The Large Synoptic Survey Telescope

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for the
LSST Collaboration

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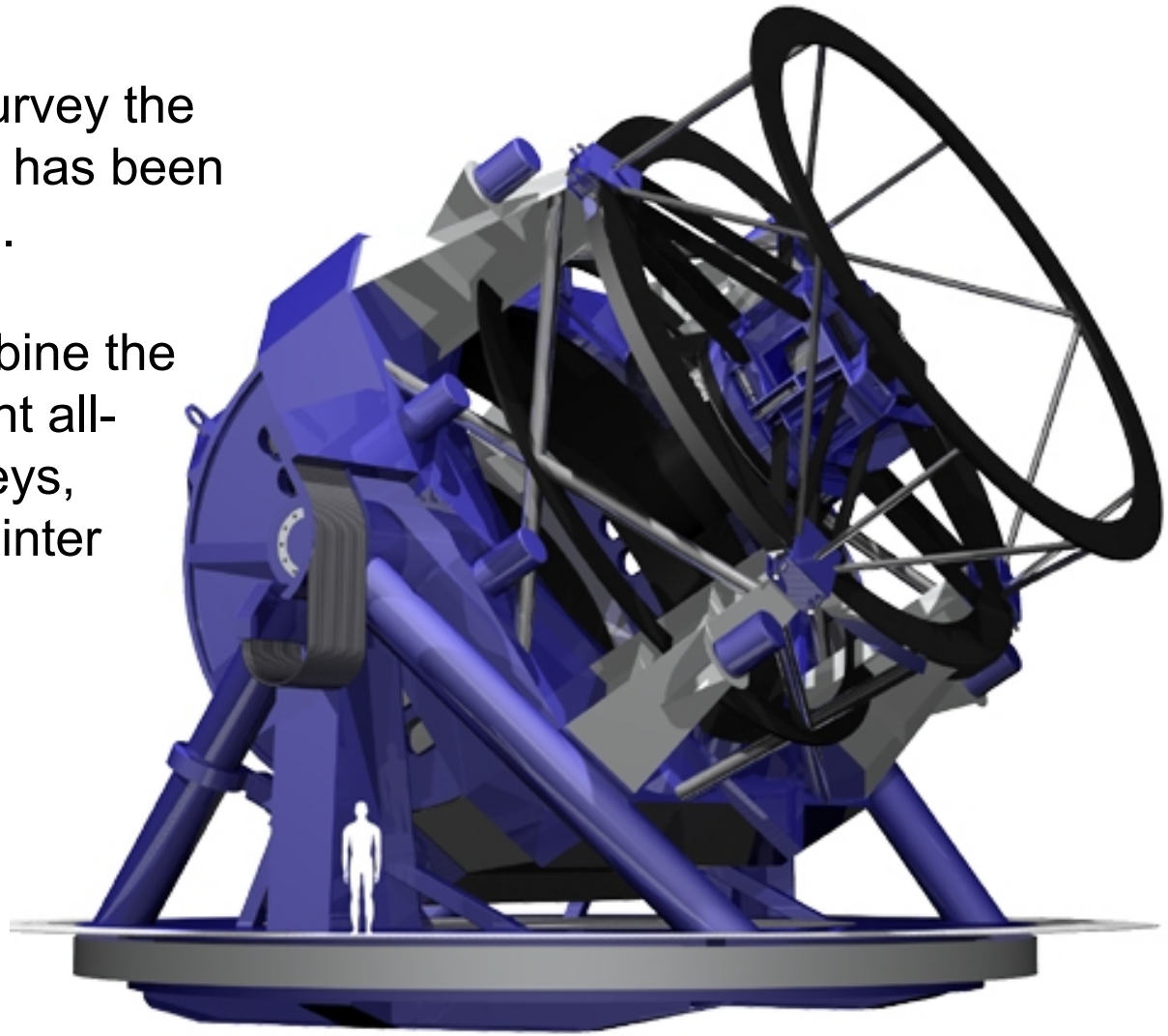
Large Synoptic Survey Telescope

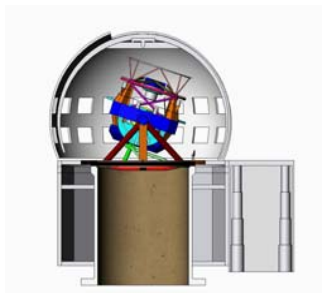
The need for a facility to survey the sky *Wide, Fast, and Deep*, has been recognized for many years.

Such a system would combine the scientific potential of current all-sky and time-domain surveys, extending them to much fainter limits.



Wide+Deep+Fast: Etendue

Large Synoptic Survey Telescope

Aperture	x	Field of view	=	AΩ
 Keck		0.2 degrees		10 m² deg²
 LSST		3.5 degrees		319 m² deg²

Science Potential

Detailed operational simulations show that a survey with AΩ > 300, operating for 10 years, can *simultaneously* provide major improvements on a wide variety of fronts.

- **Probe dark energy and dark matter**
  - **2% constraints on DE parameters by many independent means: (multiple) weak lensing, supernovæ, BAO, *etc.***
- **Open the time domain by a factor of > 1000**
  - **Faint transient sources: SNe, GRB afterglows, …**
  - **Variable sources: stars, AGN, strong lensing, …**
- **Solar system probes, esp. of faint, fast-moving objects**
  - **NEAs, KBOs, comets, debris**

Science Potential

Large Synoptic Survey Telescope

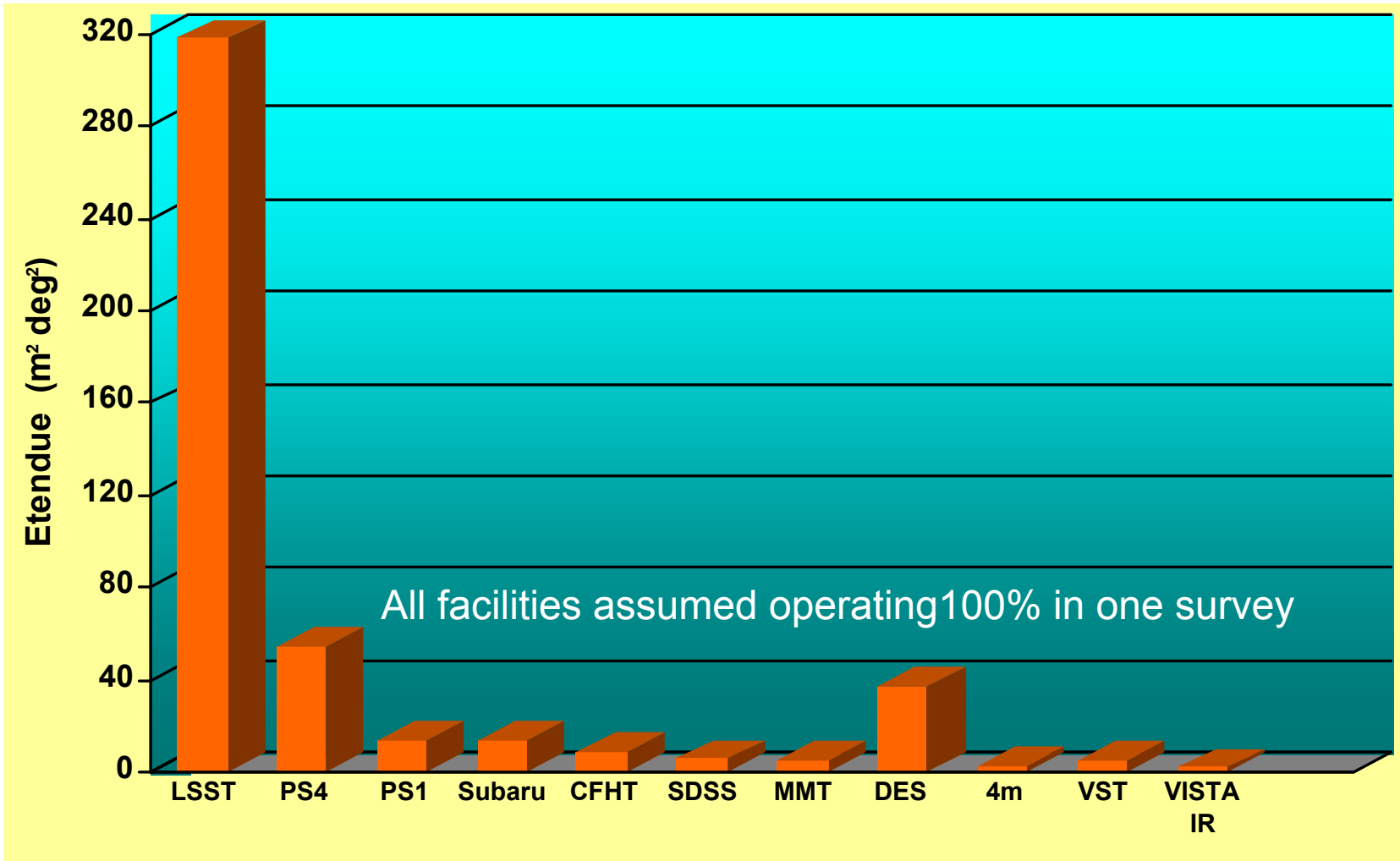
THE UNKNOWN

Such a system will gather many times more optical data than all previous astronomical images combined.

Finding now-rare events will become commonplace.

Finding the truly singular will be possible.

Optical Throughput – Etendue AΩ



The LSST Mission

Large Synoptic Survey Telescope

Photometric survey of half the sky (~ 20,000 sq. deg.)

Multi-epoch data set with return to each point on the sky every ~3 nights for 10 years (30s cadence)

Prompt alerts of transients (w/in 60 seconds of detection)

Fully open source and open data.

LSST Image Data

Calibrated Image Data

- Individual images to 24.5 AB mag (10σ, r-band)
  - 0.2 arc-second sampling (0.7 median FWHM)
  - 0.010 mag internal photometric accuracy across sky
- Deep stacked images
  - >20,000 square degrees to 27.8 AB mag (r-band, 300-400 visits)
  - grizy, w/ less-deep u-band survey
- Difference images
- Metadata
  - control system, automated quality assessment
  - world coordinate system

LSST Catalog Data

Calibrated Object Database

- Raw source detections
- Object data
  - Photometry
  - Lightcurves
  - Parallax/proper motion
  - Shape parameters
  - Classification

E.g.:

3 billion galaxies to z = 3.

250,000 Type 1a supernovae per year to z<0.8

Alert notification system

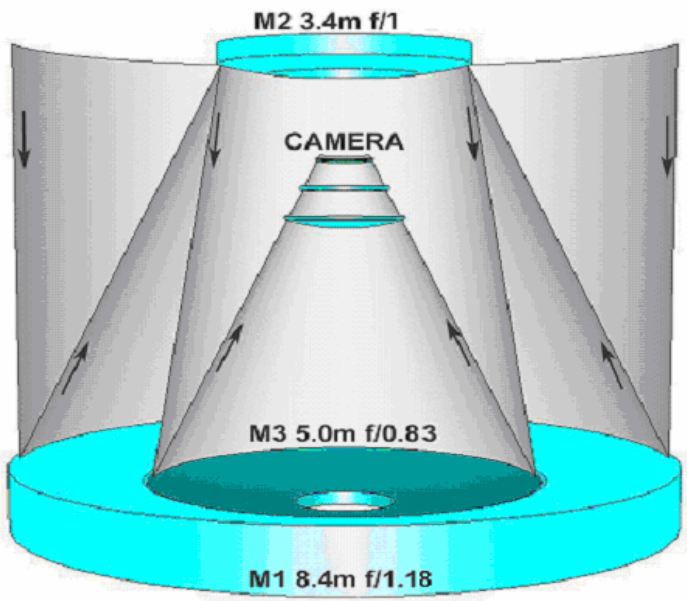
- Automated alerts based upon selected criteria
- Notification w/in 1 minute of observation

Massively Parallel Astrophysics

Large Synoptic Survey Telescope

- Dark matter/dark energy via weak lensing
- Dark matter/dark energy via baryon acoustic oscillations
- Dark energy via supernovae
- Dark energy via counts of clusters of galaxies
- Galactic Structure encompassing local group
- Dense astrometry over 20000 sq.deg: rare moving objects
- Gamma Ray Bursts and Transients to high redshift
- Gravitational micro-lensing
- Strong galaxy & cluster lensing: physics of dark matter
- Multi-image, lensed SN time delays: separate test of cosmology
- Variable stars/galaxies: black hole accretion
- QSO time delays vs z: independent test of dark energy
- Optical bursts to 25 mag: the unknown
- 5-band 27 mag photometric survey: unprecedented volume
- Solar System Probes: Earth-crossing asteroids, Comets, trans-Neptunian objects

LSST Optical Design

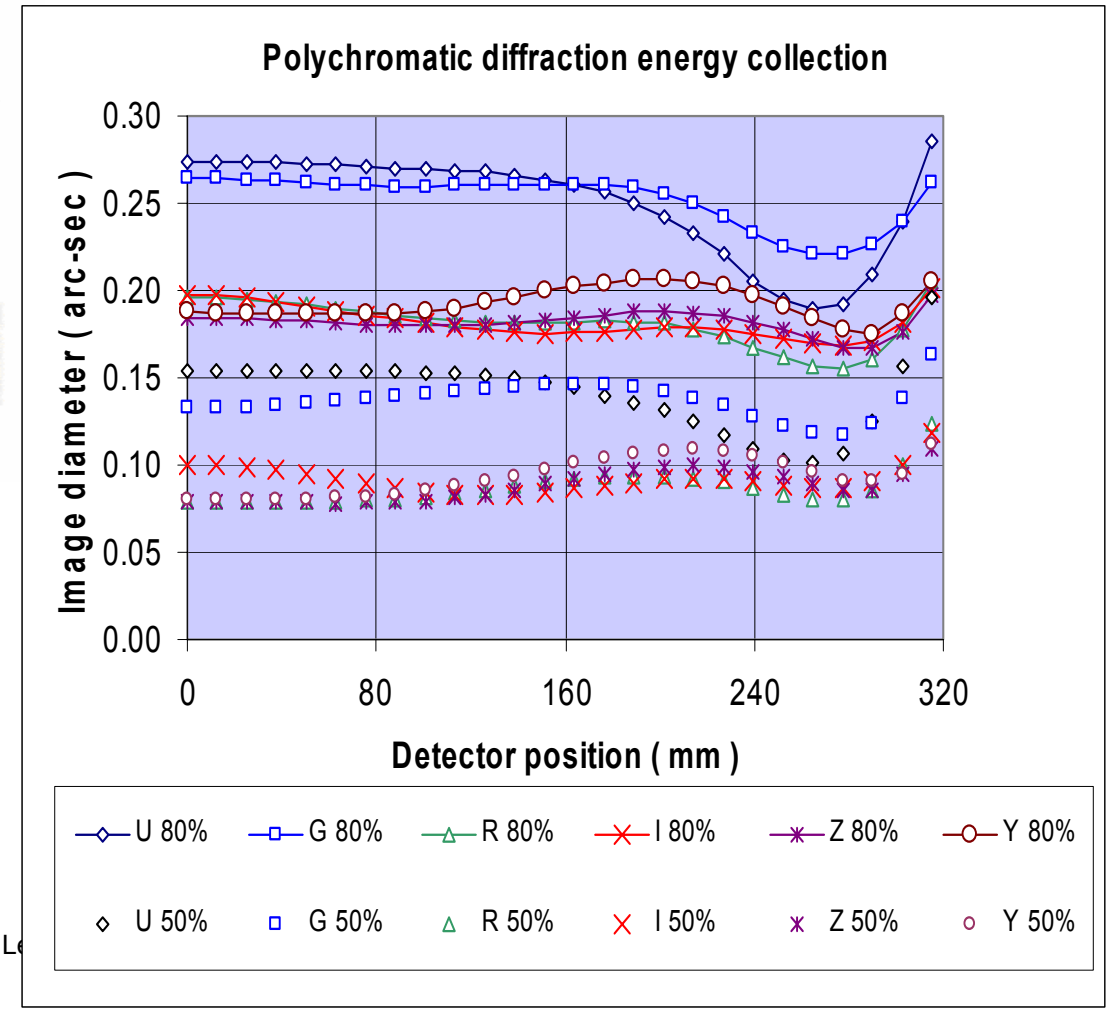


Paul-Baker Three-Mirror Optics

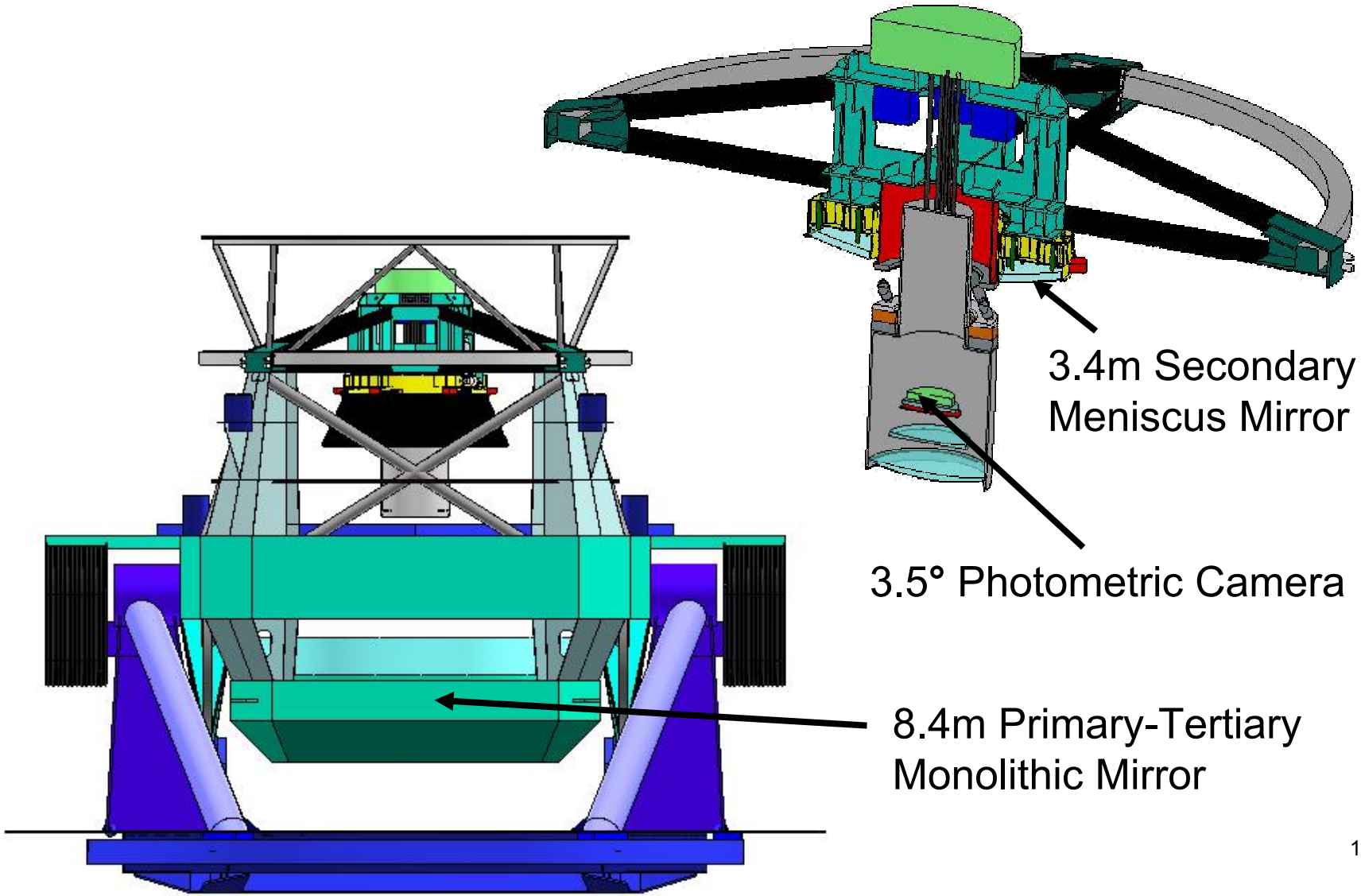
8.4 meter primary aperture.

3.5° FOV with f/1.23 beam and 0.20” plate scale.

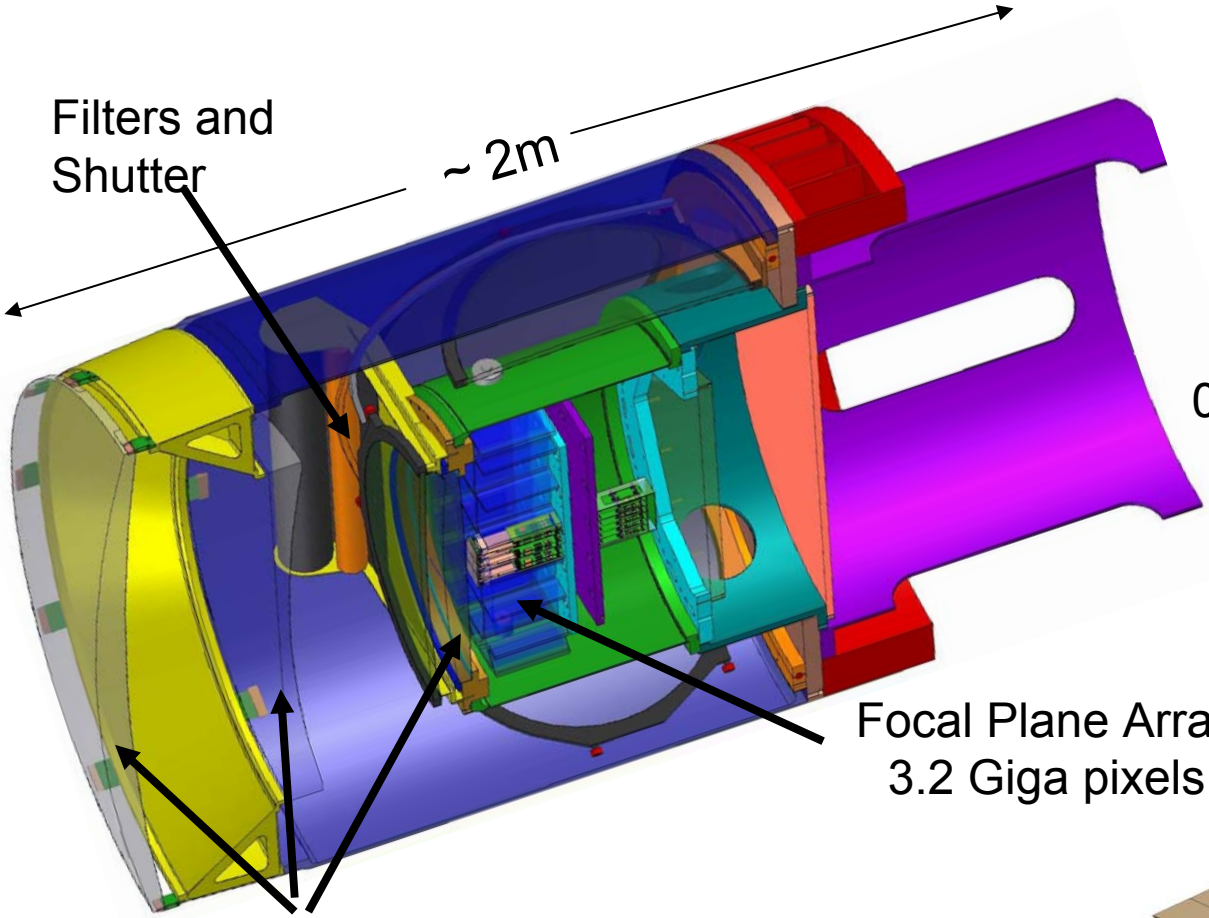
PSF controlled over full FOV.



Telescope Structure

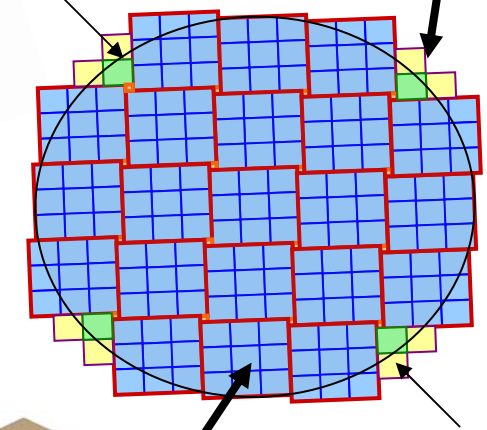


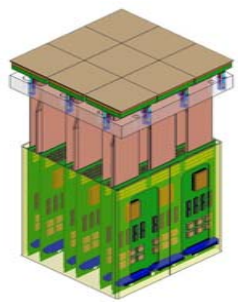
Camera and Focal Plane Array



Wavefront Sensors and Fast Guide Sensors

0.65m Diameter





"Raft" of nine 4kx4k CCDs.

LSST Dark Energy Highlights

Large Synoptic Survey Telescope

- **Weak lensing of galaxies to z = 3.**

  Two and three-point shear correlations in linear and non-linear gravitational regimes.

- **Supernovae to z = 1.**

  Discovery of lensed supernovae and measurement of time delays.

- **Galaxies and cluster number densities as function of z.**

  Power spectra on very large scales $k \sim 10^{-3}\ h\ \mathrm{Mpc}^{-1}$.

- **Baryon acoustic oscillations.**

  Power spectra on scales $k \sim 10^{-1}\ h\ \mathrm{Mpc}^{-1}$.

The Time Domain

Large Synoptic Survey Telescope

LSST goes faint and wide, fast:

- **Current surveys take hours to get to the flux levels LSST will reach in 15 seconds – a thousand-fold increase in discovery space.**

New classes of optical transients:

- **Astrophysics of matter under extreme conditions**
- **Potential for exploitation as astronomical probes**

LSST Planetary Science

Large Synoptic Survey Telescope

Detailed census of the outer Solar System

Asteroids	Interplanetary Dust
Comets	Interstellar Dust
Meteorites	Space Junk

- Increase inventory of solar system x100
- 10,000 NEAs, 90% complete >250m, 80% > 140m
- Over 10 million MBAs
- Cometary nucleii >15km @ Saturn
- Extend size-n of comets to <100m
- TNOs beyond 100AU
- rare new objects

Summary

Large Synoptic Survey Telescope

- **The LSST will be a significant step in survey capability.**
  Optical throughput ~ 100 times that of any existing facility.

- **The LSST is designed to control systematic errors.**
  We know how to make precise observations from the ground.
  We know how to accurately calibrate photo-z measurements.
  Multi-epoch with rapid return to each field on the sky.

- **The LSST will enable multiple simultaneous studies of dark energy, transient phenomena, galactic structure and evolution, and our solar system.**
  Complementary measurements to address degeneracy and theoretical uncertainties, all from a single survey.

- **The LSST technology is ready.**

The LSST Collaboration

Large Synoptic Survey Telescope

Brookhaven National Laboratory
Harvard-Smithsonian Center for Astrophysics
Johns Hopkins University
Las Cumbres Observatory
Lawrence Livermore National Laboratory
National Optical Astronomy Observatory
Ohio State University
Pennsylvania State University
Research Corporation
Stanford Linear Accelerator Center
Stanford University
University of Arizona
University of California, Davis
University of Illinois
University of Pennsylvania
University of Washington

NOAO

RESEARCH CORPORATION

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