Astronomy ESFRI & Research Infrastructure Cluster
ASTERICS - 653477

Galaxy clusters and weak lensing studies with LSST

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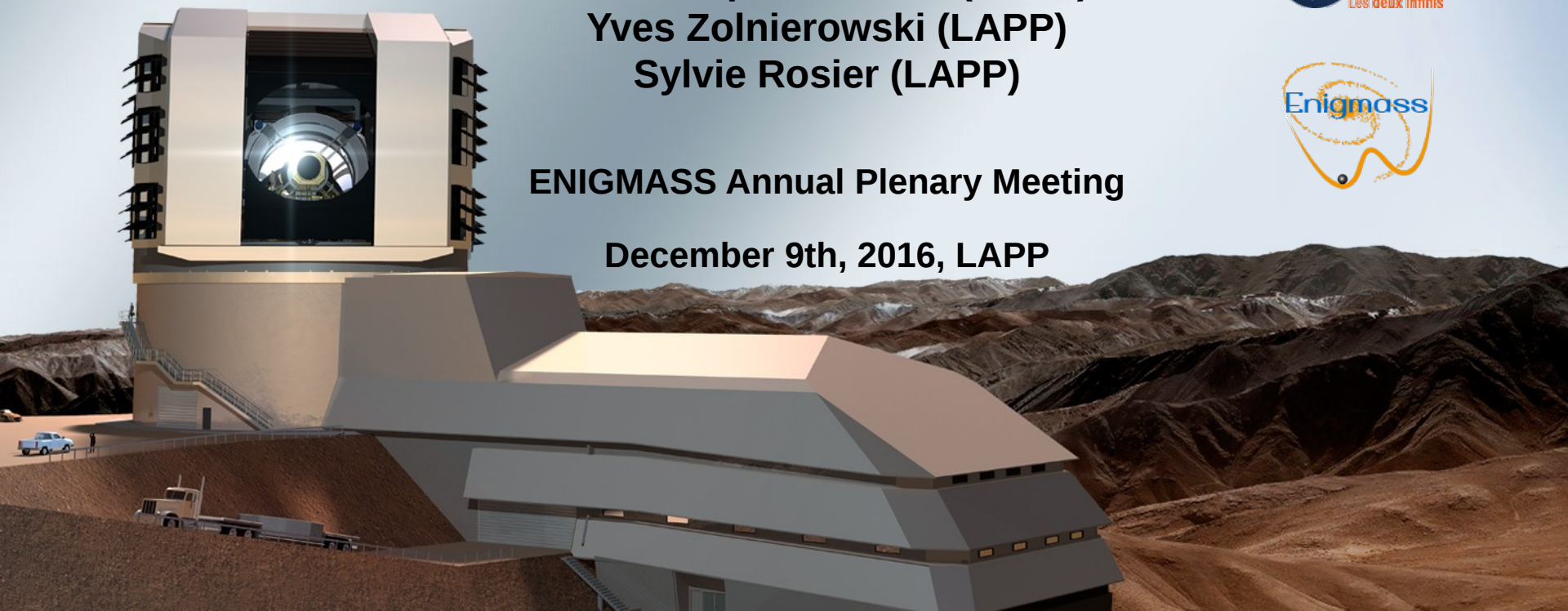
ENIGMASS Annual Plenary Meeting

December 9th, 2016, LAPP



Large – Synoptic – Survey – Telescope

LSST is an instrument designed to make **high precision images** of the **whole accessible sky in 4-D (x, y, z, t)**

-

A 10 year time-lapse movie of the southern sky

Time domain science

- Novae – Supernovae – GRBs
- Source characterization
- Instantaneous discovery

Moving sources

- Asteroids and comets
- Proper motions of stars

Mapping the Milky Way

- Tidal stream
- Galactic structure
- Complementary to GAIA

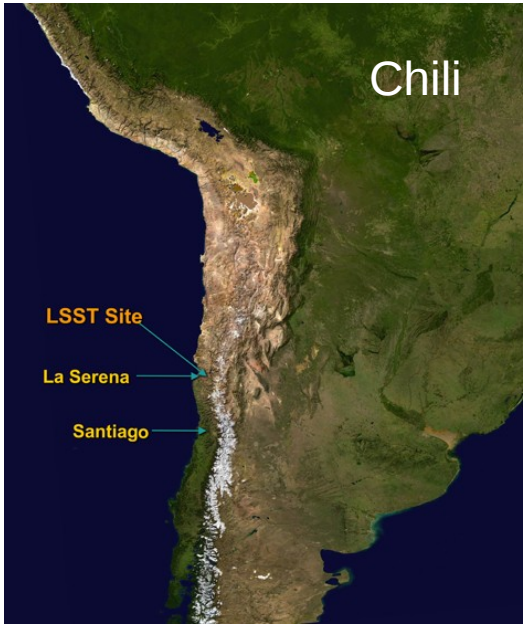
Dark energy and dark matter

- Gravitational lensing (strong and weak)
- Evolution of large scale galactic structures
- Trace the nature of dark energy

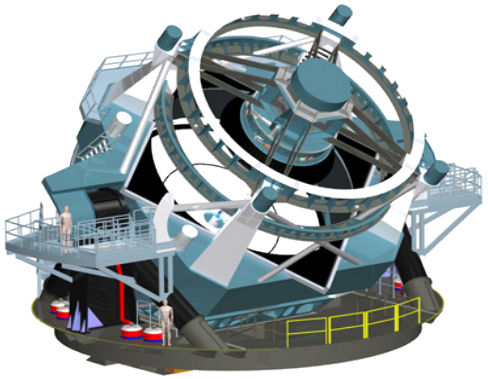
3 keywords : **Fast – Wide – Deep**

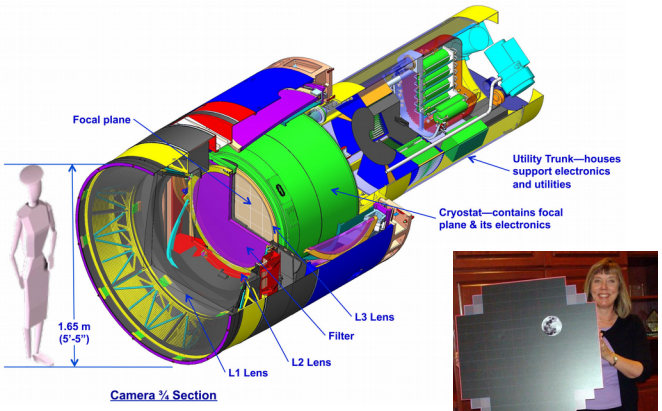
Site – Telescope - Camera

Average seeing: 0.67 arcsec



November 16th





Telescope

- 8.4 m (6.7m effecif)
- Fully corrected (sphericity, coma, astigmatisme)
- A 350 tons mobile structure

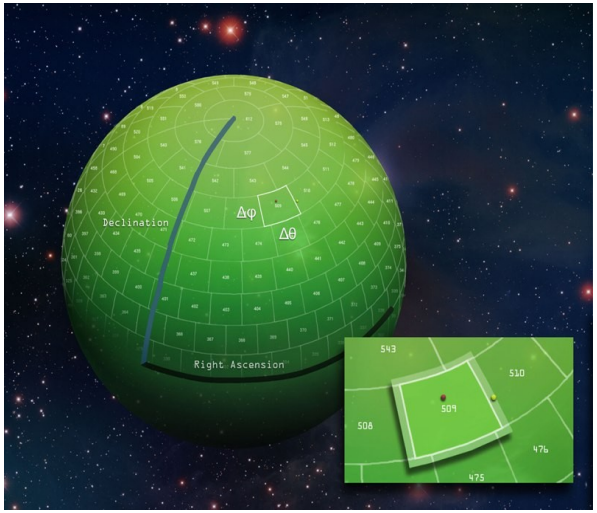
Camera

- 3.2 billion pixels @ 0.2 arcsecond / pixel
- 21 rafts
- 9 CCD / raft

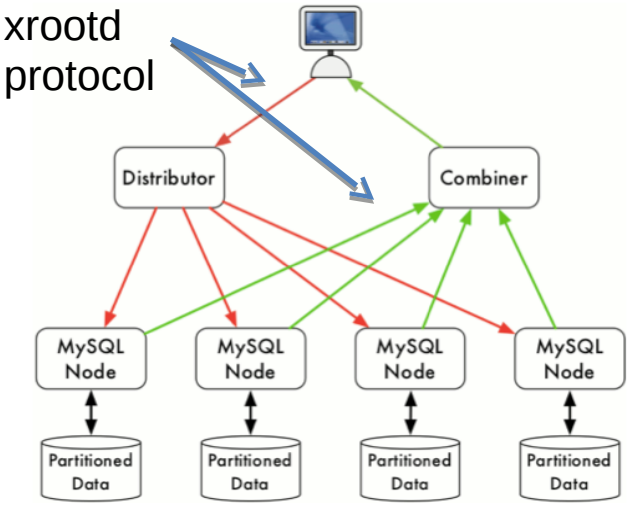
Software and database

- LSST software: the stack
  - Fully modular, efficient and versatile image analysis framework
  - Open source - github link
  - Designed to support several instruments:

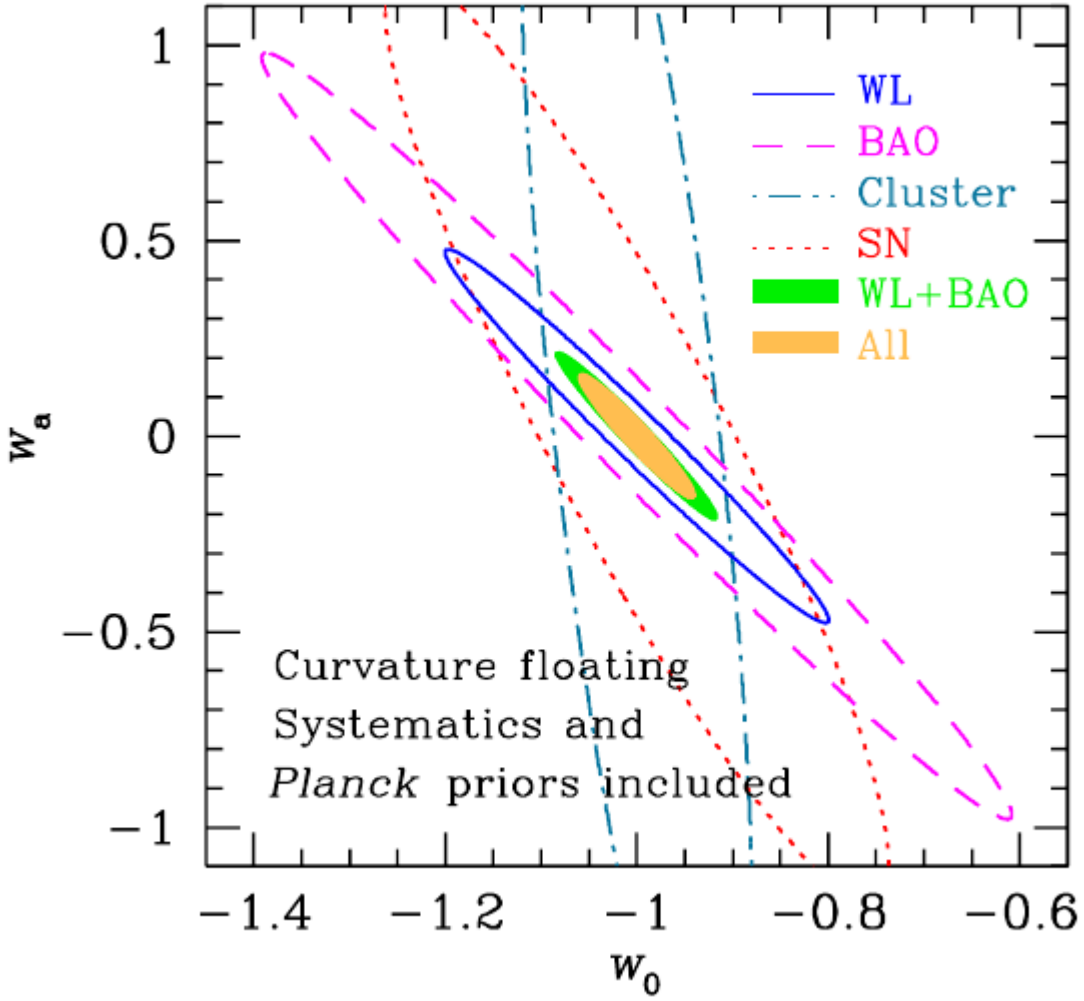
    LSST - SDSS – HSC – CFHT – DES



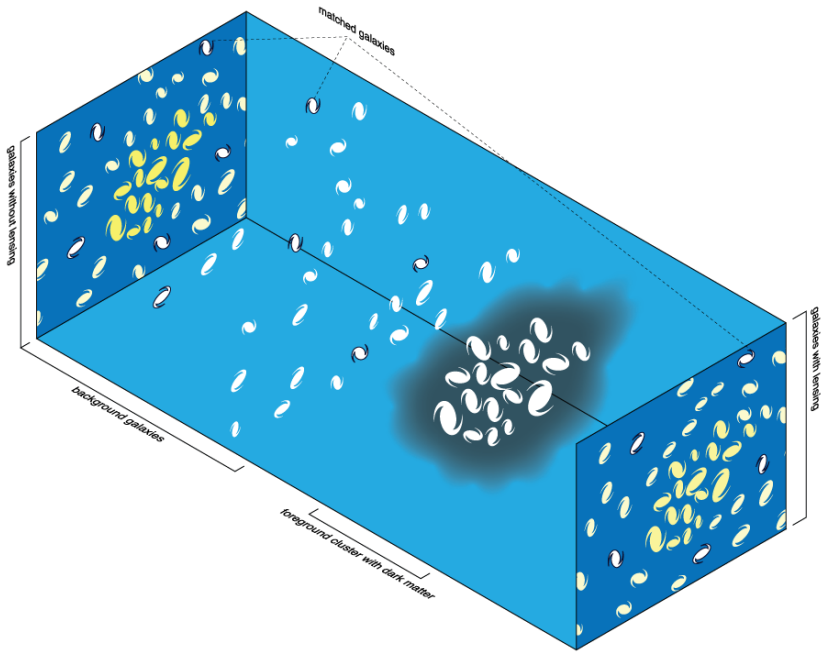
- LSST database: Qserv
  - SQL database system able to store trillions of objects while keeping a reasonable access time
  - Design optimized for astronomical queries
  - Massively parallel – distributed – fault tolerant **relational database**



Joint probes analysis



Our case study: weak lensing



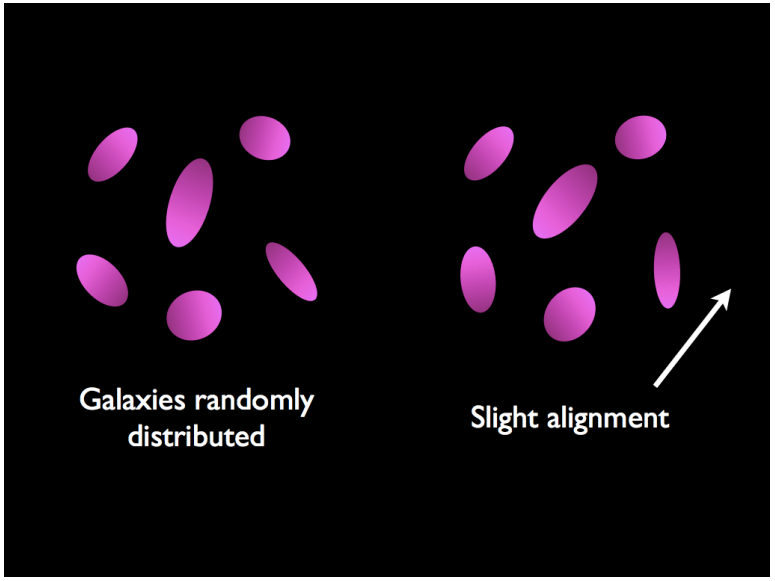
- Gravitational potential created by the mass in between a galaxy and us will change the light trajectory
- Consistent modification of background galaxies shape
- Statistical analysis of weakly lensed galaxies
- Probe the Universe at different scales & z

Mass measurement of relaxed galaxy clusters

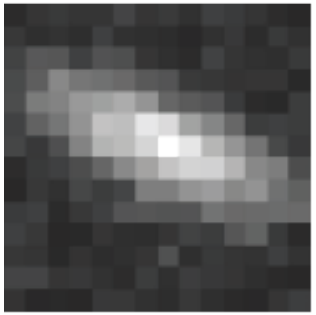
- X-Ray, SZ → baryonic mass
- WL → total mass
- Representative sample of the Universe → Ω_b/Ω_m
- CMB → Ω_b ⇒ and we get Ω_m

Precise and robust measurement of Ω_m

Our case study: weak lensing



Hypothesis: galaxies are instrinsicly elliptic and randomly oriented → null ellipticity in average



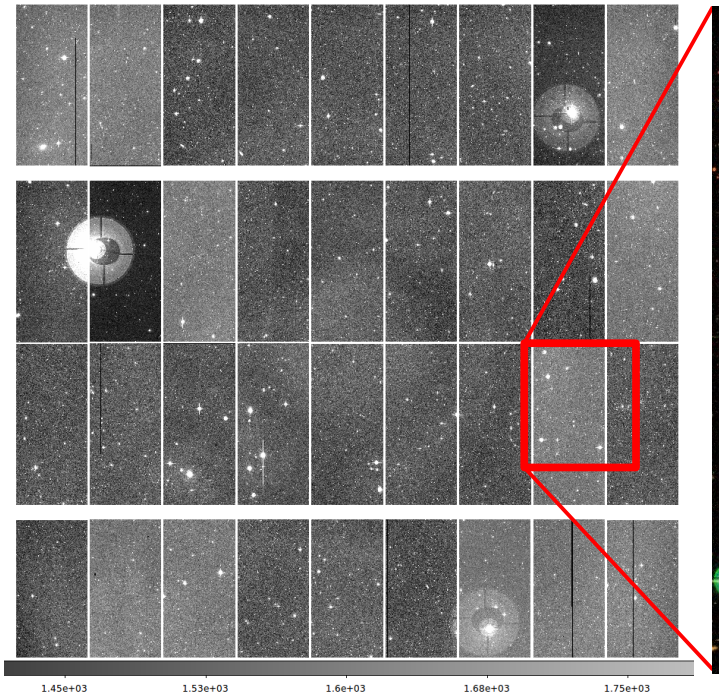
Pixels ⇒ seconds moments Q_{ij}

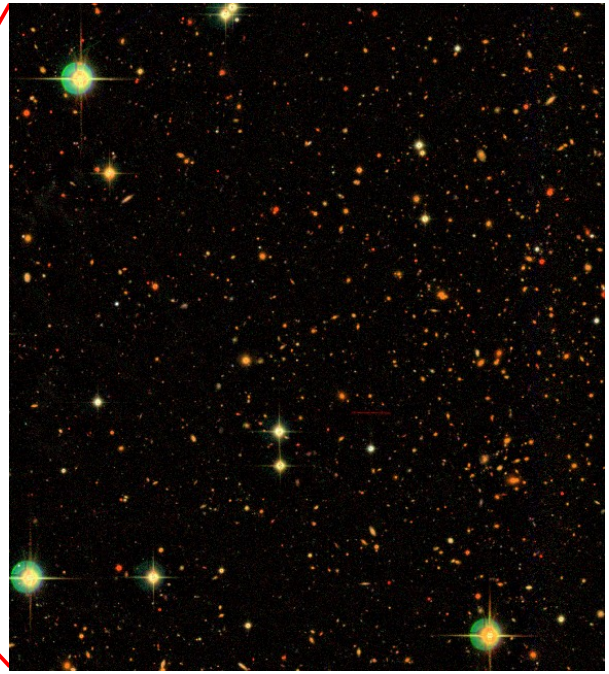
$$\epsilon = \frac{Q_{11} - Q_{22} + 2iQ_{12}}{Q_{11} + Q_{22} + 2(Q_{11}Q_{22} - Q_{12}^2)^{1/2}}$$

- Measured ellipticity is a function of the intrinsic ellipticity of the galaxy $\varepsilon^{(s)}$ and a quantity that characterize the shear g
- In the limit of weak lensing |g| < 1: $\epsilon^{(s)} = \frac{\epsilon - g}{1 - g^{\star}\epsilon}$
- If we suppose that the intrinsic orientation is random: $< \epsilon >= g$
- Not exactly true: intrinsic alignment of galaxies → systematic effect

Goal and data set

- The goal is to **develop a complete pipeline for cluster analysis in the LSST stack framework**
- Current input data are CFHT images in the 5 ugriz filters
- Three clusters under reprocessing and being analyzed





MACSJ2243.3-0935 (z=0.447)

CL0016+16 (z=0.541)

3C295 (z=0.464)

Color coding :R = I; G = r; B = g

u(5), g(6), r(9), i(12), z(10)

Clusters python package: A step by step analysis

- **Data format**: easier way to access the LSST data:

  LSST stack format → Astropy tables in hdf5 files

- **Data validation**: quality assessment of the data processing (color locus, ellipticity, etc)
- **Extinction**: correct for the MW extinction – try several available dust maps – check related systematic uncertainties
- **Photometric redshift**: wrapper to several photometric redshift estimator codes
- **Galaxy selection**: red sequence + redshif cuts + quality cuts
- Averaged tangential and cross **shear** as a function of redshift
- **Mass estimate**

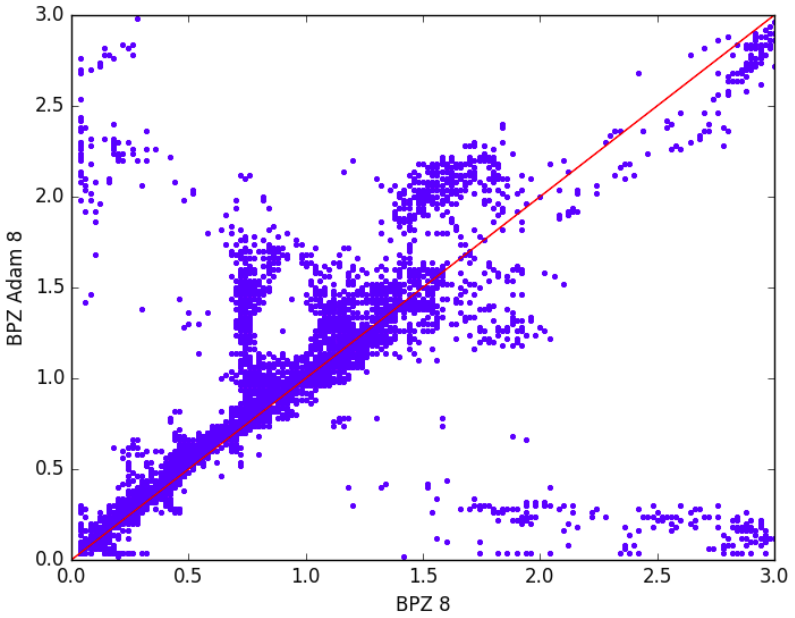
Photometric redshift

- Template fitting methods (redshift, spectral type, and extinction) + prior on z given a magnitude

$$\chi^2(z,T,E(B-V),N) = \sum_{i=1}^{N_{bandes}} \left(\frac{F_i^{obs}(m_i) - N F_i^{mod}(z,T,E(B-V))}{\sigma\left(F_i^{obs}(m_i,\sigma(m_i))\right)} \right)^2$$

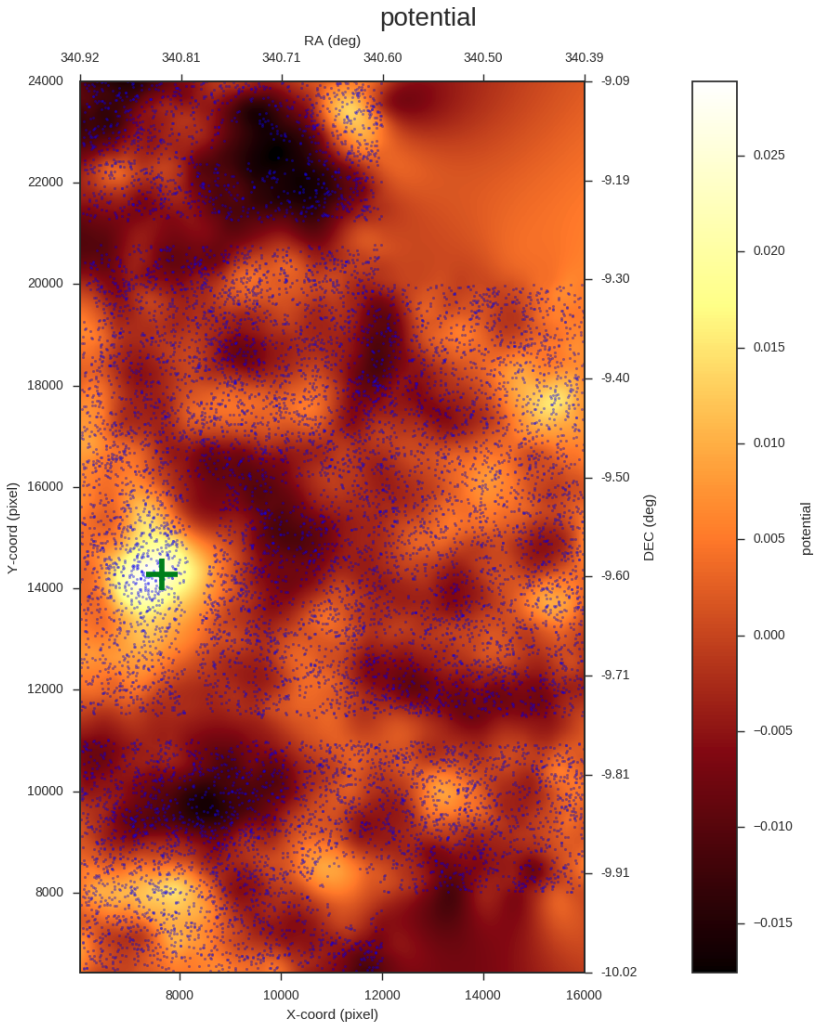
$$p(z \mid m_0) = \sum_T p(T \mid m_0) p(z \mid T, m_0)$$

- Photometric redshift needed to select lensed galaxies in the background of the cluster
- A wrapper to several photometric redshift estimators included in the Clusters pipeline (BPZ, Lephare)
- Currently testing different codes and configurations



Mass

- Code to estimate the mass has been implement very recently
  → Currently testing it
- But we can still produce different maps related to the mass
- Here, the map showing the lensing potential integrated along the line of sight
- The cluster is located at the cross position, where the potential is the strongest



Summary

- Reprocessing : Automatize, debug, quality assessment, new clusters
- Qserv: Test it on real data and implement its use in the analysis
- Analysis
  - Clean and robustify the Clusters pipeline
  - Reproduce known results on known clusters
  - Study all known and potential systematics
    - Extinction – try different maps and propagate
    - Photo-z – use of different templates, codes, methods
    - Galaxy selections – red sequence, redshift and other cuts
  - Go beyond mass estimate – cosmology

- **Work done in the official DESC clusters working group**
- **First complete analysis done on real data using the full LSST stack**