Large Synoptic Survey Telescope

The LSST Galaxies Science Collaboration

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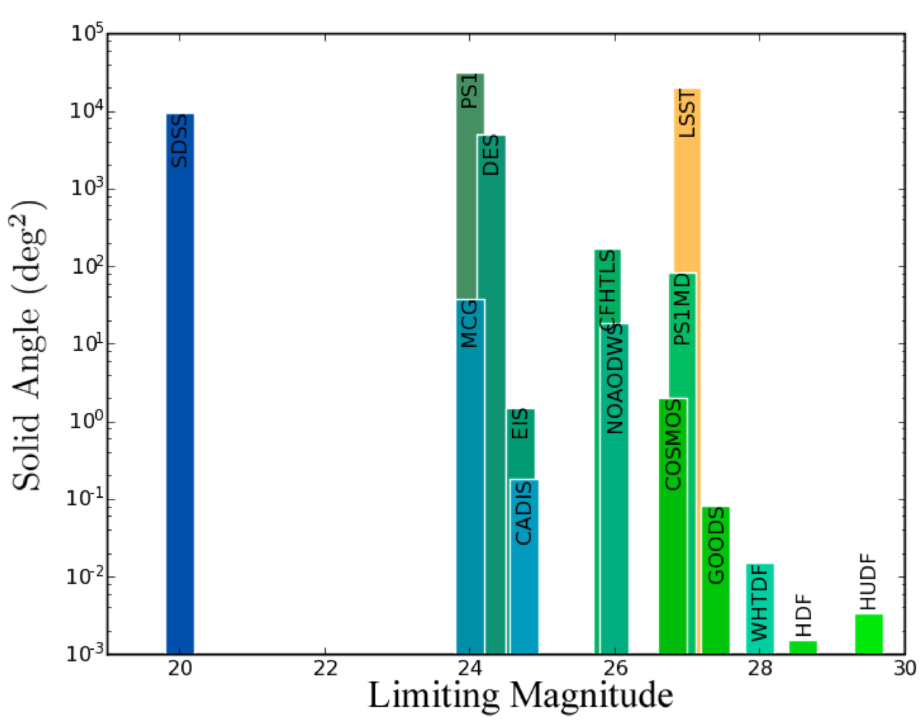
Abstract: We present extragalactic research plans that are developing for the LSST sky survey. The LSST Galaxies Science Collaboration team is a working group with several goals. One goal is to identify science use cases for the enormous LSST survey data archive and database that either stretch the capabilities of the system or else are missing from current LSST science use case scenarios. In addition, the team is working to identify gaps in other current, on-going, or planned non-LSST sky surveys, in order to develop the LSST science case for those research problems. The team is also investigating what precursor extragalactic studies need to be addressed and which data sets are missing now but which need to be available in order for LSST galaxies research to reach its full potential when the facility begins operations. Finally, the collaboration is working with the LSST Data Management team to verify that the expected science database queries for extragalactic science work with the LSST database schema.

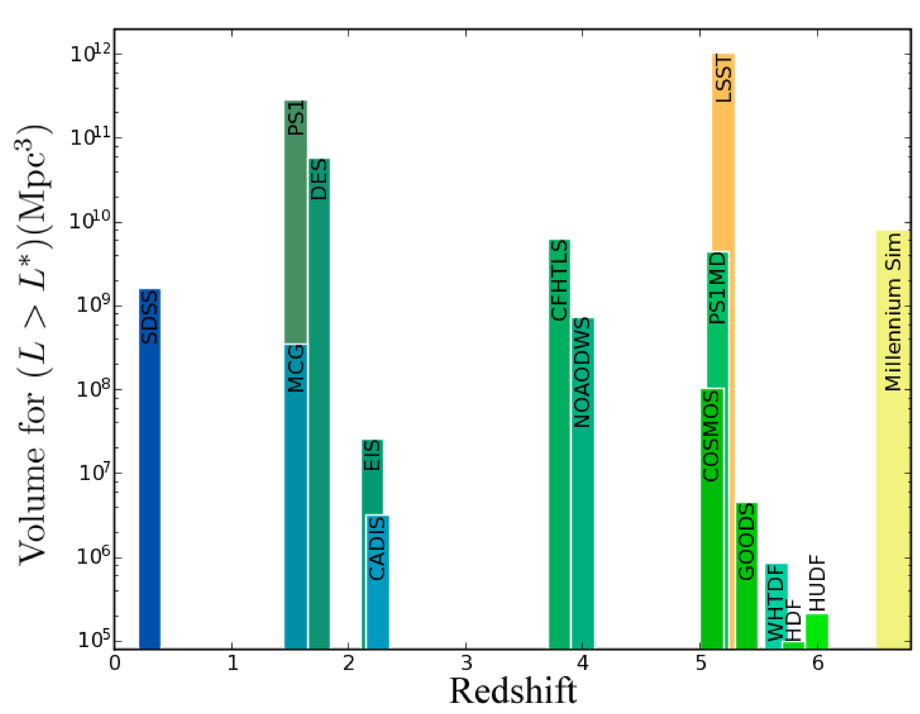
Open questions

- Do galaxies form at dark-matter peaks?
  - Really? All of them?
- Which feedback mechanisms are most important in governing star formation?
- Where are the progenitors of today's elliptical, spiral and irregular galaxies?
- How important are gas-rich and gas-poor merging? Hot accretion? Cold flows?
- Why do ΛCDM simulations generally
  - Under-predict disk galaxy sizes?
  - Fail to reproduce the thermodynamics of clusters of galaxies?
  - Produce too many dwarf galaxies?

LSST provides about 2 orders of magnitude more area than current or near-future surveys of comparable depth.
Limiting magnitudes in *u,g,r,i,z,y* = 24.3,26.5,27.8,26.6,25.5,24.7



This depth and area vastly increases the redshift range and volume for studies of normal galaxies. Shown below is the co-moving volume within which each survey can detect a galaxy with a characteristic luminosity L* (M_B~-21) assuming a typical Lyman-break galaxy spectrum. LSST encompasses about 2 orders of magnitude more volume than current or near-future surveys or the latest state-of-the-art numerical simulations.



Addressing these questions requires LARGE samples. LSST will provide them:

- Nearly 10^{10} galaxies observed in *u,g,r,i,z,y*
  - Photometric redshifts
  - Environments
  - Clustering
- ~ 3×10^9 resolved galaxies (significantly larger than the PSF)
  - Sizes
  - Morphologies
  - Interactions
  - Surface-brightness profiles to μ_R = 29 mag arcsec^{-2}

Multivariate distributions

A key to testing our understanding of galaxy formation and evolution will be to examine the full multi-dimensional distributions of galaxy properties. Tools in use today include:

$P(N|M)$ Multiplicity function vs. cluster or halo mass

$P(L|M)$ Luminosity function vs. cluster or halo mass

With several orders of magnitude larger samples, we can progress to full multi-variate distributions of a large set of measurable (or inferred) galaxy properties vs. environment:

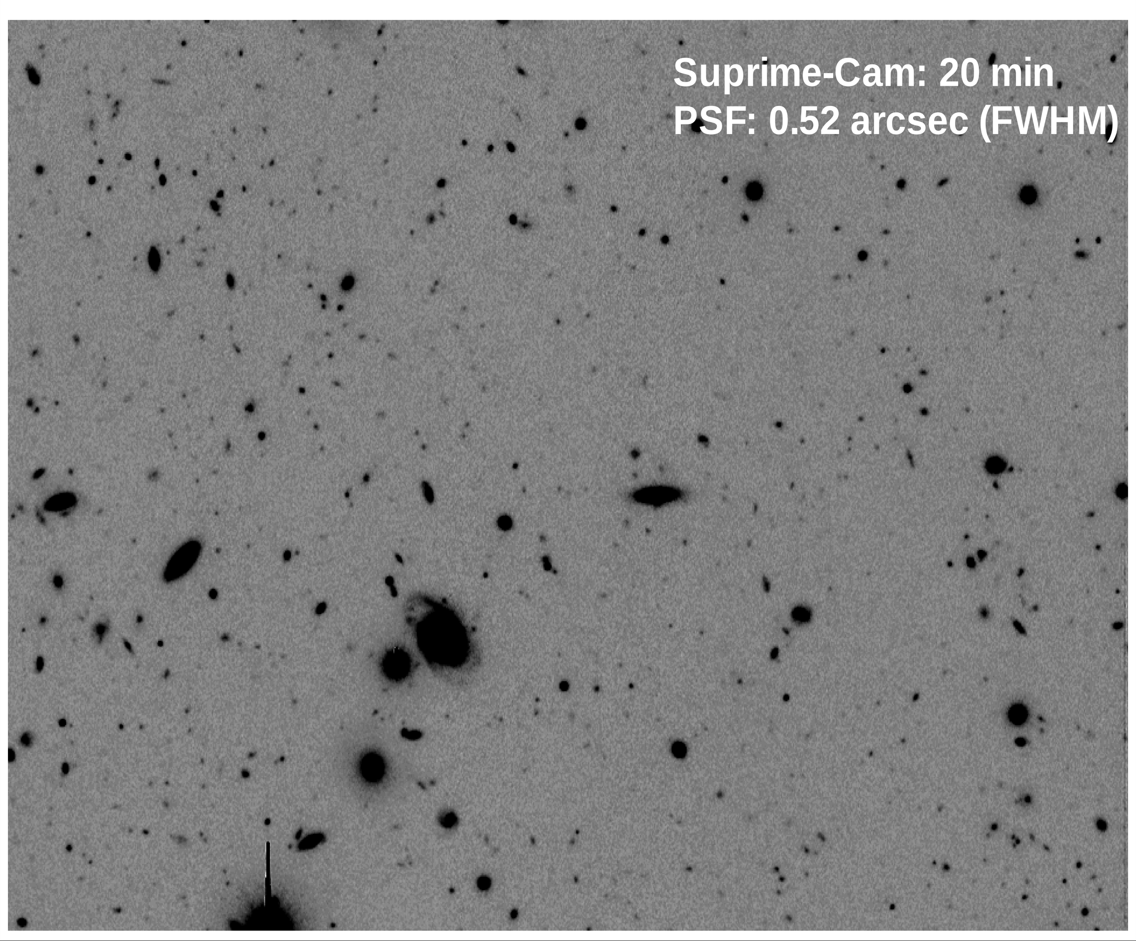
$$P(N, L, r_e, n, E(B-V), B/T, Z, \mathrm{color}, \mathrm{age}, \mathrm{sfr}|M)$$

It will be possible to subdivide the cluster or group environment not just by mass but by other properties, leading to still more general distribution functions:

$$P(N, L, r_e, n, E(B-V), B/T, Z, \mathrm{color}, \mathrm{age}, \mathrm{sfr}|M, a, b, c..)$$

Where *a,b,c* are properties of the environment (cluster or group) such as concentration or ellipticity, inferred, for example, from gravitational lensing.

LSST median seeing is expected to be 0.7 arcsec. Typical images will be about 0.7 magnitudes deeper than the Subaru image shown below. Image: 2 arcmin across.

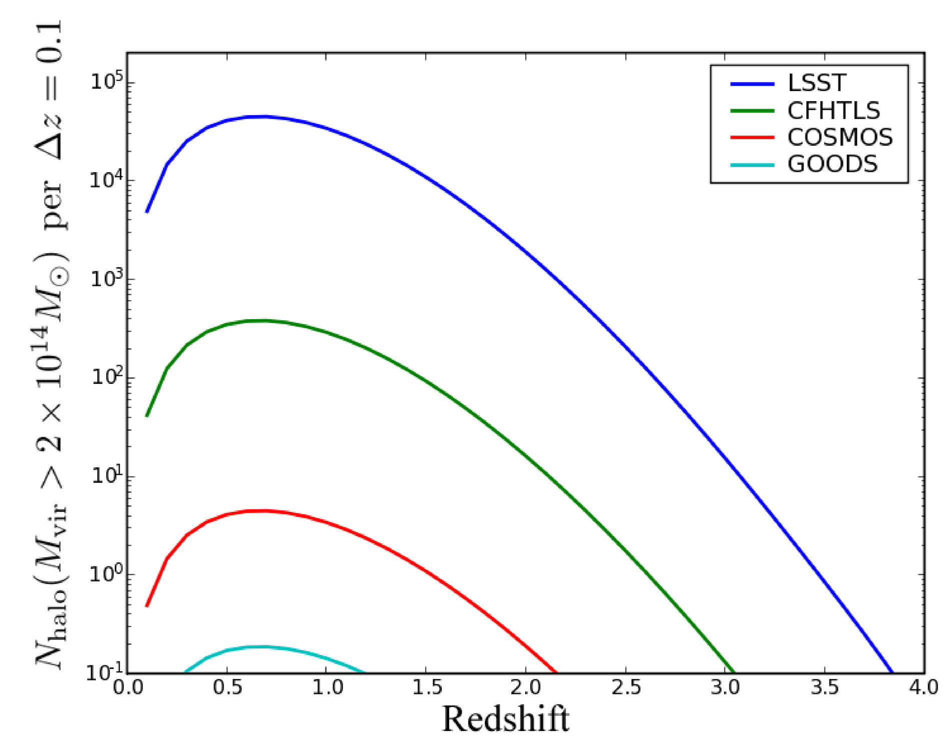


Survey Key for figures:
SDSS: Sloan Digital Sky Survey
MCG: Millennium Galaxy Catalog (Isaac Newton Telescope)
PS1: PanSTARRS-1 wide survey, starting in 2008 in Hawaii
DES: Dark Energy Survey (Cerro-Tololo Blanco telescope starting 2009)
EIS: ESO Imaging survey (complete)
CADIS: Calar Alto Deep Imaging Survey
CFHTLS: Canada France Hawaii Telescope Legacy Survey (in progress)
NOADWS: NOAO Deep Wide Survey (complete)
COSMOS: HST 2-degree survey with support from many other facilities (HST complete)
PS1MD: PanSTARRS-1 Medium-Deep Survey covering 84 square degrees
GOODS: Great Observatories Origins Deep Survey (HST, Spitzer, Chandra, and many other facilities)
WHTDF: William Herschel Telescope Deep Field (complete)
HDF, HUDF: Hubble Deep Field and Ultra Deep Field
Millennium Sim: Large cosmological simulation

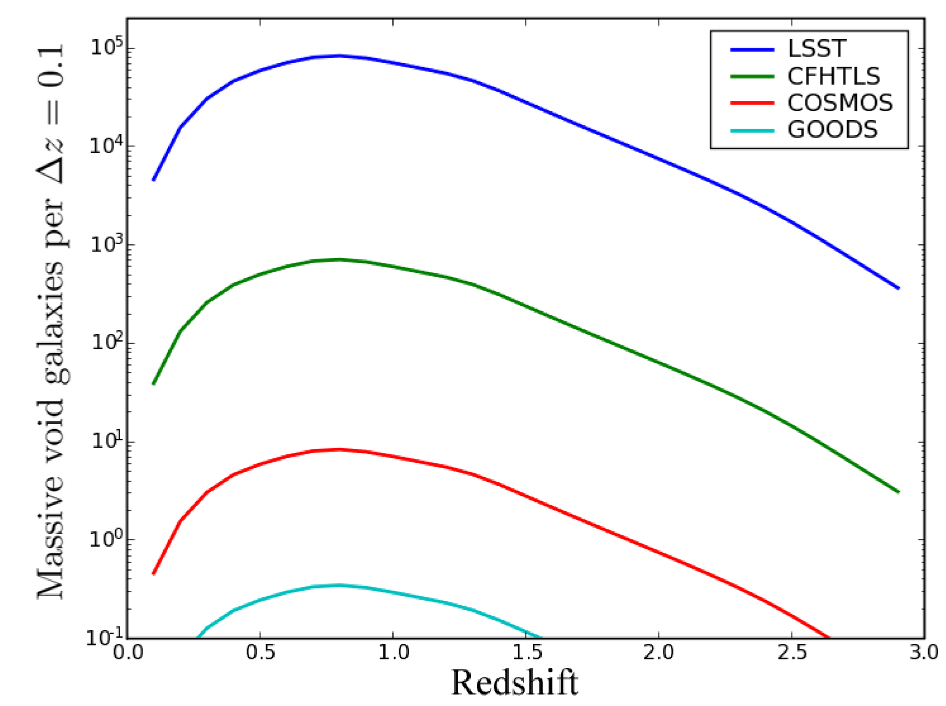
Tools for studying galaxy evolution vs. environment and redshift:

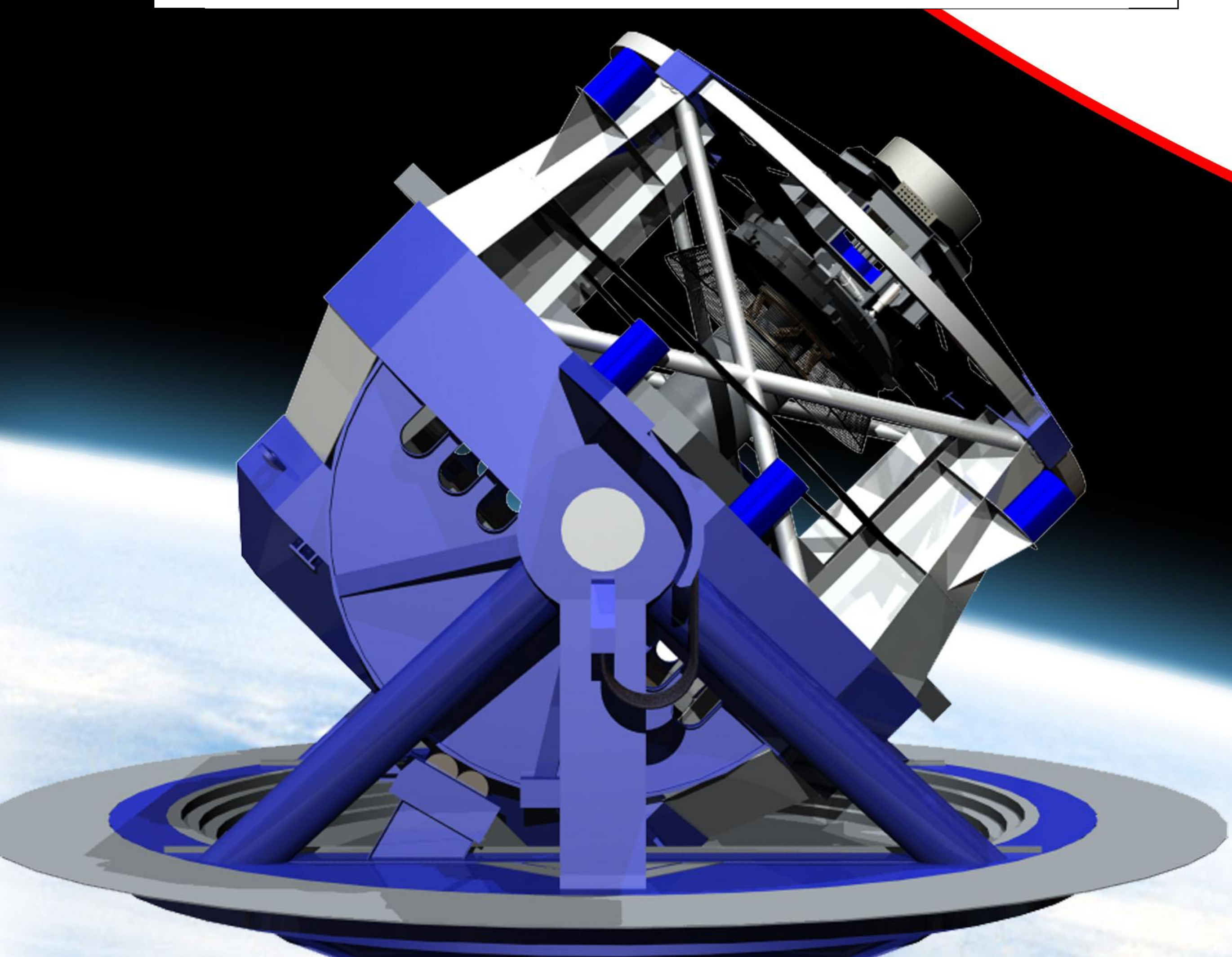
- Tagged correlation functions
  - Clustering as a function of galaxy properties
  - Cross correlations of different types of galaxies
- Group-finding
  - Galaxy properties as a function of multiplicity, baryonic mass
- Group finding via lensing
  - Galaxy properties as a function of halo mass
- Studies of clusters identified by X-ray gas or Sunyaev-Zeldovich effect

LSST will provide access to extremes of environment. The figure below shows the number of clusters with virial masses more than $10^{14}M_\odot$ vs. redshift expected for LSST, compared to a few current surveys. (Estimates are from Lukic et al. astro-ph/0702360)



At the low-density extreme, the figure below shows the number of massive galaxies in underdense regions expected as a function of redshift. The estimate is taken from the Millennium simulation (Springel et al. 2005; Bertone et al. 2007). Underdense regions are identified as regions with less than half the mean density when smoothed on scales of *r* = 5 Mpc. For the purposes of this illustration, we have scaled this to select galaxies with M_{vir} >$10^{12}M_\odot h(z)$, where h(z) is the evolution of the Hubble parameter in units of H_0. (That is, we select galaxies with present-day masses larger than the Milky Way.) Such galaxies are rare in underdense regions; it will take a large survey to find enough for meaningful comparisons to more normal galaxies.





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