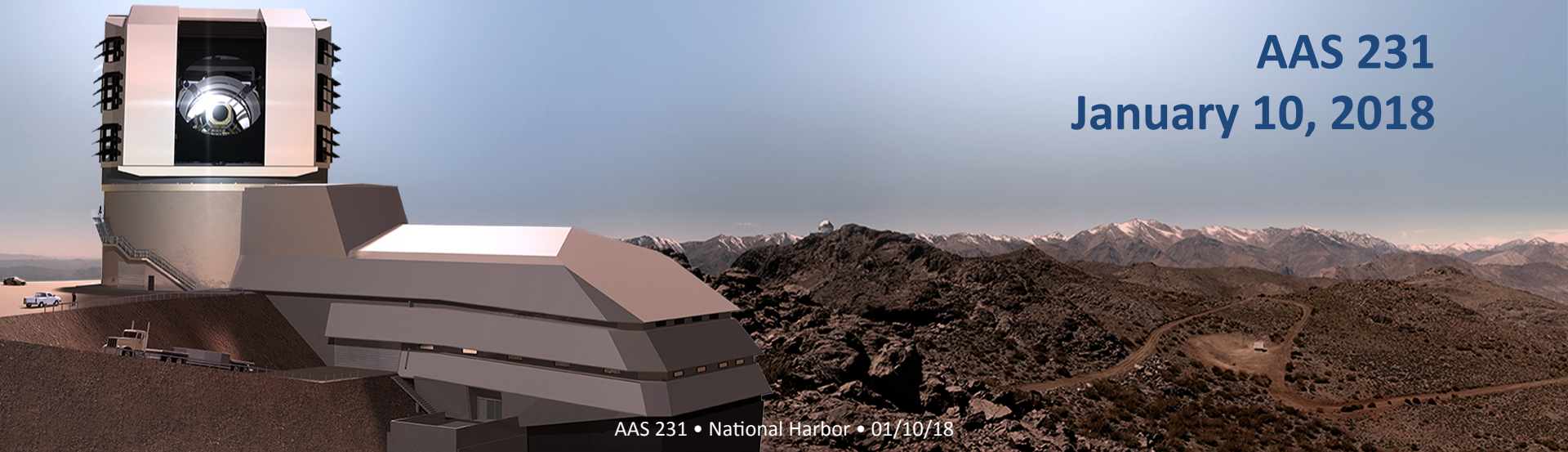
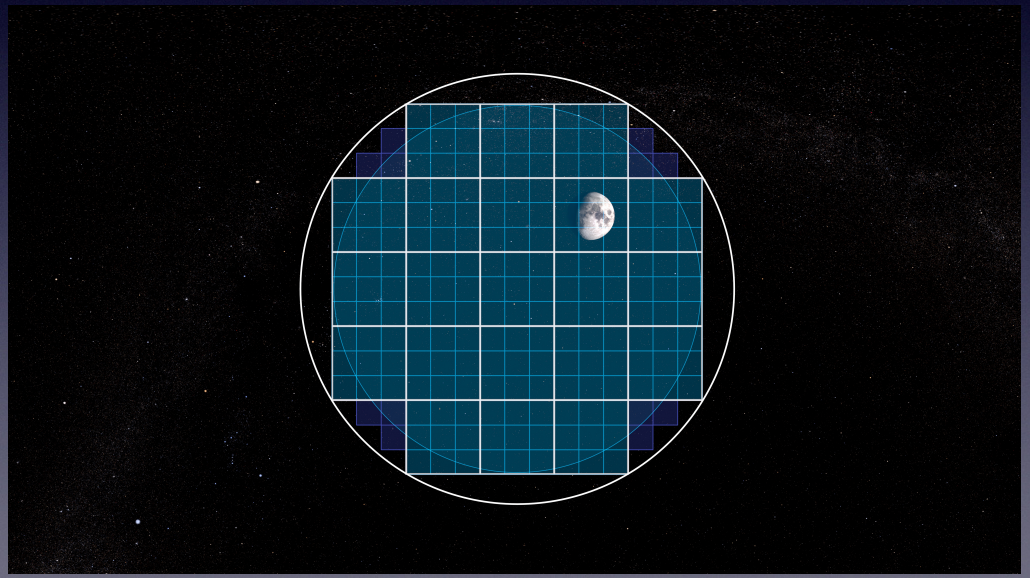
WFIRST-LSST Connection

Beth Willman
Deputy Director, LSST

AAS 231
January 10, 2018



What if we put a camera on an 8-m telescope, that could take a picture the size of 50 full moons? And what if we used this camera to take 1000 pictures of every area of the visible sky?

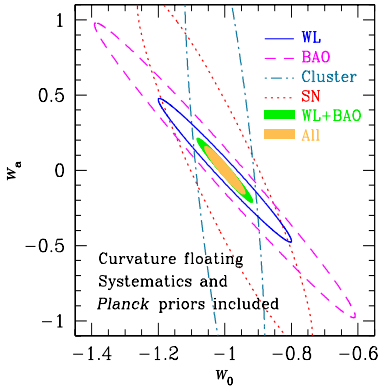


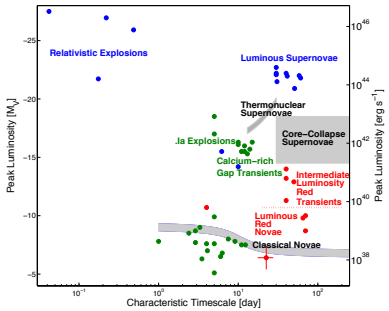

LSST Render March 2011

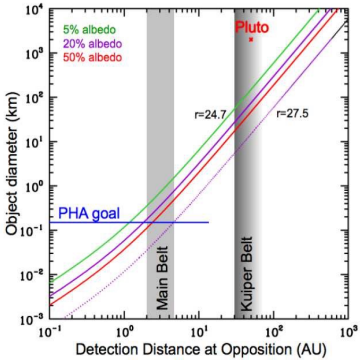
LSST Status Nov 2017

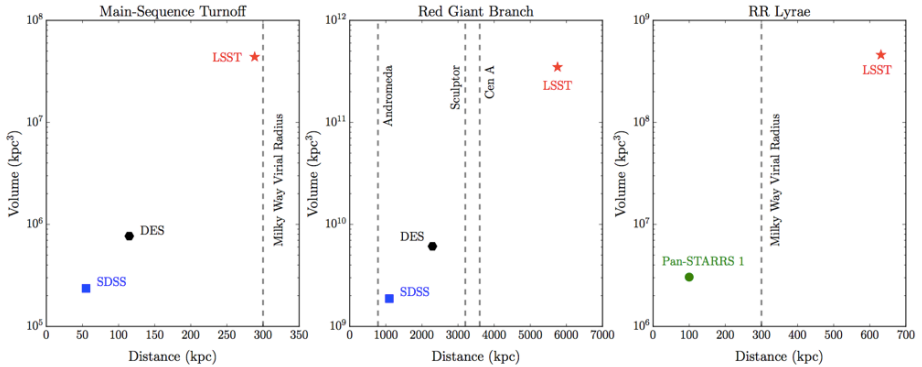
Primary Science Drivers

Cosmology
Dark energy
Dark matter
Milky Way
Stellar populations
Stellar Streams and Dwarf Galaxies
Solar System
Near-Earth Objects
Trans-Neptunian Objects
Comets
Dynamic Universe
Explosive transients
Multi-messenger counterparts
Variable stars, quasars
Lensing events







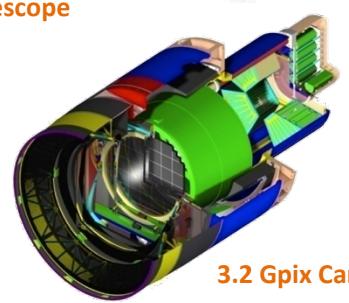


LSST is an Observatory System

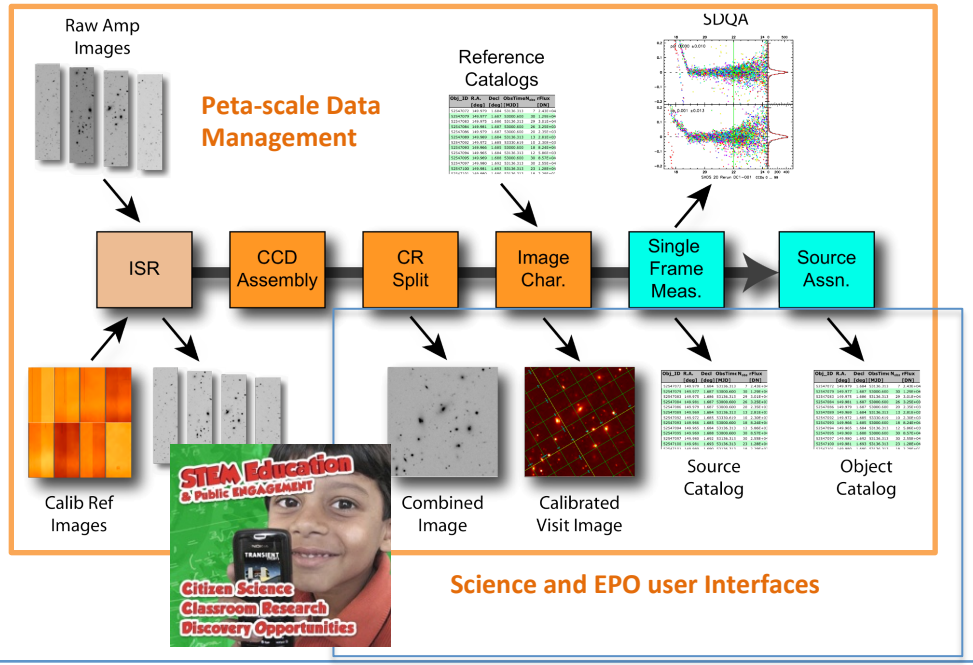
A comprehensive facility that will include: (i) an optical telescope, wide-field camera, 6 broad band optical filters, (ii) a data management system to process, archive, and serve images and data products, (iii) user interfaces.

8.4m Telescope

+



3.2 Gpix Camera

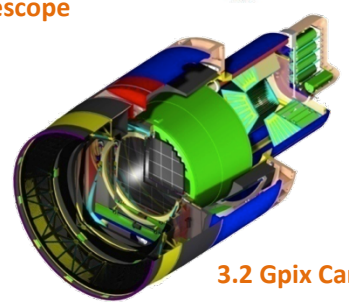


LSST is an Observatory System

We will deploy this system in October 2022, for a 10-year, time-domain survey of >18,000 deg^2 of the Southern Sky with single visits of 2x15s exposures.

8.4m Telescope

+



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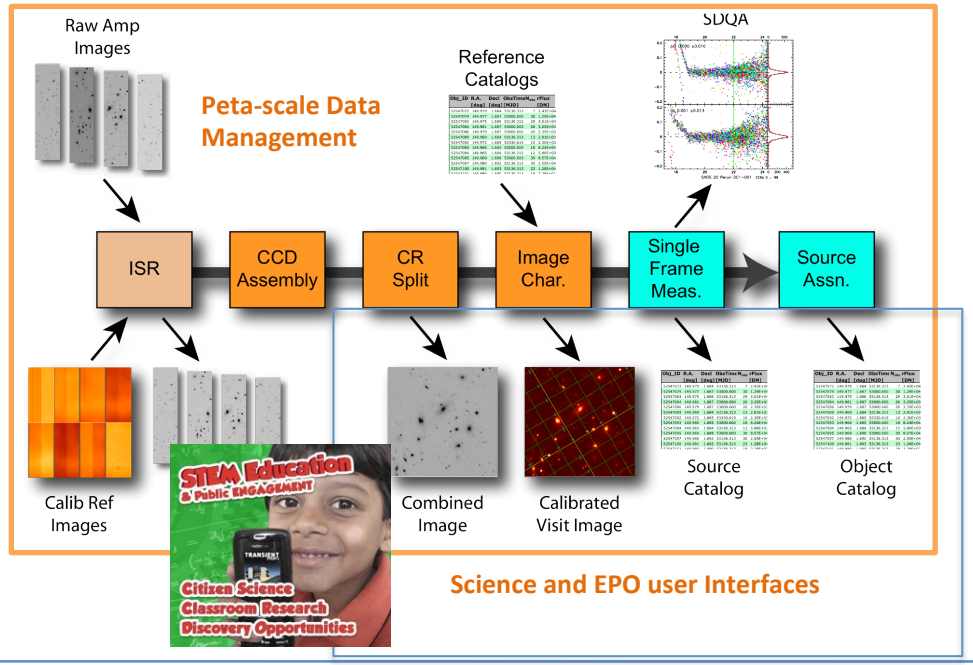
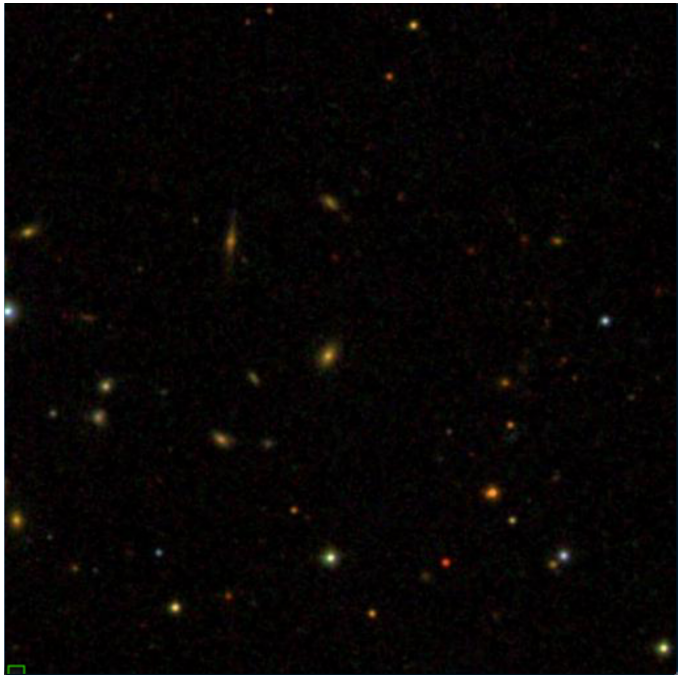
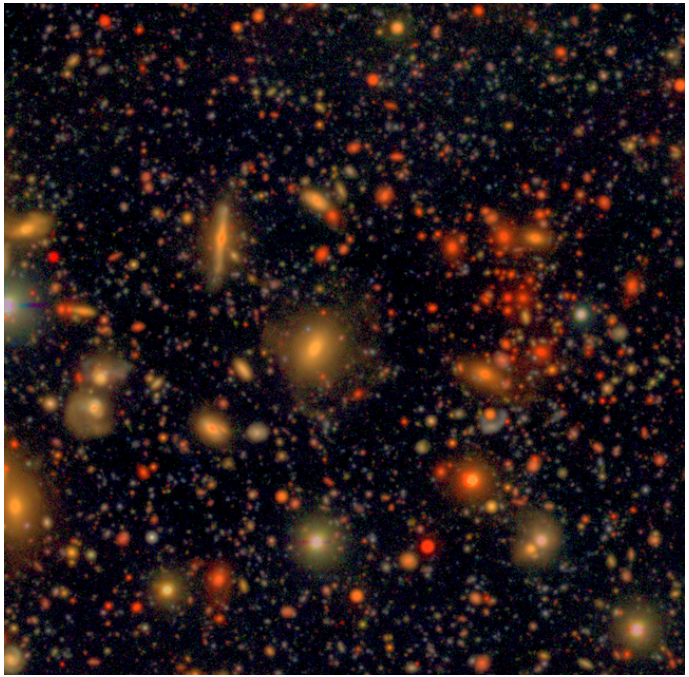


LSST-like Images



SDSS (COSMOS) ~ 3.5 arcmin
Images from SDSS, HSC collaboration, Robert Lupton



HSC image g,r (1.5 hrs) ,I (3 hrs)
PSF matched co-add (~ 27.5)
Processed with the LSST Stack

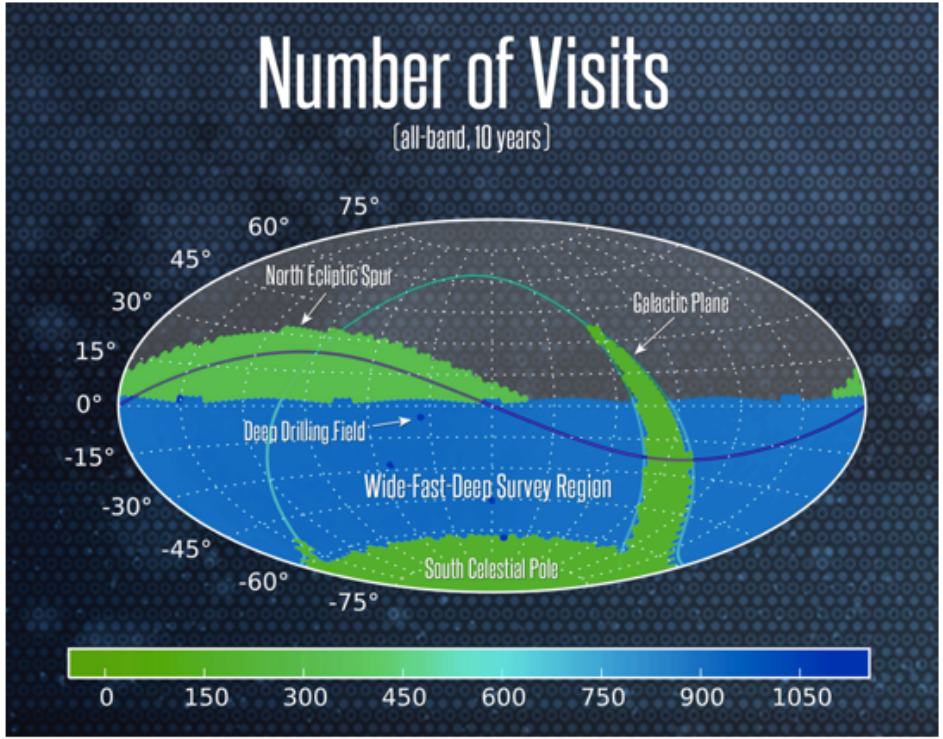
Survey:
- Telescope field of view = 9.6 deg^2
- **Main survey area = 18,000 deg^2**
- Filters = *ugrizy* (6)
- Visits per night = 1000
- Survey Duration = 10 yr
- **Total visits per pointing = 825**

Imaging depth:
- Single visit (*r*, S/N=5) = 24.7 mag
- Stack depth (*r*, S/N=5) = 27.5 mag

Expected number of objects:
- Galaxies = 20 billion
- Stars = 17 billion
- Sources (single-epoch) = 7 trillion
- Forced sources = 30 trillion

Alert production:
- Real-time alert latency = 60 sec
- Throughput = 10 million per night

Data (Data Release 11):
- Data collected per 24 hr = 15 TB
- Total image collection = 0.5 EB
- Database size = 15 PB



Coverage over the entire southern hemisphere

"Visit" = 16 second exposure
+ 2 second readout
+ 16 second exposure

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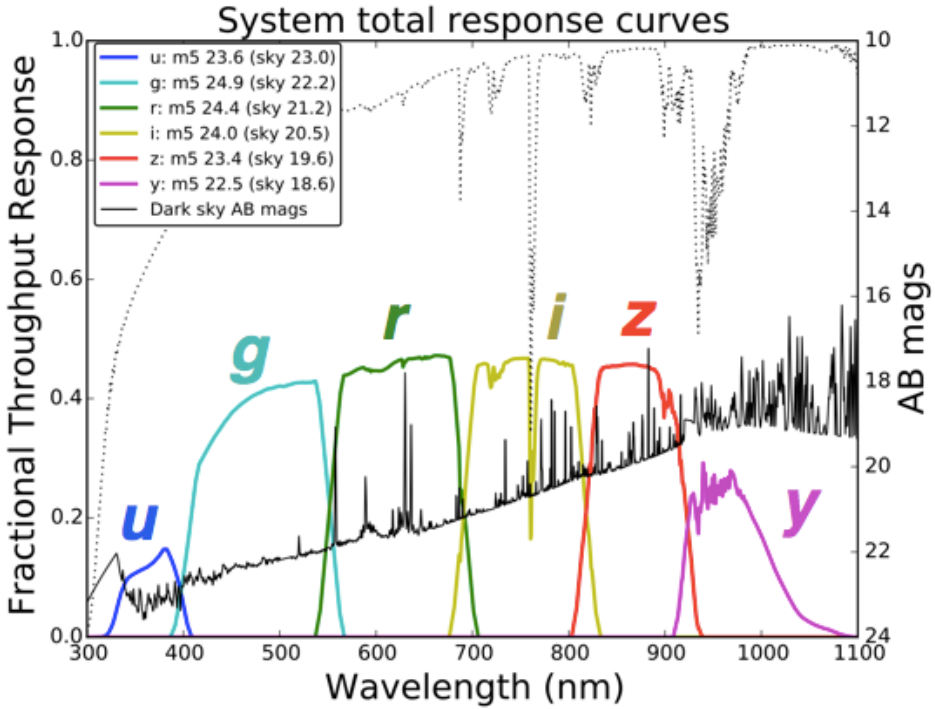

6 broad-band filters spanning 320-1050 nm
near-UV to near-IR

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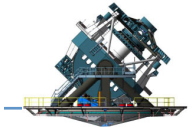
LSST will catalog more stars and galaxies than all previous astronomical surveys combined

…but perhaps even more important is the anticipated ***quality*** and ***richness*** of the data, as well as ***homogeneous*** processing

These data will be made available to all US and Chilean scientists, and named International Contributors with no proprietary period.



Data Products

- 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.

Prompt

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

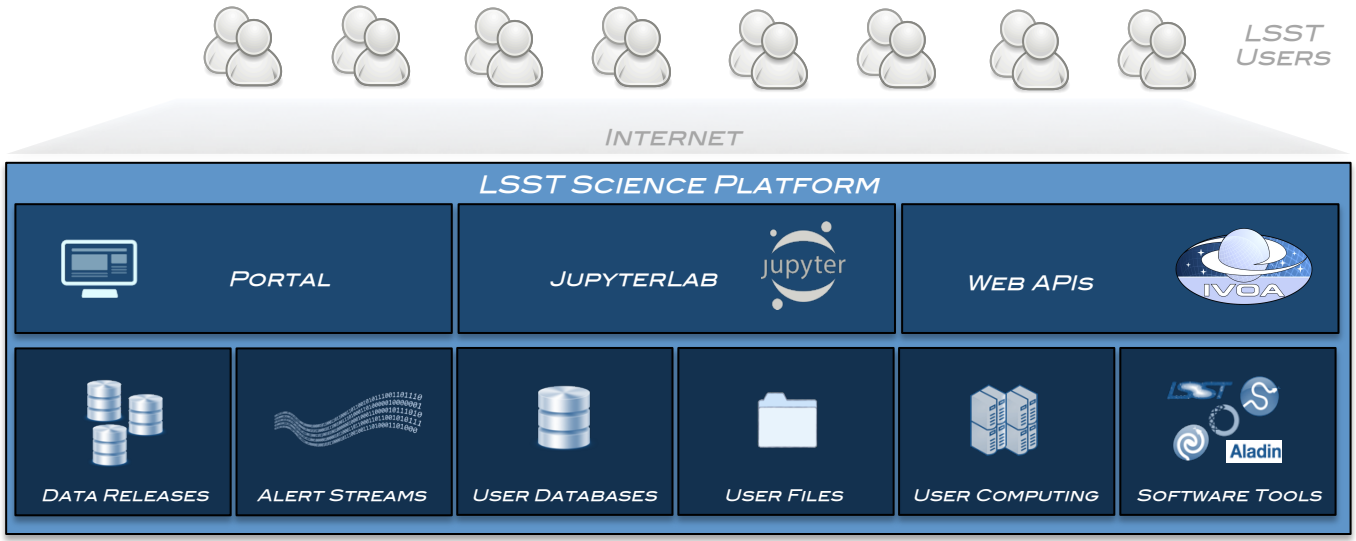
Data Releases

The production of data products will be transparent: All software is developed open-source and will be available to the community.

*For more details, see the **"Data Products Definition Document"**, http://ls.st/lse-163*

The LSST Science Platform

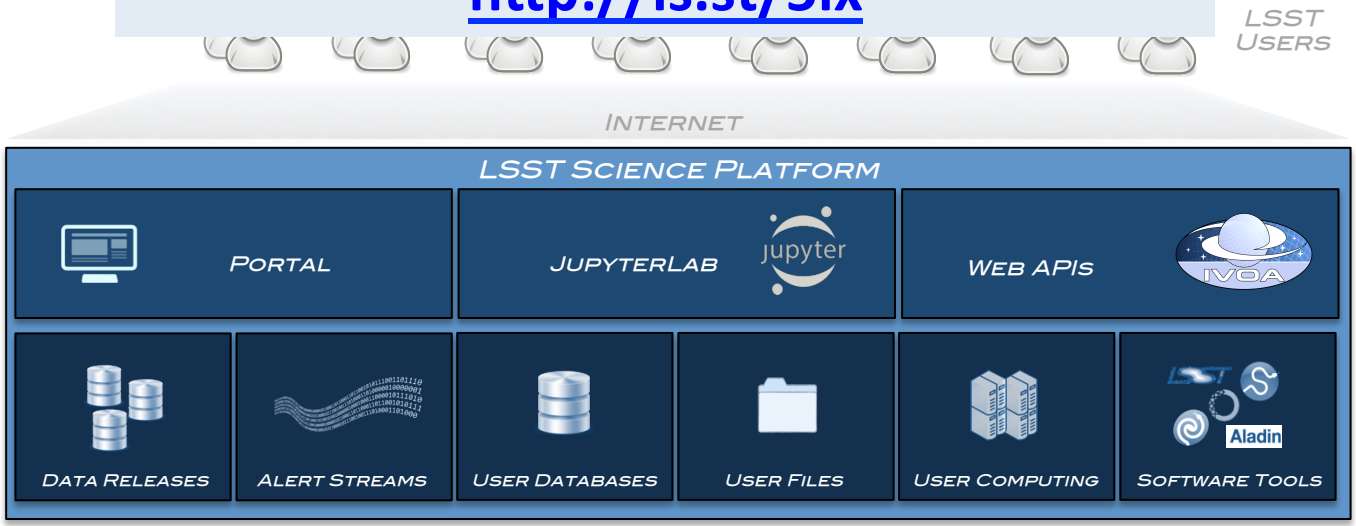
Accessing LSST Data and Facilitating LSST Science



The **LSST Science Platform** is a set of integrated web applications and services deployed at the LSST Data Access Centers (DACs) through which the scientific community will access, visualize, subset and perform next-to-the-data analysis of the data.

The LSST Science Platform

See Mario Juric's presentation at
http://ls.st/5lx



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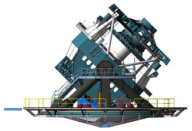
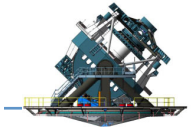


Scientific Connections With WFIRST

- Complementary approaches to many of the same scientific questions
- LSST Discovery -> WFIRST follow-up
- Improved Source Characterization
- Training Sets for LSST (e.g. photo-z, star-galaxy separation)

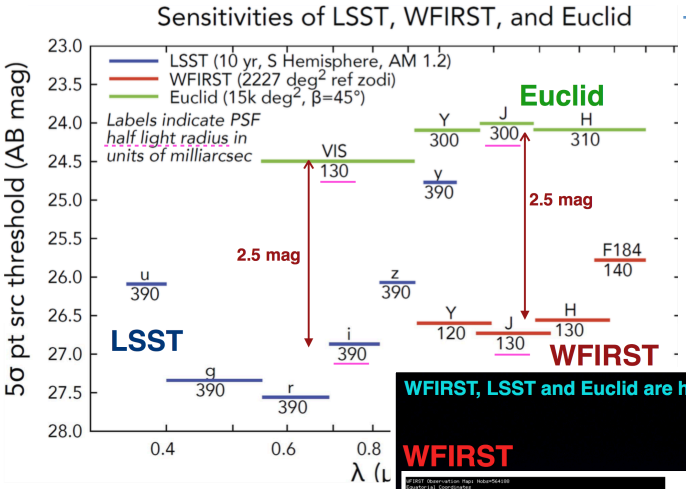


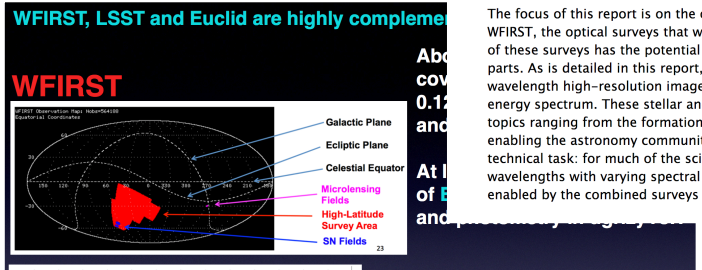
Scientific Connections With WFIRST

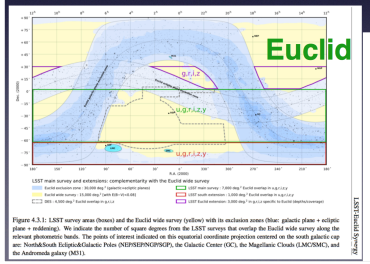
Jason Kalirai presented a detailed treatment of scientific synergies in an August 2017 talk on the LSST-WFIRST connection presented at the LSST Project and Community Workshop:

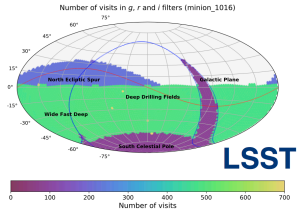
http://ls.st/dio

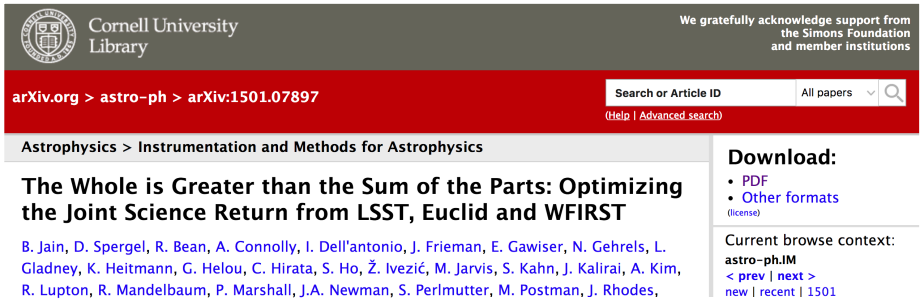
Expressing LSST-WFIRST Synergies

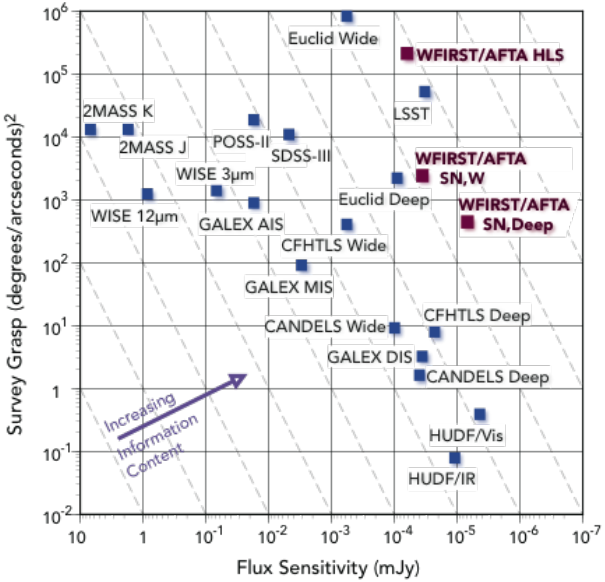






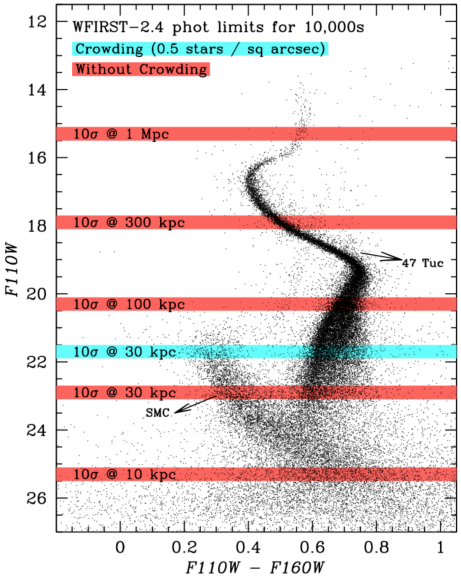






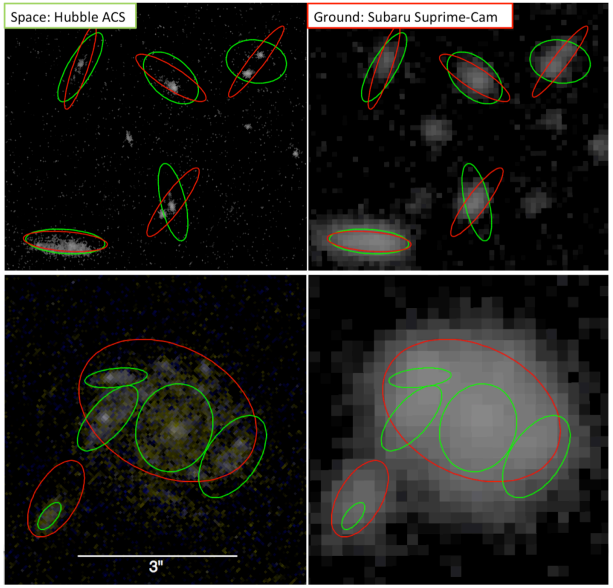
WFIRST Makes LSST Better

Better Completeness



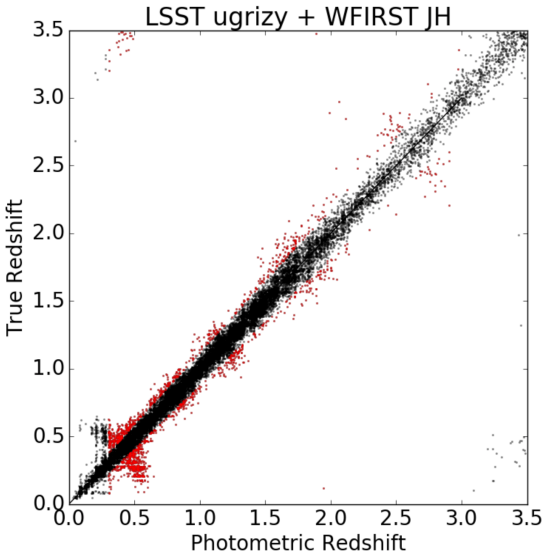
also, for extincted regions of the MW plane

Better Deblending



W. Dawson et al. (2016)

Better Photo-z's



M. Graham

Approaches to Coordination

To realize the joint potential of LSST-WFIRST analysis, photometry across multiple wavelengths with varying spectral and spatial resolution must be combined

- Joint Pixel Analysis (helps deblending, galaxy photometry, sky subtraction, calibrating systematics)
- Cadence Coordination (Deep Fields, Co-Observing)
- Data Management Coordination

The WFIRST Observing Program

Possible Survey Implementations

High Latitude Survey (2000 sq deg at 27th mag in YJHF184 + spectra)
Dark Energy — Cosmic Lensing — High-z Galaxies — Galactic Halo Substructure

Deep Field Surveys (~10 deg^2 fields at 28-29th mag, with high cadence)
Supernova Discovery — First Light — Galaxy Evolution

Guest Observer Surveys (user specified instrument, depth, area, …)
Broad astrophysics from Solar System exploration to cosmology

Galactic Bulge Survey (2.2 sq deg at high cadence)
Exoplanet Census — Free Floating Planets — Stellar Pops — Galactic Structure

Exoplanet (+ Other Objects) Imaging Survey (10^9 contrast ratio direct imaging)
Exoplanet Discovery and Characterization — Disks — Massive Star Atmospheres

Guest Investigator Surveys (funded archival research from survey data)
Broad astrophysics from Solar System exploration to cosmology

100% of WFIRST's observing time is available
The specific implementation of core surveys and all Guest Observer time, as well as associated funding, remain to be competed and selected through peer review

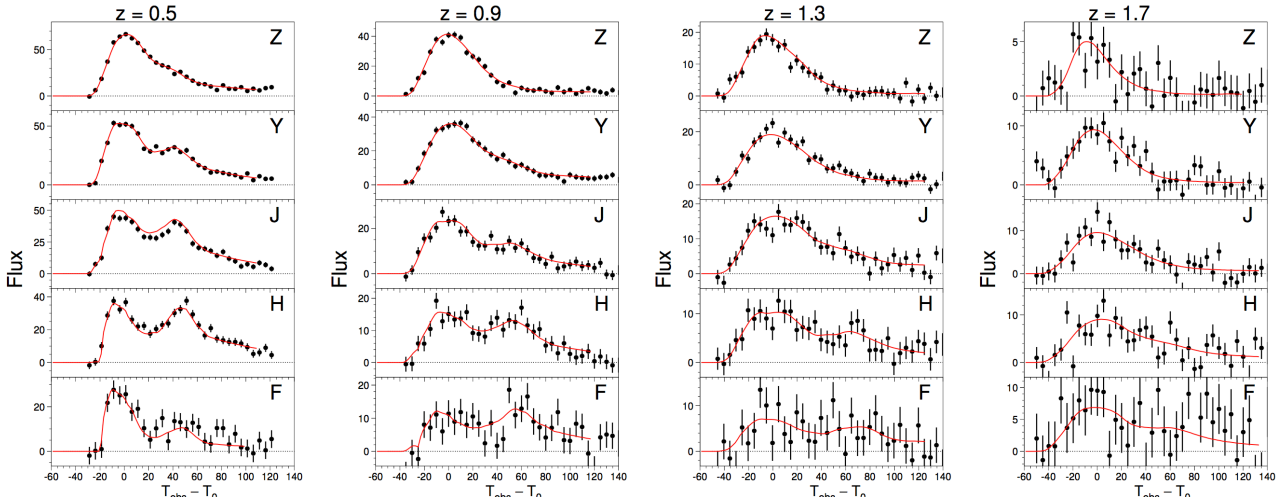
The WFIRST science teams for the operational mission phase remain to be selected
The current Formulation Science Working Group (FSWG) will be disbanded in early 2021

All WFIRST data will be non-proprietary and publicly available through an archive
Selected science teams will help define the WFIRST observing plan, but will not have privileged data access

WFIRST "Supernova" Fields (aka Deep Fields)

>50x Dither Mosaic for Depth and Image Quality

Survey Tier	Redshift Range	Area (deg^2)	Discovery Filters	Depth (mag)
Shallow	$0.1 < z < 0.4$	27.44	Y106, J129	25.0, 25.1
Medium	$0.4 < z < 0.8$	8.96	J129, H158	27.3, 27.2
Deep	$0.8 < z < 1.7$	5.04	J129, H158	28.9, 28.8



Hounsell et al. (2017)

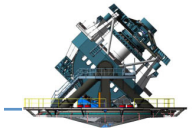
Combined light curve fitting w/ LSST+WFIRST images is highly complementary

Possible Data Management Synergies

LSST will distribute high-level calibrated data products to its user community, and enable the processing of those products close to the data. This approach would also benefit WFIRST's user community.

STScI's Data Science Mission Office (Arfon Smith, Josh Peek) is investigating the distribution of WFIRST data products through both classic archive and cloud-based infrastructure, with a possible Cloud Data Processing environment.

LSST DM (Wil O'Mullane), NOAO's Community Science and Data Center (Adam Bolton), and STScI's DSMO have started to discuss possible connections between our collective efforts.



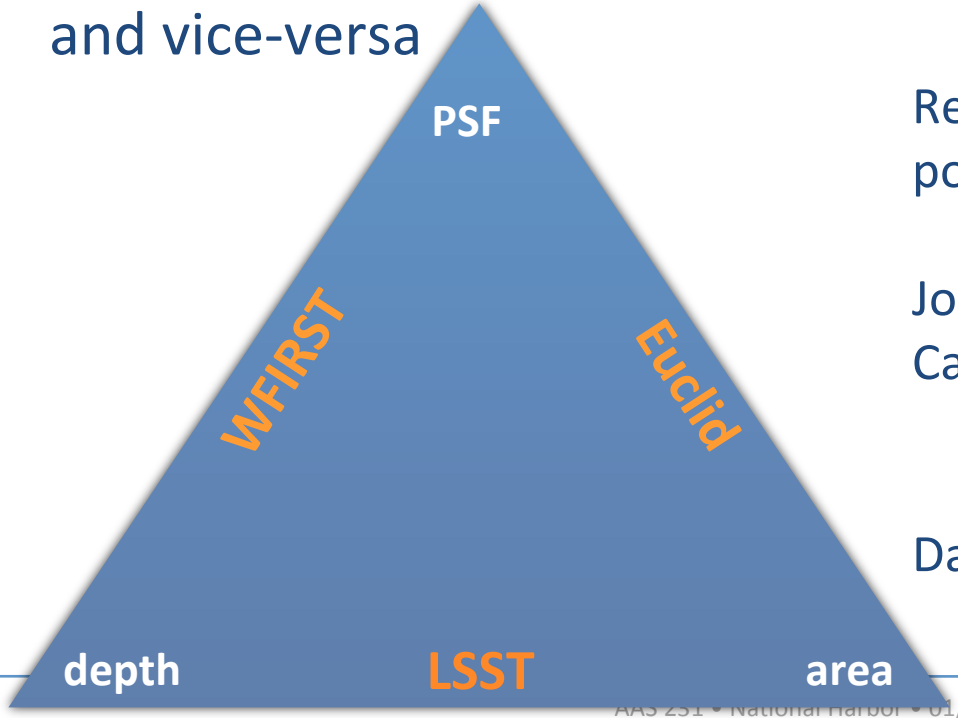
Possible Data Management Synergies

- JupyterHub/Kubernetes/Docker system being built today both at LSST and STScI/MAST
- System specifications being coordinated in push toward some global standardization
- Opportunities for consistent interfaces
- Opportunities for seamless access to LSST *and* WFIRST stacks through containerization
- Opportunities for cross-mission data access and notebook portability through data access APIs

Slide from Arfon Smith and Josh Peek

Summary

- WFIRST and LSST are highly complementary missions
- WFIRST observations will increase the scientific output of LSST and vice-versa



Realizing the full, joint WFIRST-LSST potential will require:

Joint Pixel Processing
Cadence Coordination
See mid-2018 call for White Papers!
Data Management Coordination