



# Vera C. Rubin Observatory and the Rubin LSST Science Collaborations

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Department of Physics and Astronomy  
Biden School of Public Policy and Administration  
Data Science Institute

Rubin Deputy Project Scientist  
Transients & Variable Stars SC CoChair

these slides <https://bit.ly/NAM22Rubinintro>



## *Probing Dark Energy and Dark Matter*

Exquisite measurements of strong and weak lensing, large-scale structure, clusters of galaxies, and supernovae

*LSST Science Drivers*

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***Mapping the Milky Way and Local Volume  
via resolved stellar population***

17B stars characterized in color, variability, position

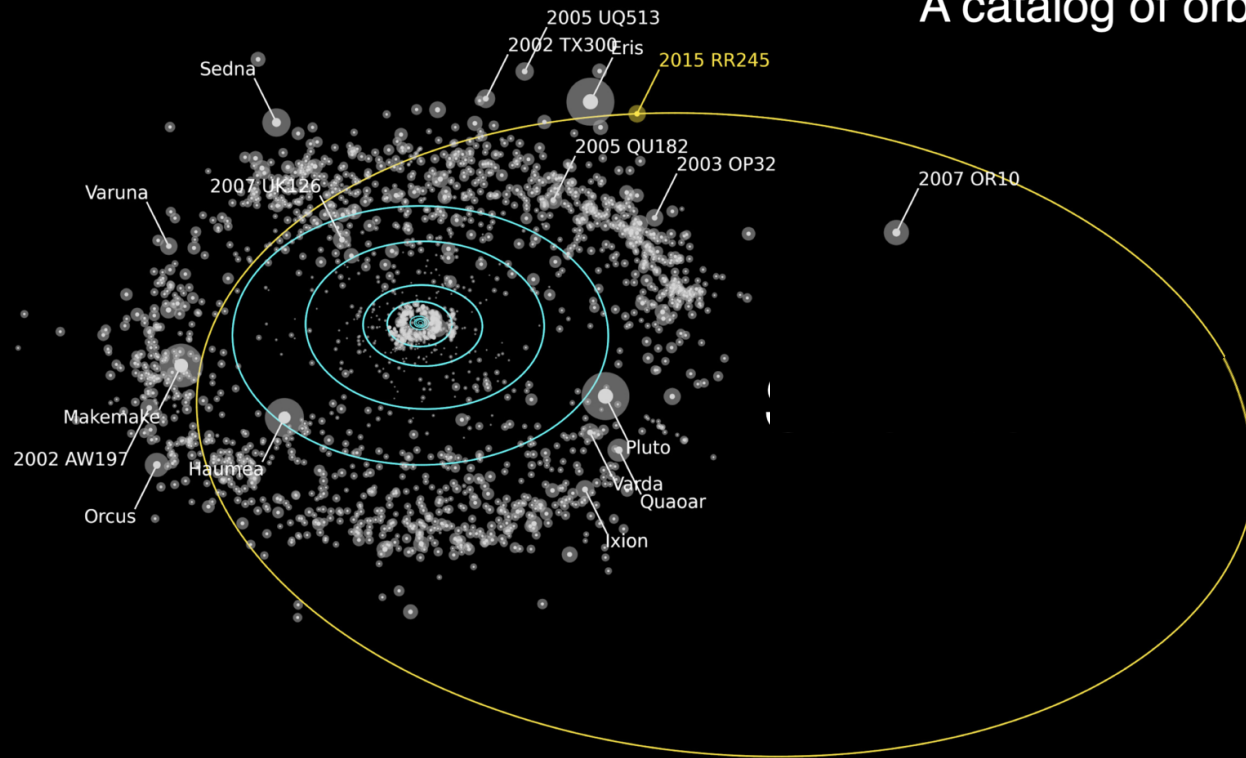


image credit ESO-Gaia

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*LSST Science Drivers*

# An unprecedented inventory of the Solar System from threatening NEO to the distant Oort Cloud



A catalog of orbits for 6 million bodies

LSST Science Drivers



## Exploring the Transients and Variable Universe

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10M astrophysical alerts per night  
picked up and distributed worldwide by  
brokers like Lasair

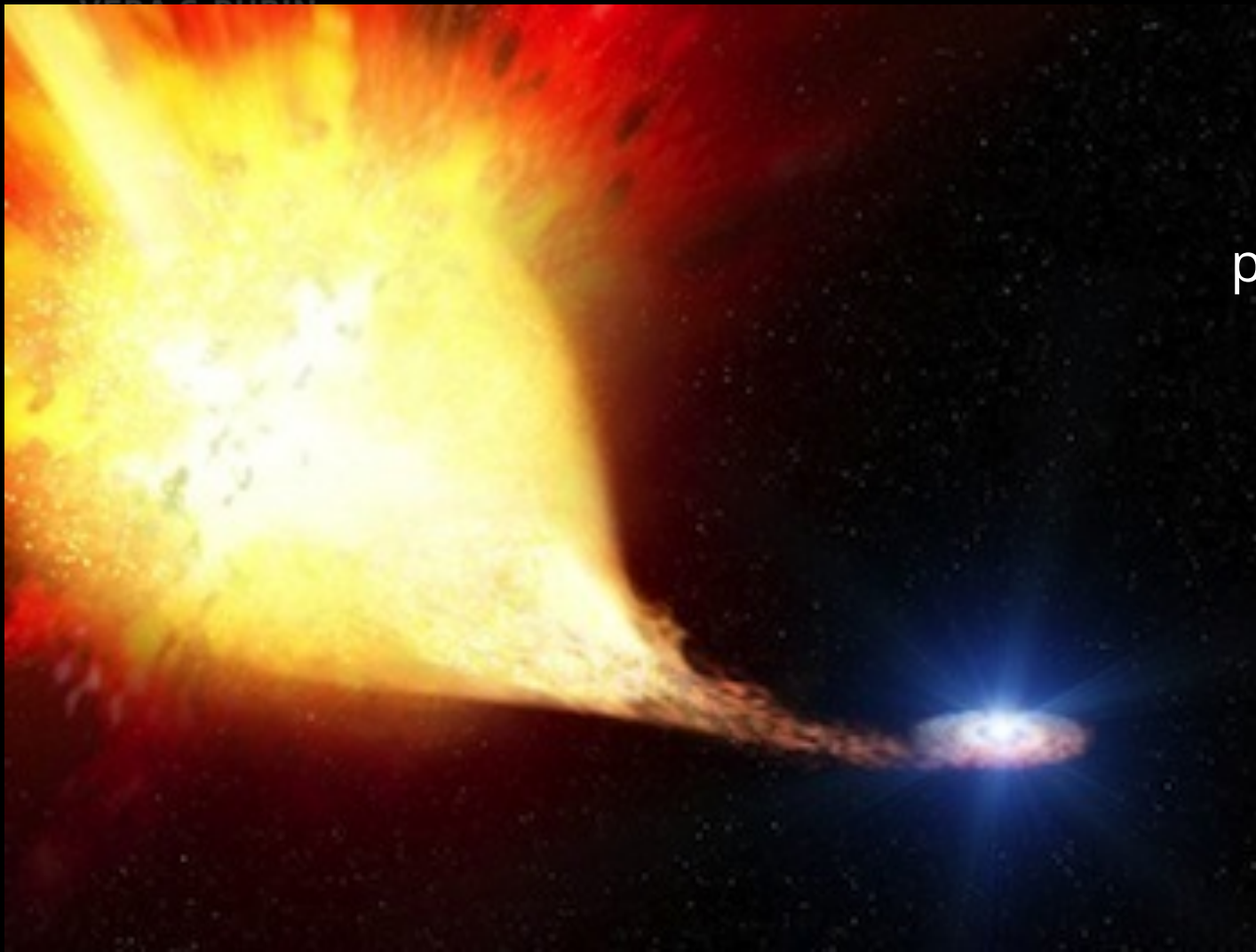


image credit: ESA-Justyn R. Maund

*LSST Science Drivers*

# Rubin Observatory

Site: Cerro Pachon, Chile

Funding: US NSF + DOE

Status: final phases of construction -  
completion expected 2023





Site was vacated (full power shutdown) in March



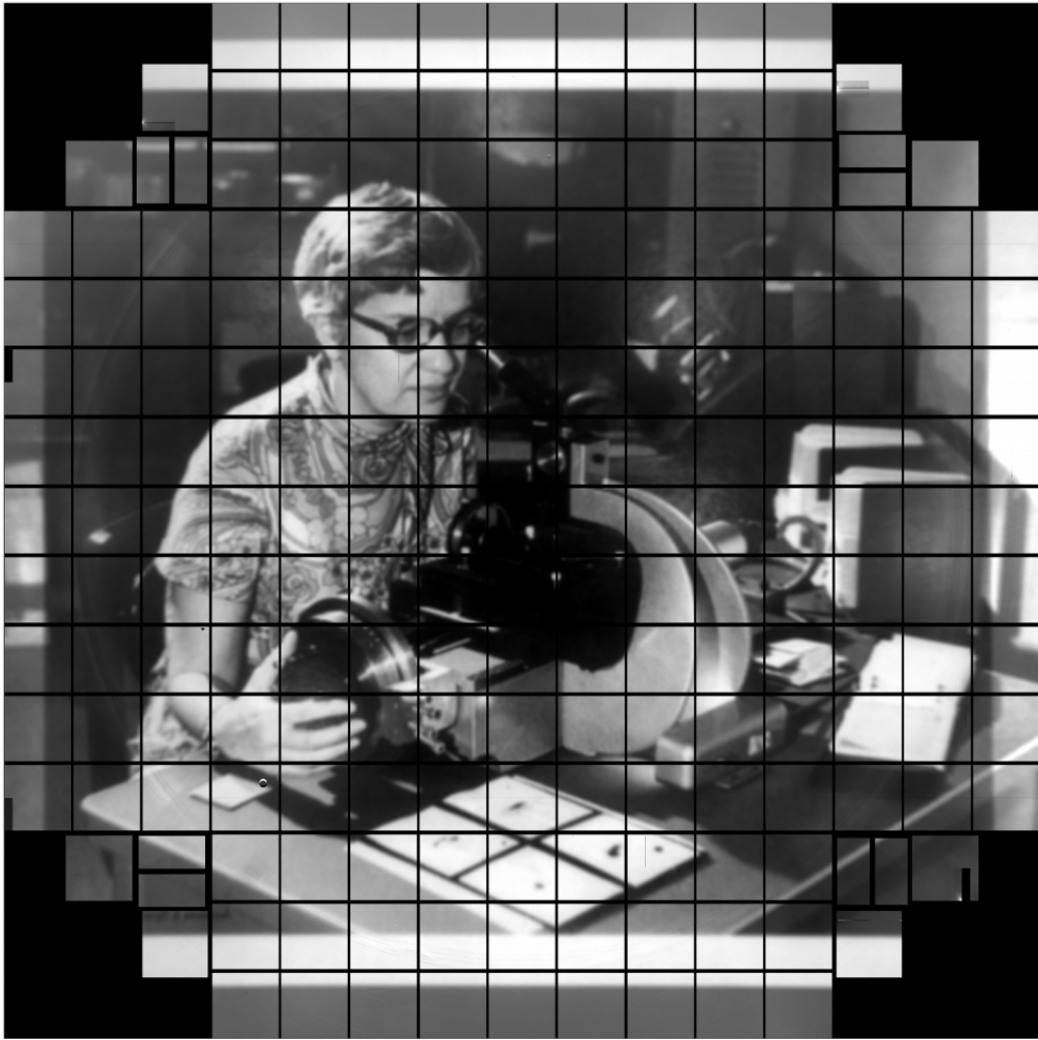
Rubin Observatory,  
Cerro Pachon  
17 February 2020







# what's in a name?



Rubin Obs is the first ground-based US National Observatory named after a woman astrophysicist, Dr.

**Vera Florence Cooper Rubin**

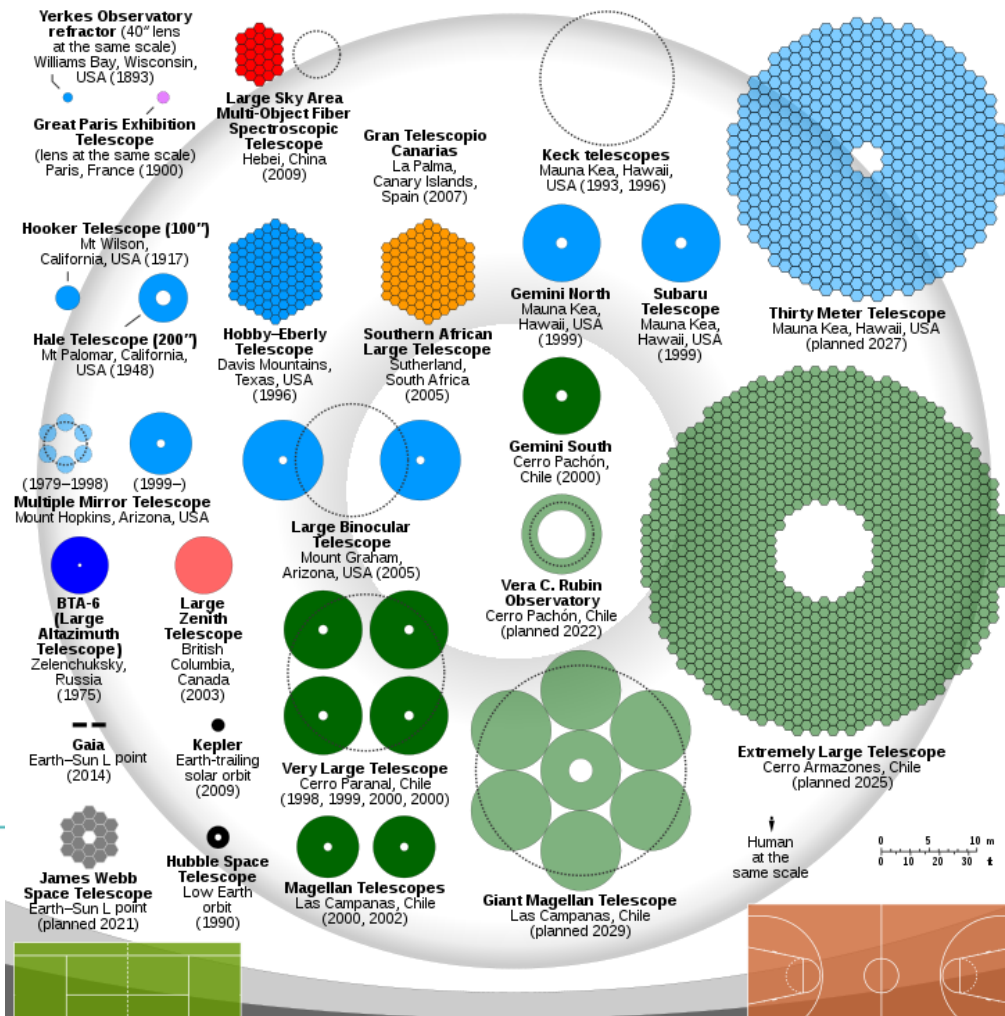
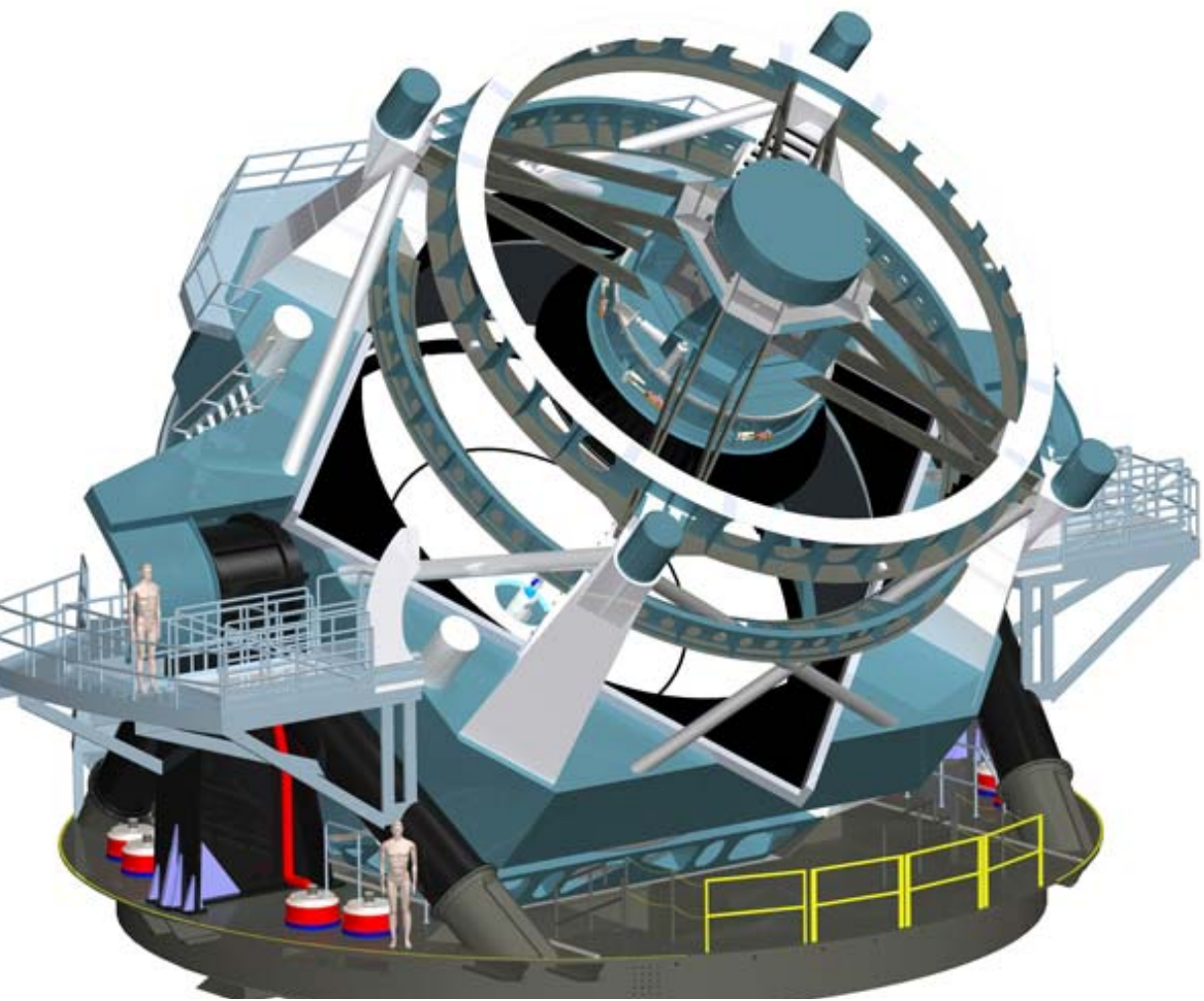
pioneered studies of Dark Matter through rotational curves

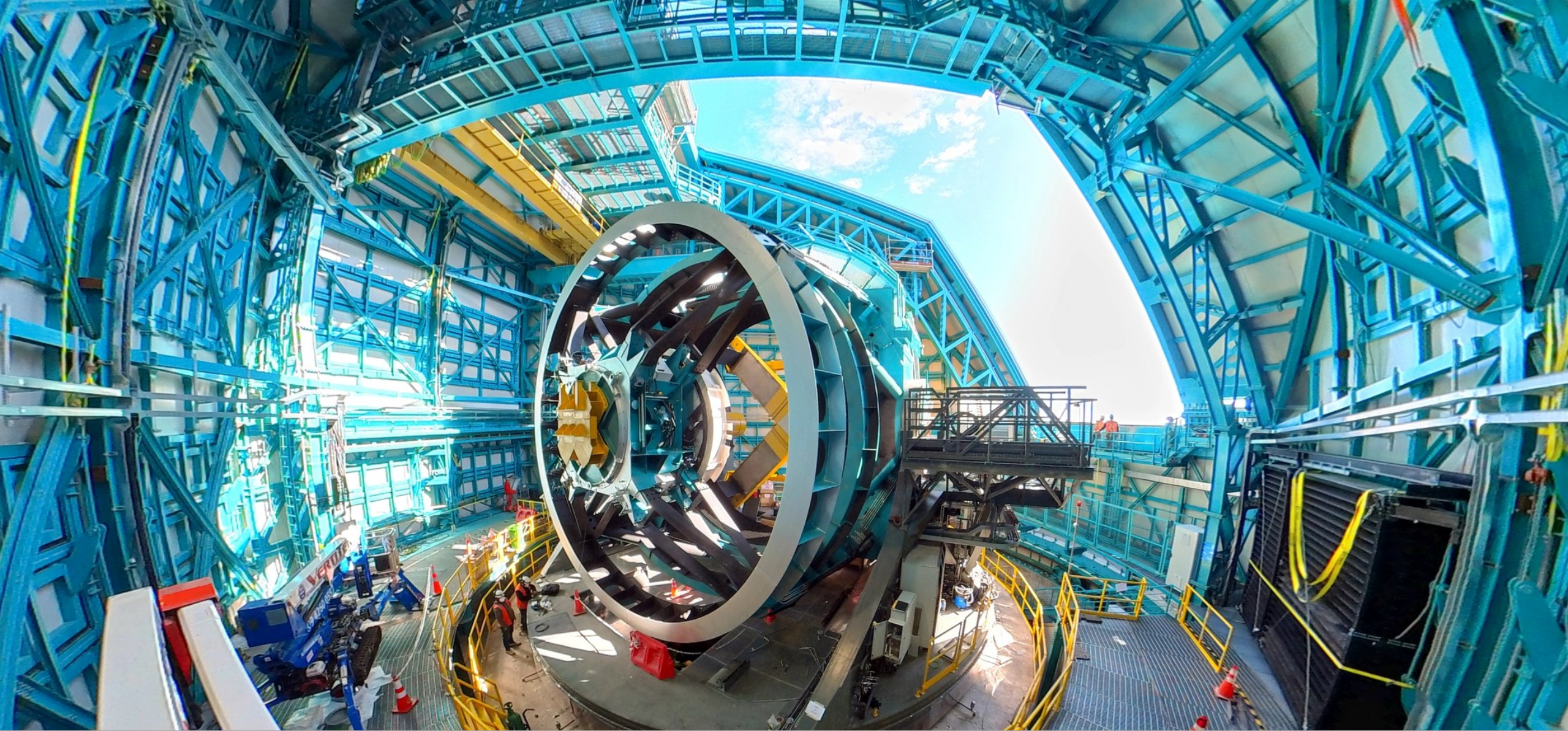


# 8m Telescope

## 9.6 deg.sq. field of view

maximizes survey entendue

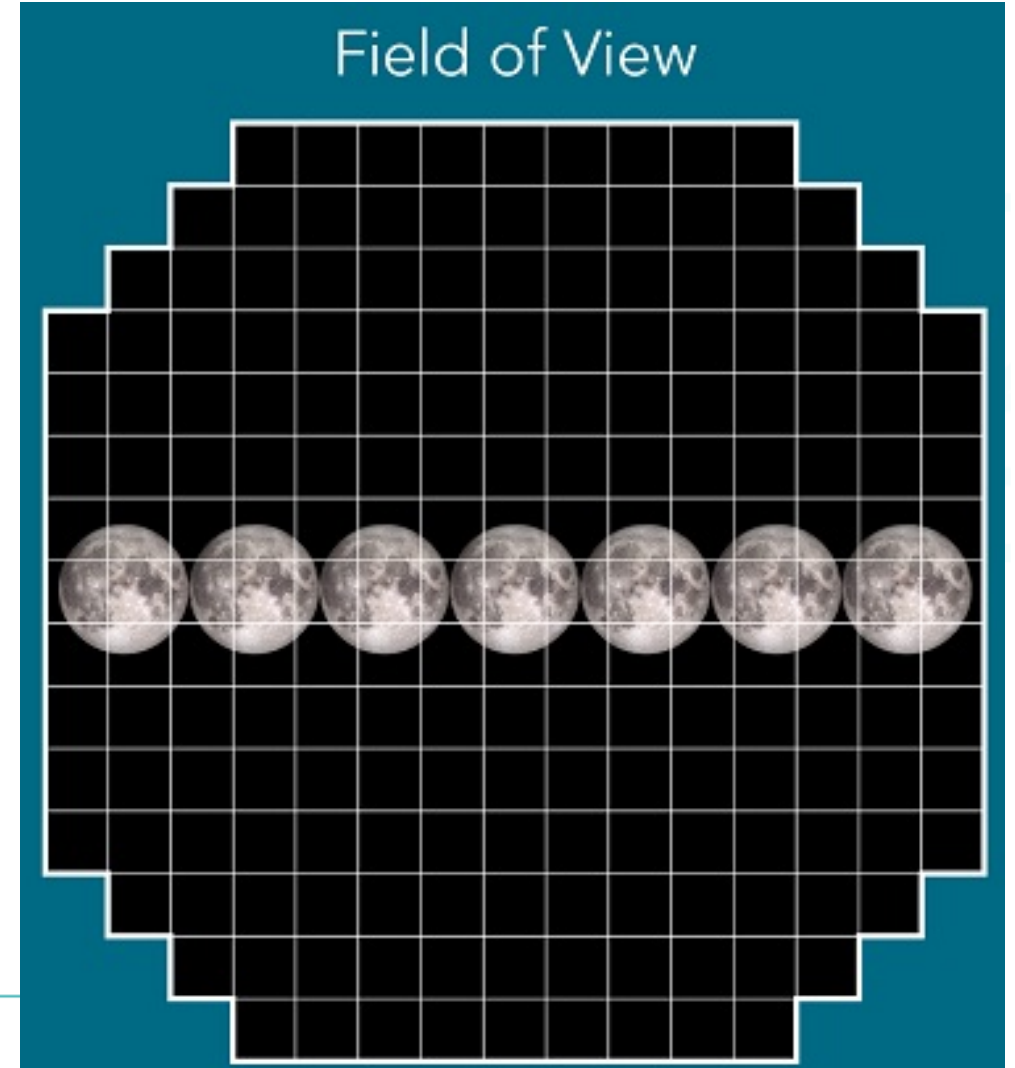
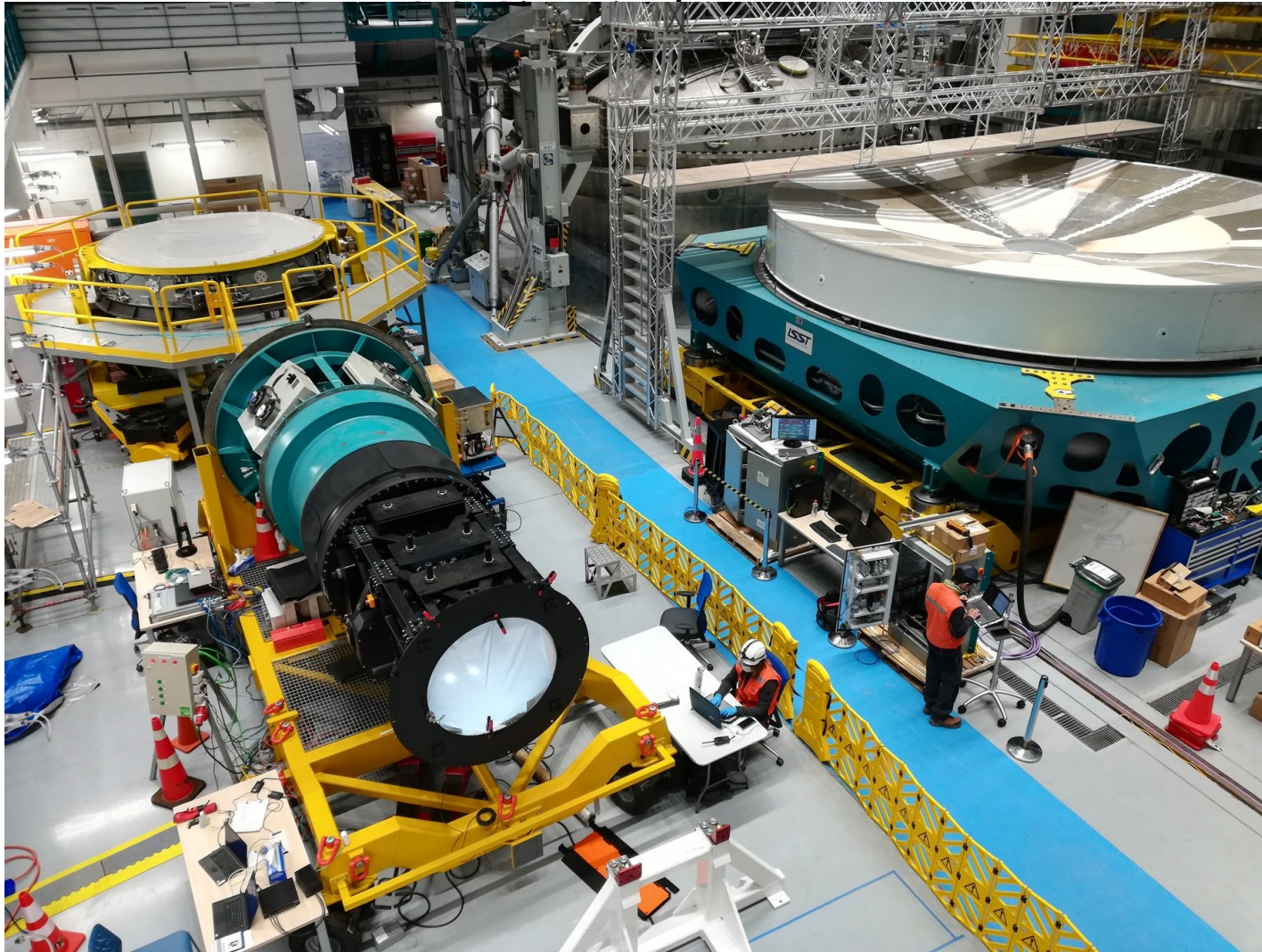




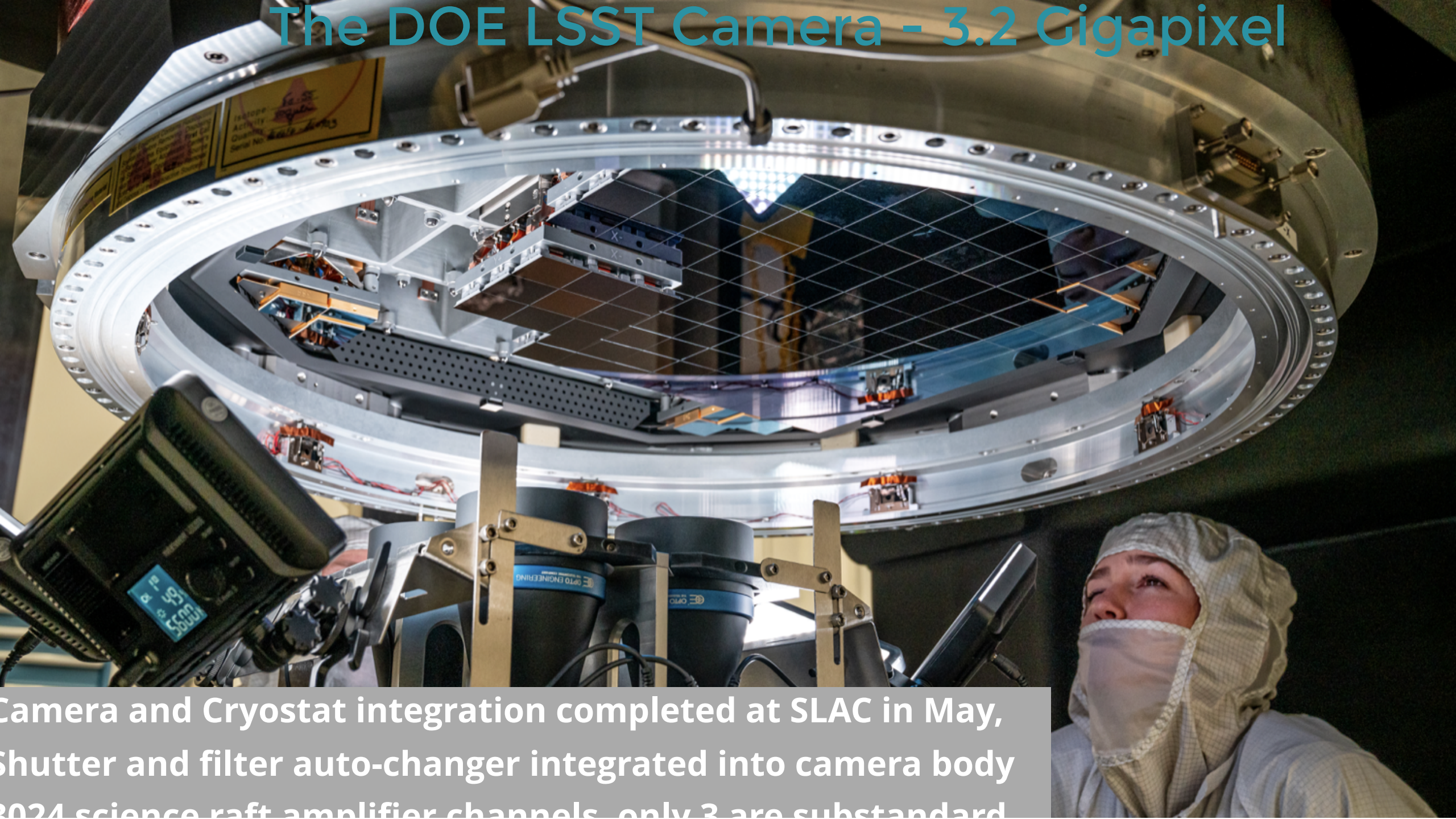
May 2022 - Telescope Mount Assembly

thus: ongoing demonstration of the Camera/Secondary Mirror (M2) removal procedures, and ComCam installation expected in August

# The DOE LSST Camera - 3.2 Gigapixel



# The DOE LSST Camera - 3.2 Gigapixel



Camera and Cryostat integration completed at SLAC in May,  
Shutter and filter auto-changer integrated into camera body  
2024 science raft amplifier channels, only 3 are substandard

# Rubin *ugrizy* filters



- Final completion of the 6 filters coating at Materion
- Final completion of the assembly of the 6 filters at LLNL
- Receipt of all filters at SLAC

Summer 2021



r-band filter in its frame during inspection at SLAC after delivery (March 2021)

z-band (left) filter inspection under bright light at LLNL prior to packing in its shipping container (April 2021) and i-band (right) filter inspection under bright light at LLNL (right after installation (August 2021)

g-band (left) and y-band (right) filter in their frame during inspection at LLNL prior to packing in their shipping container (May 2021/July 2021).

u-band filter received at LLNL (August 2021).





latest run June 28-July 1 2022

*LOVE: LSST Operations Visualization Environment*



**Summit Control Room with LOVE displays during an AuxTel run**

AuxTel is being used for monthly on-sky commissioning runs 3 nights/lunar cycle:

- Performing scheduler driven observations
- Standard star spectroscopy for characterization of atmospheric transmission
- Measure image performance as will be done in Ops



# The Rubin Observatory Construction Project



UC Berkeley College of Letters & Science @UCBLettersSci · Aug 13, 2021  
Meet the next Dean of the Division of Mathematical & Physical Sciences,  
Professor Steven Kahn:  
[ls.berkeley.edu/news/next-dean...](https://ls.berkeley.edu/news/next-dean...)



9:10 PM · Aug 13, 2021 · Twitter for iPhone



**Sandrine Thomas**  
Deputy Director for Rubin  
Construction for AURA/NSF



**Aaron Roodman**  
LSST Camera Program Lead  
and Deputy Director for  
Rubin Construction for SLAC/DOE



**Steve Ritz**  
Project Scientist for  
Rubin Construction

**Željko Ivezić appointed Director  
of Rubin Observatory Construction**

**Željko Ivezić director designado  
de del Observatorio Vera C. Rubin.**



## Project Management Office

Project Manager  
Victor Krabbendam

System Scientist  
Chuck Claver

Deputy PM - Software & IT  
William O'Mullane

Deputy PM - Camera Comm  
Vincent Riot

**LSST cadence optimization:  
deputy Project Scientist Federica Bianco**



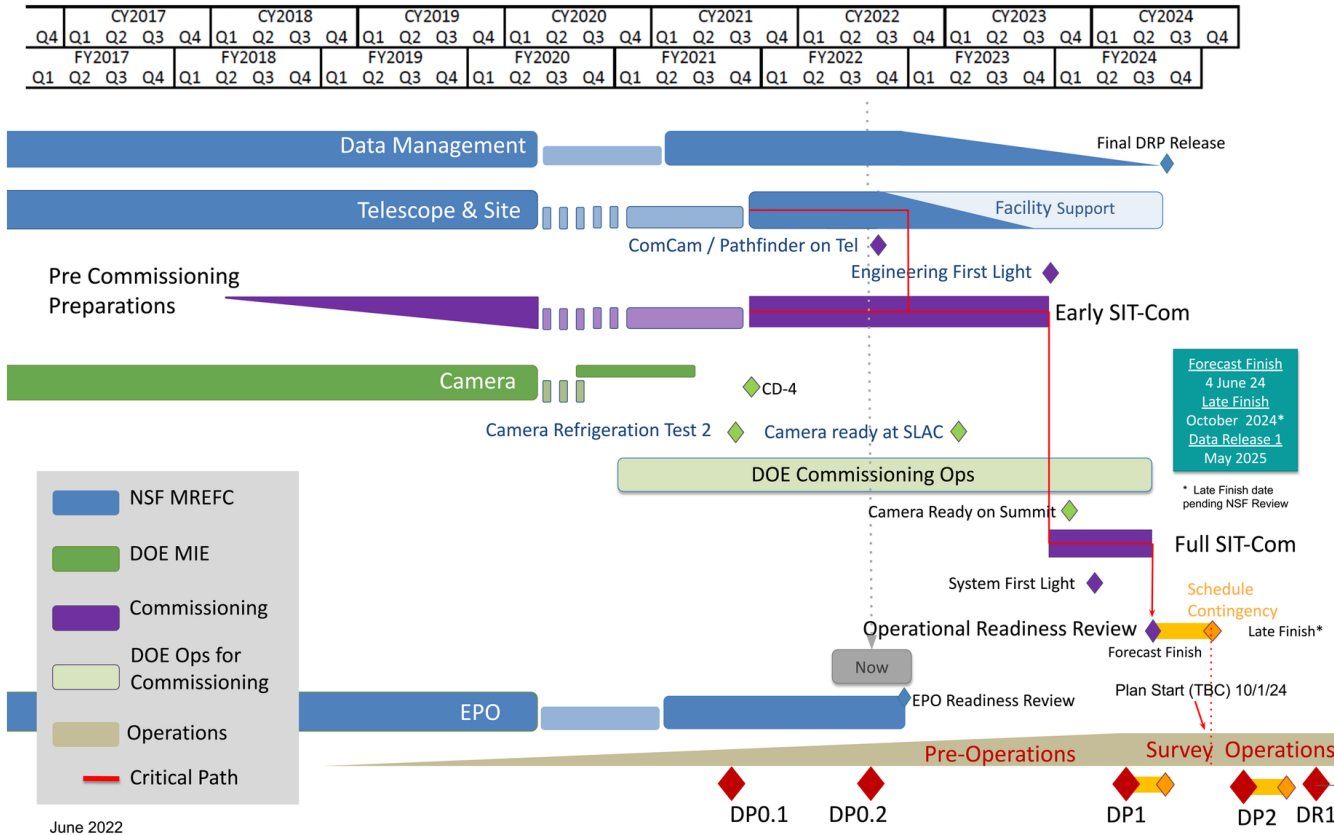
*federica bianco - fbianco@udel.edu*





# The Rubin Observatory Construction Project

## Current Rubin Observatory Schedule



Telescope Mount Assembly complete

October 2022

3-mirror Optical System Ready for Testing

July 2023

ComCam: Engineering First Light

September 2023

LSSTCam: System First Light

January 2024

Operations Readiness Review completed

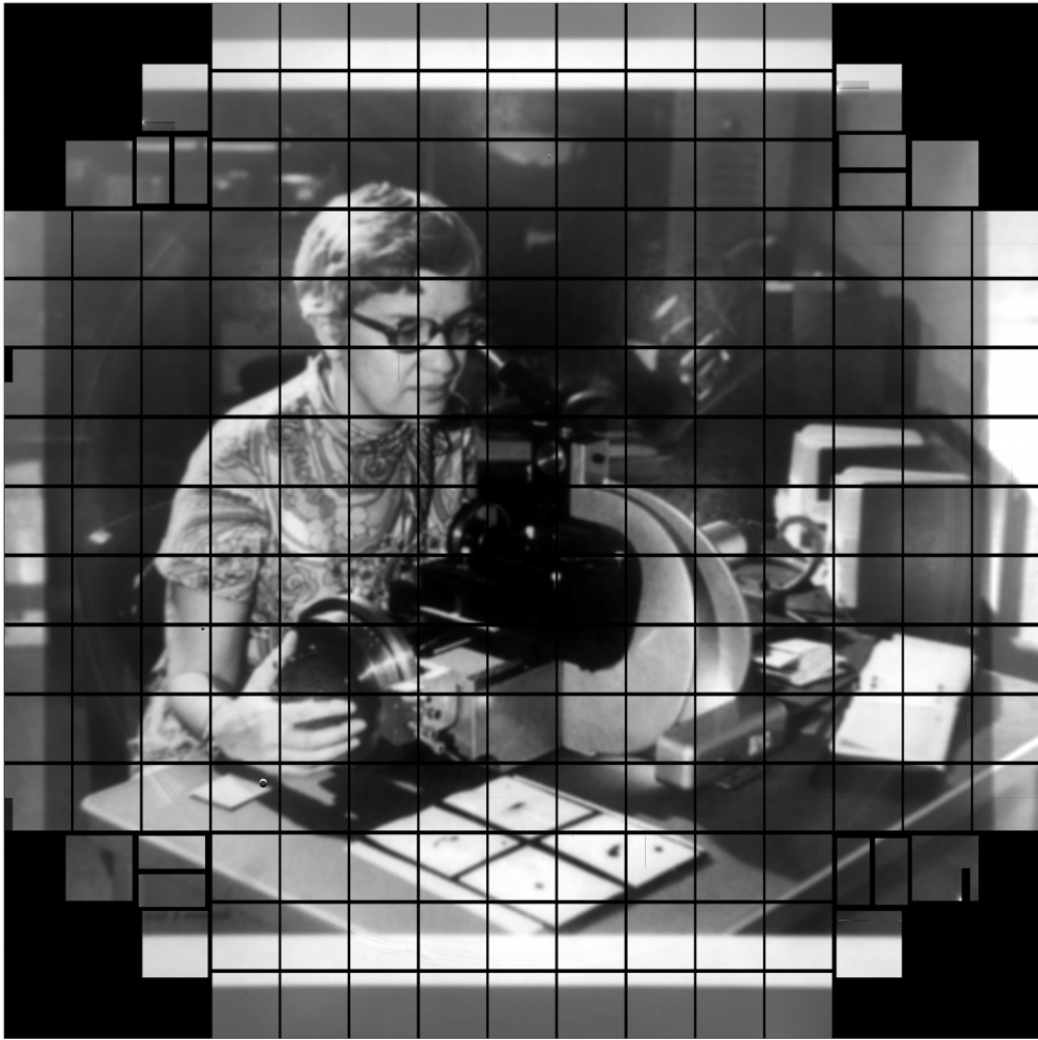
June 2024

June 2022





# Rubin Observatory's LSST



First ground based US National Observatory named for a woman, Dr.

**Vera Florence Cooper Rubin**

July 23, 1928 – December 25, 2016

**LSST: the Legacy Survey of Space and Time**

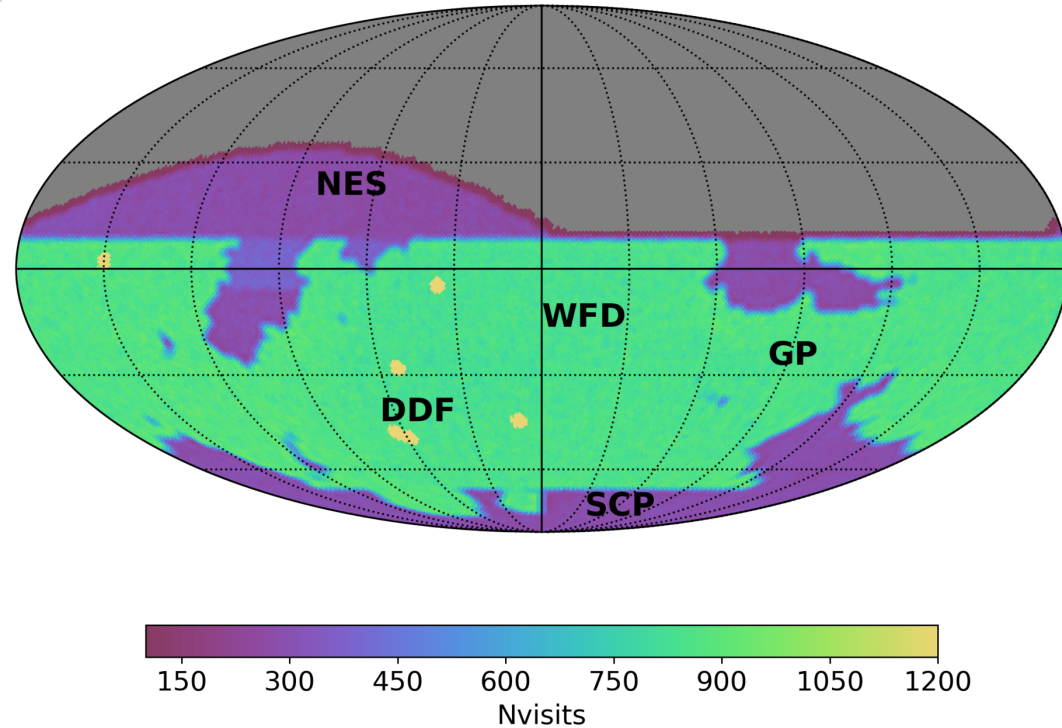
will be delivered by  
Rubin Observatory,  
as its first, 10-year, project



# survey specification



## Current baseline footprint



**5 Deep Drilling Fields fields**  
observed to higher cadence  
and more images (~18k)

**mini and micro-surveys**

**Wide Fast Deep survey**  
single image depth ~24  
10-year stack image depth ~27  
image resolution 0.2" (seeing limited)

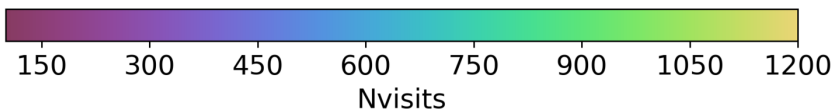
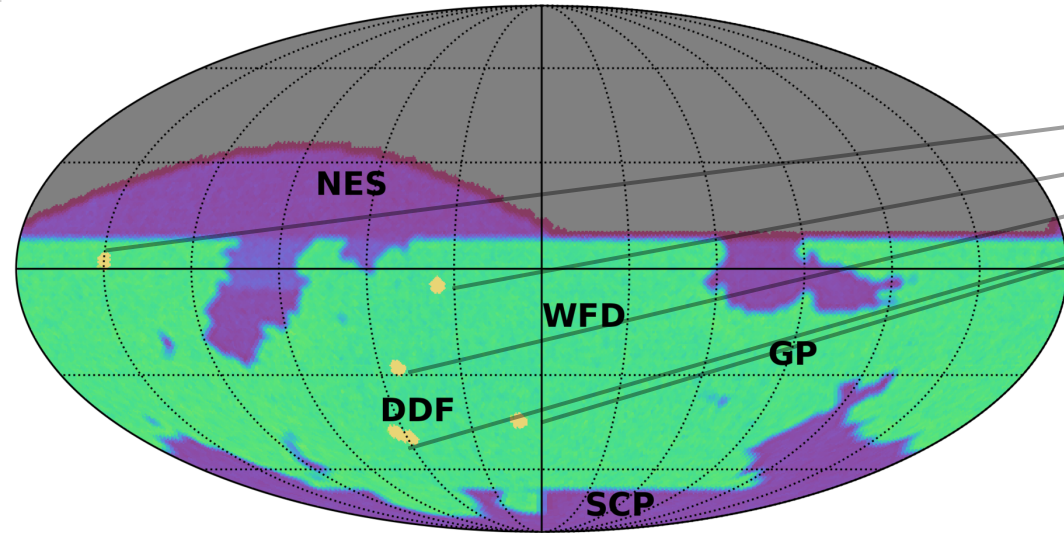
**Targets of Opportunity**

18,000 sq degrees  
815 images over 10 years in 6 filters  
2 images per night  
each fields reobserved within ~days

# survey specification



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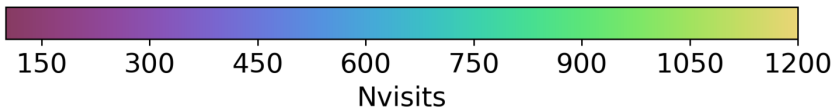
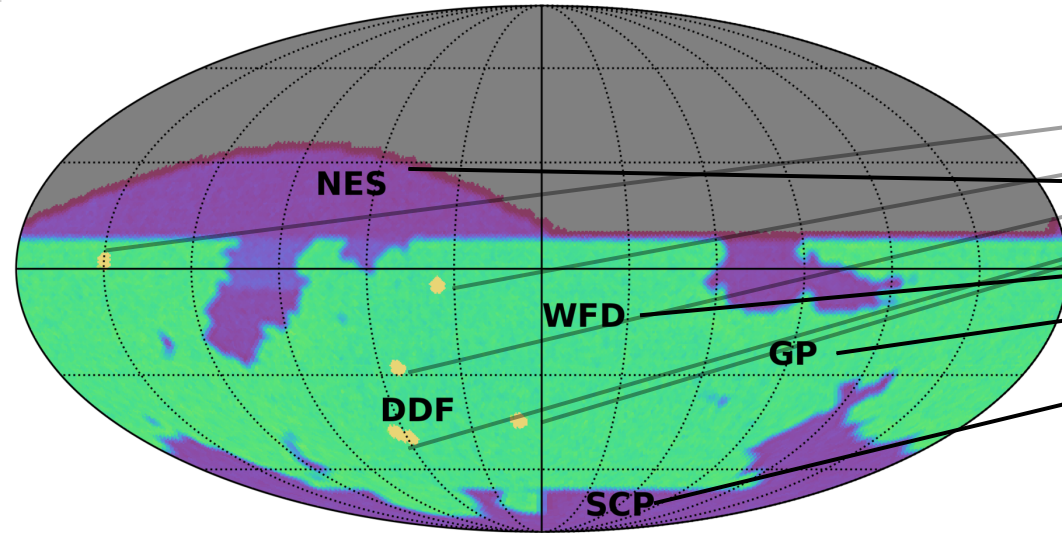
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# survey specification



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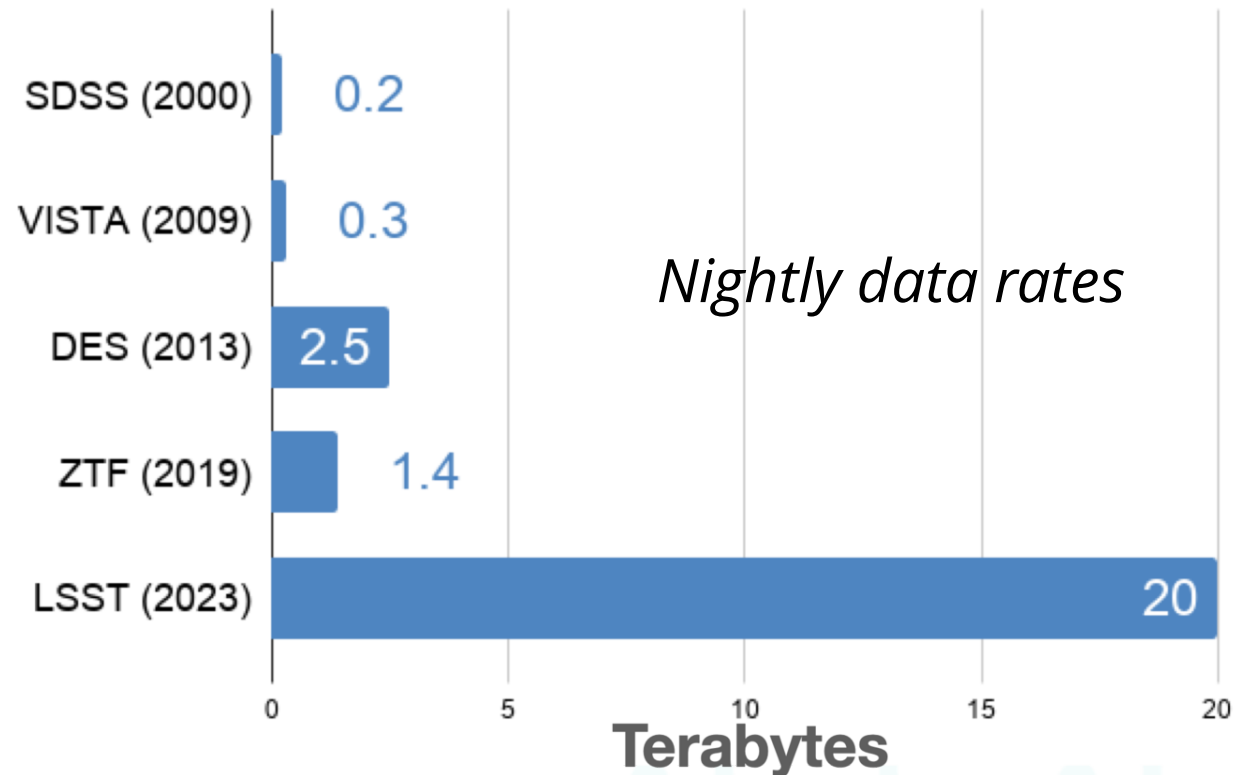
2 images per night

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# Astronomy (re)meets Data Science

x10  
increase  
in data  
volume





At this level of  
precision, everything is variable,  
everything is blended,  
everything is moving.

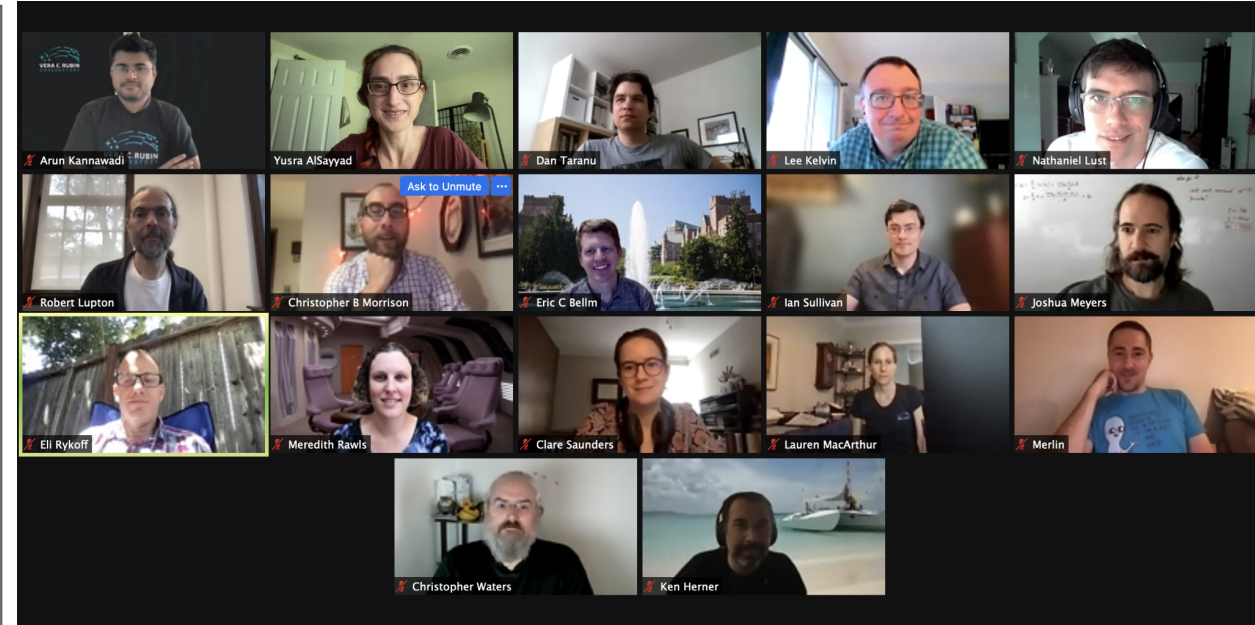
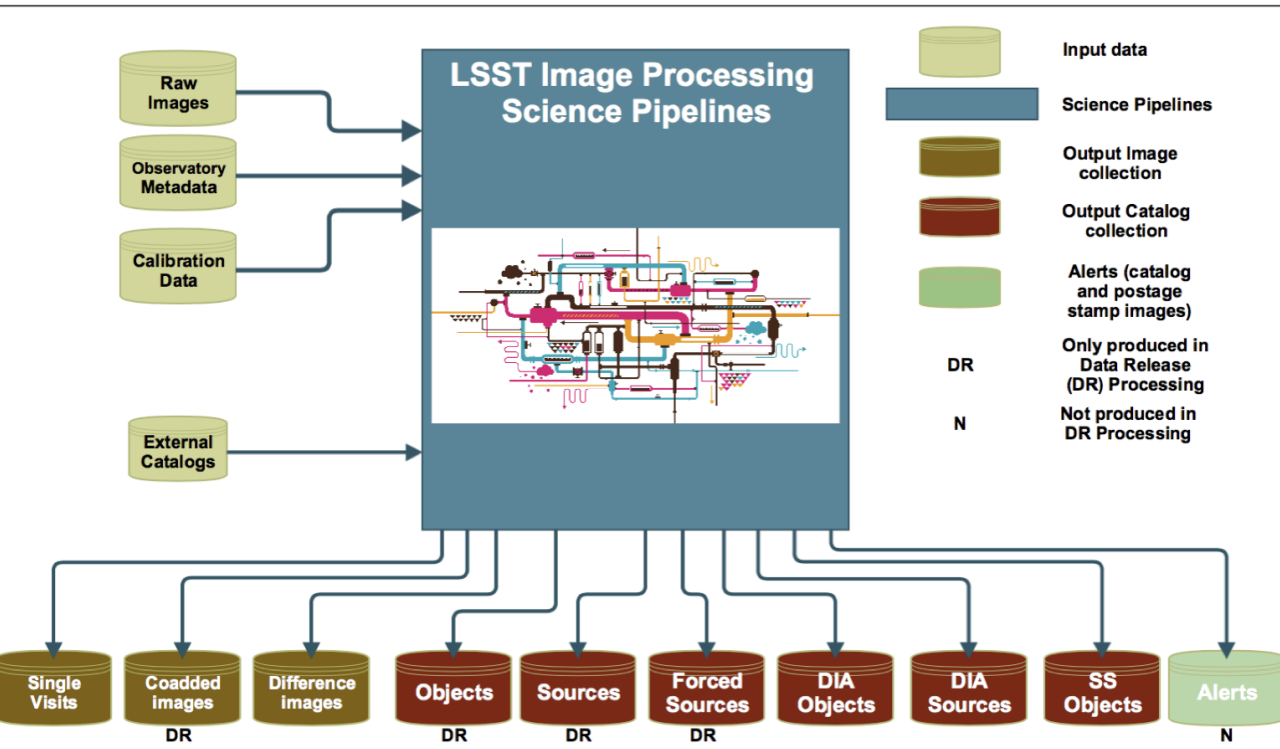
	<b>u,g,r,i,z,y</b>
Photometric precision	5 mmag
Photometric accuracy	10 mmag
Astrometric precision	10 mas
Astrometric accuracy	50 mas
# visits	56, 80, 184, 184, 160, 160
Simulated image 5 $\sigma$ depths	23.8 24.5 24.0 23.4 22.7 21.9
corresponding 10-year 5 $\sigma$ depth	25.6 26.9 26.9 26.4 25.6 24.8

<https://ls.st/srd>

Bianco et al 2022



# Rubin Data Products and the DM team



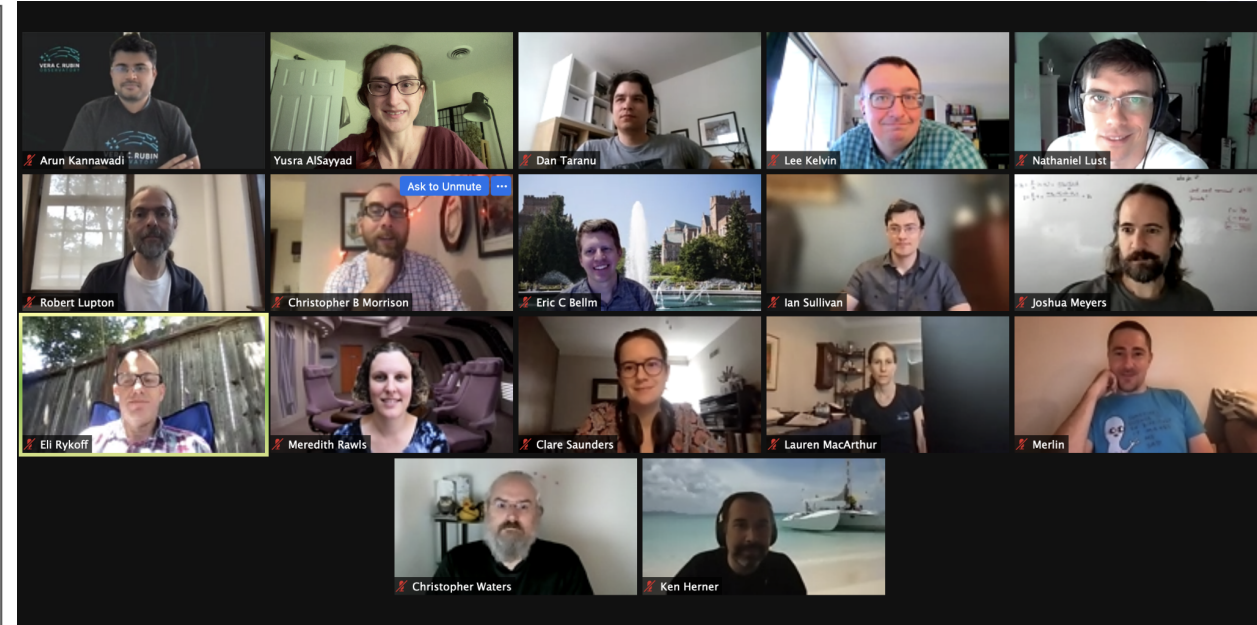
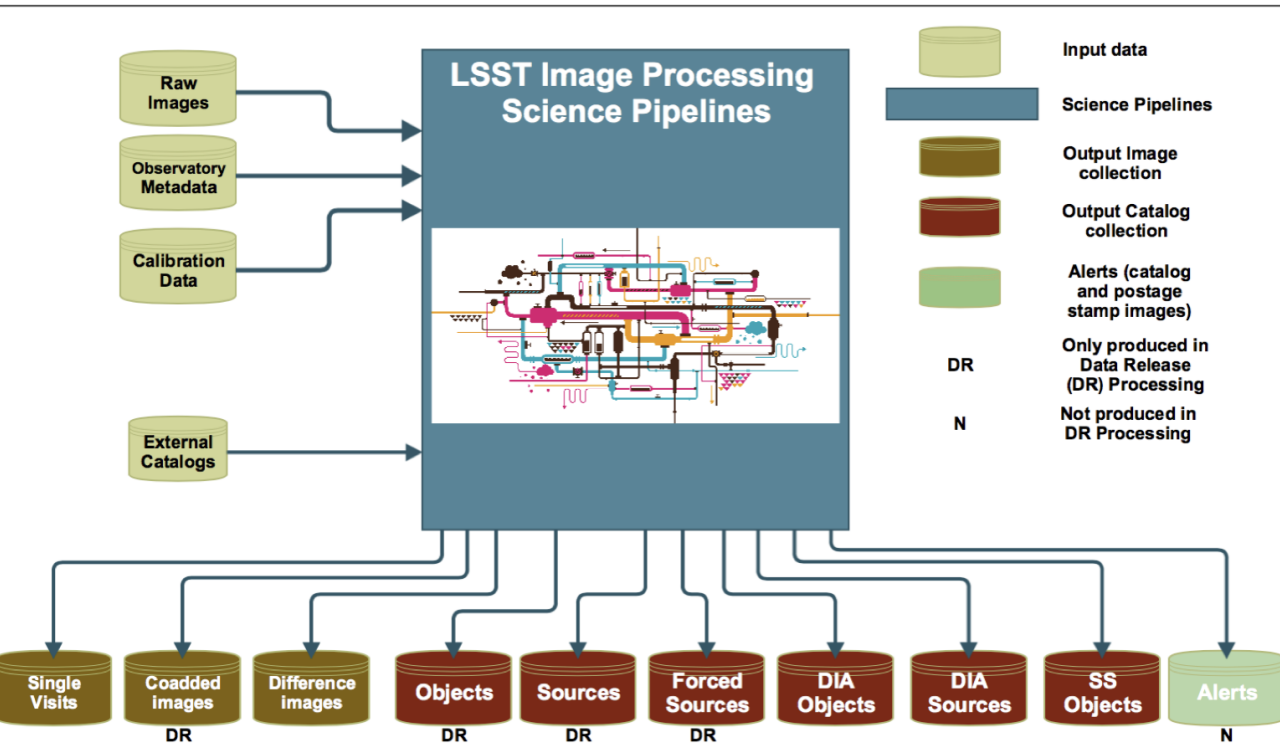
Science Pipeline v 23.0.0 released late 2021 (and v23.0.1 April 2022)

Rubin env rubin-env 4.0.0. deployed May 2022

Migration of accounts from NCSA to SLAC has started

Deployed alert distribution system - testing connection w alert brokers Jan 2022

# Rubin Data Products and the DM team



## Data Management verification phase:

Faro is a framework for automatically and efficiently computing scientific performance metrics on the LSST data products, a collaborative project between Rubin Data Management (DM) and System Integration, Test and Commissioning (SIT-Com) as part of a single coordinated project-wide science verification effort and with a view to Operations (see

<https://www.youtube.com/watch?v=XrhNkdK8hiw&list=PLPINAcUH0dXacwsNrhNnQsq0rOTRf0lfU&index=3&t=6s>)

# Rubin Data Products and the DM team

## Data Management System Overview

### Raw Data: 20TB/night



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



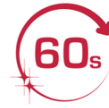
### Prompt Data Products

Alerts: up to 10 million per night

Raw & Processed Visit Images, Difference Images, Templates

Transient and variable sources from Difference Image Analysis

Solar System Objects: ~ 6 million



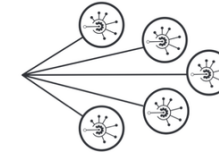
via nightly alert streams



via Prompt Products DB



via Data Releases



Community Brokers

Rubin Data Access Centres (DACs)

- USA (USDF)
- Chile (CLDF)
- France (FRDF)
- Uniter Kingdom (UKDF)

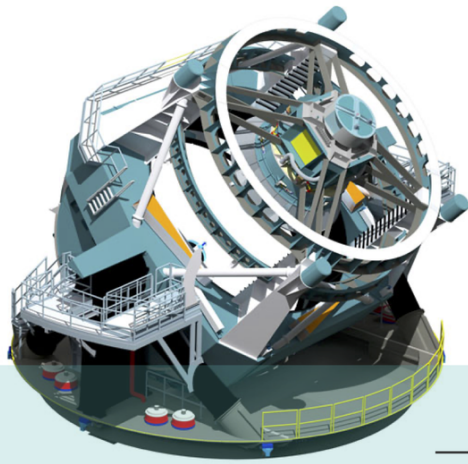
Independent Data Access Centers (IDACs)

### Data Release Data Products

Final 10yr Data Release:

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

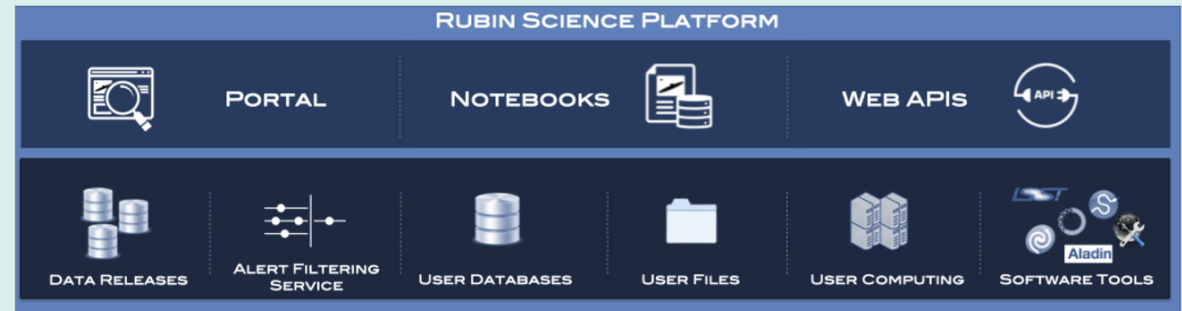
image credit: Leanne Guy



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

### LSST Science Platform

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



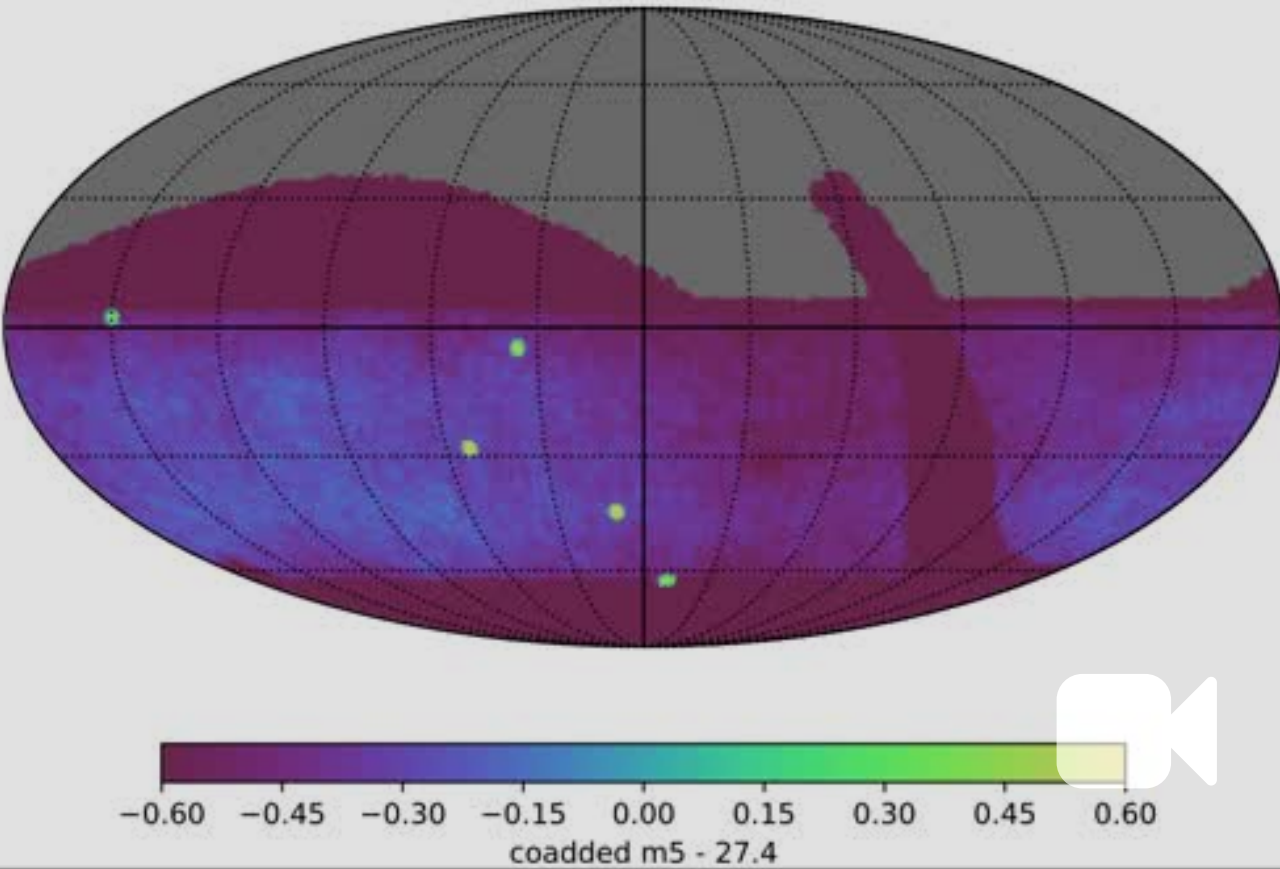
Credit: Leanne Guy

Legacy Survey of Space and Time

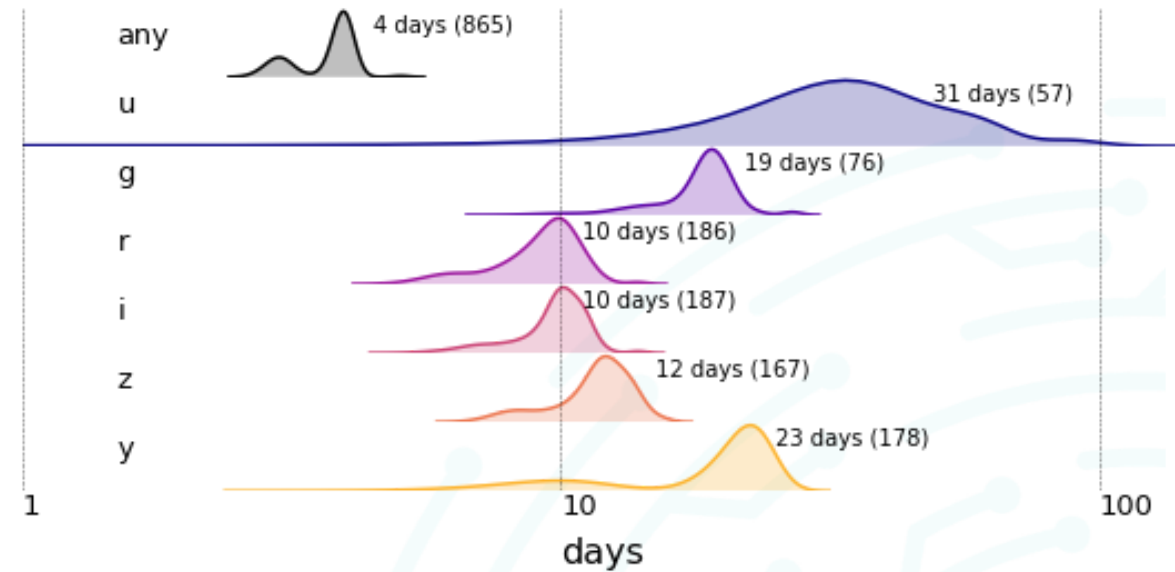
# Rubin LSST survey design



agnddf\_v1.4\_10yrs g band: CoaddM5



distributions of time gaps in 76 OpSims

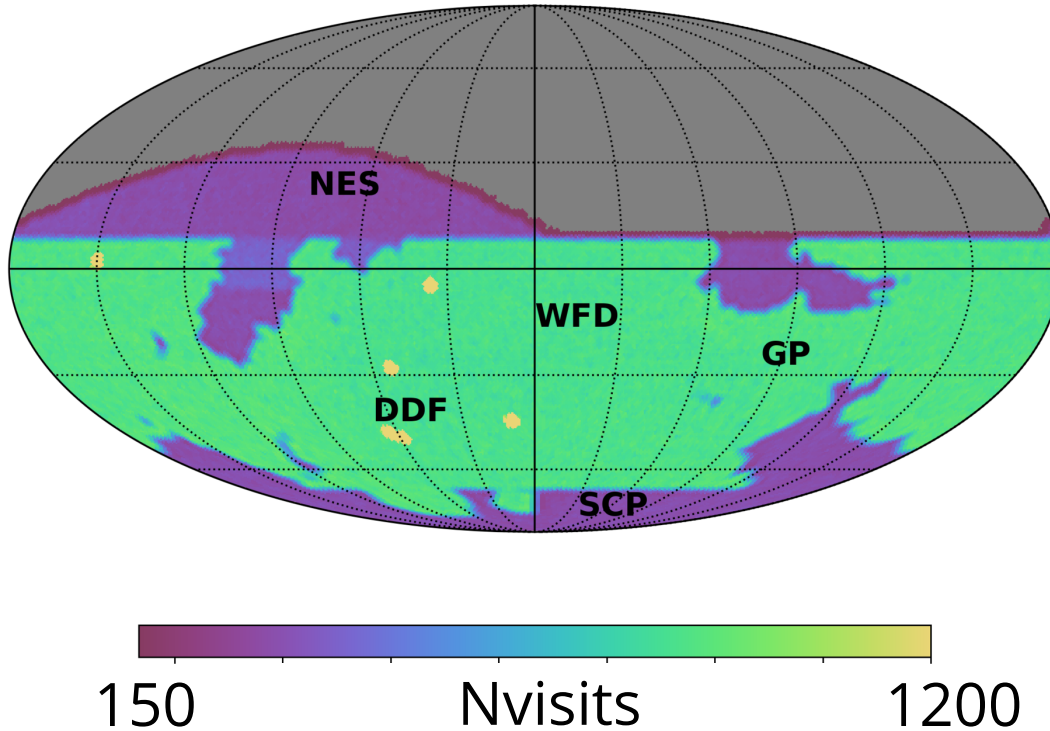


The survey strategy is being refined and will continue to be re-evaluated in Operations

# Rubin LSST survey design



Current baseline footprint



Bianco, Jones, Ivezić et al, 2021  
<https://arxiv.org/abs/2108.01683>

## The Survey Cadence Optimization Committee - SCOC

### The Purpose of the SCOC

The SCOC is advisory to the Rubin Observatory Operations Director (currently Bob Blum). It will begin its work in 2020, and will be a standing committee throughout the life of Rubin Observatory operations.

<https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc>

SCOC PCW session, August 8-12 2022

SCOC Workshop, November 2022

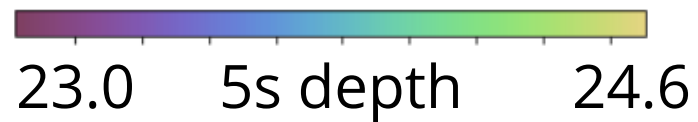
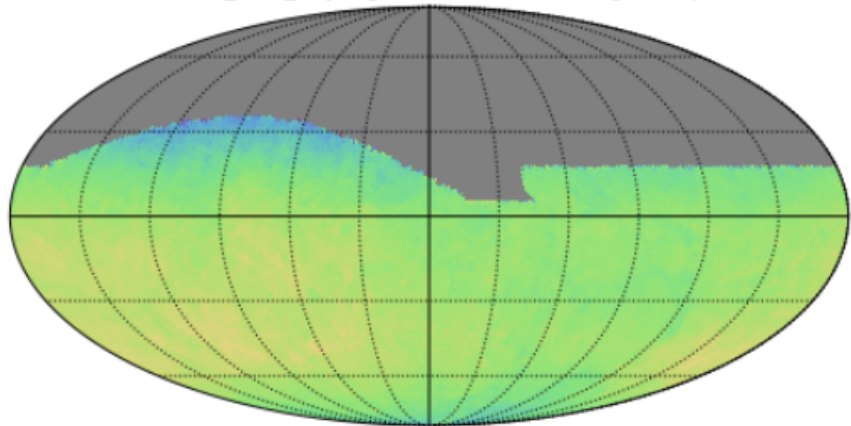
Recommendation to the Director due on December 2022

<https://community.lsst.org/t/scoc-v2-0-and-2-1-simulations-review-timeline/6712>



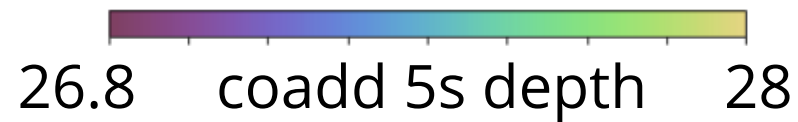
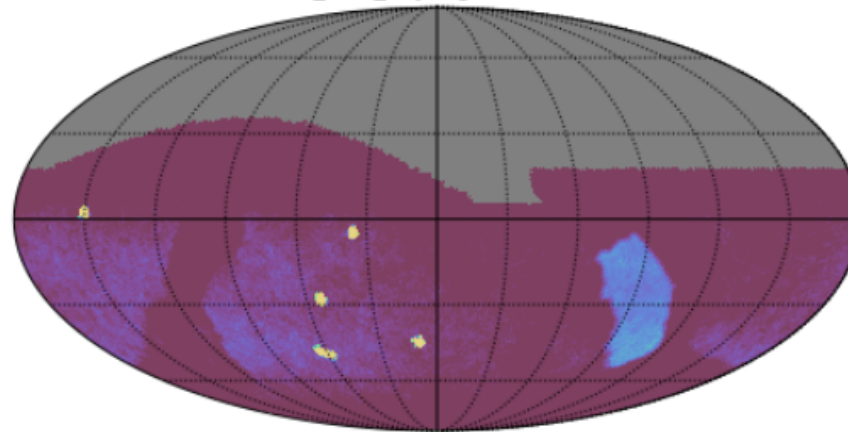
### Median fiveSigmaDepth HealpixSlicer g band

baseline\_v2.0\_10yrs g band: Median fiveSigmaDepth



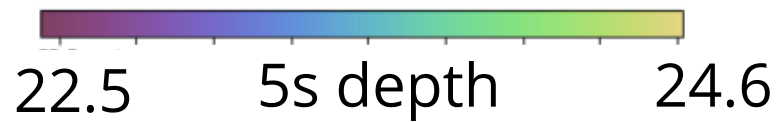
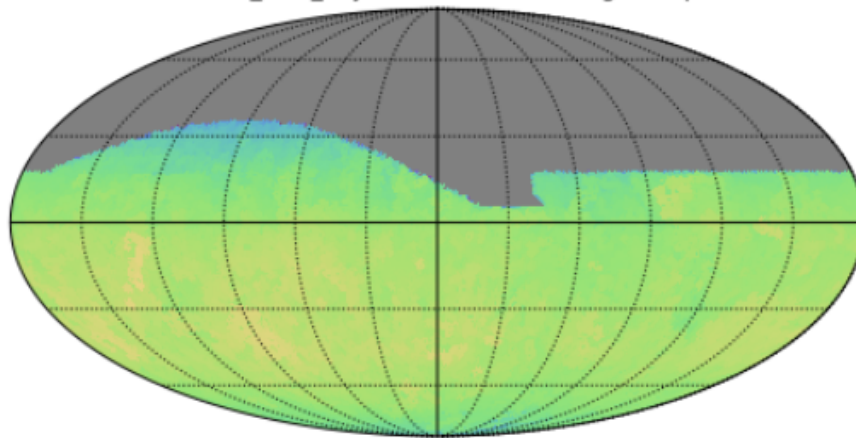
### CoaddM5 HealpixSlicer g band

baseline\_v2.0\_10yrs g band: CoaddM5



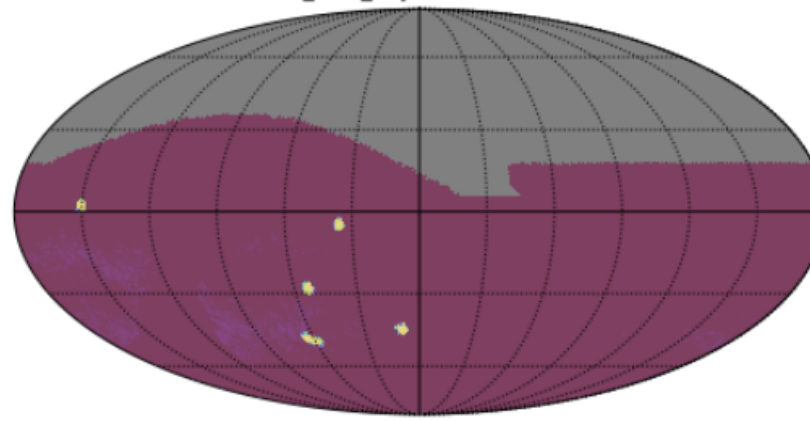
### Max fiveSigmaDepth HealpixSlicer r band

baseline\_v2.0\_10yrs r band: Max fiveSigmaDepth

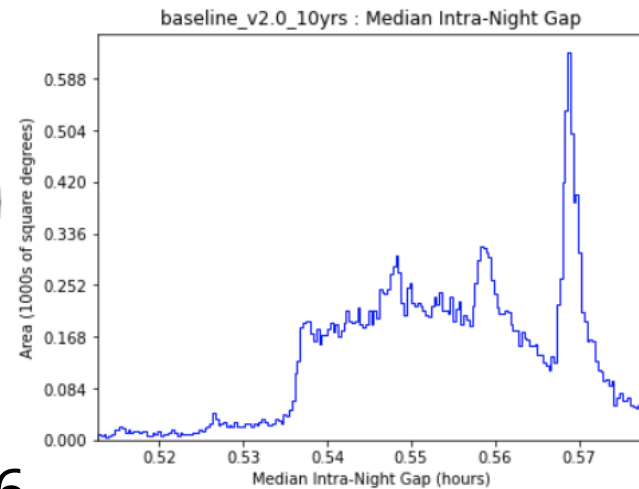
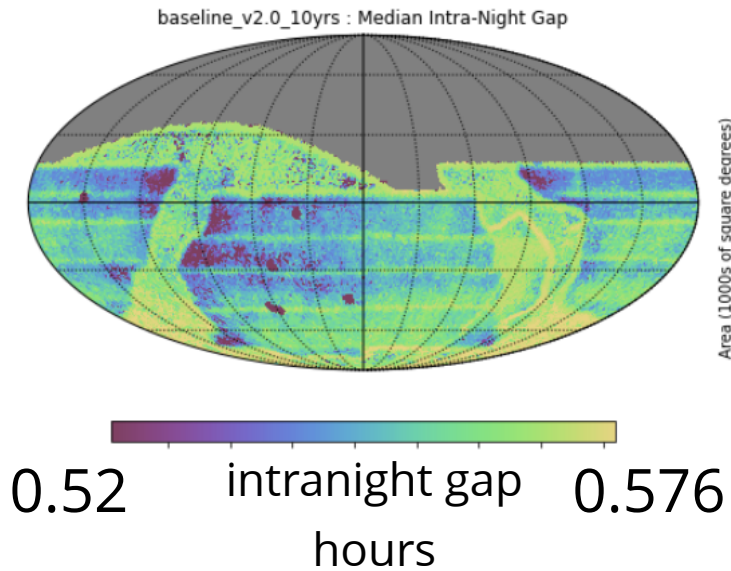


### CoaddM5 HealpixSlicer r band

baseline\_v2.0\_10yrs r band: CoaddM5

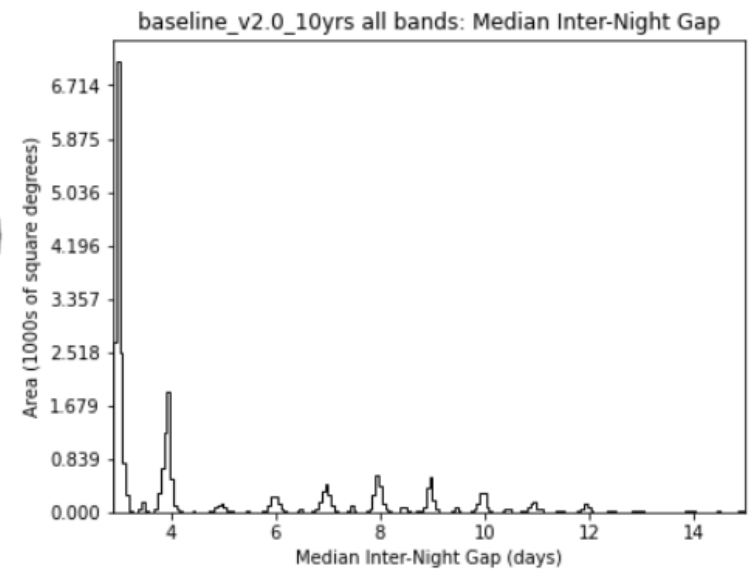
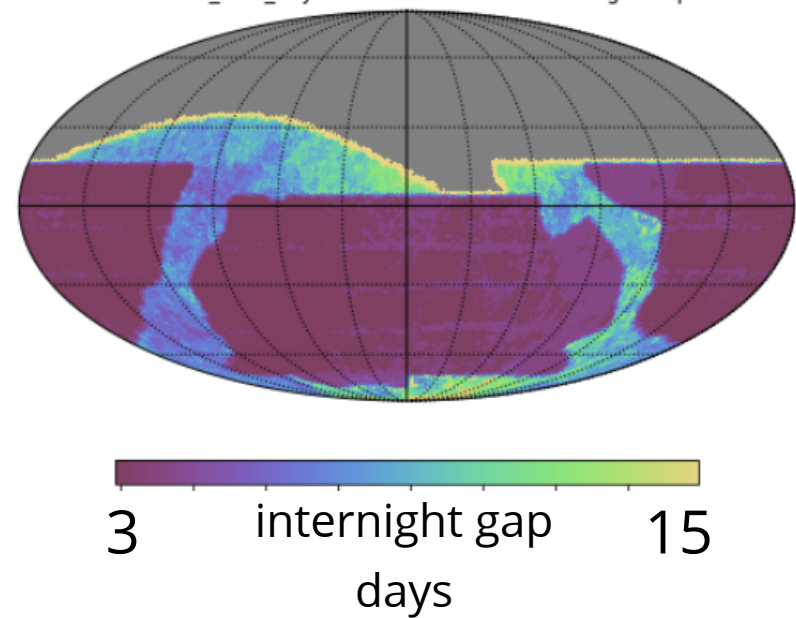


### Median Intra-Night Gap HealpixSlicer



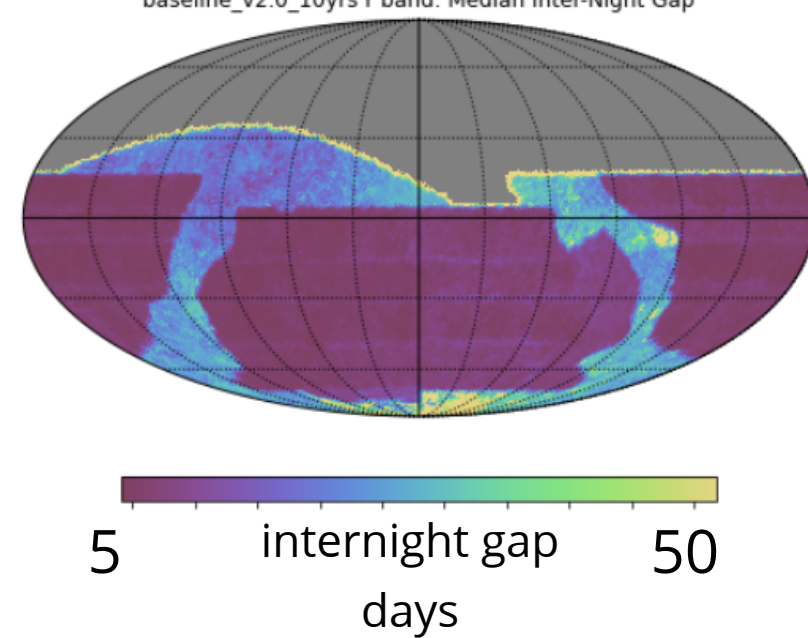
### Median Inter-Night Gap HealpixSlicer all bands

baseline\_v2.0\_10yrs all bands: Median Inter-Night Gap



### Median Inter-Night Gap HealpixSlicer r band

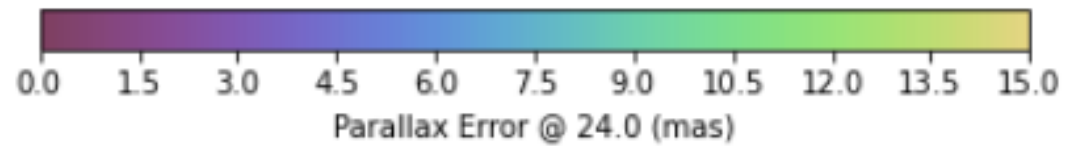
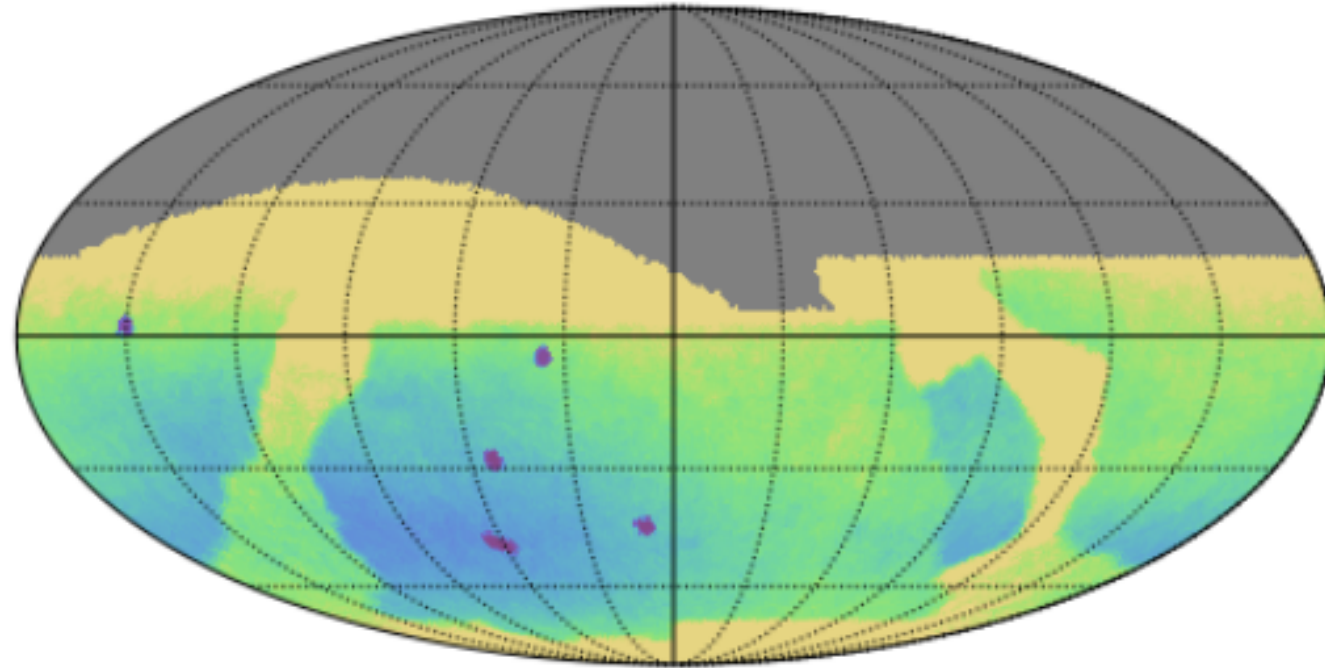
baseline\_v2.0\_10yrs r band: Median Inter-Night Gap





## Parallax Error @ 24.0 HealpixSlicer All visits

baseline\_v2.0\_10yrs All visits: Parallax Error @ 24.0



# Rubin LSST Science Collaborations



## Who are we?

- Rubin has no science-team
- 8 self-managed self-governed science teams are preparing to do science with LSST data

~2000 members,  
physicists, astronomers,  
data scientists, software engineers

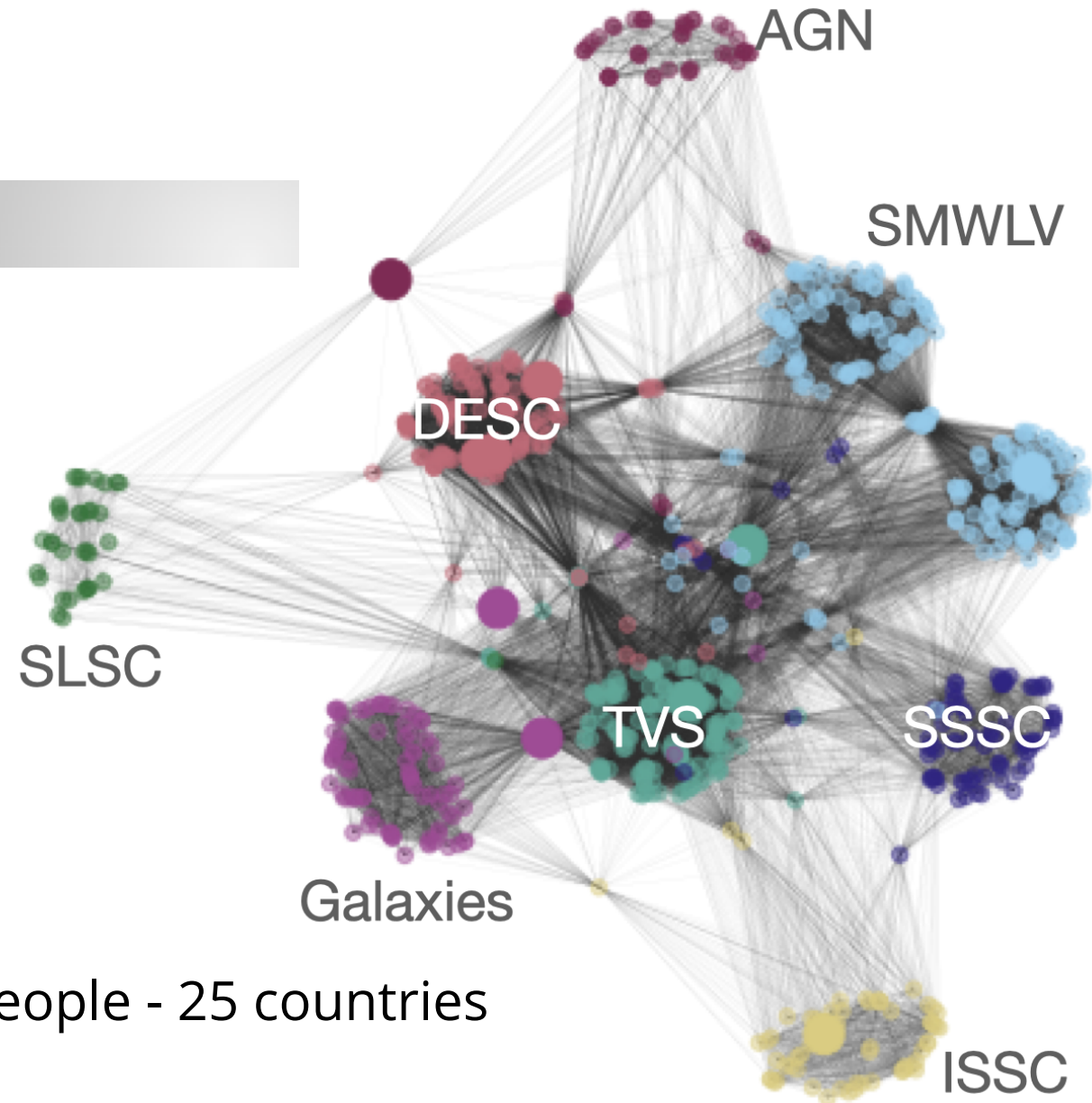
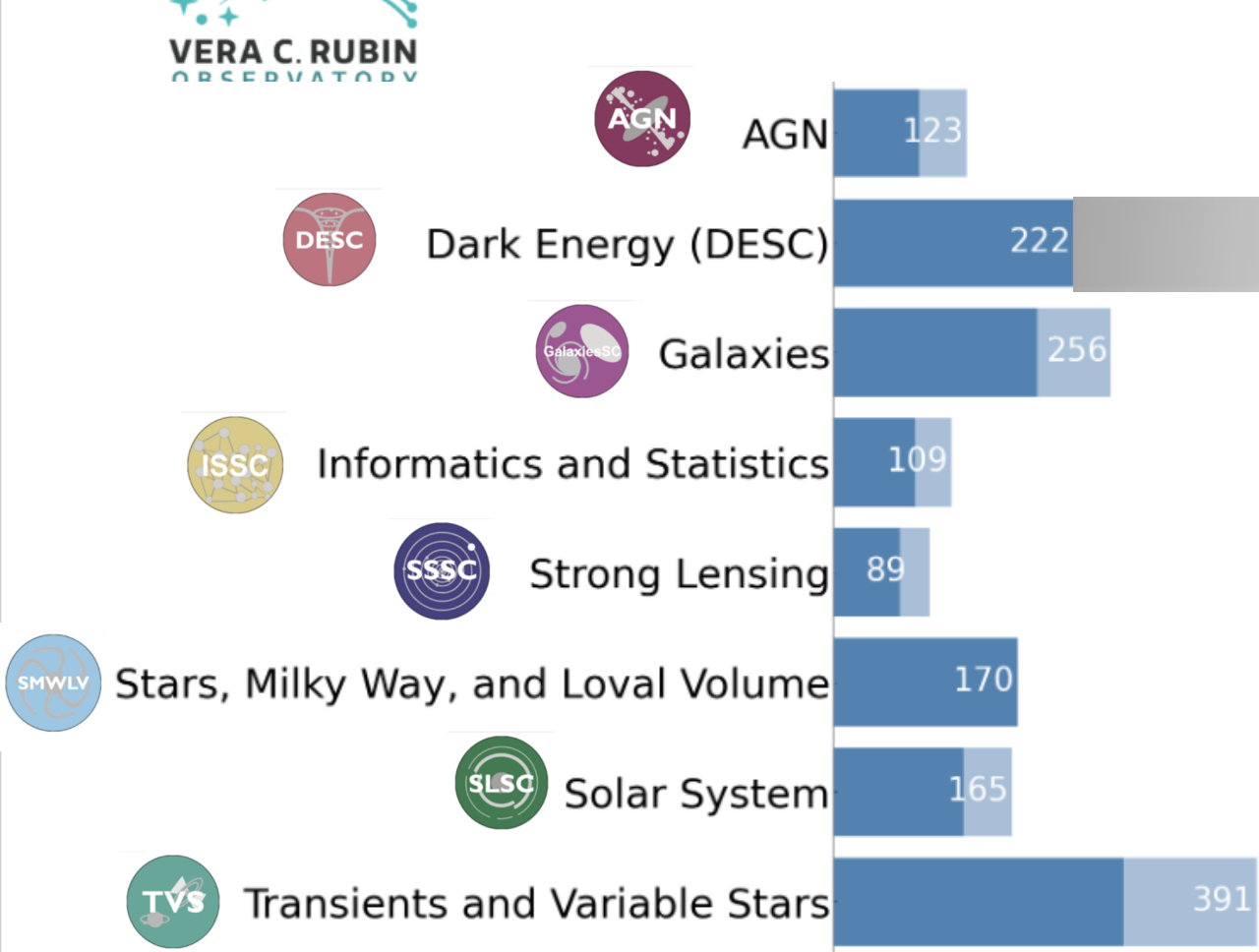


New Science Collaborations Coordinator

Dr Will Clarkson, UMichigan Deerborn



# Rubin LSST Science Collaborations



8 SCs - 6 continents - 2492 affiliations - 2090 people - 25 countries







# Rubin LSST SC Activities



SC meetings, in person and virtual



## Rubin-Euclid Derived Data Products Forum













Welcome to this space dedicated to the Rubin and Euclid scientists interested in helping define the Derived Data Products

- December 2021 : [DDP report released](#) : [Initial Recommendations](#)
- If this is your first visit, these [introduction topics to the DDP effort](#) will help you understand how the report was created
- Please take a moment to review our [code of conduct and forum guidelines](#)

**Welcome to Rubin-Euclid Derived Data Products Forum**

An account is required. Please create an account or log in to continue.

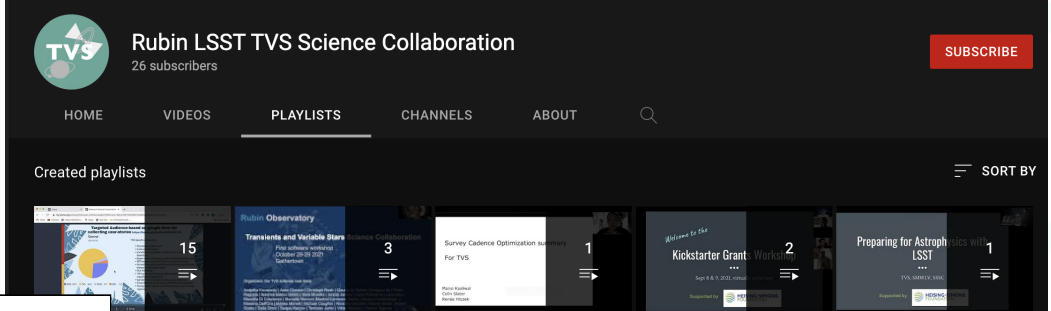
### Impact of Rubin Observatory LSST Template Acquisition Strategies on Early Science from the Transients and Variable Stars Science Collaboration: Time-critical Science Cases

R. A. Street<sup>1</sup> , F. B. Bianco<sup>2</sup> , R. Bonito<sup>3</sup> , T. Giannini<sup>4</sup> , M. L. Graham<sup>5</sup> , R. Margutti<sup>6</sup> , E. Mason<sup>7</sup> , A. Pastorello<sup>8</sup> , M. C. Stroh<sup>6</sup> , P. Szkody<sup>5</sup> 

[+ Show full author list](#)

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[Research Notes of the AAS, Volume 4, Number 3](#)

Rubin LSST TVSS Science Collaboration  
26 subscribers









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- 3
- 1
- 2
- 1

Hours of material available to the world through the SCs

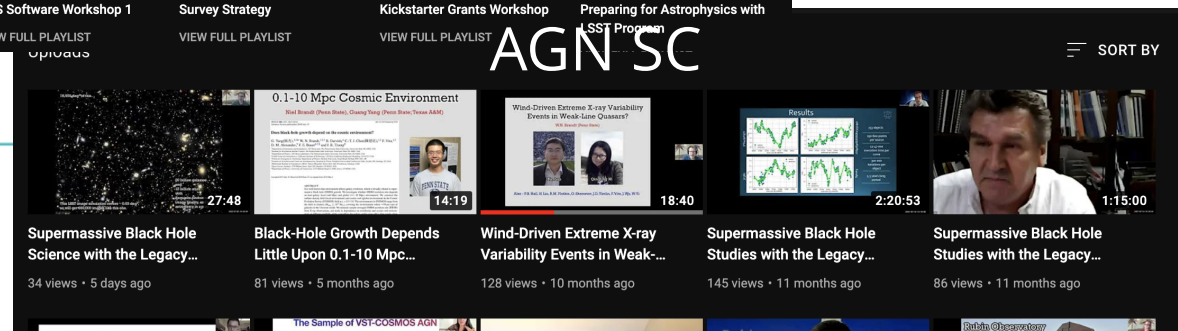
### A Software Roadmap for Solar System Science with the Large Synoptic Survey Telescope

Megan E. Schwamb<sup>1</sup> , Henry Hsieh<sup>2</sup> , Michele T. Bannister<sup>3</sup> , Dennis Bodewits<sup>4</sup> , Steven R. Chesley<sup>5</sup> , Wesley C. Fraser<sup>3</sup> , Mikael Granvik<sup>6,7</sup> , R. Lynne Jones<sup>8</sup> , Mario Jurić<sup>8</sup> , Michael S. P. Kelley<sup>9</sup>  [+ Show full author list](#)

Published March 2019 • © 2019. The American Astronomical Society. All rights reserved.

[Research Notes of the AAS, Volume 3, Number 3](#)

Citation Megan E. Schwamb *et al* 2019 *Res. Notes AAS* 3 51

## AGN SC

VIEW FULL PLAYLIST

- 27:48 Supermassive Black Hole Science with the Legacy... 34 views • 5 days ago
- 14:19 Black-Hole Growth Depends Little Upon 0.1-10 Mpc... 81 views • 5 months ago
- 18:40 Wind-Driven Extreme X-ray Variability Events in Weak... 128 views • 10 months ago
- 2:20:53 Supermassive Black Hole Studies with the Legacy... 145 views • 11 months ago
- 1:15:00 Supermassive Black Hole Studies with the Legacy... 86 views • 11 months ago



# Rubin LSST survey design

The SCs were core to this process

40+ submissions

85% led by SC members

and virtually all including SC members

[com/embed/@f7f7156e50925896/rubin-lsst-science-collaborations-cadence-white-paper-by-s?cells=chart](https://www.VERA.C.RUBIN.OBSERVATORY.COM/embed/@f7f7156e50925896/rubin-lsst-science-collaborations-cadence-white-paper-by-s?cells=chart)

# A focus issue of ApJS collects LSST cadence work

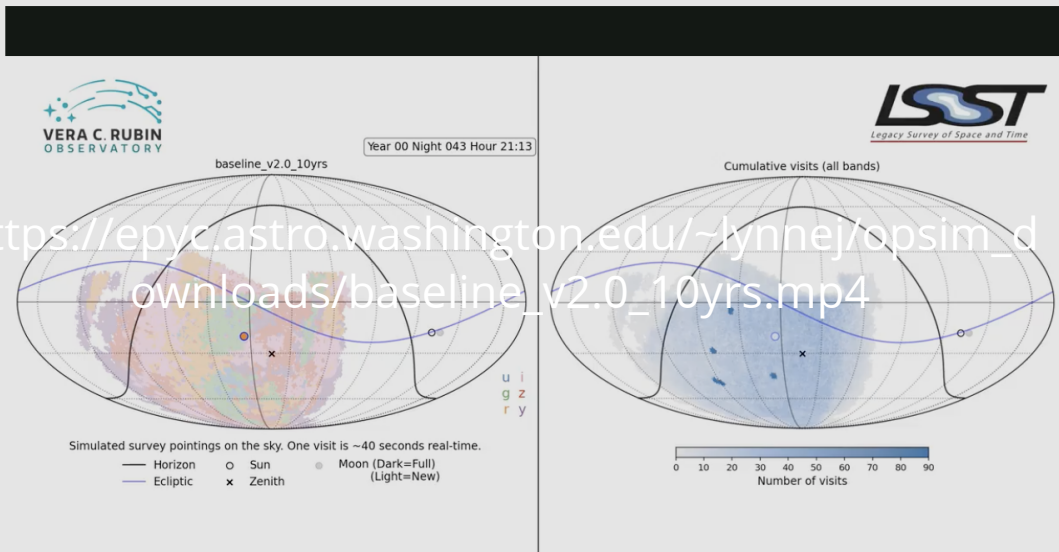


## Rubin Focus Issue of ApJS on Rubin Survey Strategy Optimization

THE ASTROPHYSICAL JOURNAL  
SUPPLEMENT SERIES

### Rubin LSST Survey Strategy Optimization

PI: Federica Bianco



[https://iopscience.iop.org/journal/0067-0049/page/rubin\\_cadence](https://iopscience.iop.org/journal/0067-0049/page/rubin_cadence)



The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will provide unprecedented data that will be made available to all US and Chilean scientists and international member scientists for a diverse range of astrophysical investigations, from cosmology to solar system studies and from stellar astrophysics to transients to galaxy evolution. In any synoptic survey such as this one, the choice of cadence—the pattern in which the telescope moves across the sky and periodically revisits each field—is of vital importance in maximizing the scientific utility of the data. Yet, identifying the optimal cadence for a broad range of scientific goals is a challenge. As part of the survey design and characterization process, Rubin Observatory involved the LSST science community by soliciting Cadence White Papers and Cadence Notes. Peer-reviewed journal articles describing scientific investigations that motivate and support these notes are published in this focus issue as a record of the factors which influenced survey design, and for guidance for future surveys that may confront many of the same issues faced by Rubin Observatory.

#### [Optimization of the Observing Cadence for the Rubin Observatory Legacy Survey of Space and Time: A Pioneering Process of Community-focused Experimental Design](#)

2022 ApJS 258 1

[+ Open abstract](#) [View article](#) [PDF](#)

#### [Preparing to Discover the Unknown with Rubin LSST: Time Domain](#)

2022 ApJS 258 2

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#### [Blazar Variability with the Vera C. Rubin Legacy Survey of Space and Time](#)

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#### [The Impact of Observing Strategy on the Reliable Classification of Standard Candle Stars: Detection of Amplitude, Period, and Phase Modulation \(Blazhko Effect\) of RR Lyrae Stars with LSST](#)

2022 ApJS 258 4

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#### [Optimizing Cadences with Realistic Light-curve Filtering for Serendipitous Kilonova Discovery with Vera Rubin Observatory](#)

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#### [Give Me a Few Hours: Exploring Short Timescales in Rubin Observatory Cadence Simulations](#)

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#### [The Impact of Observing Strategy on Cosmological Constraints with LSST](#)

Michelle Lochner et al 2022 ApJS 259 58

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# LSST critical SC-lead activities



Featured Prediction Competition

## PLAsTiCC Astronomical Classification

Can you help make sense of the Universe?

\$25,000  
Prize Money


LSST Project · 1,094 teams · 2 years ago

[Overview](#) [Data](#) [Notebooks](#) [Discussion](#) [Leaderboard](#) [Rules](#) [Join Competition](#)

Overview

Description	Help some of the world's leading astronomers grasp the deepest properties of the universe.
Evaluation	
Prizes	
Timeline	
PLAsTiCC's Team	

The human eye has been the arbiter for the classification of astronomical sources in the night sky for hundreds of years. But a new facility -- the [Large Synoptic Survey Telescope \(LSST\)](#) -- is about to revolutionize the field, discovering 10 to 100 times more astronomical sources that vary in the night sky than we've ever known. Some of these sources will be completely unprecedented!



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Dark Energy Science Collaboration  
(DESC)

+

Transients and Variable  
Science Collaboration  
(TVS SC)



 @fedhere

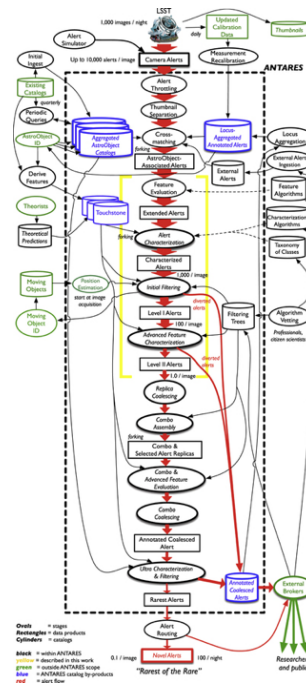
# LSST critical SC-lead activities



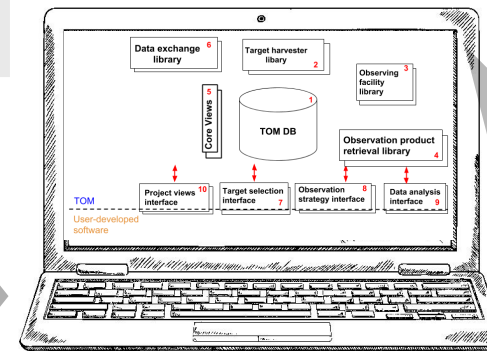
## Astronomy's Discovery Chain



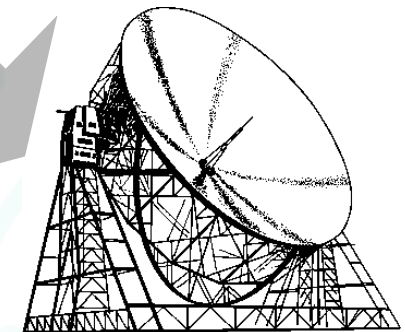
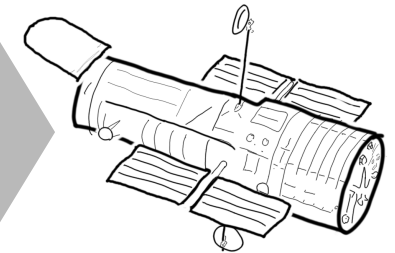
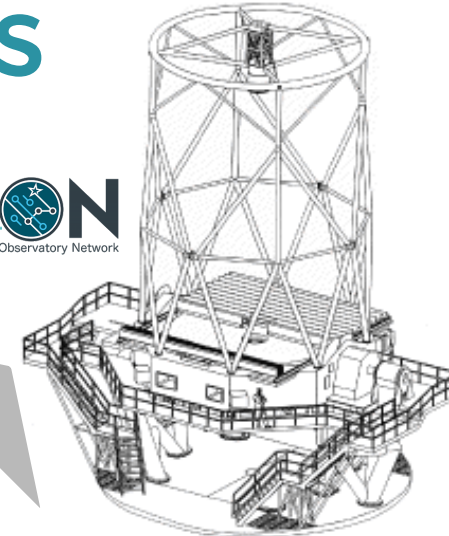
Discovery Engine  
10M alerts/night



Community Brokers



target  
observation  
managers





# Rubin LSST Science Collaborations

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“Leveling the playing field” grant \$899,689  
awarded to TVS, SMWLV, SSSC for a 1-year program

**Fund Science Publications**

**Host Meetings and  
Workshops**

**Provide Access to Software  
& Tools**

**Kickstarter Grants  
Program**



**HEISING-SIMONS  
FOUNDATION**

# Rubin LSST Science Collaborations

“Leveling the playing field” grant \$899,689  
awarded to TVS, SMWLV, SSSC for a 1-year program

Call for

Flexibl

Particu

schools

Open to all members of TVS-SMWLV-SSSC

~30 grants of ~\$20,000 (HSF max indirect 15%)

1-yr duration

International eligibility: all TVS, SMWLV & SSSC members can apply

<https://lsst-sci-prep.github.io/>



Kickstarter Grants  
Program



HEISING-SIMONS  
FOUNDATION



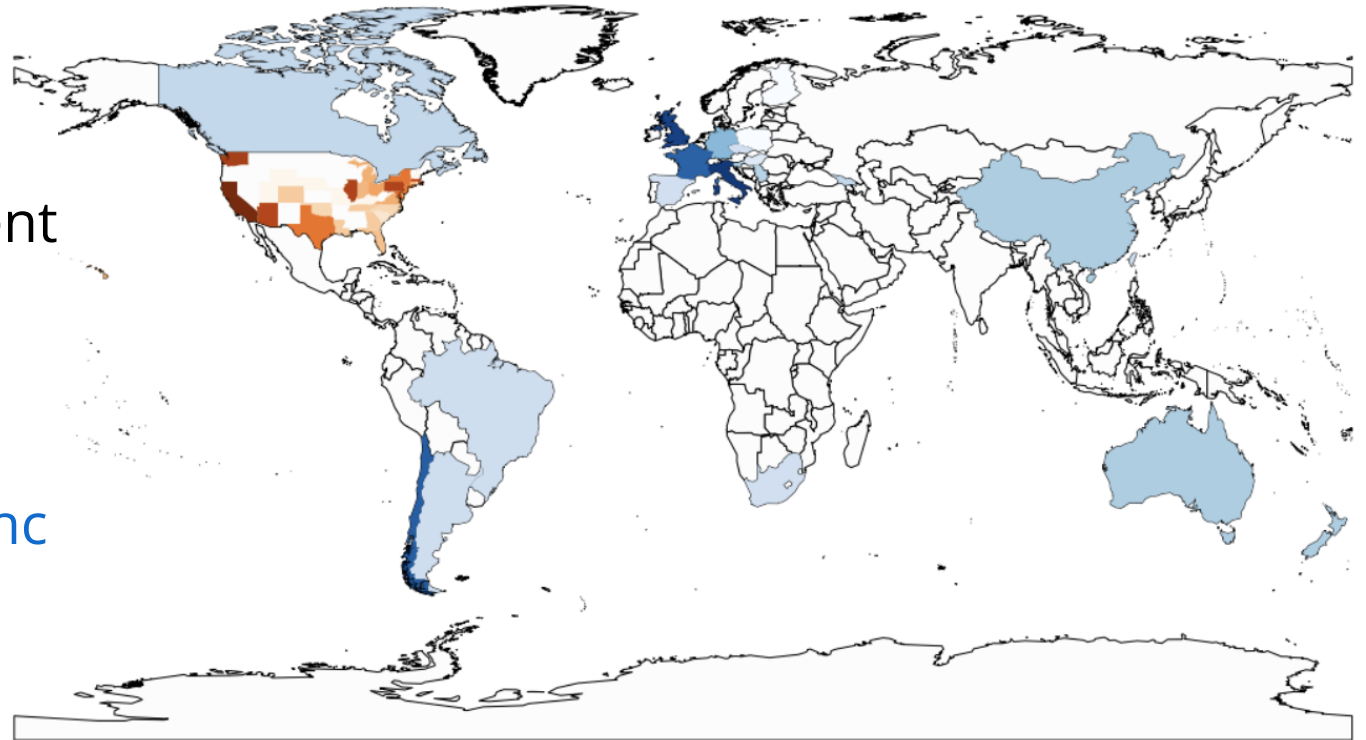
# Rubin LSST Science Collaborations

## Who can join?

The SCs aspire to be an inclusive, supportive, and nurturing environment for scientists in pursuing LSST-based science. Each SC has its own application process

<https://www.lsstcorporation.org/science-collaborations>

- No membership fees.
- No requirement to be affiliated with any organization.
- No requirements on time-commitment for basic membership.

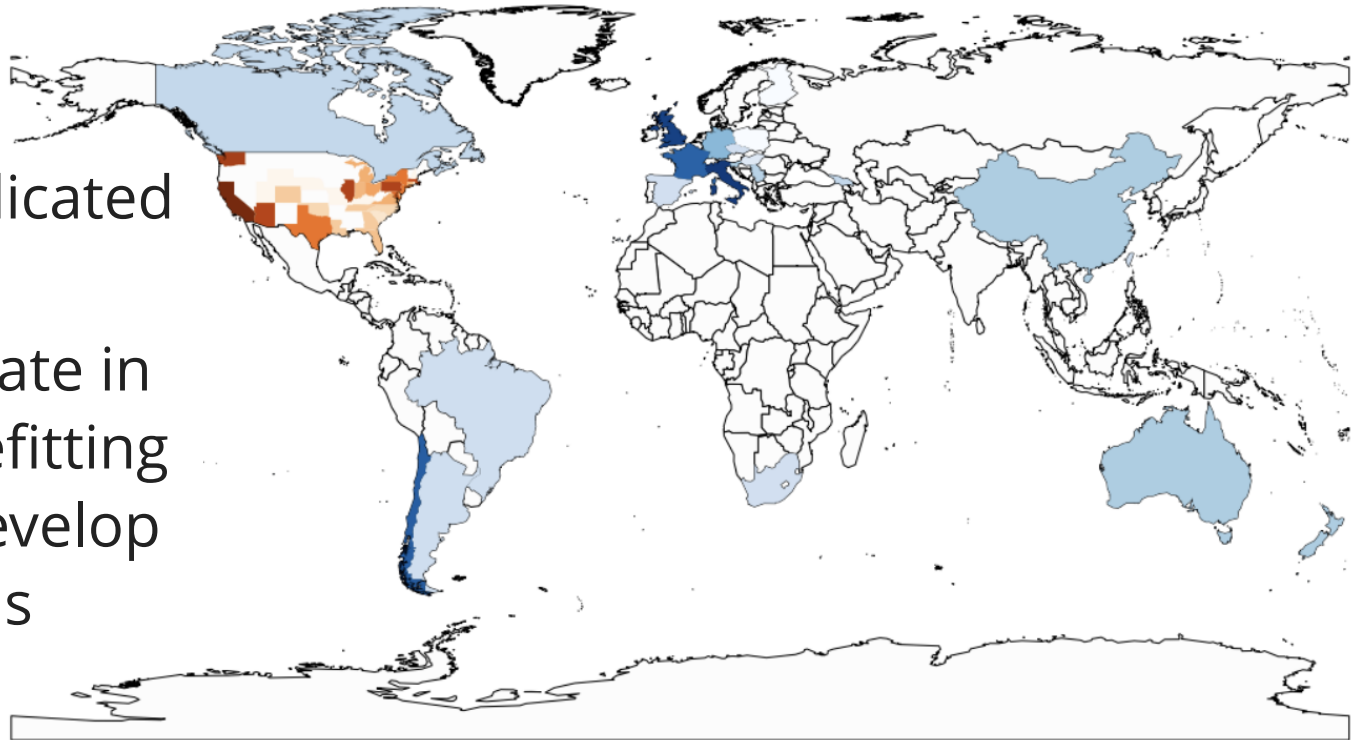




# Rubin LSST Science Collaborations

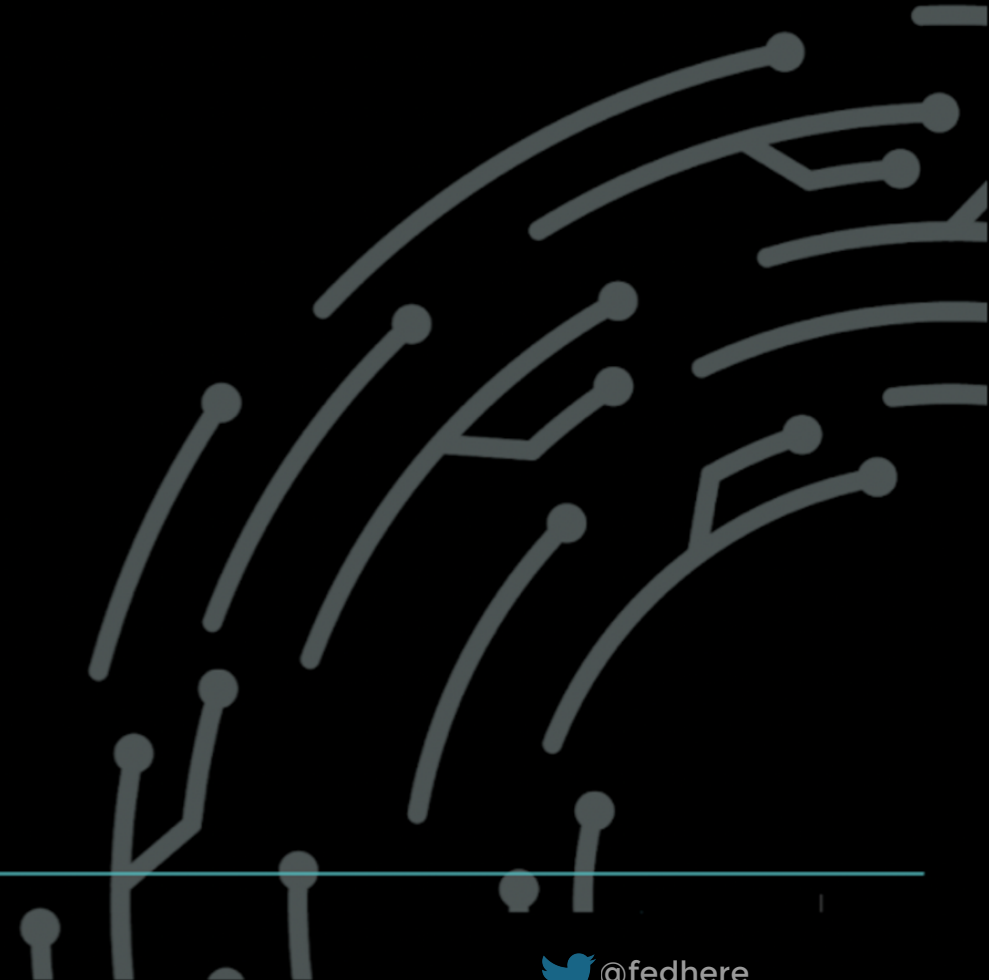
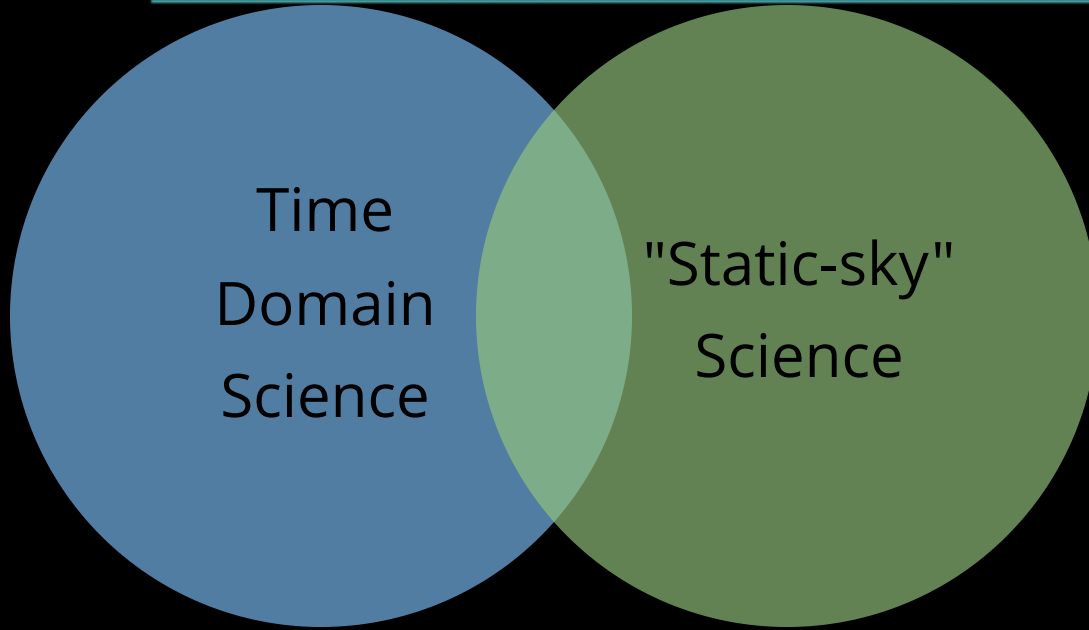
## Why should I join?

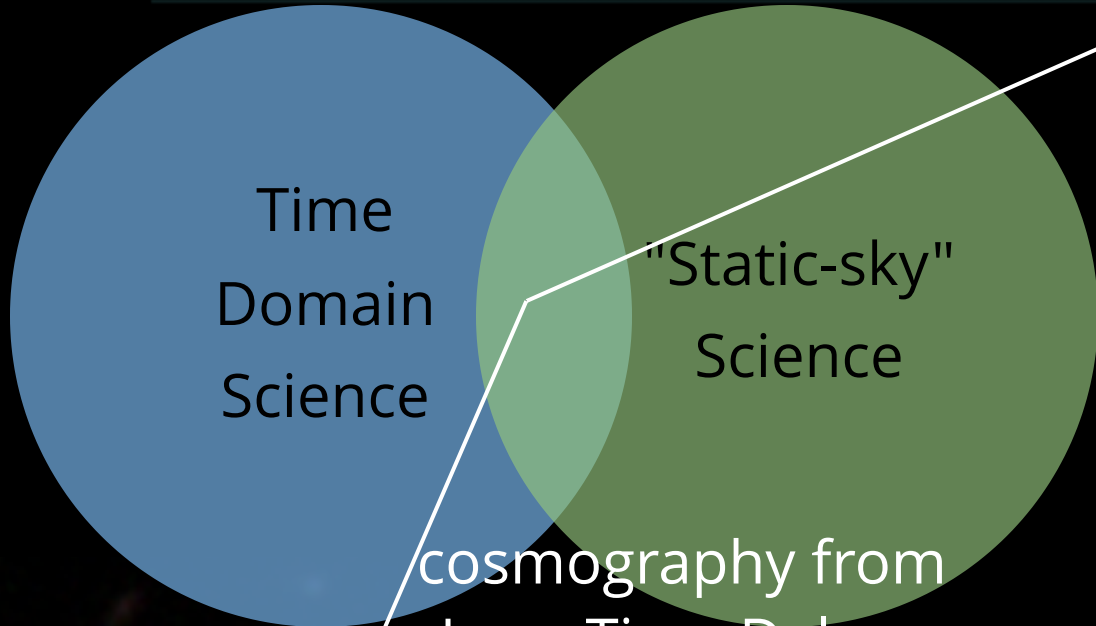
A direct line to Project through dedicated Rubin liaisons, responsibility and right to participate in decision making committees, benefitting from the expert knowledge and develop new LSST-based collaborations



Time  
Domain  
Science

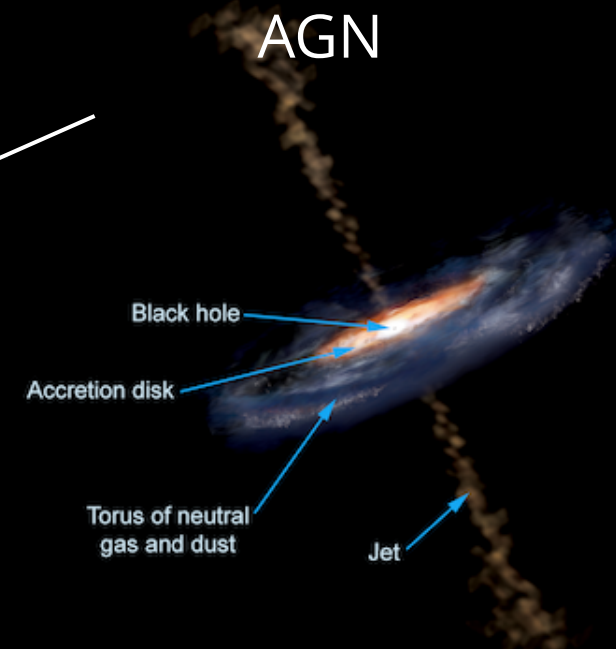
"Static-sky"  
Science





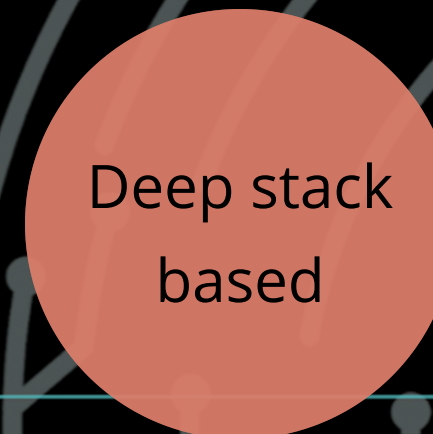
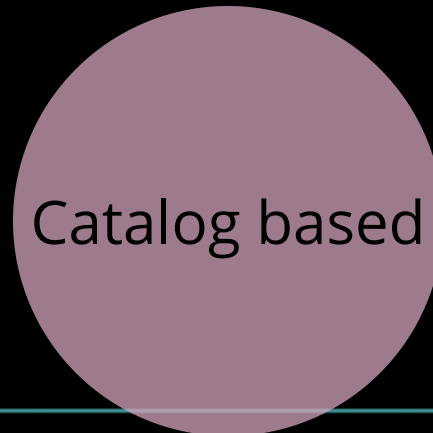
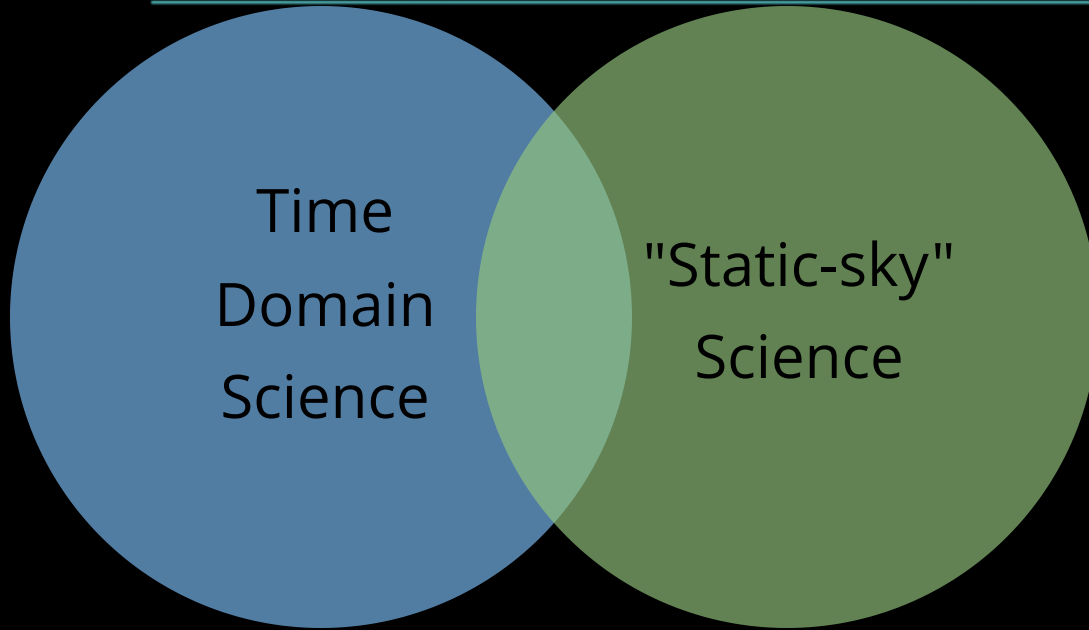
STRONG  
LENSING

cosmography from  
Lens Time Delays  
(SL+DESC)  
resolved high z  
galaxy properties  
(SL+Gal)  
calibration of cluster  
mass function with  
with S+W Lensing

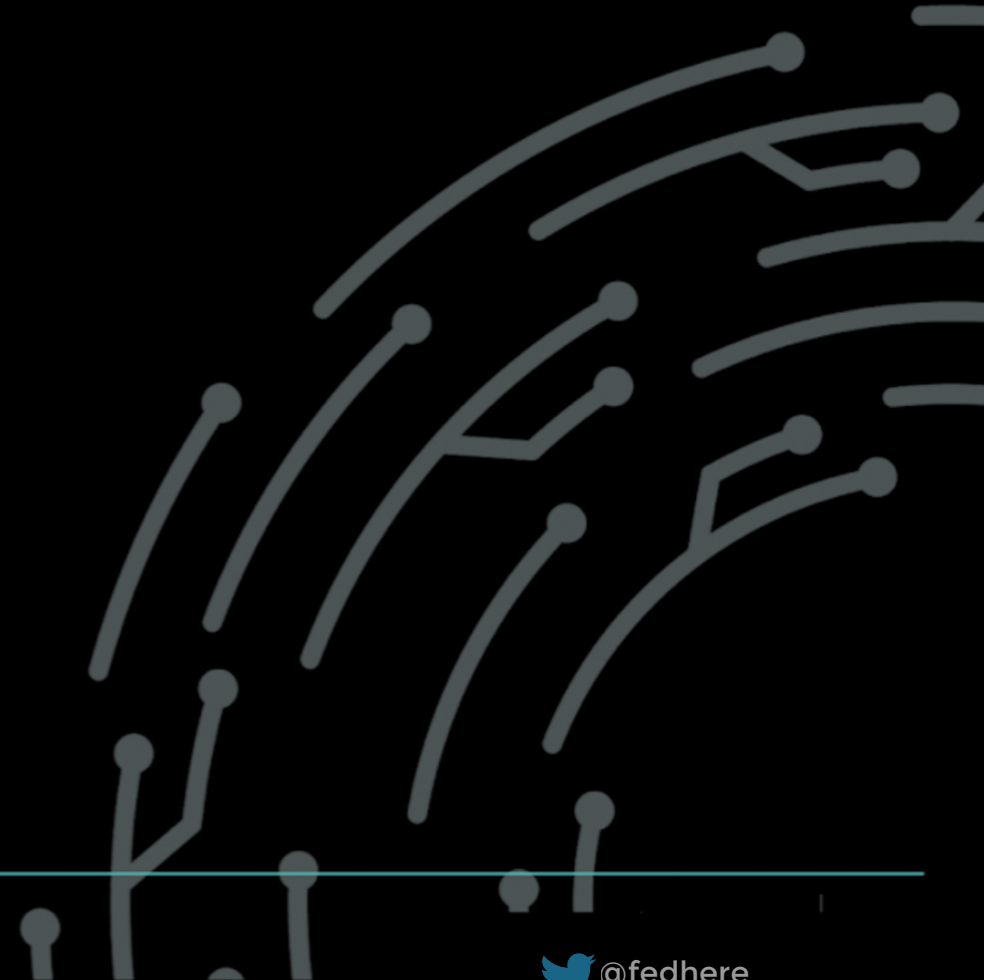
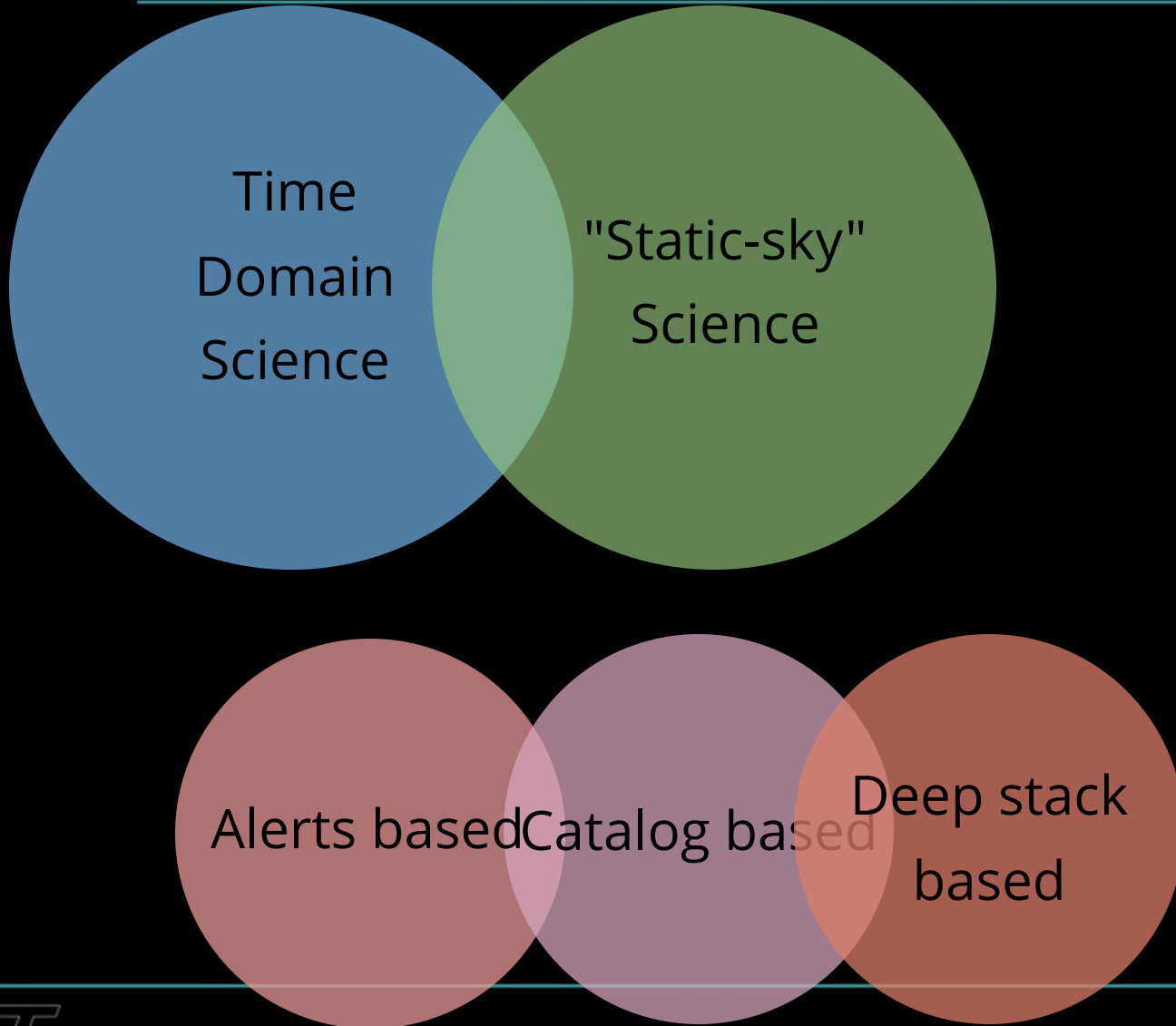


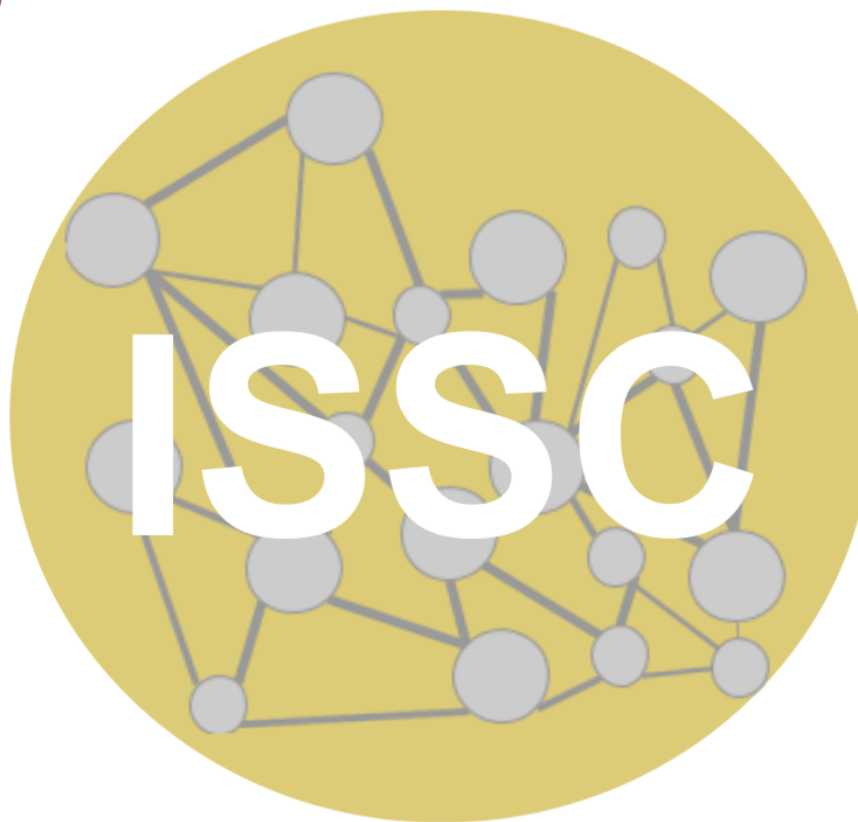
50M+ AGNs to  $z \sim 7.5$   
(AGN+Gal)  
variability,  
microlensing,  
binaries  
(AGN+TVS)



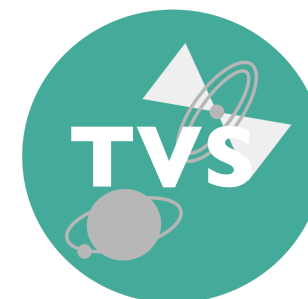








*informatics and statistics*





# I hope to see you at the Project Community Workshop

August 8-12 Tucson Arizona



8-12, August 2022 - Tucson, Arizona

We haven't all had an opportunity to meet face-to-face since 2019, and it's about time! Rubin Commissioning is well underway, and progress has been made in all areas despite challenges—both expected and unexpected. Get inspired and re-invigorated for Rubin science by interacting with your colleagues at this year's meeting.

Deadline to register is July 22, 2022

(free t-shirt with registration only until July 8)



<https://project.lsst.org/meetings/rubin2022/>

***thank you!***

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