Assembling the Jigsaw-Puzzle Picture of the Universe

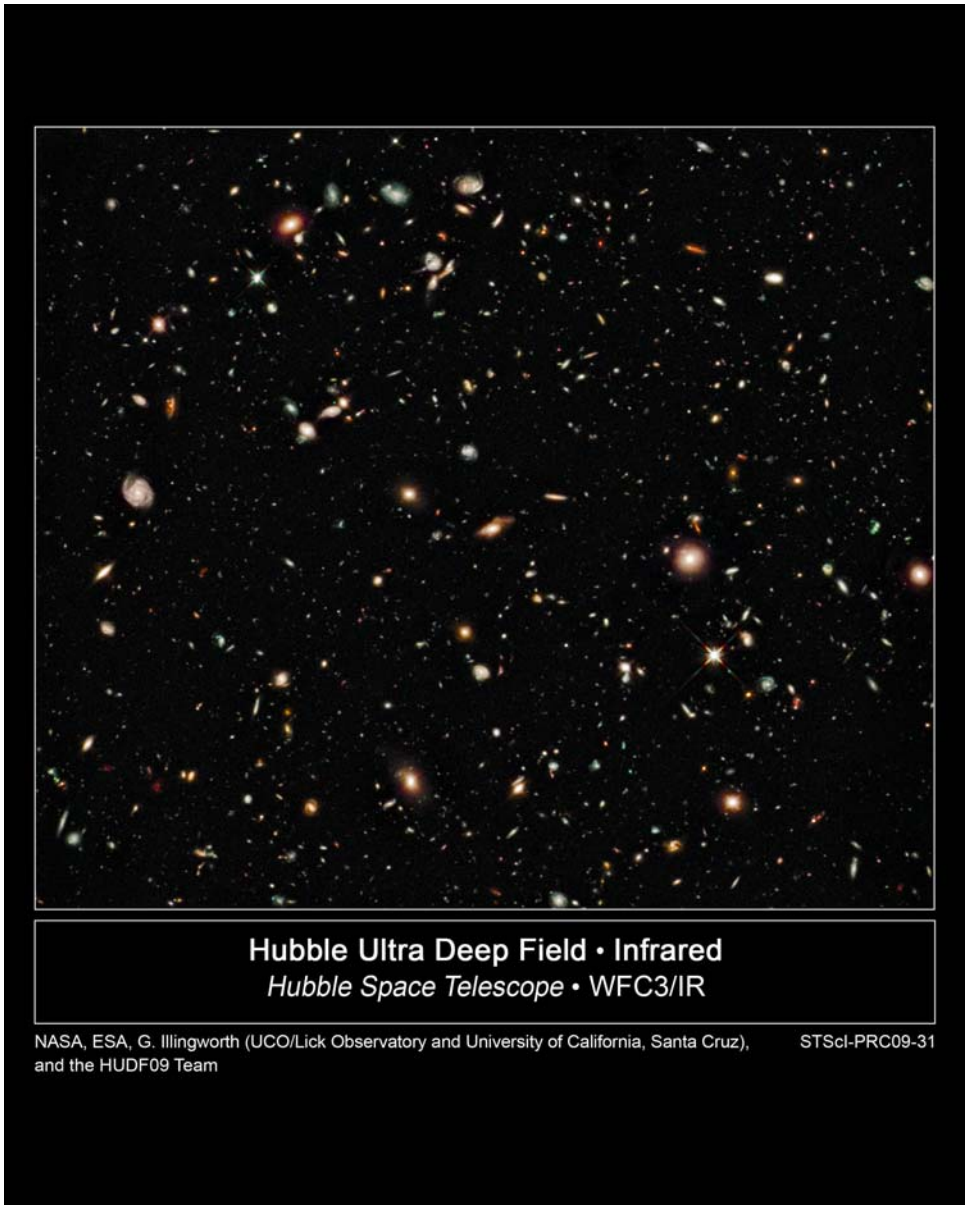
Osher Life-Long Learning Institute

Course R805: Exploring Time and Space

Dr. Jeffrey D. Rosendhal

March 23, 2010

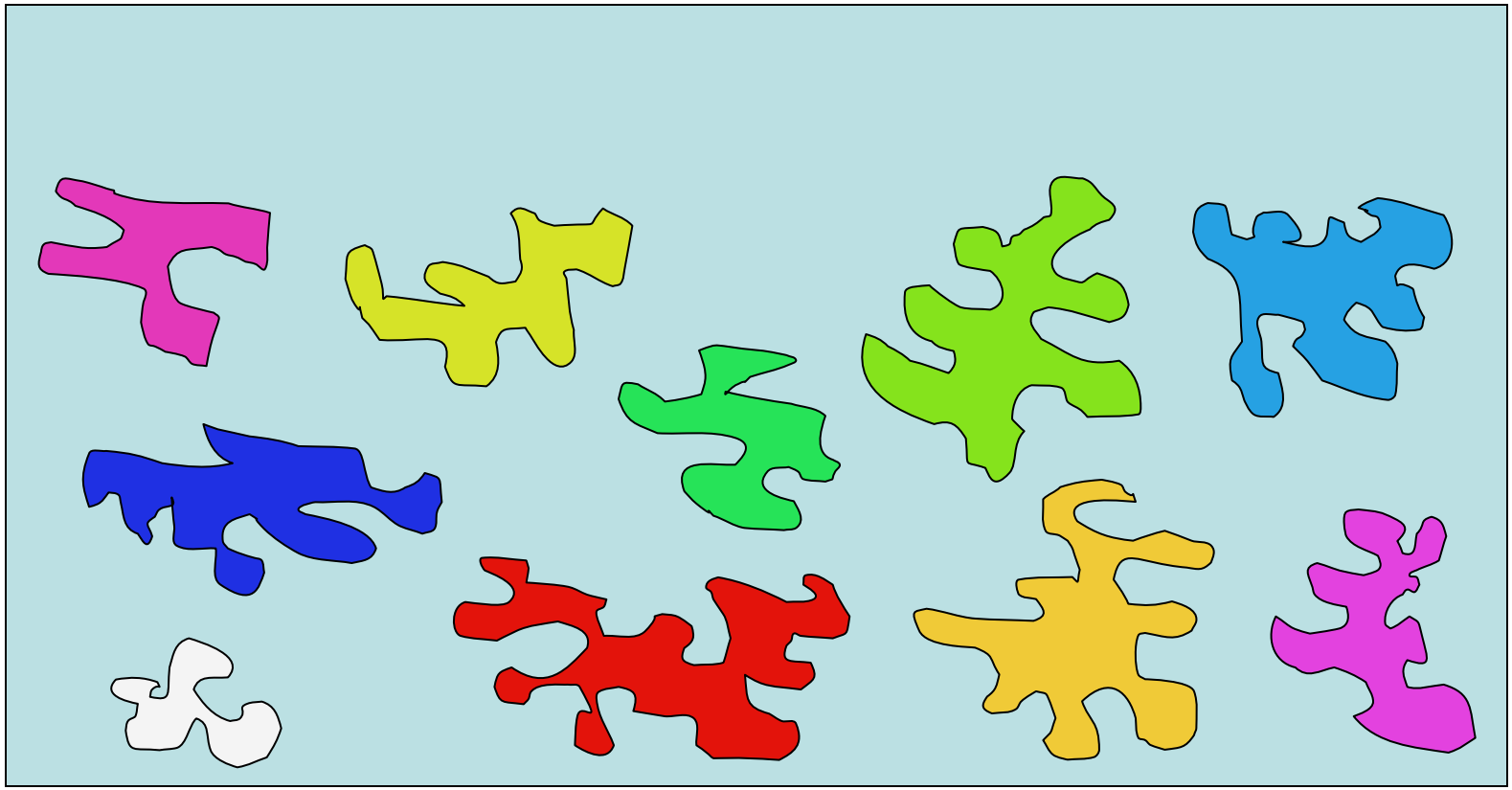
We are now living in the “Great Golden Age” of Astronomy



Factors Driving the Enormous Gain in Astronomical Knowledge

- New generation of large ground-based telescopes
- Access to space
  - Provides access to the full electromagnetic spectrum
  - Eliminates the blurring effects of the atmosphere
  - Allows telescopes to be cooled to eliminate background radiation in the infrared
- New technology, new instrumentation, and new types of detectors
  - Allow measurements of unprecedented precision
- New computational capabilities

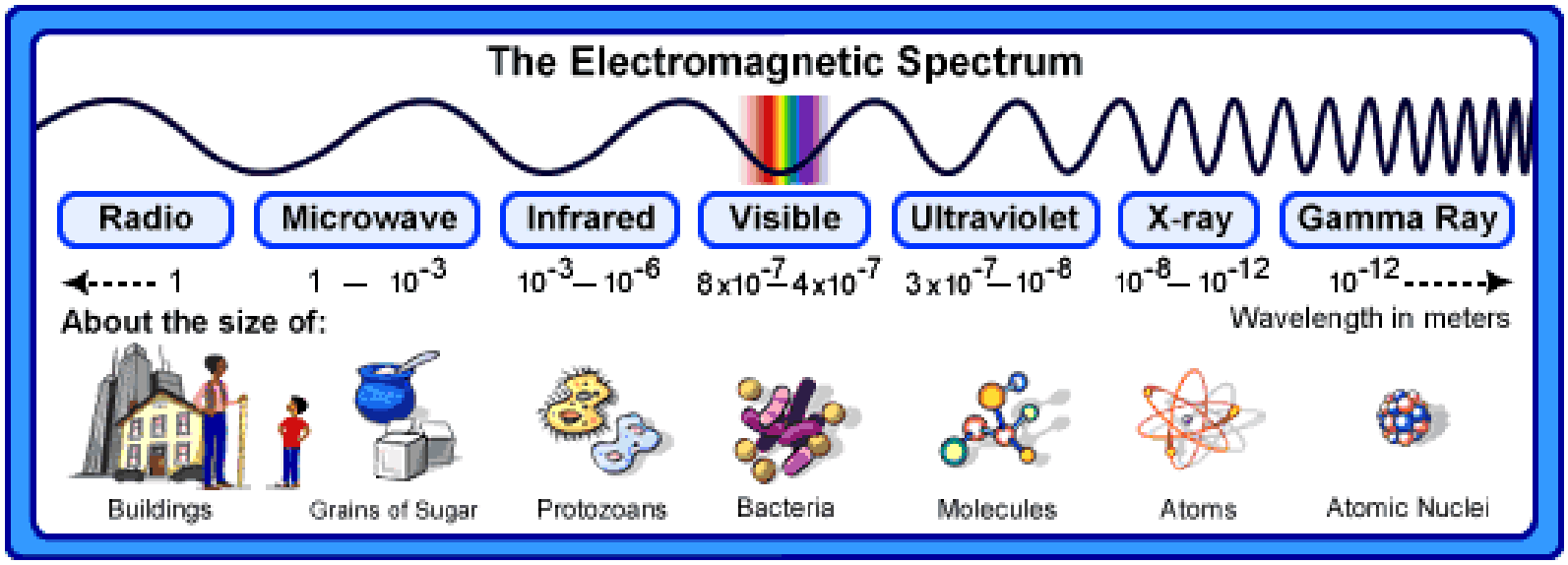
Assembling a Picture of the Universe: Some Basic Questions



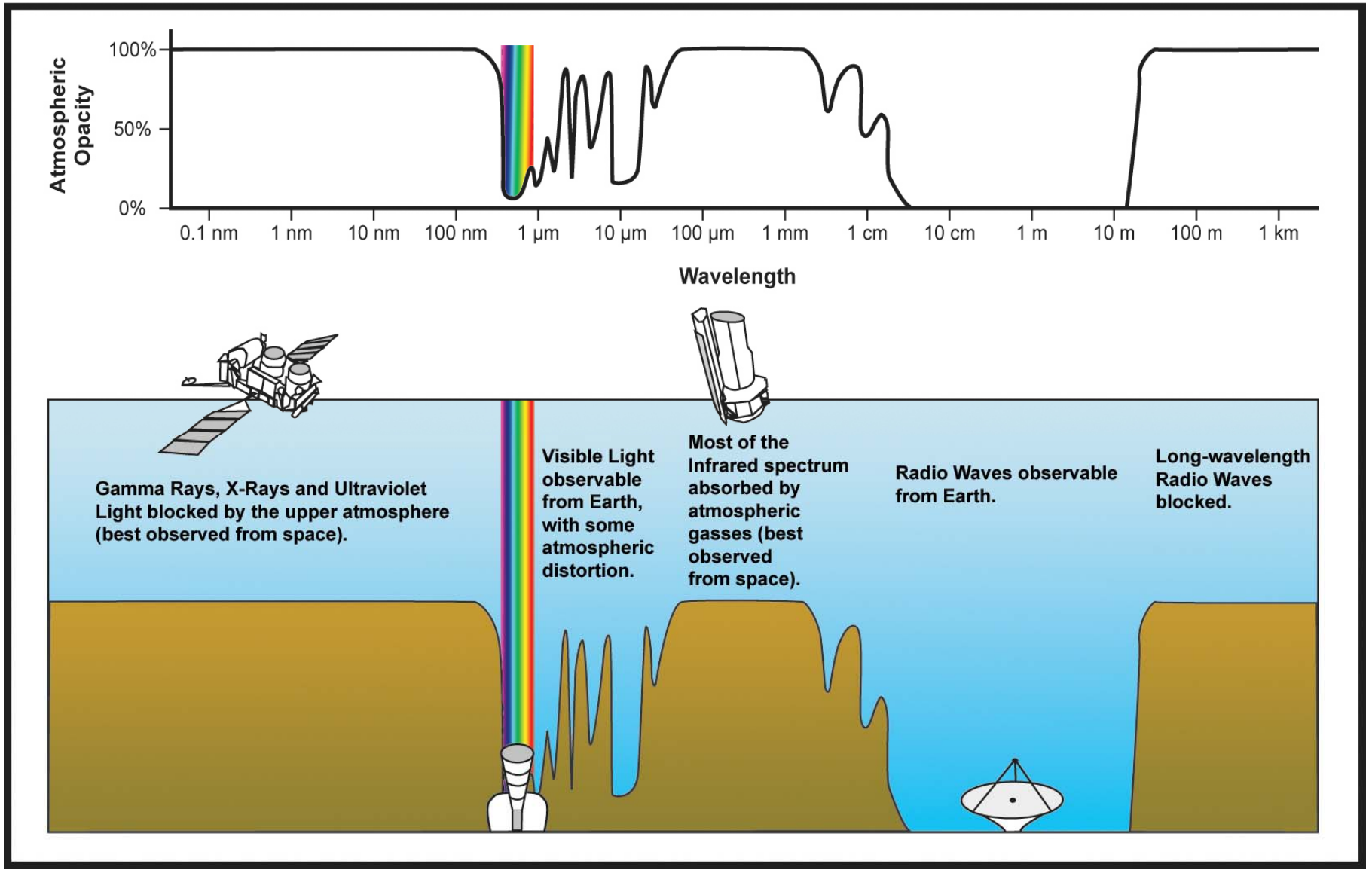
- Do we actually have all the pieces?
- Can we use all the colors?
- Can we use the smallest pieces?

The Electromagnetic Spectrum

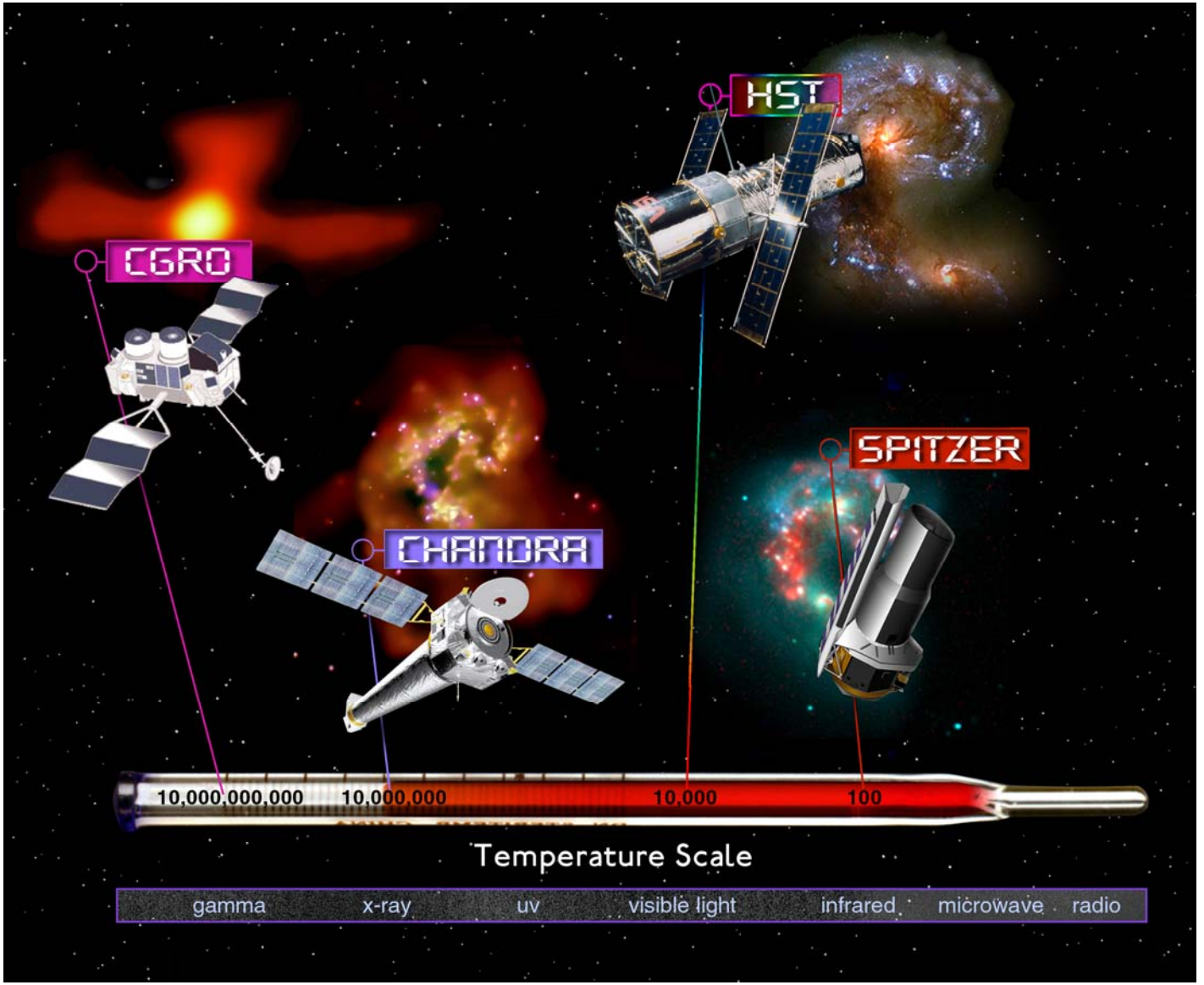
Our eyes see only part of the electromagnetic spectrum…



Going above the atmosphere is essential to gain access to the full electromagnetic spectrum



Different parts of the spectrum reveal different physical processes and different kinds of objects



“Invisible” Light in Astronomy

Each part of the spectrum provides a piece of the puzzle in understanding our universe.

Star birth & star death

Warm dust

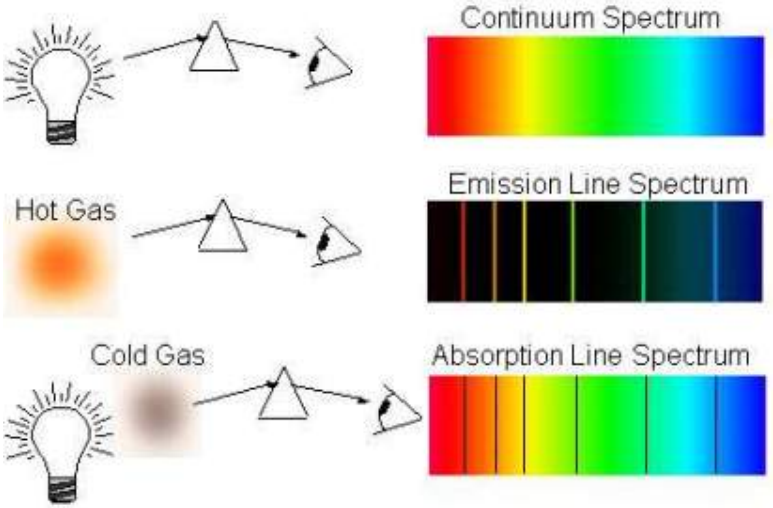
Stars & dust

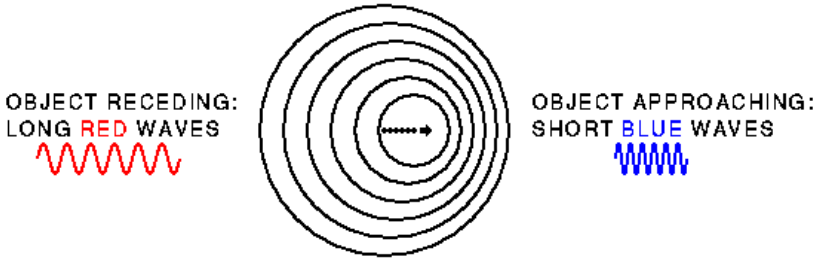
Young stars

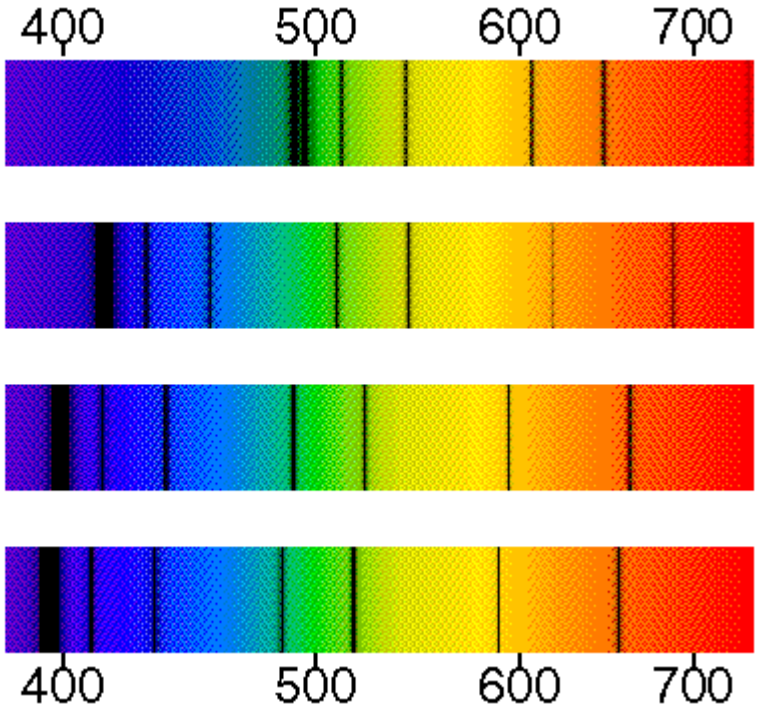
Black holes & neutron stars


QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

Astronomer's Toolbox #2:
Doppler Shift - Light







Atoms emit light at discrete wavelengths that can be seen with a spectroscope

This "line spectrum" identifies the atom and its velocity

Some Fundamental Characteristics of Telescopes

- Sensitivity - Set primarily by the number of photons that can be collected in a given amount of time/Determines the fraction of all of the possible pieces that can be used
  - Aperture
  - Image Quality
  - Background
  - Observation Time
- Angular Resolution - How close together can two objects be and still be seen as two objects/Determines the size of the pieces in the puzzle that can be used
  - Aperture
  - Wavelength
- Wavelength/The different color pieces in the puzzle
  - Much of the spectrum is blocked by the atmosphere
  - Different physical information is carried by different types of light
  - Different techniques have to be used to collect and use photons of different energies

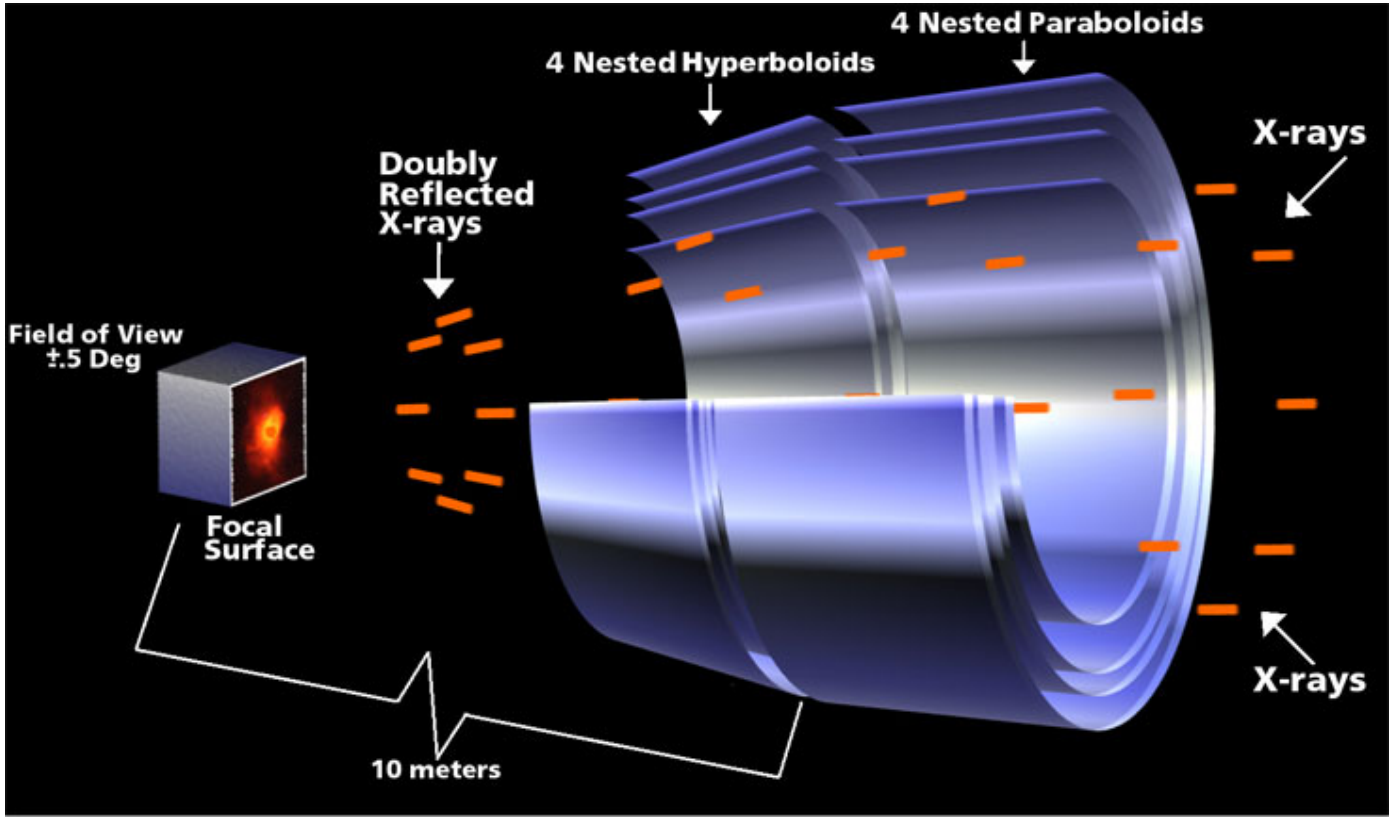

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

The World’s Most Famous Mirror

Working on Hubble’s Main Mirror

Image Credit: NASA, 1990

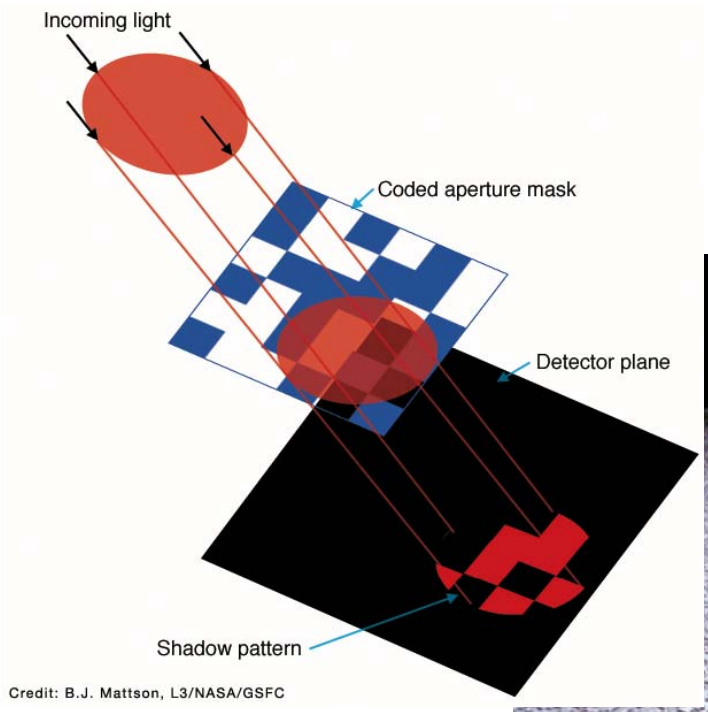
Just Skimming the Surface…

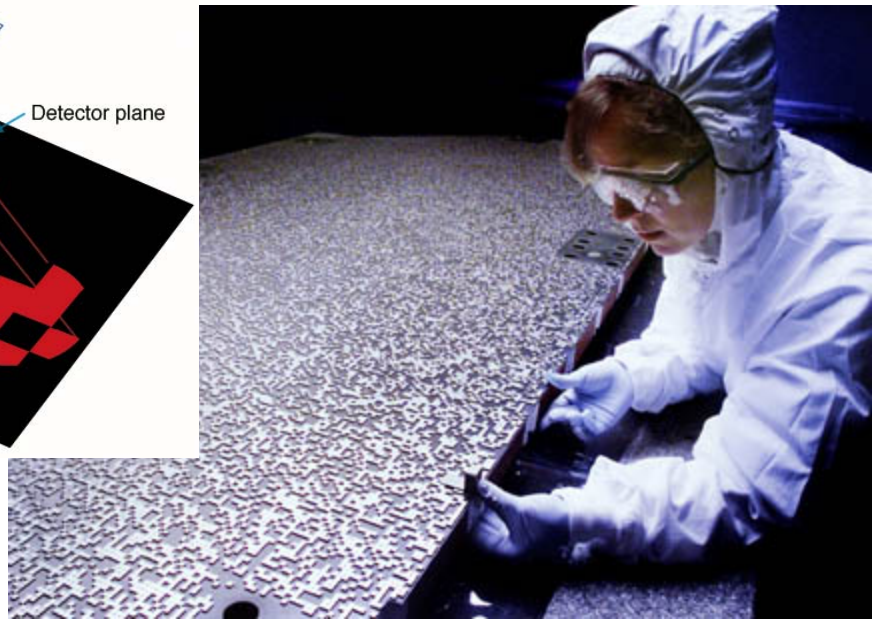


High energy x-rays must skip off the shiny mirror surface at shallow angles to be observed, much different than how optical light telescopes work.

Collecting x-rays is like skipping stones on a pond!

Shadow Play…



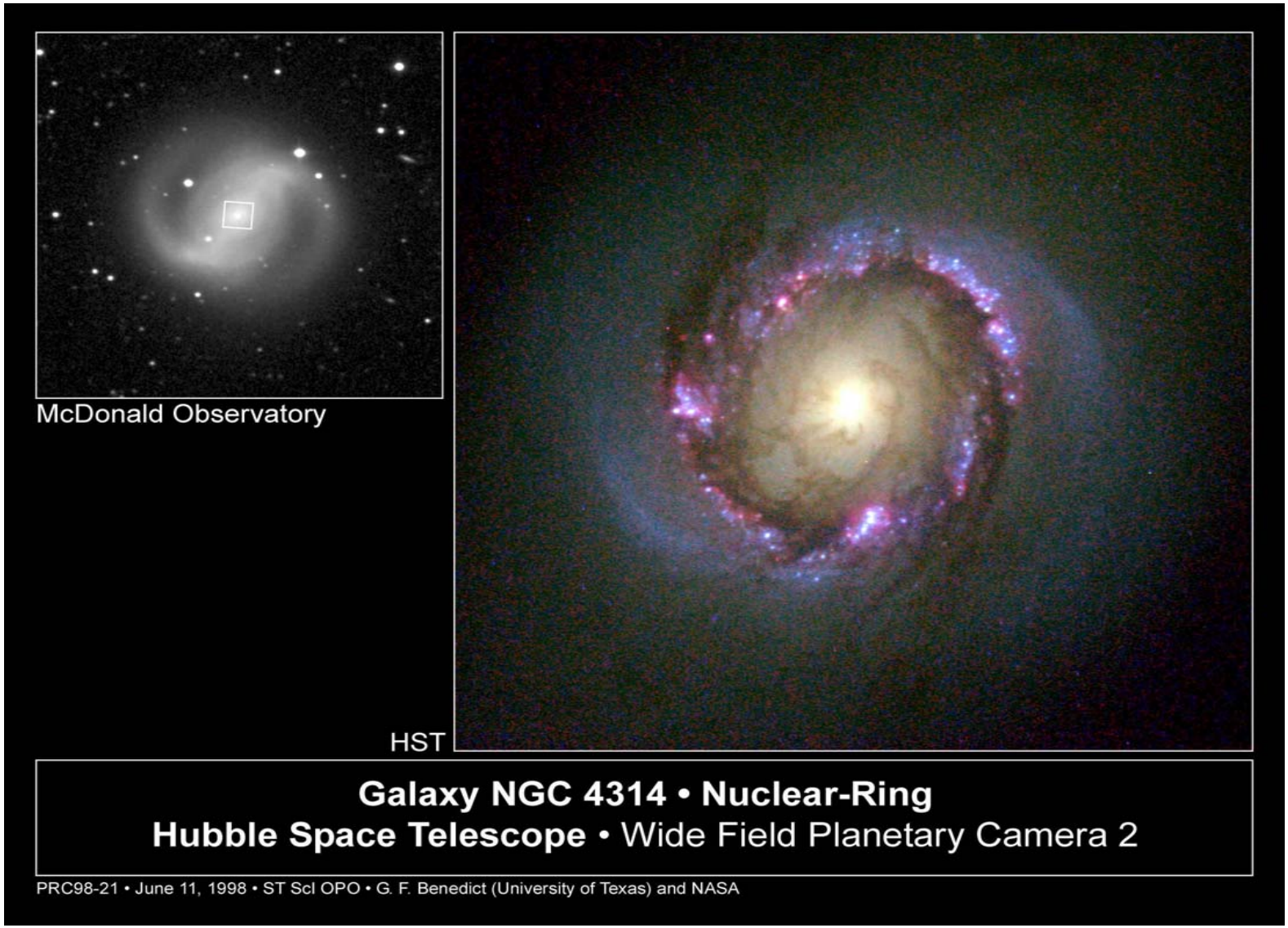


Because gamma rays cannot be focused, **Swift** uses a unique technique that pinpoints the location of a gamma-ray burst by the shadow cast on an array of detectors.

Some current key astronomical problems are really very familiar to everyone

- How high is up?
- How far can we see?
- Have we discovered everything there is to discover?
- Twinkle, twinkle little star how I wonder what you are….?
- How did we get here?
- Where are we going?
- Are there other worlds?
- Is anybody else out there?

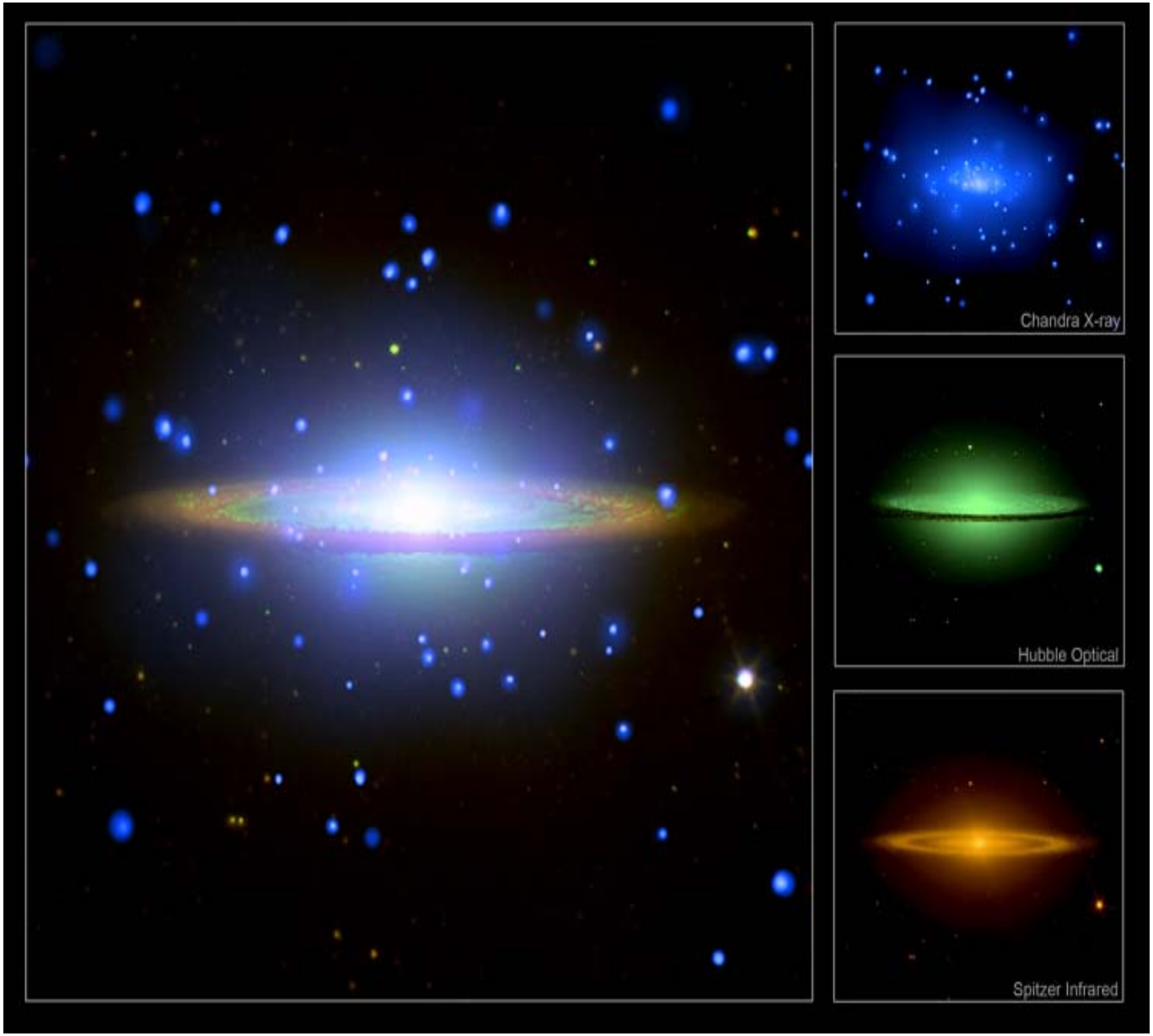
Ultraviolet Images of a Galaxy Clearly Show the Young, Hot Stars



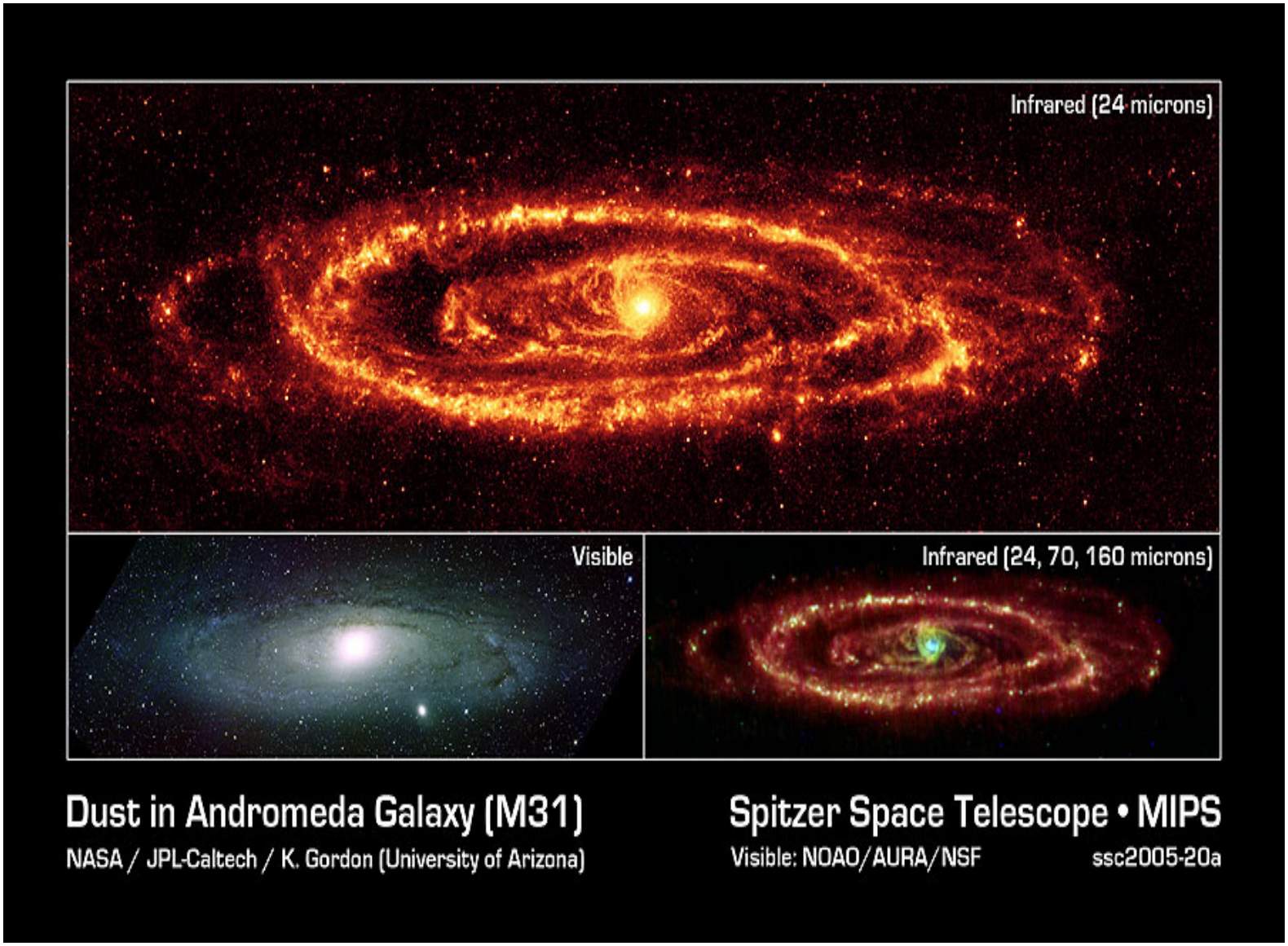
The Sombrero Galaxy as Seen by Hubble and Spitzer

Different wavelengths reveal different components of the galaxy

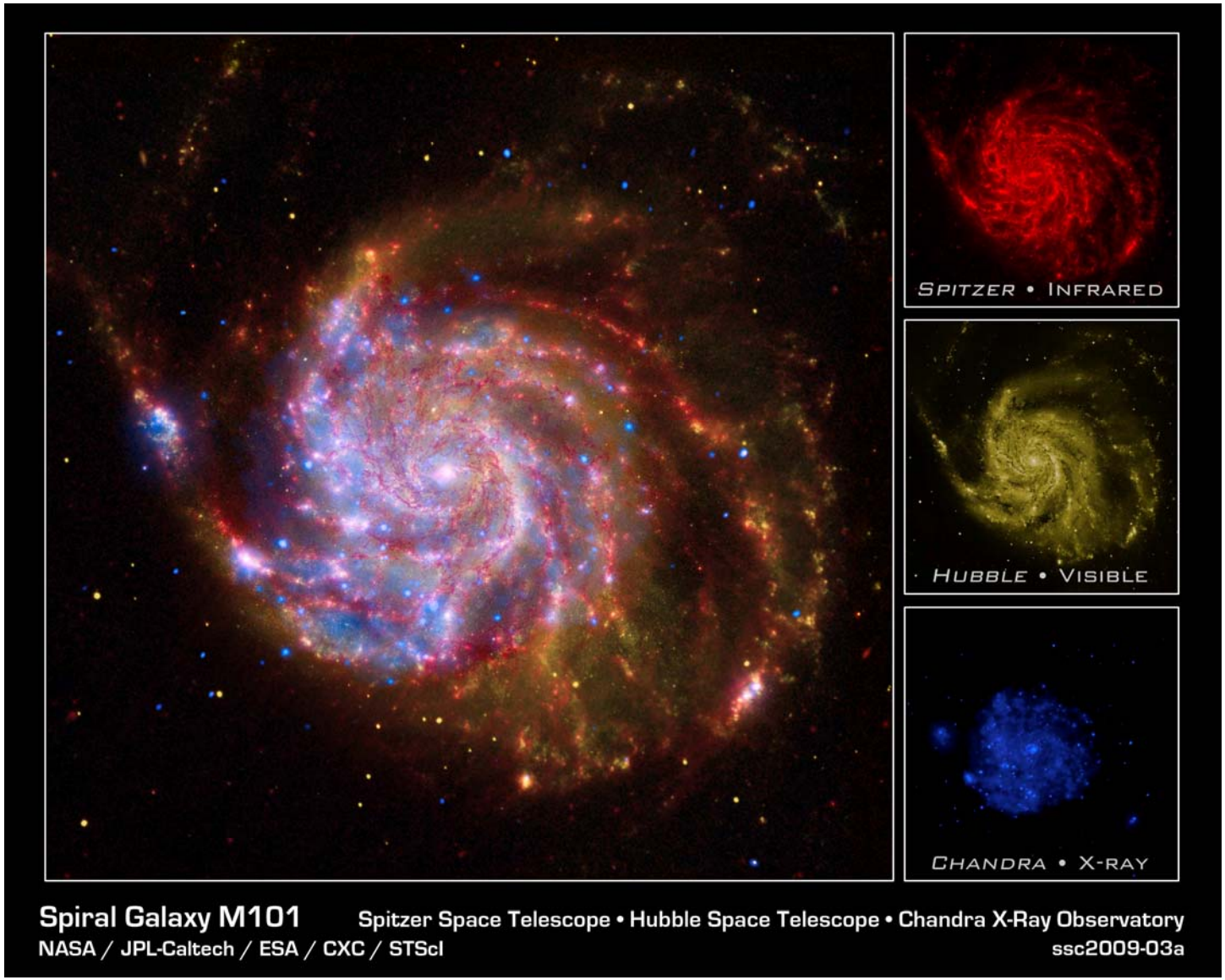
Sombrero Galaxy: X-rays show distant quasars everywhere in the field



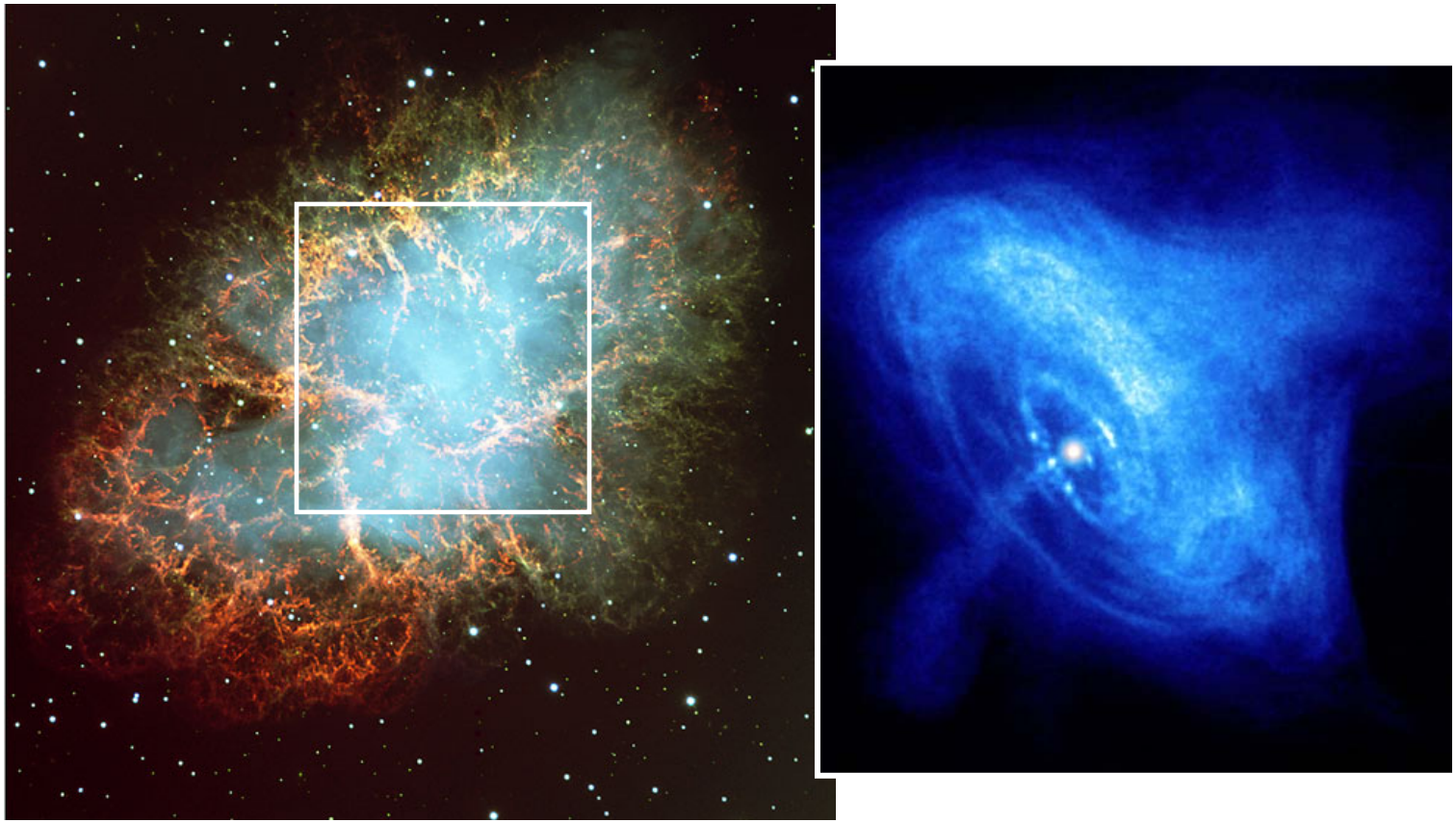
Infrared measurements in Andromeda clearly reveal the hot dust



Multi-wavelength observations reveal a wide variety of phenomena

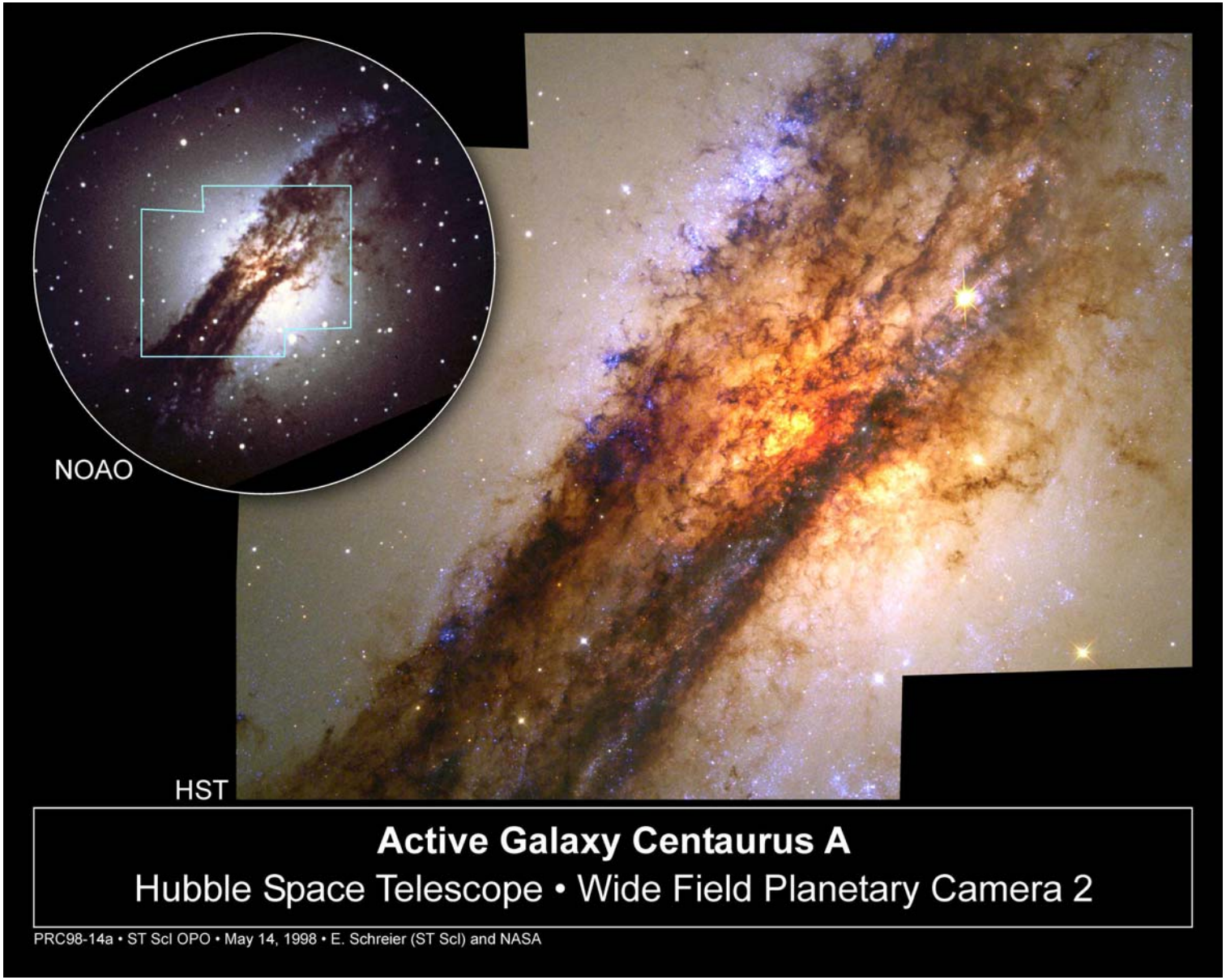


The Crab Nebula: The Aftermath of a Supernova

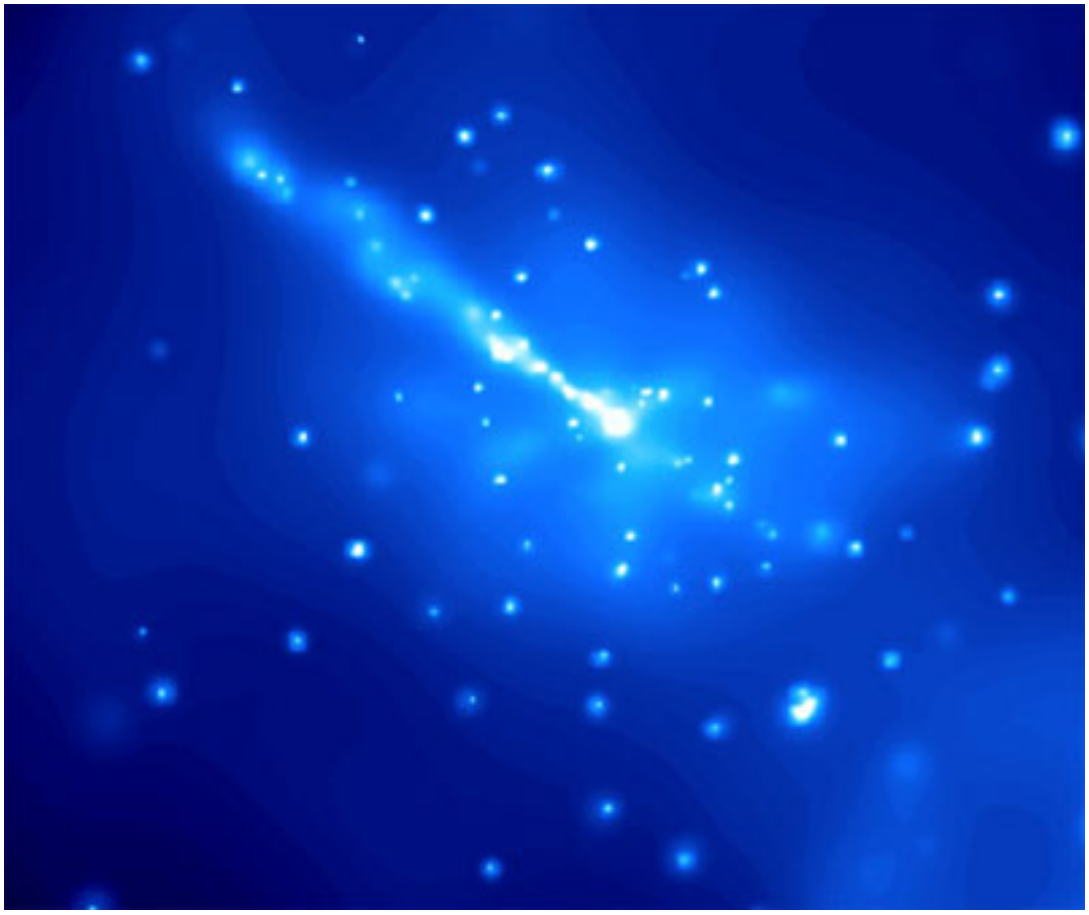


The Crab Nebula is all that remains of a once-bright star.
The white box on the left shows the area covered by the image on the right.

The Radio Galaxy Centaurus A

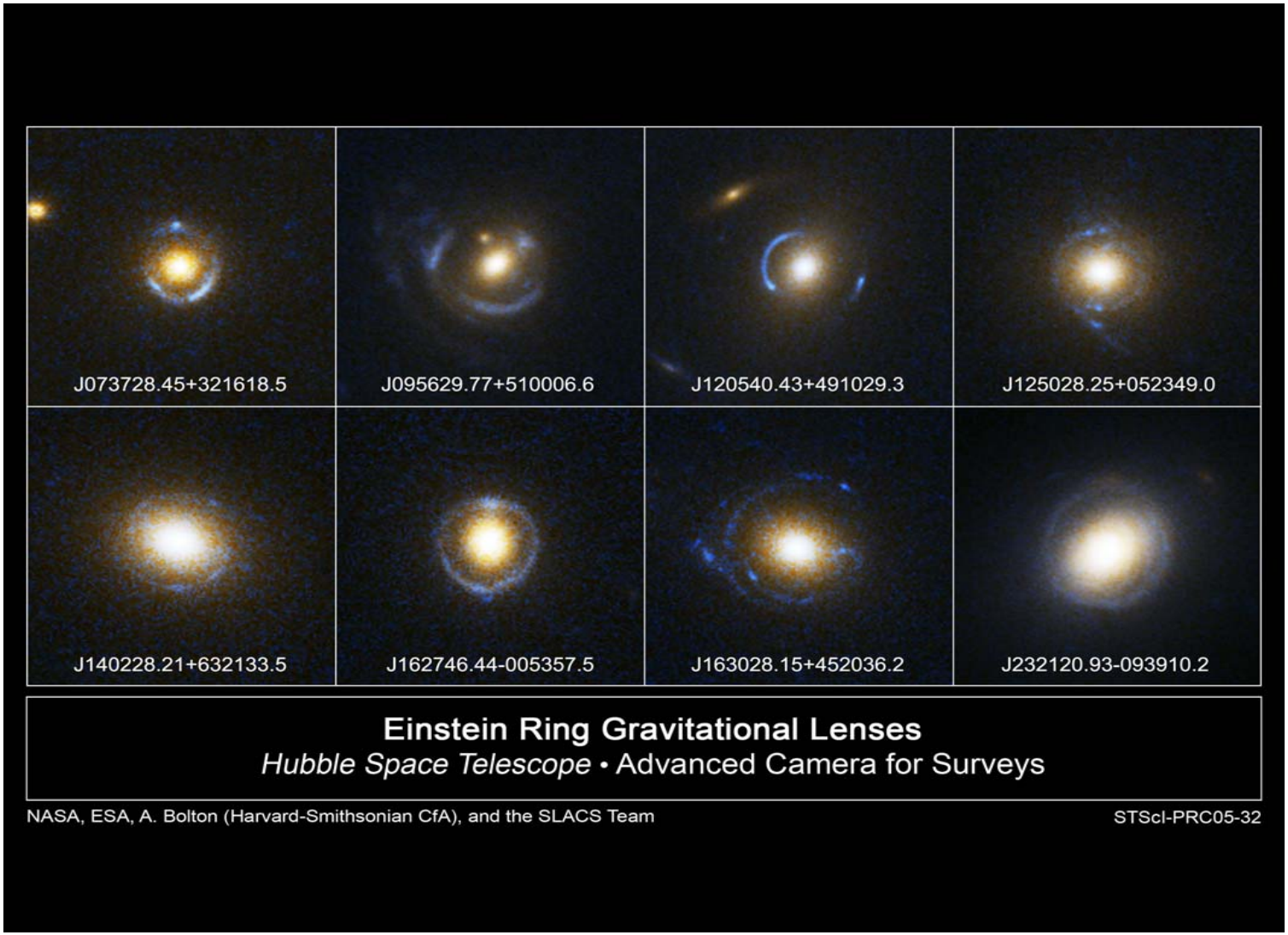


X-rays Reveal the Real Action!

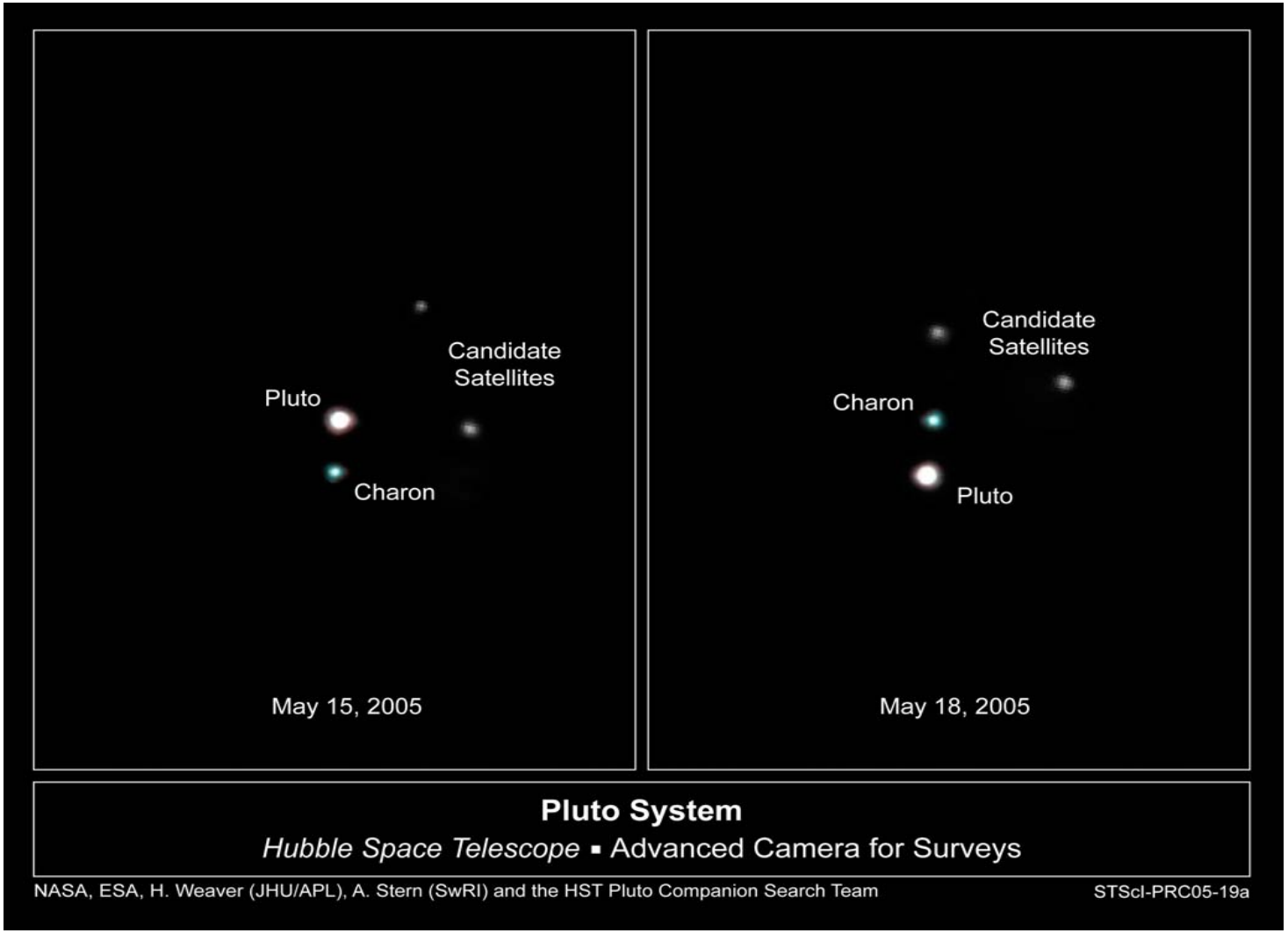


A high-energy jet blasts outward from the galaxy's center,
evidence for a powerful black hole with the mass of one billion Suns!

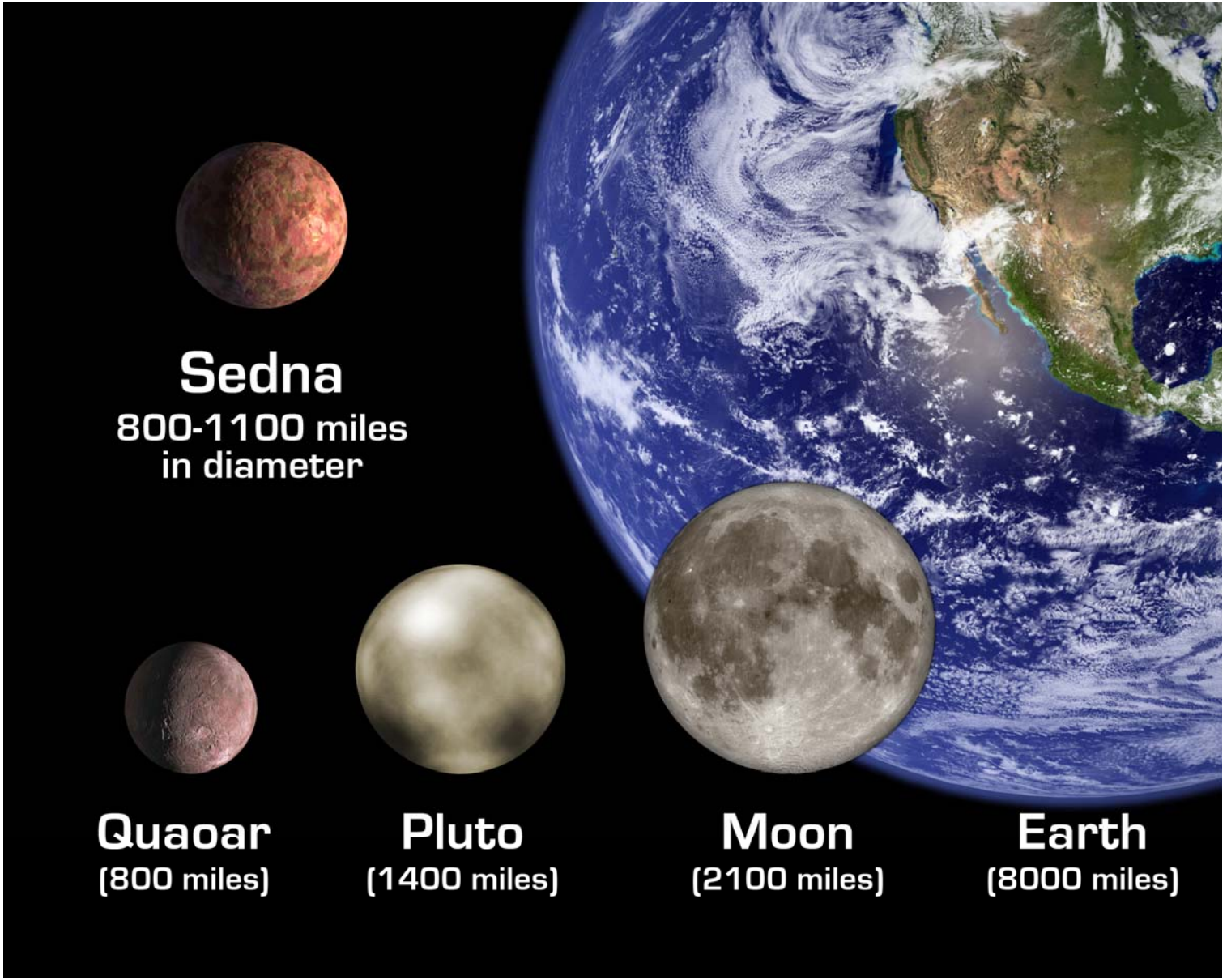
The ability to detect faint features reveals new phenomena



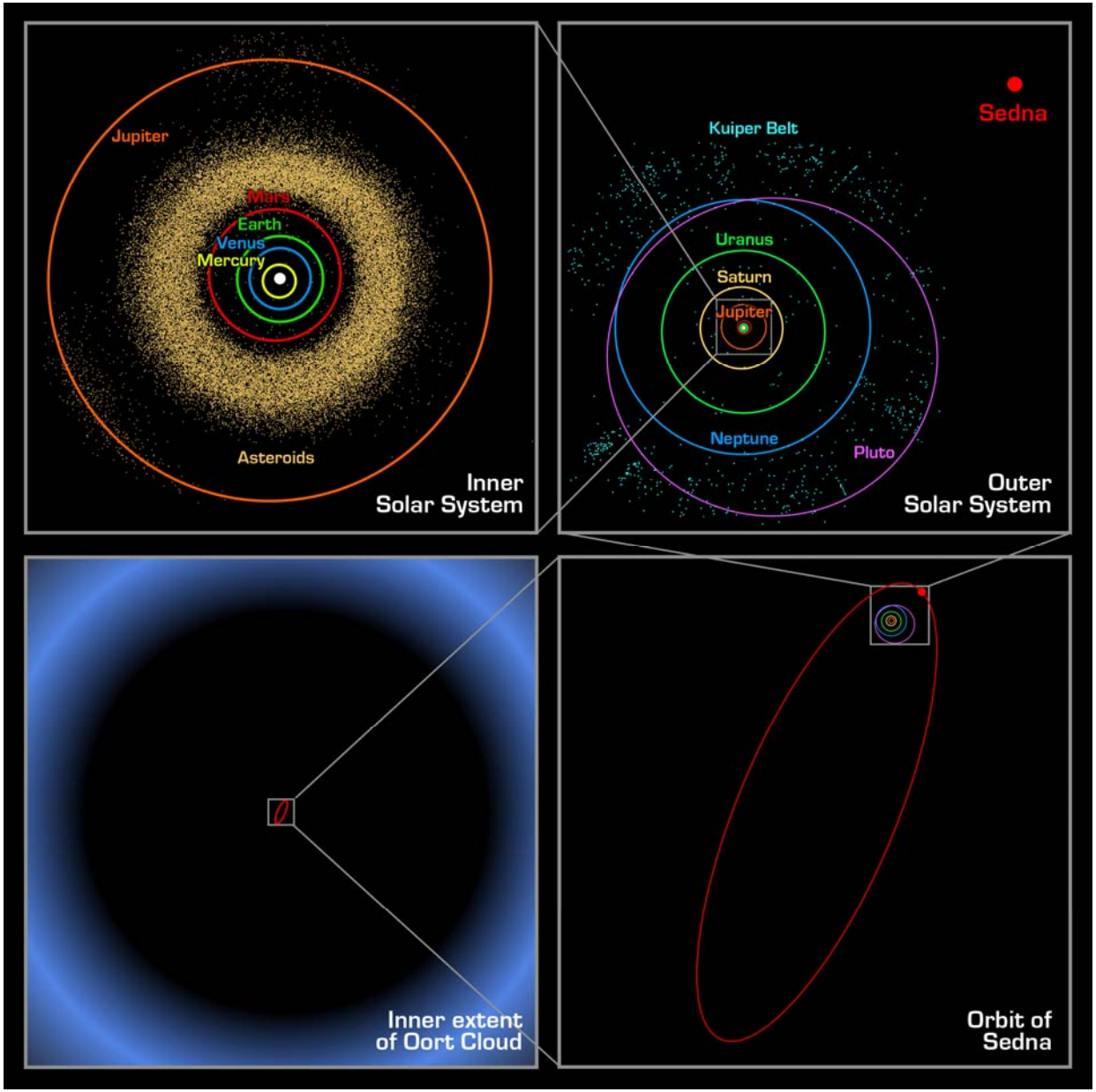
Seeing Faint Objects is Crucial…
As is Taking a Time Sequence of Images



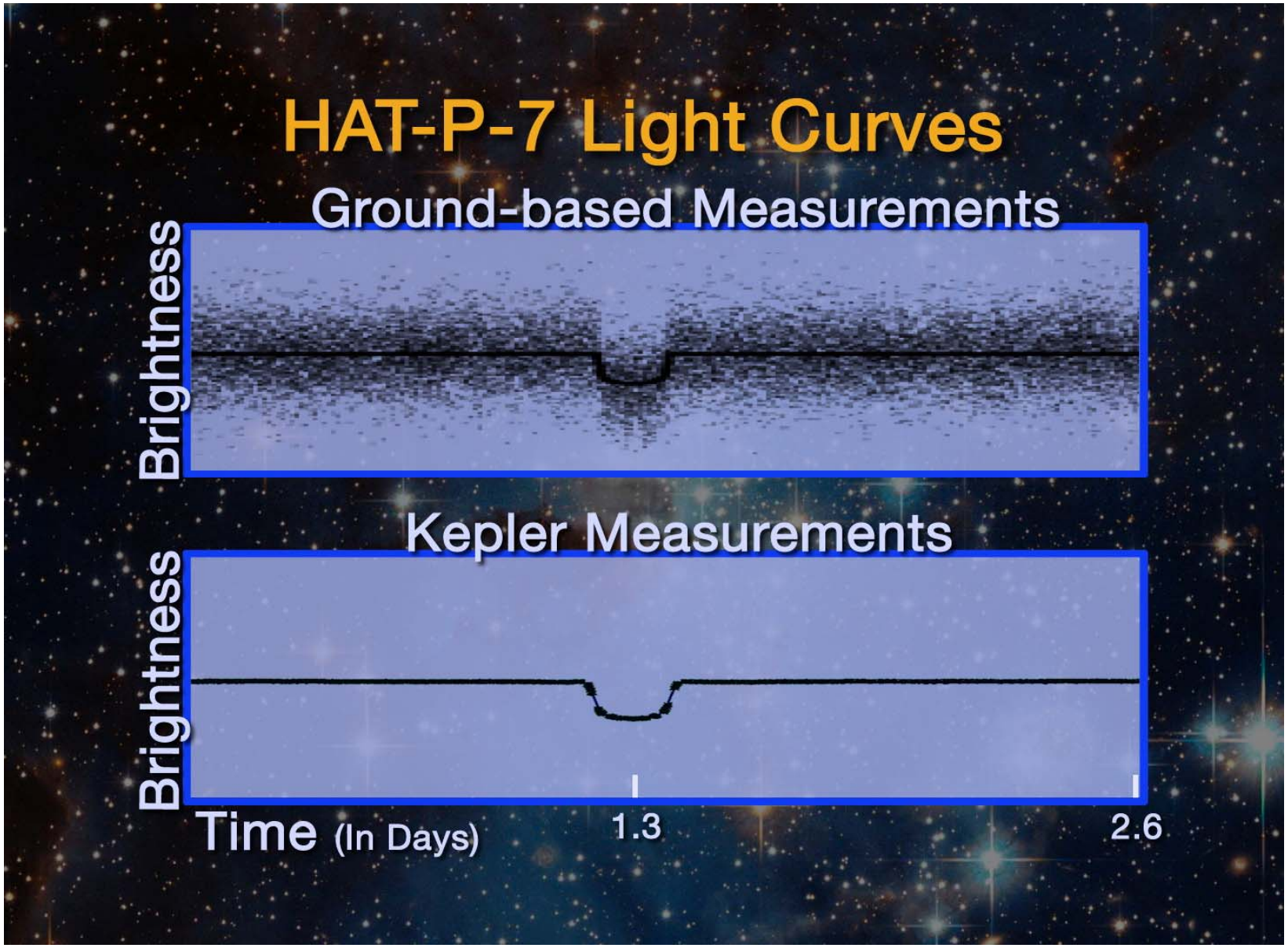
The ability to detect faint objects leads to new discoveries--even in our local neighborhood



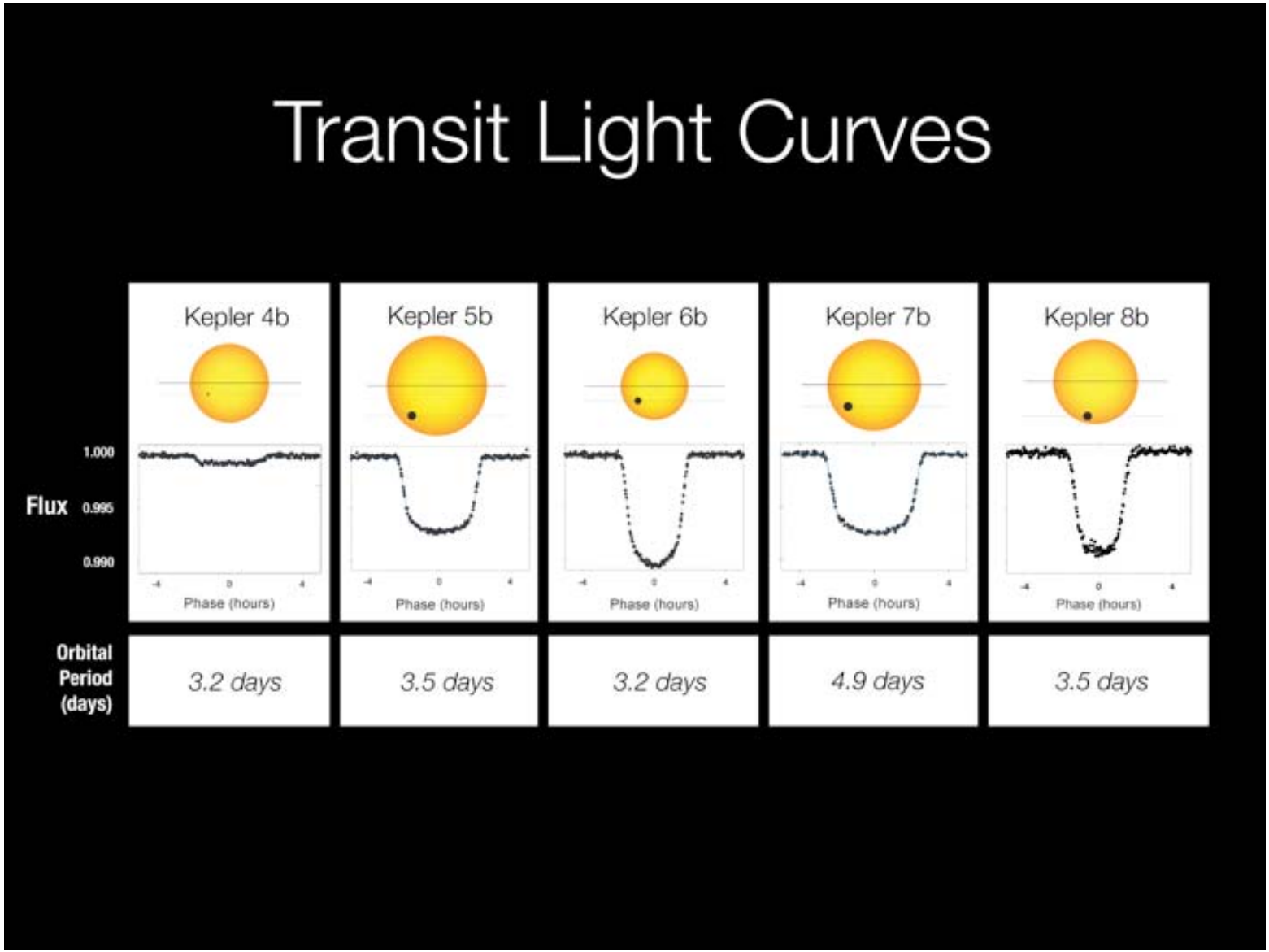
The outer solar system contains a lot of objects-- we just haven't seen most of them yet



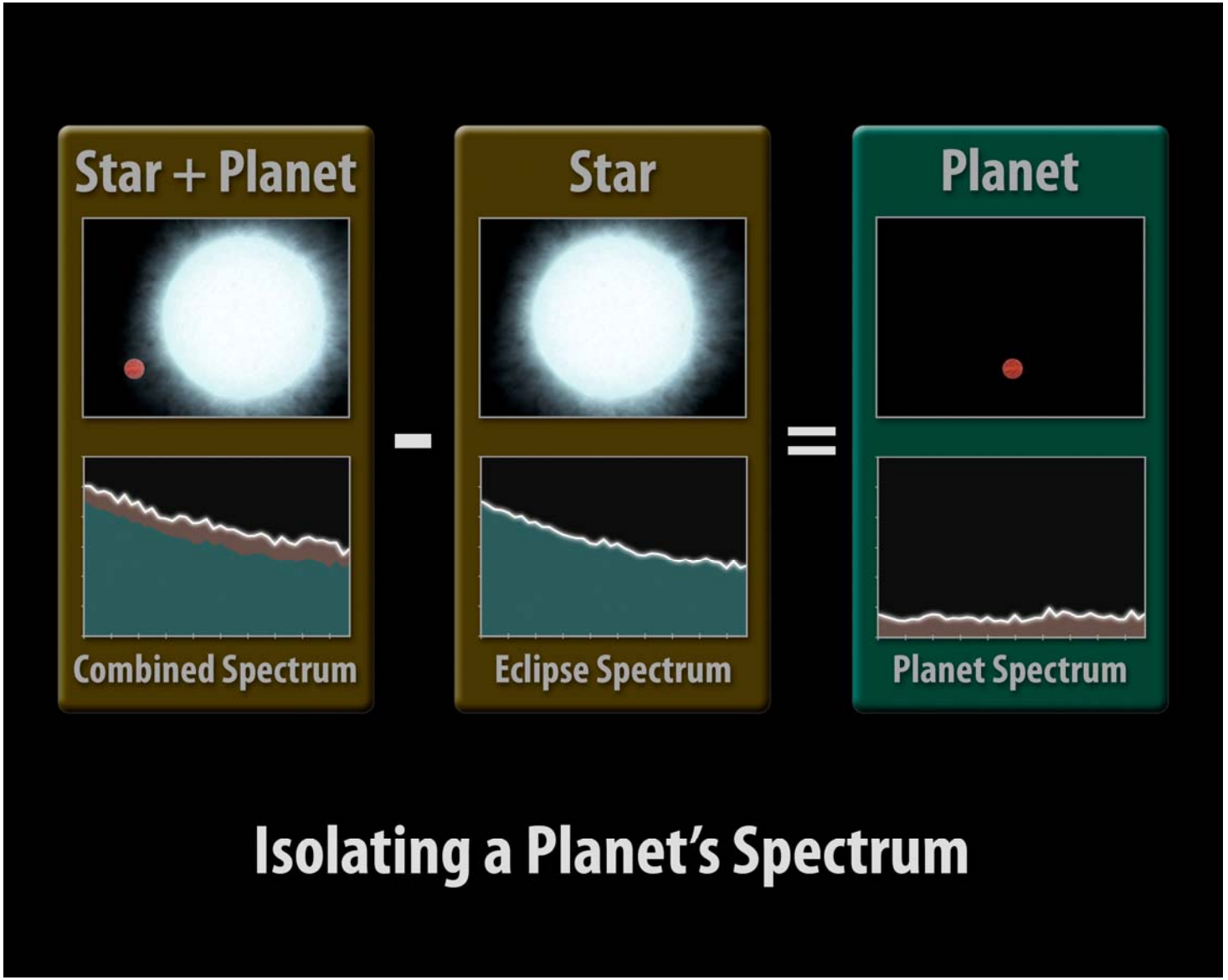
New Instrumentation and detectors allow measurements of unprecedented precision



The Kepler mission should detect hundreds of new planetary systems during the next few years



It will actually be possible to study the atmospheres of newly discovered planets



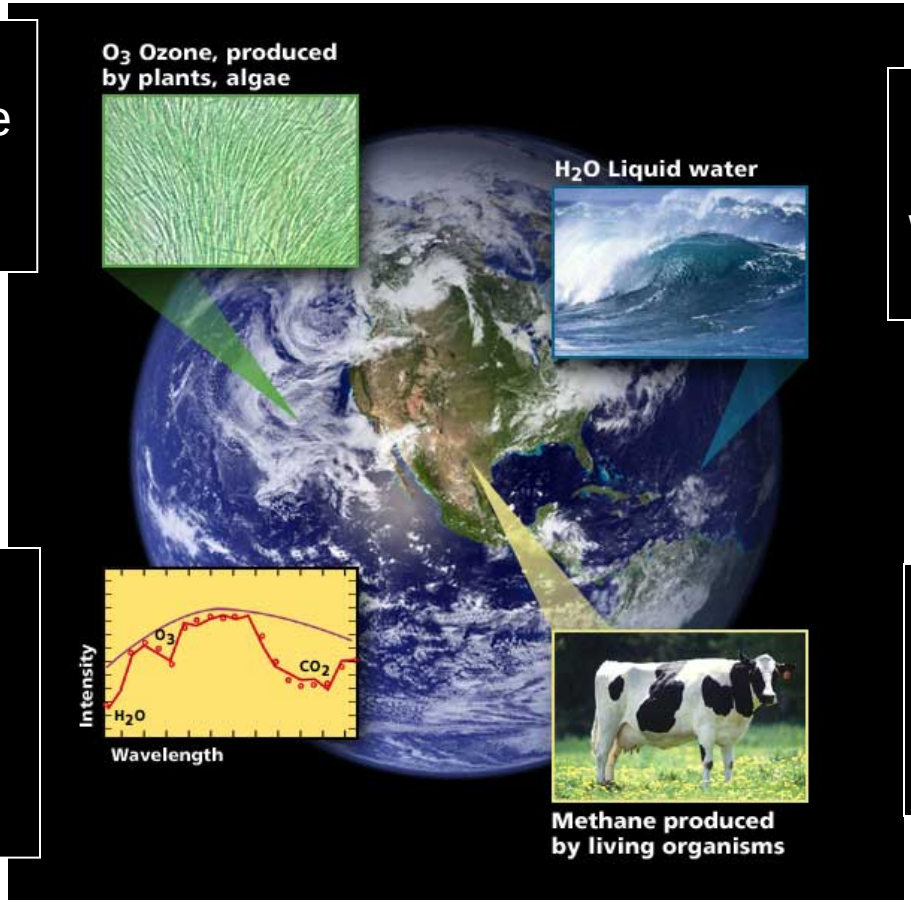
How will we know whether a planet supports life?

Look for evidence of oxygen

Look for liquid water

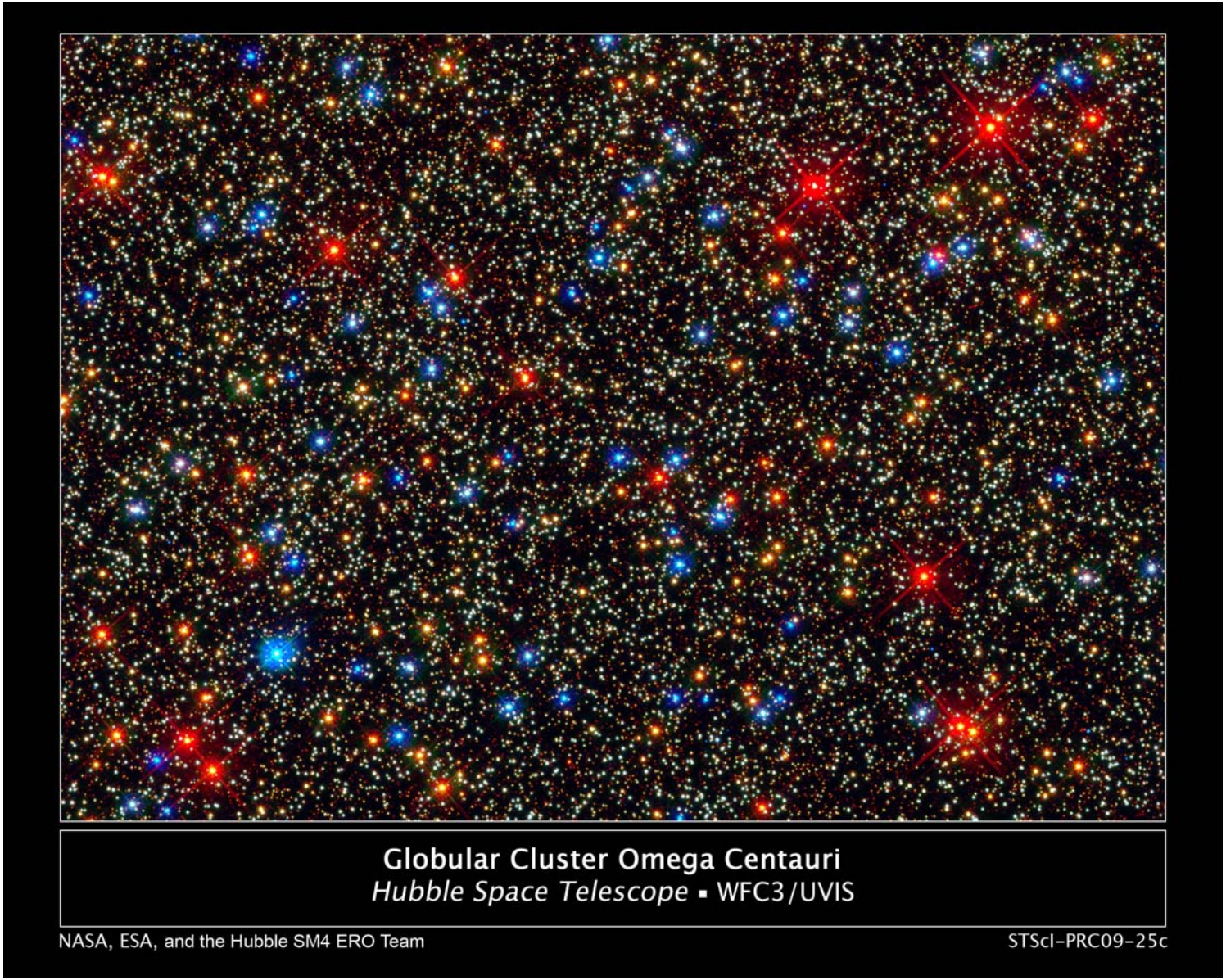
Analyze the reflected light from the planet to see if the planet has an atmosphere

Look for signs of biological activity (methane)

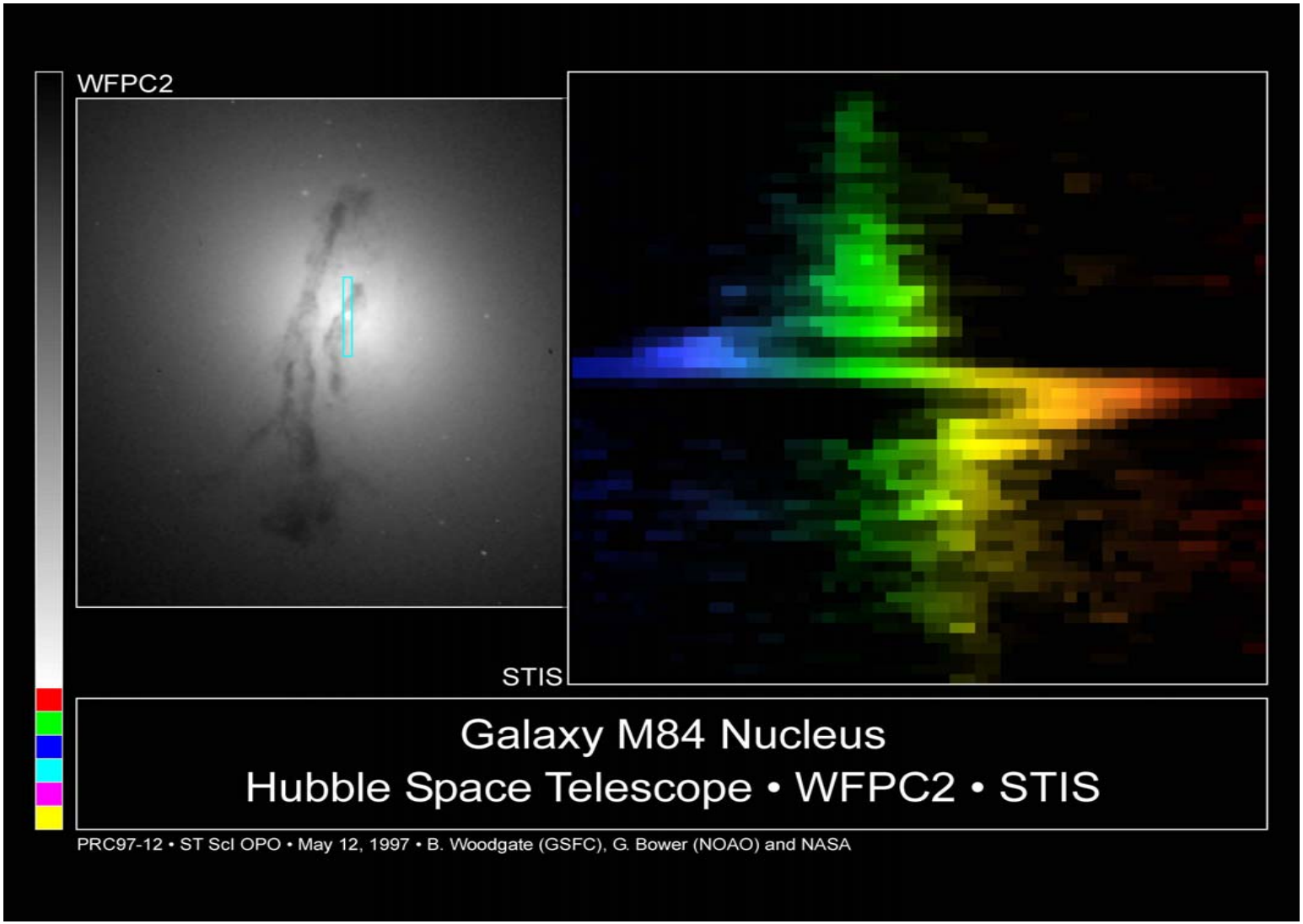


and rule out other explanations.

The fine details count:
Peering into the heart of a globular cluster

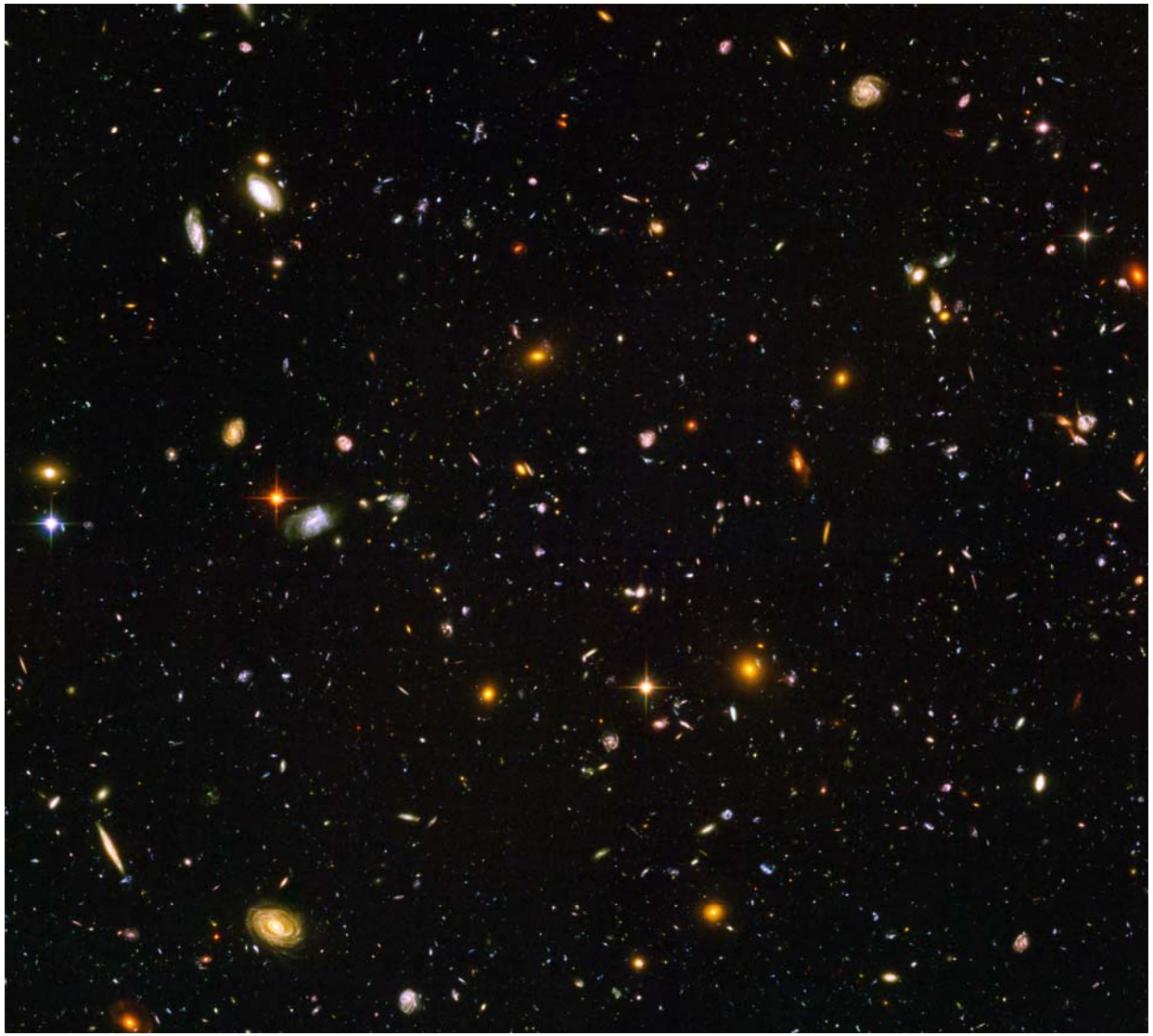


Spatially resolved spectroscopy reveals the presence of a Black Hole

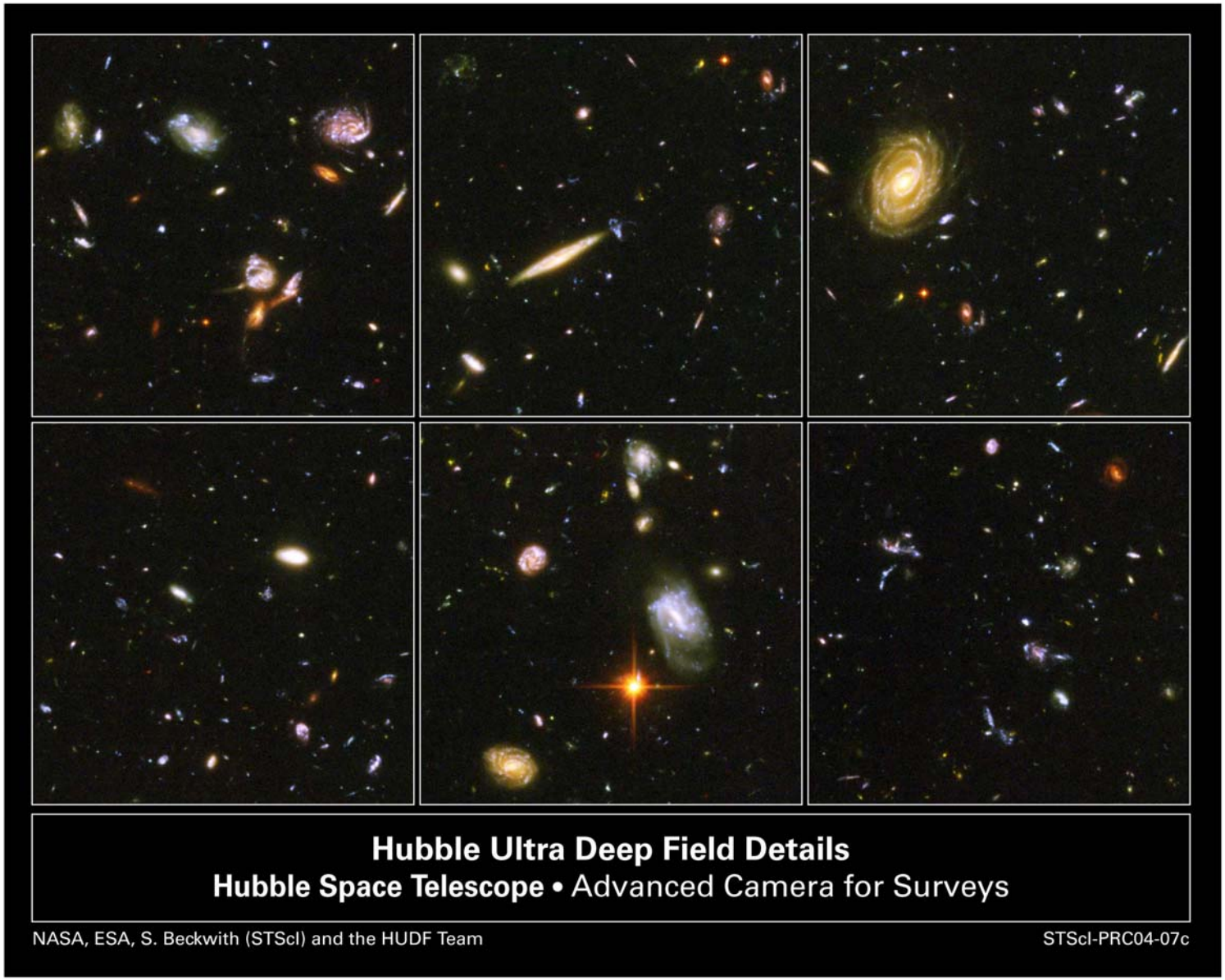


Multi-wavelength observations towards the center of our own galaxy clearly reveal the hot gas swirling into a massive black hole as well as intense star formation activity

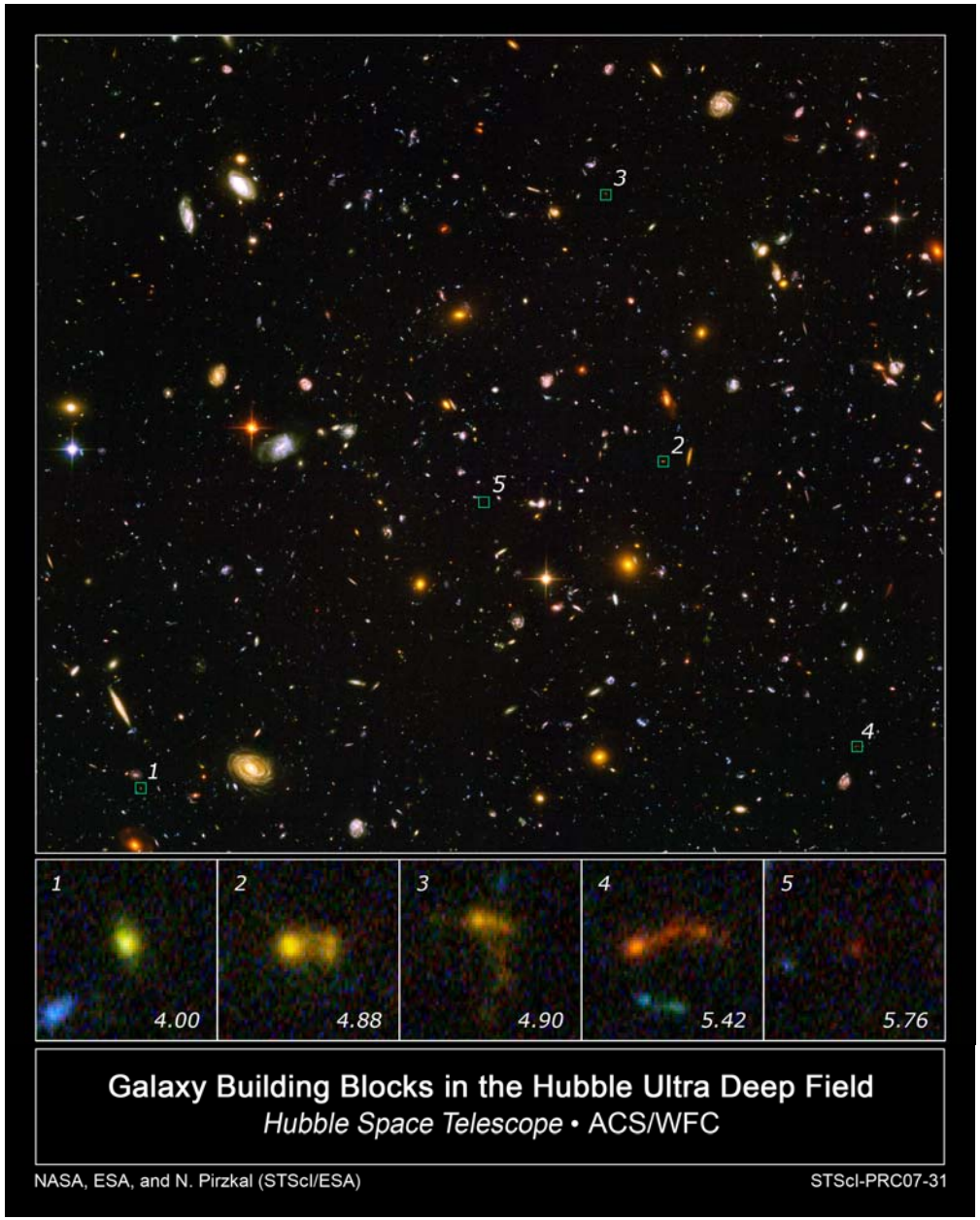
Sometimes, just thinking about the meaning of what you are looking at can be very powerful



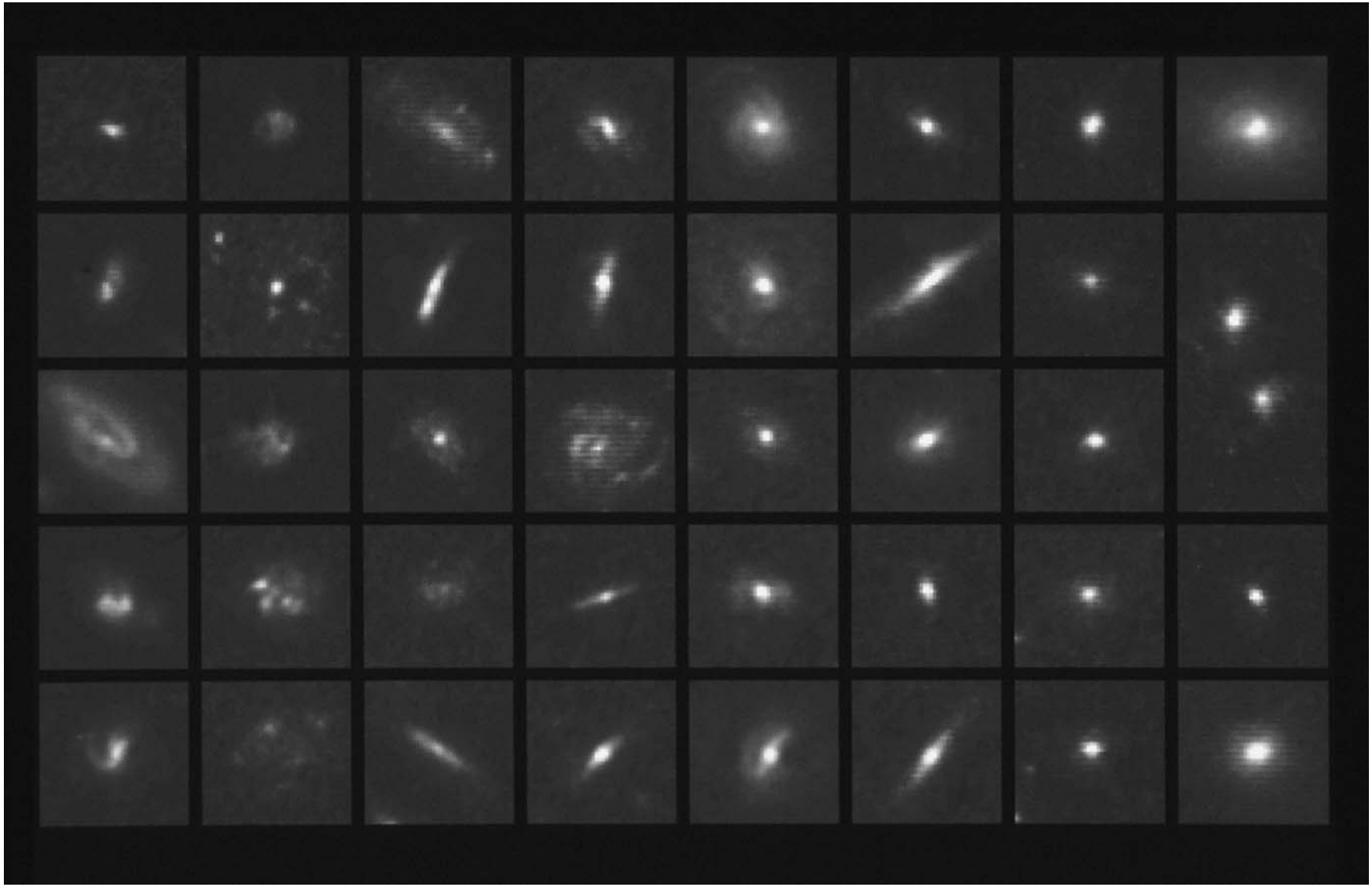
The galaxies start to look less structured as you zoom farther in to the Hubble Ultra Deep Field



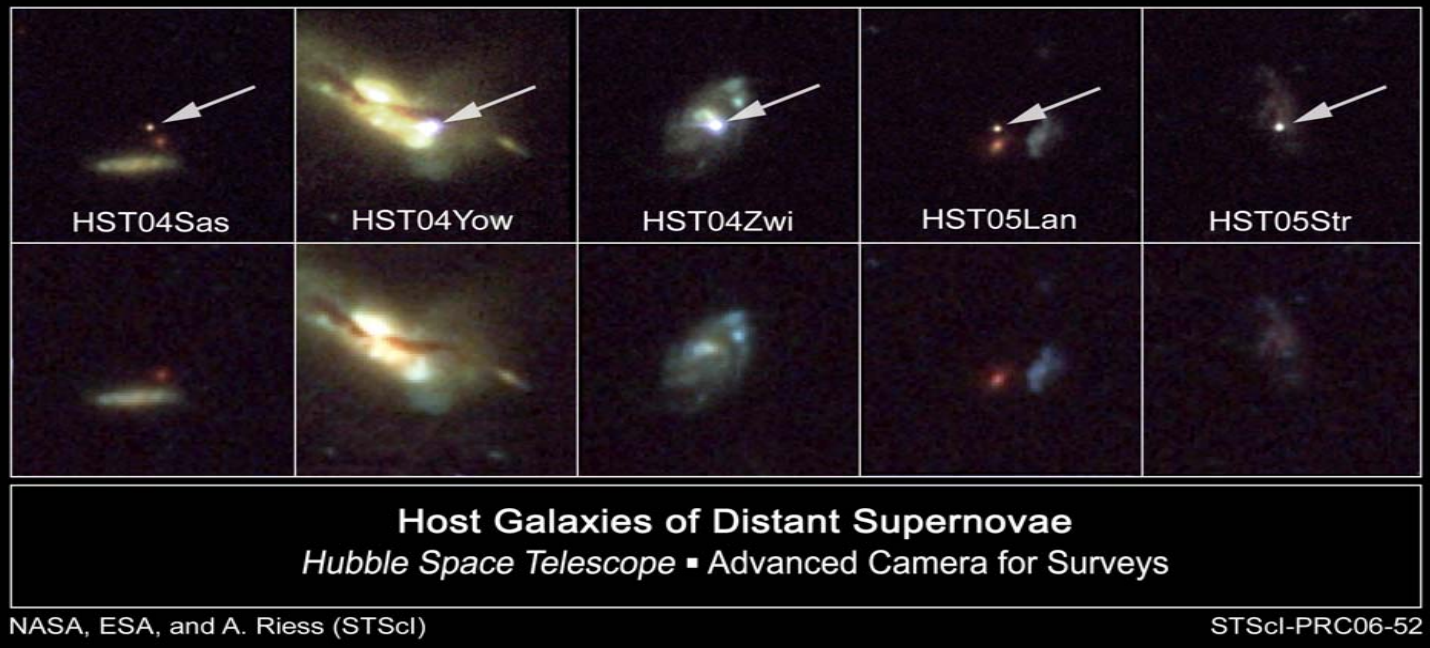
Galaxies in the ancient universe were different



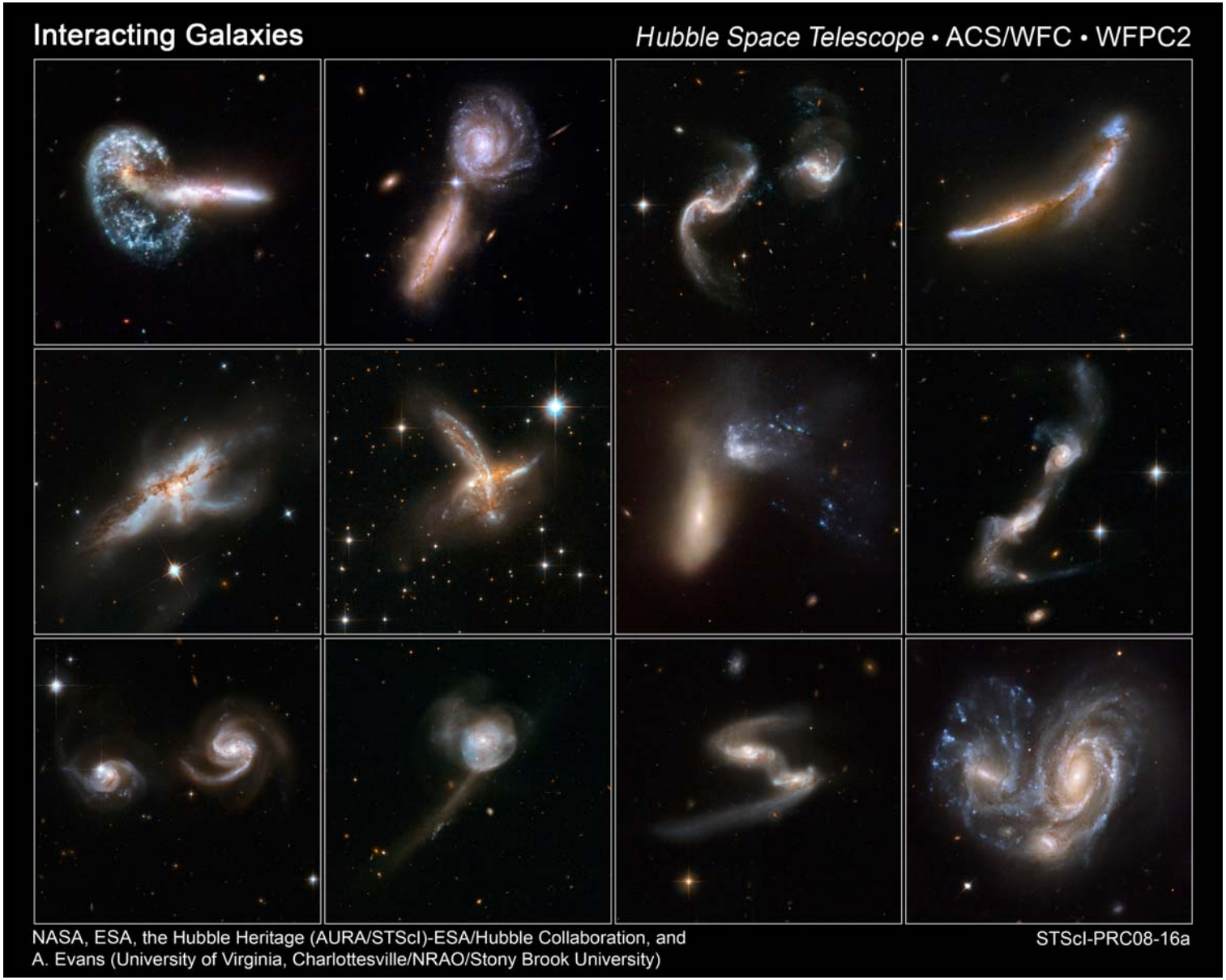
A collage of ancient galaxies



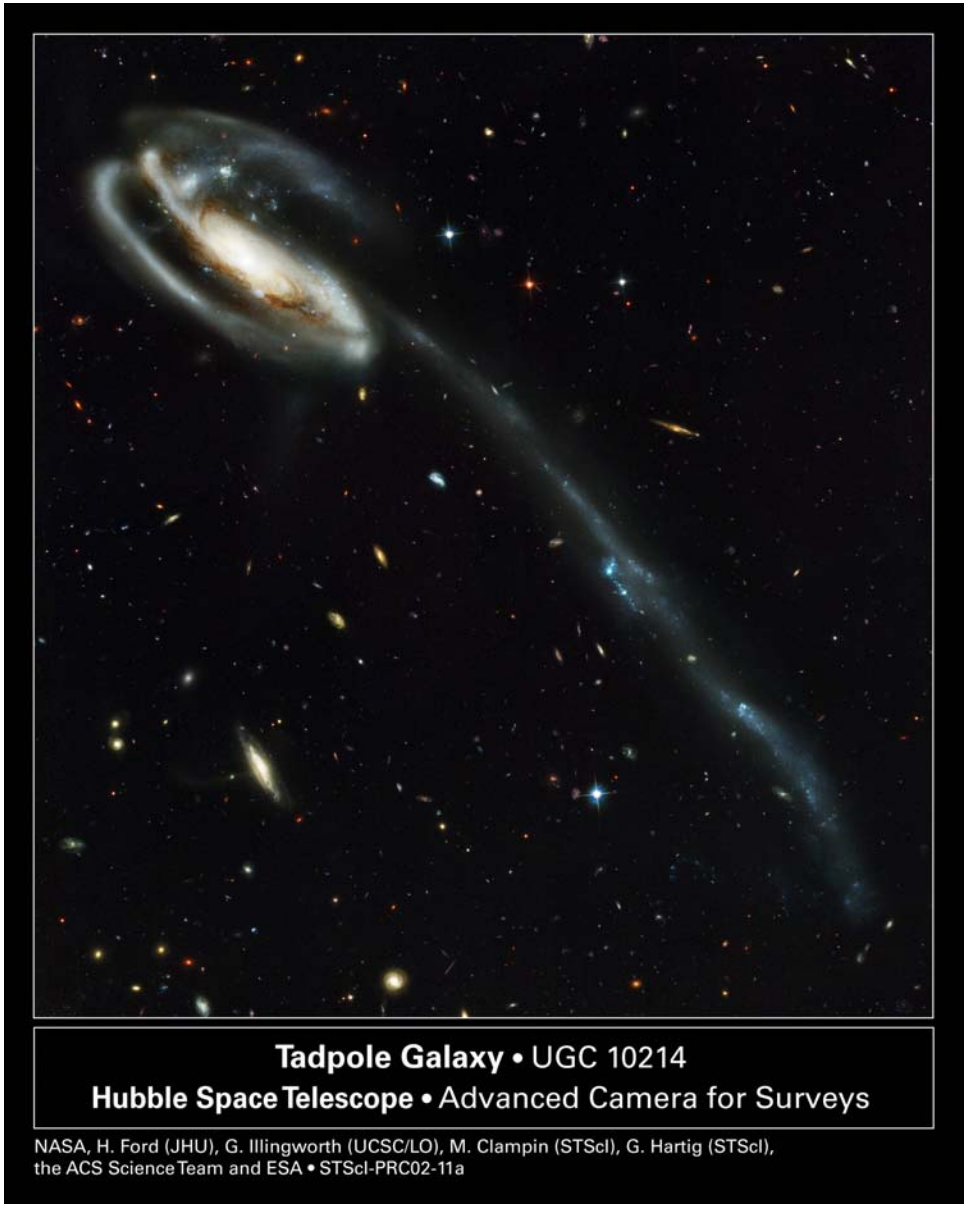
Supernovae: Titanic Stellar Explosions



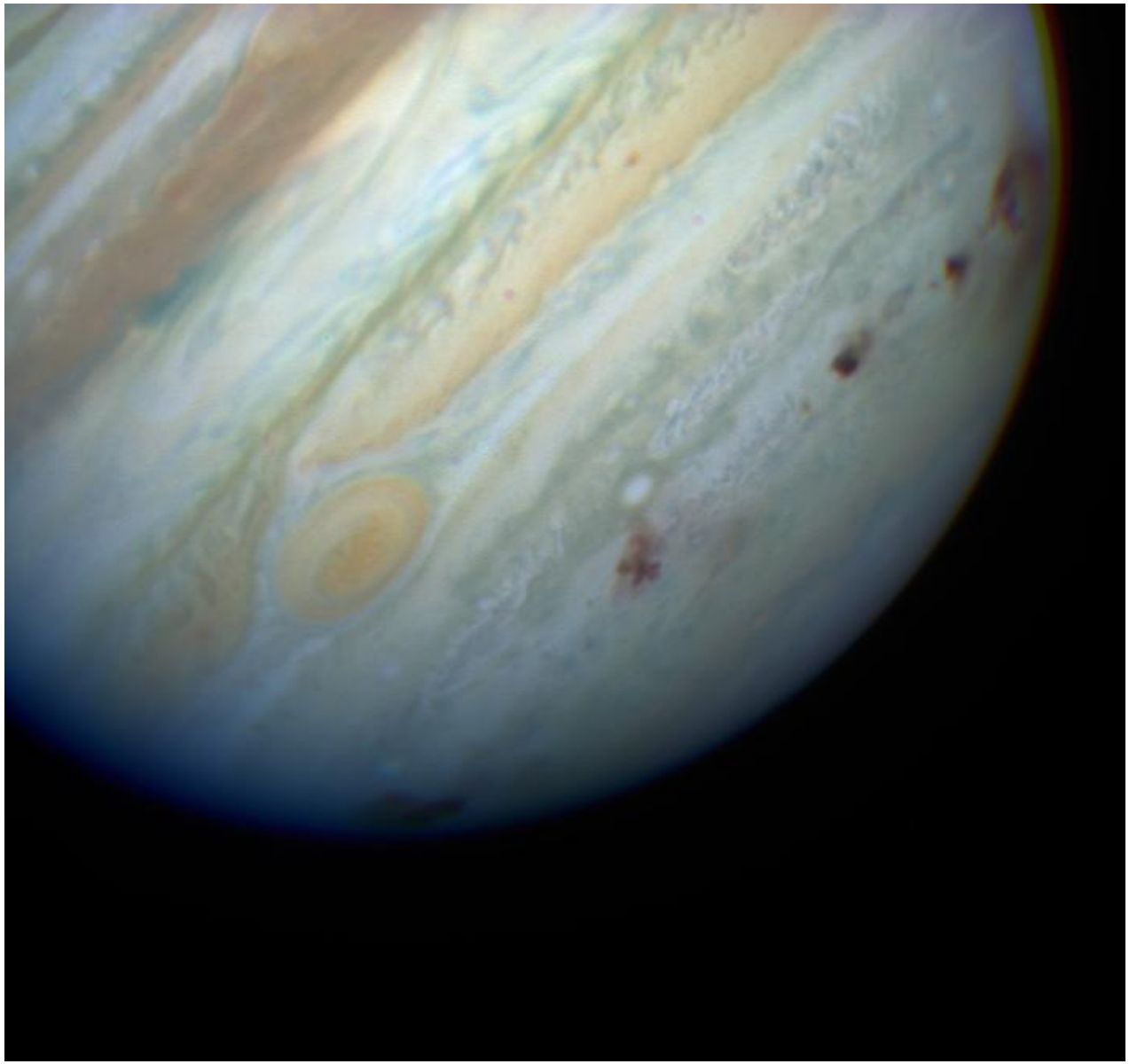
Collisions have been a key element in the history of the universe



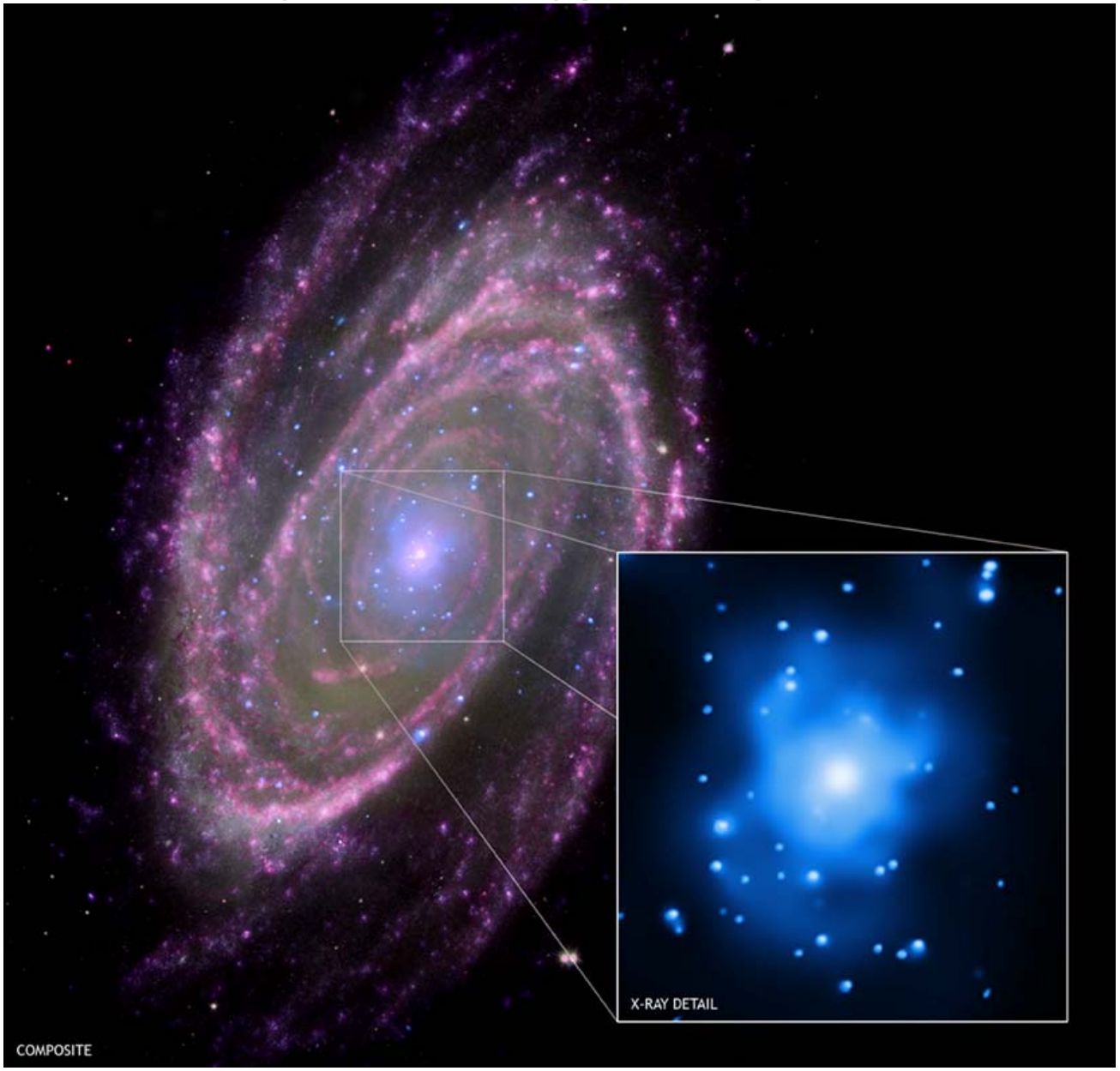
Collisions between galaxies create complex and beautiful structures



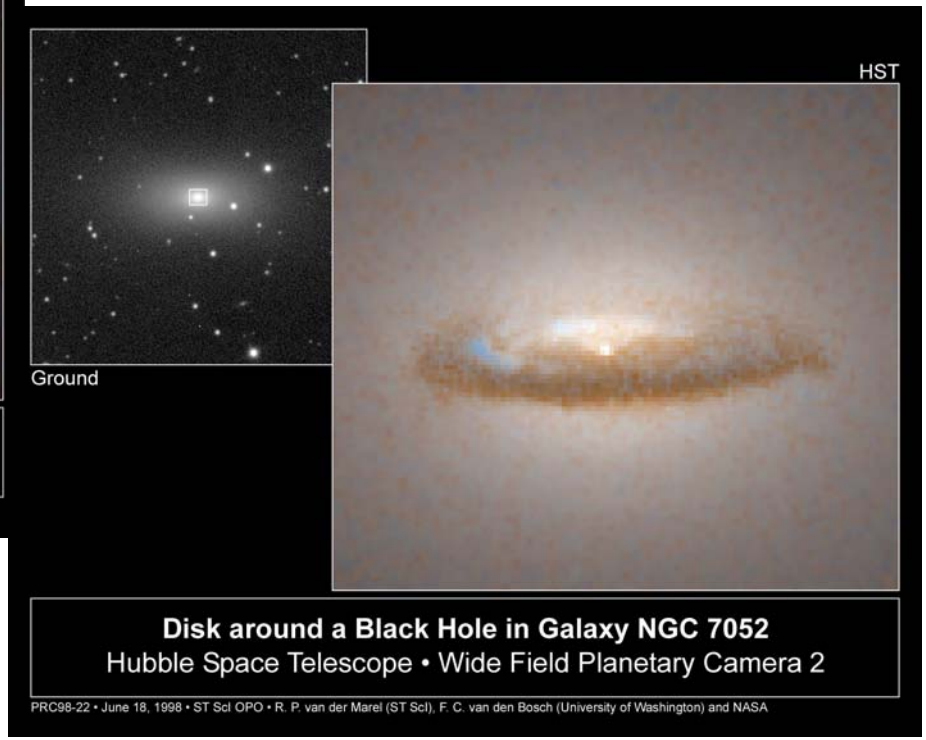
Comet Shoemaker-Levy at Jupiter: Collisions Still Happen



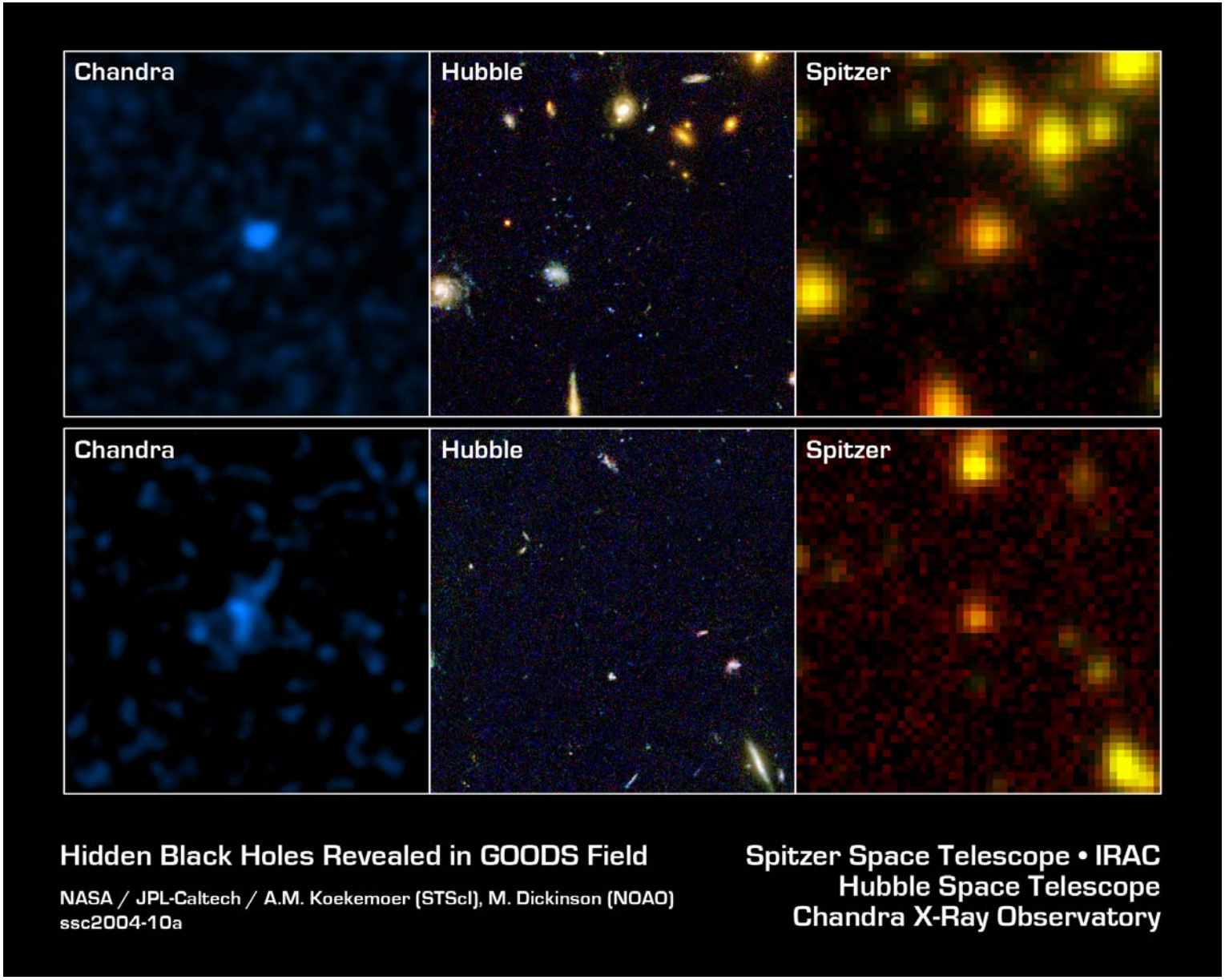
Supermassive Black Holes are found in the cores of many different types of galaxies



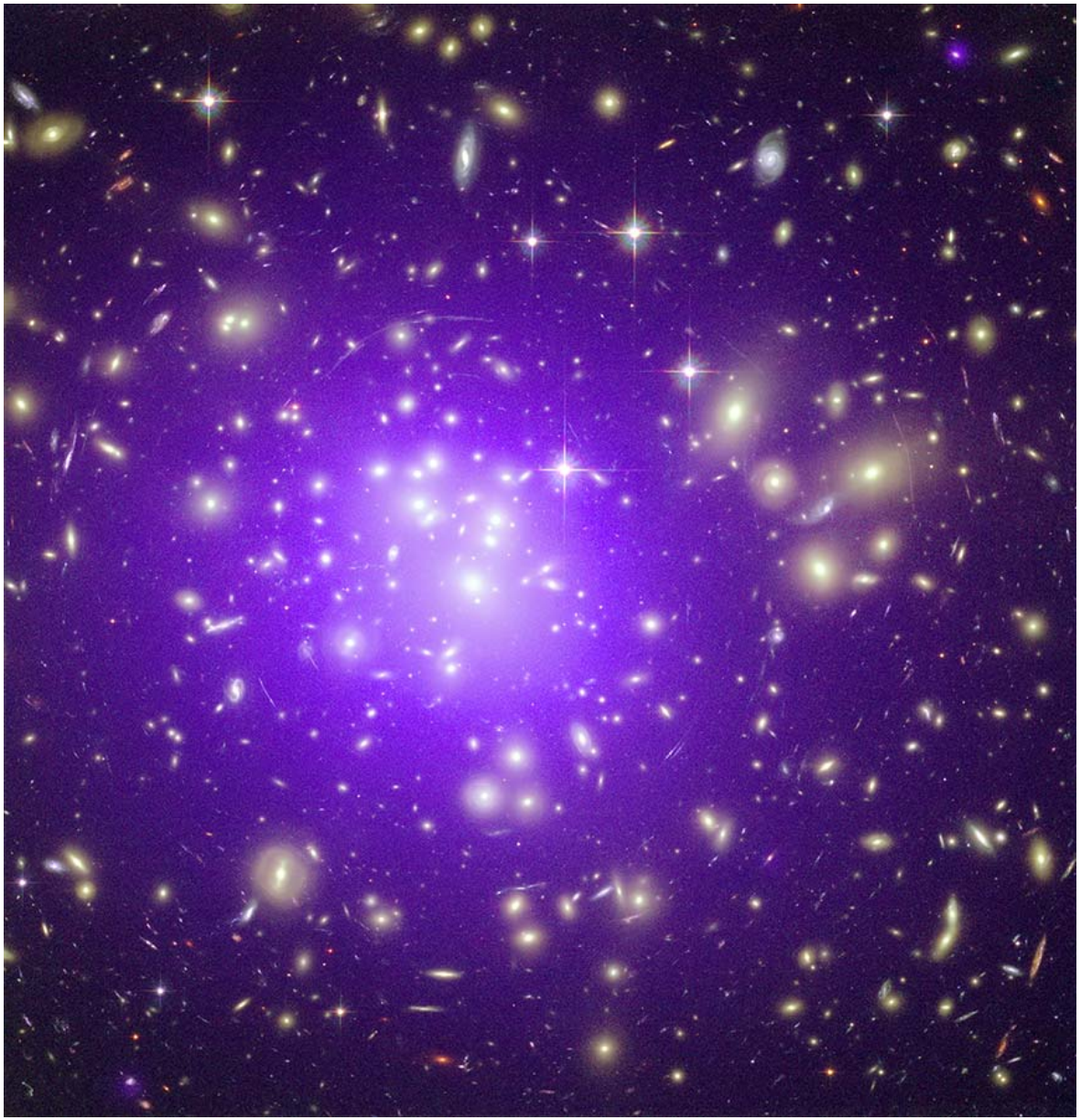
The existence of supermassive Black Holes unifies our understanding of why many types of active galaxies behave the way they do



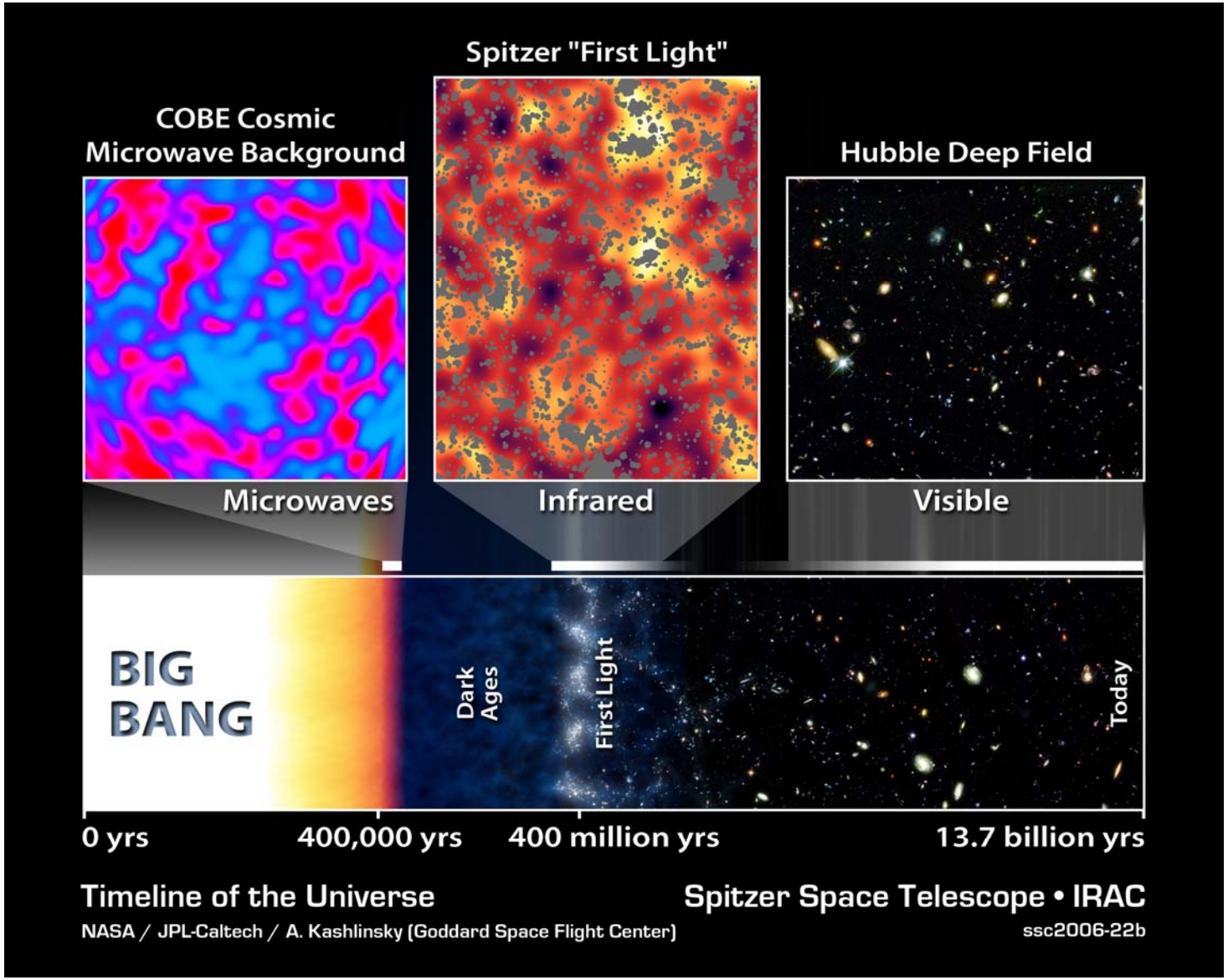
Infrared observations reveal the distant host galaxies for supermassive black holes



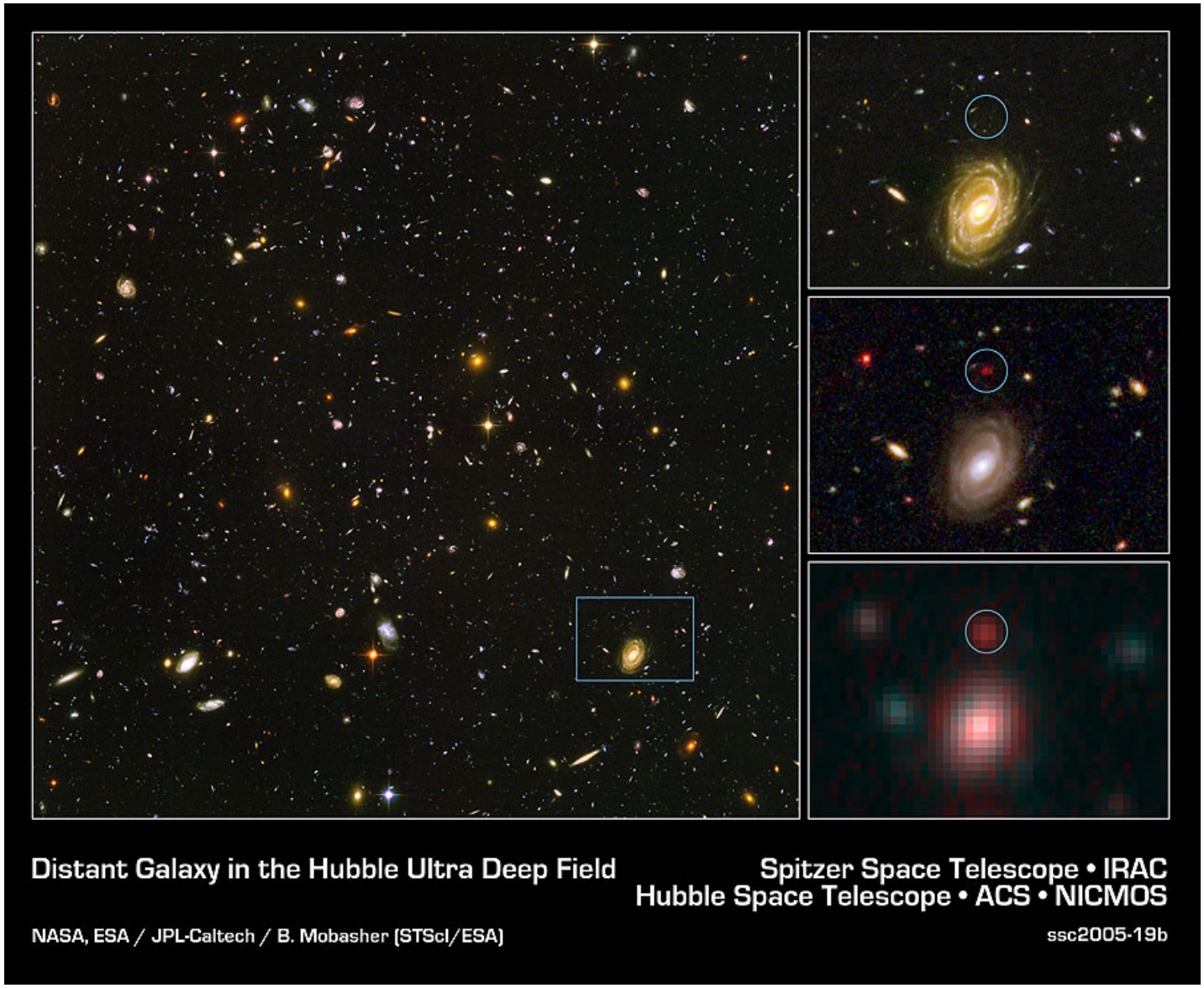
Frequently your eyes only tell a small part of the story:
Hot gas in a cluster of galaxies



The Timeline of the Universe



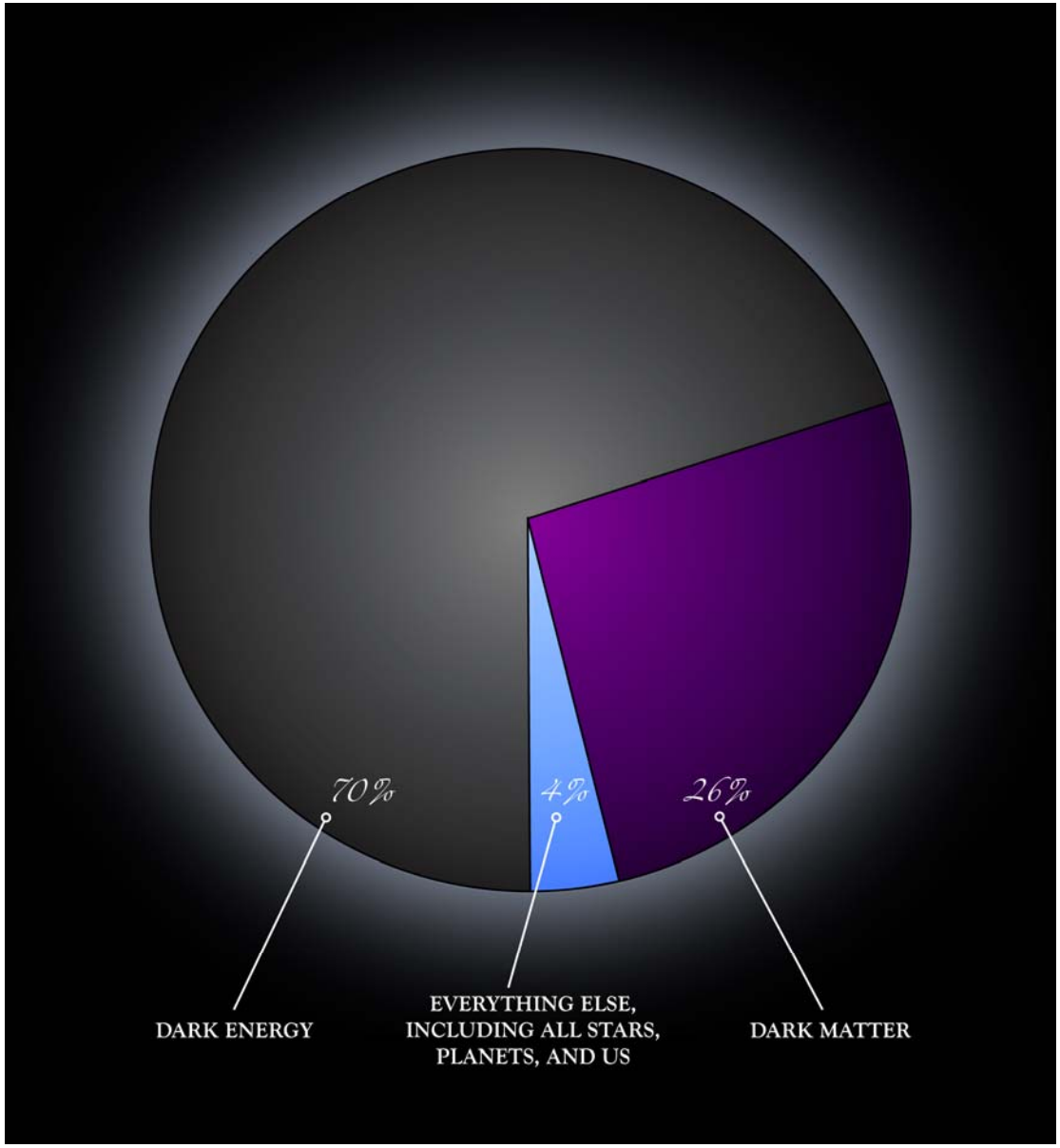
Infrared measurements reveal distant galaxies in the Hubble Ultra Deep Field



New telescopes will look back to the era when galaxies first formed

The **James Webb Space Telescope** will continue **Hubble's** legacy with more light collecting capability in a less massive package, resolving the mysteries of our universe from above the confines of Earth!

The puzzle is still incomplete--we only see a small fraction of the mass and energy in the Universe



Observatory: A place where astronomers gather to conjecture about the guesses of their predecessors.

Ambrose Bierce
The Devil's Dictionary
1911