News from

LSST

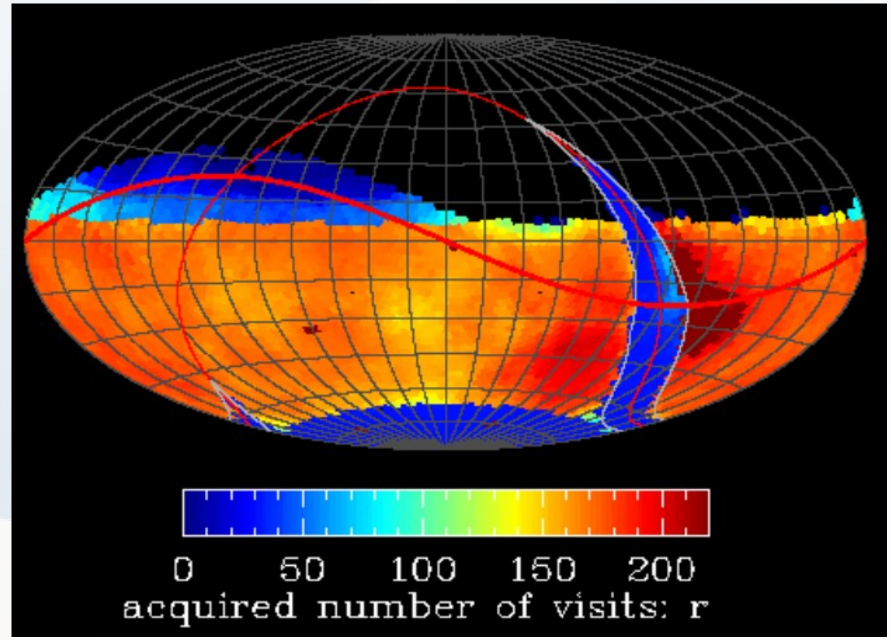
Large Synoptic Survey Telescope

Emmanuel Gangler – LPC – Clermont-Ferrand (France)

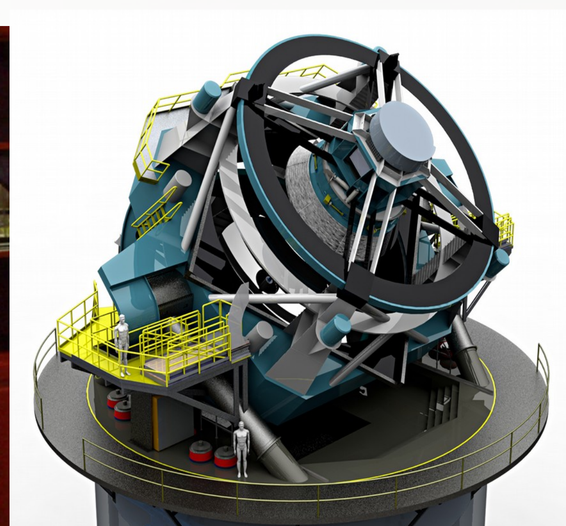
LSST Large Synoptic Survey Telescope

capabilities :

- A stage-IV survey :
  - 8.4 (6.7) m telescope
  - Cerro Pachon (Chili)
  - 3.2 Gpix 9.6□ FoV camera
  - 0.2'' pixel / 0.7'' median FWHM
  - First light 2020, Survey 2022



- All visible sky in 6 bands (ugrizy) (~18000□)
- 2x15 s exposure, 1 visit / 3 days
  r ~24.4 / visit
- During 10 years !
  → ~825 visits (all bands)
- 15TB/day 60 PB/10 years



LSST project and Science:

LSST
Large Synoptic Survey Telescope

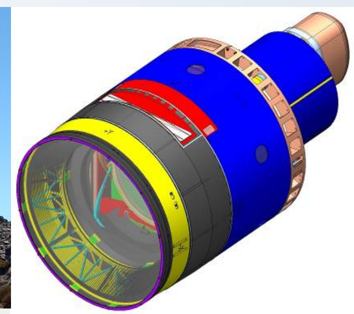
Science

Science data products

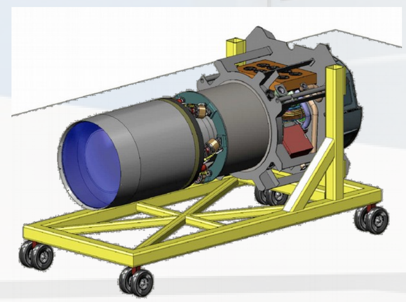
System engineering

Telescope and site

Camera



Commissionning



Data Management

Outreach

Alerts & Annual release

- **LSST covers 4 major scientific themes**
  - Dark Energy, Dark matter
  - Mapping Milky Way
  - Transient optical sky
  - Solar system
- **Scientific analysis is not part of the project**
  - Conducted by independent collaborations (**need data rights**)
  - With the help of LSSTc

LSST has open to international community

- **LSST is a now a world-wide project !**
  - Already ~*1200 scientists* have LSST data rights
    - Dark Energy is the largest group (800)
    - (Data center dimensioned for 7500)
  - ~ 1/2 from US & Chile
  - ~*420 from Europe today* (12 countries)
    - UK : ~200, IT ~70, **FR ~65**, SP ~30, DE ~20, …
  - 260 from the rest of the world *(China, Korea, Australia, Brazil, Canada, New Zealand, Taiwan)*
- International affiliates represented through **LSST Corporation**
  - 35 members including IN2P3, INAF, …
  - *LSST Project run jointly by LSSTC, NSF, DOE*

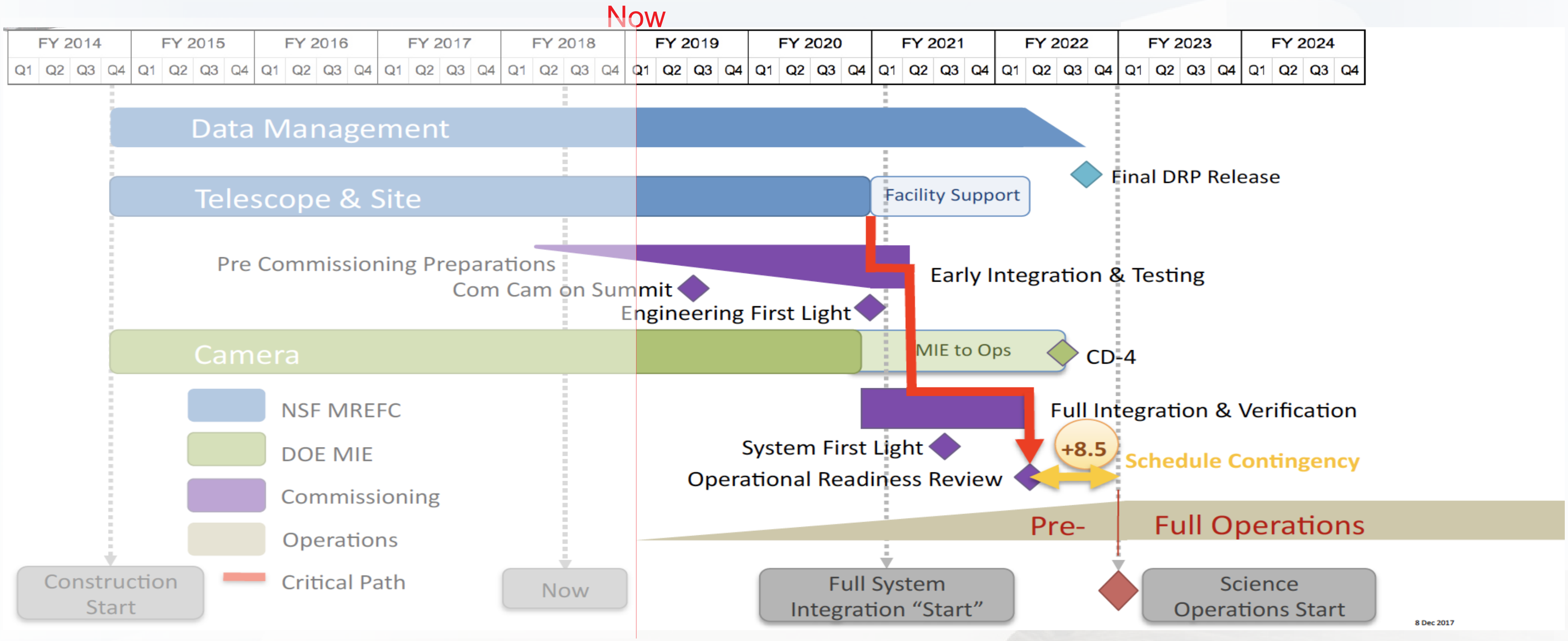
LSST in France

- **10 laboratories from IN2P3:**
  - APC, CCIN2P3, CPPM, LAL, LAPP, LMA, LPC, LPNHE, LPSC, LUPM
- **Around 130 people:** 64 researchers (17 juniors), 65 IT
- Data rights earned through **in kind contribution:**
  - Building the LSST Camera (~16 FTE/yr IT + Hardware)
  - Computing (~6 FTE/yr IT + Hardware investment + Running costs)
- **Ongoing activities:**
  - Transition between construction and commissioning is happening right now!
  - Preparing the Dark Energy scientific program
- ...and **participation from INSU/CEA ?**
  - Active discussions between IN2P3 and INSU

    … stay tuned !

LSST Construction

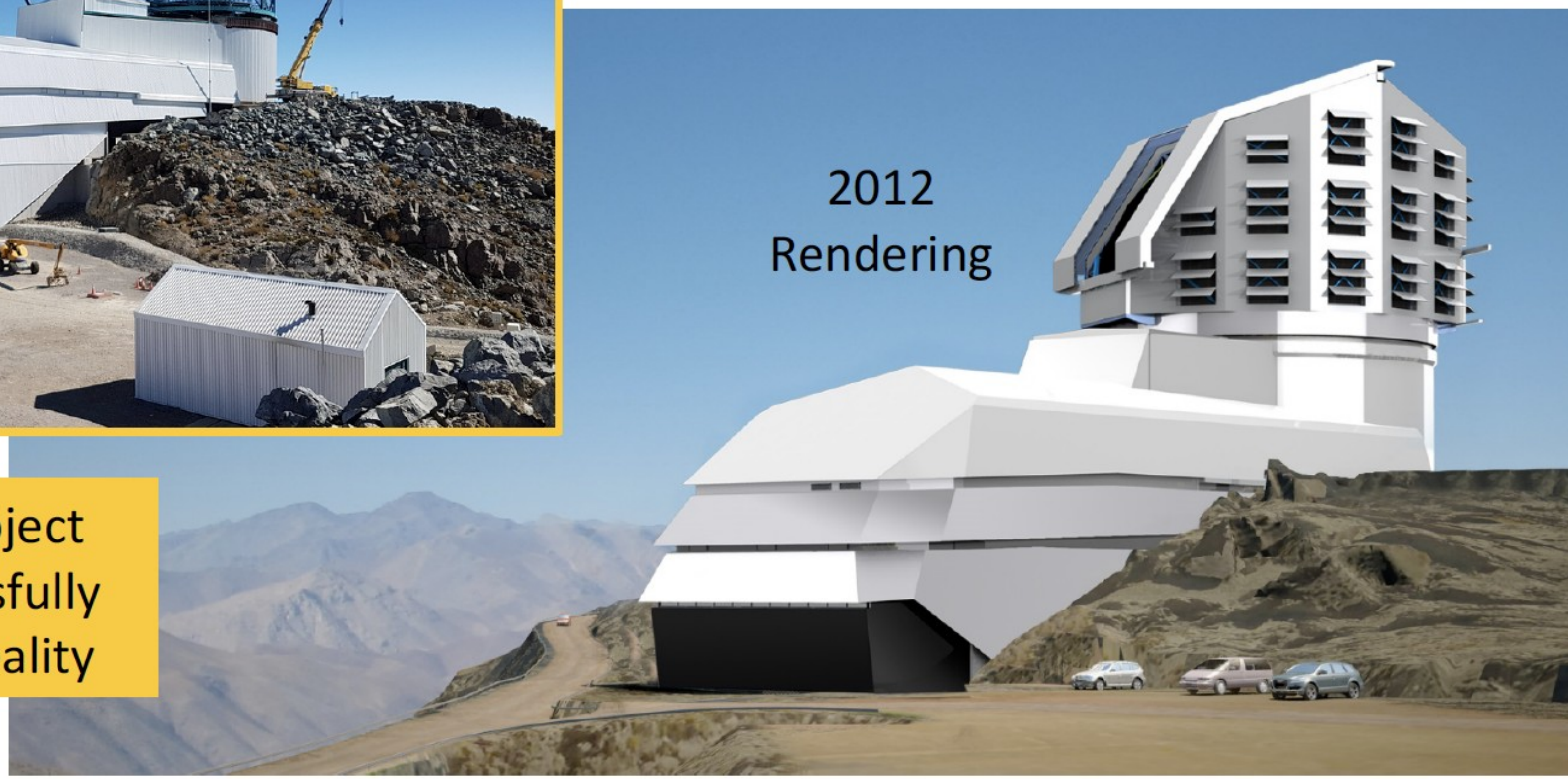
LSST Timeline



Commissioning is happening NOW !

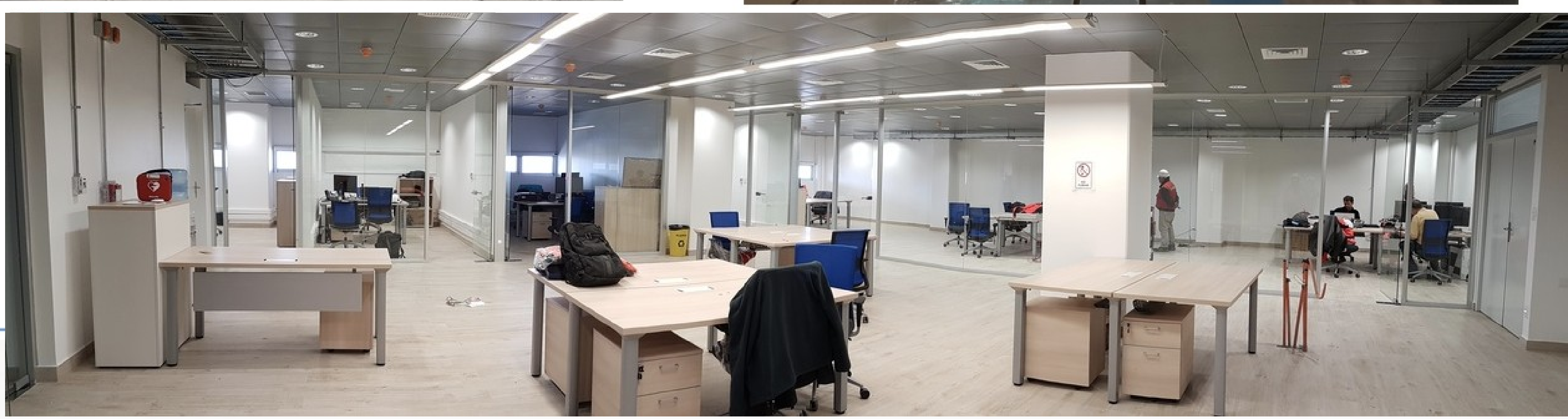
- **AuxTel (=1CCD):** commissioning autumn 2018 (Tucson), first light 2019 (Chile)
- **ComCam (=1 Raft/9 CCDs):** commissioning has started (SLAC), 2019 (Tucson), 2020 (Chile)
- **Full Focal Plane:** 2 Rafts (SLAC, Nov 2018), 9 Rafts (SLAC, March 2019), Full (SLAC, Spring 2020), First light summer 2021 (Chile)

The dream is coming true…



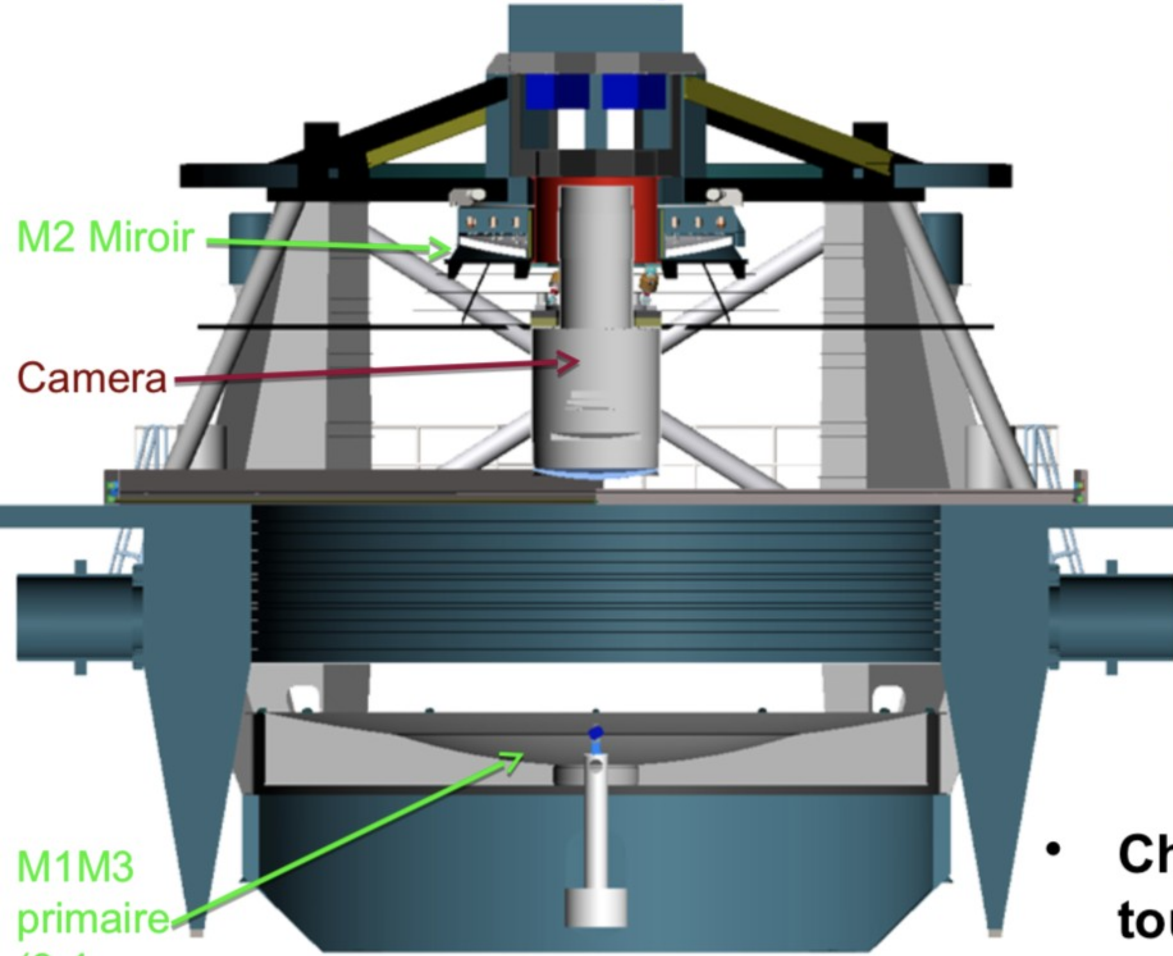
All Across the Project efforts are successfully transitioning to reality

Interior Spaces within Summit Facility



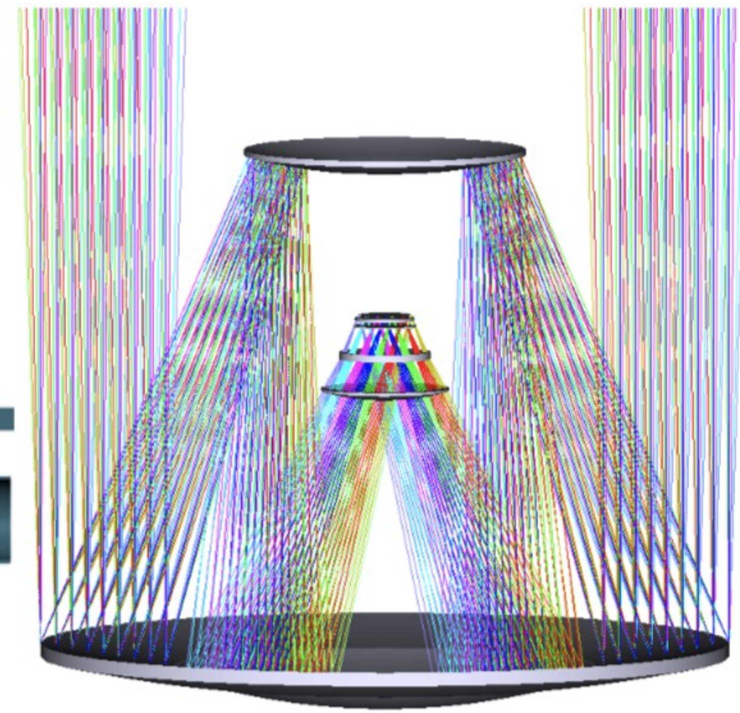
LSST : Wide , Deep and Fast (1/2)

LSST Etendue : 319 m^2 deg^2



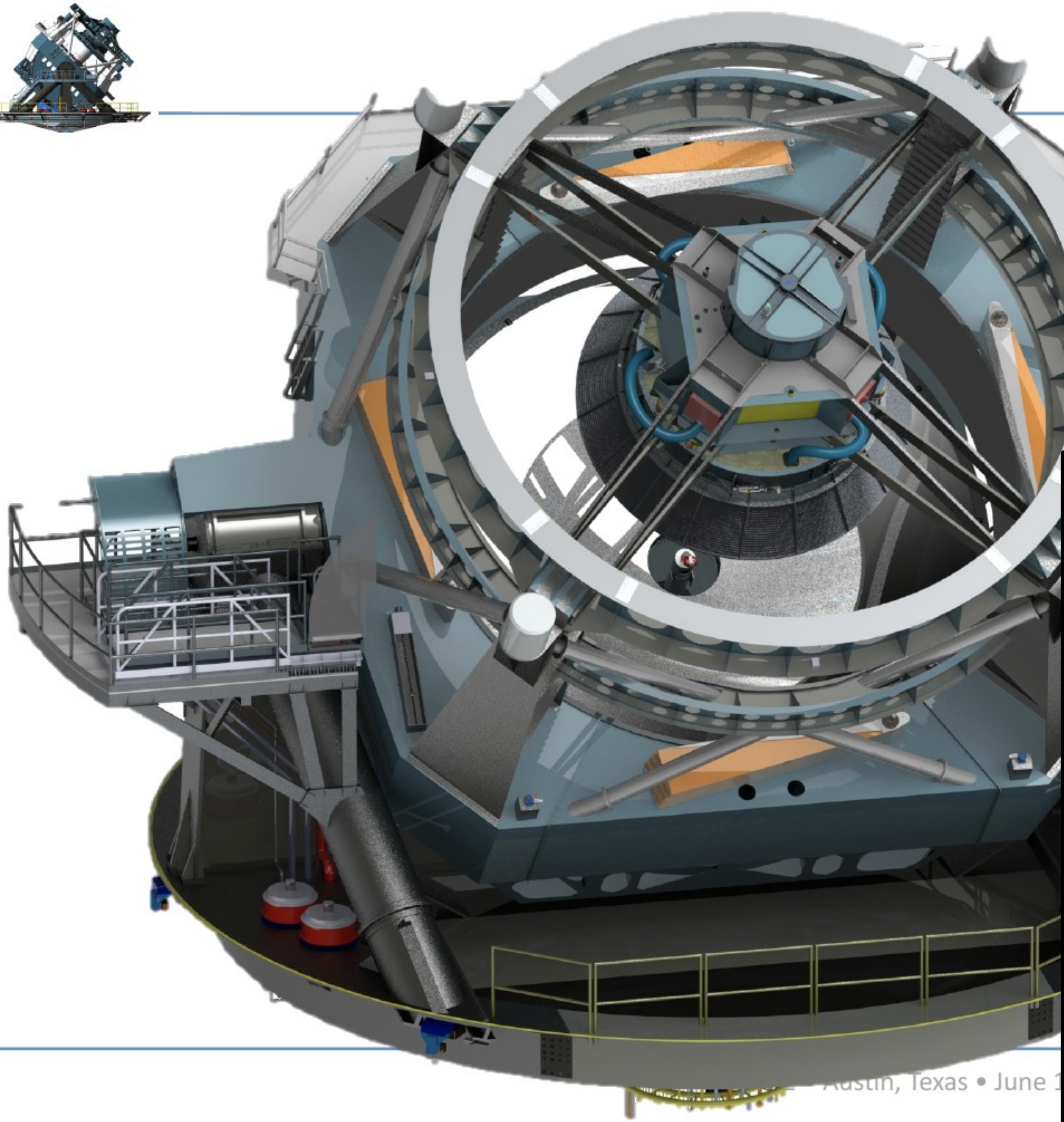
Structure de 350 tonnes
60 tonnes de système optique

Concept optique : Paul-Baker modifié



- Change de pointé dans le ciel toutes les 39 secondes
- Se déplace de 3.5° vers le champ voisin en ~ 4 secondes

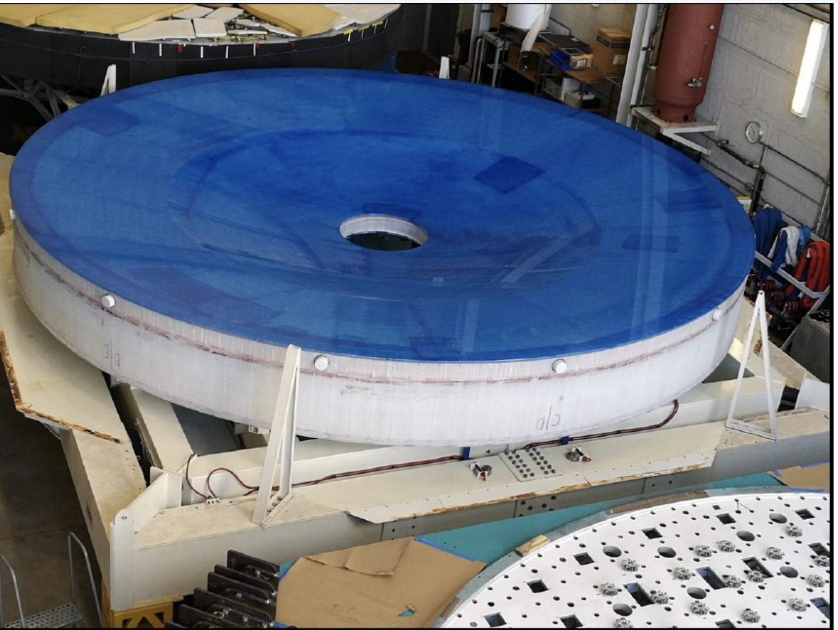
f = 10 m, ouverture = f/1.2



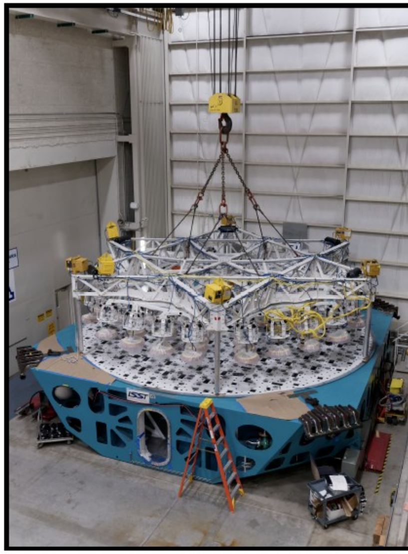
– Stiff 300 ton moving structure

At manufacturer facility

M1M3 Mirror



After ~3 years in storage the LSST 8.4m M1M3 Mirror was moved to the Mirror Lab at the University of Arizona yesterday.



The 19-ton mirror will be mounted on the Mirror Cell ~~next~~ week.
this

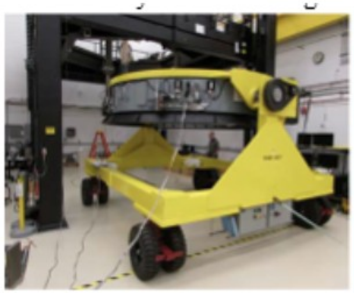
They will remain at the Mirror Lab for testing through mid-march 2019 before shipping to Chile. Scheduled arrival in Chile is ~mid-2019

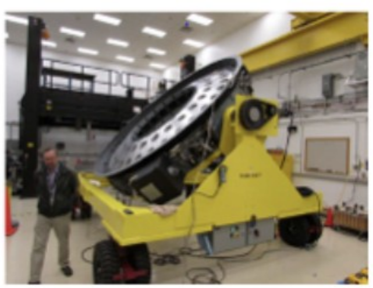
Secondary mirror

3.5m Diameter Secondary Mirror Nearing Completion

Gressler
10400-41
Wed: 2:50PM

- Corning ULE blank procured early in development phase
- Harris Corporation providing optical fabrication and cell assembly
  - Final delivery plan: October 2018
  - With surrogate mirror for testing

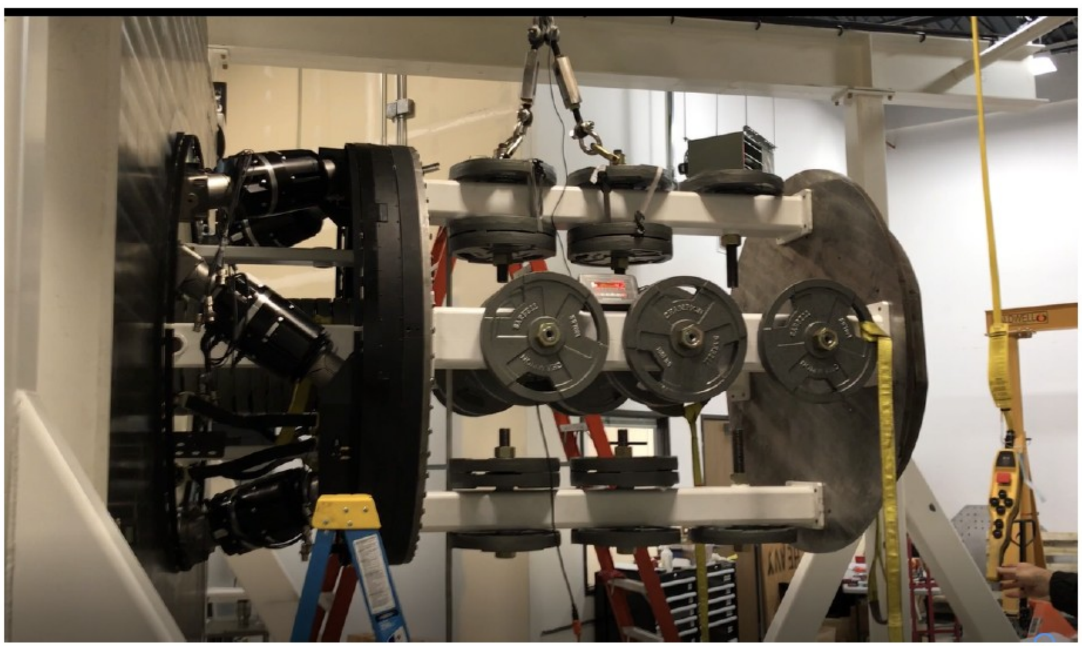




Secondary mirror mechanics

Optical alignment held with Camera and M2 motions

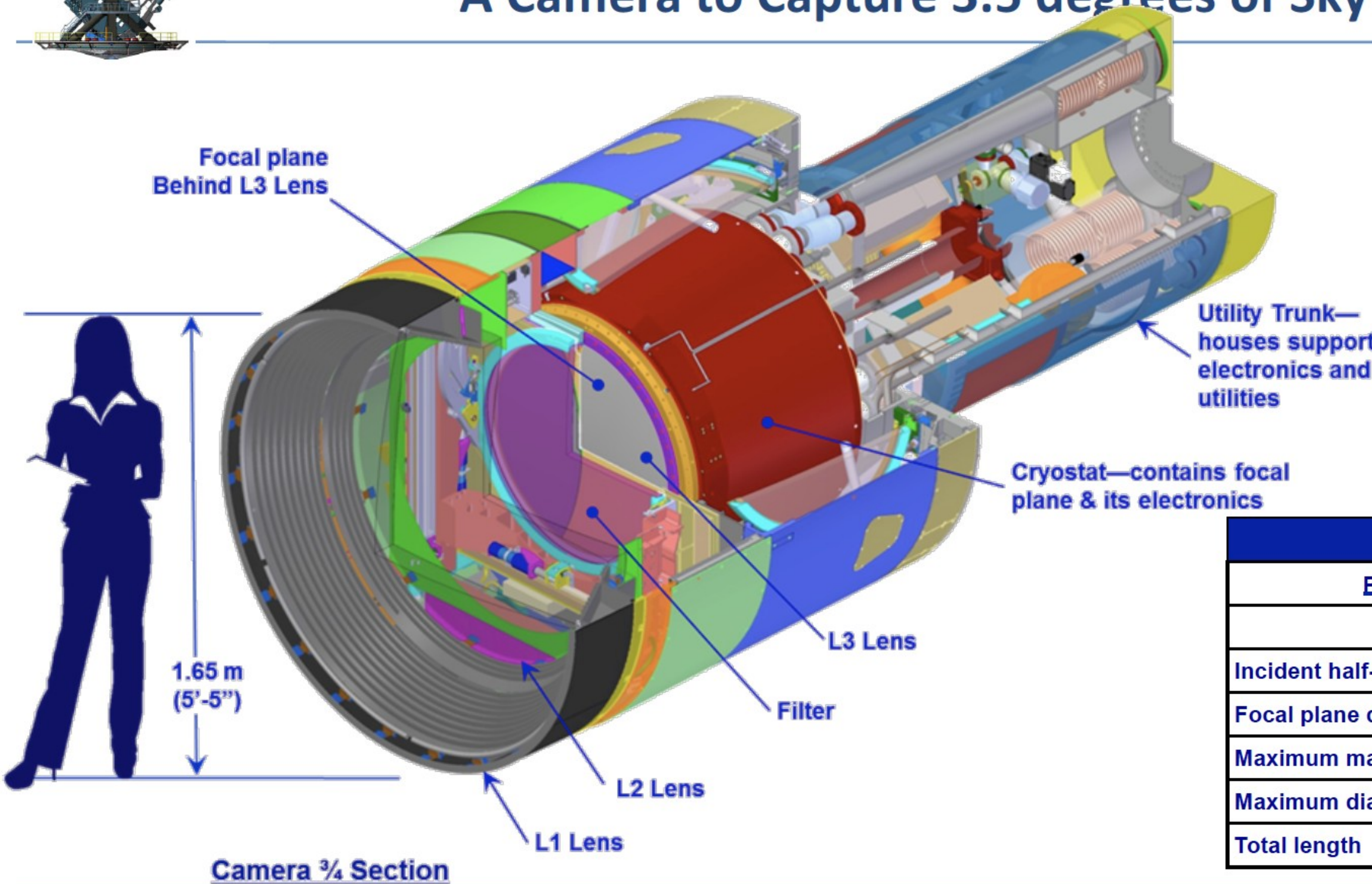
- Camera Hexapod / Rotator and M2 Hexapod being built by Moog - Final delivery August 2018



Successful 200% load test of cantilevered Camera and Integration with LSST software

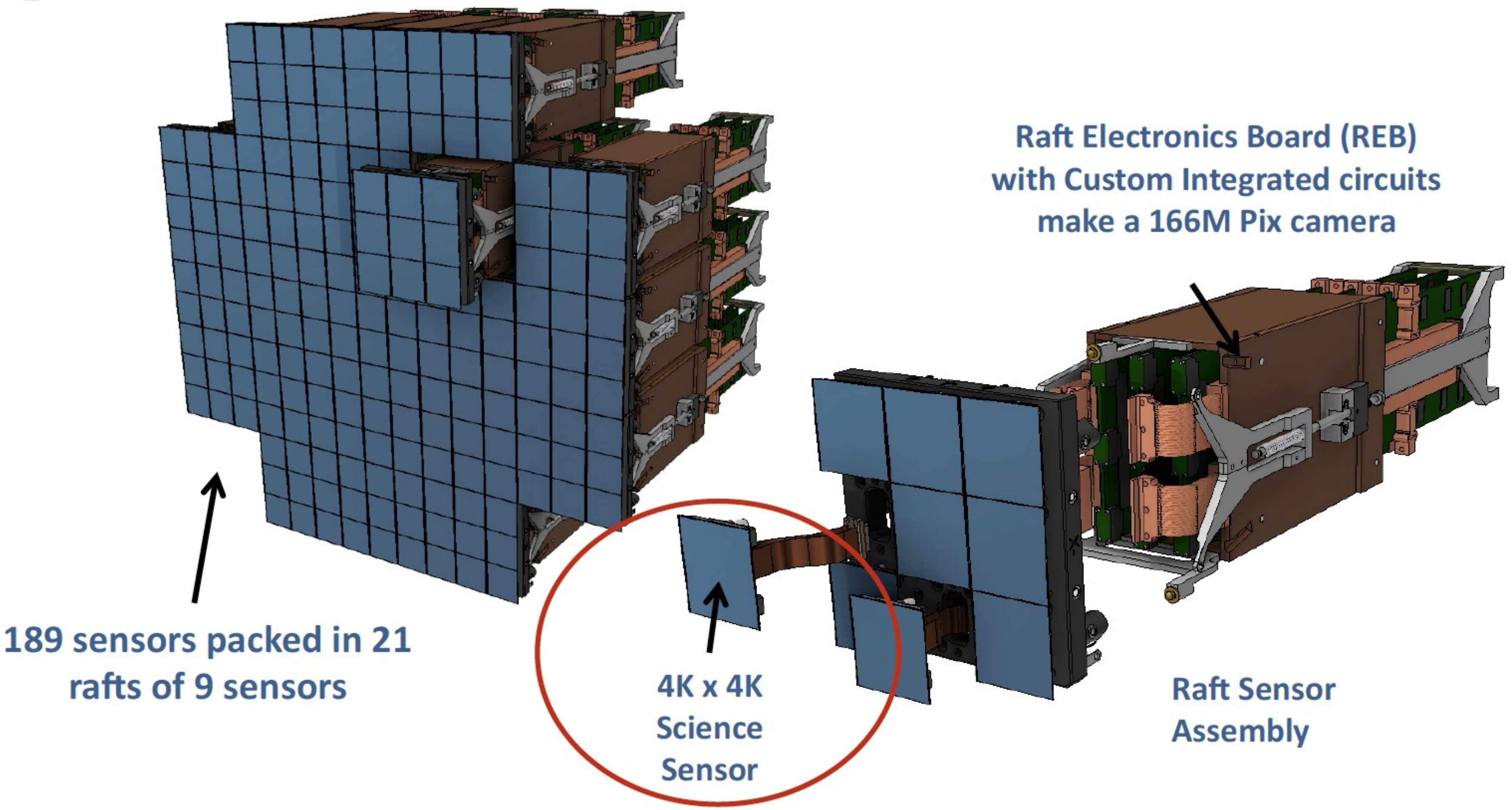
LSST Camera

A Camera to Capture 3.5 degrees of Sky



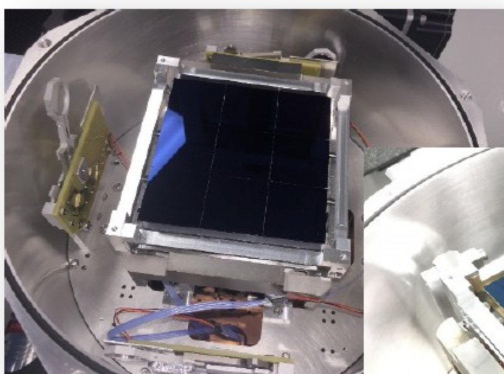
Camera Parameters	
Property	Value
	15 years
Incident half-angle in air	14.2°-23.6°
Focal plane diameter	634 mm
Maximum mass	3060 kg
Maximum diameter	1650 mm
Total length	3732 mm

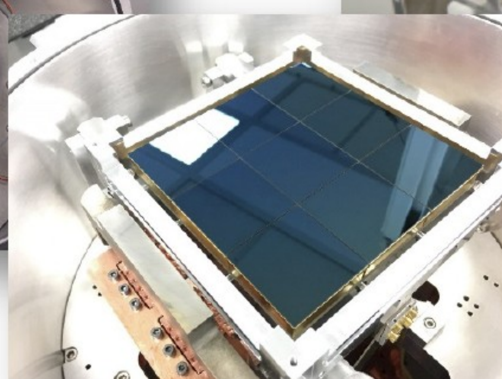
63 CM Diameter Focal Plane with 3.2 GigaPixels

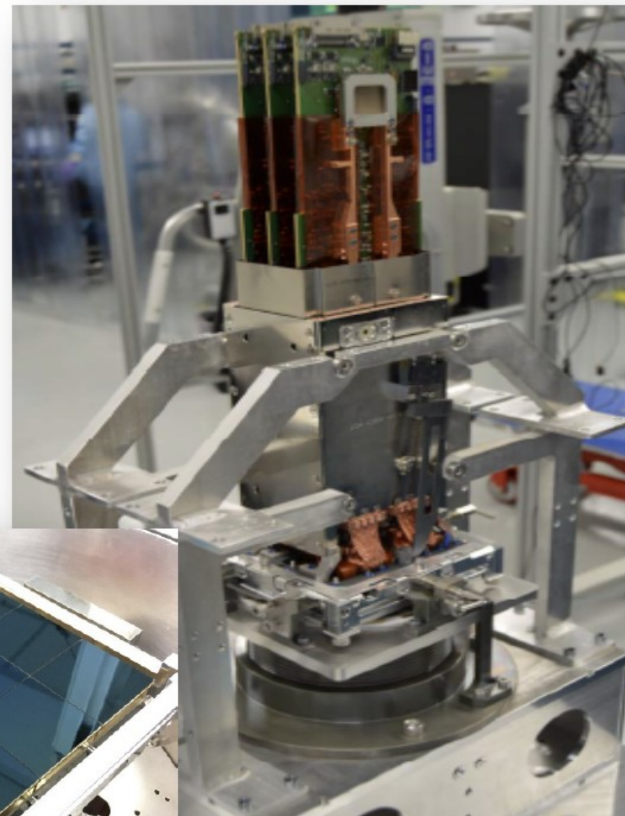


Camera Sensors Fabricated by Two Vendors

- Need 198 for focal plane and 9 for spare raft.
- 219 Science and Science Reserve Sensors delivered -







Brookhaven National Labs does Raft integration

- 8 Rafts delivered
- 5 more completed

  Over half way!

Filter Exchange Systems Complete and Tested

Successful collaboration
Within 5 IN2P3 labs !

- Collaboration with IN2P3 labs in France for key Camera elements
- Filter Autochanger and Manual loader (6th filter) full size prototype completed and tested
- Carousel full size prototype completed and tested – Only final assembly on camera back flange remains

Filter Autochanger

Filter loader on transport cart

5 Filter capacity carousel

CPPM LPSC APC LPNHE LPC

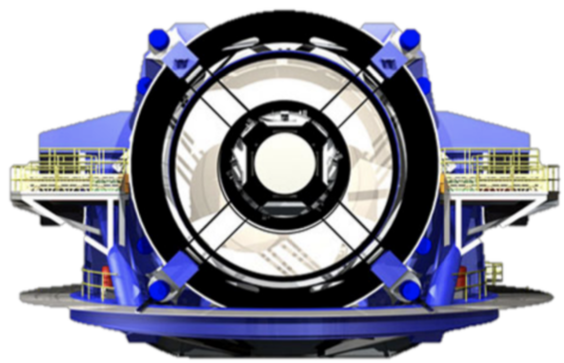
One word about the data flow

LSST Data Management System

Data Release Data Products
via Annual Data Releases

After 10 years:
- ***Database catalog: 15 PB***
- ***Images: 5.5 million***
- ***Objects: 37 billion***

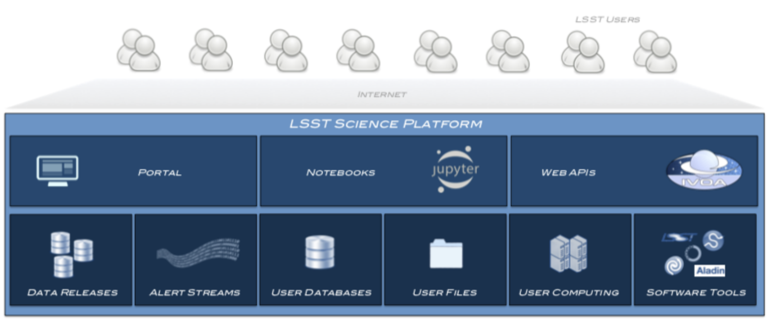
20TB raw data/night
(with calibration exposures)



Prompt Data Products
via nightly Alert Streams

Average ~ 10 million/night
Real-time latency: 60sec

Data Releases
(current & previous)



Alerts database

Mini-broker

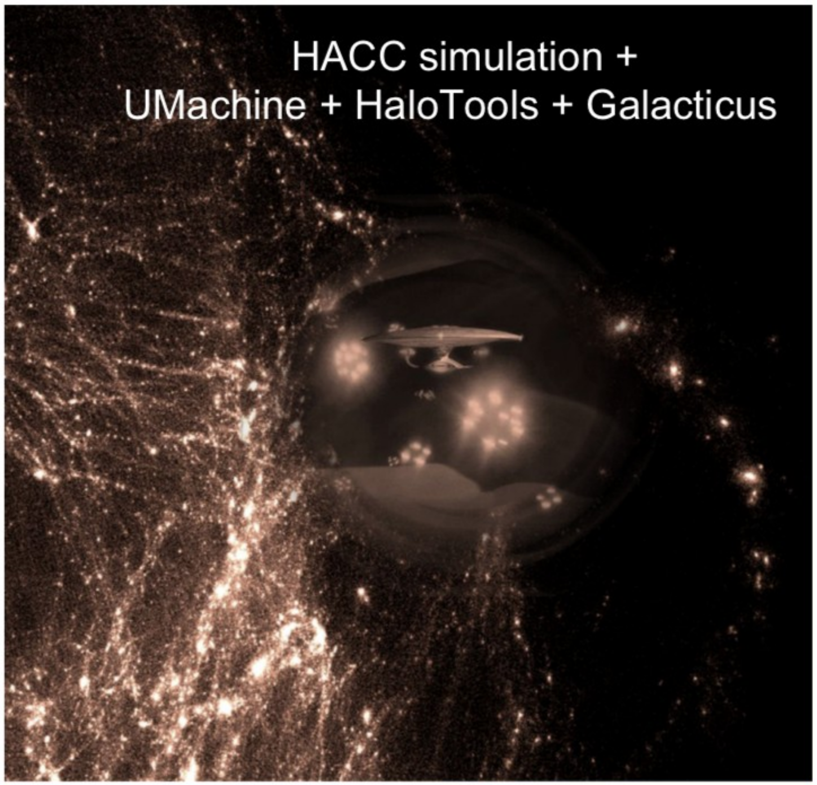
Data access via Data Access Centres & Services

Organizing the Data Access is an active subject ...

DESC End-to-End Simulation Workflow

LSST DESC Dark Energy Science Collaboration

- Responsibility of Cosmological Simulations Working Group
- Responsibility of Survey Simulation Working Group
- Input
- Output delivered to collaboration
- Users

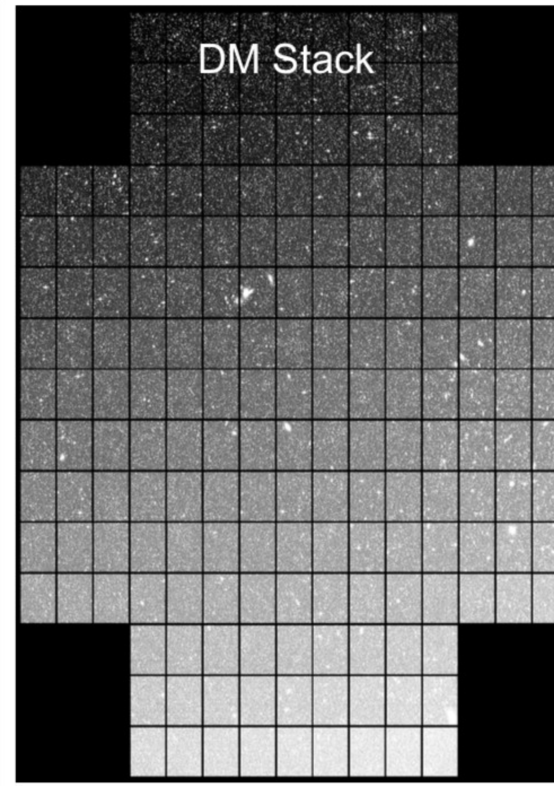


Extra-galactic catalog generation

5000 sq. degree

Image simulations

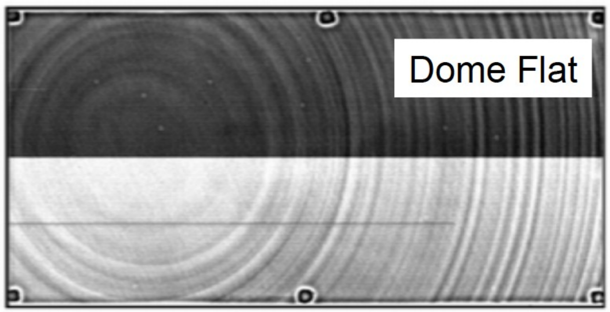
300 sq. degree
10 years

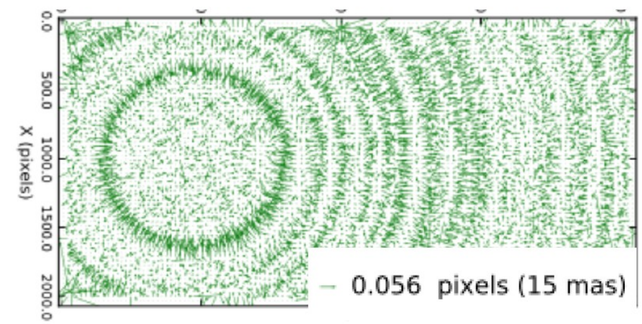


DM processing

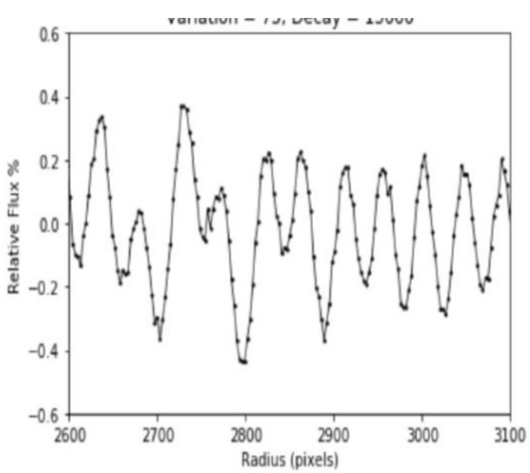
End-to-end cosmological simulations

- Getting ready for LSST data: computing, science validation
- An opportunity for testing mitigation schemes for *sensor defects*
  - One example : **Tree Rings**

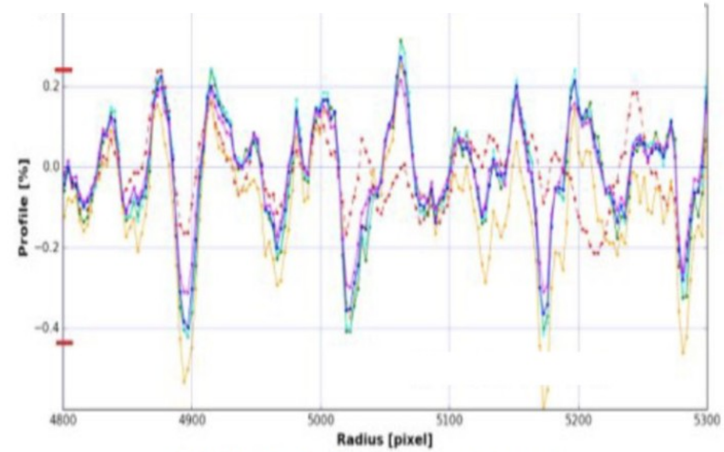




DECAM
Plazas 14



PhoSim Flat



HY Park, A. Nomerotski and D. Tsybychev, Properties of tree rings in LSST sensors, 2017 JINST 12 C05015

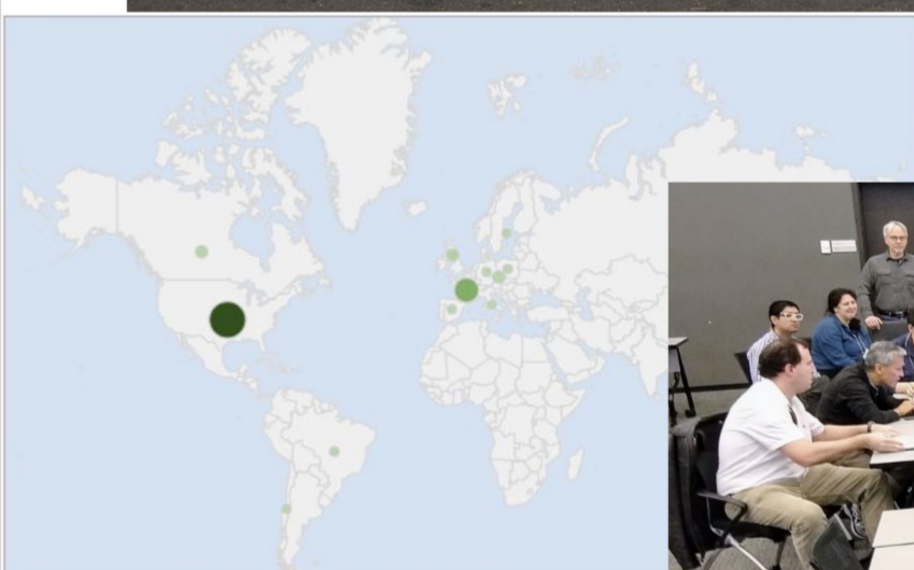
Simulation

Real Data

Preparing for the science

This is DESC!

817 Members
193 Full Members (32 FR/57 non-US)

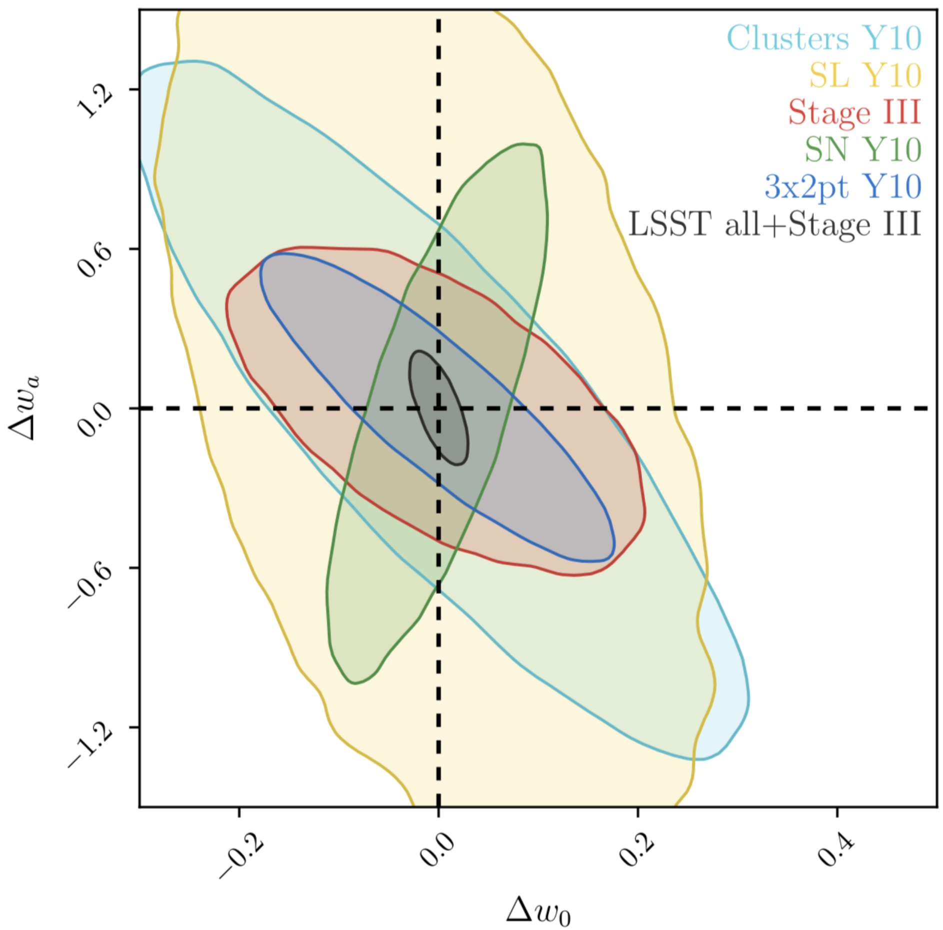


DESC and Dark Energy

- **Background Cosmology** is addressed by Type Ia supernovae[WG], Strongly lens systems[WG], (BAO)
- **Dark matter structure and growth** probed by Weak gravitational lensing[WG], Galaxy clustering[WG], and Clusters of Galaxies[WG]
- Photometric Redshifts[WG] are a common source of systematics
- LSST will constrain Dark Energy by Probe combinations[WG] (ex: 3x2 pt), it is a **systematics-limited project.**
- **Technical aspects:** Calibration[WG], Sensors[WG] play a significant role for the quality of the FoM.
- **Computing aspects:** Cosmological[WG] and Survey Simulations[WG] as well as computing infrastructure[WG] are key ingredients of the project

Science Requirements ArXiv 1809.01669

10 year forcasts



- Forecasts for 1 and 10 yr
- Full review of known systematics
  - Calibratable and self-calibrated
- Target: FoM of 500 for 10yr
  - Calibratable systematics should not dominate statistics
- Requirements for each probe

Specific requirements for Dark Energy

Shear:

Photo-z syst.: (See Johanna's talk)

mean photo-z of bin :< 0.001(1+z)

Photo-z scatter: <0.003(1+z)

Redshift-dependent shear calibration

< 0.003

PSF model size <0.1%

Stellar contamination < 0.1%

Supernovae: [+ **Cadence**, *identification*]

Calibration:

Filter 0-points < 1mmag

Filter mean wavelength < 0.1 nm

Lambda-dependent calibration

< 4.4 mmag per 550 nm

Light-Curve modelling < 3% of

SALT2 errors (See Pierre-François's talk)

MW extinction < 30% current

uncertainties

Joint Probes:

Ensure Blinding

R&D Needed:

Blending (**number density, shear**)

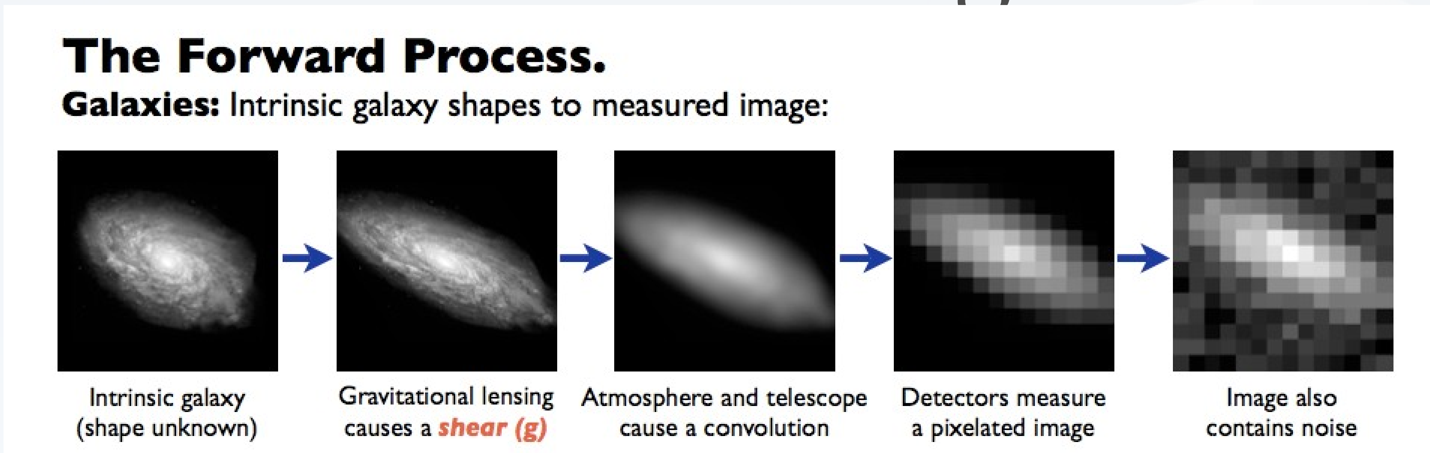
Galaxy characterization (**shear**)

Analysis	Priors	Y1 FoM (ceiling)	Y10 FoM (ceiling)	Target
LSS	Stage III (not w_0, w_a)	10 (13)	10 (14)	1.5
LSS	None	6.7 (8.4)	6.6 (9.1)	1.5
WL+LSS	Stage III (not w_0, w_a)	31 (37)	66 (87)	40
WL+LSS	None	22 (27)	49 (68)	40
CL	Stage III (not w_0, w_a)	9 (11)	17 (22)	12
CL	None	6.5 (8.2)	12 (17)	12
SN	Stage III (not w_0, w_a)	36 (44)	157 (211)	19
SN	None	10 (12)	32 (48)	19
SL	Stage III (not w_0, w_a)	1.6 (2.0)	6.9 (9.4)	1.3
SL	None	1.3 (1.7)	4.4 (6.1)	1.3
All	Stage III	142 (156)	505 (711)	500
All	None	108 (135)	461 (666)	-

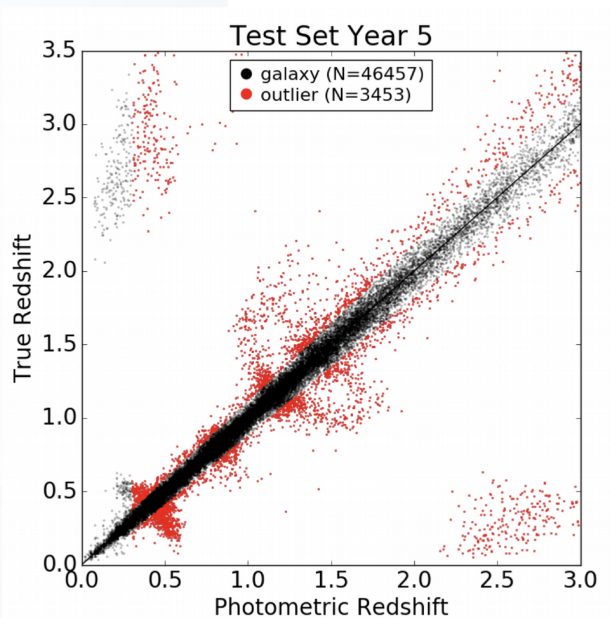
Note:

Clusters, LSS, strong lensing requirements not as difficult as for Sheer and Supernovae

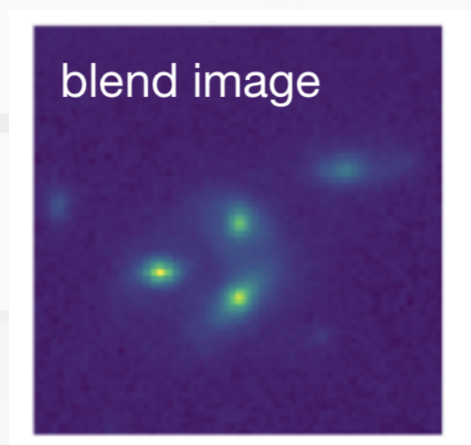
Shear challenges



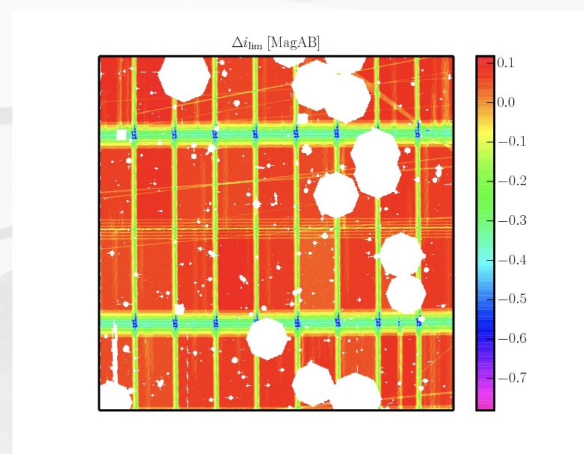
PSF + Noise



Graham 2017 **Photo-z**



Blending

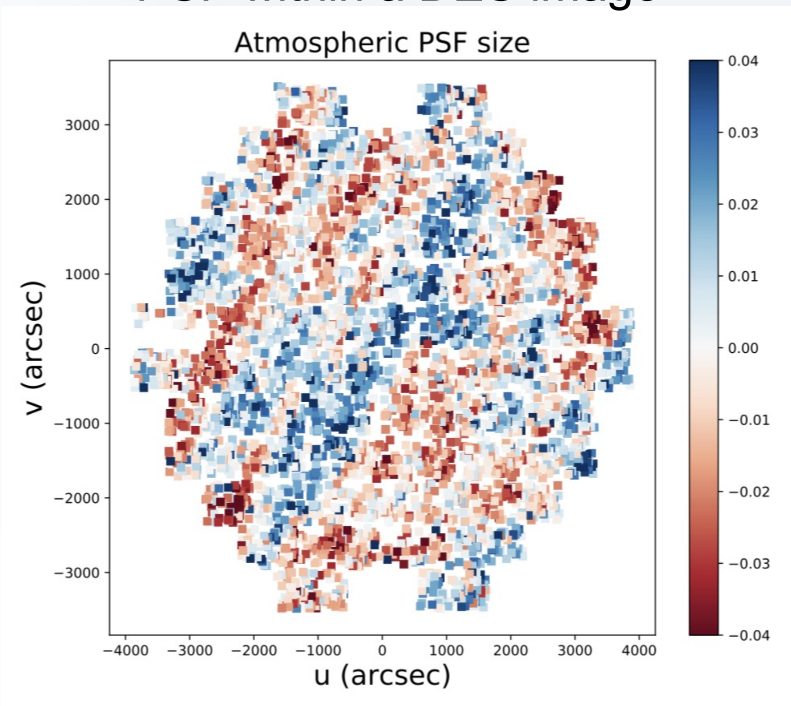


Masks, sensor effects

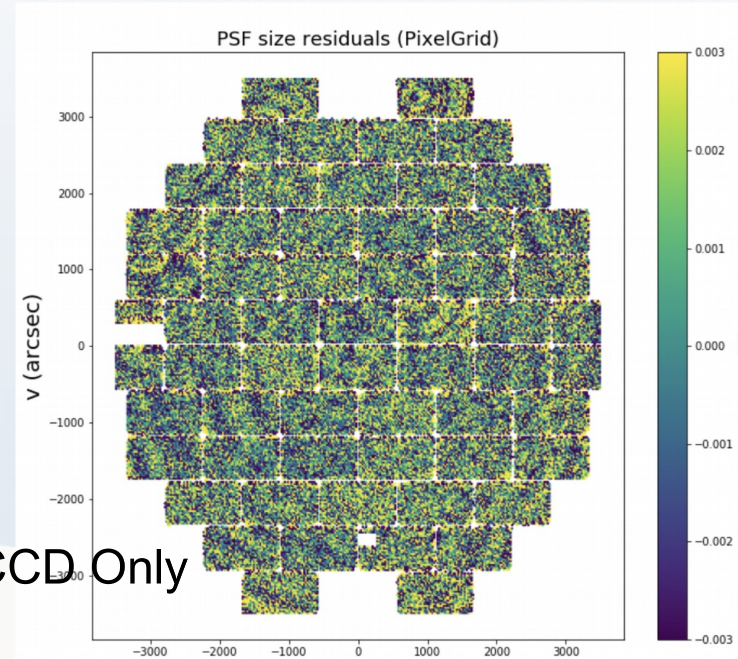
+ Astrophysics : intrinsic alignments, baryon feedback…

PSF improvement

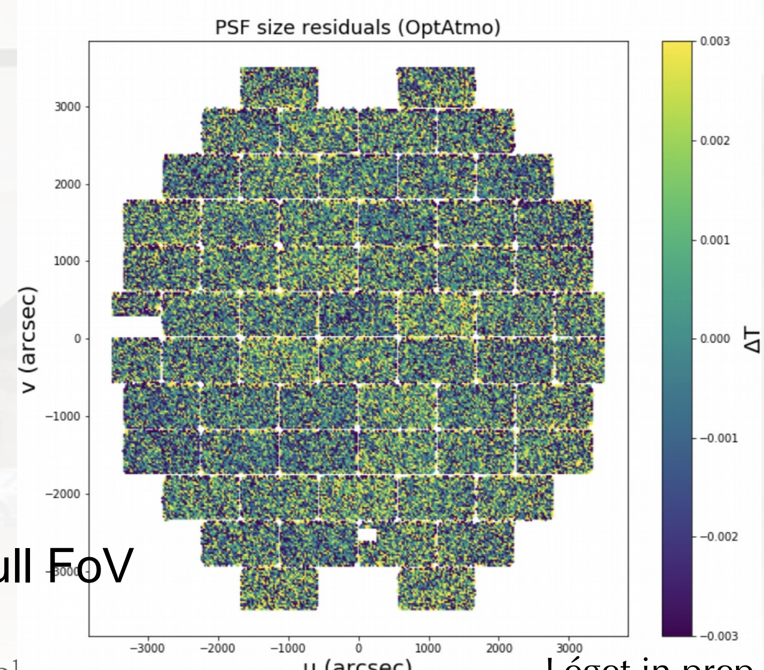
PSF within a DES image



Residuals



CCD Only



Full FoV

PSF size is correlated across full focal plane

- Single CCD treatment insufficient
- Full FoV model :
  - optical model (Zernike)
  - Von Karman atmospheric correlations

Léget in prep.

From Blending to …

… deblending !

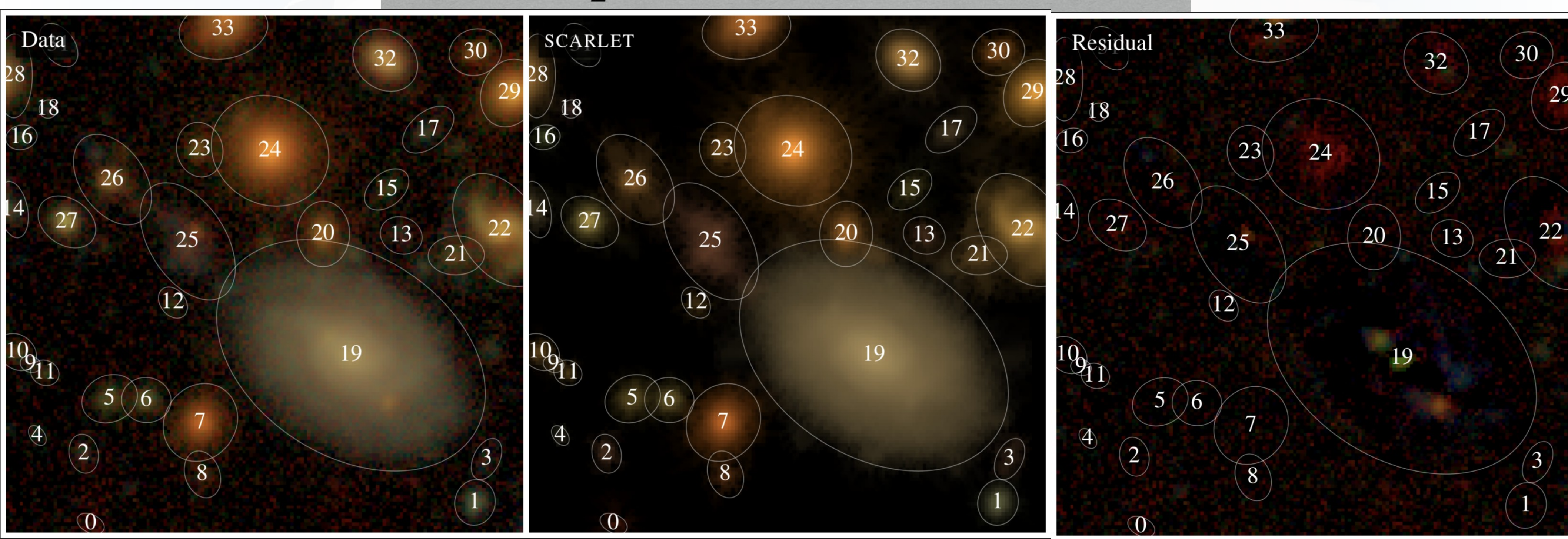
- Deep Neural Networks (of course…)
- Constrained Non-negative Matrix Factorization

$$\text{scene} = \sum_k \text{SED}_k \times \text{Morphology}_k + \text{noise}$$

$$Y = A \cdot S + \text{noise}$$ "Matrix Factorization"

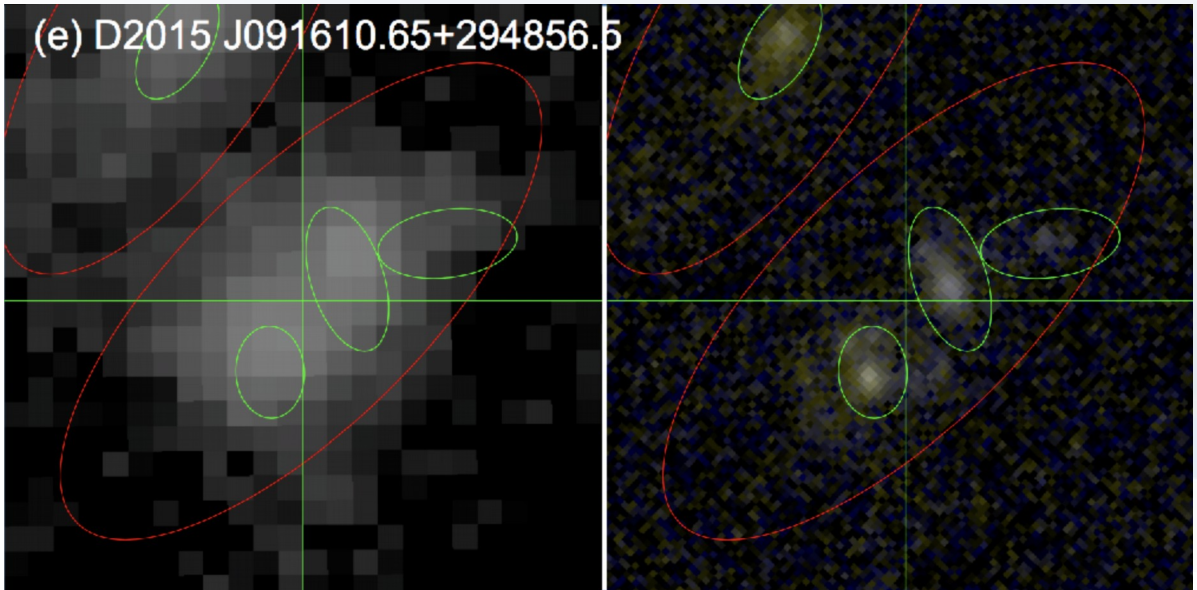
$$Y \in \mathbb{R}^{B \times N} \quad A \in \mathbb{R}^{B \times K} \quad S \in \mathbb{R}^{K \times N}$$

$$f(A, S) = \frac{1}{2}\|Y - A \cdot S\|_2^2 \; + g(A, S)$$



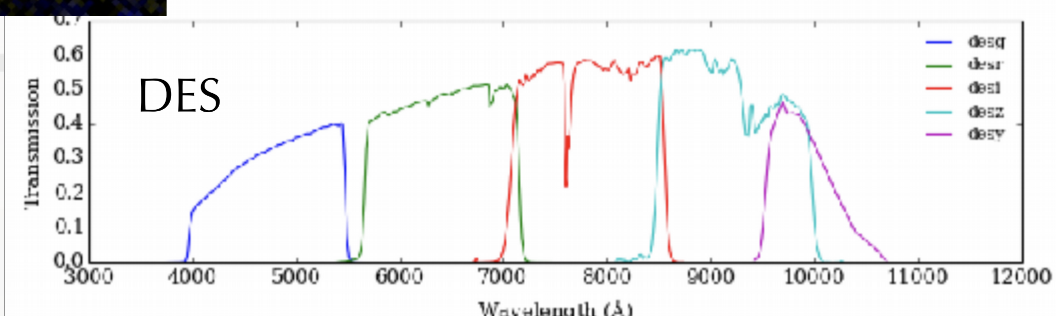
Improvement by survey combination

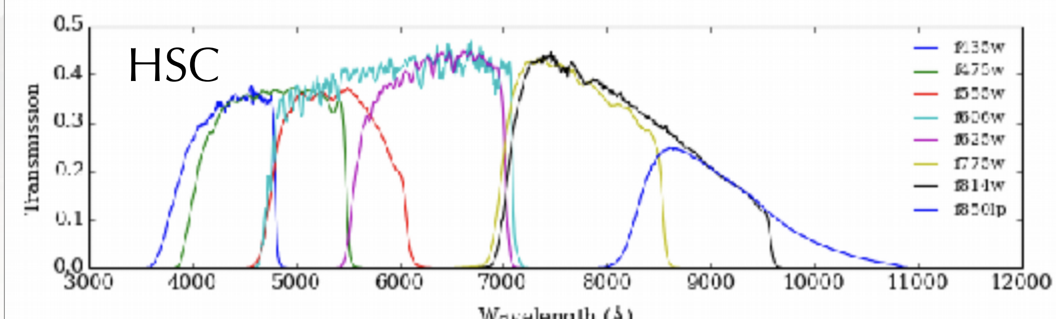
Dawson 2016



Different filter bandpasses

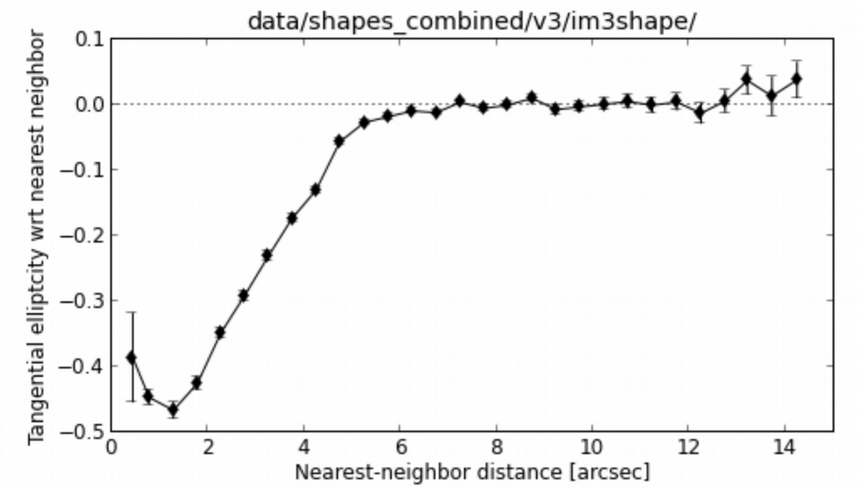
Space / Ground

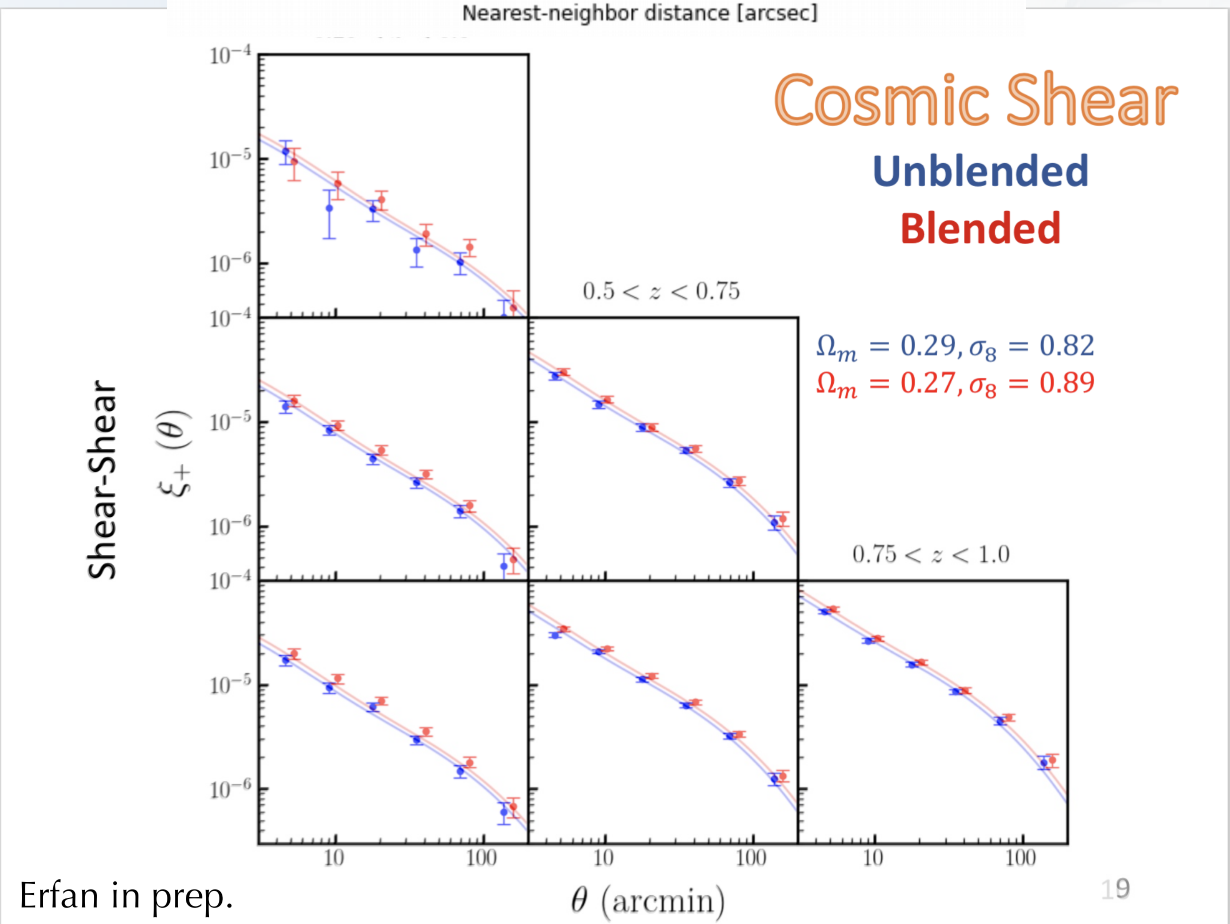




Blending will bias measurements !

DES SV data

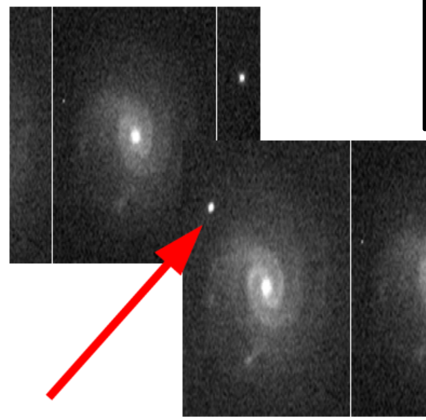




Erfan in prep.

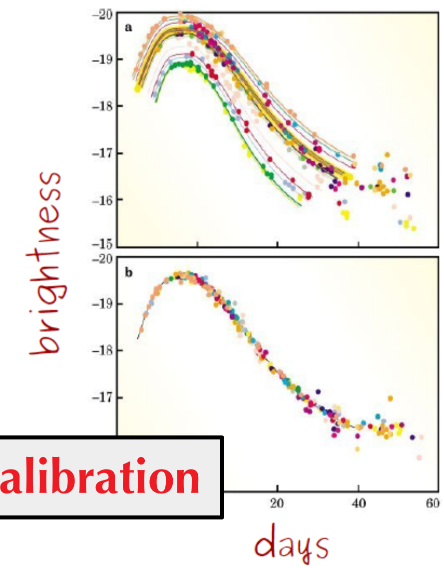
Supernova challenges

1. detection



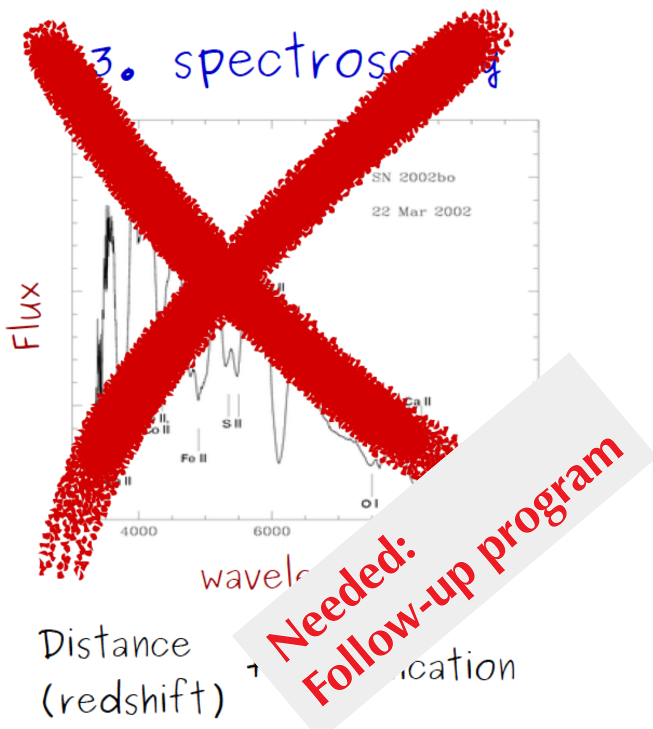
Survey strategy

2. photometry

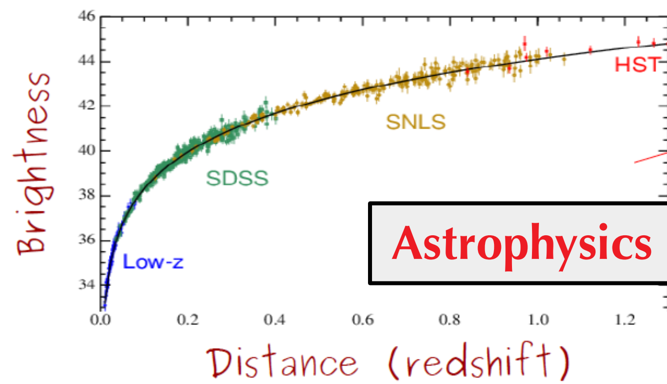


Calibration

Indentification



4. standardization + cosmological fit



Astrophysics

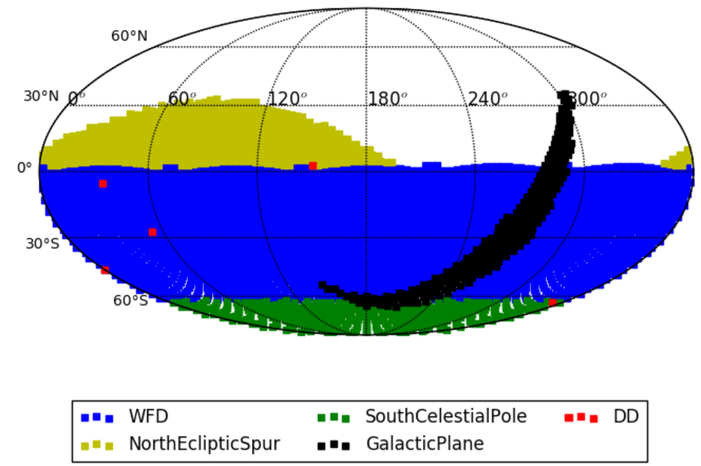
year	Number of supernova
1998	42
2014	740
2025	> 10 000

Slide borrowed from *Emille E. O. Ishida*

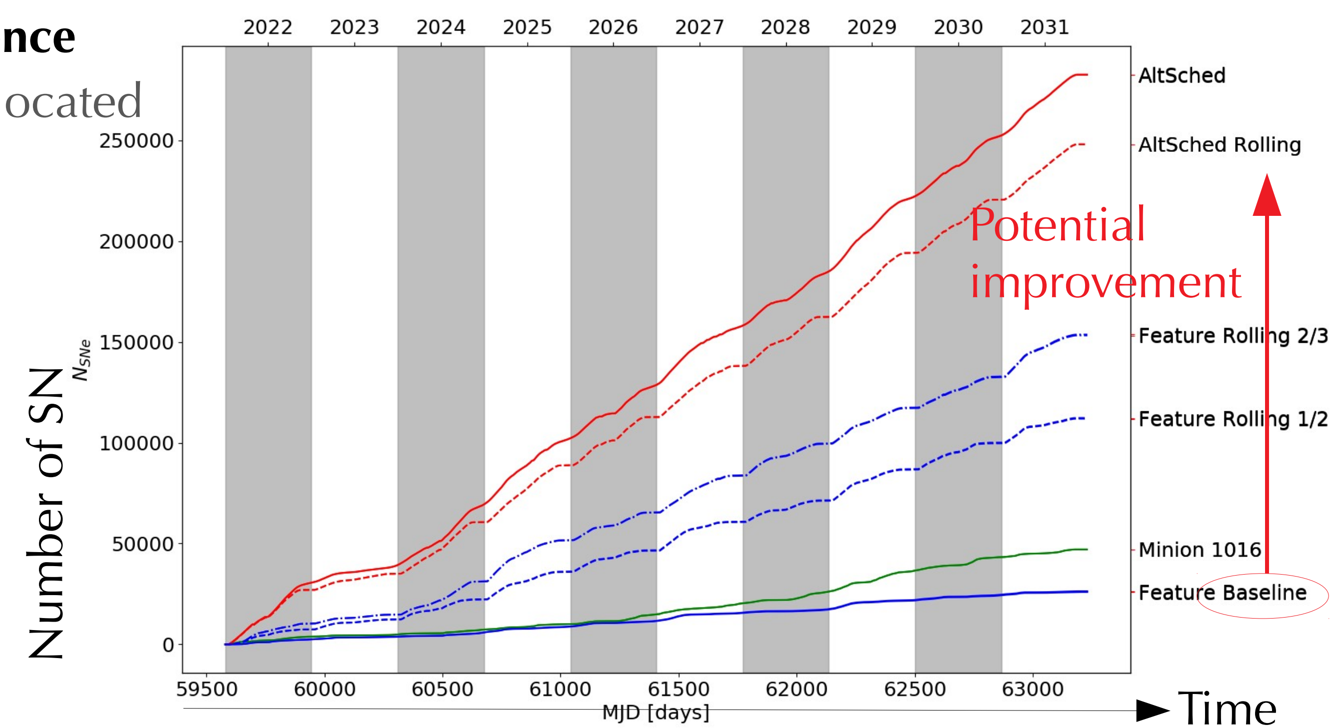
Observing Strategy (Cadence)

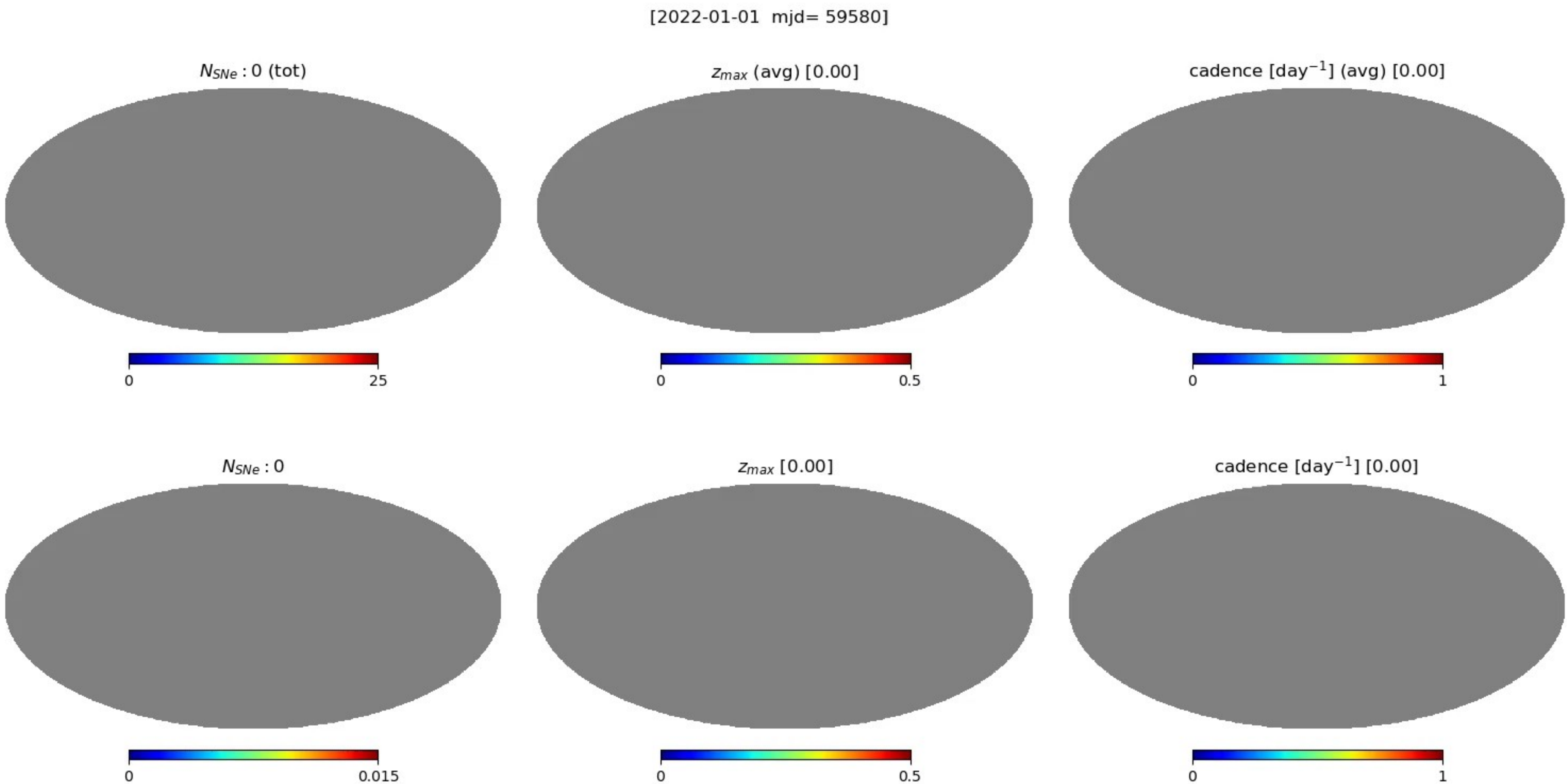
The project is revisiting the observing strategy

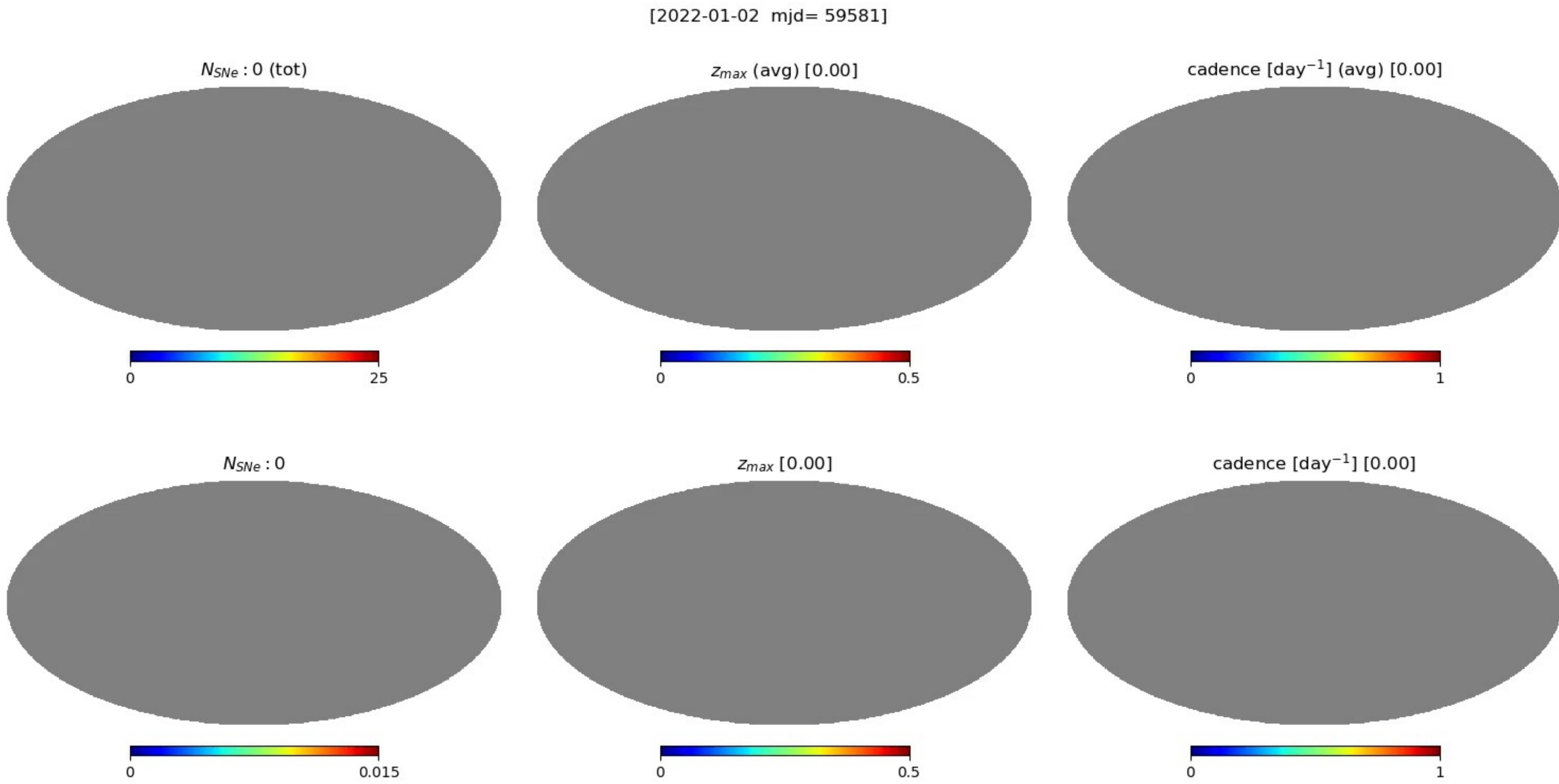
- White papers in 2018
- Decision made in 2020



- **Wide Deep Field** : 90% of observing time
  - Default cadences significantly impair the SN program
    - O(50 kSN), low z limit
  - Move toward **rolling cadence**
- **Deep Drilling Fields**: 5% of allocated time
  - Ongoing optimization
  - From 15 to 27 kSN z~0,8

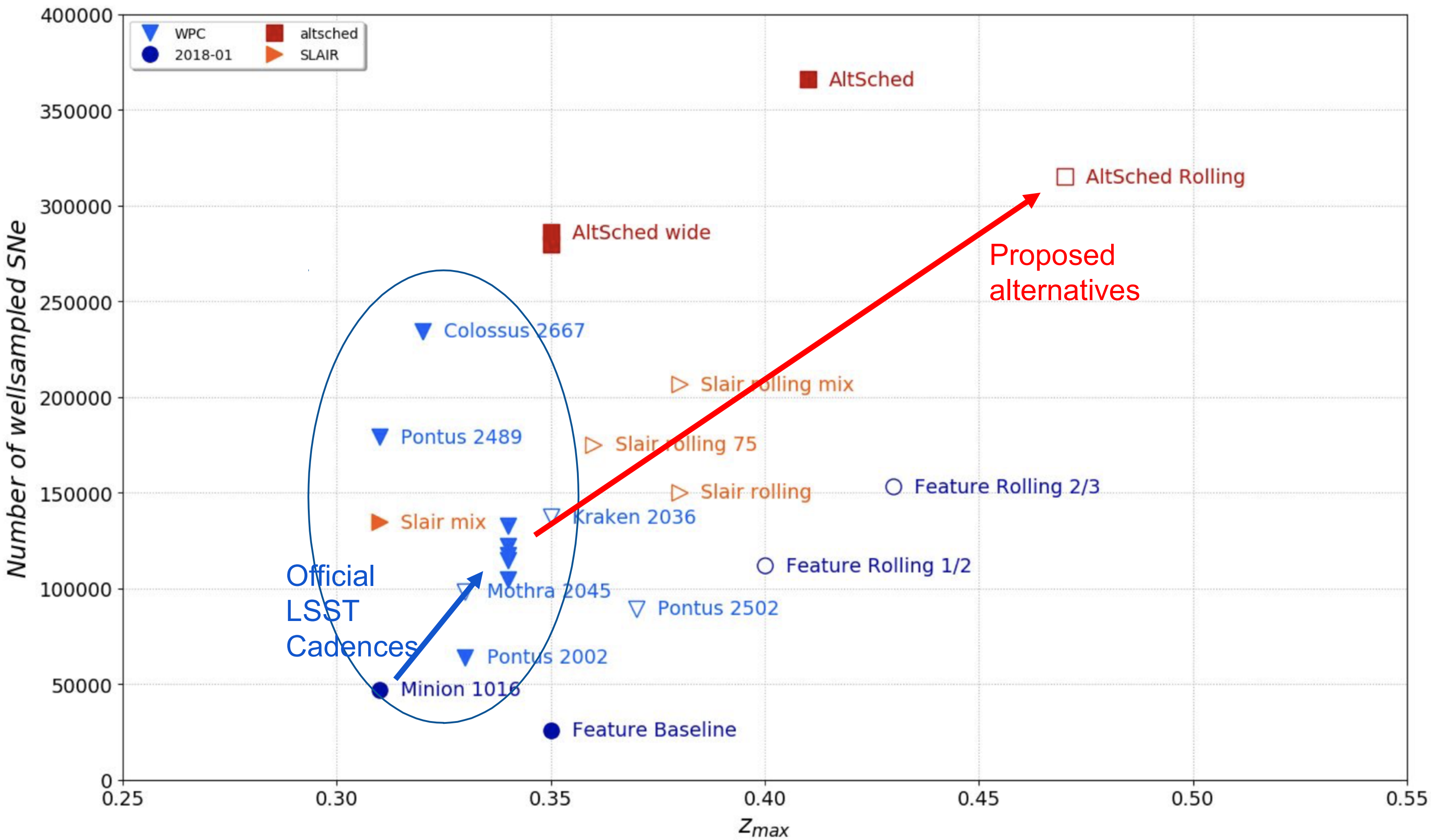



[2022-01-01 mjd= 59580]
N_{SNe} : 0 (tot)
0
25
z_{max} (avg) [0.00]
0
0.5
cadence [day^{-1}] (avg) [0.00]
0
1
N_{SNe} : 0
0
0.015
z_{max} [0.00]
0
0.5
cadence [day^{-1}] [0.00]
0
1


[2022-01-02 mjd= 59581]
N_{SNe} : 0 (tot)
z_{max} (avg) [0.00]
cadence [day^{-1}] (avg) [0.00]
0
25
0
0.5
0
1
N_{SNe} : 0
z_{max} [0.00]
cadence [day^{-1}] [0.00]
0
0.015
0
0.5
0
1

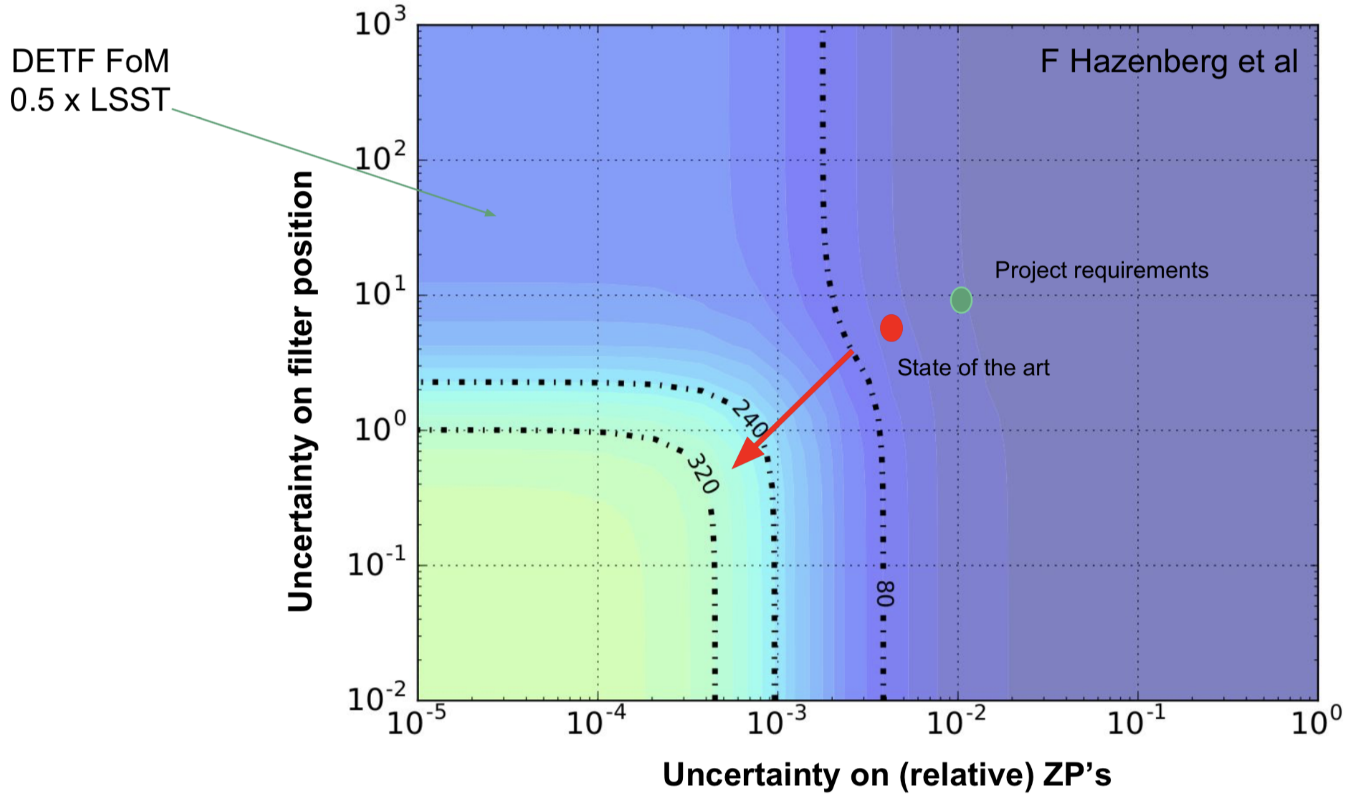
Observing Strategy (Cadence)

- **Rolling cadences:**
  - O(300 kSN), improved redshifts
  - SNIa sensitive to anisotropies: peculiar velocities studies
  - No major impact on static science !



Gris, Regnault

Calibration constraints



- LSST requirements beyond what is needed for DESC !

	DESC	LSST	Etat de l'art
Primary Flux Standards	0,1%	1%	0,5%
Filter Bandpass	0,1 nm	1 nm	0,5 nm
Flux metrology chain	0,1 %	1%	0,5%

- We are now closely working with the project for improvements

LSST-DESC Photometric correction Working Group

Conclusion…

- LSST is getting more and more real every day
- **A wealth of scientific opportunities**

  … but also of scientific challenges