Investigation of active galactic nuclei in the Legacy Survey of Space and Time (LSST)

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Department of Astronomy, Faculty of Mathematics - University of Belgrade
SER-SAG in-kind contribution to Rubin Observatory

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АСТРОНОМИЈА
И АСТРОФИЗИКА

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Rubin LSST has started!

June 29,2026

Credit: NSF–DOE Vera C. Rubin Observatory/NOIRLab/SLAC/AURA

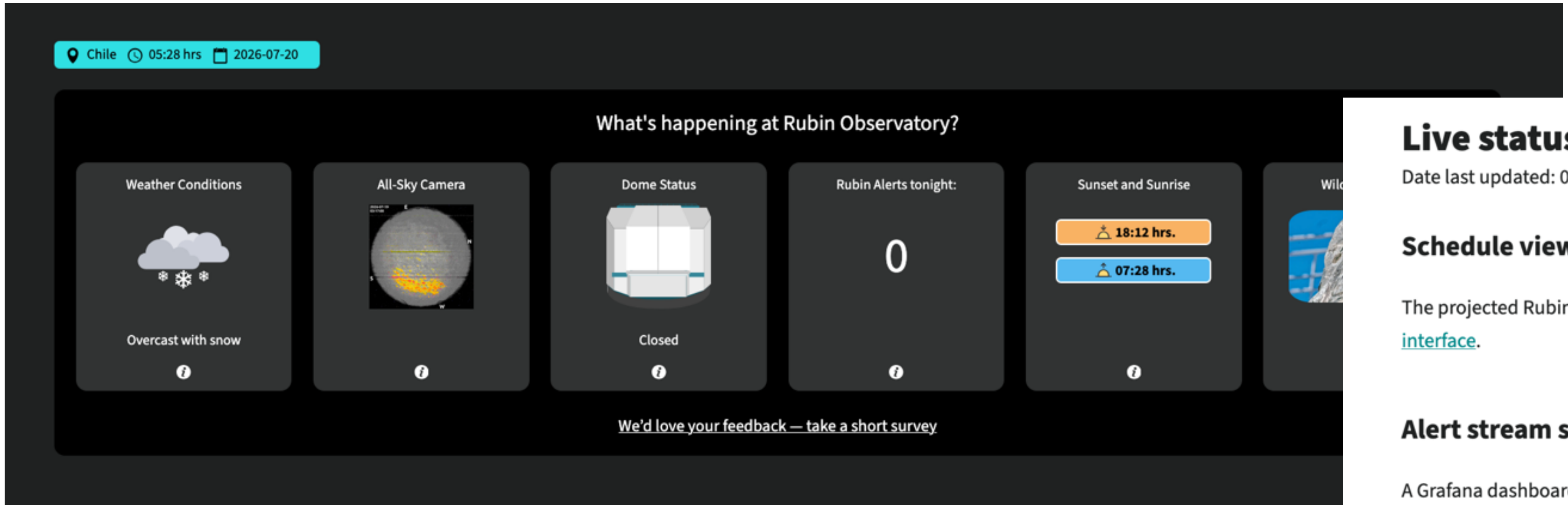
Legacy Survey of Space and Time LSST

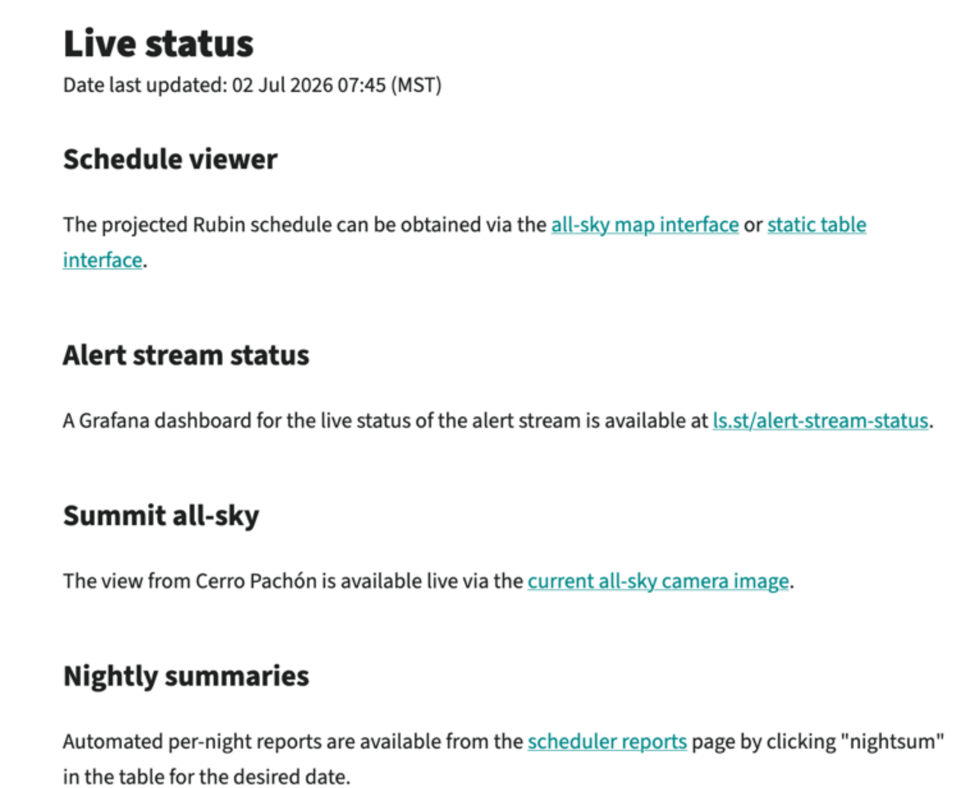
- Vera C. Rubin Observatory
- 10-year Legacy Survey of Space and Time (LSST) → [started in June 2026]
- 8.4m telescope, largest ever CCD
- 100s petabyte set of images and data products → Billions of new stars and galaxies
- Massive time domain astronomy
- **Big data, movie of the sky**

Rubin Observatory/NSF/AURA/A. Pizarro D.

Legacy Survey of Space and Time

Follow live updates at
https://rubinobservatory.org/for-scientists/rubin-101/live-status





Live status

Date last updated: 02 Jul 2026 07:45 (MST)

Schedule viewer

The projected Rubin schedule can be obtained via the all-sky map interface or static table interface.

Alert stream status

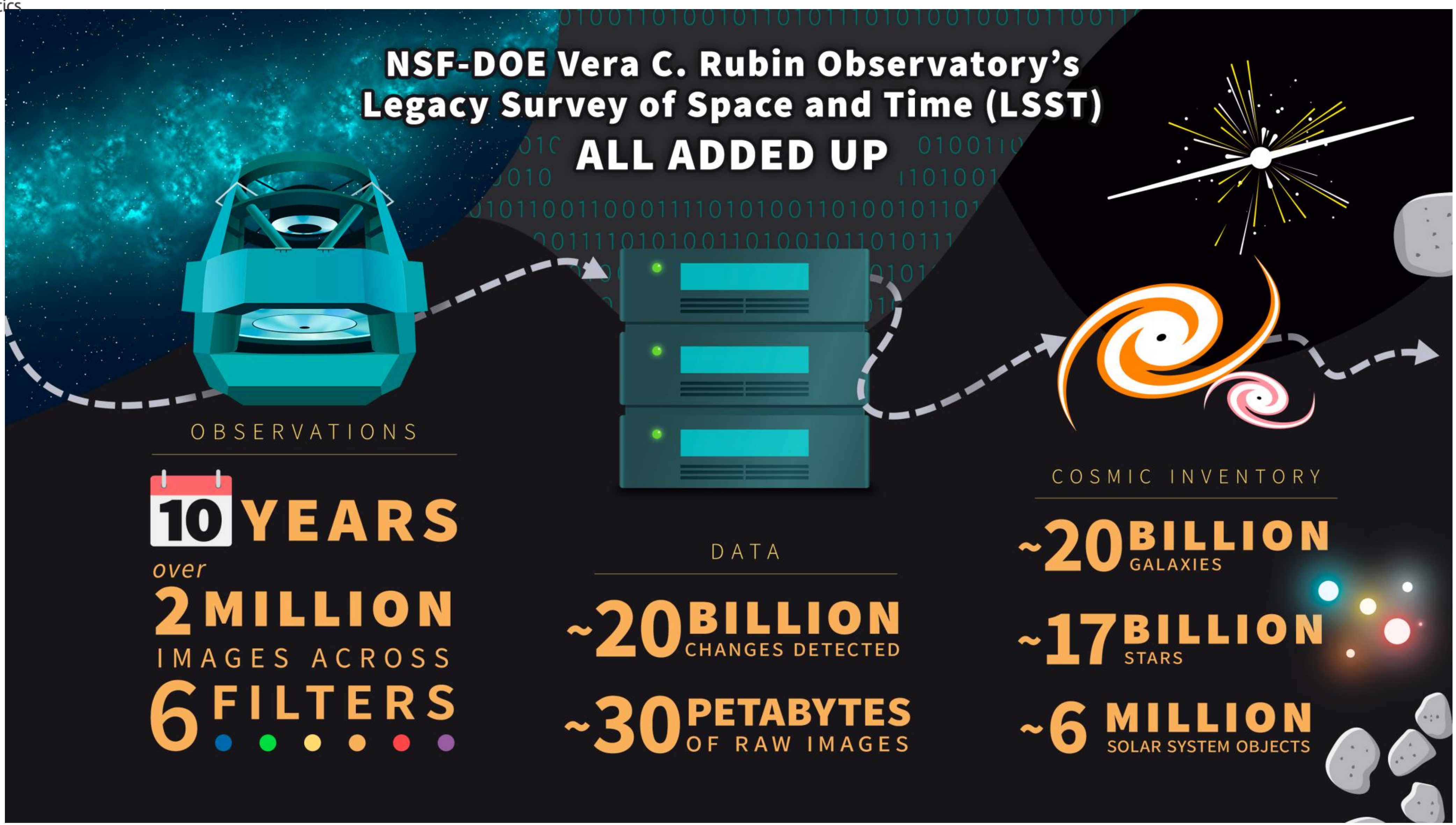
A Grafana dashboard for the live status of the alert stream is available at ls.st/alert-stream-status.

Summit all-sky

The view from Cerro Pachón is available live via the current all-sky camera image.

Nightly summaries

Automated per-night reports are available from the scheduler reports page by clicking "nightsum" in the table for the desired date.



Credit: NSF–DOE Vera C. Rubin Observatory/NOIRLab/SLAC/AURA

LSST - Key Science Pillars

1. Understanding the nature of dark matter and dark energy
2. Creating an inventory of the Solar System
3. Mapping the Milky Way
4. Exploring objects that change position or brightness over time, called "transients"

Unprecedented data volume to be leveraged for multiple science goals.

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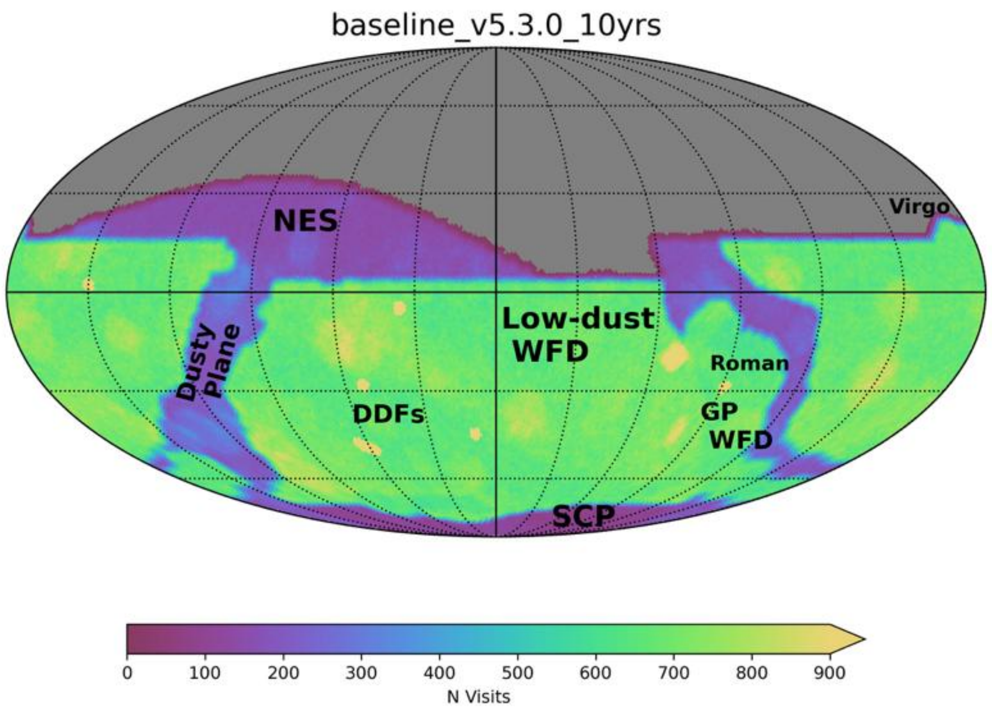
LSST operation strategies

https://survey-strategy.lsst.io/baseline/index.html

- Main survey – **Wide Fast Deep (WFD)**
  - each point around 800 visits
  - rolling cadence from year 2 in low-dust WFD
- Mini surveys – **Deep Drilling Fields** (overlap with other missions, e.g. Euclid)
- Micro Surveys

- after 10 years, coadded images will reach r~27.5 mag
- photometry in 5 bands: u g r i z y



Deep Drilling Field Locations

	ELAISS1	XMM_LSS	ECDFS	COSMOS	EDFS_a	EDFS_b
RA	9.45	35.57	52.98	150.11	58.9	63.6
Dec	-44.02	-4.82	-28.12	2.23	-49.32	-47.6

Rubin Data products and Early Science

- **Prompt Data Products**
  - **Alerts - a**s of February 24 2026, alerts were streaming in real time to brokers and became accessible to the global science community.
  - **Solar System products -** All Rubin data for solar system objects is available via the Minor Planet Center (MPC; Rubin's observatory code is X05).
- **Data Previews** (Data Rights Holders only)
  - **Data Preview 1, June 2025 -** image and catalog products from Rubin Science Pipelines v29 processing of observations obtained with the LSST Commissioning Camera of 7 ~1 square degree fields over 7 weeks in 2024.
  - **Data Preview 2, expected in July 2026 -** Data Preview 2 image and catalog products from Rubin Science Pipelines v30 processing of observations obtained with the LSST Camera.
    - **"Early DP2" release date: July 27 2026 (dp2.lsst.io).** In the early phase, deep coadded images and all catalogs will be available. **Complete DP2 target: Oct-Dec 2026**, when visit and difference images will become available.
- **Data Releases**
  - Data Release 1 anticipated by the end of June 2028,

https://rubinobservatory.org/for-scientists/resources/early-science

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The 8 Rubin Science Collaborations

SSSC — **Solar System** Science Collaboration (Colin Orion Chandler, Meg Schwamb)

GalaxiesSC — **Galaxies** Science Collaboration (Sugata Kaviraj, Simona Mei)

DESC — **Dark Energy** Science Collaboration (Renée Hložek, Tesla Jeltema)

SMWLV — **Stars, Milky Way & Local Volume** (Peregrine McGehee, Will Clarkson)

ISSC — **Informatics & Statistics** Science Collaboration (François Lanusse, Ashley Villar)

SLSC — **Strong Lensing** Science Collaboration (Graham Smith, Timo Anguita → Simon Birrer from 09/23)

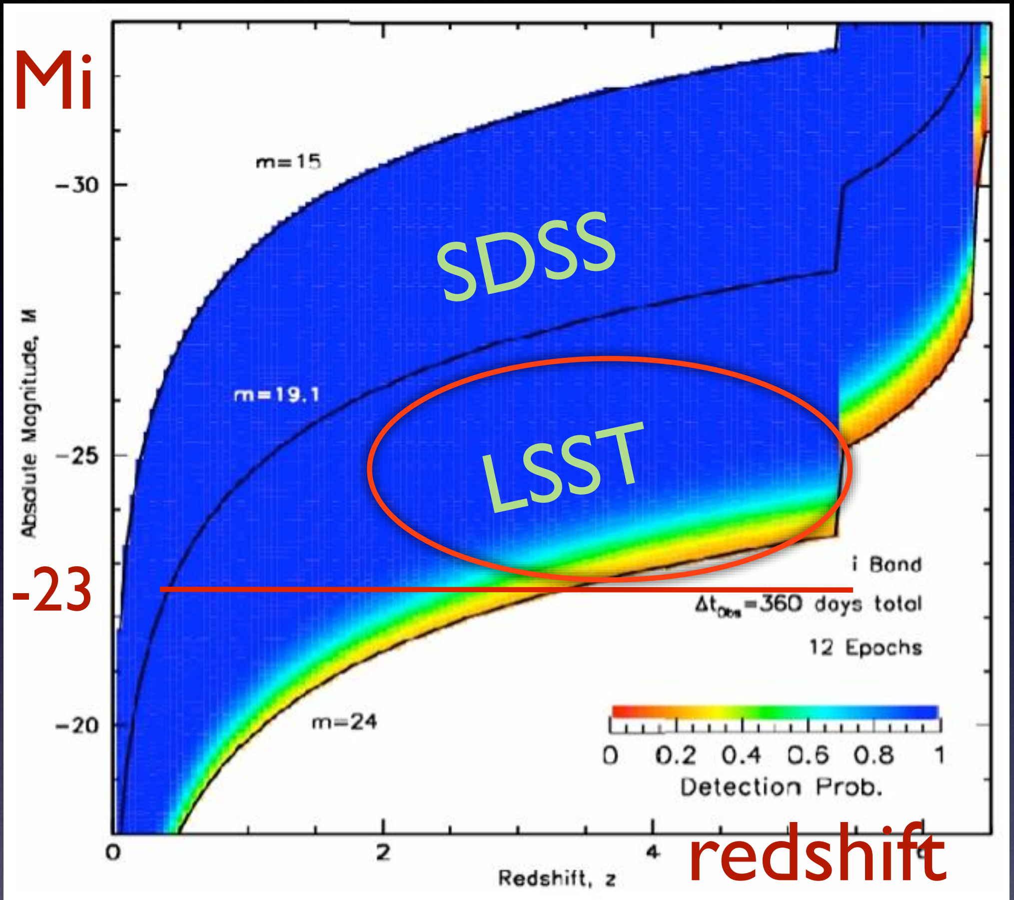
TVS — **Transients & Variable Stars** (Igor Andreoni, Sara Bonito)

AGN — **Active Galactic Nuclei** (Niel Brandt, Gordon Richards)

Vera C. Rubin Observatory | Project & Community Workshop | 7-11 August 2023 wiclarks@umich.edu Acronyms & Glossary

Talk by Science Collaboration Coordinator, Dr. Will Clarkson

Extragalactic astronomy: quasars



Top: absolute magnitude vs. redshift diagram for quasars

- About 10 million quasars will be discovered using variability, colors, and the lack of proper motions
  Really?? SDSS: yes!
- The sample will include Mi=-23 objects even at redshifts beyond 3
- Quasar variability studies will be based on millions of light curves with 1000 observations over 10 yrs

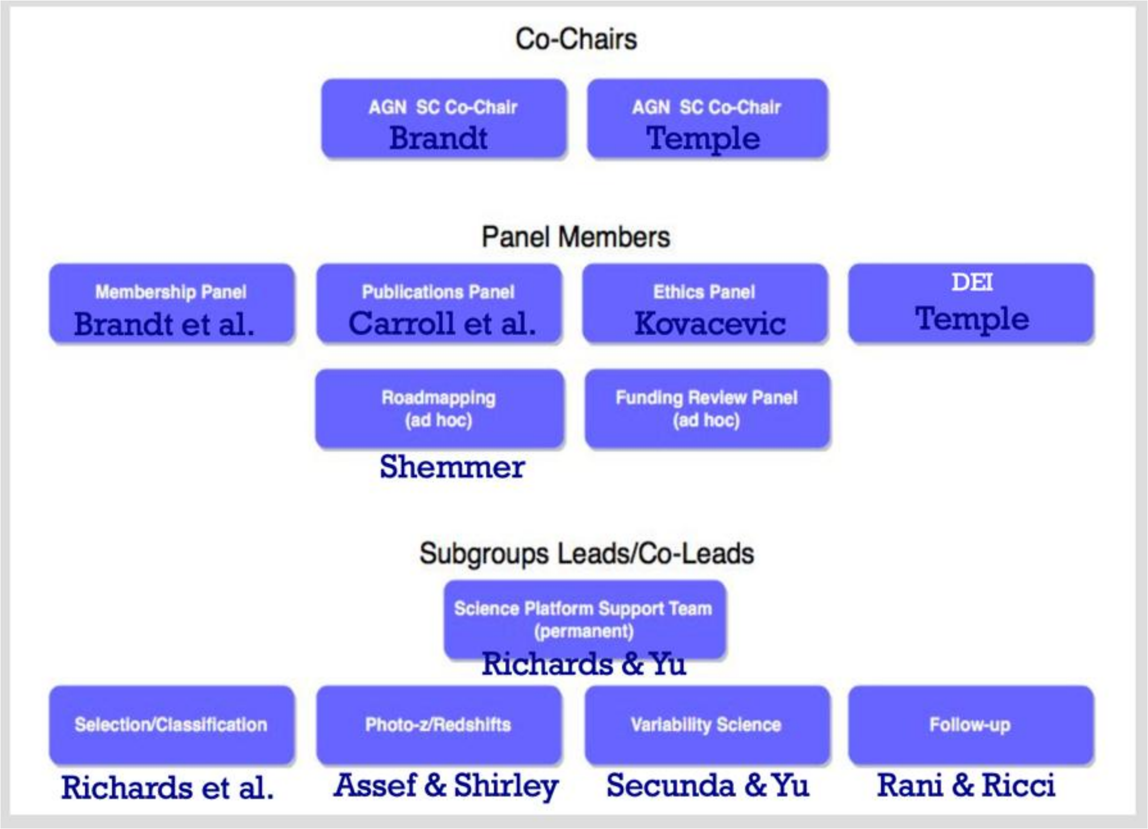
Today: ~31 quasars with 6<z<7.5 **Reionization studies!**

LSST will detect ~10,000 quasars with 6<z<7.5!

From Zeljko Ivezic slides
Rubin Observatory Director

LSST AGN Science Collaboration

AGN SC co-chairs: Niel Brandt, Metthew Temple



https://agn.science.lsst.org

1.	United States	140	8.	Germany	12	14.	Argentina	4	20.	Croatia	1	24.	Spain	1
2.	United Kingdom	31	9.	Japan	6	15.	Greece	3	21.	Finland	1	25.	Switzerland	1
3.	Italy	26	10.	South Korea	6	16.	Denmark	2	22.	India	1	26.	Ukraine	1
4.	Brazil	21	11.	Poland	6	17.	Turkey	2	23.	Netherlands	1			
5.	Chile	18	12.	China	5	18.	Austria	1						
6.	Australia	16	13.	South Africa	5	19.	Canada	1						
7.	Serbia	13												

Liaison to SCOC – Assef
Liaison to DM – Reed
Users committee – Petrecca & Sarajedini
In-kind coordinators – Hoenig & Coppi

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Home » Meetings

Meetings

The 2026 meeting of the LSST AGN Science Collaboration will be hosted in Heraklion, Greece, from Monday 24th to Thursday 28th May.

See this page for full details and to register.

The 2025 July meeting of the LSST AGN Science Collaboration was hosted in Durham, UK, from Monday 14th to Thursday 17th July.

Details of the 2025 meeting are in this link.

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Home » Project Proposal

Project Proposal

An AGN SC Project is any scientific investigation or infrastructure development undertaken within the AGN SC environment. Projects are collaborative from the start, allowing members to contribute and provide feedback, ensuring transparency throughout the process.

Once approved, projects are recorded in the AGN SC Project Database, a searchable resource that provides visibility into ongoing projects and connects researchers with shared interests and expertise.

This form is used to propose new projects within the AGN SC. Proposals should be submitted early to allow for feedback and potential collaboration. After submission, the Publication Panel will review the proposal for alignment with ethical standards and collaboration policies. Approved projects will be announced, inviting further contributions from the AGN SC.

Please complete the following sections with as much detail as possible to facilitate a thorough review and effective project coordination.

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The Astrophysical Journal, 998:144 (18pp), 2026 February 10 https://doi.org/10.3847/1538-4357/ae28d3

Scalable and Robust Multiband Modeling of AGN Light Curves in Rubin-LSST

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Abstract

The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) will monitor tens of millions of active galactic nuclei (AGNs) for a period of 10 yr with an average cadence of 3 days in six broad photometric bands. This unprecedented data set will enable robust characterizations of AGN UV/optical variability across a wide range of AGN physical properties. However, existing tools for modeling AGN light curves are not yet capable of fully leveraging the volume, cadence, and multiband nature of LSST data. We present `EzTaoX`, a scalable light-curve modeling tool designed to take advantage of LSST's multiband observations to simultaneously characterize AGN UV/optical stochastic variability and measure interband time delays. `EzTaoX` achieves a speed increase of $\sim 10^2$–$10^4\times$ on CPUs over current tools with similar capabilities, while maintaining equal or better accuracy in recovering simulated variability properties. This performance gain enables continuum time-delay measurements for all AGNs discovered by LSST—both in the Wide Fast Deep survey and the Deep Drilling Fields—thereby opening new opportunities to probe AGN accretion-flow geometries. In addition, `EzTaoX`'s multiband capability allows for robust characterization of AGN stochastic variability down to hourly timescales, facilitating the identification of accreting low-mass AGNs—such as those residing in dwarf galaxies—through their distinctive variability signatures.

Astronomy & Astrophysics manuscript no. aa58627-25 ©ESO 2026
March 18, 2026

AGILE: an end-to-end Rubin-LSST simulation of AGNs, galaxies, and stars

I. Software description and first data release

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(Affiliations can be found after the references)

Received Month DD, YYYY

ABSTRACT

Aims. Contemporary large-scale surveys such as the Vera C. Rubin Observatory Legacy Survey of Space and Time (LSST) and Euclid present an unprecedented discovery potential for studying active galactic nuclei (AGNs) at the population level in the big data era. However, one major challenge is the accurate identification and classification of AGNs from optical and near-infrared photometry, or variability data alone. In order to optimize AGN selection, classification, and systematics, as well as to test different data analysis tools, we present AGILE (AGNs In the LSST Era), an LSST end-to-end simulation software. AGILE – developed as part of the INAF LSST in-kind contribution – is capable of simulating the anticipated AGN population in LSST and Euclid.
Methods. We based AGILE on existing simulations of galaxies and stars, while we developed an AGN recipe based on empirical relations. AGILE populates complete galaxy samples with AGNs according to the observed AGN accretion rate distribution, and each AGN is assigned an optical/UV spectral energy distribution. Optical AGN variability is added using a damped random walk model connected to the AGN physical parameters. Finally, AGILE creates both LSST-like images and related data products.
Results. Using AGILE, we build a 24 deg^2 complete mock truth catalog of AGNs, galaxies, and stars with $0.2 < z < 5.5$, $\log_{10}(M_{\rm star} / M_\odot) > 8.5$ (AGNs and galaxies), and $r < 27.5$ mag (stars). We also perform a pilot simulation (AGILE DR1) consisting of 1 deg^2 of LSST operations in the COSMOS field observed up to three years in accordance with the survey strategy. We use AGILE DR1 to quantify the accuracy of the LSST Science Pipelines in recovering the true fluxes of AGNs, galaxies, and stars. We quantify the LSST completeness and purity in recovering Type 1 AGNs using typical color-color and variability selections. We share the AGILE DR1 dataset, an ideal test-bench for further scientific exploitation and forecasts in the context of LSST AGNs.

A&A, 708, A121 (2026)
https://doi.org/10.1051/0004-6361/202557223

Astronomy & Astrophysics

VAR-PZ: Constraining the photometric redshifts of quasars using variability

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(Affiliations can be found after the references)

Received 12 September 2025 / Accepted 13 February 2026

ABSTRACT

The Vera C. Rubin Observatory's Legacy Survey of Space and Time (LSST) is expected to obtain observations of over ten million quasars. The survey's exceptional cadence and sensitivity will enable a significant fraction of these objects to be monitored in the *ugrizy* bands, spanning observed wavelengths of approximately 0.3–1.0 μm. The unprecedented number of sources makes spectroscopic follow-up for the vast majority of them unfeasible in the near future, so most studies will have to rely on photometric redshift estimates which are traditionally much less reliable for Active Galactic Nuclei (AGNs) than for inactive galaxies. This work presents a novel methodology to constrain the photometric redshift of AGNs that leverages the effects of cosmological time dilation, and of the luminosity and wavelength dependence of AGN variability. Specifically, we assume that the variability can be modeled as a damped random walk (DRW) process, and we adopted a parametric model to characterize the DRW timescale (τ) and asymptotic amplitude of the variability (SF_∞) based on the redshift, the rest-frame wavelength, and the AGN luminosity. We constructed variability-based photometric redshift (photo-z) priors by modeling the observed variability using the expected DRW parameters at a given redshift. These variability-based photo-z (VAR-PZ) priors were then combined with traditional spectral energy distribution (SED) fitting to improve the redshift estimates from SED fitting. Validation was performed using observational data from the Sloan Digital Sky Survey (SDSS), demonstrating significant reduction in catastrophic outliers by more than 10% in comparison with SED fitting techniques and improvements in redshift precision. The simulated light curves with both SDSS and LSST-like cadences and baselines confirm that VAR-PZ will be able to constrain the photometric redshifts of SDSS-like AGNs by bringing the outlier fractions down to below 15% from 32% (SED alone) at the end of the survey.

The Astrophysical Journal, 1000:165 (12pp), 2026 April 1 https://doi.org/10.3847/1538-4357/ae3164

Predicting Quasar Counts Detectable in the LSST Survey

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Abstract

The Legacy Survey of Space and Time (LSST), being conducted by the Vera C. Rubin Observatory, is a wide-field multiband survey that will revolutionize our understanding of extragalactic sources through its unprecedented combination of area and depth. While the LSST survey strategy is still being finalized, the Rubin Observatory team has generated a series of survey simulations using the LSST Operations Simulator to explore the optimal survey strategy that best accommodates the majority of scientific goals. In this study, we utilize the latest simulated data and the Metrics Analysis Framework to predict the number of quasars detectable by LSST in each band and evaluate the impact of different survey strategies. We find that the number of quasars and lower-luminosity active galactic nuclei (AGNs) detected in the baseline strategy (v4.3.1) in the redshift range $z = 0.3$–6.7 will be highest in the i band (about 12 million) and lowest in the u band (about 6 million). Over 70% of quasars are expected to be detected within the first year in all bands, as LSST will have already reached the break in the luminosity function at most redshifts. With a limiting magnitude of 25.7 (26.9) mag, we expect to detect 184 (199) million AGNs in the z band (r band) over the 10 yr survey, with quasars constituting only 6% of the total AGNs in each band. This arises because, considering that the luminosities of most low-luminosity AGNs are affected by contamination from their host galaxies, we set a magnitude threshold when predicting the number of quasars. We find that variations in the u-band strategy can impact the number of quasar detections. Specifically, the difference between the baseline strategy and that with the largest total exposure in u is 15%. In contrast, changes in rolling strategies, Deep Drilling Field strategies, weather conditions, and Target of Opportunity observations result in variations below 2%. These results provide valuable insights for optimizing approaches to maximize the scientific output of quasar studies.

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AGN SC Data and Code Challenges

LSST AGN Science Collaboration 2021 Data Challenge

G. Richards and W. Yu

We are announcing the LSST AGN Science Collaboration's 2021 Data Challenge. The purpose of this challenge is to help get more people involved in the work needed to do AGN science with the upcoming LSST data. For this purpose, we have produced a common exploratory dataset that can be used to develop tools for 1) parameterization of AGN light curves, 2) AGN selection, and 3) AGN photo-z. A panel of judges (consisting of the AGN SC leadership team and multiple members of other LSST science collaborations) will award prizes for derivative work that advances the goals of the LSST AGN SC and AGN science with LSST in general. We have LSSTC funding to award 1st, 2nd, and 3rd prizes of $2000, $1500, and $1000, respectively. In addition there is $5000 of funding for participation awards (10-20 at $250-$500) and $3000 for page charges to encourage publications that are derived from the competition. The deadline for submissions will be **17 September 2021**.

More details about the competition and the data set(s) available for your use can be found at https://github.com/RichardsGroup/AGN_DataChallenge.

Submissions would ideally be in the form of Jupyter notebooks, but the panel of judges will consider all reasonable submissions adhering to the following format:

1. Introduction (What is the main goal your submission addresses with the data challenge? Does this goal relate to items in the AGN SC roadmap? If not, should a new item be added to the AGN SC road map?)
2. Data (What data sets are you using for the challenge (see details about what data are available? Why do these data sets allow you to address your main goal?)
3. Methods (Describe your method to extract the information for your main goal from the data. What is innovative about your implementation/application of this method to the data?)
4. Results (Summarize your results. Include plots and statistics that illustrate your results. Discuss future improvements to the method or what future features could help to improve your results.)
5. Code (Provide enough code that your results can be confirmed and tested by the judges on a "blinded" subsample; see below. Prize winners will be required to make their code available to the AGN SC and/or broader LSST community.)

→

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The LSST AGN Data Challenge: Selection Methods

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Abstract

Development of the Rubin Observatory Legacy Survey of Space and Time (LSST) includes a series of Data Challenges (DCs) arranged by various LSST Scientific Collaborations that are taking place during the project's preoperational phase. The AGN Science Collaboration Data Challenge (AGNSC-DC) is a partial prototype of the expected LSST data on active galactic nuclei (AGNs), aimed at validating machine learning approaches for AGN selection and characterization in large surveys like LSST. The AGNSC-DC took place in 2021, focusing on accuracy, robustness, and scalability. The training and the blinded data sets were constructed to mimic the future LSST release catalogs using the data from the Sloan Digital Sky Survey Stripe 82 region and the XMM-Newton Large Scale Structure Survey region. Data features were divided into astrometry, photometry, color, morphology, redshift, and class label with the addition of variability features and images. We present the results of four submitted solutions to DCs using both classical and machine learning methods. We systematically test the performance of supervised models (support vector machine, random forest, extreme gradient boosting, artificial neural network, convolutional neural network) and unsupervised ones (deep embedding clustering) when applied to the problem of classifying/clustering sources as stars, galaxies, or AGNs. We obtained classification accuracy of 97.5% for supervised models and clustering accuracy of 96.0% for unsupervised ones and 95.0% with a classic approach for a blinded data set. We find that variability features significantly improve the accuracy of the trained models, and correlation analysis among different bands enables a fast and inexpensive first-order selection of quasar candidates.

Papers Assessing LSST Cadences for Scientific Projects

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Blazar Variability with the Vera C. Rubin Legacy Survey of Space and Time

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The LSST Era of Supermassive Black Hole Accretion Disk Reverberation Mapping

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Predicting Quasar Counts Detectable in the LSST Survey

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Abstract

The Legacy Survey of Space and Time (LSST), being conducted by the Vera C. Rubin Observatory, is a wide-field multiband survey that will revolutionize our understanding of extragalactic sources through its unprecedented combination of area and depth. While the LSST survey strategy is still being finalized, the Rubin Observatory team has generated a series of survey simulations using the LSST Operations Simulator to explore the optimal survey strategy that best accommodates the majority of scientific goals. In this study, we utilize the latest simulated data and the Metrics Analysis Framework to predict the number of quasars detectable by LSST in each band and evaluate the impact of different survey strategies. We find that the number of quasars and lower-luminosity active galactic nuclei (AGNs) detected in the baseline strategy (v4.3.1) in the redshift range $z = 0.3$–6.7 will be highest in the i band (about 12 million) and lowest in the u band (about 6 million). Over 70% of quasars are expected to be detected within the first year in all bands, as LSST will have already reached the break in the luminosity function at most redshifts. With a limiting magnitude of 25.7 (26.9) mag, we expect to detect 184 (199) million AGNs in the z band (r band) over the 10 yr survey, with quasars constituting only 6% of the total AGNs in each band. This arises because, considering that the luminosities of most low-luminosity AGNs are affected by contamination from their host galaxies, we set a magnitude threshold when predicting the number of quasars. We find that variations in the u-band strategy can impact the number of quasar detections. Specifically, the difference between the baseline strategy and that with the largest total exposure in u is 15%. In contrast, changes in rolling strategies, Deep Drilling Field strategies, weather conditions, and Target of Opportunity observations result in variations below 2%. These results provide valuable insights for optimizing approaches to maximize the scientific output of quasar studies.

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Astronomy & Astrophysics

Expectations for time-delay measurements in active galactic nuclei with the *Vera Rubin* Observatory★

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Reevaluating LSST's Capability for Time Delay Measurements in Quasar Accretion Discs

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ABSTRACT

The Legacy Survey of Space and Time (LSST) at the Vera C. Rubin Observatory is poised to observe thousands of quasars using the Deep Drilling Fields (DDF) across six broadband filters over a decade. Understanding quasar accretion disc (AD) time delays is pivotal for probing the physics of these distant objects. Pozo Nuñez et al. (2023) has recently demonstrated the feasibility of recovering AD time delays with accuracies ranging from 5% to 20%, depending on the quasar's redshift and time sampling intervals. Here we reassess the potential for measuring AD time delays under the current DDF observing cadence, which is placeholder until a final cadence is decided.

We find that contrary to prior expectations, achieving reliable AD time delay measurements for quasars is significantly more challenging, if not unfeasible, due to the limitations imposed by the current observational strategies.

LSST: how to get involved

- https://www.lsst.org/participate
- Attend Rubin Community Workshop (RCW)
- Join different science collaboration, e.g. AGN (does not ask for Data Rights Holder)

- Participate in Data Challenges
  - E.g. AGN Data Challenge, 2021 https://github.com/RichardsGroup/AGN_DataChallenge, Savic et al. 2022
  - MALLORAN MALLORN Astronomical Classification Challenge: Can you catch stars being torn apart by black holes? (https://www.kaggle.com/competitions/mallorn-astronomical-classification-challenge/data), De Bonis et al. in prep

SER-SAG In-kind contribution to the LSST

University Belgrade - Faculty of Mathematics & Astronomical observatory Belgrade → Data Rights for 6 PIs

Project Lead: Luka Popović

Project Manager: Dragana Ilić (1 PI)

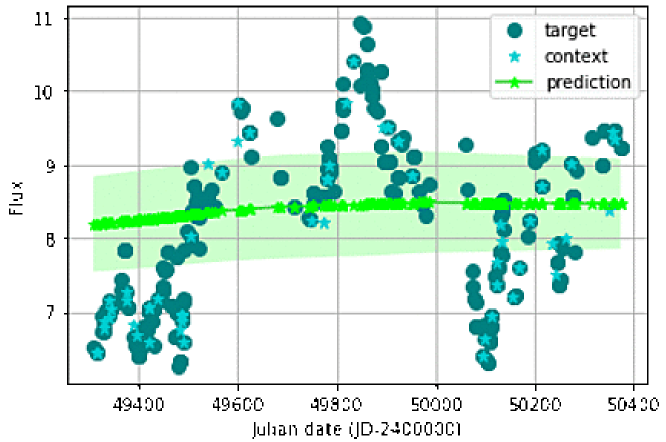
SER-SAG1: directable software contribution (MATF) - 4 PIs

Anđelka Kovačević (lead), https://github.com/LSST-sersag/

SER-SAG2: Telescope follow-up (AOB) – 1 PI

Maša Lakićević (lead)

Čvorović-Hajdinjak et al. 2022, 2024



Neural process modeling of quasar signals

Bob Blum, Director for Rubin Operations

“Participation of our outstanding Serbian colleagues in Rubin’s LSST is crucial to maximizing the impact of science we can do with the US led Legacy Survey of Space and Time.
Their contributions to analysis code and additional telescope resources will greatly enhance the tools and capabilities available to our community.”
September 2023

Bob Blum

☆ Agreement with AURA signed in 2025

We are grateful to the Rubin Observatory and LSST for the opportunity to be part of this ground-breaking observatory.