Large Scale Structure with Pan-STARRS .

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Outline

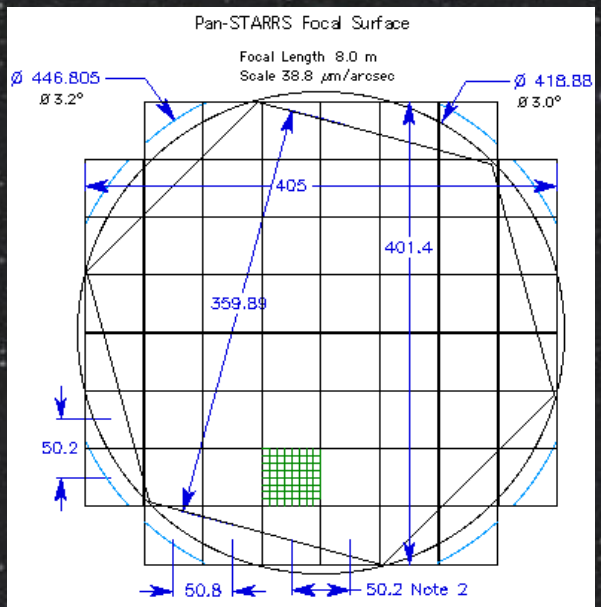
The Pan-STARRS telescope and surveys
Survey Status
Photometry and Zeropoints
Clustering in SAS2
Photometric redshifts
Galaxy Clusters
Conclusions

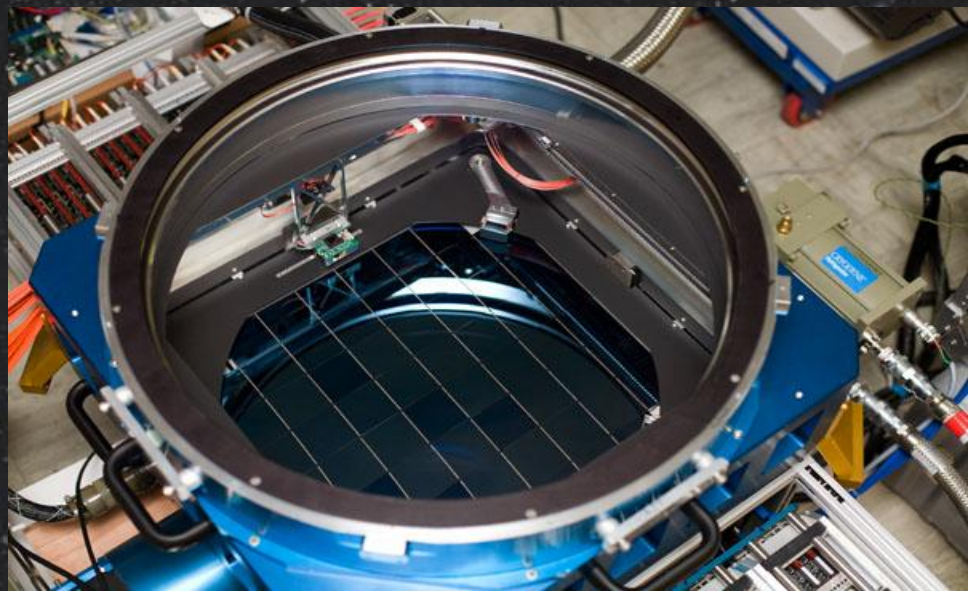
Pan-STARRS

(Panoramic Survey Telescope and Rapid Response System)

1.8m mirror on Haleakala, Maui

- Optics delivers a 3° field of view
- PSF sampling is 0.26”
- 60 CCDs
- Each CCD is composed of 64 cells, each of 600x600 pixels (=>1.4 Gpixels)
- Each cell can be read out separately in 7 sec with 6e read noise





PS1 Mission

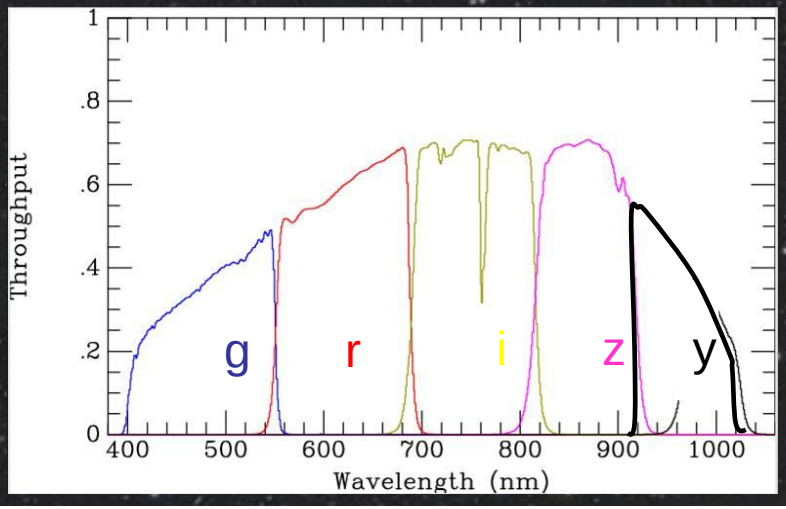
Table 2: *The PS1 Mission Concept Surveys and time distribution.*

PS1 Surveys	Filters	Percent time
3 π Steradian Survey	g, r, i, z, y	56
Calibration Fields	g, r, i, z, y	2
Medium Deep Survey	g, r, i, z, y	25
Solar System "Sweet Spot" Survey	r	5
Stellar Transit Survey -"PanPlanets"	i	4
Microlensing in M31 "Pandromeda" Survey	g, r, i, z, y	2
Principal Investigator Discretionary Time		6

data flow: 50Tbytes/month

The 3π Survey

- Survey the entire visible sky (from Hawaii)
- In five filters



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
g	405–550	24.90	21.90	60	23.06	23.24	2	4	12
r	552–689	25.15	20.85	38	22.62	22.70	2	4	12
i	691–815	25.00	20.15	30	22.48	22.59	2	4	12
z	815–915	24.63	19.26	30	21.53	21.59	2	4	12
y	967-1024	23.03	17.98	30	210.07	20.12	2	4	12

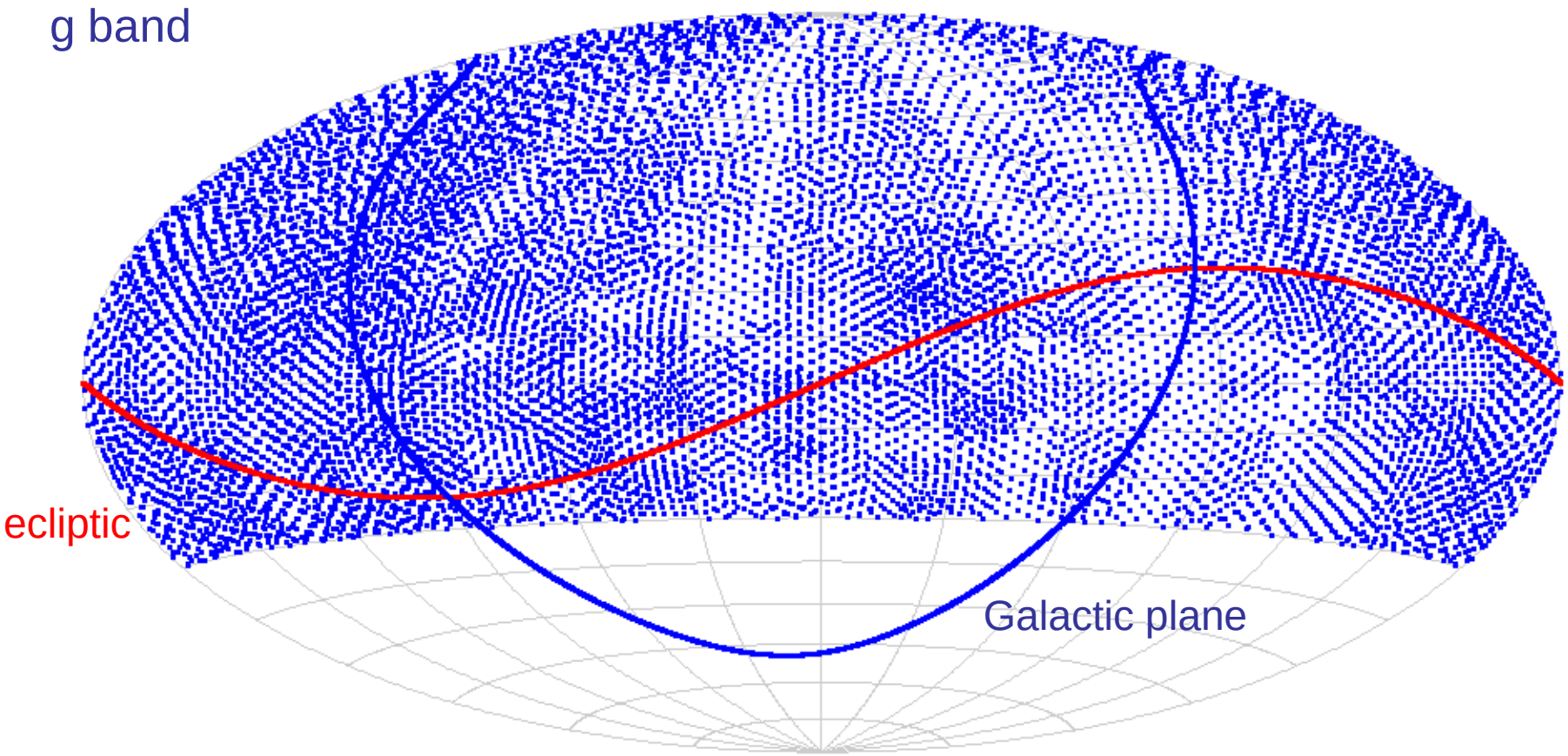
PS1SC

The Medium Deep Survey

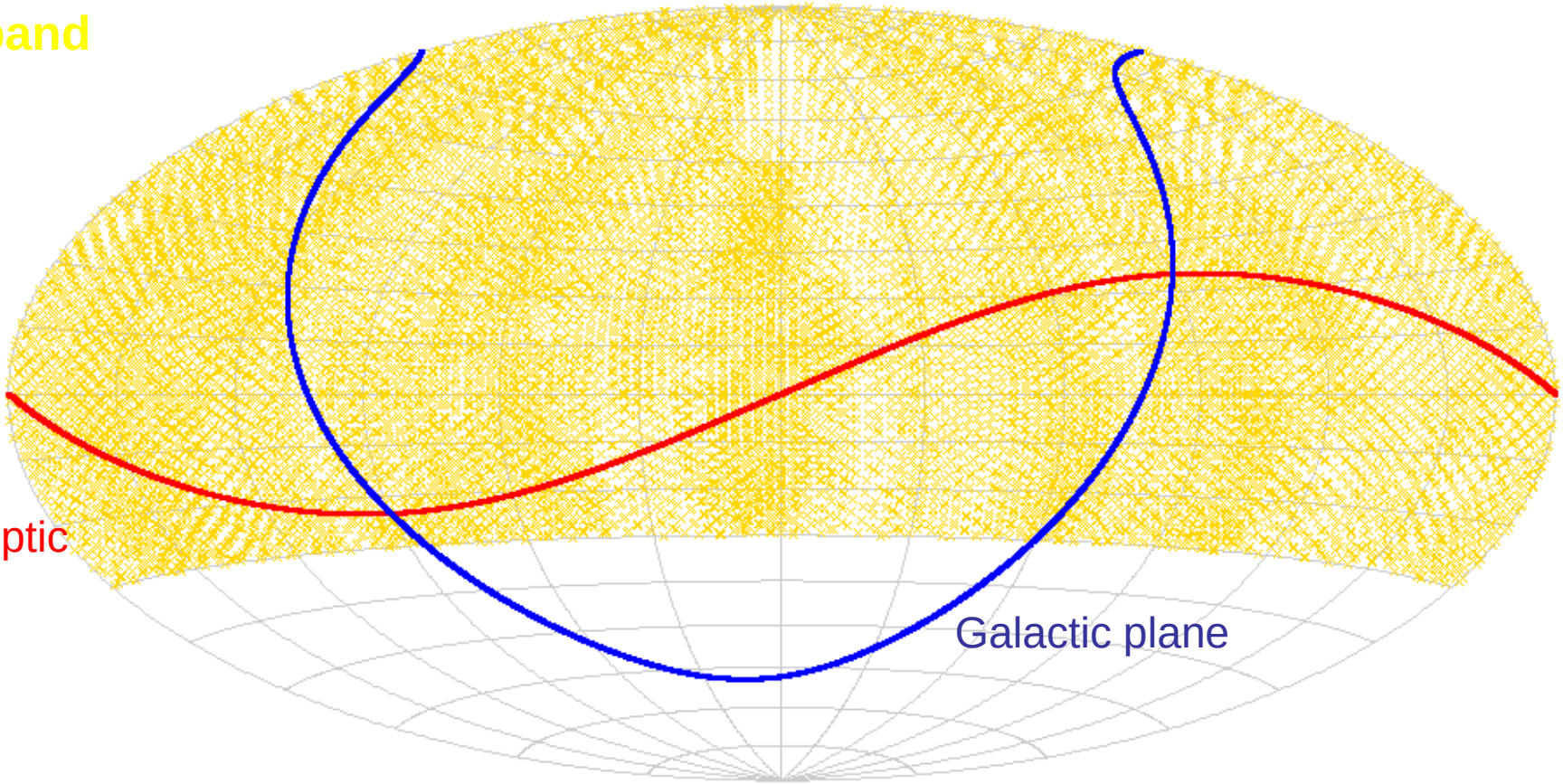
- 10 GPC1 footprints distributed uniformly across the sky (optimized SNIa studies)

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

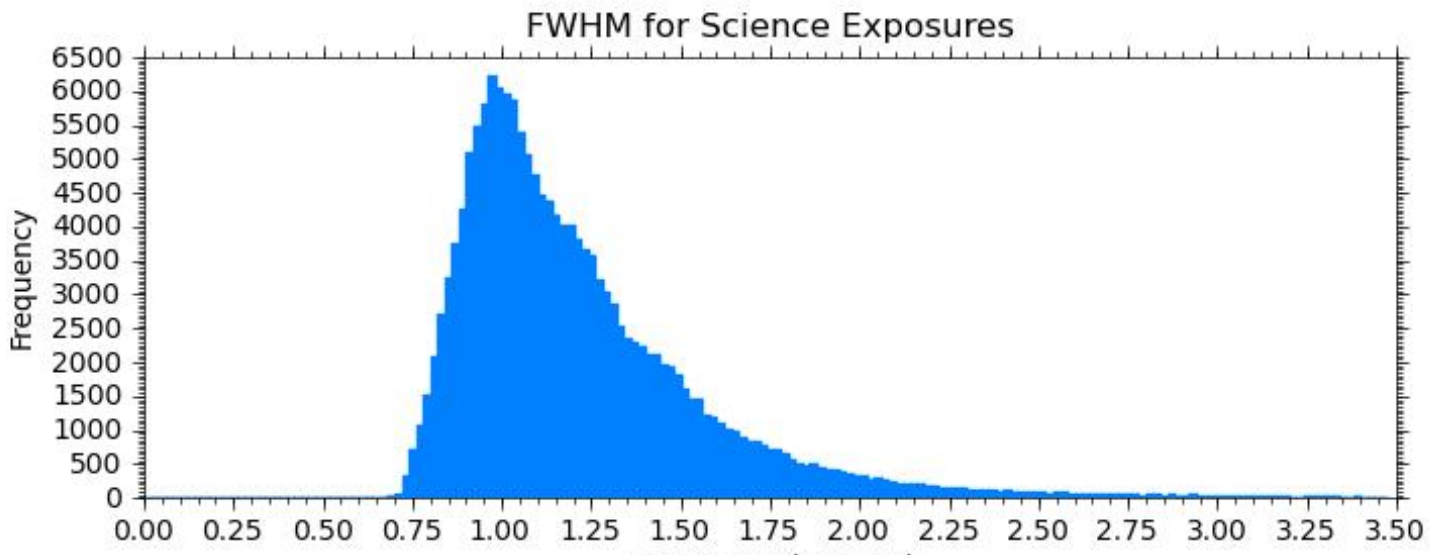
3π sky coverage to Jan1, 2012



3π sky coverage to Jan 1, 2012



Observing Metrics: 13 May 2010 to 1 Jan 2012



Data Quality Statistics:

	Average	Median	Mode	Min	Max
ZL DIMM	1.02	0.85	0.66	0.21	3.50
PS1 FWHM	1.22	1.13	0.96	0.60	3.50*

Key Projects

1. Populations of objects in the Inner Solar System
2. Populations of objects in the Outer Solar System
3. Low-Mass Stars, Brown Dwarfs, and Young Stellar Objects
4. Search for Exo-Planets by dedicated Stellar Transit Survey
5. Structure of the Milky Way and the Local Group
6. A Dedicated Deep Survey of M31
7. Massive stars and supernova progenitors
8. Cosmology Investigations with Variables and Explosive Transients
9. Galaxy Properties
10. Active Galactic Nuclei and High Redshift Quasars
11. Cosmological Lensing
12. Large Scale Structure

Ubercalibration

Finkbeiner and Schlafly

The photometric model:

$$N = K f$$

A star of flu

(Aperture, throughpu
Magni

m

Where f_0 is AB

m

and is r

r

We refer to Z as the zero
of these for an exposure

The photometric model:

More specifically, we write Z in terms of the photometric parameters as:

System throughput on night *n*

Flat for season *i*

$$Z = a_n - k_n x + f_i + w(F)$$

Atmospheric transparency on night *n*

Airmass of observation

Quadratic correction for FWHM

Parameter	Number	Note
a	~ 200	system (nightly)
k	~ 200	atmosphere (nightly)
f	$4 \times 60 \times 4$	illumination correction
w	2	FWHM correction (quadratic)

1.2 Residuals of photometric model

By using a rigid photometric model (one a,k per night) we assume the site, camera, etc. are stable over the course of a night. How good is this assumption?

- For each star in each exposure, compute

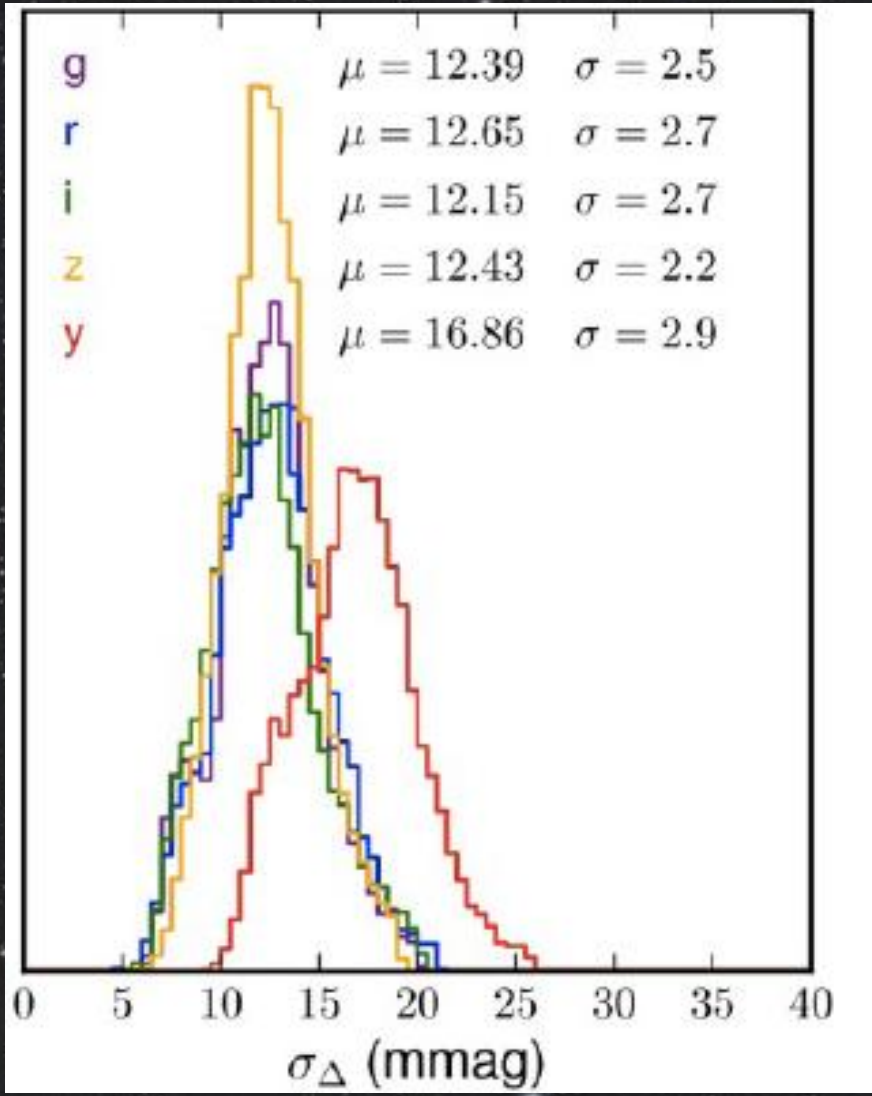
$$\Delta = m - \overline{m}$$

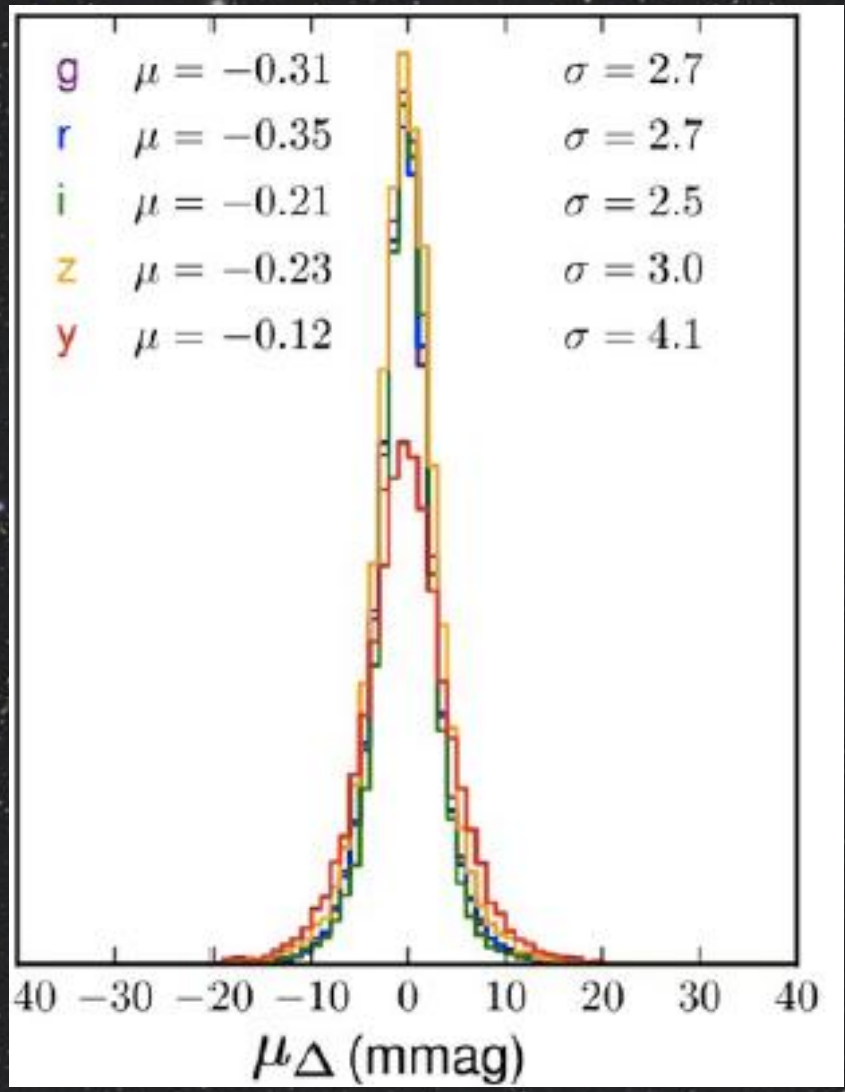
- Compute the mean and standard deviation of these *for each exposure*:

$$\mu_\Delta \text{ and } \sigma_\Delta$$

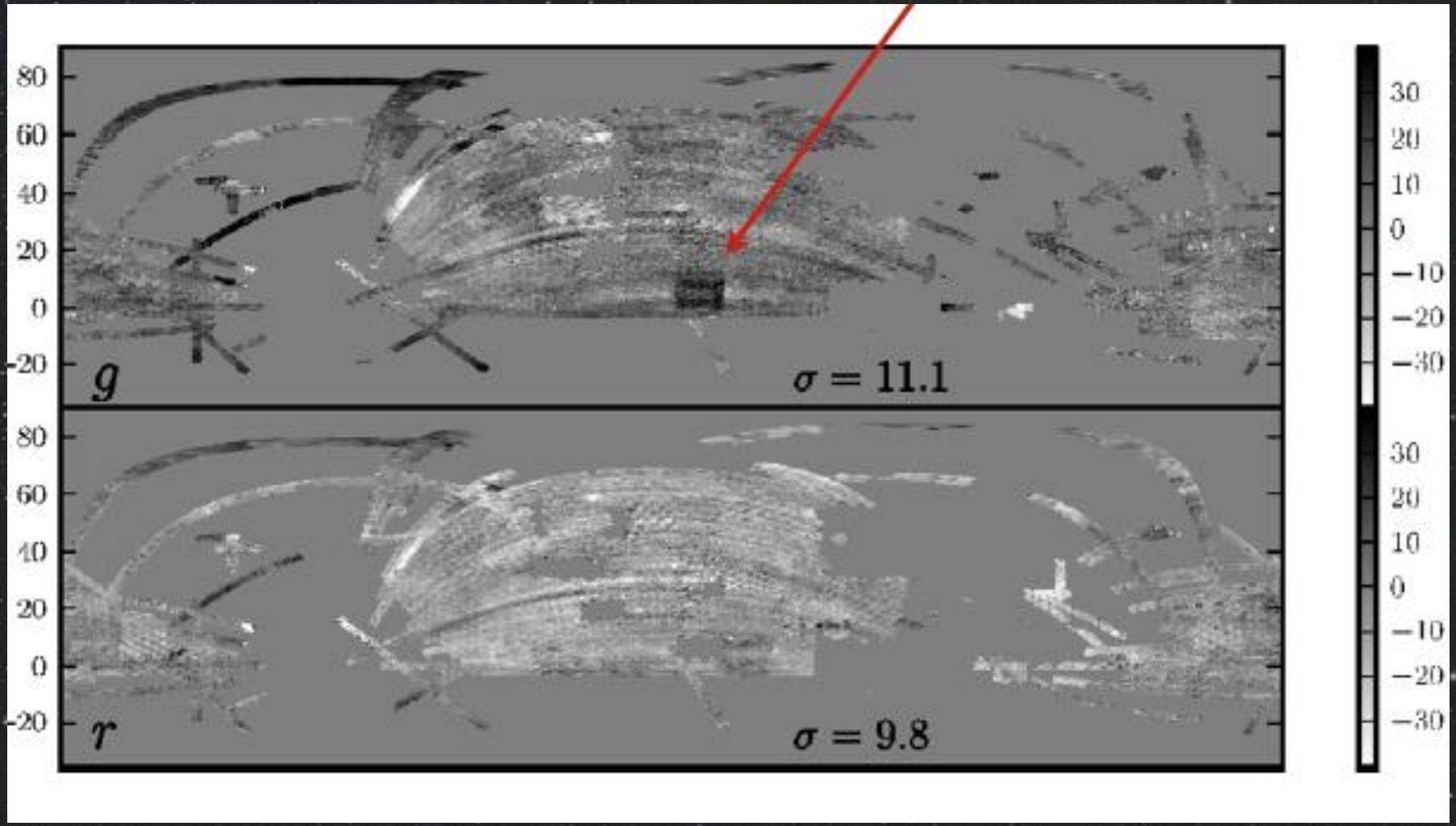
- Now look at maps and histograms of these.

Ubercalibration

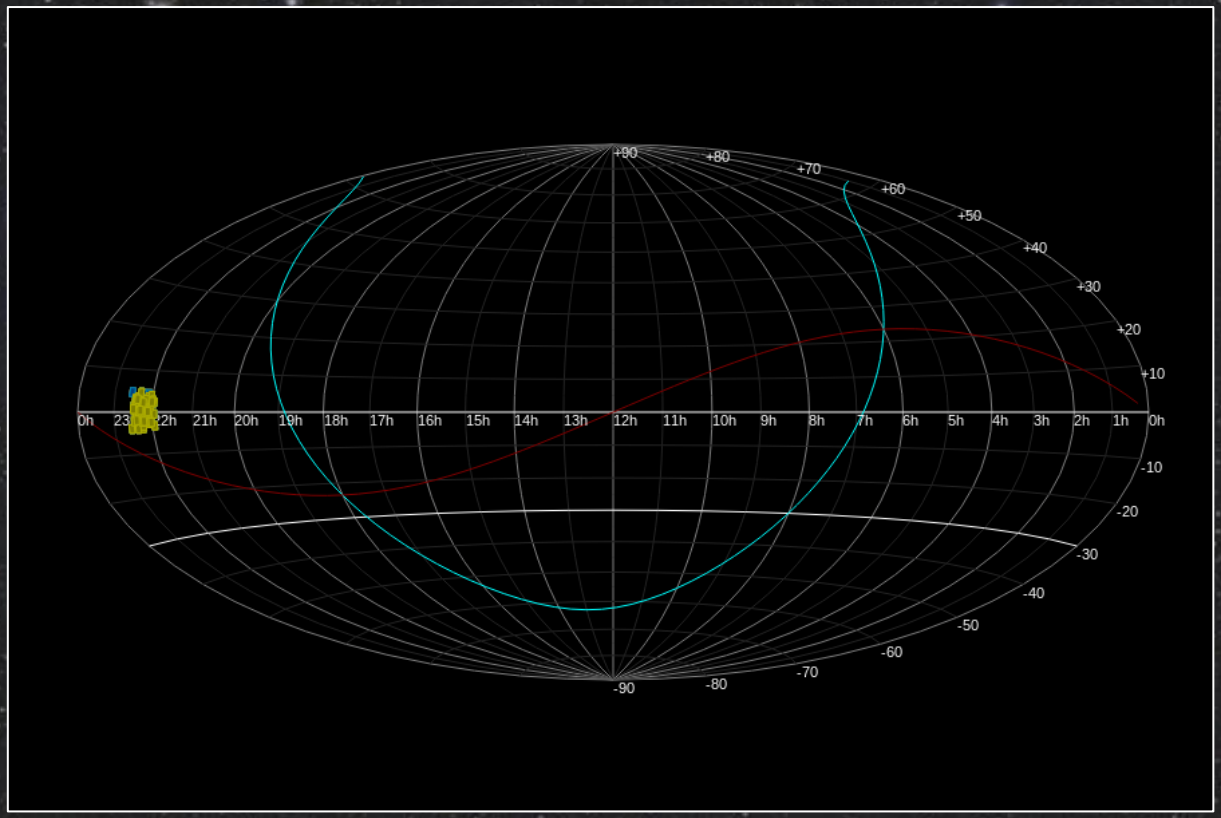




Comparison to SDSS



The Small Area Survey MkII (SAS2)

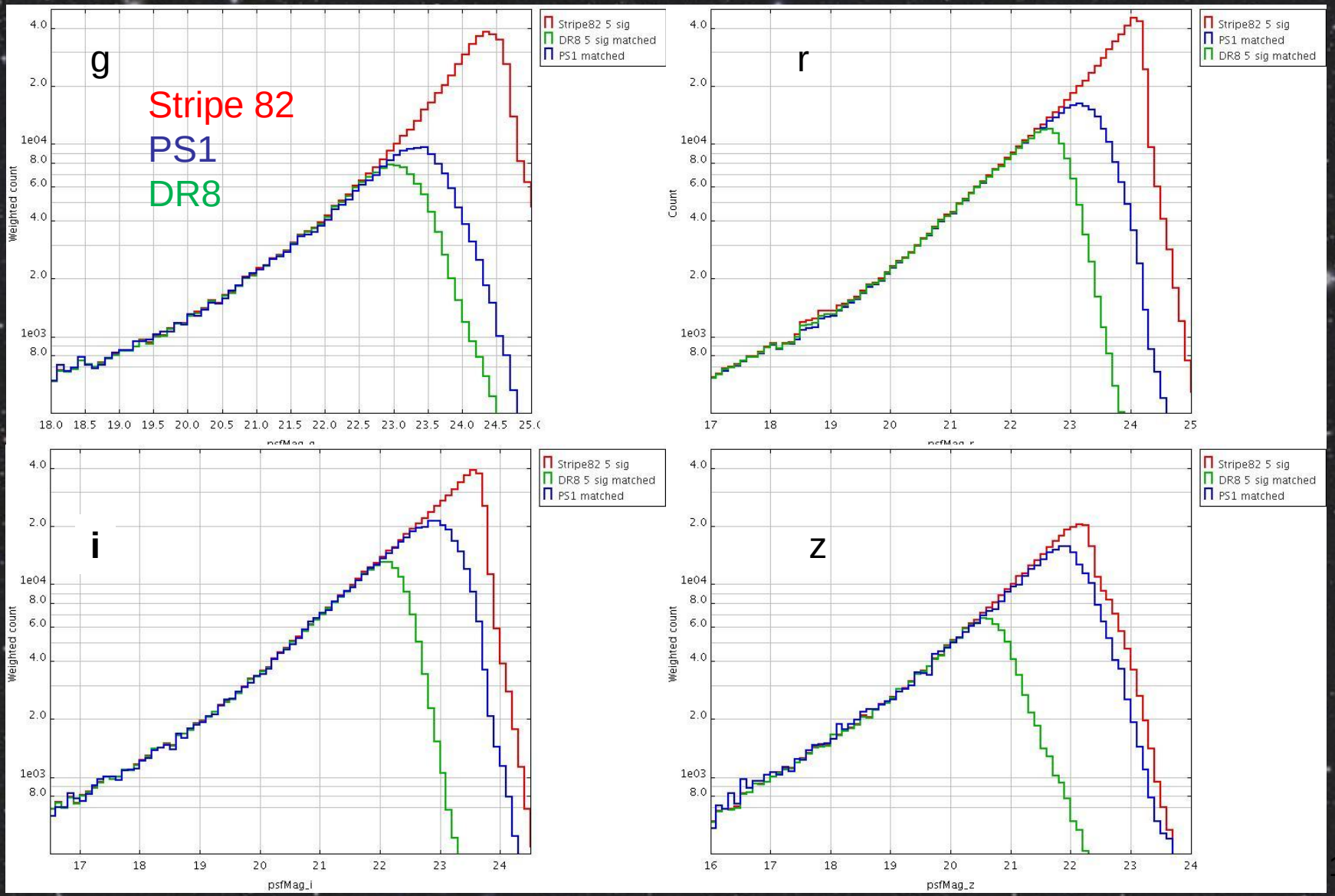


64 sq deg, mimicking final 3πicoverage

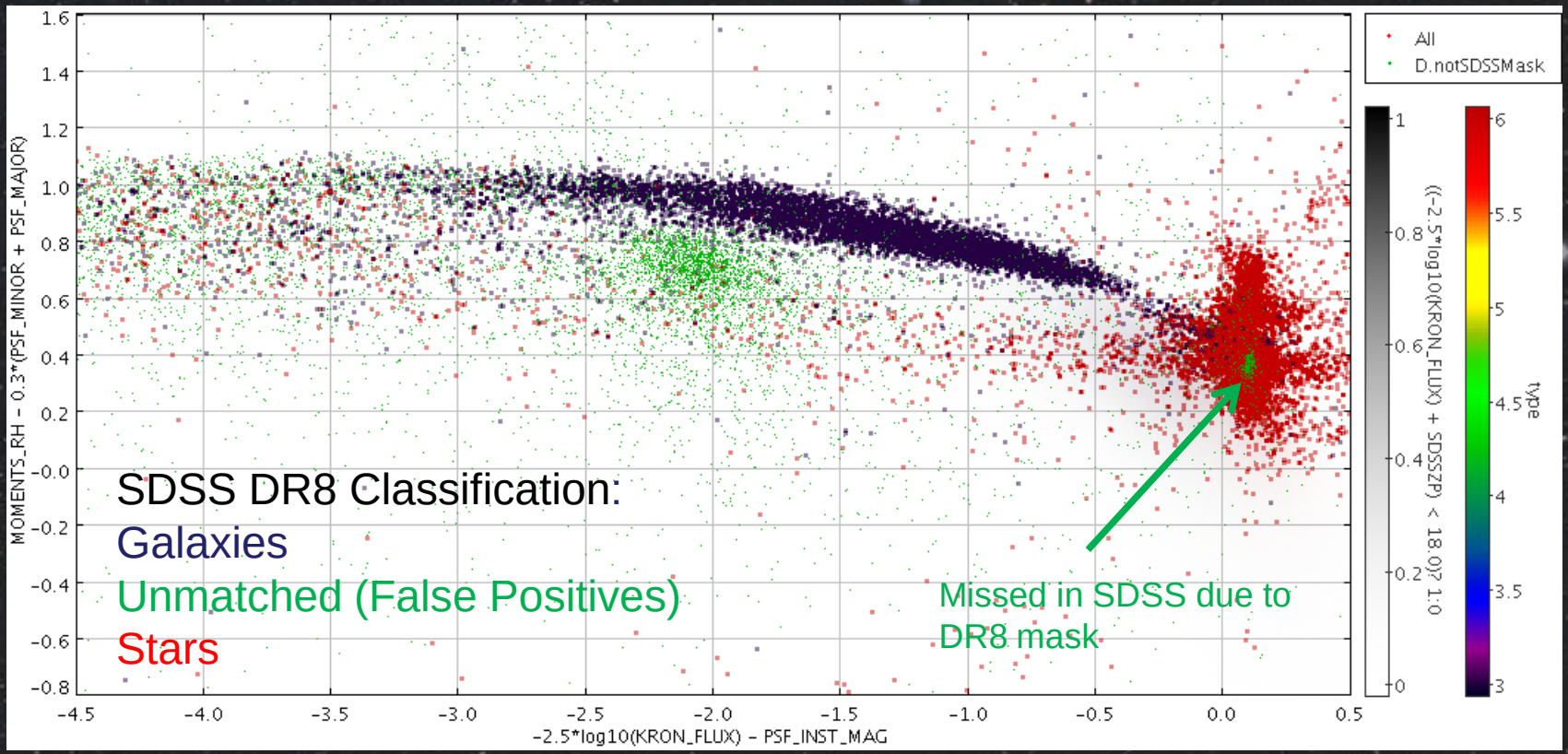
Taken in median conditions over two nights

Overlaps with SDSS DR8 (full) and stripe 82 (partial)

SAS2 Counts/Depth



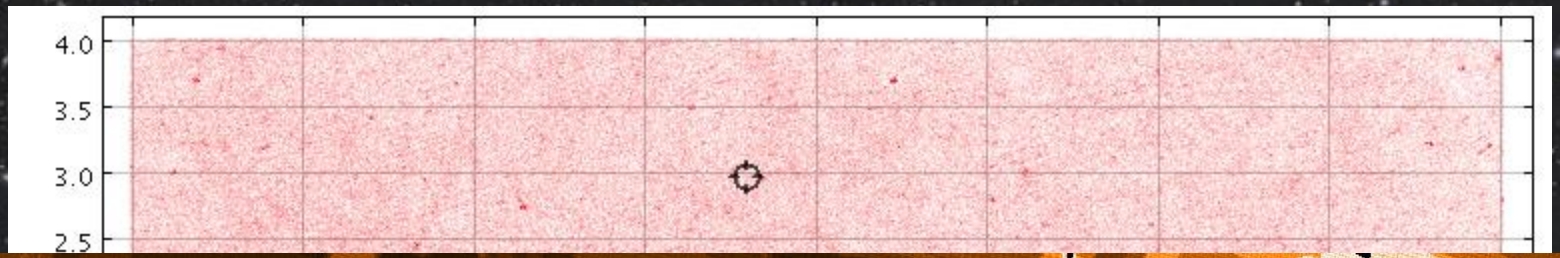
Star galaxy separation

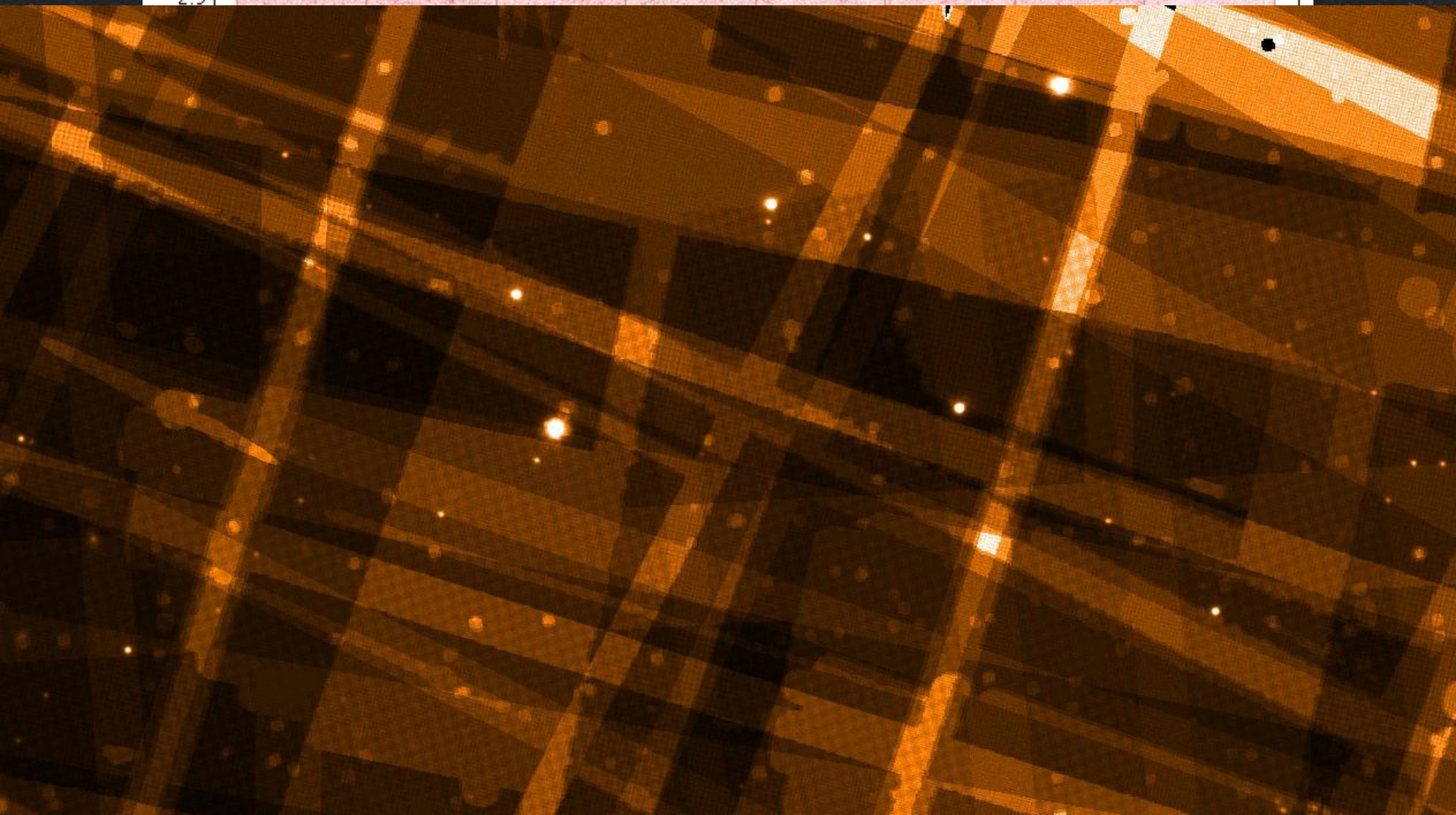


Kron-PSF magnitude

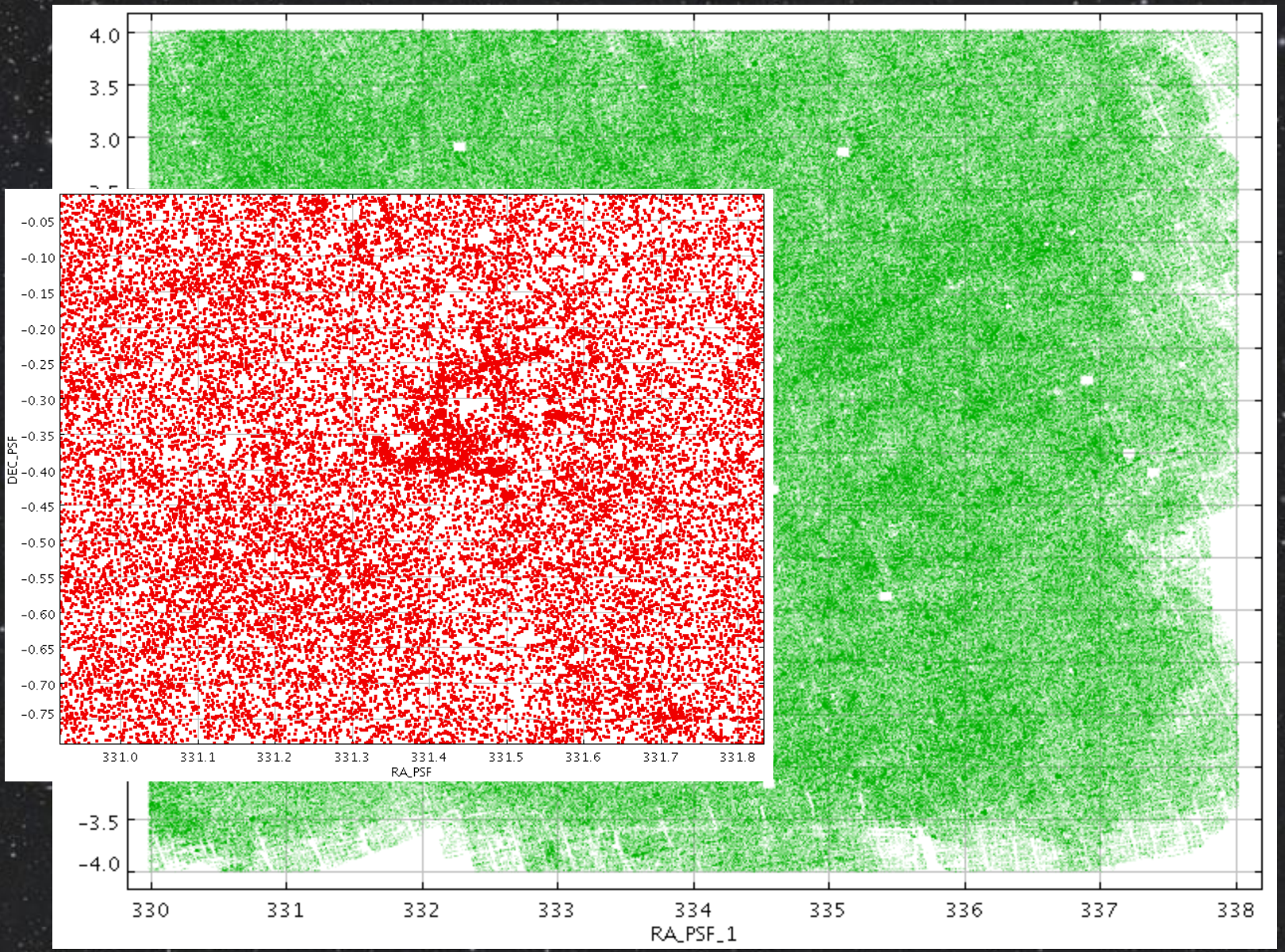
r<18 no masking

Source catalogue

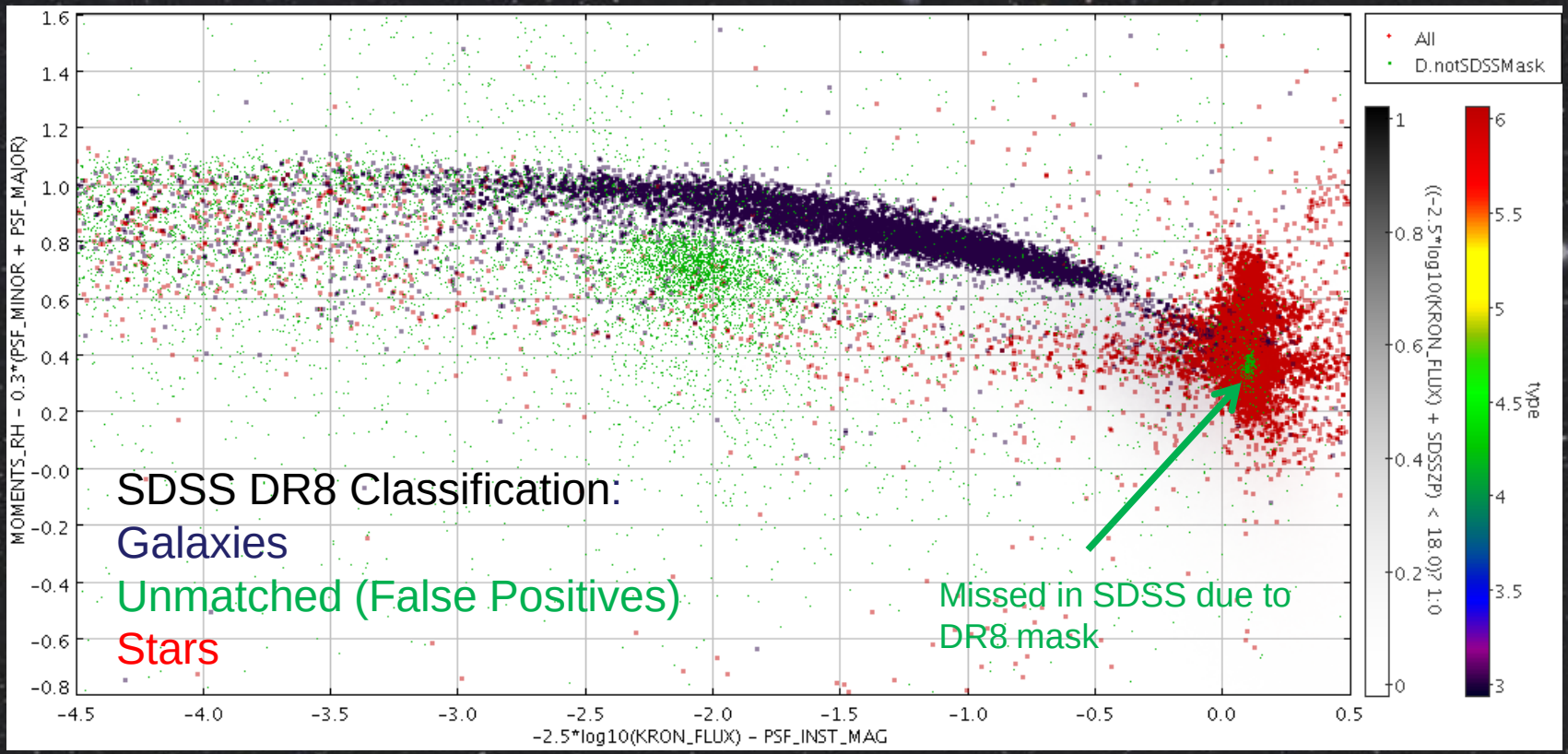




Source catalogue



Star galaxy separation

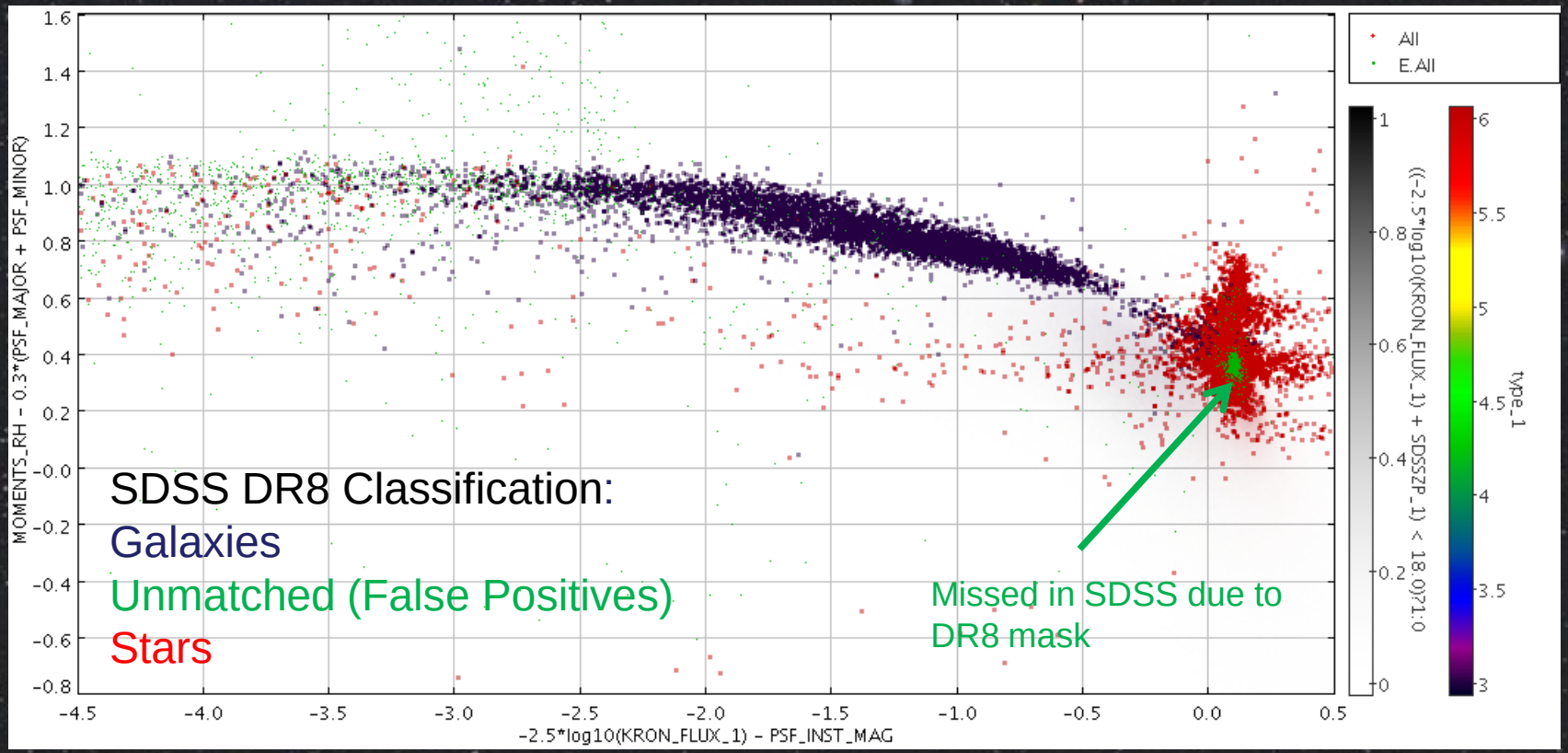


Kron-PSF magnitude

r<18 no masking

Daniel Farrow

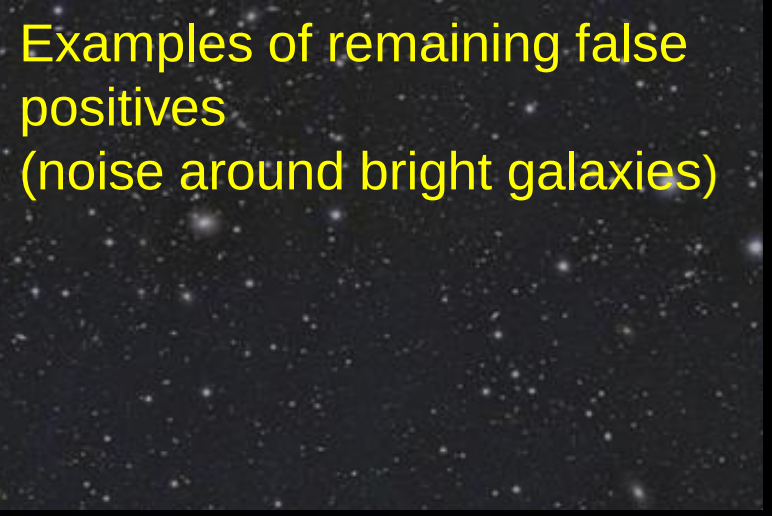
Star galaxy separation

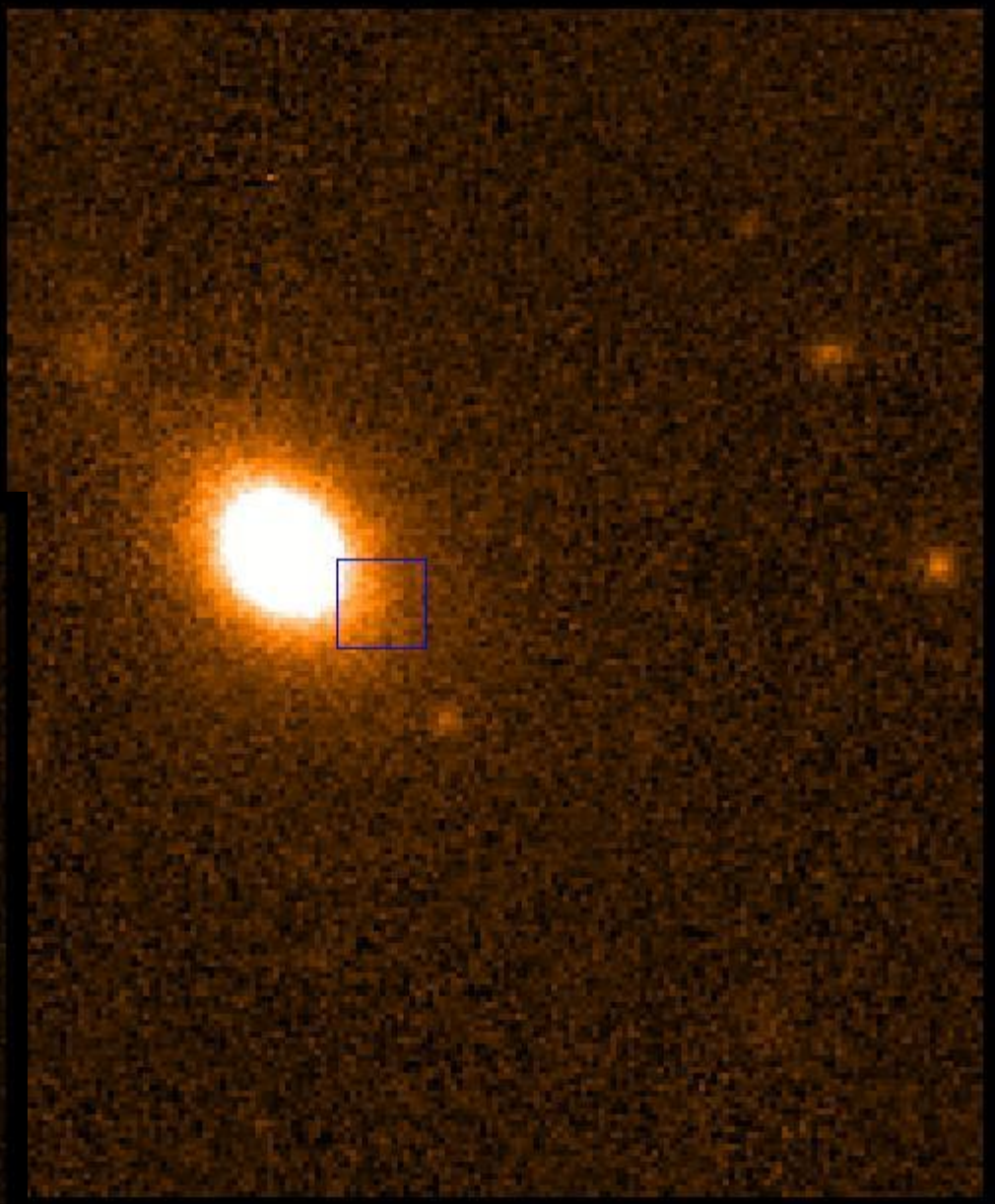


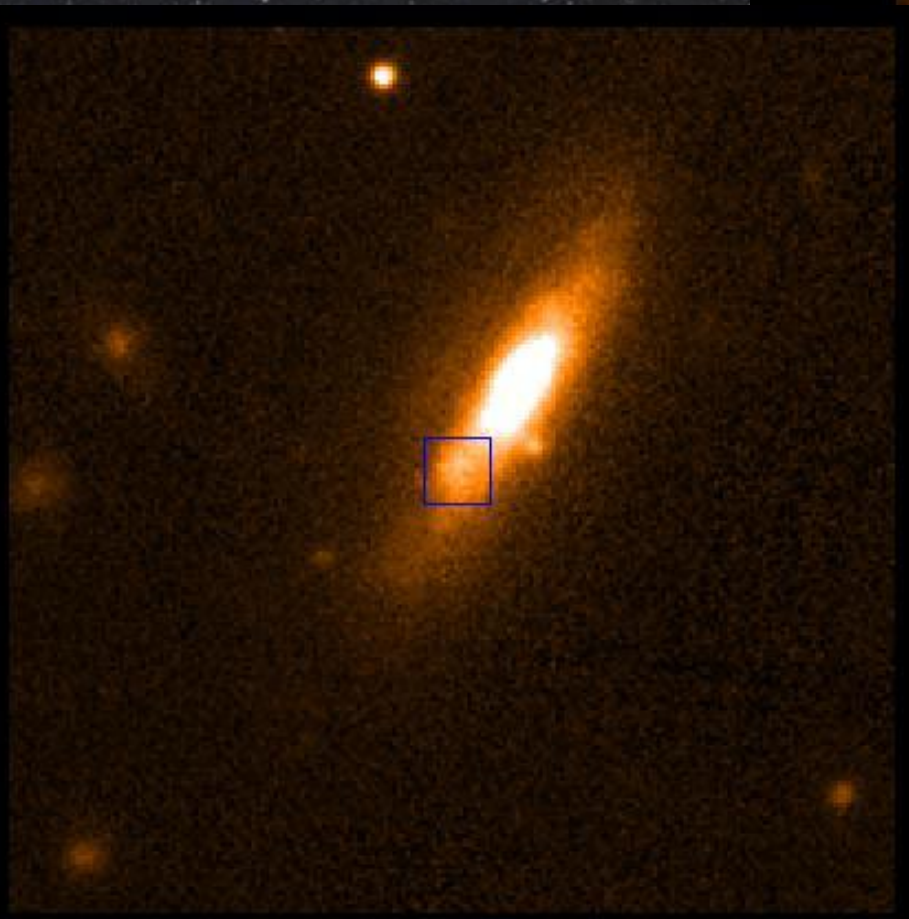
Kron-PSF magnitude

r<18, Bright stars masked

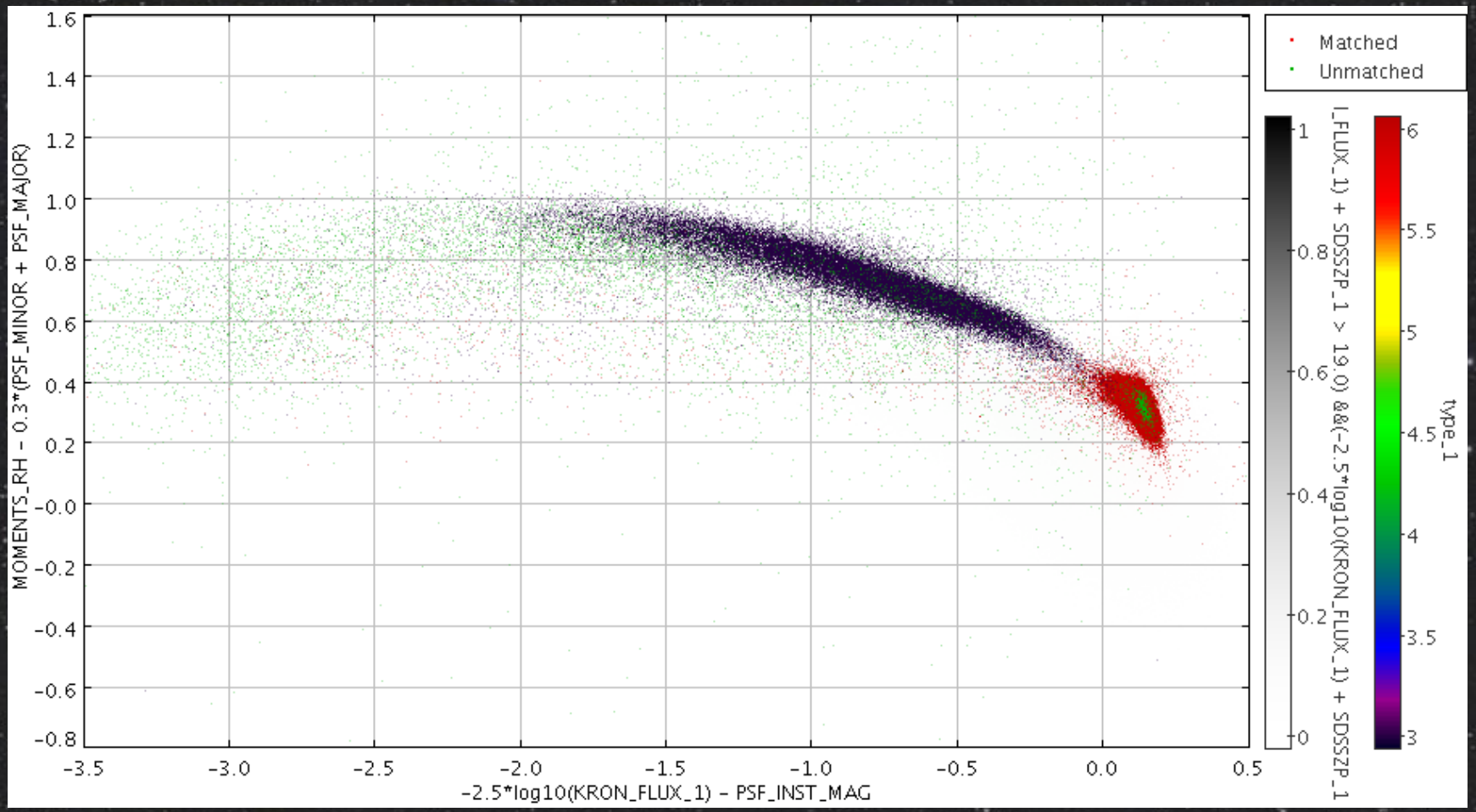
Examples of remaining false positives
(noise around bright galaxies)







Star galaxy separation

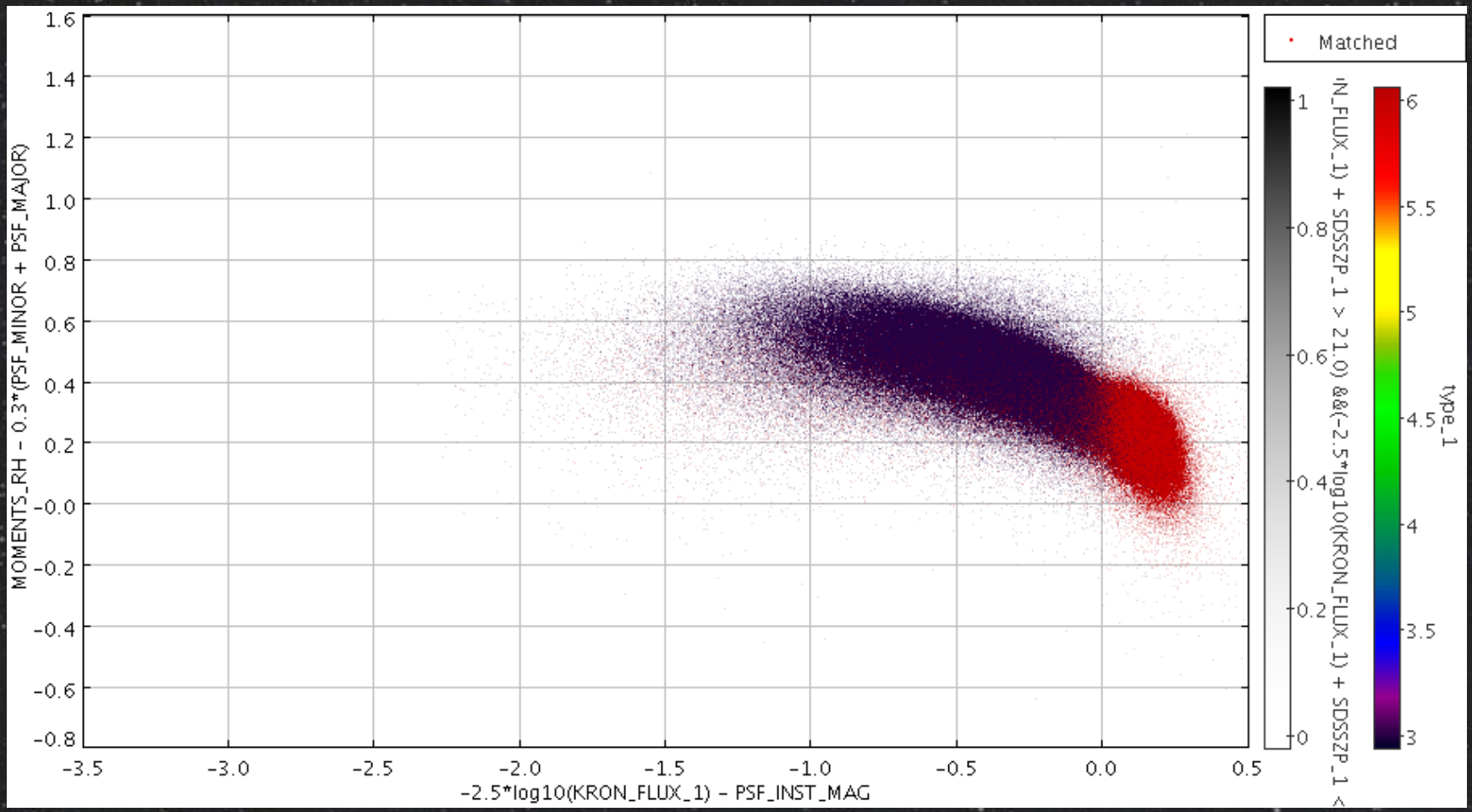


Size-PSF width

Kron-PSF magnitude

19<r<20, Bright stars masked

Star galaxy separation

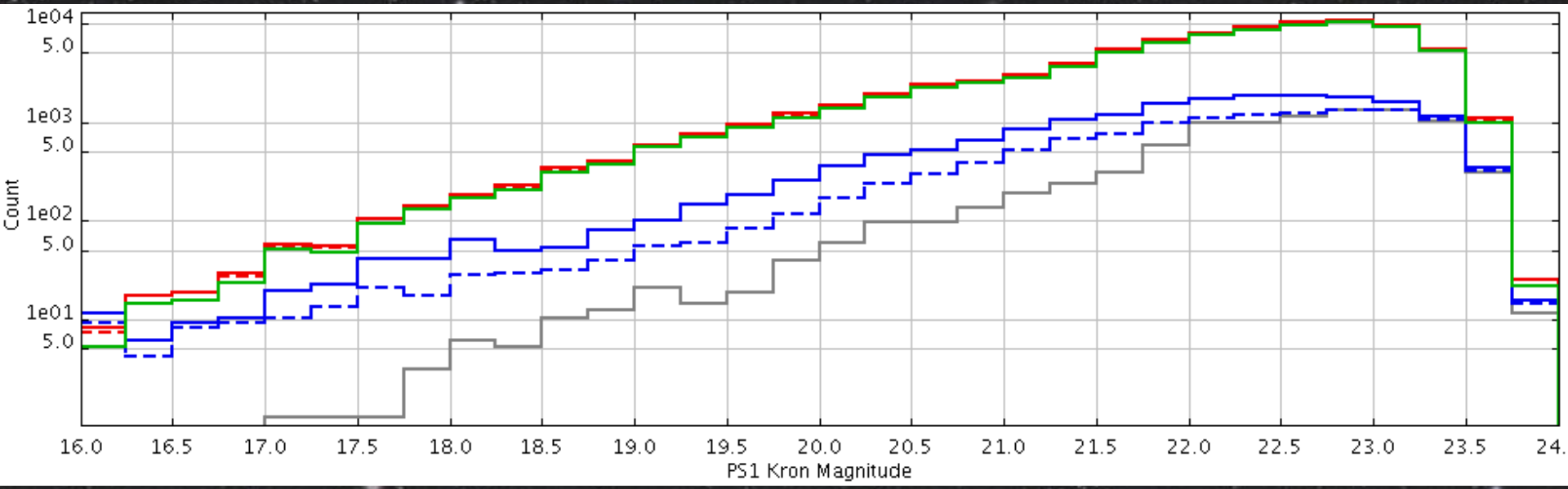


Size-PSF width

Kron-PSF magnitude

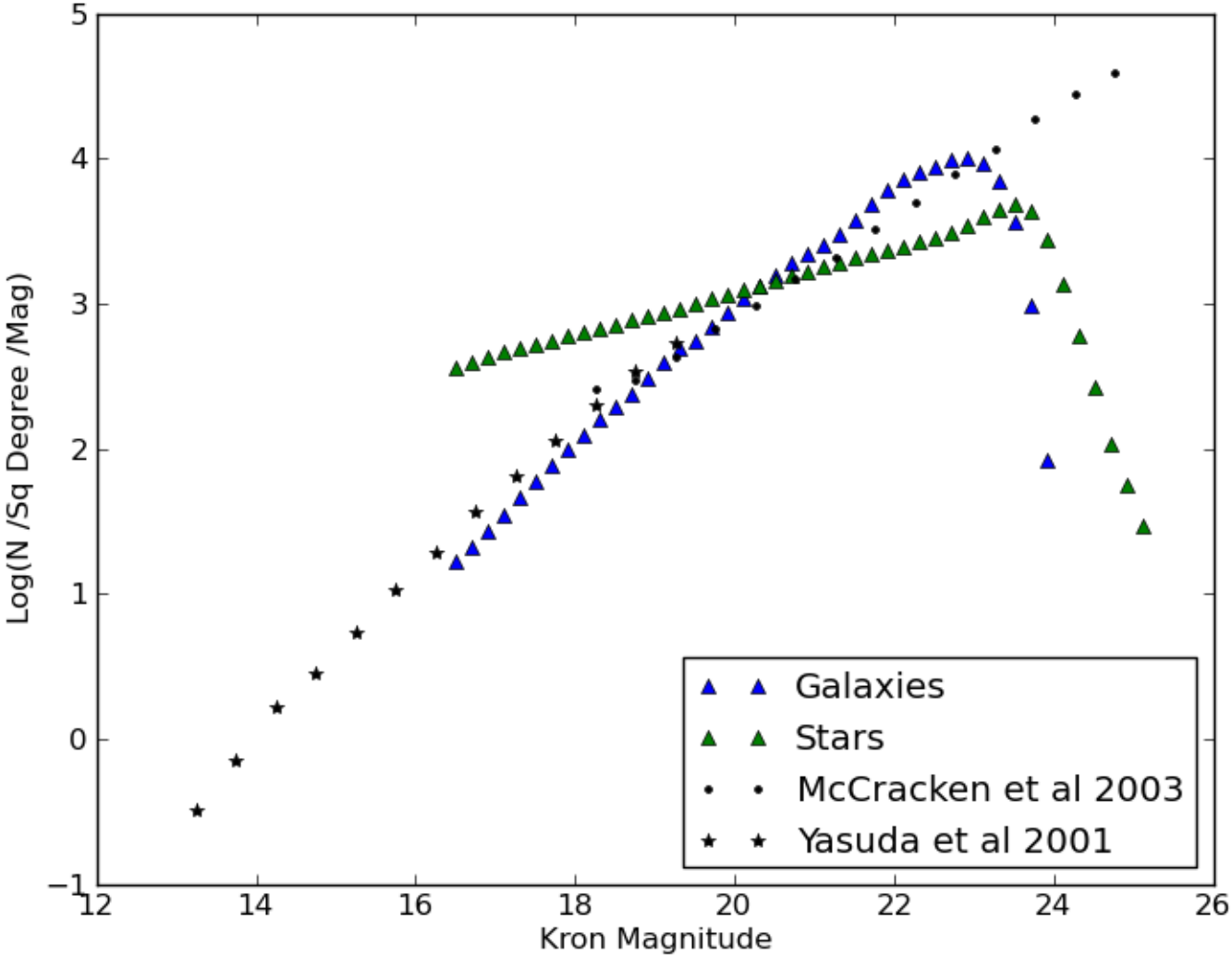
21<r<22, Bright stars masked

Counts of galaxies and false positives relative to stripe 82

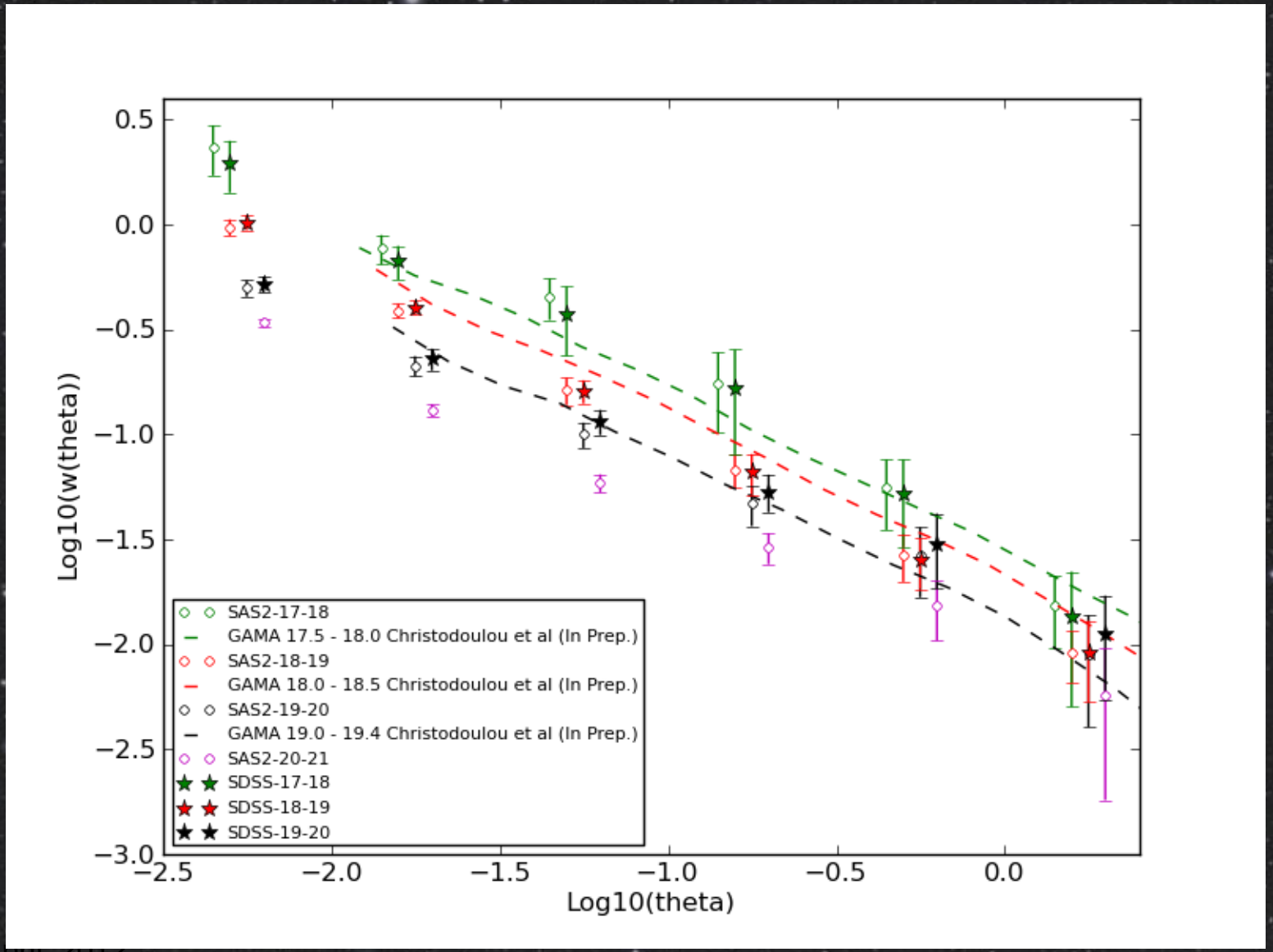


Solid – matched galaxy counts
Solid – unmatched objects
Dashed – close blends removed
Dashed – unmatched when blends removed
Solid – matched after additional cuts in “star-galaxy classification plane”
Solid – unmatched after cuts in “star-galaxy classification plane”

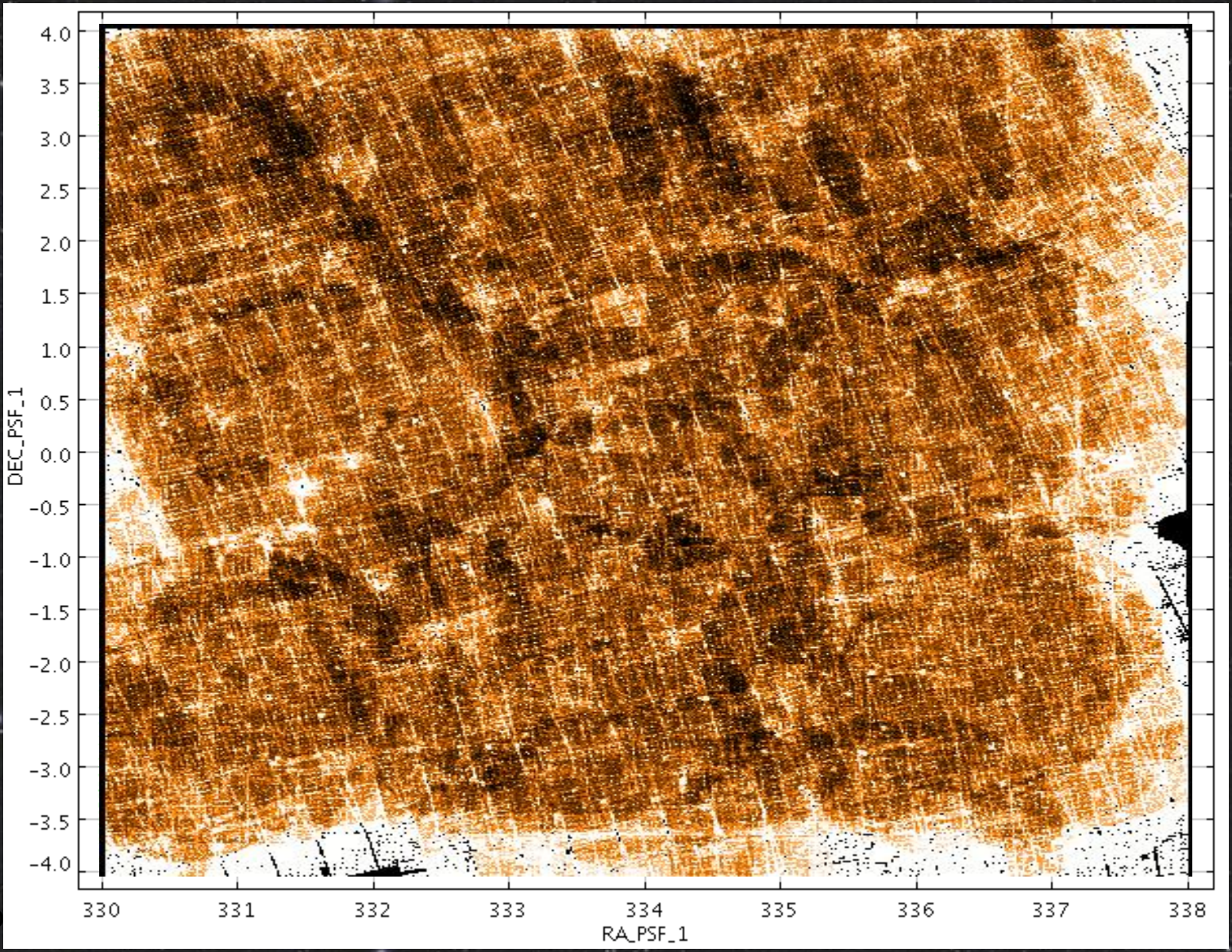
Galaxy and star counts from SAS2



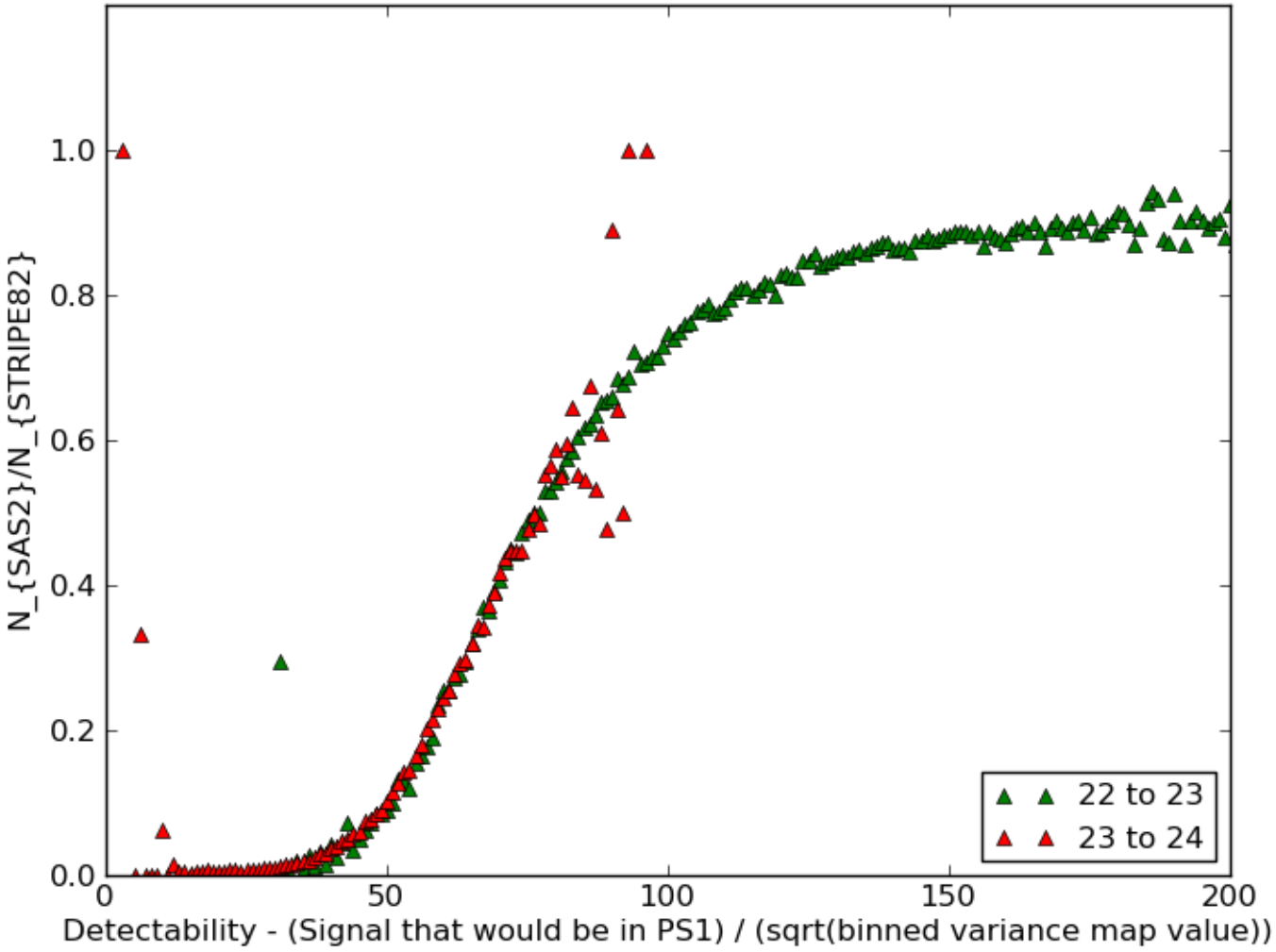
The angular 2-pt correlation function from SAS2



Pushing to the limit



Detection Efficiency

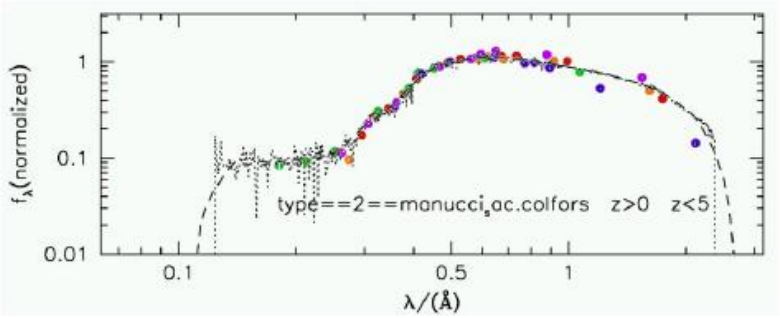


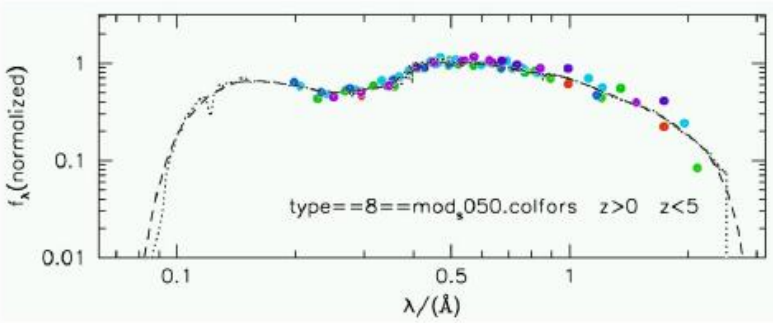
Photometric redshifts (the third dimension)

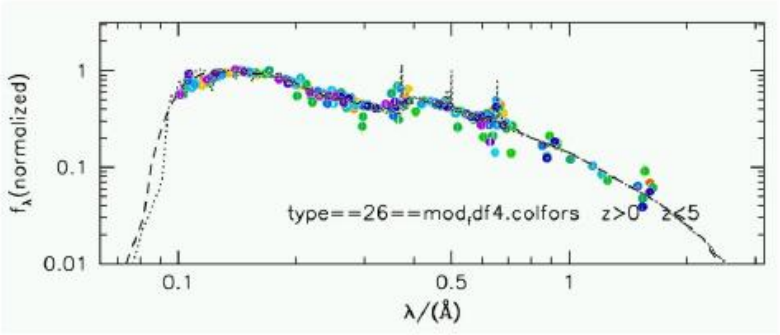
Semi-empirical SEDs derived from broad-band fluxes of galaxies with spectroscopic z by fitting them with SEDs of Bruzual&Charlot, Maraston and spectra from FDF, Kinney&Calzetti, Manucci

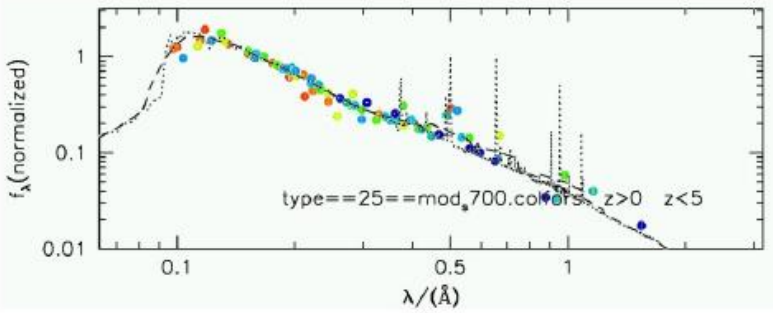
=> used as templates to determine PhotoZ

Stellar SEDs also fitted to check if the objects are really galaxies



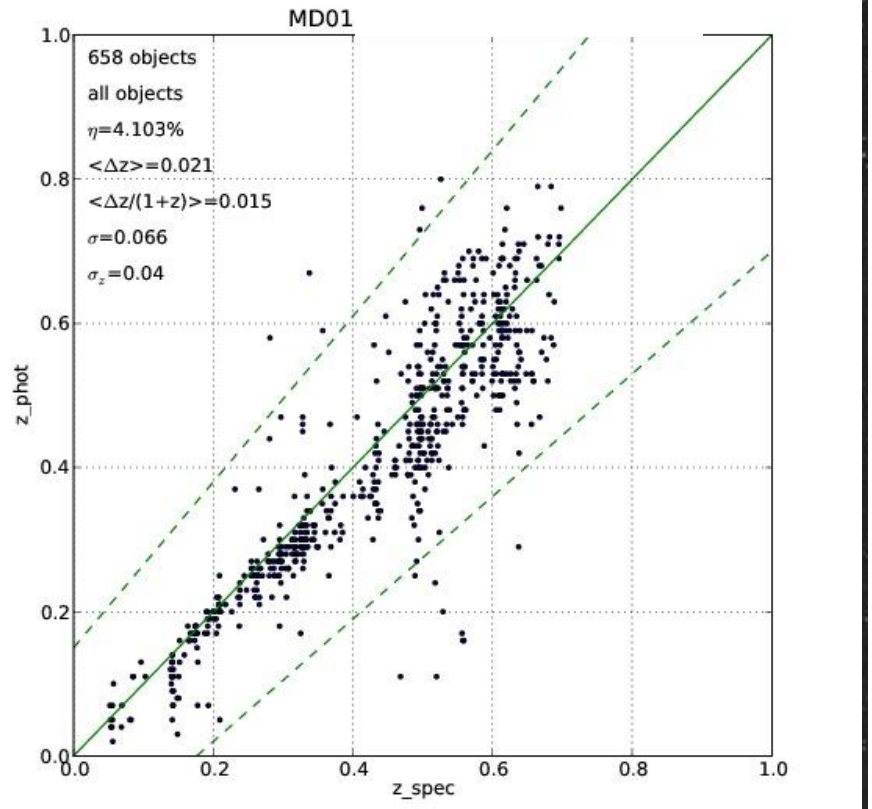


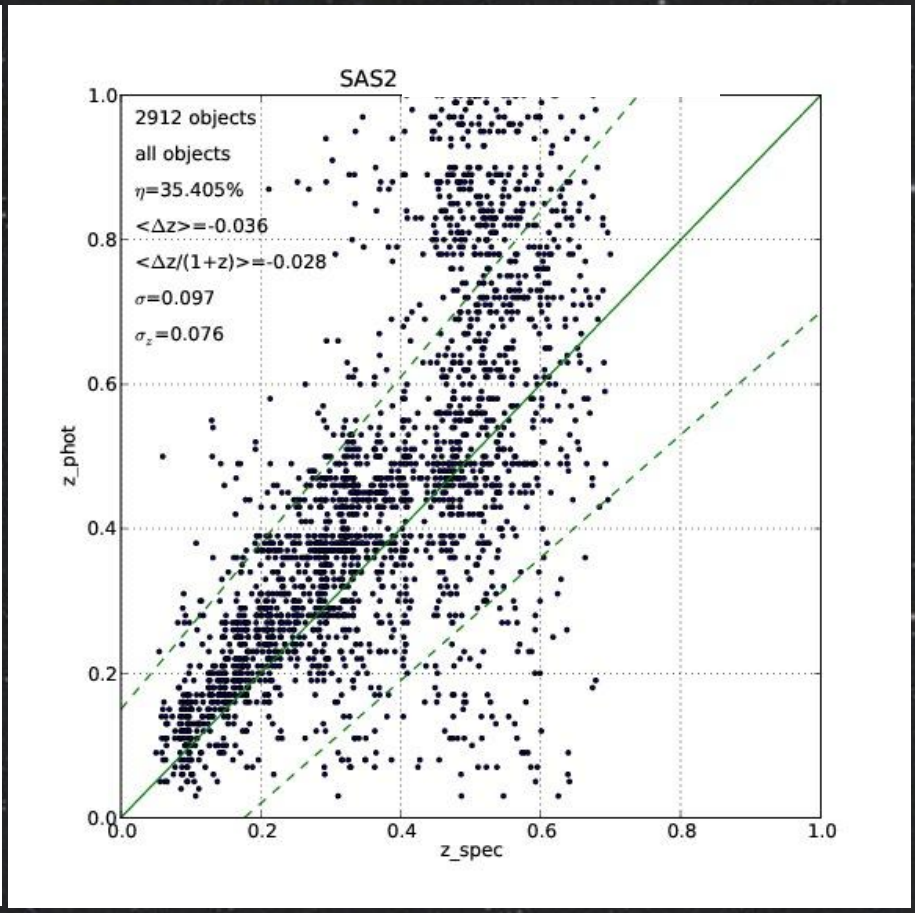




Greisel, Seitz, Bender Snigula, Saglia, (MPE)

Photometric redshift tests





Saglia et al

Clusters in Pan-STARRS: expectations and goals

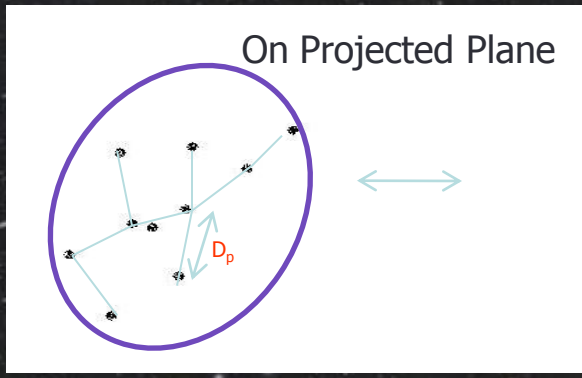
- Medium Deep Surveys (MDS; 10 ~8deg^2/field):
  - Cluster detections to z ~ 1.2
  - ~10^3 distant clusters / galaxy groups
- 3π Survey (~27,000deg^2):
  - Cluster detections to z ~ 0.6
  - ~10^5 clusters / galaxy groups
- Volume & depth of data needs a finder that:
  - Is automated
  - Is robust, complete, efficient
  - Can use complimentary data (eg Spitzer IRAC)

PFOF Algorithm (Liu et al. 2008)

- *Use the information of photometric redshift and its probability distribution function*
- *Applicable to find medium-size groups/clusters as well*

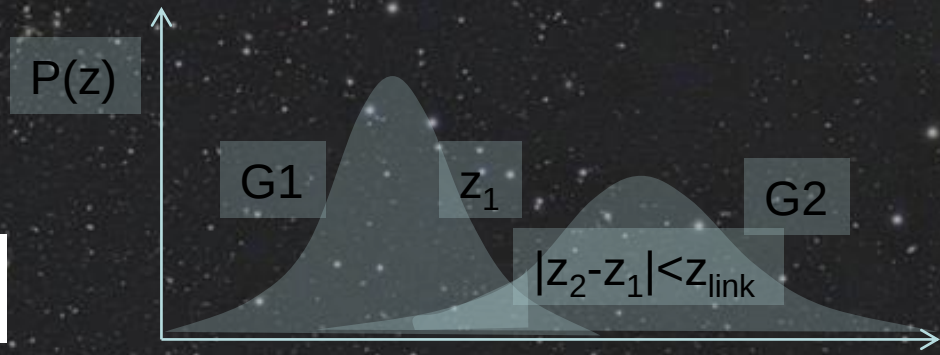
A neighbour is a "Friend", if

(1) The projected separation is less than xy_{link}



(2) Probability of line-of-sight separation less than z_{link} , is greater than a threshold P_{th}

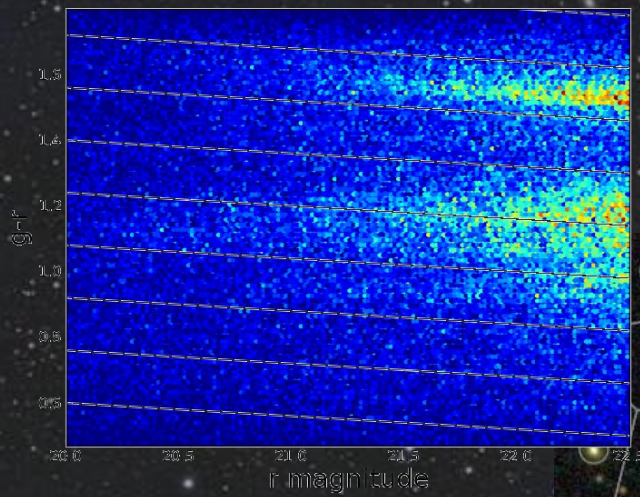
$$P(|z_1 - z_2| < z_{link}) \equiv \int_0^{\infty} dz G_1(z) \int_{z-z_{link}}^{z+z_{link}} dz' G_2(z')$$



Overdense Red-sequence Cluster Algorithm (ORCA)

1. Cluster red sequence

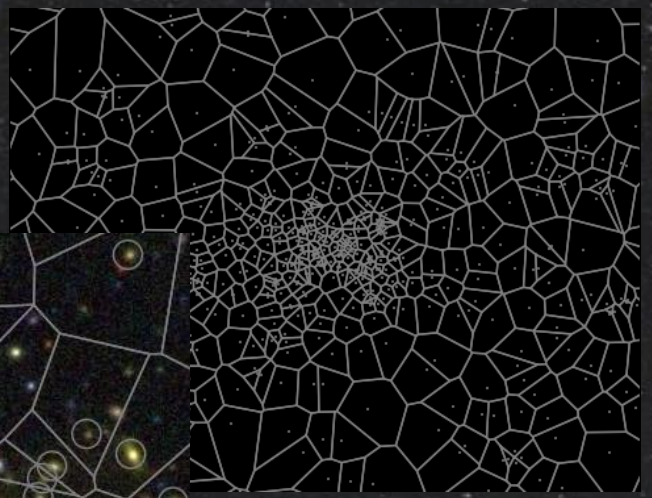
- Photometric selection filters: exhaustive search in CM space

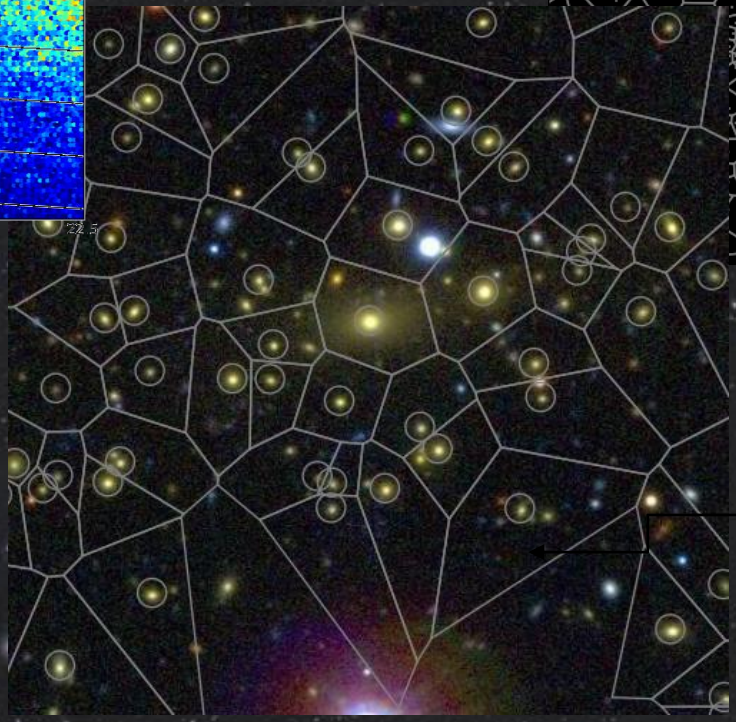


- Redder selection filters track 4000Å break to higher redshifts

- Projected galaxy overdensity

- Voronoi mesh: unbiased density field estimator



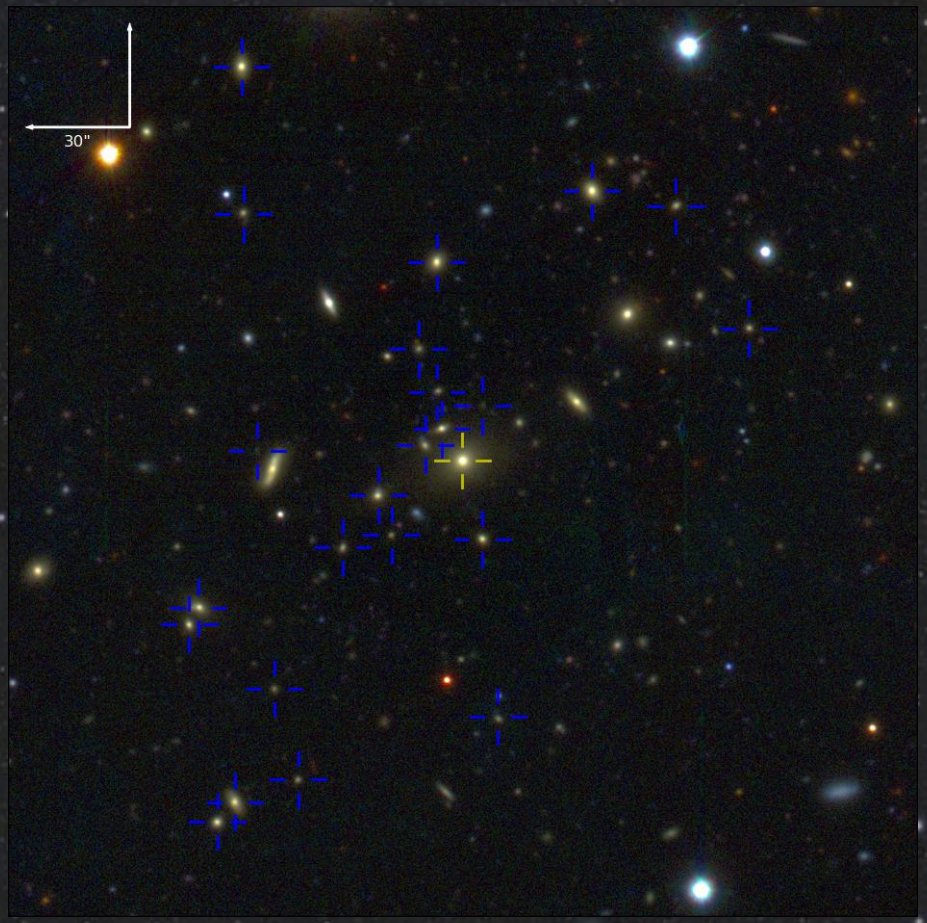


- Identify high-density cells, connect them with Friends-of-Friends

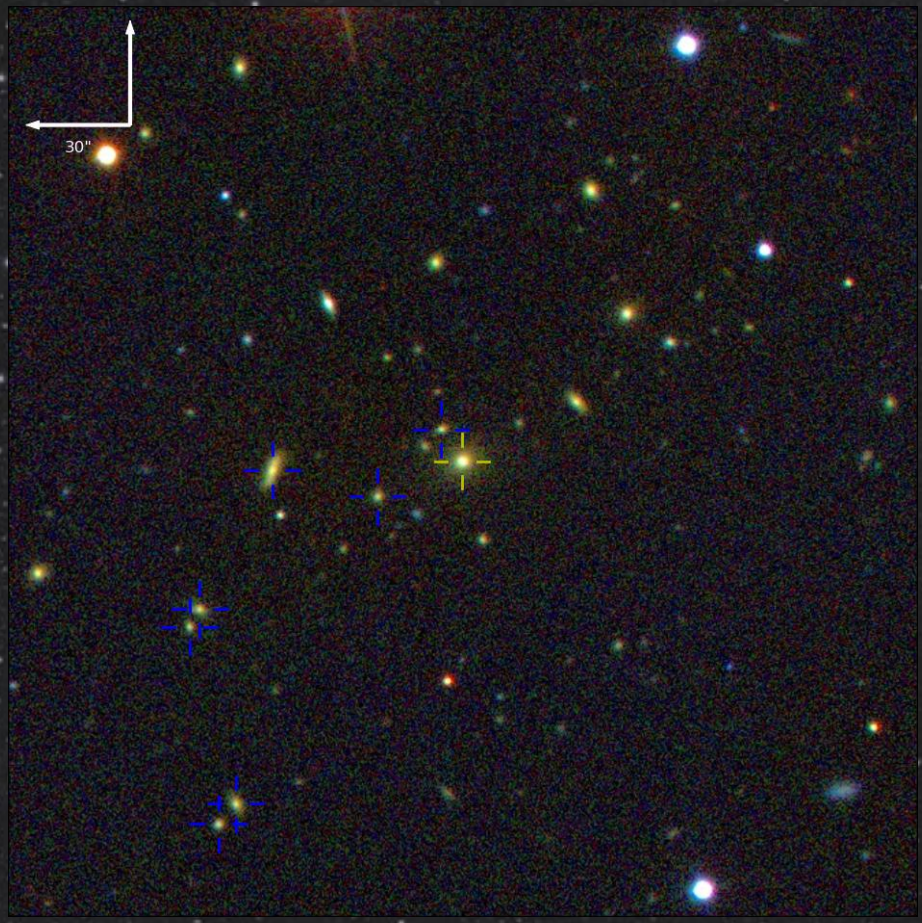
Murphy, Bower, Geach

Cluster detected in PS1 MDS / SDSS

- Cluster detected @ z=0.208 by maxBCG algorithm (Koester+ 2007) and found by ORCA in SDSS DR7 & Pan-STARRS photometry:



PS1 g,r,i imaging Estimated z=0.199



SDSS DR7 g,r,i imaging Estimated z=0.198

Concluding Remarks

The 2 main Pan-STARRS1 surveys are well underway and are both of interest for studies of large scale structure, but analysis is at an early stage.

We are developing clean galaxy catalogues in both MDS and the 3π survey.

Colour and photometric data are being used to build large galaxy cluster catalogues in both MDS and the 3π survey

One particular strength of the 3π survey will be the ISW split by photometric redshift.