# Estimating the Astrometric Accuracy of LSST

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## Abstract

**LSST will be an important tool for astrometric research since it will probe magnitude and temporal ranges unavailable to any other telescope. What astrometric accuracy will the LSST science require? These requirements in some cases drive the design. Can we check these new levels of astrometric precision using existing new technology 8-meter telescopes? This poster summarizes a few of the astrometric topics, and presents an analysis of frames taken by the *Subaru Suprime-Cam* supplied by the SMOKA archive.**

## Astrometric Risk Reduction

**ASTROMETRIC CHALLENGES**:

- Camera: The current LSST camera design calls for a large mosaic of monolithic devices (CCD or CMOS censors). The LSST baseline is for 3x3 rafts of sensors and these sensors and rafts must be stable mechanically. These tolerances are a specification of the camera.
- Exposure Time: The current LSST baseline is for 10 second exposures. There is little astrometric heritage for exposures. The USNO parallax program uses a minimum exposure of 100 sec.
- Relative vs. Absolute measurements: Existing astrometric catalogs such as Hipparcos, Tycho-2, and UCAC do not provide astrometric standards faint enough for routine LSST calibration. Programs needing differential astrometry (parallax, proper motion, etc.) do not need to be tied into the ICRS, but many other programs such as asteroid orbit determination need an accurate transformation from pixel coordinates to the ICRS.
- Systematic error: The tremendous astrometric potential of LSST can be realized only if the systematic errors can be controlled, thereby allowing the accuracy to improve according to the statistics of the observing process. Comparisons to external catalogs will be critical, and collaboration between the LSST project and other projects with enhanced astrometric capabilities (GAIA, Pan-STARRS, etc.) is essential.

**RISK REDUCTION:**

Although LSST first light is almost a decade away, important astrometric decisions need to be made in the next few years. In many cases, data from existing sensors and telescopes can be used to predict LSST performance, and these results can be of critical importance to the LSST design process.

- Sensor characterization: LSST has a program of sensor characterization.
- Mosaic stability: The LSST camera will be a mosaic composed of a hierarchy of chips, rafts, and support structures. Although the performance of the actual LSST camera cannot be characterized until it is built, the astrometric performance of other CCD mosaic cameras (Suprime-Cam, MegaPrime/MegaCam, MMT's Megacam, etc.) can be evaluated.
- Short exposures: Various estimates are being collected, data archives are being mined, and new observing proposals are being prepared. An end-to-end LSST simulator, including atmosphere, is being constructed.

## Heritage Estimates

**EXTERNAL ASTROMETRIC PROJECTS:**

- Deep Astrometric Standards (DAS): Platais (http://www.pha.jhu.edu/iau_comm8/das.html) has proposed defining and measuring at least two deep astrometric calibration fields. With sufficient access to large aperture telescopes with large mosaic CCD cameras, a 10-square degree area could be mapped to about 10 milliarcseconds astrometric accuracy down to about V=25. Given these data, LSST could bootstrap its astrometric calibration over the rest of its observable sky.
- USNO Robotic Astrometric Telescope (URAT): Zacharias (USNO) has proposed a 0.9 meter, symmetric pupil telescope and associated camera for the purpose of extending the UCAC catalog (http://ad.usno.navy.mil/ucac) down to about 20th magnitude with an accuracy of about 10 milliarcseconds. This telescope would be moved from the southern to the northern hemisphere to complete the coverage of the whole sky, and would need about 5 years to collect the observations.
- Pan-STARRS PS1 Astrometric and Photometric Catalog (PS1 AP): Pan-STARRS (http://www.pan-starrs.org) is proceeding with a single telescope and Gigapixel camera prototype called PS1 to be located on Haleakala. First light is expected in 2006, and one of the first tasks for PS1 will be the compilation of its astrometric and photometric catalog. Because of the smaller aperture and longer exposure time of PS1, astrometric calibration may be simplified.
- Early release of the GAIA catalog: The current expectation is that the GAIA mission (http://astro.estec.esa.nl/GAIA) will fly some time after 2010. Given the exceptional astrometric accuracy of this mission, an early release catalog of astrometric and photometric data would provide the milliarcsecond-class data needed for LSST.

**HERITAGE ESTIMATES FOR ASTROMETRIC ACCURACY:**

- Studies: There are very few CCD-based surveys that cover a large portion of the sky. USNO's UCAC survey used a 120-second exposure time and an 8-inch lens to produce a 20-30 milliarcsecond accuracy, but this system is sufficiently different from LSST as to render the comparison of little value. More relevant are the results reported by Pier et al (2003; AJ 125, 1559) which suggested that the astrometric uncertainty, after removal of all known error sources, was in the range of 20-30 milliarcseconds for a 55 second exposure and a 2.5 meter aperture, and by Platais et al. (2002; AJ 125, 601) who report a 26 milliarcsecond error using an 10 second exposure on a 4 meter telescope.
- Scaling: The SDSS results suggest that a single LSST exposure may have an astrometric accuracy in the range of 50-70 milliarcseconds on the basis of scaling the exposure time, but the difference in aperture of more than a factor of 3 will improve the estimate.
- Differential astrometry: Photon statistics and scaling current small-field astrometric programs (USNO, etc.) suggest that the differential accuracy for measuring the position of target with respect to a local reference frame should be in the range of 20-30 milliarcseconds (pixel/100). A software pipeline that handles both narrow-field and wide-field solutions is critical to the astrometric utility of LSST.

## Tests using Subaru

The SMOKA archive (http://smoka.nao.ac.jp) was used to access a sequence of multiple, short exposure frames taken in 2002. These data were used to study the astrometric accuracy as a function of separation with 10 and 30 second exposure times.

Although these data reflect performance on a single night, they serve to demonstrate that the expectations presented above are at least reasonable. In each of the ten 2Kx4K CCD images, the 100 brightest stars were identified, and the distances between all pairs of stars were computed using the assumption that the CCDs did not move in the camera between the 5 exposures. Figure 1 shows the growth of astrometric error over separations measured with a single CCD, and demonstrates that over small fields (~30 arcseconds) even the 10 second exposure allows for the measurement of differential position with an accuracy of a few milliarcseconds. Figure 2 shows the spatial scales measured by the entire camera, and demonstrates that accuracies in the vicinity of 30 to 40 milliarcseconds over scales of half a degree can be measured. The increase at larger scales is due to the finite size of the SuprimeCam array (27 arcminutes).

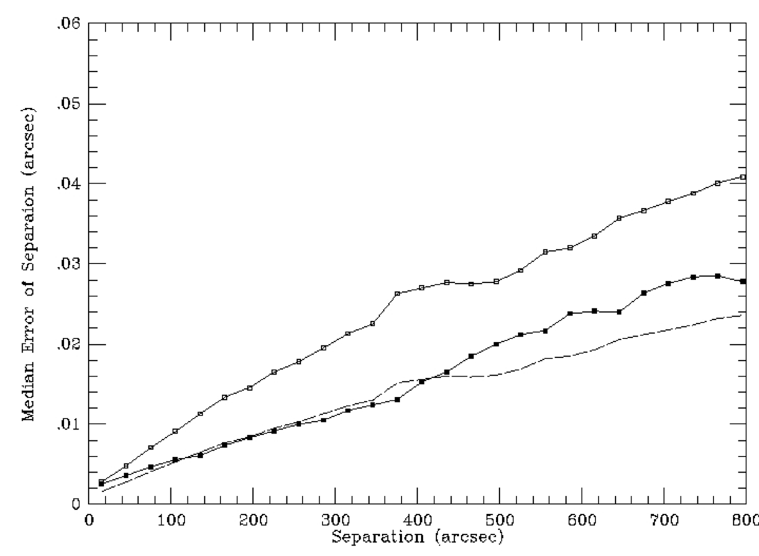


**Figure 1.** Short scale astrometric accuracy. Upper curve from 10 second exposures, lower from 30 second exposures.

Dashed line is 30 sec prediction based on 10 sec results.

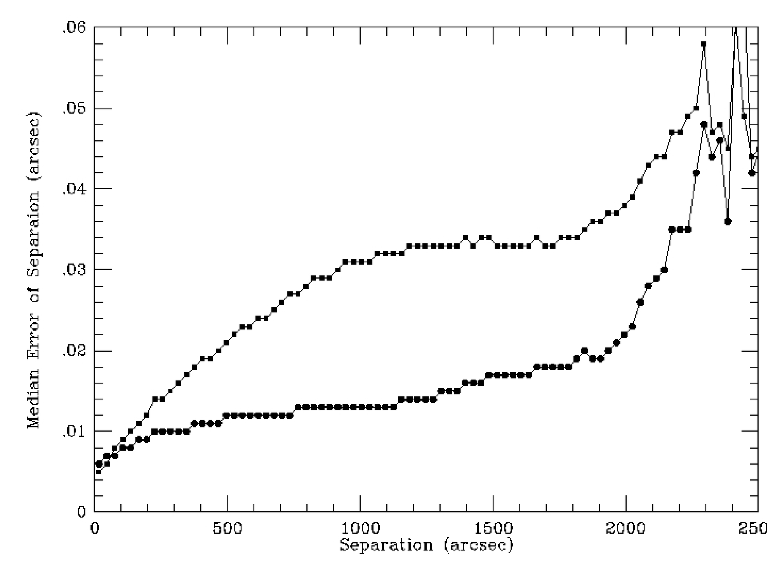


**Figure 2.** Large scale astrometric accuracy. Upper curve from 10 second exposures, lower from 30 second exposures.

Upturn is due to size of the SuprimeCam field (27 arcminutes).

**SUMMARY: Get involved! The Subaru data are encouraging!**