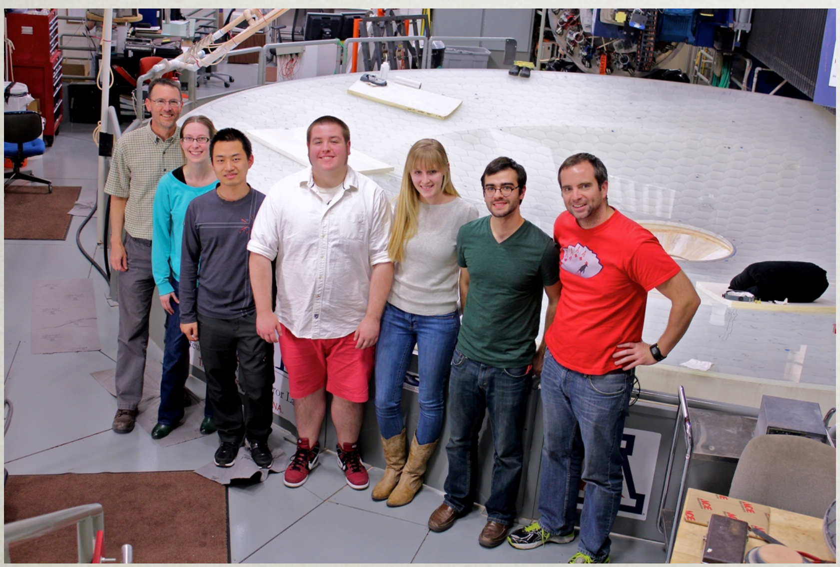
The Large Synoptic Survey Telescope

Beth Willman, Haverford College

LSST Basics

- O/NIR imaging survey from Cerro Pachon, Chile; 6.5m effective telescope aperture, 9.5 deg^2 field-of-view



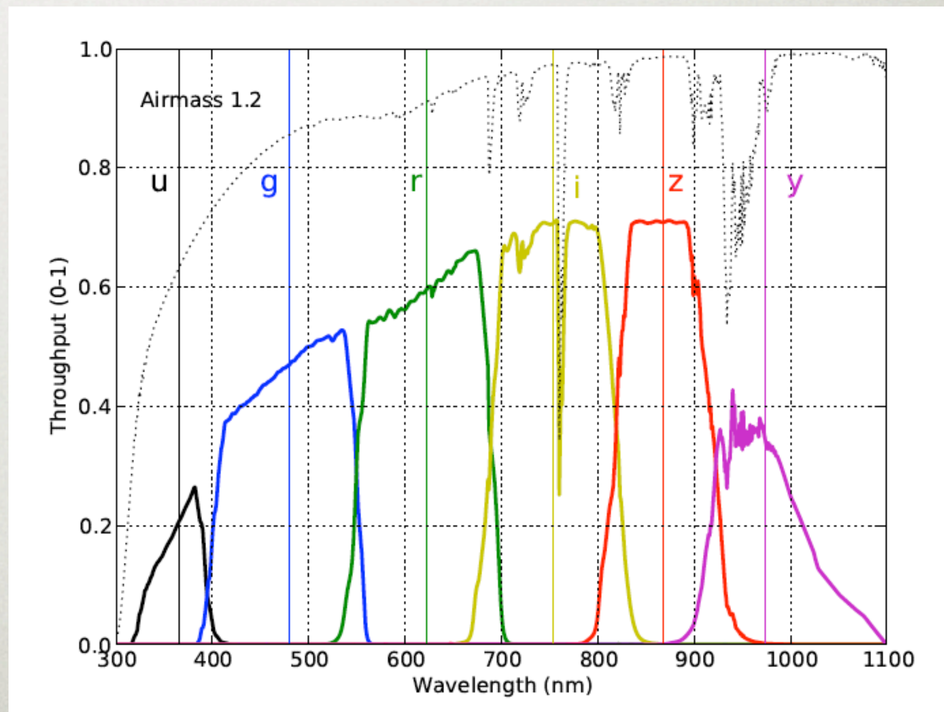
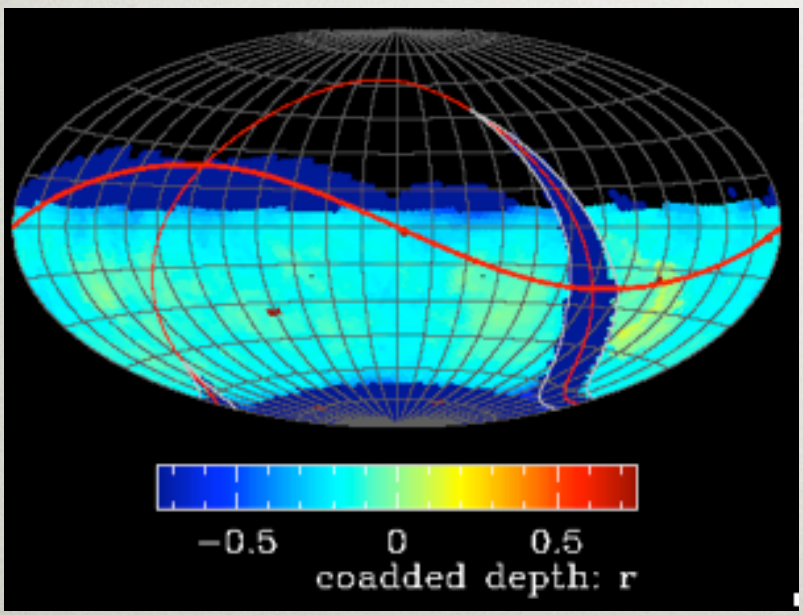
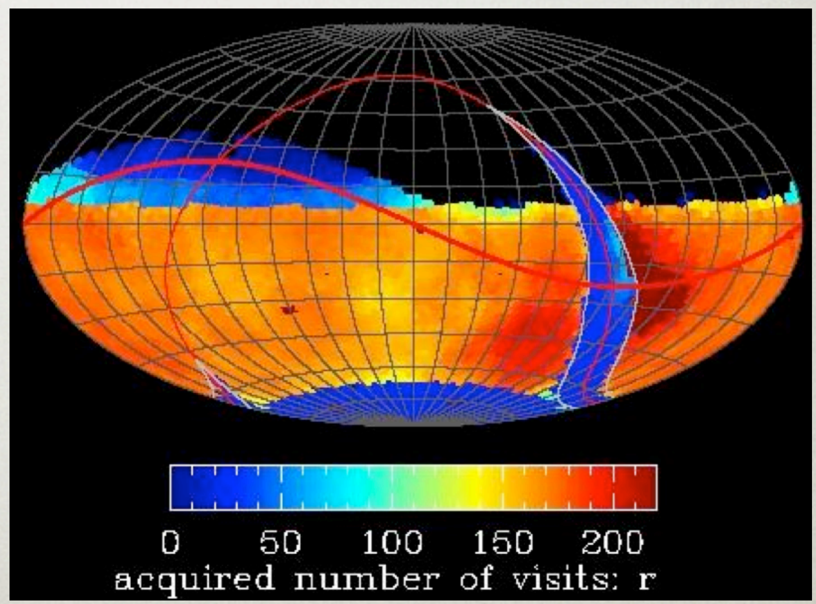


Figure from Ivezic et al. arXiv:0806.2366

LSST Cadence

- ~1/2 the sky - ~18,000 deg^2 in fiducial survey, ~25,000 deg^2 total
- 90% of time on a universal survey - the cadence is still up for discussion; Other 10%: deep drilling fields and mini-surveys
- ~900 visits per location over a 10 year period; $r_{limit,single}$ ~ 24.5 mag, $r_{limit,stack}$ ~ 27.5 mag





Figures from www.lsst.org and Ivezic et al. arXiv:0806.2366

LSST Astrometry

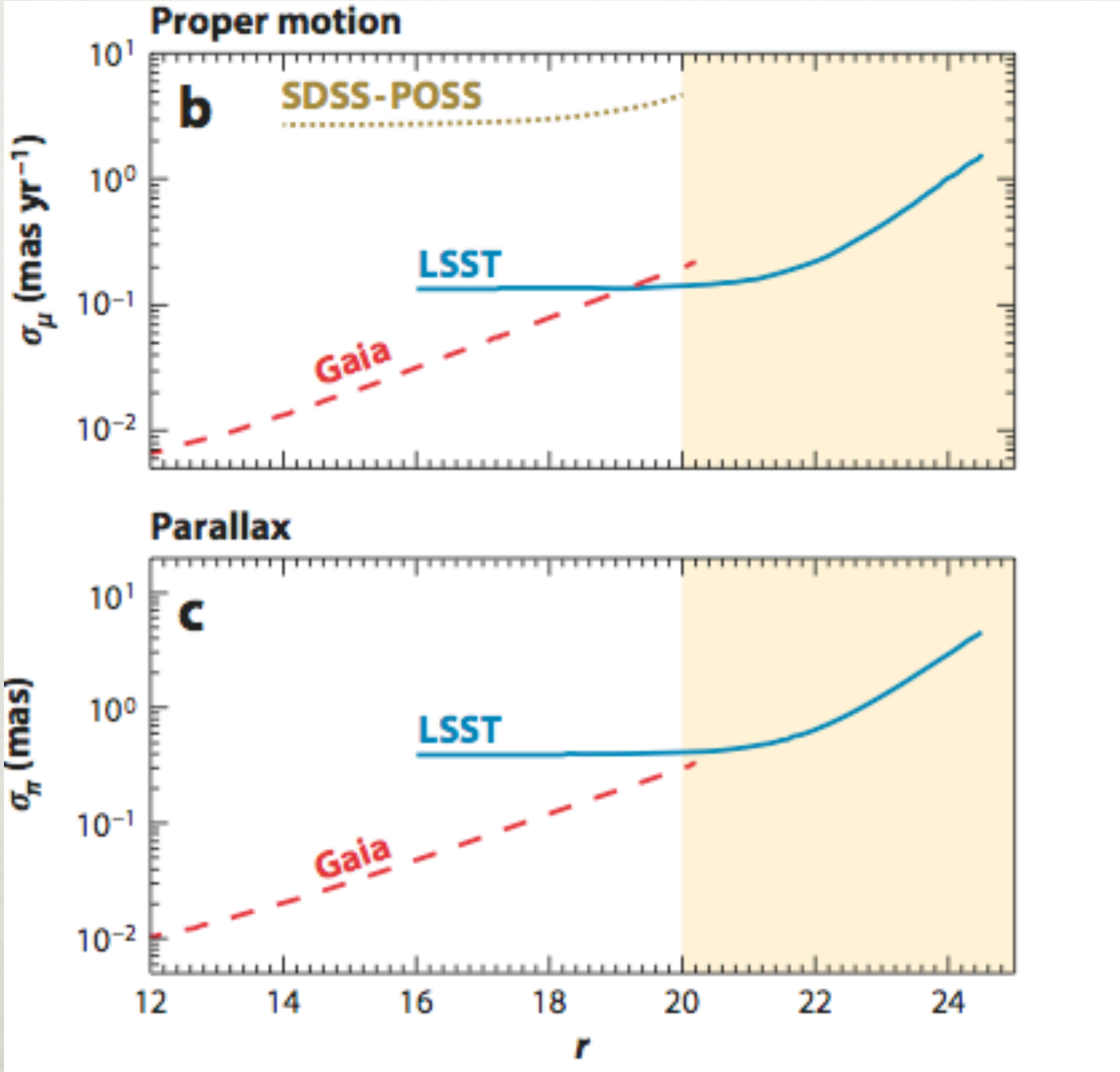
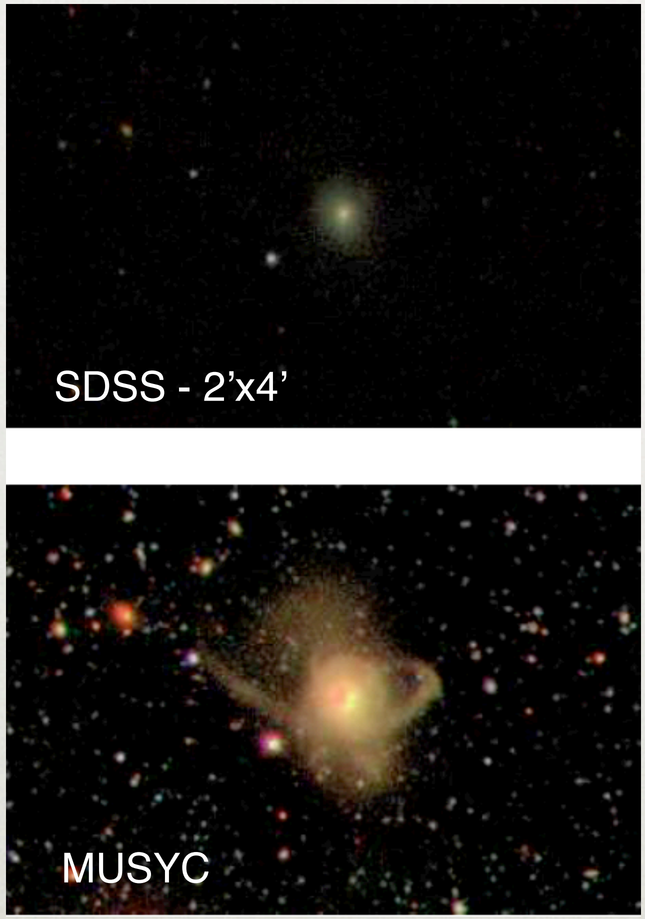


Figure from Ivezic, Beers & Juric 2012

LSST-like Images



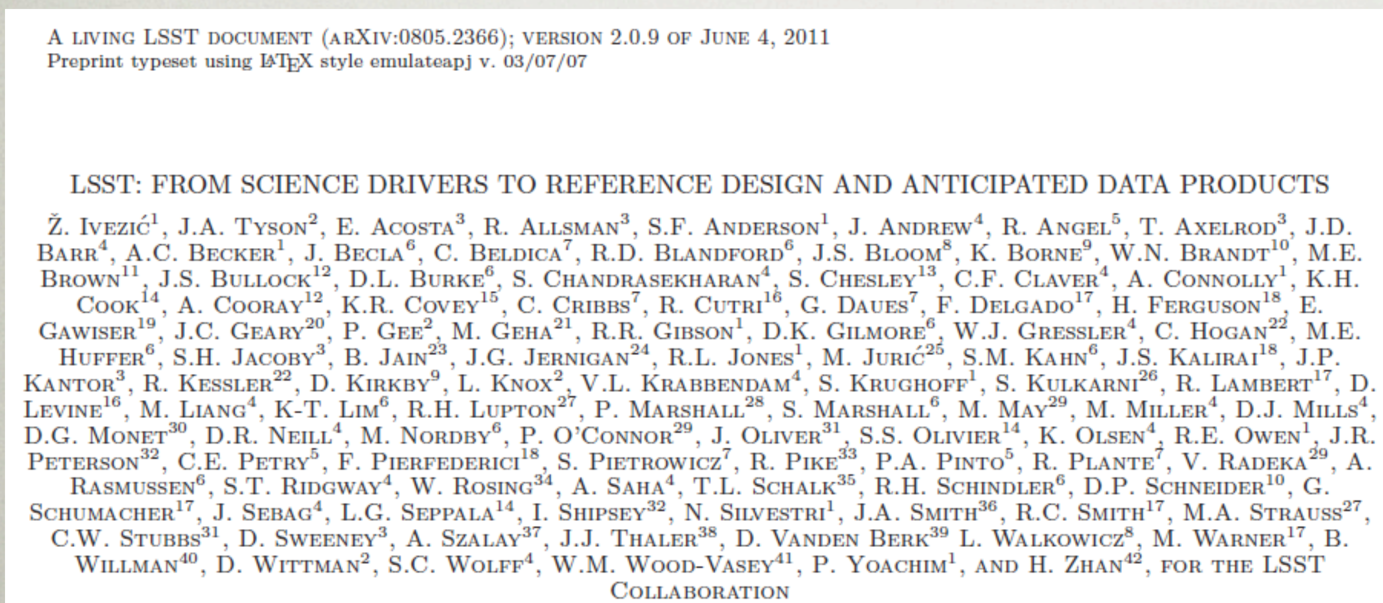
The Deep Lens Survey image is an analog in depth and image quality to a single LSST epoch

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

images from Ivezic et al. arXiv:0806.2366

Universal Cadence - Diverse Science Drivers

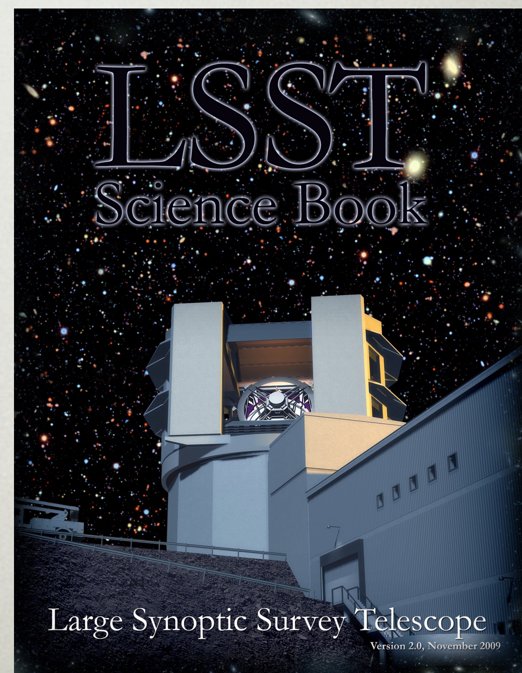
- Dark energy, dark matter and cosmology (galaxies, SNe, quasars, lensing)
- Time domain (proper motions, variable stars, cosmic explosions)
- Solar system structure (asteroids)
- Milky Way structure and near-field cosmology (stars)



A LIVING LSST DOCUMENT (ARXIV:0805.2366); VERSION 2.0.9 OF JUNE 4, 2011
Preprint typeset using LaTeX style emulateapj v. 03/07/07

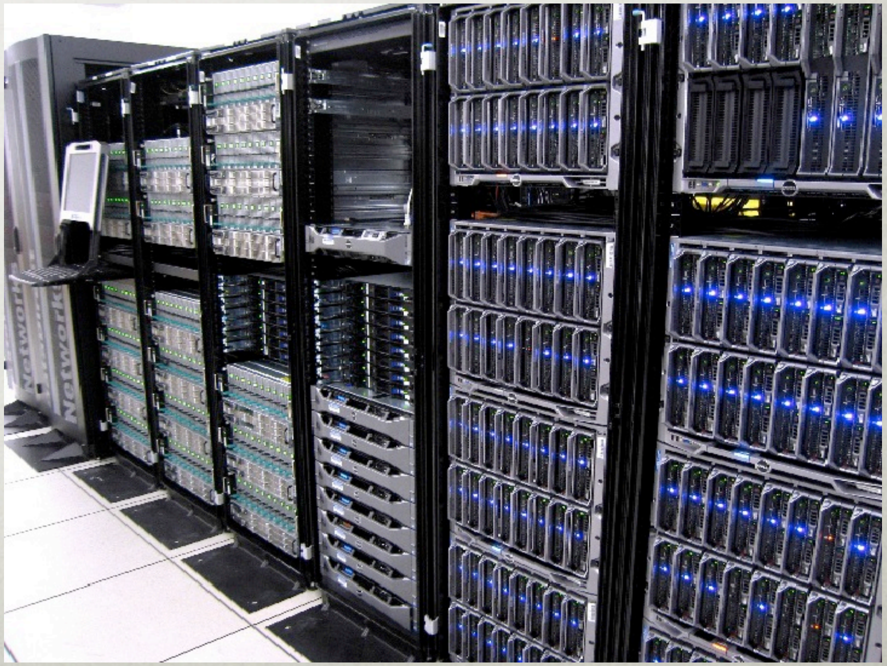
LSST: FROM SCIENCE DRIVERS TO REFERENCE DESIGN AND ANTICIPATED DATA PRODUCTS

Ž. Ivezić[1], J.A. Tyson[2], E. Acosta[3], R. Allsman[3], S.F. Anderson[1], J. Andrew[4], R. Angel[5], T. Axelrod[3], J.D. Barr[4], A.C. Becker[1], J. Becla[6], C. Beldica[7], R.D. Blandford[6], J.S. Bloom[8], K. Borne[9], W.N. Brandt[10], M.E. Brown[11], J.S. Bullock[12], D.L. Burke[6], S. Chandrasekharan[4], S. Chesley[13], C.F. Claver[4], A. Connolly[1], K.H. Cook[14], A. Cooray[12], K.R. Covey[15], C. Cribbs[7], R. Cutri[16], G. Daues[7], F. Delgado[17], H. Ferguson[18], E. Gawiser[19], J.C. Geary[20], P. Gee[2], M. Geha[21], R.R. Gibson[1], D.K. Gilmore[6], W.J. Gressler[4], C. Hogan[22], M.E. Huffer[6], S.H. Jacoby[3], B. Jain[23], J.G. Jernigan[24], R.L. Jones[1], M. Jurić[25], S.M. Kahn[6], J.S. Kalirai[18], J.P. Kantor[3], R. Kessler[22], D. Kirkby[9], L. Knox[2], V.L. Krabbendam[4], S. Krughoff[1], S. Kulkarni[26], R. Lambert[17], D. Levine[16], M. Liang[4], K-T. Lim[6], R.H. Lupton[27], P. Marshall[28], S. Marshall[6], M. May[29], M. Miller[4], D.J. Mills[4], D.G. Monet[30], D.R. Neill[4], M. Nordby[6], P. O'Connor[29], J. Oliver[31], S.S. Olivier[14], K. Olsen[4], R.E. Owen[1], J.R. Peterson[32], C.E. Petry[5], F. Pierfederici[18], S. Pietrowicz[7], R. Pike[33], P.A. Pinto[5], R. Plante[7], V. Radeka[29], A. Rasmussen[6], S.T. Ridgway[4], W. Rosing[34], A. Saha[4], T.L. Schalk[35], R.H. Schindler[6], D.P. Schneider[10], G. Schumacher[17], J. Sebag[4], L.G. Seppala[14], I. Shipsey[32], N. Silvestri[1], J.A. Smith[36], R.C. Smith[17], M.A. Strauss[27], C.W. Stubbs[31], D. Sweeney[3], A. Szalay[37], J.J. Thaler[38], D. Vanden Berk[39] L. Walkowicz[8], M. Warner[17], B. Willman[40], D. Wittman[2], S.C. Wolff[4], W.M. Wood-Vasey[41], P. Yoachim[1], and H. Zhan[42], for the LSST Collaboration



LSST Data Overview

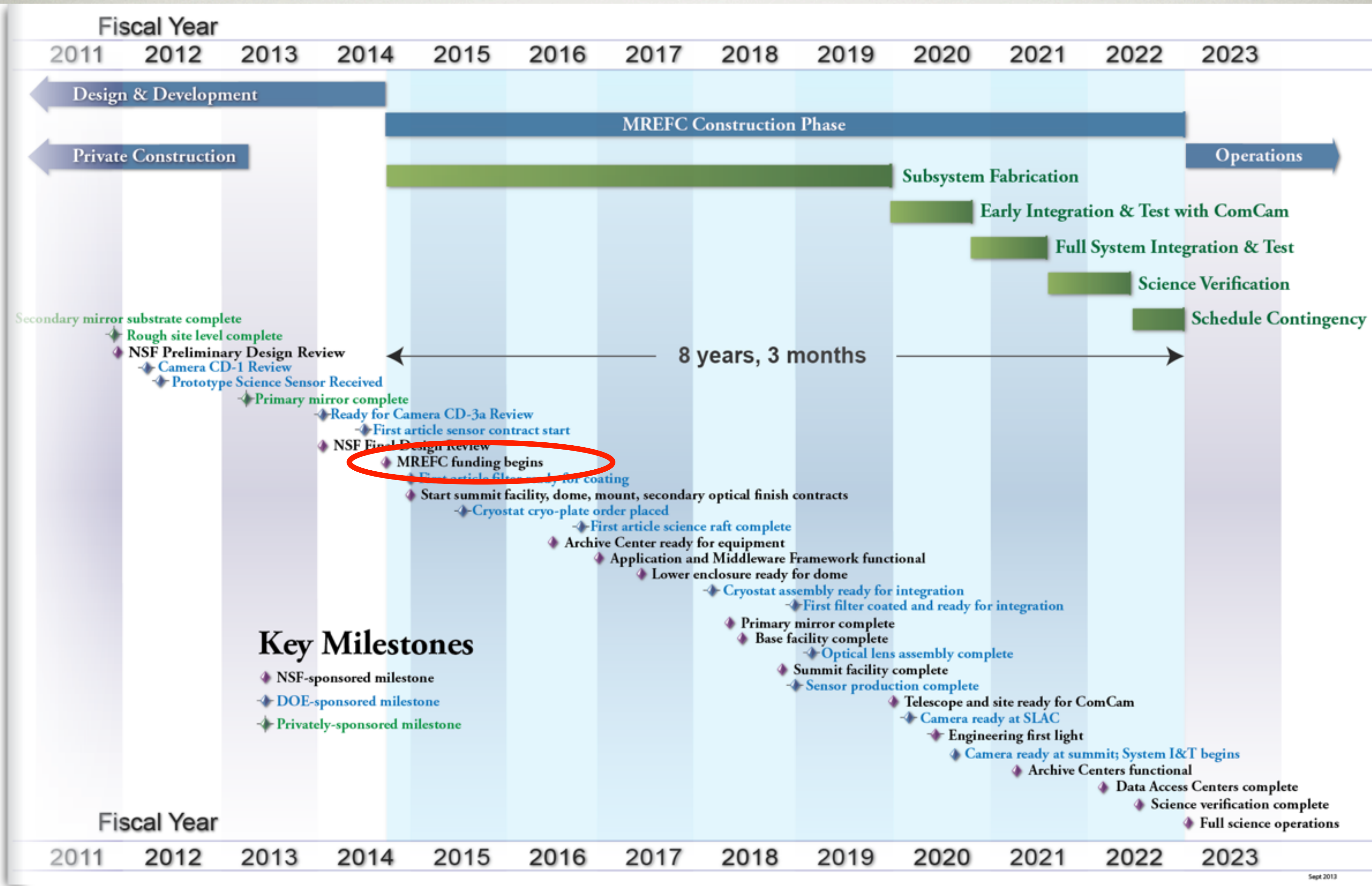
- 6.4 GB per exposure → ~15 TB per day
- ~ 37 billion objects in the final catalog (20B galaxies, 17B stars)
- ~ 30 trillion forced photometry, single-epoch measurements
- ~ 10 million variable source alerts per night
- 11 data releases total, 3 within the first 2 years



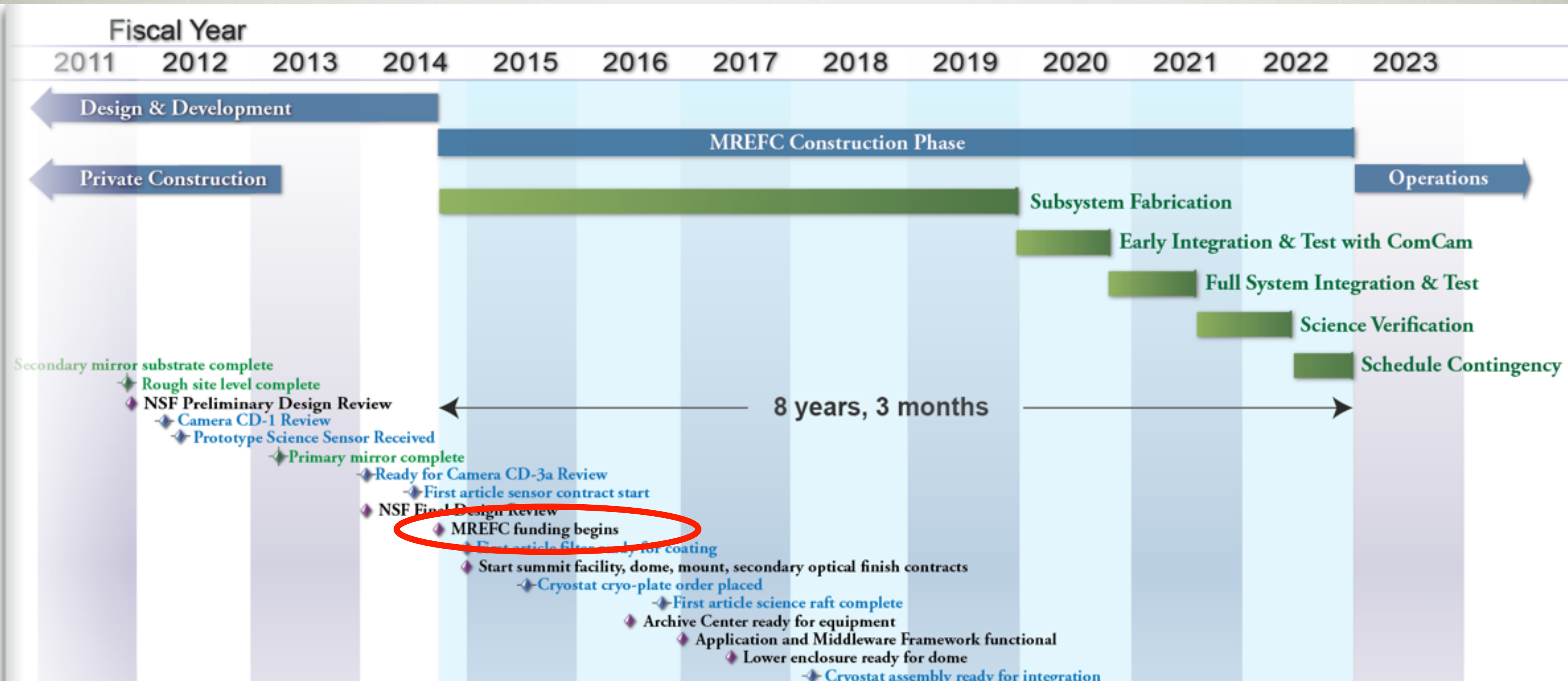
LSST Data Rights

At present:

- Anyone from a US or Chilean institution
- Members of the LSST French participation group at IN2P3
- Named individuals at several European and Chinese institutions that have signed MOUs with LSST Corporation



from www.lsst.org, timeline steady since September 2013



- July 2014 construction start date
- 8.5 years until survey operations, 7 years until science verification

from www.lsst.org, timeline steady since September 2013

LSST Science Collaborations and their chairs

Supernovae: Richard Kessler(University of Chicago); Tom Matheson(NOAO);
Weak lensing: Bhuvnesh Jain(University of Pennsylvania); David Wittman(University of California Davis);
Active Galactic Nuclei: Niel Brandt(Pennsylvania State University);
Solar System: Michael Brown(Caltech); Lynne Jones(University of Washington);
Galaxies: Michael Cooper(UC Irvine); Brant Robertson(University of Arizona);
Transients/variable stars: Ashish Mahabal(Caltech); Lucianne Walkowicz(Princeton University);
Large-scale structure/baryon oscillations: Eric Gawiser(Rutgers The State University of New Jersey); Shirley Ho(Carnegie Mellon University);
Stars, Milky Way and Local Volume: John Bochanski(Haverford College); Nitya Jacob Kallivayalil(University of Virginia); Beth Willman(Haverford College);
Strong Lensing: Phil Marshall(KIPAC);
Informatics and Statistics: Kirk Borne(George Mason University);
Dark Energy (DESC): Bhuvnesh Jain (University of Pennsylvania)

~550 science collaboration members

www.lsst.org

New science collaboration developments

- Science collaborations are now individually responsible for setting their own membership policies and rules.

- Anyone with data rights may now join science collaborations, according to the membership policies set by each collaboration.

Example: Milky Way etc. collaboration

Draft membership policy

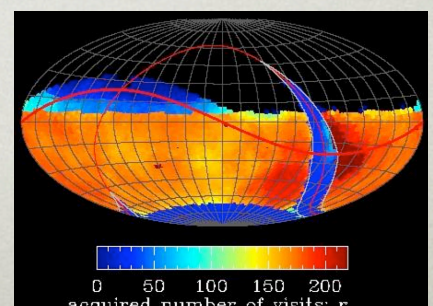
• New applicants submit a CV with publications list. New applications may be submitted at any time, and will be reviewed quarterly by Collaboration chairs. All new members must identify and belong to at least one of our Working groups.

• Submit a 1-2 page document of 2 year planned contributions to the collaboration chairs, including a set of six month milestones/deliverables. Each year submit one paragraph on collaboration activities. Every two years membership will be reviewed by Collaboration chairs, in consultation with Working group leads.

• Commit to ~5% time investment in LSST endeavors, broadly defined.

Science Collaboration Activities:
Cadence planning

- static LSST science (dark energy, galaxies, & stellar pops)
- transient and variable science (astrometric science, fast & slow variables & transients, SNe, moving objects)
- mini-surveys (Magellanic clouds, Galactic bulge & disk)
- novel strategies for optimizing the main LSST survey



Science Collaboration Activities: Dark Energy

Dark Energy Science Collaboration

Home | Featured Projects | Working Groups | Information for Collaborators | Large Synoptic Survey Telescope | Contacts

Home

- Home
- Featured Projects
  - Weak Lensing - Chromaticity
  - SuperNovae: Cadence Generator
  - Clusters: Shear Measurement Challenge
  - Strong Lensing - Time Delay Challenge
  - Photometric Redshifts: Calibration
  - Cosmological Simulations: Power Spectrum Emulator
  - Cosmological Simulations: Power spectra via perturbation theory

Featured Projects

We are very happy to announce the first release of DESC Featured Projects.

As described in the DESC white paper, the collaboration has identified a number of high-priority tasks that need to be completed in the near-term in order to help prepare for LSST analysis, make synergistic connections with ongoing cosmological surveys and provide the dark energy community with state of the art analysis tools. Every six months we will select some of these tasks of relevance to the wider cosmological community and release products that we expect will be useful to the community. The first release is in April 2014. In the following links you can find out more about the work we've completed on subjects ranging from studying the impact of chromaticity on the LSST PSF, to an emulator to predict the power spectrum of galaxies in the Universe.

- Weak Lensing: Chromatic PSFs (Josh Meyers, Pat Burchat)
- Supernovae: Cadence Generator (David Cinabro)
- Clusters: Shear Measurement Challenge (Ian Dell'Antonio, Doug Clowe)

www.lsst-desc.org

Science Collaboration Activities: Tackling Priority Pre-cursor Science and Technical Challenges

Some collaborations (e.g. Stars, MW and Local Volume and Transients) are now developing roadmaps to define primary collaboration activities for the next 7 years

Science Collaboration Activities: Tackling Priority Pre-cursor Science and Technical Challenges

Milky Way etc. chairs:

- Do a better job connecting collaboration members with necessary resources

Everyone:

- Star-galaxy separation
- Photometric metallicity calibration
- What necessary measurements will not be provided by the Project?
- Variable source classification algorithms

Why join an LSST science collaboration?

LSST Resources

Operations Simulations (OpSim)
Image Simulations (ImSim)
Base & photometered catalogs of stars and galaxies for/from ImSim
Some phases of the photometric pipeline

http://lsst.astro.washington.edu/

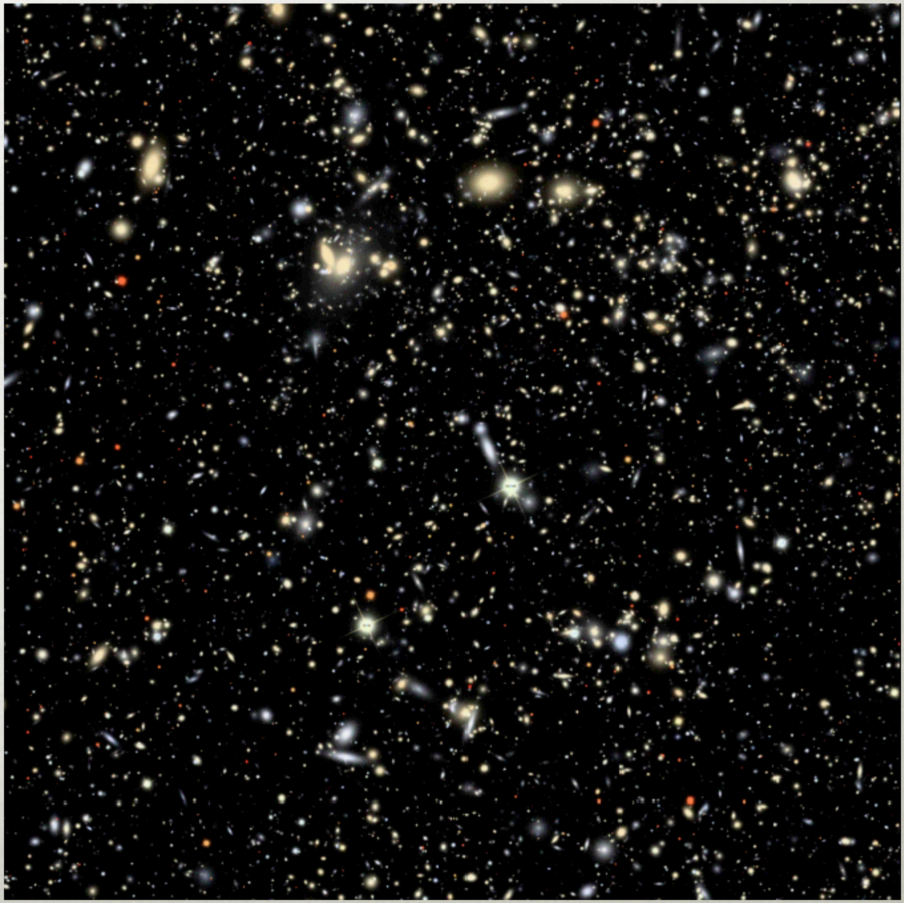


image from Ivezic et al. arXiv:0806.2366

LSST Publication Board

Pat Burchat (Stanford), chair

Science Collaborations are generating publications: 8 science + technical peer reviewed publications formally vetted thus far

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

MNRAS **434**, 2121–2135 (2013) doi:10.1093/mnras/stt1156
Advance Access publication 2013 July 19

The effective number density of galaxies for weak lensing measurements in the LSST project

C. Chang,[1★] M. Jarvis,[2] B. Jain,[2] S. M. Kahn,[1] D. Kirkby,[3] A. Connolly,[4] S. Krughoff,[4] E.-H. Peng[5] and J. R. Peterson[5]

[1] *KIPAC, Stanford University, 452 Lomita Mall, Stanford*
[2] *Department of Physics and Astronomy, University of P*
[3] *Department of Physics and Astronomy, University of C*
[4] *Department of Astronomy, University of Washington, S*
[5] *Department of Physics, Purdue University, West Lafay*

The Astronomical Journal Volume 147 Number 1

David L. Burke *et al.* 2014 *The Astronomical Journal* **147** 19 doi:10.1088/0004-6256/147/1/19

ALL-WEATHER CALIBRATION OF WIDE-FIELD OPTICAL AND NIR SURVEYS

David L. Burke[1], Abhijit Saha[2], Jenna Claver[2], T. Axelrod[3], Chuck Claver[2], Darren DePoy[4], Željko Ivezić[5], Lynne Jones[5], R. Chris Smith[6], and Christopher W. Stubbs[7]

LSST's Hallmark Science Stands Alone

A living LSST document (arXiv:0805.2366); version 2.0.9 of June 4, 2011
Preprint typeset using LaTeX style emulateapj v. 03/07/07

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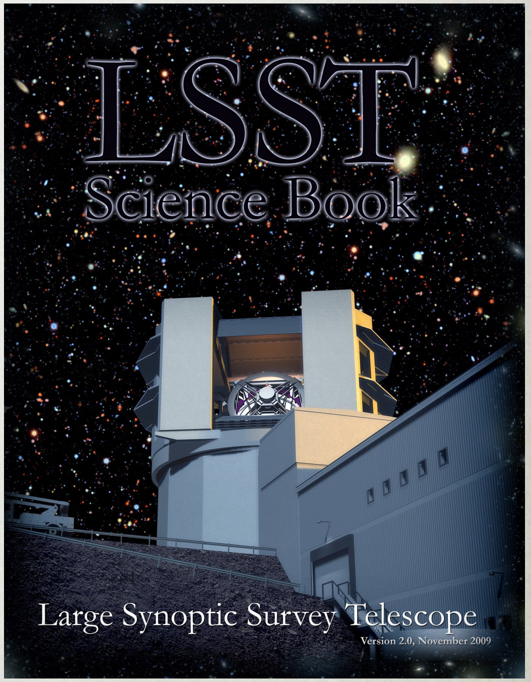
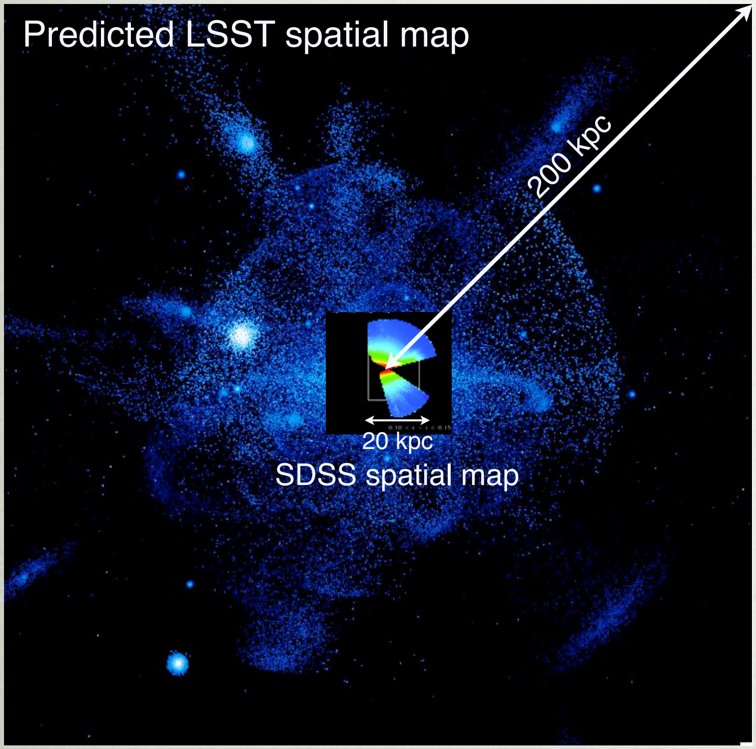
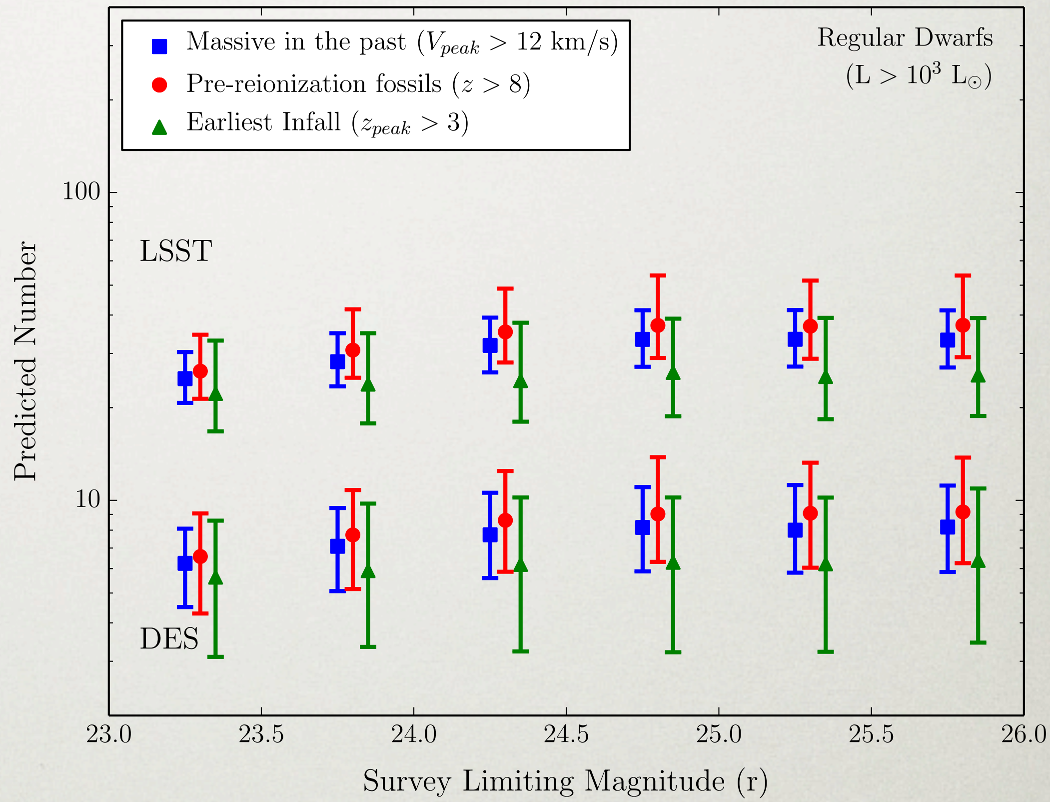


LSST's Hallmark Science Stands Alone



To appear in update of
Ivezic et al. arXiv:0806.2366



Predicted # of Milky Way dwarf satellites
Hargis, Willman & Peter ApJL submitted

LSST Science and Synergies

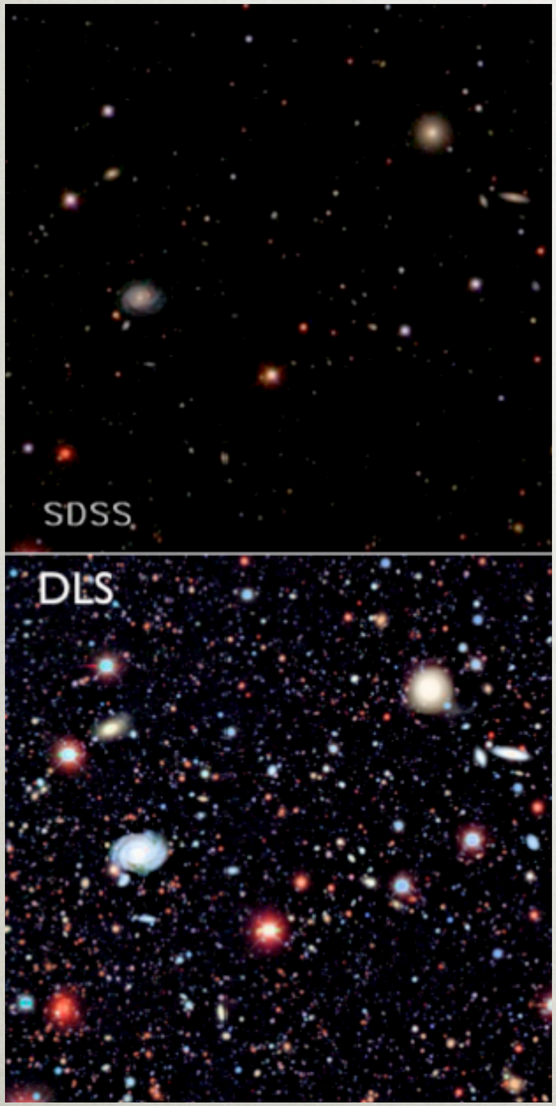
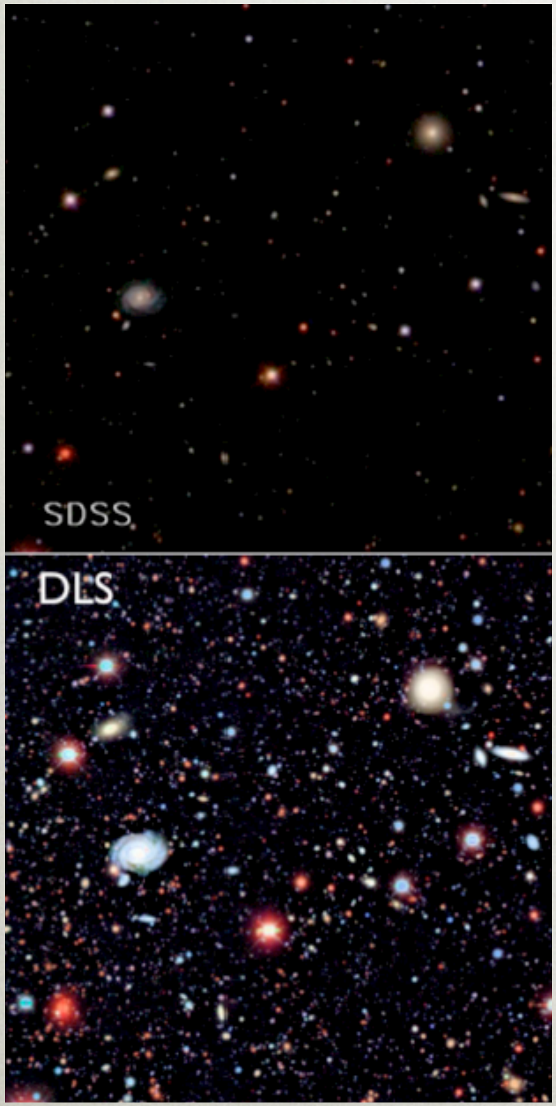


image from Ivezic et al. arXiv:0806.2366

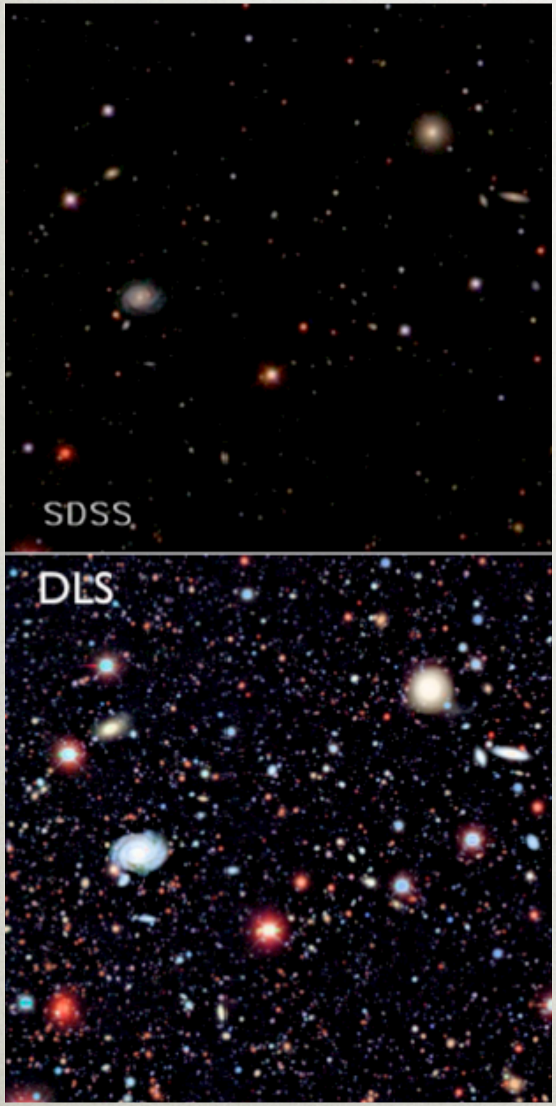
LSST Science and Synergies



LSST: A super-SDSS discovery machine

image from Ivezic et al. arXiv:0806.2366

LSST Science and Synergies



LSST: A super-SDSS discovery machine

LSST is needed to provide field-defining samples
TM/GM/ELTs are needed to fully characterize LSST discoveries

Thinking inside the box - Individual PIs or groups follow up small numbers of faint, rare, unusual objects; Larger groups rally around key questions to acquire necessary follow-up.

image from Ivezic et al. arXiv:0806.2366

LSST Science and Synergies

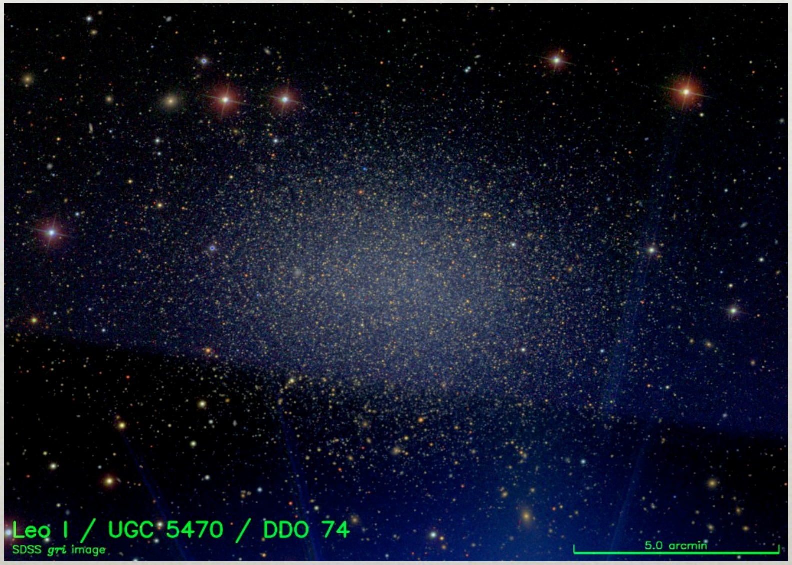
Near-field cosmology - LSST will discover numerous dwarf galaxies, star clusters, and unusual objects; TM/GM/ELT follow-up is needed to answer:

- Where is the bottom of the galaxy hierarchy and what sets it?
- What is the ‘temperature’ of dark matter?

LSST Science and Synergies

Near-field cosmology - LSST will discover numerous dwarf galaxies, star clusters, and unusual objects

- Basic characterization - kinematics and chemical abundances
- Internal dynamics of nearby dwarf galaxies using adaptive optics imaging over (relatively) wide field-of-view; e.g. IRIS



LSST Science and Synergies

Galaxy Science, Brant Robertson (Arizona)

Follow-up of rare and unusual objects, e.g. particularly distant quasars and massive galaxies; IR spectroscopic studies of high-z intergalactic/circumgalactic medium.

Solar System Science, Lynne Jones (UW) and Mike Brown (Caltech)

NIR spectroscopic follow-up of trans-Neptunian objects. LSST will ID targets for follow-up and characterize the population as a whole.

Supernova Science, Maryam Modjaz (NYU)

Spectroscopic follow-up of interesting & faint SNe, e.g. Superluminous SNe, Fast transients & exotic SNe; Spectra of faint, low-metallicity host galaxies with e.g. WFOS (for low-z objects) or IRIS (for high-z objects)

Proposed Aspen 2015 workshop: Near-field Cosmology With the Next Generation of O/IR Facilities

B. Willman (Haverford), J. Kalirai (STScI), C. Rockosi (UCSC), M. Steinmetz (AIP), J. Strader (MSU)

TABLE 1

THE LSST BASELINE DESIGN AND SURVEY PARAMETERS

Quantity	Baseline Design Specification
Optical Config.	3-mirror modified Paul-Baker
Mount Config.	Alt-azimuth
Final f-ratio, aperture	f/1.234, 8.4 m
Field of view, étendue	9.6 deg^2, 319 $\mathrm{m}^2\mathrm{deg}^2$
Plate Scale	50.9 μm/arcsec (0.2” pix)
Pixel count	3.2 Gigapix
Wavelength Coverage	320 – 1050 nm, *ugrizy*
Single visit depths[a] (5σ)	23.9, 25.0, 24.7, 24.0, 23.3, 22.1
Mean number of visits	56, 80, 184, 184, 160, 160
Final (coadded) depths[a]	26.1, 27.4, 27.5, 26.8, 26.1, 24.9

[a] The listed values for 5σ depths in the *ugrizy* bands, respectively, are AB magnitudes, and correspond to point sources and zenith observations (about 0.2 mag loss of depth is expected for realistic airmass distributions). See Table 2 for more details.