Bringing the Night Sky to Life

NSF–DOE Vera C. Rubin Observatory will revolutionize the way we explore the cosmos

Seminar for Science Writers
245th American Astronomical Society Meeting
16 January 2024

H. Stockebrand

VERA C. RUBIN OBSERVATORY
U.S. National Science Foundation
ENERGY | Office of Science
NOIRLab AURA SLAC

Bringing the Night Sky to Life

with Vera C. Rubin Observatory's
Legacy Survey of Space and Time (LSST)

Repeatedly scan the sky for **10 years** using the **largest digital camera in the world**…

…to create an **ultra-wide, ultra-high-definition** time-lapse record of our Universe:

…the greatest cosmic movie ever made!

M.Hernández/H.Stockebrand

NEW: Fully-stocked media kit

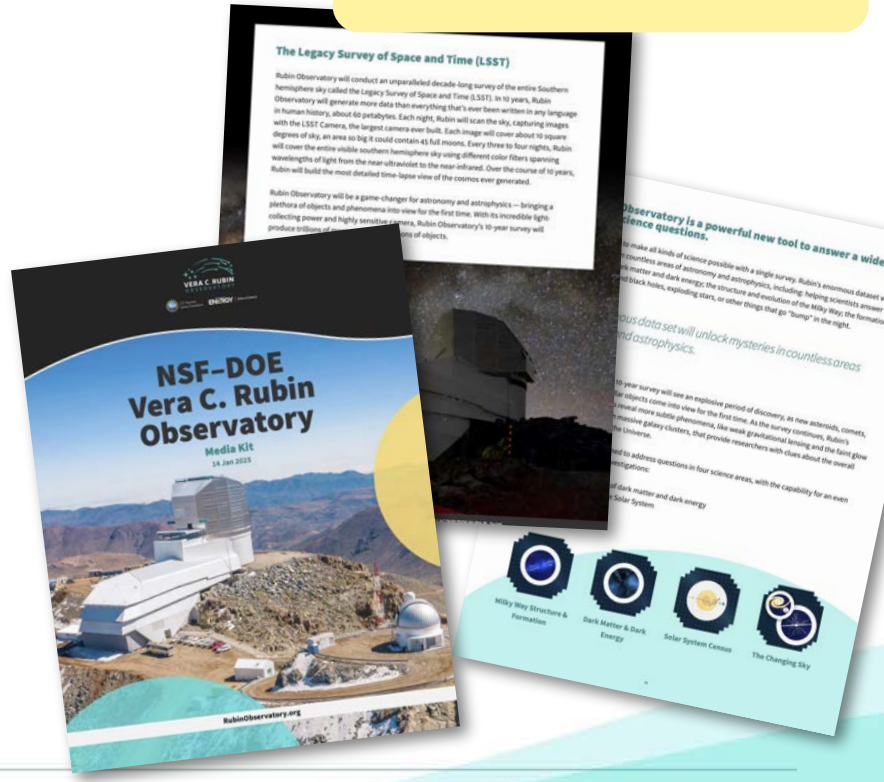
Available in English now!
Coming soon in Spanish.

- ✓ Basic and detailed information about Rubin
- ✓ Library of selected imagery and videos
- ✓ Downloadable pdf

Released 14 January 2024!

rubinobservatory.org/media

Access visuals, fact sheets, and more:
ls.st/resources



VERA C. RUBIN OBSERVATORY

U.S. National Science Foundation

U.S. Department of ENERGY | Office of Science

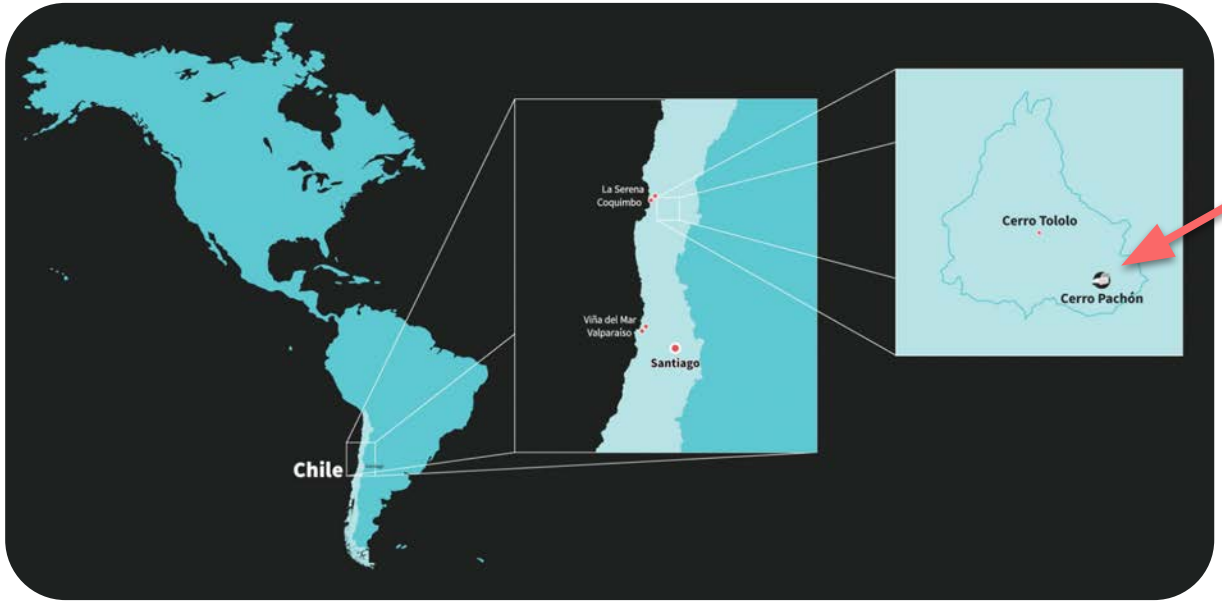
Rubin 101

Basics of Rubin Observatory

Sandrine Thomas

Deputy Director for Rubin Observatory Construction /
Associate Director for Rubin Summit Operations

Meet Rubin Observatory



Located on **Cerro Pachón**, in the Coquimbo region of Chile

Jointly funded by the **U.S. National Science Foundation** and the **U.S. Department of Energy, Office of Science**

VERA C. RUBIN OBSERVATORY | U.S. National Science Foundation | U.S. Department of Energy, Office of Science

NOIRLab | AURA | SLAC National Accelerator Laboratory

Honoring Vera C. Rubin — A Cosmic Trailblazer

Who was she?

- Provided the first convincing evidence for dark matter
- Advocate for women in astronomy

Rubin Observatory is the **first major US Observatory named for a woman**

When referring to us, use:

- ✔ NSF–DOE Vera C. Rubin Observatory
- ✔ Vera C. Rubin Observatory
- ✔ Rubin Observatory

Just say no to “VRO!”

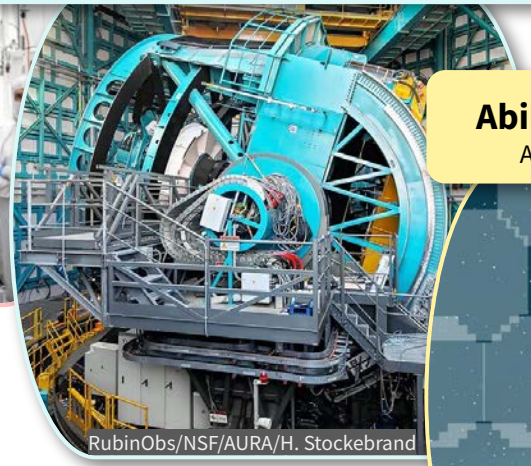
Mission: Capture the Cosmos

The greatest astronomical movie of all time

Wide Field of View
Largest digital camera ever built


J. Orrell/SLAC National Accelerator Lab

Speed
Novel three-mirror design


RubinObs/NSF/AURA/H. Stockebrand

Ability to see faint objects
Across the entire Southern sky

Bringing the Night Sky to Life

Rubin will be a **discovery machine,** detecting a treasure trove of:

- asteroids and comets
- pulsating stars
- supernova explosions

10 years of data to use to unravel boundless mysteries

Milky Way Structure & Formation

Dark Matter & Dark Energy

Solar System Census

The Changing Sky

Cutting Edge Technology for a New Era

Olivier Bonin/SLAC National Accelerator Laboratory

DOE-LSST Camera

Largest digital camera ever (3200 Mpx)
6 filters, near-ultraviolet to near-infrared

Simonyi Survey Telescope

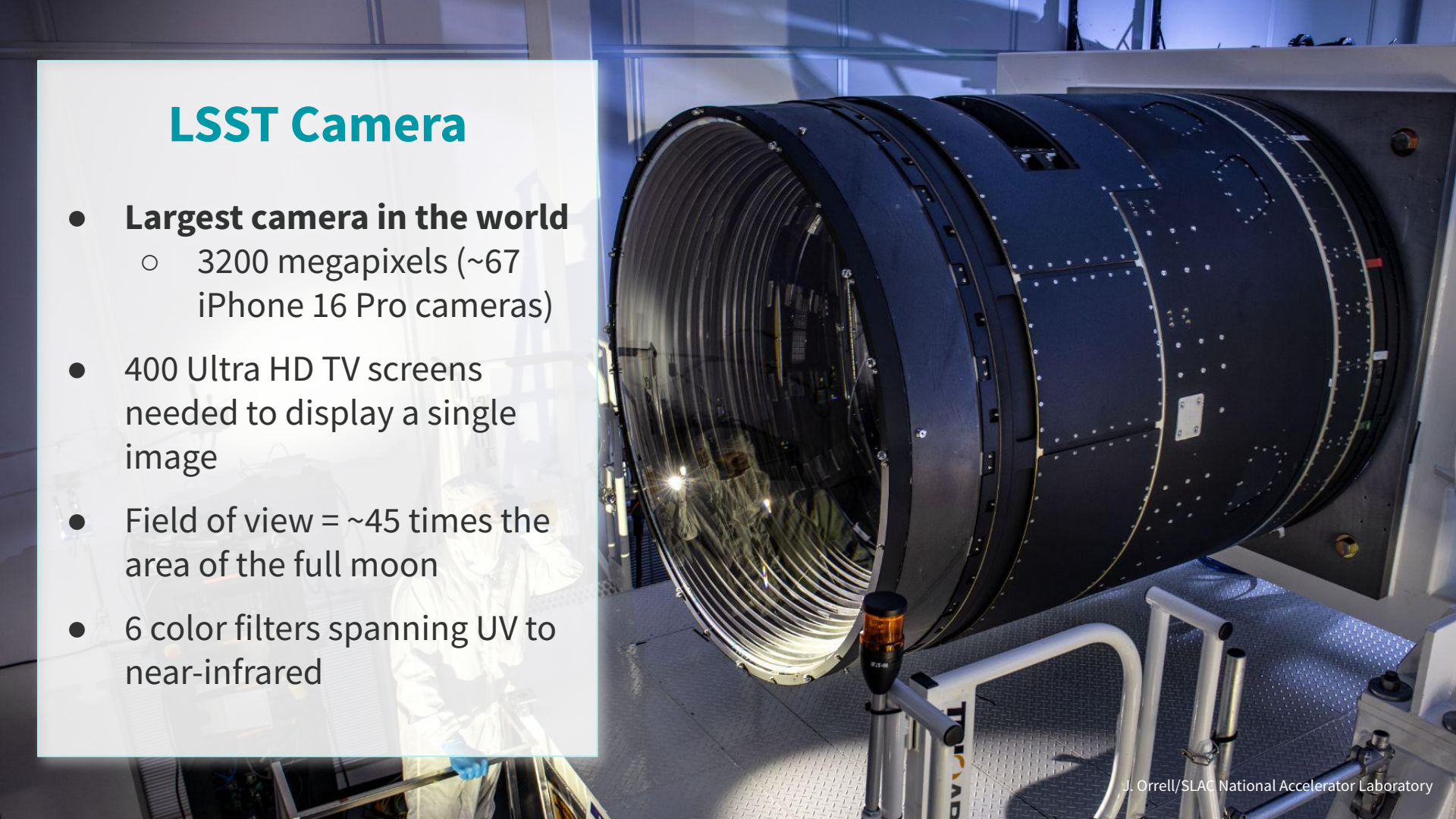
Novel three-mirror design = fast
Full-sky scan every 3-4 nights

Global Data Management System

20 TB/night transferred to US, France, UK
~10 million changes identified each night

LSST Camera

- **Largest camera in the world**
  - 3200 megapixels (~67 iPhone 16 Pro cameras)
- 400 Ultra HD TV screens needed to display a single image
- Field of view = ~45 times the area of the full moon
- 6 color filters spanning UV to near-infrared



J. Orrell/SLAC National Accelerator Laboratory

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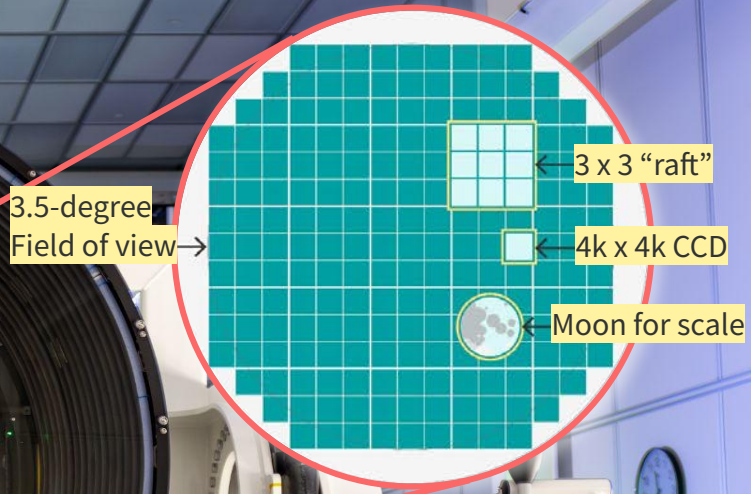
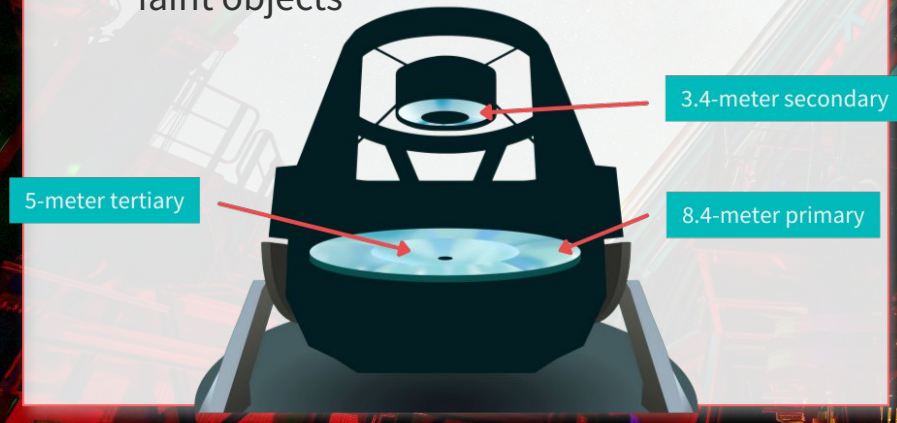


Simonyi Survey Telescope

- 2-in-1 primary/tertiary mirror — first of its kind
- Compact telescope quickly moves 350 tons of steel
- Automated (with oversight)
- Large aperture & high reflectivity to detect faint objects



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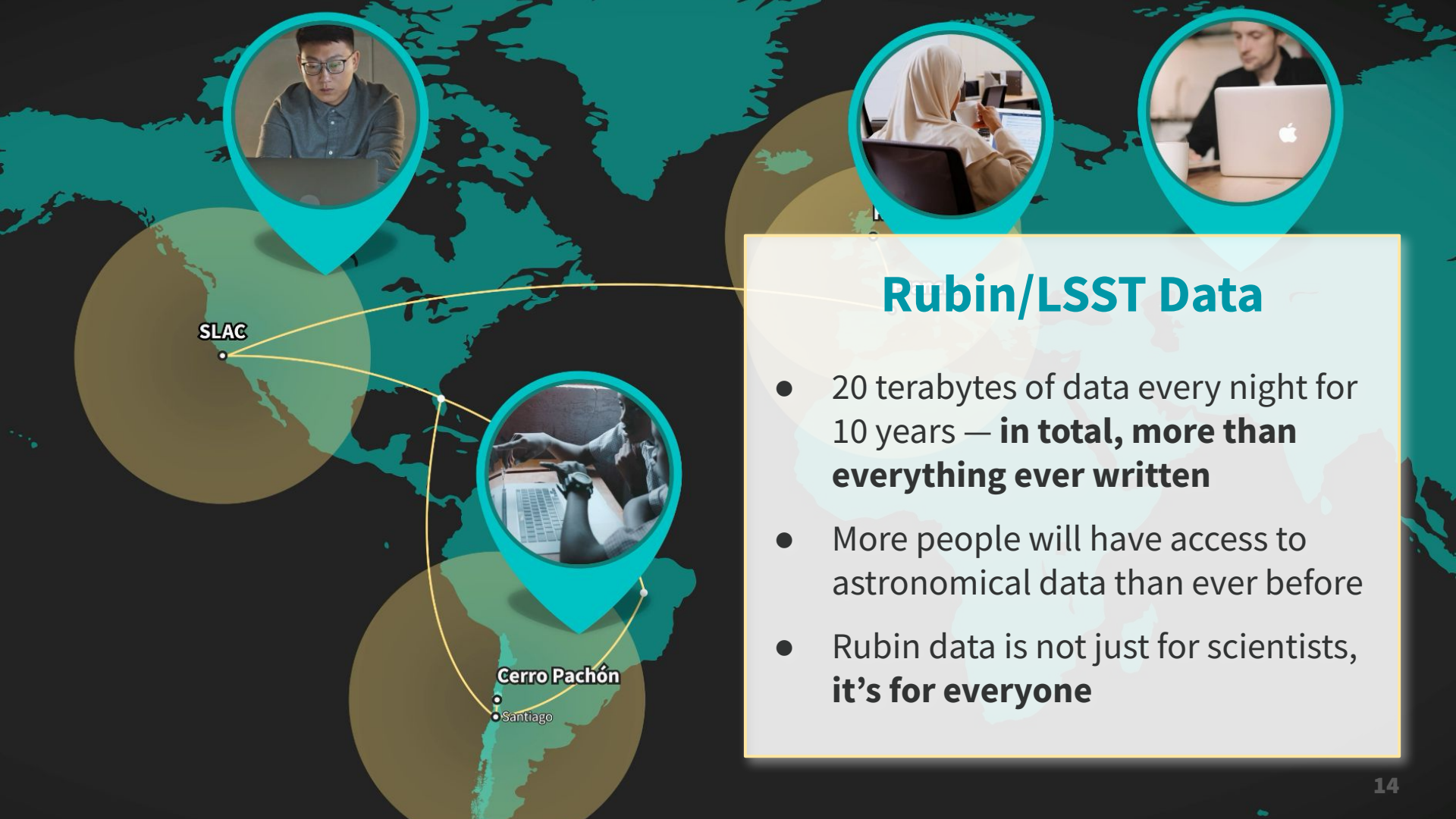


Rubin/LSST Data

- 20 terabytes of data every night for 10 years — **in total, more than everything ever written**
- More people will have access to astronomical data than ever before
- Rubin data is not just for scientists, **it's for everyone**

Rubin Education and Public Outreach (EPO)

Fully funded by NSF since start of construction

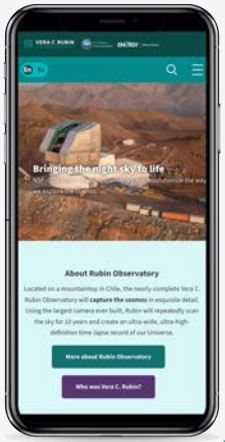
➔ This is the **first time EPO has been built in from the beginning** of a project of this scale

Formal education

Free, online, classroom-ready materials for students

Public Outreach

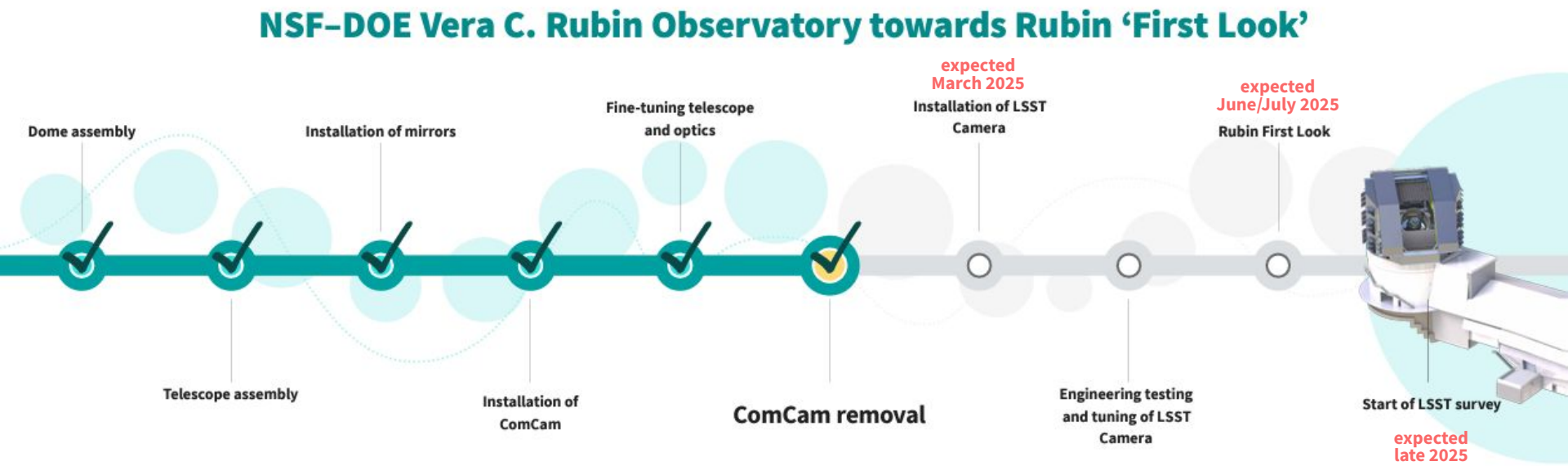
Mobile-friendly website, visuals, videos, interactives, and more



Citizen Science

Opportunities to contribute to Rubin research on Zooniverse

A Big Year Ahead



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A Treasure Trove of Discoveries on the Horizon

Leanne Guy

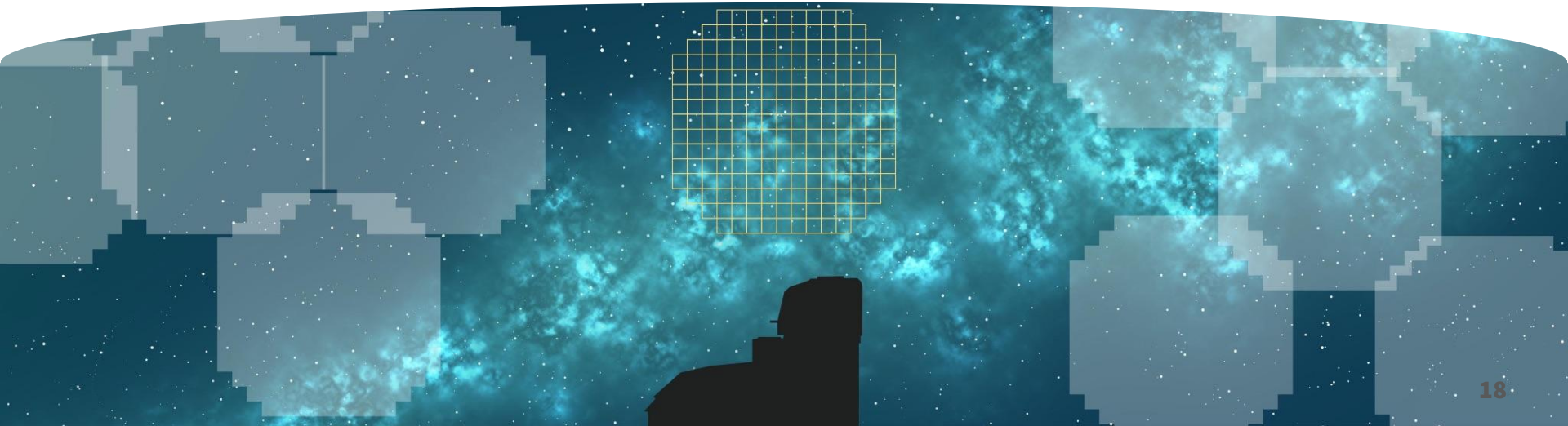
Rubin Observatory Data Management Scientist /
Associate Director for System Performance

Rubin’s Legacy Survey of Space and Time (LSST)

Repeatedly scan the Southern sky every ~3 nights for 10 years

Wide-field survey conducted with a fast cadence to faint magnitudes in 6 filters

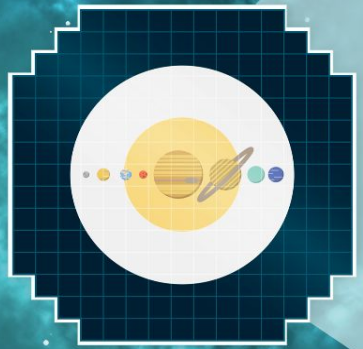
LSST will build the most detailed time-lapse view of the cosmos ever generated.



KEY SCIENCE AREAS

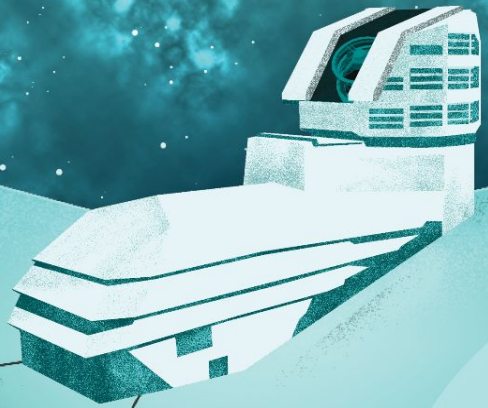
Milky Way Structure & Formation

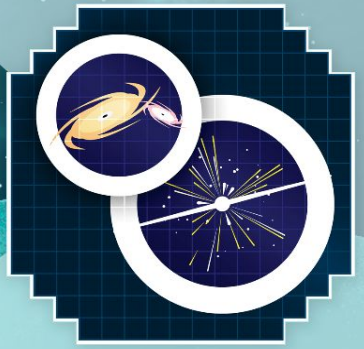
How did the Milky Way form and evolve? Rubin will help us make the best map of our home galaxy yet.



Solar System Census

What will a detailed inventory of our Solar System reveal that we couldn't see before? Rubin will show us millions of new asteroids and comets, and so much more.





Dark Matter & Dark Energy

They make up 95% of our Universe, but what are they… and what are they doing? Rubin is a brand new tool to help us learn more about their nature & behavior.

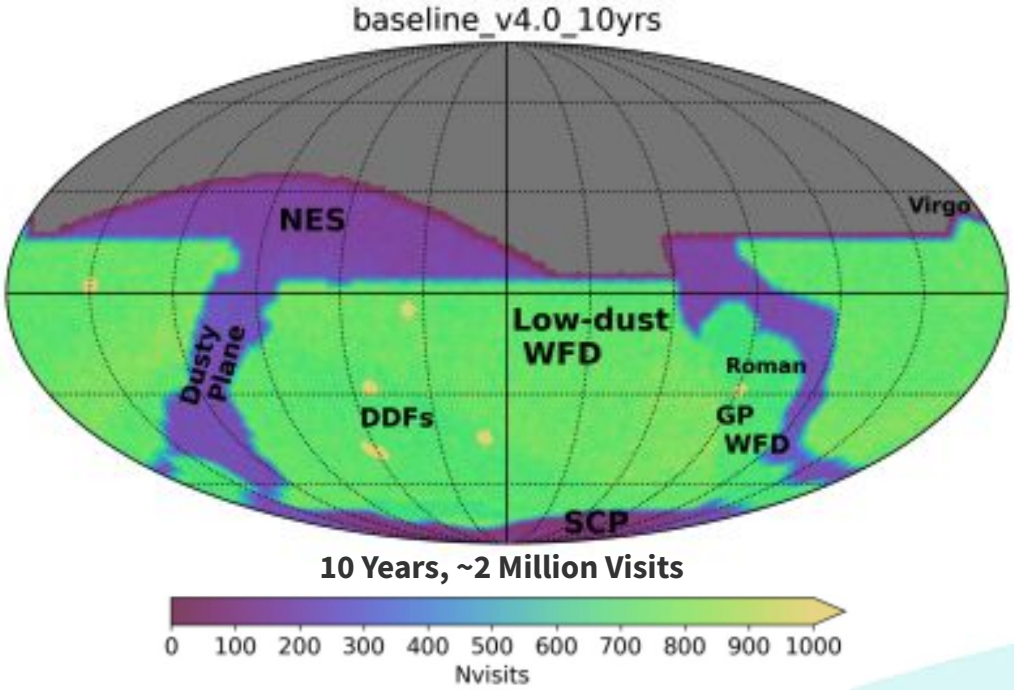
The Changing Sky

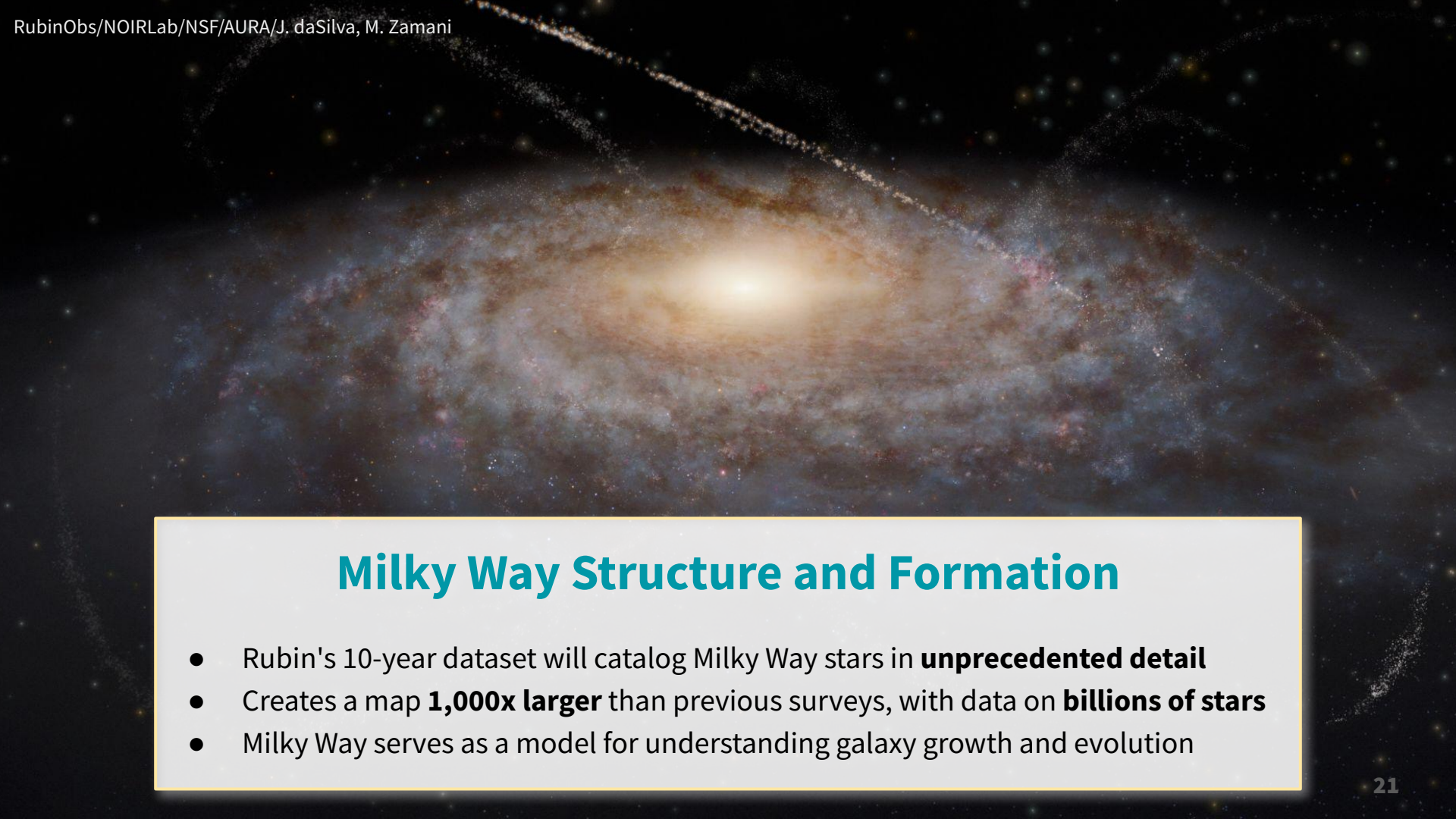
What can we learn from dynamic events like pulsating stars and supernova explosions? Rubin will bring the night sky to life, yielding a treasure trove of discoveries.

How to Build A Discovery Machine

NES: North Ecliptic Spur
WFD: Wide-Fast-Deep
GP: Galactic Plane
DDF: Deep Drilling Field

- Satisfy priorities across **a wide range of science areas with a single survey**
- Survey cadence **developed collaboratively**: Rubin + scientific community
- Multiple surveys in one → **cover wide range of science goals**
- **Automated cadence** maximizes the science possible with one survey



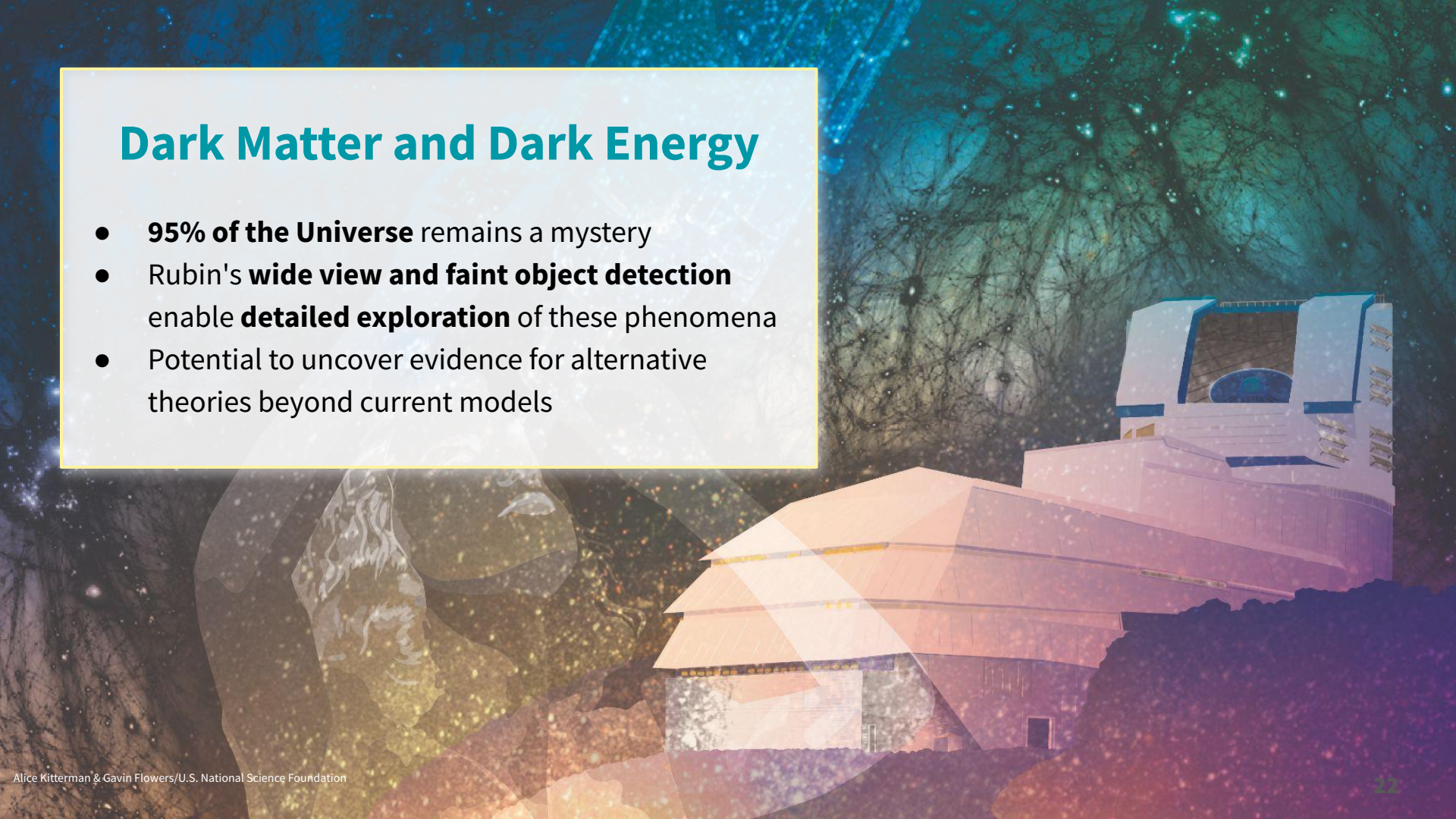


Milky Way Structure and Formation

- Rubin's 10-year dataset will catalog Milky Way stars in **unprecedented detail**
- Creates a map **1,000x larger** than previous surveys, with data on **billions of stars**
- Milky Way serves as a model for understanding galaxy growth and evolution

Dark Matter and Dark Energy

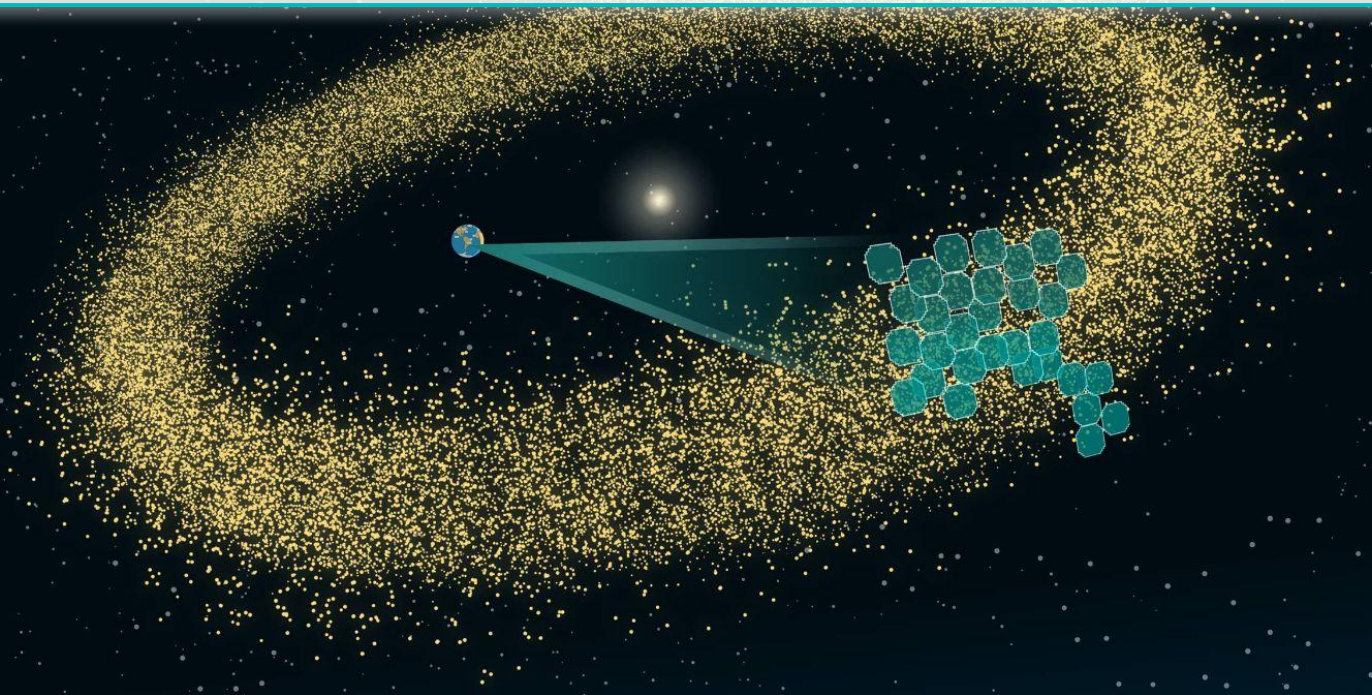
- **95% of the Universe** remains a mystery
- Rubin's **wide view and faint object detection** enable **detailed exploration** of these phenomena
- Potential to uncover evidence for alternative theories beyond current models

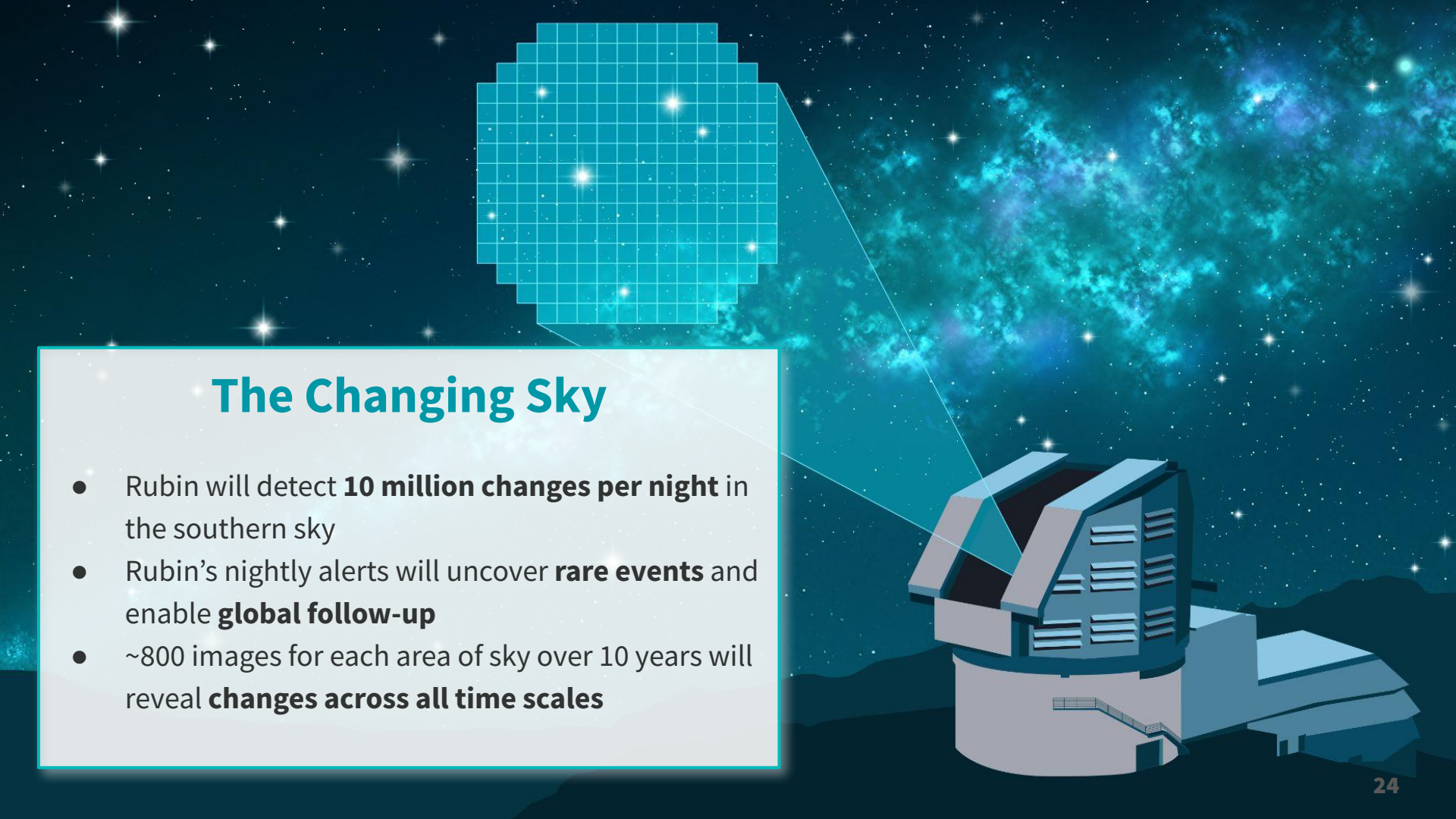


Alice Kitterman & Gavin Flowers/U.S. National Science Foundation

Solar System Census

- Rubin will uncover **4 times more Solar System objects** than we currently know
- Rubin's asteroid-detection capability is a **game-changer for planetary defense**
- Studying our Solar System reveals key insights into how **other planetary systems** form





The Changing Sky

- Rubin will detect **10 million changes per night** in the southern sky
- Rubin's nightly alerts will uncover **rare events** and enable **global follow-up**
- ~800 images for each area of sky over 10 years will reveal **changes across all time scales**

Opening Doors for Follow-Up

- Rubin detection is a critical first step, but it's **just the first step**
- Velocity of data demands global innovation and collaboration to reach full discovery potential
- A **global community** follow-up network is in place

A Key Follow-up Facility

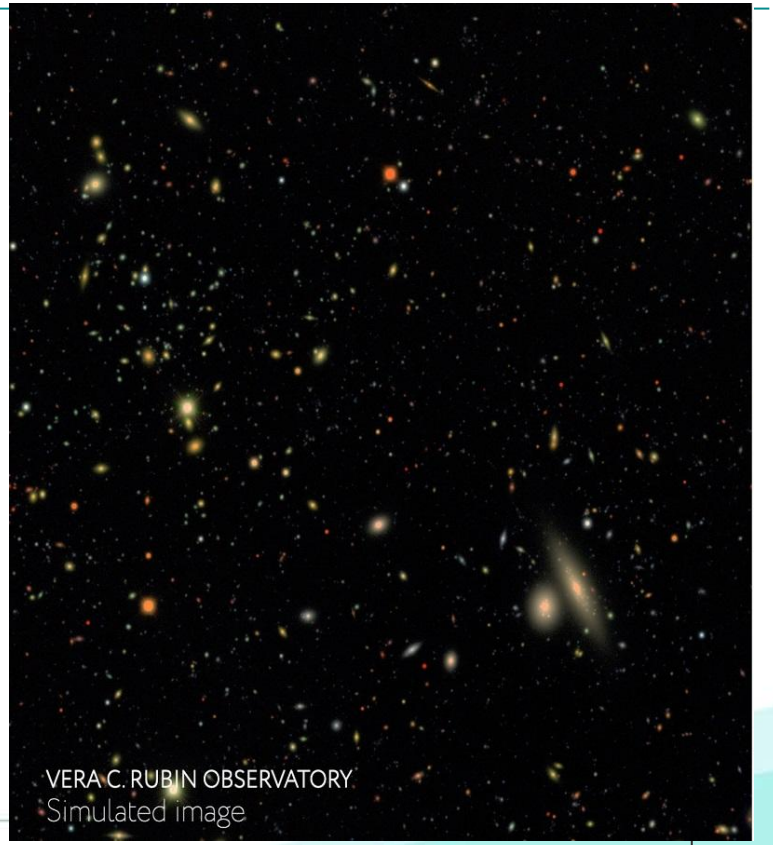
- Rubin will also operate in “**Target of Opportunity**” mode
- It will be **the** best facility in the world for **gravitational wave event follow-up**

Uncovering the Unexpected

- Rubin will **reveal new mysteries** and lead to **questions we haven't thought to as**k
- Will uncover unknown classes of objects, new transients, and phenomena that challenge existing theories

Every time we look at the Universe in a new way, we make discoveries we never could have predicted. And now **we will see more than we ever have before.**

Processing: LSST DESC;
Image: J. Chiang/SLAC, C. Hirata/Ohio State University and NASA's Goddard Space Flight Center



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Challenging Data Frontiers

Yusra AlSayyad

Rubin Observatory Deputy Associate Director for Data Management

From Discs to Data-Driven Discovery

20 years ago, we were still ordering DVDs by mail

T. Lawson (Flickr)

Now, we have the computing and data technology to manage the coming deluge of data from Rubin

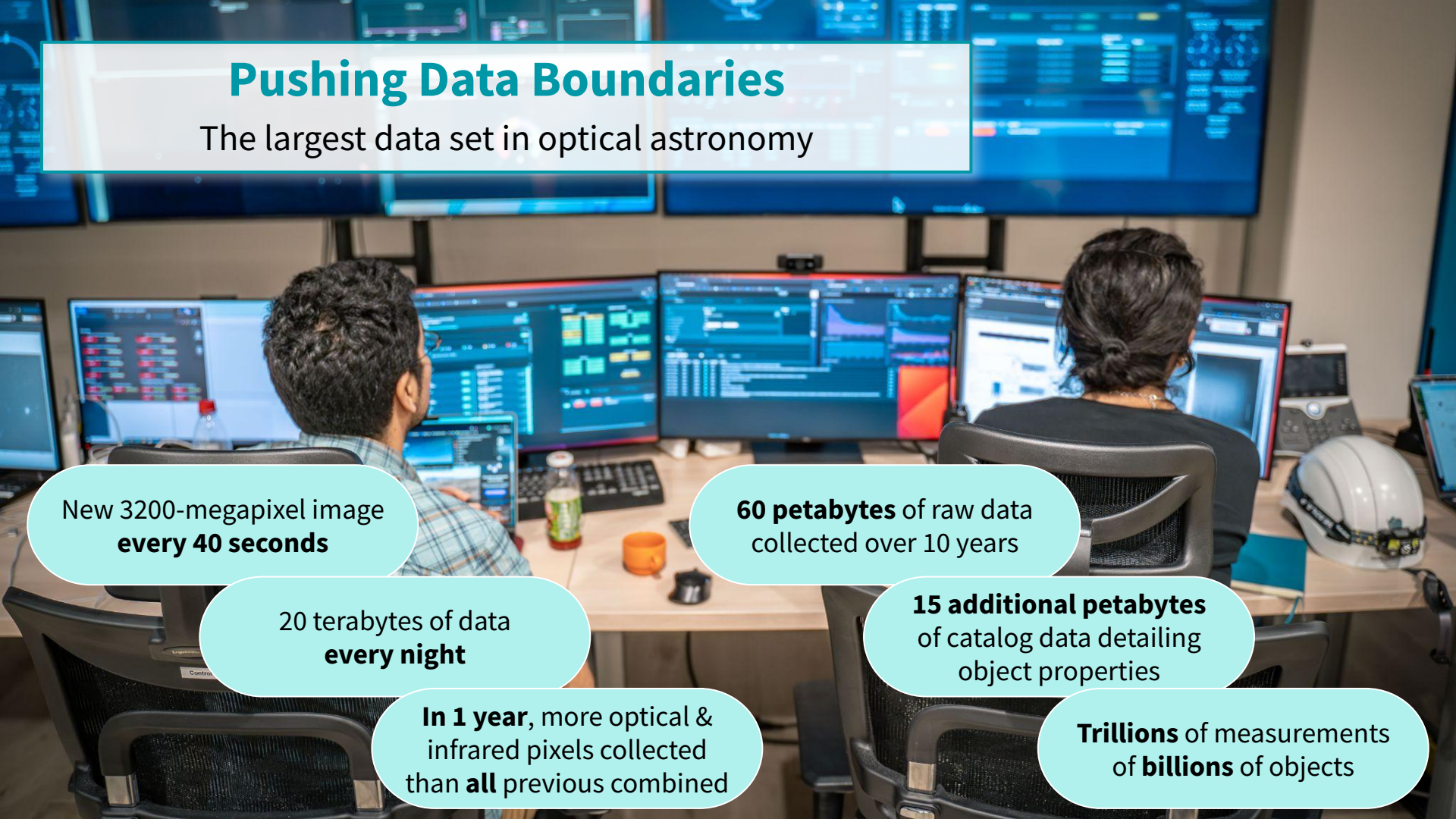
1. Storage capacity and compute power

2. Network bandwidth

3. Advances in algorithms

Pushing Data Boundaries

The largest data set in optical astronomy



New 3200-megapixel image **every 40 seconds**

60 petabytes of raw data collected over 10 years

20 terabytes of data **every night**

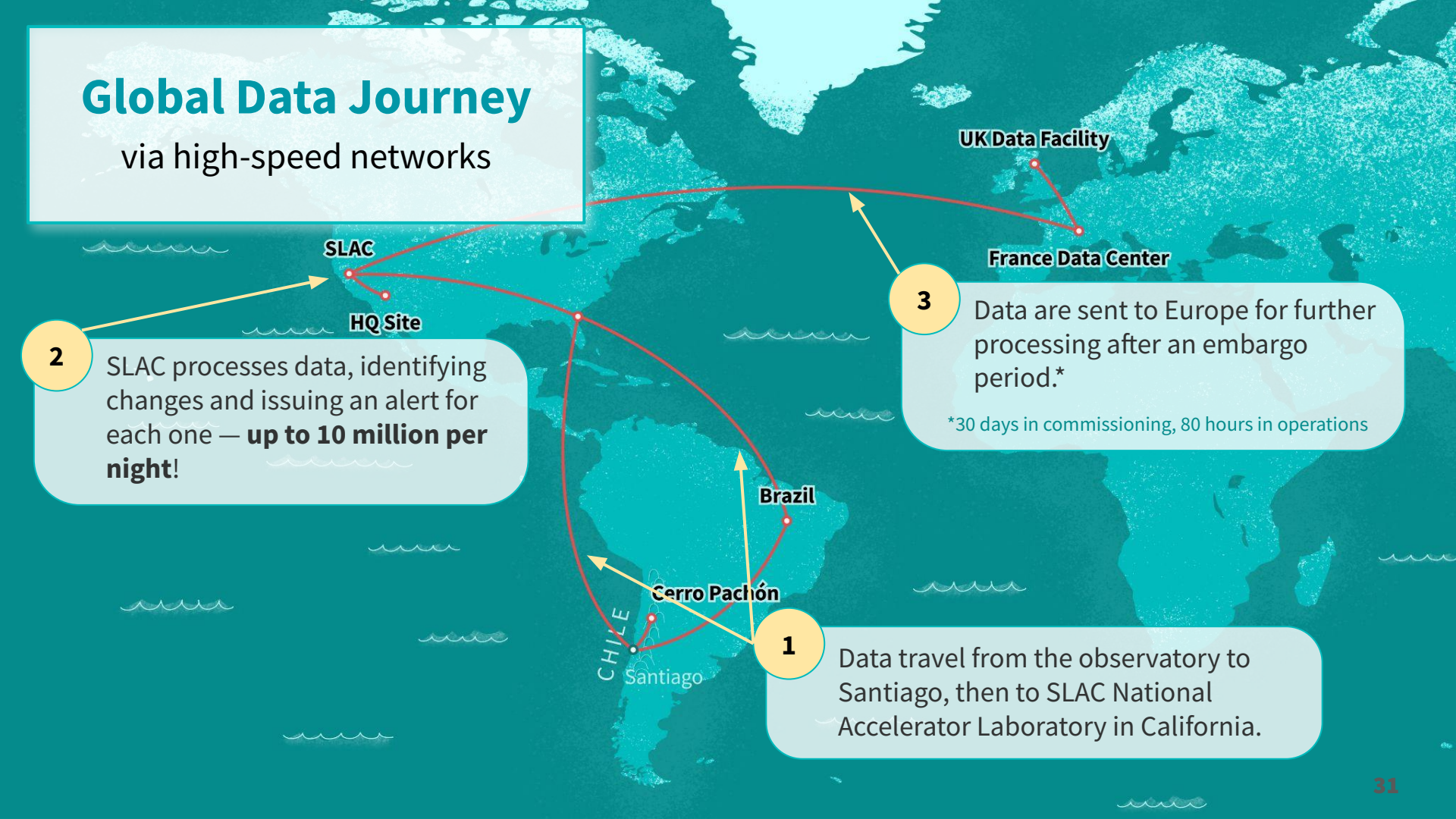
15 additional petabytes of catalog data detailing object properties

In 1 year, more optical & infrared pixels collected than **all** previous combined

Trillions of measurements of **billions** of objects

Global Data Journey

via high-speed networks



1 Data travel from the observatory to Santiago, then to SLAC National Accelerator Laboratory in California.

2 SLAC processes data, identifying changes and issuing an alert for each one — **up to 10 million per night**!

3 Data are sent to Europe for further processing after an embargo period.*

*30 days in commissioning, 80 hours in operations

Fast Data for a Dynamic Universe

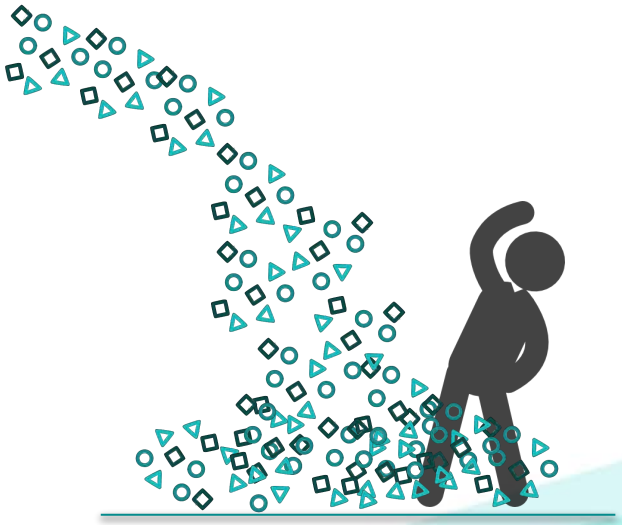
Produced by Rubin

Prompt Products

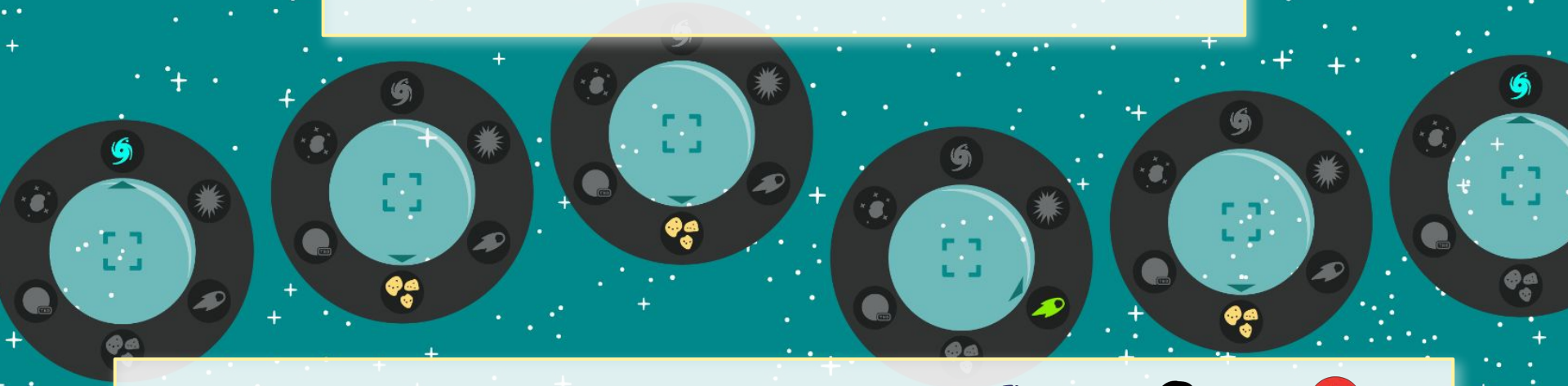
Near-real-time processed data released within minutes to days

- **Alerts (within minutes):** Notify scientists of detected sky changes
- **Catalogs (~24 hours):** Databases of information about detected objects
- **Raw & Processed Images (~80 hours):** Available to data-rights holders

Up to 10 million alerts per night
Alert stream or alert tsunami?



Navigating the Alert Stream



- To manage, Rubin uses **community brokers** — software systems that process & serve alerts to scientists
- Scientists access alerts via broker websites & can filter on their research area
- Alerts are **world public**

Alerce | Antares | AMPEL

Fink | Lasair | Babamul

Pitt-Google Broker

Vast Data for a Deep Universe

Produced by Rubin

Annual Data Releases

Calibrated images and catalogs of billions of objects, including positions, shapes, and brightness

1. Take all data collected to date
2. Combine to emulate longer exposures…
3. …to reveal fainter objects and extract most info possible

Bringing Scientists to the Data

Data release year 1: 50 PB

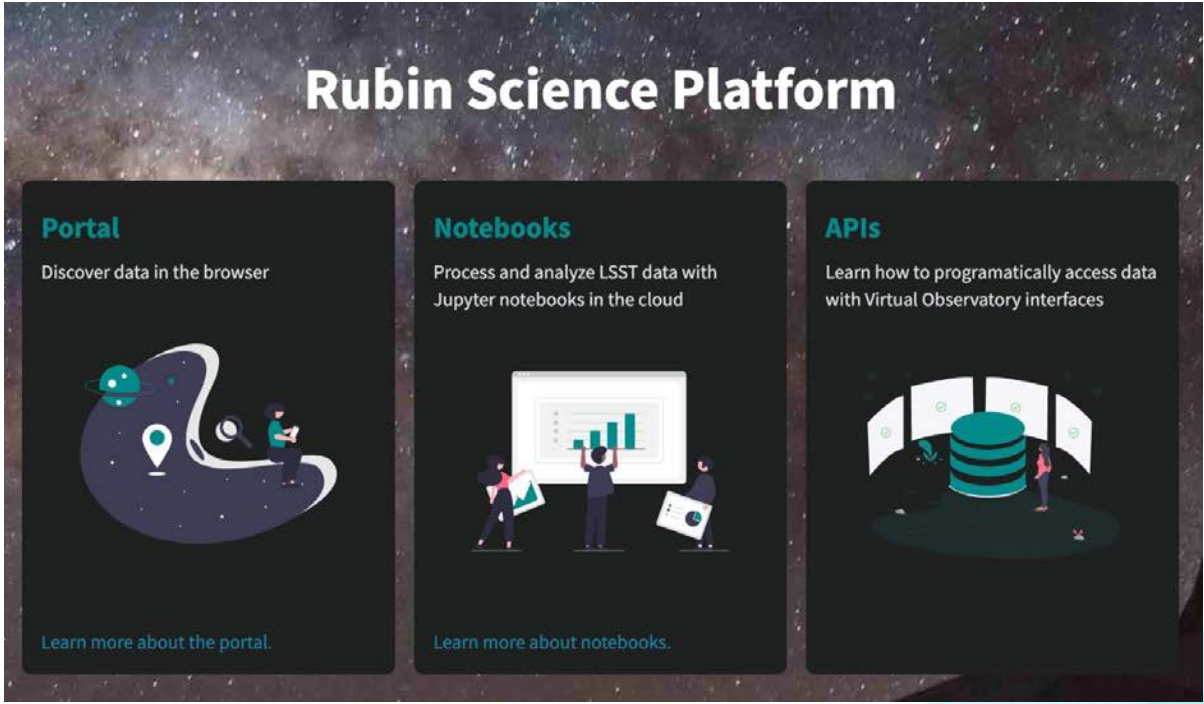
Data release year 10: 500 PB

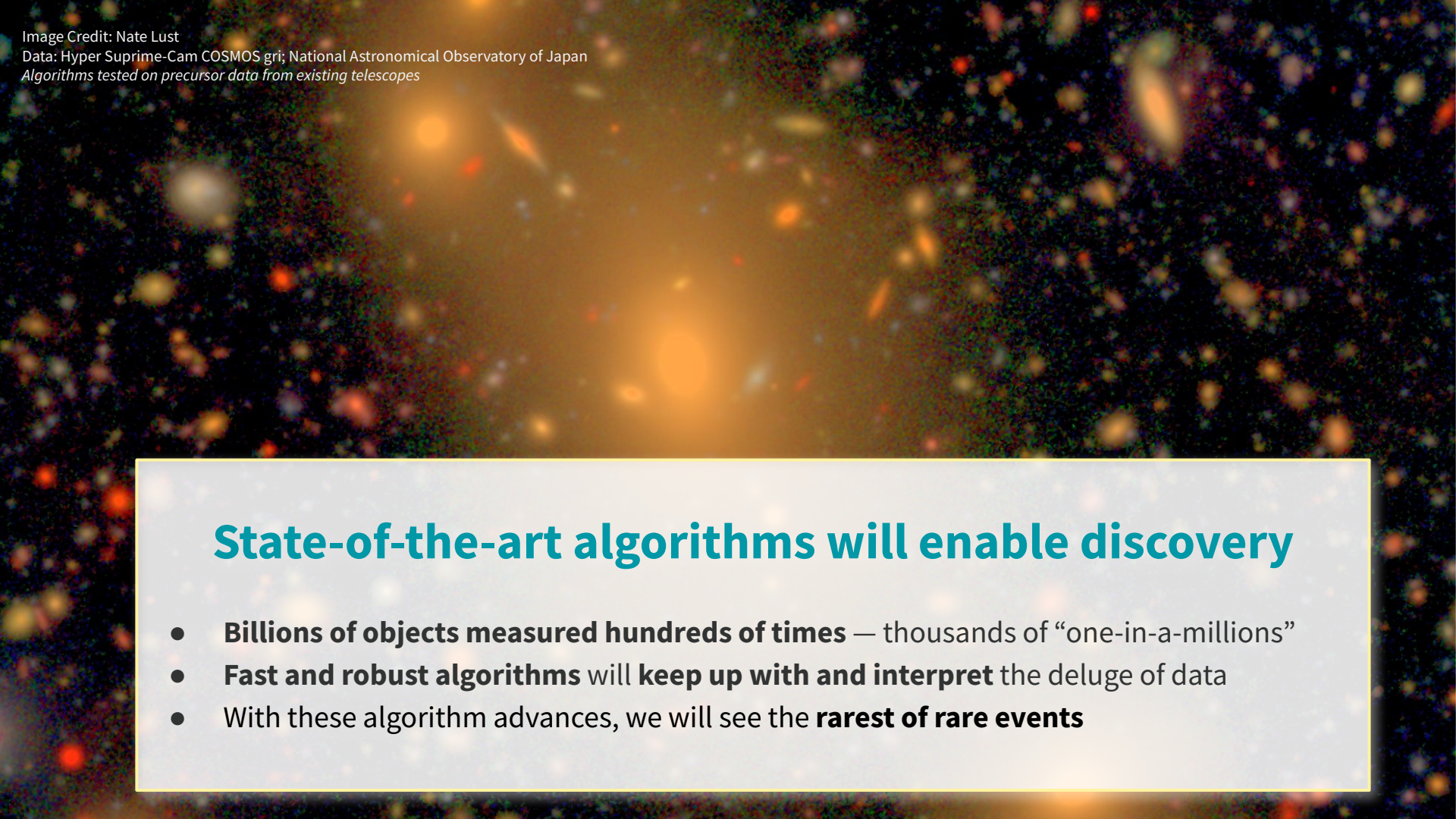
➜ Too much to download

Rubin Science Platform:

Data access via the web & cloud

- Increases accessibility
- Tools & support included





State-of-the-art algorithms will enable discovery

- **Billions of objects measured hundreds of times** — thousands of “one-in-a-millions”
- **Fast and robust algorithms** will **keep up with and interpret** the deluge of data
- With these algorithm advances, we will see the **rarest of rare events**

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A Global Vision for Cosmic Access

Beth Willman
CEO, LSST Discovery Alliance

Cosmic Disruption

New paradigm for how science is done

Community engagement from the earliest days

28 countries involved in physical or software construction

2000+ Science Collaboration members

Data for Everyone, Everywhere

- Making data **accessible to everyone**
- Enabling scientists from **all over the world and all backgrounds** to participate
- Volunteers **around the world** will contribute via Zooniverse **citizen science**

Scientists at LSST@Europe5 in 2023
Credit: LSST-DA/T. Licul

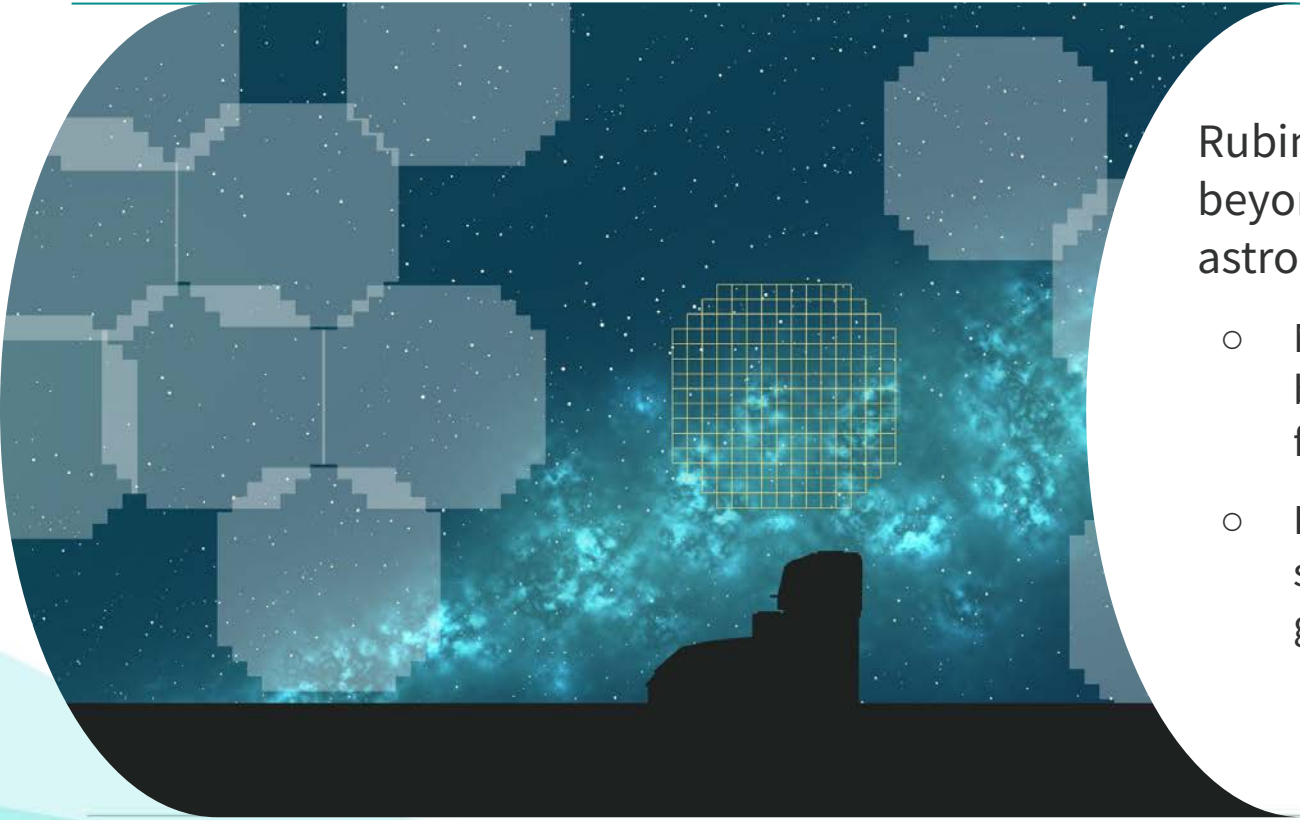
This is the first time this much astronomical data will be available to so many people

Collaborative Innovation for LSST Success

Dozens of institutions around the globe are in an Alliance to achieve the full discovery potential for LSST:

- **Innovation across disciplines**, training, inclusive collaborative networks
- **Novel approaches** to software and data engineering
- Public-private collaboration

Blueprint for Big Challenges



Rubin's impact will extend far beyond astronomy and astrophysics

- New methods of discovery will be applied to other big data fields
- Lessons learned will inform solutions to other complex global challenges

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Resources for you to Bring Rubin Observatory to Life

Stephanie Deppe

Rubin Observatory Astronomy Content Strategist

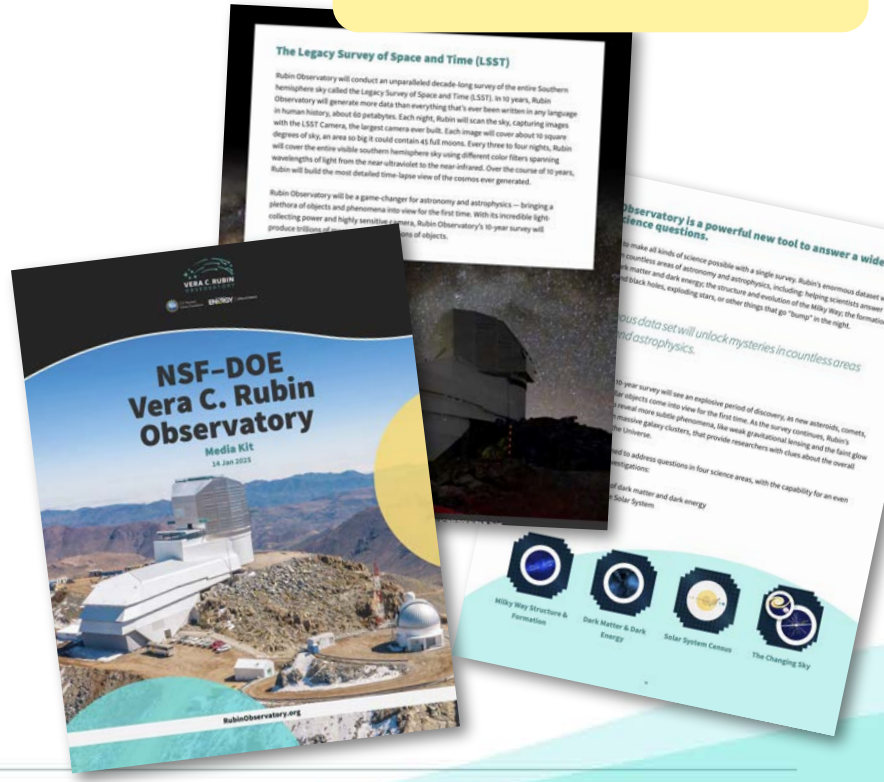
A fully-stocked media kit

Available in English now!
Coming soon in Spanish.

- ✓ Basic and detailed information about Rubin
- ✓ Library of selected imagery and videos
- ✓ Downloadable pdf

rubinobservatory.org/media

Access visuals, fact sheets, and more:
ls.st/resources



Media resources

Media Contacts

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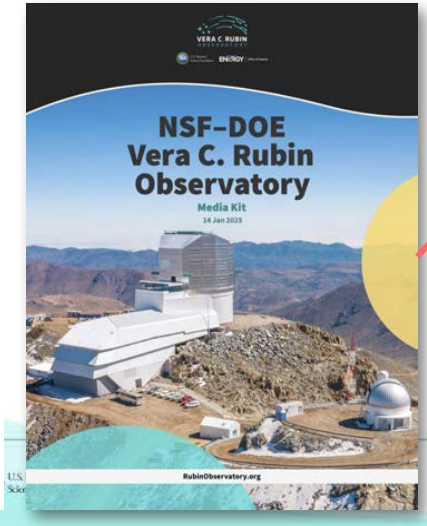


Ranpal Gill
Head of Program Operations/Head of Construction Communications Office
Vera C. Rubin Observatory / NSF NOIRLab
ranpal.gill@noirlab.edu
communications-team@lists.lsst.org

Shari Lifson
Corporate Communications Coordinator
Association of Universities for Research in Astronomy (AURA)
+1(202) 769-5232
slifson@aura-astronomy.org

Josie Fenske
Jr. Public Information Officer
NSF NOIRLab
josie.fenske@noirlab.edu

For inquiries to the U.S. National Science Foundation
media@nsf.gov

Aaron Groff
Media Relations Lead
SLAC National Accelerator Laboratory
+1-650-926-3019
agroff@slac.stanford.edu

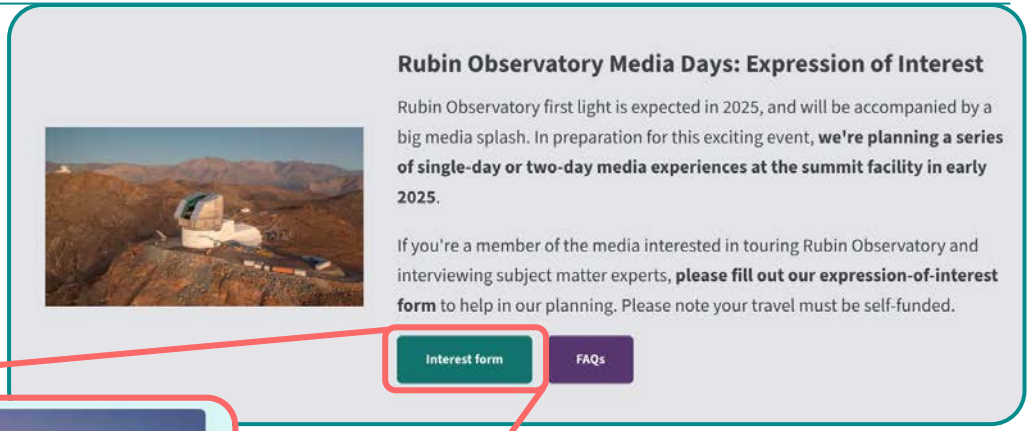
For inquiries to the U.S. Department of Energy, Office of Science
news@science.doe.gov

Vera C.

Opportunities for media to visit Rubin Observatory

rubinobservatory.org/media

Access visuals, fact sheets, and more:
ls.st/resources

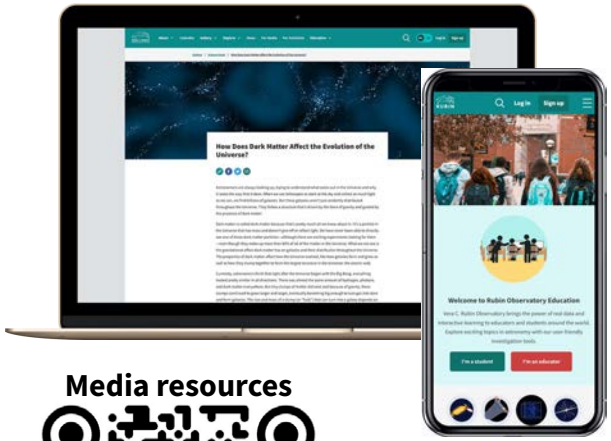


Media resources

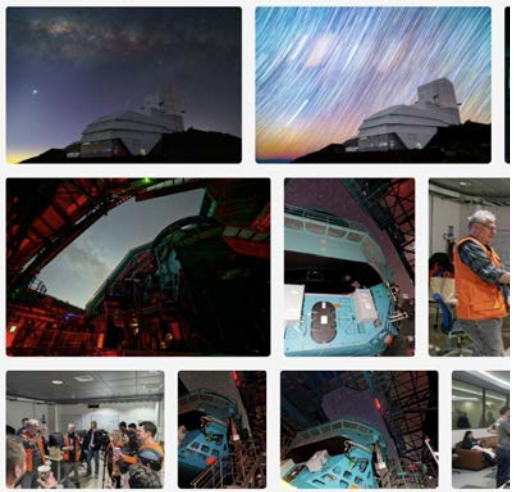
Media days expected to occur in May 2025

More resources

Mobile-friendly website with all the information in English and Spanish
rubinobservatory.org



Media resources



Multimedia gallery
rubinobservatory.org/gallery

And lots more!

- A biweekly email digest with recent Rubin news

  To subscribe: send a blank email to rubinobs-digest-join@lists.lsst.org & respond to the message you receive
- Press releases and announcements at **rubinobservatory.org/news**
- Short, animated videos about Rubin and its science at **youtube.com/RubinObservatory**

> Don’t shoot for the stars, we already know what’s there. Shoot for the space in between because that’s where the real mystery lies.
>
> —*Vera C. Rubin*

Rubin Observatory media resources

H. Stockebrand