

The Vera C. Rubin Observatory and the Legacy Survey of Space and Time (LSST)

Slides from LSST:UK consortium

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Project Lead : Bob Mann (University of Edinburgh)



Legacy Survey of Space
and Time (LSST)



Starting points :

<https://www.lsst.org>

<https://www.lsst.ac.uk>

<https://lsst-uk.atlassian.net>

Slides reviewed and last
updated :
28 November 2022

“Large Synoptic Survey Telescope” concept



Image Credit: Rubin Observatory,
March 2022
<https://gallery.lsst.org>

The large synoptic survey telescope concept :
Ivezic et al: <http://arxiv.org/pdf/0805.2366.pdf>

Construction progress : as of August 2022



Projected (post-Covid)
start of science operations:
third quarter-2024

Image
Credit:
Rubin
Obs.

Simonyi Telescope completed in Spain 2019 (now in dome on site)



Image
Credit:
Rubin
Obs.

<https://www.youtube.com/watch?v=NOaS8jzkTMI>

Charles Simonyi telescope : 8.4m but really 6.5m effective aperture

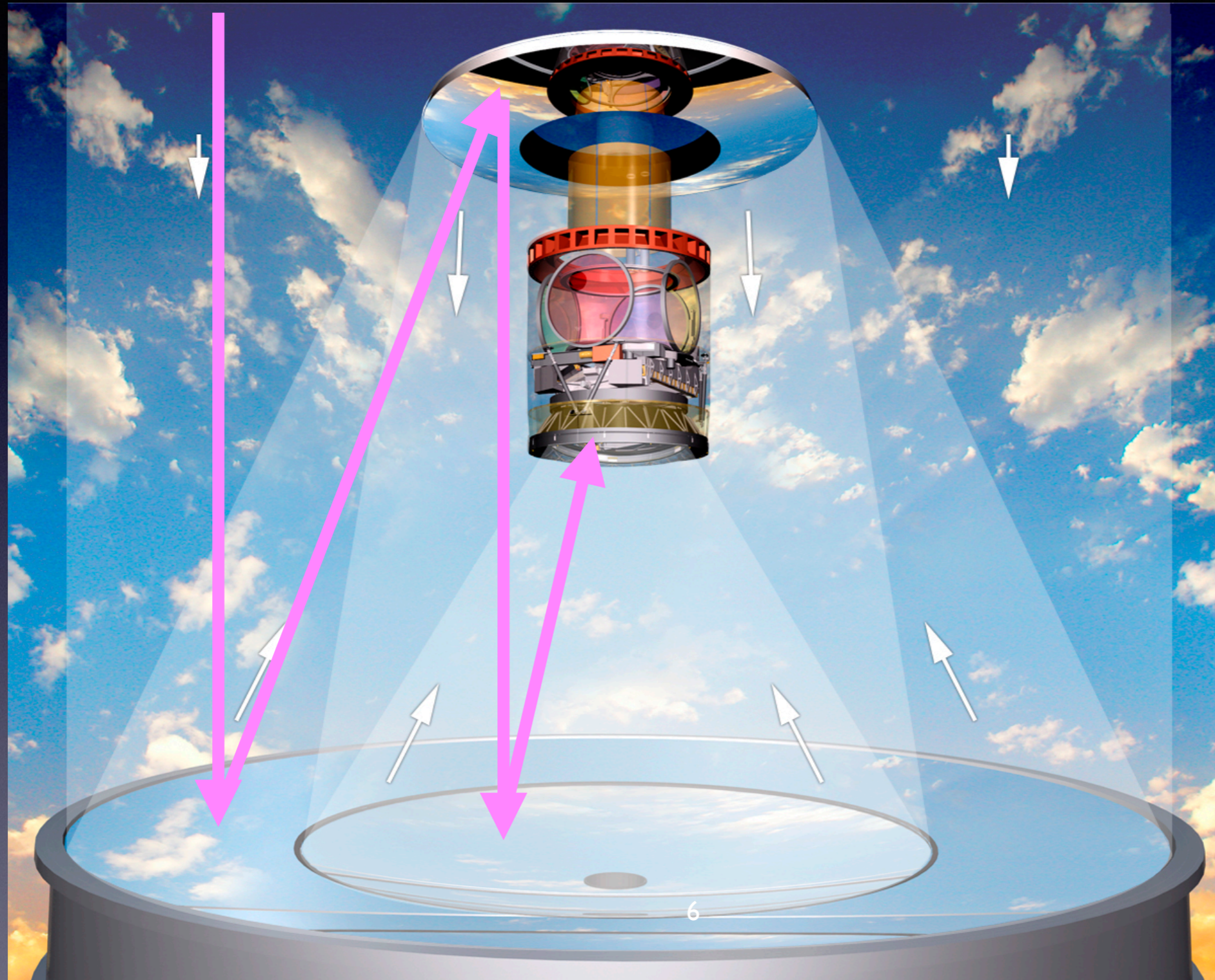


Image Credit:
Rubin Obs.

8.4m primary, with 5.0m tertiary inset \Rightarrow 6.5m effective diameter of primary

Vera Rubin Observatory Camera 3.2 Gigapixels Constructed at SLAC,

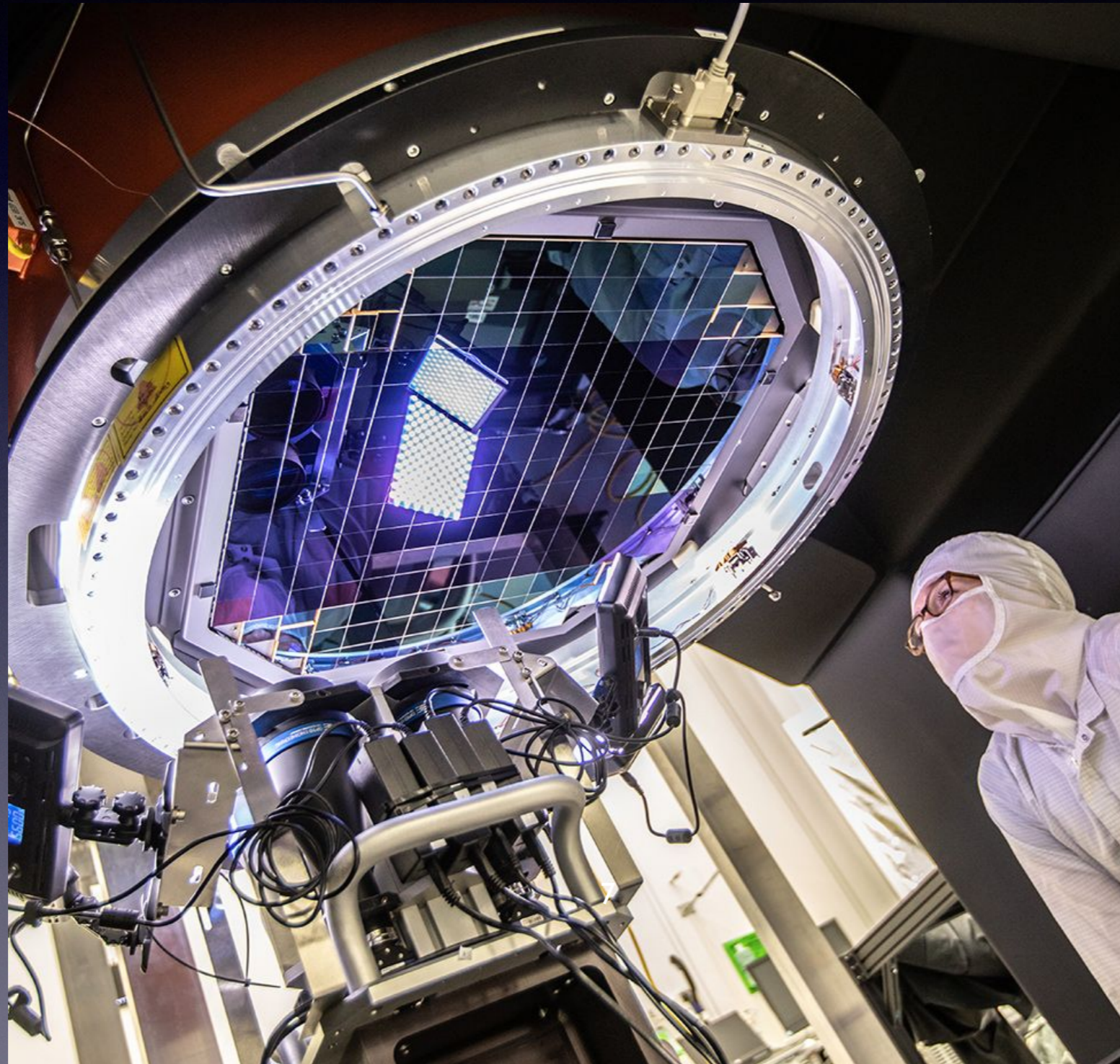
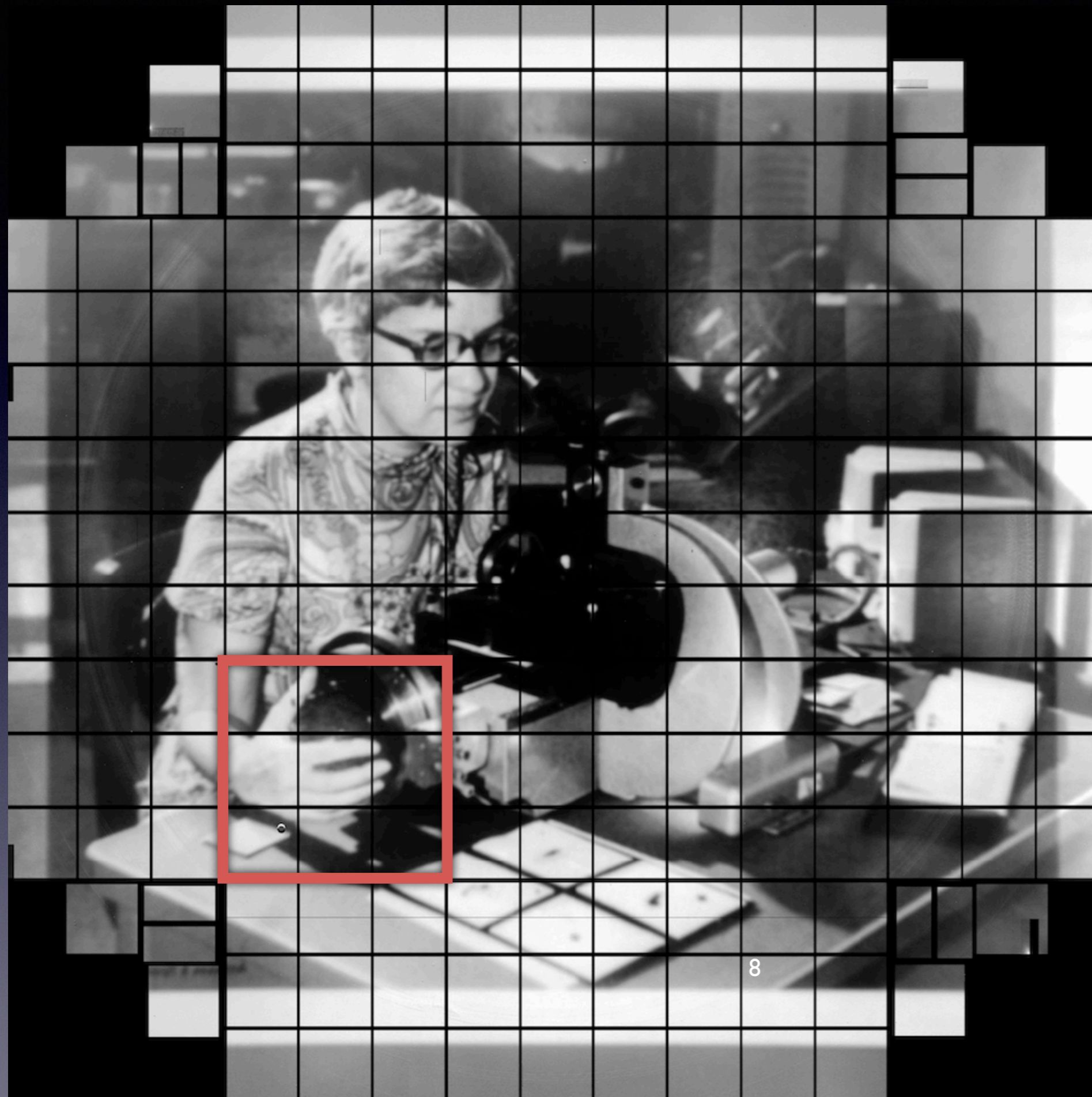


Image Credit:
J. Orrel/SLAC



3.2 Gigapixels
3 x 3 CCD “raft”
21 full rafts
198 CCDs

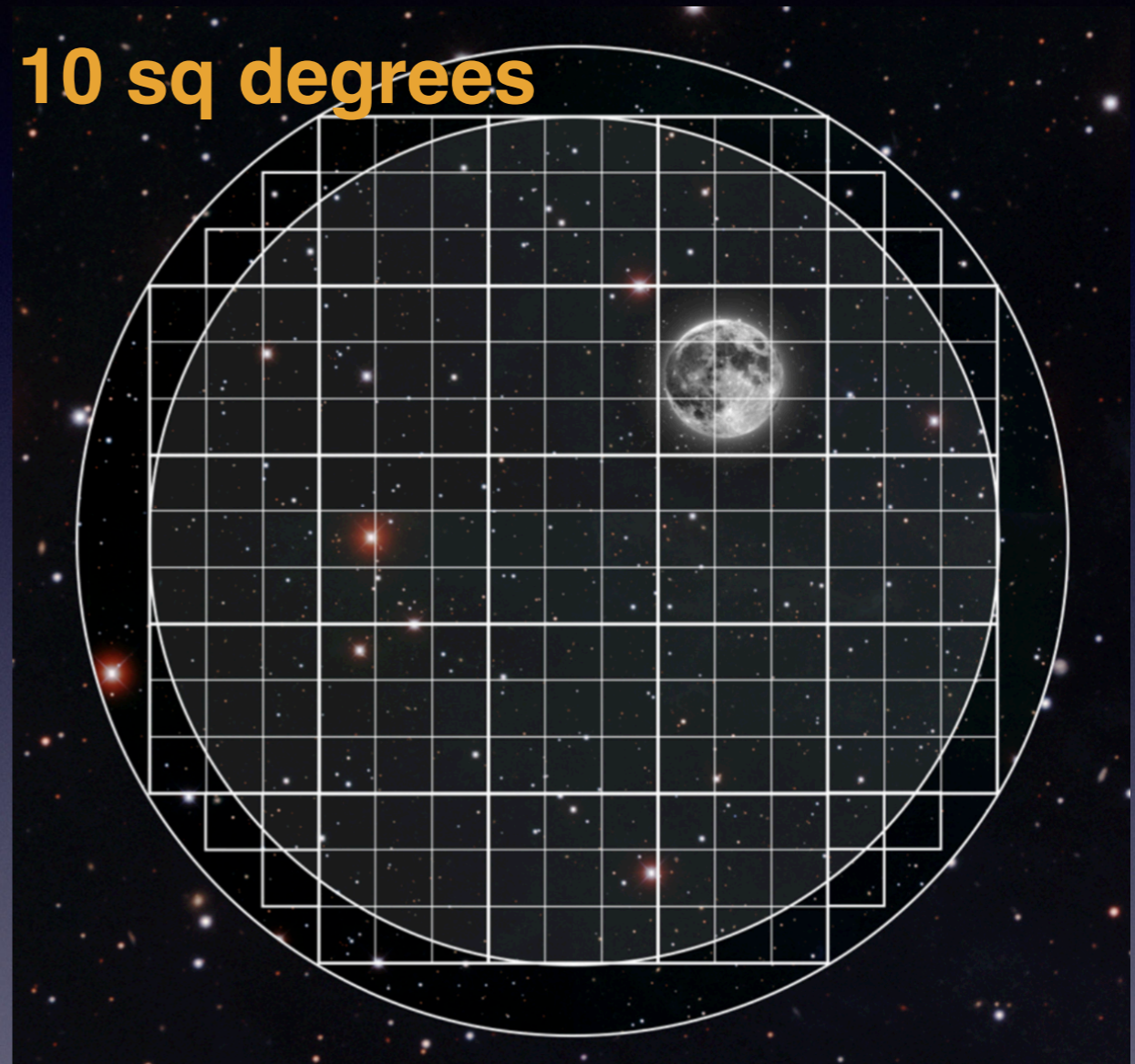
Scheduled to
ship to Chile
late 2022

Image Credit:
Rubin Camera
Team

Where to point and when ?

- Rubin Observatory
 - 8m telescope (6.5 m clear aperture) on Cerro Pachon, Chile
 - 3.5 gigapixel camera, impressive detector quality
 - Real time alert stream and multi-colour deep image of the sky
- **Science Requirements**
 - 18,000 square degrees observed 825 times over 10 yrs
 - Multi-Colour deep image of southern sky
 - Parallax and proper motion precision requirements
 - Rapid revisit timescale requirements

10 sq degrees



Cadence problem in a nutshell:

Can do all southern, visible sky once per night : but we need 2 visits and we have 6 filters

Average return time (in same filter)⁹ would be $2 \times 6 = 12$ days

Multi-colour and deep

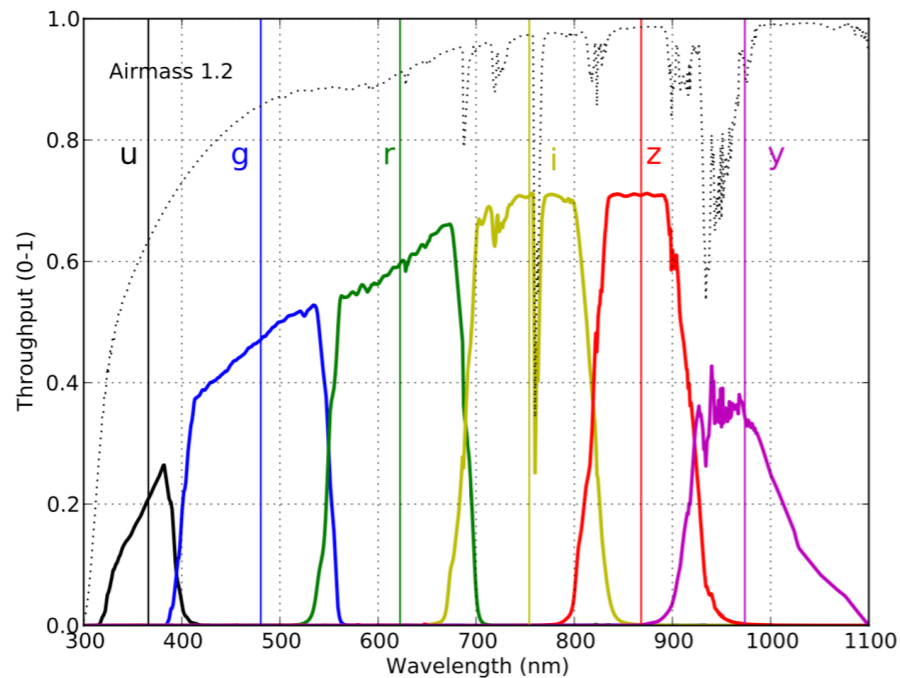


Figure 4. The LSST bandpasses. The vertical axis shows the total throughput. The computation includes the atmospheric transmission (assuming an airmass of 1.2, dotted line), optics, and the detector sensitivity.

	5 σ single visit	10 yr depth
<i>u</i>	23.9	26.1
<i>g</i>	25.0	27.4
<i>r</i>	24.7	27.5
<i>i</i>	24.0	26.8
<i>z</i>	23.3	26.1
<i>y</i>	22.1	24.9

LSST Observing sequence and cadence

- Observe a camera footprint with 2x15 second exposures, taken back-to-back (they are called “snaps”. They will be co-added automatically to make a 30 second image, allowing cosmic ray mitigation
- Come back on the same night, about 30mins later, and observe *exactly* the same footprint. Still to be decided if the 2nd visit will be in the same filter as the 1st or a suitable different pair (e.g. *g+r*, *i+z* *u* and *y* would not be paired of course)

When does LSST revisit this footprint again ?

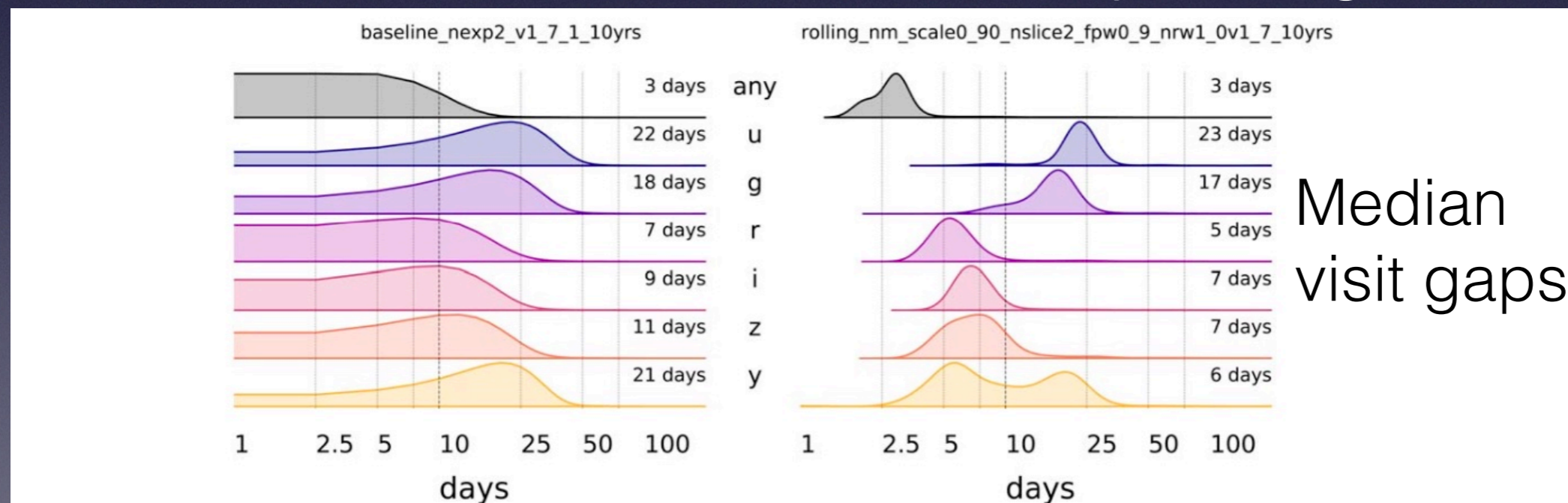
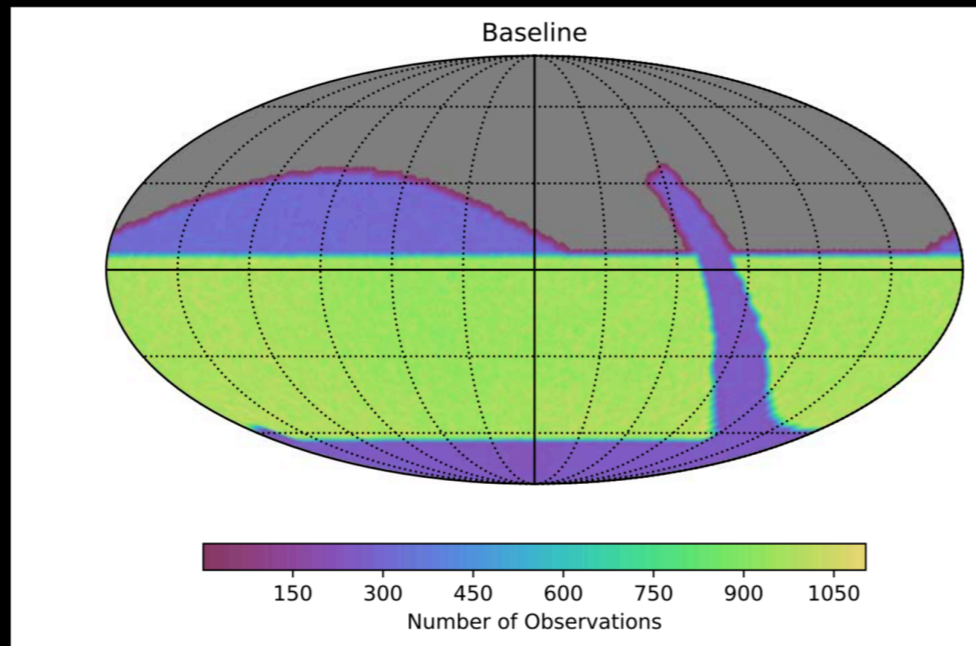


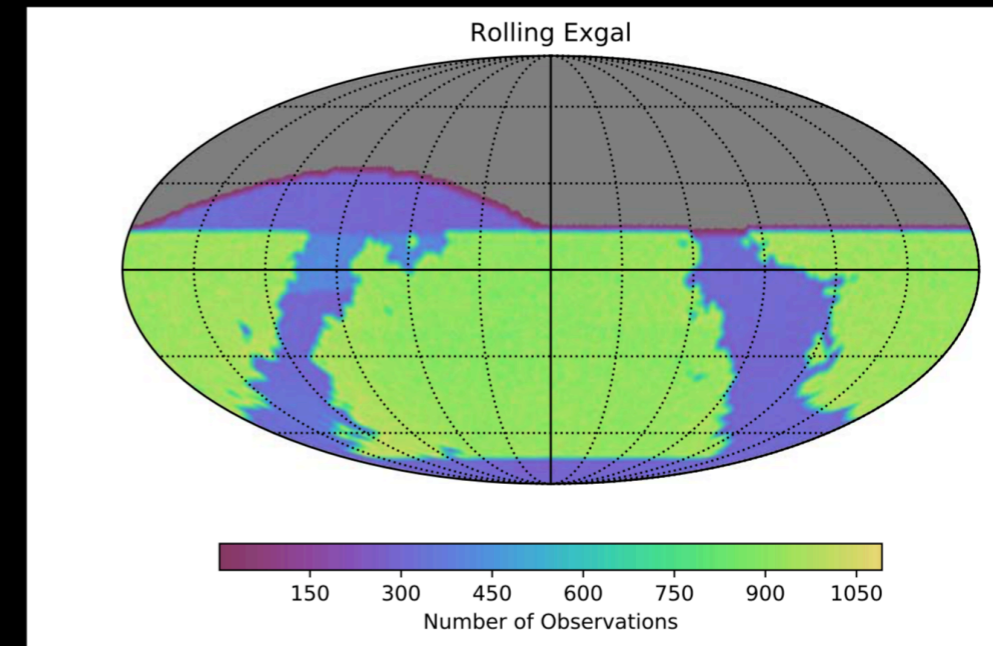
Figure 2. Distribution of median internight visit gaps (the time elapsed between visits to the same field in different nights) at a given location in the sky for two simulated LSST OpSim strategies: baseline_nexp2_v1.7.1_10yrs (left) and rolling_nm_scale0.90_nslice2_fpw0.9_nrw1.0v1.7_10yrs

2 example strategies

Baseline



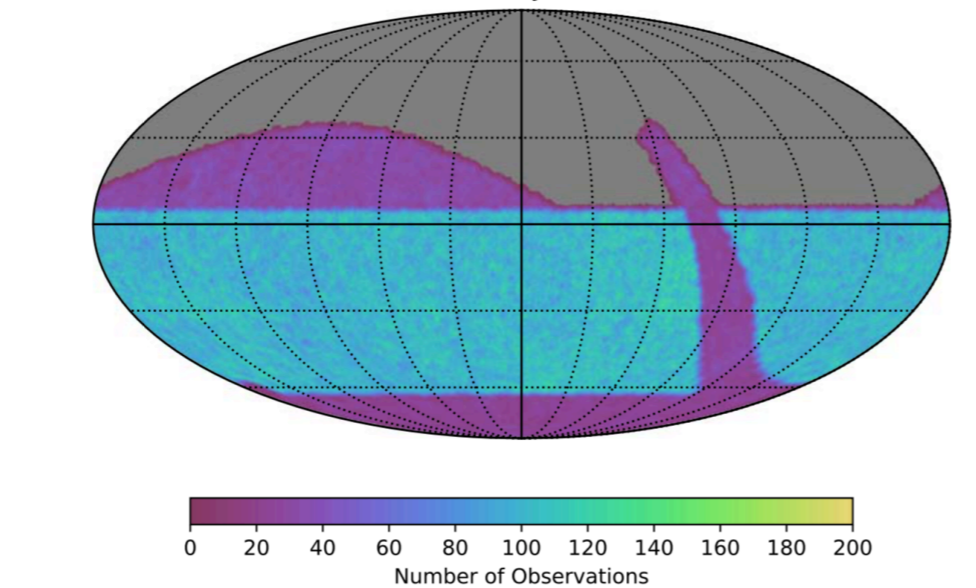
Rolling



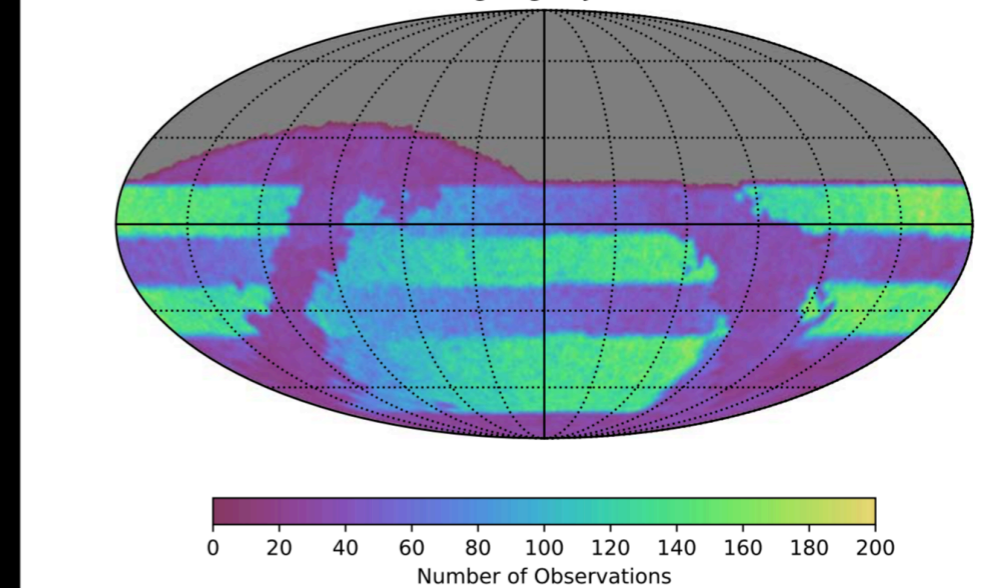
Number of observations after 10 years (DDF visits removed)

Year 3.5-4.5

Baseline, y3.5-4.5



Rolling Exgal, y3.5-4.5



Process and timescale for selection

- Science Advisory Committee (inc. Smartt, Meg Schwamb from QUB) appointed and charged “SCOC”
 - *Science Survey Optimisation Committee*
 - *Work closely with Rubin Project staff : Lynne Jones and Peter Joachim*
 - *Review the “White Papers” and Lynne & Peter’s simulation runs*
 - *Make **specific** recommendations, communicate, track progress and review*
 - *SCOC : expert, transparent, diverse and inclusive*
 - *UK involvement : Meg Schwamb (QUB), Hiranya Peiris (UCL)*
- “Cadence diplomacy” : committee should be communicative with the SCs
 - Phase I SCOC report delivered (see link below)
 - Phase II finalised recommendation : December 2022
 - 2023 : further simulations and refinements, and the science baseline strategy to be adopted

Membership and info on the SCOC :

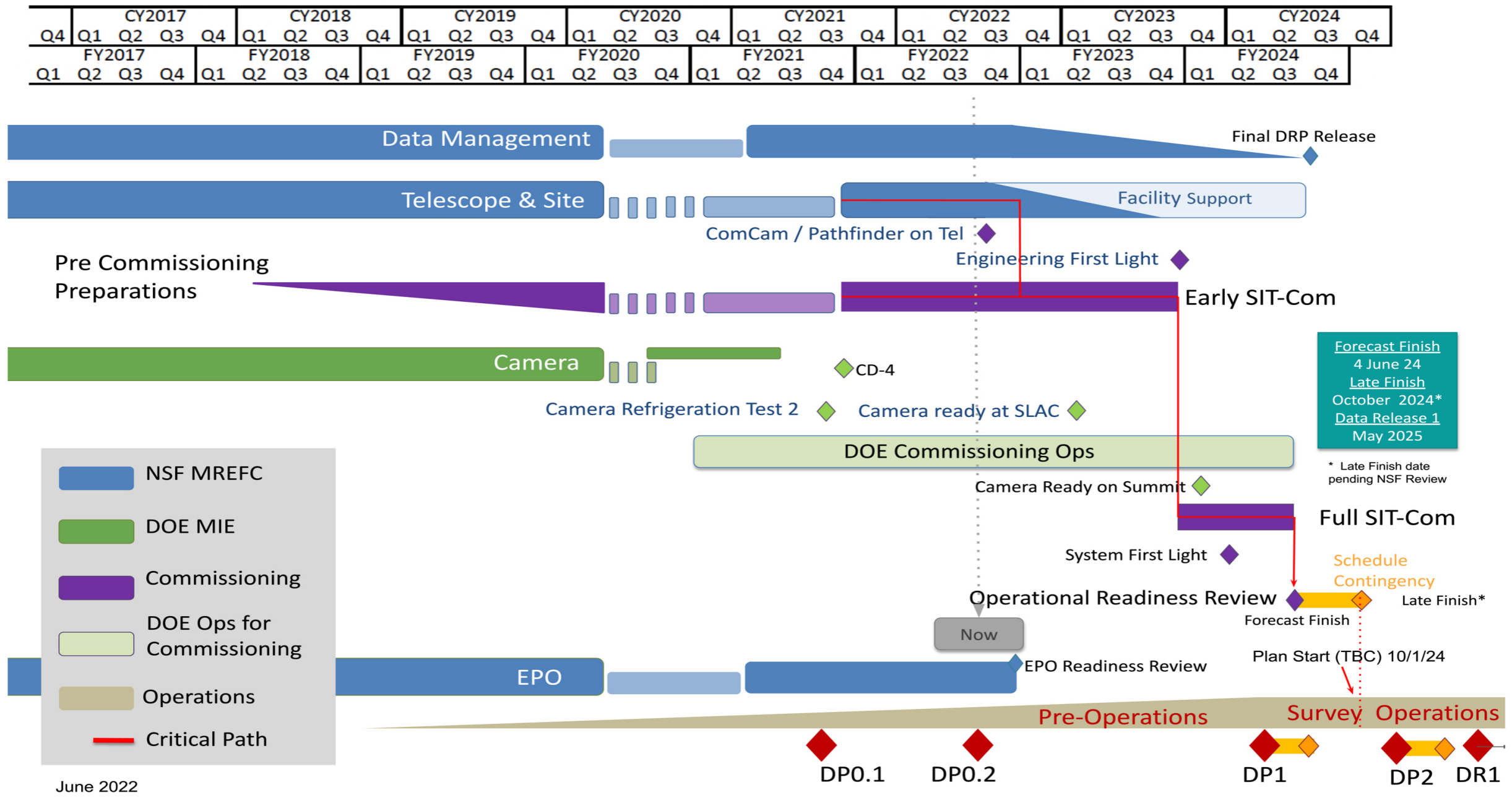
Useful info : <https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc>

Latest - 3rd SCOC-Science Collaborations Workshop <https://project.lsst.org/meetings/scoc-sc-workshop3/home>

<https://project.lsst.org/meetings/rubin2020/agenda/session/community-evaluation-rubin-survey-strategies>

Rubin schedule - projected science operations Jun-Oct 2024

Rubin Observatory Schedule



Monthly updates (including diagram updates) : <https://www.lsst.org/about/project-status>

When will data arrive ?

I keep an updated web page on data release schedule

<https://lsst-uk.atlassian.net/wiki/spaces/exec/pages/2946007041/LSST+Data+Preview+and+release+schedule>

Two useful Rubin documents which are continually updated :

Release Scenarios for Rubin - LSST Commissioning and Survey data
Marshall et al. RDO-11

<https://docushare.lsstcorp.org/docushare/dsweb/Get/RDO-11>

Rubin Observatory Plans for an Early Science Program
Guy et al. RTN-11

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

Marshall et al RDO-11 Table 10

Rubin Baseline Data Release Scenario	Jun 2021	Jun 2022	Mar 2024 - Jun 2024	Jul 2024 - Dec 2024	Apr 2025 - Jul 2025	Apr 2026 - Jul 2026
	DP0.1	DP0.2	DP1	DP2	DR1	DR2
Data Product	DC2 Simulated Sky Survey	Reprocessed DC2 Survey	ComCam On-Sky Data	LSSTCam On-Sky Data	LSST First 6 Months Data	LSST Year 1 Data
Raw images	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
DRP Processed Visit Images and Visit Catalogs	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
DRP Coadded Images	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
DRP Object and ForcedSource Catalogs	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
DRP Difference Images and DIASources	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE
DRP ForcedSource Catalogs including DIA outputs	FALSE	TRUE	TRUE	TRUE	TRUE	TRUE
PP Processed Visit Images	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
PP Difference Images	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
PP Catalogs (DIASources, DIAObjects, DIAForcedSources)	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
PP Alerts (Canned)	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE
PP Alerts (Live, Brokered)	FALSE	FALSE	FALSE	TRUE	TRUE	TRUE
PP SSP Catalogs	FALSE	FALSE	TRUE	TRUE	TRUE	TRUE

LSST Science Collaborations

SCs Federation Document [Ⓔ]

Overview Posters [Ⓔ]

There are currently eight active Rubin Observatory LSST Science Collaborations. Additional information about their work and membership can be found at the links below or by contacting the individual chairs, or the [LSSTC Science Collaborations Coordinator \(LSSTCSCC\)](#), [Federica Bianco](#).

Galaxies [Ⓔ]

Chair(s): [Manda Banerji](#) (Institute of Astronomy, University of Cambridge); [Sugata Kaviraj](#) (University of Hertfordshire);
DM Liaison: [Dan Taranu](#)

Stars, Milky Way, and Local Volume [Ⓔ]

Chair(s): [William Clarkson](#) (University of Michigan-Dearborn); [John Gizis](#) (University of Delaware); [Ting Li](#) (University of Toronto);
[Nicolas Lodieu](#) (Instituto de Astrofísica de Canarias); [Peregrine McGehee](#) (College of the Canyons);
DM Liaison: [Colin Slater](#)

Solar System [Ⓔ]

Chair(s): [Meg Schwamb](#) (Queen's University Belfast); [David Trilling](#) (Northern Arizona University);
DM Liaison: [Mario Jurić](#)

Dark Energy [Ⓔ]

Chair(s): [Katrin Heitmann](#) (Argonne National Laboratory); [Renee Hlozek](#) (University of Toronto);
DM Liaison: [Robert Lupton](#), [Leanne Guy](#)

Active Galactic Nuclei [Ⓔ]

Chair(s): [Niel Brandt](#) (Pennsylvania State University);
DM Liaison: [Yusra ALSayyad](#)

Transients/variable stars [Ⓔ]

Chair(s): [Federica Bianco](#) (University of Delaware); [Rachel Street](#) (Las Cumbres Observatory);
DM Liaison: [Melissa Graham](#), [Eric Belm](#)

Strong Lensing [Ⓔ]

Chair(s): [Timo Anguita](#) (Universidad Andres Bello); [Graham Smith](#) (University of Birmingham); [Aprajita Verma](#) (University of Oxford);
DM Liaison: [Jim Bosch](#)

Informatics and Statistics [Ⓔ]

Chair(s): [Tom Loredó](#) (Cornell University); [Chad Schafer](#) (Carnegie Mellon University);
DM Liaison: [Leanne Guy](#)

LSST Core Science :

1. Dark matter and dark energy
2. Hazardous asteroids and remote solar system
3. Transient Optical sky
4. Formation and structure of the Milky Way

Important :

You are advised to join a Science Collaboration. Very useful for information flow, expertise, influence. Science Collaborations do not have exclusive rights to any science. There is no Rubin project level publication policy. Most SCs have their own publication policy for use of software/ derived data products etc.

Status of UK in LSST

- The LSST:UK team are in process of negotiating LSST data rights for at least 300 UK scientists (called Affiliate PIs, or APs). Each AP (faculty staff) comes with 4 junior affiliates (students/postdocs etc, called JAs). Data rights for AP or JA are identical - there is no hierarchy
- All APs and JAs are collectively known as International Data Rights Holders
- Full list of all approved International Data Rights Holders <https://www.lsst.org/scientists/international-drh-list>

- We submitted the proposal “ *LSST:UK In-kind Contributions to the Vera C. Rubin Observatory Legacy Survey of Space and Time* ” on 25th September 2020
- *Contribution to the annual Data Release Processing*
 - *International Data Access Centre hosted in the UK*
 - *Software development programme 2020 - 2033*
 - *EPO software through Zooniverse*
- This has been approved by Rubin and “Contribution Evaluation Committee”
- It requires BEIS level approval and STFC are negotiating with the US agencies (DOE and NSF)
- We are aiming for full national access for all UK based scientists, or a number over 300 (with 1200 associated JAs)
- We hope for conclusion by early 2023.

LSST:UK Consortium



Every astronomy department and group in UK



How do I get started ?

<https://lsst-uk.atlassian.net>

- Subscribe to the LSST:UK email list - go to the link “LSST:UK Announcement email list, info and instructions”
- Get an LSST:UK wiki account - “apply for account” on this page
- Read the monthly LSST:UK Newsletters linked on this page
- Apply for “Affiliate PI” or “Junior Associate” status through the UK - details will always be posted on this wiki and the LSST:UK email list
- After you get formal approval - recommendations on next slide

Useful source of info and place to ask questions:

<https://community.lsst.org>

When you have AP or JA status approved

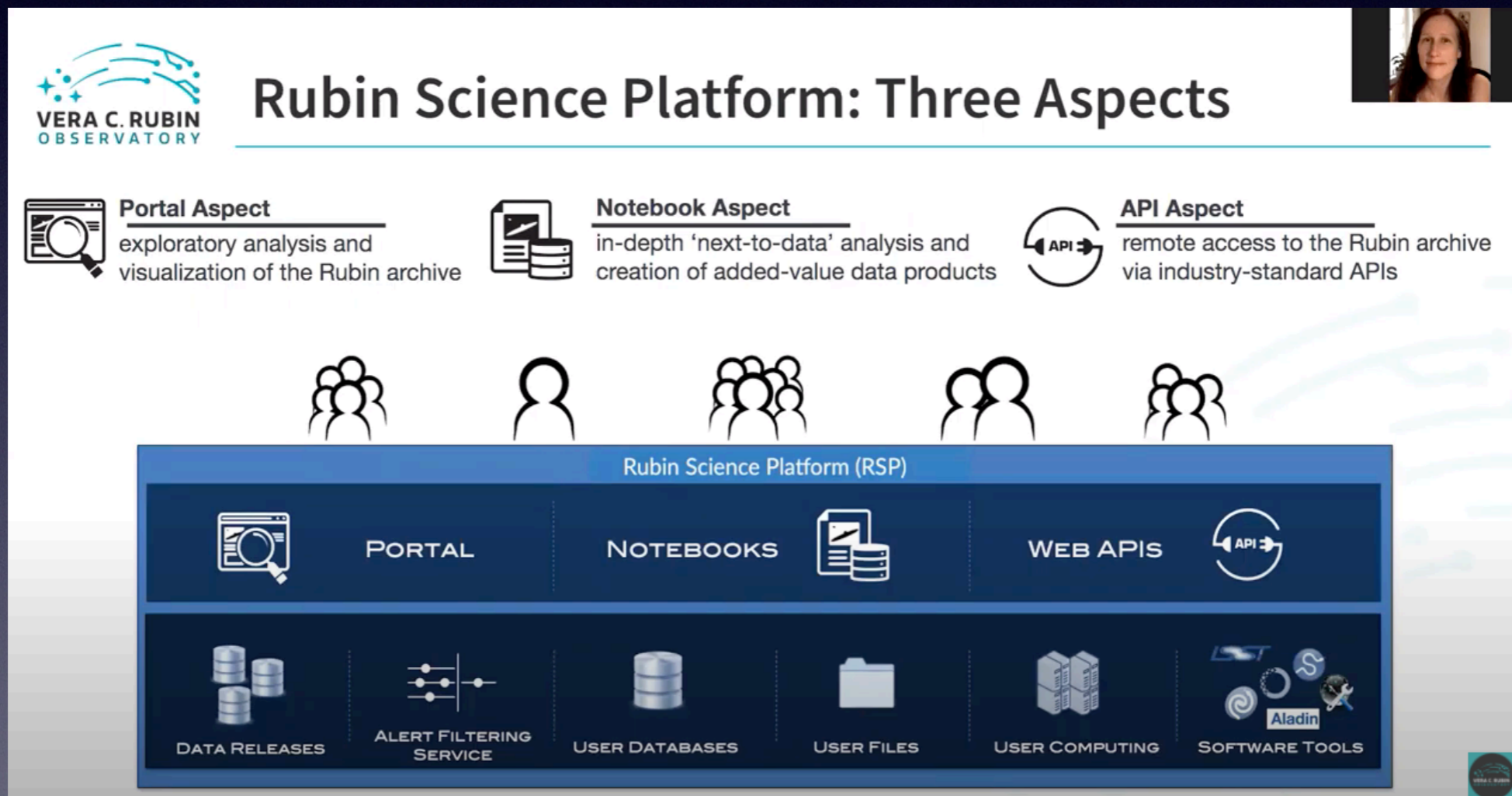
- After you get formal approval as an International Data Rights holder : sign up for login on <https://project.lsst.org>
- Join a Science Collaboration (through the above link)
- Join the LSST Slack and join <https://community.lsst.org>
- Watch videos, tutorials from the Annual Project and Community Workshop (PCW)
2022 : <https://project.lsst.org/meetings/rubin2022/program/agenda>
When you get approved as a data rights holder, you can login



Annual Project and Community workshops are held each August in Tucson. All data rights holders welcome.

Rubin Science Platform (RSP)

Can't download all data - bring analysis tools to the data
“next-to-the-data” analysis



Melissa Graham's "Intro to the RSP" from the Winter 2021 AAS
<https://www.youtube.com/watch?v=wA6732tr8fk>

Data Previews

See Melissa Graham's talk on Data Previews from NAM 2022 :

<https://lsst-uk.atlassian.net/wiki/spaces/HOME/pages/3000729601/LSST+UK+Newsletter+24+July+2022>

Rubin will release a series of Data Previews before real data comes from either the commissioning camera (ComCam) or the real camera (LSSTCam). Data previews will be simulated data first then Subaru HSC example data through the RSP. Calls to join these Data Previews are made on <https://community.lsst.org>

Data Preview 0 : see the latest on <https://dp0-1.lsst.io>

Timescales for data previews and releases

Release Scenarios for Rubin - LSST Commissioning and Survey Data” (Marshall et al. RDO-11) - continually updated, this is the reference source

<https://docushare.lsstcorp.org/docushare/dsweb/Get/RDO-11>

The basic plan is for annual Data Releases. The schedule as of of Aug 2022 is below - but see link above for official latest

Table 2: the LSST Data Preview schedule.

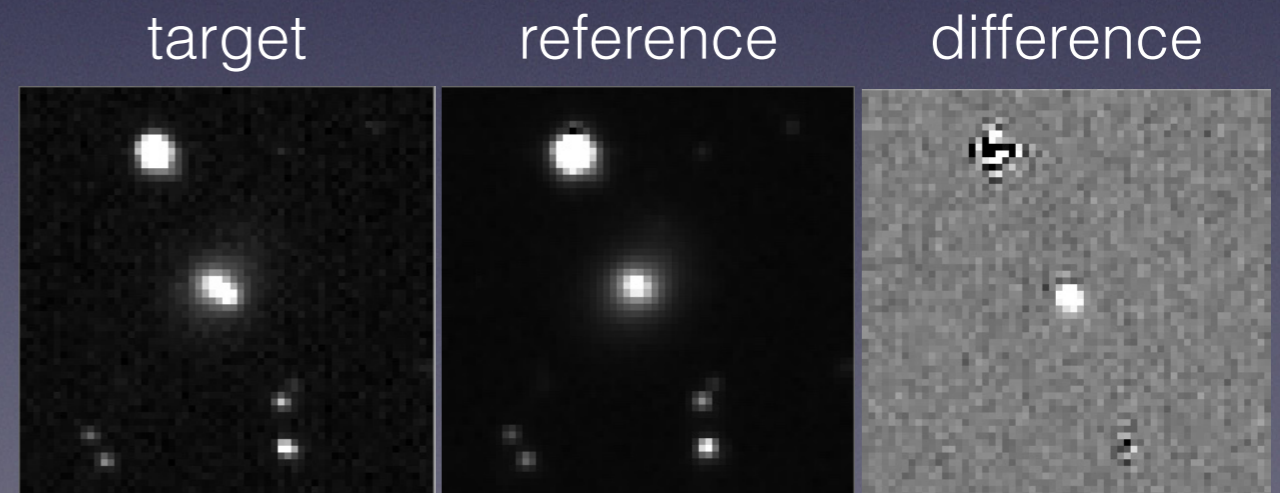
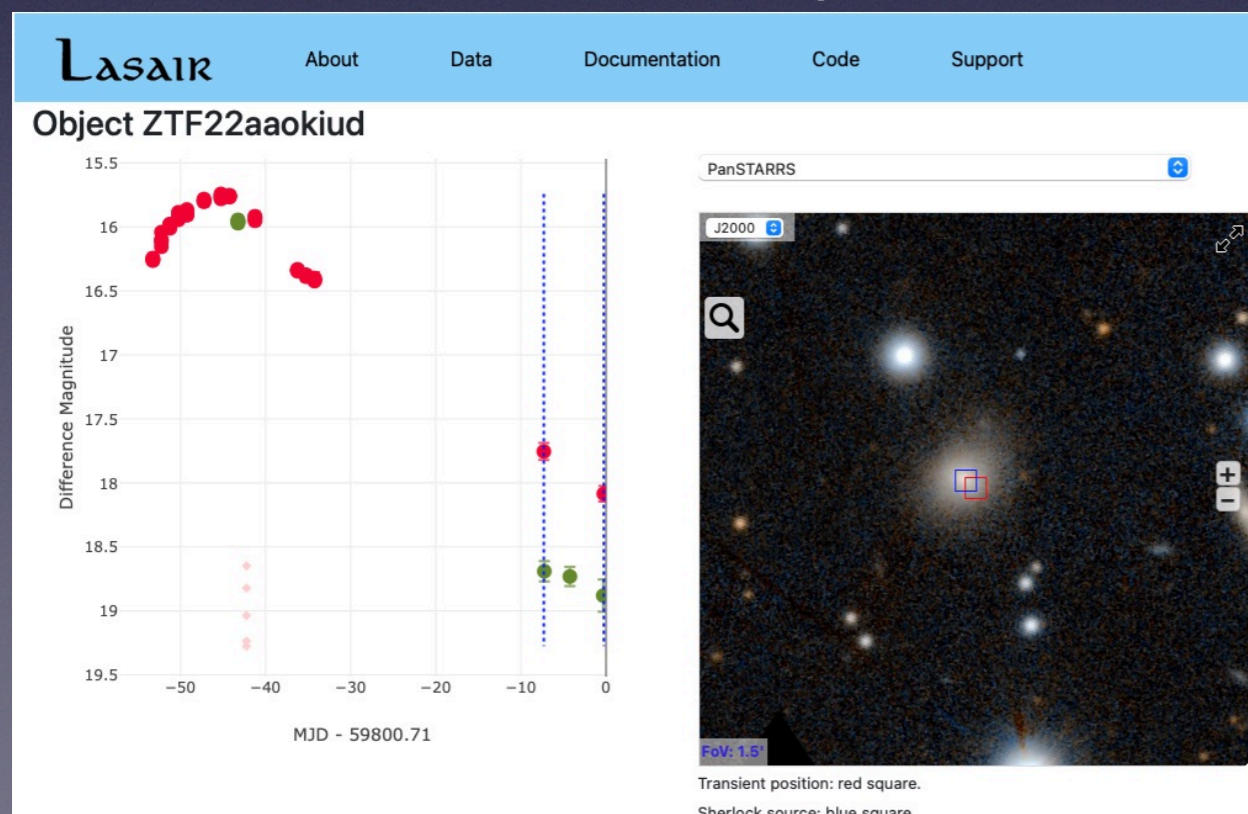
Data Preview/Release		Date	FY22	2022	FY23	2023	FY24	2024	FY25	2025	FY26	2026	FY27	2027
DP0.1	DC2 Simulated Sky Survey	June 2021												
DP0.2	Reprocessed DC2 Survey	June 2022												
DP1	ComCam On-Sky Data	Jan 2024 - Apr 2024												
DP2	LSSTCam On-Sky Data	Jul 2024 - Sep 2024												
DR1	LSST First 6 Months Data	Apr 2025 - Jul 2025												
DR2	LSST Year 1 Data	Apr 2026 - Jul 2026												
DR3	LSST Year 2 Data	Apr 2027 - Jul 2027												

Calendar years start at dotted red lines. US financial years start in October

Time domain : Alert Data

The first real science data to be released will be alert data, based on detections on difference images. Once the templates are available, of sufficient quality then the difference images (diff = target - reference) will be made and detections released.

The UK's broker will serve these data and you can access a prototype and real stream from ZTF now <https://lasair-ztf.lsst.ac.uk>



LSST Alerts - Key numbers

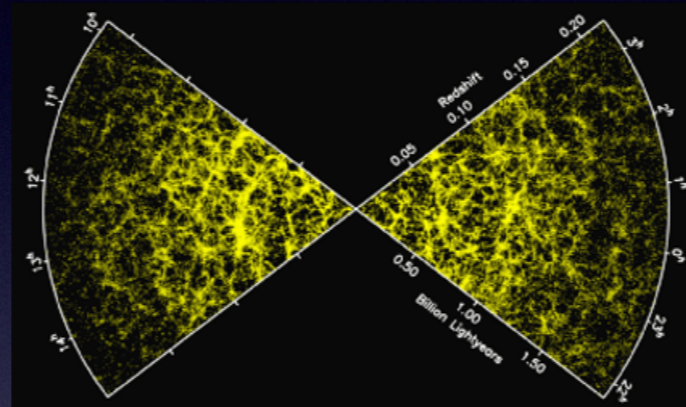
Goal is 60 seconds to send an alert. Every 60 seconds the following tables give an idea of number of alerts and their types that will be released.

Alert numbers : per visit

Type	Extragalactic (80% of sky)	Galactic (20% of sky)
Movers	3000	3000
Stars	1800	30000
AGN	70	70
Supernovae and extragalactic transients	200	200

	5 σ single visit	10 yr depth
<i>u</i>	23.9	26.1
<i>g</i>	25.0	27.4
<i>r</i>	24.7	27.5
<i>i</i>	24.0	26.8
<i>z</i>	23.3	26.1
<i>y</i>	22.1	24.9

LSST:UK Synergies



Spectroscopy:
4MOST
WEAVE
DESI, Euclid
MOONS



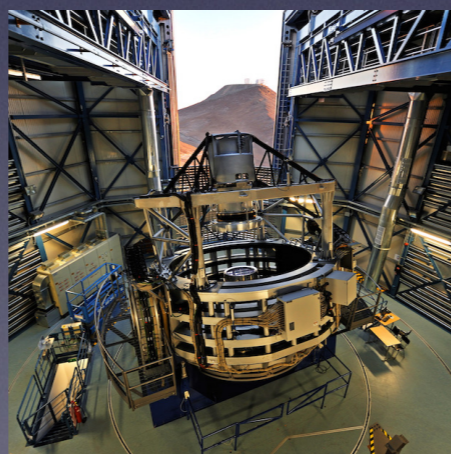
The UK has an unprecedented opportunity to lead the exploitation of this combined suite of facilities - particularly southern hemisphere and all-sky surveys

Summary: Rubin and LSST for all

- Beginning 2024, the LSST by the Rubin observatory will change the landscape
- Very deep images of the sky, plus time domain survey of unprecedented depth
- Data are available to all with data rights - we hope for all UK scientists
- The alert data are world-wide public
- Scientists can work alone, in their own teams, or within Science Collaborations (everyone has equal data rights)
- Analysis of data on the RSP with Python Notebooks, APIs or other code
- LSST data combined with ESO follow-up puts UK in strong position



LasAIR



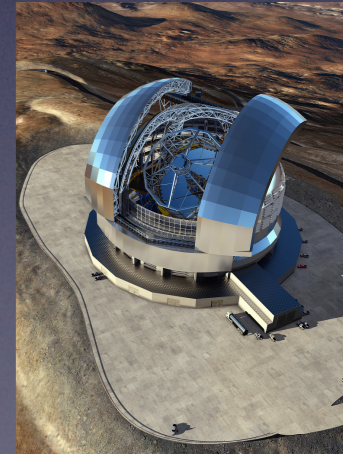
4MOST



NTT+SOXS



VLT



ELT

