Large Synoptic Survey Telescope

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AGN Science with the LSST

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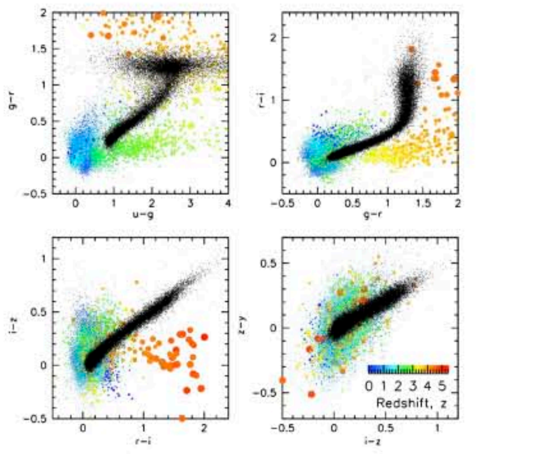
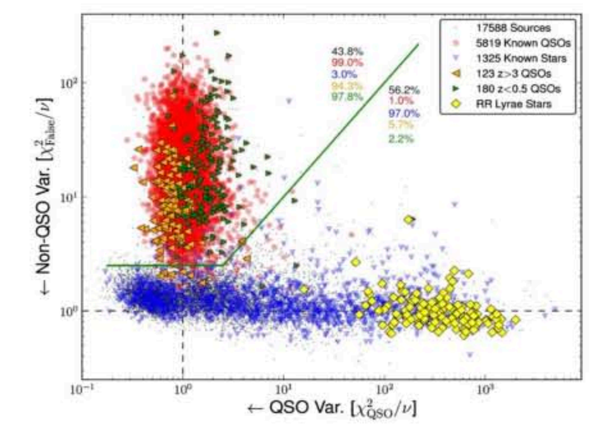
The Large Synoptic Survey Telescope (LSST; http://lsst.org) will revolutionize our understanding of active galactic nuclei (AGN) and their environments. The decade-long survey will discover at least 10 million AGN across 18,000 square degrees on the sky, with between about 50 to 200 visits per source for each of the *ugrizy* filters. A combination of the LSST sub-arcsecond astrometry, six-band photometry, and unprecedented cadence will enable the most efficient AGN selection, with additional characterization through the use of sophisticated star-galaxy separation techniques. The time-domain nature of the survey will provide invaluable information on the physics of the AGN central engine, as well as on transient fueling events, and will allow real-time alerts that will trigger follow-up observations. Several LSST "deep drilling" fields will help discover the faintest AGN at high redshift, enhancing the value of current and planned multiwavelength pencil-beam surveys while providing hours-to-years temporal information on thousands of AGN. The wide ranges of both luminosity and redshift spanned by LSST, including the discovery of over 1000 quasars at z>6.5, will dramatically improve the quantification of the optical AGN luminosity function. Measurements of AGN clustering at high redshift will be used to determine the relationship between AGN and dark matter. The discovery of about 8000 gravitationally lensed quasars, including 1000 systems with measurable time delays, will place significantly tighter constraints on key cosmological parameters.

AGN Census

The main LSST survey is expected to discover over 10 million AGN, dwarfing current AGN samples by more than an order of magnitude. These sources will lie in the 15.7 < i < 26.3 magnitude range, and will have M_i <= -20 up to a redshift of 7.5. AGN classification and characterization will be based on a joint likelihood distribution using the following selection algorithms.

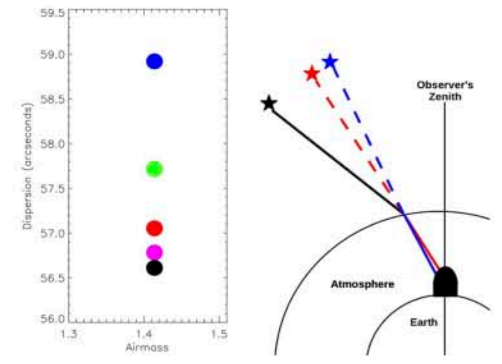


Location in color-color space – the widely used AGN identification method employing the six LSST bands.



Variability – AGN have variability patterns distinct from those of variable stars (e.g., Butler & Bloom 2011).

Astrometry – the milliarcsecond precision of LSST combined with its ten-year baseline will enable selection of sources that lack proper motion. This will also enable selection of AGN based on their distinctive differential chromatic refraction patterns as a function of redshift (Kaczmarczik et al. 2009).



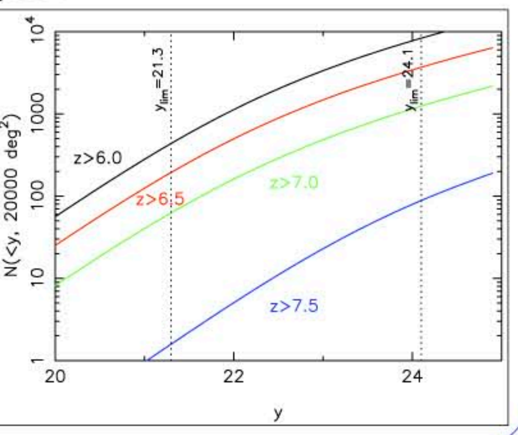
Multiwavelength matching – cross-correlating known AGN from current and planned surveys with LSST data will aid in source classification.

Morphology – new star-galaxy separation algorithms, developed for weak lensing science with LSST, will improve AGN classification by excluding stellar contaminants.

AGN at the dawn of the modern Universe

LSST will discover over 1000 AGN at redshifts greater than 6.0, down to optical luminosities of 10^{44} erg s^{-1}, enabling a much clearer view of the cosmic environment at the end of the `Dark Ages'.

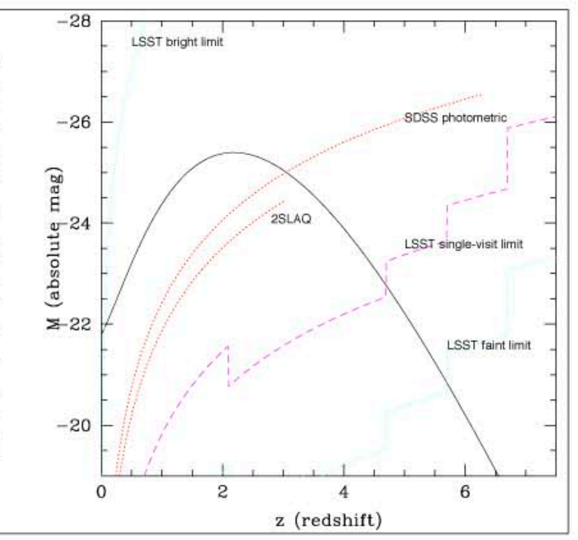
AGN up to redshift 7.5 will be discovered as *i*- or *z*-band dropouts, and *y*-band dropouts detected in other wavelengths (e.g., in X-rays) will be followed-up as candidates for AGN at even higher redshifts. This figure shows the expected number of LSST AGN detected above certain redshift thresholds as a function of *y*-band magnitude for both the single epoch and final survey sensitivities (dotted lines). Currently, there are ~50 known AGN above a redshift of 6.0.



AGN Luminosity Function

The AGN luminosity function (LF) can trace the history of accretion onto supermassive black holes in the Universe as well as provide insights into the AGN-host feedback mechanism, AGN duty cycle, and cosmic downsizing. The wide coverage of the AGN luminosity-redshift plane provided by LSST will dramatically improve the quantification of the optical AGN LF. In particular, LSST will probe the ultrafaint (m > 22.5) AGN population at moderate to high redshift, enabling a much better characterization of the LF shape and its evolution with cosmic time. In each redshift bin, the LF is composed of two power-laws with differing slopes, and the break luminosity L_* is observed to be redshift dependent. It is thought that the faint end of the LF constrains the AGN duty cycle in the sub-Eddington accretion phase and the bright end reflects on the AGN-host connection. Tracing the evolution of both ends of the LF is thus central to understanding cosmic downsizing.

The solid line in the figure shows the evolution of L_* inferred from the double power-law AGN LF model of Hopkins et al. (2007). Superposed are dotted red curves representative of the faint limits of the 2SLAQ (Croom et al. 2009) and the SDSS photometric surveys (e.g., Richards et al. 2005, 2009). The LSST sensitivity (dashed magenta and dotted cyan curves) will enable tracing the LF above L_* up to redshift ~5.5 (for the final survey), thus allowing us to probe AGN feedback and its influence on galaxy evolution in the early Universe.



AGN Clustering

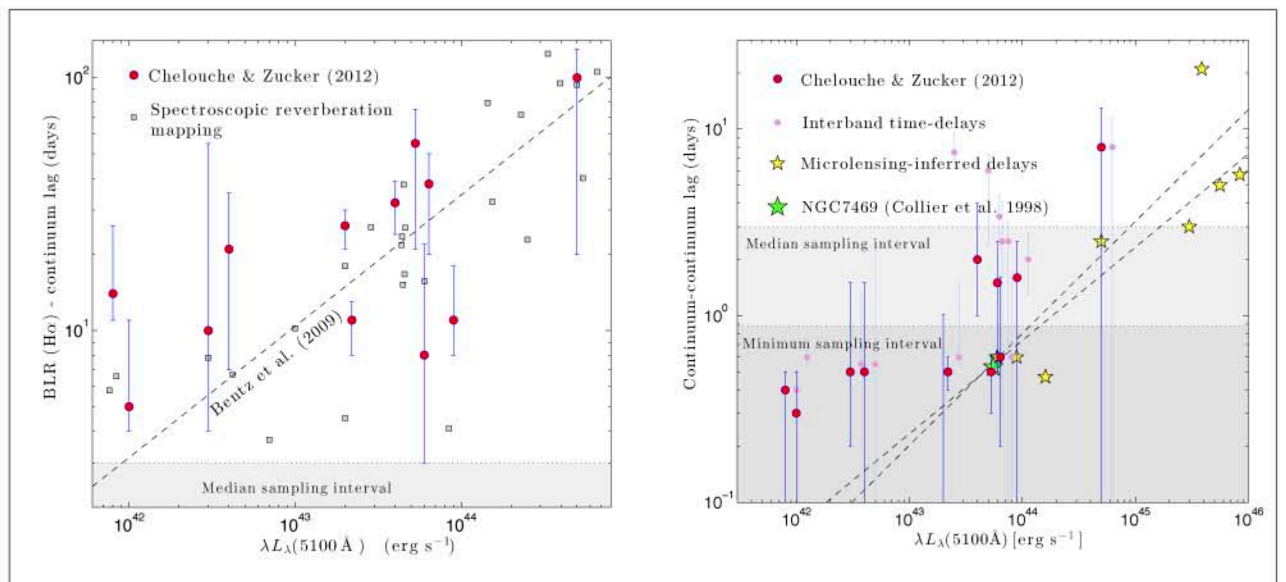
Measurements of the spatial clustering of AGN with respect to those of quiescent galaxies can provide clues as to how galaxies form inside their dark-matter halos and what causes the growth of their supermassive black holes. Unlike the galaxy clustering properties that have been well determined at least at low redshift (e.g., Zehavi et al. 2005), it is more difficult to derive the clustering properties of AGN that are much rarer. The impressive inventory of LSST AGN, spanning the widest possible ranges of luminosity and redshift, will enable the clustering, and thus the host galaxy halo mass, to be determined over a wide range of cosmic epoch and accretion rate.

Lensed AGN

LSST will discover ~8000 gravitationally lensed quasars including ~1000 systems with measurable time delays that will help to constrain basic cosmological parameters (e.g., Coe & Moustakas 2009). The unprecedented cadence and multiband nature of LSST will enable the monitoring of gravitational microlensing events in some of these systems which can be used to determine the accretion disk size and structure in AGN. LSST AGN exhibiting excess variability over that expected from their luminosity will be further scrutinized as candidates for lensed systems having unresolved images with the excess variability being attributed mainly to microlensing.

Photometric Reverberation Mapping of AGN Interiors

Searching for reverberation signals in AGN light curves can teach us about the physics of accretion flows and the structure of the broad line region (BLR). Traditionally, such studies have been carried out spectroscopically allowing different emission processes to be identified and their deduced light curves to be analyzed. Nevertheless, reliable results are scarce, and current understanding is limited to small samples of objects. Recently, several studies have shown that it is possible to identify different emission mechanisms that contribute to the broadband light curves with little or no spectroscopic information (e.g., Chelouche & Daniel 2012; Chelouche & Zucker 2012). This is possible provided that the contributions of such processes to the broadband flux in each band have distinct characteristics, and that appropriate statistical estimators are defined. Given its multiband nature and unprecedented cadence, LSST is likely to transform the field of reverberation mapping of AGN interiors shedding light on the physics of accretion and supermassive black hole demography over cosmic time.

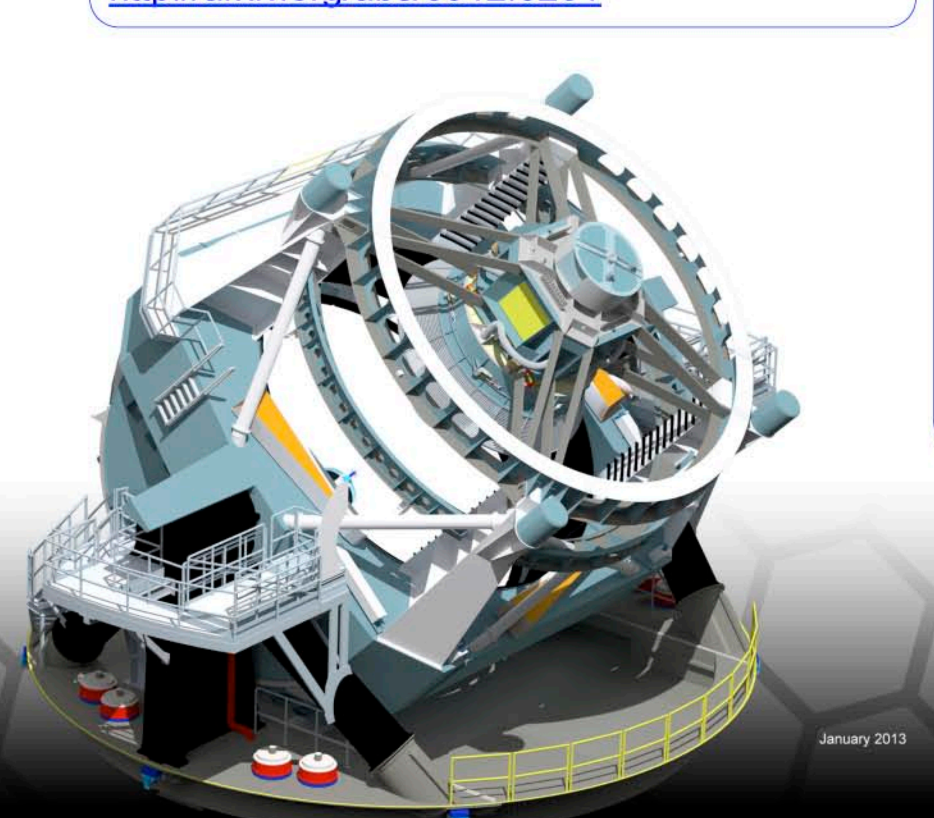


These figures, adapted from Chelouche & Zucker (2012), show that it is possible to recover the BLR size-luminosity relation (*left*), and provide new constraints on the size-luminosity relation of AGN accretion disks (*right*) by using photometric light curves.

Transient AGN

Transient outbursts from galactic nuclei lasting over a month or more can occur when a star, a planet, or a gas cloud is tidally disrupted and partially accreted by the supermassive black hole. LSST will be a premier facility for discovering and monitoring such transient AGN, enabling and aiding multiwavelength studies by releasing real-time alerts that will trigger follow-up observations. It is predicted that LSST will discover at least 130 tidal disruption events per year (Gezari et al. 2009). This will provide an assessment as to whether such events have a measurable contribution to the faint end of the optical AGN luminosity function (e.g., Milosavljevic et al. 2006; Luo et al. 2008). The frequent monitoring and large area covered by the survey may also allow us to detect the relatively faint and rapid outbursts associated with intermediate-mass black holes, enabling the discovery of such sources in the nuclei of nearby galaxies.

See also the LSST Science Book at http://arxiv.org/abs/0912.0201



AGN in Deep-Drilling Fields

About 20 to 40 LSST fields will be devoted to a "deep-drilling" survey, utilizing up to 10% of the LSST time, providing deeper images with much more frequent time sampling (see the LSST Deep Drilling Program poster in this session for more details). It is expected to result in the discovery of ~40,000 additional, mainly ultrafaint, AGN on top of the main survey, providing hours-to-years temporal information on thousands of these sources. This sample will be used to enhance the value of current and planned multiwavelength pencil-beam surveys, refine star-galaxy separation algorithms, reduce photo-z systematics needed for the main survey, as well as improve measurements of the AGN luminosity function and spatial clustering at high redshift. The following four deep-drilling fields were recently selected for LSST, enabling preparatory AGN surveys with observatories that have limited lifetime.

	ELAIS S1	XMM-LSS	Extended Chandra Deep Field-South	COSMOS
RA (2000.0)	00 37 48	02 22 50	03 32 30	10 00 24
DEC (2000.0)	-44 00 00	-04 45 00	-28 06 00	+02 10 55

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