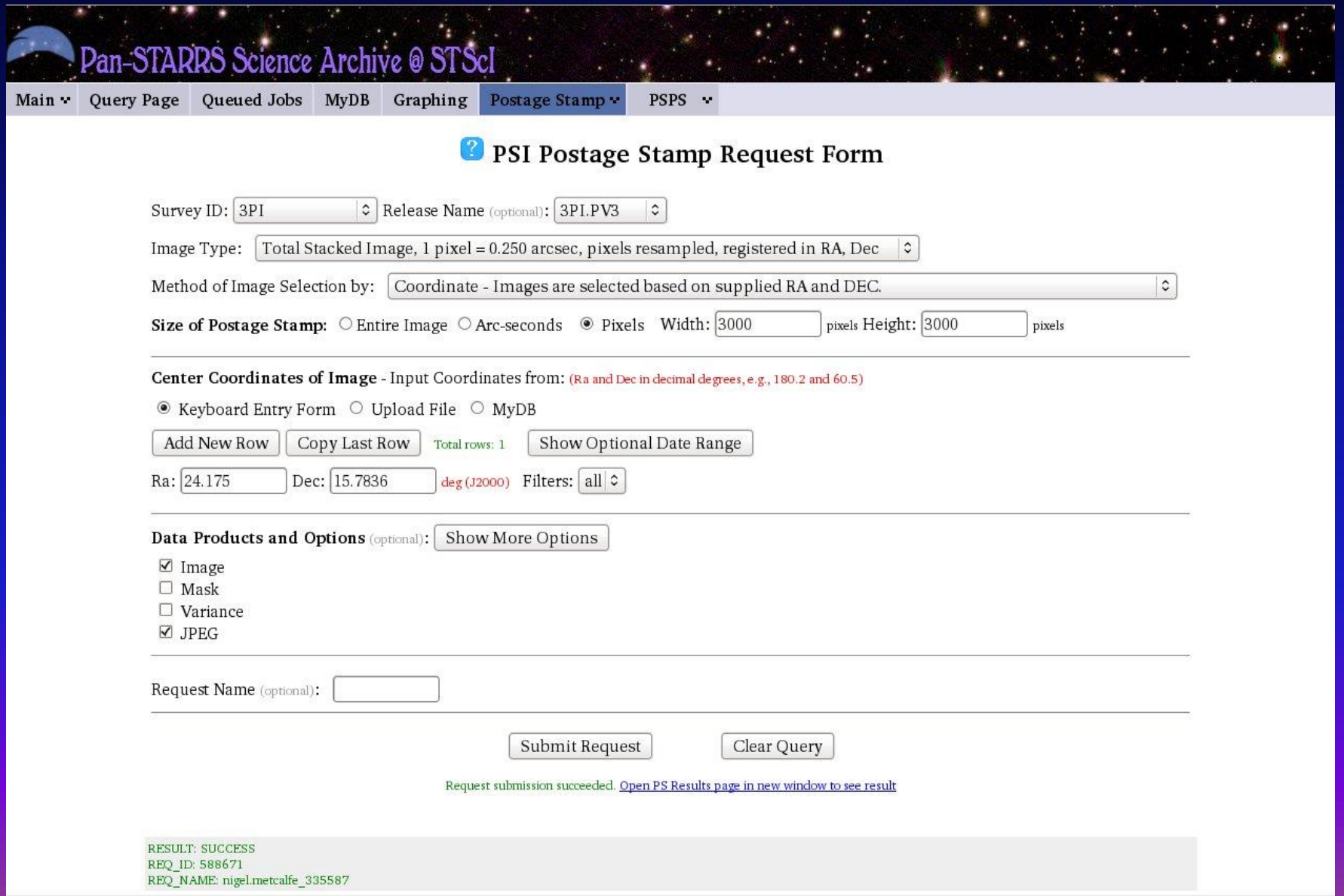
- Petrosian magnitudes/radii
- DeVaucoulers/Exponential/Sersic mags/radii
- Elliptical aperture mags, asymmetry parameters

Images:

- Stacks, exposures as FITS files, with WCS and zeropoints.
- Also variance and mask files
- Note: up to one skycell in size, no mosaicing

All will be accessed via an interface at STScI

Data Products



Data Products

Pan-STARRS Science Archive @ STScI

Main | Query Page | Queued Jobs | MyDB | Graphing | Postage Stamp | PSPS

PS Request List

Submitted After (yyyy-mm-dd): Submitted Before (yyyy-mm-dd): Refresh

Request List

First Prev 1 Next Last [Total: 1]

Action	req_id	req_name	state	numRows	numJobs	Sub
Delete	588671	nigel.metcalfe_335587	stop	1	5	2015-06

First Prev 1 Next Last [Total: 1]

Job List for Request: 588671 [Display data store results set: PS1SC institutions only]

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none	80603395	1	stop	0		stack	4088345	y	skycell.1596.095
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File List for Job: 80603397

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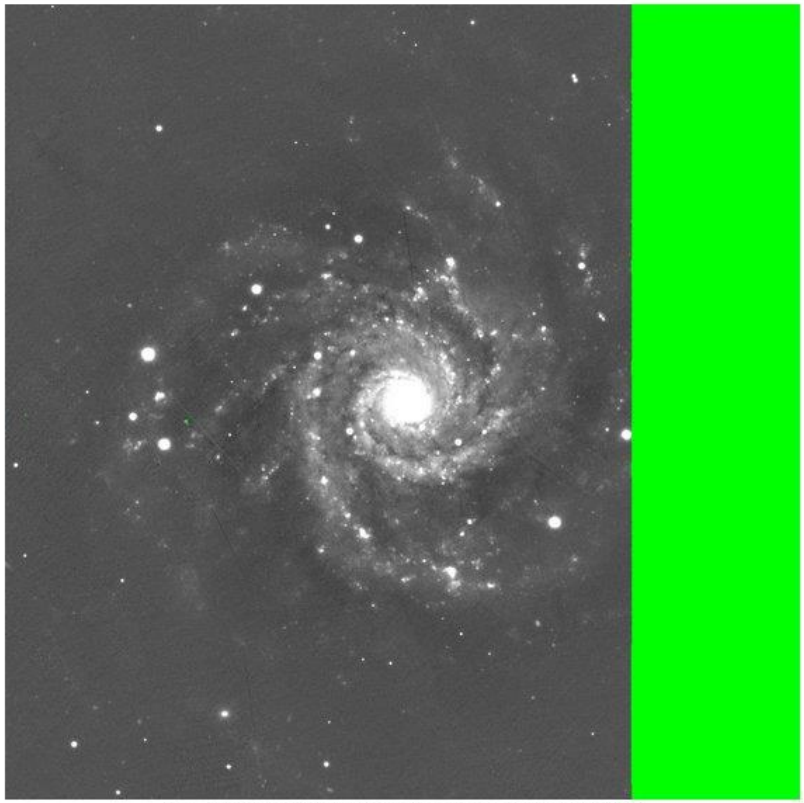

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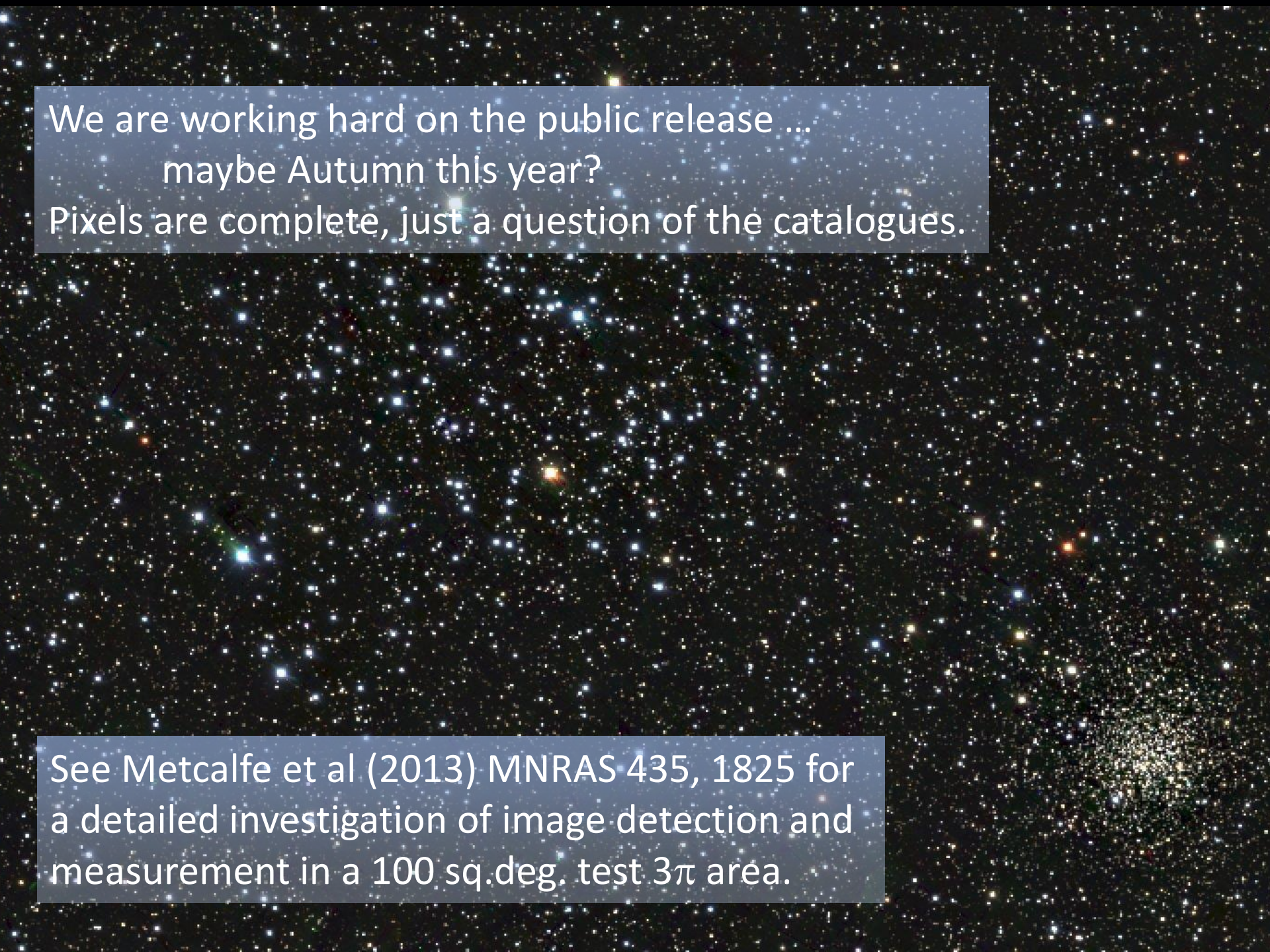
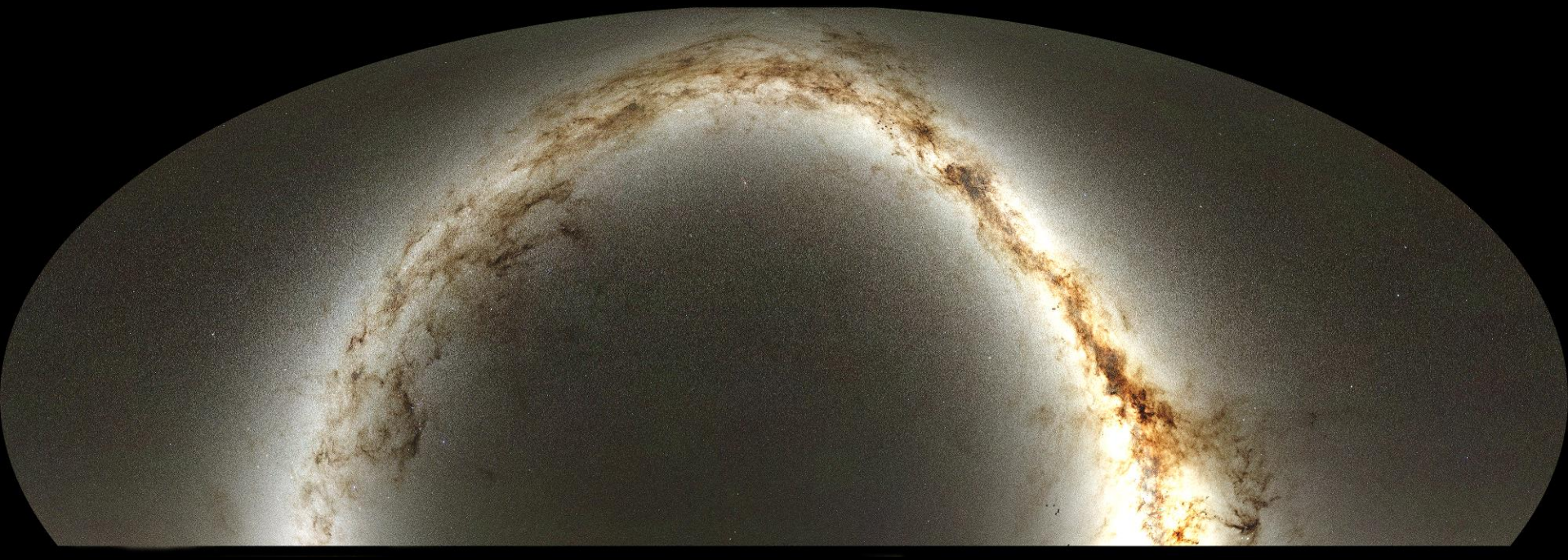


We are working hard on the public release …
maybe Autumn this year?
Pixels are complete, just a question of the catalogues.

See Metcalfe et al (2013) MNRAS 435, 1825 for a detailed investigation of image detection and measurement in a 100 sq.deg. test 3π area.

The PS1 Sky



This is a gri colour image of the whole 3π survey
(thanks to Danny Farrow, MPE)