Large Synoptic Survey Telescope

Strong Lensing Studies with the LSST

C. D. Fassnacht (UC Davis), P. J. Marshall, E. A. Baltz, R. D. Blandford (KIPAC), P. L. Schechter (MIT), J. A. Tyson (UC Davis)

The LSST will obtain hundreds of images of 20,000 square degrees, integrating to 26.5 AB mag in each of 5-6 bands. Photometric redshifts will be available for the ~3 billion detected galaxies. The data set will provide deep multicolor photometry and variability monitoring. One of the many strengths of the LSST will be its ability to use strong gravitational lensing to study dark matter distributions on galaxy and cluster scales.

Finding Rare Lenses

The unprecedented combination of depth and area provided by the LSST will be exploited to find rare alignments, such as clusters in which background sources are lensed into multiple images. By sampling the gravitational potential at several radii in these systems, the LSST imaging will allow accurate, high-angular resolution reconstructions of cluster mass distributions. Our simulations predict that the LSST dataset will provide at least an order of magnitude increase in the number of such systems known. Other rare lensed image configurations will provide important insights into cosmography and source astrophysics. These include multiply-imaged supernovae, multiple-plane lensing, and unusual strong lenses with higher-order catastrophes.

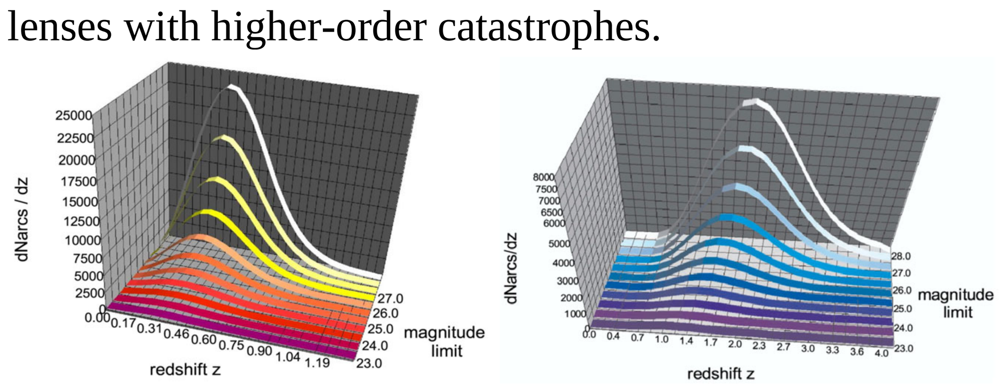

Figure 1: Redshift distribution of lenses (left) and sources (right) that produce giant arcs in clusters. The number densities are for a 20000 square degree survey; the lensing cross-section was approximated following Dalal et al 2004, and the HDF faint galaxy counts (Casertano at al 2000) were used for the source population.

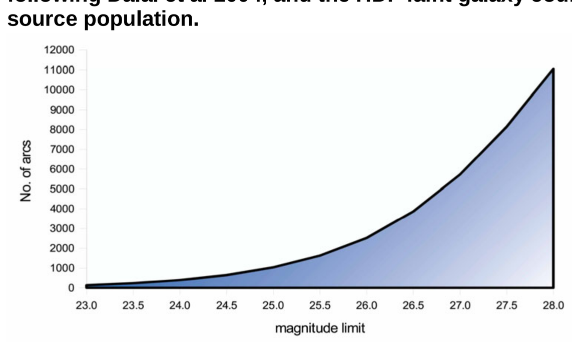

Figure 2: Integrated arc number counts as a function of magnitude limit. LSST will reach magnitude ~24 in each exposure, and ~27 in the final stacked image.

Galaxy Cluster Abell 370

Figure 3: Example of a cluster containing a giant arc. This arc is easily detected by a ground-based telescope, in this case the VLT.

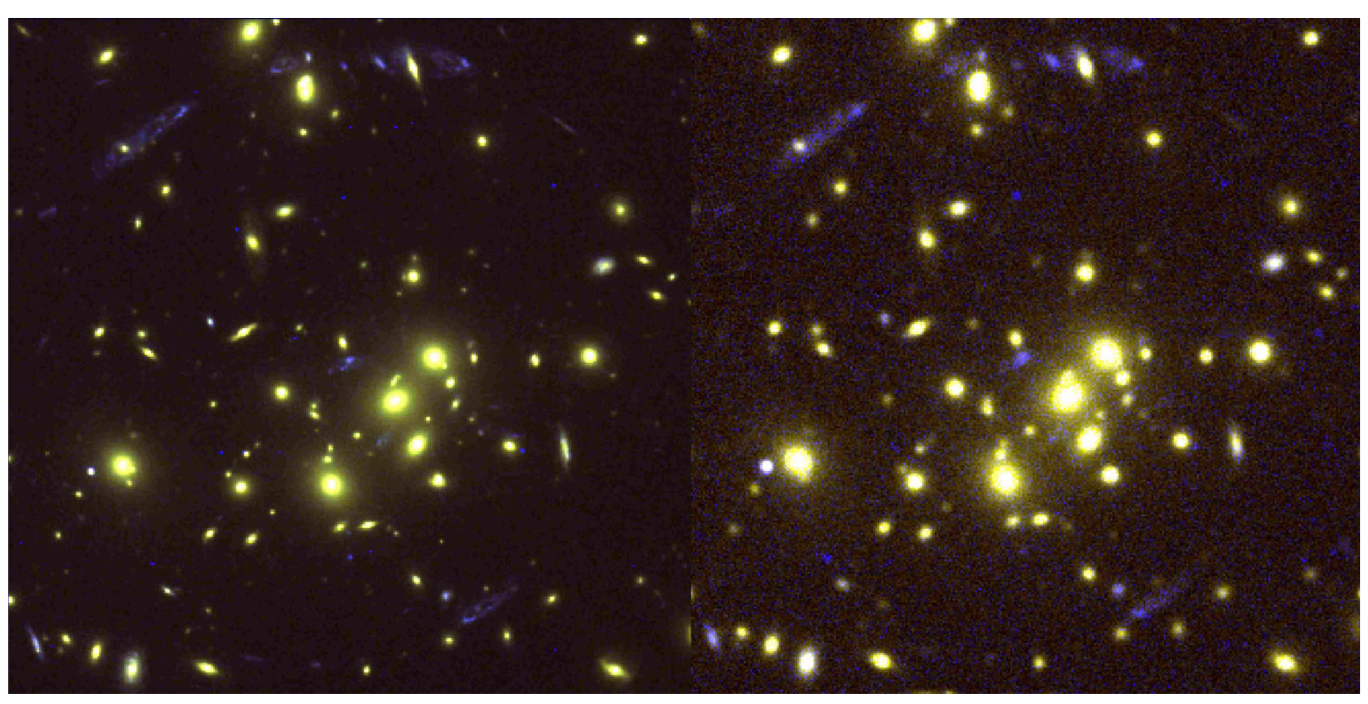

Figure 4: CL0024 as seen by the Hubble Space Telescope and as it would be seen in one year's stacked image from the LSST survey (assuming 0.7 arcsec seeing). The multiple images of the background galaxy are clearly visible.

Galaxy-scale Lenses

In addition to the rare cluster lenses that will be found in the LSST survey, the survey images will produce at least an order of magnitude increase in galaxy-scale lenses. Our simulations predict that the final stacked data set will contain approximately 5000 detectable cases of a background galaxy being multiply-imaged by a foreground system. In addition, we predict that there will be ~150 systems in which the lensed objects are AGN or quasars and the lens system can be identified in a one-epoch image with an integration time of 20 seconds (assuming seeing of 0.7 arcsec). This number increases to ~1500 systems if the seeing is 0.4 arcsec. Figure 5 shows a Keck R-band image of the CLASS B1600+434 lens system, a double with a separation of 1.4 arcsec. More generally, with shapes and redshifts of billions of source galaxies LSST will measure the compact dark matter distribution on these scales with precision.

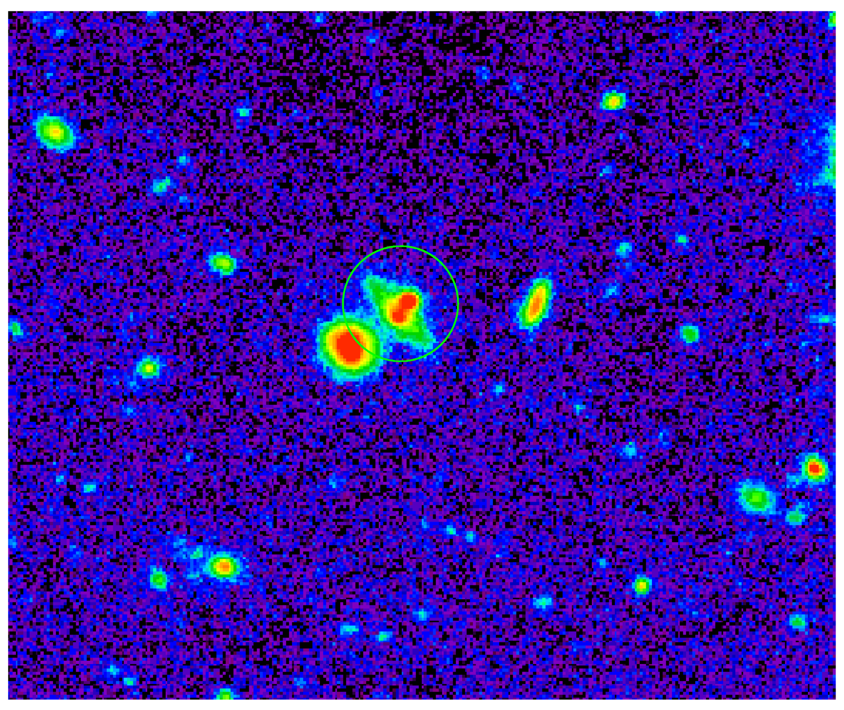

Figure 5: Keck R-band image of the double lens CLASS B1600+434. The two lensed quasar images, which are separated by 1.4 arcsec, can be seen in the center of the image. The seeing for this image was 0.7 arcsec. Figure from Fassnacht et al., in preparation.

The Time Domain

The LSST strategy of repeated imaging of the survey area will provide automatic monitoring of these lensed sources. Burud et al. (2002) have shown that it is possible to use a joint deconvolution method (the MCS method; Magain, et al. 1998) to extract accurate photometry in ground-based optical monitoring of arcsecond-separation lenses (Figure 6). The resulting light curves can be used to measure the difference in light travel time along the rays producing the multiple images of the background source. These time delays can either be combined with a well-constrained model of the lensing galaxy to produce a measurement of the Hubble Constant or, conversely, be combined with a knowledge of the Hubble Constant and model constraints from space-based imaging to provide a sensitive probe of the overall matter distribution in the lensing galaxies. Furthermore, these systems can provide information on the clumping of matter on sub-galaxy scales, through the investigation of flux-ratio anomalies and time-domain variations due to microlensing (Figure 7).

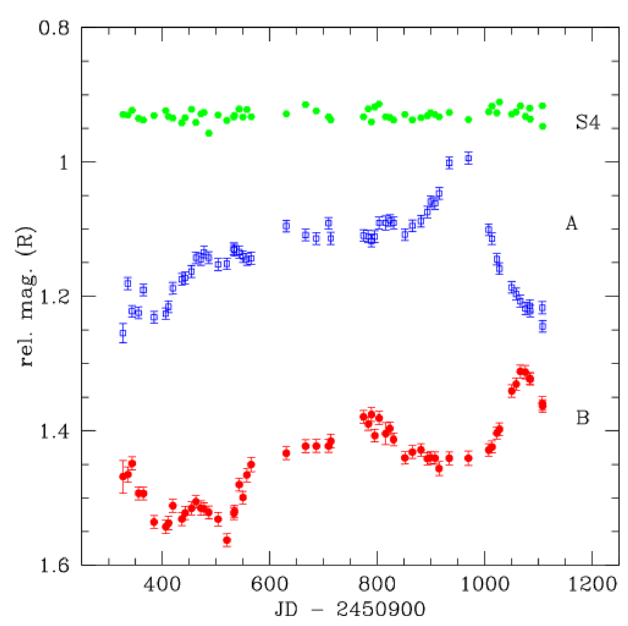

Figure 6: Light curves of the two lensed images in the SBS1520+530 lens system (blue and red) and a nearby comparison star (green). The photometry of the system was obtained from ground-based observations in moderate seeing, but yield good results when the data are processed using the MCS deconvolution scheme. Figure from Burud et al. (2002).

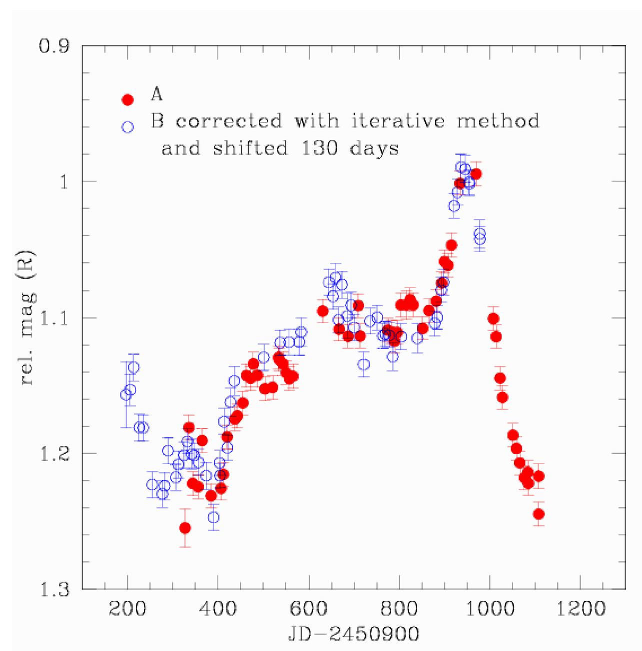

Figure 7: The SBS1520+530 light curves after shifting and correcting for microlensing signature. A clear time delay of 130 days is measured. Figure from Burud et al. (2002).

Lens Modeling

To achieve full impact from the lens systems for which time delays have been measured, it is especially important to properly model the mass distribution of the lens. For this, space-based imaging is crucial. LSST and JDEM imaging are thus complementary. Generally there will be huge astrophysics value added by co-observing the sky with other space and ground facilities (EVLA, JWST, EXIST, LISA).

Cosmography from time delays

In the several hundred special lenses of the sort shown on the left in Figure 4, there will likely be a few supernovae in the source galaxy. The resulting multiple time delays will be measured by LSST and, together with the strong and weak lens mass tomography, will lead to an independent measure of geometry. Since the times of the subsequent bursts are predictable, SN astrophysics could be address via JWST etc. targeted observing.

The University of Arizona Tucson Arizona
Research Corporation
University of Washington
NOAO
Illinois University of Illinois at Urbana-Champaign
UC Davis University of California, Davis
Leland Stanford Junior University 1891
SLAC
Brookhaven National Laboratory
Johns Hopkins University
VE RI TAS