A new era of survey science with the LSST

Yonsei University
(Lee Jaehyun, Oh Seulhee, Ji Inchan,
Choi hoseung, Kim jaemin)

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Contents

1. **Introduction to LSST**
   ; Mission concept, Survey parameters, and Timeline

2. **Science topics**
   ; Solar system, Optical transients, Milky Way, DM and DE

Introduction

Large Synoptic Survey Telescope

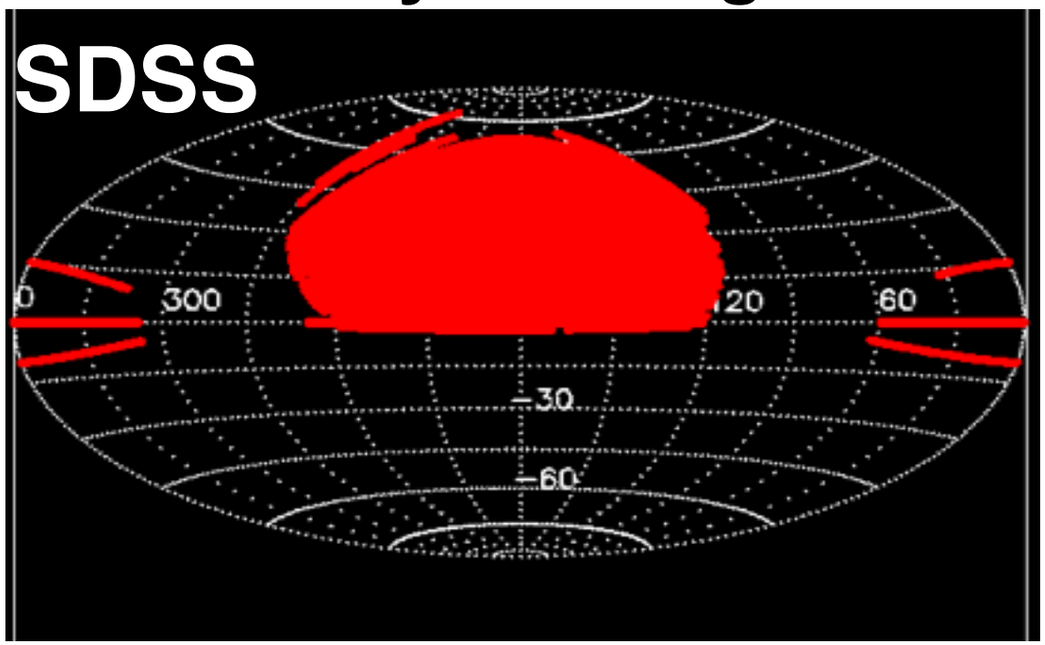
Credit: C. Claver, NOAO/LSST

Mission concept

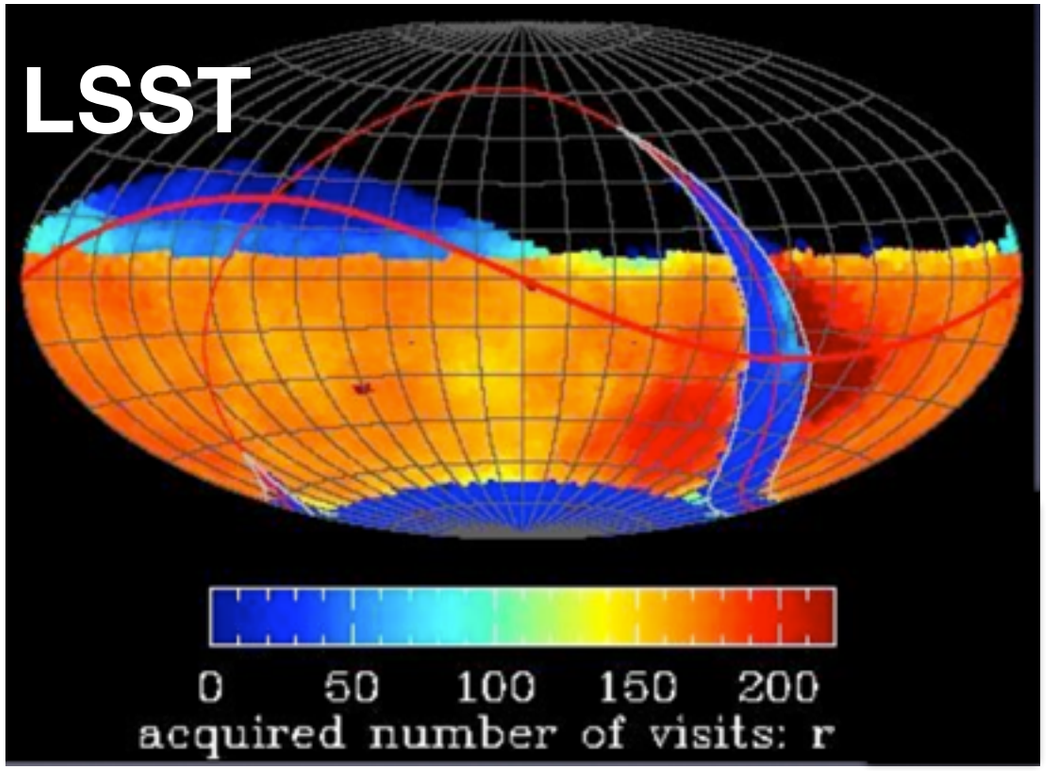
1. Main surveys
   (deep-wide-fast, 90%)
   a. Whole southern sky
   b. ~1000 visits over 10years
      (1 visit = 15 * 2)
   c. 10 billion stars and
      10 billion galaxies

2. Mini Surveys (10%)
   a. Deep image
   b. Time series

Sky Coverage



http://www.sdss.org/



http://www.lsst.org/

System characteristics

Telescope and Site	
Configuration	three-mirror, Alt-azimuth
Final f/ratio; plate scale	f/1.23 50 microns/arcsec **0.2 ”/ pixel**
Physical diameter of optics	M1: 8.4m M2: 3.4m M3: 5.02 m
First camera lens; focal plane diameter	Lens: 1.55 m field of view: 63 cm
Diameter of 80% encircled energy	u: 0.26″ g: 0.26″ r: 0.18″ i: 0.18″ z: 0.19″ y: 0.20″
spot due to optics	

Camera	
Pixel size; pixel count	10 microns (0.2 arcsec); 3.2 Gpixels
Readout time	2 sec
Dynamic range	16 bits
Focal plane device configuration	4-side buttable, > 90% fill factor
Filter change time	120 seconds

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4K x 4K x 189 CCD array
http://www.astropilot.info/camera.htm

System characteristics

Main System and Survey Characteristics	
Étendue	319 m^2 deg^2
Area and diameter of field of view	9.6 deg^2 (3.5 deg)
Effective clear aperture (on-axis)	6.7 m (accounting for obscuration)
Wavelength coverage (full response)	320-1080 nm
Filter set	u, g, r, i, z, y (five concurrent in camera at a time)
Sky coverage	20,000 deg^2 (Main Survey)
System Capability	
Single-visit depths (point sources; 5σ)	u: 23.9 g: 25.0 r: 24.7 i: 24.0 z: 23.3 y: 22.1 AB mag
Baseline number of visits over 10 years	u: 70 g: 100 r: 230 i: 230 z: 200 y: 200
Coadded depths (point sources; 5σ)	u: 26.3 g: 27.5 r: 27.7 i: 27.0 z: 26.2 y: 24.9 AB mag
Photometry accuracy (rms mag)	repeatability: 0.005; zeropoints: 0.01
Astrometric accuracy at $r = 24$ (rms)	parallax: 3 mas; proper motion: 1 mas yr^{-1}

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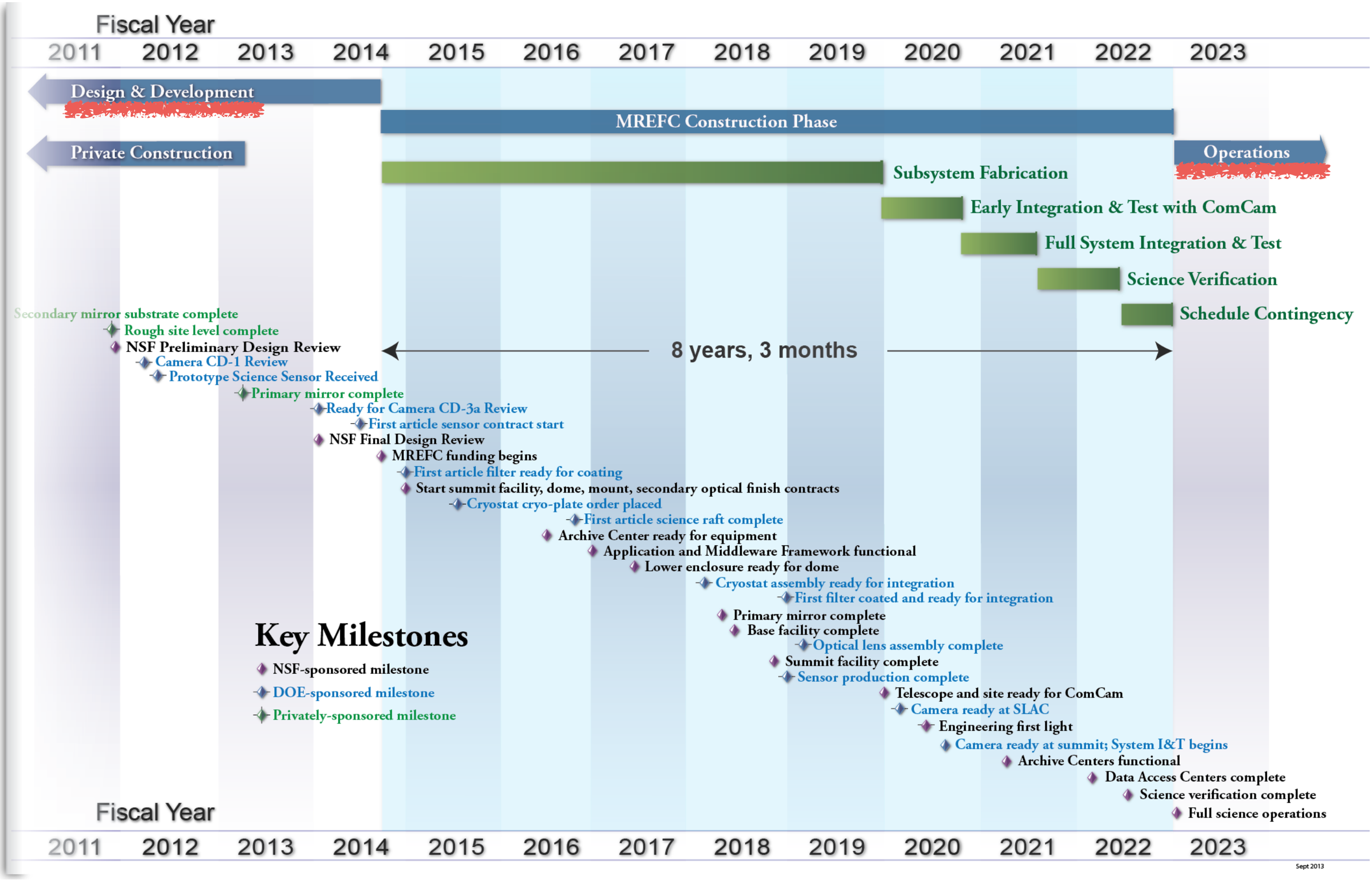
Timeline


Fiscal Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Design & Development
MREFC Construction Phase
Private Construction
Operations
Subsystem Fabrication
Early Integration & Test with ComCam
Full System Integration & Test
Science Verification
Schedule Contingency
8 years, 3 months
Secondary mirror substrate complete
Rough site level complete
NSF Preliminary Design Review
Camera CD-1 Review
Prototype Science Sensor Received
Primary mirror complete
Ready for Camera CD-3a Review
First article sensor contract start
NSF Final Design Review
MREFC funding begins
First article filter ready for coating
Start summit facility, dome, mount, secondary optical finish contracts
Cryostat cryo-plate order placed
First article science raft complete
Archive Center ready for equipment
Application and Middleware Framework functional
Lower enclosure ready for dome
Cryostat assembly ready for integration
First filter coated and ready for integration
Primary mirror complete
Base facility complete
Optical lens assembly complete
Summit facility complete
Sensor production complete
Telescope and site ready for ComCam
Camera ready at SLAC
Engineering first light
Camera ready at summit; System I&T begins
Archive Centers functional
Data Access Centers complete
Science verification complete
Full science operations
Key Milestones
NSF-sponsored milestone
DOE-sponsored milestone
Privately-sponsored milestone
Fiscal Year
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Sept 2013

Data products

Processing Cadence	Image Category (files)	Catalog Category (database)	Alert Category (database)
Nightly	Raw science image Calibrated science image Subtracted science image Noise image Sky image Data quality analysis	Source catalog (from difference images) Object catalog (from difference images) Orbit catalog Data quality analysis	Transient alert Moving object alert Data quality analysis
Data Release (Annual)	Stacked science image Template image Calibration image RGB JPEG Images Data quality analysis	Source catalog (from calibrated science images) Object catalog (optimally measured properties) Data quality analysis	Alert statistics & summaries Data quality analysis

Final Image Archive	345 PB
Final Catalog Archive	46 PB

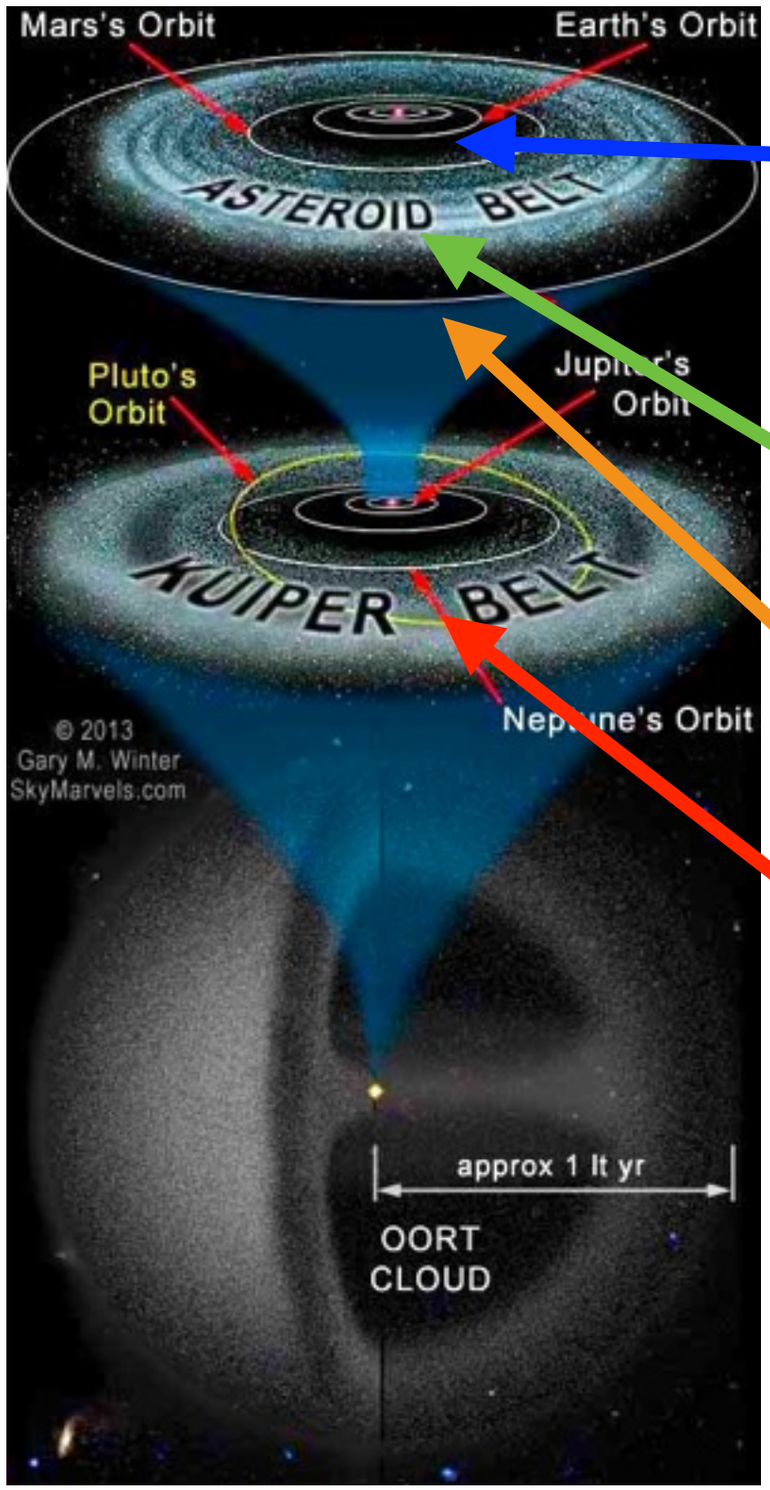
* SDSS DR7 = 17TB

Science topics

Main science topics

1. Solar system
2. The Milky Way
3. The transient and variable Universe
4. The evolution of galaxies
5. DM and DE

Small bodies in the solar system



NEA (Near Earth Astroids)
PHA (Potentially Hazardous Astroids)

MBA (Main Belt Astroids)

Jovian (Jovian Trojans)

TNO (Trans-Neptunian Objects)
SDO (Scattered disk object)

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An inventory of the solar system

1. Dynamics, mass, size and color of many small bodies ; Origin of solar system
2. Monitoring hazardous astroids
3. Detecting faint objects

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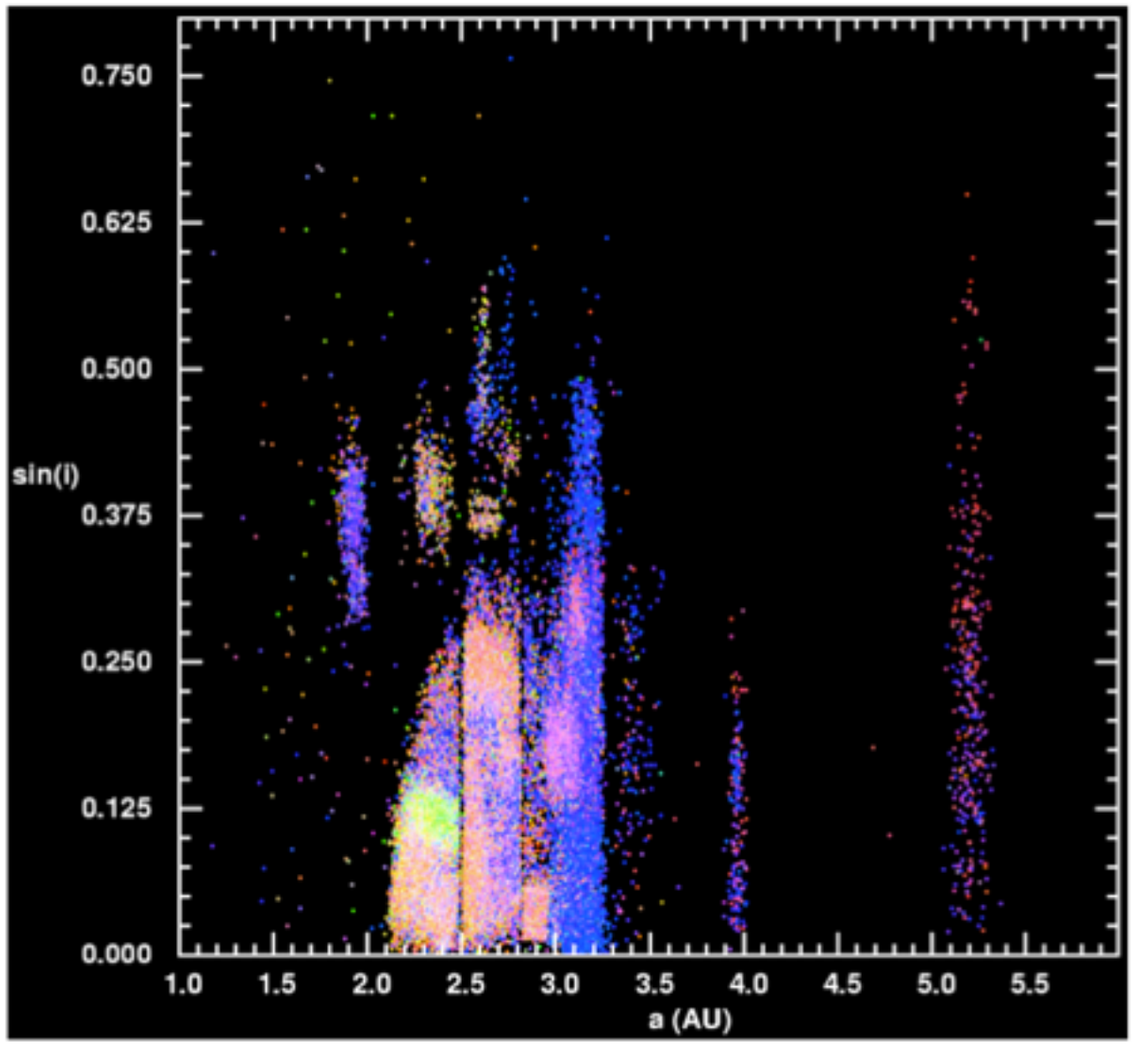


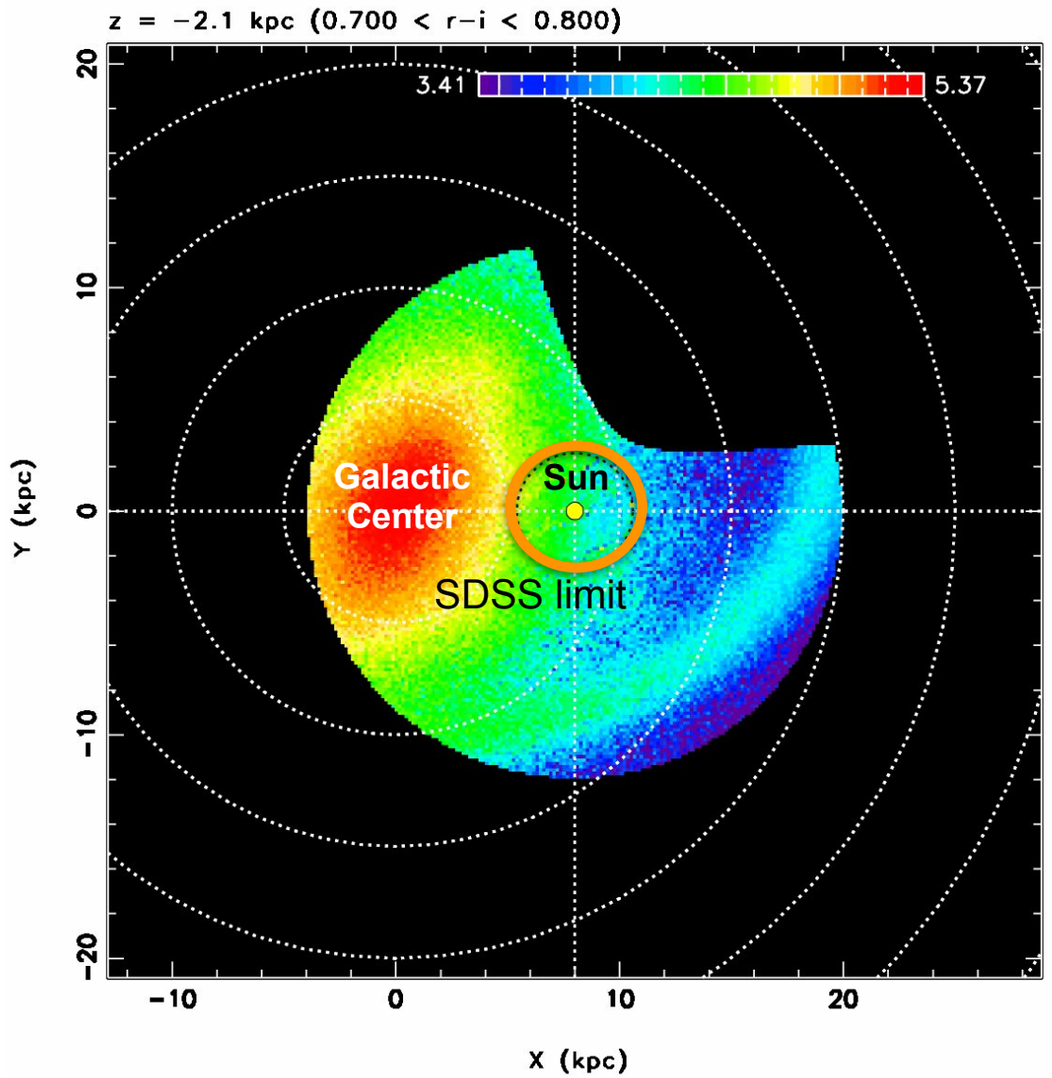
sin(i)

a (AU)

SDSS moving objects in their color revealing inhomogeneity and distinctiveness of populations.

Mapping the Milky Way with LSST

1. LSST will give us
   a. Map of the stellar number density to 100kpc over 20,000deg^2
   b. Map of stellar metallicity using the photometry of near turn-off MS stars
2. These data will enable us to study
   a. The overall smooth distribution of stars in the Milky Way and nearby galaxies
   b. Large scale chemical gradients in the Milky Way
   c. The distribution of mass and the potential of the Milky Way



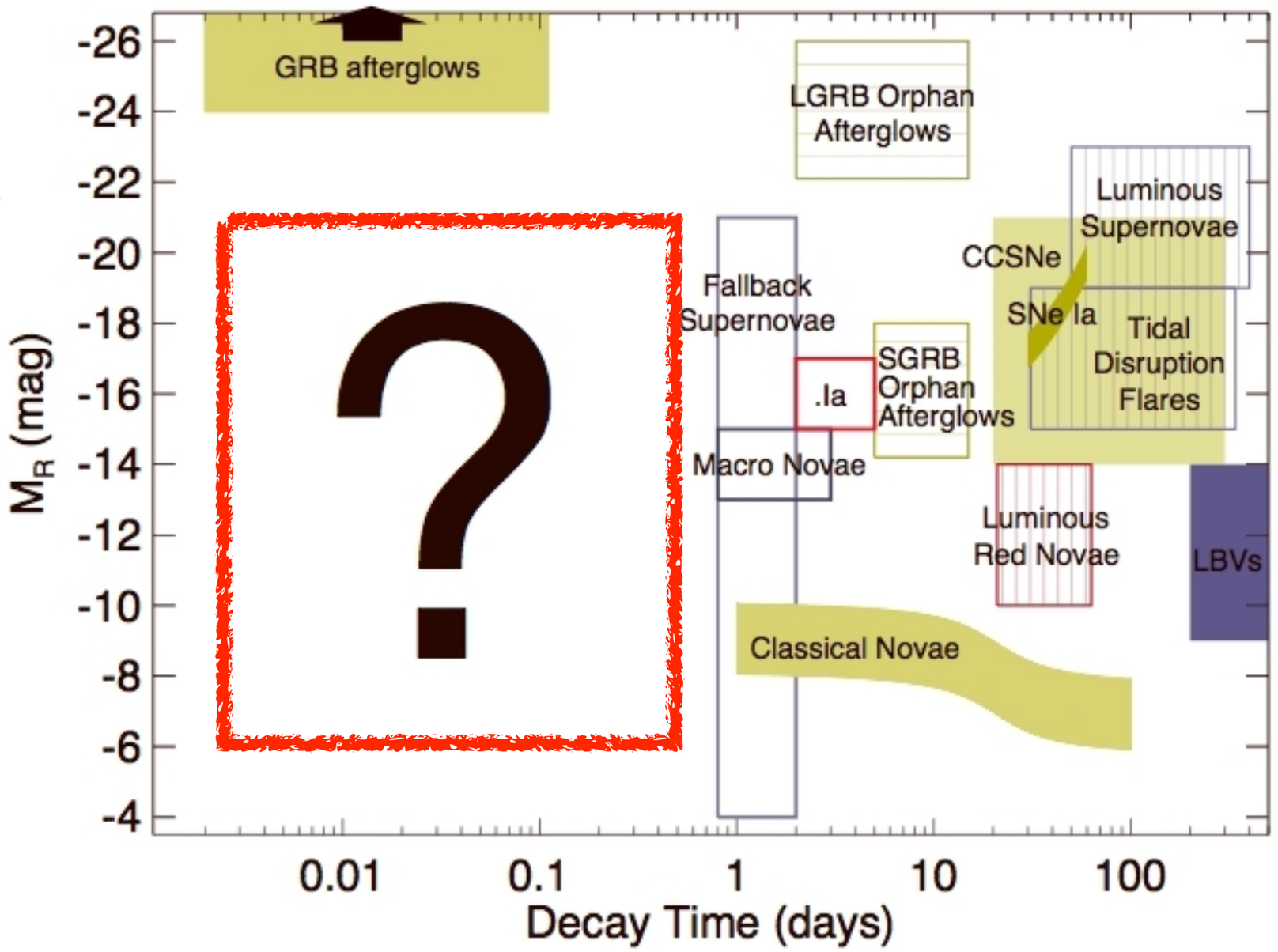
LSST view of inner galaxy (simulation)
(LSST Science Book Version 2.0)

The Transient and Variable Universe

Incredible diversity (L, P)

Checking theory

Discovery of new class



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The evolution of galaxies

1. Demographics of Galaxy Population

   a. Passively evolving galaxies

   - Early-type galaxies, with little or no star formation
   - LSST will be sensitive to L_* early-type galaxies out to $z \sim 2$ for the wide area surveys and to $z \sim 3$ for the deep-drilling fields

   b. High-z star forming galaxies

   - Photometric sample sizes have grown to $> 10^4$ galaxies at $z \sim 3$ and $> 10^3$ galaxies at $z > 5$
   - LSST will provide data for roughly 10^9 galaxies at $z > 2$, of which $\sim 10^7$ will be at $z > 4.5$

The evolution of galaxies

1. Demographics of Galaxy Population

   c. **Dwarf galaxies** (dE & dSph)

   - A dwarf galaxy with $M_V = -6$ wil be visible and distinguishable from the background out to ~ 4 Mpc

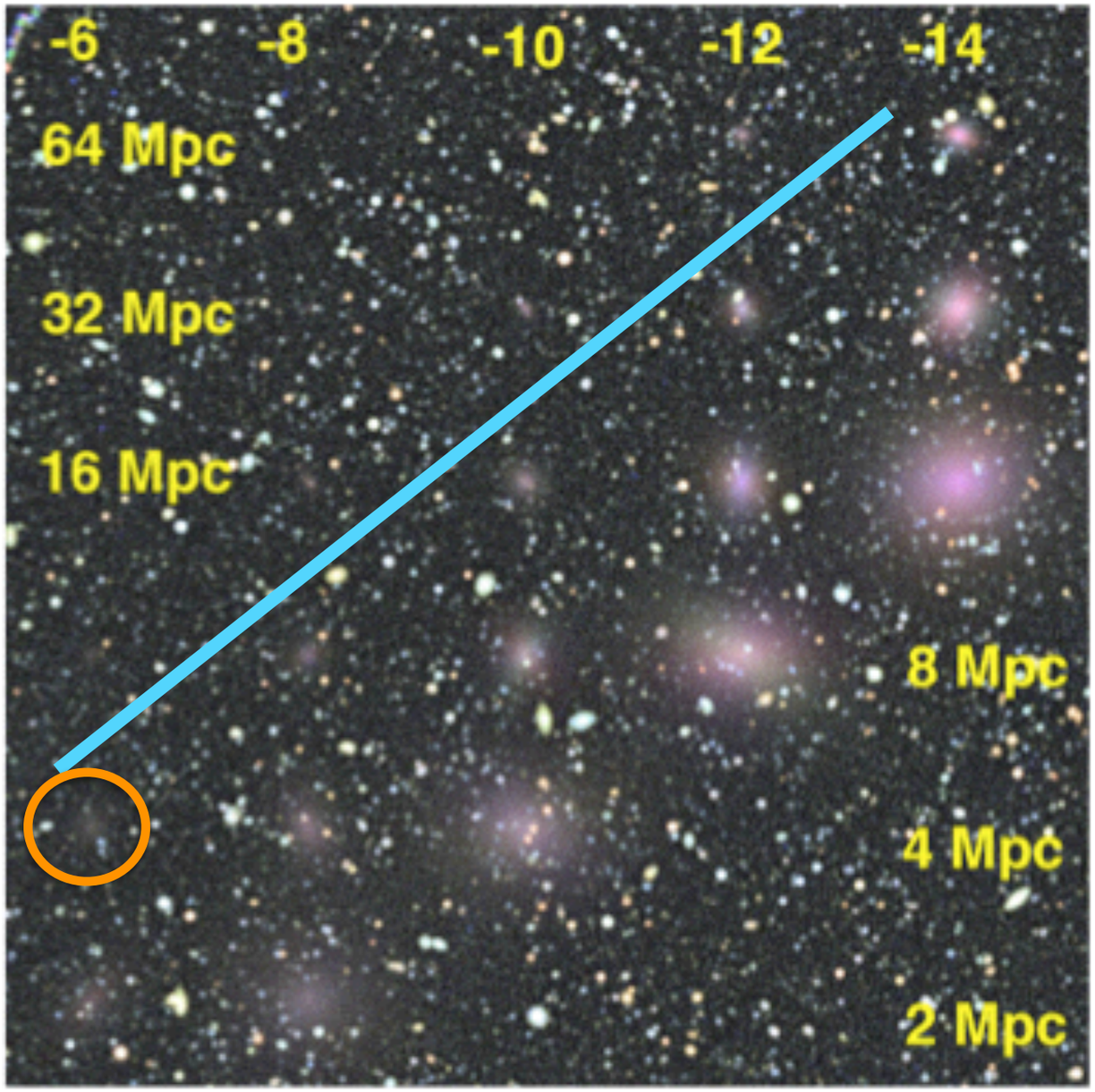


Fig 9.6 of LSST Science Book Version 2.0

The evolution of galaxies

2. Galaxy Mergers and Merger Rates
   a. The importance of galaxy mergers to galaxy assembly, star formation, bulge formation, and supermassive black hole growth
   b. LSST has the depth, volume, and wavelength coverage needed to perform a uniform study of $\mathbf{L}_*$ mergers out to $z \sim 2$, and a statistical study of **bright** galaxy mergers out to $z \sim 5$

The evolution of galaxies

2. Galaxy Mergers and Merger Rates

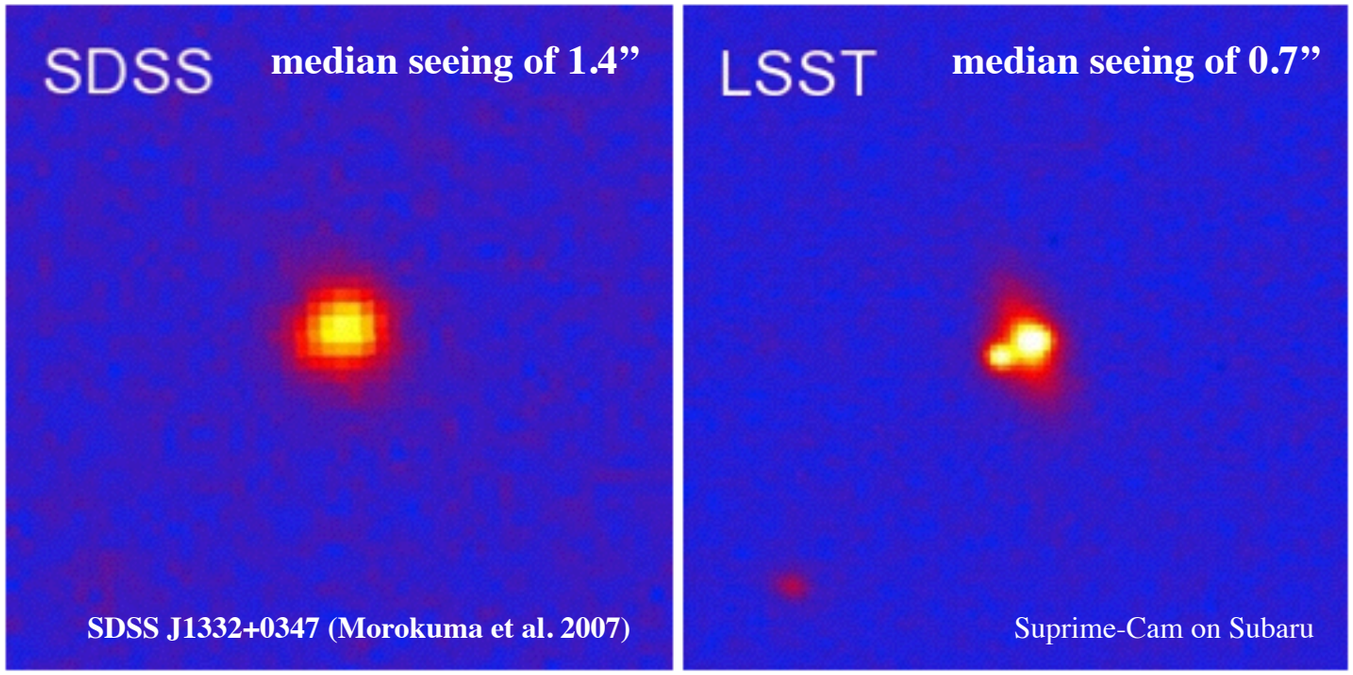
c. A variety of approaches to identify mergers in the LSST data

- Short-lived strong morphological disturbances ($z < 0.2$)
- Longer-lived but lower surface brightness extended tidal tails ($z<1$)
- Residual fine structures detected in smooth model subtracted images
- Galaxy pairs with projected separations enough to give a high probability for merging within a few hundred Myr

d. The galaxy merger rate as a function of redshift, stellar mass, color, and environment

(Strong) Lenses & Dark Matter

Advantage of LSST
: Excellent image quality
(spatial resolution)



Images of gravitationally lensed quasars.

Expected number of lenses

Galaxy lens	~10
Group lens	~10
Cluster lens	~50
Lensed quassar	~10
Lensed SN	~300

1. Distribution of DM
2. DM properties (the self-interaction cross-section, interplay with the baryon)

the Bullet cluster 1E065756

X-ray NASA/CXC/CfA Optical: NASA/STScI; Magellan/U.Arizona; Clowe et al. (2006); Bradaˇc et al. (2006)

SNe & Dark Energy

	Current studies	LSST
# of SNe	10	>10m (over 10yrs) >10
Hubble diagram	various telescopes, instruments, and passbands systematic-error dominated	one instrument statistical-error dominated

1. Constraint on DE (w_0,σ_8,Ω_m)
2. Probe of large-scale homogeneity and isotropy
3. Measuring baryon acoustic oscillations

Thank you