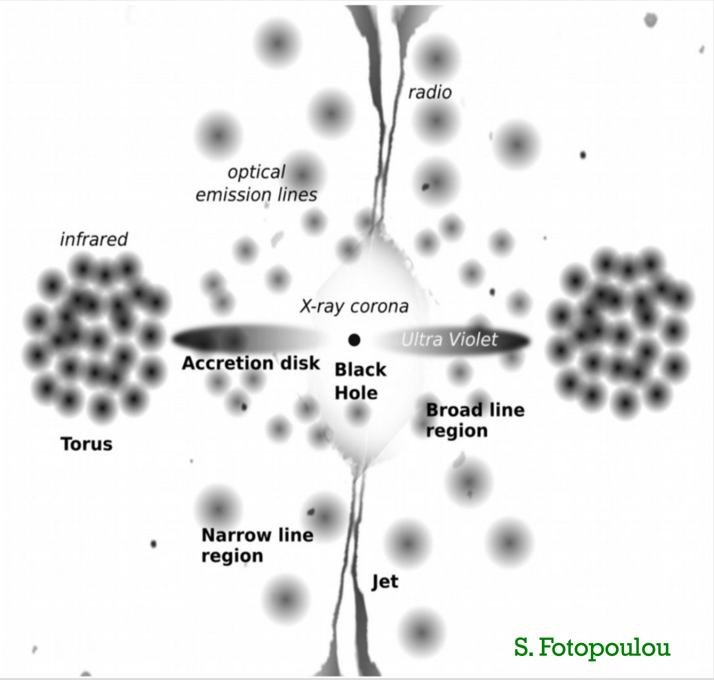
The LSST AGN Science Collaboration and Its Early Science Plans

Niel Brandt (Penn State) and Matthew Temple (Durham) - For the LSST AGN SC



Overall AGN SC Goals

Maximize the AGN science return of the LSST.

Give feedback to the Project to ensure excellent AGN science.

Educate the broader community about LSST AGN science.

Current Membership

Currently have 248 members

Grew by 52 (21%) over past year

230 associate and 18 full/core members

Six largest national memberships:

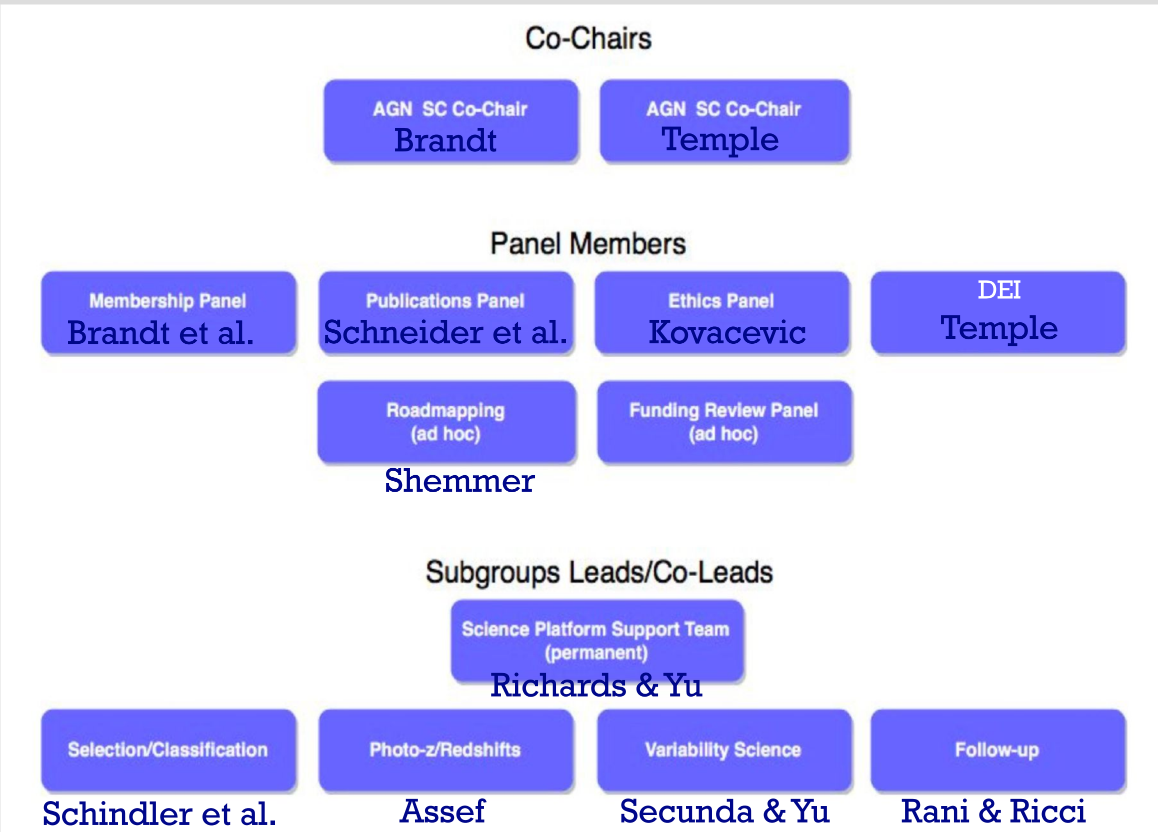
Country	Number of Members
USA	110
UK	*21*
Italy	20
Brazil	19
Chile	15
Serbia	11

Membership applications are welcome, even from people who lack data rights.

AGN SC membership does not provide data rights.

Application instructions are at https://agn.science.lsst.org

Overall Organization



Adapted from AGN SC Charter

Leader/coordinator names are listed.

Also:

Liaison to SCOC – Assef

Users committee – Petrecca & Sarajedini

In-kind coordinators – Hoenig & Coppi

In-Kind Contributions

AGN SC in-kind contribution representatives are Sebastian Hoenig and Paolo Coppi.

Six in-kind projects ongoing – mostly European.

Name	Lead
Italian simulations of high-z AGNs and galaxies in the LSST survey	Bongiorno
AGN reverberation-mapping time delays	Czerny
SER-SAG pipeline for periodic variability detection	Kovacevic
TIMEDOMES: VST Monitoring of the LSST DDFs	Paolillo
Canadian contribution to the LSST AGN SC: Data-analysis tools for AGN photometric variability	Ruan
MPE photometric redshifts for LSST-detected AGNs	Salvato

Some Recent and Ongoing Activities

2020-2022 meetings were over Zoom.

Recordings for 2020-2024 meetings on YouTube (30+ hours of material).

Supermassive Black Hole Studies in the Legacy Survey of Space and Time: 2025 edition

View Edit Revisions

Update April 2025:
Abstract submission closed on April 4th. Please pay the registration fee by June 3rd!
There are still a few spaces for in-person attendance, please fill in this form if you would like to attend (whether in-person or remotely):
https://forms.office.com/e/X6crXhz06Q
Please note that we are limited to ~65 in-person participants, so we ask all potential attendees to complete the form, even if you don't want to present a talk.
Those who requested a visa invitation letter should have received an email - please let the organisers know if not.

Date: Monday 14th to Thursday 17th July 2025
Venue: Ogden Centre West, Durham University, United Kingdom

Meeting rationale:

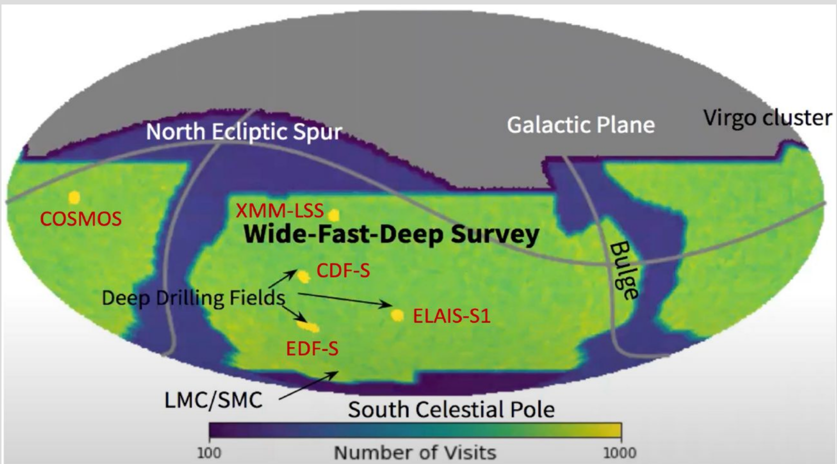
Starting in 2025, Rubin Observatory's 10-year LSST will probe deeper than any previous wide-field time-domain survey in astronomy, giving 6-band multi-colour light-curves for every active galactic nucleus (AGN) in the southern sky. The first commissioning data are now being taken, meaning it is extremely timely to prepare for science with these observations.

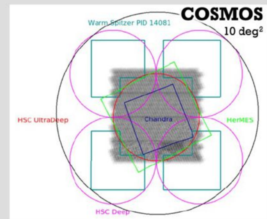
However, we first need to address some open questions:
1. how to identify AGN using a combination of photometry, astrometry, variability and morphology information from LSST?
2. how best to quantify the large amount of AGN variability data from LSST?
3. how to use that information to yield new insights into SMBH accretion physics, demographics, and host-galaxy connections?

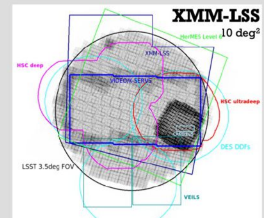
Motivated by these challenges, this workshop aims to:
1. Bring together AGN experts to present their ongoing work related to LSST.
2. Foster new collaborative projects to develop methods for AGN selection, classification and variability analyses.
3. Equip early-career researchers (ECRs) with the skills required to access and exploit the upcoming LSST data, and networking opportunities to develop their careers.

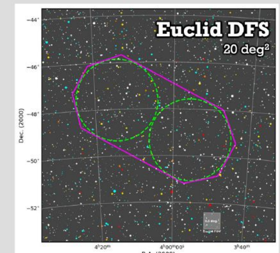
Next week in Durham!

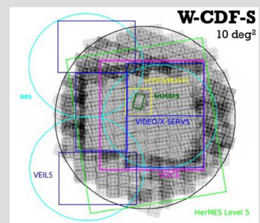
Rubin's LSST Deep-Drilling Fields

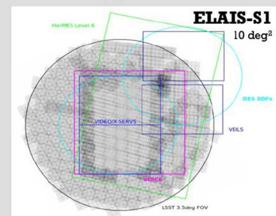












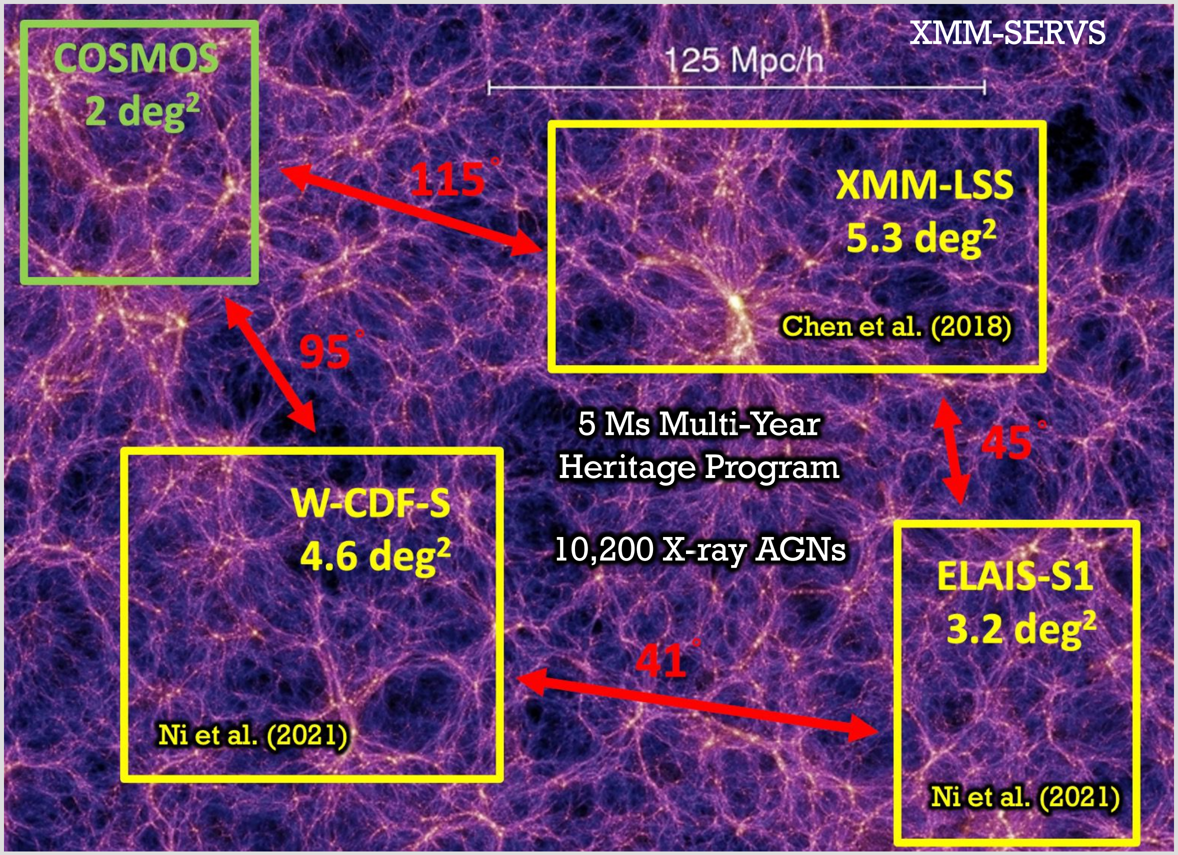
Rubin likely will observe DDFs every 2-3 nights in *grizy* (also *u*).

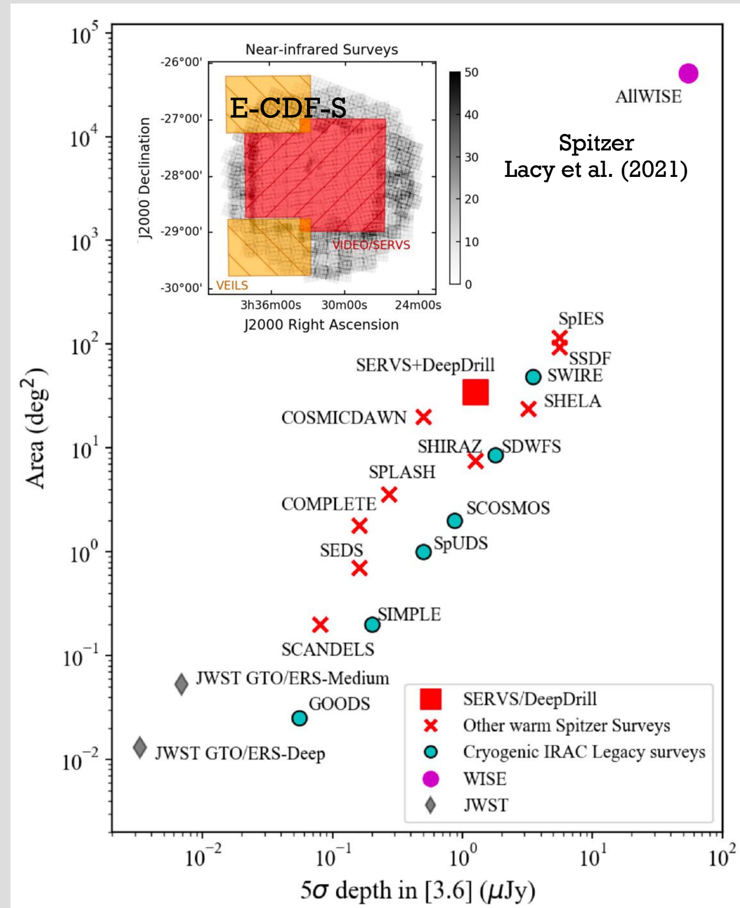
	ELAIS-S1	XMM-LSS	Wide Chandra Deep Field-South	Euclid Deep Field-South	COSMOS
RA 2000	00 37 48	02 22 18	03 31 55	04 04 58	10 00 26
DEC 2000	-44 01 30	-04 49 00	-28 07 00	-48 25 12	+02 14 01
Galactic l	311.28	171.10	224.07	256.06	236.78
Galactic b	-72.88	-58.91	-54.60	-47.17	42.13
LSST Solid Angle (deg^2)	10	10	10	20	10
Prime Multiwavelength Solid Angle (deg^2)	3.2 (XMM-SERVS)	5.3 (XMM-SERVS)	4.6 (XMM-SERVS)	TBD	2 (COSMOS)
Relevant Reference	Ni et al. (2021)	Chen et al. (2018)	Ni et al. (2021)	Laureijs et al. (2019)	Civano et al. (2016)

The SERVS and COSMOS areas in the DDFs have superb deg^2 multiwavelength coverage.

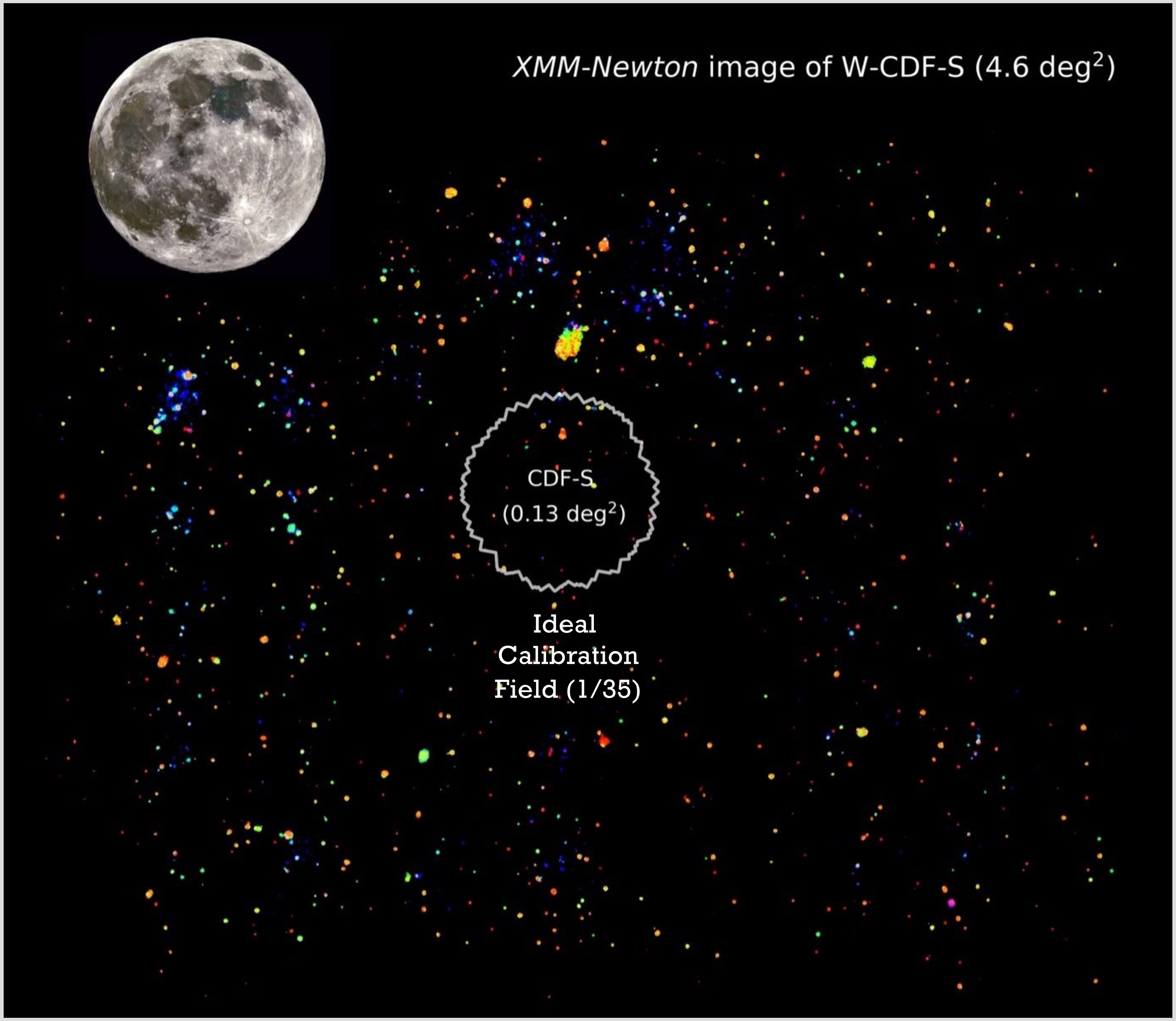
We plan to use this extensively in early science studies.

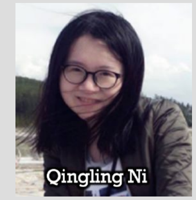
XMM-Newton and Spitzer Coverage of DDFs





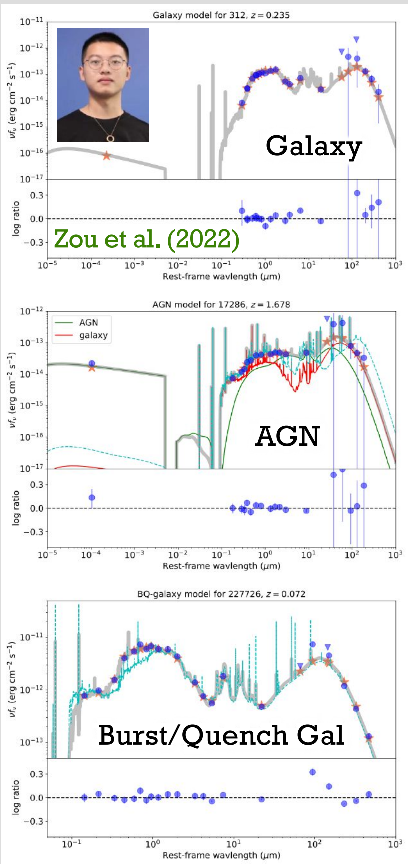
Panoramic CDF-S Coverage

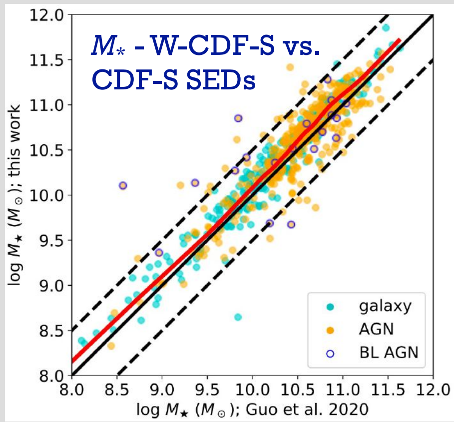


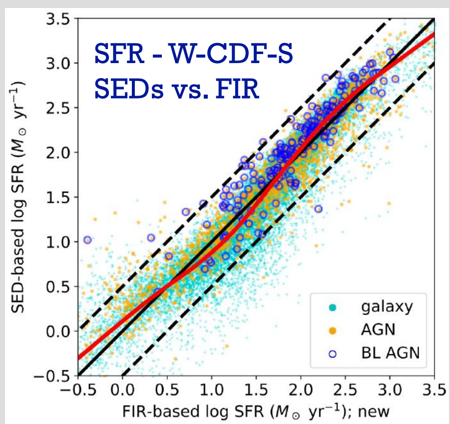


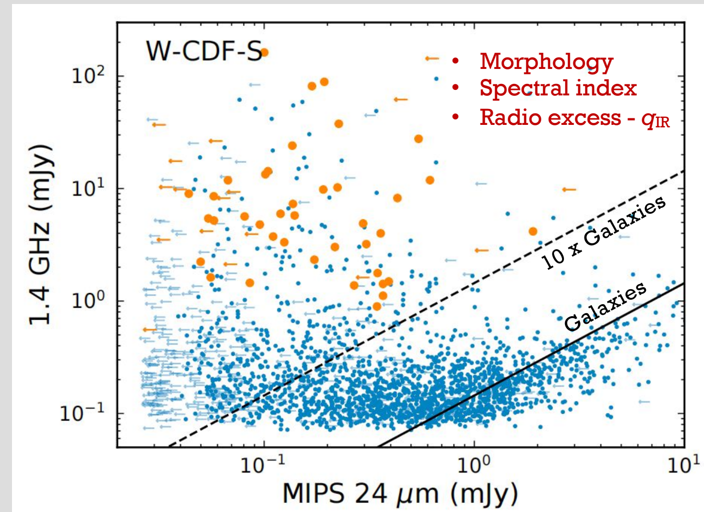
Even wider field XMM-Newton data being gathered for CDF-S.

SED and Radio AGN Selection in DDFs

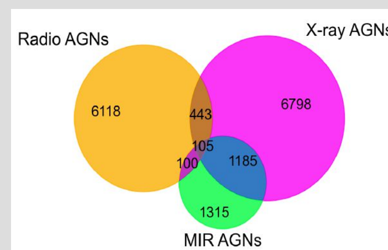


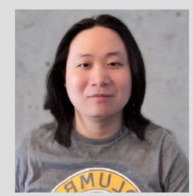






6800 radio AGNs selected - most not X-ray/MIR

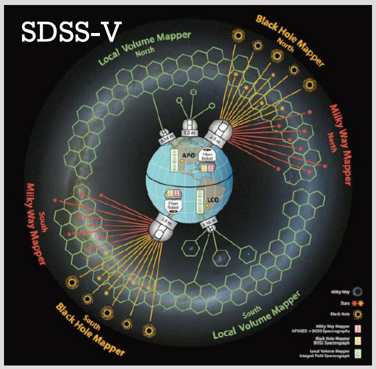




Zhu et al. (2023)
Zhang et al. (2025)

Also optical variability selection – e.g., De Cicco et al., Falocco et al., Poulain et al.

Complementary Multiwavelength Data Flooding In for the DDFs!



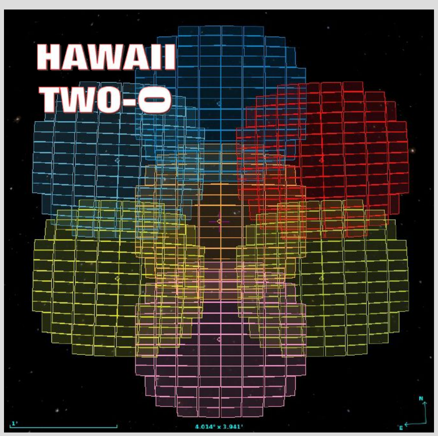
Prime Focus Spectrograph

SuMIRe

4MOST

WAVES

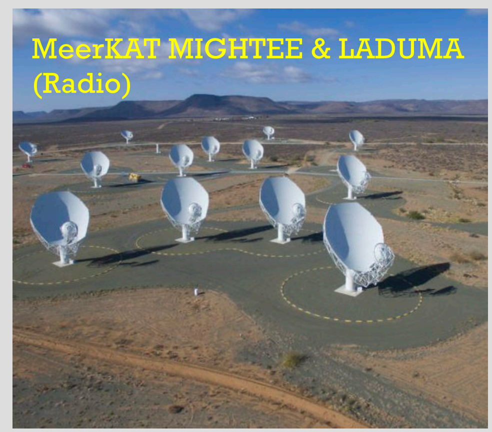
wide area vista extragalactic survey



LMT

ToITEC

ASU Cardiff INAOE Michigan NIST Northwestern UMass Wisconsin



LSST AGN SC First Data Challenge

LSST AGN Science Collaboration 2021 Data Challenge

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.)

Led by G. Richards and W. Yu.

Part of general efforts to prepare students, postdocs, and others for LSST AGN science.

5 submissions - monetary prizes awarded.

Data-challenge dataset made public.

The LSST AGN Data Challenge: Selection methods

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arXiv:2307.04072v1 [astro-ph.GA] 9 Jul 2023

ABSTRACT

Development of the Rubin Observatory Legacy Survey of Space and Time (LSST) includes a series of Data Challenges (DC) arranged by various LSST Scientific Collaborations (SC) 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 AGN data, aimed at validating machine learning approaches for AGN selection and characterization in large surveys like LSST. The AGNSC-DC took part in 2021 focusing on accuracy, robustness, and scalability. The training and the blinded datasets 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 DC submitted solutions using both classical and machine learning methods. We systematically test the performance of supervised (support vector machine, random forest, extreme gradient boosting, artificial neural network, convolutional neural network) and unsupervised (deep embedding clustering) models when applied to the problem of classifying/clustering sources as stars, galaxies or AGNs. We obtained classification accuracy 97.5 % for supervised and clustering accuracy 96.0 % for unsupervised models and 95.0 % with a classic approach for a blinded dataset. 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.

Survey Cadence Contributions

We have delivered 4 journal articles, 8 cadence notes (in addition to the 2018 white papers), and 4 coded metrics.

We continue communicating with the SCOC via, e.g., feedback to Roberto Assef and the DDF cadence task force, SCOC-SC workshops.

AGN SC members continue working through new operations simulations to assess if these allow desired AGN science to be achieved.

Continue coordinating with other SCs to see if we can push for mutually acceptable cadence solutions – e.g., DESC discussions.

Papers Assessing LSST Cadences for Scientific Projects

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 258:3 (13pp), 2022 January https://doi.org/10.3847/1538-4365/

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

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THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 262:49 (37pp), 2022 October https://doi.org/10.3847/1538-4365/ac88ce

CrossMark

The LSST Era of Supermassive Black Hole Accretion Disk Reverberation Mapping

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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 AGN SC Cadence Notes - 8 Total

LSST AGN SC Cadence Note: Type-1 Quasar Colors in the Context of Photometric Redshifts

Roberto J. Assef, Matthew Temple (UDP), Gordon Richards, Weixiang Yu (Drexel), and Franz Bauer (PUC) – on behalf of the AGN SC

1. EXECUTIVE SUMMARY

We have developed two metrics to evaluate the 10yr co-added depths expected for each band in the context of photometric redshifts for type-1 quasars as function of OpSim runs from FBS 1.5, 1.6 and 1.7. Each metric focuses on a different aspect. The first one focuses exclusively on the depth expected for u-band with the aim of detecting the SED break short of Lyα. The second one compares the depths of contiguous bands in wavelength to the expected colors of type-1 quasars. In both cases, while we find that some OpSim runs perform better than others, we do not find any of them to be critically detrimental for type-1 quasar photometric redshifts in the context of these metrics, although we remark on the usefulness of having as deep u-band coverage as possible.

Active Galaxy Science in the LSST Deep-Drilling Fields: Additional Points on Footprints, Cadence Requirements, and Total-Depth Requirements

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LSST AGN SC Cadence Note: Two metrics on AGN variability observables

Andjelka Kovačević, Dragana Ilić, Isidora Jankov, Luka Č. Popović, Ilsang Yoon, and Viktor Radović, Neven Caplar , Iva Čvorović-Hajdinjak – on behalf of the AGN SC

1. EXECUTIVE SUMMARY

We have developed two metrics related to AGN variability observables (time-lags, periodicity, and Structure Function (SF)) to evaluate LSST OpSim FBS 1.5, 1.6, 1.7 performance in AGN time-domain analysis. For this purpose, we generate an ensemble of AGN light curves based on AGN empirical relations and LSST OpSim cadences. Although our metrics show that denser LSST cadences produce more reliable time-lag, periodicity, and SF measurements, the discrepancies in the performance between different LSST OpSim cadences are not drastic based on Kullback-Leibler divergence. This is complementary to Yu and Richards results on DCR and SF metrics (see Yu's talk https://docs.google.com/presentation/d/12Q1zKiWtoQAXsh7GS6J9TYhEKsWfkN5sVDufEyCKkEE/edit#slide=id.gc6954dd1ce_0_3), extending them to include the point of view of AGN variability.

LSST CADENCE NOTE: BLAZAR VARIABILITY

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April 15, 2021

[1]TVS, [2]AGN, and [3] SMWLV Science Collaborations

LSST AGN SC Cadence Note: Non-Parametric Structure Function Metric

Weixiang Yu and Gordon Richards – on behalf of the AGN SC

1. EXECUTIVE SUMMARY

We have developed a model-independent metric ("SFErrorMetric") to assess the level to which we can derive the "structure function" of variable sources (e.g., AGNs) in LSST as a function of OpSims from versions FBS 1.5, 1.6 and 1.7. No presumptions about the actual underlying process that is responsible for the observed variability are used in this metric; this metric depends solely on the survey parameters (e.g., number of visits). Most of the survey simulations being considered for LSST operations performed equally well, with one exception being the u_long family, which significantly enhance this metric in the u-band without inducing observable drawbacks in other filters. Thus, we would favor longer u-band exposure time if the total number visits in the u-band can stay relatively unchanged.

LSST AGN SC Cadence Note: Differential Chromatic Refraction

Weixiang Yu and Gordon Richards – on behalf of the AGN SC

1. EXECUTIVE SUMMARY

We have developed a metric to evaluate both the relative and absolute signal that can be expected from differential chromatic refraction (DCR) in LSST (Yu et al. 2020a) as a function of OpSims from versions FBS 1.5, 1.6 and 1.7. While there are LSST survey simulations that would significantly enhance this metric to the benefit of AGN classification and photo-z (and the study of objects exhibiting strong emission lines), such OpSims were meant as tests and not for operations. Among the feasible choices for LSST operations, we identify no simulations that are particularly bad or particularly good when it comes to DCR. Thus the choice of cadence can largely be made without consideration of this work. Nevertheless the tools are in place to double check that this remains true for the finalist(s).

Available at https://www.lsst.org/content/survey-cadence-notes-2021

Survey Cadence Contributions

We have delivered 4 journal articles, 8 cadence notes (in addition to the 2018 white papers), and 4 coded metrics.

We continue communicating with the SCOC via, e.g., feedback to Roberto Assef and the DDF cadence task force, SCOC-SC workshops.

AGN SC members continue working through new operations simulations to assess if these allow desired AGN science to be achieved.

Continue coordinating with other SCs to see if we can push for mutually acceptable cadence solutions – e.g., DESC discussions.

Other Key Activities in 2023-2025

AGN SC has several members on the Rubin-Euclid Derived Data Products Working Group.

15+ AGN SC members are involved in Data Previews.

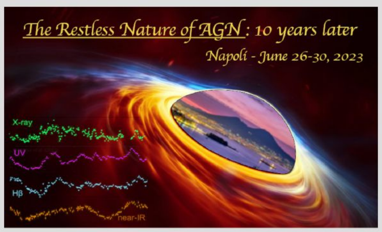
Charter and publication policies updated.

Ongoing demographic census.

Coordinate with other AGN projects; e.g., reverberation mapping and X-ray missions (e.g., Athena).

Relevant Outreach Activities

Worldwide LSST AGN Talks



LSST Workshop on AGN Variability for Students from Ethiopia and Serbia

Title:
Student intro training on Python for data processing of AGN variability within the Large Survey of Space and Time (LSST)

Time: March 26, 2022

Lecturers: Andjelka Kovacevic, Dragana Ilic, Robert Nikutta, Paula Sanchez, Viktor Radovic, Isidora Jankov, Rachel Street

Penn State Teacher Workshops

LSST Community Demo Sessions and Outreach Events


The End
NASA
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PennState
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of Science

Extra Slides

Very Brief History

The AGN SC has existed since Fall 2006 – has become more organized over time.

Has always been, by design, distinct from the Project, and has thus never received direct funding from Project.

LSST Science Collaboration Chairs phonecon minutes, 08/09/06

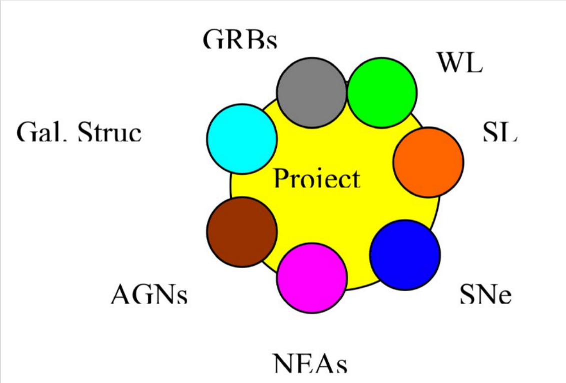
Attending: Harry Ferguson (galaxies), Andrew Hamilton (LSS), Niel Brandt (AGN), Michael Wood-Vasey (SN), Bhuvnesh Jain (weak lensing), Dave Wittman (weak lensing), Abi Saha (stellar pops), Connie Rockosi (MW structure), Steve Chesley (Solar system), Michael Strauss (chair)

This was the first phonecon to discuss the nature of the LSST Science Collaborations. We're somewhat feeling our way on how to make this all work. The science collaborations represent a bridge between the LSST collaboration (with its focus at the moment on hardware and software issues) and the broad astronomy and high-energy physics communities which it serves. One novel aspect of this for astronomers is that we're trying to fold in the culture of the high-energy physicists, where people typically concentrate hard on a single aspect of a single experiment, rather than the multi-plexing that astronomers are so used to (it is this that motivates the desire that members of the Science Collaborations put some serious commitment to the collaboration).

Draft Plan for the Formation of the LSST Collaboration and for the Science Organization of LSST Major Projects

S. M. Kahn

2005 Dec



The AGN SC Roadmap

LSST
AGN Science Collaboration
Roadmap

Prepared by the LSST AGN Science Collaboration,
with support from the LSST Corporation

Version 2.0
July 11, 2022

Contents

3

Defines and prioritizes AGN SC activities needed to prepare for Rubin operations.

Work ongoing to address many Roadmap goals.

Coming LSST AGN DDF Science

Accretion-disk reverberation mapping via continuum lags

Multi-object spectroscopic + photometric reverberation mapping of BLR

Variability of X-ray (and other) dwarf-galaxy AGNs

Optimizing AGN color and variability selection for the LSST main survey

Transient phenomena – e.g., TDEs, changing-look AGNs, jet flares, microlensing

Binary SMBH searches

Improved SMBH growth constraints