Large Synoptic Survey Telescope

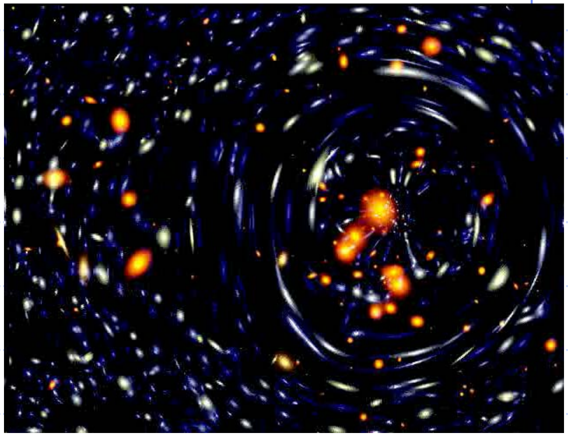
HEP Program Review

April 22-23, 2004

Sam Aronson, Physics Department

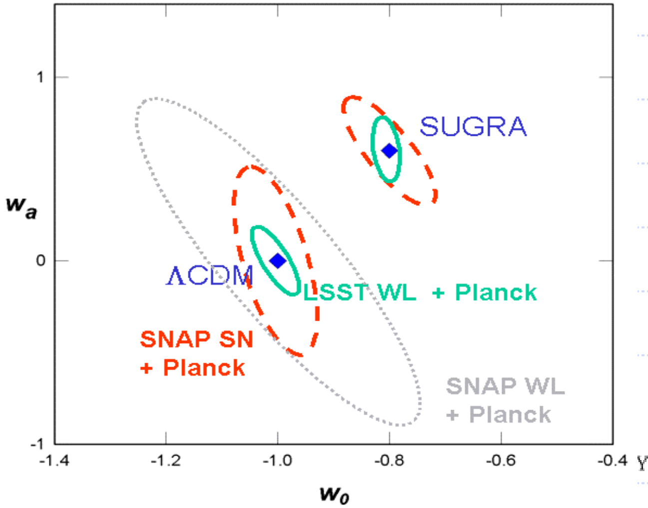
The Science of LSST

- Probe Dark Energy & Dark Matter



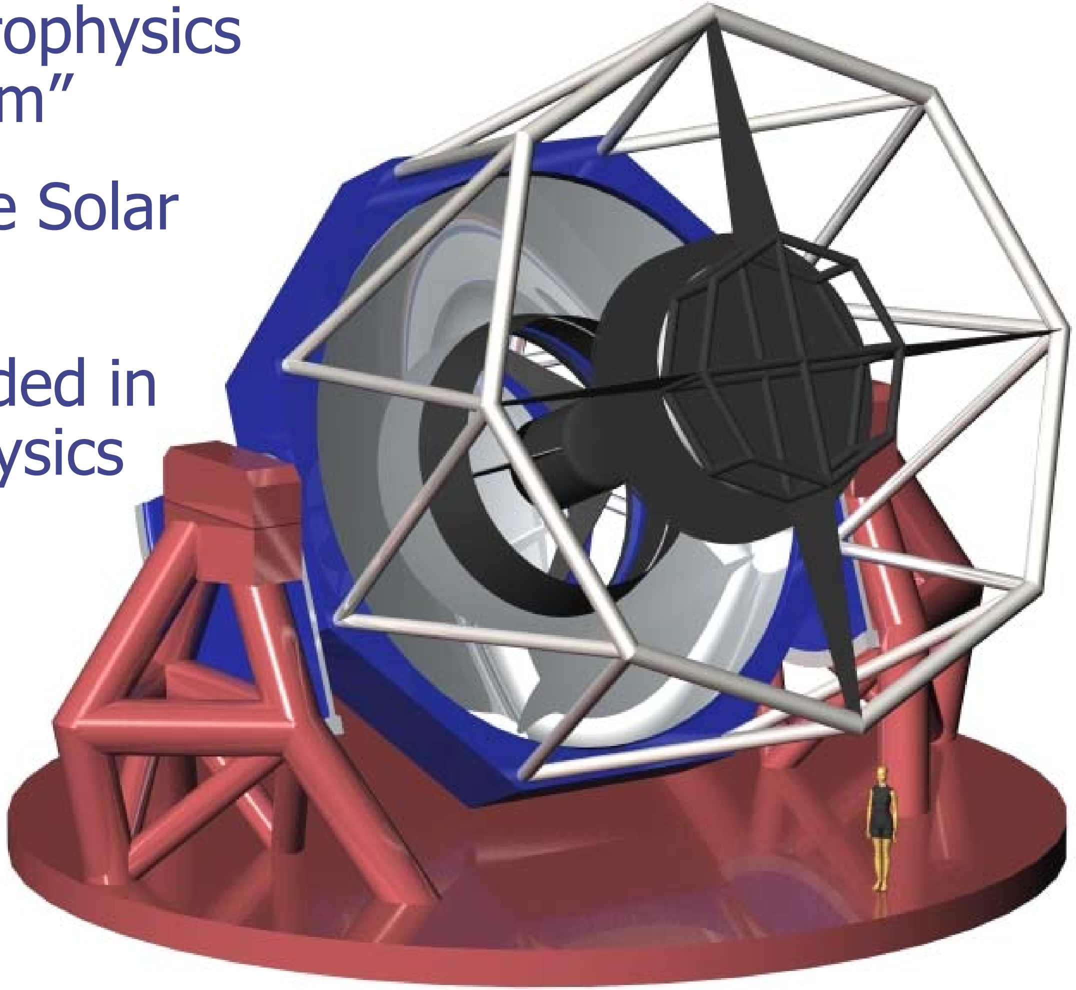
"A high-priority independent approach to place constraints on the nature of Dark Energy will be made by studying the weak lensing produced by Dark Matter. This is a scientific goal of the ground-based … LSST. Significant technology investments to enable the LSST are required, and NSF and DOE will begin technology development of detectors, optical testing, and software algorithms leading to possible construction with first operations in 2012." Physics of the Universe recommendation

- New BNL group will study Dark Energy via weak gravitational lensing
  - Wide, deep, frequent imaging of the entire visible sky
  - Complementary to supernova surveys



LSST endorsed by three NAS studies:

- “From Quarks to the Cosmos”
- “Astronomy and Astrophysics in the New Millennium”
- “New Frontiers in the Solar System”
- And now recommended in the OSTP report “Physics of the Universe”



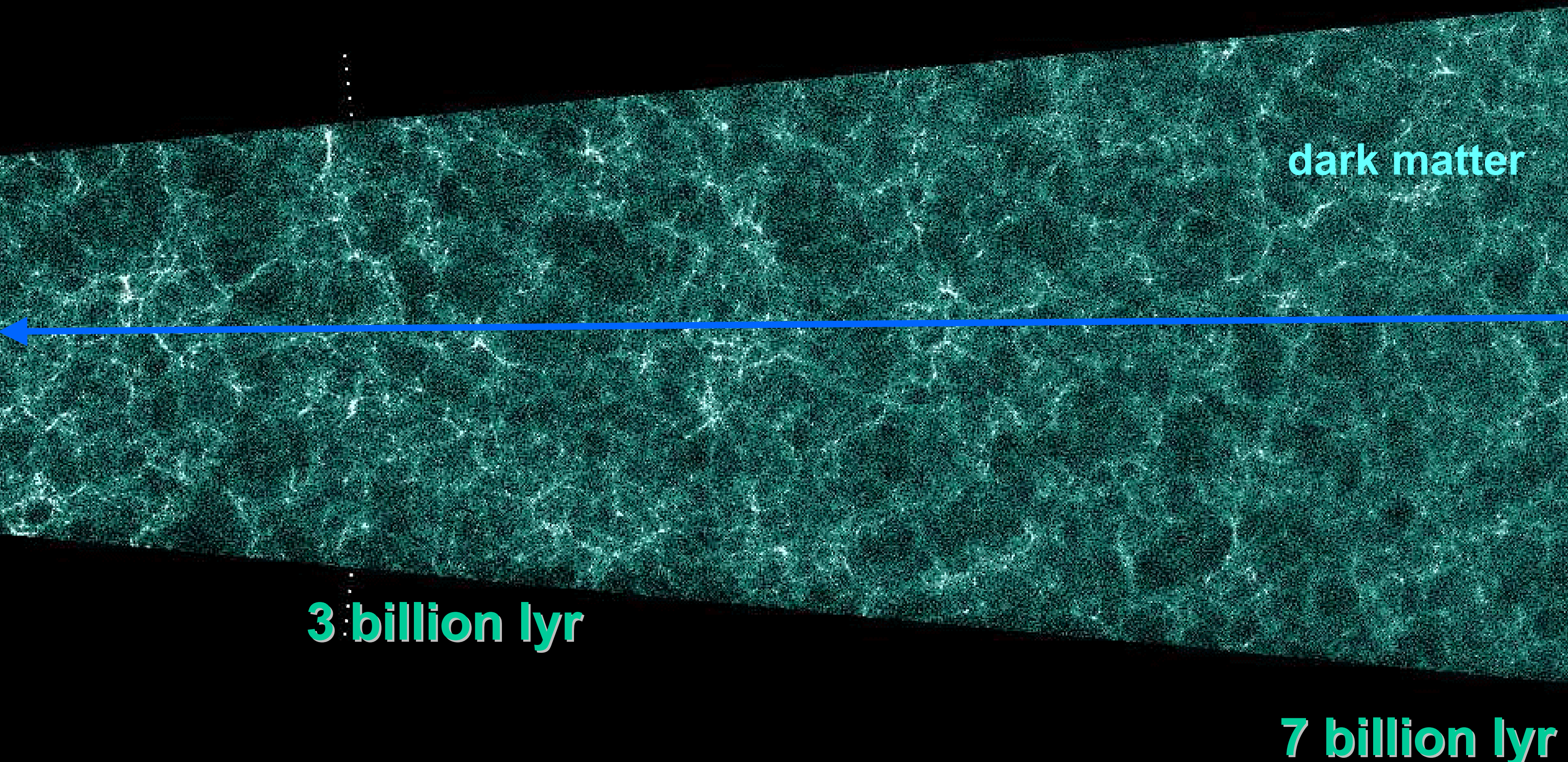
LSST probes of Dark Energy

1. Mass cluster counts vs. redshift:
   *Co-moving Volume element $dV/dzd\Omega$
   *Growth rate of density perturbations
   Counts of mass clusters: 3-D tomography

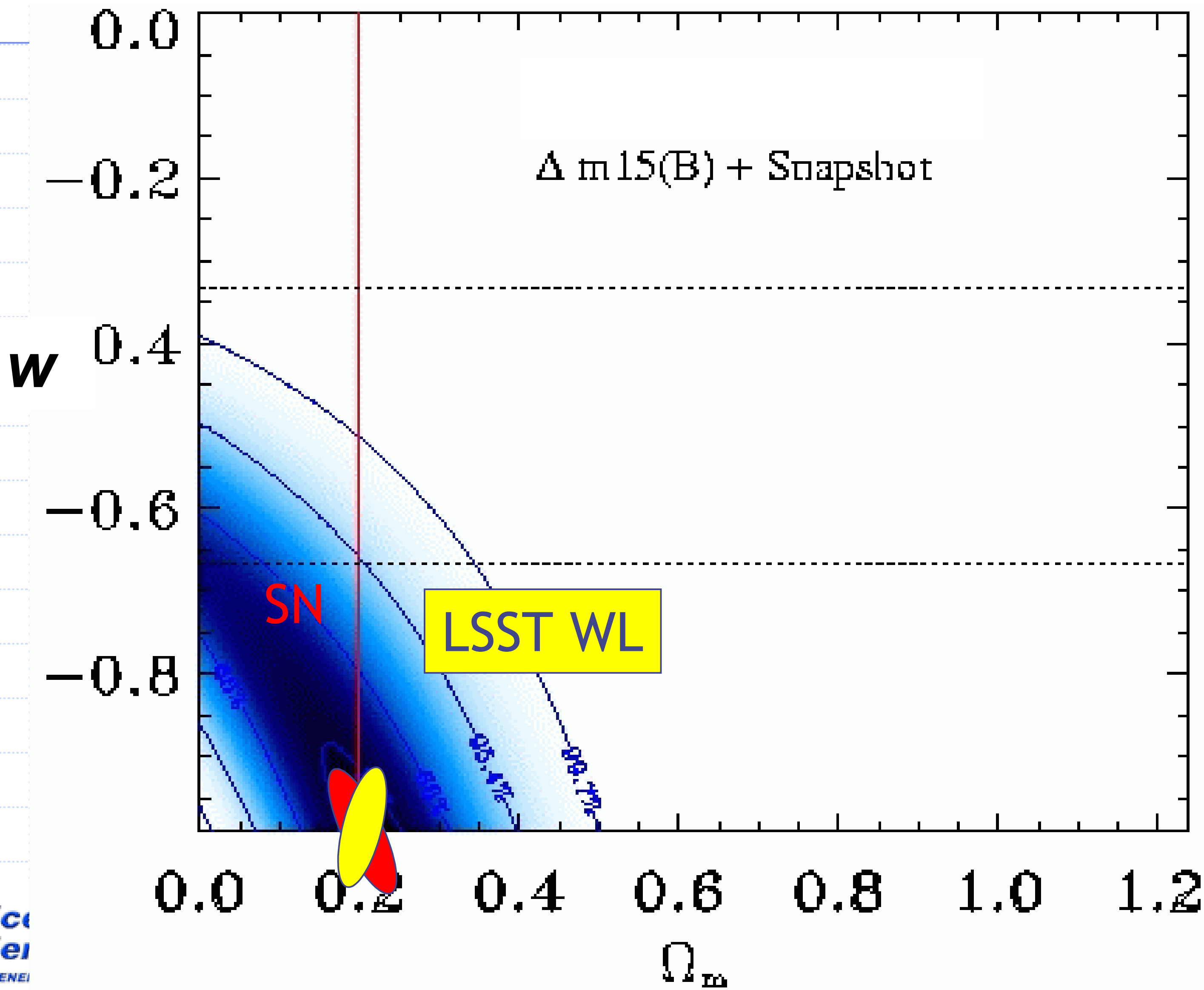
2. Shear Tomography: $<\gamma(z_1)\ \gamma(z_2)>$
   Several independent tests

3. Supernovae: luminosity distance vs. z
   Huge numbers of SN

mass structure vs time



Supernova – lensing complementary

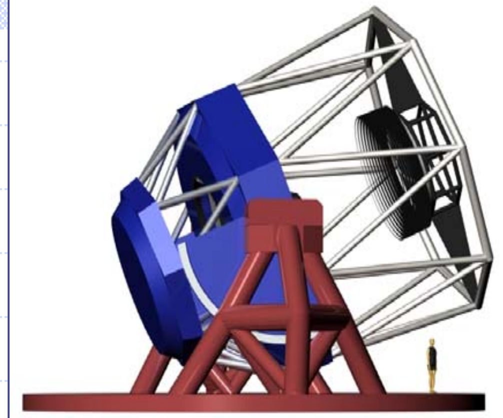


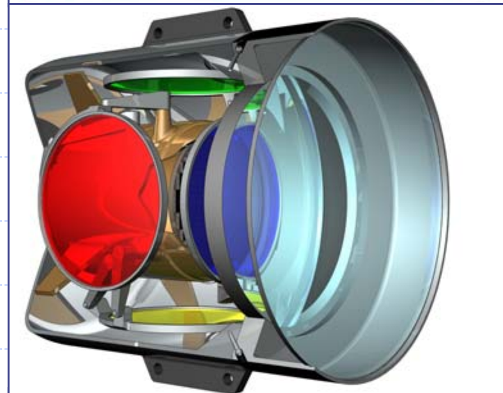
Dark Energy - conclusions

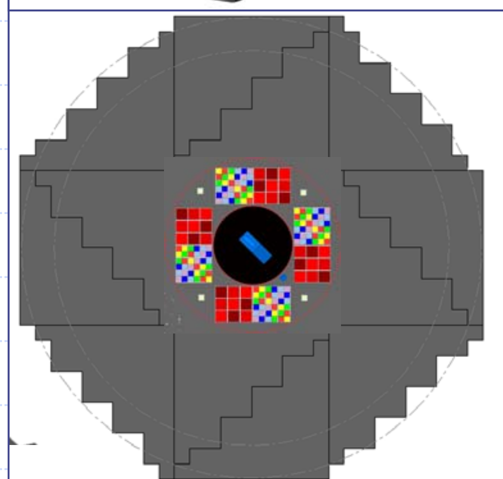
- Shear power co-spectra vs. redshift on large angular scales are a powerful probe of dark energy (and many other things).
- Supernovae and all-sky cosmic shear are complementary probes: both for systematic errors, statistical errors and testing basic cosmological model assumptions.

LSST Project Overview

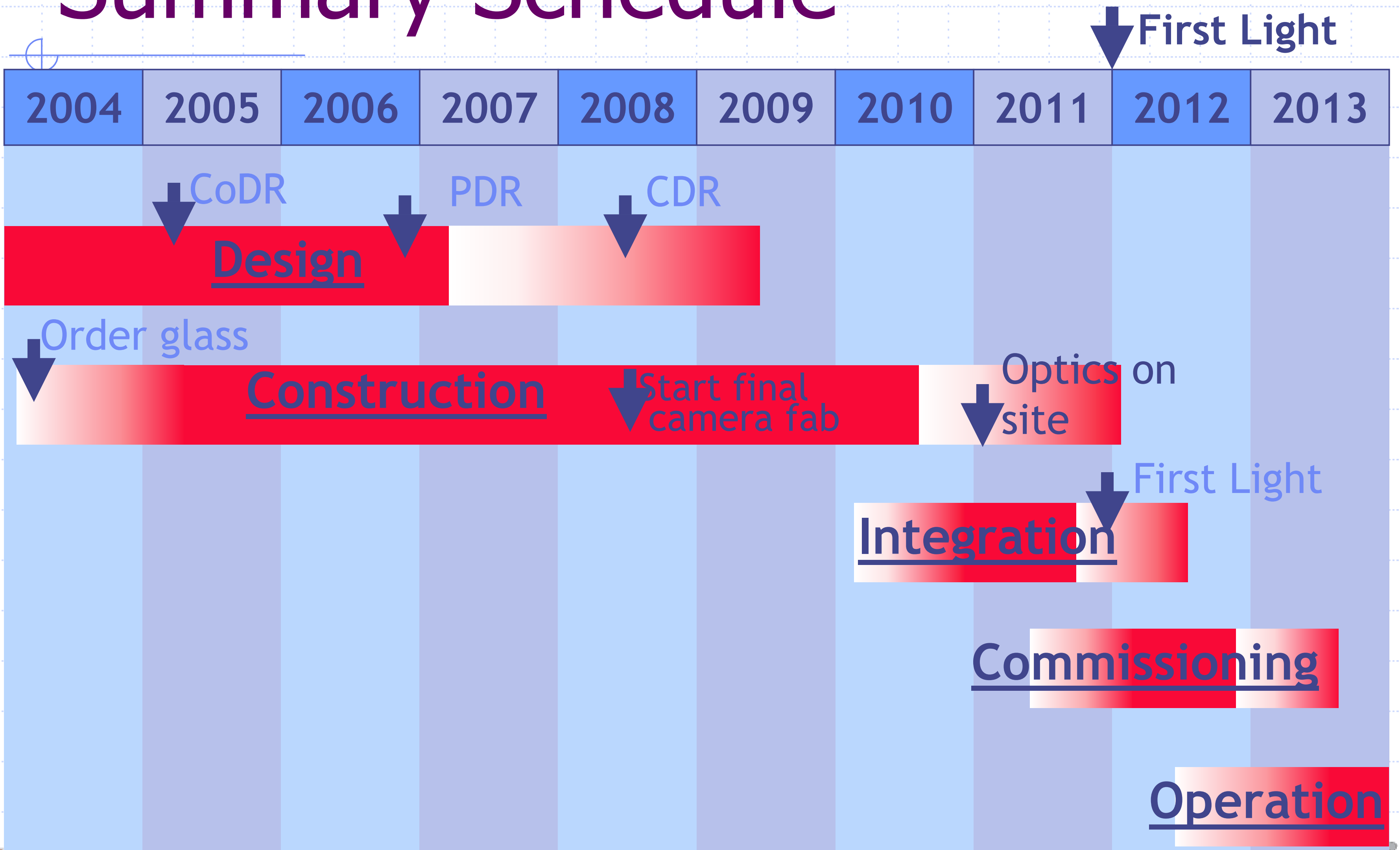
- Ground-based telescope
  - 8.4m diameter f/1, 8.6° field of view
- DOE institutions will deliver the Camera
  - BNL, Harvard, Illinois, LLNL, SLAC
- BNL will deliver the Focal Plane Array
  - 2.8 Gigapixel CCD or CMOS array
  - BNL expertise in large Si detectors & low-noise electronics
- First light 2011-2012



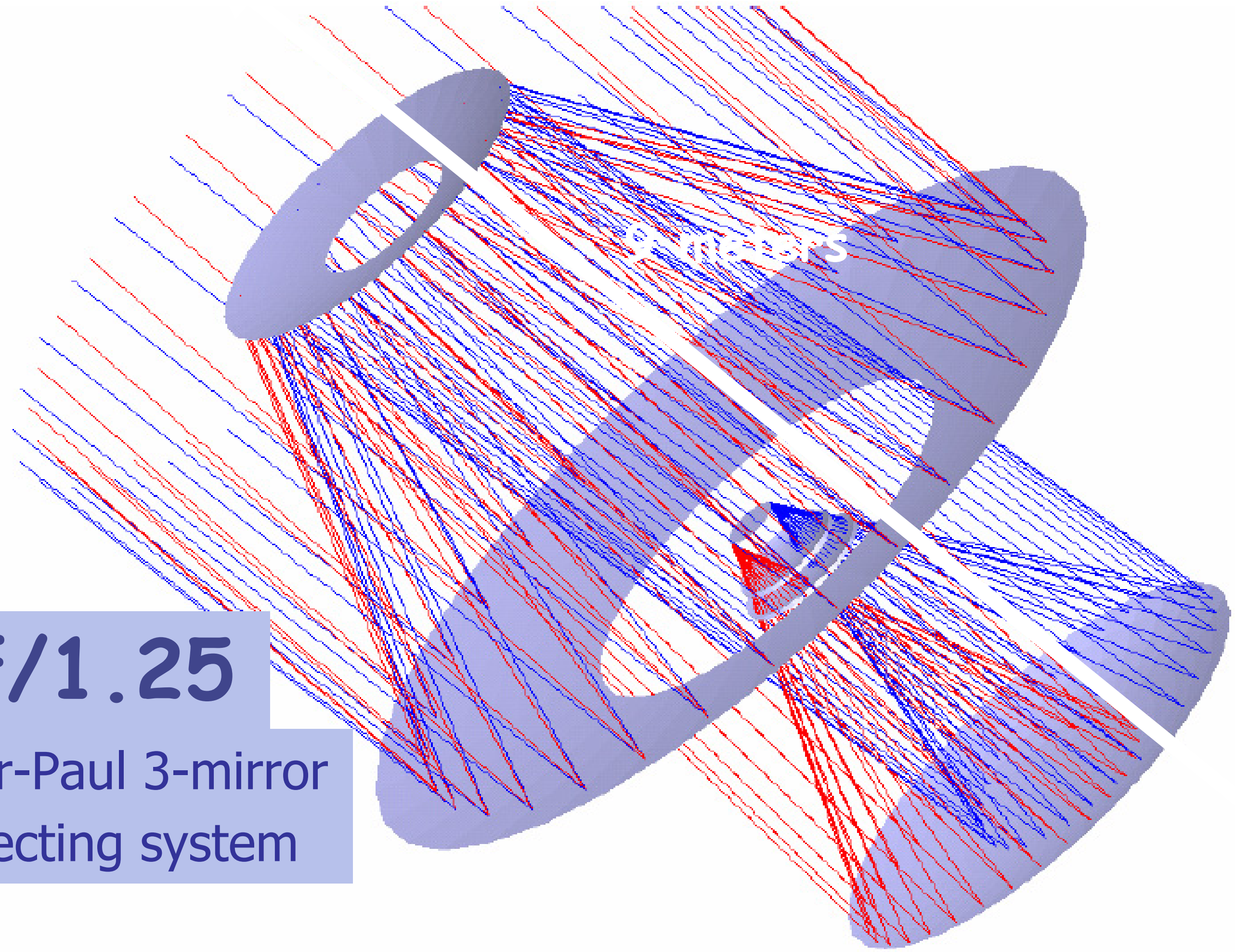




Summary Schedule



Schematic optics design



f/1.25

Baker-Paul 3-mirror reflecting system

Primary Mirror

- University of Arizona Mirror Lab
- 8.4m spun-cast borosilicate glass

LSST Data Rates

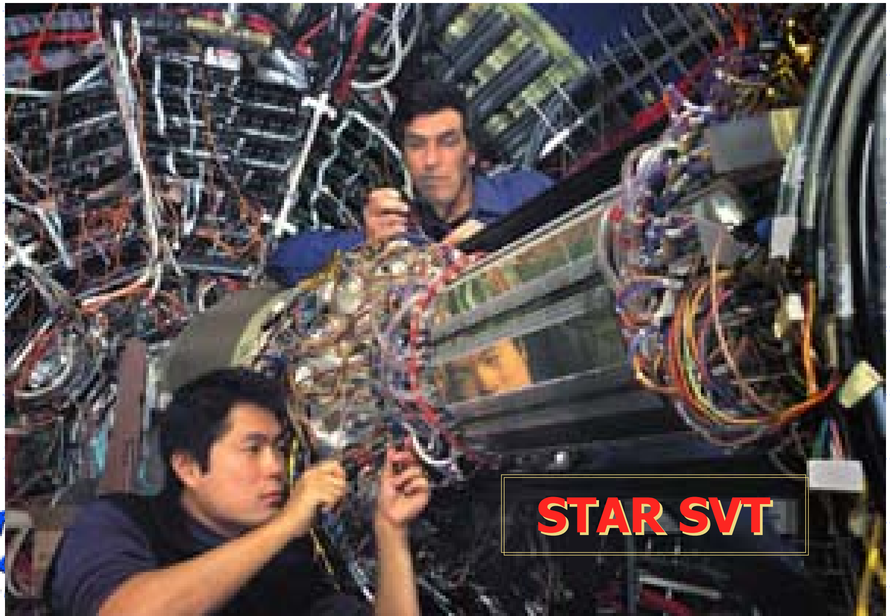
- 2.8 Gpixels read out in < 2 sec, every 12 sec
- Dynamic range: 4 Bytes/pixel
- Over 3 GBytes/sec peak raw data from camera
- Real-time processing and transient detection: < 10 sec
- > 0.6 GBytes/sec average in pipeline
- Real-time reduction requires ~ 140 Tflops peak
- Data rate is comparable to ATLAS on LHC.

Camera Challenges

- Detector requirements:
  - 10 μm pixel size
  - Pixel full-well > 90,000 e^-
  - Low noise (< 5 e^- rms), fast (< 2 sec) readout (→ < –30°C)
  - High Quantum Efficiency 400 – 1000 nm → ≥ 100μ Si
  - All of above exist, but not simultaneously in one detector
- Focal plane position precision of order 3 μm
- Package large number of detectors, with integrated readout electronics, with high fill factor and serviceable design
- Large diameter filter coatings
- Constrained volume (camera in beam)
  - Makes shutter, filter exchange mechanisms challenging
- Constrained power dissipation to ambient
  - To limit thermal gradients in optical beam

Si Detector Development and Processing at BNL

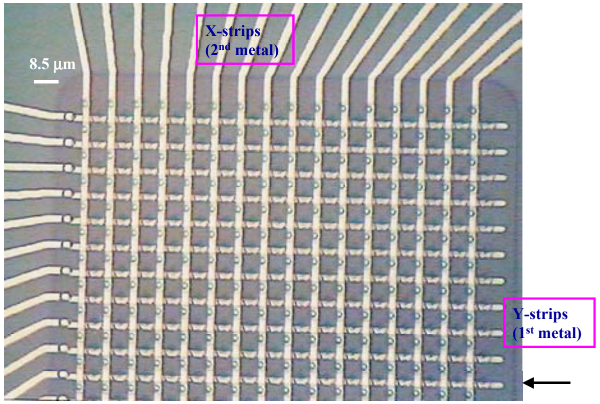
- **Instrumentation Division has**
  - **A unique ability within the DOE labs and US universities to fabricate complex silicon detector devices**
    - **The highest sensitivity low noise ICs**
  - **Experience designing Si pixel detectors with low noise ASIC readout for RHIC and ATLAS**
  - **Experience in large-scale integration of Si-based detectors:**



Novel Detectors

- **Stripixel detectors**

  1-sided 2D position sensing (PHENIX barrel VTX)

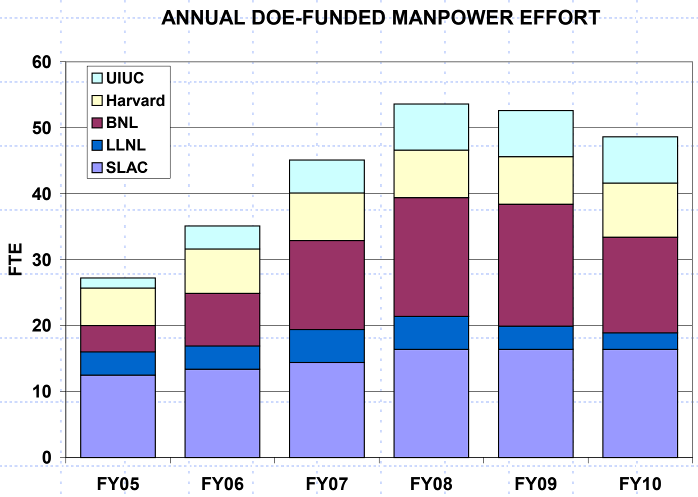


- **Active matrix pixel sensors**
- **Edgeless detectors**
- **Semi-3D rad-hard sensors**

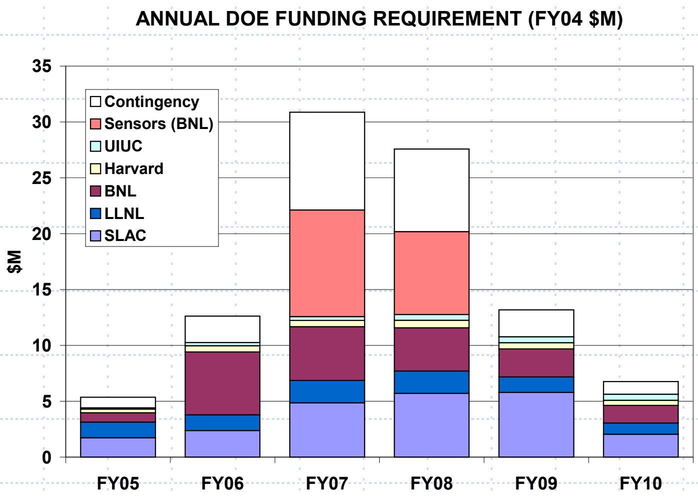
LSST Camera Project Organization

- **Camera**
  S. Kahn, Sci Lead
  W. Althouse, Proj Mgr
  - **Camera Project Support**
    - Project Controls & Risk Mgmt
    - Performance & Safety Assur.
    - Administration
  - **System Engineering**
    T. Thurston, SLAC
  - **Lead Mech. Engr**
    T. Decker, LLNL
  - **Lead Elect. Engr**
    J. Oliver, Harvard
  - **Focal Plane Assy**
    S. Aronson, BNL
  - **Optics**
    S. Olivier, LLNL
  - **Mechanisms**
    L. Hale, LLNL
  - **Thermal & Structural**
    T. Thurston, SLAC
  - **Control S/W**
    J. Thaler, UIUC
  - **Camera I&T & Sup. Equip.**
    W. Craig, SLAC

DOE Manpower



DOE Funding

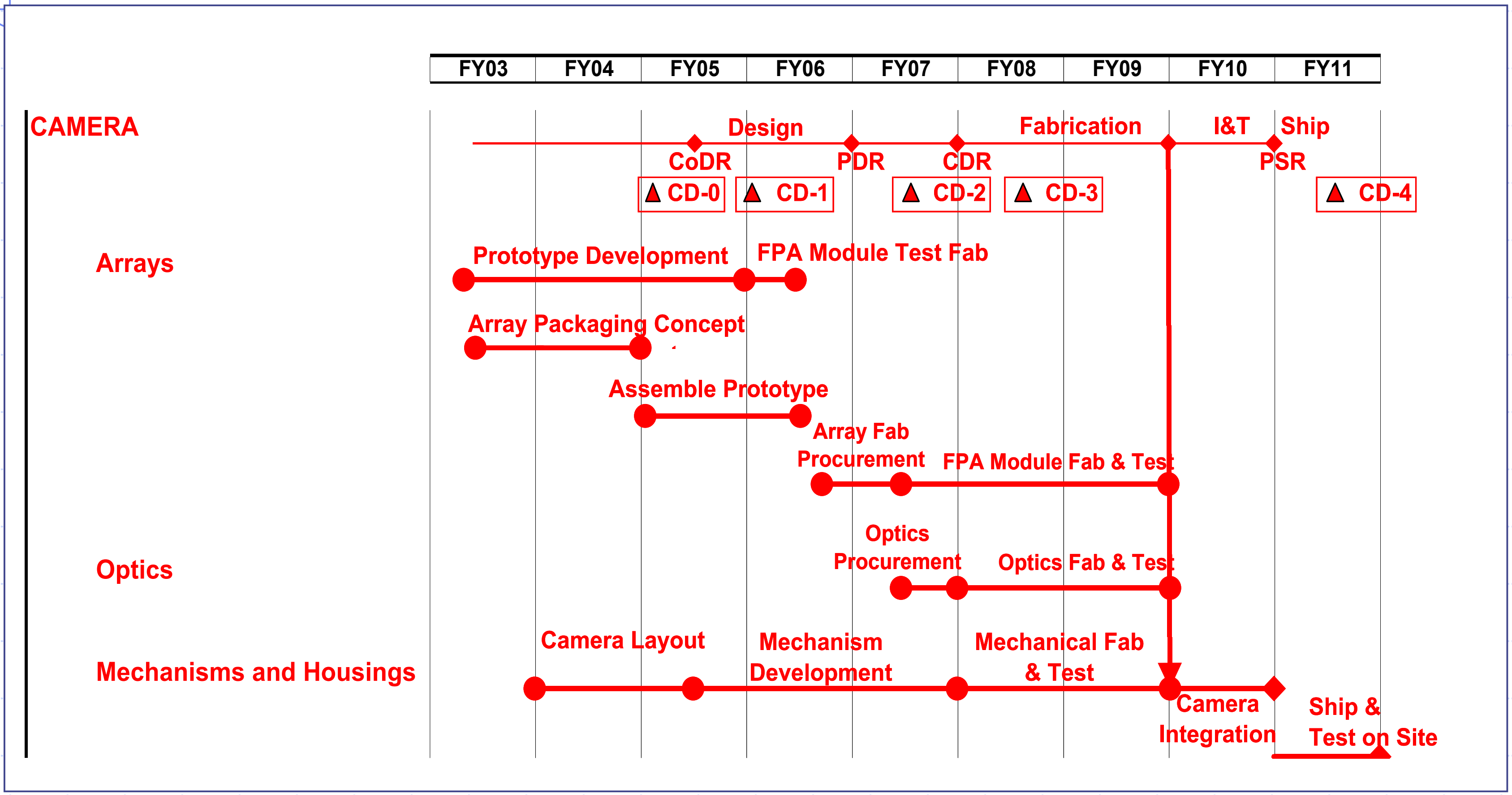


31% Contingency

DOE Manpower & Funding

	FY05	FY06	FY07	FY08	FY09	FY10	TOTAL
Manpower FTEs (includes manpower contributed by DOE-funded institutions)							
SLAC	*12.5*	*13.4*	*14.4*	*16.4*	*16.4*	*16.4*	*89.5*
LLNL	*3.5*	*3.5*	*5.0*	*5.0*	*3.5*	*2.5*	*23.0*
BNL	*4.0*	*8.0*	*13.5*	*18.0*	*18.5*	*14.5*	*76.5*
Harvard	*5.7*	*6.7*	*7.2*	*7.2*	*7.2*	*8.2*	*42.2*
UIUC	*1.5*	*3.5*	*5.0*	*7.0*	*7.0*	*7.0*	*31.0*
Total Manpower, FTEs	***27***	***35***	***45***	***54***	***53***	***49***	***262***
Estimated Cost (FY04 $M)							
SLAC	$1.7	$2.4	$4.9	$5.7	$5.8	$2.1	$22.5
LLNL	$1.4	$1.4	$2.0	$2.0	$1.4	$1.0	$9.2
BNL	$0.8	$5.6	$5.3	$4.3	$2.5	$1.6	$20.2
Harvard	$0.3	$0.6	$0.6	$0.7	$0.6	$0.5	$3.1
UIUC	$0.1	$0.3	$0.3	$0.5	$0.5	$0.5	$2.3
Sensors (BNL)			$9.5	$7.4			$17.0
Total Estimated Cost	**$4**	**$10**	**$23**	**$21**	**$11**	**$5**	**$74**
Proposed Contingency (FY04 $M) (to be held at LSST project level)							
Contingency	**$1**	**$2**	**$9**	**$8**	**$2**	**$1**	**$23**

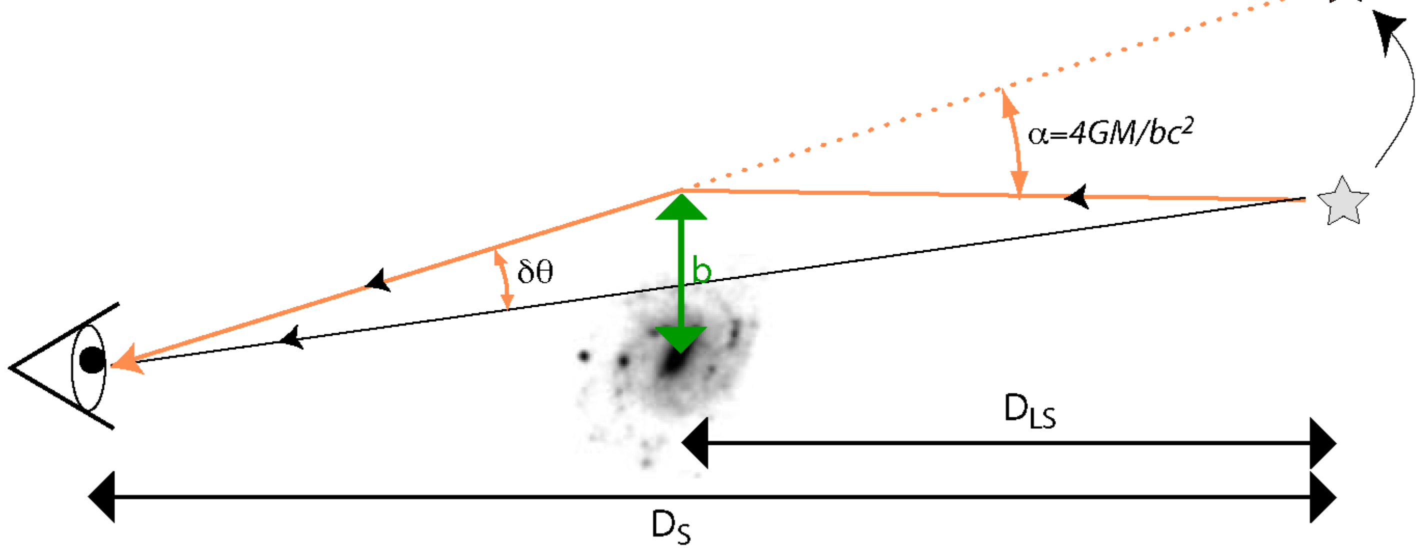
Summary Camera Schedule



Additional material….

Lensing and cosmology

Cosmological Dependence of Lensing Deflections



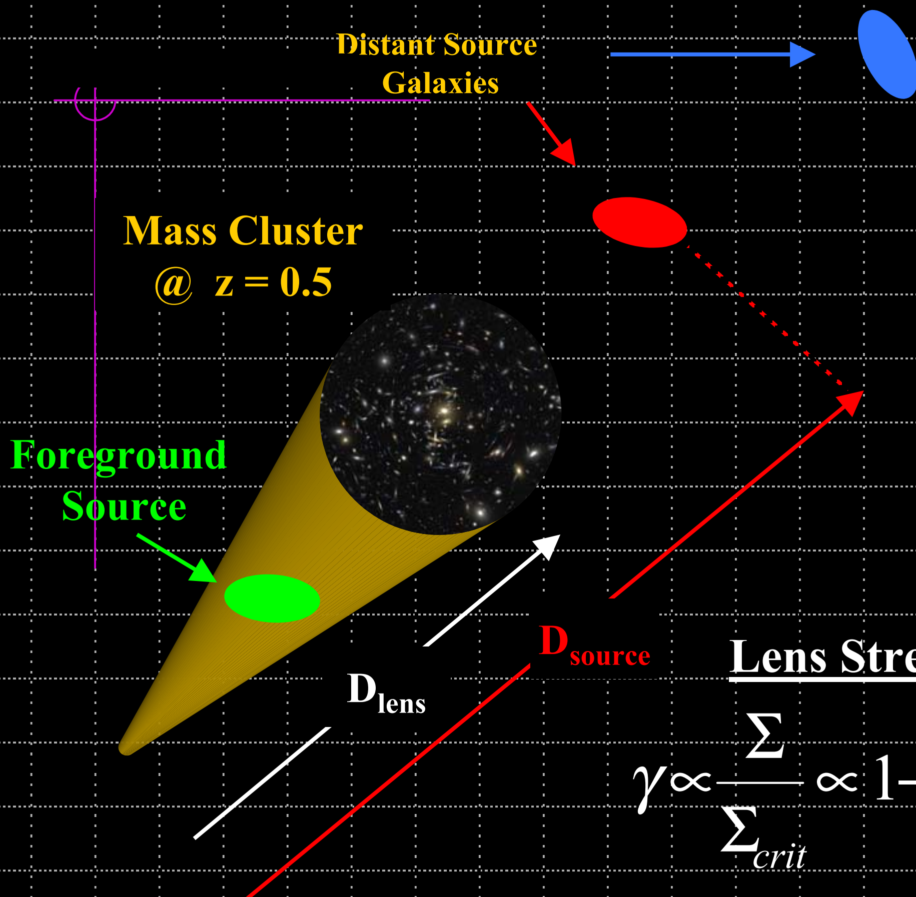
$$\delta\theta = \frac{4GM}{bc^2} \quad \frac{D_{LS}}{D_S}$$

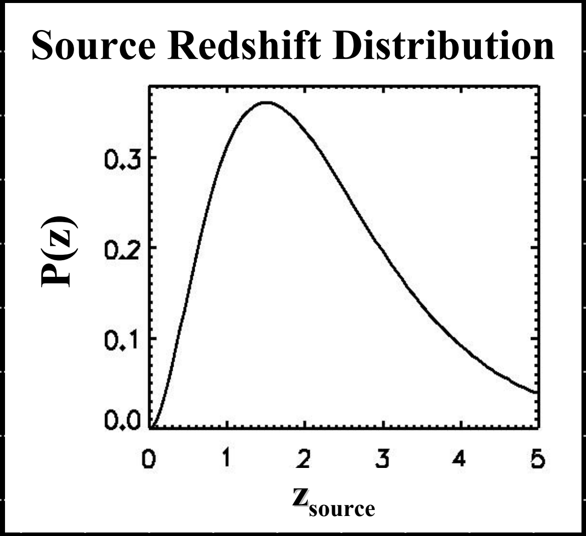
We observe this deflection angle (more precisely, gradients of the deflection angle).

Cosmology changes growth rate of mass structures in the Universe.

Cosmology changes the geometric distance factors.

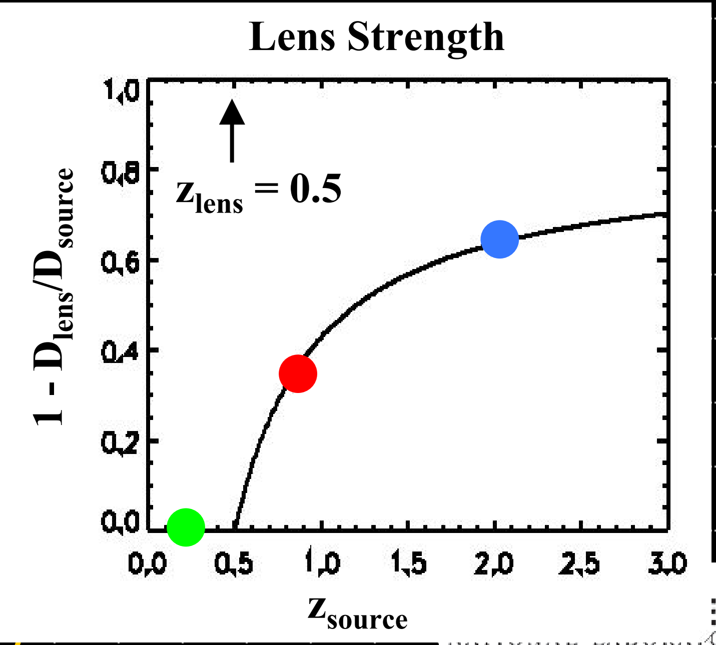
Cluster Tomography





Lens Strength

$$\gamma \propto \frac{\Sigma}{\Sigma_{crit}} \propto 1 - \frac{D_{lens}}{D_{source}}$$

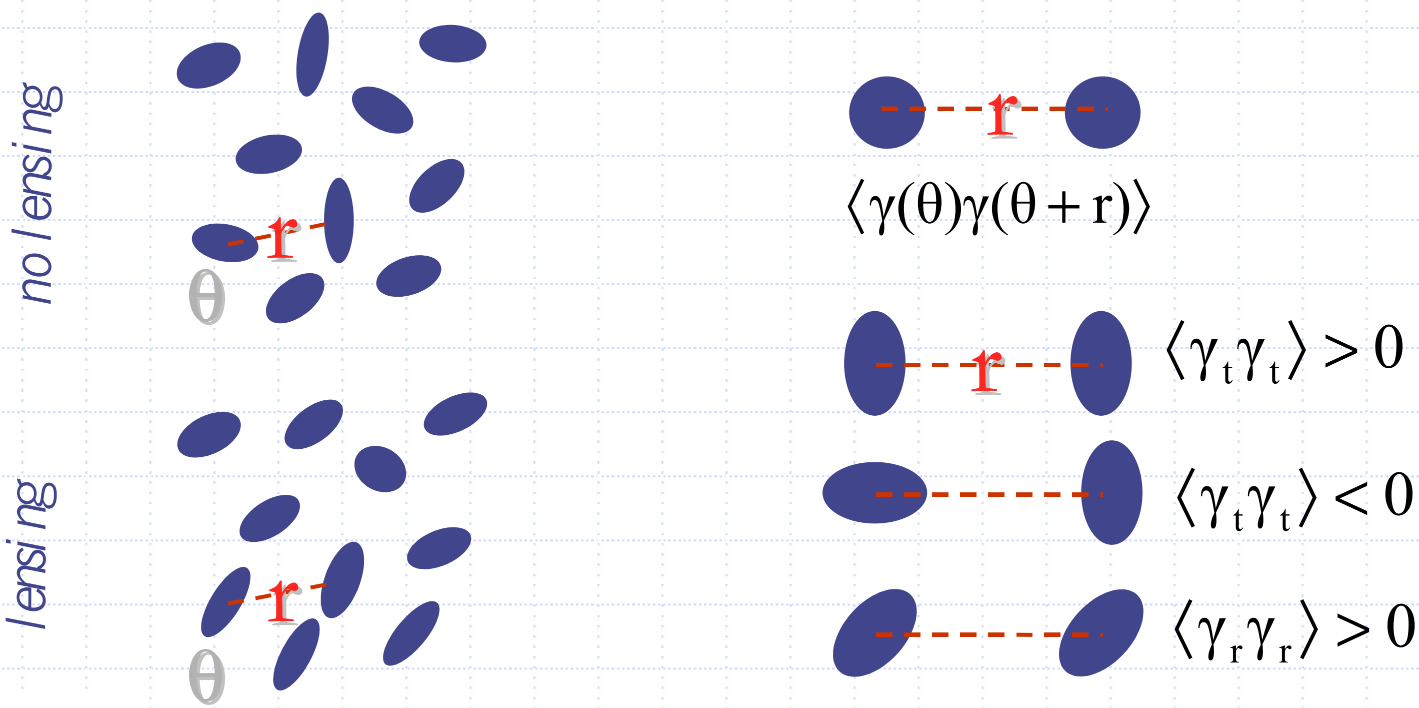


The blue galaxy is sheared more than the red galaxy.

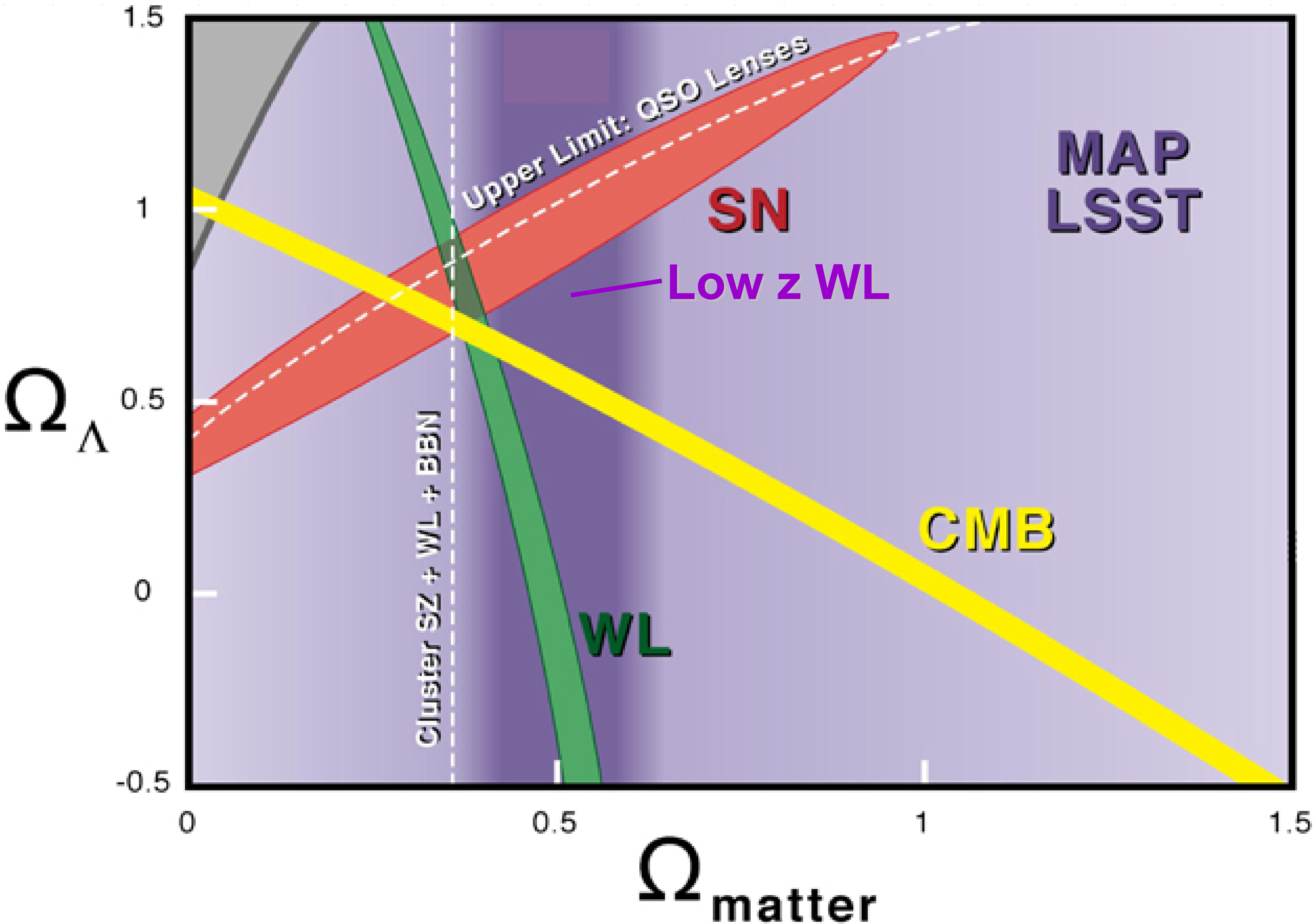
The green galaxy is not sheared.

What do we measure from the data?

- To quantify the cosmic shear signal we use the ellipticity correlation functions. The results
  - do not depend on survey geometry.
  - provide a measure of the residual systematics.

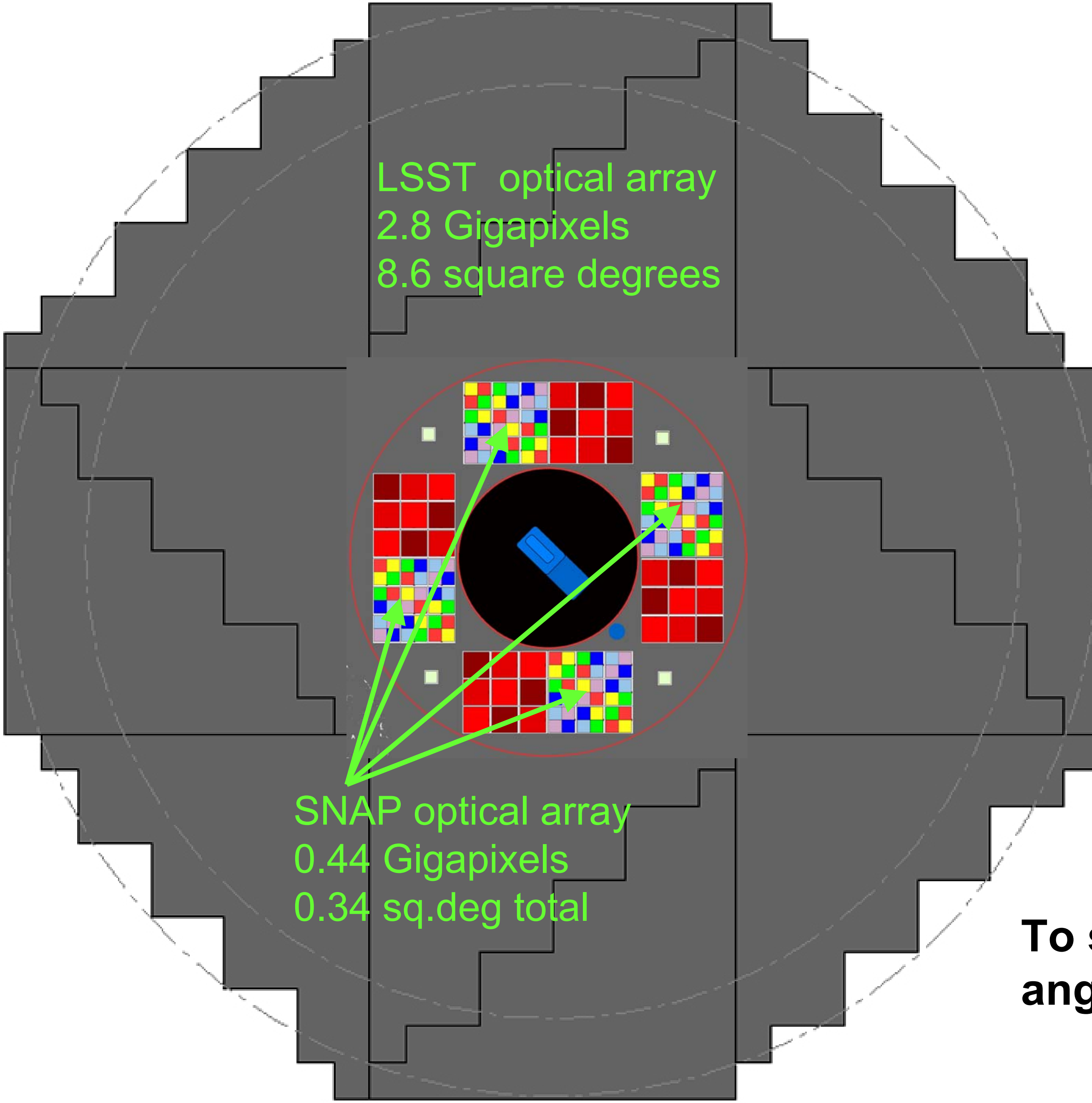


LSST Weak Lensing survey



Camera Components

- Focal plane array
  - 10 μm pixels → 0.2 arcsecond/pixel (~1/3 seeing-limited PSF)
  - 60 cm diameter → 8.6 square degree FOV→ 2.8 Gpixels
  - Integrated front-end electronics
  - 2.8 GB/sec → parallel readout
- Housings (environmental control)
- Filters
- Optics
- Mechanisms
  - L2 position varies with wavelength (filter)
  - Filter insertion
  - Mechanical shutter



To same angular scale