The Big Picture:
Science & Public Outreach with Astronomical Surveys

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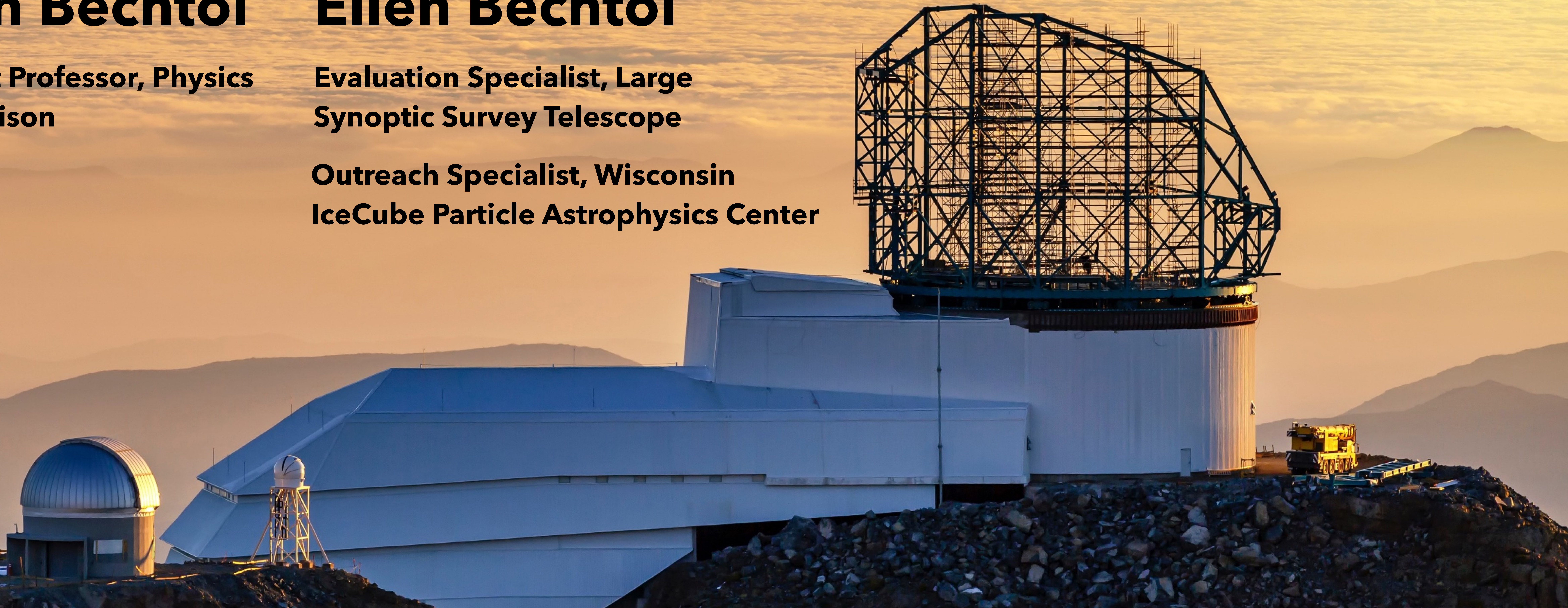


Wednesday Nite @ The Lab | April 17, 2019

Photo: Gianluca Lombardi (Gemini)

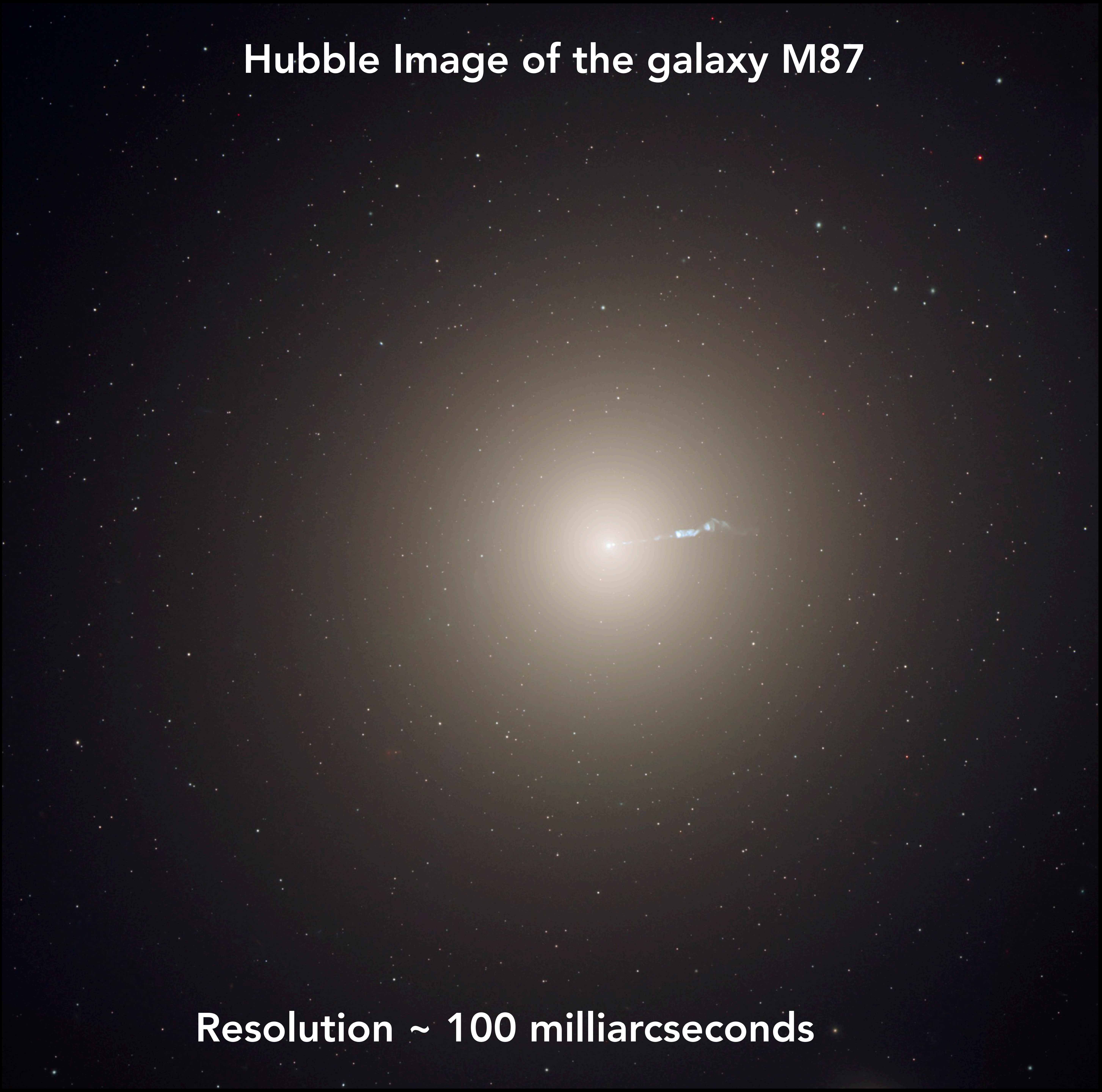

Hubble Image of the galaxy M87
Resolution ~ 100 milliarcseconds


Image of supermassive black hole at
center of M87 using the
Event Horizon Telescope
Resolution ~ 25 microarcseconds

Hubble Ultra Deep Field

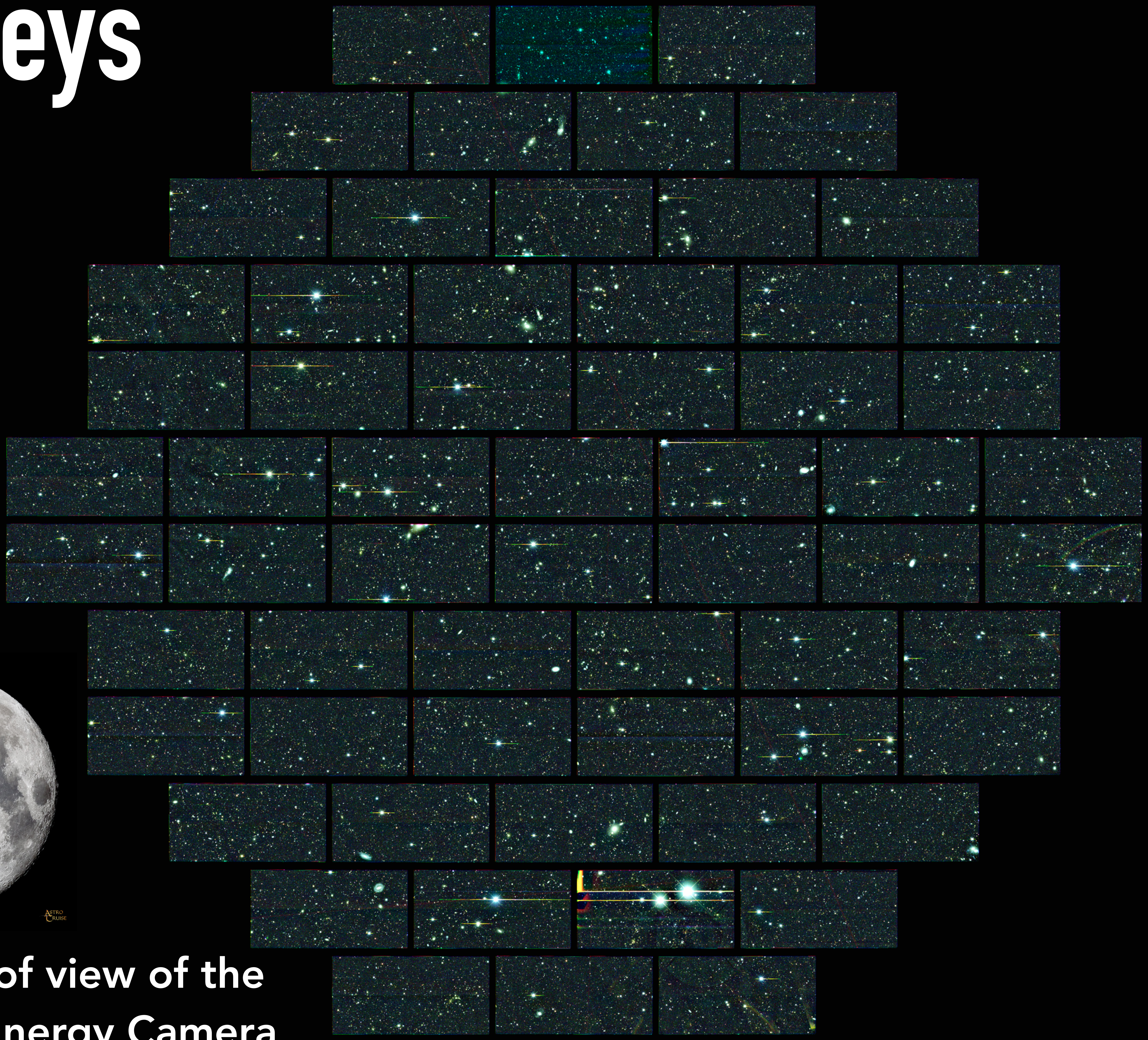
It would take more than **10 million** photos this size to cover the full sky

Each smudge of light is a galaxy

There are **> 2 trillion** galaxies in the observable universe

Astronomical Surveys

Wide, Fast, Deep



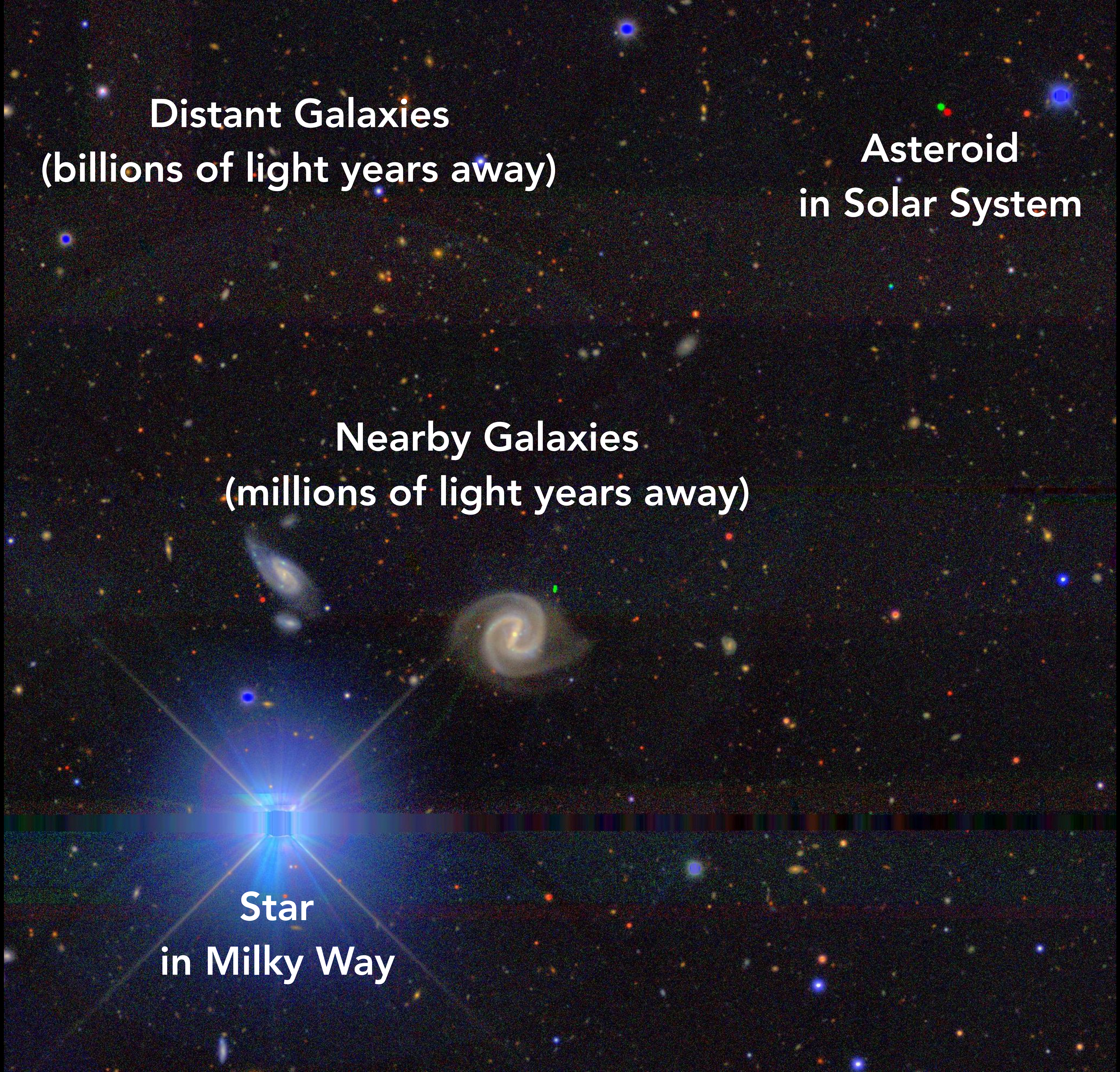
Field of view of the
Dark Energy Camera

Half of One DECam CCD

Half of One DECam CCD

Brightest 2 billion stars visible from Earth measured with Gaia

Credit: ESA/Gaia/DPAC



Distant Galaxies
(billions of light years away)
Asteroid
in Solar System
Nearby Galaxies
(millions of light years away)
Star
in Milky Way

Why Astronomical Surveys?

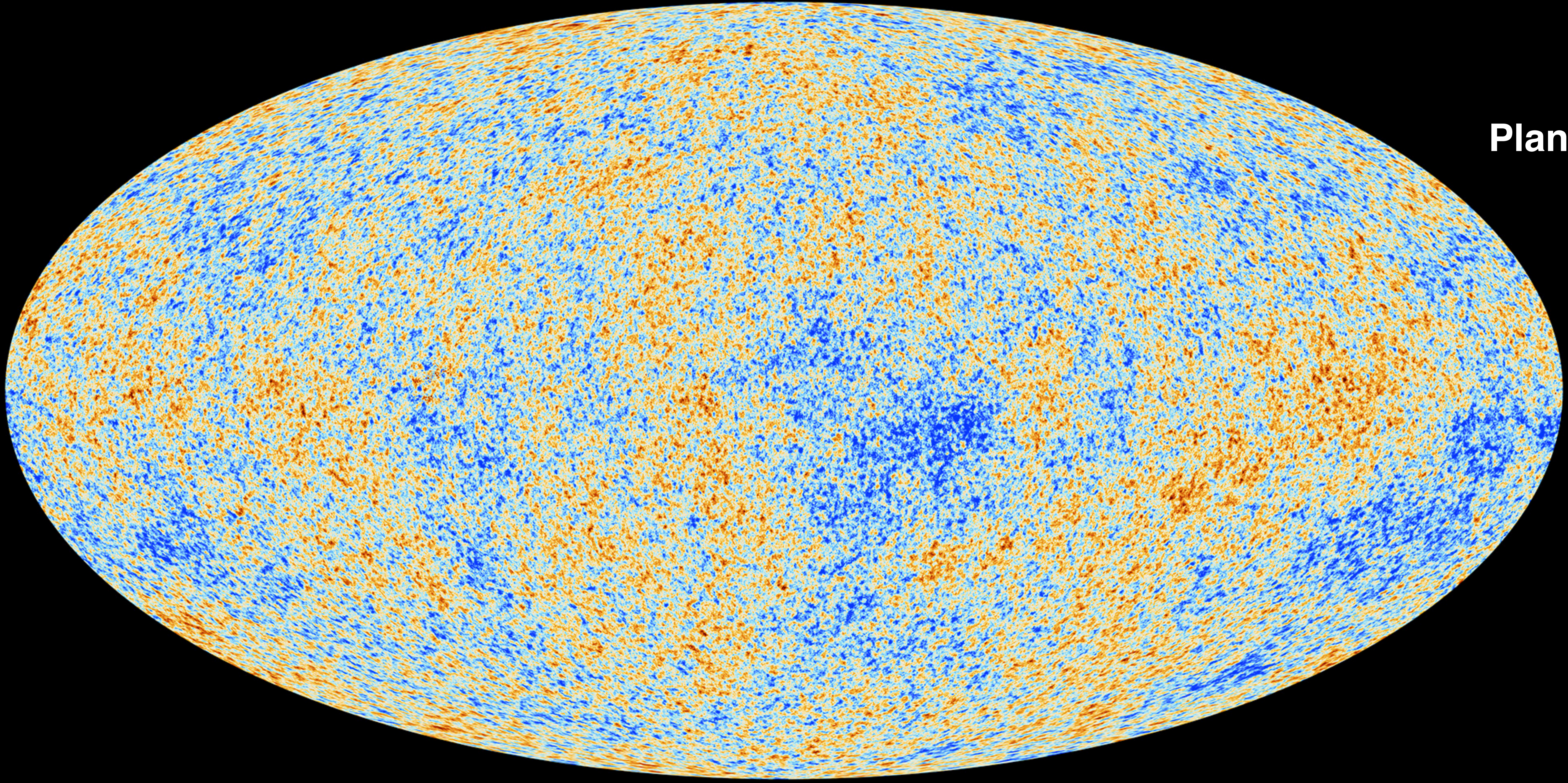
Why Astronomical Surveys?

Our Universe is one realization of a *statistical process* governed by the rules of nature

We aim to discovery these rules

Some patterns are *emergent* and/or only appear when we look at the Universe on the *largest possible scales*

Density fluctuations at $\delta \sim 10^{-5}$ imprinted on the cosmic microwave background (age of Universe ~ 380,000 yr)



Planck

Quantum fluctuations expanded to a macroscopic scale; the seeds of cosmic structure formation


HUMAN

Dark Energy, Dark Matter, Neutrinos

95% of the mass-energy content in the Universe today is NOT made of atoms

These three distinct “dark” components are invisible — you can’t touch them or feel them — but they determine the fate of the Universe…

Dark Energy

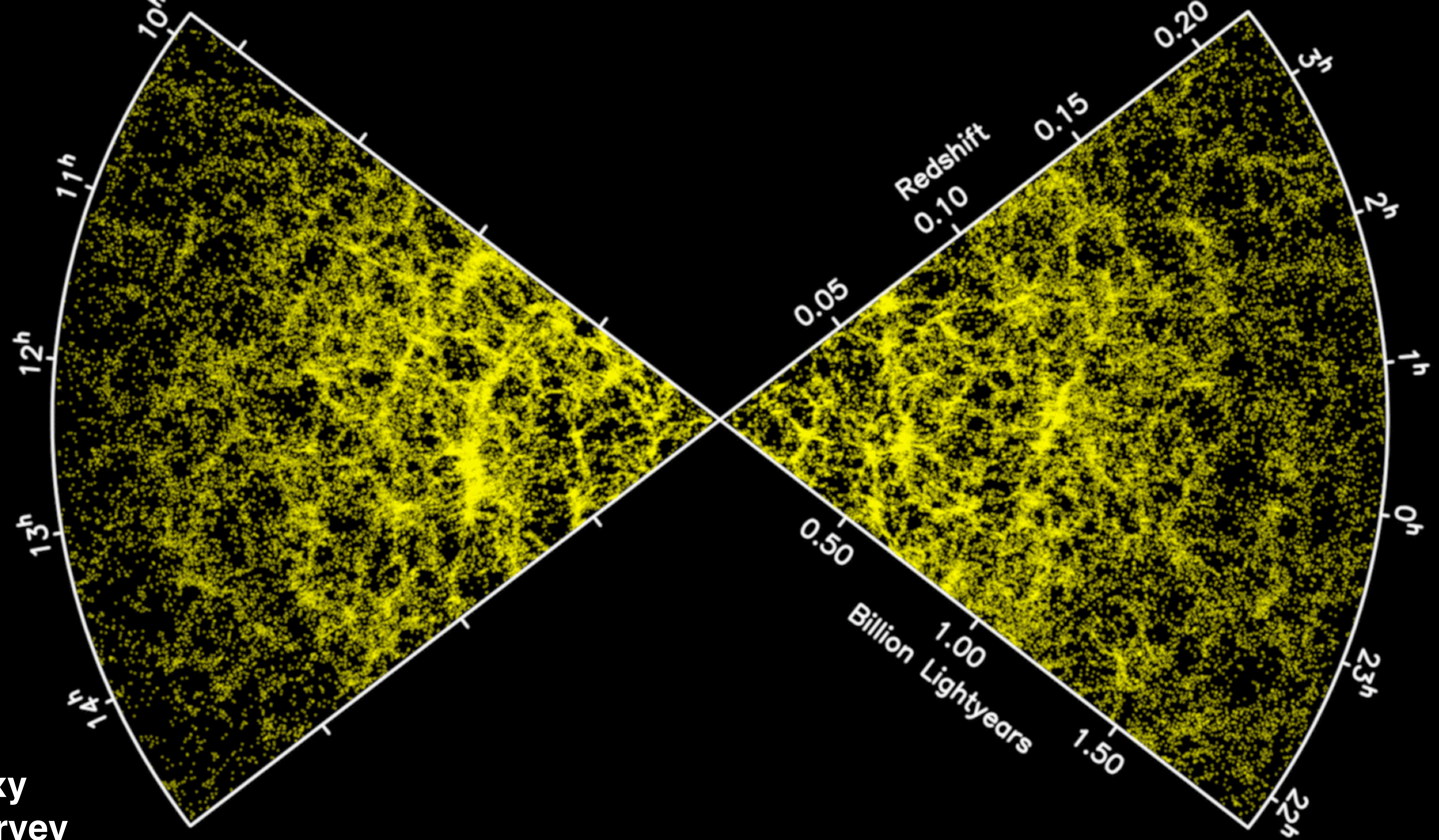
Consistent with an energy density that permeates all of space and maintains constant *density* as Universe expands

Dark Energy

Consistent with an energy density that permeates all of space and maintains constant *density* as Universe expands

Dark energy (using $E = mc^2$)	~4 protons / m^3
Interstellar Space	~ 10^6 protons / m^3
Air ~ 1 kg / m^3	~ 10^{27} protons / m^3
Water ~ 10^3 kg / m^3	~ 10^{30} protons / m^3

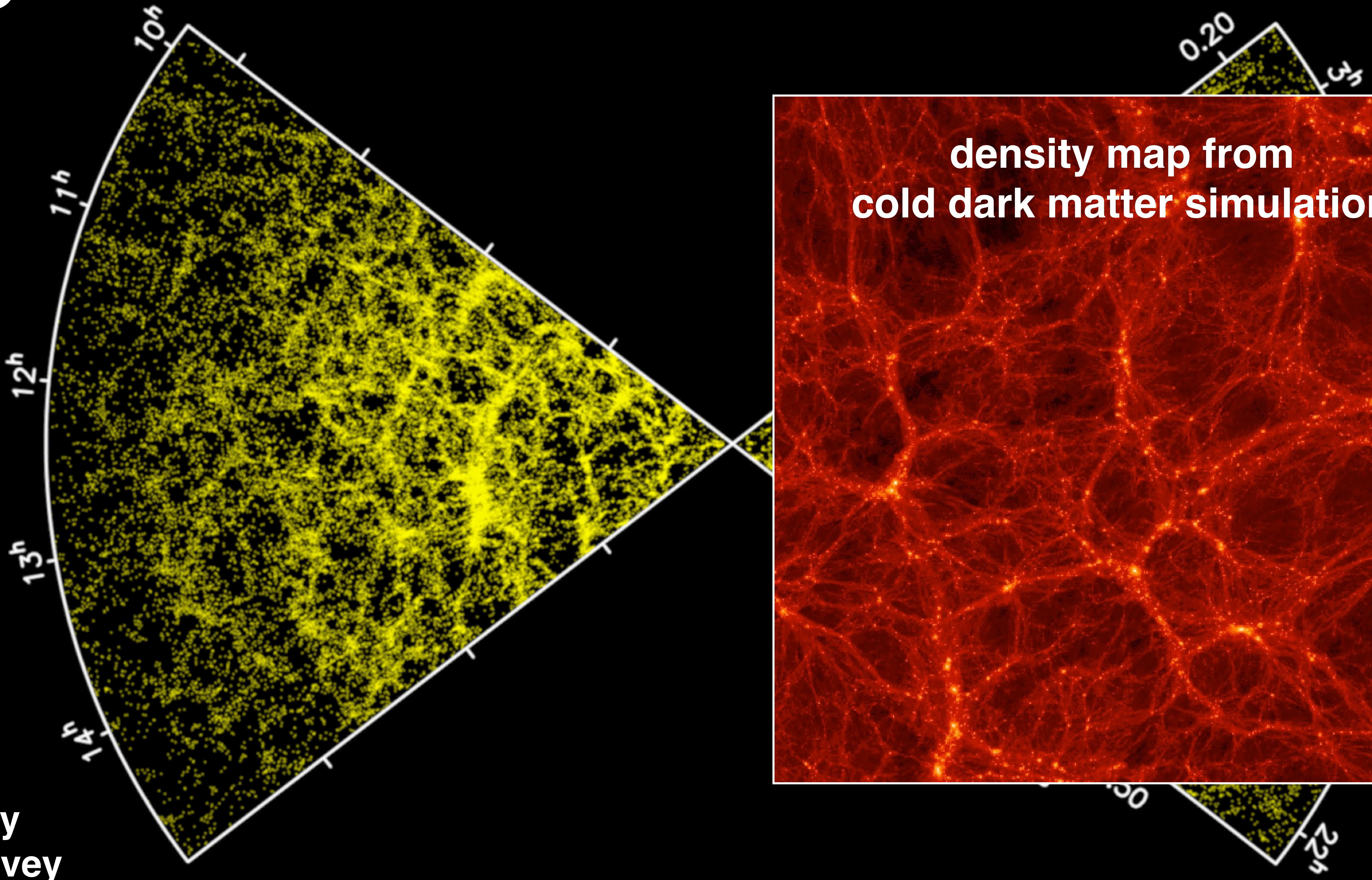
Large-Scale Structure



2dF Galaxy Redshift Survey
1997-2002

Slice of a three-dimensional map of galaxies

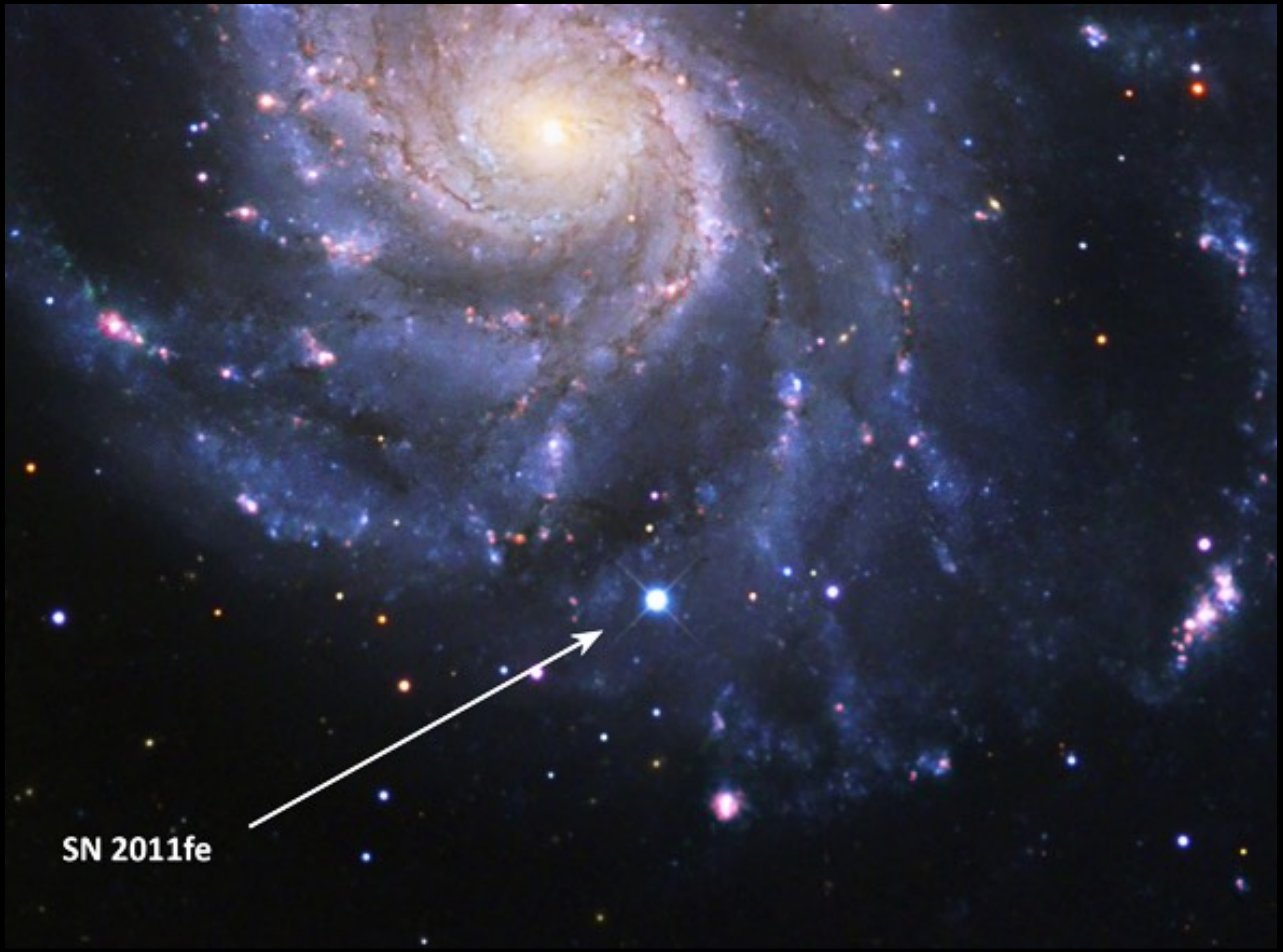
Large-Scale Structure



2dF Galaxy Redshift Survey
1997-2002

Slice of a three-dimensional map of galaxies

Supernovae



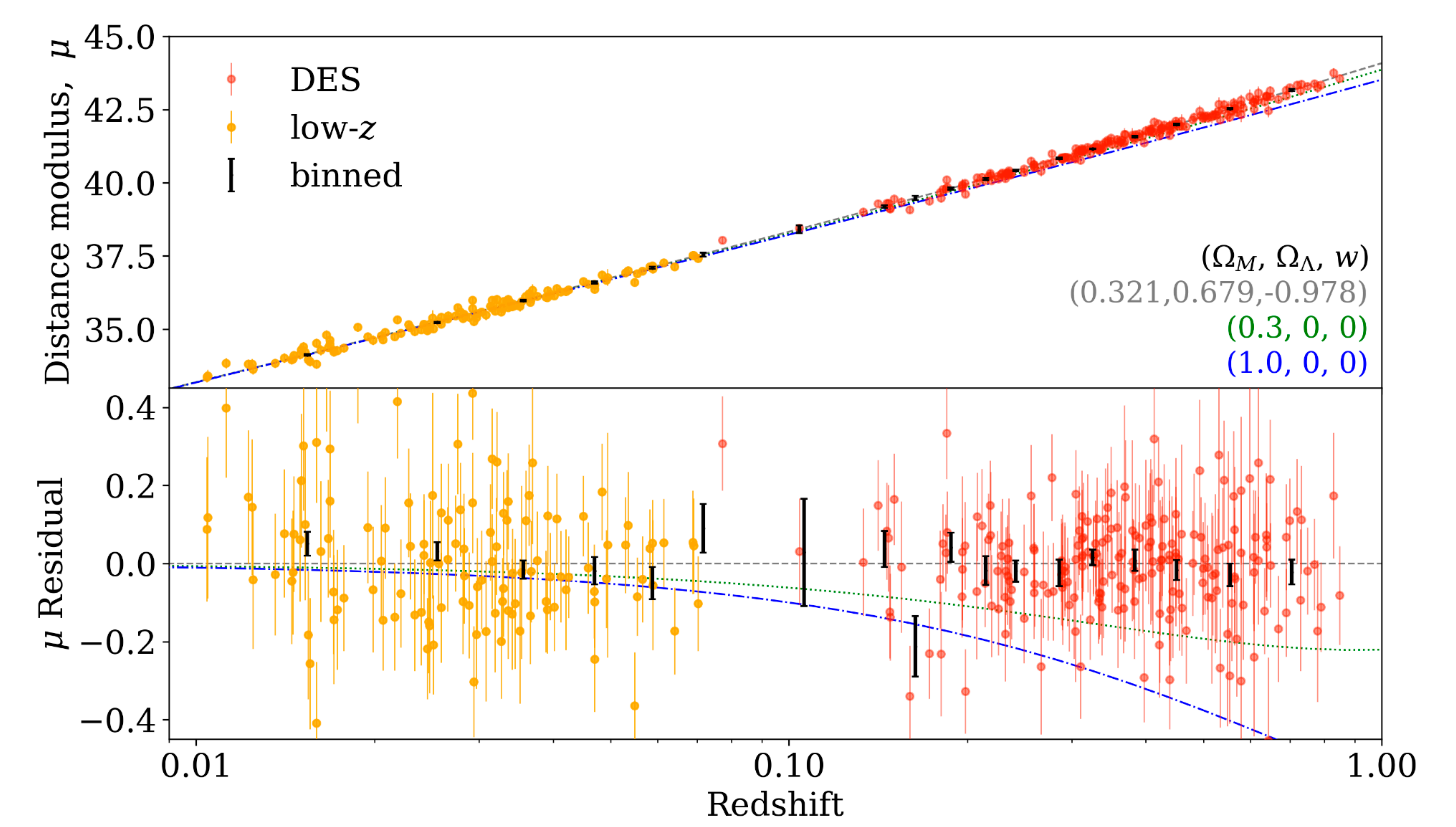
Type Ia supernovae are *rare* and *unpredictable*; **~1 per 1000 yr** in a typical galaxy

But need to schedule follow-up time for deep imaging and spectroscopic observations months in advance…

Solution: generate supernovae sample by observing 50-100 fields each containing ~1000 galaxies

"Supernova on demand"

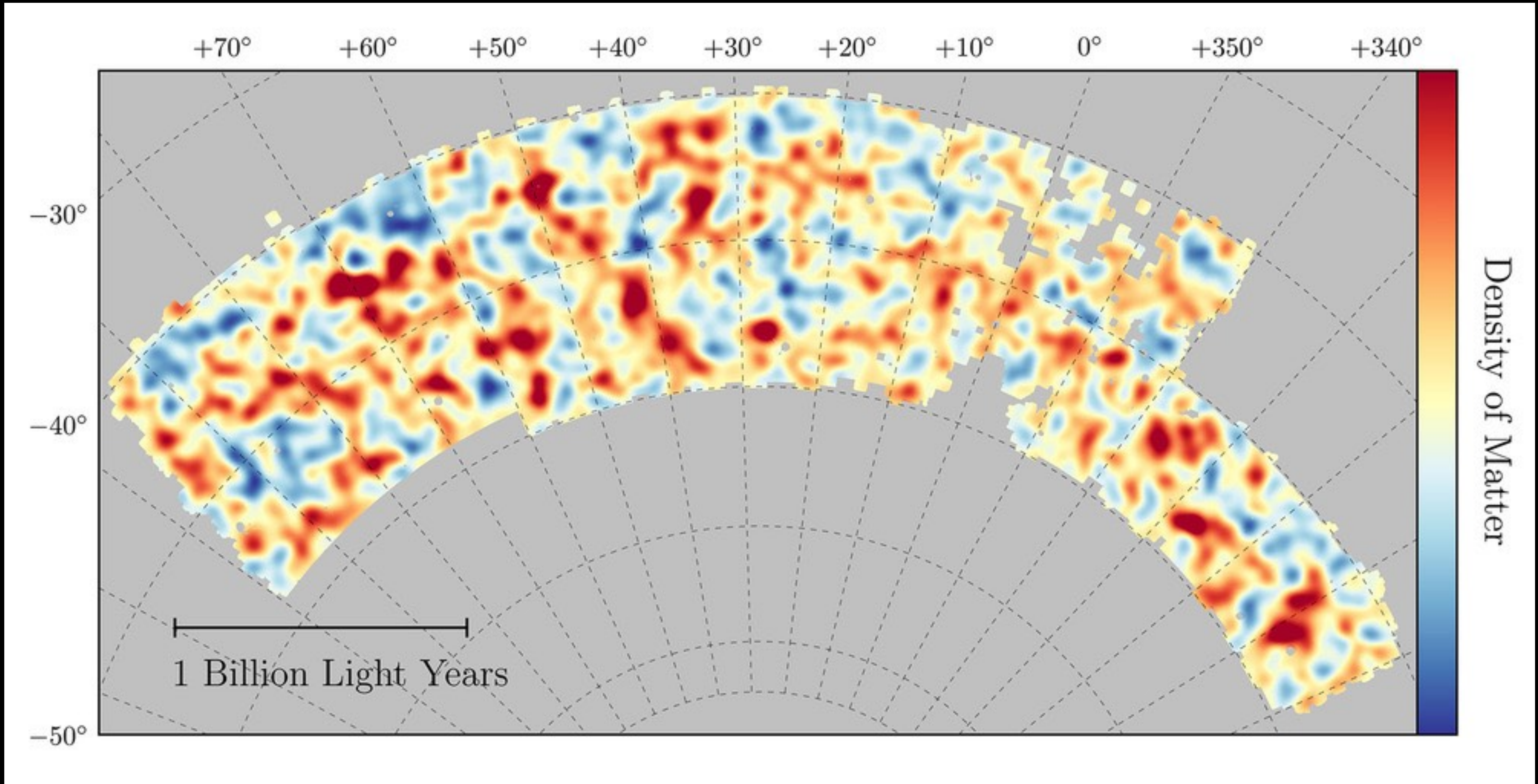
Supernovae



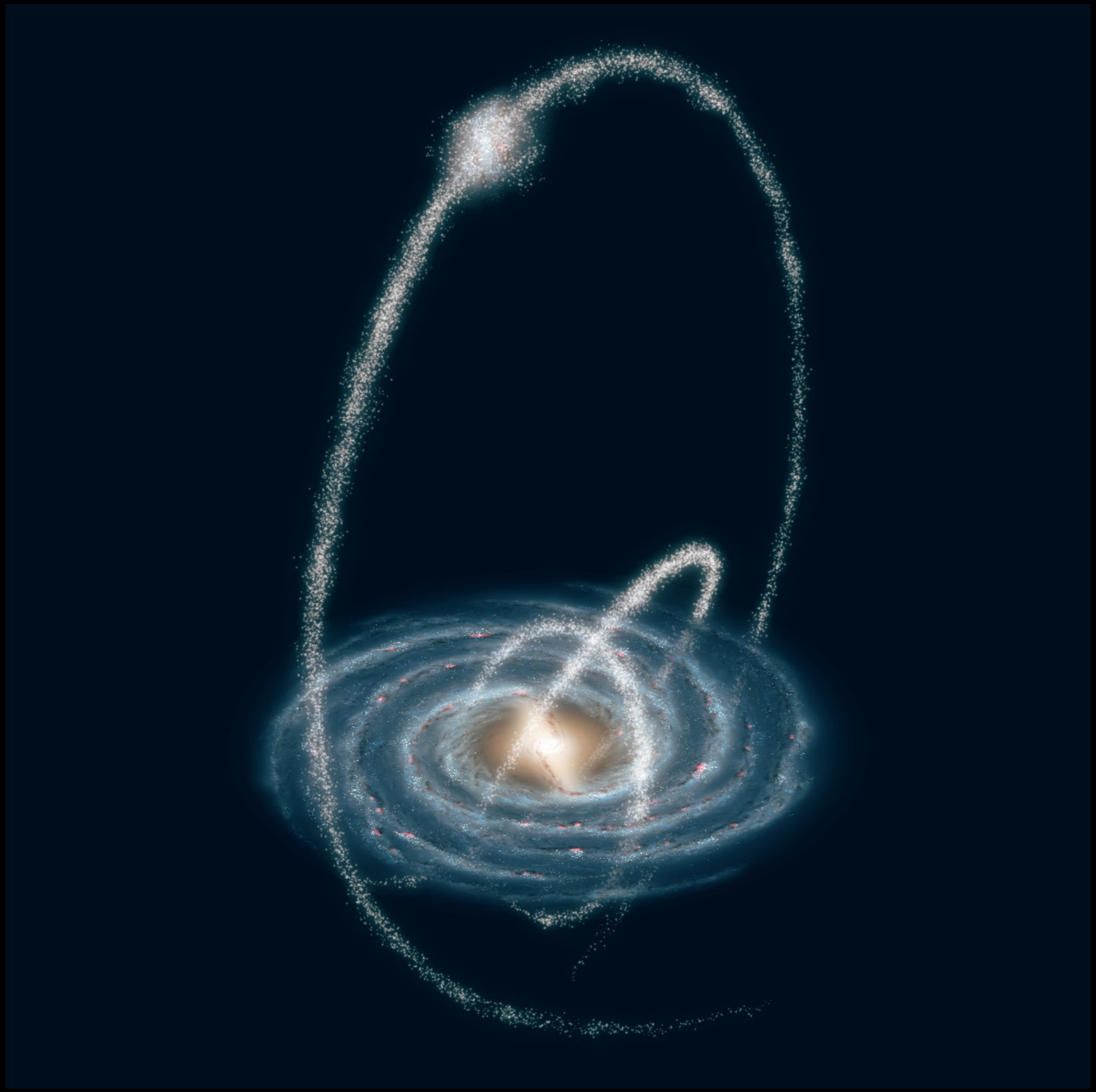
Time that Light has Travelled to Reach Earth

Expansion of the Universe

Weak Gravitational Lensing

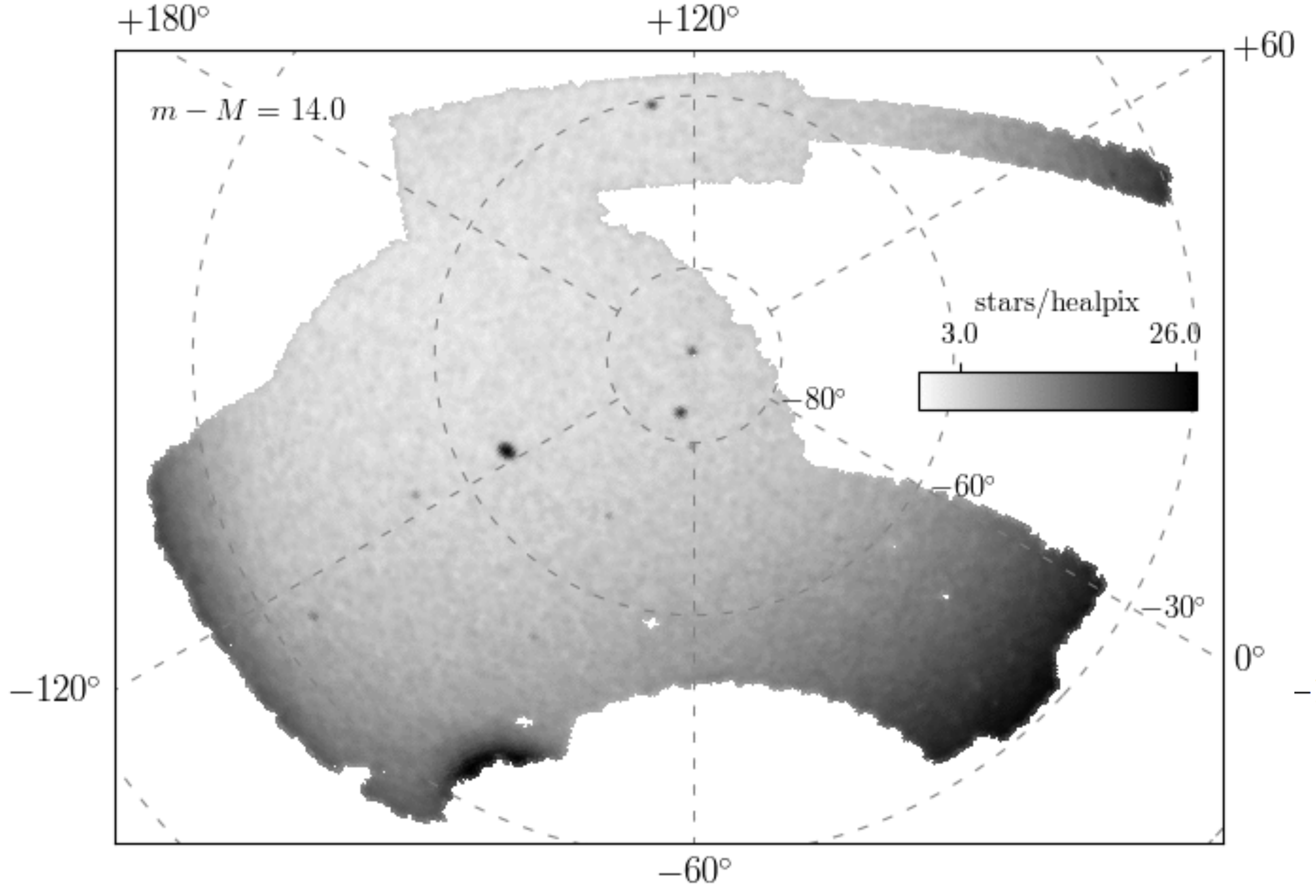


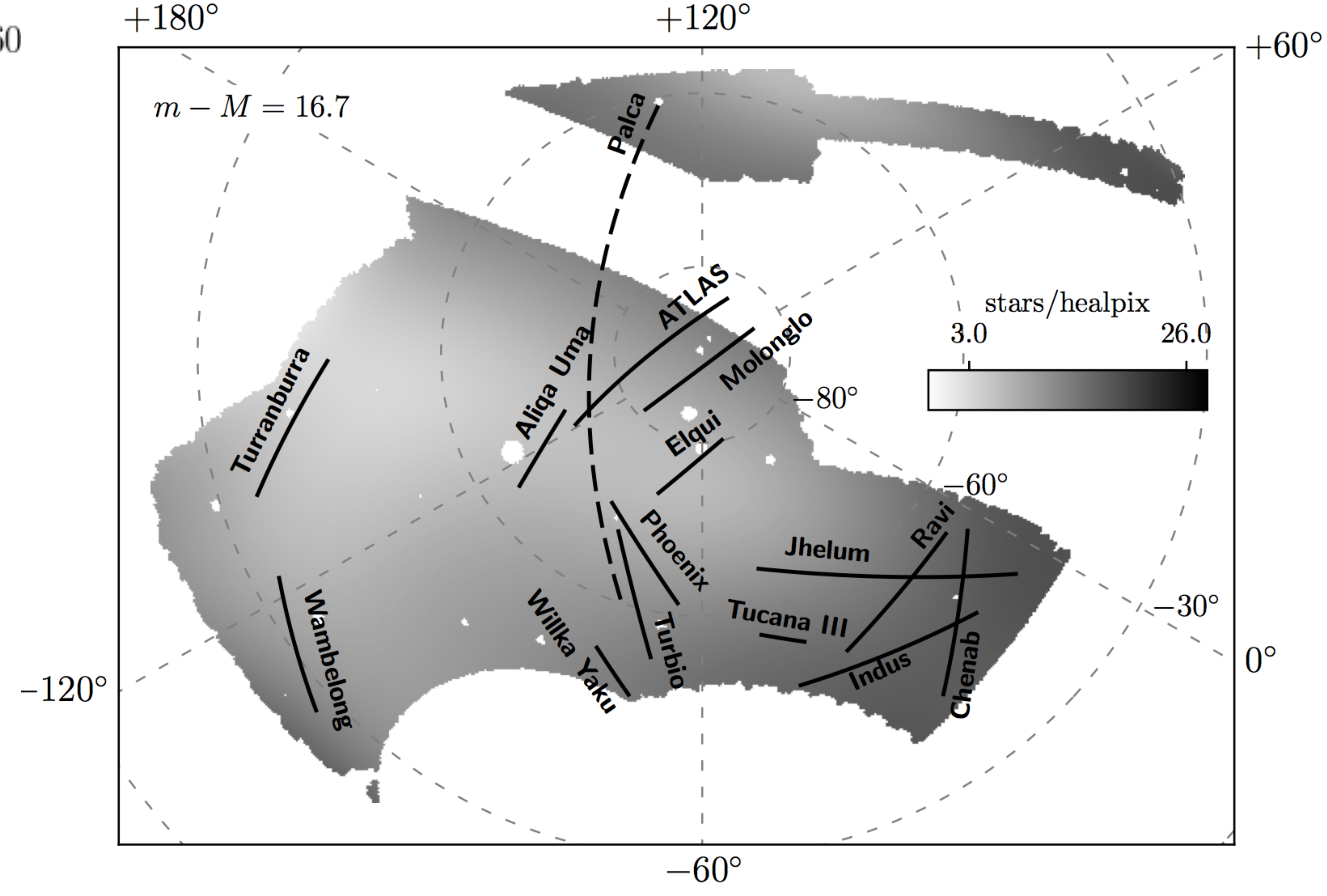
Milky Way Stellar Streams



Milky Way stellar streams visible in stellar density map from the DES survey
(1/8th of full sky)

Milky Way Stellar Streams

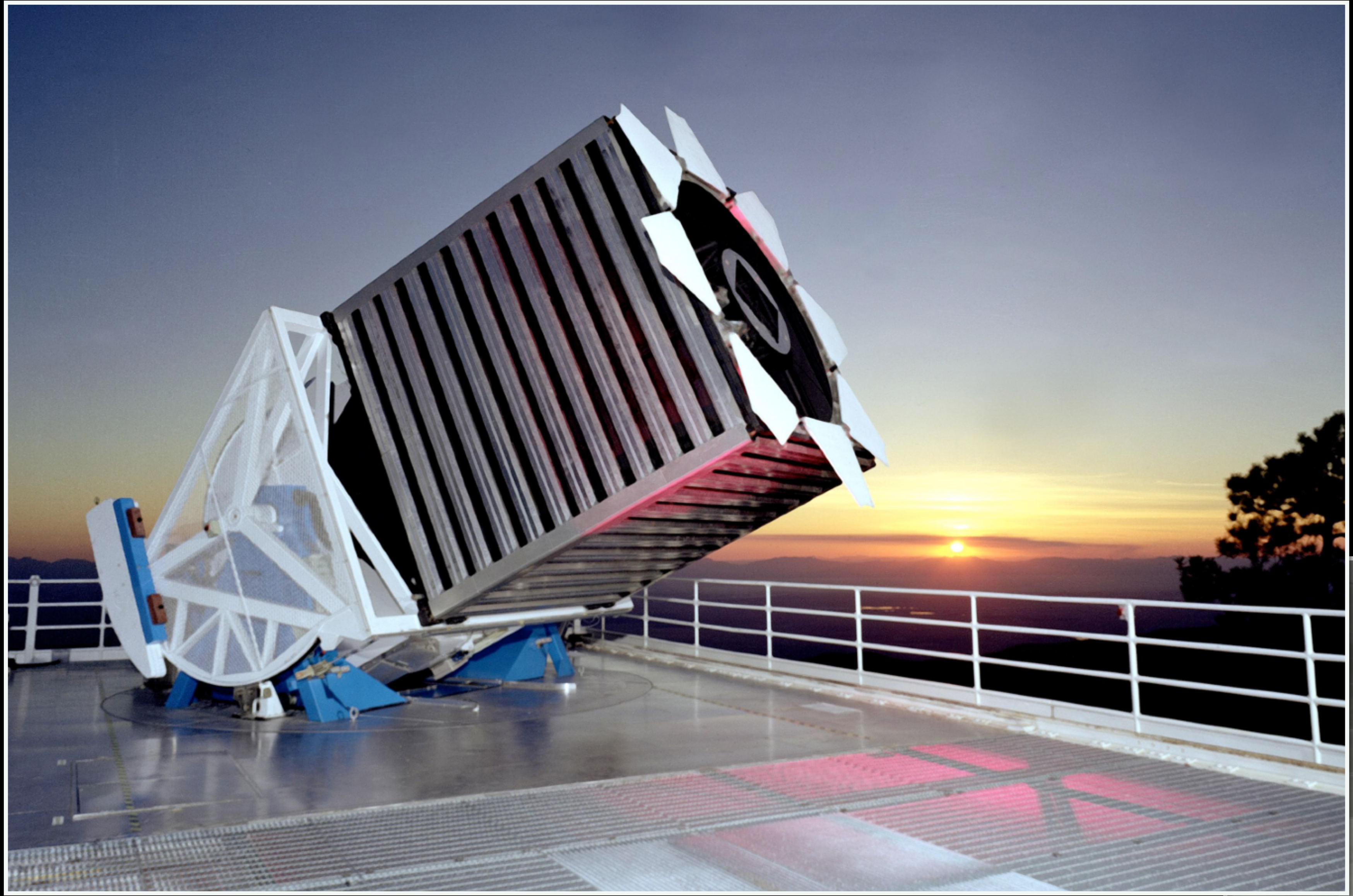




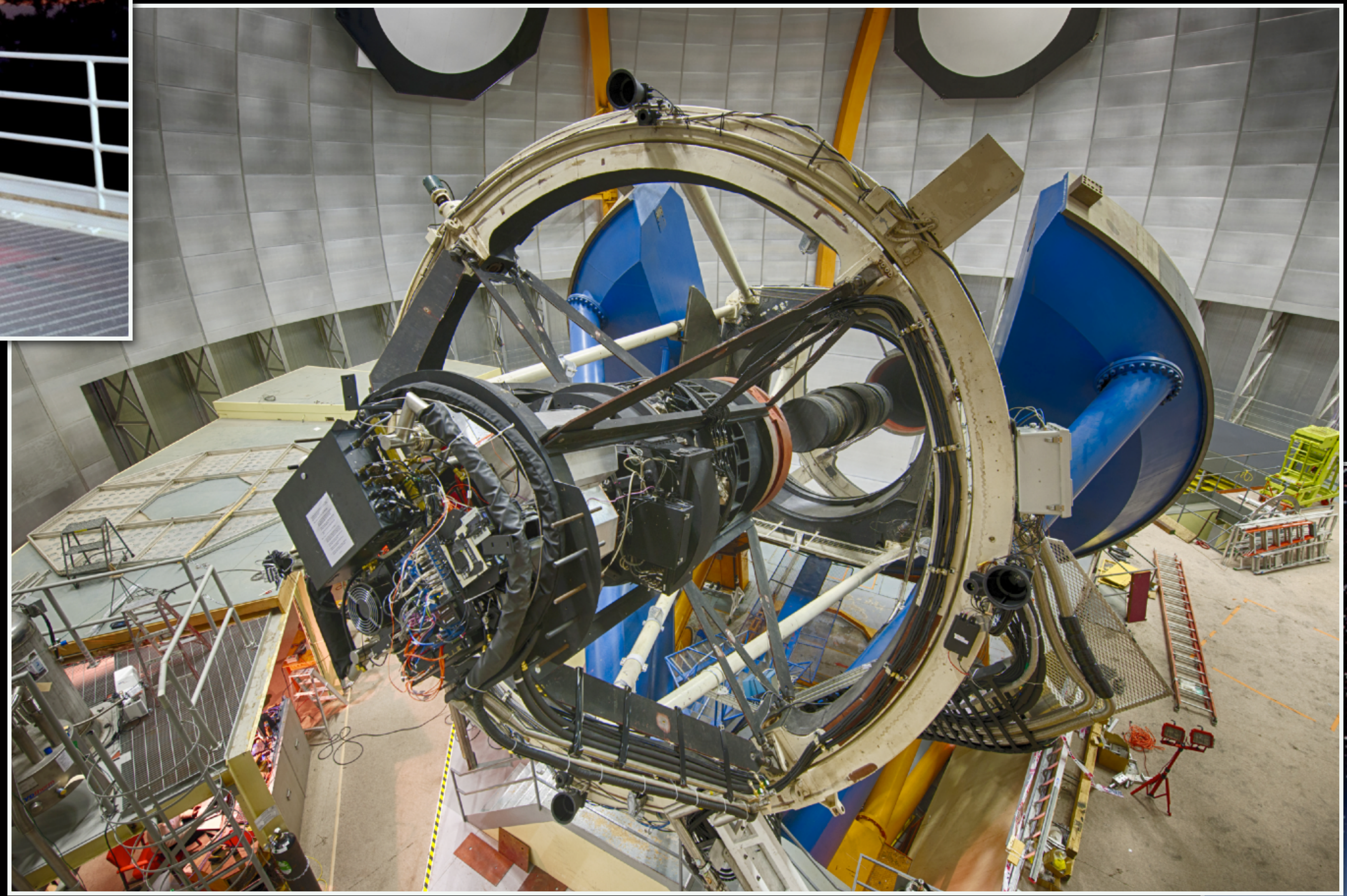
Scanning in distance

Progression Of Wide-Field Optical Imaging Surveys

Sloan Digital Sky Survey
(SDSS), 2000 -

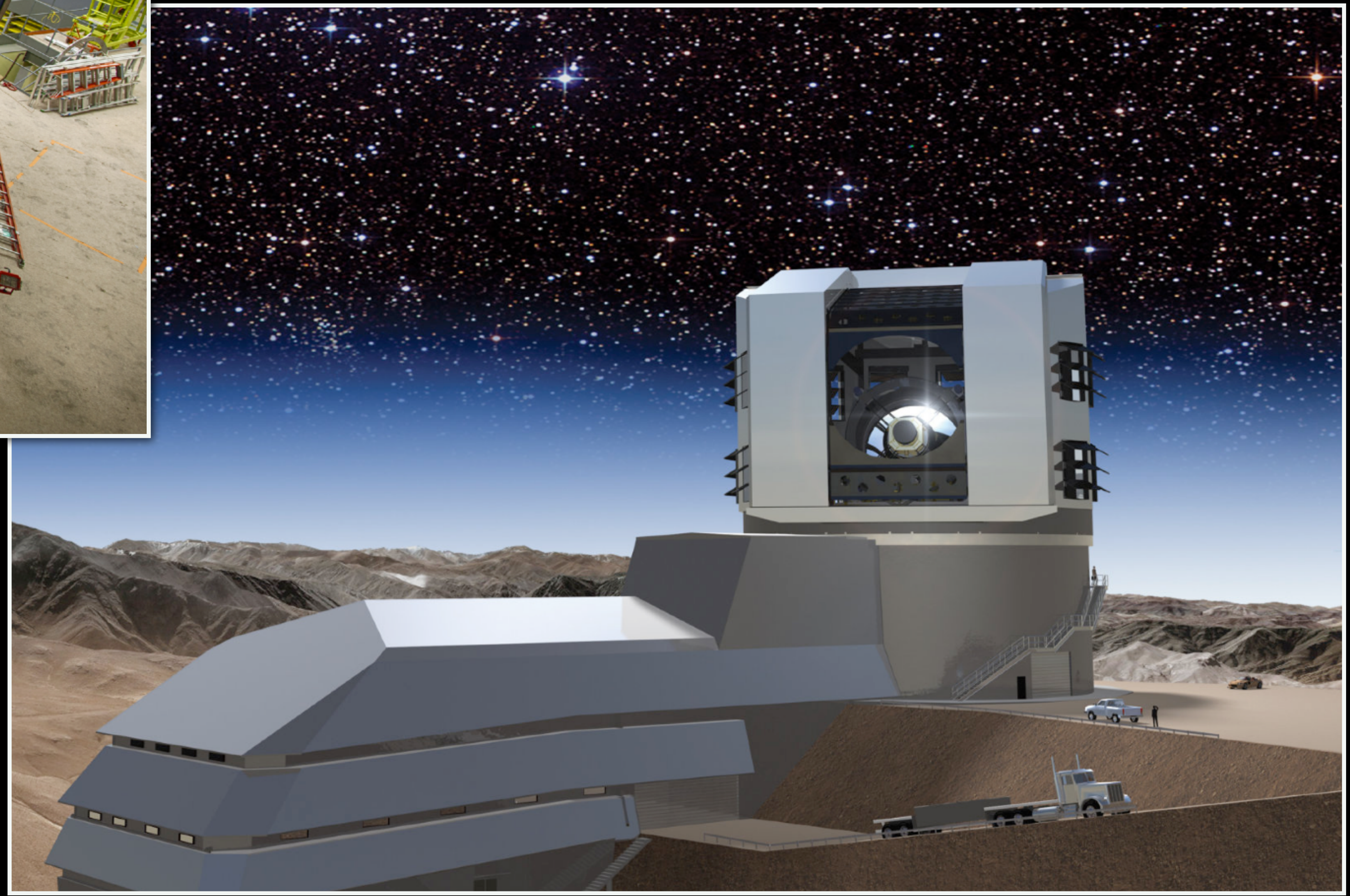


Dark Energy Survey
(DES), 2012 -



~10 deeper
than SDSS

Large Synoptic Survey Telescope
(LSST), 2023 - 2033



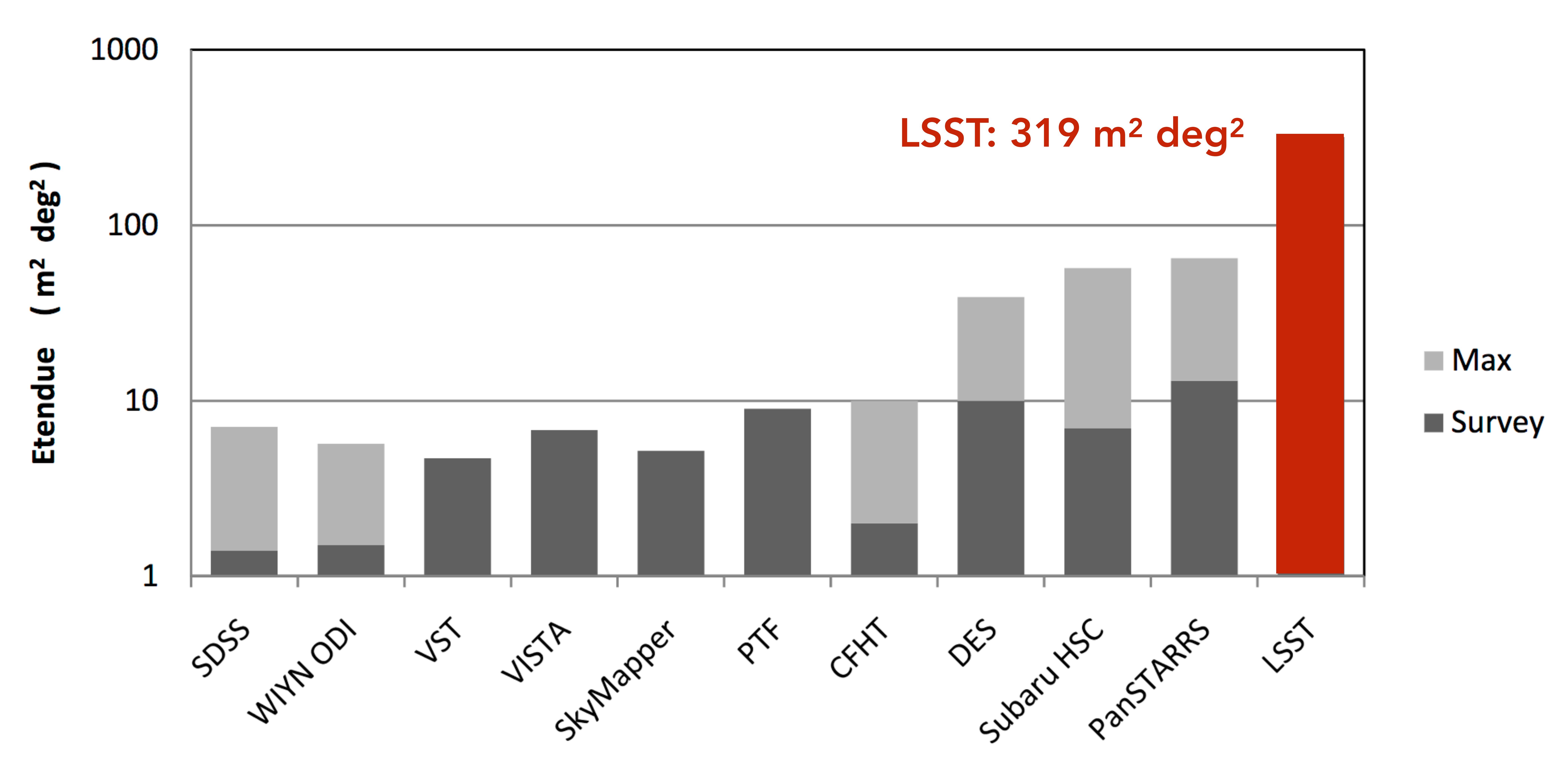
~100 deeper
than SDSS

* Representative selection

Etendue = Field of View × Effective Aperture (× Efficiency)

Measure of light-collecting power

Log Scale



A New Kind Of Telescope Optimized For Surveys

1998-2000

Modified 3-mirror Paul-Baker Design
Seeing limited over 3.5 deg field of view
"Dark Matter Telescope"

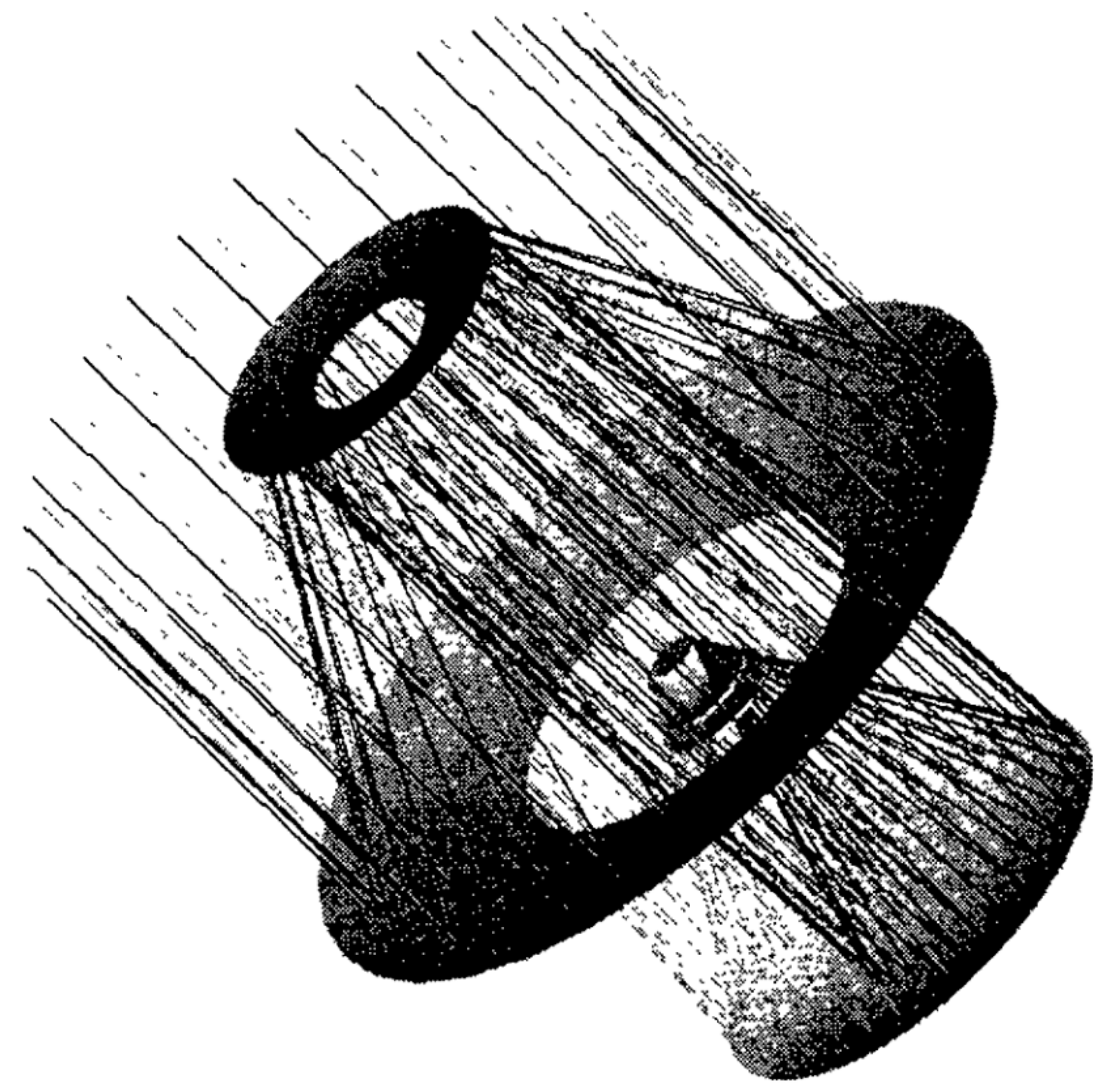
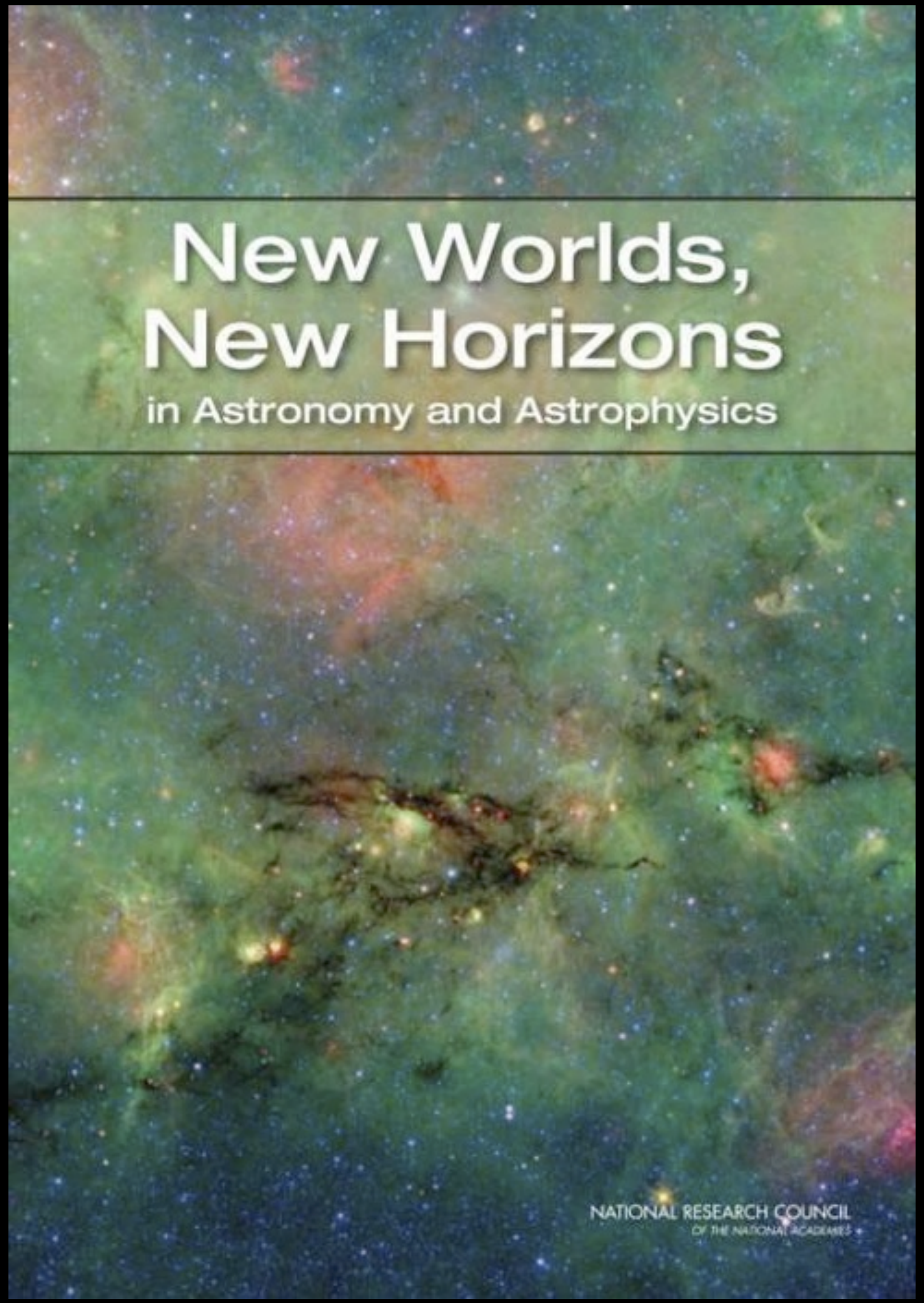


Figure 1. Optical layout with rays at ± 1.5° field angle.

2010

LSST selected as the highest priority ground-based instrument for the coming decade

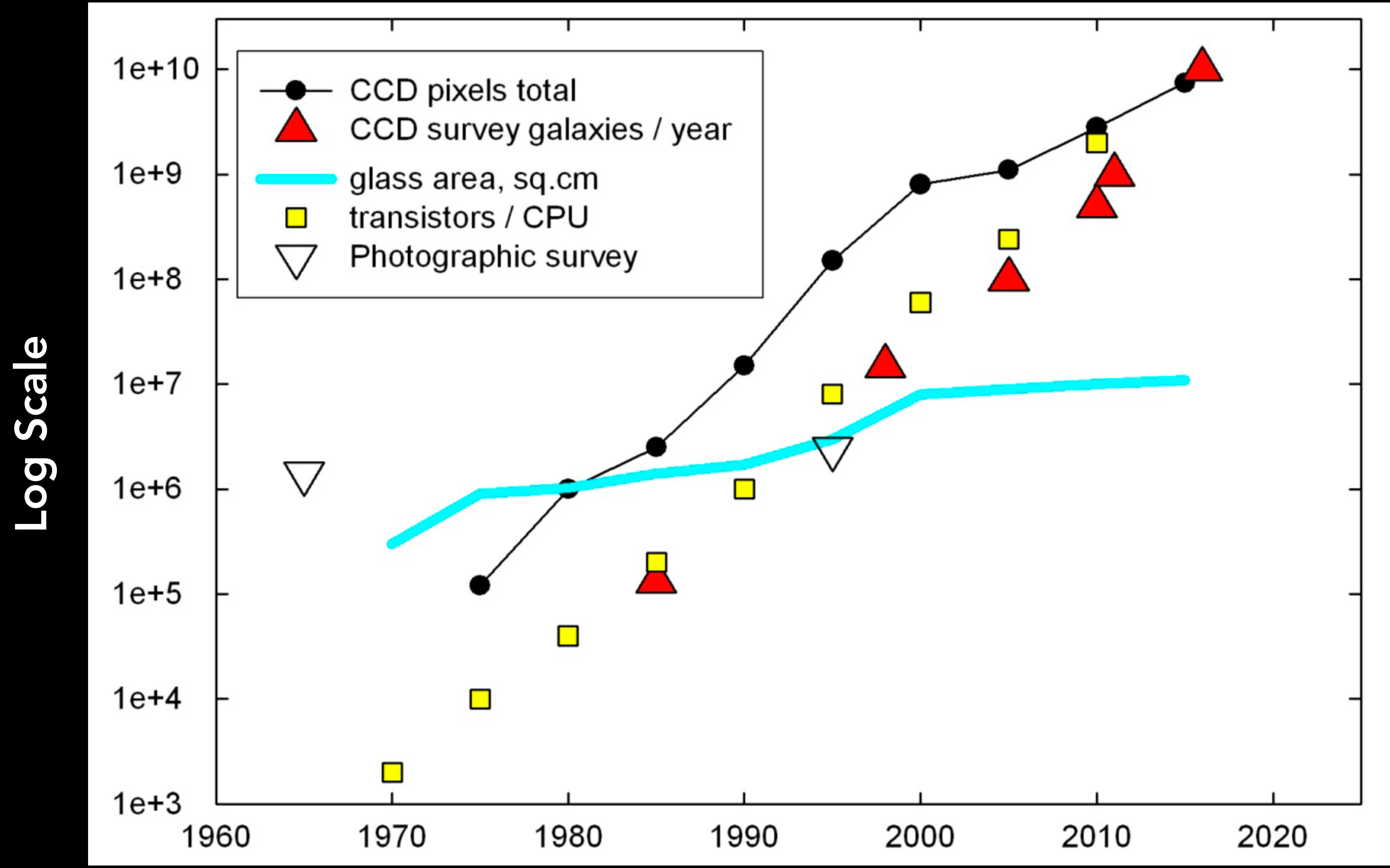


2014

Formal construction start!
Joint project between
National Science Foundation (NSF)
+ Department of Energy (DOE)
+ international partners

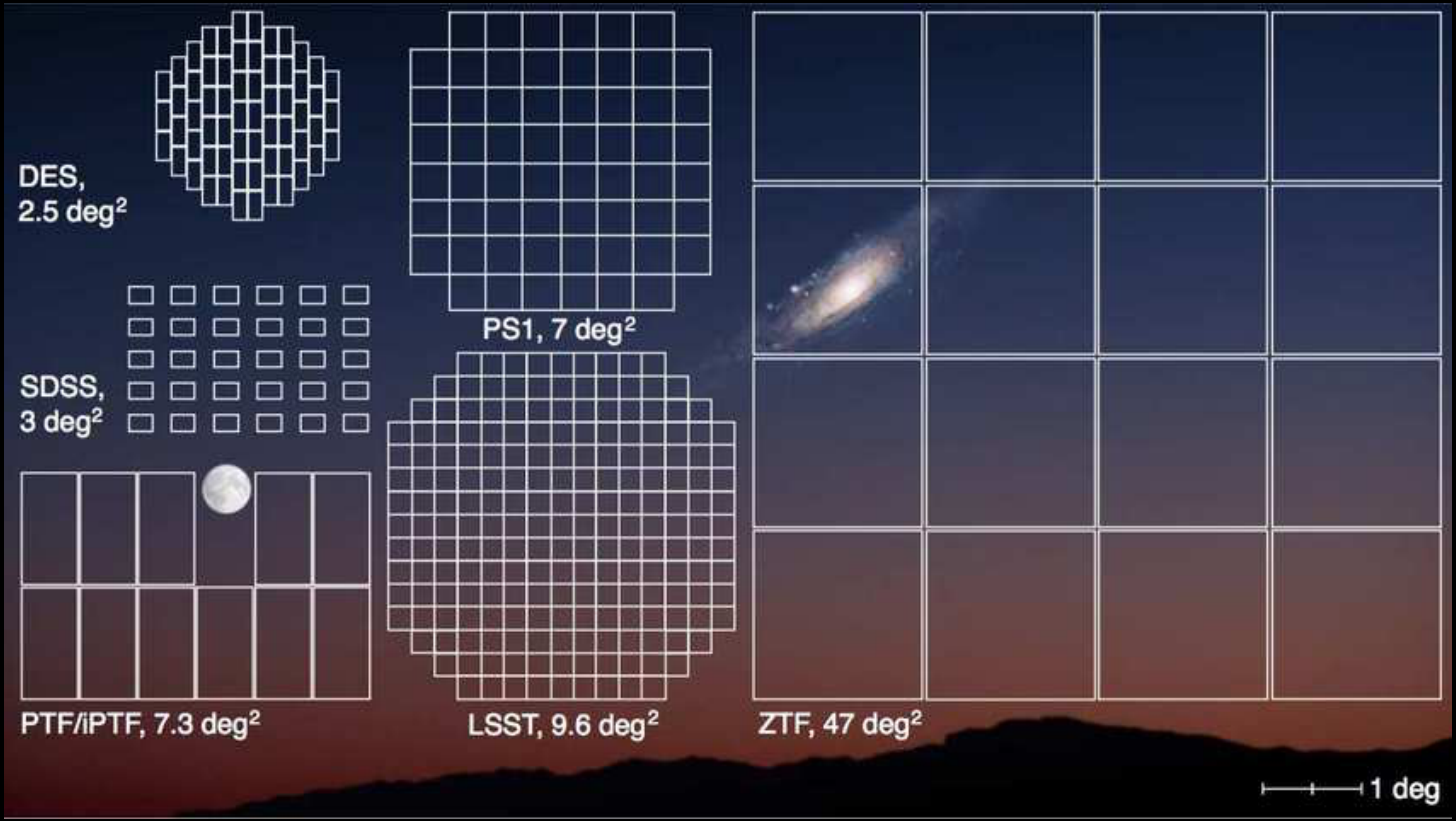
LSST 2014
CONSTRUCTION START

Confluence Of Enabling Technologies



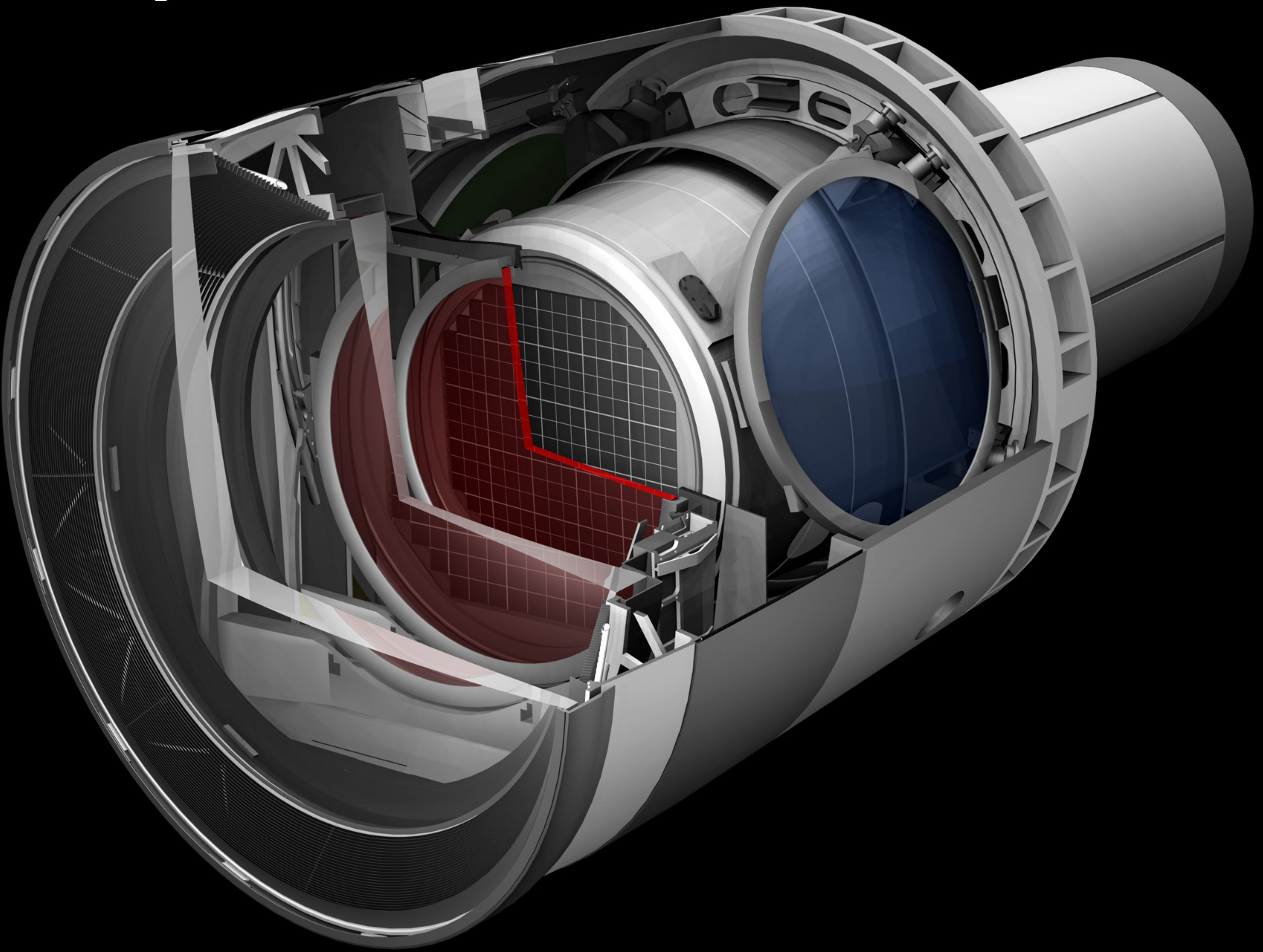
- ✓ 8 meter class aspheric mirrors
- ✓ Mosaic of high quantum efficiency CCDs w/ near-IR sensitivity
- ✓ Exponentially increasing computational power

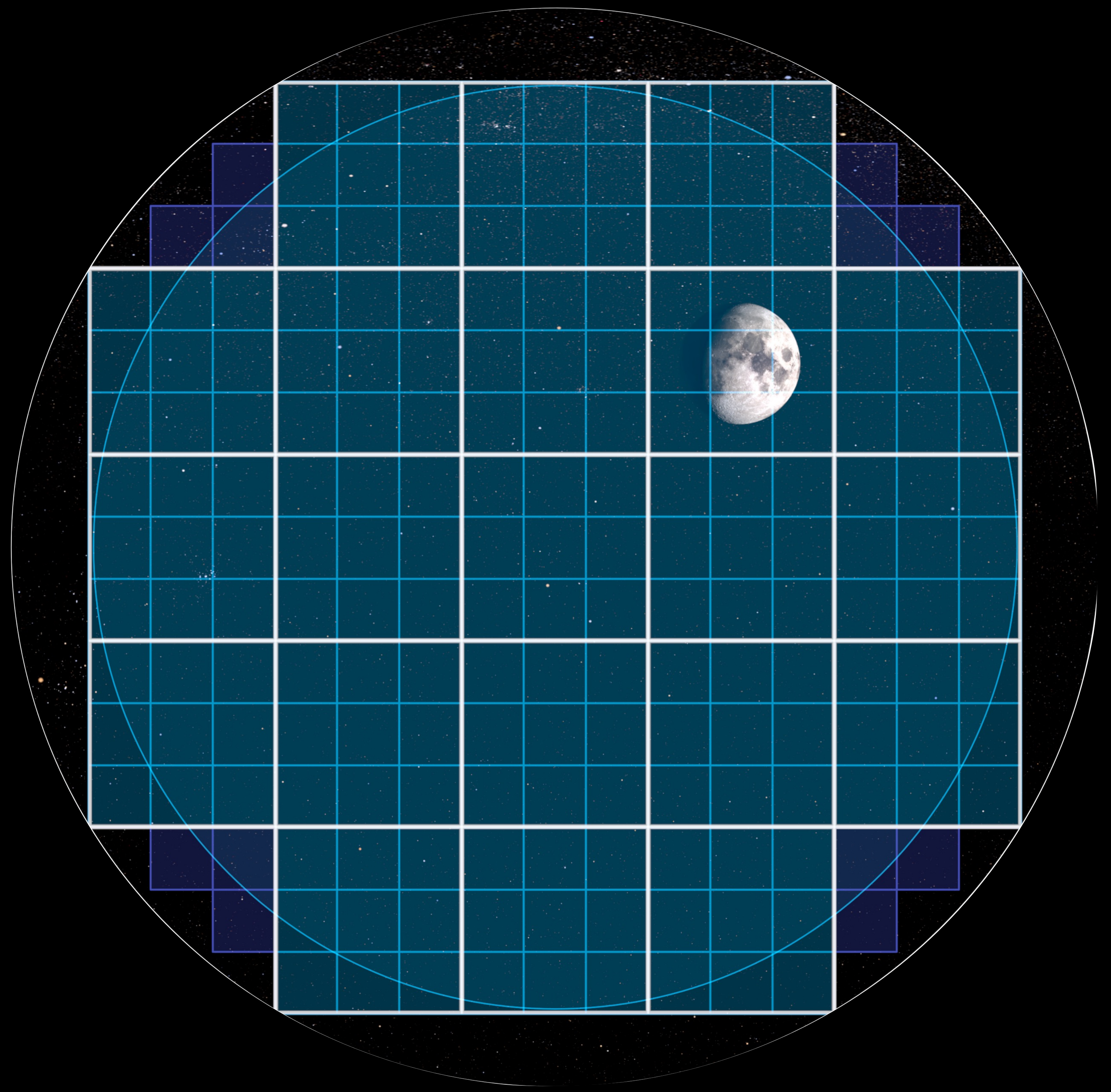
Wide Field Of View




Large Aperture
8.4 m diameter

Large Camera



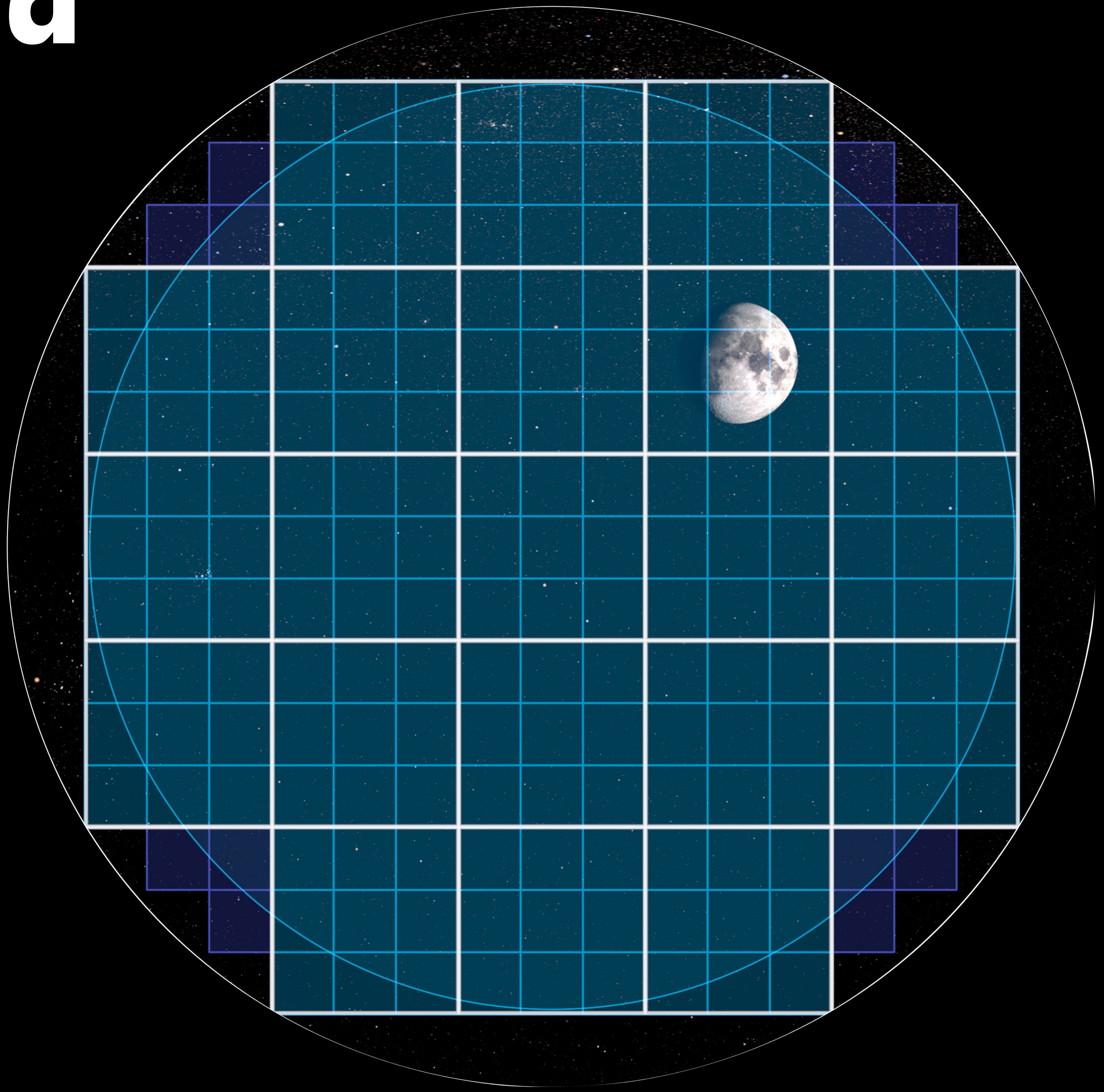


Large Camera

LSST

3,200,000,000

pixels



HDTV

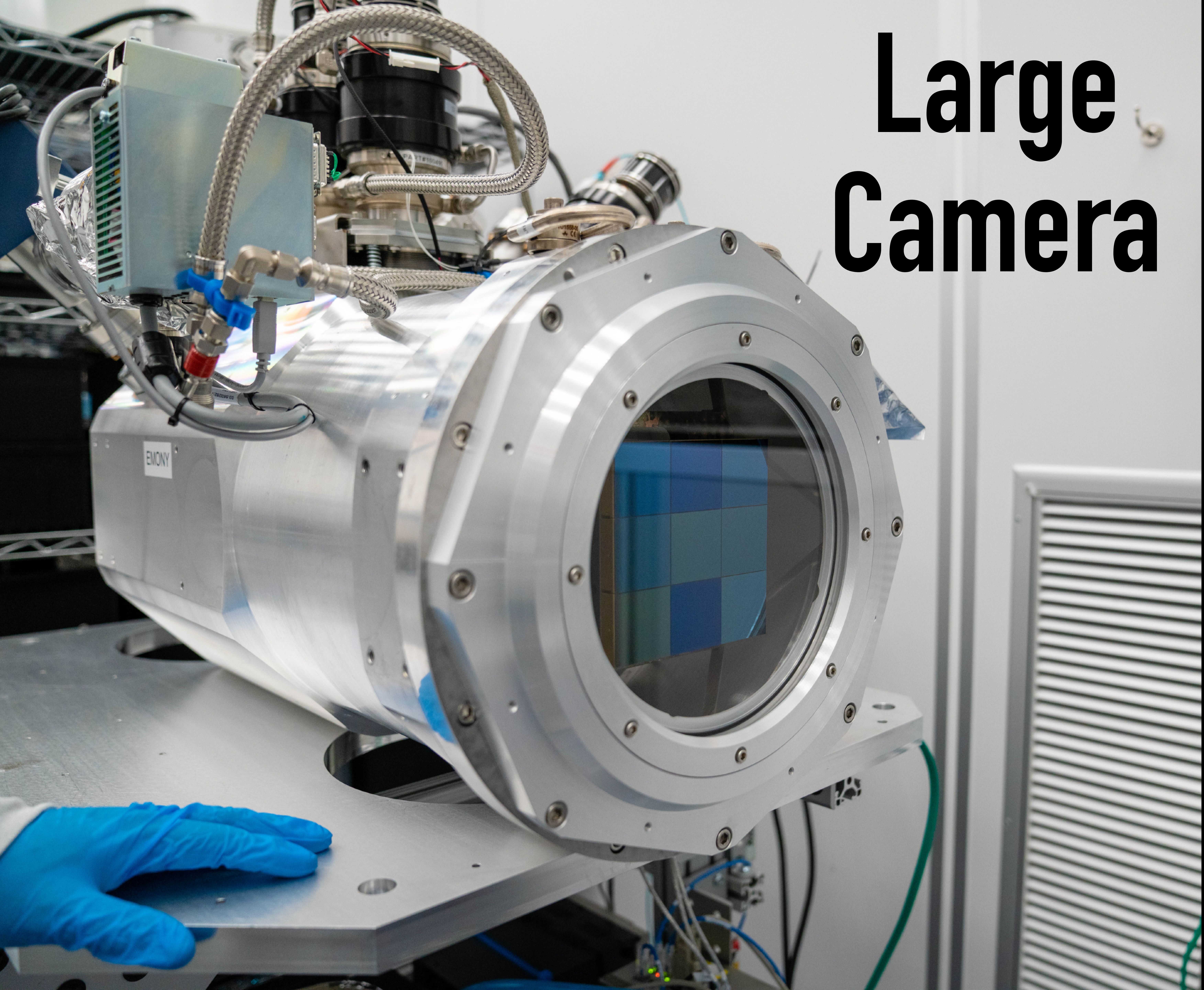
2,073,600

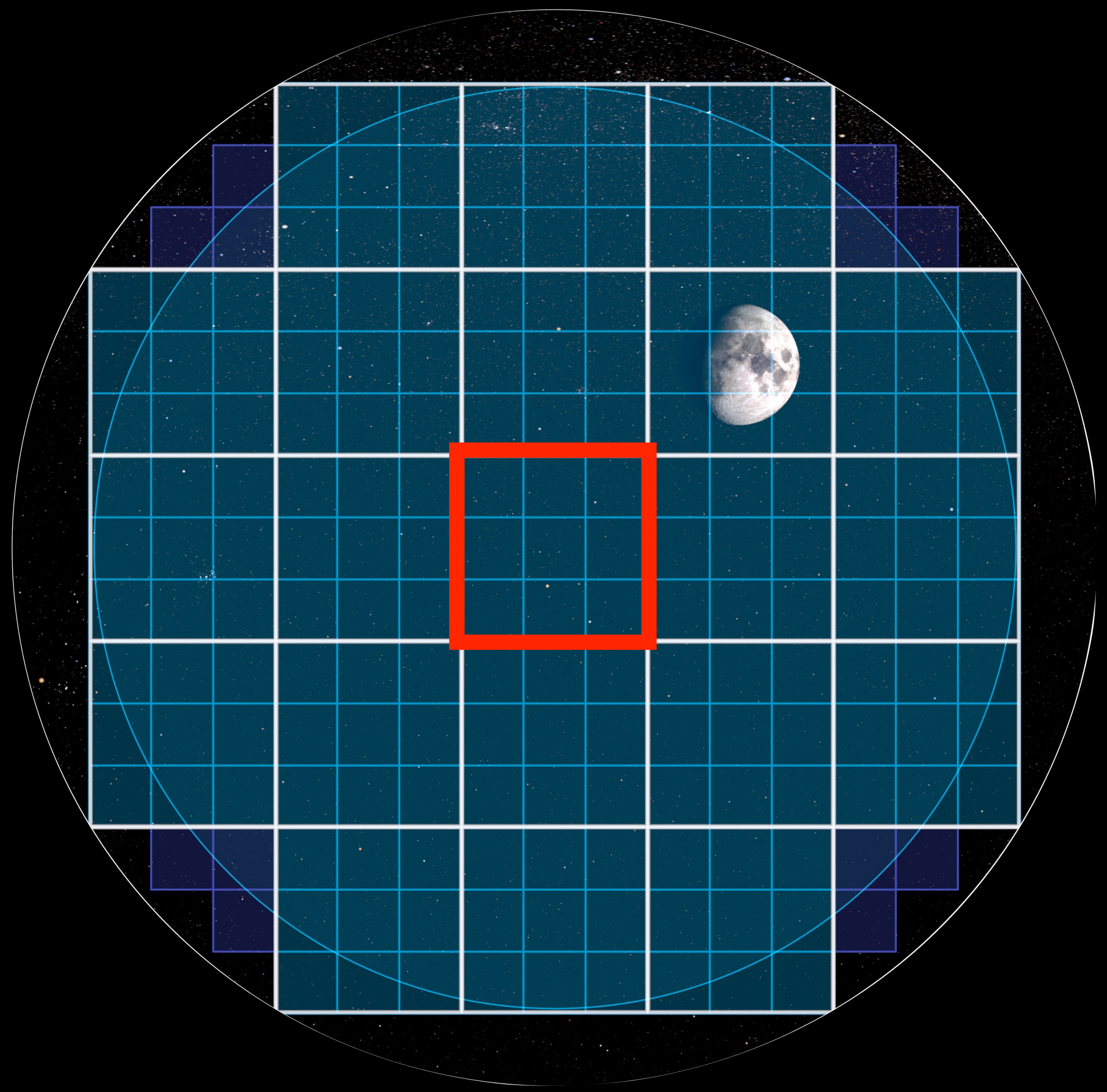
pixels

Need 1,500 HDTV screens to view a single image taken by LSST

That’s enough 4k TVs to cover half a basketball court!

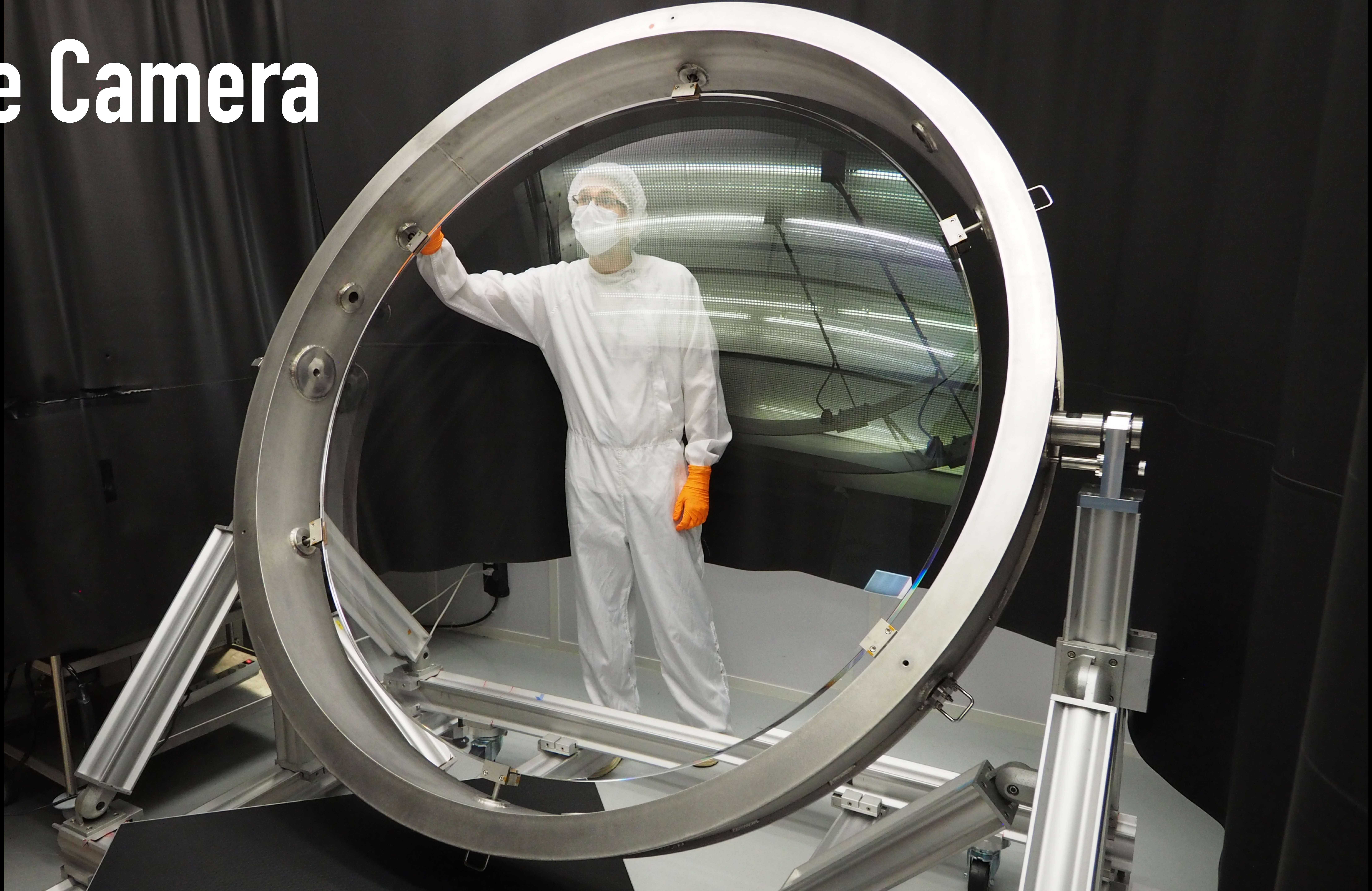
Large Camera





"Commissioning camera" using 1 of 21 rafts that make up the full camera focal plane

Large Camera



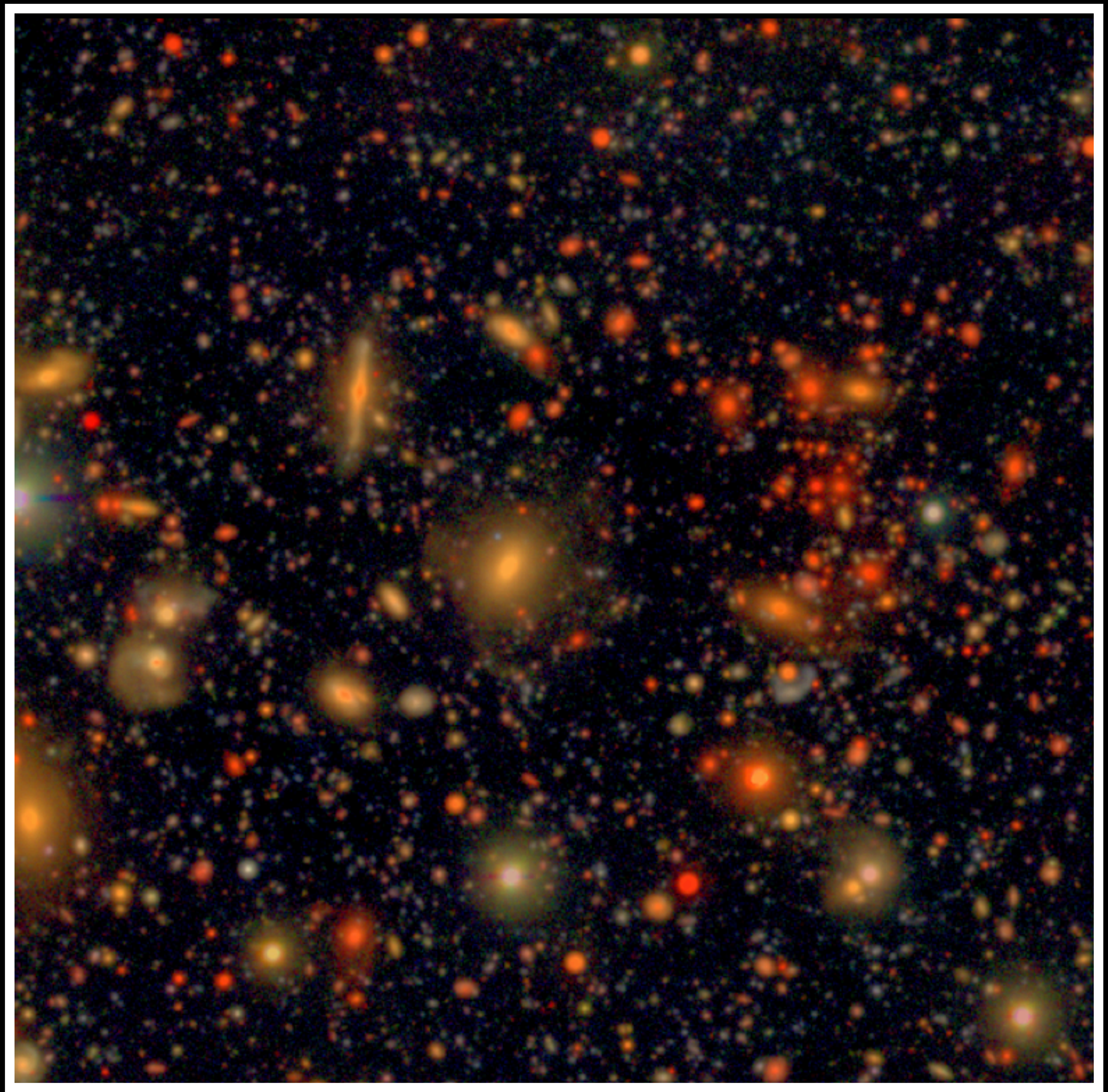
Data Management

Data Processing Facility at National Center for Supercomputing Applications at U. of Illinois (up to ~2 PFLOPS)

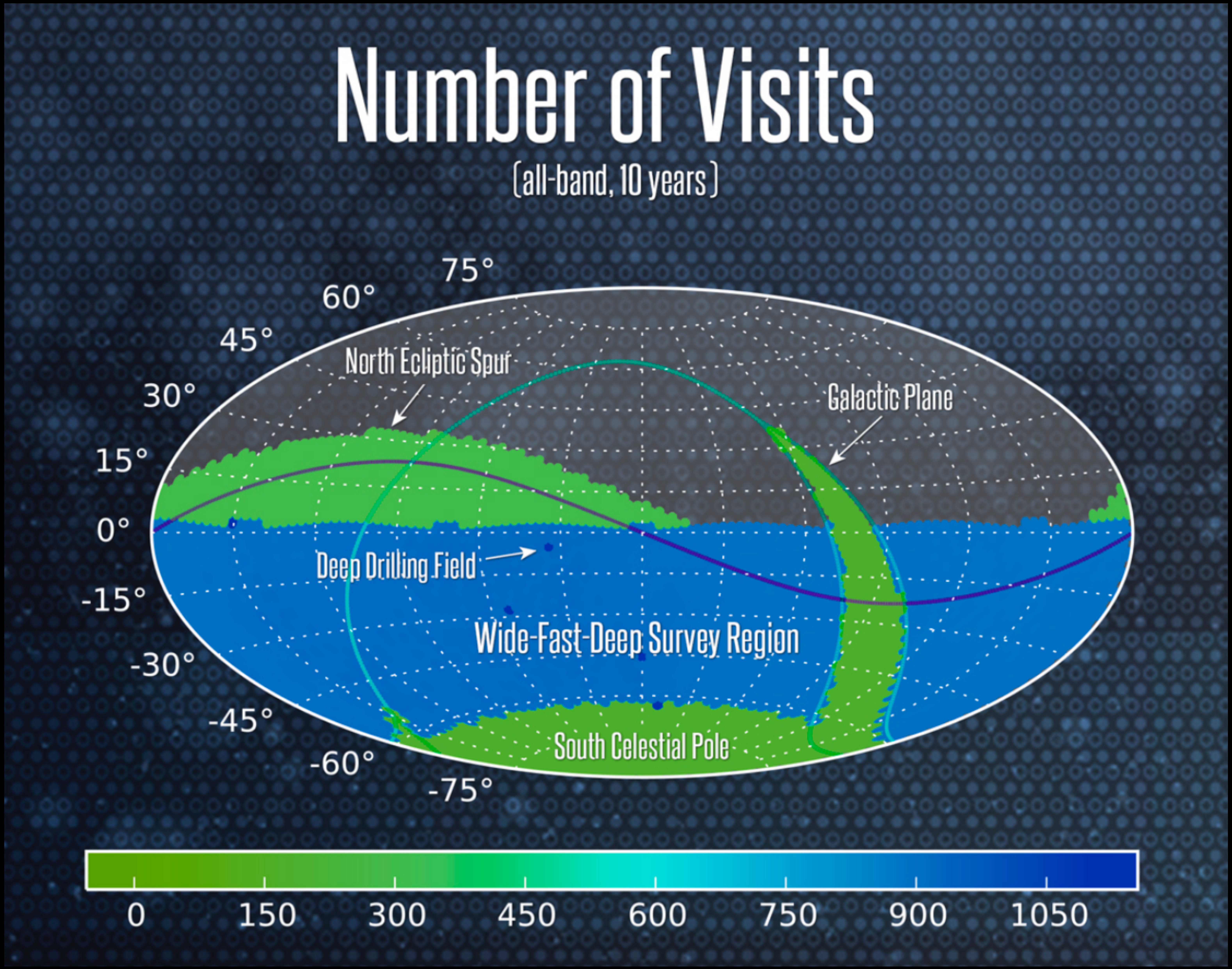
Laying fiber optical cable from summit

Data Management

SDSS



HSC image at **LSST depth**

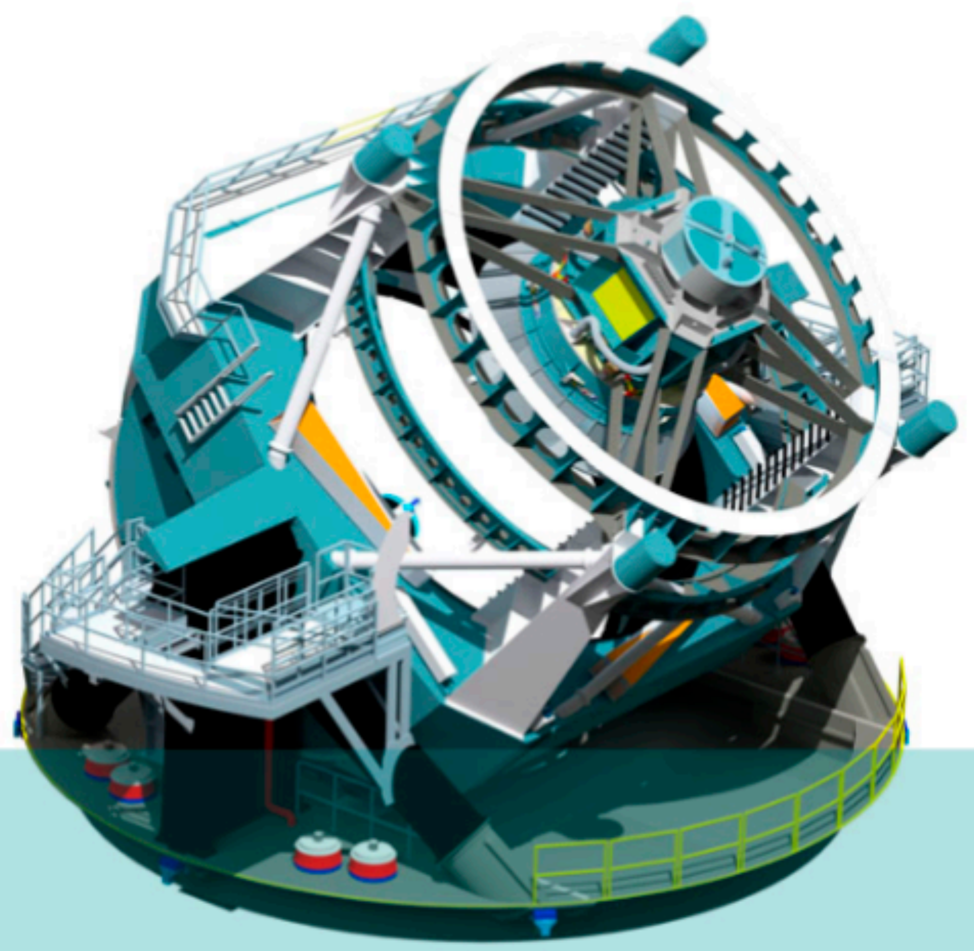


Capable of re-visiting every patch of the night sky visible from Chile every 3 nights

LSST Key Numbers

Raw Data: 20TB/night

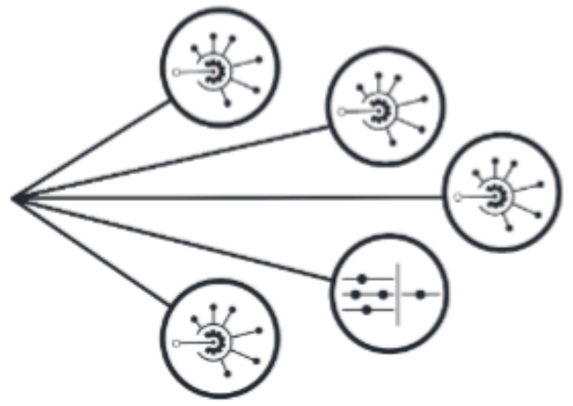
Sequential 30s images covering the entire visible sky every few days



Prompt Data Products

Alerts: up to 10 million per night

60s via nightly alert streams



LSST Alert Filtering Service

Community Brokers

Raw, calibrated, and difference images and their source and object catalogs

Solar System Objects: ~ 6 million

24h via Prompt Products Database

Data Release Data Products

Final 10yr Data Release:

- Images: 5.5 million x 3.2 Gpx
- Catalog: 15PB, 37 billion objects

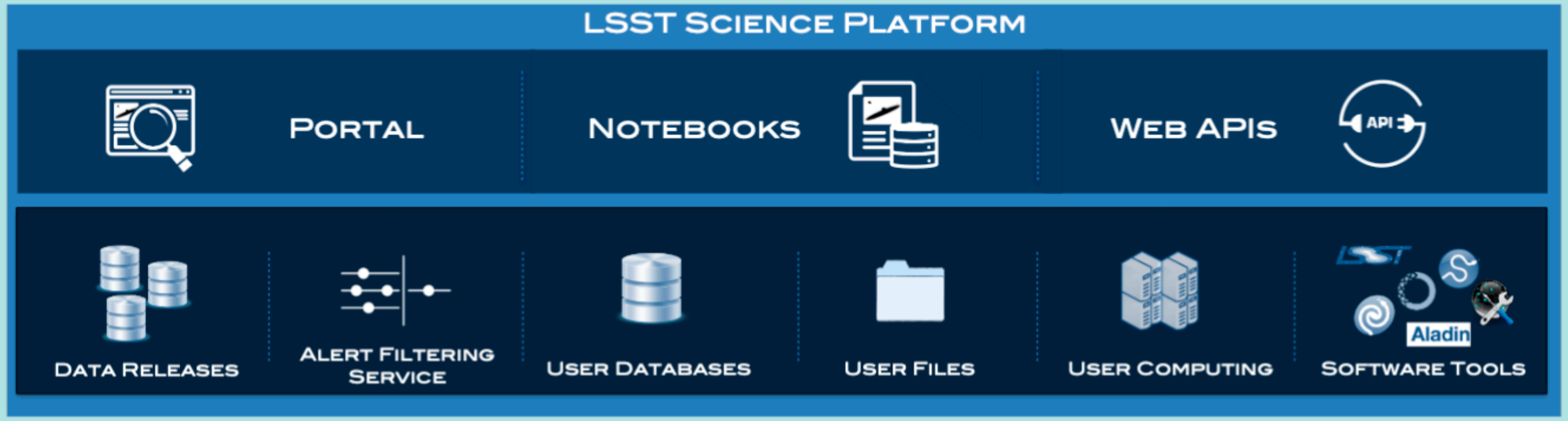
via Data Releases

LSST DAC (NCSA)

Independent DACs (iDACs)

LSST Science Platform

Provides access to LSST Data Products and services for all science users and project staff



LSST Key Numbers

3.2 Gpix image every 15 seconds 365 nights/yr for 10 yrs (5.5 million images)

~500 Pb of images over 10 yrs

~10 million alerts per night (distributed w/in 60 sec)

~20 billion stars

~20 billion galaxies (~1 % of observable Universe)

~30 trillion individual flux measurements

Modern Landscape Of Astrophysics

Modern Landscape Of Astrophysics

Ask not what observations you can propose, but what science you can do with archival data...

DARK ENERGY SURVEY desaccess

bechtol
kbechtol@lsst.org

- Home
- **DB access**
- DR1 Table Schema
- Example Queries
- Cutout Service

Query box

Insert your query in the box below. Data results for "Quick" Jobs (30 sec.) will be displayed at the bottom.

```
--
-- Example Query --
-- This query selects stars around the center of glubular cluster M2
SELECT
  COADD_OBJECT_ID,RA,DEC,
  MAG_AUTO_G G,
  MAG_AUTO_R R,
  WAVG_MAG_PSF_G G_PSF,
  WAVG_MAG_PSF_R R_PSF
FROM DR1_MAIN
WHERE
   RA between 323.36-0.12 and 323.36+0.12 and
   DEC between -0.82-0.12 and -0.82+0.12 and
   WAVG_SPREAD_MODEL_I + 3.0*WAVG_SPREADERR_MODEL_I < 0.005 and
   WAVG_SPREAD_MODEL_I > -1 and
   IMAFLAGS_ISO_G = 0 and
   IMAFLAGS_ISO_R = 0 and
   FLAGS_G < 4 and
   FLAGS_R < 4

```

Submit Job | Clear | Check | Quick | See Examples

Modern Landscape Of Astrophysics

Open source code

Public data

Reproducibility

Collaboration

Equal Opportunity

Sloan Digital Sky Survey Education & Public Outreach

SDSS

This is Data Release 15.

Data | Surveys | Instruments | Collaboration | Results | Education | The Future | Contact

Search www.sdss.org | Search

Overview | REU | FAST | Galazy Zoo | SDSS Voyages

Education and Public Engagement

The Sloan Digital Sky Survey is committed to working towards making the science and engineering results of our surveys accessible to the public. We are also enthusiastic about supporting the use of SDSS data for training and education. We aim to do this through informal and formal education, citizen science, news, and social media. A selection of our Education and Public Engagement activities are described below.

SDSS in Schools

SDSS Data for Education

SDSS VOYAGES

SDSS Voyages is a custom resource for education focused explorers of the Sloan Digital Sky Survey. Specifically designed to meet the needs of educators, SDSS Voyages provides the pathways and supporting resources needed to enable student-led discovery of a variety of astronomfical phenomena using the same data utilized by professional astronomers.

Explore SDSS Voyages

Printable Resources

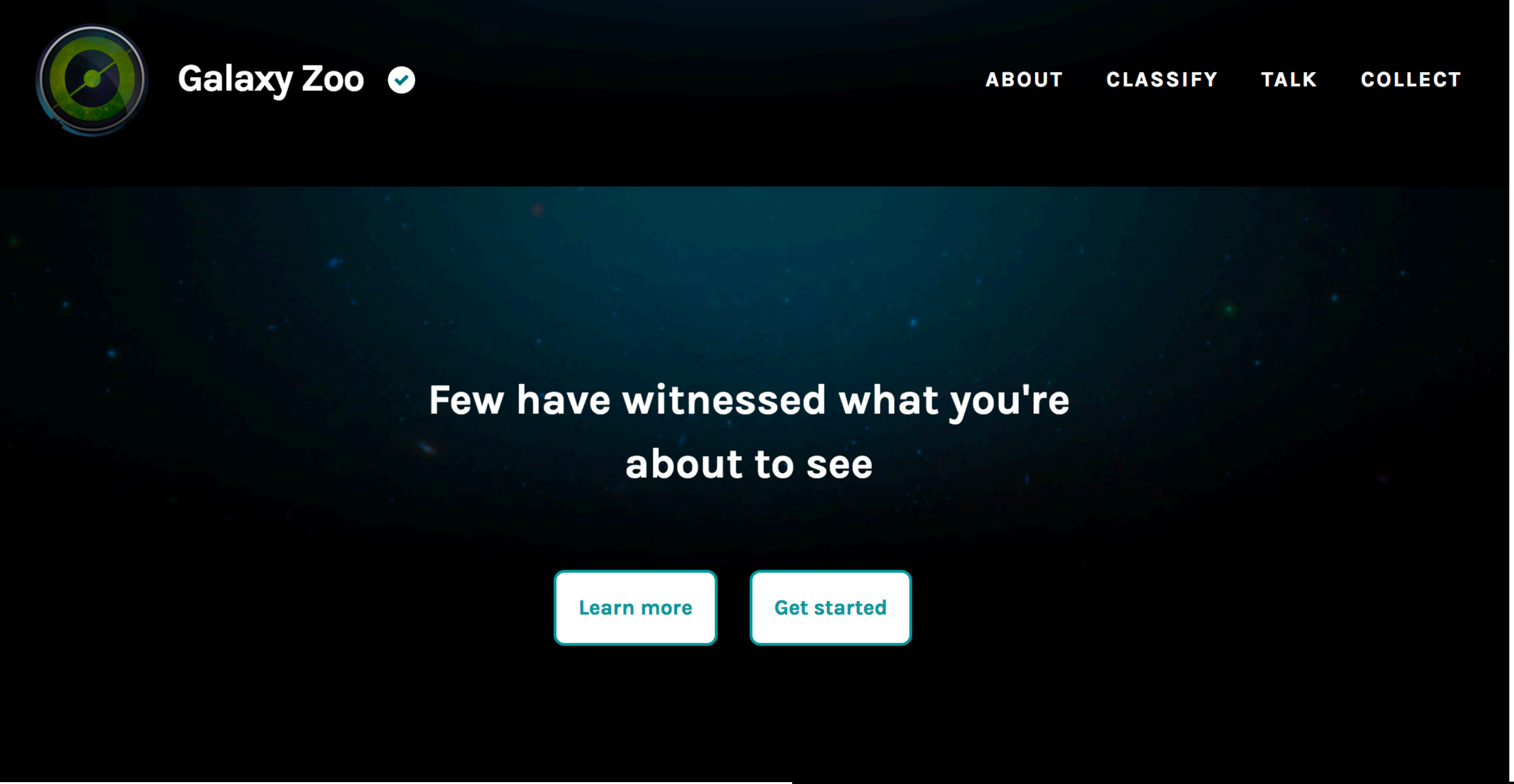
Downloadable Resources on SDSS Voyages.

SDSS Plates for Education

Through our program "Your Piece of the Sloan Sky" we distribute used plug plates to educators at formal and informal educational institutions. Plates are distributed via SDSS Institutions and accompanied by a custom-made poster showing the patch of sky the plate was used to observe, a package of educational materials, and training on the use of SDSS Voyages.

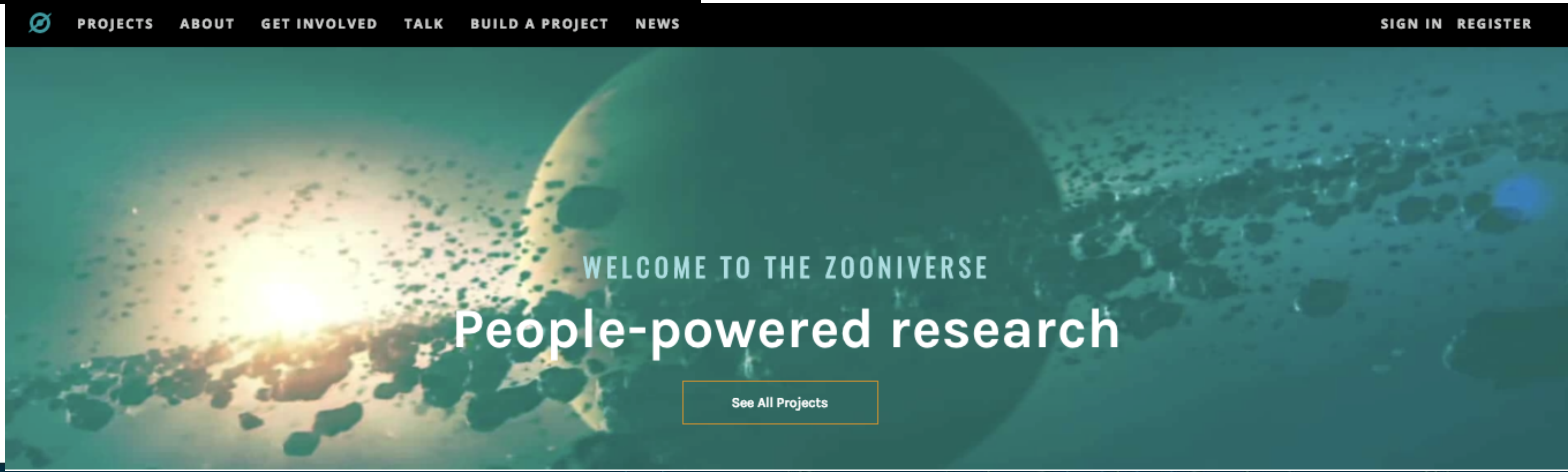
If you are interested in participating in this program, please contact us, and we will help to link you to your nearest SDSS Institution.

SDSS has a long history with bringing survey data, and objects from the survey itself, into the classroom.



Subset of SDSS data made available to the public through the Galaxy Zoo citizen science project. Over 100,000 volunteers made more than 40 million classifications in ~175 days.

(Lintott et al., December 2010. https://doi.org/10.1111/j.1365-2966.2010.17432.x)

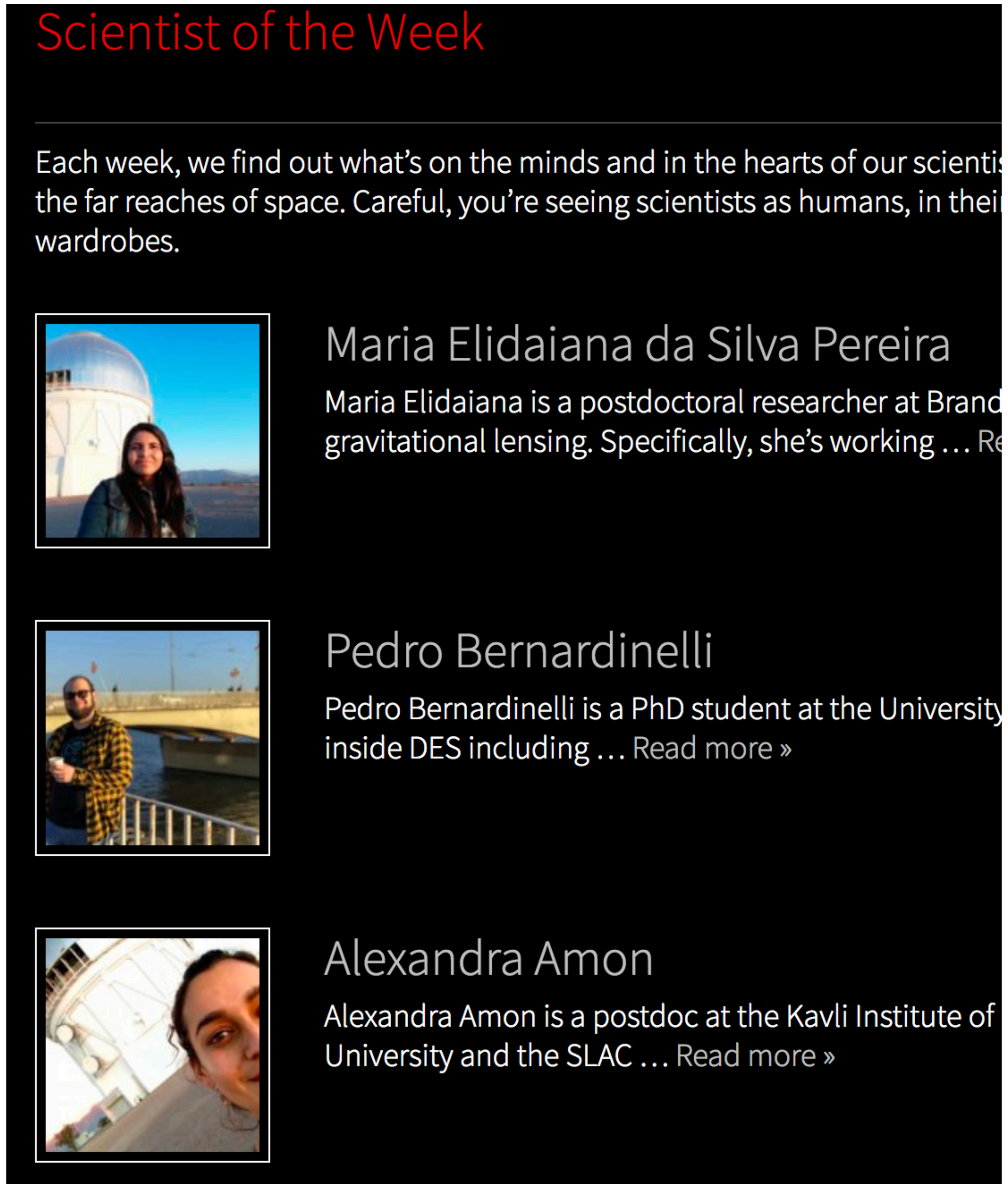


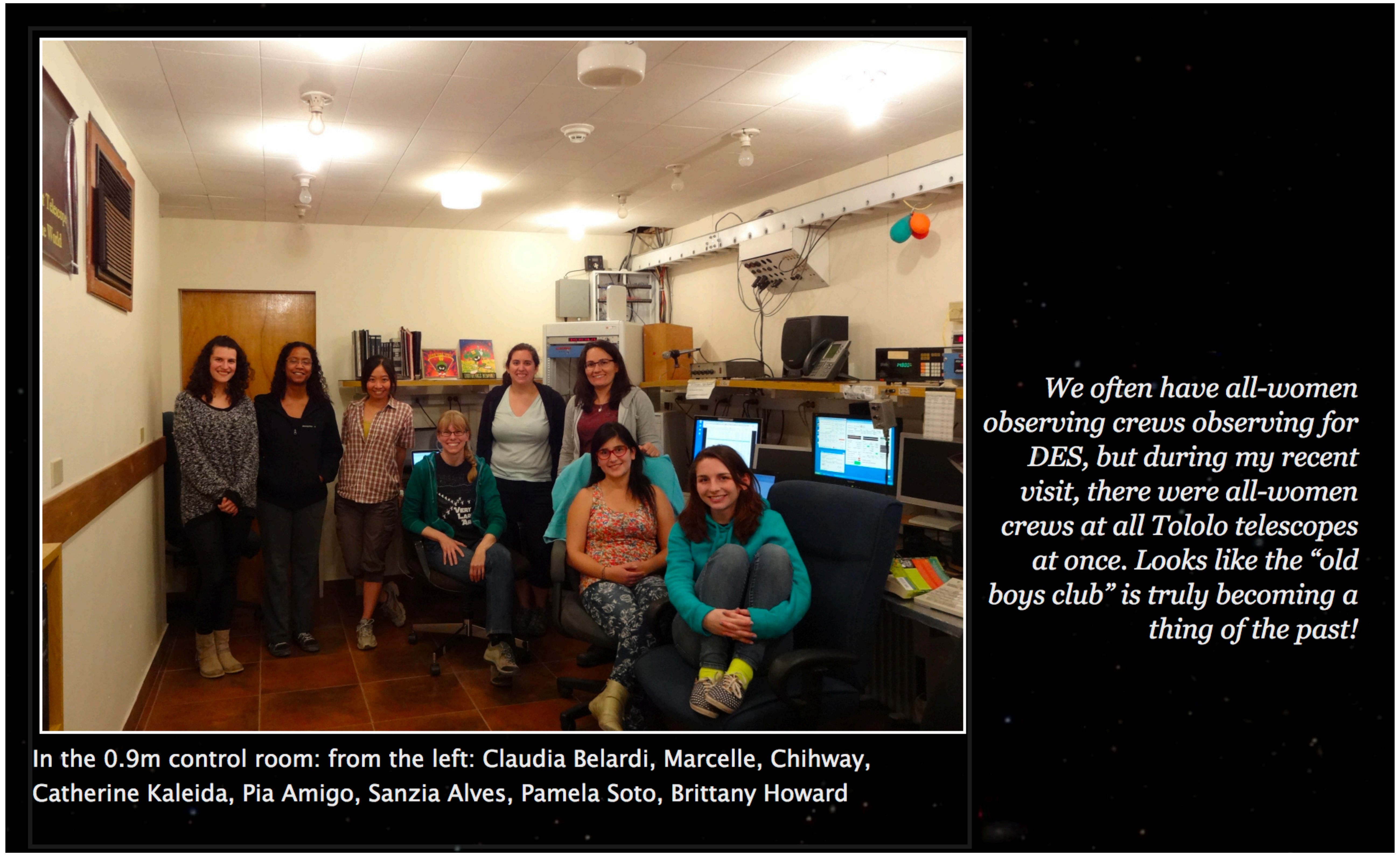
Dark Energy Survey

Dark Bites

The ratio of the weight of an average human to that of a moose to that of a black rhinoceros is roughly the same as the percentage of regular matter to dark matter to dark energy in the universe.

Dark Bites, one of many DES education and outreach projects, connects science and art through astronomy facts and analogies to every day life.





Scientist of the Week and reflections from the observing teams highlighted diverse individuals. Some parts of the DES Education webpages are translated in as many as four languages.

LSST Education and Public Outreach (EPO) Mission

We provide worldwide access to, and context for, LSST data through accessible and engaging online experiences so anyone can explore the universe and be part of the discovery process.

Credit: LSST Project/NSF/AURA

Audiences

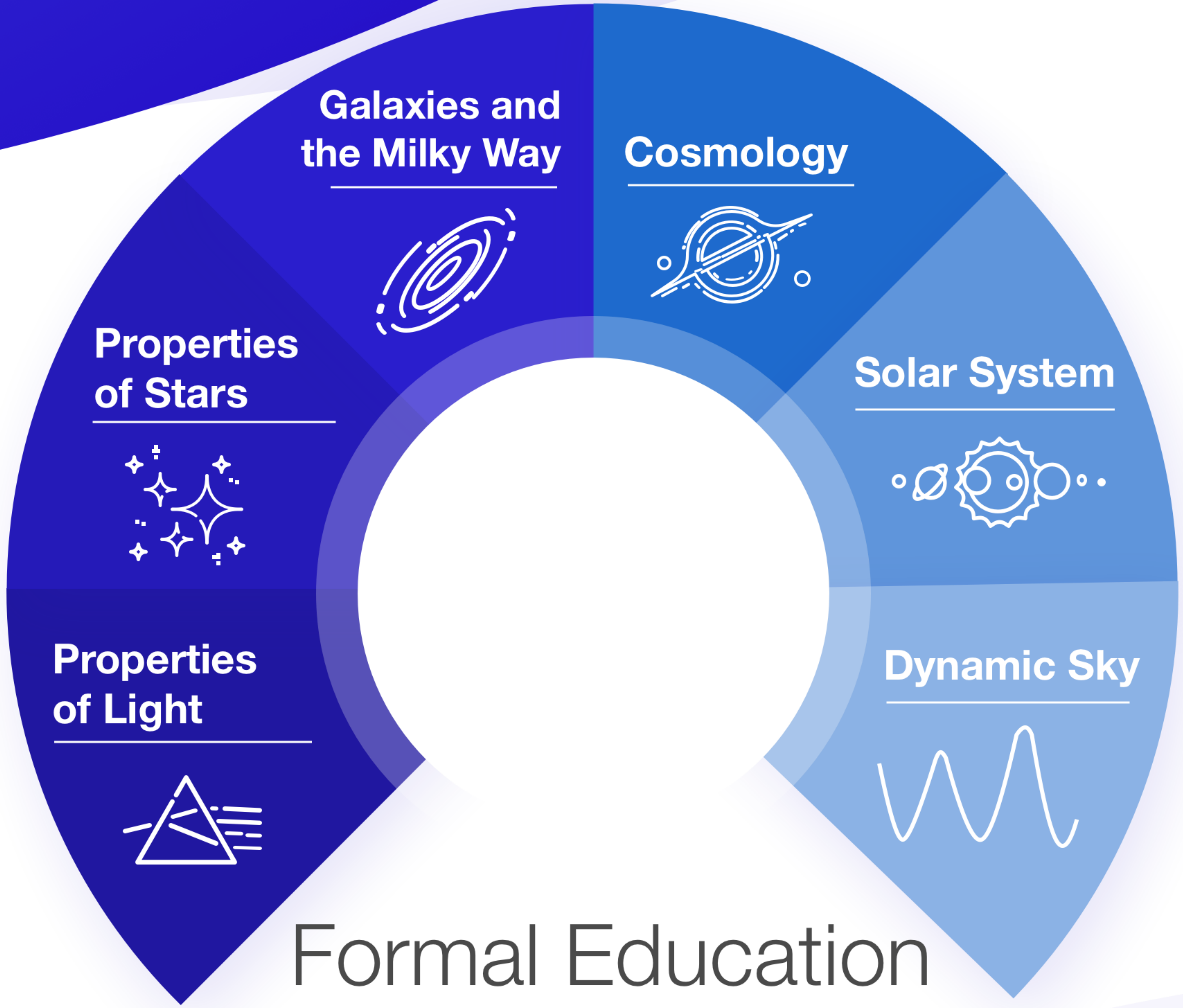
- **Formal educators** at advanced middle school, high school, college level
- **Citizen science** principal investigators
- Content developers at **science centers and planetariums**
- **Science-interested** teens and adults ("General Public")

During Construction, EPO will build:

- Operations website and materials in English and Spanish
- Formal education program based on online notebooks
- Repository of multimedia resources
- Interactive Skyviewer
- Cloud-based EPO Data Center
- Capability to build citizen science projects
- Communications and Marketing Plans for Operations
- Strategy for measuring success

Formal Education

Credit: LSST Project/NSF/AURA



Formal Education Themes

Introduction

Nearly everything astronomers know about the stars and galaxies in the Universe comes from the light we receive from these objects. Fortunately, that light contains a wealth of information. In this investigation, you will learn how astronomers use light and filters to learn about things such as distant galaxies, dusty nebulae and types of stars.

- How do filters pass light of specific energies and wavelengths,
- What types of filters are used in astronomical cameras?
- What can astronomers learn by using these filters?
- How are color astronomy images made?

Types of Light

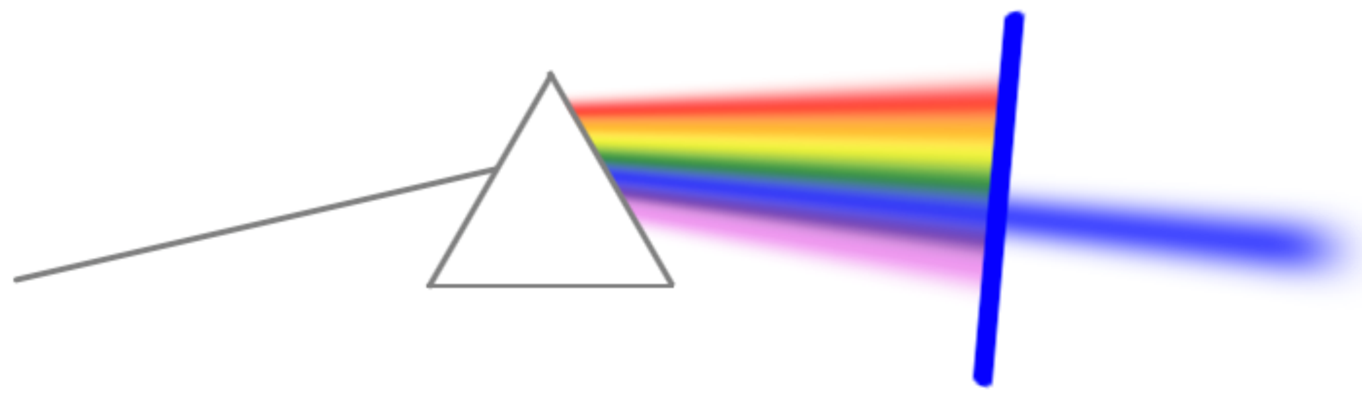
There are many types of electromagnetic radiation: radio waves, infrared, visible, ultraviolet (UV), X-rays, etc. Astronomers use all of these types of light to study objects in our Universe. Each type of light has specific ranges of wavelengths and energies. The type of light we can see with our eyes is called "visible" light. Visible light consists of all of the colors of the rainbow, as shown below. You may have learned the acronym "Roy G. Biv" to remember the seven colors of the rainbow. The different colors correspond to different wavelengths and energies. Red light is the lowest energy of light we can see and has the longest wavelengths; violet is the highest energy of light we can see, and has the shortest wavelengths.

Visible Spectrum

How Filters Work

Digital cameras cannot see color. They can only measure the amount of light that falls on the photosensor. To build a color image, we use filters when we take pictures of an object. A filter is designed to allow only certain wavelengths (or colors) of light to pass through it. All other wavelengths (or colors) are blocked. The image below on the left (Figure 2) shows an example of how an orange filter allows some wavelengths of light to pass through while blocking others. There are filters like this inside a digital camera (e.g., the one on a smartphone.) Tiny red, green, and blue filters are placed over the pixels of the photosensor as shown in the picture below (Figure 2) on the right. When you take a picture, your camera measures light simultaneously through all three kinds of filters.

To better understand how filters work, try out the filter tool below:



○ Red ○ Orange ○ Yellow ○ Green ◉ Blue ○ Indigo ○ Violet

1. What does the prism do to the white light?

   Choose the red filter.
2. What does the filter do to the red light? What does it do to the other colors of light?

   Now choose the blue filter.
3. What does the filter do to the blue light? What does it do to the other colors of light?

Constructing an Image with Three Filters

Looking at a rainbow you might think that we need to use (at least) seven filters to produce a color image. But you actually only need three. This is because our eyes contain sensors called "cones" that are designed to detect red, green, and blue light. Much like the electronics in a camera, the cones in our eyes only see in black and white, but our brain knows how to turn the relative amounts of red, green, and blue light measured by the cones into a color image. This is known as the "three-color process." Remarkably, our eyes can see over a million different colors with this method. Now let's explore how the three-color process works.

Below is a color image made from red, green and blue filters.

Each of the three images of filtered light start out as black and white images.

A color (red, green, or blue) is assigned to each image, and then the three images are combined.

Figure 3: Comparison of the light passed by filters.

4. In which of the three filters is the red shirt the brightest?
5. In which of the three filters is the green shirt the brightest?
6. How does the red shirt appear in the green filter? Why is that?

Wednesday Nite @ The Lab | April 17, 2019

Color The Universe

Learn how to make astronomy images.

- [x] u — Select
- [x] g — Select
- [x] r — Select
- [x] i — Select
- [x] z — Select
- [x] y — Select

Reset Print

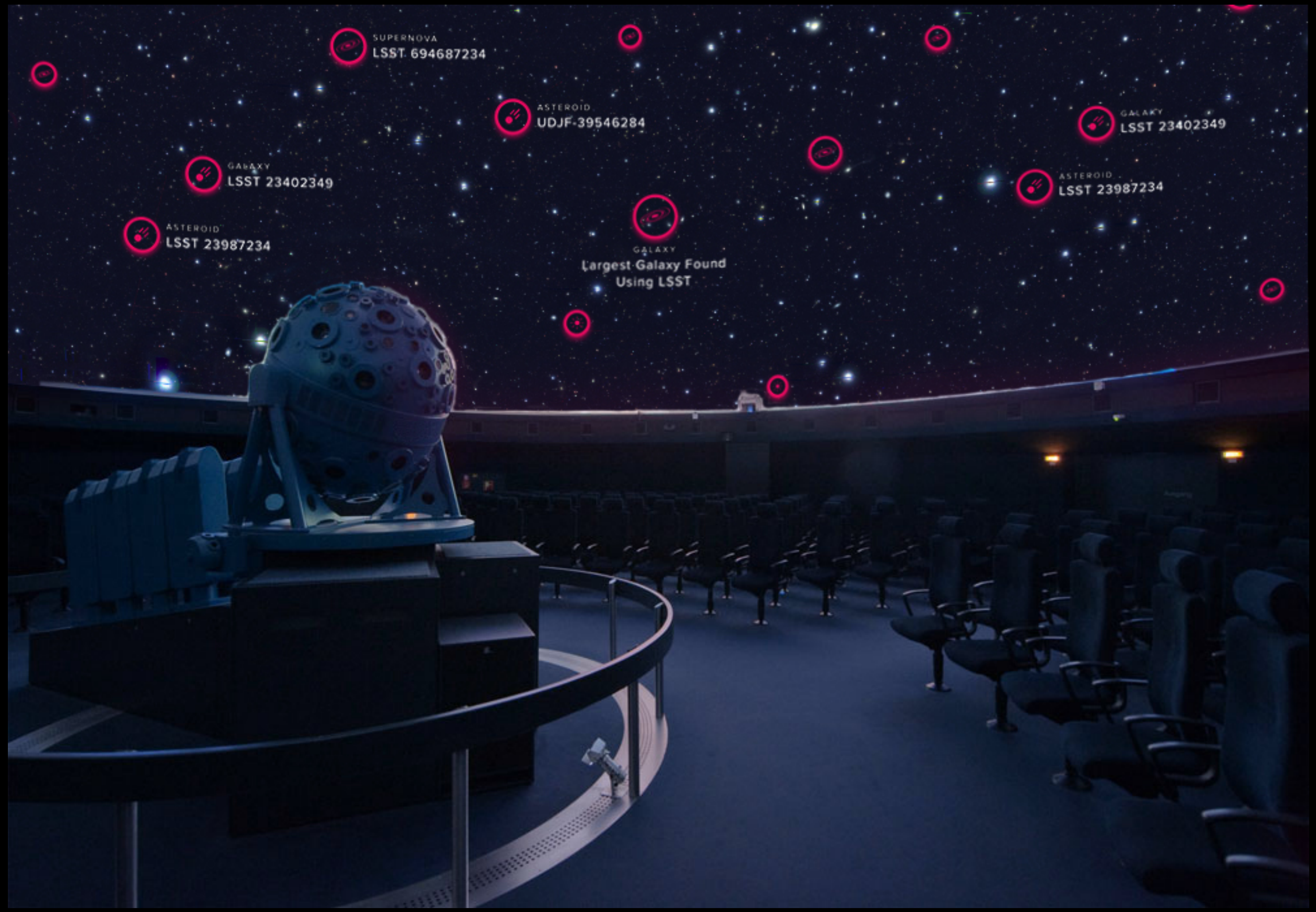
+ -

M33

Planetariums And Science Centers

Credit: LSST Project/NSF/AURA

LSST EPO deliverables:



Library of digital multimedia assets

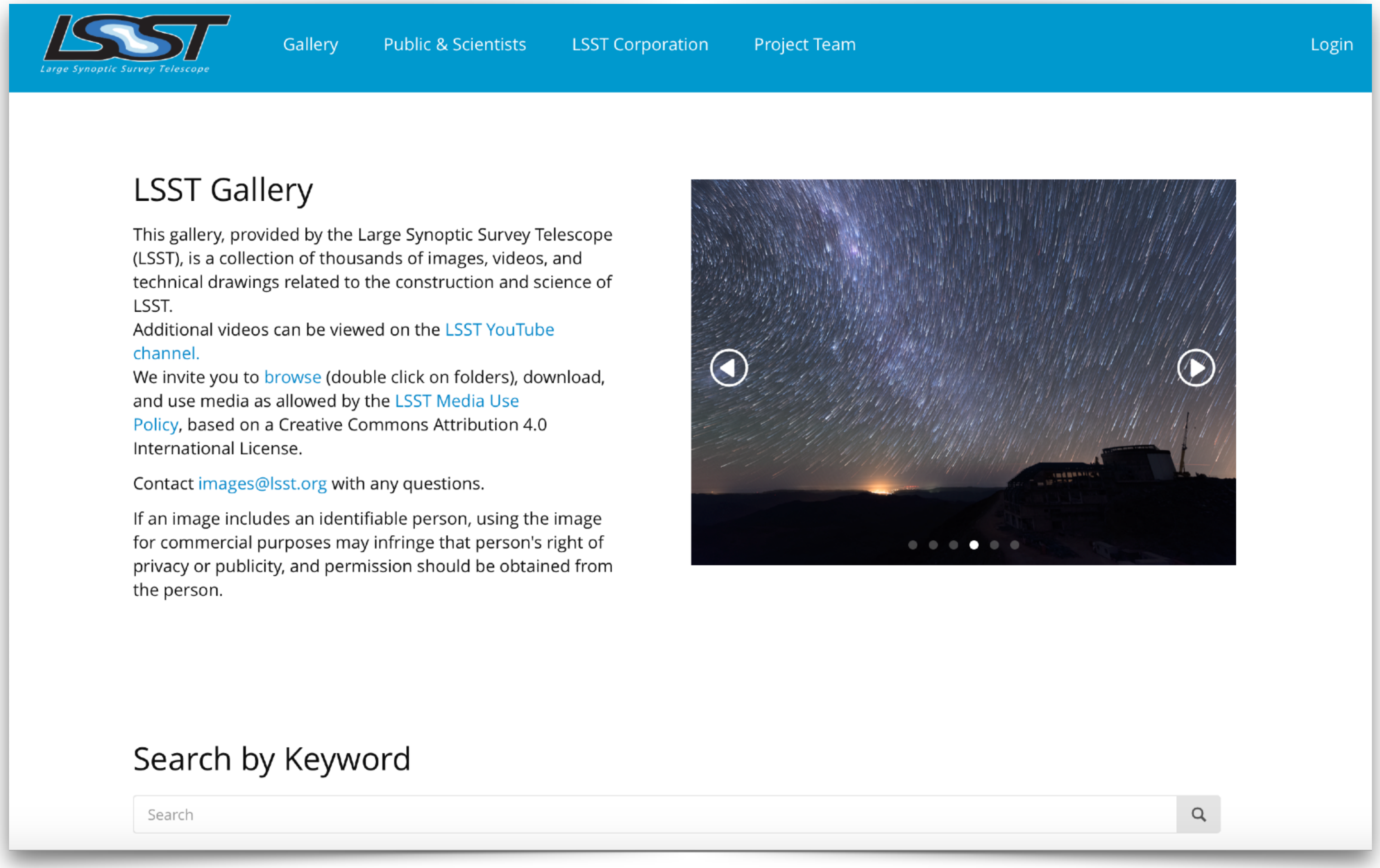
Fulldome sky view with LSST Alert stream overlay

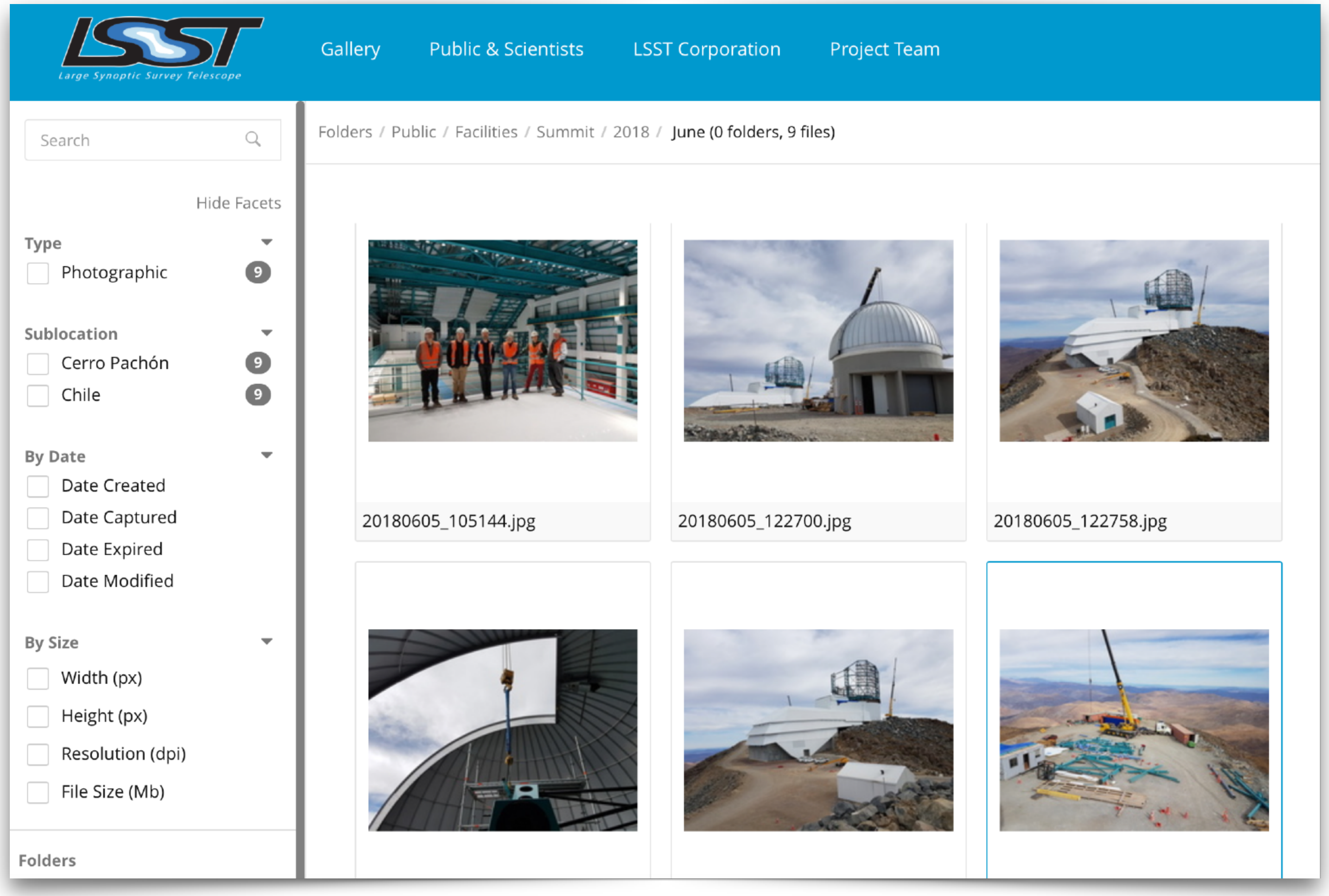
Media specific for Chilean audiences

3D multimedia

Multimedia Gallery

LSST EPO will produce video clips, images, and 3D models to be used throughout the Operations website. Assets will also be provided in formats that support emerging industry standards (IMERSA Dome Master, AVM, Data2Dome) to enable content creators at informal science centers to freely incorporate them as they deem best.



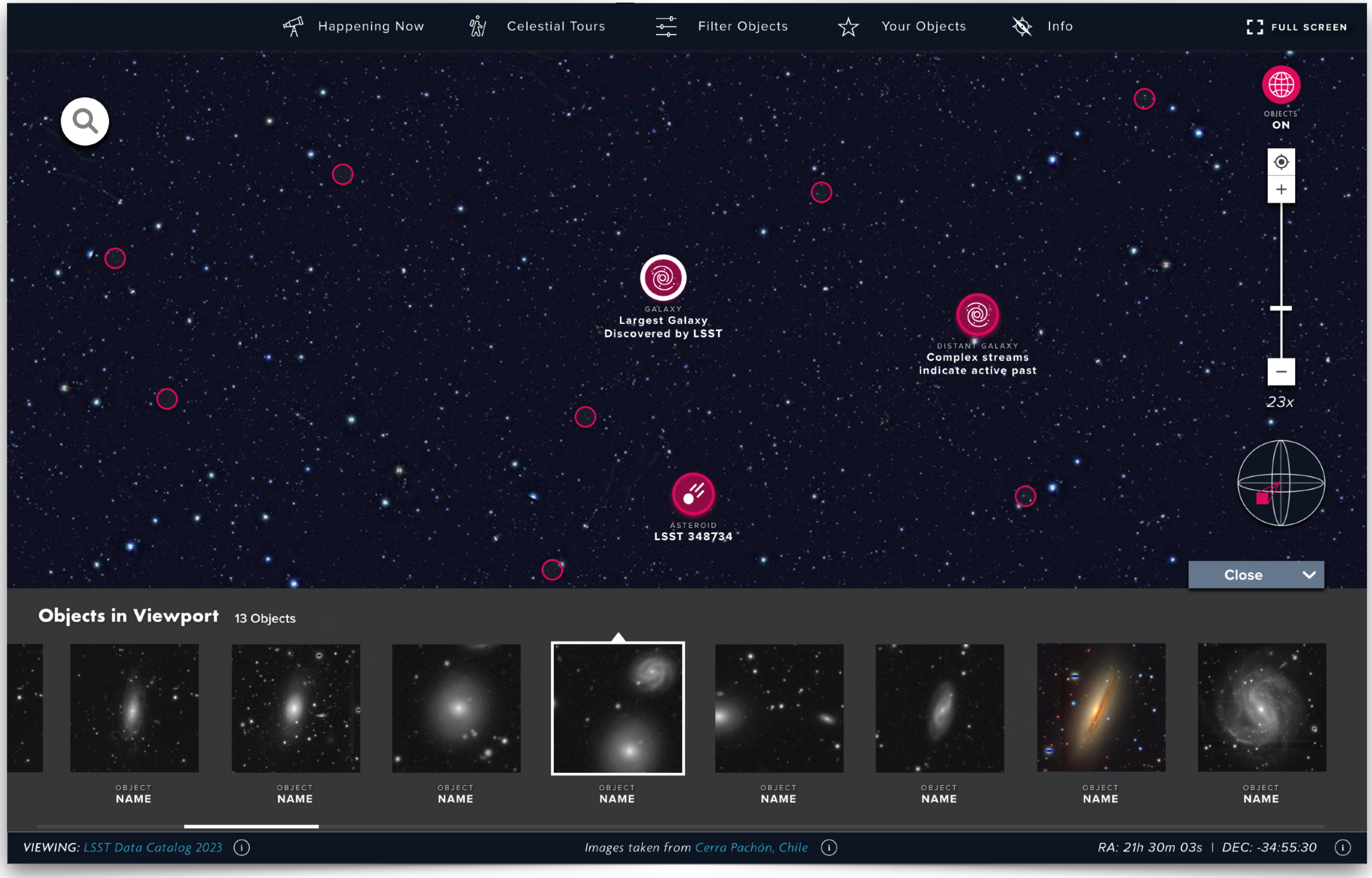


https://gallery.lsst.org

Skyviewer

Credit: Manuel Paredes/NSF/AURA/Gemini

The viewport highlights objects within the current skyviewer to suggest options for user



- Curated objects highlighted
- Links to recommended features

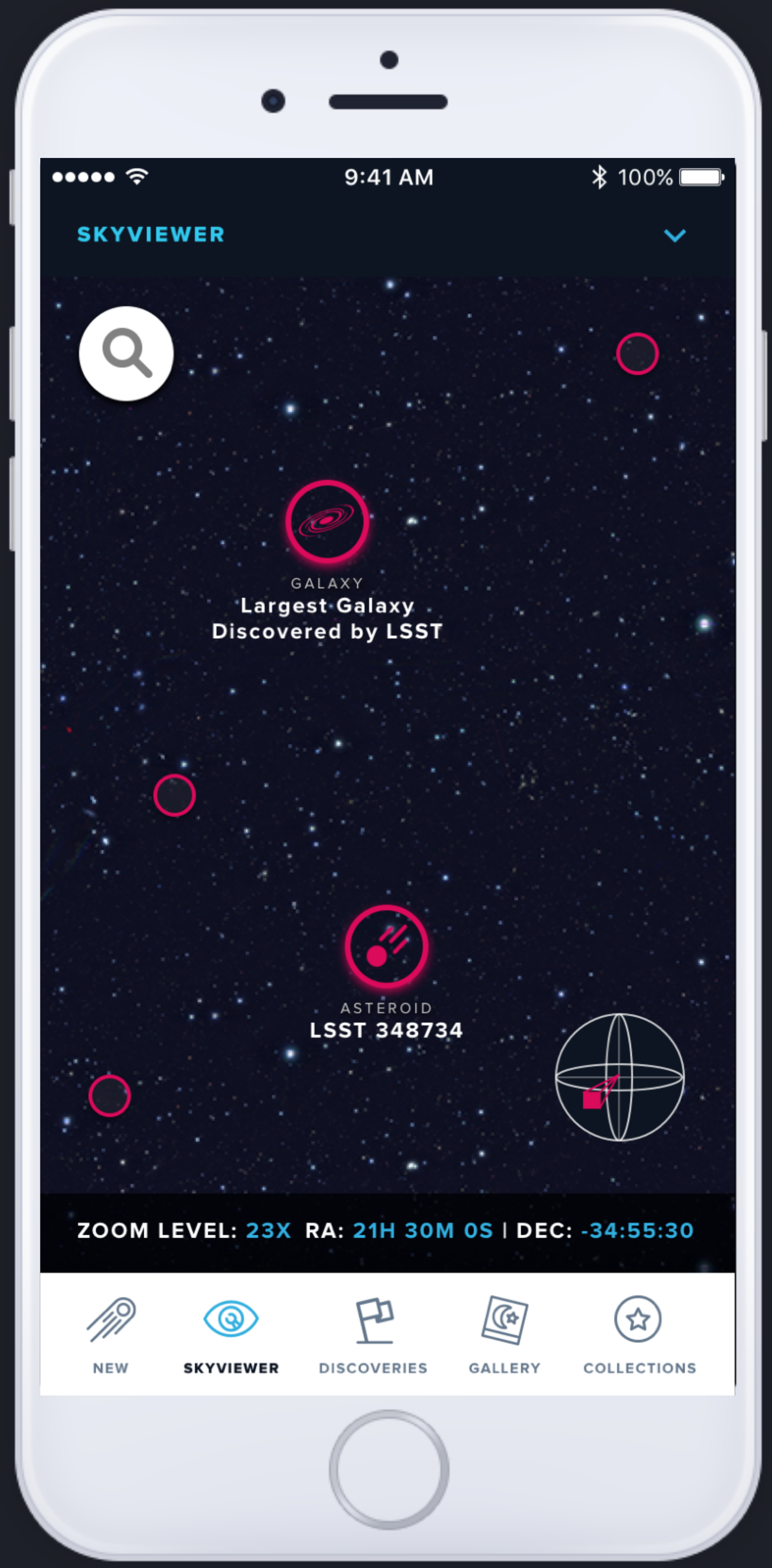
Skyviewer as a Self-Guided Educational Tool

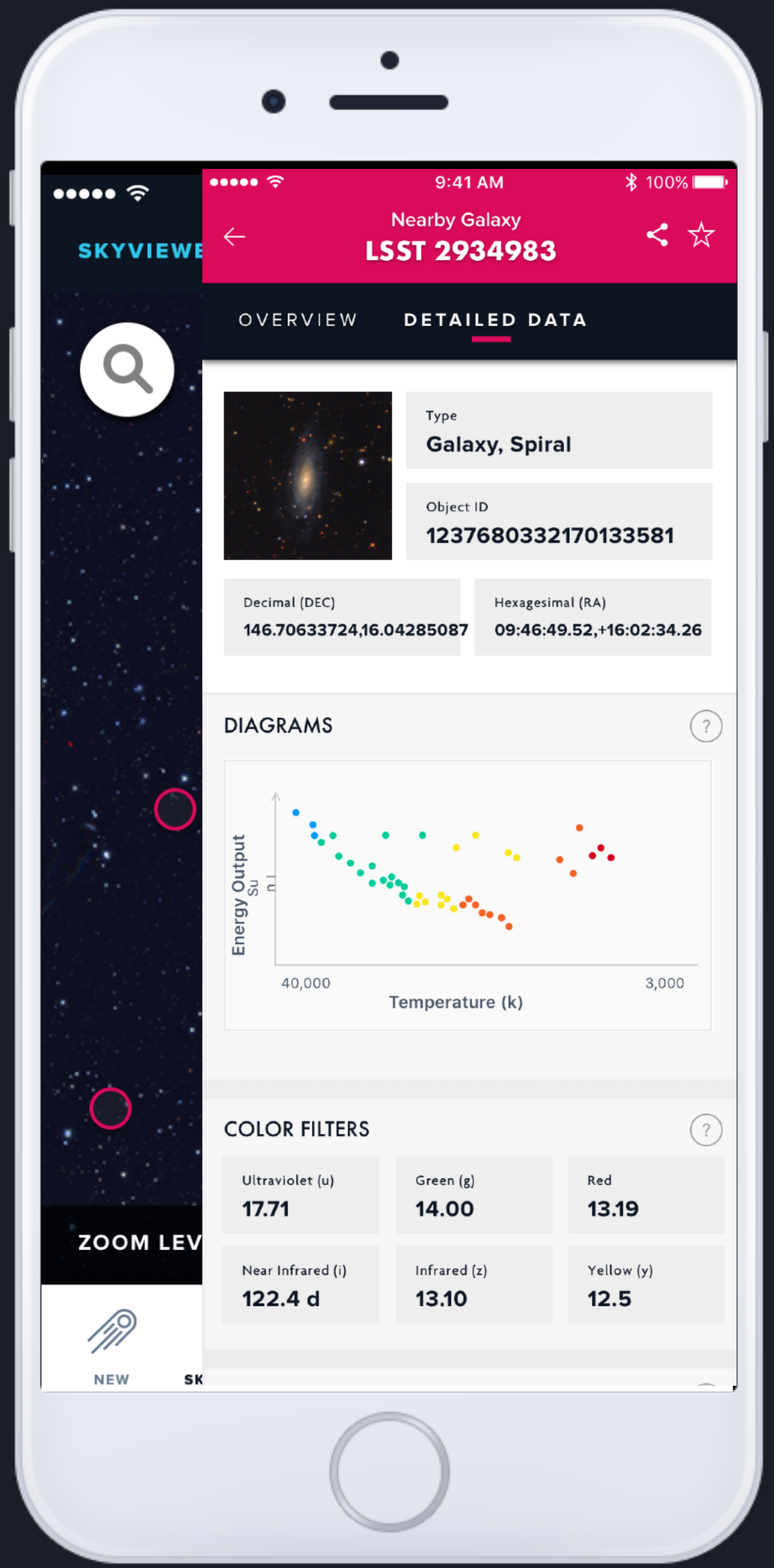
"I saw a lot of information about something that is so intangible"

"An exploratory site where you get to just delve into what the telescope sees"

Wednesday Nite @ The Lab | April 17, 2019

The website will be mobile friendly and features will be shareable.





Citizen
Science
Credit: LSST Project/NSF/AURA
Summit facility November 2018

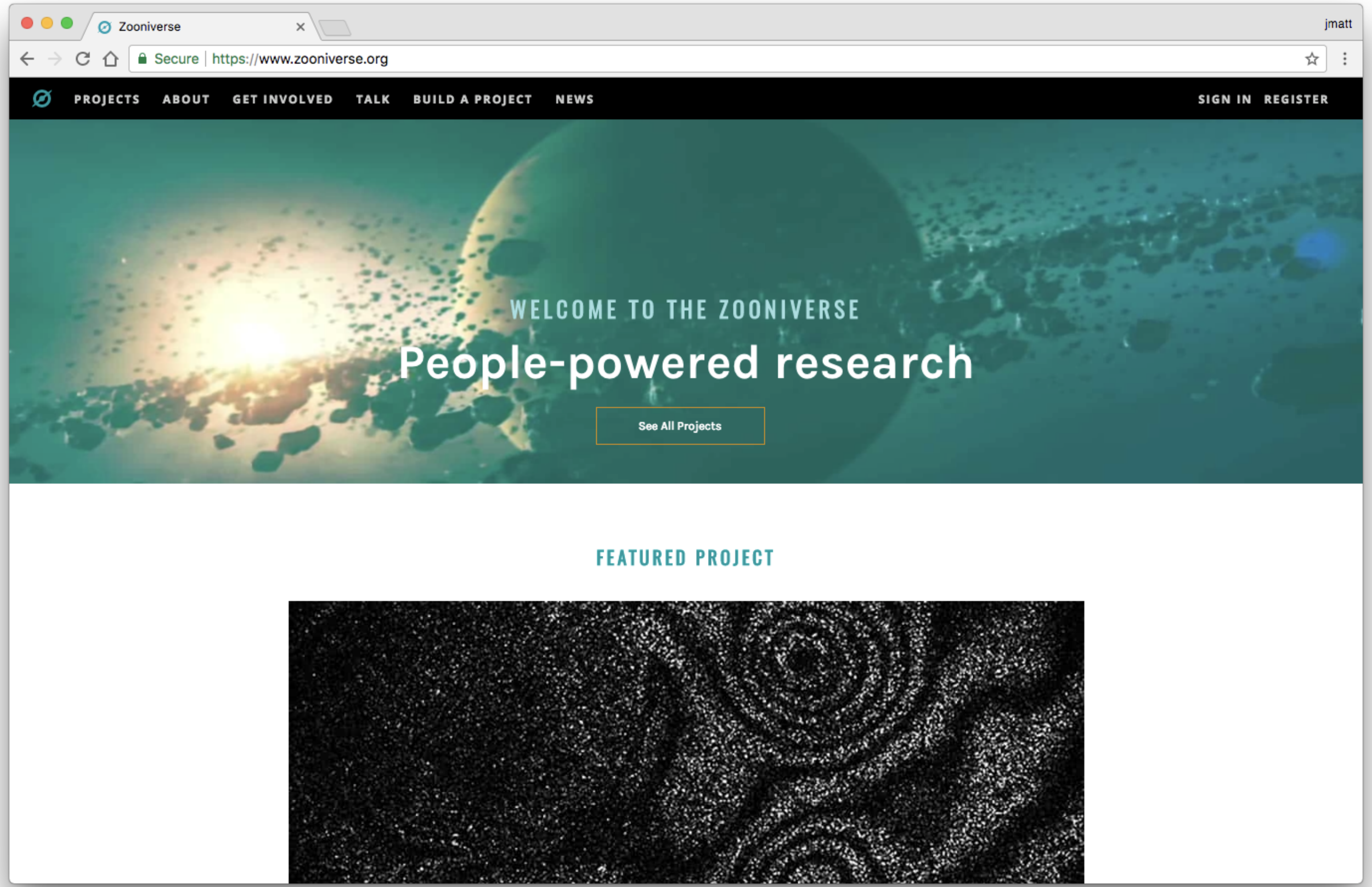
Citizen Science

People-Powered Research

Public volunteers help make science happen by contributing to real research projects

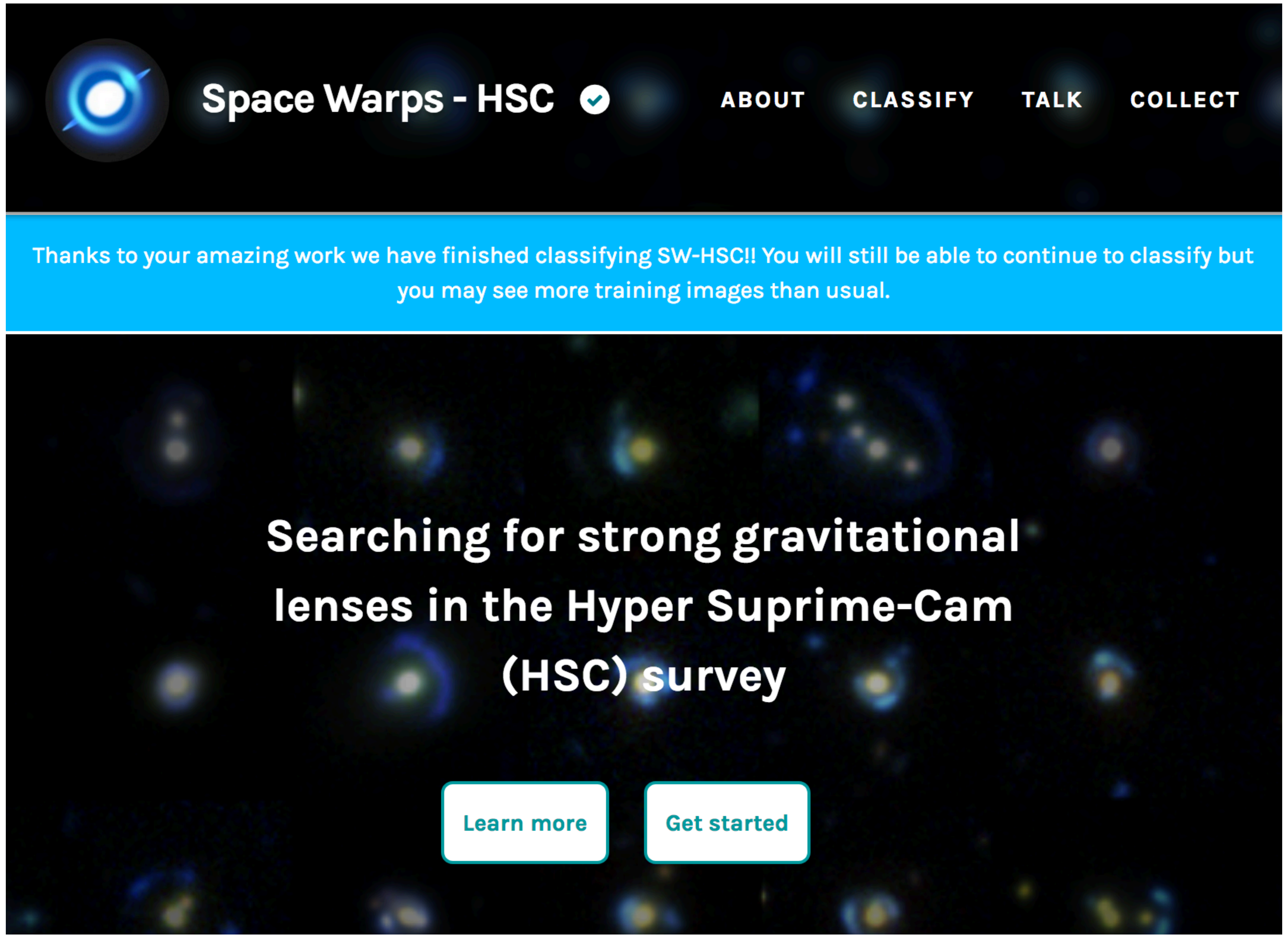
Citizen science can be a research tool enabling more science with LSST

LSST EPO will enable researchers to initiate Citizen science projects using any LSST data



We are working with *Zooniverse* to maximize flexibility in the types of projects that can be created by LSST citizen science principal investigators.

Space Warps-HSC used data from the Hyper Suprime-Cam survey. The data is similar to that of LSST.

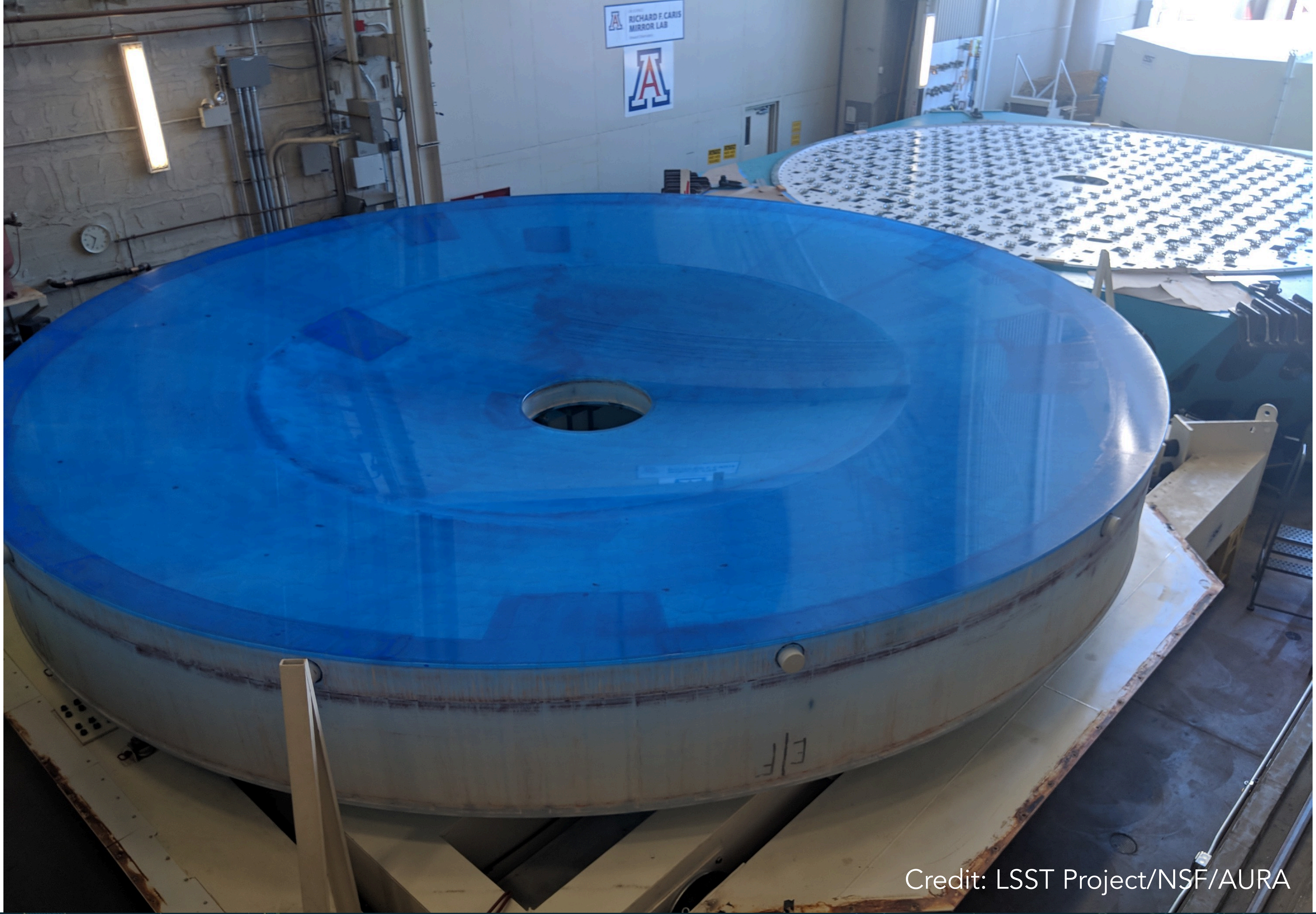


Recent Events

Coating Chamber riding to summit - Oct 2018

Photo Credit: LSST Project/NSF/AURA

Credit: LSST Project/NSF/ AURA



Credit: LSST Project/NSF/AURA


Credit: LSST Project/NSF/AURA

Credit: Precision Heavy Haul Inc./LSST Project/NSF/AURA

Credit:
B Shoening/LSST Project/NSF/AURA

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