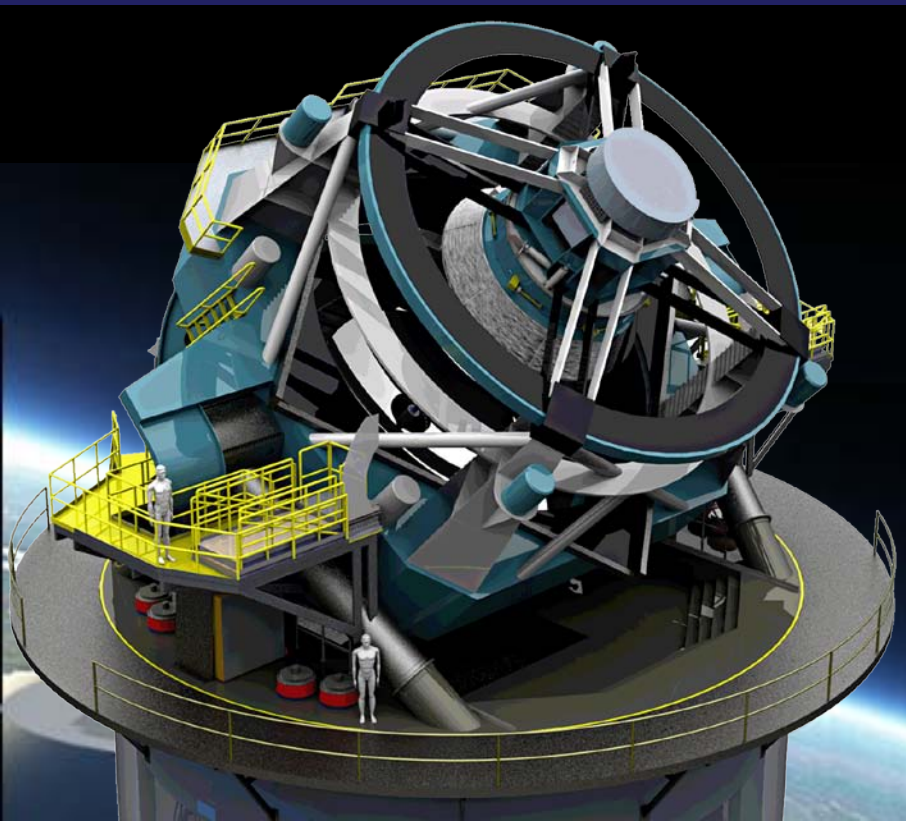
LARGE SYNOPTIC SURVEY TELESCOPE

AZ AAPT
March 2011

Forming a comprehensive summary



Dr. Charles F. Claver

Outline

- An Brief Introduction to LSST
- An Overview of the Science Behind LSST
  - Dark Energy and Weak Lensing
  - Mapping the Solar Neighborhood
  - Opening the Time Domain
  - The Formation History of the Galaxy
- Technical Summary of the 8.4m LSST
  - The Telescope & Site
  - The Camera
  - Data Reduction and Analysis
- Why LSST Matters for Educators

For more information see: www.lsst.org

Introducing the Large Synoptic Survey Telescope

- 8.4 M Primary Aperture
- 3.5 Degree Field Of View
- 3.2 Billion Pixel Camera
- ~40 Second Cadence
  - Two 15 second Exposures
  - Full Sky Coverage Every 4 nights
- Public Data
  - Alerts of New Events
  - Catalogs of Object
  - Archives of Images
- Telescope Located on Cerro Pachón, Chile
- Operations Center Located in La Serena, Chile

LSST is designed to image the whole sky every 4 nights for 10 years, giving us a movie like window into our dynamic Universe.

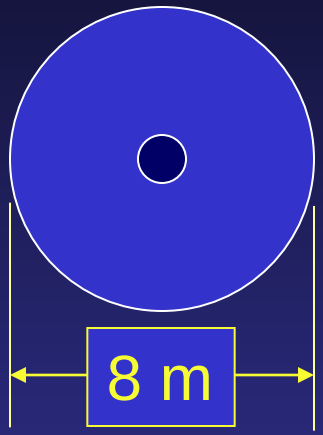
Why is the LSST unique?

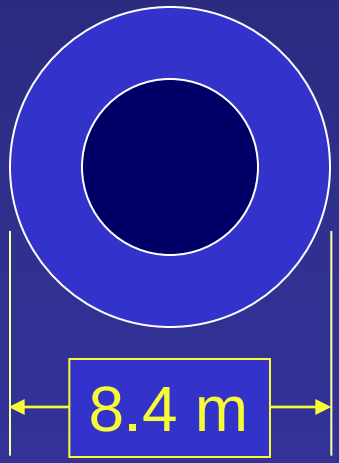
Large Synoptic Survey Telescope

Gemini South Telescope

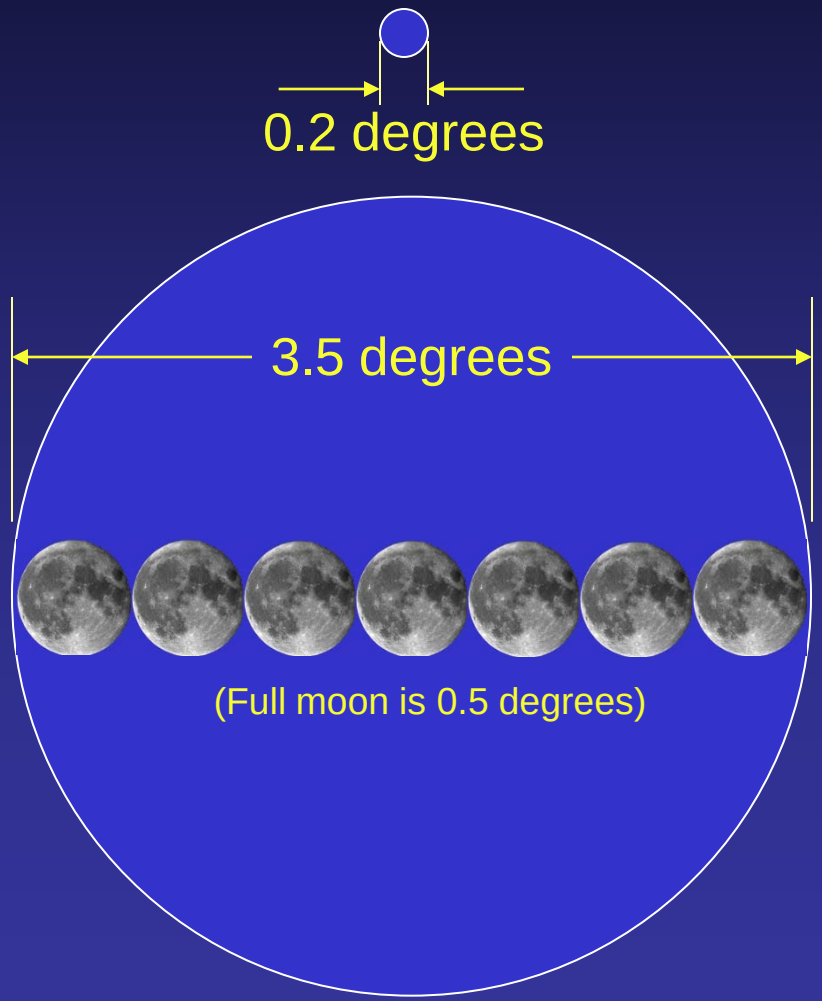
LSST

Primary Mirror Diameter

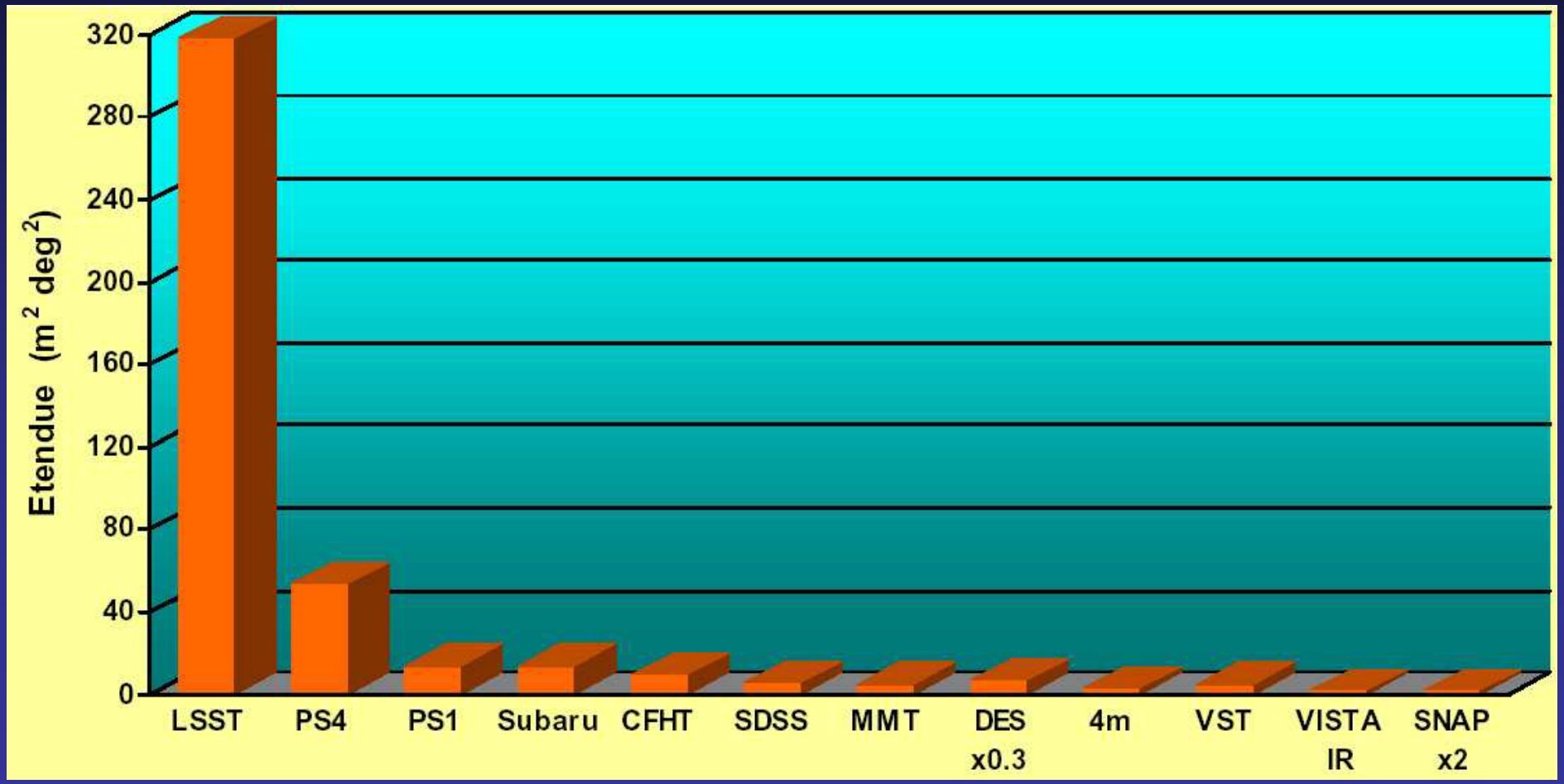




Field of View



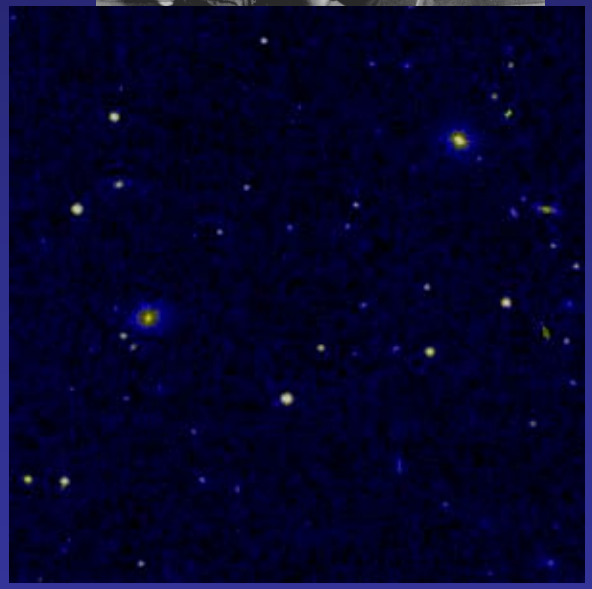
LSST will have by far the highest information throughput of any telescope



LSST is the next great advance to our vision and will answer a wide range of today's pressing questions in cosmology and fundamental physics

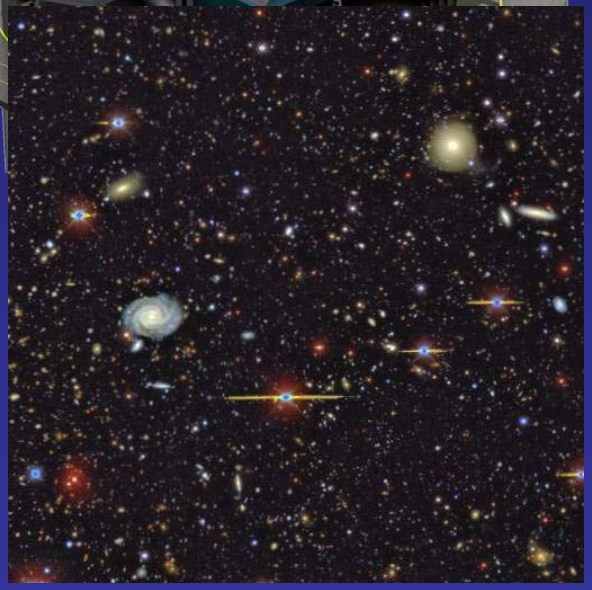
Large Synoptic Survey Telescope

ca. 1950 POSS
(Photographic)



ca. 2000 SDSS
(Digital)

ca. 2014 LSST
(Digital + Time Domain)



LSST probes 100x fainter & enables the exploration of the time domain.

Science Behind the LSST

Requirements Driven by:

- Dark Energy / Matter
- Exploring Our Solar System
- Optical Transients and Time Domain
- Formation and Structure of our Milky Way galaxy

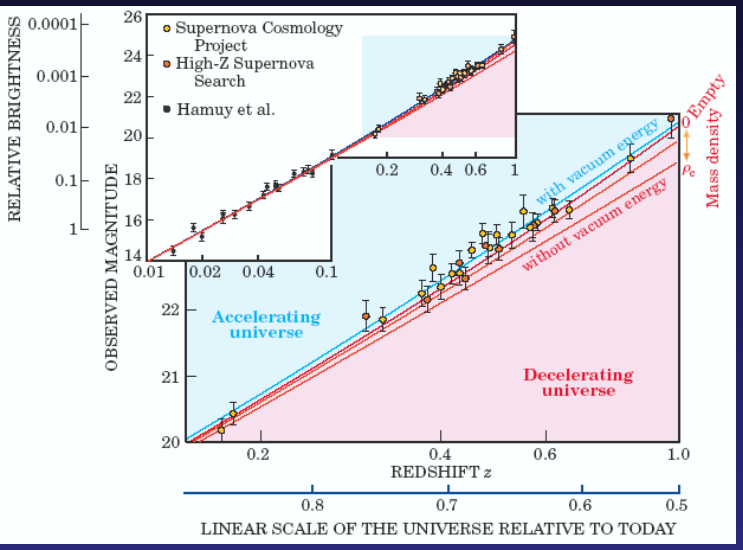
Motivated by Massively Parallel Astrophysics

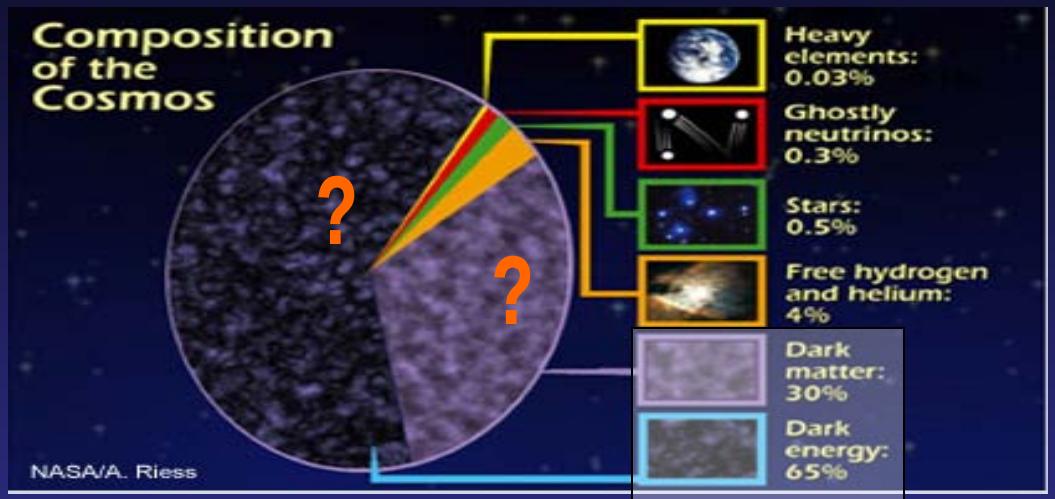
- Many simultaneous investigations are enabled by the LSST.
- Details can be found in the LSST Science Book http://www.lsst.org/lsst/scibook.

Cosmology: A Standard Model

- Type 1a SN

[Tonry *et al.* (2003), Knop *et al.* (2003), Perlmutter *et al.* (2003) + others]

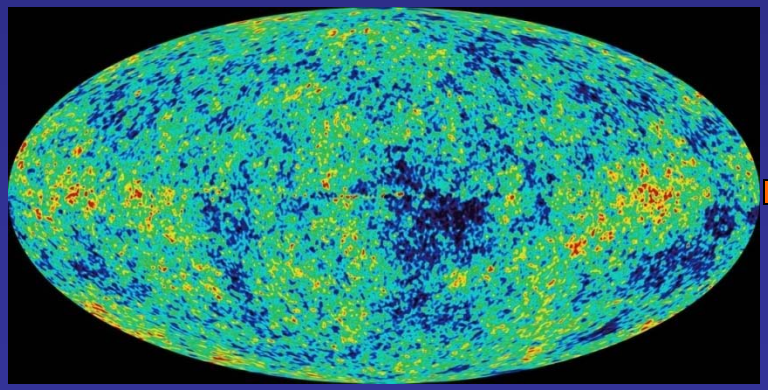


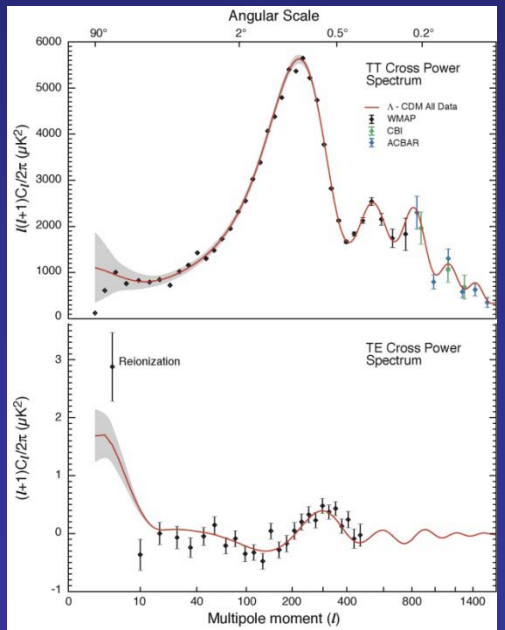


95% !!!

- **WMAP CMB** +

[Spergel *et al.* + references therein]

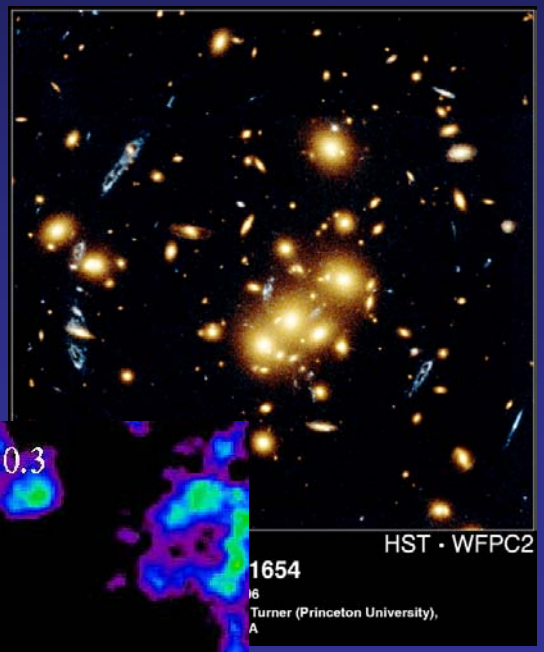


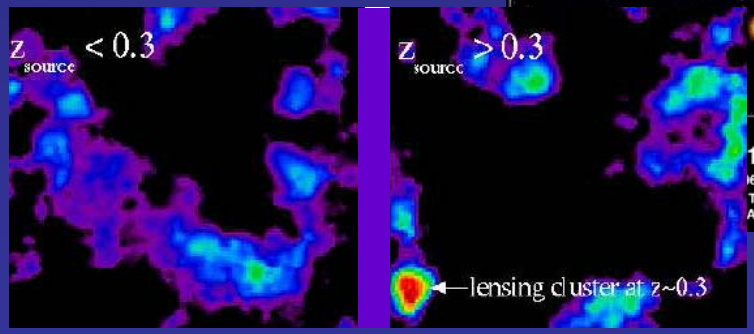


=Flat Universe

Cosmology: Questions today

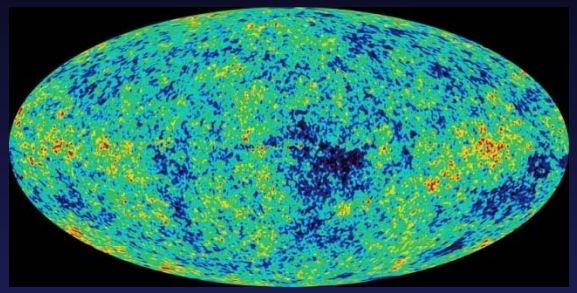
- **Dark Energy**
  - **What is it?**
  - **What is its equation of state, w=ρ/p?**
  - **Does w evolve with z (time)? If so, how?**
  - **Are there spatial variations? Is it the same everywhere?**
- **Dark Matter**
  - **What is its origin?**
  - **What is its composition?**

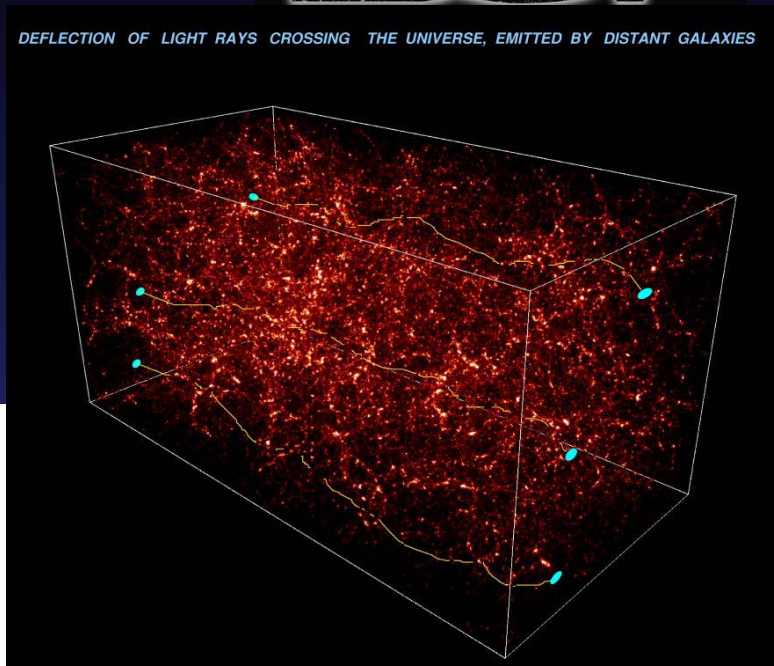


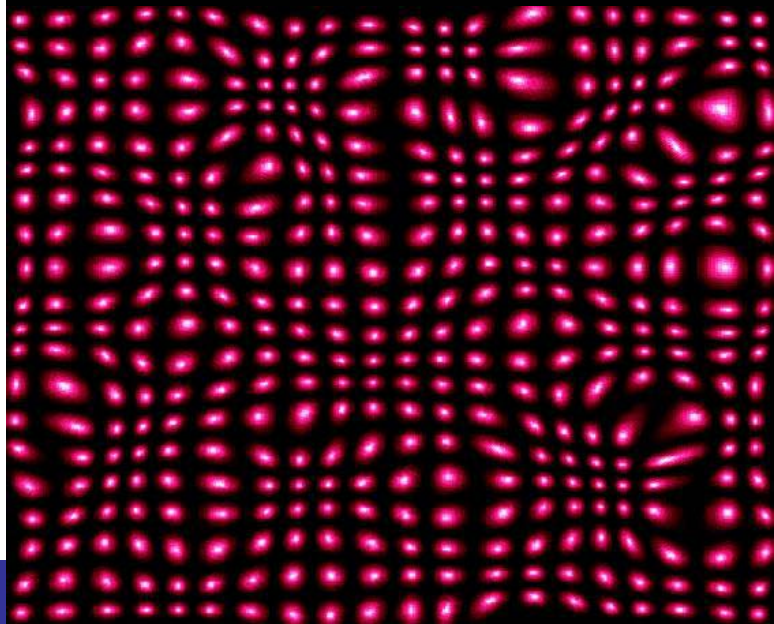


LSST will enable multiple investigations into this mystery, probing below the surface of our understanding of the Universe.

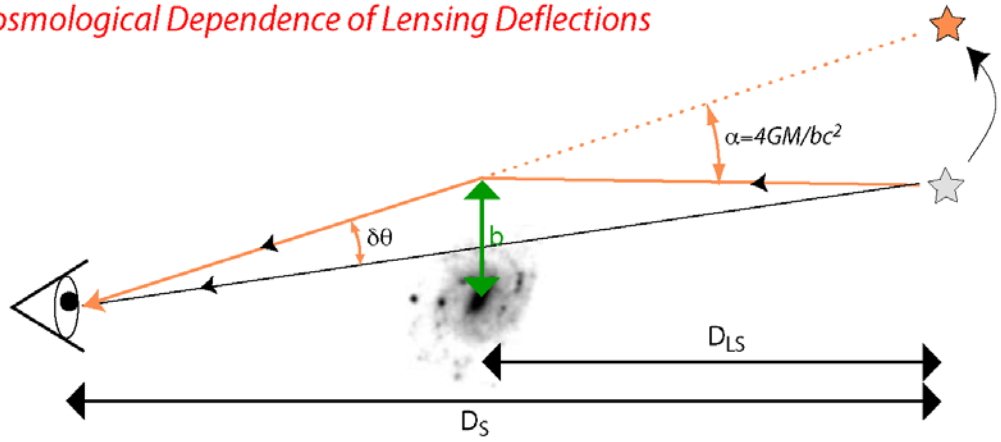
Weak Lensing







Cosmological Dependence of Lensing Deflections



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

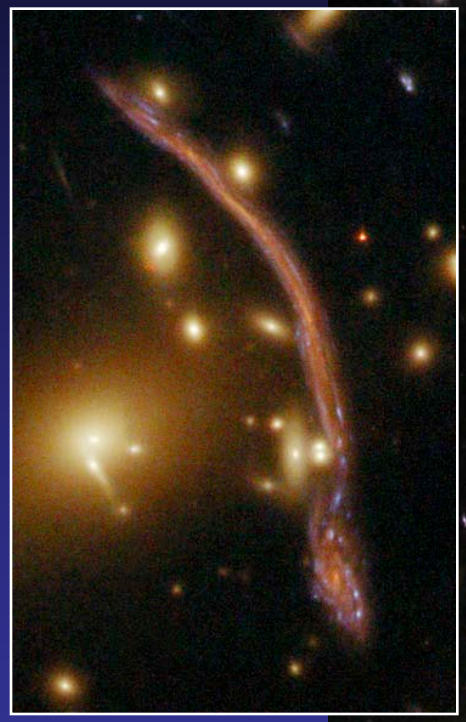
We observe this deflection angle (more precisely, gradients of the deflection angle).

Cosmology changes growth rate of mass structures in the Universe.

Cosmology changes the geometric distance factors.

Gravitational Lensing in Action

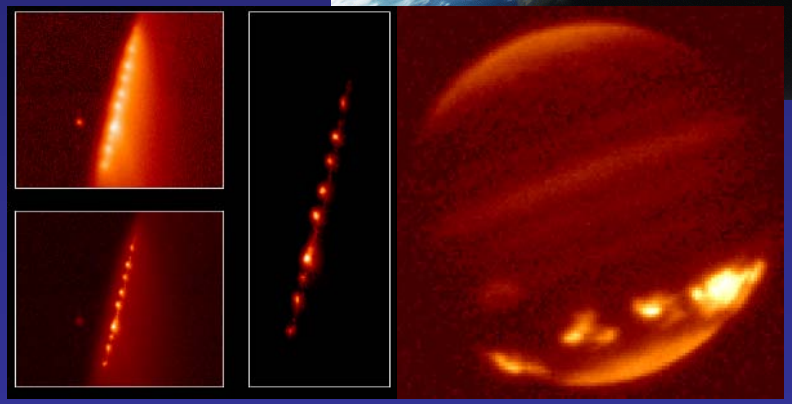
Large Synoptic Survey Telescope



Abell-370

Exploring Our Solar System.

LSST will find 90% of all potentially hazardous asteroids down to 140 meters within first 10 years

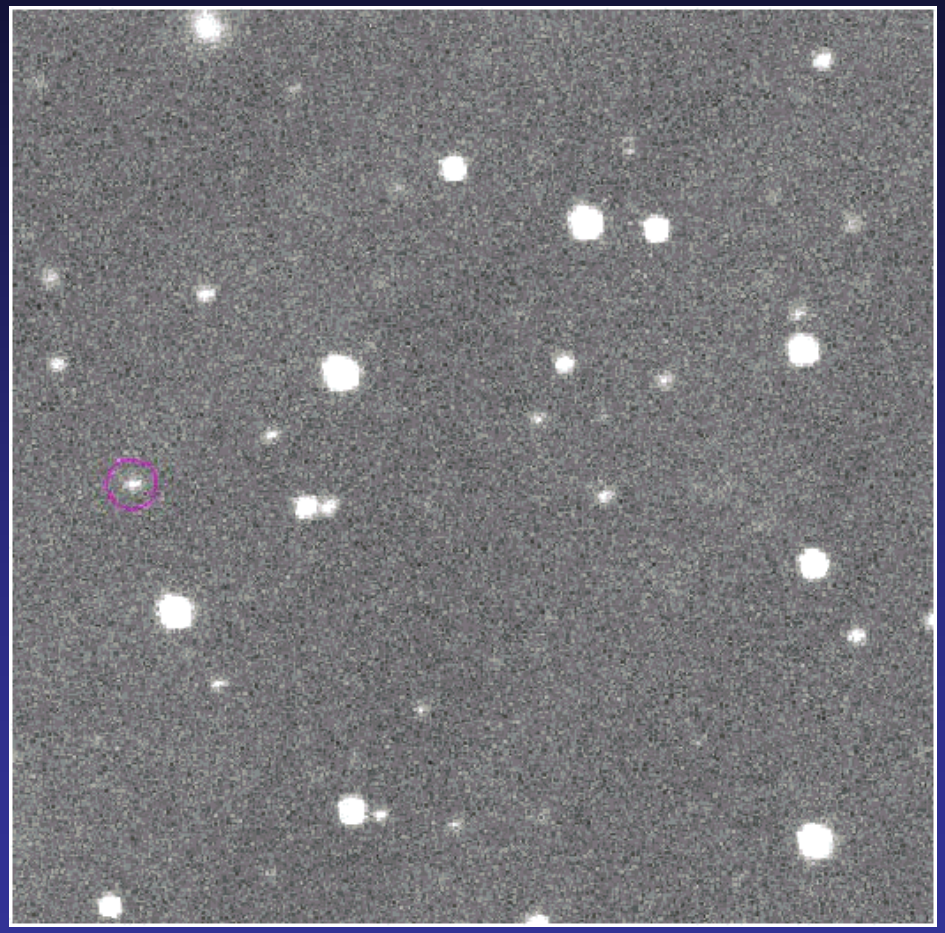


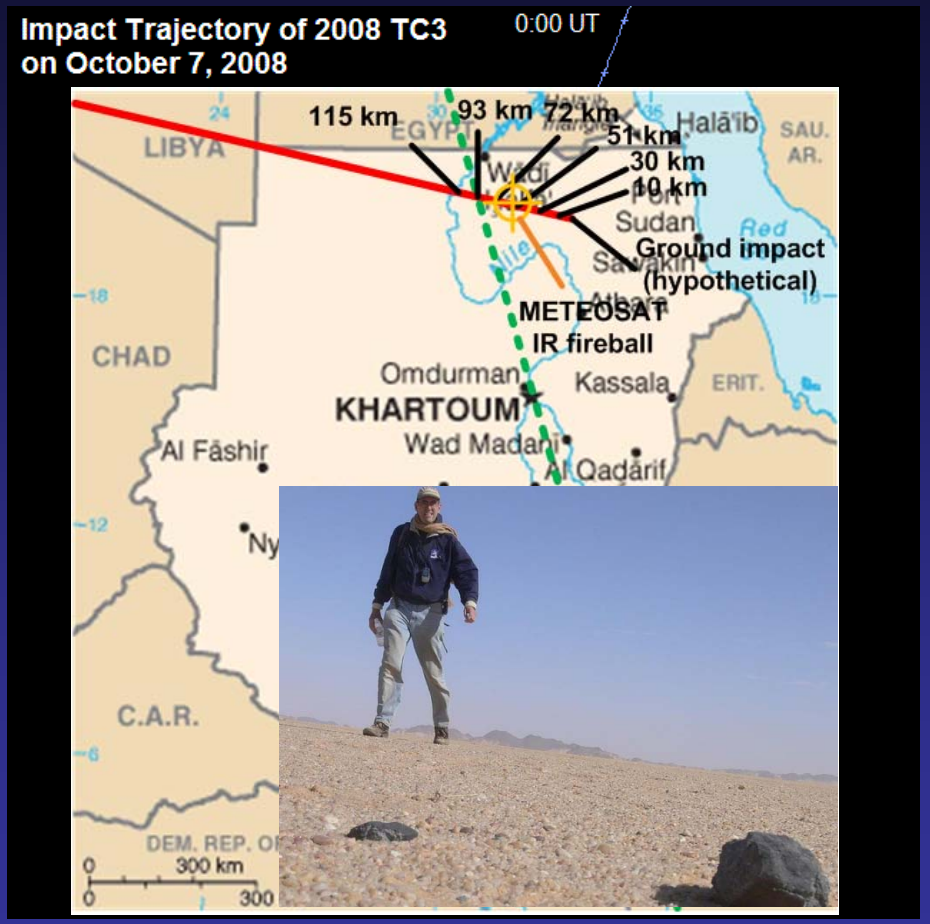
Shoemaker-Levy 9
(1994)

Tunguska
(1908)

Recent Impact of TC3

Discovered by R. Kowalski at the Catalina Sky Survey 1.5m Mt lemmon telescope.





Infrasound and Meteosat detections led to the discovery of TC3 fragments

A “Movie” of the Visible Universe

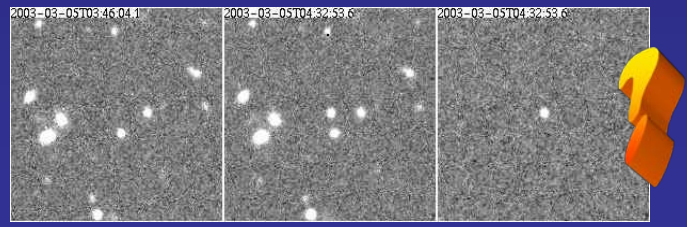
Large Synoptic Survey Telescope

Variable Stars

Exploding Super Novae

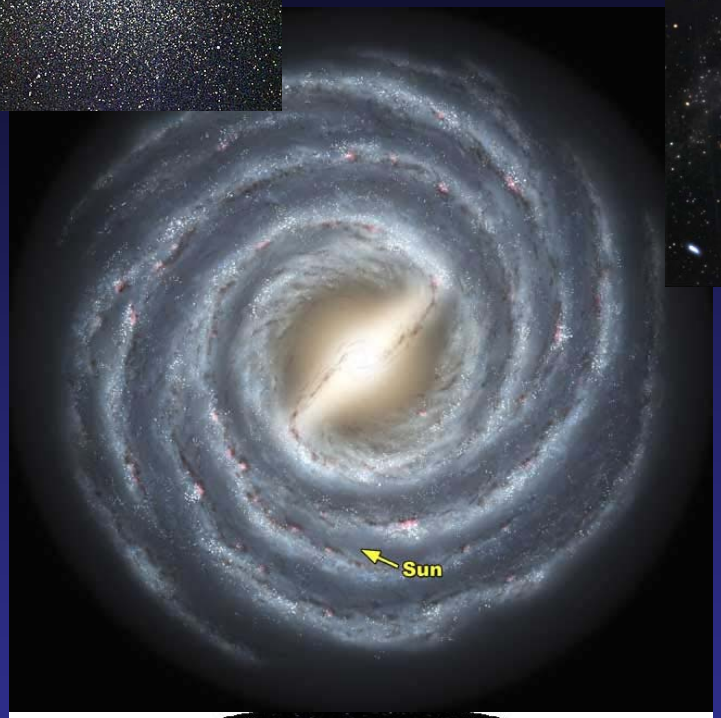
Moving Solar System Objects

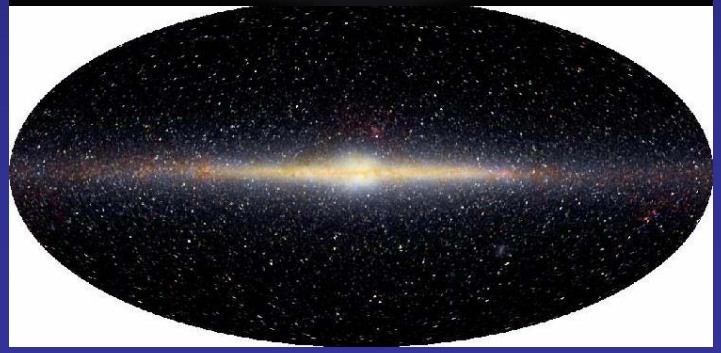
Light Echoes



Discovery of the Unknown

Structure of our Milky Way galaxy



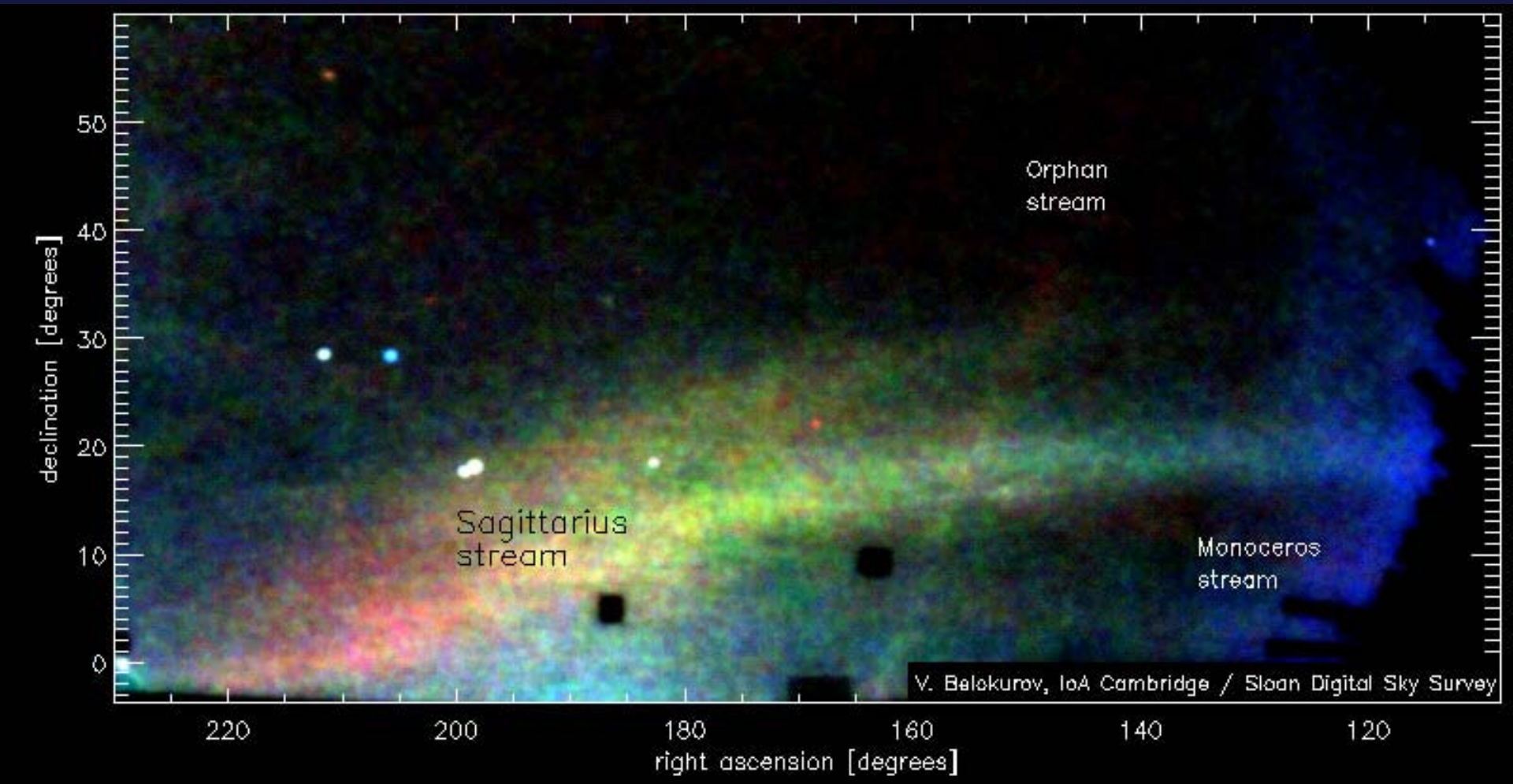


Milky Way Galaxy has a complex history of galactic cannibalism.

8 known residual streams from past mergers.

LSST will map the rich and complex structure of our Galaxy.

A full mapping of streams and dwarf Milky Way satellites

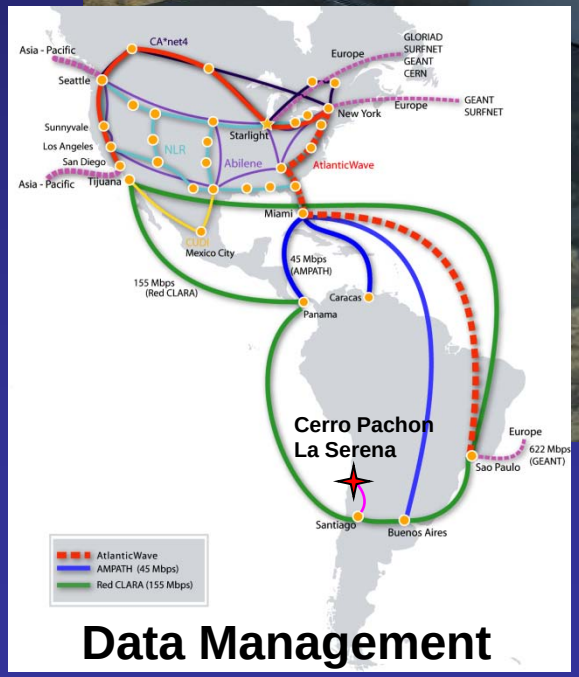


The LSST Project is a complete system:

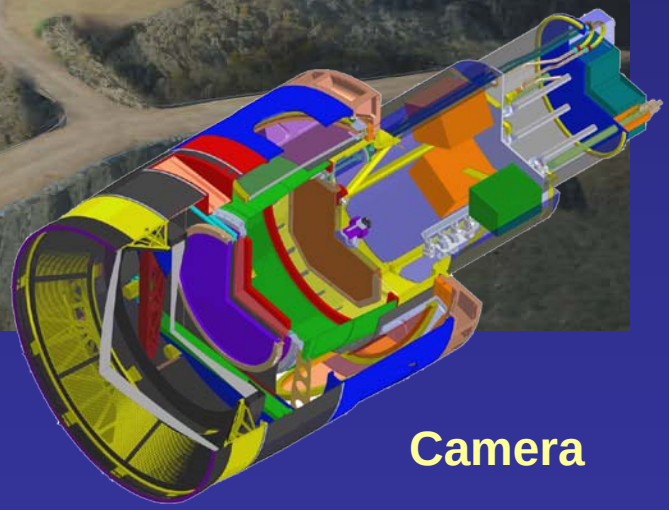
Image, Analyze, Archive, & Publish

Large Synoptic Survey Telescope

Telescope and Site



Data Management



Camera

LSST Site Selected from Worldwide Competitive Search: Cerro Pachón, Chile

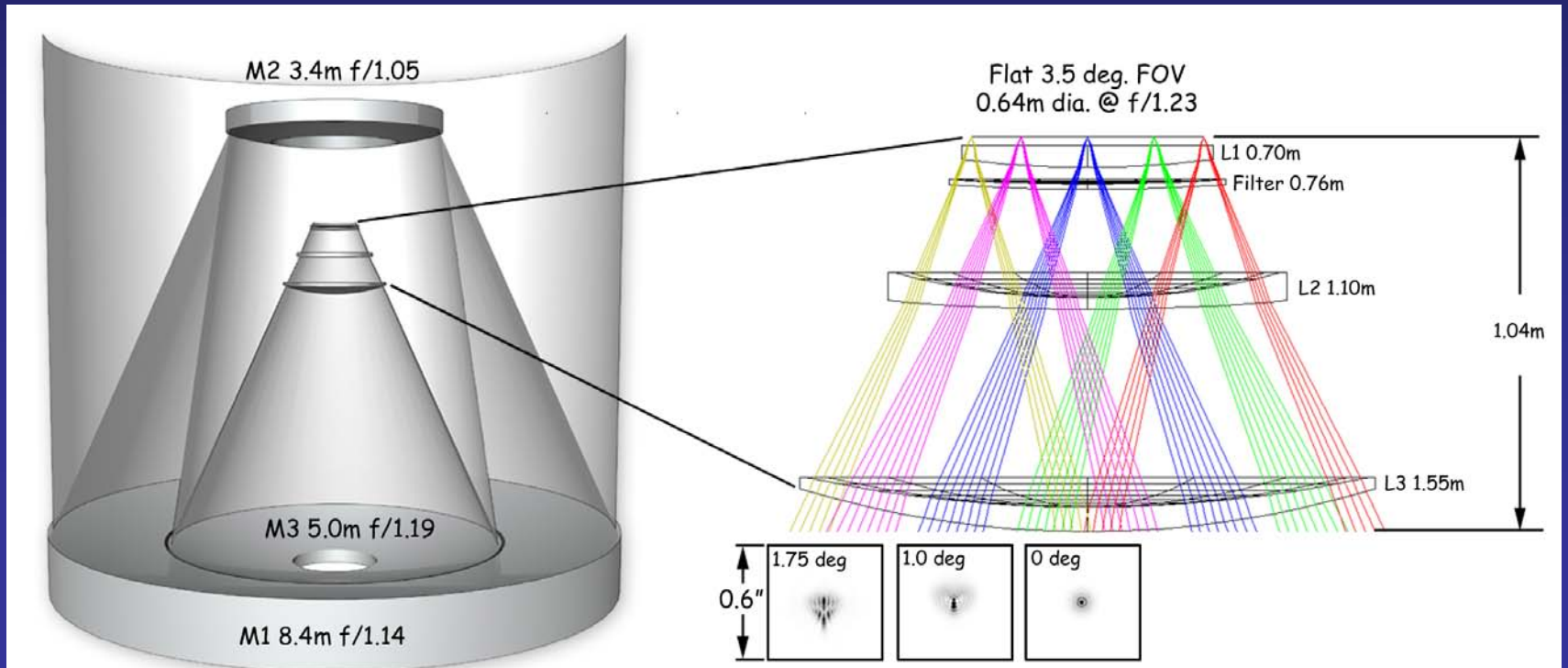
port
Coquimbo
LSST
Base Facility
50 km paved highway
Puclaro
dam & tunnel
Vicuña
AURA
property
(Totoral)
40km dirt road
CTIO
Gemini & SOAR
proposed
LSST SITE
N
0
10
20 km

Site Preparation is Underway

Unique 3-Mirror Optical Design

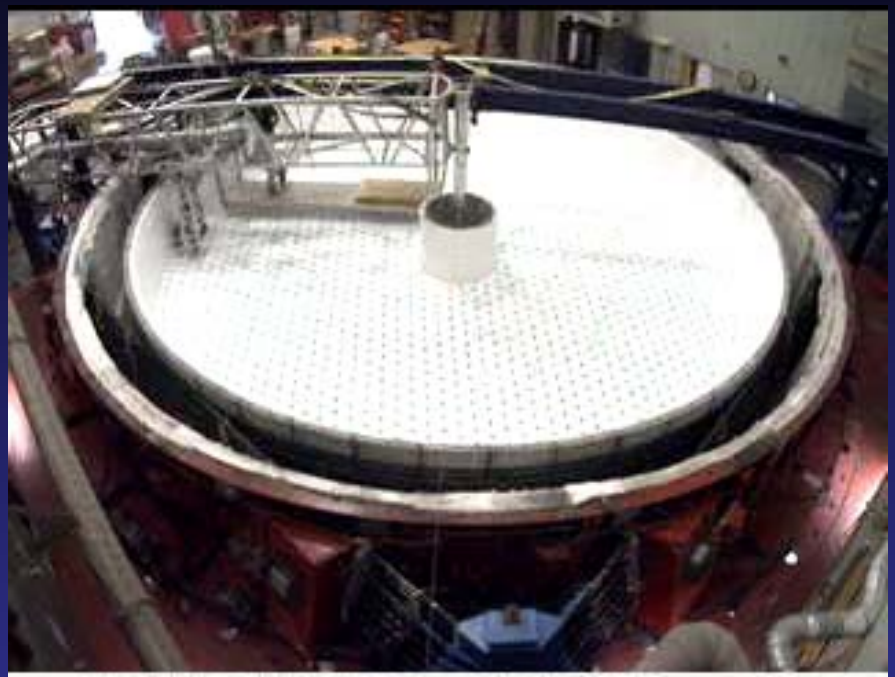
- 3-Mirror Mersenne-Schmidt
- Aperture: 6.7-m effective CA
- FOV: 3.5 deg. dia., 9.6 deg2
- Etendue: 319 m2deg2

Wavelength	80% Encircled Energy
u: 330 - 403 nm	0.26 arcsec
g: 403 - 552 nm	0.26 arcsec
r: 552 - 691 nm	0.18 arcsec
i: 691 - 818 nm	0.18 arcsec
z: 818 - 922 nm	0.19 arcsec
y3: 970 - 1015 nm	0.20 arcsec



The LSST optical system is 3 mirrors and 3 lenses to form 3.5° field of view

Primary-Tertiary Mirror casting at the University of Arizona



How to bake (make) a mirror:

- Make mold
- Add 30,000 lbs glass
- Close lid, bake on high at 1200C
- and spin at 6.7 rpm for 2-days
- Lower temperature to 500C, cool slowly (35 days) to 375C
- Slowly (90days) bring to room temperature
- Open oven lid and serve

First view of finished casting:

24 July 2008

M1M3 front surface generation completed – M3 Appears!

M2 Substrate purchased and completed by Corning using LSST non-federal funding

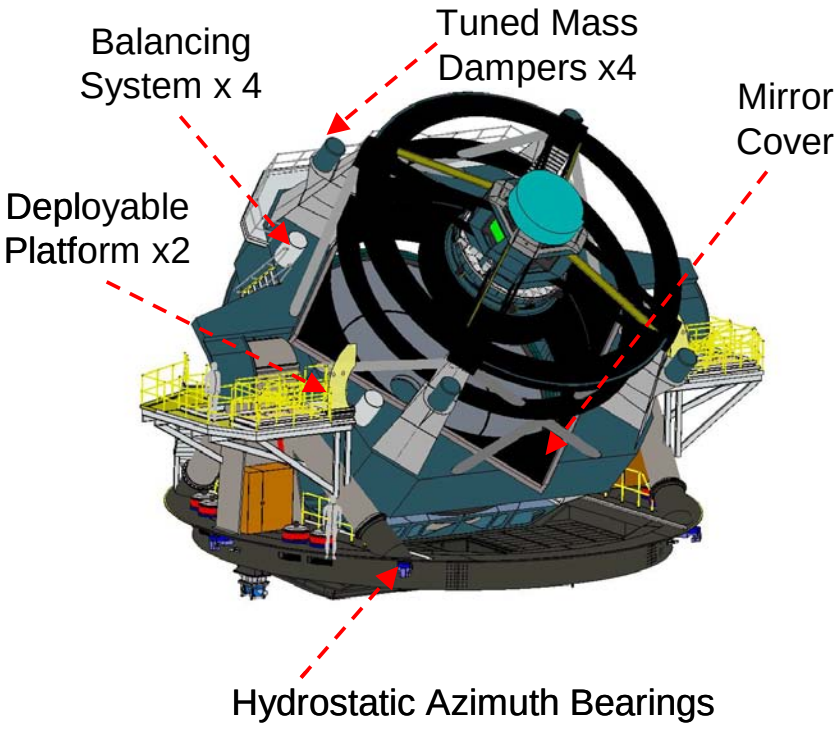
The Tucson based telescope team continues detailed mount development

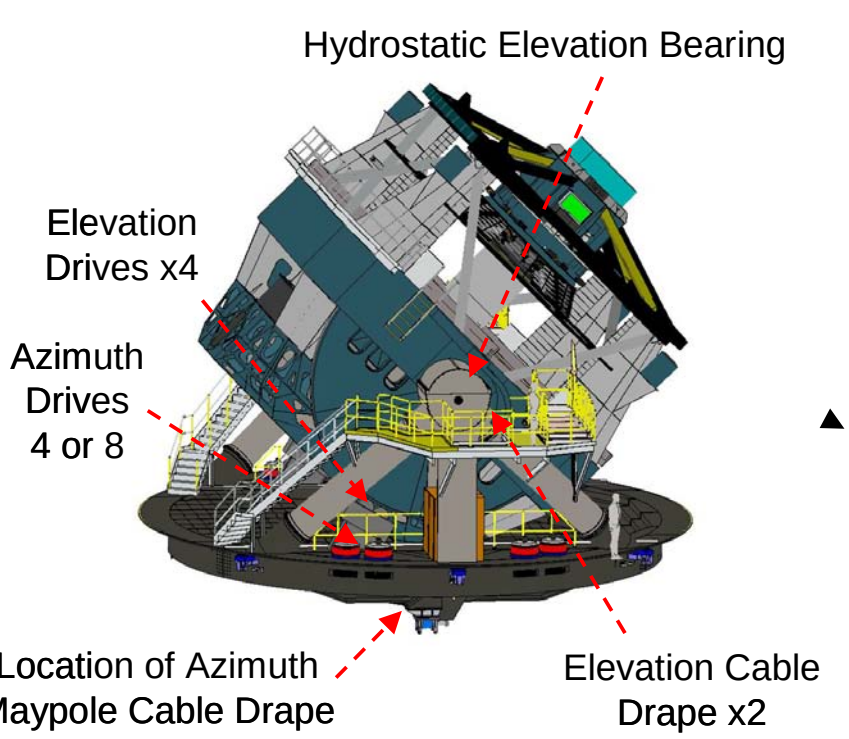
Moving structure: 300 tons

Drive power: 450 hp

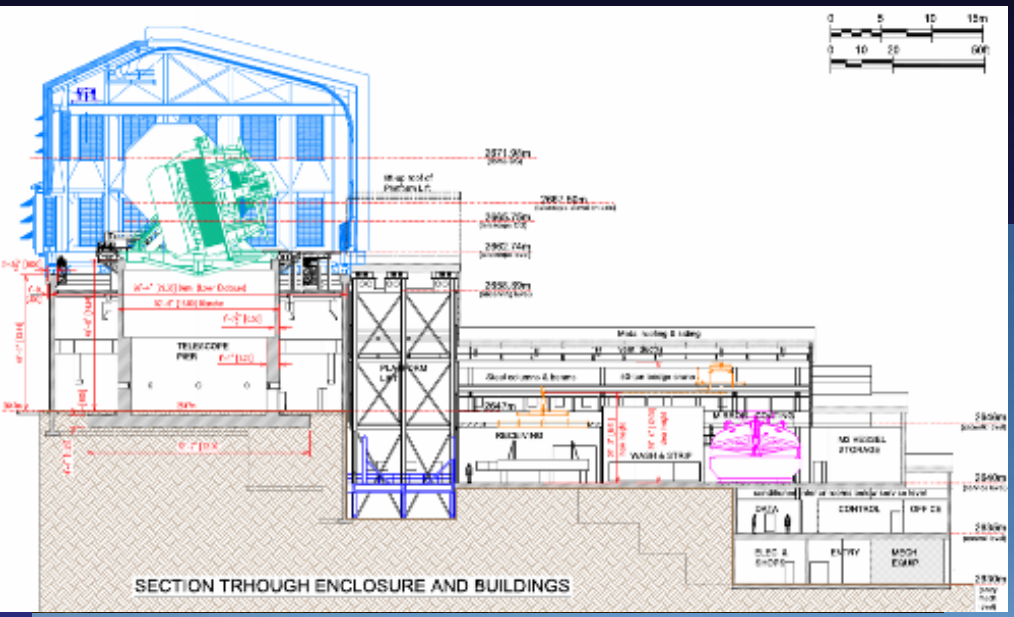
Damping: Tuned masses raise damping to 5%

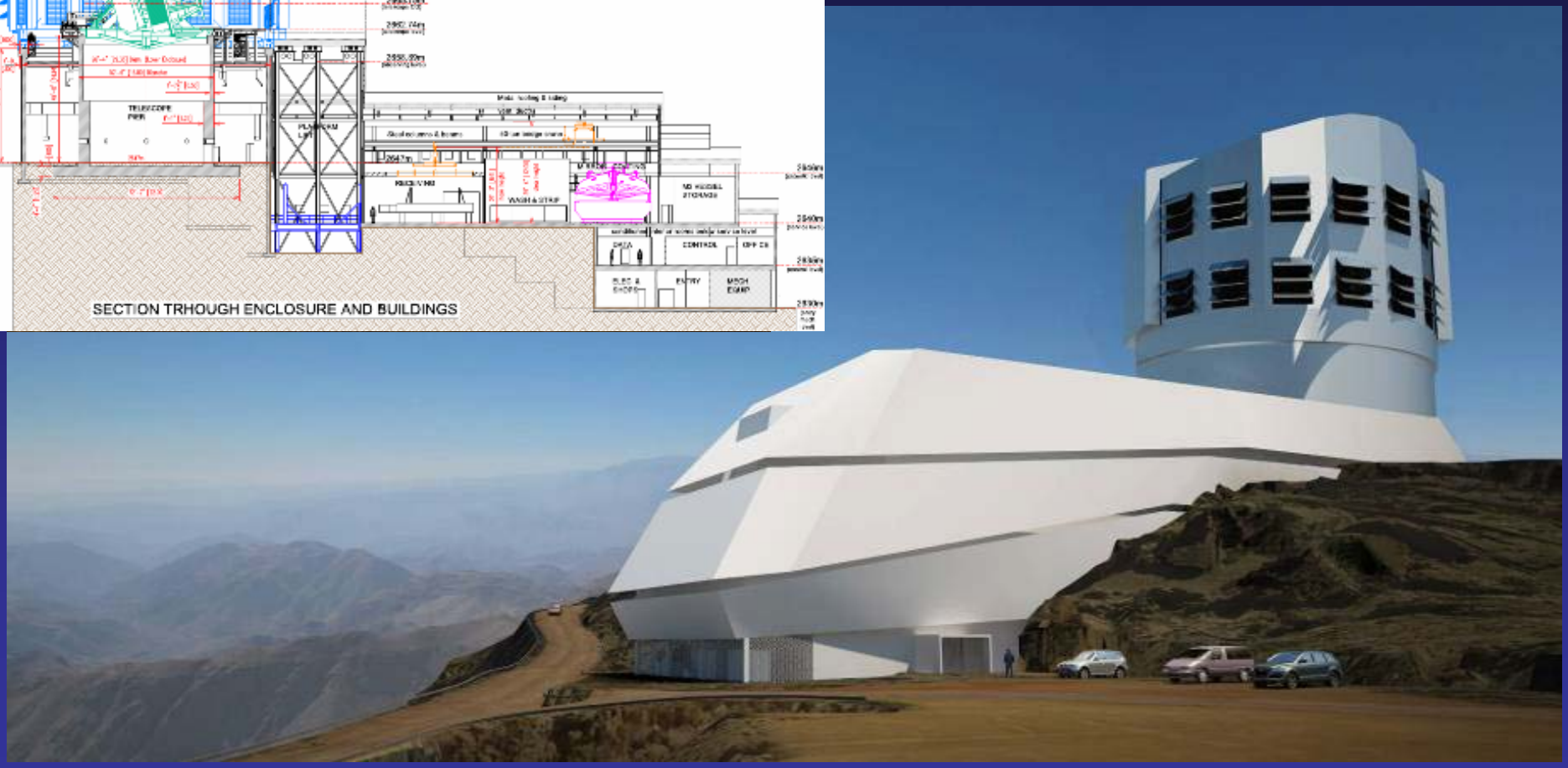
First Frequency: 8.2 hz (loaded structure on bearings, pier, and summit rock)



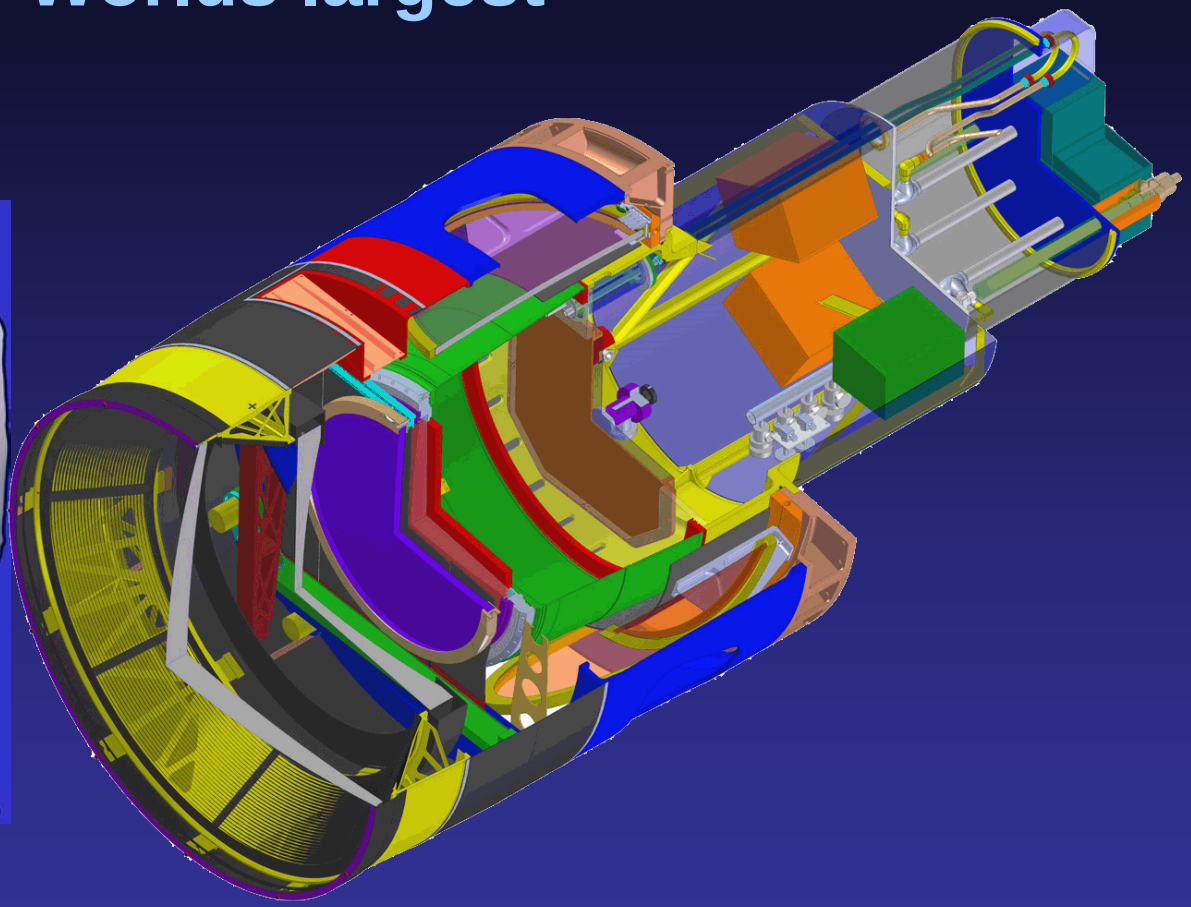


Summit facility final design under contract with ARCADIS Geotecnica, Santiago Chile





SLAC (Stanford) based team is developing the LSST's digital camera that will become the Worlds largest

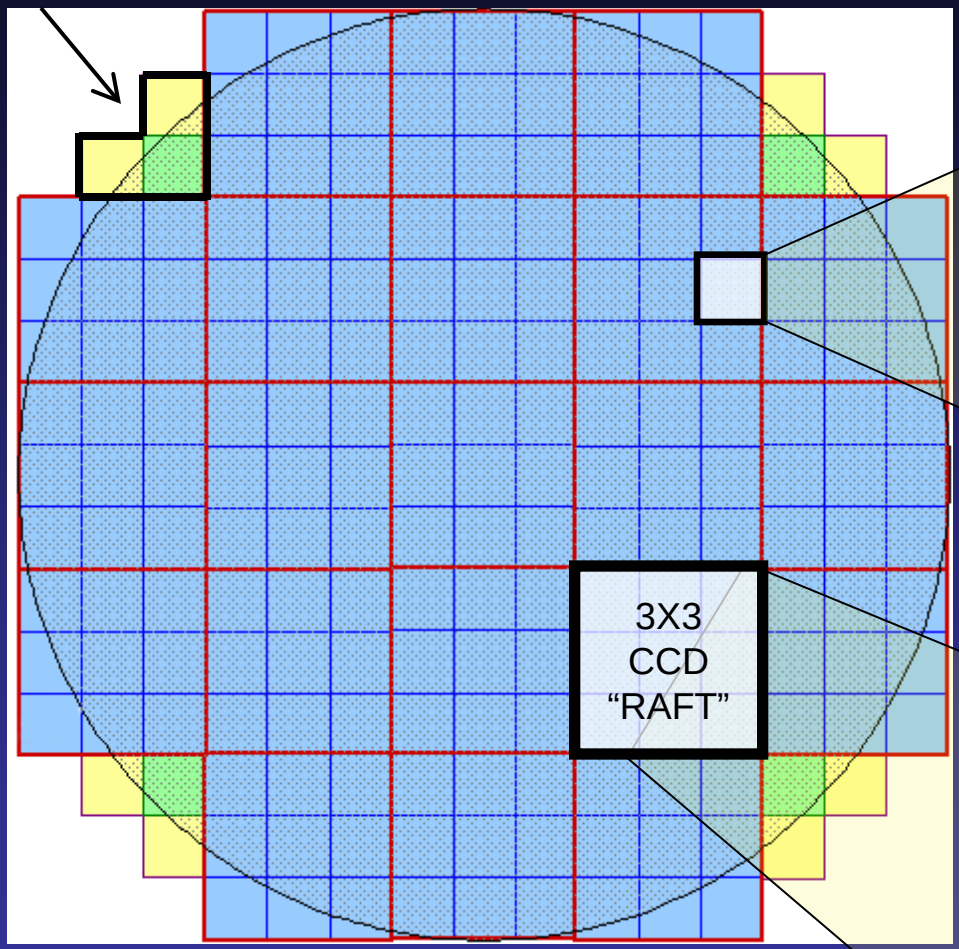


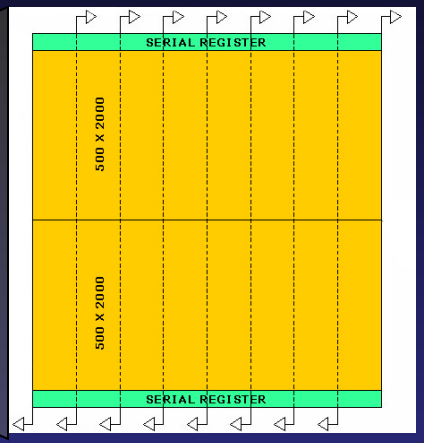
- 64cm diameter
- 189 Sensors
- 3.2 billion pixels

The camera reads out in 2 seconds for efficient observing and caries 5 colored filters.

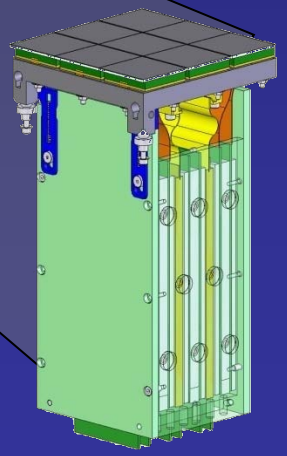
The LSST focal plane is highly segmented and modular

4 Corner areas for wavefront sensing and guiding





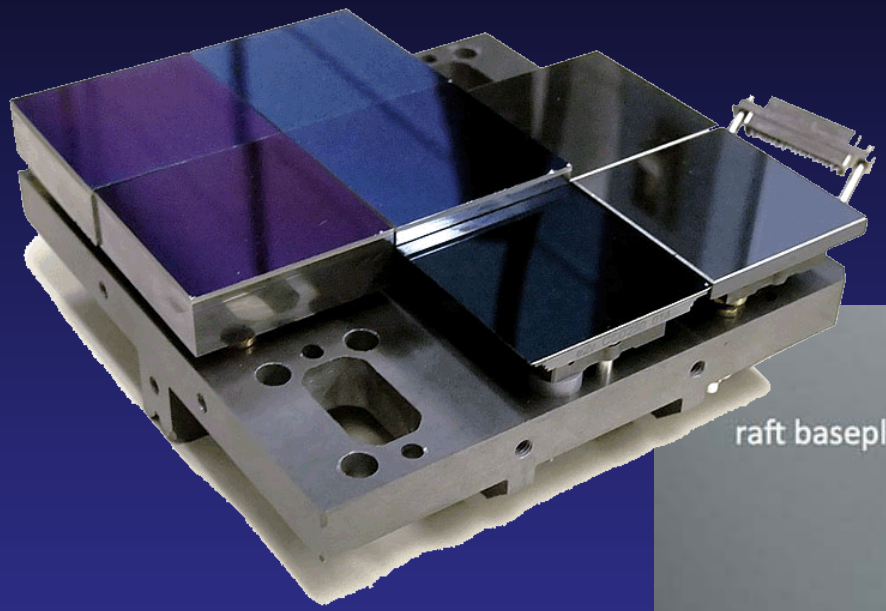
4K x 4K CCD with 10µm pixels is divided into 16 1Mpix segments with individual readout



Each raft has front end electronics and thermal elements to be autonomous 144 Mpixel array

Several Industrial sensor study contracts complete and devices being tested – Full prototype contract(s) to be awarded Q4 '08

Sensor development underway at Brookhaven National Lab

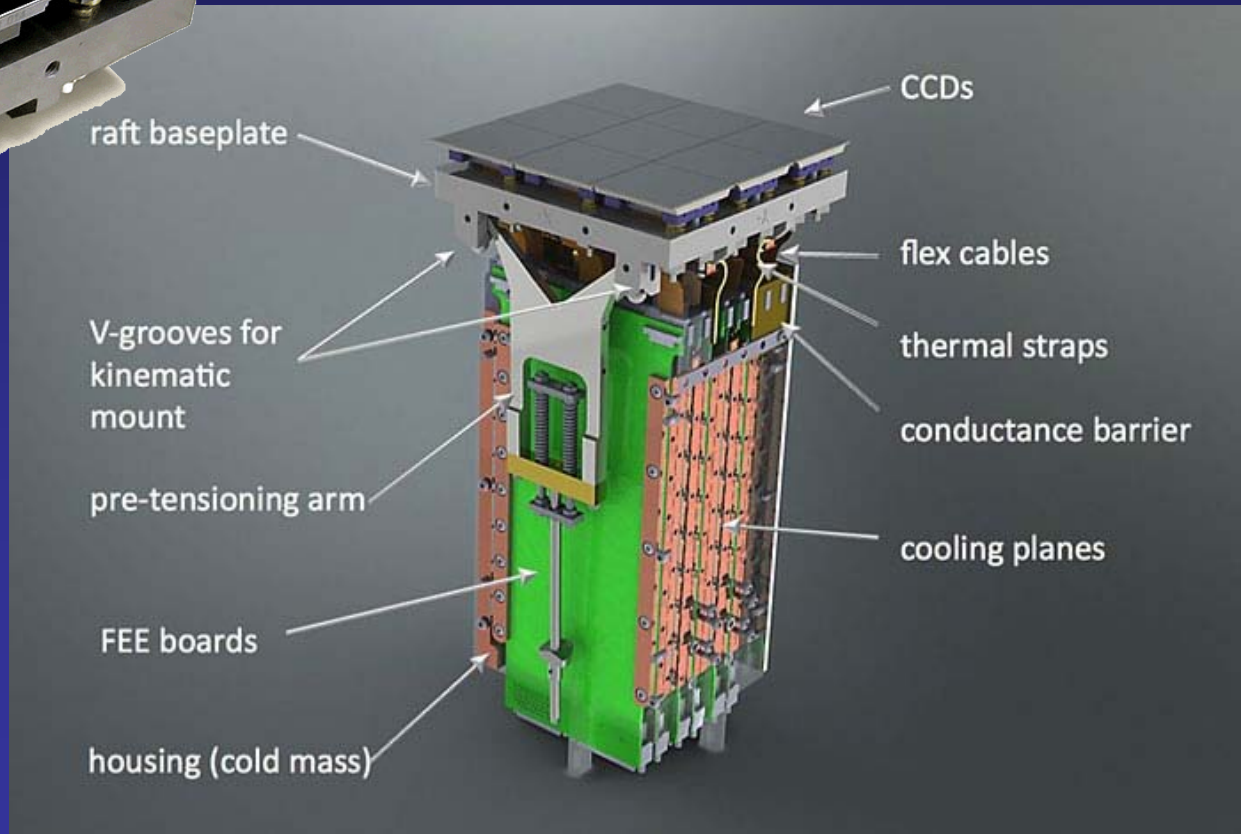


Modular

10μ pixels, 0.2 arcseconds/pixel

Highly integrated front-end electronics

3 Gb/s parallel readout



Data Management system is distributed and leverages world-class facilities and cyber-infrastructure

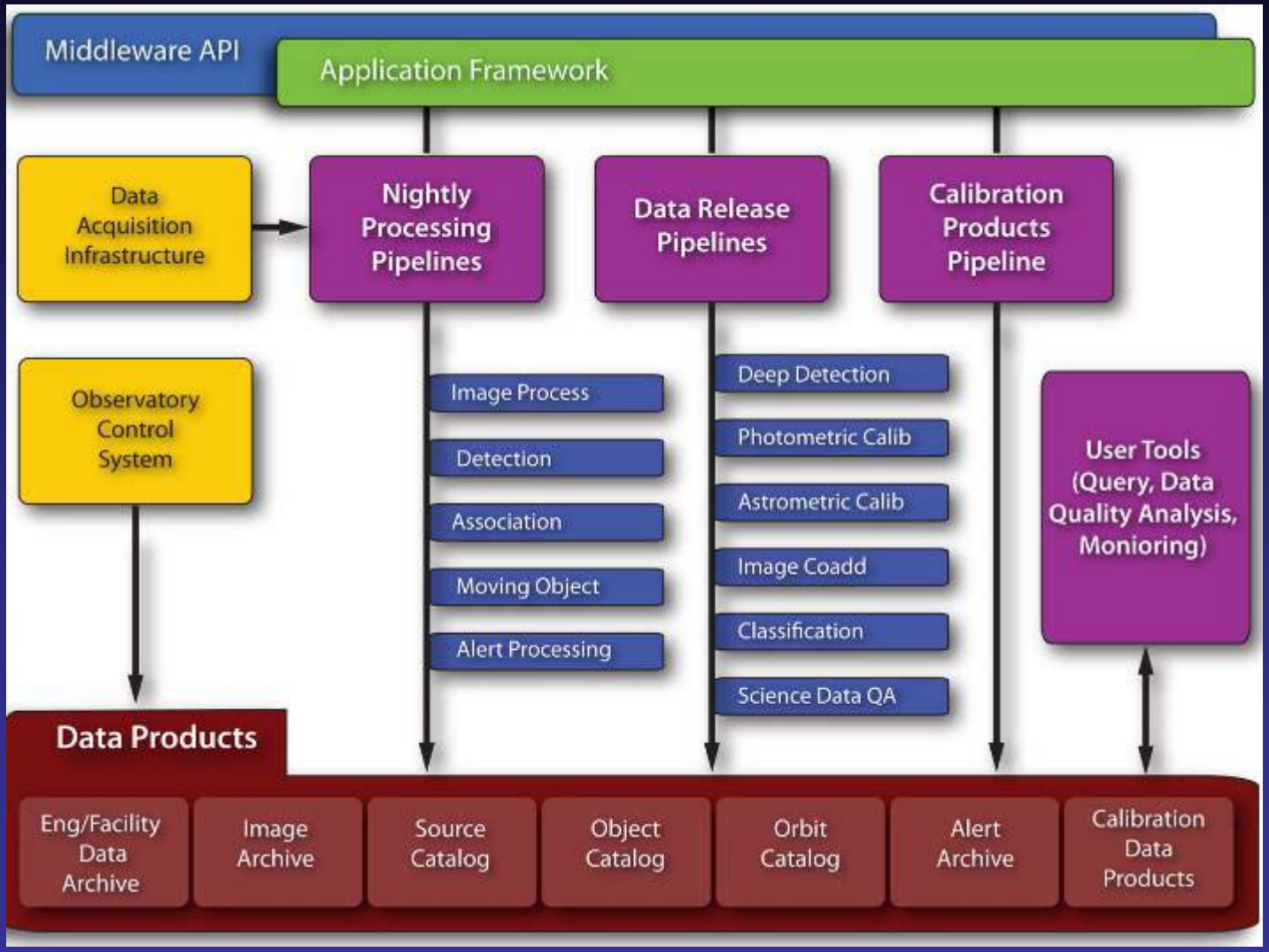
Data Access Centers
U.S. and Chile
~40 TFLOPS, 87 PB

Archive Center
NCSA, Champaign, IL
100 to 250 TFLOPS, 75 PB

Mountain Summit/Base Facility
Cerro Pachon, La Serena, Chile
~20 TFLOPS, 150 TB

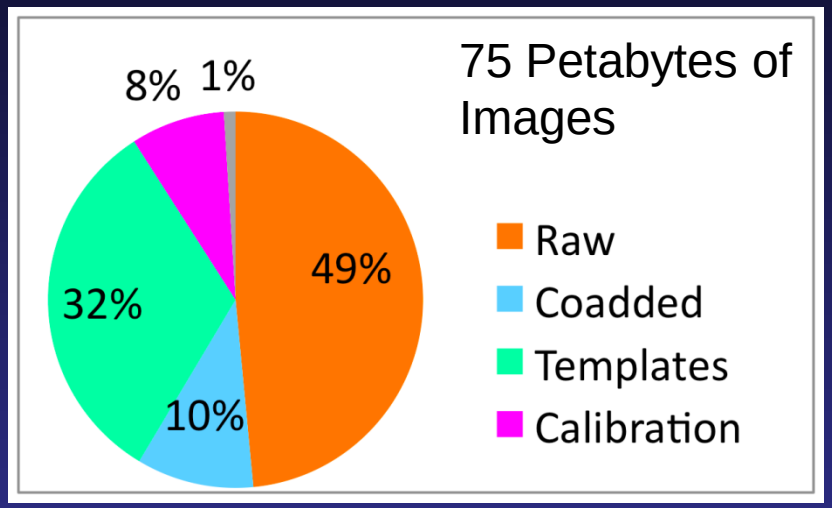
Long-Haul Communications
Chile - U.S.
2.5 Gbps avg, 10 Gbps peak

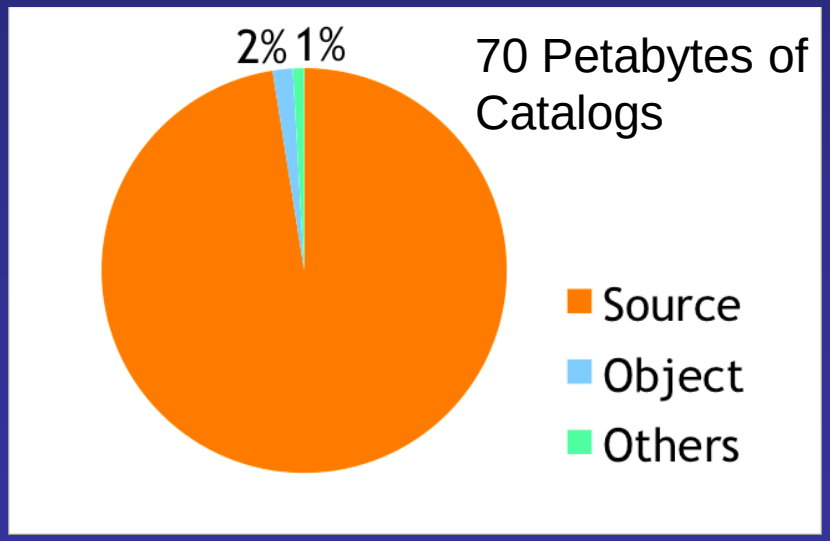
The data management architecture is well defined using industry standard practices



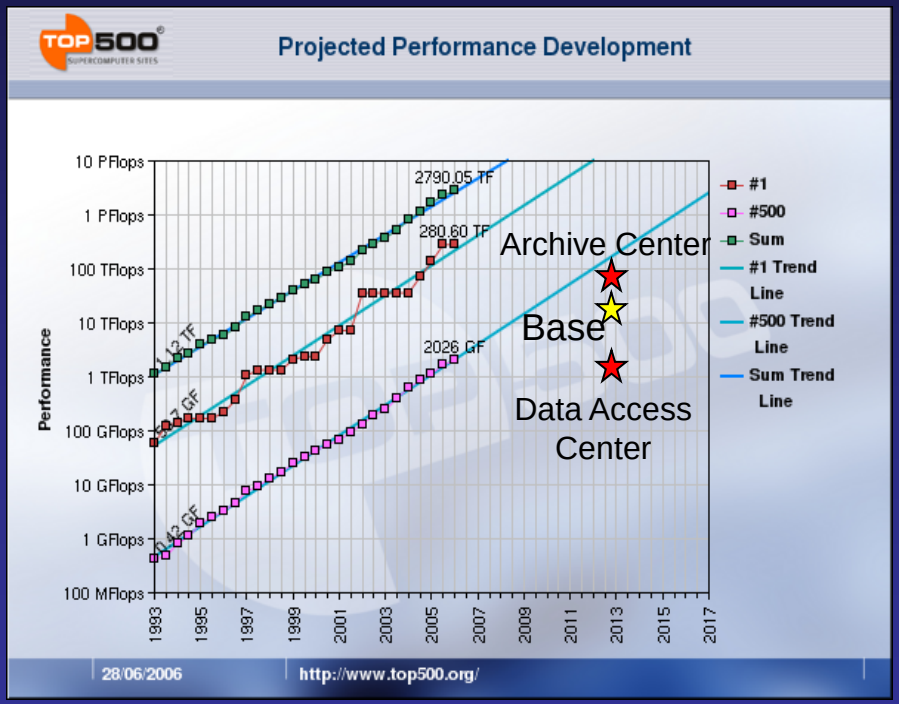
The data system faces challenges of scale

>100 Petabyte data storage (>10^{17} bytes total)





Tera-FLOPS (10^{12} floating point operations)

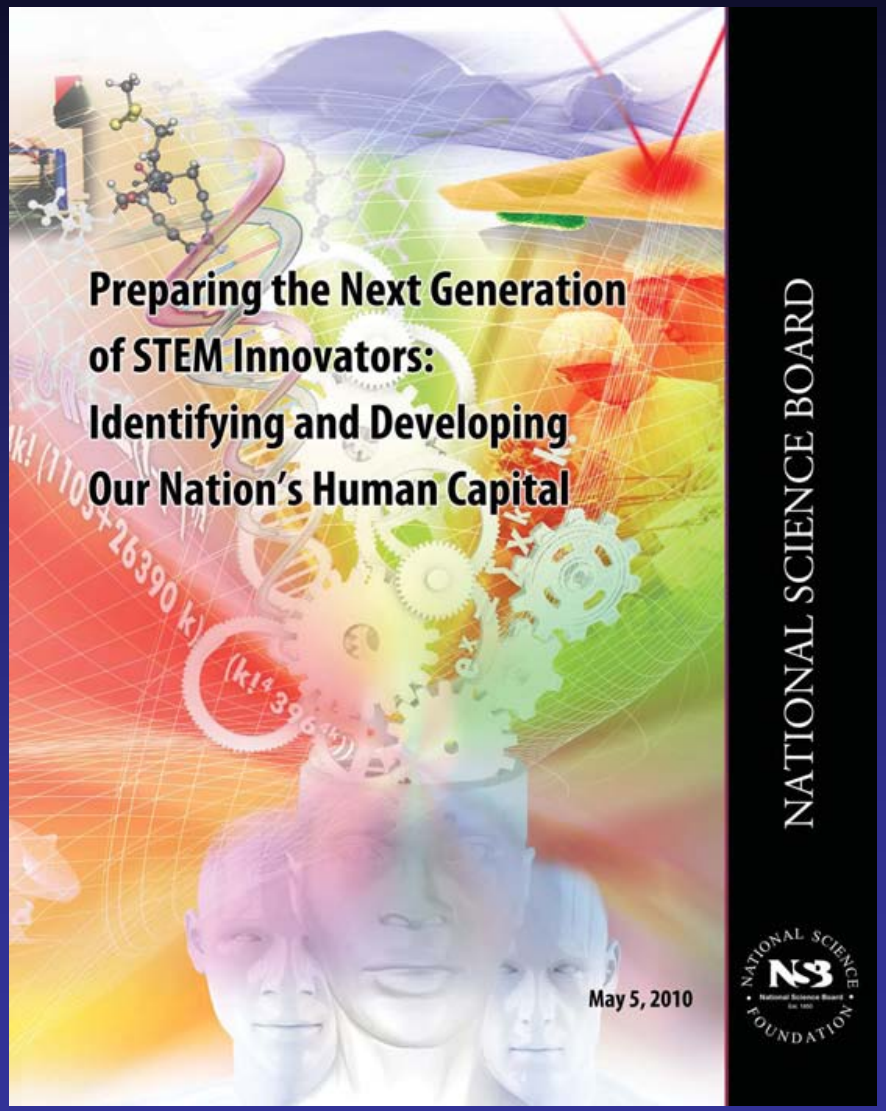


LSST in the Information Age

- Transforming the night sky into a searchable database to create the World's largest open data archive.
- This places the LSST at the crossroads of scientific and information technology research, and
- Will provide unprecedented access to science and technology to the broadest range of users, including
  - Researchers,
  - College Students,
  - K-12 students and educators, and
  - the general public

STEM Education is Essential

- Economic imperative to promote innovation and research
- Skilled workforce required to maintain US leadership
- Public involvement promotes support of research process and extends science productivity
- Astronomy is unmatched in promoting an initial interest in STEM careers and science in general.



EPO - Sharing LSST with Everyone

•Leveraging Emerging Trends:

Bandwidth, accessibility
User-centric learning environments
Lifelong learners

•Serendipitous discovery is a natural consequence of exposing data to large numbers of diverse users.

•Public involvement is encouraged and even *required* to maximize science output of LSST database.

EPO features unique aspects of LSST





- Open Data
- Survey Mode of Operations
- Opening the time domain
- Data products with high potential for discovery

Anticipate having a dynamic public web presence

Physical presence in classrooms and science centers

Active engagement with data products and research process

LSST promotes Transformative Education

- **Formal Education - LSST will place a multi-million dollar instrument in every classroom as “the ultimate network peripheral device to explore the universe” with research projects and associated professional development opportunities.**

- **Citizen Science - Engaging non-specialists in the research process is an integral part of the LSST EPO program, challenging the conventional wisdom that only PhD scientists can produce bona fide new scientific knowledge.**

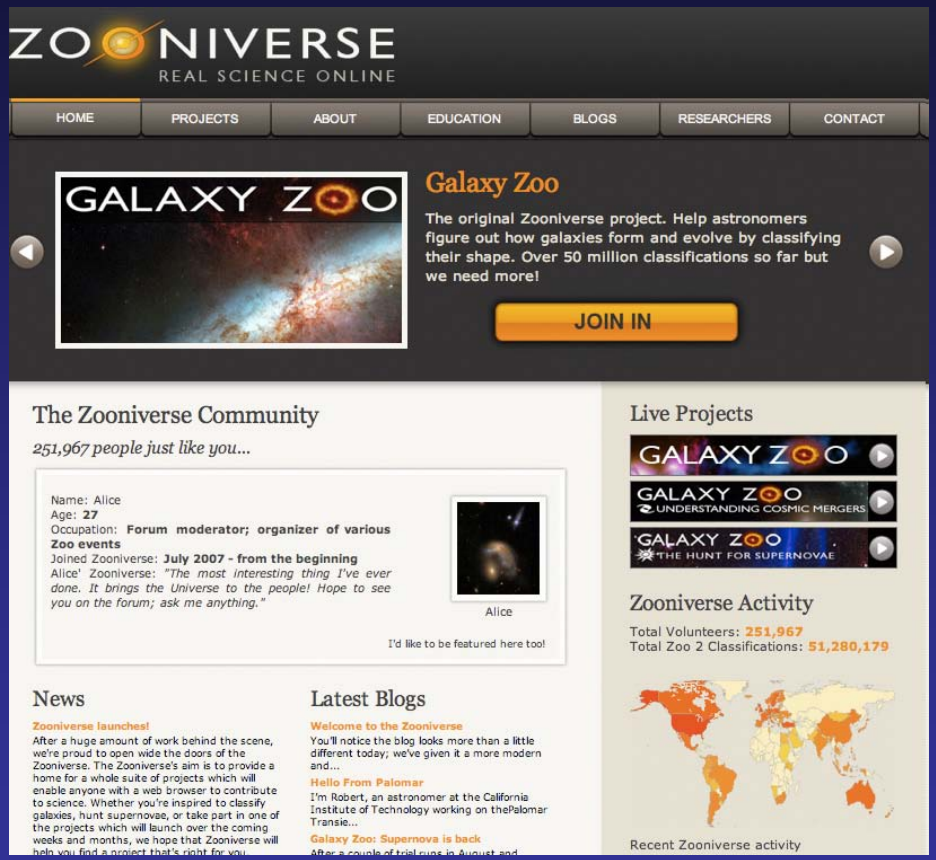
- **New Media Technologies - A virtual environment such as Blue Mars is a natural repository for LSST’s integrated approach to EPO: transgressing artificial boundaries between learning environments, acknowledging our role as learners in all phases of life, and promoting collaboration and networking while discovering knowledge.**

- **Data Sciences – LSST addresses the grave need for a workforce with skills in the management, analysis, mining, and handling of the enormously large data sets that are being generated in all disciplines, business sectors, agencies, and social contexts.**

Citizen Science – leveraging success

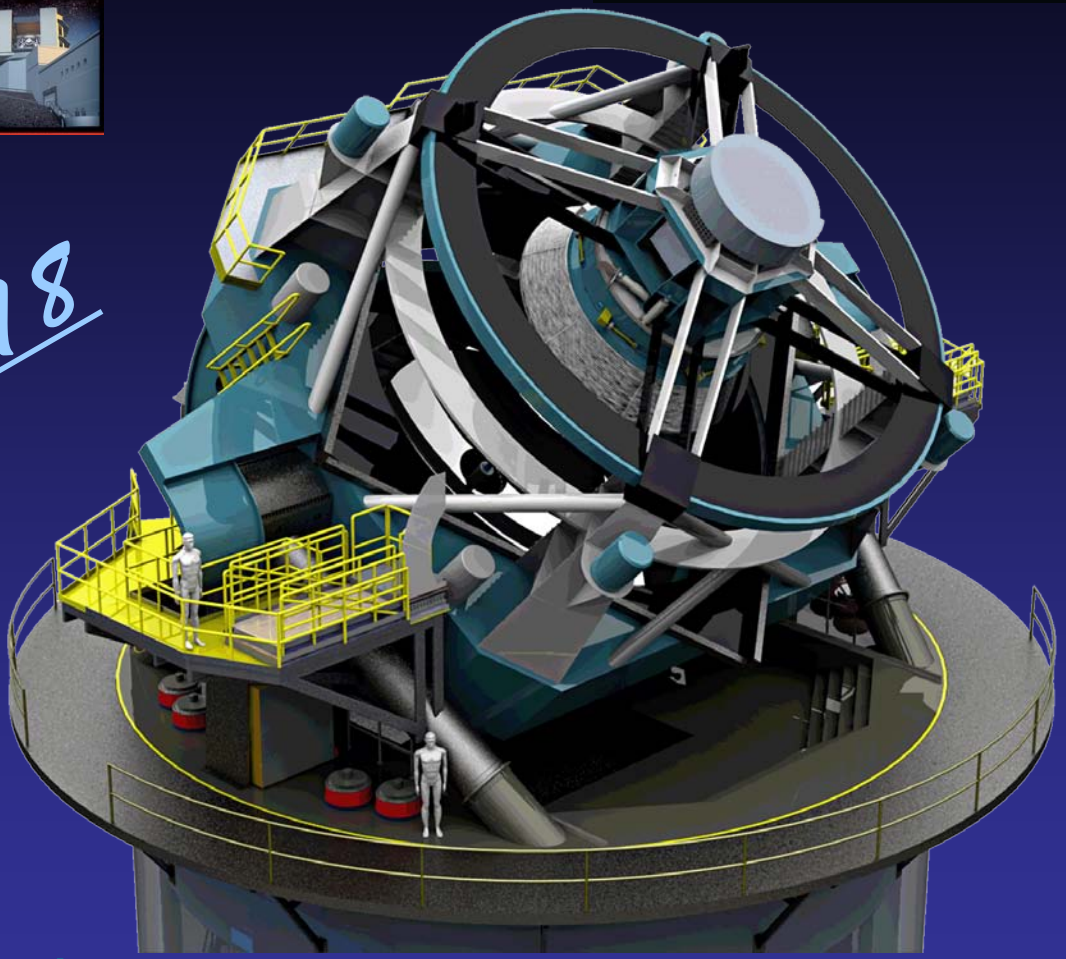
Citizen Science –Galaxy Zoo and a suite of multidisciplinary projects now under the Zooniverse framework have resulted in more than 25 publications in refereed scientific journals and led to unexpected insights that have enabled new techniques and methodologies for discovery.

Over 400,000 participants



Keeping Informed and Getting Involved

First Light in 2018



- www.lsst.org
- http://www.lsst.org/lsst/news/enews

Suzanne Jacoby
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Converting the night sky into a searchable database.

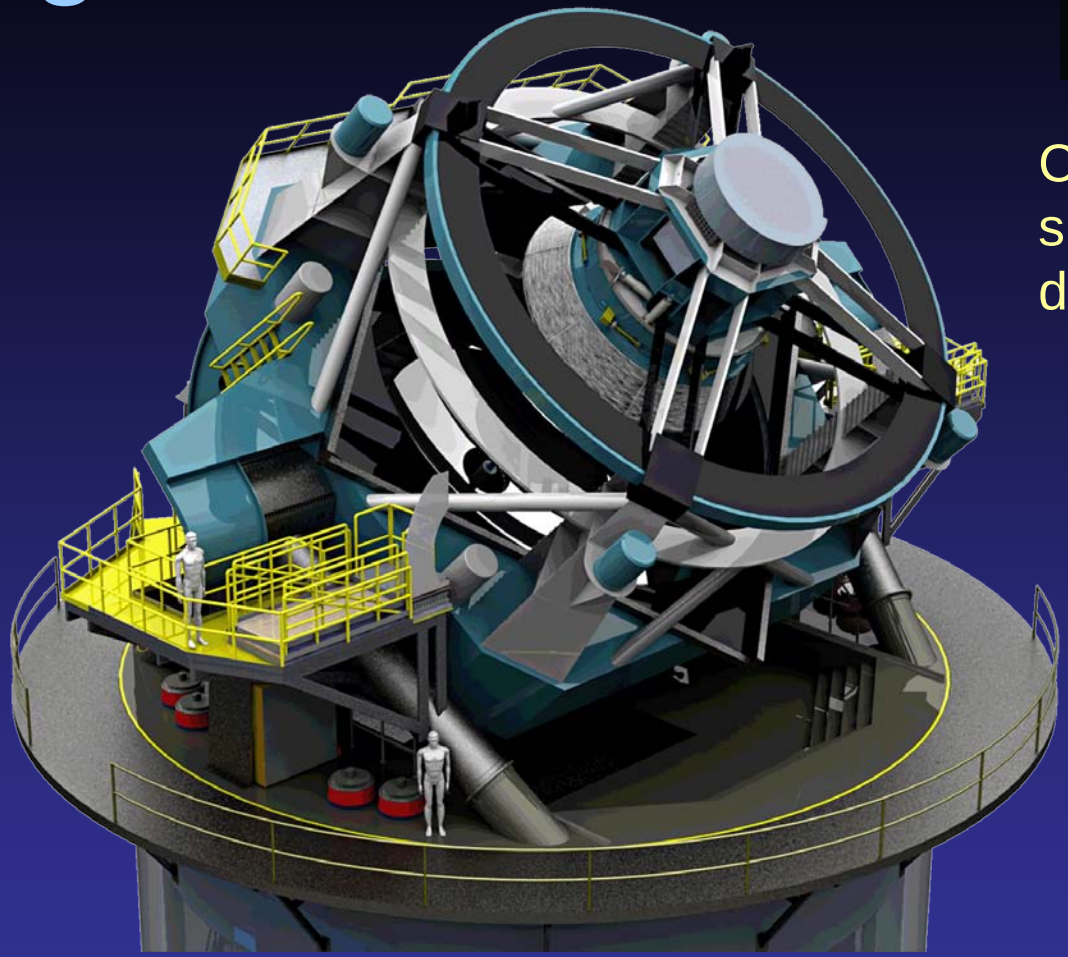
First Light in 2018

LSST
Large Synoptic Survey Telescope

Deep

Wide

Fast



Converting the night sky into a searchable database.

Seeing invisible dark matter and mysterious dark energy
Searching for asteroids which threaten Earth
Finding new solar systems
Watching the cosmos unfold

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