Large Synoptic Survey Telescope

Synergies between the Large Synoptic Survey Telescope and WFIRST

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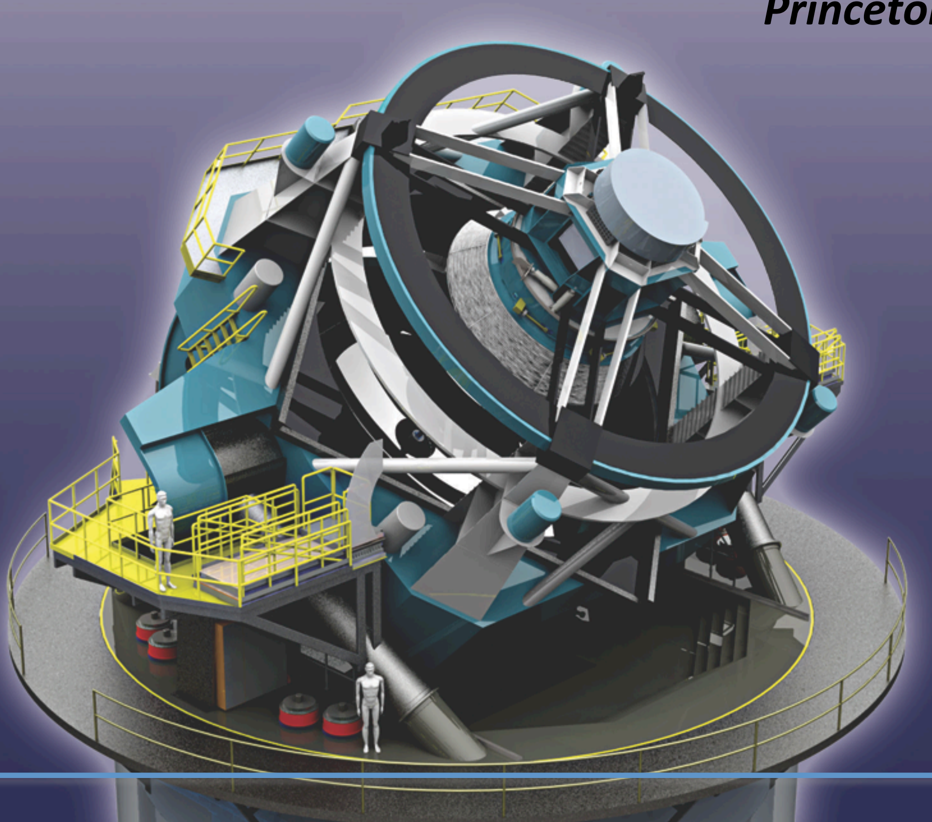
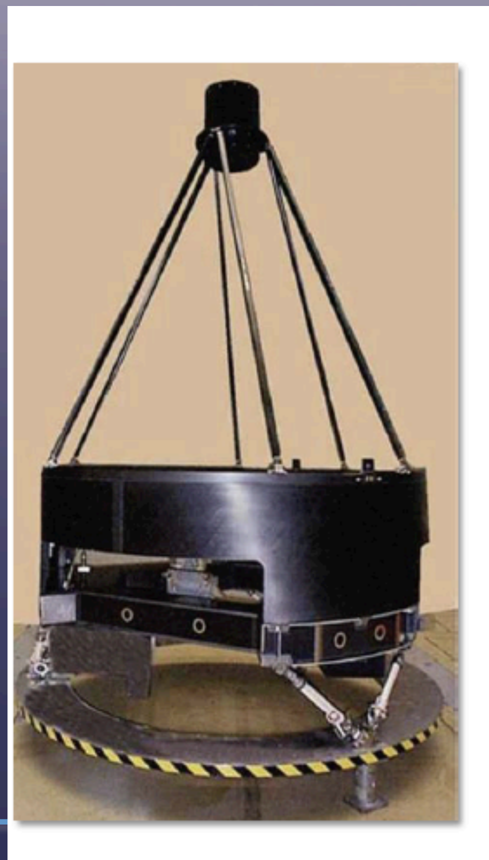




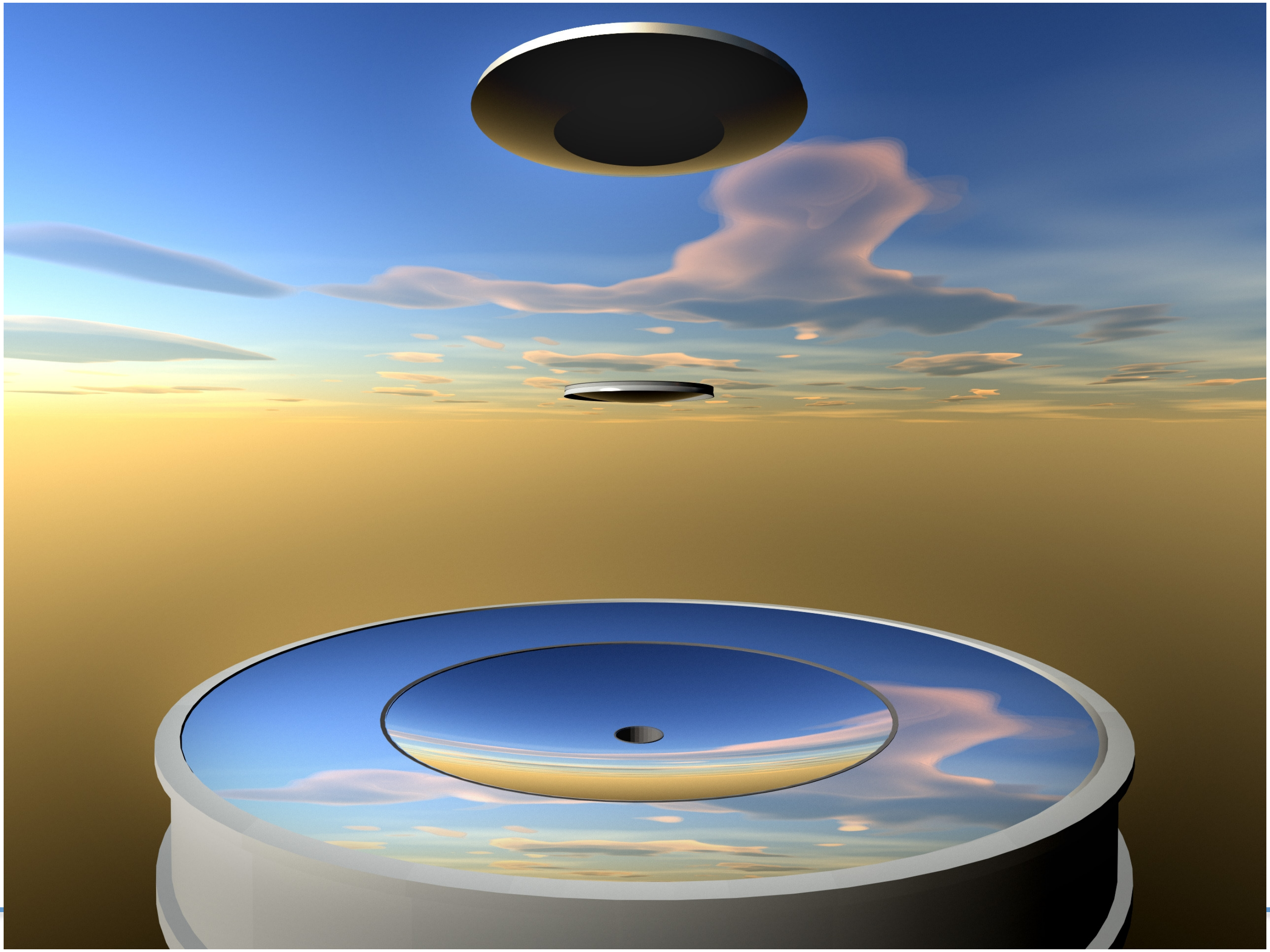
LSST: 6.7-m wide-field telescope on Cerro Pachón in Chilean Andes

Telescope will be dedicated to imaging survey, and will operate for ten years.

Site has been leveled.

The LSST optics

3-mirror design gives 9.6 deg^2 field of view.

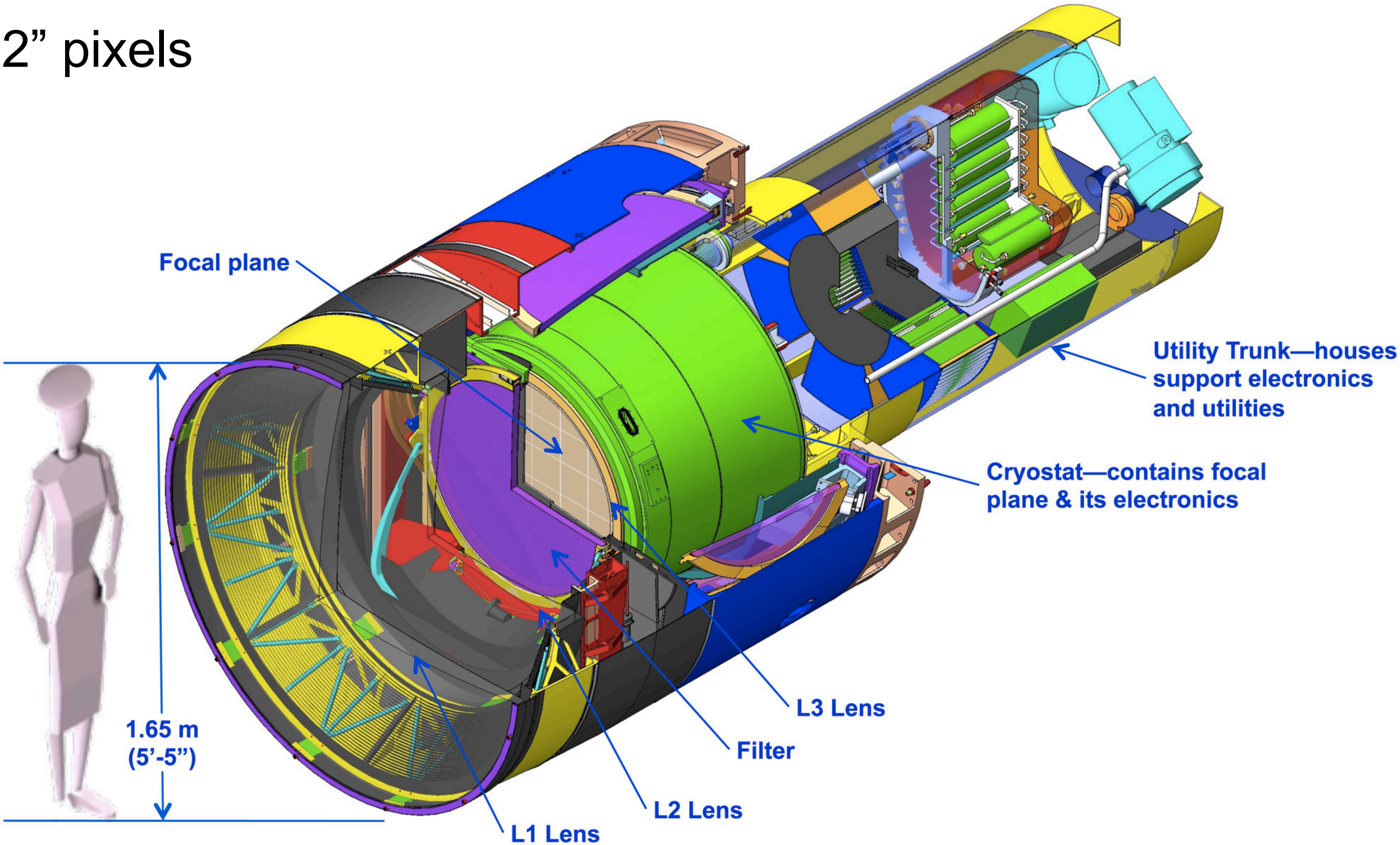


Primary/Tertiary was cast in 2009

Grinding/polishing is just about complete.

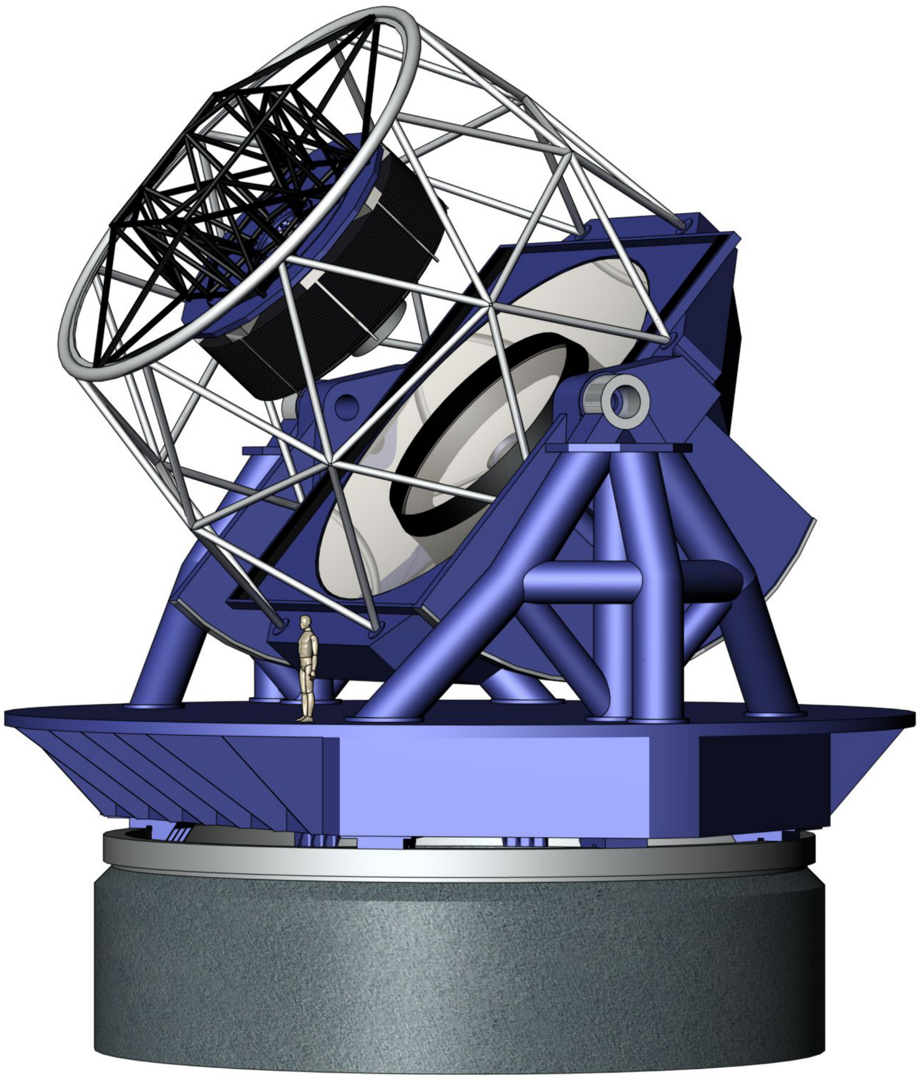
3.2 gigapixel camera. 9.6 deg^2 FoV

0.2” pixels



Camera ¾ Section

A very fast compact design, f/1.23



LSST: A dedicated 10-year survey

Large Synoptic Survey Telescope

- Main survey will cover 18,000 deg^2 in Southern Hemisphere. Each "visit" is 2 15-second exposures. >800 30-sec visits across 6 filters over 10 years.
- 5σ point-source depth (1 visit, dark sky, at zenith) : 23.9 (*u*), 25.0 (*g*), 24.7 (*r*), **24.0** (*i*), 23.3 (*z*), 22.1 (*y*)
- Depth at end of the survey: 26.3 (*u*), 27.5 (*g*), 27.7 (*r*), **27.0** (*i*), 26.2 (*z*), 24.9 (*y*)
- Perhaps 10% of the time will be devoted to 'deep fields' ~1 mag deeper. Plus observations of ecliptic plane, low latitudes, South pole.
- ***40 trillion observations of 40 billion objects***

Extremely high-quality data

Large Synoptic Survey Telescope

- Median delivered image quality of 0.67”.
- Probes of variability on timescales from 15 seconds to 10 years.
- Stellar photometric calibration to 1% or better; stellar repeatability to 0.5%.
- Astrometry to 10 milli-arcsec per visit, allowing proper motion uncertainty of 0.2 mas/year, and parallax uncertainty of 0.6 mas over the course of the survey. LSST matches Gaia’s astrometric precision at r~20, and extends it 4 magnitudes fainter.

Current status

LSST was the top-ranked large ground-based facility in Decadal Survey.

Private funds (~$40M) paid for big optics (including the primary) and site leveling. NSF and DOE funds have supported design and development.

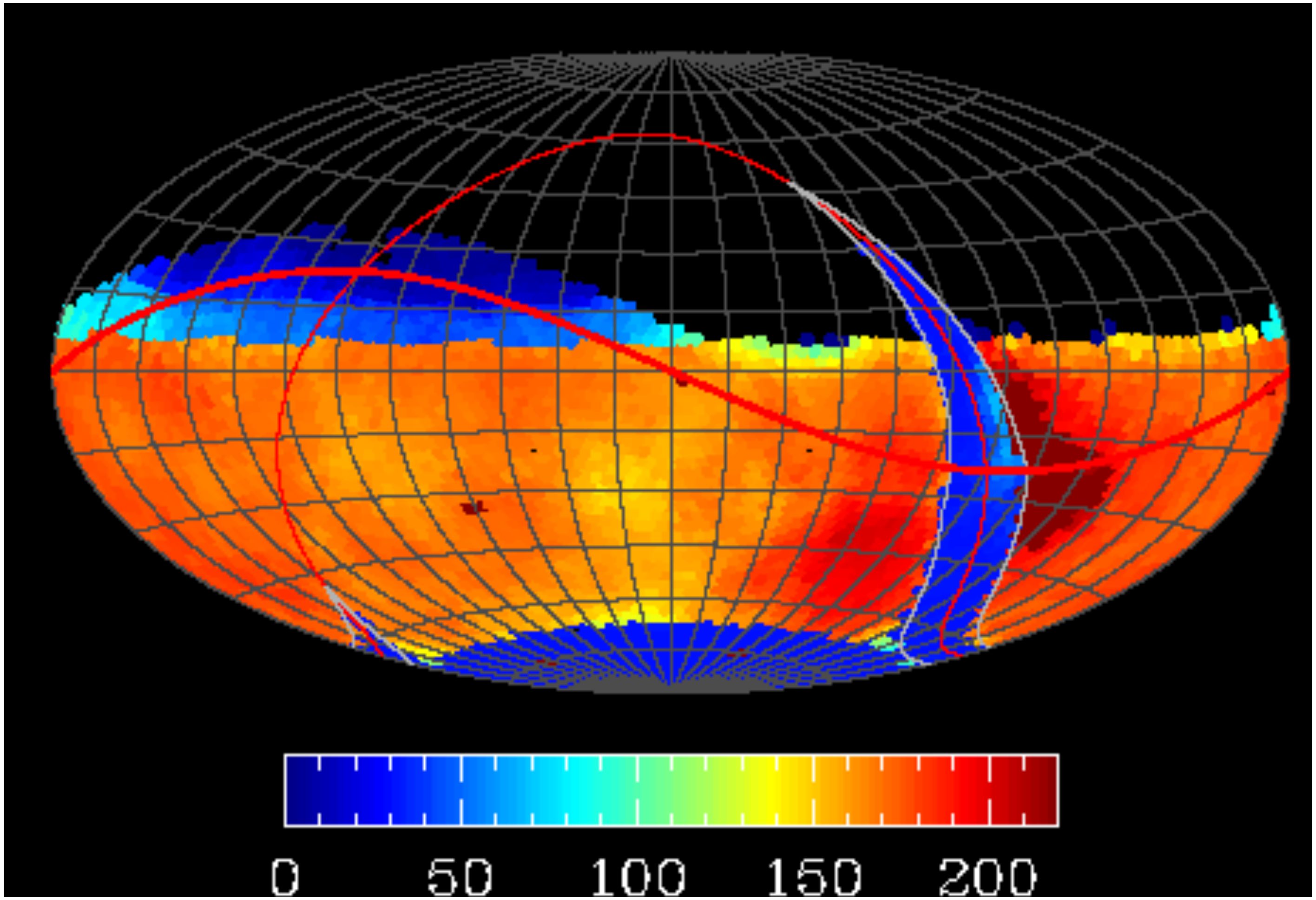
We got NSF approval for construction on August 1. DOE CD-2 review happened last week, and was very successful.

The NSF and DOE will together support about 2/3 of operation costs; the remainder will be contributed by international partners in return for data rights. We're actively talking to 17 countries.

DOE is supporting Dark Energy science. NSF plans to support LSST science through individual investigator grants.

LSST Cadence

A realization of a default cadence to demonstrate that LSST can reach its core goals.



Based on LSST operations simulations

We can do better!

- Current "uniform cadence" aims to cover as much sky as possible in a given night. A "rolling cadence", which observes less of the sky in a given month, will give better sampling of short timescale variability.
- Refinements in dithering will give superior uniformity.
- Ancillary programs (low Galactic latitude, Northern ecliptic, deep drilling fields, etc.) need considerable refinement.
- A process of engaging the community to explore cadence options, and define quantifiable metrics, has begun.
- Do we want to use the same cadence through the entire survey? What about target of opportunity observations?
- Go to full LSST depth in the 2400 deg^2 of WFIRST coverage early in the survey?

LSST Data Products

The philosophy is that "most" LSST science can be done from the output catalogs. The LSST pipelines are currently roughly at the sophistication level of the SDSS pipelines (and will get better).

Data will be released at two "levels":

- **Level 1:** Each visit will be differenced with a reference image; all objects that differ by more than 5 sigma will be released, together with their past history, within 60 seconds. In addition, photometry will be done on each night's coadded data, and asteroid orbits will be calculated.
- **Level 2:** Once a year, all the data taken to date will be coadded and processed self-consistently.

Users will also have the opportunity to run their own codes on LSST platforms ("**Level 3**").

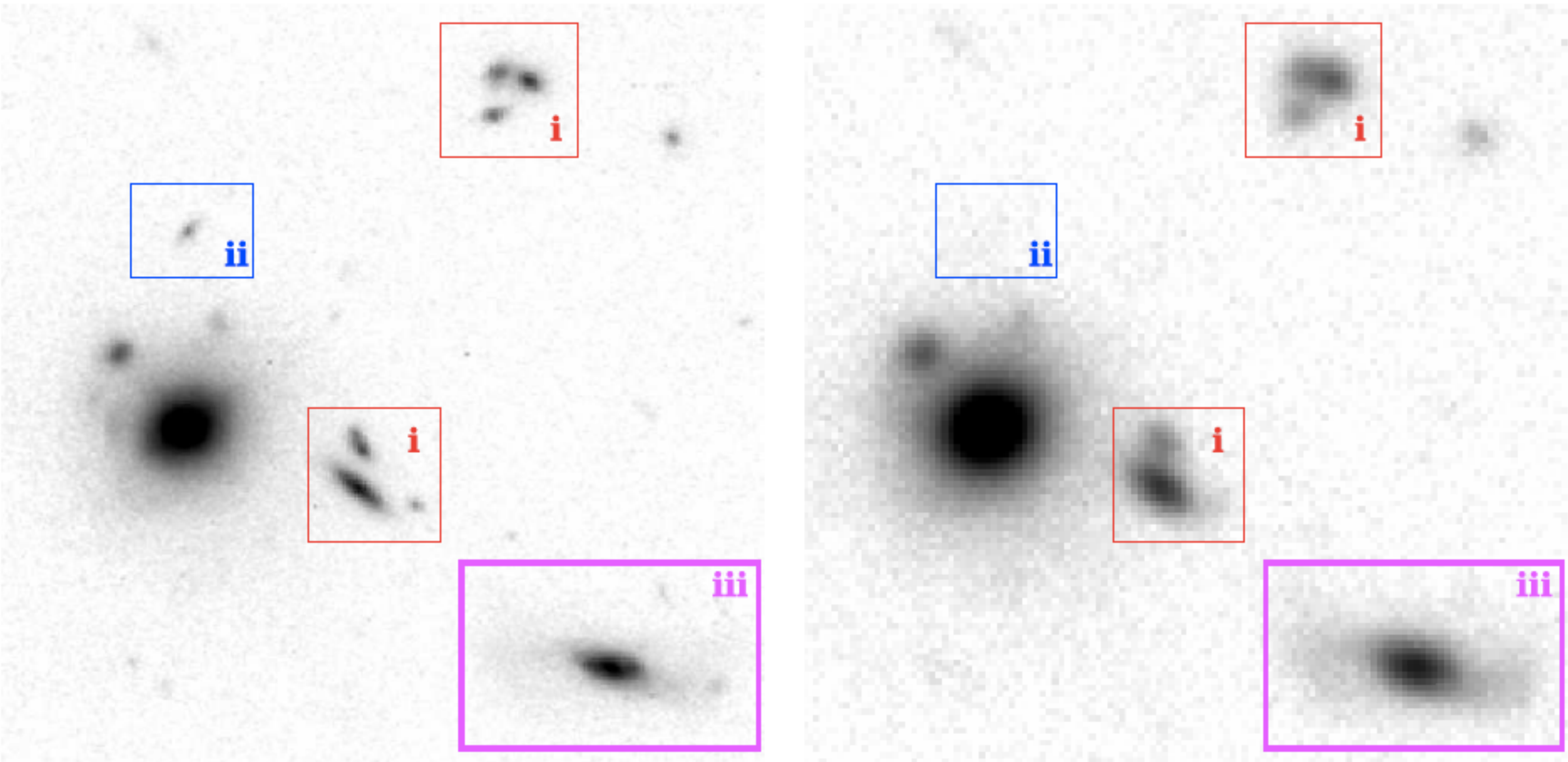
LSST + WFIRST

- Combining the data
- Considering the footprint. Deep fields should overlap!
- Coordinating the cadence. Opportunities for transient, supernova science?

Challenge of Combining LSST and WFIRST Data

- At LSST's full depth, half of galaxies will be blended (i.e., overlapping isophotes).
- The different resolutions of WFIRST and LSST mean that one cannot simply combine the datasets at the catalog level.
- Color gradients and objects with extreme colors will make the comparison between WFIRST and LSST a challenge.

Effects of different resolution, different passbands



(a) Hubble Space Telescope WFC3 $F125$ (125μm) (b) Subaru Hyper Suprime-Cam i band (0.75μm)

(Like WFIRST)

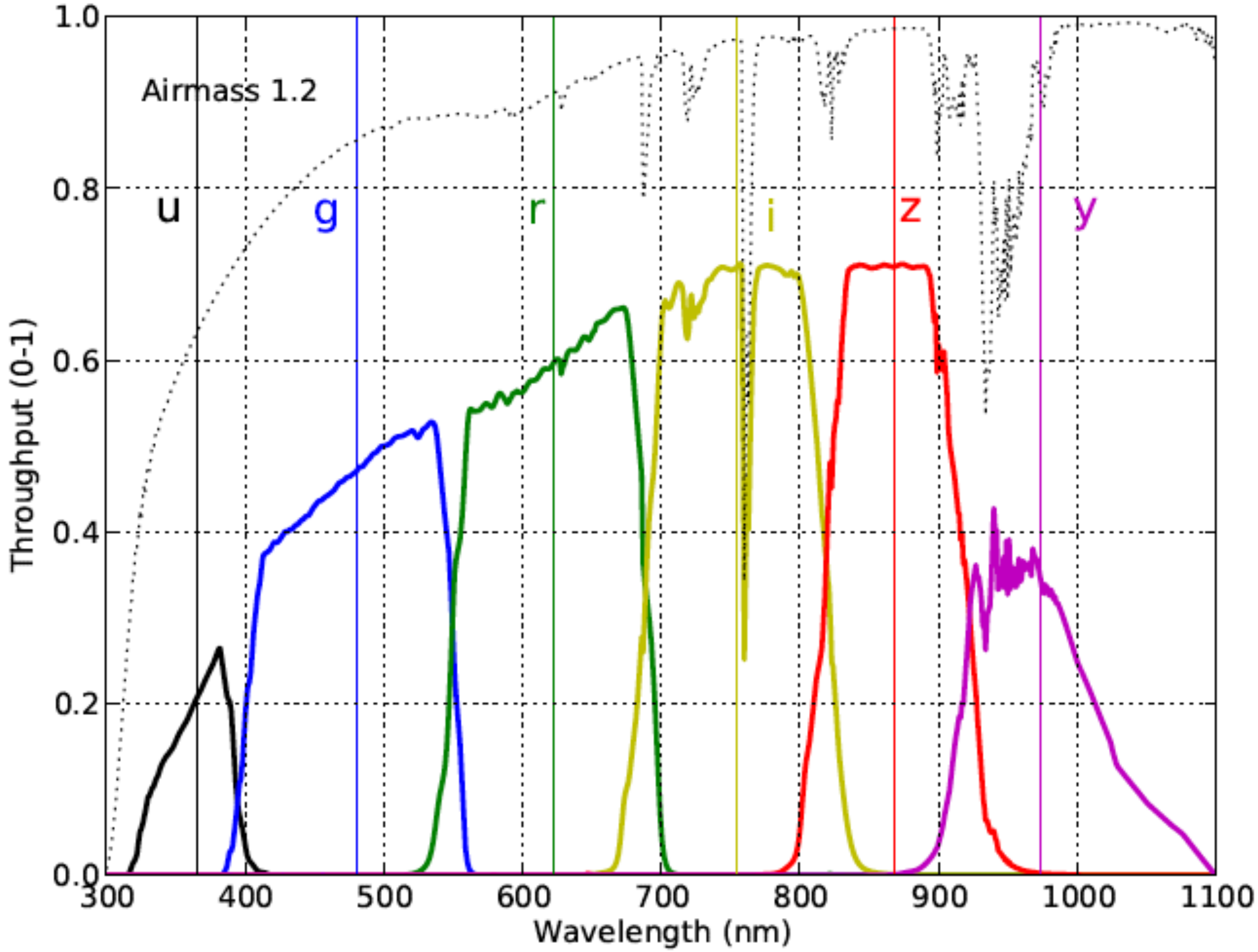
See also Michael Schneider's talk

(Like LSST)

Challenges

- Self-consistent deblends from a common set of peaks
- Self-consistent photometry of extended objects
- Different PSF between WFIRST and LSST
- Color gradients within galaxies
- Galaxies don’t always follow the simple morphological models we use for them!
- Joint forward modeling of LSST and WFIRST data together?

LSST + WFIRST: 9-band photometry!



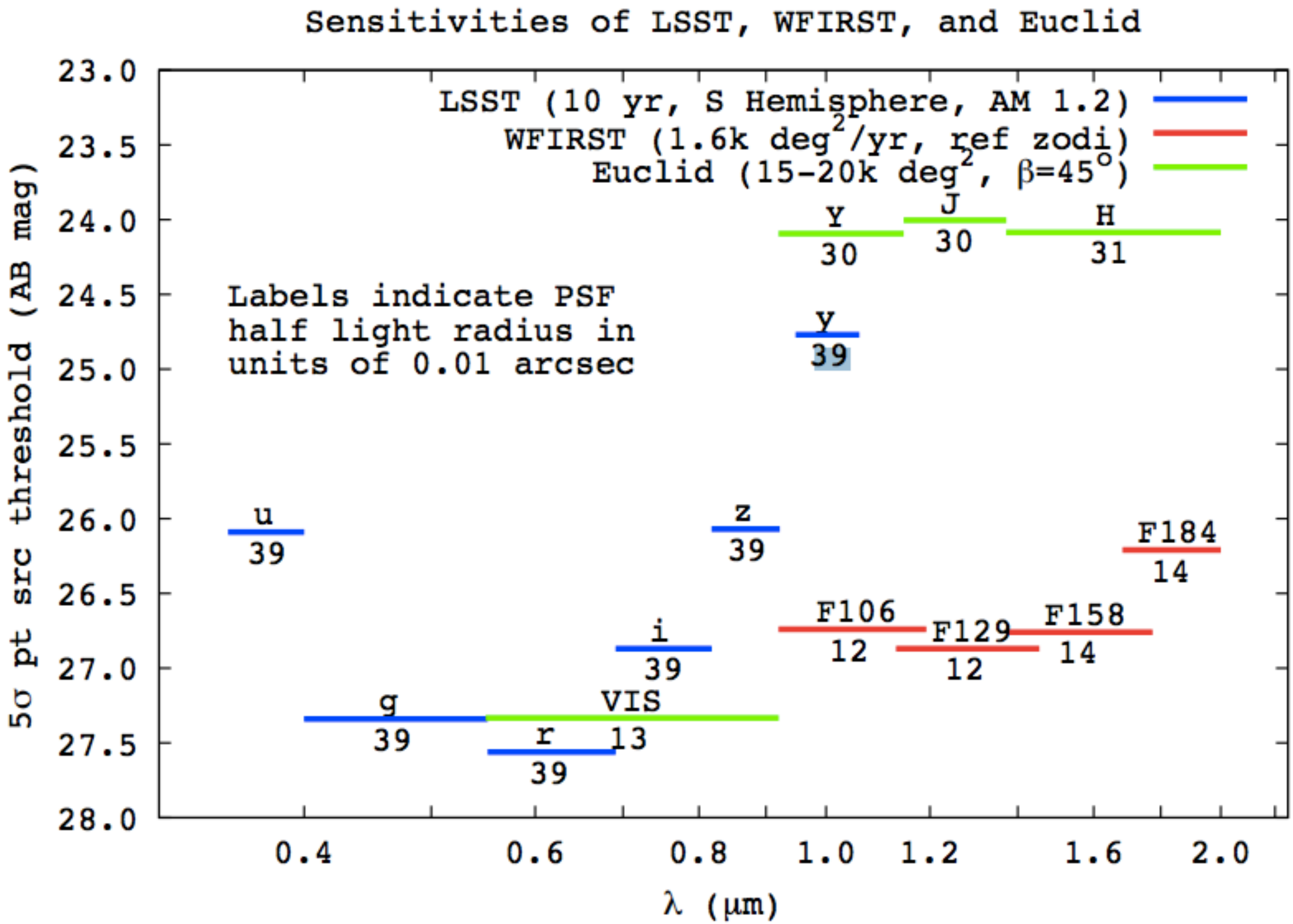
A Filter System similar to SDSS (+ y band)

Broad wavelength coverage

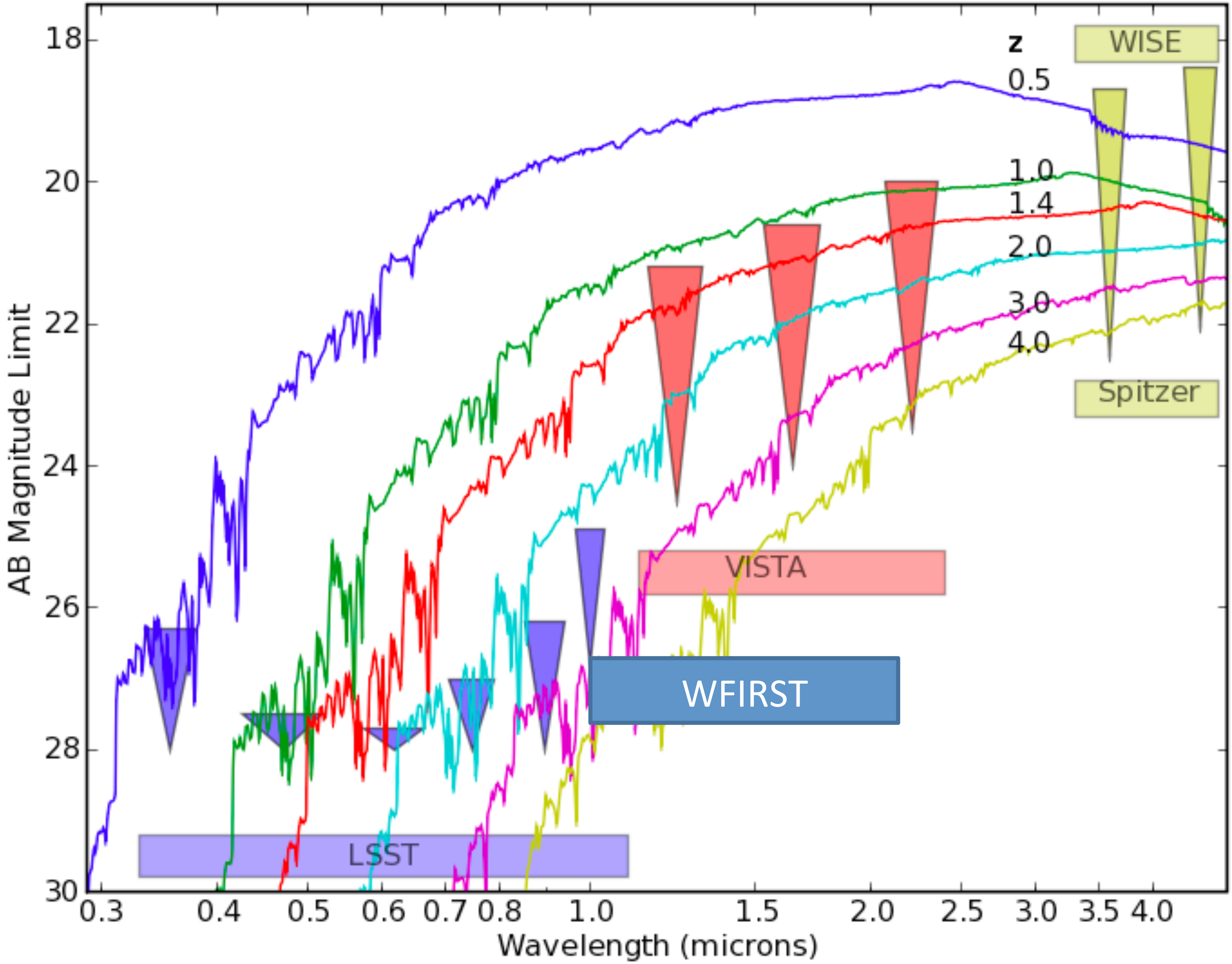
- 9-band photometry (0.3-1.8μm) will allow exquisite photometric redshifts of galaxies, star-galaxy separation, stellar masses, and star-formation histories. WFIRST spectroscopic survey will be a powerful calibrator of photo-zs.
- 9-band precise photometry of stars will constrain surface temperatures, metallicities, and gravities to the outer halo (especially important for RGB, AGB stars).
- A beautiful dataset to look for extremely cool stars/brown dwarfs, high-redshift galaxies and quasars.

LSST + WFIRST is like the CANDELS survey over 10,000 times more area!

- Rare objects
- Environmental effects
- MW structure



Sensitivities of LSST, WFIRST, and Euclid
LSST (10 yr, S Hemisphere, AM 1.2)
WFIRST (1.6k deg²/yr, ref zodi)
Euclid (15-20k deg², β=45°)
Labels indicate PSF half light radius in units of 0.01 arcsec
5σ pt src threshold (AB mag)
λ (μm)
23.0
23.5
24.0
24.5
25.0
25.5
26.0
26.5
27.0
27.5
28.0
0.4
0.6
0.8
1.0
1.2
1.6
2.0
Y 30
J 30
H 31
y 39
u 39
z 39
F184 14
F106 12
F129 12
F158 14
i 39
g 39
VIS 13
r 39



AB Magnitude Limit
18
20
22
24
26
28
30
0.3
0.4
0.5
0.6
0.7
0.8
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Wavelength (microns)
z
0.5
1.0
1.4
2.0
3.0
4.0
WISE
Spitzer
VISTA
WFIRST
LSST

Measurements of Galaxy Shapes

- Weak lensing cosmic shear is a powerful constraint on cosmological models, especially at large scales. The limitation is always systematics.
- Systematics will be quite different for LSST and WFIRST. LSST is affected by atmosphere, but will have hundreds of visits per field. WFIRST is affected by finite pixel size. WFIRST will do better star-galaxy separation. Both will be affected by detector effects (CTE, etc).
- Synergy of WFIRST spectroscopic survey and weak lensing is powerful for cosmology.

Time-Variable Phenomenae

- LSST will take ~1700 exposures at each pointing.
- Perhaps 40 fields will be chosen as "Deep Drilling Fields", with much faster cadence: studies of high-z supernovae, faint Kuiper-belt objects, the faintest galaxies, unusual transients, etc.
- Coordinating the LSST Deep Drilling fields with the SN fields of WFIRST at South Ecliptic Pole (3 deg^2) makes a lot of sense. WFIRST will go to 29 AB; this will be a challenge to match with LSST, but is worth considering for one or two pointings.

Document prepared by Bhuvnesh Jain and David Spergel

The Sum of the Whole is Greater than the Parts: Optimizing the Joint Science Return from LSST, Euclid and WFIRST

November 14, 2014

Conclusions

- The science opportunities offered by the joint LSST and WFIRST WFI data are manifold.
- Realizing these opportunities in full will require:
  - Joint processing of LSST and WFIRST images
  - Prioritization of WFIRST WFI footprint in LSST cadence
  - Consideration of opportunities for synergy in microlensing survey as well.
  - Coordination of Deep Fields
  - Discussion of mutual cadence
  - Coordination of science teams, and mechanisms to support joint work.