Large Synoptic Survey Telescope

The Large Synoptic Survey Telescope Science

J.A. Tyson (University of California, Davis) and the LSST Collaboration

Abstract

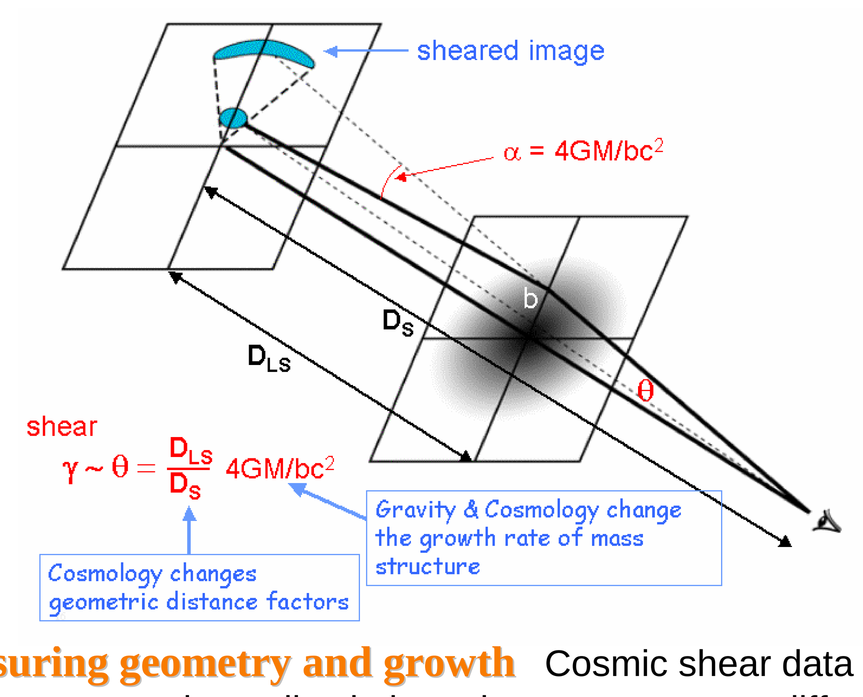
The Large Synoptic Survey Telescope (LSST) is a wide-field facility that will add a qualitatively new capability in astronomy and will address some of the most pressing open questions in astronomy and fundamental physics. The 8.4-meter telescope and 3 billion pixel camera covering ten square degrees will reach sky in less than 10 seconds in each of 5-6 optical bands. This is enabled by advances in microelectronics, software, and large optics fabrication. The unprecedented optical throughput drives the ability to go faint-wide-fast. The LSST will produce time-lapse digital imaging of faint astronomical objects across the entire visible sky with good resolution.

For example, the LSST will provide 3-dimensional maps of the mass distribution in the Universe, in addition to the traditional images of luminous stars and galaxies. These weak lensing data over 20,000 square degrees can be used to better understand the nature of Dark Energy. The LSST will also provide a comprehensive census of our solar system. By surveying deeply the entire accessible sky every few nights, the LSST will provide large samples of events which we now only rarely observe, and will create substantial potential for new discoveries. The LSST will produce the largest non-proprietary data set in the world.

Several key science drivers are representative of the LSST system capabilities: Precision Characterization of Dark Energy, Solar System Map, Optical Transients, and a map of our Galaxy and its environs. In addition to enabling all four of these major scientific initiatives, LSST will make it possible to pursue many other research programs. The community has suggested a number of exciting programs using these data, and the long-lived data archives of the LSST will have the astrometric and photometric precision needed to support entirely new research directions which will inevitably develop during the next several decades.

Dark Energy or New Gravity?

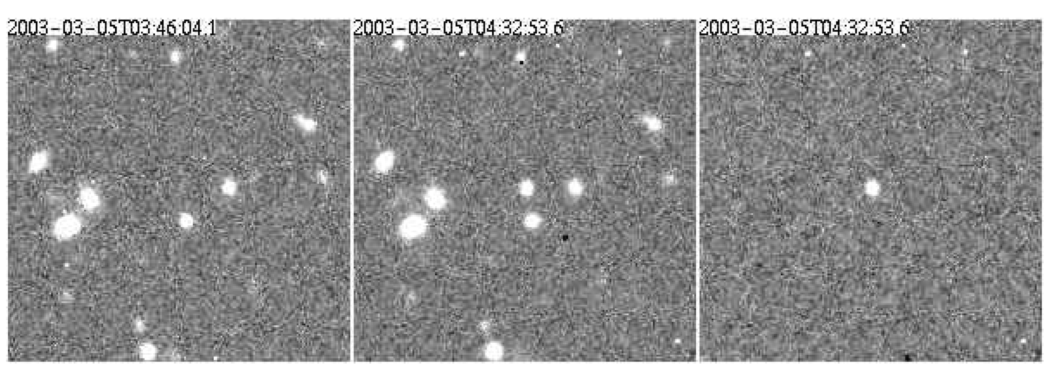
- **What drives the recent acceleration of the expansion?** The observed acceleration of the universe is driving a revolution in our understanding of fundamental physics. This revolution could transform our understanding of particles and fields (through the discovery of a new ingredient, the "dark energy") or revise our understanding of space and time (by forcing fundamental changes to our theory of gravity). The next generation of observations will need to cover both these possibilities. LSST will measure the geometry of spacetime and also chart the evolution of dark matter structures over cosmic time, addressing the nature of the "dark energy." Utilizing the same data, different analysis methods (cosmic shear, three-point shear correlations, mass cluster counts vs z) yield independent measures.



Measuring geometry and growth Cosmic shear data provide us with an opportunity to discriminate between two very different explanations for acceleration. This ability is due to the sensitivity of cosmic shear data not just to the history of the Hubble expansion rate, but also to the rate of growth of the large-scale density field. In effect, we have two windows on the mechanism driving acceleration. By measuring shear on large scales, LSST is uniquely capable of separating geometry effects and growth of mass structure. Geometry will also be measured via SNe. Consistency may prove illuminating.

New Optical Burst Phenomena

- **LSST will open a new window on the transient optical universe.** Exploration of the variable optical sky is one of the true observational frontiers in astrophysics. Vast regions of parameter space remain un-probed: no existing facilities have the apertures and fields of view required to survey faint, fast, and wide simultaneously. At the faint flux levels that will be reached by LSST, current surveys are only able to probe down to timescales of hours. LSST will survey the sky on a variety of timescales down to 20 seconds. This factor of a thousand increase in discovery space holds the promise of the discovery of rare, violent events and new astrophysics.



Optical burst with no host Optical burst detected by difference imaging (right hand frame) in the Deep Lens Survey. Only a few of these have been seen in the DLS and in supernova searches. They have no stellar or galaxy precursor and last less than 30 minutes. LSST will likely find tens of thousands of these and other new phenomena.

Massively Parallel Astrophysics

- **LSST will enable many investigations.** By taking 2x10 second exposures and returning to each patch of the visible sky multiple times per month, LSST will enable many new explorations in addition to giving precision to those underway. The community has suggested the following list of exciting projects, which surely is not exhaustive. Two are discussed on the left. Some of these are discussed in other posters at this meeting.

- Dark matter/dark energy via weak lensing
- Dark matter/dark energy via supernovae
- Galactic Structure encompassing local group
- Dense astrometry over 20000 sq.deg: rare moving objects
- Gamma Ray Bursts and transients to high redshift
- Gravitational micro-lensing
- Strong galaxy & cluster lensing: physics of dark matter
- Multi-image lensed SN time delays: separate test of cosmology
- Variable stars/galaxies: black hole accretion
- QSO time delays vs z: independent test of dark energy
- Optical bursters to 25 mag + co-observing by other facilities (EVLA, EXIST, JWST): the unknown
- 5-band 27 mag photometric survey: unprecedented volume
- Solar System Probes: Earth-crossing asteroids, Comets, TNOs

A unique result of having a very high optical throughput (*étendue*) is that many such programs can proceed in parallel with the same data. These science missions set the requirements for the LSST design in the key areas of image quality, *étendue*, cadence, astrometric precision, and photometric accuracy. The LSST mission will thus include several key science deliverables in addition to the vetted data deliverables.

The University of Arizona, Tucson Arizona — University of Washington — NOAO — Illinois, University of Illinois at Urbana-Champaign — Leland Stanford Junior University — Brookhaven National Laboratory — Research Corporation — UC Davis, University of California, Davis — SLAC — Johns Hopkins University — Harvard (VE RI TAS)