AGN Science with the LSST


1Drexel Univ., 2Univ. of Washington, 3Georgia Tech, 4UC Irvine, 5Penn State, 6KICU, 7College of Charleston, 8Yale, 9JHU, 10Univ. of Arizona, 11LBT, 12Spitzer Science Center, 13Universidad de Chile, 14SLAC, 15Univ. of Pittsburgh, 16Univ. of North Texas, 17CITA, 18Princeton, 19JHU, 20Hawaii, 21St. Vincent College

Although the numbers of known quasars and active galactic nuclei (AGN) have grown considerably in the past decade, a vast discovery space remains to be explored. LSST will fill the gaps by producing a sample of at least 1.0 million optically-selected AGNs that will span more than a factor of 1,000,000 in luminosity, and will allow detection of ~1000 AGN beyond a redshift of 7. Utilizing a combination of colors, photometric variability, and lack of proper motion, this large-area AGN survey will dwarf the current sample sizes by more than an order of magnitude. Each LSST region will receive ~1000 visits, allowing variability to be explored on timescales from minutes to a decade. The ground-breaking combination of area, depth, and cadence will allow extreme AGN (and other related transient) science. LSST will break the luminosity-redshift degeneracy inherent to shallower flux-limited surveys and provide unprecedented quantification of the optical AGN luminosity function. Such statistical studies will help define the demographics and accretion history of supermassive black holes with cosmic time, and relate these to the formation and evolution of galaxies. LSST will discover sufficient numbers of faint, high-redshift AGN to enable clustering measurements that will place important constraints on models for the relationship between AGN and the dark matter distribution. LSST will also investigate multi-wavelength phenomena in AGN, using wide-area and pencil-beam surveys at other wavelengths. The former is important for investigations of rare objects, the latter for probing intrinsically more numerous, but undersampled populations. In short, LSST will produce transformative results in our understanding of AGN fueling mechanisms, the physics of accretion disks, the contribution of AGN feedback to galaxy evolution, the cosmic dark ages, and science based on the use of AGN as background sources. 

Introduction

The LSST AGN survey will produce a high-purity sample of at least ten million well-defined, optically-selected AGN. The LSST AGN sample will span a luminosity range of more than a factor of 1000 at a given redshift, and will allow the detection of AGN out to z=7. Such a sample will revolutionize our understanding of the growth of super-massive black holes with cosmic time, AGN fueling mechanisms, the detailed physics of accretion disks, the contribution of AGN feedback to galaxy evolution, the cosmic dark ages, and gravitational lensing. 

SMIRFs at the centers of galaxies are intimately connected to the evolution of galaxies. Observations and simulations suggest that feedback from AGN regulates star formation, thereby directly influencing galaxy evolution. Thus, the goal of LSST AGN statistical studies is to define and measure the changing demographics and accretion history of SMBHs with cosmic time, and to relate these to the formation and evolution of galaxies. By virtue of their numbers, LSST will enable much more sophisticated clustering analyses. AGN clustering reflects the dark matter halos in which these objects are embedded. The relationship between AGN clustering and that of "ordinary" galaxies can give important clues about how the two are physically related. The galaxy correlation function at low redshift has been measured precisely, using samples of hundreds of thousands of galaxies (e.g., Zehavi et al. 2005), allowing quite accurate determination of the bias as a function of scale for various subsets of galaxies. However, AGN are rarer, and the measurements are not as accurate (for example, the mean separation between 2-3 quasars in the X-ray sample of Croston et al. 2008). The observed AGN samples selectable from LSST data will cover a very large range of luminosities at each redshift, allowing the clustering, and thus bias and host galaxy halo mass, to be determined over a large range of cosmic epoch and black hole accretion rate. The figure below shows both the angular quasar auto-correlation, and the quasar-galaxy cross-correlation, that we expect to model for a sample of 1000 quasars (to z=2) in 1000 square degrees (one visit). In fact, our photometric redshifts will be good enough to explore clustering in substantially their redshift bins, strengthening the clustering signal. Even with broad redshift bins, correlation function errors are small enough that we can divide the sample into many bins in luminosity, color, or other properties, allowing us to explore both the redshift and luminosity dependence of the clustering signal.

Clustering

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By the Numbers

Utilizing large sky coverage, depth, six filters spanning the optical and near-infrared, and temporal information, the LSST AGN survey will dwarf the current sample sizes by more than an order of magnitude. The table below indicates that, in the deep 2dF survey, as many as 15 million AGN samples will be detected to i=22.5 according to the Hopkins et al. (2007) luminosity function. At high redshift, a better estimate is provided by Jiang et al. (2009). The figure on the right graphically illustrates the vast numbers of AGN that will be found at z=6. The current number is only ~40.

Transients SMIRF Phenomena

Strong transient outbursts from galactic nuclei can occur when a star, planet, or gas cloud is totally disrupted and partially accreted by a central SMBH. An optical flare lasting several months is expected when a star destranges into the outer event horizon. LSST will be a premier facility for discovering and monitoring such transient SMIRF phenomena, enabling and aiding studies across the electromagnetic spectrum as well as detections with gravitational waves. Gezari et al. (2008) predict that LSST should detect the least at 100 detectable transients per year.

Multiwavelength

AGN are an inherently broad-band phenomenon with emission from the highest-energy gamma-rays to long-wavelength radio probing different aspects of the physics of the central engine (e.g., Elvis et al. 1994). The rich diversity of radiation that adds complexity to their SEDs also enable a more detailed understanding of their composition, multi-region structure from the accretion disk to the jets to the outflowing winds. LSST will overlap surveys carried out in a broad range of wavelengths, allowing studies of a large number of broad-band phenomena. LSST’s multi-wavelength AGN survey will cover the spectrum from 200 nm to 200 μm as compared to the existing surveys that cover the entire mid-infrared region. Together, the LSST AGN SEDs will provide the large inventory of AGN SEDs over a very wide wavelength range, allowing better constraints on typical accretion and reprocessing mechanisms.

Luminosity Function

The LSST AGN sample will produce a measurement of the AGN luminosity function and its evolution that will break the luminosity-redshift degeneracy inherent to most flux-limited samples. Only ultraviolet (m<23.5) surveys can probe the populous, faint end of the AGN LF, especially at moderate to high redshifts. For example, an AGN with absolute magnitude M=-23.3, i.e., a high space density object from the faint end of the luminosity function, will have apparent magnitude m=-2.5 at z=1. In the currently popular merger plus feedback model of Hopkins et al. (2008), the faint-end slope of the luminosity function is a measure of how much time quasar spectra accretion at sub-Eddington rates (either before or after a maximally accreting state). The bright-end slope, on the other hand, tells us about the intrinsic properties of quasar hosts (such as merger rates). Understanding the evolution of the bright- and faint-end quasar LF slopes is central to understanding cosmically downsizing.

The figure on the right shows a realization of one of these downsizing models: it adopts the double power-law shape, but allows for a break luminosity L* that evolves with redshift, as shown by the solid line. The two dotted lines are dotted red curves representing the faint limits of the 2dF-LAS and the DSS photometric surveys (Richards et al. 2005, 2009). These surveys, however, don’t probe significantly beyond the break luminosity redshift for redshifts much larger than 2. The faint limit in a single visit (dashed magenta line) probes the break luminosity to z = 4.5, and to z = 5.5 in the co-added magenta line (shifted open line), even in this model in which the break luminosity decreases rapidly beyond z=5.5. The LSST-detected quasar LF will provide crucial insights to our understanding of AGN feedback in the early Universe and how it influences the evolution of massive galaxies.

References


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