Early Science with Rubin - What to Expect

Leanne Guy
Rubin/LSST Data Management Scientist,
AD System Performance Department

Solar System Science Collaboration Meeting
Flagstaff, AZ, 2023-06-17/18

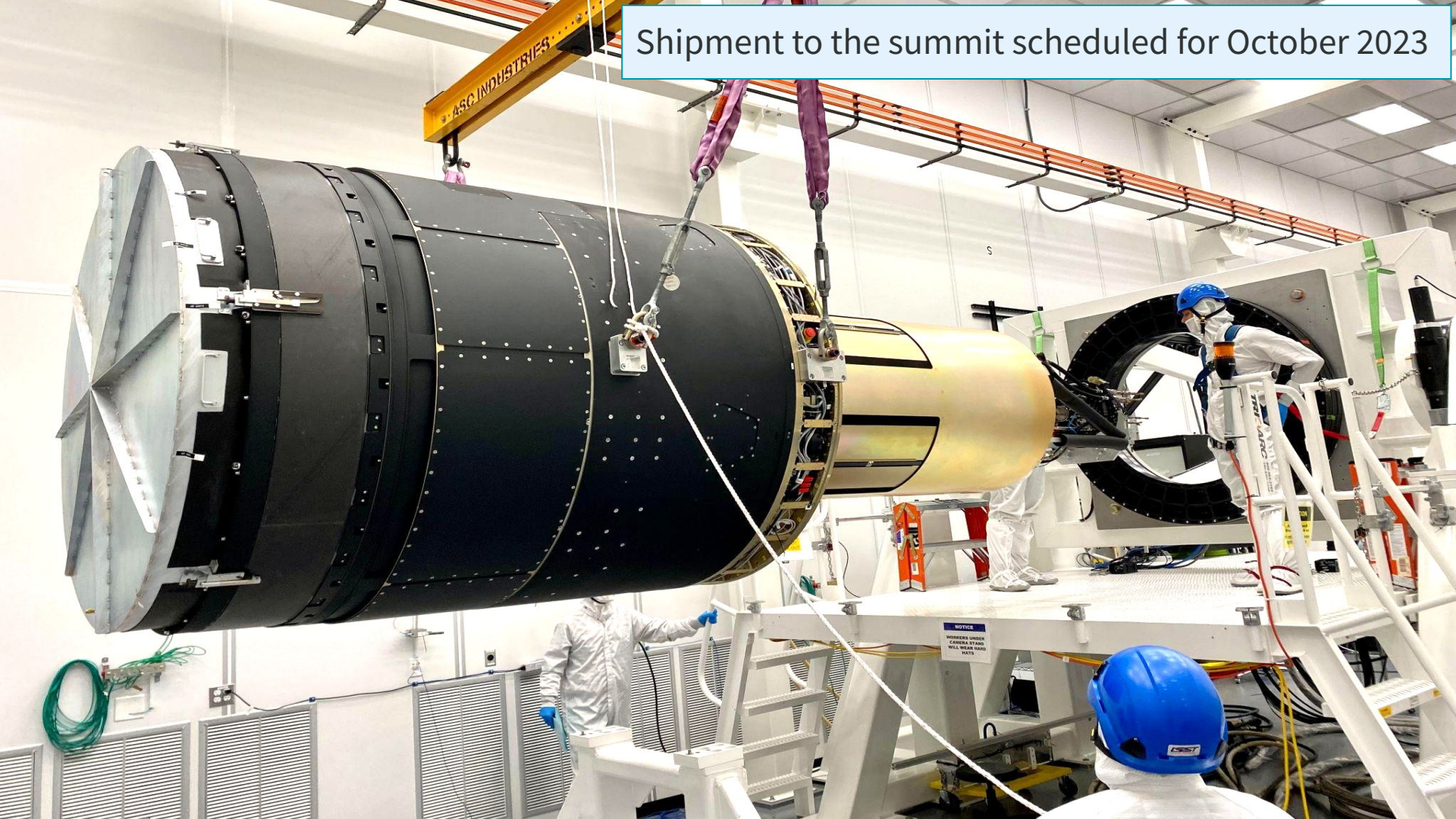
VERA C. RUBIN OBSERVATORY

- Project Status
- Early Science
- DP0.3

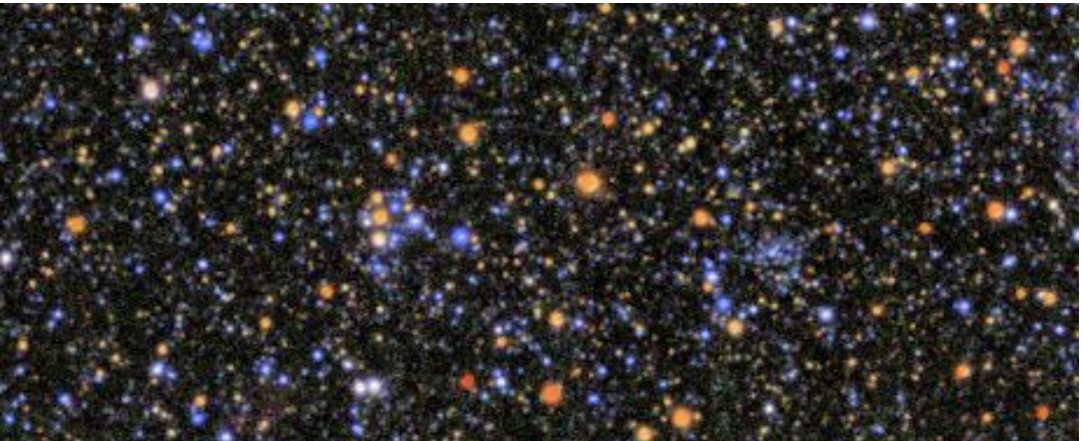
NSF AURA U.S. DEPARTMENT OF ENERGY SLAC CHARLES AND LISA SIMONYI FUND FOR ARTS AND SCIENCES LSST CORPORATION

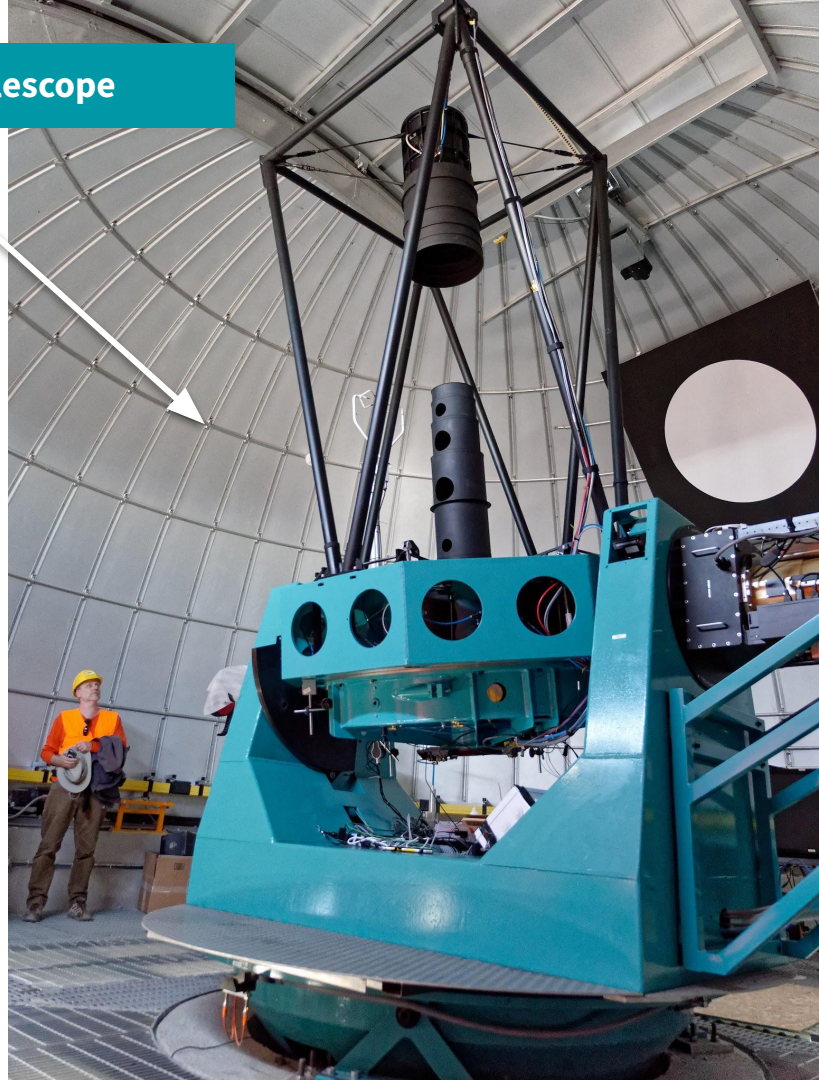
Project Status

Shipment to the summit scheduled for October 2023

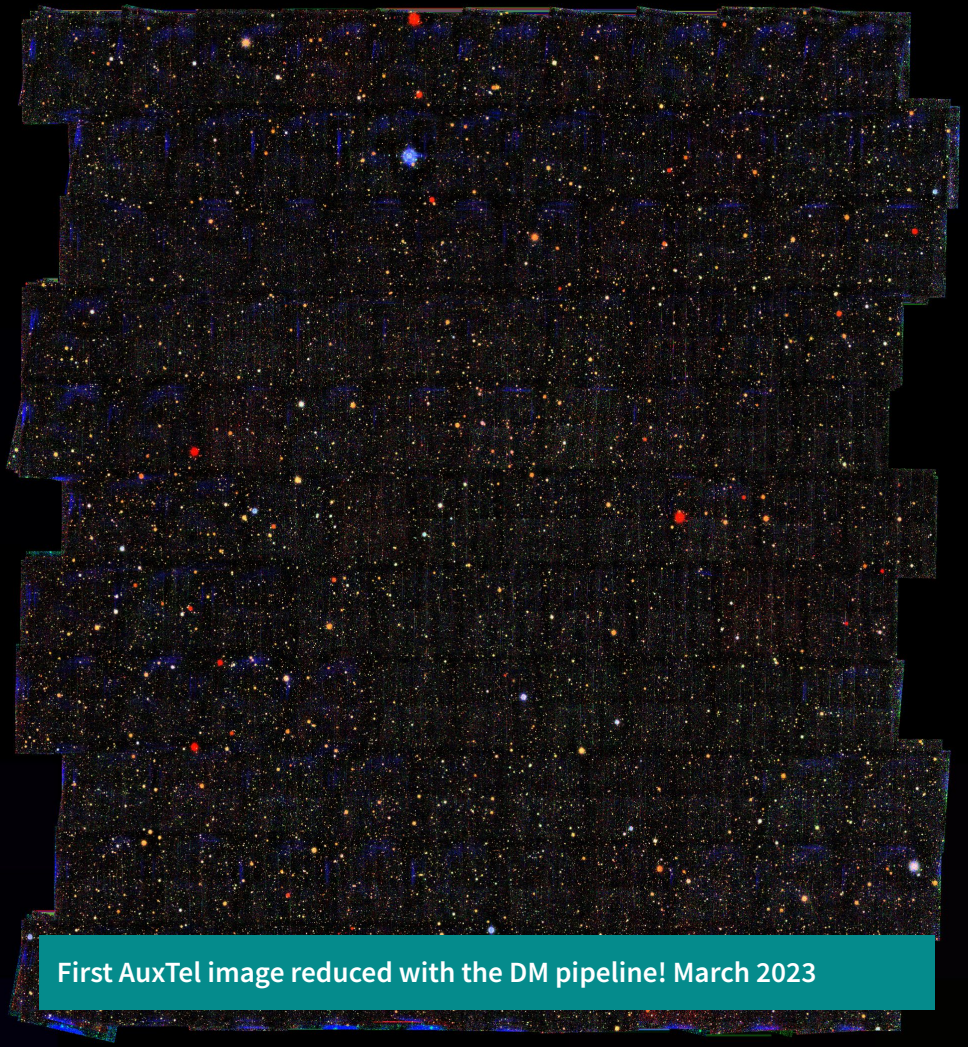


1.2 meter Auxiliary Telescope

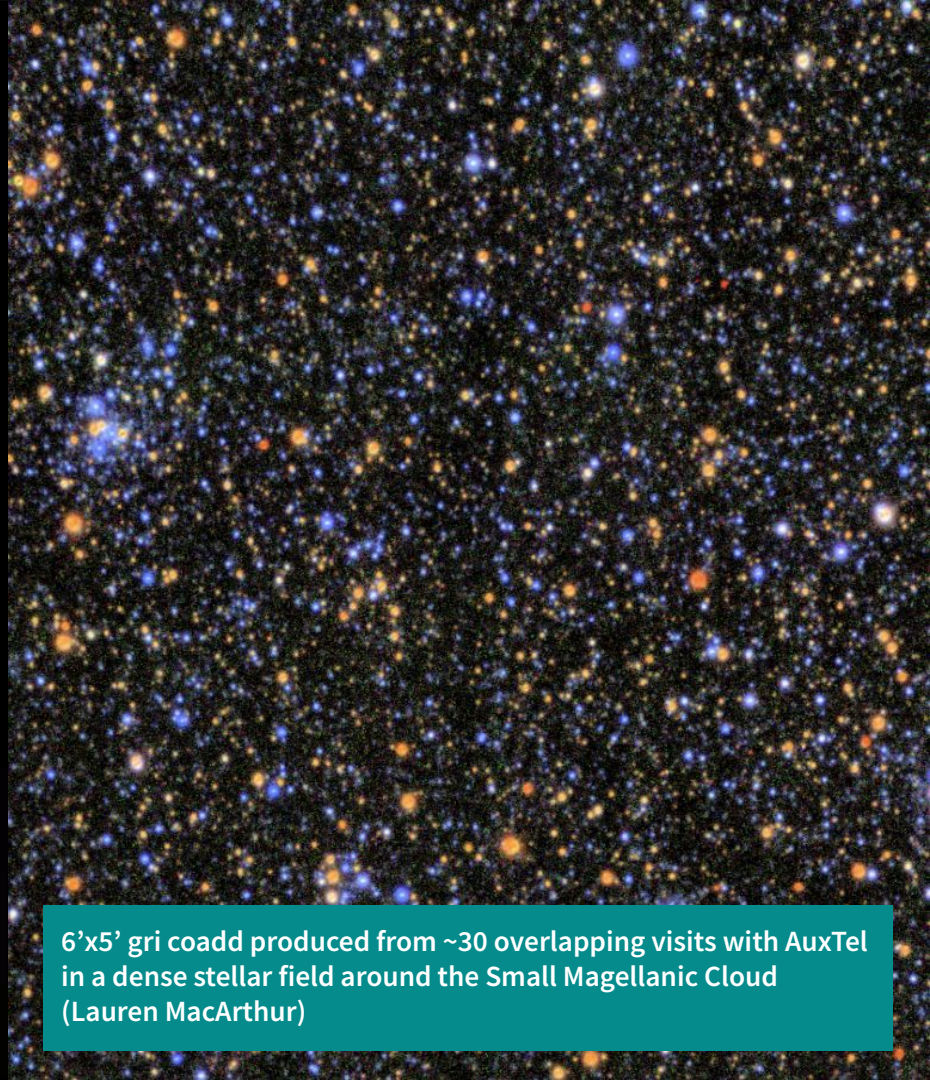




Data transfer to USDF and processed by DM science pipelines



First AuxTel image reduced with the DM pipeline! March 2023



6’x5’ gri coadd produced from ~30 overlapping visits with AuxTel in a dense stellar field around the Small Magellanic Cloud (Lauren MacArthur)

Celebratory Milestone Forecast

Published monthly at: ls.st/dates

Due	Name
30-Sep-2022	EPO Construction Finish (Completed 30-Sep-2022)
03-Apr-2023	TMA Handoff to Rubin
01-Sep-2023	COMP: Camera Pre-Ship Review at SLAC
20-Mar-2024	Dome Complete
22-Apr-2024	Camera Ready for Full System AI&T
23-May-2024	3-Mirror Optical System Ready for Testing
15-Jul-2024	LSSTCam Ready for On Sky (First Photon)
23-Oct-2024	System First Light with LSSTCam
18-Feb-2025	Test report: Final Pipelines Delivery
18-Feb-2025	COMP: Science Validation Surveys Complete
25-Feb-2025	Operation Readiness Review Complete

Using March 2023 project controls data.

Rubin Timeline

2023 is a key year for full system integration and commissioning!

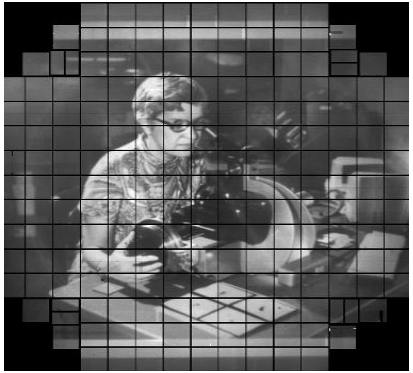
2023 **2024** **2025**

Analysis software ready for commissioning

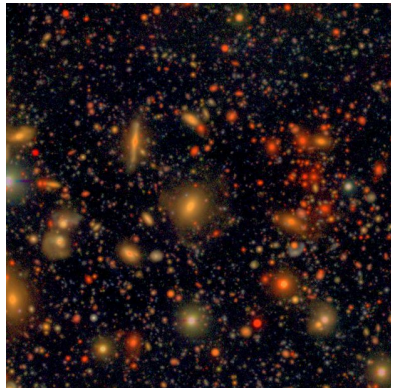
Oct 2023 : Arrival of LSSTCam on the summit

System First Light ~ October 2024.

Legacy Survey of Space and Time (LSST) starts FY25



The COSMOS field seen by Hyper Suprime-Cam, courtesy of the HSC Collaboration, R. Lupton, and N. Lust.



Early Science

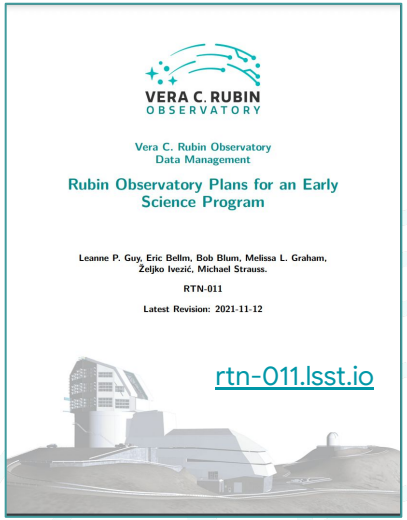
VERA C. RUBIN OBSERVATORY

Early Science is defined as any science enabled by Rubin for its community through and including the first data release, Data Release 1 (DR1)

RTN-011: A Roadmap for Early Science

RTN-011: Plans for Early Science is the guiding document for Early Science with Rubin. It is a living document that will evolve over the course of the pre-operations period.

- Provides the plans for a Early Science Program
- Describes the Early Science Data Products
- Provides a timeline for execution
- Can and should be cited in research proposals: https://ls.st/esp (10.5281/zenodo.5683848)
- See also the community forum https://community.lsst.org/c/sci/early-science



Cite RTN-011 as follows:
Leanne P. Guy, Eric Bellm, Bob Blum, Melissa L. Graham, Željko Ivezić, Phil Marshall & Michael Strauss. (2022). Rubin Observatory Plans for an Early Science Program (2.0). Zenodo. https://doi.org/10.5281/zenodo.5683849

BibTex available via the DOI zenodo link

Motivations for an Early Science Program

- To **enable high-impact science prior to the first data release**, **DR1**, both before and during the first year of regular survey operations.
- To provide **early access to both static-sky and time-domain science-ready data products** to support the community as they develop their LSST analyses in preparation for DR1,
- To **enable time-domain astronomy via Alert Production** during commissioning and in the first year of operations. ♯

Elements of the Early Science Program

- A series of three **Data Previews (DP), DP0, DP1 and DP2**, based on either simulated LSST-like data (DP0) or data taken during the Rubin Observatory commissioning period with the LSST Science Camera (LSSTCam) (DP1 & 2).
- **A world-public stream of Alerts** from transient, variable, and moving sources that will be scaled up continuously during commissioning and year 1.
- **Template generation,** both prior to the start of regular survey operations using LSSTCam commissioning data, and incrementally during the first year of regular survey operations to maximize the number of templates available for Alert Production during year 1.
- **LSST Data Release 1 (DR1)**, which will be based on the Data Release Processing (DRP) of the first six months of LSST data

‡ Due to the need for Data-Release-derived templates, Alert Production cannot run at full scale nor full fidelity during commissioning and year one.

Early Science Scenarios

Scenario A
Rubin Observatory is ready to execute the 10-year LSST at the completion of the construction project.

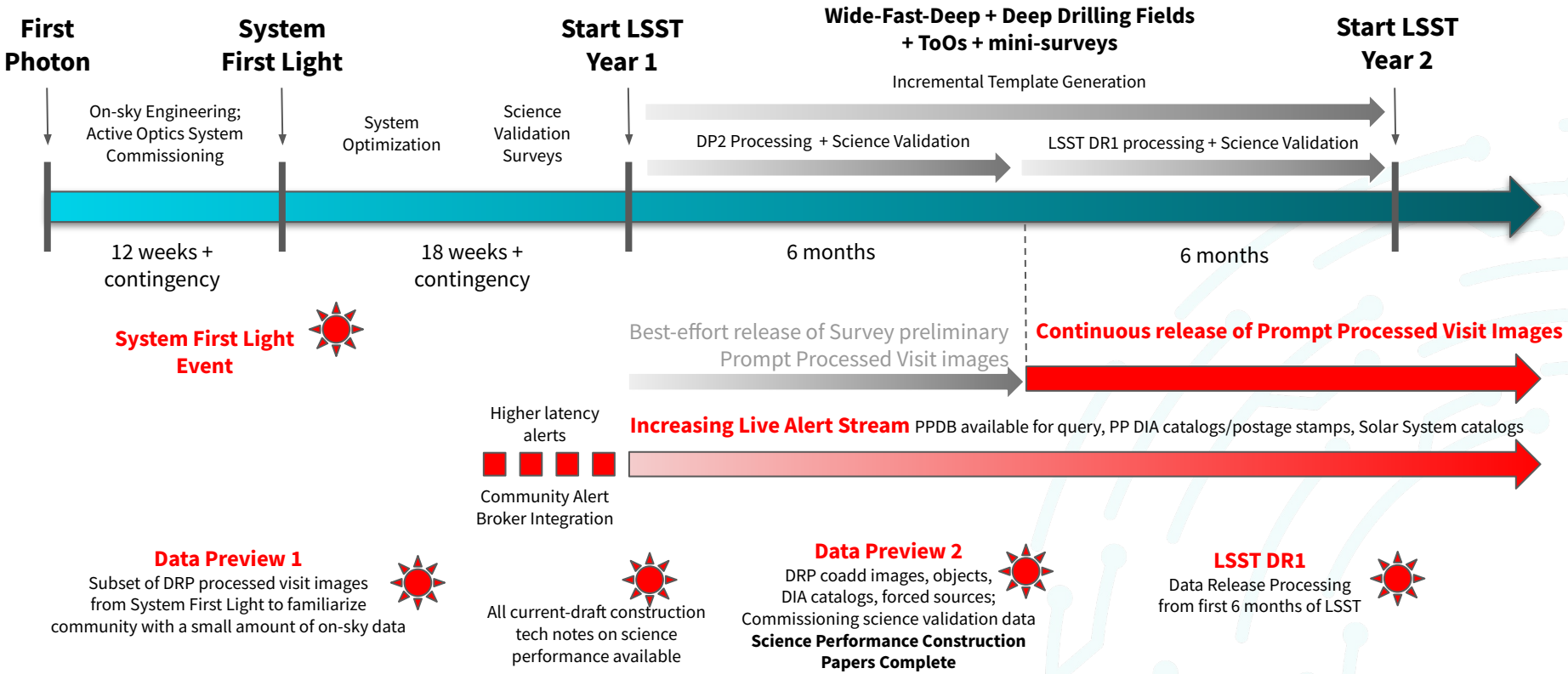
Scenario B
Prior to commencing the 10-year LSST, the operations team spends up to 2 months collecting more on-sky data to complement and extend the commissioning datasets This additional data would serve the dual goals of 1) ensuring that we are fully prepared to start the 10-year survey and 2) providing the community with an exquisite early dataset to work with before DR1.

In both scenarios, the operations team may decide to first conduct a short (few days) full dress rehearsal of science operations to demonstrate team readiness prior to commencing execution of the LSST.

Early Science Scenarios – Key Points

- Contents of DP2 will be the same irrespective of which Early Science Scenario materializes – Only the timing of the release of DP2 and the start of the 10-year survey is different between the two scenarios.
- In both scenarios it is assumed that the Rubin Construction project delivers an integrated system that can capture, transfer and process science-grade data at the time full/survey operations begins.
- Both scenarios will include alert generation of some type, with the major distinction being the relative availability of templates in time, sky position, and filter.
- As we approach full/survey operations and the commissioning program emerges and is executed, a single scenario will be adopted and executed.

Early Science Timeline Overview



Milestones & Detailed Timeline

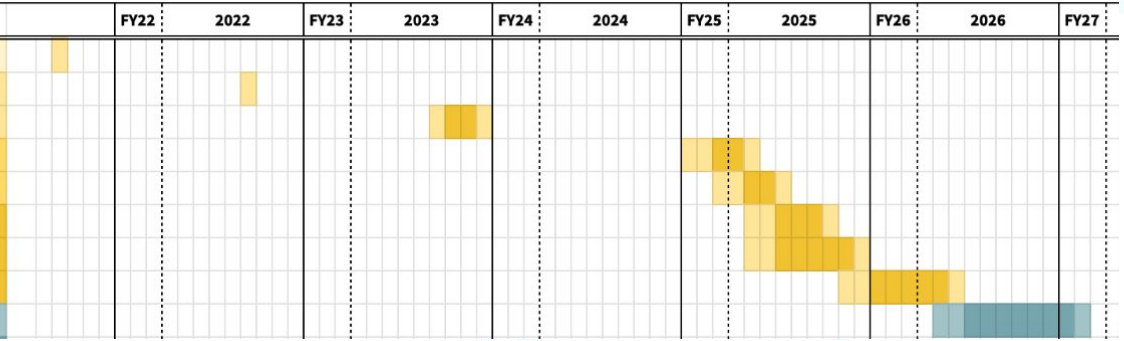
ls.st/dates

Rubin Operations Top Milestones

- **Jun 2023 - Sep 2023** Complete Delivery of Data Preview 0.3 (DP0.3)
- **Oct 2024 - Feb 2025** System First Light with LSSTCam
- **Dec 2024 - Apr 2025** Complete Delivery of Data Preview One (DP1) (= System First Light with LSSTCam + 2 months)
- **Feb 2025 - Sep 2025** LSST Survey Start (= Science Validation Surveys Complete + 1 day)
- **Aug 2025 - Mar 2026** Complete Delivery of Data Preview Two (DP2) (= Science Validation Surveys Complete + 6 months)
- **Feb 2026 - Nov 2026** Complete Delivery of Data Release One (DR1) (= LSST Survey Start + 12 months)

Nominal LSST Survey Start Date: June 2025

Event		Date	Milestone Date
DP0.1	DC2 Simulated Sky Survey	June 2021	2021-06-30
DP0.2	Reprocessed DC2 Survey	June 2022	2022-06-30
DP0.3	Solar System PPDB Simulation	Jun 2023 - Sep 2023	2023-07-31
FL	System First Light	Oct 2024 - Feb 2025	2024-12-23
DP1	First Light LSSTCam Data	Dec 2024 - Apr 2025	2025-02-22
OPS	Start of Operations	Feb 2025 - Jul 2025	2025-06-01
SVY	Start of Survey	Feb 2025 - Sep 2025	2025-06-27
DP2	LSSTCam Science Validation Data	Aug 2025 - Mar 2026	2025-11-26
DR1	LSST First 6 Months Data	Feb 2026 - Nov 2026	2026-06-27



Early Science Data Products

Prompt Data Products

Alerts: Alert packet containing: alertId, DIASource, DIAObject or SSObject, previous up to 12 months of detections, science/template/difference image cutouts

Images: Single visit images, difference images, template

Catalogs: DIASource, DIAObject, SSObject, ForcedSource.

Prompt Products Database Timescale

The prompt products database, containing the prompt catalogs will be updated on a 24hr timescale.

Static Science Data Products

DR data products from DP1 and 2 based on commissioning and SV survey data, and DR1 based on the first 6 months of data.

Definitions

Source = A detection in an image with SNR>5
Object = Sources associated by coordinate
DIA = Difference Image Analysis
DIASource = A detection in a difference image with SNR>5
DIAObject = DIASources associated by coordinate
SSObject = Solar System Object
Template = Transient-free image

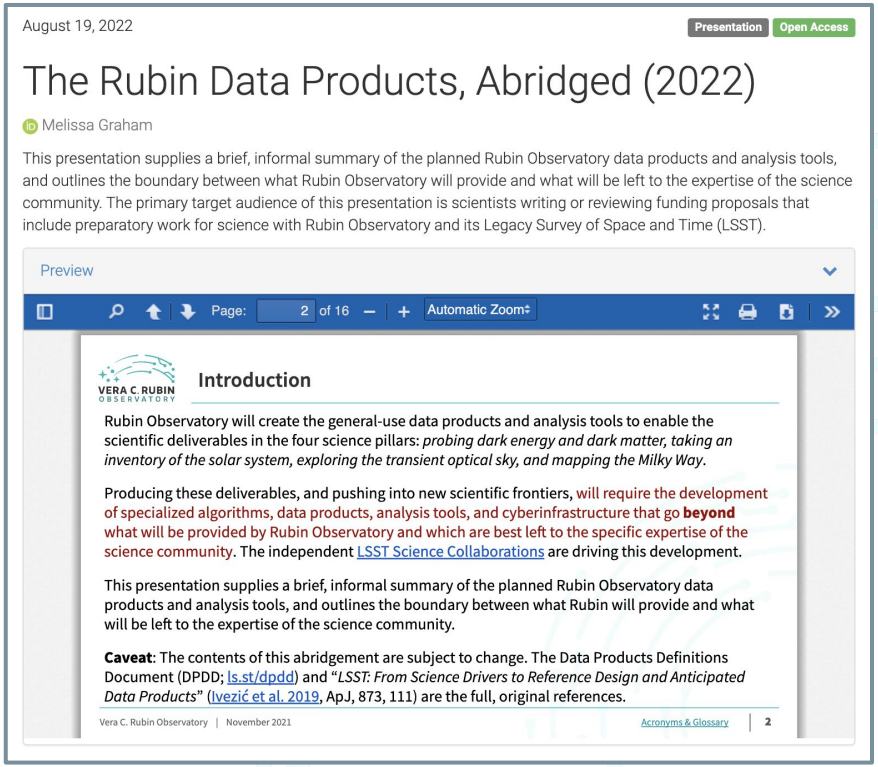
The Rubin Data Products, Abridged

- Introduction to the Rubin Data Products and Rubin Science Platform
- Tells your proposal reviewers what Rubin will provide, and hence what will still need to be developed e.g. by you, if your proposal is successful
- *Can and should be cited in research proposals*

Cite Graham (2022) as follows:

Melissa Graham. (2022, August 19). The Rubin Data Products, Abridged (2022). Zenodo. https://doi.org/10.5281/zenodo.7011229

BibTex available via the DOI zenodo link



August 19, 2022

Presentation | Open Access

The Rubin Data Products, Abridged (2022)

Melissa Graham

This presentation supplies a brief, informal summary of the planned Rubin Observatory data products and analysis tools, and outlines the boundary between what Rubin Observatory will provide and what will be left to the expertise of the science community. The primary target audience of this presentation is scientists writing or reviewing funding proposals that include preparatory work for science with Rubin Observatory and its Legacy Survey of Space and Time (LSST).

Preview

Page: 2 of 16 Automatic Zoom

VERA C. RUBIN OBSERVATORY

Introduction

Rubin Observatory will create the general-use data products and analysis tools to enable the scientific deliverables in the four science pillars: *probing dark energy and dark matter, taking an inventory of the solar system, exploring the transient optical sky, and mapping the Milky Way*.

Producing these deliverables, and pushing into new scientific frontiers, will require the development of specialized algorithms, data products, analysis tools, and cyberinfrastructure that go **beyond** what will be provided by Rubin Observatory and which are best left to the specific expertise of the science community. The independent LSST Science Collaborations are driving this development.

This presentation supplies a brief, informal summary of the planned Rubin Observatory data products and analysis tools, and outlines the boundary between what Rubin will provide and what will be left to the expertise of the science community.

Caveat: The contents of this abridgement are subject to change. The Data Products Definitions Document (DPDD; ls.st/dpdd) and "*LSST: From Science Drivers to Reference Design and Anticipated Data Products*" (Ivezić et al. 2019, ApJ, 873, 111) are the full, original references.

Vera C. Rubin Observatory | November 2021 Acronyms & Glossary 2

Data Preview/Release Schedule & Contents

Rubin Early Data Release Scenario	Jun 2021	Jun 2022	Jun 2023 - Sep 2023	Dec 2024 - Apr 2025	Aug 2025 - Mar 2026	Feb 2026 - Nov 2026
	DP0.1	DP0.2	DP0.3	DP1	DP2	DR1
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
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	☐	☐	☐	☐	☐	✓

Alert Generation in Commissioning and Year 1

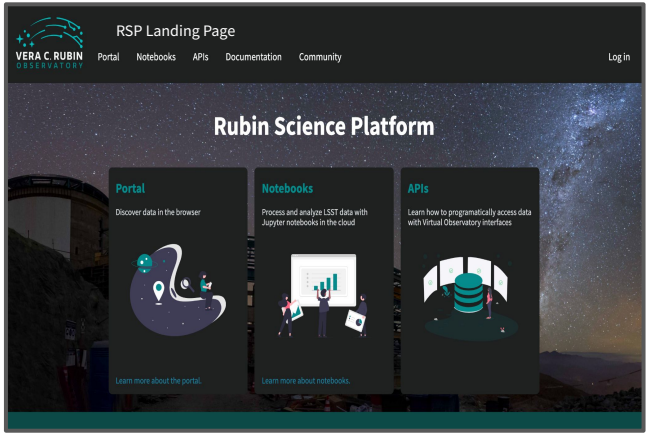
We aim to release high-quality alerts as soon as is feasible, sometime following System First Light. Once Alert Production begins, it is expected to continue without interruption through the ten-year duration of the LSST survey

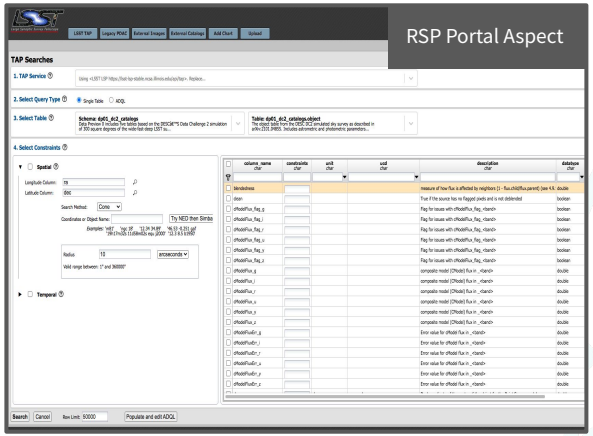
To enable alert production prior to DR1, templates will be generated incrementally using the best images available from commissioning and year 1 data:

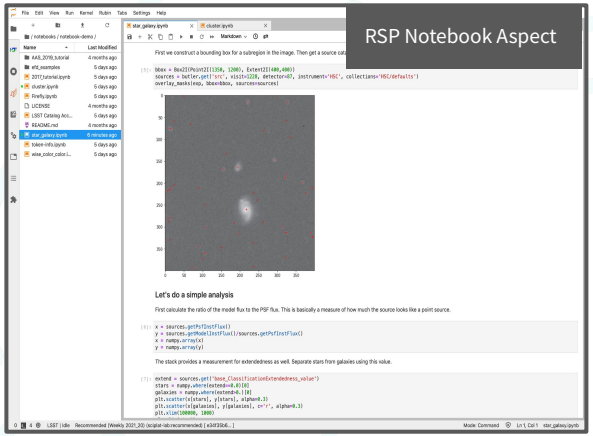
- **Commissioning Data Templates**: Build templates, where possible, from all science-quality commissioning data before the start of year one, and use them to generate alerts during year one
- **Year One Data Templates**: Build templates progressively from data obtained during year one (e.g., on a weekly or monthly timescale), and use them to generate alerts during year one, either instead of, or in addition to using commissioning data to build templates.

Rubin Science Platform (RSP)

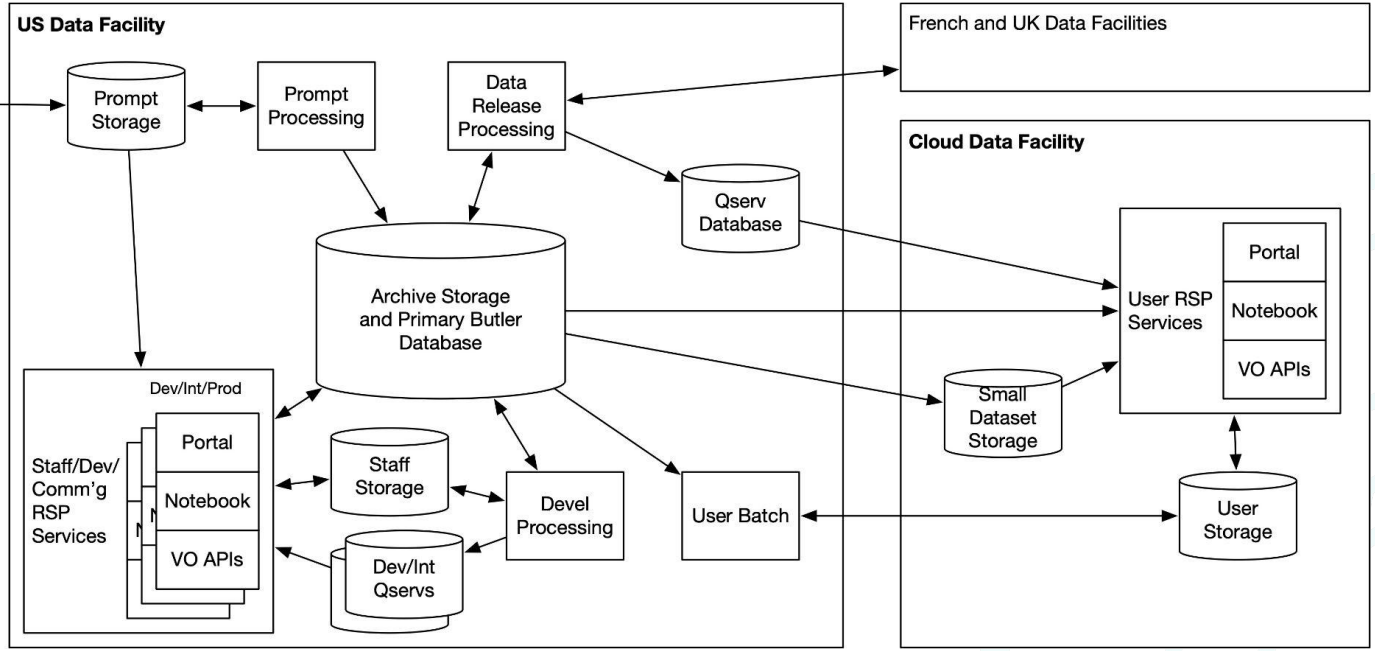
The Rubin Science Platform enables peta-scale analysis of LSST data by providing services for scientists to access, visualize, subset and perform next-to-the-data analysis of Rubin Data products. Deployed in the Google cloud the RSP provides 1TB storage and 2 cores per user. See LSE-319: LSST Science Platform Vision Document







Hybrid Model – Data at SLAC, Users on Cloud



Hybrid model – Data at SLAC but users on the Cloud – allows separation of security concerns, burst response and reduced risk

Cloud/Rubin Data Facilities – Division of Scope

Cloud

- Science users, with access provided by the Rubin Science Platform
- Provide personal storage/CPU + cloud access to coadds
- Services run here to take advantage of elasticity, but storage is limited to user-generated data, small portions of DRP datasets, and caches.

Rubin Data Facilities

- Prompt processing
- DRP processing (SLAC, France, UK)
- Qserv catalogue server
- Storage archive for all data
- Serving alerts to the community
- Home for developers and staff (and commissioners)

Community Alert Brokers

Alerts are fully world-public and will be accessible via one or more of the nine Rubin-endorsed Community Brokers

LSST Full-Stream Community Brokers

- Alerce
- AMPEL
- ANTARES
- BABAMUL
- Fink
- Lasair
- Pitt-Google

Downstream Brokers

SNAPS
POI/Variables

Community alert brokers provide the public interface to the LSST alert stream and are critical partners for delivering Rubin data to scientists worldwide.

Alerts & Brokers - where to find more details

Visit lsst.org/scientists

ABOUT | PARTICIPATE | GALLERY | NEWS | FOR SCIENTISTS

Home / For Scientists / Alert Brokers

- Science Collaborations
- Community Forum
- Early Science
- Survey Strategy
- **Alert Brokers**
- Data Preview 0
- Glossary & Acronyms
- FAQ
- Codes of Conduct
- Working Groups, Boards, Committees
- Users Committee
- Community Science team
- International Data Rights Holder List
- In-Kind Program
- Citing Rubin Obs.

Key Numbers

Alert Brokers

View | Edit | Manage display | Revisions | Node export | Convert

Information for Rubin Observatory Alerts and Community Brokers

What is an Alert Broker?

One of the results of Rubin Observatory's real-time difference image analysis processing is a world-public stream of alerts containing data about transient, variable, and moving sources (find out more about Rubin Observatory processing and products like alerts in the Data Products Definitions Document). These alerts will be distributed to community brokers: software systems that will ingest, process, and serve astronomical alerts from Rubin Observatory and other surveys to the broader scientific community. Typical broker functionality includes cross-match association with archival catalogs, the identification and prioritization of objects in need of follow-up observations, and photometric classification based on light-curve analysis.

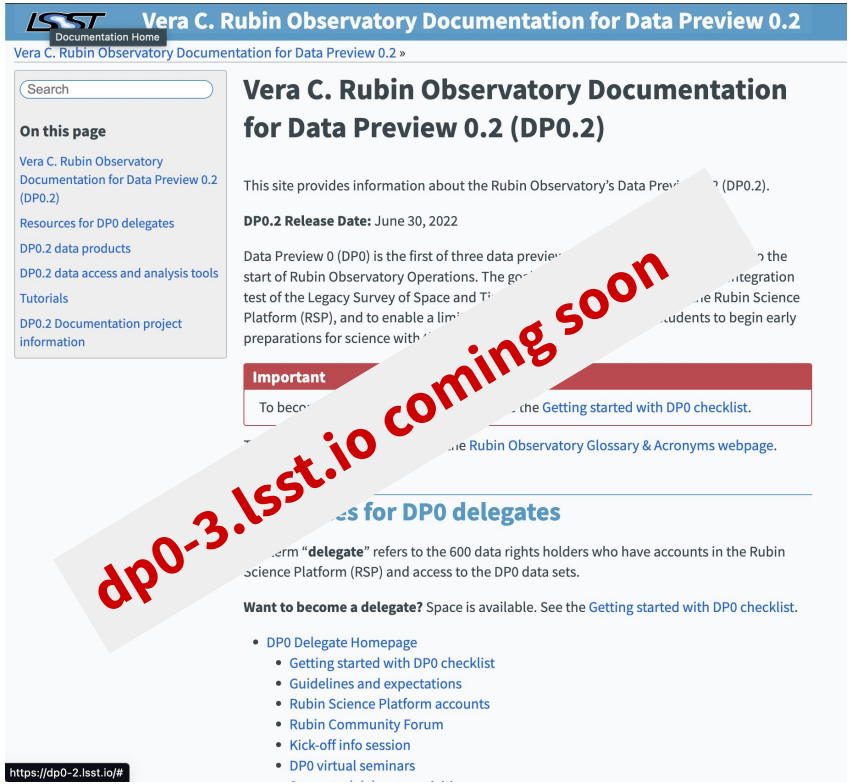
How are the Rubin Observatory Alert Brokers Selected?

Due to the anticipated high bandwidth of the Rubin Observatory alert stream, only a limited number of brokers can receive the stream directly from Rubin Observatory. The broker selection process is detailed in LDM-612; all decisions are the responsibility of Rubin Observatory Operations. In May 2019 the process began with Letters of Intent submitted from 15 teams, and in June 2019 a Community Brokers Workshop was held in Seattle WA. In August 2019 the SAC announced that all LOI teams were encouraged to submit full proposals. In December 2020, nine teams submitted full proposals. The SAC

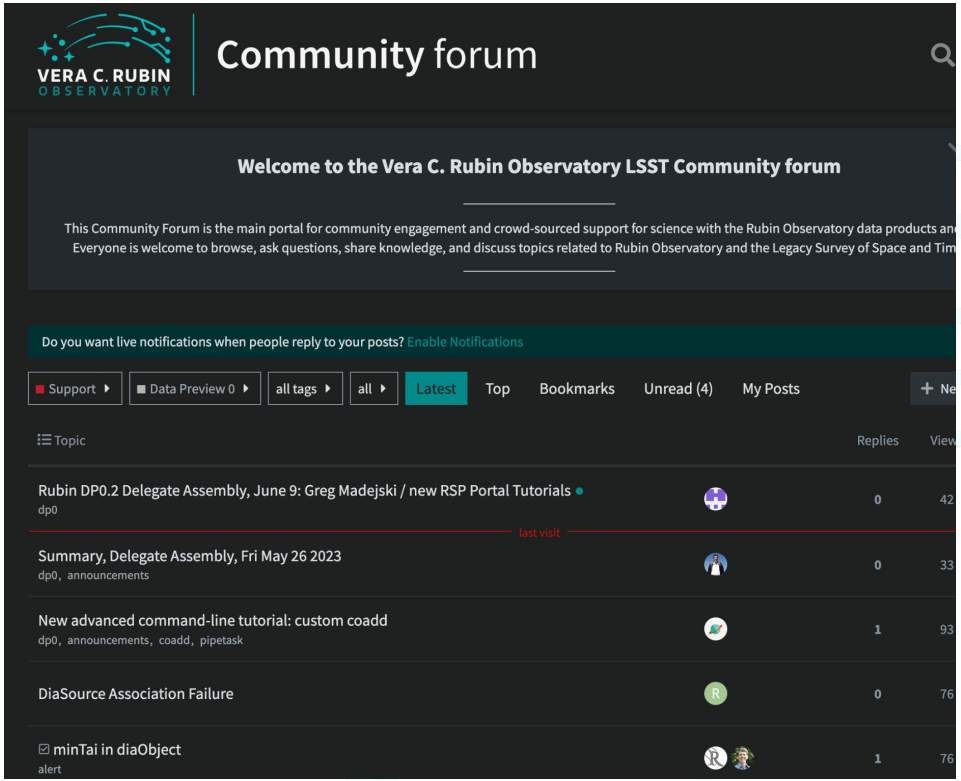
Data Preview 0.3

Solar System Science Data

DP0.3 Documentation & forum



dp0-3.lsst.io coming soon



data.lsst.cloud

VERA C. RUBIN OBSERVATORY

Portal Notebooks APIs Documentation Support Community leanne

Weekly 21 is now the new recommended (default) image for notebooks Show more

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

DP0.3 Catalog Access (Portal)

There is a separate TAP service set up to access the DP0.3 data – you must select this in the Portal

data-int.lsst.cloud/portal/app/?__action=layout.showDropDown&view=TAPSearch

RSP TAP Search | External Images | External Catalogs | Add Chart | Upload

TAP Searches

Select TAP Service — LSST DP0.3 SSO https://data-int.lsst.cloud/api/ssotap

LSST DP0.3 SSO Tables — Table Collection (Schema): **dp03_catalogs**
Data Preview 0.3 contains the catalog products of a Solar System Science Collaboration simulation of the results of SSO analysis of the w...

Table: **dp03_catalogs.DiaSource**
Table to store 'difference image sources'; - sources detected at SNR >=5 on difference images.

TAP Services: Show | Hide
View: UI assisted | Edit ADQL

Enter Constraints

Reset Column Selections & Constraints

Spatial

Spatial type: Single Shape / Multi-object
Shape Type: Cone
Coords or Obj Name: Try NED then Simbad
Examples: '62, -37' '60.4 -35.1' '4h11m59s -32d51m59s equ j2000' '239.2 -47.6 gal' 'NGC 1532' (NB: DC2 is a simulated sky, so names are not useful)
Radius: 10 arcseconds
Valid range between: 1" and 360000"
Position Columns: ▶ **ra, decl** (from the selected table on the right)

Temporal

Temporal Column: midPointTai
Use: UTC date/times (ISO format) / MJD values
Start Time
e.g.: 2019-02-07T08:00:20
2019-02-07 08:00:20
2019-02-07
End Time
e.g.: 2019-02-07T08:00:20
2019-02-07 08:00:20

Output Column Selection and Constraints

Name *char*	constraints *char*	unit *char*	ucd *char*	description *char*	datatype *char*	arraysize *char*
_decTrue					double	
_magTrue					float	
_name					char	20
_raTrue					double	
_v					float	
ccdVisitId			meta.id;obs.image	Id of the ccdVisit where this diaSource was m	long	
decl		deg	pos.eq.dec	Decl-coordinate of the center of this diaSourc	double	
declSigma		deg	stat.error;pos.eq.dec	Uncertainty of decl.	float	
diaObjectId			meta.id;src	Id of the diaObject this source was associate	long	
diaSourceId			meta.id;obs.image	Unique id.	long	
filter					char	1
mag				Magnitude. This is a placeholder and should b	float	
magSigma				Magnitude. This is a placeholder and should b	float	
midPointTai		d	time.epoch	Effective mid-exposure time for this diaSourc	double	
ra		deg	pos.eq.ra	RA-coordinate of the center of this diaSource.	double	
ra_decl_Cov		deg^2	stat.covariance	Covariance between ra and decl.	float	
raSigma		deg	stat.error;pos.eq.ra	Uncertainty of ra	float	

Search | Cancel | Row Limit: 50000 | Populate and edit ADQL

DP0.3 Catalog Access (Portal)

There are four dp0.3 tables

TAP Searches

Select TAP Service — LSST DP0.3 SSO https://data-int.lsst.cloud/api/ssotap

LSST DP0.3 SSO Tables — Table Collection (Schema): **dp03_catalogs**
Data Preview 0.3 contains the catalog products of a Solar System Science Collaboration simulation of the results of SSO analysis of the w...

Table: **dp03_catalogs.DiaSource**
Table to store 'difference image sources'; - sources detected at SNR >=5 on difference images.

4 TABLES

dp03_catalogs.DiaSource
Table to store 'difference image sources'; - sources detected at SNR >=5 on difference images.

dp03_catalogs.MPCORB
The orbit catalog produced by the Minor Planet Center. Ingested daily. O(10M) rows by survey end. The columns are described at https://mi...

dp03_catalogs.SSObject
LSST-computed per-object quantities. 1:1 relationship with MPCORB. Recomputed daily, upon MPCORB ingestion.

dp03_catalogs.SSSource
LSST-computed per-source quantities. 1:1 relationship with DIASource. Recomputed daily, upon MPCORB ingestion.

Enter Constraints

▼ ☐ **Spatial**

Spatial type: ◉ Single Shape ○ Multi-object

Shape Type: Cone

Coords or Obj Name: Try NED then Simbad

Examples: '62, -37' '60.4 -35.1' '4h11m59s -32d51m59s equ j2000' '239.2 -47.6 gal' 'NGC 1532' (NB: DC2 is a simulated sky, so names are not useful)

Radius: 10 arcseconds

Valid range between: 1" and 360000"

Position Columns: ▶ **ra, decl** (from the selected table on the right)

Output C

ccdVisitId			meta.id;obs.image	Id of the ccdVisit where this diaSourc
decl		deg	pos.eq.dec	Decl-coordinate of the center of this
declSigma		deg	stat.error;pos.eq.dec	Uncertainty of decl.

DP0.3 Catalog Access (Notebook)

```
from lsst.rsp import get_tap_service

service_sso_url = “https://data-int.lsst.cloud/api/ssotap"
service_sso = get_tap_service("ssotap")

assert service_sso is not None
assert service_sso.baseurl == service_sso_url
```

```
# Inspect the tables
query = """
SELECT * FROM tap_schema.tables   WHERE
tap_schema.tables.schema_name = 'dp03_catalogs'
 ORDER by table_index
ASC
"""
results = service_sso.search(query).to_table()
assert len(results) == 4
```

Table length=4

description	schema_name	table_index	table_name
str512	str512	int32	str64
The orbit catalog produced by the Minor Planet Center. Ingested daily. O(10M) rows by survey end. The columns are described at https://minorplanetcenter.net//iau/info/MPOrbitFormat.html	dp03_catalogs	0	dp03_catalogs.MPCORB
LSST-computed per-object quantities. 1:1 relationship with MPCORB. Recomputed daily, upon MPCORB ingestion.	dp03_catalogs	0	dp03_catalogs.SSObject
LSST-computed per-source quantities. 1:1 relationship with DIASource. Recomputed daily, upon MPCORB ingestion.	dp03_catalogs	0	dp03_catalogs.SSSource
Table to store 'difference image sources'; - sources detected at SNR >=5 on difference images.	dp03_catalogs	0	dp03_catalogs.DiaSource

Data Preview Tutorials

https://github.com/rubin-dp0/tutorial-notebooks

RTN-045: Guidelines for User Tutorials
ls.st/rtn-045
The Rubin Observatory Community Engagement Team

1 Abstract

2 Pedagogical principles

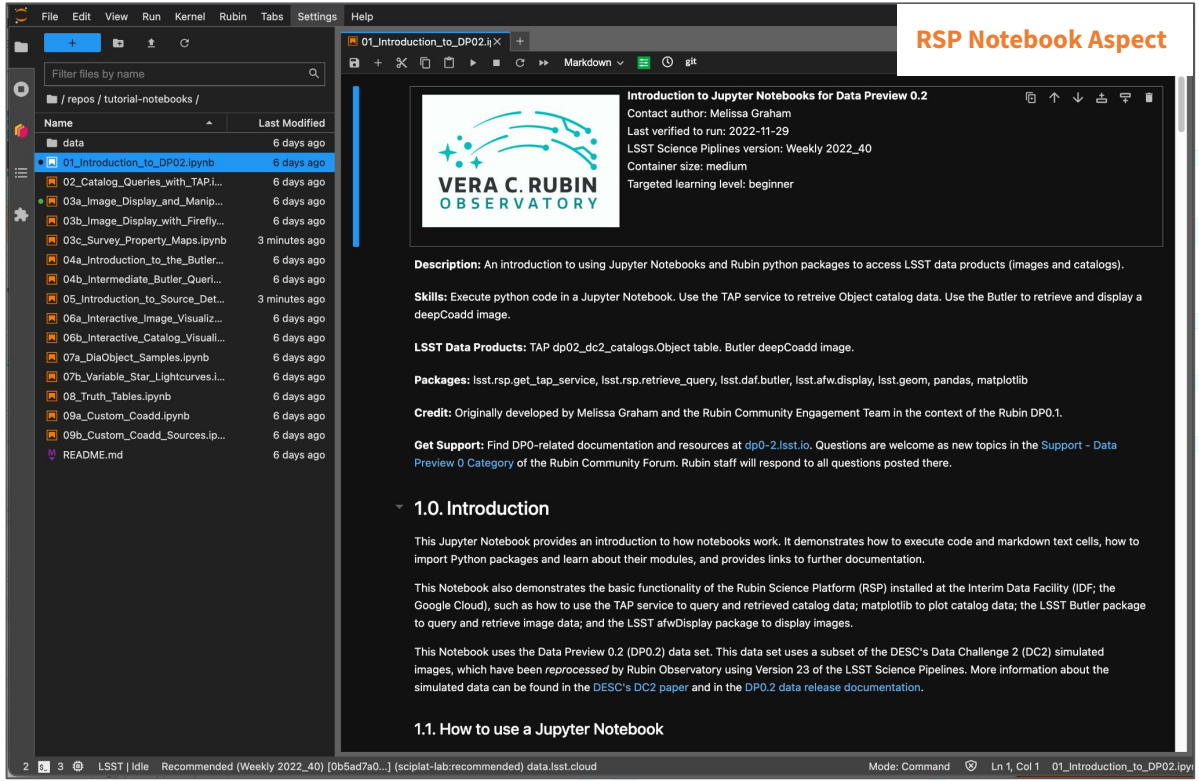
3 Jupyter notebook format, style, and code standards

4 Git branch, merge, and review policy for tutorial-notebooks repository

5 Portal tutorial format and style

6 Git branch, merge, and review policy for portal tutorials

7 Stretch goals



What would you like to see from the DP0.3 tutorial notebooks being developed by the Community Science Team (CST)?

Rubin Observatory's mission is to build a well-understood system that will produce an unprecedented astronomical data set for studies of the deep and dynamic universe, make the data widely accessible to a diverse community of scientists, and engage the public to explore the Universe with us.

Image Credit: Y. AlSayyad/Rubin Obs/NSF/Princeton