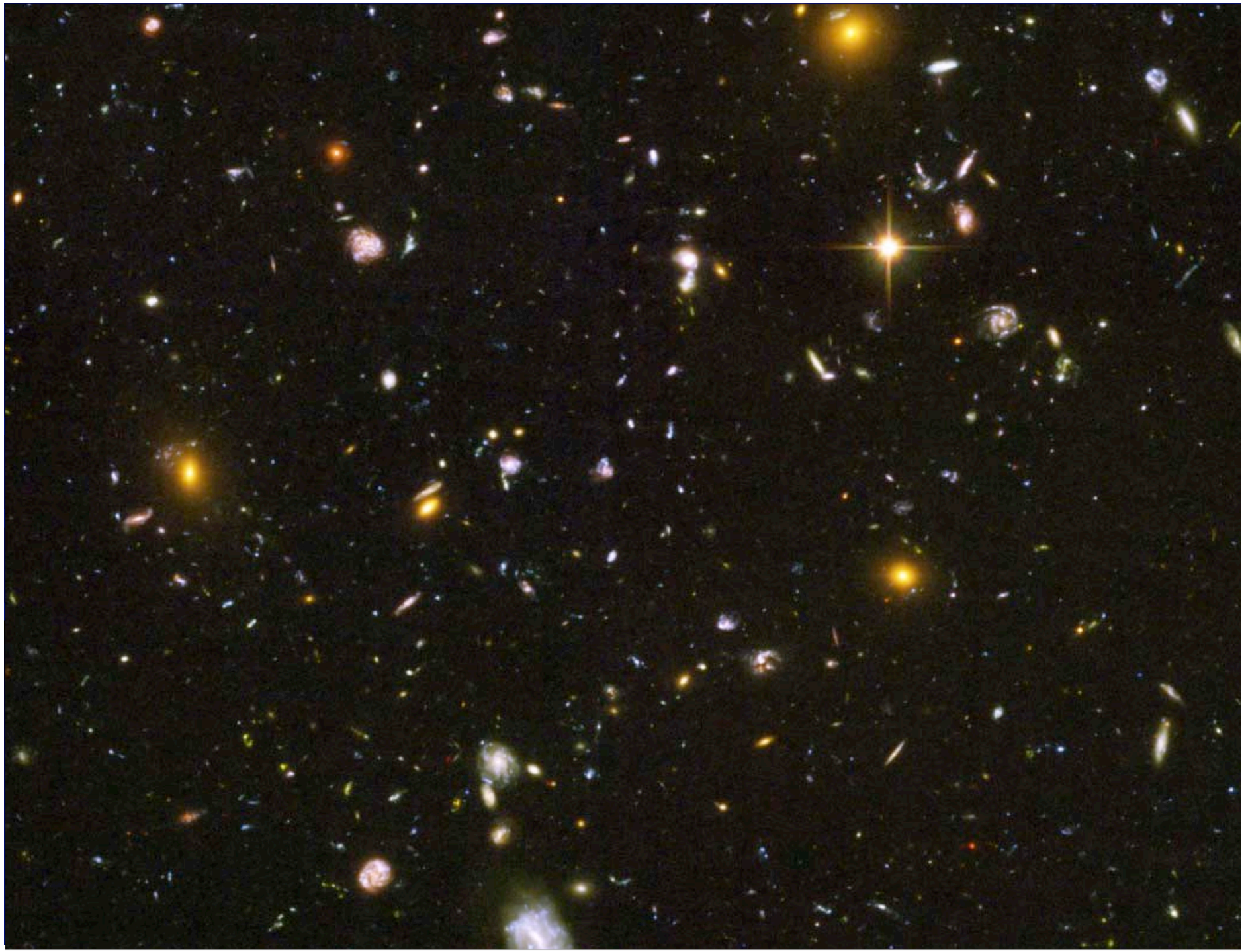

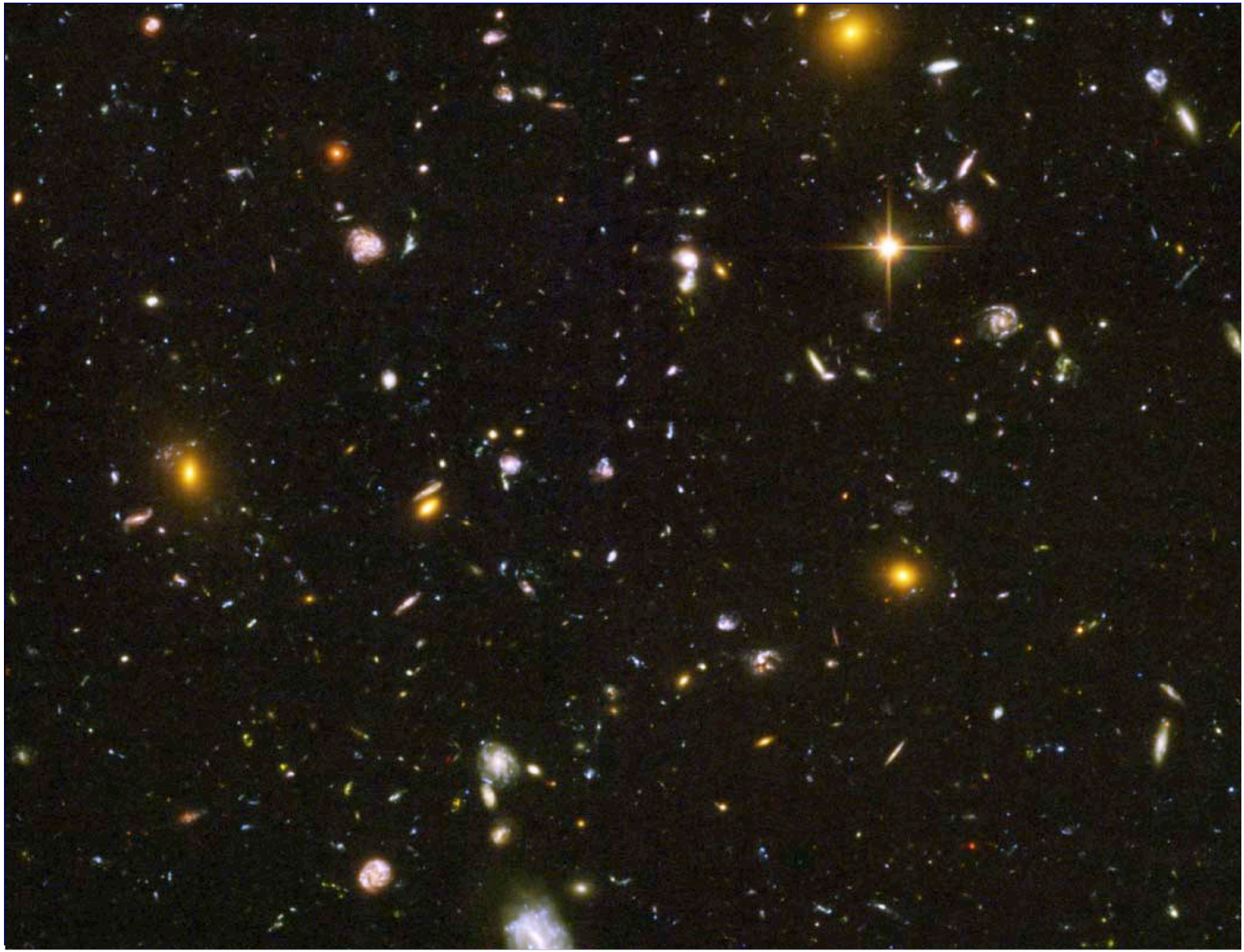

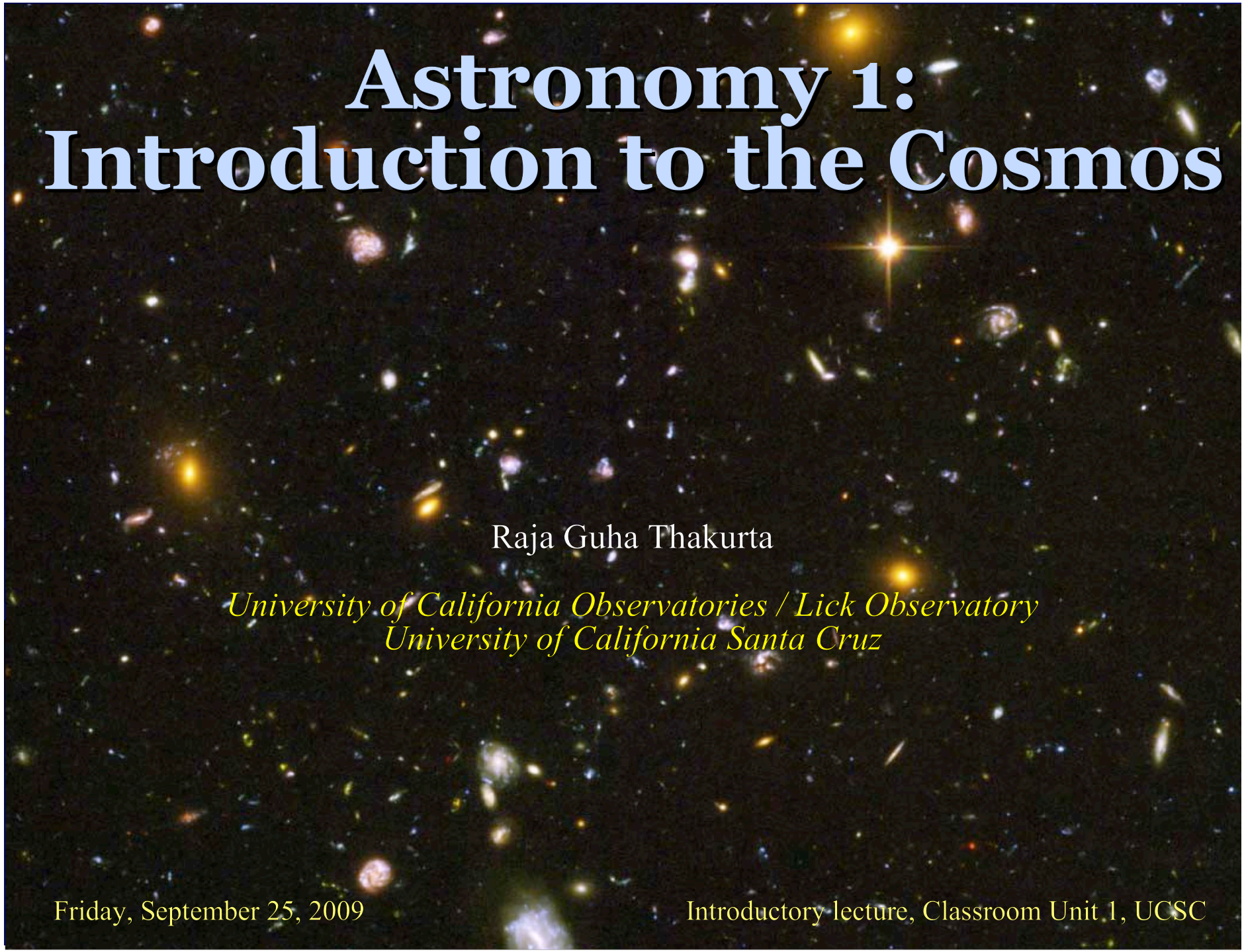

Astronomy 1: Introduction to the Cosmos

Raja Guha Thakurta

University of California Observatories / Lick Observatory
University of California Santa Cruz

Friday, September 25, 2009

Introductory lecture, Classroom Unit 1, UCSC

Astronomy 1: Introduction to the Cosmos

.... not to be confused with

Astrology, Gastronomy, and Cosmetology

Raja Guha Thakurta

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Outline

- Our Place in the Universe
- Cosmic Chemical Recycling
- The Andromeda Galaxy:
  A Cannibal Caught in the Act
- Formation of Galaxies
- Early Ripples in the Universe
- Telescopes as Time Machines:
  Testing Theoretical Predictions
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Our Place in the Cosmos

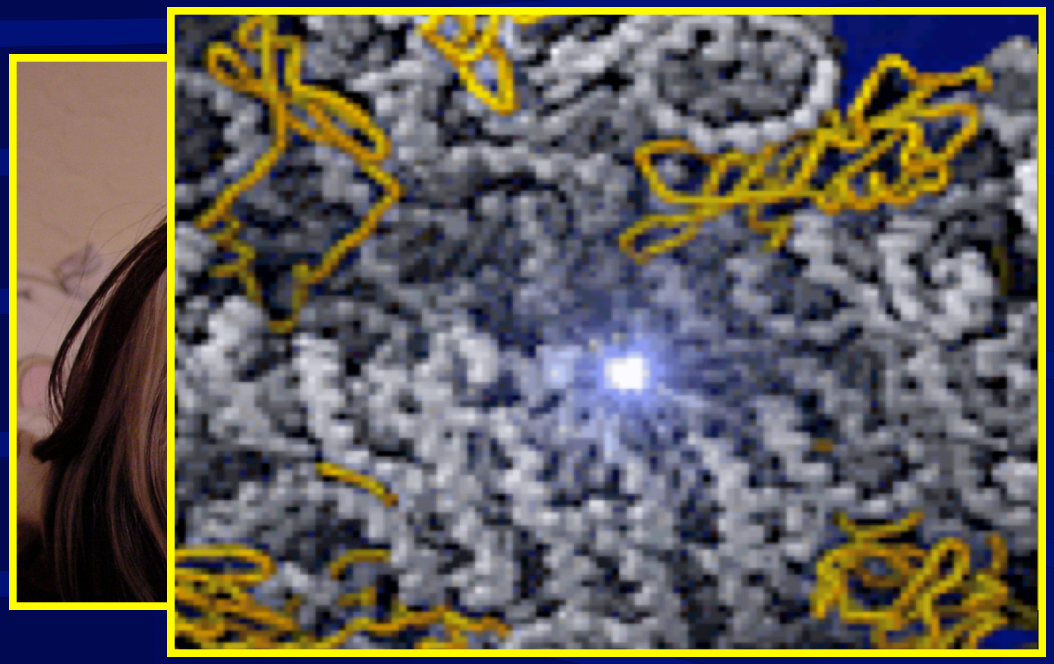
Our Place in the Cosmos

Our Place in the Cosmos



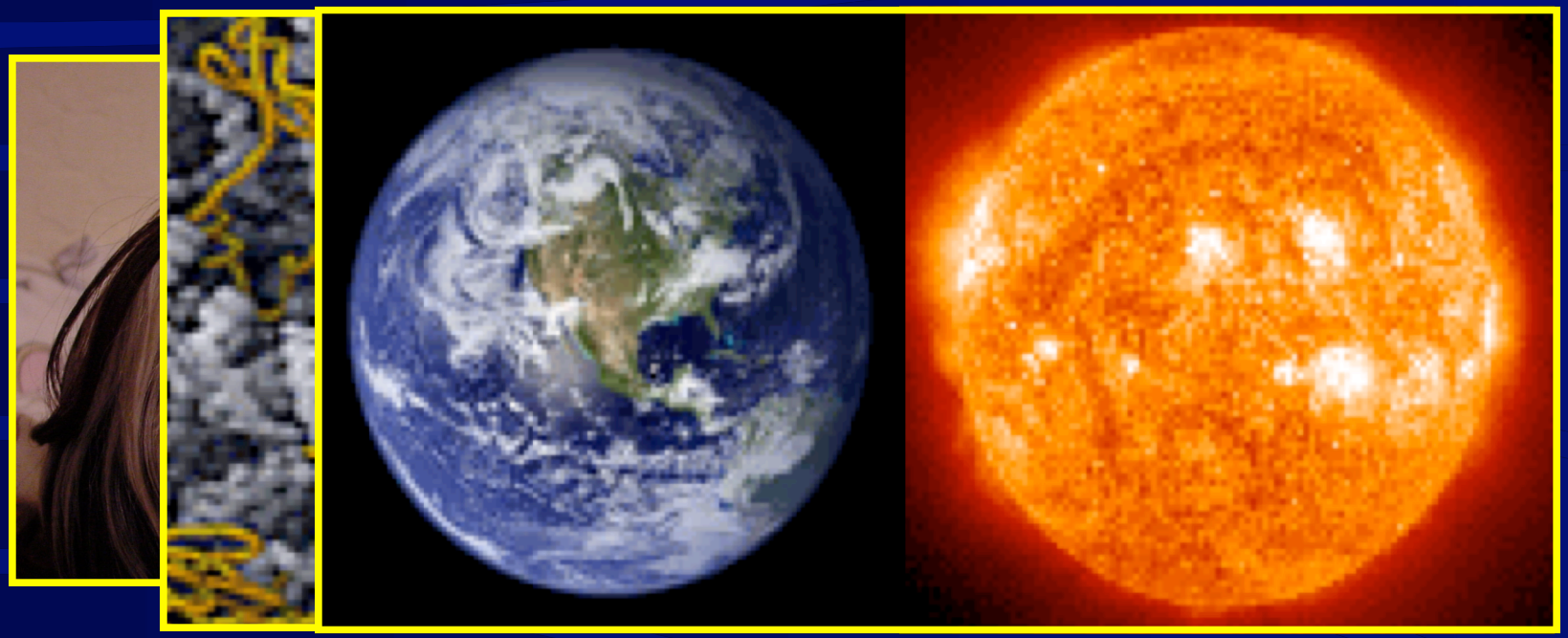
You!

Our Place in the Cosmos



Protein molecules:
Basic building blocks of life

Our Place in the Cosmos



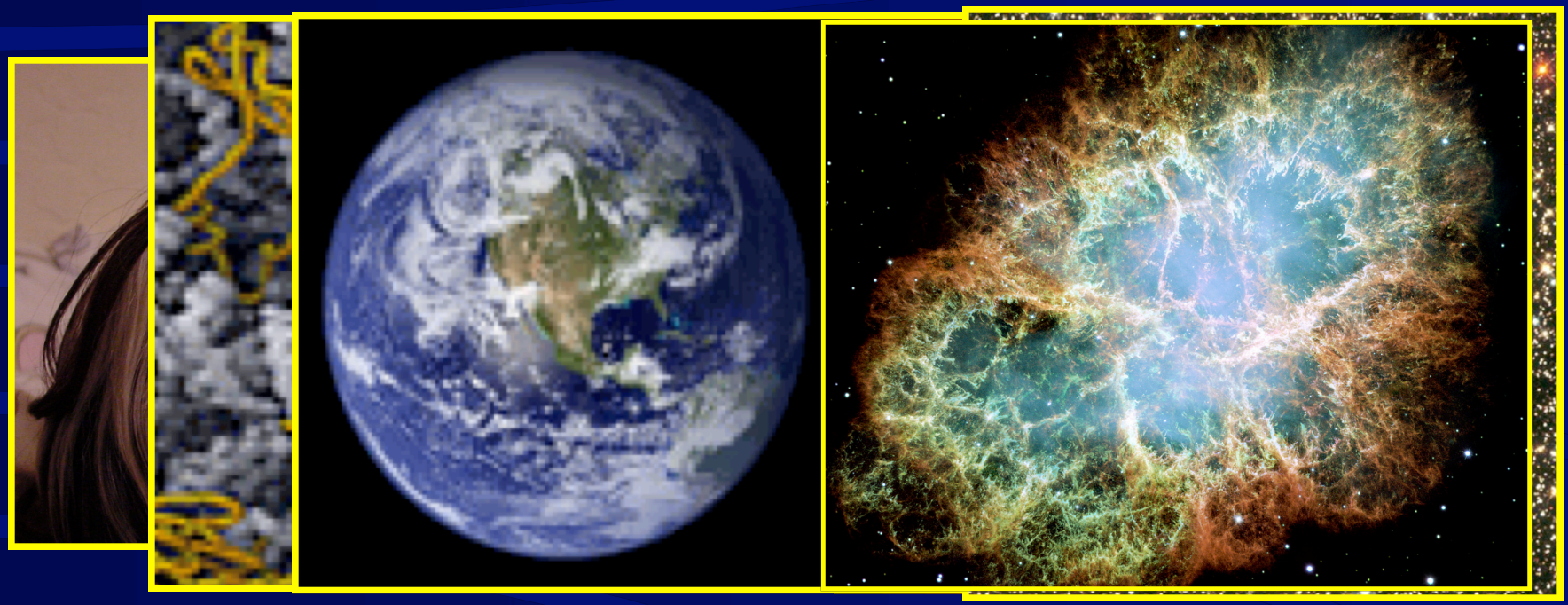
Earth and Sun:
Home of the C,N,O atoms from which
these protein molecules were assimilated

Our Place in the Cosmos



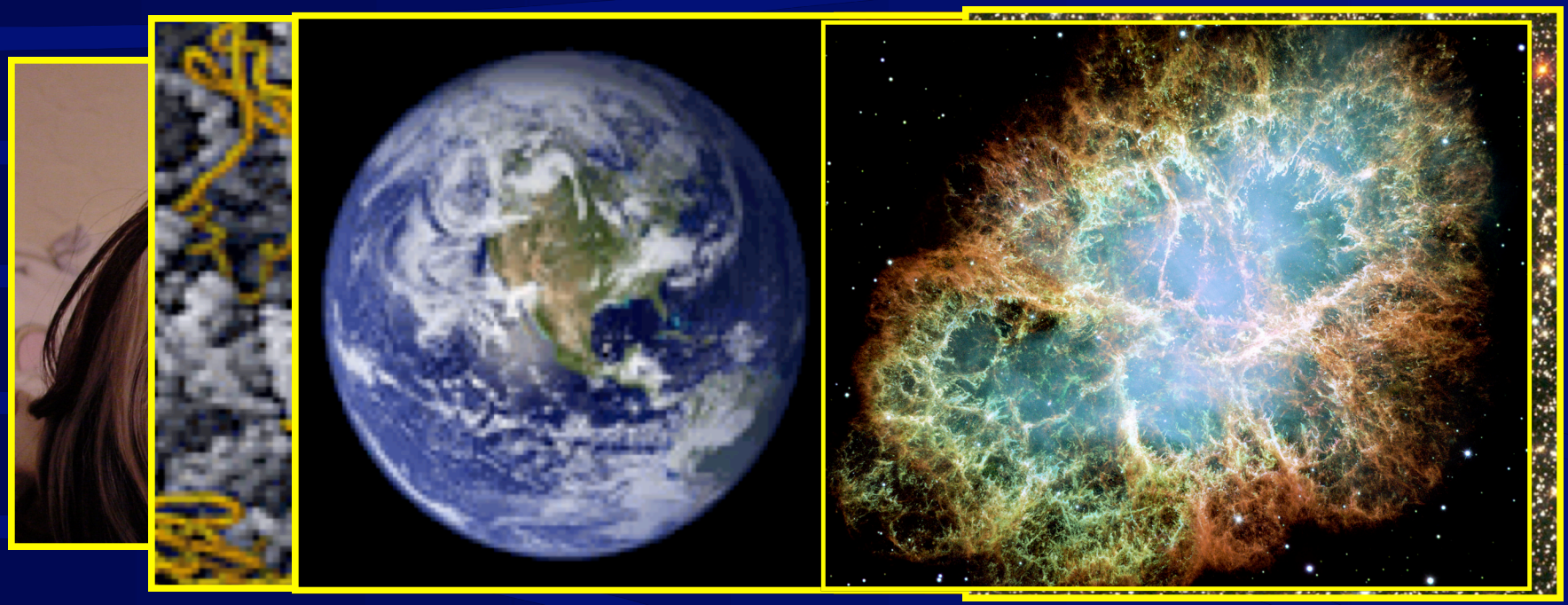
Sun's ancestral stars:
Their nuclear fusion reactions
produced these C,N,O atoms

Our Place in the Cosmos



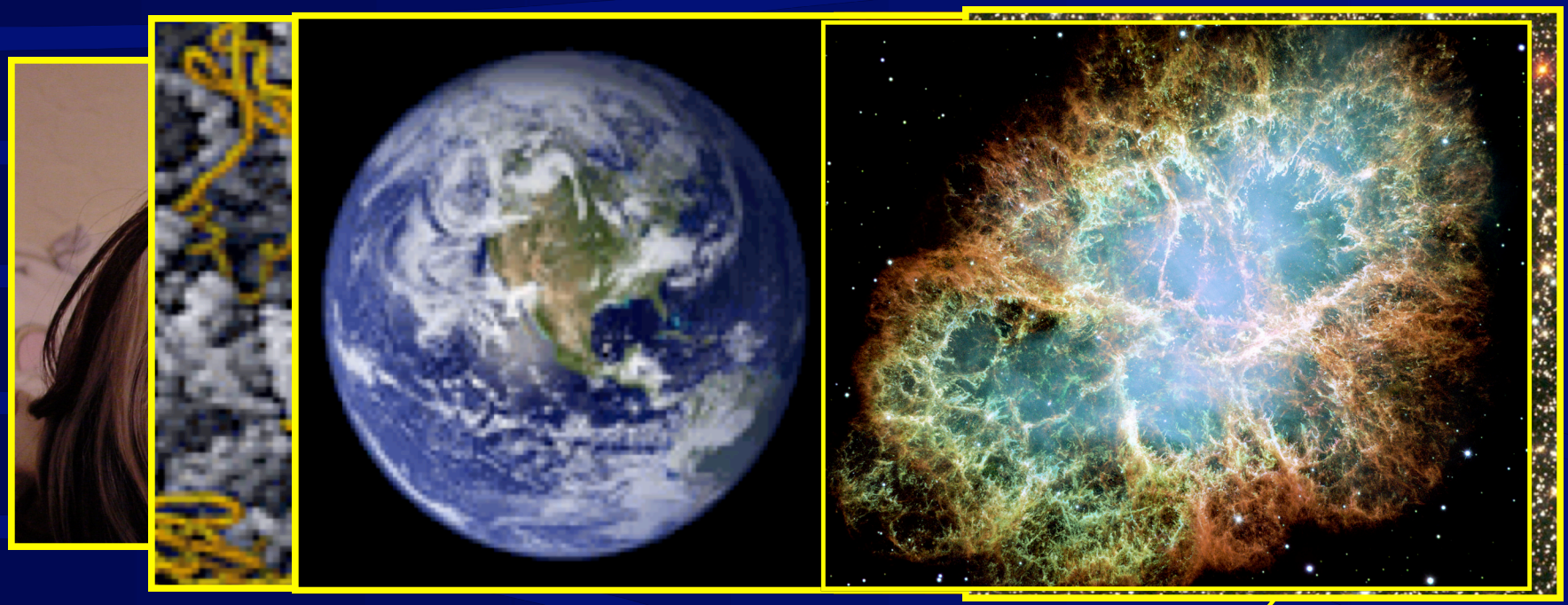
Supernova explosion injects complex elements into surrounding gas clouds

Our Place in the Cosmos



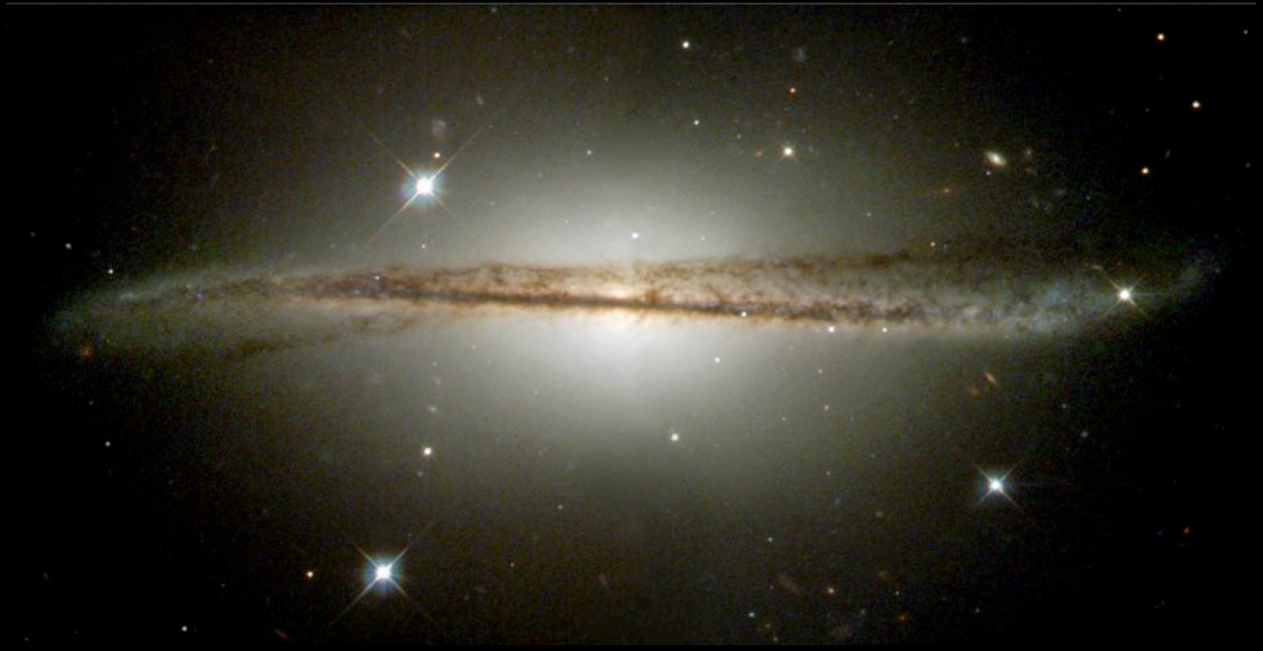


Our Place in the Cosmos





Galaxies come in many shapes and sizes



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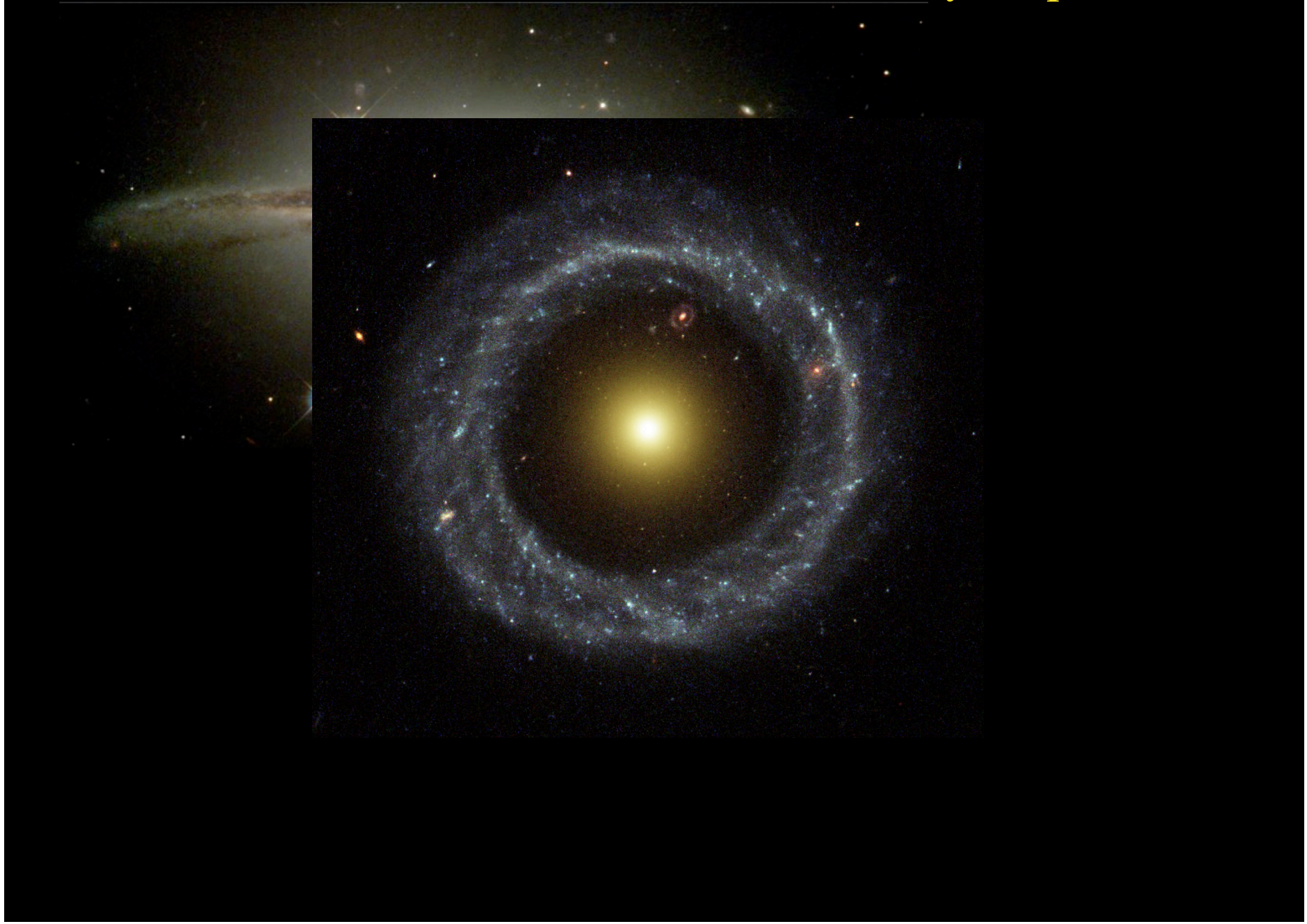

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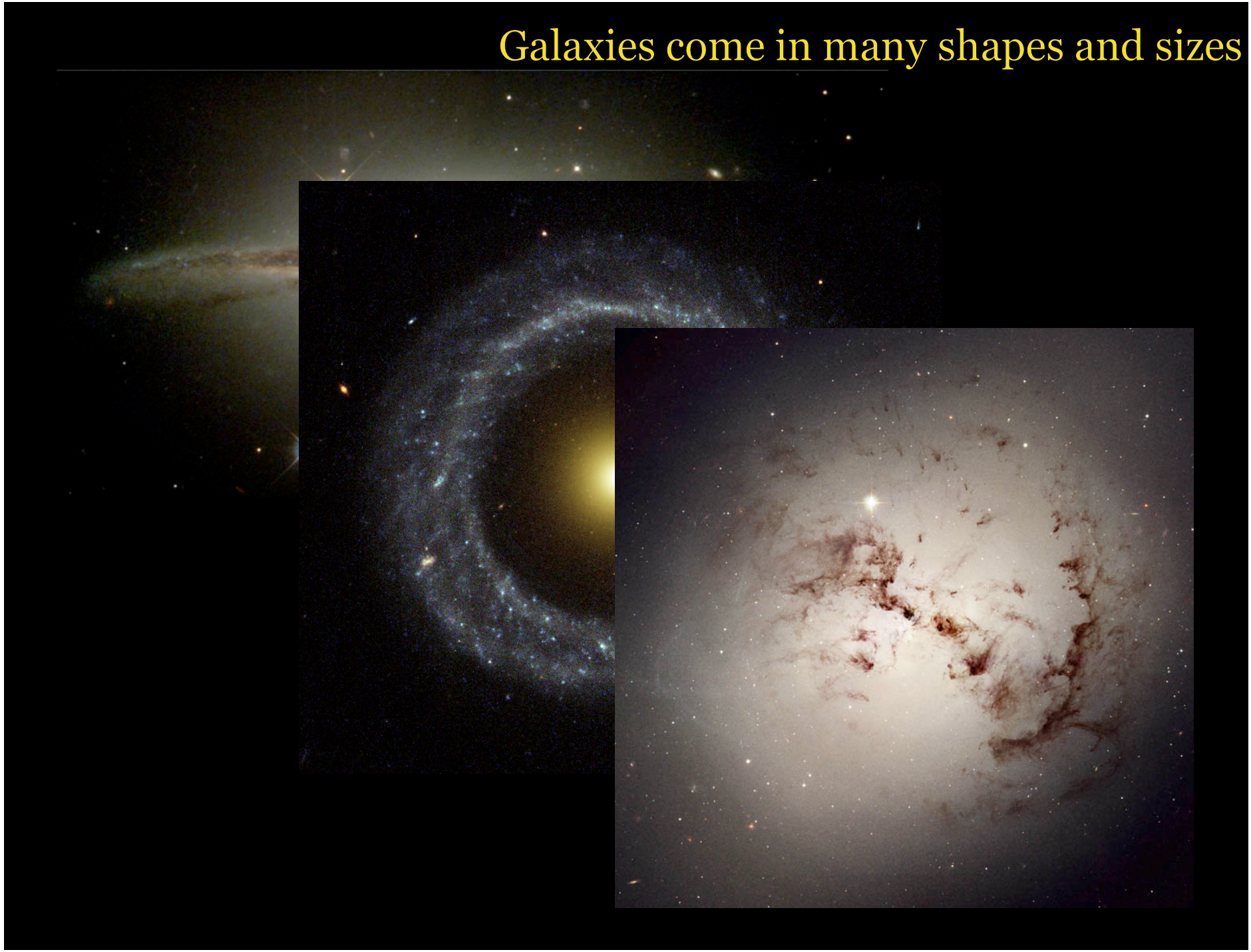

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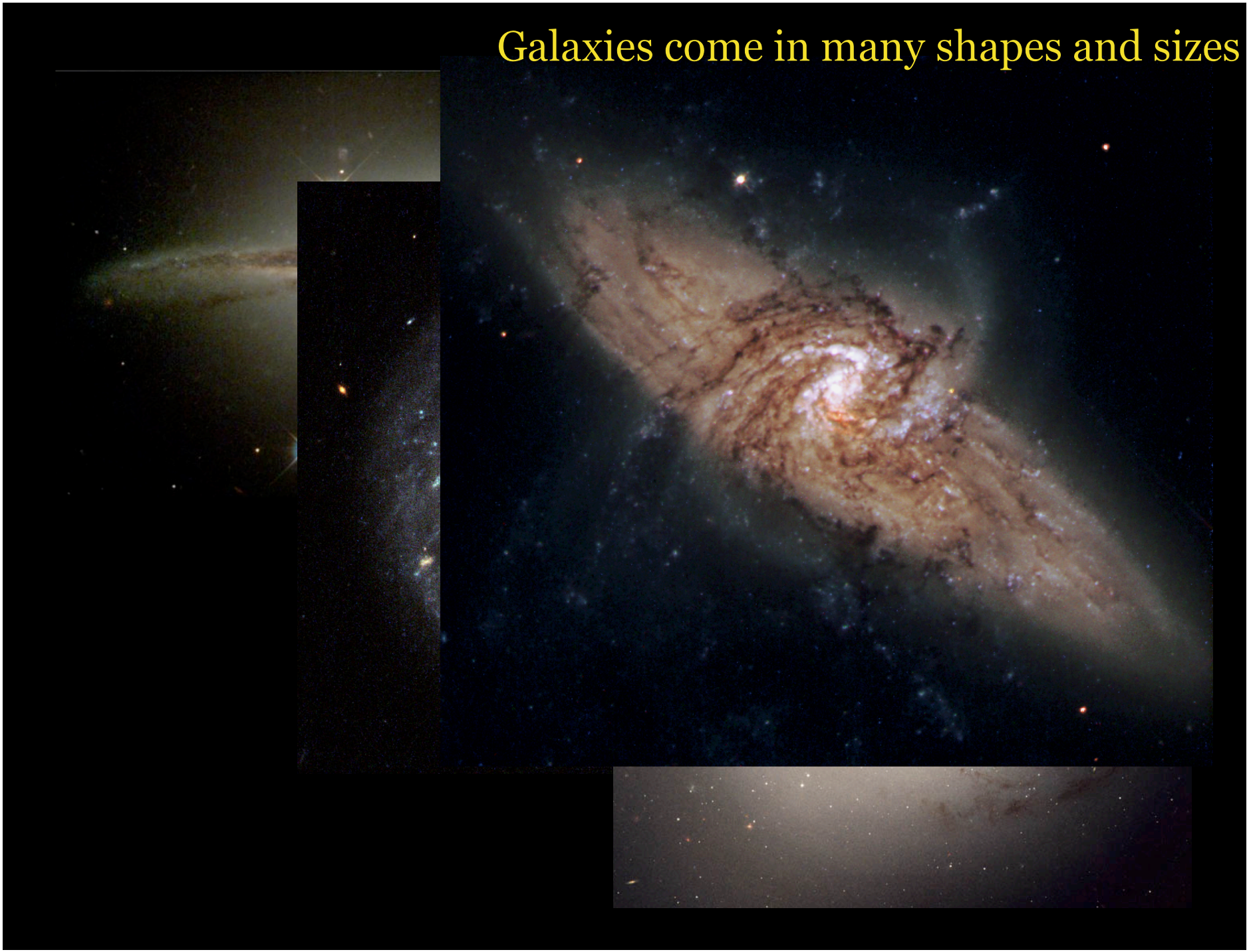

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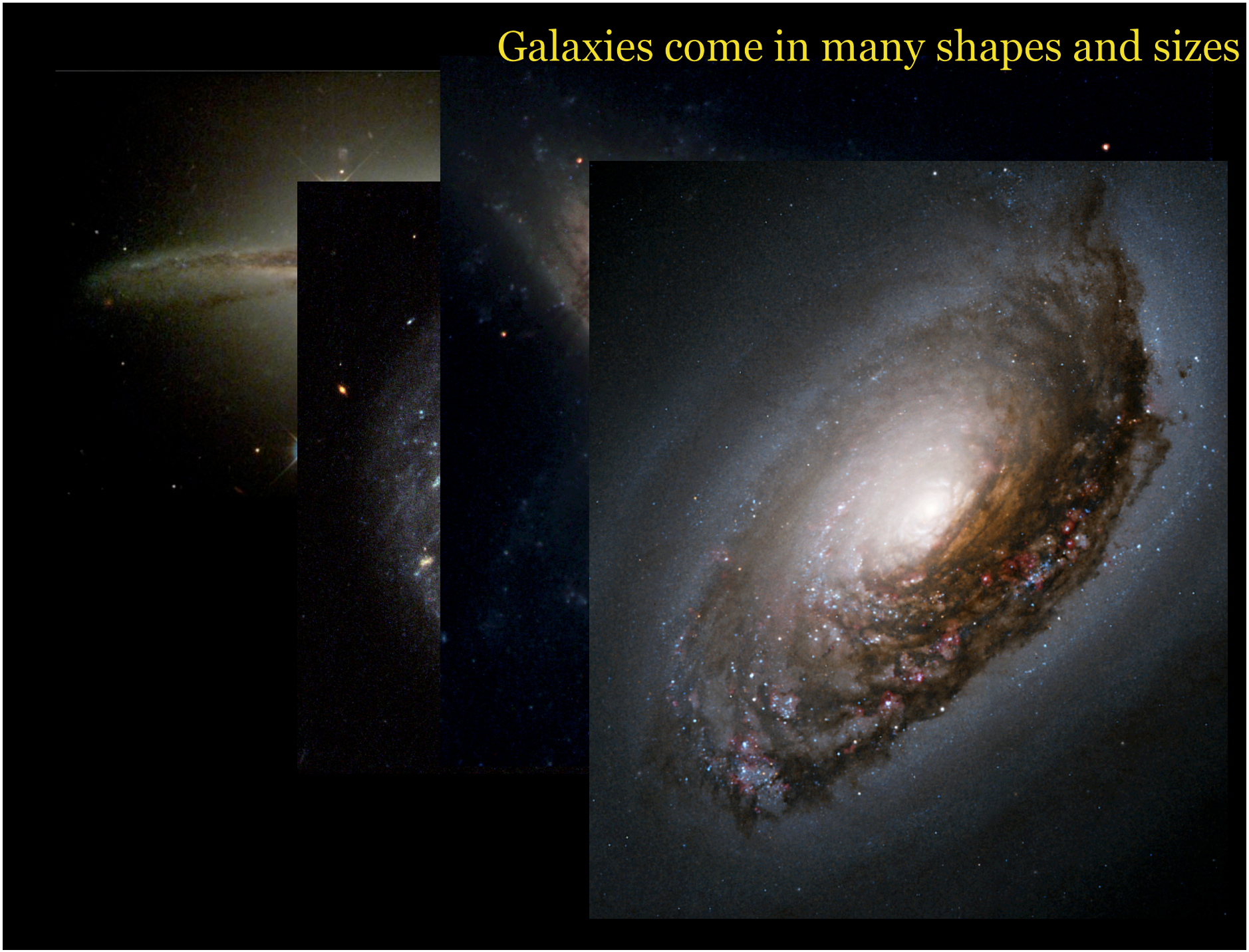
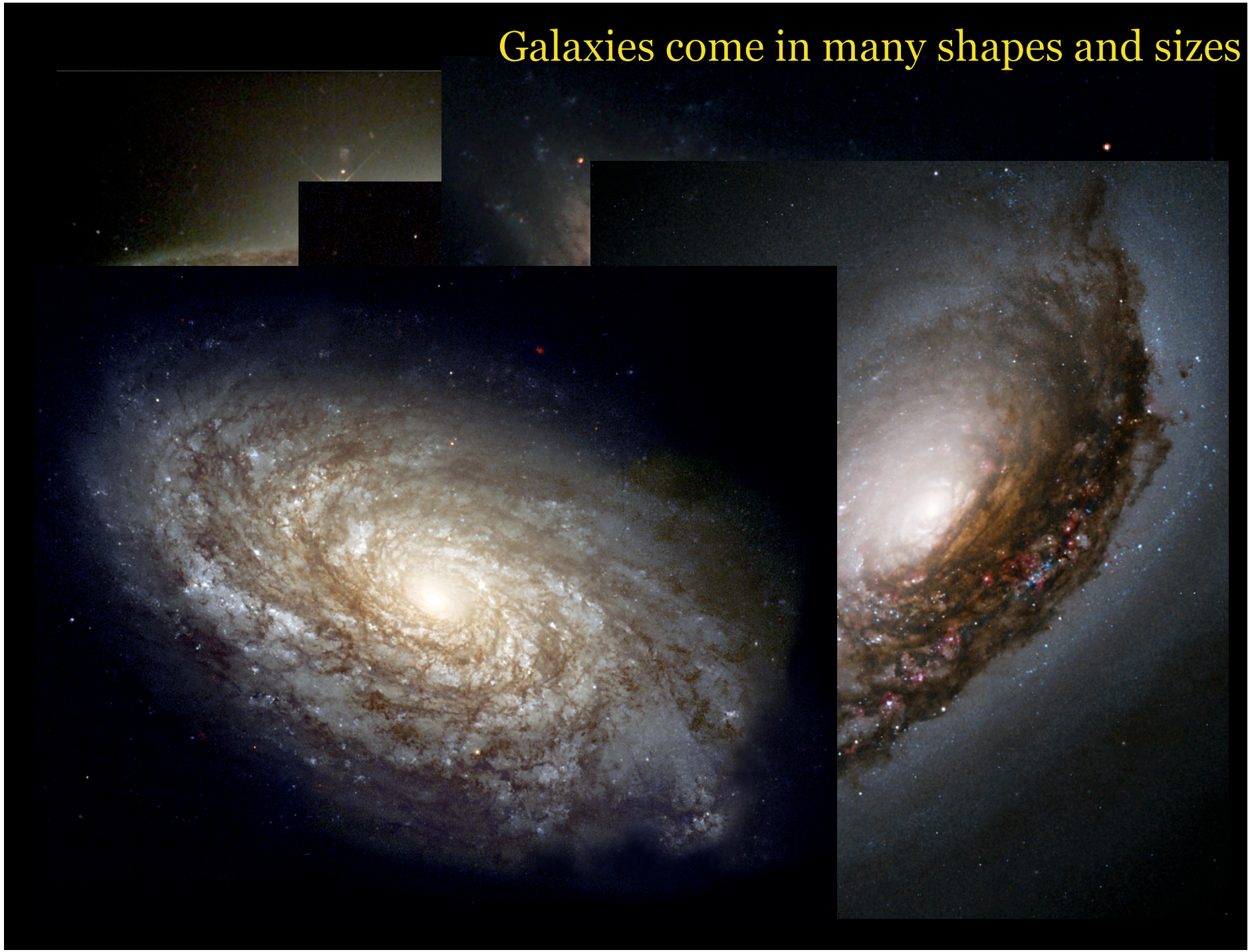



Galaxies come in many shapes and sizes

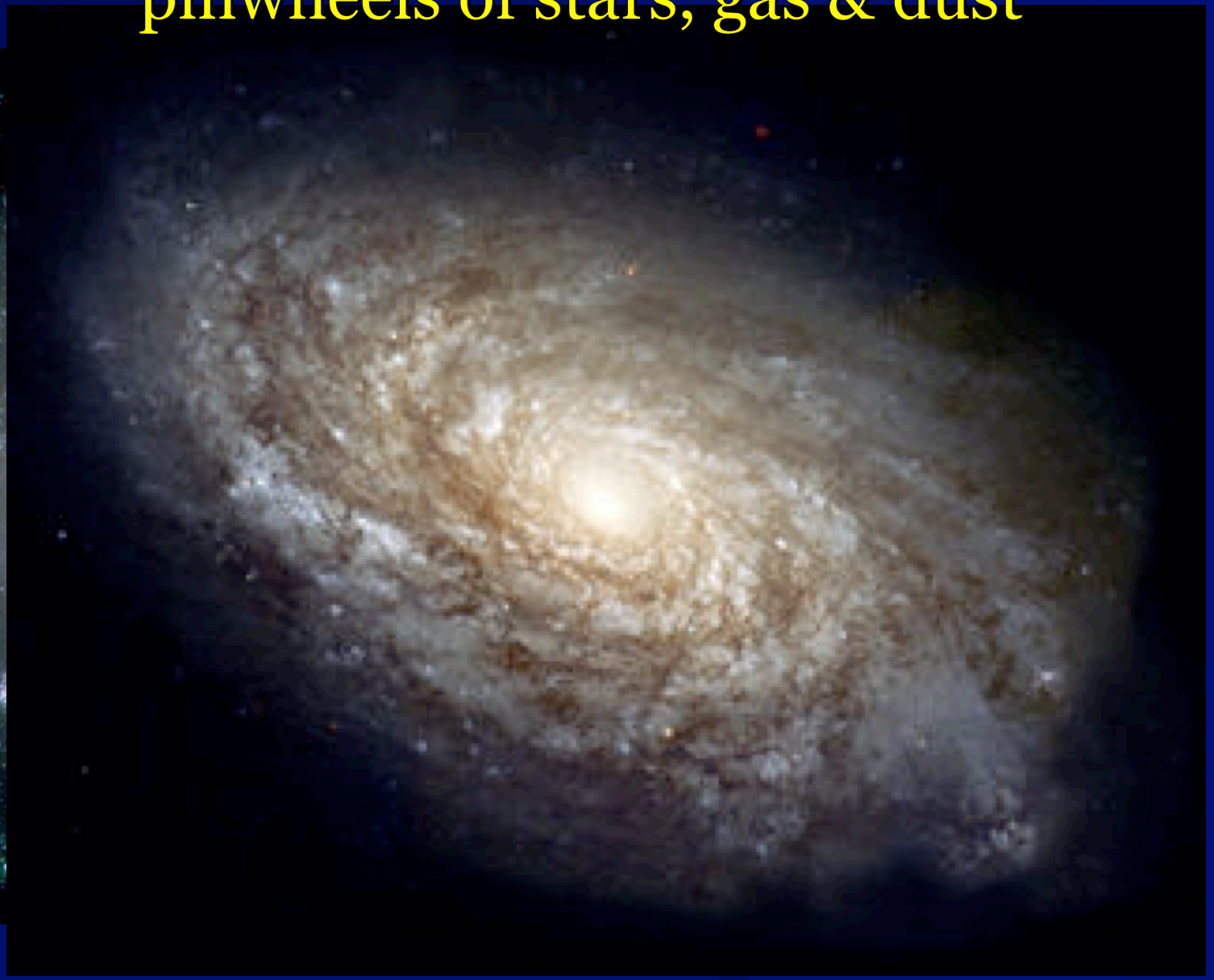
Spiral galaxies are flattened rotating pinwheels of stars, gas & dust

Spiral galaxies are flattened rotating pinwheels of stars, gas & dust



Spiral galaxies are flattened rotating pinwheels of stars, gas & dust





Spiral galaxies are flattened rotating pinwheels of stars, gas & dust



Spiral galaxies are flattened rotating pinwheels of stars, gas & dust

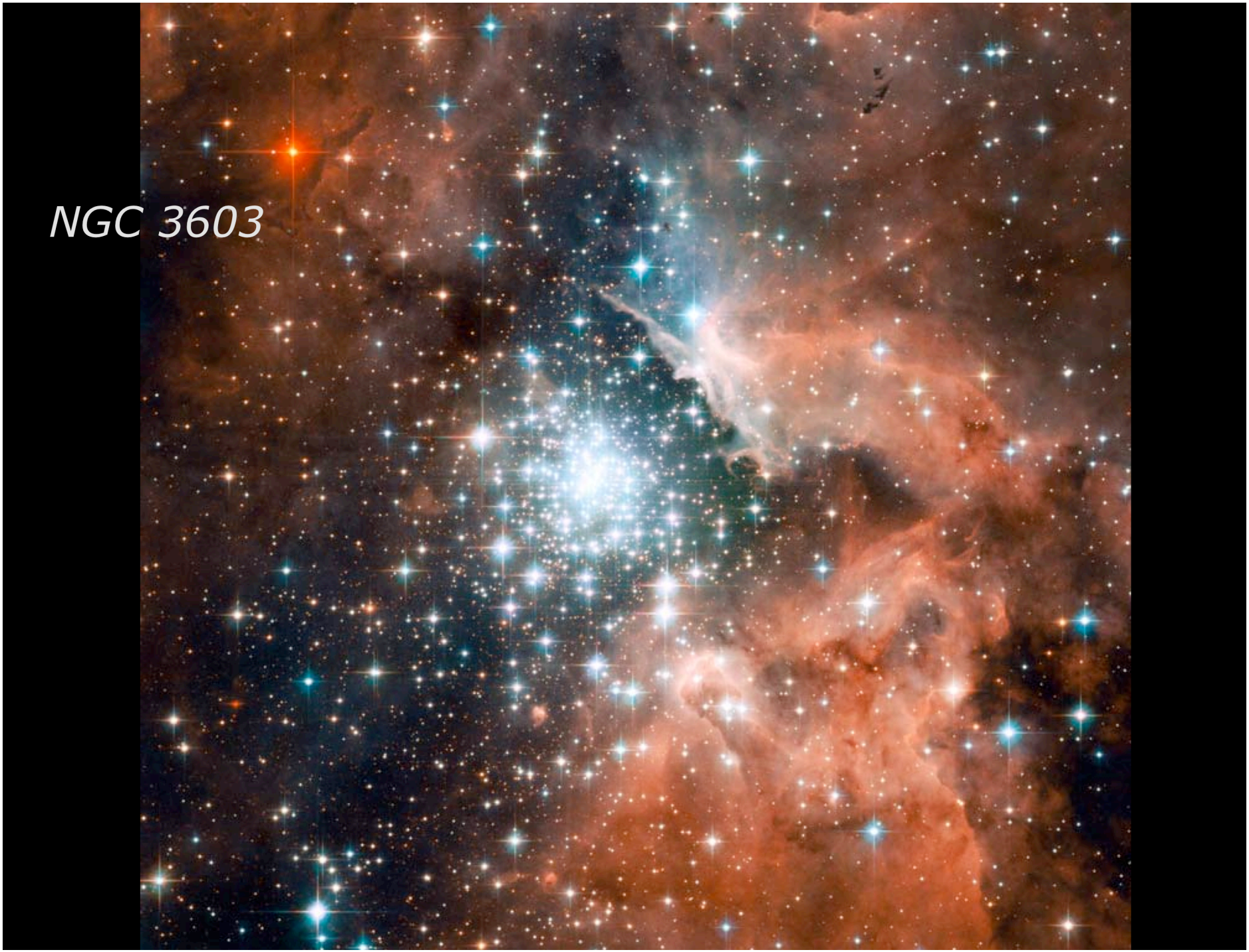


Spiral galaxies are flattened rotating pinwheels of stars, gas & dust



Milky Way


Wally Pacholka


NGC 3603

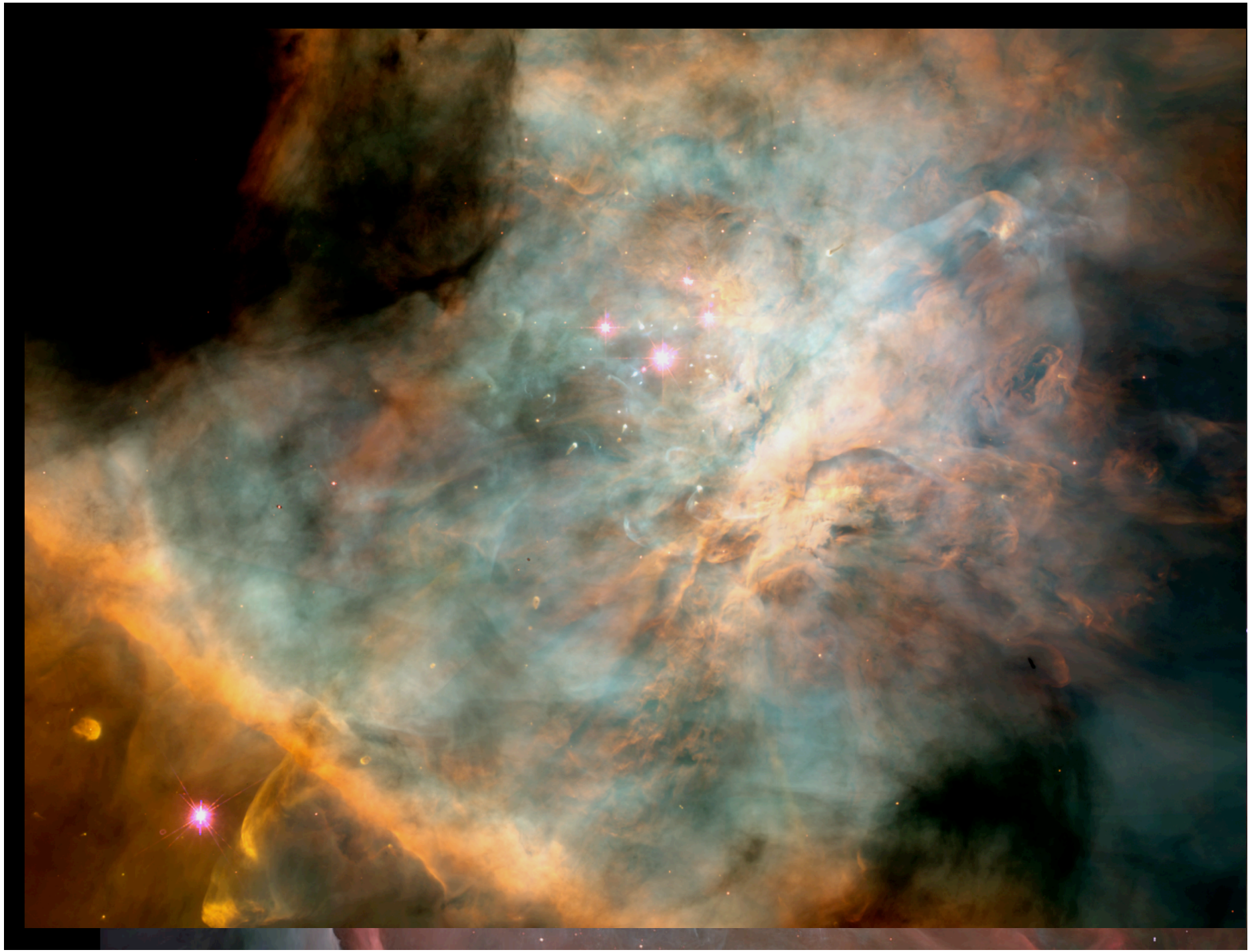
NGC 6357

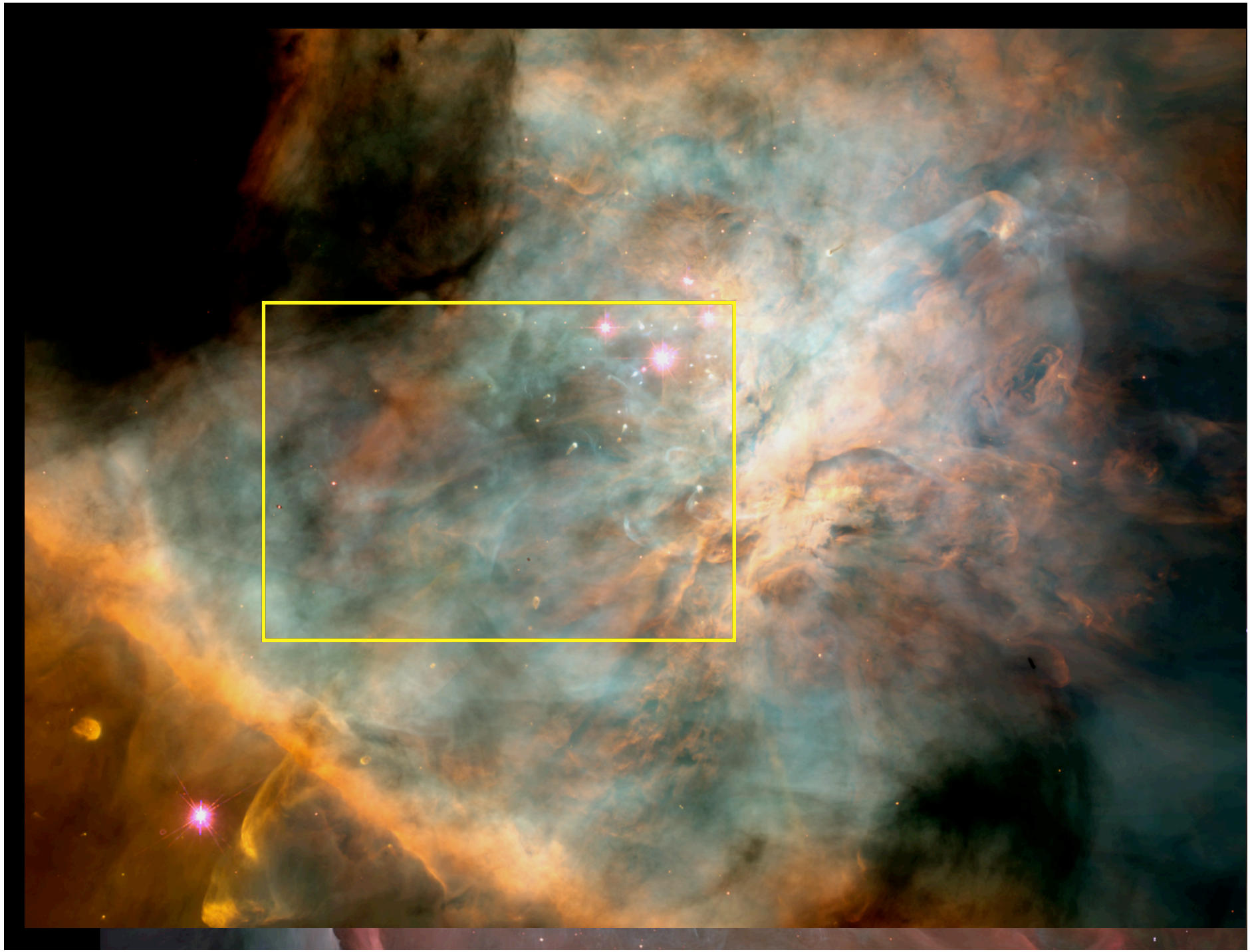


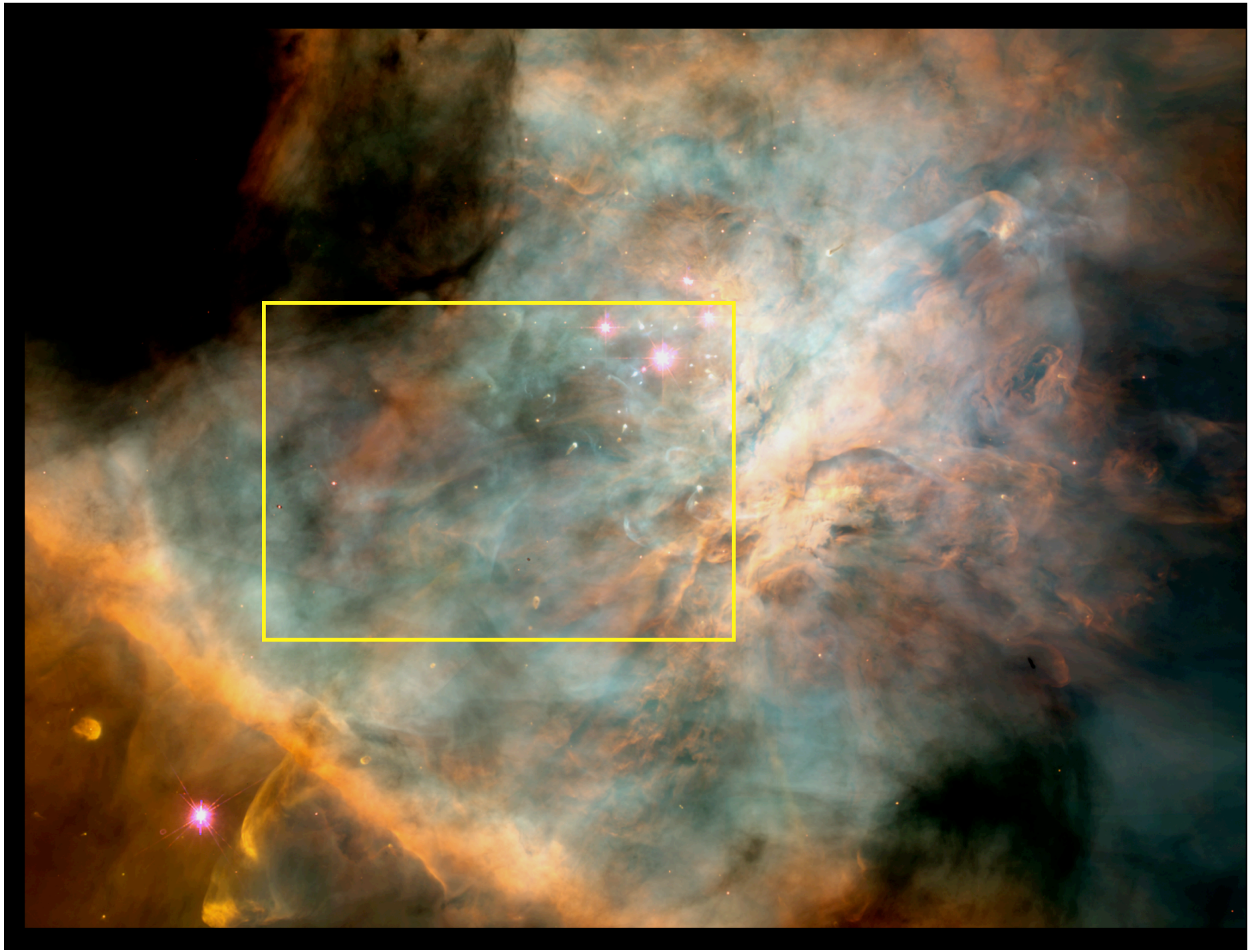


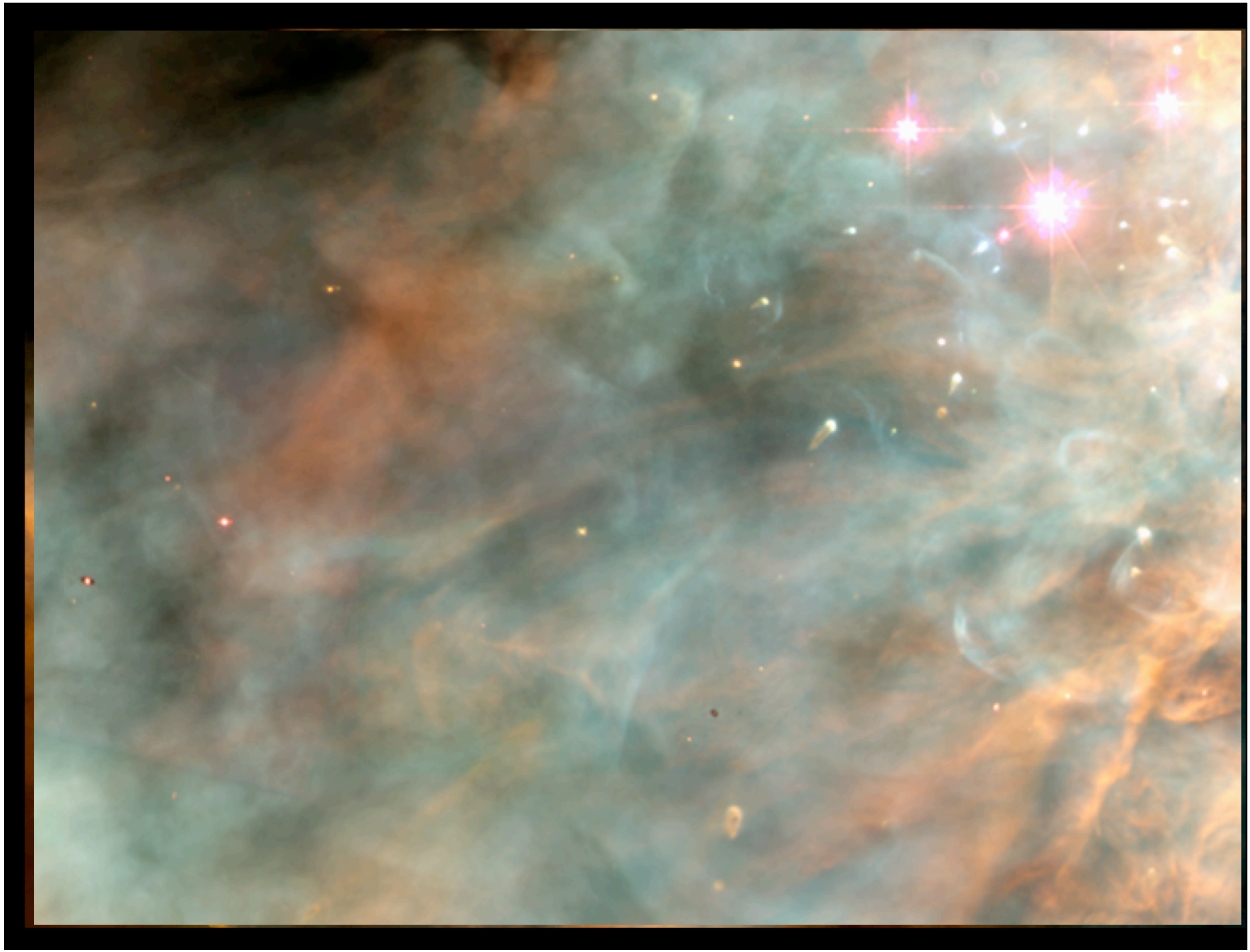


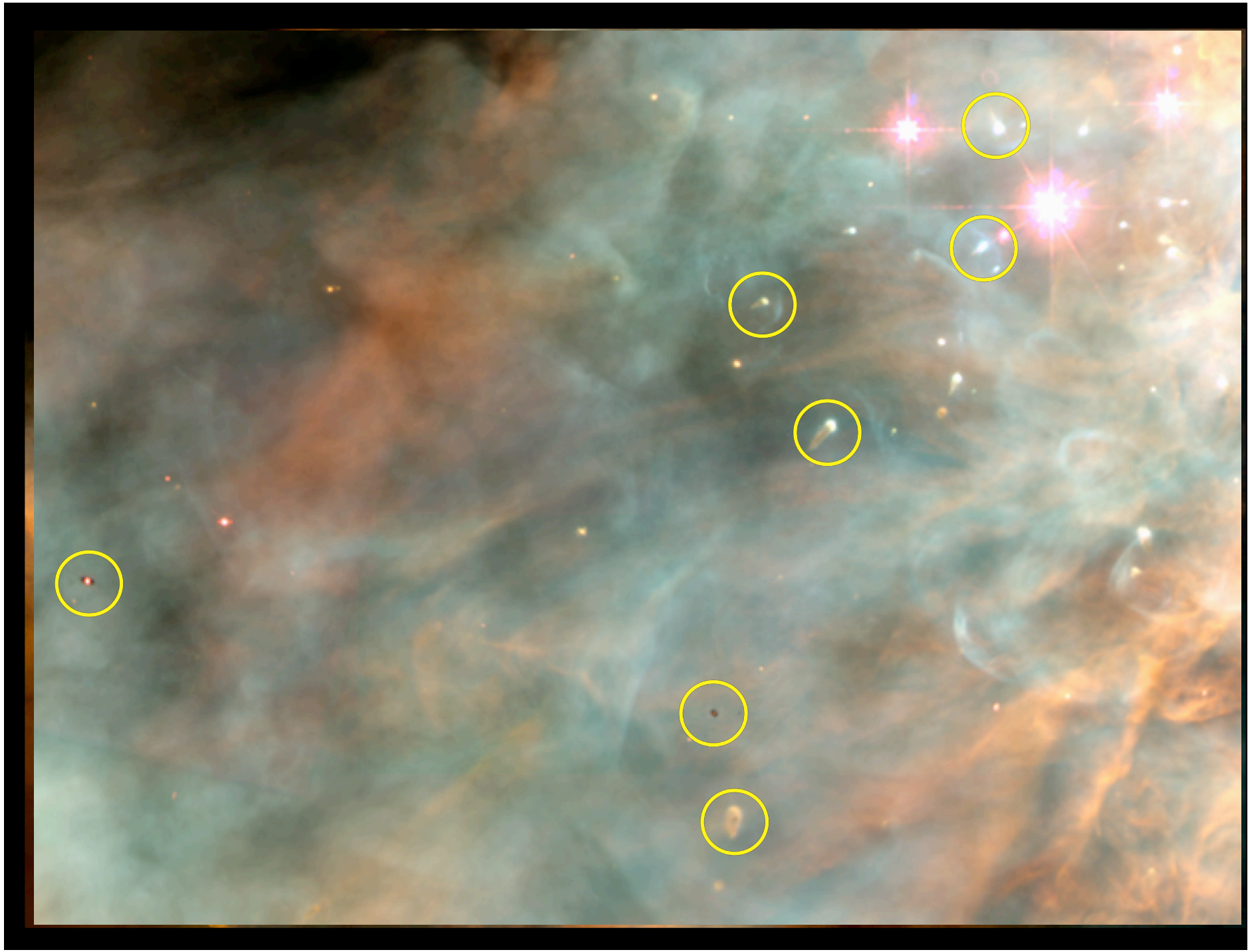


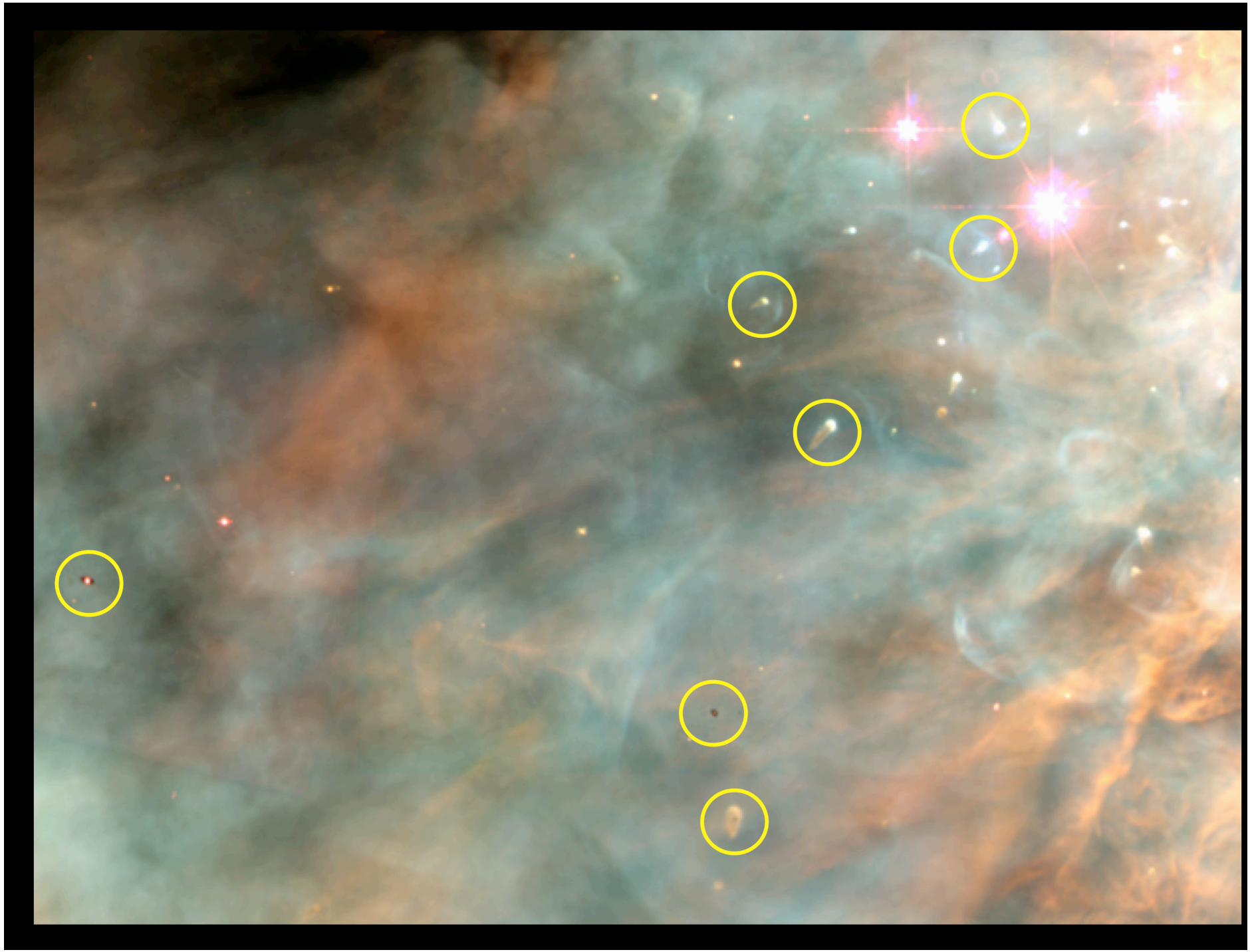


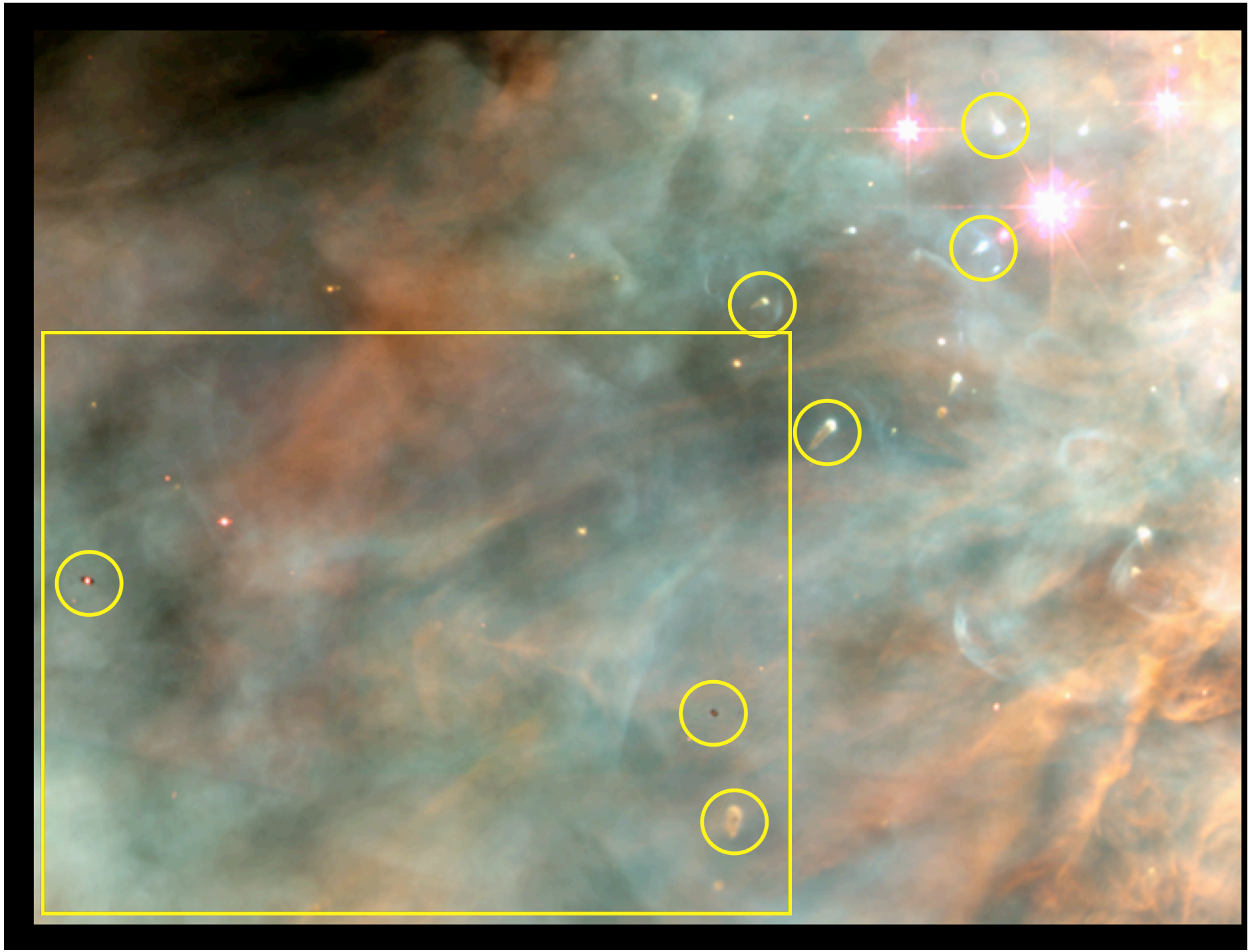


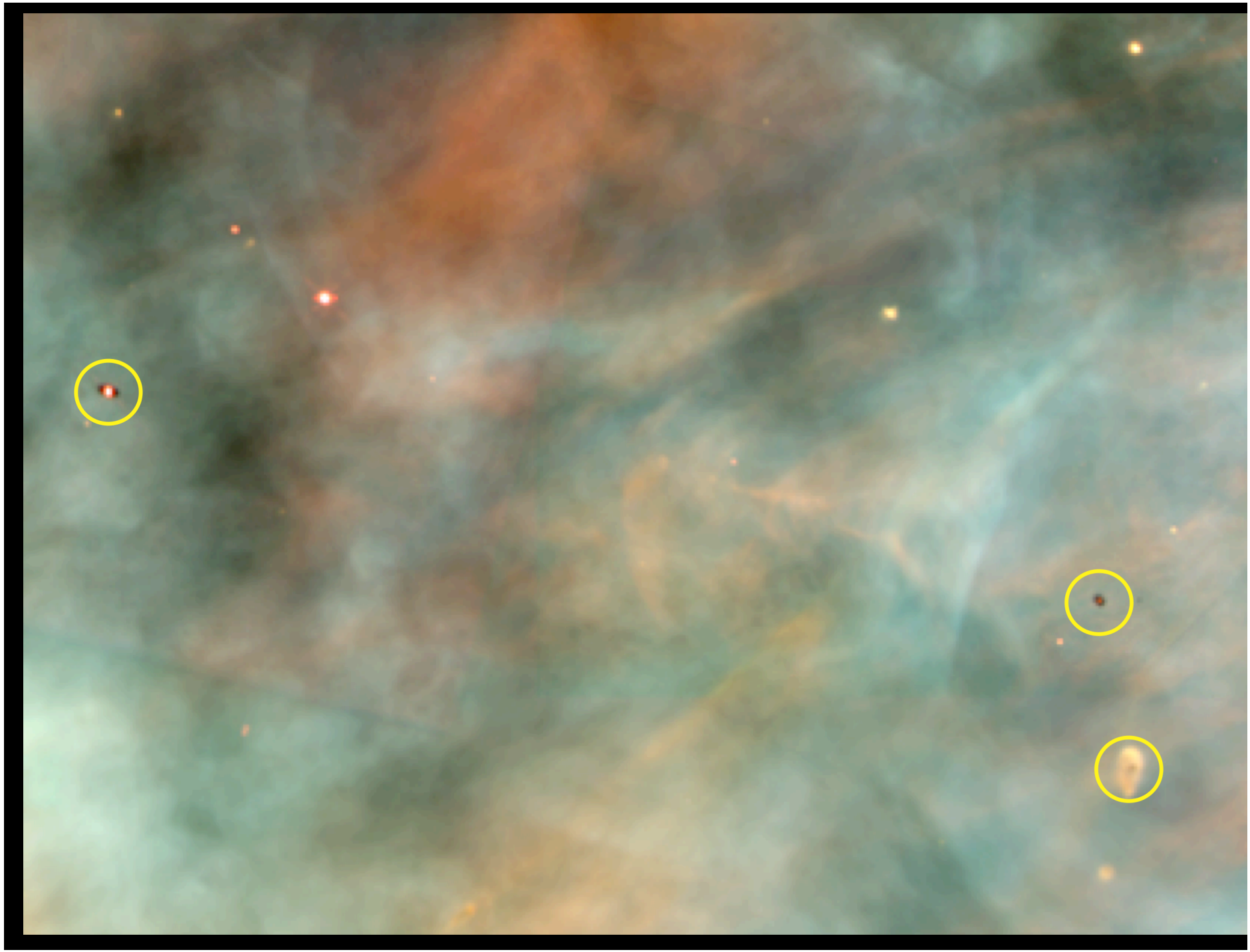


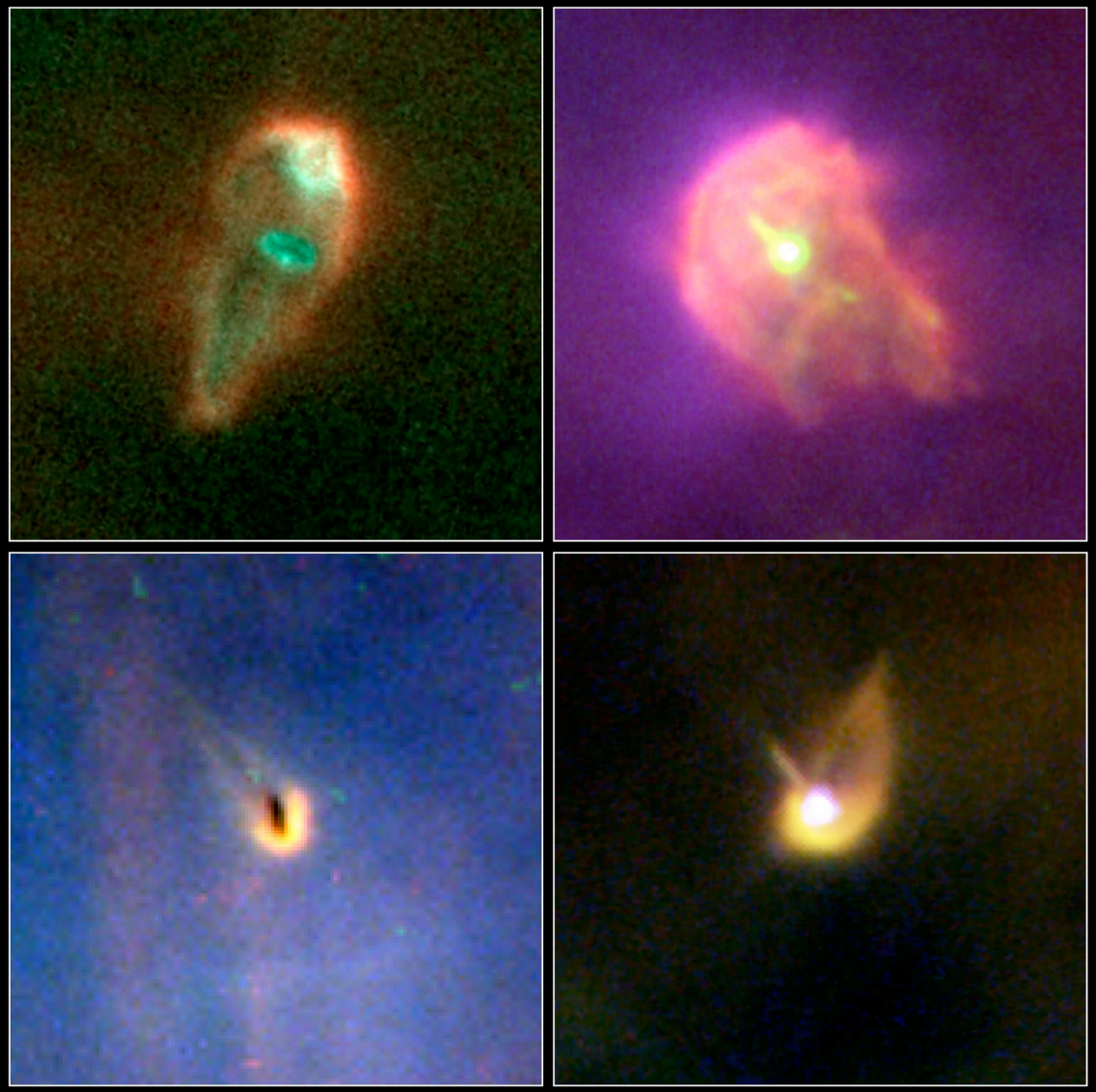




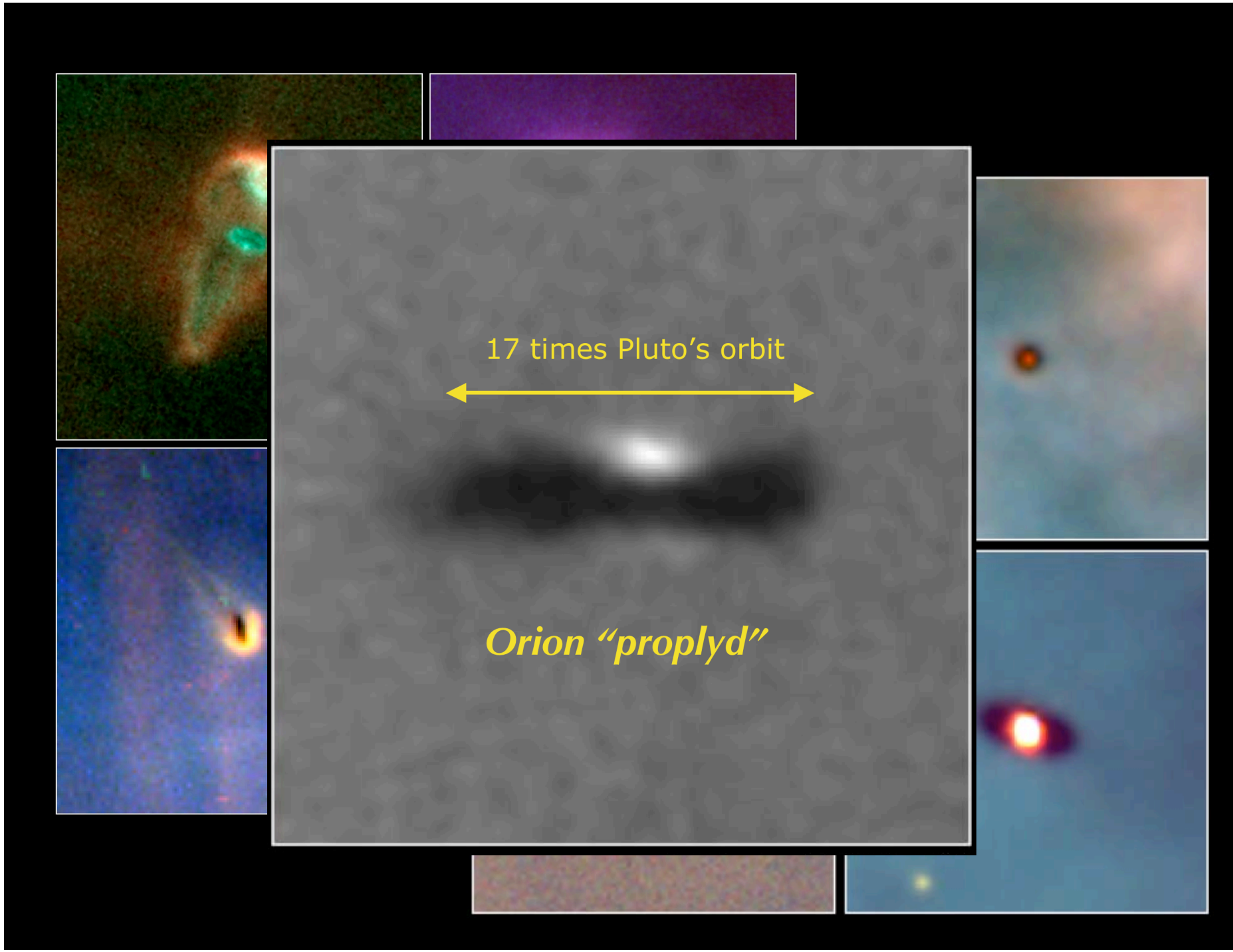




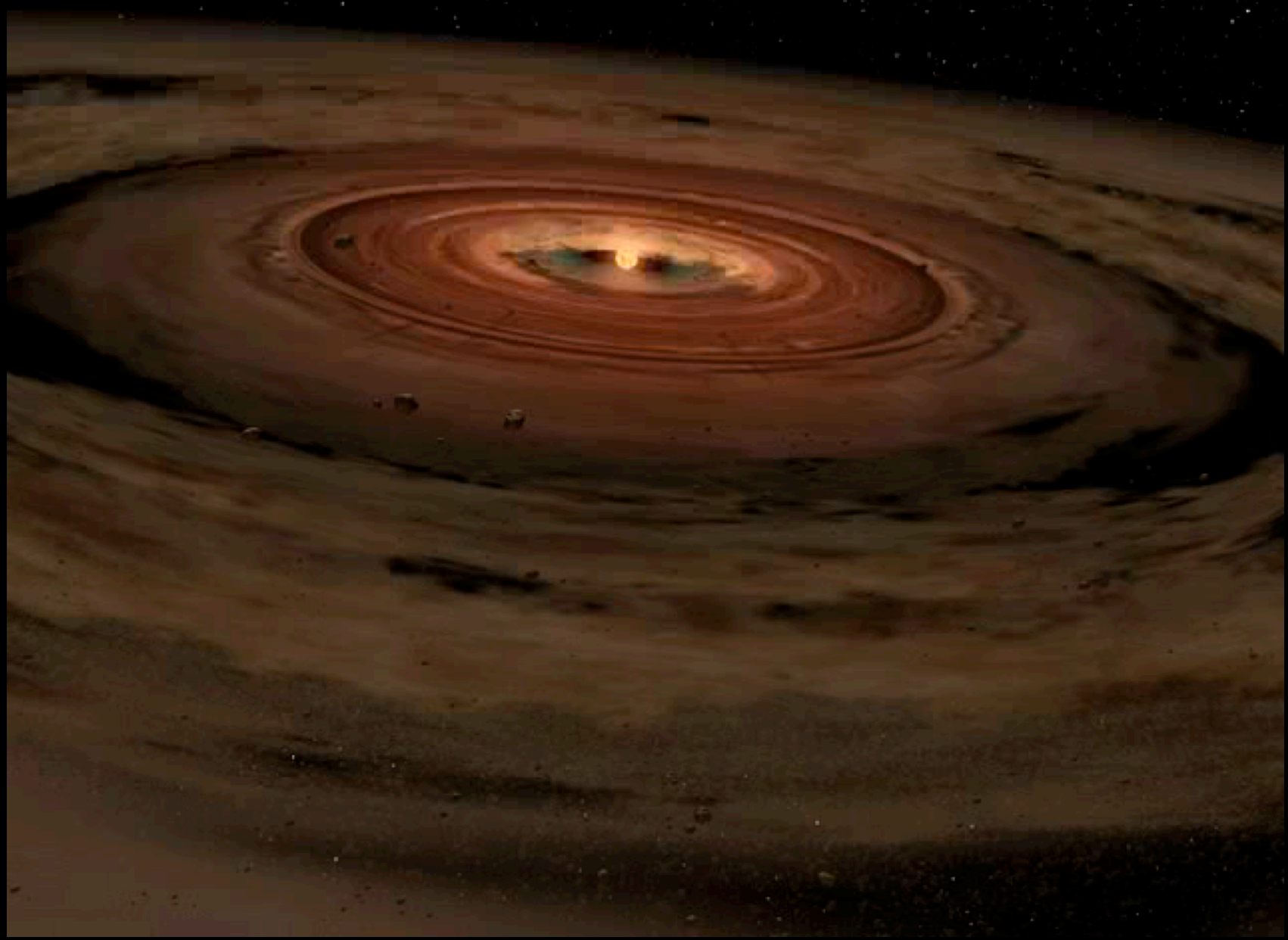


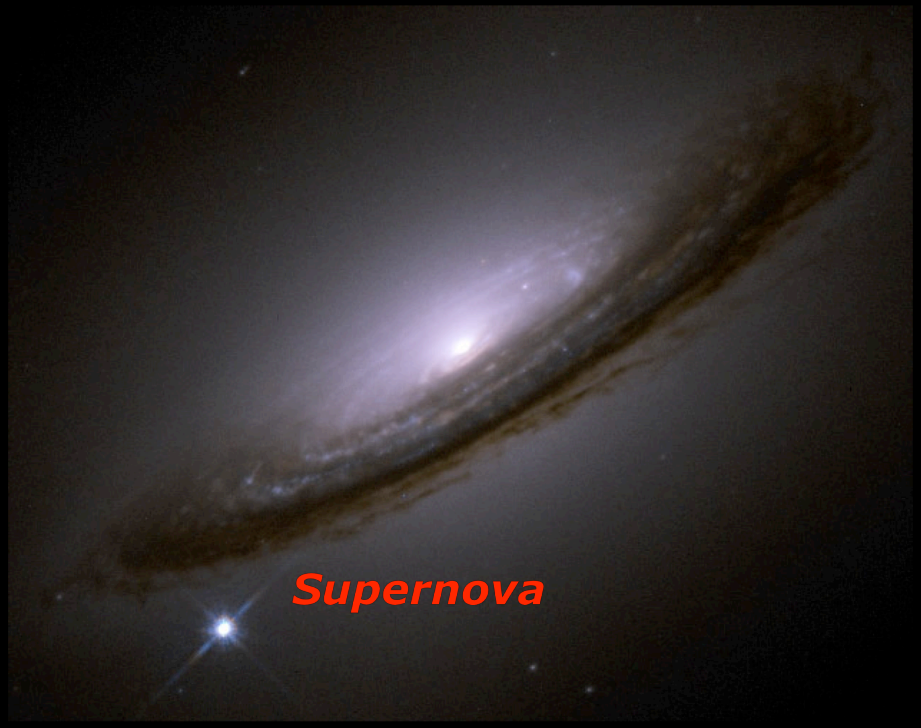


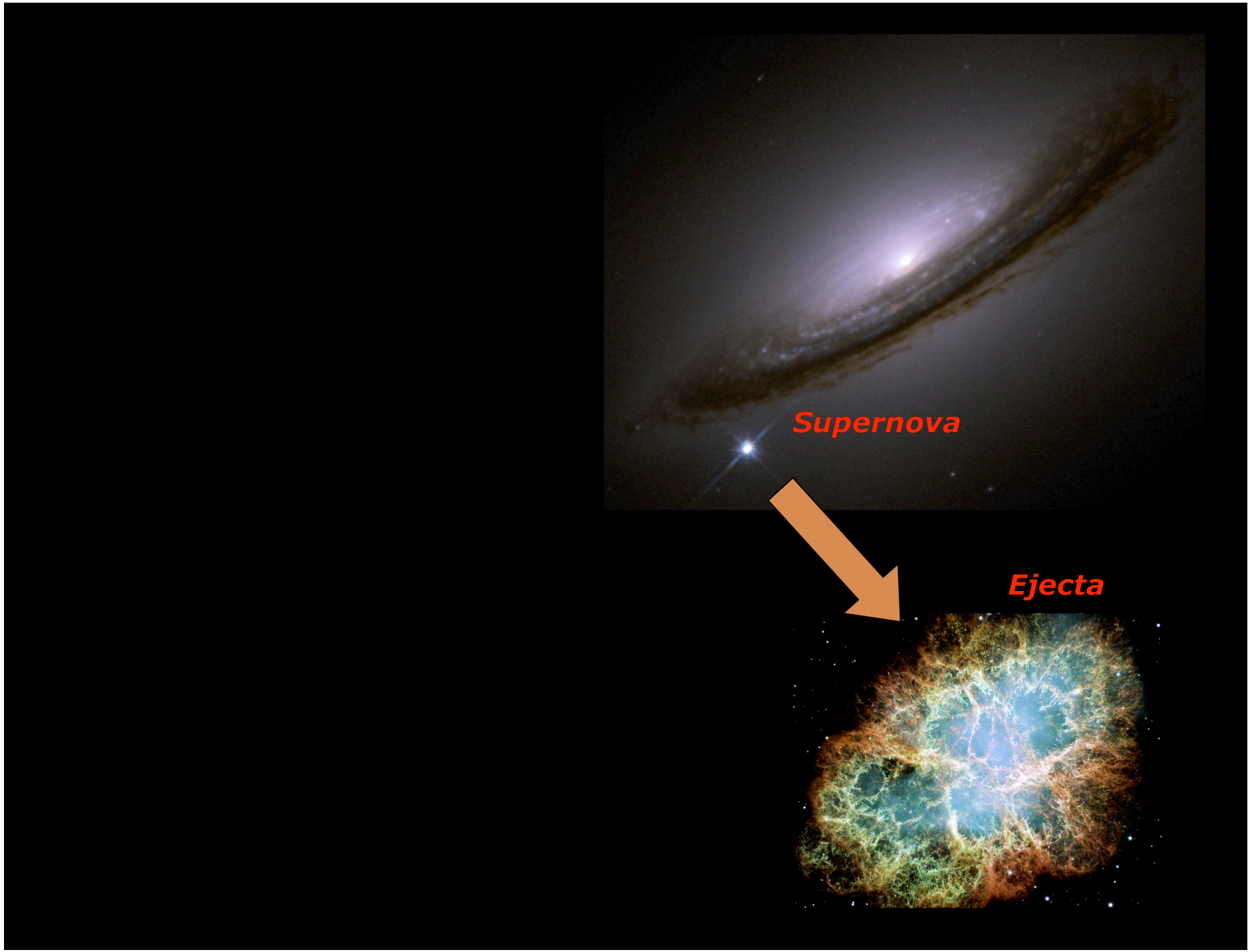


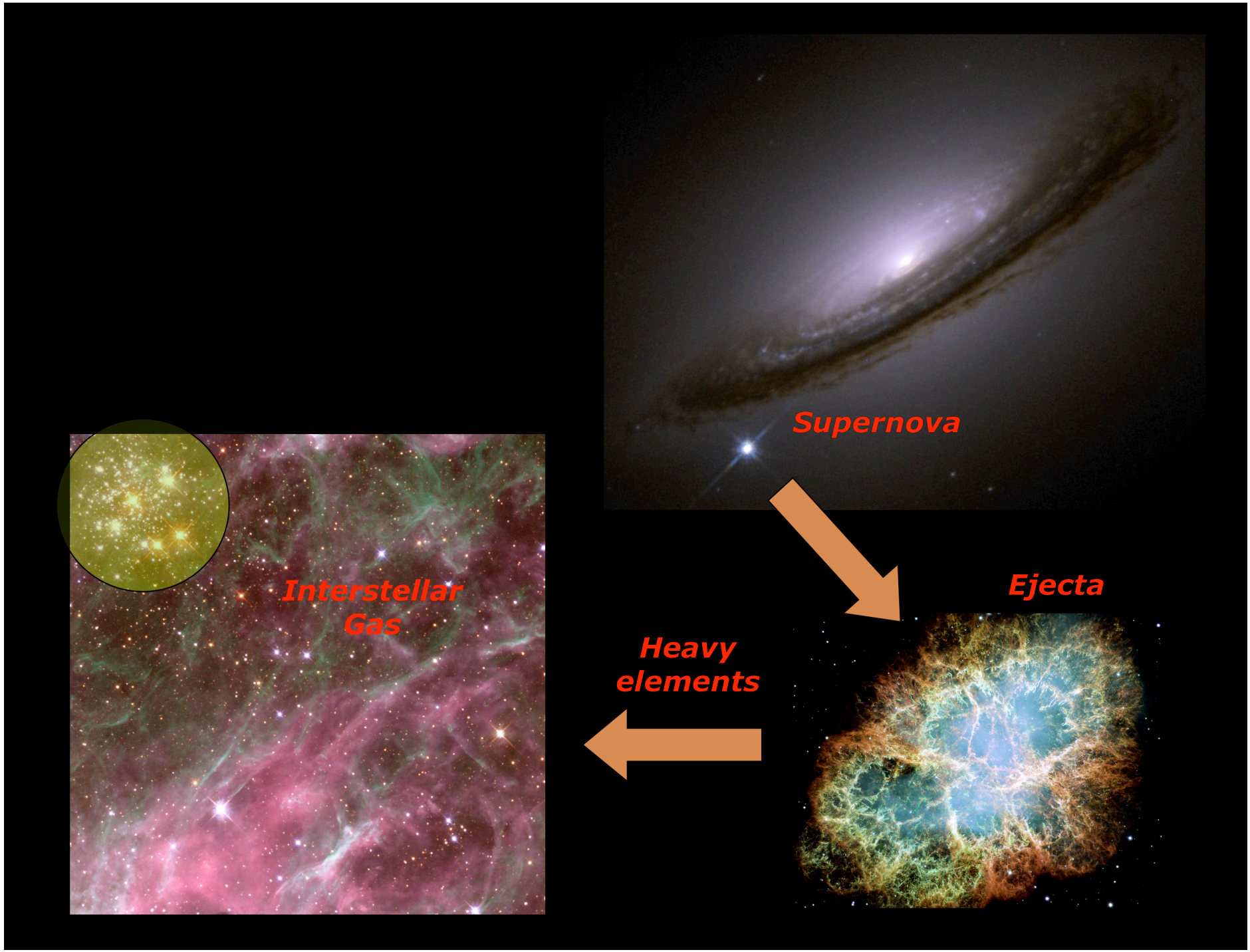

17 times Pluto's orbit
Orion "proplyd"

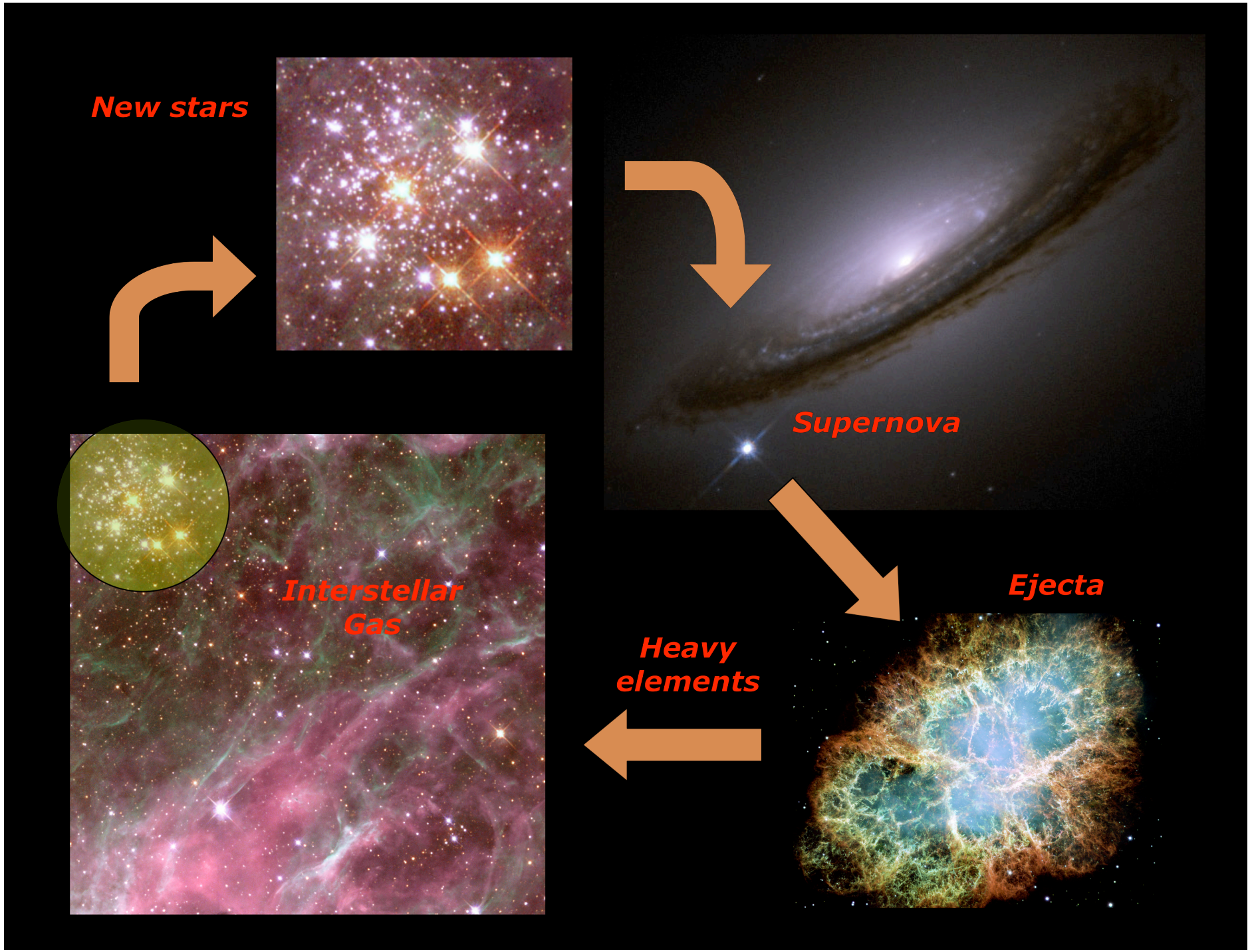
A rotating proto-solar nebula




Supernova


Supernova
Ejecta


Supernova
Ejecta
Heavy elements
Interstellar Gas


New stars
Supernova
Ejecta
Heavy elements
Interstellar Gas

Where did the Milky Way and Other Galaxies Come From?

Where did the Milky Way and Other Galaxies Come From?

The Answer Will Take Us Back to the Earliest Moments of the Universe

A fly-through the Milky Way galaxy and into intergalactic space



Courtesy Brent Tully, Institute for Astronomy, University of Hawaii

The Andromeda Galaxy (M31): A Global, Yet Detailed View



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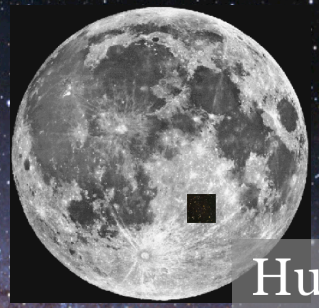
The Andromeda Galaxy (M31): A Global, Yet Detailed View

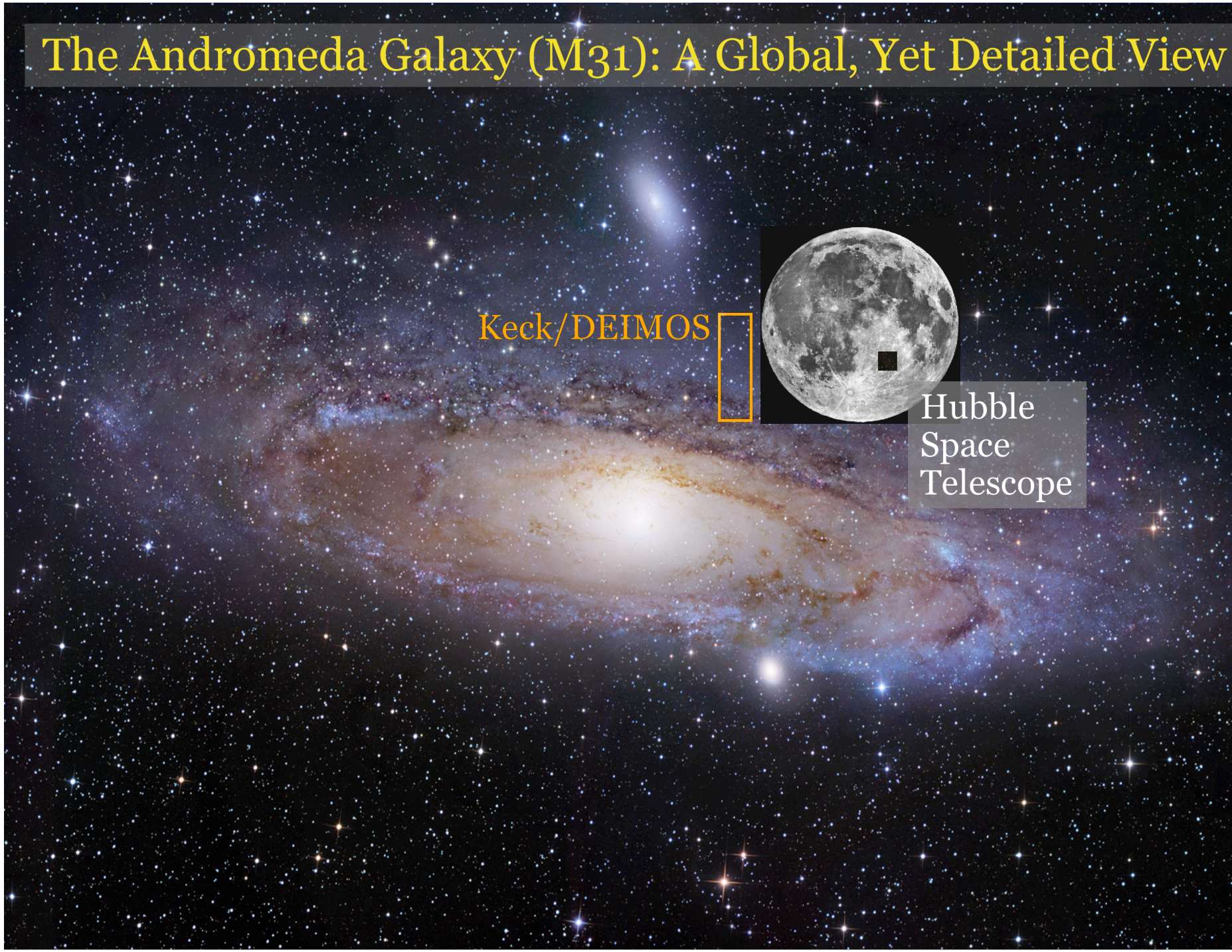


The Andromeda Galaxy (M31): A Global, Yet Detailed View



Hubble Space Telescope

The Andromeda Galaxy (M31): A Global, Yet Detailed View

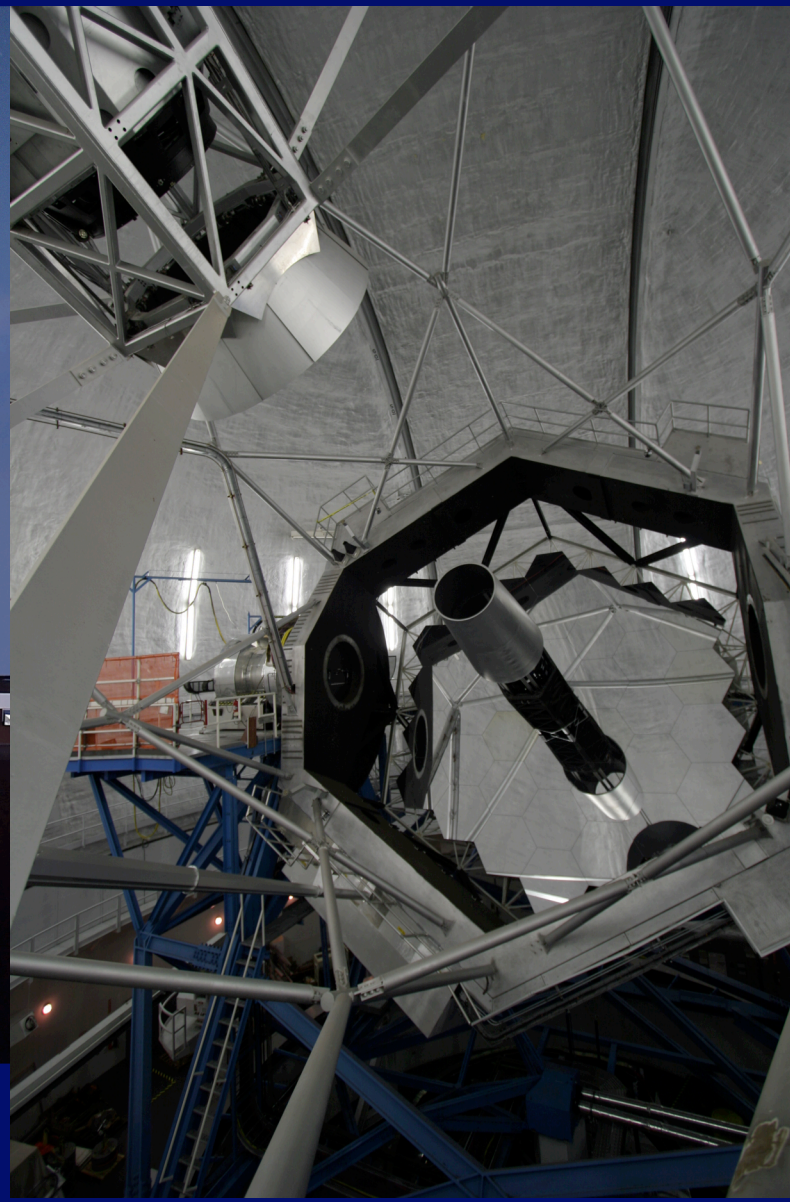


Using the Keck Telescope and its Spectrographs to Dissect M31



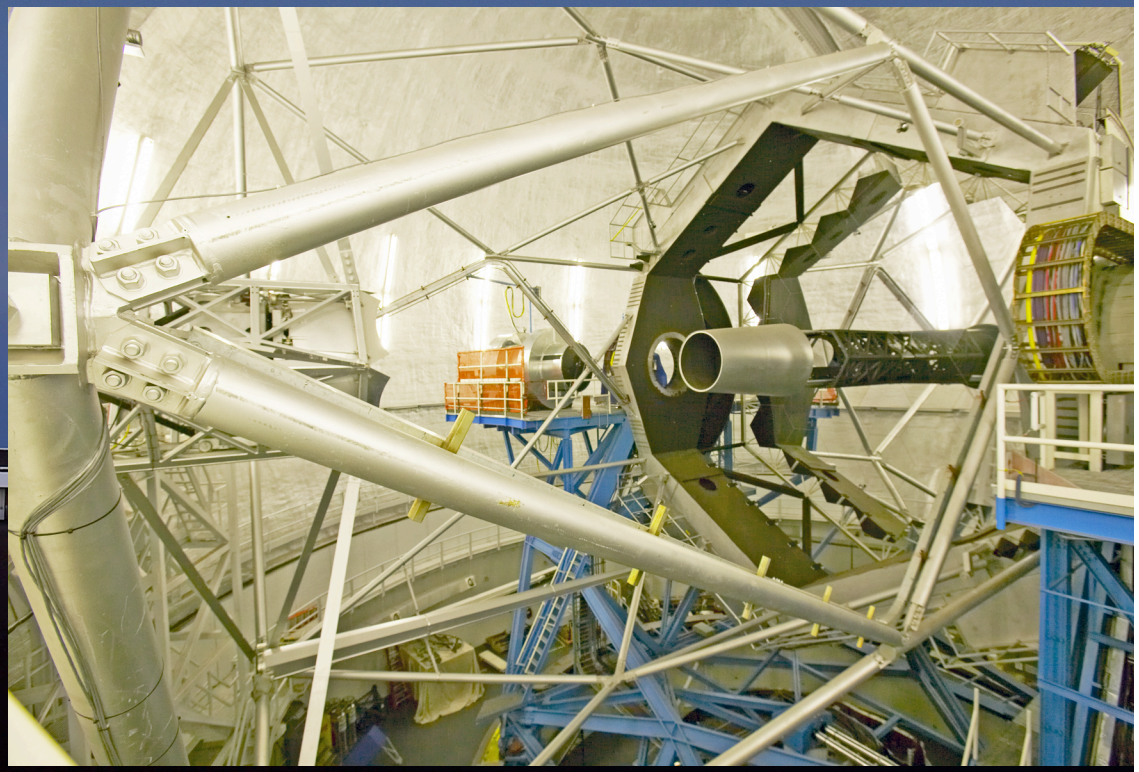
Using the Keck Telescope and its Spectrographs to Dissect M31





Using the Keck Telescope and its Spectrographs to Dissect M31



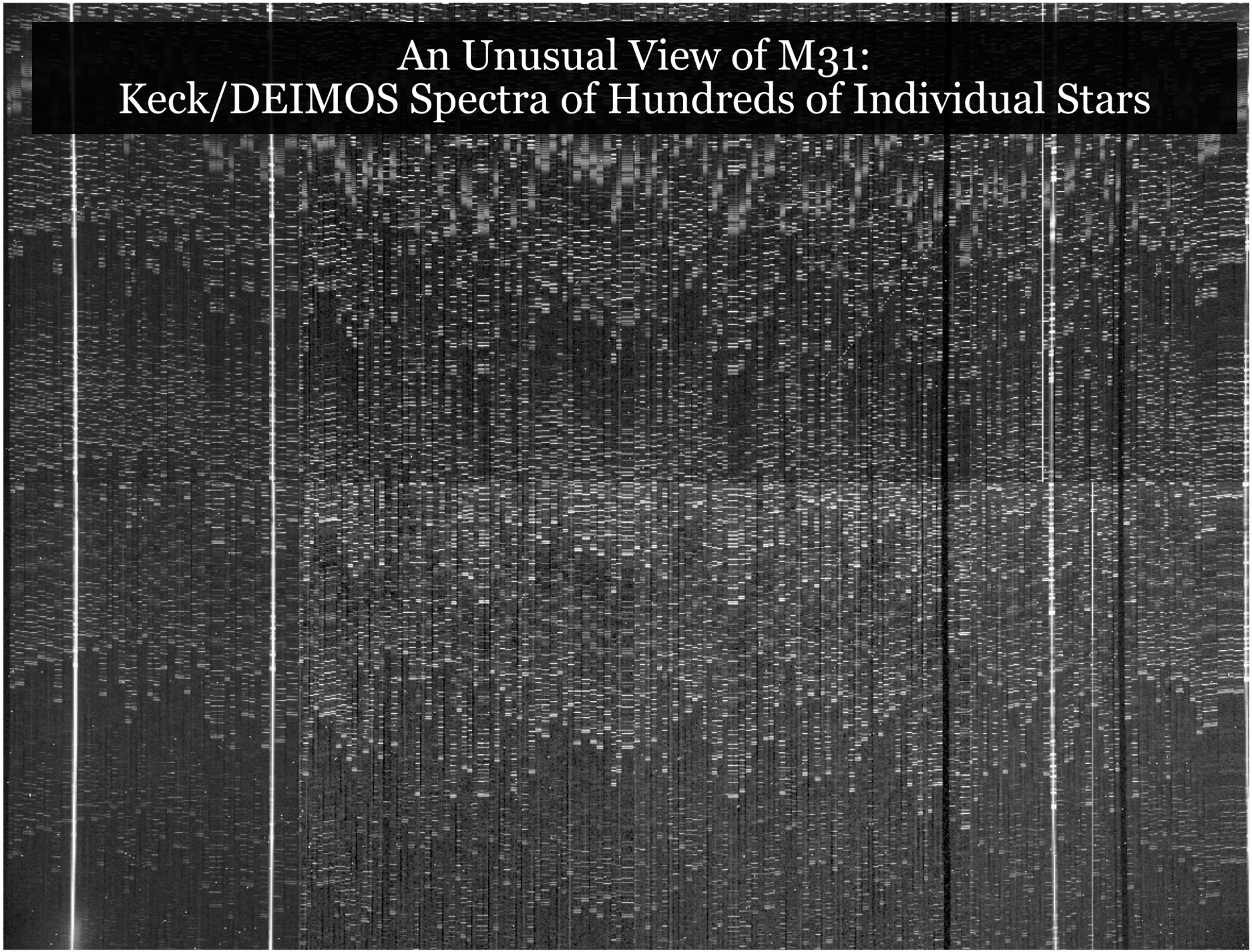


Using the Keck Telescope and its Spectrographs to Dissect M31





An Unusual View of M31: Keck/DEIMOS Spectra of Hundreds of Individual Stars



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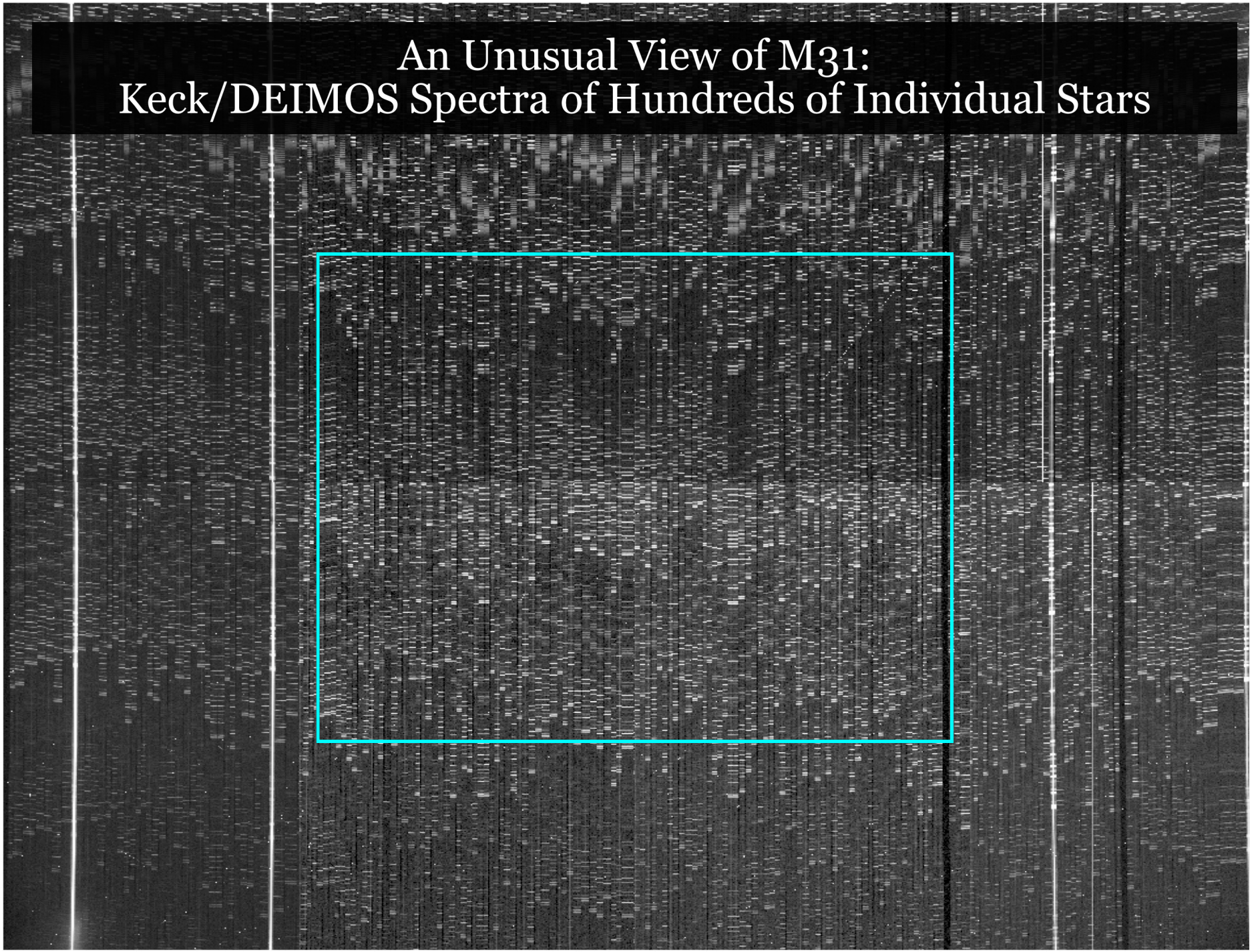

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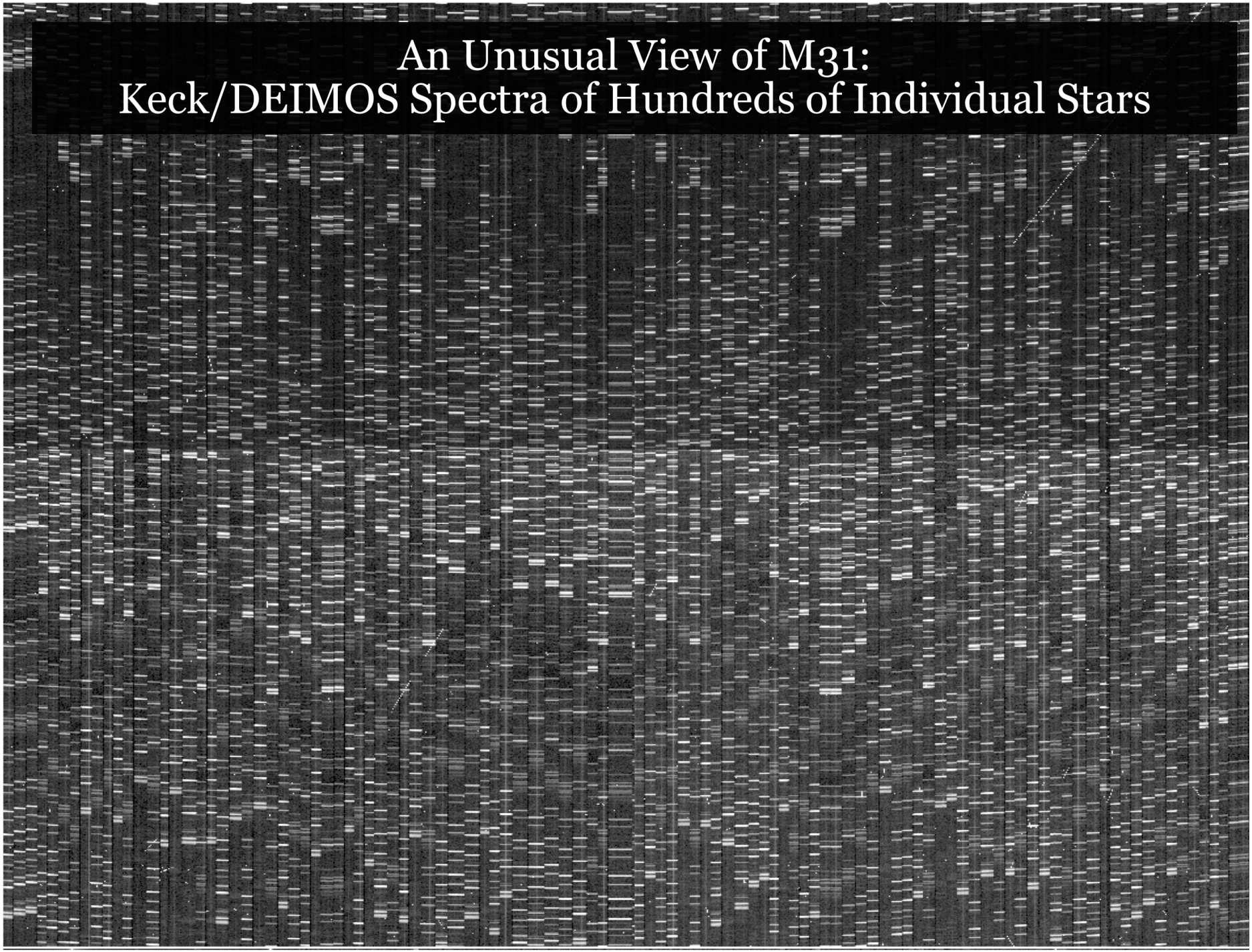

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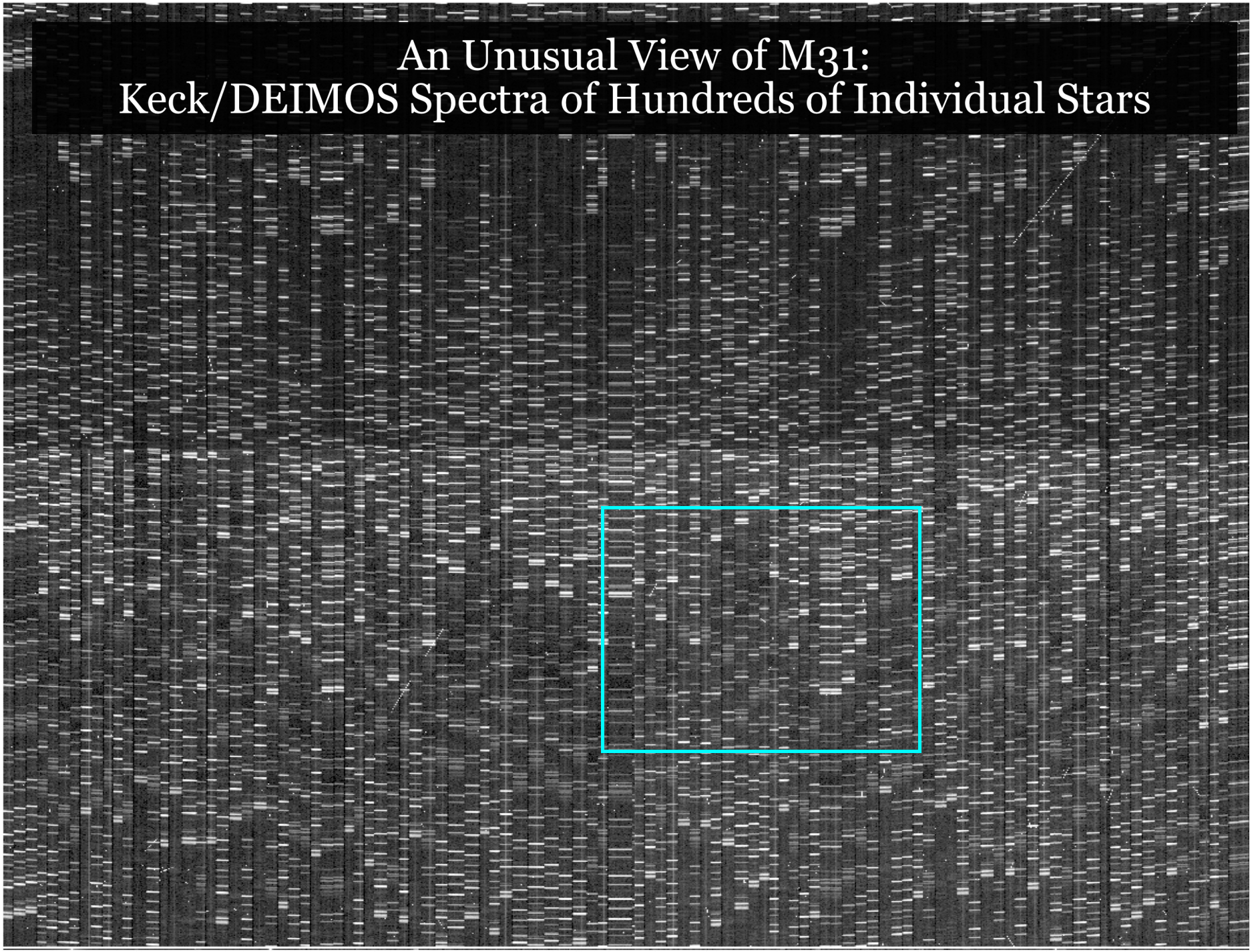

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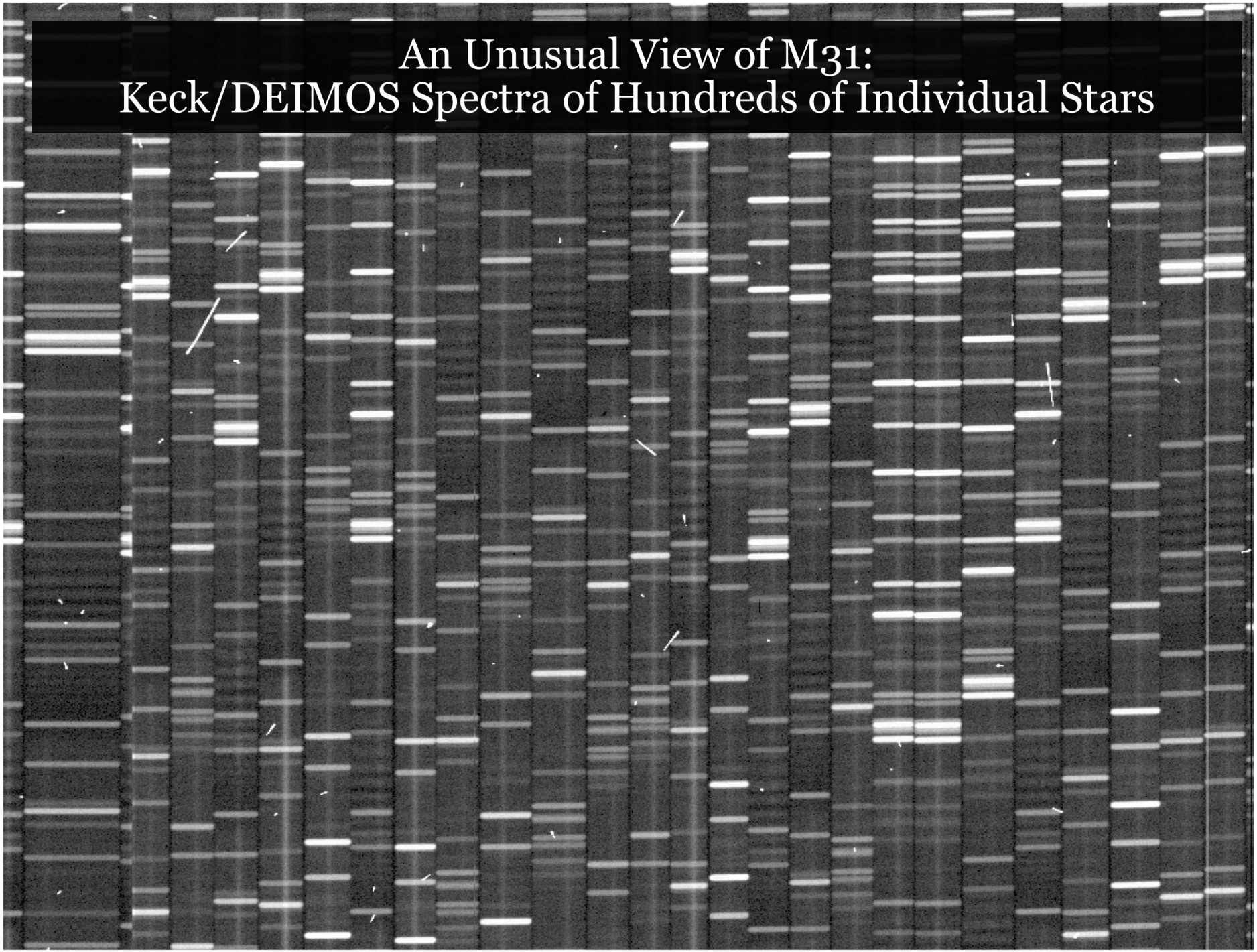

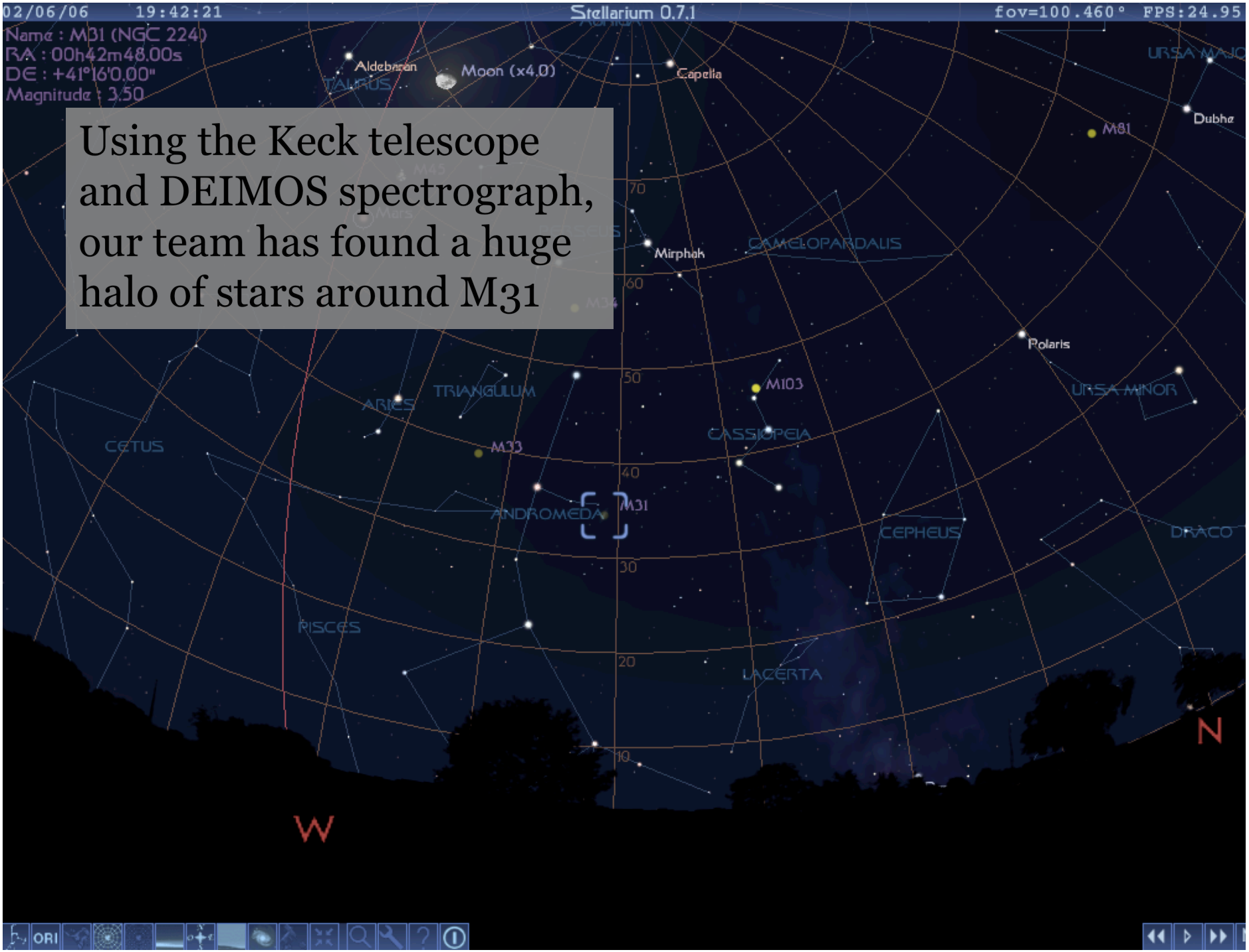
02/06/06 19:42:21
Stellarium 0.7.1
fov=100.460° FPS:24.95
Name : M31 (NGC 224)
RA : 00h42m48.00s
DE : +41°16'0.00"
Magnitude : 3.50
Using the Keck telescope and DEIMOS spectrograph, our team has found a huge halo of stars around M31
Aldebaran
Moon (x4.0)
Capella
Dubhe
M81
Mirphak
CAMELOPARDALIS
Polaris
M103
URSA MINOR
TRIANGULUM
ARIES
CASSIOPEIA
CETUS
M33
M31
ANDROMEDA
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40
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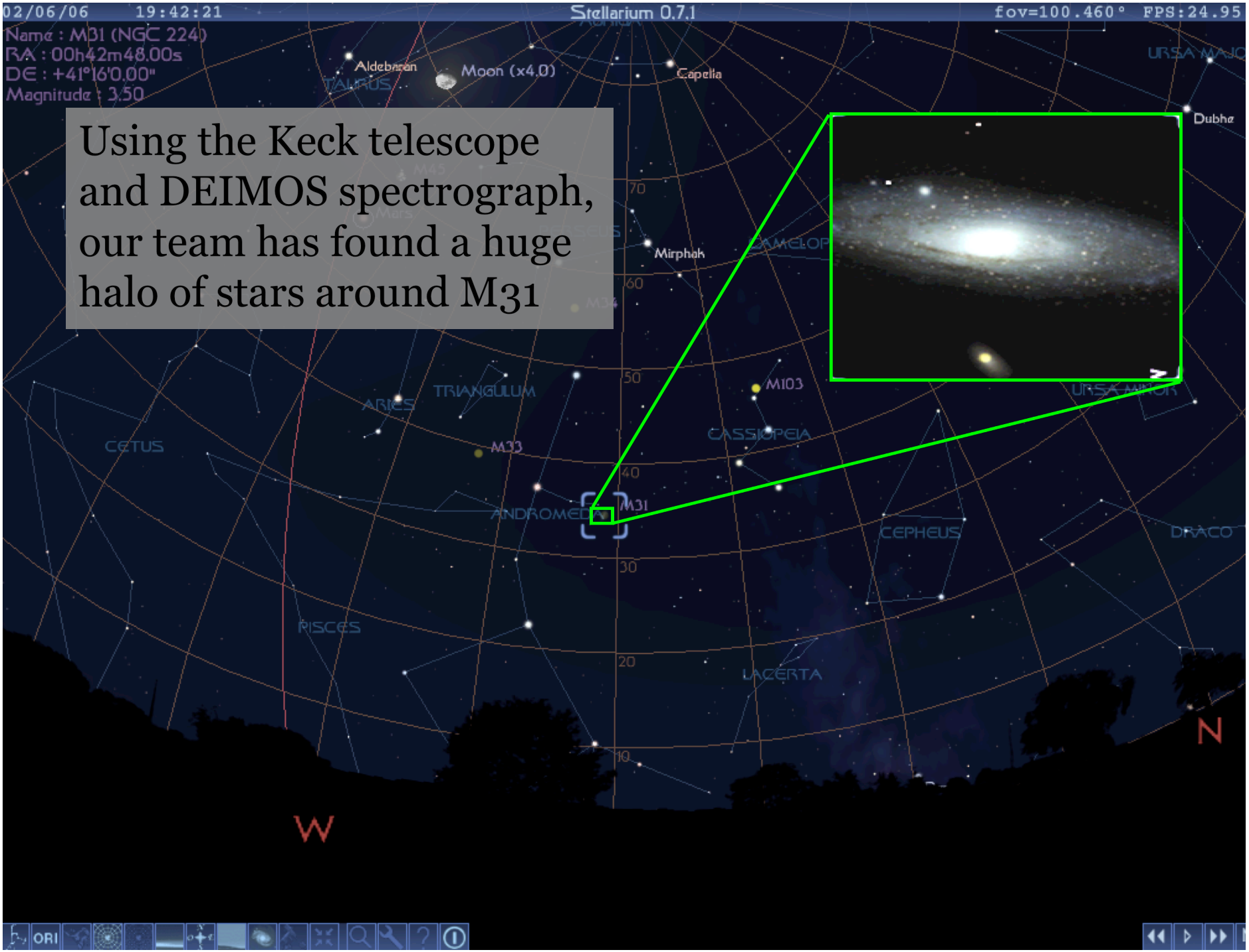
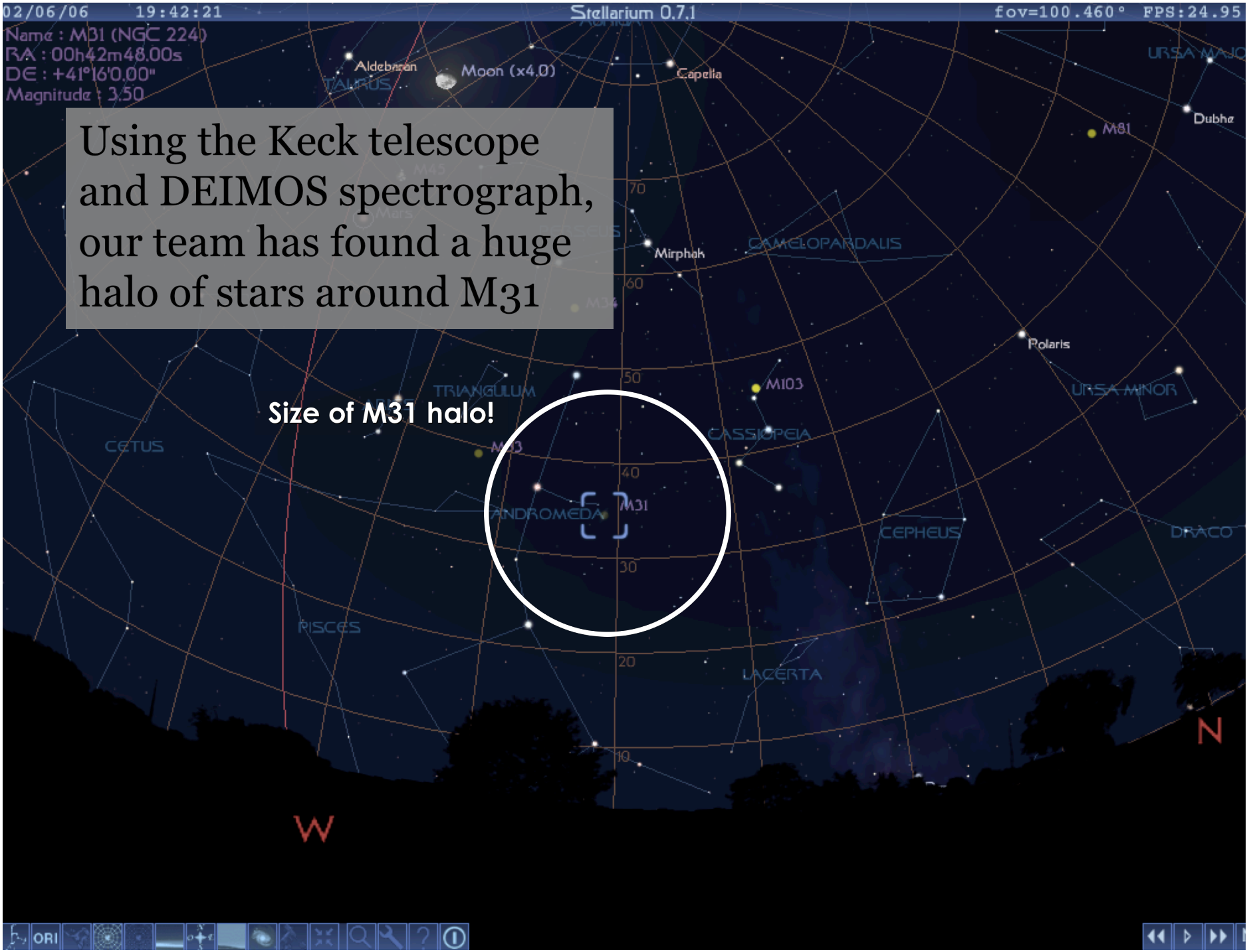


Using the Keck telescope and DEIMOS spectrograph, our team has found a huge halo of stars around M31



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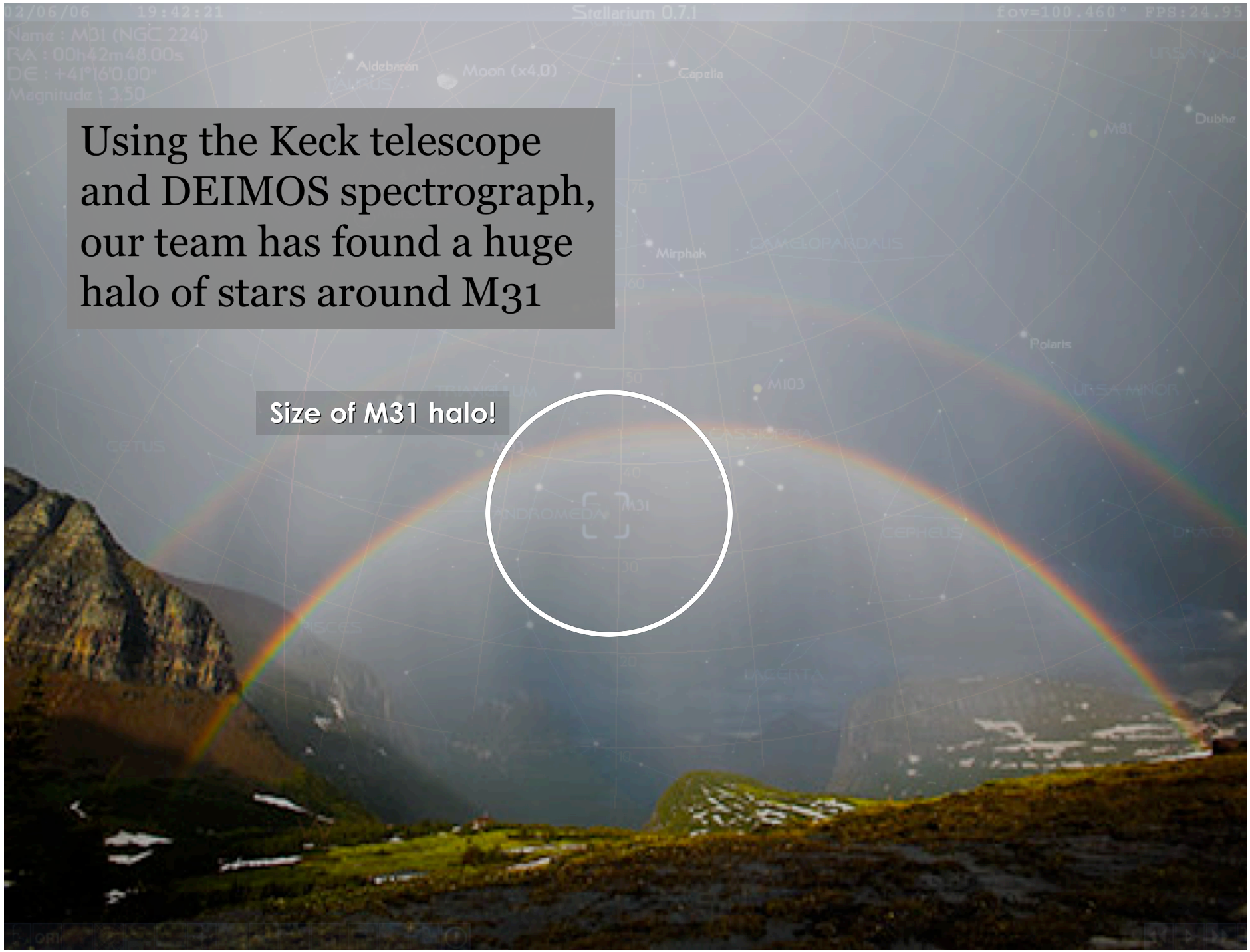
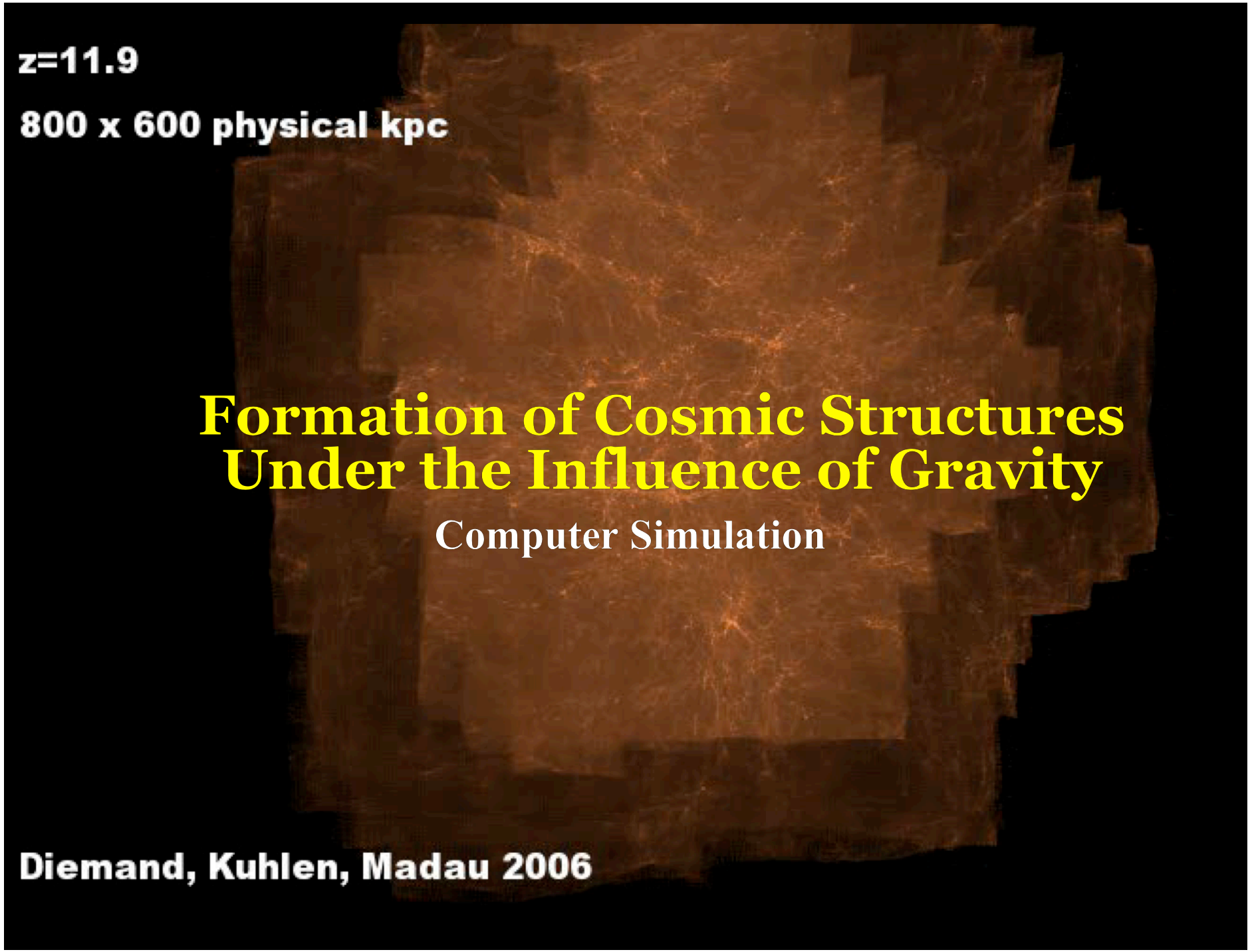
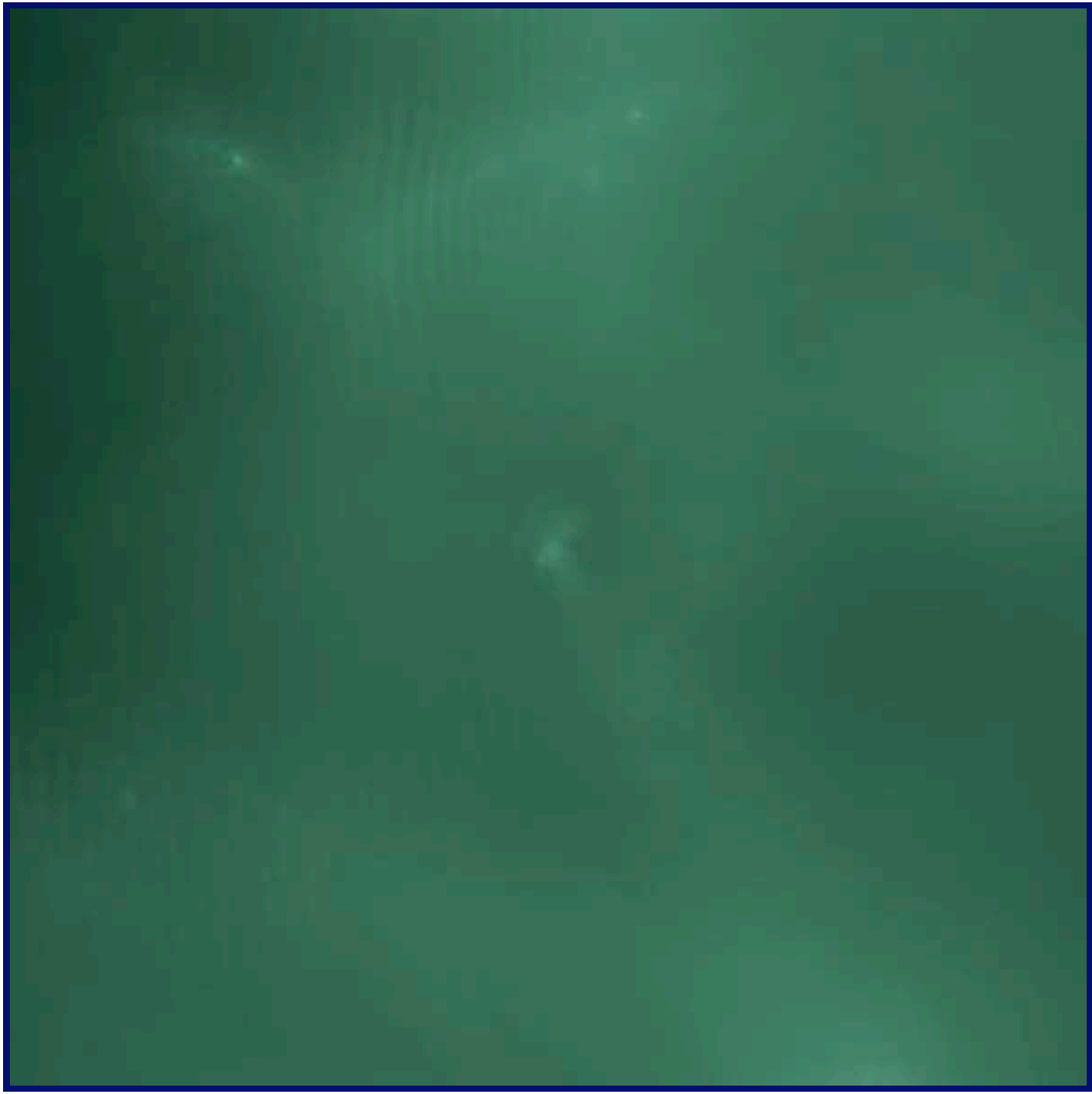

Using the Keck telescope and DEIMOS spectrograph, our team has found a huge halo of stars around M31
Size of M31 halo!


Fly Through the Universe


z=11.9
800 x 600 physical kpc
Formation of Cosmic Structures
Under the Influence of Gravity
Computer Simulation
Diemand, Kuhlen, Madau 2006



Formation of the Milky Way

Courtesy Fabio Governato, Univ of Washington

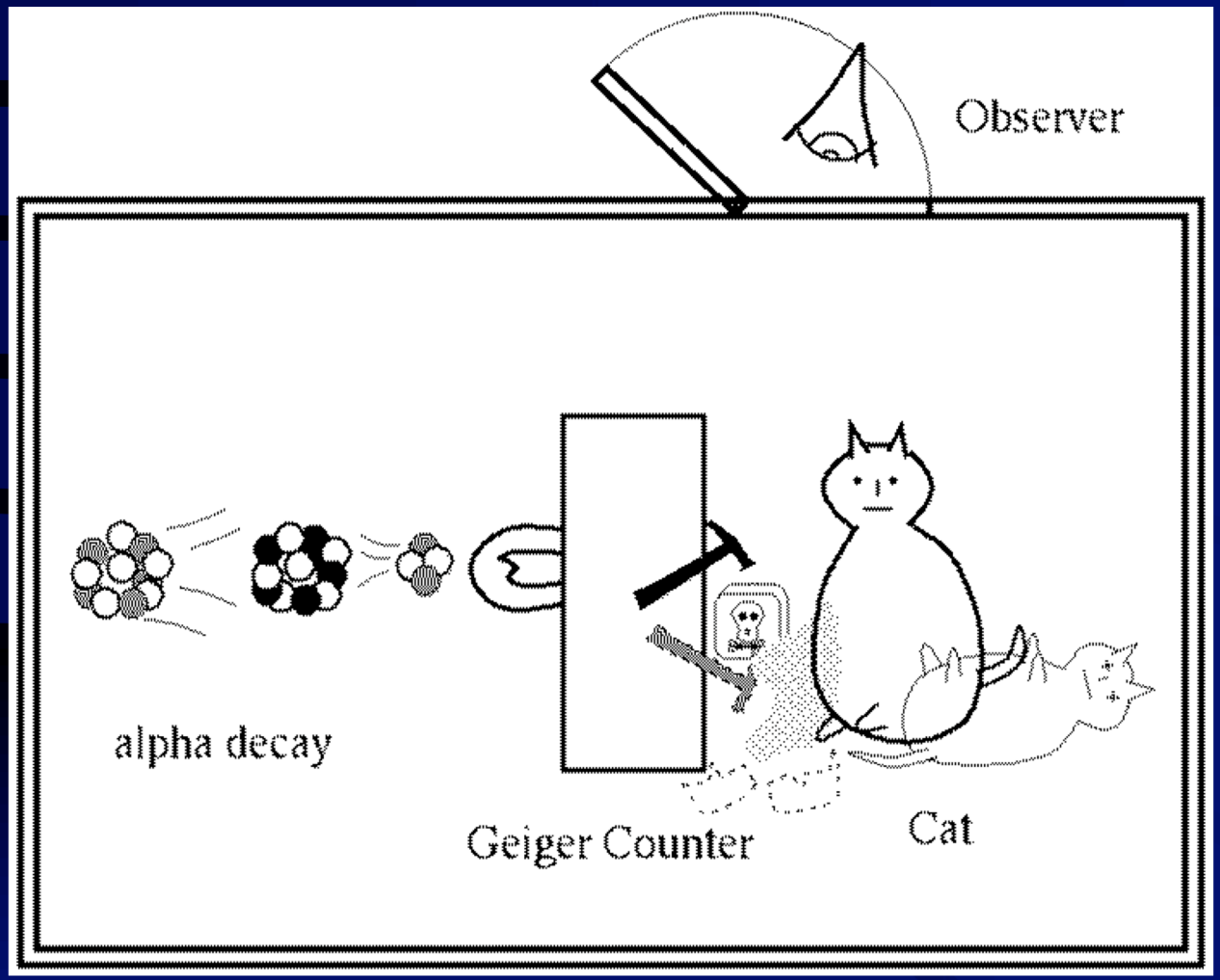
But Where Did the "Seeds" of Cosmic Structure Come From?

But Where Did the "Seeds" of Cosmic Structure Come From?



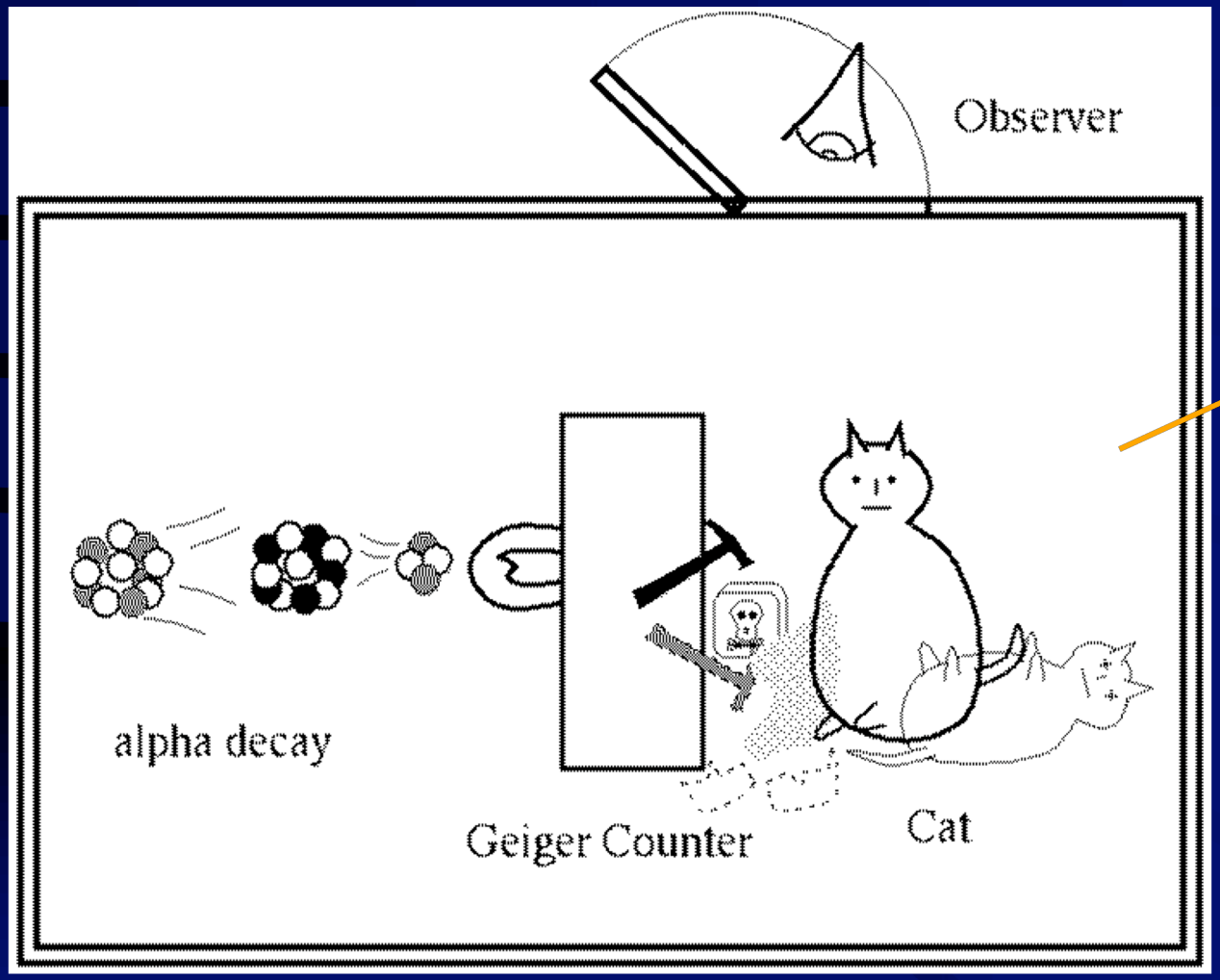
Schrödinger's Cat

(a "thought experiment" by Erwin Schrödinger)



Schrödinger's Cat

(a "thought experiment" by Erwin Schrödinger)

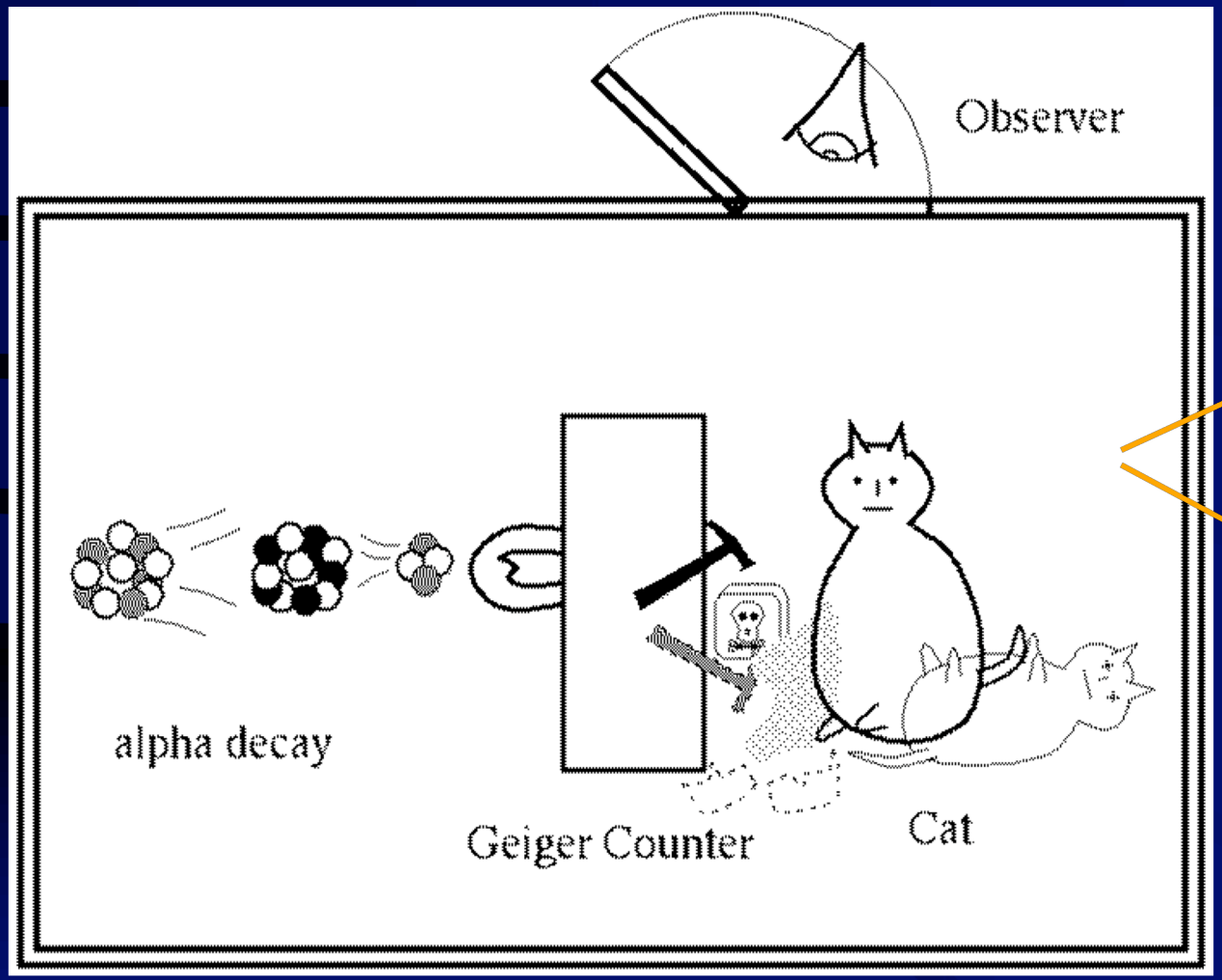




…or…

Schrödinger's Cat

(a "thought experiment" by Erwin Schrödinger)



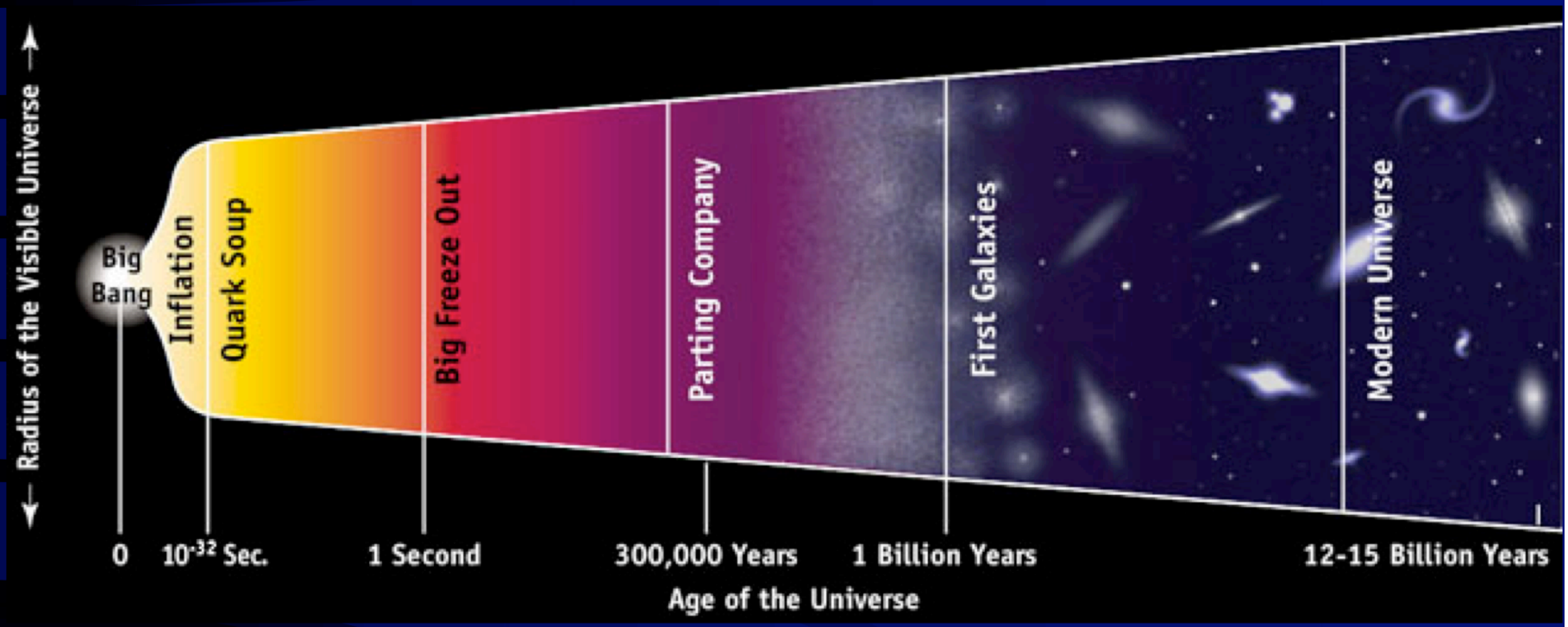


…or…

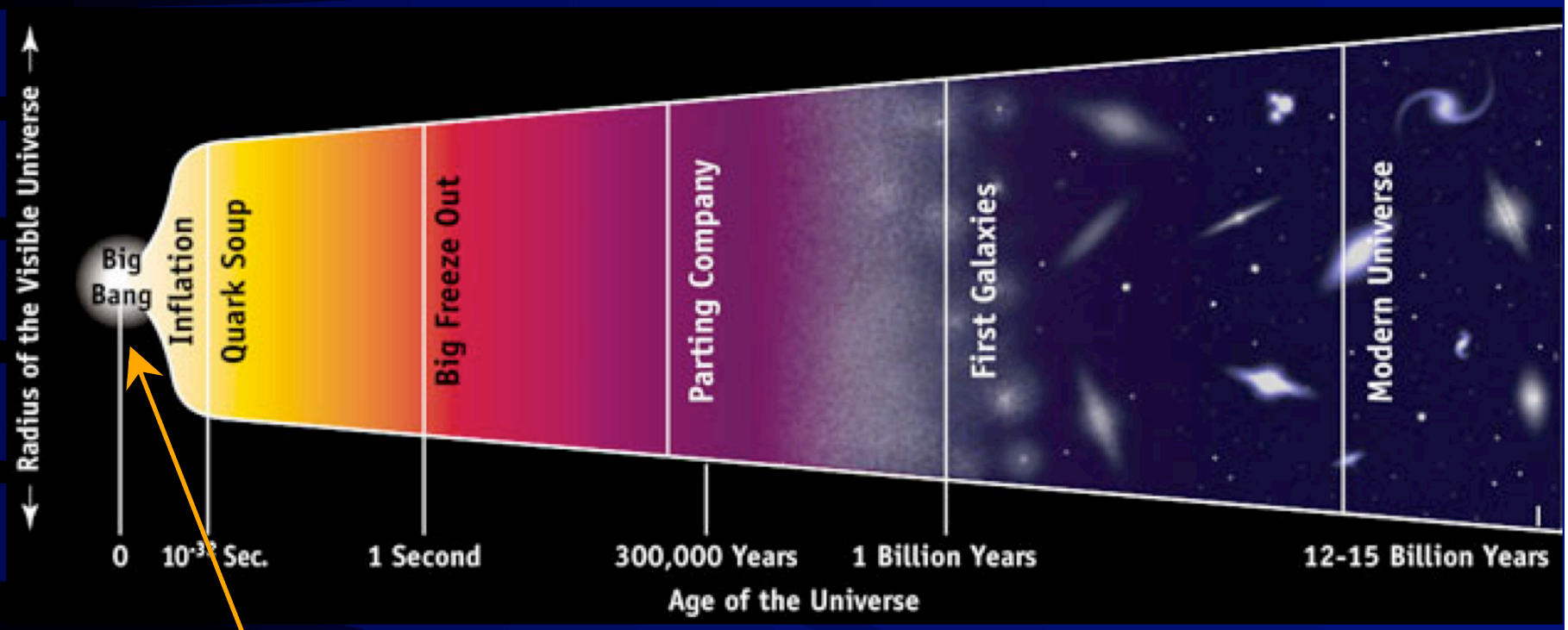


???

Inflation


Radius of the Visible Universe
Big Bang
Inflation
Quark Soup
Big Freeze Out
Parting Company
First Galaxies
Modern Universe
0
10-32 Sec.
1 Second
300,000 Years
1 Billion Years
12-15 Billion Years
Age of the Universe

Inflation

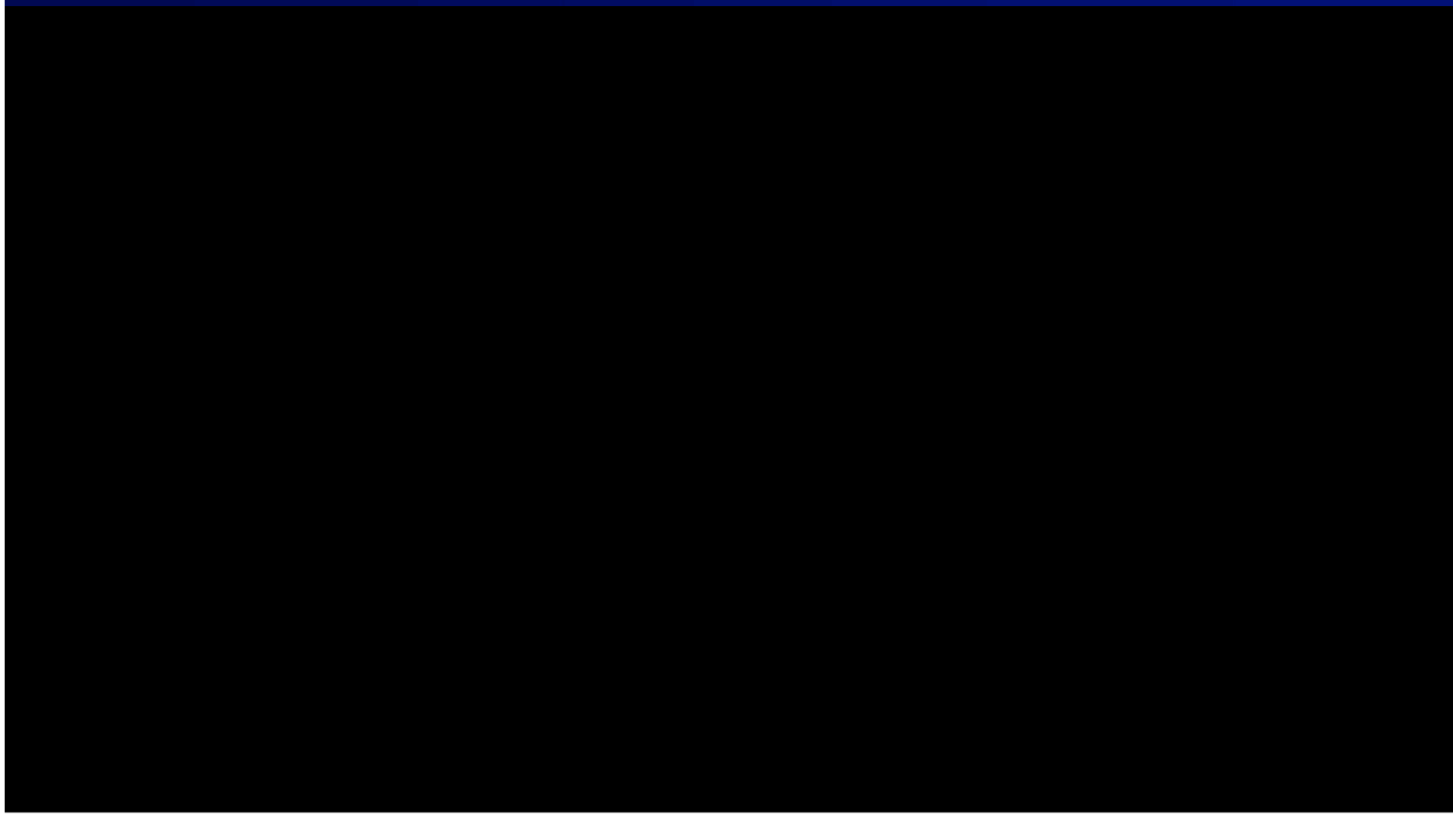


A rapid and dramatic phase of expansion shortly after the Big Bang blows up these quantum fluctuations and "freezes" them into the fabric of the Universe. These are the seeds of cosmic structure.

Prediction:

Galaxy collisions should be common and easily visible

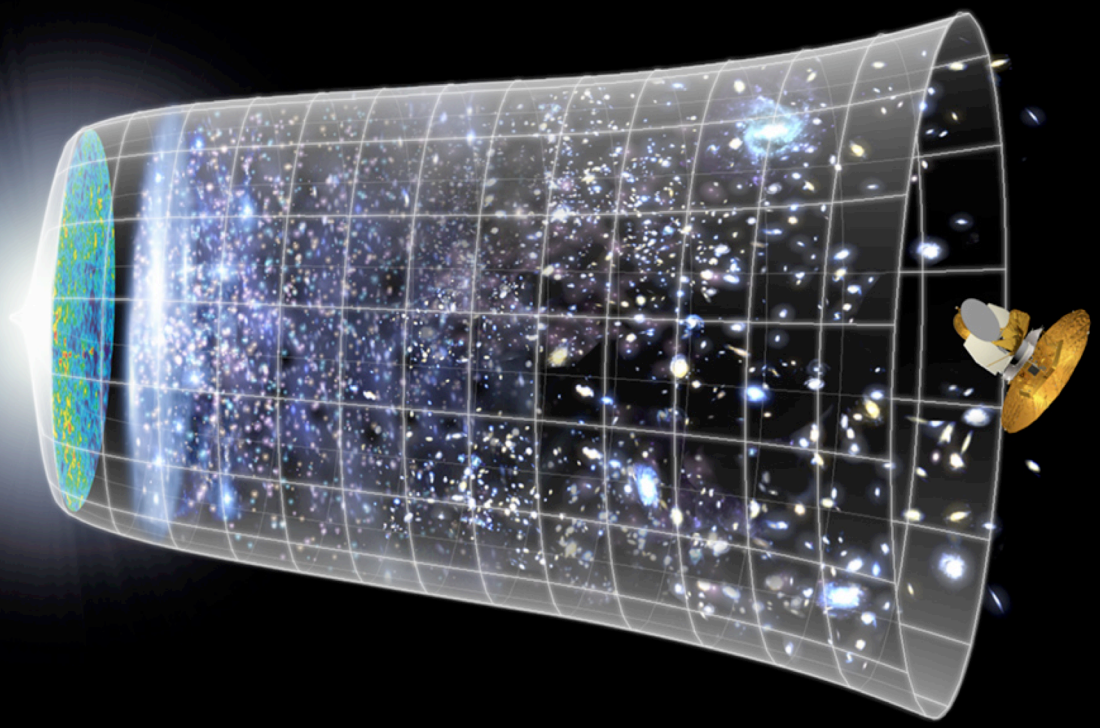
Computer Simulations Compared to Snapshots of Actual Galaxy Collisions



Prediction:

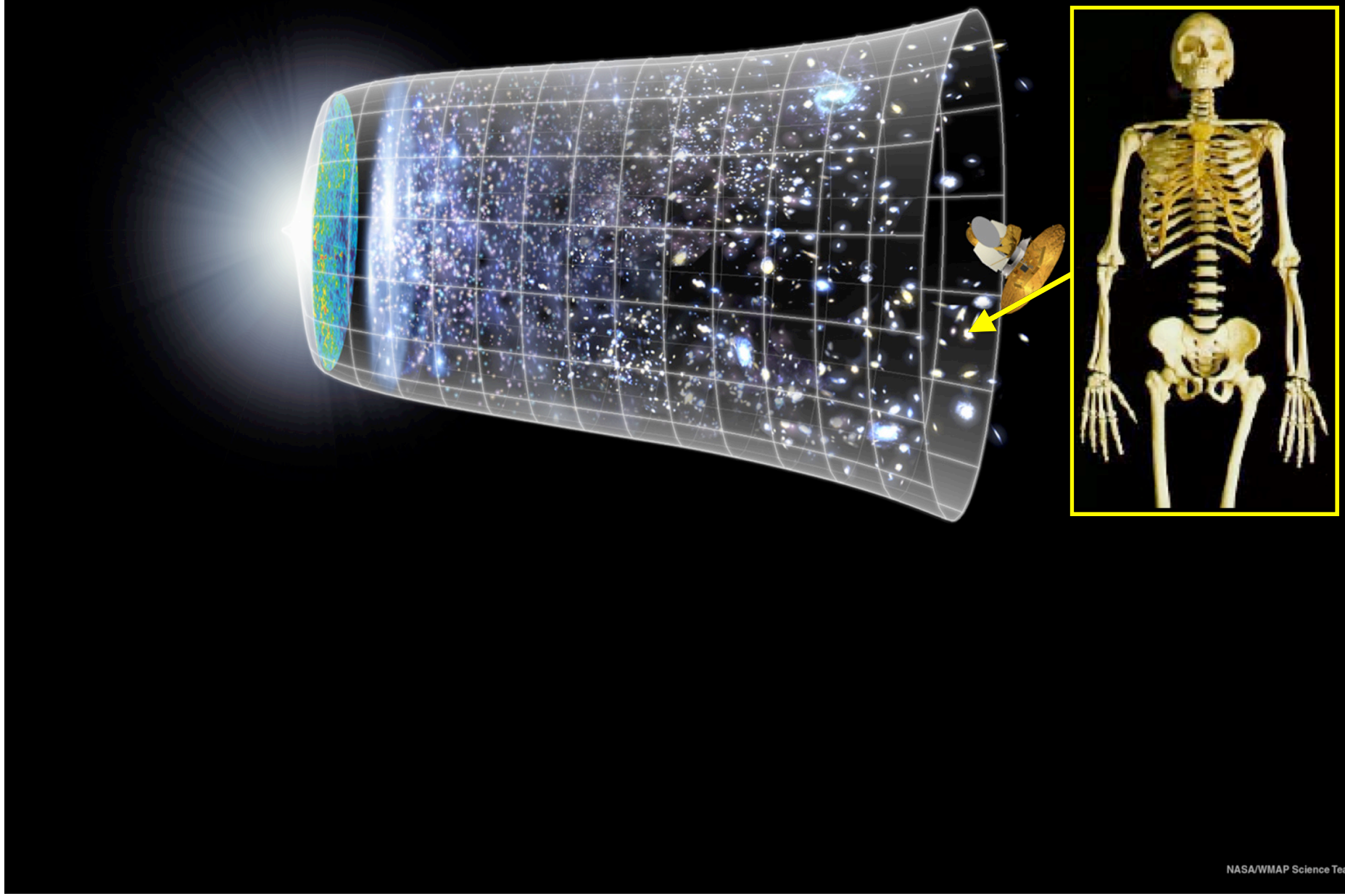
“Infant” galaxies should look different from mature galaxies

Using Telescopes as Time Machines



NASA/WMAP Science Team

Using Telescopes as Time Machines



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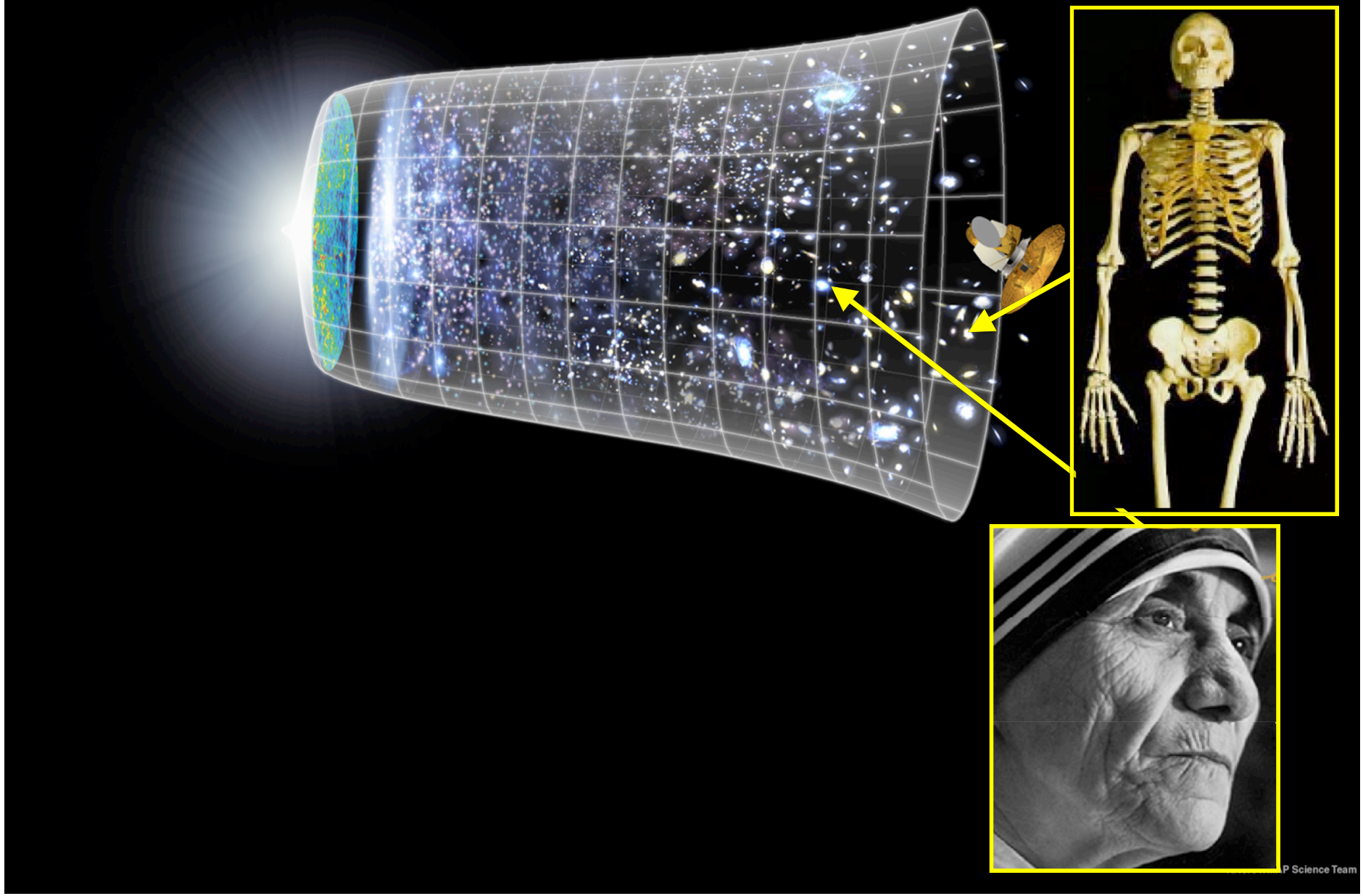

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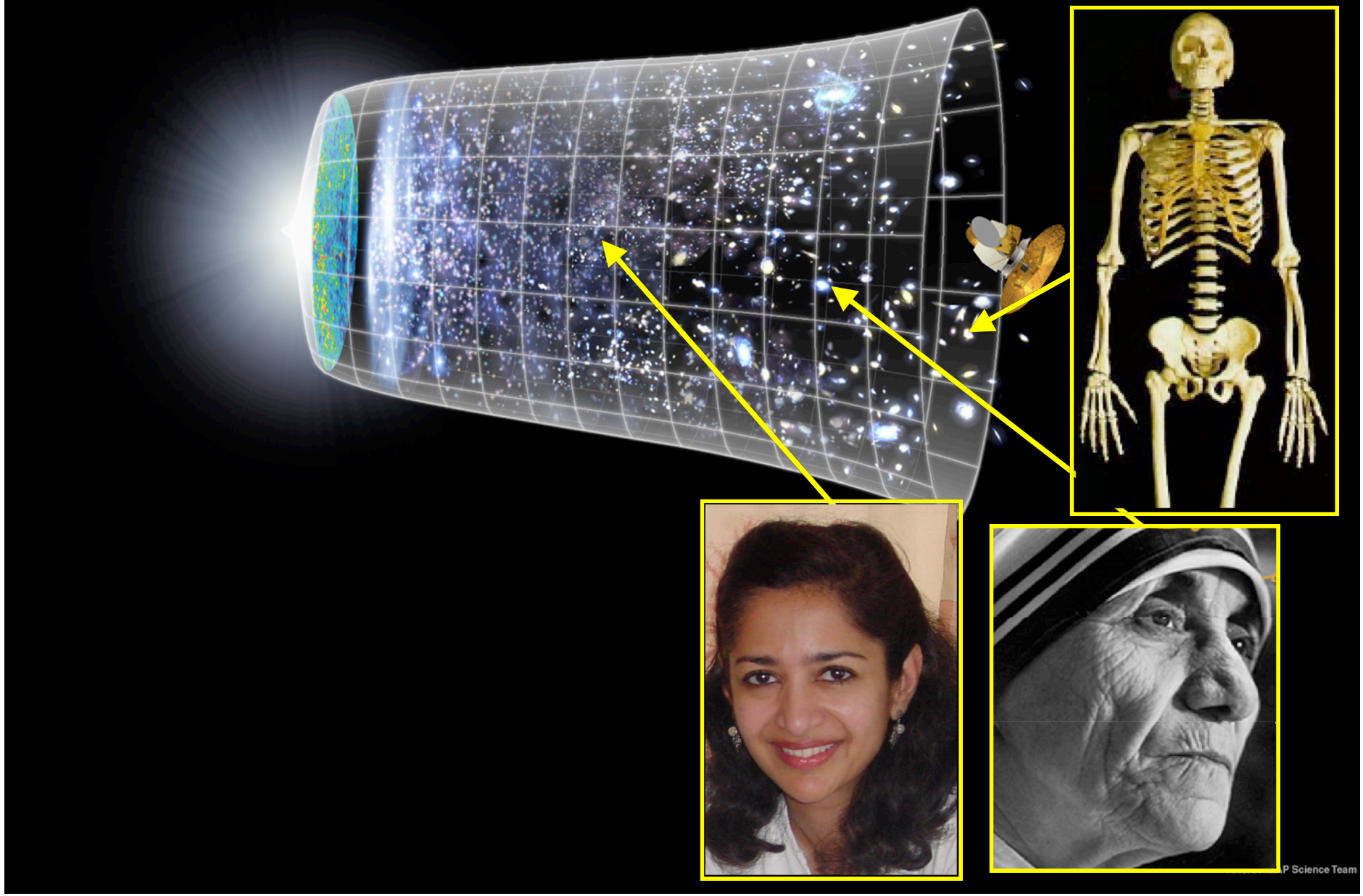

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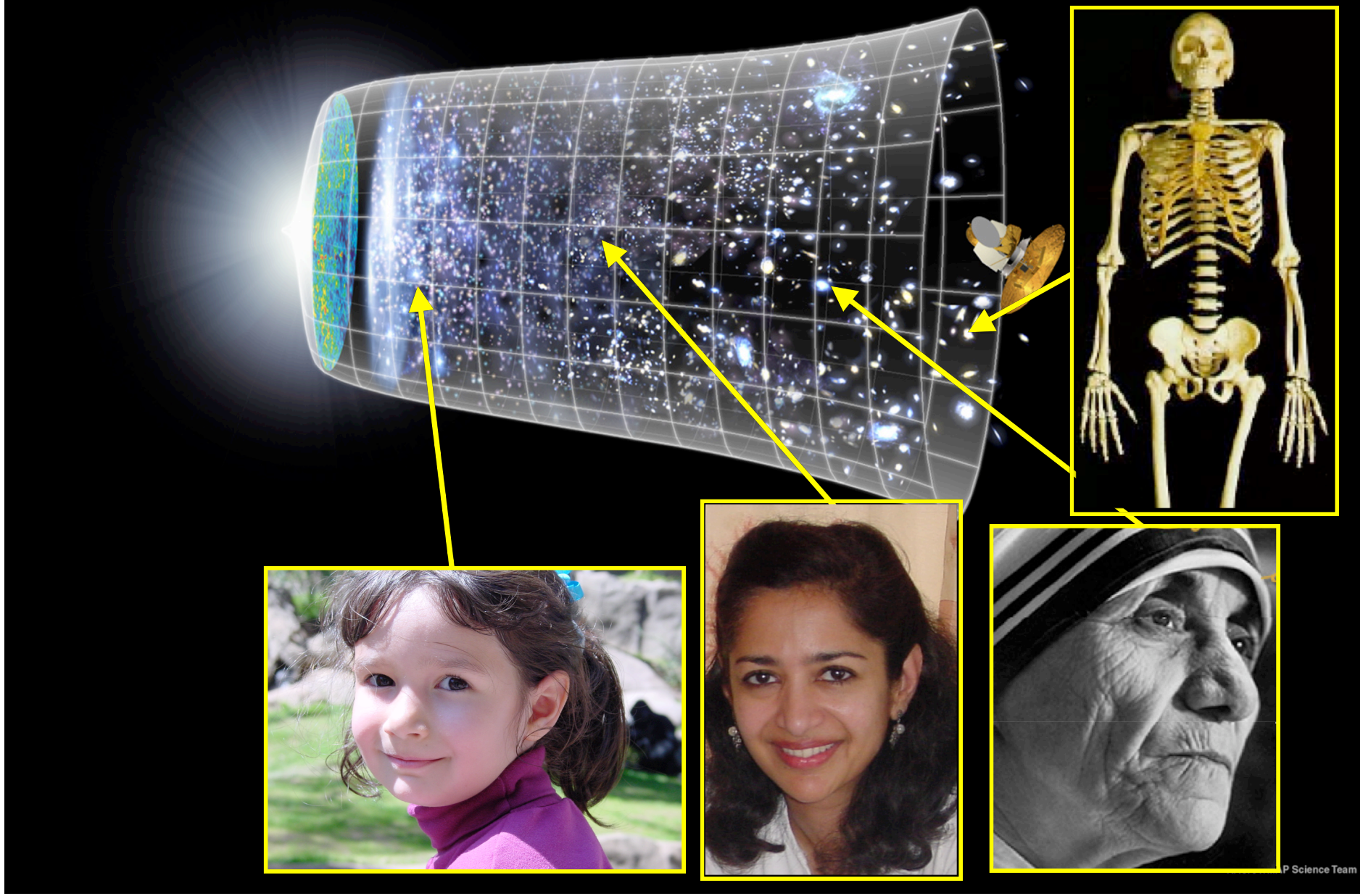

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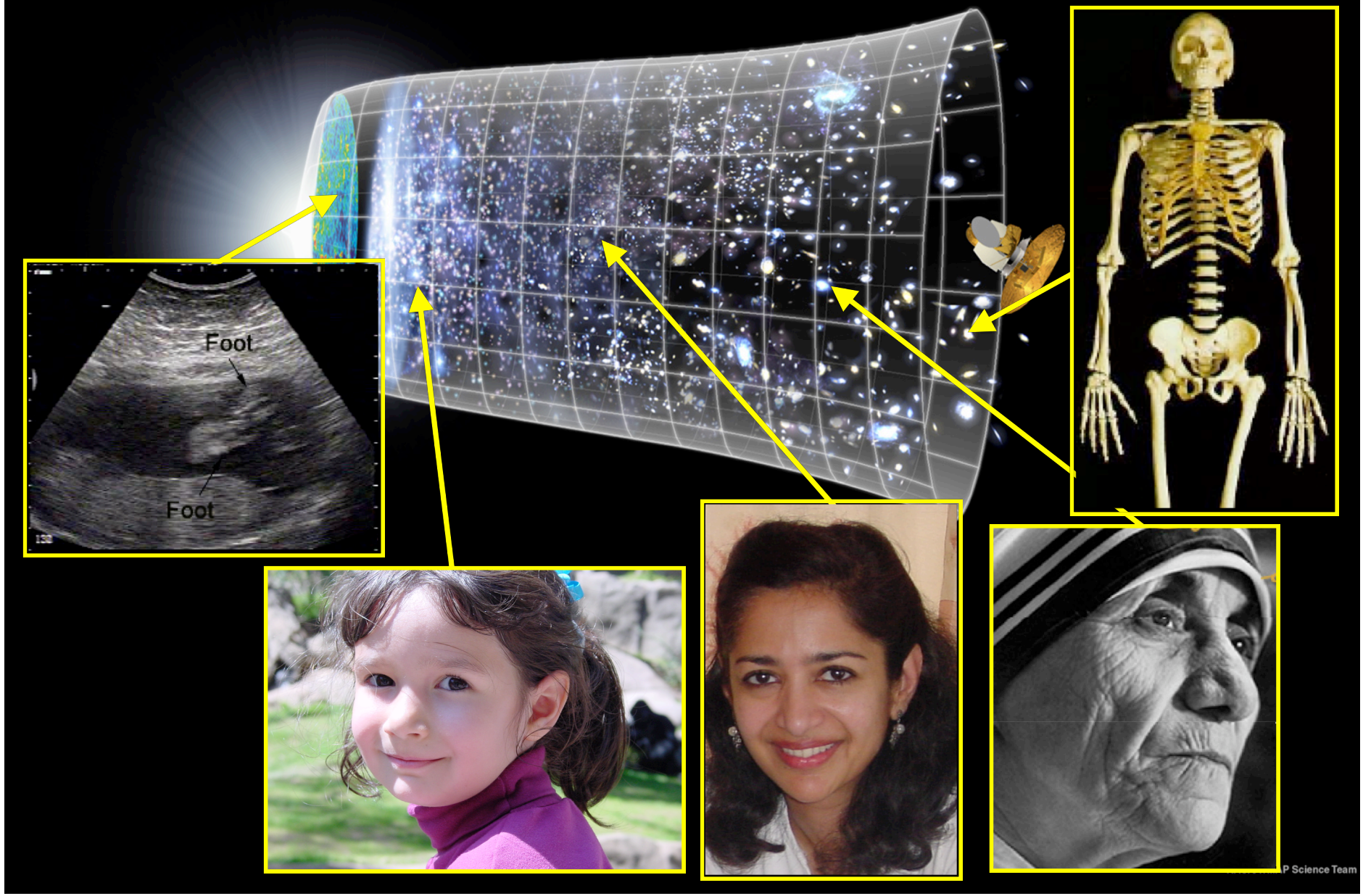

Distant Galaxies Are Small and Ragged



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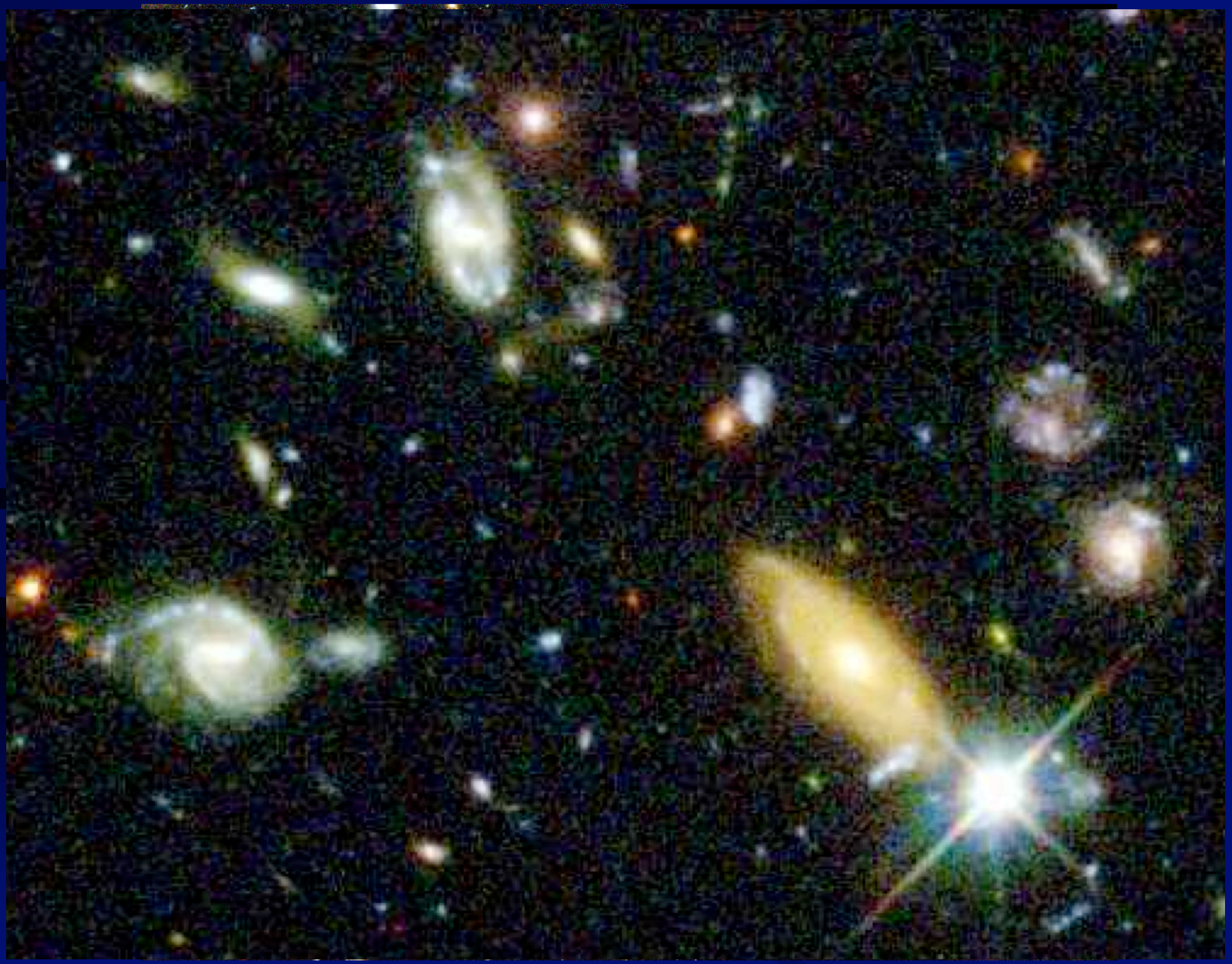
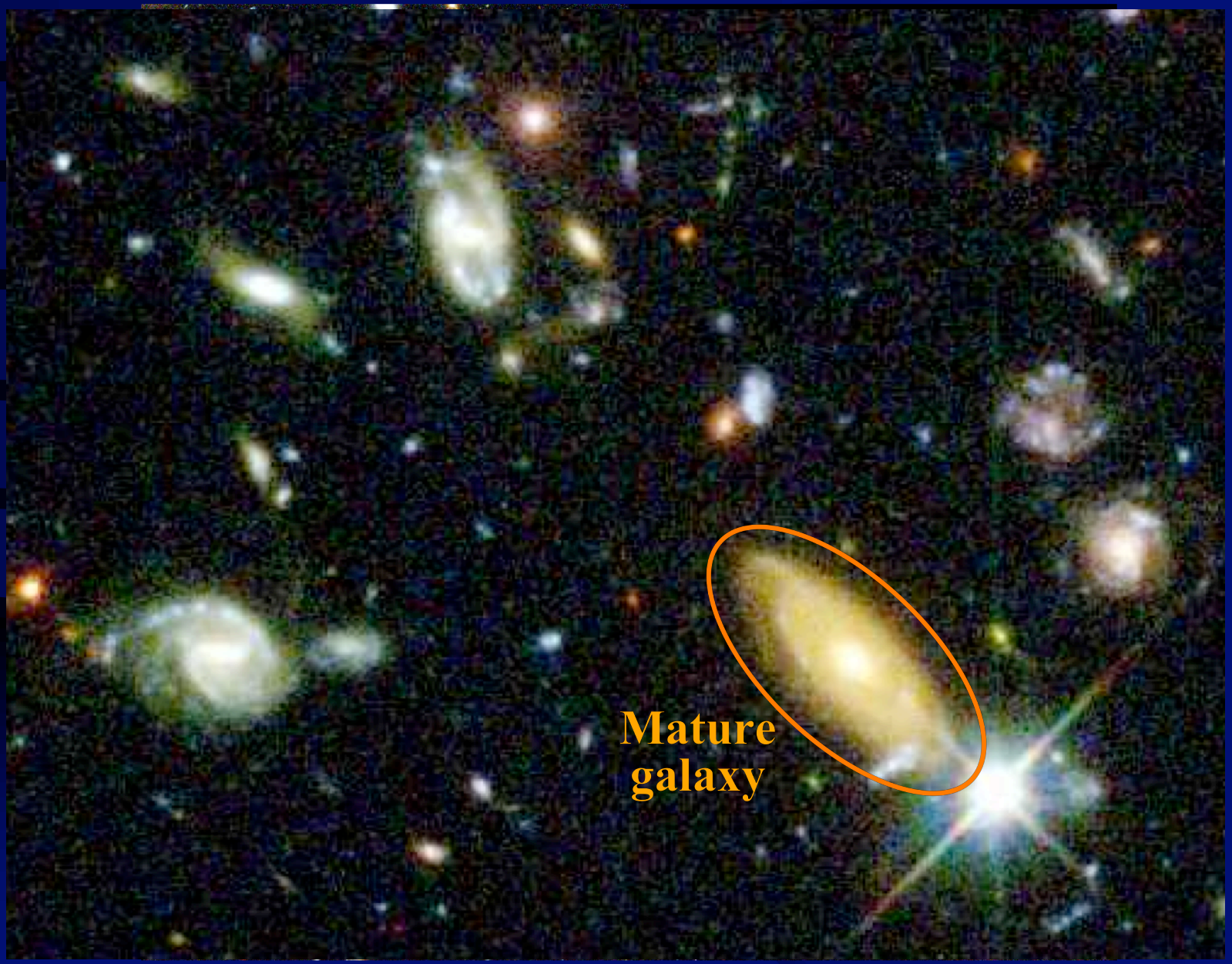


Distant Galaxies Are Small and Ragged



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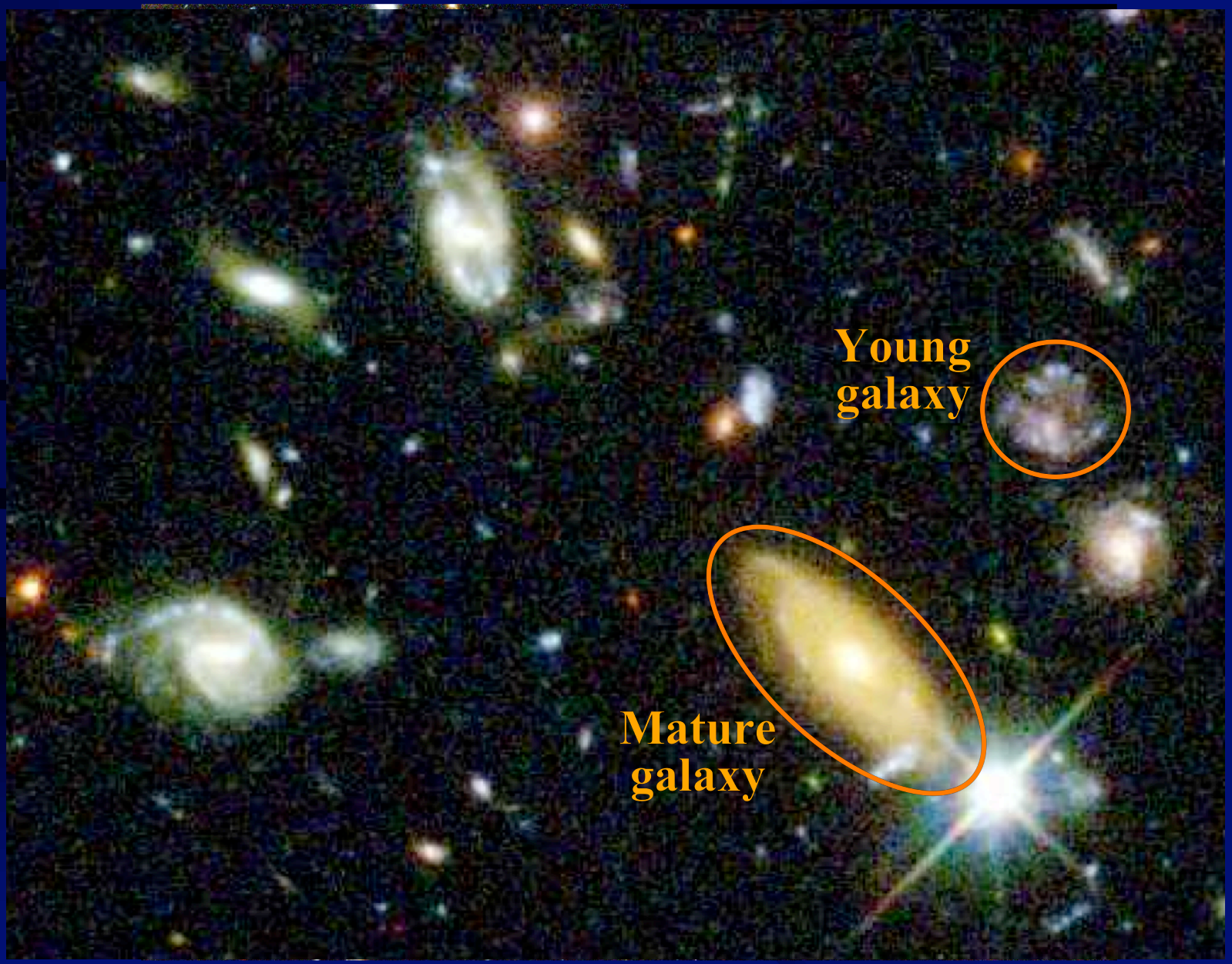

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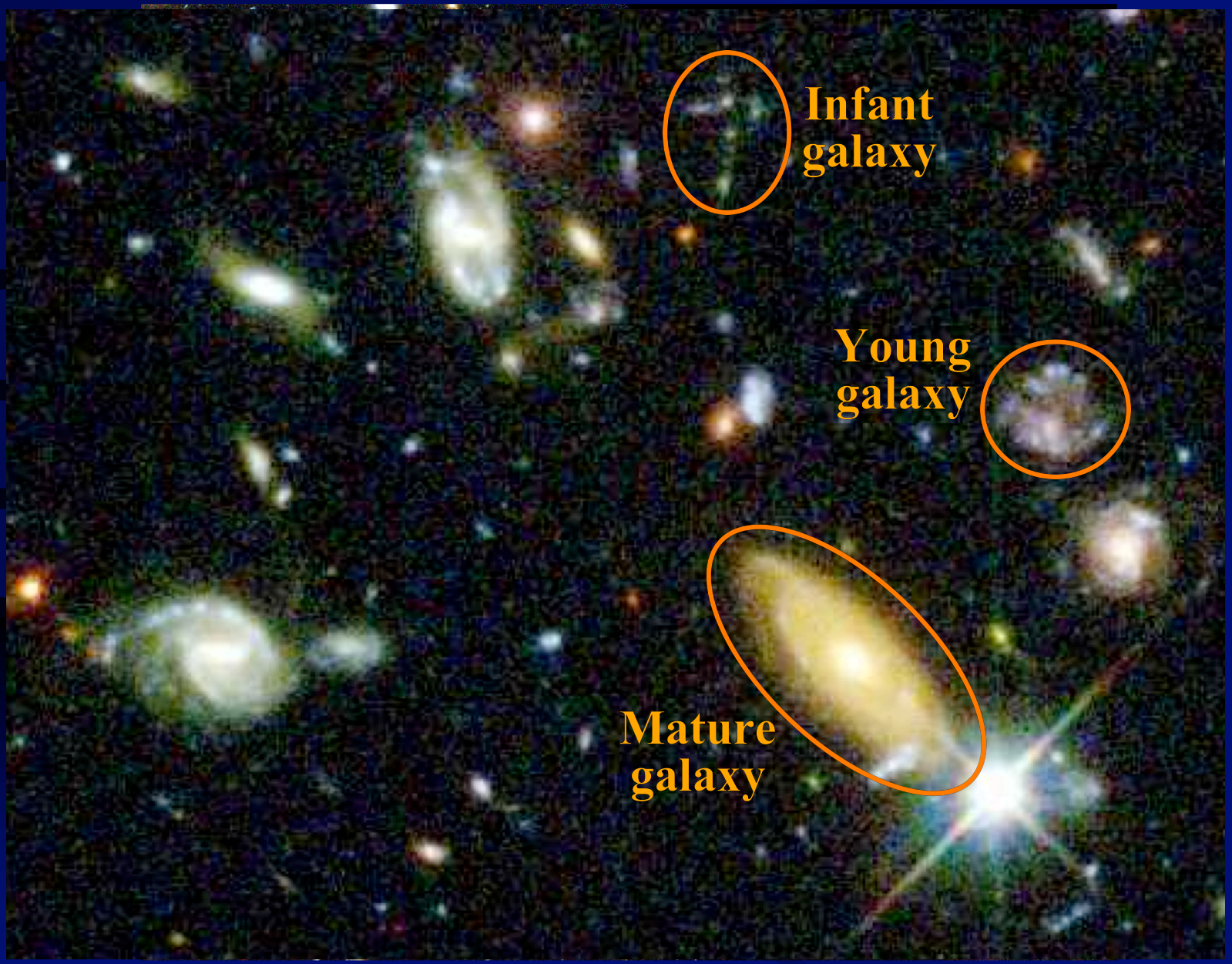

Deepest Image of Distant Galaxies



Deepest Image of Distant Galaxies



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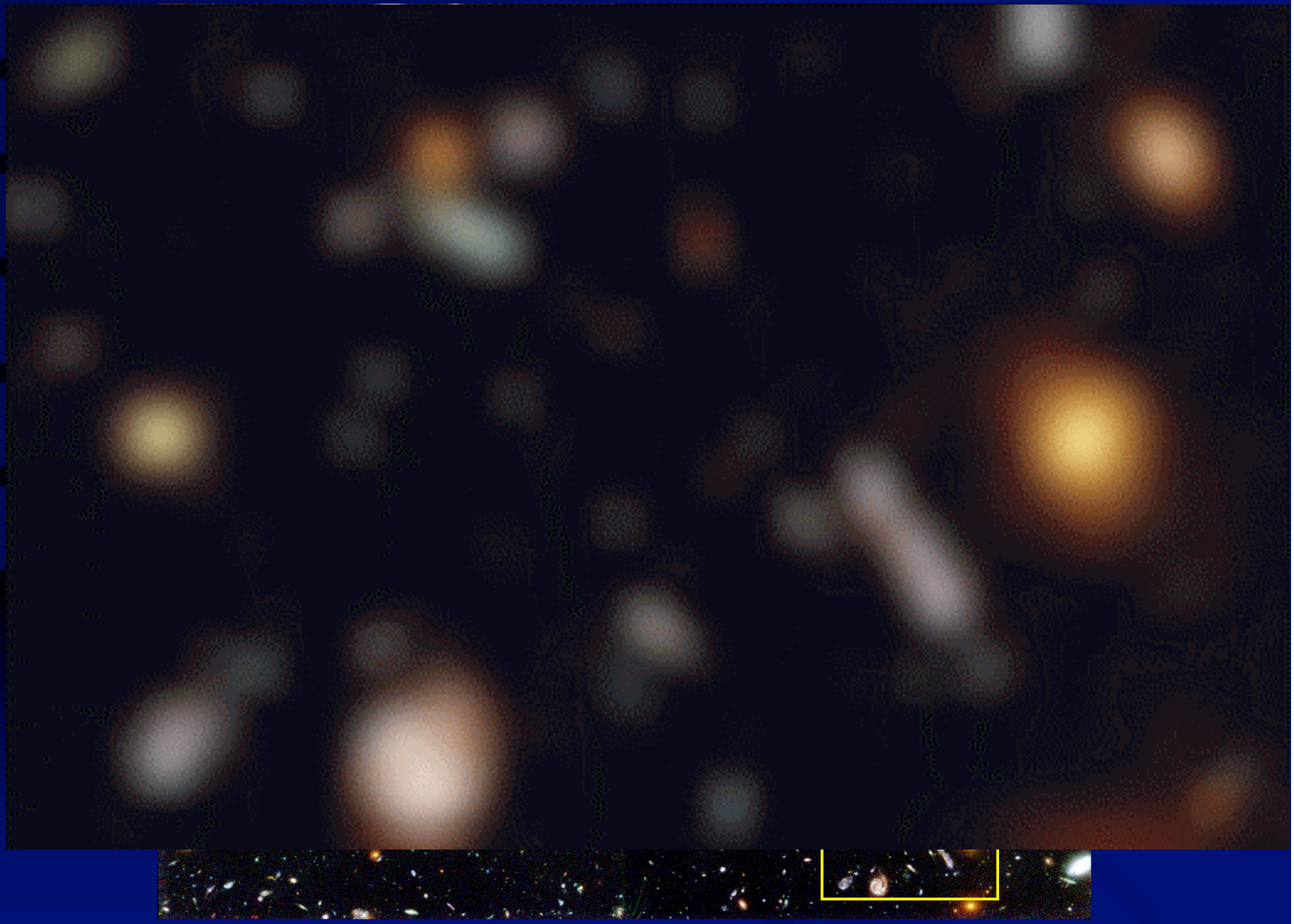

The Hubble Space Telescope is in orbit above the Earth's atmosphere and so is able to take sharp pictures……but…..

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….. it is prohibitively expensive to build telescopes that are based in space

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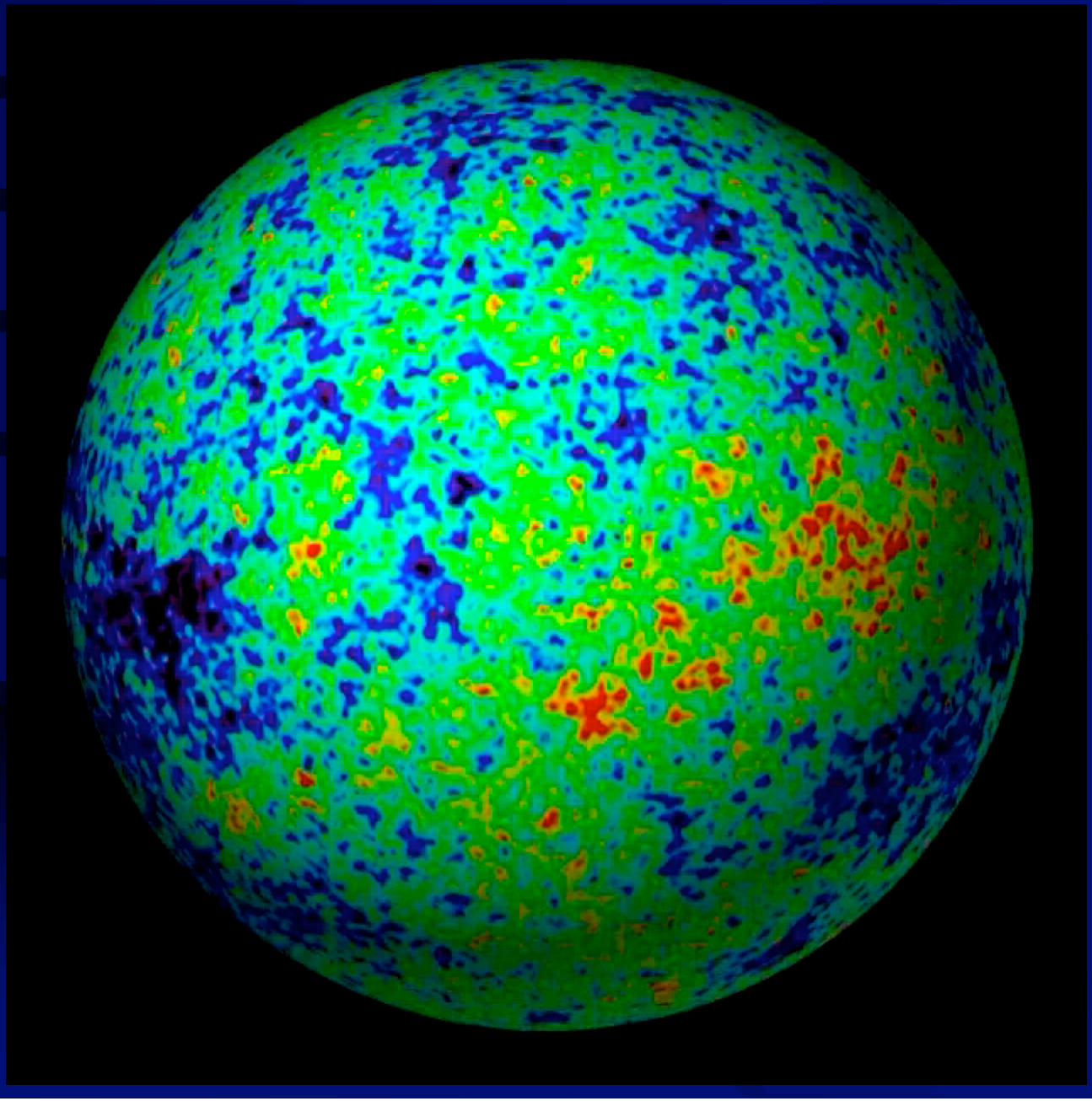
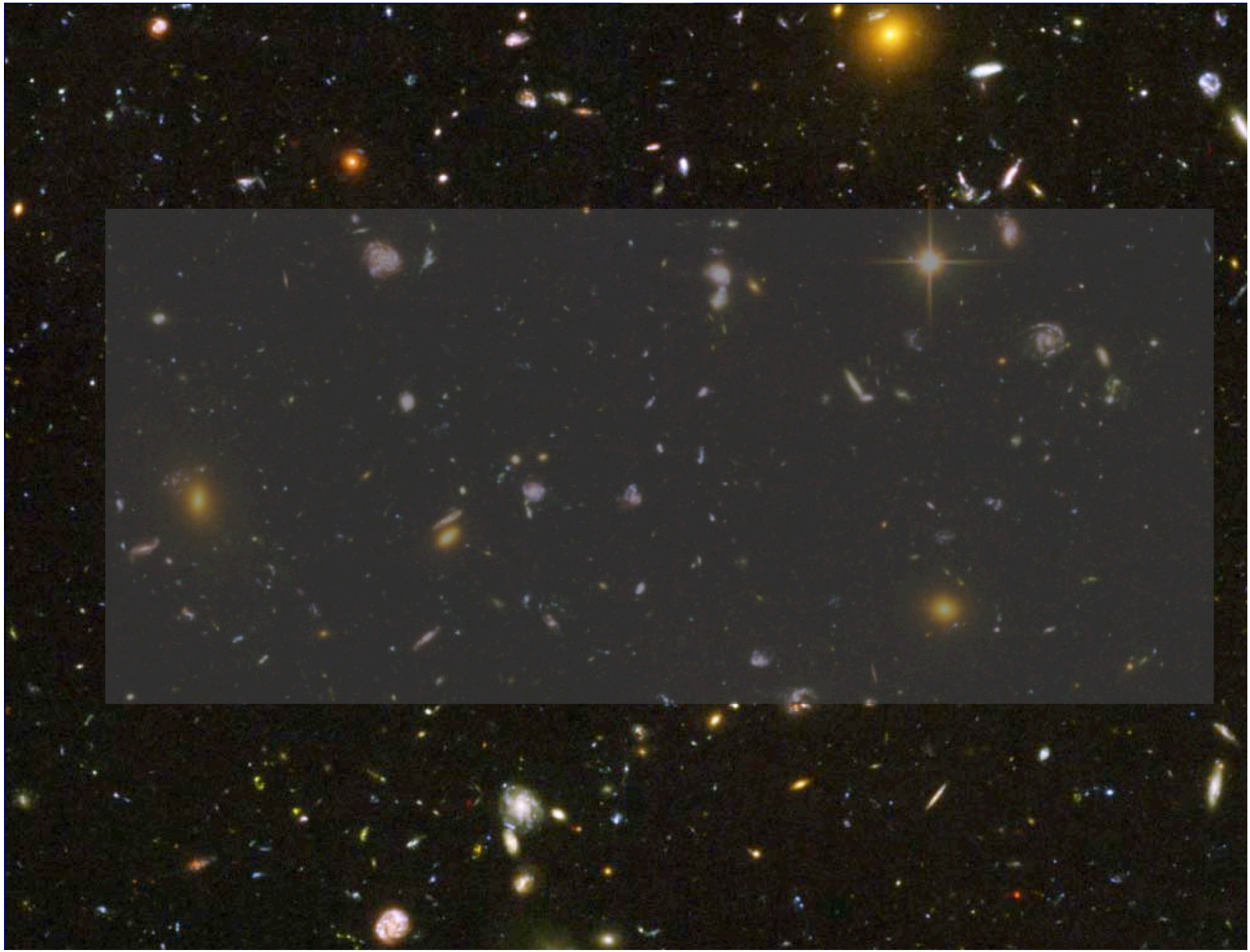
A new method called "Adaptive Optics" allows us to sharpen the vision of telescopes that are on the ground, by correcting for the blurring caused by the Earth's atmosphere

Prediction:

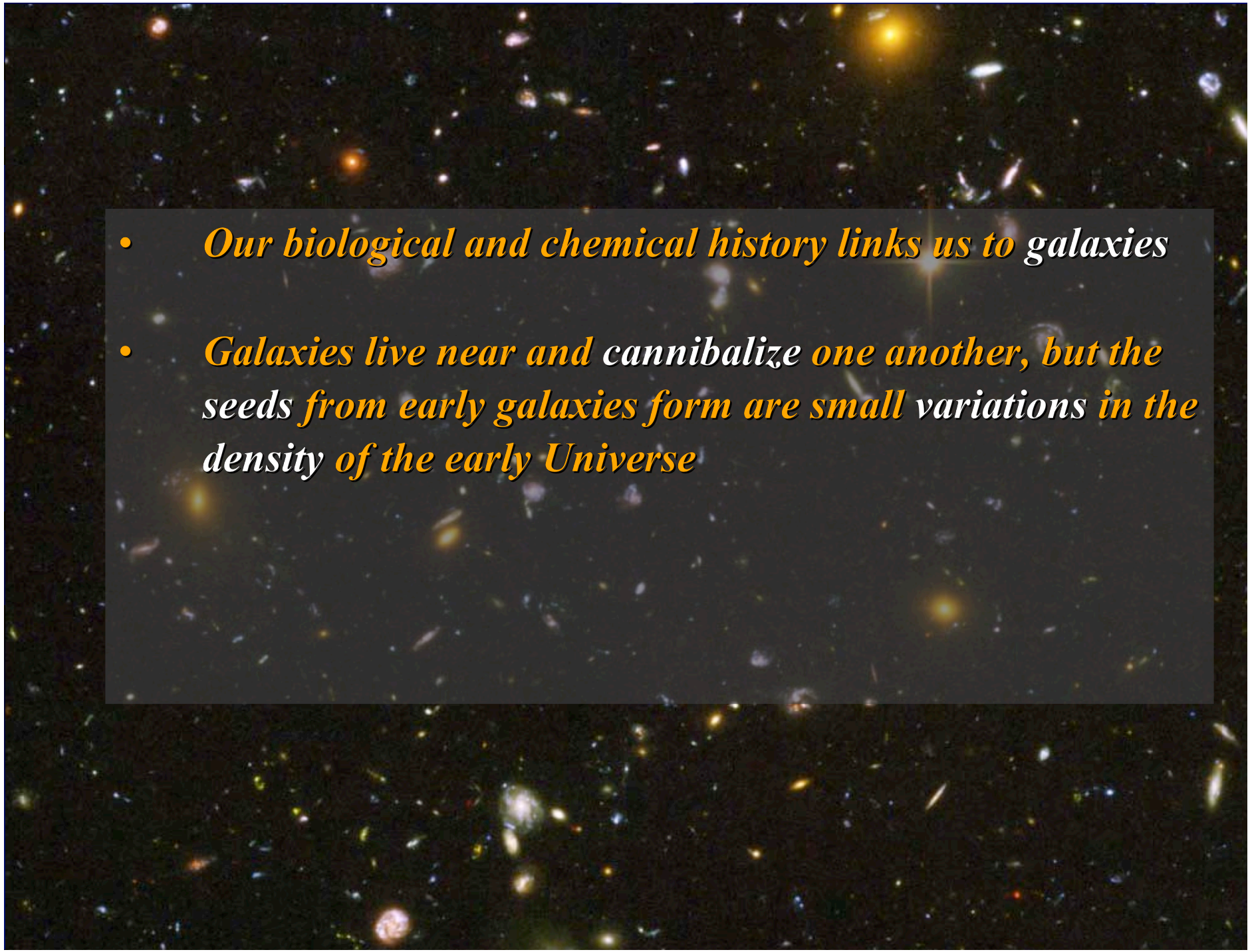
The farthest things we see should be the early ripples in the cosmic ocean from which galaxies are made

Early Ripples in the Cosmic Ocean

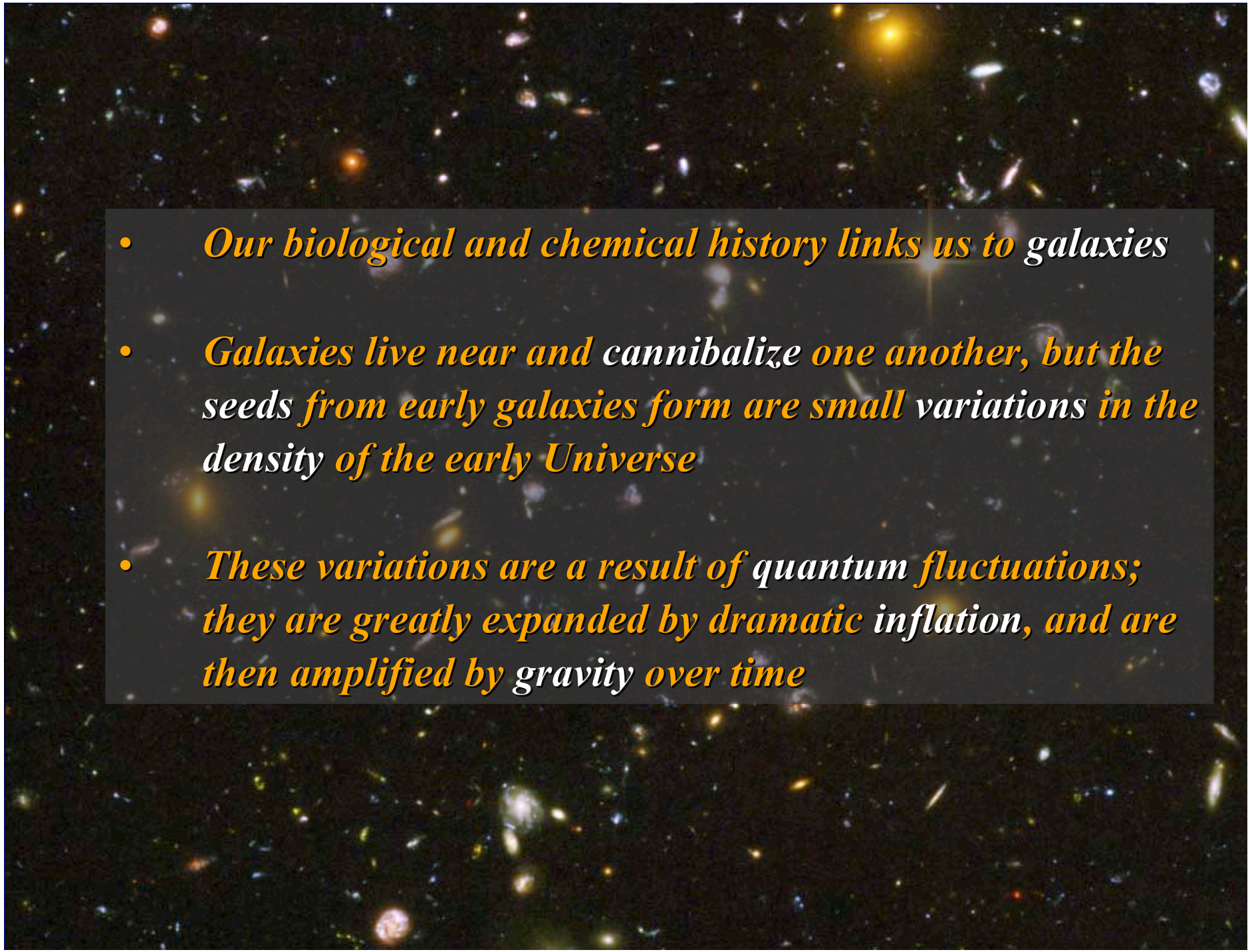





• Our biological and chemical history links us to galaxies

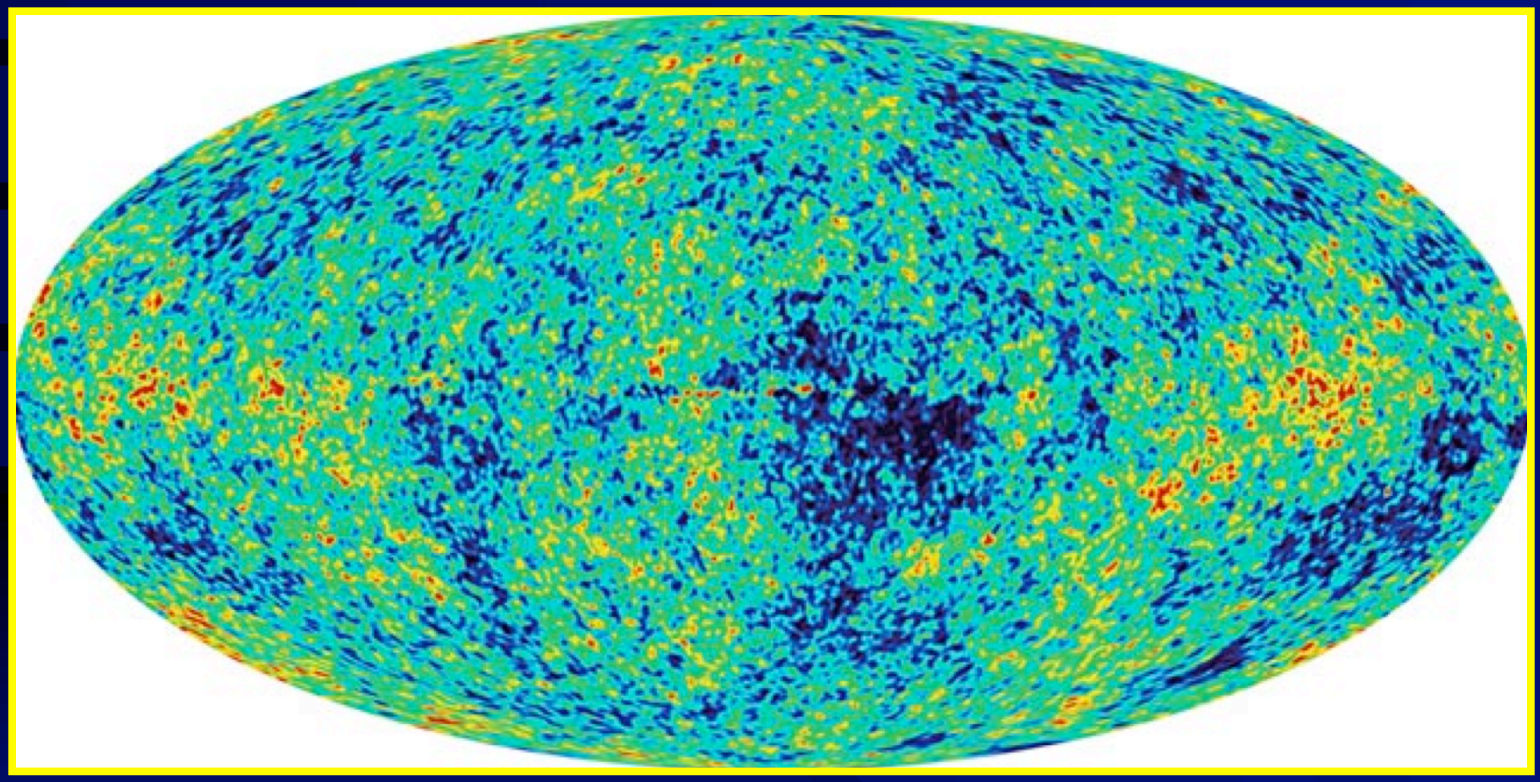


- *Our biological and chemical history links us to galaxies*
- *Galaxies live near and cannibalize one another, but the seeds from early galaxies form are small variations in the density of the early Universe*



- *Our biological and chemical history links us to galaxies*
- *Galaxies live near and cannibalize one another, but the seeds from early galaxies form are small variations in the density of the early Universe*
- *These variations are a result of quantum fluctuations; they are greatly expanded by dramatic inflation, and are then amplified by gravity over time*

Completing the Cycle……



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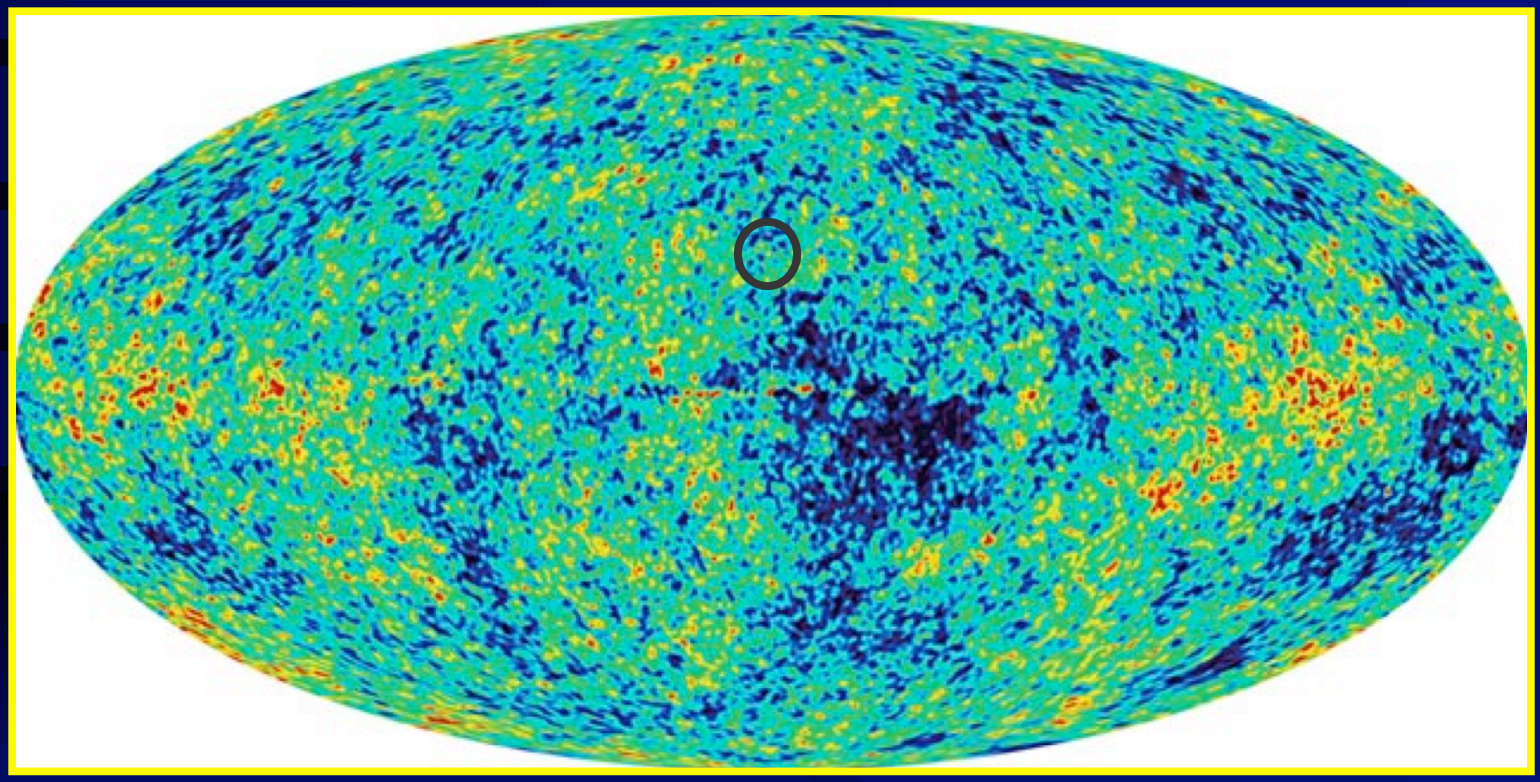

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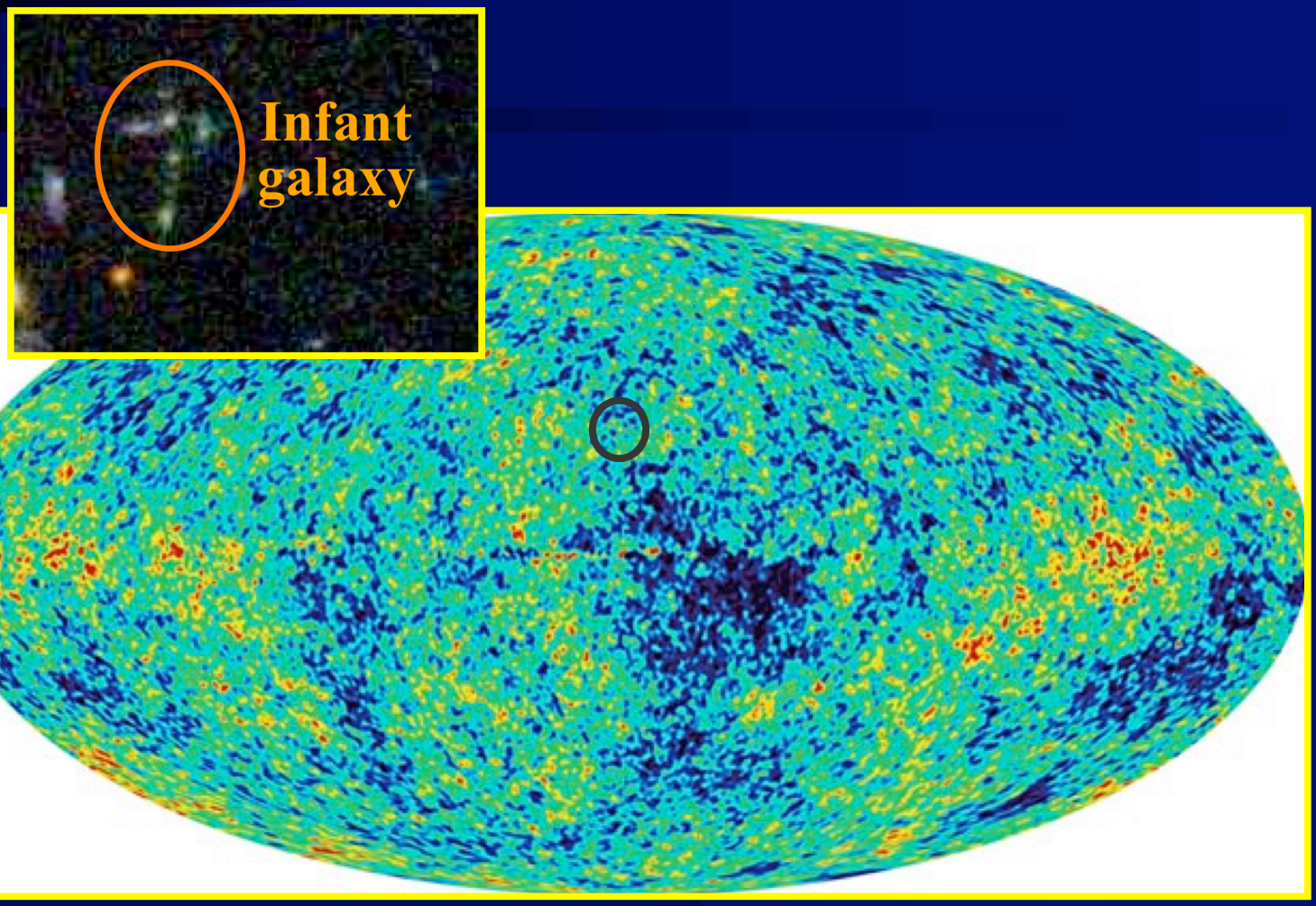

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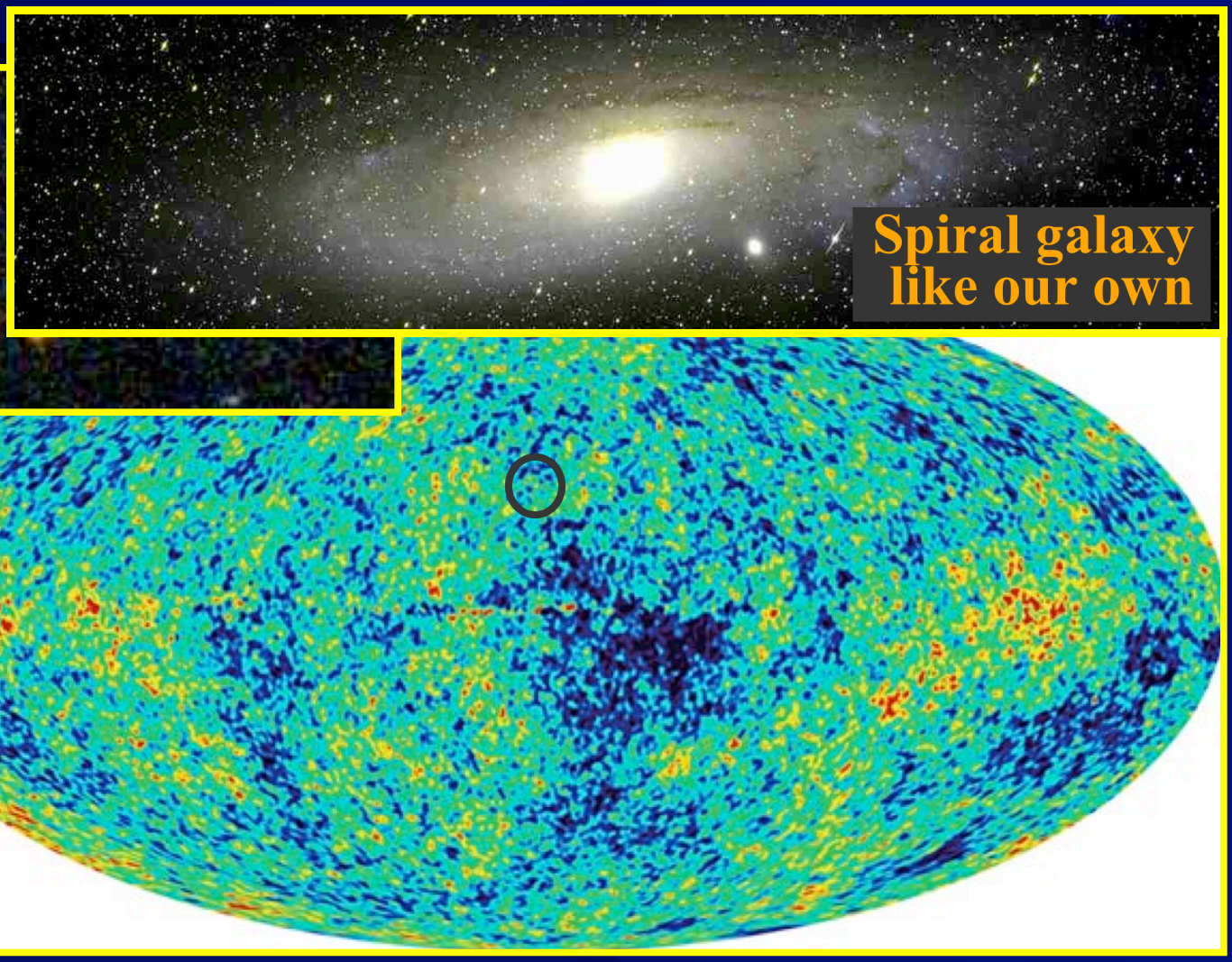

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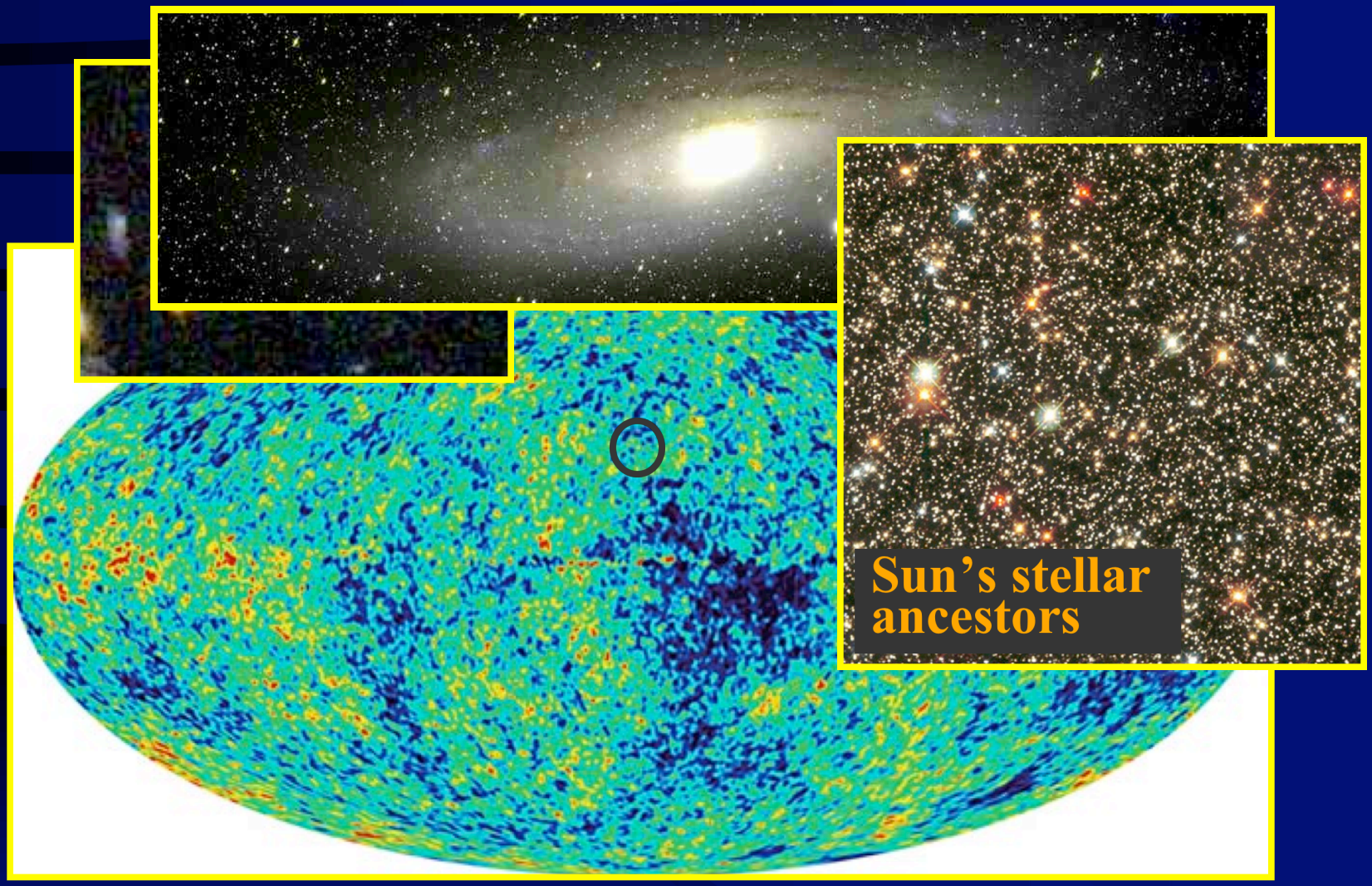

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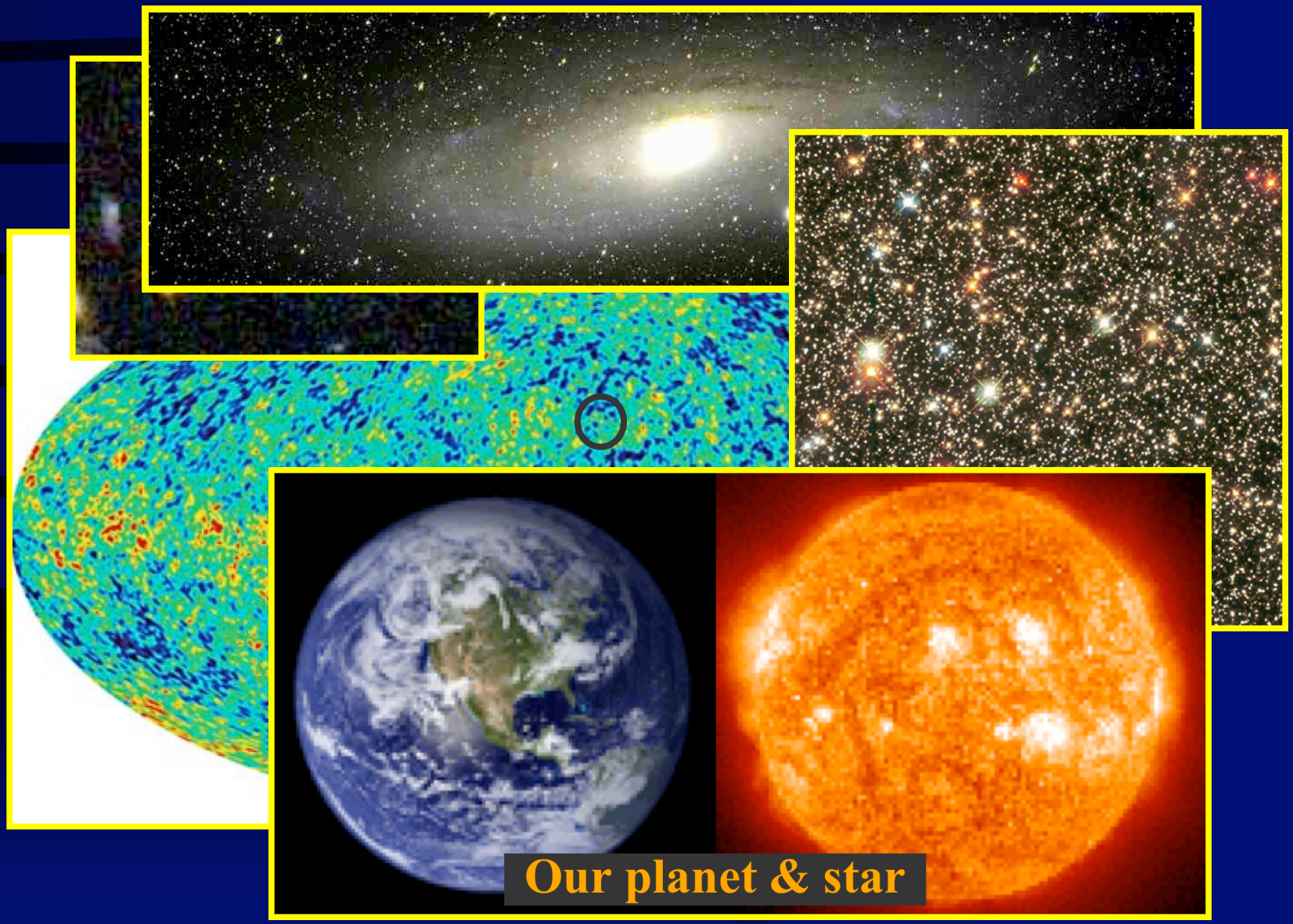

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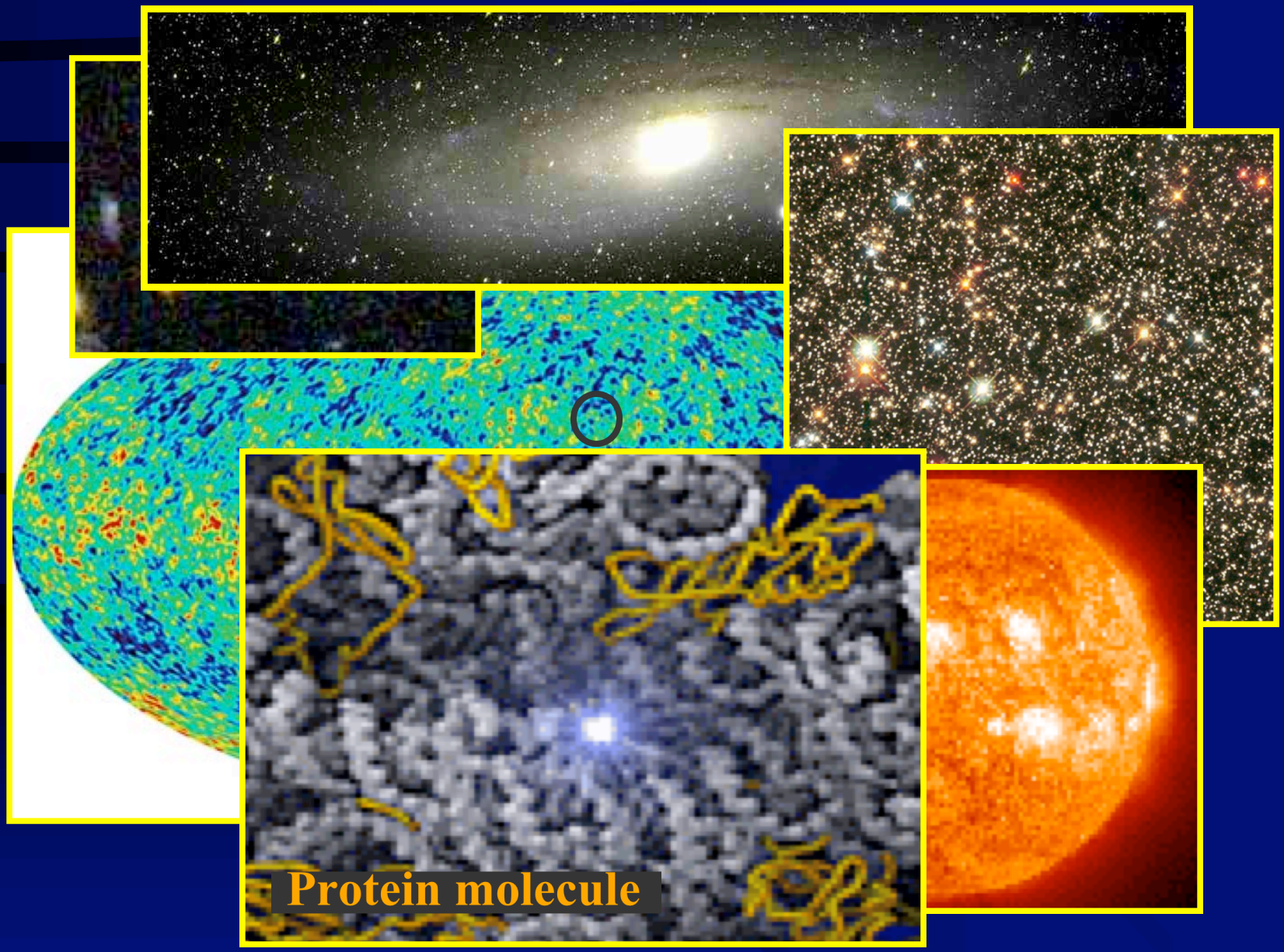

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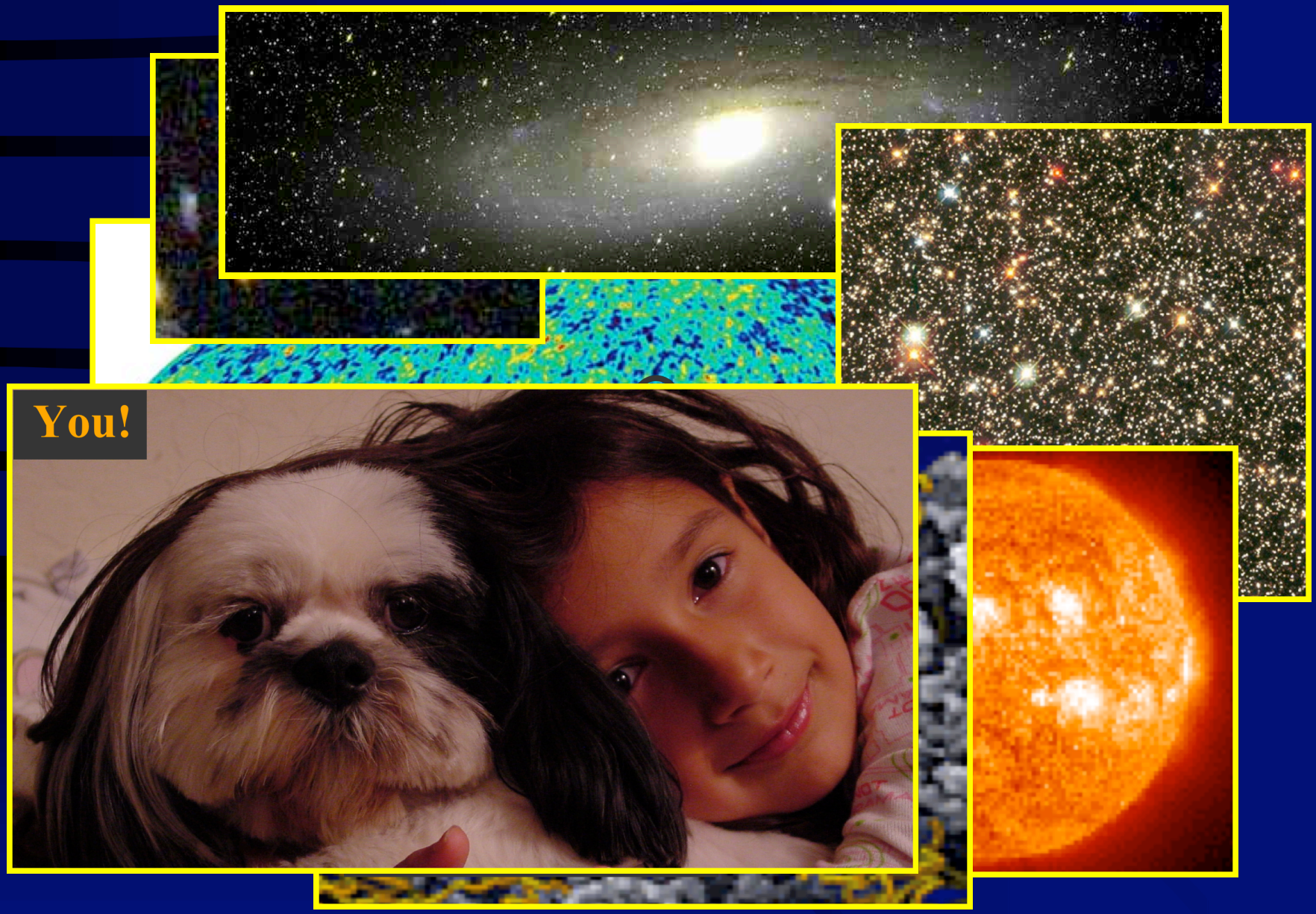

At Home in the Milky Way



"False Kiva" by Wally Pacholka