

The Most Powerful Space Telescope Ever Built Will Look Back In Time To the Dark Ages of the Universe



Hubble took pictures of the oldest galaxies it could – seen here – but the James Webb Space Telescope can go back much farther in time.

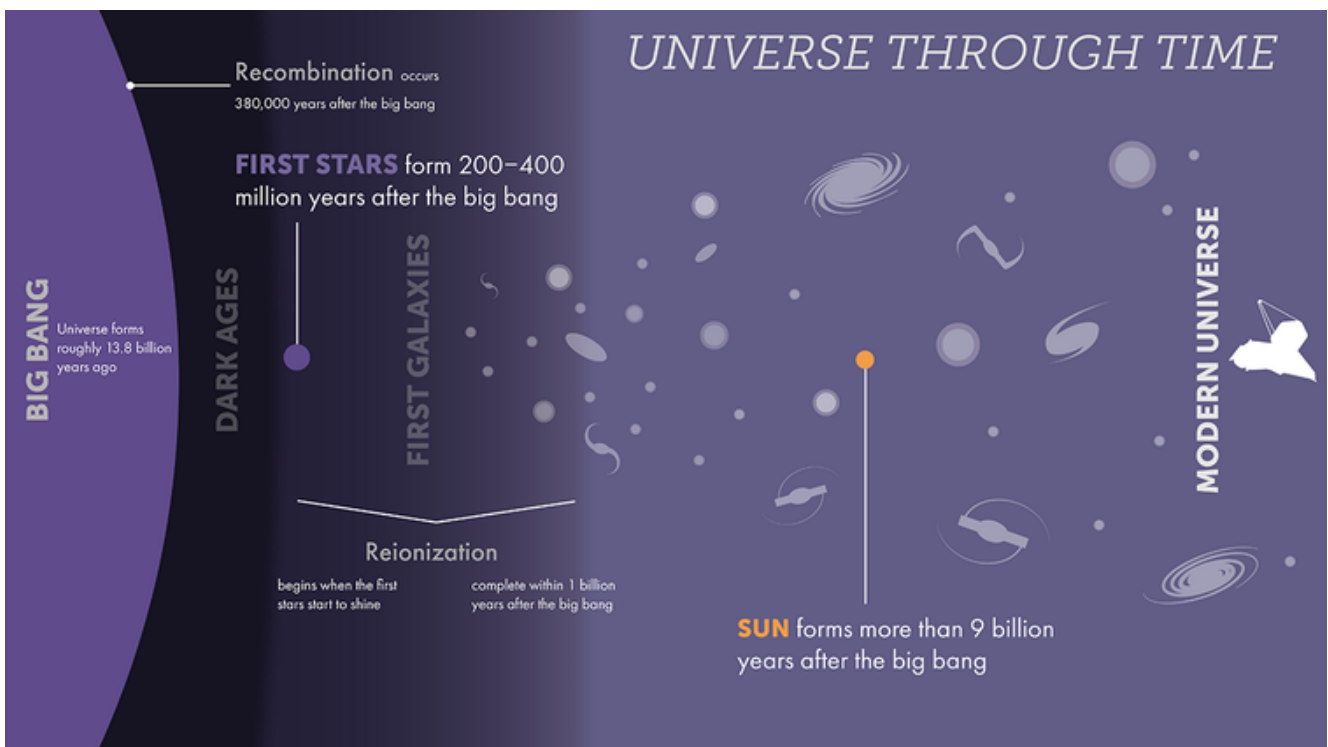
[NASA](#)

[Chris Impey, *University of Arizona*](#)

Some have called NASA's James Webb Space Telescope the

“[telescope that ate astronomy](#).” It is the [most powerful space telescope](#) ever built and a complex piece of mechanical origami that has pushed the limits of human engineering. On Dec. 18, 2021, after years of delays and billions of dollars in cost overruns, the telescope is [scheduled to launch into orbit](#) and usher in the next era of astronomy.

I’m an [astronomer](#) with a specialty in observational cosmology – I’ve been studying distant galaxies for 30 years. Some of the biggest unanswered questions about the universe relate to its early years just after the Big Bang. When did the first stars and galaxies form? Which came first, and why? I am incredibly excited that astronomers may soon uncover the story of how galaxies started because James Webb was built specifically to answer these very questions.



The Universe went through a period of time known as the Dark Ages before stars or galaxies emitted any light.

[Space Telescope Institute](#)

The ‘Dark Ages’ of the universe

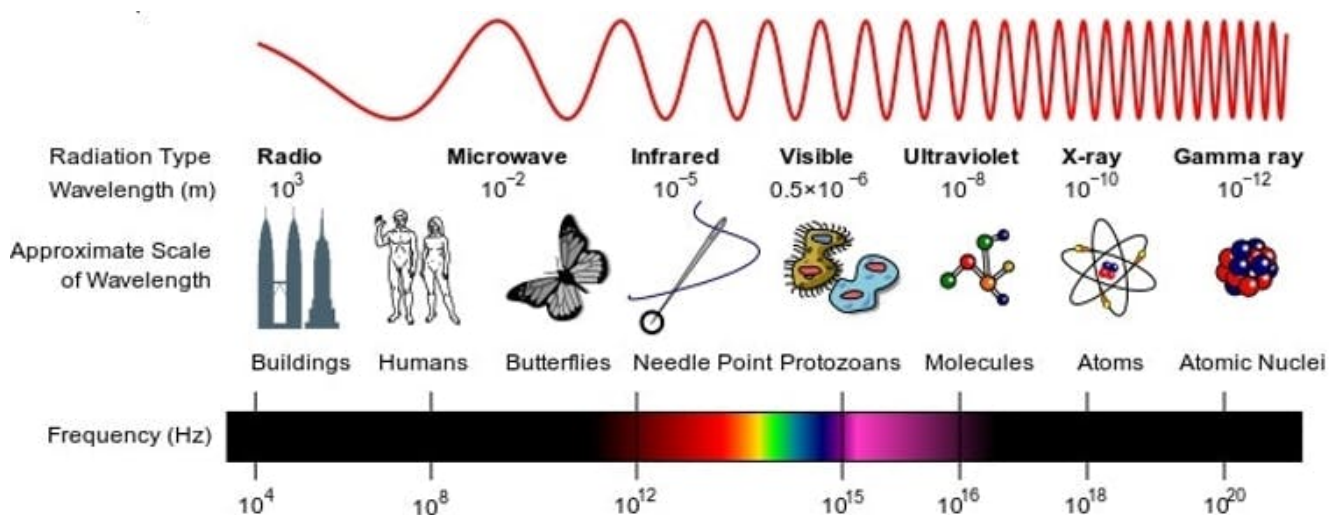
Excellent evidence shows that the universe started with an

event called the [Big Bang](#) 13.8 billion years ago, which left it in an ultra-hot, ultra-dense state. The universe immediately began expanding after the Big Bang, cooling as it did so. One second after the Big Bang, the universe was a hundred trillion miles across with an average temperature of an incredible 18 billion F (10 billion C). Around 400,000 years after the Big Bang, the universe was 10 million light years across and the [temperature had cooled](#) to 5,500 F (3,000 C). If anyone had been there to see it at this point, the universe would have been glowing dull red like a giant heat lamp.

Throughout this time, space was filled with a smooth soup of high energy particles, radiation, hydrogen and helium. There was no structure. As the expanding universe became bigger and colder, the soup thinned out and everything faded to black. This was the start of what astronomers call the [Dark Ages](#) of the universe.

The soup of the Dark Ages was [not perfectly uniform](#) and due to gravity, tiny areas of gas began to clump together and become more dense. The smooth universe became lumpy and these small clumps of denser gas were seeds for the eventual formation of stars, galaxies and everything else in the universe.

Although there was nothing to see, the Dark Ages were an important phase in the evolution of the universe.



Light from the early universe is in the infrared wavelength – meaning longer than red light – when it reaches Earth.

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Looking for the first light

The Dark Ages ended when gravity formed the first stars and galaxies that eventually began to emit the first light. Although astronomers don't know when first light happened, the best guess is that it was [several hundred million years](#) after the Big Bang. Astronomers also don't know whether stars or galaxies formed first.

[Current theories](#) based on how gravity forms structure in a universe dominated by dark matter suggest that small objects – like stars and star clusters – likely formed first and then later grew into dwarf galaxies and then larger galaxies like the Milky Way. These first stars in the universe were extreme objects compared to stars of today. They were [a million times brighter](#) but they lived very short lives. They burned hot and bright and when they died, they left behind [black holes](#) up to a hundred times the Sun's mass, which might have [acted as the seeds for galaxy formation](#).

Astronomers would love to study this fascinating and important era of the universe, but detecting first light is incredibly challenging. Compared to massive, bright galaxies of today, the first objects were very small and due to the constant expansion of the universe, they're now tens of billions of light years away from Earth. Also, the earliest stars were surrounded by gas left over from their formation and this gas acted like fog that absorbed most of the light. It took several hundred million years for [radiation to blast away the fog](#). This early light is very faint by the time it gets to Earth.

But this is not the only challenge.

As the universe expands, it continuously stretches the wavelength of light traveling through it. This is called [redshift](#) because it shifts light of shorter wavelengths – like blue or white light – to longer wavelengths like red or infrared light. Though not a perfect analogy, it is similar to how when a car drives past you, the pitch of any sounds it is making drops noticeably.

Similar to how a pitch of a sound drops if the source is moving away from you, the wavelength of light stretches due to the expansion of the universe.

By the time light emitted by an early star or galaxy 13 billion years ago reaches any telescope on Earth, it has been stretched by a factor of 10 by the expansion of the universe. It arrives as infrared light, meaning it has a wavelength longer than that of red light. To see first light, you have to be looking for infrared light.

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Telescope as a time machine

Enter the James Webb Space Telescope.

Telescopes are like time machines. If an object is 10,000 light-years away, that means the light takes 10,000 years to reach Earth. So the further out in space astronomers look, the [further back in time we are looking](#).



The James Webb Space Telescope was specifically designed to detect the oldest galaxies in the universe.

[NASA/JPL-Caltech, CC BY-SA](#)

Engineers [optimized James Webb](#) for specifically detecting the faint infrared light of the earliest stars or galaxies. Compared to the Hubble Space Telescope, [James Webb has a 15 times wider field of view on its camera](#), collects six times more light and its sensors are tuned to be most sensitive to infrared light.

The strategy will be to [stare deeply at one patch of sky for a long time](#), collecting as much light and information from the most distant and oldest galaxies as possible. With this data, it may be possible to answer when and how the Dark Ages ended, but there are many other important discoveries to be made. For example, unraveling this story may also [help explain the nature of dark matter](#), the mysterious form of matter that makes up about [80% of the mass of the universe](#).

James Webb is the [most technically difficult mission](#) NASA has ever attempted. But I think the scientific questions it may

help answer will be worth every ounce of effort. I and other astronomers are waiting excitedly for the data to start coming back sometime in 2022.

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