Clusters mass measurement using weak lensing

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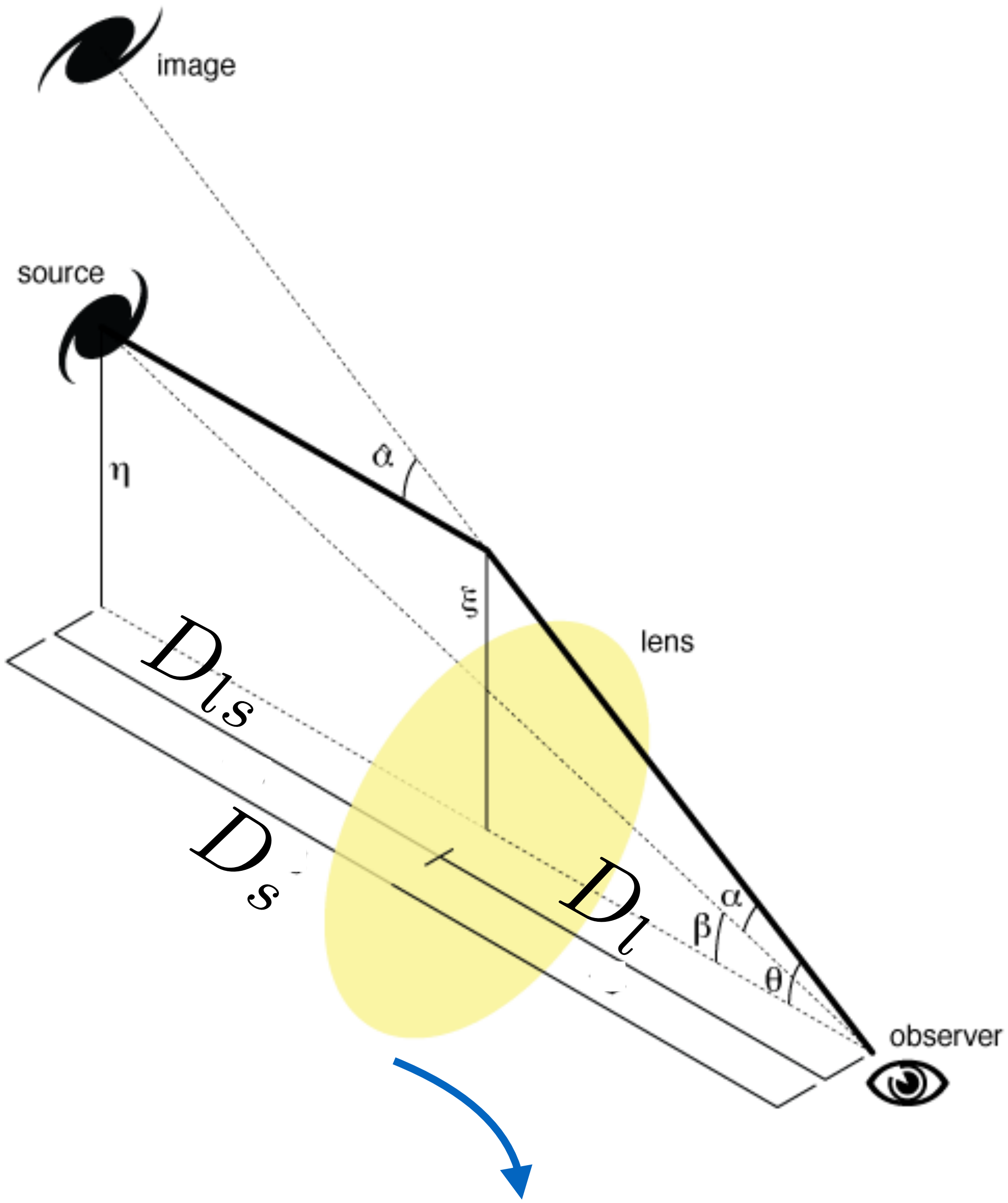
LSST France - LPNHE - December 2015

Gravitational lensing



Lensing can be used to infer the distant gravitational potential

All observables derive from a scalar field : « the projected mass »

$$\nabla^2_\theta \psi = \frac{8\pi G}{c^2} \int \frac{D_L D_{LS}}{D_S} \rho d\ell$$

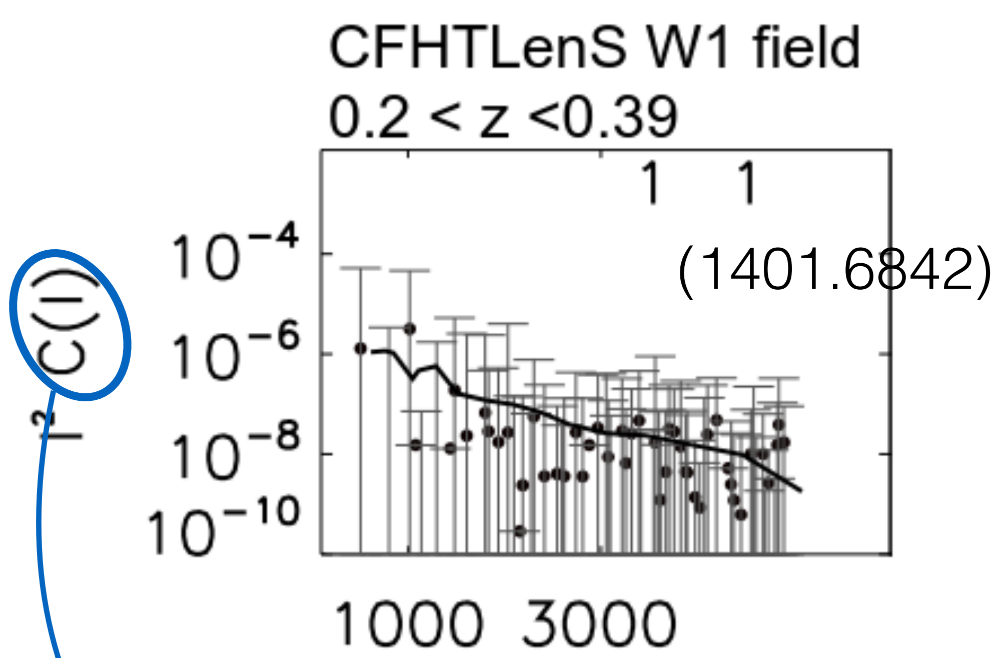
Effects on the image of an object (weak regime):
- → Rotation
- → Displacement
- → Magnification
- → Shear

Ellipticity : $\epsilon_{gal} = \left(\frac{gm_{xx} - gm_{yy}}{gm_{xx} + gm_{yy}}\right) + i\left(\frac{gm_{xy}}{gm_{xx} + gm_{yy}}\right)$

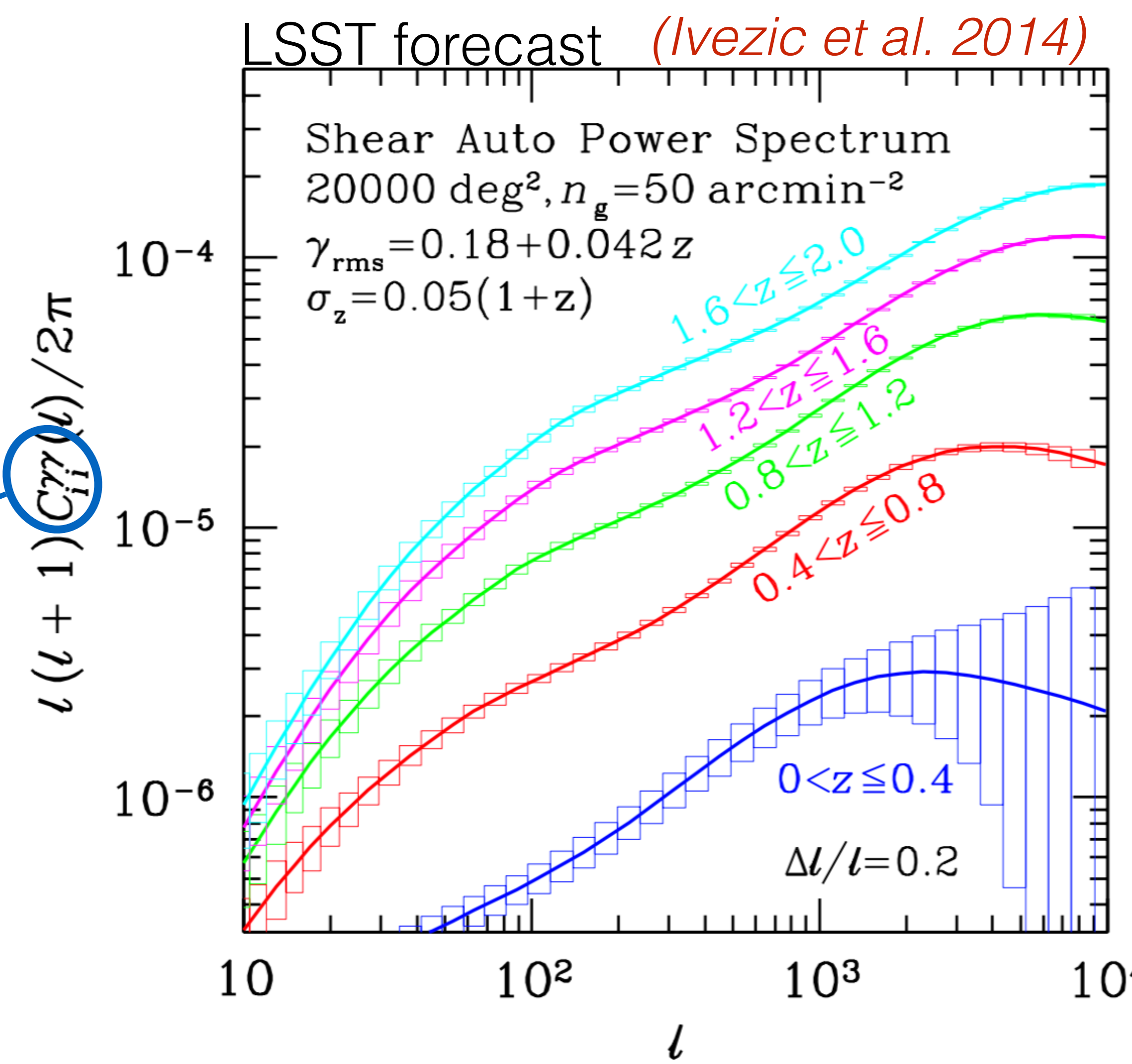
Relation between ellipticity and shear : $\epsilon_{gal} = \epsilon_{int} + g$

Shear as a cosmological probe : Cosmic shear

Best current results : CFHTLenS
Fields = 154 deg^2
n_g = 11 arcmin^{-2}
400 < l < 5000



The probe is at the top of LSST priority list

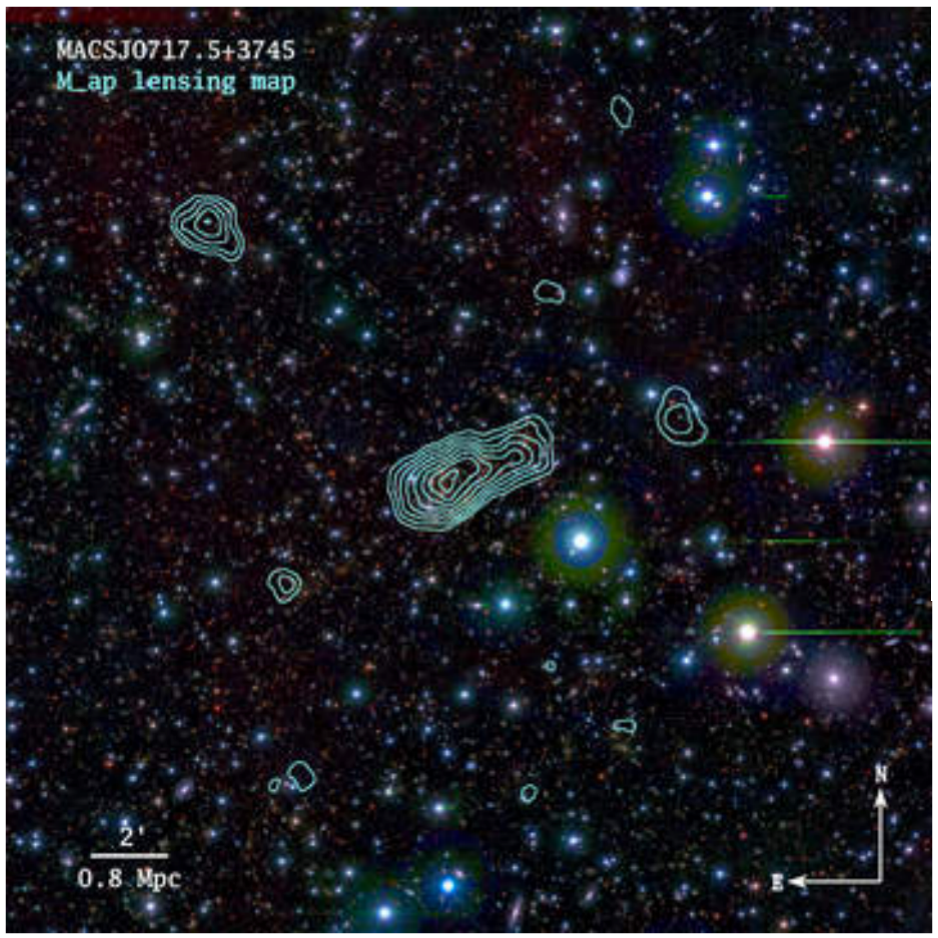


$$C_l = \int_0^\infty d\chi \left(\frac{3}{2}\Omega_m H_0^2 \int_\chi^\infty d\chi' \frac{dn}{d\chi'}(1-\frac{\chi}{\chi'})\right)^2 P_\delta\left(k = l/\chi, z(\chi)\right)$$

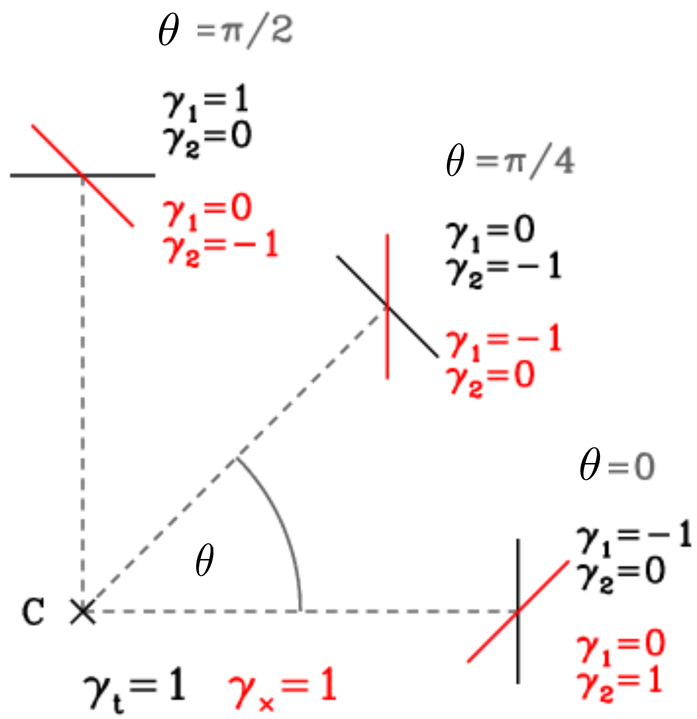
(Lin et al. 2011)

Shear as a cosmological probe : Lensing by clusters of galaxy (I)

Weighting the Giants I
(1208.0597)



Contours of mass distribution

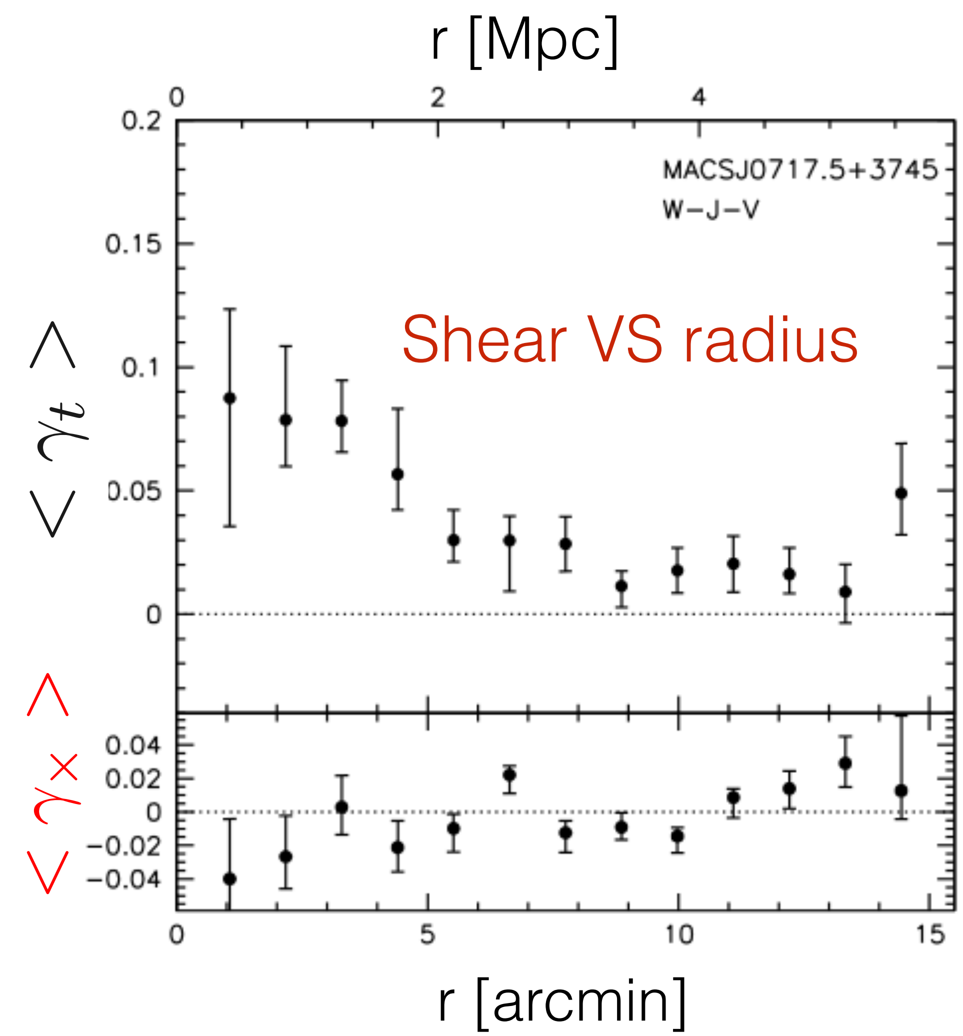


$$\gamma_1 = \frac{gm_{xx} - gm_{yy}}{gm_{xx} + gm_{yy}}$$

$$\gamma_2 = \frac{gm_{xy}}{gm_{xx} + gm_{yy}}$$

$$\gamma_t = -(\gamma_1 cos(2\theta_c) + \gamma_2 sin(2\theta_c))$$

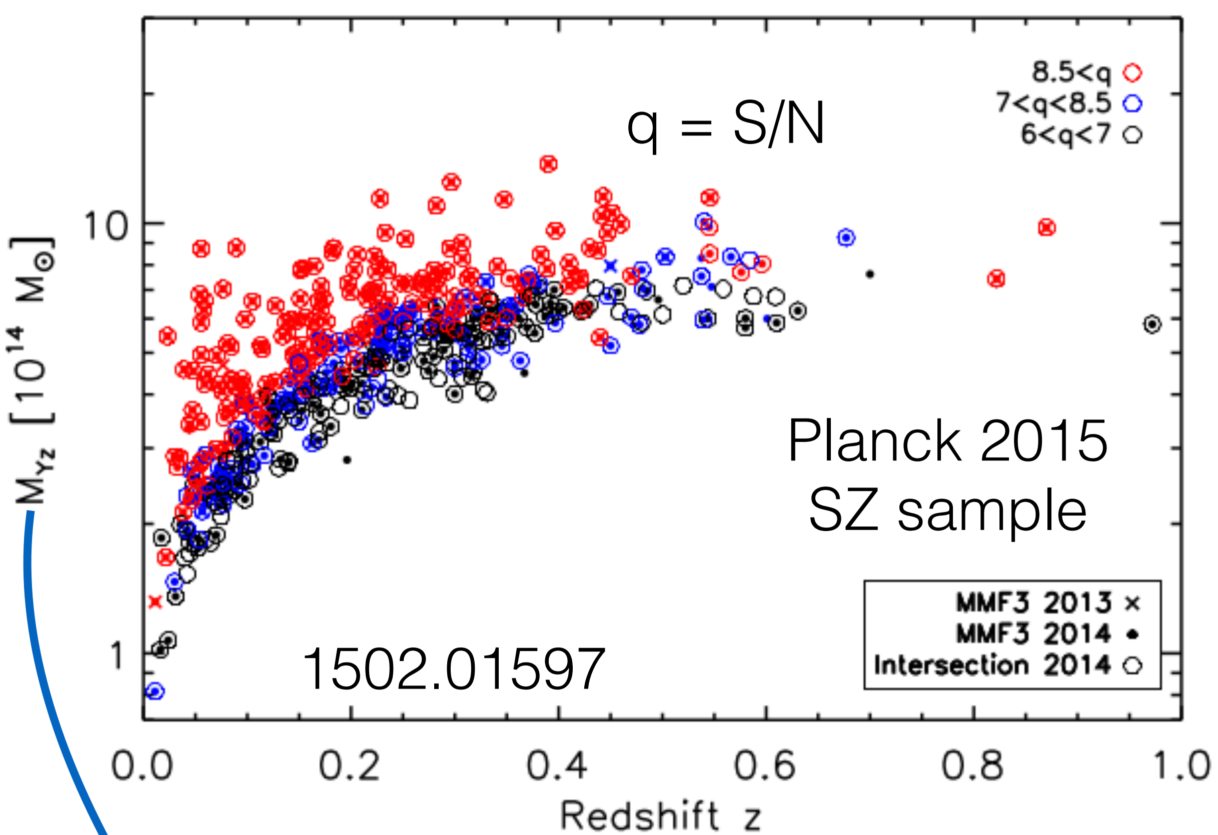
$$\gamma_\times = -\gamma_1 sin(2\theta_c) + \gamma_2 cos(2\theta_c)$$



The signal is strong.
Convenient training !

Shear as a cosmological probe : Lensing by clusters of galaxy (II)

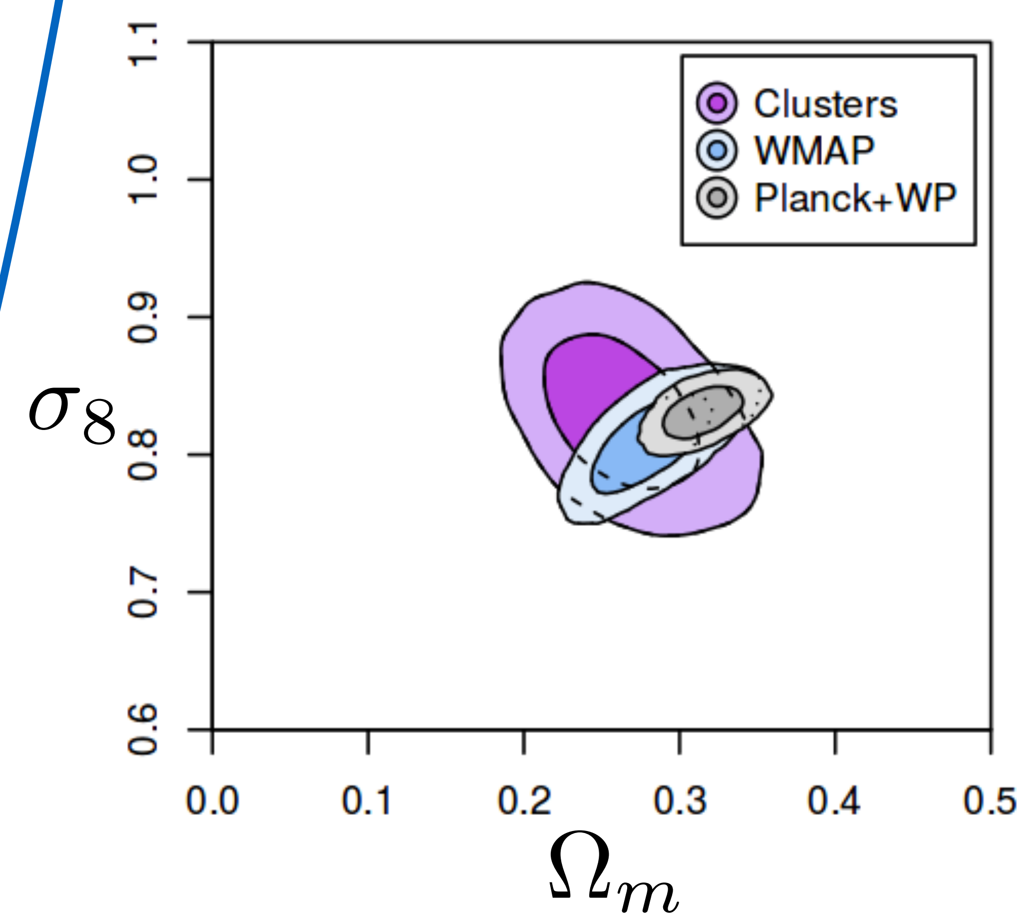
SZ cluster counts



Masses are measured using a mass proxy
from SZ decrements from Planck :
this is the largest source of uncertainty (20%)
New methods uses lensing

Weighting the Giants IV
(1407.4516)

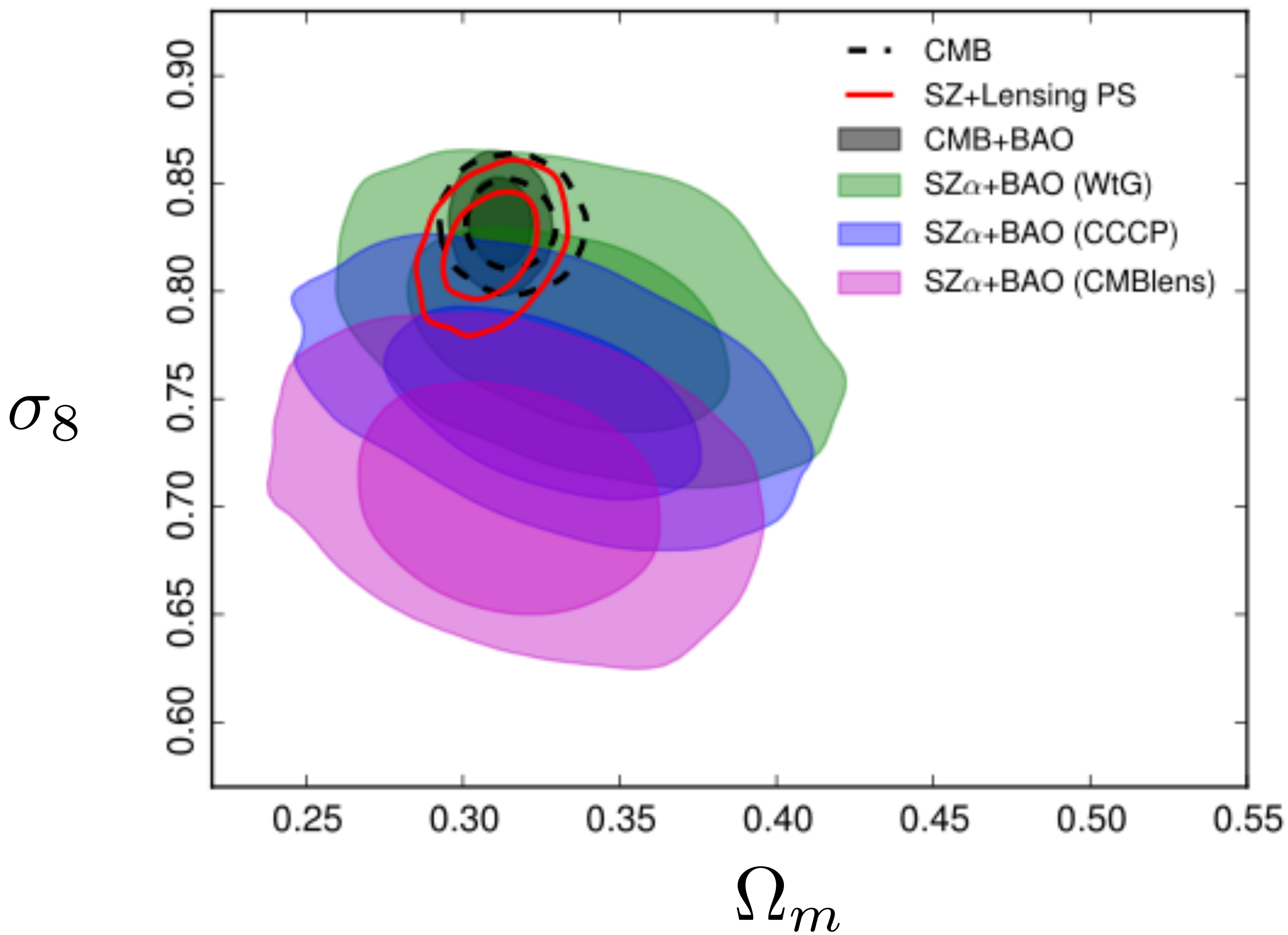
Masses from gas mass fraction



uncertainty of 8% on
the absolute mass scale of clusters

Shear as a cosmological probe : Lensing by clusters of galaxy (II)

Planck Collaboration 2015. results. XXIV.



Lensing at LPNHE + « Weighting the Giants »+ M2C project (M. Arnaud)

Astier **16AF026**

Weighing the f_gas clusters

Semester : 2016A

Abstract

The most massive cluste
Universe. The gas-to-tot
estimate of Omega_b/O
most robust constraints
currently largest system
total cluster mass estim
lensing mass estimates
reduced. Currently, only
lensing data, and only 6
galaxies. We here propo
fgas clusters. Along with
to 5% precision - a rema
parameters from a single

Telescopes

Telescope
CFHT

Applicants

Name
Dr Pierre Astier
Ludovic Van Waerbeke
Anja von der Linden
Prof. Steven Allen
Dominique Boutigny
Adam Mantz
Dr Douglas Applegate
Pat Kelly

CANADA-FRANCE-HAWAII TELESCOPE

Astier **15BF008**

Weighing the f_gas clusters

Semester : 2015B **Science Cat. : High-z universe**

Abstract

The most massive clusters of galaxies provide nearly fair samples of the matter content of the
Universe. The gas-to-total ma
estimate of Omega_b/Omega
most robust constraints on Or
currently largest systematic u
total cluster mass estimates.
lensing mass estimates for a
reduced. Currently, only 12 ou
lensing data, and only 6 of those have 5-filter imaging for robust photo-z estimates of background
galaxies. We here propose to expand this sample by taking weak lensing and photo-z observations of 3
fgas clusters. Along with future observations, these data form part of a project to determine Omega_m
to 5% precision - a remarkable prospect for the determination of one of the key cosmological
parameters from a single experiment.

Two proposals submitted and accepted :
The objective is to increase the sample of clusters
→ 5% uncertainty on the mass calibration.

Telescopes

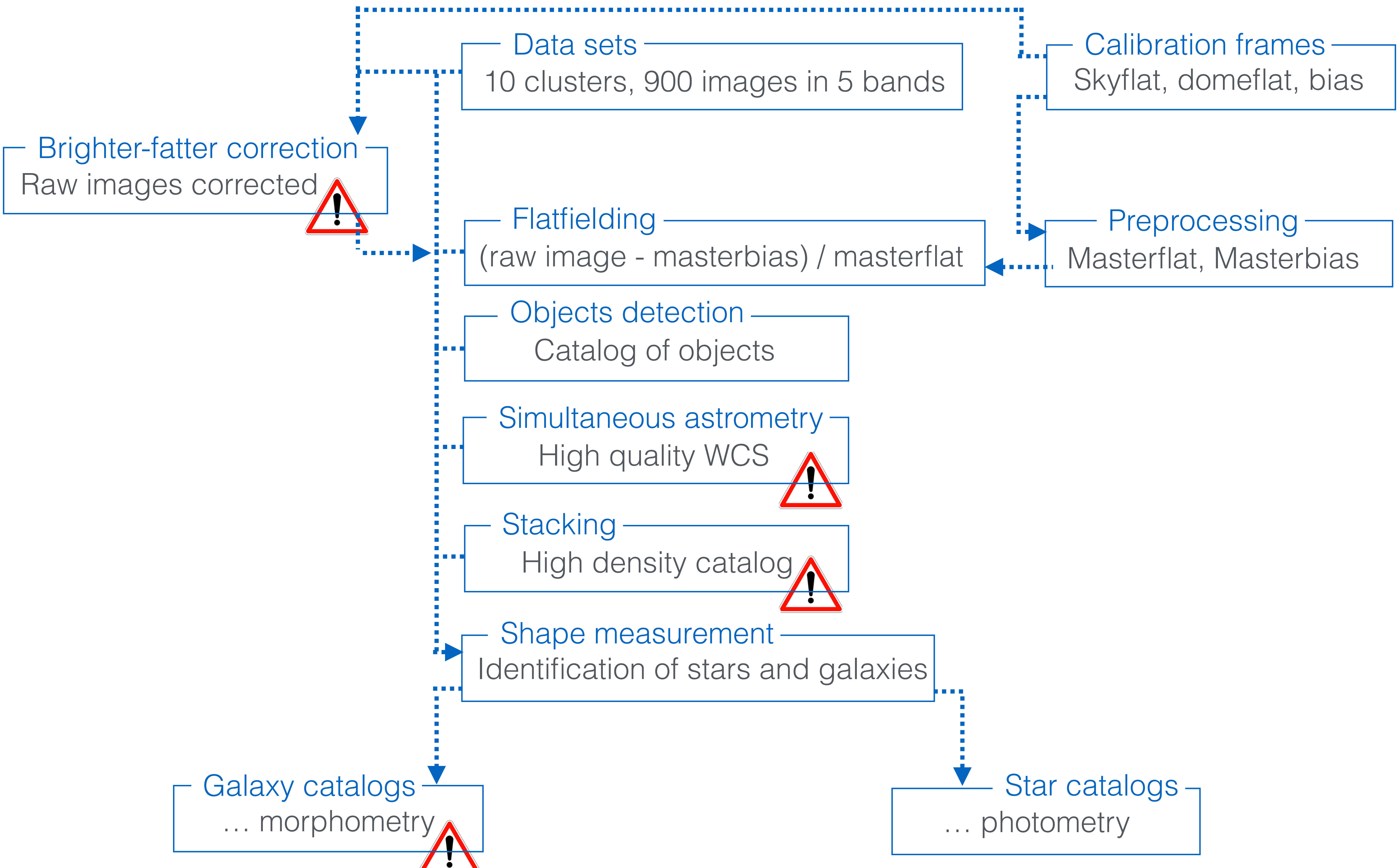
Telescope	Observing mode	Instruments
CFHT	QSO Regular	MegaCam

Applicants

Name	Affiliation	Email	Country		Potential observer
	LPNHE)	pierre.astier@in2p3.fr	France	PI	
	ty of British ia (Physics and my)	waerbeke@phas.ubc.ca	Canada		
		anja@slac.stanford.edu	United States		
	University	swa@stanford.edu	United States		
Dominique Boutigny	CC IN2P3 (CNRS)	boutigny@in2p3.fr	France		
Matthieu Roman	LPNHE (CNRS)	matthieu.roman@lpnhe.in2p3.fr	France		
Marc Betoule	LPNHE (CNRS)	marc.betoule@lpnhe.in2p3.fr	France		
Augustin Guyonnet	LPNHE (CNRS)	auguyonnet@lpnhe.in2p3.fr	France		
Jean-Stéphane Ricol	LPSC (CNRS)	ricol@lpsc.in2p3.fr	France		
Adam Mantz	Kavli Institute for Cosmological Physics	amantz@slac.stanford.edu	United States		
Dr Douglas Applegate	Argelander Institute for	dapple@astro.uni-bonn.de	Germany		

The goal is to contribute by an
independent analysis chain for cross-checks.

Data reduction pipeline



Impact of the brighter-fatter on the observed shape of a galaxy

quantifying the problem :

Usual parametrization of shear bias

→ $\hat{\gamma} = (1+m)\gamma + c$

Impact of a 1% « brighter-fatter » on the LSST

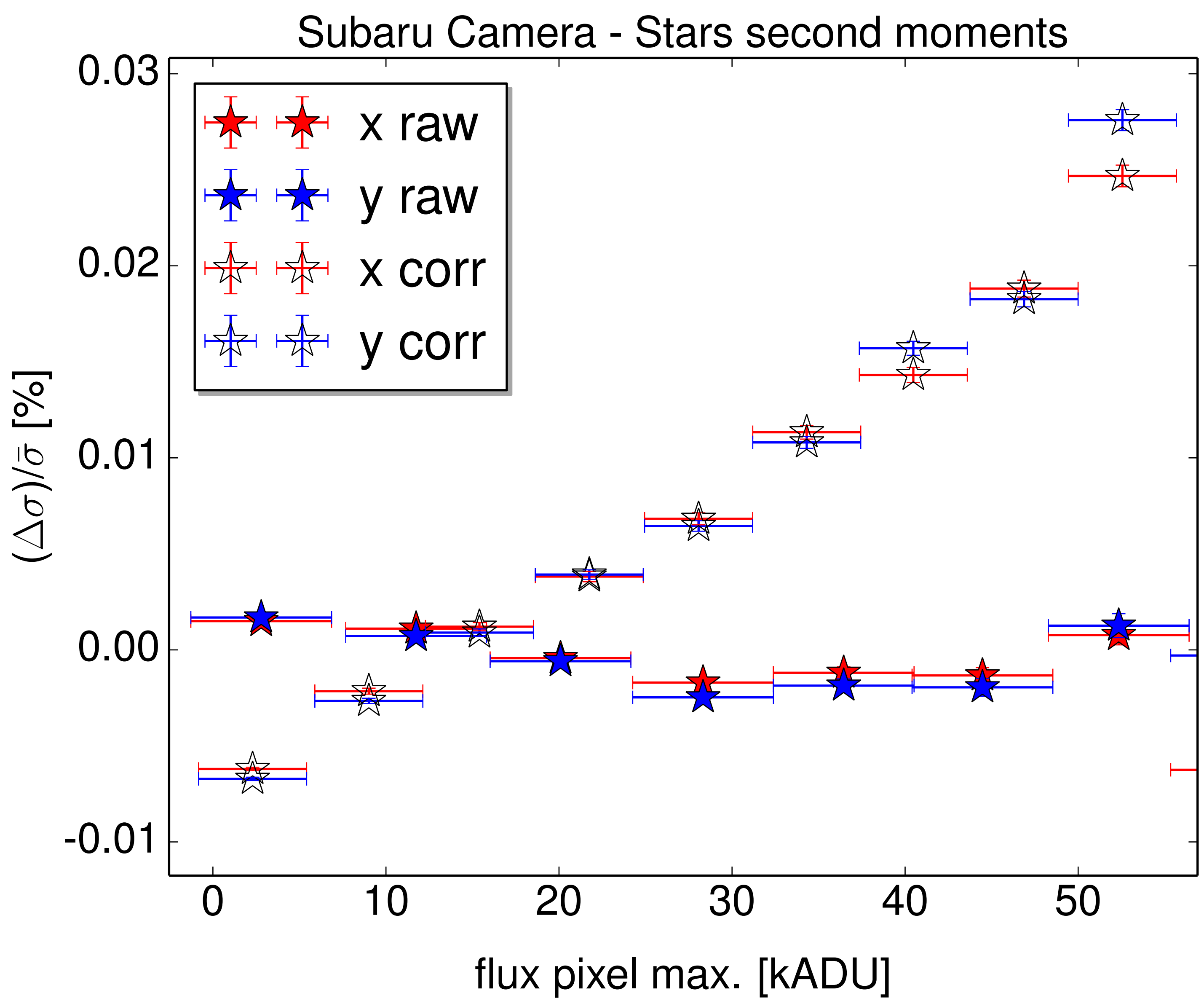
→ $m \approx 0.027$

Meanwhile, the requirement is

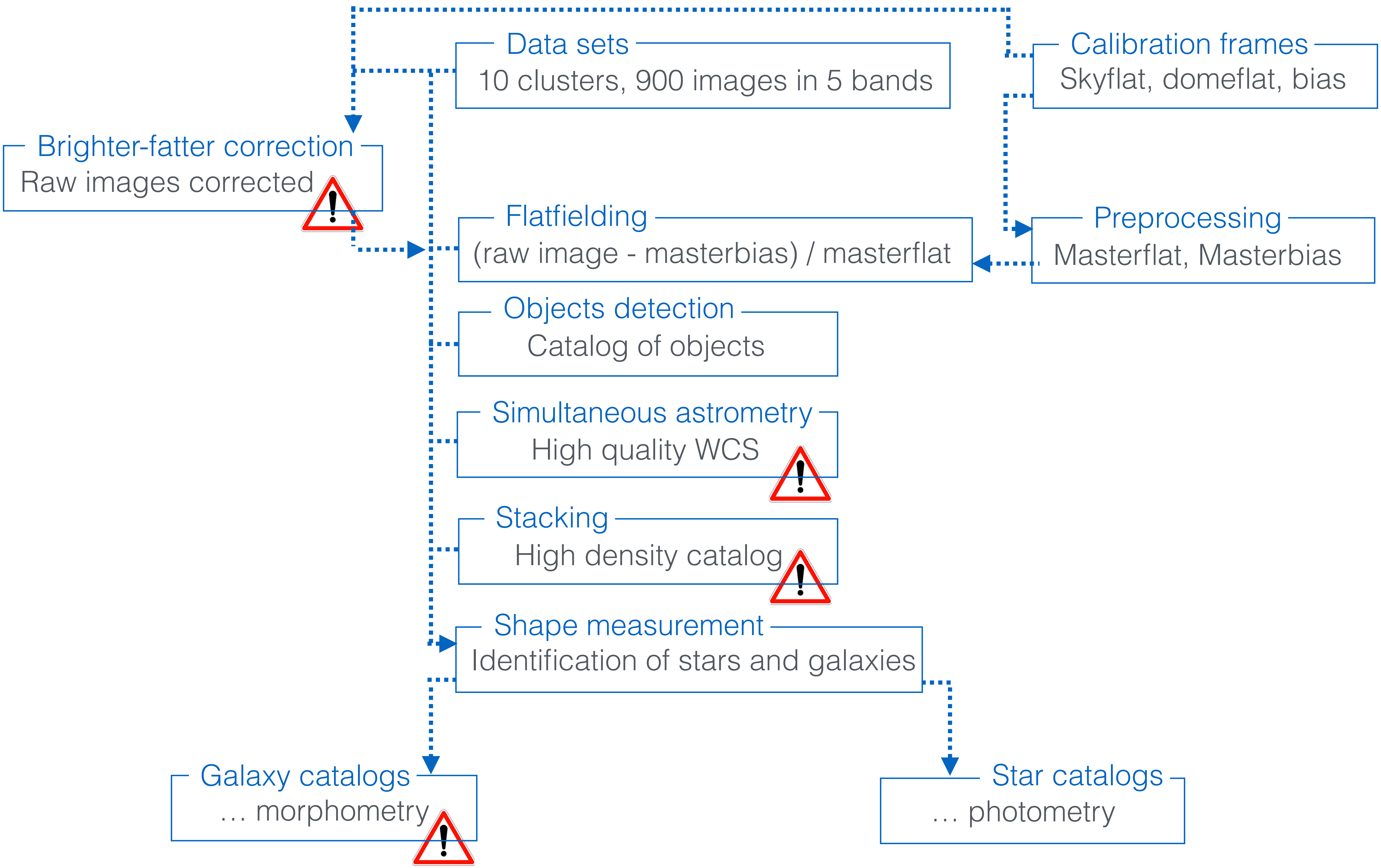
→ $m_{req} \approx 0.003$

Correction at the pixel level for the Subaru Camera

Brighter-fatter effect
before and after redistribution of charges



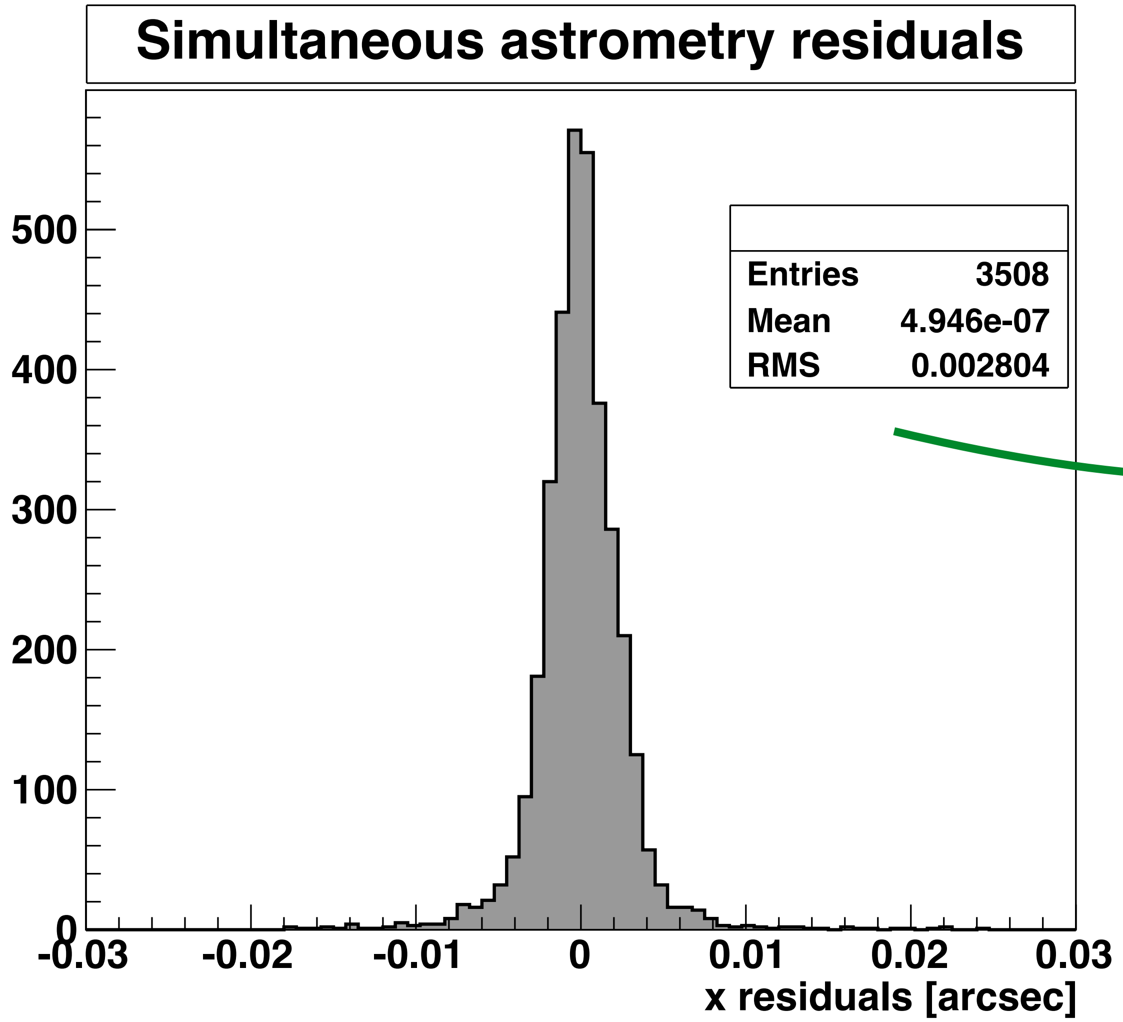
Data reduction pipeline



Simultaneous Astrometry

An astrometric solution is :
a map from pixel coordinates to celestial coordinates (WCS).

The game of simultaneous astrometry is to :
→ Adjust WCS of a series of images,
→ Associate their catalogs of objects,
→ Associate this catalog to an external catalog to fix the sidereal coordinates,
→ Adjust the sidereal positions of common objects and the WCS taking the measurement errors into account.



rms = 0.003 arcsec

rms = 0.015 arcsec for DES (Jarvis et al. 2015)

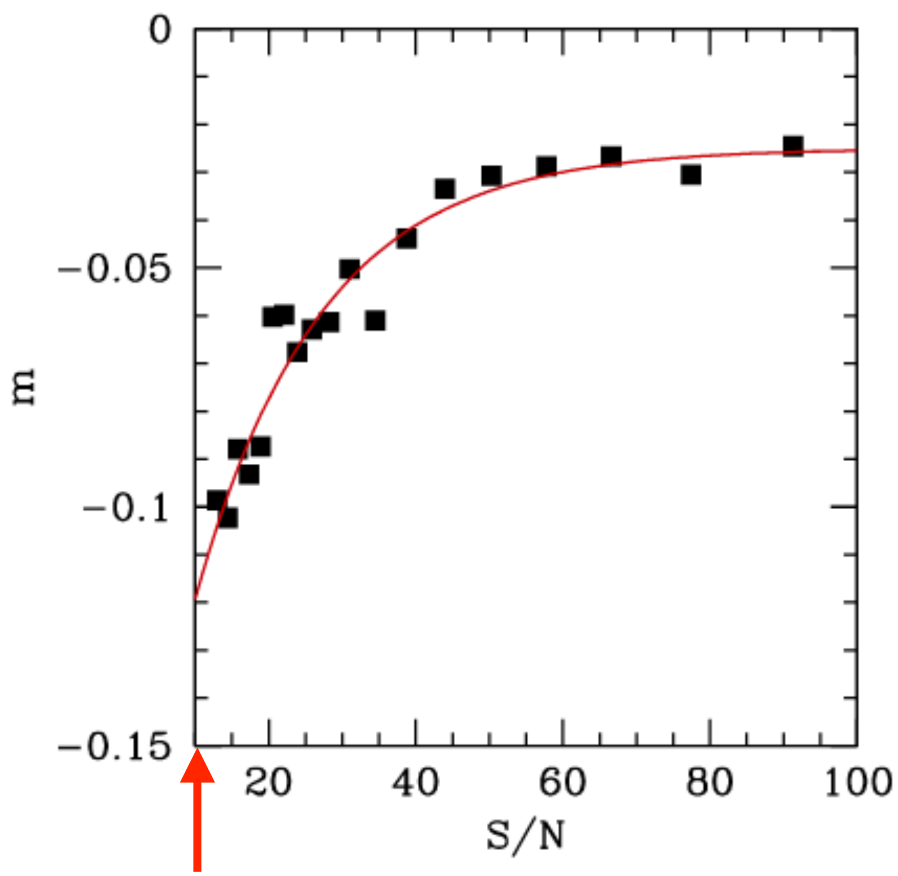
Why do we want simultaneous astrometry ?

Strong contribution from the centroid bias

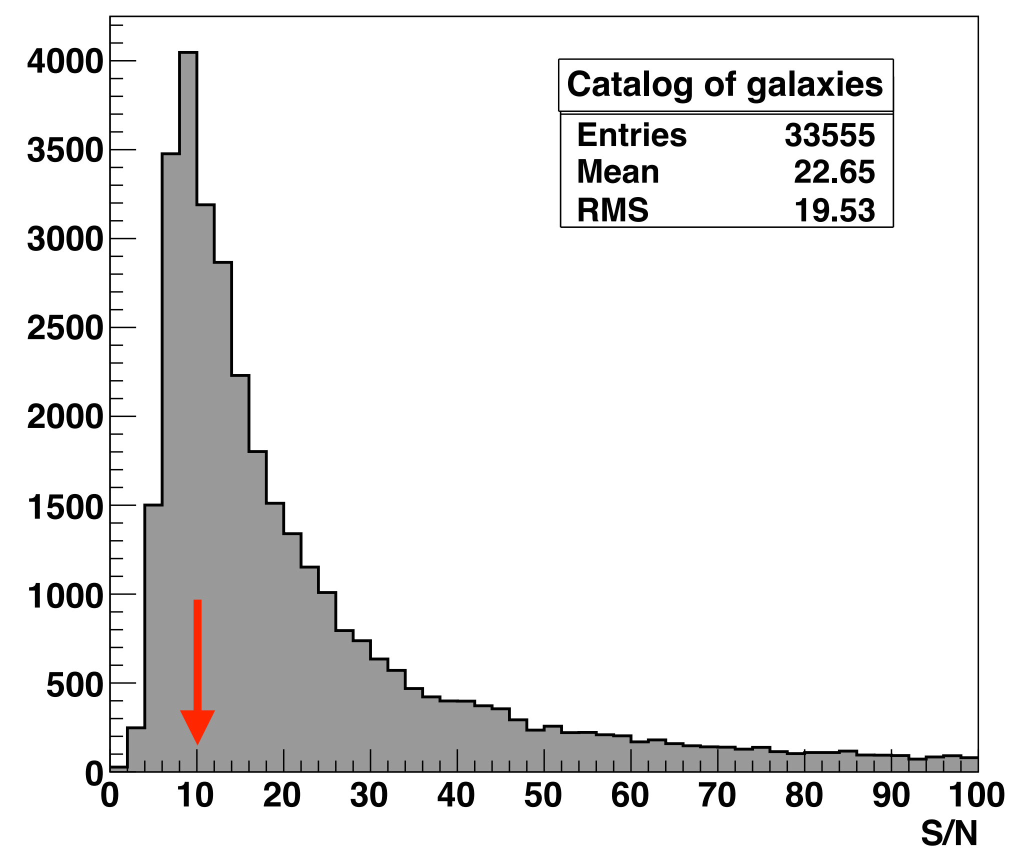
$$\text{An error } \delta x_0 \rightarrow \text{inflates } g m_{xx} \propto \delta x_0^2$$

(Bernstein & Jarvis 2001)

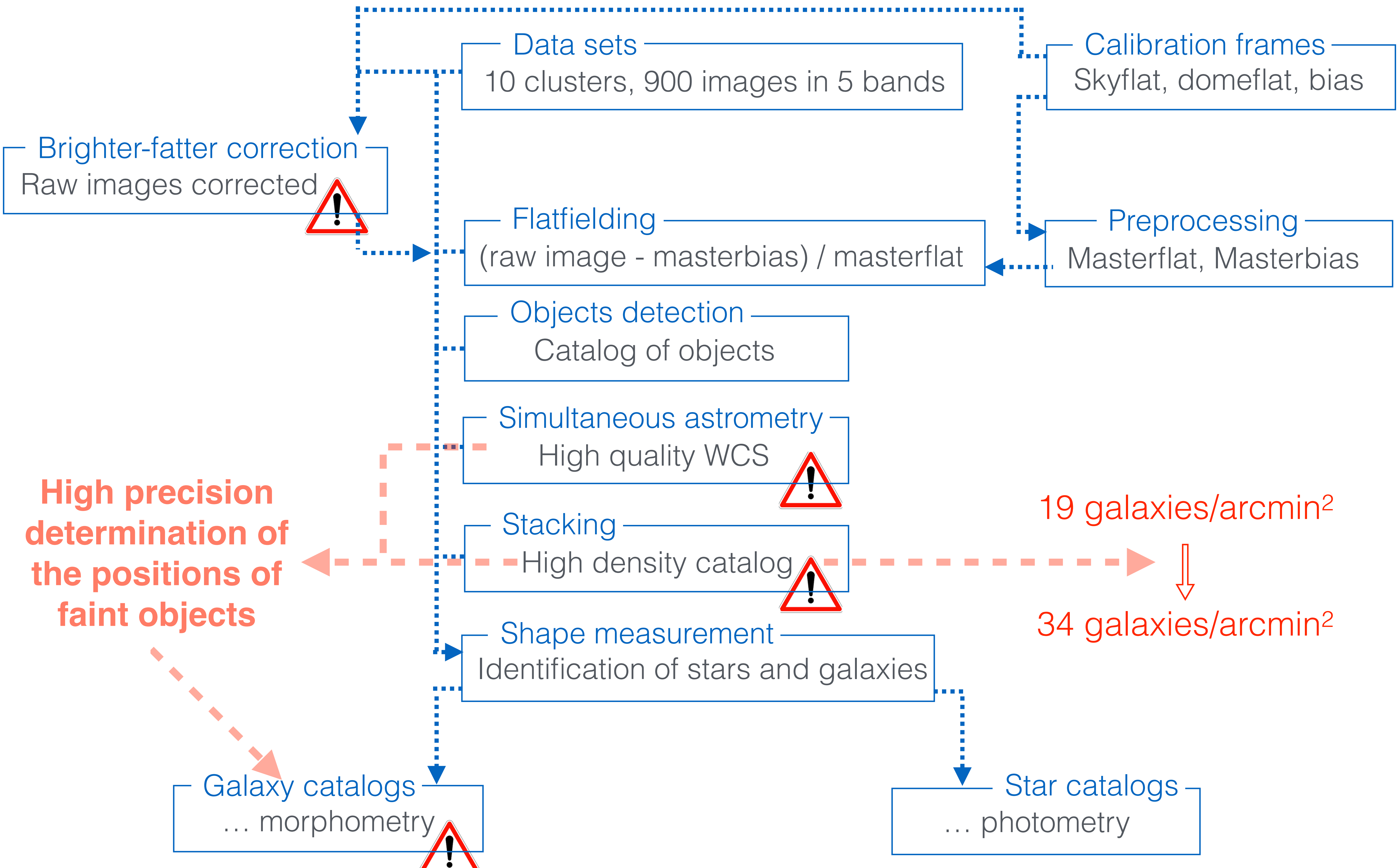
Multiplicative bias as a function of S/N for DES shape pipeline (Gruen et al. 2013) (1304.0764)



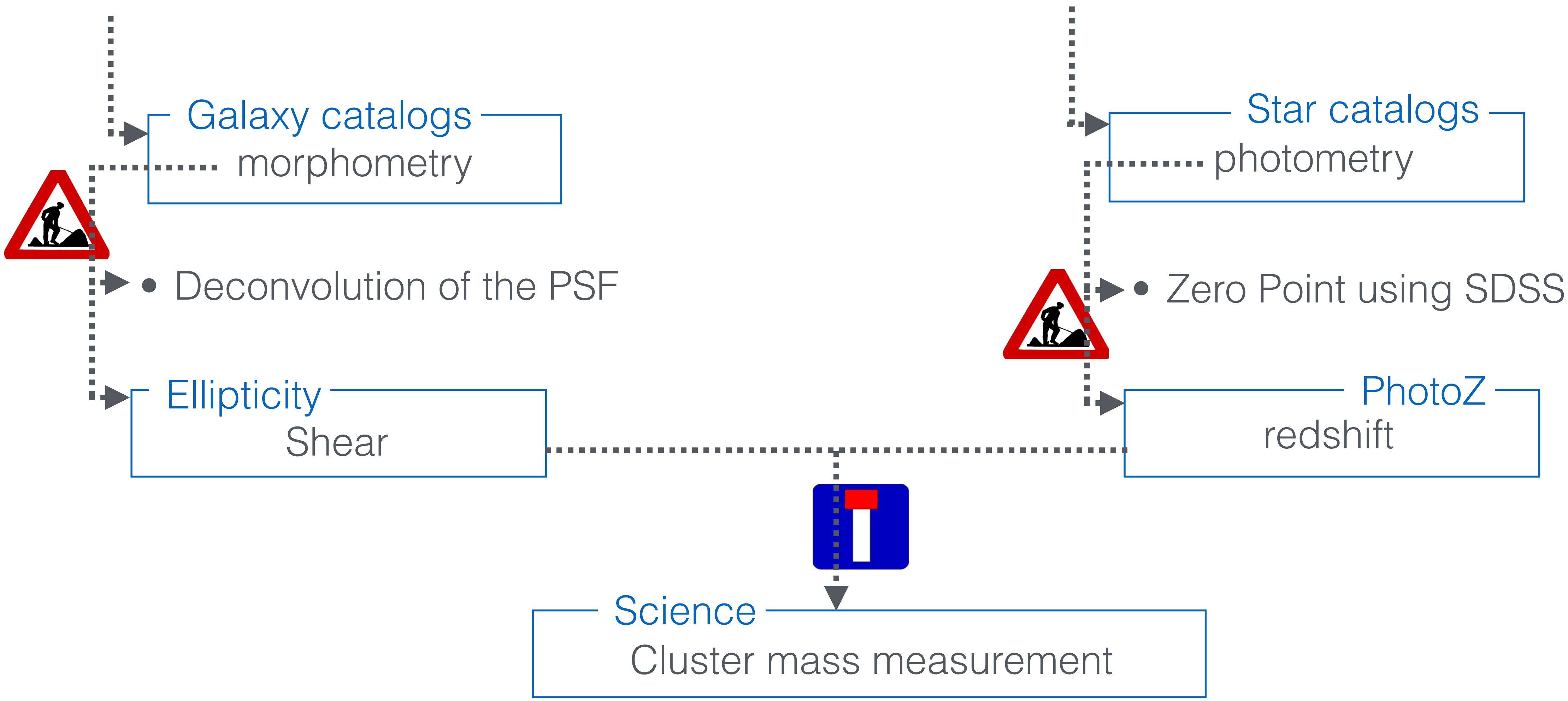
S/N of our input catalog



Data reduction pipeline



From the catalogs to science



How to measure the ellipticities of the galaxies ?

Galaxy catalogs
morphometry

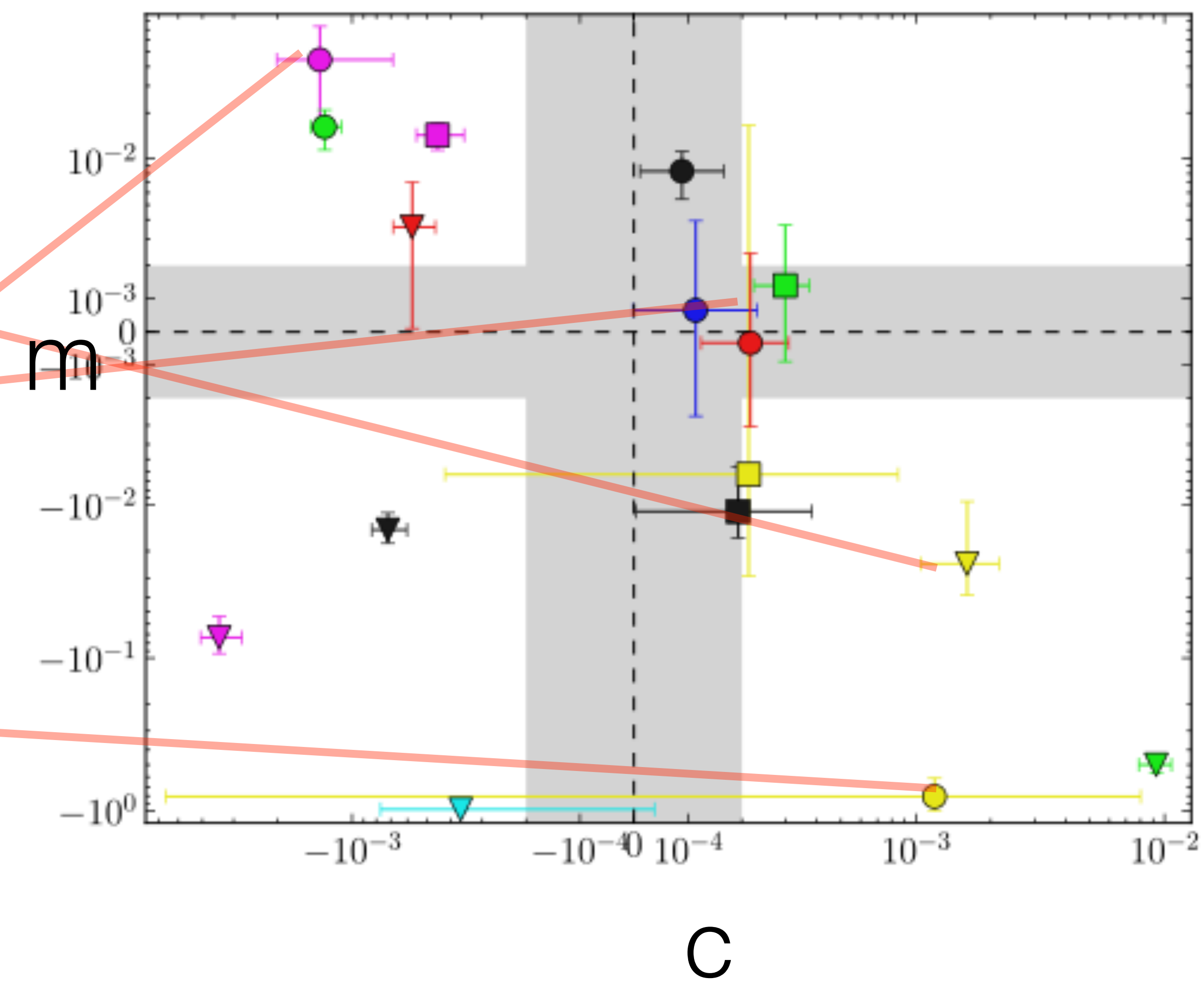
- Deconvolution of the PSF (Bernstein & Jarvis 2001)

Ellipticity
Shear

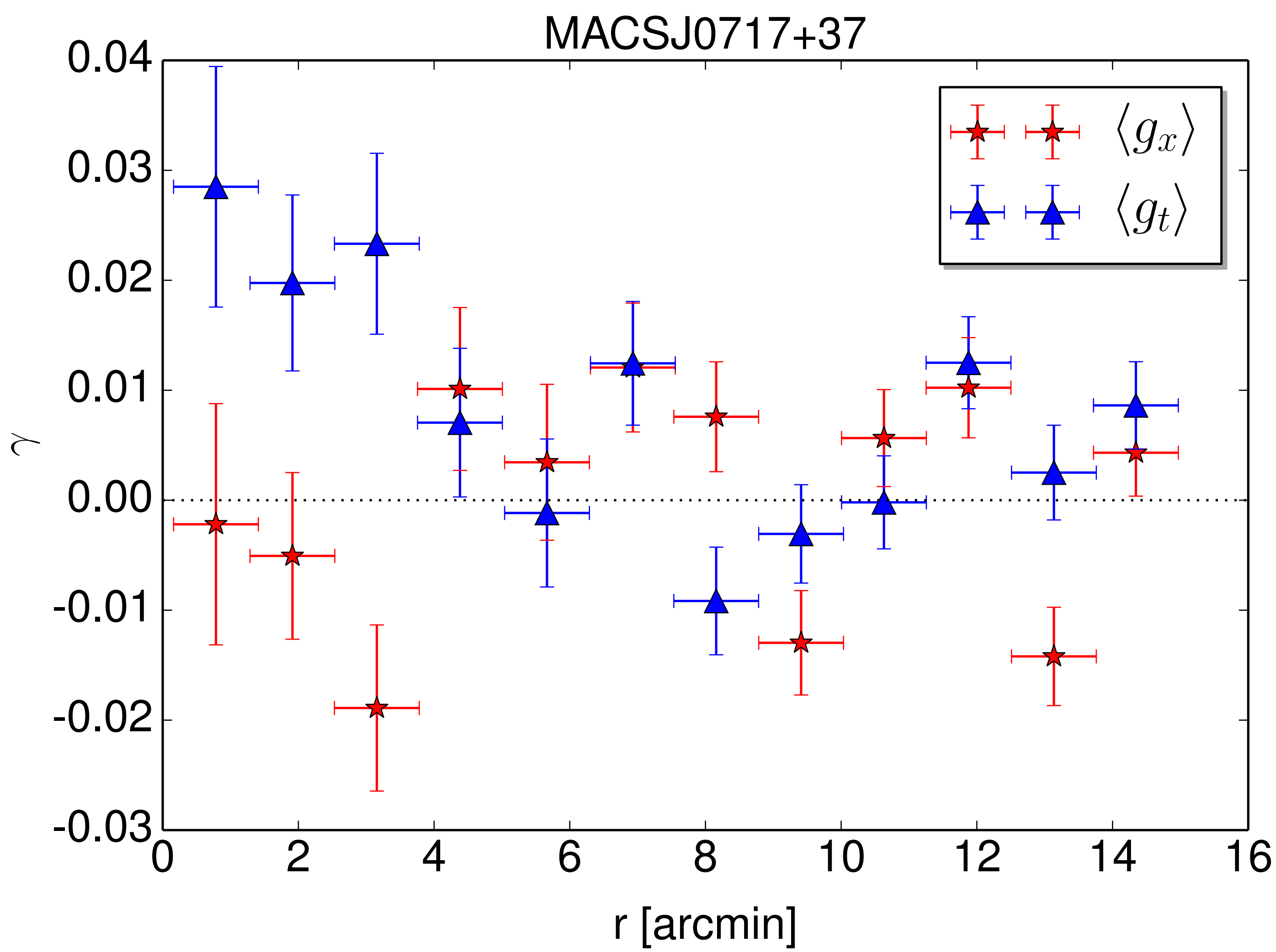
Shear inference methods :

Moments-based methods :
(Fourier-space, real-space),
(Sersic profiles, shapelets),
Maximum likelihood :
(model fitting methods: Sersic profiles,
shapelets, …),
Bayesian (full, partial, hierarchical…),
Neural network

GREAT 3 (1412.1825)

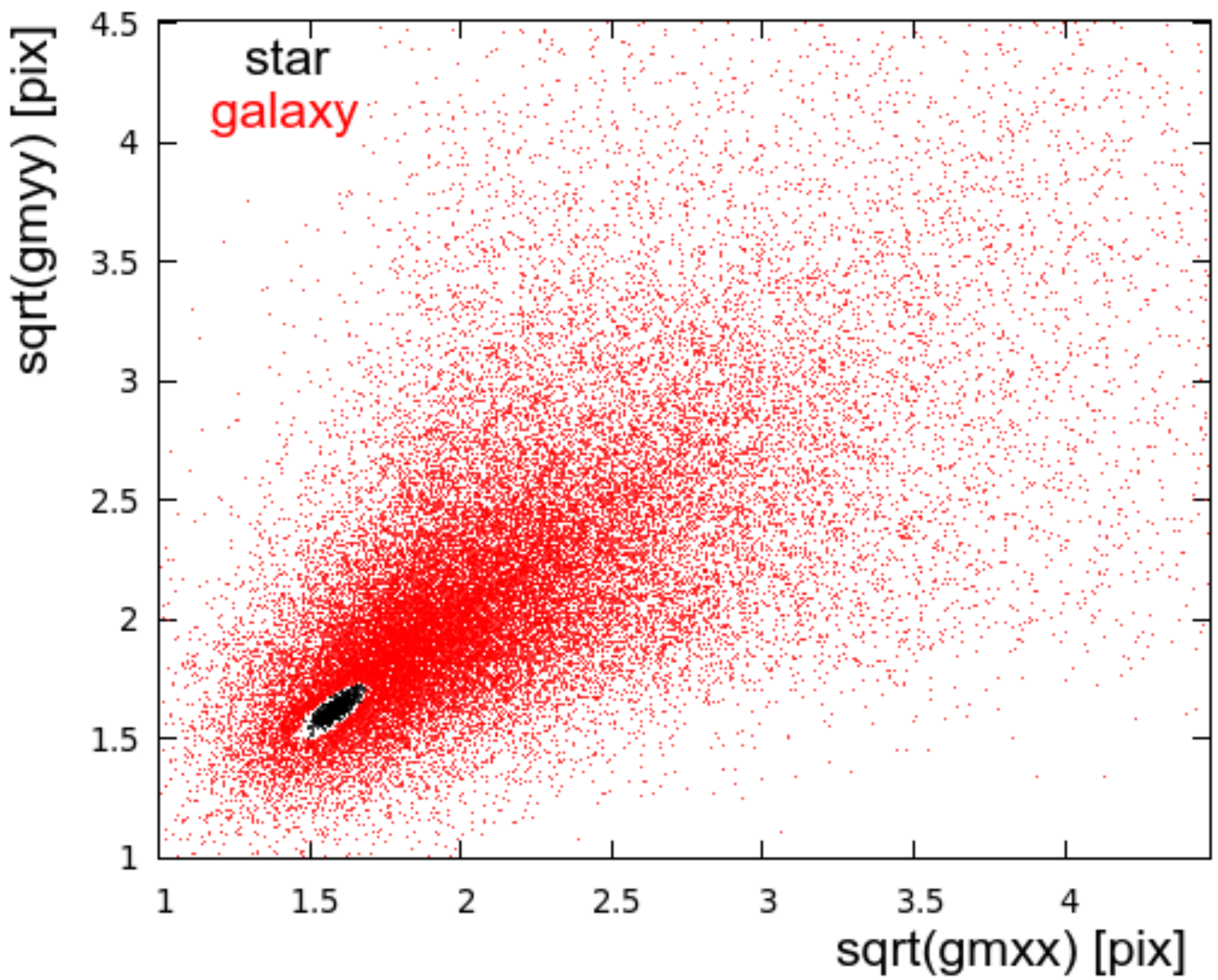


The mass of the cluster is estimated by fitting the tangential ellipticity of background galaxies with the weak lensing shear profile of a NFW/… halo.

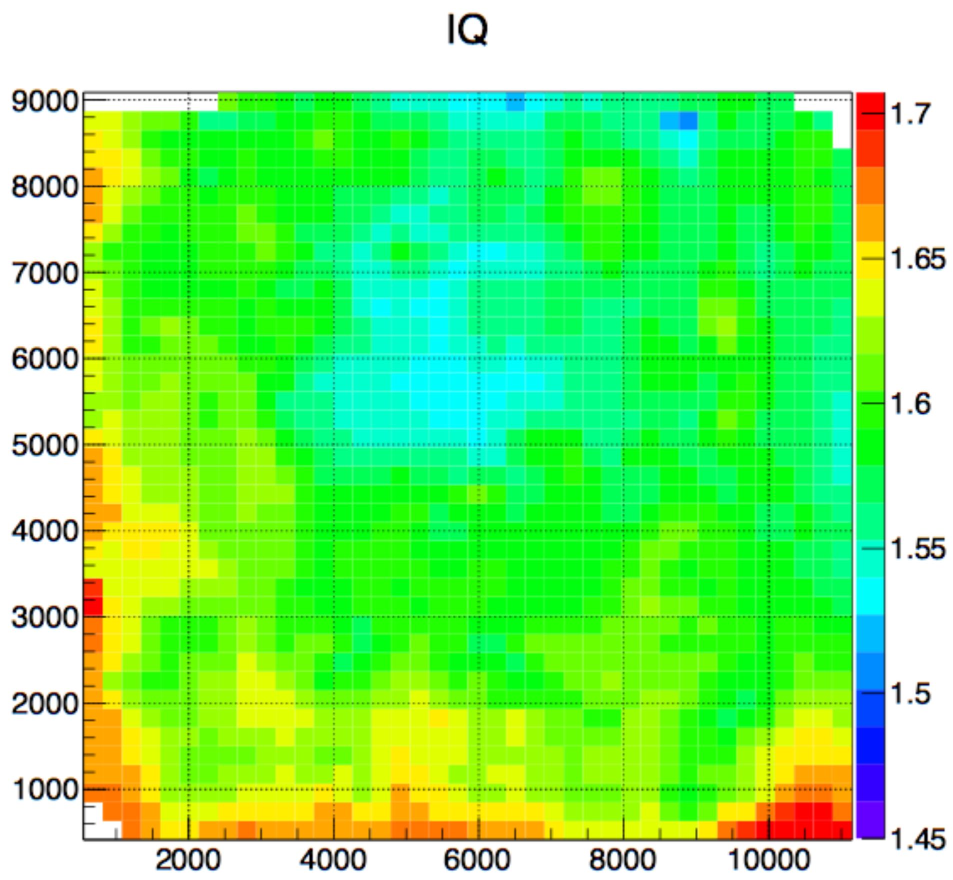


A common density profile :
(singular isothermal sphere)

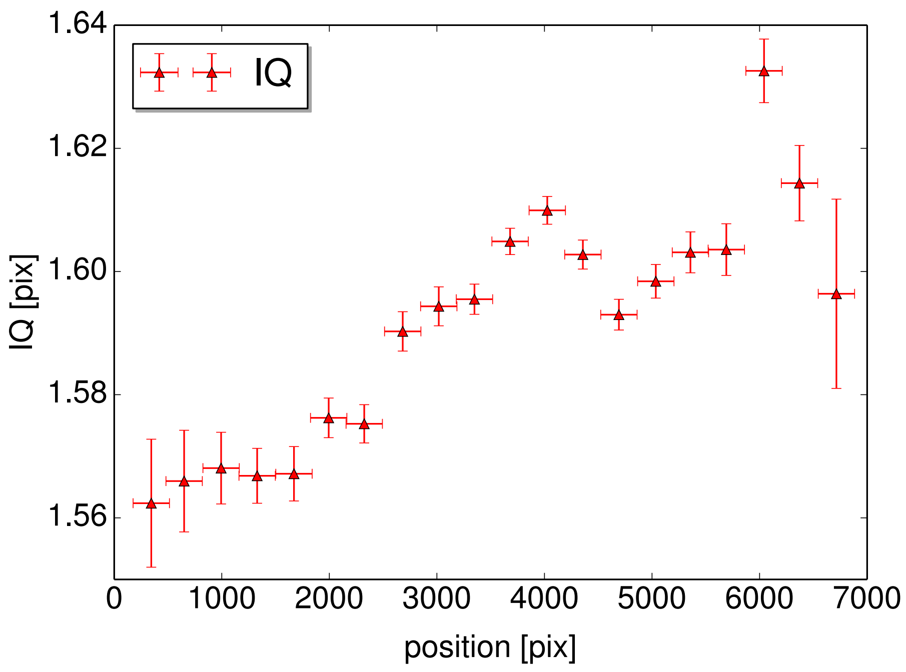
$$\gamma_t(r) = 2\pi \left(\frac{\sigma_v}{c}\right)^2 \frac{D_{ls}}{D_s} \frac{1}{r}$$


star
galaxy
sqrt(gmyy) [pix]
sqrt(gmxx) [pix]
4.5
4
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
4

Stack



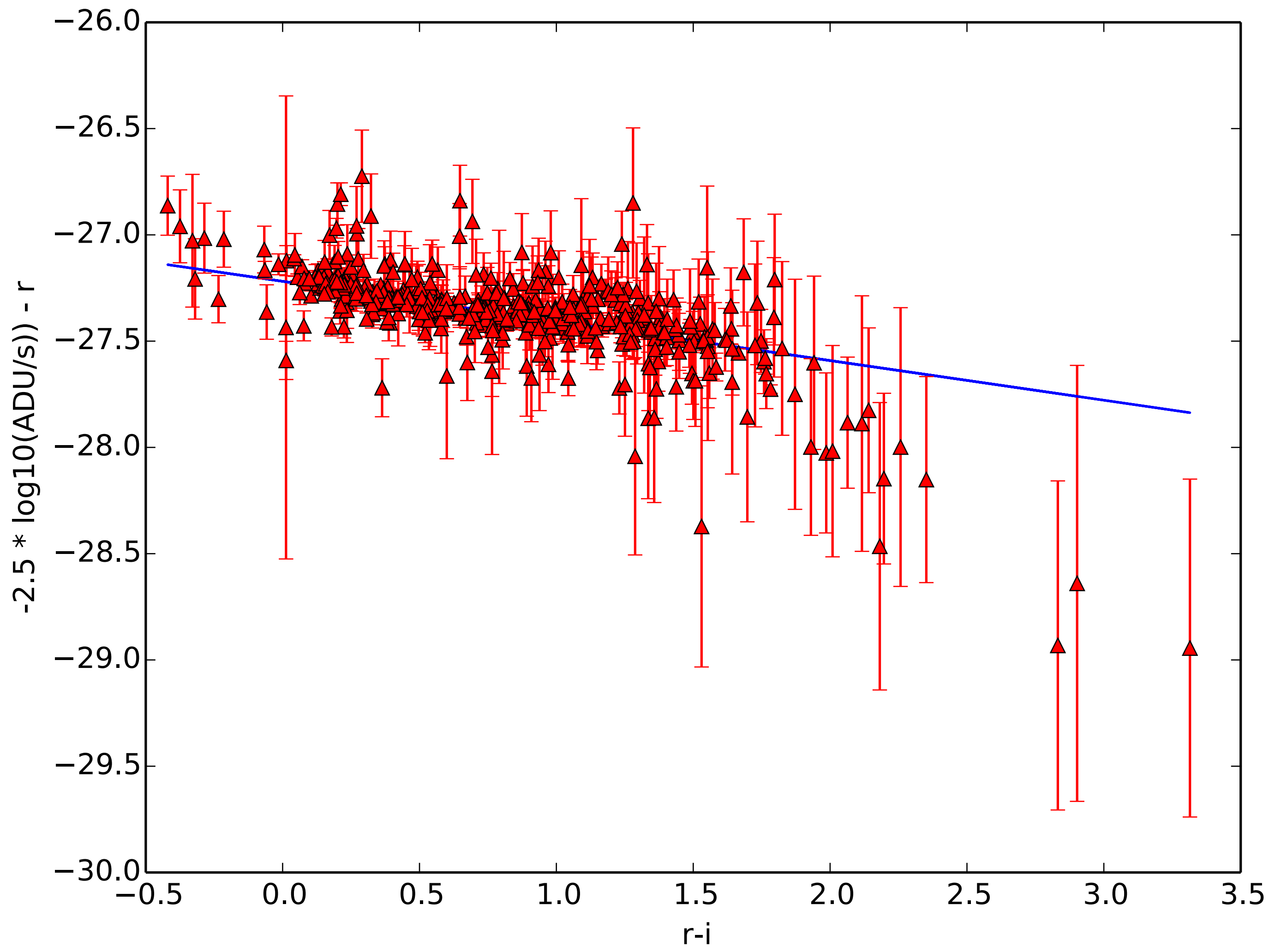
IQ
9000
8000
7000
6000
5000
4000
3000
2000
1000
2000
4000
6000
8000
10000
1.7
1.65
1.6
1.55
1.5
1.45

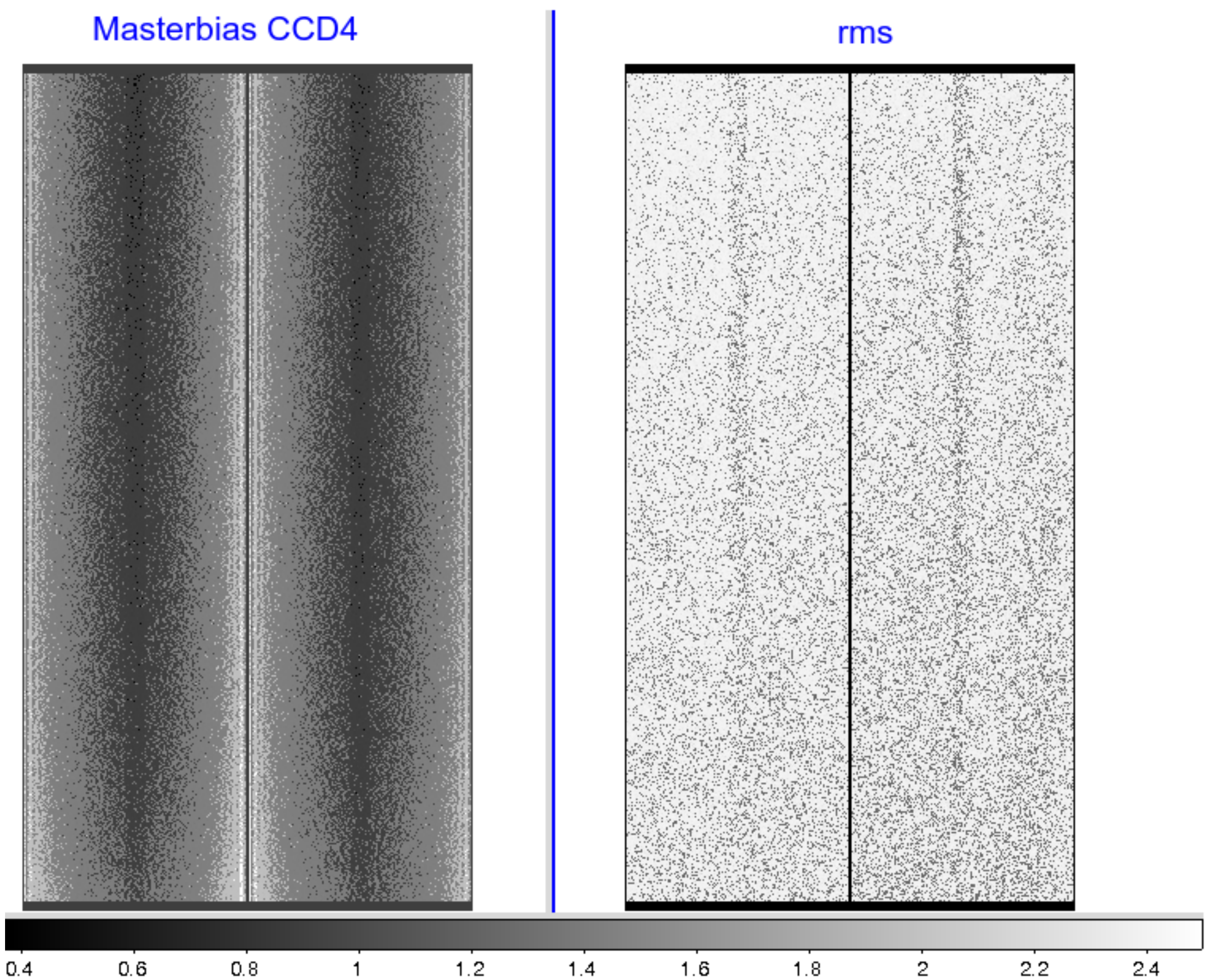


IQ
1.64
1.62
1.60
1.58
1.56
IQ [pix]
0
1000
2000
3000
4000
5000
6000
7000
position [pix]

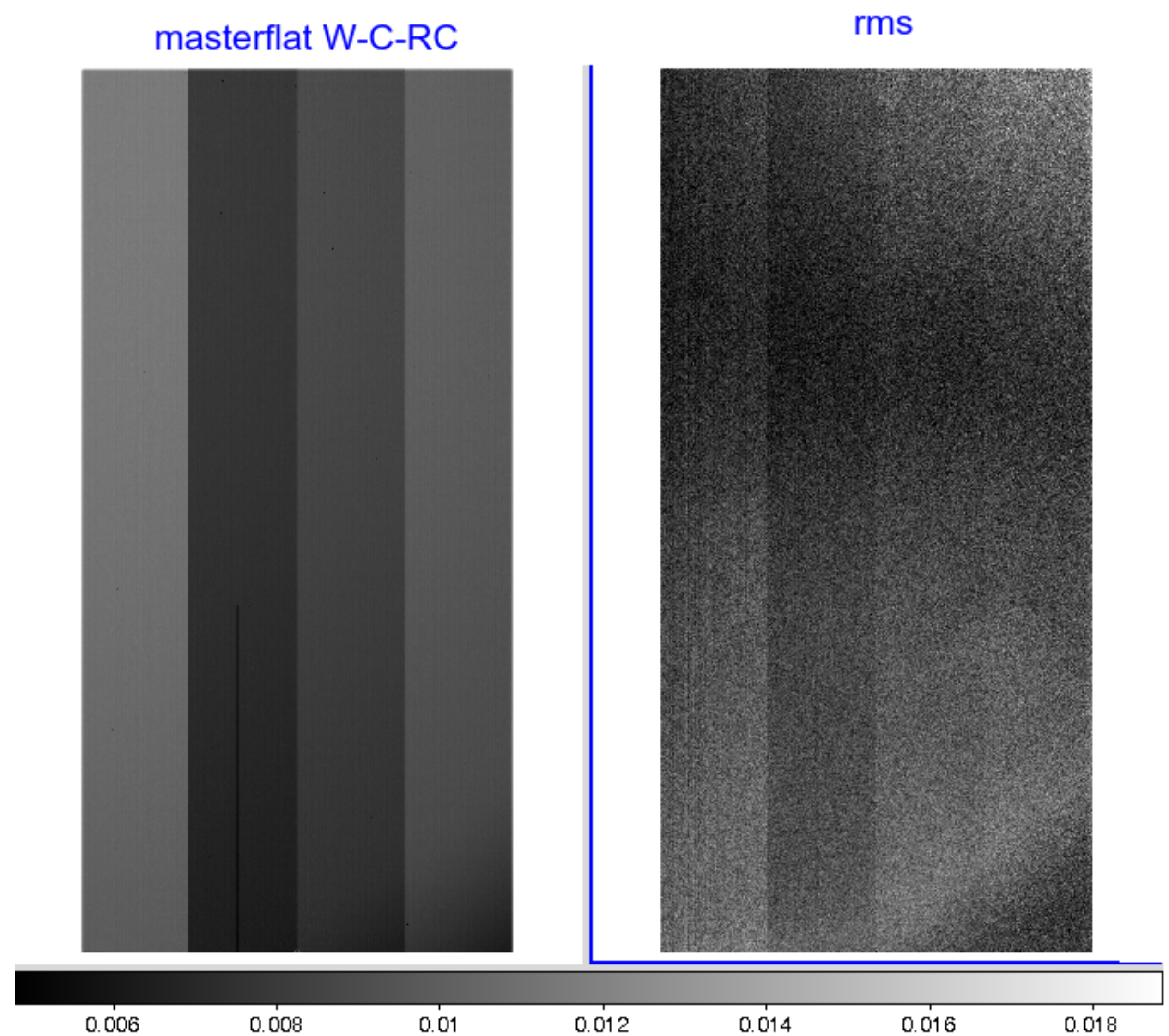
Photometric zero point

- Use of the astrometry to match the stars with SDSS catalogs.
  → color transformation between SDSS and Subaru to fit zero point for each CCD and each night   (ongoing work).





RO noise ~ 2 ADUs



Rms ~ 0.01 (over a period of 2.5 years)

for a few bands and periods, I fail to build a masterflat

equations

$$\Sigma_{crit} = \frac{c^2}{4 \pi G}\frac{D_s}{D_l D_{ls}}$$

$$\kappa = \frac{\Sigma}{\Sigma_{crit}}$$

$$\gamma_1 = \frac{gm_{xx} -gm_{yy}}{gm_{xx} +gm_{yy}}$$

$$\gamma_t = - \left(\gamma_1 cos(2 \theta_c) + \gamma_2 sin(2 \theta_c)\right)$$

$$\gamma_t(r) = 2 \pi \left(\frac{\sigma_v}{c}\right)^2 \frac{D_{ls}}{D_s} \frac{1}{r}$$

$$\text{An error $\delta x_0 \rightarrow$ inflates }$$

$$\epsilon_{gal}= \left(\frac{gm_{xx} -gm_{yy}}{gm_{xx} +gm_{yy}} \right)+ 2i \left(\frac{gm_{xy}}{gm_{xx} +gm_{yy}} \right)$$

$$\epsilon_{gal} = \epsilon_{int} + g$$