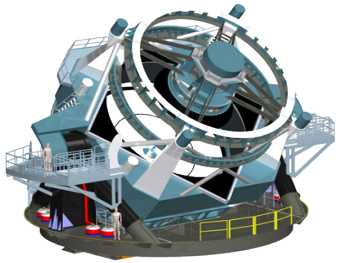
The Large Synoptic Survey Telescope (LSST)



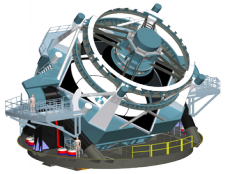
Dominique Boutigny

1st ASTERICS-OBELICS Workshop

12-14 December 2016, Rome, Italy.

H2020-Astronomy ESFRI and Research Infrastructure Cluster
(Grant Agreement number: 653477).

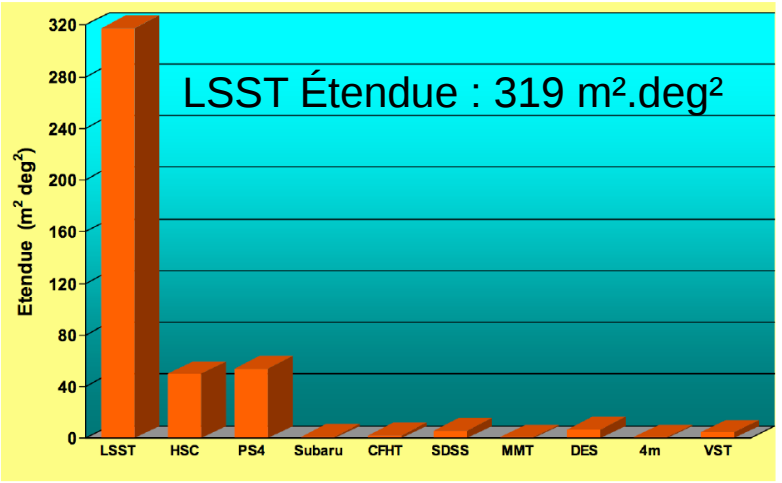
Συνοπτικός : “Seeing the whole together at a glance”

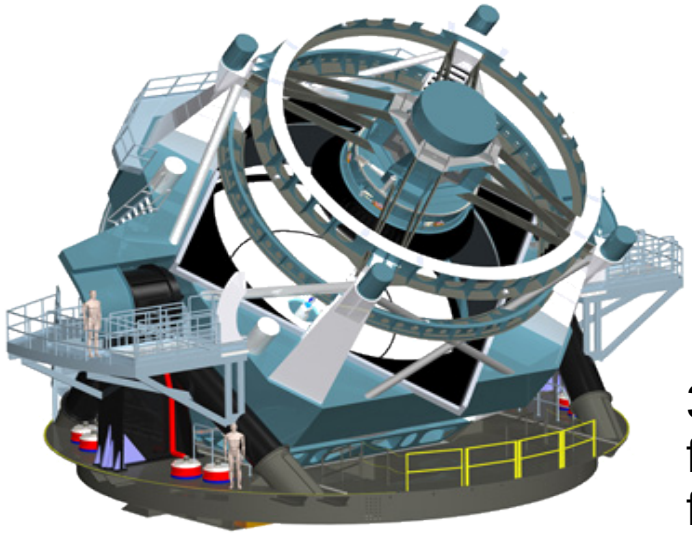


LSST is an instrument designed to make high precision images of the whole accessible sky in 4D (x, y, z, t) ⇒ 10 year time-lapse movie of the sky

- Mirror diameter : 8.4 m (6.7 m effective aperture)
- Field of view : 9.6 deg²

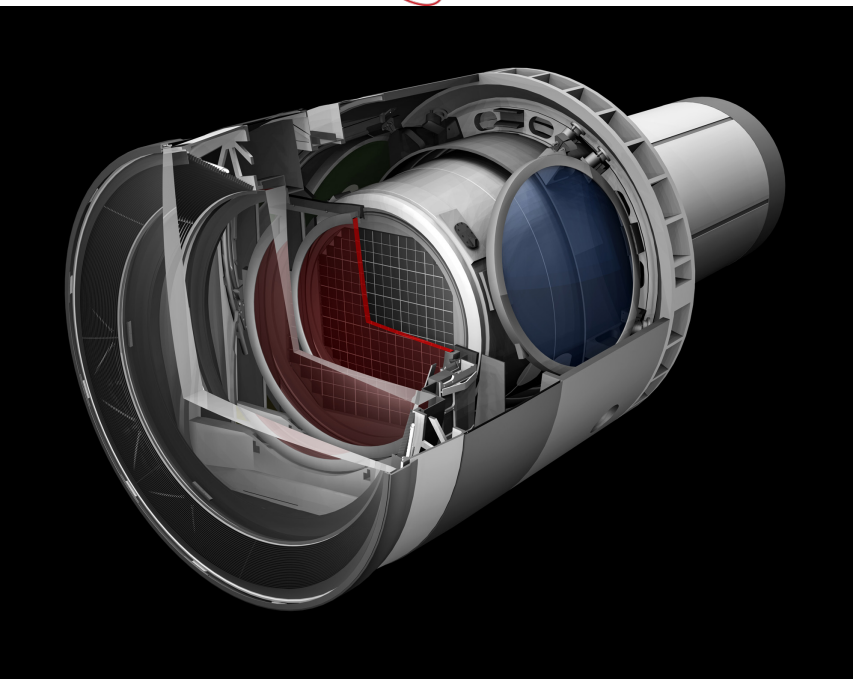
⇒ depth (24.5 mag single exposure → 27.5)
⇒ cadence (revisit time : 3 – 4 days)

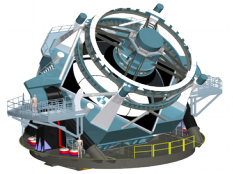




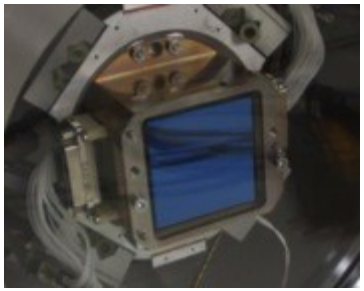
3 mirror, aberration free optics
f = 10.3 m
f / d = 1.23

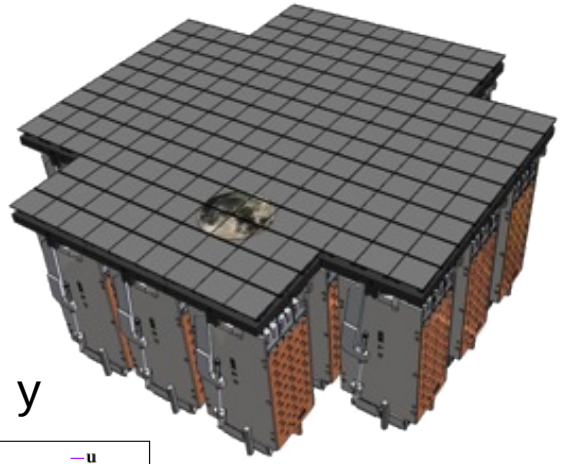
Camera



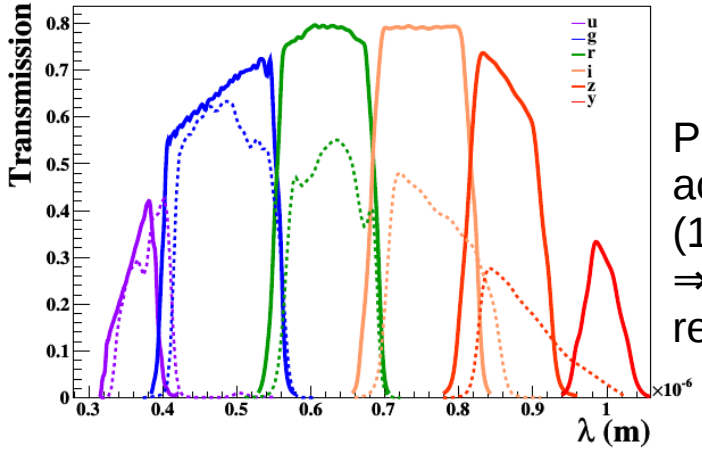


- 3.2 Gpixels
- 0.2 arcsec / pixels
- 189 thick deep depleted CCD (UV - IR)





6 filters u, g, r, i, z, y



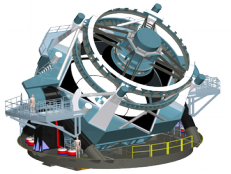
- 2 successive 15 sec exposures
- 2 sec readout time

- 1 visit every <40 sec>

Fast – Wide – Deep

Photometric accuracy : 0.01 mag (1%)
⇒ photometric redshifts

The LSST survey



20 000 deg²
10 year survey : Every area of the sky will be revisited ~800 times
Some areas will be revisited several times during each night

Time domain science
- Novae – Supernovae – GRBs
- Source characterization
- New phenomena on very faint objects

Mapping the Milky Way
- Galactic structures / tidal streams
- Astrometry over 20 000 deg² complementary to Gaia

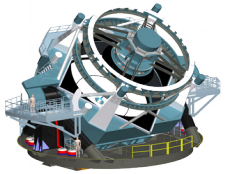
Moving sources
- Asteroids and comets
- Proper motion of stars

Dark energy and dark matter
- Gravitational lensing (strong and weak)
- Large scale galactic structure / BAO
- 1A supernovae / standard candles

⇒ *Understand the nature of dark energy*

⇒ 8 science collaborations

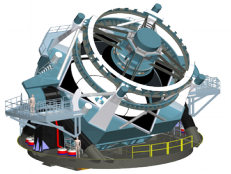
Site



Commissioning start : Q4 2020
Survey start : **2023**

Image Subaru HSC at the LSST depth

The LSST Software Stack



The LSST Data Management (DM) team is developing a modular, efficient and versatile astronomical image analysis framework

- 50 M$ funding for construction and commissioning of the LSST stack and associated middleware
- Open source

Reuse existing algorithms and develop new state of the art ones

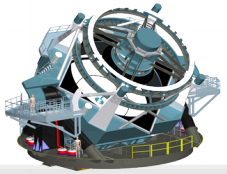
- Rewrite everything from scratch
- Mostly Python (User interface – High level code)
- Interfaced to C++ (via SWIG) when speed is crucial

Designed to support any Optical / CCD instrument

- Already have implementation for SDSS, Subaru / HSC, CFHT / Megacam, Blanco / DECam (DES) + LSST-Sim
- Provides the ability to develop coherent multi-instrument analyses

LSST from the astronomer's perspective

slide borrowed from Mario Jurić (UW)



Level 1

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.

Level 2

- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion observations ("sources"), and ~30 trillion measurements ("forced sources"), produced annually, accessible through online databases.
- Deep co-added images.
  - *0.5 EB by the end of the project*
  - *1.8 PFlops*

Level 3

- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

LSST DATA CENTERS

HEADQUARTERS SITE

HQ facility
- *observatory management*
- *science operations*
- *education & public outreach*

ARCHIVE SITE

Archive center
- *alert production*
- *data release production*
- *calibration products production*
- *long-term storage (copy 2)*
- *education & public outreach*
- *infrastructure*

Data access center
- *data access and user services*

SATELLITE RELEASE PRODUCTION SITE

Archive center
- *data release production*
- *long-term storage (copy 3)*

BASE SITE

Base facility
- *long-term storage (copy 1)*

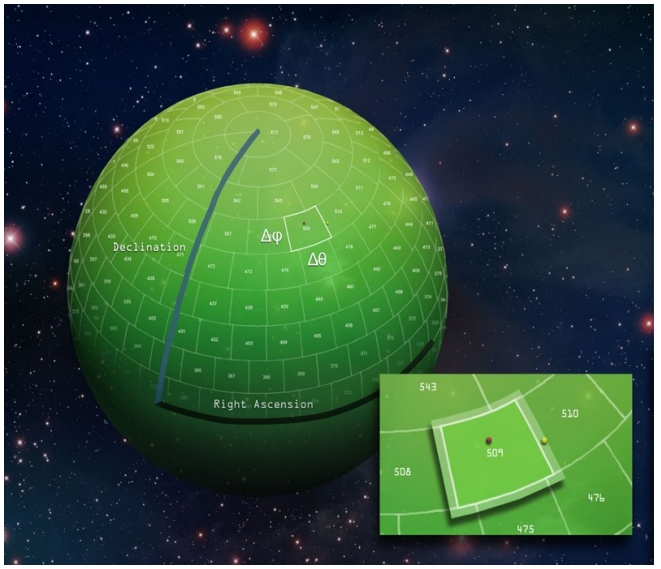
Data access center
- *data access and user services*

SUMMIT SITE

Summit facility
- *telescope & camera*
- *data acquisition*
- *crosstalk correction*

Sources: LSST, Google

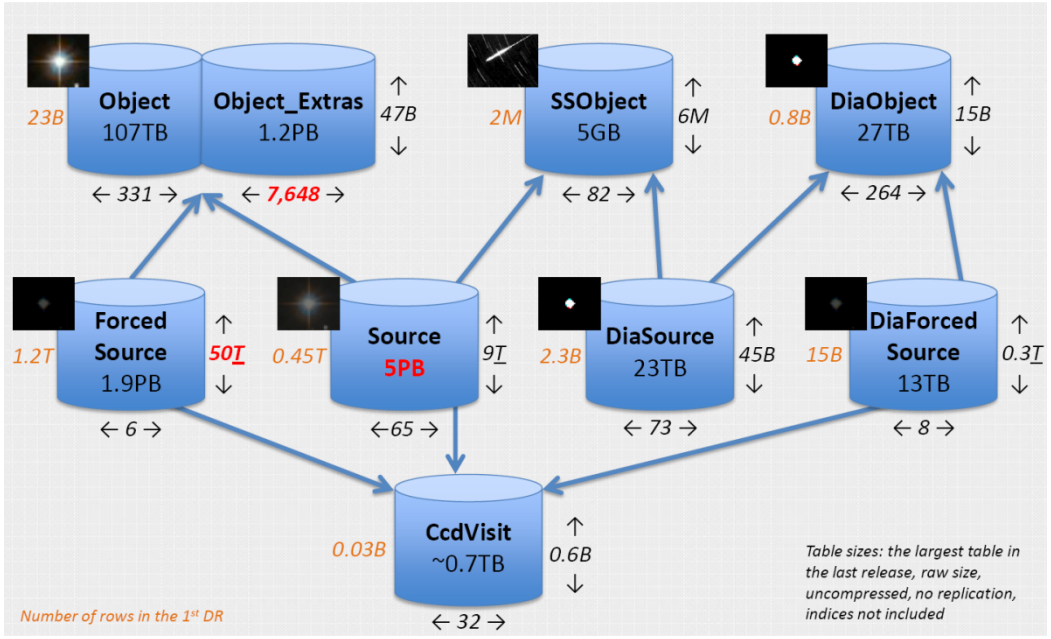
The Qserv Database System

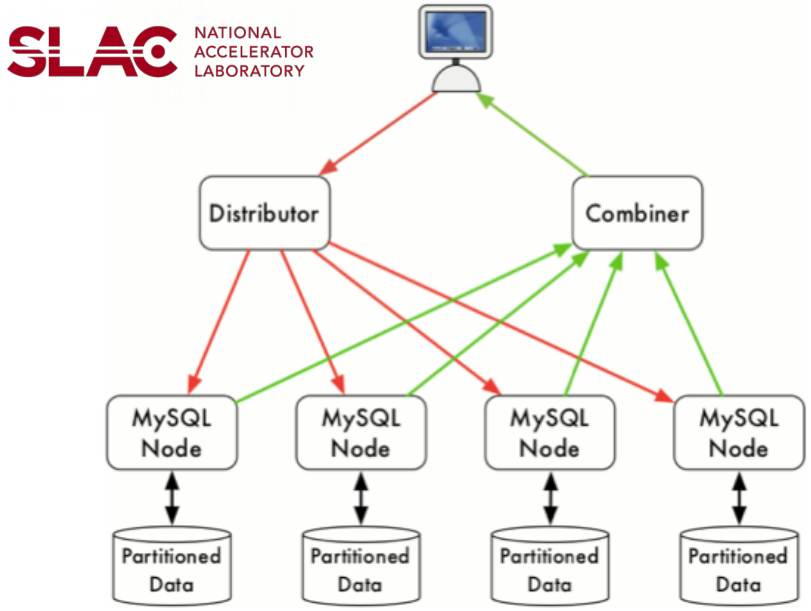


DB distributed over 1000s nodes

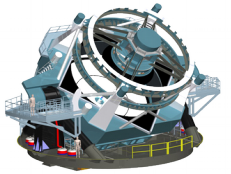
- SQL queries
- Final release : 15 PB
- Open source

Large scale test benches deployed at NCSA and CC-IN2P3 (50 nodes – 0.5 PB)
See Fabrice Jammes' talk and demo





Science Driven Software Testing



- Core software often developed independently of the science groups
- Especially true in LSST where Instrument (+ DM)
- and Science are separate collaborations

Test software on precursor datasets

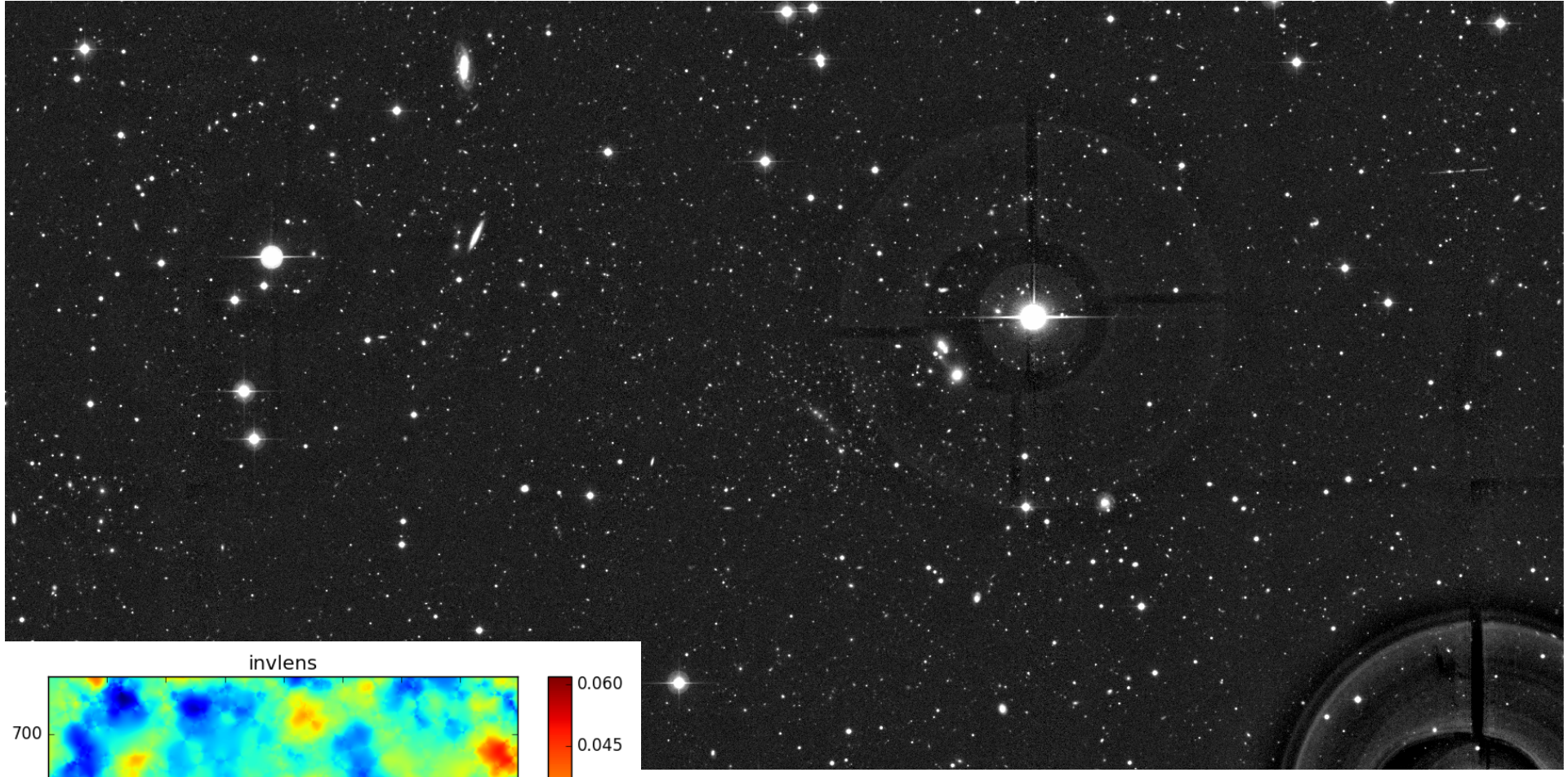
- CFHT / Megacam
- Image reduction – photometry / astrometry calibration
- Image coaddition
- Source detection and measurement
- Multifilter photometry
- Galaxy shape measurement

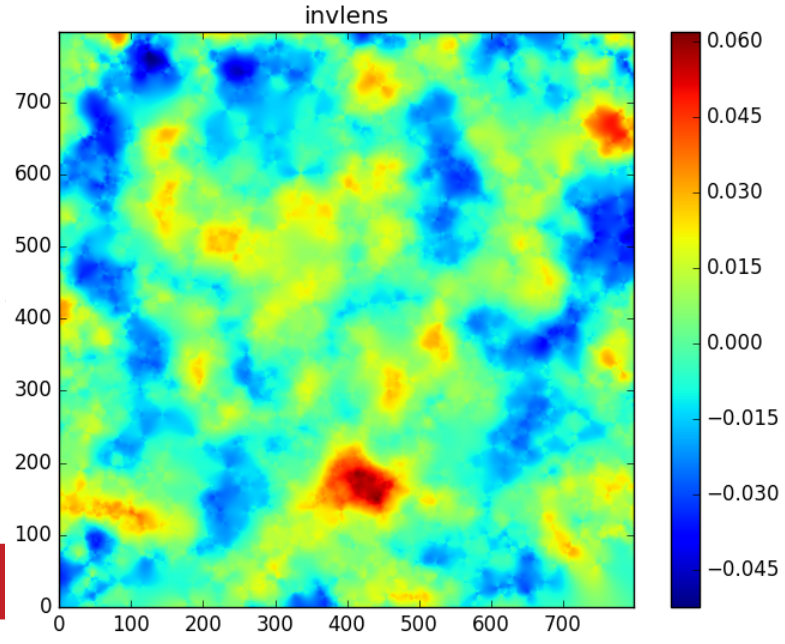
- Save produced catalogs in astropy tables / hdf5
- Run analysis pipelines

⇒ **Repeat with catalog stored and indexed in Qserv**

- Complementary to scalability / performance tests
- Check adequacy to science needs

⇒ Postdoctoral work of Nicolas Chotard (LAPP - Asterics)

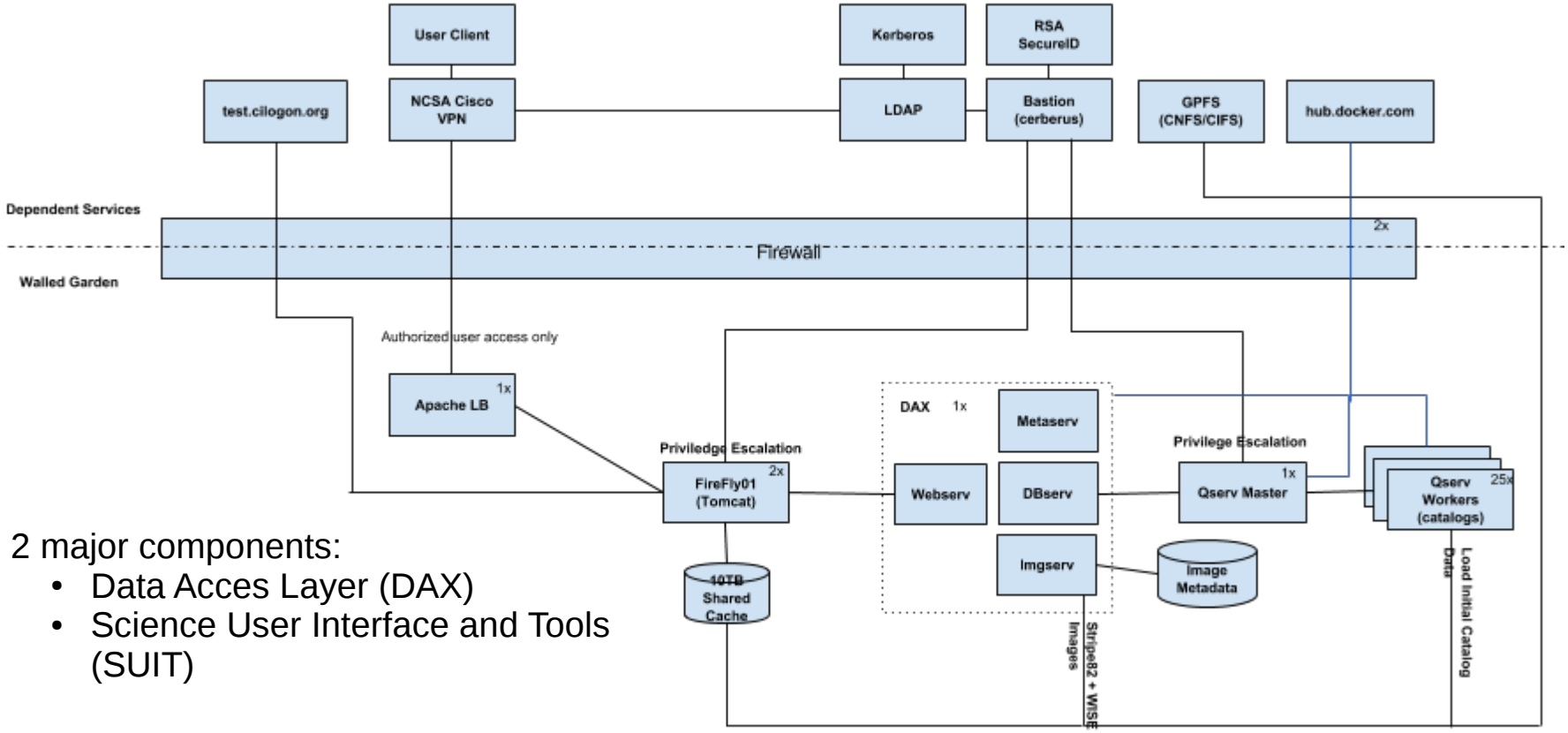




Mass reconstruction of galaxy cluster CL0016+16 using Weak Lensing

Data Access Center(s)

Access to the data products (L1, L2 catalogs – images - calibration - L3 user products) will be provided in Data Access Centers (DAC)



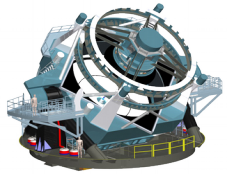
2 major components:

- Data Acces Layer (DAX)
- Science User Interface and Tools (SUIT)

Prototype (PDAC) deployed and tested at NCSA with SDSS Stripe 82 data - To be replicated at CC-IN2P3 and in UK.

Next : extend to larger datasets : WISE, PanSTARRS, …)

Firefly

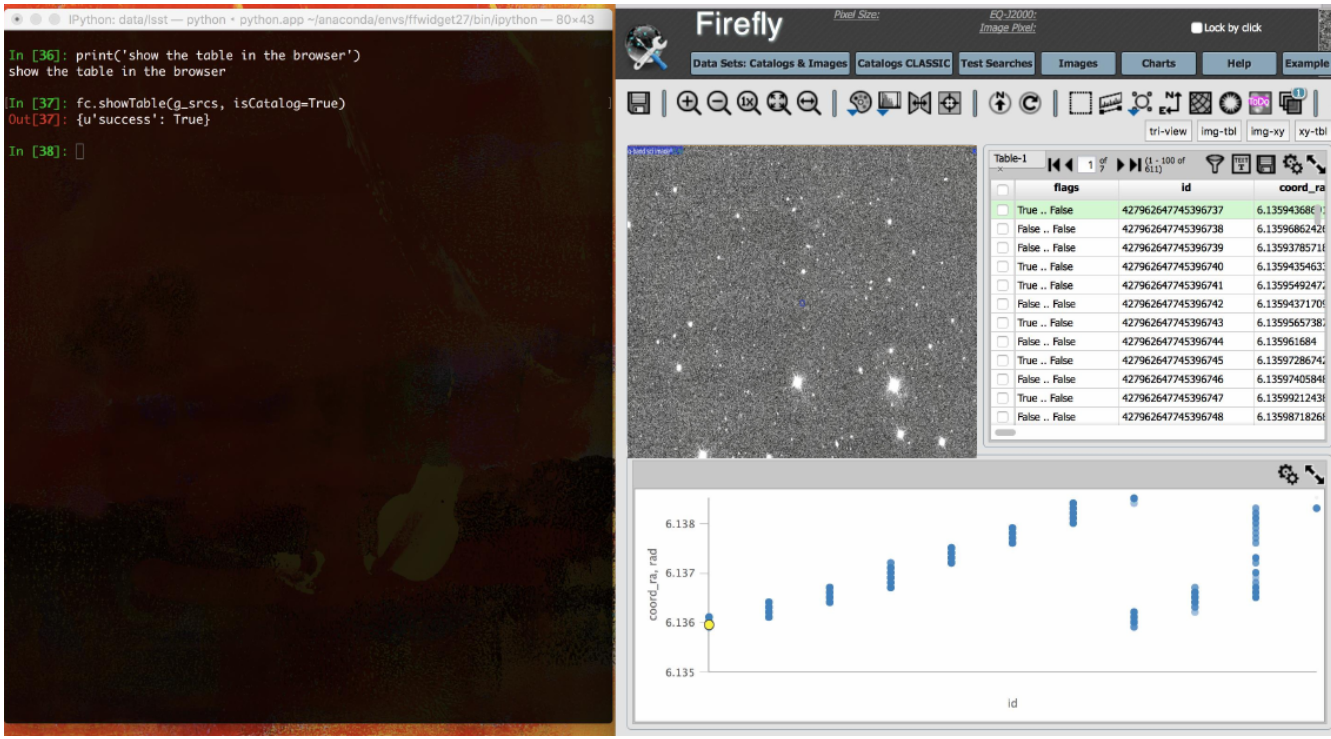


Firefly is the central component of SUIT

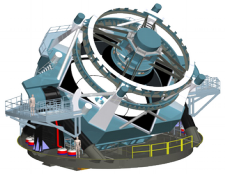
- Developed at IPAC
- Embed visualization and interactive analysis tools in a web portal
- Highly optimized and scalable
- Open source

Integrated with Python / Jupyper notebooks

Allows complex processing and analysis on top of visualization



Credit : D. Ciardi - IPAC



Questions ?

Acknowledgements

H2020-Astronomy ESFRI and Research Infrastructure Cluster (Grant Agreement number: 653477).