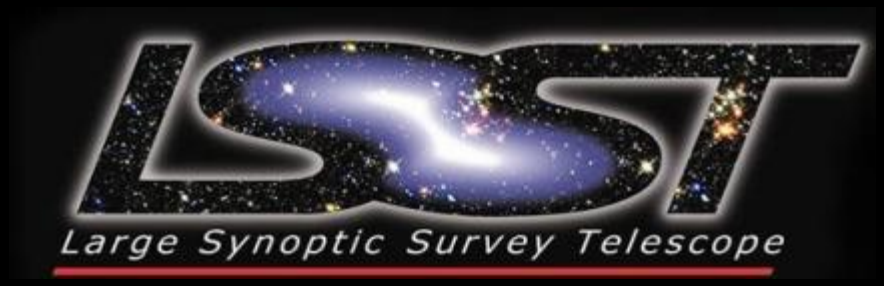
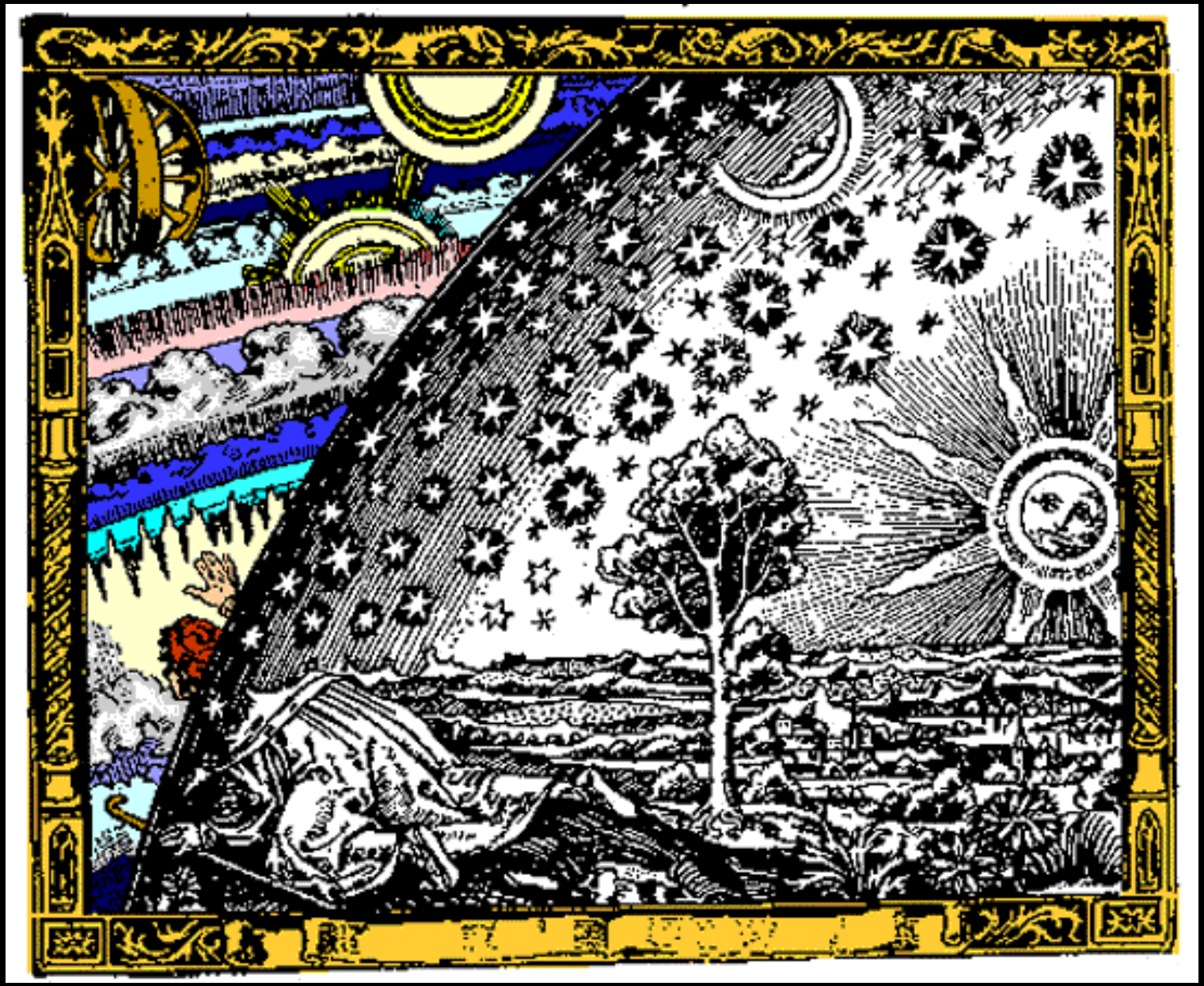


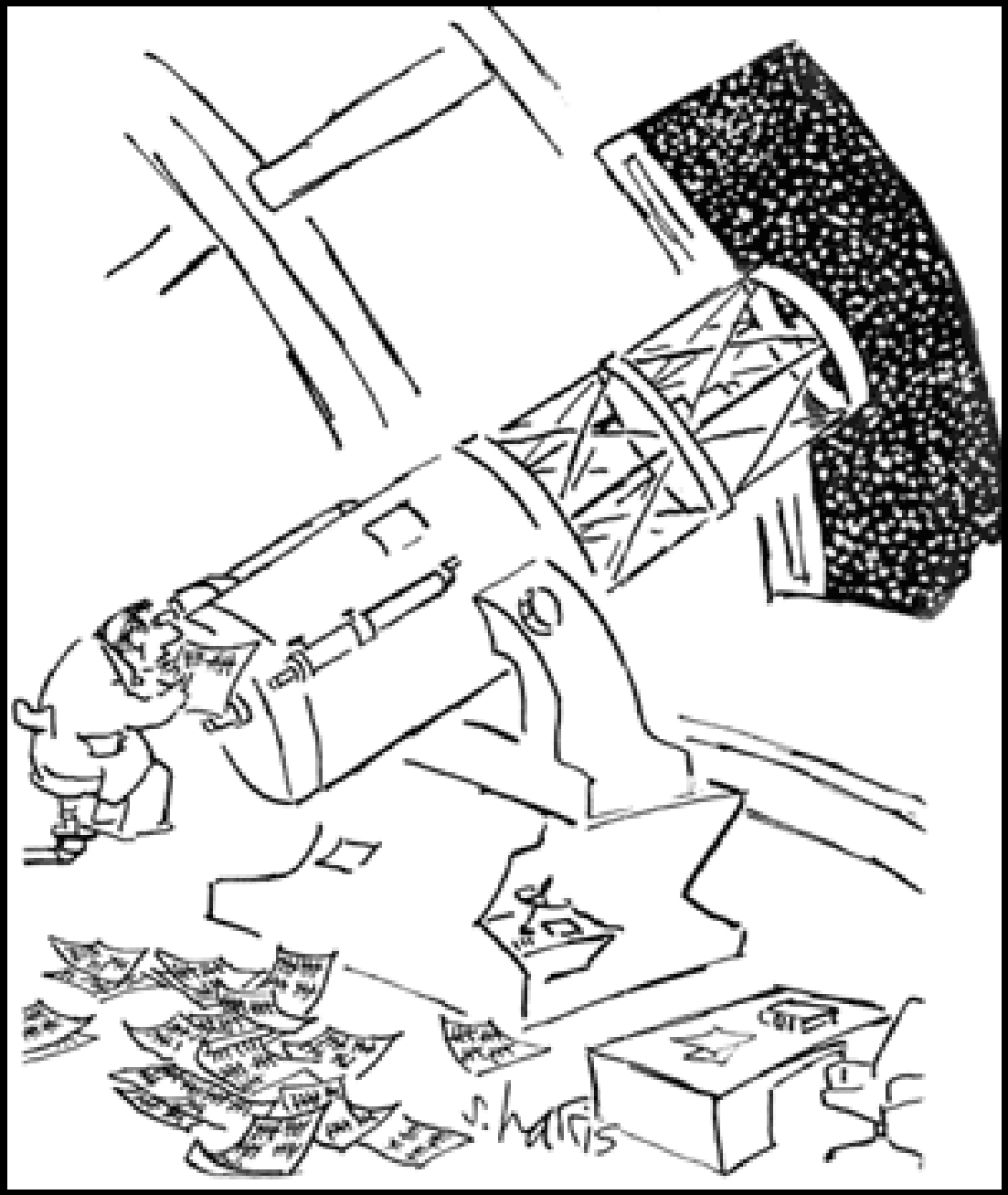
Astroinformatics: massive data research in Astronomy

Kirk Borne
Dept of Computational & Data Sciences
George Mason University
kborne@gmu.edu , http://classweb.gmu.edu/kborne/

Ever since humans first gazed into the heavens …



… Astronomy has been a Data-Driven Science



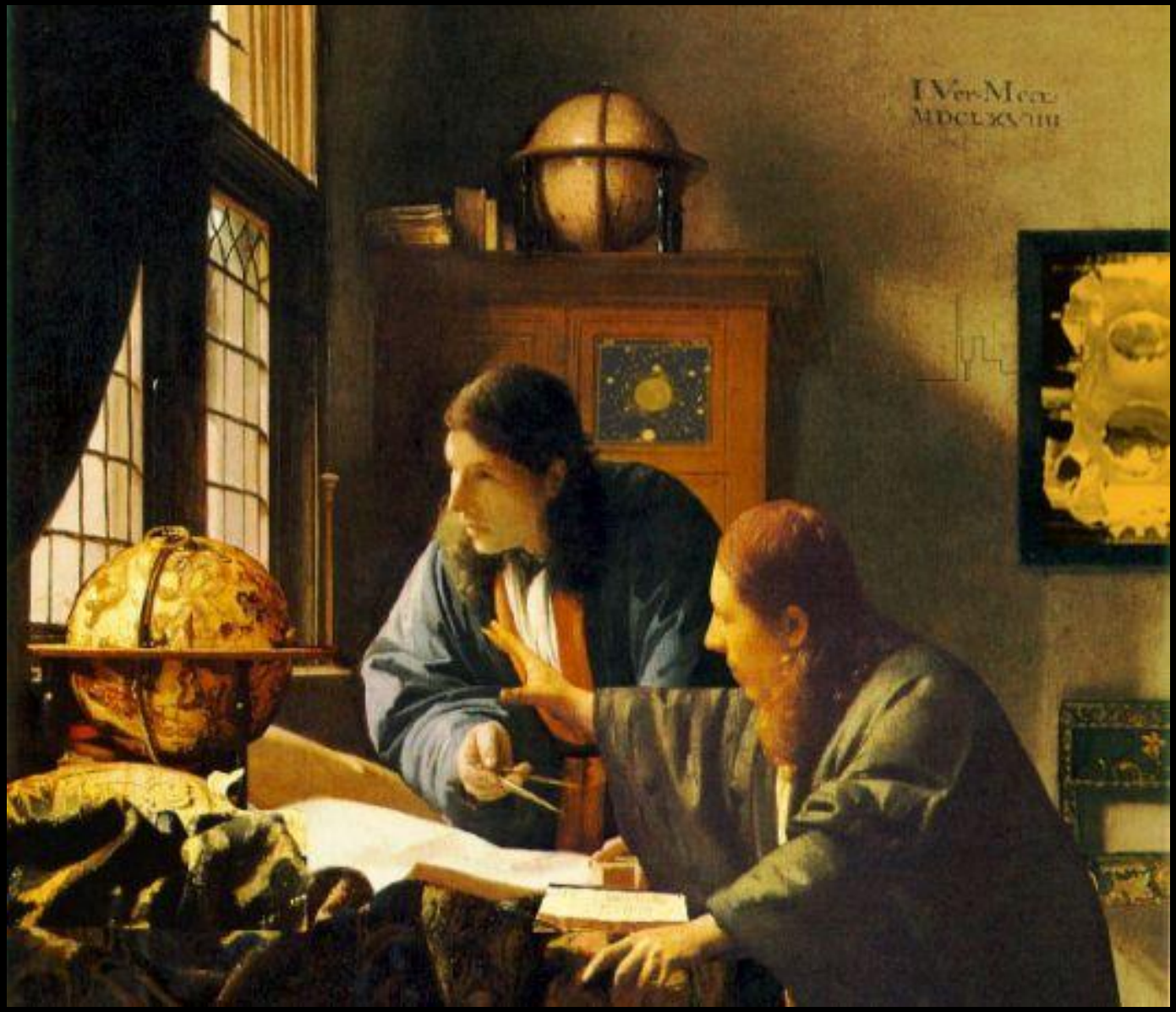
From Data-Driven to Data-Intensive

- Astronomy has always been a data-driven science
- It is now a data-intensive science
- It will become even more data-intensive in the coming decade(s) ….
- Hence, a new field of data-oriented research and education in Astronomy is emerging:

Astroinformatics

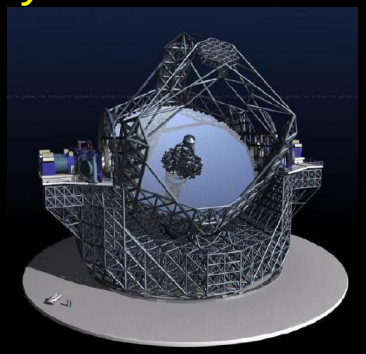
Vermeer's "Astronomer & Geographer"

(2 mappers, collaborating on Astroinformatics and Geoinformatics)



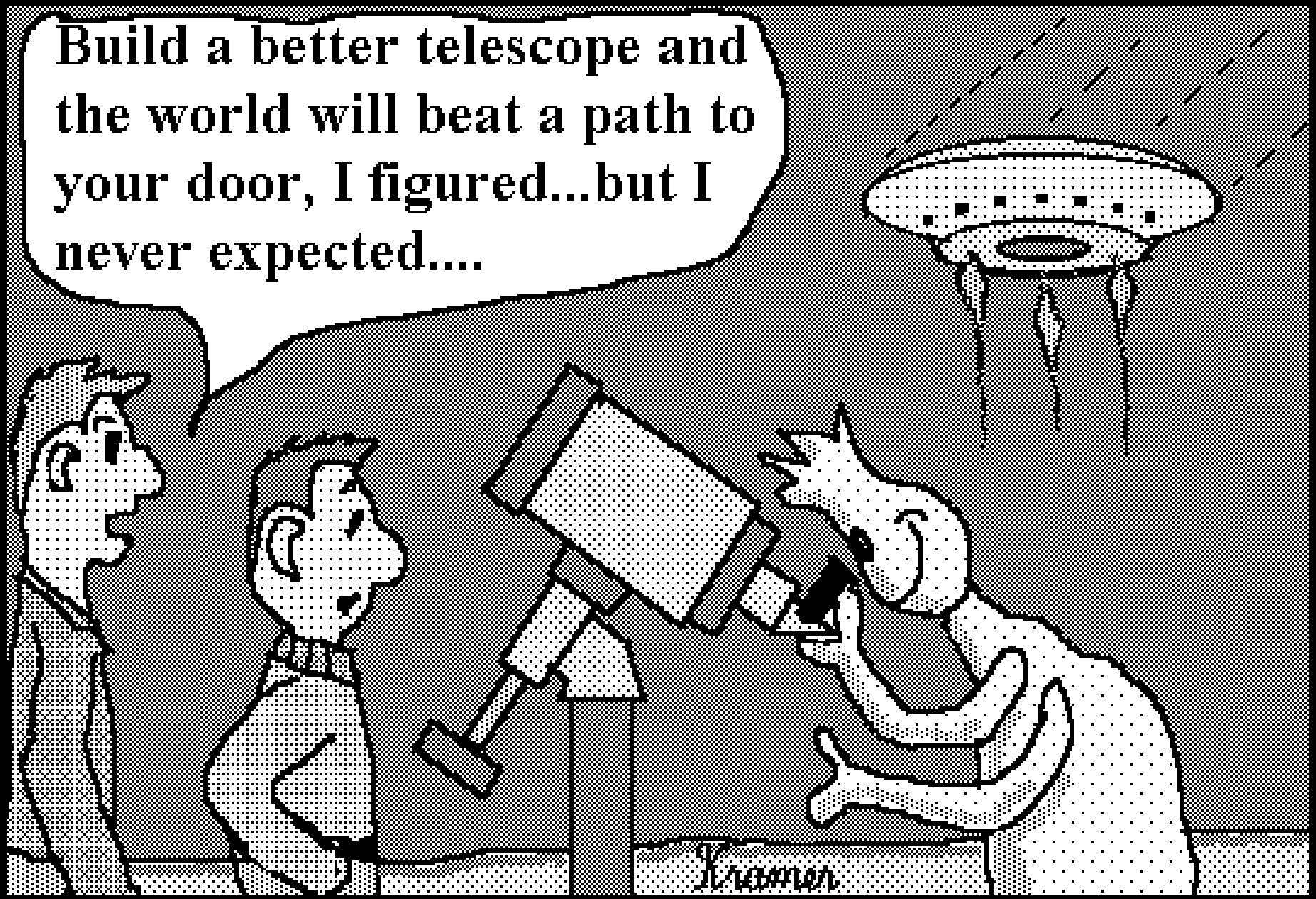
Astronomy Data Environment: Sky Surveys

- To avoid biases caused by limited samples, astronomers now study the sky systematically = **Sky Surveys**
- Surveys are used to measure and collect data from all objects that are contained in large regions of the sky, in a systematic, controlled, repeatable fashion.
- These surveys include (... this is just a subset):
  - MACHO and related surveys for dark matter objects: ~ 1 Terabyte
  - Digitized Palomar Sky Survey: 3 Terabytes
  - 2MASS (2-Micron All-Sky Survey): 10 Terabytes
  - GALEX (ultraviolet all-sky survey): 30 Terabytes
  - Sloan Digital Sky Survey (1/4 of the sky): 40 Terabytes
  - and this one is just starting: Pan-STARRS: 40 **Peta**bytes!



- **Leading up to the big survey next decade:**
  - **LSST (Large Synoptic Survey Telescope):** 100 Petabytes!

The LSST : a better sky survey

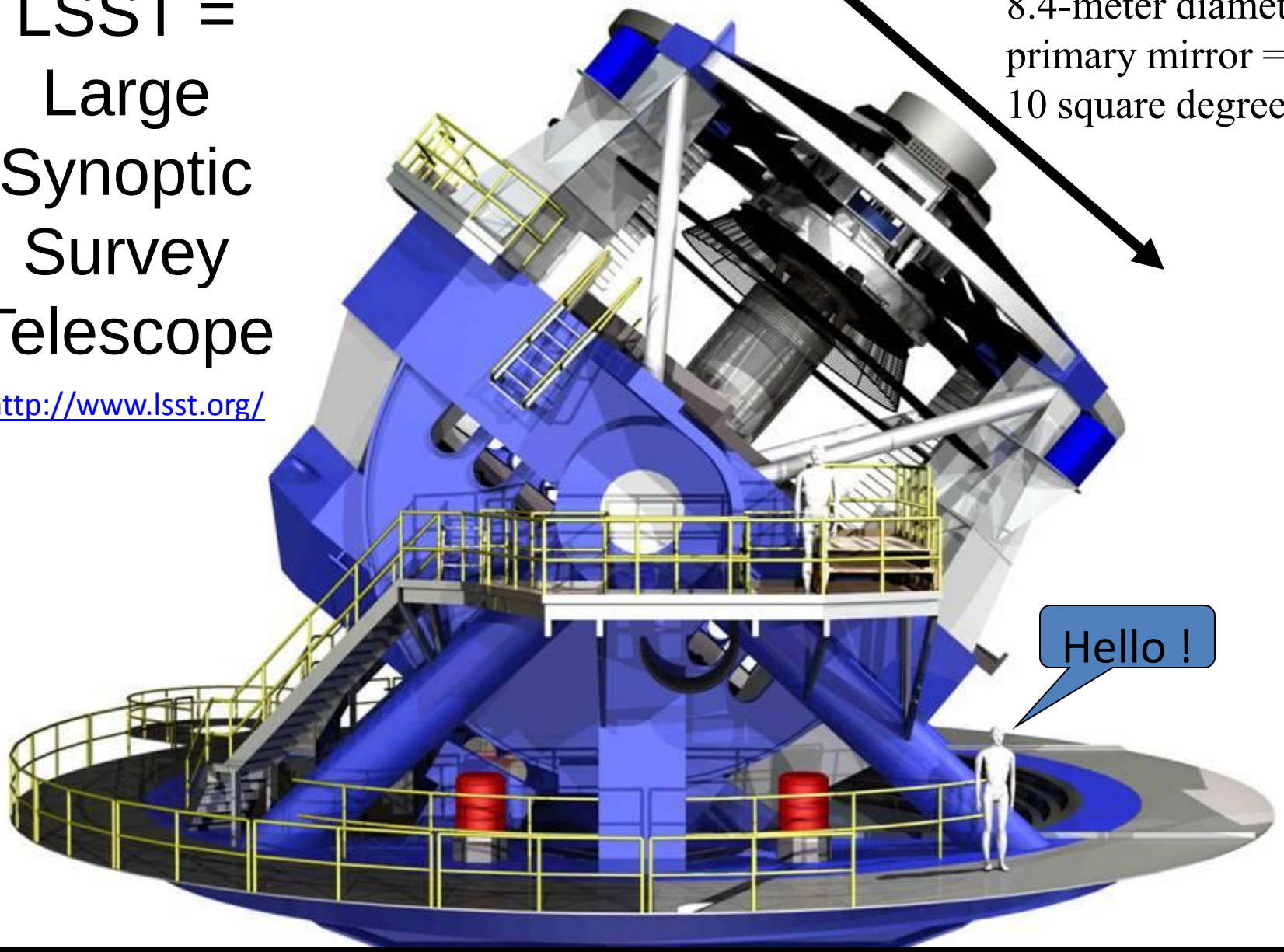


LSST = Large Synoptic Survey Telescope

http://www.lsst.org/

(mirror funded by private donors)

8.4-meter diameter primary mirror = 10 square degrees!



(design, construction, and operations of telescope, observatory, and data system: NSF) (camera: DOE)

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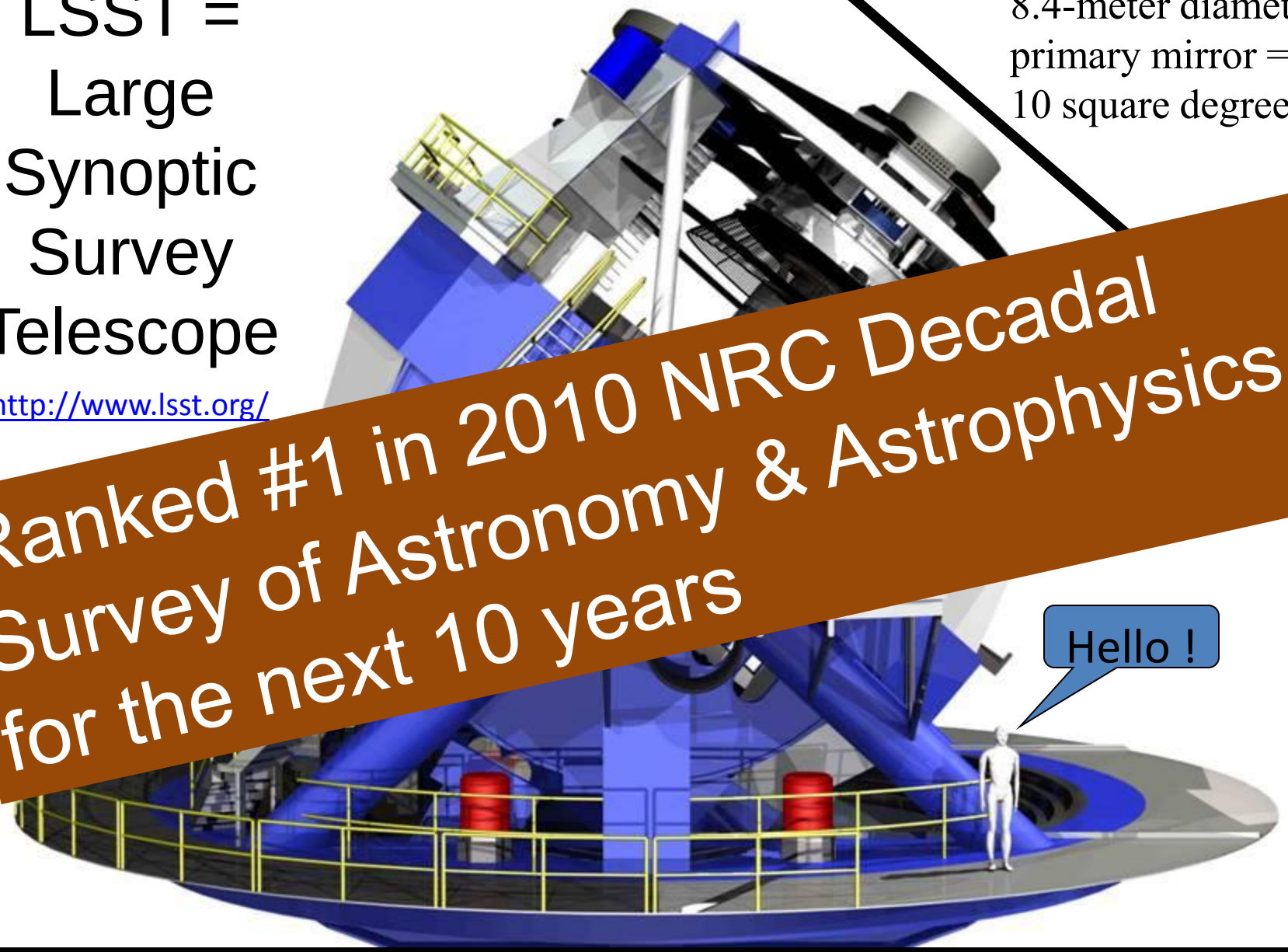


Ranked #1 in 2010 NRC Decadal Survey of Astronomy & Astrophysics for the next 10 years

(design, construction, and operations of telescope, observatory, and data system: NSF) (camera: DOE)

LSST Key Science Drivers: Mapping the Universe

– Solar System Map (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)
– Galactic Structure (proper motions, stellar populations, star streams)

South America

Chile

Region de Coquimbo

Summit of Cerro Pachon -

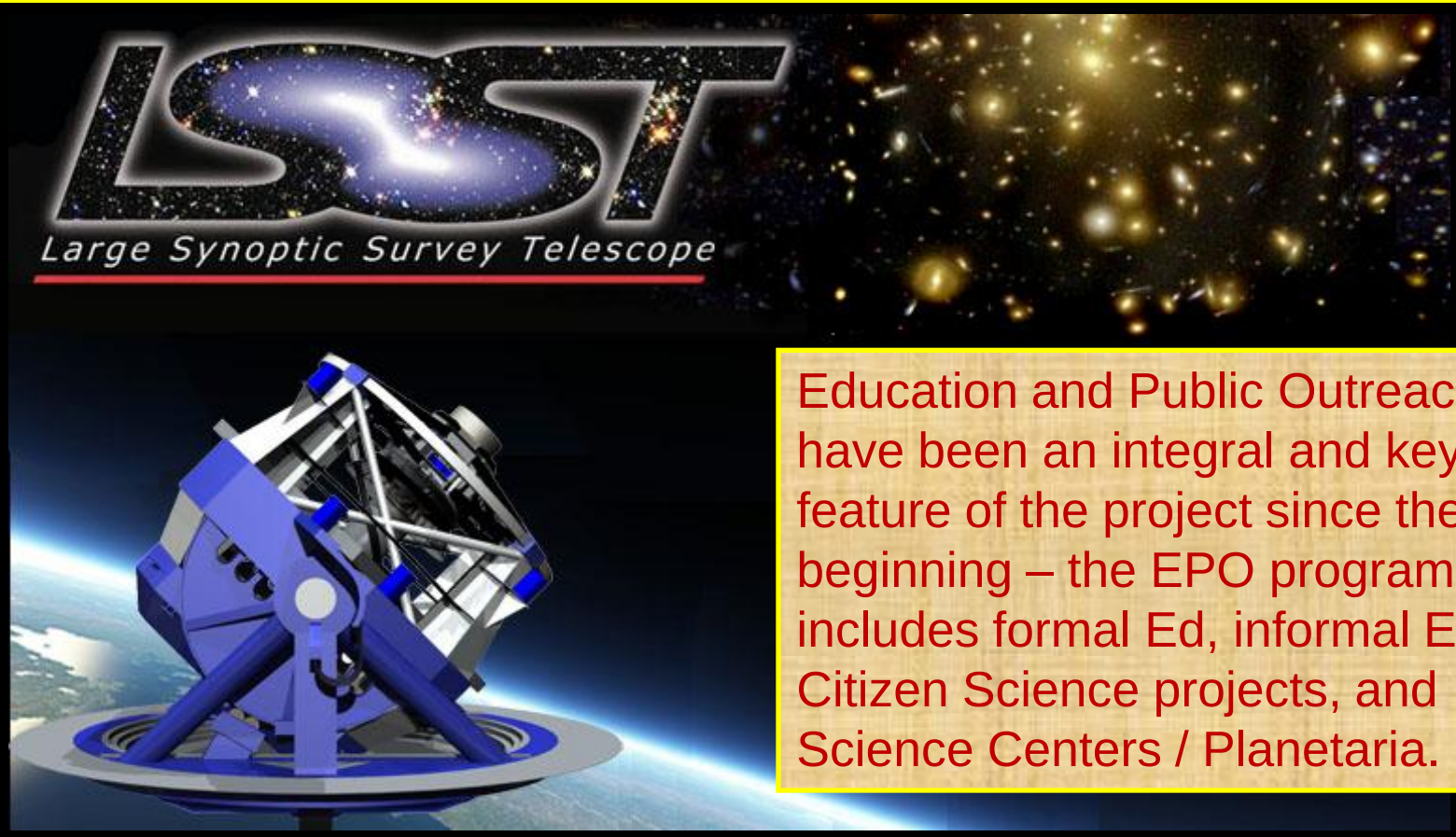
Model of LSST Observatory

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

– When? 2016-2026
– Where? Cerro Pachon, Chile

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 (2016-2026), with time domain sampling in log(time) intervals (to capture dynamic range of transients).

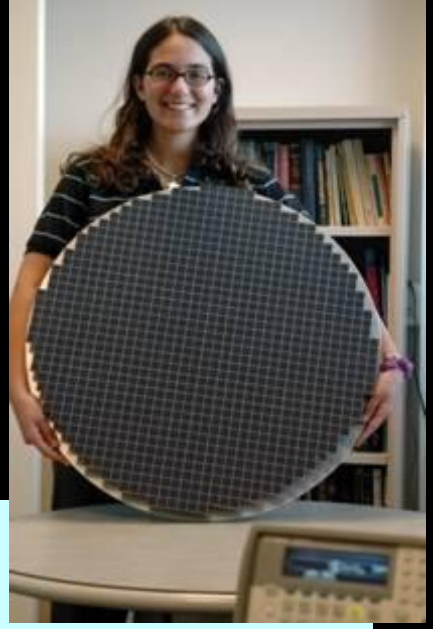
- **LSST (Large Synoptic Survey Telescope):**
  - Ten-year time series imaging of the night sky – mapping the Universe !
  - **100,000 events each night** – *anything that goes bump in the night !*
  - ***Cosmic Cinematography! The New Sky! @ http://www.lsst.org/***



Education and Public Outreach have been an integral and key feature of the project since the beginning – the EPO program includes formal Ed, informal Ed, Citizen Science projects, and Science Centers / Planetaria.

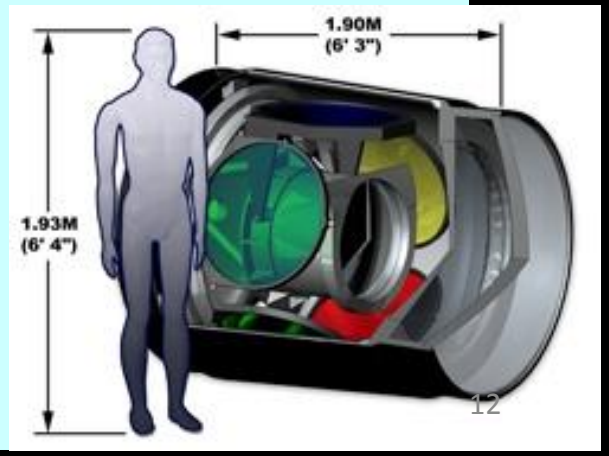
The LSST focal plane array

Camera Specs: (pending funding from the DOE)
201 CCDs @ 4096x4096 pixels each!
= 3 Gigapixels = 6 GB per image, covering 10 sq.degrees
= ~3000 times the area of one Hubble Telescope image



LSST Data Challenges

- Obtain one 6-GB sky image in 15 seconds
- Process that image in 5 seconds
- Obtain & process another co-located image for science validation within 20^s (= 15-second exposure + 5-second processing & slew)
- Process the 100 million sources in each image pair, catalog all sources, and generate worldwide alerts within 60 seconds (e.g., incoming killer asteroid)
- Generate 100,000 alerts per night (VOEvent messages)
- Obtain 2000 images per night
- Produce ~30 Terabytes per night
- Move the data from South America to US daily
- Repeat this every day for 10 years (2016-2026)
- Provide rapid DB access to worldwide community:
  - **100-200 Petabyte image archive**
  - **20-40 Petabyte database catalog**



The LSST Data Challenges

- Massive data stream: ~2 Terabytes of image data per hour that must be mined in real time (for 10 years).
- Massive 20-Petabyte database: more than 50 billion objects need to be classified, and most will be monitored for important variations in real time.
- Massive event stream: knowledge extraction in real time for 100,000 events each night.

Informatics-based Science Education

- Informatics enables transparent reuse and analysis of scientific data in inquiry-based classroom learning (http://serc.carleton.edu/usingdata/).
- Students are trained:
  - to access large distributed data repositories
  - to conduct meaningful scientific inquiries into the data
  - to mine and analyze the data
  - to make data-driven scientific discoveries
- The 21st century workforce demands training and skills in these areas, as all agencies, businesses, and disciplines are becoming flooded with data.
- Numerous Data Sciences programs now starting at several universities (GMU, Caltech, RPI, Vanderbilt, Michigan, Cornell, …).
- CODATA **ADMIRE** initiative: ***A****dvanced* ***D****ata* ***M****ethods and* ***I****nformation technologies for* ***R****esearch and* ***E****ducation*

Citizen Science

- Exploits the cognitive abilities of **Human Computation**!
- Citizen Science = Volunteer Science = Participatory Science
  - **Crowdsourcing for science !**
  - *e.g.,* Galaxy Zoo @ http://www.galaxyzoo.org/
- Citizen science refers to the involvement of volunteer non-professionals in the research enterprise.
- The Citizen Science experience …
  - must be engaging,
  - must work with real scientific data/information (all of it),
  - must not be busy-work (all clicks must count),
  - **must address authentic science research questions** that are beyond the capacity of science teams and enterprises, and
  - must involve the scientists.

ZOONIVERSE
REAL SCIENCE ONLINE

The Zooniverse: http://zooniverse.org/

Advancing Science through User-Guided Learning in Massive Data Streams

- Building a framework for new Citizen Science projects
- Includes user-based research tools
- Science domains:
  - Astronomy (Galaxy Merger Zoo)
  - The Moon (Lunar Reconnaissance Orbiter)
  - The Sun (STEREO dual spacecraft)
  - Egyptology (the Papyri Project)
  - and more (… accepting proposals from community)

Concluding comment: Why do this? Ans: to respond to the science data flood

- ***X-Informatics*** (*e.g.,* X = Bio, Geo, Astro, …) (*in silico*):
  - addresses the scientific data lifecycle challenges in the era of data-intensive science and the data flood
  - defines lightweight ontologies, semantics, taxonomies, concepts, content descriptors for a science domain
  - for the purpose of organizing, accessing, searching, fusing, integrating, mining, and analyzing massive data repositories.
- ***Citizen Science*** (user-guided, informatics-powered):
  - Human computation (*e.g.,* tagging, labeling, classification)
    - characterized by enormous cognitive capacity and pattern recognition efficiency (**carbon-based computing**)
  - Semantic e-Science **and** Volunteer Citizen Science
  - Tagging everything, everywhere: ***Analytics in the Cloud***