LSST in the starting blocks

Cyrille Doux
LPSC Grenoble (CNRS/IN2P3)
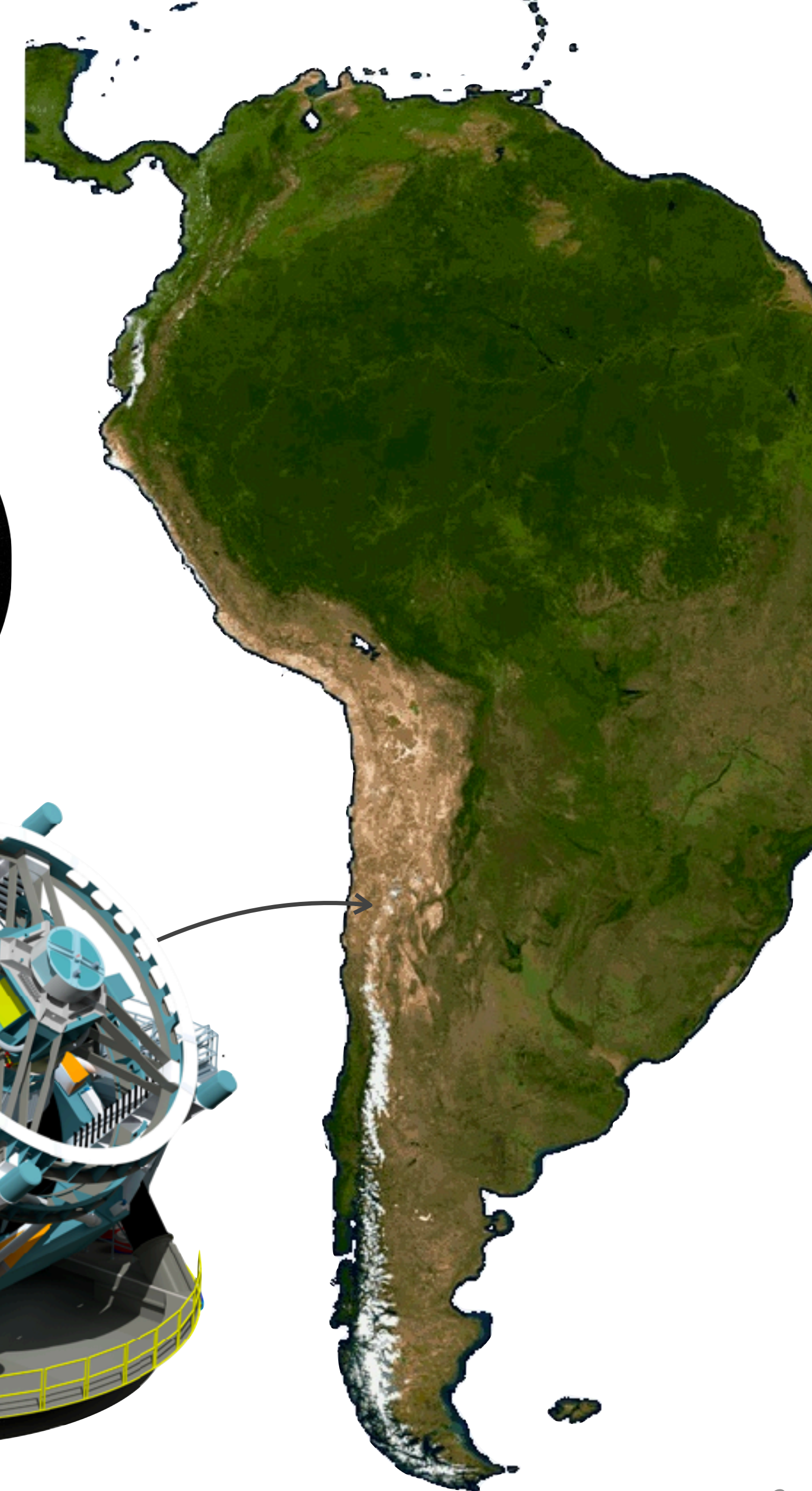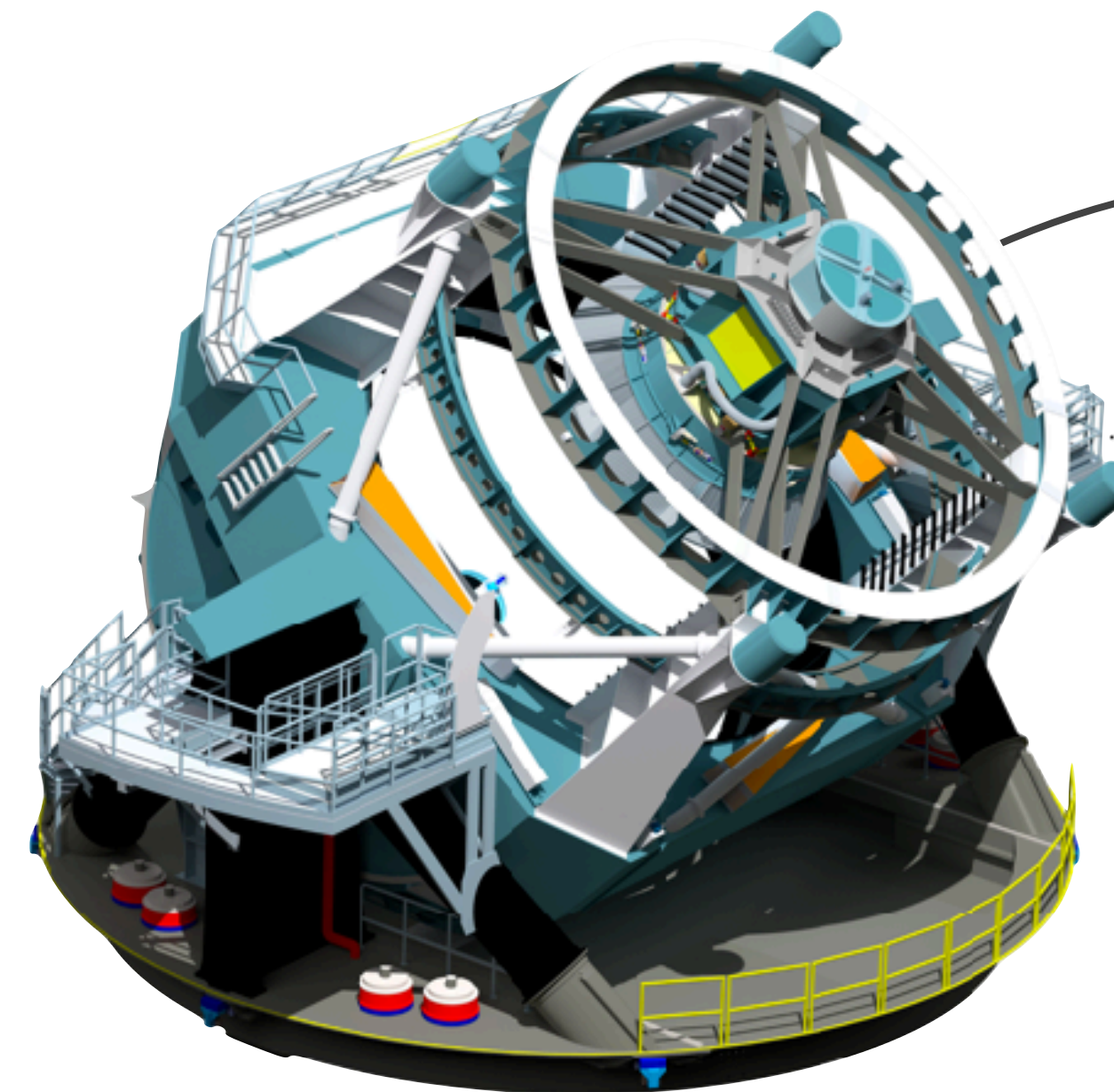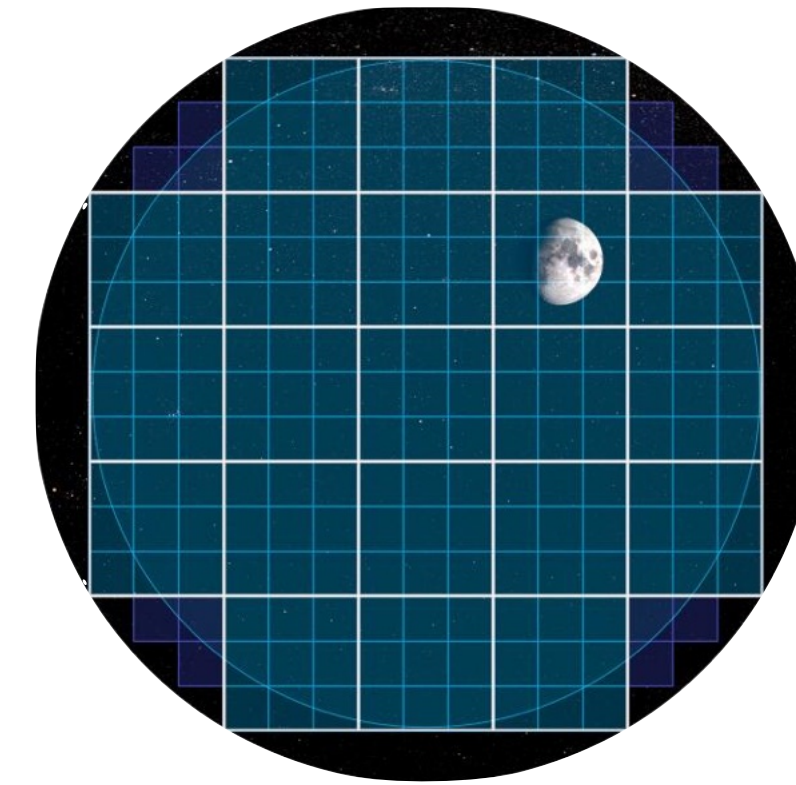
on behalf of the Rubin/LSST-France group

GDR CoPhy - May 21st 2024

Vera C. Rubin Observatory

‣ Located at Cerro Pachón, Chili
Atacama desert - 2647m high

‣ Wide-field telescope
3.5° FoV - 8.4 primary mirror - 6.4m effective

‣ LSSTCam camera
3.2 Gpix - 0.2"/pix - optical filters *ugrizy*

Legacy Survey of Space and Time

- **Wide-fast-deep photometric survey 2025-2035**

  - wide: 18000 deg2 in the southern sky

  - fast: scanned every 3 days

  - deep: up to magnitude r<27.5

- **Goals**

  - **Probing dark energy and dark matter**

  - Taking an inventory of the solar system

  - Exploring the transient optical sky

  - Mapping the Milky Way

- **Expected number of objects (full survey, DR11)**
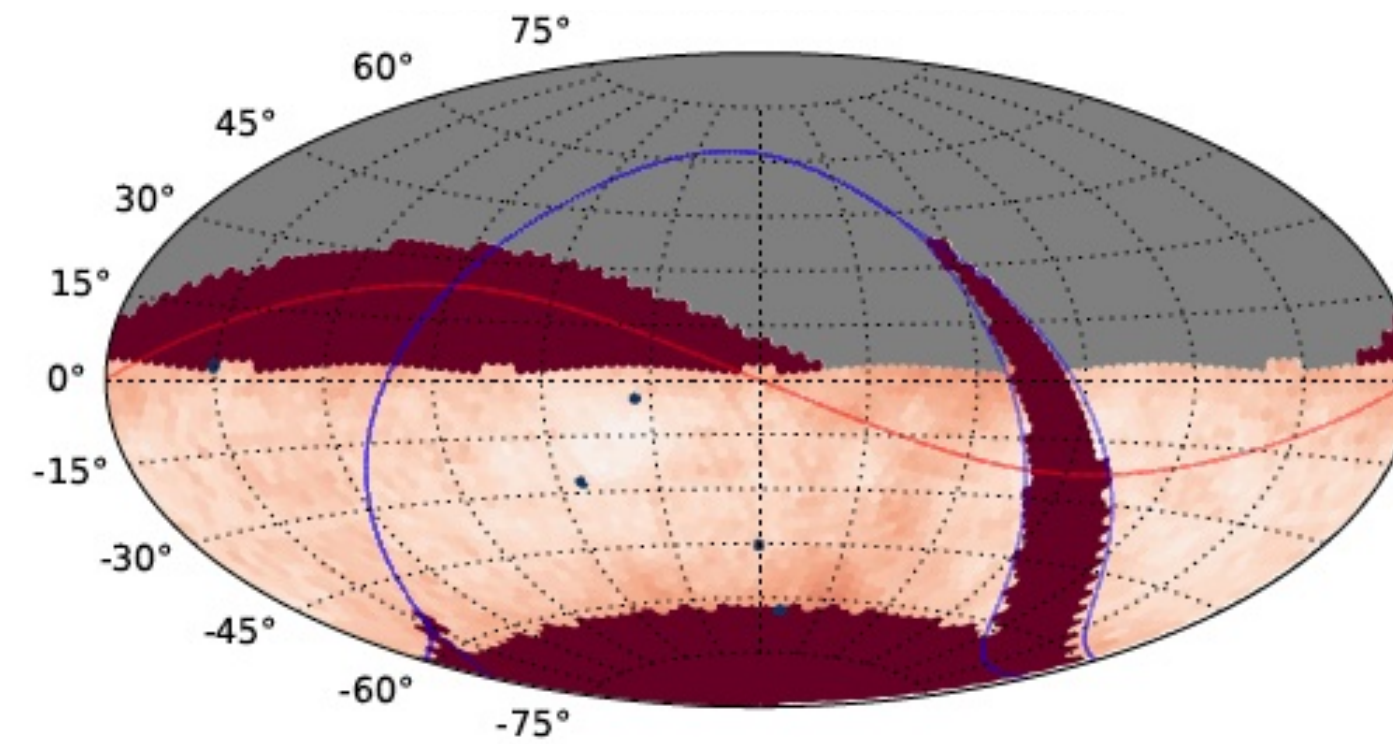
  - 20B galaxies, 17B resolved stars, 6M orbits of solar system bodies

  - ~10 million live alerts every night = 10^6 SNIa, 10^6 asteroids, see lse-163.lsst.io

Zahn & Tyson 17

Number of visits i band
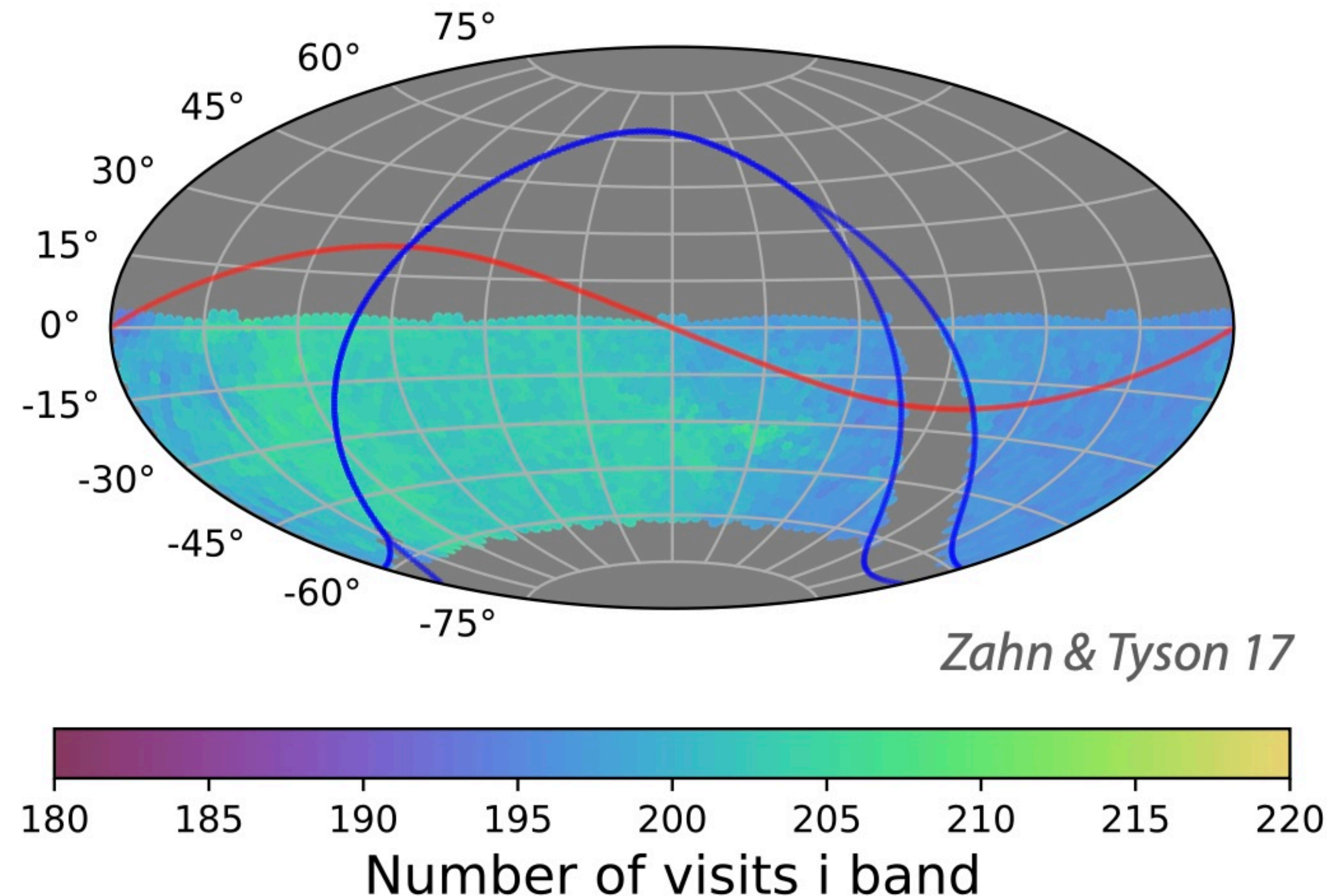
Project organization in a nutshell

LSST Science collaborations

- Dark Energy Science Collaboration
- Transients and Variable Stars Science Collaboration
- Strong Lensing Science Collaboration
- Active Galactic Nuclei Science Collaboration
- Galaxies Science Collaboration
- Stars, Milky Way, and Local Volume Science Collaboration
- Solar System Science Collaboration
- Informatics and Statistics Science Collaboration

▸ Rubin Observatory team serves high quality data to the community

▸ LSST science collaborations perform scientific analyses

Lots of exciting news from

- ▸ Vera C. Rubin Observatory
- ▸ DESC
- ▸ LSST France
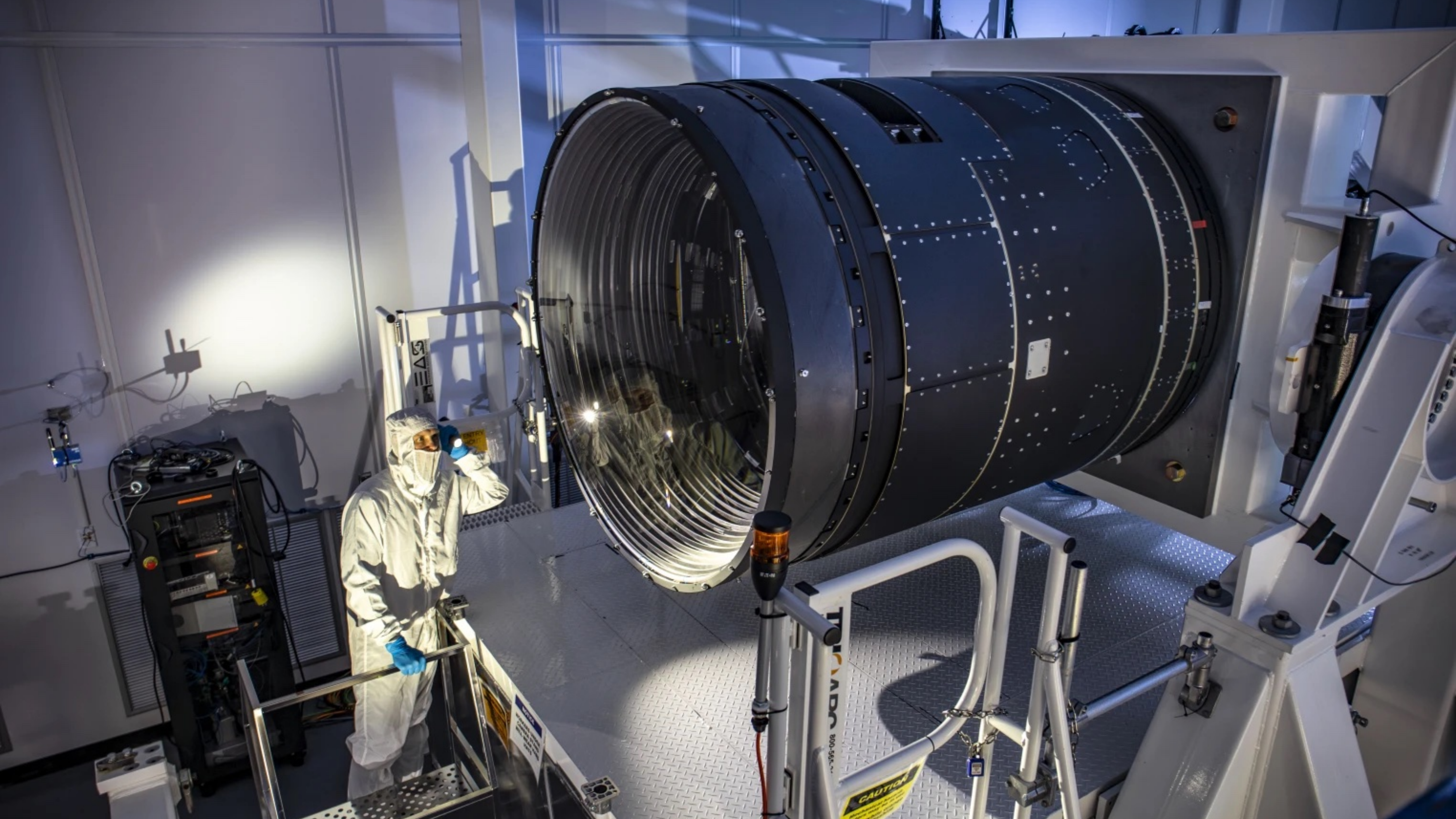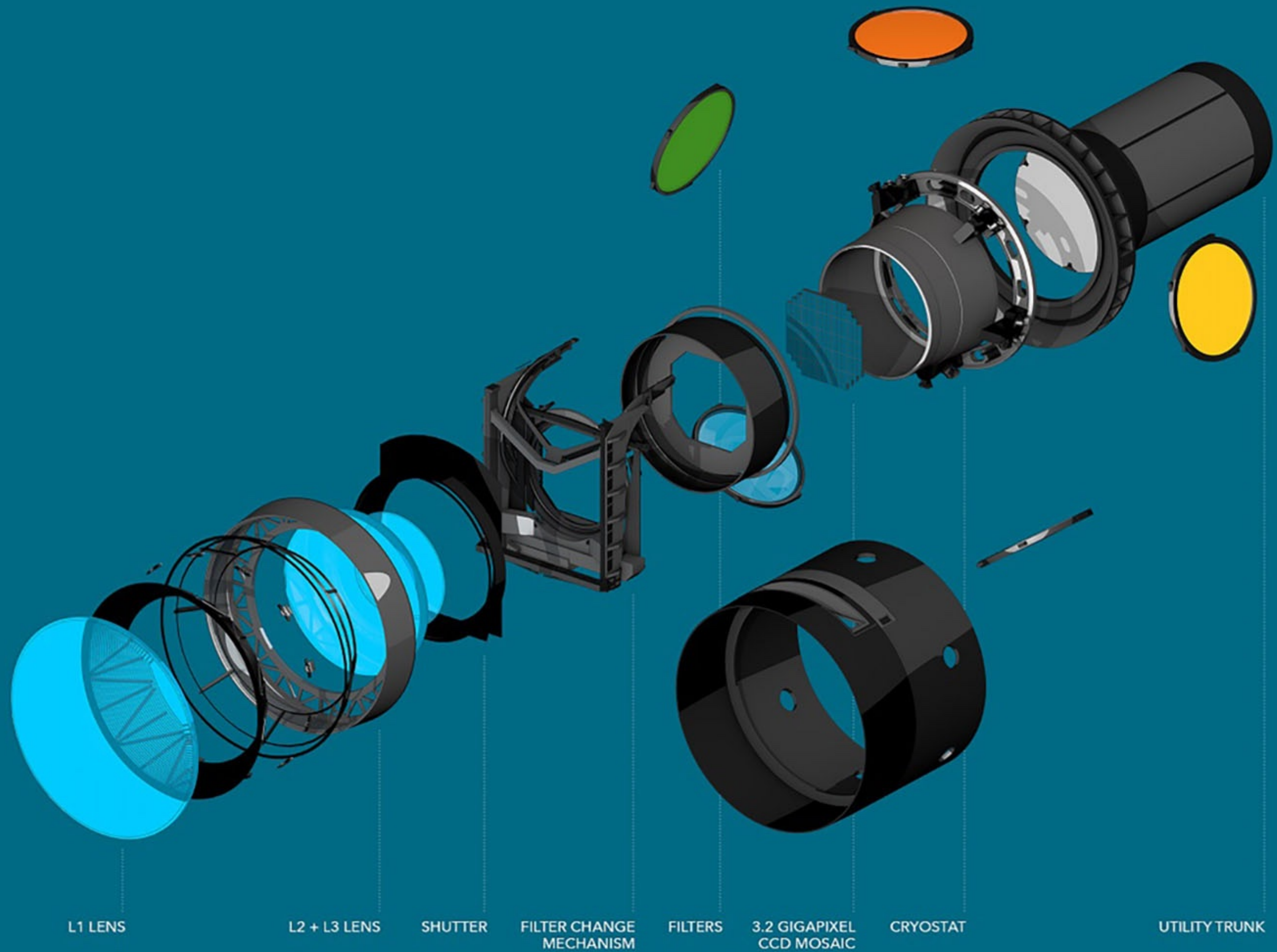
L1 LENS   L2 + L3 LENS   SHUTTER   FILTER CHANGE MECHANISM   FILTERS   3.2 GIGAPIXEL CCD MOSAIC   CRYOSTAT   UTILITY TRUNK

Optical design

3 x 3
CCD "raft"

4K x 4K
science CDD
with 16 outputs

3.5-degree
field of view
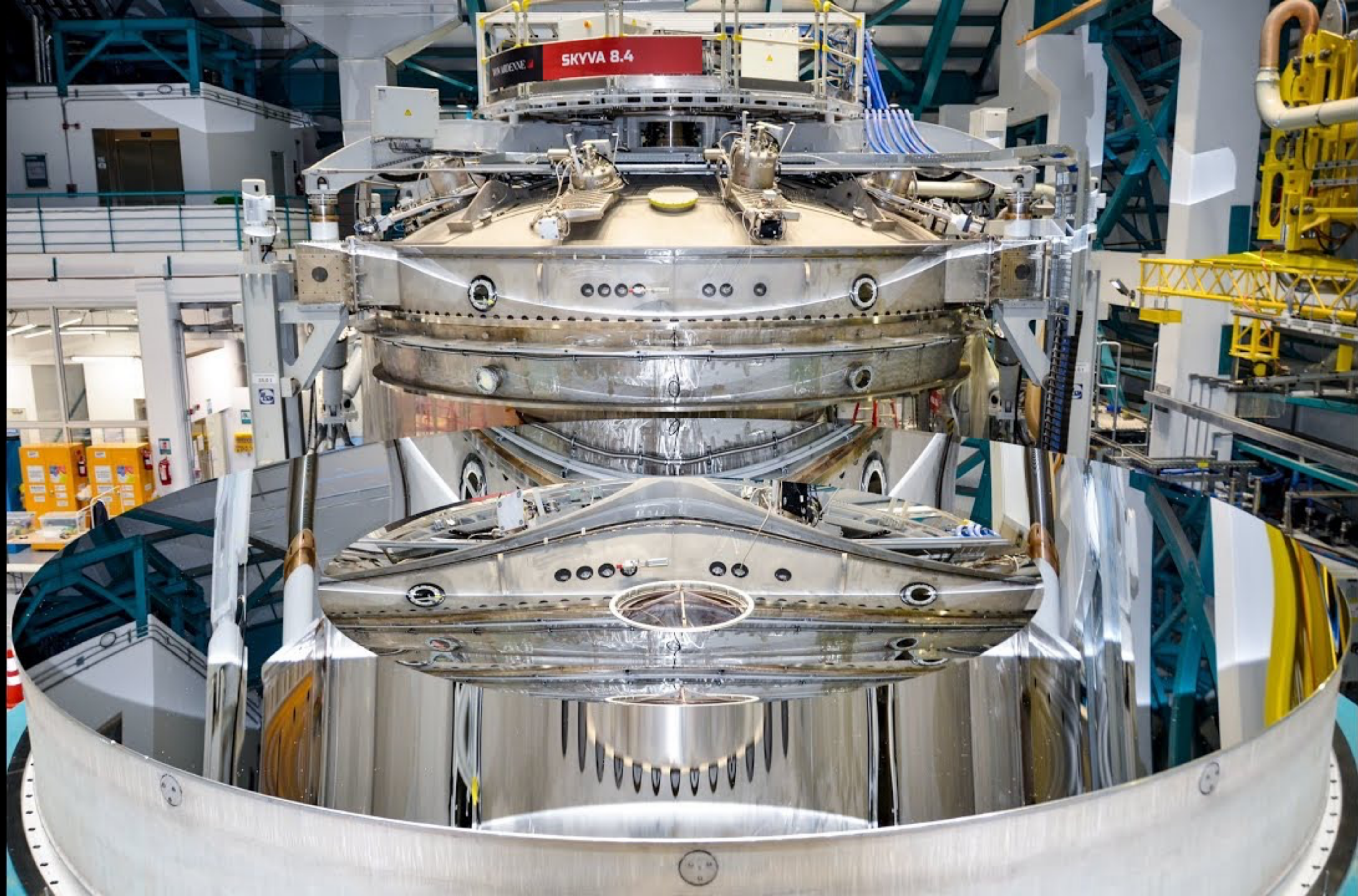
Angular size of the
moon in comparison
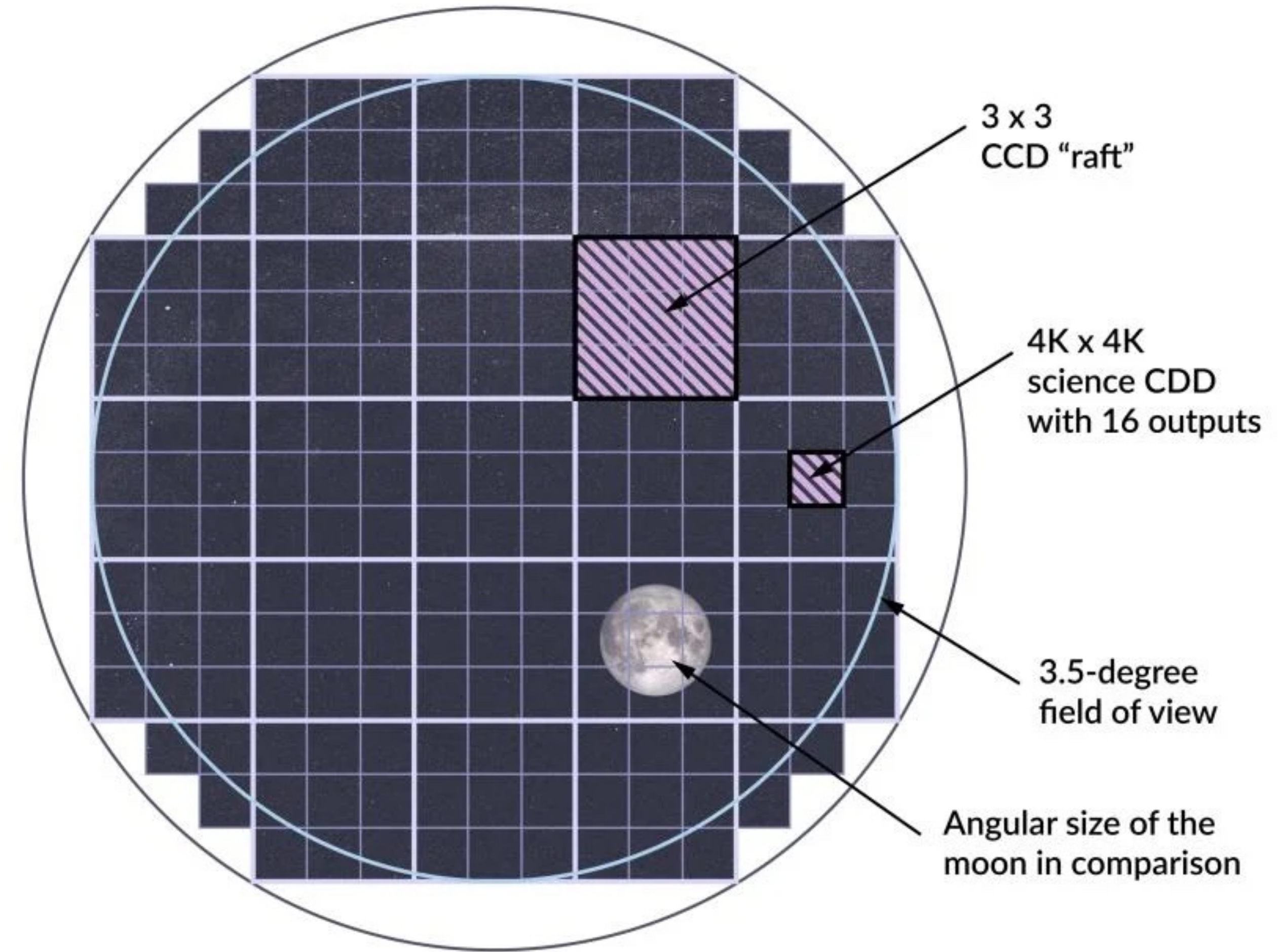
Many milestones in 2024!

Date	Milestone
March 1 2024	**TMA Final Testing Complete**
April 27 2024	**M1M3 Coating Complete**
May 15 2024	LSSTCam Shipping to Summit
July 3 2024	M2 Glass on TMA
July 12 2024	ComCam Installed on TMA
July 19 2024	LSSTCam Reverification Start
July 26 2024	M1M3 Glass on TMA
July 29 2024	ComCam First Photon
Sept 25 2024	LSSTCam Reverification End
Nov 11 2024	LSSTCam on TMA
Jan 3 2025	Rubin First Photon
March 26 2025	Rubin First Light 🦖

Subset of milestones listed on https://dmtn-232.lsst.io/

Telescope Mount Assembly (TMA)
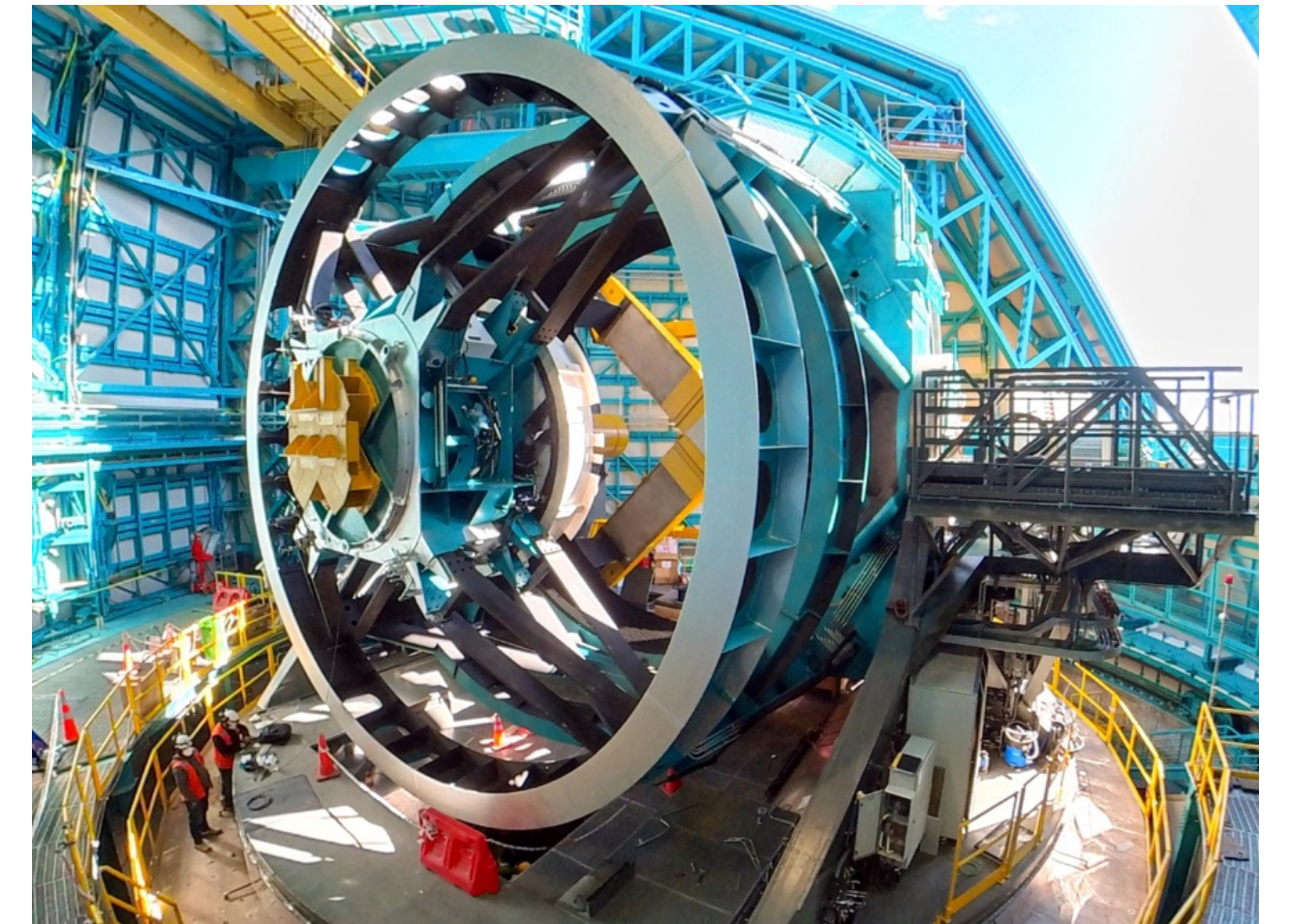
Top to bottom: M2 mirror, LSST/ComCam, M1M3 mirror

BTW, they're hiring devs, techs, etc.

Rubin data release timeline

Rubin Operations Survey and Data Release Timeline

Nominal LSST Start Date: August 2025

Event	Date Range	2024	2025	2026	2027	2028
Data Preview 0.1	Delivered Jun 2021					
Data Preview 0.2	Delivered Jun 2022					
Data Preview 0.3	Delivered Jun 2023					
Data Preview 1	Oct 2024 – Jul 2025					
System First Light	Jan 2025 – May 2025					
Start of Operations	May 2025 – Sep 2025					
Start of LSST (SVY)	May 2025 – Nov 2025					
Data Preview 2	Nov 2025 – May 2026					
Data Release 1	May 2026 – Jan 2027					
Data Release 2	May 2027 – Jan 2028					
Data Release 3	May 2028 – Nov 2028					
		J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D	J F M A M J J A S O N D

https://rtn-011.lsst.io/

DP2 = science validation data ~ early 2026

DR2 = LSST Y1 data ~ early 2028

Commissioning

in-dome/on-sky engineering - system optimisation - science validation surveys

Observing strategy

Balancing science drivers

▶ **Wide-fast-deep survey**

  ‣ 18,000 deg² in *ugrizy* observed 3 times/week

  ‣ 800 visits/patch after 10 years (uneven across bands)

▶ **Deep drilling fields**
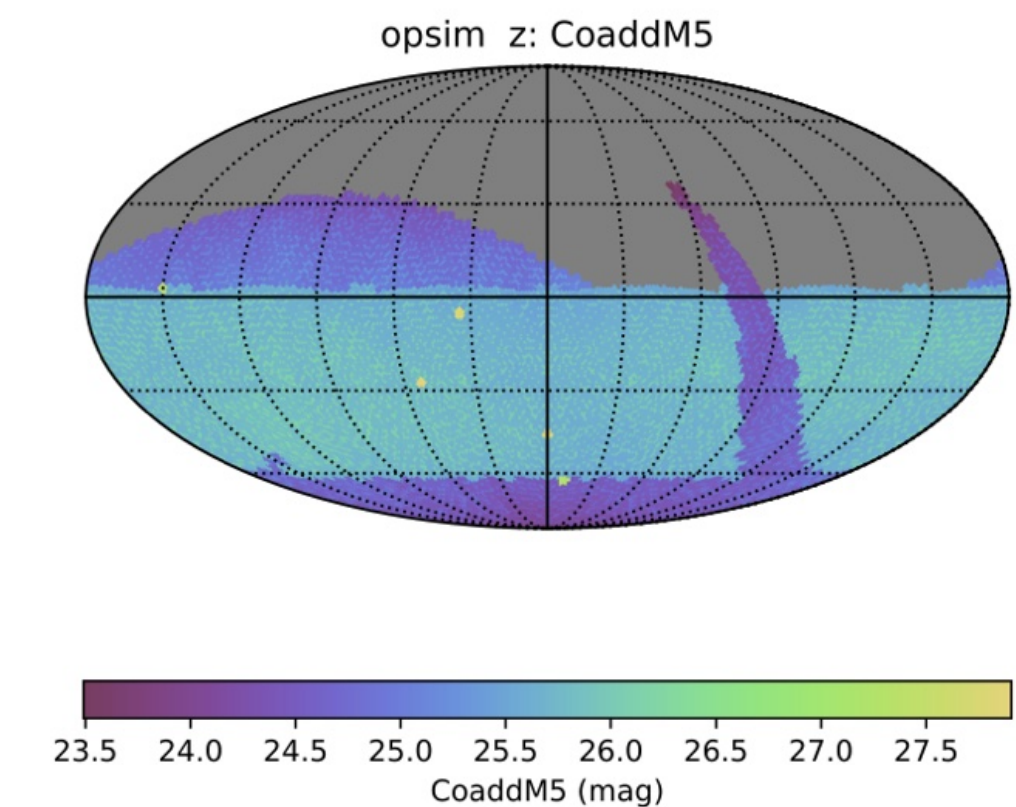
  ‣ 5 DDFs, 21000 visits (40000 for COSMOS)

  ‣ ~6% of total survey time

▶ **See survey-strategy.lsst.io**

  ‣ SCOC reports (due fall 2024) and more

▶ DESC recommendations to update *rolling* cadence for WFD, DDF and ultra DF to balance SN and WL requirements

(see Gris+23; Gris+24 for SN+WL deep fields)

Coadded depth in *griz* bands
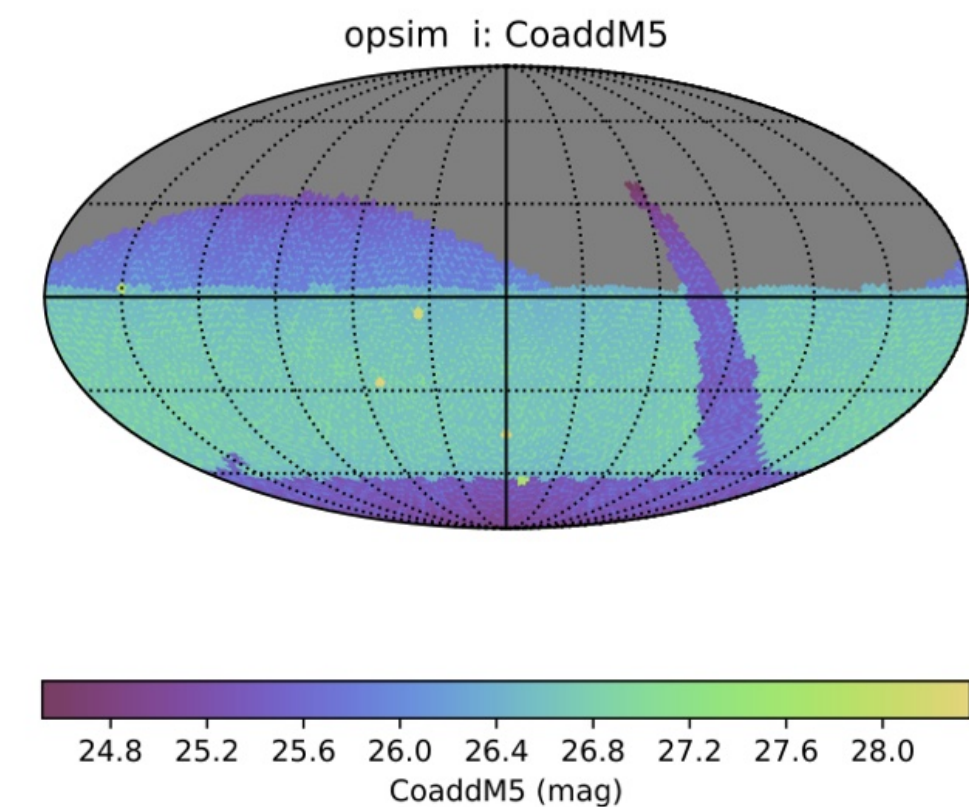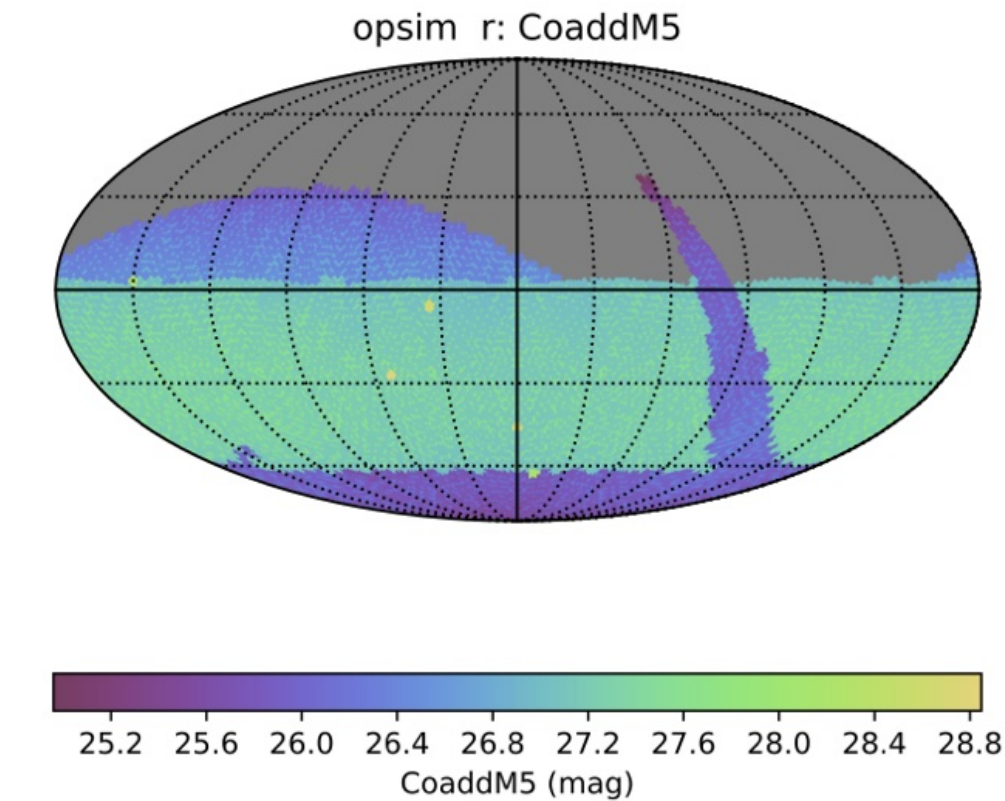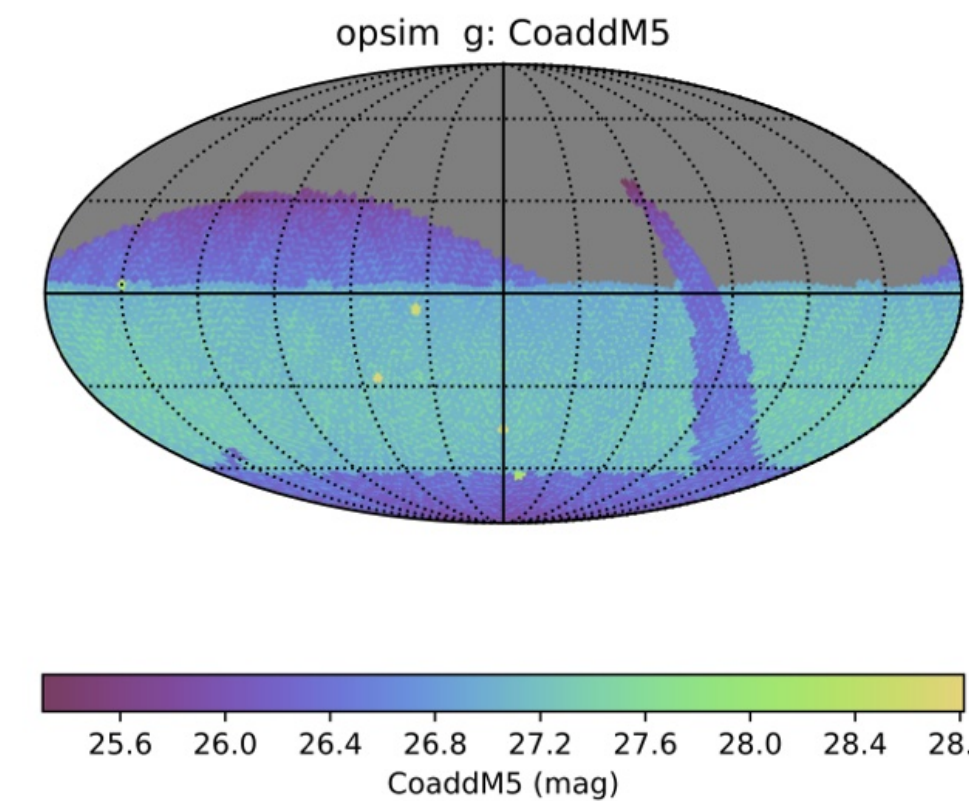
survey-strategy.lsst.io

Dark Energy Science Collaboration

Spokesperson: Renée Hložek; deputy spokesperson: Tesla Jeltema

‣ <u>DESC</u> = 1100+ members in 20+ countries

‣ **Goals**

1. Four main probes: galaxy lensing and clustering, galaxy clusters and type-Ia supernovæ

2. Constraints on dark energy, dark matter, neutrinos, inflation, etc.

3. Combinations with external data: spectro, CMB, etc.

4. More probes: strong lensing, stellar streams, etc.

‣ **News**

‣ DESC members taking part in Rubin commissioning (rehearsals)

‣ Getting ready for early science (DR1) and LSST Y1 (DR2) in 2027

‣ DESC-Roman simulations - effort to include Euclid starting

DESC-Roman image simulation

Troxel+23

LSST France 🐓

Camera, commissioning, computing, science activities

- **LSST-France**

  IN2P3-PI: J Bregeon; Camera: P. Antilogus; Computing: D. Boutigny; Tech: F. Hernandez; Commissioning: J. Neveu, T. Guillemin; Science: C. Doux; INSU: S. Blondin

  - 10 IN2P3 labs + ~10 INSU PIs Rubin data right holders

  - Frequent news/articles (Gaëlle Shifrin) at lsst.fr

- **French contributions to LSST**

  1. Camera hardware/software contributions

  2. Computing: storage/processing of LSST data

  3. Science analysis in DESC, ISSC, Galaxies, TVS, etc.

- See details in https://sitcomtn-050.lsst.io/ and LSST-France plaquette

Camera

- **Camera hardware contributions**
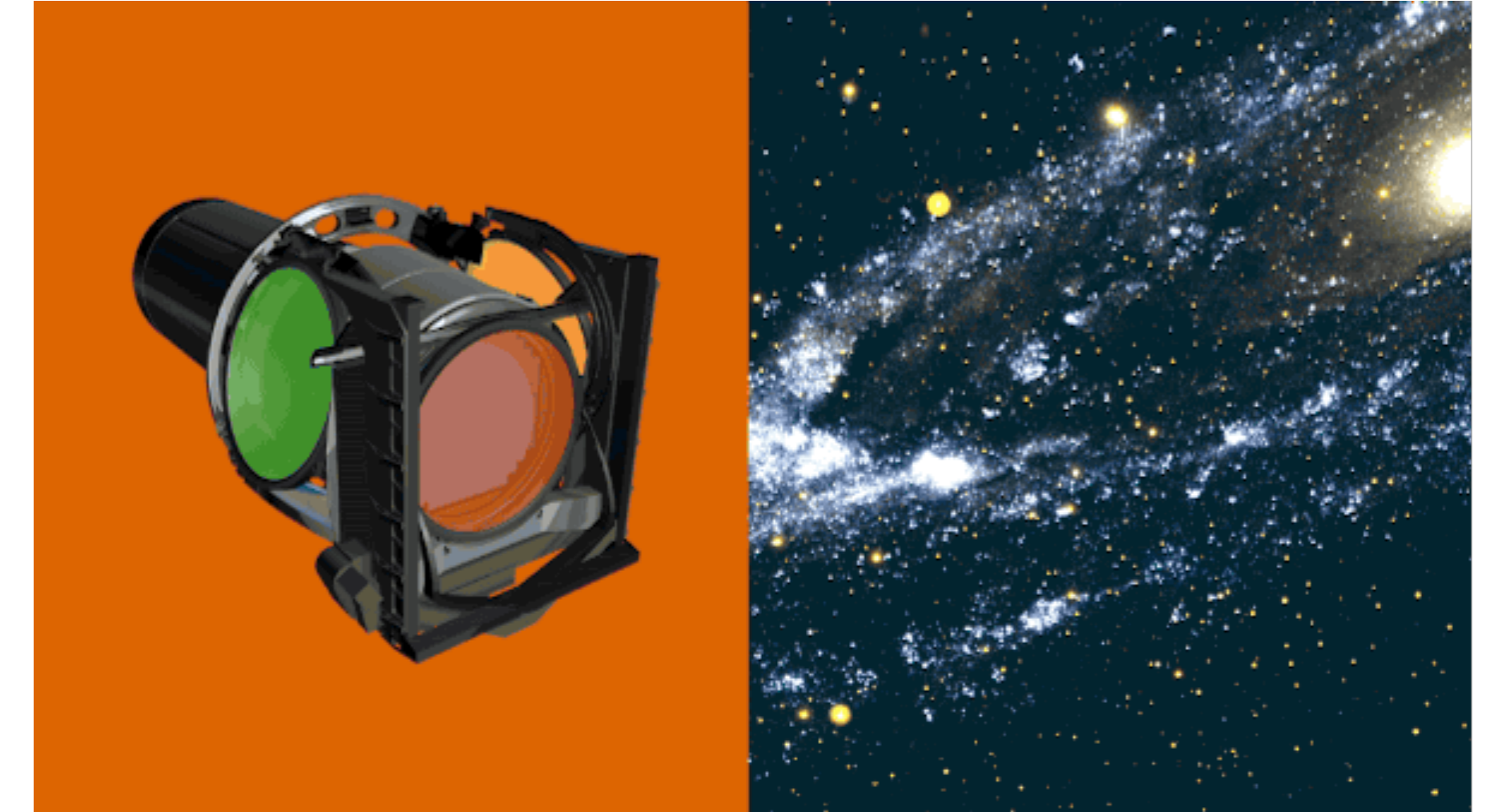 - CCD electronics ✓
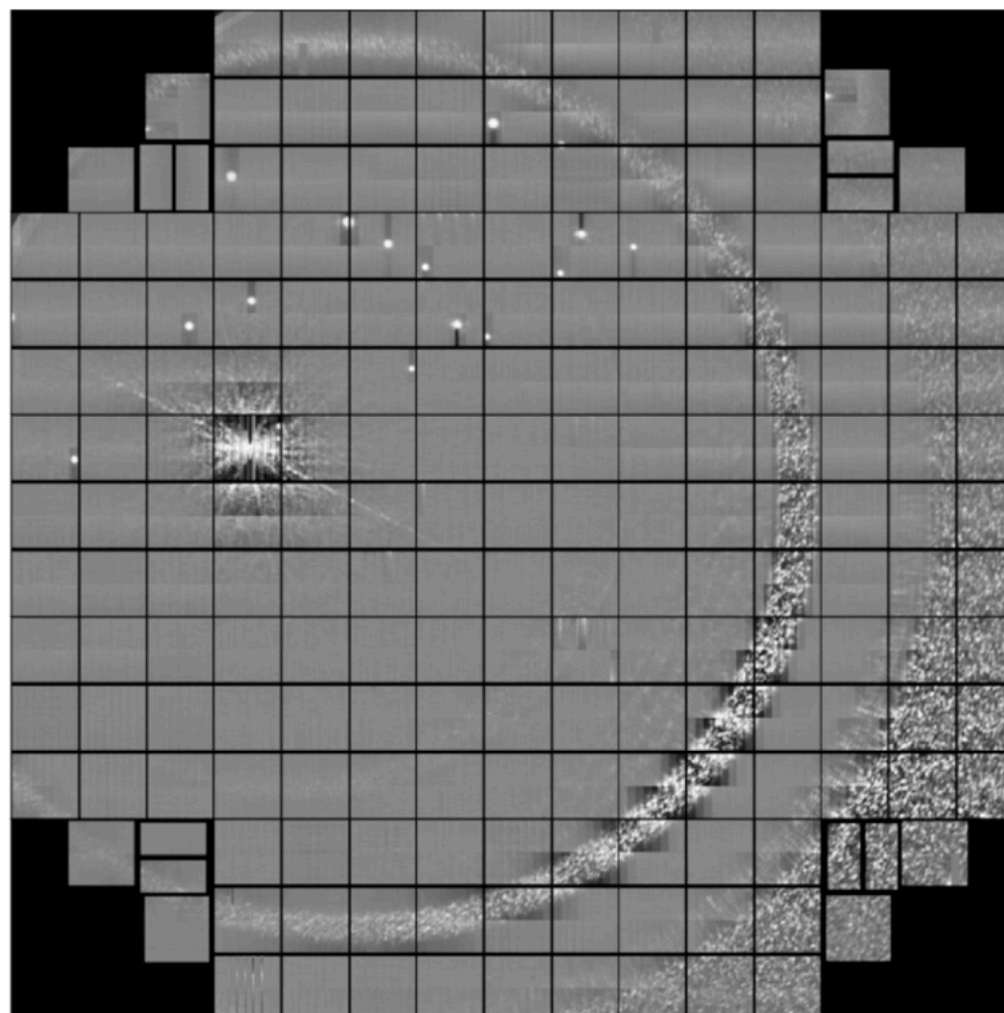 - Filter exchange/loading system ✓
  - Control command ✓

LSSTCam CCD + electronics
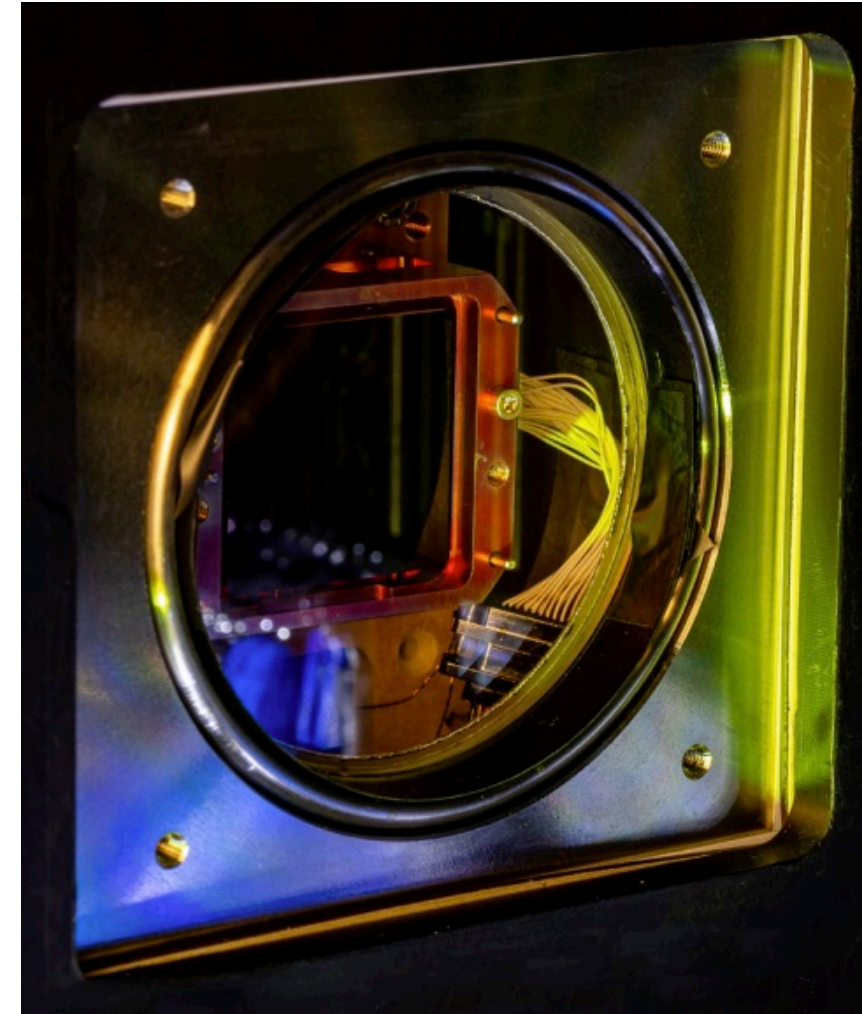
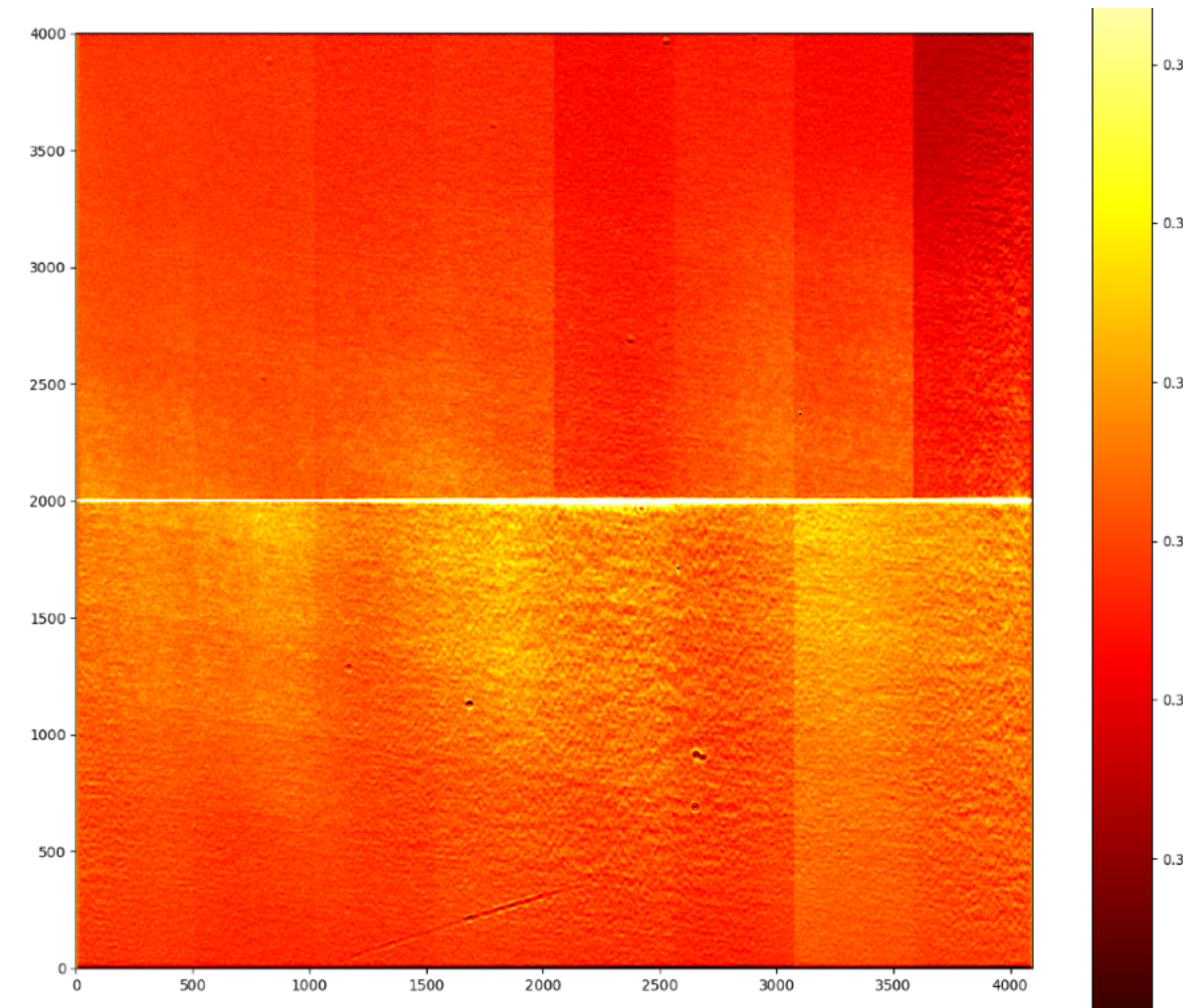LSSTCam filter exchange system

Study of LSSTCam ghosts

Johan Bregeon (LPSC)

LSSTCam CCD raft flat

Thibault Guillemin (LAPP)

- **Camera commissioning (ongoing)**
  - Ghosts and optics alignment
  - Amplifier biases and stability
  - Brighter-fatter effect and other distortions

Photometric calibration

▸ **Auxiliary Telescope (AuxTel)**

M. Rodriguez Monroy, M. Moniez, S. Dagoret, J. Neveu (IJCLab) et al.

  ‣ Characterization of atmosphere (water vapor *vs* airmass) from slitless spectroscopy for color correction

▸ **Collimated Beam Projector (CBP)**

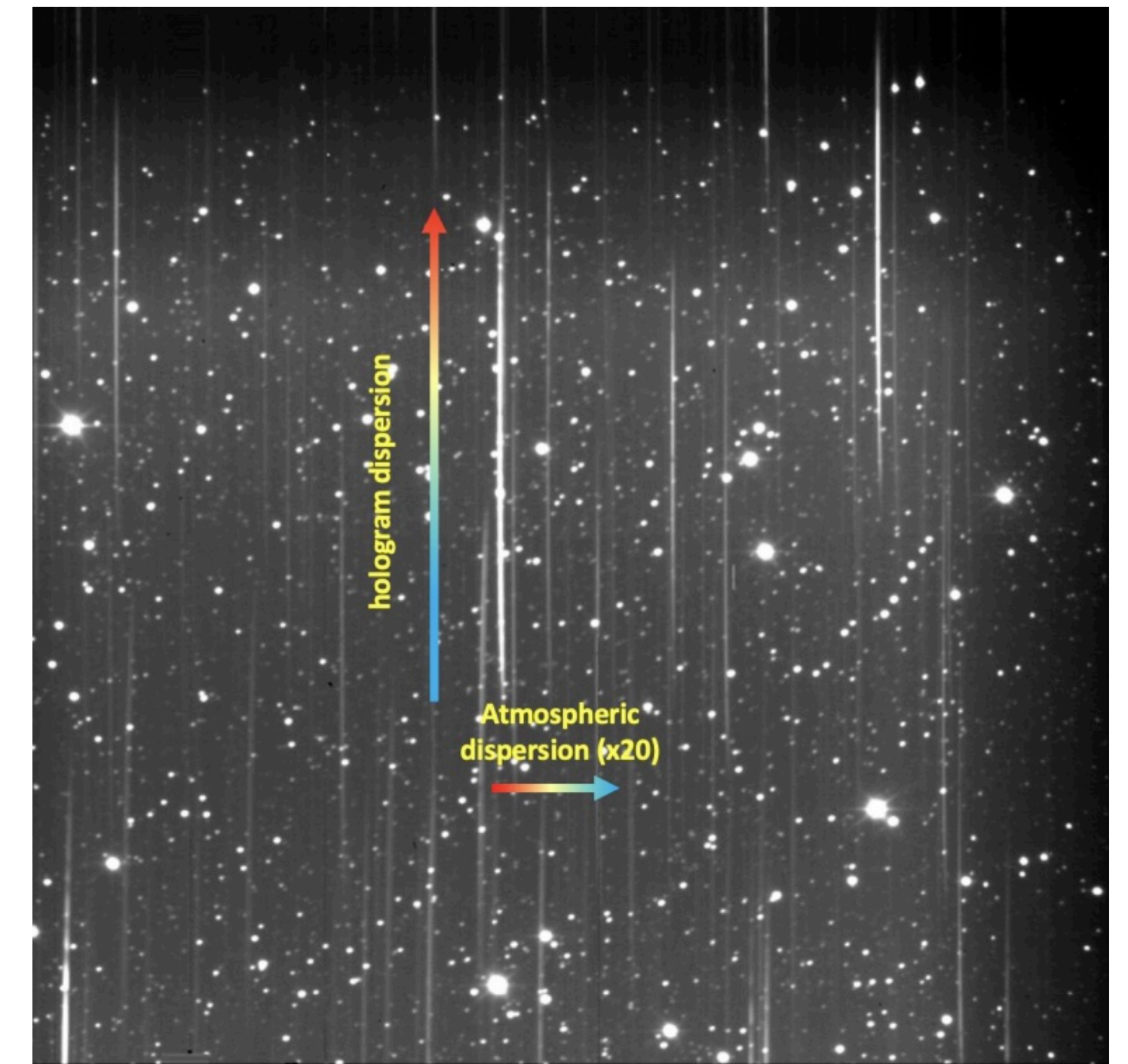*T. Souverin, J. Neveu, P. Fagrelius, E. Urbach et al.*

  ‣ Reversed telescope to calibrate LSST filter+CCD throughputs from artificial stars (monochromatic collimated beam)
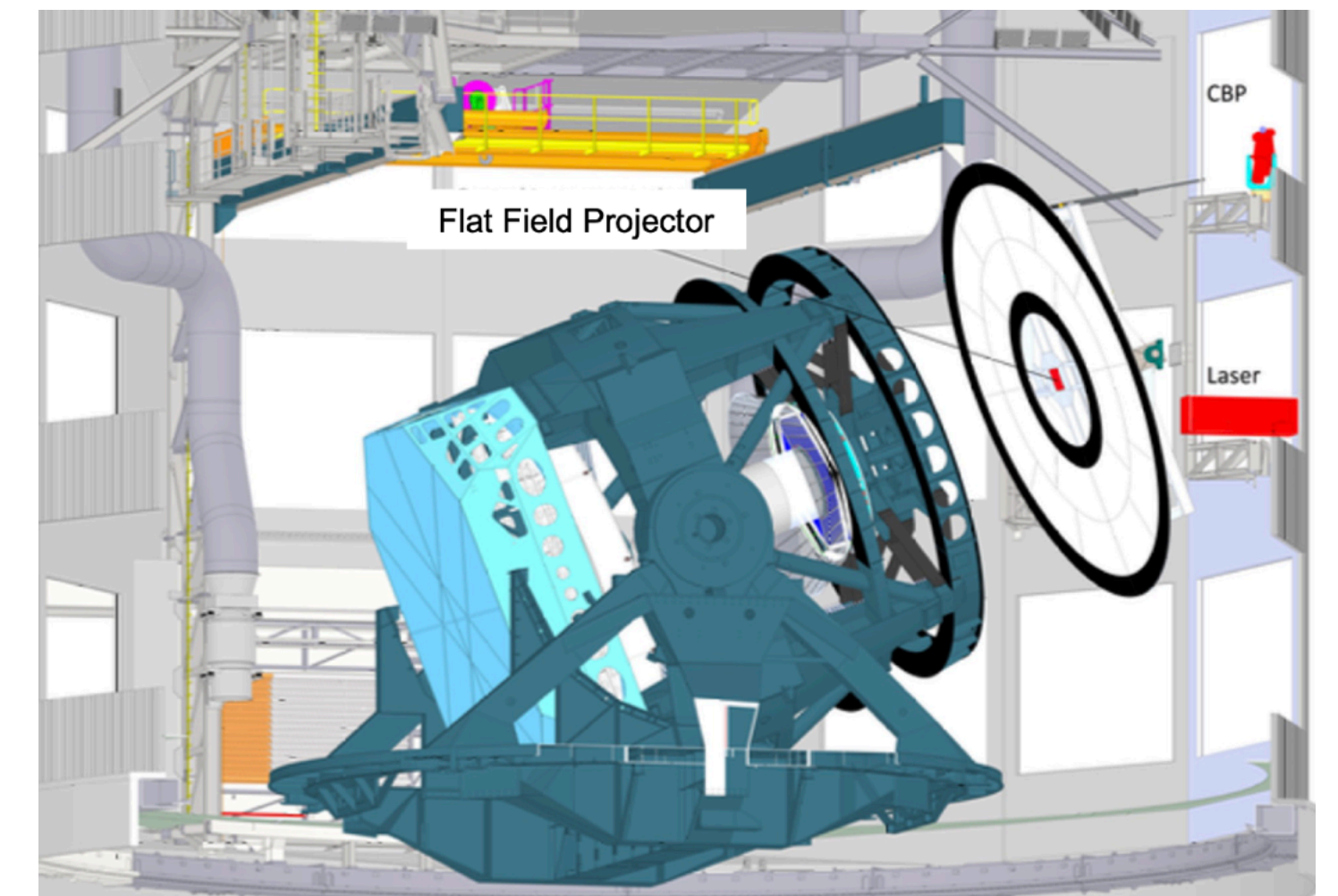
▸ **StarDICE**

M. Betoule et al.

  ‣ Accurate photometry (<mmag) reference stars for photometric calibration (SNIa)

  ‣ First light at Observatoire de Haute Provence in 2023
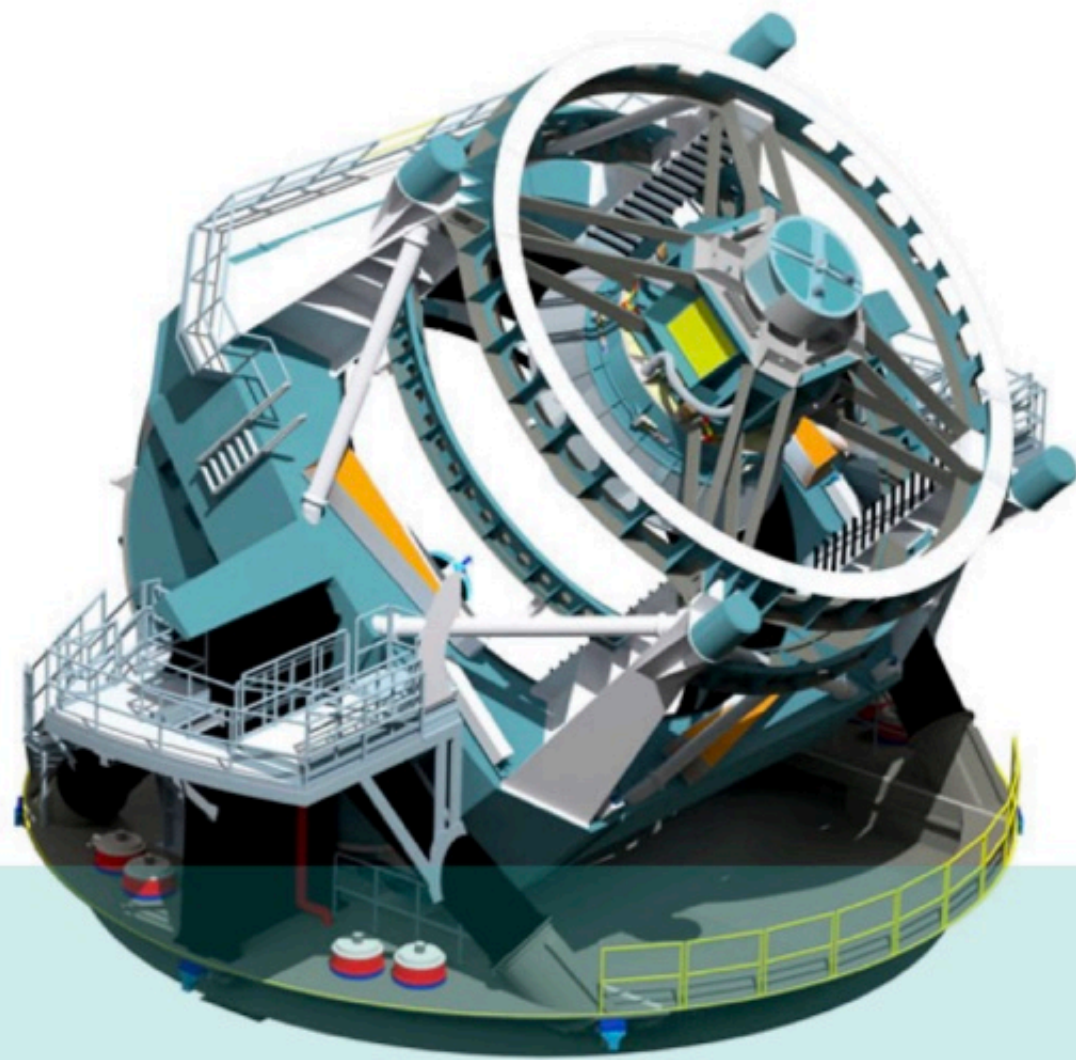
AuxTel holograms

LSST telescope with flat field + CBP

LSST data

Raw Data: 20TB/night

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

Prompt Data Products

- Alerts incl. science, template and difference image cutouts
- Catalogs of detections incl. difference images, transient, variable & solar system sources
- Raw & processed visit images (PVIs), difference images

60s via Alert Streams

24h via Prompt Products

80h via Image Services

Data Release Data Products

Final 10yr Data Release:
- Images: 5.5 million x 3.2 Gpixels
- Catalog: 15PB, 37 billion objects

via Data Releases

Community Brokers
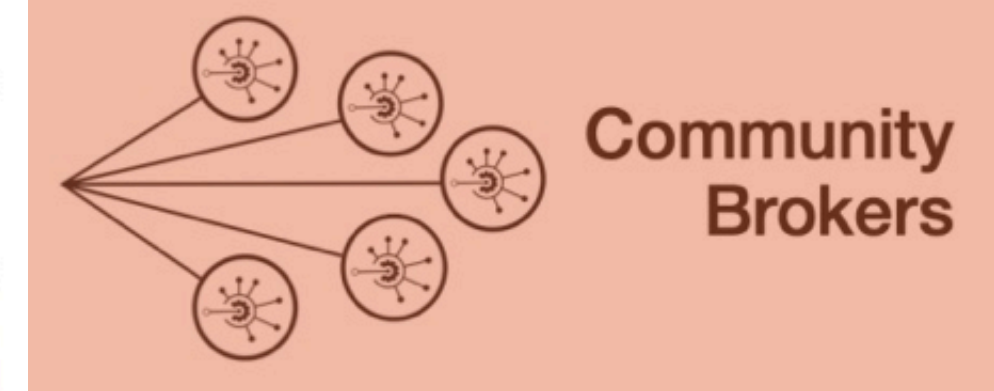
Rubin Data Access Centres (DACs)

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.

RUBIN SCIENCE PLATFORM

PORTAL   NOTEBOOKS   WEB APIS

DATA RELEASES   ALERT FILTERING SERVICE   USER DATABASES   USER FILES   USER COMPUTING   SOFTWARE TOOLS
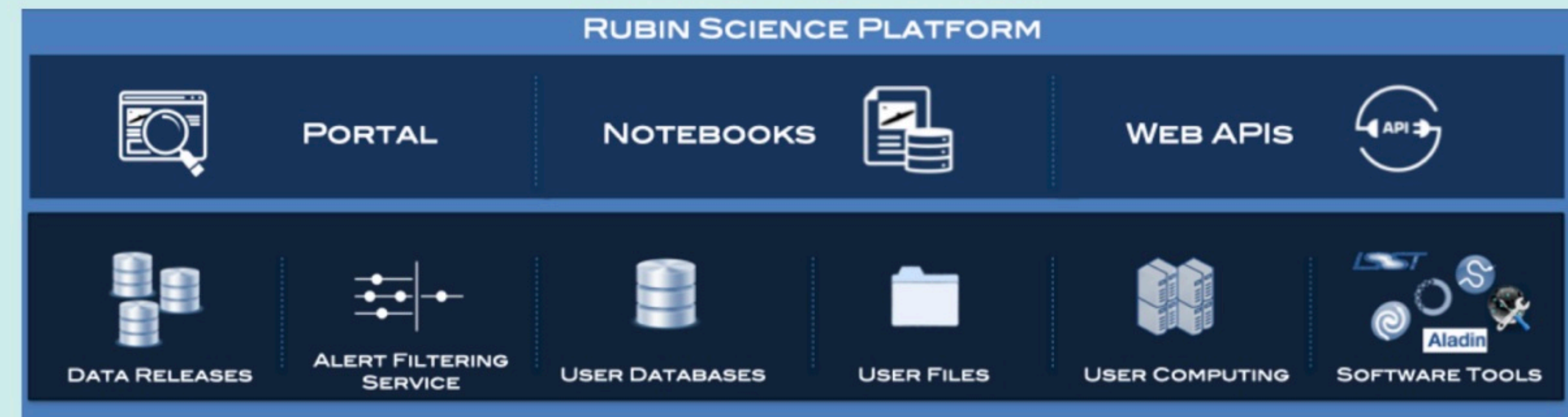
Credit: Leanne Guy

Computing

Cloud
EPO Data Center

Dedicated Long Haul Networks

Two redundant 100 Gb/s links from Santiago to Florida (existing fiber)
Additional 100 Gb/s link (spectrum on new fiber) from Santiago-Florida (Chile and US national links not shown)

**UK Data Facility
IRIS Network, UK**

Data Release Production (25%)

**US Data Facility
SLAC, California, USA**

Archive Center
Alert Production
Data Release Production (35%)
Calibration Products Production
Long-term storage
Data Access Center
Data Access and User Services

**France Data Facility
CC-IN2P3, Lyon, France**

Data Release Production (40%)
Long-term storage

**HQ Site
AURA, Tucson, USA**

Observatory Management
Data Production
System Performance
Education and Public Outreach

Summit and Base Sites

Observatory Operations Telescope and Camera
Data Acquisition
Long-term storage
Chilean Data Access Center

Computing

▶ **Data Release Processing**

  ‣ Split = 40% CC-IN2P3 🇫🇷 + 35% SLAC 🇺🇸 + 25% IRIS/UK 🇬🇧

  ‣ 20TB/night → 5PB of additional data to reprocess yearly

  ‣ 11th data release (DR11) after 10 years ~500 PB

▶ **LSST at CC-IN2P3**

  D. Boutigny, F. Hernandez, Q. Le Boulc'h, G. Mainetti

  ‣ Getting ready to import, process and export data

    ‣ Data transfer (Rucio+FTS3), storage (dCache), catalogs database (Qserv), Rubin Science Platform (TBC)

    ‣ Installed 1300+ additional cores for LSST

  ‣ Optimization of Instrument Signature Removal pipeline

LSST racks at CC-IN2P3

https://lse-163.lsst.io/
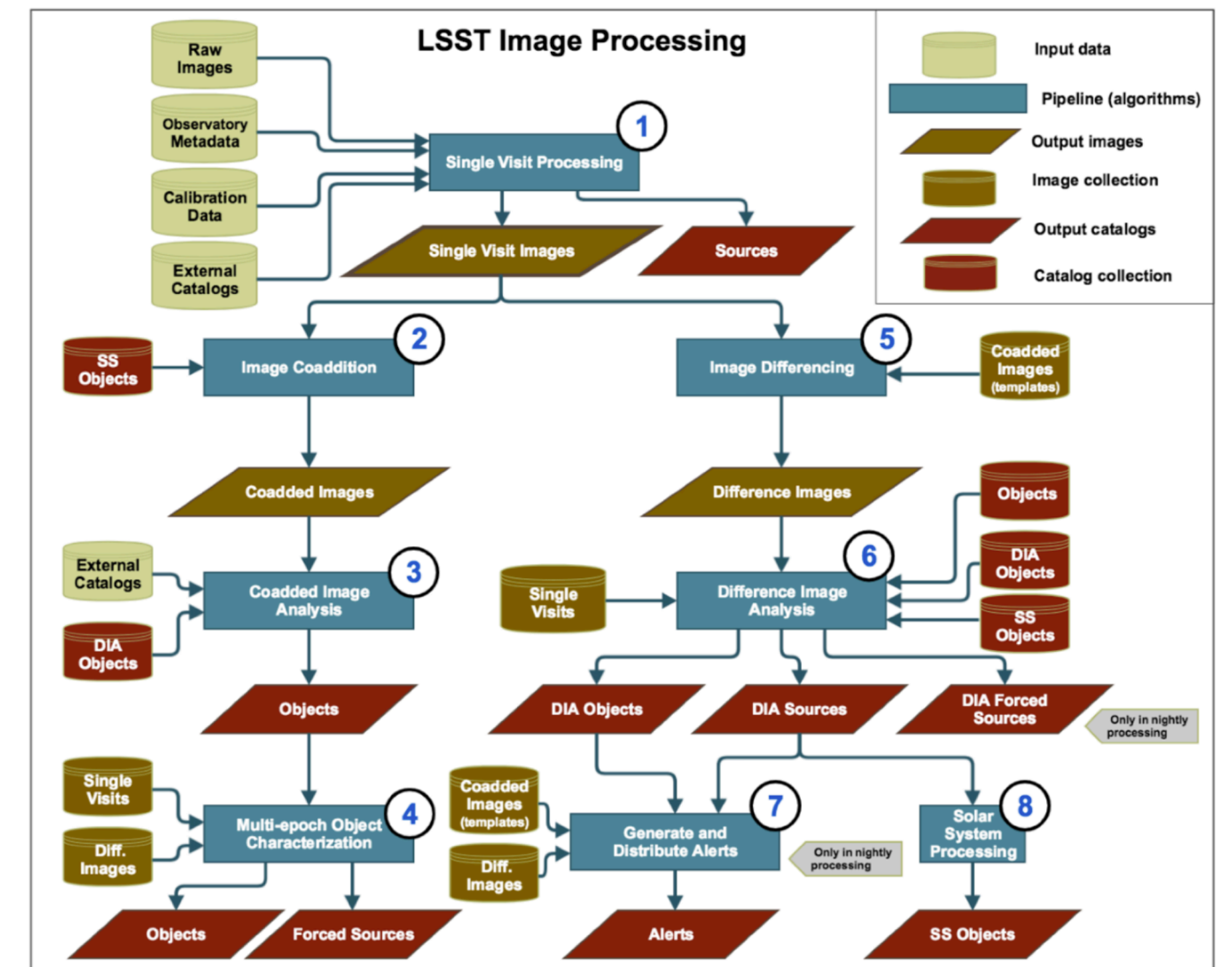
The FINK alert broker

Operating 24/7 since 2019, serving 100+ unique users per day (scientists & follow-up facilities).

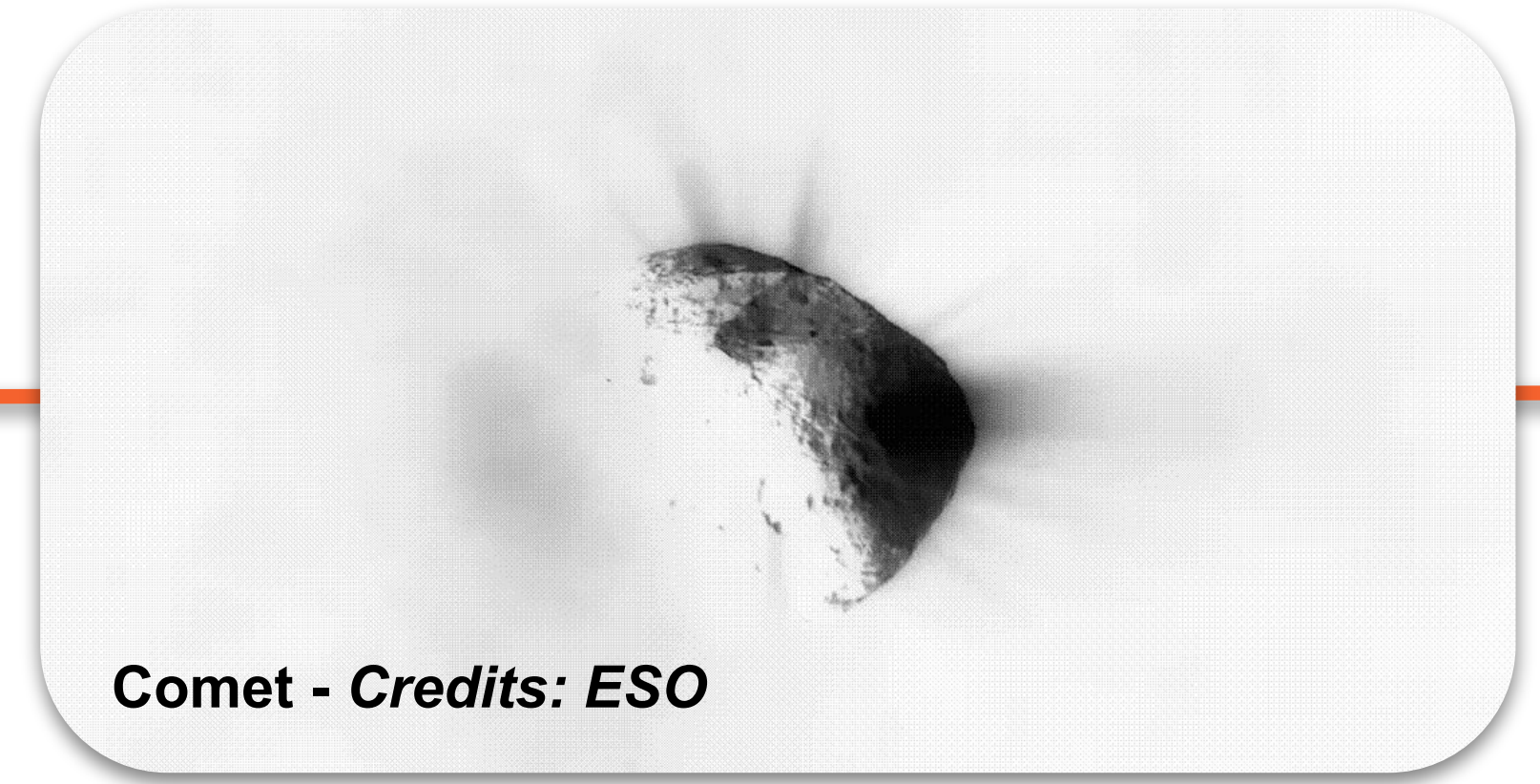- Real-time components (million+ event/night)
- Event database (~1B entries)

Processing the ZTF alert stream since 2019

- 225 million ZTF alerts received
- ⅔ is classified: 40% galactic, 15% Solar System few% extra-galactic
- Coupled to GCN: Fermi, Swift, Icecube, LVK, …

Community-driven: scientists bring building bricks
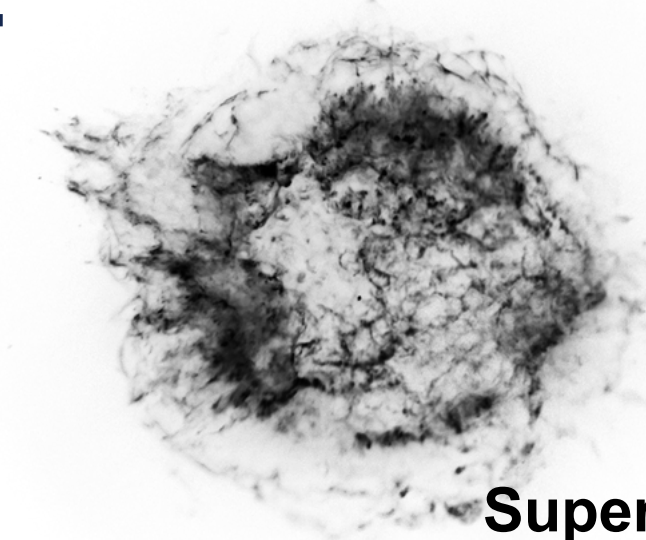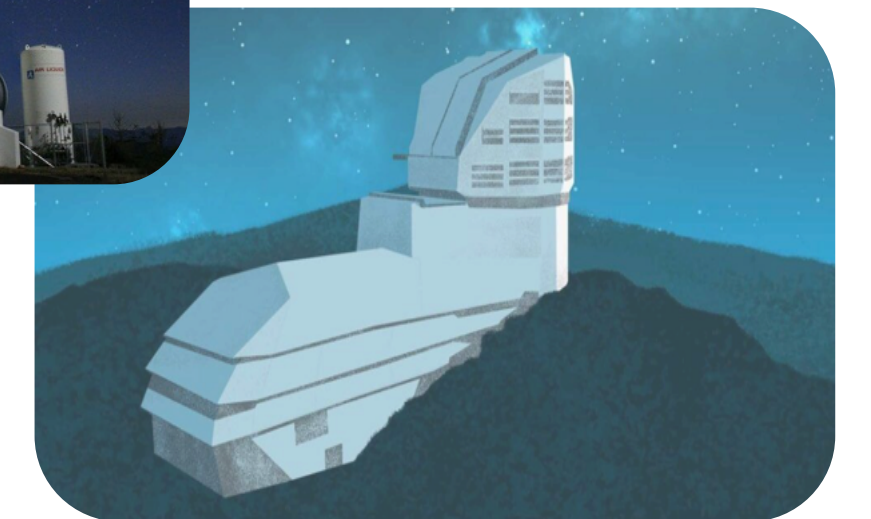
- 60+ members, 15+ scientific topics covered

https://fink-broker.org

Comet - *Credits: ESO*

Active Galactic nucleus

Supernova

Tidal disruptive event

Supernovæ

- Observing strategy and deep drilling fields

  P. Gris et al.

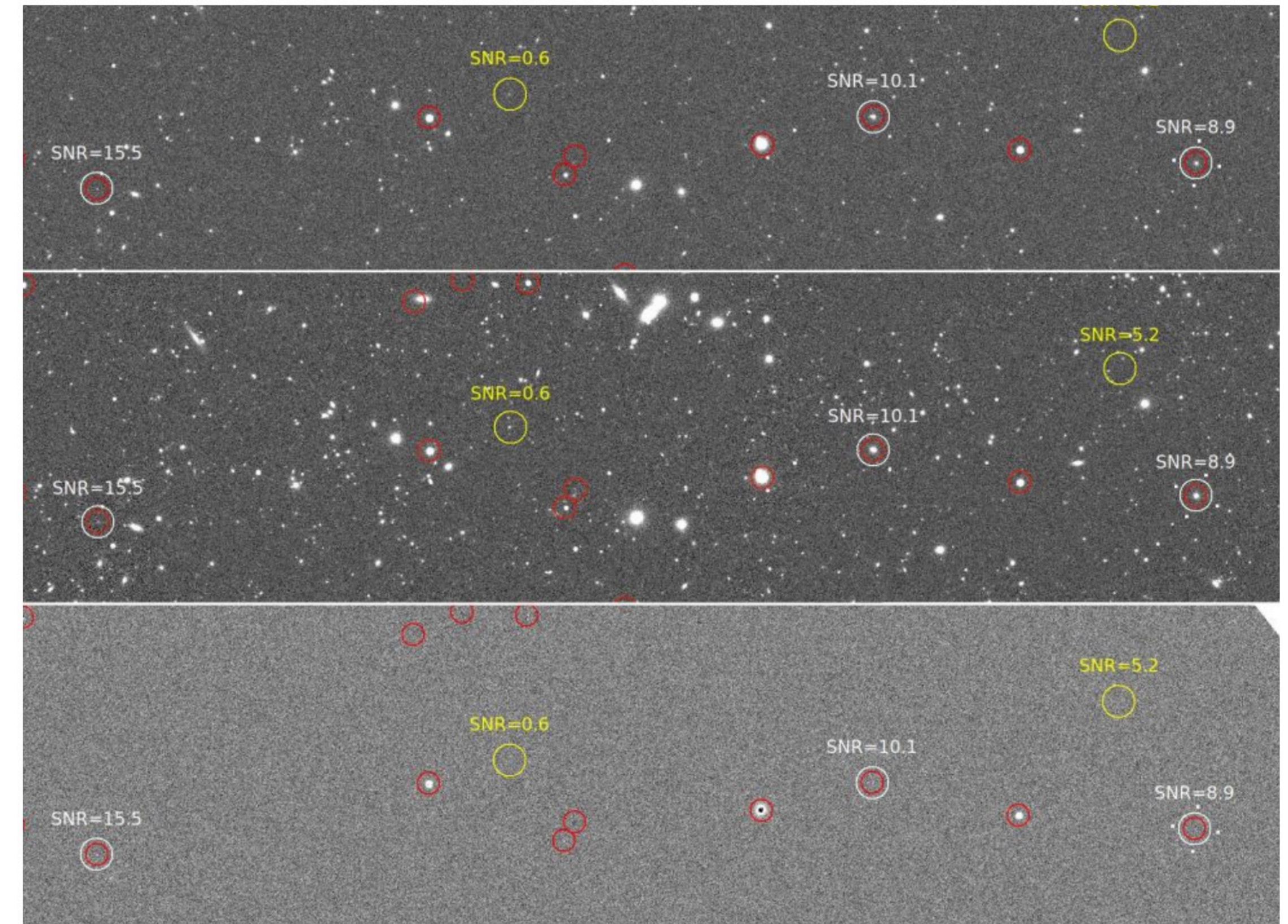- DC2 analysis with LSST difference imaging pipelines

  B. Sanchez et al.

  - Photometric calibration from scene modelling

  - Comparison between DC2 and DES Y5 SN

- Peculiar velocities and $f\sigma_8$ measurements

  D. Rosselli et al.

- ZTF : see Mickaël's and Madeleine's talks!

Difference Image Analysis (DIA) with LSST pipelines


Bruno Sanchez (CPPM) et al.

Clusters

- ▸ **Characterization of cluster finders on DC2 simulation**
  - ▸ Calibration of mass-richness relation
  - ▸ Impact of LSST photo-z's

- ▸ **Cluster cosmology pipeline for LSST Y1**
  - ▸ Cluster count and stacked lensing profiles
  - ▸ Public and modular code CLMM

- ▸ **LSST DESC Data Challenge 2**
  - ▸ N-body + image sims
  - ▸ See data.lsstdesc.org

Mass-richness for the WaZP and redMaPPer cluster finders on DC2
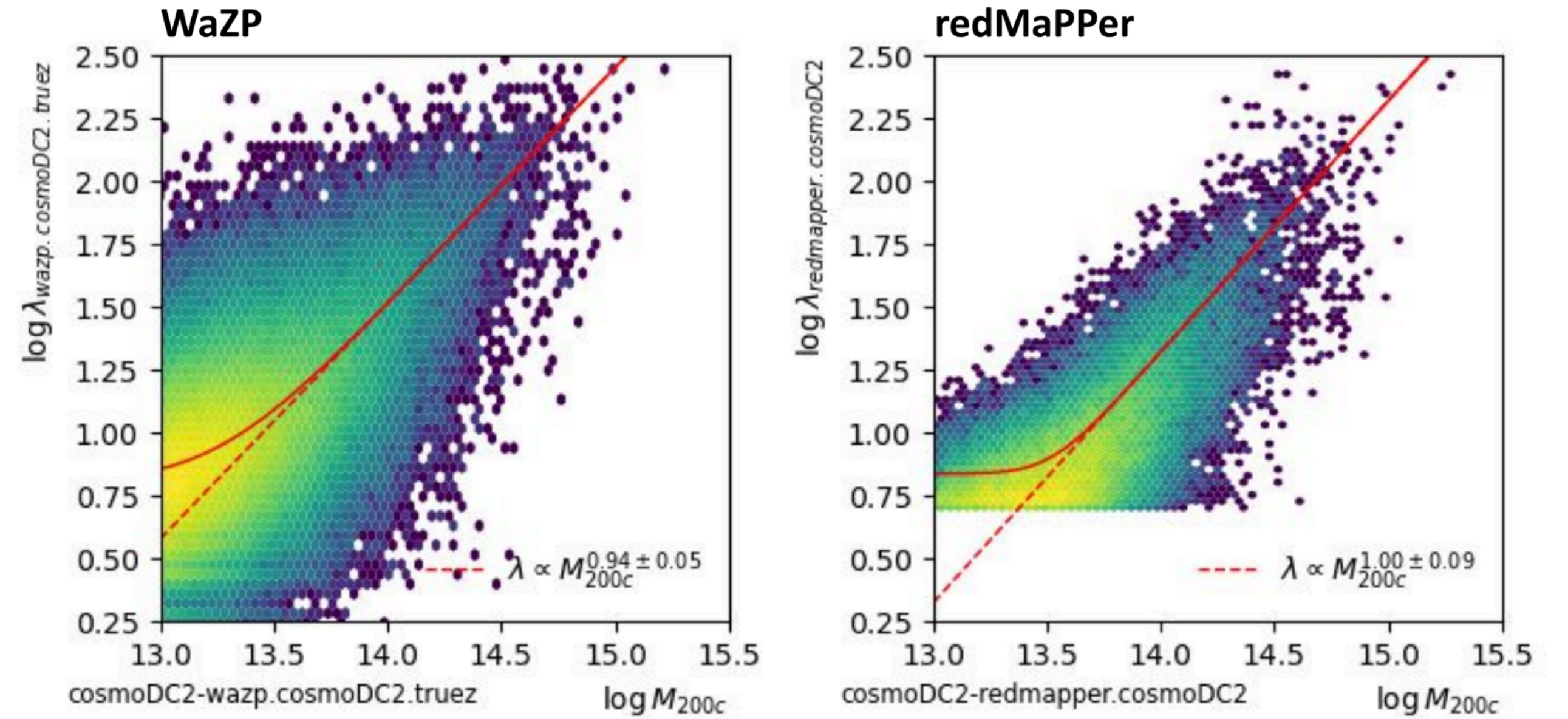
Rance Solomon (LAPP), Michel Aguena, Marina Ricci (APC) et al.

Cluster lensing profiles on DC2 *vs* CLMM theory predictions
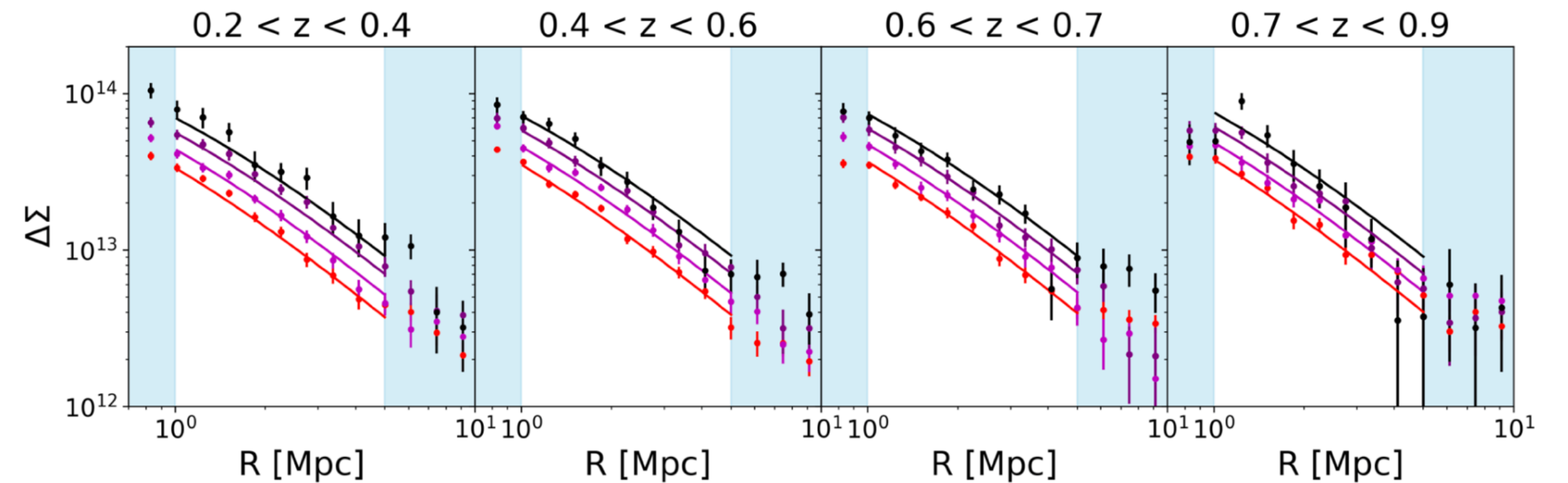
C. Payerne, C. Combet (LPSC), M. Ricci (APC) et al.

Weak lensing and clustering

Blending in LSST

▸ **Key figures**

    ▸ 2/3 of galaxies will be blended *Sanchez+22*

    ▸ 40% recognized + 20% unrecognized by pipelines

    ▸ Rubin uses the Scarlet deblender *v1:Melchior+18 and v2:Sampson+24*

▸ **DESC (de)blending projects**

    ▸ Impact on detection, shear and photo-z measurements (see M. Ramel's talk!)

    ▸ Deblending with galaxy priors encoded by deep generative models (B. Biswas et al., in prep.) using the Blending ToolKit (Mendoza et al., in prep.)

▸ **Combining LSST+Roman+Euclid…**

HSC image showing blended galaxies
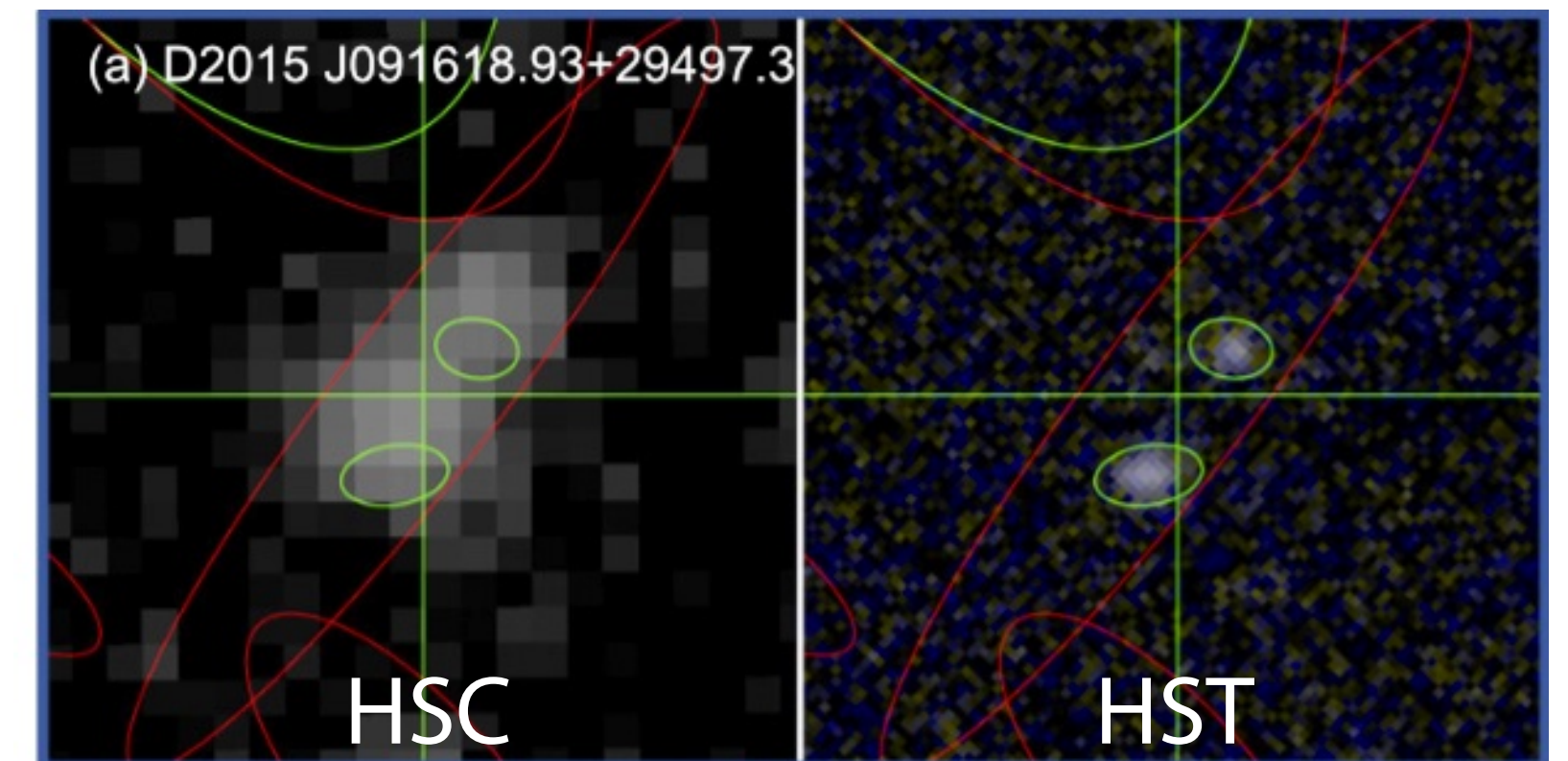
Dawson+15

Weak lensing and clustering

Beyond two-point statistics

- **LSST Y1 joint clustering + lensing cosmology**

  - 3x2pt analysis…

  - …but also higher-order statistics

  - High S/N expected in (mildly) non-linear scales

- **Simulation suite for LSST Y1 in development**

  - Testing hyperparameters (J. Mena-Fernandez et al., in prep.)

  - Including systematic effects (in progress)
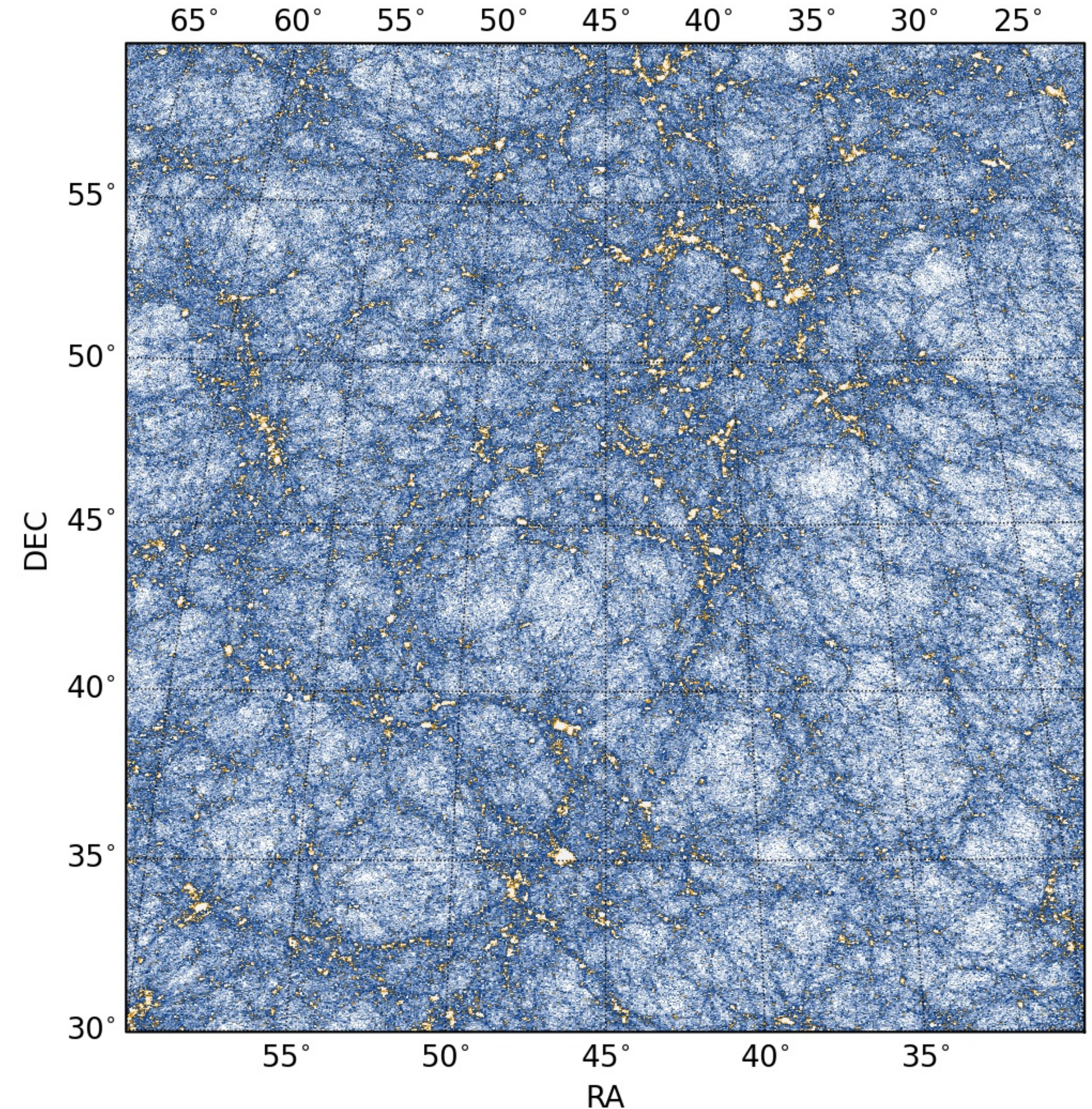
C. Doux, J. Mena-Fernandez, J. Harnois-Déraps, K. Heitman et al.

Summary

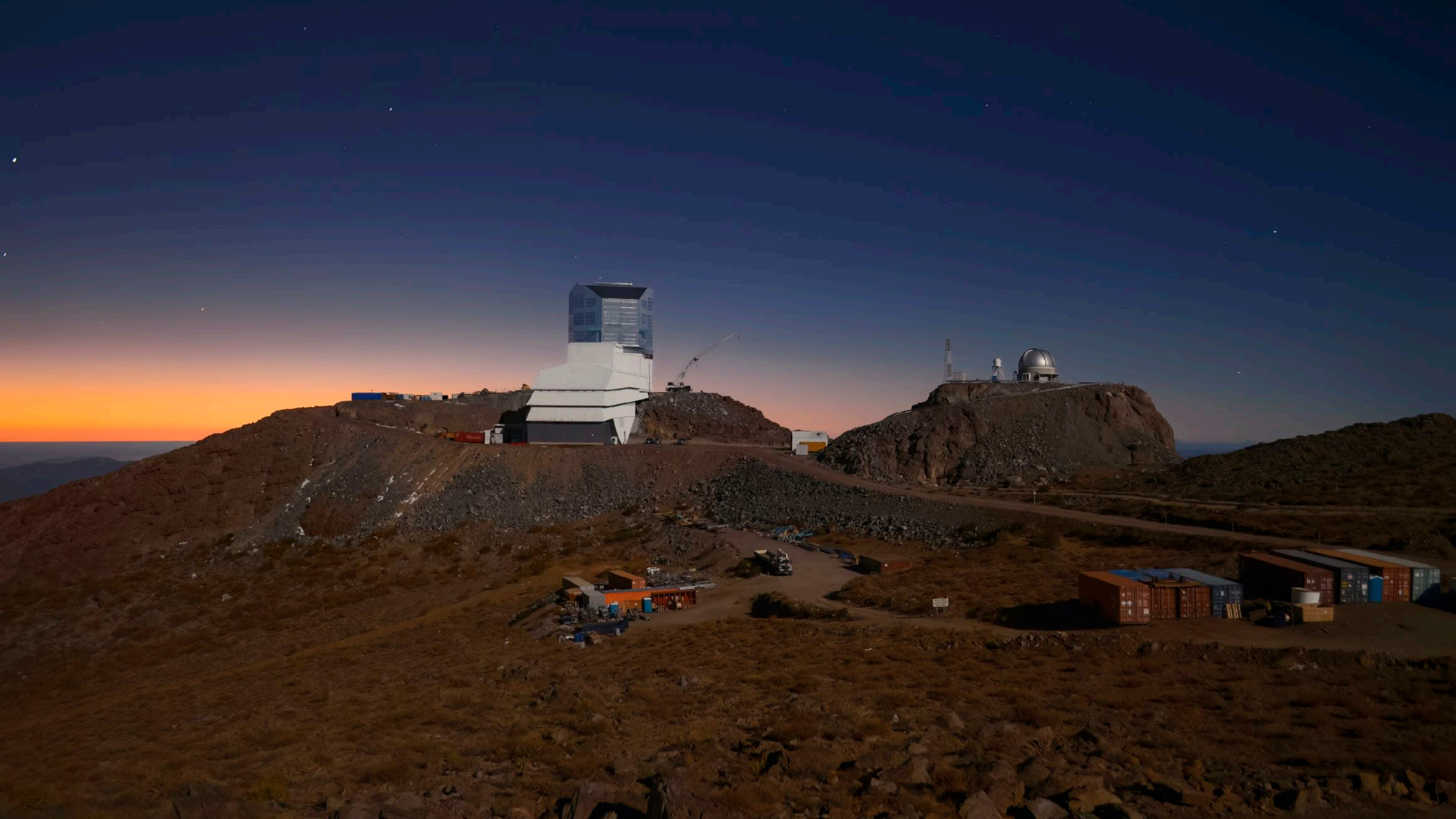- ▸ Rubin Observatory has a mirror and a camera!

- ▸ Hardware commissioning is about to start

- ▸ Science pipelines commissioning will follow by fall 2024

- ▸ Beginning of LSST 10-year survey by mid 2025

Rubin/LSST-France meeting at CPPM, Marseille, 10-12 June 2024

Thanks!

DESC organization

DESC is a large international collaboration sharing collegial values and aiming at homogeneous, reproducible results, with percent precision on systematics, over the next 10+ years.

- ‣ DESC is a **representative democracy**. Policies are ratified by the CC, the CC members and spokesperson are elected for 2 yrs. Each role is rotated regularly.
- ‣ DESC is committed to actively fostering an **equitable, diverse, and inclusive** environment
- ‣ **Junior scientists** represents ~40 % of the collaboration : they can serve in committees and lead WG
- ‣ Software must follow **coding guideline**, be made public and most are available on https://github.com/LSSTDESC
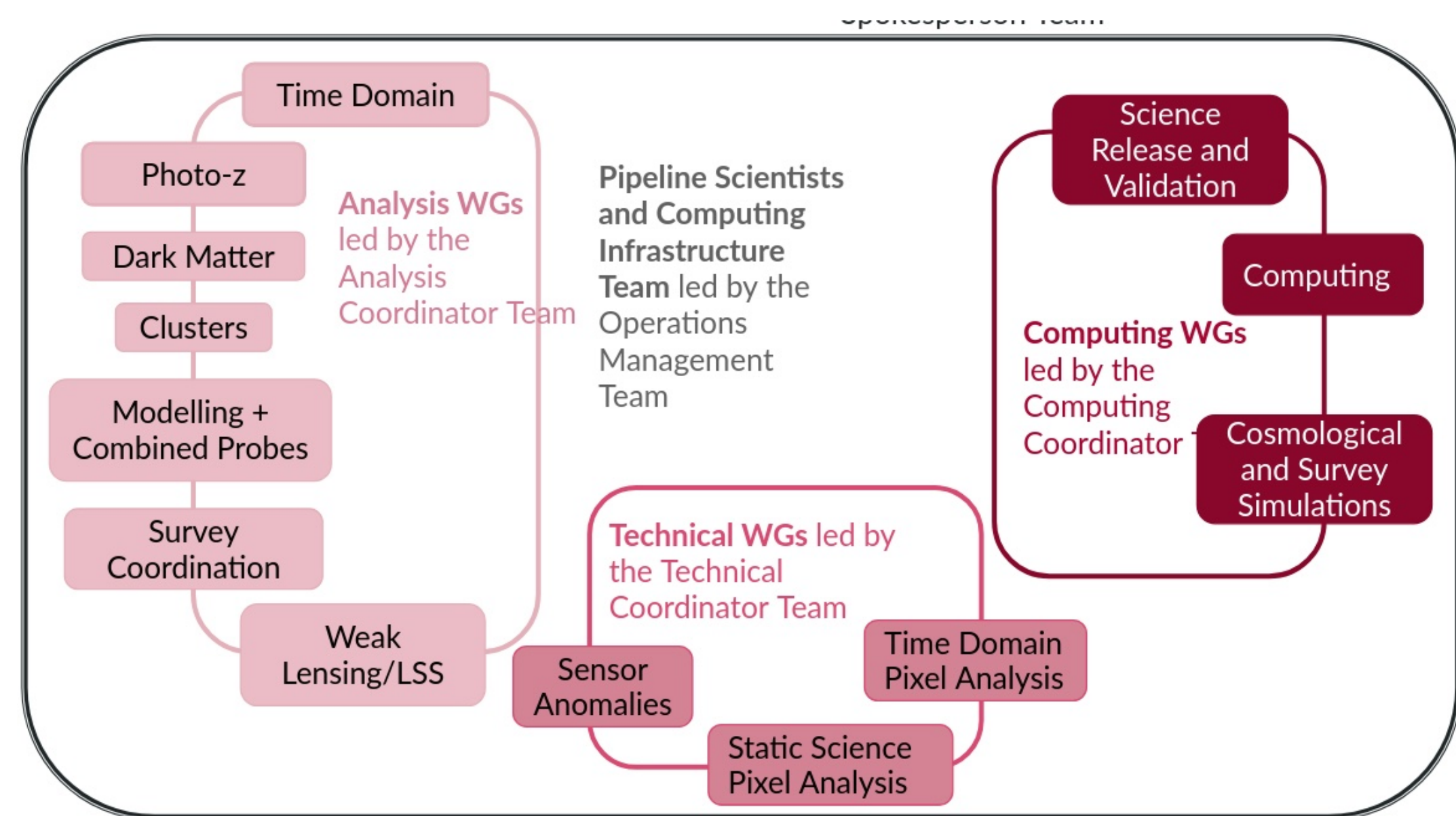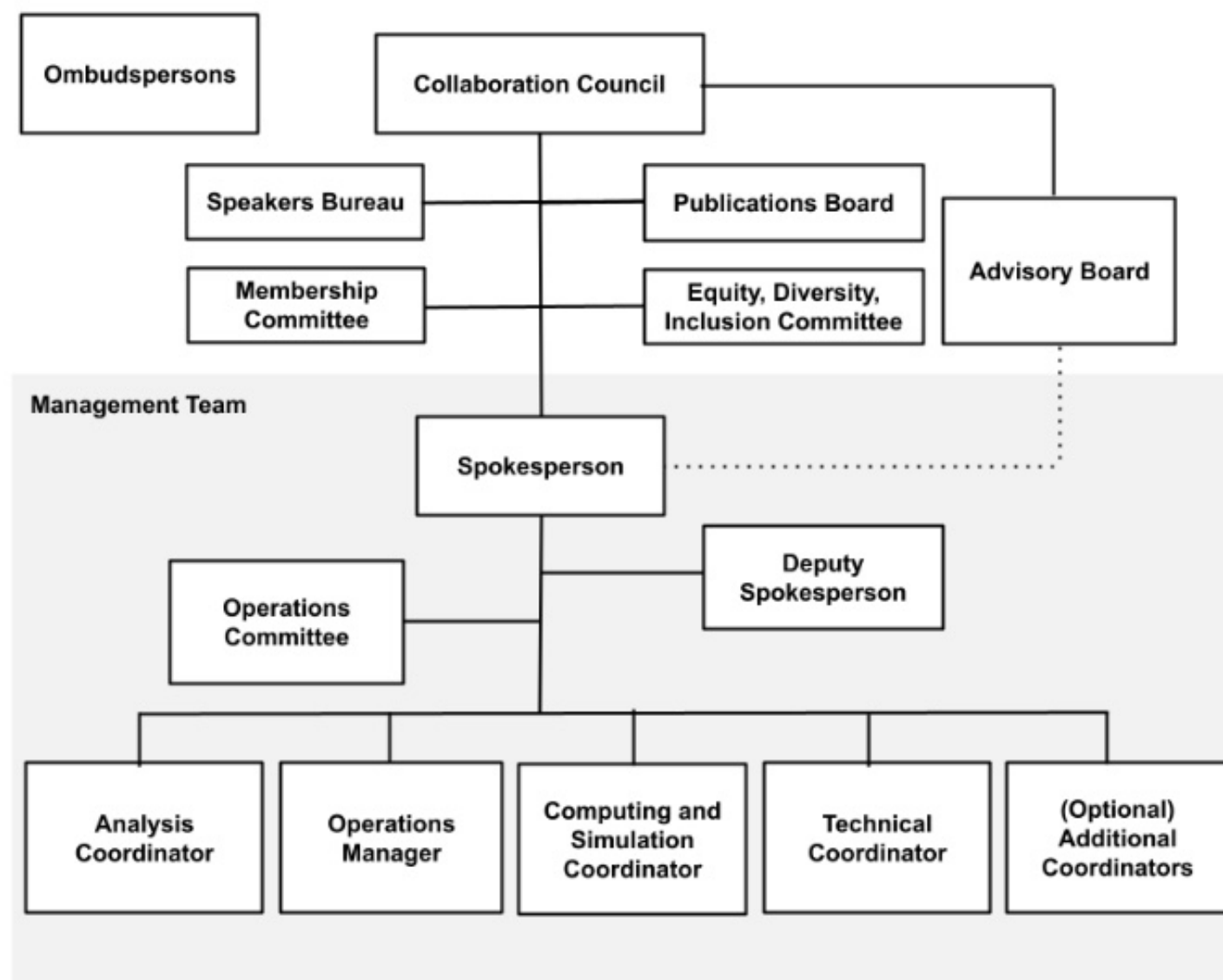
Commissioning data collection

Outline plan for the collection of commissioning data, as of October 2023.

Electro-optical Testing at Level 3	In-dome Engineering	On-sky Engineering	System Optimization	Science Validation Survey(s)
biases, darks, flats	suite of in-dome calibration	Initial alignment, pointing re-verification, AOS testing star flats, dithering around bright stars, airmass scans	20-year LSST WFD equivalent depth in fields for extragalactic, Galactic, and Solar System science, ~100 deg^2 in multiple bands with dense temporal sampling	Menu includes pilot LSST WFD survey, ~1000 deg^2 in multiple bands to 1-2 year LSST equivalent depth Increase coverage of LSST DDFs Astrophysical targets / ToO
	Start On-Sky Engineering	**System First Light**	**Start Science Validation Surveys**	**Start 10-year LSST**

https://rtn-011.lsst.io/

Commissioning timeline

Detailed schedule of commissioning and early science activities relative to System First Light, as of October 2023.

https://rtn-011.lsst.io/
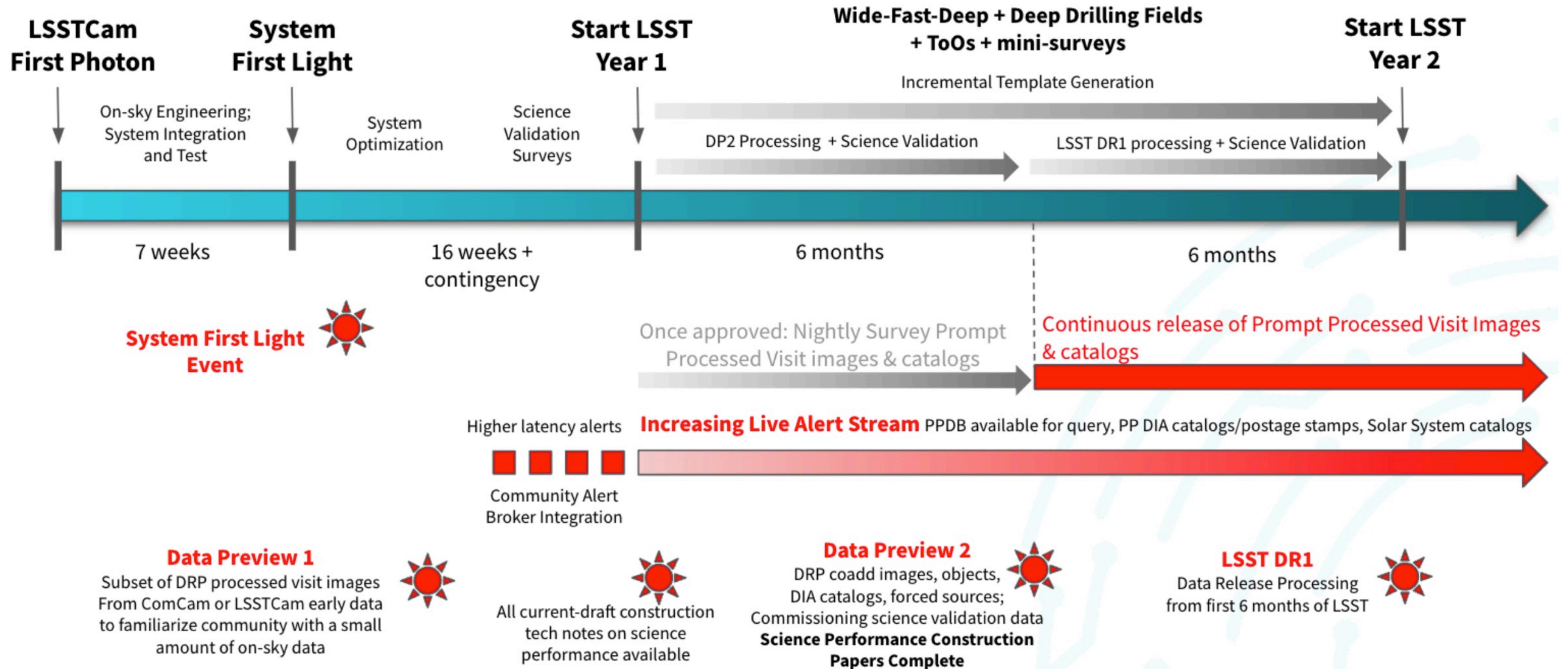
Weak lensing surveys

Stage I to Stage IV

Survey	Area	Bands	Depth	Density
SDSS-II and III	$\sim 10\,000\,\text{deg}^2$ [8]	$ugriz$	$r \sim 23.5$	$\sim 2\,\text{gal/arcmin}^2$
DES	$\textbf{5\,000\,deg}^2$	$grizY$	$r \sim 24.3\,(10\sigma)$	$\sim 6\,\text{gal/arcmin}^2$
KiDS (+VIKING)	$1350\,\text{deg}^2$	$\boldsymbol{ugri(+ZYJHK_s)}$ [9]	$r \sim 24.9\,(5\sigma)$	$\sim 6\,\text{gal/arcmin}^2$
HSC	$1400\,\text{deg}^2$	$grizy$	$\boldsymbol{r \sim 26.1\,(5\sigma)}$	$\sim 20\,\text{gal/arcmin}^2$
LSST	$\textbf{18\,000\,deg}^2$	$ugrizY$	$\boldsymbol{r \sim 27.5\,(5\sigma)}$	$\sim 30\,\text{gal/arcmin}^2$
Euclid	$\textbf{15\,000\,deg}^2$	$\textbf{Visible+}\boldsymbol{YJH}$ [10]	$m_{\text{AB}} \sim 24.5\,(10\sigma,\text{ext})$	$\sim 30\,\text{gal/arcmin}^2$
Roman HLS	$2\,000\,\text{deg}^2$	$\boldsymbol{YJH}$	$\boldsymbol{Y \sim 26.5}$	$\sim 30\,\text{gal/arcmin}^2$