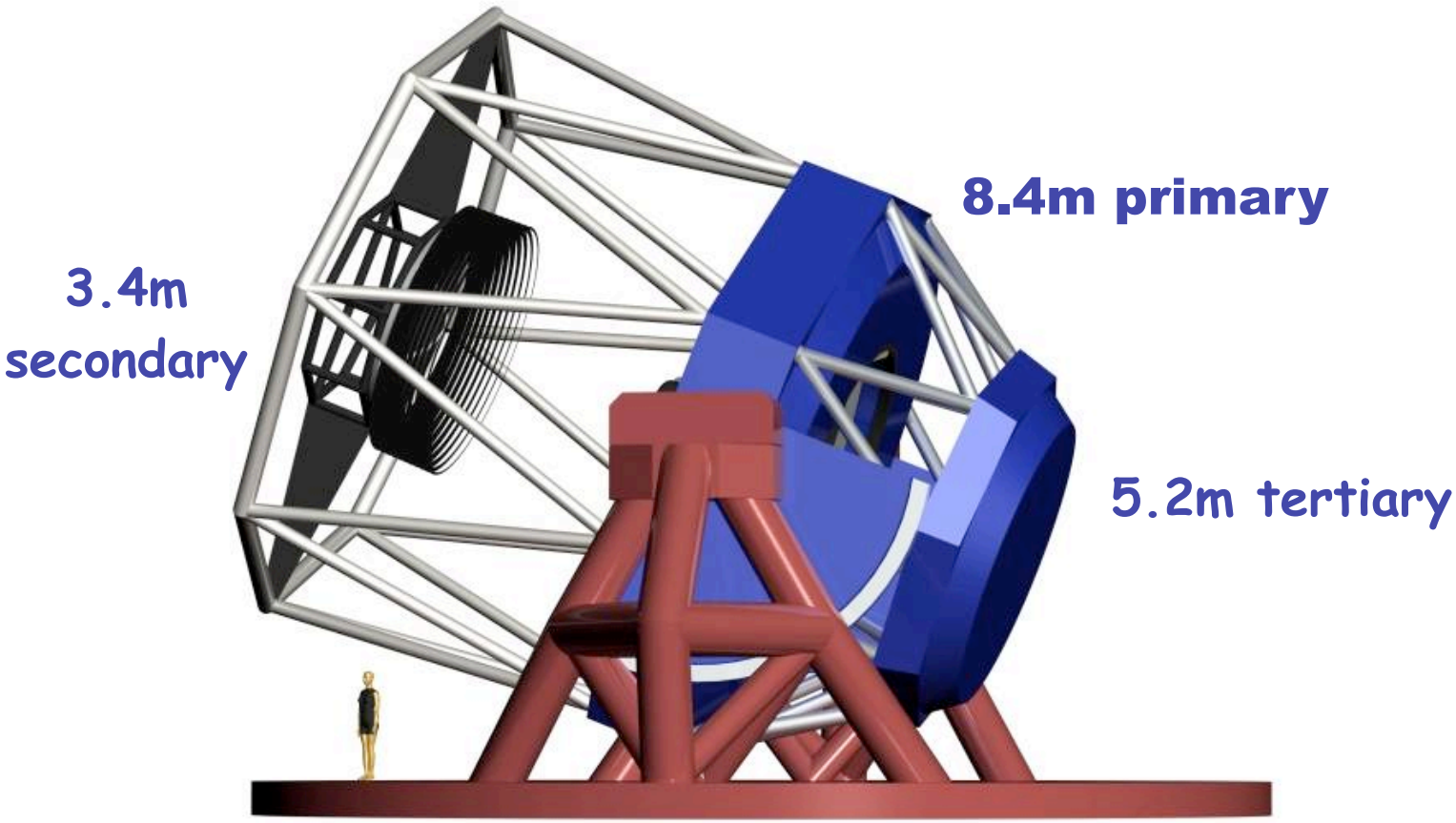
LSST

Large Synoptic Survey Telescope

Dr. Don Dossa
Lawrence Livermore
National Lab

UCRL-PRES-216187

Large Synoptic Survey Telescope

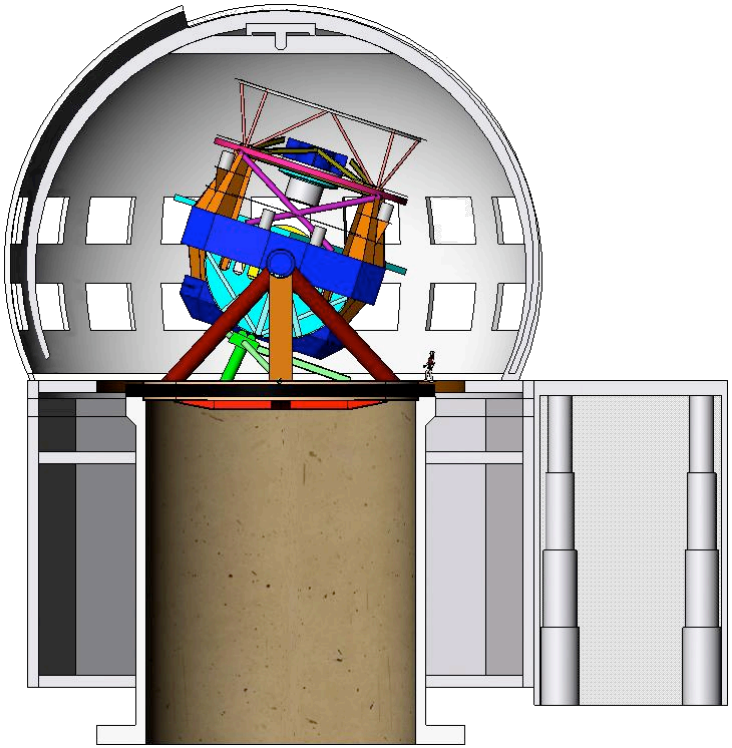


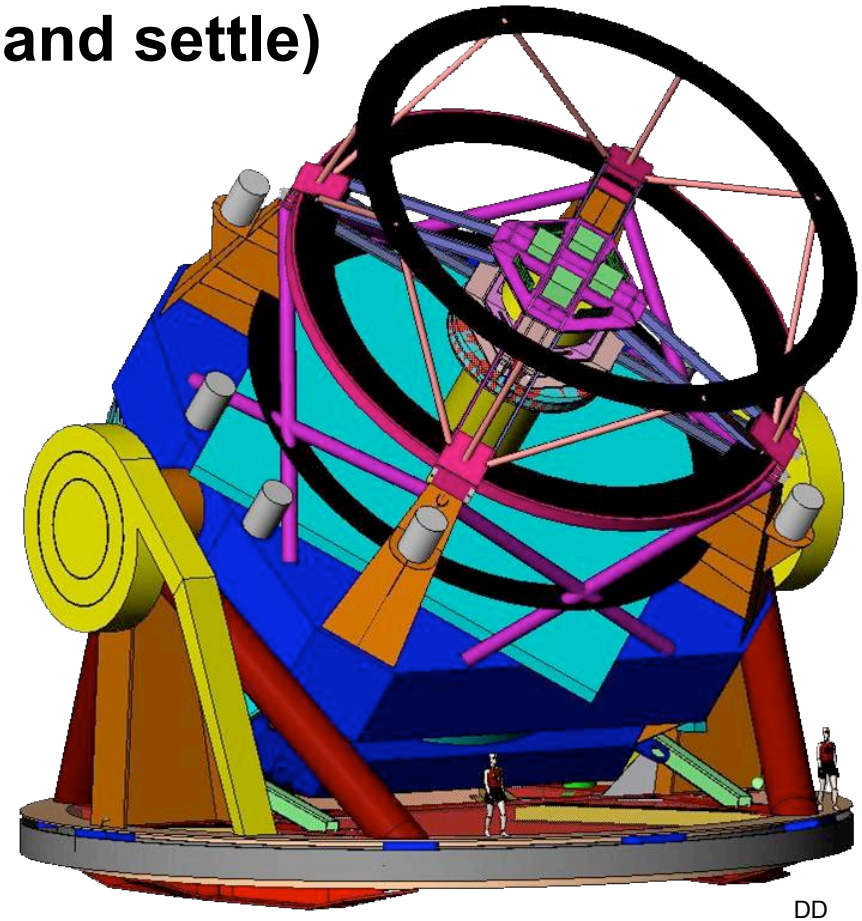
DD

An 8.4 Meter Telescope

Three-mirror design is only 6.3 meters long:

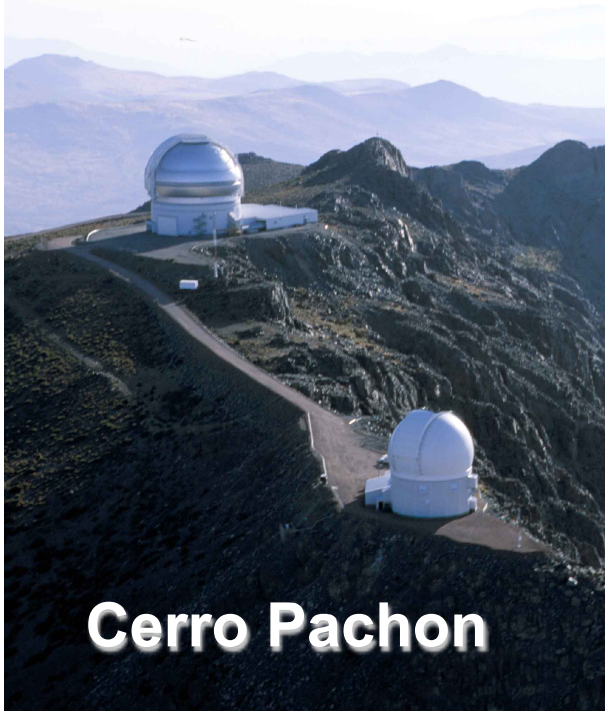
- **It is light (200 tons)**
- **It is agile (<5 seconds slew and settle)**

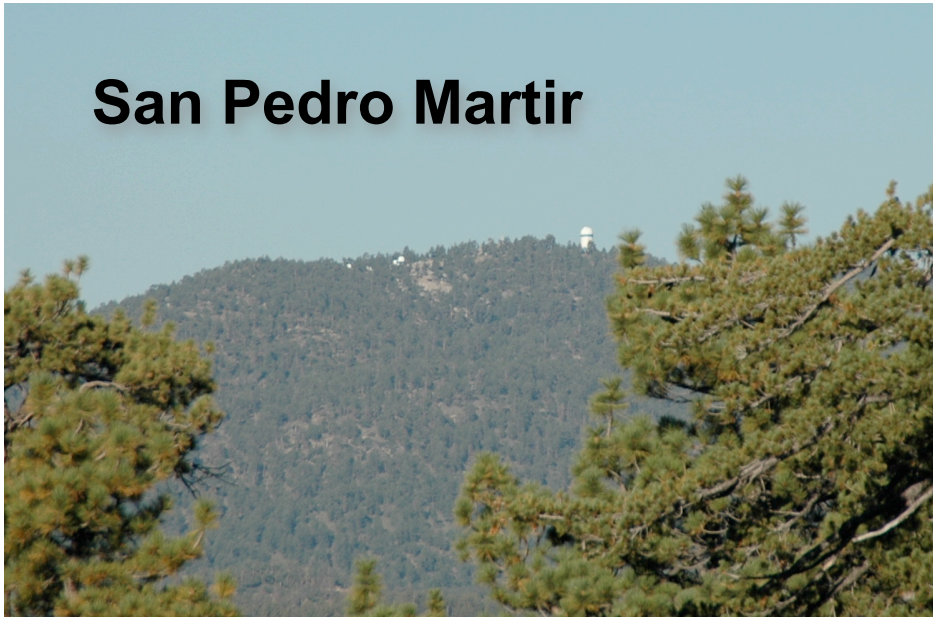




DD

Telescope will be built at one of these locations



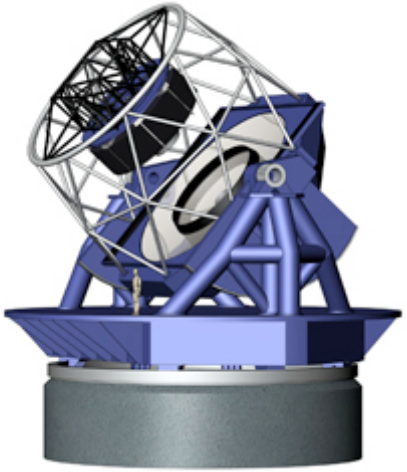


8.4 Meter Mirrors are Big

Getting large mirrors up steep mountain roads is tough on the nerves.
OVERSIZE LOAD

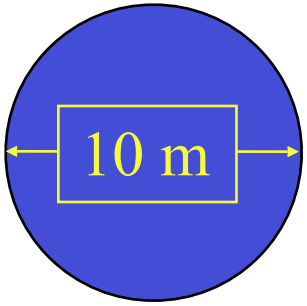
Why is the LSST unique?

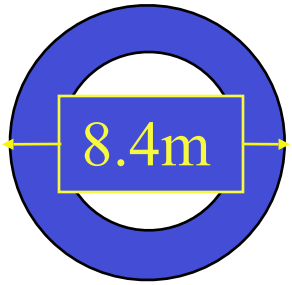
Keck Telescope



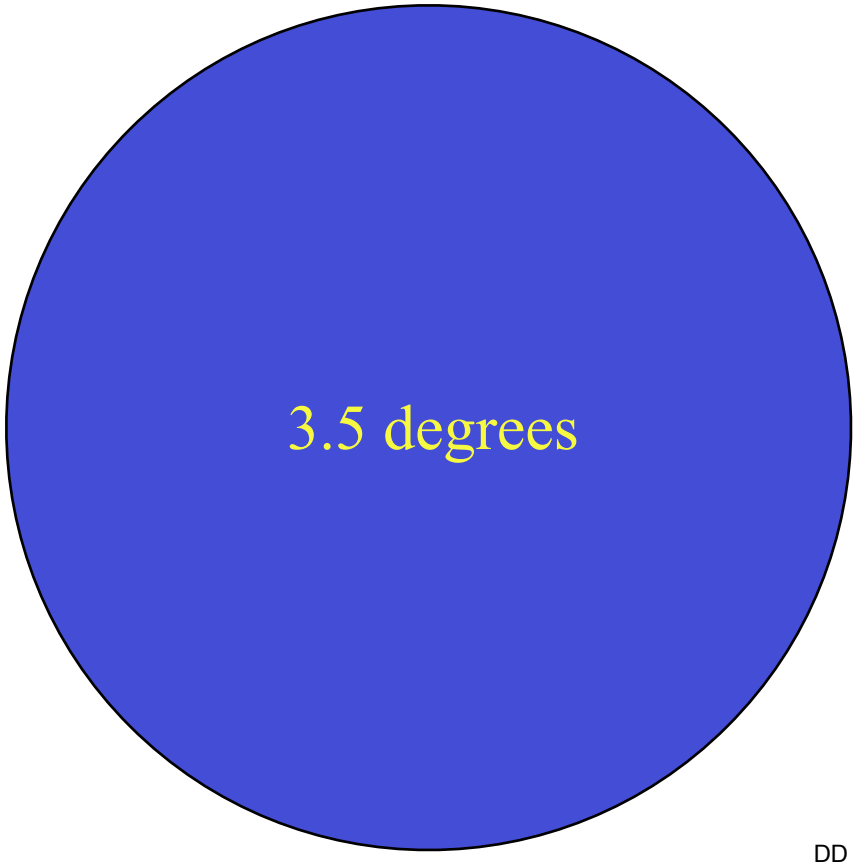
LSST

Primary mirror diameter





Field of view
(full moon is 0.5 degrees)



DD

LSST Science Requirements and Data Rates are Primary Data Management System Driver

Science requirements have 2 time scales:

Short

- 18 seconds image analysis
- 10^9 objects every night

Long

- 10 year history of objects
- Fully indexed + searchable
- Re-analyze years of images
- Correlate objects across petabytes of data
- Software ready at ‘first light’

- **Data Management is LSST’s greatest challenge.**

Why not build another Hubble Space Telescope?

NGC 3370
3 exposures
8 hours

Credit: NASA, StSci

DD

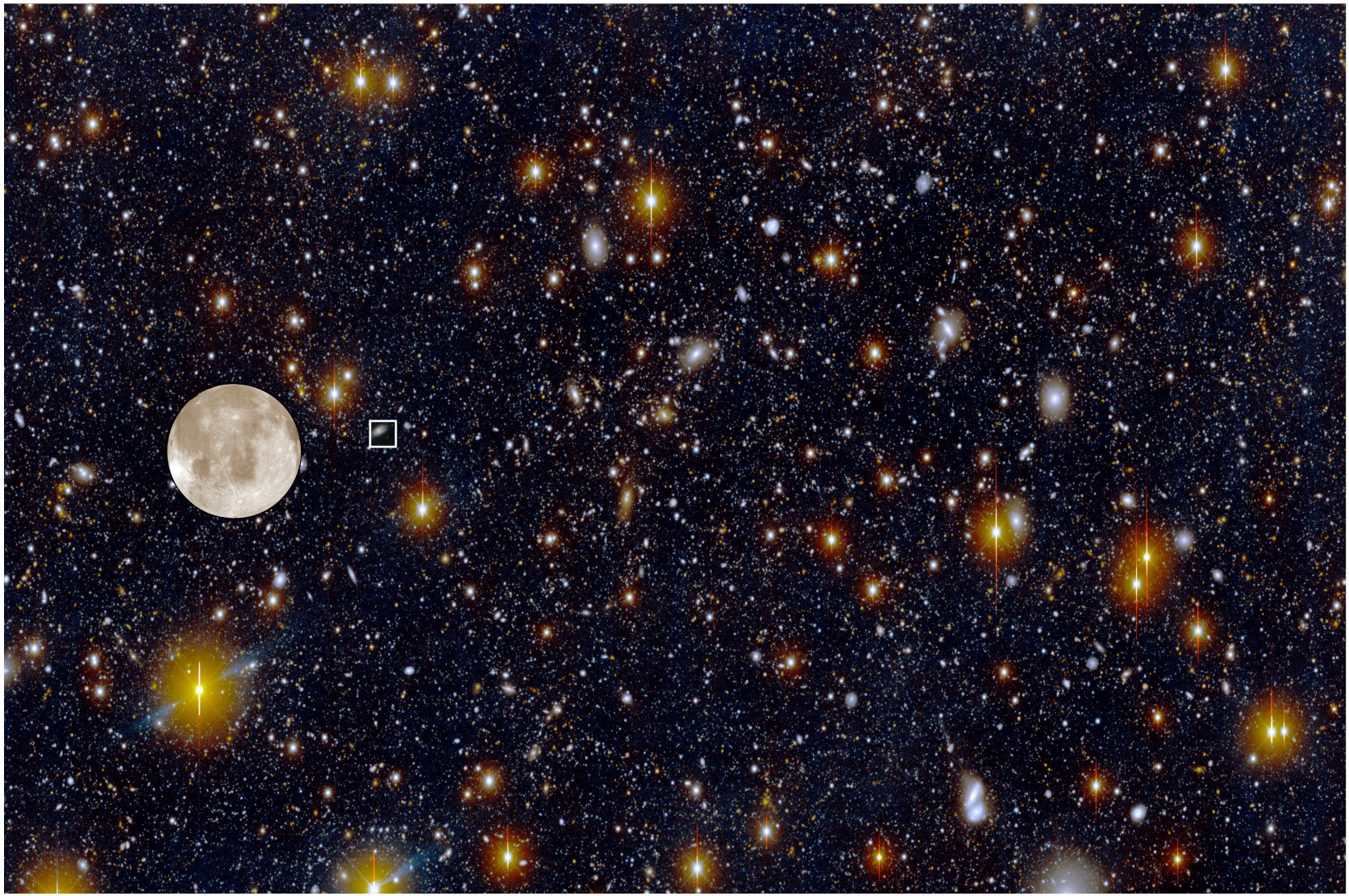
A familiar object

Images at same scale

Moon - 0.5 degrees

Hubble
Field of view
0.056 degrees

Compare Hubble Image size to LSST Image size



DD

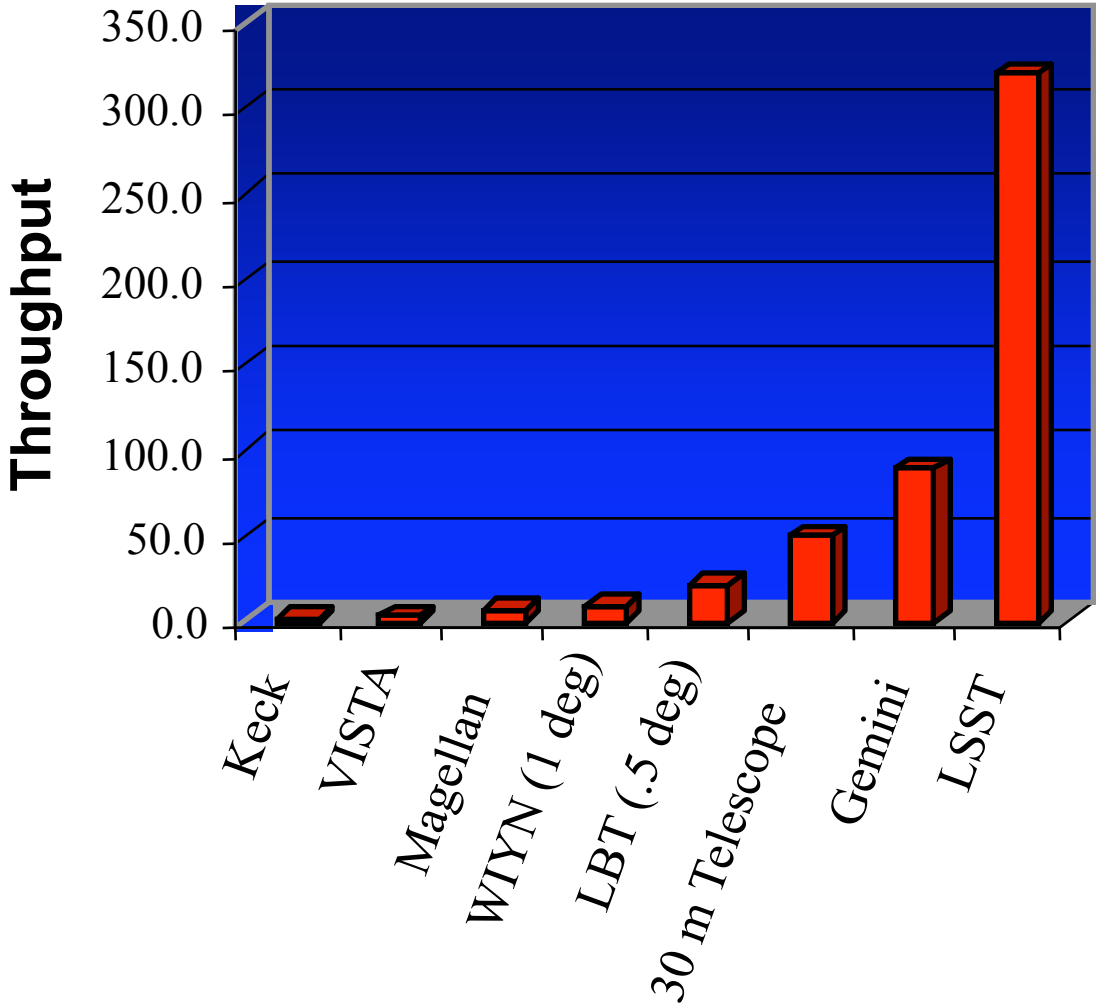
Large image size and short exposures drive high data rates

- Each image is 6 Gigabytes
- A new image every 18 seconds
- 2,000 or more images per night
- 6 GB * 2,000 = 12 Terabytes of raw data every night
- 300 nights/yr * 10 years => 36 Petabytes raw data
- Add analysis results, object catalogs, and backup copies => 100+ Petabytes
- Several data mirror sites
- Everything indexed and searchable via DB Query
  - How big is your database?

Data management is LSST's greatest challenge

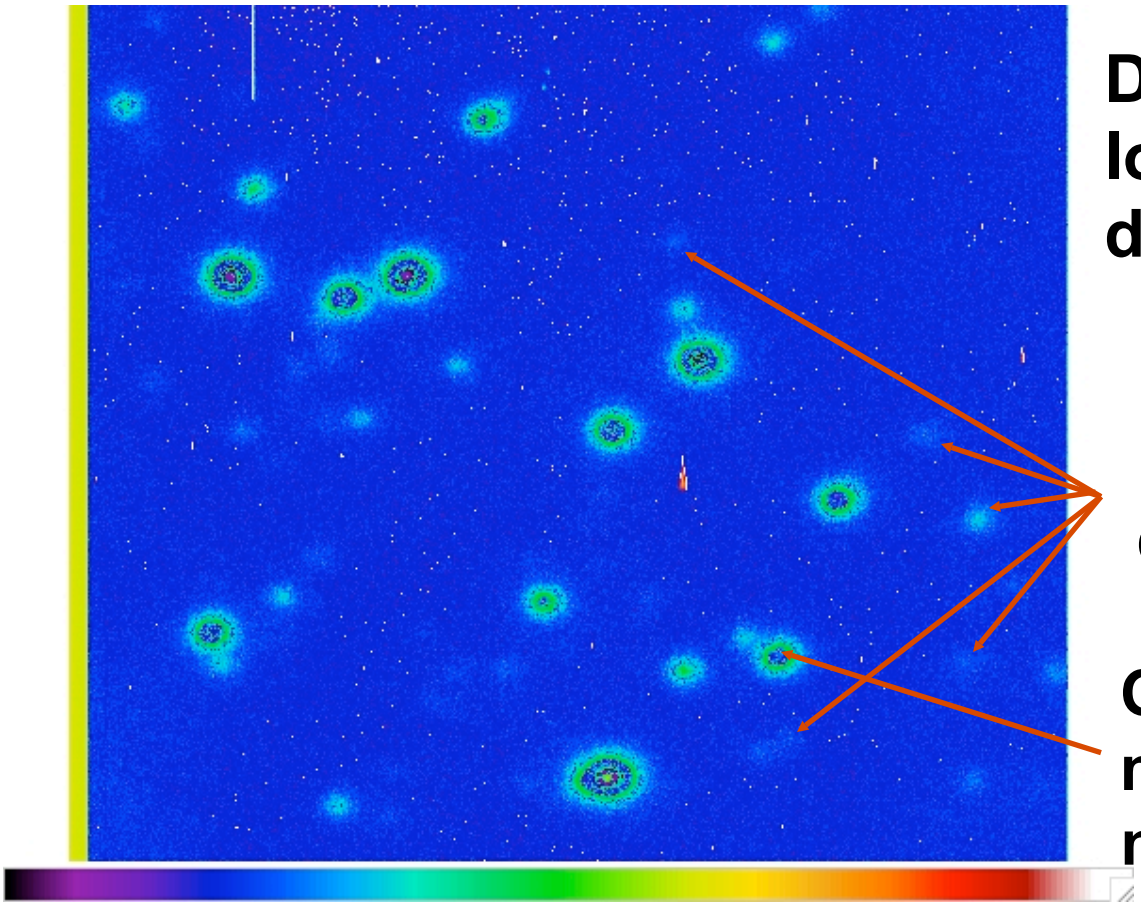
LSST will have the highest information output of any major optical telescope

because of its wide field of view and fast optics



DD

LSST Images will contain many objects with Low Signal/Noise Ratios



Databases don't handle low signal/noise ratio data well.

Features at limit of detection

Objects appearing to merge or separate need novel algorithms

How does the database handle these situations?

DD

Find all objects above the noise level

- If this a known object => add to object history
- Characterize newly detected objects
  - Maybe it's a nova. What kind is it?
    - A regular nova? A supernova? Or just a pretty good nova?
  - Maybe it's an asteroid?
    - Known object in expected position?
    - Possibly a new discovery?
    - Can we find object in a previous image?

Will have several hundred or thousands of objects like this each image.

Lots of DB look ups. High compute and IO bandwidth requirements

DD

Association and Moving Objects Software Pipeline

Examine all newly detected objects

- Is this new object a nova?
  - A supernova? Or just a pretty good nova? Need to generate automated alerts
- Maybe it's an asteroid?
  - Known object in expected position?
  - Possibly a new discovery?
  - Can we find object in a previous image?

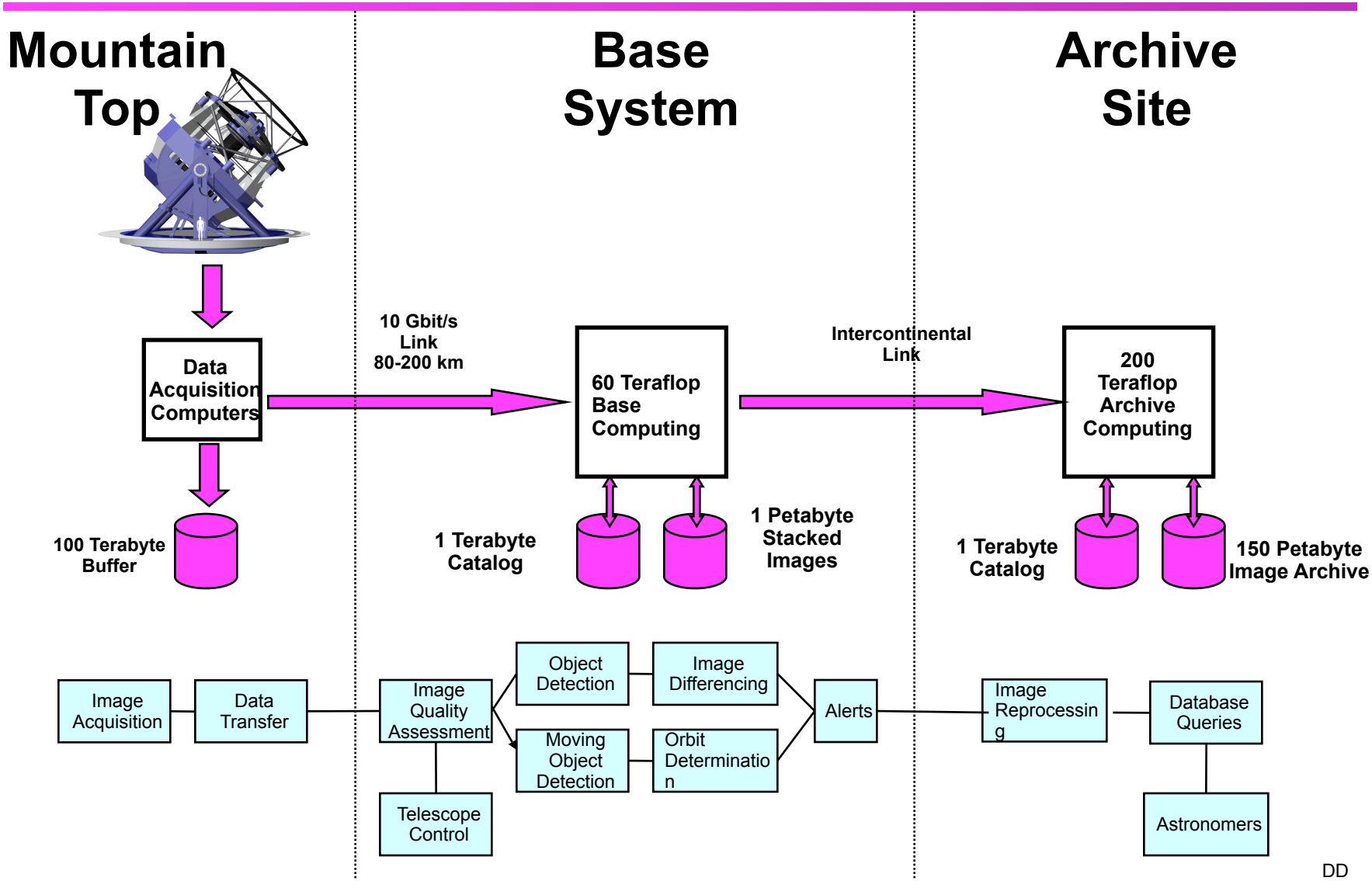
Will have several hundred or thousands of objects like this each each image

Lots of DB look ups. Compute requirements *difficult* to predict

Basic Software Architecture

- Science goals requires the computing system to keep up with 18 second image rate.
- Camera output is 6,400 channels
- Process data as 6,400 independent data streams
  - 6,400 CPUs
- Program model is data parallel, not MPI
  - This might have to change…
  - Almost no communication needed <u>except</u> for bright stars on boundaries
  - Data parallel approach increases reliability
- Analysis software written mostly by astronomers (heaven help us)

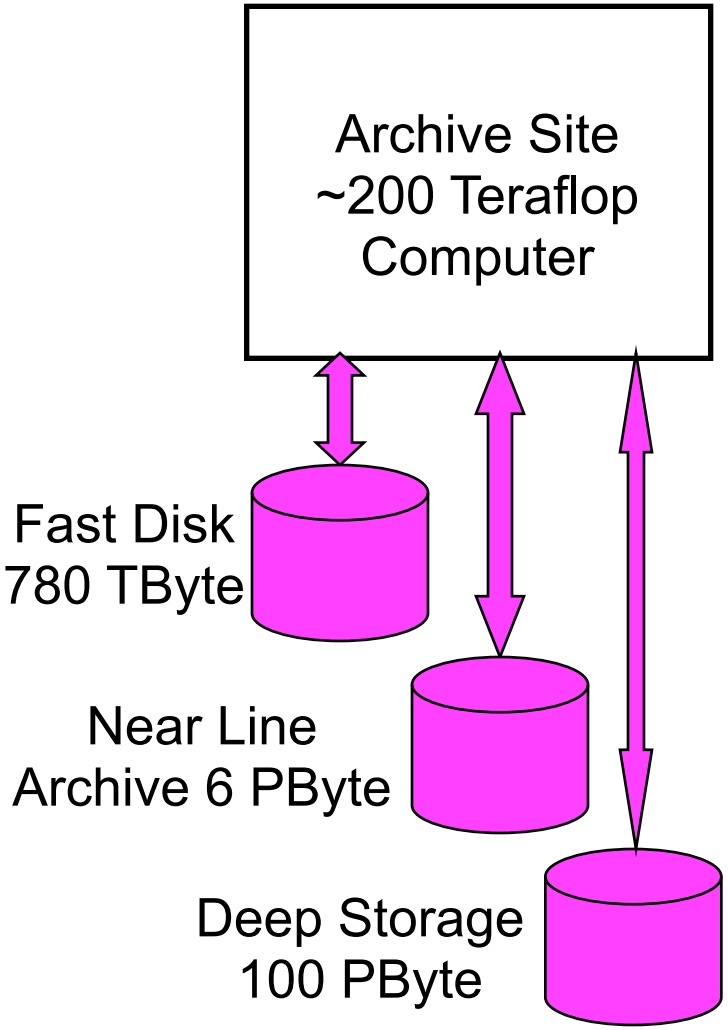
LSST Science Goals Require Multi-location, Low Cost Supercomputing Systems



DD

Analyzing Petabytes of Data Requires Research in Smart Data Pre-Staging

- Disk and tape access times are very different - millisec to minutes.
- Pre-stage data from deep storage to faster disk due to finite astronomer lifetime.
- Significant research problem
- Problem similar to CPU cache design and web proxy servers.
- Both approaches have significant drawbacks to data staging.



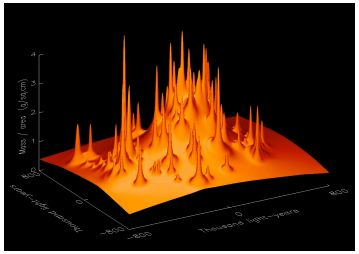
DD

Major Unanswered Questions

- Will it be built in Chile or Mexico?
  - Practical questions… Does the site have electricity?
- Which CPU architecture is best for this?
  - Clusters, Cell, Blue Gene, FPGA, Graphic chips
- How do we build databases for low S/N ratio data?
- What software hints are needed to pre-stage data?
- How much will the link from telescope to base cost to build and operate?
  - Moving 6 Gbytes in 6 sec over 120-200 km is *expensive* and pushes technology limits at reasonable costs.
- Need final astronomical algorithms defined
  - You want to install a supercomputer *where*?

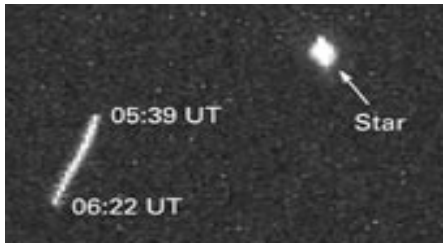
Major Science Goals for LSST

Study of dark matter and dark energy

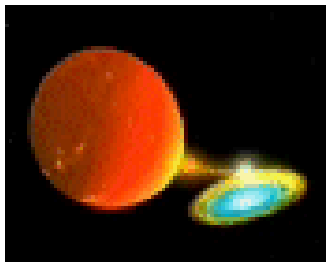


Search for Near Earth Asteroids

Search for trans-Neptunian objects



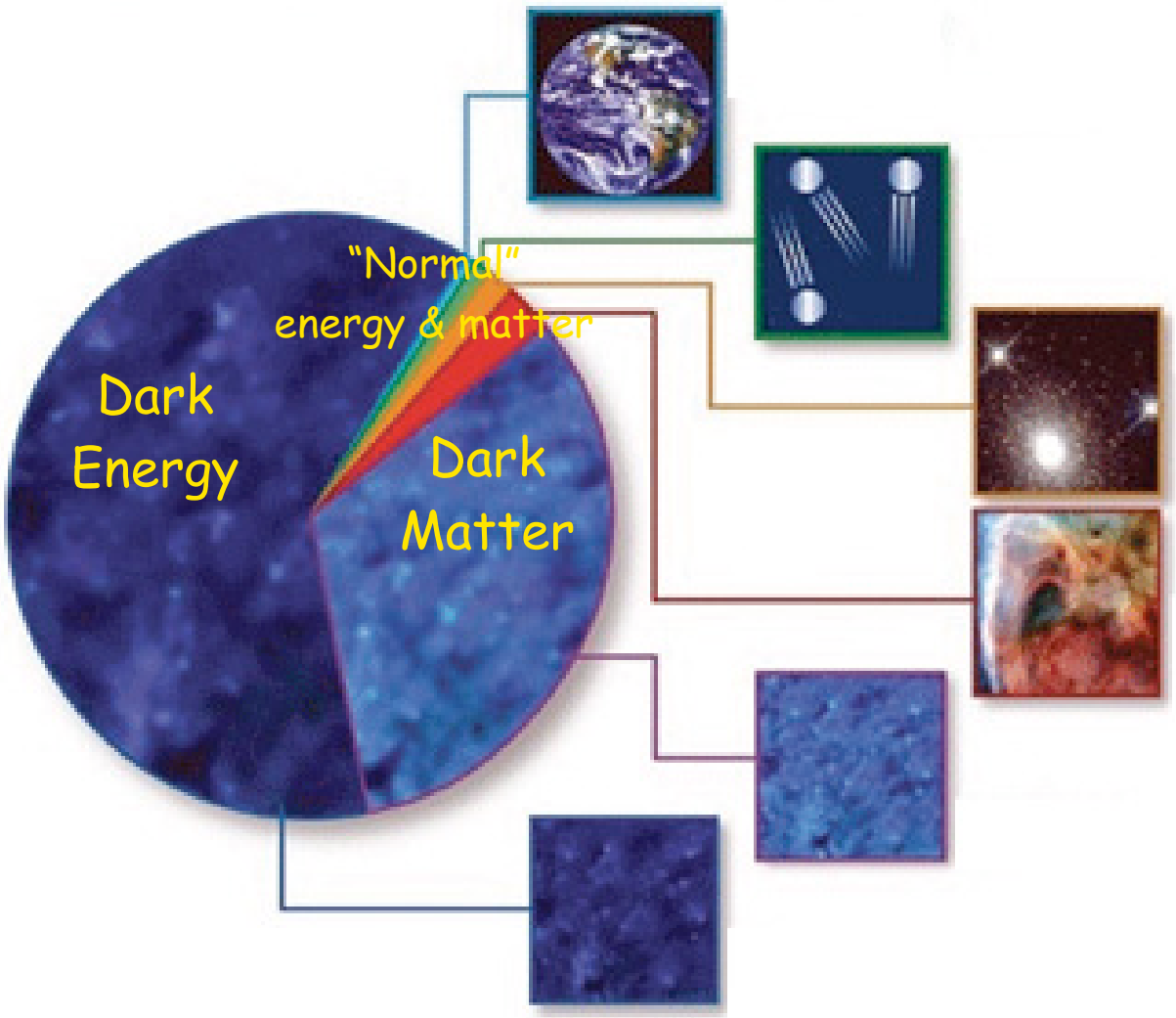
Study of the variable sky



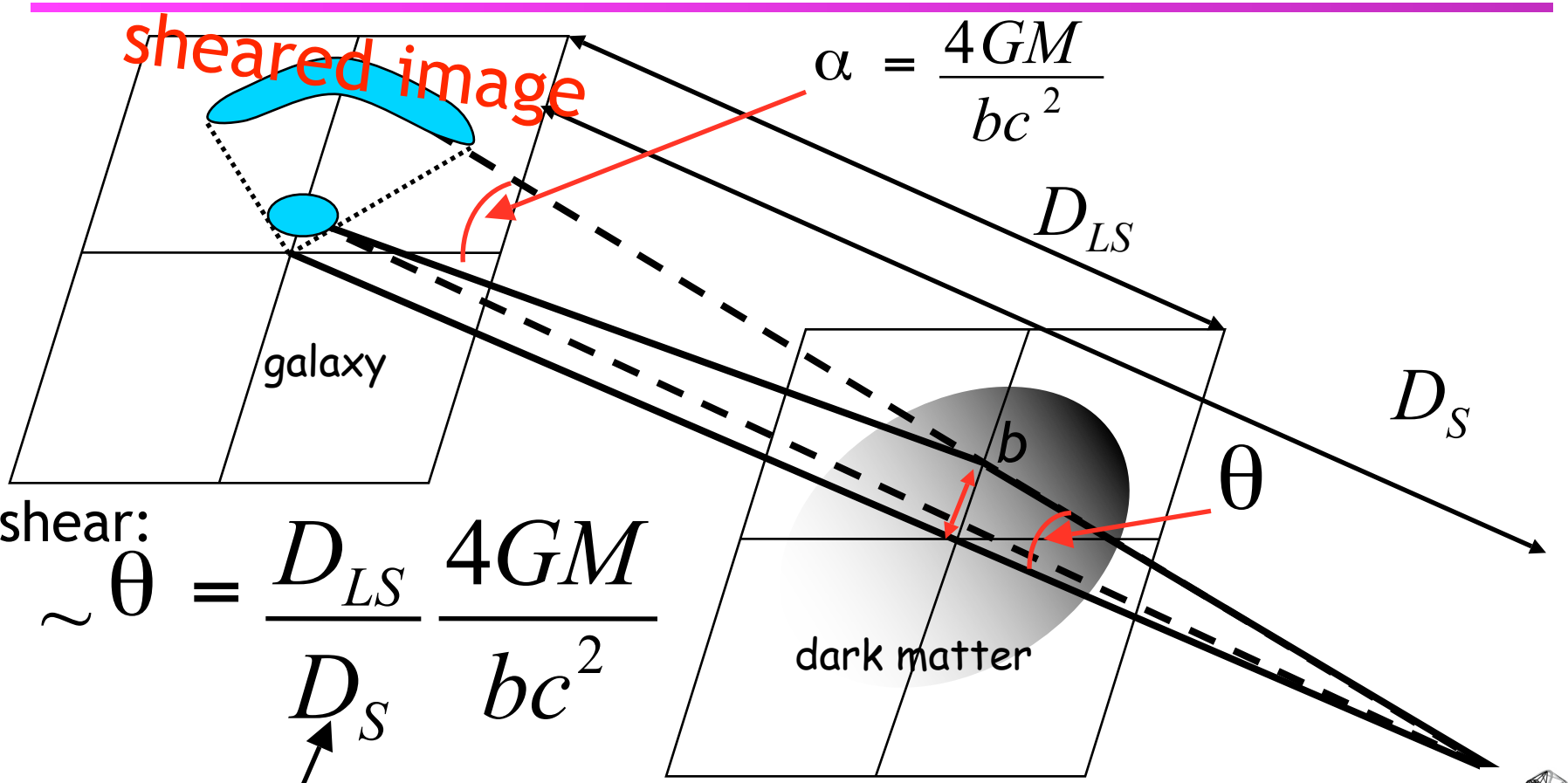
DD

95% of the mass-energy in the universe is “dark”

Cosmological way of looking at Dark Matter and Dark Energy



Dark Matter can be mapped by Gravitational Weak Lensing



shear:

$$\gamma \sim \theta = \frac{D_{LS}}{D_S} \frac{4GM}{bc^2}$$

Cosmology changes geometric distance factors

It's Star Trek Moment !

DD

LSST Images will be Crucial in Exploration of Dark Matter and Dark Energy

- **Weak Lensing maps distribution and evolution of dark matter over half the life time of the universe.**

- **Dark Energy - Other than its existence, we know *nothing* about it.**
  LSST will discover 1,000 novae a night - constrains many dark energy theories.

Dark Energy - Be sure you <u>really</u> want to find what you are looking for!

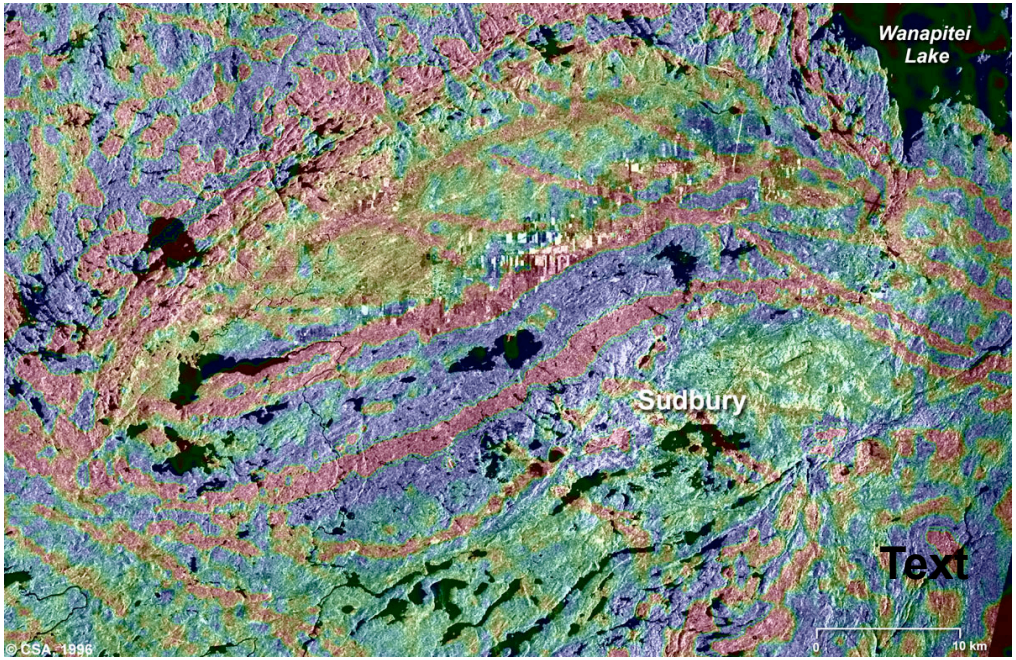
DD

And now for something completely different.

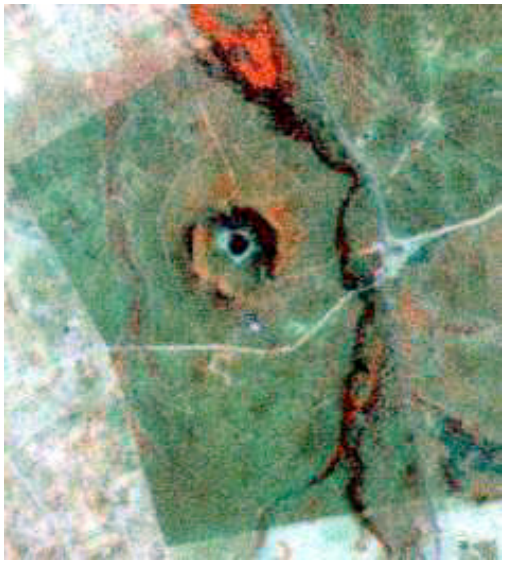
Near Earth Objects

- Inventory of solar system is incomplete
- LSST would get orbits of 90+% of NEOs larger than 250m
- Demanding project: requires mapping the sky every few days, individual exposures not to exceed ~15 sec

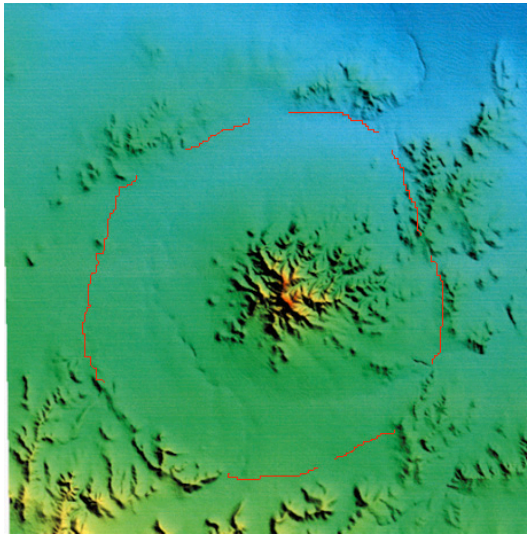
Over 150 Recognized Terrestrial Impact Craters



Sudbury Crater
1.8 billion years old
200 km diameter
31,000 cubic kilometers of impact melt
(Chicxulub was about 18,000)



Tswaing Crater
South Africa
220,000 years old
1.1 km diameter



Sierra Madera Crater
Ft. Stockton Texas
<100 million years old
13 km diameter

3,552 Near Earth Objects are KNOWN

- Primarily found by ground based optical searches
- Size range from 10 meters to 30 Km
- Estimates of 1,000,000 objects larger than 50 meters
- 500 new objects discovered just in 2004

Diameter (meters)	*Collisions/ year*	*Energy*	*Impact Effect*	*Solution*
10	$3*10^{-2}$	150 Ktons	Bad Locally	Run away!
100	$5*10^{-4}$	150 Megatons	Km Size Impact Crater	Book a very long flight now. Prices will only go up.
1,000	10^{-6}	100 Gigatons	Serious Global Problem	You can run, but you can't hide

DD

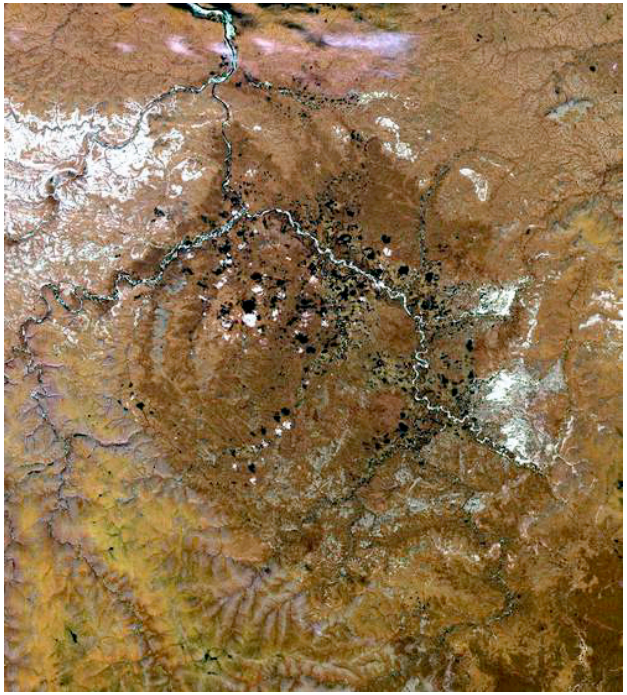
Near Earth Objects coming to a place *near* you Real Soon Now

Object Name	Approach Date	Miss Distance (AU)	Miss Distance (LD)	Diameter*	Velocity (km/s)
(2005 QY151)	2006-Apr-12	0.089	34.7	790 m - 1.8 km	11.97
(2004 WG1)	2006-Apr-15	0.0826	32.2	860 m - 1.9 km	17.07
(2006 FH)	2006-Apr-15	0.0479	18.6	36 m - 80 m	6.67
(2006 GC)	2006-Apr-16	0.0418	16.3	33 m - 74 m	12.22
(2005 TF49)	2006-Apr-16	0.0517	20.1	430 m - 960 m	12.5
(2004 RQ252)	2006-Apr-21	0.1307	50.9	90 m - 200 m	15.66
(2001 SG276)	2006-Apr-26	0.09	35	800 m - 1.8 km	14.69
(2006 GB1)	2006-Apr-27	0.0375	14.6	36 m - 80 m	7.67
(2004 GU9)	2006-Apr-30	0.1684	65.5	150 m - 340 m	7
(2003 SN214)	2006-Apr-30	0.1779	69.2	69 m - 150 m	15.47
(2000 EM26)	2006-May-02	0.1092	42.5	120 m - 270 m	10.42
(2002 CD)	2006-May-03	0.1181	45.9	230 m - 510 m	8.58
41429 (2000 GE2)	2006-May-10	0.1826	71.1	250 m - 550 m	11.39
(2005 YA37)	2006-May-13	0.1287	50.1	87 m - 190 m	7.72
68950 (2002 QF15)	2006-May-13	0.1253	48.7	1.5 km - 3.4 km	14.04

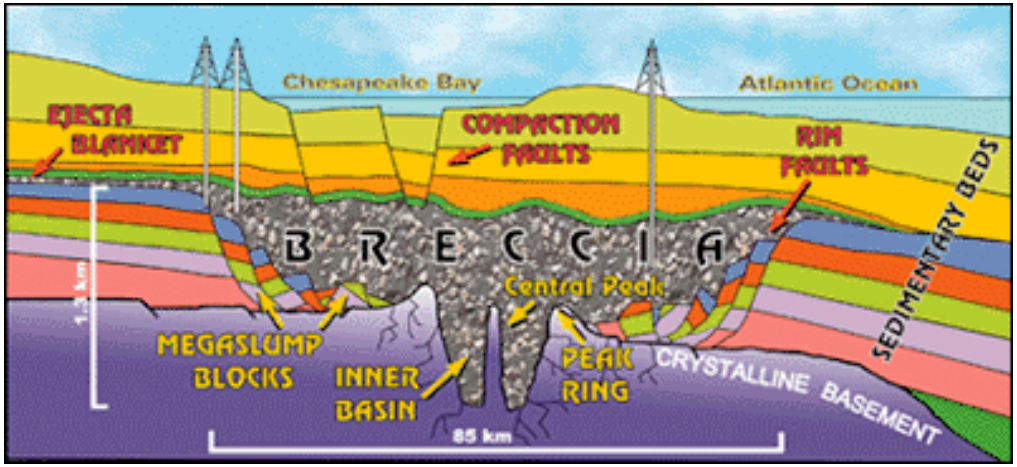
- No known Earth-crushers on the way. At least none I know of. DD

Impacts on the earth are only natural

Both impact structures are about 35 million years old, with diameters near 100 km.



Popigai crater in Siberia



Chesapeake Bay Crater, US

There will be another large impact resulting in global catastrophe any mega-year now.

DD

LSST Partners

Large Synoptic Survey Telescope

RESEARCH CORPORATION

THE UNIVERSITY OF ARIZONA®

NOAO

UNIVERSITY OF WASHINGTON

SLAC

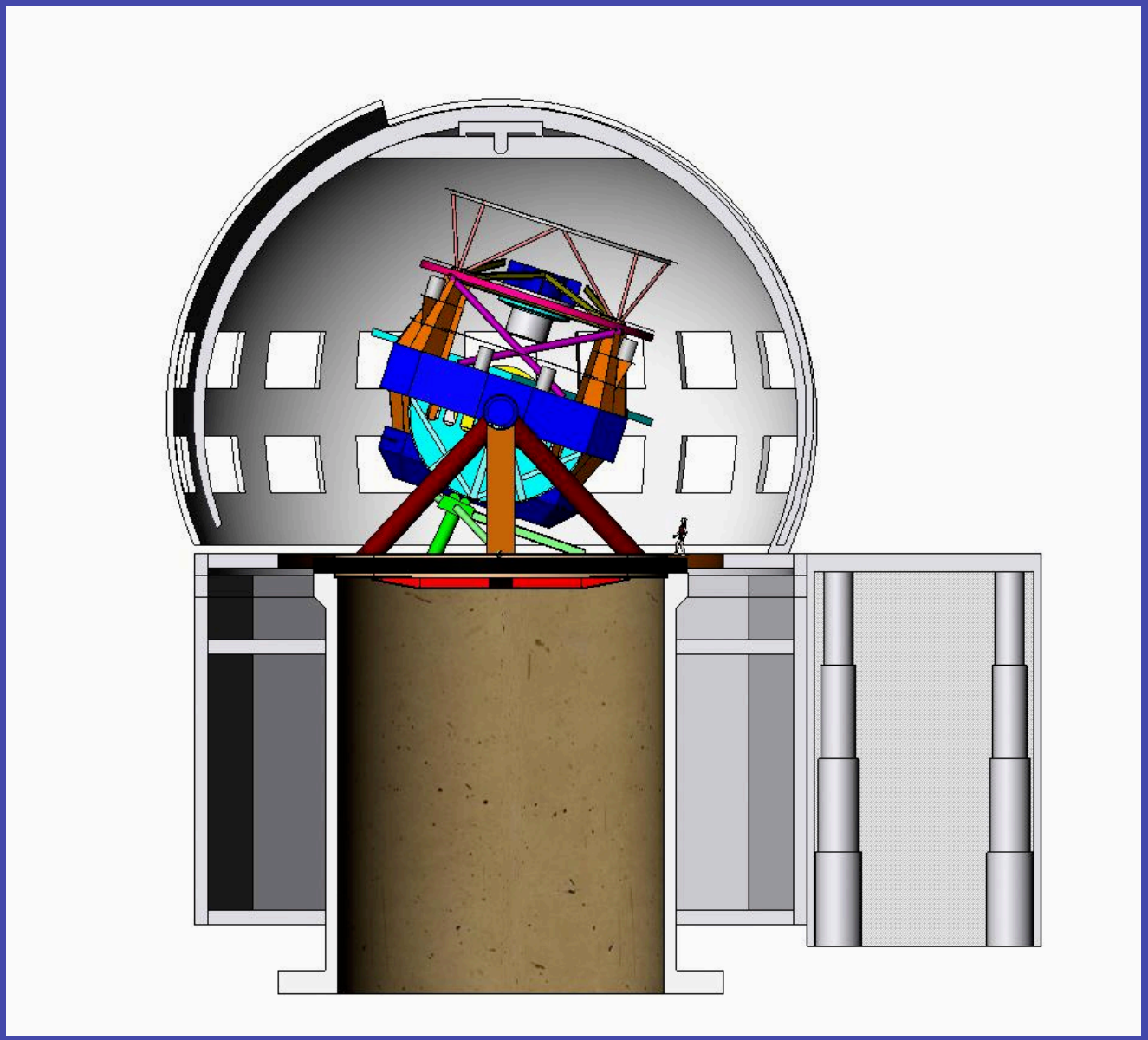
BROOKHAVEN NATIONAL LABORATORY

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
TM

LELAND STANFORD JUNIOR UNIVERSITY
DIE LUFT DER FREIHEIT WEHT
1891

VE RI TAS

UCDAVIS
University of California, Davis

JOHNS HOPKINS
UNIVERSITY

Visit our site at **www.lsst.org**