

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 :
8 February 2023

“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 Feb 2023



Image
Credit:
Rubin
Obs.

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



Image Credit: Rubin Obs.

8-metre wide-field
survey telescope



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

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

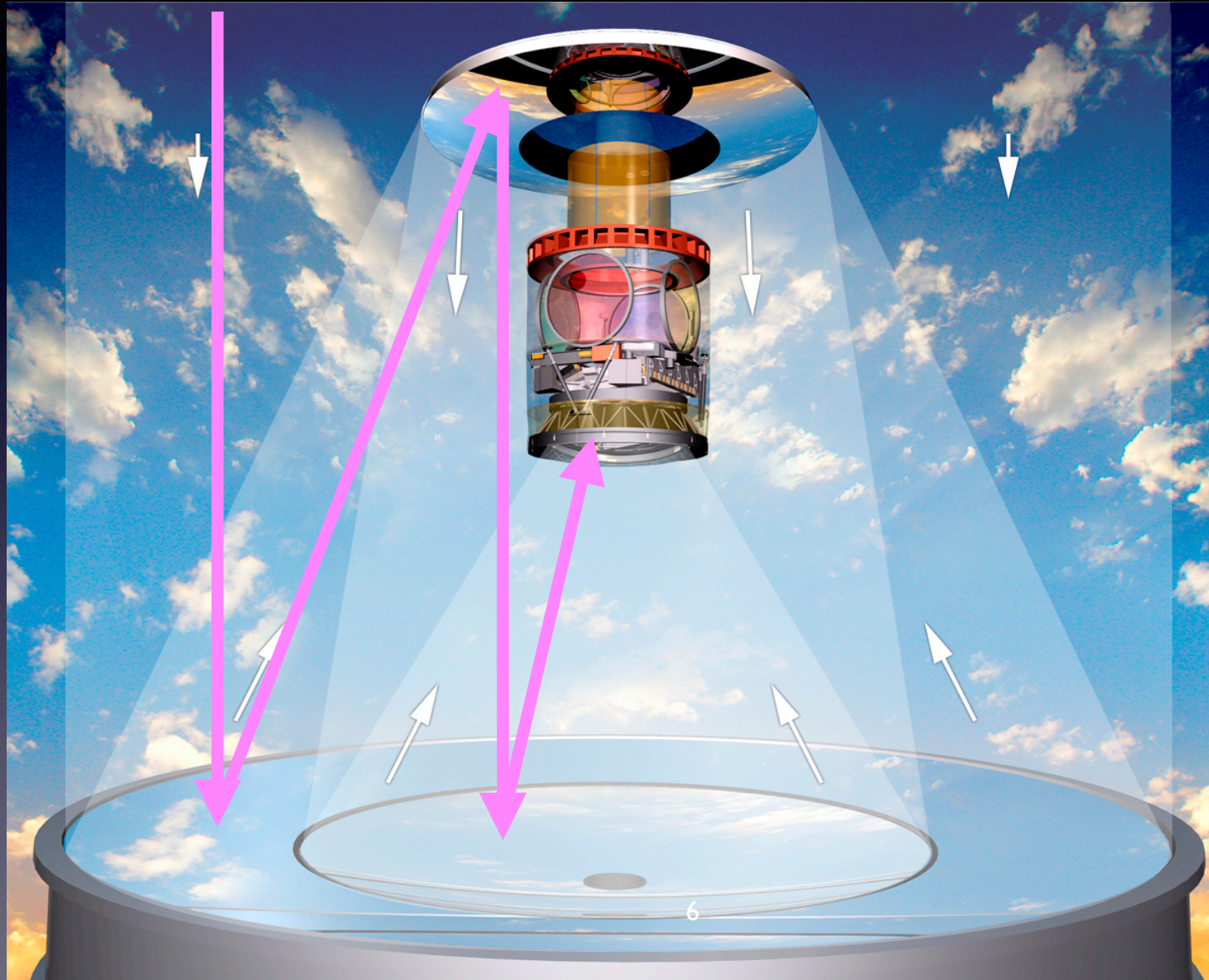


Image Credit:
Rubin Obs.

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,

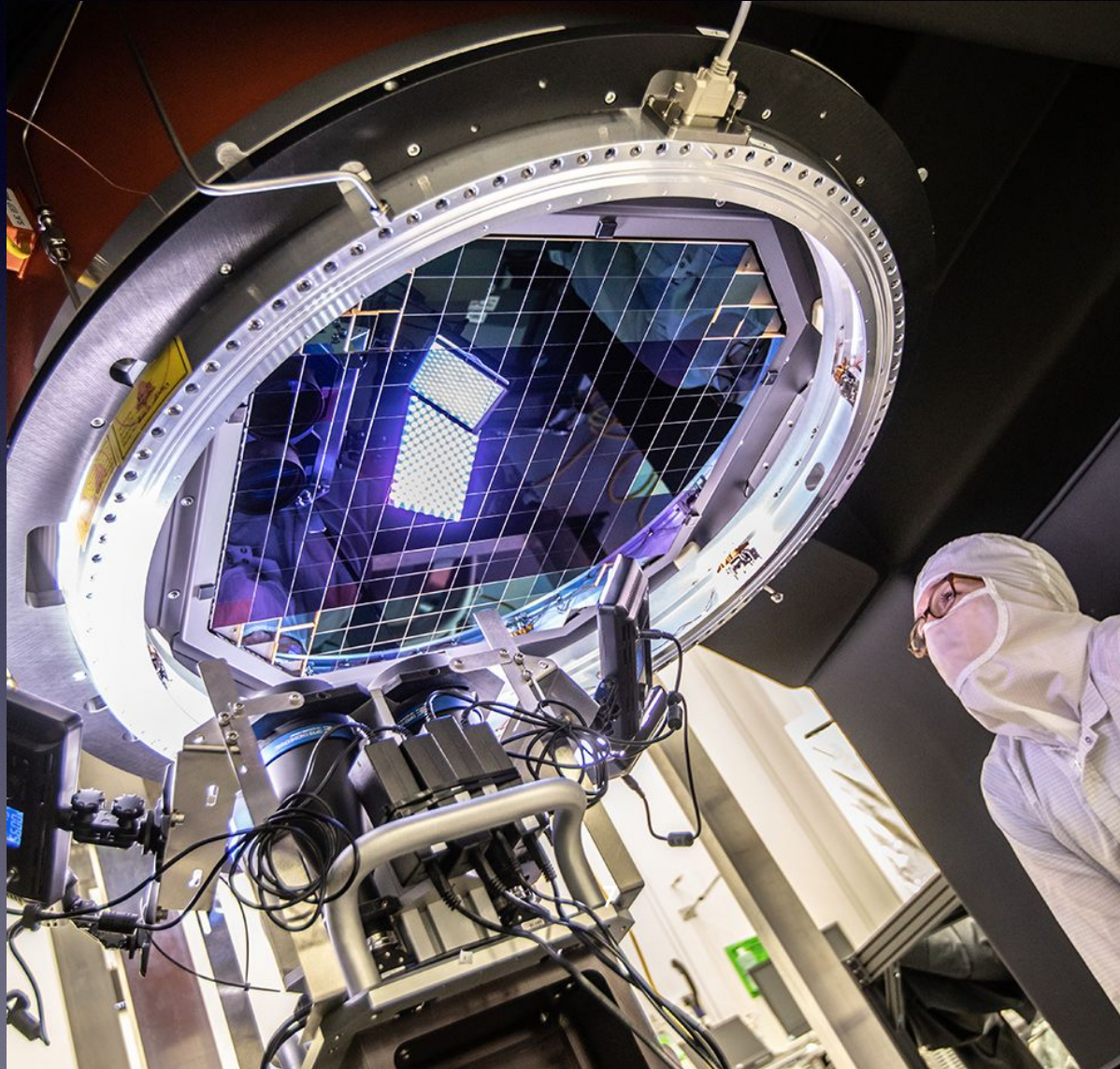
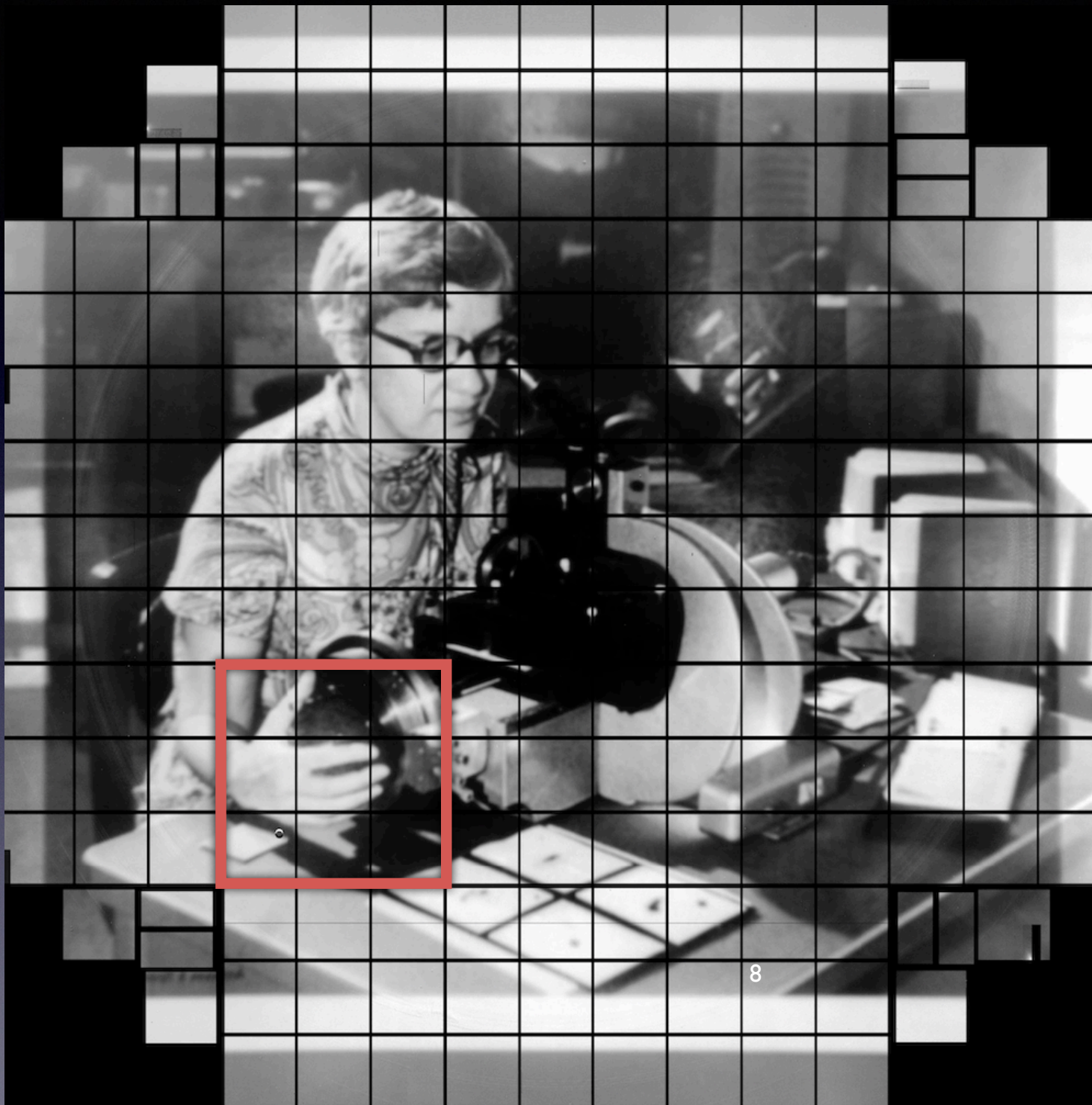


Image Credit:
J. Orrel/SLAC



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

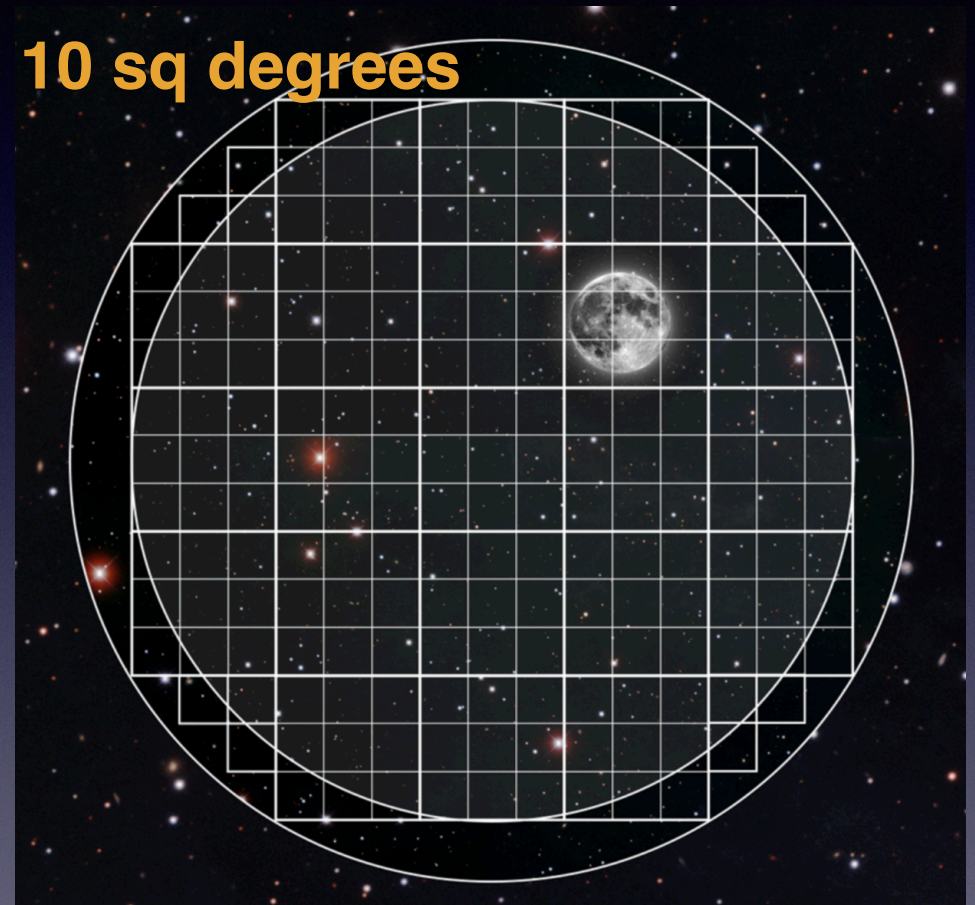
Scheduled to
ship to Chile
late 2022

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

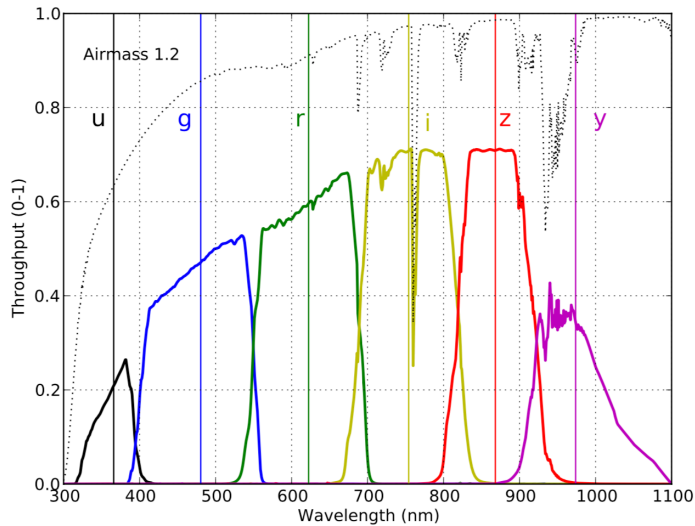


Figure 4. The LSST bandpasses. The vertical axis shows the total throughput. The computation includes the atmospheric transmission (assuming an airmass of 1.2, dotted line), optics, and the detector sensitivity.

	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 ?

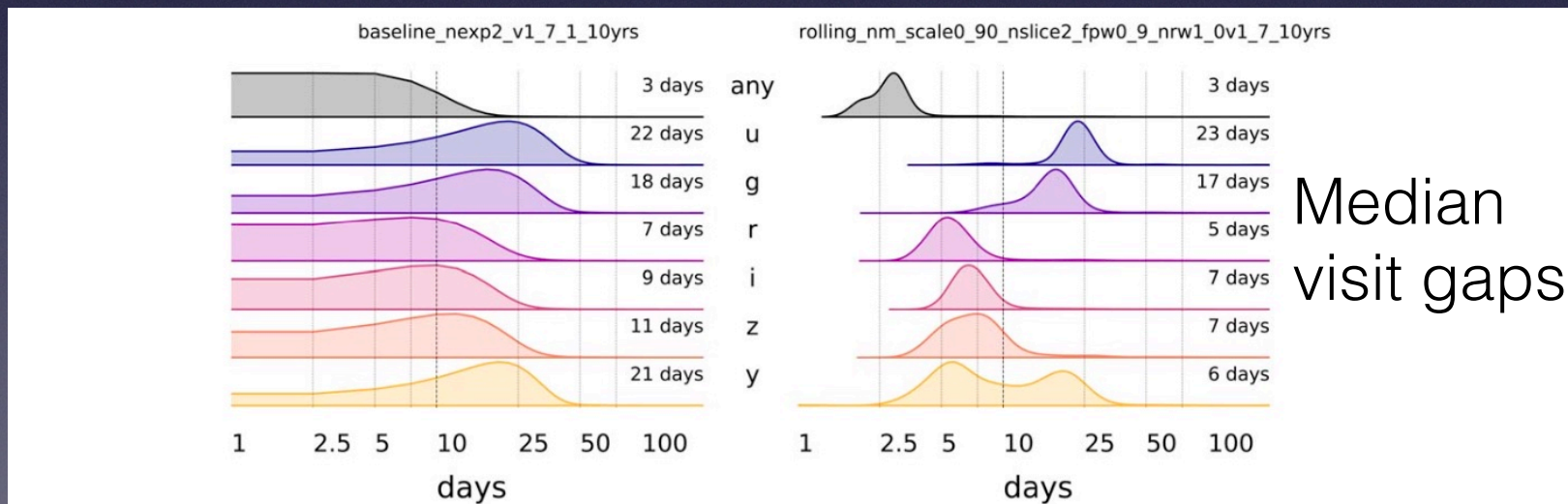
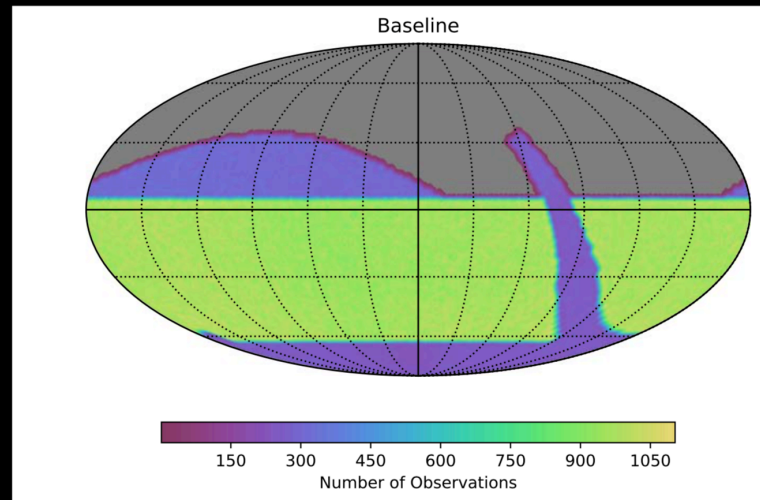


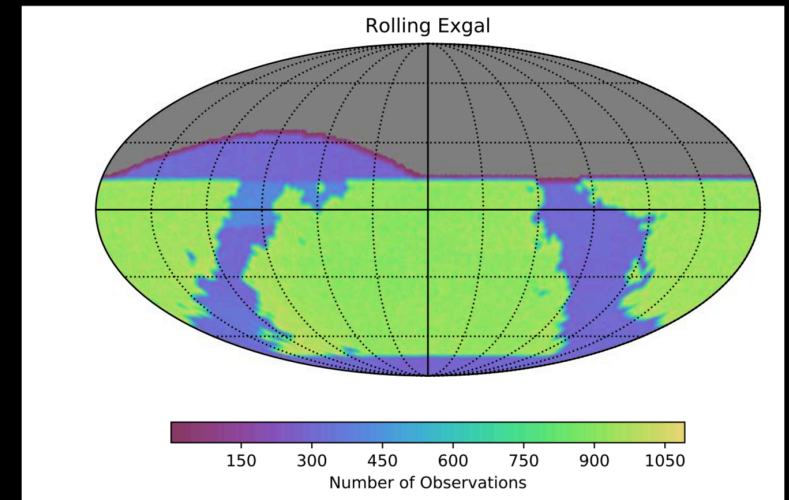
Figure 2. Distribution of median internight visit gaps (the time elapsed between visits to the same field in different nights) at a given location in the sky for two simulated LSST OpSim strategies: `baseline_nexp2_v1.7.1_10yrs` (left) and `rolling_nm_scale0.90_nslice2_fpw0.9_nrw1.0v1.7_10yrs` (right)

2 example strategies

Baseline



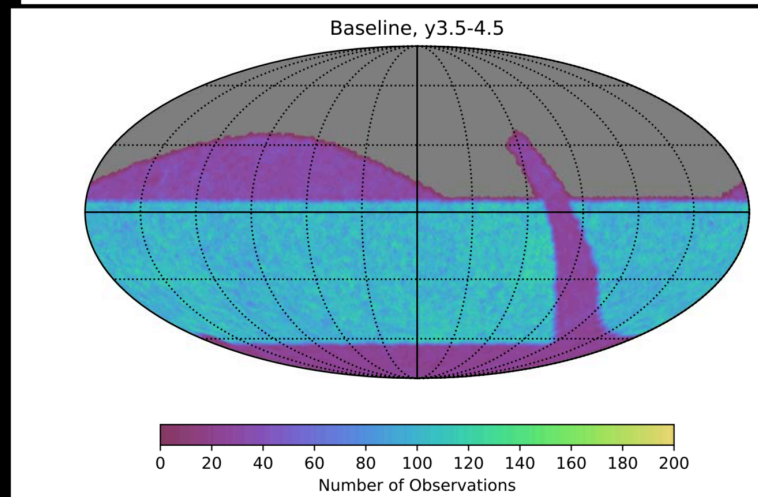
Rolling



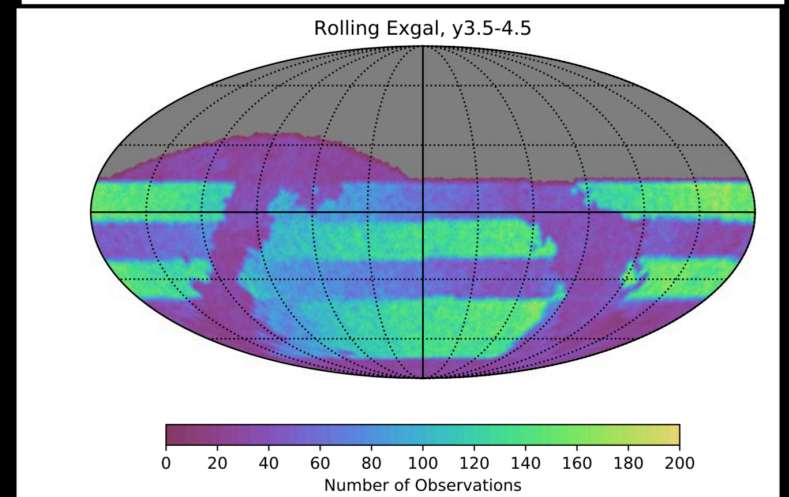
Number of observations after 10 years (DDF visits removed)

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”
 - *Survey Cadence 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 :

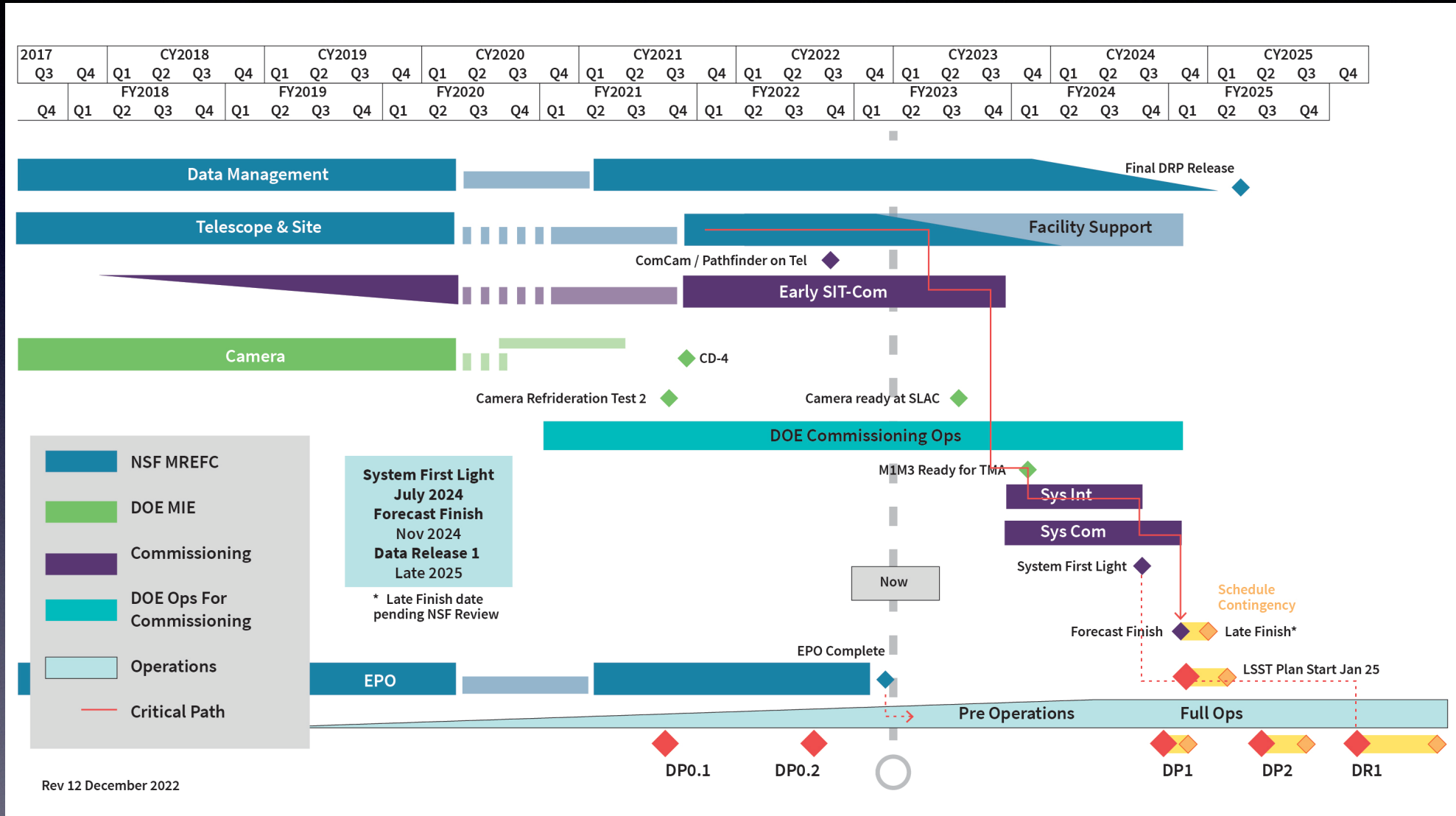
Useful info : <https://www.lsst.org/content/charge-survey-cadence-optimization-committee-scoc>

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

<https://project.lsst.org/meetings/rubin2020/agenda/session13/community-evaluation-rubin-survey-strategies>

Rubin schedule

Projected science operation start December 2024



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/HOME/pages/3141074949/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/>

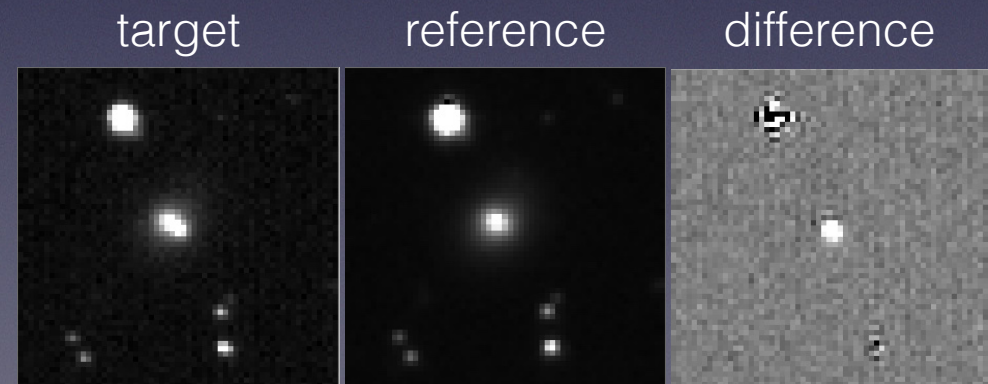
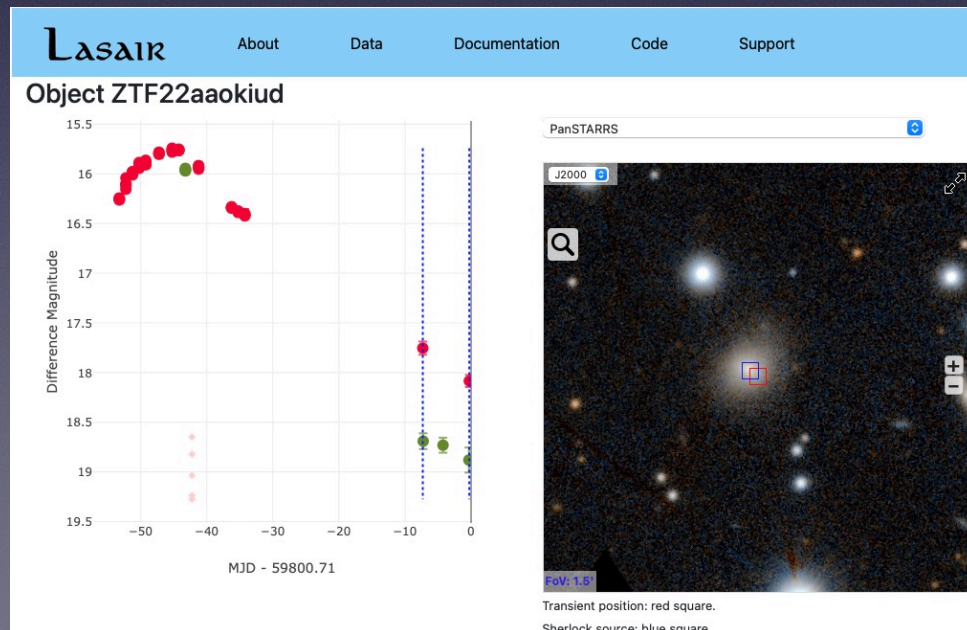
Guy et al. Table 1

Rubin Early Data Release Scenario	Jun 2021	Jun 2022	Jun 2023 - Sep 2023	Sep 2024 - Oct 2024	May 2025 - Aug 2025	Nov 2025 - Apr 2026	Nov 2026 - Apr 2027	Nov 2027 - Feb 2028	Nov 2028 - Feb 2029
	DP0.1	DP0.2	DP0.3	DP1	DP2	DR1	DR2	DR3	DR4
Data Product	DC2 Simulated Sky Survey	Reprocessed DC2 Survey	Solar System PPDB Simulation	First Light LSSTCam Data	LSSTCam Science Validation Data	LSST First 6 Months Data	LSST Year 1 Data	LSST Year 2 Data	LSST Year 3 Data
Raw images	✓	✓	☐	✓	✓	✓	✓	✓	✓
DRP Processed Visit Images and Visit Catalogs	✓	✓	☐	✓	✓	✓	✓	✓	✓
DRP Coadded Images	✓	✓	☐	☐	✓	✓	✓	✓	✓
DRP Object and ForcedSource Catalogs	✓	✓	☐	☐	✓	✓	✓	✓	✓
DRP Difference Images and DIASources	☐	✓	☐	☐	✓	✓	✓	✓	✓
DRP ForcedSource Catalogs including DIA outputs	☐	✓	☐	☐	✓	✓	✓	✓	✓
PP Processed Visit Images	☐	☐	☐	☐	☐	✓	✓	✓	✓
PP Difference Images	☐	☐	☐	☐	☐	✓	✓	✓	✓
PP Catalogs (DIASources, DIAObjects, DIAForcedSources)	☐	☐	☐	☐	✓	✓	✓	✓	✓
PP SSP Catalogs	☐	☐	✓	☐	✓	✓	✓	✓	✓
DRP SSP Catalogs	☐	☐	☐	☐	☐	✓	✓	✓	✓

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.

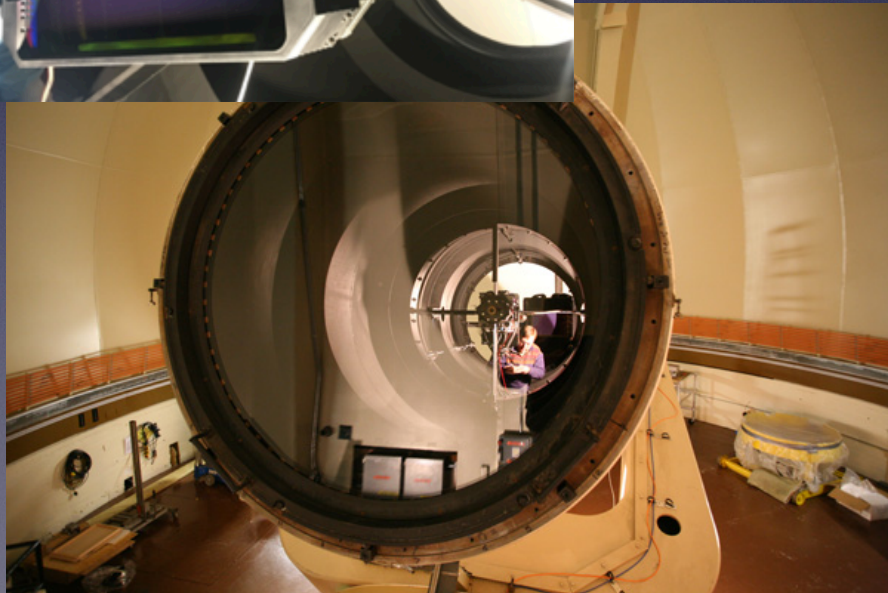
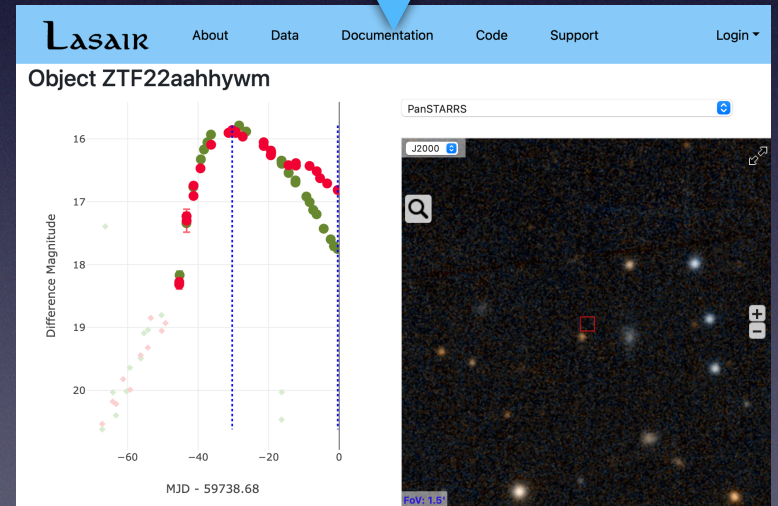
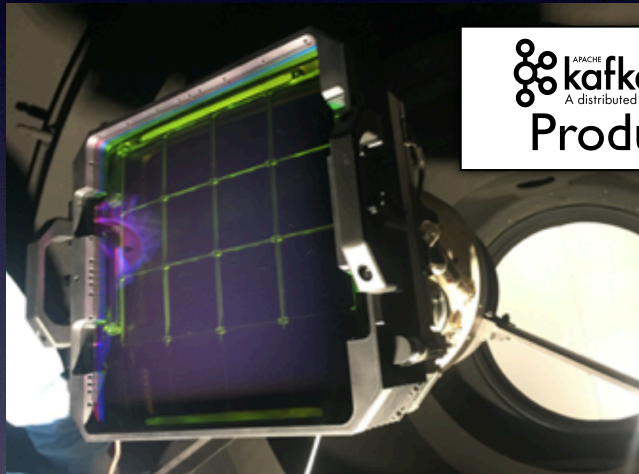
The UK's broker will serve these data and you can access a prototype and real stream from ZTF now <https://lasair-ztf.lsst.ac.uk>



Zwicky Transient Facility and brokers



47 sq degrees
 $g, r < 20.5$



<https://lasair-iris.roe.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

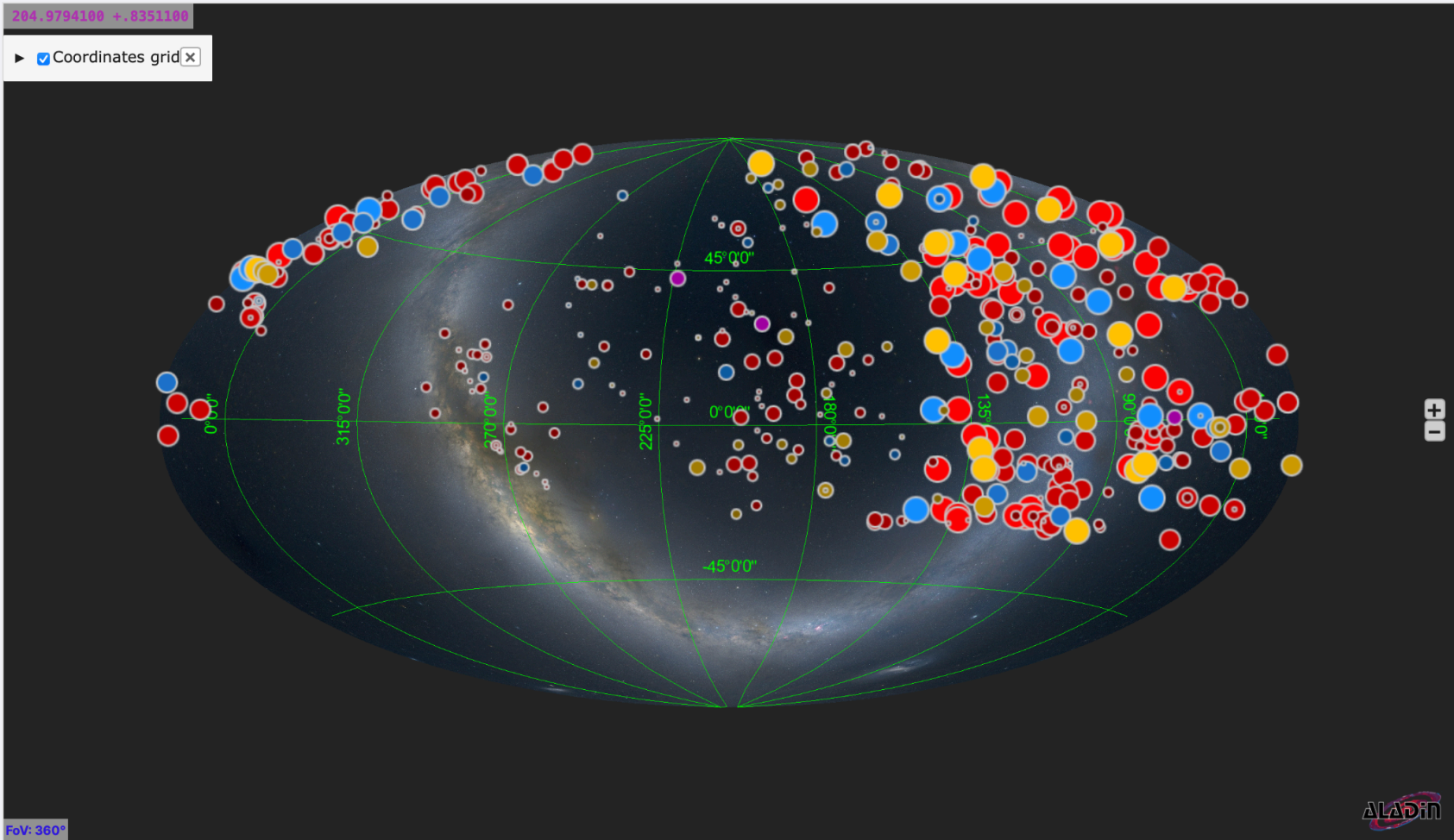
Type	Extragalactic (80% of sky)	Galactic (20% of sky)
Movers	3000	3000
Stars	1800	30000
AGN	70	70
Supernovae and extragalactic transients	200	200

	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

This is for news about Lasair

204.9794100 +.8351100

Coordinates grid



- Possible Supernova
- Nuclear Transient
- Cataclysmic Variable
- Active Galaxy

Some of the brightest and most recent alerts are shown, classified by sky context. Smaller and darker markers show time since most recent alert (age), up to 7 days. Click on a marker for information about that object; then click on the 'ZTF' link for full information.

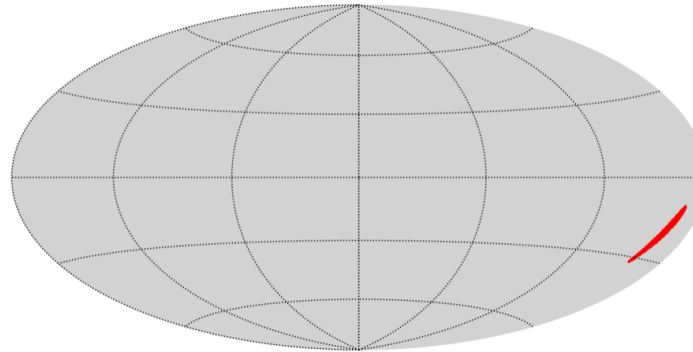


'Bayestar' Watched watchmap Associations

From https://emfollow.docs.ligo.org/userguide/tutorial/multiorder_skymaps.html

The watchmap is active ⓘ.

export ▾



Watchmap Results

A list of objects located within the 'Bayestar' watchmap

Search table...

objectId	ra ^{mean}	dec ^{mean}	rmag	gmag	last detected (days ago)
ZTF23aabuqpw	198.91378	-23.895702	17.617		3.9
ZTF23aabuqbi	198.75301	-24.457368	19.295		3.9
ZTF23aabueve	192.72439	-17.151061	18.998		3.9
ZTF23aabuevc	192.44982	-17.673753	17.878		3.9
ZTF23aabqods	196.03664	-24.300704		17.176	10.9
ZTF23aabqodp	196.22546	-24.608258		17.039	10.9
ZTF23aabqnhn	195.54850	-23.714473		17.348	10.9
ZTF23aabqnhi	195.51230	-23.617271		16.917	10.9

Finally the last word the latest on alerts from LSST 7th Feb 2023

The LSST Survey start: 4-7 months after System First Light. Some “near-live” alerts are planned around the time of the LSST Survey start, and then alert production is planned to increase smoothly to "live" during the early months of the LSST Survey, covering more regions over time as the static-sky templates are built up.

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

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 \(LSSTCCS\), 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 Juric](#)

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 Lored](#) (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 mid-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

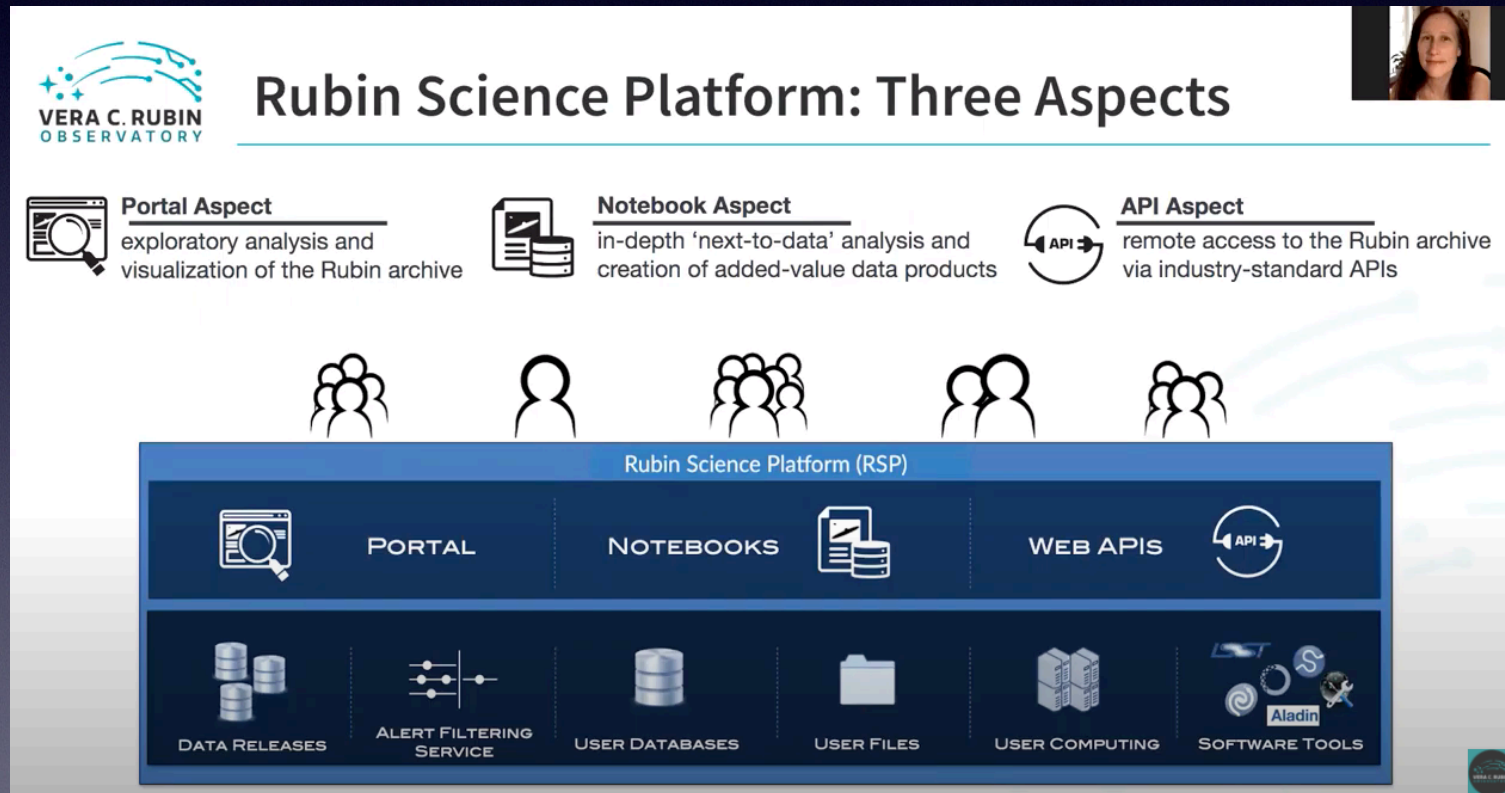
- After you get formal approval as an International Data Rights holder : sign up for login on <https://project.lsst.org>
- Join a Science Collaboration (through the above link)
- Join the LSST Slack and join <https://community.lsst.org>
- Watch videos, tutorials from the Annual Project and Community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

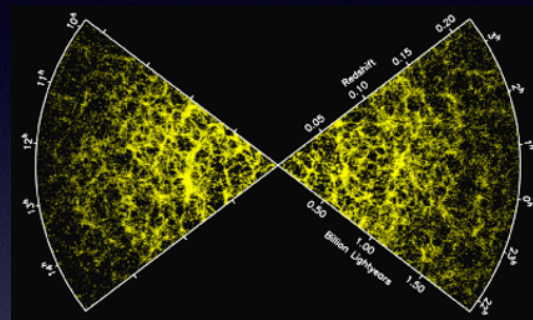
The basic plan is for annual Data Releases. The schedule as of of Aug 2022 is below - but see link above for official latest

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

LSST:UK Synergies



Spectroscopy:
4MOST
WEAVE
DESI, Euclid
MOONS



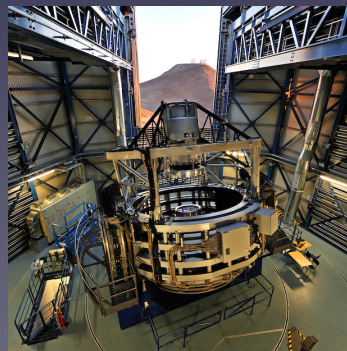
The UK has an unprecedented opportunity to lead the exploitation of this combined suite of facilities - particularly southern hemisphere and all-sky surveys

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



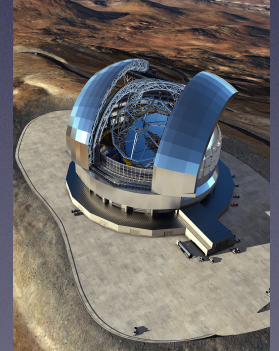
4MOST



NTT+SOXS



VLT



ELT