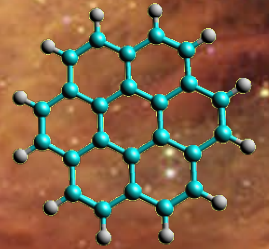
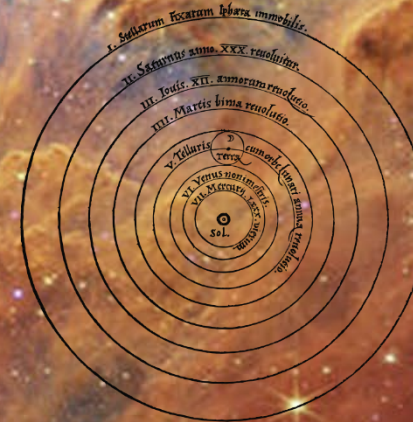
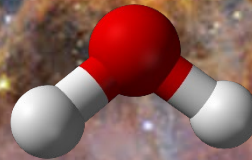
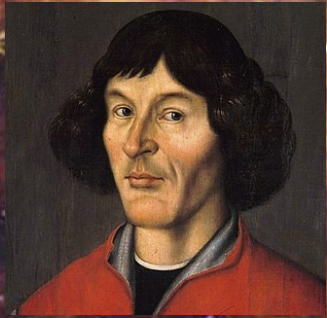
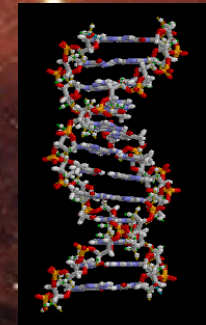


From Nicolaus Copernicus to James Webb: *New World Views*



Ewine F. van Dishoeck
Leiden Observatory, past-President IAU

550 years Copernicus Symposium, Torun,
September 15 2023



Viewing the night sky is available to all, everywhere in the world

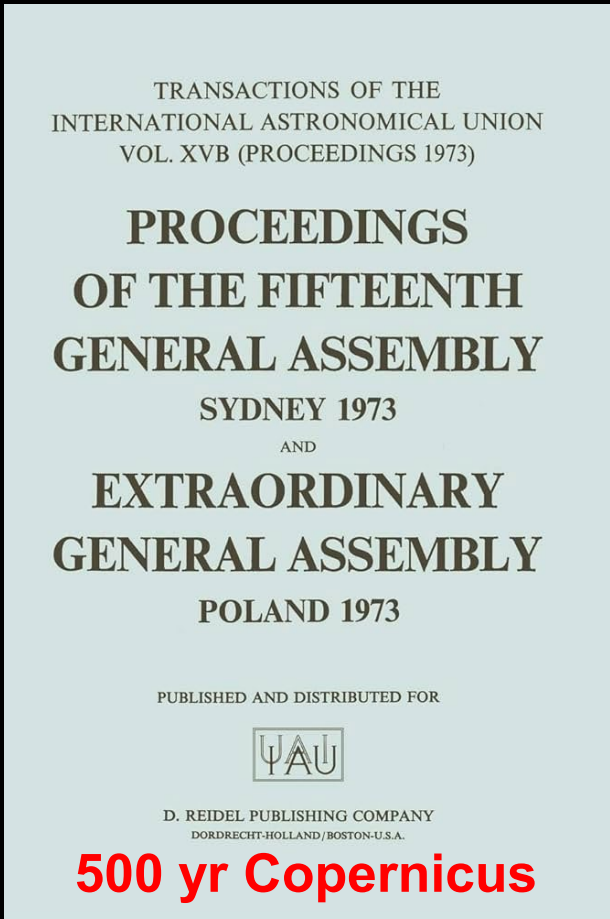


Warsaw Telescope

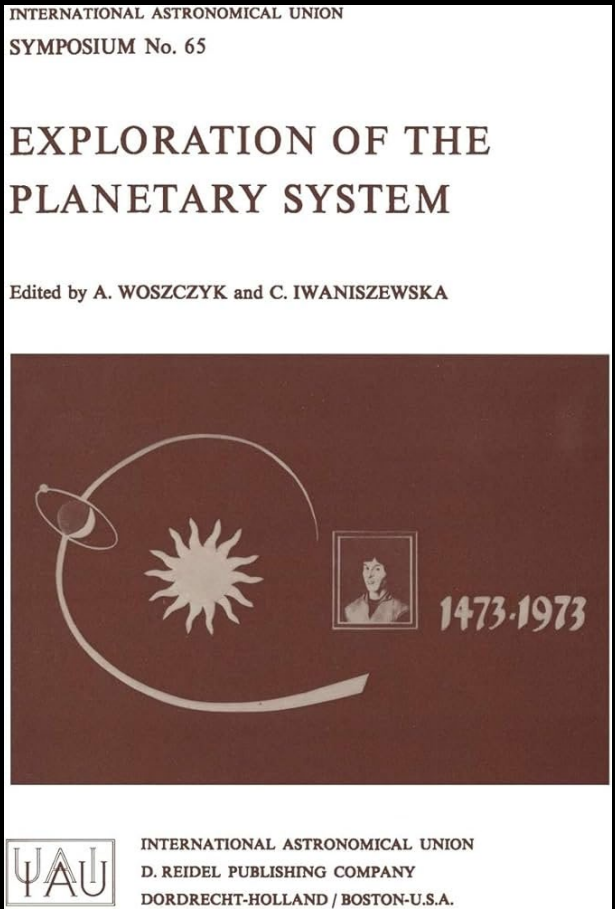


Where do we come from? What is our place in the Universe?

Poland and the International Astronomical Union



Member since 1992



**IAU Symposium 384
in Krakow last week**

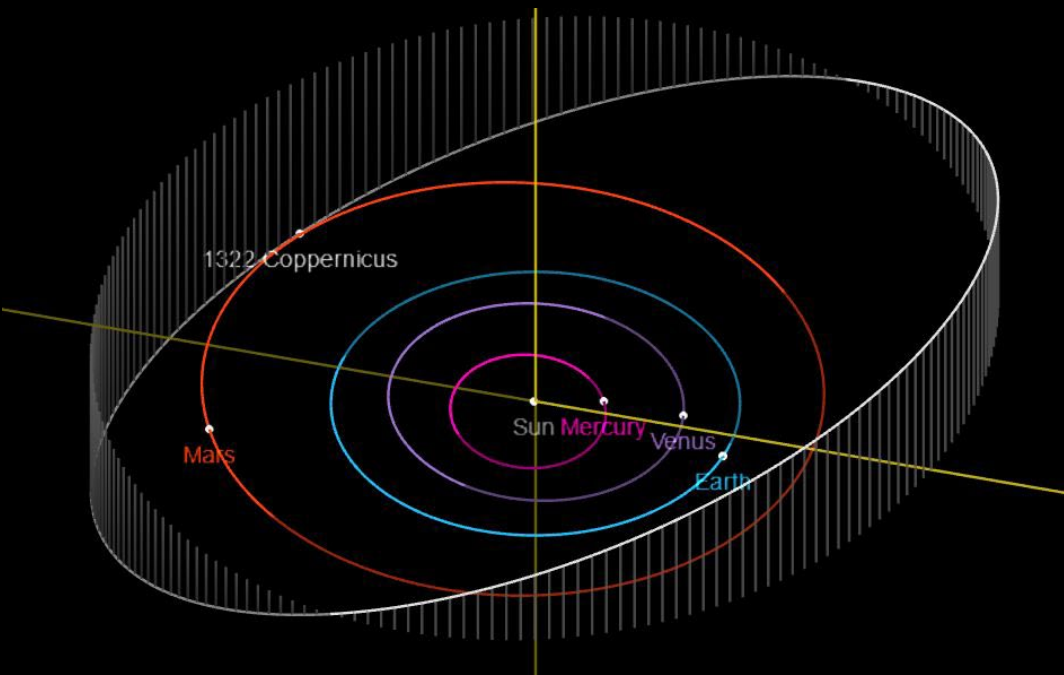


Wilhelmina Iwanowska
1905 – 1999
First female vice-president of IAU
1973 - 1979

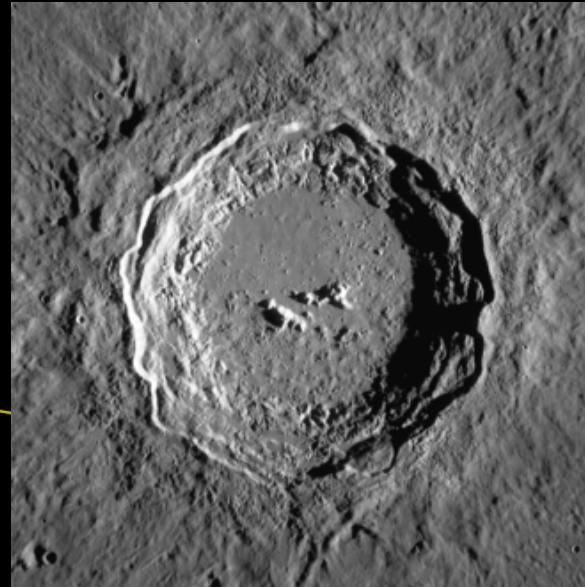


**Education
and Outreach!**

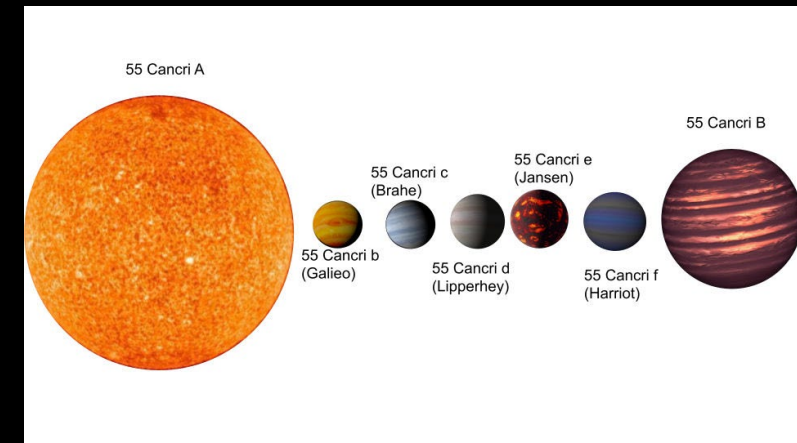
IAU naming of objects



Asteroid 1322 Copernicus
currently at 2.9 au



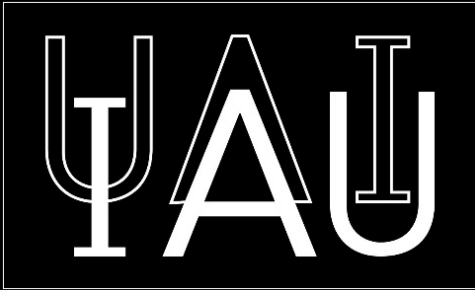
Lunar Crater



55 Cancri A=Copernicus
Star + planetary system

NameExoWorld

Poland and world-wide astronomy



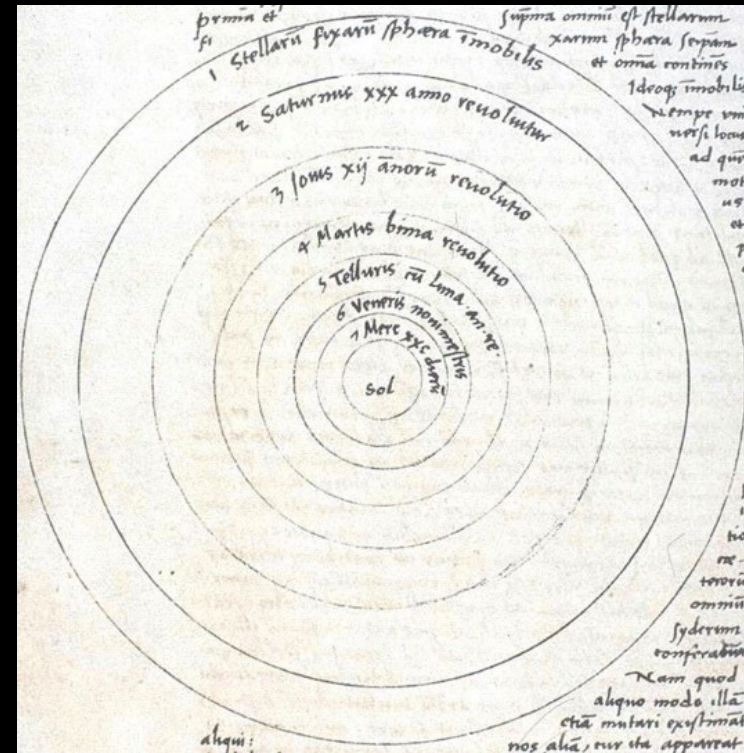
Bohdan Paczynski
1940 – 2007
“Father of OGLE” → Talk Udalski



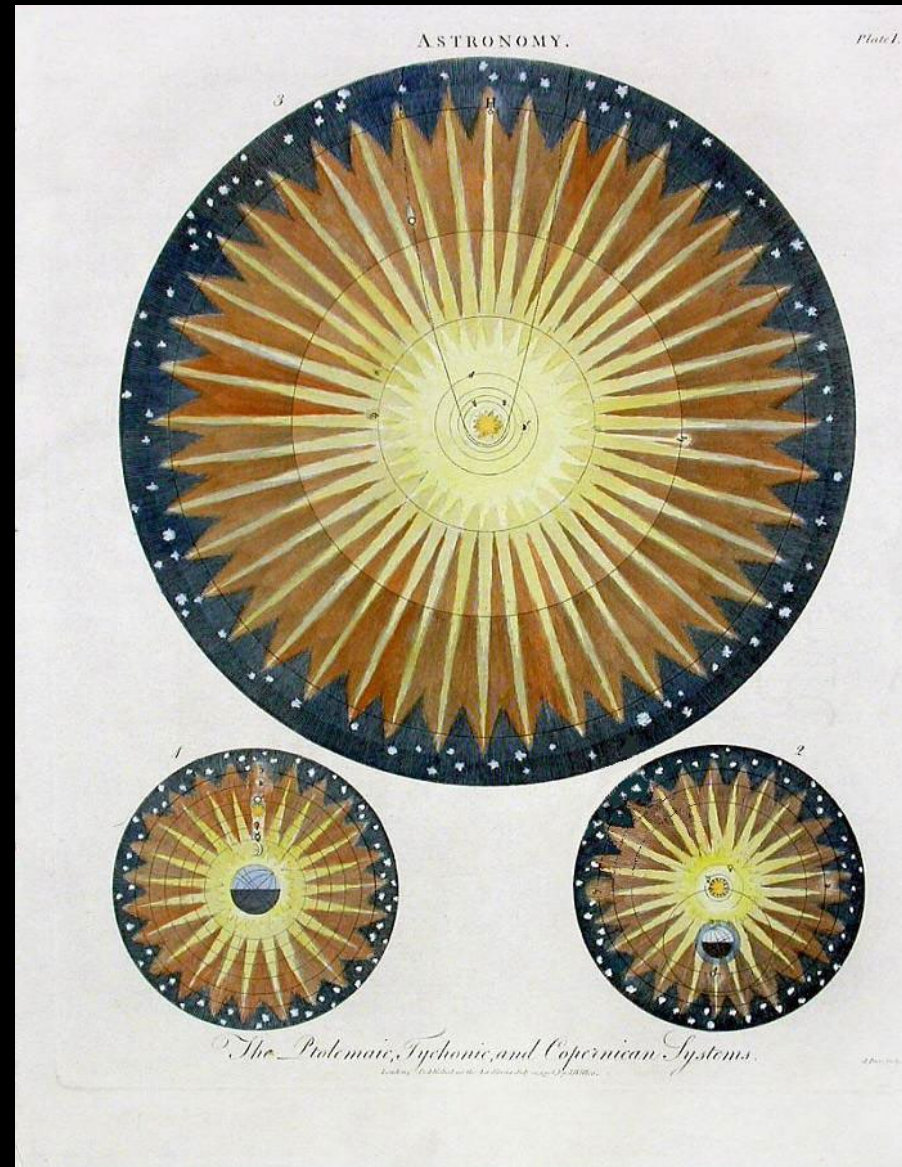
Aleksander Wolszczan
1946-
First (pulsar) exoplanet



New world views then



The Ptolemaic, Tychoinic and Copernican systems



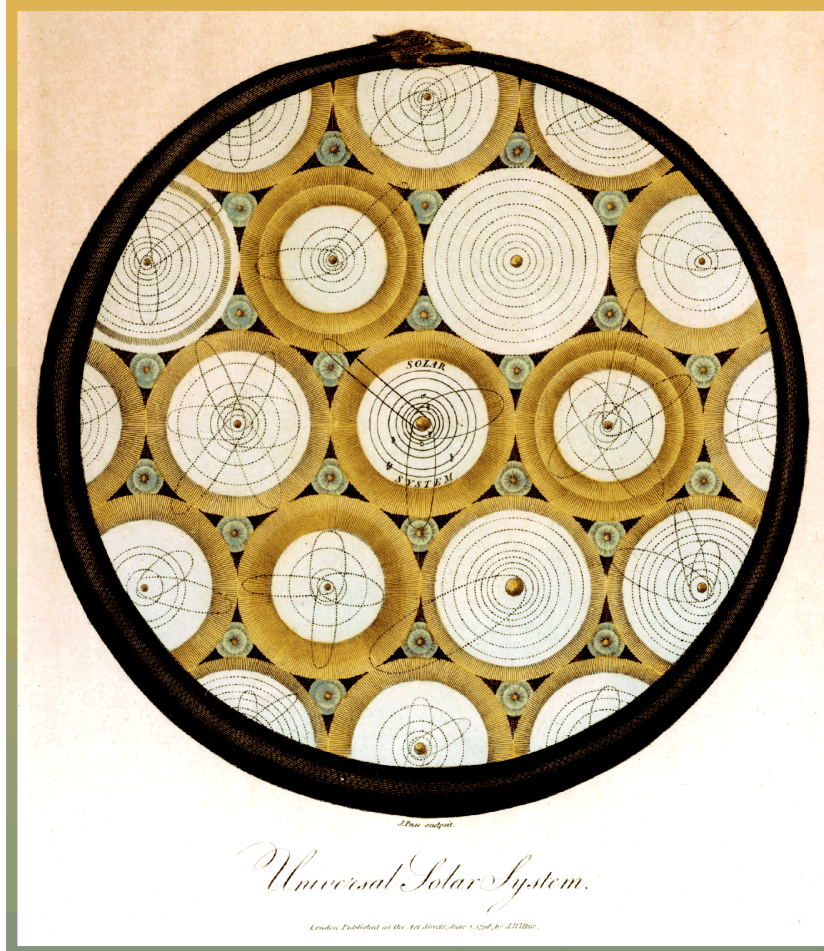
Collection
EvD+TdZ

J. Wilkes
~1798

Diversity of Planetary Systems

APRIL
2004

PHYSICS TODAY



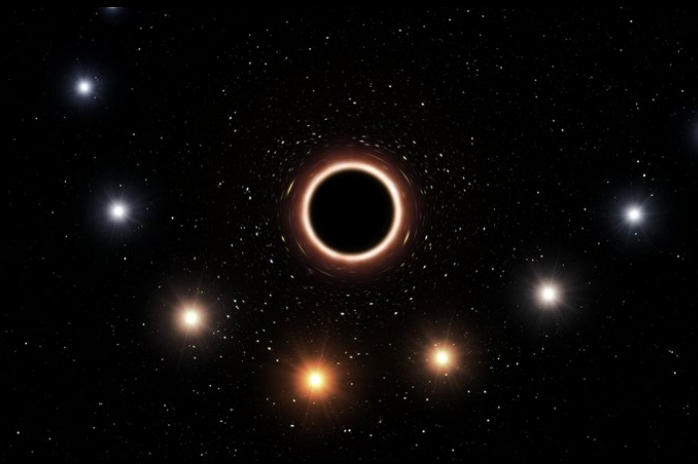
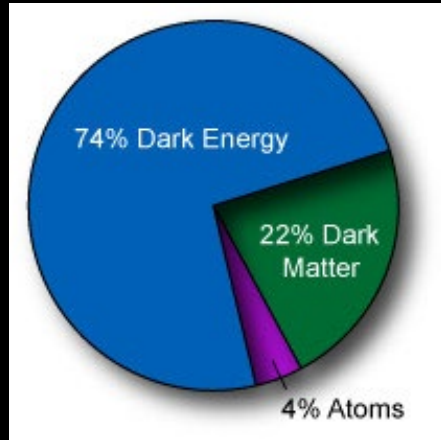
English engraving
John Wilkes, ~1798

Collection EvD+TdZ

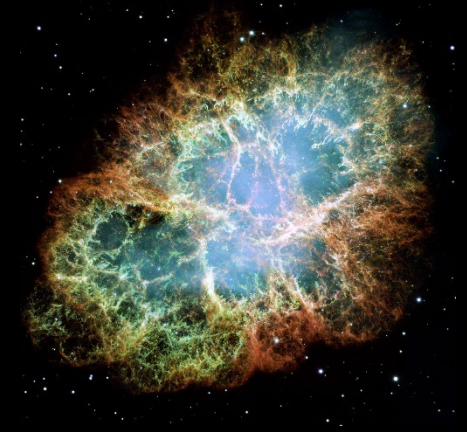
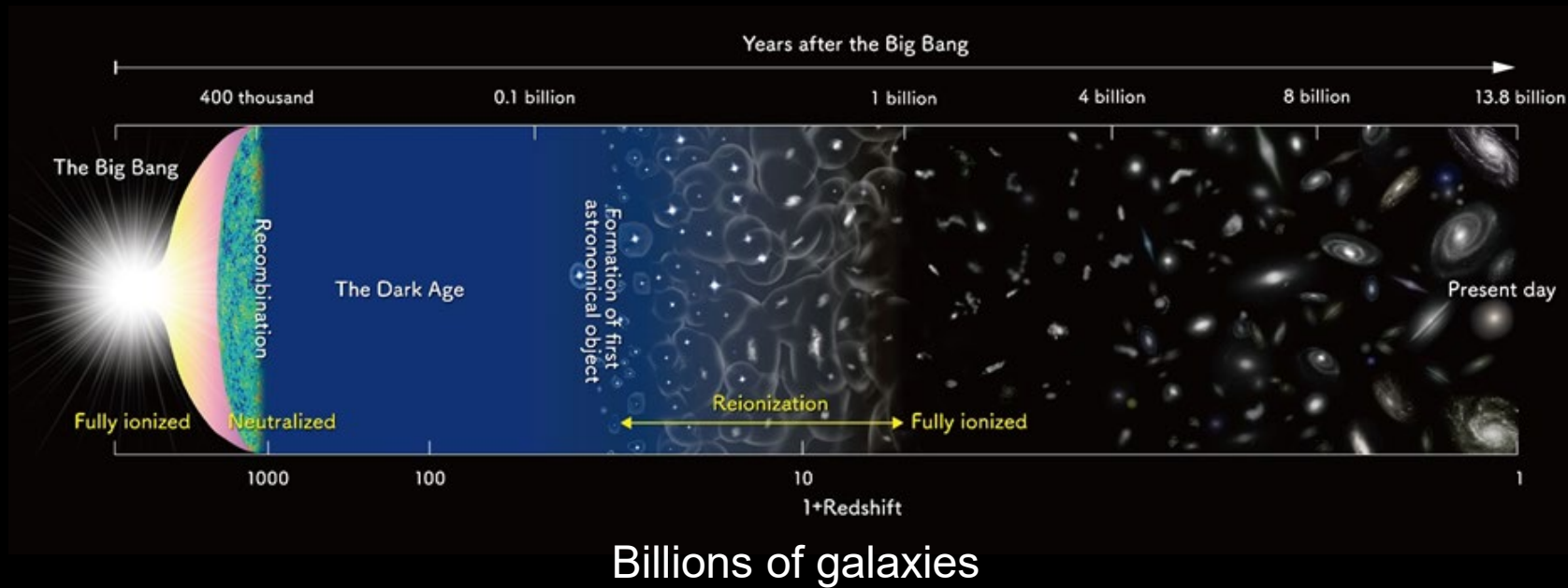
Special issue:
Planetary diversity

New World Views now

Our view of the Universe has changed dramatically over the last 100 years

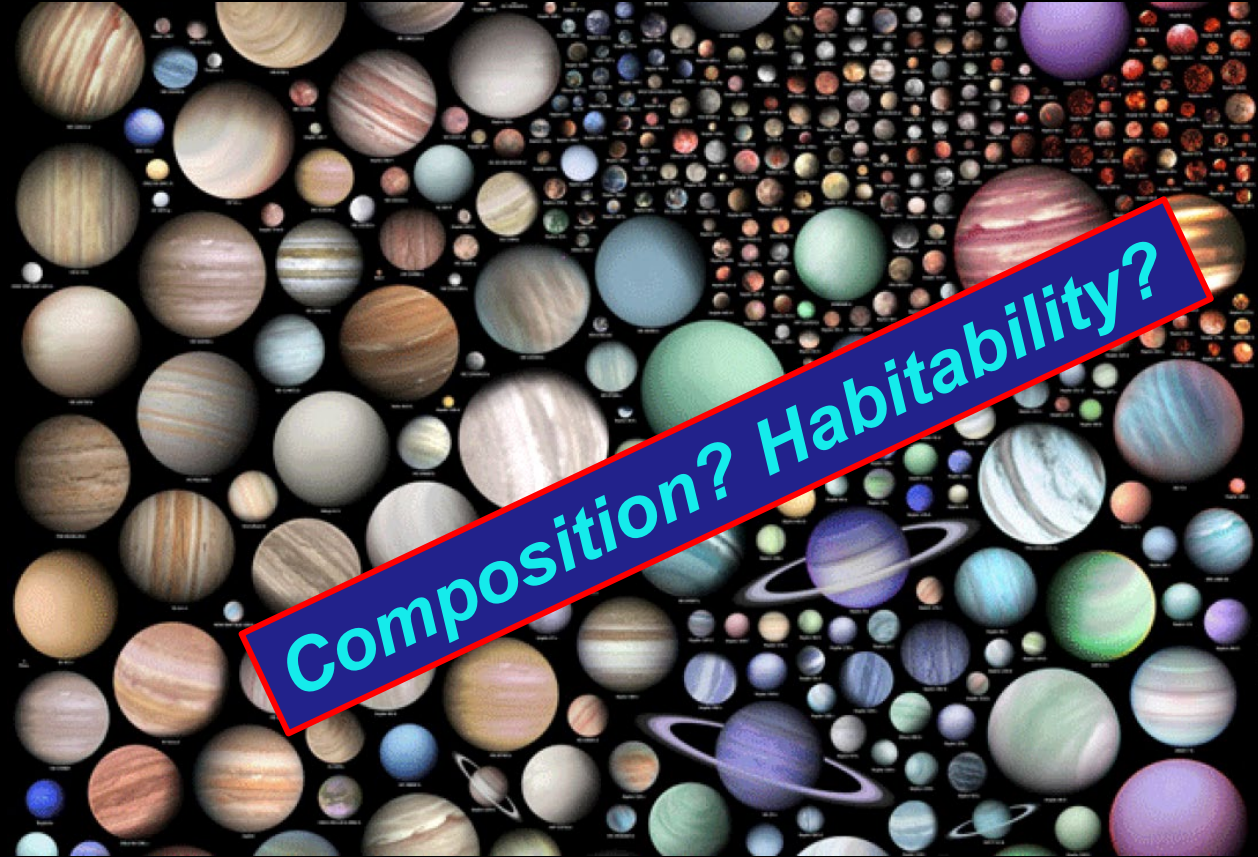


Supermassive black holes
(also center of our Milky Way)



Origin of elements

Discovery of exoplanets



Kepler satellite: Borucki et al. 2011, Batalha et al. 2013

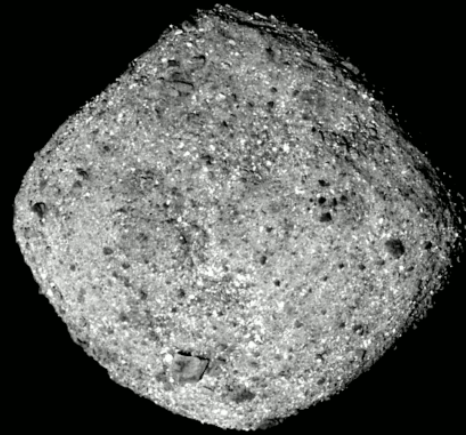
Artist impression

Every star has at least one planet



Nobel Prize 2019

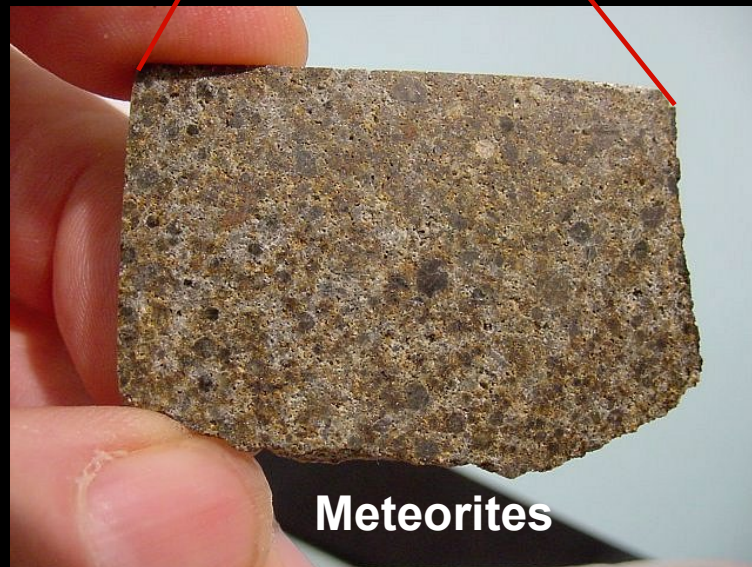
How were 'we' formed 4.6 billion years ago?



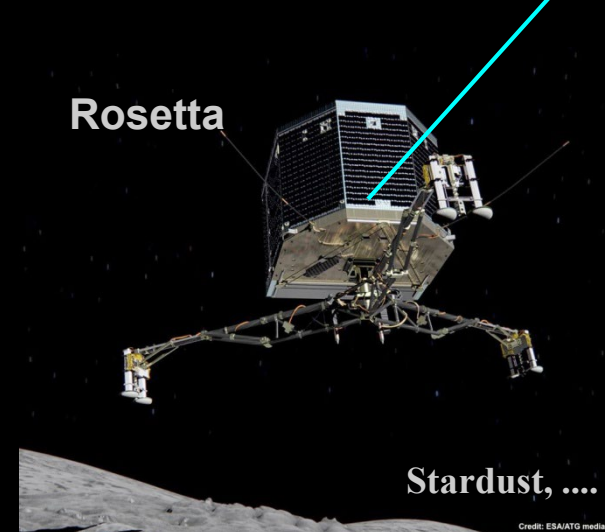
Asteroid



Comet



Meteorites



Rosetta

Stardust,

Credit: ESA/ATG medialab

Messengers from the early solar system

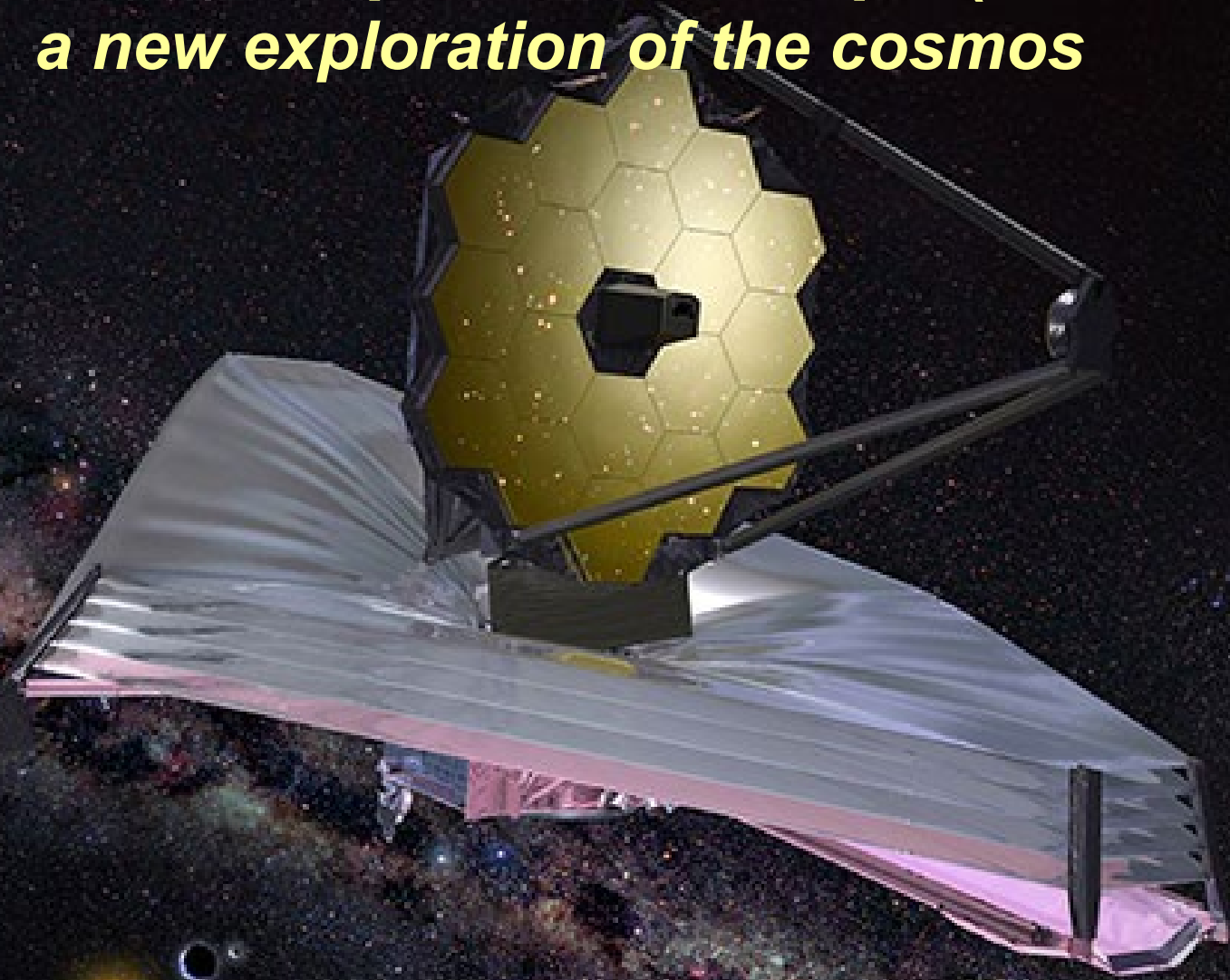
New views are driven by major facilities in space and on the ground



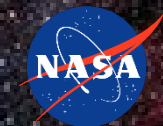
Multi-national,
intercontinental
collaborations

Open data, open archives accessible anywhere in the world (Machine learning, AI)

James Webb Space Telescope (“Webb”) *a new exploration of the cosmos*

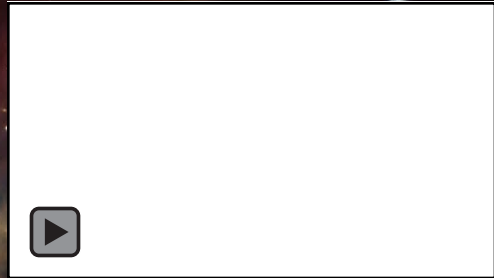


James Edwin Webb (1906 – 1992) second **NASA administrator** 1961-1968 (moon program)

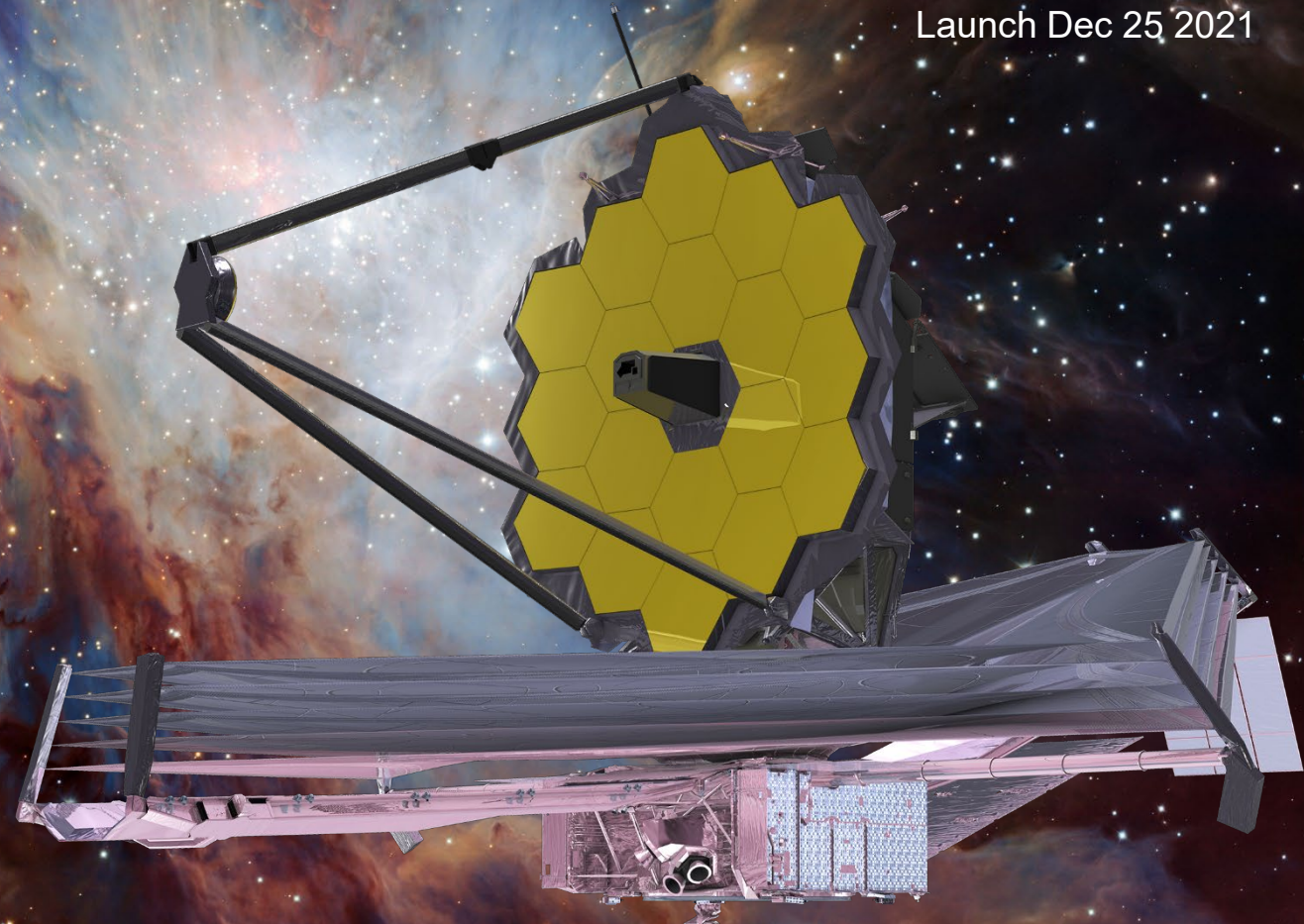


A 30 year journey...

Planning started in early 1990's
Budget ~10 billion \$ over 30 yr
(bulk of it to high-tech industry)



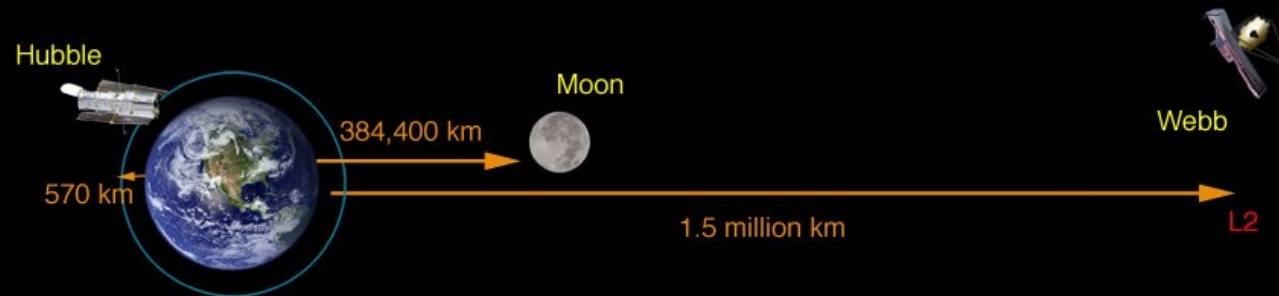
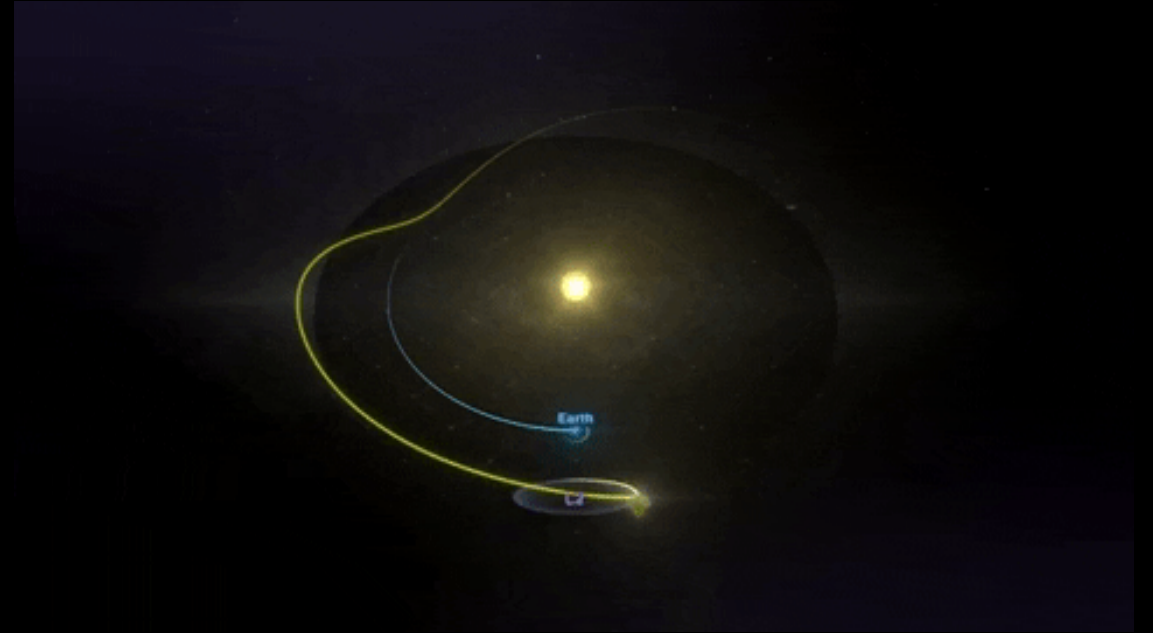
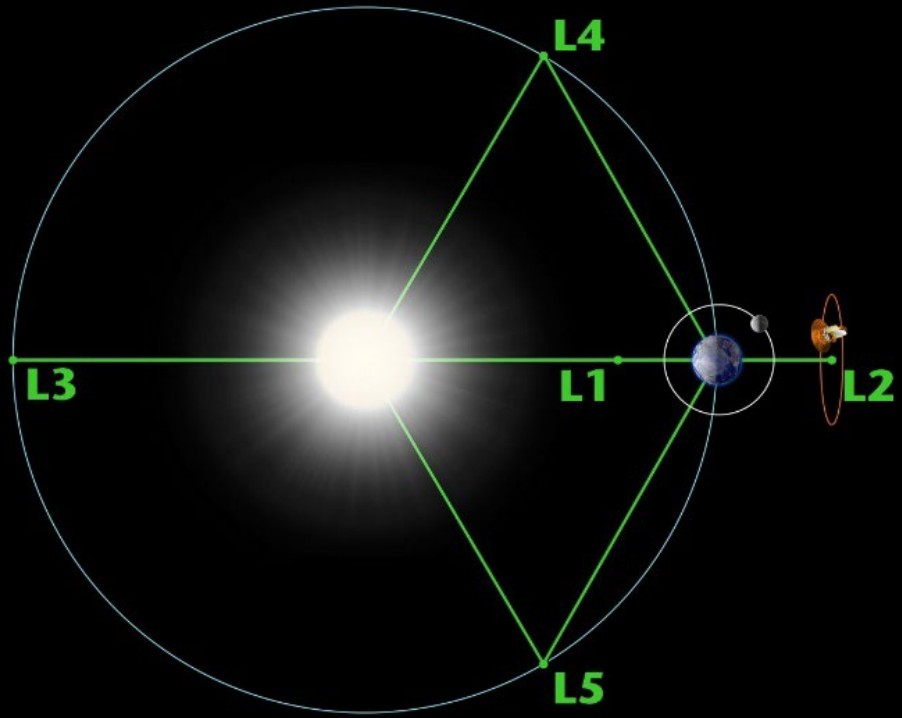
Launch Dec 25 2021



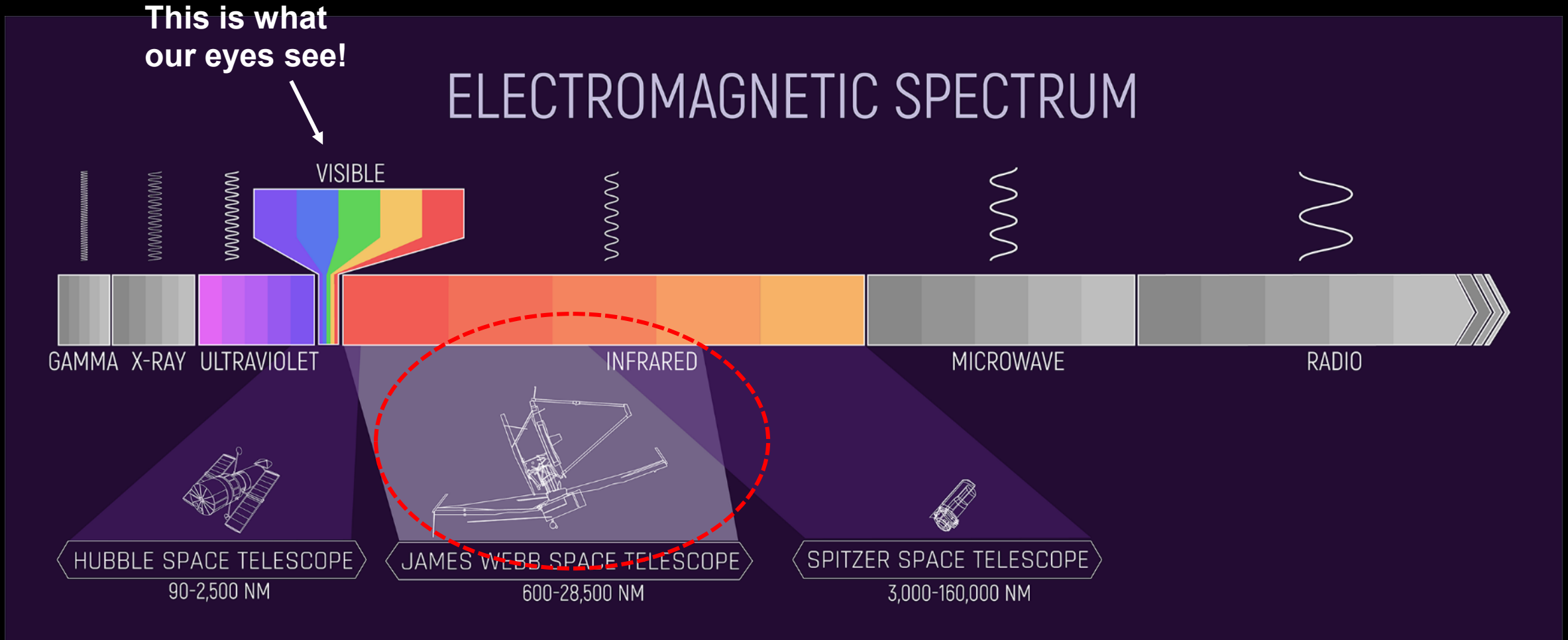
*Thanks to thousands of engineers, technicians,
managers, scientists,*



Webb's orbit



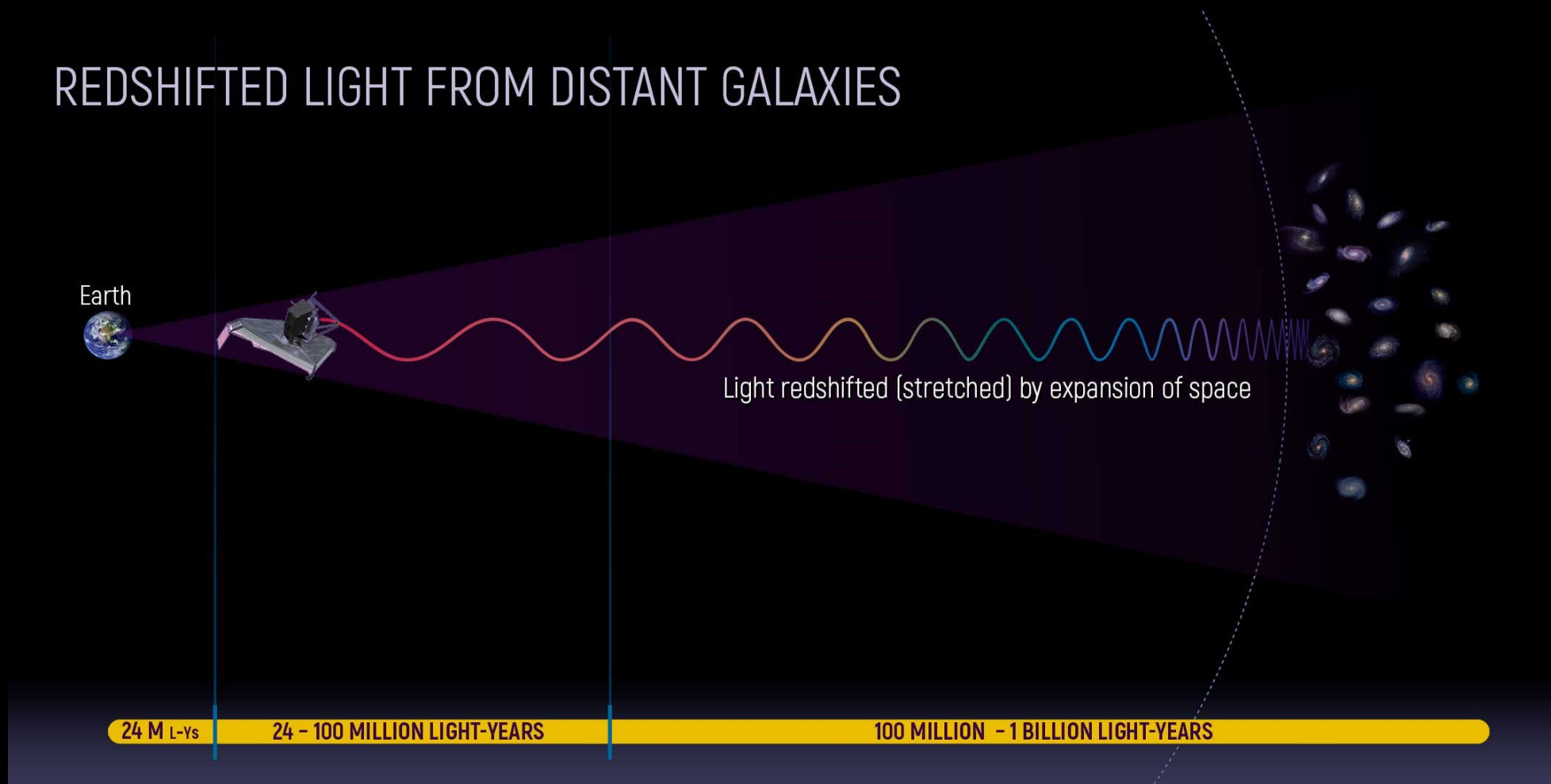
Webb's eyes: infrared



**Four instruments: cameras, spectrographs
near-infrared, mid-infrared**

Why infrared?

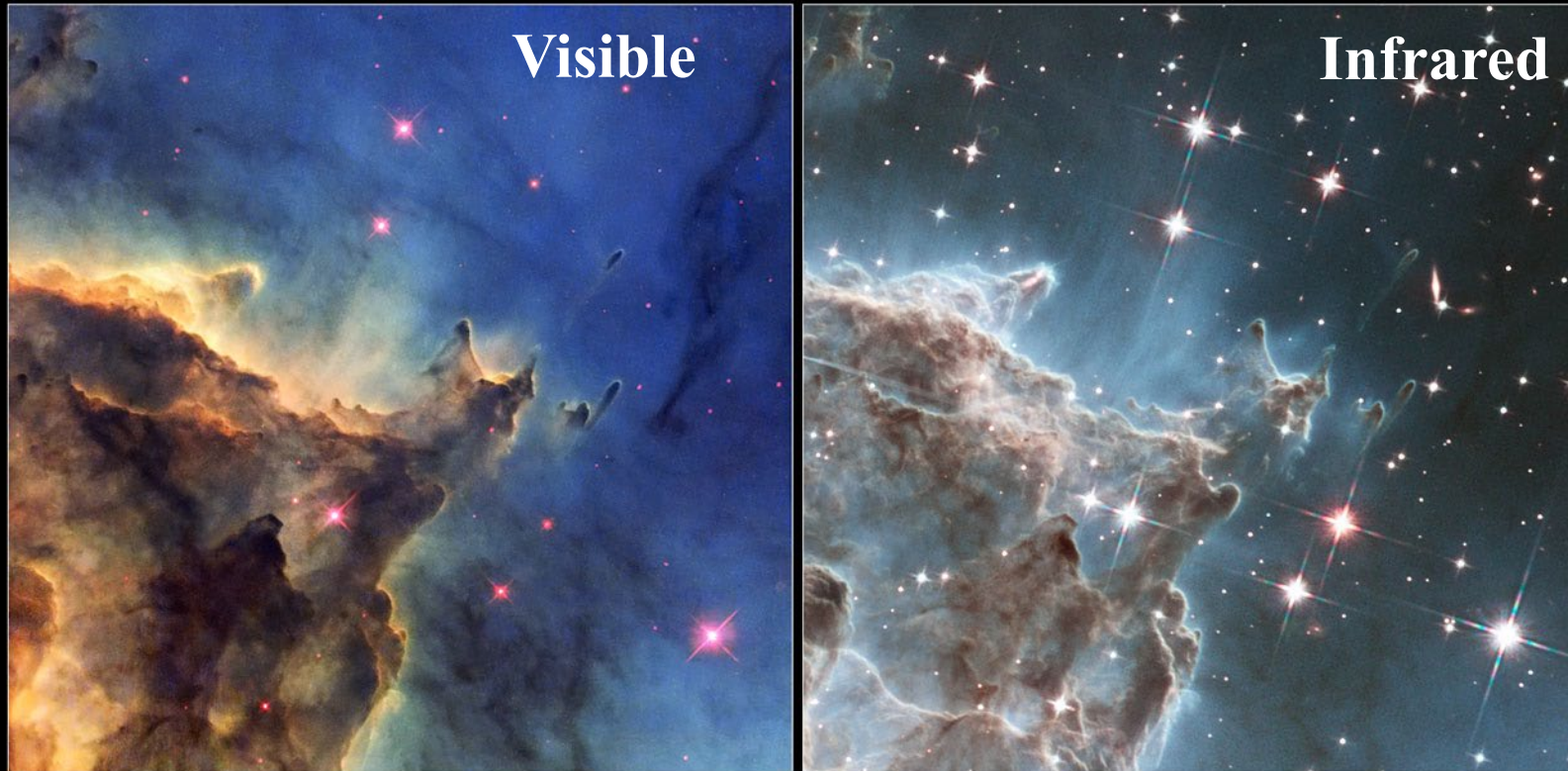
REDSHIFTED LIGHT FROM DISTANT GALAXIES



Light from distant galaxies is shifted to the red
“Far away = Long ago”

Why infrared?

Peer into dust clouds



Visible ■ WFC2 ■ 2001

Infrared ■ WFC3/IR ■ 2014

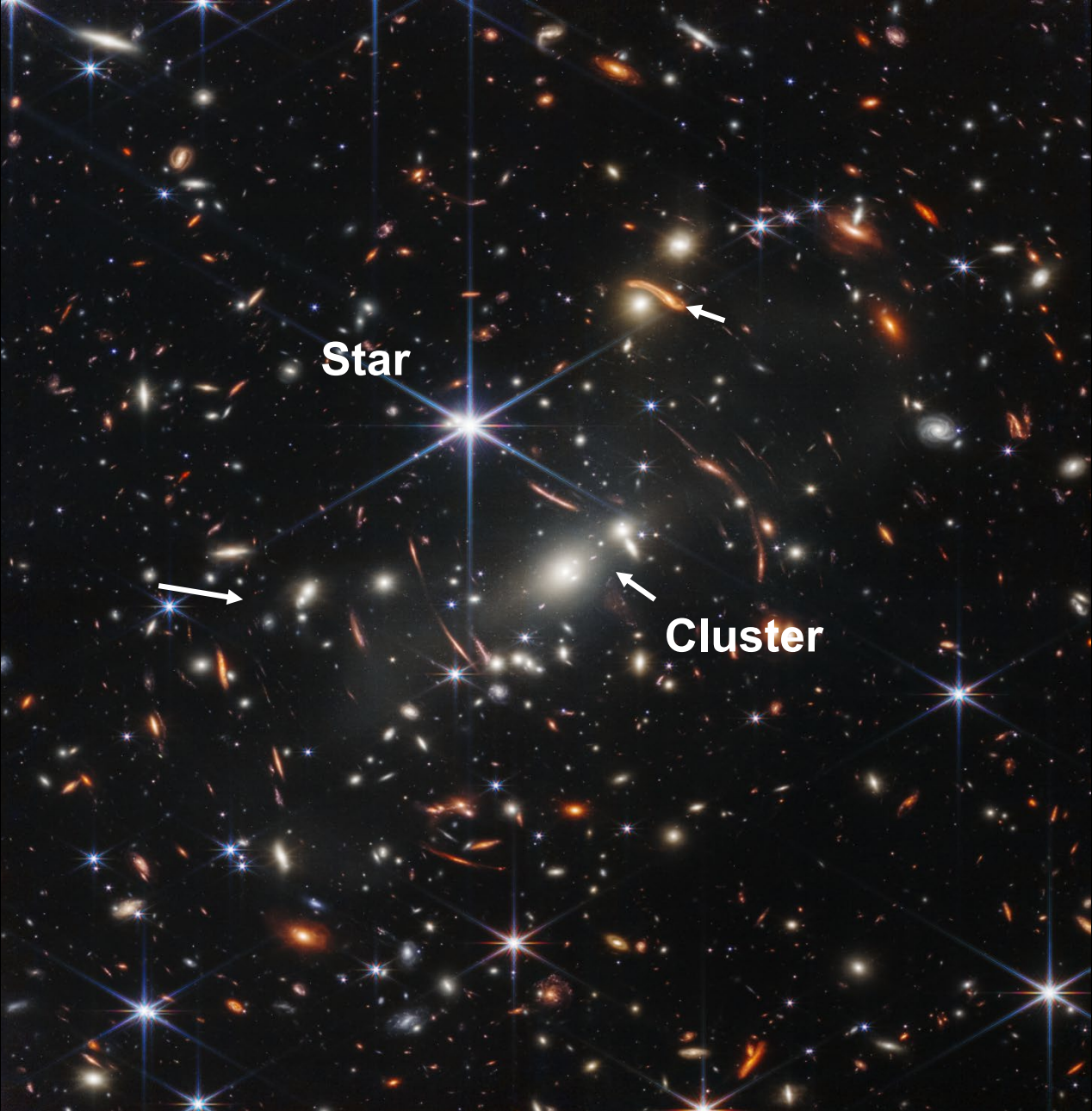
Birthplaces of galaxies, stars, planets

Webb science: From first light to new planets

Deepest image of the universe



>13 billion years old



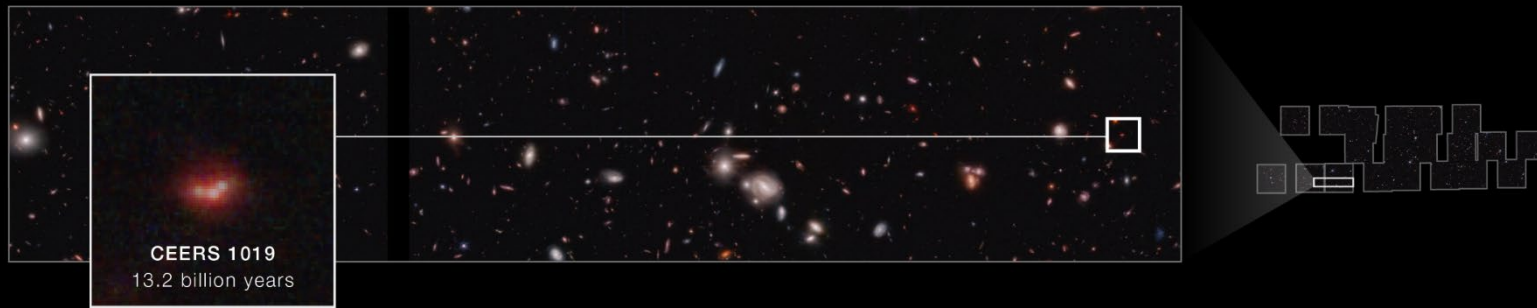
Distant lensed galaxy

Most distant supermassive black holes

COSMIC EVOLUTION EARLY RELEASE SCIENCE (CEERS) SURVEY

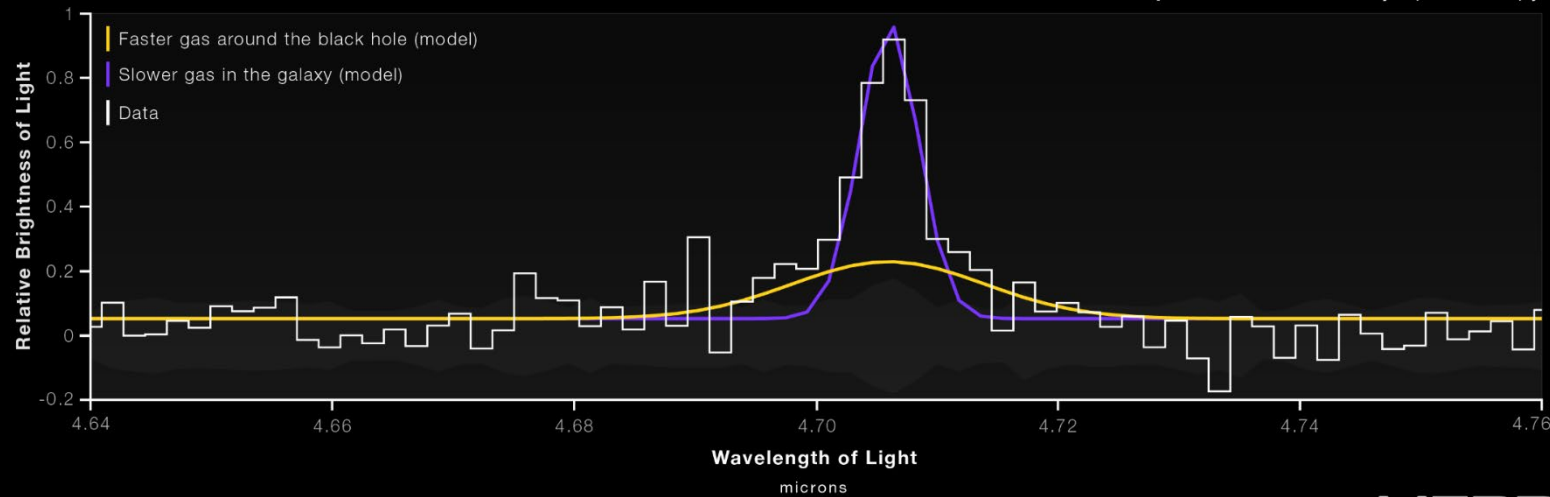
BLACK HOLE EXISTED 570 MILLION YEARS AFTER BIG BANG

NIRCam Imaging



Mass
 $\sim 10^6 M_{\text{Sun}}$

NIRSpec Microshutter Array Spectroscopy



(low, but
comparable
with Galactic
Center)

Beautiful star-forming galaxies with Webb



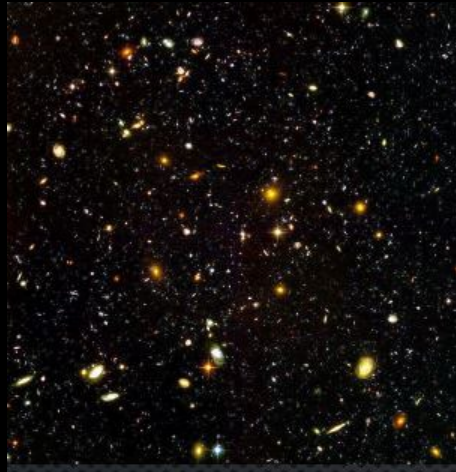
**M74
Phantom
Galaxy**

Interacting galaxies: burst of star formation



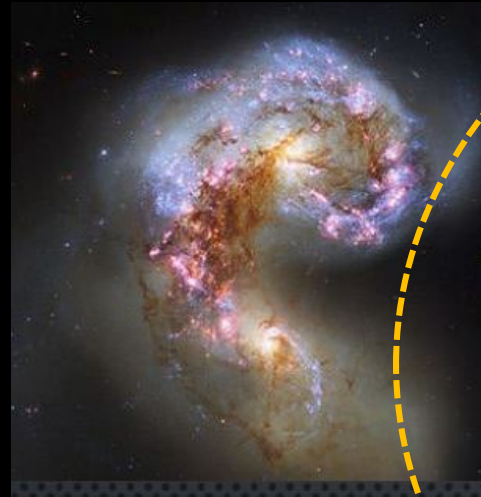
Cartwheel galaxy

Science with JWST



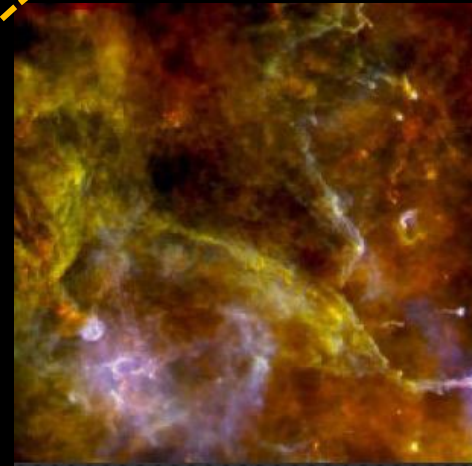
Early Universe

**Early
Universe**



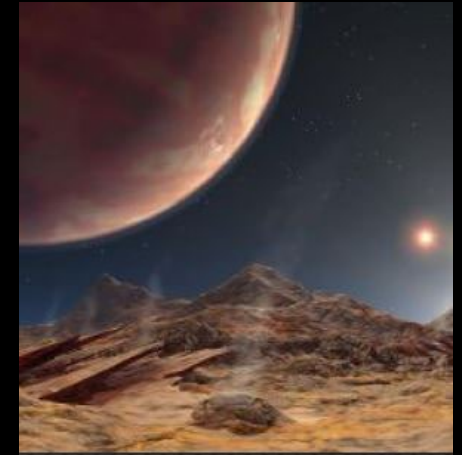
Galaxies Over Time

**Galaxy
evolution**



Star Lifecycle

**Lifecycle
of stars**



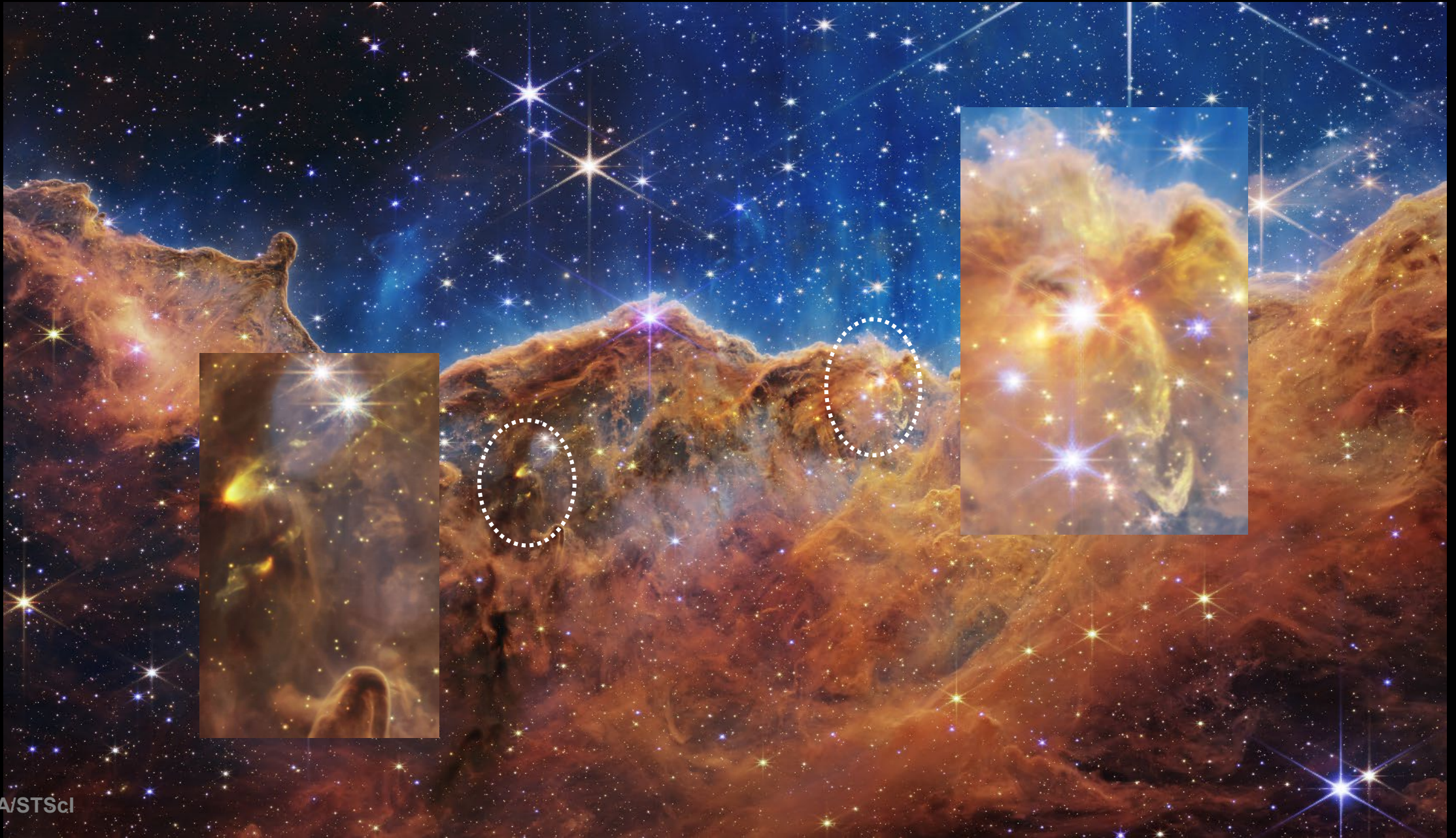
Other Worlds

**Other
worlds**

Our origins start in the very dilute gas between the stars



Carina nebula: nursery of new stars and planets



Star formation: “Pillars of Creation”



JWST-MIRI

Protostars and jets



Ophiuchus
July 12 2023

Protostar with molecular jet



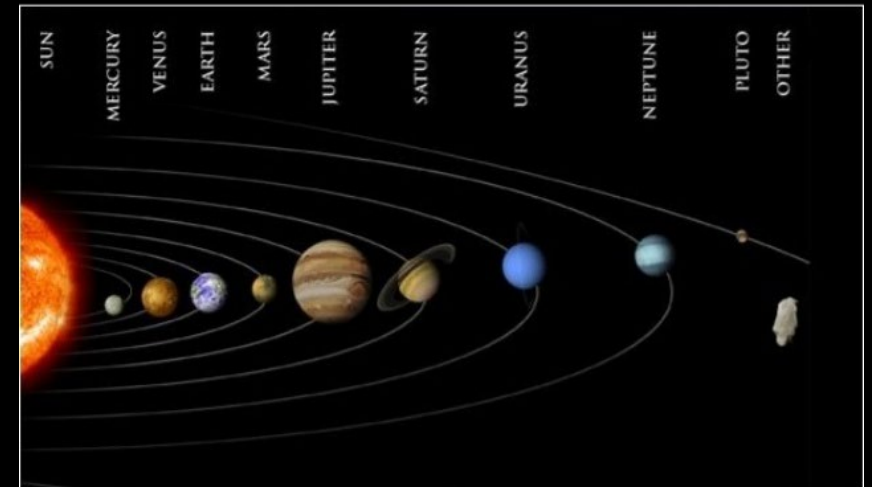
JWST-NIRCAM
T. Ray et al. 2023
NASA/ESA PR Sept. 14, 2023

Planets form in disks around young stars



Animation
NASA/SSC/R. Hurt

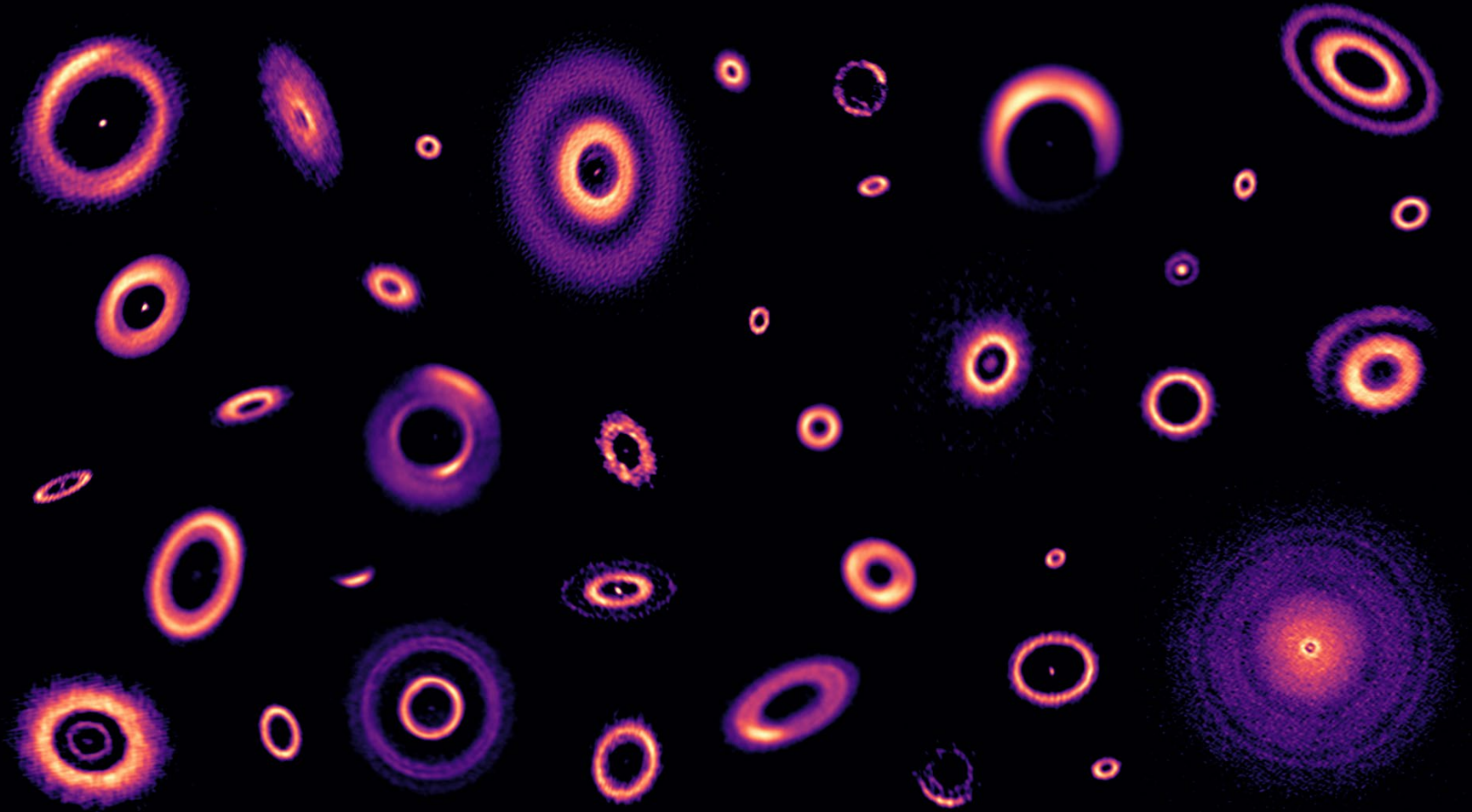
Analogy:
Solar nebula hypothesis



Kant 1755, Swedenborg 1734

These disks can now be imaged

gallery of planet-forming disks



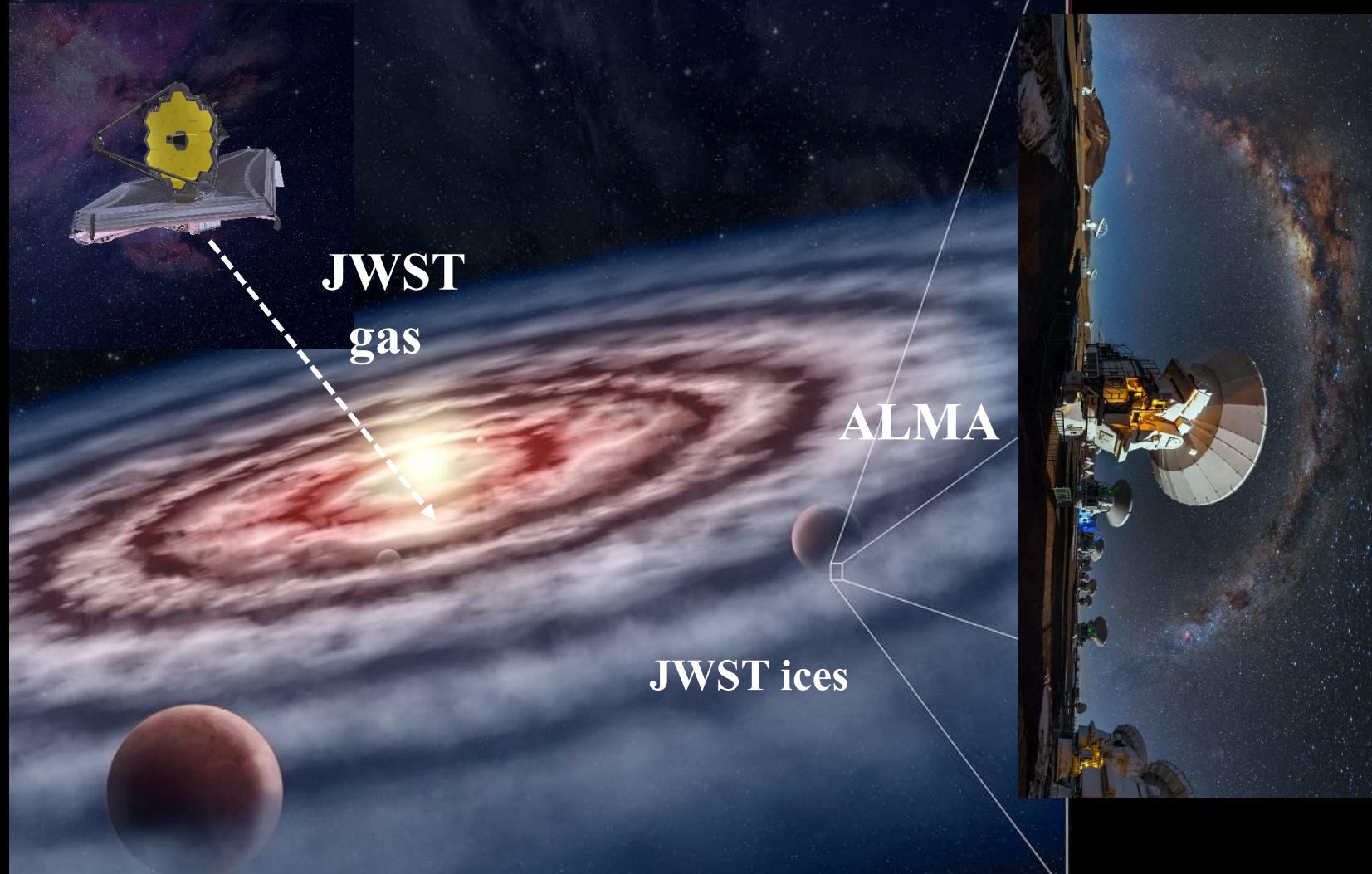
ALMA
1 mm, cold
dust emission

50 au
↔
Size of our solar system

What is the composition out of which new planets are made?

Francis & van der Marel 2020
Atacama Large Millimeter Array (ALMA)

Building planets in disks: composition material?

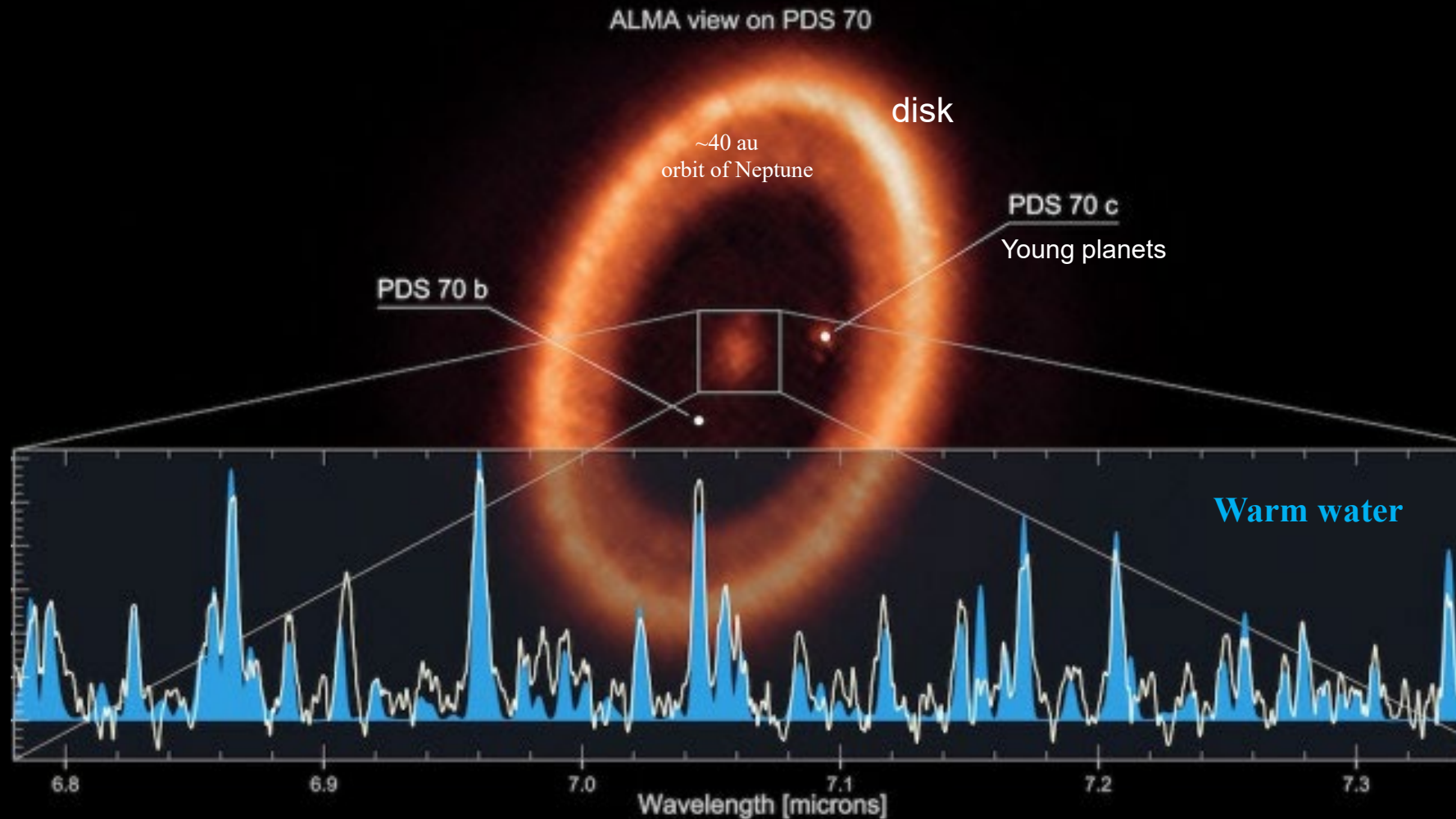


Synergy JWST-ALMA

M. Weiss, CfA
MAPS Öberg et al. 2021

Water in the terrestrial planet-forming zones of disks

NASA-ESA press release July 24, 2023



Perotti et al. 2023



Building planets: what sets their composition?



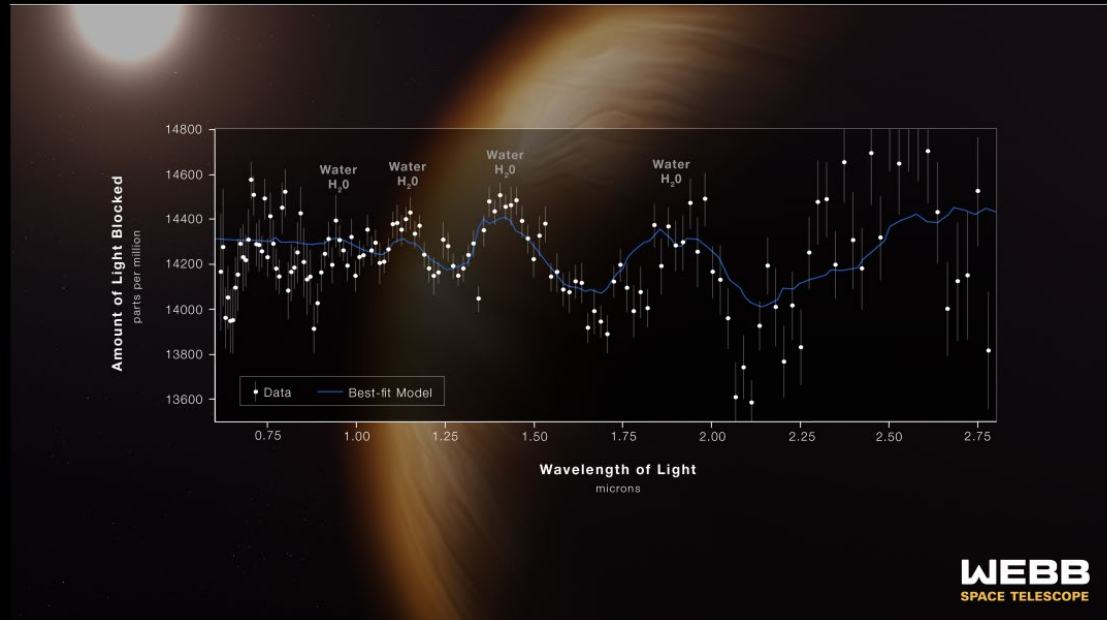
Chemistry as a probe of formation location and history of mature planets

Webb: Water and CO₂ in exoplanet atmospheres

HOT GAS GIANT EXOPLANET WASP-96 b
ATMOSPHERE COMPOSITION

H₂O

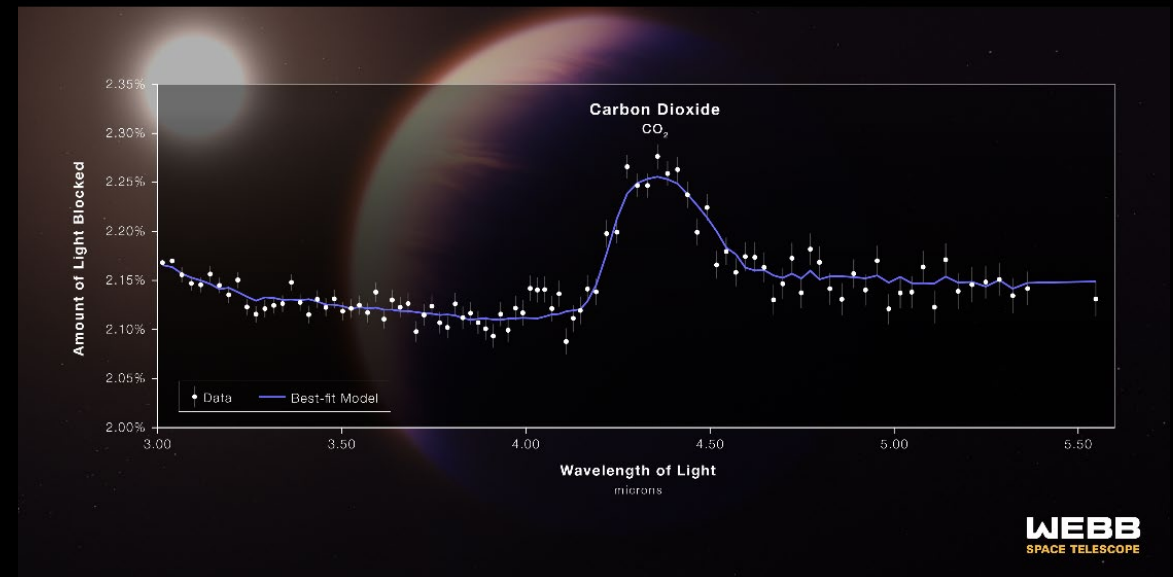
NIRISS | Single-Object Slitless Spectroscopy



HOT GAS GIANT EXOPLANET WASP-39 b
ATMOSPHERE COMPOSITION

CO₂

NIRSpec | Bright Object Time-Series Spectroscopy

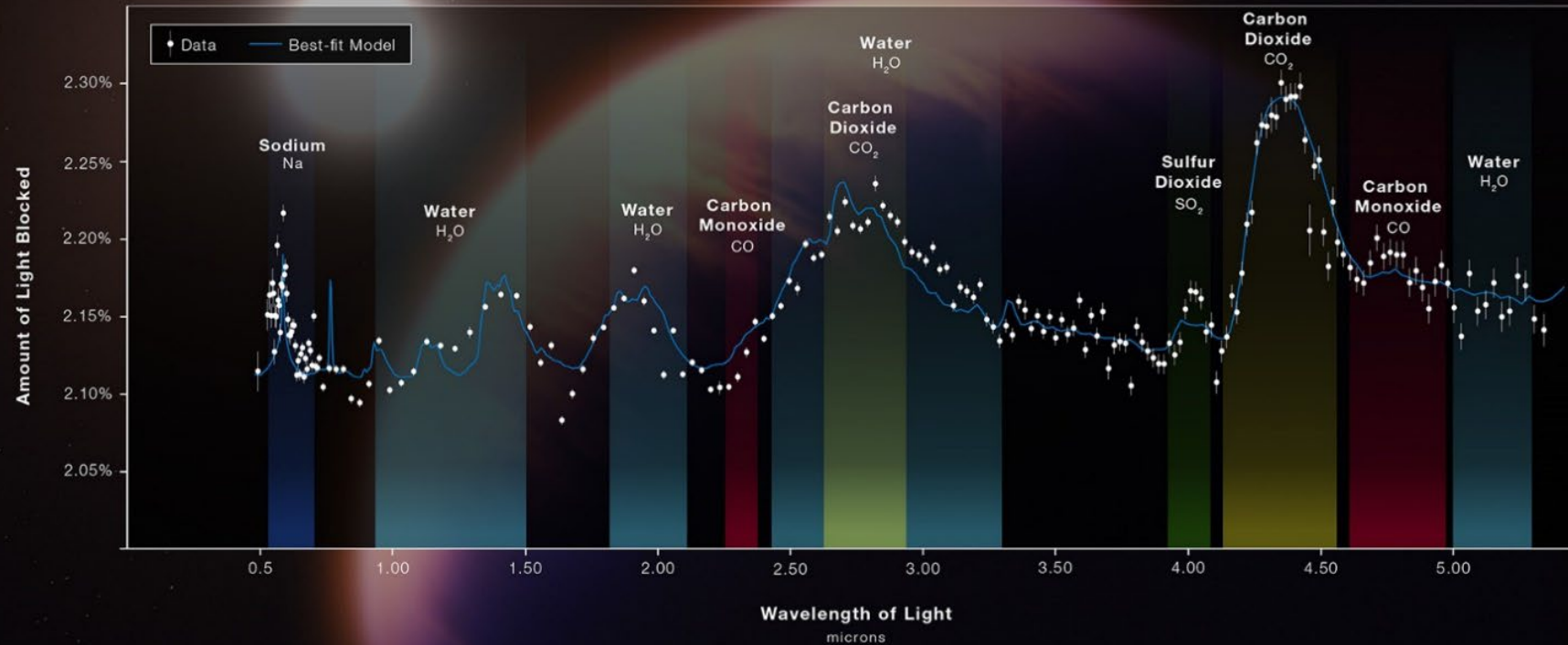


Probing the composition of exoplanet atmospheres

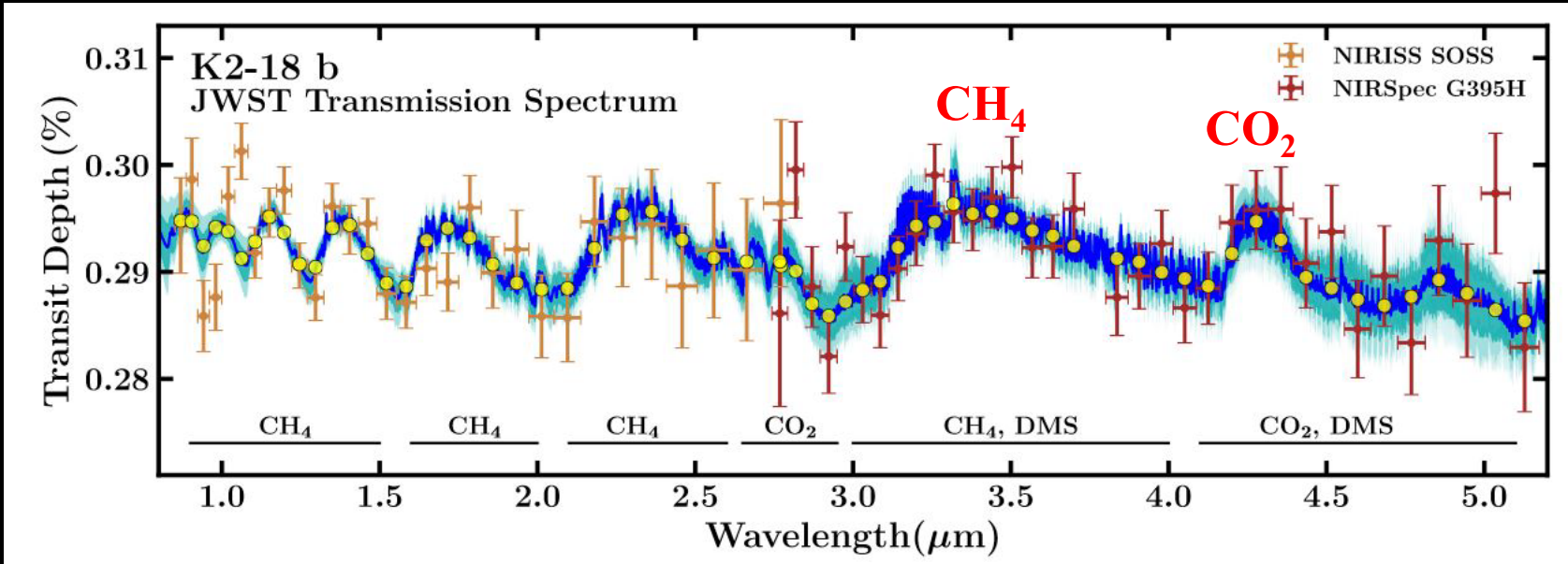
HOT GAS GIANT EXOPLANET WASP-39 b

ATMOSPHERE COMPOSITION

NIRSpec PRISM



Atmosphere of a Neptune-mass planet



- Clear detections of CH₄ and CO₂, no NH₃
- Consistent with ocean under H₂ atmosphere



Future New Views

From Fromberg to Cerro Armazones



Extremely Large Telescope



Construction progressing
Sept 5 2023



We are all world citizens under
the same beautiful sky

*Science and astronomy provide inspiration,
perspective (sense of vulnerability), modesty, tolerance*

