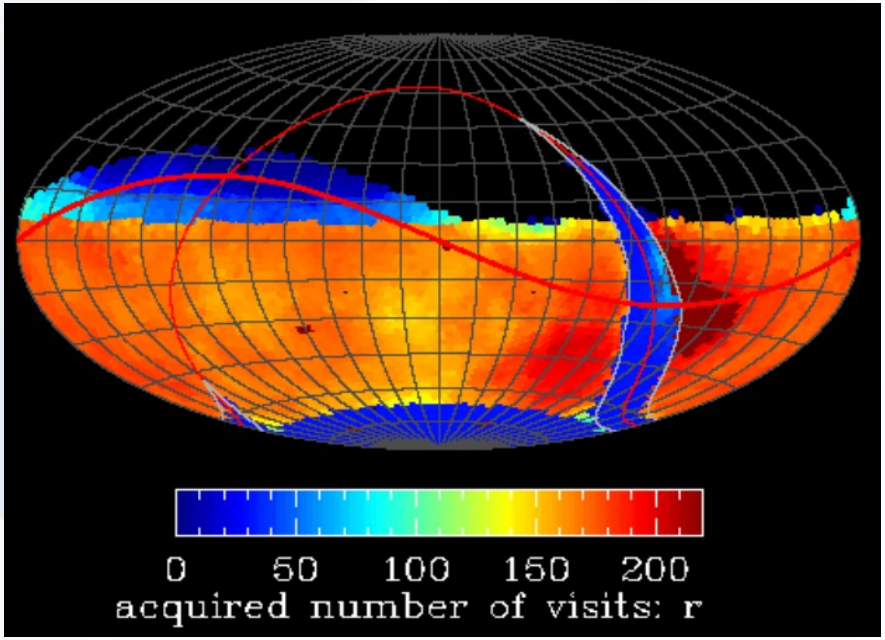
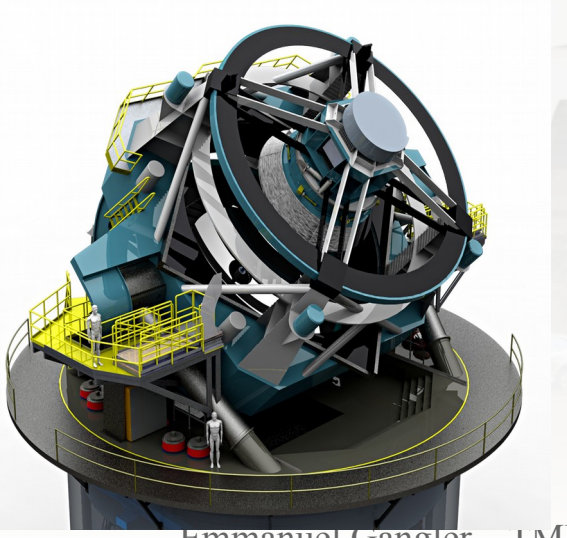
Emmanuel Gangler – LPC – Clermont-Ferrand (France)

summary :

- A stage-IV cosmological 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 2021, Survey 2022





- All visible sky in 6 bands (ugrizy) (~18000□)
- 1x30 s exposure, 1 visit / 3 days
  r ~24.4 / visit
- During 10 years !
  → ~825 visits (all bands)
- 20TB/day 60 PB/10 years

Welcome to the Vera Rubin Observatory

January 6, the Large synoptic Survey Telescope was renamed after
Vera Rubin

Vera Rubin among other work, uncovered the peculiar rotation curves of galaxies, confirming the presence of *Dark Matter*

The Vera Rubin Observatory will conduct the LSST
(Legacy Survey of Space and Time)
With the help of the LSST Camera
mounted on the Simonyi Survey Telescope

Vera Rubin Observatory, LSST and Science:

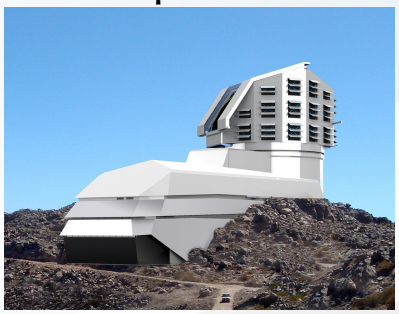
Communication
Commissioning
Advisory
Operations

VRO

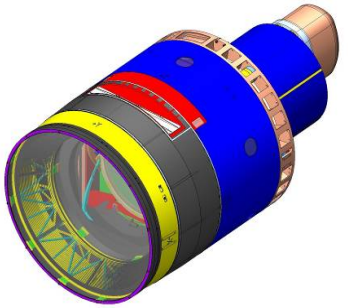
Science

8 Science Collaborations

Telescope and Site



LSST Camera



Data Management

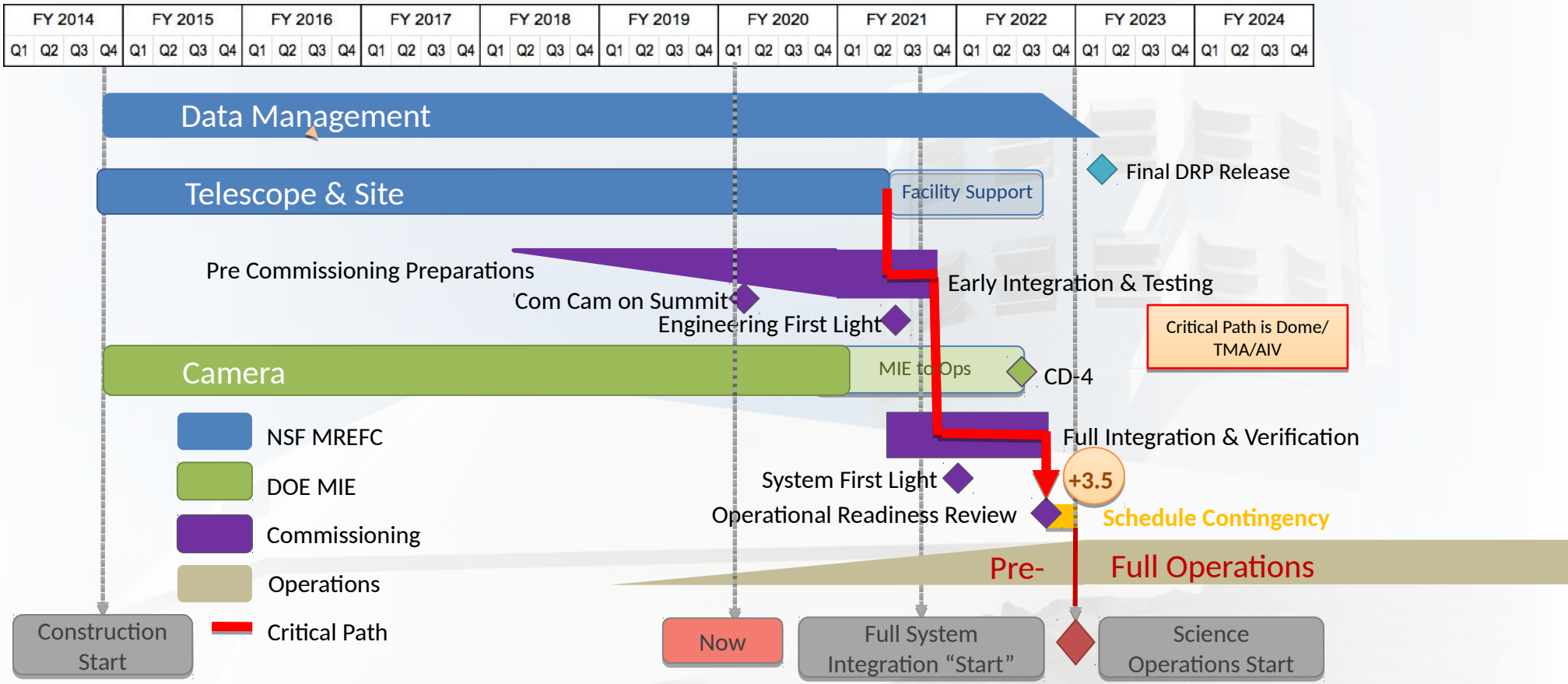
Outreach

- **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 Survey**
  - Conducted by independent collaborations
  - LSST delivers reduced data, scientists analyze them

LSST DESC Dark Energy Science Collaboration

TVSSC

VRO/LSST Timeline

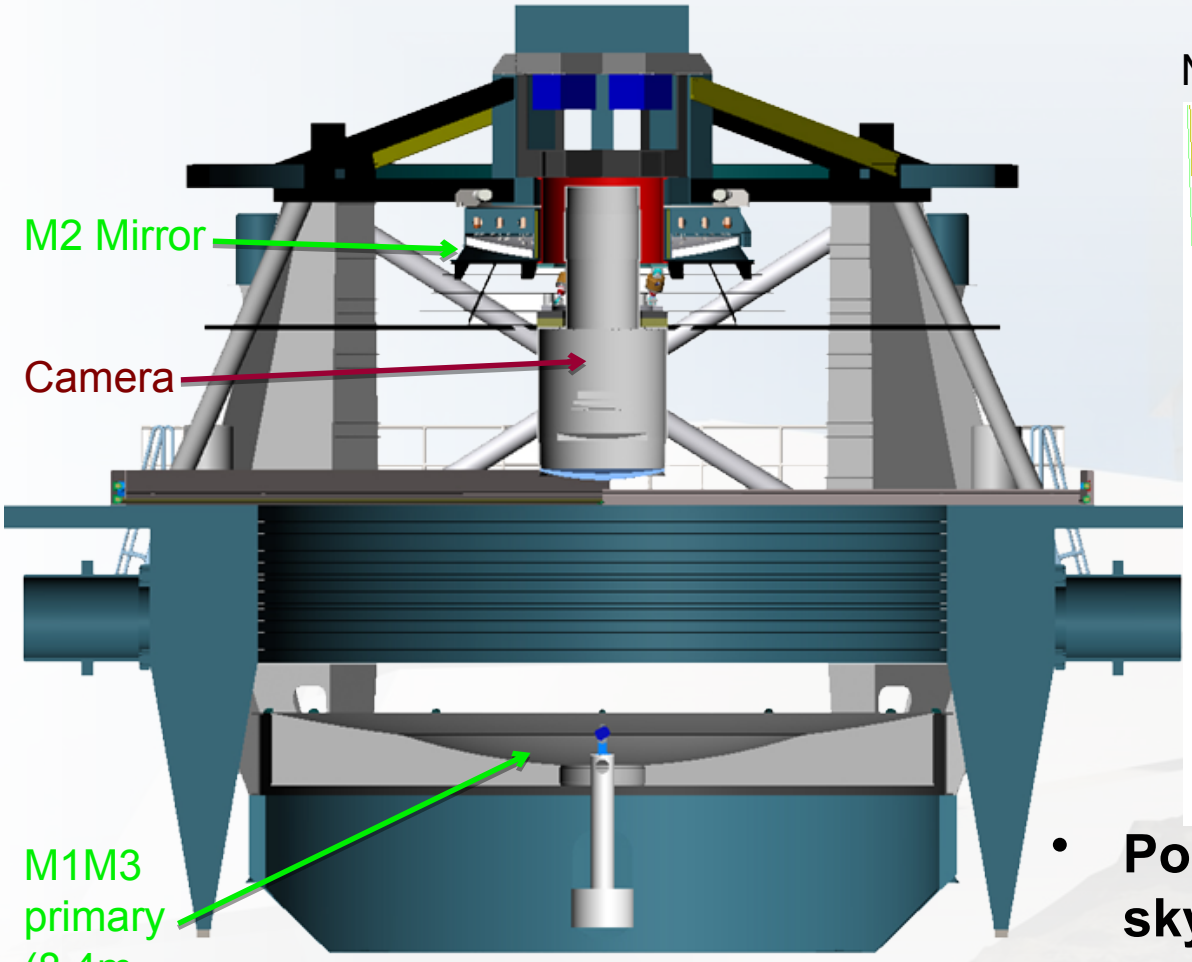


Commissioning is happening NOW !

- **AuxTel (=1CCD):** First light with spectrograph 2019 (Chile)
- **Full Focal Plane:** End of integration (SLAC, Jan 2020), First light fall 2021 (Chile)

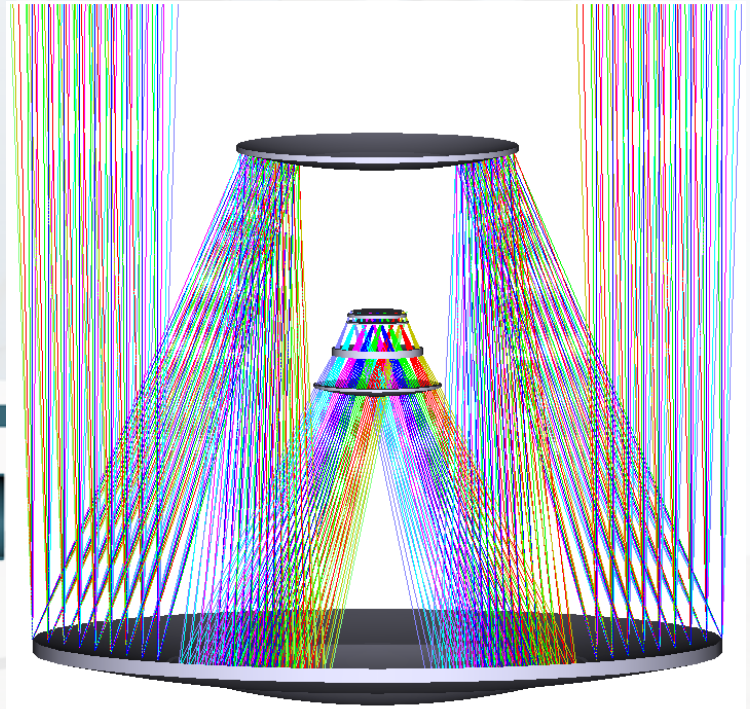
Telescope Mount Enables Fast Slew and Settle

LSST Etendue : 319 m^2 deg^2



Moving Structure 350 tons
60 tons optical systems

Modified Paul-Baker Optical Design



- **Points to new positions in the sky every 39 seconds**
- **Tracks during exposures and slews 3.5° to adjacent fields in ~ 4 seconds**

The dream is coming true !

Dec. 2019

2012 rendering

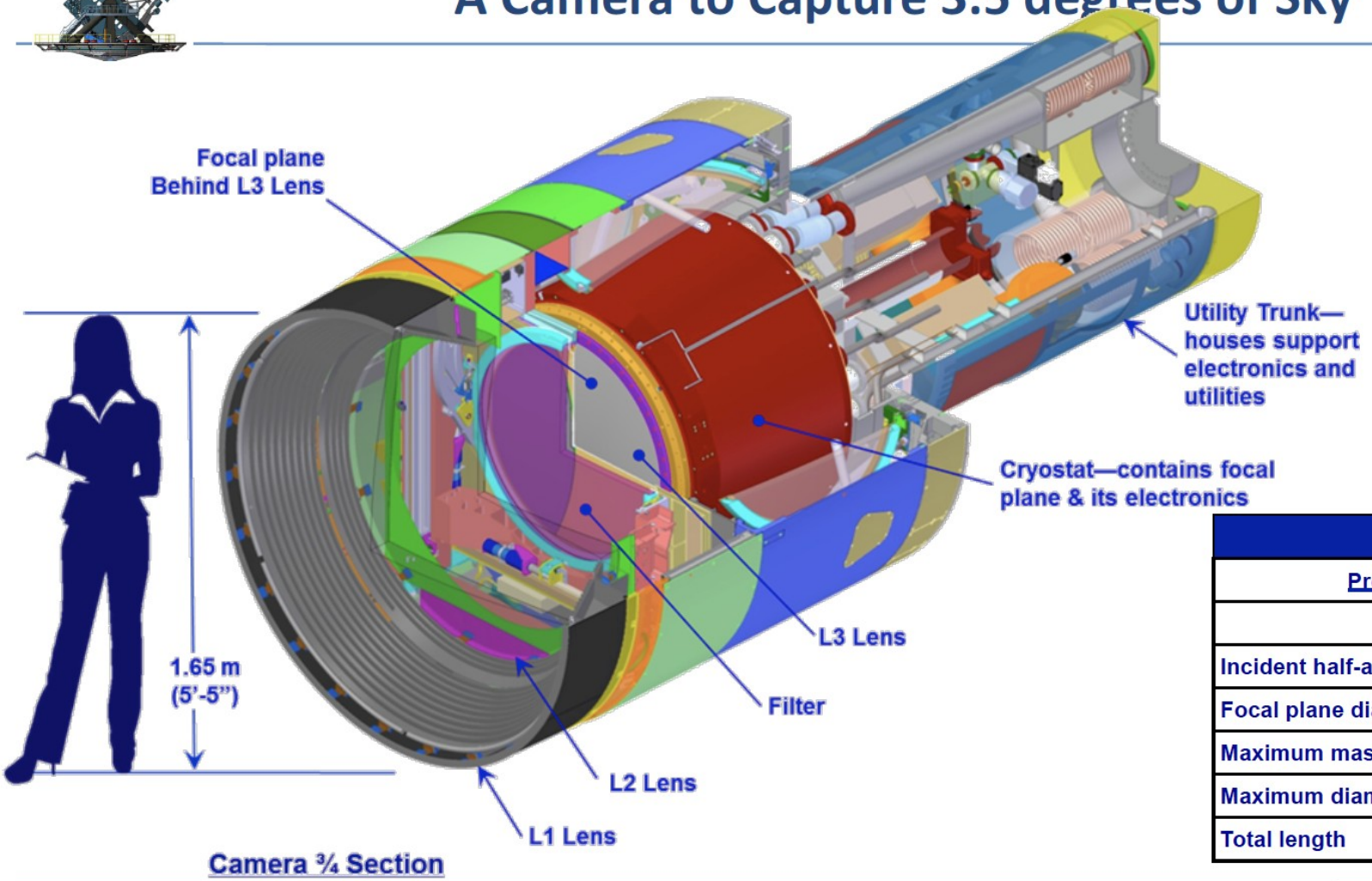
Summit Facility is complete
while Dome is constructed

Telescope at manufacturer Facility
→ being mounted at Summit

M1M3 mirror on site

LSST Camera

A Camera to Capture 3.5 degrees of Sky



Camera ¾ Section

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

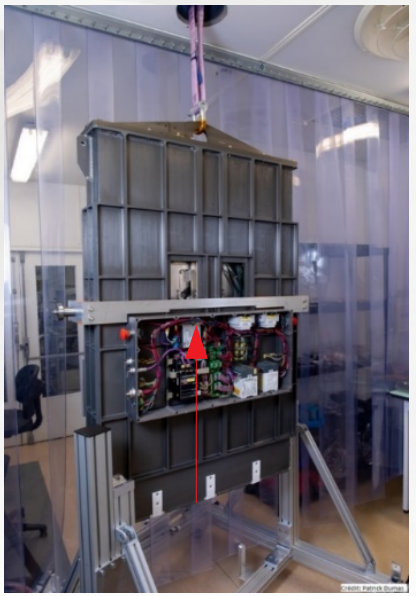
Filter exchange System:

- **Fast filter exchange (<2 minutes swap time)**
- 5 filters within the camera for automatic switching + 1 filter swapped out depending on moon phase
- Delivered at SLAC oct. 2019,
- *Installed in the camera jan. 2019*
- *Check out the Video !*

Control Command

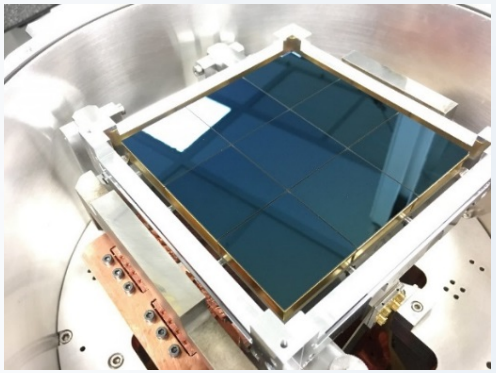
CPPM

Carrousel

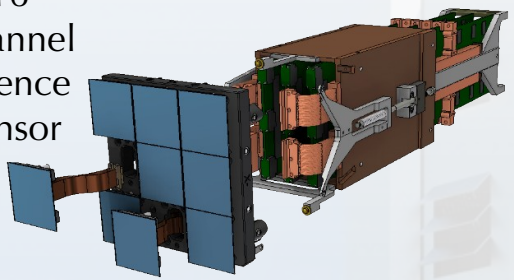


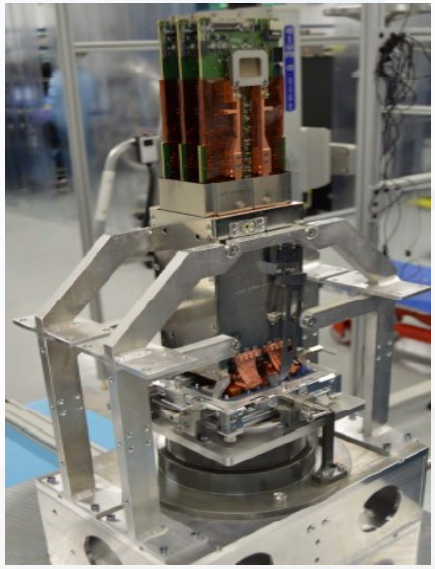
Filter Loader

Focal plane: 63 cm and 3.2 Gpix

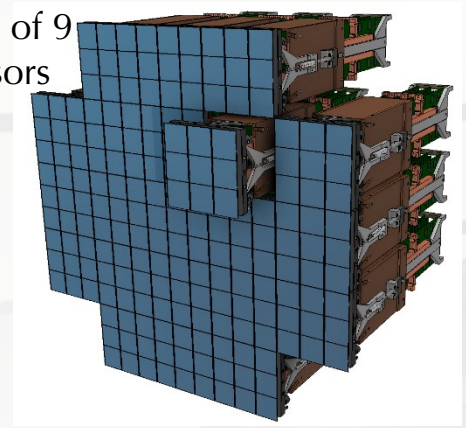


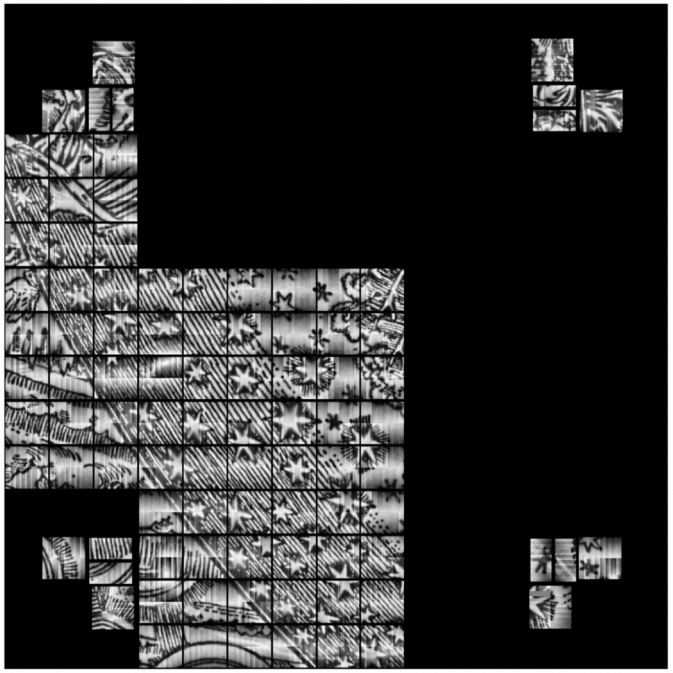
4K x 4K
16
Channel
Science
Sensor





189 sensors
packed in 21
rafts of 9
sensors





All 21 Rafts
have been
assembled

Focal plane fully assembled next week !

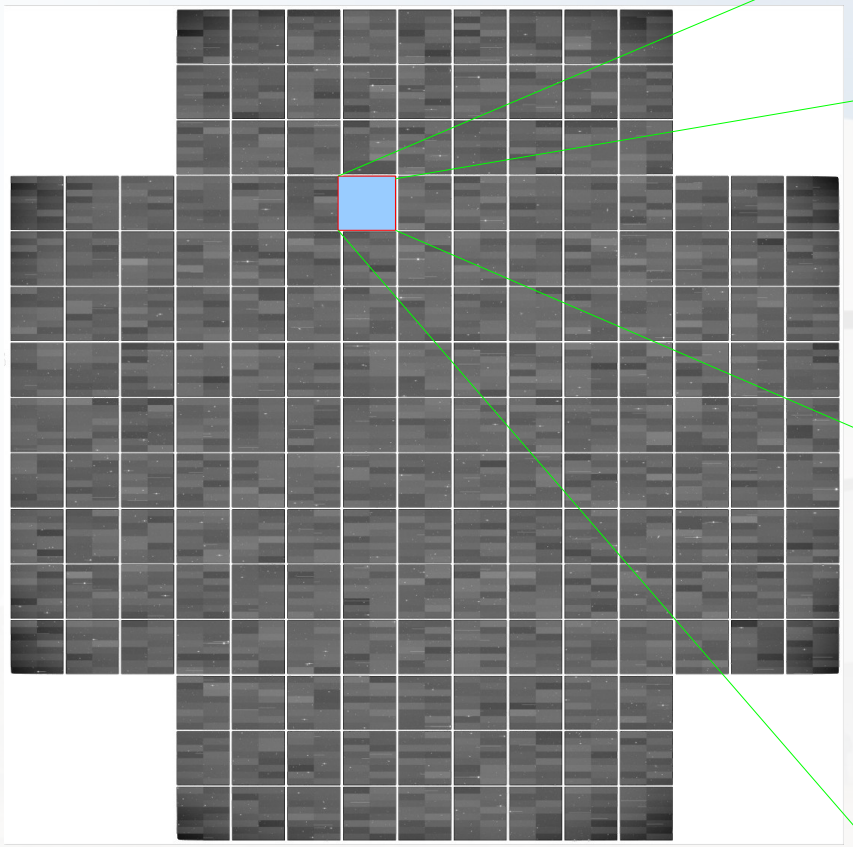
VRO/LSST data flow

Camera : 189 CCD (16 Mpix) read in parallel

→ 3,2 G pixels !

~ 6 Gbyte / 30 seconds

→ 20 TB / night

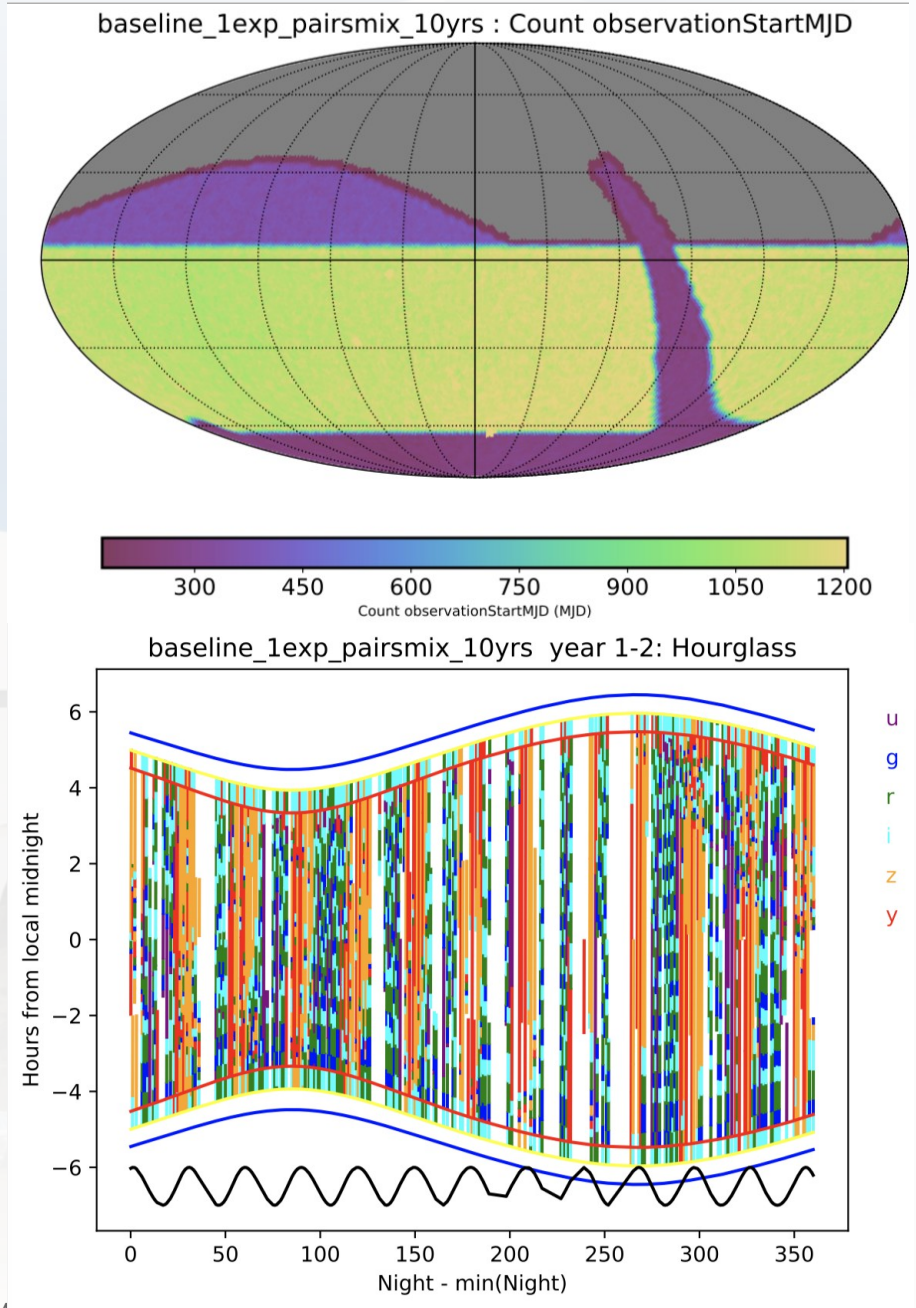


~ 1/1 000 000 000 of LSST data

LSST observation strategy

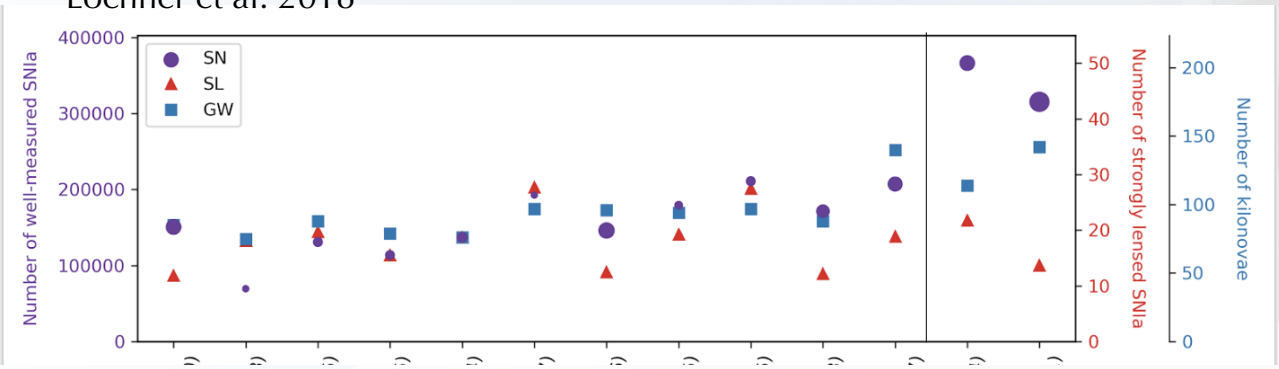
The project is optimizing the observing strategy : only proposals at this stage !

- **Wide Deep Field** : 90% of observing time
  - Keep global survey uniformity and band allocation
  - At least 2 visits per night
    - 1 color if possible
  - u and y band swapped depending on lunation
  - Optimization of revisit time
    → Move toward **rolling cadence**



The importance of optimizing the cadence

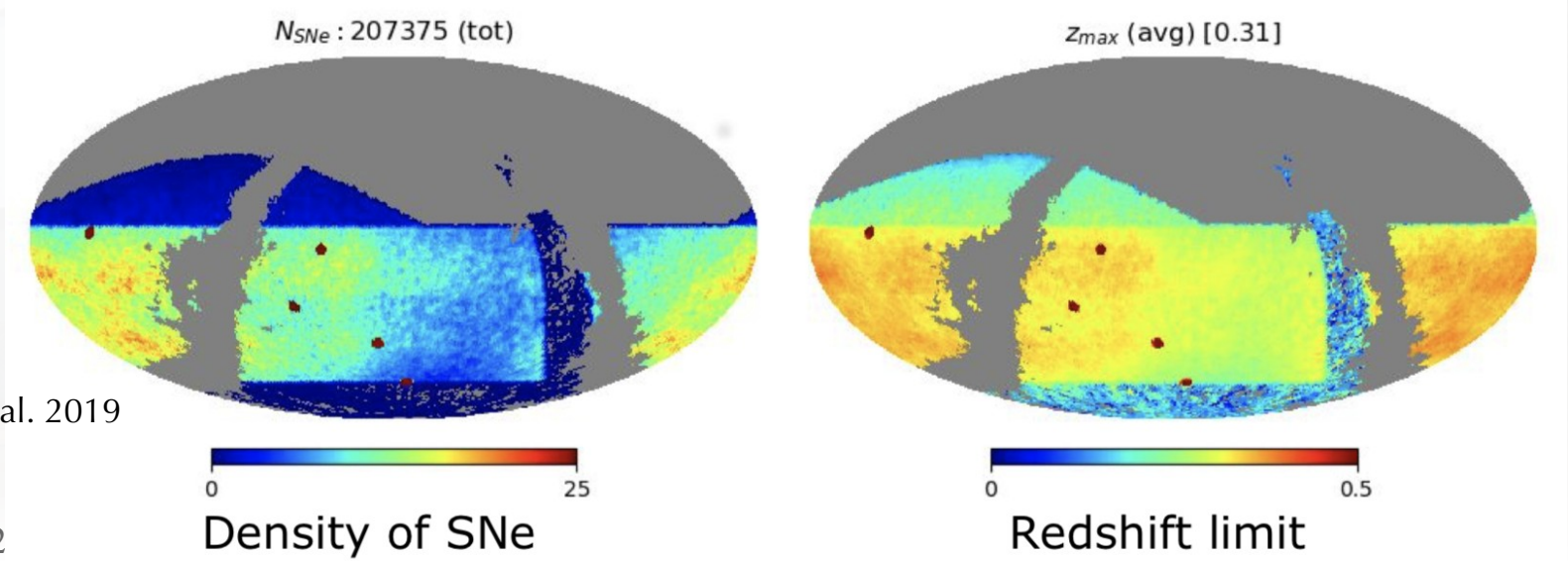
Lochner et al. 2018



Why Rolling candences ?

- O(2-300 000) SNIa
- O(100) Kilonovae
- O(20) Strongly lensed SN systems
- + Tidal Disruption events,
- + …
- → **this enables new science !**

Regnault et al. 2019

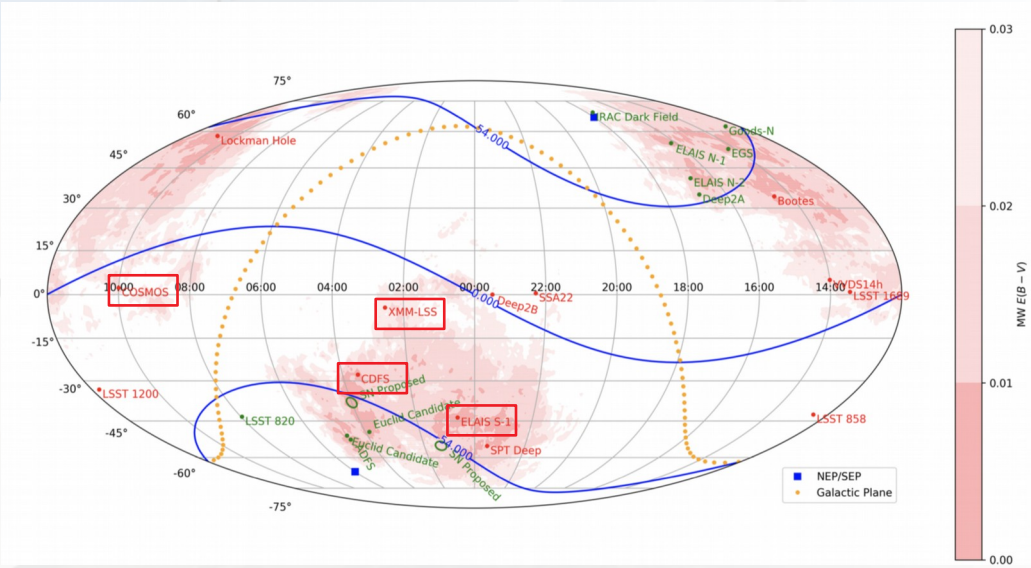


LSST observation strategy

The project is optimizing the observing strategy : only proposals at this stage !

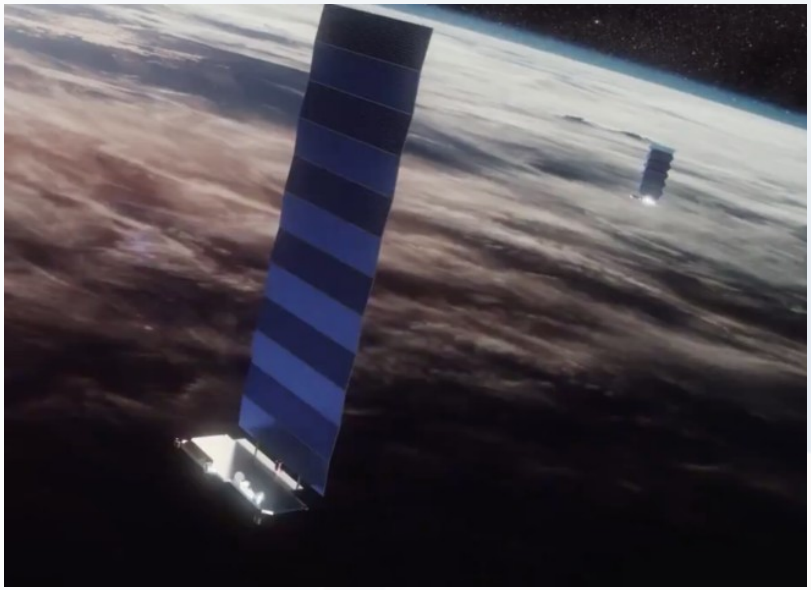
- **Deep Drilling Fields**: 5% of allocated time
  - 4 fields selected (ELAIS-S1, XMM-LSS, CDF-S, and COSMOS), 1 in discussion
  - SN and AGN are in competition

- **Minisurveys :** up to 5% of cadence
  - Light survey on enlarged footprint
  - Twilight program (NEA, ADR)
  - **Target of opportunity :**
    - ***GW, Neutrino SN or Blazar alerts***

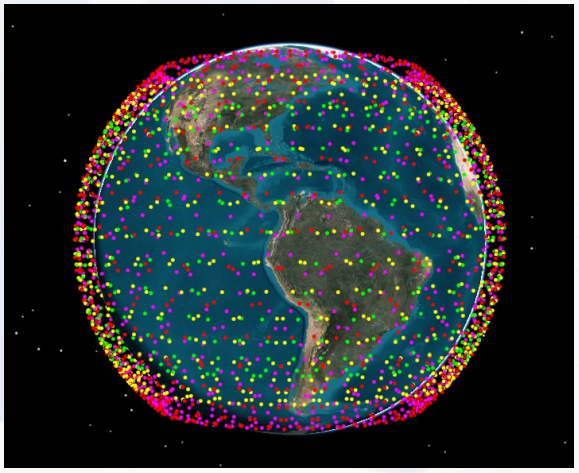


But StarLink ...

N x 62 satellite already deployed



4820 already planned: Starlink, Kuiper,
O(10^4) to come in a few years

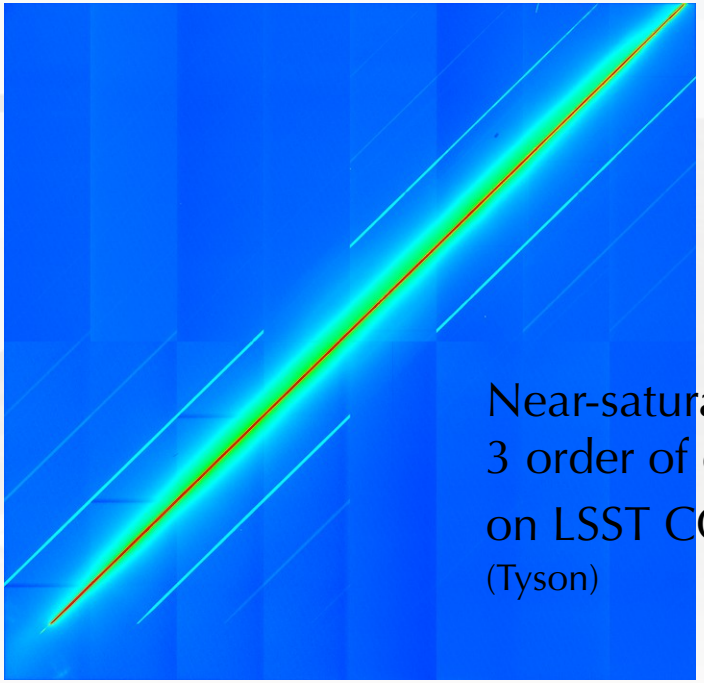


Starlink constellation:

Impact under study
~4-10 satellites visible at night
4 mag above LSST staturation

Mitigation

→ Black painting for next ones
+3.5 mag
→ LSST repeatability

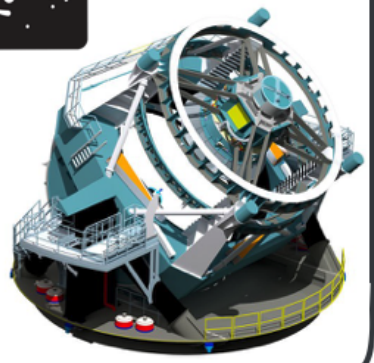


Near-saturation trail:
3 order of cross-talk
on LSST CCD
(Tyson)

VRO Data Management

Raw Data: 20TB/night

Sequential 30s images that cover the entire visible sky every few days.

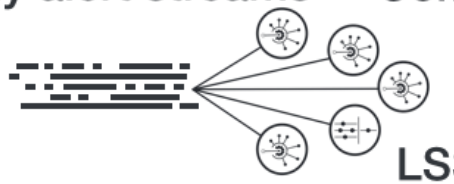


Prompt Data Products

Alerts: up to 10 million per night

60s

via nightly alert streams



Community Brokers

LSST Alert Filtering Service

Results of Difference Image Analysis (DIA): transient and variable sources

Solar System Objects: ~6 million by year 10

24h

via Prompt Products Database

Data Release Data Products

Final 10 year Data Release images: 5.5 million x 3.2 Gpx
catalogs: 37 billion objects, 15PB

via Data Releases

LSST DACs (Chile & NCSA)

Independent DACs (iDACs)

Processing split 50-50 between US and France (CCIN2P3)

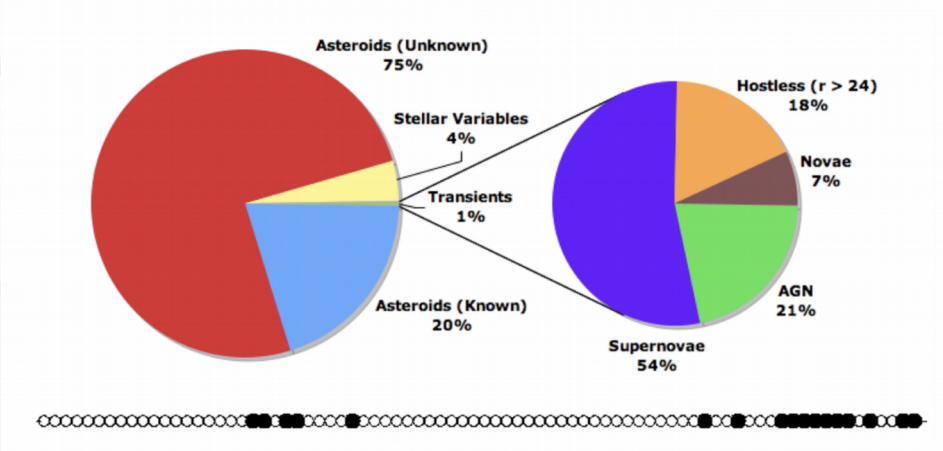
VRO Science Platform

Provides access to LSST Data Products and services for all science users and project staff.

How to deal with the alert stream ?

- **VRO distributes the alert stream to a limited set of community brokers**

- **Community brokers filter the stream for science cases**



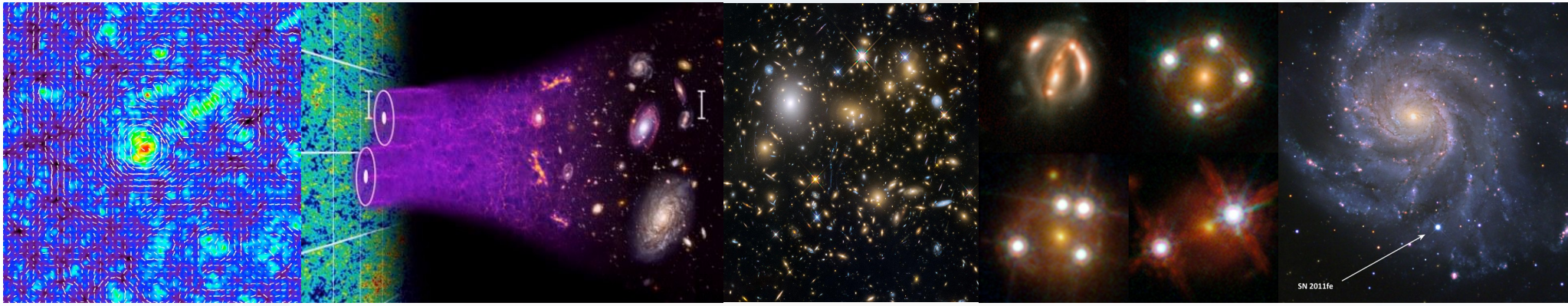
- Only a fraction of science cases needs minute time-scale response !
- **Alert data are public : this is a great entry point in the project !**

Preparing for Cosmology

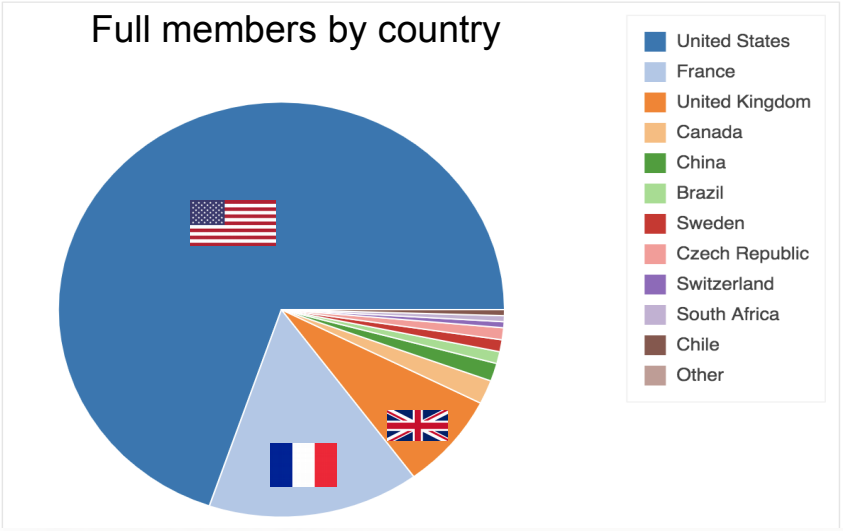
DESC: Dark Energy Science collab.

5 Dark Energy Probes

Weak Lensing Large Scale Structures Clusters Strong Lensing **Supernovae**



952 Members – 222 Full Members

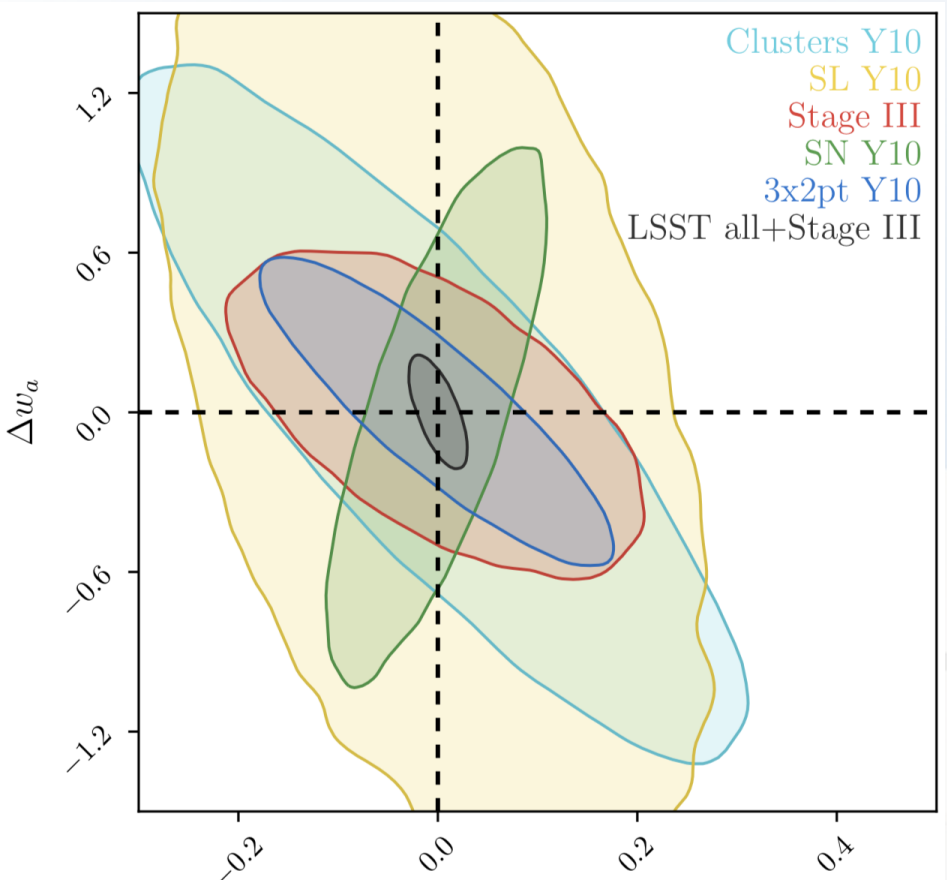


~15%

Science Requirements

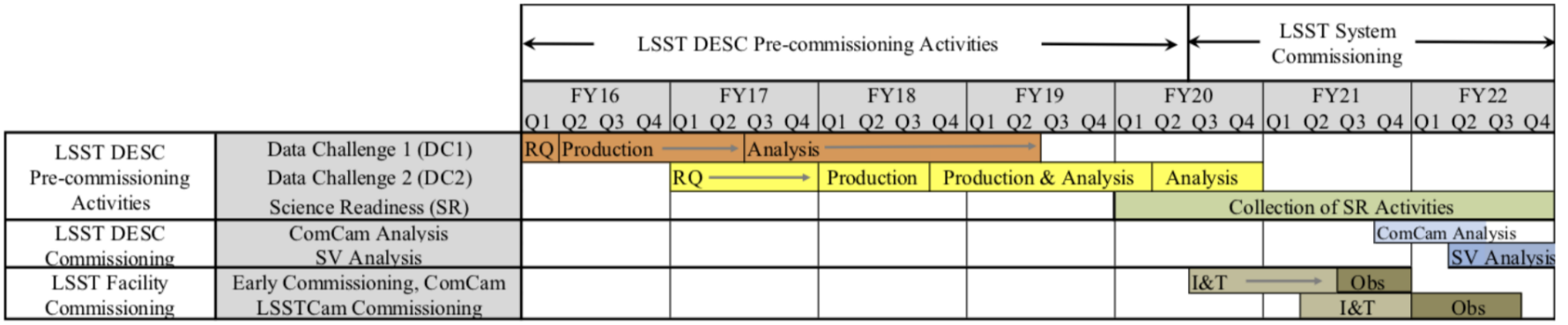
ArXiv 1809.01669

10 year forcasts

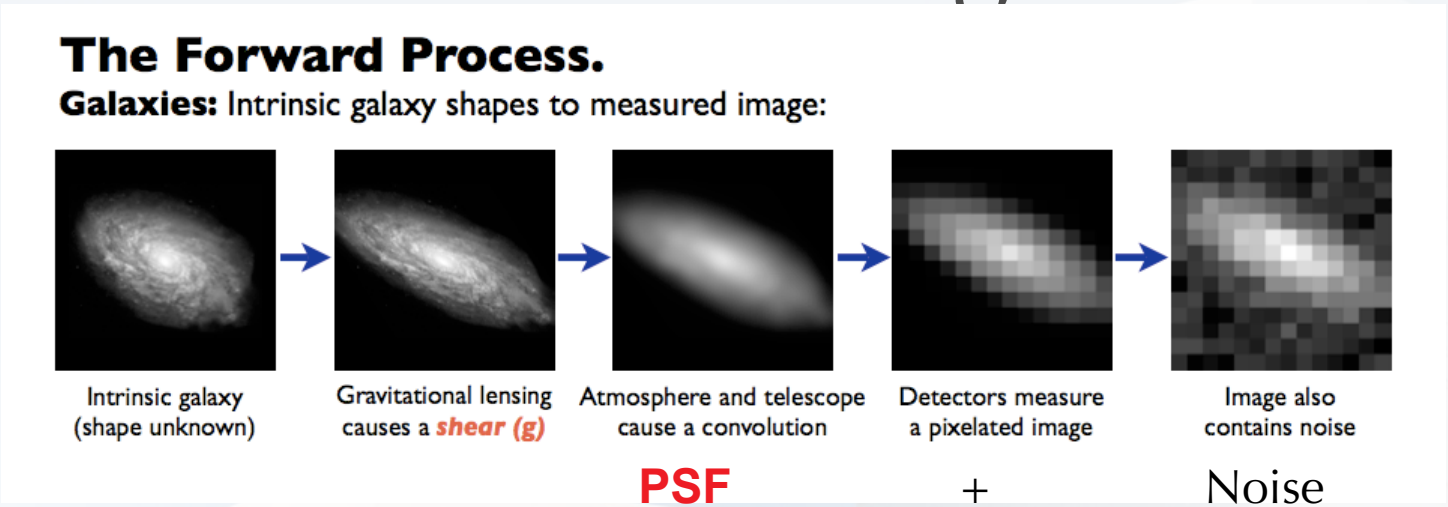


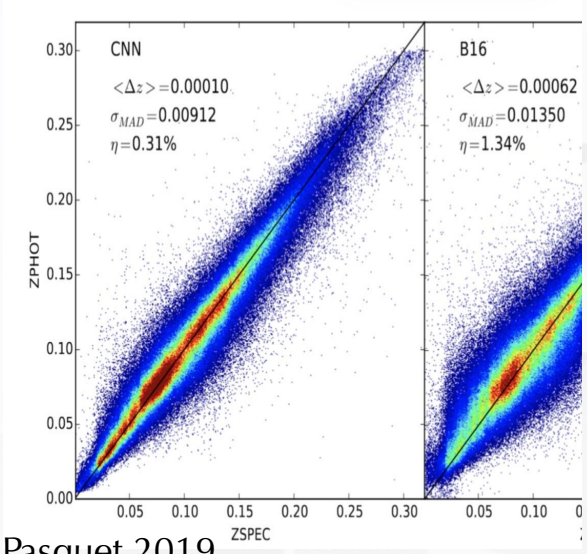
- Forecasts for 1 and 10 yr
- Full review of known systematics
  - Calibratable and self-calibrated
- Target: FoM of 500 for 10yr
  - Calibratable systematics should not dominate statistics
- Requirements for each probe

DESC Roadmap



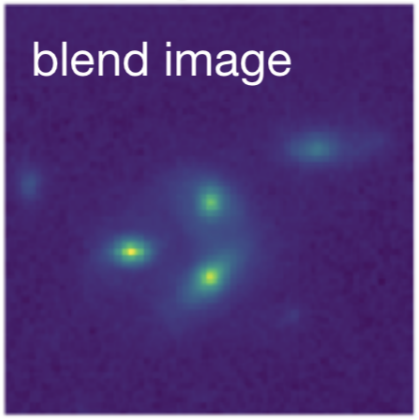
Shear challenges



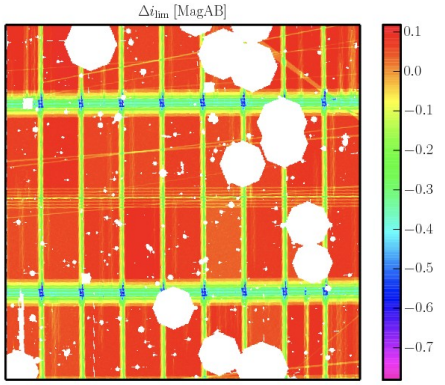


Pasquet 2019

Photo-z



Blending



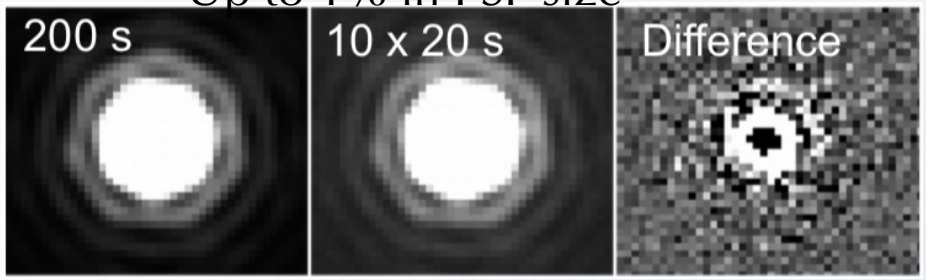
Masks, **Sensor effects**

+ Astrophysics : intrinsic alignments, baryons feedback…

Brighter-Fatter effect

Size of star spots depends on flux

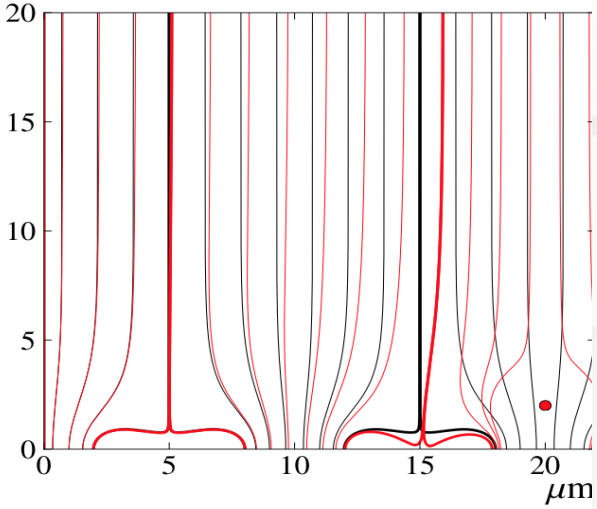
→ Up to 1% in PSF size

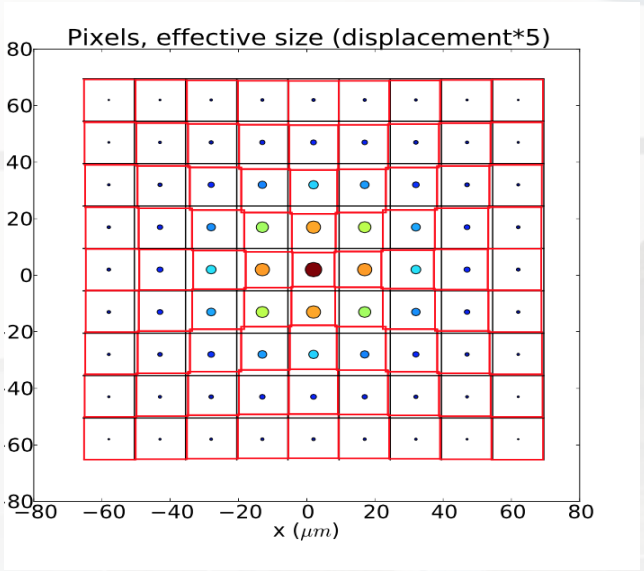


Different in x and y !

→ induces an **anisotropic shape distorsion depending on flux**

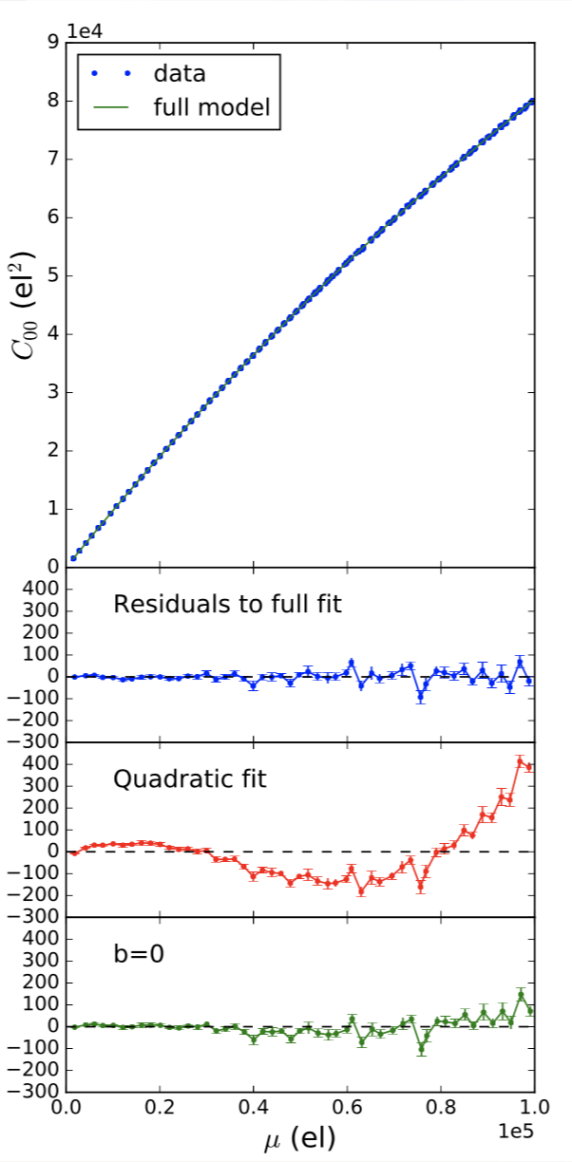
This is electrostatics...





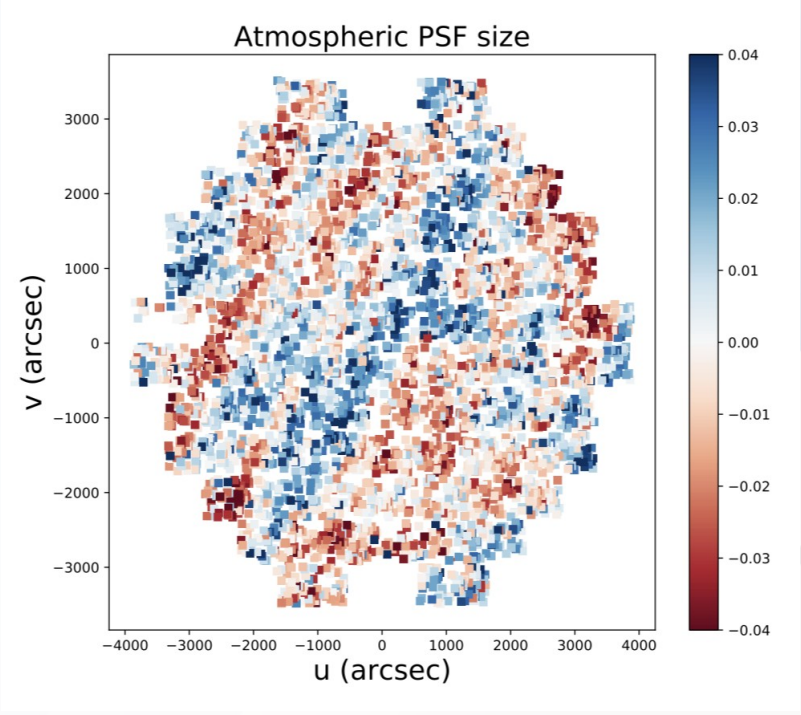
→ we now have an Analytical model

Astier 2019

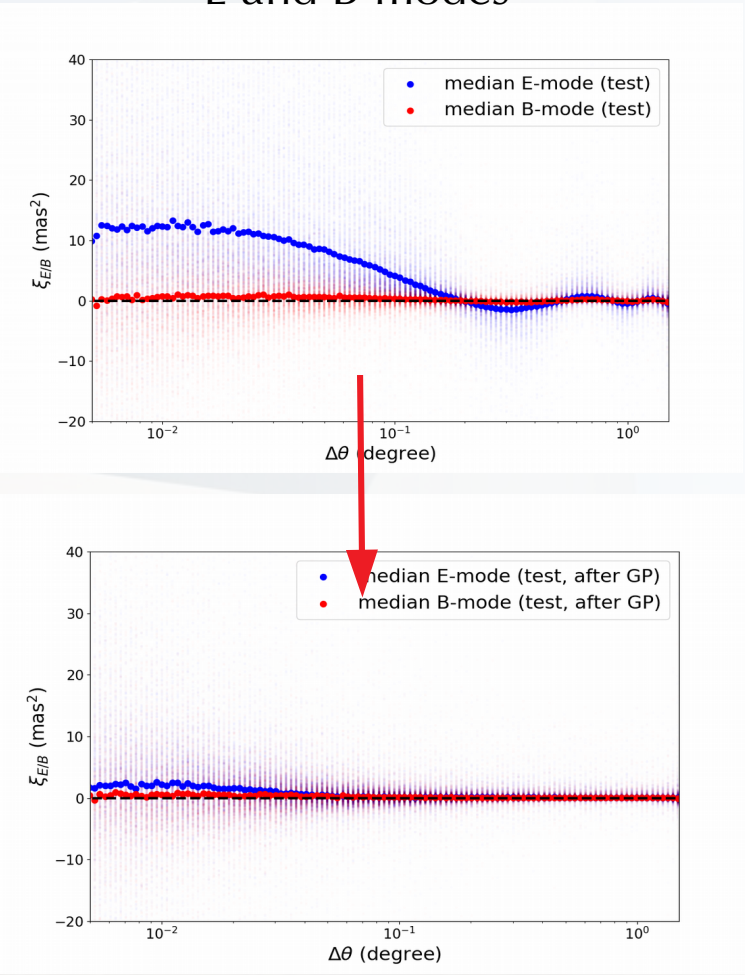


PSF improvement

PSF within a DES image



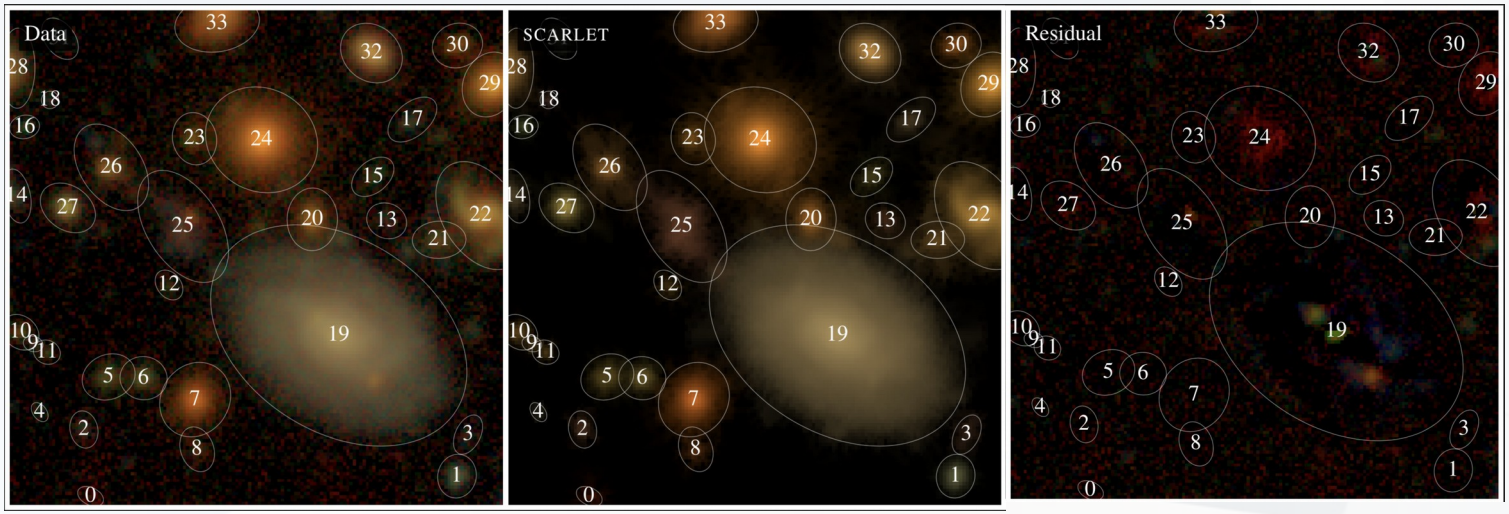
Centroids
E and B modes

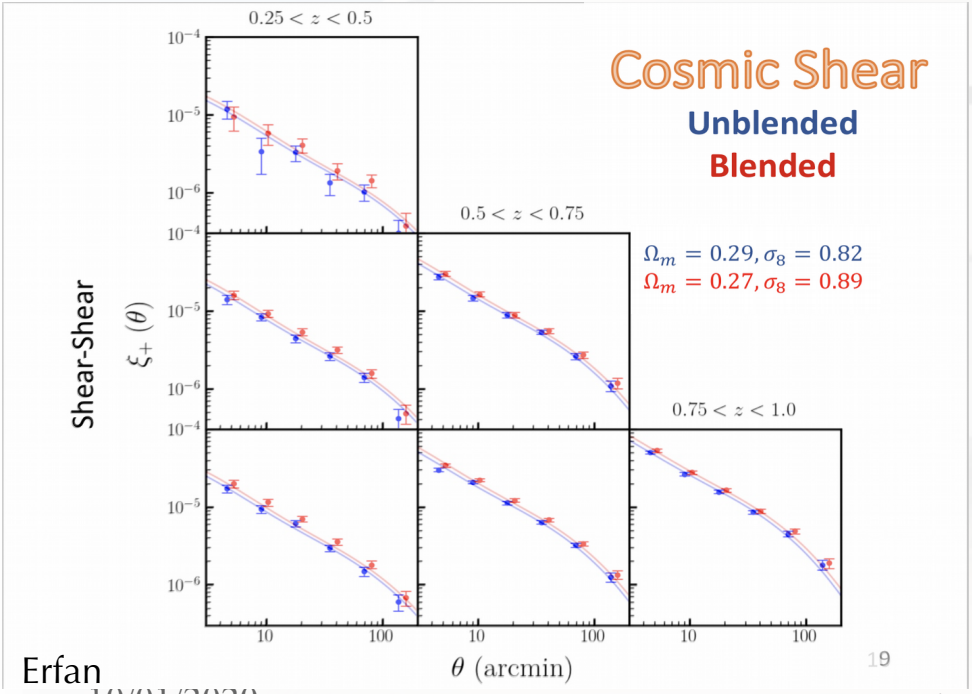


Atmosphere induces long-range correlations
→ this is a major systematics for the Weak Shear

Léget in prep.

Deblending is an issue !



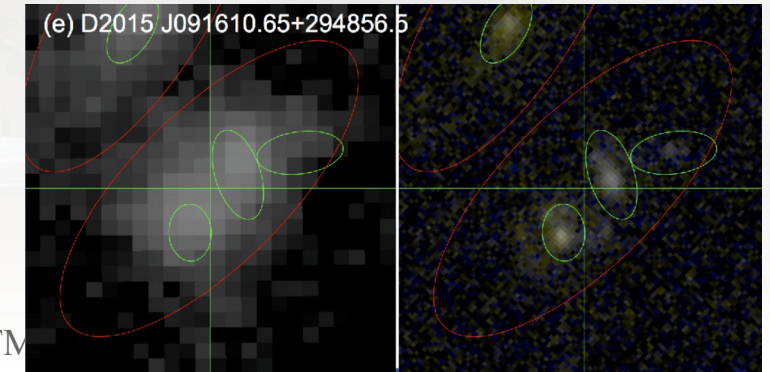


Erfan

- Assess current algorithm performance
- Develop new approaches (Deep learning)

- Synergies with other data
  - Space-based (Euclid)
  - Other filter set (HSC)

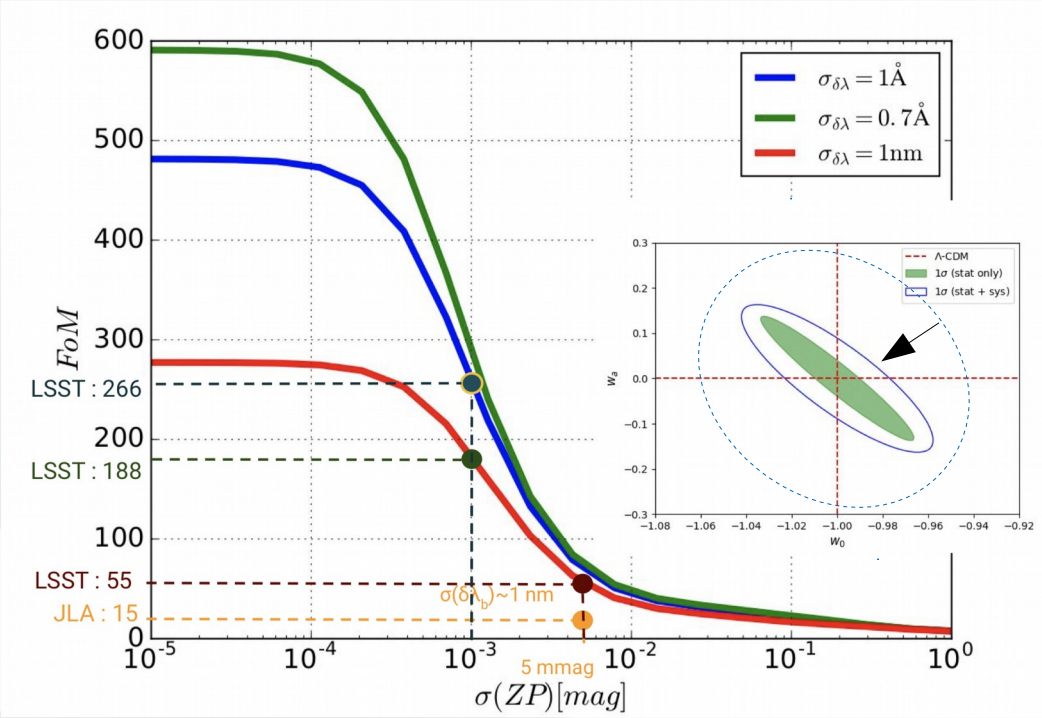
Dawson 2016

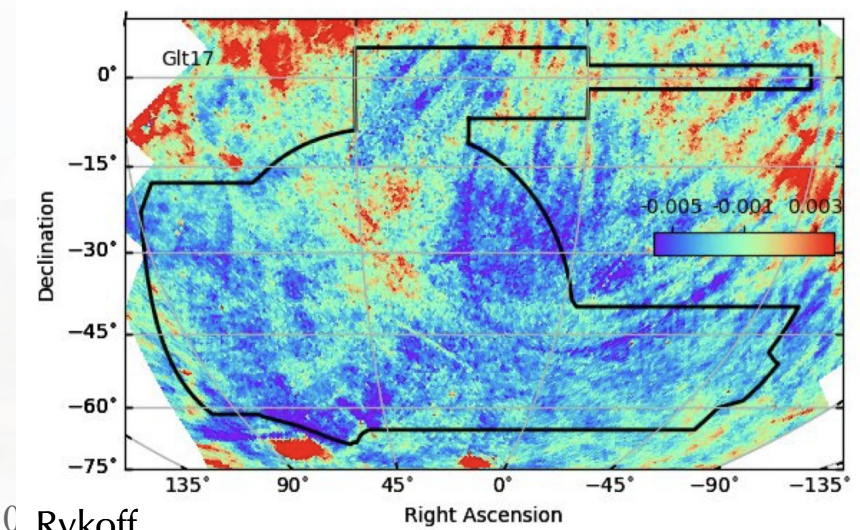


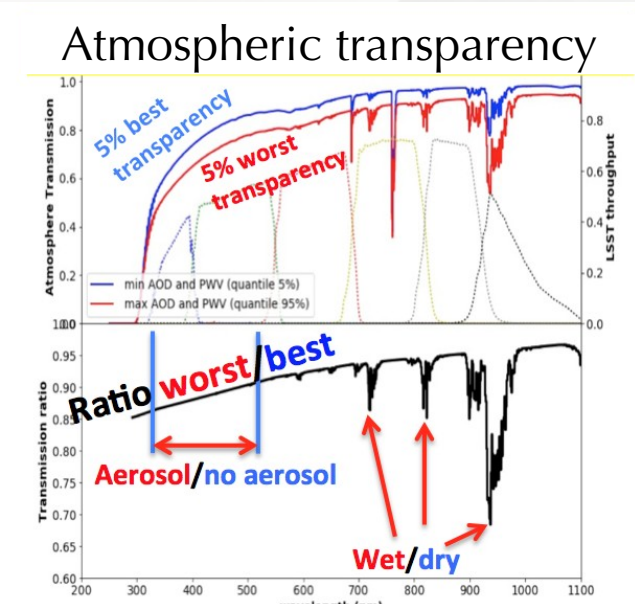
Supernova

Hazenberg 2019

- Calibration is a **limiting systematics**
  - 1 mmag needed
- Improvement for LSST:
  - *Primary flux measurements*
    - Stars → NIST metrology
  - *Survey uniformity*
    - Use GAIA as a reference
  - *Survey throughput*
    - Filter transmission and bandpass
    - Atmospheric transmission

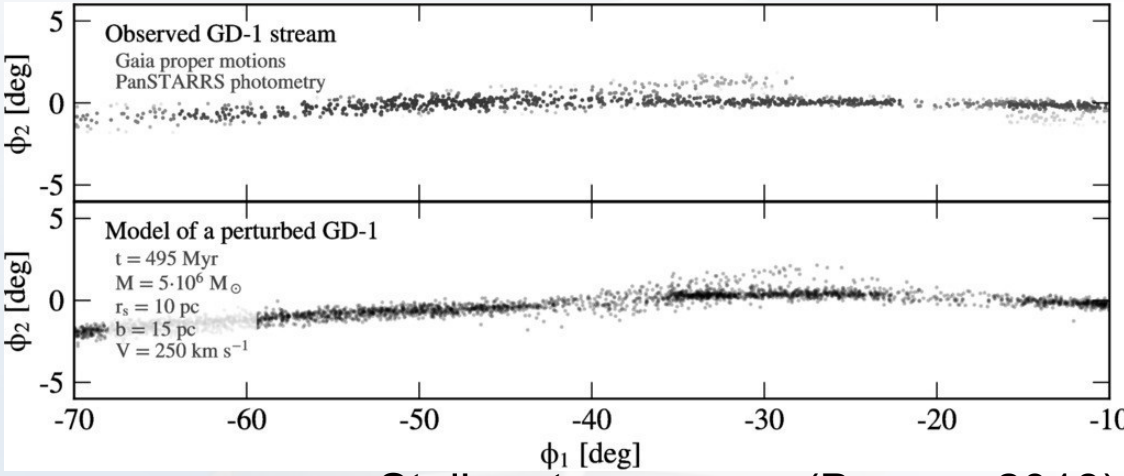




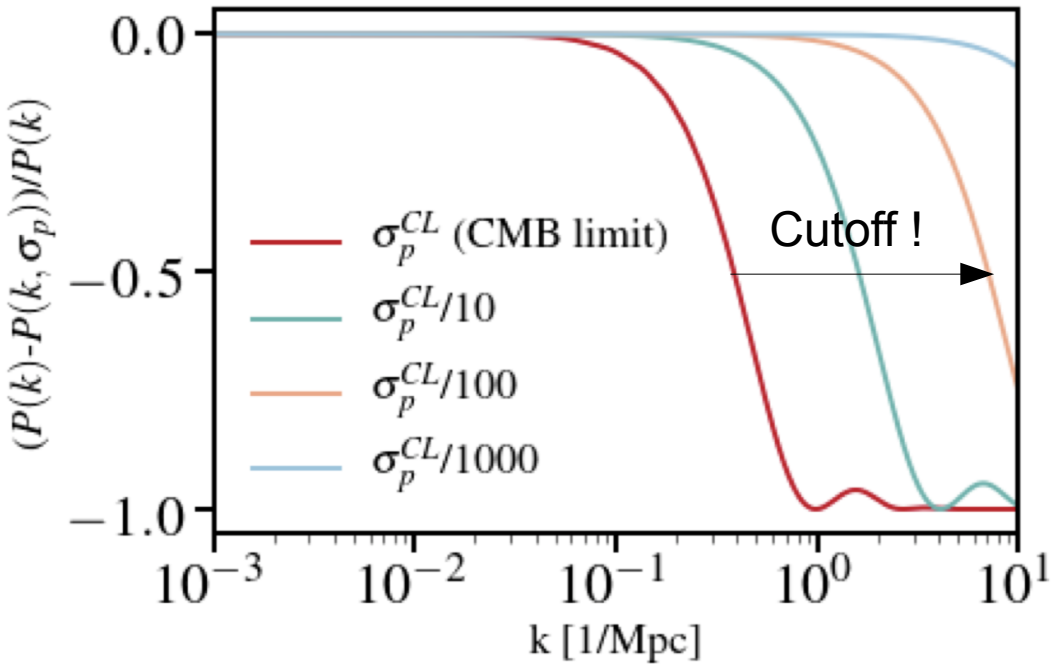


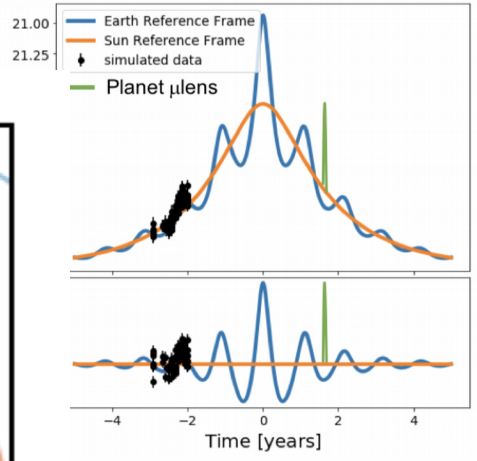
DESC and **dark matter**

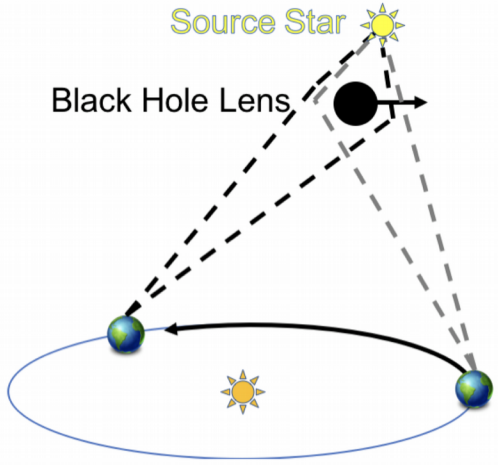
- ArXiv:1902.01055
  - Minimum halo masses
  - Halo profiles
  - Microlensing
  - Anomalous energy loss
  - Large scale structure



Stellar stream gaps (Bonaca 2018)







Matter power spectrum is sentitive to Dark Matter microphysics !

Conclusion:

- **LSST conducted at VRO** is an incredible project !

- **Coming soon :** first light 2021

- **YOUR** science case has likely links with LSST !

→ ***Still time to get ready !***


Rome, 8-12 June 2020
LSST@EUROPE4:
Shaping the European contribution to LSST
https://indico.ict.inaf.it/event/883/