Supermassive Black Hole Studies with the LSST

Niel Brandt for the LSST AGN Science Collaboration
Talk Outline

AGN selection with LSST and multiwavelength data.

Examples of exciting science investigations:
- Massive AGN variability studies
- Transient SMBH fueling events
- AGN investigations at high redshift

The LSST AGN Science Collaboration and its future plans.
AGN Selection
LSST AGN Selection

Multicolor selection in *ugrizy* from $z = 0-7.5$

- Ultraviolet excess and color outliers below $z \sim 2.5$
- Lyman-$\alpha$ forest at high redshifts
- Works best when $L_{\text{AGN}} > L_{\text{Host}}$

Variability

- 55-185 samplings per band over 10 yr
- Highly effective complement to color selection
- Need more effectiveness assessments for $L_{\text{AGN}} \sim L_{\text{host}}$

Astrometry - Lack of proper motion and differential chromatic refraction

- Will reach $\sim 1$ mas yr$^{-1}$ at $r \sim 24$
- Minimizes confusion with stars
Example AGN Spectral Energy Distribution
Some Future Large Survey Projects

(Some projects extend beyond 2030)
Multiwavelength AGN Selection

$L_R, T_b, \text{morphology}$

Infrared-optical colors

$L_X$ and $\Gamma_X$

ASKAP

MeerKAT

SKA

Euclid

eROSITA

Chandra

WFIRST-AFTA

XMM-Newton
Will detect ~ 300+ million AGNs in 18000 deg$^2$ primary LSST survey area.

Obscuration and host-galaxy dilution will hinder AGN selection.

Confidently can select 20 million.

Hope to select 50+ million, especially using multiwavelength data.

Overwhelming statistics to investigate, e.g., AGN evolution as a function of environment.
The Chandra Deep Fields

CDF - North
2 Ms coverage
Gathered over 2.5 yr
448 arcmin²
755 point sources
87% AGNs

CDF - South
7 Ms coverage
Gathered over 16 yr
484 arcmin²
1055 point sources
71% AGNs

Alexander et al. (2003)
Xue et al. (2016)

Xue et al. (2011)
Luo et al. (2017)

Faintest sources have 1 count per 10.0 days!
### Plausible AGN Yields

**Variability Selected Quasar Predictions from Palanque-Delabrouille et al. (2013)**

Table 8. Predicted number of quasars over 15.5 < $g$ < 25 and 0 < $z$ < 6 for a survey covering 10,000 deg$^2$, based on our best-fit luminosity function.

<table>
<thead>
<tr>
<th>$g/z$</th>
<th>0.5</th>
<th>1.5</th>
<th>2.5</th>
<th>3.5</th>
<th>4.5</th>
<th>5.5</th>
<th>Total</th>
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<tr>
<td>15.75</td>
<td>76</td>
<td>15</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>92</td>
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<tr>
<td>16.25</td>
<td>174</td>
<td>55</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>239</td>
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<tr>
<td>16.75</td>
<td>402</td>
<td>172</td>
<td>61</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>635</td>
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<tr>
<td>17.25</td>
<td>939</td>
<td>535</td>
<td>180</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1661</td>
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<tr>
<td>17.75</td>
<td>2163</td>
<td>1630</td>
<td>508</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td>4323</td>
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<tr>
<td>18.25</td>
<td>4740</td>
<td>4720</td>
<td>1409</td>
<td>57</td>
<td>2</td>
<td>0</td>
<td>10,928</td>
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<td>18.75</td>
<td>9456</td>
<td>12,380</td>
<td>3784</td>
<td>156</td>
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<td>19.25</td>
<td>16,612</td>
<td>27,796</td>
<td>9409</td>
<td>422</td>
<td>14</td>
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<td>19.75</td>
<td>25,537</td>
<td>51,561</td>
<td>20,579</td>
<td>1128</td>
<td>39</td>
<td>1</td>
<td>98,846</td>
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<td>20.25</td>
<td>35,185</td>
<td>80,209</td>
<td>38,096</td>
<td>2923</td>
<td>107</td>
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<td>156,523</td>
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<td>20.75</td>
<td>45,008</td>
<td>110,341</td>
<td>59,393</td>
<td>7085</td>
<td>289</td>
<td>10</td>
<td>222,671</td>
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<tr>
<td>21.25</td>
<td>54,980</td>
<td>141,918</td>
<td>82,650</td>
<td>15,386</td>
<td>779</td>
<td>27</td>
<td>295,740</td>
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<td>21.75</td>
<td>64,988</td>
<td>176,959</td>
<td>103,733</td>
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<td>217,815</td>
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<td>22.75</td>
<td>80,370</td>
<td>266,716</td>
<td>141,310</td>
<td>65,652</td>
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<td>23.25</td>
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<td>61,347</td>
<td>398,006</td>
<td>182,048</td>
<td>97,320</td>
<td>37,756</td>
<td>3632</td>
<td>780,110</td>
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<td>24.25</td>
<td>15,976</td>
<td>480,676</td>
<td>206,510</td>
<td>109,295</td>
<td>55,090</td>
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<td>24.75</td>
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<td>492,283</td>
<td>234,874</td>
<td>120,118</td>
<td>71,481</td>
<td>17,111</td>
<td>935,866</td>
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<tr>
<td>Total</td>
<td>571,169</td>
<td>2,789,734</td>
<td>1,368,583</td>
<td>578,092</td>
<td>206,489</td>
<td>31,444</td>
<td>5,545,510</td>
</tr>
</tbody>
</table>

**Notes.** Bins are centered on the indicated magnitude and redshift values. The ranges in each bin are $\Delta g = 0.5$ and $\Delta z = 1$.

where we call “quasar” an object with a luminosity $M_L(z = 2) < -20.5$ and either displaying at least one emission line with FWHM greater than 500 km s$^{-1}$ or, if not, having interesting/complex absorption features.
Example

AGN Science Investigations

See Chapter 10 of the LSST Science Book for more details and other examples.
Nightly LSST SMBH Science

Monitoring of ~ 3 million AGNs (~ 10+ million total).

Discovery of ~ 50 large AGN flares (e.g., blazars and accretion-disk instabilities).

Discovery of ~ 3 stellar tidal disruption events.

Discovery of ~ 0.1 strong quasar microlensing events.

Binary SMBH inspirals and mergers?

Also ~ 2500 supernovae and ~ 5 “orphan” GRB afterglows.
Massive AGN
Variability Studies
Massive AGN Variability Studies

Millions of well-sampled, accurate, multicolor AGN light curves, spanning minutes-to-years (billions of photometric measurements).

Even better sampling and depth for \( \sim 10^5 \) AGNs in the DDFs.

Can combine with DES, HSC, Pan-STARRS, SDSS for longer baselines.

Can powerfully study general luminosity and spectral variability as a function of \( L, z, \lambda, \Delta t, \) color, radio properties, line properties, \( M_{\text{BH}}, L/L_{\text{Edd}} \) (some require one-epoch spectra).

Rare but important events - large disk instabilities, strong jet flares, swan-song events, QPOs.

![Eddington-Ratio Dependence of Long-Timescale RMS Variability](image)
Triggered Spectroscopic Follow-Up: RM

Strong Quasar Continuum Variations Can Trigger Reverberation Mapping Follow-Up

Multi-Object AGN Reverberation Mapping with SDSS

Also photometric RM (e.g., Chelouche et al. 2012, 2014).
SDSS-V Connections

AS4 Executive Summary

Juna Kollmeier (AS4 Director) and the AS4 Science Management Team

AS4 is the first all-sky, time-domain spectroscopic survey, with observational capabilities that will remain unmatched for the foreseeable future. This unique survey facility is poised to transform broad areas of astrophysics, in particular: understanding the formation of our Milky Way and other galaxies, along with the astrophysics of stars and of supermassive black holes.

In one flagship program, AS4 will provide spectroscopic data for stars across the Milky Way. This survey is unrivaled in its combination of sky coverage, time sampling, and systematic target selection throughout our Galaxy, enabled by dual-hemisphere, wide-field infrared spectroscopy. From this, we will:

- Understand the genesis of our Galaxy by acquiring
  - a first global picture of Milky Way structure and dynamics, placing our Galaxy precisely in the overall realm of galaxies,
  - comprehensive constraints on the evolutionary processes that shaped our Milky Way and other galaxies, and
  - a map of when and where the broad range of chemical elements were created in our Galaxy.

- Take the understanding of fundamental stellar physics, the pillar upon which much of astrophysics rests, to a new level. In combination with the Gaia, Kepler and TESS space missions, AS4 will transform our understanding of
  - the origin of supernovae,
  - the difference between planet-hosting and non-hosting stars,
  - binary stars across the Hertzsprung-Russell diagram -- as witnesses to star-formation physics, as drivers of stellar evolution and as laboratories to test stellar evolution, and
  - young, massive stars, through a vast sample of (near-IR) spectra.

At the same time, AS4 will open new frontiers in extragalactic astrophysics: it will enable us to understand quasars as dynamical phenomena -- through both reverberation mapping and direct black hole mass estimates from multi-epoch spectroscopy that samples time-scales from days to more than a decade. In addition, AS4 will be the only dual-hemisphere spectroscopic complement to the eROSITA mission, unveiling the nature of X-ray sources that shine brightly across the sky.

See arXiv:1711.03234
Triggered Spectroscopic Follow-Up: BALs

Color Changes Will Trigger Spectroscopic Follow-Up of Strong BAL Variations

Also other absorption changes; e.g., variable dust reddening.

Also “changing look” quasars.
Microlensing of Accretion Disks

LSST will find and monitor ~ 4000 AGNs lensed into multiple images.

LSST cadence well-suited to rapid identification of microlensing events by stars in lensing galaxy - these give effective μas resolution.

Can trigger dense targeted multicolor and UV/X-ray monitoring, aiming to constrain the accretion-disk temperature profile.

With a large sample, can examine $L$, $L/L_{\text{Edd}}$, $M_{\text{BH}}$, $z$ effects.

Hainline et al. (2012) Q0957+561
Small-Separation Binary SMBH

For SMBHs to move from pc to $10^{-3}$ pc separations, likely need gas accretion to remove binary angular momentum.

Accretion rate onto both SMBHs may vary on timescales of the binary period.

Month-to-year timescales at $\sim 10^{-2}$ pc, well-suited to LSST monitoring and hard to find in other ways.

Massive LSST variability survey can find or usefully constrain the uncertain frequency of $10^{-2}$ pc binary SMBHs.

Already some candidates being found, but detailed interpretation still unclear.
Transient SMBH Fueling Events
Transient Fueling of Dormant SMBH

A dormant SMBH can flare to AGN luminosities for months-years via tidal disruption and partial accretion of stars, planets, or gas clouds.

De Colle et al. (2012)

Originally found in the X-ray band with ROSAT with sparsely sampled light curves.

Now possible to identify in wide-field optical/UV (GALEX, SDSS, PTF, Pan-STARRS) and X-ray (Swift) monitoring surveys.

Expect to detect several thousand events per year with LSST, but will likely need to enforce selection cuts for unambiguous detections (confusion with SNe, AGNs).
LSST and Transient SMBH Fueling

Measure outburst rates as a function of galaxy type, redshift, and level of nuclear activity.

Assess the contribution of tidal disruptions to the AGN luminosity function (e.g., Milosavljevic et al. 2006).

Determine fraction with jets via radio follow-up and comparison with radio transient surveys (e.g., VAST, ThunderKAT, LOFAR transients).

Understand diversity of these events ($L_{\text{Bol}}, kT, \text{jet power}$)

Find remarkable events - e.g., white dwarf disruptions by IMBH, giant planet disruptions, gas cloud captures.
AGN Investigations at High Redshifts
LSST alone will provide significant numbers of AGNs to $z \sim 7.5$ down to moderate luminosities ($L_{\text{Opt}} \sim 10^{44}$ erg s$^{-1}$).

Also enables effective follow-up of X-ray and radio high-redshift AGN candidates.
High-Redshift Quasars from Euclid, WFIRST, and LSST

Combination of Euclid, WFIRST, and LSST will be very powerful for finding the first quasars.

According to Dan Stern:

Euclid should deliver ~ 1360 luminous quasars at z > 7, and 24 at z > 10.

WFIRST+LSST will push considerably deeper than Euclid over ~ 15% of the area.

Expect ~ 29 quasars at z > 10 (~ 1490 at z > 7).

According to Rhys Barnett, the yields may be a factor of ~ 3 lower.
Luminosity vs. Redshift for Future High-Redshift AGN Samples

Adapted from Barret et al. (2013)

Euclid
WFIRST+LSST at $z > 8$

Lots of great high-$z$ targets for multiwavelength follow-up studies.
Generally, multiwavelength follow-up studies of the highest redshift quasars have shown little spectral evolution.

But there are notable exceptions, such as apparently dust-free quasars.
Massive Mining of Chandra and XMM-Newton Archives

Combine Chandra and XMM-Newton source catalogs, especially for deeper observations, with LSST, DES, HSC, Euclid, WFIRST, etc.

Can aim for an effective $z \sim 4 - 8$ AGN survey, including obscured AGNs, over $\sim 1100$ deg$^2$.

Identify X-ray sources with optical / NIR colors indicating high redshifts.

Only new cost is follow-up spectroscopy, which could use DESI, PFS, 4MOST.

Measure XLF bright end and $f_{\text{obsc}}$ with 500-1100 sources at $z = 4 - 6$ and 10-100 sources at $z = 6 - 8$. 

Brandt & Vito (2017)
The LSST AGN Science Collaboration and Its Future Plans
The LSST AGN Science Collaboration currently has 47 members. New members welcome!

Presently working as a loose confederation, but hope to become a hard-core collaboration in the future as LSST construction proceeds.

Given funding constraints, basic plan is to “bootstrap” our way along: e.g., Deep Fields and Stripe 82 - Pan-STARRS - DES - SUMIRE – LSST.

Also gathering key multiwavelength data.

A huge amount of work is needed including on basic AGN selection, analysis of LSST simulations, detailed science planning, and pooling of observational resources.

Feedback welcome at lsst-agn@lsstcorp.org
Some Chilean AGN SC Members (and Soon to Join)
The Four Selected DDFs: Multiwavelength Coverage

ELAIS-S1

Selected early to enable gathering of precursor multiwavelength data

Extended CDF-S

XMM-LSS

COSMOS
Spitzer DEEPDRILL Survey

A warm Spitzer survey of the LSST/DES "Deep drilling" fields

Principal Investigator: Mark Lacy
Institution: National Radio Astronomy Observatory (NRAO)
Electronic mail: mlacy@nrao.edu
Technical Contact: Mark Lacy, National Radio Astronomy Observatory (NRAO)
Co-Investigators: Duncan Farrah, Virginia Tech
Niel Brandt, Penn State
Masao Sako, U Penn
Gordon Richards, Drexel
Ray Norris, CSIRO/Macquarie University
Susan Ridgway, NOAO
Jose Afonso, Lisbon
Robert Brunner, Illinois
Dave Clements, Imperial College

Abstract:
We propose a warm Spitzer survey to microJy depth of the four predefined Deep Drilling Fields (DDFs) for the Large Synoptic Survey Telescope (LSST) (three of which are also deep drilling fields for the Dark Energy Survey (DES)). Imaging these fields with warm Spitzer is a key component of the overall success of these projects, that address the "Physics of the Universe" theme of the Astro2010 decadal survey. With deep, accurate, near-infrared photometry from Spitzer in the DDFs, we will generate photometric redshift distributions to apply to the surveys as a whole. The DDFs are also the areas where the supernova searches of DES and LSST are concentrated, and deep Spitzer data is essential to obtain photometric redshifts, stellar masses and constraints on ages and metallicities for the >10000 supernova host galaxies these surveys will find. This "DEEPDRILL" survey will also address the "Cosmic Dawn" goal of Astro2010 through being deep enough to find all the >10^{11} solar mass galaxies within the survey area out to z~6. DEEPDRILL will complete the final 24.4 square degrees of imaging in the DDFs, which, when added to the 14 square degrees already imaged to this depth, will map a volume of 1-Gpc^3 at z>2. It will find ~100 >10^{11} solar mass galaxies at z~5 and ~40 protoclusters at z>2, providing targets for JWST that can be found in no other way. The Spitzer data, in conjunction with the multwavelength surveys in these fields, ranging from X-ray through far-infrared and cm-radio, will comprise a unique legacy dataset for studies of galaxy evolution.
**X-SERVS: X-ray Coverage of the Deep-Drilling Fields**

**X-SERVS Fields**

At 50 ks XMM-Newton depth, expect 12,000 AGNs and 760 X-ray groups/clusters. Study SMBH growth across the full range of cosmic environments – voids to massive clusters. Will have incredible legacy value when combined with LSST, DES, HSC, MOONS, PFS, VEILS, Euclid, MIGHTEE, etc.
Example Multiwavelength Coverage

### Table 1: Some of the Current/Scheduled 1–10 deg² Multiwavelength Coverage of XMM-SERVS

<table>
<thead>
<tr>
<th>Band</th>
<th>Survey Name</th>
<th>Coverage (W-CDF-S, ELAIS-S1, XMM-LSS); Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radio</strong></td>
<td><strong>Australia Telescope Large Area Survey (ATLAS)⁸</strong></td>
<td>3.7, 2.7, - deg²; 15 µJy rms depth at 1.4 GHz</td>
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<tr>
<td></td>
<td><strong>MIGHTEE Survey (Starting Soon)⁹</strong></td>
<td>4.5, 3, 4.5 deg²; 1 µJy rms depth at 1.4 GHz</td>
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<tr>
<td><strong>FIR</strong></td>
<td><strong>Herschel Multi-tiered Extragal. Surv. (HerMES)¹⁰</strong></td>
<td>0.6–18 deg²; 5–60 mJy depth at 100–500 µm</td>
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<tr>
<td><strong>MIR</strong></td>
<td><strong>Spitzer Wide-area IR Extragal. Survey (SWIRE)¹¹</strong></td>
<td>8.2, 7.0, 9.4 deg²; 0.04–30 mJy depth at 3.6–160 µm</td>
</tr>
<tr>
<td><strong>NIR</strong></td>
<td><strong>Spitzer Extragal. Rep. Vol. Survey (SERVS)¹²</strong></td>
<td>4.5, 3, 4.5 deg²; 2 µJy depth at 3.6 and 4.5 µm</td>
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<td></td>
<td><strong>VISTA Deep Extragal. Obs. Survey (VIDEO)¹³</strong></td>
<td>4.5, 3, 4.5 deg²; ZYJHKa to m_AB ≈ 23.8–25.7</td>
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<tr>
<td></td>
<td><strong>VISTA Extragal. Infr. Legacy Survey (VEILS)¹⁴</strong></td>
<td>3, 3, 3 deg²; JK_s to m_AB ≈ 24.5–25.5</td>
</tr>
<tr>
<td></td>
<td><strong>Euclid Deep Field</strong></td>
<td>10, 7, - deg²; YJH to m_AB ≈ 26, VIS to m_AB ≈ 26.5</td>
</tr>
<tr>
<td><strong>Optical Photometry</strong></td>
<td><strong>Dark Energy Survey (DES)¹⁵</strong></td>
<td>9, 6, 9 deg²; Multi-epoch griz, m_AB ≈ 27 co-added</td>
</tr>
<tr>
<td></td>
<td><strong>Hyper Suprime-Cam (HSC) Deep Survey¹⁶</strong></td>
<td>-, - deg²; grizy to m_AB ≈ 25.3–27.5</td>
</tr>
<tr>
<td></td>
<td><strong>Pan-STARRS1 Medium-Deep Survey (PS1MD)¹⁷</strong></td>
<td>8, - deg²; Multi-epoch grizy, m_AB ≈ 26 co-added</td>
</tr>
<tr>
<td></td>
<td><strong>VST Opt. Imaging of CDF-S and ES1 (VOICE)¹⁸</strong></td>
<td>4.5, 3, - deg²; Multi-epoch ugri, m_AB ≈ 26 co-added</td>
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<tr>
<td></td>
<td><strong>SWIRE optical imaging</strong></td>
<td>7, 6, 8 deg²; u’g’r’i’z’ to m_AB ≈ 24–26</td>
</tr>
<tr>
<td></td>
<td><strong>LSST deep-drilling field (Planned)</strong></td>
<td>10, 10, 10 deg²; ugrizy, ≥ 10 000 visits per field</td>
</tr>
<tr>
<td><strong>Optical/NIR Spectroscopy</strong></td>
<td><strong>Carnegie-Spitzer-IMACS Survey (CSI)¹⁹</strong></td>
<td>4.8, 3.6, 6.9 deg²; 140 000 redshifts, 3.6 µm selected</td>
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<tr>
<td></td>
<td><strong>PRLsm Multi-object Survey (PRIMUS)²⁰</strong></td>
<td>2.0, 0.9, 2.9 deg²; 77 000 redshifts to i_AB ≈ 23.5</td>
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<td></td>
<td><strong>AAT Deep Extragal. Legacy Survey (DEVILO)²¹</strong></td>
<td>1.5, 3, 3.0 deg²; 43 500 redshifts to Y = 21.2</td>
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<td></td>
<td><strong>VLT MOONS Survey (Scheduled)²²</strong></td>
<td>4.5, 3, 4.5 deg²; 210 000 redshifts to H_AB ≈ 23.5</td>
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<tr>
<td><strong>UV</strong></td>
<td><strong>GALEX Deep Imaging Survey²³</strong></td>
<td>7, 7, 8 deg²; Depth m_AB ≈ 25</td>
</tr>
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</table>

Current Status of the X-SERVS XMM-LSS Field

1.1 Ms additional good XMM-Newton exposure

5.3 deg$^2$ at ~ 46 ks depth

5252 total X-ray sources – 2386 new
Current Status of the X-SERVS XMM-LSS Field

5252 total X-ray sources - 90% good identification rate (assessed with Chandra)
Mostly AGNs - will be extremely useful for AGN science in this LSST DDF
The LSST AGN SC Web Site

Welcome to the LSST AGN Science Collaboration!

Please note our upcoming meeting, to be held on 2017 January 3:
LSST AGN Science Collaboration Roadmap Development Meeting

Contributions welcome!
Meetings

LSST AGN Science Collaboration Roadmap Development Meeting

An Open Splinter Meeting as part of the

229th AAS Meeting, Grapevine, TX

Tuesday, January 3, 2017, 9:00 AM - 6:00 PM; Appaloosa 2 (Gaylord Texan Resort & Convention Center)

The goals of the meeting are to: 1) start the development of a comprehensive Roadmap for the Active Galactic Nuclei (AGN) Science Collaboration of the Large Synoptic Survey Telescope (LSST), presenting a coherent vision for AGN research pre- and post-LSST commissioning, 2) form dedicated Working Groups within the Science Collaboration who will work on specific projects described by the Roadmap, 3) explore funding opportunities to support the highest-ranked projects described by the Roadmap, and 4) encourage eligible active extragalactic researchers to join the AGN Science Collaboration.

Organizing Committee:

Ohad Shemmer (University of North Texas); ohad@unt.edu
Niel Brandt (The Pennsylvania State University); wnbrandt@gmail.com
Gordon Richards (Drexel University); grtr@physics.drexel.edu
Organizing committee members may be contacted with any questions.
Talk slides available on AGN SC Web page.

Audio recordings for all talks available from Niel Brandt or Ohad Shemmer.
Not endorsed by the American Heart Association!
International Outreach - UK AGNs and Galaxies Folks
LSST AGN SC Roadmap

Draft 3: September 20, 2017

INTRODUCTION

Ohad Shenker

The LSST AGN Science Collaboration (SC) held a meeting on January 3, 2017 in Grapevine, TX. The main goal was to start the development of a comprehensive Roadmap that will guide the SC activities during the pre- and post-commissioning phase of the LSST survey. The Roadmap builds on past and current LSST-related AGN studies, including the AGN chapters in the LSST Science Book\(^1\) and the LSST Observing Strategy White Paper\(^2\) and the various contributions that can be linked to from the LSST AGN SC website.\(^3\) The purpose of this document is to describe and prioritize critical AGN science goals identified at the meeting along with timelines to achieving these goals.

The following science goals are considered the top-ranked tasks for the AGN SC to complete in a timely fashion prior to LSST operations:

1. AGN selection, classification, and characterization, utilizing both traditional criteria based on a combination of colors, variability, and astrometry, as well as non-traditional methods intended for, e.g., low-luminosity AGN (LLAGN), or AGN with extreme variability patterns.
2. Develop a broker for short-time events that require rapid response.
3. Assess, quantitatively, the effects of the LSST Observing Strategy on AGN science using the LSST Metrics Analysis Framework.
4. Improve photometric redshift (photo-z) algorithms.
5. Identify the most important multiwavelength precursor observations, e.g., spectroscopy in the deep-drilling fields (DDFs), and follow-up observations, starting with the DDFs (for developing “truth tables”), as well as forming a network of “ambassadors” to various missions and bandpasses as a means for incorporating the multiwavelength data.

Additional tasks identified at the meeting include:

- Analysis of light curve and power spectral density (PSD) simulations, detecting quasi-periodic oscillations (QPOs), and measuring time delays in lensed quasars. This should be done in conjunction with the Strong Lensing SC and will be crucial for AGN selection.
- Develop simulations of photometric reverberation mapping (PRM; continuum-continuum and emission line-continuum) using simulated LSST light curves, especially in the DDFs (e.g., Chelouche et al. 2014; Jiang et al. 2017).
- Quantifying the effects of quasar spectral diversity on LSST photometry and the implications for AGN selection and science.

Five dedicated Working Groups (WGs), composed of AGN SC members, have been formed in order to work on specific projects described by the Roadmap. Each WG and its tasks/projects are described in detail in each of the following chapters, which appear in the order that paves the way to AGN investigations during and after LSST operations. The first three chapters are focused on optimizing AGN selection in order to construct the largest possible census, followed by developing methods for improving the crucial redshift information. The last two chapters involve precursor AGN variability studies in order to optimize AGN selection and prepare for the millions of AGN light curves.

\(^1\)http://www.lsst.org/sites/default/files/docs/sciencebook/SB.10.pdf

\(^2\)https://arxiv.org/abs/1708.04088

\(^3\)https://agnc.science.lsst.org/
Science-Driven Optimization of the LSST Observing Strategy

Prepared by the LSST Science Collaborations, with support from the LSST Project.

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8 Active Galactic Nuclei

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Summary

To zeroth order, AGN science with LSST will benefit from the longest temporal baseline (to aid both selection and variability studies), the most uniform cadence in terms of even sampling for each band, and uniform sky coverage while maximizing the area, but excluding the Galactic plane. It is also expected that any reasonable perturbation to the nominal LSST observing strategy will not have a major effect on AGN science. While denser sampling at shorter wavelengths will aid investigations of the size and structure of the AGN central engine via intrinsic continuum variability and microlensing, care must be taken not to compromise the coadded Y-band depth which is crucial for detecting the distant-most quasars. Assuming two visits per night, two different bands are preferred. Science cases related to intrinsic continuum and broad-emission line variability will benefit from the denser sampling offered in the DDFs. These fields will provide powerful "truth tables" that are crucial for AGN selection algorithms, enable construction of high-quality power spectral density functions, and enable measurements of continuum-continuum and line-continuum time lags. The benefits and tradeoffs with respect to the main survey involve high-quality light curves but for only a small fraction (~1%) of all sources, preferentially those at lower luminosities. Certain science cases will benefit greatly from even denser sampling, i.e., ~1-1000 d^-1, of a smaller area, perhaps during the commissioning phase, as long as the temporal baseline will extend over the ten years of the project. Another justification to this strategy is the fact that very few AGNs, or transient AGNs, have been monitored at these frequencies on such a long baseline, leaving room for discovery.

8.1 Introduction

The purpose of this chapter is to identify AGN science cases that may be affected by the LSST observing strategy and to specify the metrics that can be used to quantify any potential effects. Since the total number of metrics that can be quantified is quite large, and the potential effects are not likely to be significant in most cases, the goal of this chapter is to identify potential "show stoppers" that may undermine key AGN research areas. For example, certain perturbations may reduce significantly the number of "interesting" AGNs, such as z > 6 quasars, lensed quasars, or transient AGNs. Another example is photometric reverberation mapping which is one of LSST's
Need to Get Going!

Joint Technical Meeting – 2017 March

M1M3 after polishing (Tucson Airport)

LSST Summit Facility – 2017 November
The End