Practical implementation of a shear measurement pipeline

-Challenges in the images processing and in the shear methods-

Augustin GUYONNET + Josquin ERRARD

LSST France - LPSC - June 2016

Lensing at LPNHE + « Weighing 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
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
Matthieu Roman
Marc Betoule
Dr Augustin Guyonnet
Pat Kelly

CANADA-FRANCE-HAWAII TELESCOPE

Astier **15BF008**

Weighing the f_gas clusters

e Cat. : High-z universe

ter content of the
rovide an excellent
these yield some of the
most robust constraints on Omega_m, largely independent of the assumed cosmological model. The currently largest systematic uncertainty on the Omega_m constraint stems from the uncertainties in total cluster mass estimates. By comparing X-ray-derived mass estimates with high-quality weak-lensing mass estimates for a su
reduced. Currently, only 12 out
lensing data, and only 6 of those
galaxies. We here propose to ex
fgas clusters. Along with future
to 5% precision - a remarkable
parameters from a single experi

Telescopes

Telescope	Observing mode	Instruments
CFHT	QSO Regular	MegaCam

Applicants

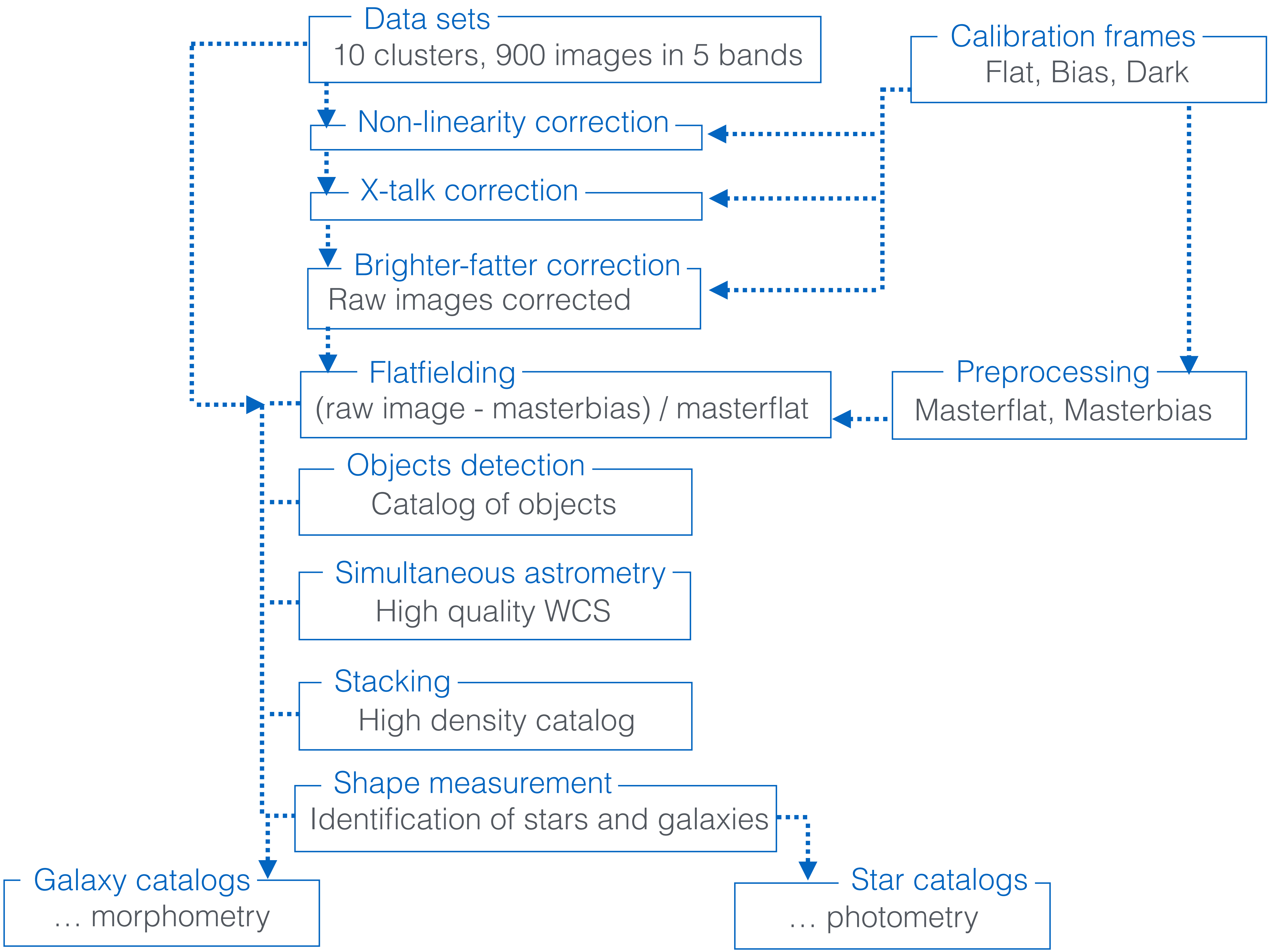
Name	Affiliation	Email	Country		Potential observer
Dr Pierre Astier	CNRS (LPNHE)	pierre.astier@in2p3.fr	France	PI	
Ludovic Van Waerbeke	University of British Columbia (Physics and Astronomy)	waerbeke@phas.ubc.ca	Canada		
	C	anja@slac.stanford.edu	United States		
	ord University ics)	swa@stanford.edu	United States		
	2P3 (CNRS)	boutigny@in2p3.fr	France		
	E (CNRS)	matthieu.roman@lpnhe.in2p3.fr	France		
	E (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 Institut for	dapple@astro.uni-bonn.de	Germany		

For the current generation of X-ray cluster surveys, the uncertainty in the absolute mass calibration (15%) dominates the systematic uncertainty on the matter power spectrum normalization $\sigma 8$.

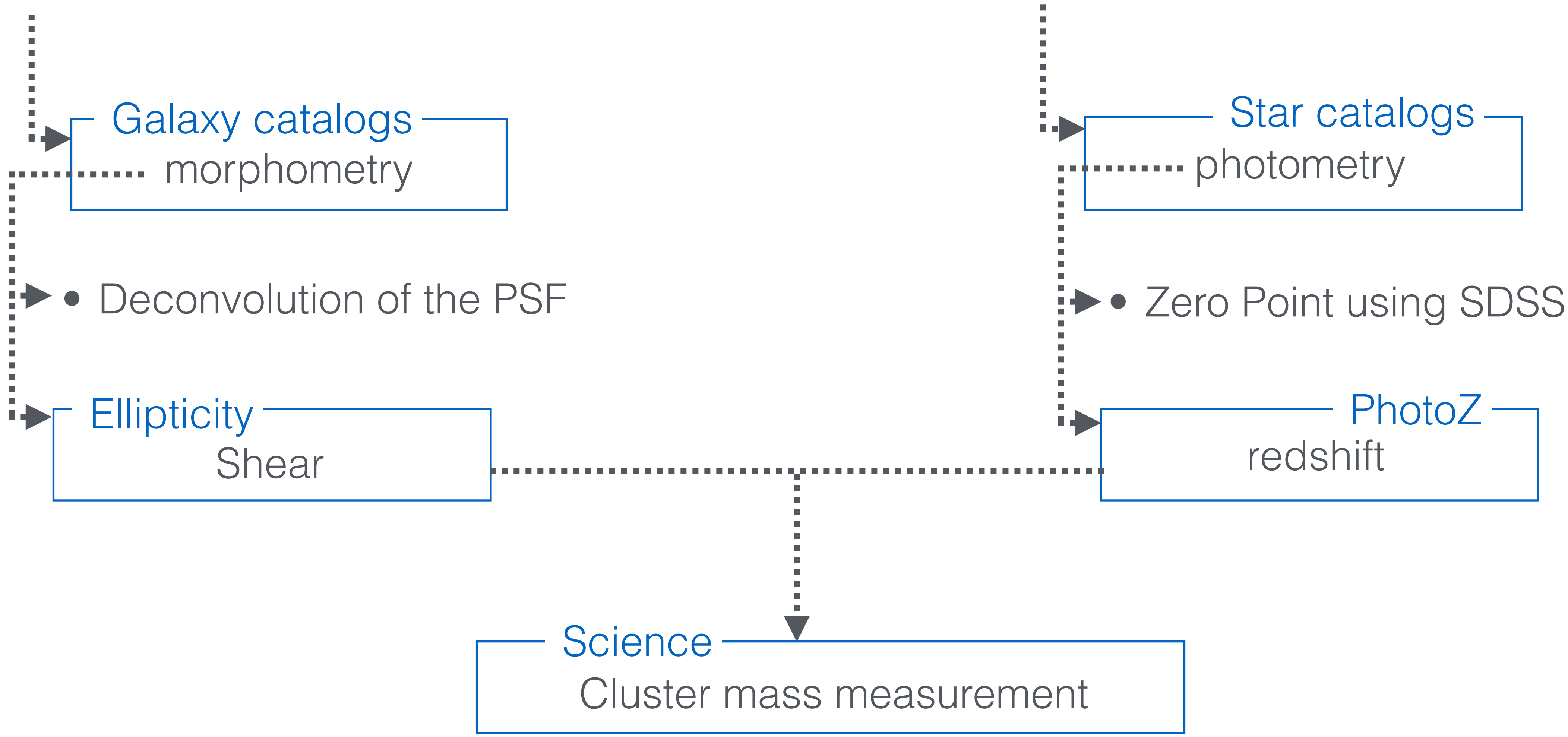
Two proposals submitted and accepted :
The objective is to increase the sample of clusters
→ 5% uncertainty on the mass calibration.

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

Image processing for shear measurement



From the catalogs to the science

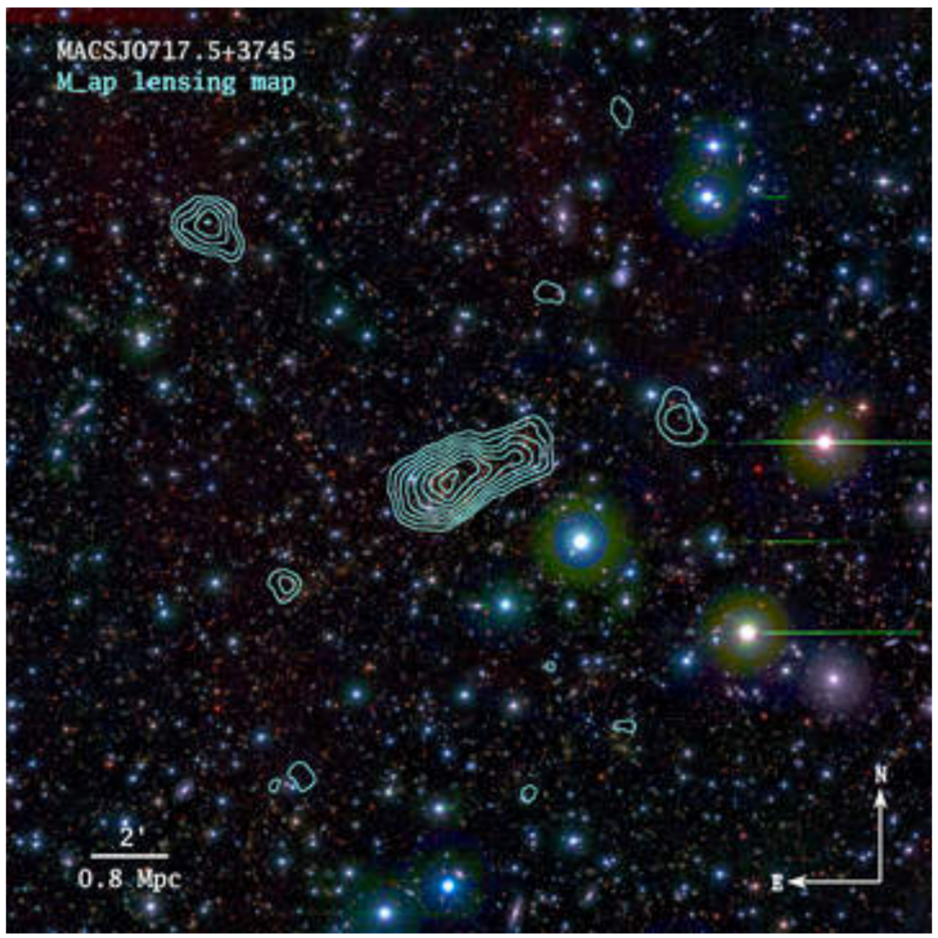


Shear as a cosmological probe : Lensing by clusters of galaxy

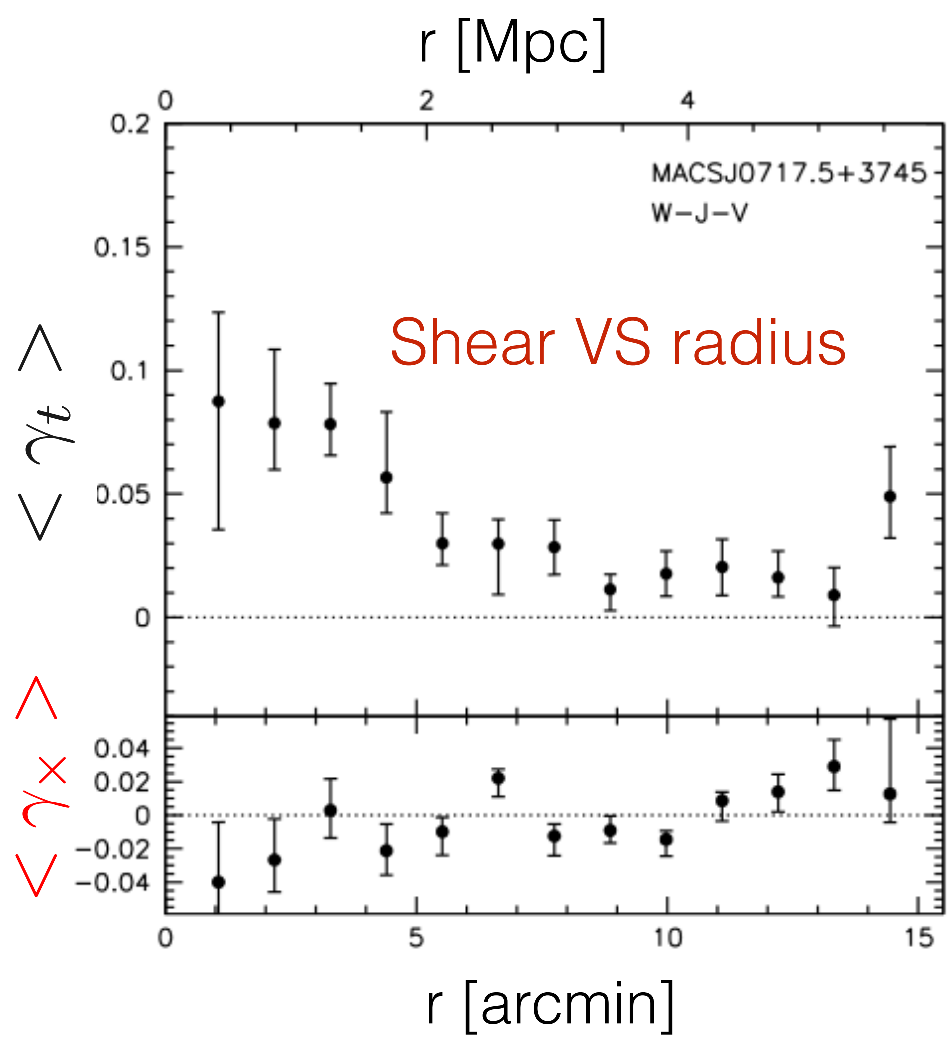
$$\gamma_t = -\left(\gamma_1 cos(2\theta_c) + \gamma_2 sin(2\theta_c)\right)$$

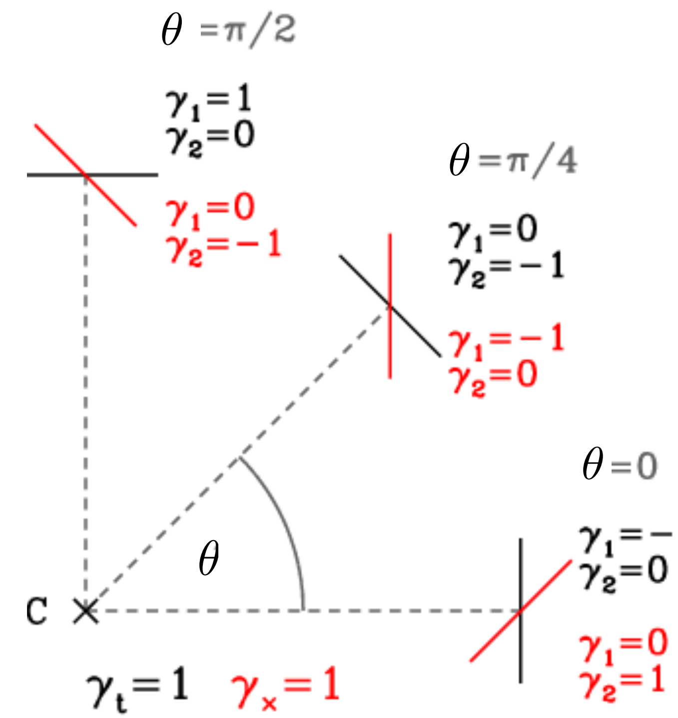
$$\gamma_\times = -\gamma_1 sin(2\theta_c) + \gamma_2 cos(2\theta_c)$$

Weighing the Giants I
(1208.0597)



Contours of mass distribution





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

$$\gamma_2 = \frac{2\, gm_{xy}}{gm_{xx} + gm_{yy}}$$

Ingredients of the images processing

- Remove sensor signatures.

(already discussed last LSST-France meeting)

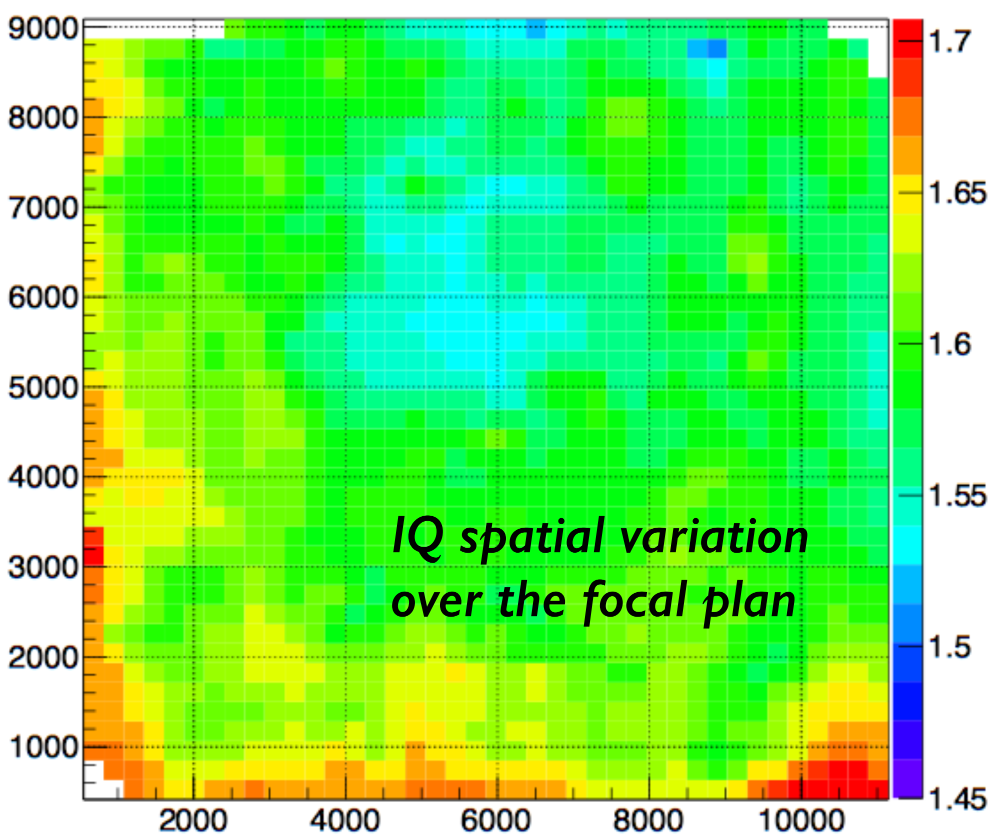
- Minimizing the centroid bias (an error δx_0 inflates $gm_{xx} \propto \delta x_0^2$) → simult. astro. 3 mas.

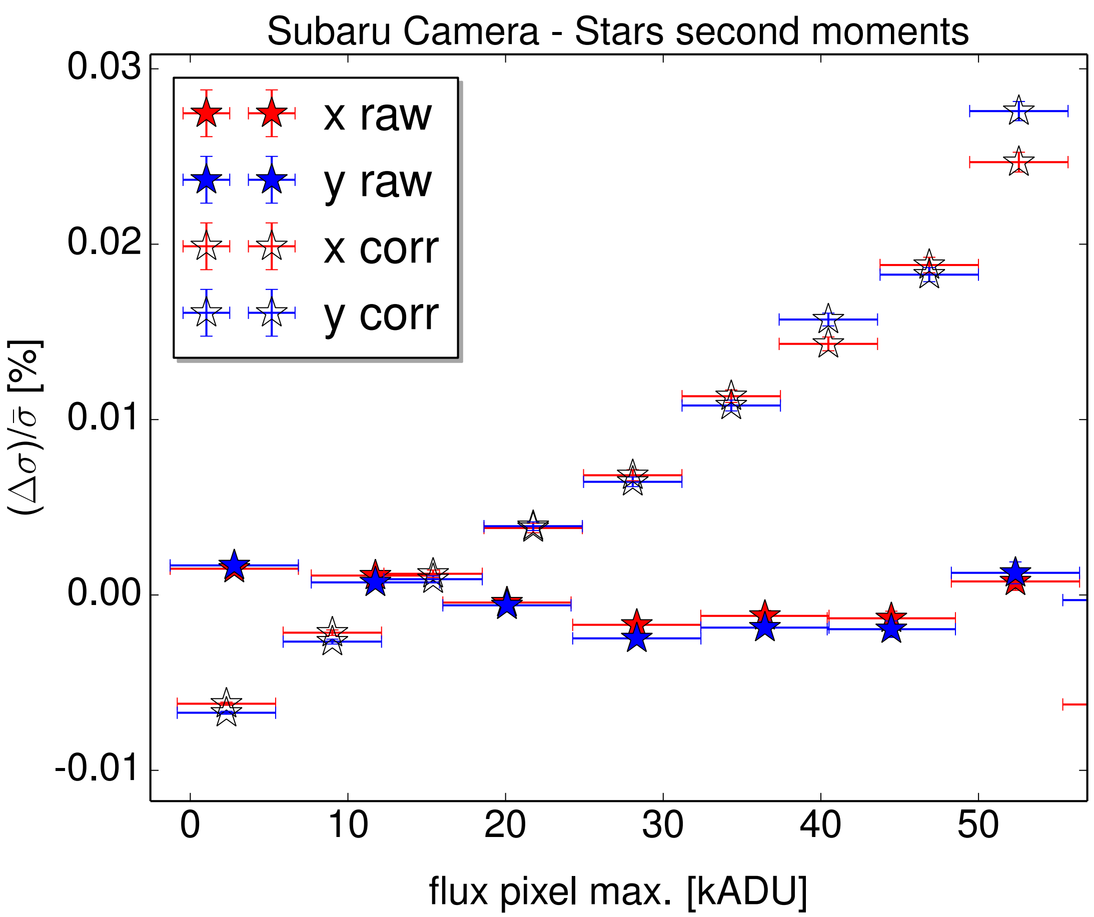
(already discussed last LSST-France meeting)

- Large statistics → Stacking 10 exposures : 19 gal/arcmin^2 ⇒ 34 gal/arcmin^2 .

(already discussed last LSST-France meeting)

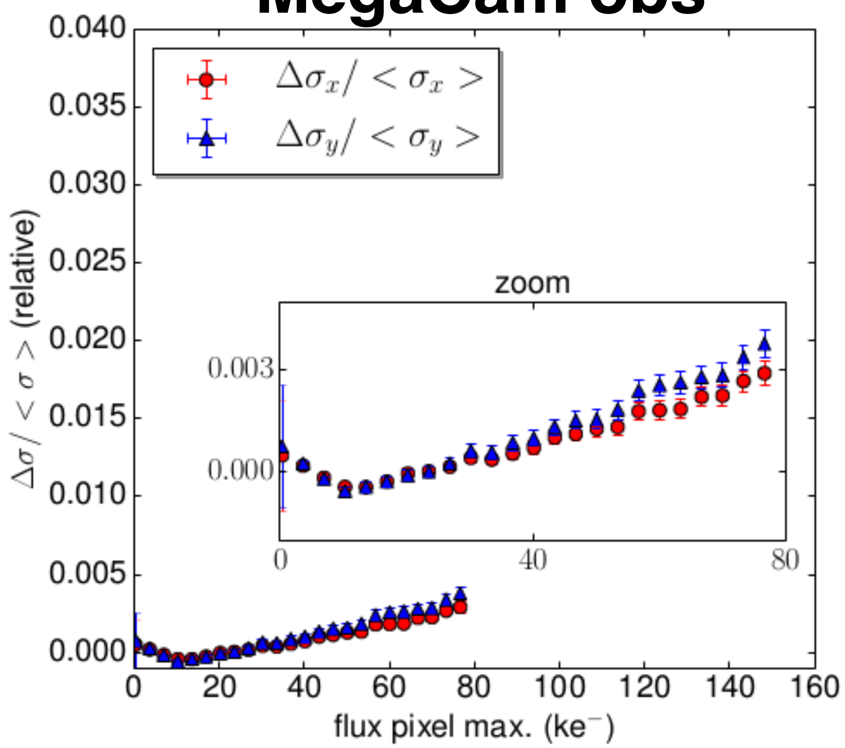
- Deconvolution (Know the PSF at the permil level)/shear estimator.
- Background subtraction.



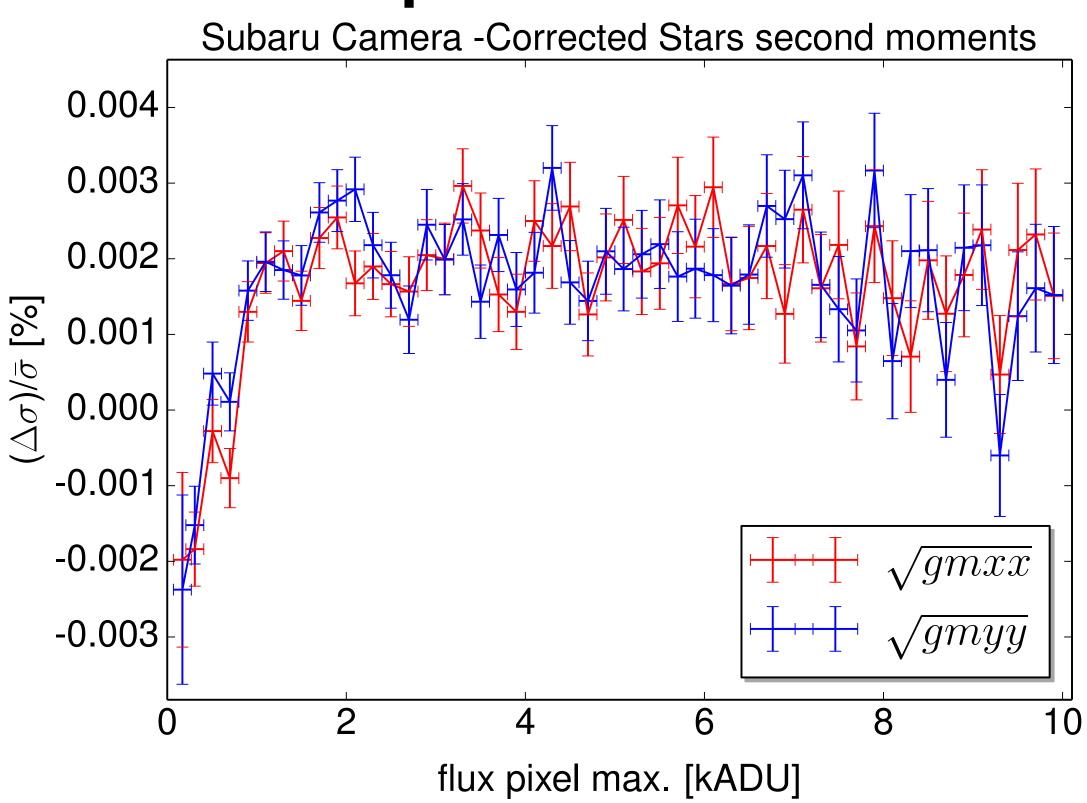


Impact of a background subtraction error

MegaCam obs



SuprimeCam obs

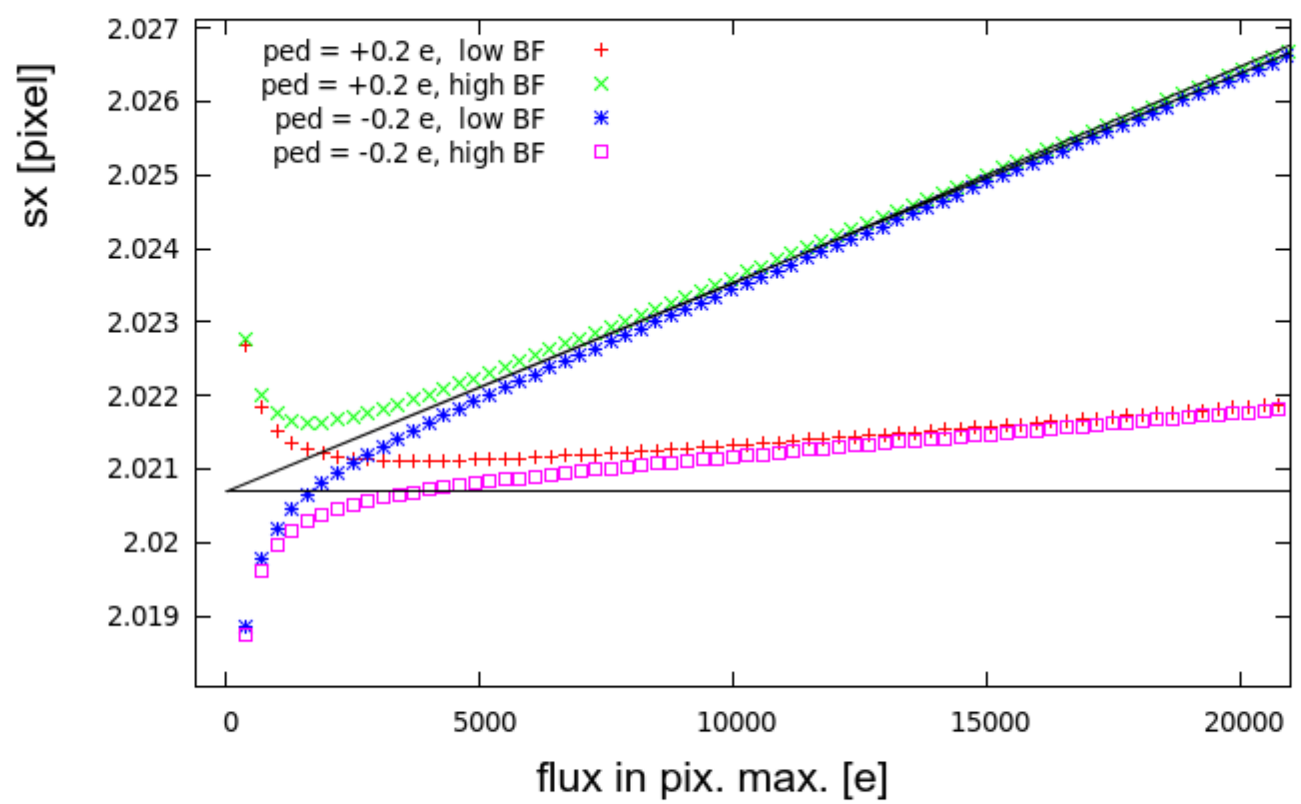


Over(-0.2e)/Under(+0.2e)estimation of the 'skylevel'

↓

Under/Overestimation of the moments at low flux

Simulation of a background subtraction error



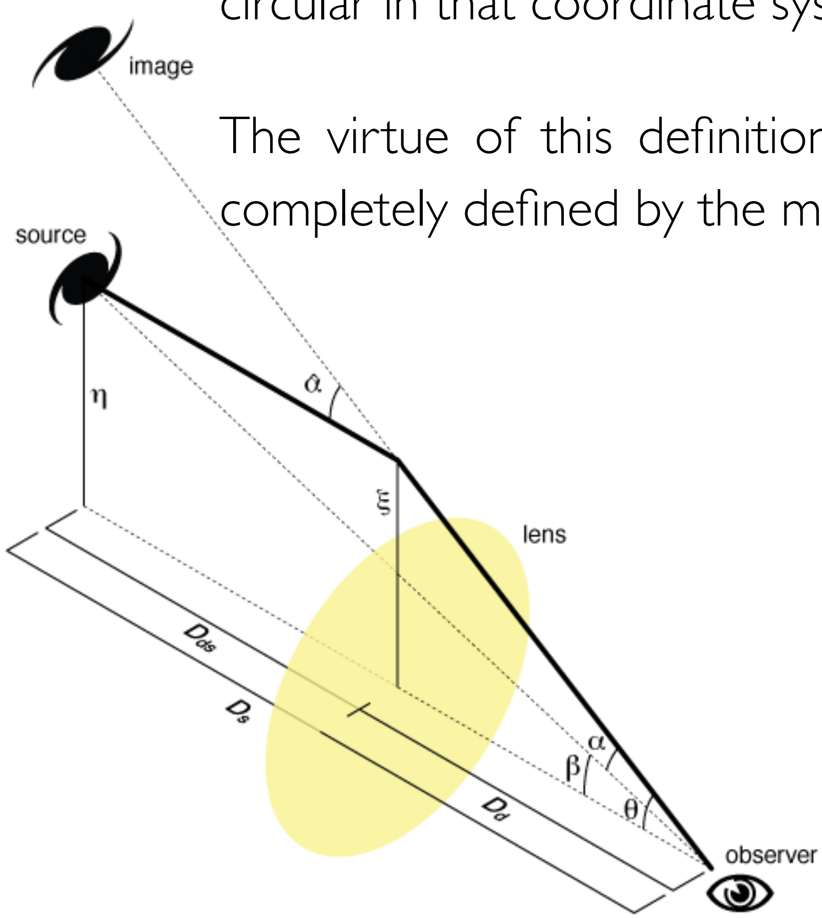
Shear estimator : the «optimal» Gauss-Laguerre technique

Define galaxy ellipticity via the transformation that restores a « round » galaxy (Berntein & Jarvis 2001) :

As in other technique, the task is to assign some shape e_i to observed galaxy i, then to derive from it an estimate of the applied lensing shear γ.

The B&J strategy is to find the shear η that when applied to the system θ makes the image appear circular in that coordinate system and declares the galaxy shape to be this shear.

The virtue of this definition is that the effect of a lensing distortion upon the galaxy shape is completely defined by the multiplication of shear matrices.



Shear estimator : the «optimal» Gauss-Laguerre technique

Decomposition of an image :

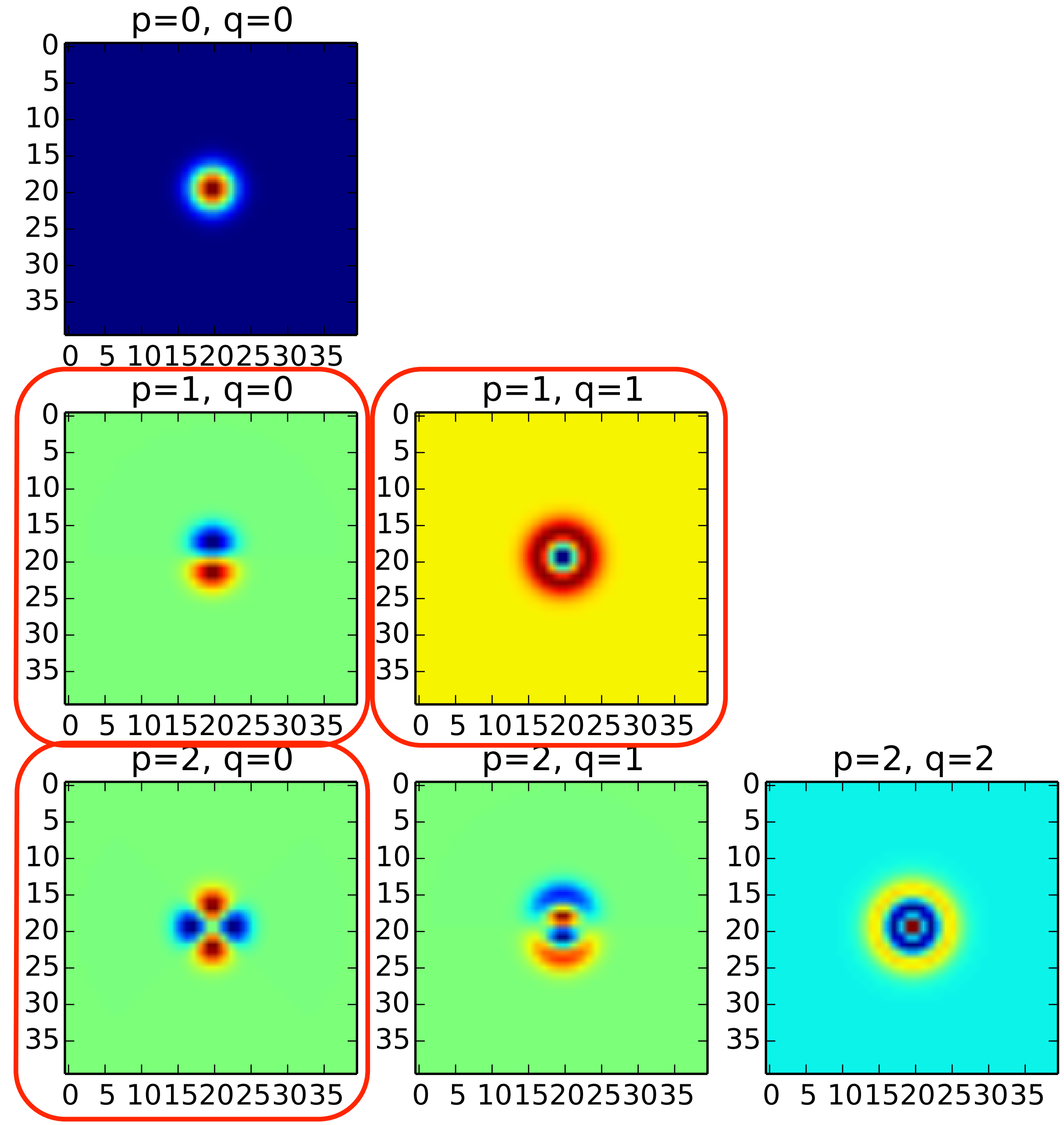
$$I(r,\theta) = \sum_{p,q\geq 0} b_{pq}\psi^{\sigma}_{pq}(r,\theta)$$

The Gauss-Laguerre decomposition implement eigenfunctions of the 2-D QHO, expressed as complex functions of 2 integers p, q :

$$\psi^{\sigma}_{pq}(r,\theta) \equiv \frac{(-1)^q}{\sqrt{\pi\sigma^2}}\sqrt{\frac{q!}{p!}}\left(\frac{r}{\sigma}\right)^m e^{im\theta}e^{-r^2/2\sigma^2}L_q^{(m)}(r^2/\sigma^2)$$

The b_{pq} are Gaussian-weighted moments of the intensity image.

$$b_{pq} = \sigma^2 \int d^2x I(\mathbf{x})\bar{\psi}^{\sigma}_{pq}(\mathbf{x})$$



The algorithm for measuring object shapes requires

A centroiding condition $b_{10} = 0$

A circularity condition $b_{20} = 0$

and a size matching condition $b_{11} = 0$

These operations + deconvolution are found by manipulating the b_{pq}

Shear estimator : the «optimal» Gauss-Laguerre technique

Assume $\boldsymbol{\sigma}$

⇊

calculate b_{pq} from

$$b_{pq} = \sigma^2 \int d^2x I(\vec{x}) \bar{\Psi}^{\sigma}_{pq}(\vec{x})$$

⇊

$$\chi^2 = \sum_i \frac{\left[I_i - \sum_{pq} b_{pq^0} \Psi^{\sigma}_{pq}(\vec{x_i}) \right]^2}{var(I_i)}$$

⇊

→Find the least $\mathbf{X}^2$ and get the b_{pq}

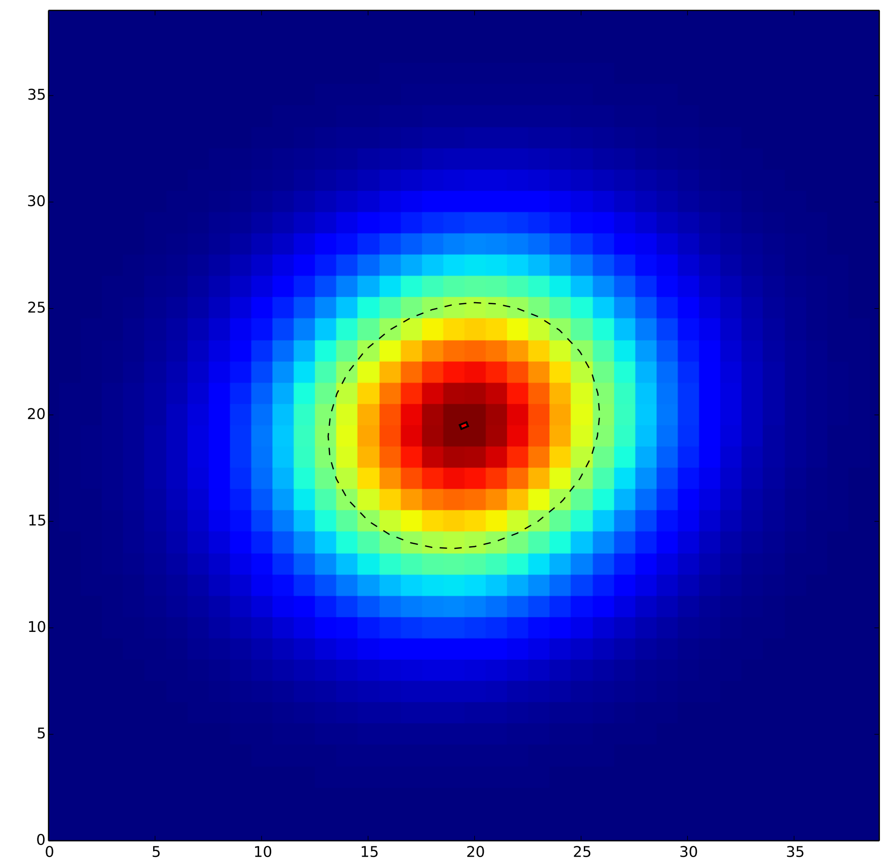
→The observed, intrinsic and PSF weighted coefficients b are related :

$$b^{obs} = \mathbf{C}(b^*) \cdot b^{int}$$

→ $\eta = \frac{-2\sqrt{2} b^{int}_{02}}{b^{int}_{00} - b^{int}_{22}}$ → $e = tanh(\eta)$

→ [1-4%] syst. err. @ [50-20]S/N(Nakajima & Bernstein 2006)

observed galaxy image and reconstructed *intrinsic* shear



→Gaussian psf convolve with :

$e_{1,gal}$ = 0.100585, $e_{2,gal}$ = 0.099256

→Deconvolution :

$e_{1,deconv}$=0.100571 $e_{2,deconv}$= 0.099285

Shear estimators : Towards permil precision …

Shear estimator : What we do here is we go from **Object → Moments → e_i → γ**

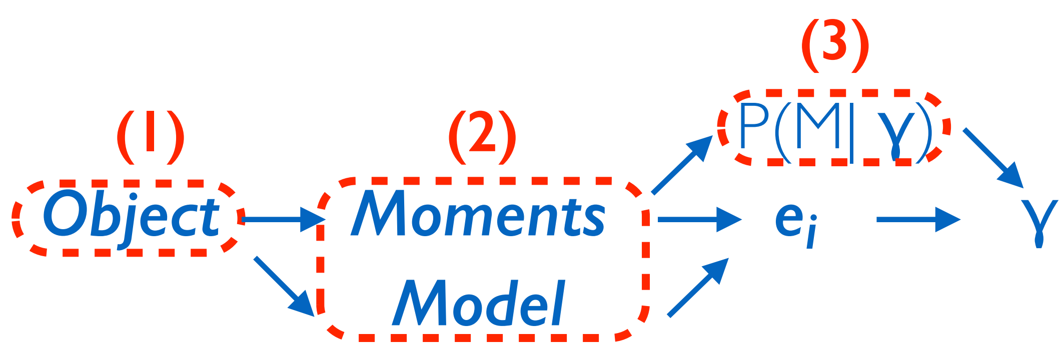
Possible improvement on :

e_i : Re-gaussiannization method Elliptical Laguerre expansion (Hirata&Seljak 2003)

γ : We think : $e_{obs} = e_i + \gamma$. This holds only for $e_i, \gamma \to 0$. Must go to higher order. Fourier Domain Null Testing (Bernstein 2010) : $e_{obs} = R_1\gamma + R_3\gamma^3 + \ldots$ include R_3 term for 1/1000 accuracy when $\gamma \sim 0.03$.

But the central question is : Does the method really measure gravitational shear ?

We do not know the correct answers because there are no "standard shear" lenses on the sky ⇄ simulation of artificial galaxy images to calibrate a given **Shear estimator** strategy (see GREAT challenge).



(1) Galaxy population ?

(2) Model (in)dependent ? Assumptions on galaxy profiles (Miller et al 2013). The use of a finite set of weighted moments lead to a bias similar to the use of truncated basis sets. All methods that aim to measure galaxy shapes from noisy, PSF-convolved data have the risk of producing biased results, and choosing a so-called 'model-independent' method does not alleviate this concern. In both approaches, γ is produced from some weighted sum of the e_i (Kochanek 1990; Miralda–Escude 1991; Bonnet & Mellier 1995).

(3) Bayesian Fourier Domain (Bernstein & Armstrong 2014, Bernstein et al. 2015): Skip the estimation of galaxy shape properties. Rely on a high S/N observations of a subset of the survey region to provide an analytic expression for the probability P(M| γ)

Conclusion