Centre de Calcul
de l'Institut National de Physique Nucléaire
et de Physique des Particules

Legacy Survey of Space and Time

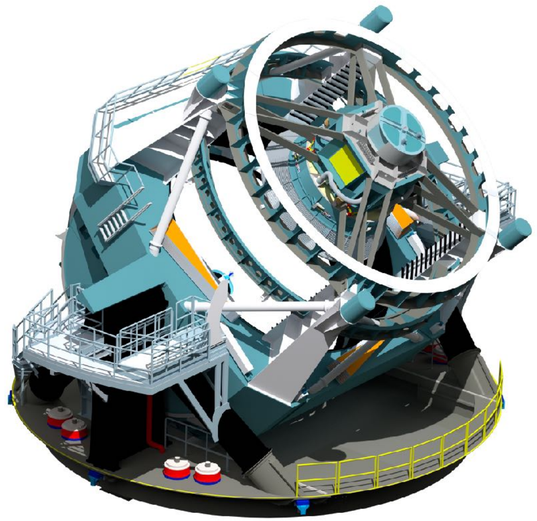
Vera C. Rubin Observatory

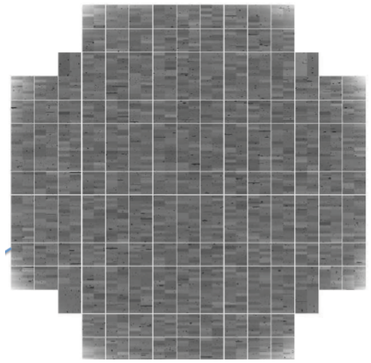
fabio hernandez

IN2P3 Journées Recherche et Technologie, October 18th, 2022

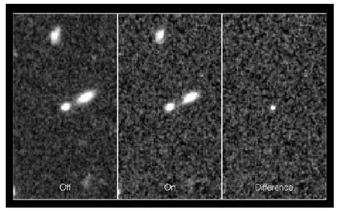
Overview

RUBIN OBSERVATORY LEGACY SURVEY OF SPACE AND TIME

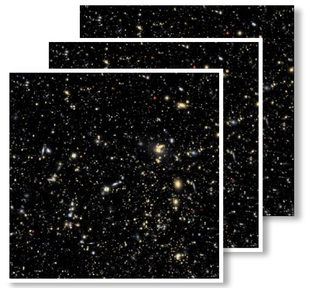




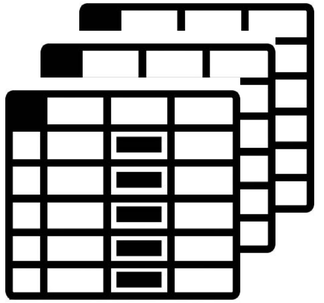
raw images



alerts



co-added images



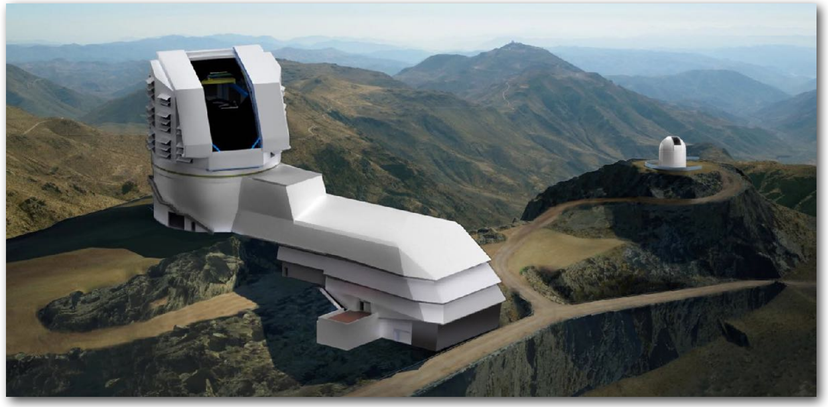
astronomical catalog

science collaborations

LSST aims to deliver a catalog of 20 billion galaxies and 17 billion stars with their associated physical properties

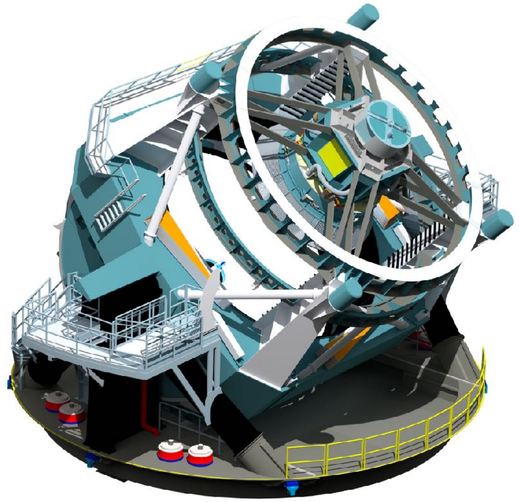
LSST OVERVIEW

OBSERVATORY



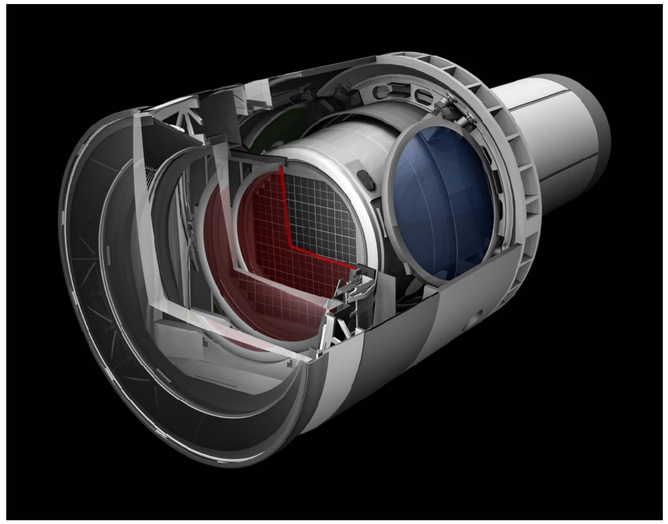
southern hemisphere | 2647m a.s.l. | stable air | clear sky | dark nights | good infrastructure

TELESCOPE



main mirror ⌀ 8.4 m (effective 6.4 m) | large aperture: f/1.234 | wide field of view | 350 ton | compact | to be repositioned about 3M times over 10 years of operations

CAMERA



3.2 G pixels | ⌀ 1.65 m | 3.7 m long | 3 ton | 3 lenses | 3.5° field of view | 9.6 deg² | 6 filters *ugrizy* | 320-1050 nm | focal plane and electronics in cryostat at 173K

Source: LSST: from Science Drivers to Reference Design and Anticipated Data Products

Source: Rubin Observatory

LSST OVERVIEW (CONT.)

- ## Principle of operations

  *90% of the observing time of the telescope devoted to a **deep-wide-fast survey***

  one complete visit of the southern hemisphere sky every 3-4 nights, from 2024 for 10 years

  each patch of the observable sky to be visited about 800 times

  43% of the celestial sphere will be covered by this survey

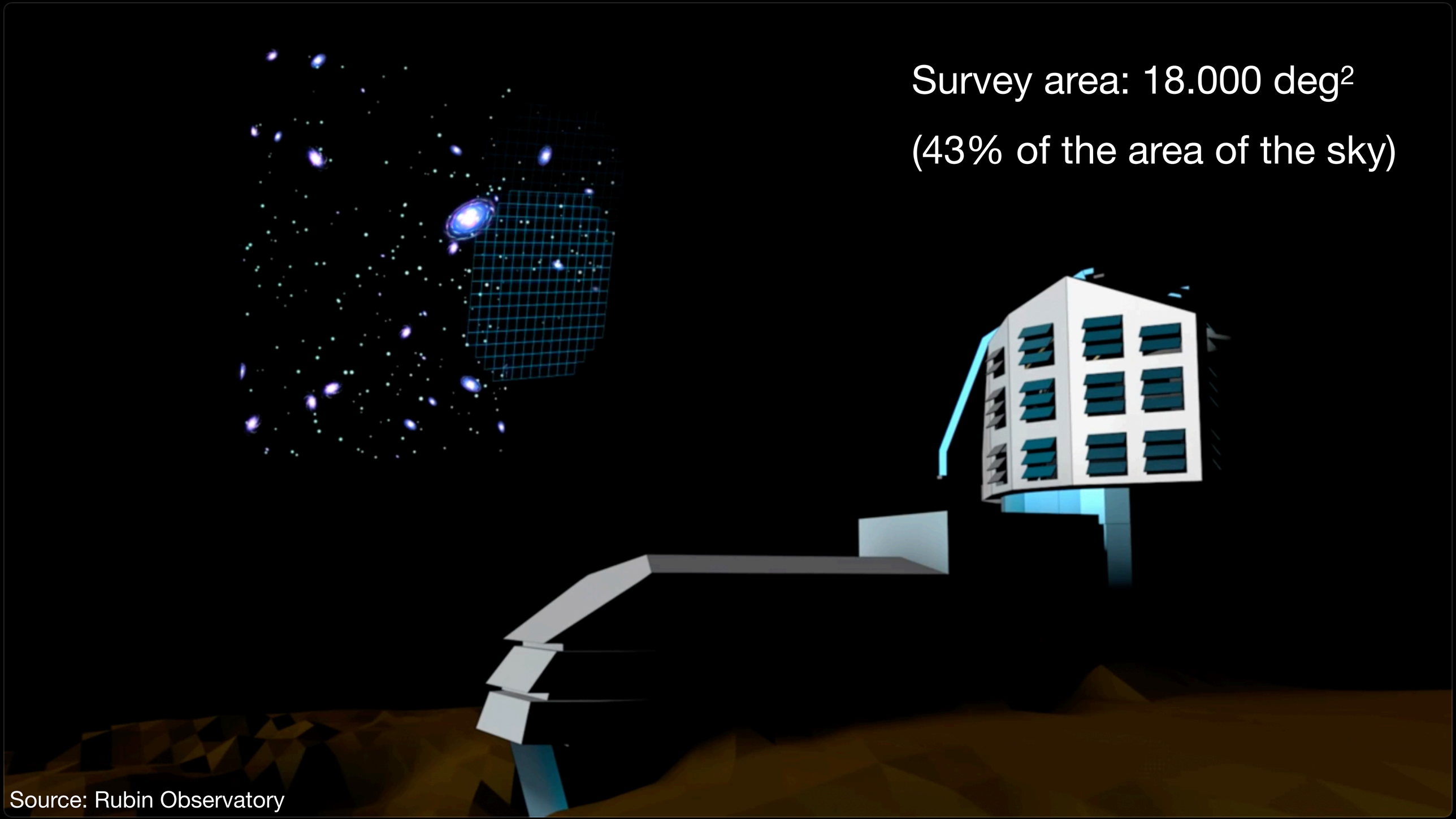
- ## Science themes

  *determining the nature of **dark energy** and **dark matter***

  *taking an inventory of the **solar system***

  *exploring the **transient** optical sky*

  *mapping the structure and evolution of the **Milky Way***


Survey area: 18.000 deg^2
(43% of the area of the sky)
Source: Rubin Observatory

Raw data

6.4 GB per exposure (compressed)

2000 science + 500 calibration images per night

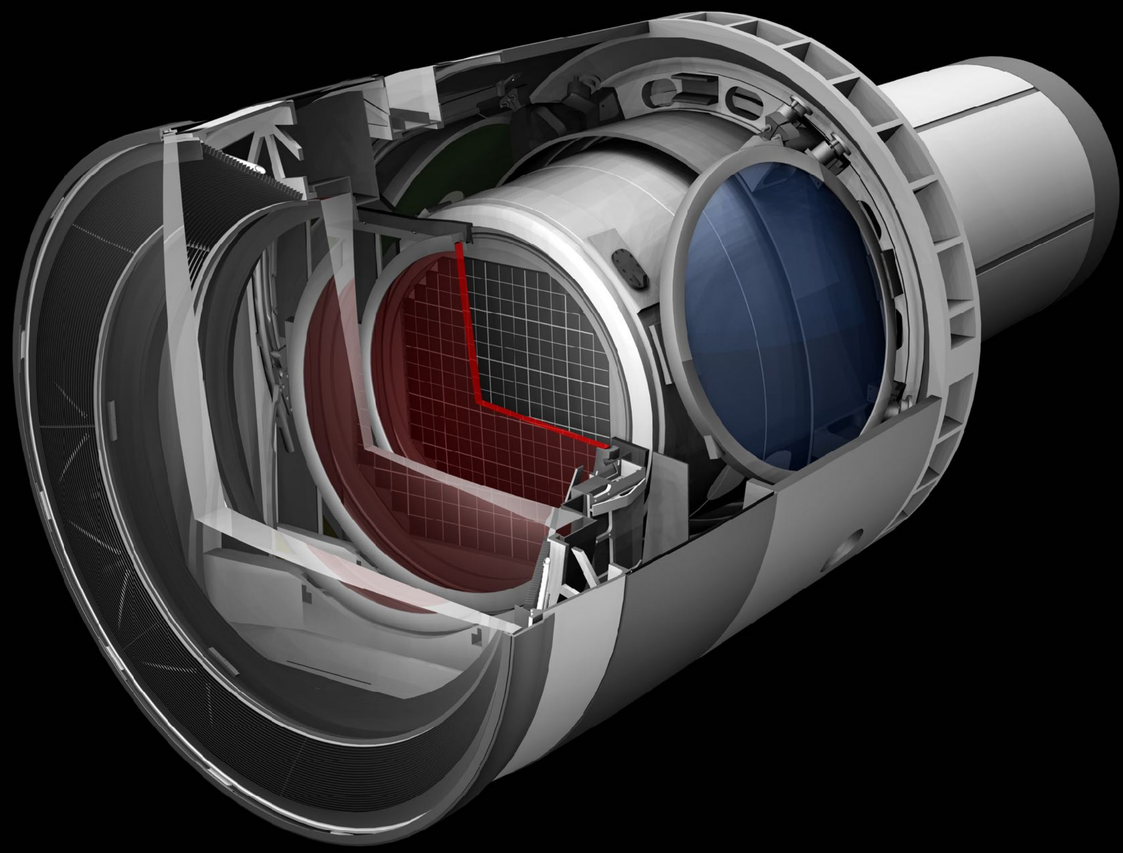
16 TB per night

300 nights per year, ~5 PB per year

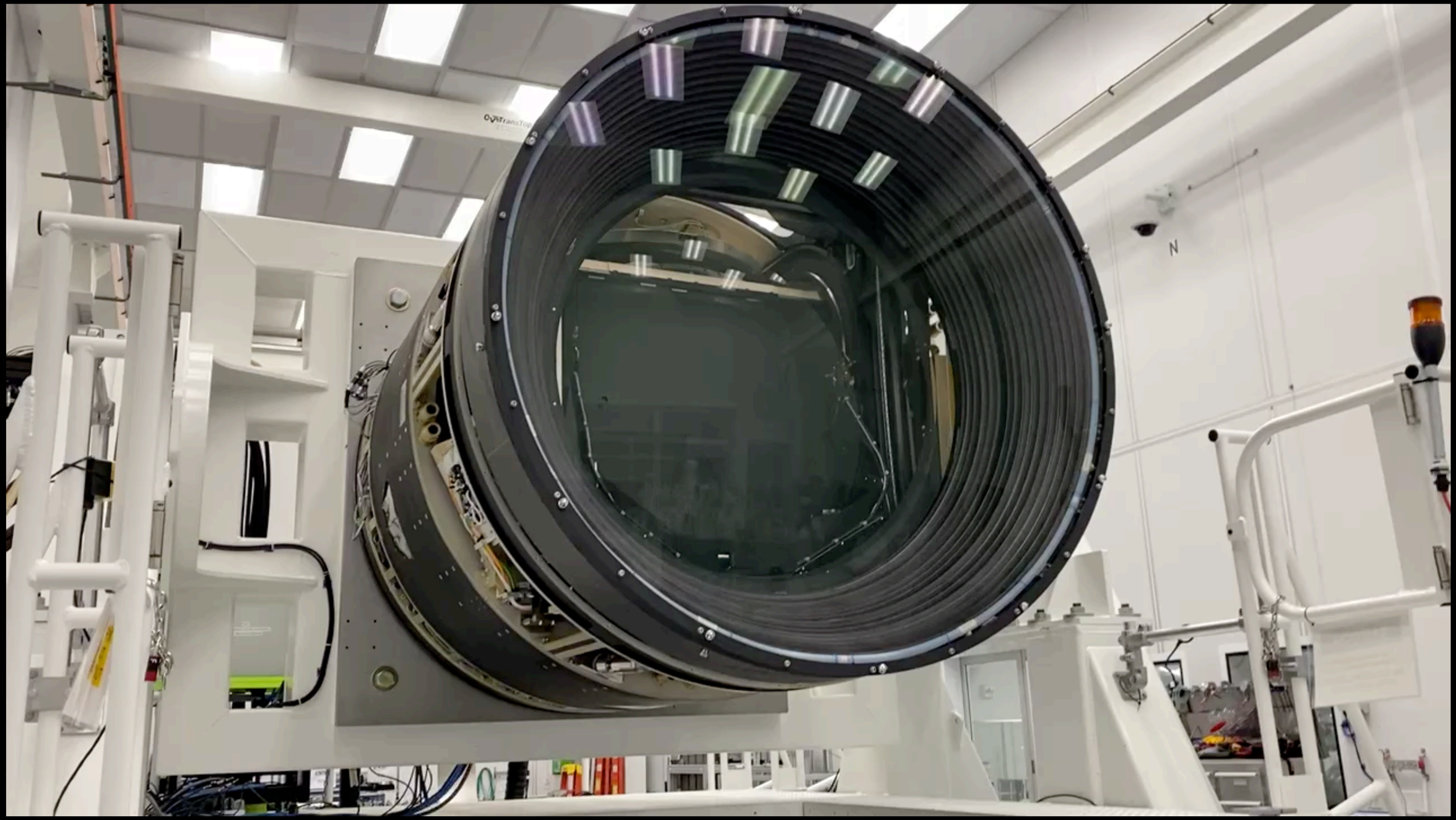
Aggregated data over 10 years of operations*, including derived data

image collection: ~6M exposures

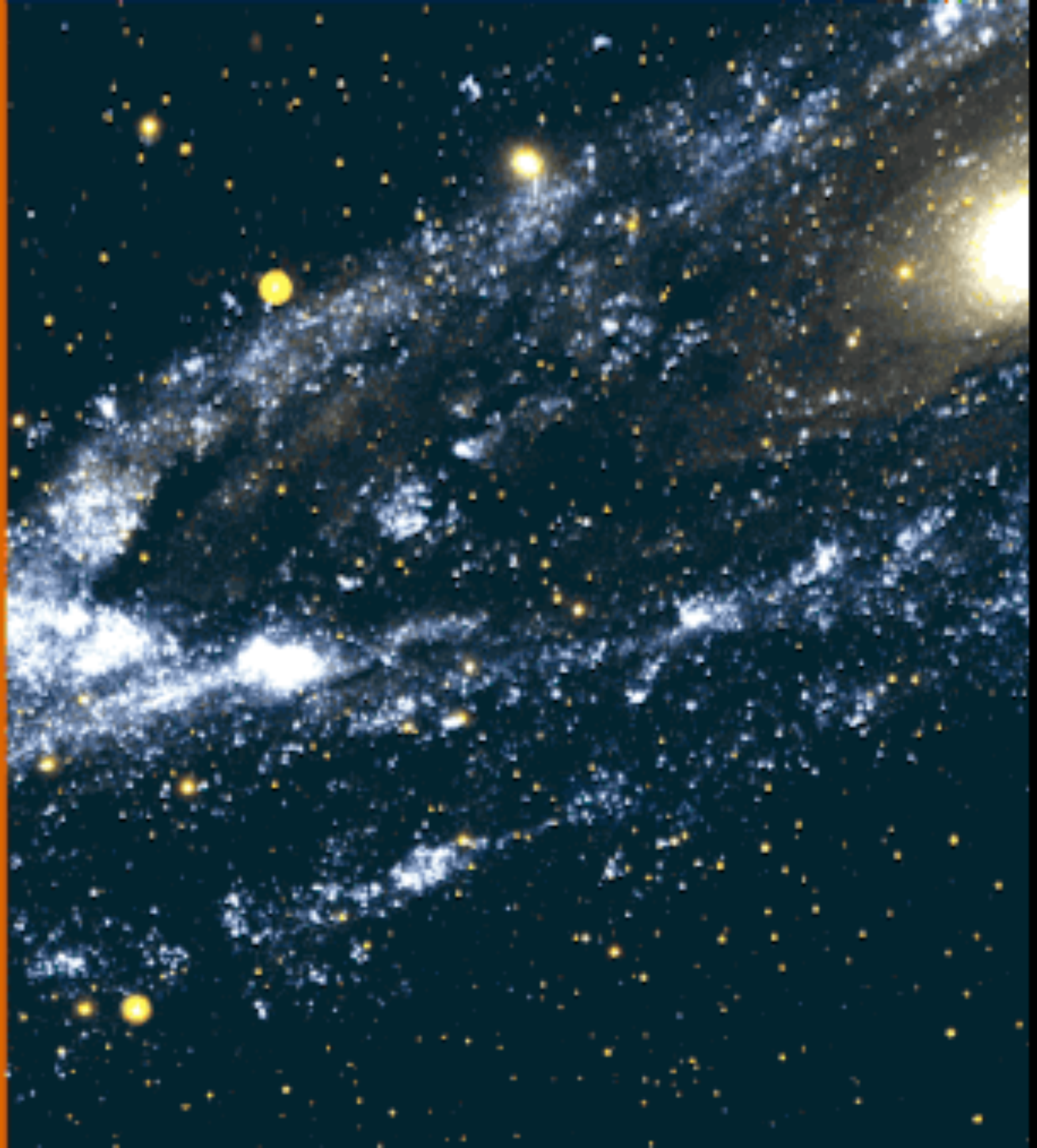
final catalog database: 15 PB

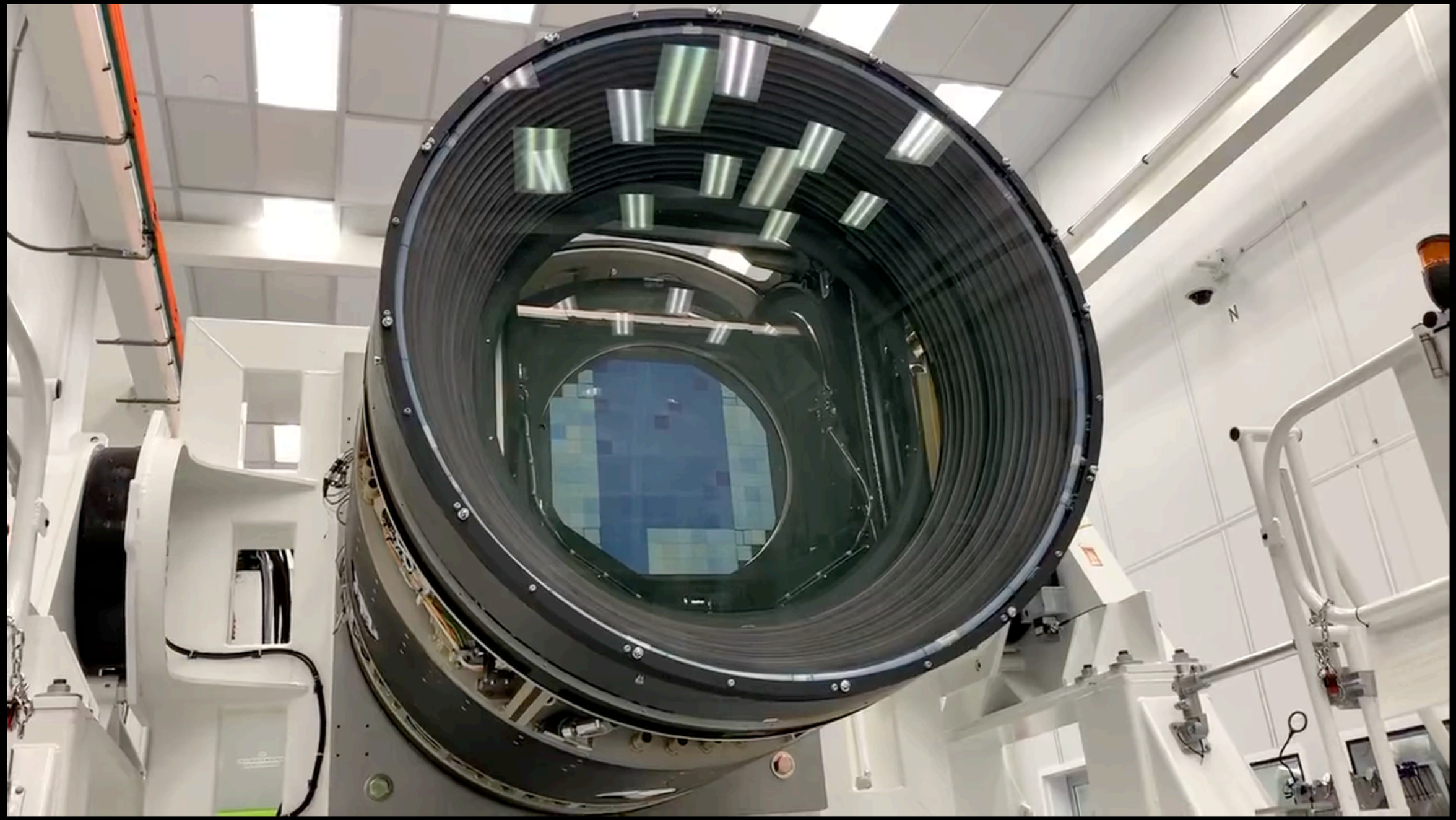


* source: LSST Key Numbers



Source: Rubin Observatory





Source: Rubin Observatory

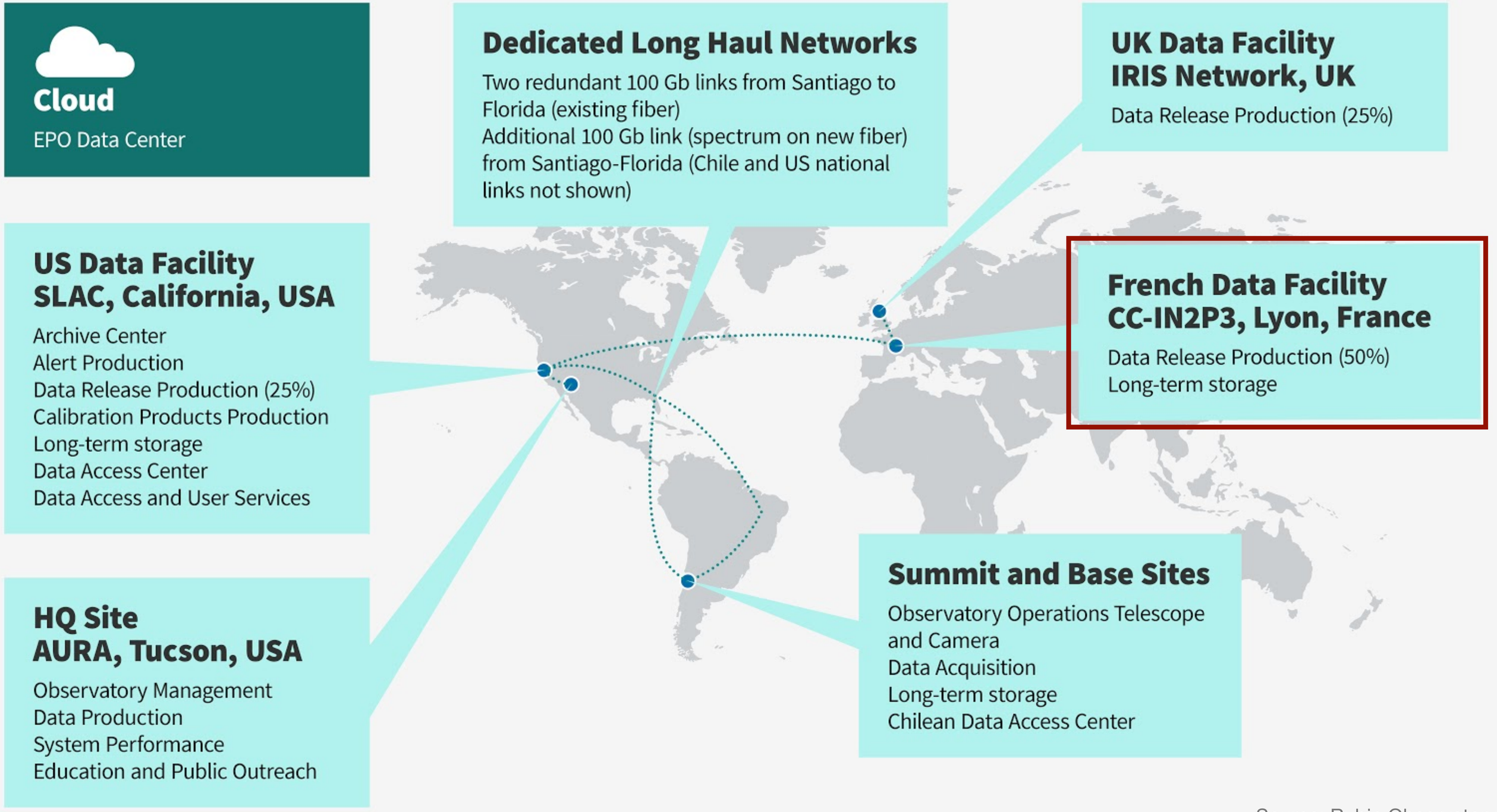
LSST-FRANCE

LSST-FRANCE

- 10 IN2P3 laboratories participating
  APC, CC-IN2P3, CPPM, IJCLab, IP2I, LAPP, LPC, LPNHE, LPSC, LUPM
- Effort: 56 FTEs per year on average (2012-2022)
  100+ individuals (scientists, engineers, technicians)

  contributions to camera design and construction, filter exchange system, data management
- Significant contributions to the Dark Energy Science Collaboration (DESC)

Data Management

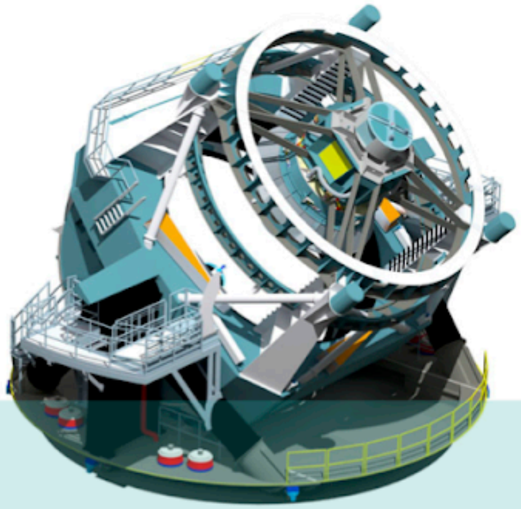


Source: Rubin Observatory

LSST DATA

Raw Data: 20TB/night

Sequential 30s images covering the entire visible sky every few days

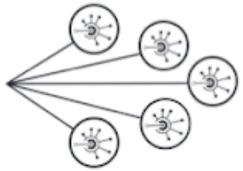


LSST SCIENCE PIPELINES

Prompt Data Products

Alerts: up to 10 million per night

60s via nightly alert streams



Community Brokers

Raw & Processed Visit Images, Difference Images, Templates

Transient and variable sources from Difference Image Analysis

Solar System Objects: ~ 6 million

24h via Prompt Products DB

Data Release Data Products

Final 10yr Data Release:

- Images: 5.5 million x 3.2 Gpixels
- Catalog: 15PB, 37 billion objects

via Data Releases

Rubin Data Access Centres (DACs)

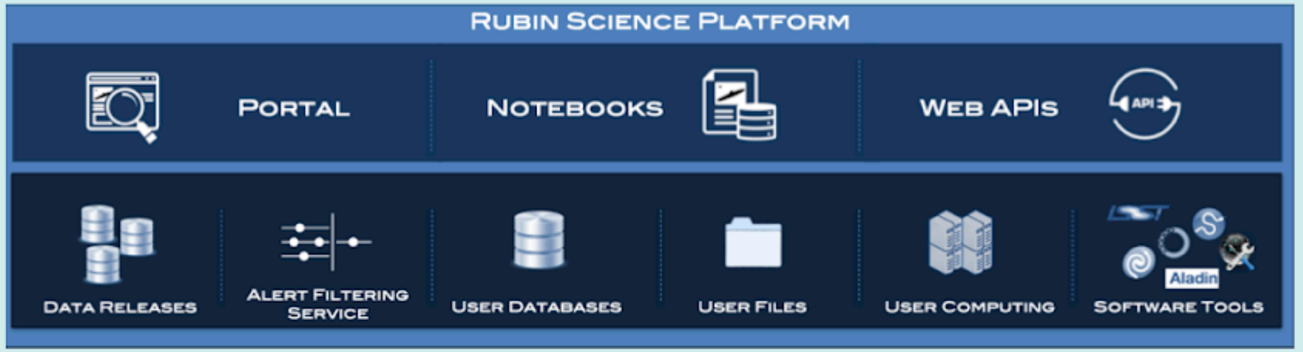
USA (USDF)
Chile (CLDF)
France (FRDF)
United Kingdom (UKDF)

Independent Data Access Centers (IDACs)

Access to proprietary data and the Science Platform require Rubin data rights

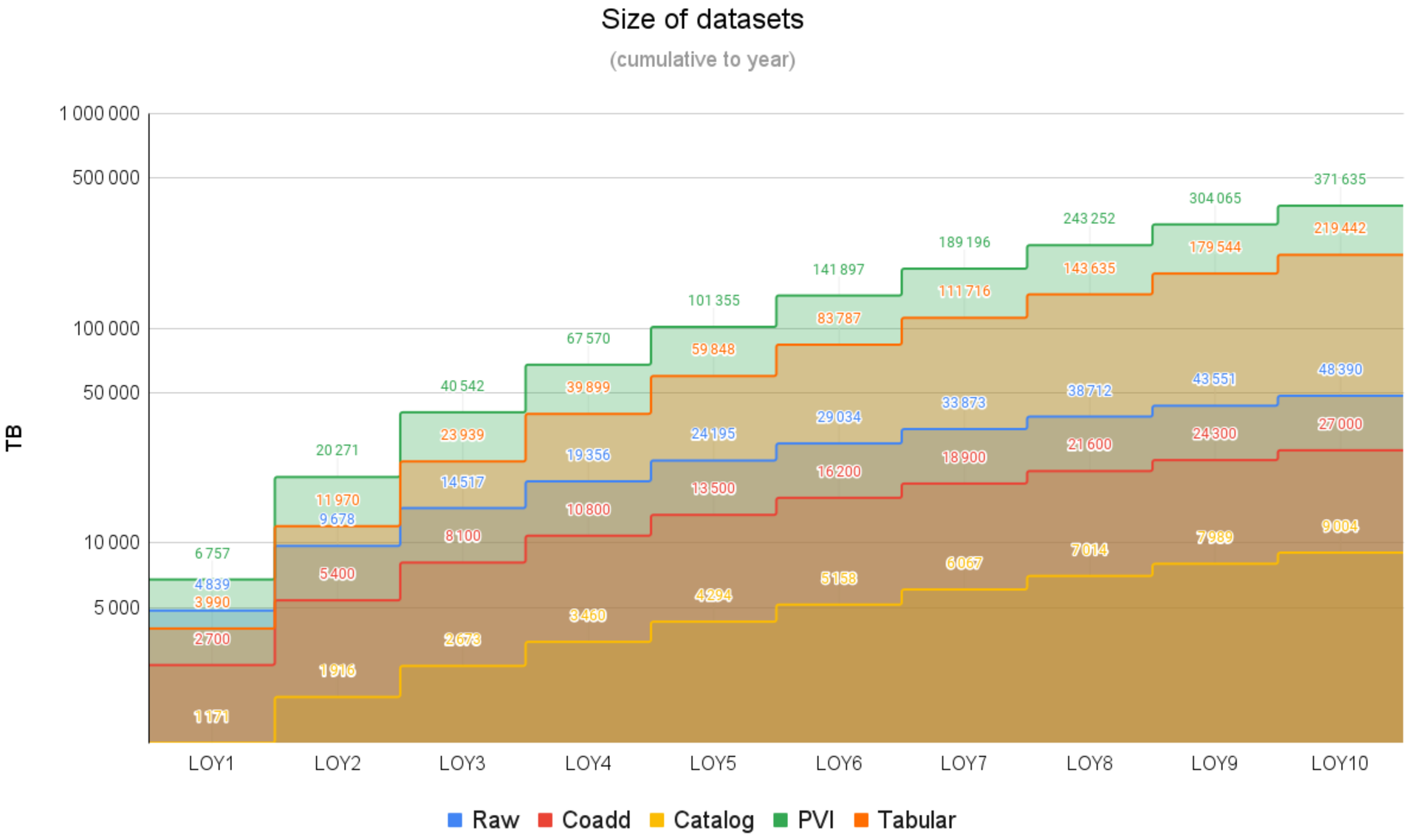
Rubin Science Platform

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



Credit: Leanne Guy

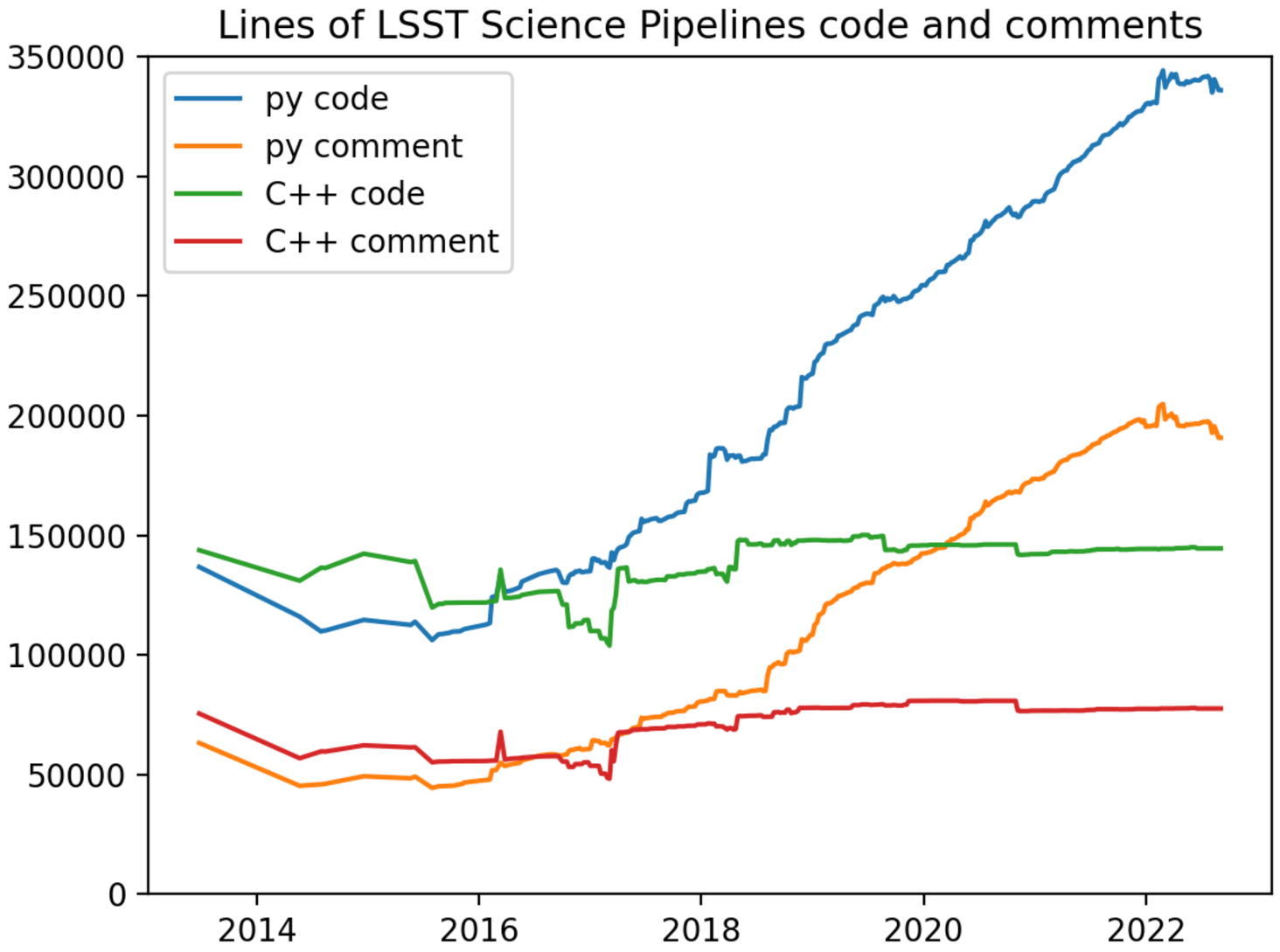
LSST DATA VOLUME



~0.5 EB of data by the end of the survey in 2035

← raw image data

IMAGE PROCESSING



Source: T. Jenness, Rubin Observatory

Lower layer written in C++ for performance

Upper layer in Python for convenience and expressivity

Open source development:
https://github.com/lsst

Very good documentation
https://pipelines.lsst.io

IMAGE PROCESSING (CONT.)

- Observed ratio RAM per CPU core higher than typical accelerator experiment*

  most stages of the image processing pipelines require less than 20 GB

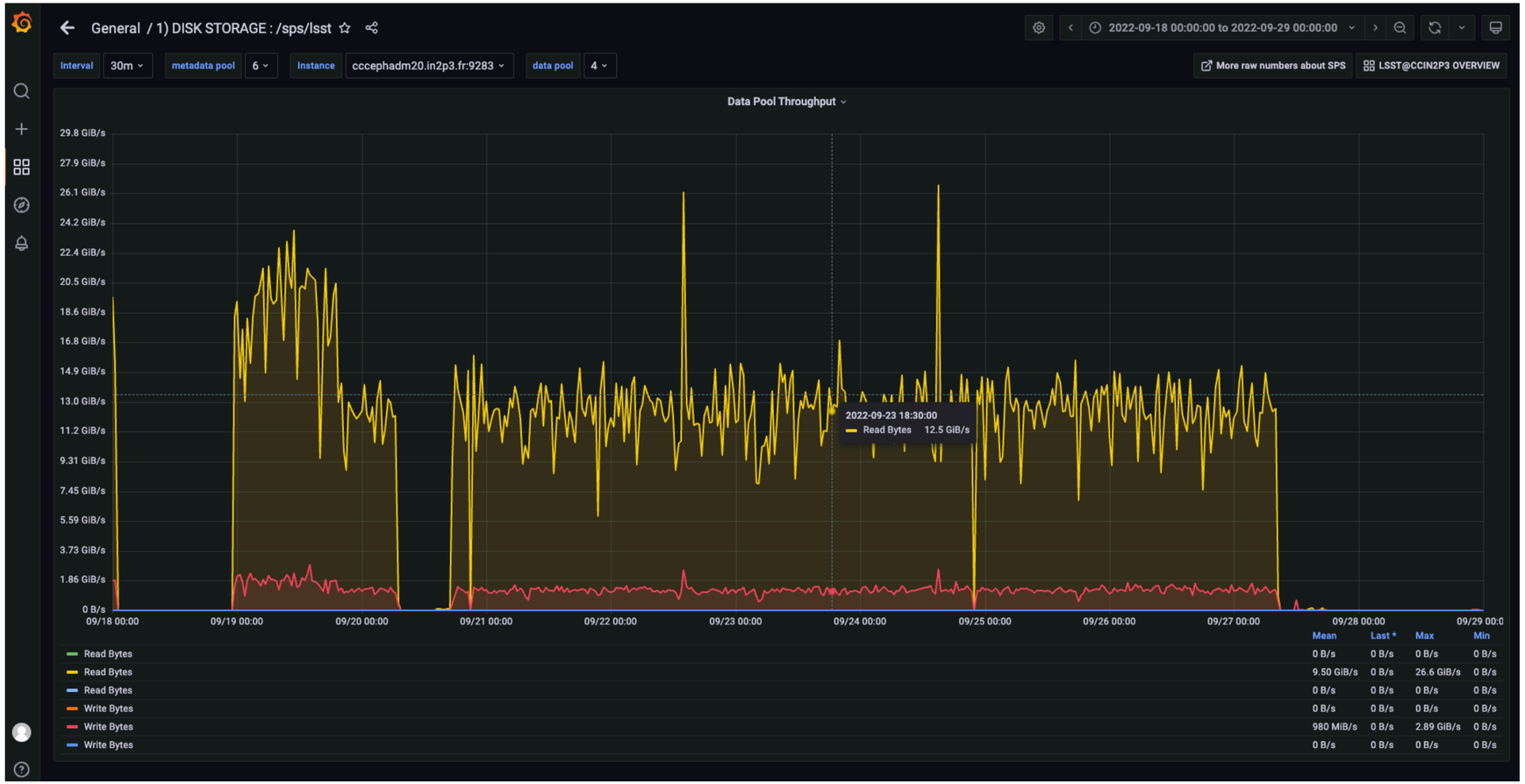
  a few require up to 170 GB

  for comparison, typical LHC ratio is 3 to 4 GB per CPU core

- This has direct consequences on the configuration of the hardware that we need to provision, its cost as well as the configuration of the batch farm

* observations made by processing images from the DESC DC2 simulated sky survey for Rubin Data Preview 0.2

IMAGE PROCESSING (CONT.)



Observed I/O throughput delivered and ingested by CephFS for image processing needs*:

read: 12 GB/s

write: 1.6 GB/s

3000+ CPUs were used simultaneously for processing images in the Slurm batch farm

* for comparison, aggregated throughput for ATLAS, CMS and LHCb (July-Sep 2022):
read: 5.4 GB/s
write: 2.8 GB/s

ASTRONOMICAL CATALOG DATABASE

- Read-only relational database

  contains the physical properties of the celestial objects and light sources extracted by processing the science images

  exposes subset of SQL to scientists

- Few number of very tall tables

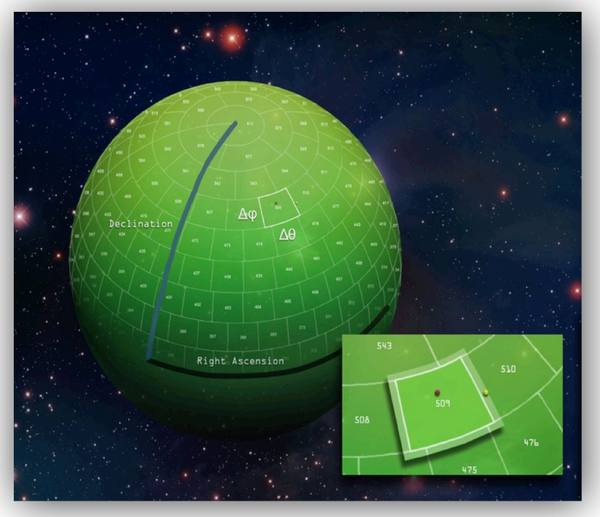
table	rows	columns	storage
ForcedSource	50 T	10s	2 PB
Source	9 T	100s	5 PB
Object Extra	1.5 T	1000s	1.2 PB
Object	47 B	1000s	100 TB

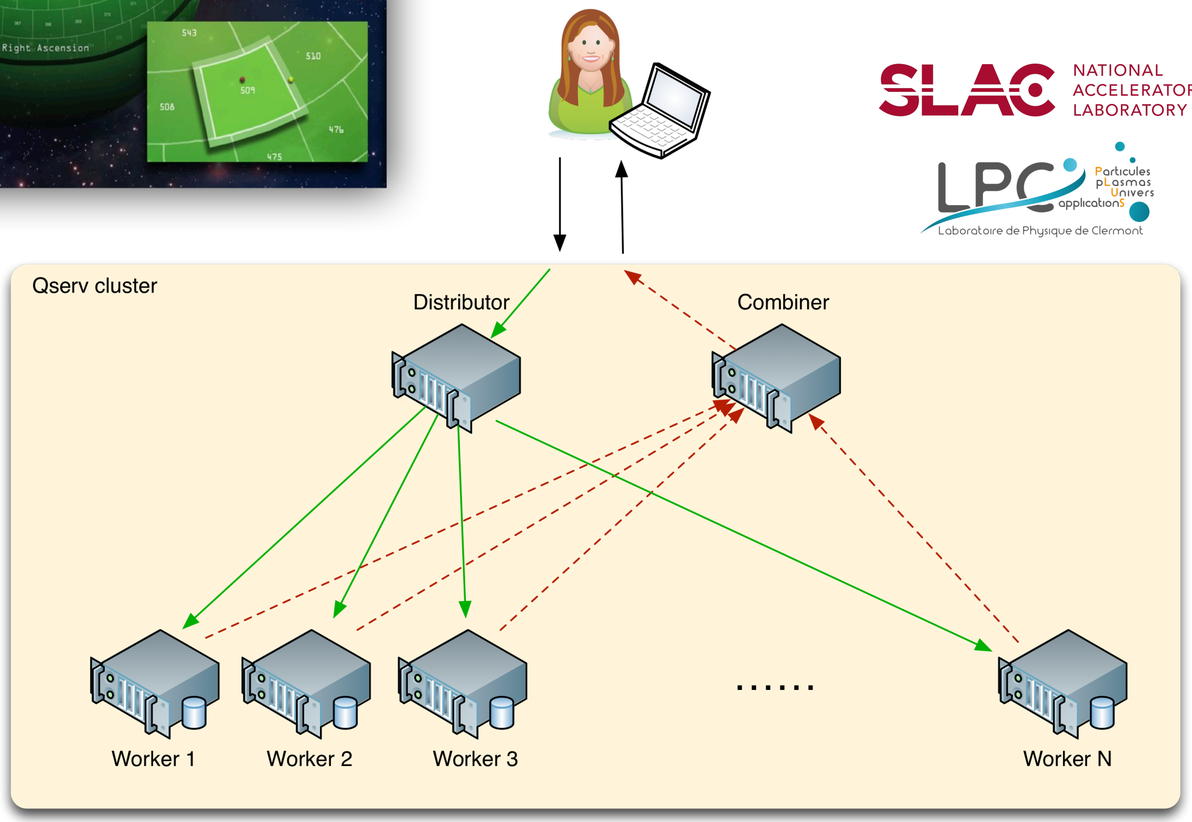
(see Data Preview 0.2 schema browser)

Adapted from F. Mueller, Rubin Observatory

ASTRONOMICAL CATALOG DATABASE (CONT.)

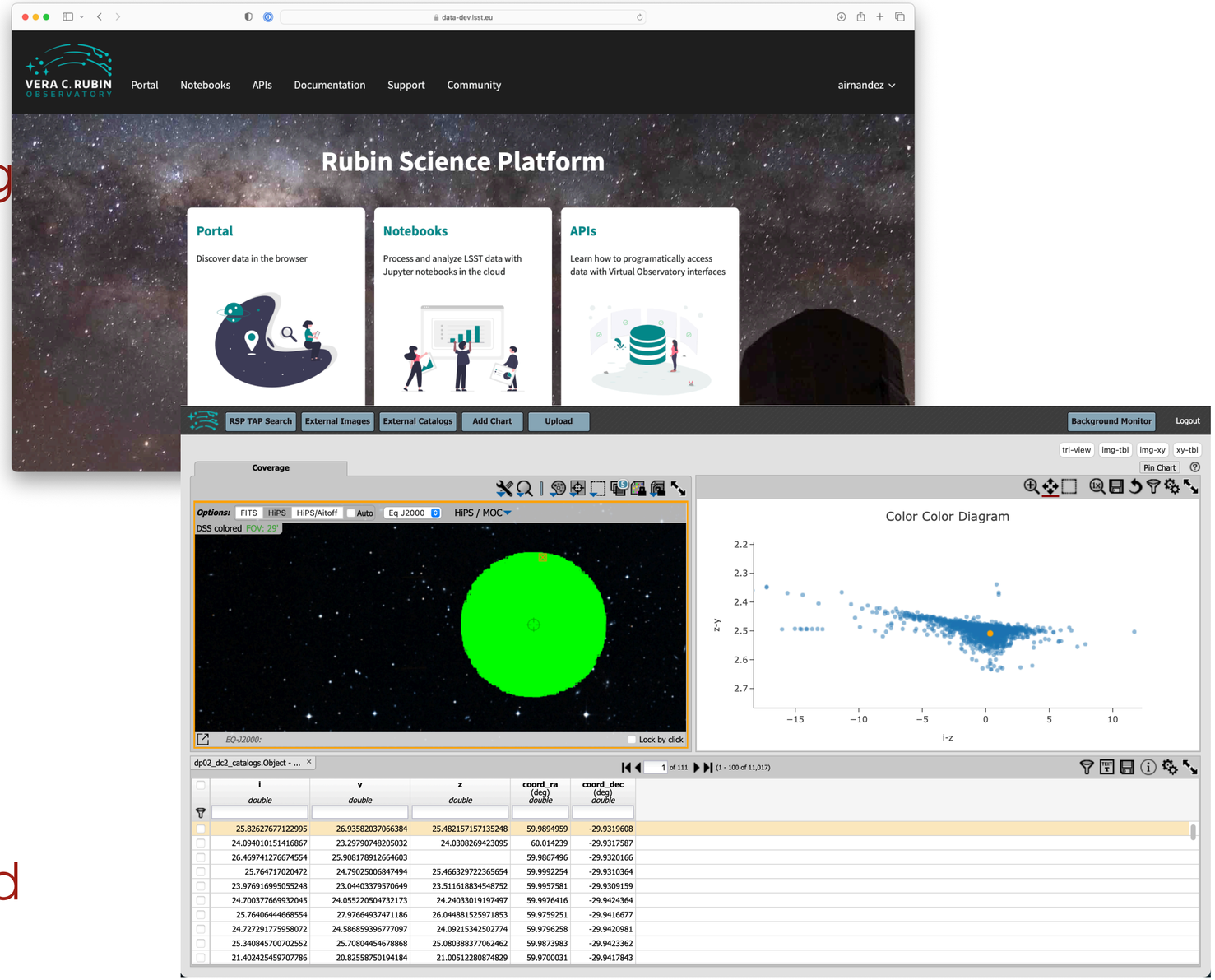
- Data spatially partitioned
  catalog contents physically distributed over a set of independent database servers
- CC-IN2P3 instance
  15 database servers
- Packaged as a Kubernetes application





INTERACTIVE DATA ANALYSIS PLATFORM

- Integrated web-based environment for scientific exploration of image and catalog data
  - *both GUI and programmatic interfaces*
  - *execution of Python notebooks*
  - *allows for execution of heavier analysis exploiting the capacity of the batch farm (via Dask)*
  - *visualisation of images, navigation, tabular data, graphics*
  - *interfaced with LSST own catalog as well as external catalogs (via IVOA interfaces)*
- Architected as a set of cooperating services orchestrated by Kubernetes



Source: G. Mainetti

INFRASTRUCTURE SOFTWARE SYSTEMS

- Rubin uses (or evaluates) software systems developed by or for other science projects, e.g.

global software distribution: CernVM-FS (see https://sw.lsst.eu)

data storage: dCache

distributed job execution: ATLAS' PanDA, Nordugrid's ARC CE

workflow execution: Parsl

inter-site data replication: Rucio, FTS

virtual organisation membership: VOMS

…

Conclusions

- Data set of significant size
  challenging in terms of transport and storage

  image processing requirements somehow different from processing particle collision events

- Platforms for interactive scientific data analysis are new challenges for us
  e.g. astronomical catalog, science analysis platform, alert broker

- We are actively preparing and progressively getting ready to meet those challenges

our goal is to equip science teams with the best possible environment to scientifically exploit the data collected by this unique instrument

See also

- Vera C. Rubin Observatory
  https://www.lsst.org
- Rubin LSST-France
  https://www.lsst.fr