Large Synoptic Survey Telescope

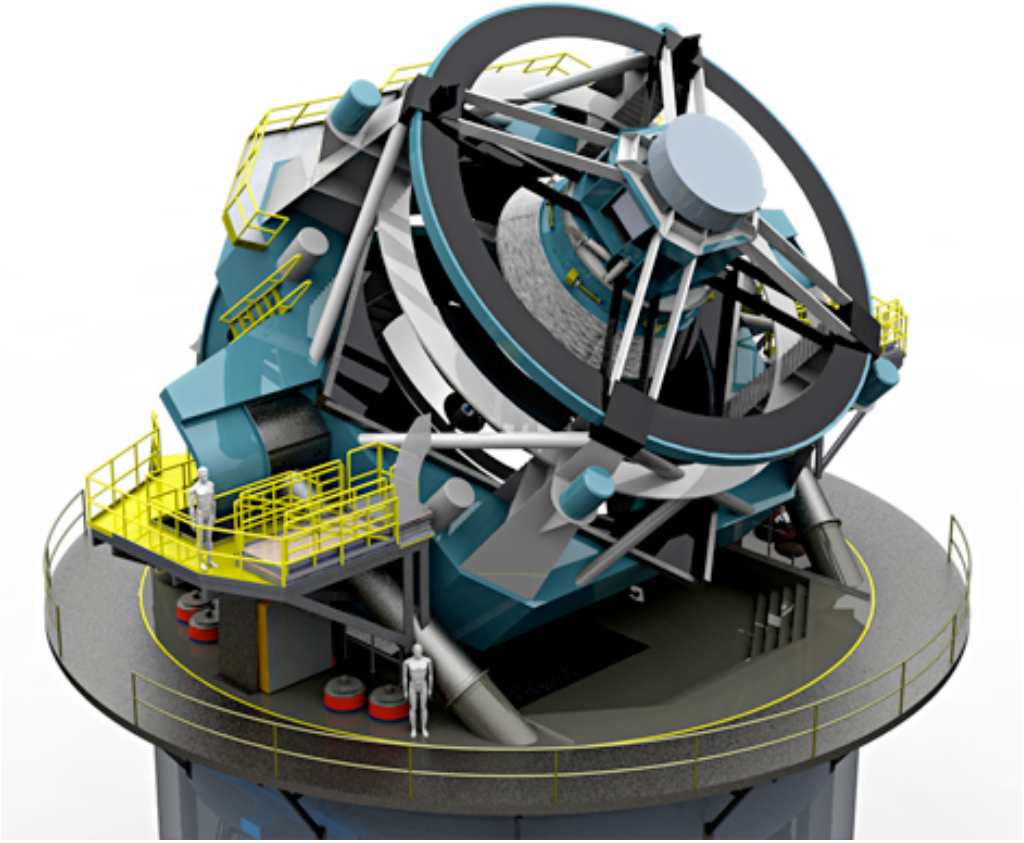
LSST
Overview &
Context in France

Pierre Antilogus

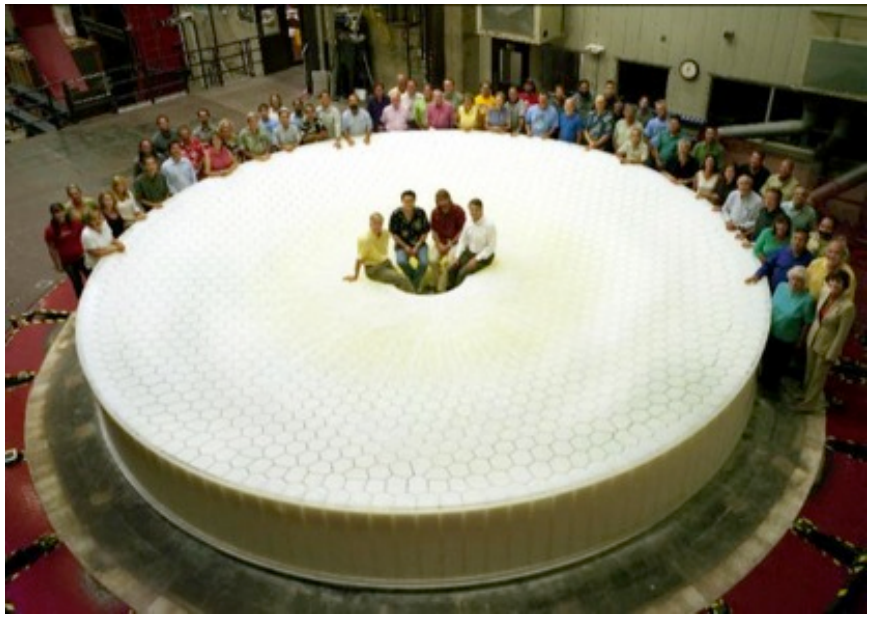
LPNHE
PARIS

Colloque LSST-France , 10 Juin 2014

Large Synoptic Survey Telescope



LSST Overview

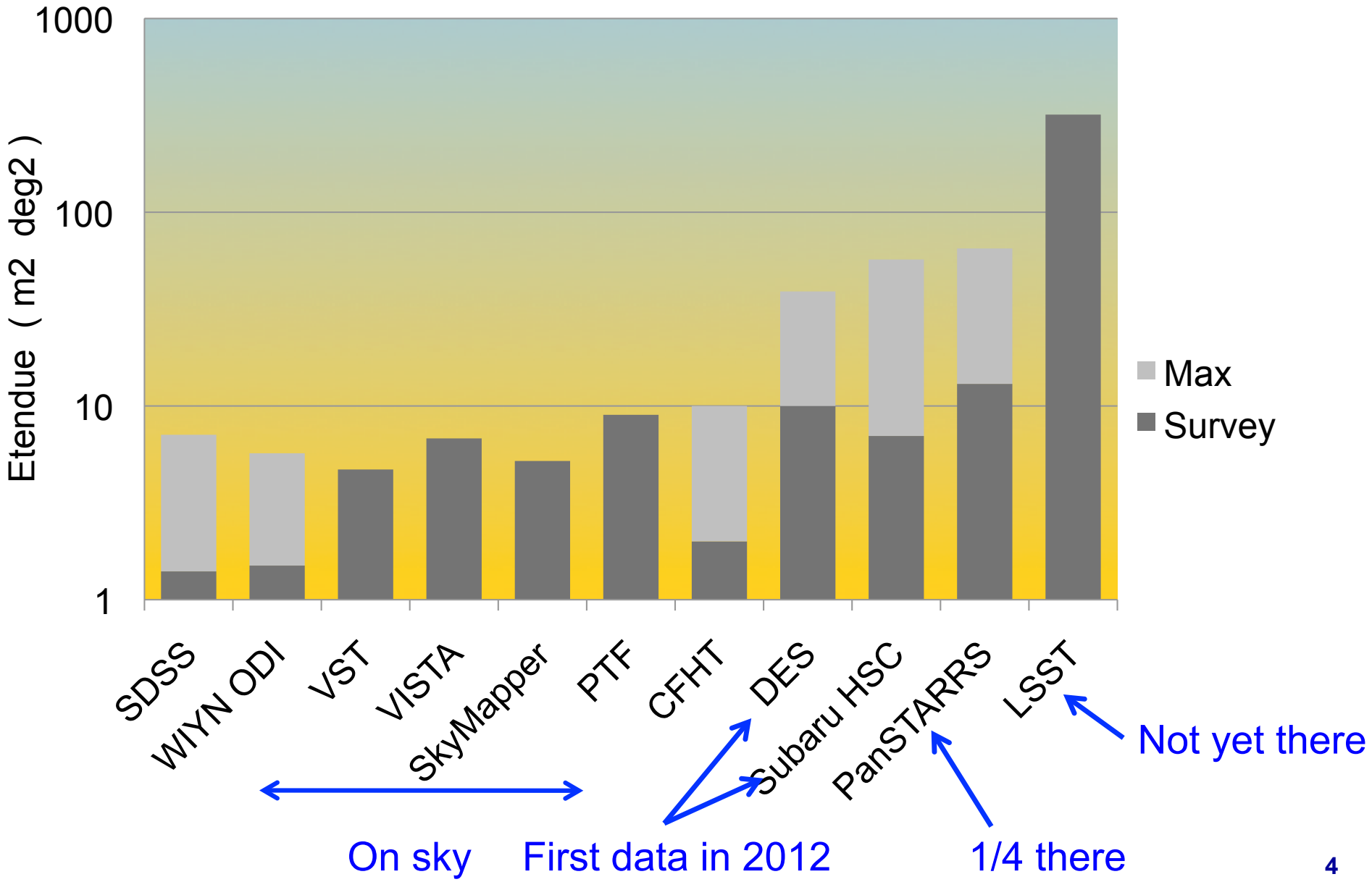


Trend in telescope development in Wide Field Survey from ground

Large Synoptic Survey Telescope

- Increase of the Etendue by
  - Slow increase in mirror surface
  - Large increase in number of pixels / Field of view
- Increase of the fraction of time used / dedicated observatory
- From ground the sensitivity in InfraRed is highly constrained by the atmosphere .
  - With a limiting mag ~ 26.5 , you'll get to the "ground asymptote" of ~50 galaxies per arcmin2 : so increasing mirror size doesn't help at some point : high redshift / red object once above the atmosphere cut off will not be visible from ground .

Etendue associated to a few projects



The Essence of LSST is *Wide, Deep, Fast*

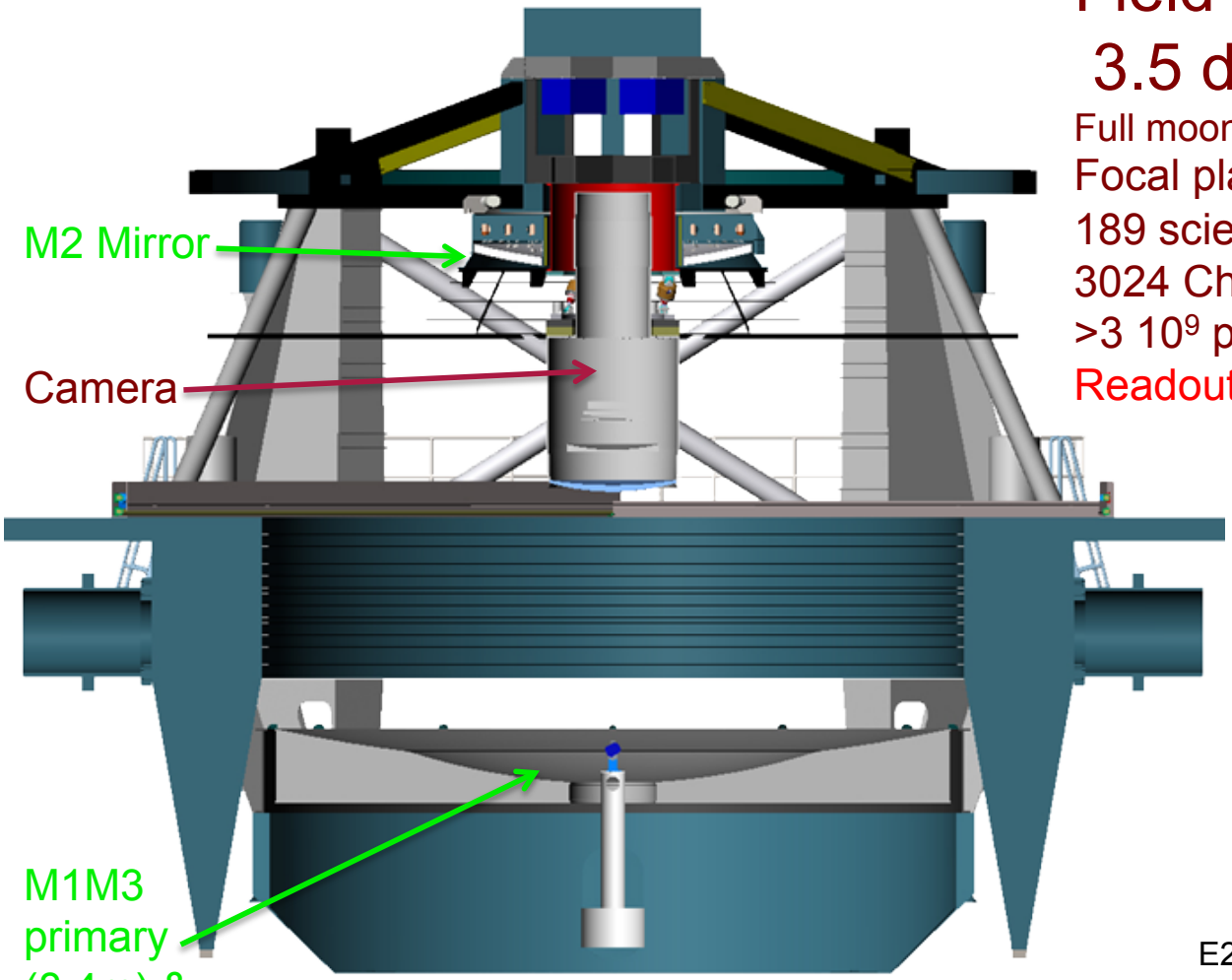
Large Synoptic Survey Telescope

- **The LSST will be a large, wide-field ground-based telescope designed to provide time-lapse digital imaging of faint astronomical objects across the entire visible sky every few nights.**

- **As such, it will enable an enormous variety of complementary scientific investigations, utilizing a common database. These range from searches for small bodies in the solar system to precision astrometry of the outer regions of the galaxy to systematic monitoring for transient phenomena in the optical sky.**

- **Of particular interest for cosmology and fundamental physics, LSST will provide strong constraints on models of dark matter and dark energy through statistical studies of the shapes and distributions of faint galaxies at moderate to high redshift, and the detection of large numbers of Type Ia supernovae.**

LSST : Wide , Deep and Fast



Moving Structure 350 tons
60 tons optical systems

Field of view :

3.5 deg (9.6 deg^2 =.023% sky sphere)

Full moon = 0.5 deg = 4.8 10^{-6} of sky sphere

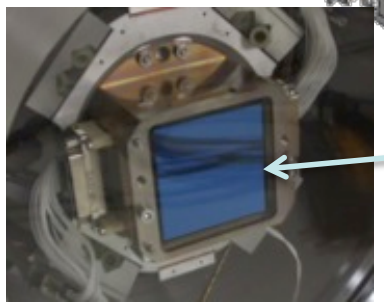
Focal plane diameter : 64 cm

189 science CCD (21 rafts)

3024 Channels

>3 10^9 pixels

Readout: 2s



E2v CCD 250 ,
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated R&D for LSST

1 raft = 3x3 CCD
150 M pixels
(1/2 Megacam)

LSST concept : a single observation plan

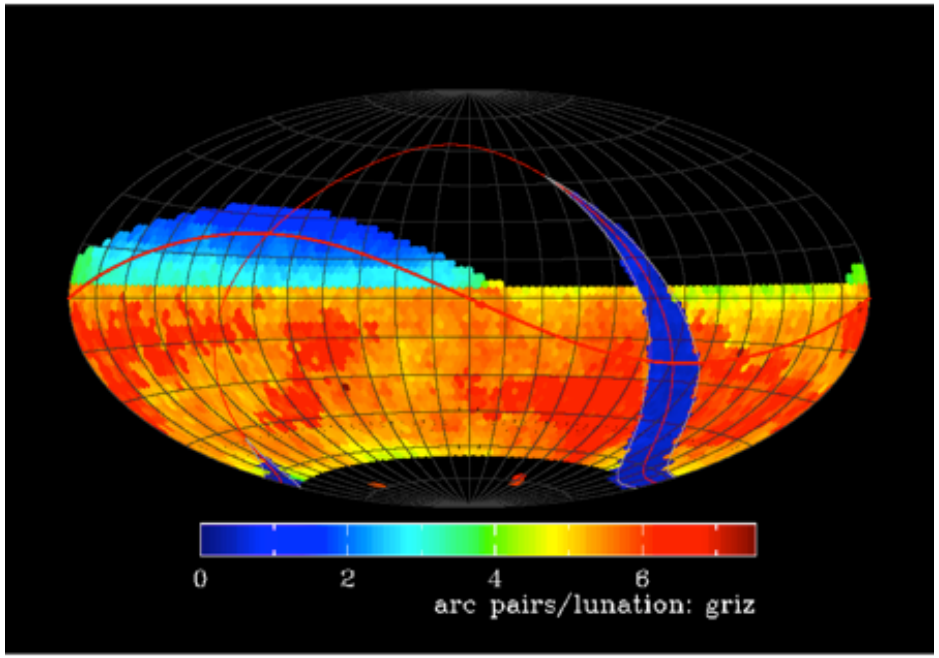
6-band Survey:
ugrizy 320–1070 nm
Survey(s) Area (with 0.2 arcsec / pixel)
Main : 18,000 square degrees to a uniform depth
Total : 25,000 square degrees (equatorial spur/asteroid +southern galactic cap / Magellanic clouds)

Total Visits per unit area and Visits per filter (Main survey)

	u	g	r	i	z	y
Nb Visit	70	100	230	230	200	200
1 visit mag	23.9	25.0	24.7	24.0	23.3	22.1
10 year	26.1	27.4	27.5	26.8	26.1	24.9

Image Quality
Median seeing at the site is ~ 0.6 arcsec
PSF FWHM < 0.4 arcsec (no atmospheric seeing).
PSF Ellipticity < 0.04
(referenced to 0.6 arcsec FWHM circular Gaussian)

Photometric precision:
0.01 mag absolute; 0.0005 mag repeatability



More than 2.75 10^6 visits & 5.5 x10^6 exposures
following the sequence:
15 s pose + 1 s shutter + 2 s read + 15 s pose
+ 1s shutter + 5s new pointing as reading
➔ **Points to new positions in sky every 39 seconds**
Number of visits per night : ~1000

Temporal Visit Distribution in Main Survey Area
Revisit after 30-60 minutes
Visit pairs every 4 nights
3 pairs per lunation

LSST data volume: 1 night ~ 15 TB … and in 10 years :

Number of objects	~37 10^9 (20 10^9 galaxies /17 10^9 stars)
Number of forced measurements	~37 10^9 * 825 ~ 30 10^{12}
Average number of alerts per night	2 10^6 (10 ^{7} including galactic plane)
Number of data collected per 24 hr period	~ 15 TB
Final Image Collection	0.5 EB (500 PetaBytes)
Final database size	15 PB

LSST & US Agencies : Status

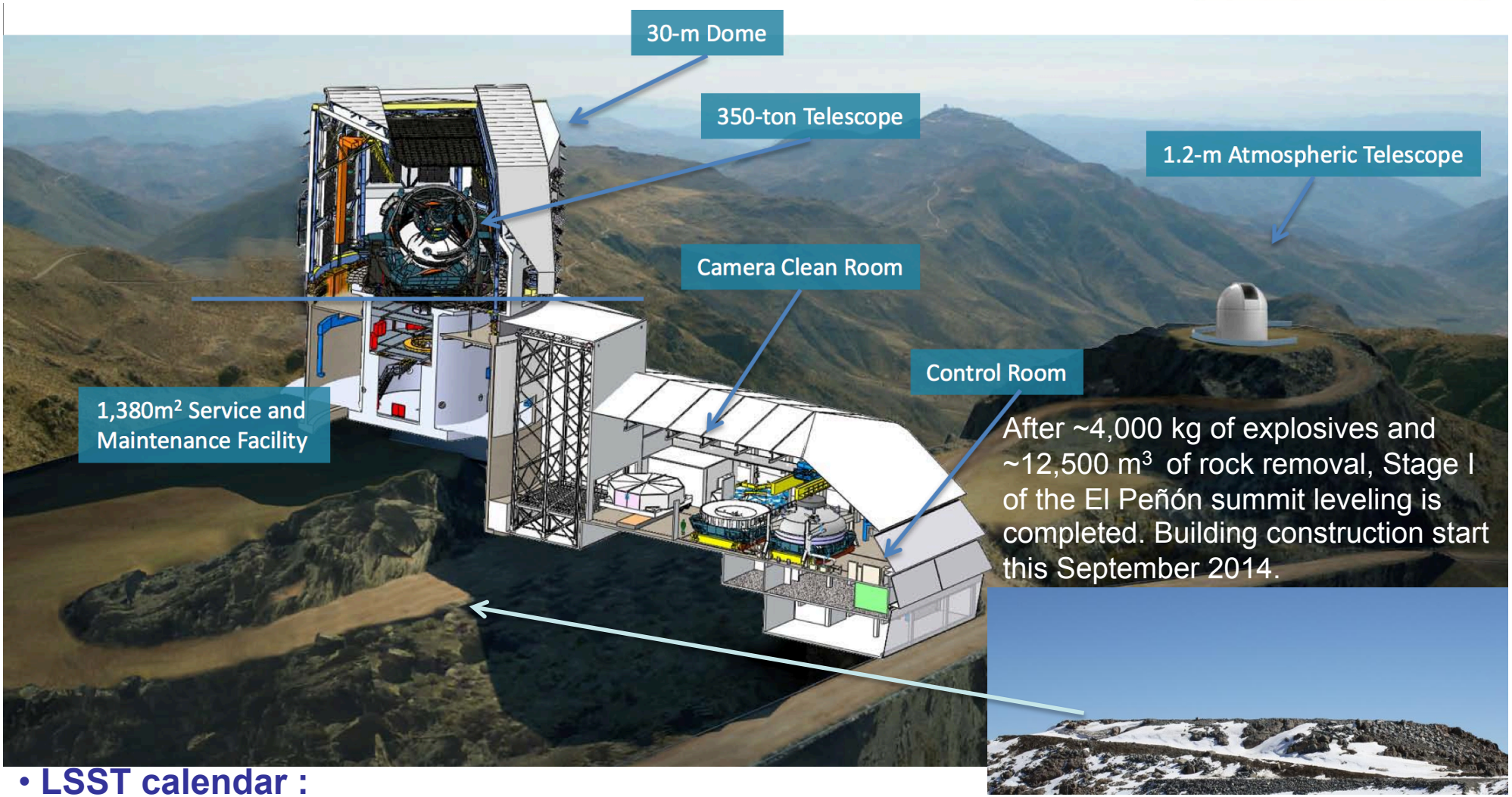
- **LSST ranked as the highest priority large ground-based facility for the next decade. (Astro10 , August 2010)**
- **Following this recommendation, NSF and DOE went ahead with LSST : LSST passed its final design review (NSF) last year (Dec. 2013) allowing the construction to start in 2014.**
- **LSST will federate a community of ~ 900 scientists over the world (50% from US) :**
  - **Except for France (in kind contribution) , integration of non-US scientist in LSST , will be associated to a fee of 200 000 $ / PI : the goal is to cover ~30% of the LSST running cost**
  - **In Europe (most of it still under discussion) :**
    - France : 130 – 150 PI
    - UK : ~ 100 – 180 PI (200 UK's scientists declared interest today, priority at STFC)
    - Czechy, Croatia , Hungary , Poland, Serbia,… : ~ 50 PI

LSST & French Agencies : Status

- **IN2P3 (8 laboratories) is involved since 2007 in the LSST .**
- **IN2P3 is involved in the LSST camera construction . This is a join DOE-IN2P3 effort , where IN2P3 contribution should reach the 15-20 % range. This the only non-US contribution to the core of LSST construction**
- **50% of LSST computing foreseen at CCIN2P3 + copy of all LSST data . This is the only in kind/non-US contribution to the running under discussion today.**
- **IN2P3 team includes in 2014 45 Scientists and 40 Engineers and Technical staff , for a total effort of 40 FTE in LSST in 2013. + ~10% by the end of 2014.**
- **Integration in LSST for 30-50 Non-IN2P3 scientist is foreseen associated to CNRS-IN2P3 in kind contribution during LSST running . This will be associated to the MOA's signature between LSST and IN2P3 : we hope to conclude in 2015.**

  ➔ This workshop is a seed to start the discussion with interested French scientist outside the current IN2P3 LSST-France team .

LSST Status – News (1/2)



- **LSST calendar :**
  - **– Official Construction start : 2014 (but private funds used for construction since 2008)**
  - **–Telescope first light 2019**
  - **–Camera delivered at summit 2020**
  - **– mid 2021 Start of the LSST "Science Verification survey"**
  - **– May 2022 "LSST delivery" / start of 10 years survey**

LSST Status – News (2/2)

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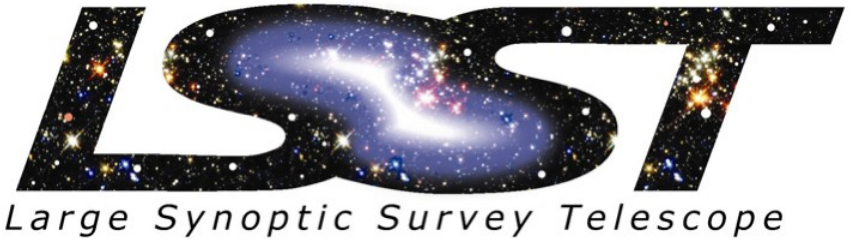
Project is moving from R&D to construction at all level (coordination , hardware , ..), for example :

- **–End of sensor R&D : fully operational sensors received and tested , they fulfill all the key requirements: format, flatness , noise & sensitivity. Sensor First article contract is "now".**
- **– Prototype of the CCD readout chain operational , including dedicated ASICs for CCD control and readout developed at IN2P3 , LAL & LPNHE ,(in-cryostat electronic , 3 10^9 pixels read in 2s)**

Data Management (DM) has continued to deliver high quality software and data releases :

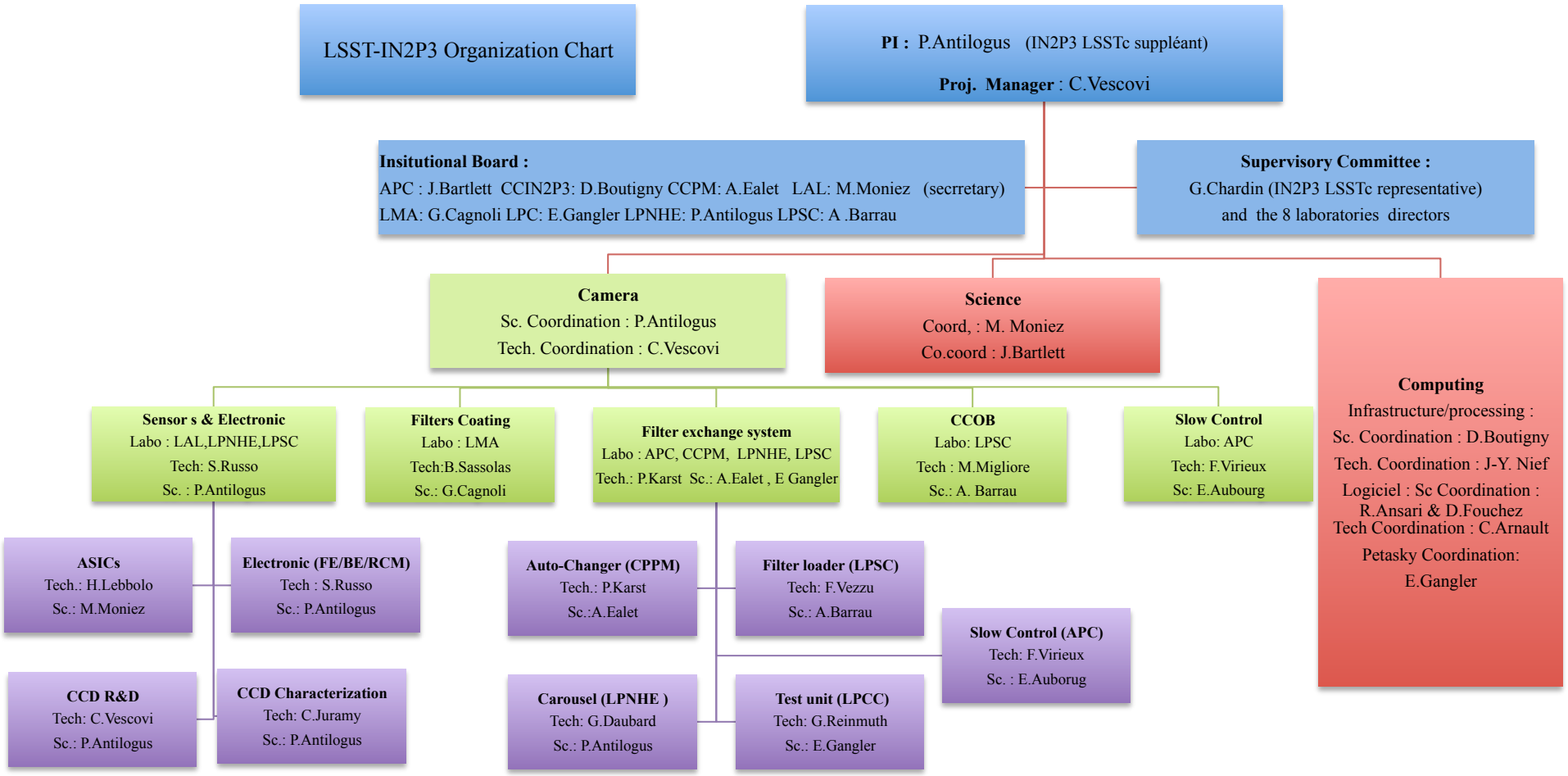
-LSST DM delivered over last summer its 9th consecutive data challenge release.
-CC IN2P3 contributed to the processing of SDSS Stripe 82 runs through the LSST pipeline and this year we are thinking to re-process CHTLS data at CC IN2P3.
-Work on the software is going on since ~7 years , construction will inject 168 M$ in computing development between now and the start of the running.

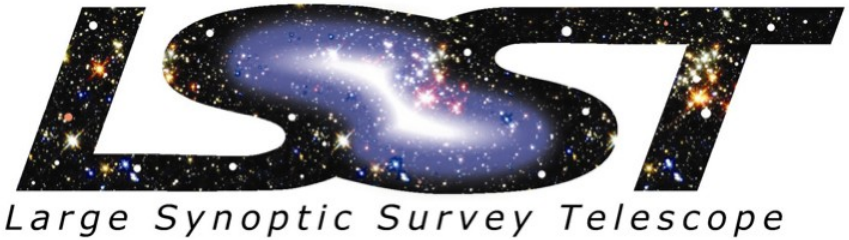


Highlight on LSST through IN2P3 contribution

LSST-France coordination in 2014

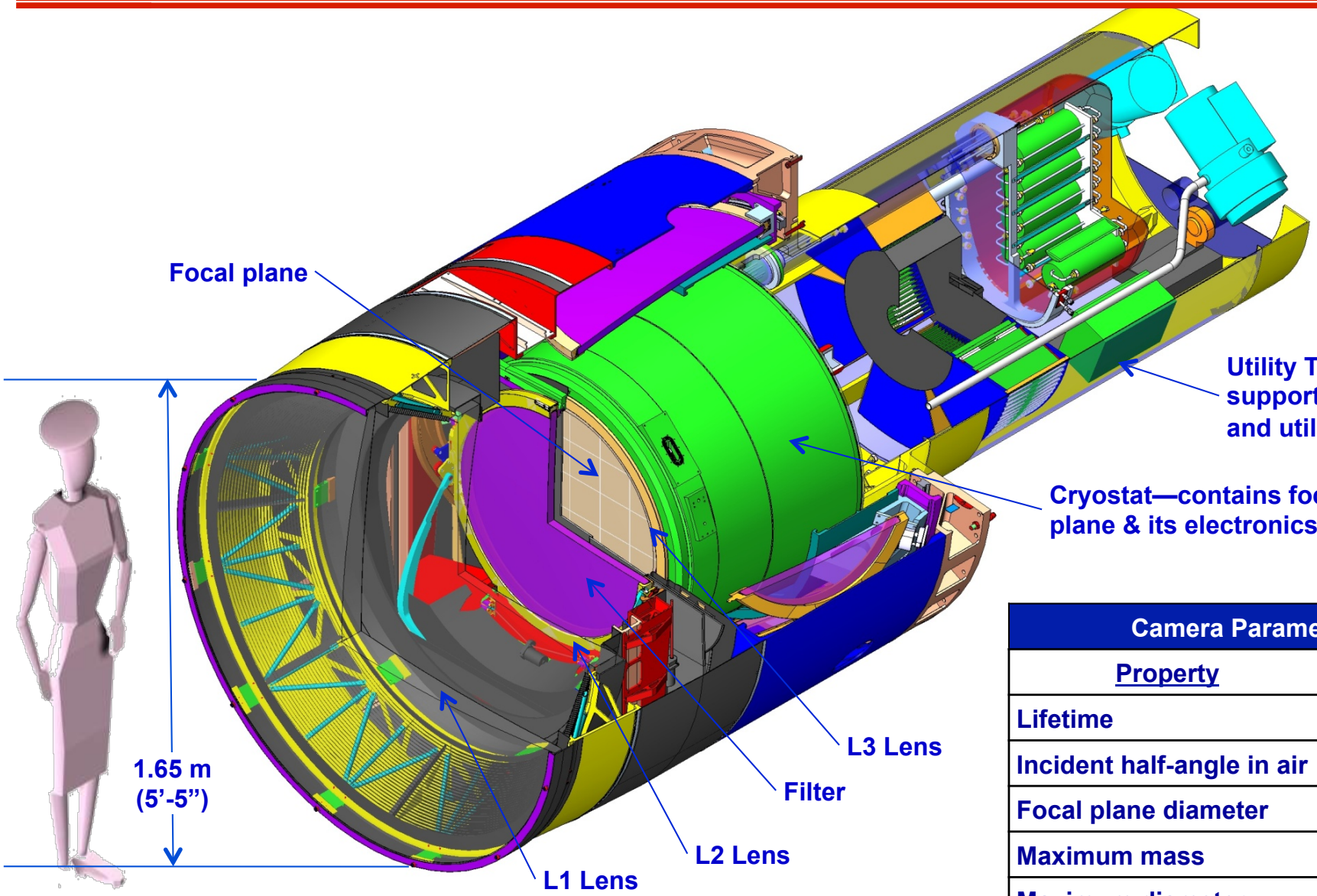
45 Scientists (10 FTE) / 50 ITA (30 FTE) 8 IN2P3 laboratories (9 expected by the fall) :
APC , CCIN2P3, CCPM,LAL,LMA,LPC,LPNHE,LPSC
Contribution to the camera fully structured (started in 2007, construction started in 2014)
Contribution to Science and Computing taking off now





IN2P3 contribution to the LSST camera

Camera Layout



Camera Parameters	
Property	Value
Lifetime	15 years
Incident half-angle in air	14.2°-23.6°
Focal plane diameter	634 mm
Maximum mass	3000 kg
Maximum diameter	1650 mm
Total length	3732 mm

Baseline of the IN2P3 contribution to the LSST camera (as agreed between DOE and IN2P3 since CD1 / fall 2011)

Large Synoptic Survey Telescope

LSST CCD and associated electronics :

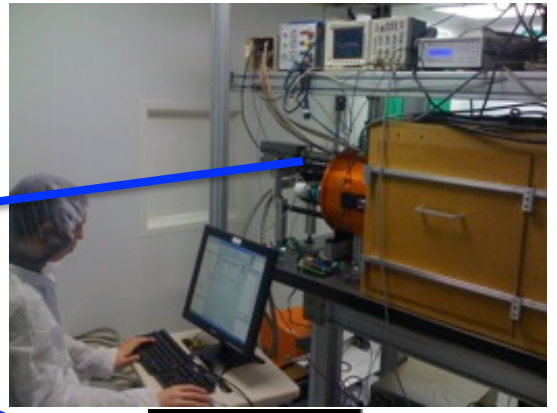
- Procurement of 25% of the LSST CCDs (~55 CCDs for a total of 225 CCDs foreseen by LSST),
- Initial testing of at least 25% of the CCD production,
- Design, qualification, production and testing of the focal plane ASICs: ASPIC for the CCD readout & CABAC for CCD control
- Responsibility for the design, implementation and qualification of the FPGA micro-code controlling the LSST Raft (a raft is an autonomous camera of 9 CCDs, with a total of 21 making up the LSST focal plane).

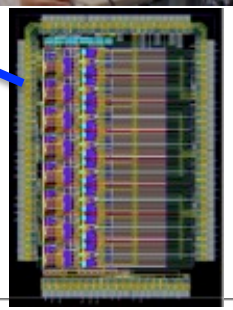
Filter Exchange system & control :

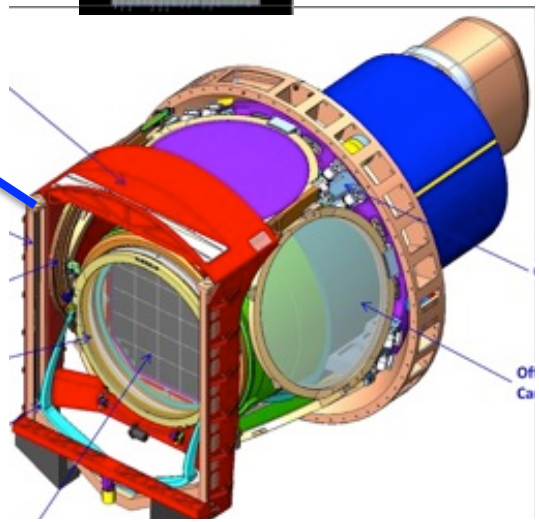
- Delivery of the *filter exchange system*
- *Support on Filter and optics coating (LMA)*
- Contribution to the core of the camera slow control , and provide the *filter exchange system* slow control.

Calibration :

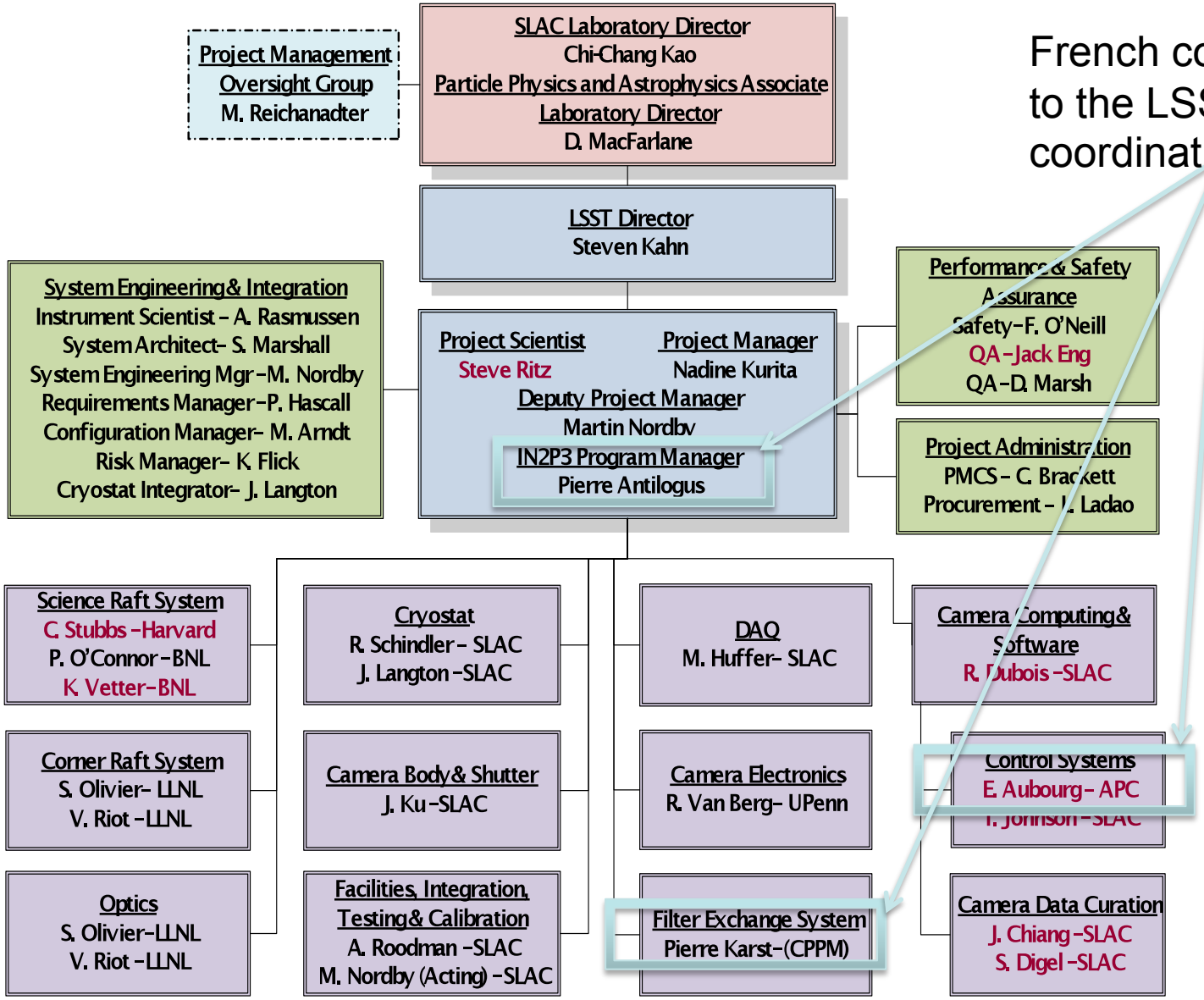
- Studies on the survey calibration design (atmosphere , auxiliary telescope)
- Delivery of the CCOB : a system to characterize the LSST camera during assembly at SLAC







Camera Management & IN2P3 :



French contribution to the LSST-camera coordination

Sensor & Readout electronic

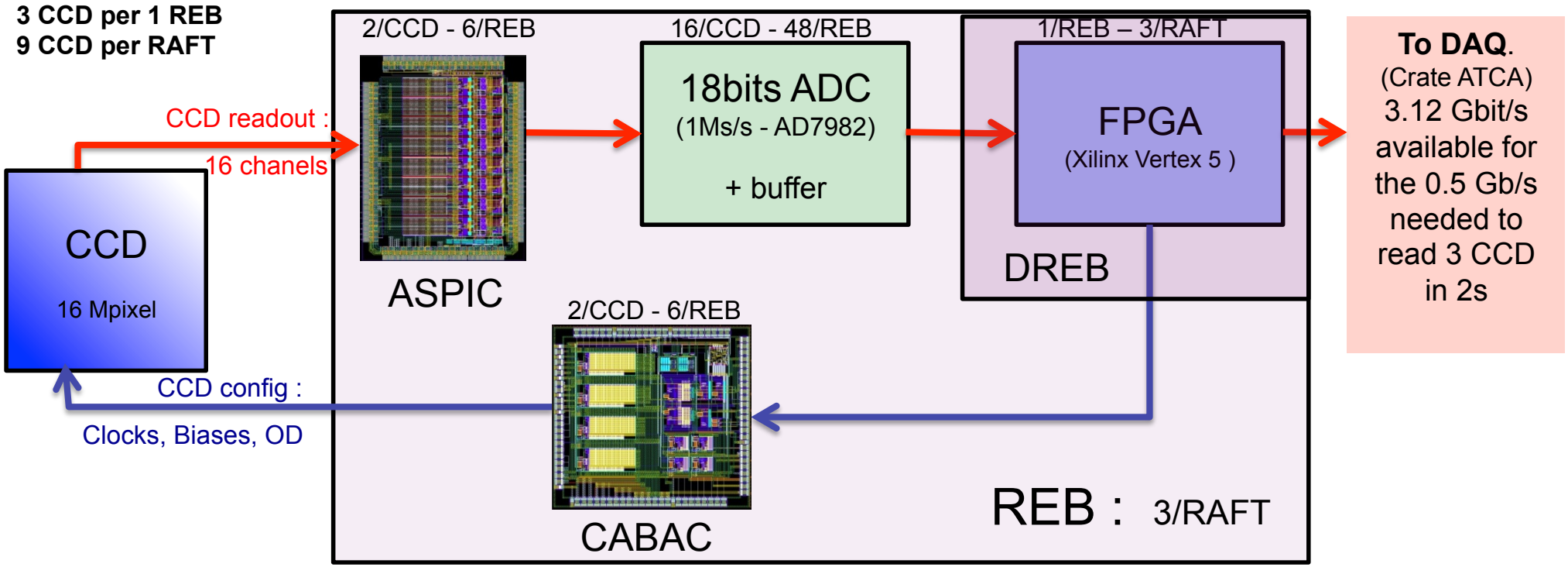
(LAL/LPNHE) →20 People / 12 ETP

-CCD readout chip (ASPIC III, design final: under test since the fall)

-CCD control HV (CABAC I, final design: submitted in May 2014 , CABAC 0 under test since end 2012, ok.

-FPGA Microcode / full board/CCD control : includes an extended clocking and diagnostic capability for in cryostat optimization and monitoring

- Sensor: Sensor reception test , sensor study , readout optimisation



Sensor studies Brighter-Fatter effect
(LPNHE)

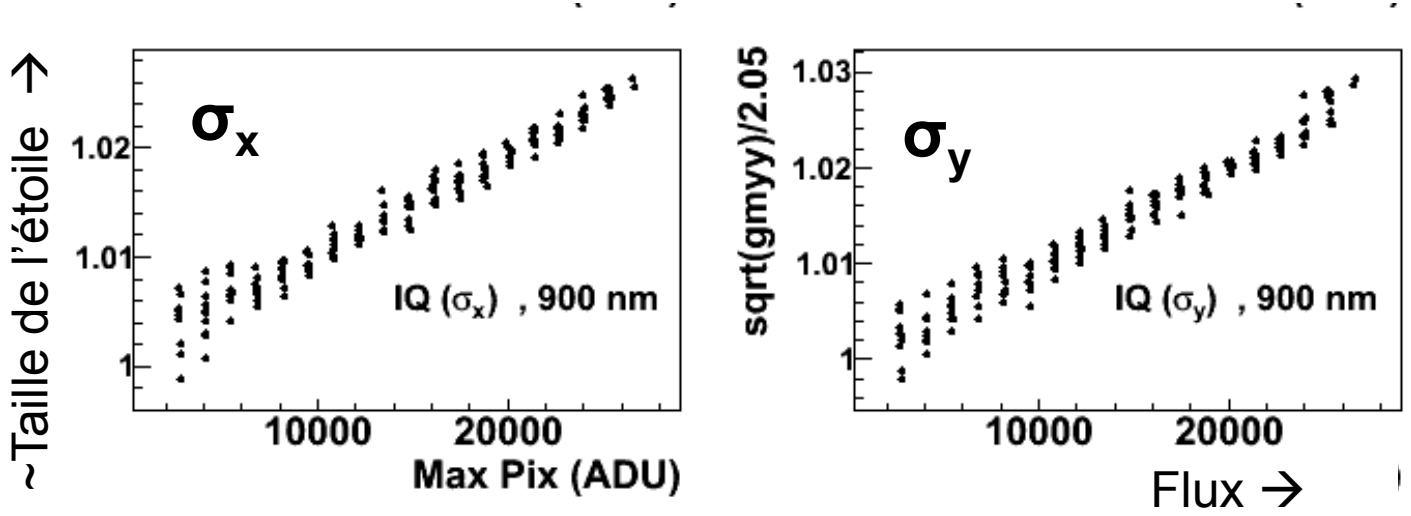
– **Understanding instrument properties is a key for the LSST science. Our contribution to the CCD and CCD readout allows us to contribute to this sector in an unique way.**

– **This hardware&science approach has been successful in 2013 with our discovery of the brighter-fatter effect :**

- « brighter / fatter » : «the psf of an object is flux dependant » : charge collected in a pixel pushes field lines (=drifting charges) toward neighbor/less filed pixels.

- This effect is present in all CCD , but wasn't understood/fully identified up to this work in LSST (see for example : **arXiv:1402.0725 ,** new paper ready soon**)**

- This effect cannot be neglected in lensing studies any "psf analysis" , where "bright" stars are used to constrain the psf of faint objects. We have a frame work to correct this effect (from studies in LSST,DES and SNL) and today there is also work in DES and HSC collaboration.



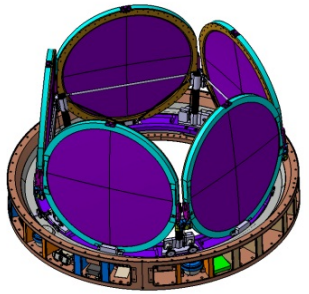
Filter Exchange system
(APC,CCPM,LPC,LPNHE,LPSC)

Filter Control System
FCS (APC)
PARIS

Françoise Virieux, PM & Eng
Bernard Amade, Eng

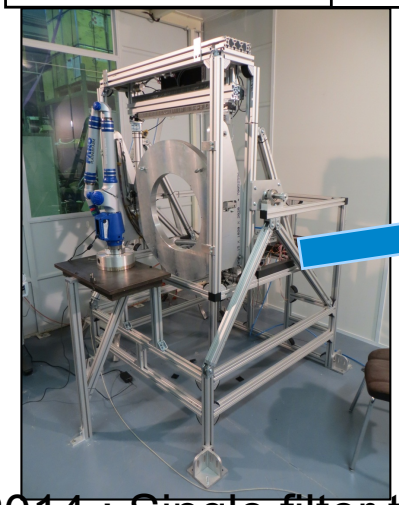
Carousel (LPNHE)
PARIS

Daniel Vincent, PM
Guillaume Daubard, PM & Eng
Christophe Evrard, Designer
Felipe De Matos, Eng
Yann Orain, Designer
Diego Terront, HCU



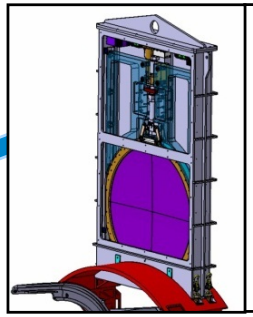
Full Scale Prototype
Test Bench (LPC)
Clermont Ferrand

Guy Reinmuth, PM & Eng
Patrick Lafarguette
Philippe Chassagny
Romeo Bonnefoy



Loader (LPSC)
GRENOBLE

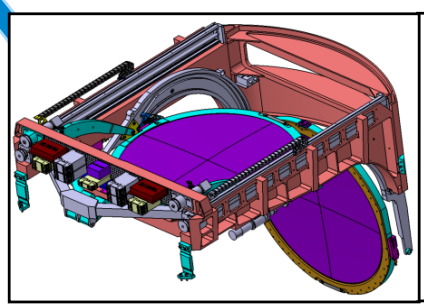
Francis Vezzu, PM & Engineer
E. Perbet, Designer
E Lagorio, Eng
J. Giraud, Analyst
Y. Cargagno, Engineer



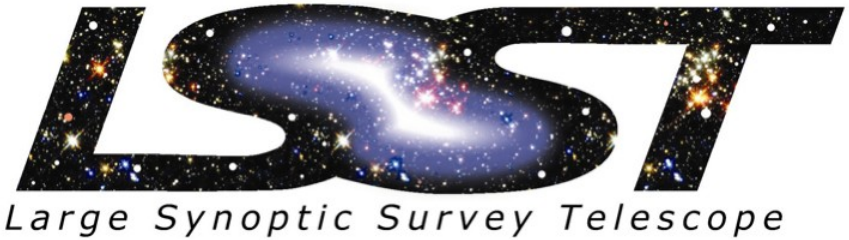
Total Manpower
22 people – 12 ETP

Auto-Changer (CPPM)
MARSEILLE

Pierre Karst, PM & Eng
Daniel Labat, Designer
Françoise Rivière, Designer
Patrick Breugnon, Elect Eng
Fabrice Gallo, Fab & Assy



2014 : Single filter test



LSST computing at IN2P3

LSST computing at IN2P3 (1/3)

• The French scientific community involved in LSST will not have access to computing facilities in the US for science analysis.
• Efficient access to the very large LSST dataset will be one of the primary challenges for scientific exploitation, and most particularly for dark energy science
• To support running costs/share of the data reduction effort and to ensure competitive data access on this side of the Atlantic – a letter of intent was sent by the IN2P3 director to the LSSTc in December 2011 :

- The CC-IN2P3 will provide CPU and storage resources corresponding to 50% of the LSST needs for the Data Release Processing (level 2)
- The full LSST dataset will be resident at the CC-IN2P3.

CC-IN2P3 new data center

This proposal has been elaborated with a strong support from all parties (LSST , IN2P3 , CCIN2P3 , LSST-France).
This in-kind contribution is evaluated by LSST to be equivalent to a cash contribution of 1-2 M$/year.
Significant investment at CCIN2P3 should start in 2017. MOA is under discussion .

LSST computing at IN2P3 (2/3)

Large Synoptic Survey Telescope

Associated to the processing plan at CCIN2P3 , a computing activity with contribution from different LSST IN2P3 laboratories has been ramping up since 2012 :

- Software installation & Hardware ramp-up since mid-2012
- Contribution to the summer 2013 LSST data challenge (SDSS stripe 82) :
  - 100 TB of data , 1000 jobs in // for ~ 1 month
- Contribution from 7 IN2P3 laboratories , 5 FTE in 2013 , regular meeting and common working session . Work in close contact with the US.
- Dominique Boutigny, director of the CCIN2P3 up to the end of 2012, is full time at SLAC since summer 2013 (for 2 years). He is coordinating our infrastructure effort at CCIN2P3 and smooth our integration in the LSST computing.

LSST computing at IN2P3 (3/3)

•Contribution to the Dark Energy , "3rd level processing", not discussed/ agreed yet

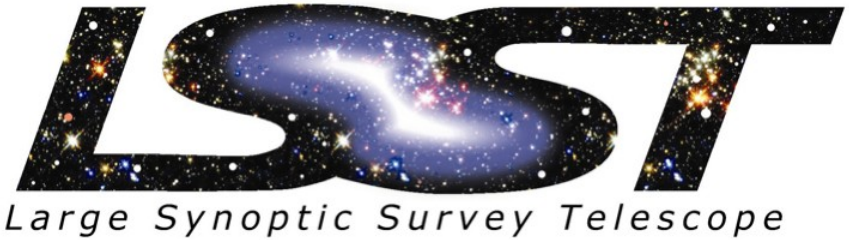
•Contribution to the 1-2 level computing started but not formally integrated in the project yet (from NSF point of view any contribution to the construction should be subtracted to the US budget …), interest/work in DB and job control , ex :

- Evaluation of Qserv / LSST database work has been initiated in 2012 with a grant to our PetaSky project (E.Gangler et al.) within the MASTODONS call .

➔LSST will produce 15 TB / night , 7 PB of archive / year , 70 PB total at the end

➔11 PB of storage space on disk (image access /processing cache) at the start of the project , reaching 22-25 PB at the end of the survey

➔~ 100 TF (10^{12} FLOPS) sustained computing power at the start of the survey, which should reach ~ 900 TF in 2029 (dominated by the object measurement step)



Dark Energy Science Collaboration

The Science Opportunities are Summarized in the LSST Science Book

- Contents (~600 pages) :
  - Introduction
  - LSST System Design
  - System Performance
  - Education and Public Outreach
  - The Solar System
  - Stellar Populations
  - Milky Way and Local Volume Structure
  - The Transient and Variable Universe
  - Galaxies
  - Active Galactic Nuclei
  - Supernovae
  - Strong Lenses
  - Large-Scale Structure
  - Weak Lensing
  - Cosmological Physics

Dark Energy

- Until 2012 the science in LSST was focused on 11 autonomous "LSST Science Collaborations" covering the different science topics of LSST
- Since the DOE urged LSST to set up a collaboration "à la" High Energy Physics on Dark Energy (Dark Energy Science Collaboration ,DESC). This collaboration explicitly manages all the aspects of the project, including the technical tasks, associated to Dark Energy. IN2P3 scientific involvement in LSST is centered on DESC .

DESC (1/2)

Although the "LSST Science Collaborations" have been successful in producing the LSST Science Book in 2009, we see the DESC as the correct collaboration structure to face the complex challenges of the Dark Energy science

We/IN2P3 actively contributed to the DESC creation:

- The French-PI was involved in the initial process (P.Antiliogus)
- 3 of us attended the founding meeting in June 2012 (P.Antilogus, E.Aubourg, M.Moniez)
- One of us sits in the DESC executive committee. (R.Pain)
- Over the Summer 2012 as the collaboration took shape with production of a white paper, 23 French members joined DESC working groups with dark energy science tasks involving all major probes, as well as strategic activities in calibration and photometric redshift determination.
- in 2014 DESC collaboration will be fully operational (30 IN2P3 scientists applied to full membership), meeting next week at Upenn .

Large Synoptic Survey Telescope
Dark Energy Science Collaboration

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DESC (2/2)

- IN2P3 scientist are involved in all the faces of the LSST multi-probe cosmology, from the calibration aspect to the metrology with each DE probe.
- 46 IN2P3 scientists in LSST-France , 23 already joined DESC in 2012, we should be ~ 30 this year.
- Many scientists active in other surveys (Planck, SNLS...) will transfer progressively their activity to LSST over the next 5 years .

SN (LPNHE, CPPM, LPC – 10 scientists)
- observing strategies
- Synergies with IR observations (EUCLID)
- Imroving image subtraction technique

Weak lensing (APC – 3 scientists)
- Cosmic magnification
- Cluster mass measurements
- Weak lensing analysis algorithm

Large scale structures incl. BAO (APC, LAL, LPSC – 9 scientists)
- Simulation

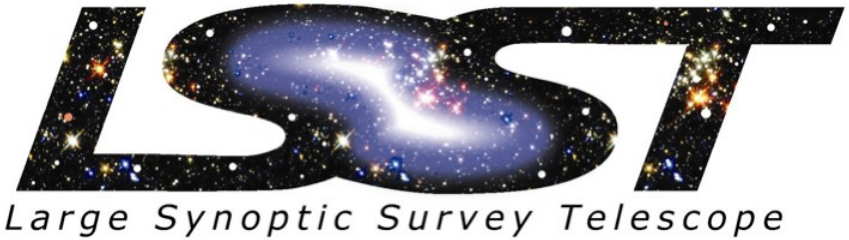
Galaxy clusters (APC -1 scientist)
- Detection and mass determination techniques

Combination of probes (LAL, CPPM – 4 scientists)
- Combine CMB+LSST -> neutrino mass contraint
- Statistical analysis (compare bayesian/ frequentist...)

Transverse tasks (APC, LAL, LPNHE, LPSC - 12 scientists)
- Photometric calibration
- Determination of redshifts through photometry
- Complementary observations: follow-up

Conclusion

La construction de LSST est en cours
Son exploitation scientifique , dès 2021 , permettra une percée observationnelle de l'univers et de ses composants.
Le retour scientifique de la contribution Français sera , je l'espère, significative.



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LSST Schedule