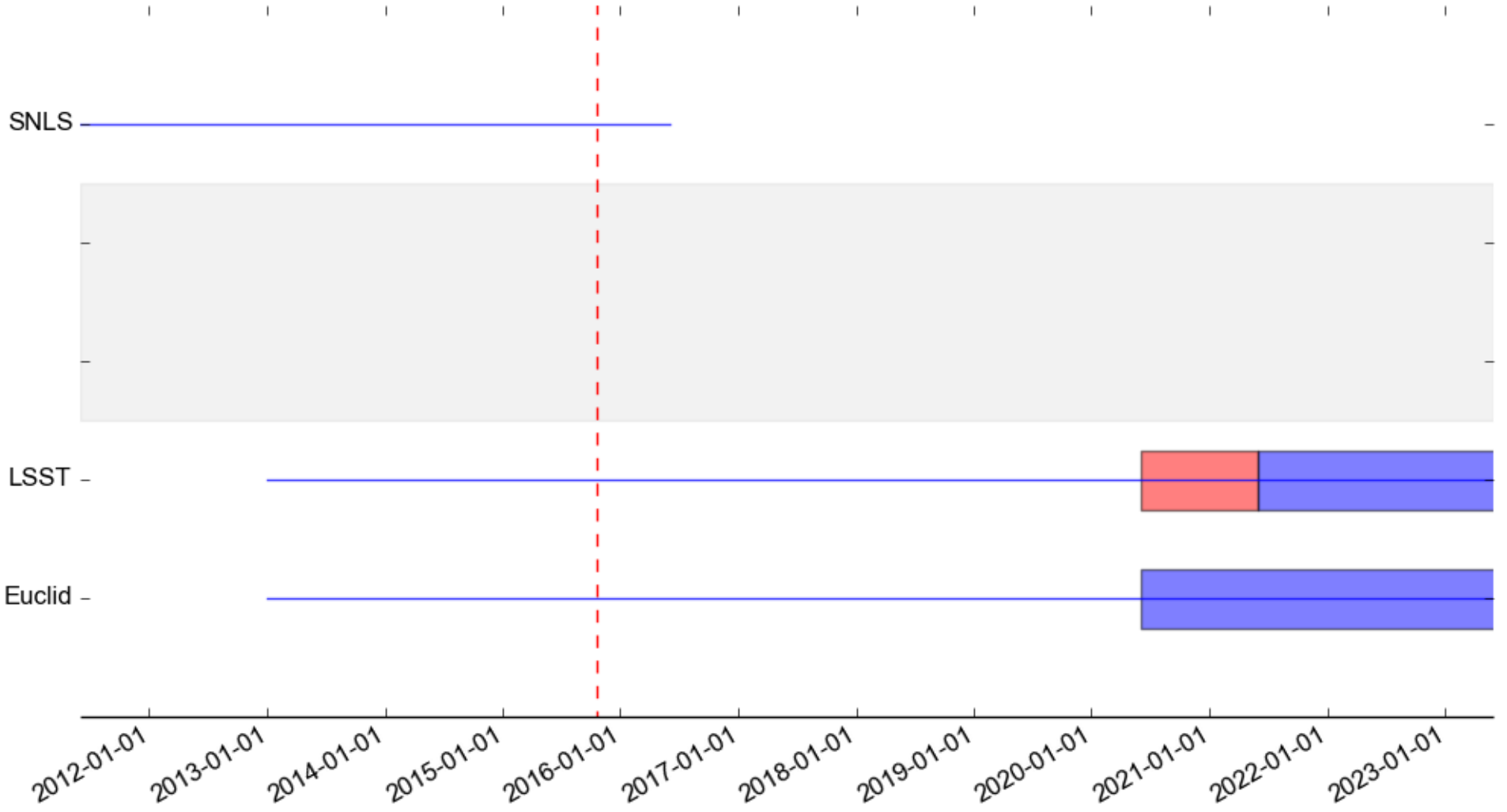
Projets intermédiaires en imagerie : Lensing & Supernovae

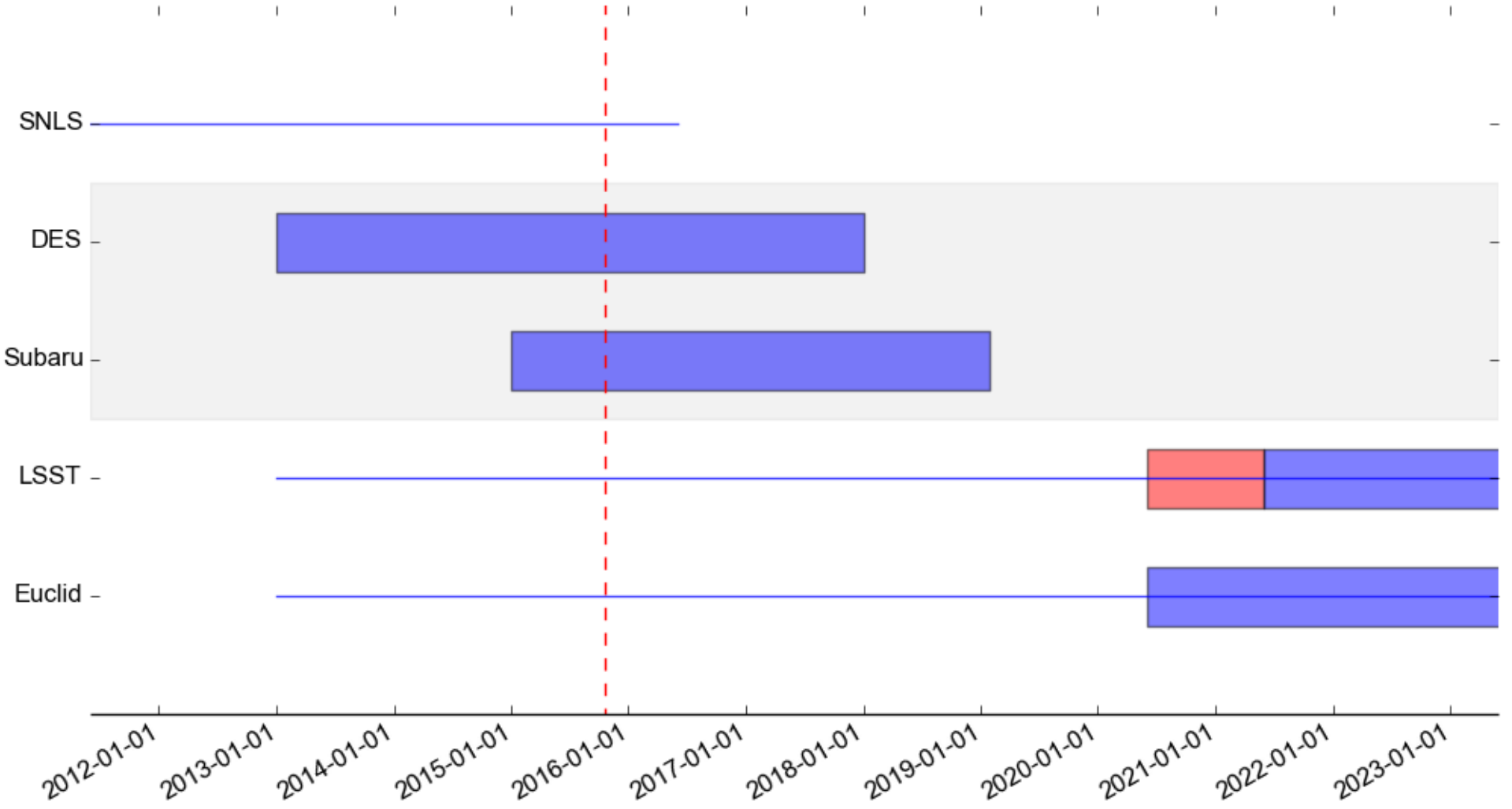
N. Regnault

(LPNHE, Paris)

Timeline


SNLS
LSST
Euclid
2012-01-01
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
2020-01-01
2021-01-01
2022-01-01
2023-01-01

Timeline


SNLS
DES
Subaru
LSST
Euclid
2012-01-01
2013-01-01
2014-01-01
2015-01-01
2016-01-01
2017-01-01
2018-01-01
2019-01-01
2020-01-01
2021-01-01
2022-01-01
2023-01-01

Intermediate projects

- Bottom-up initiatives within the LSST/Euclid IN2P3 community
- Goals
  - prepare LSST/Euclid analyses
  - maintain a close contact
    - with the community
    - with fresh data
- Intermediate projects / activities
  - Small (a few individuals + grad students)
  - No hardware contribution
  - Fast (science papers by 2019 - 2020)

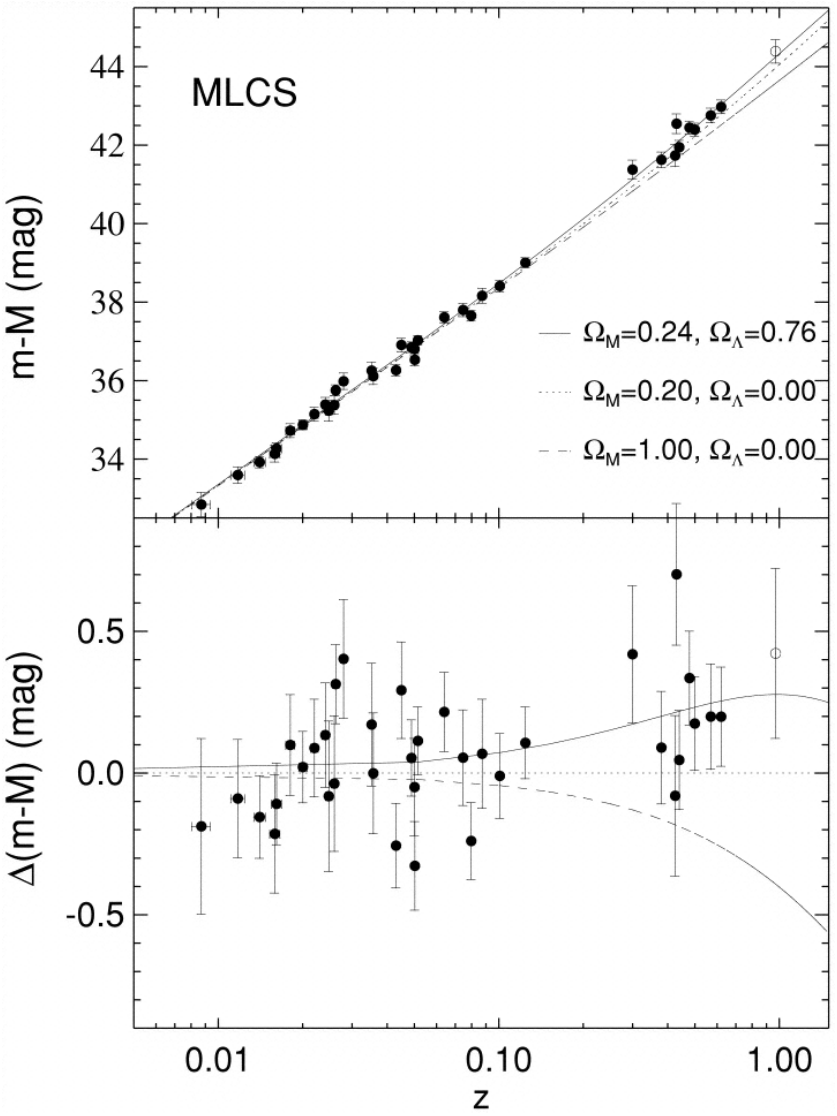
Intermediate projects
(wide field imaging)

- Identified activities (as of today)
  - Type Ia supernovae with Subaru/HyperSuprimeCam
  - Measuring cluster masses with lensing (MegaCam & HSC)
  - Photometric redshifts (Subaru/HSC, in collaboration. with LAM/Marseille).
  - ...

The Supernova Program

Scientific Context

- What drives the expansion of the Universe ?



$$\left(\frac{\dot{a}}{a}\right)^2 + \frac{k}{a^2} = \frac{8\pi G}{3}\rho + \frac{\Lambda}{3}$$

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(\rho + 3p) + \frac{\Lambda}{3}$$

Cosmological constant ?
Vaccum energy density ?
Exotic source of energy ?
Signature of modified gravity ?
…. ???

$$p = w\,\rho$$

w < -1/3 for acceleration

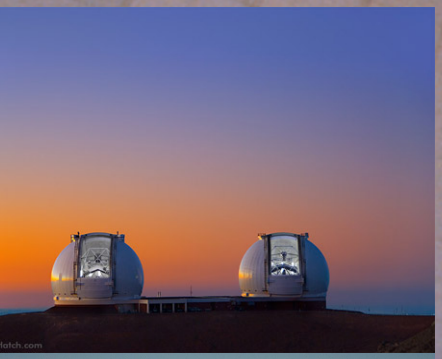
Does *w* vary with time ?

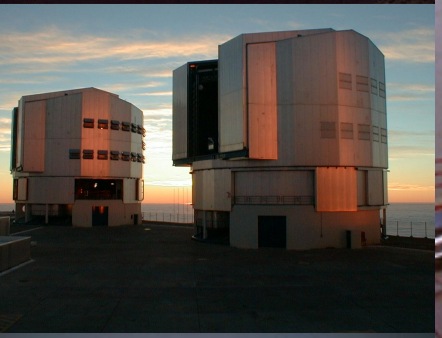
MegaCam : 1 deg2

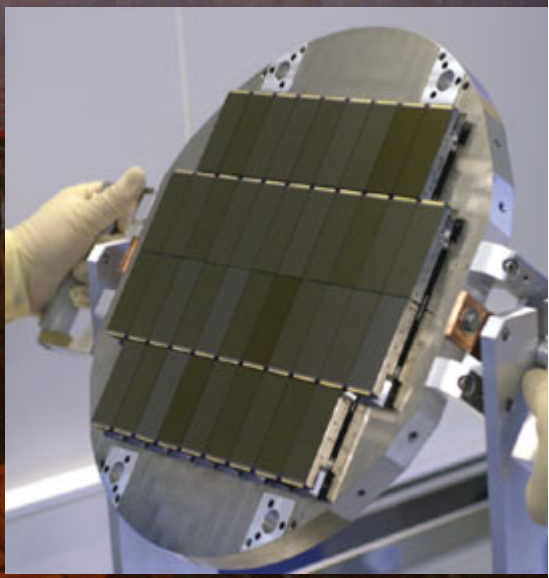
- SNLS : 4 deg2
- **1200** hours on CFHT
- 1200 hours on 8-m telescope
- ~ 500 SNeIa with spec-id

Collaborators

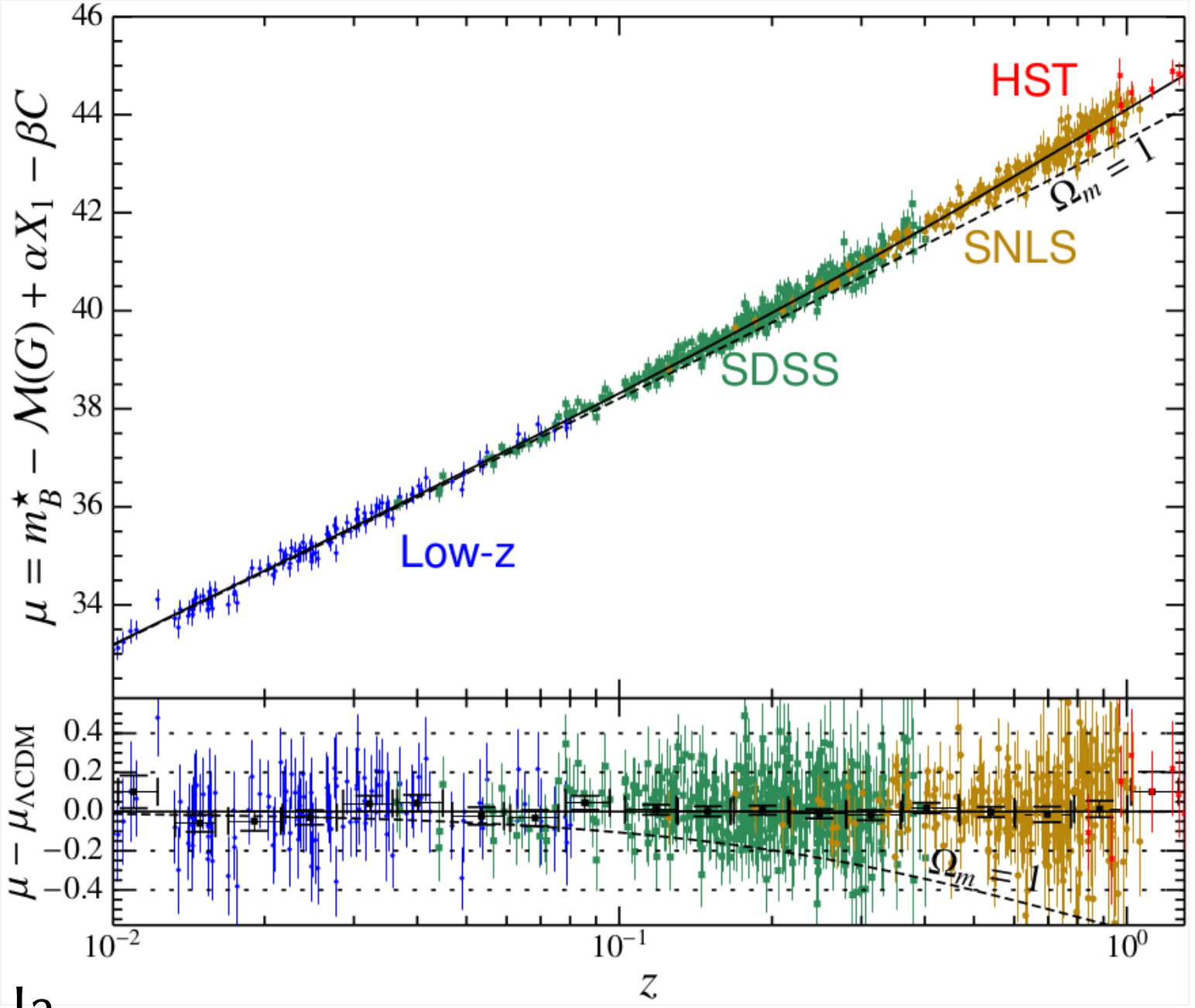
- LPNHE (Paris)
- CPPM (Marseille)
- Saclay
- Toronto
- Victoria
- LBNL







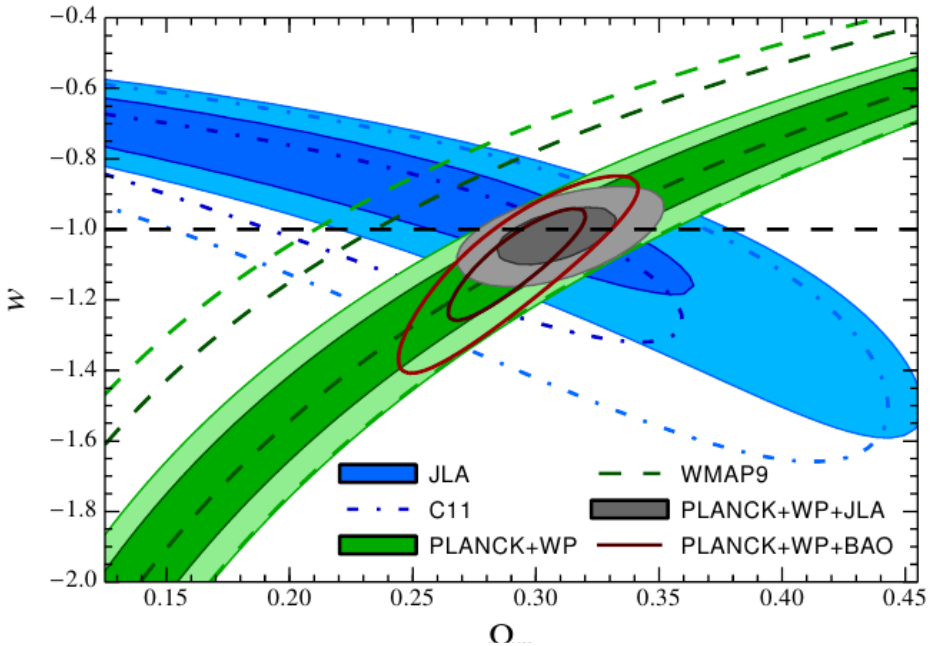
SNLS/SDSS-II Hubble diagram



(Betoule et al, 2014)

740 SNe Ia

SNLS/SDSS-II constraints on *w*

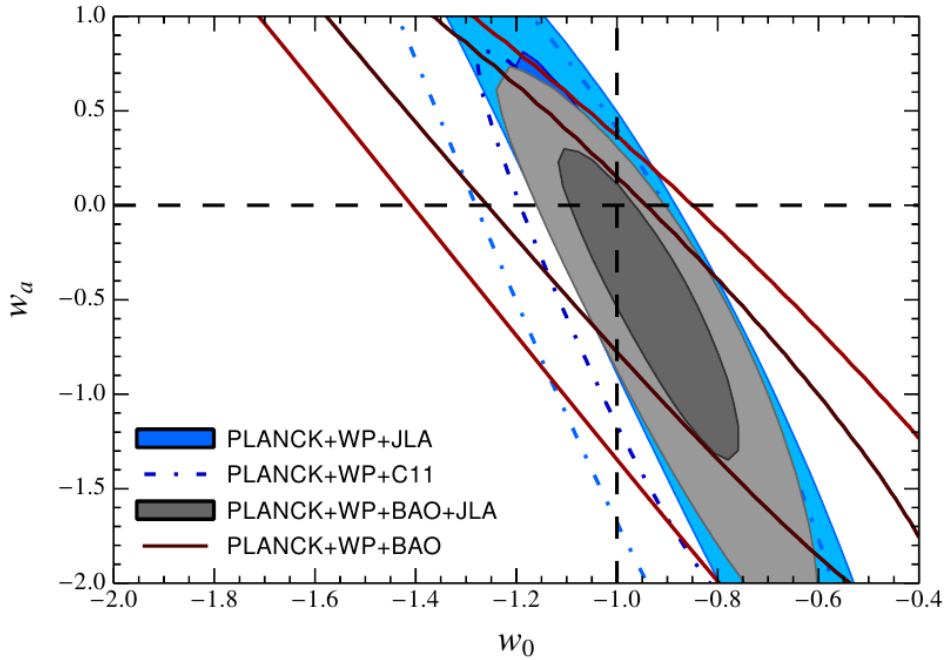


- Planck + SNe Ia

$$w = -1.018 \pm 0.057$$

- Note : Planck + BAO

$$w = -1.01 \pm 0.08$$

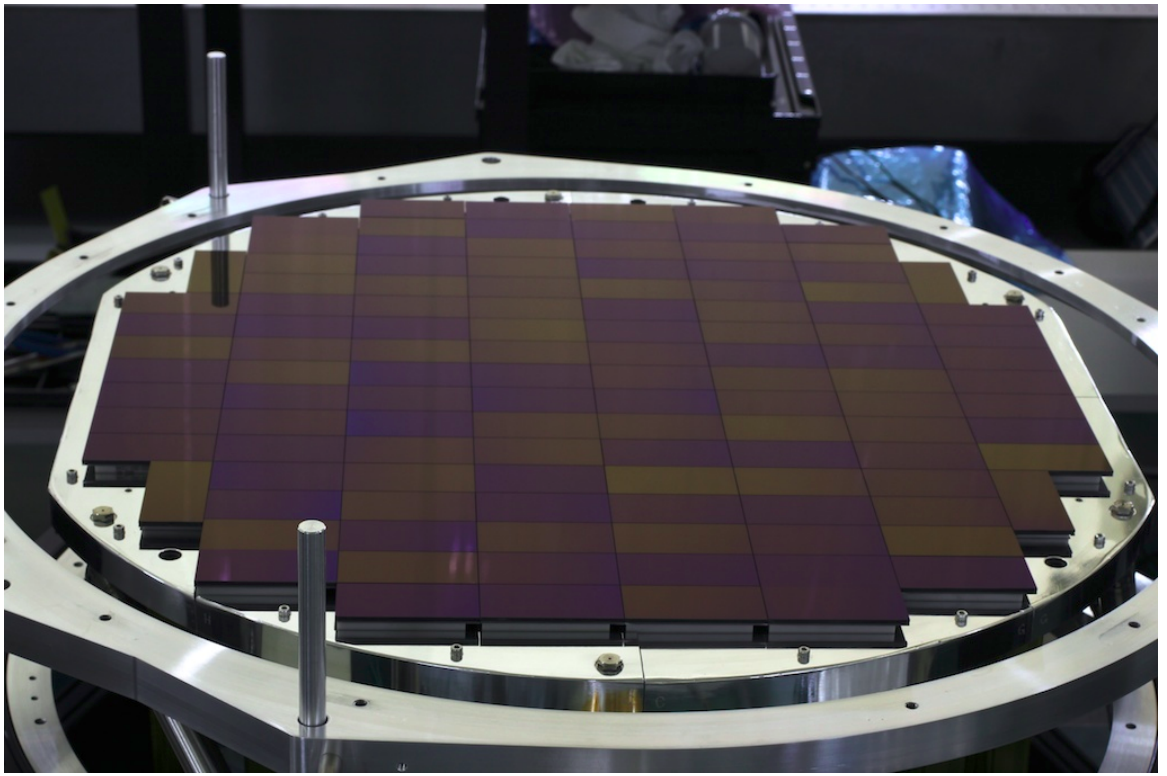


$$w(z) = w_0 - \frac{z}{1+z} w_a$$

No constraints (yet) on possible variations of w with redshift

(see also Suzuki et al '12, Rest et al '13, Scolnic et al '13...)

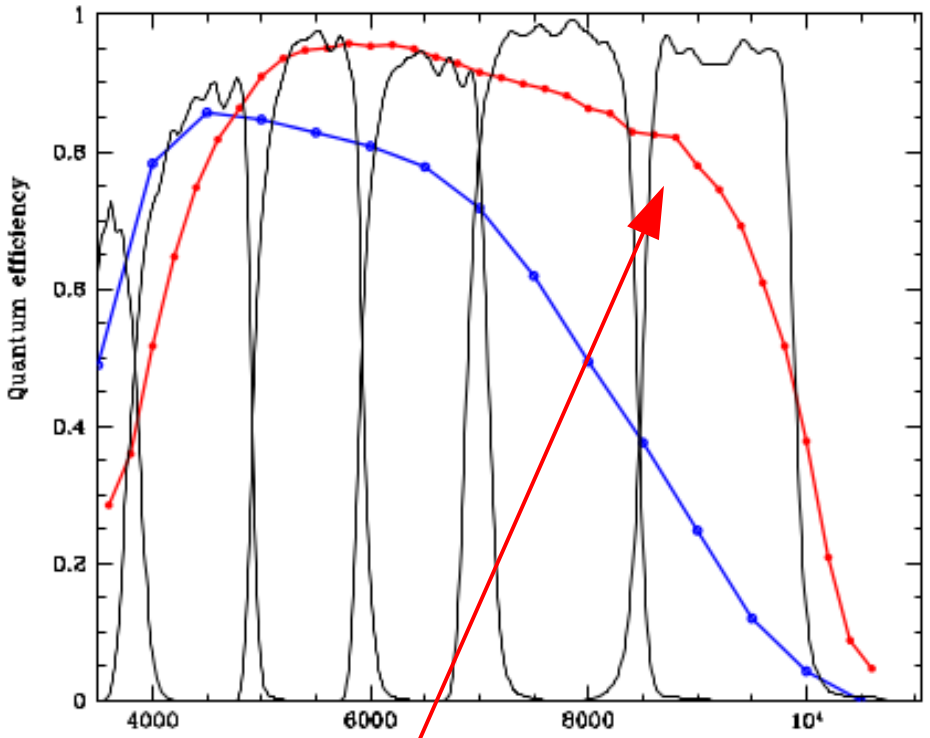
HyperSuprimeCam



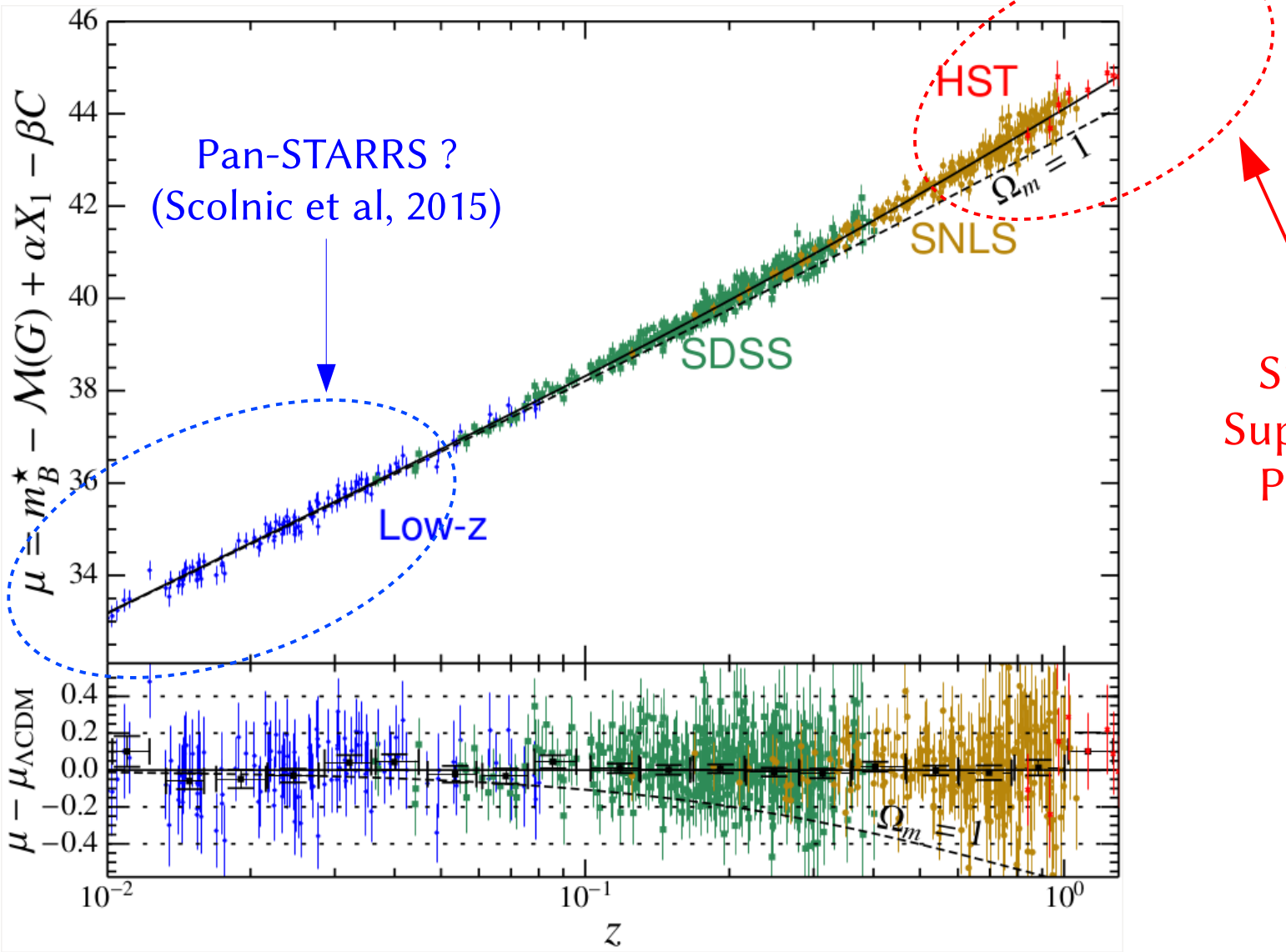
- 1.8 deg^2 camera
- 116 red-sensitive CCDs
- Subaru 8.2-m telescope

The Subaru Imaging Survey

- 300 nights provisioned ⟶ Subaru Imaging Survey
- 3 layers
  - 1400 deg² *Wide* survey
  - 28 deg² *Deep* survey
  - 3.5 deg² *Ultra-Deep* survey
- Cosmology
  - Lensing (weak, strong)
  - Cluster
  - SNe Ia
- Ideal to detect SNe Ia at redshifts z > 0.8



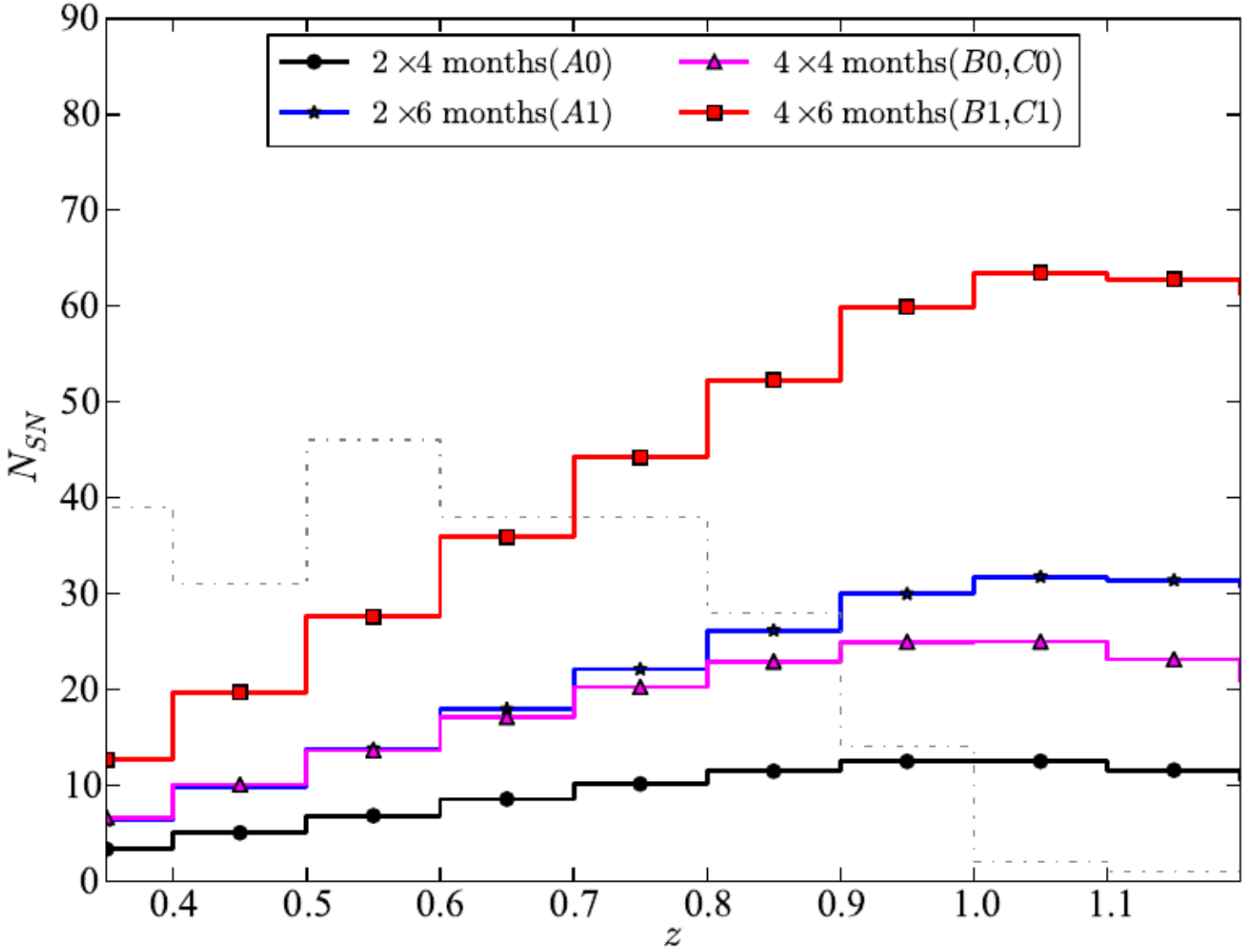
A SN rolling search with Subaru/HSC



Subaru Supernova Project

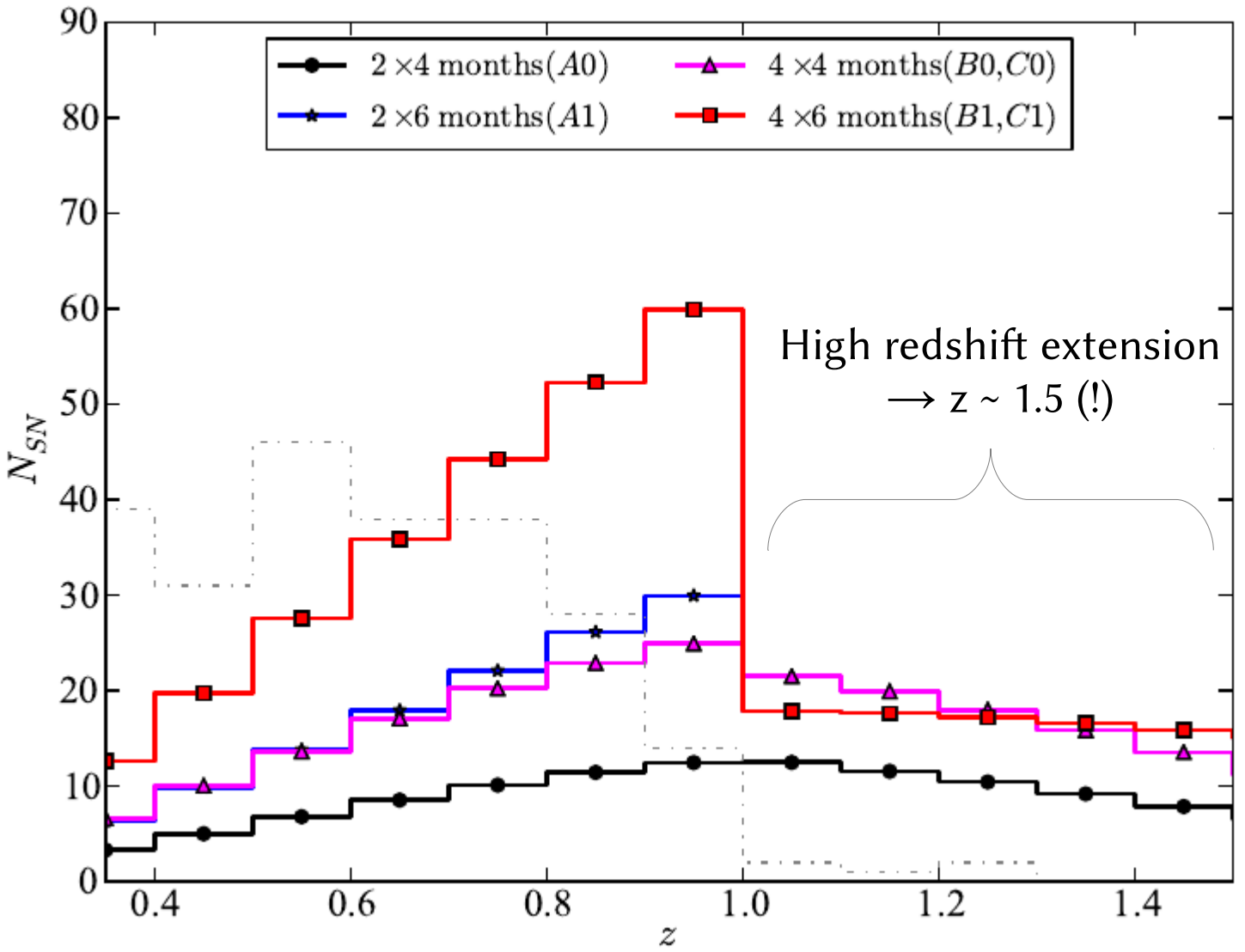
Betoule et al, 2014

Subaru only ...



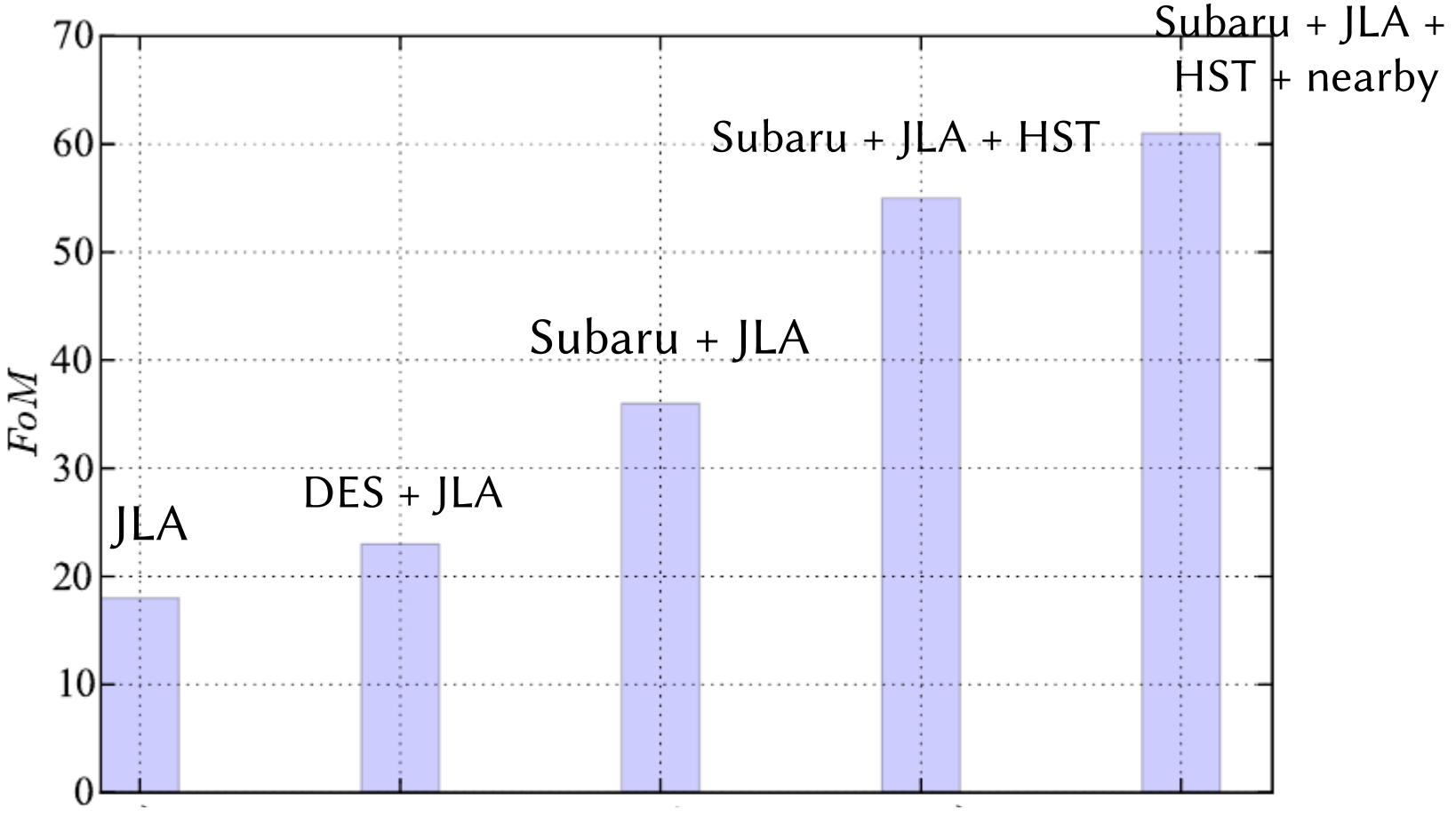
(Suzuki (IPMU), Regnault, Rubin (LBNL) et al, in prep)

… with ~ 100 HST orbits



(Suzuki (IPMU), Regnault, Rubin (LBNL) et al, in prep)

Expected constraints



$$\mathrm{FoM} = \frac{1}{|\mathrm{Cov}(w_0, w_a)|^{1/2}}$$

How well you constrain (w_0,w_a)

Subaru + HST have the potential to constrain variations of the DE equation of state by 2019

Contributions discussed

- Participation to the survey design
- SN photometry + survey calibration
  - Code (derived from SNLS + early LSST pipeline)
- SN light curve analysis (SALT+)
- Spectroscopy @ VLT
  - FORS2 / VIMOS
  - No live spectral identification (too expensive)
  - But spectoscopic redshift of host galaxies

Timeline

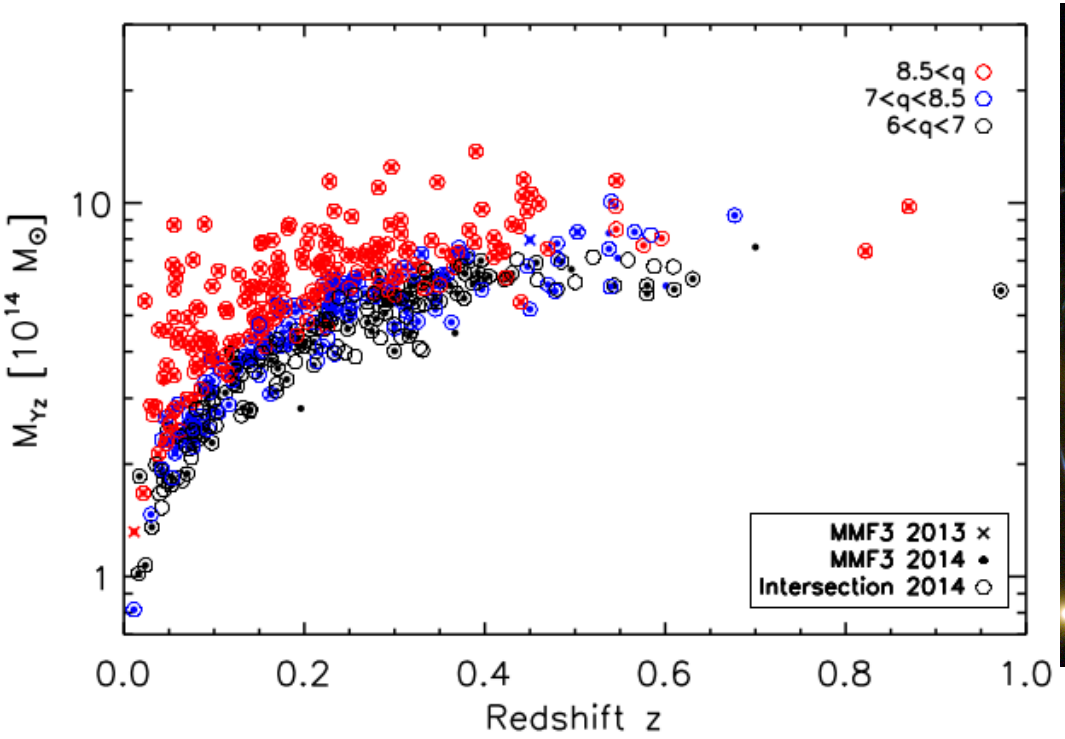
- Short term plans (⟶ mid 2016)
  - Forecast paper (Suzuki, Regnault et al, in prep)
  - SNLS Photometry pipeline ⟶ Subaru/HSC dataset
  - mid 2016 : proposal Subaru (additional time)
  - External collaborator agreement(s)
- Then
  - Dec. 2016 ⟶ Jan 2018 : data taking
  - 2018 - 2019 : cosmology analysis

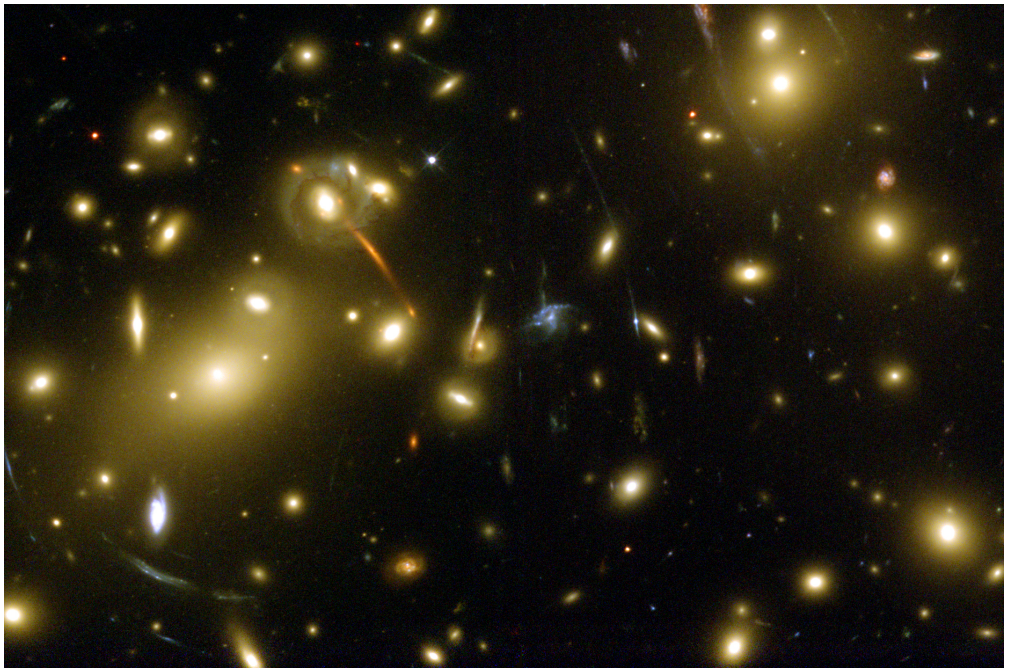
Funding aspects

- Organization
  - 2 collaboration meetings per year (JP/FR)
  - Student exchange
- This project will need
  - At least one PhD student(s) (2016 – 2019/2020)
  - Financial support from IN2P3 (mostly for travel)
- To help starting the project, grant proposals submitted to
  - Programme National Cosmologie et Galaxies (10 k€)
  - Programme CNRS/JSPS (10 k€)

Lensing

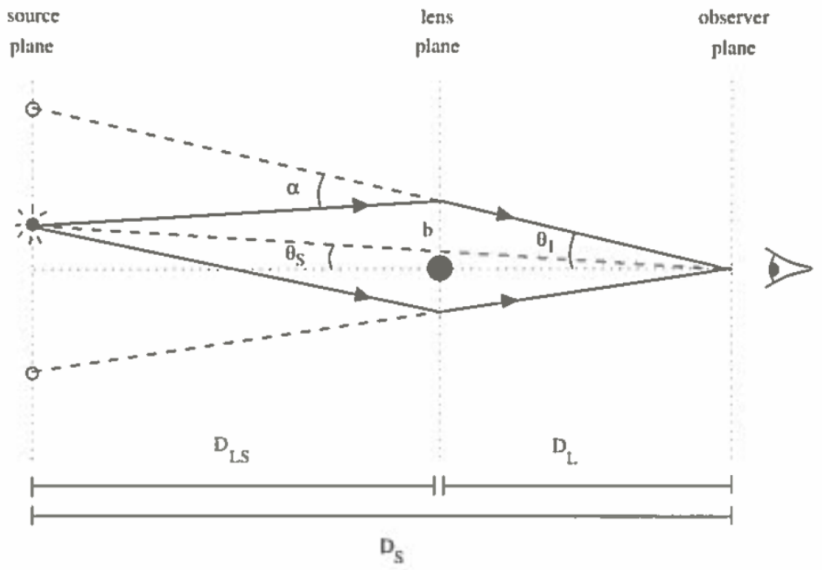
Weak lensing measurements (a newborn activity)





(Planck coll. et al, 2015, SZ clusters)

Relation with the sources of gravitation



Cosmological physics (Peacock).

$$\theta_I - \theta_S = \frac{D_{LS}}{D_S}\alpha = \nabla_\theta \psi(\theta_I)$$

Deflection potential

"Poisson equation" :

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

All observables derive from a scalar field: the "projected mass"

At cosmological distances

- Magnification ?
  - Sometimes spectacular but rarely (strong lensing)
  - Detectable when the source brightness is known, e.g. SNe~Ia (Kronborg et al, 2010)
  - Induces a variation of (galaxy) counts above some flux limit per unit area. Lensing alters both flux and area....
- Shear ?
  - Detected in the early 90's around clusters.
  - Cosmic shear detected in 2000

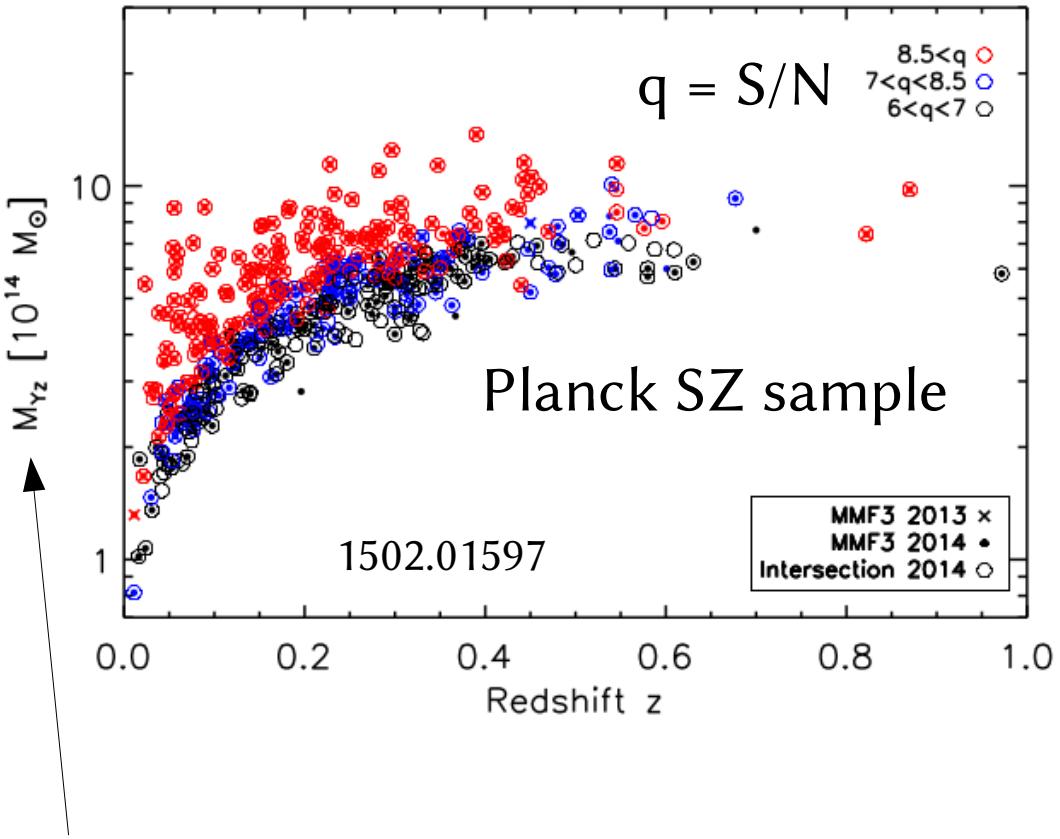
What does lensing probe?

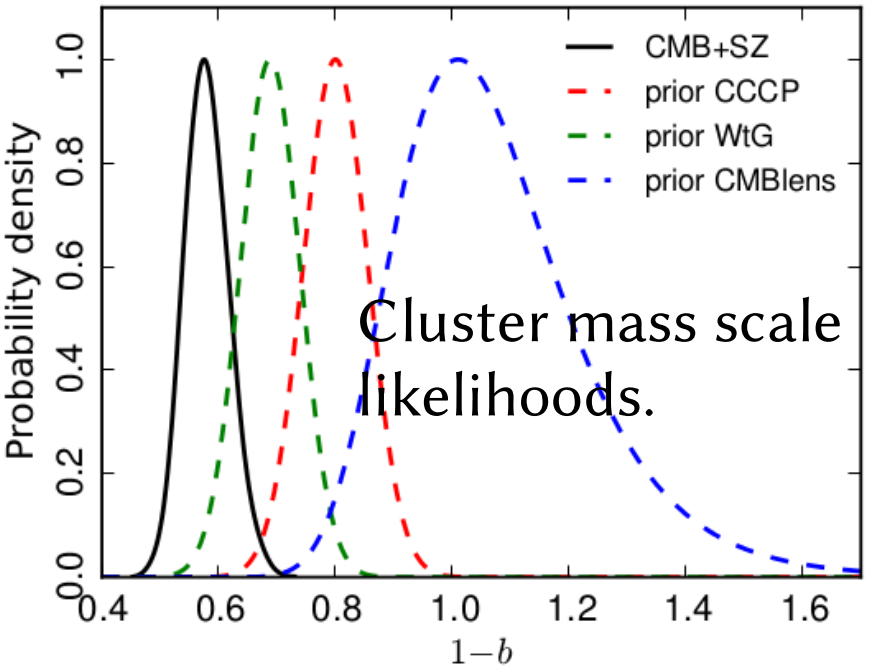
- In the Milky Way
  - microlensing probes stars
- Galaxy-galaxy lensing (shear), SNe Ia lensing (magnification):
  - galaxy halos
- Lensing by galaxy clusters:
  - overall mass, mass profile
- Cosmic shear correlations:
  - matter power spectrum
  - and its time-evolution

This is our entry point in the business. Signal is 5 – 10 times higher

This is our long term goal

Galaxy cluster counts, cluster masses





b=0: mass calibration from X-rays

How are masses measured ?

- cook up a mass proxy from SZ decrements from Planck
- use gravitational lensing measurements of a subsample to set the scale.

⟶ global scale uncertainty (10-20%)

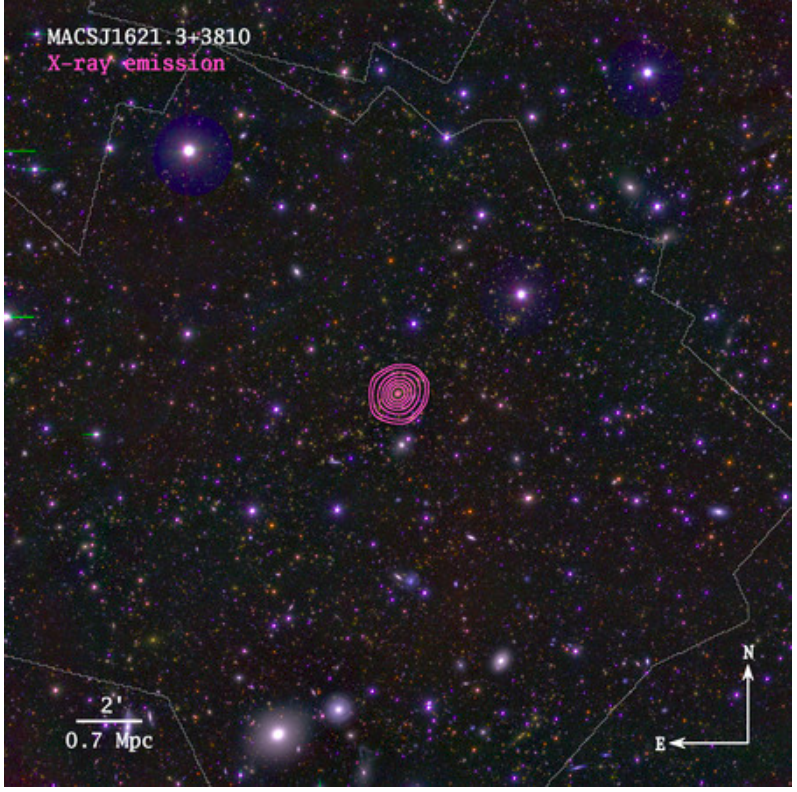
Cluster cosmology

- If we use cosmology to set the mass scale, there is no cluster cosmology.
- Setting the mass scale using lensing is the obvious avenue (see the Planck paper)
- Collaborations around this goal are small. They appreciate good will, and get their data through small observing proposals. They are looking for collaborators to get time, and/or some work to be done.
- Shear by galaxy clusters is strong. Convenient training !

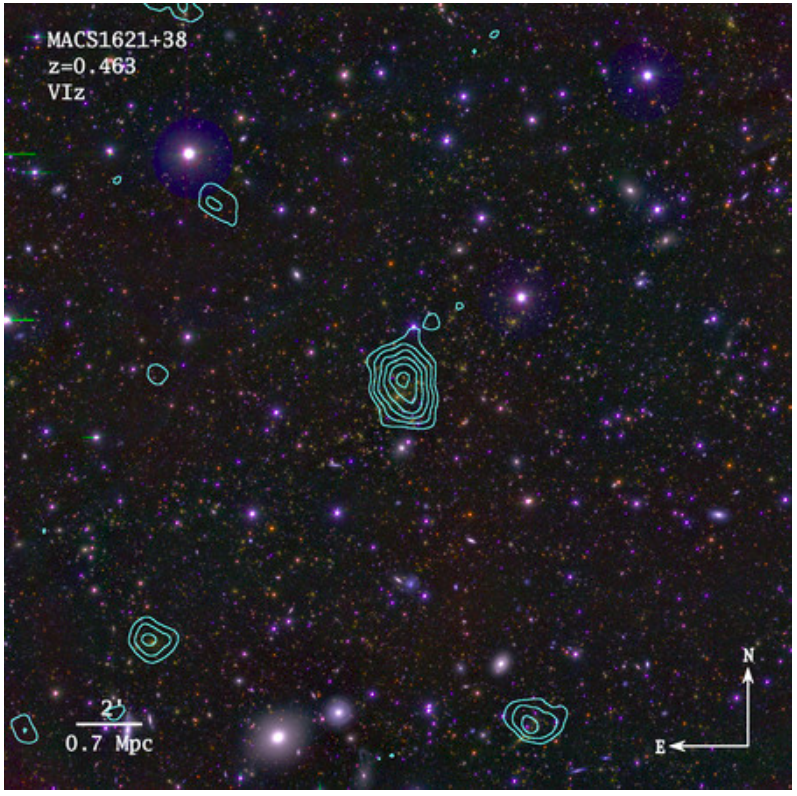
Actors in cluster cosmology

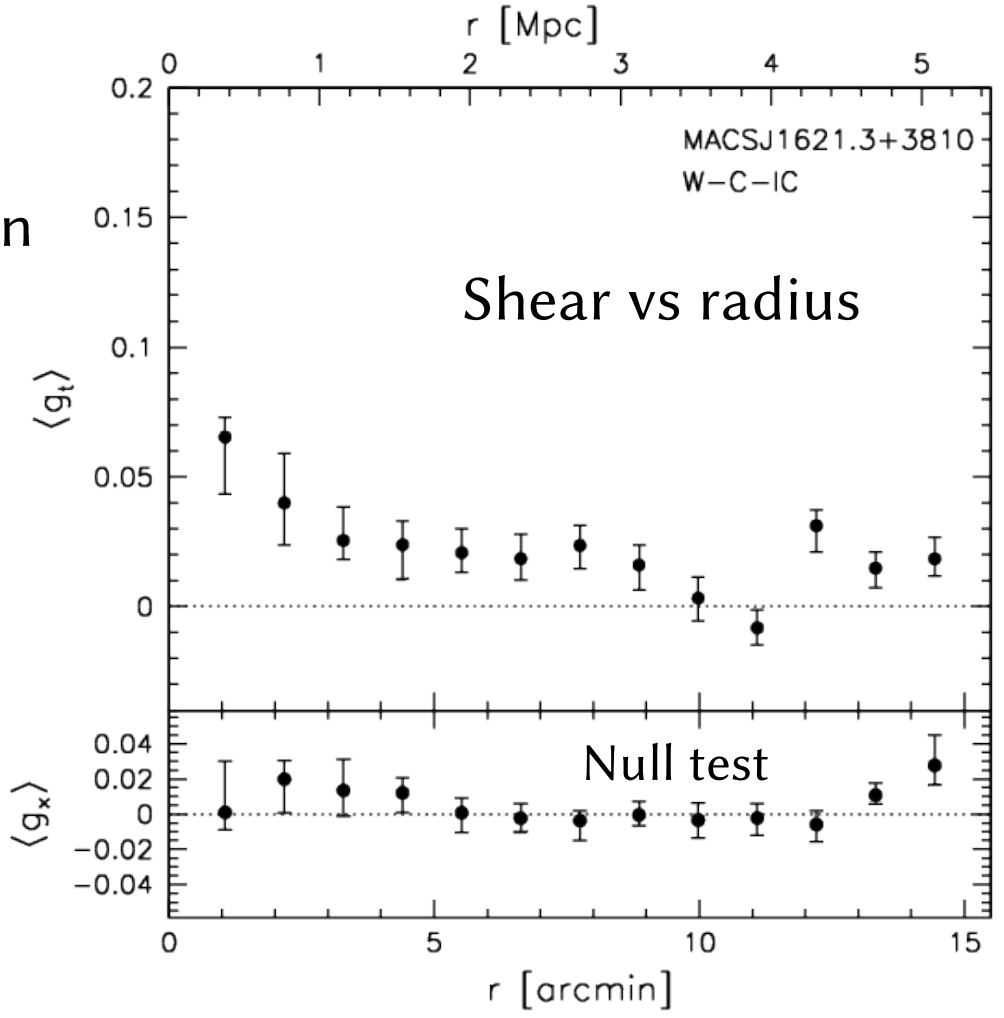
- Planck cluster community:
  - Monique Arnaud (CEA@Saclay) et al,
  - Nabila Aghanim (IAS@Orsay) et al, ...
- US X-ray cluster community:
  - Steve Allen (Stanford)
  - Anja von der Linden (Stony Brook), et al
- Canadian weak shear community :
  - Ludovic van Waerbeke et al.
- All these people are carrying out lensing (mostly) observing programs at CFHT and Subaru (and CTIO).

Weighing the Giants (1208.0597)



X-ray emission





Convergence Map (i.e. lensing)

MACS 1621+38[28]

CFHT proposal for semester 15 B

Science : increase the sample of clusters that have both a baryonic mass (from X), and a total mass (from lensing).

Collaboration: “Weighing the Giants”
- Stanford, Vancouver, ….

We target 3 clusters:
- CFHT: photometry for photo-z
- SUBARU/HSC: lensing images.
- “revolving proposals”.

Proposal accepted and currently in the observing queue.

IN2P3: P. Astier, A. Guyonnet, M. Roman, D. Boutigny, S. Ricol

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 mass ratio (fgas) in dynamically relaxed clusters provide an excellent estimate of Omega_b/Omega_m; with existing measurements of Omega_b, 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 subset of fgas clusters, the associated error budget can be substantially reduced. Currently, only 12 out of the 40 rigorously selected fgas clusters have high-quality weak 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.

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		
Anja von der Linden	KIPAC	anja@slac.stanford.edu	United States		
Prof. Steven Allen	Stanford University (Physics)	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 Astronomy	dapple@astro.uni-bonn.de	Germany		
Pat Kelly	UC Berkeley	pkelly@astro.berkeley.edu	United States		
Mr. Adam Wright	Stanford (Physics)	awright3@stanford.edu	United States		

New CFHT observing proposal submitted last week

... before we have got anything observed....

CANADA-FRANCE-HAWAII TELESCOPE

Astier **16AF026**

Weighing the f_gas clusters

Semester : 2016A **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 mass ratio (fgas) in dynamically relaxed clusters provide an excellent estimate of Omega_b/Omega_m; with existing measurements of Omega_b, 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 subset of fgas clusters, the associated error budget can be substantially reduced. Currently, only 12 out of the 40 rigorously selected fgas clusters have high-quality weak 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.

Telescopes

Telescope	Observing mode	Instruments
CFHT	QSO Regular	MegaCam

Applicants

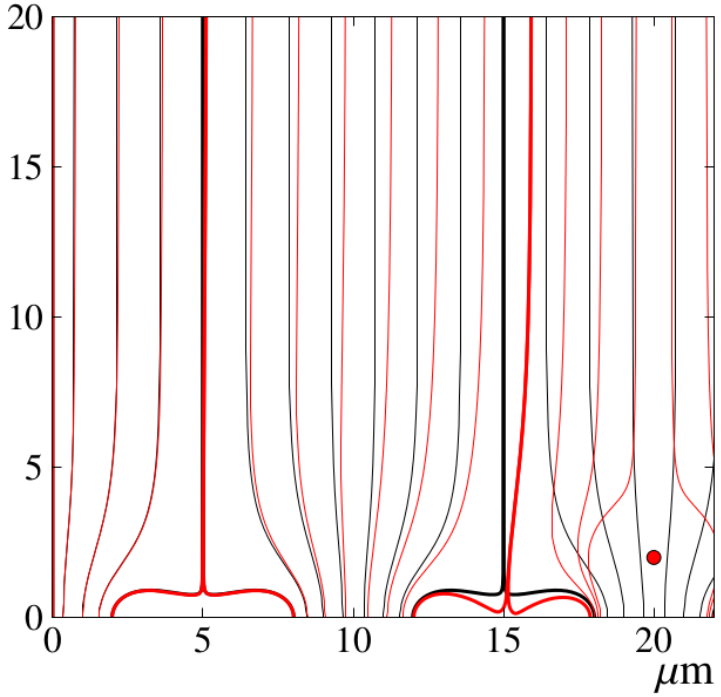
Name	Affiliation	Email	Country		Potential observer
Dr Pierre Astier	CNRS (LPNHE)	pierre.astier@in2p3.fr	France	PI	
Ludovic Van Waerbeke	University of British Columbia (Physics and Astronomy)	waerbeke@phas.ubc.ca	Canada		
Anja von der Linden	KIPAC	anja@slac.stanford.edu	United States		
Prof. Steven Allen	Stanford University (Physics)	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		
Dr Augustin Guyonnet	CNRS - IN2P3 - LPNHE	guyonnet@lpnhe.in2p3.fr	France		
Josquin Errard	LPNHE (CNRS)	josquin.errard@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 Astronomy	dapple@astro.uni-bonn.de	Germany		
Pat Kelly	UC Berkeley	pkelly@astro.berkeley.edu	United States		

Local Team

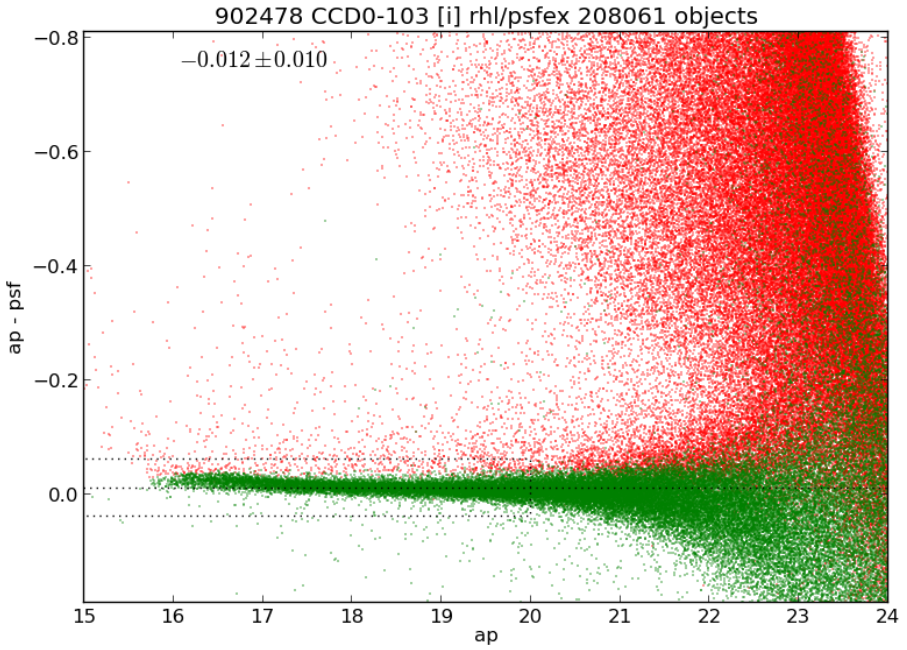
- We teamed up with:
  - Weighing the Giants, through the CFHT proposal
  - M2C project (M. Arnaud)
- As of today : 7 individuals from IN2P3
  - goal : contribute an independent analysis chain
  - from the pixels to the shear measurements
- Current activities
  - Work on Subaru / CFHT data + archival (public) data
  - Code contributions : astrometry for stacking

    → in the framework of LSST pipeline development

A new concern for shear studies : the brighter-fatter effect



Drift lines in CCD depend on the image.

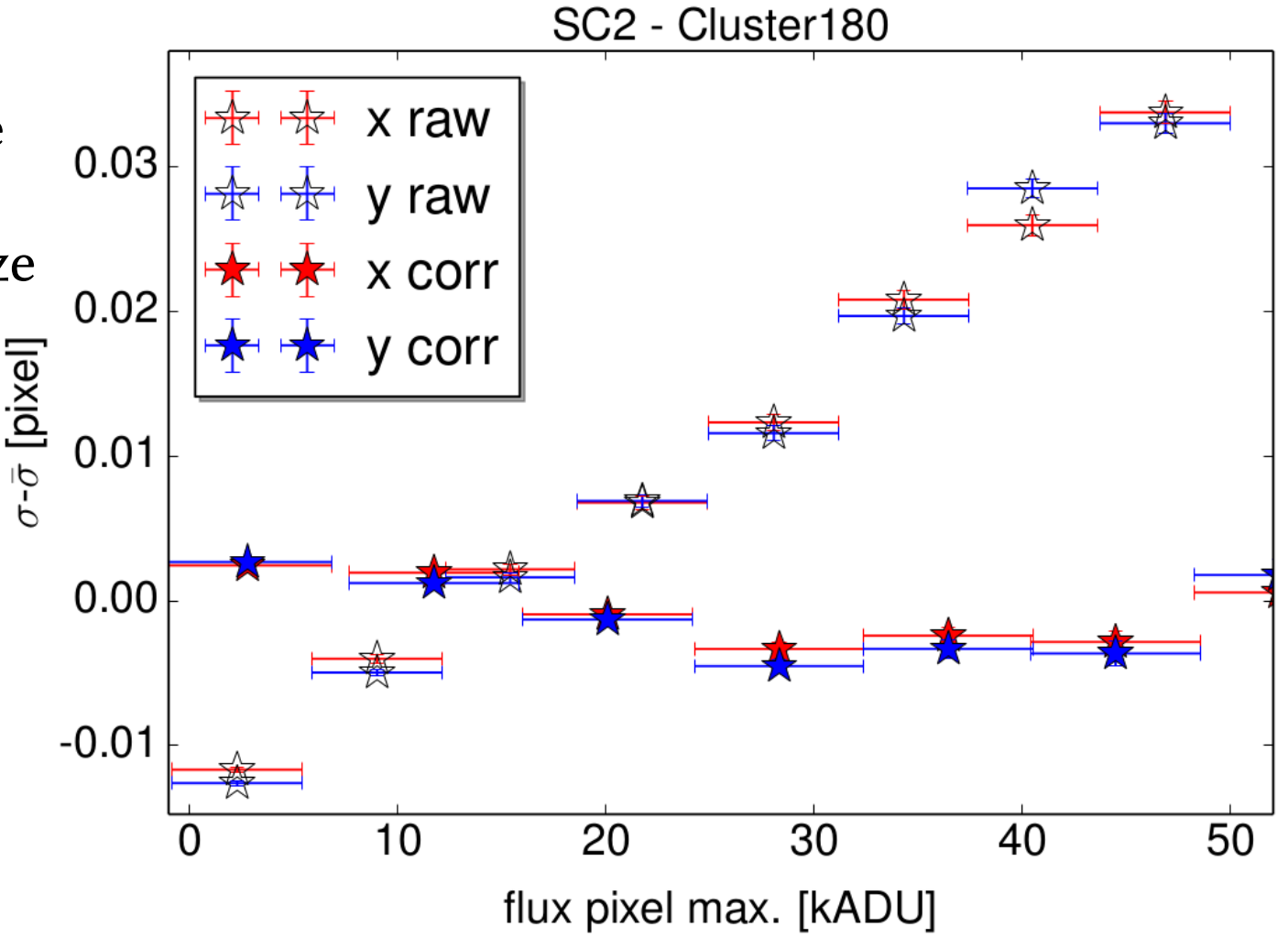


The apparent size of stars depends on their brightness

The PSF concept has become complex!

Correction at the pixel level for the Subaru camera

Difference of star size to the average size



Before correction

After correction

Augustin Guyonnet,
following the pioneering method from Guyonnet et al (2015)

Conclusion

- We have presented two examples of intermediate projects, with a potentialy high scientific return :
  - Hubble diagram of SNe Ia

    $\longrightarrow$ detection of a variable w by 2019 ?
  - Mass of cluster through gravitational lensing

    $\longrightarrow$ cosmology with cluster counts, baryon frac. in clusters

    $\longrightarrow$ training for cosmic shear
- Intermediate projects are all about
  - actively preparing the LSST/Euclid analyses
  - training the researchers who will be active in the LSST/Euclid working groups
  - producing exciting results !