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Office of Science

Direktni softverski doprinos u in-kajnd formi sa Katedre za astronomiju Univerziteta u Beogradu (SER-SAG-S1), za Opservatoriju Vera C. Rubin (2020–2025)

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Matematički fakultet
Astronomska opservatorija Beograd



Modern observational methods in astronomy:

- Large telescopes on the ground
- Telescopes above the atmosphere (spacecrafts)
- Large sky surveys: digital sensor technology (CCD), information technology (data processing and data distribution), many objects observed at the same time



Modern astronomical surveys detect billions of objects: huge statistical power for studying the history and structure of the Universe

Why do we need another sky survey, such as LSST?

Is it worth the investment of 1,400,000,000 USD?

Credit: Launch Pad Astronomy (YouTube)



James Webb Space Telescope

Nancy Grace Roman Space Telescope

ELT: 40m TMT: 30m GMT: 30m LSST: 8m

LSST will be delivered by the Vera C. Rubin Observatory as its first, 10-year long project.



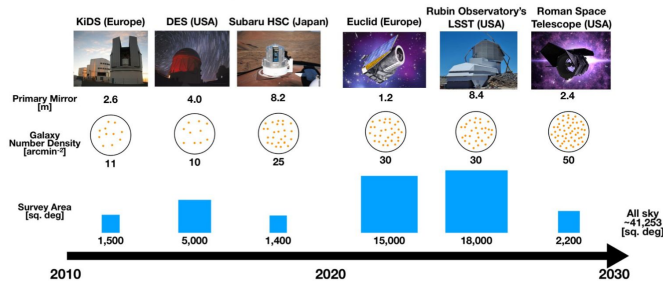
6



SLAC

Galaxy Imaging Surveys

Slide credit: Hironao Miyatake



Inspired by E. Krause Credit: ESO, Fermilab/Reidar Hahn, NAOJ, ESA/C. Carreau, Rubin Obs/NSF/AURA, NASA

LSST will not have the largest mirror but will have by far the largest the mirror area X the field-of-view size (etendue or throughput)



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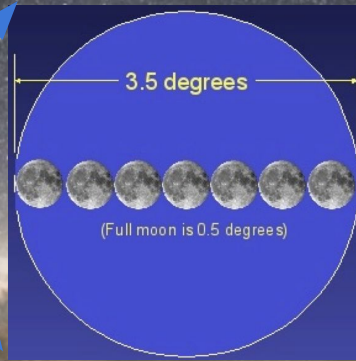
Office of Science

Rubin Science Assembly

[Acronyms & Glossary](#)

Every circle contains 10 million galaxies

Andy
Connolly
University
of WA

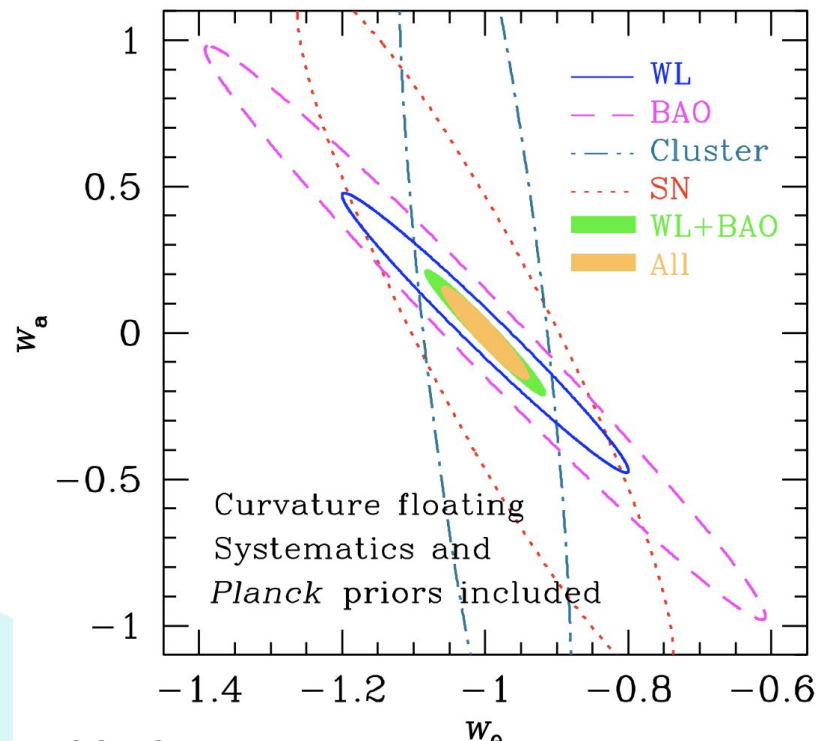


Science motivation for undertaking the Legacy Survey of Space and Time:

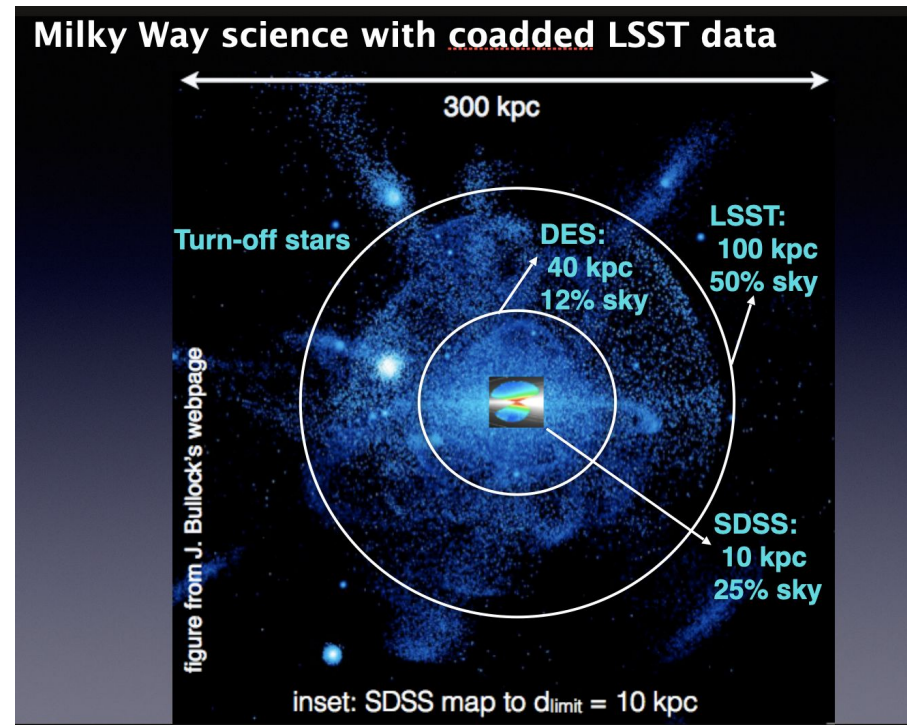
- Expansion and history of the Universe and the growth of structure
(dark matter, dark energy, cosmology, spatial distribution of galaxies, gravitational lensing, supernovae):
“Was Einstein right?”
- Time domain: what changes on the sky? (cosmic explosions, variable stars, unknown unknowns)
- The Solar System structure
(near-Earth hazardous asteroids, main-belt asteroids, trans-Neptunian objects, comets)
- The Milky Way structure
(stars as tracers of the structure and evolution of our Galaxy, interstellar matter, the physics of stars)

All these diverse goals addressed with essentially a single dataset!

By simultaneously measuring growth of structure and curvature, LSST data will tell us whether the recent acceleration is due to dark energy or modified gravity.



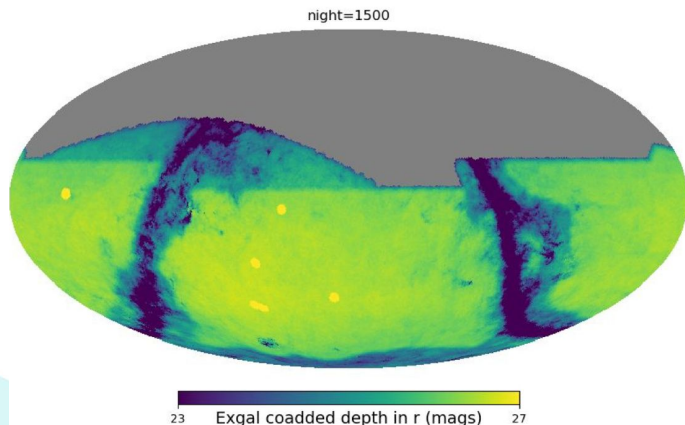
LSST Science Book 2020, figure 15.3



Ivezic+20

Basic idea behind LSST: A uniform sky survey.

- ~90% of time will be spent on a uniform survey: every 3-4 nights, the whole observable sky will be scanned twice per night
- after 10 years, half of the sky will be imaged about 1000 times (in 6 bandpasses, ugrizy): a digital color movie of the sky
- ~100 PB of data: about 2.5 million 3.2 Gpix images (visits), enabling measurements for 40 billion objects



10-year simulation of LSST survey: the number of visits in the r band (Aitoff projection of eq.

coordinates)



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SDSS-LSST comparison: $LSST = d(SDSS)/dt$, $LSST = SuperSDSS$

3x3 arcmin, gri

20x20 arcsec; lensed SDSS quasar
(SDSS J1332+0347, Morokuma et al. 2007)

SDSS

SDSS

LSST

(Subaru)

LSST

(Deep Lens Survey)

Visit: basic unit for data taking; baseline assumes a total exposure time per visit of 30 sec, split into two back-to-back exposures of 15 sec each

LSST in one sentence:

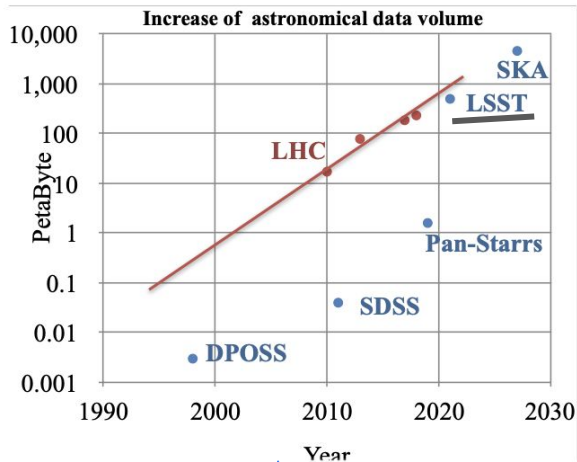
An optical/near-IR survey of half the sky in ugrizy bands to $r \sim 27.5$ (36 nJy) based on ~825 visits over a 10-year period: **deep wide fast.**

LSST will collect about 2.5 million visits. Each visit results in a 3.2 Gpix image of 9.6 sq.deg.

Getting ready for ...

Legacy Survey of Space and Time

IVEZIĆ et al. +19, ApJ



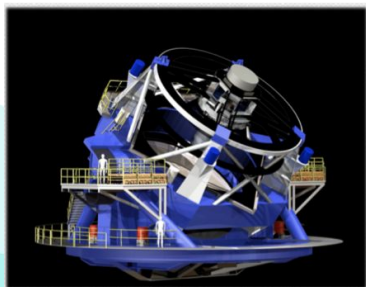
The telescope will produce the deepest, widest, image of the Universe:

- 8.4-m mirror, the width of a singles tennis court
- 3200 megapixel camera
- Each image the size of 40 full moons
- 37 billion stars and galaxies
- 10 year survey of the sky
- Up to 10 million alerts,
- 20 Terabytes of data .. every night!



$LSST = \int \text{Observatory} + \text{Telescope} + \text{Camera} + \text{Data Management System}$
= Fully Reduced Data

www.lsst.org



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LSST (images+catalogs)



Scientific discoveries

```
$ head -n 3 output/galaxy_catalog.dat
galtilid, objectId, raJ2000, decJ2000, redshift, u_ab, g_ab, r_ab, i_ab, z_ab,
222500350435, 222500350435, 199.56648010, -9.28911042, 0.87100780, 24.72078514,
222501392641, 222501392641, 199.57937323, -9.29996667, 0.70250392, 26.08153725,
```

catalogues

Rubin Science Assembly

[Acronyms & Glossary](#)

Announcements

rubinobservatory.org/news/lsst-camera-installed



- The LSST Science Camera has been installed on the telescope.

-Next steps - taking place now:

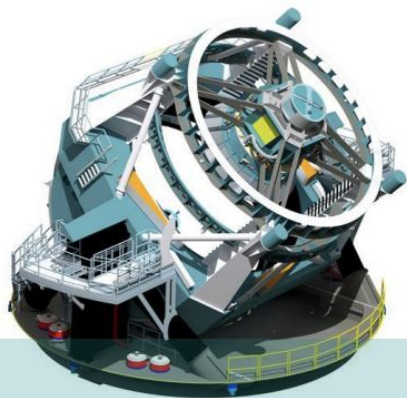
- * connecting the refrigeration system
- * hooking up power and data lines
- * alignment

Data Management System Vision

Raw Data: 20TB/night



Sequential 30s images covering the entire visible sky every few days



Access to proprietary data and the Science Platform require Rubin data rights



Prompt Data Products

Alerts: up to 10 million per night

Results of Difference Image Analysis (DIA): transient and variable sources

Solar System Objects: ~ 6 million

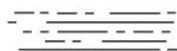
Data Release Data Products

Final 10yr Data Release:

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



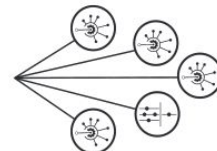
via nightly alert streams



via Prompt Products Database



via Data Releases



Community Brokers

Alert Filtering Service

Rubin DACs (USDF & Chile)

Independent DACs (iDACs)

Rubin Science Platform

Provides access to Rubin Data Products and services for all science users and project staff

Malagon +22

Rubin Science Platform (RSP)



PORTAL

NOTEBOOKS



WEB APIS



DATA RELEASES



ALERT FILTERING SERVICE



USER DATABASES



USER FILES



USER COMPUTING



SOFTWARE TOOLS

Rubin Observatory

Rubin Operations:
Sites & Data Flows

HQ Site Tucson, AZ

Science Operations
Observatory Management
Education & Public Outreach

Base Site La Serena, Chile

Base Center
Long-term storage (copy 1)
Data Access Center
Data Access & User Services

French Site
CC-IN2P3, Lyon, France
French Data Facility
Data Release Production
Long-term Storage (copy 3)

Rubin Observatory Data Facility

National Center for Supercomputing
Applications (NCSA), Urbana-Champaign, IL

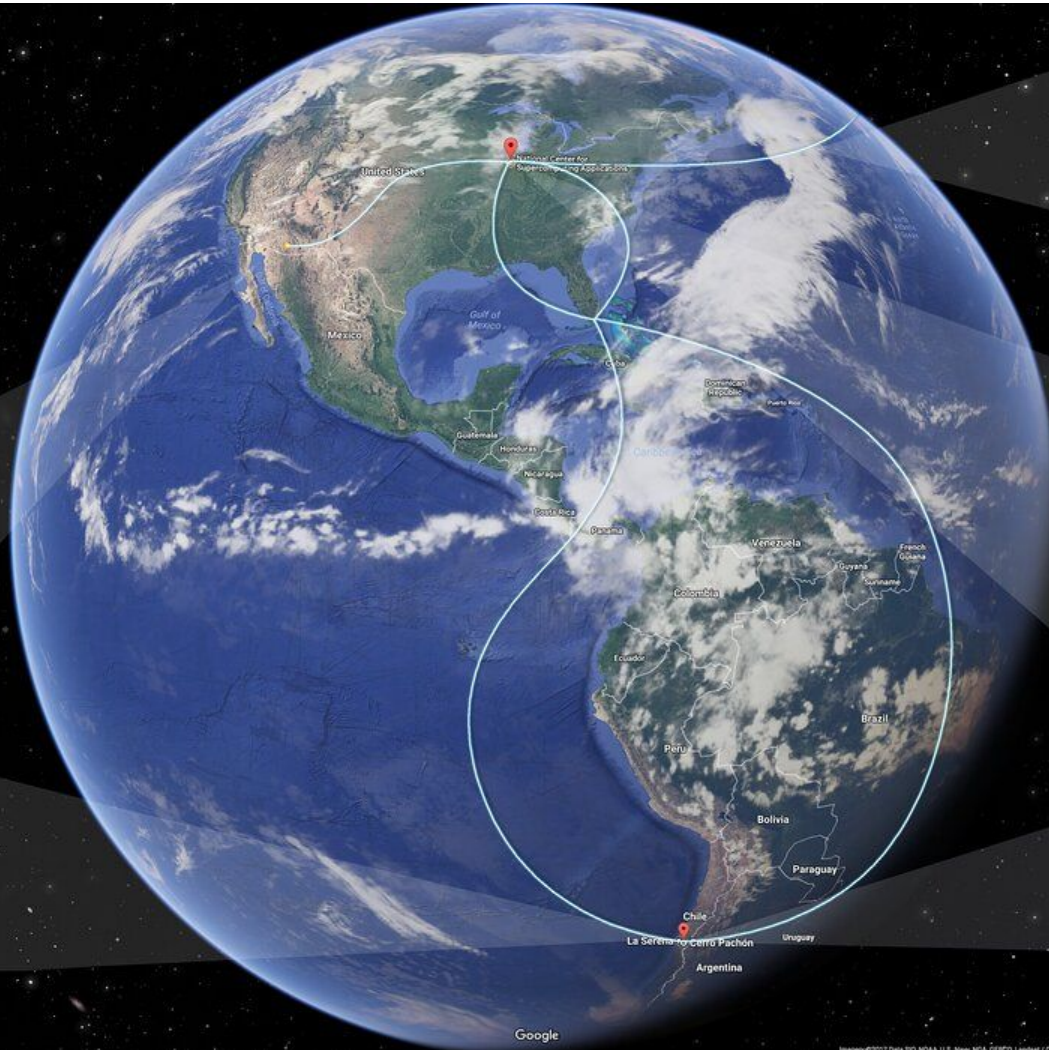
Processing Center

Alert Production
Data Release Production
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)

Data Access Center
Data Access and User Services

Summit Site Cerro Pachón, Chile

Telescope & Camera
Data Acquisition
Crosstalk Correction



This is a massive software development project

Software underpins all DM services: from hardware management and controlling data flows, through scientific pipelines and algorithms, to making data accessible to users.

The Rubin system undertakes a uniquely complex, systematics-limited, latency-sensitive process, which makes the quality of our software critical.

We have over one million lines of code & comments in a mixture of C++/Python/Java/JavaScript/Kotlin ([Jenness et al., Proc SPIE, 2018](#)).

Malagon +22

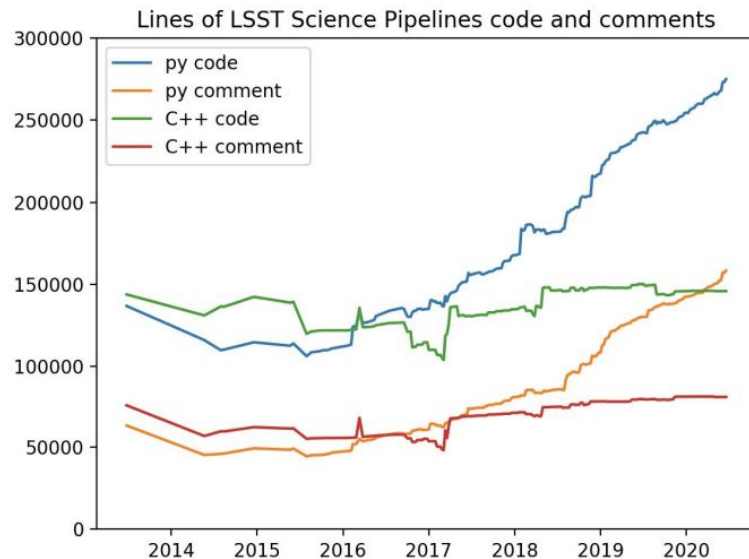
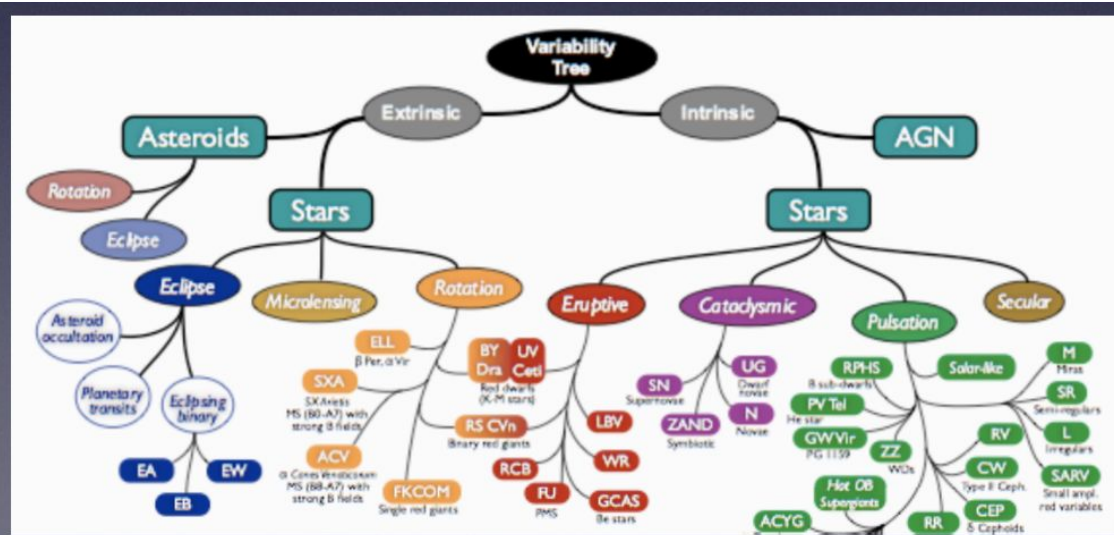


Figure courtesy Tim Jenness.
Based on the Science Pipelines codebase only.

"objects changing in time"

- a) fast: asteroids, comets
- b) slow: stellar proper motions

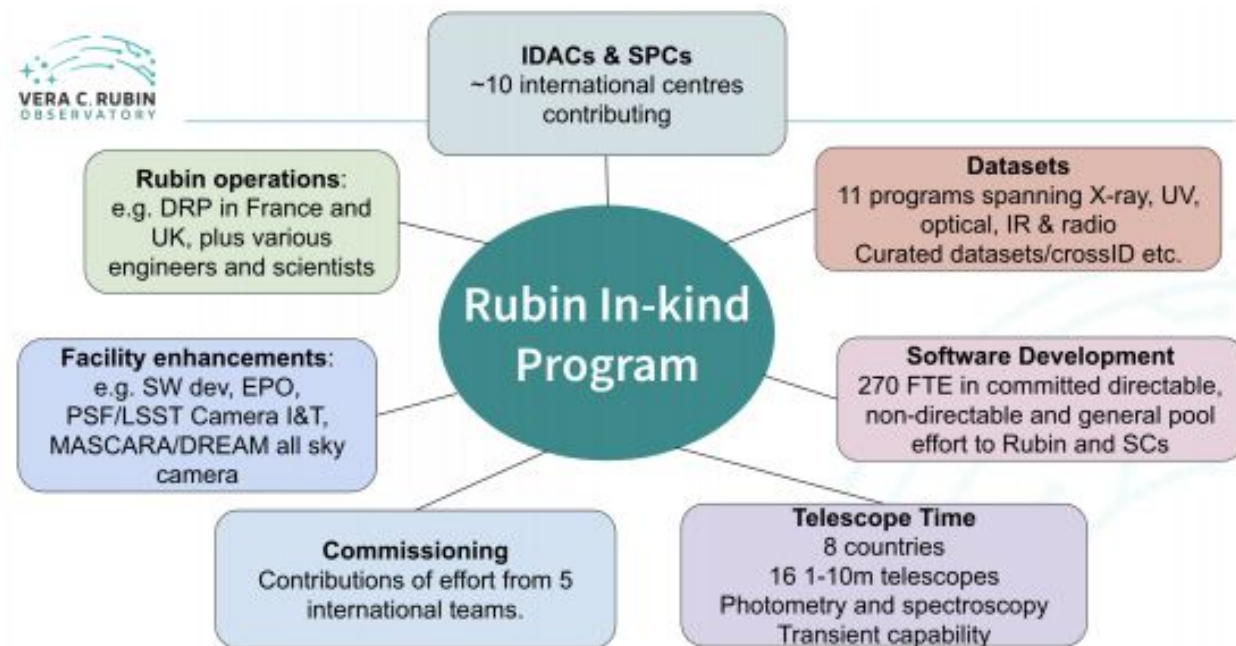
cosmic explosions, variable stars
(or periodic vs. irregular, etc.) and everything else



Eyer & Mowlavi 2007

What is the Rubin LSST In-kind Program?

43 teams outside the US and Chile are making in-kind contributions to Rubin Observatory and LSST Science in return for LSST data rights.



Proposal for
SER-SAG in-kind
LSST contribution

**to provide
access to
LSST data
rights**

submitted in
september 2020

Proposal Title: AOB's and UBMaTf's In-kind Contributions to the Vera C. Rubin Observatory Legacy Survey of Space and Time

Participating Institutions: Astronomical Observatory – Belgrade (AOB) and University of Belgrade - Faculty of Mathematics (UBMaTf)

Program Code: SER-SAG

Key Personnel:

Proposal Lead: Dr Luka C. Popovic

Email: ipopovic@aob.rs

Address: Astronomical Observatory - Belgrade, Volgina 7, Belgrade, Serbia

Program Manager: Dr Dragana Ilic

Email: dilic@matf.bg.ac.rs

Address: University of Belgrade - Faculty of Mathematics, Studentski trg 16, Belgrade, Serbia

Contribution Lead: Dr Masa Lakicevic

Email: mlakicevic@aob.rs

Address: Astronomical Observatory - Belgrade, Volgina 7, 11000 Belgrade, Serbia

Contribution Lead: Dr Andjelka Kovacevic

Email: andjelka@matf.bg.ac.rs

Address: University of Belgrade - Faculty of Mathematics, Studentski trg 16, Belgrade, Serbia



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Acronyms & Glossary

Letter of Interests

Rubin Observatory

950 N. Cherry Avenue,
Tucson, AZ 85719.
www.lsst.org

Luka Popovic,
Serbia SAGNT Proposal Team.
Program Code: SER-SAG

Friday July 31, 2020

Feedback on your Rubin LSST in-kind contribution ideas

Dear Luka,

The Rubin Legacy Survey of Space and Time (LSST) International In-kind Contribution Evaluation Committee (CEC) has completed its evaluation of your Letter of Intent (LOI), and has prepared some brief feedback for you to help you prepare a full proposal for LSST data

LOI Code	Contribution Title	CEC/Rubin Priority	Contribution Feedback
SER-SAG-1	Software for analysis of variability of celestial sources	(2) Medium	The CEC recommends you develop and include this contribution in your proposal, if your funding constraints require it. The contribution would fall under the category of “non-directable” effort since the software is offered “as is” incorporating methods developed by the proposing team. We strongly suggest to develop the proposed contribution together with the targeted Science Collaboration to receive endorsement of the final proposal. Based on feedback from the AGN SC, while some of the features of the packages may be of broader interest, a full proposal should be developed under close guidance of the SC, particularly with respect to the methodology, software design, and output. The recipient group expected for this contribution is the LSST AGN Science Collaboration, please do work with them as you develop your proposal.
SER-SAG-2	Optical follow-up of bright LSST transients	(2) Medium	The CEC recommends you develop and include this contribution in your proposal, if your funding constraints require it. Though these facilities offer limited visibility of LSST sources, their potential could be enhanced by exploring networking options via AEON. Indeed, Rubin expects all observing time at facilities with apertures less than 4-m to be contributed to the AEON network. The recipient group expected for this contribution is the NOIRLab Observatories and the AEON network, please do work with them



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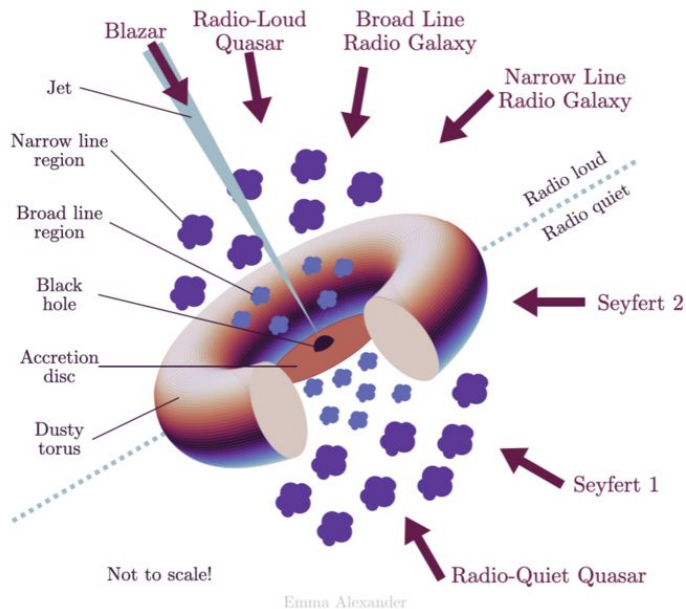
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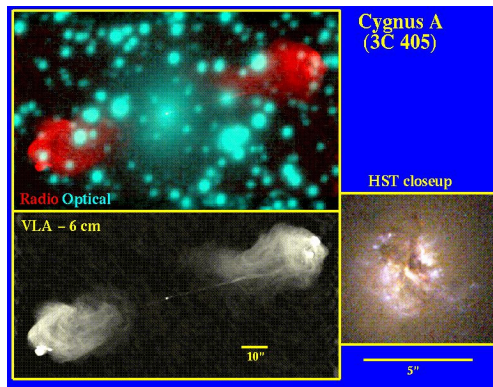
Rubin Science Assembly

[Acronyms & Glossary](#)

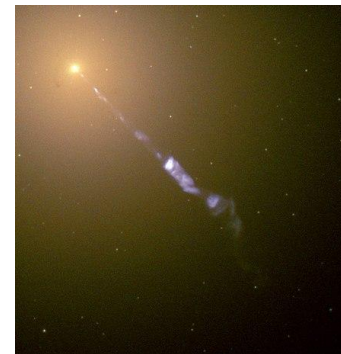
Taxonomy of AGN



- The difference between the “Broad line (or “Seyfert type 1”) and “Narrow line” (“Seyfert type 2”) AGN can be explained by the orientation of the system to our line of sight
- When observed perpendicular to the axis of symmetry - the broad line emission is absorbed by the dusty torus surrounding the nucleus



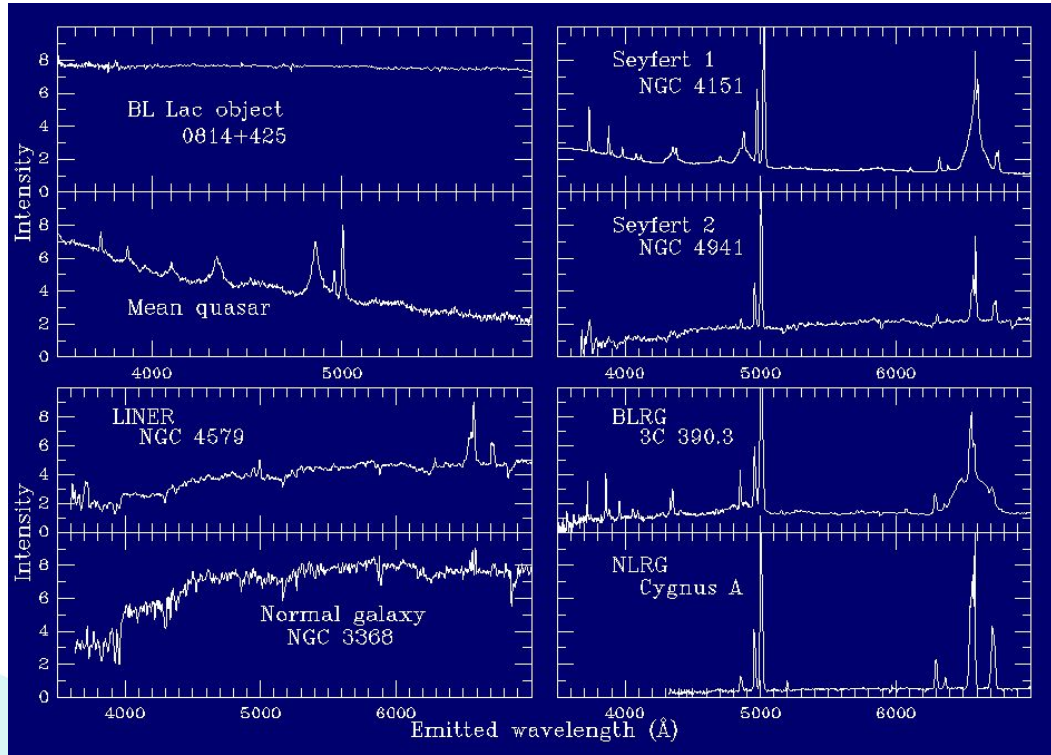
Some, but not AGN show powerful radio emission often in a form of relativistic jet



Optical image of M87 revealing its jet

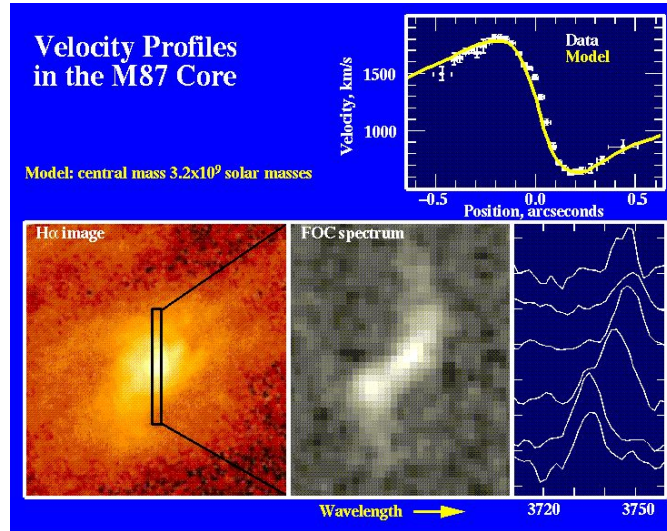
Various classes of AGN

Optical spectra of active galactic nuclei

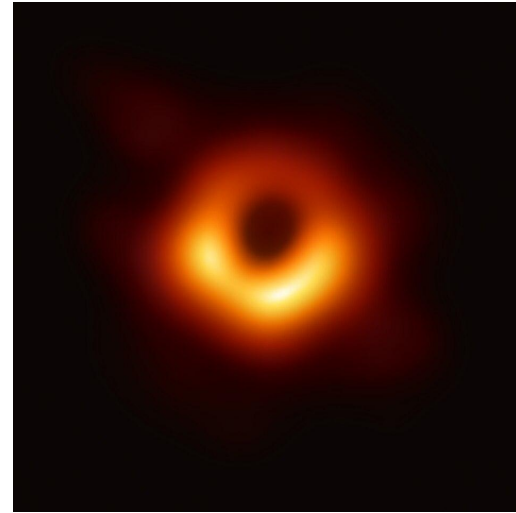


- Most if not all AGN show prominent emission lines allowing the determination of redshift and thus their distance
- The luminosity of the compact nucleus can be greater than the host galaxy, often reaching 10^{46} erg/s in the optical / UV

Line of evidence for a black hole in AGN



Hubble Space Telescope data



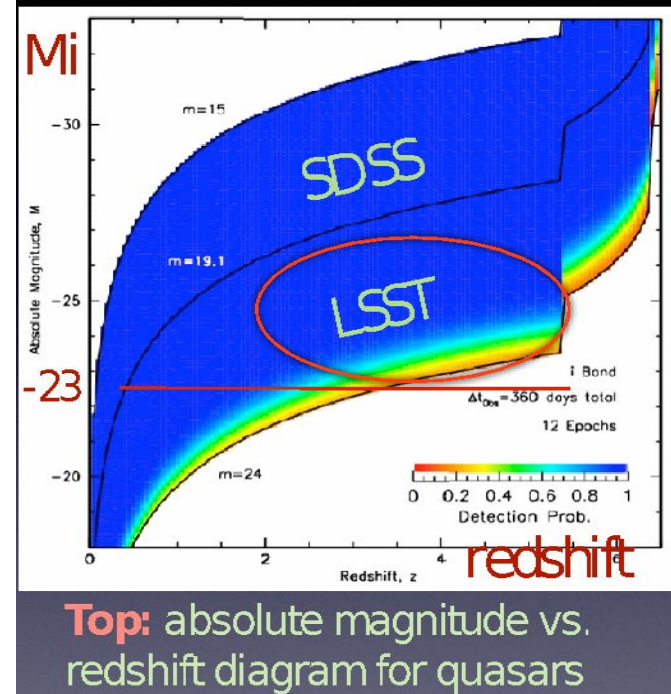
Event Horizon Telescope data: “shadow of the black hole”

Positionally-resolved optical spectroscopy, and radio imaging of circum-nuclear gas around the nucleus of M87:

- Requires compact and massive ($\sim 3 \times 10^9$ Solar masses) central object

AGN within the LSST

- discovery about 10 million quasars
 - based on colors, variability, lack of proper motion
 - detection of $\sim 10,000$ quasars at $6 < z < 7.5$
- 5 Deep Drilling Fields (DDFs):
 - COSMOS, XMM-LSS, ECDFS, ELAIS-S1, EDFS
- AGN Variability – based on million of light curves with 1000 epochs over 10 years

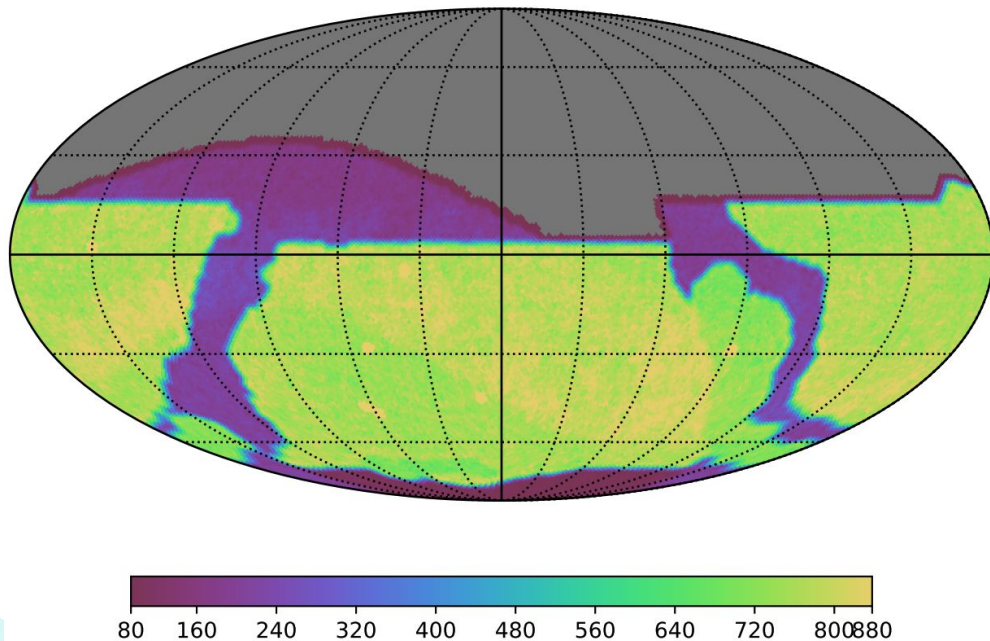


Learn more through AGN Science Collaboration

@<https://agn.science.lsst.org>

The Legacy Survey of Space and Time (LSST)

Observing Strategy Simulation v4.2



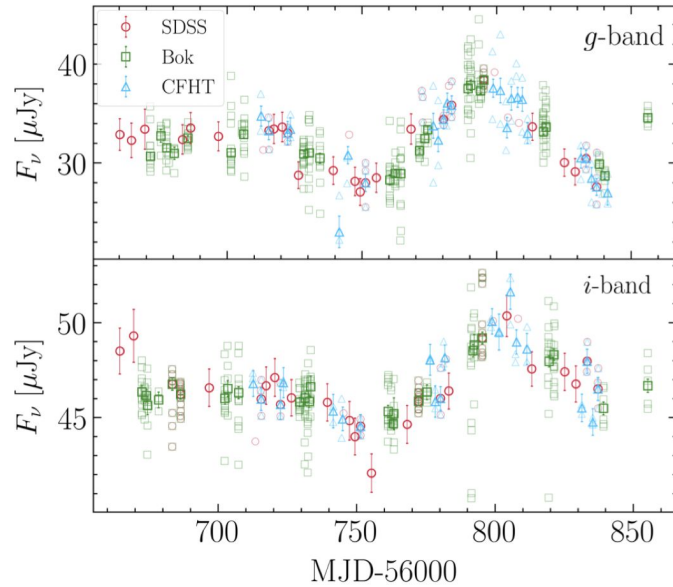
Number of observations at 10 years in all filters *ugrizy*

LSST will contribute to AGN studies primarily by its:

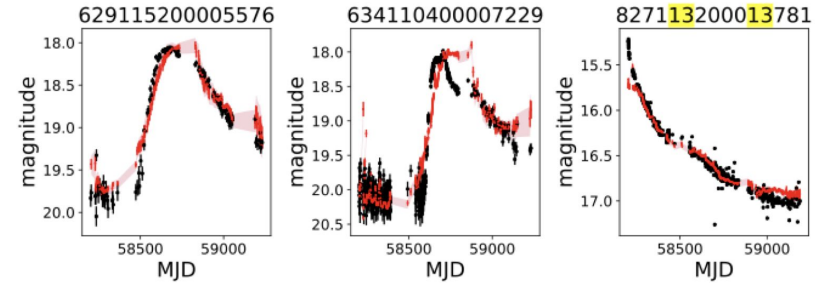
1. Large volume
2. Fast cadence multi-band time series events

Rolling cadence and target-of-opportunity (ToO) observations will be adopted, with details to be determined (ls.st/pstn-056)

Variability Studies

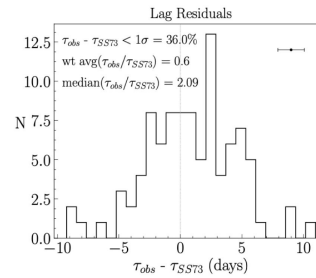


Accretion disk reverberation mapping.
(Homayouni et al. 2019)



Sánchez-Sáez et al. 2021

Anomalous variability events.



Periodic variability?

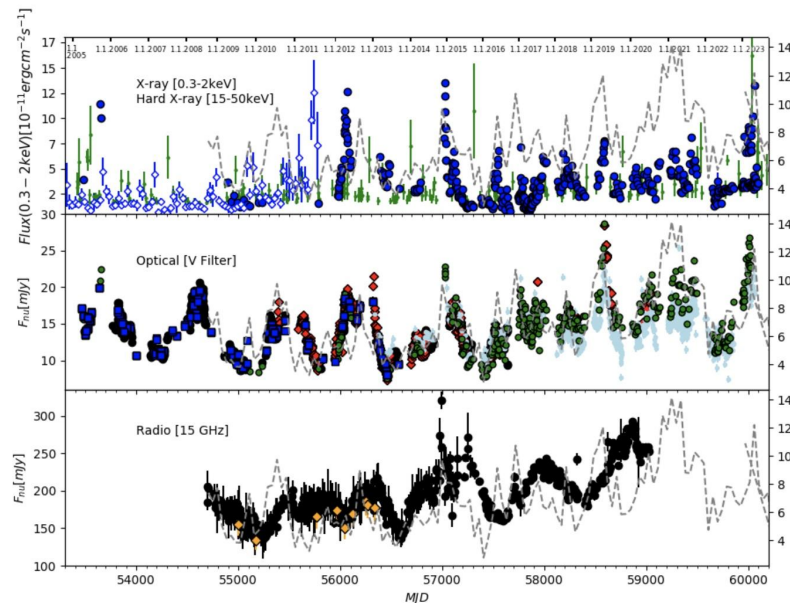
Rapid formation of supermassive black holes at high redshifts is a mystery!

- hard to grow a black hole rapidly

One viable scenario is a growth of black holes in the early Universe via mergers

Before a merger, a binary black hole should reveal nearly-strictly-periodic variability of flux (ending in a “chirp”)

Long time series obtained with Rubin could be able to discover such periodic emission from binary black holes



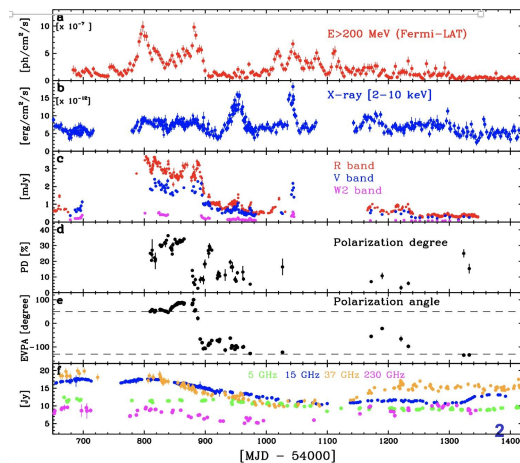
Multi-band light curve of a possibly periodic AGN - PG 1553, Abdollahi et al., [arXiv:2501.08015](https://arxiv.org/abs/2501.08015)

Multi-wavelength variability

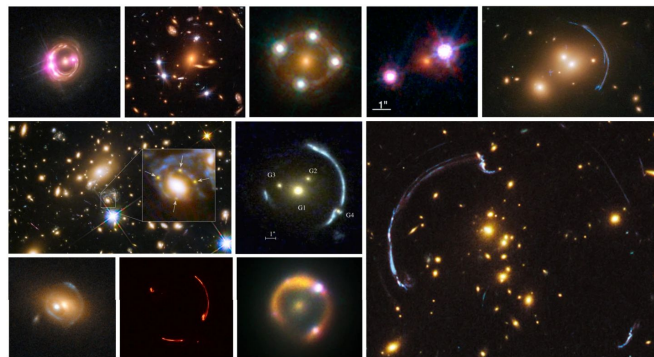
“Radio-quiet” AGN show emission in optical, UV, and X-rays

“Radio-loud” AGN, in addition, radiate in radio, X-ray, and gamma-ray bands

Flux variability in all bands is a common characteristic of AGN

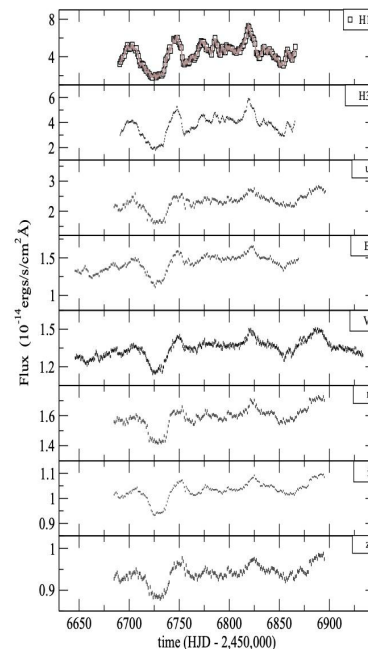


Multi-band light curve of a jet-dominated, “radio-loud” AGN 3C279 (Hayashida et al., arXiv:1502.04699)



When a quasar is gravitationally lensed resulting in multiple images, the time-delay of multiple light curves can constrain the Hubble constant (Melissa’s Assembly of March 27)

4 Panagiotou et al.



Multi-band opt/UV light curve of a radio-quiet AGN NGC 5548 (Panagiotou et al. arXiv:2009.09693)

SER-SAG In-kind contribution to the LSST

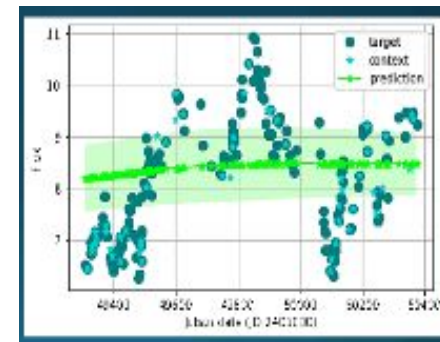
University Belgrade - Faculty of Mathematics and Astronomical
observatory Belgrade, Data Rights for 6 PIs

Project Managers: Luka Popović, Dragana Ilić

**4PI-SER-SAG1: directable software contribution
(MATF):**

Anđelka Kovačević (lead), Sasa Simić, Mladen Nikolić

SER-SAG2: Telescope follow-up (AOB): Maša Lakićević (lead)



Neural process modeling of
quasar signals



MATΦ
University of Belgrade
Faculty of Mathematics

150
MATΦ
Година
Универзитет у Београду
Математички факултет





Administrative update: IDRA signed by Rubin, AURA, SER-SAG

We thank to all institutions, Rubin
Observatory, AGNSC, TVSSC

Jan-2025

INTERNATIONAL CONTRIBUTIONS AND DATA RIGHTS AGREEMENT

FOR

VERA C. RUBIN OBSERVATORY

(HEREINAFTER "ICDR AGREEMENT," "IDRA," or "Agreement") NO. R0013

BY AND AMONG

ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY, INC.

(HEREINAFTER "AURA")

AND

ASTRONOMICAL OBSERVATORY,
UNIVERSITY OF BELGRADE, FACULTY OF MATHEMATICS (DEPARTMENT OF ASTRONOMY)

(HEREINAFTER "PARTICIPANT")

AURA AND PARTICIPANT COLLECTIVELY REFERRED TO

AS THE "PARTIES" AND SEPARATELY AS A "PARTY"



VERA C. RUBIN
OBSERVATORY



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

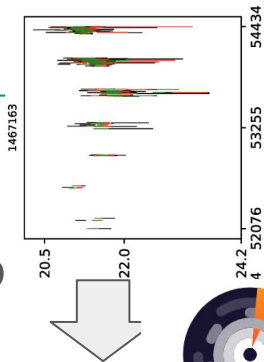


Agreement with AURA has been finalized!



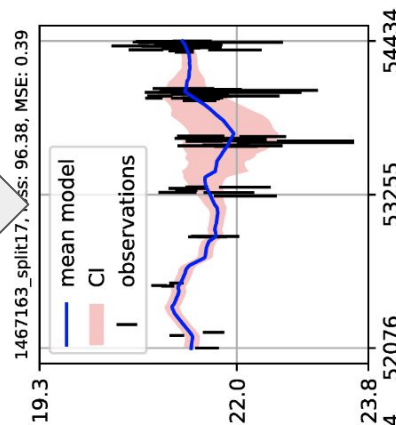
Neural Process Probabilistic Modeling + Nonlinear Analysis of Periodic Quasar Light Curves

Input light curves



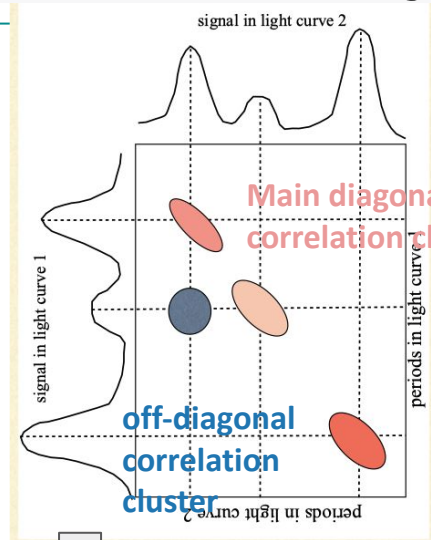
A. Direct analysis

B. Single shot learning



Kovačević et al. 2023

Output: Database of modeled light curves



Non linear
2D Hybrid
method for
periodic
variability
analysis

Output:
Database of
flagged
periodic
objects

	name	m3	m4	m5	m6	m7_1	m7_2	iou	classification
14	6.141570	252.525253	8.159090	0.879751	1.0	12.0	13.0	0.993552	reliable
16	6.141589	252.525253	10.017668	1.688906	1.0	12.0	13.0	0.991405	reliable
21	6.141618	260.586319	6.278084	1.863829	1.0	12.0	13.0	0.998226	reliable
29	6.141865	269.179004	15.195377	1.405620	1.0	12.0	13.0	0.990652	reliable
47	6.142591	252.525253	7.947057	1.096532	1.0	12.0	13.0	0.991234	reliable
...
2311	6.163502	184.162063	9.265578	2.366355	1.0	13.0	12.0	0.998042	reliable
3191	6.164730	192.864031	12.328656	4.242182	1.0	13.0	14.0	0.993799	reliable
3313	6.142214	260.586319	18.112149	0.459091	1.0	14.0	12.0	0.999122	reliable
3790	6.158829	278.357690	7.566145	4.420626	1.0	14.0	12.0	0.995612	reliable
4428	6.151545	278.357690	26.301400	2.858240	1.0	14.0	13.0	0.993991	reliable

Cvorović-Hajdiniak et al. 2022

Software availability

QhX

Project description

QhX: Quasar harmonics eXplorer

Python CI Workflow passing pages-build-deployment passing

Framework for 2D Hybrid Method.



QhX 0.2.0

`pip install QhX` 



[Latest version](#)

Released: Nov 17, 2024

JOSS Submitted

QNPpy two flavours

Project description

Conditional neural process
QNPpy Documentation



[Latest version](#)

Released: Mar 25, 2024

Project description

QNPpy_Latte **Attentive Latent NP**

Latent ATTentive Neural Processes for Quasar Light Curves with parametric recovery

By Aman Nadimpalli Raju, Andjelka Kovacevic, Marina Pavlovic, Dragana Ilic, Iva Cvorovic-Hajdinjak (SER-SAG-S1 team)



[Latest version](#)

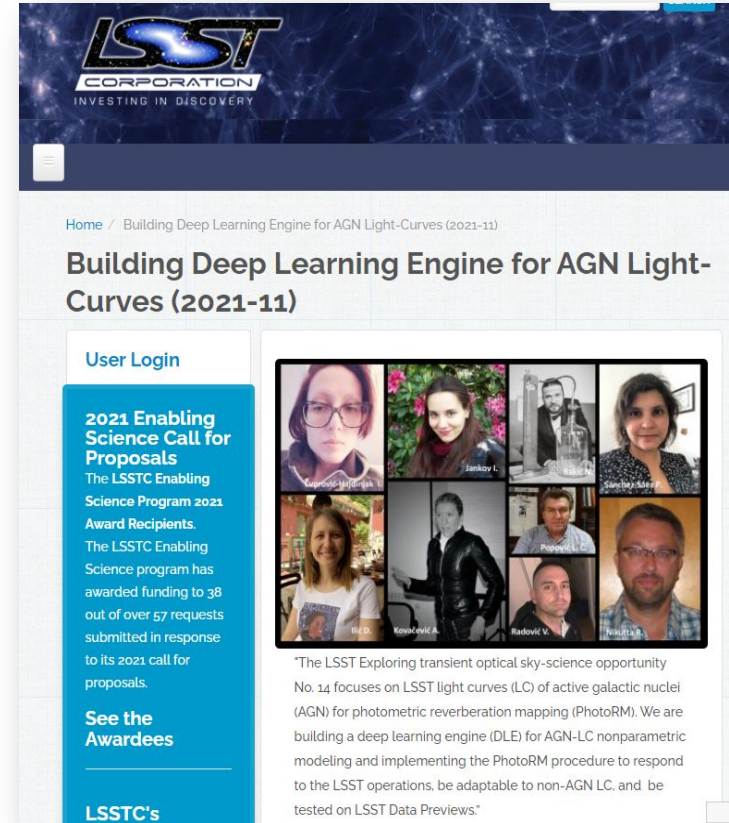
Released: Oct 24, 2024



- Developing deep learning engines (DLEs) for non-parametric modeling and extracting of information from AGN light-curves



- support for student research for 10 months in 2021-2022
- Publicly available Jupyter notebooks as final products
- <https://github.com/LSST-sersag/dle>

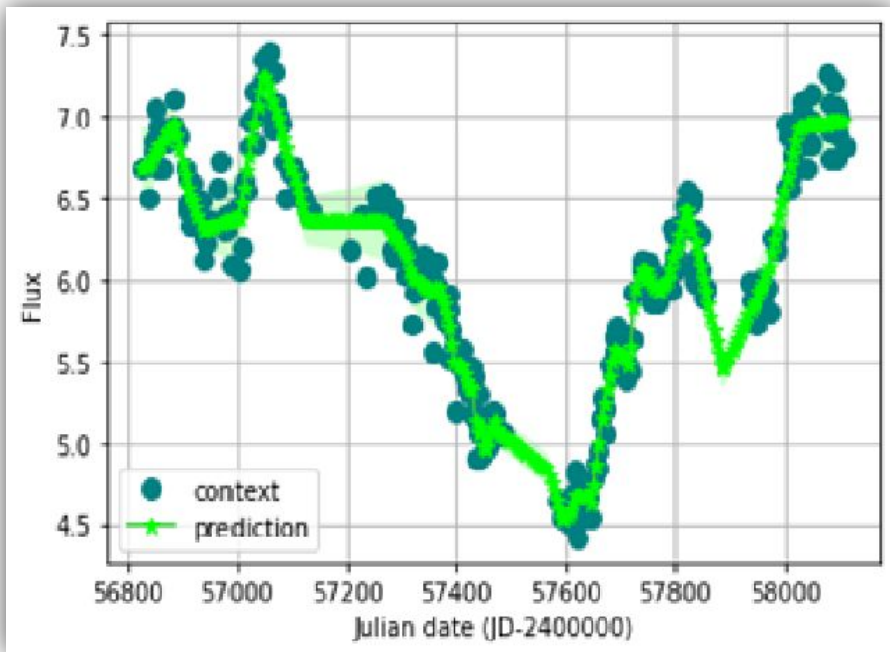




Two projects --> papers published



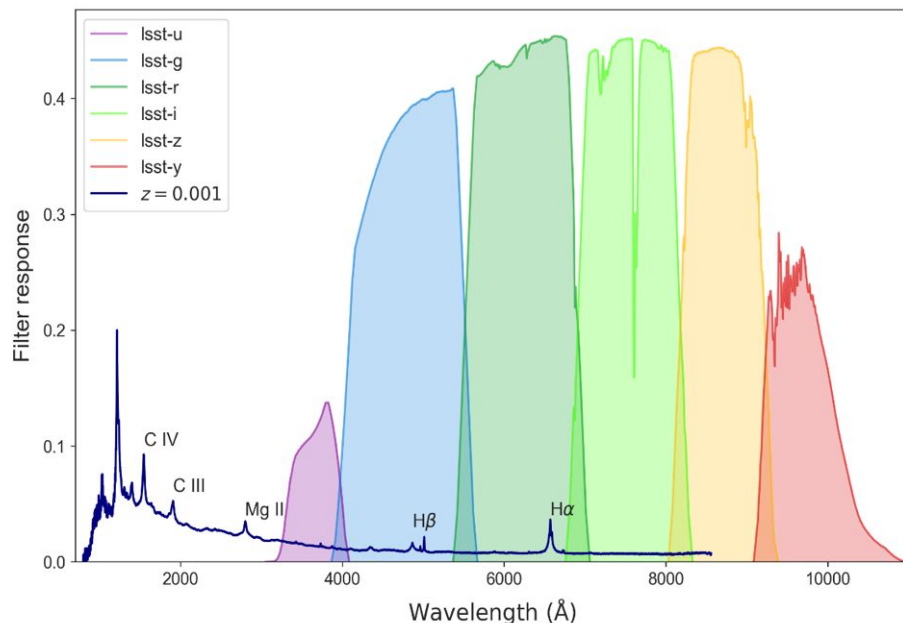
DLE subtask 1 (DLE1): LC nonparametric modeling (Conditional Neural Process)



Learned LC will enable us to improve time-lag determination as a goal of PhotoRM.



DLE subtask 2 (DLE2): photometric reverberation mapping (PhotoRM)



New tools for PhotoRM based on the formalism by Chelouche & Daniel (2012).



SER-SAG-S1 Publications

OPSIM EVALUATION

Andjelka B Kovačević, Dragana Ilić, Luka Č Popović, Viktor Radović, Isidora Jankov, Ilsang Yoon, Neven Caplar, Iva Čvorović-Hajdinjak, Saša Simić, On possible proxies of AGN light-curves cadence selection in future time domain surveys, *Monthly Notices of the Royal Astronomical Society*, Volume 505, Issue 4, August 2021, Pages 5012–5028, <https://doi.org/10.1093/mnras/stab1595>

Kovacevic, Andjelka, Ilic, Dragana, Jankov, Isidora, Popovic, Luka C., Yoon, Ilsang, Radovic, Viktor, Caplar, Neven, and Cvorovic-Hajdinjak, Iva: LSST AGN SC Cadence Note: Two metrics on AGN variability observable. https://docushare.lsst.org/docushare/dsweb/Get/Document-37645/Cadence_Notes-AGN_var.pdf

Kovacevic A.-B., Radovic V., Ilic D., Popovic L. C., Assef R.-J., Sanchez-Saez P., Nikutta R., et al. *The LSST Era of Supermassive Black Hole Accretion Disk Reverberation Mapping*, *ApJS*, 2022, 262, 49

LINCC White Paper: From Data to Software to Science with the Rubin Observatory LSST: Deep Learning of LSST Light curves:

SER-SAG; Conditional Neural Processes for learning AGN light curves

SER-SAG: Developing machine learning methods for AGN selection and calculating photometric redshift

LSST AGN SC Data Challenge

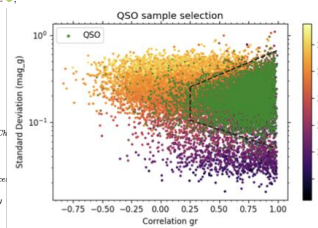
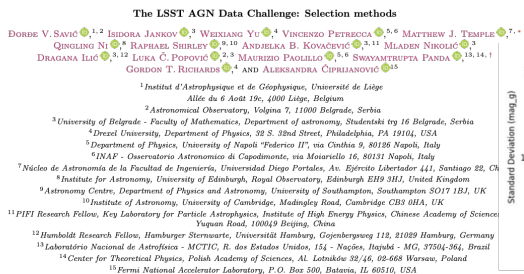


Figure 7. Standard deviation of the light curves vs. $g-r$ band correlation for a random sample of sources. Points are color-coded according to the g -band average magnitude. The black dashed lines define the *wedge* where QSOs (green points) tend to group.

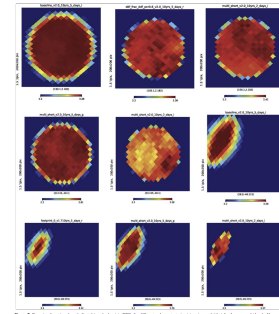


Figure 8. AGN light curve cadence selection. The color bar indicates the magnitude of the light curve.

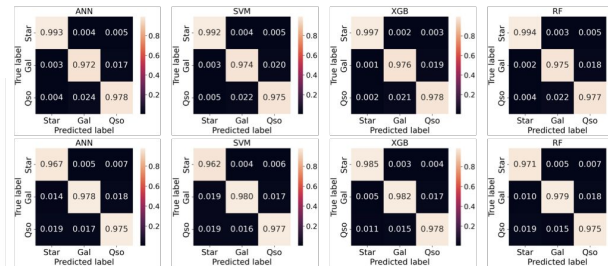


Figure 9. Confusion matrices for each method normalized by purity for tabular data. From left to right: ANN, SVM, XGB, RF. Upper panels were computed on a test set, while lower panels were computed for a blinded set. True labels are placed on vertical axis, while the predicted labels are on the horizontal axis.

ABSTRACT

The Rubin Observatory Legacy Survey of Space and Time (LSST) development comprises a series of Data Challenges (DC) arranged by various LSST Scientific Collaborations (SC) that take place during the project's preoperational phase. The AGN Science Collaboration Data Challenge (AGNSC-DC) is a partial prototype of the expected LSST AGN data, aimed to validate various machine learning approaches for AGN selection and characterization in large surveys. AGNSC-DC took part in 2021 focusing on accuracy, robustness and scalability. The training datasets were constructed to mimic the future LSST release catalogs using the publicly available data from the Sloan Digital Sky Survey Stripe 82 region and the XMM-Newton Large Scale Structure Survey region, with data features divided into astrometry, photometry, color, morphology, redshift, variability and class label.



THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 262:49 (37pp), 2022 October






















<https://doi.org/10.3847/1538-4365/ac88ce>

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The LSST Era of Supermassive Black Hole Accretion Disk Reverberation Mapping

Andjelka B. Kovačević^{1,2} , Viktor Radović¹ , Dragana Ilić^{1,3} , Luka Č. Popović^{1,4} , Roberto J. Assef⁵ ,
Paula Sánchez-Sáez^{6,7} , Robert Nikutta⁸ , Claudia M. Raiteri⁹ , Ilsang Yoon¹⁰ , Yasaman Homayouni¹¹ , Yan-Rong Li¹² ,
Neven Caplar¹³ , Bozena Czerny¹⁴ , Swayamtrupta Panda^{14,15,16} , Claudio Ricci^{17,18} , Isidora Jankov¹, Hermine Landt¹⁹,
Christian Wolf^{20,21} , Jelena Kovačević-Dojčinović⁴ , Maša Lakićević⁴ , Đorđe V. Savić^{4,22} , Oliver Vince⁴, Saša Simić²³ ,
Iva Čvorović-Hajdinjak¹, and Sladjana Marčeta-Mandić⁴ 

LSST AGN Classification Data Challenge DL-winner D. Savić

THE ASTROPHYSICAL JOURNAL, 953:138 (15pp), 2023 August 20












<https://doi.org/10.3847/1538-4357/ace31a>

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The LSST AGN Data Challenge: Selection Methods

Đorđe V. Savić^{1,2} , Isidora Jankov³ , Weixiang Yu⁴ , Vincenzo Petrecca^{5,6} , Matthew J. Temple^{7,16} , Qingling Ni⁸ ,
Raphael Shirley^{9,10} , Andjelka B. Kovačević^{3,11,17} , Mladen Nikolić³ , Dragana Ilić^{3,12,18} , Luka Č. Popović^{2,3} ,
Maurizio Paolillo^{5,6} , Swayamtrupta Panda^{13,14,19} , Aleksandra Ćiprijanović¹⁵ , and Gordon T. Richards⁴ 

Time Evolution of Mg II in SDSS J2320+0024: Implications for a Subparsec Binary Supermassive Black Hole System

Marta Fatović^{1,2,3} [★], Dragana Ilić^{4,5} , Andjelka B. Kovačević^{4,6} , Lovro Palaversa² , Saša Simić⁷ , Luka Č. Popović^{4,6,8} , Karun Thanjavur⁹ , Oleksandra Razim² , Željko Ivezić¹⁰ , Minghao Yue^{11,12} , and Xiaohui Fan¹² 

Accepted in A&A, follow-up case study for LSST

Updates@AGNSC subgroups by :Marta Fatovic, ITA-CRO, Sasa Simic, SER-SAG-S1

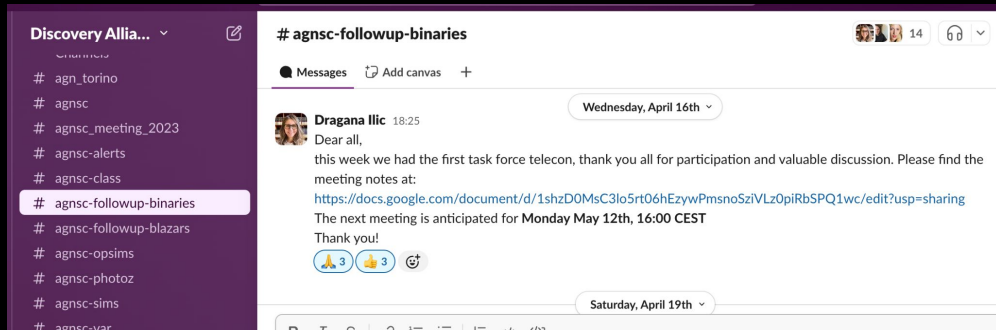
QNPY Raju et al. submitted

¹ QhX: A Python package for periodicity detection in red
² noise **JOSS submitted**

³ Andjelka B. Kovačević ^{1*}†, Dragana Ilić ¹, Momčilo Tošić^{1*}, Marina
⁴ Pavlović ², Aman Raju ¹, Mladen Nikolić ¹, Saša Simić ³, Iva Čvorović
⁵ Hajdinjak ¹, and Luka Č. Popović ⁴

⁶ 1 University of Belgrade-Faculty of Mathematics, Studentski trg 16, Belgrade, Serbia 2 Mathematical
⁷ Institute of Serbian Academy of Science and Arts, Serbia 3 University of Kragujevac-Faculty of Natural
⁸ Sciences, Serbia 4 Astronomical Observatory, Belgrade, Serbia † Corresponding author * These authors
⁹ contributed equally.

SUPPORTING FOLLOW-UPS-D.ILIC COLEADER OF AGN SC follow up subgroup



noirlab-gemini-prop-25a

@Suhail Dhawan created this channel on February 4th. This is the very beginning of the **# noirlab-gemini-prop-25a** channel. Discussions for NOIRLab Survey Proposals and Gemini Large/Long Program proposals beginning in 2025.



Dragana Ilic Friday at 17:13

We suggest to include some best short-period close-binary supermassive black holes candidates discovered in the 1st year (see e.g., example study that used Gemini data,

<https://ui.adsabs.harvard.edu/abs/2021MNRAS...501.16877I>

SER-SAG-S1 effort in follow up lead

Rubin (LSSTCam) First Photon- April 15th 2025, THE LSST CONTROL ROOM



Marina Pavlovic,
former SER-SAG-S1
member, now LSST
Commissioning
scientist

across the focal plane, a median image quality of about 1.8 arcsec FWHM, before any detailed tuning with the active optics system (AOS). The Data Management system successfully transported and processed the 3-gigapixel images at the US Data Facility within about a minute of acquisition.



Rubin Observatory Construction
director Zeljko Ivezic, visited
Department of astronomy in
January 2024



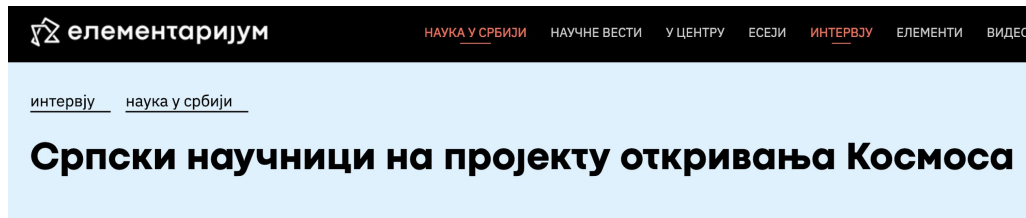
CPG in-kind lead manager Lovro
Palaversa, visited Department of
astronomy in January 2024

Outreach and Community Engagement

February 2024: Two articles in the journal of the Ministry of Science - *Elementarium*:

- LSST, Zeljko Ivezic interview:
<https://elementarium.cpn.rs/intervju/popularizacija-nauke-je-vazan-deo-projekta/>
- SER-SAG contribution, Luka Popovic, Dragana Ilic and Andjelka Kovacevic:
<https://elementarium.cpn.rs/intervju/srpski-naucnici-na-projektu-otkrivanja-kosmosa/>

Organizing LSST@Europe conference series (2016 Belgrade, 2022 Rome, 2023 Porec, 2024 La Palma)



Истраживачи са Математичког факултета и Астрономске опсерваторије Београд ће током наредне деценије учествовати на великом међународном пројекту LSST, који би требало да реши мистерију тамне материје и тамне енергије



MILESTONES: CRO-CPG+SER-SAG-S1



MILESTONES: CRO-CPG+SLO+SER-SAG



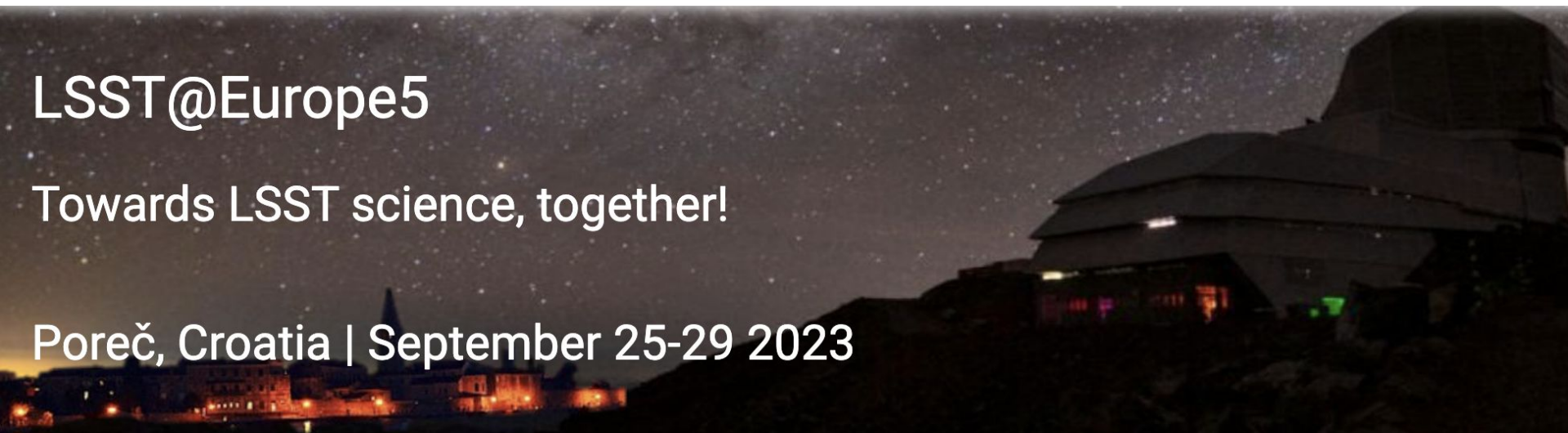
[Registration ▼](#) [Venue & accomodation](#) [Speakers](#) [Programme](#) [Observatories workshop](#) [SOC/LOC](#) [Abstracts](#) [Registration & support](#) [Location](#)

[Social events](#) [For speakers and posters](#) [For chairs](#) [Code of Conduct](#) [Travel info](#)

LSST@Europe5

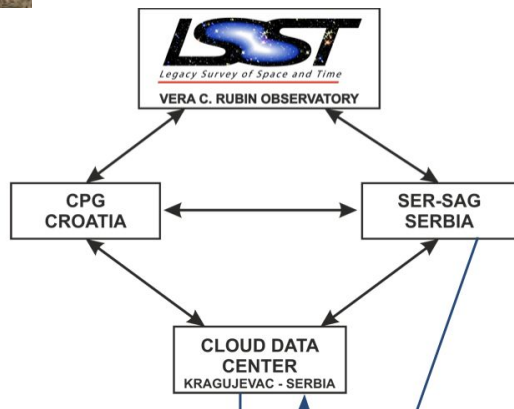
Towards LSST science, together!

Poreč, Croatia | September 25-29 2023





Cooperation with CPG in-kind team



SPECIFICATION OF COMPUTE SERVICE:

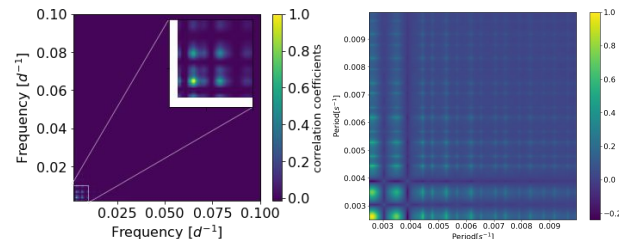
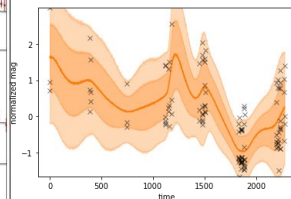
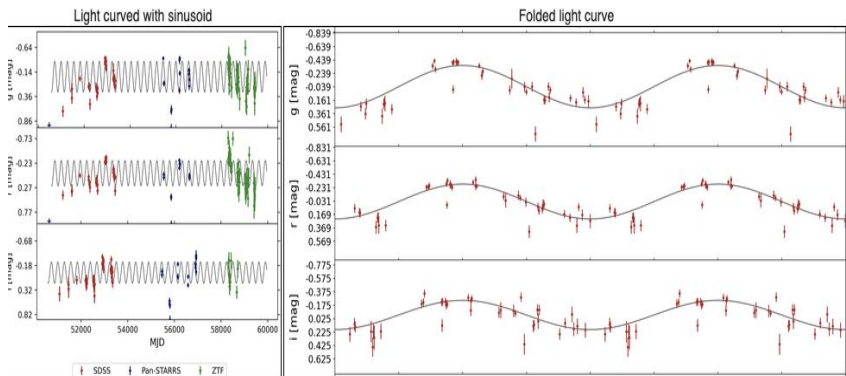
- **Temporary Data storage** based on QNAP platform with over 250TB of available disk space. **Realized as LSST TVS SC Kickstarter Heising Simons Foundation project of SER-SAG&CPG**

Kickstarter Leads:

SER-SAG: Sasa Simic, Luka Popovic, **CPG:** Lovro Palavesra, Tomislav Jurkic

CPG team M. Fatović, L. Palavesra et al 2022 submitted

- investigation of short period (< 300 days) binary QSO candidate;
- example how 2D Hybrid method complement standard Fourier periodicity mining





D. Ilic, A. Kovacevic full members of AGN SC

D. Ilic member of AGN SC membership committee

A. Kovacevic member of AGN SC Ethics committee,
designer and analyst of AGN SC census

LSST AGN Science Collaboration



How to join:

<https://agn.science.lsst.org/apply>

Subgroups:

- AGN selection/classification
- Photo-Z/Redshift estimates
- AGN variability science
- Follow-up

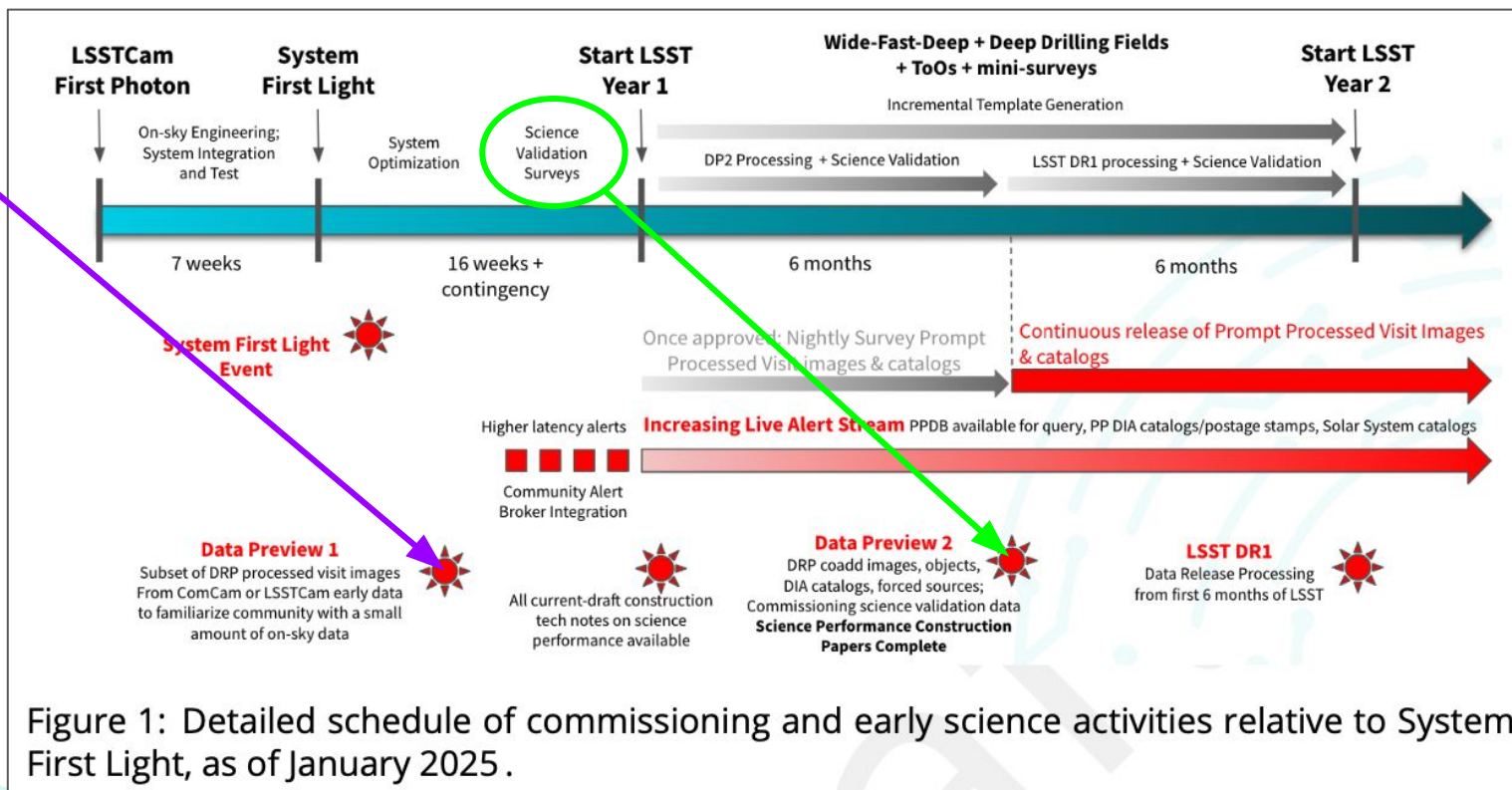
Co-chairs:

W. Niel Brandt, Penn State

Matthew Temple, Durham University

Early Science Timeline (RTN-011, Fig 1)

ComCam on-sky
late 2024.



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

Thank you for your attention!

