BREAKING THE UNIVERSE:

DISCOVERIES FROM THE BEGINNING OF TIME

Caitlin M Casey

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JWST's First Glimpses of Early Galaxies Could Break Cosmology

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BY JONATHAN O'CALLAGHAN

Vox

SCIENCE

Astronomers spo
something perple
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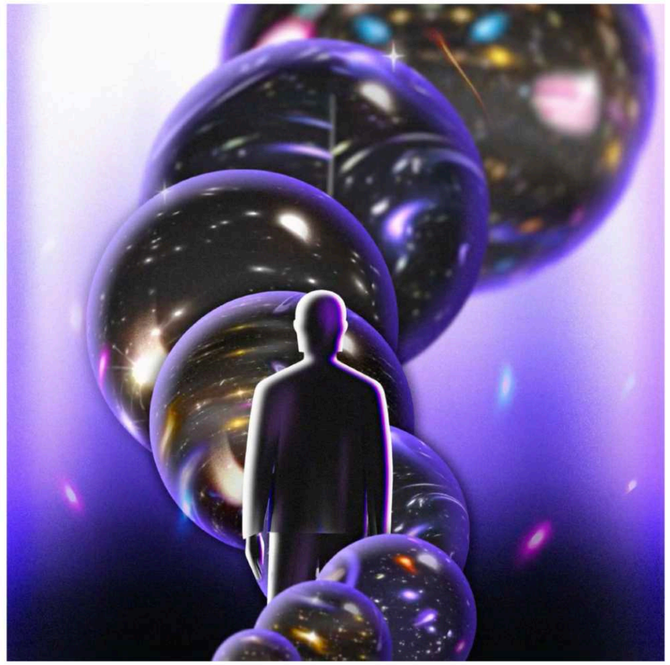
By Brian Resnick | @B_resnick | brian@vox.com | Jan 17, 2024, 11:35am EST

The New York Times

The Story of Our Universe May Be Starting to Unravel

Sept. 2, 2023



Virginia Gabrielli

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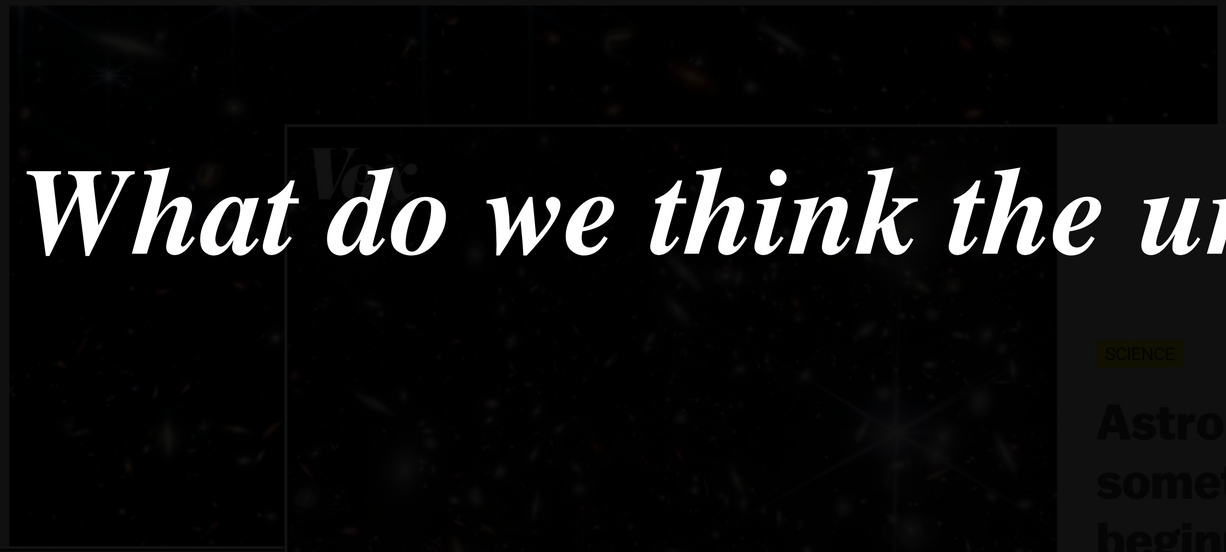

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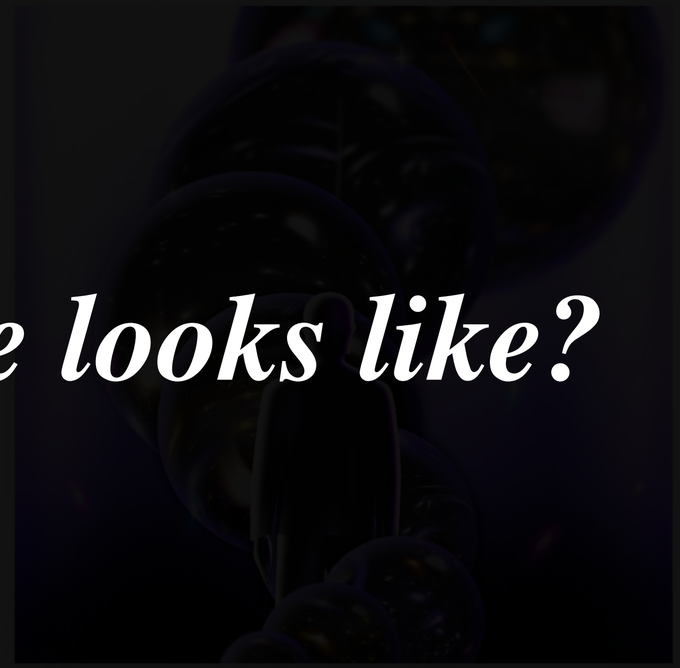


Virginia Gabrielli

What do we think the universe looks like?

The Cosmological Model

The Cosmological Model

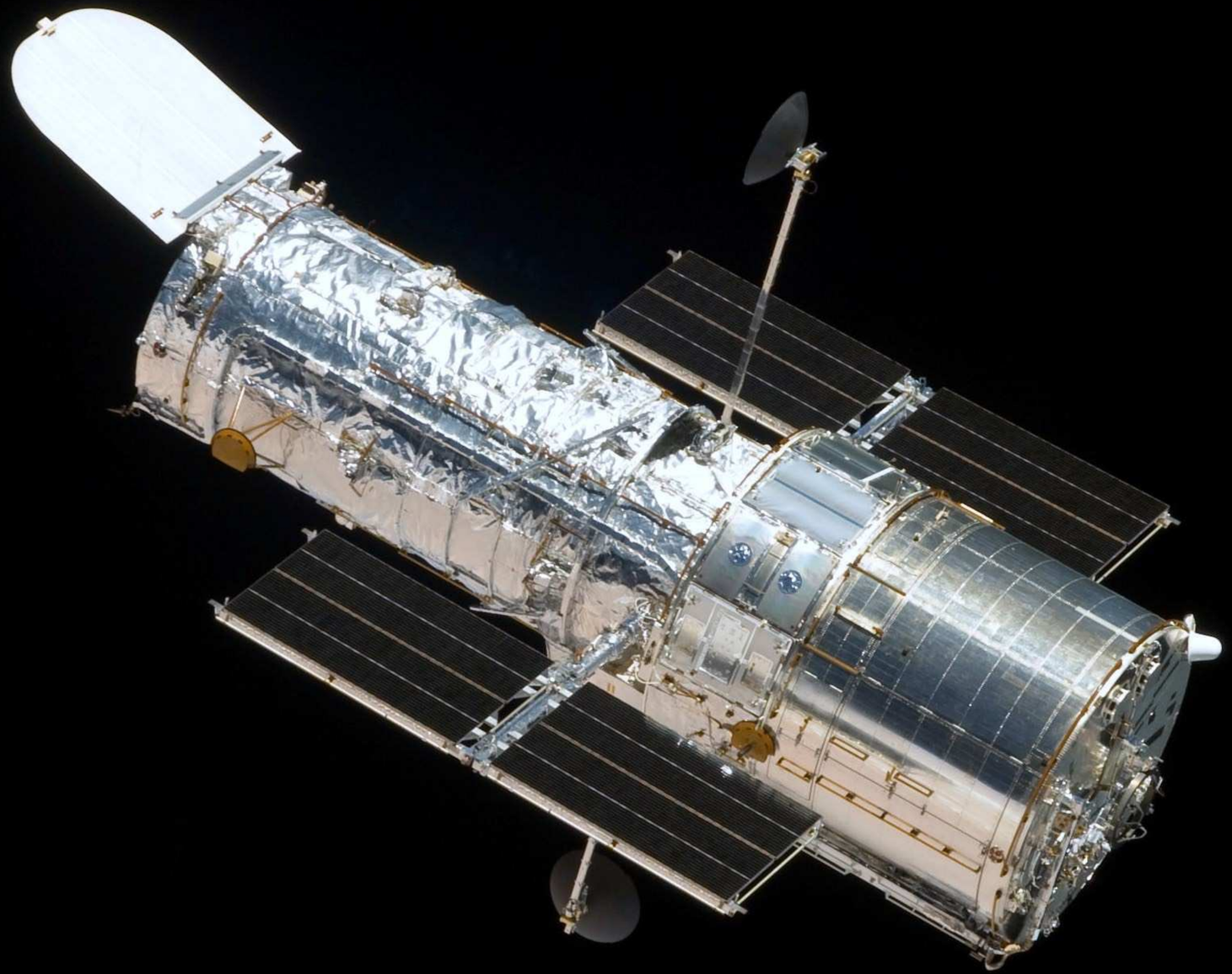
What goes up
must come down.

It’s reallllly hot in Austin
in the summer.

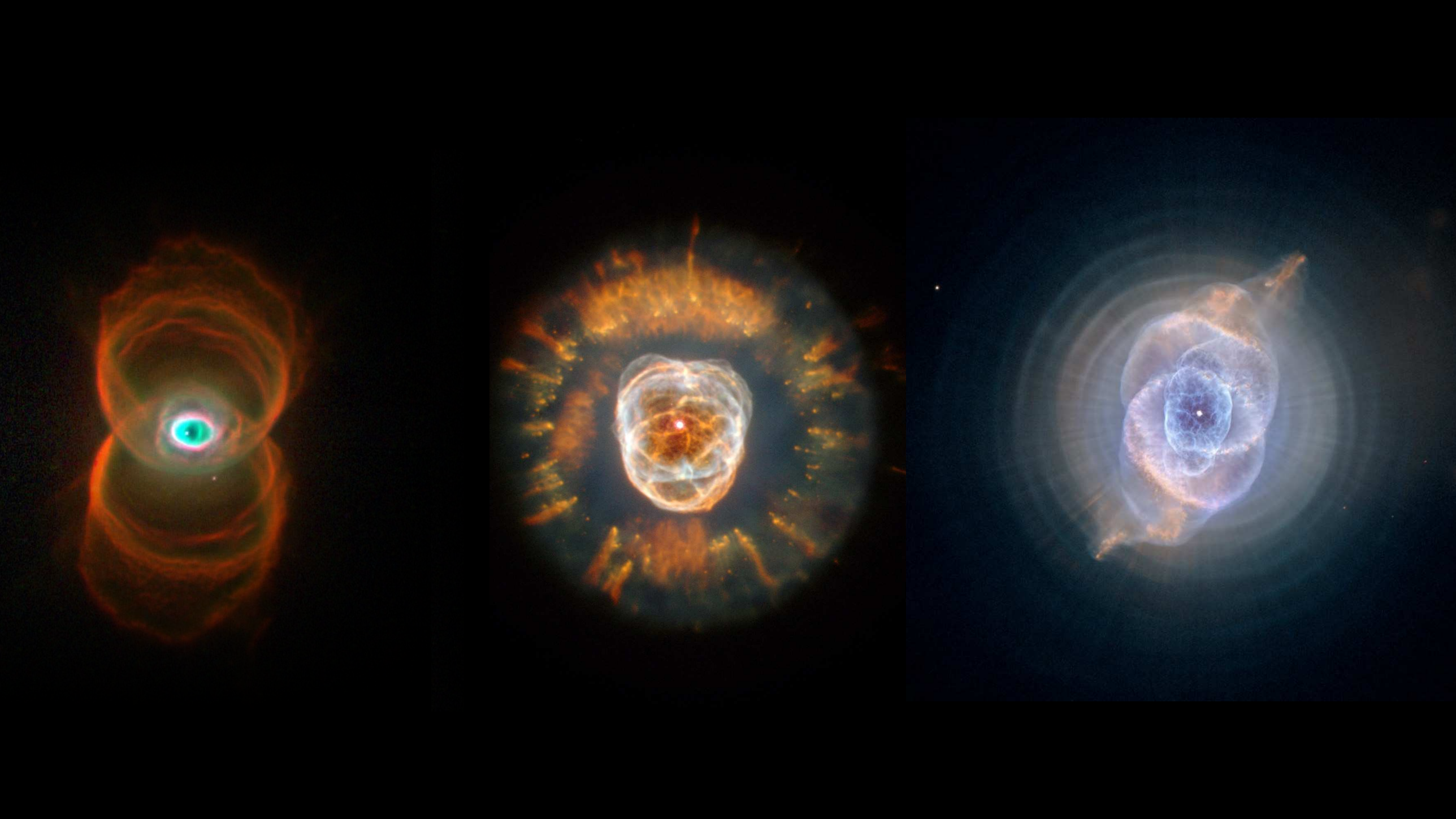
There’s always traffic on
Mopac.

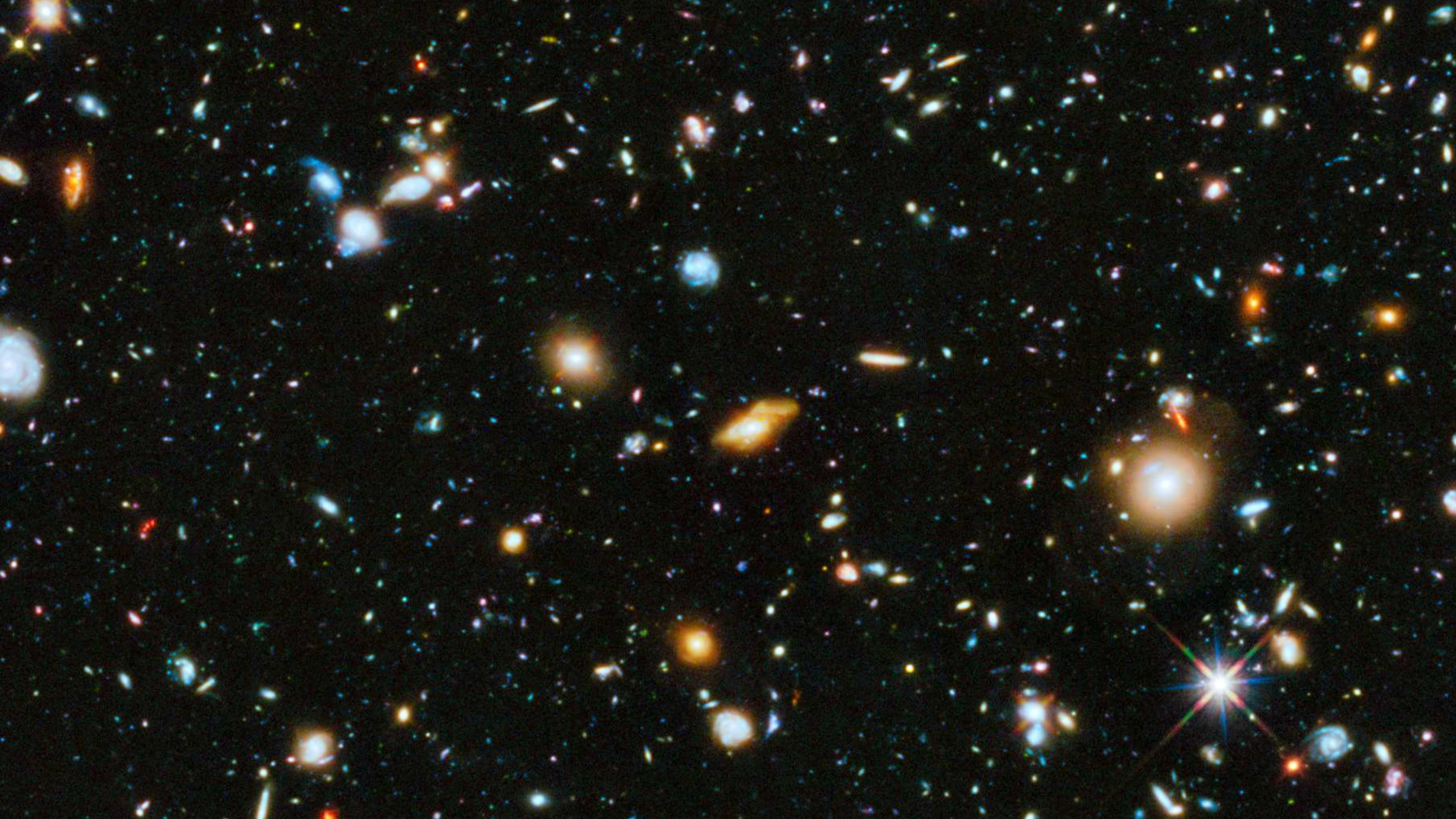
How do cities grow?

How long did it take to build NYC?

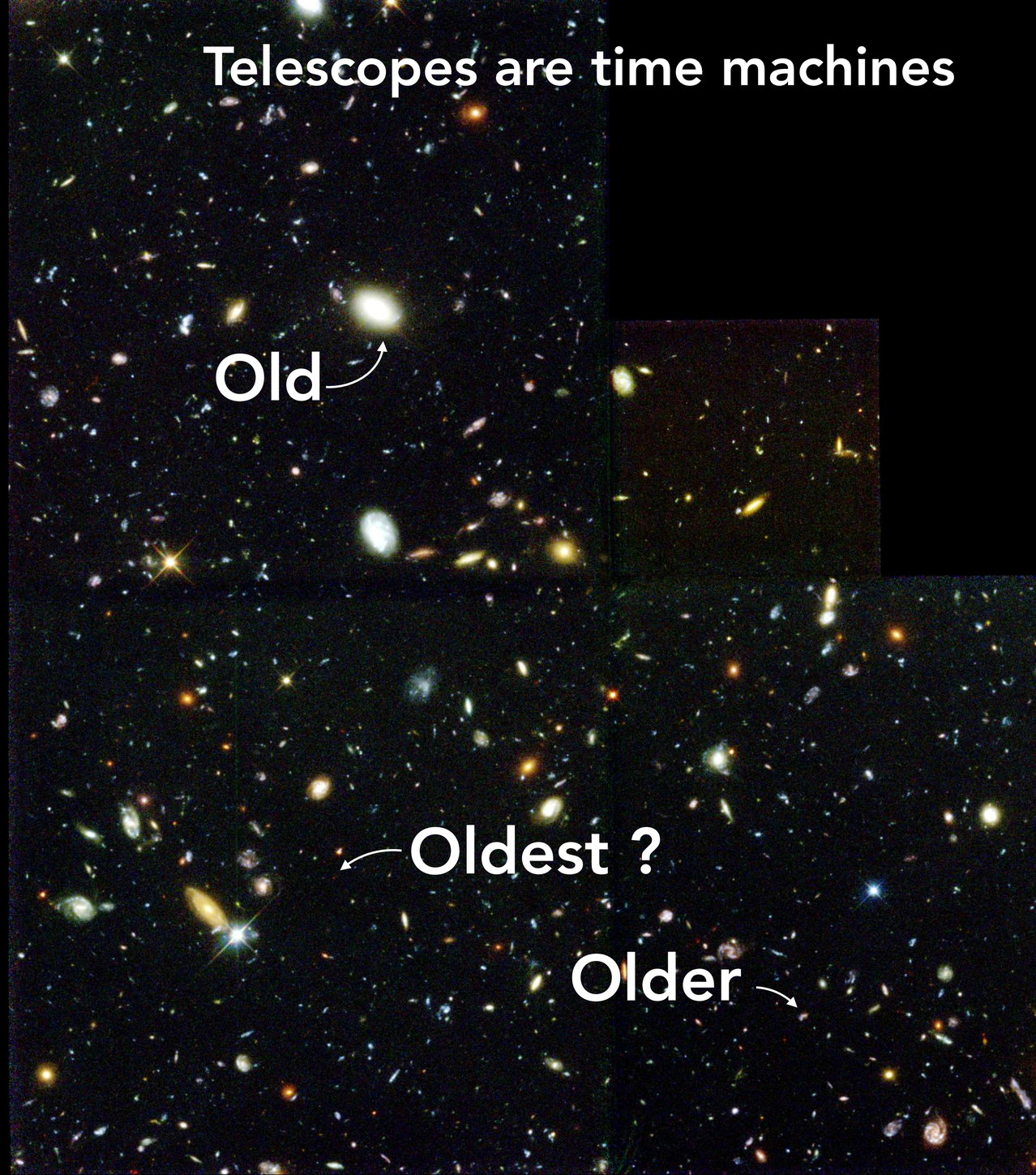


Hubble Space Telescope,
launched 1990






Old
Older
Oldest

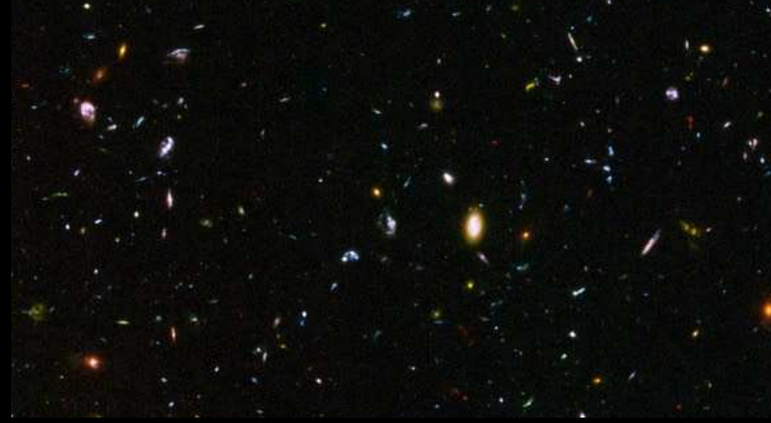

Telescopes are time machines
Old
Oldest ?
Older

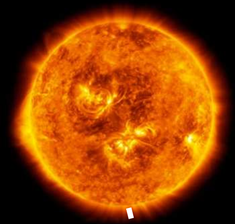
The speed of light is finite.

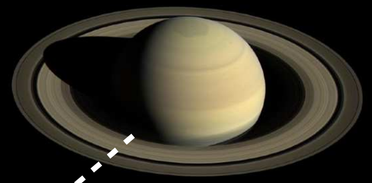
67 million miles per hour (!)

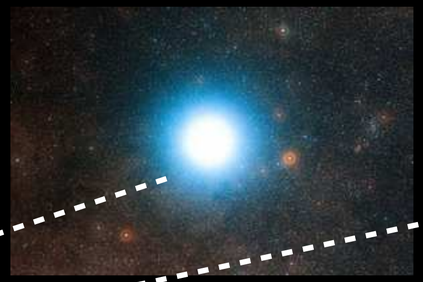
$(3 \times 10^8\,\mathrm{m\,s^{-1}})$

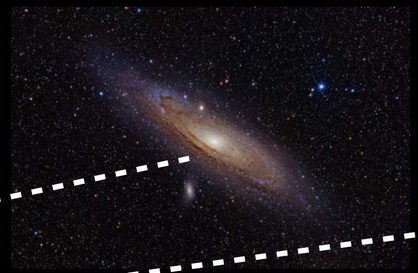
More distant galaxies? Millions to billions of years…

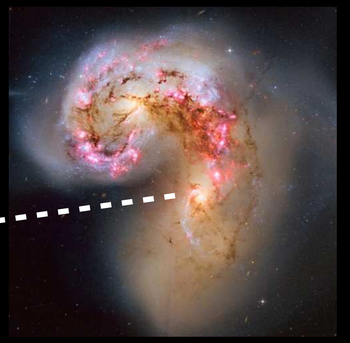






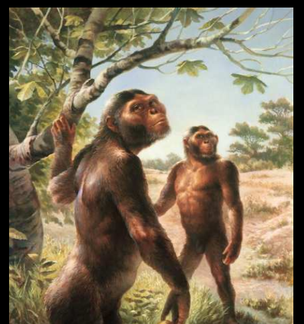






Light from nearby galaxies used to infer cosmic expansion has taken several 10s-100s of millions of years to reach us (think dinosaurs).

Light from the Andromeda galaxy takes 2 million years (longer than humans have been around).



Light from the nearest star outside of the solar system takes 4.3 years.

Reflected light from Saturn takes ~1 hour.

The Sun's light takes ~8 minutes to reach Earth.


Uranus and its rings
~3 light hours
Umbriel
Ariel
Puck
Miranda
Titania
galaxies whose light has traveled ~5 billion years!
Oberon

How we write the cosmic history books

the big bang

t=0

the earliest galaxy Hubble could see, GN-z11

t=500 Myr

first galaxies like the Milky Way emerge

t=2-3 Gyr

the sun and earth form

t=8-9 Gyr

today

t=13.8 Gyr

time

??

the dark ages

Our telescopes can’t see everything…

The farthest objects tend to be bright

Firefly

Lightbulb

Lighthouse

The farthest objects tend to be bright

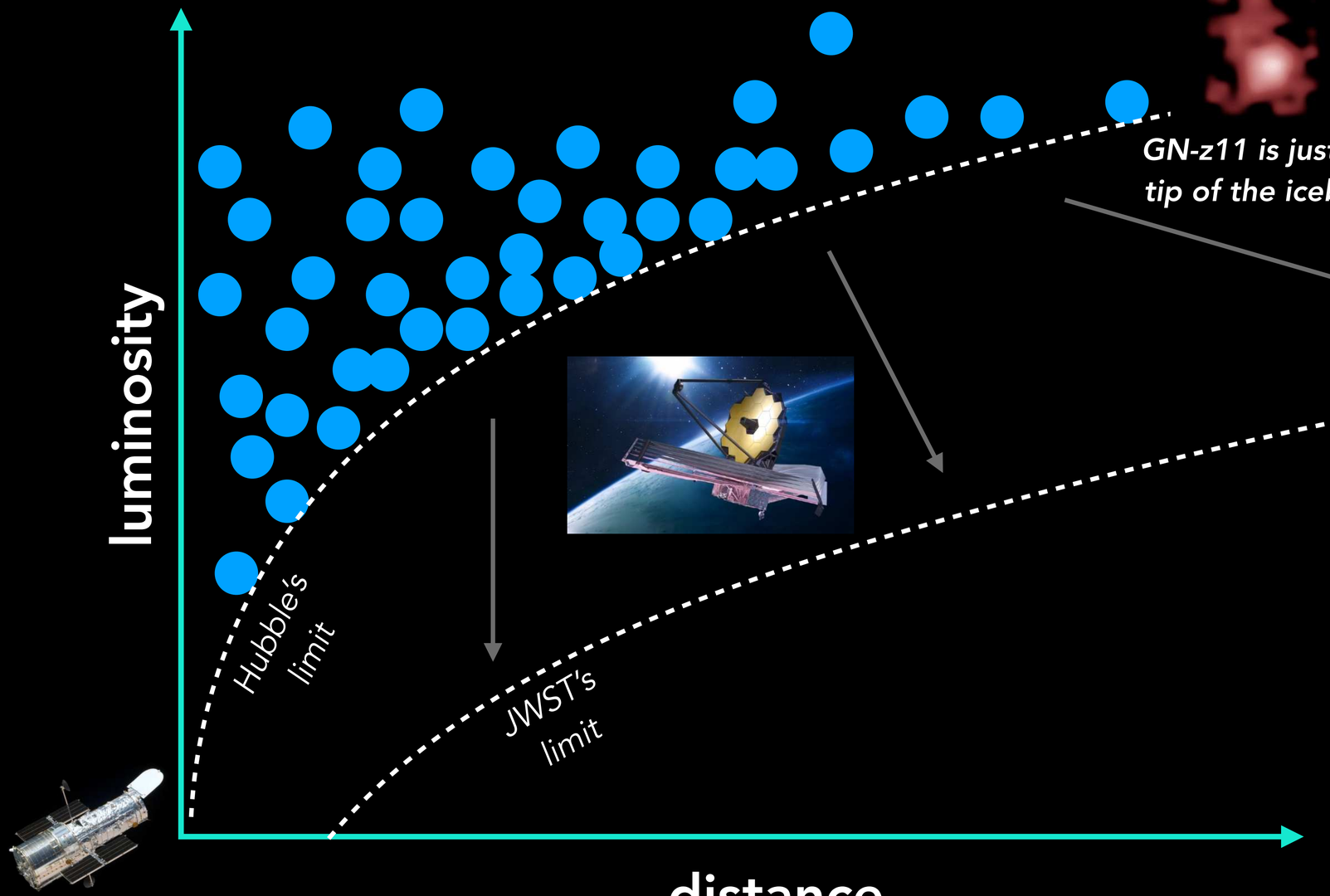
Lighthouse

Lightbulb

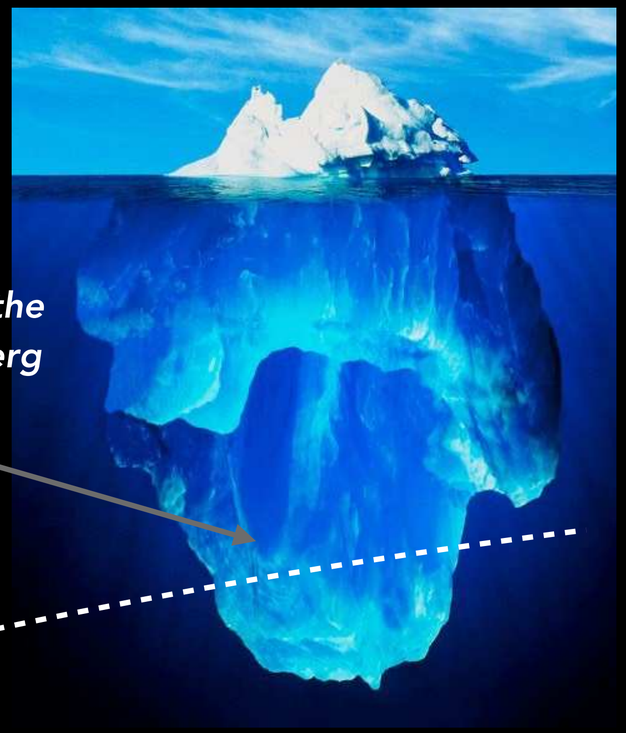
Firefly

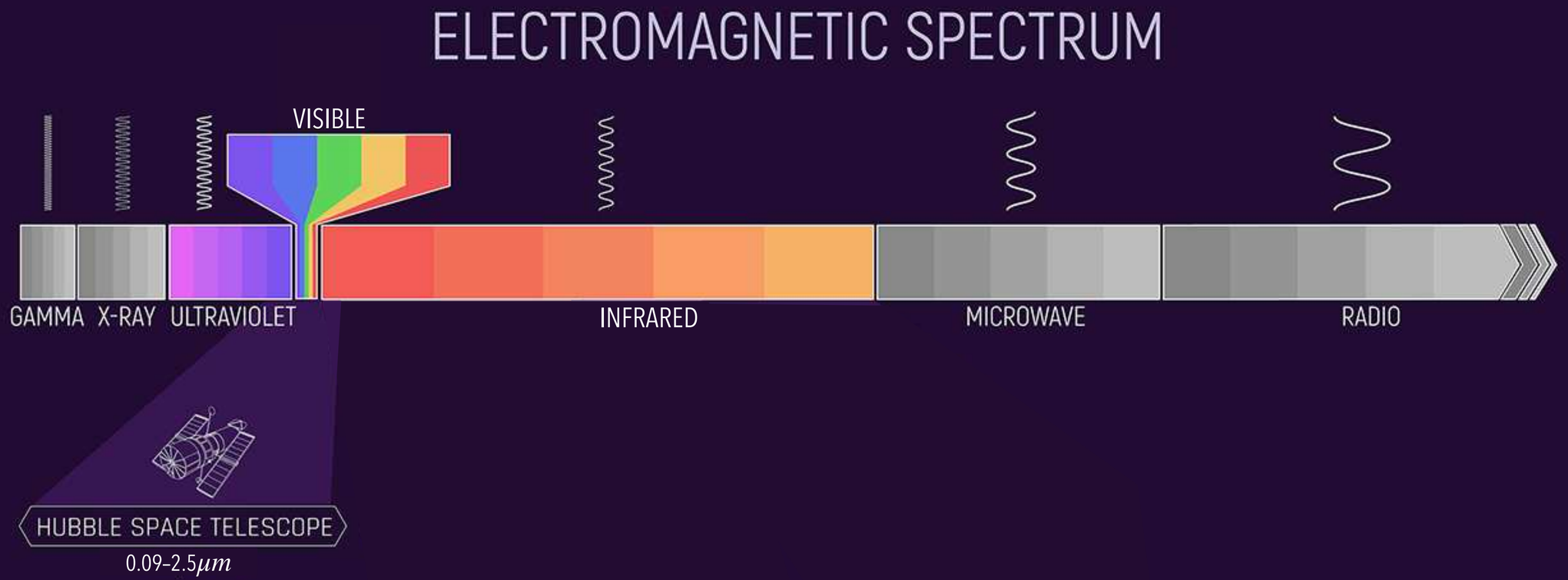
Malmquist bias

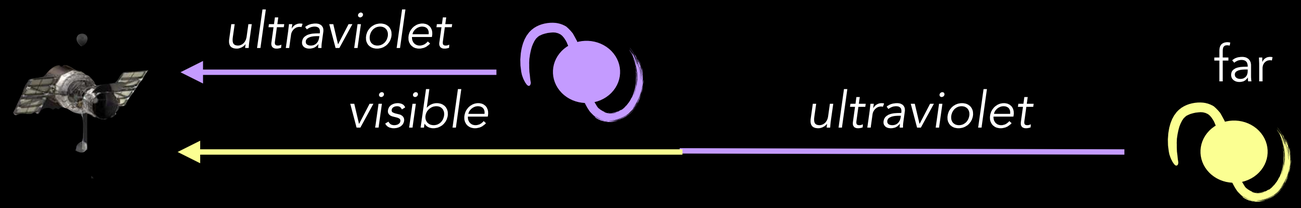
The farthest objects tend to be bright

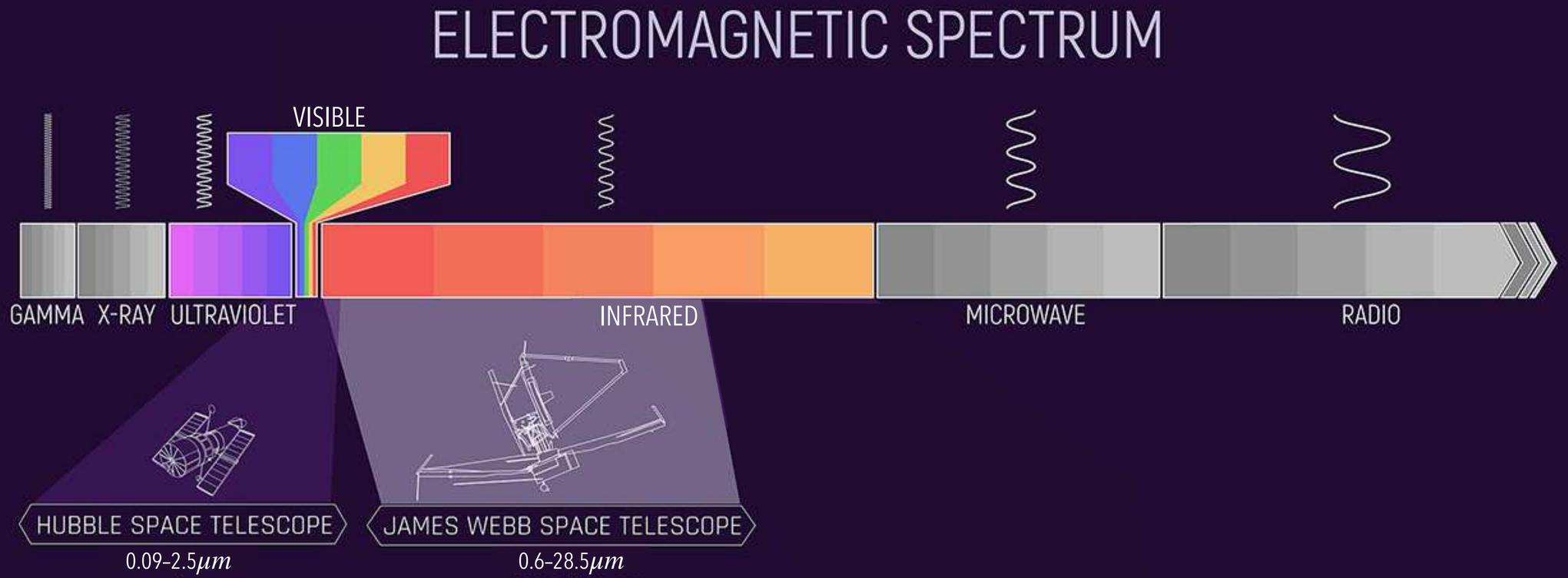


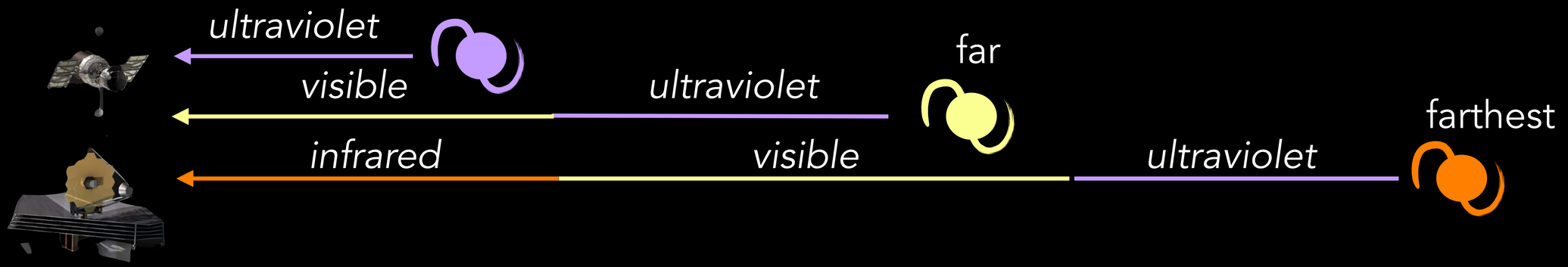
GN-z11 is just the tip of the iceberg




ELECTROMAGNETIC SPECTRUM
VISIBLE
GAMMA
X-RAY
ULTRAVIOLET
INFRARED
MICROWAVE
RADIO
HUBBLE SPACE TELESCOPE
0.09–2.5μm

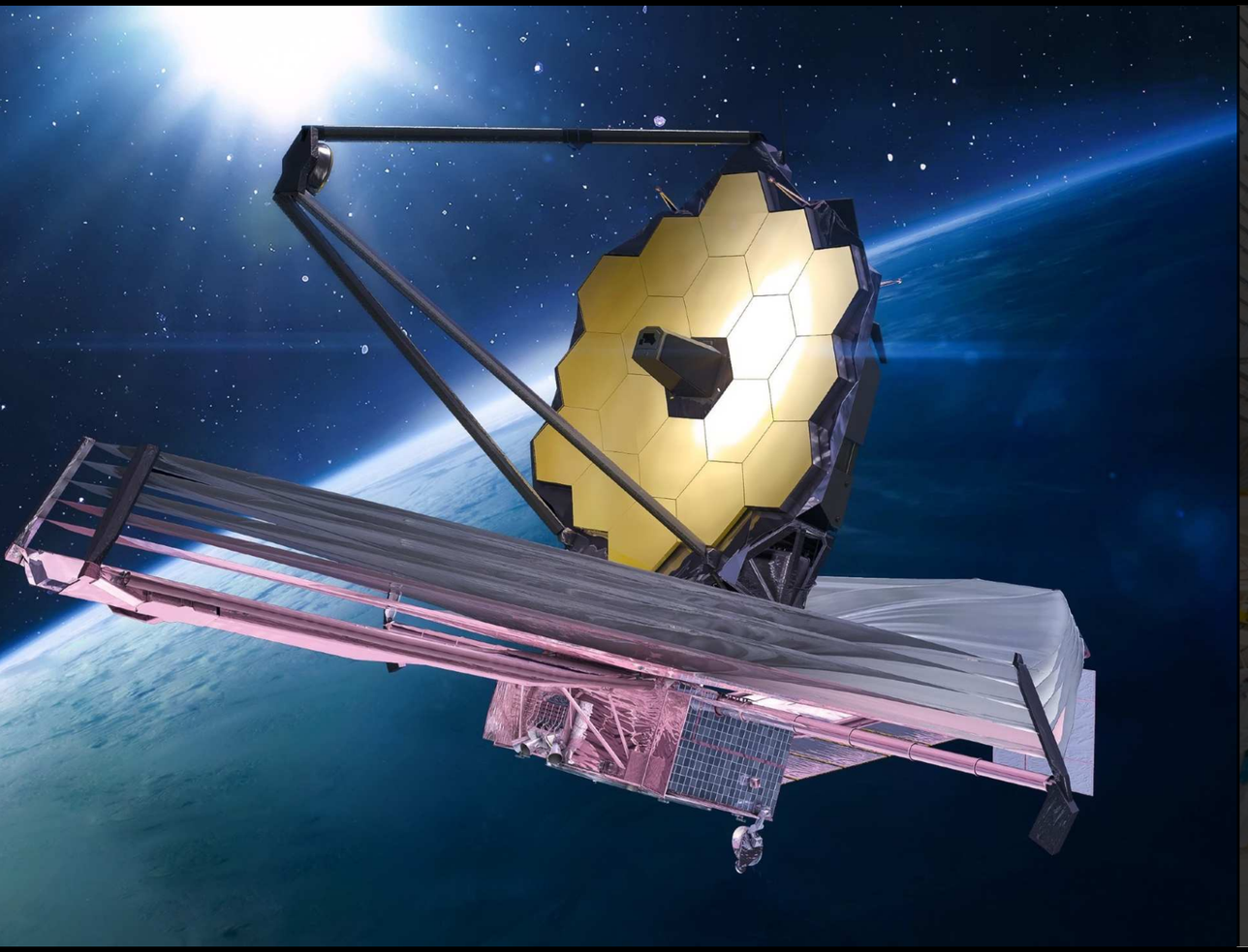

ultraviolet
visible
ultraviolet
far


ELECTROMAGNETIC SPECTRUM
VISIBLE
GAMMA
X-RAY
ULTRAVIOLET
INFRARED
MICROWAVE
RADIO
HUBBLE SPACE TELESCOPE
0.09–2.5μm
JAMES WEBB SPACE TELESCOPE
0.6–28.5μm


ultraviolet
visible
infrared
far
ultraviolet
visible
farthest
ultraviolet

James Webb Space Telescope

A journey that began when Hubble launched…



Final cost ~$10B, >10x over initial estimates.

Plagued by delays and technical challenges; initially set for launch in 2007.

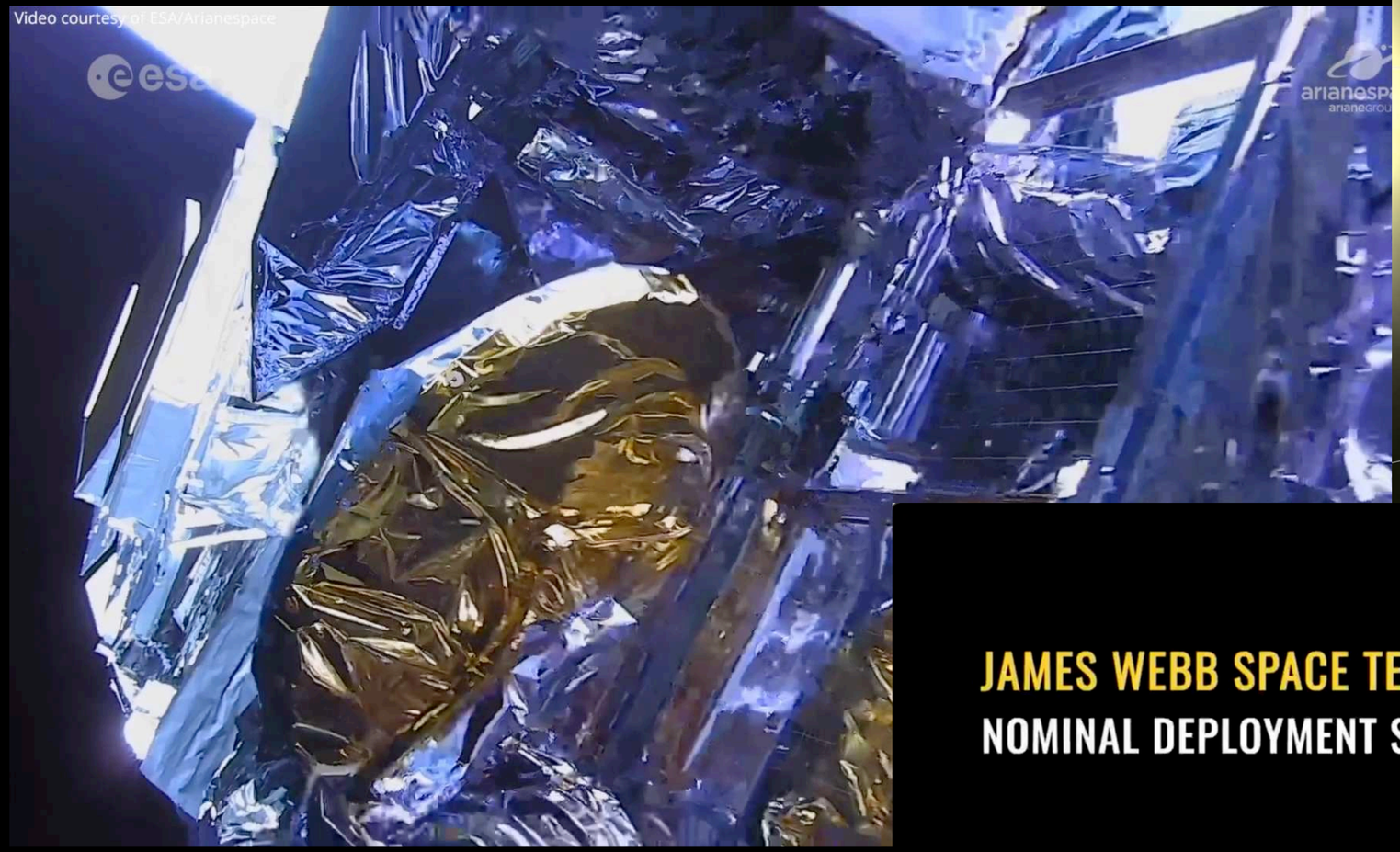
About what the US population spends on **potato chips** every year.

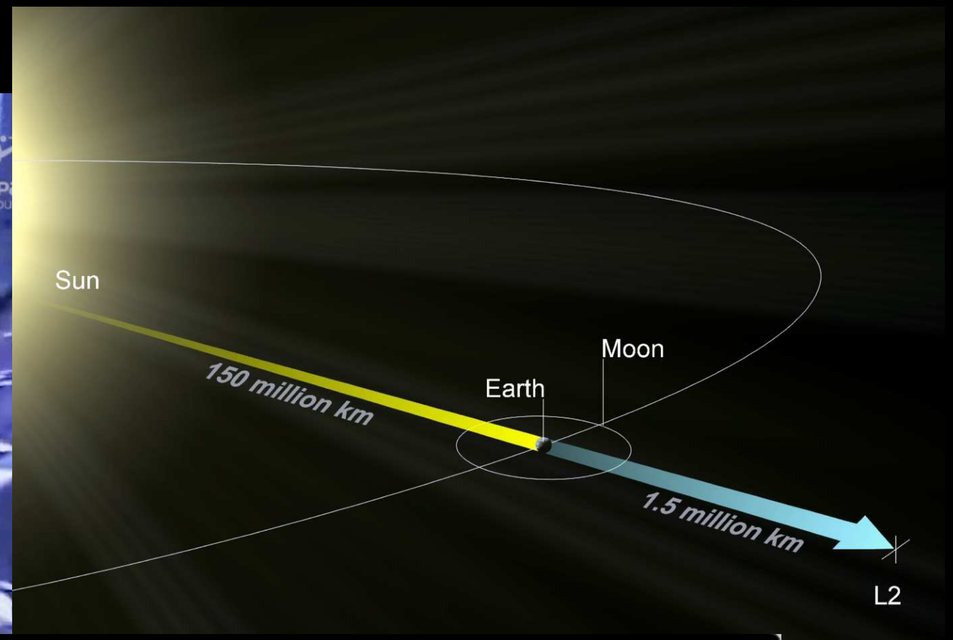
Funded careers of 10,000 scientists & engineers

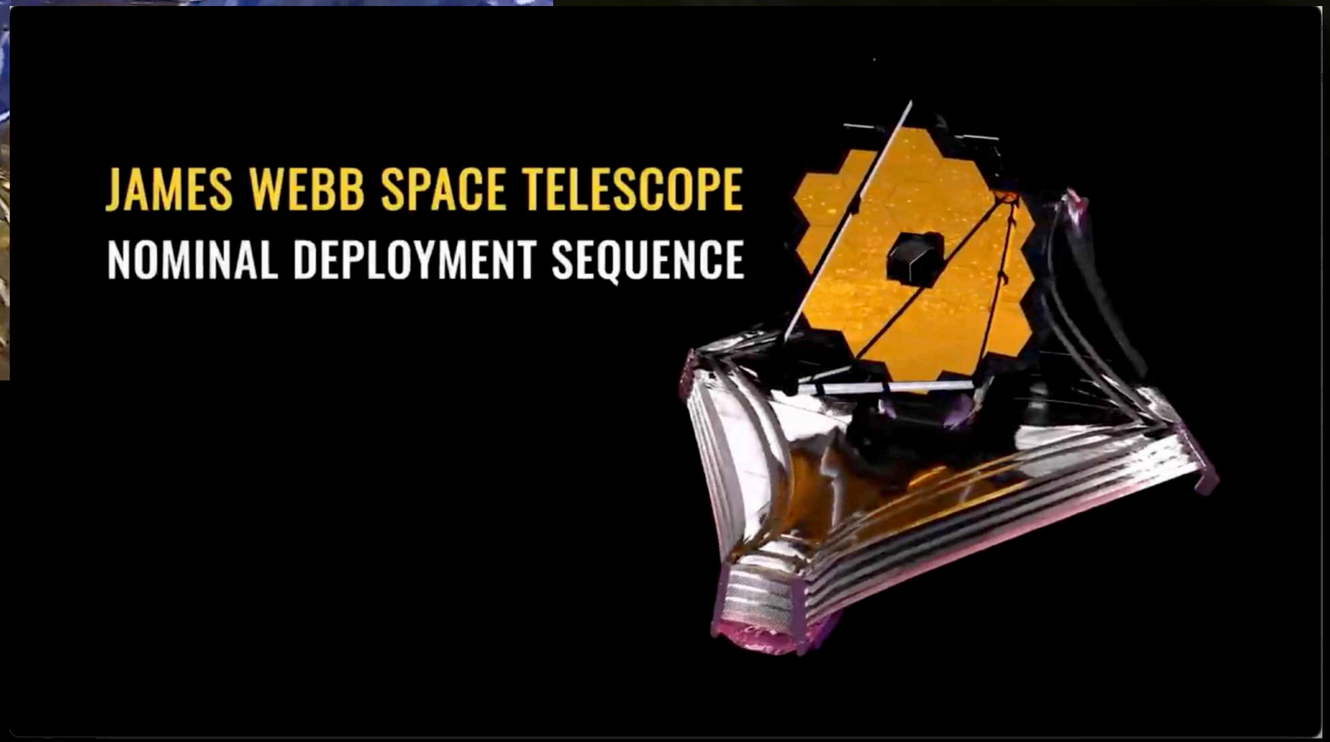
Turning the dream into reality had its challenges…

JWST Launch Day. December 25, 2021.

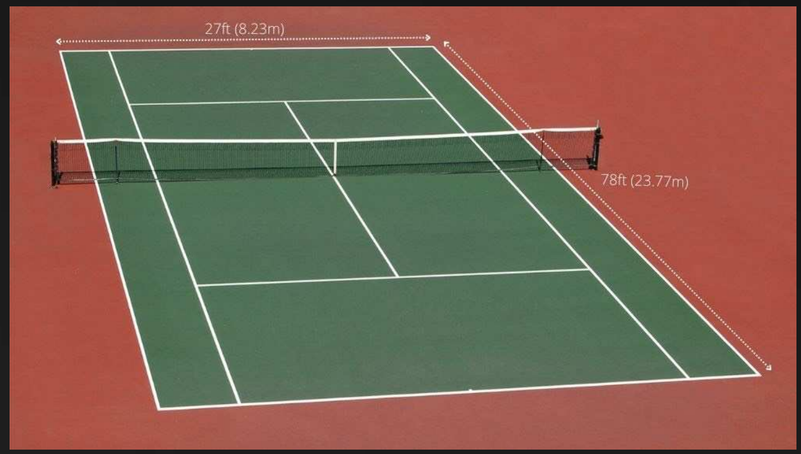
The long journey post-launch…





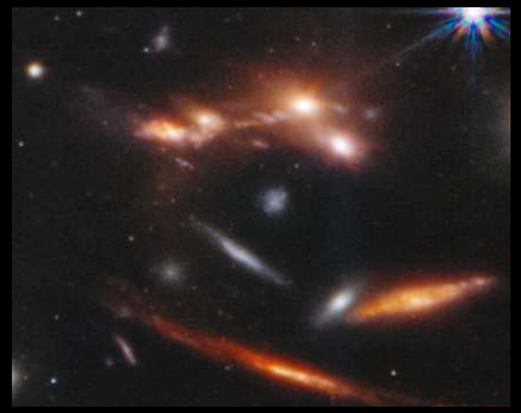


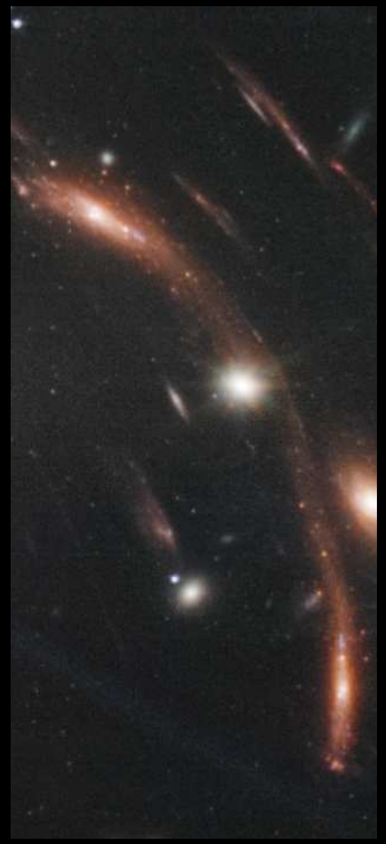
JWST at launch: a complex piece of origami that needed to be unfolded…

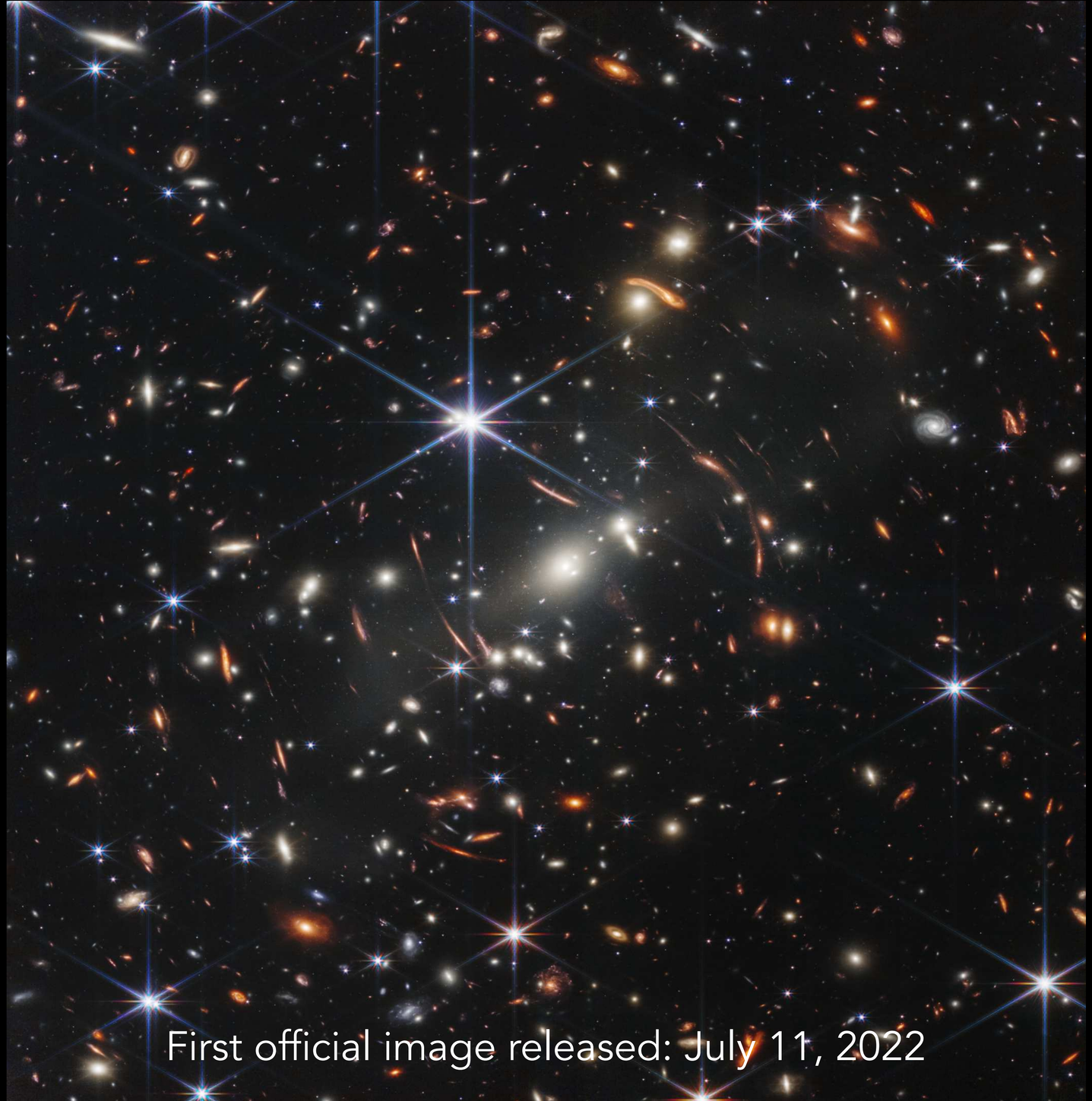


Hubble Space Telescope

James Webb Space Telescope





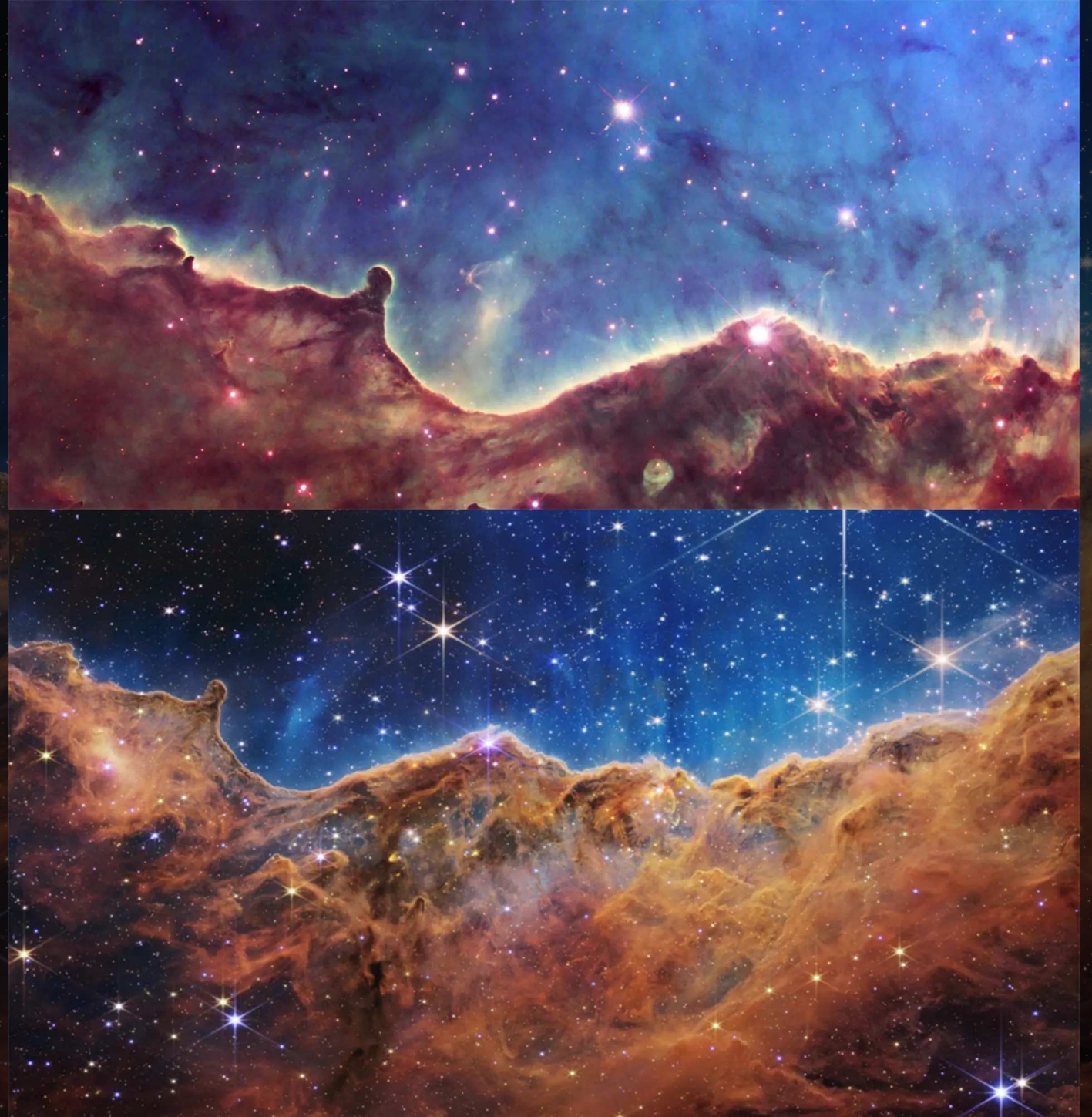


First official image released: July 11, 2022

Southern Ring Nebula

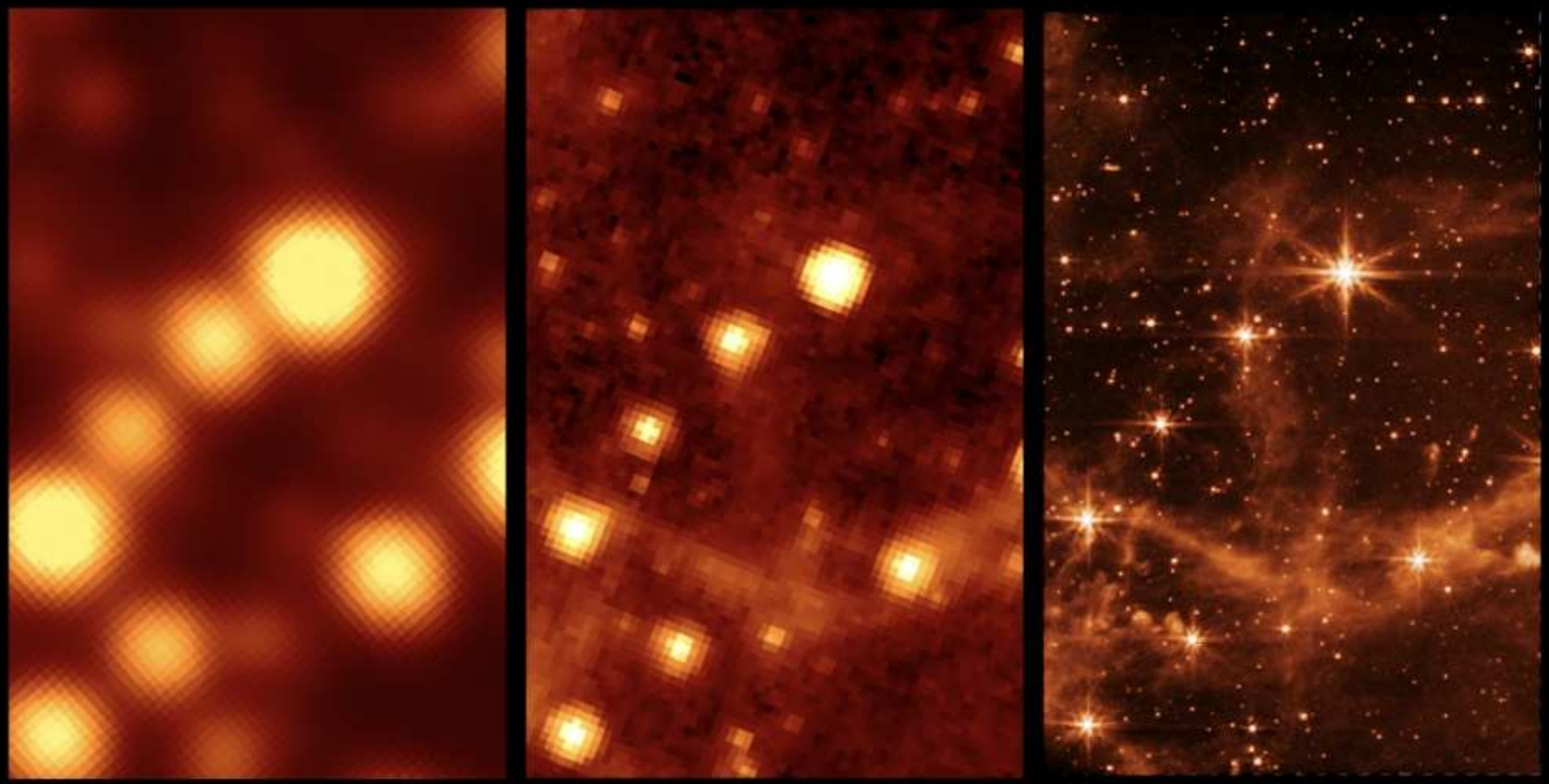
Stephan’s Quintet *(of 5 galaxies)*

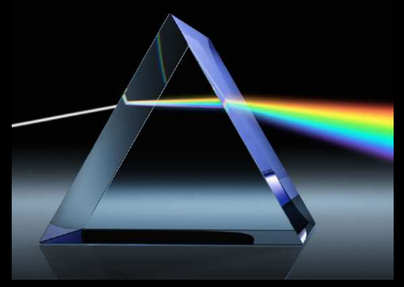
Carina Nebula — Cosmic Cliffs



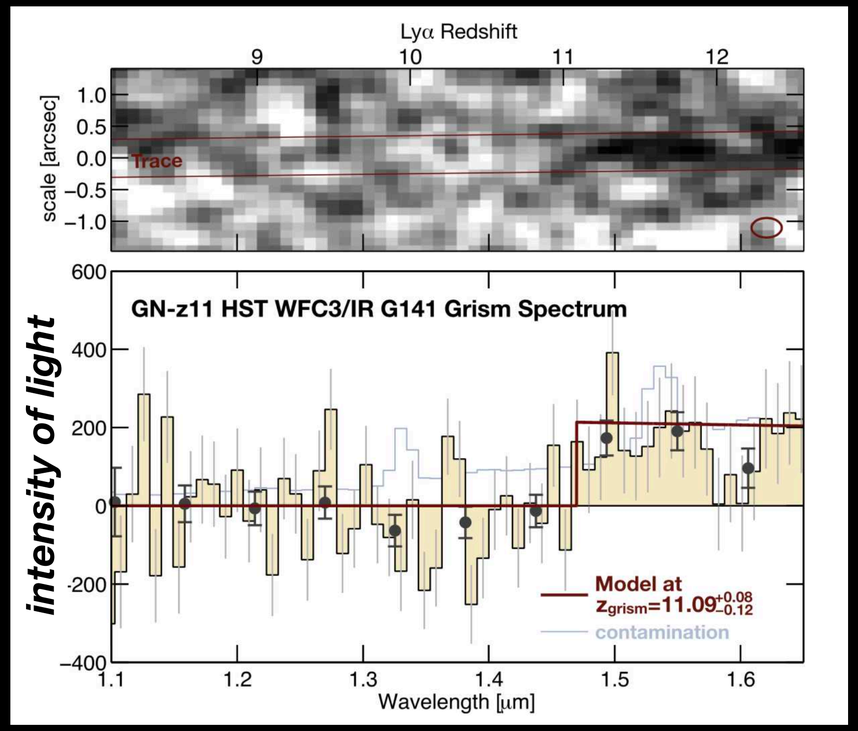
Tarantula Nebula

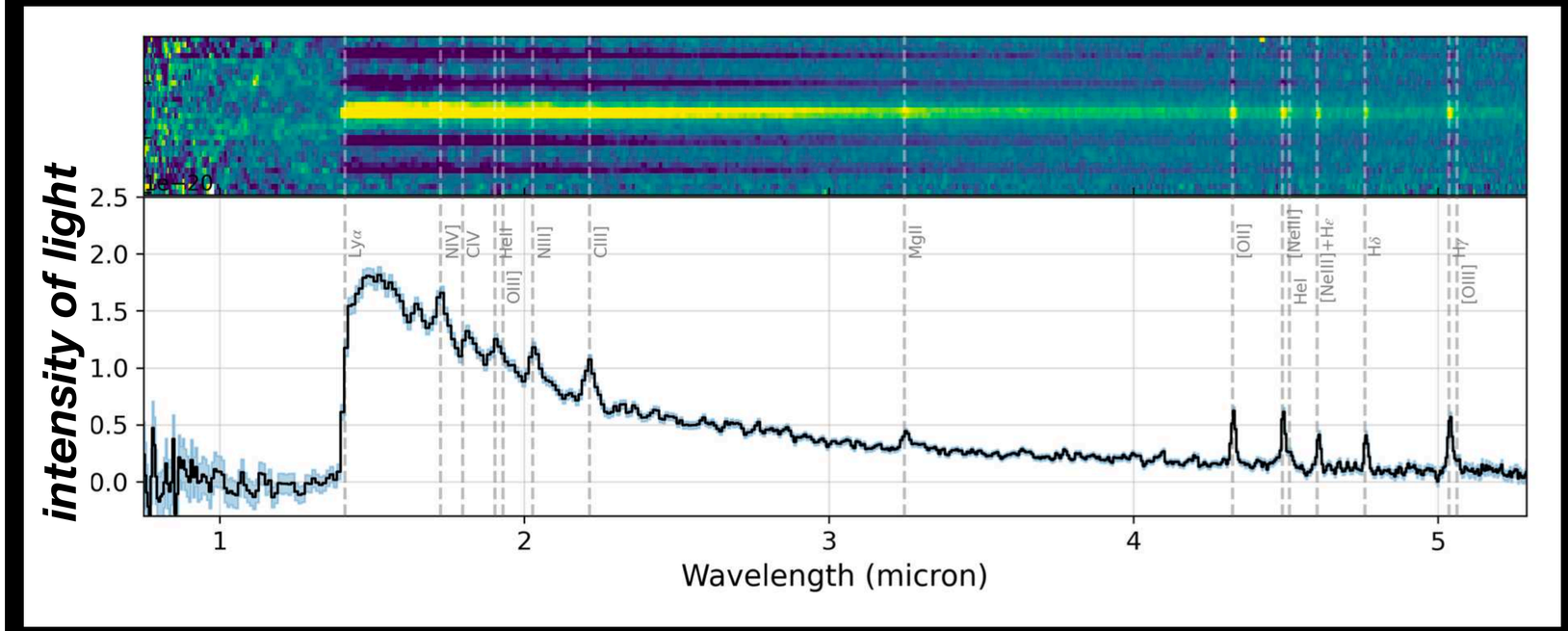
The remarkable resolution of JWST





The most distant galaxy known pre-JWST

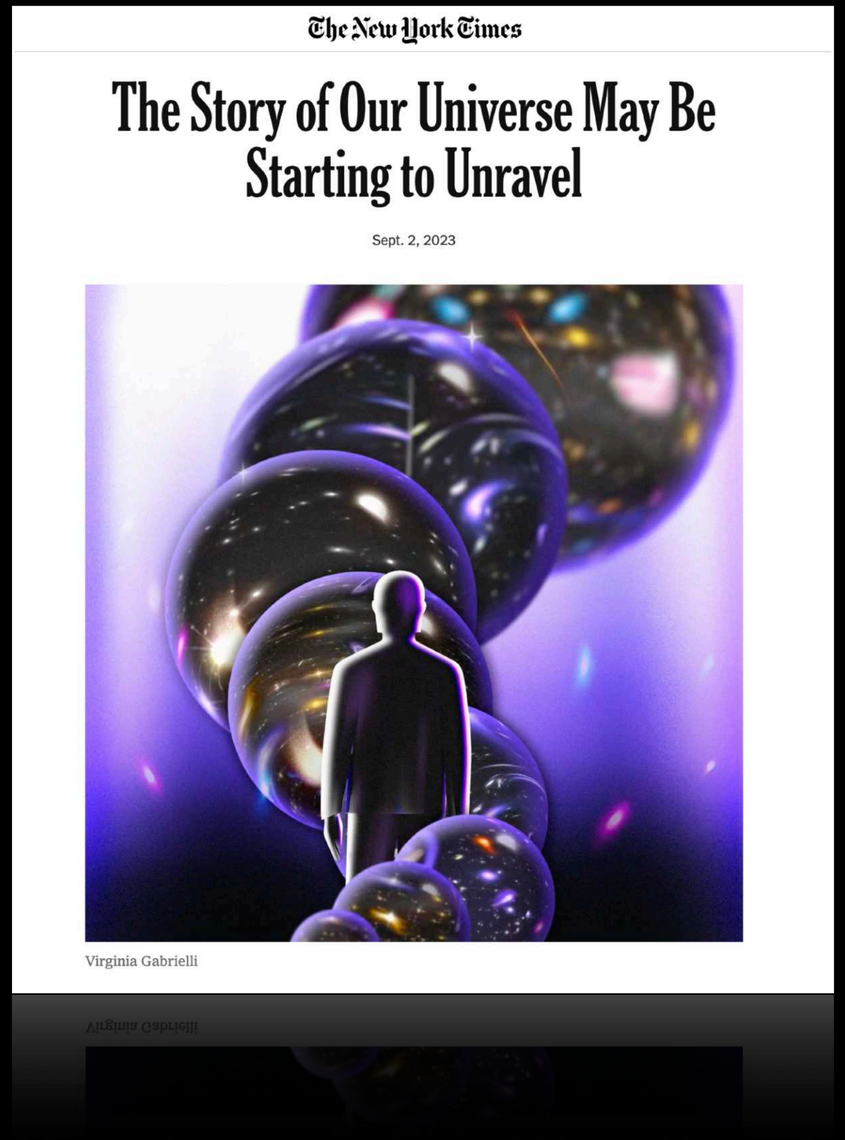




Hubble's best spectrum of GN-z11.

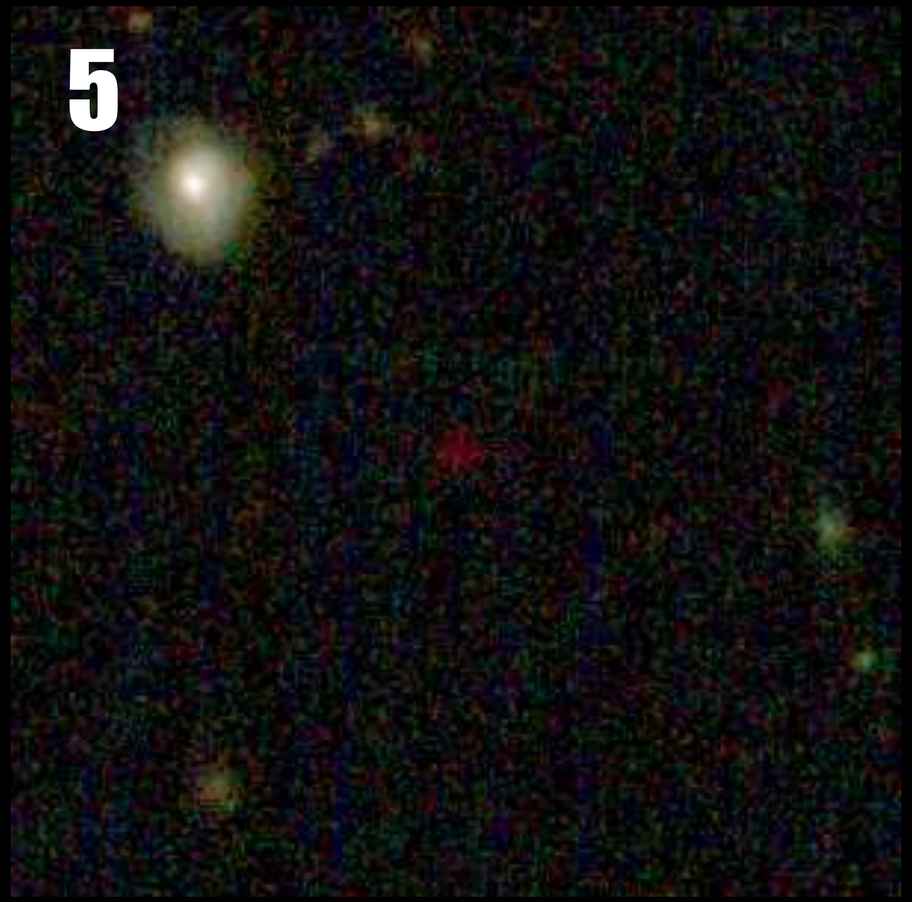
JWST's spectrum of GN-z11.

So why the headlines?



The color of galaxies tells us how far away they are.

(roughly)



The color of galaxies tells us how far away they are.

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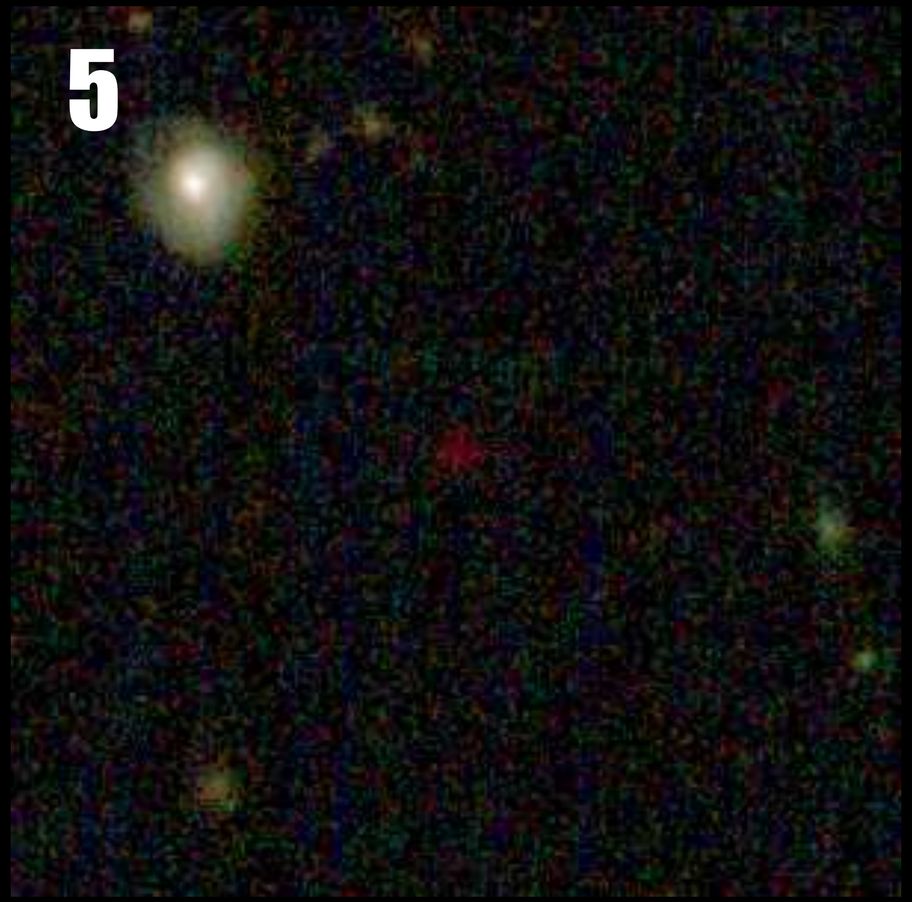
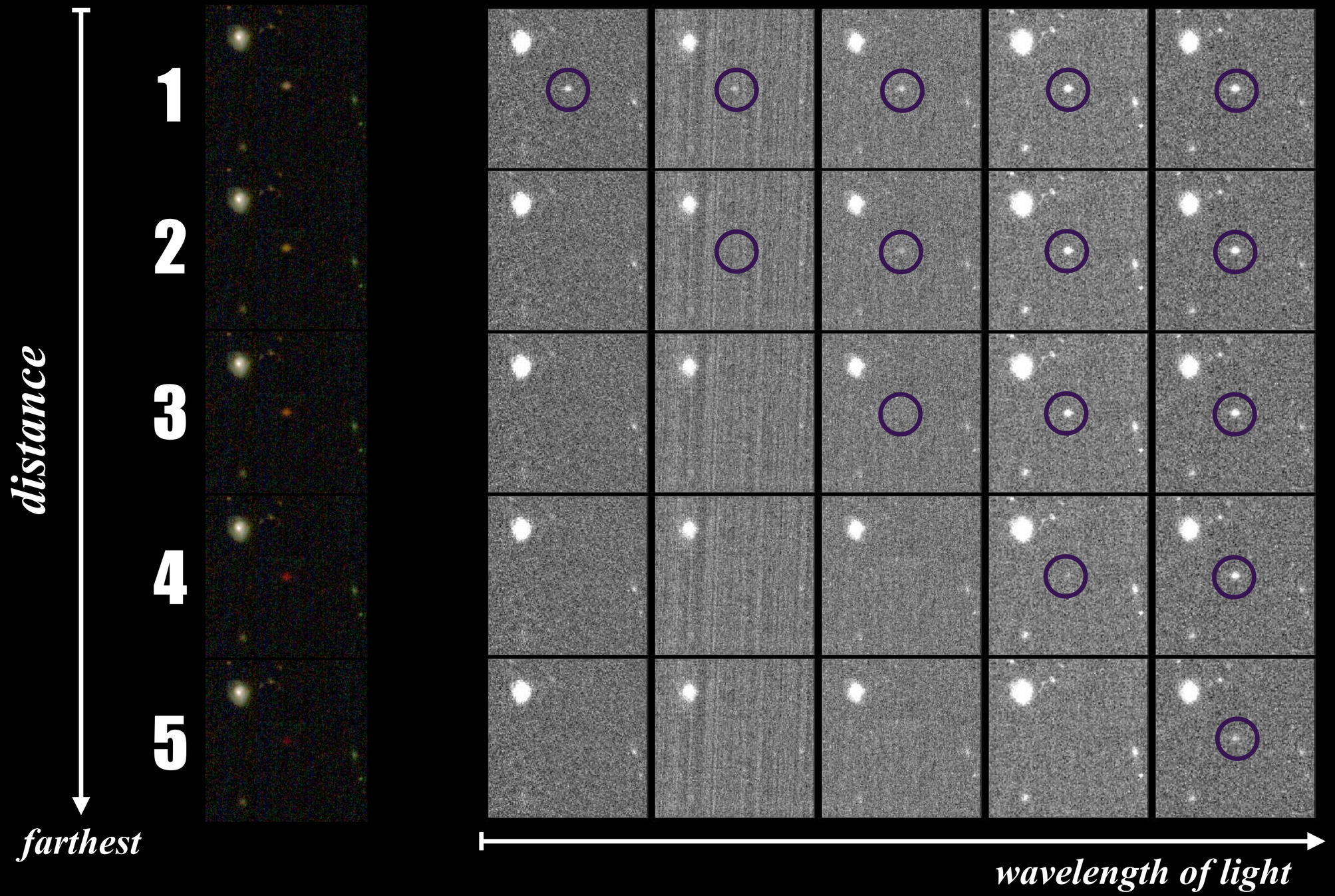
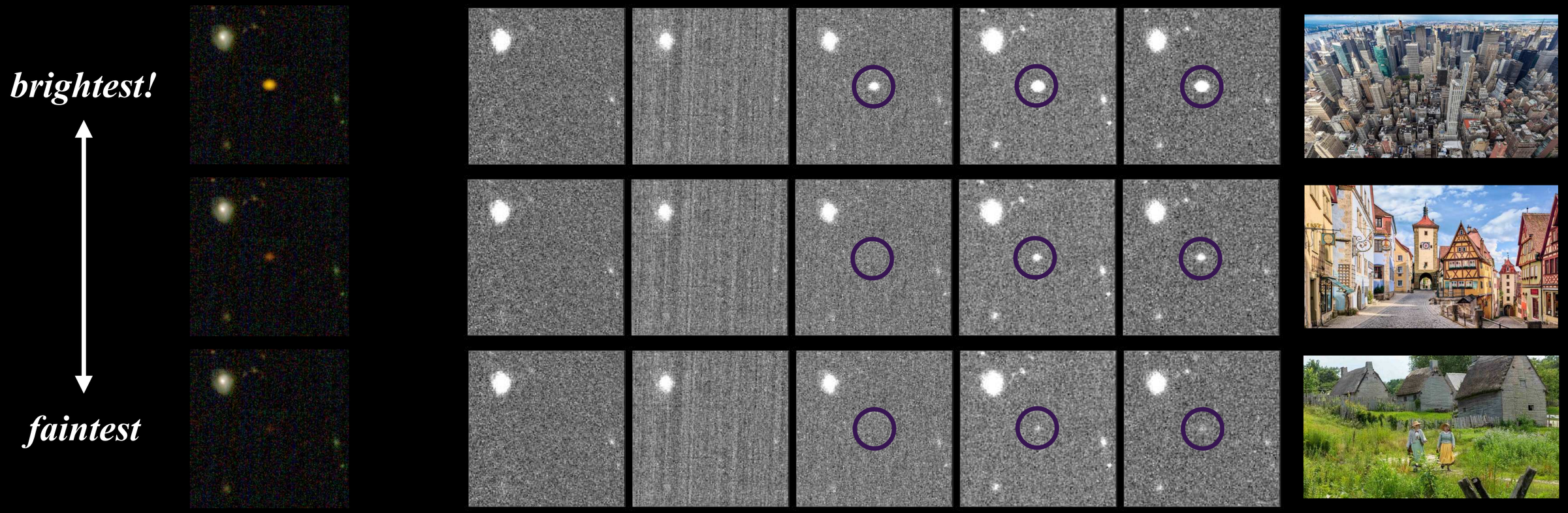



1
2
3
4
5
distance
farthest
wavelength of light

The brightness of galaxies tells us how many stars they have.



The discovery of “little red dots”

nature

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Article | Published: 22 February 2023

A population of red candidate massive galaxies ~600 Myr after the Big Bang

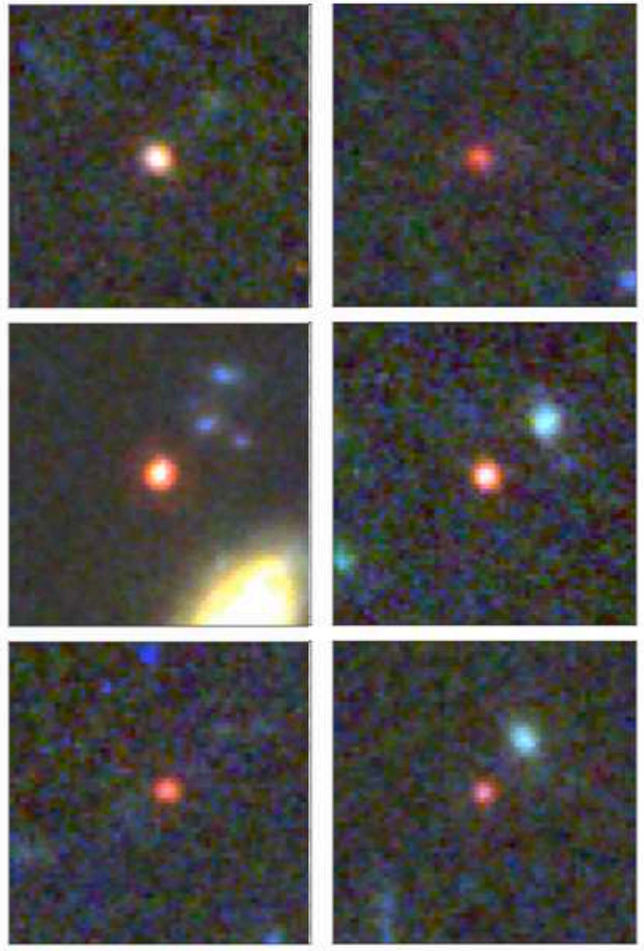
Ivo Labbé ✉, Pieter van Dokkum, Erica Nelson, Rachel Bezanson, Katherine A. Suess, Joel Leja, Gabriel Brammer, Katherine Whitaker, Elijah Mathews, Mauro Stefanon & Bingjie Wang

Nature **616**, 266–269 (2023) | Cite this article

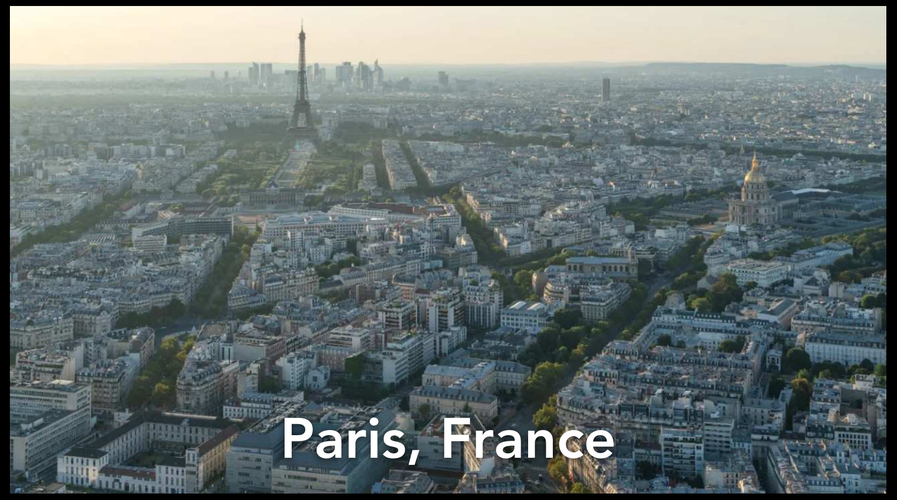
107k Accesses | **36** Citations | **4450** Altmetric | Metrics

Abstract

Galaxies with stellar masses as high as roughly 10^{11} solar masses have been identified[1,2,3] out to redshifts z of roughly 6, around 1 billion years after the Big Bang. It has been difficult to find massive galaxies at even earlier times, as the Balmer break region, which is needed for accurate mass estimates, is redshifted to wavelengths beyond 2.5 μm. Here we make use of the 1–5 μm coverage of the James Webb Space Telescope early release observations to search for intrinsically red galaxies in the first roughly 750 million years of cosmic history. In the




New York, USA


Paris, France


Santiago, Chile


Singapore

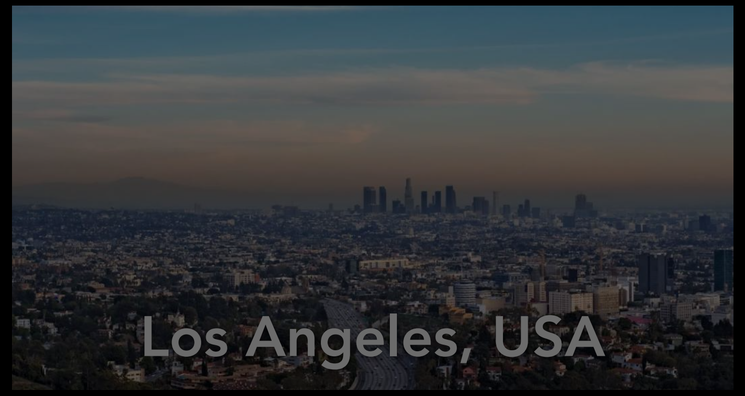

Dubai, UAE


Shanghai, China

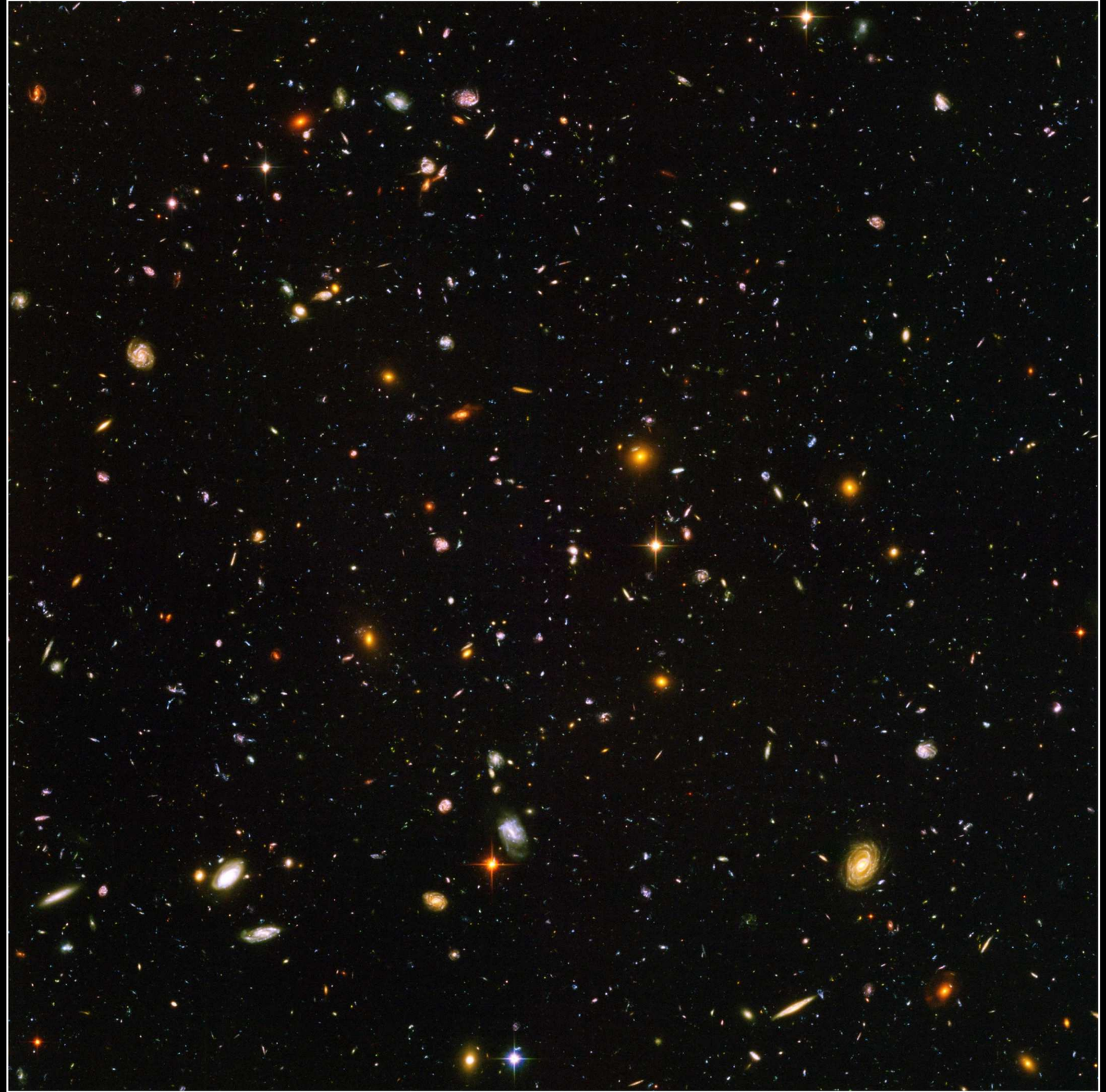

Cairo, Egypt


Los Angeles, USA

Not all cities are the same!!



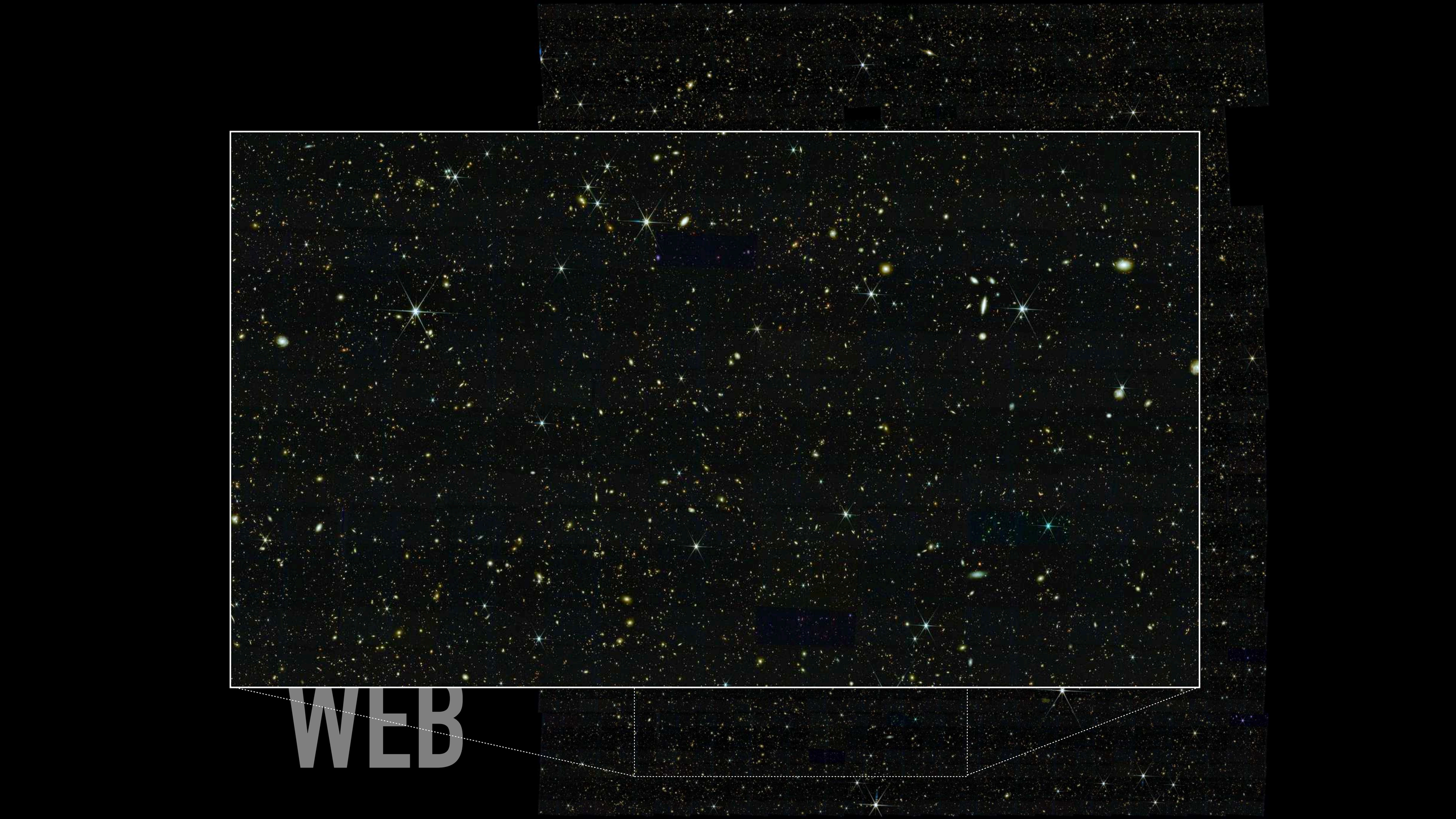

COSMOS-Web Team at the
Institut d'Astrophysique de
Paris, July 2022




HUDF

HUDF

COSMOS
WEB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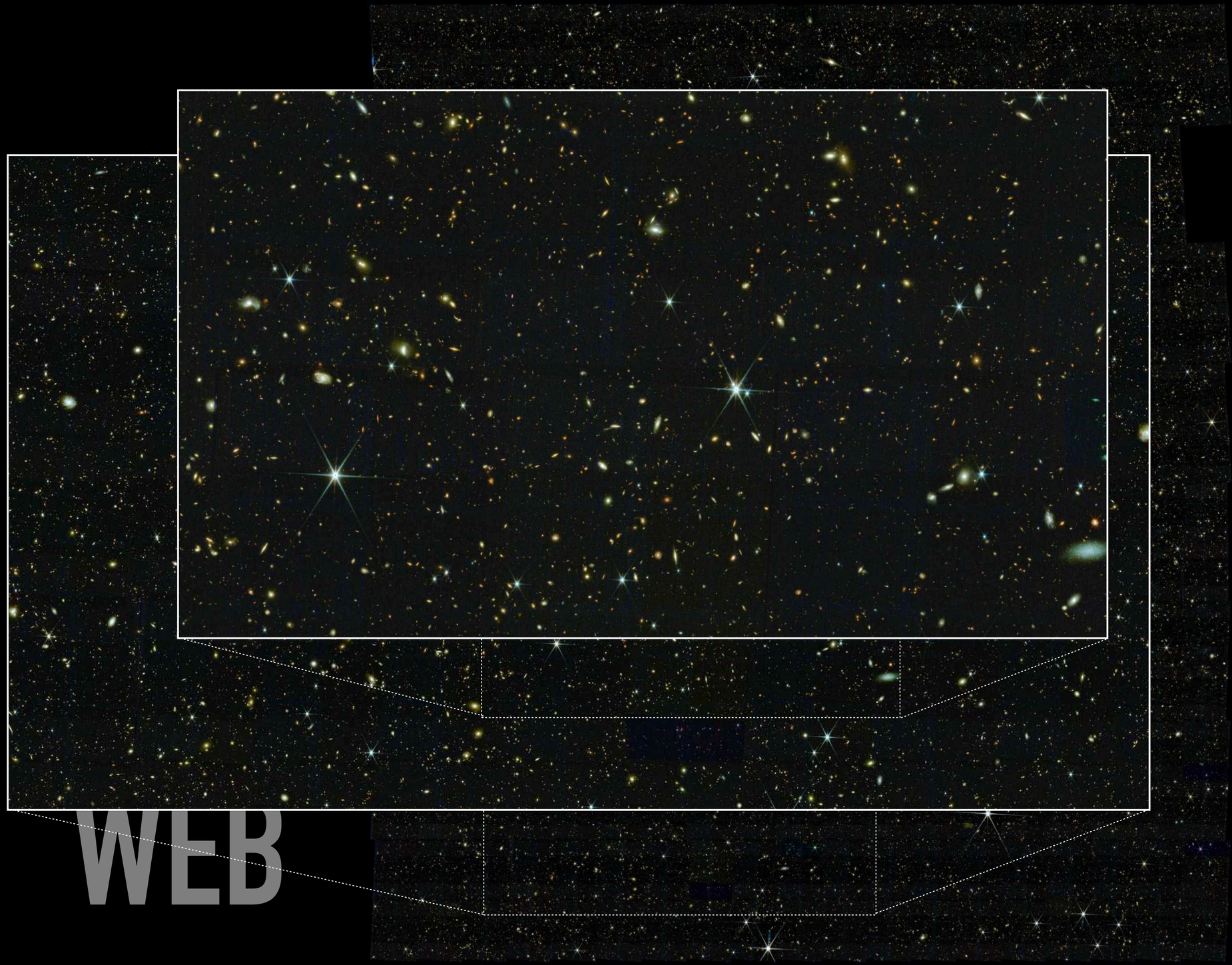
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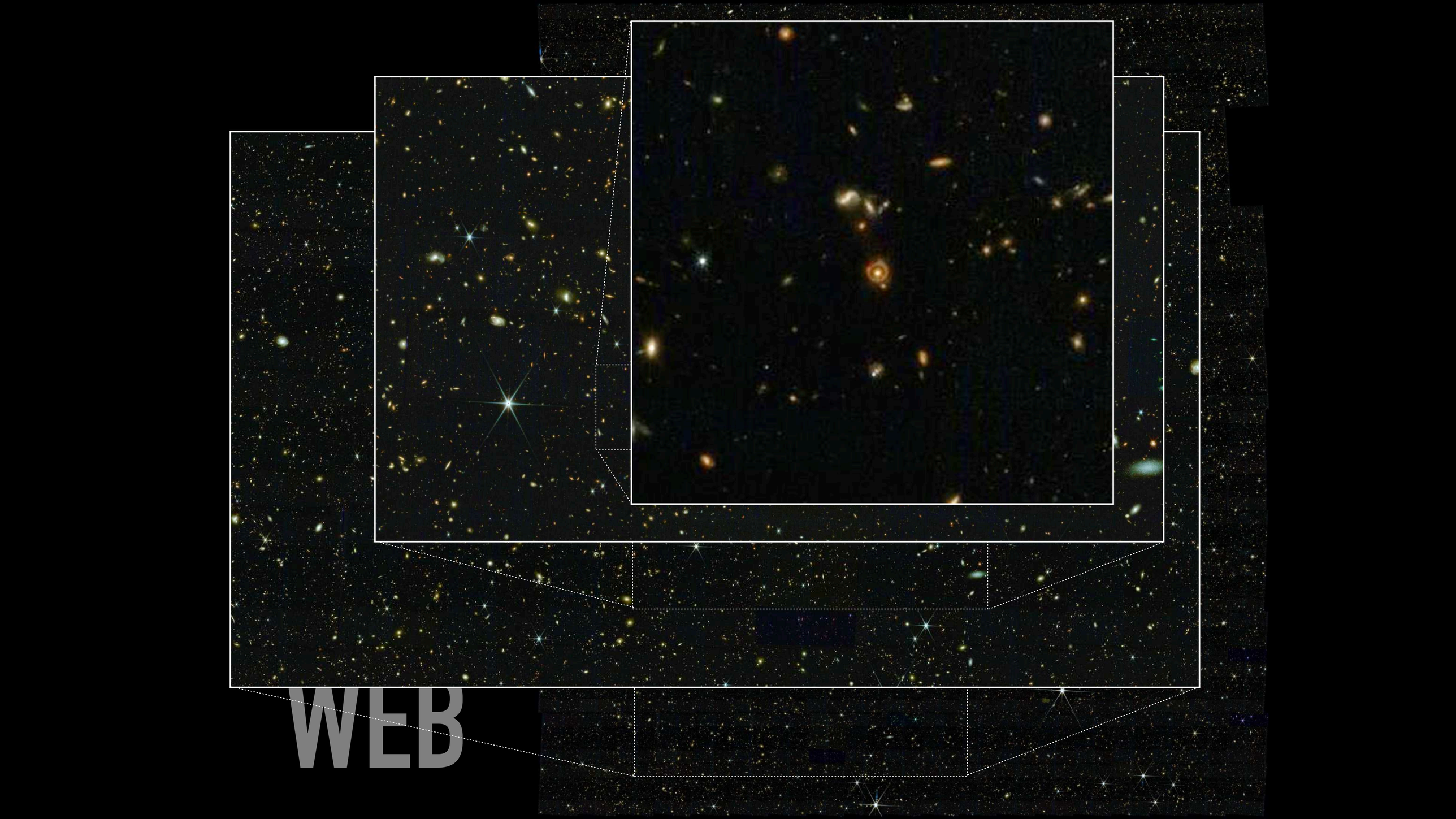
WEB

Many open questions!

How and when did the first galaxies assemble?

Do they really have so many stars, or does something else make them so bright?

Do they grow in groups?

Do they contain massive black holes?

Thank you! Happy to take your questions.