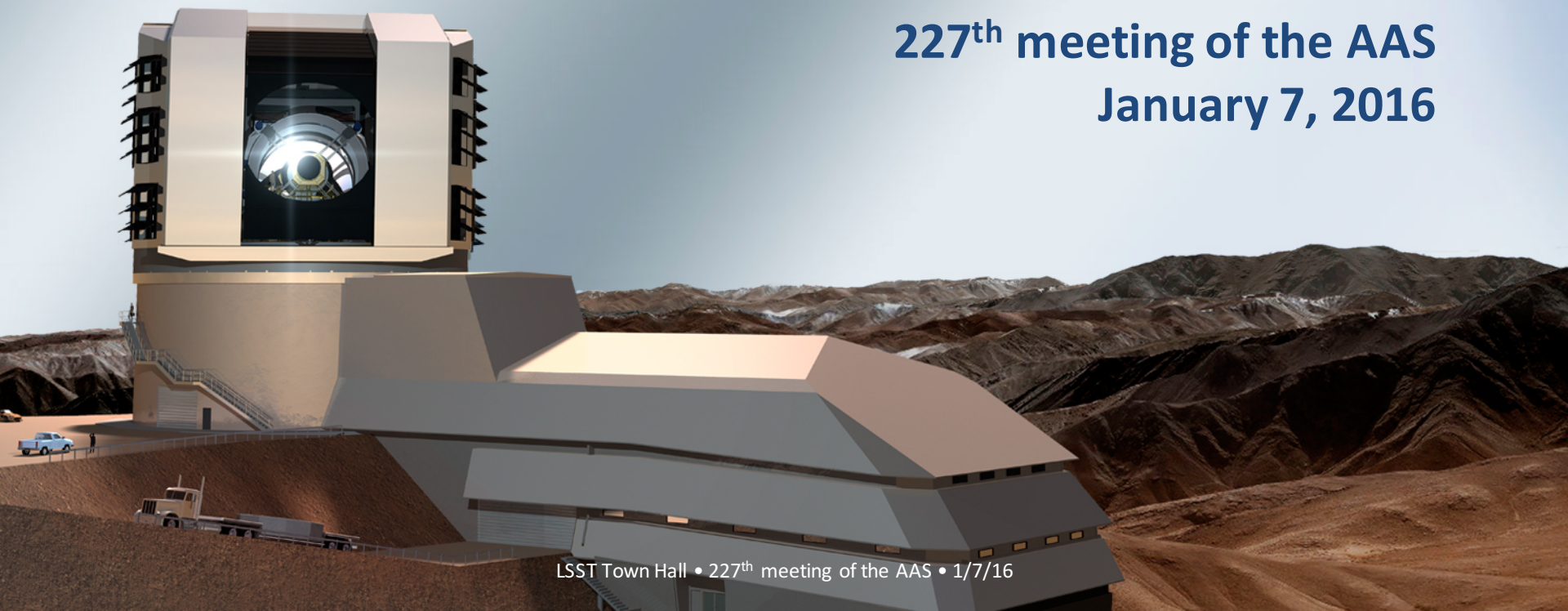
Large Synoptic Survey Telescope Town Hall

Beth Willman
LSST Deputy Director

227th meeting of the AAS
January 7, 2016



Town Hall Agenda

LSST Project Status and Community Resources

Beth Willman (LSST/Steward Observatory)

LSST Science Collaborations

Lucianne Walkowicz (Adler Planetarium)

LSST Corporation

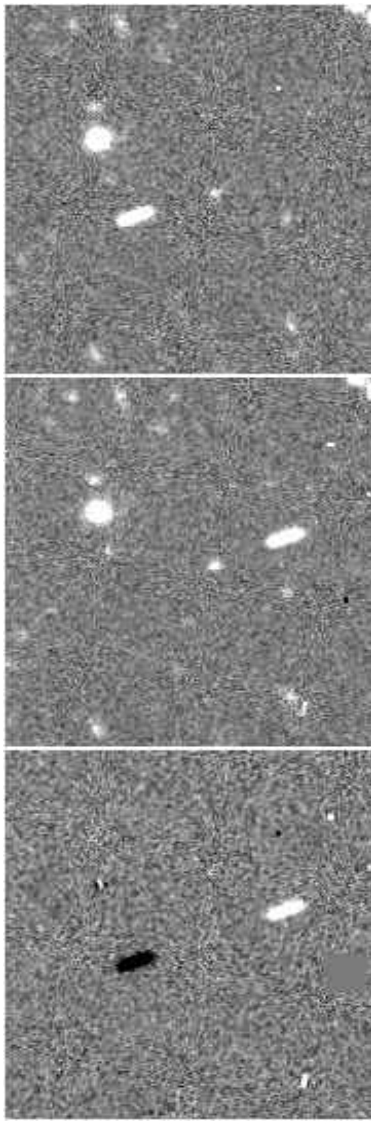
Pat Eliason and Pat Osmer (LSSTC)

Q&A

Willman, Walkowicz, Eliason, and Osmer

LSST was designed to deliver in four key science areas

- Time domain science
  - Nova, supernova, GRBs
  - Source characterization
  - Instantaneous discovery
- Census of the Solar System
  - MBAs, NEOs, Comets
  - KBOs, Oort Cloud
- Mapping the Milky Way
  - Tidal streams
  - Galactic structure
- Dark energy and dark matter
  - Strong Lensing
  - Weak Lensing
  - Constraining the nature of dark energy



Exposure 1

Exposure 2

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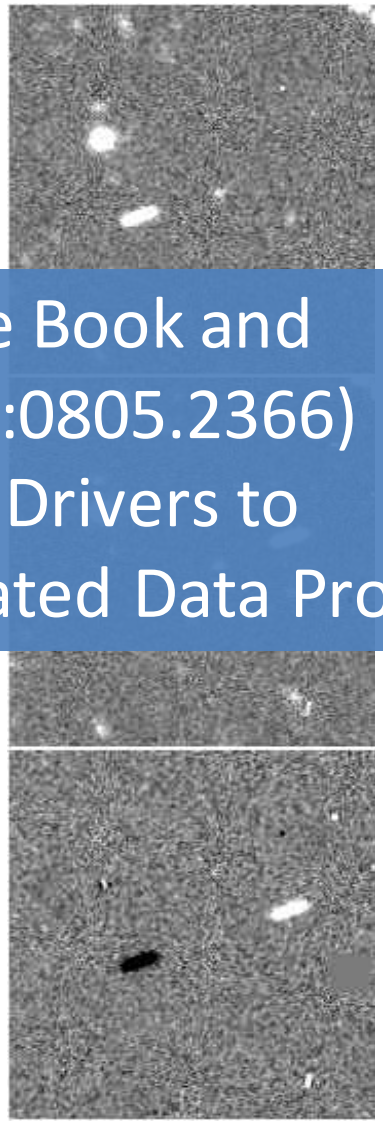
See the LSST Science Book and Ivezic et al 2008 (arXiv:0805.2366) "LSST: From Science Drivers to Reference Design and Anticipated Data Products"



What is the LSST?

The LSST system will include:

(i) an 8.4m (6.7m effective aperture) optical telescope with a 3.5-degree diameter field-of-view, a 3.2 billion pixel camera, and 6 broad-band, optical filters

(ii) a data facility that will process, archive, and distribute survey images, associated transient alerts, and calibrated catalogs, as well as calibration and other metadata.

We will deploy this system for a 10 year, time domain survey covering > 18,000 deg^2

What is the LSST?

Survey Property	Performance
Main Survey Area	18000 sq. deg.
Total visits per sky patch	825
Filter set	6 filters (ugrizy) from 320 to 1050nm
Single visit	2 x 15s exposures, 2s readout
Single Visit Limiting Magnitude	u = 23.5; g = 24.8; r = 24.4; I = 23.9; z = 23.3; y = 22.1
Photometric calibration	2% absolute, 0.5% repeatability & colors
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	60 sec after last visit exposure
Data release	Full reprocessing of survey data annually

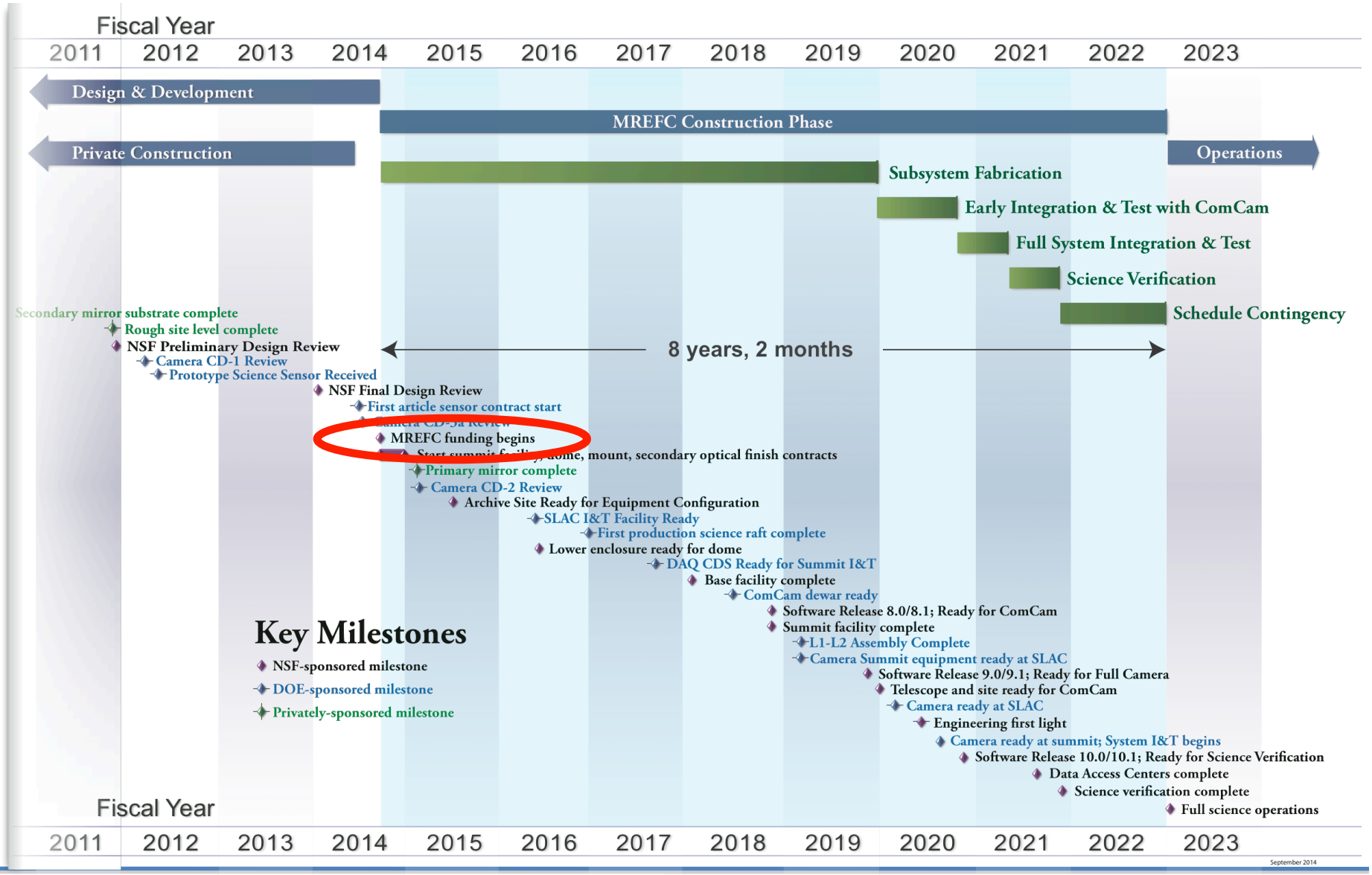
What is the LSST?

The LSST is an interagency construction project.

- **The National Science Foundation:**
  - Telescope and site facility construction, data management system, project management office, systems engineering, EPO
  - Major Research Equipment and Facility Construction (MREFC). Total not to exceed cost is $473M.
  - Under Cooperative Agreement with the Association of Universities for Research in Astronomy (AURA)
- **The Department of Energy:**
  - Camera fabrication.
  - Major Item of Equipment (MIE), through the Office of High Energy Physics in the Office of Science. Total projected cost is $168M.
  - SLAC National Accelerator Laboratory is the lead DOE lab.

The Project also received private funds (~$50M) that supported the primary/tertiary mirror, secondary mirror blank, preliminary site preparation, early sensor studies. The responsible organization is the LSST Corporation.

Project Schedule



Laying of the First Stone Event on the Cerro Pachon

Summit Facility Construction

Products to be Delivered by the LSST Project

Nightly (Level 1)

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.

Annual DRs (Level 2)

- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion single-epoch detections ("sources"), and ~30 trillion forced sources, produced annually, accessible through online databases.
- Deep co-added images.

Added Value (Level 3)

- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

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See the Data Products Definition Document, http://ls.st/dpdd and the backup slides for this talk at http://ls.st/wep (later on the website)

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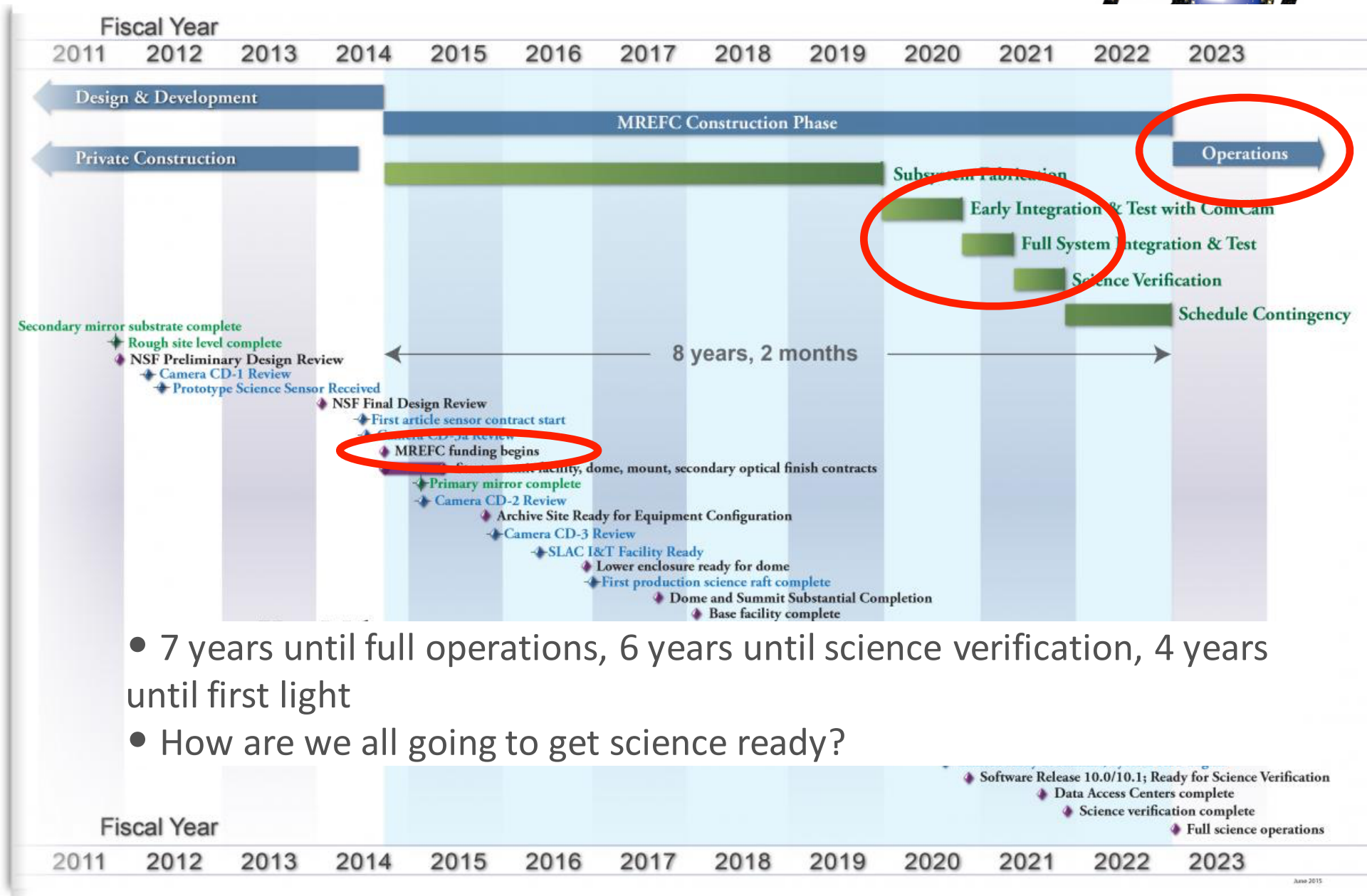
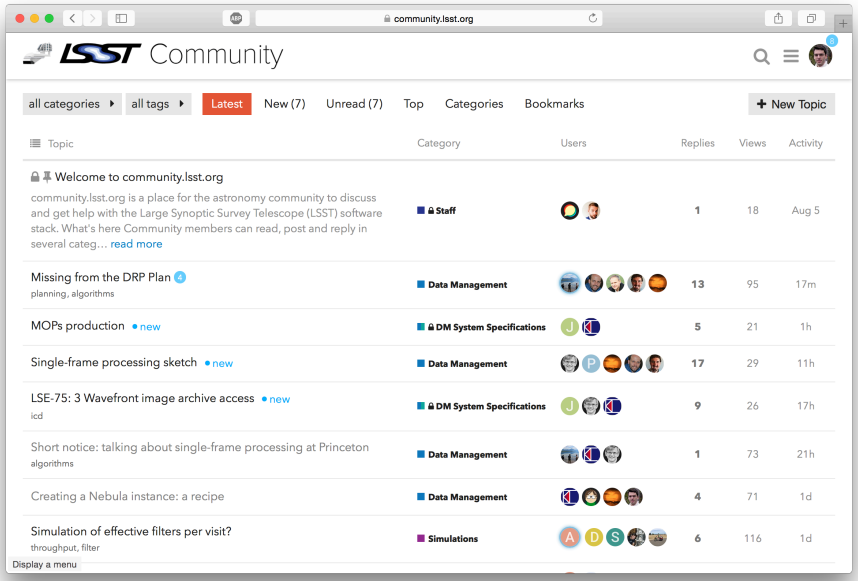


- 7 years until full operations, 6 years until science verification, 4 years until first light
- How are we all going to get science ready?

Community Engagement – Project Communication

- Key project information, including software and simulations, at www.lsst.org
- Weekly email digest (Spanish + English) and email exploder for scientists – Anyone can subscribe
- Science Advisory Committee minutes and membership



http://community.lsst.org

Community Engagement – Resources

- Operations Simulations (OpSim)
- Image Simulations (ImSim)
- Base catalogs of stars and galaxies in LSST filters (CatSim)
- Key Project Documents (Science Requirements Document, Data Products Definition Document)

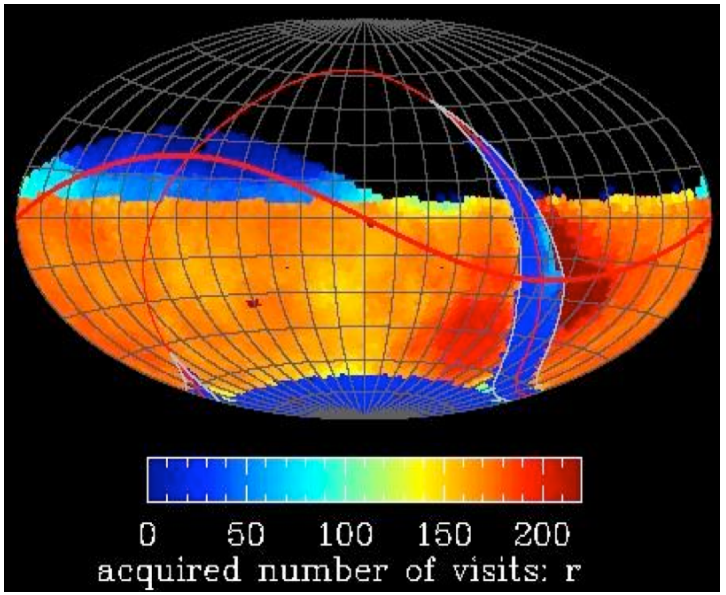
http://www.lsst.org

image from Ivezic et al. arXiv:0805.2366

Community Engagement – Observing Strategy

The implementation of this basic strategy can be optimized for science output.

See Z. Ivezic talk @ NSF Pavillion Friday 1:30 pm



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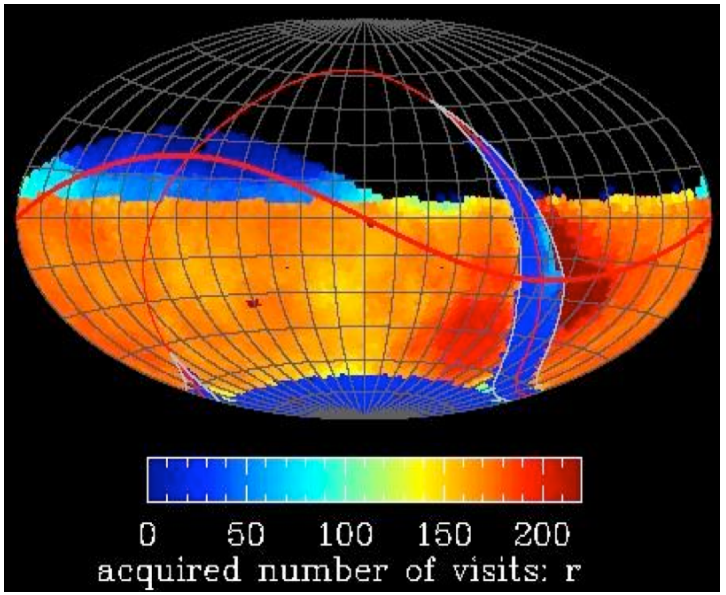
http://ls.st/o5k



The Project invites the community to contribute metrics for how well a given simulated 10-year survey delivers science:

August 2014 and 2015 – Community workshops on observing strategy

November 2015 – Working meeting to develop a white paper

2016 – White paper to be posted on the arXiv. *This will be the first step. We hope this first white paper inspires the community to contribute more input.*

Community Engagement – OIR Resources

NOAO and LSST are leading a community-based study (funded by the Kavli Foundation and endorsed by NSF/AST) that builds on the Elmegreen report and NOAO's 2013 *Spectroscopy in the Era of LSST* report.

What: Quantify and prioritize LSST-enabled science cases, and their necessary supporting capabilities (e.g., observing modes, instrumentation, software, computing infrastructure, archives).

Why: Provide input to funding sources and observatories (federal and non-federal) to guide funding priorities.

Participate: By **15 Jan 2016 at http://www.noao.edu/meetings/lsst-oir-study/**

1. Describe your LSST-enabled science goals and supporting capabilities they require;
2. Indicate if you are interested in joining a study group to develop example science cases in quantitative detail.

A workshop will take place in May 2016, with a report planned for Summer 2016

The End

Supplementary Slides

Reporting Time-domain Events

- For every source detected in a difference image, LSST will emit an "Event Alert" within 60 seconds of observation. **The primary use case is to enable real-time recognition and follow-up of transients of special interest.**

- Each alert will include the following:
  - Alert and database ID: IDs uniquely identifying this alert.
  - The photometric, astrometric, and shape characterization of the detected source
  - 30x30 pixel (on average) cut-out of the difference image (FITS)
  - 30x30 pixel (on average) cut-out of the template image (FITS)
  - The time series (up to a year) of all previous detections of this source
  - Various summary statistics ("features") computed of the time series

- **The goal is to transmit nearly everything LSST knows about any given event, enabling downstream classification and decision making *without* the need to call back into LSST databases (thus introducing extra latency)**

LSST Alert Filtering

- Based on models of the rates of observed asteroids as well as stellar variability (dominant sources of event alerts), we expect a high rate of alerts, approaching 10 million per night.
- A typical LSST user will not have sufficient bandwidth to receive this full stream. Size and bandwidth in the current LSST baseline will allow for transmission of ~three copies of the full data stream to public VOEvent brokers.
- Most end-users will not be interested in only a subset that matches their scientific interest (e.g., SNe candidates, variable stars, or moving objects).
- To support selecting subsets of alerts, LSST will provide a basic alert filtering service. This service will let astronomers create simple *filters* that limit which alerts are ultimately forwarded to them.
- This is the Level 1 analog of querying the database in Level 2, a service we also provide. The (significantly smaller) returned subset will then be transmitted to the end-user for analysis.

Limitations of the LSST Filtering Service

- The complexity and run time of user defined filters will be limited by available resources and may be throttled depending on load.
- The number of VOEvents transmitted to each user will be limited and dynamically throttled depending on load.
  - E.g., with a maximum of ~20 events per visit per user (20k/night), we can serve about ~500 simultaneous users at any one time utilizing total bandwidth equivalent to one full stream.
- No information beyond what is contained in the VOEvent packet will be available to user-defined filters (eg., no cross-matches to other catalogs, or other alert streams).
- We will not provide any astrophysical classification (eg., "is the light curve consistent with an RR Lyra?", or "a Type Ia SN?").

Public VOEvent Brokers and Networks

- We also anticipate that advanced, public, filtering services – VOEvent brokers – will be established by the community (e.g. the ANTARES project)

- These may provide advanced functionality such as cross-correlation of LSST alerts with external catalogs and other alert streams, classification engines, more extensive annotation of alerts, coordination of follow-up groups, and (more generally) incorporation of other contextual information needed to decide on whether a transient is worth following up.

- Because of their advanced functionality, we expect these will be preferred by the end-users, compared to the more limited LSST filtering service.

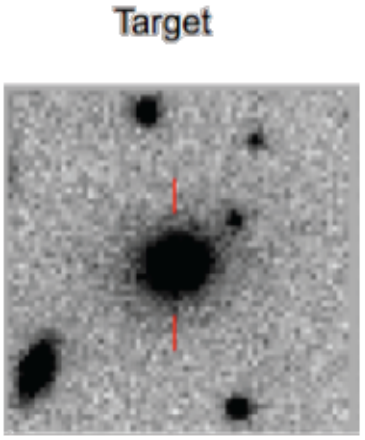
- However, if such public brokering facilities fail to materialize, we expect the filtering service provided by LSST will be sufficient to enable initial Level 1 science.

Level 2: Annual Data Releases

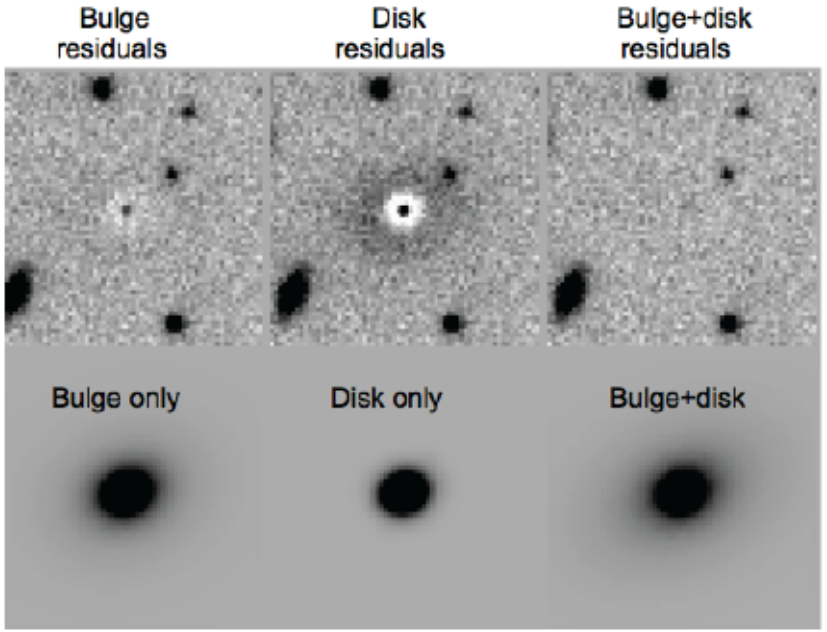
- **Well calibrated, consistently processed, catalogs and images**
  - Catalogs of objects, detections, detections in difference images, etc.
- **Made available in *Data Releases***
  - Annually, except for Year 1
    - Two DRs for the first year of data
- **Complete reprocessing of all data, for each release**
  - Every DR will reprocess ***all*** data taken up to the beginning of that DR
- **Projected catalog sizes:**
  - **18 billion objects** (DR1) ➔ **37 billion** (DR11)
  - **750 billion observations** (DR1) ➔ **30 trillion** (DR11)

LSST Catalog Contents (Level 2)

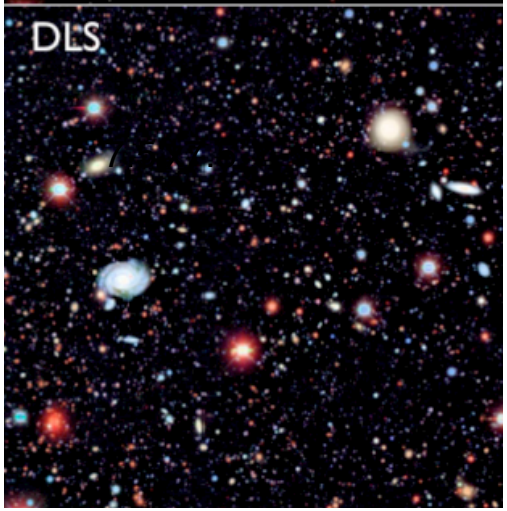
- **Object characterization (models):**
  - Moving Point Source model
  - Double Sérsic model (bulge+disk)
    - Maximum likelihood peak
    - **Samples of the posterior (hundreds)**
- **Object characterization (non-parametric):**
  - Centroid: (α, δ), per band
  - Adaptive moments and ellipticity measures (per band)
  - Aperture fluxes and Petrosian and Kron fluxes and radii (per band)
- **Colors:**
  - Seeing-independent measure of object color
- **Variability statistics:**
  - Period, low-order light-curve moments, etc.

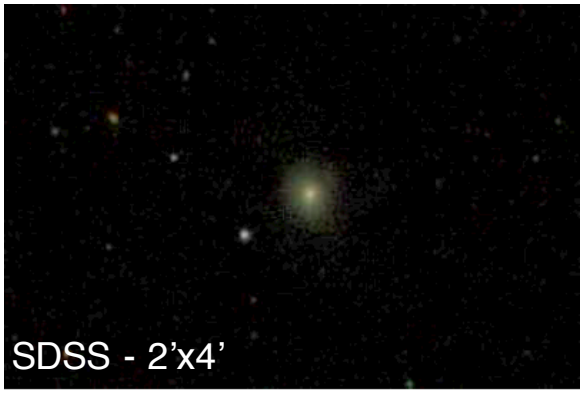


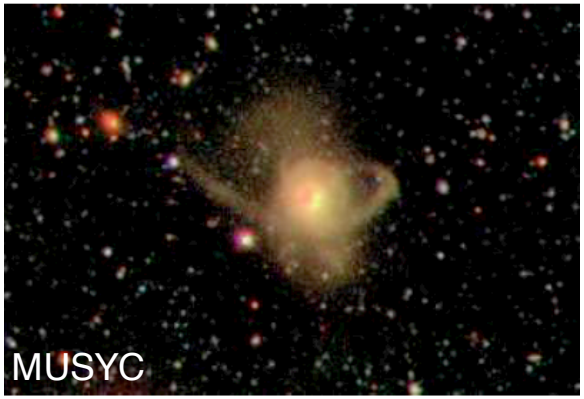
LSST Science Book, Fig. 9.3



LSST-like Images







The Deep Lens Survey image is an analog in depth and image quality to a single LSST epoch

The MUSYC image is ~1 mag shallower than the co-added LSST; highlights possible LSB science

images from Ivezic et al. arXiv:0805.2366

LSST Astrometry

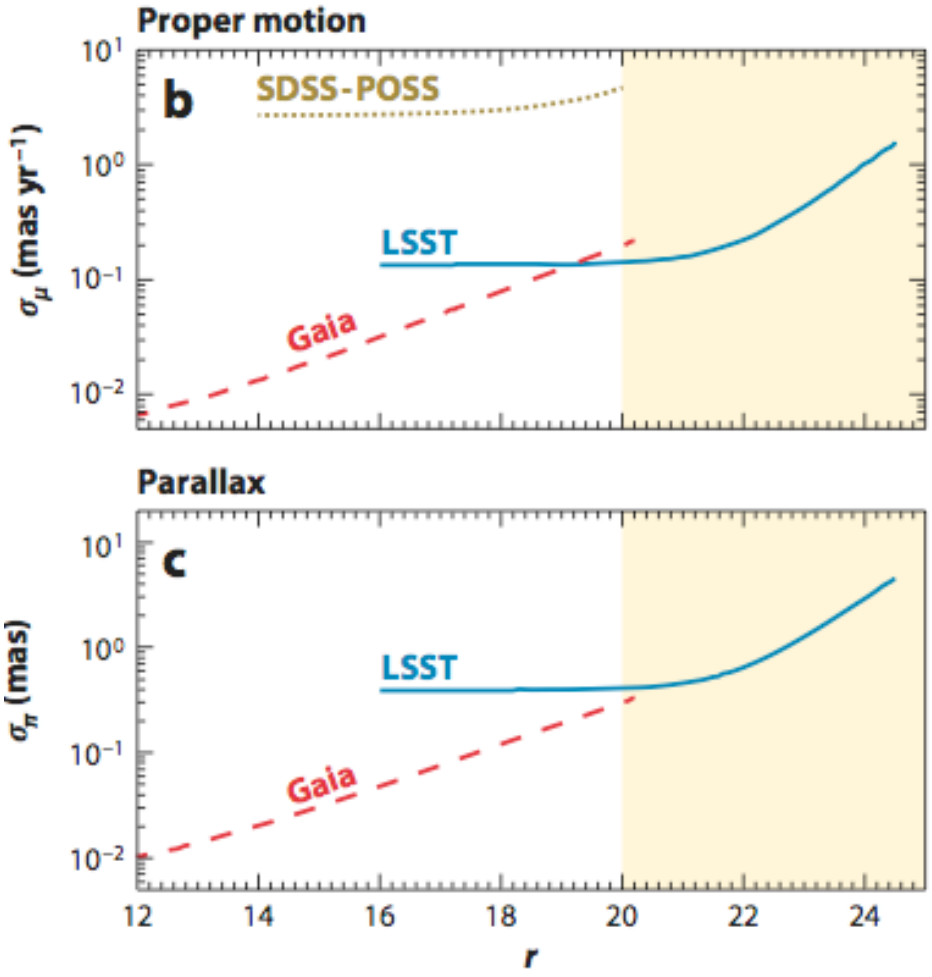


Figure from Ivezic, Beers & Juric 2012