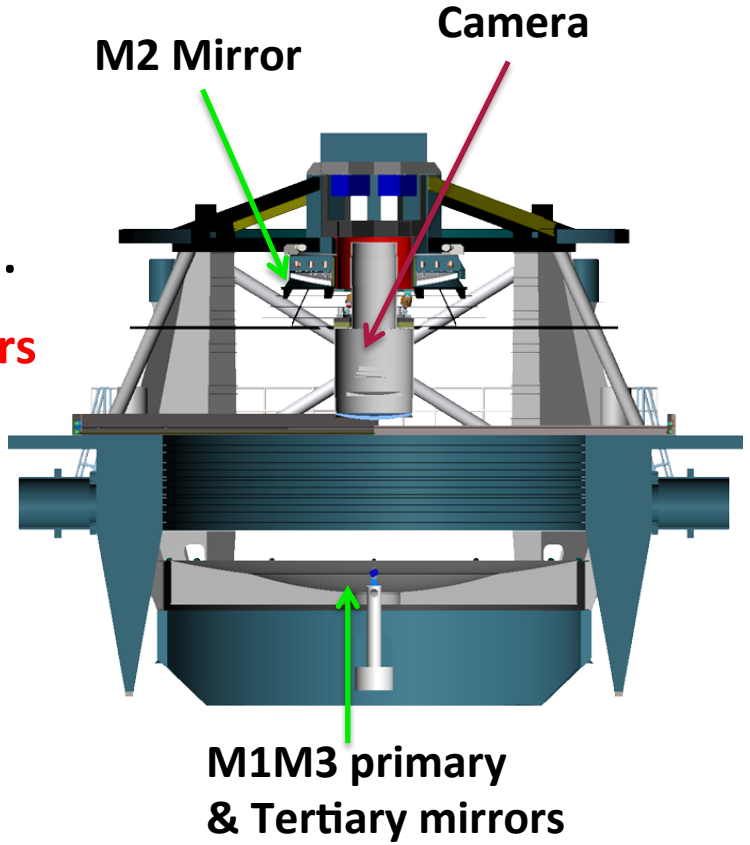

Marc Moniez
LAL-IN2P3
ESO Rainbows2015
5/10/2015
LSST-Project
Large Synoptic Survey Telescope

LSST in a few figures

- Optical telescope 8.4 m diameter
- Wide-field camera : 3.5°, 3.2 Gpixels
- 6 wide-band filters u g r i z y
- Galaxies: r_{lim}=27.5 after 10 year coadd.
- Final catalogue: 10^{10} galaxies, 10^{10} stars
- Final database 15 PetaBytes
- Weak lensing up to z ~ 3
- 2,500,000 SNIa up to z ~ 1
- BAO: 3.10^9 galaxies up to z ~ 3
- Transients with alerts (2.10^6/night)
- See LSST science-book in http://www.lsst.org

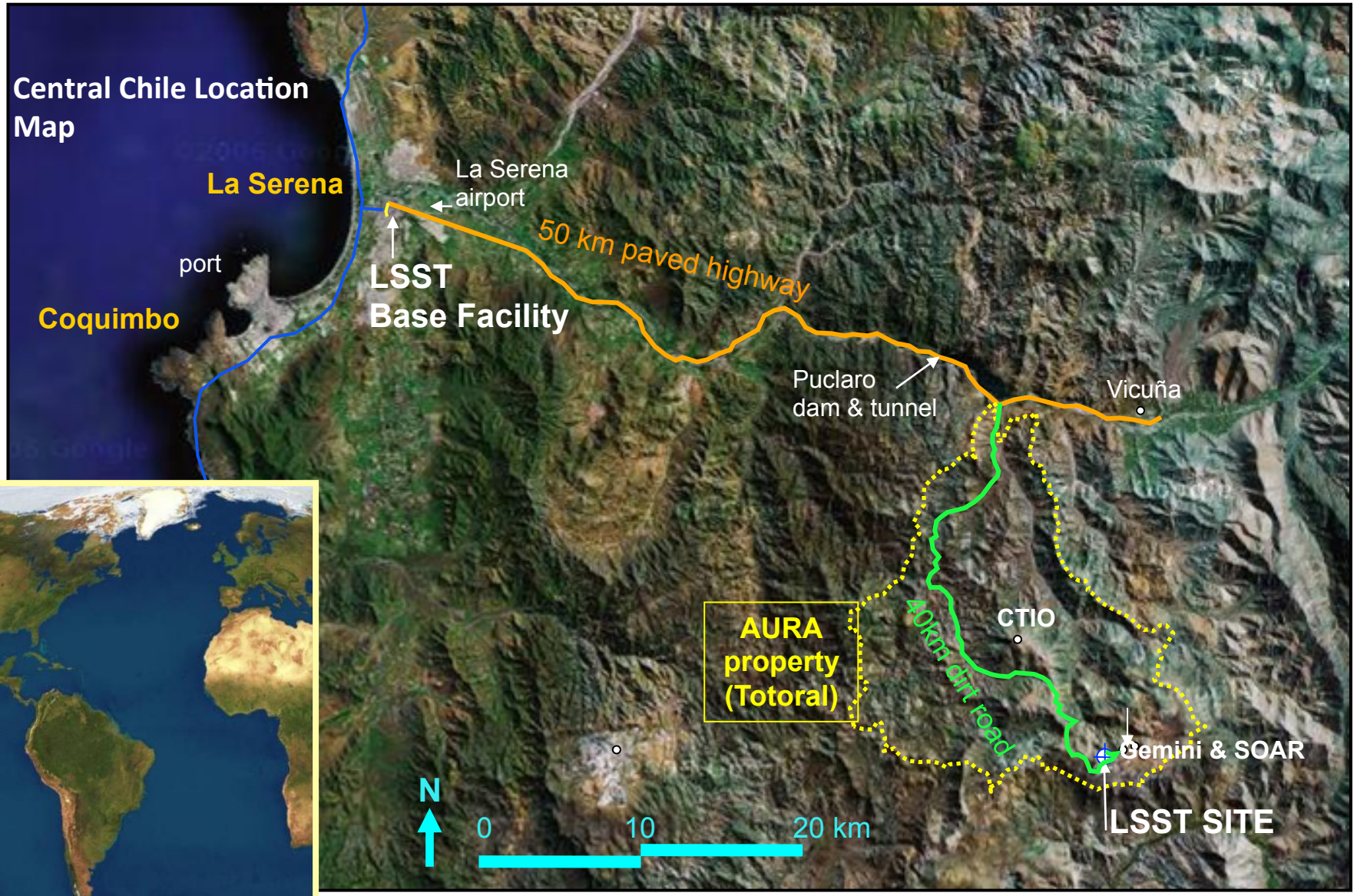


http://www.lsst.org/

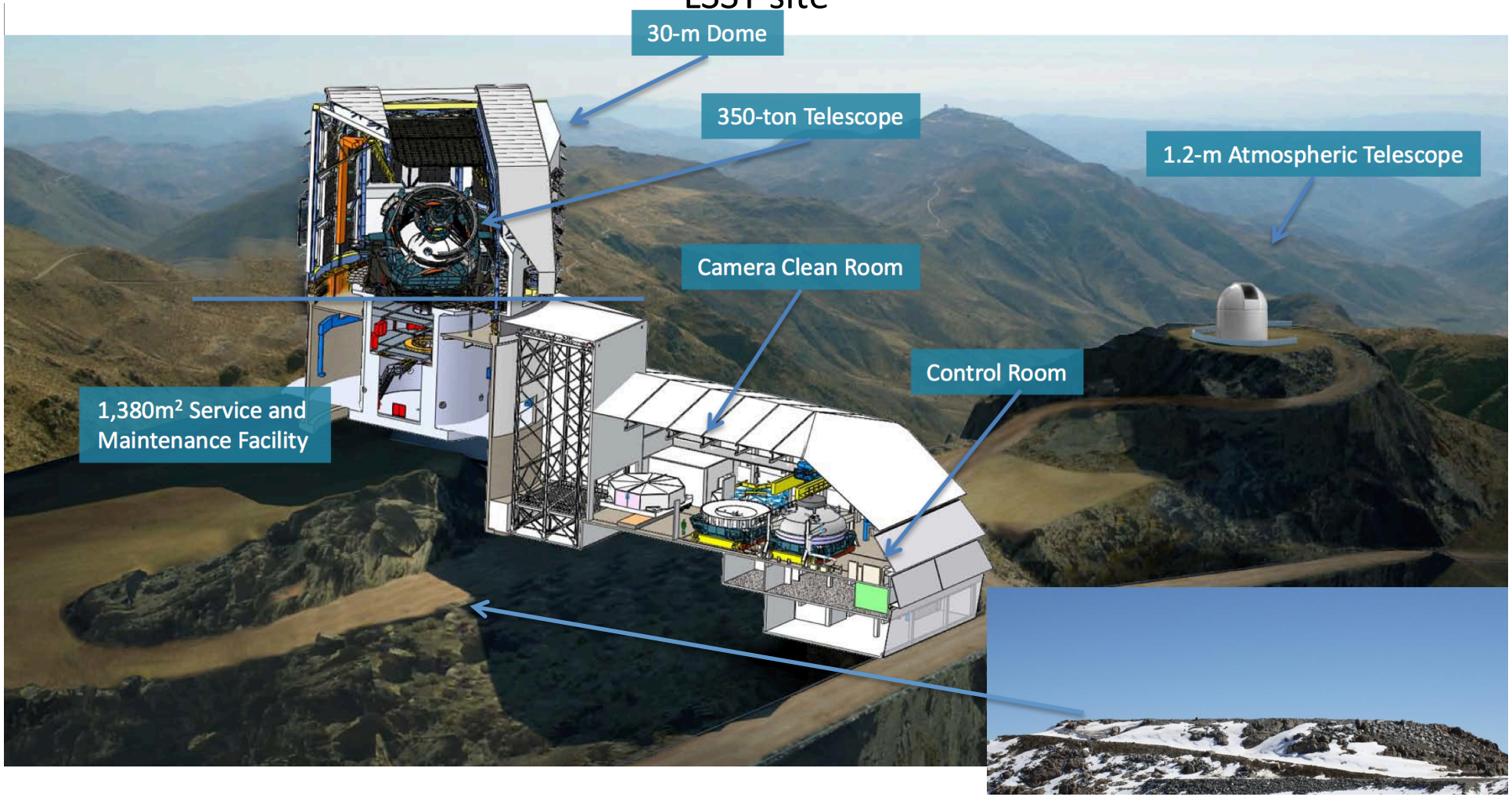
Summary of High Level Science Requirements

Survey Property	Performance
Main Survey Area / duration	18000 sq. deg. / 10 years
Total visits per sky patch	825 (1 visit per ~4 nights)
Filter set	6 filters (ugrizy) from 320-1050nm
Single visit	2 x(15 second exposures + 1s shutter + 2s readout)
Single Visit Limiting Magnitude	u = 23.9; g = 25.0; r = 24.7; I = 24.0; z = 23.3; y = 22.1
10 year coadd. Limiting Magnitude	u = 26.1; g = 27.4; r = 27.5; I = 26.8; z = 26.1; y = 24.9
Photometric calibration	< 5mmag repeatability & colors, <10mmag absolute
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	60 sec after last visit exposure
Data release	Full reprocessing of survey data annually

LSST Will be Sited in Central Chile (cerro Pachon)

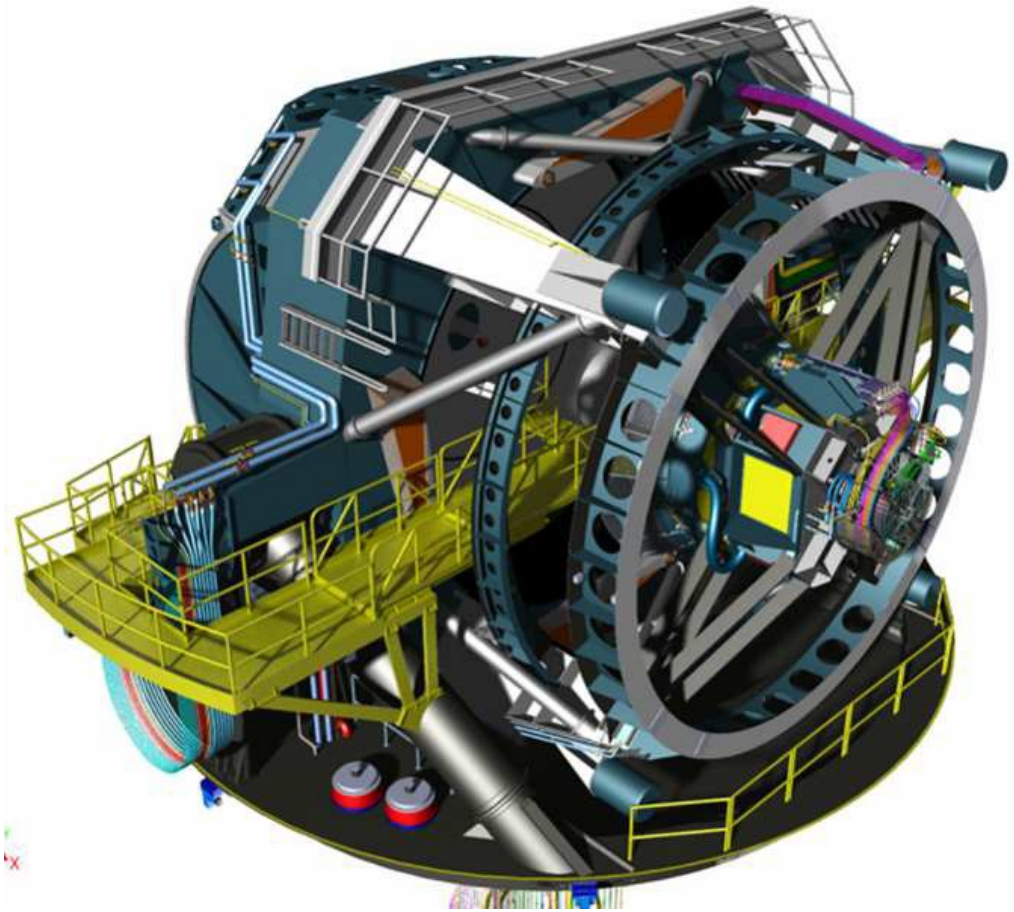


LSST site



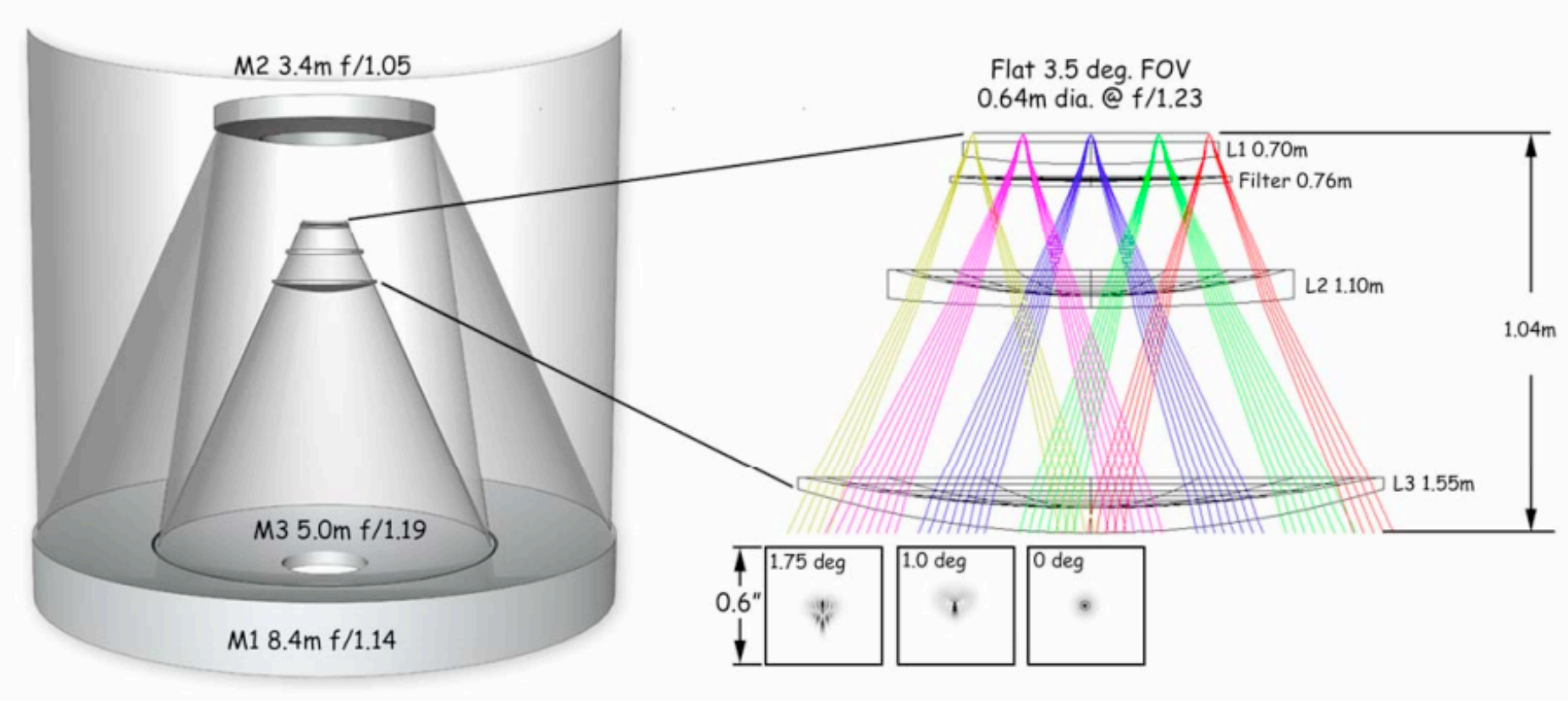
After ~4,000 kg of explosives and ~12,500 m^3 of rock removal, Stage I of the El Peñón summit leveling is completed. Building construction is now underway .

Telescope Mount Enables Fast Slew and Settle

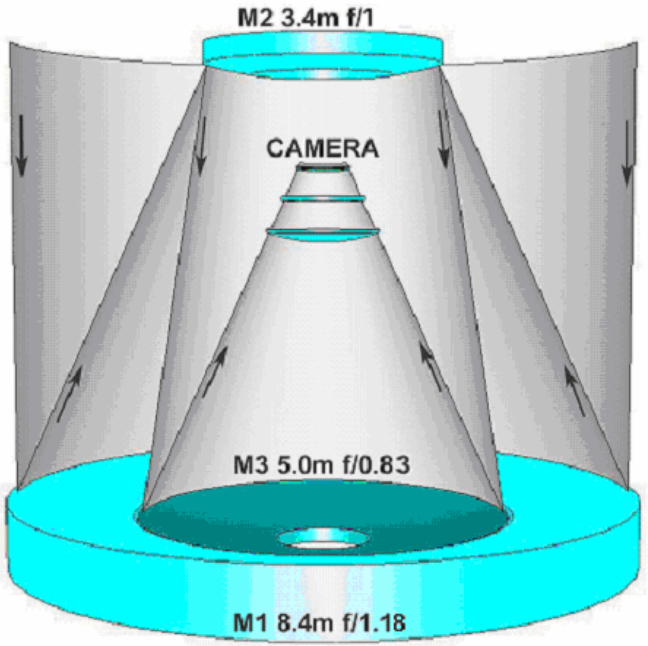


- **Points to new positions in the sky every 39 seconds**
- **Tracks during exposures and slews 3.5° to adjacent fields in ~ 4 seconds**

Modified Paul-Baker Optical Design

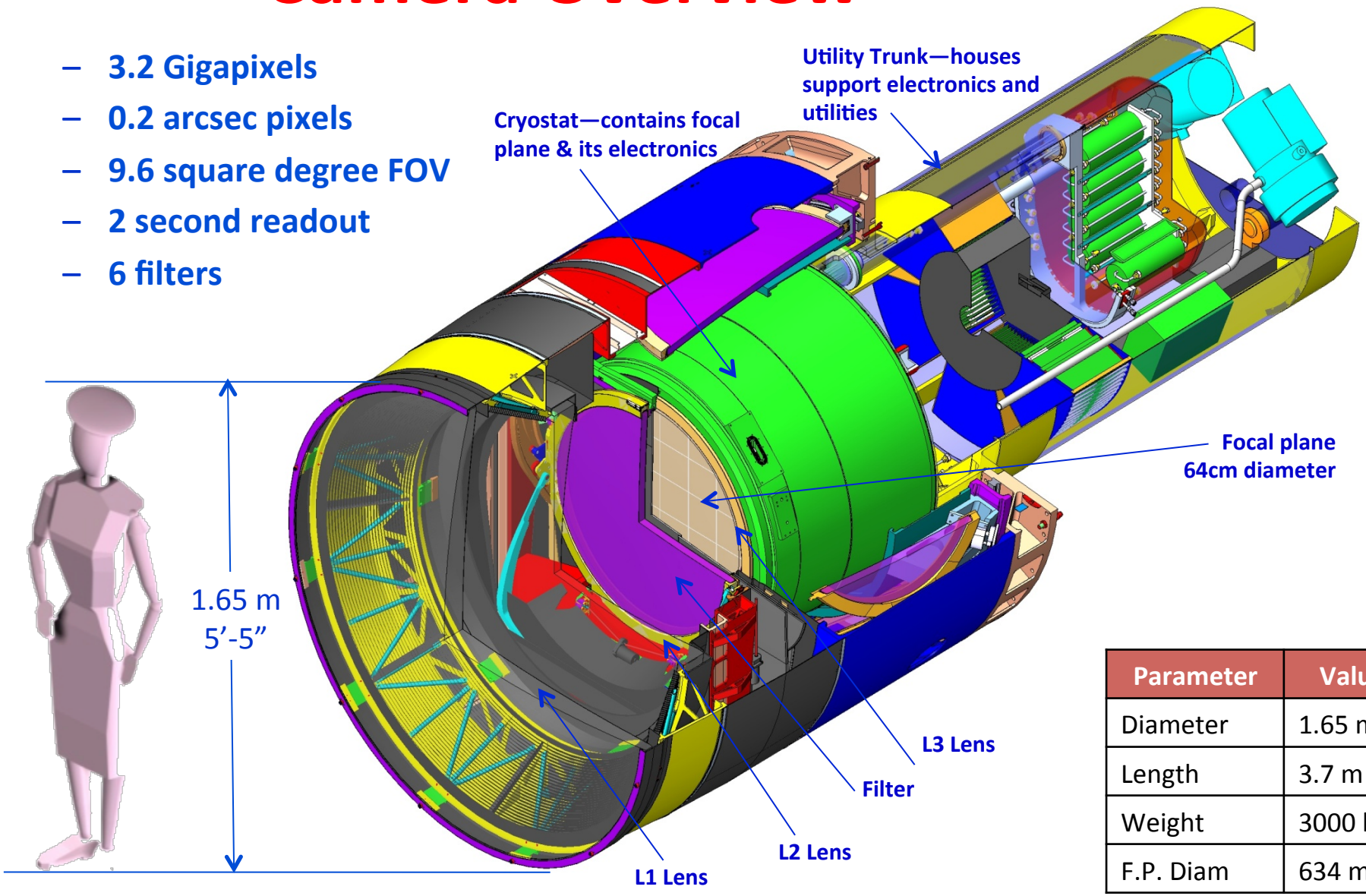


M1M3 Fabrication



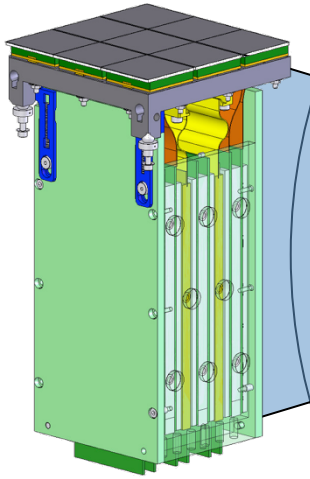
Camera Overview

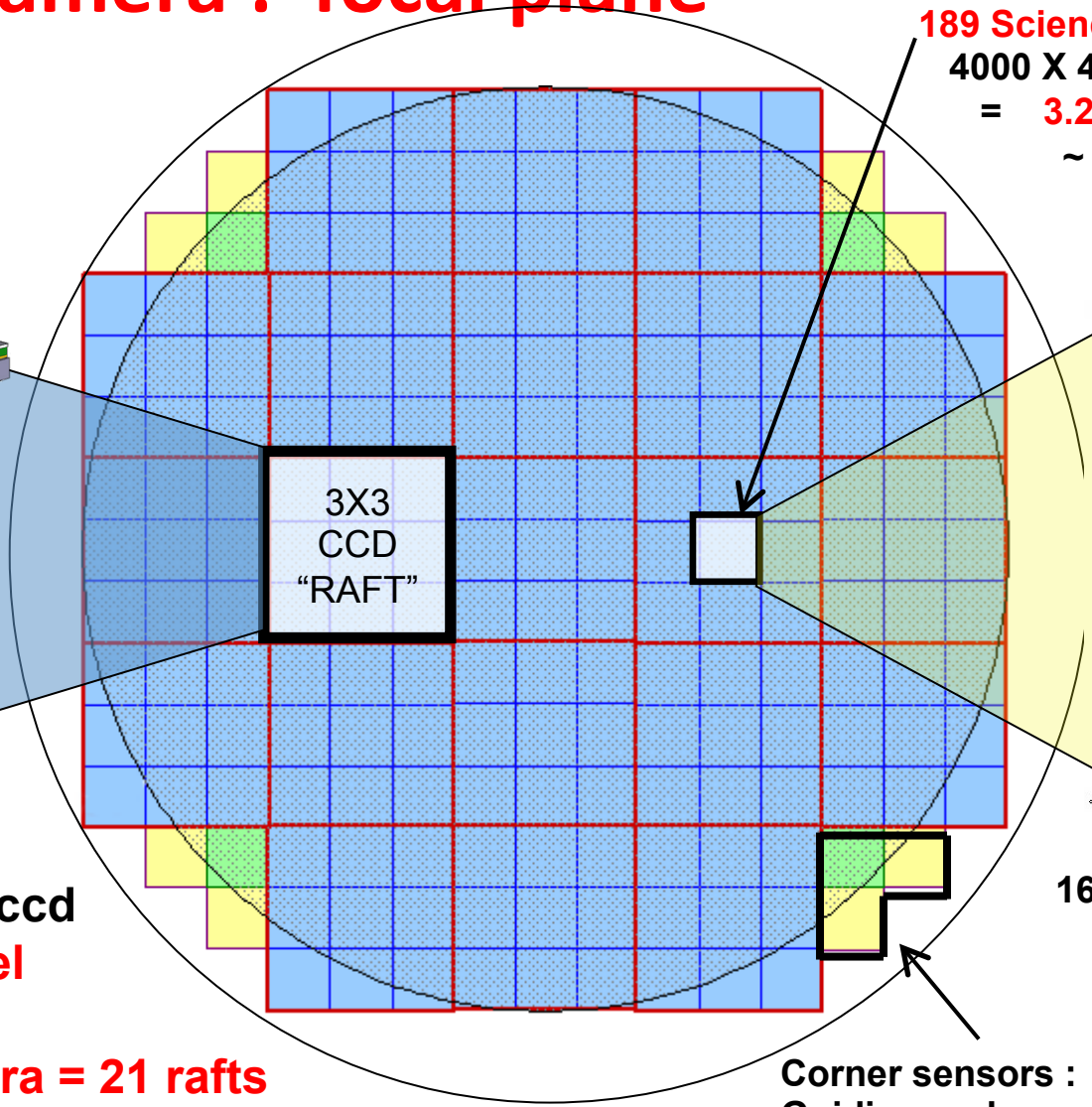
- 3.2 Gigapixels
- 0.2 arcsec pixels
- 9.6 square degree FOV
- 2 second readout
- 6 filters

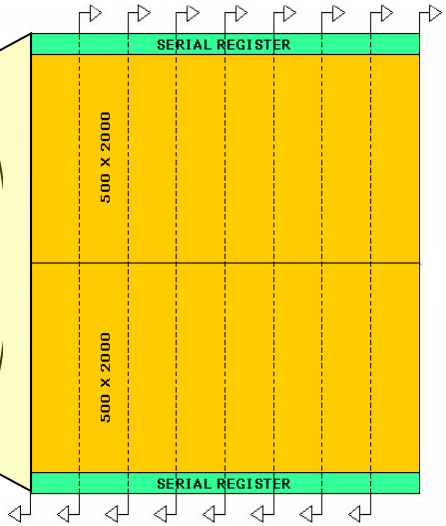


Parameter	Value
Diameter	1.65 m
Length	3.7 m
Weight	3000 kg
F.P. Diam	634 mm

LSST camera : focal plane







189 Science CCD 100μ deep depleted
4000 X 4000 10μm pixels
= 3.2 x10^{9}pixels
~ 9.6 Deg ^{2}

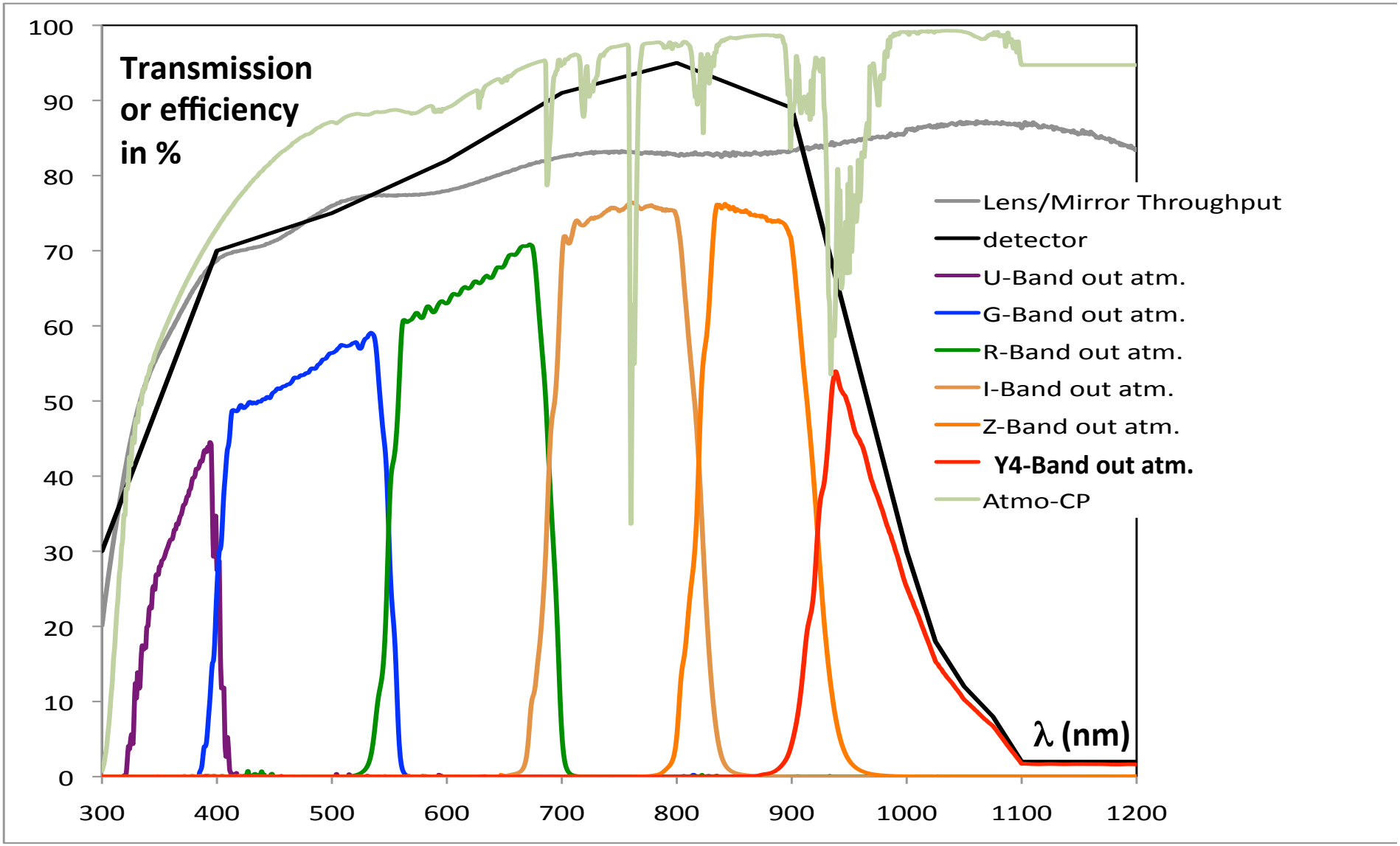
Raft :
Matrix of 9 ccd
= 144 Mpixel

LSST camera = 21 rafts

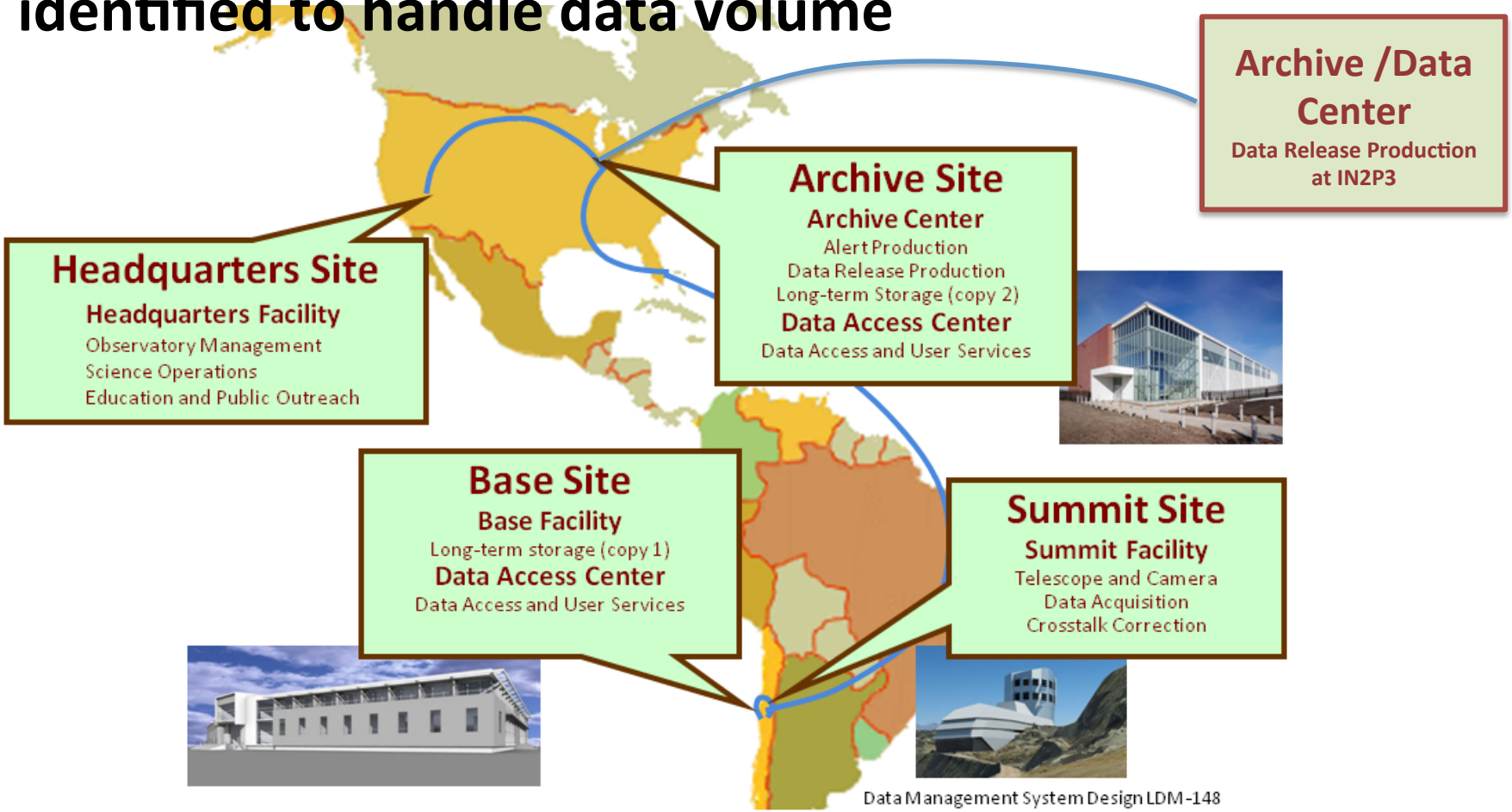
Segmented CCD
16 segments of 1M pixels
Highly parallelised
readout in 2s

Corner sensors :
Guiding and wave-front analysis

System throughput



Cyber infrastructure is defined and capacity has been identified to handle data volume



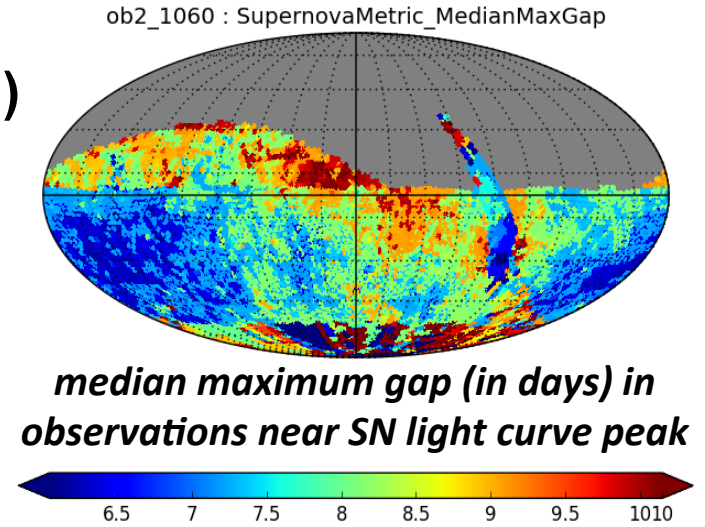
Data Management System Design LDM-148

- Summit-Base network will be installed by the project.
- Working with NSF funded network consortiums on capacity.
- International protected network identified and quoted (upgraded.)

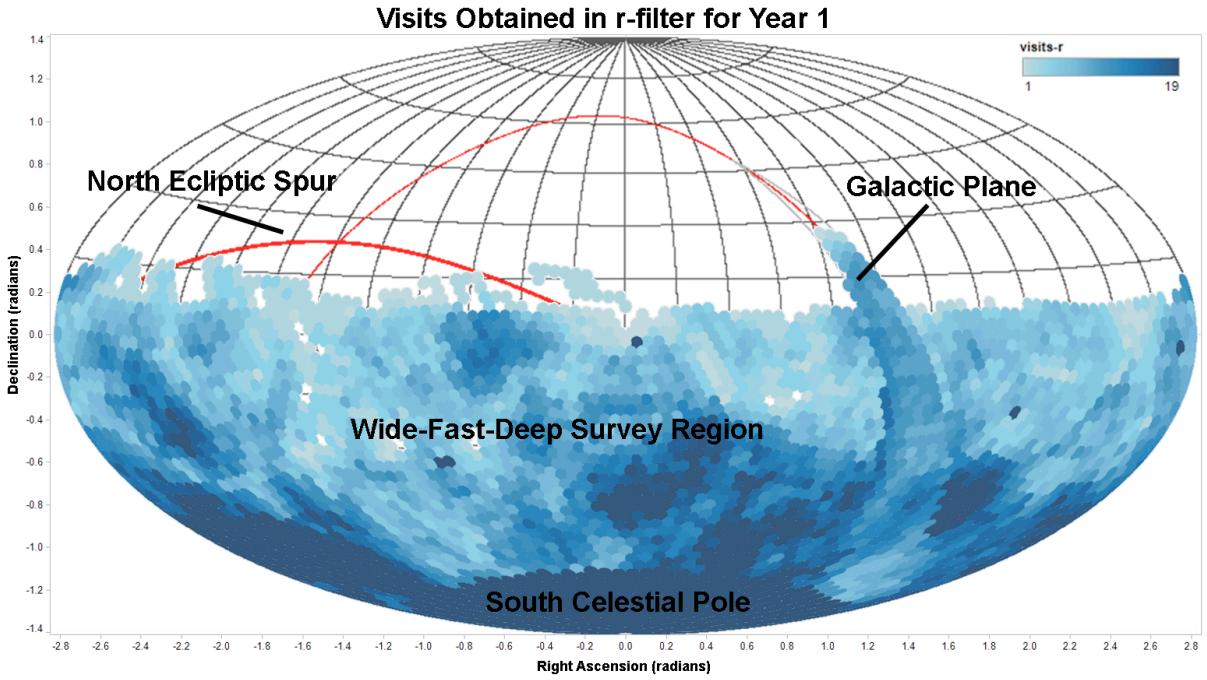
LSST main survey deliverable

« 4D » object mapping (stars, galaxies...) of 18,000 sq. deg. to an uniform depth

- **(α,δ) positions on the sky**
- **Redshifts z**
- **Time variations**
  - **-> SN, lensing, AGN…**



median maximum gap (in days) in observations near SN light curve peak

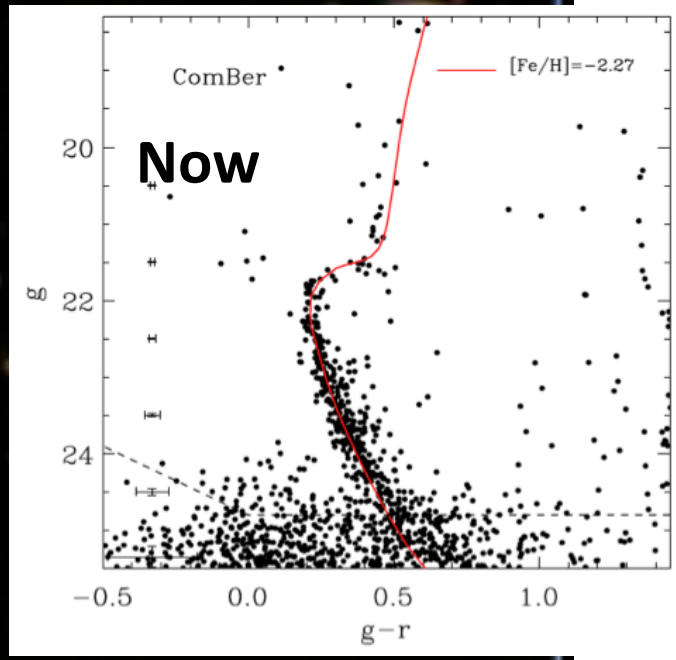


Other survey modes

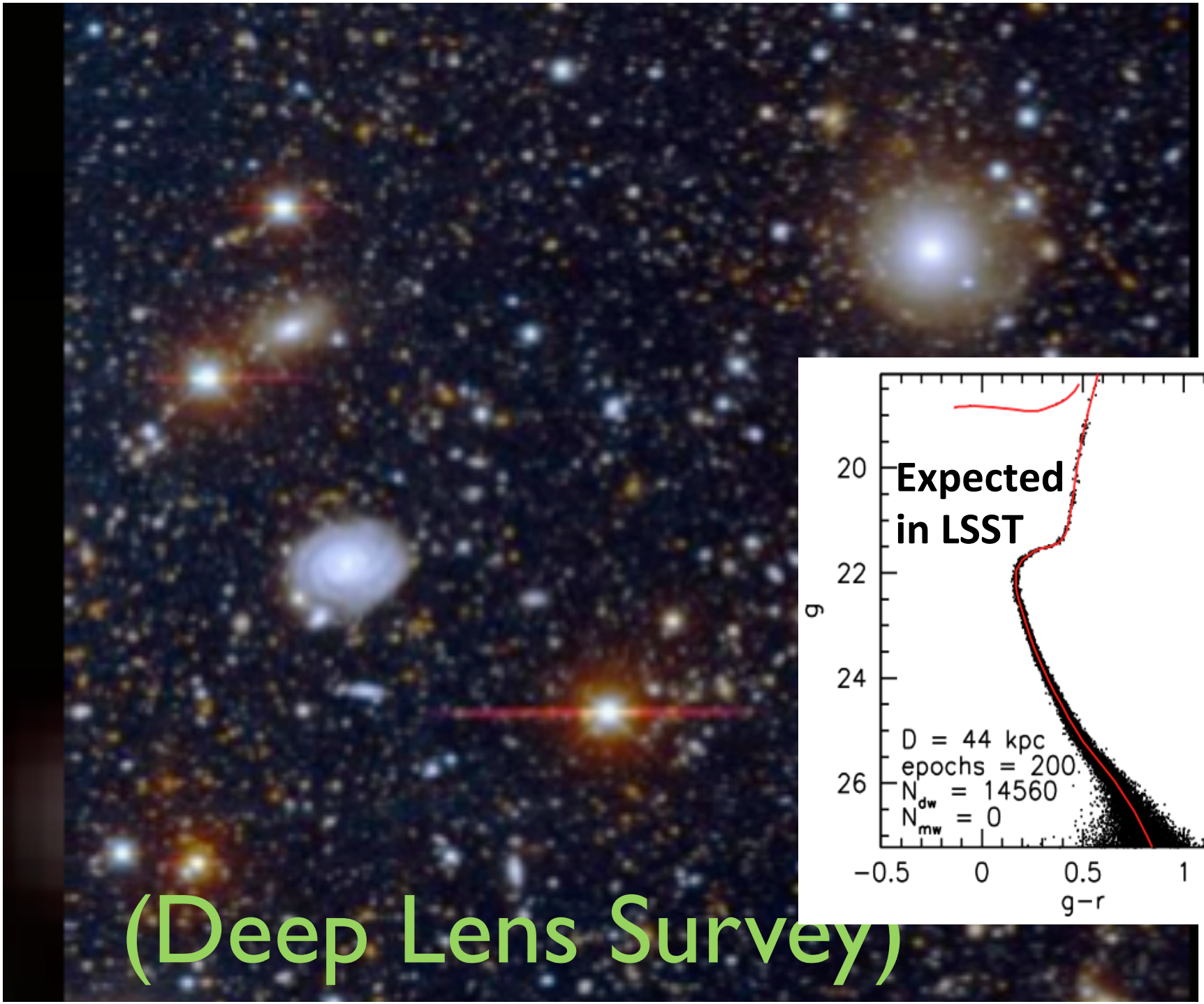
~10% of time ~1h/night

Very Deep + fast time domain + special zones (ecliptic, galactic plane, Magellanic clouds)

3x3 arcmin, gri



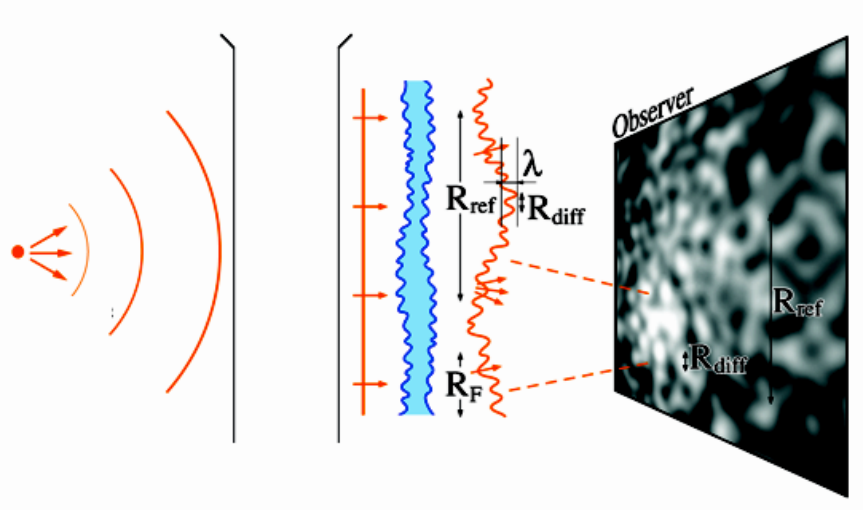
SDSS

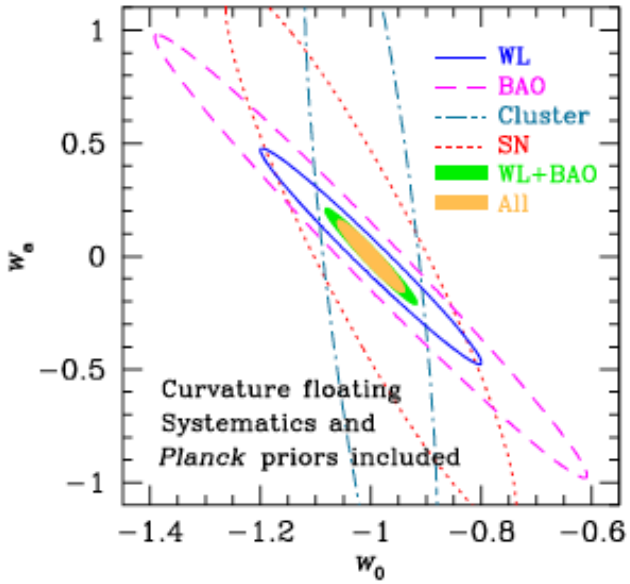


(Deep Lens Survey)

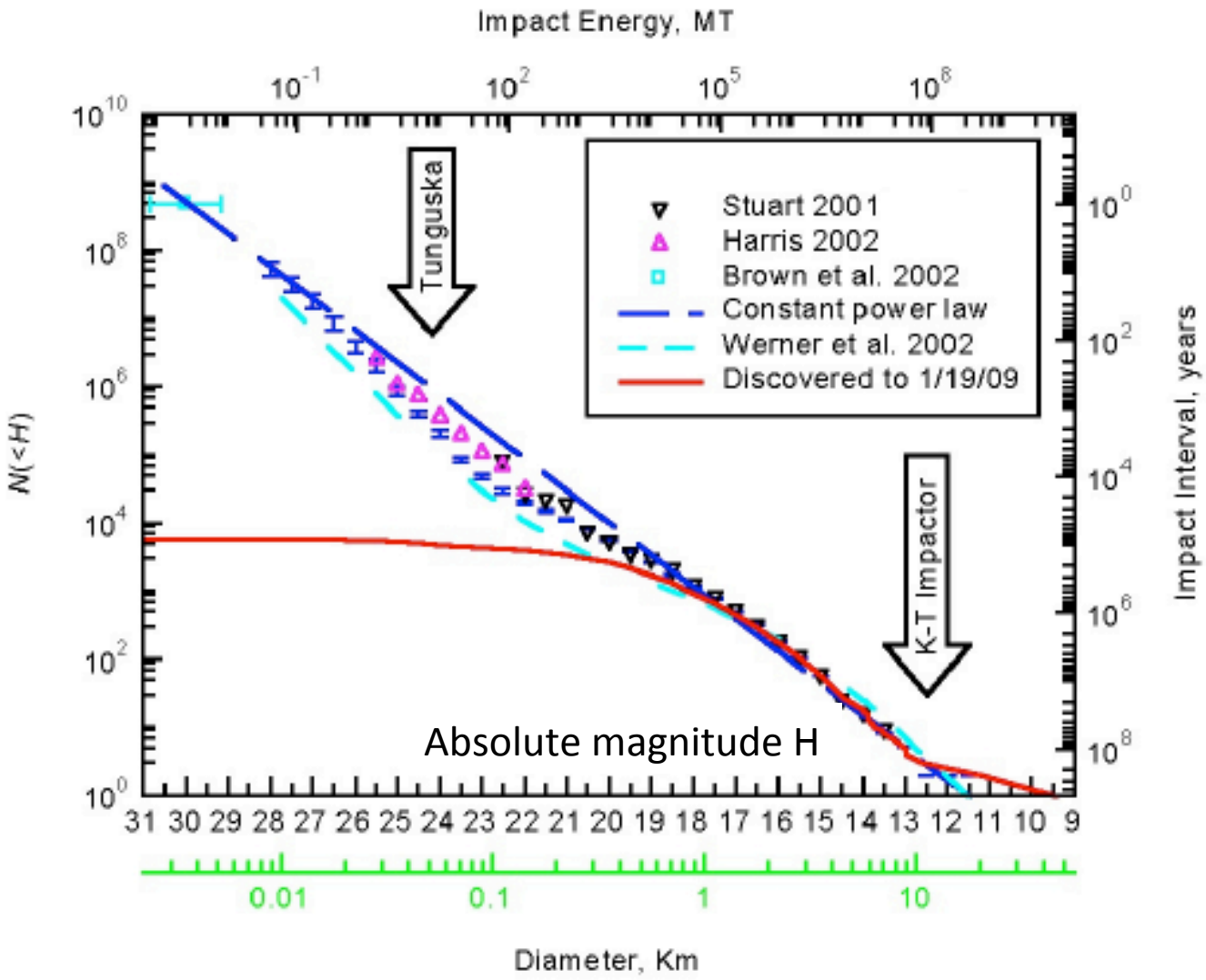
The Science Enabled by LSST
(see science book: arXiv:0912.0201)

- **Time domain science**
  - Nova, supernova, GRBs
  - Source characterization
  - Gravitational microlensing
  - Interstellar scintillation
- **Finding moving sources**
  - Asteroids and comets
  - Proper motions of stars
- **Mapping the Milky Way**
  - Tidal streams
  - Galactic structure
- **Dark energy and dark matter**
  - Gravitational lensing
  - Supernovae studies
  - Large scale structures (incl. BAO)
  - Slight distortion in shape
  - -> Trace the nature of dark energy





The "Threat" from "Earth killers"



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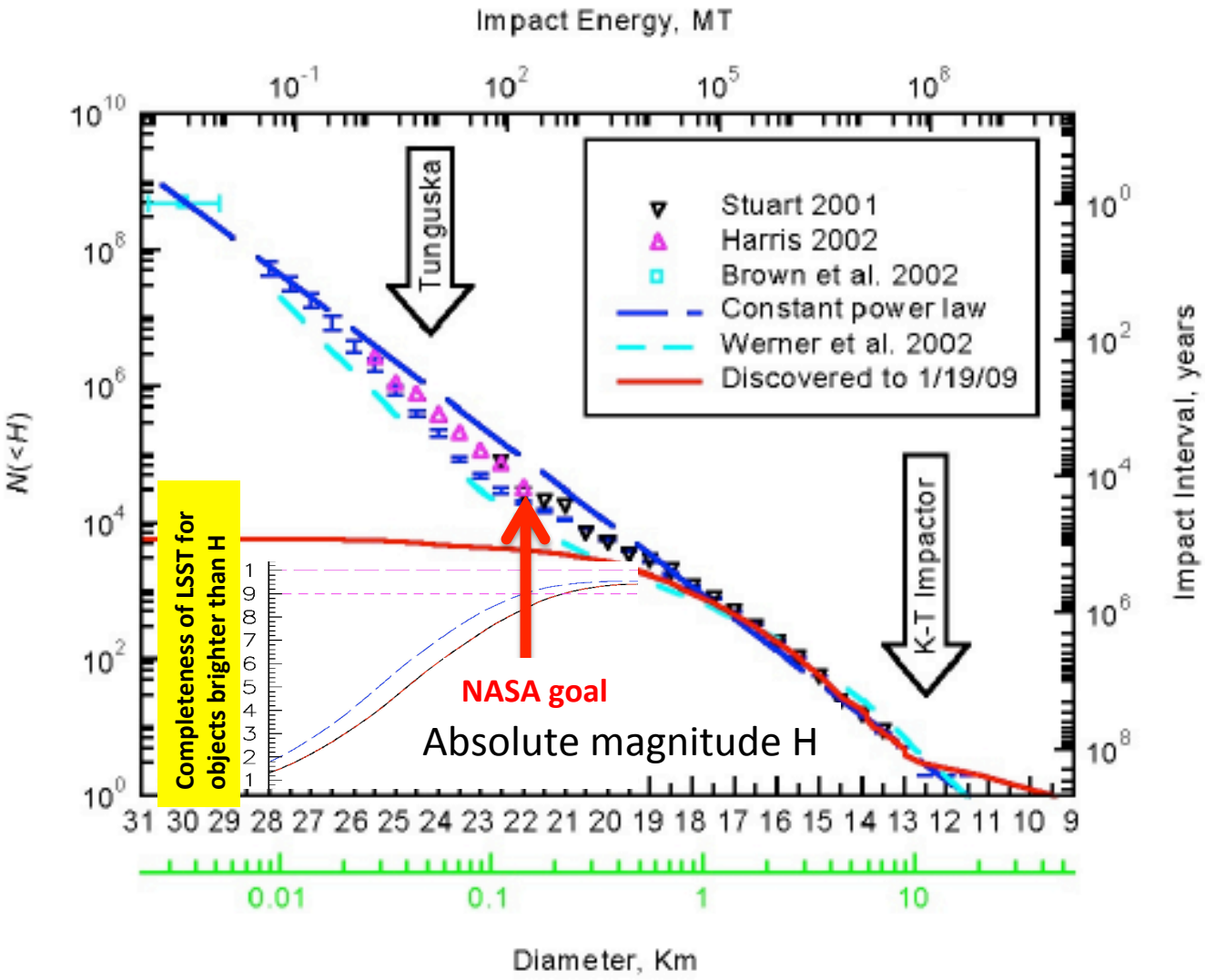
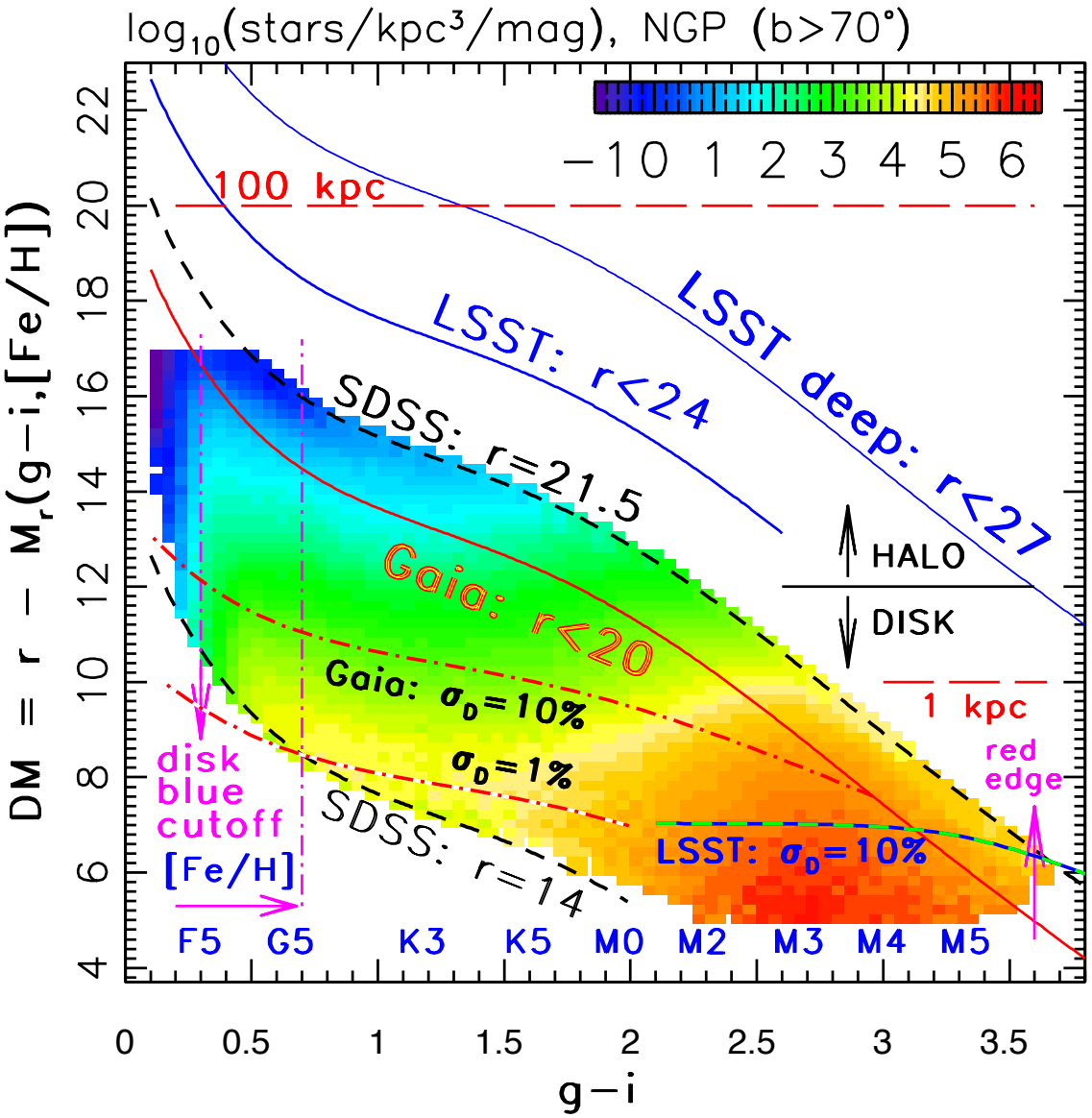


Volume number density of stars



Number density of ~2.8x10^6 SDSS stars with 14 < r < 21.5 and b > 70◦ in the ***(distance modulus, g–i)*** diagram

- Mag. limits for Gaia (r < 20)
- Mag. limits for LSST's single epoch data (r < 24, 10 σ)
- Mag. limits for LSST's stacked data (r < 27, 10 σ)
- Dist. limits for obtaining 10% accurate parallaxes with LSST
- limits for obtaining 1% and 10% parallaxes with Gaia's

LSST will detect
~ 4 billion stars with r< 24.5
and 10 billion stars with r< 27.8

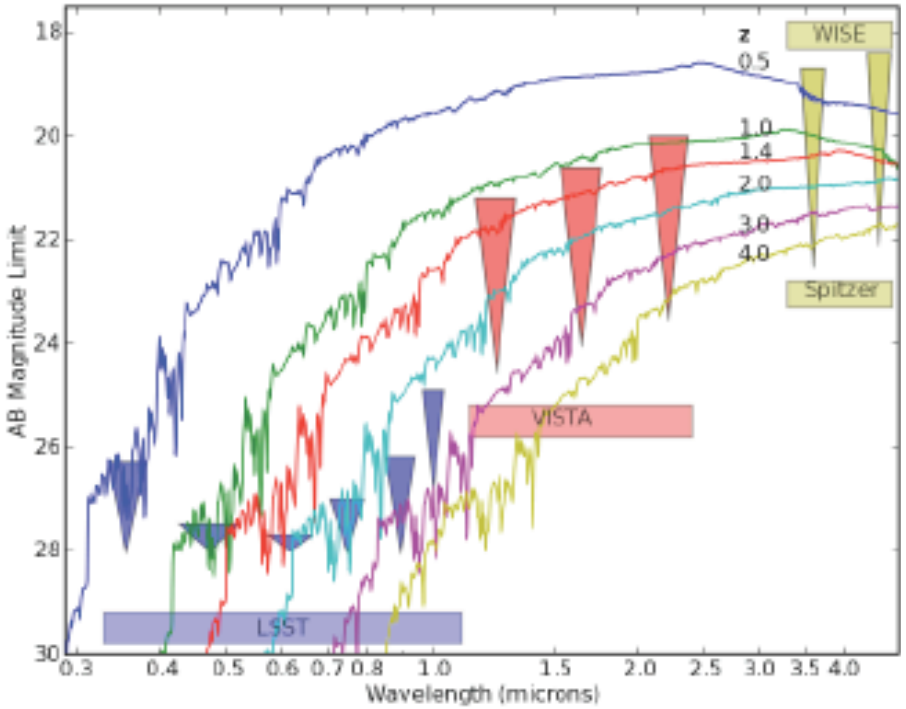
Galaxies

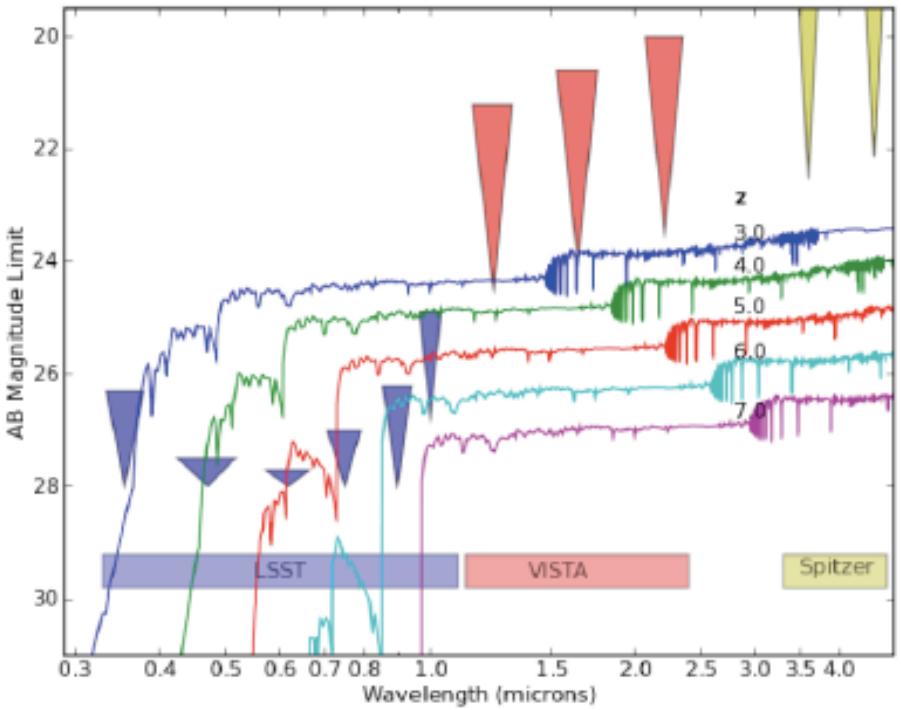
- LSST will be a unique tool for studies of galaxy formation and galaxy properties
- Probes a Co-Moving Volume ~2 Orders of Magnitude Larger than Current or Near-Future Surveys
- The survey will reach up to **50 galaxies / arcmin^2**
- Database will include photometry for **10^{10} galaxies** from Local Group to z > 6
- LSST will have 6-band photometry for 4 x 10^9 galaxies.

How LSST survey will contribute to Galaxies Studies

- Constrain both the bright and faint end of the Luminosity Function
  - With great statistics, over wide redshifts
- Understanding low-mass galaxies
  - Destruction mechanisms
  - Do gas-poor dwarfs exist in low-density environments?
- Quantifying Galaxy interactions
  - Merger rates, tidal destruction
- Detailed mapping of galaxy properties vs. environment

The Expected Sensitivity Leads to Near Complete Samples Out to High Redshifts





Evolving L* Red Sequence Galaxy

Full survey

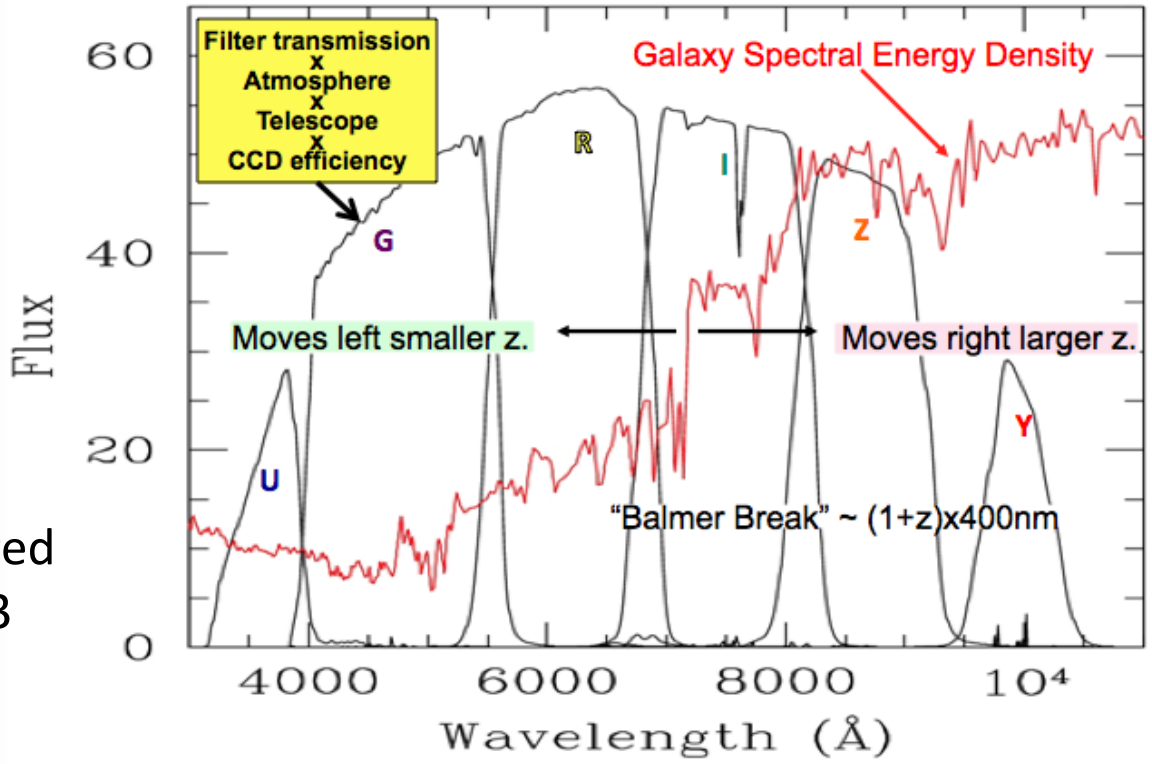
10's sq. deg.

Evolving L* Lyman-Break Galaxy

Photometric redshift

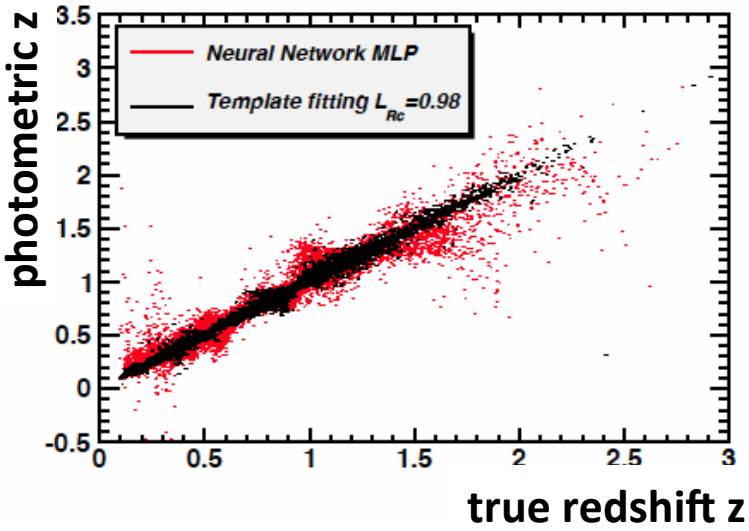
A critical issue for cosmology with LSST

- 10^{10} galaxies *cannot* be spectroscopically measured
- LSST: Calibration until z=3
  -> need 75 000 spectra
  (~50% already exist)



Measure z with only 6 colors ugrizy

- Simultaneous fit of galaxy type, reddening and z
- Template fitting and neural network techniques validated with data and tuned with simulation



LSST & ESO ?

Photometric redshift

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  (~50% already exist)
- Synergies with **VISTA**

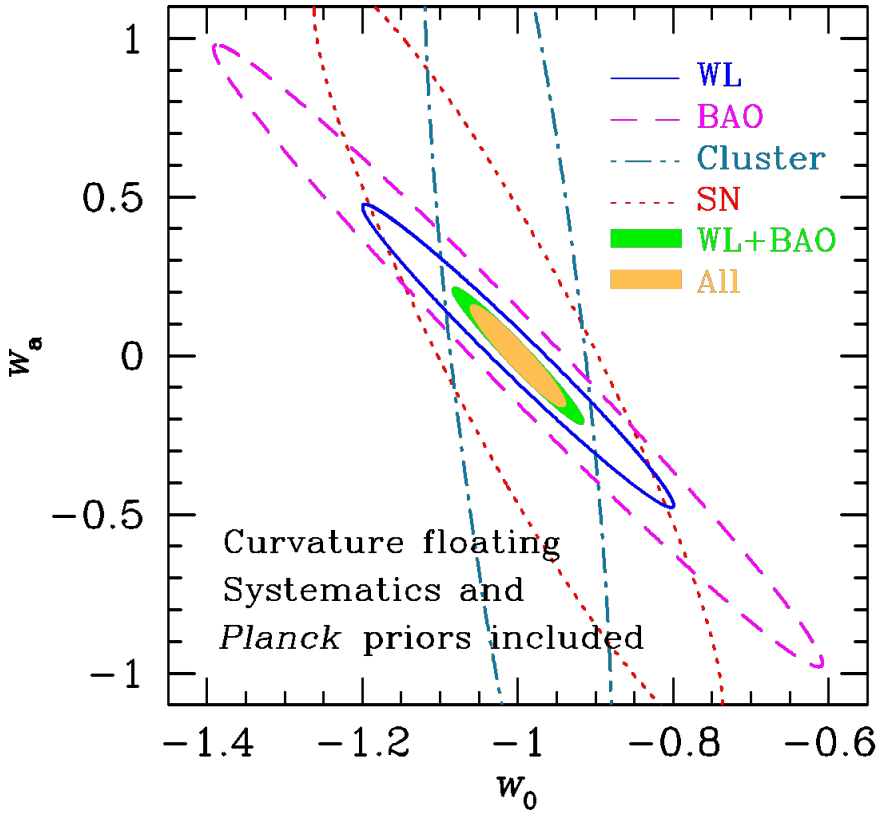
LSST: Stage IV Dark Energy Experiment

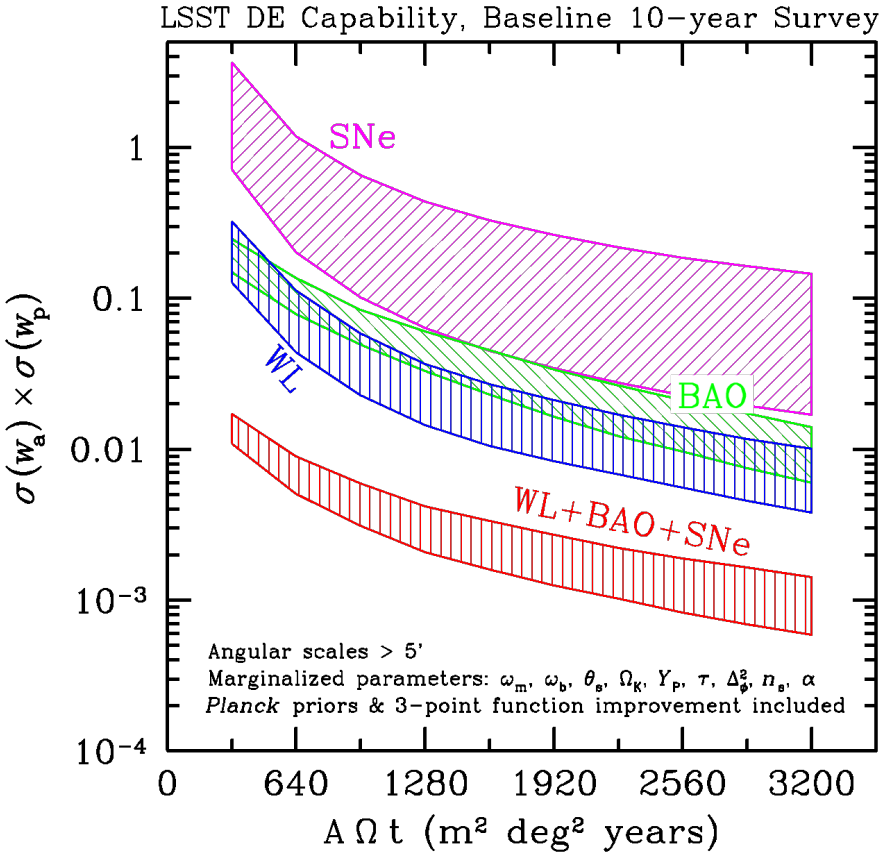
LSST complementary techniques to constrain Dark Energy state equation:

$$p/\rho = w(z) = [w_0 + w_a . z/(1+z)]$$

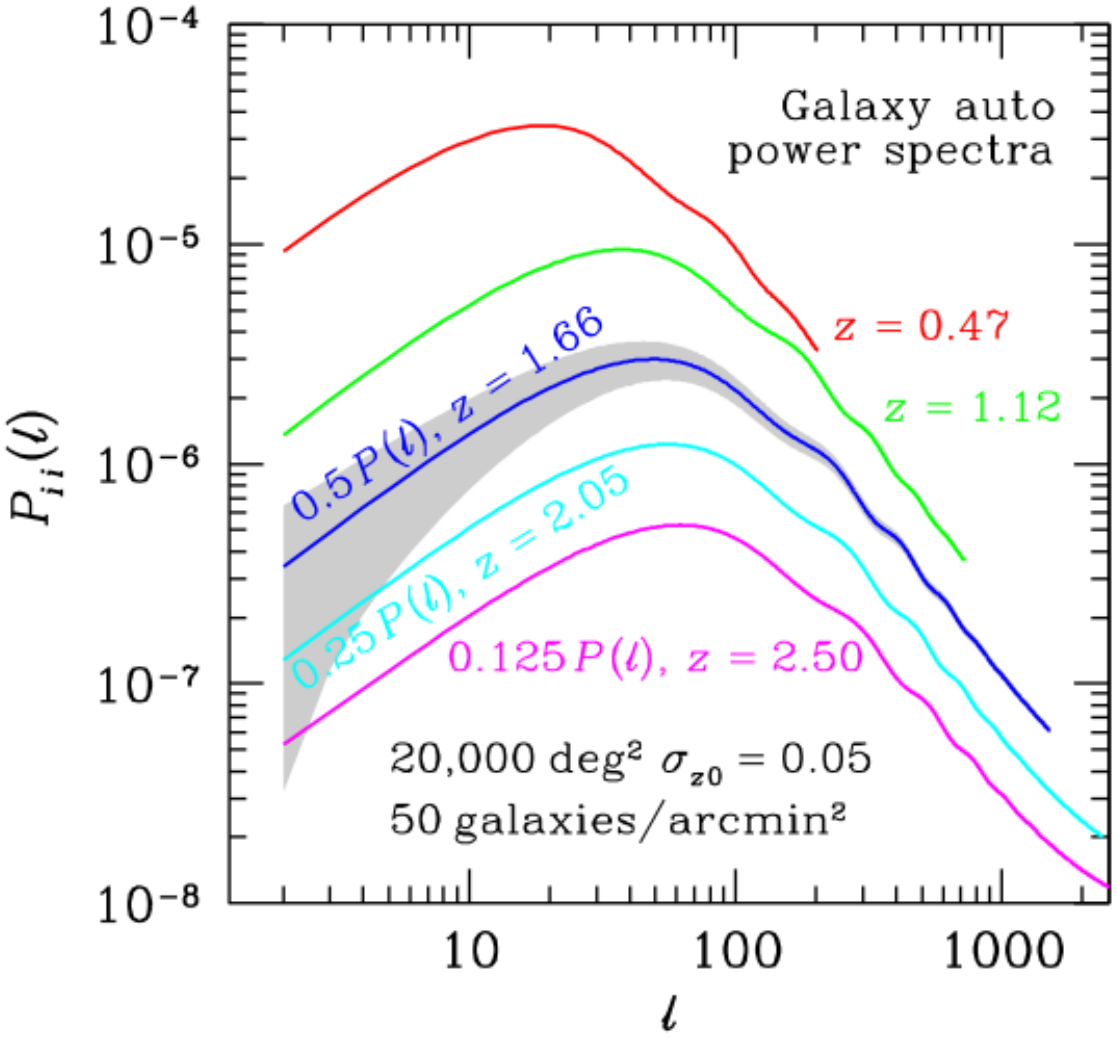
- Weak gravitational lensing
- Baryon acoustic oscillations
- Type 1a supernovae
- Statistics of clusters of galaxies

- Remark : LSST Key properties to remove instrumental/atmospheric signature : > 800 exposures of each field
- Stage IV criterion defined in terms of the error ellipse area in the w_a-w_0 plane.





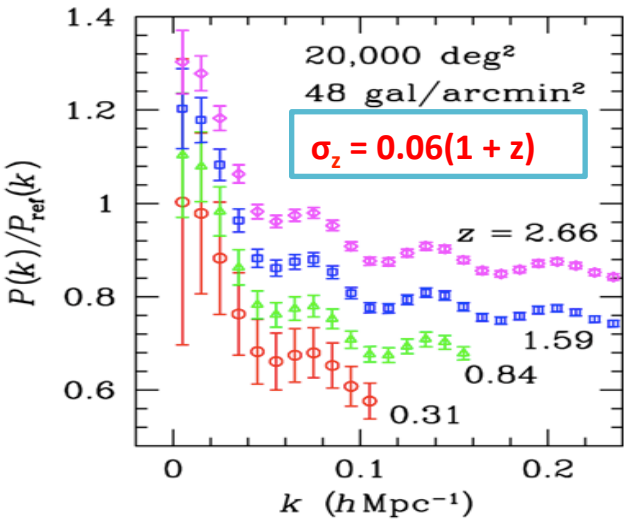
BAO standard ruler: LSST expectations



Assumed photometric redshift errors: $\sigma_z = 0.05(1 + z)$.

BAO features are prominent at multipole ℓ of several 100's.

Grey area indicates the statistical error (cosmic variance and shot noise) per multipole for z = 1.66.

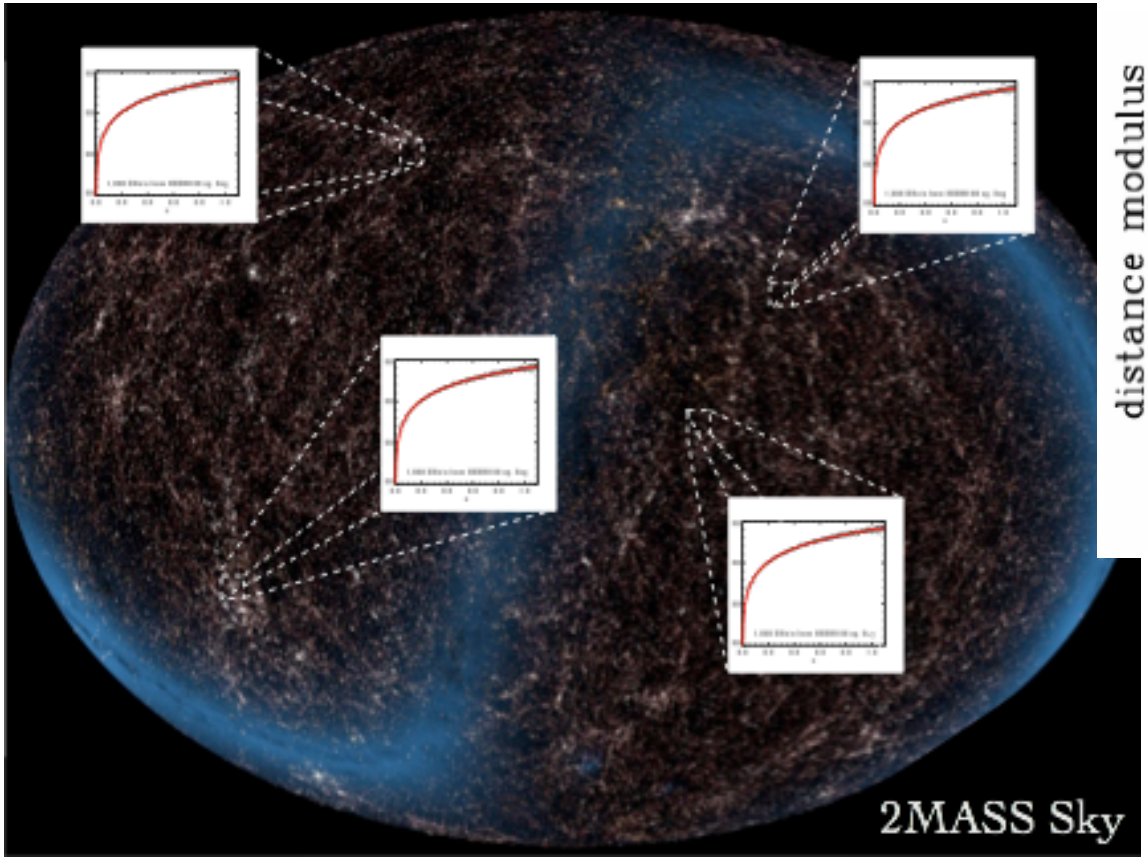


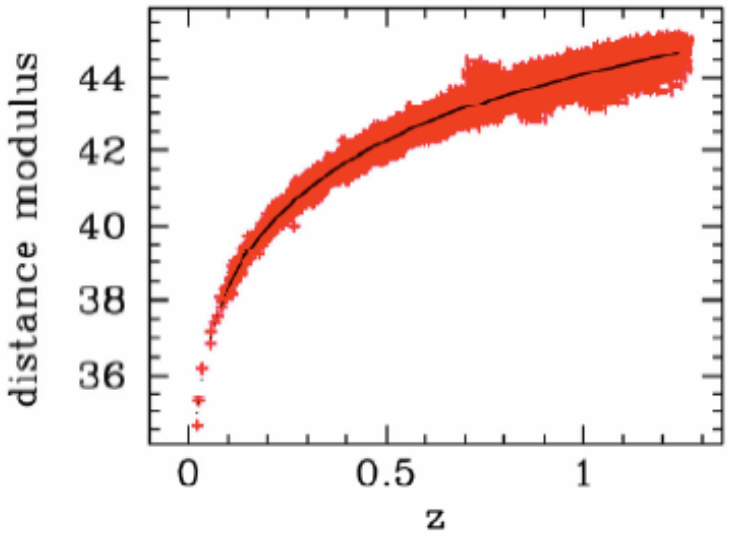
LSST & Optical Transients : an unique way to probe/survey the universe

Hubble diagrams for several directions :

with 250 000 SNIa @ z<1 per year LSST will be able to probe the isotropy of the Dark Energy properties.

-> build SNIa hubble diagrams for different directions in the sky.





Expected Hubble Diagram with 30 000 SN1a from photometric redshift + lightcurve fitting

Alerts…

Sources detected in difference images (images with respect to coadded templates, called DIASources) reported in 60s

- Filter a stream of ~ 10 million DIAsources / night
  variable stars, SNe, asteroids, and “everything else »
  -> Robust filtering + rapid followup

Given a stream of ~ 10,000 DIASources every ~ 40s (per 10 sq.deg. field)

- Asteroids will dominate on the Ecliptic, become insignificant >30° from it.
- Variable stars (~ 1 % of all stars) will dominate in the Galactic plane, always significant (~ 400/field @ Galactic pole)
- Quasars will contribute up to 500/field (but likely several times lower)
- SNe will contribute up to about 100/field

Discovery rates will drop fast (factor of ~ 100 after 2 years)

new DIASources will become dominated by cataclysmic variable stars and quasars

LSST & ESO ?

Photometric redshift

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- LSST: Calibration until z=3
  -> need 75 000 spectra
  (~50% already exist)
- Synergies with **VISTA**

Alerts…

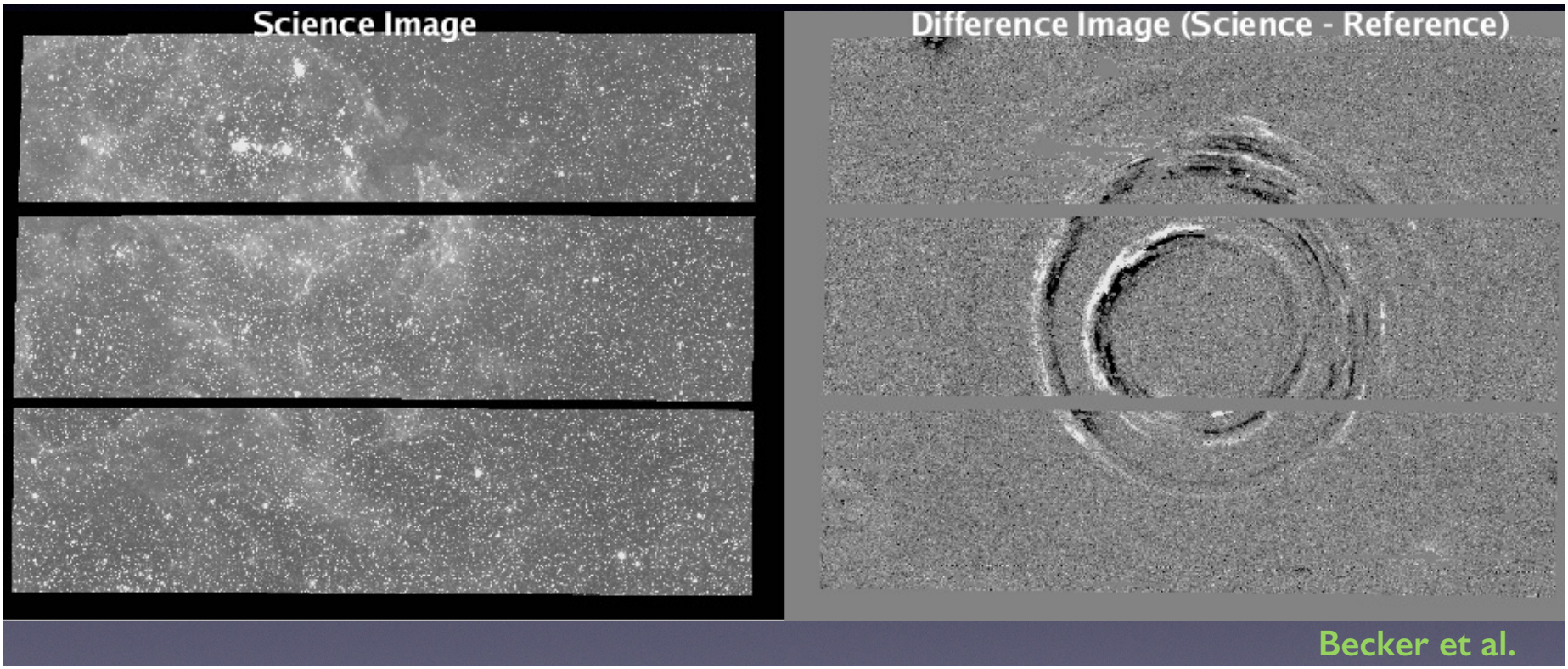
Rapid followup

Huge telescope time will be needed to fully exploit the alerts:

- **Spectroscopy (SN…)**
- **Photometry** (ex: microlensing)
- Astrometry

Not only point-sources

- LSST will extend time-volume space a thousand times over current surveys (new classes of object?)!
- Not only point sources - echo of a supernova explosion



LSST : members

Community of ~ **900 scientists** over the world (50% from **US**) :

- **Chile** (site) & **France-IN2P3** (in-kind contribution to the camera, computing and data management) are LSST members / have data rights.
- **Non-US** scientists in LSST will be associated to a fee of 20,000 U$ / year / (PI+4 Pdoc/Grad) for the 10 years of running.

  -> goal: cover ~30% of the LSST running cost.

  - **Europe** :
    - **France** : ~ 120 PIs (including ~+45 PIs on top of the camera contribution)
    - **UK** : ~ 100 – 180 PIs (200 UK's scientists declared interest)
    - **Czechy, Croatia , Hungary , Poland, Serbia**… : ~ 20-40 PI
  - **China** (existing consortium), **India** (strong interest), **Brazil**, **Australia**, **New Zeeland**…

LSST cost & calendar

Cost

- Total cost ~ 1 B$, Construction + 10 years running included
- Telescope & Data Management : $473M(NSF)
- Camera : $168M (DOE + France-IN2P3 total in-kind contribution ~$15M)
- Private Funds : $40M (early mirrors contribution & site preparation…)
- Other than US/France/Chile: expected to cover ~30% of running costs

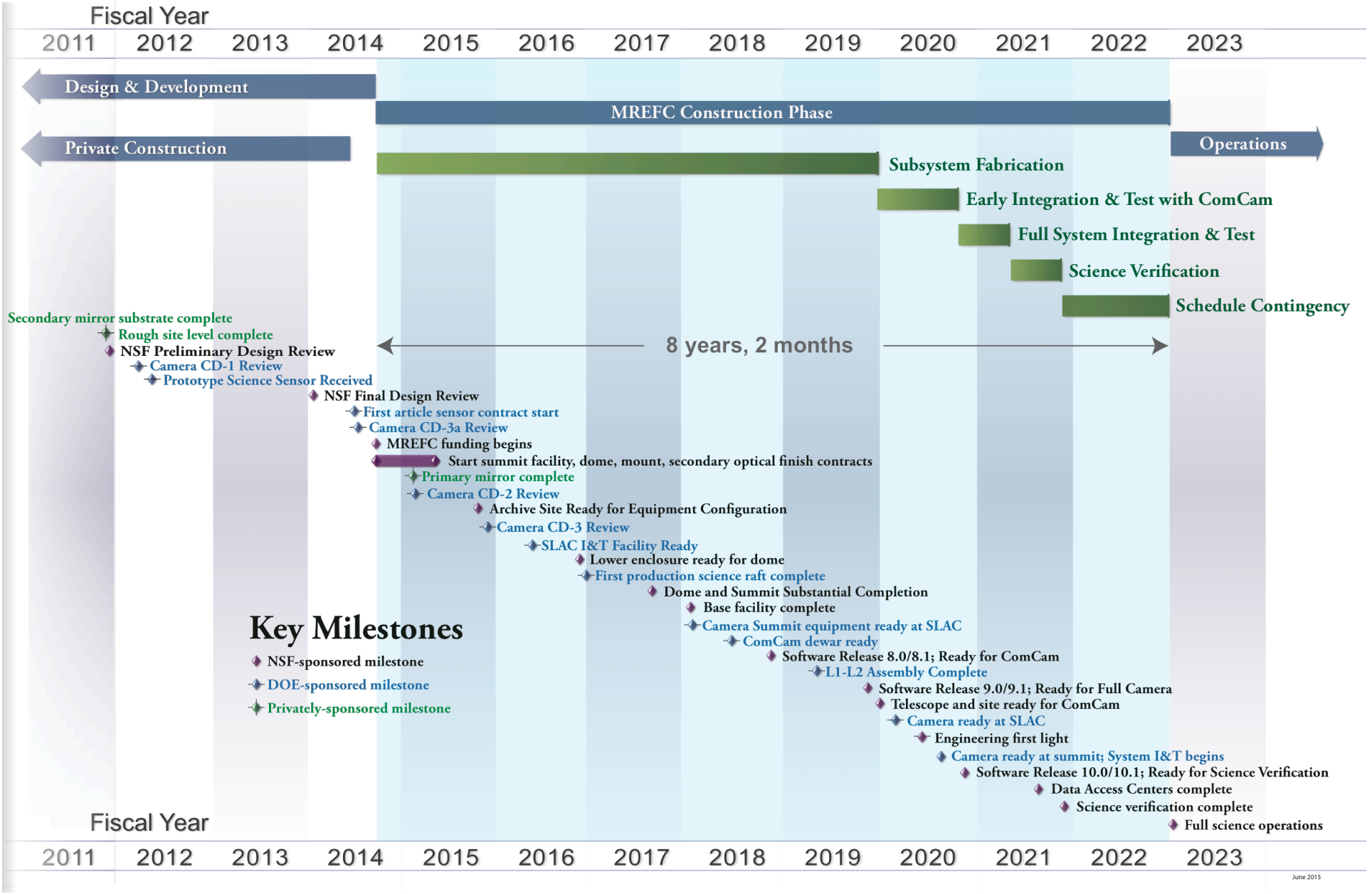
Calendar

- Official Construction started : 2014
- Telescope engineering first light : end 2019
- Camera integrated at summit : 2020
- Start of the LSST “Science Verification survey” : 2021
- “LSST delivery” / start of 10 years survey : spring 2022

SUPPLEMENTS

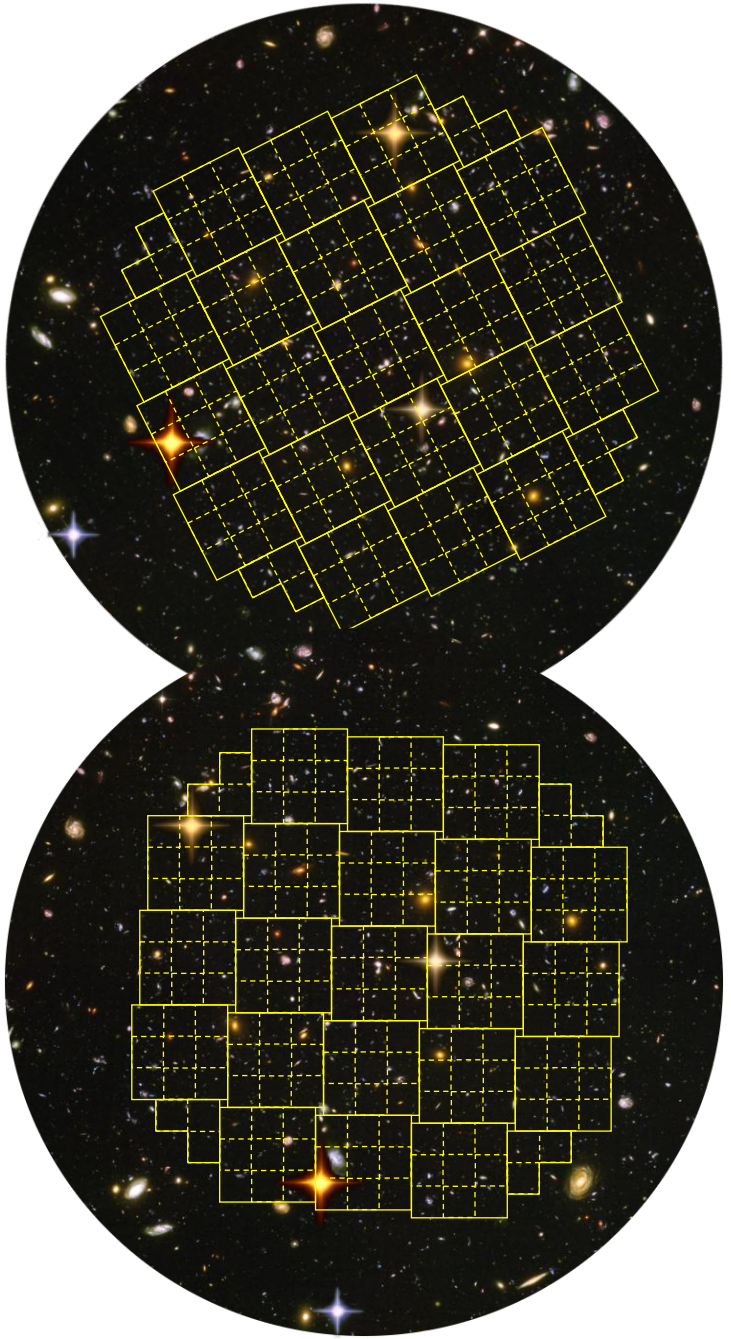
Besalco Construcciones, S.A., summit mobilization has begun

Integrated Project Schedule



Observational Strategy

- Multi-epoch observations
- 15s exposures
  - Variability studies
  - Co-addition of images taken in various conditions (instrumental and atmospheric)
- Uniform photometric quality
  - In any atmospheric condition
  - **Real time measurement of the atmospheric transmission** with a 1.2m auxilliary telescope



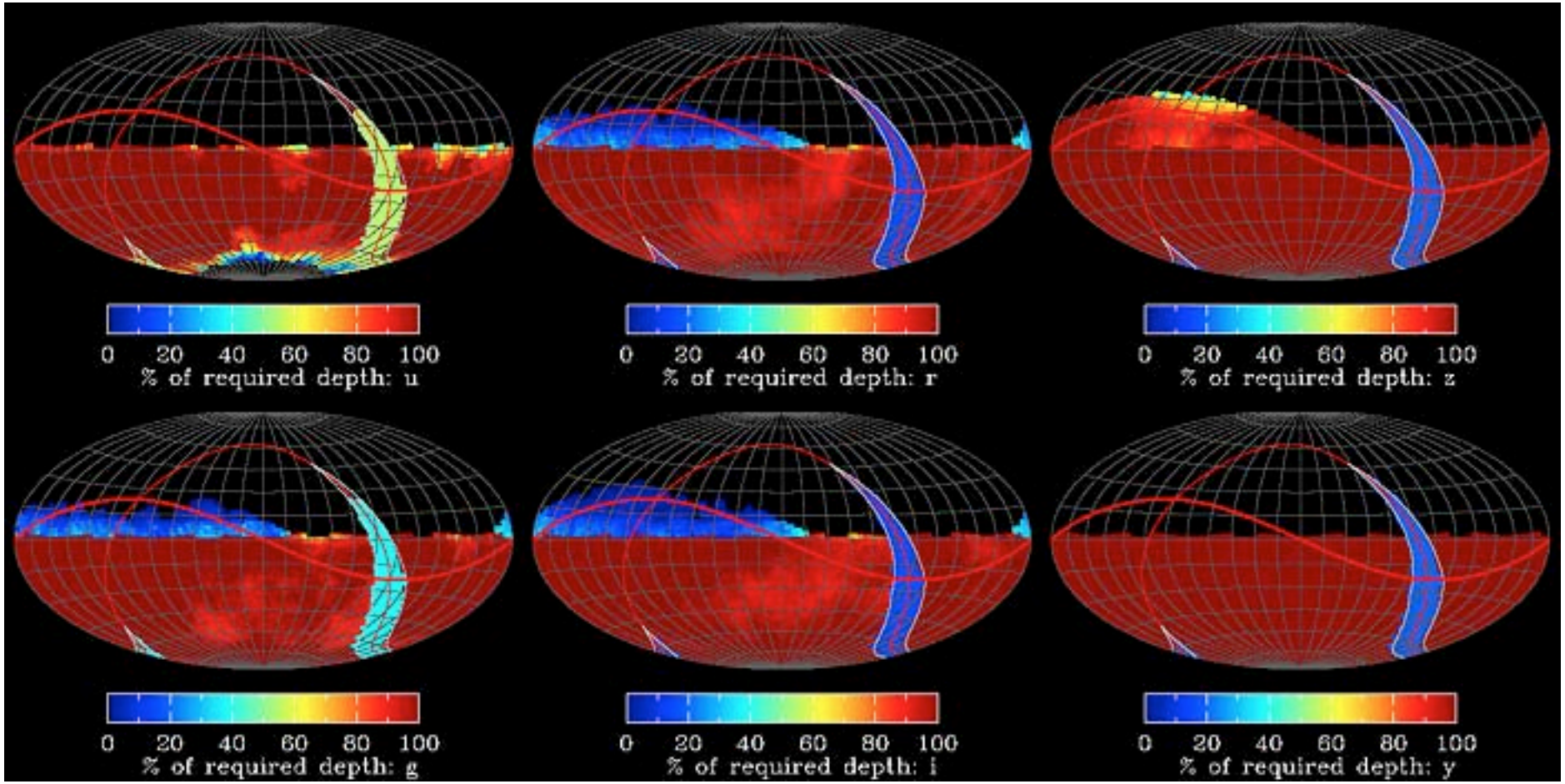

0 20 40 60 80 100
% of required depth: u
0 20 40 60 80 100
% of required depth: r
0 20 40 60 80 100
% of required depth: z
0 20 40 60 80 100
% of required depth: g
0 20 40 60 80 100
% of required depth: i
0 20 40 60 80 100
% of required depth: y

Photo-z calibration : cross-correlation option

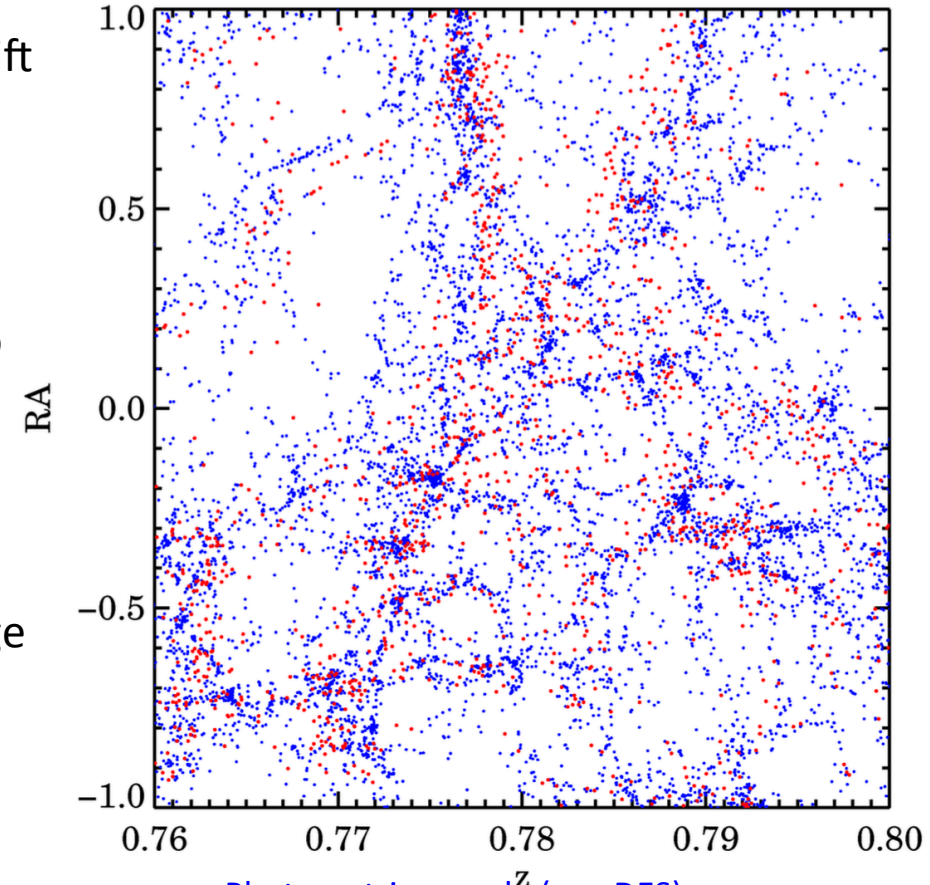
- Most LSST planned targets are too dim to get spectroscopic redshifts for *en masse*
- Existing redshift surveys are highly and systematically incomplete & redshift success rate depends on both color and magnitude

➔**cross-corelation methods:** exploiting redshift information from galaxy clustering

• Galaxies of all types cluster together: trace same dark matter distribution
• Galaxies at significantly different redshifts do not cluster together
•From observed clustering of objects in one sample with another (as well as information from their autocorrelations), can determine fraction of objects in overlapping redshift range

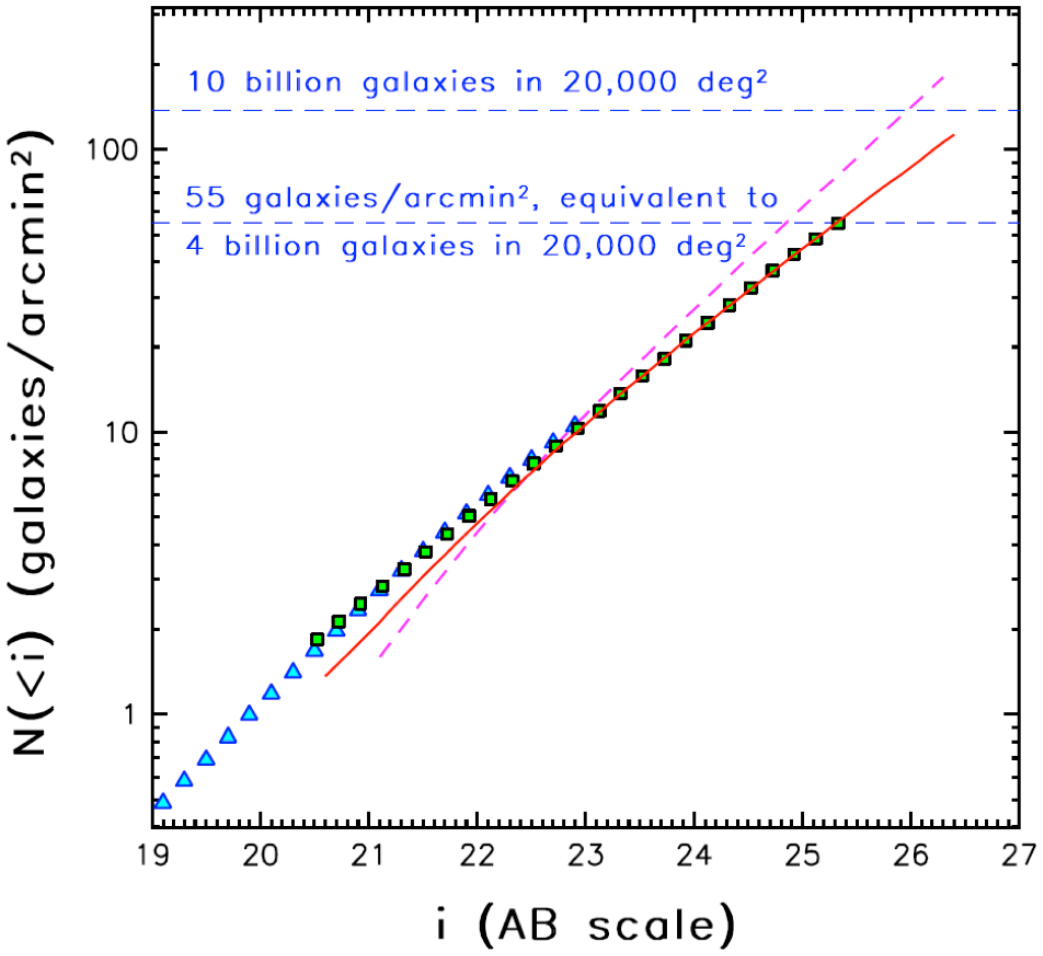
A few tens of thousands of spectra per unit *z* are required to calibrate LSST

More : J.Newman et al. http://arxiv.org/abs/1309.5384

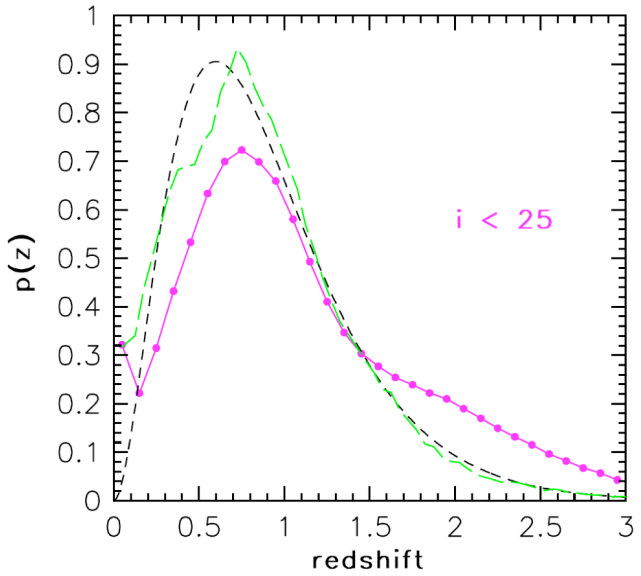


Photometric sample (e.g DES)
Spectroscopic sample (e.g DEEP2)

Galaxy studies (over 20,000 deg^2)



- LSST will be a unique tool for studies of galaxy formation and galaxy properties
- Probes a Co-Moving Volume ~2 Orders of Magnitude Larger than Current or Near-Future Surveys
- The survey will reach up to 50 galaxies / arcmin^2
- The database will include photometry for **10^{10} galaxies** from the Local Group to z > 6.
- LSST will have 6-band photometry for 4 x 10^9 galaxies.



Active Galactic Nuclei

- Active Galactic Nuclei involve **massive black holes at the centers of galaxies** that release prodigious amounts of energy through gravitational in-fall.

- In recent years, we have learned that the formation and growth of central black holes plays a crucial role in galaxy evolution through "AGN feedback".

- The enormous dynamic range offered by LSST in luminosity and redshift will revolutionize our understanding of AGN demography and the correlation between AGN properties and their host dark matter haloes.

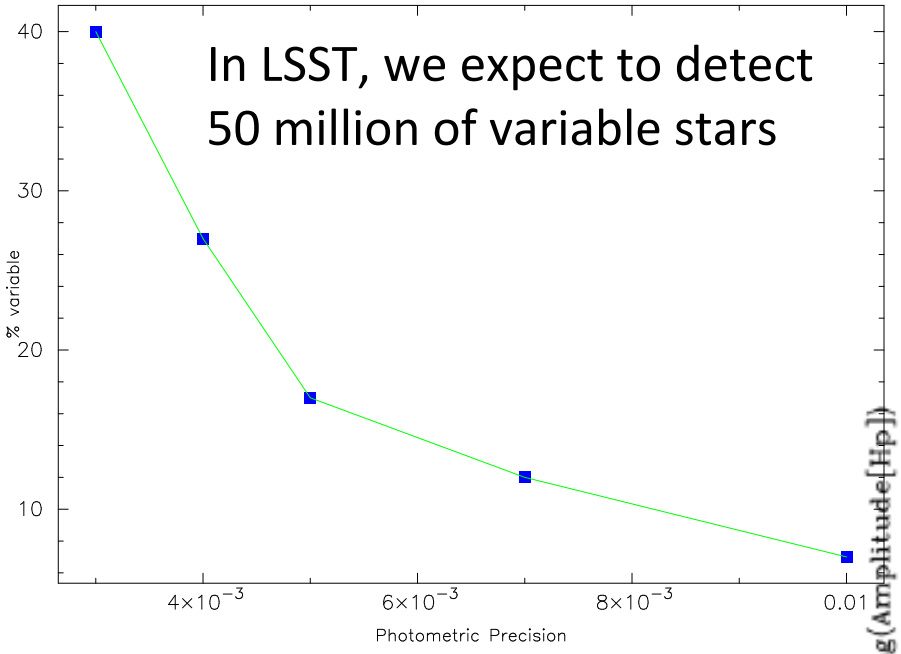
- **LSST will produce a high purity sample of > 10^7 optically-selected AGNs**. This is at least an order of magnitude larger than current AGN samples using all wavelengths.

Transients and Variable Stars

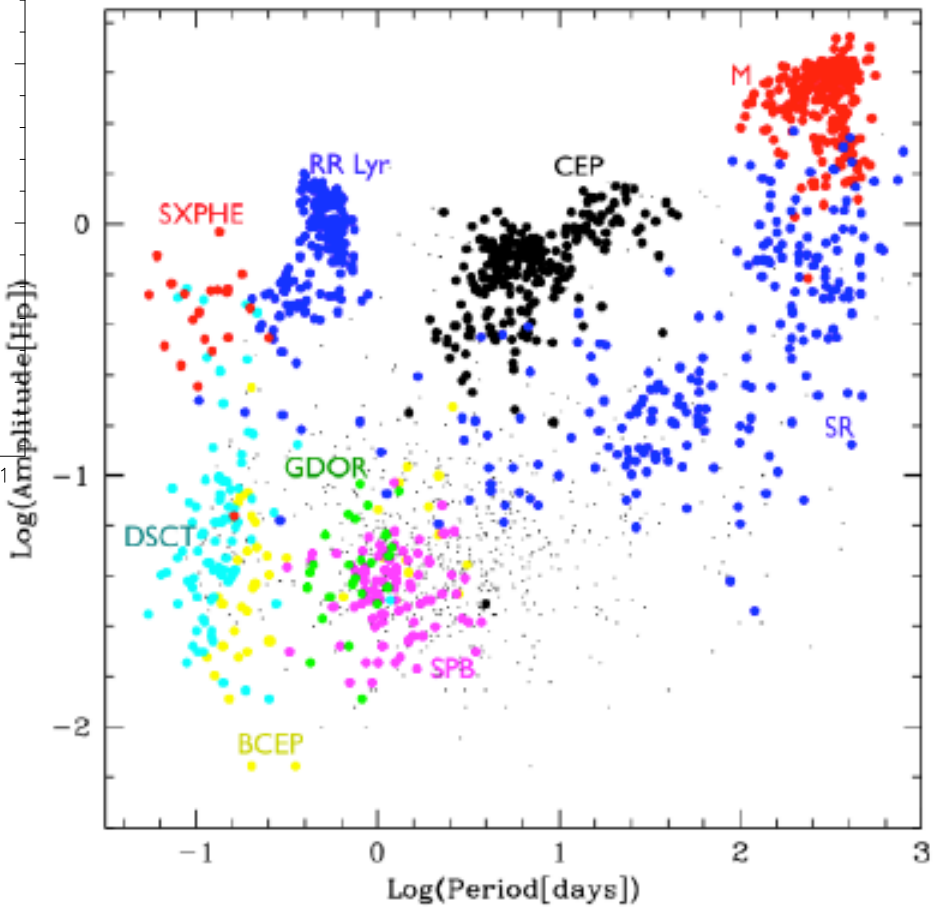
- LSST's unique time sampling allows the detection of stellar variability on timescales **from seconds to years**.

- A wide range of phenomena can be studied with such a rich dataset:
  - Explosive events (supernovae, novae, gamma-ray bursts)
  - Periodic variability associated with binarity
  - Intrinsic stellar variables like Cepheids, RR Lyrae, Miras, which are important for distance measurements
  - Geometrical effects such as gravitational microlensing
  - Dimming of stars as they are occulted by transiting planets

Search for variable stars



Variable Star Classes Can Be Readily Identified Via Their Periods and Amplitudes



The LSST Corporation

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- University of Washington
- National Optical Astronomy Observatory
- Research Corporation for Science Advancement
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