Decades before the Hubble Space Telescope was launched into orbit around Earth, a Yale professor named Lyman Spitzer Jr. dreamed of a large space telescope that would snap crystal-clear views of the universe.

A space telescope, Spitzer wrote in 1946, would reveal much clearer images of far-off objects than any ground-based telescope. It would not be hampered by our Earth’s atmosphere, which blurs light from stars and makes them appear to twinkle. Fifty years later, on April 24, 1990, he watched NASA launch the Hubble Space Telescope into space.

Hubble initiated a new era of space-based astronomy, delivering breathtaking views of planets, stars,
and galaxies. Among Hubble’s most significant contributions are its images, taken in visible and near-infrared light, of the faraway universe.

Hubble’s snapshots of deep space revealed young galaxies in a variety of shapes. Some of them formed more than 13 billion years ago, only several hundred million years after the universe began in an explosive burst of energy called the Big Bang. Those images gave astronomers hints about the evolution of stars and galaxies.

**Webb: The future trailblazer**

Hubble has blazed a trail deep into the unexplored universe, but more mysteries are beyond the telescope’s vision. Unraveling those mysteries is the promise of the James Webb Space Telescope, now being built by NASA.

Webb will see farther into the infrared than Hubble does.

The telescope therefore will reach even farther into the universe to answer questions that challenge the human imagination: How did the first galaxies form? How do stars, galaxies, and planets come into existence? Are we alone in the universe?

The Webb telescope, scheduled for launch in 2018, will see in infrared light as well as Hubble sees in visible light. It will look at young...
Infrared reveals the hidden universe

These two close-up images by the Hubble Space Telescope reveal how different the star-forming nebula NGC 2174 appears in visible and near-infrared light. On the top is a visible-light view, revealing a rugged landscape, with ridges and tall pillars of gas.

The near-infrared image below shows how infrared light penetrates more dust and gas than visible light, revealing details within the nebula. Background stars and several galaxies appear in the infrared view.

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galaxies and exploding stars in the early universe, disks of dust around stars in our own galactic neighborhood that could be forming planets, and more. By using Webb to see the development of the early universe, astronomers hope to better understand how stars, planets, and galaxies came to be.

The need for infrared vision

Infrared astronomy is important because light from the most distant objects in space is also light that started traveling billions of years ago. Because the universe is expanding, visible light gets stretched as it travels through space, turning it into infrared light. So very distant stars and galaxies fade from view, in part from extreme cosmic distances and in part because space itself continues its breakneck expansion begun by the Big Bang.

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Cosmic beginnings

This view of nearly 10,000 galaxies is the deepest visible-light image of the cosmos. Called the Hubble Ultra Deep Field, this image represents a “deep” core sample of the universe, cutting across billions of light-years. The smallest, reddest galaxies may be among the most distant known, existing when the universe was just a few hundred million years old.

The birth of stars

The sparkling centerpiece of this colorful Hubble image is a giant cluster of about 3,000 stars called Westerlund 2. The star cluster is only about 2 million years old and contains some of our Milky Way galaxy’s hottest, brightest, and most massive stars. Some newborn stars are still buried in dense pillars of gas and dust. The region could be the home of young solar systems.

IMAGE: NASA, ESA, S. Beckwith (STScI) and the HUDF Team
Also, objects that are not quite hot enough to glow with visible light glow with infrared light.

Finally, infrared light pierces layers of dust that can hide objects in space, allowing Webb to see objects that would normally be blocked from view.

Although there are many infrared telescopes on Earth, the best place to do infrared astronomy is in space. Earth’s atmosphere glows brightly in infrared light, making it difficult to accurately measure light from faint celestial infrared objects.

A couple of space-based infrared observatories, including the Spitzer Space Telescope, have already made a path for Webb. Spitzer, along with Hubble, paved the way for envisioning and perfecting the technology for Webb. Webb will have the resolution of Hubble and roughly the combined infrared wavelength coverage of Hubble and Spitzer.

**Uncovering the secrets of our cosmic beginnings**

Webb’s exploration of the universe begins where the most powerful modern observatories reach their limits. New mysteries await Webb’s penetrating vision into the infrared universe, as well as answers to questions as old as human imagination. How did galaxies form? How did stars and planets form? Is there life on other planets?

**Hunting for the first galaxies**

The universe began 13.8 billion years ago as an expanding fireball. But how did stars and galaxies arise from this raw fury? Webb’s vision will be able to witness the flicker of the first galaxies popping into existence in the early universe.

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Extrasolar planet and parent star

Webb will chart the growth of galaxies from shapeless masses to the giant spiral shapes we see today.

The birth of stars and planets
Webb’s infrared vision will reveal the chaotic and turbulent regions of star birth. It will uncover the swirling disks that surround newly forming stars, and study new planets in the making. Webb will see the dust, gas, and icy objects that swirl around young stars. It also will observe the jets and winds of material ejected from these systems.

Seeking living planets
We are surrounded by a galaxy of a hundred billion stars, yet we live in cosmic isolation and loneliness. Does life exist around other stars? We suspect that Earth-sized planets are abundant in the universe, but are they Earth-like, too? Do they have oceans of liquid water for nurturing life? Webb will study planets around nearby stars to look for the spectral fingerprints of water vapor. The telescope also will search for atmospheres rich in carbon dioxide and methane, the chemical byproducts of life.

Webb’s giant mirror
With a primary mirror towering more than two stories high, Webb will be the largest observatory ever sent into space. The Webb mirror is seven times larger than Hubble’s.

Longer wavelengths of light, such as infrared, result in lower-resolution images. To improve image sharpness, astronomers need a large mirror to collect a lot of light. The bigger the mirror, the more light it can collect. Webb will be able to see back to a few hundred million years after the Big Bang, when the very first stars and galaxies began to form. Hubble, which sees mostly in visible light and has the largest mirror currently in space, can see back to roughly 600 million years after the Big Bang.

The telescope’s engineers and scientists are getting such a large mirror into space by constructing it out of 18 hexagonal segments.

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This artist’s illustration shows the extrasolar planet HD 189733b with its parent star peeking above its top edge. Astronomers used the Hubble Space Telescope to detect methane and water vapor—the raw ingredients for life—in the Jupiter-sized planet’s atmosphere.

The planet is so massive and so hot, however, it is considered an unlikely host for life. Astronomers discovered this by studying how light from the host star filters through the planet’s atmosphere.

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then folding it up inside the rocket that will launch it into space. Once the telescope is in space, ground controllers will send a message ordering the mirror to open, like a butterfly opening its wings.

**Staying cold to see hot**
Webb will operate at frigid temperatures because infrared telescopes must be kept extremely cold so that the heat from their own devices or nearby objects doesn’t overwhelm the distant infrared radiation they’re trying to detect. To keep Webb cold, engineers have built a sunshield the size of a tennis court to protect the telescope from light emitted by the Sun or reflected by the Earth and Moon.

The observatory also will orbit at a distance much farther than Hubble, at a point four times farther away from Earth than the Moon. About 940,000 miles (1.5 million kilometers) from Earth is a place called the Second Sun-Earth Lagrange Point, or L2. Here, Earth’s gravity will pull Webb along, so it can “keep up” with Earth in its path around the Sun. Only at the L2 point are the Sun and Earth always on the same side of Webb’s sunshield, giving the telescope almost full protection from their light and heat.

**Vision for the future**
The James Webb Space Telescope promises to continue the grand journey of exploration and discovery that was first begun by Hubble. If Hubble’s history is any example, Webb’s most important discoveries will provide answers to questions we do not yet know how to ask as it uncovers celestial phenomena we have not yet even imagined.

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**Webb’s Orbit**
The James Webb Space Telescope will follow Earth around the Sun, orbiting around an area called the Second Lagrange Point (L2), and always in a straight line with Earth and the Sun.

Webb orbits L2 once every 168 days.

![Webb’s Orbit Diagram](image_url)
SEE MORE Hubble images and read more Star Witness news stories at Amazing Space, NASA’s award-winning educational website for K-12 students and teachers.