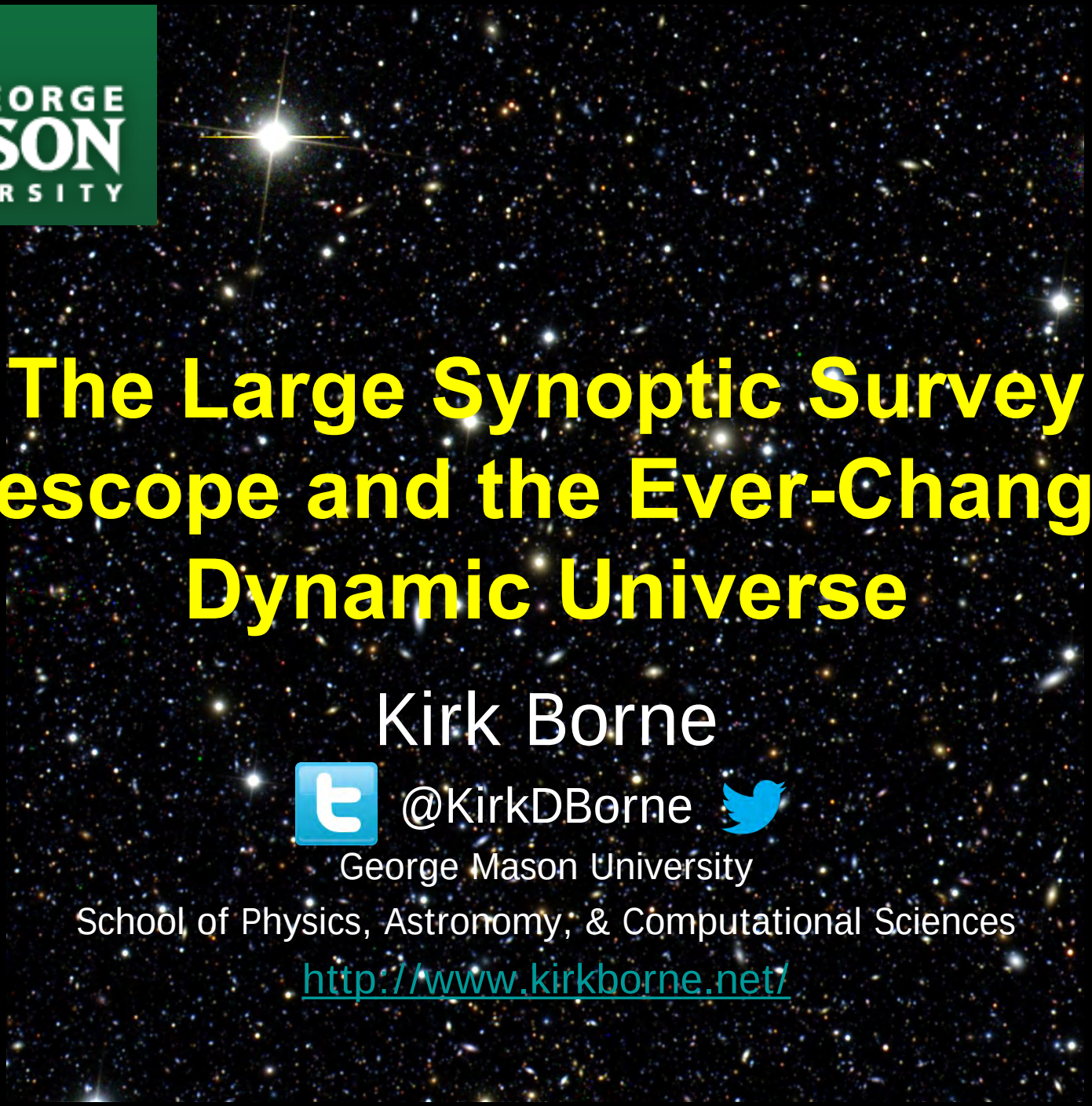


The Large Synoptic Survey Telescope and the Ever-Changing Dynamic Universe

Kirk Borne

@KirkDBorne

George Mason University

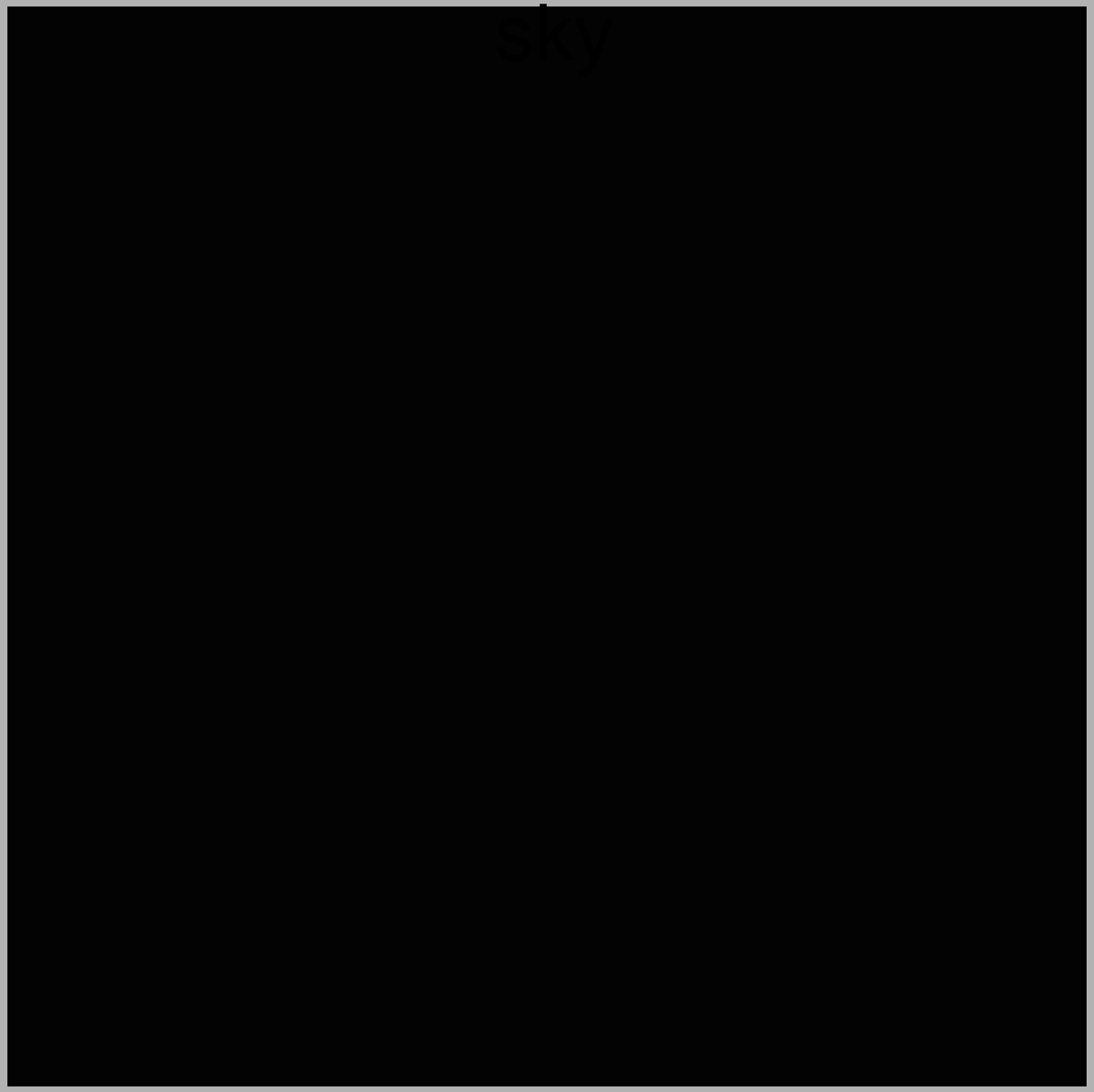
School of Physics, Astronomy, & Computational Sciences

http://www.kirkborne.net/

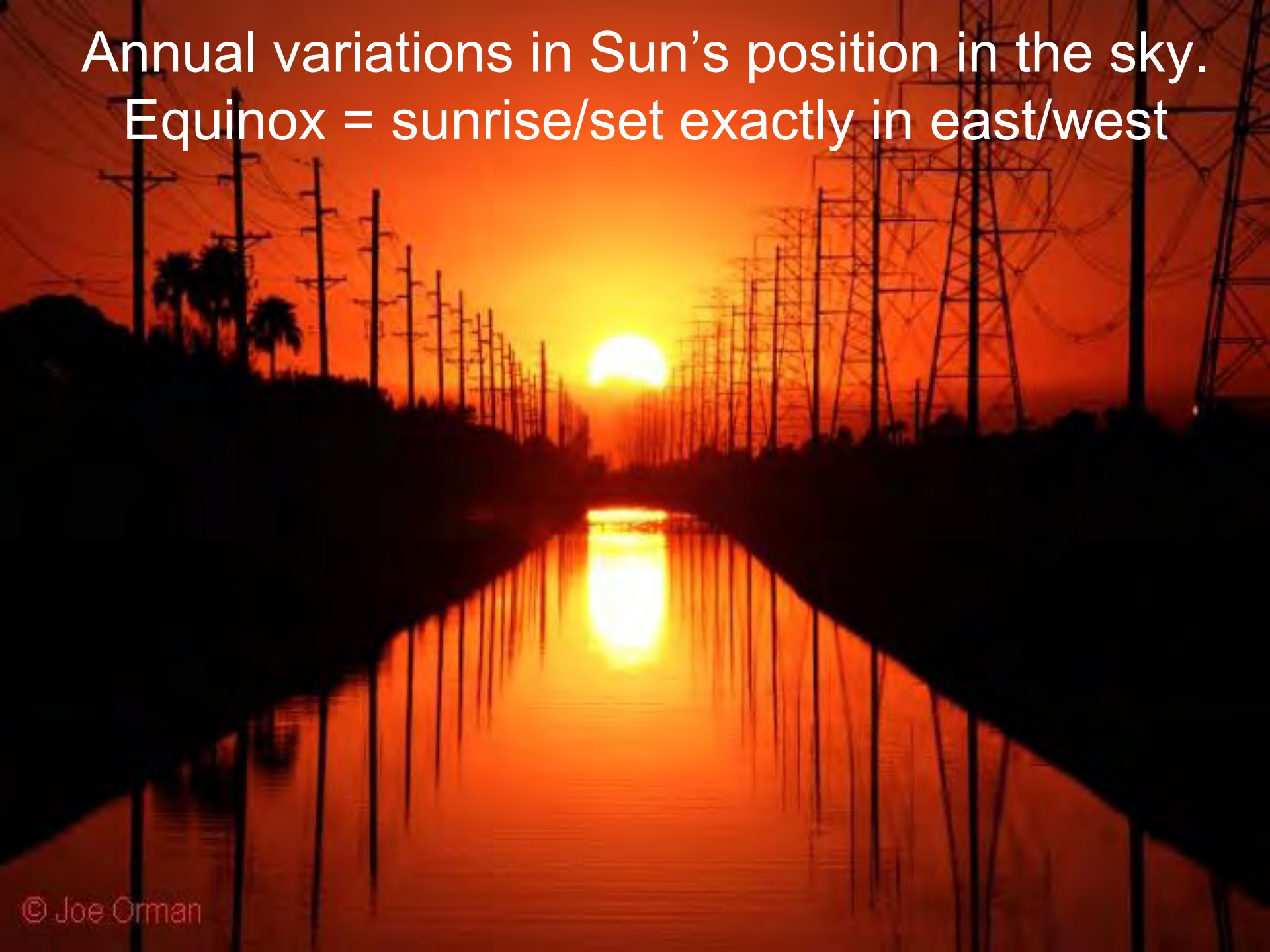
Ancient Civilizations studied the sky and noticed many exciting things


Daily motion of the stars around the sky

Monthly Phases of the Moon – known since humans first gazed into the night sky



Annual variations in Sun's position in the sky.
Equinox = sunrise/set exactly in east/west



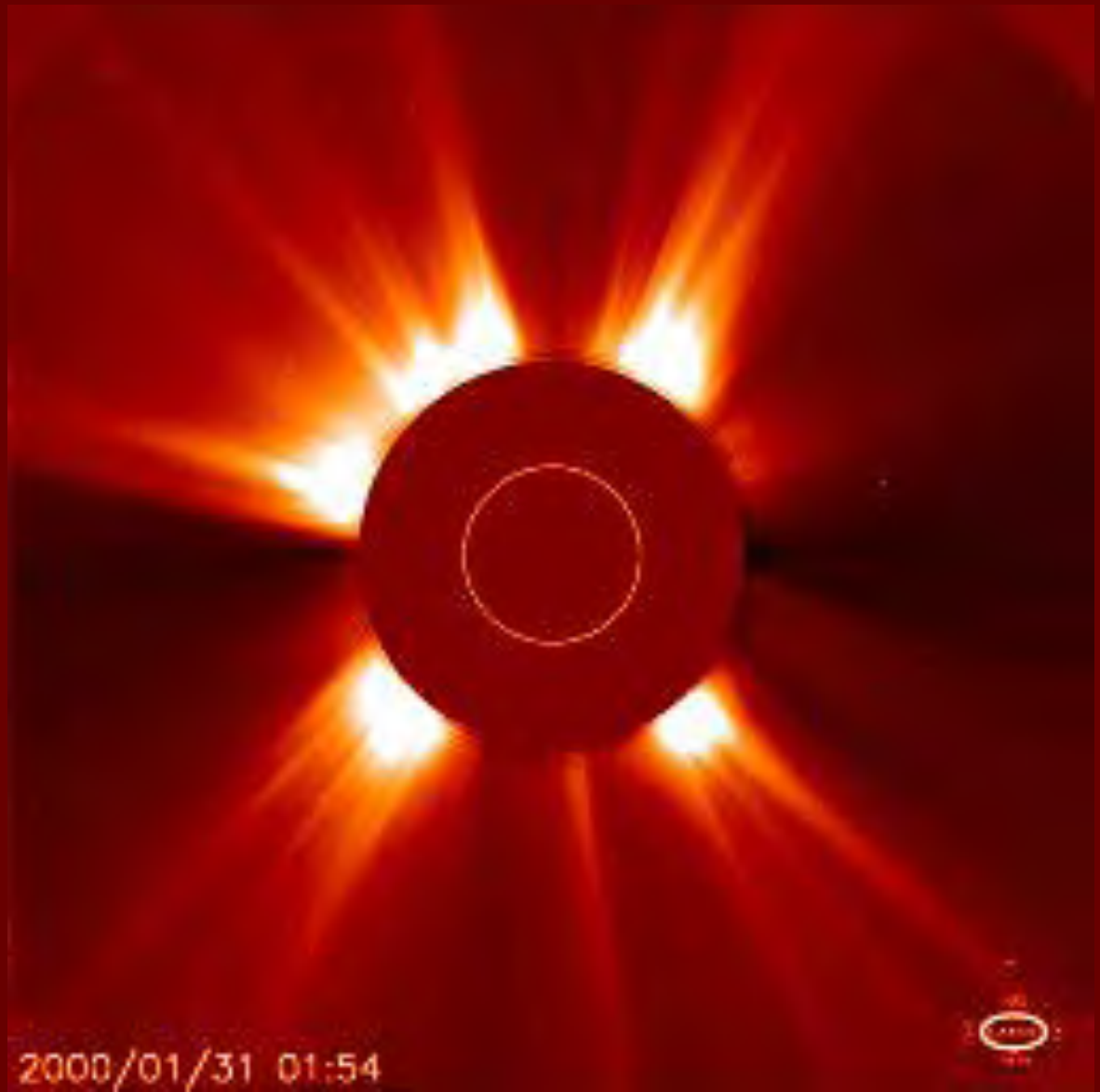
Wandering Motion of Venus (and other planets)

Solar Eclipse = Sun blocked by the Moon

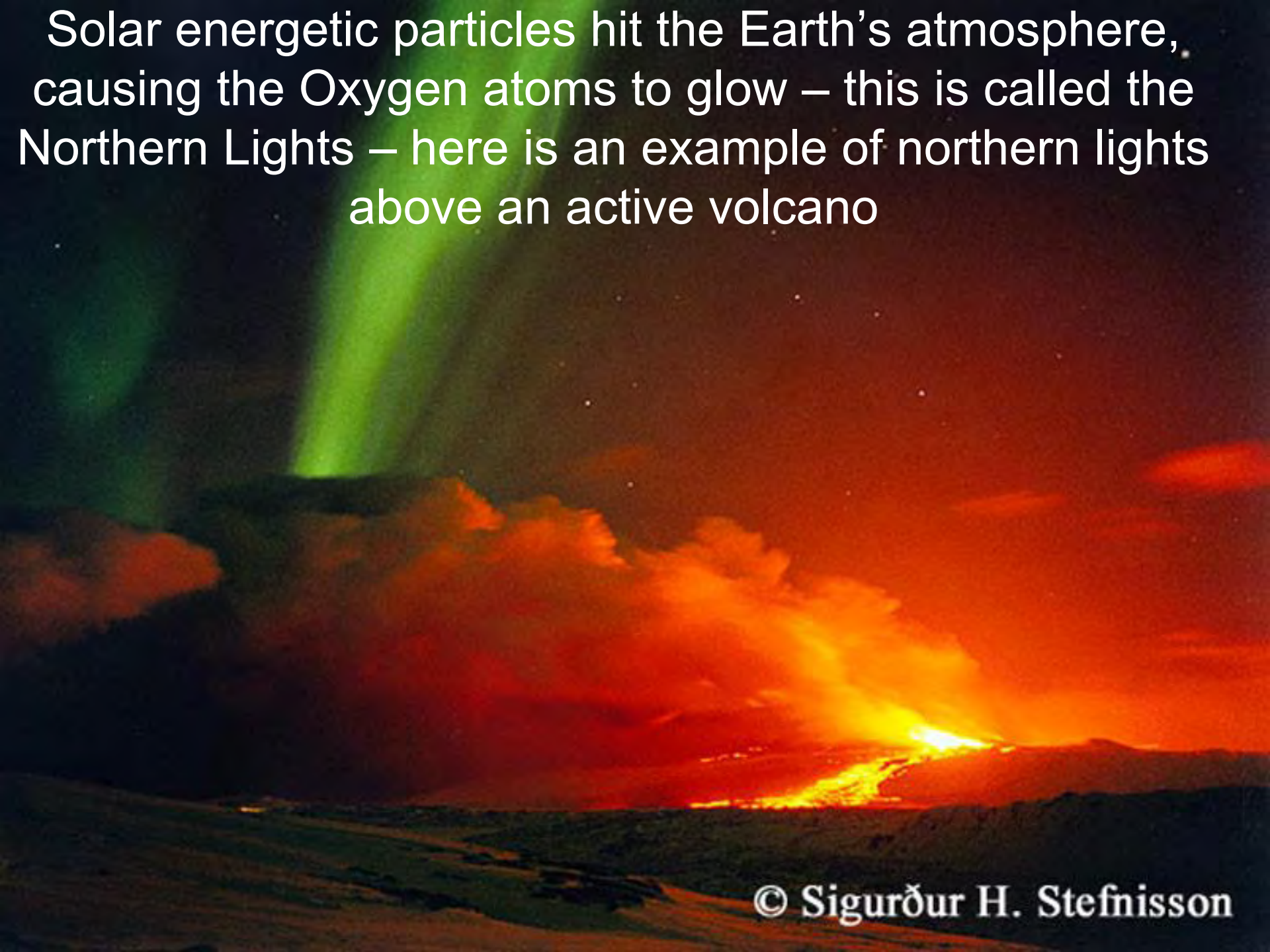
Lunar Eclipse = the Moon passes through the Earth's shadow

Comets = occasional, spectacular visitors from deep space

Telescopes in space watch the eruptions of hot gas from the Sun

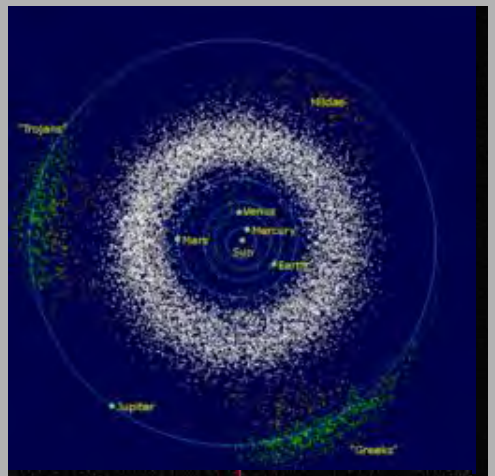


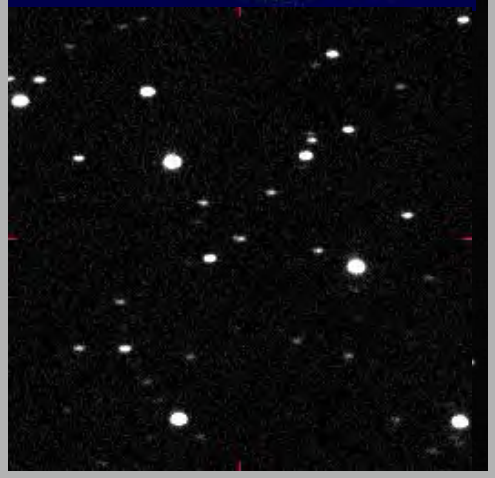
Solar energetic particles hit the Earth's atmosphere, causing the Oxygen atoms to glow – this is called the Northern Lights – here is an example of northern lights above an active volcano



Dynamic Astronomy: The Universe is not static !

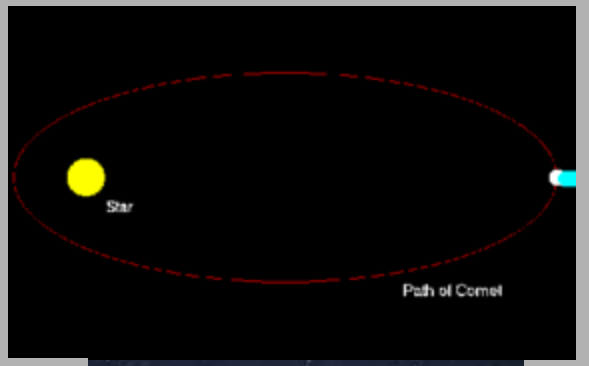
Asteroids





Supernovae

Comets




Far beyond our Solar System,
in Deep Space, we see new stars being born
Everything is
moving and dynamic!

Star Death – last gasp of star's life

NOVA !!!!

Supernovae: exploding stars

BEFORE

Supernovae: exploding stars

AFTER

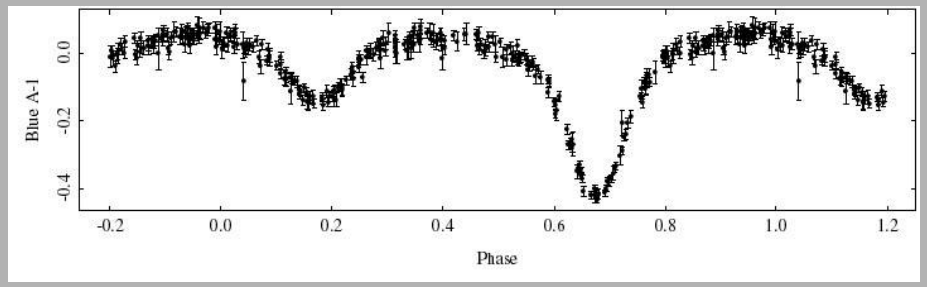
Supernovae: exploding stars

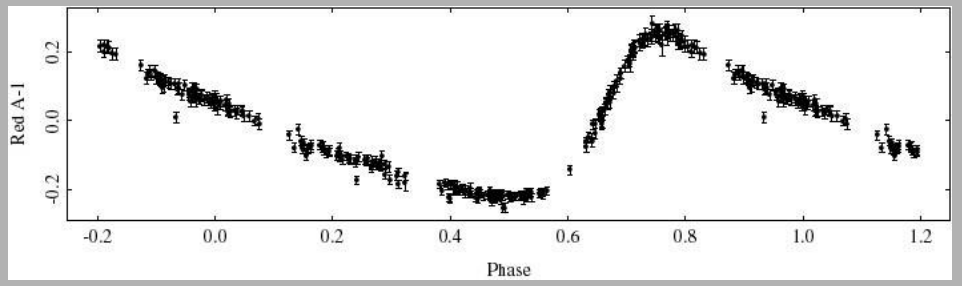
AFTER

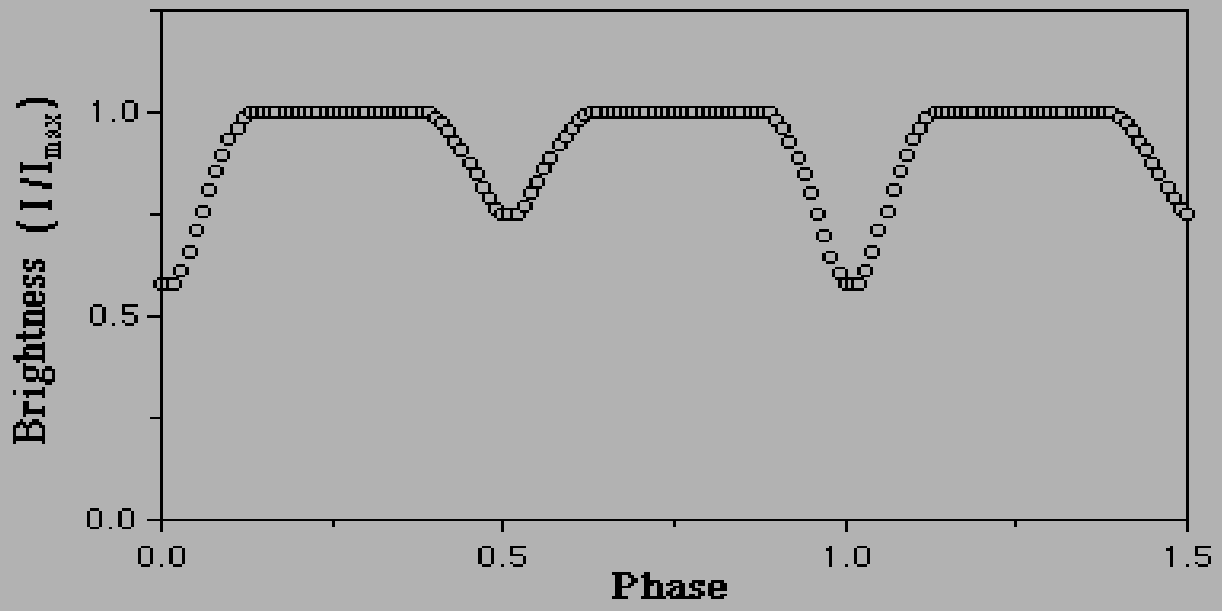
BEFORE

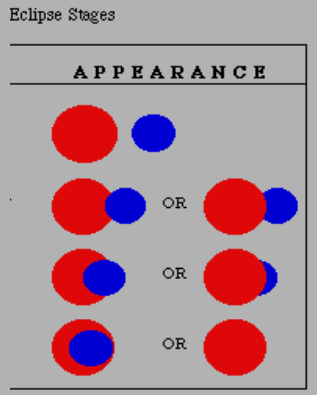
Some stars change brightness more gradually on a more regular schedule:

Variable Stars –eclipsing, pulsating, etc.



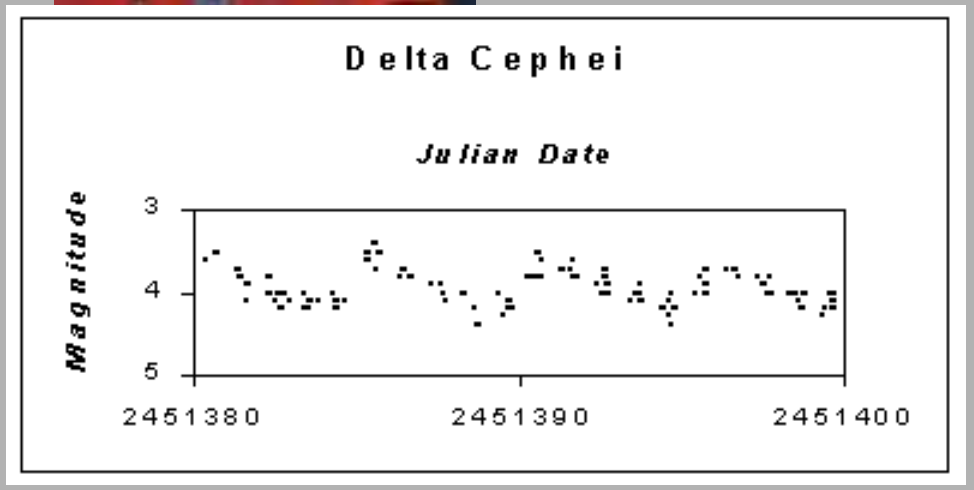






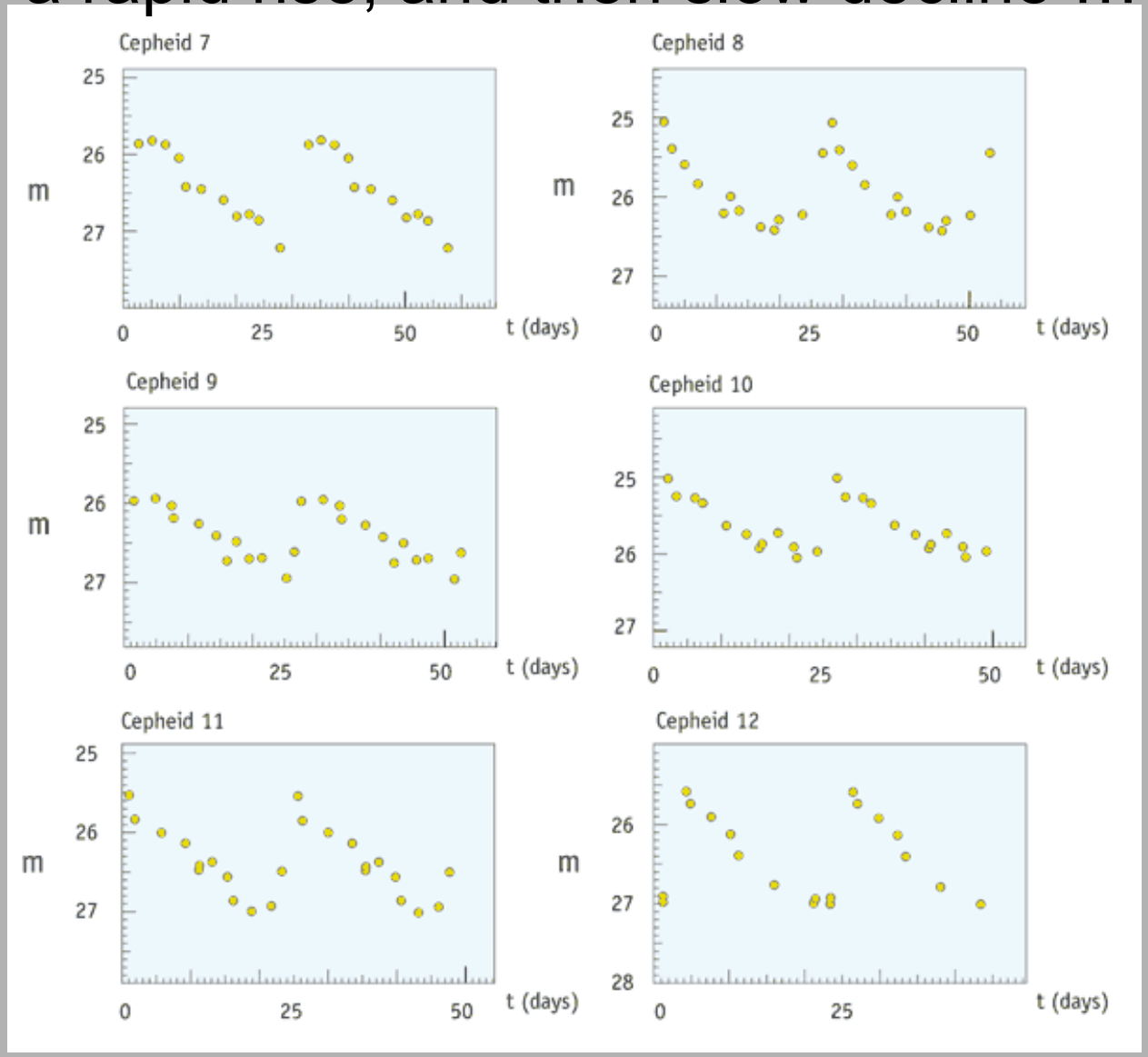
Scientist in history: Henrietta Leavitt (1868-1921) measured brightness variations of 1000's of stars – the basis for the distance scale of the Universe

The Cephus Constellation: "The King"



Real Cepheid data: pulsating variable stars.

Note the characteristic light curve shape –
a rapid rise, and then slow decline …



Scientist in history:

Edwin Hubble (1889-1953) measured distances to galaxies using distances to Cepheid variable stars, and thereby he discovered the expansion of the Universe, confirming Einstein's original Theory of General Relativity.

And so we named a certain famous space telescope in his honor.

Astronomers now study the sky with large systematic Sky Surveys

Why do we need another big telescope?

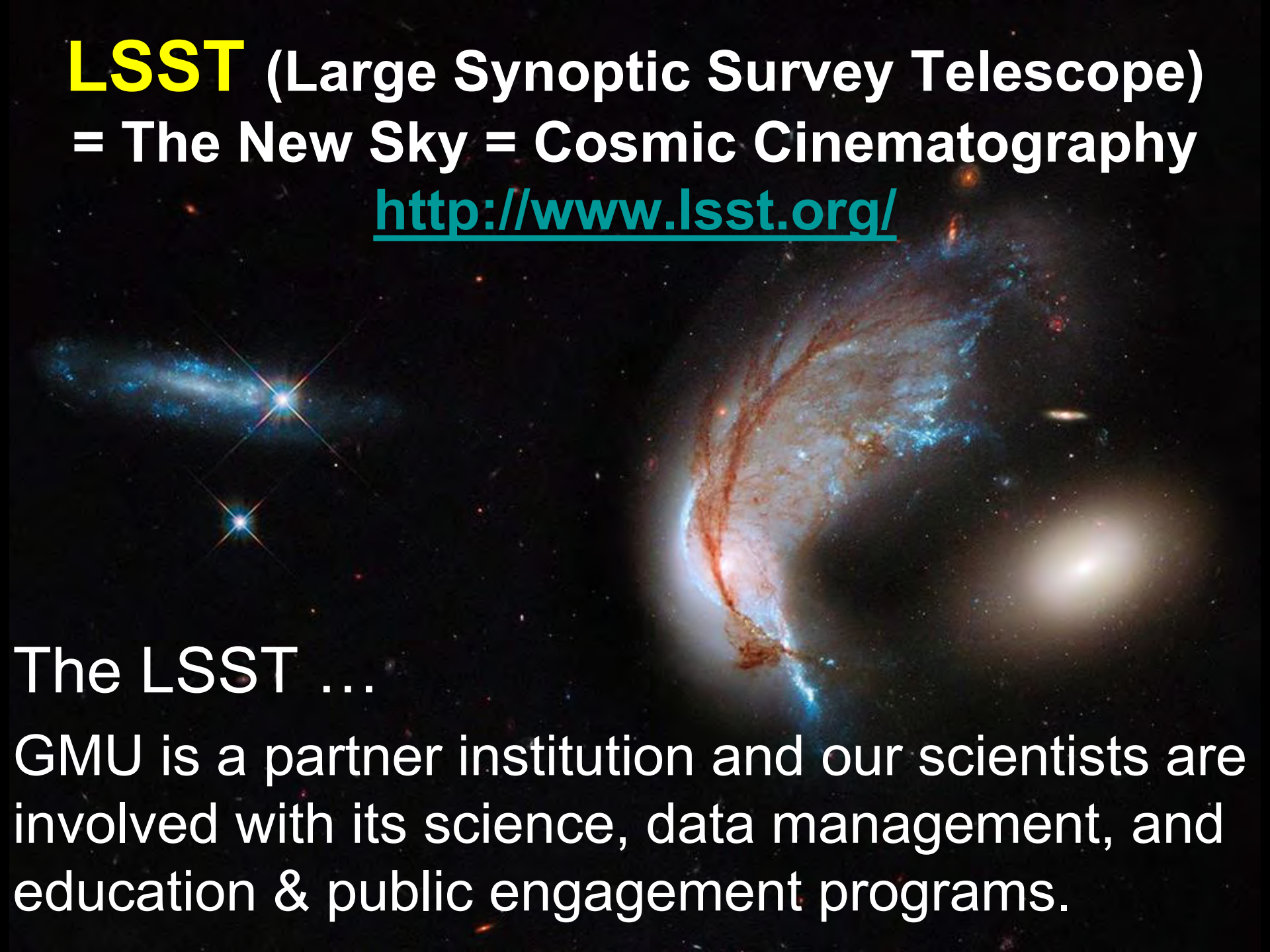
Because …

… many great scientific discoveries have come from inter-comparisons of diverse data sources:

- **Quasars**
- **Gamma-ray bursts**
- **Ultraluminous IR galaxies**
- **X-ray black-hole binaries**
- **Radio galaxies**
- **. . .**

LSST (Large Synoptic Survey Telescope) = The New Sky = Cosmic Cinematography

http://www.lsst.org/

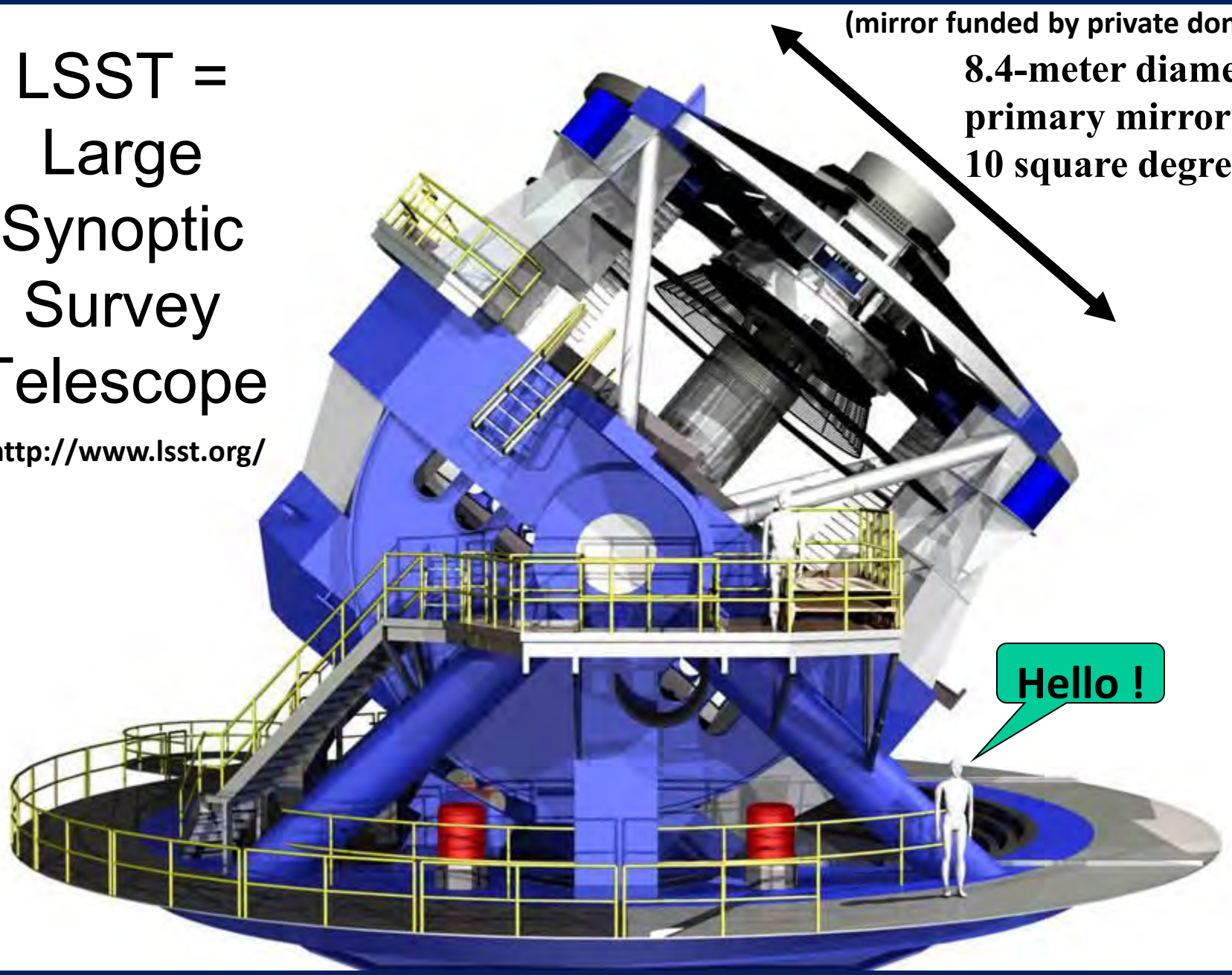


The LSST …

GMU is a partner institution and our scientists are involved with its science, data management, and education & public engagement programs.

LSST = Large Synoptic Survey Telescope

http://www.lsst.org/

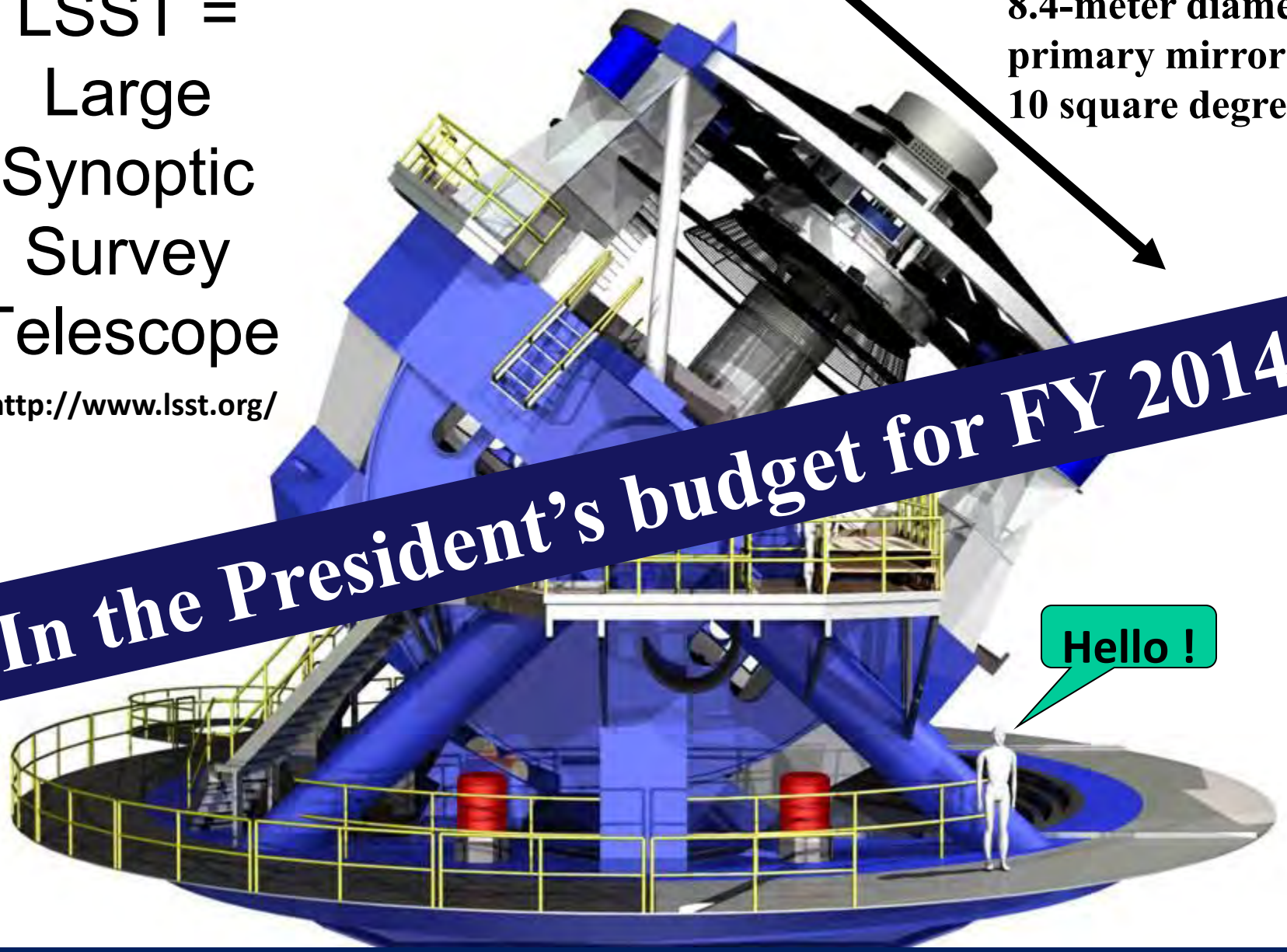


LSST =
Large
Synoptic
Survey
Telescope

http://www.lsst.org/

(mirror funded by private donors)

8.4-meter diameter primary mirror = 10 square degrees!



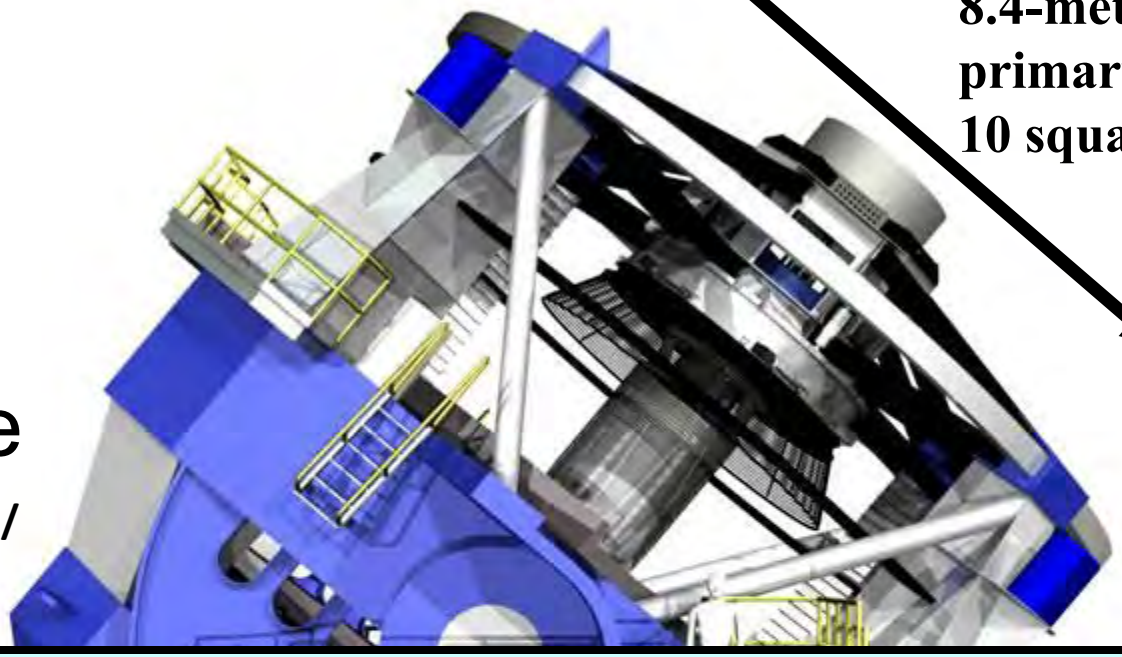
In the President's budget for FY 2014

LSST = Large Synoptic Survey Telescope

http://www.lsst.org/

(mirror funded by private donors)

8.4-meter diameter primary mirror = 10 square degrees!



- **100-200 Petabyte image archive**
- **20-40 Petabyte database catalog**

LSST design – architectural rendering #1

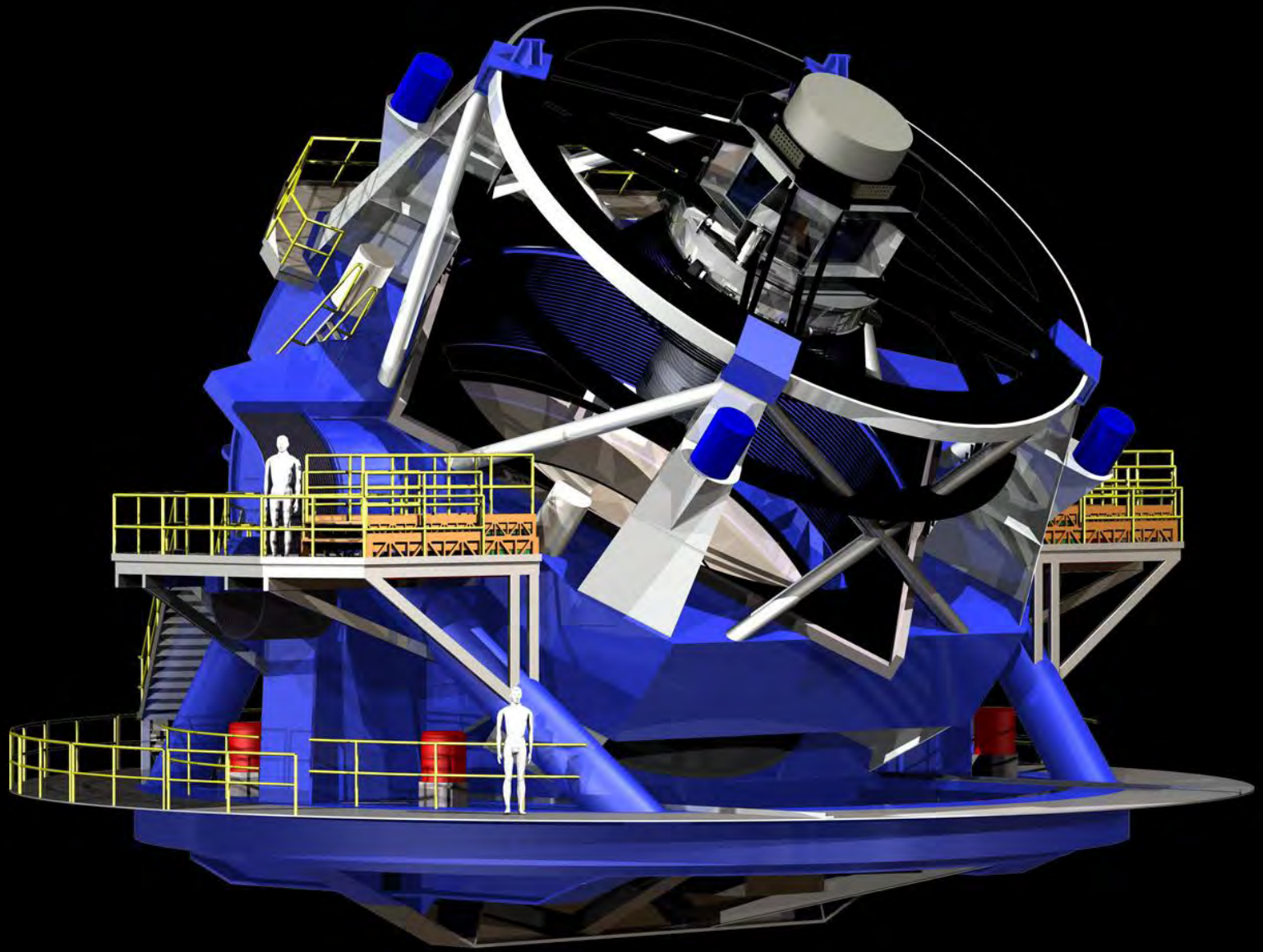
LSST design – architectural rendering #2

LSST design – architectural rendering #3

LSST – real steps toward construction (3/8/2011) – first of many blasts to level the mountaintop

Boom!

LSST design – architectural rendering #4



LSST design – architectural rendering of 3-mirror system, plus camera optics shown here

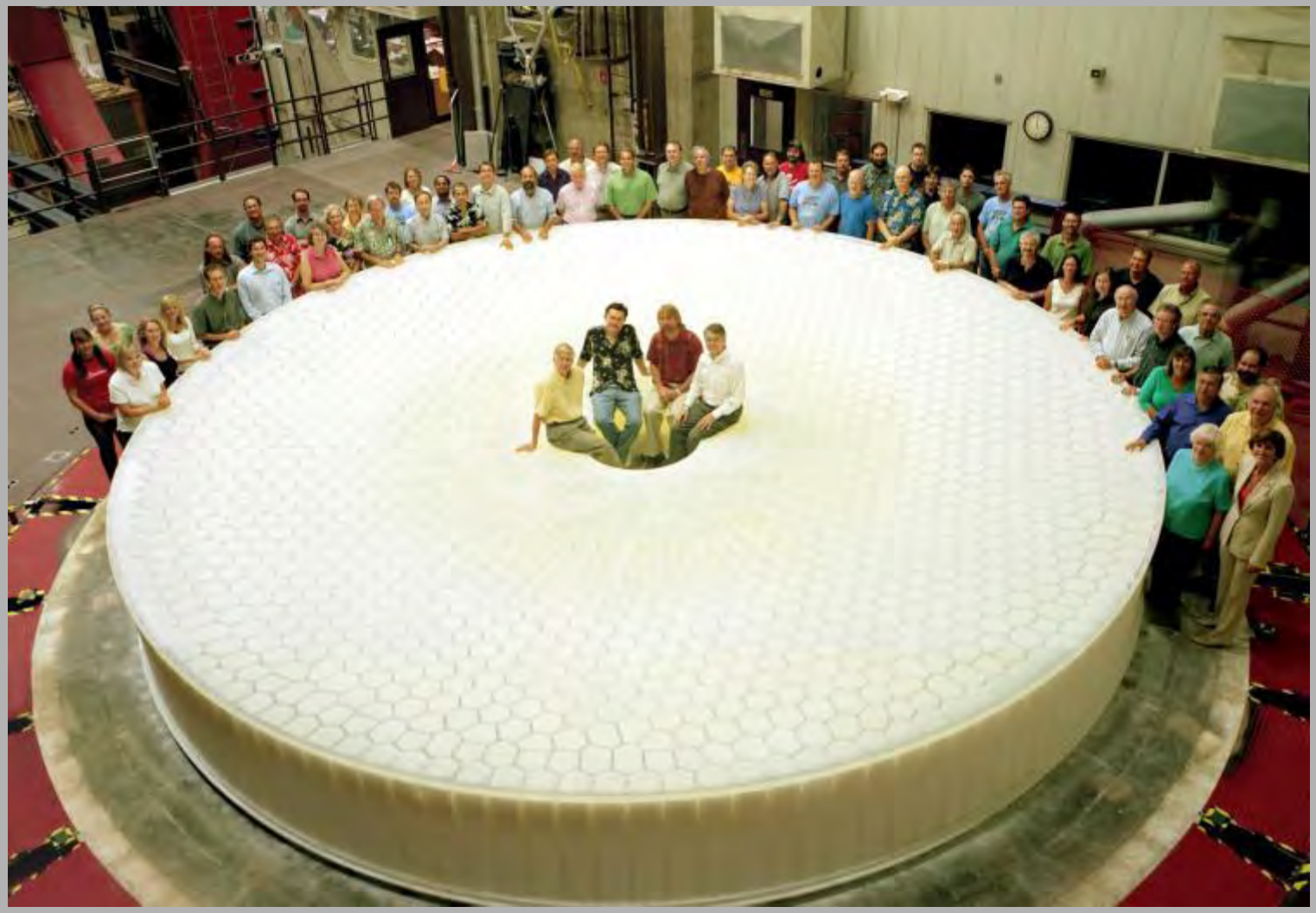
Large Mirror Fabrication (for large telescopes, such as LSST)

That's big!

(Univ. of Arizona Mirror Laboratory)

This is LSST's real mirror blank –
the first piece of the Large Synoptic Survey Telescope

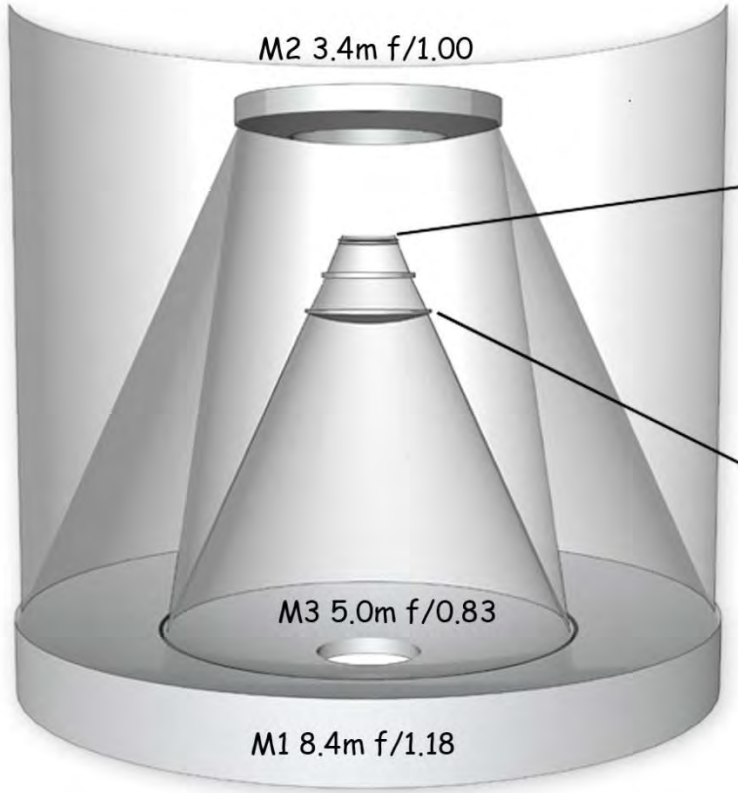
http://www.lsst.org/

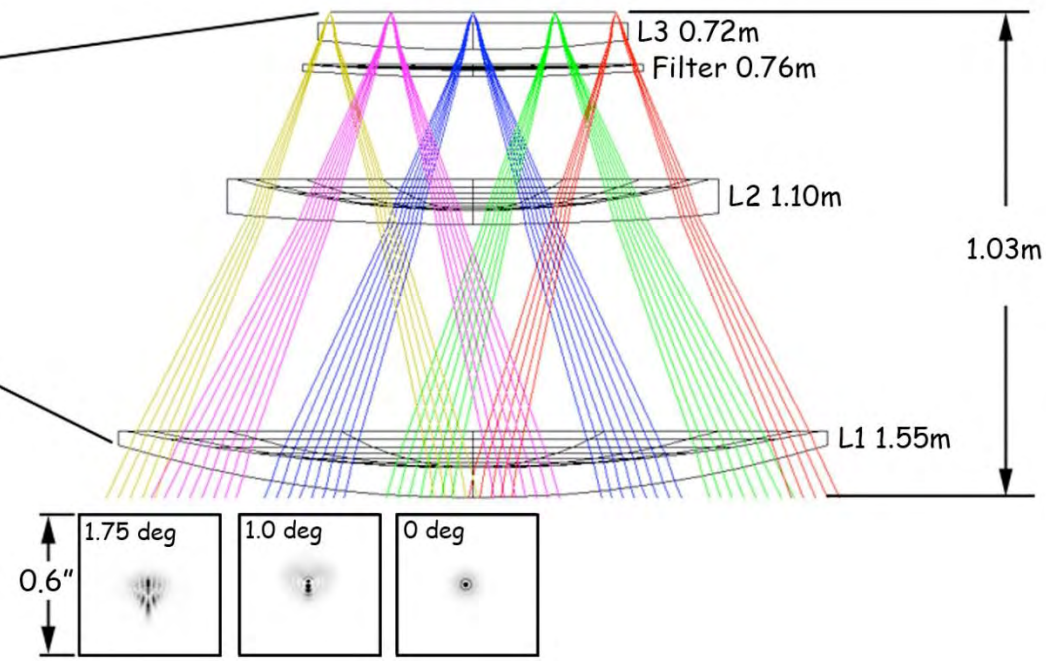


This is the real LSST mirror (August 2008), which will be figured and polished over the next several years

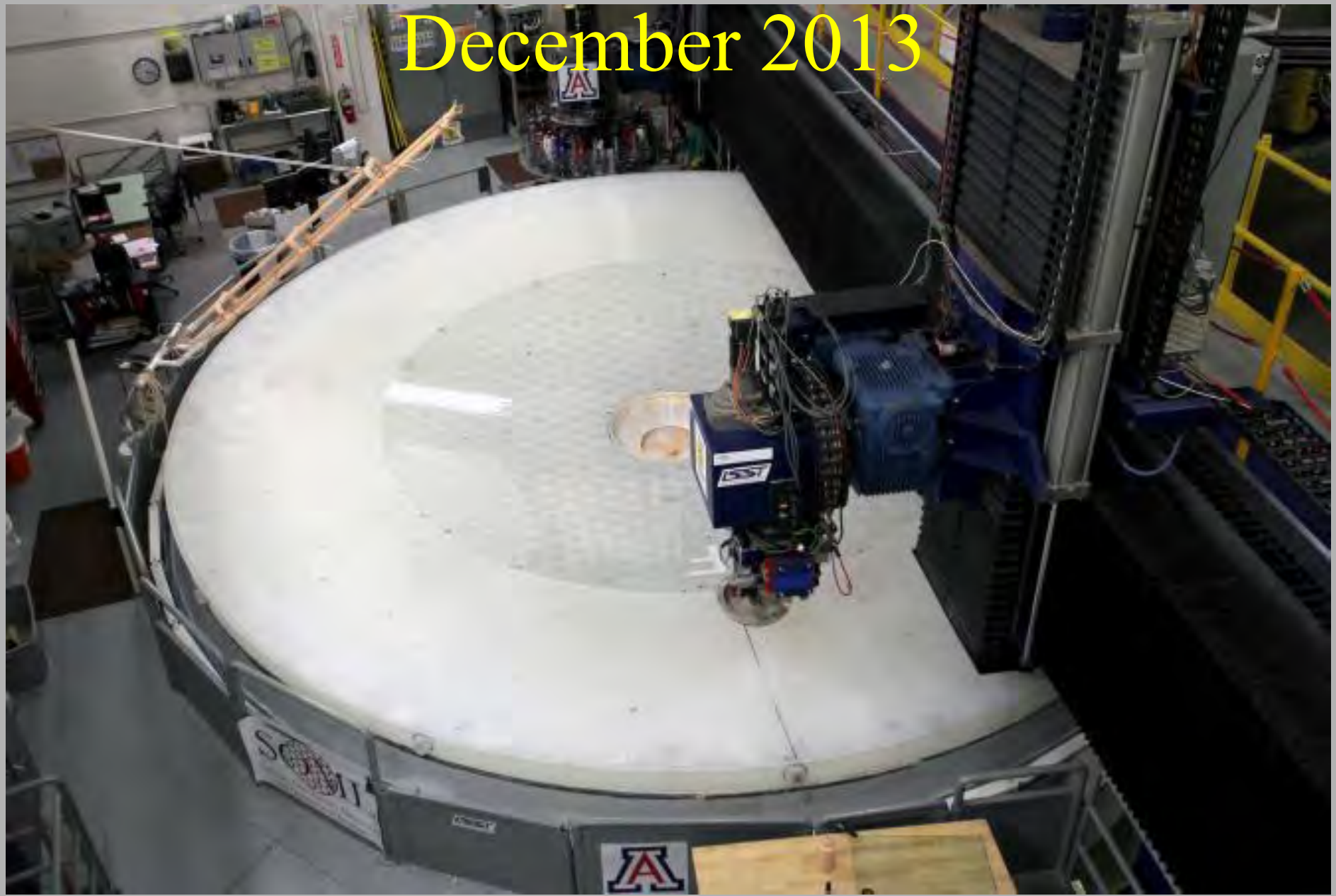
(notice the cool guy in the middle of the back row in the gold LSU tigers shirt)

LSST optical design – ray tracing through main mirrors and camera optics



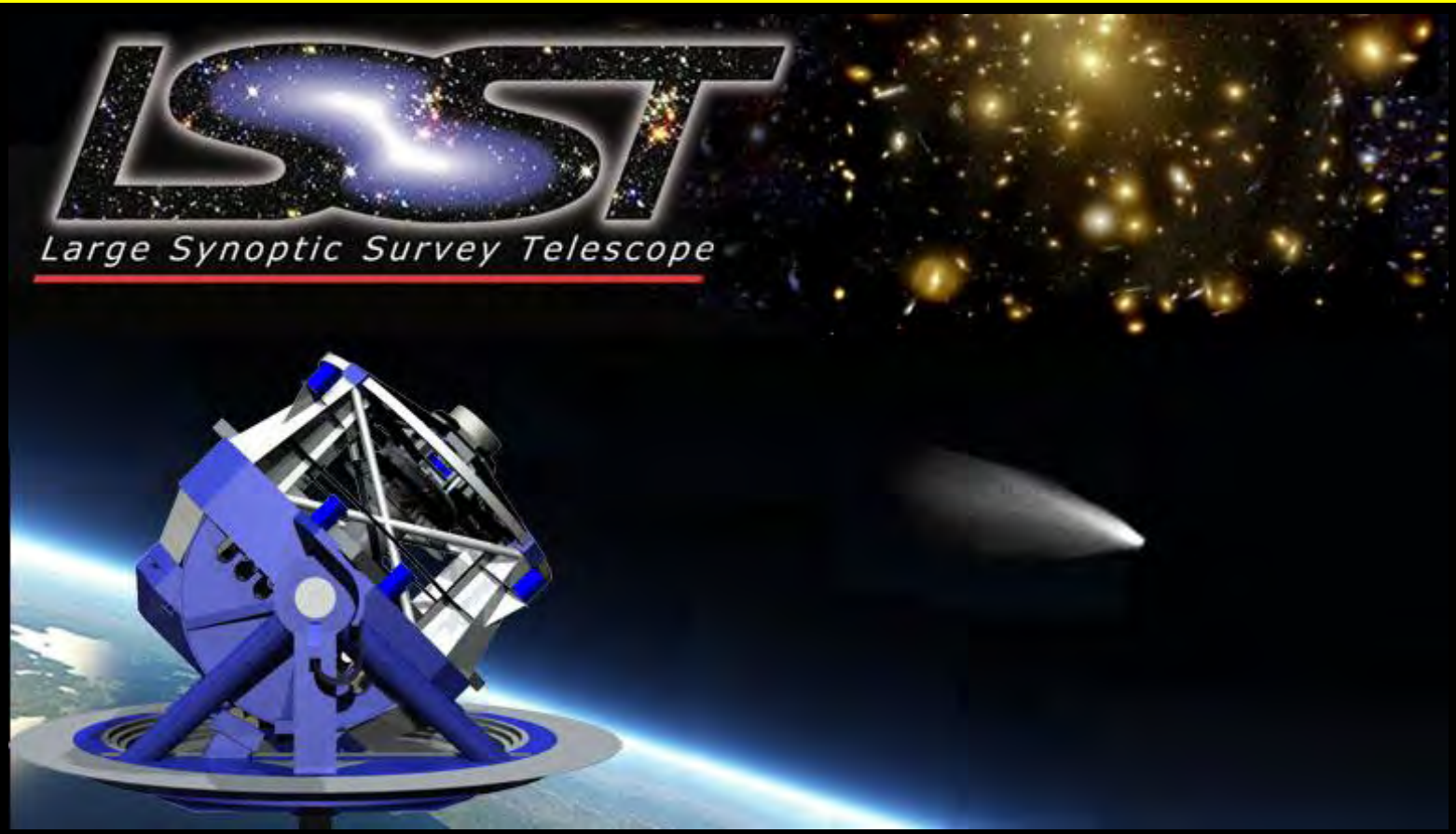


Polishing M1/M3 (mirror 1 & 3)



Observing Strategy: One pair of images every 40 seconds for each spot on the sky, then continue across the sky continuously every night for 10 years (~2022-2032), with time domain sampling in log(time) intervals (to capture dynamic range of transients).

- **LSST (Large Synoptic Survey Telescope):**
  - Ten-year time series imaging of the night sky – mapping the Universe !
  - **~10,000,000 events each night** – *anything that goes bump in the night !*
  - ***Cosmic Cinematography! The New Sky! @ http://www.lsst.org/***



LSST Key Science Drivers: Mapping the Dynamic Universe

– Solar System Inventory (moving objects, NEOs, asteroids: census & tracking)
– Nature of Dark Energy (distant supernovae, weak lensing, cosmology)
– Optical transients (of all kinds, with alert notifications within 60 seconds)
– Digital Milky Way (proper motions, parallaxes, star streams, dark matter)

South America

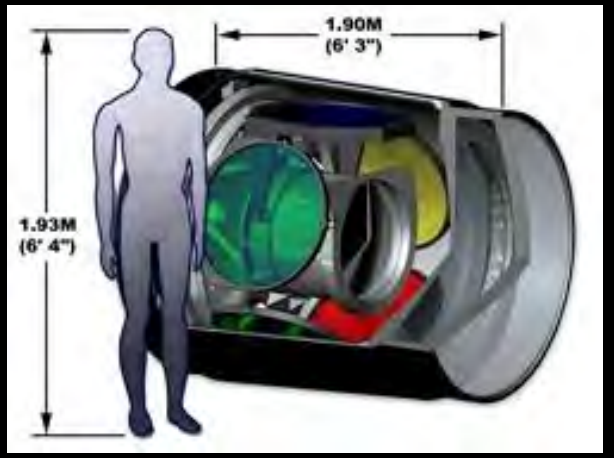
Chile

Region de Coquimbo

<u>LSST in time and space:</u>

– When? ~2022-2032
– Where? Cerro Pachon, Chile

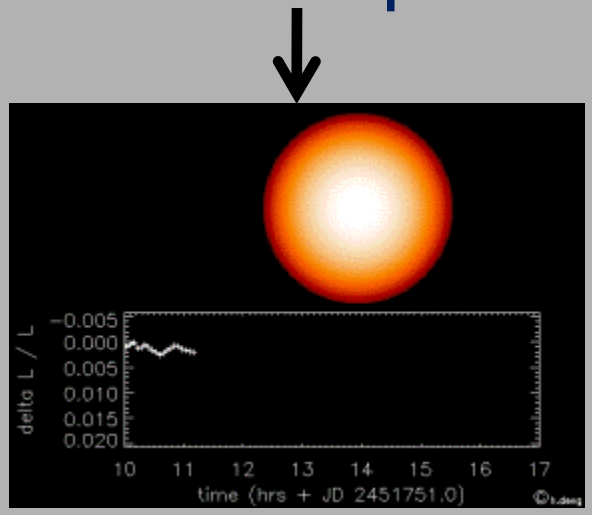
LSST Summary
http://www.lsst.org/



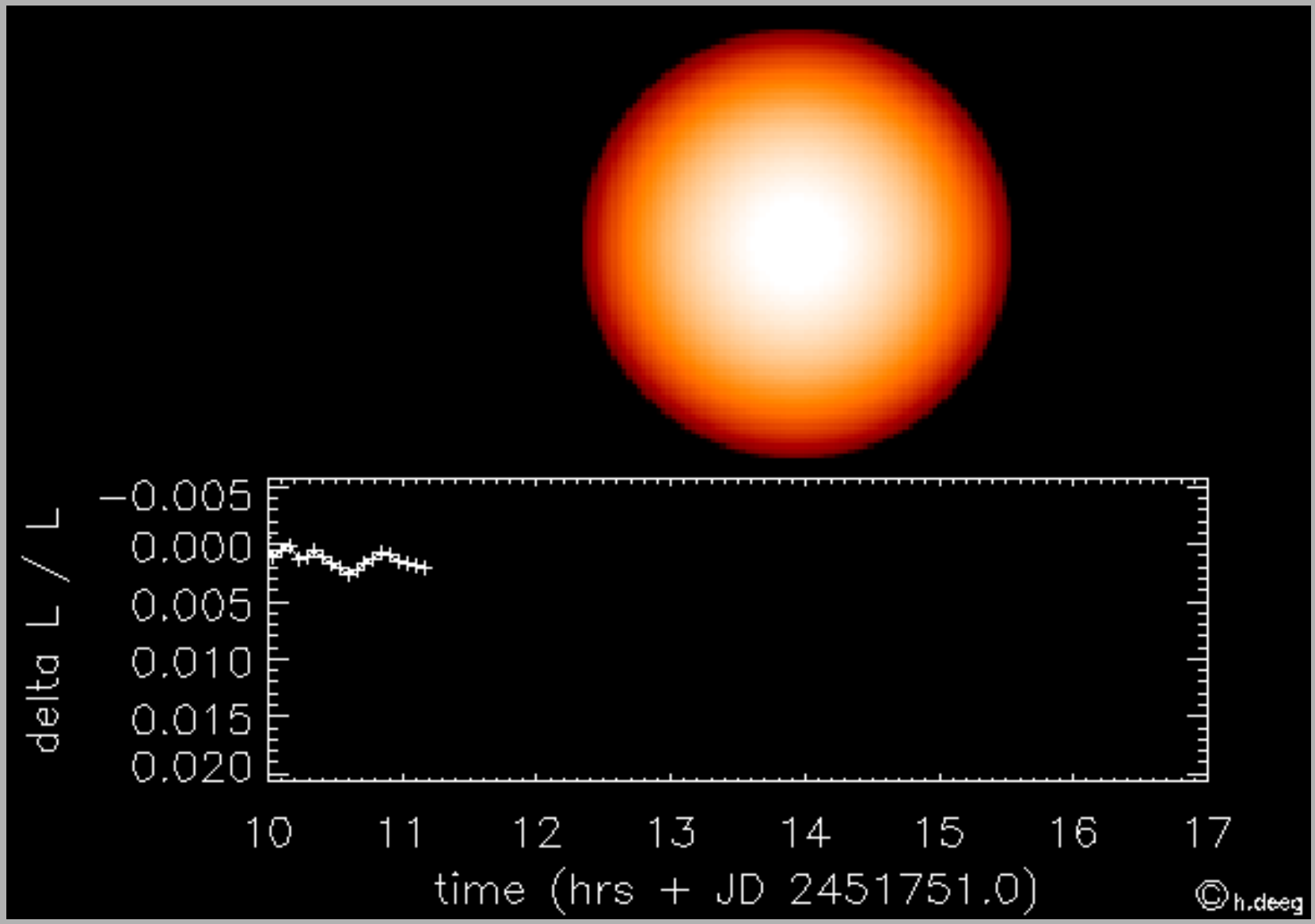
- 3-Gigapixel camera
- One 6-Gigabyte image every 20 seconds
- 30 Terabytes every night for 10 years
- 100-Petabyte final image data archive anticipated – **all data are public!!!**
- **20-Petabyte final database catalog anticipated**
- Real-Time Event Mining: ~10 million events per night, every night, for 10 yrs
  - Follow-up observations required to classify these
- Repeat images of the entire night sky every 3 nights: ***Celestial Cinematography***

What is an Event?

- Anything that changes (motion or brightness)
- Variable stars of all kinds
- Optical transients: e.g., extra-solar planets
- Supernova
- Gamma-ray burst
- New comet
- New asteroid
- Incoming Killer Asteroid
- Anything that goes bump in the night

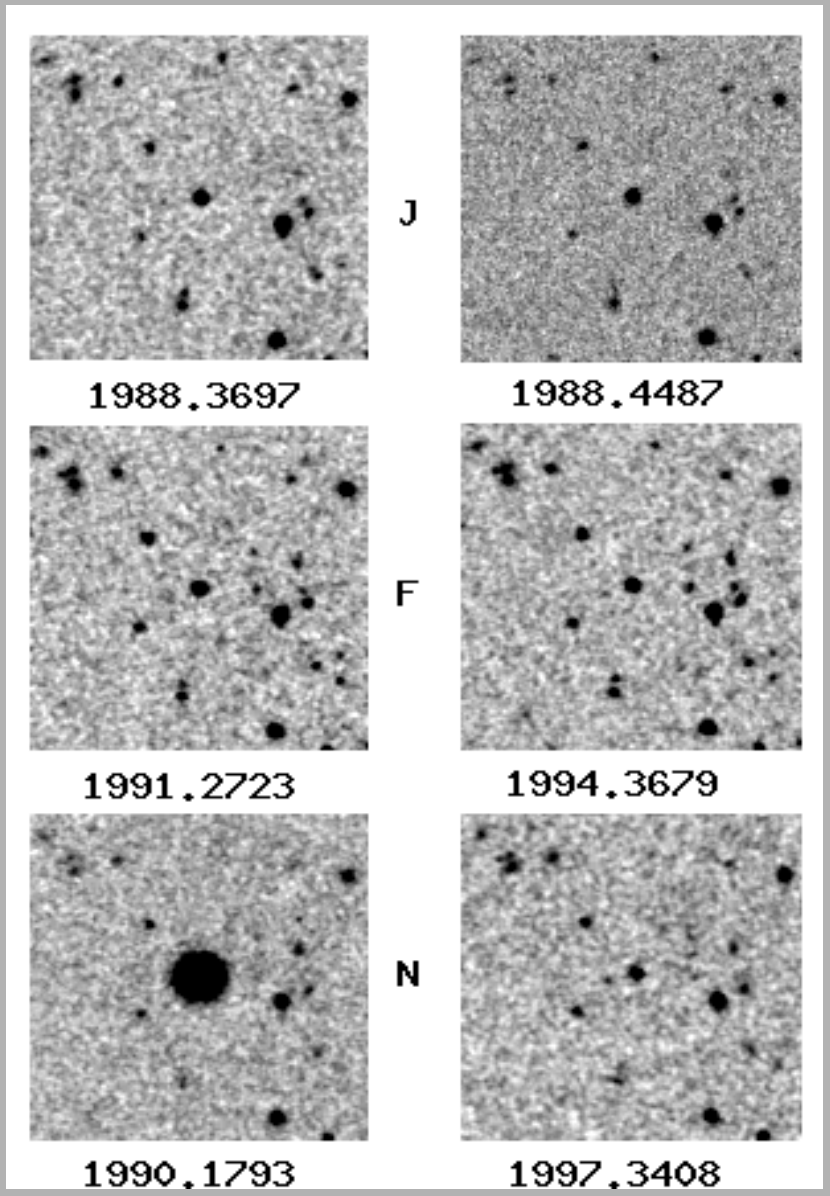


Example of a planet transiting a star …



Here is another type of event ***

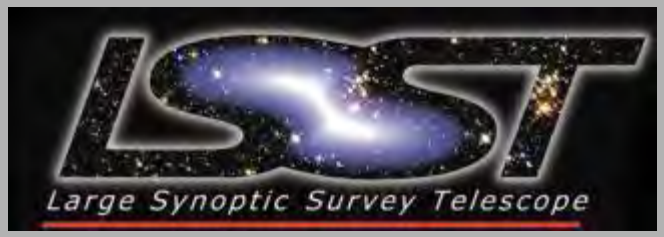
- **Optical Transient:** here today, gone tomorrow
- It is a normal dwarf star, similar to our sun, except …
- **it increased in brightness by 300x in one night** …
- and then returned to normal.



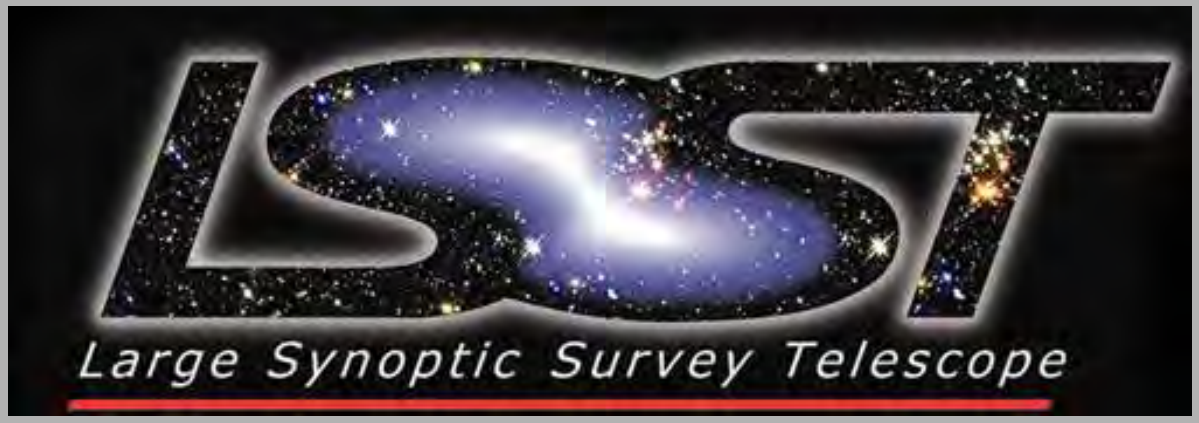
***Courtesy: Caltech / Palomar Quest Survey

Transient Astronomy: A Different Paradigm

- Events are dynamic
- Experience is dynamic
- Discovery potential is high for new objects
  (though most of that is done by HTN and follow-up networks – e.g., Las Cumbres Observatory http://lcogt.net)
- The “data” are event messages
- Interaction may include robotic telescopes for education
- Science experience:
  - Follow-up observation
  - Add new knowledge to new objects (events)



The LSST will represent a 100,000-fold increase in the number of events detected each and every night, for ten years!



LSST: How you can become involved

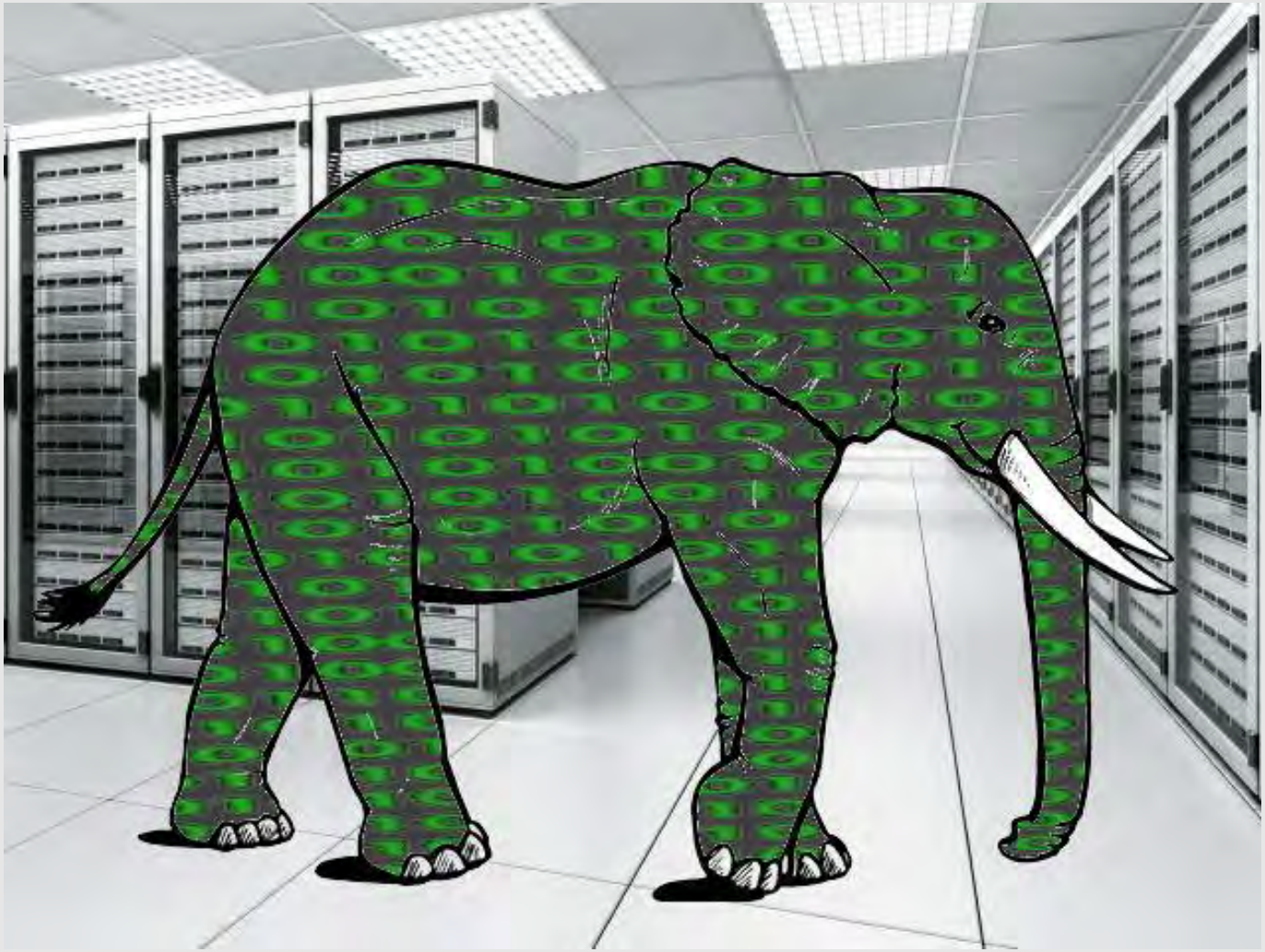
The LSST Data Challenges

The Problem: Big Data is a Big Challenge

There are many technologies associated with Big Data

http://siliconangle.com/blog/2012/07/13/big-data-nightmares/

One approach to Big Data: Computational Science (Hadoop,Map/Reduce)



http://www.bigdatabytes.com/wp-content/uploads/2012/01/big-data.jpg

Another approach to Big Data: Data Science (Informatics)

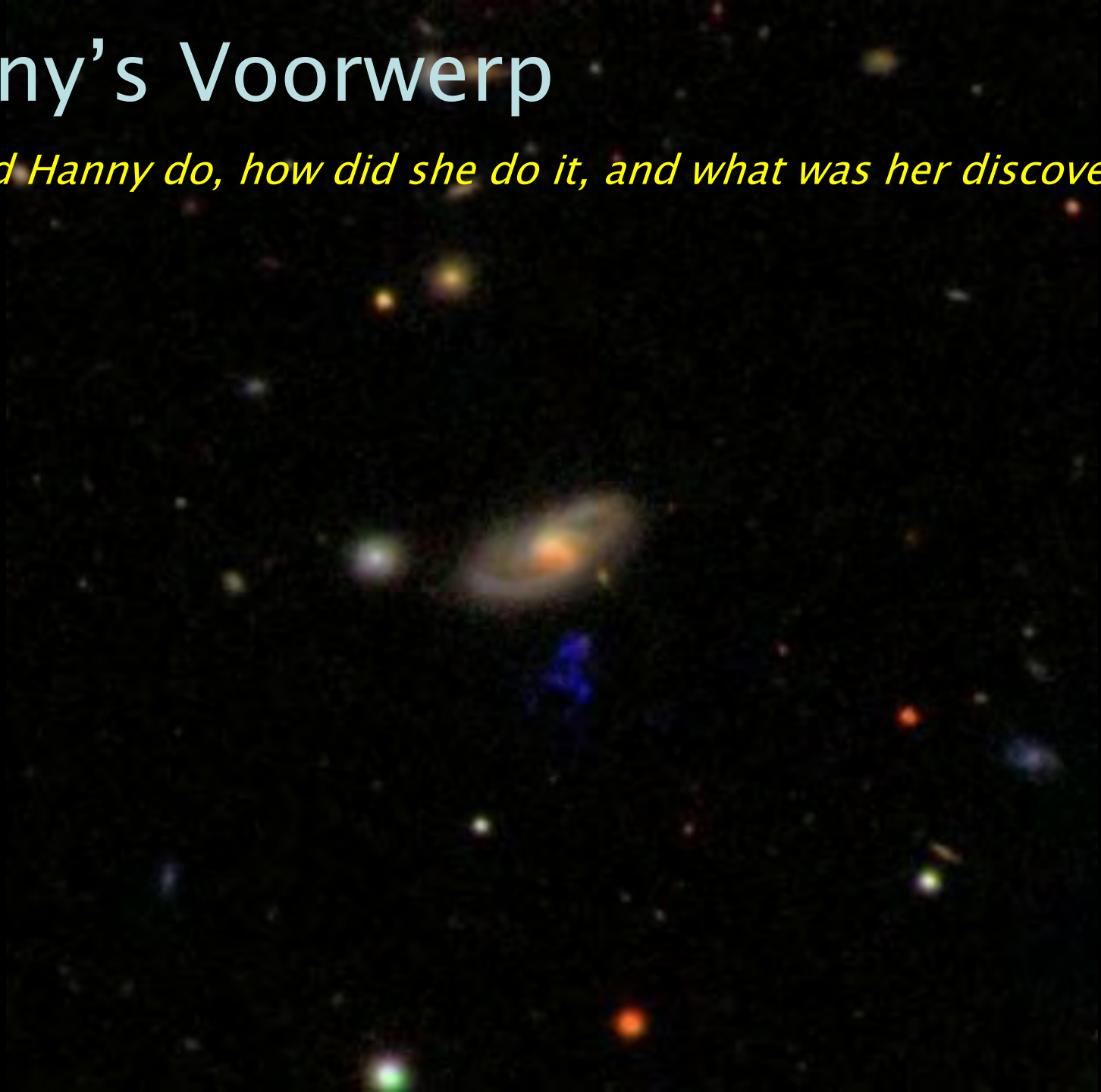
A third approach to Big Data: Citizen Science (crowdsourcing)

Galaxy Zoo: example of Citizen Science (crowdsourcing)

http://astrophysics.gsfc.nasa.gov/outreach/podcast/wordpress/index.php/2010/10/08/saras-blog-be-a-scientist/

Hanny's Voorwerp

What did Hanny do, how did she do it, and what was her discovery?



True color picture of Hanny's Voorwerp:

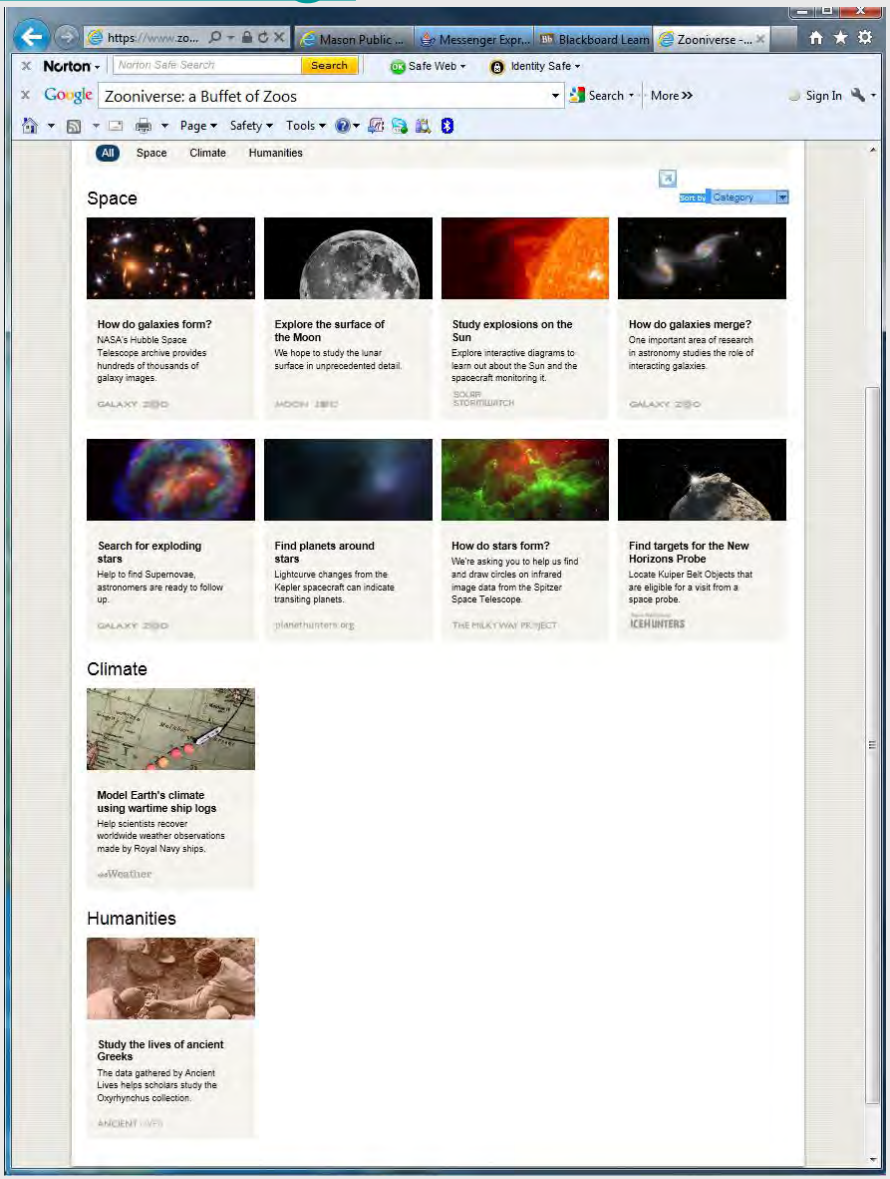
Hanny's Object – the green blob is probably a light echo from an old Quasar that burned out 100,000 years ago

True color picture of Hanny van Arkel and KB!

The Zooniverse: a Buffet of Zoos

http://zooniverse.org/

Live Projects at http://zooniverse.org/

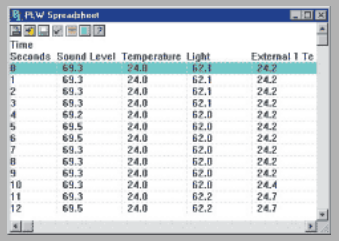


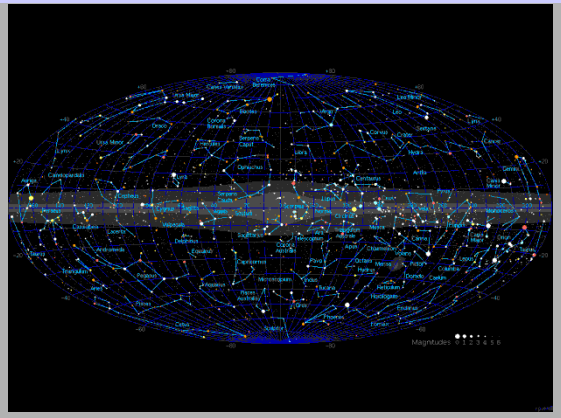
LSST: Bringing the Dynamic Universe to the Public

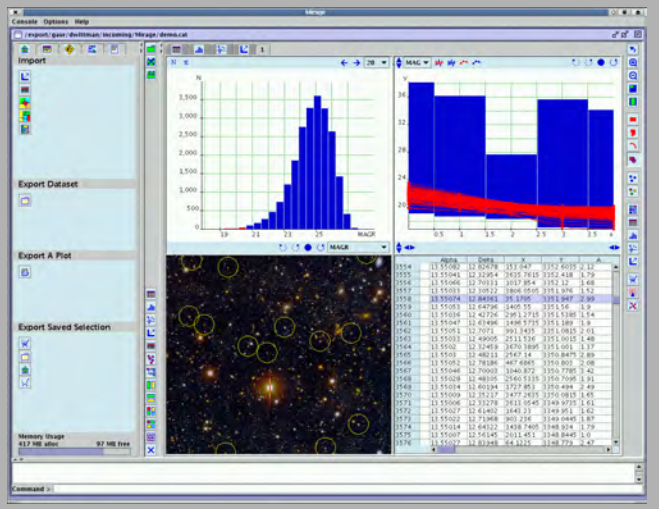
- Strong public interest in the dynamic sky:
  - Asteroids: motion, variability, colors, incoming!
  - Comets
  - Novae & Supernovae
  - Variable stars
  - Anything that moves or changes in brightness
- Strong desire to be involved by:
  - Amateurs (AAVSO)
  - Teachers / Students / Classrooms:
    - “Using Data in the Classroom” initiative
  - Citizen scientists (museums, planetaria, @home)

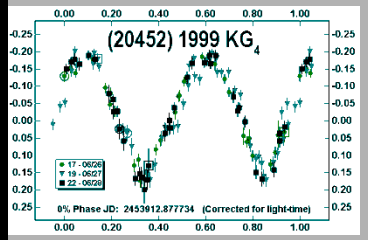
LSST – enabling you to interact with the huge scientific database to make new discoveries about our Universe

- *Data Discovery*
  - Query Survey Catalog Database:
    - What was observed?
    - Retrieve observation parameters
    - Retrieve object parameters
- *Data Browse*
  - Query Survey Image Archive:
    - View thumbnails
    - Retrieve images
    - Binary vs. JPEGs?
- *Data Immersion*
  - Tools, tools, tools – Unified software for astronomy EPO:
    - Data Analysis
    - Data Mining
    - Visualization
  - Feedback and Annotation:
    - Report Discoveries
    - AstroDAS







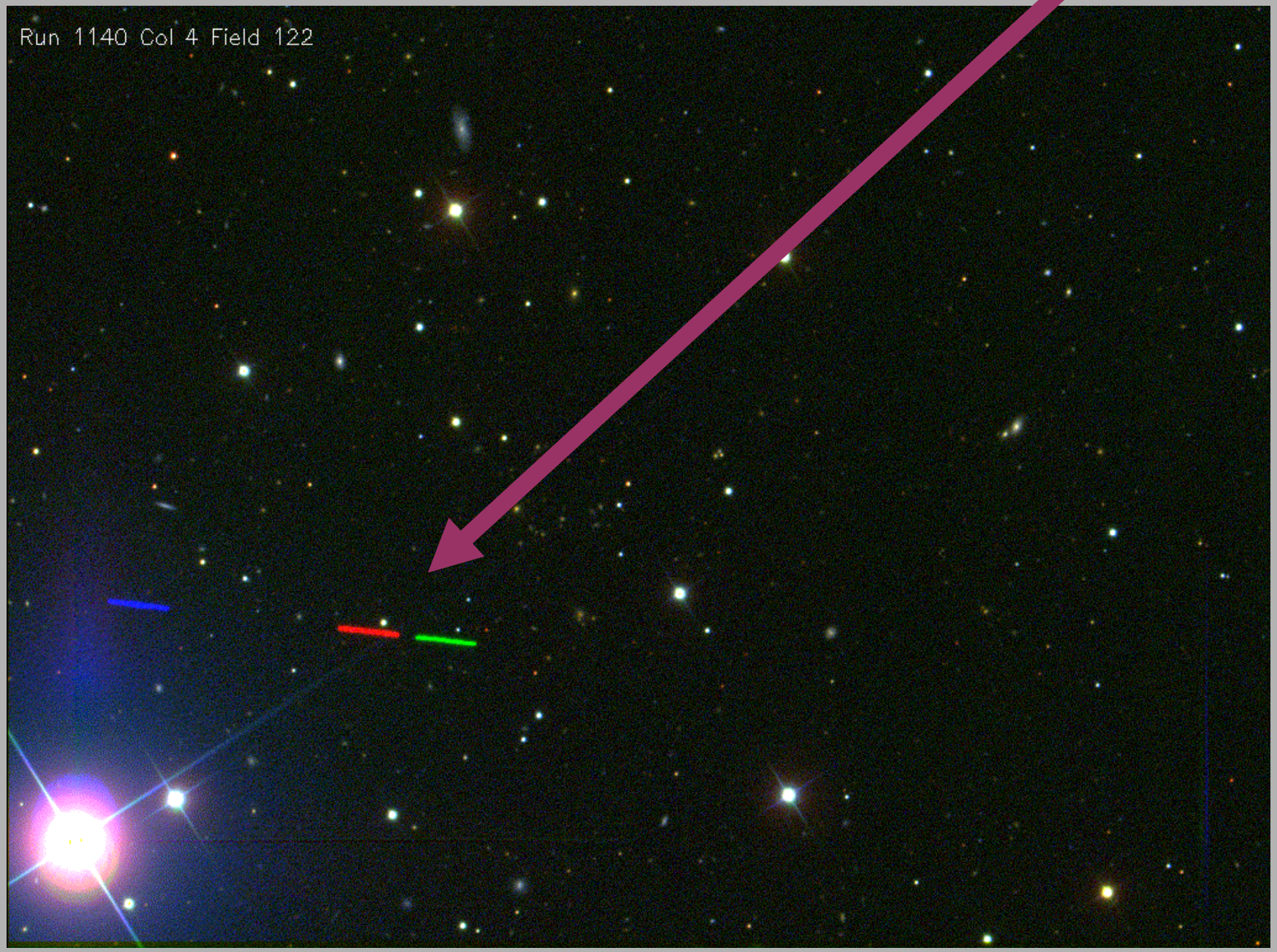


SkyMine – YourSky – KnowMySky – Astro@home

We are looking for a name!

Adopt your own patch of sky

Astro@home:
Can you help us to find the Killer Asteroid?

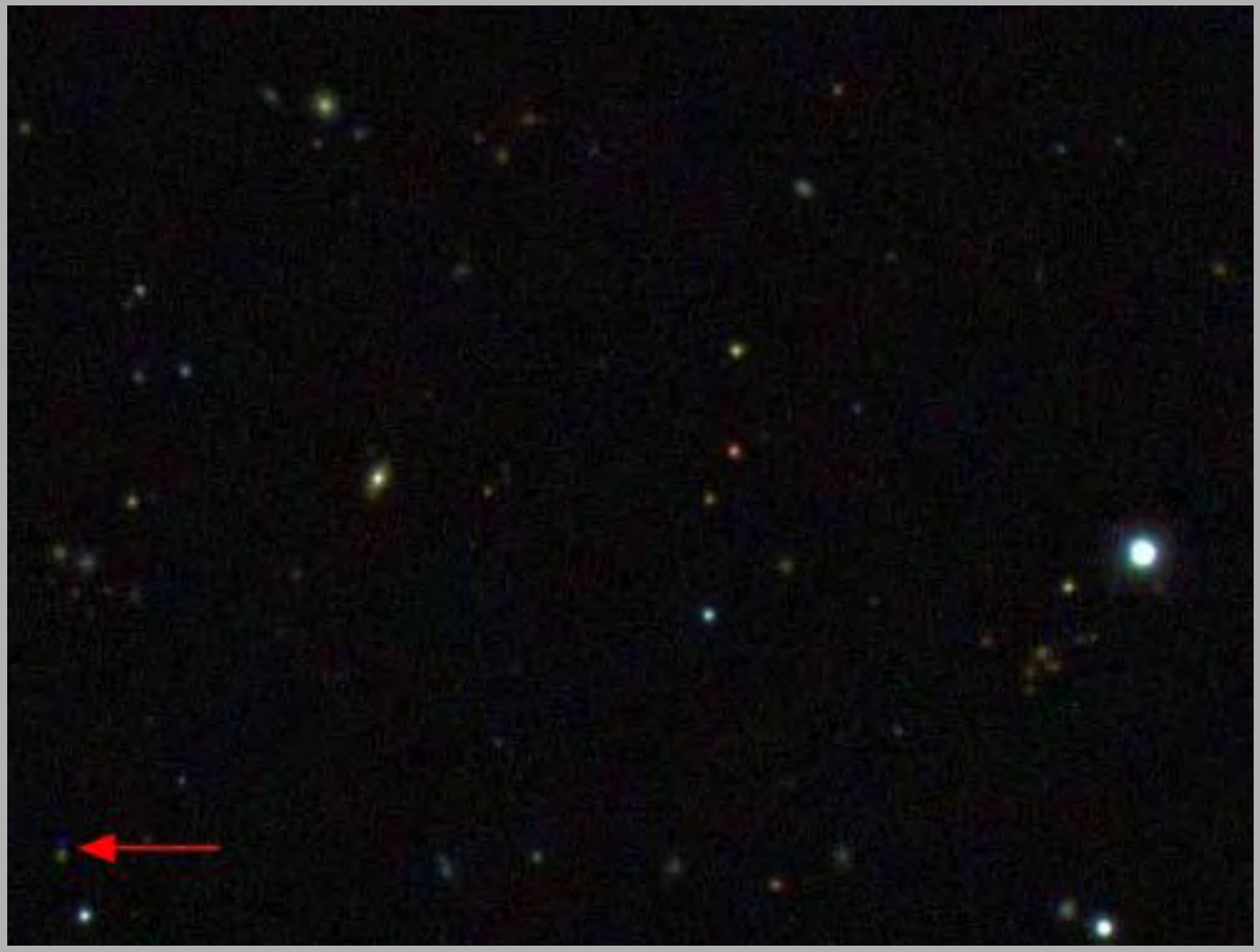


Astro@home:

Sometimes it is not so easy. **Where is it?**

Astro@home:

The more folks who are looking, then the more likely we will find it.



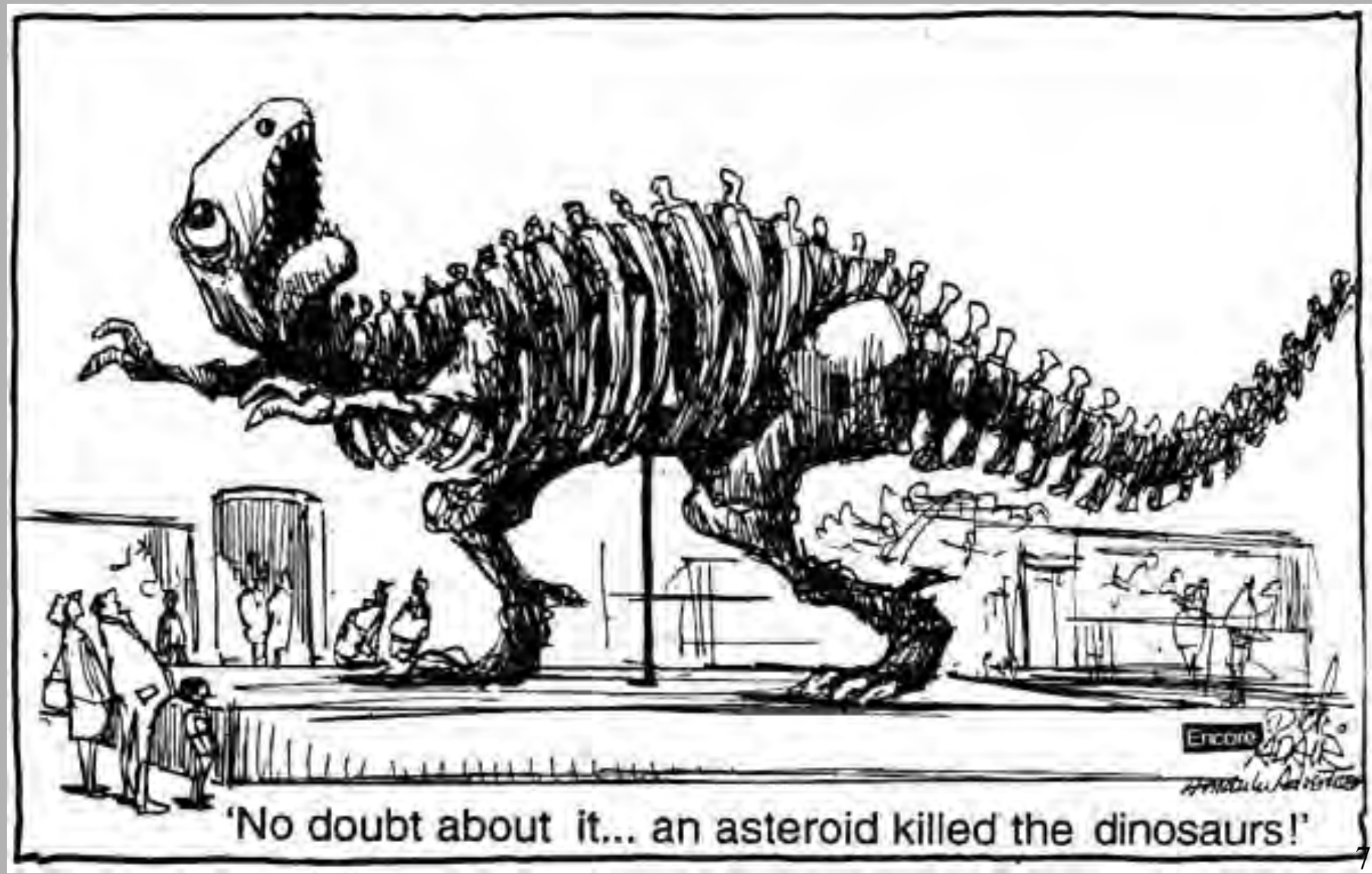
Forget about ...

- Numb3rs
- Person of Interest
- CSI Las Vegas
- CSI Miami
- CSI New York

- It’s time for data mining to go public

- Introducing ....

CSI Astronomy: *"No doubt about it ... an asteroid killed the dinosaurs!"*




The Large Synoptic Survey Telescope (LSST) Project
wants you to help us discover the secrets
of our dynamic Universe
LSST
Large Synoptic Survey Telescope