

# Rubin Observatory's LSST at Fermilab: From Construction to Physics

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Fermilab 2021: Summer School at LNF

04 Aug 2021

# Construction



## Construction is at an advanced stage



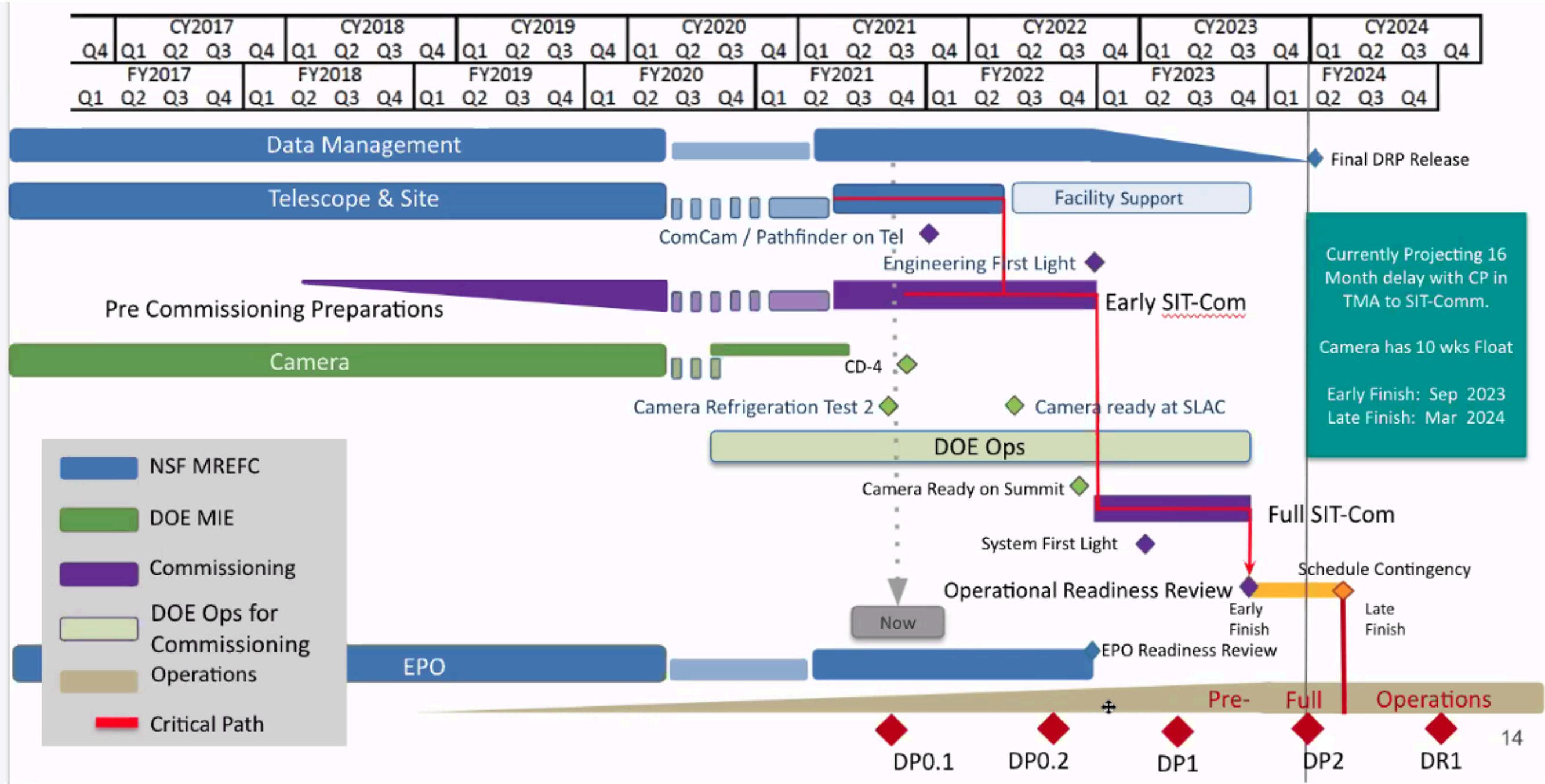


# All camera components fabricated





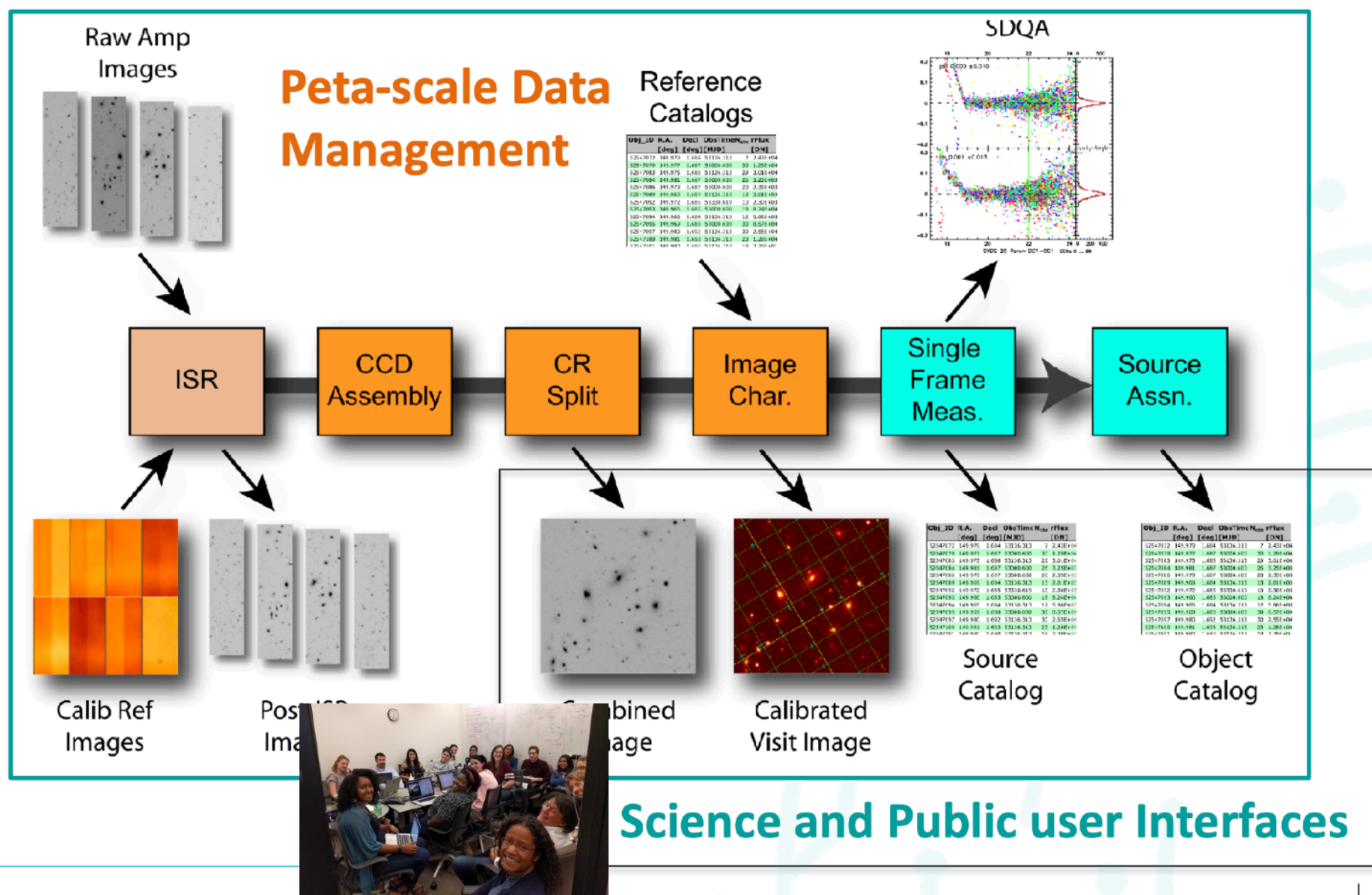
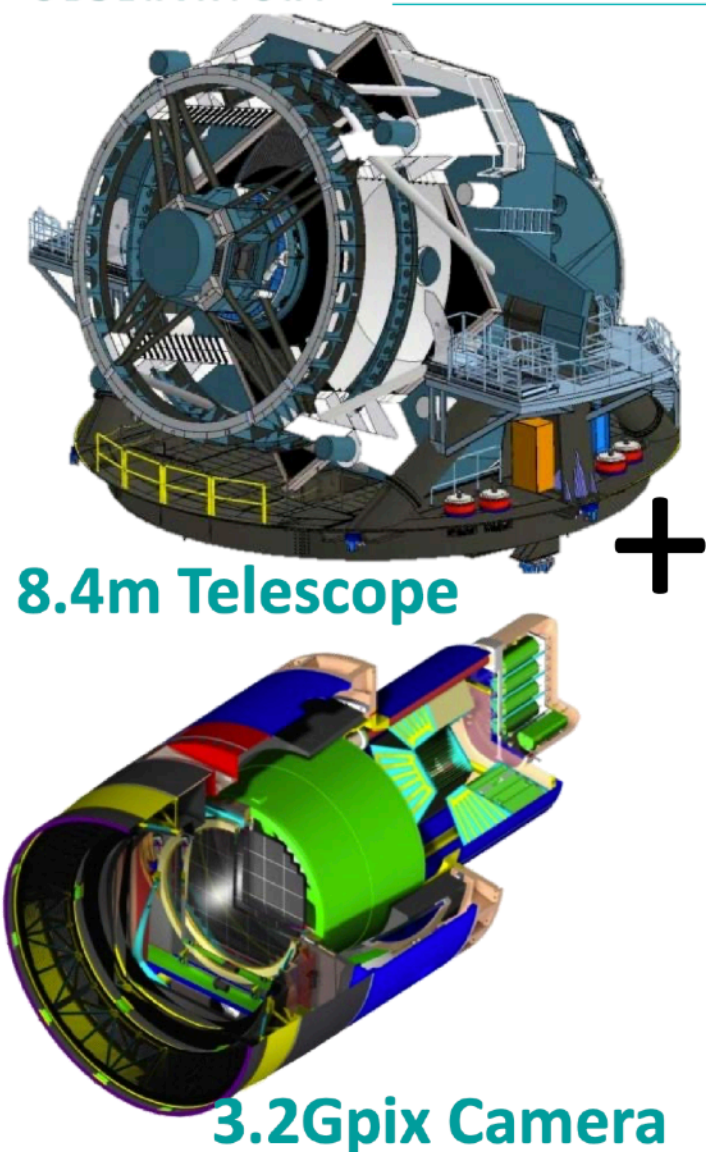
# Current Schedule





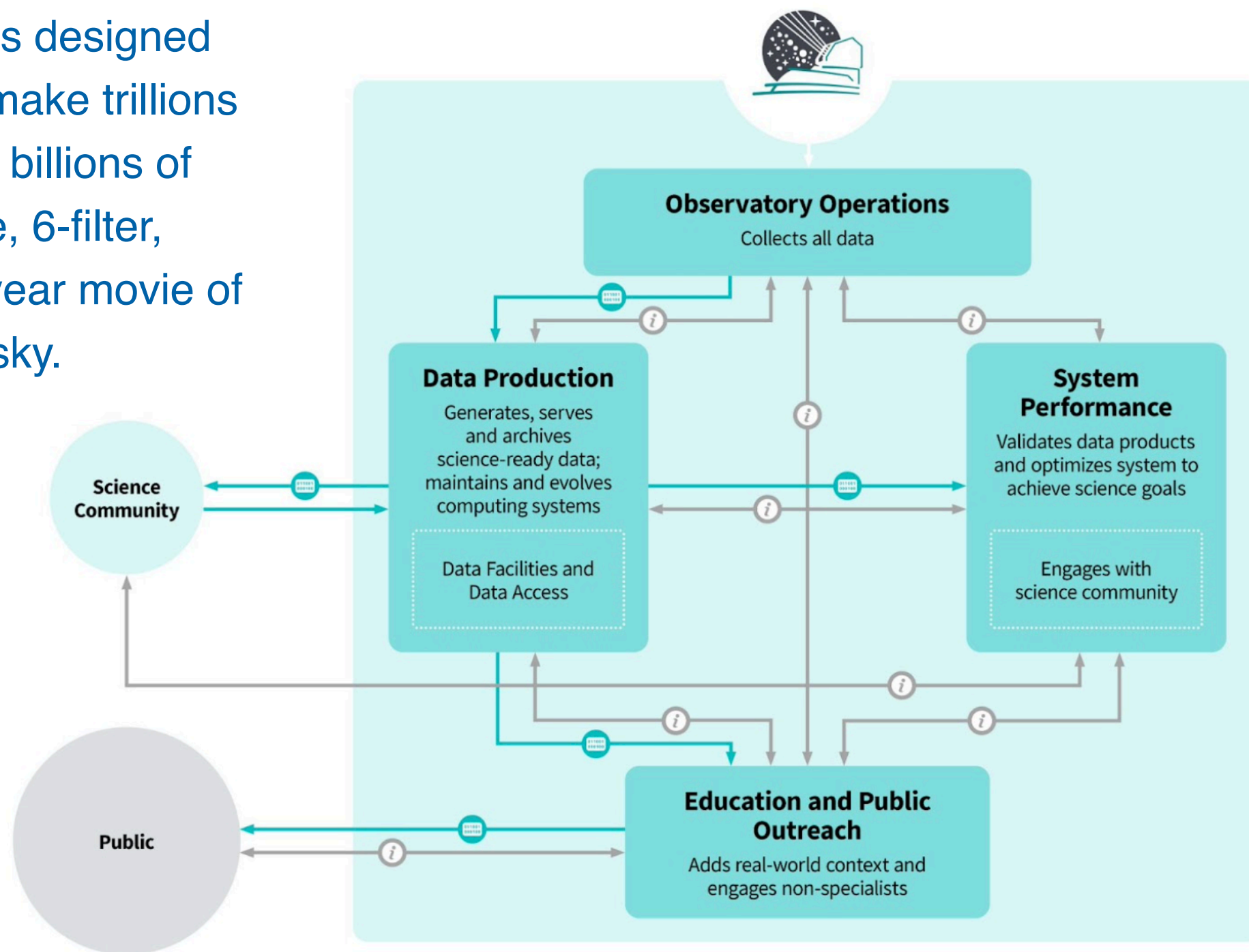
# The full machine

# The Rubin Observatory's LSST: A wide-field telescope, optical CCD camera, & data reduction system



# Operating the Rubin Observatory's LSST:

The survey system is designed and constructed to make trillions of measurements of billions of objects in 825-frame, 6-filter, optical/near-IR, 10 year movie of the entire southern sky.





# The system feeds eight science collaborations

Our primary science collaboration is DESC, but often we are members of more than one SC.



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




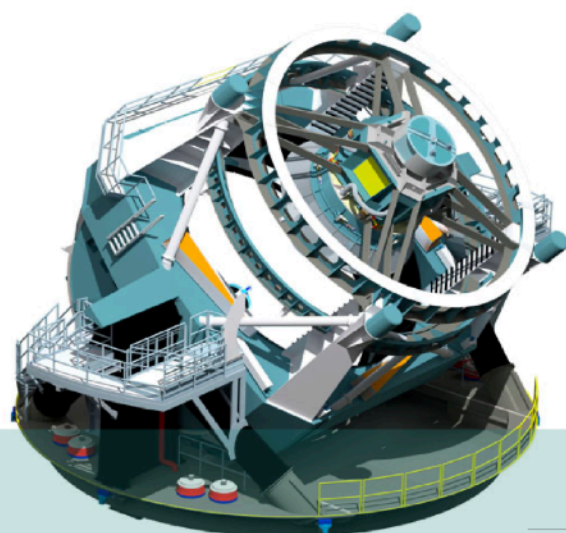
Informatics and Statistics Science Collaboration

# Connecting the machine to the science collaborations: the community engagement team

# The Rubin Science Platform- where analysis starts

## Raw Data: 20TB/night

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



## Prompt Data Products

Alerts: up to 10 million per night

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

Solar System Objects: ~ 6 million

## Data Release Data Products

Final 10yr Data Release:

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



via nightly alert streams



via **Prompt Products Database**



via **Data Releases**

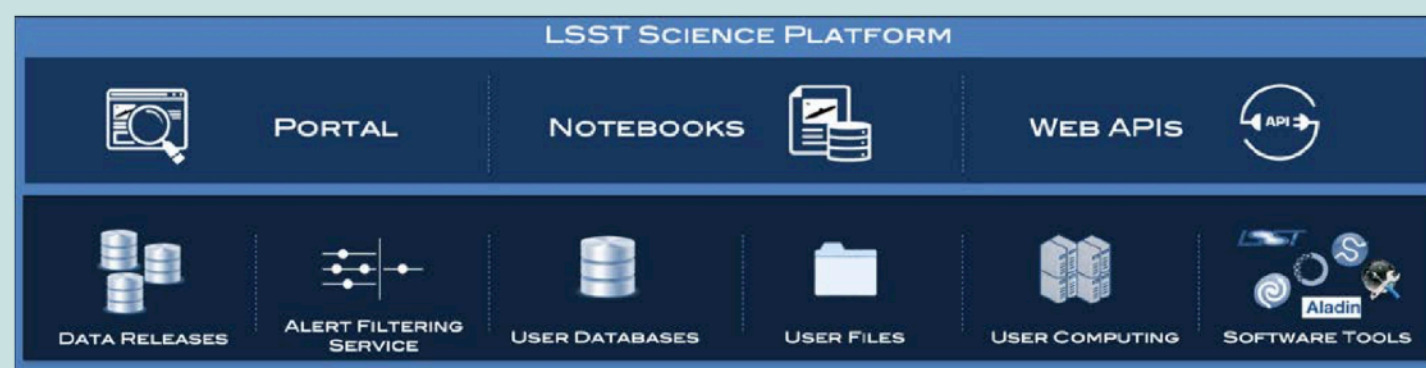


**LSST DACs**  
(Chile & NCSA)

Independent  
DACs (iDACs)

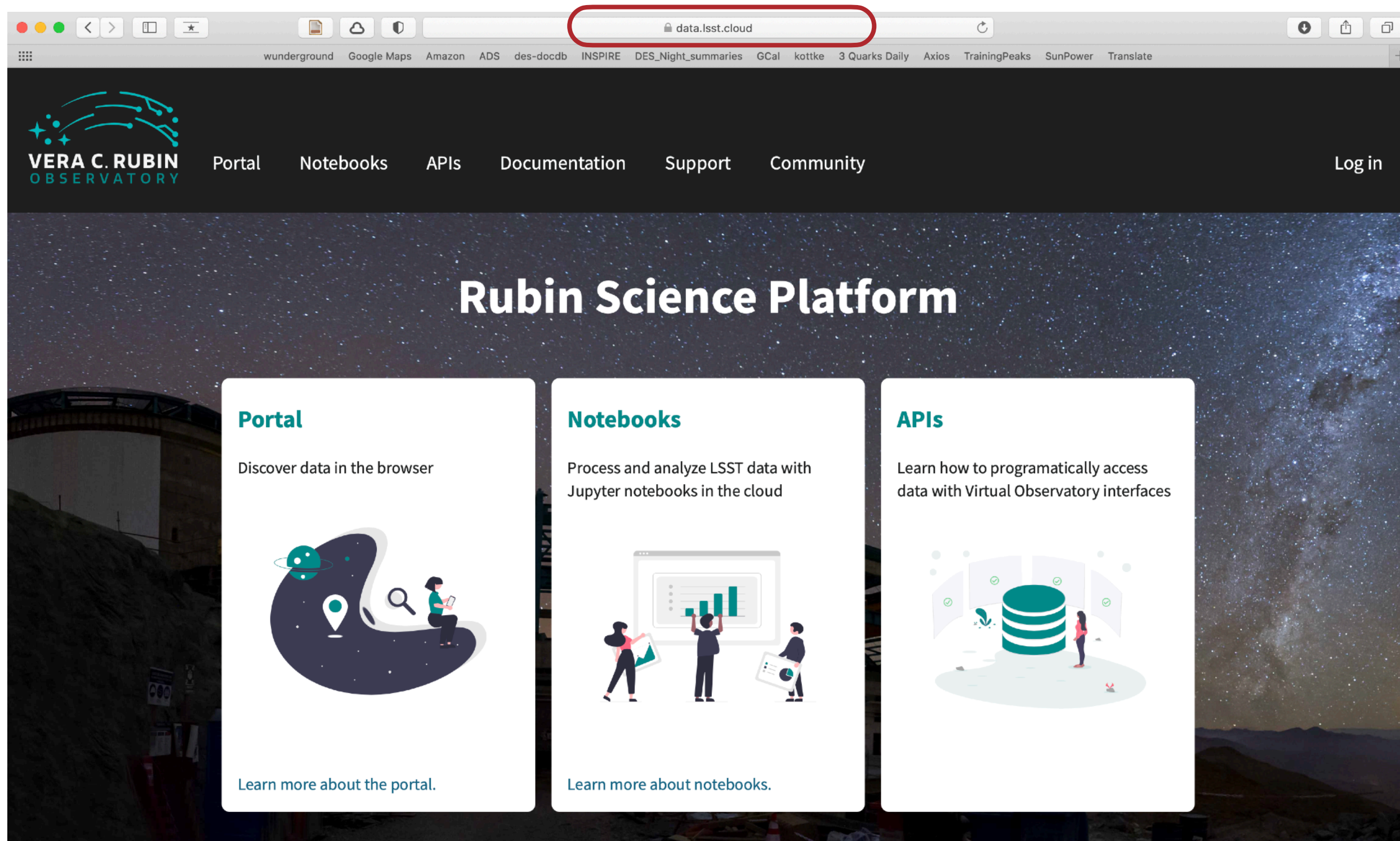
## Rubin Science Platform

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





# RSP currently on Google Cloud



The screenshot shows a web browser window with the address bar displaying `data.lsst.cloud`, which is circled in red. The browser's tab bar shows several open tabs including 'wunderground', 'Google Maps', 'Amazon', 'ADS', 'des-docdb', 'INSPIRE', 'DES\_Night\_summaries', 'GCal', 'kottke', '3 Quarks Daily', 'Axios', 'TrainingPeaks', 'SunPower', and 'Translate'. The website header features the VERA C. RUBIN OBSERVATORY logo on the left and navigation links for 'Portal', 'Notebooks', 'APIs', 'Documentation', 'Support', and 'Community' in the center. A 'Log in' link is located on the right. The main content area has a dark, starry background with the title 'Rubin Science Platform' in large white text. Below the title are three white cards: 'Portal' (Discover data in the browser), 'Notebooks' (Process and analyze LSST data with Jupyter notebooks in the cloud), and 'APIs' (Learn how to programatically access data with Virtual Observatory interfaces). Each card includes an illustration and a 'Learn more' link.


VERA C. RUBIN  
OBSERVATORY

Portal Notebooks APIs Documentation Support Community Log in

## Rubin Science Platform

### Portal


Discover data in the browser



[Learn more about the portal.](#)

### Notebooks


Process and analyze LSST data with Jupyter notebooks in the cloud



[Learn more about notebooks.](#)

### APIs

Learn how to programatically access data with Virtual Observatory interfaces



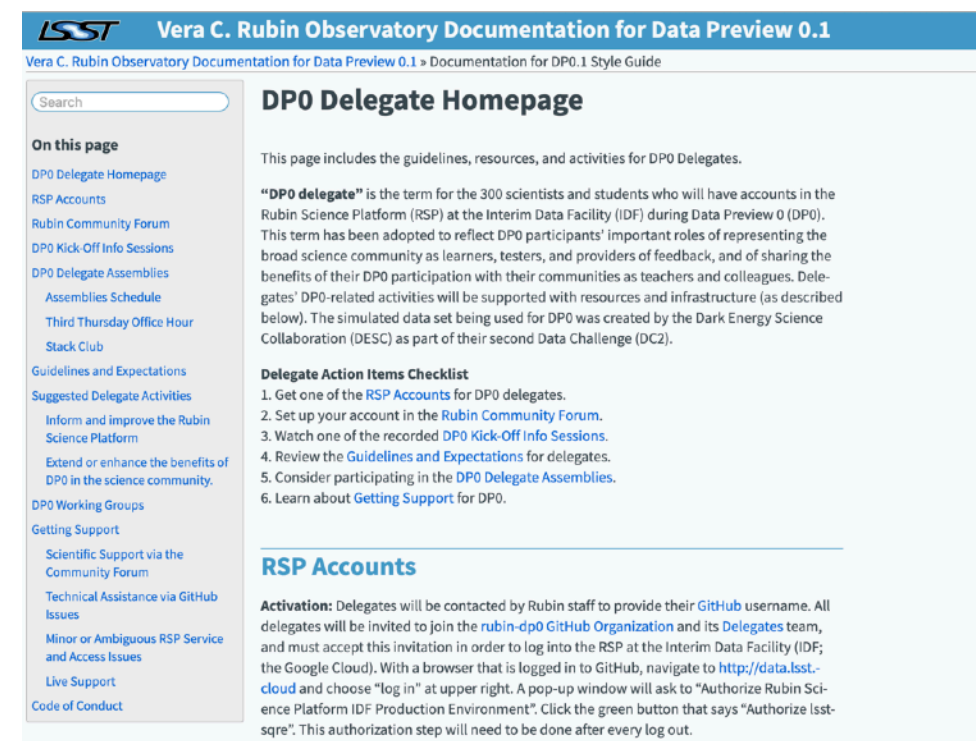
# The Community Engagement Team

The Rubin Observatory's LSST has an pores boundary between the science platform and the science collaborations.

The Community Engagement Team provides support for the science community and ensures spaces where one's identify as a scientist is forefront, where loud voices do not crowd out all voices, where one has an equitable chance to preform creative, innovative, important science.

The CET first activity is the Delegate Assemblies, where 300 delegates from the science collaborations work together.

- Delegates are given documentation on using the RSP.
- Delegate Assemblies occur every two weeks on Friday
- A series of notebooks provide the starting point to using the Rubin Science Platform effectively to do science.
- The Rubin Project and Community Workshop meeting is next week!



**LSST Vera C. Rubin Observatory Documentation for Data Preview 0.1**

Vera C. Rubin Observatory Documentation for Data Preview 0.1 » Documentation for DP0.1 Style Guide

**DP0 Delegate Homepage**

This page includes the guidelines, resources, and activities for DP0 Delegates.

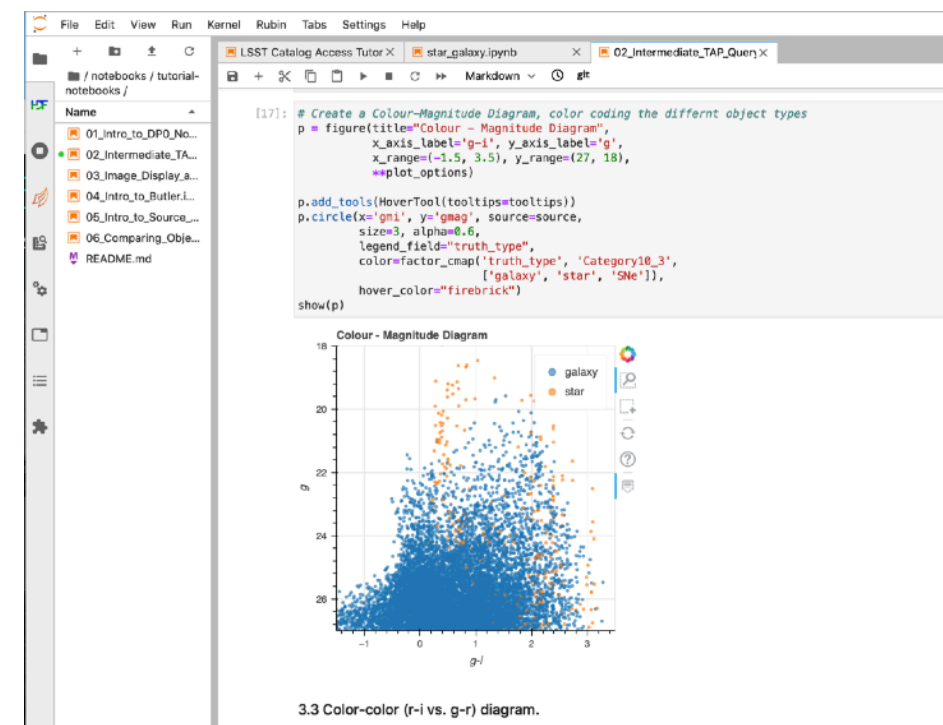
**"DP0 delegate"** is the term for the 300 scientists and students who will have accounts in the Rubin Science Platform (RSP) at the Interim Data Facility (IDF) during Data Preview 0 (DP0). This term has been adopted to reflect DP0 participants' important roles of representing the broad science community as learners, testers, and providers of feedback, and of sharing the benefits of their DP0 participation with their communities as teachers and colleagues. Delegates' DP0-related activities will be supported with resources and infrastructure (as described below). The simulated data set being used for DP0 was created by the Dark Energy Science Collaboration (DESC) as part of their second Data Challenge (DC2).

**Delegate Action Items Checklist**

1. Get one of the [RSP Accounts](#) for DP0 delegates.
2. Set up your account in the [Rubin Community Forum](#).
3. Watch one of the recorded [DP0 Kick-Off Info Sessions](#).
4. Review the [Guidelines and Expectations](#) for delegates.
5. Consider participating in the [DP0 Delegate Assemblies](#).
6. Learn about [Getting Support](#) for DP0.

**RSP Accounts**

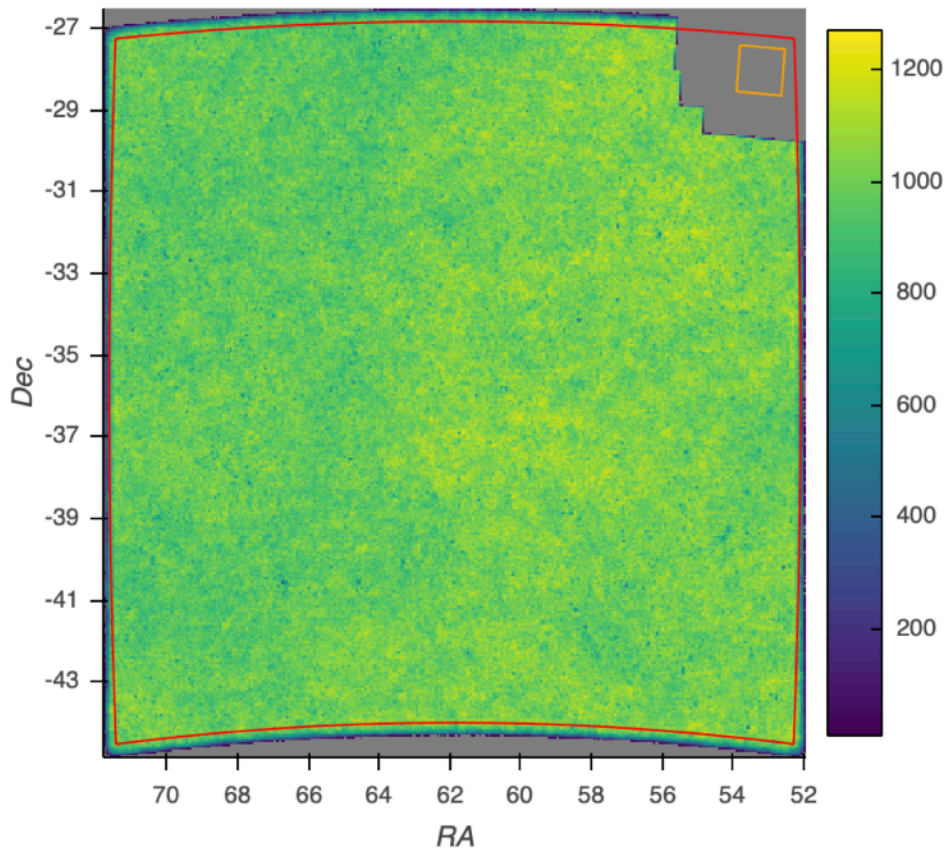
**Activation:** Delegates will be contacted by Rubin staff to provide their GitHub username. All delegates will be invited to join the [rubin-dp0 GitHub Organization](#) and its [Delegates team](#), and must accept this invitation in order to log into the RSP at the Interim Data Facility (IDF; the Google Cloud). With a browser that is logged in to GitHub, navigate to <http://data.lsst-cloud> and choose "log in" at upper right. A pop-up window will ask to "Authorize Rubin Science Platform IDF Production Environment". Click the green button that says "Authorize lsst-sqre". This authorization step will need to be done after every log out.



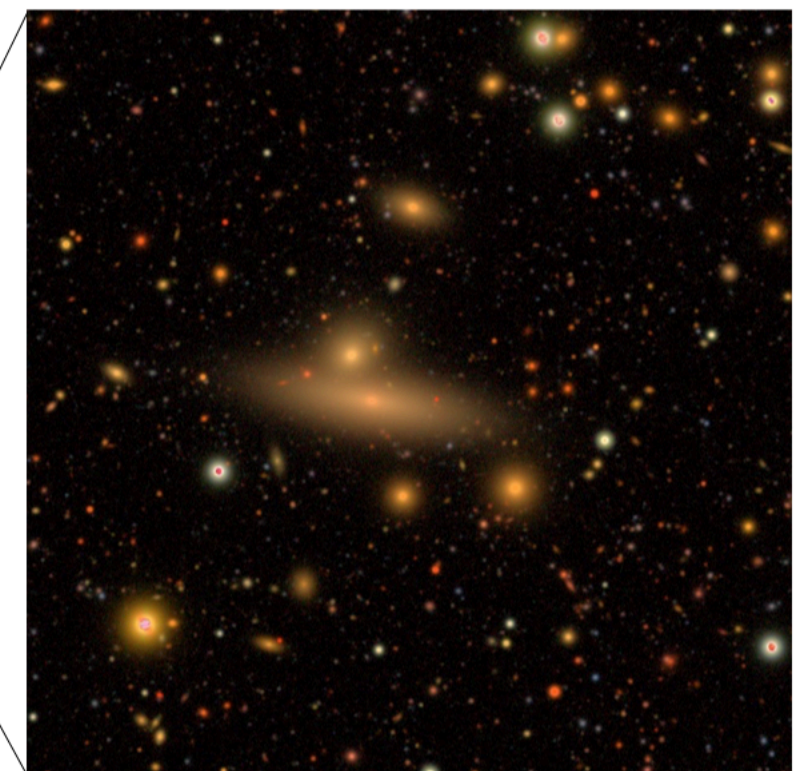
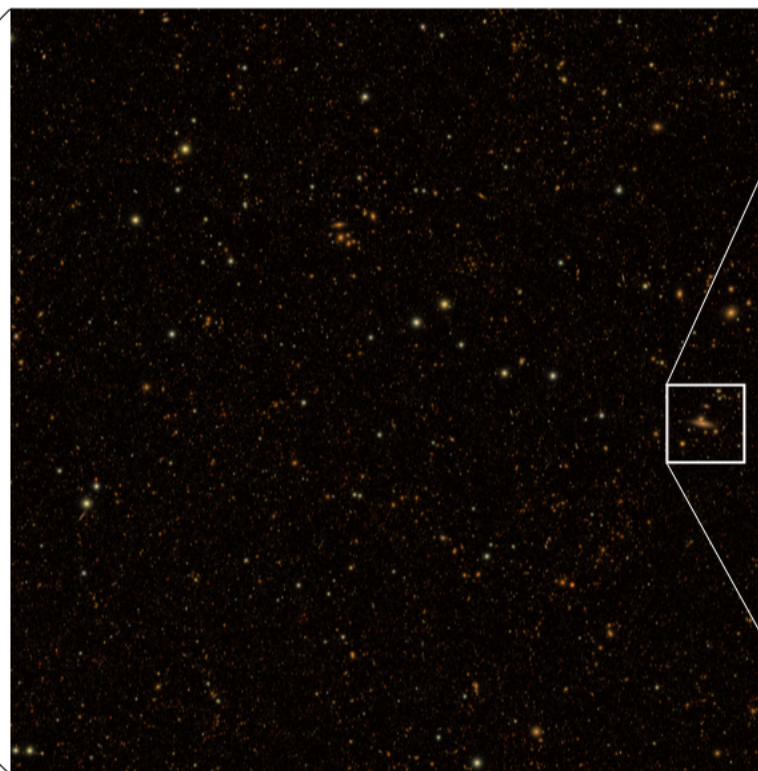
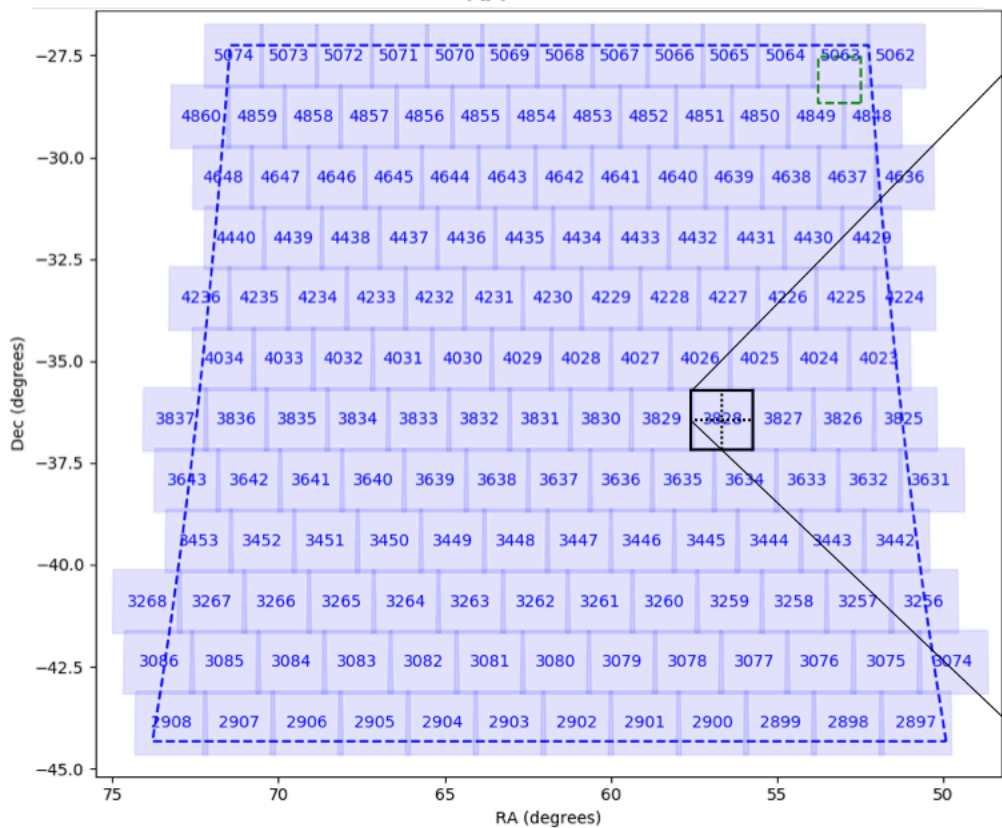
# Dark Energy Science Collaboration



# DESC DC2 currently fills the Rubin Science Platform



The DESC Data Challenge 2 simulation performed ray tracing simulation of images based on cosmological dark matter simulations with semi-analytic galaxy placements. The LSST data reduction pipeline were run to produce catalogs. The images and catalogs were placed in the RSP.





# DESC is a well-organized and capable collaboration aimed at understanding the second era of cosmic acceleration

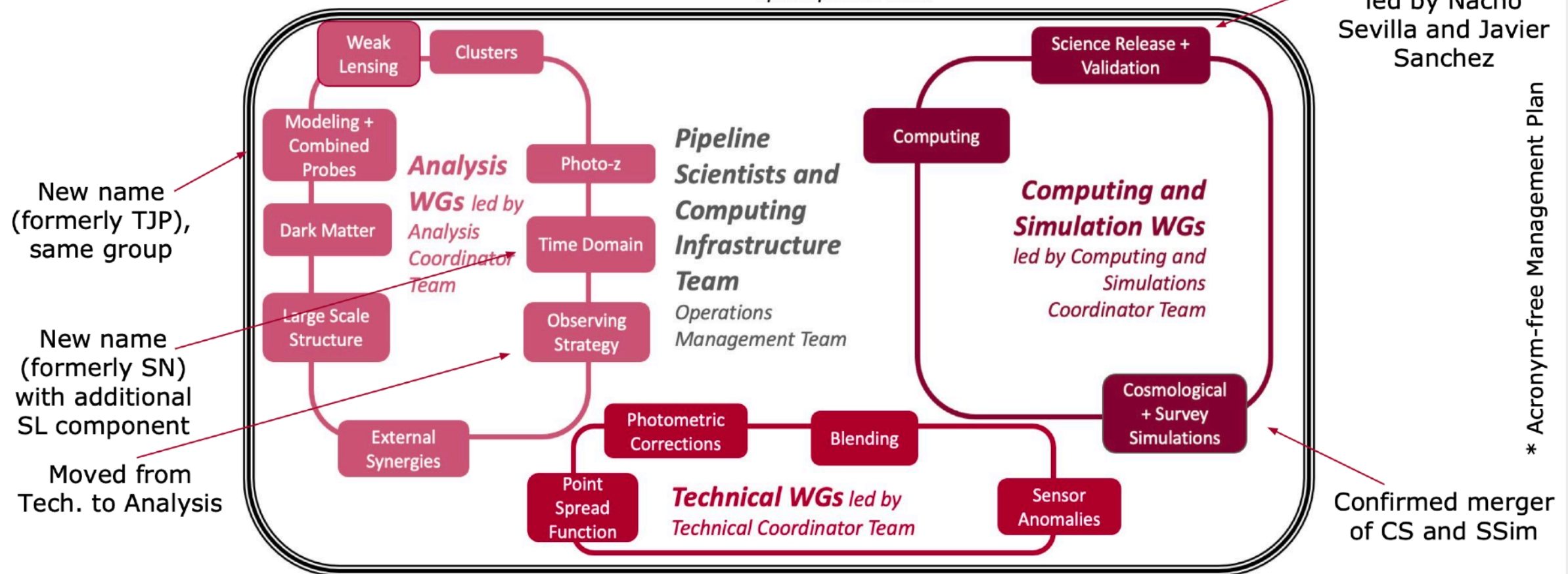
## The New Management Plan

Find the new AFMP\* [here](#).

**DESC Management** led by  
Spokesperson Team



Newly established  
Working Group;  
led by Nacho  
Sevilla and Javier  
Sanchez





# Collaborations are made of individual scientists



*Three wall-mounted metallic prints of DC2 image featuring DESC members*

## Opportunities to pursue science and technology with us:

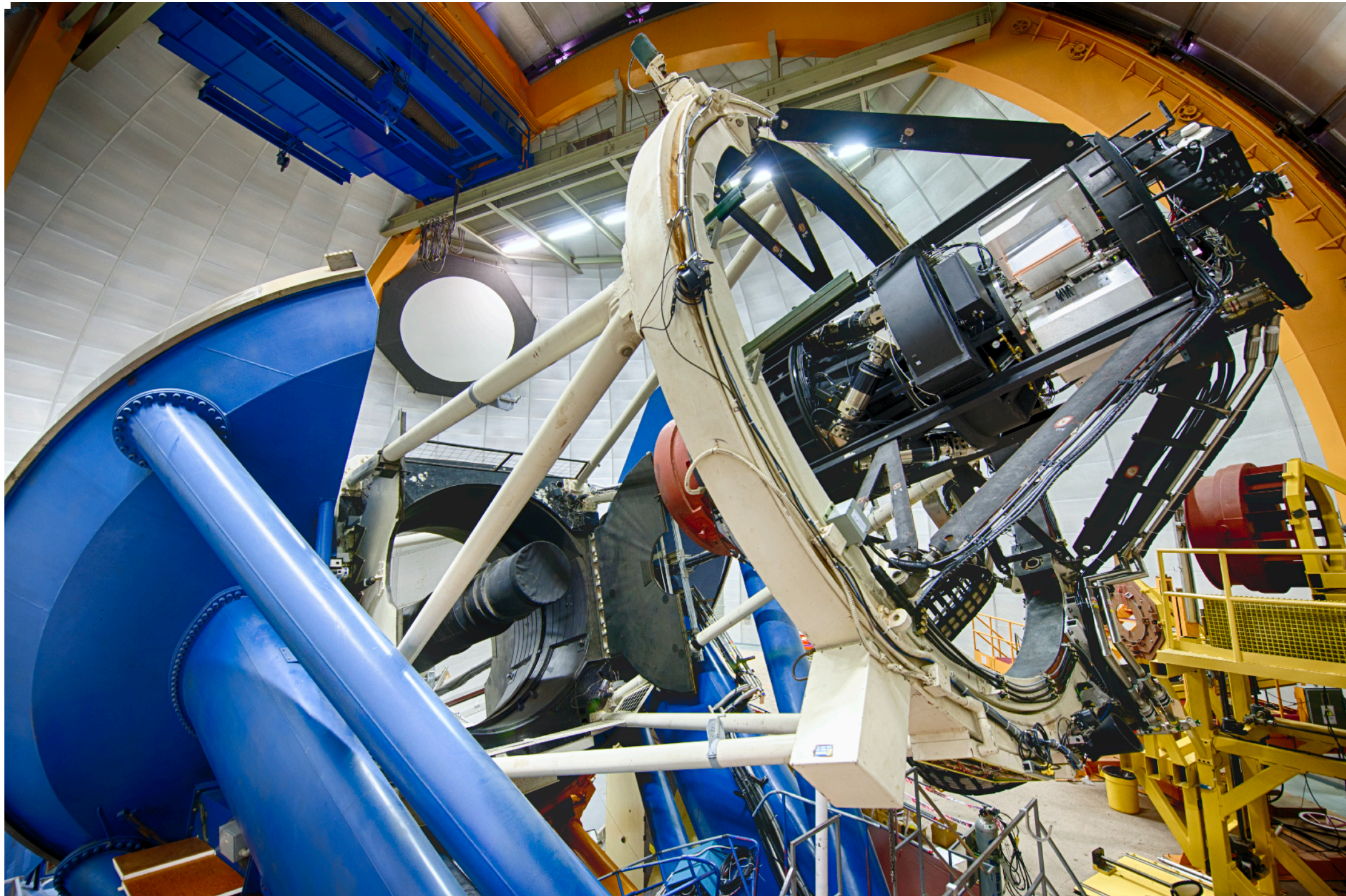
- Dark energy programs in
  - cluster weak lensing, (James Annis, Marc Paterno, & Yuanyuan Zhang)
  - large scale structure correlation functions, (Javier Sanchez)
  - strong lens discovery & follow-up (Elizabeth Buckley-Geer, Huan Lin)
- Dark matter programs in
  - dwarf galaxies near the Milky Way, (Alex Drlica-Wagner)
  - the structure of the dark matter about the Milky Way (Brian Yanny)
- The rising field of using gravitational wave sources as cosmological tools (James Annis, Ken Herner)
- Artificial intelligence and machine learning program (Brian Nord, Aleksandra Ciprijanovic)



# Precursor Science: The DES

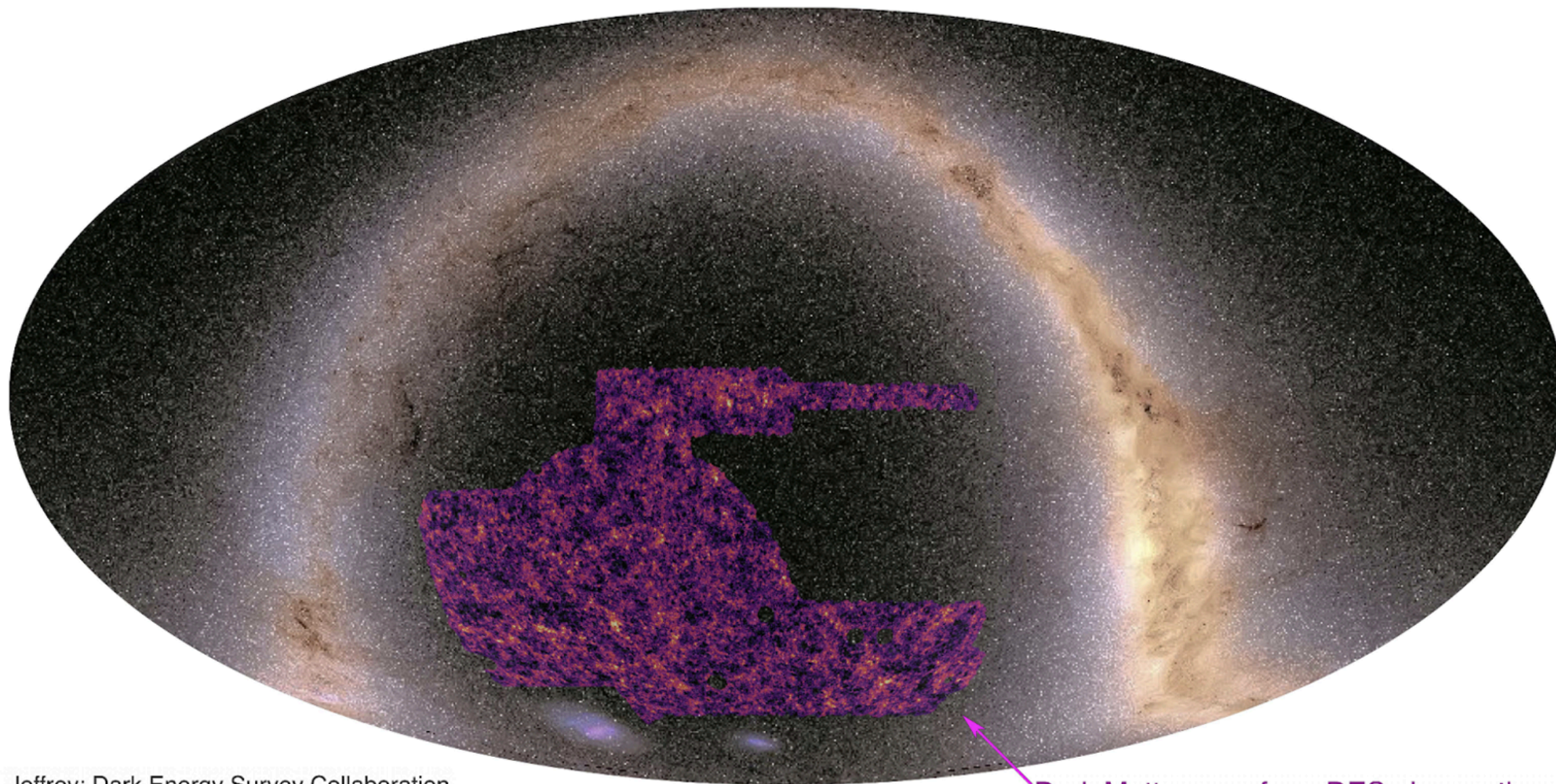


# Dark Energy Survey (DES)- precursor survey





# Cosmic surveys for cosmological physics



N. Jeffrey; Dark Energy Survey Collaboration

Dark Matter map from DES observations

DES Year 3 Results: curved-sky weak lensing mass map reconstruction,  
Jeffrey, Gatti, Chang et al 2021



# The statistical distribution of galaxies and mass

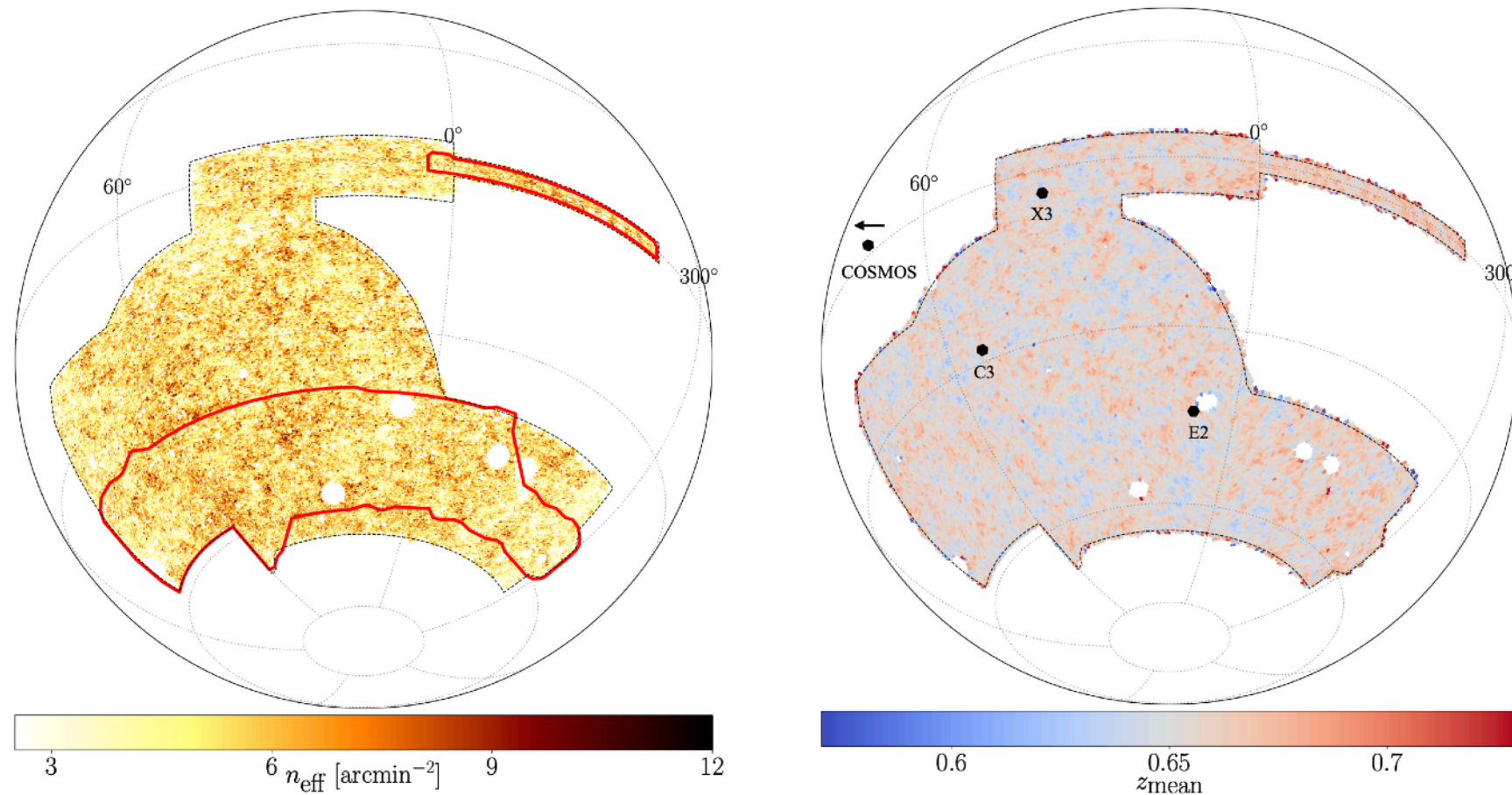
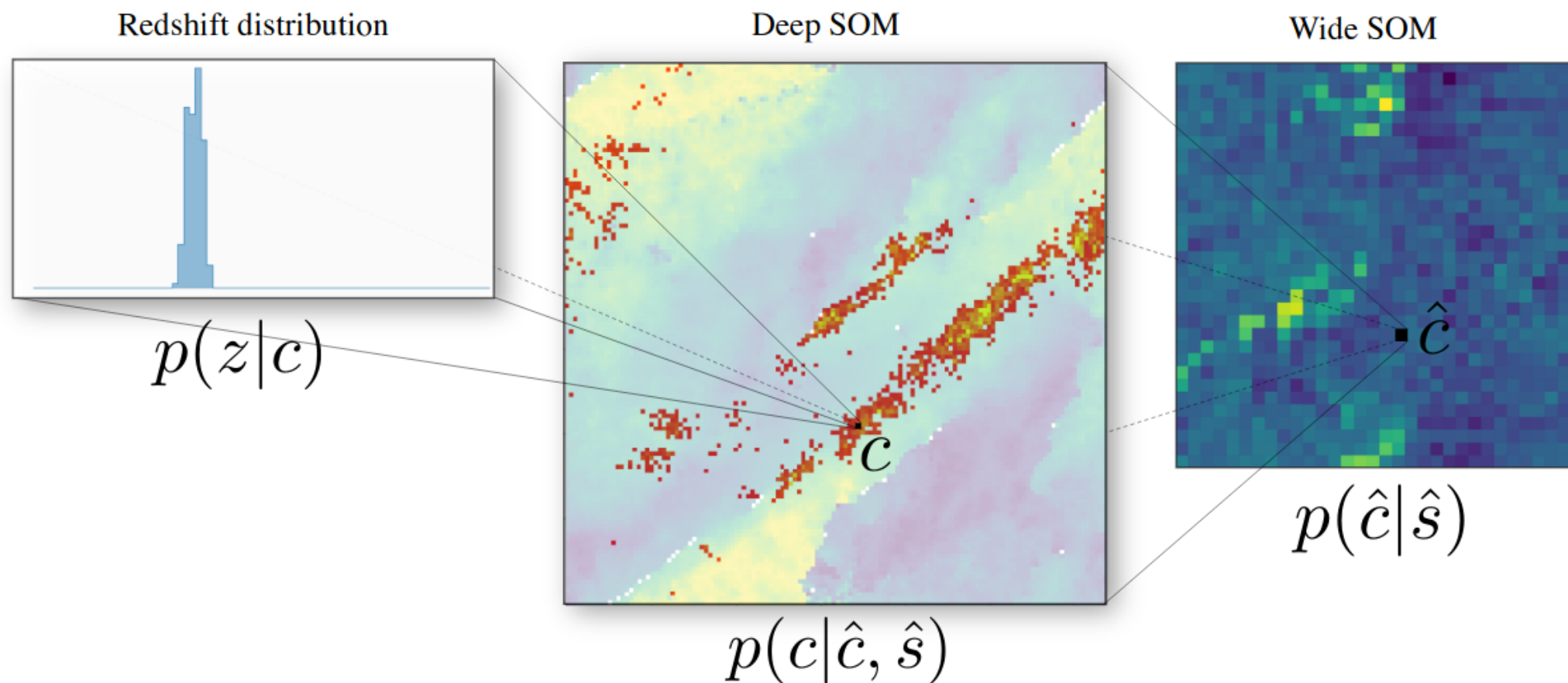


FIG. 1: DES Y3 footprint showing the variation in the number density across the sky, as determined with the METACALIBRATION catalog (left) and the variation in mean redshift of that catalog (right). Overlaid on the left is the red outline of the Y1 footprint and on the right, the locations of the four DES Deep Fields [106] (the fourth field, COSMOS, is positioned at  $\sim 150^\circ$ , outside of the DES footprint, but has been rotated here to be shown on the map). The catalog spans a final effective area of  $4143 \text{ deg}^2$  with an average number density of  $5.59 \text{ arcmin}^{-2}$  and a mean redshift of 0.63.

DES Year 3 Results: Cosmology from Cosmic Shear and Robustness to Data Calibration,  
Amon, Gruen, Troxel et al 2021

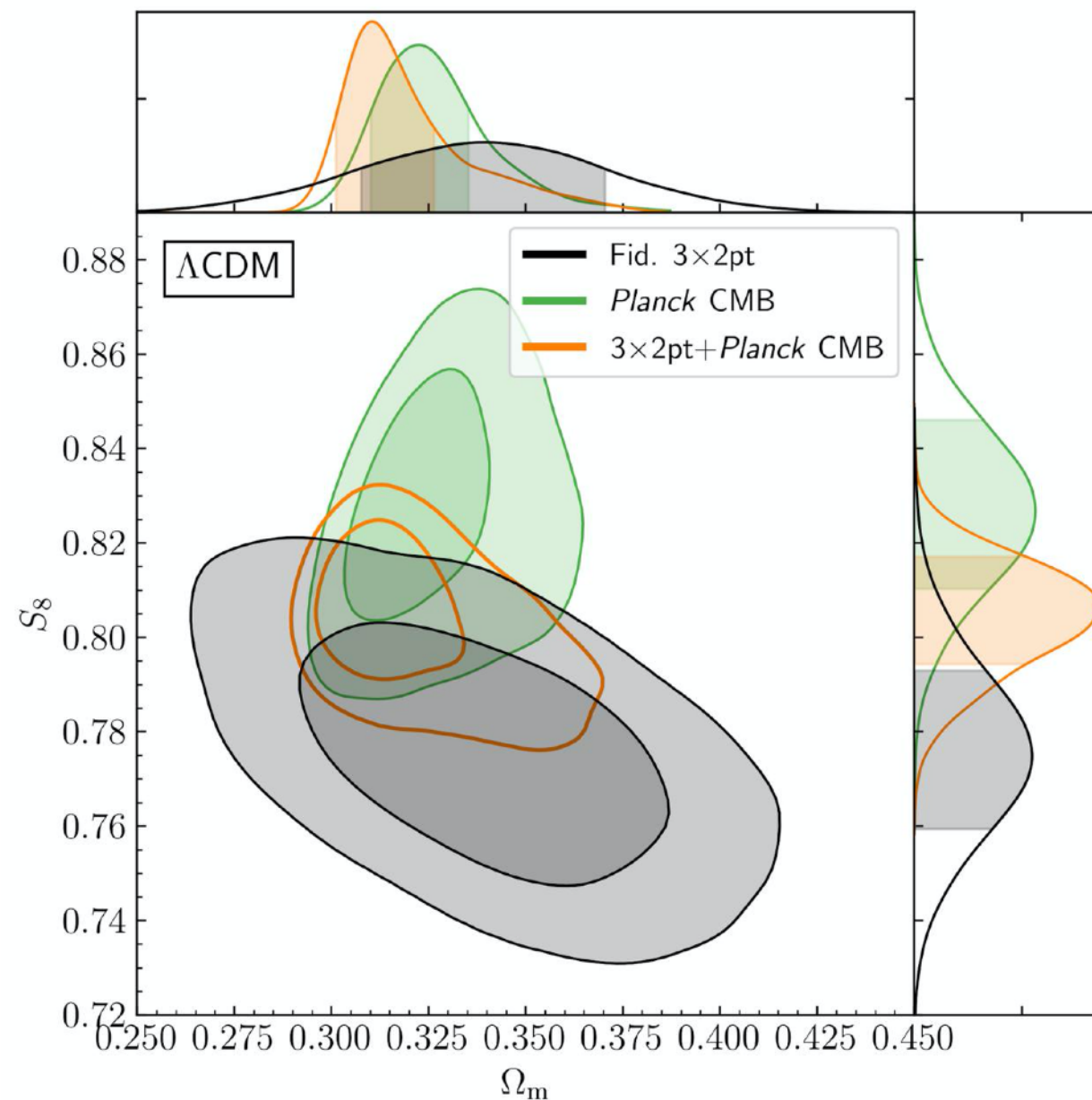


# Photometric Redshifts for Galaxies using Machine Learning Techniques: Self-Organizing Maps



Phenotypic redshifts with self-organizing maps: A novel method to characterize redshift distributions of source galaxies for weak lensing  
 Buchs, DeRose, Alacorn et al

# Cosmological Constraints using advanced statistics: is there tension between Planck and DES?



“We find that the parameter differences, Eigentension, and Suspiciousness metrics all yield similar results on both simulated and real data, while the Bayes ratio is inconsistent with the rest due to its dependence on the prior volume.”

Assessing tension metrics with Dark Energy Survey and Planck data,  
Lemos, Raveri, Campos et al 2021

# Aiming at the acceleration of the universe

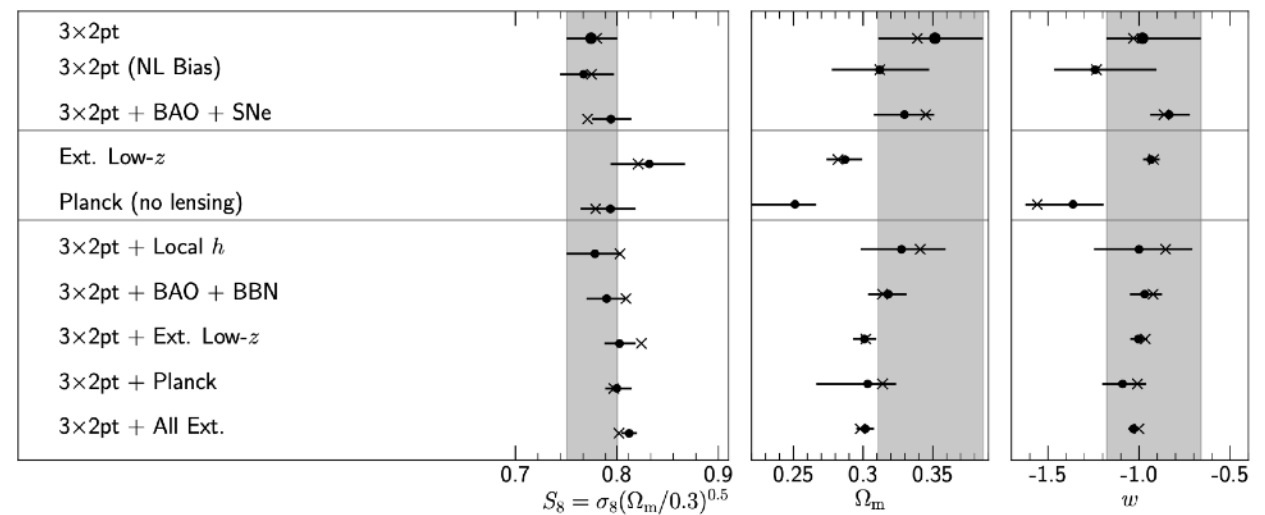
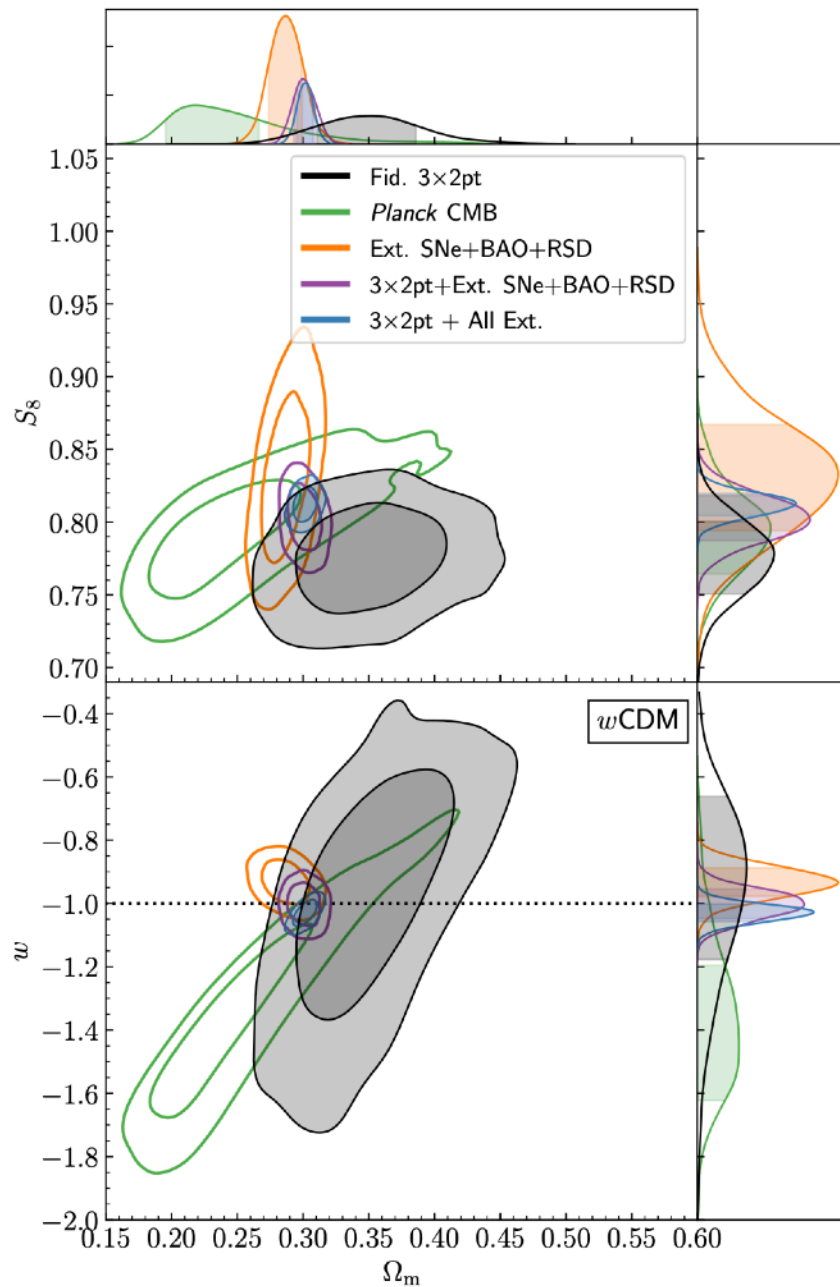


FIG. 10. Summary of marginalized constraints (mean and 68% CL) and maximum posterior values (crosses) on  $S_8$ ,  $\Omega_m$ , and  $w$  in  $w$ CDM. ‘Ext. Low- $z$ ’ data consists of external SNe Ia, BAO, and RSD, while ‘All Ext.’ data consists of external SNe Ia, BAO, RSD, and *Planck* CMB with lensing. The top section shows constraints using only DES data, the middle section only external data, and the bottom section combinations of DES and external data.

DES Year 3 Results: Cosmological Constraints from Galaxy Clustering and Weak Lensing,  
Abbott et al 2021

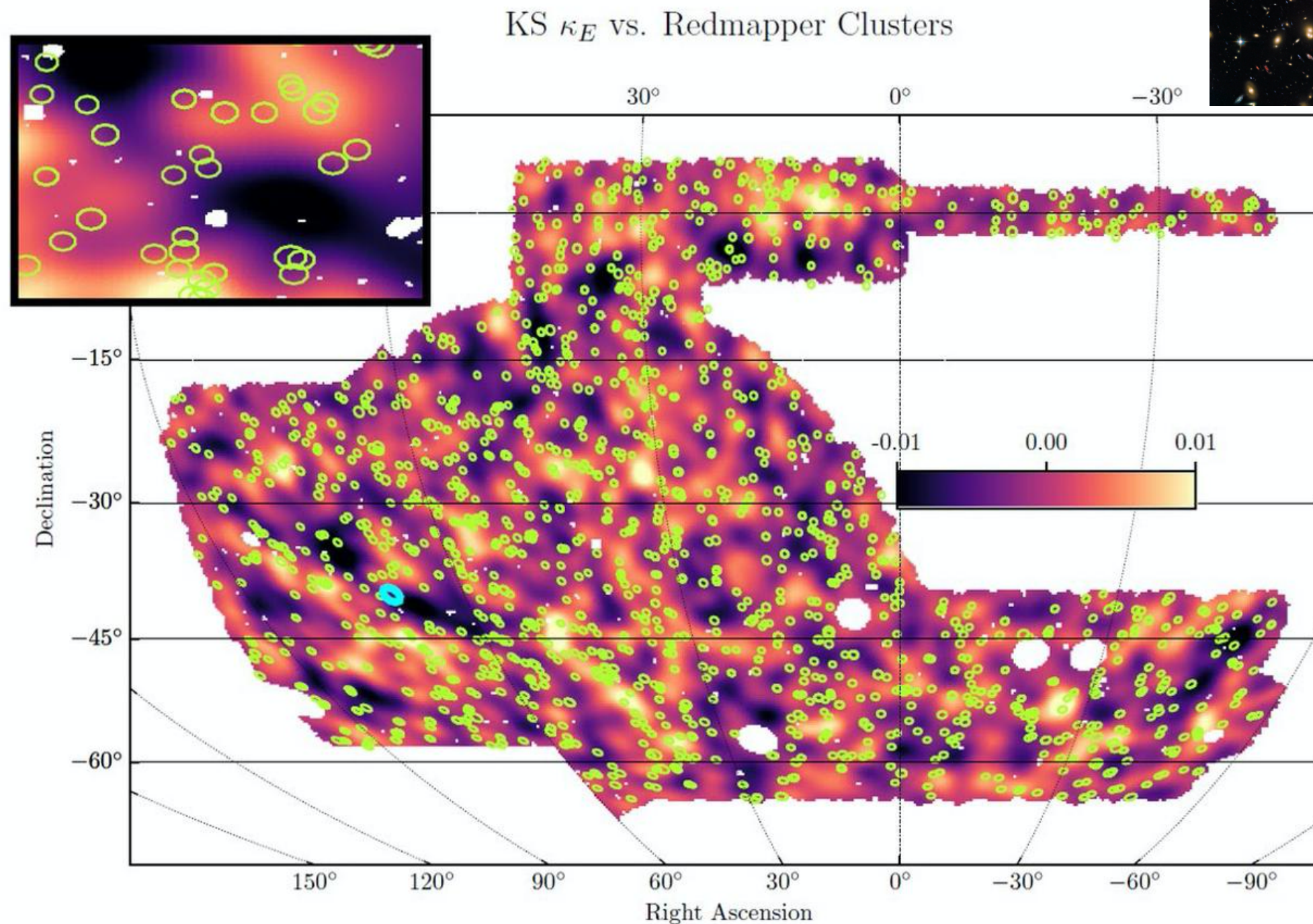
# Cosmology from clusters of galaxies





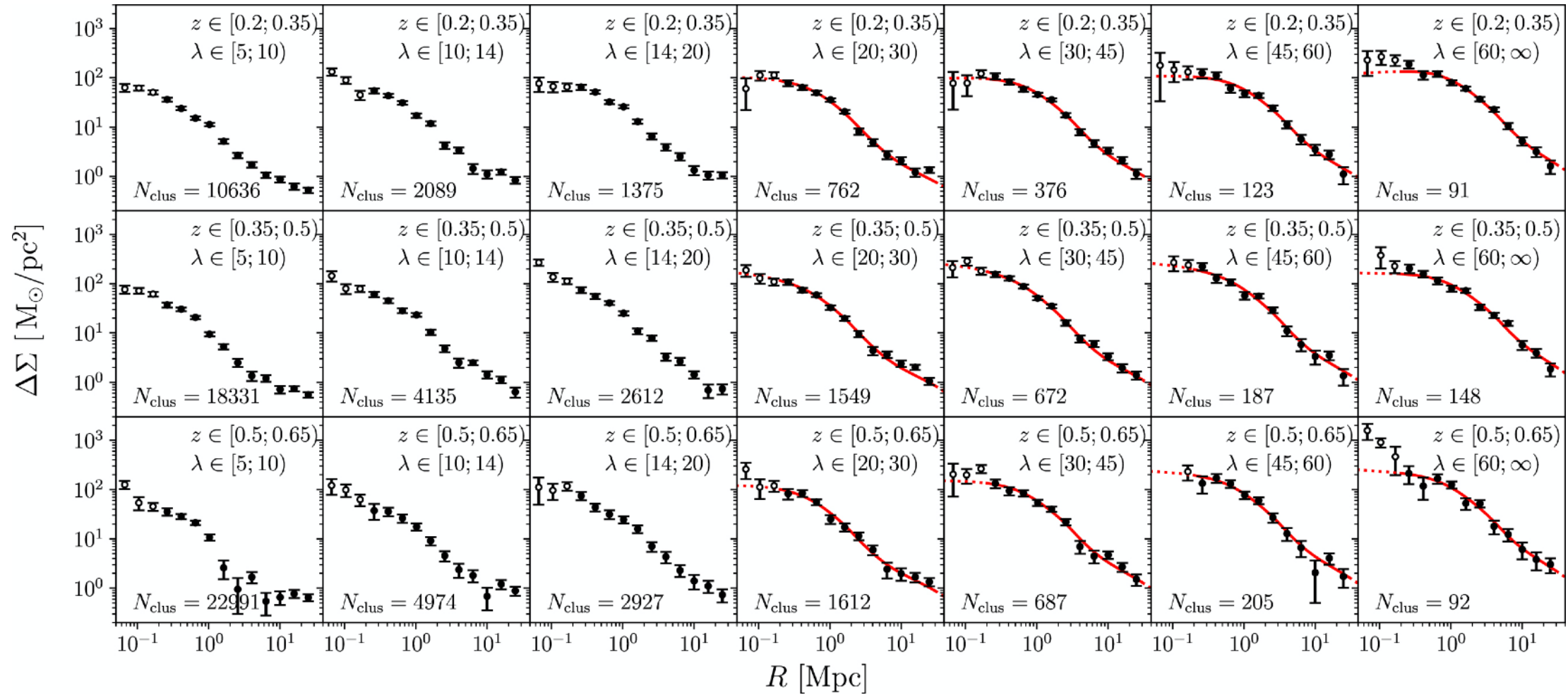
DARK ENERGY  
SURVEY

# Mass maps and cluster of galaxies



DES Year 3 Results: curved-sky weak lensing mass map reconstruction,  
Jeffrey, Gatti, Chang et al 2021

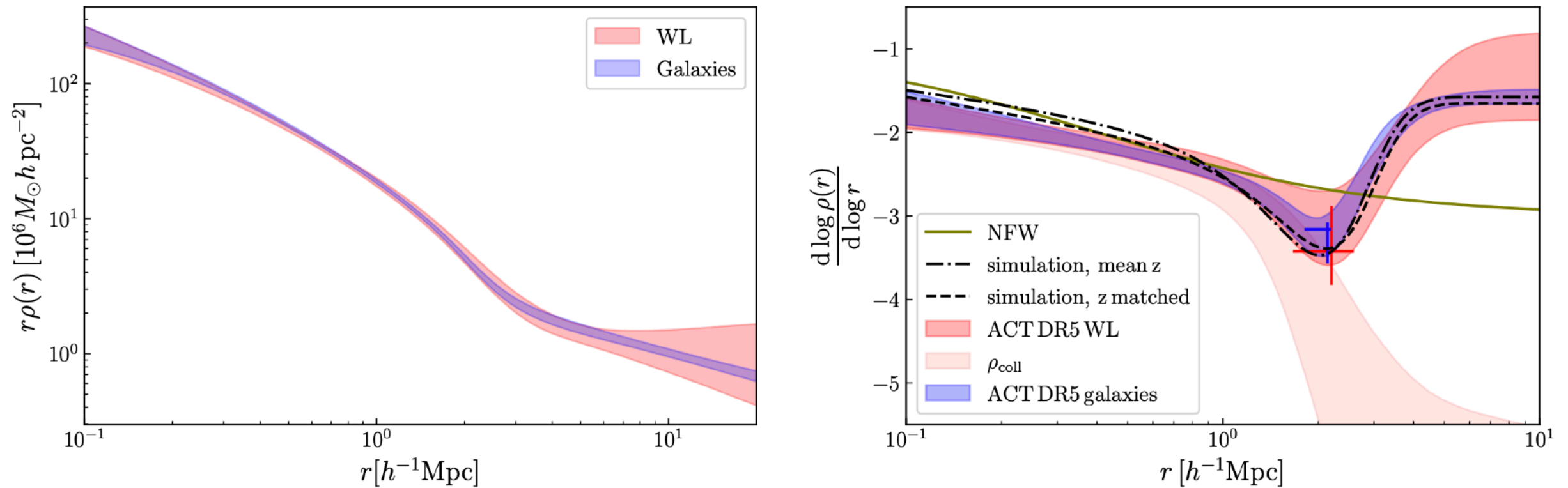
# Weak lensing profiles of dark matter about clusters as a function of red galaxy count and redshift



DES Year 1 Results: Weak Lensing Mass Calibration of redMaPPer Galaxy Clusters  
McClintock, Varga, Gruen et al 2018



# Learning about the edges of clusters!



**Figure 4.** *Left panel:* The 3D density profiles inferred from the measured WL (red) and projected galaxy number density profiles (blue) as described in Sec. 3.5. The galaxy density profile normalization is shifted so that the difference between the two curves is minimized. *Right panel:* The logarithmic slope of the 3D dark matter profile inferred from the WL (red shaded region) and the galaxy density (blue shaded region) profiles via the model fits as in the previous figures. The crosses represent the 1- $\sigma$  constraints on the splashback radius,  $r_{\text{sp}}$ , and the corresponding slopes. The mean dark matter profiles from mass-matched halos from  $N$ -body simulations (Sec. 2.5) are shown as the black lines. See Sec. 4.1, 4.3 and 4.5 for details.

The mass and galaxy distribution around SZ-selected clusters  
Shin, Jain, Adhikari et al 2021



# Summary

- The Rubin Observatory is nearing completion
- The Rubin Science Platform is being released to the community
- The science collaborations are formed to work with the data
- DESC is a strong collaboration within which to measure cosmological parameters using the imaging sky survey LSST
- Weak lensing combined with galaxies are the primary DESC technique
- The technologies involved include machine learning and advanced statistics as well as astrophysics
- Clusters of galaxies, my particular field, is rich in physics as well as cosmological potential.
- We'd prefer to do this in person, with you at Fermilab! Next year!