AGN Science with the Large Synoptic Survey Telescope

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and
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Large Synoptic Survey Telescope

- The LSST will be an 8.4-m wide-field telescope for imaging surveys in the time domain.
- It will have a 3.5 deg square Field of View filled with a 3 Gpix CCD mosaic camera.
- Typical exposure cadence: two 15-sec exposures per field every 40 seconds.
- Data generation rate: 15 Tbytes / night
- Planned to run for 5 years with possible extension.
- Sold as “Dark Energy Machine” through weak lensing shear and Type Ia supernovae precision measurement, but has powerful capabilities for AGN detection.
3-element Paul-Baker design, with tertiary and primary on the same blank
Fast Primary Combined with Tertiary Leads to Very Compact Design
Steward Observatory will cast and polish the 8.4-m mirror.

Installing the first LBT 8.4-m Primary Mirror in its Cell on the mountain

March 2004
Chosen for the combination of clear weather fraction and available infrastructure and support.
Camera

- **Focal Plane Array**
  - 10 μm pixels $\rightarrow$ 0.2 arcsecond/pixel ($\sim\frac{1}{3}$ seeing-limited PSF)
  - 64 cm diameter $\rightarrow$ 10 square degree FOV
    $\rightarrow$ 3 Gpixels
  - Integrated front-end electronics
  - 16 bits/pixel, 2 sec readout time $\rightarrow$ 3 GB/sec
    $\rightarrow$ Parallel readout

- Construction costs are $\sim\frac{1}{3}$ telescope, $\frac{1}{3}$ camera, and $\frac{1}{3}$ software

- If not limited by funding profile, science scheduled to begin in 2012.
Data Management & Project Plan

- Real-time alert latency: 1 minute
- Nightly data generation rate: 15 Tbytes
- Yearly data generation rate: 7 PBytes
- Total spinning disk: 200 Pbytes
- Nominal computer requirements: 60 Tflops
- Long-haul communications BW: 10 Gbits/sec
- Basic catalogue and subscription to alerts intended to be open to the world.
- Special image data access and custom pipelines competitive access.
## Survey Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Units</th>
<th>Design Spec</th>
<th>Minimum Spec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median number of visits per sky location (min)</td>
<td>Design Depth (ref)</td>
<td>24.3</td>
<td>Nv1 (u)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.5</td>
<td>Nv1 (g)</td>
<td>—</td>
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<tr>
<td></td>
<td></td>
<td>27.8</td>
<td>Nv1 (r)</td>
<td>—</td>
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<tr>
<td></td>
<td></td>
<td>26.6</td>
<td>Nv1 (i)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.5</td>
<td>Nv1 (z)</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24.7</td>
<td>Nv1 (Y)</td>
<td>—</td>
</tr>
<tr>
<td>Survey Cadence</td>
<td>Observing time allocated to special programs, min &amp; max</td>
<td>SPTmin</td>
<td>%</td>
<td>5</td>
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<tr>
<td></td>
<td></td>
<td>SPTmax</td>
<td>%</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Area with fast (30–1,800 sec) revisits (min)</td>
<td>RVA1</td>
<td>deg$^2$</td>
<td>2,000</td>
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<tr>
<td></td>
<td>Area with 25% of visits separated by &gt;5 yrs (min)</td>
<td>RVA2</td>
<td>deg$^2$</td>
<td>15,000</td>
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<td></td>
<td>Area with 25% of visits spanning at least 4 calendar months (min)</td>
<td>RVA3</td>
<td>deg$^2$</td>
<td>15,000</td>
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</tbody>
</table>
The surface density of quasars with $i < 24$ was estimated from the survey depth and the LF of Croom et al. (2004) and Fan et al. (2001), with considerable extrapolation to the faint end, a goal of the new survey. High completeness should yield over 100 / sq deg.
Colors of quasars and stars were computed in the LSST system by transforming SDSS DR1 spectra through convolution with a synthetic quasar spectrum and stellar spectra from the Gunn & Stryker atlas.

The absence of deep u exposures makes it more difficult for low-z objects. High-z objects will be easily distinguished. Most contamination is $2.5 < z < 3$. 
The Time Domain Adds Two New Discriminants: Variability & Proper Motion

Purifying the Sample with Proper Motions

- Zero proper motion will further distinguish faint quasars from stars to varying degrees of success.

- The $3\sigma$ upper limit on proper motion for the full 10 years of the LSST survey is intended to be $0.006"/yr$.

- The stringent upper limit on proper motions will essentially eliminate L and T dwarfs as contaminants of the very high-z quasar candidate lists.
Purifying the Sample with Proper Motions

- Cool white dwarfs will also be effectively screened. Hotter white dwarfs and main sequence stars earlier than K spectral type will be eliminated from the magnitude range typical of the current SDSS samples.

- An increasing fraction of the halo white dwarfs will remain as contaminants as the LSST survey limits are approached. The decrease in surface density of very distant halo main sequence stars will somewhat counteract the increasing fraction of the population with apparently zero PM from the relaxing of tangential velocity limits toward the faintest survey magnitudes.
Detection through Variability

• It is well-known that AGNs vary in brightness at optical and UV wavelengths. The amplitude of variability depends upon rest frame time lag, wavelength, luminosity, and possibly redshift (Vanden Berk et al. 2004).

• We use the parameterized description of AGN variability from the SDSS (Ivezic et al. 2004) extrapolated to fainter apparent magnitudes, to estimate the fraction of AGNs in the LSST that may be detected as significantly variable.

• We calculate the magnitude difference at which only 1% of the non-variable stars will be flagged as a variable candidates due to measurement uncertainty.

• The probability that the single-band rms magnitude difference of an AGN will exceed this value -- and will therefore be flagged as a variable candidate – depends upon redshift (as it determines rest wavelength and rest time lag), luminosity, observed time lag, and the number of observing epochs.
Good probability of detection is achieved after only 2 epochs, and after 12 epochs in a year, almost all the AGNs to $i<24$ will be detected as variable. Multi-colors improve it.
Through its frequent time monitoring, LSST should be able to constrain the frequency of optical flares and other rare light curve events, expanding the range of timescales and redshifts over which they have now been explored.

The expectation is that tidal disruption of stars, planets, or gas clouds should happen with finite frequency, leading to such observable outbursts.

LSST data can act as a trigger for prompt multi-wavelength follow-up.
Brandt’s thesis showed this spectrum, blue during an X-ray outburst and red after.
The LSST will automatically provide sensitive imaging data for thousands of archival X-ray fields observed by Chandra, XMM-Newton, eROSITA, and other X-ray observatories. These fields will contain hundreds of thousands of X-ray AGN, many of which are not easily identifiable via standard optical techniques due to obscuration and dilution by host-galaxy light. LSST data will enable high-quality photometric redshift estimation for the majority of these AGN, and the most notable sources will be targeted for spectroscopic and multiwavelength follow-up studies. The resulting unprecedented AGN samples will address critical questions on AGN physics and evolution. For example, X-ray sources that have counterparts in only the reddest LSST filters will be prime candidates for moderate-luminosity AGN at $z \sim 4-8$; a thousand or more such AGN should be found and will provide a definitive AGN luminosity function throughout the end of the cosmic dark ages.
I-band magnitude versus 0.5-2 keV flux for extragalactic X-ray sources in the Chandra Deep Field-North (triangles) & Chandra Deep Field-South (squares). Sources with redshifts of 0-0.5, 0.5-1, 1-2, and 2-6 are shown as violet, blue, green, and red symbols, respectively.
Science Potential

- PSD determinations -> BH masses
- Interesting statistical test for BH growth with cosmic time - $L / L_{\text{Edd}}$ decreasing at fixed $L$?
- Quasars turning off - lifetime determination (Martini & Schneider) and/or incidence of type transition (1->2) from transiting dust clouds.
- Substantial expansion of samples of favorite rare types - NLQ1, strongly lensed, FeLoBAL, …
- Key difference from SDSS - as yet undefined path to wholesale spectroscopic follow-up.
LSST

• Unprecedented combination of	solid angle - 15,000 sq deg,
photometric accuracy - 0.01-0.02 mag internal
astrometric accuracy - 20-30 mas internal
sensitivity, I~26.6 @ 5σ
broad wavelength coverage (u)grizY
and time sampling - minutes-months-years
will provide a new window into the nature of AGNs.

Well-defined, large (> 10^7 objects) samples of AGNs at
0 < z < 7 can be constructed via three approaches:
location in color-color space, lack of proper motion, and
variability.