



Transient and Variable Science Opportunities with Early Alerts from the Rubin Observatory

Eric Bellm

Alert Production Science Lead

UIUC Transient & Variable Universe | 20 June 2023



U.S. DEPARTMENT OF ENERGY

SLAC

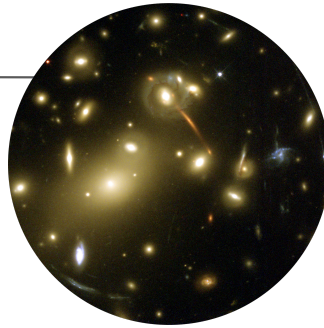
CHARLES AND LISA SIMONYI FUND
••• FOR ARTS AND SCIENCES •••



Rubin Observatory data will support four major science pillars.

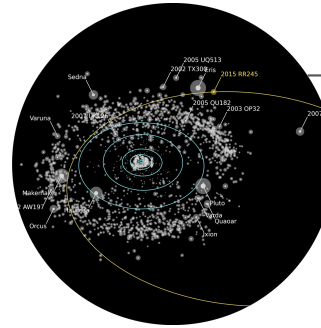
Probing Dark Matter & Dark Energy

- Strong & Weak Lensing
- Large Scale Structure
- Galaxy Clusters, Supernovae



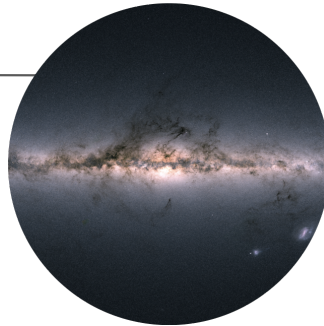
Inventory of the Solar System

- Comprehensive small body census
- Comets & ISOs
- Planetary defense



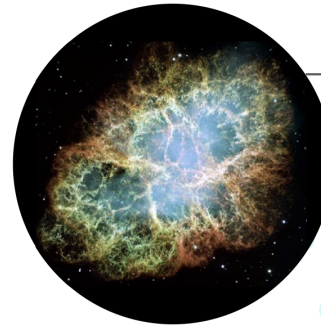
Mapping the Milky Way

- Structure and evolutionary history
- Spatial maps of stellar characteristics
- Reach well into the halo



Exploring the Transient Optical Sky

- Variable stars, Supernovae
- Fill in the variability phase-space
- Discovery of new classes of transients



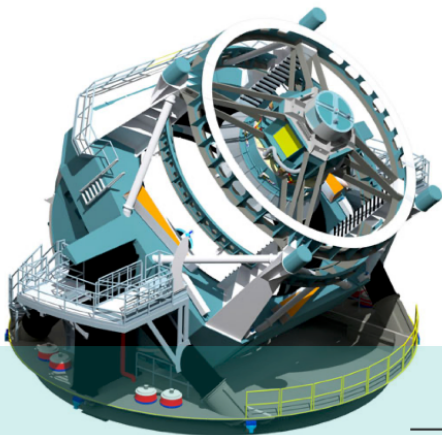


A powerful Data Management system will provide science-ready data products on rapid timescales.

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

Data Release Data Products

Final 10yr Data Release:

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



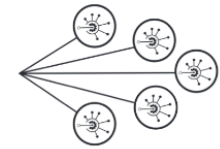
via nightly alert streams



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)

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

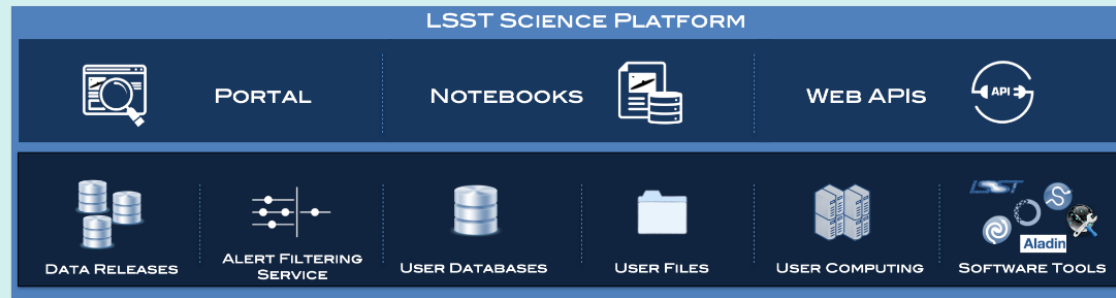


Figure credit: Leanne Guy

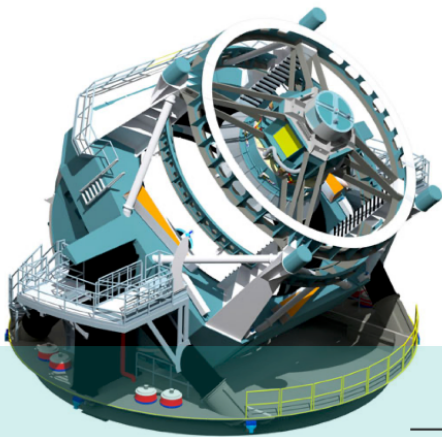


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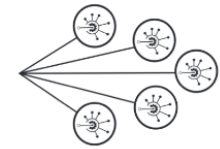
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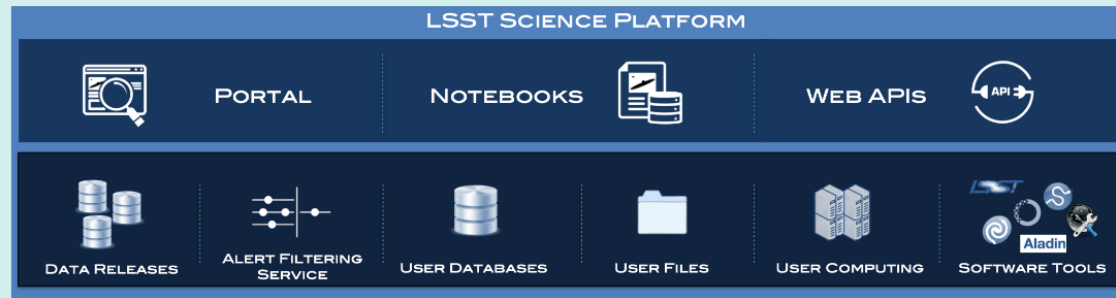


Figure credit: Leanne Guy

Rubin has agreed to send the full alert stream to seven brokers; others will operate downstream.

Seven brokers were selected for direct access to the full alert stream:

- [ALeRCE](#)
 - [AMPEL](#)
 - [ANTARES](#)
 - [Babamul](#)
- 
- [Fink](#)
 - [Lasair](#)
 - [Pitt-Google](#)

Two additional brokers were recommended to operate downstream:

- SNAPS
 - POI/Variables
- 

All brokers have active prototypes working with ZTF data.

Rubin Observatory construction continues to advance rapidly.





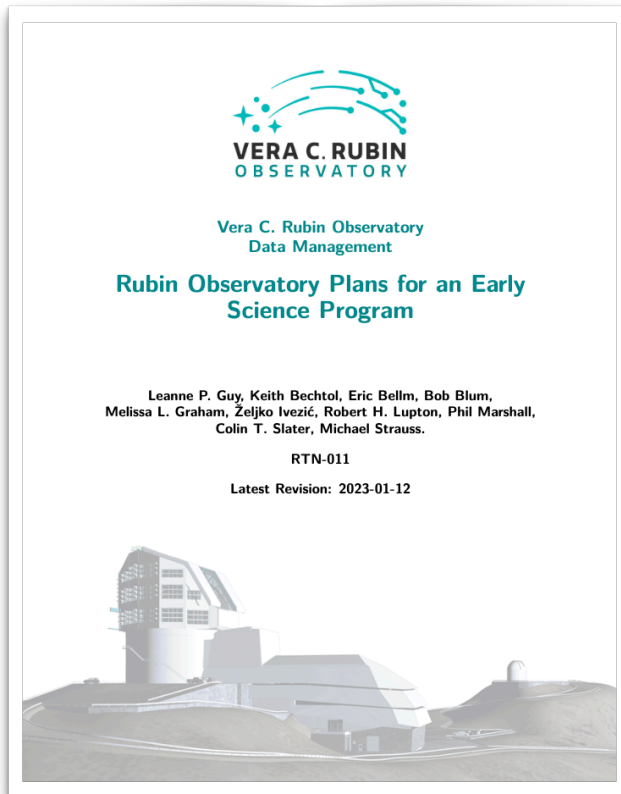
On-sky commissioning with LSSTCam is approaching.

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

Using April 2023 project controls data.

ls.st/dates provides the canonical and up-to-date estimate of the milestone dates.

RTN-011 provides a public-facing guide to early science opportunities with LSST.



A living document summarizing the Early Science program:

- Planned data releases
- Availability of data products
- Commissioning survey plans
- Alert Production during the early survey
- Optimizations for early science
- Schedule and timeline

Can be cited in research proposals

Further discussion at

<https://community.lsst.org/c/sci/early-science>

lsst.org/RTN-011 or lsst.org/esp



A series of Data Previews provide access to simulated and commissioning data ahead of DR1.

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	☐	☐	☐	☐	☐	✓	✓	✓	✓

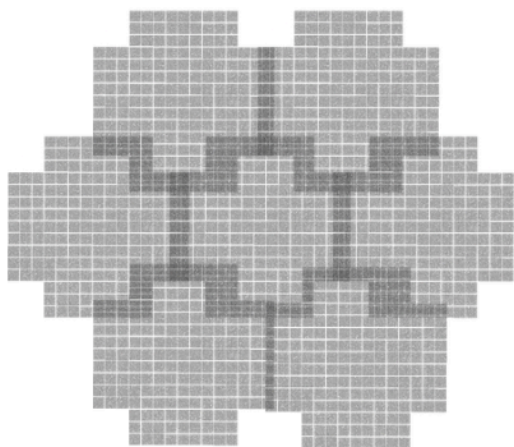
ls.st/RTN-011

Commissioning observations will include technical tests as well as intensive observing campaigns of small regions.

Choose 3 fields separated in RA to facilitate full-night observing; LSST WFD dithers

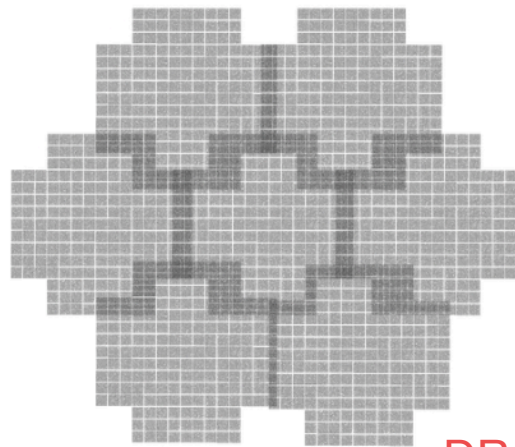
Extragalactic

(e.g., centered on an LSST DDF)



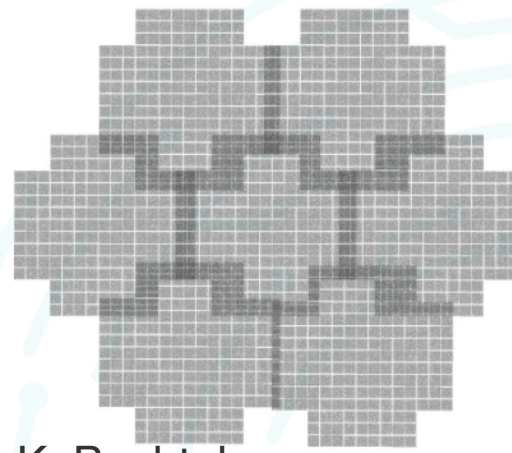
Resolved Stars

(e.g., centered on Cen A, LMC, near Galactic plane)



Solar System

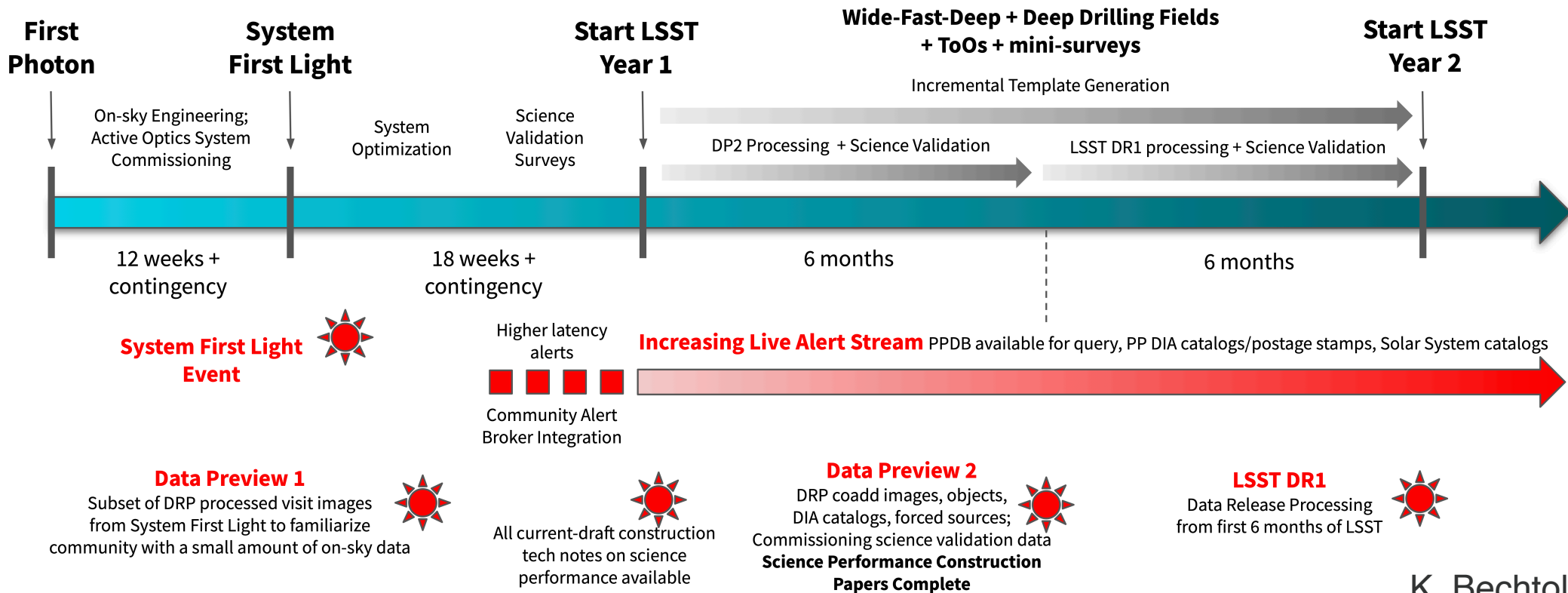
(e.g., near ecliptic)



DRAFT; K. Bechtol

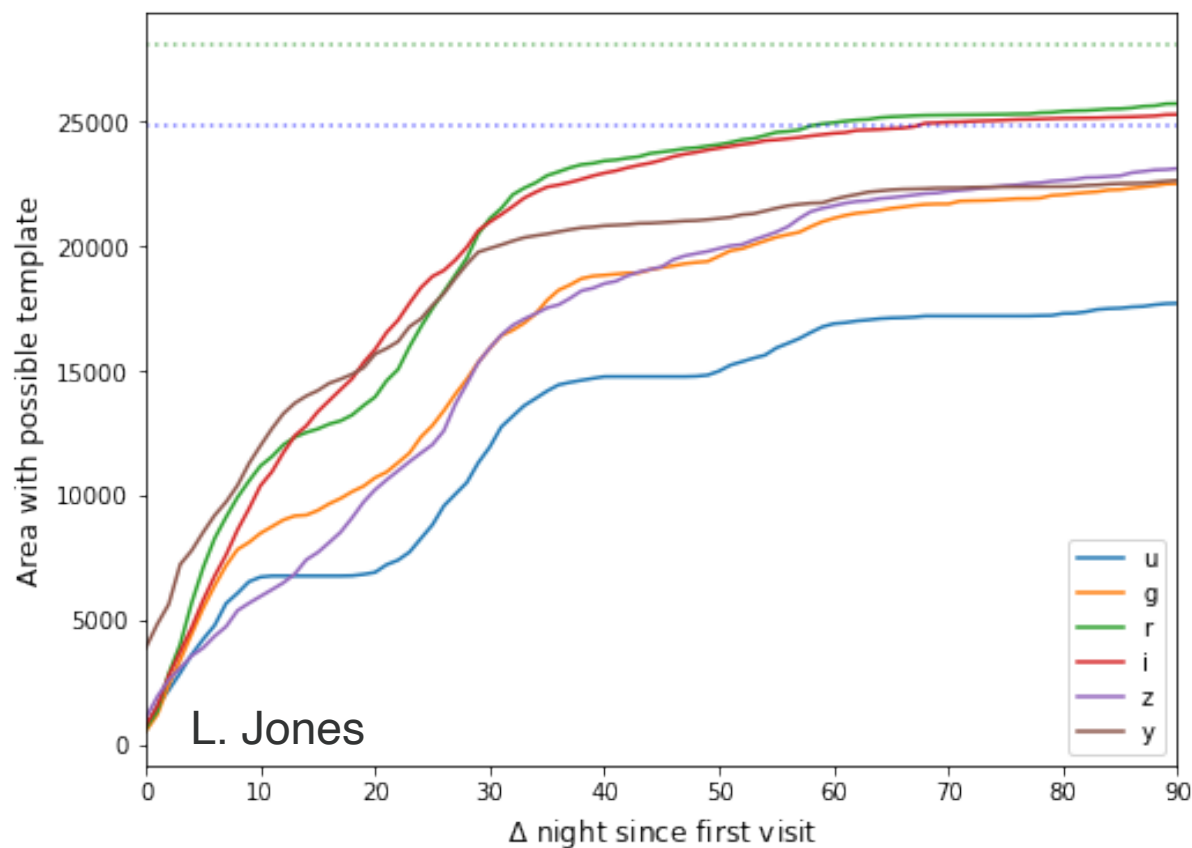
aim to acquire 10-20 year depth over 30-60 days.

Alert Production will ramp up as templates become available.



K. Bechtol

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Commissioning and Deep Drilling fields will provide earliest template coverage.

Early time-domain science projects should plan for this unique time period.

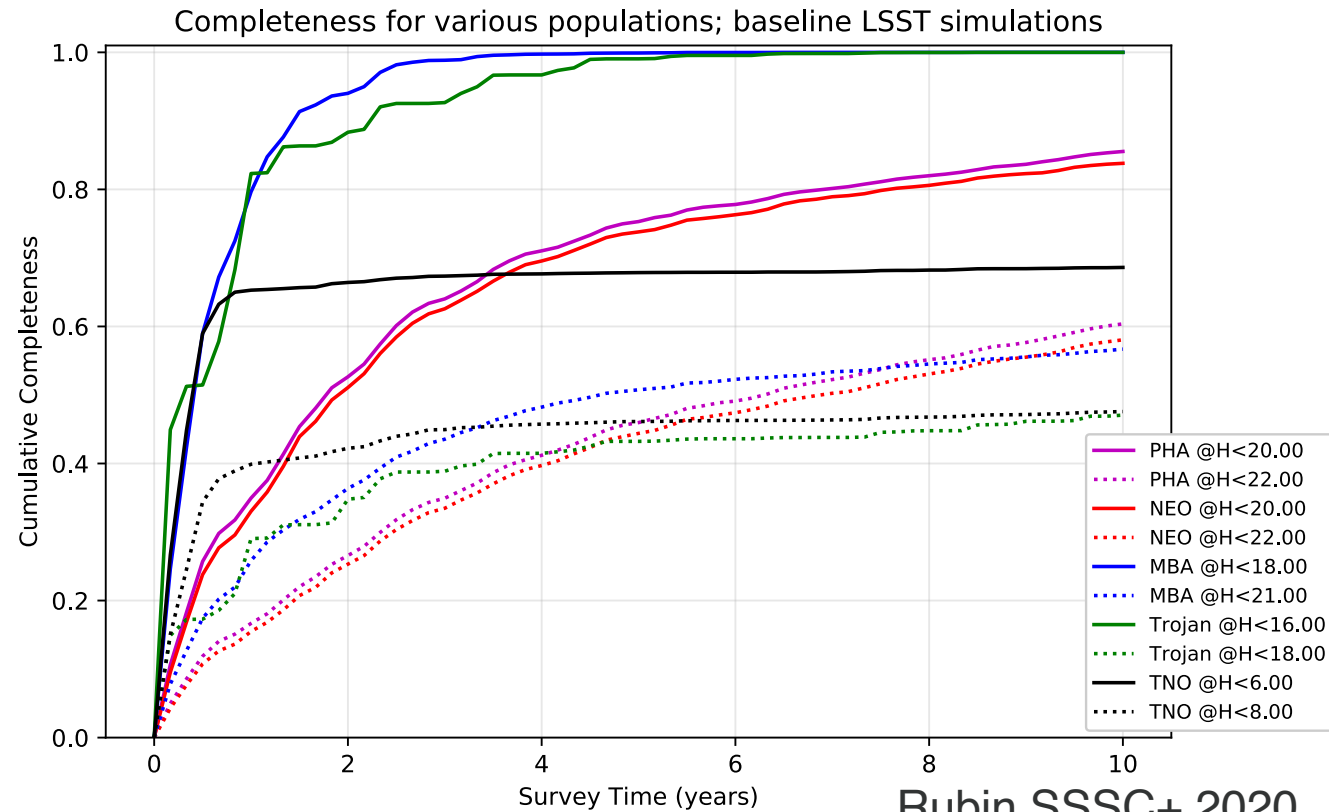
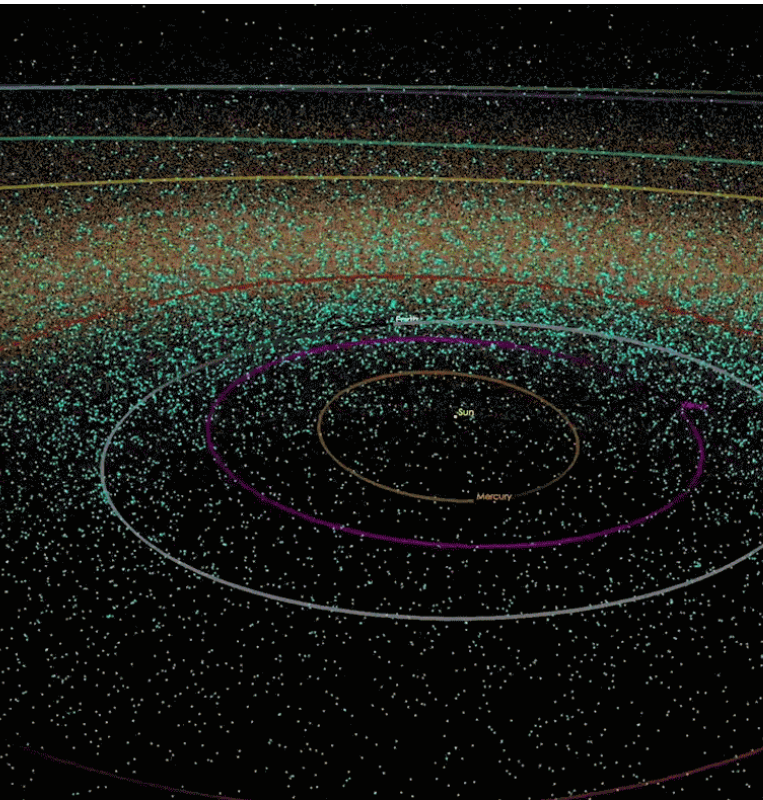
Challenges

- very sparse sampling as templates are built
- limited timeseries history
- greater rate of false positives and other systematics
- evolving data quality and machine-learning reliability scores
- no association to a static sky
Data Release

Opportunities

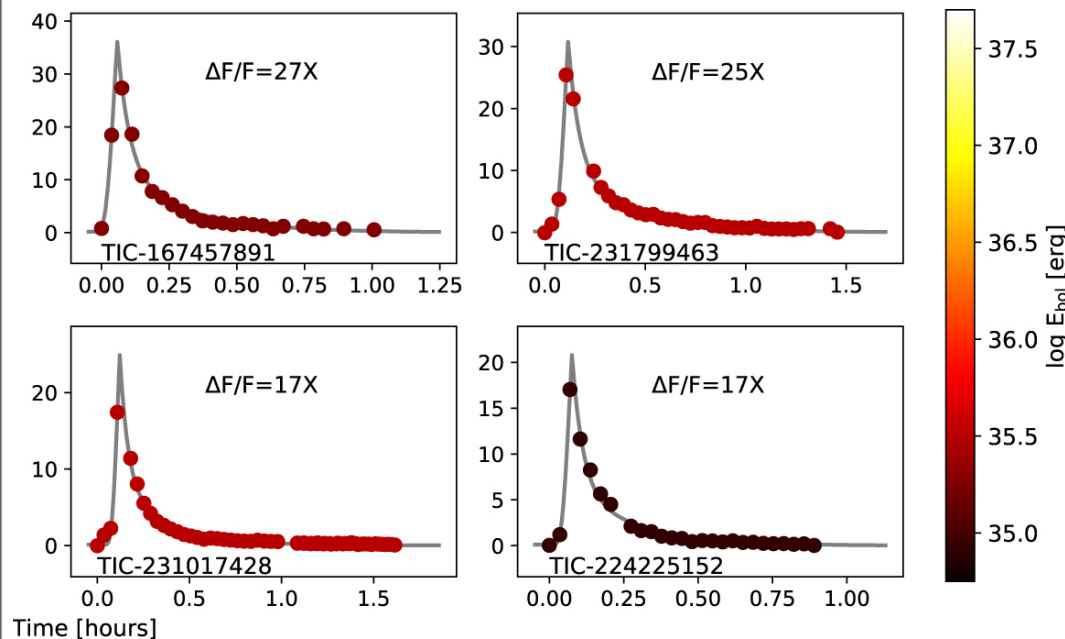
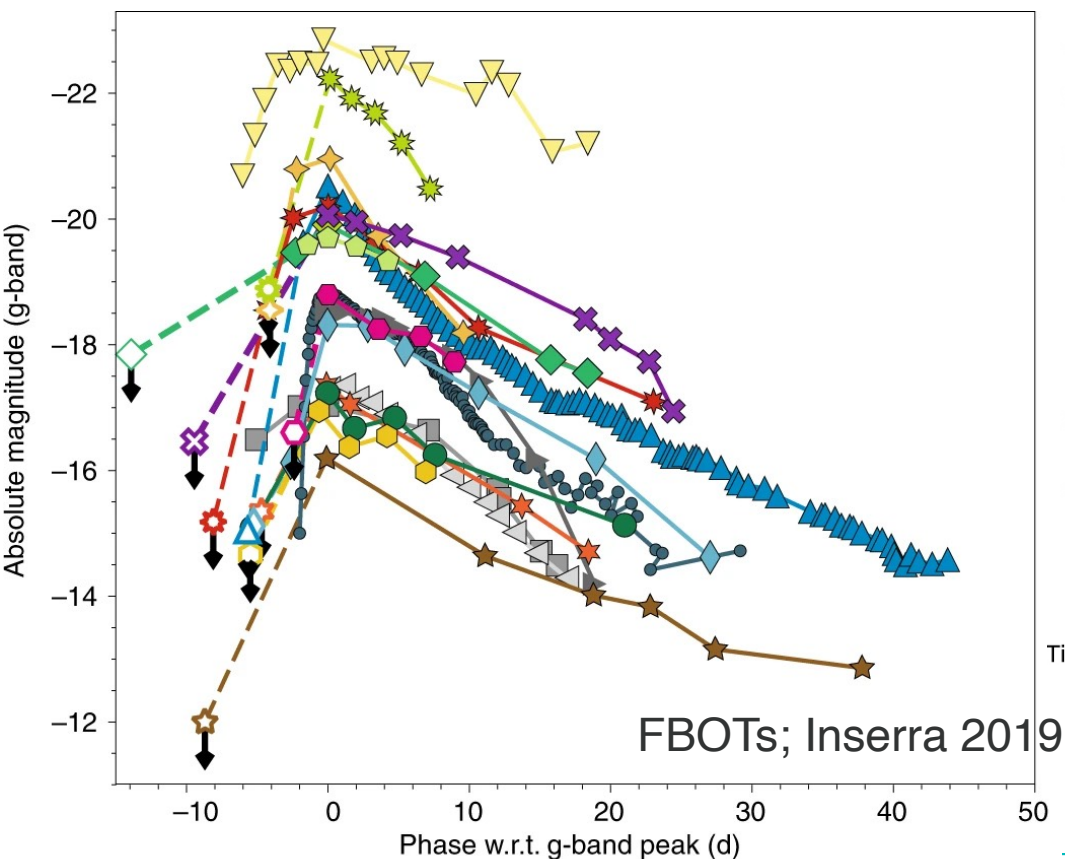
- unprecedented survey speed
- unusually densely-sampled observations in commissioning
- rich data products and services
- chance to prepare for a decade of discovery!

We can expect the first flush of solar system discovery...



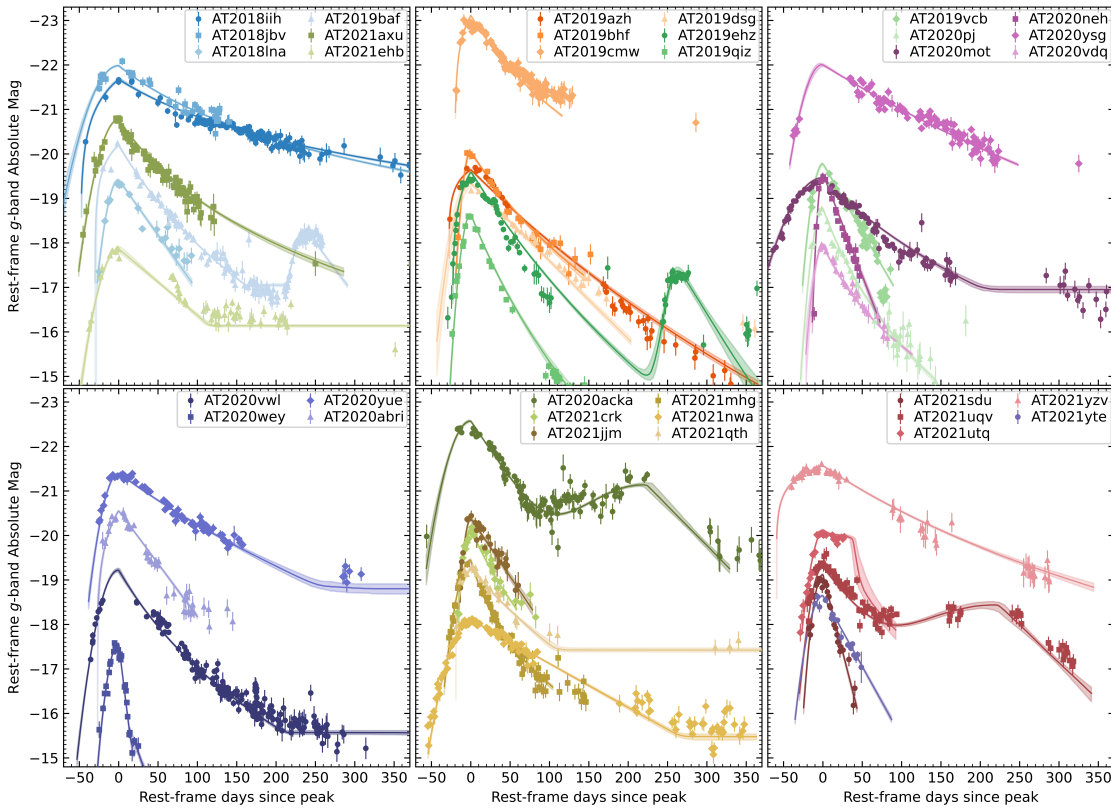
Rubin SSSC+ 2020

... transients fast...

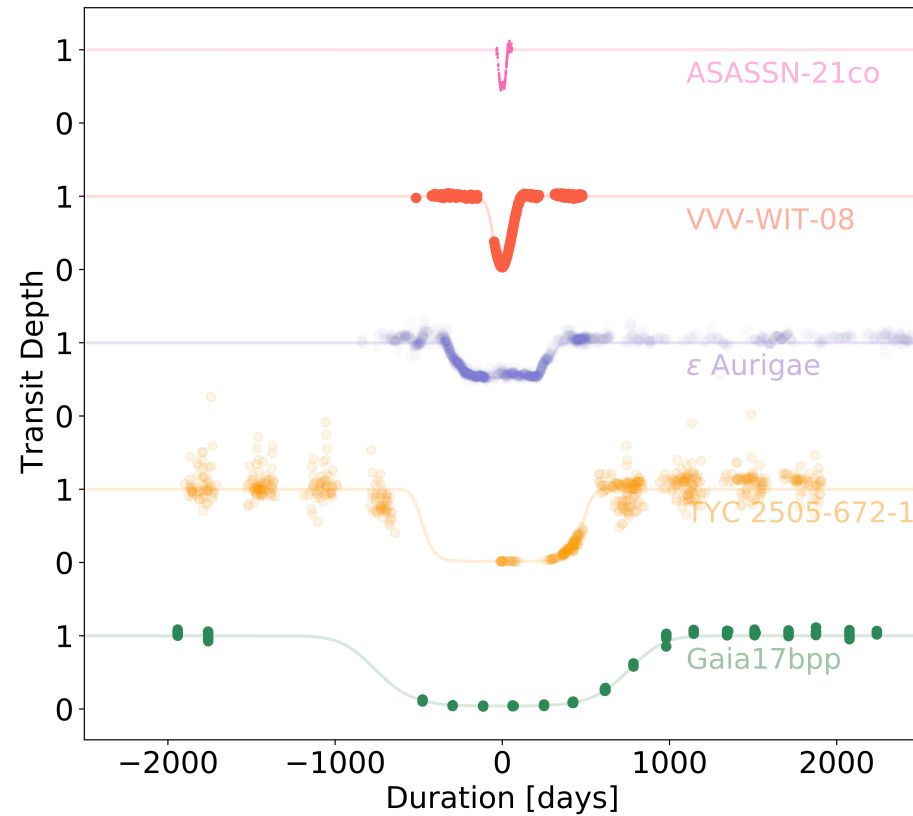


superflares; Ward+2019

... and slow...

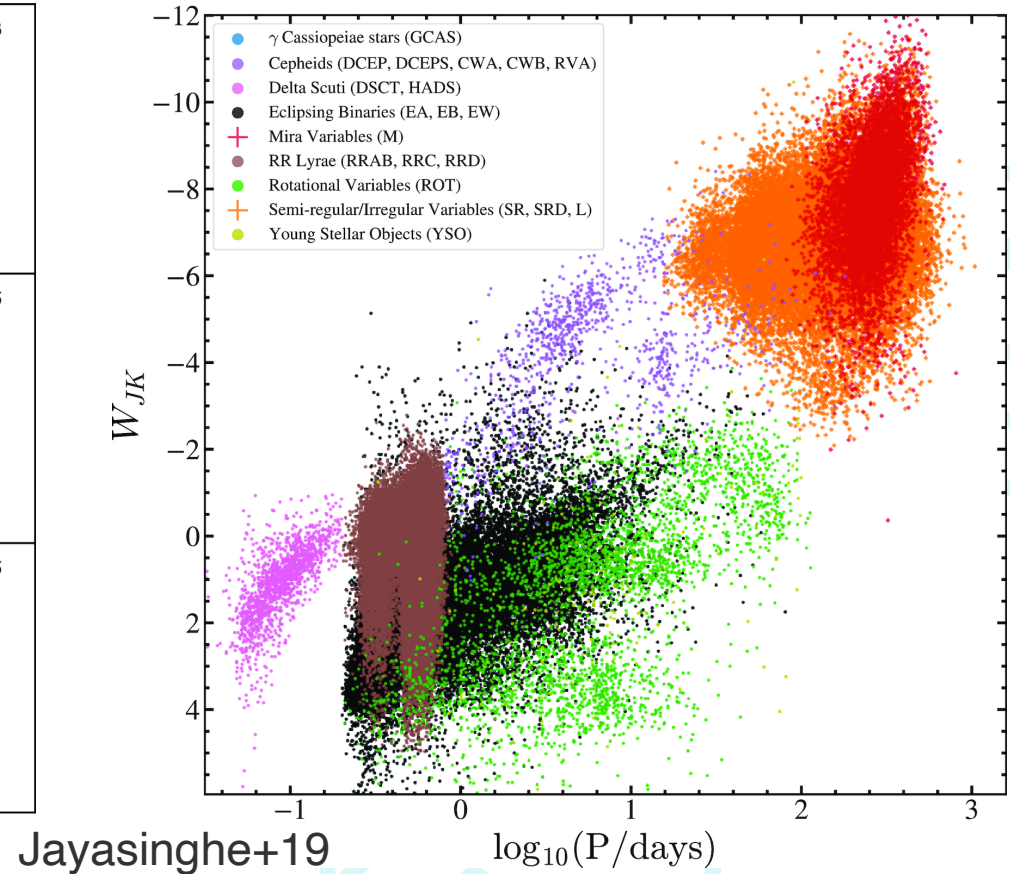
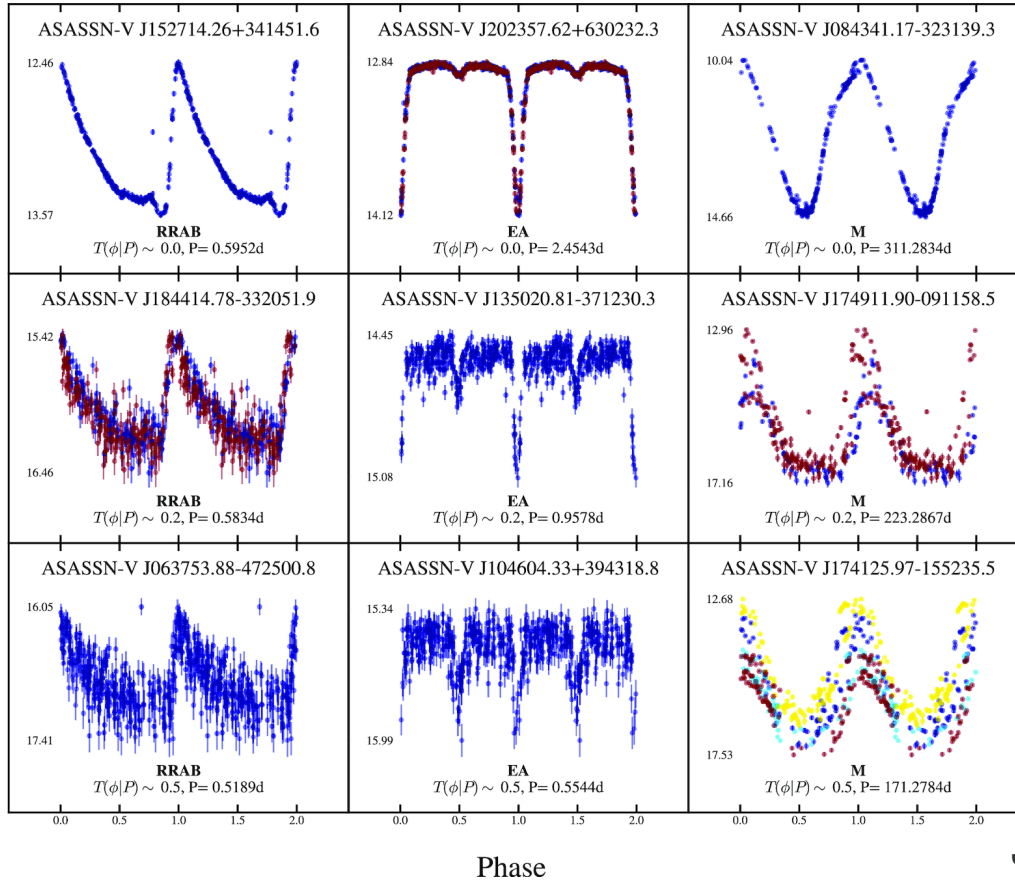


TDEs; Yao+23



ϵ Aur analogues; Tzanidakis+23

... and well-sampled lightcurves of variable stars and AGN ripe for classification.



Rubin Observatory will provide a powerful resource for time-domain astronomy.

Commissioning and early operations data will have unique characteristics.

Community alert brokers will be vital for enabling followup-driven science.

Rubin commissioning will begin next year, with the full survey expected in 2025.

You can get involved with preparatory activities and precursor data now!





VERA C. RUBIN
OBSERVATORY