



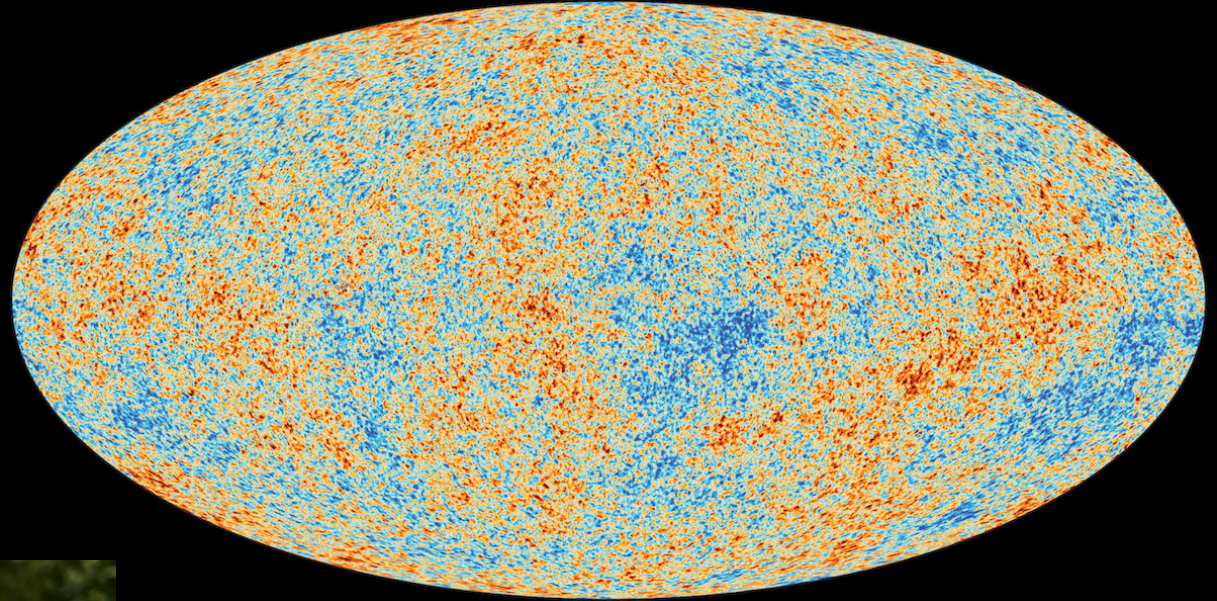
Two Years of Galaxies
with the
WEBB
SPACE TELESCOPE

December, 2023 – June, 2024



The Story of Us

- How do we get from this:



Hydrogen & Helium

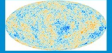





- To this?



Carbon, Oxygen, Nitrogen, Calcium, Iron...
All arranged in complex molecules



The Origin of elements

1 H	big bang fusion 										cosmic ray fission 					2 He	
3 Li	4 Be	merging neutron stars? 					exploding massive stars 					5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	dying low mass stars 					exploding white dwarfs 					13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
87 Fr	88 Ra																
		57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
		89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	Very radioactive isotopes; nothing left from stars									

Graphic created by Jennifer Johnson
<http://www.astronomy.ohio-state.edu/~jaj/nucleo/>

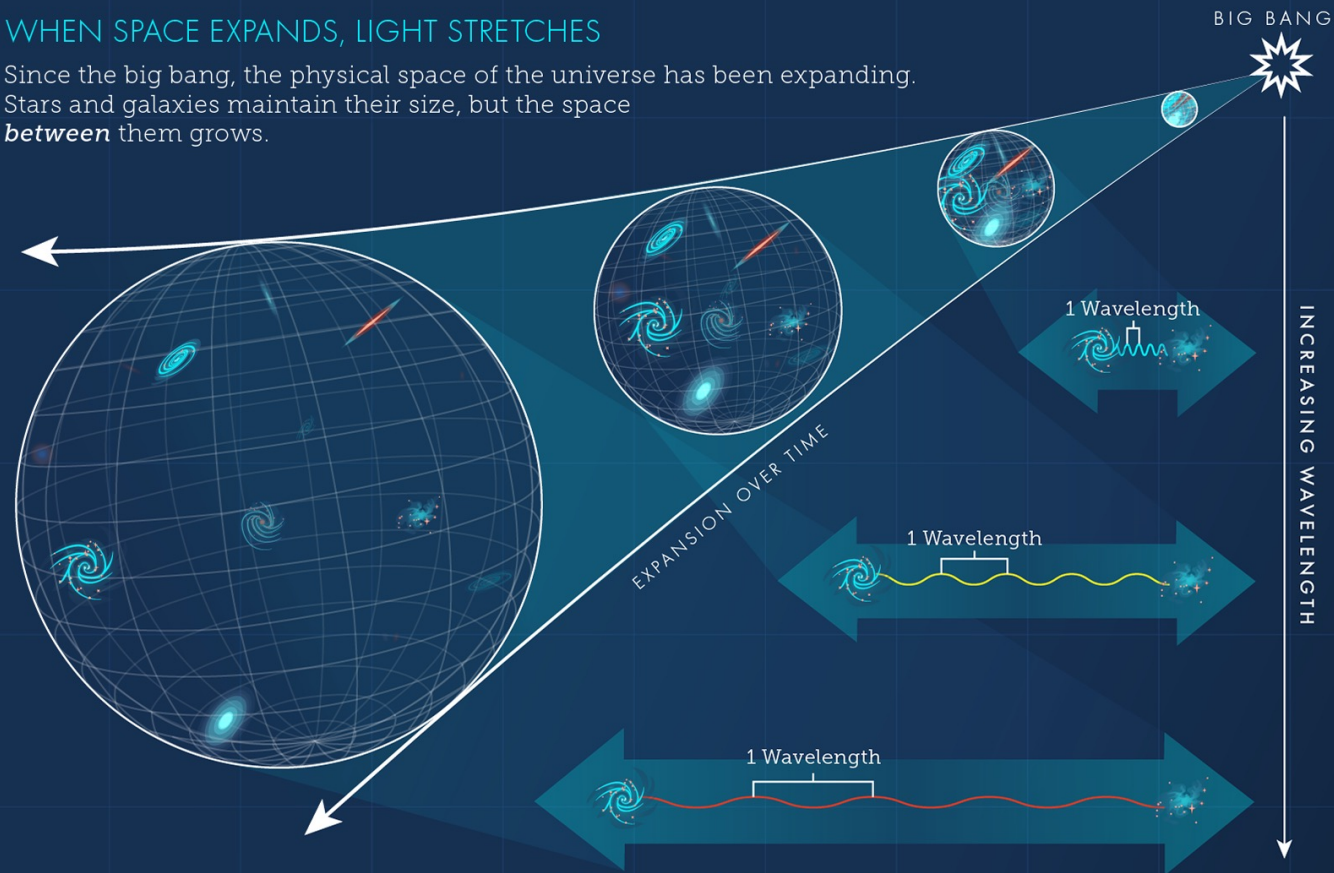
Astronomical Image Credits:
 ESA/NASA/AASNova

Telescopes are time machines

WHAT IS COSMOLOGICAL REDSHIFT?

WHEN SPACE EXPANDS, LIGHT STRETCHES

Since the big bang, the physical space of the universe has been expanding. Stars and galaxies maintain their size, but the space *between* them grows.



As light travels through expanding space, it is stretched to longer wavelengths.





How did we get here?

UNIVERSE THROUGH TIME

BIG BANG

Universe forms roughly 13.8 billion years ago

Recombination occurs 380,000 years after the big bang

FIRST STARS form 200–400 million years after the big bang

DARK AGES

FIRST GALAXIES

Reionization

begins when the first stars start to shine

complete within 1 billion years after the big bang

SUN forms more than 9 billion years after the big bang

MODERN UNIVERSE





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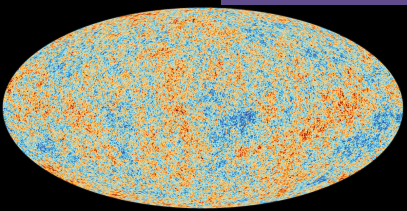
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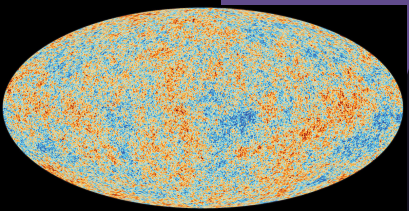
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Cosmic Noon

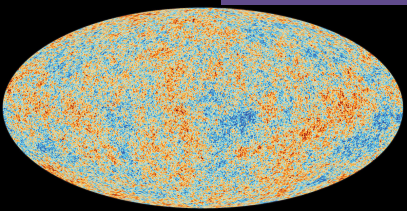
MODERN UNIVERSE

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Lingering questions

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DARK AGES

???

FIRST GALAXIES

Hubble limit

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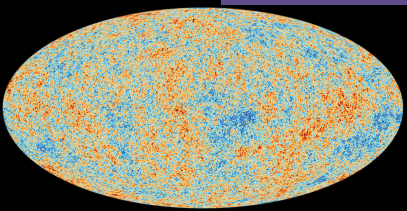
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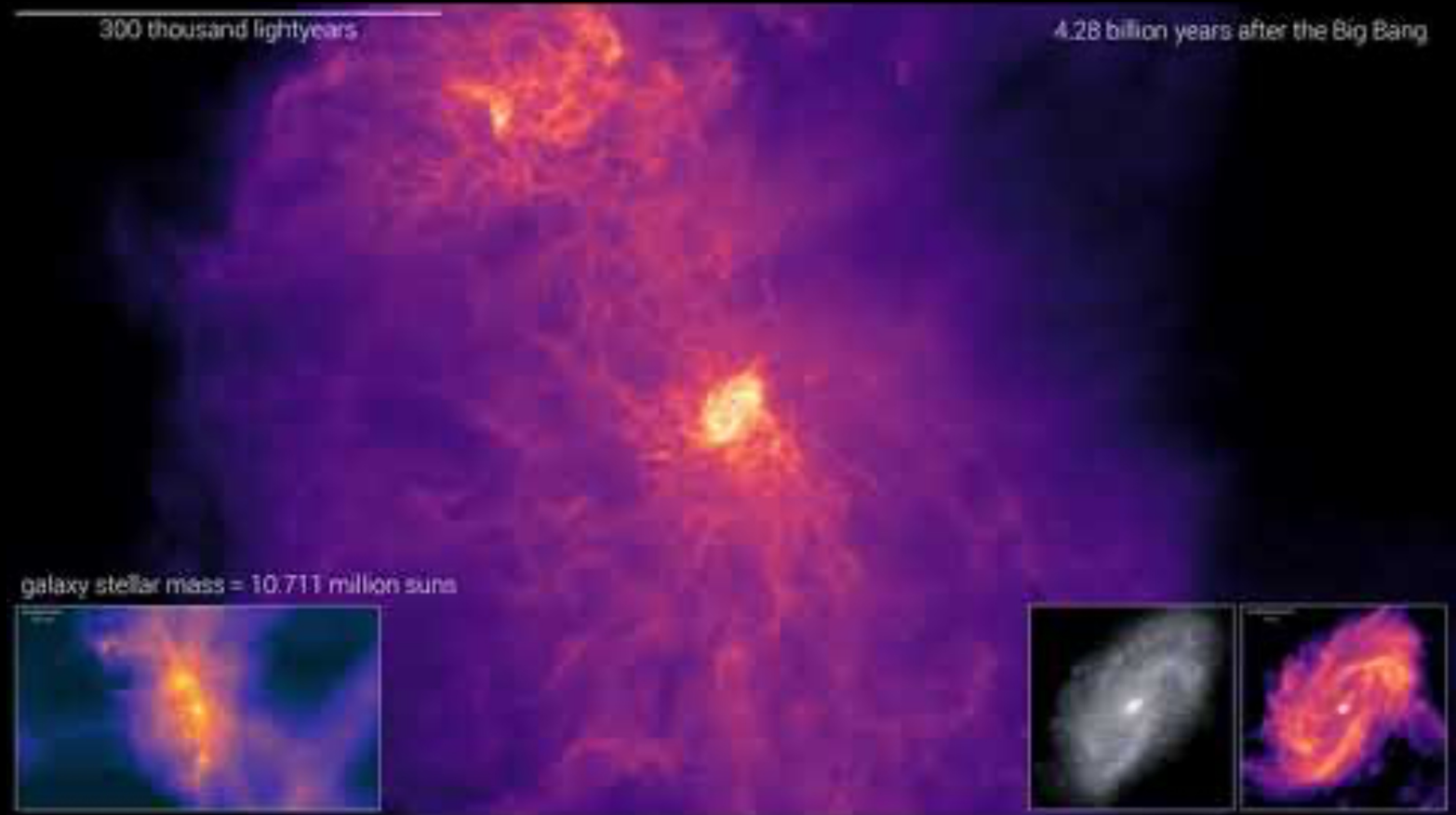
MODERN UNIVERSE





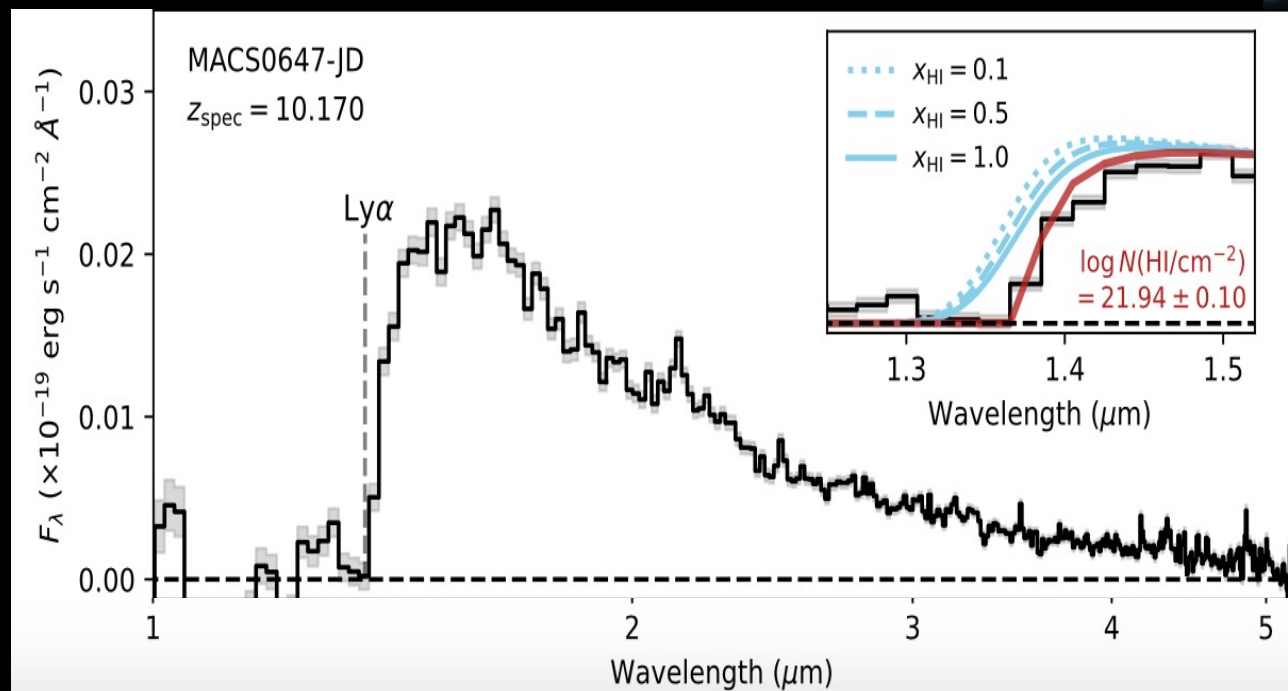
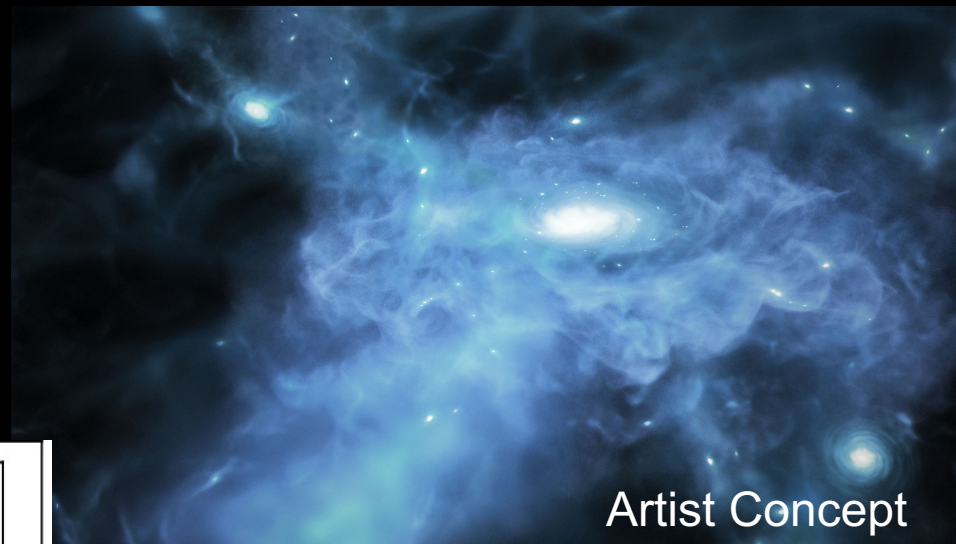
Galaxy assembly simulations

- Dark matter's gravity forms the deep “wells” that material follows onto nascent galaxies



Webb is showing this earlier epoch

- For the first time, we have seen direct evidence of galaxies pulling in primordial, neutral H





What are the biggest surprises?

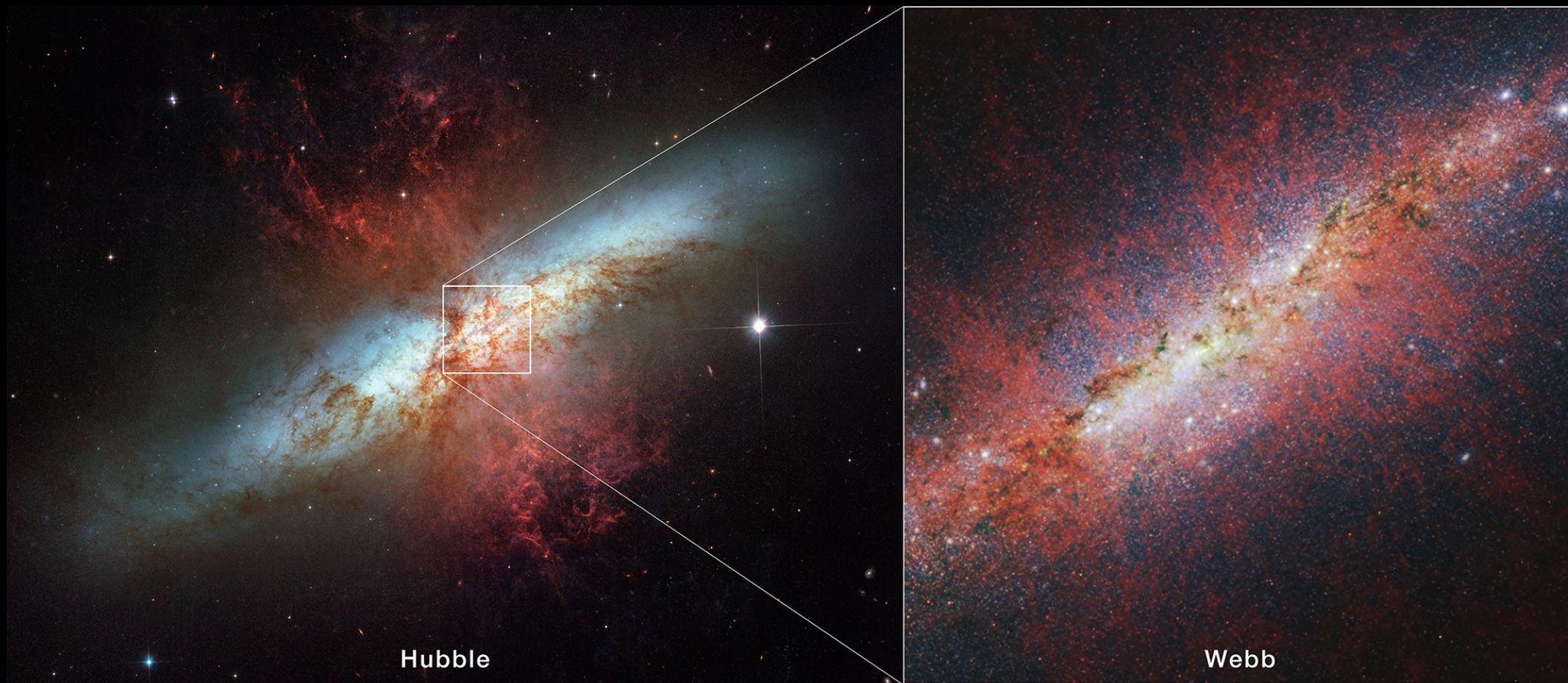
- Webb is seeing more bright galaxies than expected.
- There could be many reasons for this:
 - Dust cleared out of smaller galaxies by intense star formation?

We can see something similar happening locally after all...



M82: Example of nearby dust clearing

- Burst of star formation blows gas out of the galaxy





What are the biggest surprises?

- Webb is seeing more bright galaxies than expected.
- There could be many reasons for this:
 - Dust cleared out of smaller galaxies by intense star formation?
 - Star formation happens in brief, bright bursts?
 - Easier to form massive stars with fewer heavy elements?
 - Webb happened to look so far at a sight line along a dense strand of the cosmic web?
 - “Extra light” from growing black holes throwing off models that assume starlight?
 - Dark matter has a somewhat different nature than we thought?
 - And more!



More surprises: the most distant galaxy known so far

- Seeing some relatively enriched galaxies at very early times
- <300 million years after the Big Bang, ~3% as many heavy elements as the Sun
- Already reddened by dust!



Surprises in galaxy evolution

Modern galaxies follow a “tuning fork”

*Edwin Hubble's
Classification
Scheme*

No dust
Few stars forming
Redder

Ellipticals

E0 E3 E5 E7 S0

Sa

Sb

Sc

Spirals

Lots of dust
Many stars forming
Bluer

SBa

SBb

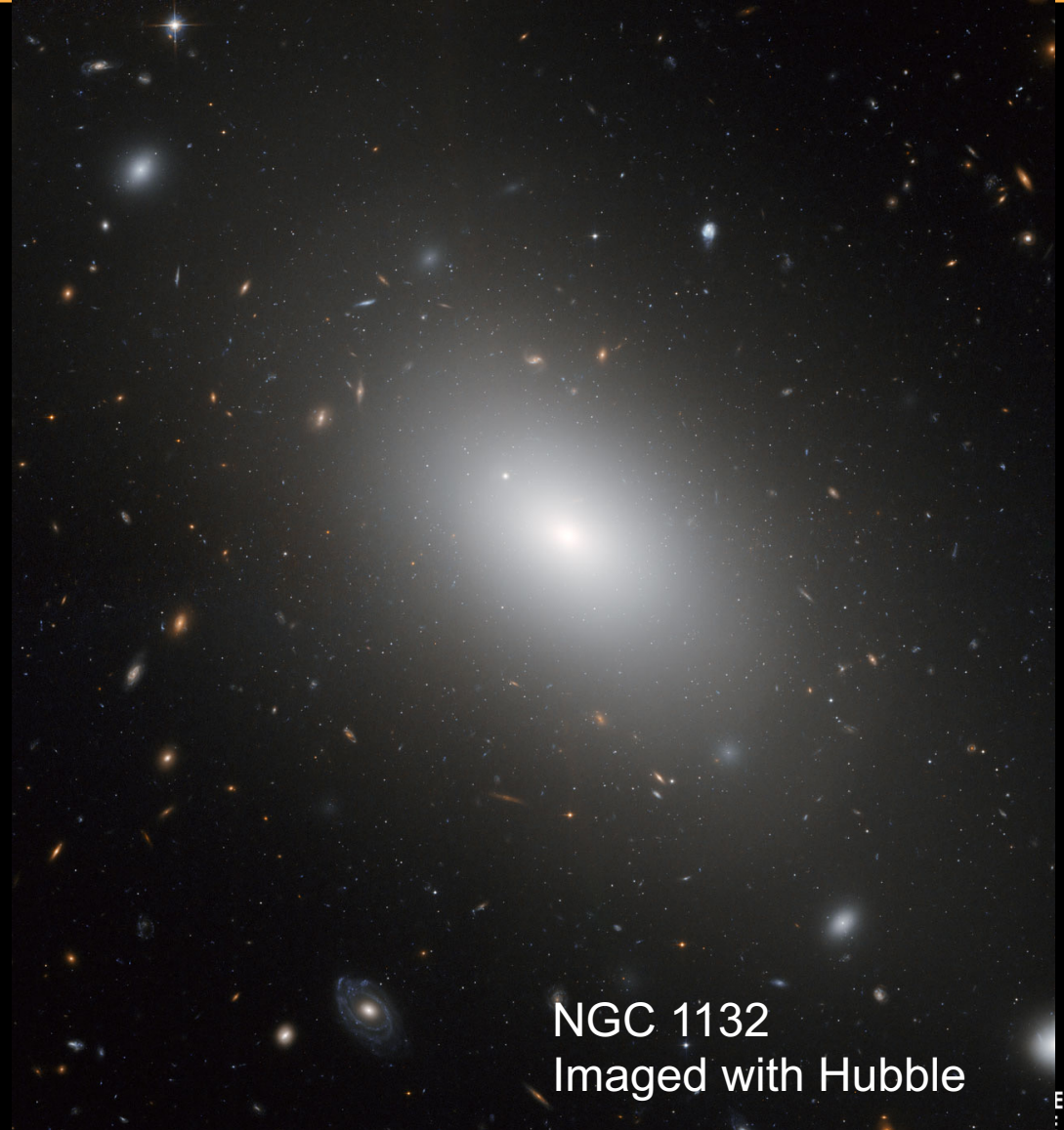
SBc

Surprises in galaxy evolution



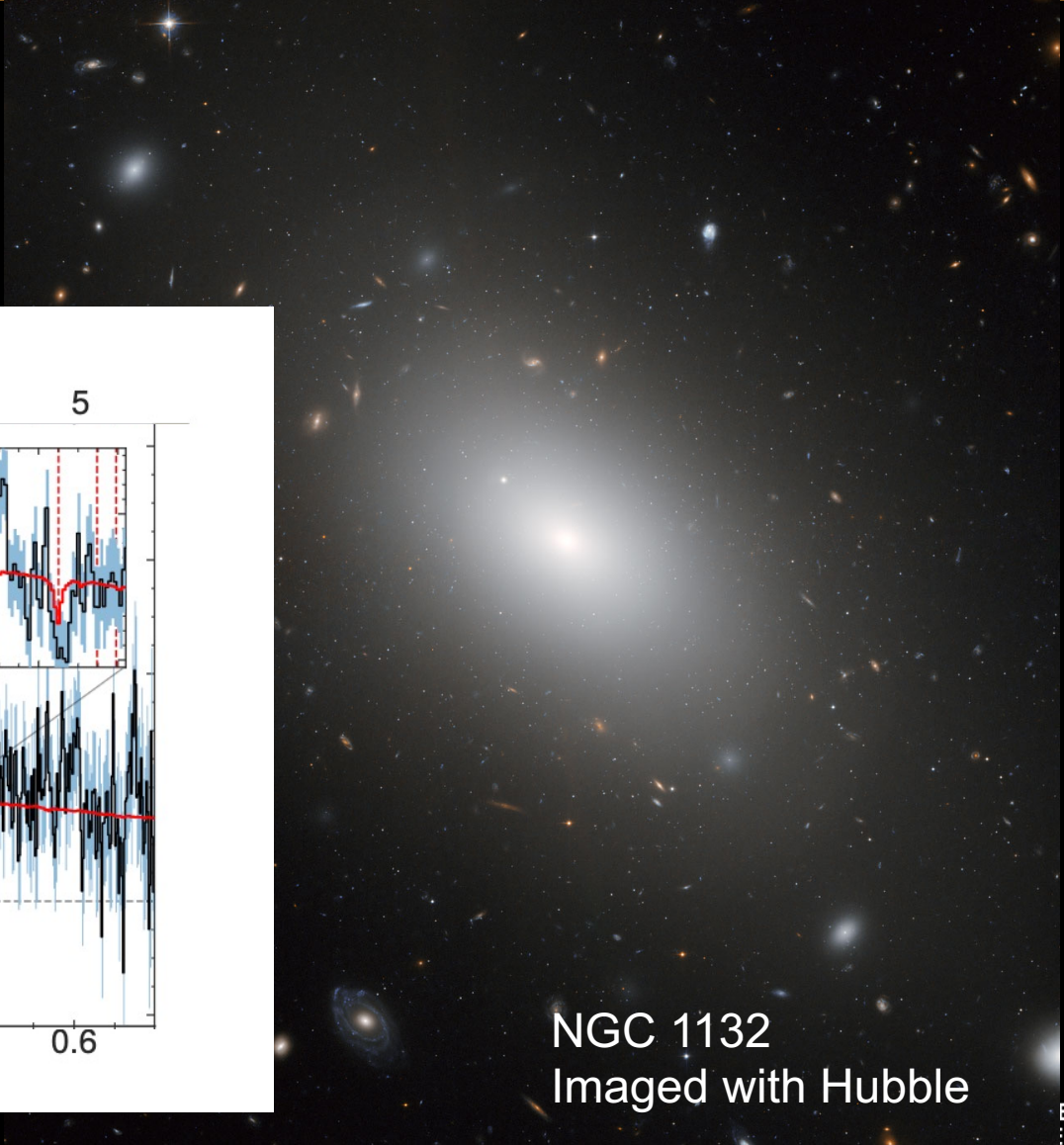
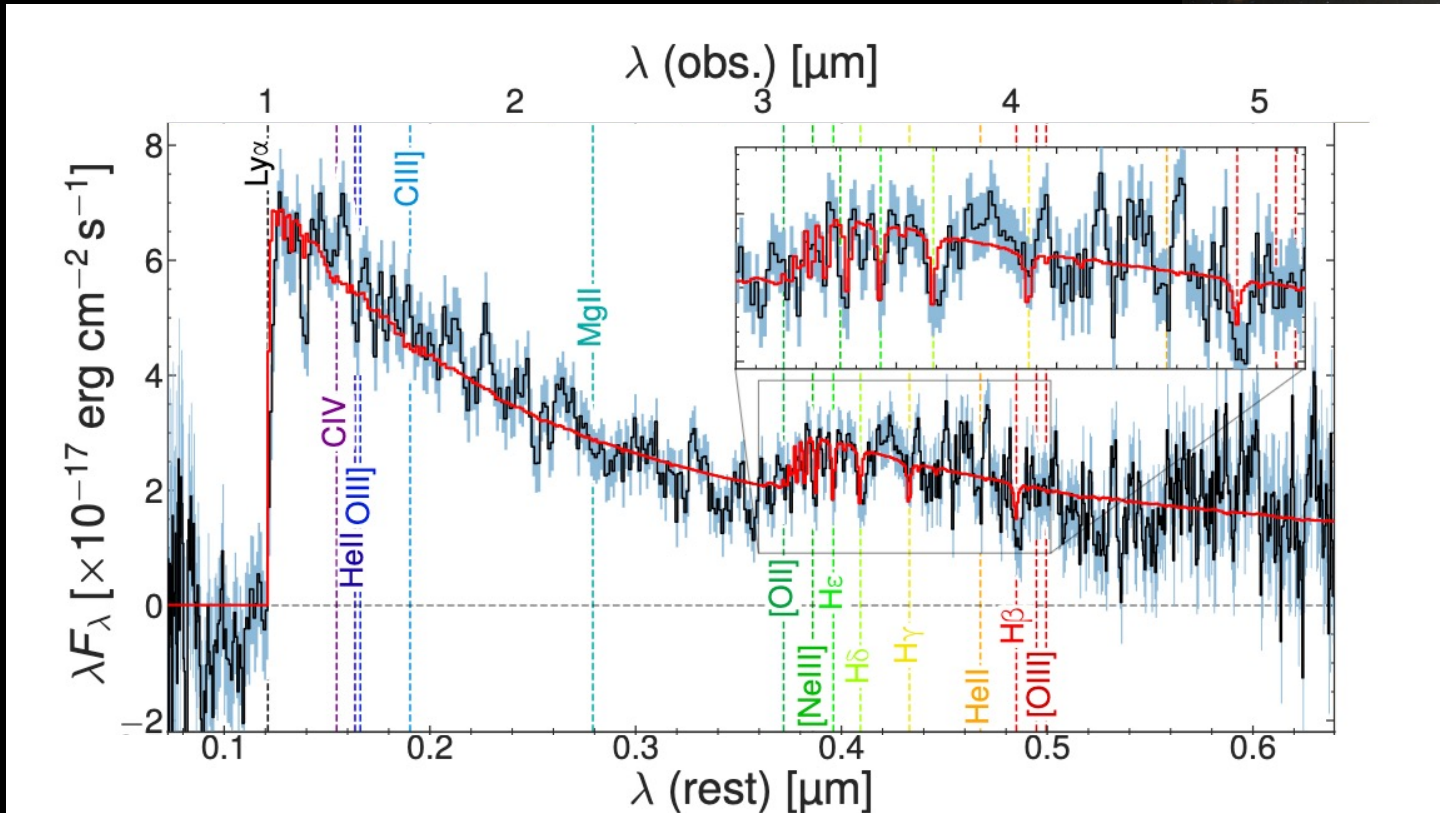
NGC 3147
Imaged with Hubble

VS



NGC 1132
Imaged with Hubble

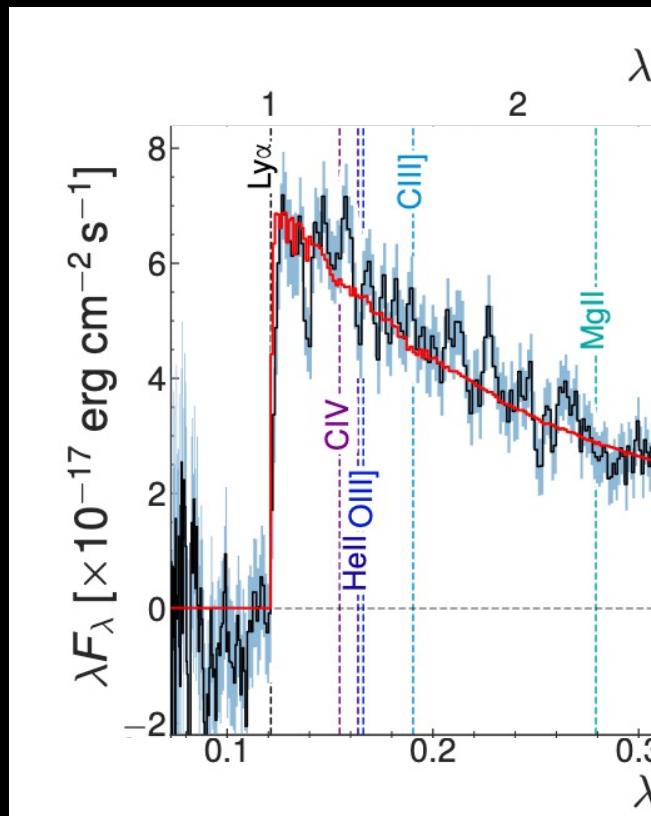
More surprises: Red & Dead early galaxies



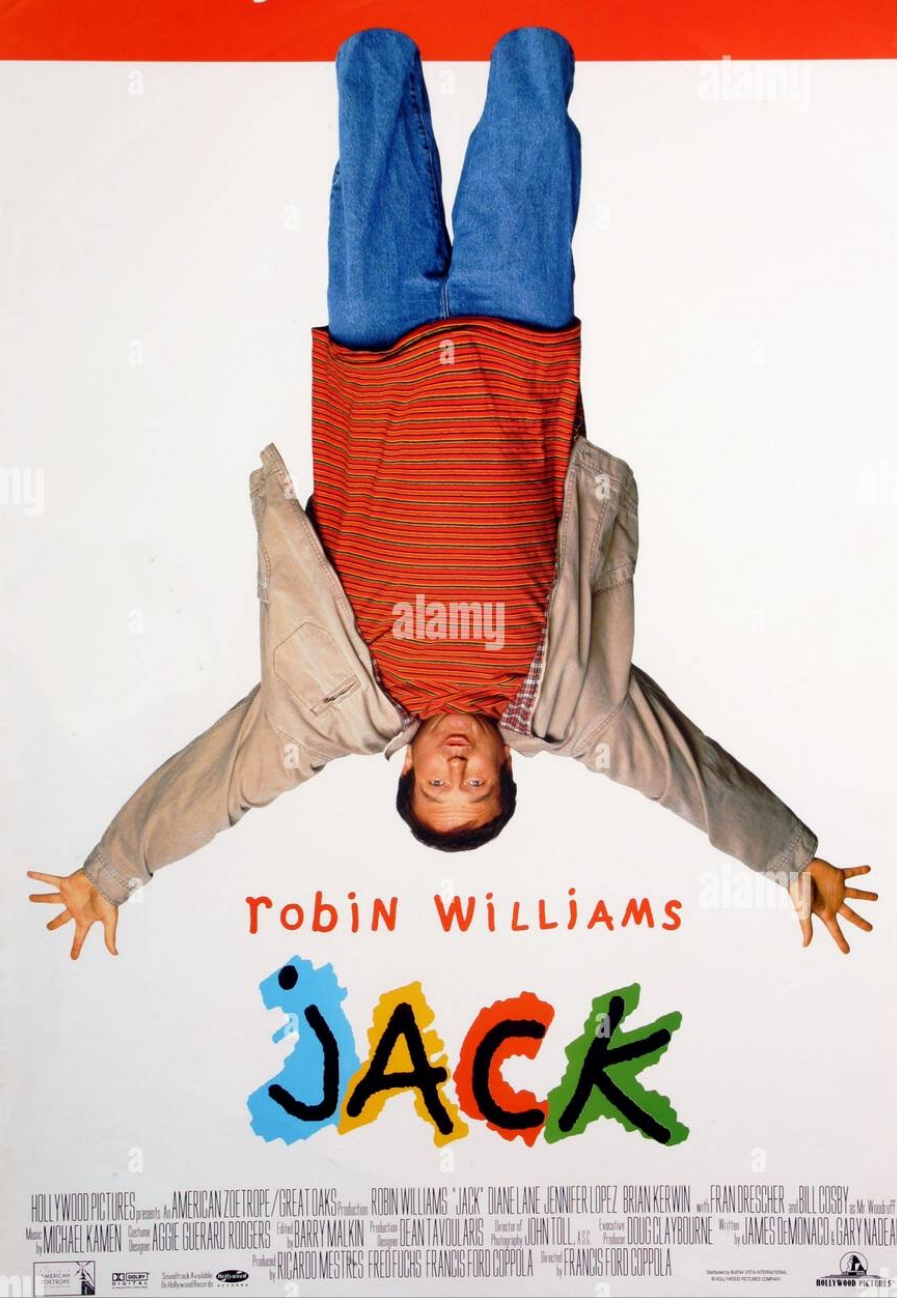
NGC 1132
Imaged with Hubble



More s galaxi



A comedy "for the kid in all of us."



alamy

Image ID: 2JHN63H
www.alamy.com

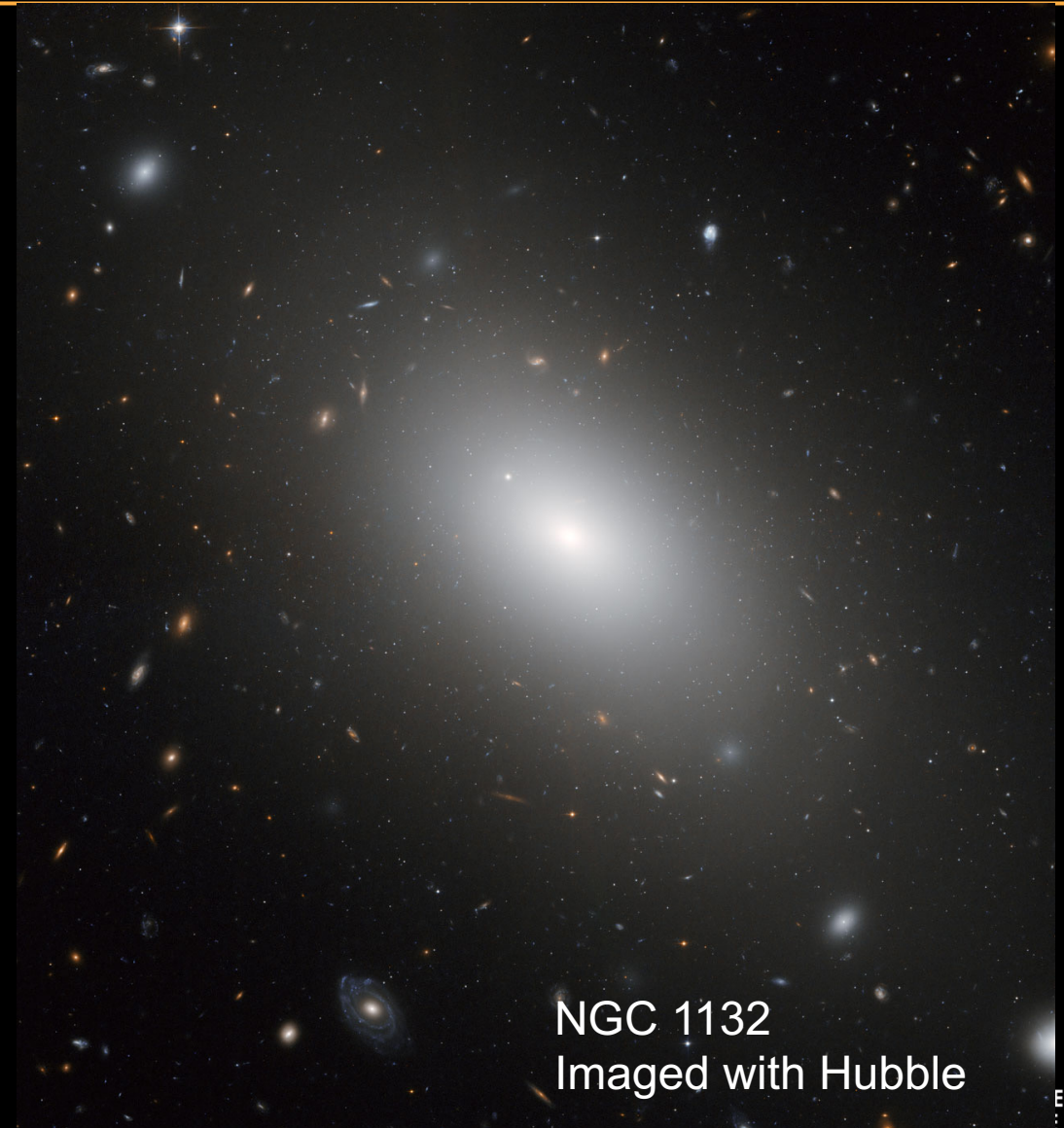
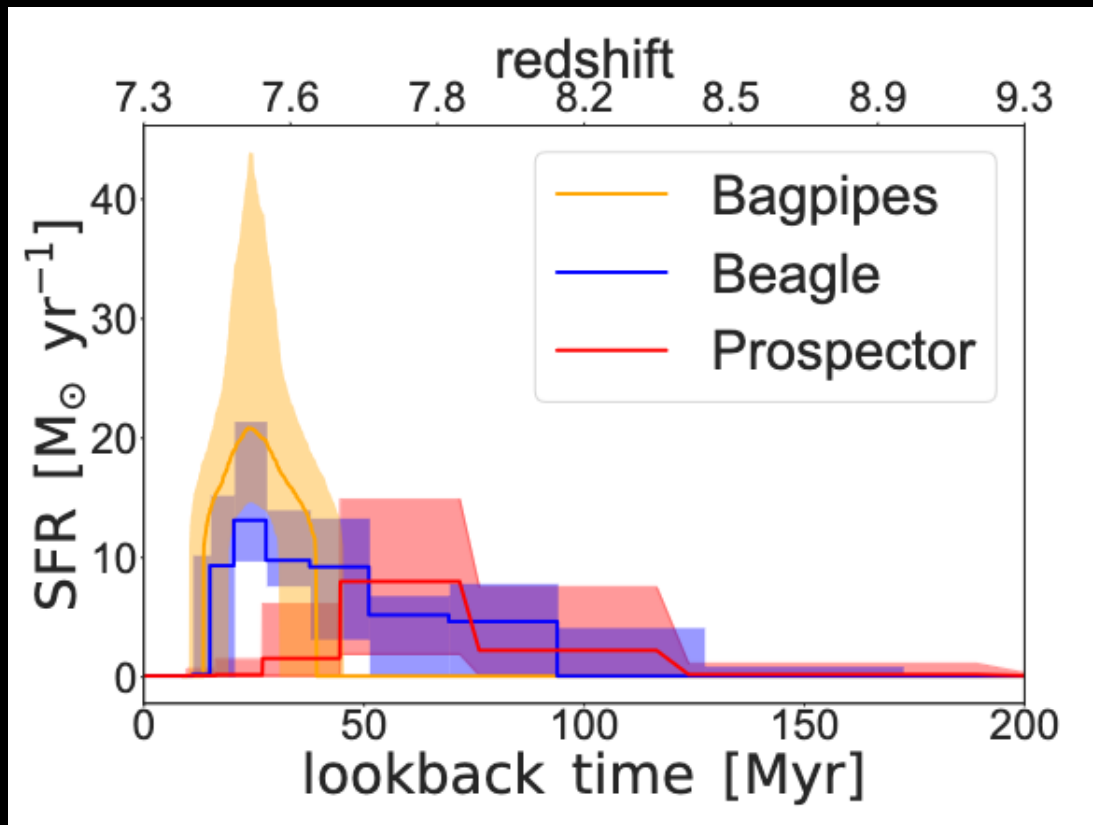
Dead early



NGC 1132
Imaged with Hubble

ELESCOPE
INSTITUTE

More surprises: Red & Dead early galaxies

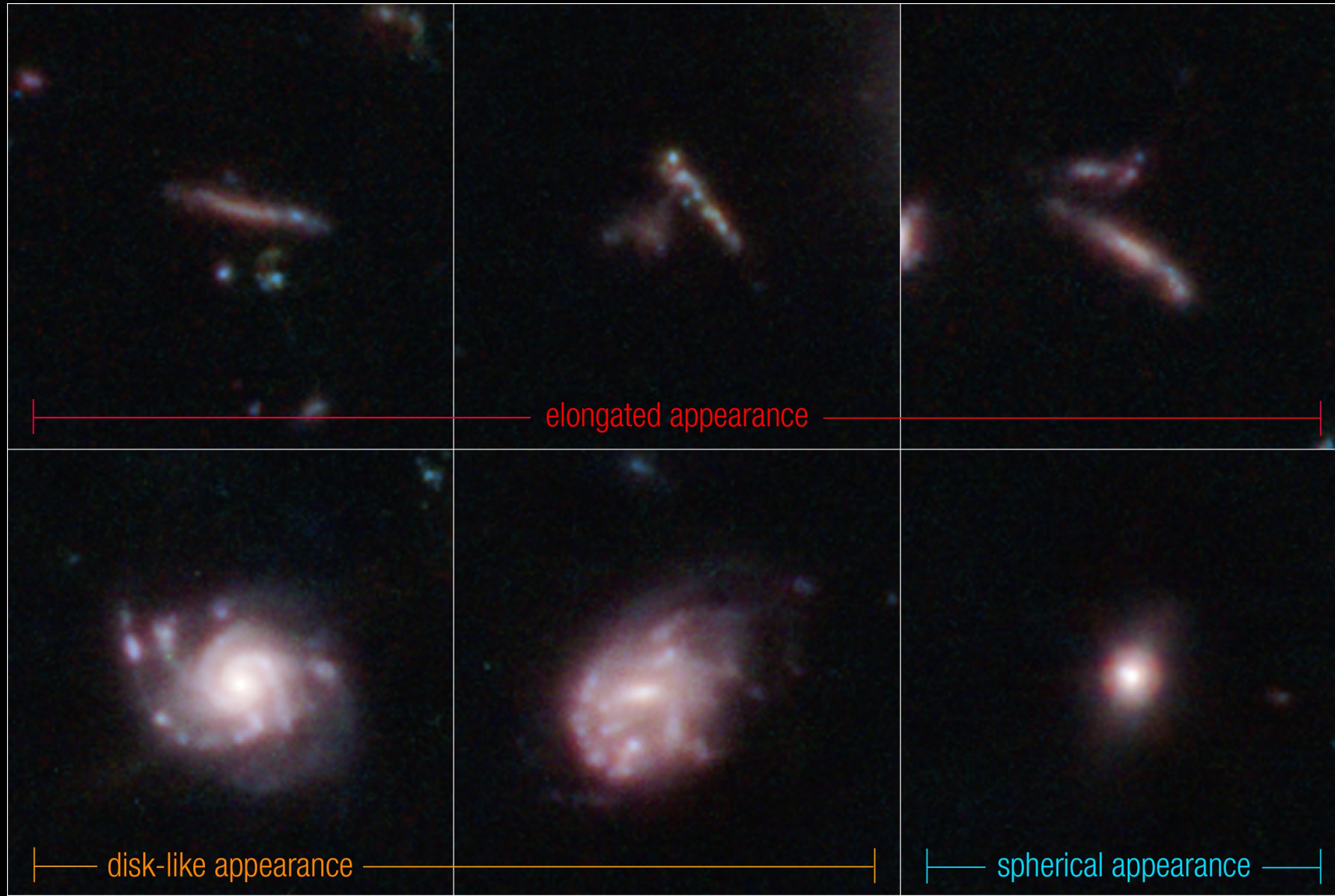




More surprises: Disks and Noodles

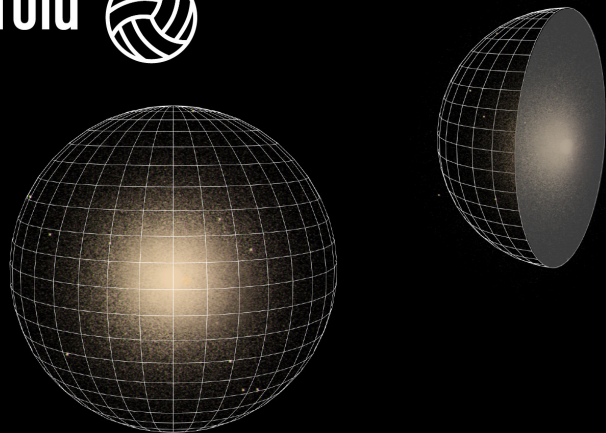


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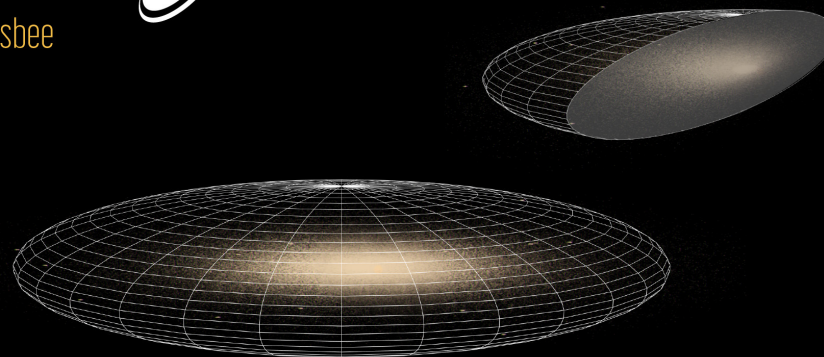


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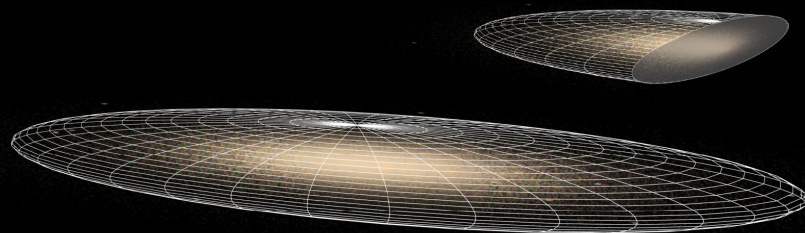
Spheroid 
Volleyball



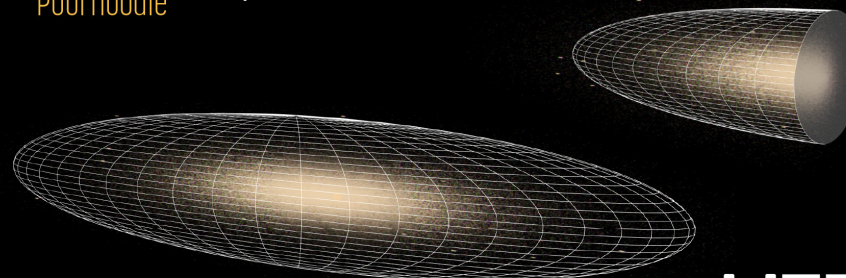
Oblate 
Frisbee

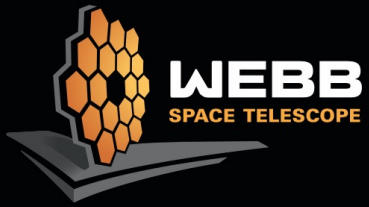


Oval 
Surfboard



Prolate 
Pool noodle





More surprises: Hints of the first stars?



GN-z11

More surprises: Hints of the first stars?

GALAXY GN - z11

PRISTINE GAS CLUMP NEAR GN - z11

NIRCam Imaging



Wavelength
specific to
ionized helium

All observed
wavelengths

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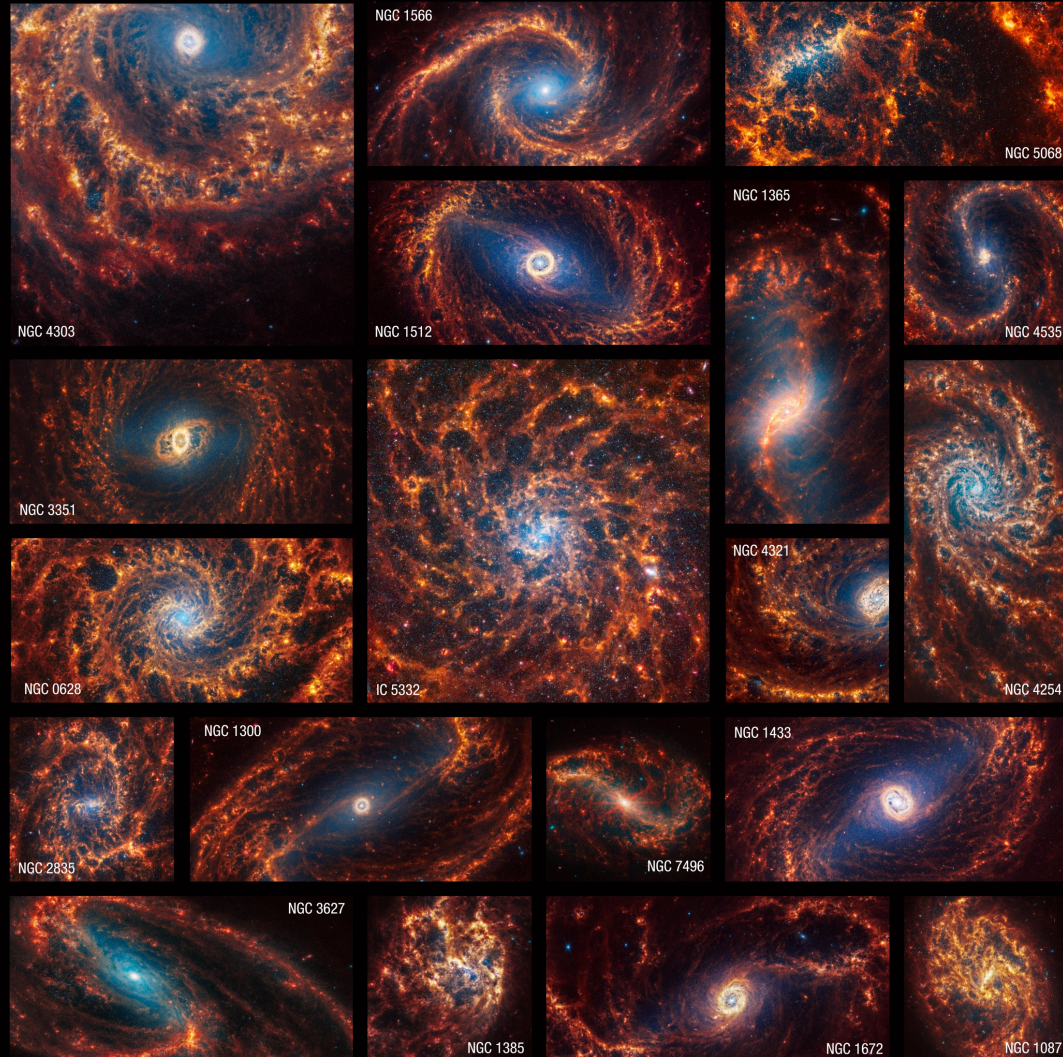
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A close look at how star formation shapes a galaxy

- PHANGS survey – many high resolution images





The “Phantom Galaxy”, M74



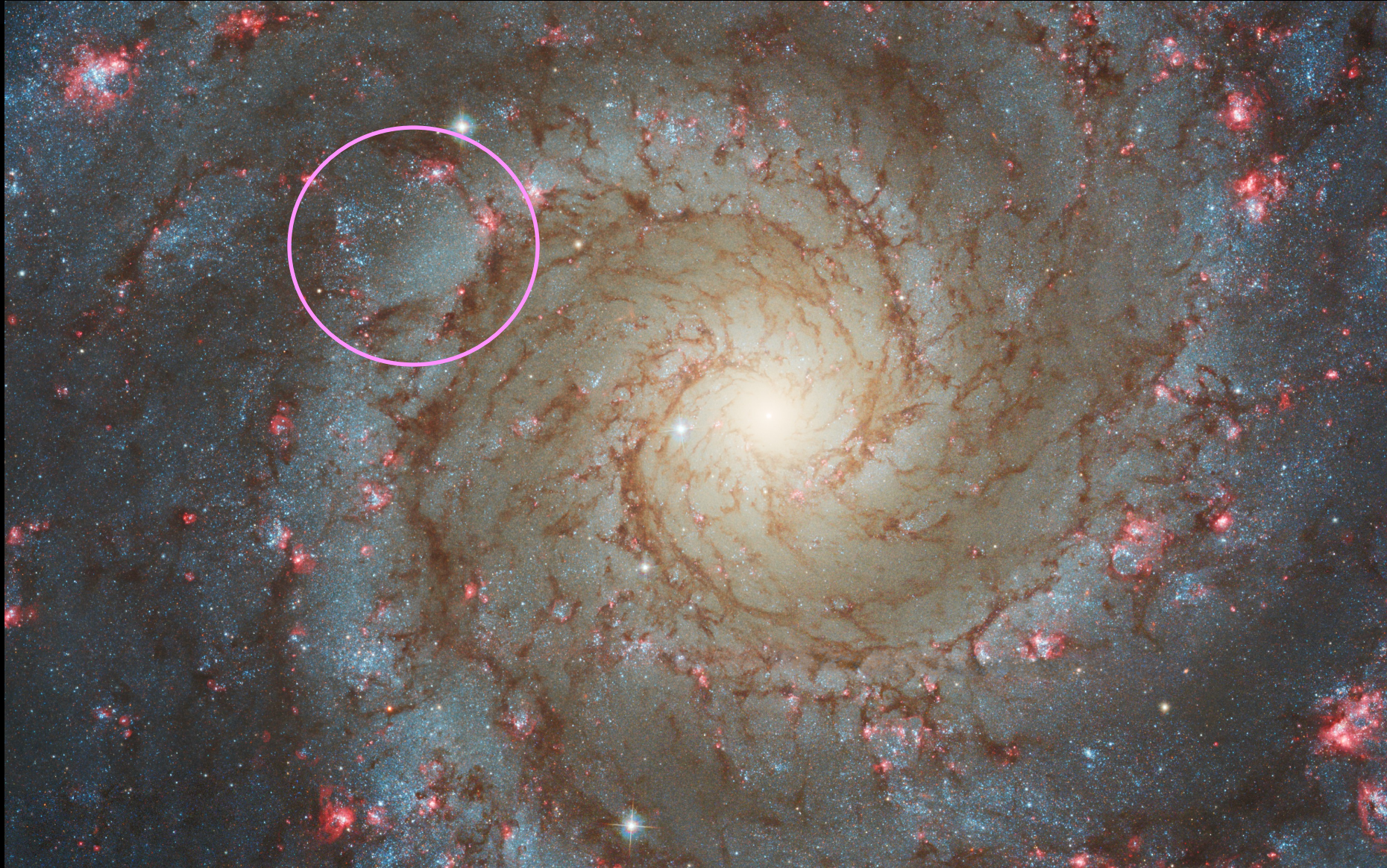


The “Phantom Galaxy”, M74



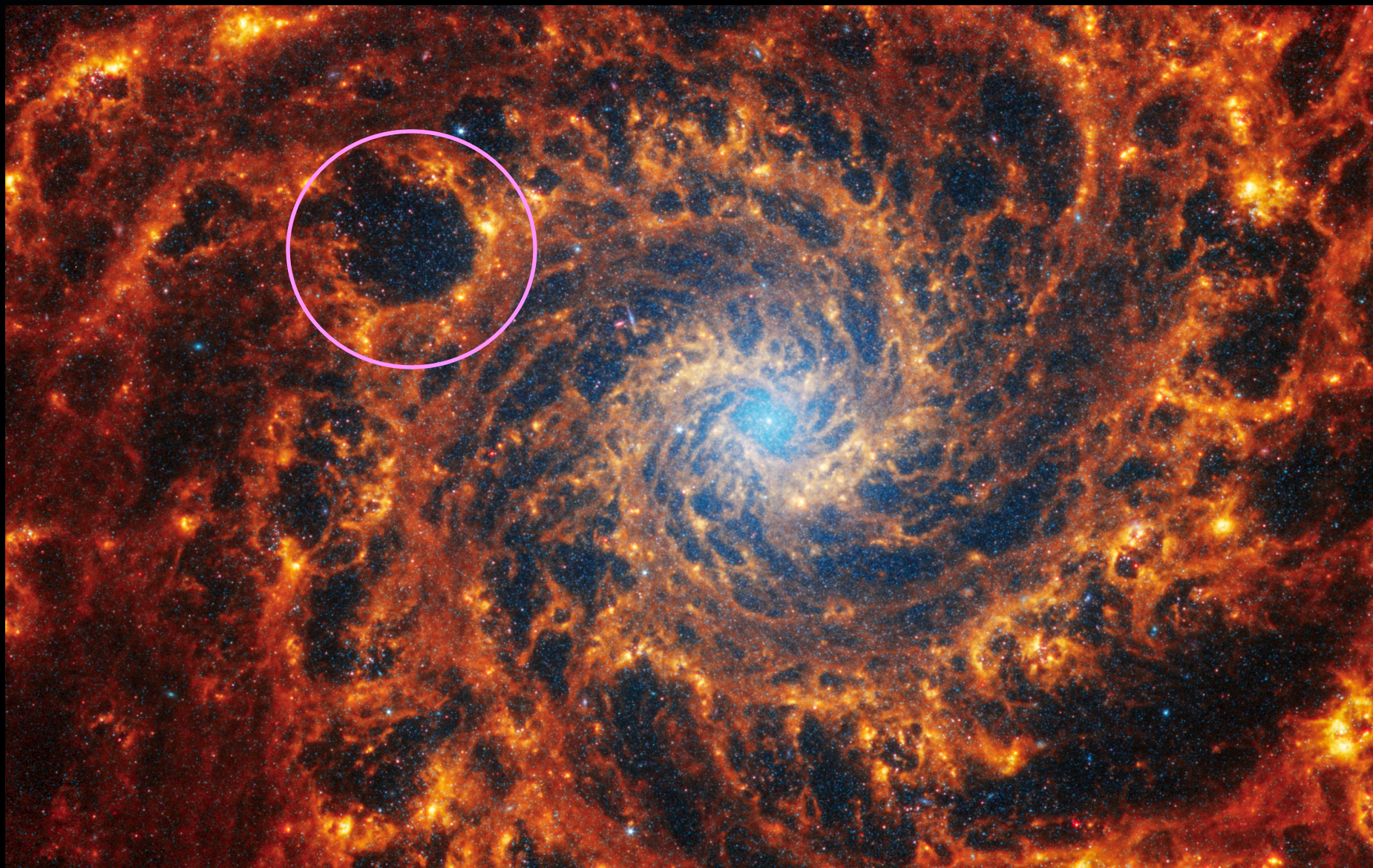


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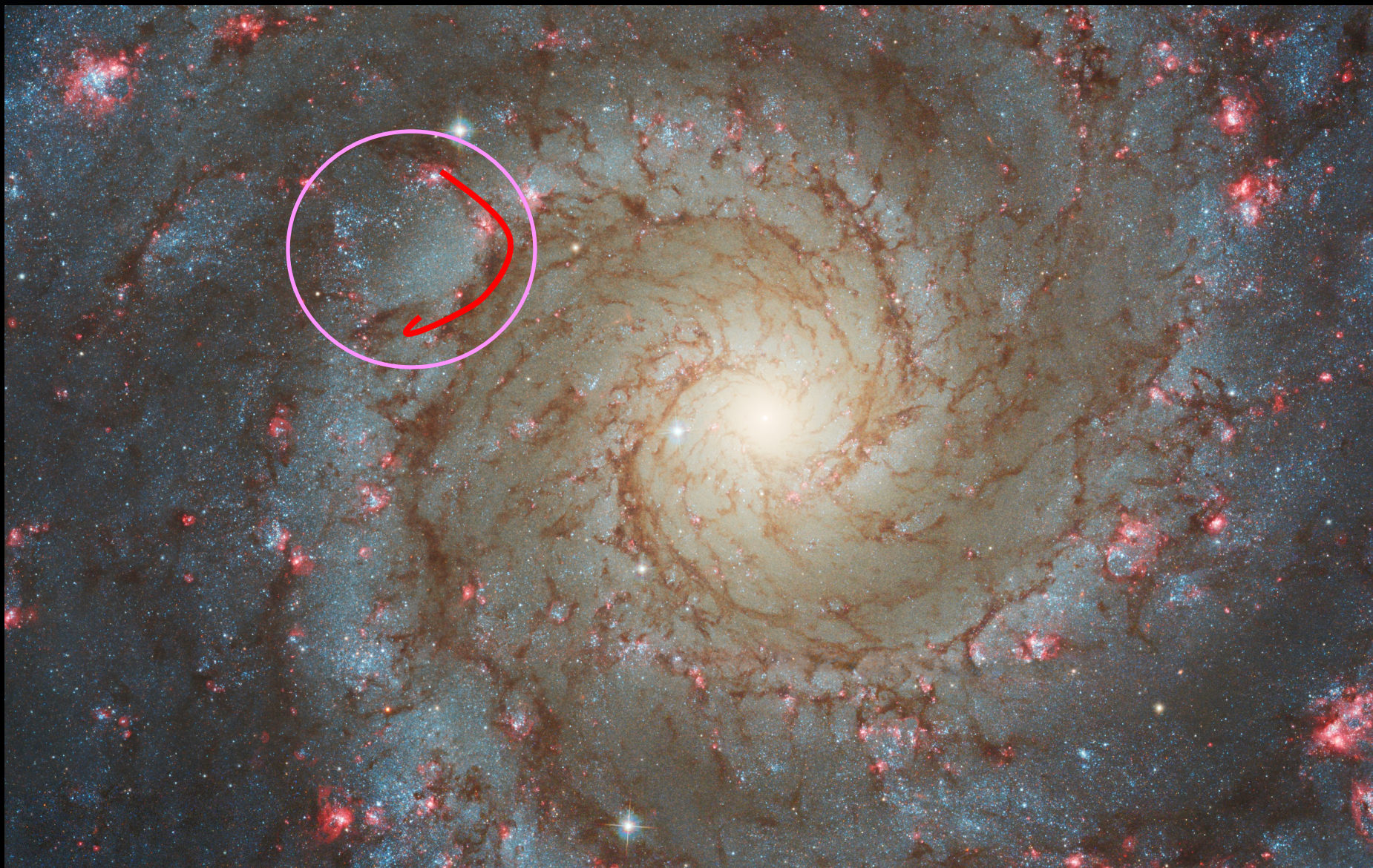




The “Phantom Galaxy”, M74



The “Phantom Galaxy”, M74





The “Phantom Galaxy”, M74





The “Phantom Galaxy”, M74





NGC 7496

- Face-on barred spiral
- Is the center a bit bright?





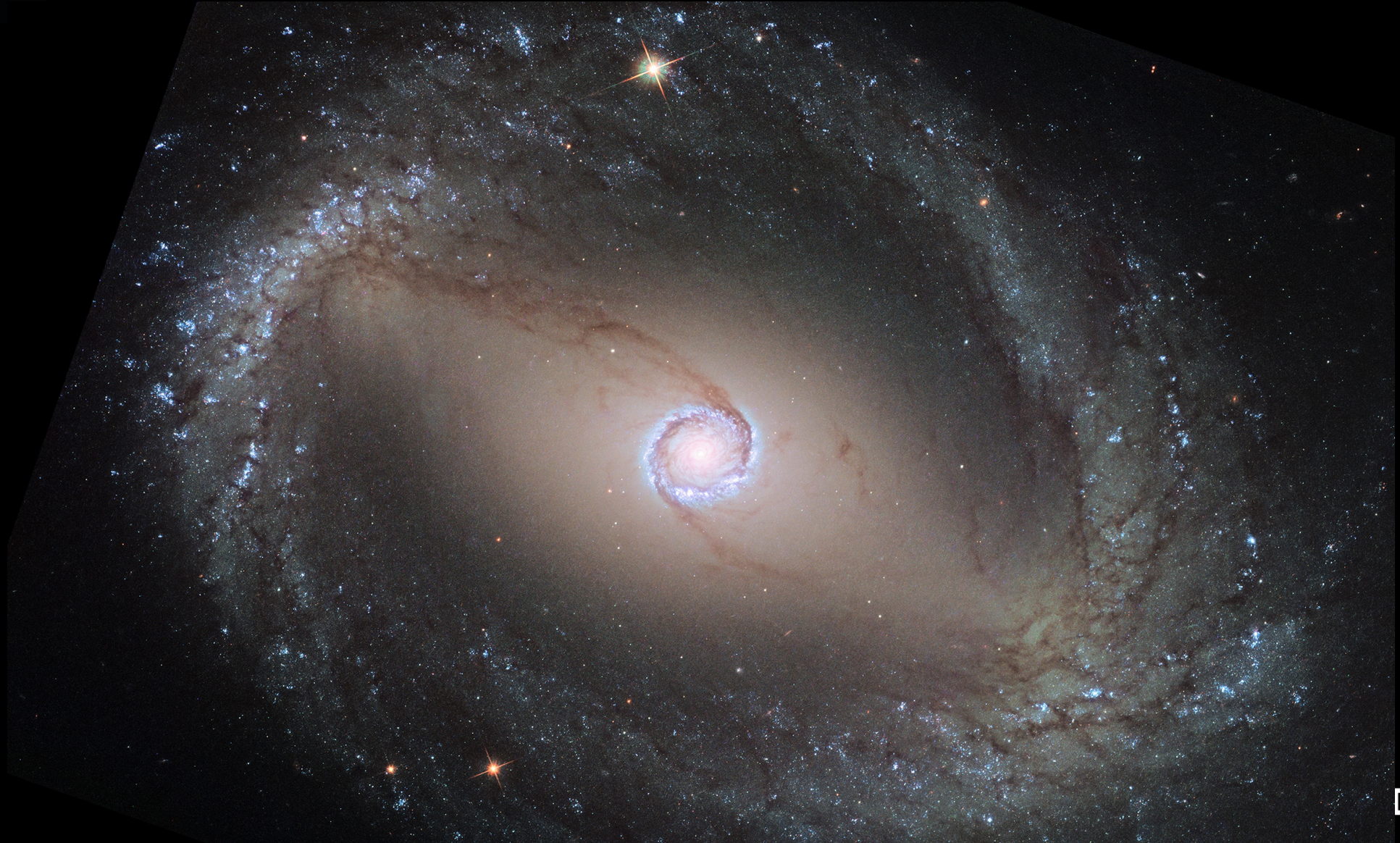
NGC 7496

- Face-on barred spiral
- Is the center a bit bright?
 - Yes! There's an active black hole in the center



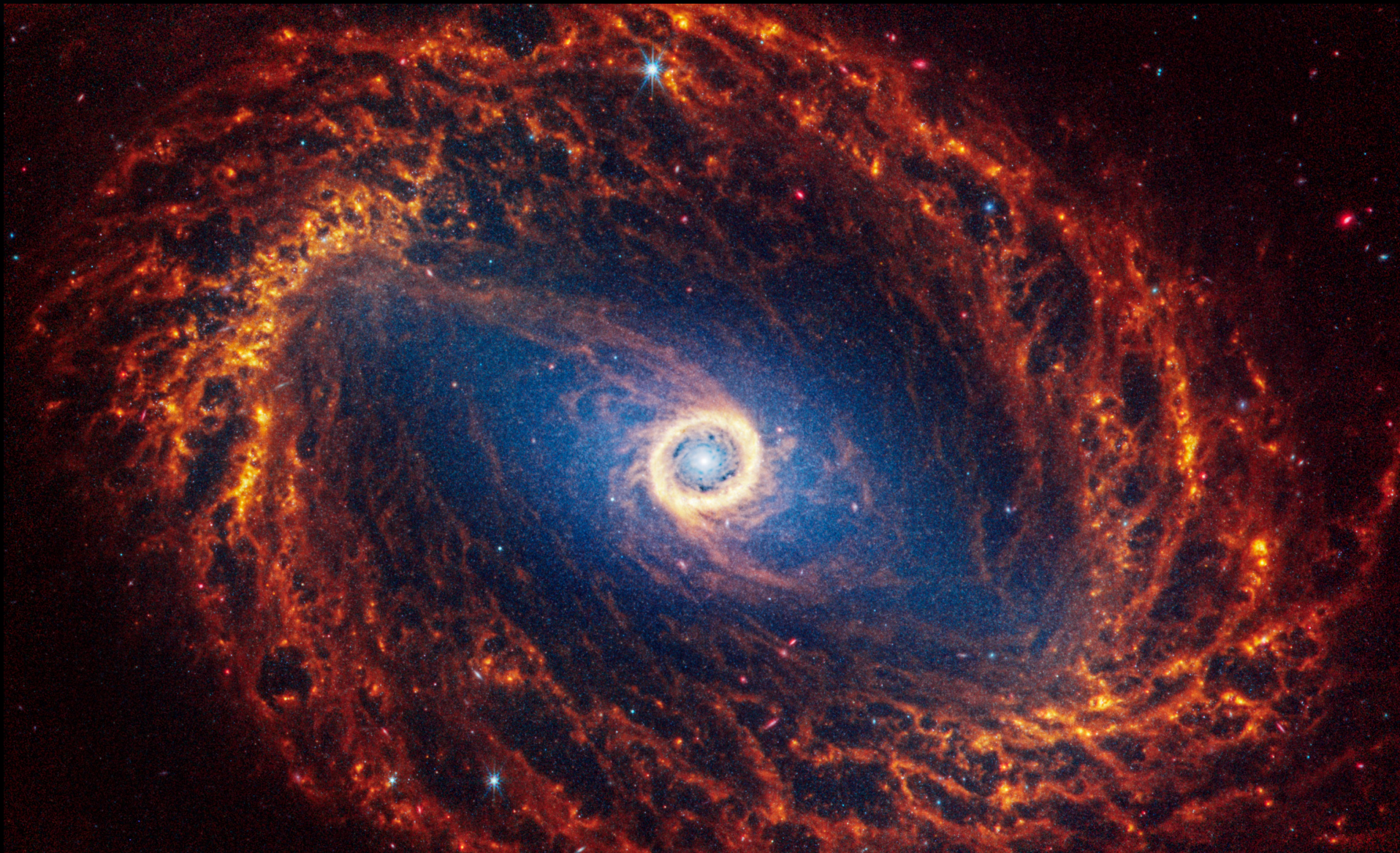


NGC 1512





NGC 1512

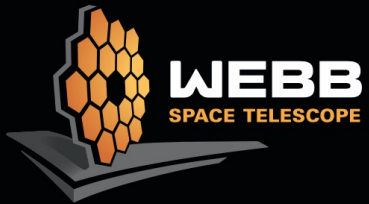




The Changing Universe

Can you spot the differences?





The Changing Universe

2022



2023



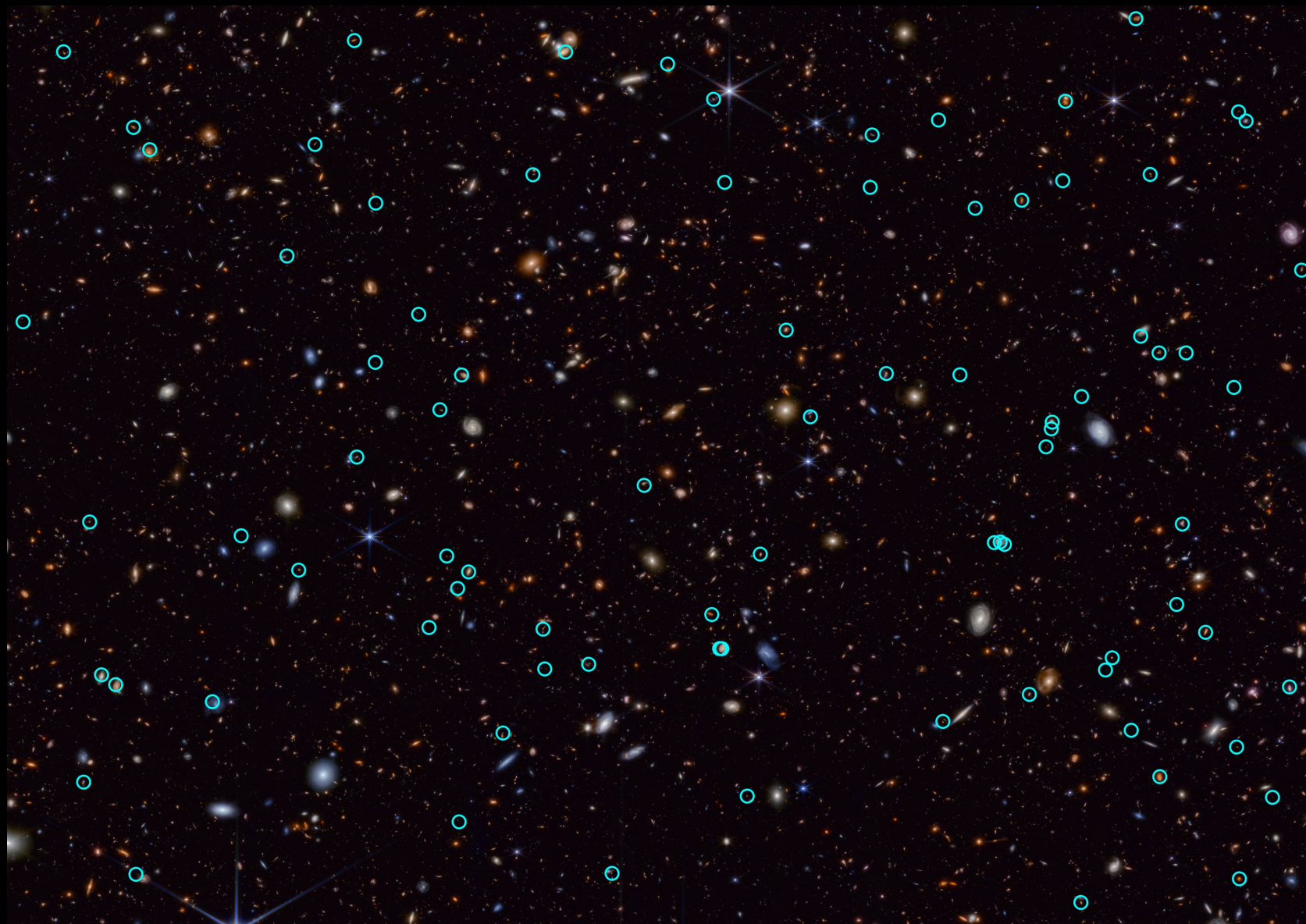
Can you spot the differences?



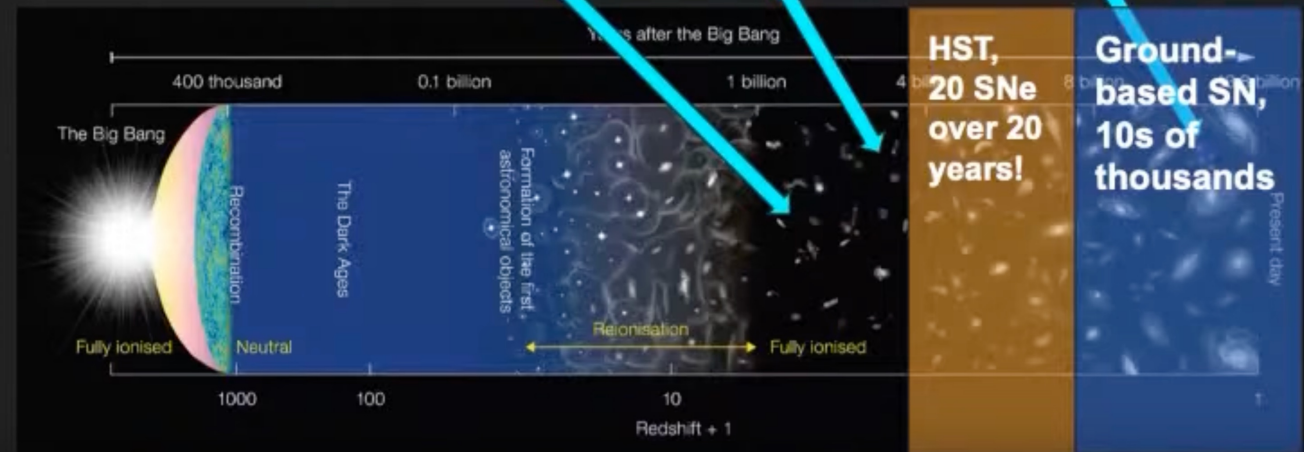
The Changing Universe

Webb found over
80 supernovae in
this field

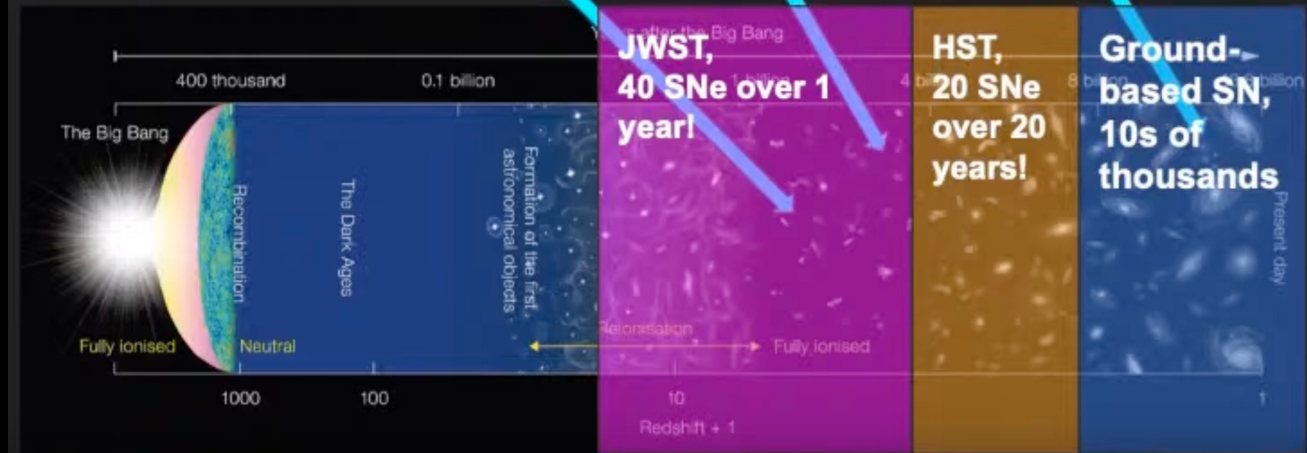
~40 per year



The Changing Universe



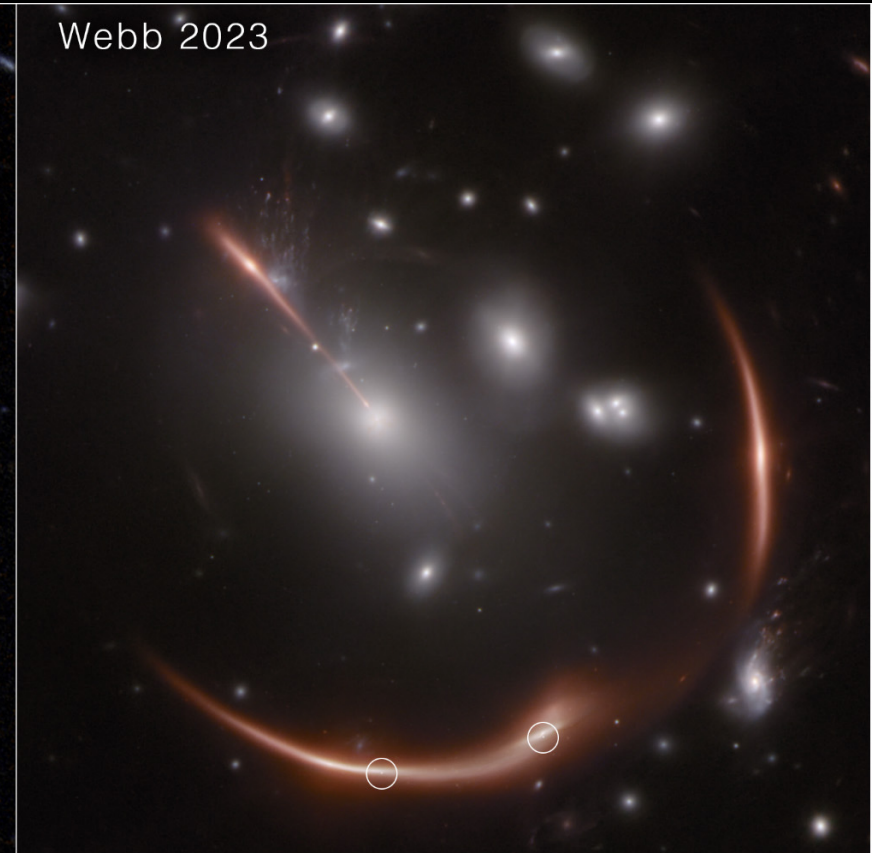
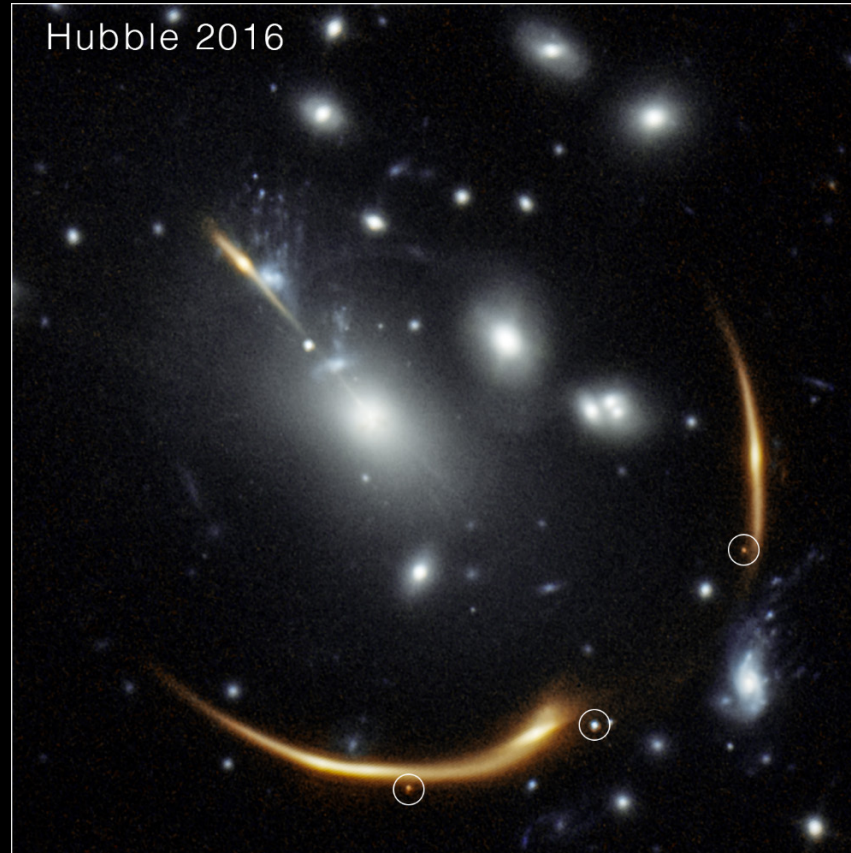
The Changing Universe





SN Requiem and Encore

- Multiple images of same SN
- A second SN happened in the same galaxy!





New resources

- Articles broadly summarizing new science:
 - Galaxies through time
 - Exoplanets
 - Solar System Science
- More articles and videos coming soon!

Webb Science: Galaxies Through Time

[VIEW ALL ARTICLES >](#)

Catch up on Webb's latest discoveries about galaxies and the universe's development over time.

The James Webb Space Telescope was designed and built to investigate questions raised in previous decades of astronomy, which revealed the vastness of the universe and extreme phenomena like [supermassive black holes](#). A view into the [distant past](#) left us wanting to know more. So what is Webb revealing? Below are some of the big questions astronomers had before Webb, and the answers the telescope is providing so far.

In This Article:

- [How were galaxies in the early universe different from our own cosmic neighborhood?](#)
- [How did light first spread through the universe?](#)
- [How did supermassive black holes first form?](#)
- [What's next?](#)

How were galaxies in the early universe different from our own cosmic neighborhood?

Webb's combination of resolution and sensitivity to [infrared](#) wavelengths of light is revealing cosmic dust in the early universe that was previously undetectable, allowing astronomers to use real data for the first time to study the relationship between dust, star formation, and galaxy growth over the history of the universe. In the [local universe](#), [many galaxies](#) are where [stars](#) and [star-forming stars](#) are found. However, [Webb is finding](#) that, in the early universe, star formation and dust are not necessarily aligned. [Using](#) Webb to investigate how the universe evolved from a soup of hydrogen and helium to finding ourselves in the midst of a massive, spiral-structured Milky Way galaxy.



Exploring Our Solar System with Webb

[VIEW ALL ARTICLES >](#)

Viewing our cosmic neighbors in a new light

Whether exploring the small bodies or giant planets of our solar system, the James Webb Space Telescope is revolutionizing our understanding of our closest cosmic neighbors. With its powerful infrared instruments, sharp spatial resolution, and exquisite sensitivity, Webb is forever changing our view of our celestial backyard. It is helping scientists answer important questions about our solar system, including:

- How was the solar system formed and how has it changed over time?
- Where did the chemicals necessary for life on Earth, like water and carbon compounds, come from?
- What are the icy small bodies in the outer solar system made of?
- How are planets around other stars like planets in our solar system?

Webb's extraordinarily sensitive spectroscopic instruments and state-of-the-art imaging capabilities enable analysis and mapping of solar system objects' atmospheres and surfaces. This is critical for studying planets, dwarf planets, moons, comets, asteroids, and ring systems. However, because Webb cannot point toward the Sun, it cannot observe objects between it and the Sun: Mercury, Venus, Earth, or Earth's moon.

Scientists are now using Webb to conduct detailed investigations of terrestrial Mars, gas giants Jupiter and Saturn, and ice giants Uranus and Neptune. Webb is also



[Expand Image](#)

[Jupiter \(NIRCam Image\): Get Jupiter's image details and downloads.](#) Credit: NASA, ESA, CSA, STScI. [Image credit: NASA, ESA, CSA, STScI](#)

Webb's Impact on Exoplanet Research

[VIEW ALL ARTICLES >](#)

What are planets around other stars like? What are they made of? How did they form? How different are they from each other and the planets in our solar system?

Building on the legacy of NASA's Hubble Space Telescope, Spitzer Space Telescope, and other ground- and space-based observatories, the James Webb Space Telescope is expanding our understanding of exoplanet atmospheres. A few are highlighted below.

- **WASP-96 b:** The first [exoplanet transmission spectrum](#) collected by Webb showed clear signs of water vapor that previous spectra only hinted at. It is the first transmission spectrum that includes wavelengths longer than 1.6 microns with high resolution and accuracy, and the first to cover the entire wavelength range from 0.6 microns (visible red light) to 2.8 microns (near-infrared) in a single shot. WASP-96 b is a gas giant exoplanet.
- **TRAPPIST-1 b:** Webb performed the first [thermal emission](#) observation on any planet as small as Earth and as cool as the rocky planets in our solar system. These observations suggest that the planet does not have a significant atmosphere.
- **WASP-39 b:** Webb detected carbon dioxide and sulfur dioxide in the atmosphere of a gas giant exoplanet for the first time. The detection of sulfur dioxide in this "hot Saturn" provides evidence of photochemistry – chemical reactions initiated by energetic stellar light.

Exoplanets: From Small and Rocky to Gas Giant

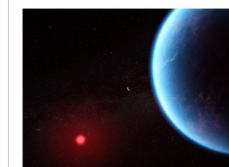
Between the early 1990s, when the first [exoplanets](#) were discovered, and the beginning of Webb's observations in 2022, more than 5,000 exoplanets had been discovered every year. Over the past three decades, researchers have identified a wide range of exoplanets, including rocky planets called ["habitable zones"](#) of their stars; have observed the [planet-forming disks](#) that surround young stars; and have detected molecules in exoplanet atmospheres.

In its first 18 months, Webb has begun to expand our knowledge through successful observations of a wide variety of exoplanets.



[Expand Image](#)

[Gas Giants \(Artist Concept\) WASP-17 b.](#) As the term suggests, gas giants are large



[Expand Image](#)

[Neptune-like \(Artist Concept\) Sub-Neptune K2-18 b.](#) Neptune-like ex



WEBB

2023 YEAR IN HEADLINES



Questions?

