LSST & BLACK HOLES

8.15.2019 @ 7pm

Hilton El Conquistador, Turquoise Ballroom

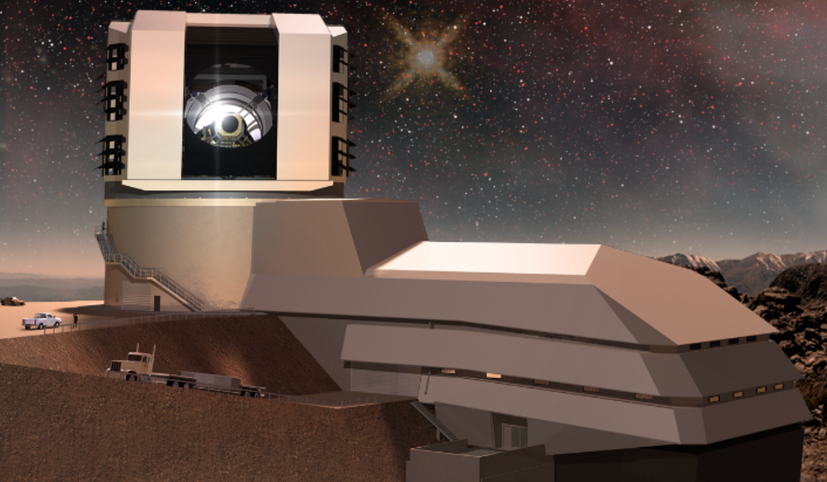
10000 North Oracle Road,Tucson, Arizona, 85704

NSF AURA U.S. DEPARTMENT OF ENERGY Office of Science SLAC CHARLES AND LISA SIMONYI FUND LSST CORPORATION

LSST & BLACK HOLES

The Large Synoptic Survey Telescope (LSST) is approaching completion on the Cerro Pachón ridge in north-central Chile. When science operations begin in 2022, LSST will scan the sky with the world's largest digital camera, creating a 500 petabyte set of images and data products that will address the most pressing questions about the structure and evolution of the universe and the objects in it. Among these objects are black holes, objects so dense they warp the fabric of space-time, objects whose incredible properties are only recently becoming known to us. You are invited to join us for an evening of black hole science and learn about Tucson's leadership role in LSST's voyage of scientific discovery.

During this public event, LSST Project Manager Victor Krabbendam will provide an update on LSST construction progress,University of Arizona astrophysicist Feryal Özel will discuss the latest black hole discoveries from the Event Horizon Telescope (EHT) and Northwestern University's Raffaella Margutti will describe what we have learned from the first multi-messenger observations of a neutron star merger with gravitational waves and light, and what might be revealed when LSST begins its ten-year survey.



Hilton El Conquistador Turquoise Ballroom

10000 North Oracle Road,Tucson, Arizona, 85704

SPEAKERS

Victor Krabbendam,
LSST

Victor Krabbendam has been LSST Project Manager since 2012, after eight years as Project Manager for the LSST Telescope & Site subsystem. Trained as a mechanical engineer, Victor has worked in industry, government, and with major astronomical research facilities including the Hobby-Eberly Telescope at McDonald Observatory and the Southern Astrophysical Research (SOAR) Telescope, a 4.1 meter telescope that is LSST's neighbor on Cerro Pachón.

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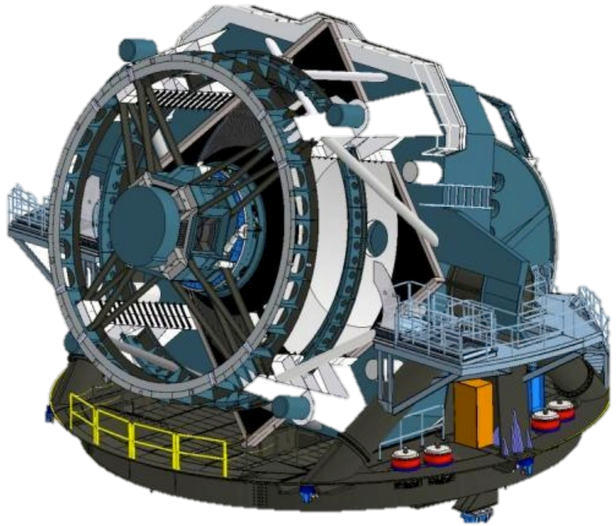
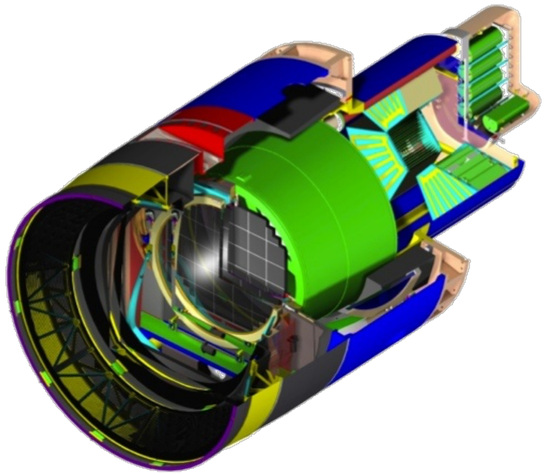
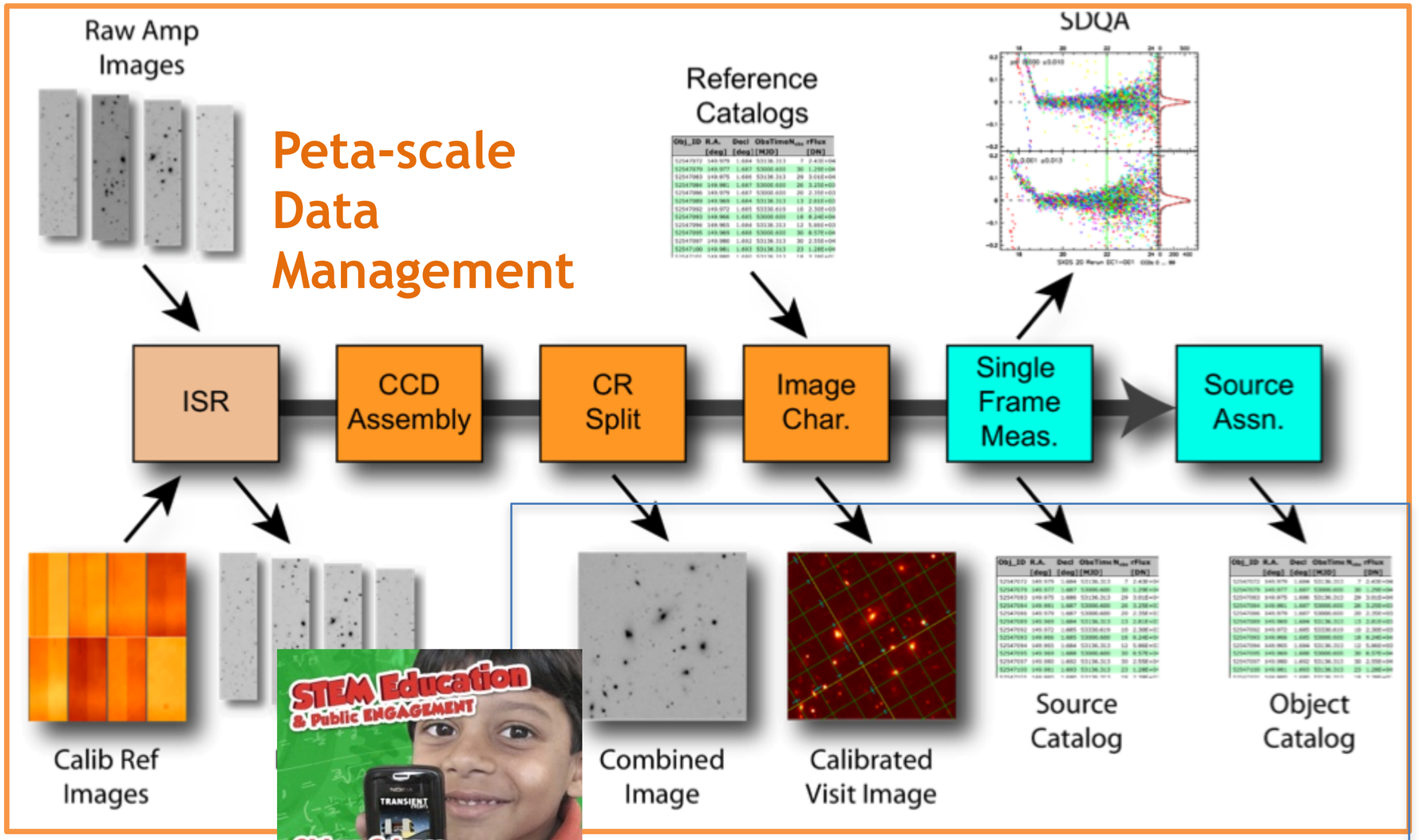


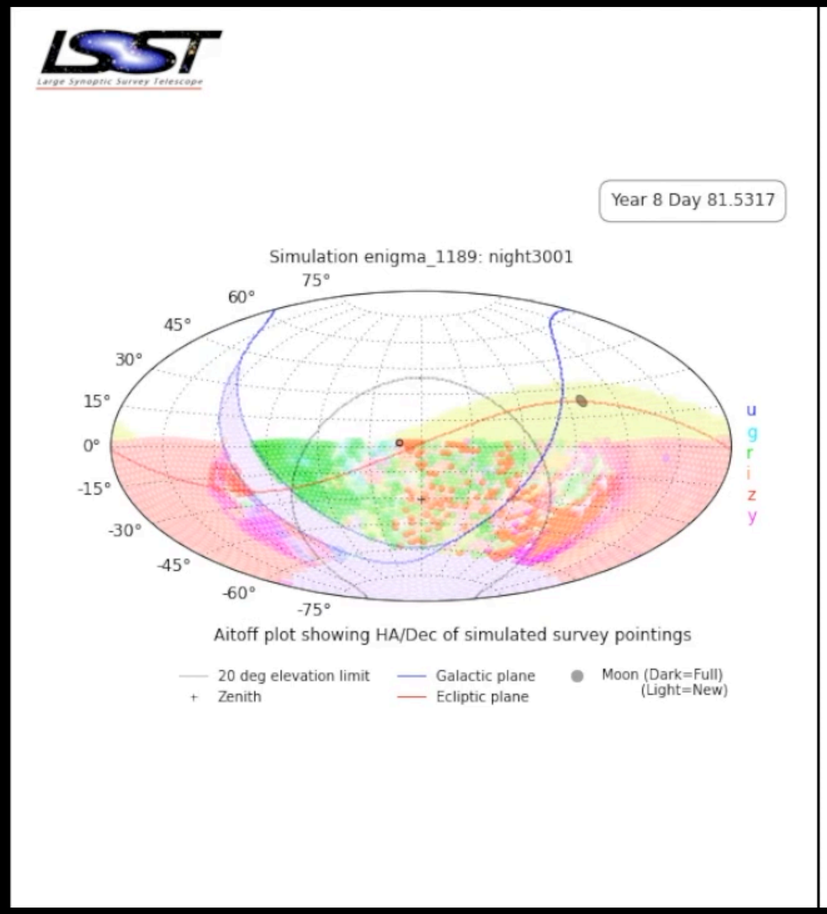
8.4m Telescope +

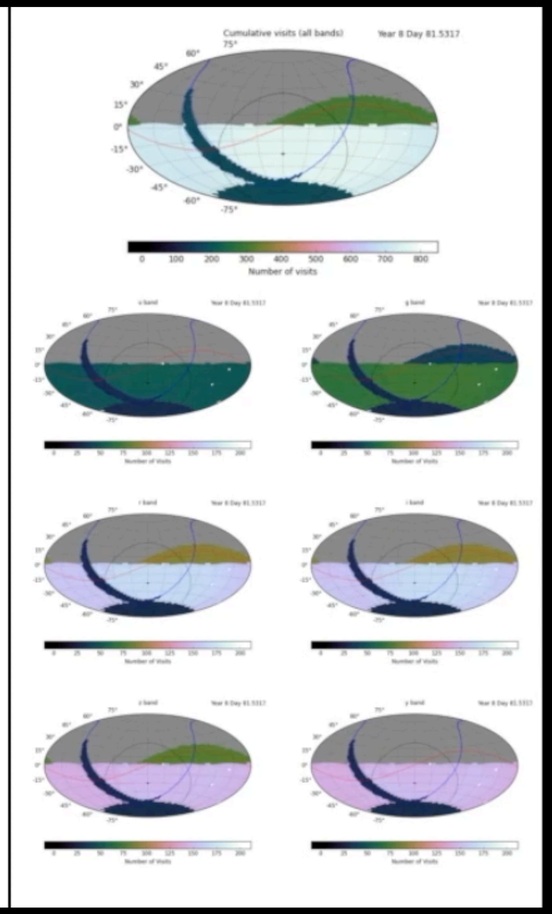


3.2Gpix Camera



A single Survey of the night sky





Prompt Data Products

Real Time Difference Image Analysis (DIA)

Data Release Data Products

Reduced single-epoch & deep co-added images, catalogs, reprocessed DIA products

User Generated Data Products

User-produced derived, added-value data products

Construction Funding Partners and Managing Organizations

US$ 473 M → AURA

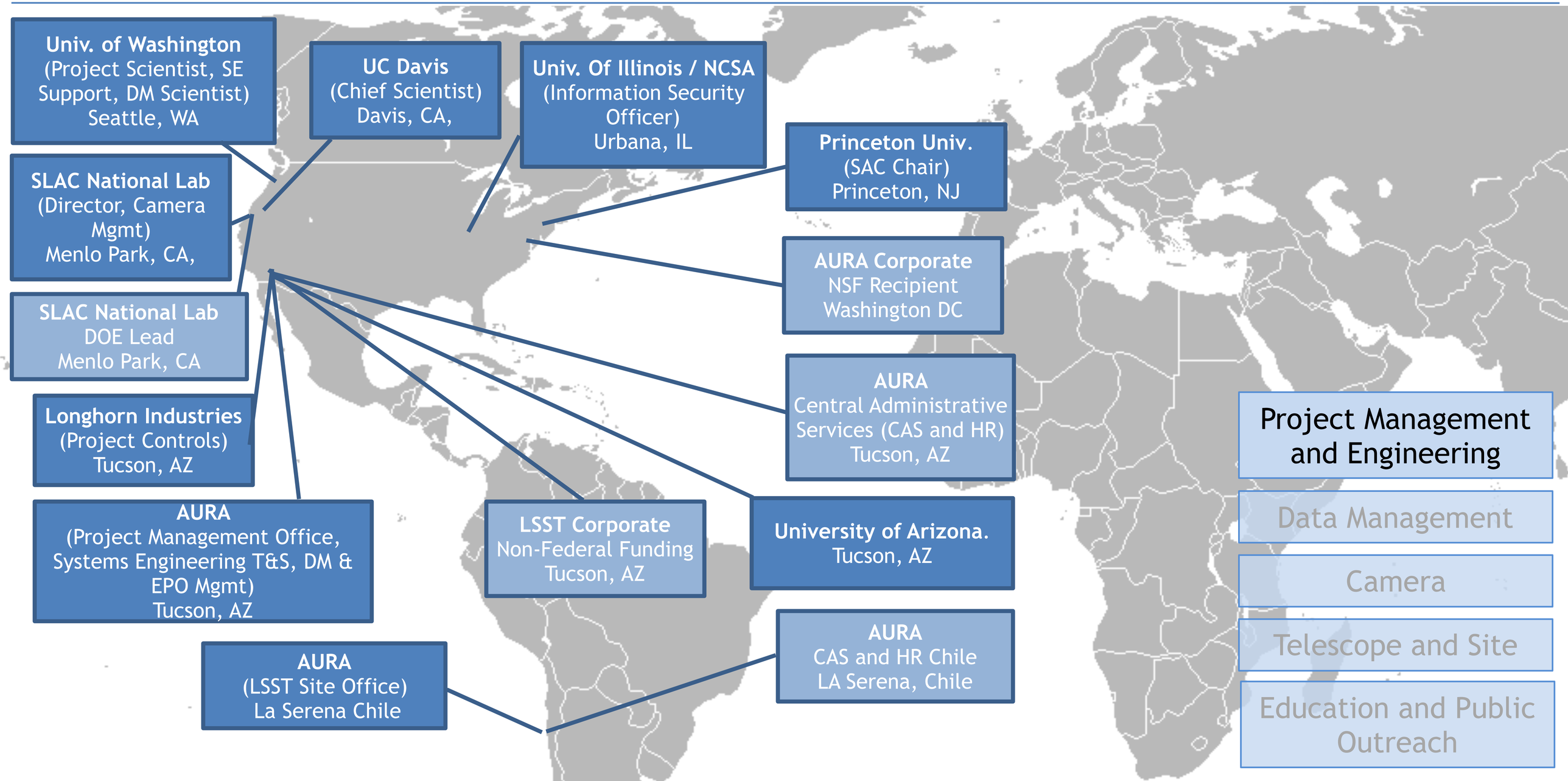
U.S. DEPARTMENT OF ENERGY

US$ 168 M → SLAC NATIONAL ACCELERATOR LABORATORY

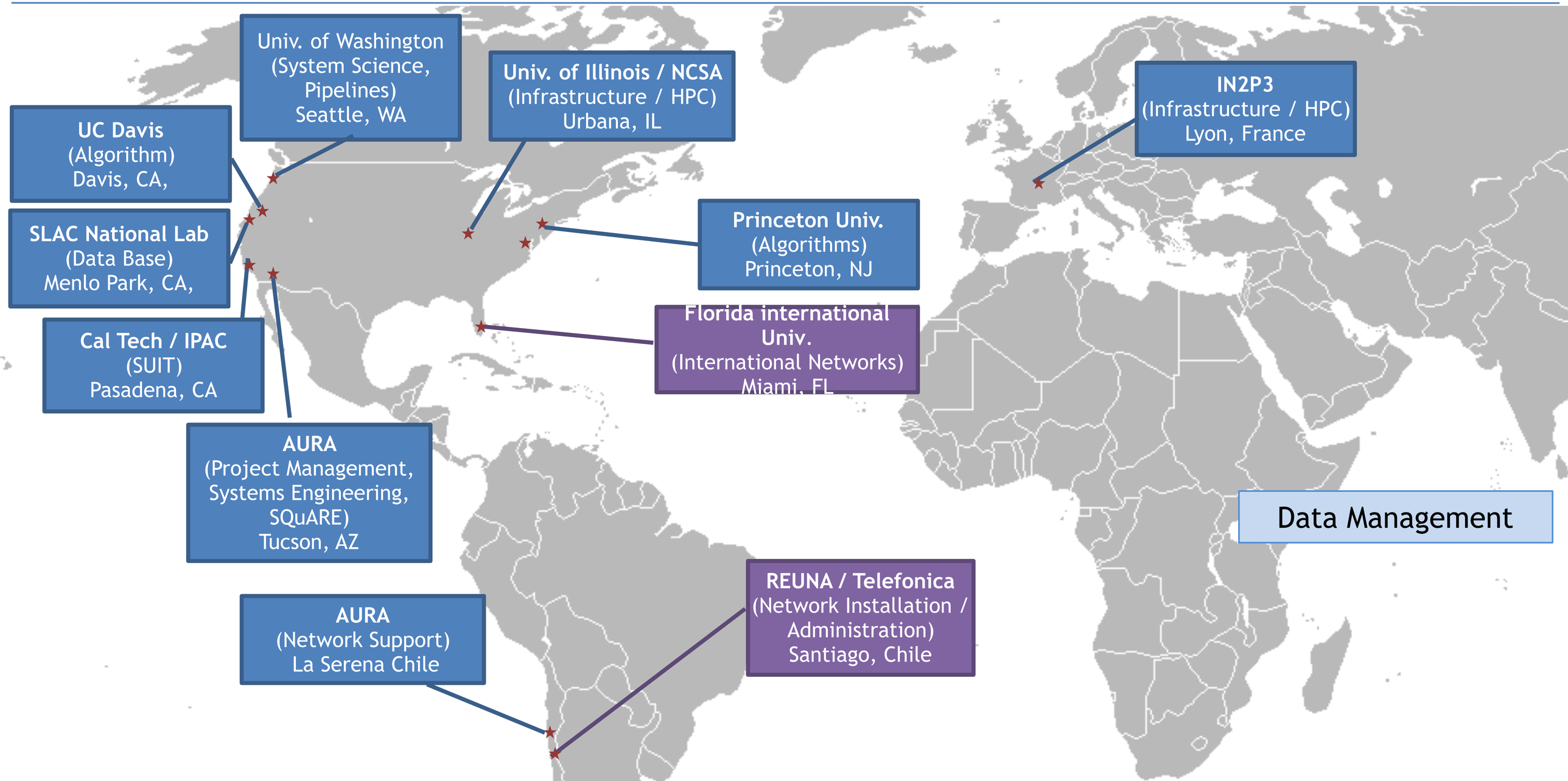
Private, Corporate, and Institutional Donors

US$ 40 M → LSST CORPORATION

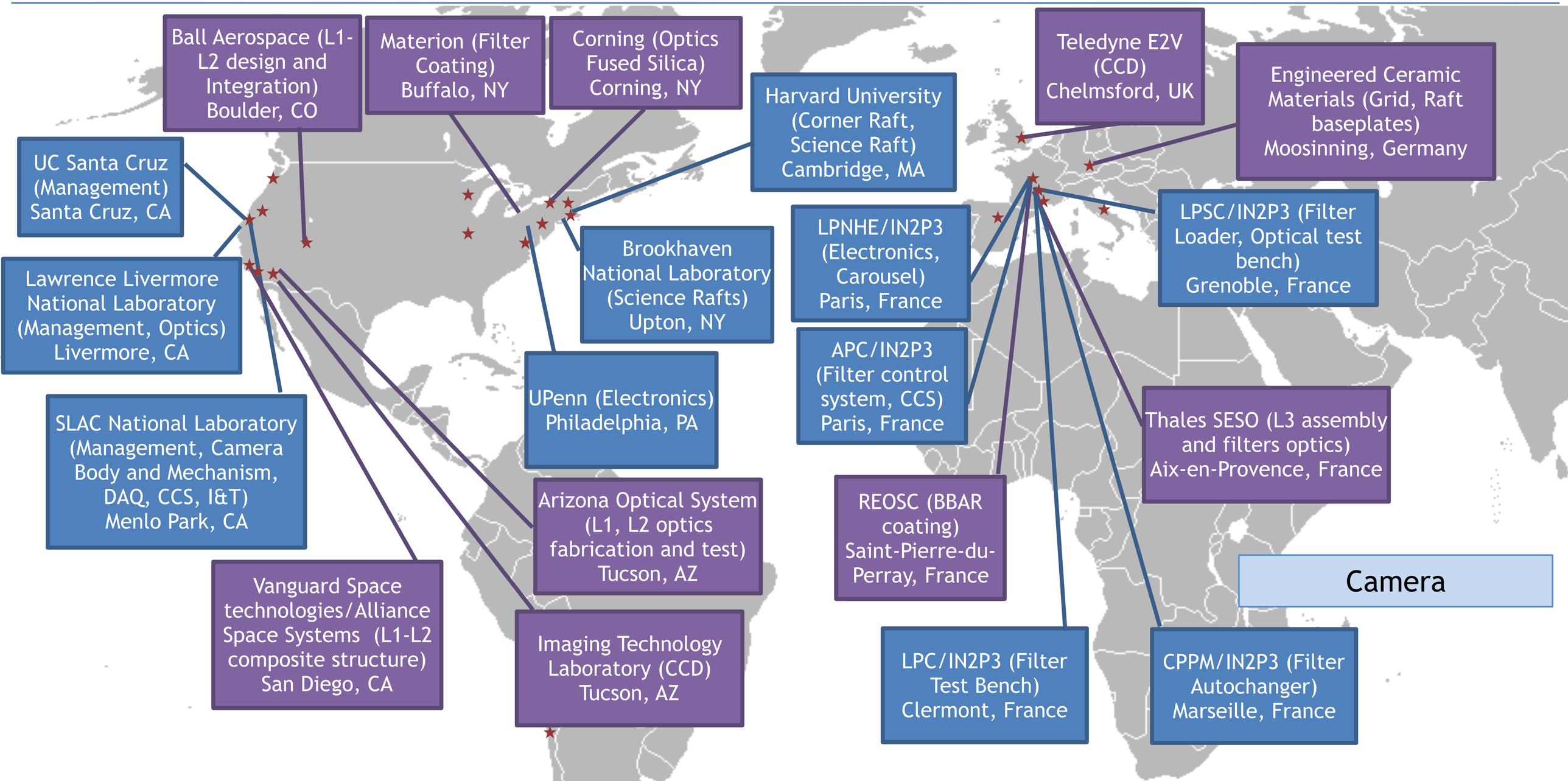
Project Executed by Global Team of Staff and Contractors



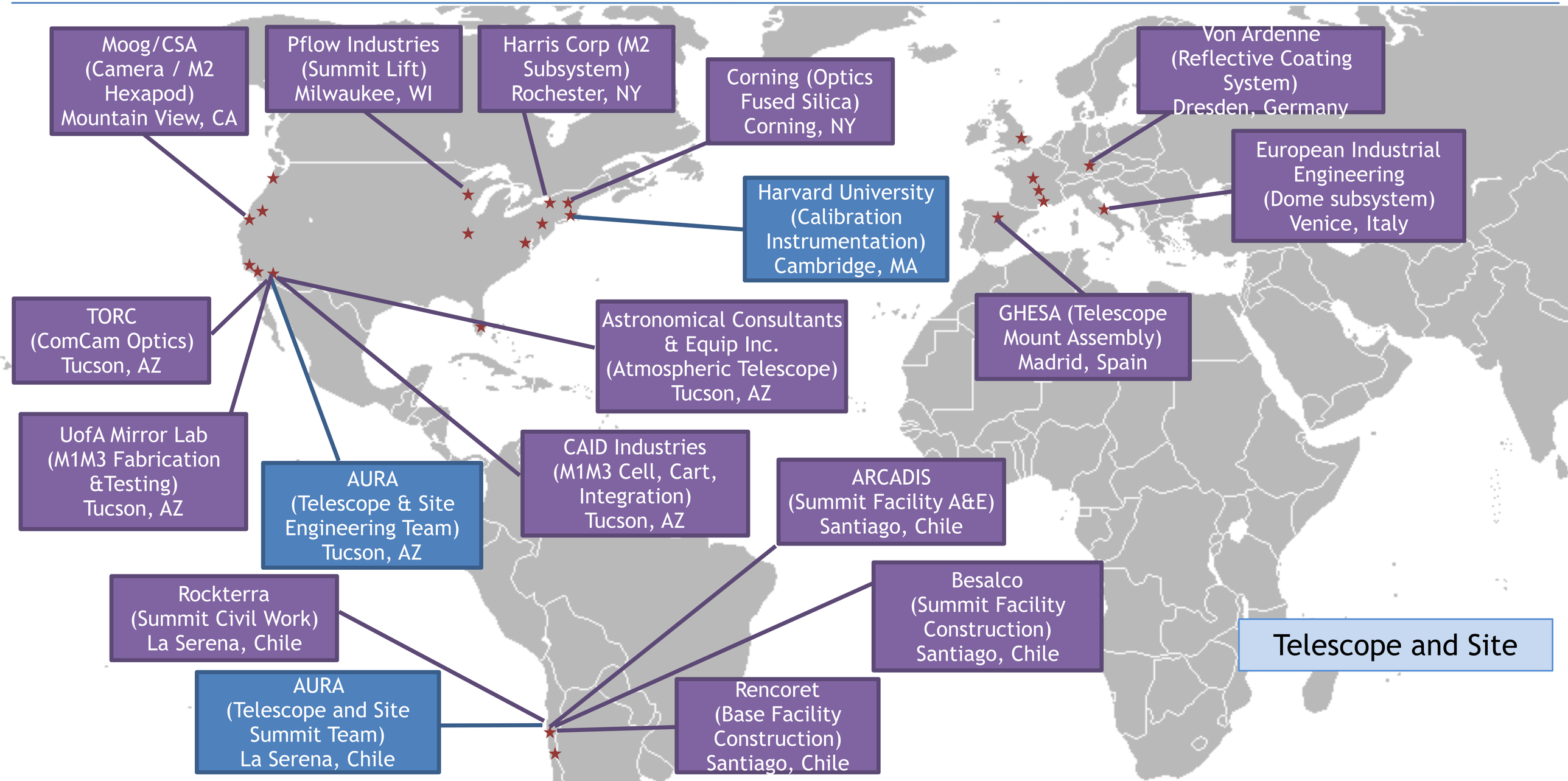
Project Executed by Global Team of Staff and Contractors



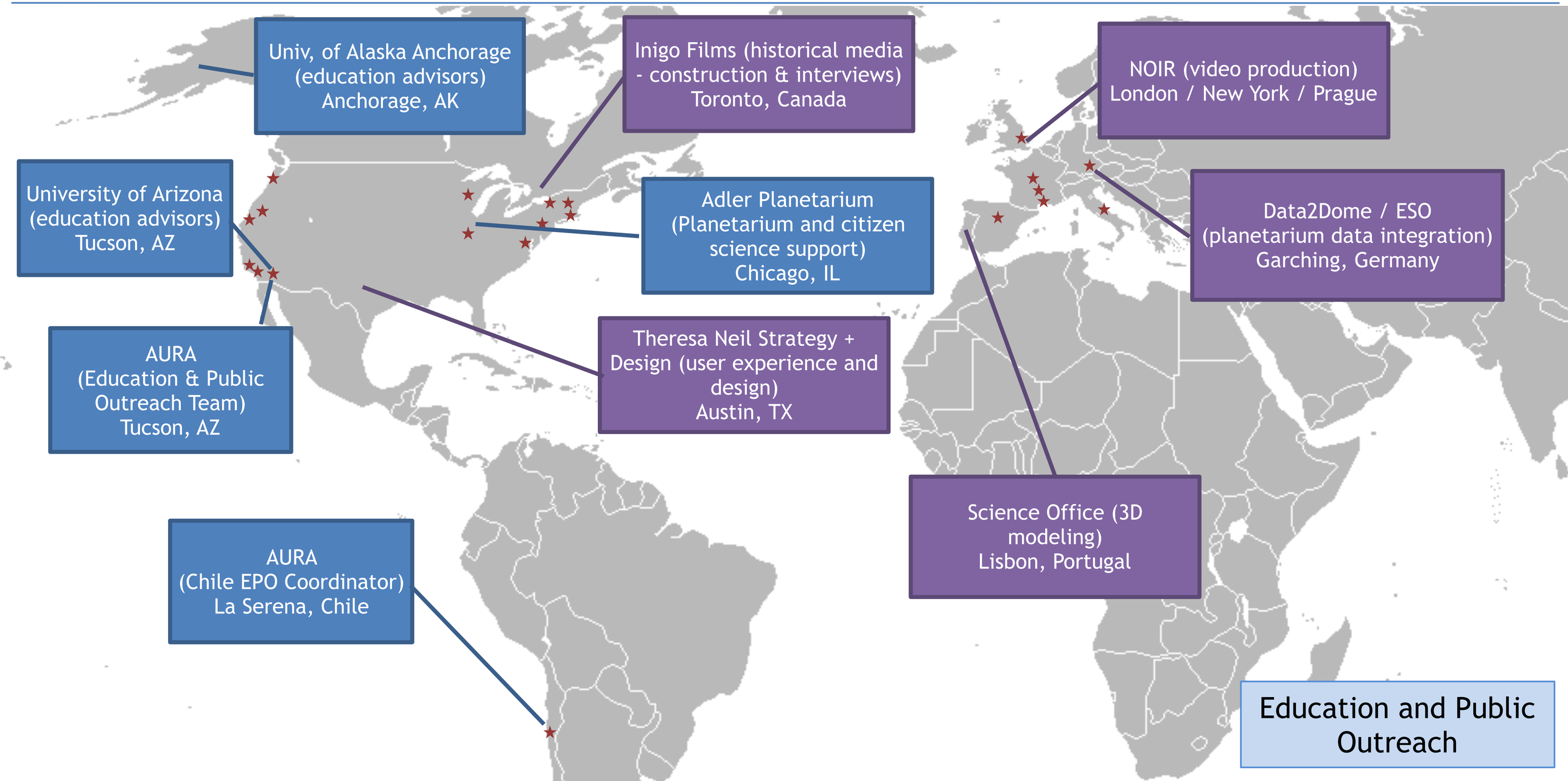
Project Executed by Global Team of Staff and Contractors



Project Executed by Global Team of Staff and Contractors



Project Executed by Global Team of Staff and Contractors



Education and Public Outreach

Previous Public Talks and much much more……

Available on LSST YouTube Channel and our public website www.lsst.org

Follow us

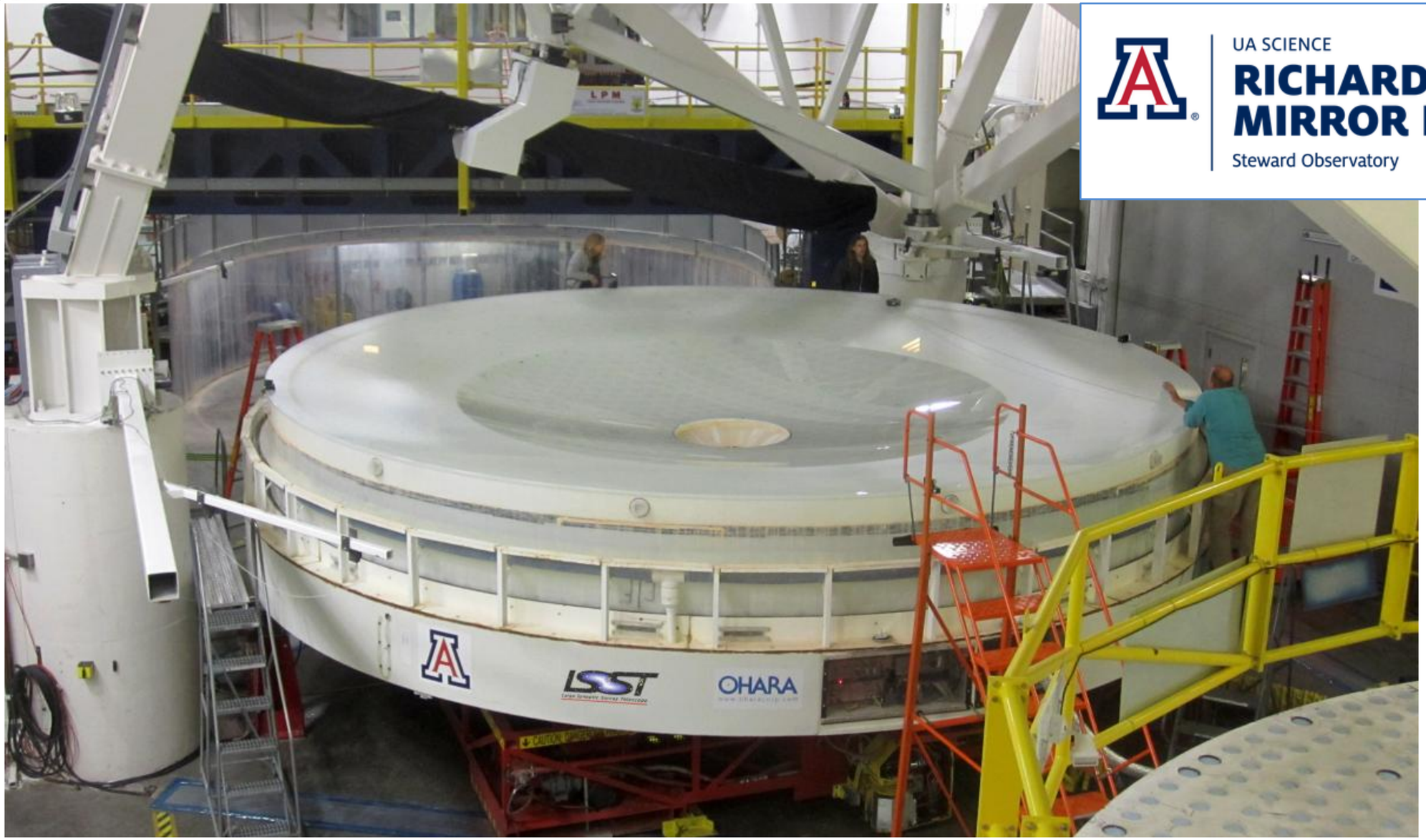
Large Synoptic Survey Telescope
854 subscribers

Large Synoptic Survey Telescope (LSST) Status

All Across the Project efforts are successfully transitioning to reality

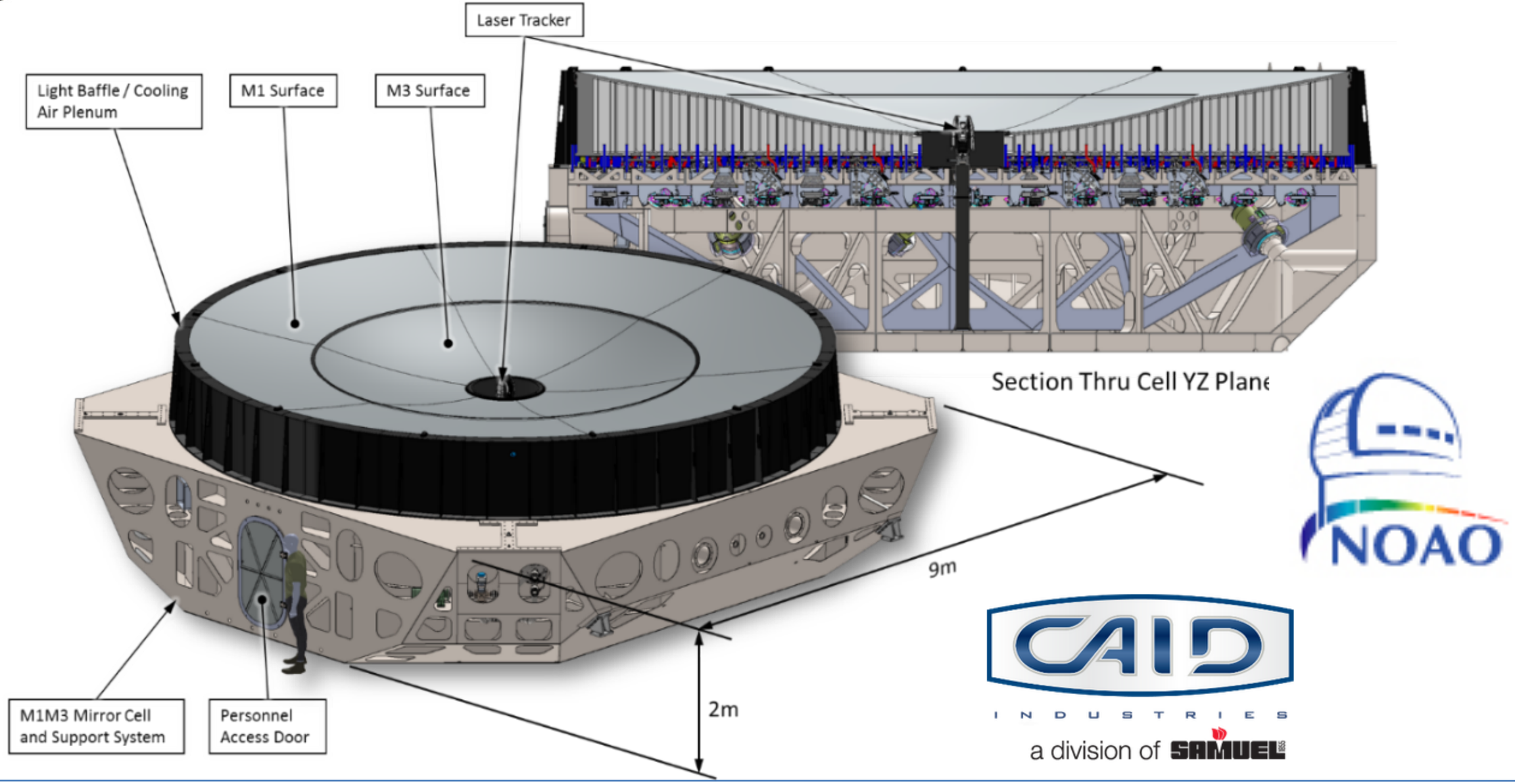

LSST Summit – 15 August 2019
Live WebCam #2
http:/ls.st/cyc

Primary Mirror Polishing Completed in 2014



UA SCIENCE
RICHARD F. CARIS MIRROR LAB
Steward Observatory

A “Mirror” is a Complex Assembly



NOAO

CAID INDUSTRIES a division of SAMUEL


OVERSIZE LOAD

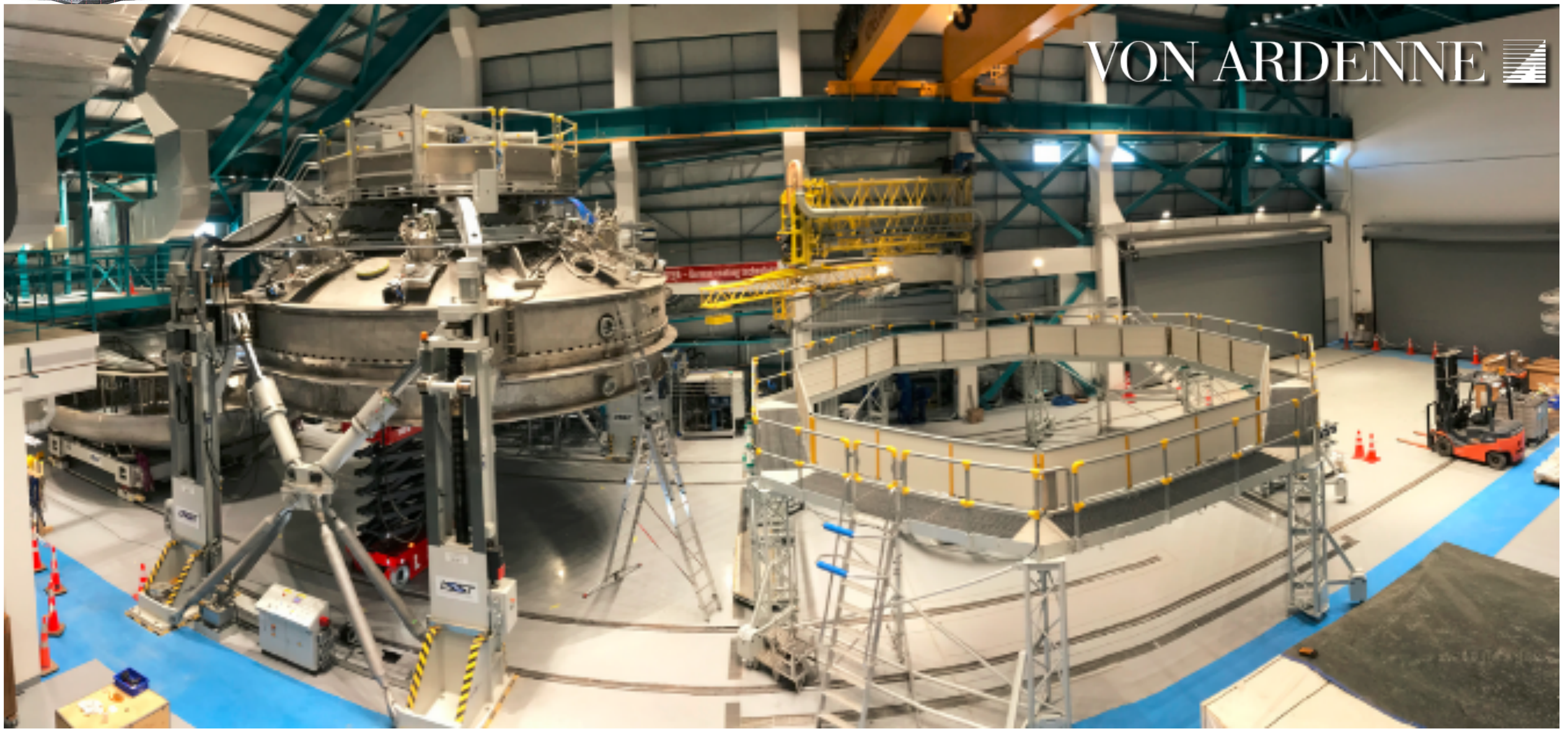

OVERSIZE LOAD


AURA
STRENGTH
NMF
2-1

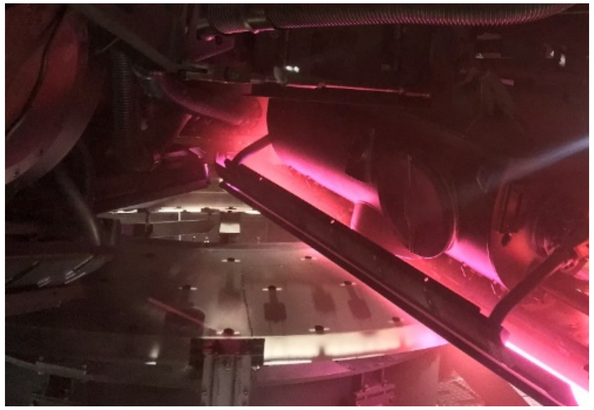
Puclaro Tunnel Chile

M1M3 video thru tunnel

LSST Optical Coating Facility on Summit



M2 Coating - 16 July 2019



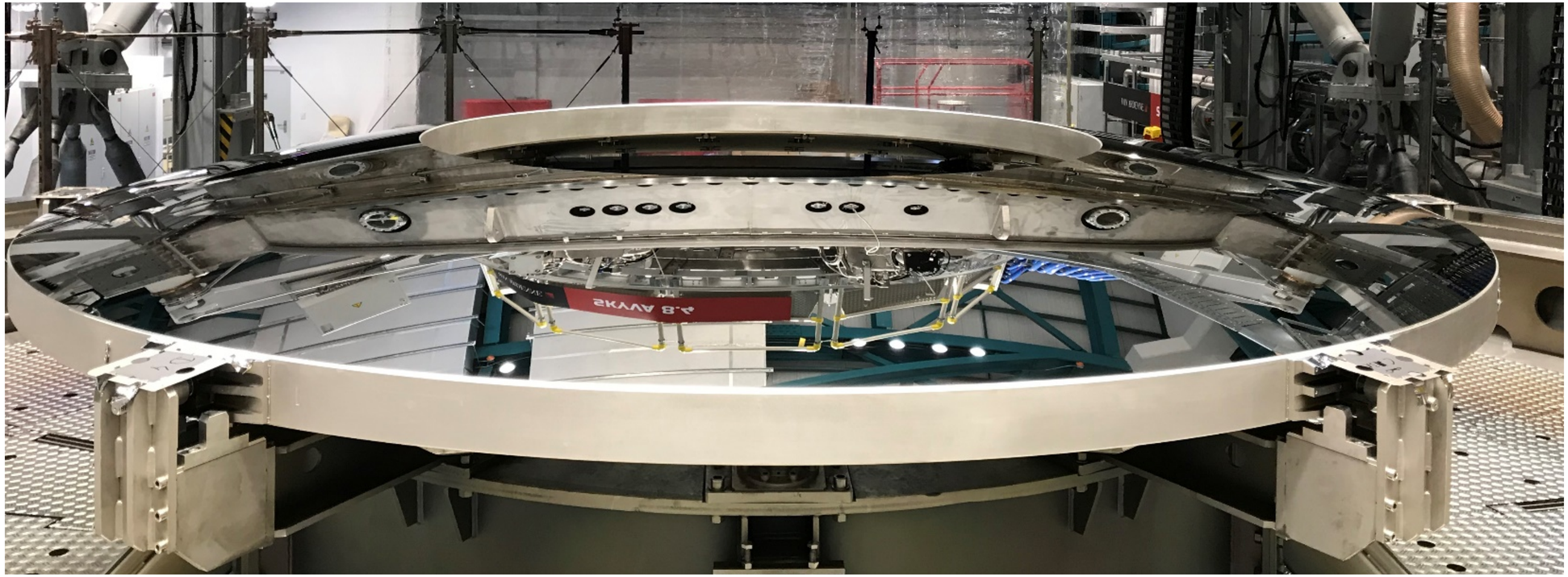
Protection Layer: Si_3N_4 @ 4nm

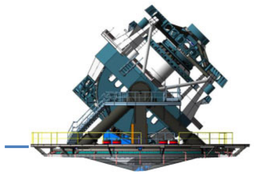
Adhesion Layer: NiCr @ 0.5nm

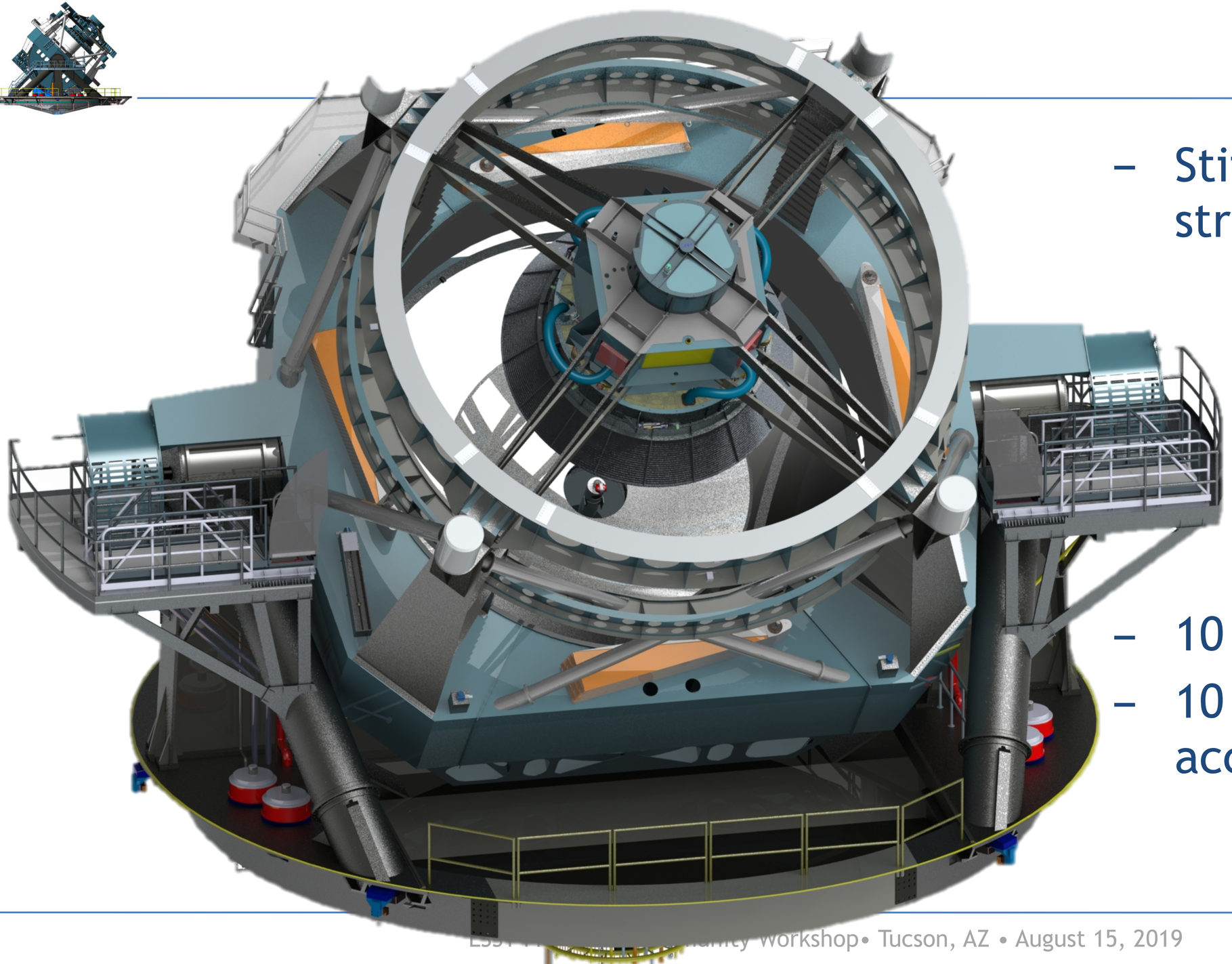
Reflector Layer: Ag @ 86 nm

Adhesion Layer: NiCr @ 5nm

Glass substrate





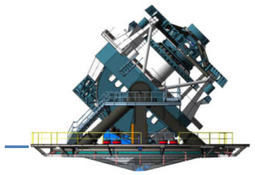


- Stiff 300 ton moving structure

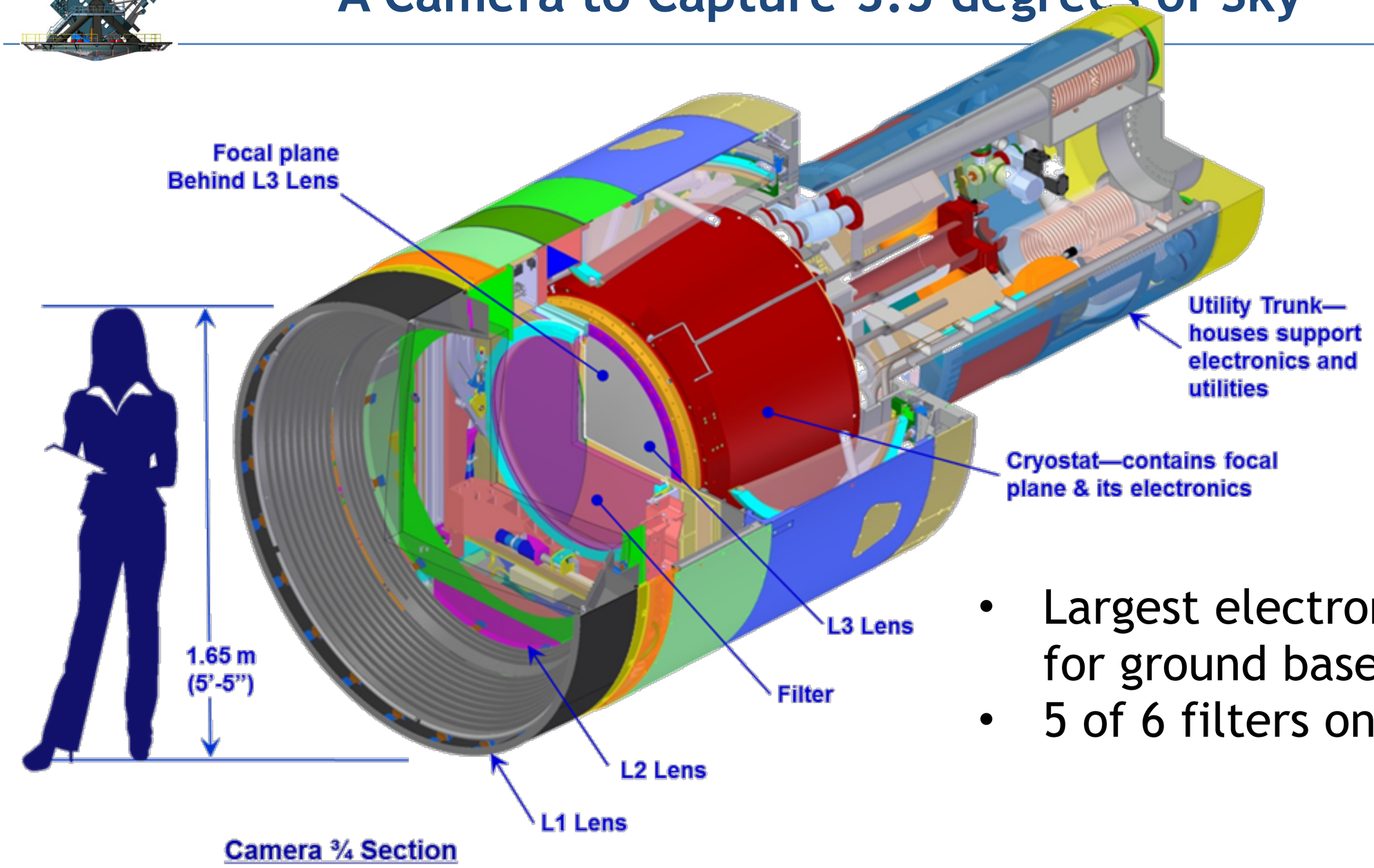
- 10 deg /sec rotation
- 10 deg/sec^2 acceleration


JASP
JASP

Telescope Mount Assembly in Factory Test

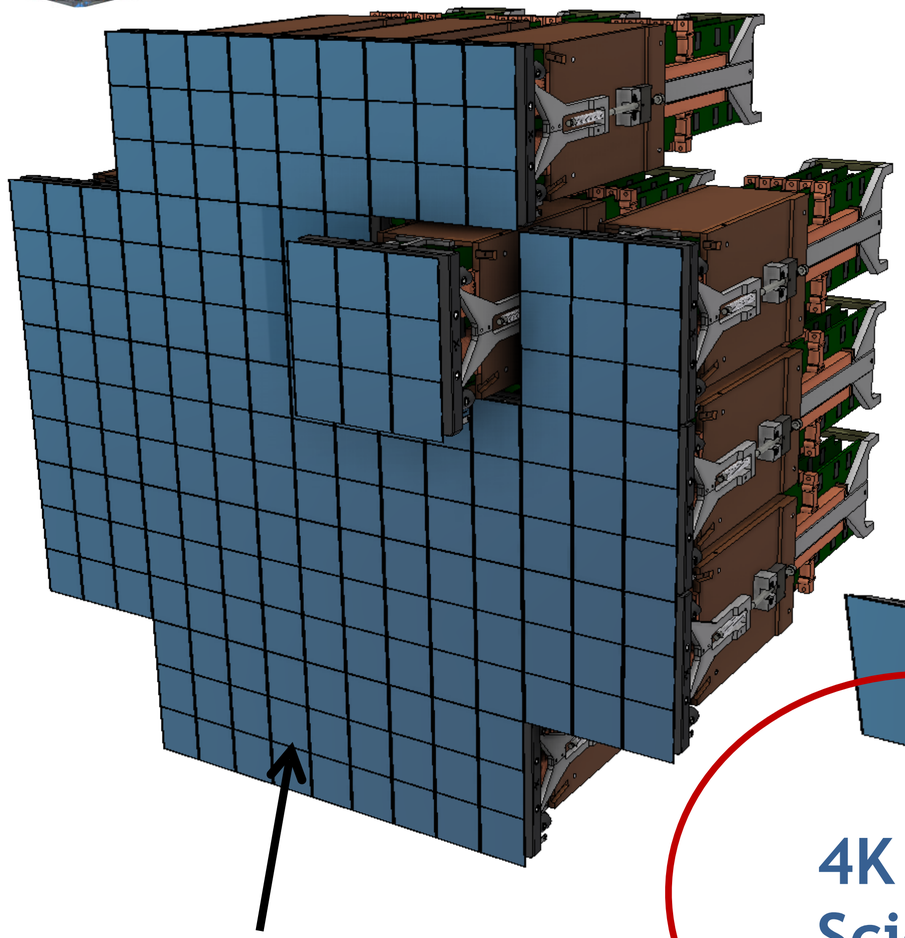


A Camera to Capture 3.5 degrees of Sky



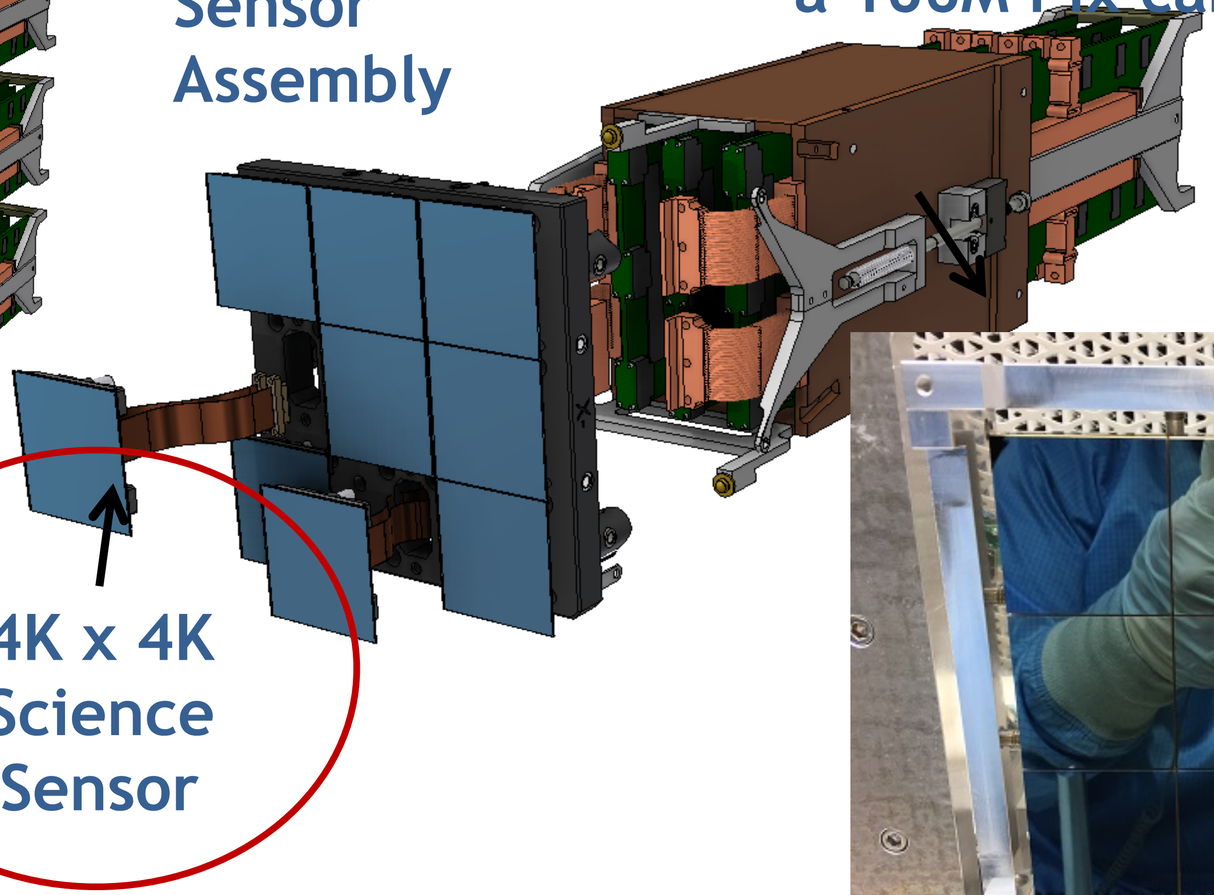
- Largest electronic camera built for ground based astronomy
- 5 of 6 filters on board

63 CM Diameter Focal Plane with 3.2 GigaPixels



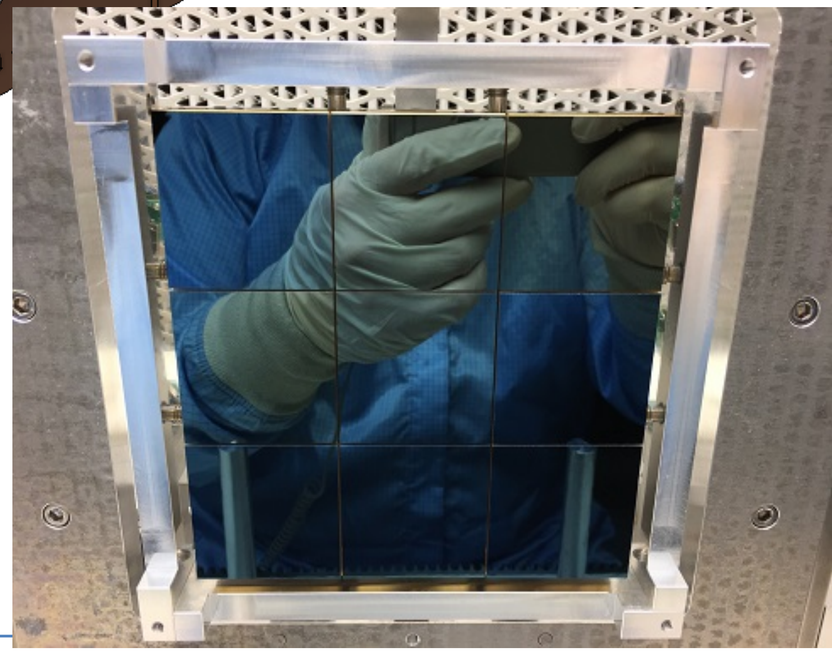
189 sensors packed in 21 rafts of 9 sensors

Raft Sensor Assembly



4K x 4K Science Sensor

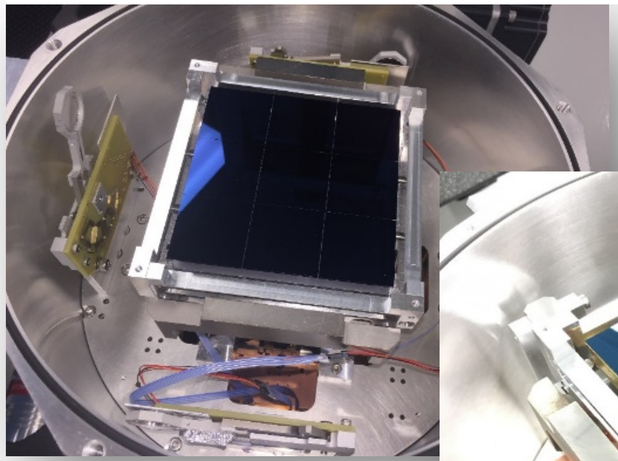
Raft Electronics Board (REB) with Custom Integrated circuits make a 166M Pix camera

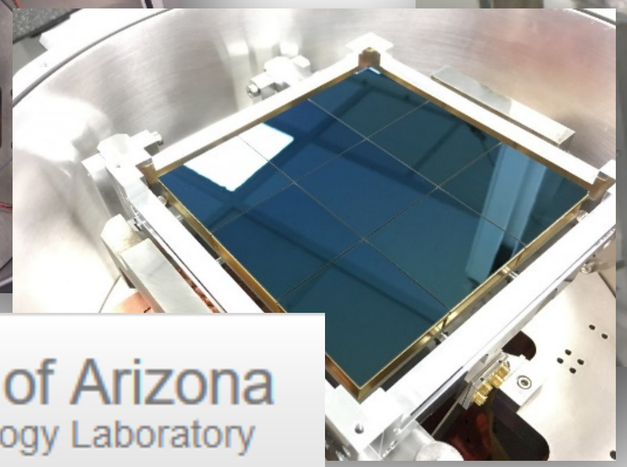


Camera Sensors Fabricated by Two Vendors

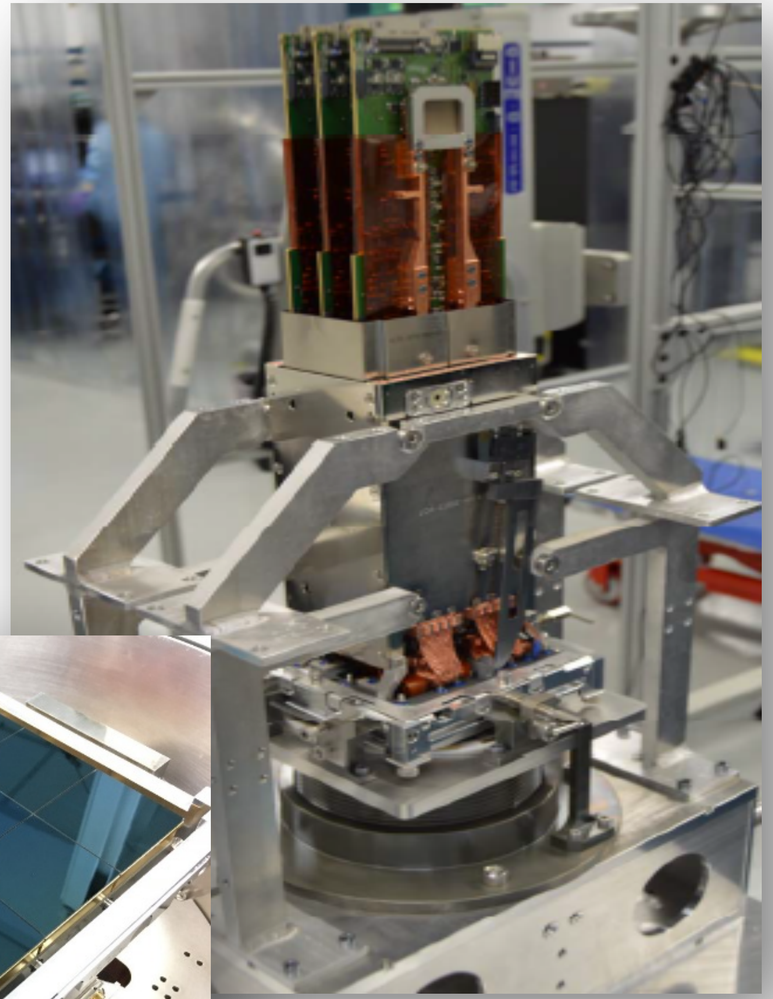
- More than 380 Science Sensors Delivered

TELEDYNE e2v
Everywhereyoulook™



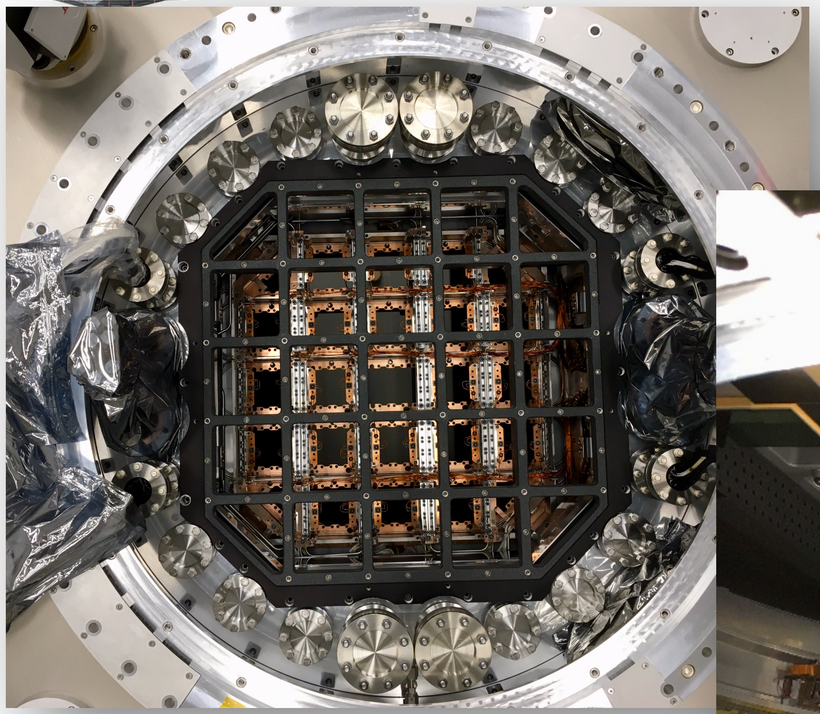


University of Arizona
Imaging Technology Laboratory

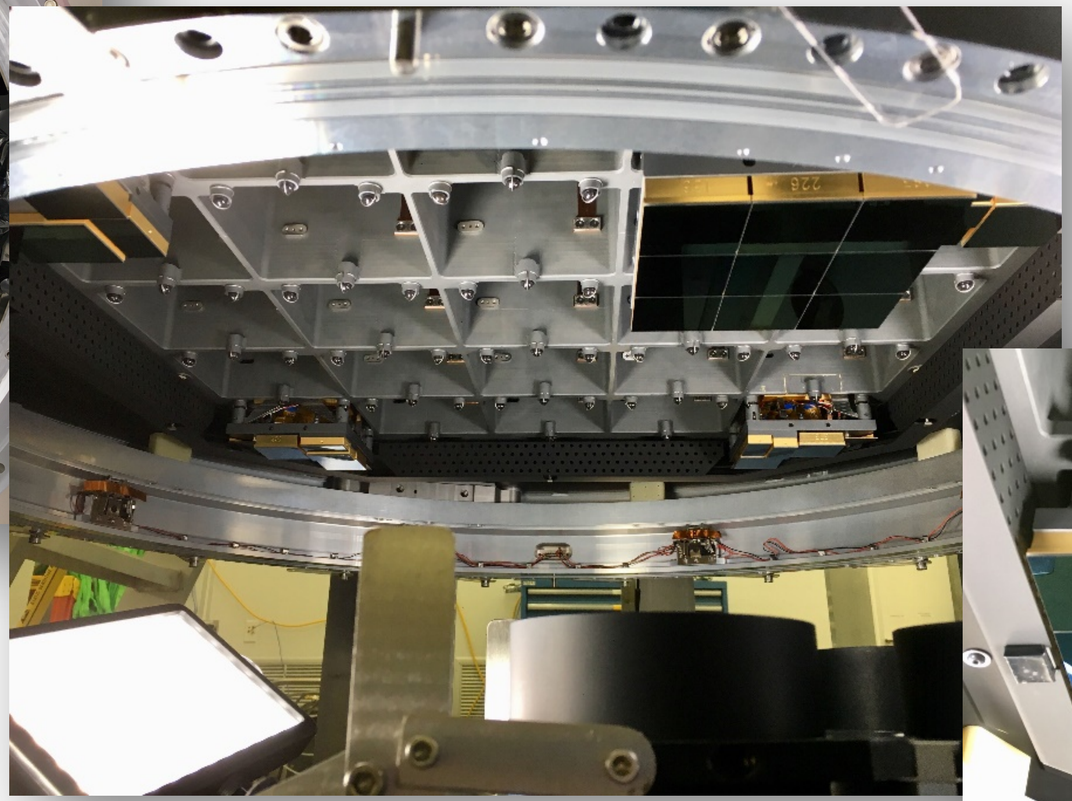


All Rafts assembled at Brookhaven National Labs

Science Raft Installation has begun!

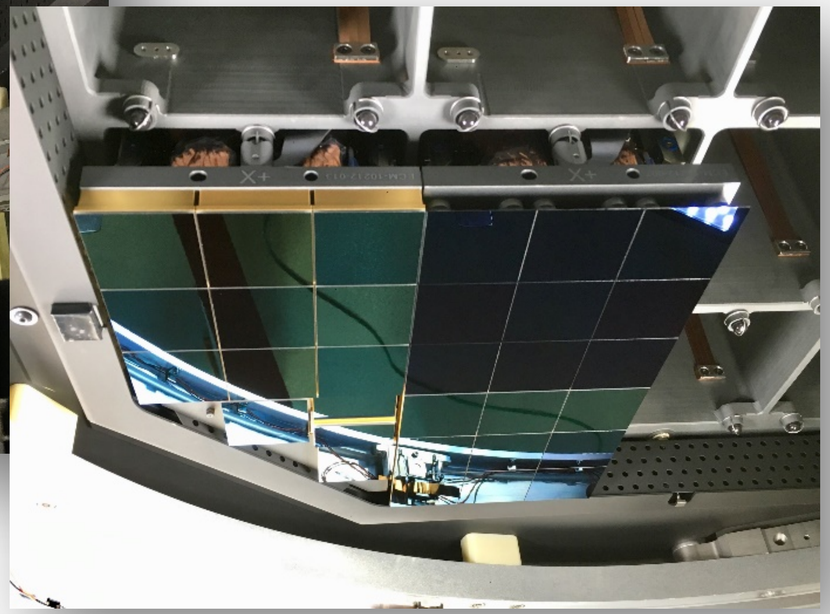


Front View of empty Cryostat



Cryostat with first rafts installed

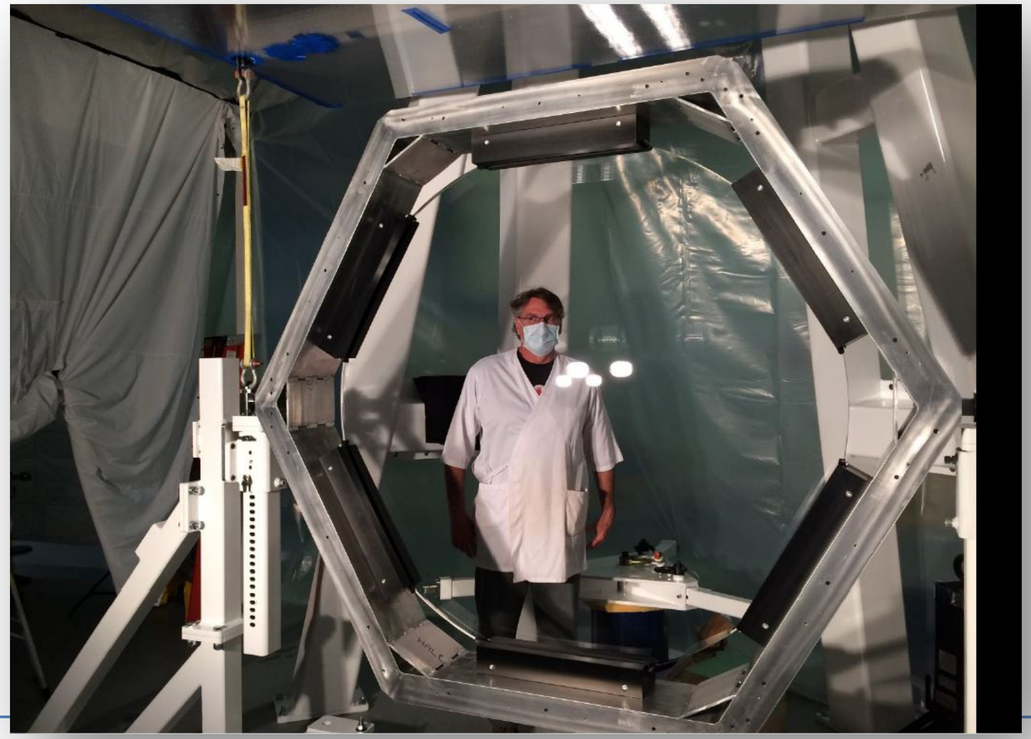
Three Sensor Rafts installed



Camera Lenses Finished

- Ball Aerospace leading L1 and L2 Assembly fabrication
  - Lenses polished at Arizona Optical
  - L1-L2 composite structure completed

L1-L2 assembly



L1 inspection

AOS
Arizona Optical Systems

Large Synoptic Survey Telescope

LSST Operations: Sites & Data Flows

HQ Site

Science Operations
Observatory Management
Education & Public Outreach

Base Site

Base Center
Long-term storage (copy 1)

Data Access Center
Data Access & User Services

French Site

Satellite Processing Center
Data Release Production
Long-term Storage (copy 3)

LSST Data Facility

Processing Center
Alert Production
Data Release Production
Calibration Products Production
EPO Infrastructure
Long-term Storage (copy 2)

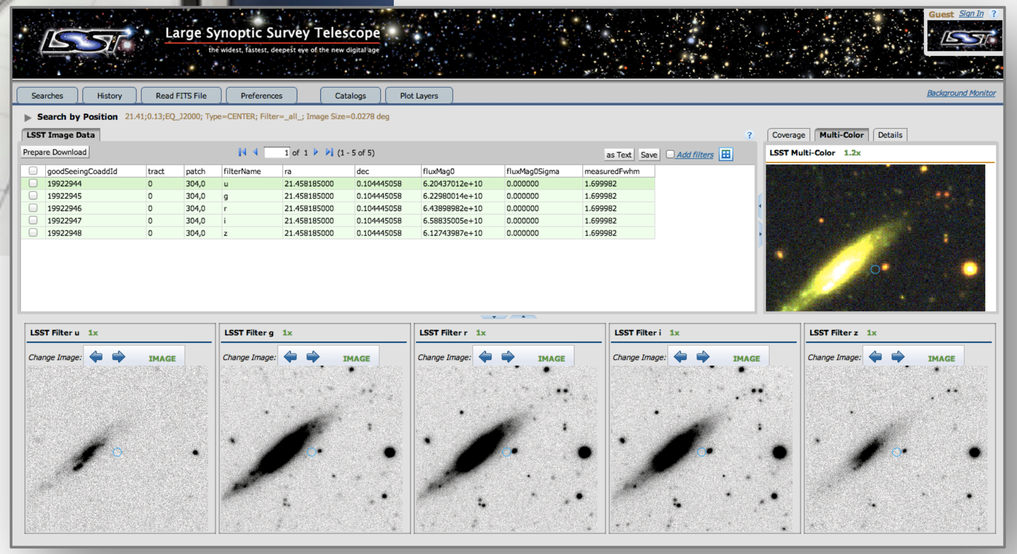
Data Access Center
Data Access and User Services

Summit Site

Telescope & Camera
Data Acquisition
Crosstalk Correction

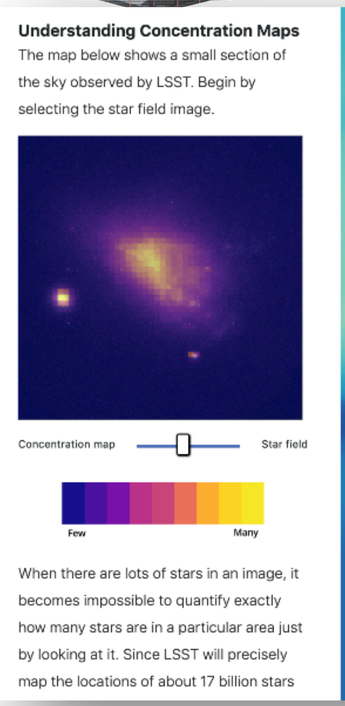
LSST Data Processing and Data Access

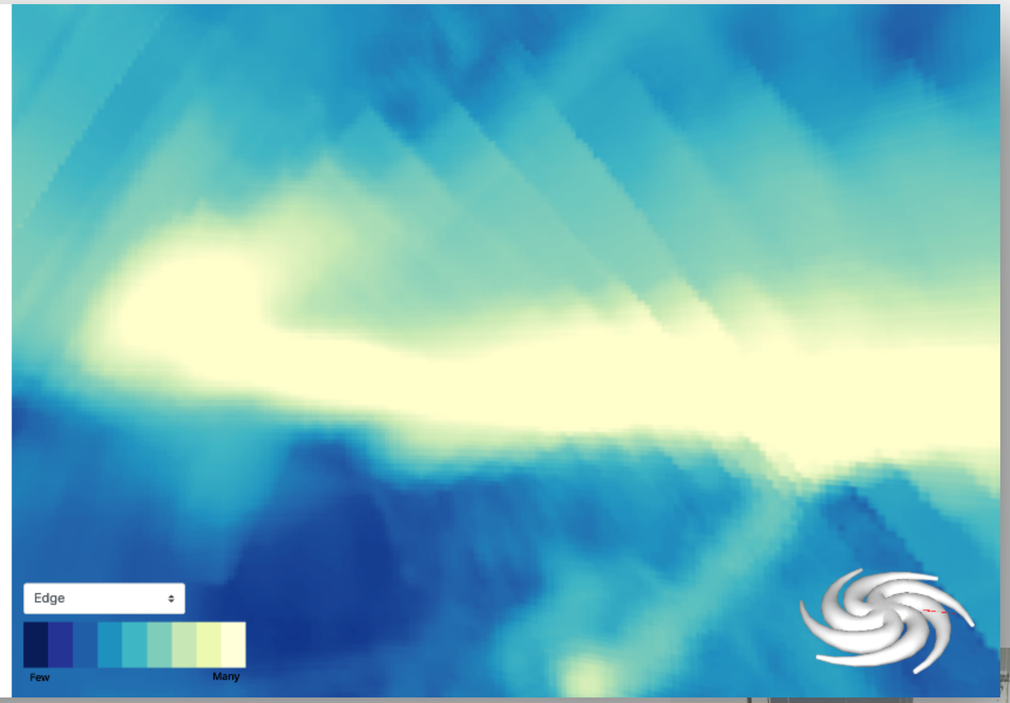
*A petascale supercomputing system at the **LSST Archive** (at NCSA) will process the raw data, generating reduced image products, time-domain alerts, and catalogs.*

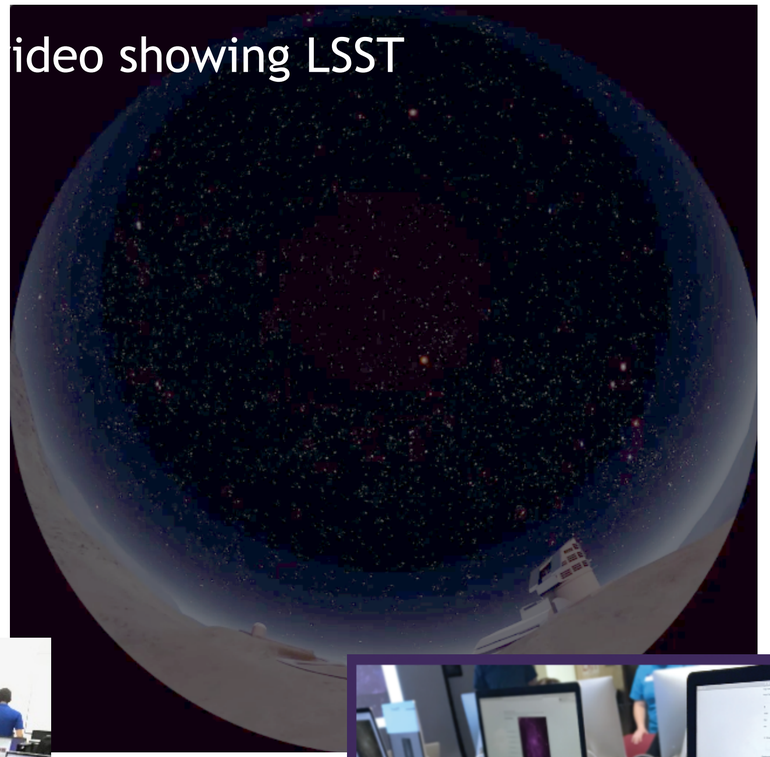


***Data Access Centers** in the U.S. and Chile will provide end-user analysis capabilities and serve the data products to LSST users.*

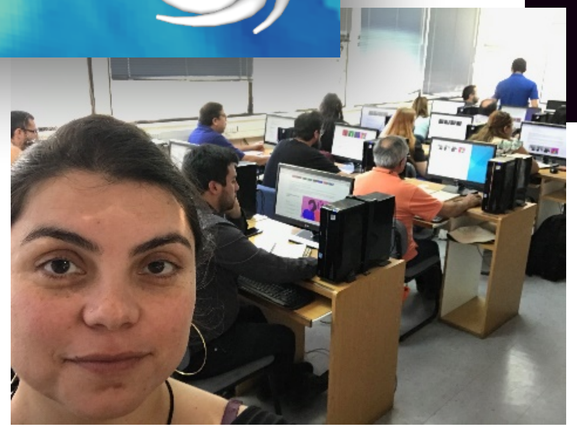
Education and Public Outreach Development Progressing well







In *Mapping the Milky Way*, students use LSST's extensive sky coverage and object density to discover the shape of our Galaxy and where we live within it



First Spanish-language user testing at Chile summer school

On schedule for First Light in 2021 and start of 10-year Survey in 2022

LSST & BLACK HOLES

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Hilton El Conquistador Turquoise Ballroom

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SPEAKERS

Feryal Özel,
University of Arizona

Feryal Özel is a Professor of Astronomy and Astrophysics in the Department of Astronomy at University of Arizona. She has made pioneering contributions to the physics of neutron stars and black holes, as well as to the co-evolution of black holes and galaxies in the early Universe. Dr. Özel led the Model Comparison group for the Event Horizon Telescope (EHT) that released the first image of a black hole in April of 2019. She made the first accurate measurements of the neutron star radii that constrain the ultradense matter equation of state. Based on her work on accretion flows, she made the first size predictions of the images of nearby supermassive black holes at different wavelengths.

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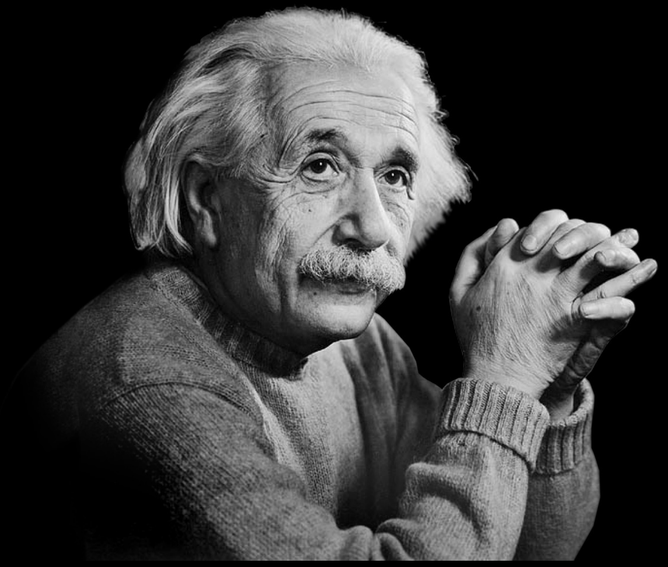
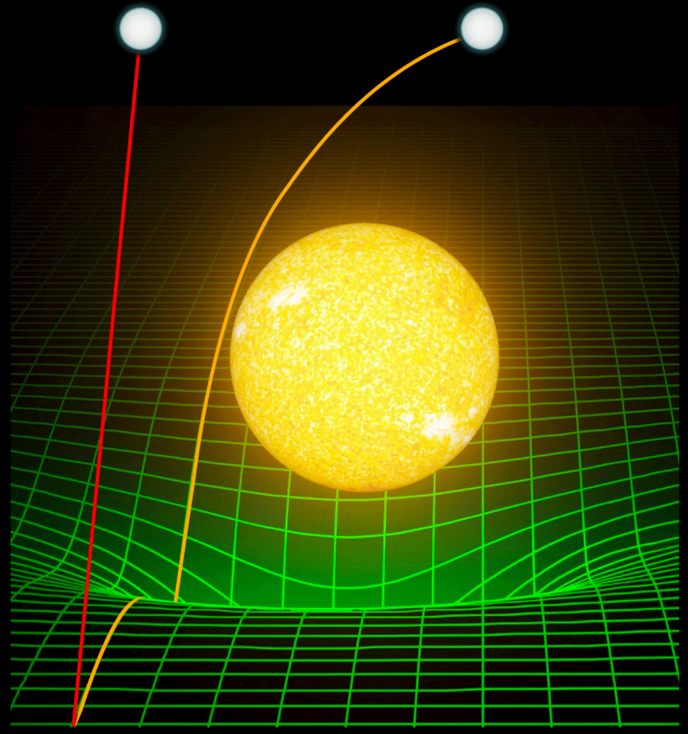
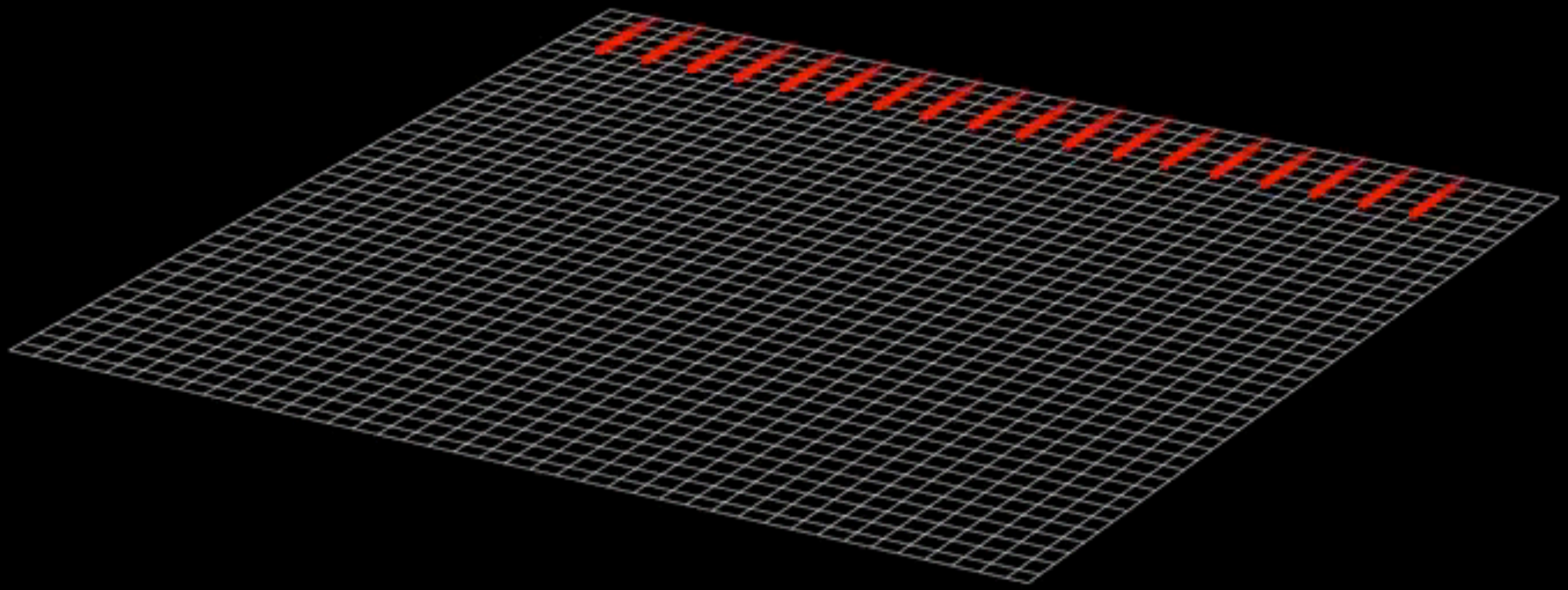
What IS a Black Hole?





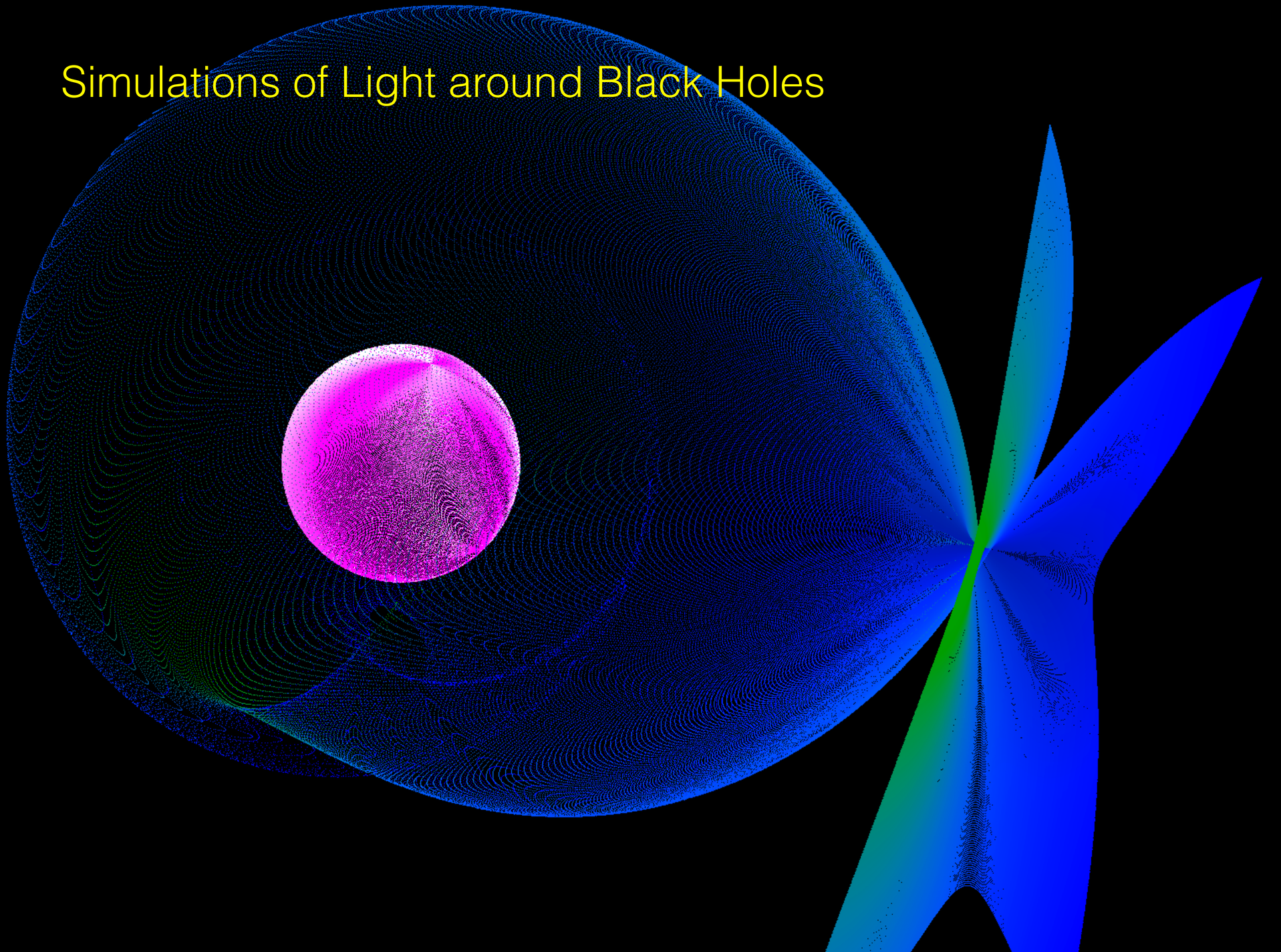
$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

The Event Horizon of a Black Hole

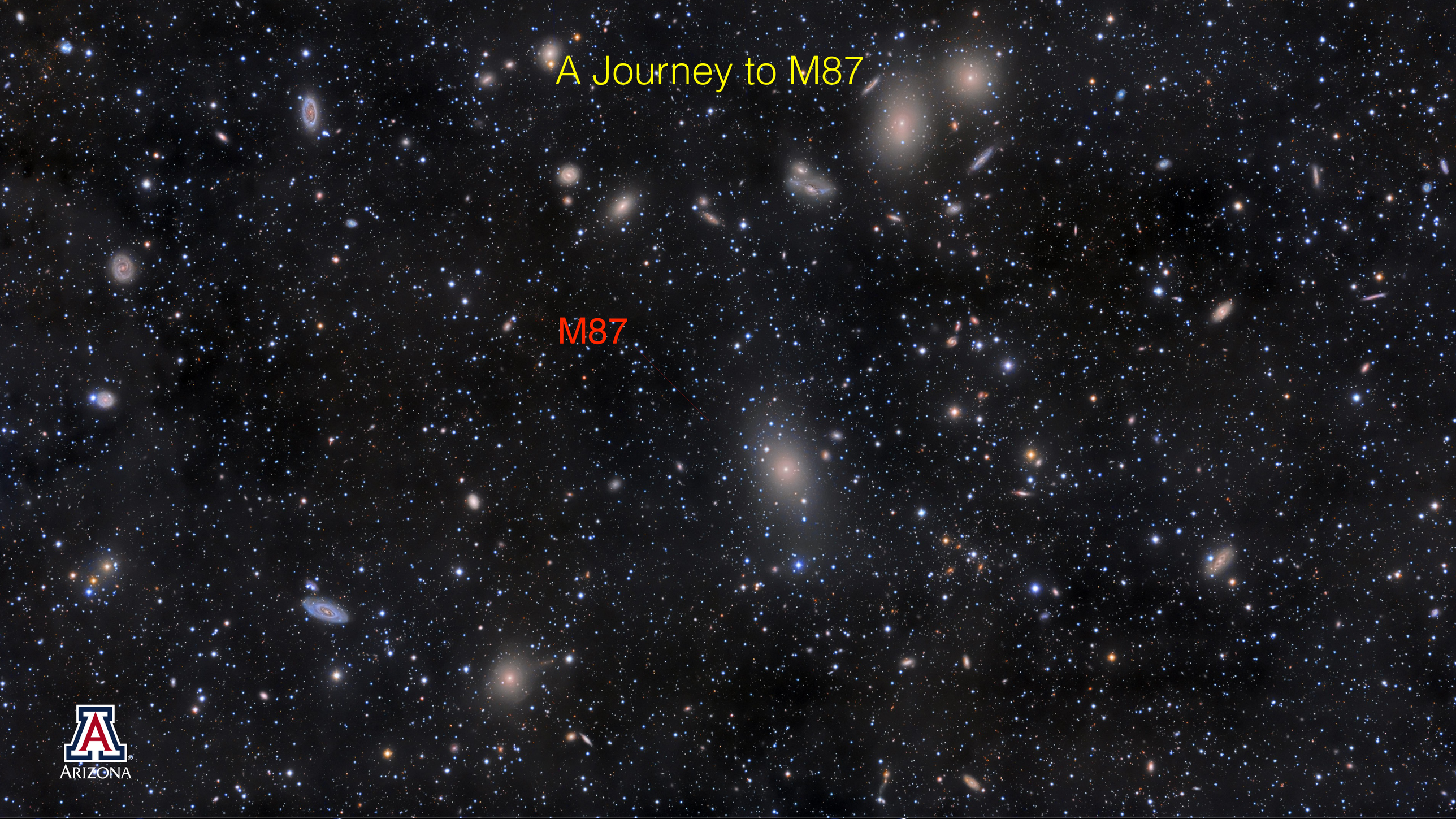


ARIZONA

Simulations of Light around Black Holes



A Journey to M87



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A Journey to M87

ARIZONA

Degree

60 Arcminutes

60 Arcseconds

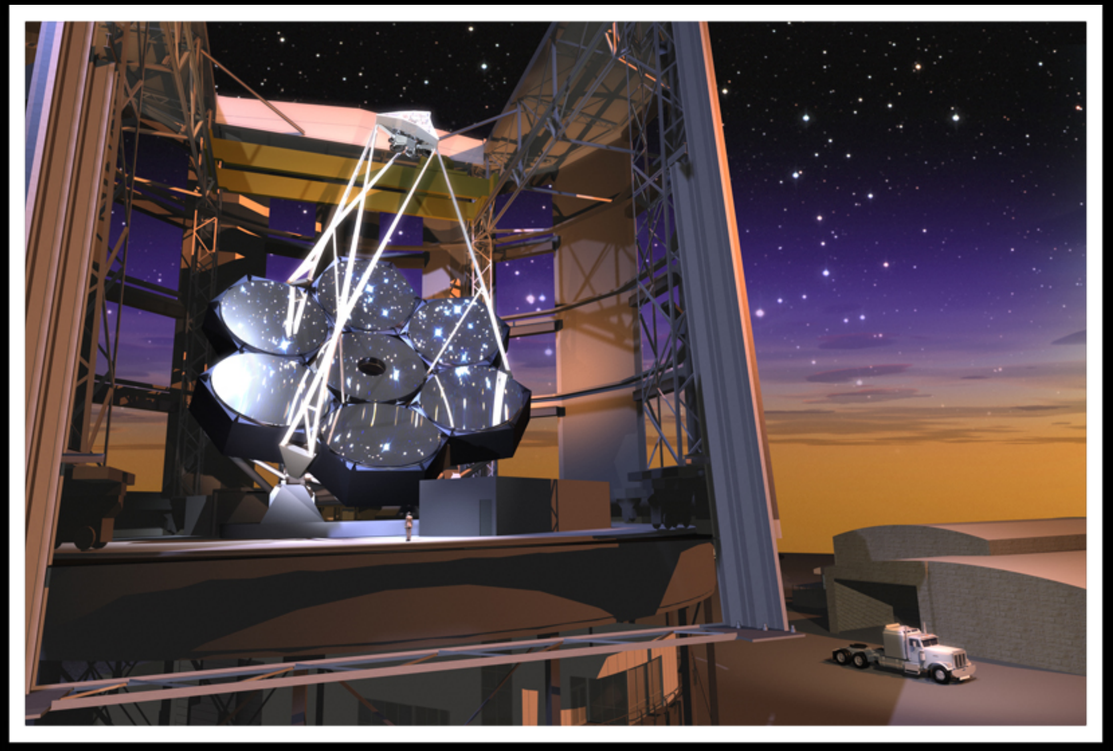
1000 Milliarcseconds

1000 Microarcseconds

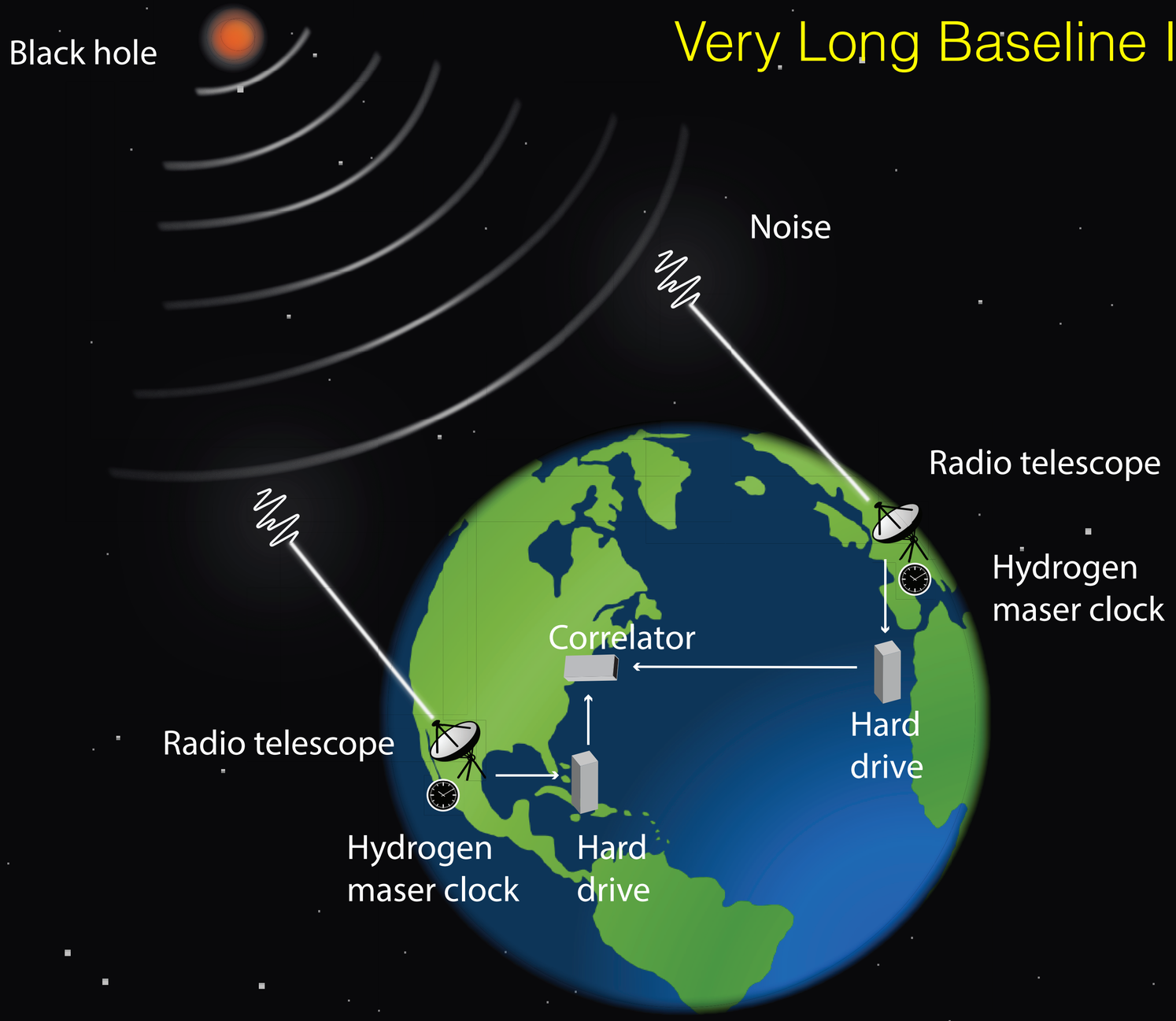
M87: 40 microarcsec!
1/100Millionth of a degree

ARIZONA


MEADE



Very Long Baseline Interferometry



ARIZONA

The Event Horizon Telescope

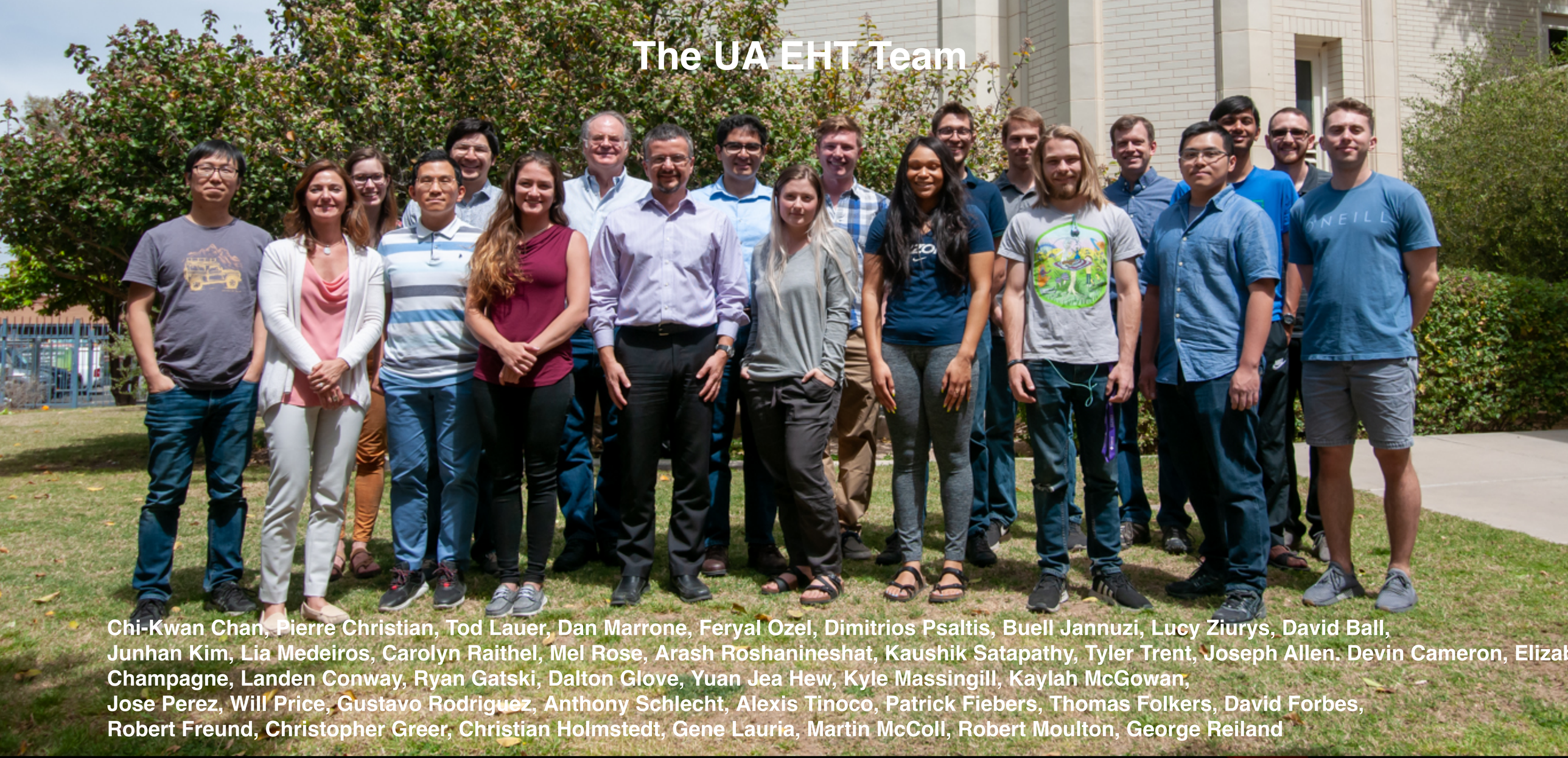
2017 Observations

ARIZONA

The Event Horizon Telescope Collaboration in 2018

ARIZONA

The UA EHT Team



Chi-Kwan Chan, Pierre Christian, Tod Lauer, Dan Marrone, Feryal Ozel, Dimitrios Psaltis, Buell Jannuzi, Lucy Ziurys, David Ball,
Junhan Kim, Lia Medeiros, Carolyn Raithel, Mel Rose, Arash Roshanineshat, Kaushik Satapathy, Tyler Trent, Joseph Allen. Devin Cameron, Elizab
Champagne, Landen Conway, Ryan Gatski, Dalton Glove, Yuan Jea Hew, Kyle Massingill, Kaylah McGowan,
Jose Perez, Will Price, Gustavo Rodriguez, Anthony Schlecht, Alexis Tinoco, Patrick Fiebers, Thomas Folkers, David Forbes,
Robert Freund, Christopher Greer, Christian Holmstedt, Gene Lauria, Martin McColl, Robert Moulton, George Reiland

UA SCIENCE
Astronomy
& Steward Observatory

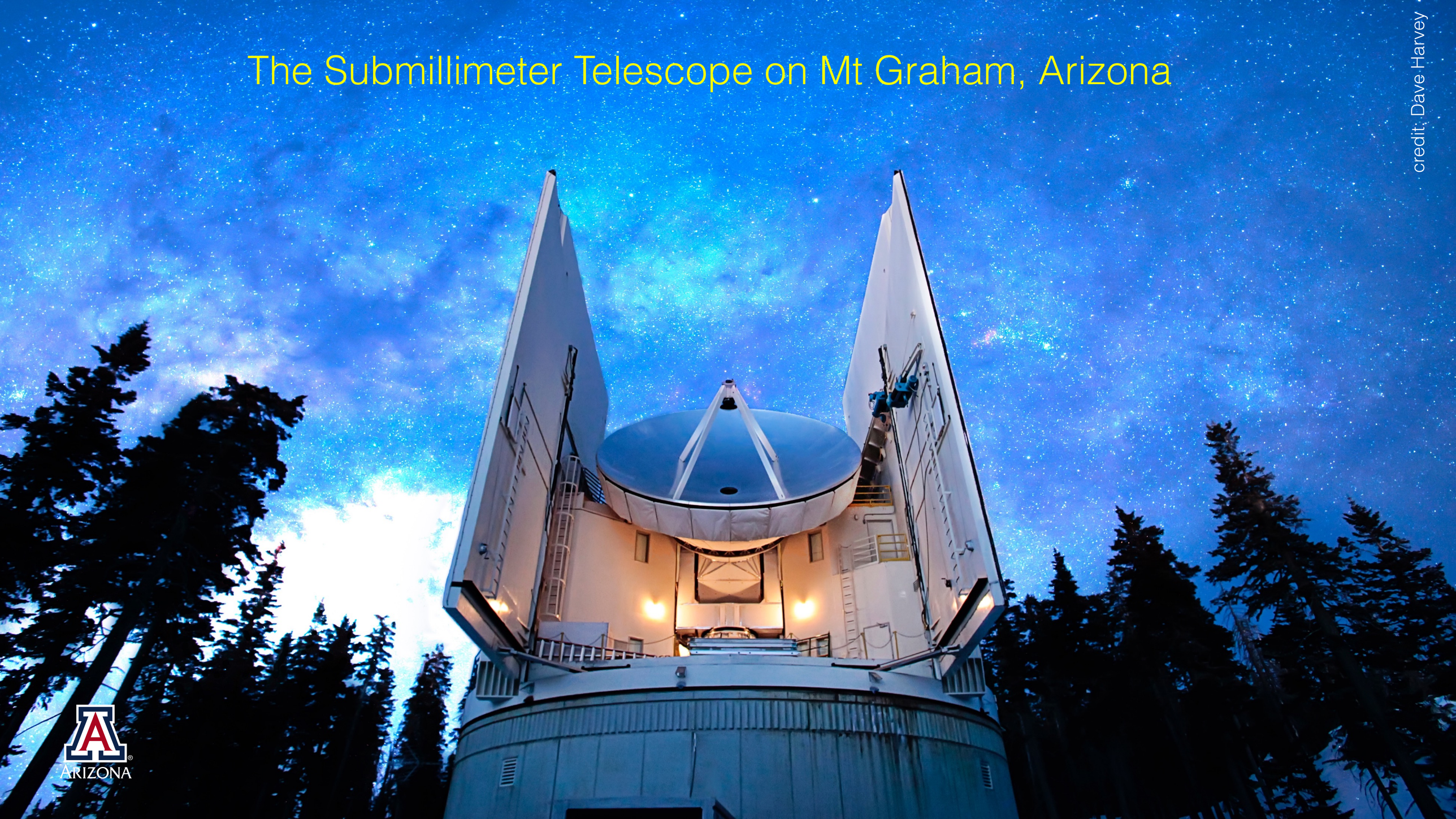
Event Horizon Telescope

NOAO

NSF

Black Hole
PIRE

The Submillimeter Telescope on Mt Graham, Arizona



credit: Dave Harvey

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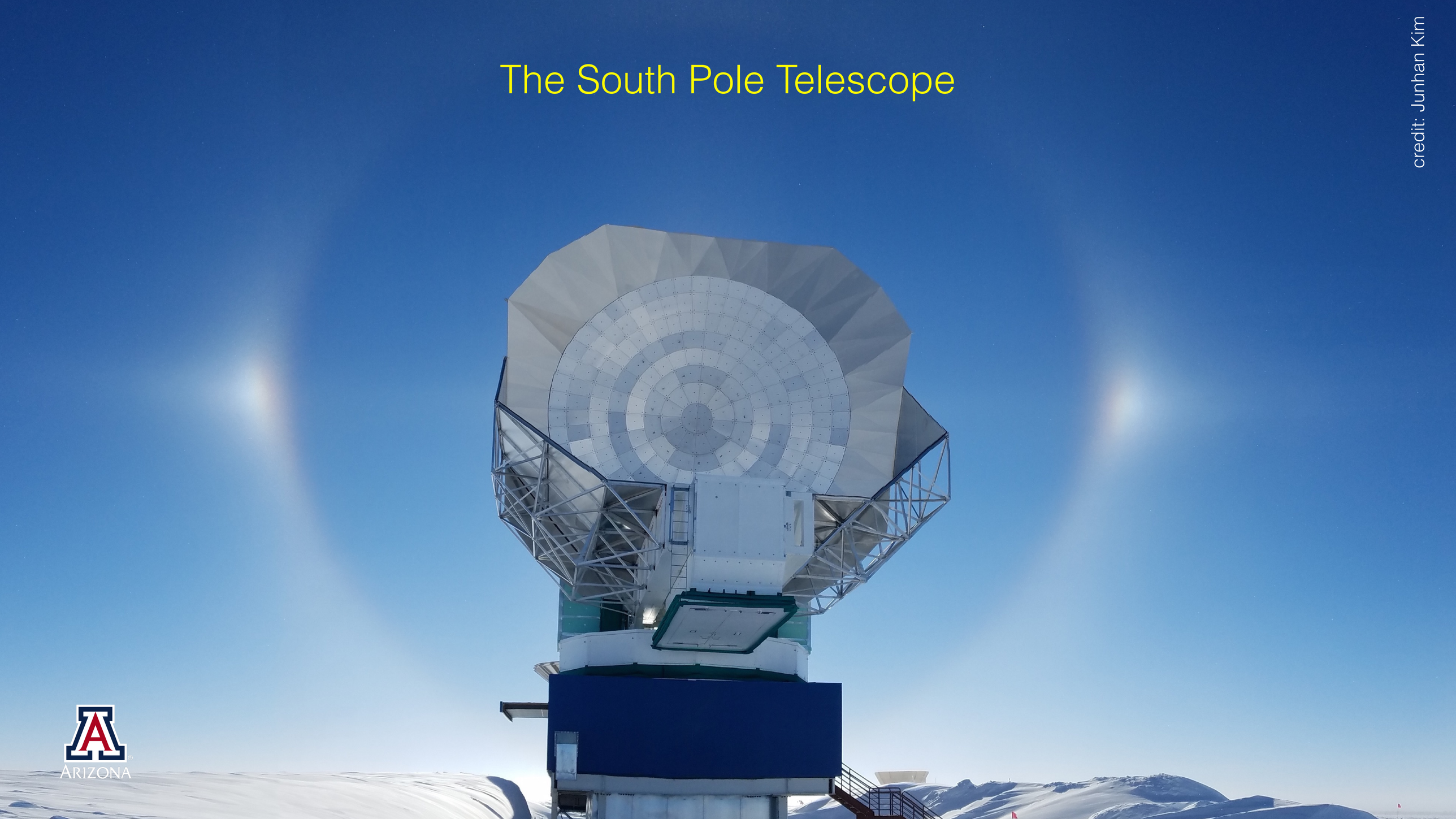
The South Pole Telescope



credit: Junhan Kim

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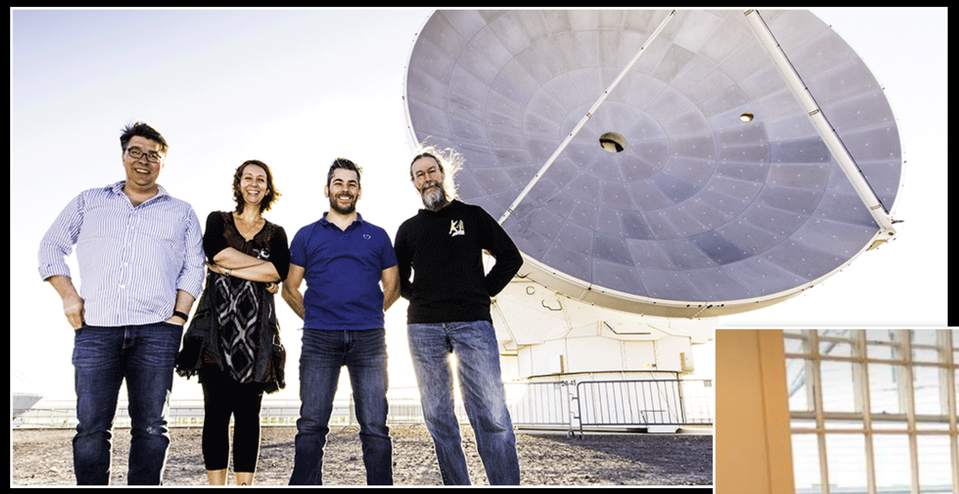
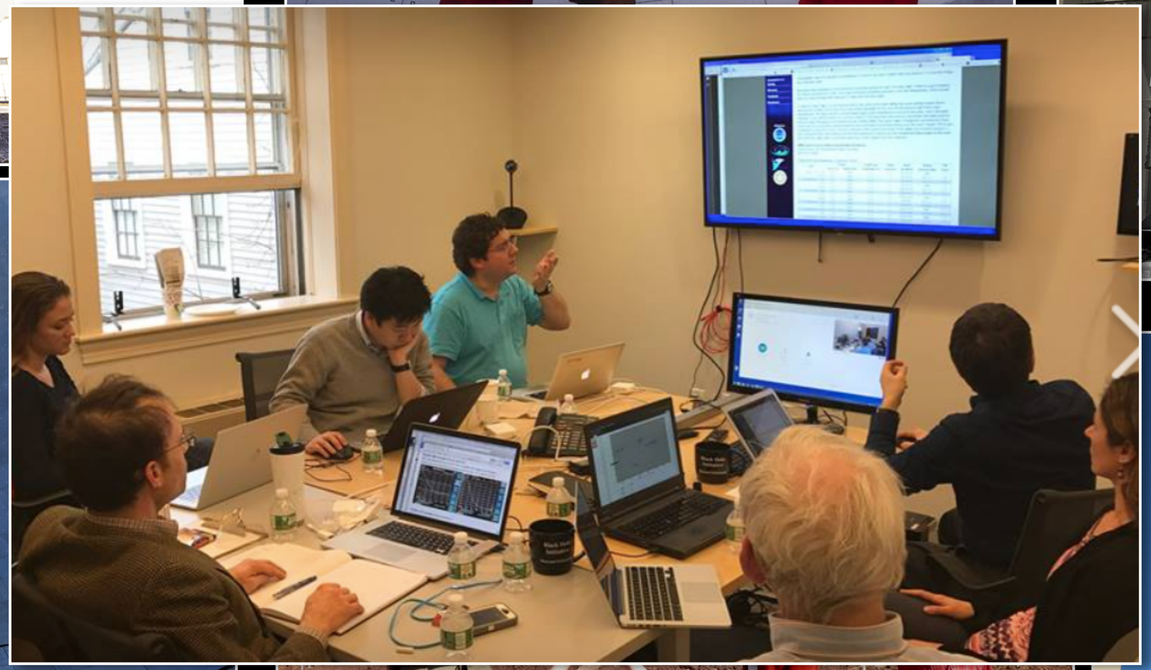
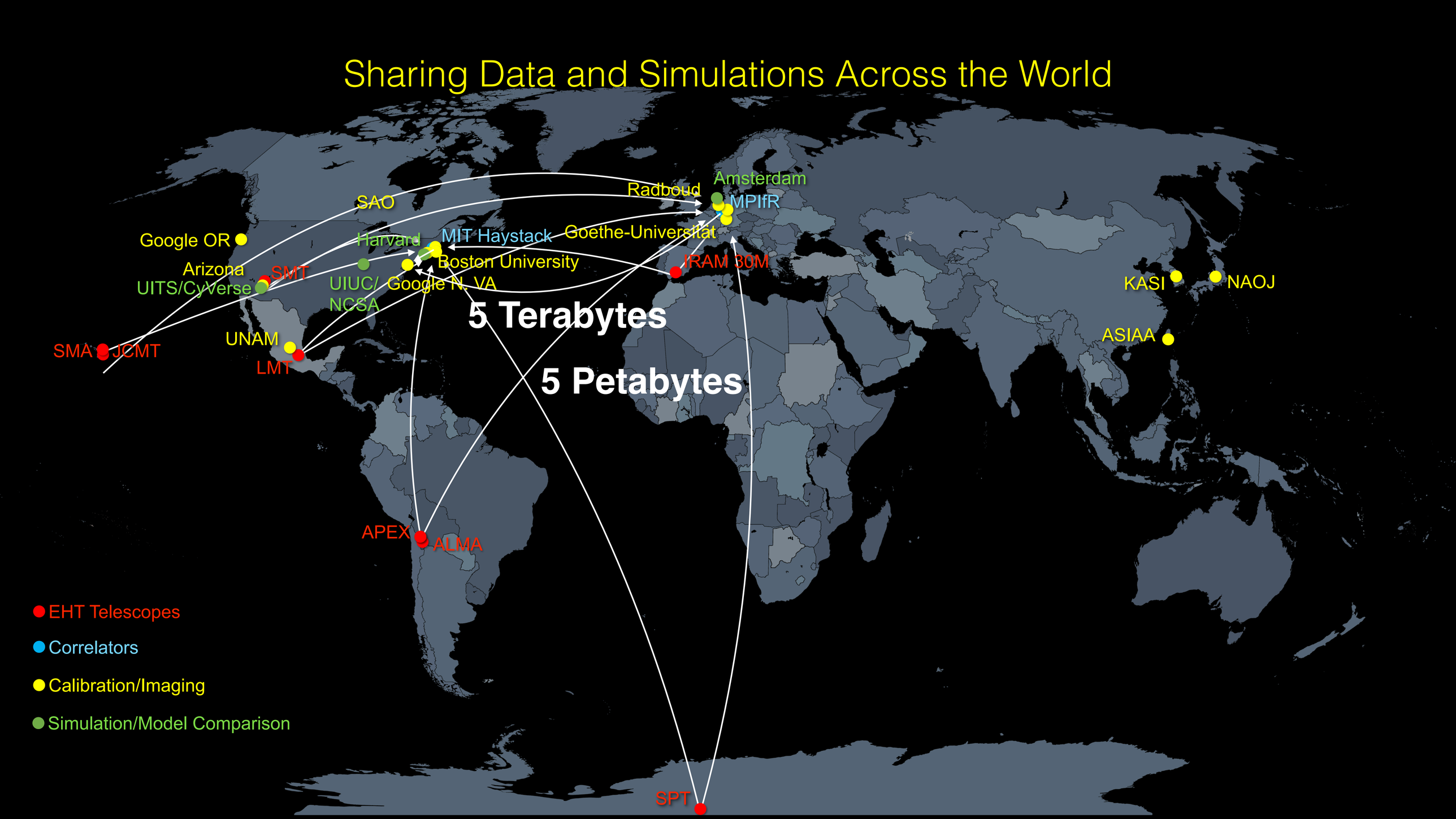
April 5-11, 2017: First Observations



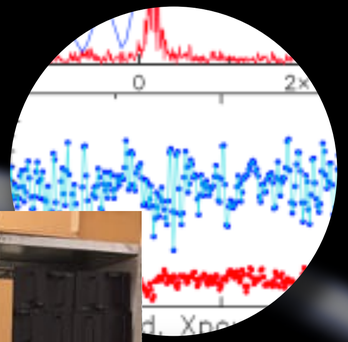


Sharing Data and Simulations Across the World



Correlation
1/1,000

Fringe Fitting
1/10,000



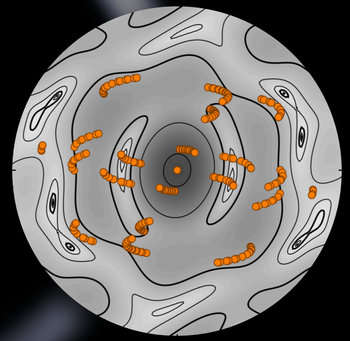
Data Modules
5 petabytes

Nov 2017

Apr 2017

h 2018

Imaging
1/1,000



August 2018

Announcement
April 2019

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The New York Times
Frankfurter Allgemeine
THE TIMES
May defies Tory rebels with pledge to stay on
LE FIGARO
Européennes : Macron veut orchestrer la campagne
THE WALL STREET JOURNAL.
EL PAÍS
deVolkskrant
Jyllands-Posten
Süddeutsche Zeitung
ブラックホール初撮影
Le Télégramme
VERTIGINEUX !
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General-Anzeiger
ClarínX
Preparan un acuerdo para frenar los precios en medio de una pulseada interna
DE TIJD
DERSTANDARD
ST. LOUIS POST-DISPATCH
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FINANCIAL TIMES
Microsoft under fire over AI work with Chinese military university
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wyborcza
EGZAMIN Z KSIĘDZEM I TELEFONEM
DIE WELT
Rechtsgutachten kritisiert Steuervorteile für ARD und ZDF
Militias, chaos and starvation
The Guardian
May defies critics with vow to stay on and see Brexit deal through
Los Angeles Times
la Repubblica
La luce in quel pozzo
Italia-Libia il negoziato segreto
GARA
LA VANGUARDIA
theindependent
Nusrat loses battle for life
DER TAGESSPIEGEL
Union-Tribune
CHINA DAILY
HOSPODÁŘSKÉ NOVINY
Miliardová žaloba proti Vítkovi
EL MUNDO
Casado envía a Aznar a las provincias que le disputa Vox
ブラックホール 初撮影
THE IRISH TIMES
MORGENAVISEN Jyllands-Posten
The Boston Globe
Créditos de construtor que deu prenda a Salgado põem Montepio sob pressão
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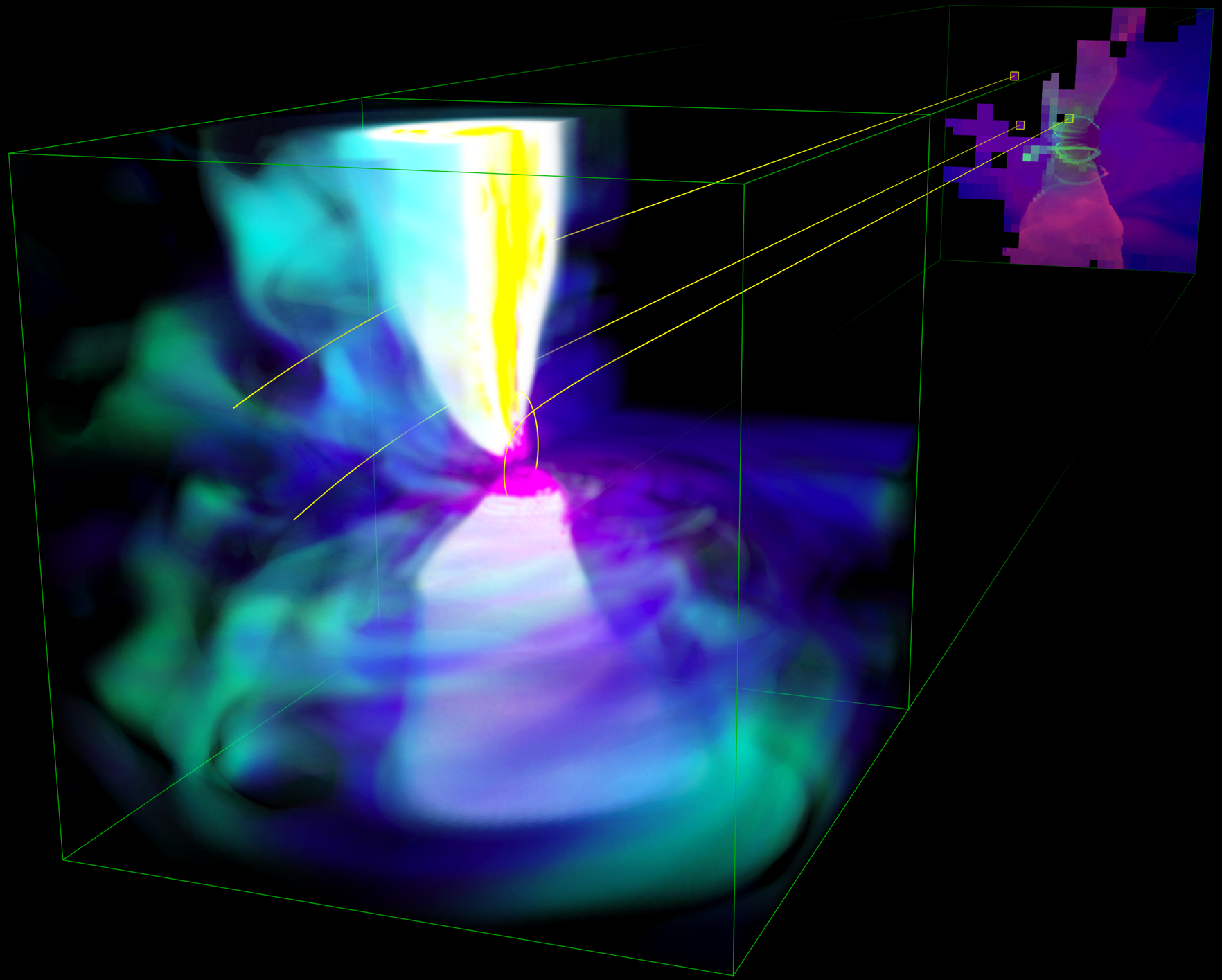

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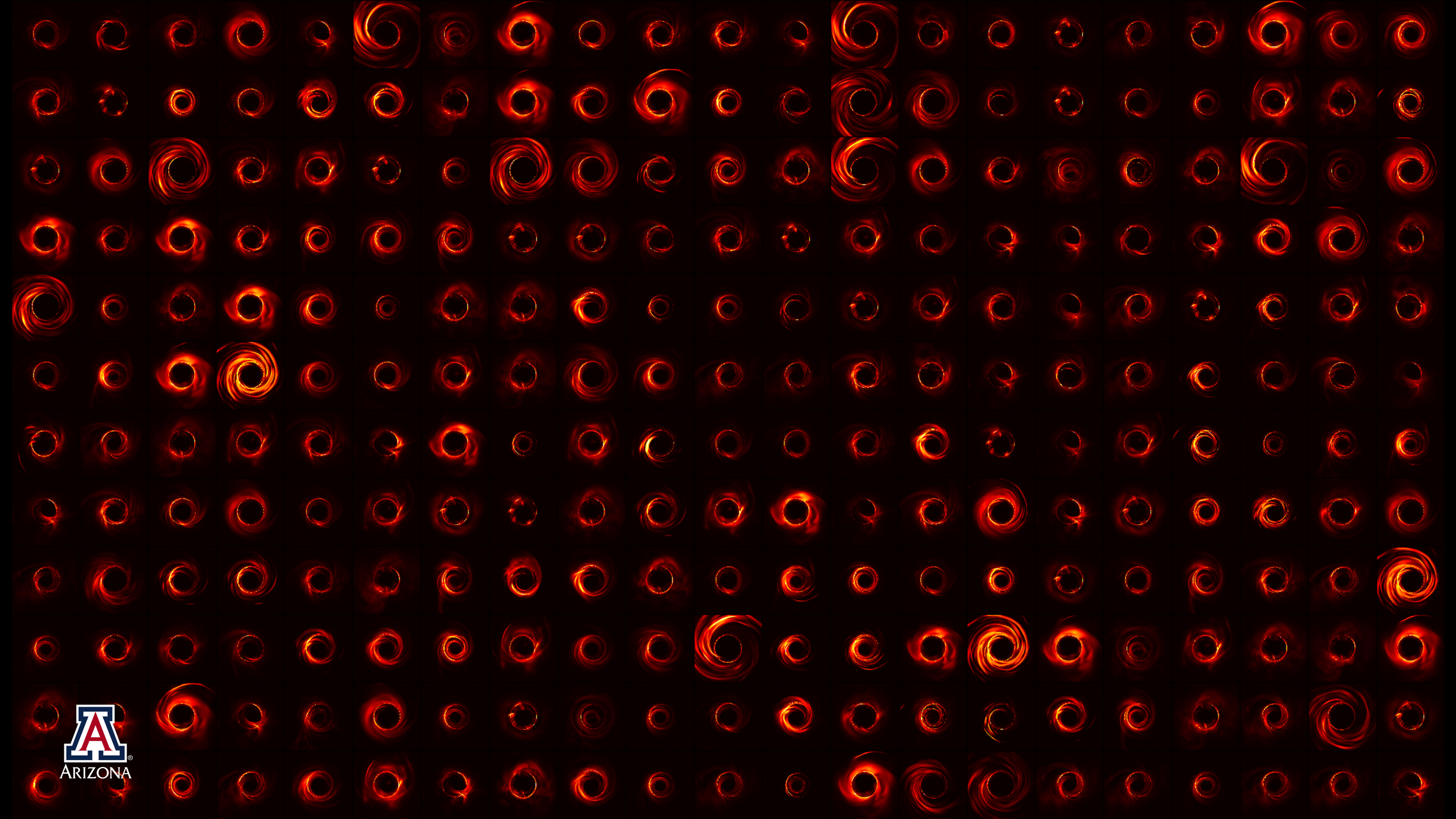
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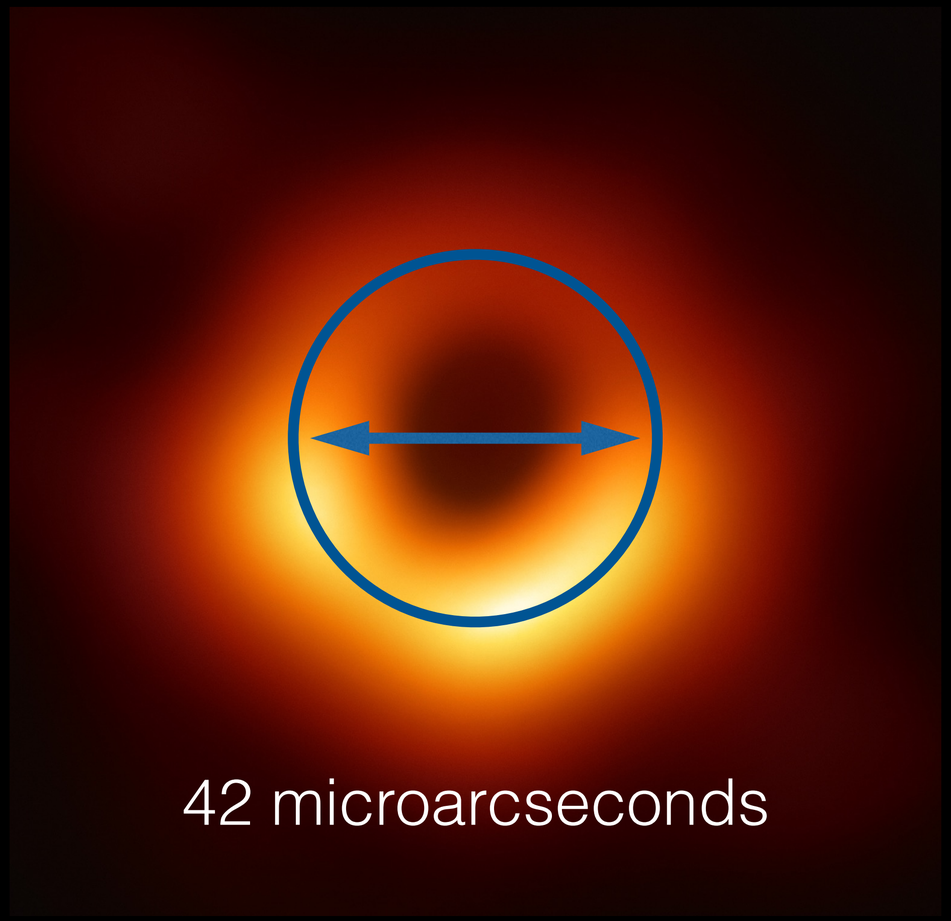
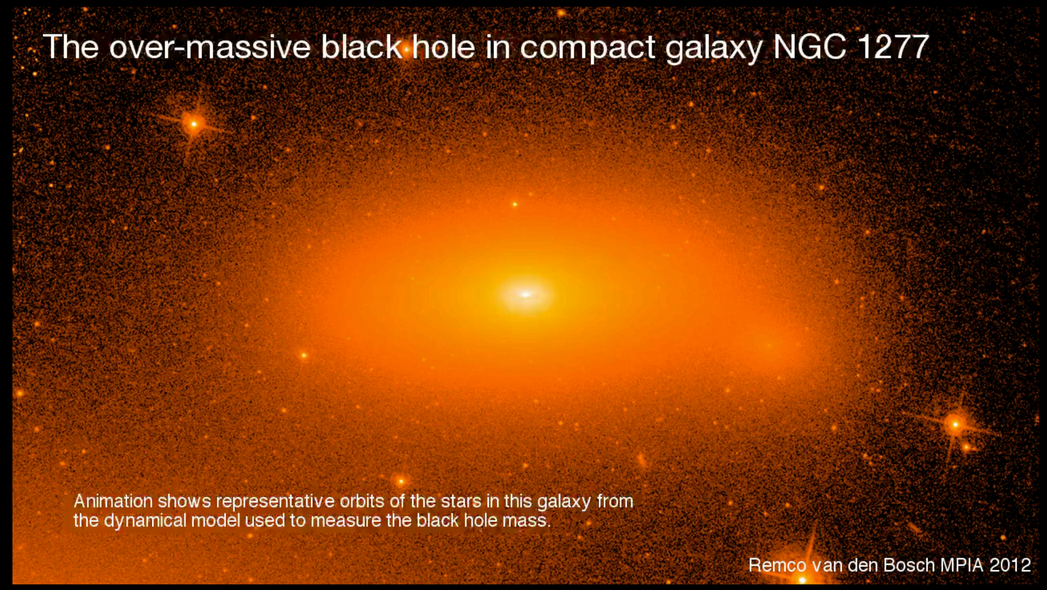
Measuring the Mass of the Black Hole





Black Hole Mass
=6.5 Billion Solar Masses

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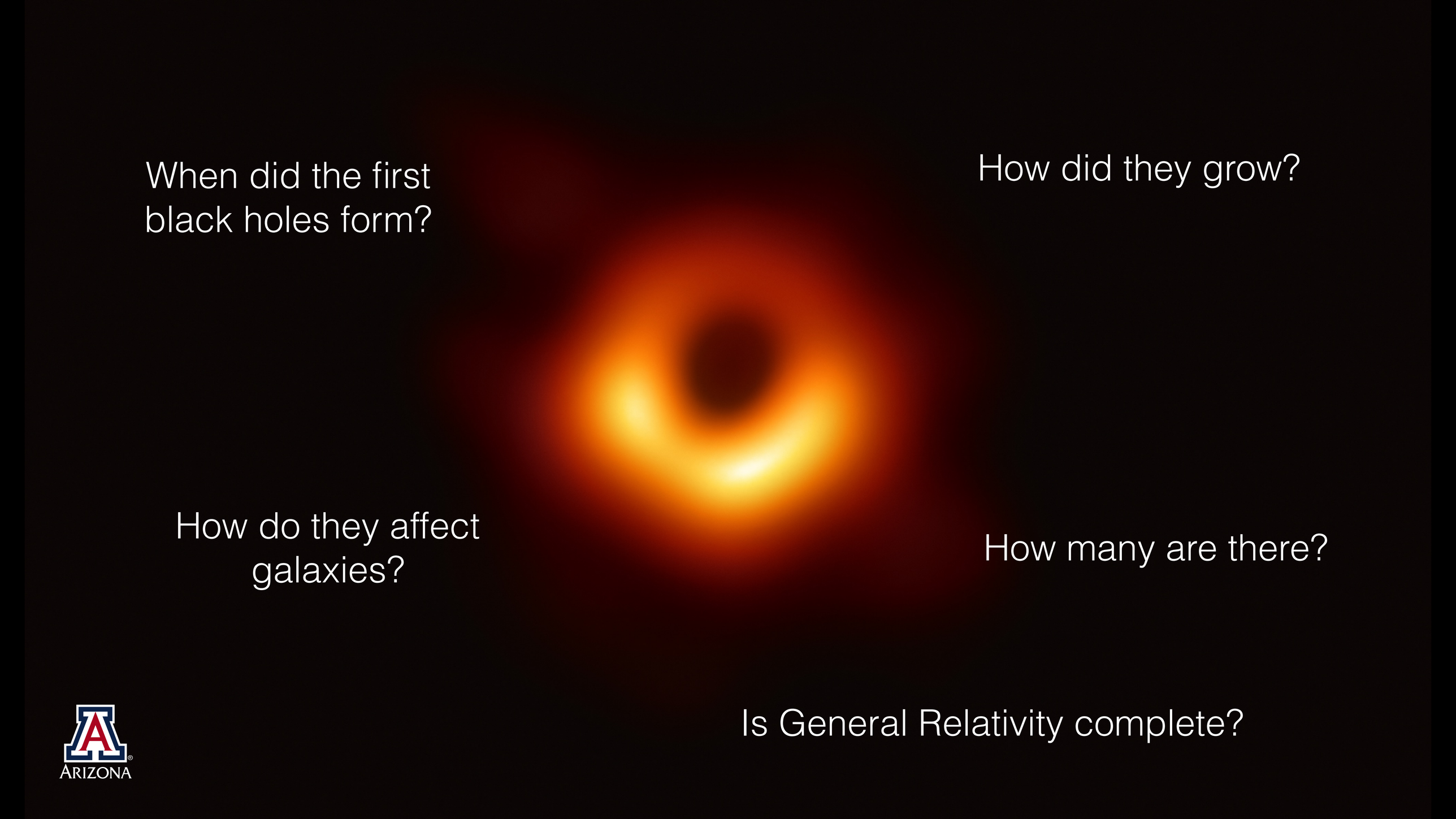
When did the first black holes form?

How did they grow?



How do they affect galaxies?

How many are there?

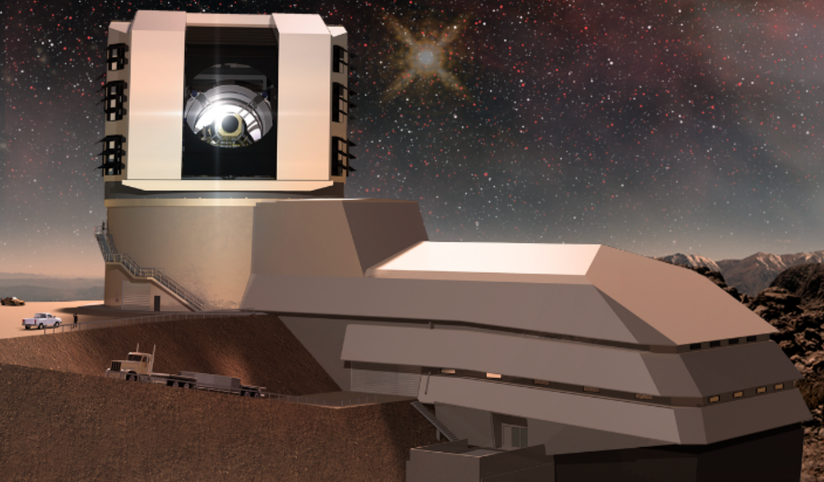
Is General Relativity complete?

ARIZONA

LSST & BLACK HOLES

The Large Synoptic Survey Telescope (LSST) is approaching completion on the Cerro Pachón ridge in north-central Chile. When science operations begin in 2022, LSST will scan the sky with the world's largest digital camera, creating a 500 petabyte set of images and data products that will address the most pressing questions about the structure and evolution of the universe and the objects in it. Among these objects are black holes, objects so dense they warp the fabric of space-time, objects whose incredible properties are only recently becoming known to us. You are invited to join us for an evening of black hole science and learn about Tucson's leadership role in LSST's voyage of scientific discovery.

During this public event, LSST Project Manager Victor Krabbendam will provide an update on LSST construction progress,University of Arizona astrophysicist Feryal Özel will discuss the latest black hole discoveries from the Event Horizon Telescope (EHT) and Northwestern University's Raffaella Margutti will describe what we have learned from the first multi-messenger observations of a neutron star merger with gravitational waves and light, and what might be revealed when LSST begins its ten-year survey.



Hilton El Conquistador Turquoise Ballroom

10000 North Oracle Road,Tucson, Arizona, 85704

SPEAKERS

Raffaella Margutti,
Northwestern University

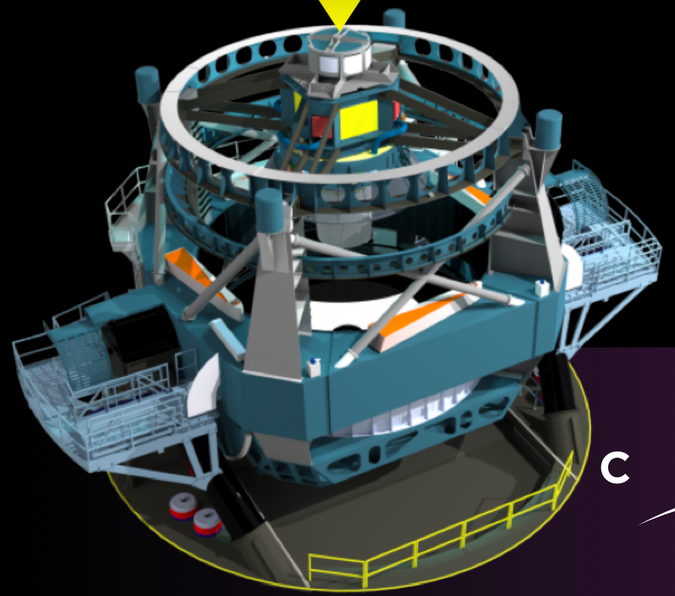
Raffaella Margutti is an Assistant Professor in the Department of Physics & Astronomy at Northwestern University. She utilizes observations of transient astrophysical phenomena including stellar explosions and stellar tidal disruptions by supermassive black holes. She serves as the chair of the Gravitational Wave source follow-up with LSST within the LSST Transient and Variable Stars science collaboration. As an astrophysicist, her research s pecifically focuses on the biggest explosions and disruptions that occur in our Universe: Supernovae, Gamma-Ray Bursts, compact stellar mergers that are sources of gravitational waves and tidal disruption events. Dr. Margutti investigates the physics of these events by combining broad-band observations across the electromagnetic spectrum, including X-ray, UV, optical, IR, and radio. The primary goal of her research is to understand the nature of the physical processes that regulate such dramatic displays.

8.15.2019 @ 7pm

Hunting for Black Holes in our Universe with The Large Synoptic Survey Telescope

Raffaella Margutti

"We always find something, eh Didi, to give us the impression we exist?"



NORTHWESTERN UNIVERSITY

CIERA

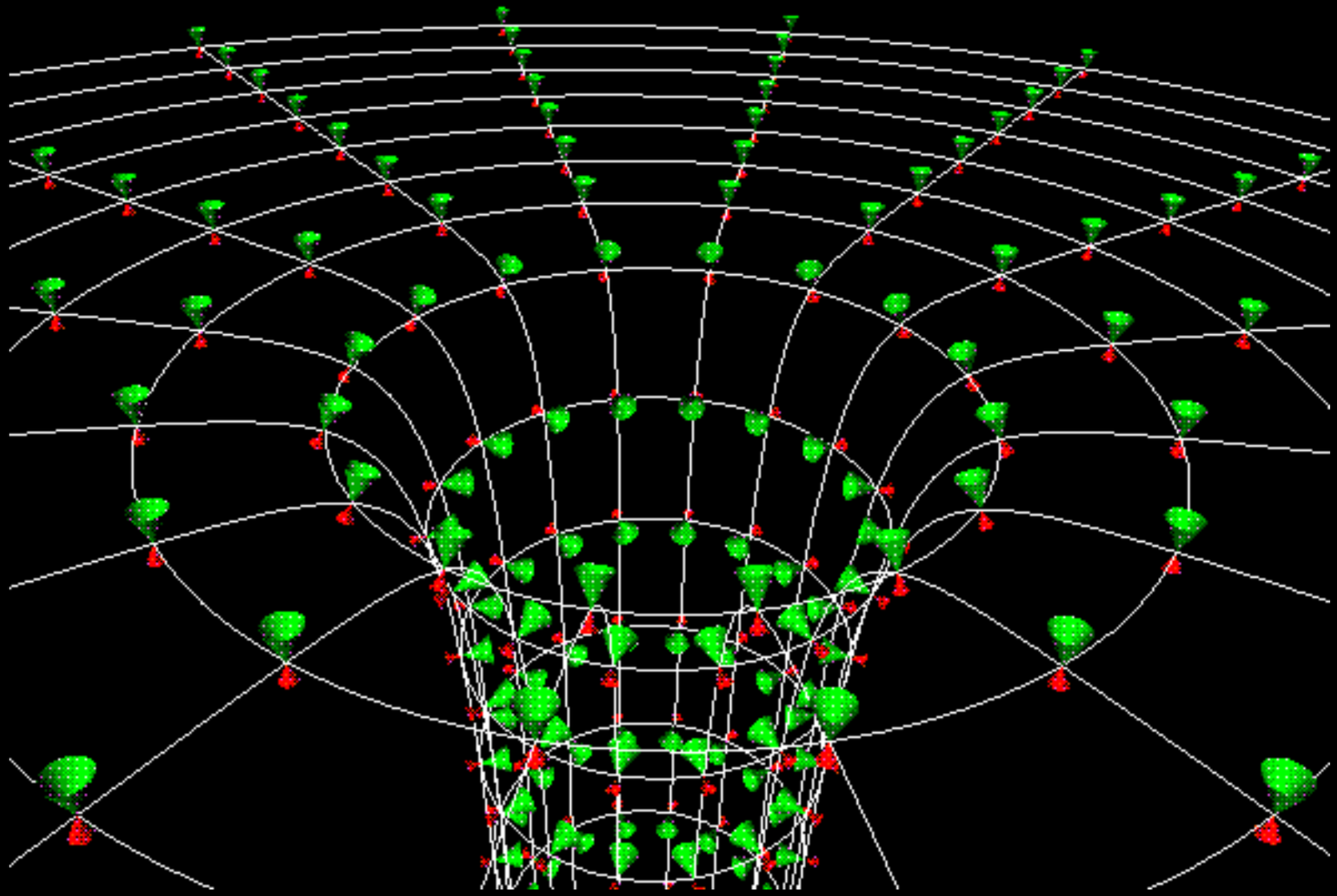
Stellar Mass BHs
Mass~1 ✹

Intermediate Mass BHs
Mass ~ 10^2-10^4 ✹

Supermassive BHs
Mass>10^6 ✹

Black Hole Mass

Extreme Gravity



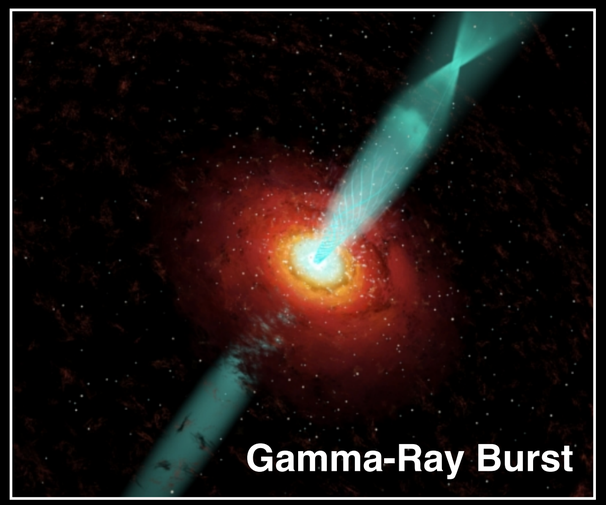
Black Hole

Stellar Mass BHs
Mass~1 ✹

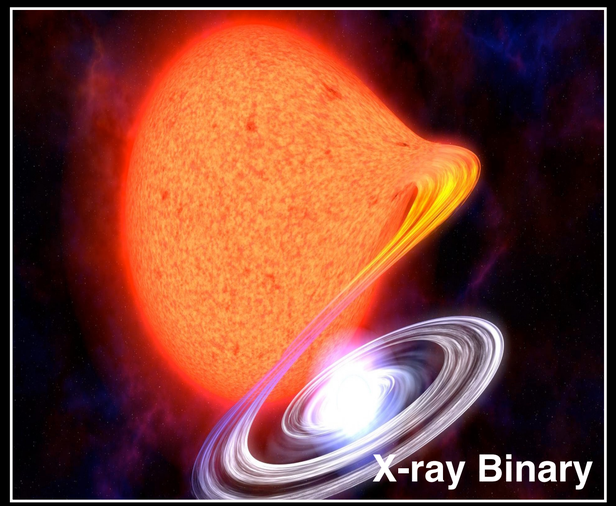
Intermediate Mass BHs
Mass ~ 10^2-10^4 ✹

Supermassive BHs
Mass>10^6 ✹

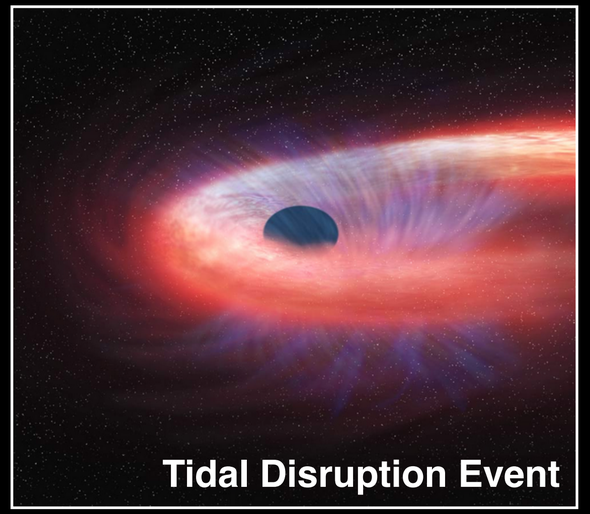
Feeding on its own progenitor star



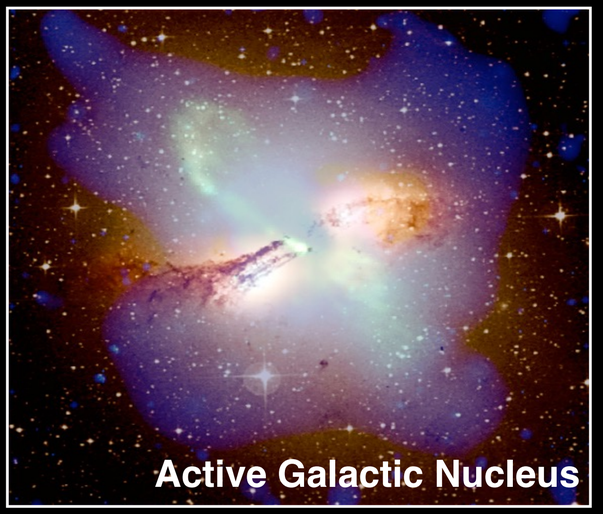
Feeding on the companion star



Feeding on host galaxy stars

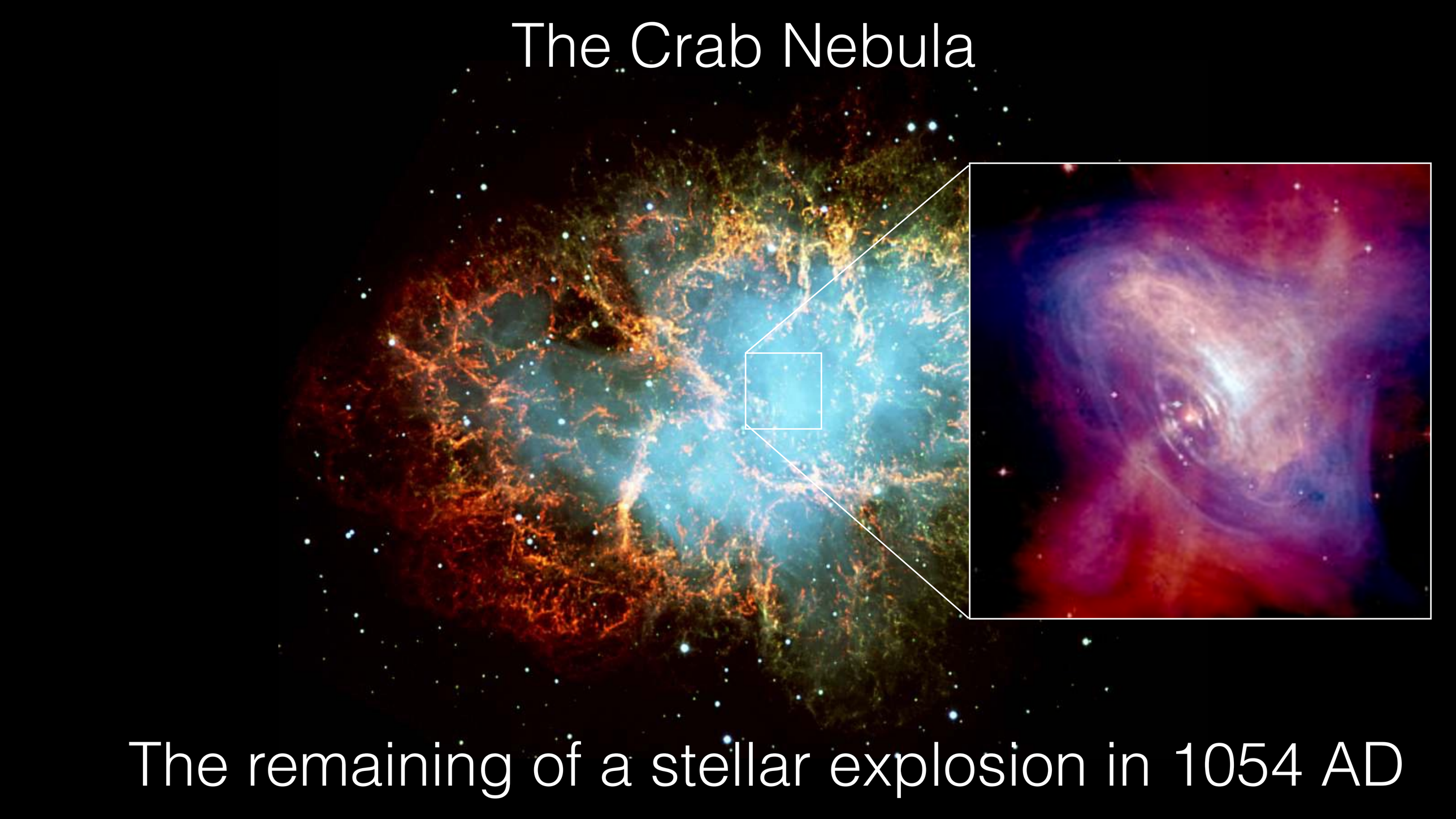


Feeding on host galaxy gas



An ongoing fight for survival

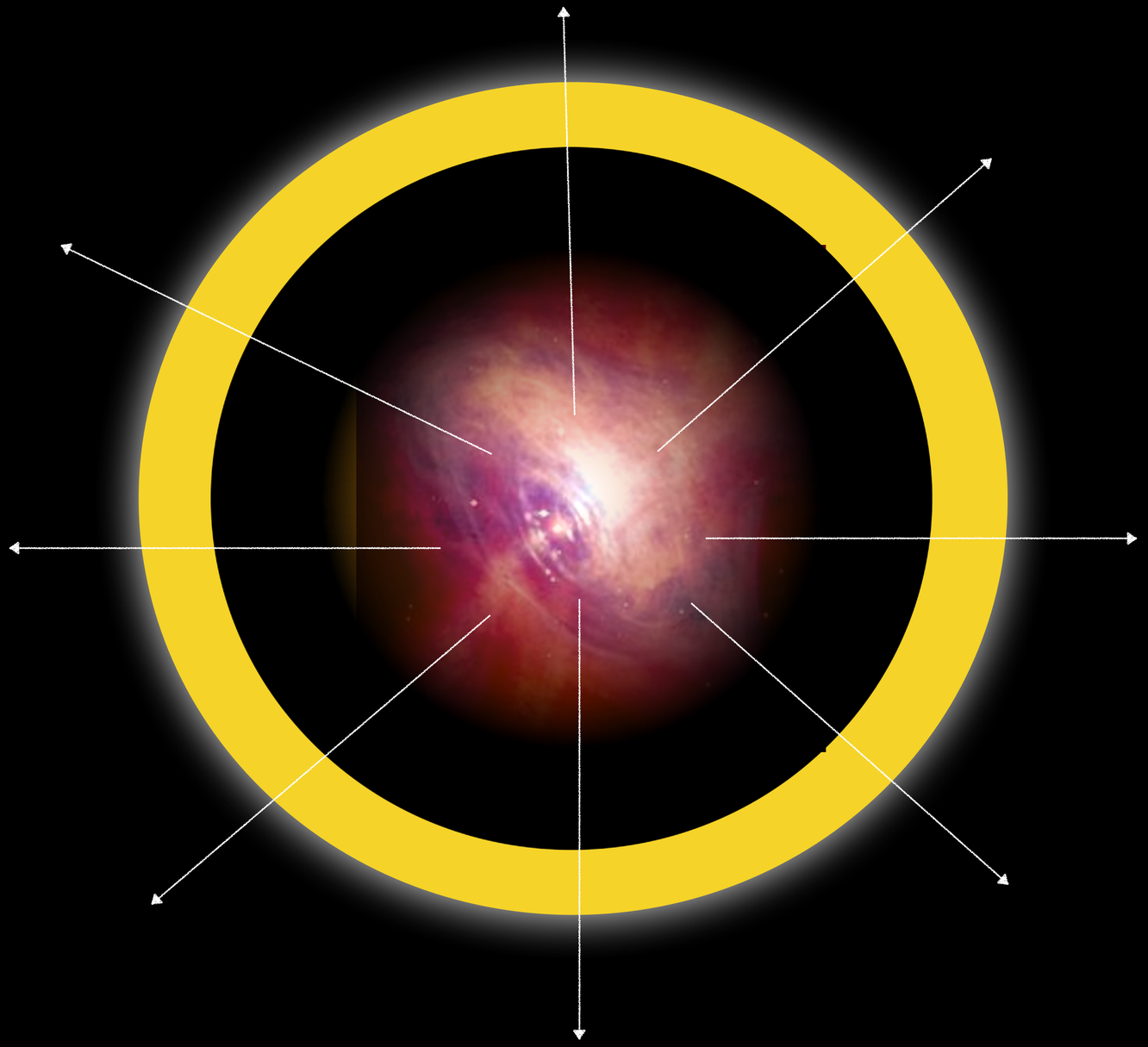
The Crab Nebula



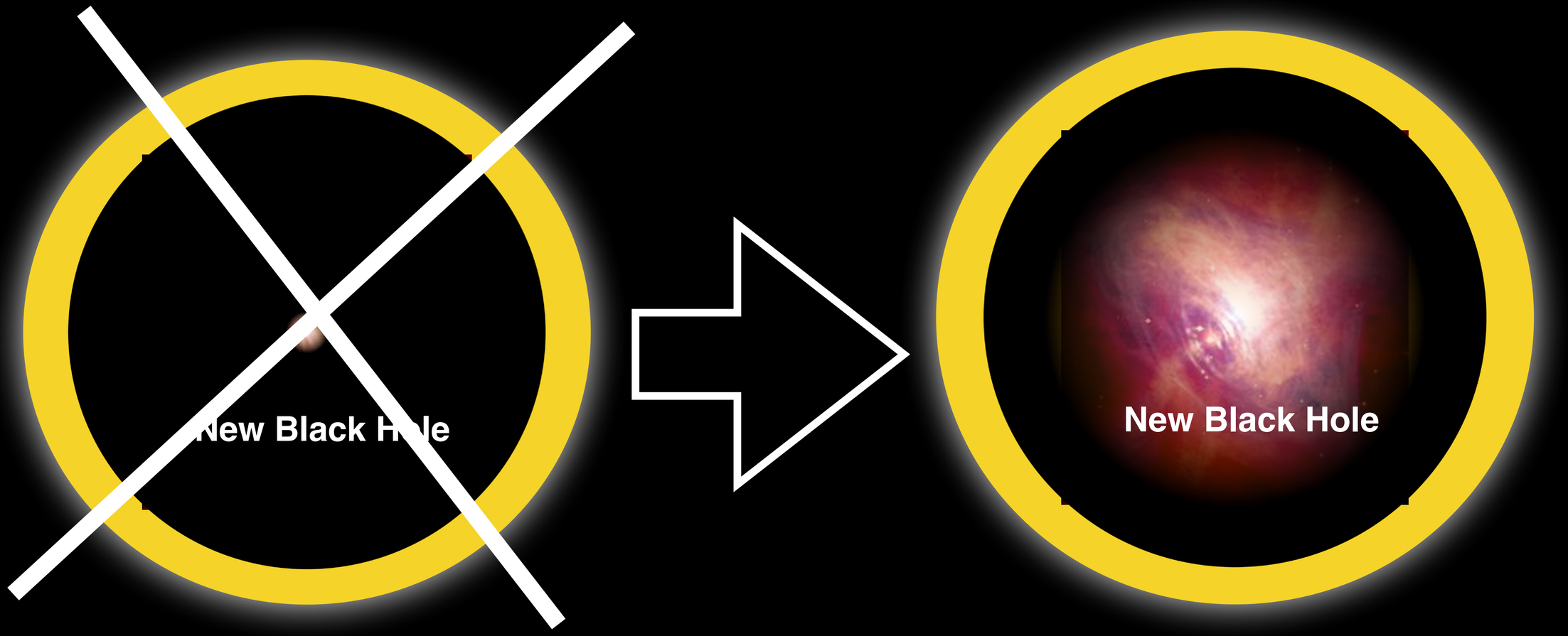
The remaining of a stellar explosion in 1054 AD


New Black Hole


New Black Hole



Light from
the compact object can escape

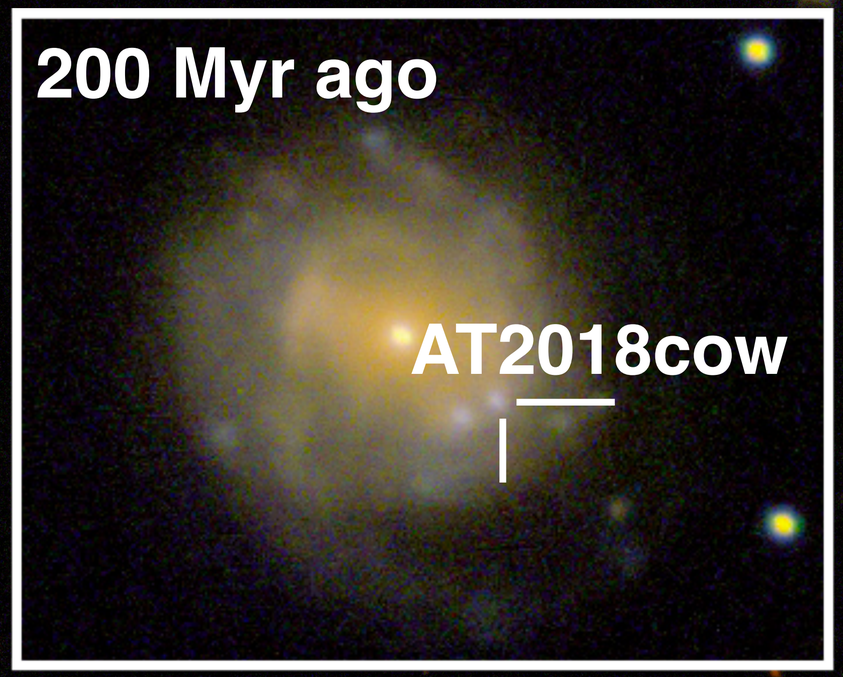

New Black Hole
New Black Hole

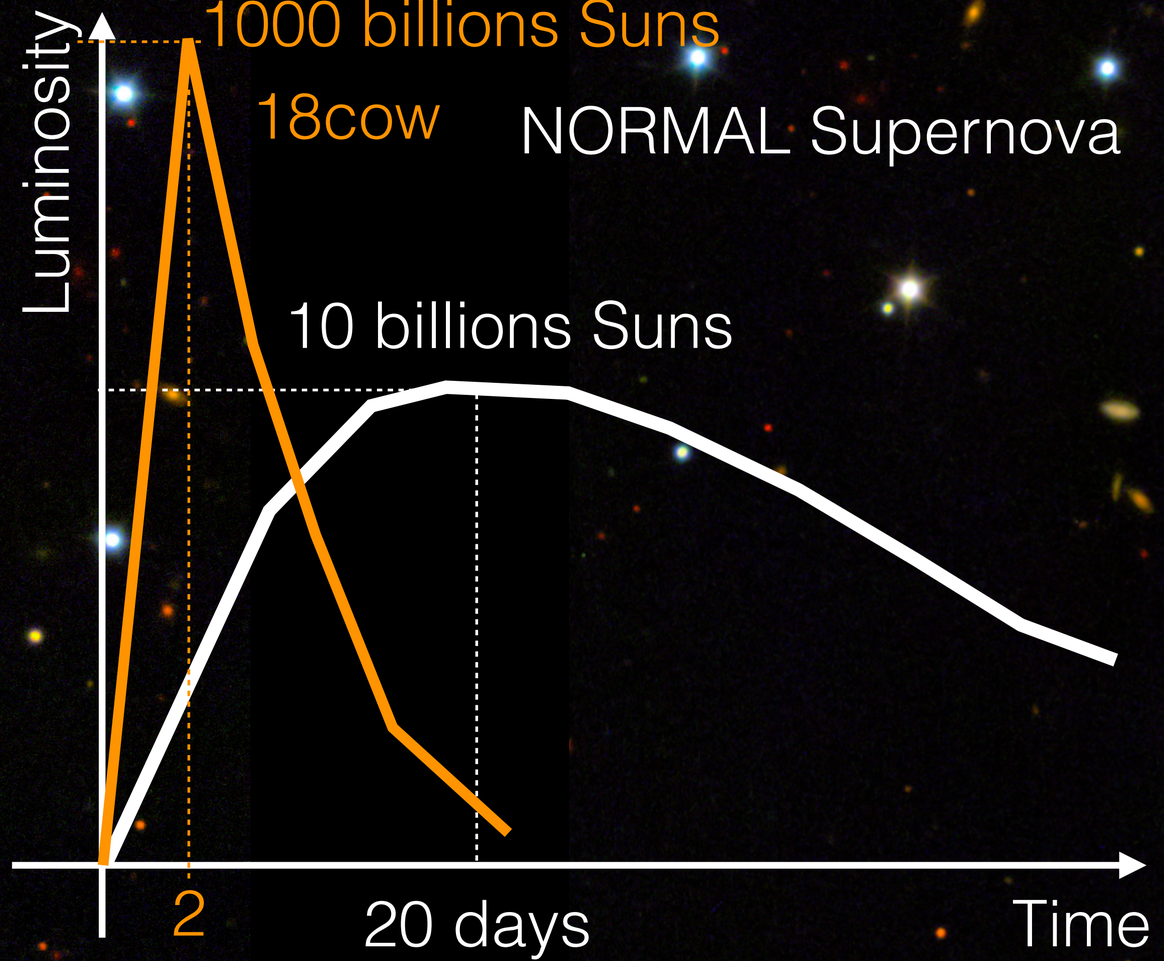
HIC SUNT LEONES

[here be dragons]

(or maybe cows…)

Image acquired with Keck-DEIMOS





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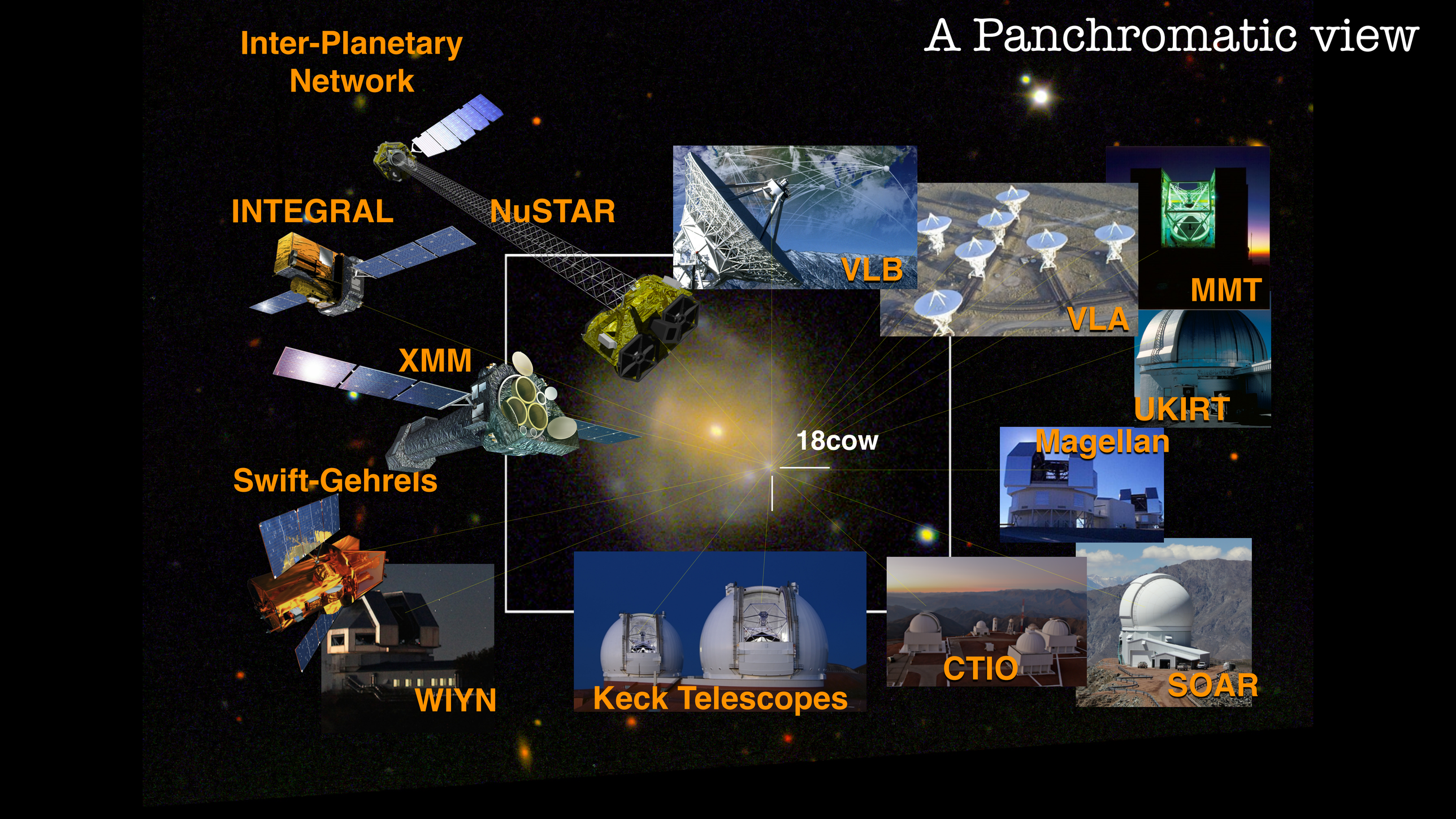
NEWS · 02 NOVEMBER 2018

Holy Cow! Astronomers agog at mysterious new supernova

An event known as 'Cow' that has rocked astronomy since June likely offers a close look at the birth of a neutron star or black hole.

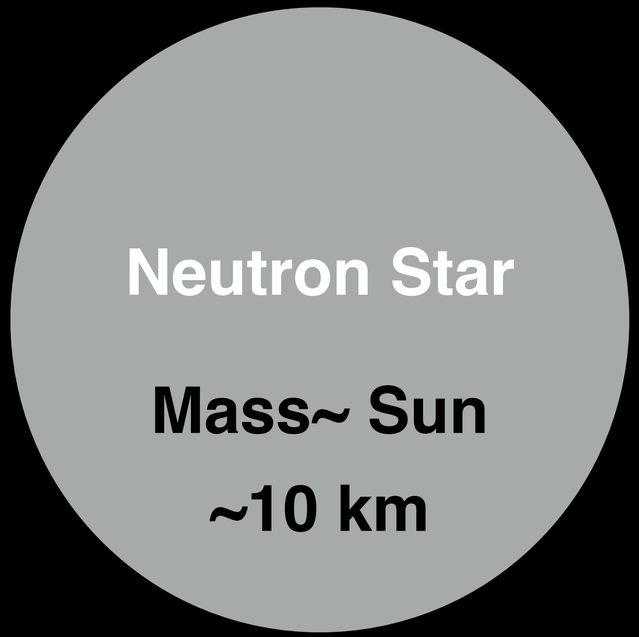
A Panchromatic view



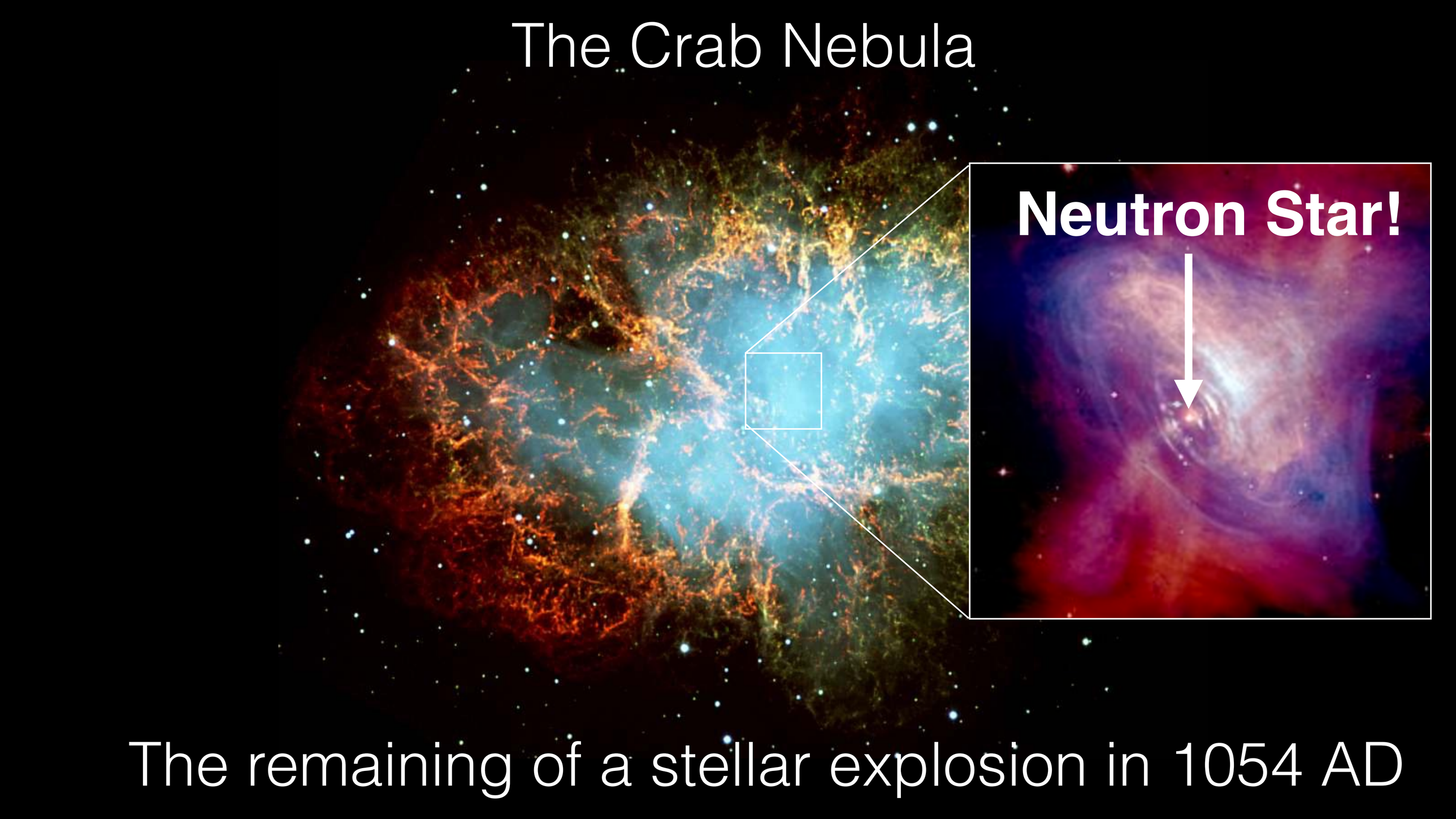
How to form a (small) Black Hole

Method 1: Make a Big Star Explode

Method 2: Make two Neutron Stars Collide

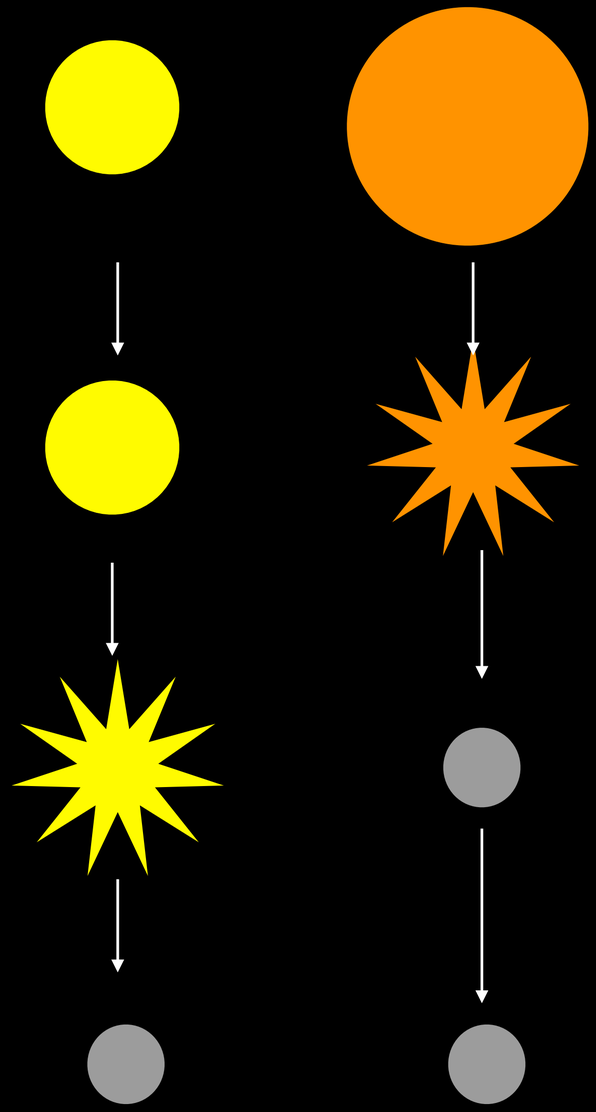


The Crab Nebula



The remaining of a stellar explosion in 1054 AD

How do we form two Neutron Stars?



TOTAL= 1 out of 100,000 makes it to the end

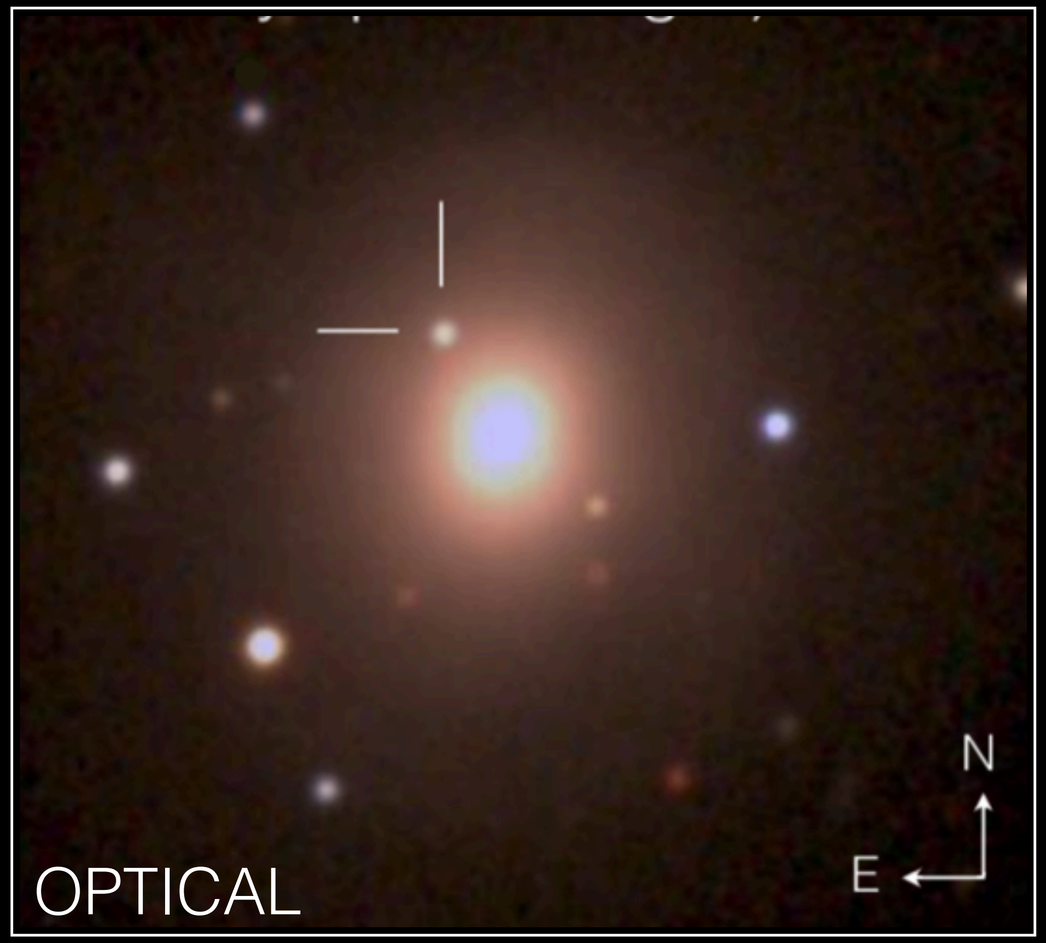
We have two Neutron Stars:
why they can't just keep orbiting each other forever?

Their orbit shrinks as energy is lost in gravitational-wave emission

130 Myr ago in the galaxy NGC 4933

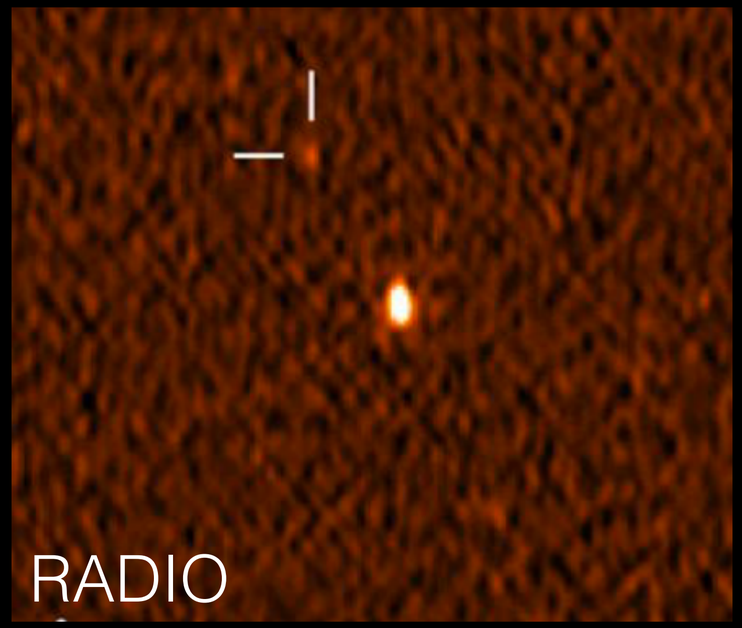
The collision of two neutron stars

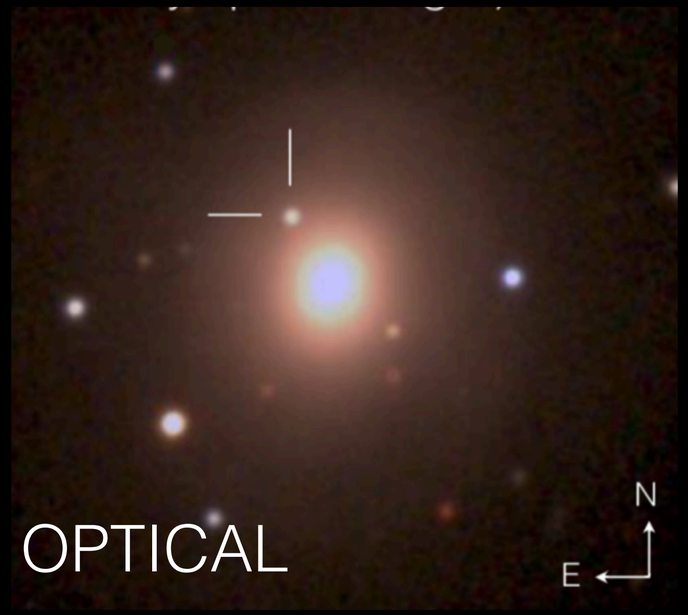
GW170817: the first (and only so far) detection of gravitational waves and light from the same celestial object

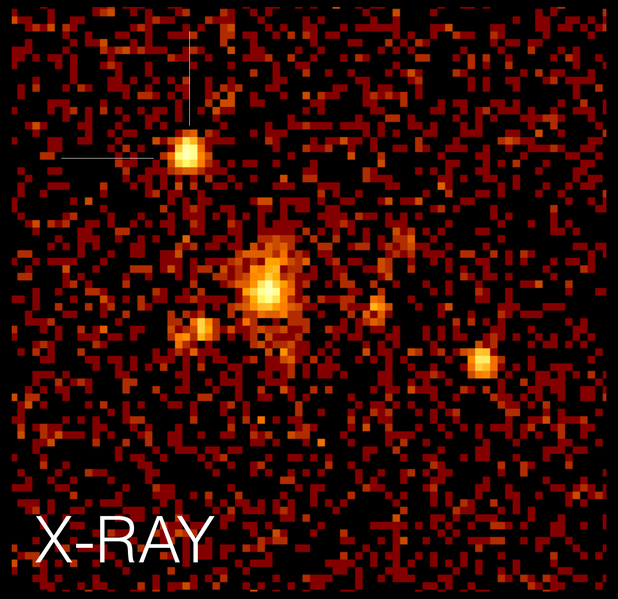


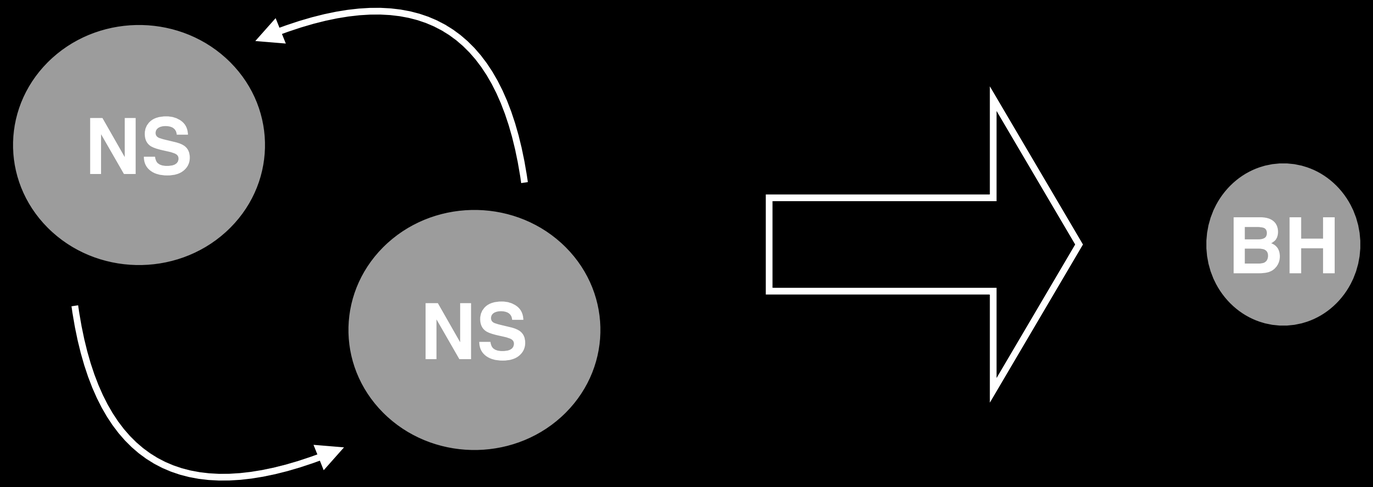
Work by 70+ teams worldwide, 3000+ scientists (Abbott+2017)

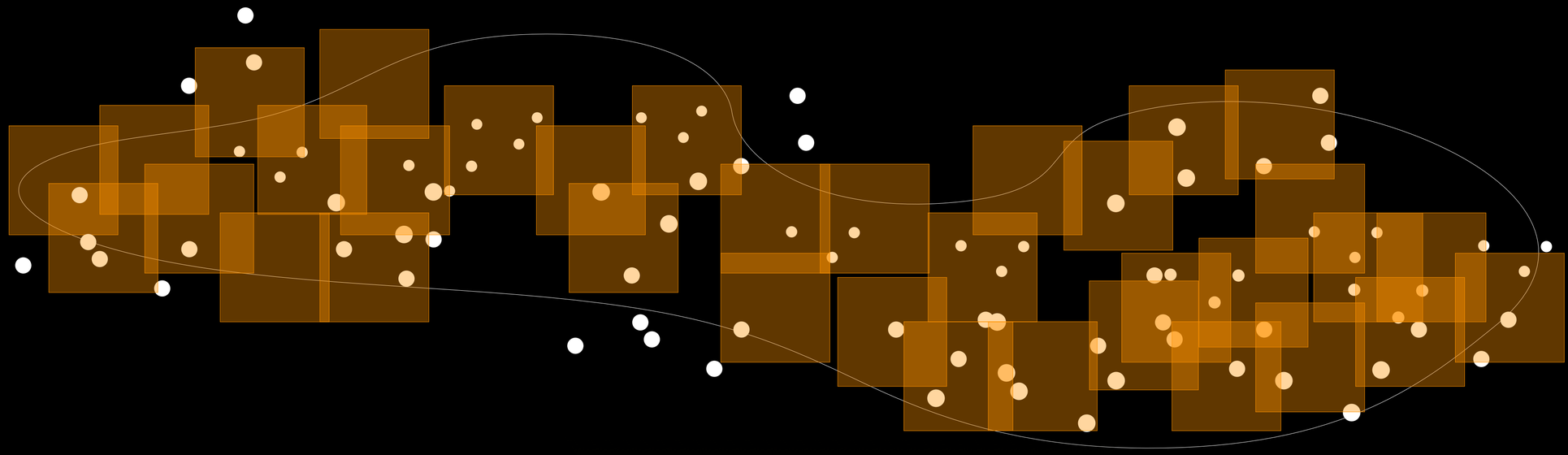
GW170817: the first (and only so far) detection of gravitational waves and light from the same celestial object





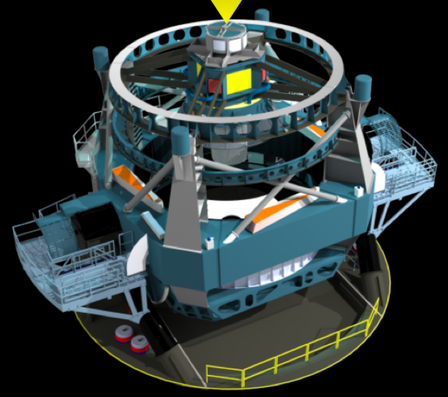






Region of localization from the detected gravitational wave emission

The unique role of LSST:



The electromagnetic signal is faint, fades quickly and we do not know well where to look

How to form a Black Hole

Method 1: Make a Big Star Explode

Method 2: Make two Neutron Stars Collide

Method 3: Make two Black Holes Collide


The collision of two black holes produces Gravitational Waves:
Use the LIGO app to receive real-time updates on collisions of BHs and NSs!

How to form a Black Hole

Method 1: Make a Big Star Explode

Method 2: Make two Neutron Stars Collide

Observed one event with GWs and light

Method 3: Make two Black Holes Collide

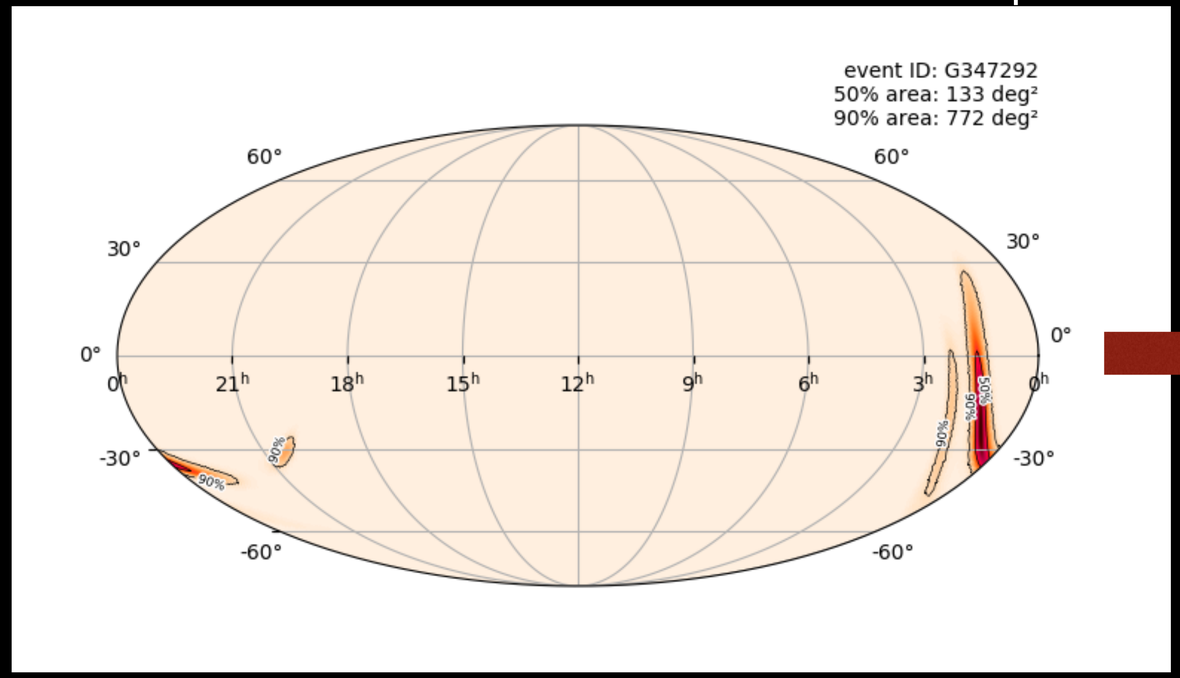
Observed many events with GWs

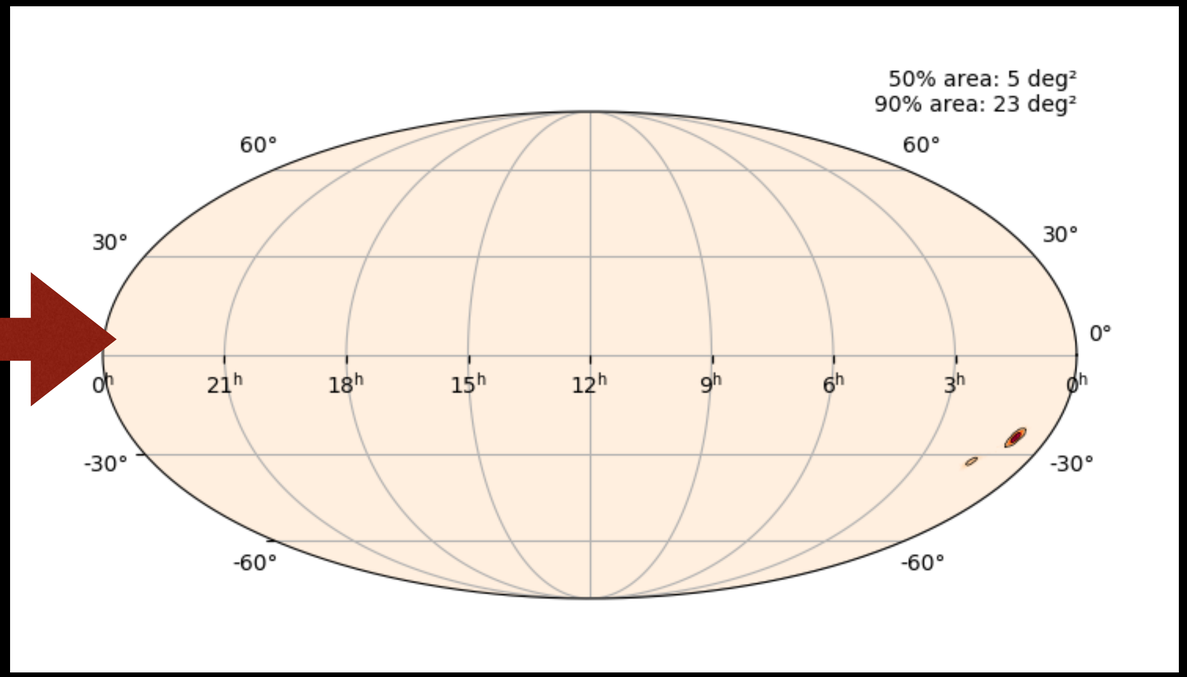
Method 4: Make one Black Hole and a Neutron Star Collide

Never observed

Black Hole - Neutron Star Merger

Gravitational Wave localization map fro LIGO/Virgo:





...from last night ...

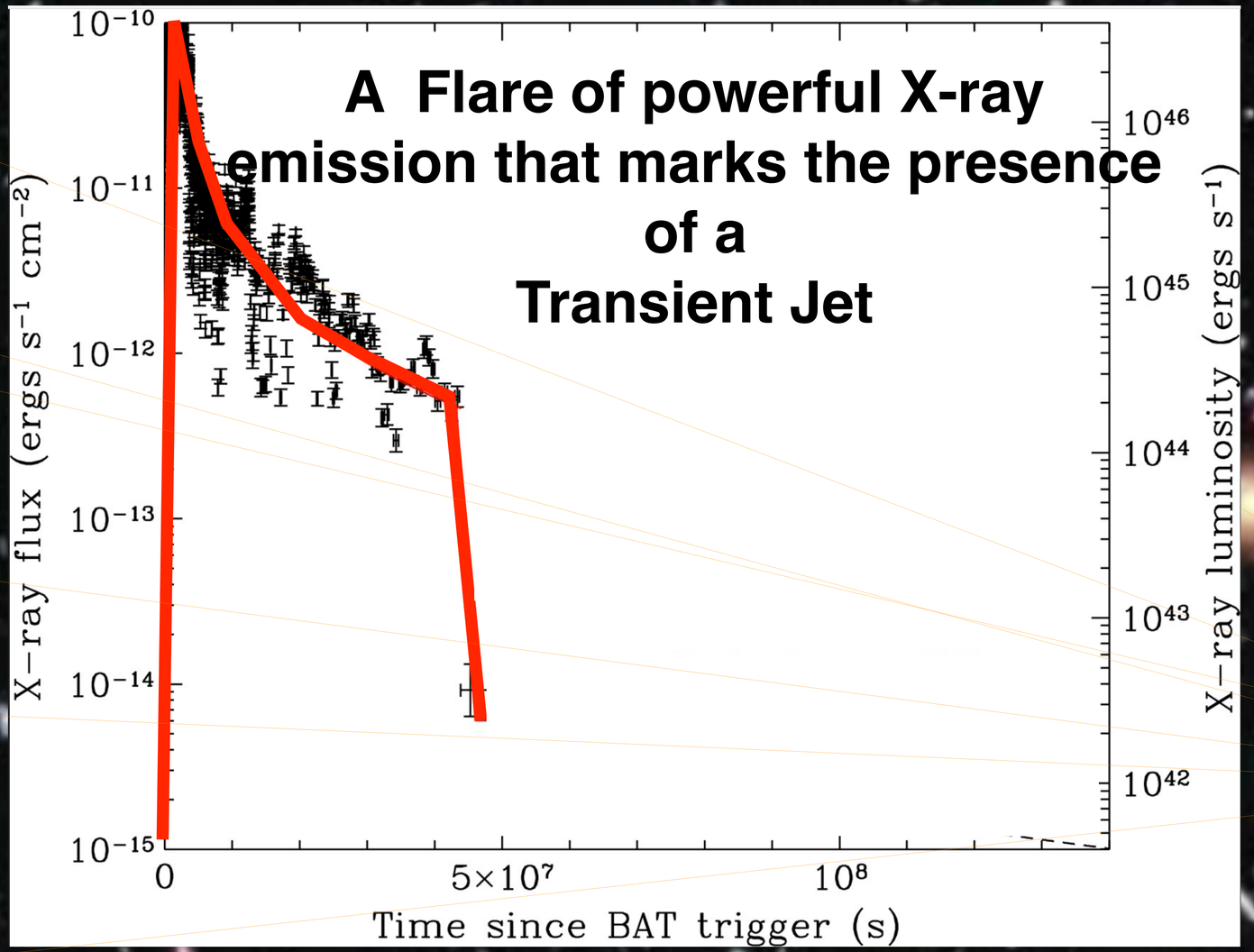
Stay tuned!!

Active Supermassive Black Hole in the Galaxy M87

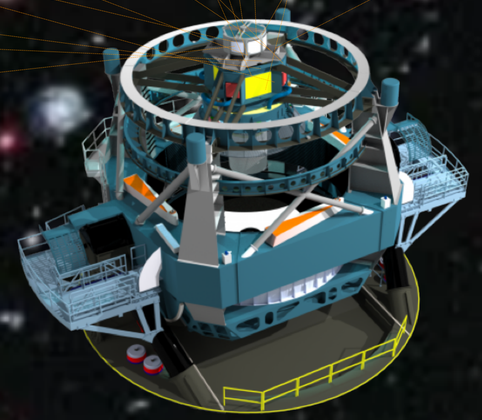
Unveiling the population of dormant supermassive black holes

with Stellar Tidal Disruptions

Unveiling the population of dormant supermassive black holes



Levan+2015



with Stellar Tidal Disruptions

“. . . The END

is where we start from. . .”

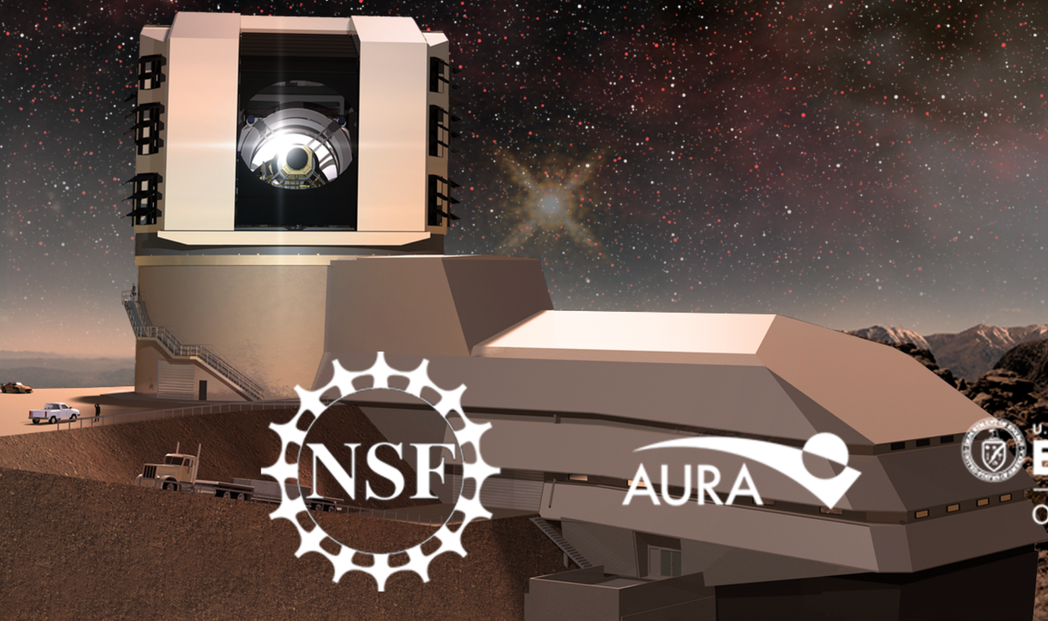
The Little Gidding by T. S. Eliot

LSST & BLACK HOLES

Victor Krabbendam
LSST Project Manager

Feryal Özel
University of Arizona

Raffaella Margutti
Northwestern University



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