The Science Behind the James Webb Space Telescope

DISCOVER WHAT’S REVEALED BY INVISIBLE LIGHT FROM THE UNIVERSE

PLUS: GET THE LONG-DOWN ON WEBB, THE NEXT BIG SPACE OBSERVATORY

BEYOND THE VISIBLE

INFRARED

THE COMIC BOOK!
The James Webb Space Telescope is a joint project from NASA, the European Space Agency, and the Canadian Space Agency.

This book was produced in 2013 by the Space Telescope Science Institute (STScI), which runs the science mission of the Hubble Space Telescope and the upcoming Webb Space Telescope for NASA.
HUMANITY HAS ALWAYS BEEN DRAWN TO THE NIGHT SKY.

WE DRAW PICTURES IN THE STARS, TRACK THE PLANETS, AND SEE SIGNS AND PORTENTS IN CELESTIAL OBJECTS.

BUT SO MUCH OF THE UNIVERSE IS BEYOND OUR REACH.

VAST DISTANCES SEPARATE US FROM THE SIGHTS THAT MIGHT ANSWER SOME OF OUR BIGGEST QUESTIONS:

HOW DO GALAXIES FORM?

HOW DO STARS AND PLANETS COME TO BE?

DO DISTANT PLANETS HAVE THE CONDITIONS REQUIRED FOR LIFE?
To construct and test our theories, we need to see what’s happening in the cosmos.

So we build tools to extend our vision.

They get bigger. More powerful. More advanced.

As time goes on, we look beyond even the realm of visible light - the light we can see with our eyes - and gaze into a universe ablaze with invisible radiation.
When you look at the world, you're seeing something we call "visible light.

But visible light is really only a certain form of radiation.

Our universe is full of many different types of radiation. It surrounds us.

Our bodies evolved to detect visible light with our eyes.

But they also evolved to detect another kind of radiation: infrared light. Our bodies feel infrared light as heat.

But we didn't always know that's what it was...
Back in the year 1800...

“Infrared radiation” was discovered by the astronomer Frederick William Herschel.

He wanted to know whether the colors had different temperatures.

But then Herschel measured the empty space just beyond the red light....

Herschel knew that a prism could be used to break white light - like sunlight - into colors.

They did!

Herschel had just discovered invisible infrared radiation.

Though no sunlight was visible, it was hot.

Infrared light

Visible light

Humanity now knew there were forms of radiation that could not be seen.
Electromagnetic radiation is a type of energy that travels through the universe in the form of waves.

The entire range of it, from high-energy gamma rays to low-energy radio waves, is called the electromagnetic spectrum.

Objects can emit all kinds of radiation. Observing the entirety of that radiation gives us a true picture of an object.
Although our eyes can detect only visible light, we can build tools, like infrared-detecting cameras, to see other forms of radiation.

These tools are man-made “eyes” that view invisible radiation for us, and transform it into pictures.

When we turn these tools on space, they open up the entire cosmos to us, in its full glory.
When we gaze up at the night sky, we see stars and planets, galaxies and nebulae, in the form of visible light.

But if we could see in infrared light, the sky would appear very different.

Visible light is made up of shorter wavelengths that are prone to being stopped and scattered as they fight their way through clouds of gas and dust.

But infrared’s longer wavelengths have a smoother path, and they easily pass through the dust.

So by detecting infrared light, we can actually see through clouds of gas and dust to warm objects inside...

...like just-forming stars.
Objects that don’t glow with any visible light of their own like planets... are still often warm enough to radiate infrared light, perhaps allowing us to glimpse them.

And by observing how infrared light from a planet’s star passes through its atmosphere, we acquire clues about the planet’s composition.

We break that light down into its components, in a technique called spectroscopy, to see how it has been influenced by materials in the planet’s atmosphere. This gives us information about the planet’s makeup.

The dust left behind by distant planets as they form also glows in infrared, helping to show us how planets are born.

So infrared light lets us see objects in our own galaxy that would otherwise be hidden from us.

But it can also help us see some of the most distant objects in the universe – stars and galaxies that were forming just after the Big Bang.

Infrared light opens a window onto our universe’s past.
How is this possible?

Because light moves, and as fast as it goes - 186,000 miles per second - it still takes time to cross the immensity of space.

Imagine you gave a letter to the post office in a galaxy billions of light-years away, and addressed it to Earth.

It would travel for an incredibly long time.

When it finally arrived at its destination, the person who opened it would be getting news from billions of years earlier.

The light from the first stars to shine in the universe is something like that. It left the stars ages ago and is still out there in space, traveling the vast distances between galaxies.

If we could see it, we could see those galaxies as they were in the early universe. Essentially, we would be seeing back in time.

But we haven't been able to see it...
As light travels across space, it’s stretched like taffy by the expansion of the universe. The first stars gave off mostly visible and ultraviolet light, but the stretching changes those wavelengths: from ultraviolet and visible light... into infrared light.... This is called: REDSHIFTING.

The only way to see that light as it arrives in our region of the universe is to look for that faint infrared glow.
By capturing it, we can create images of the first galaxies to form in the universe. There are many questions we would finally be able to answer.

By witnessing the birth of the first stars and galaxies, we deepen our knowledge of how the universe as we know it came to be.

Exactly how do galaxies grow and evolve?

How did we get from those first blazing stars to the islands of billions of stars we see today?

How did the chaos of the early universe transform into order and structure?
NASA and its partners are currently building the James Webb Space Telescope.

With its huge, infrared-capturing mirror and distant orbit far beyond the Moon, Webb will allow us to view the cosmos as we’ve never seen it before.

It will search for signs of water vapor on planets around other stars.
It will take pictures of the universe’s infancy. It will reveal the hidden stars and solar systems forming within cocoons of dust. The answers to some of the universe’s biggest mysteries—and more questions we haven’t thought yet to ask—are waiting out there for us, in the form of infrared radiation.

All we have to do is look.
The Webb Telescope is unique in many ways... here are just some of them!

**The Webb Telescope's primary mirror is made up of 18 segments and is over 21 feet across - that's taller than a giraffe!**

(By comparison, the Hubble Telescope's mirror is only 8 feet across.)

The entire surface of the mirror is covered in gold to better reflect infrared light... but in a layer so microscopically thin that if you scraped it all together you wouldn't even have enough to make a set of gold teeth.

**Webb’s Amazing Mirror**

Webb’s Super Sunshield

Webb’s Sunshield is made of five layers of insulating material the size of a tennis court. It protects the sensitive instruments from the heat and light of the sun. It’s like having a sunscreen that’s SPF 1,000,000!

**Webb’s Sunshield**

Specially designed extenders spread the sunshield like a kite and separate the layers.

The Transforming Telescope

To get into space, Webb has to squeeze into the capsule of an Ariane 5 rocket - one of the largest rockets we have. After it launches, Webb needs to unfold to its full size before it can work.

1. During launch, a capsule protects the folded-up telescope, then splits open and falls away.
**A Tale of Two Temperatures**

Webb’s instruments and mirrors need to be super-cold! It’s designed so the sunshield keeps the heat from the sun — and from Webb’s own mechanical parts — away from the sensitive infrared detectors.

**Cold Side**
-388° Fahrenheit (−233° Celsius)

**Hot Side**
185° Fahrenheit (85° Celsius)

**Webb’s Odd Orbit**

Webb will follow Earth around the Sun, orbiting a point called “L2,” always in a straight line with Earth and the Sun.

Webb orbits L2 once every 168 days... and orbits the sun once every 365 days, just like Earth!

Except for rare glints from the Sun, the Webb will appear as a very faint star in the night sky when seen from the Earth, more than 10,000 times fainter than the faintest star seen by the naked eye.

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Explore the mysteries of the universe with Space Telescopes

When you're trying to unravel the mysteries of the cosmos, sometimes a telescope on the ground just can't give you the whole picture; no matter how big it is... especially if you need to look at the invisible light from the far ends of the electromagnetic spectrum.

That's when you need a space telescope to show you the hidden corners of the universe!

**Here's how they work:**

**Earth's atmosphere protects us from dangerous radiation from space.... but we need to see those wavelengths to understand the universe...**

Putting your telescope up above the atmosphere lets you see things you can't from the ground!

**Ground-based telescopes are great at seeing the light that makes it down to the ground.**

**The right tool for the right job:**

**Hubble**
- **Wavelengths:** visible, with some infrared and ultraviolet
- **Special powers:** removable parts can be switched out, large mirror (comes with extended warranty), exceptional service plan - we come to you!
- **Sees:** distant galaxies, nearby planets, dying stars, and more!

**Spitzer**
- **Wavelengths:** infrared
- **Special powers:** super-cold for super-deep views of the cosmos, peering far into the infrared!
- **Sees:** just-forming stars, galaxy centers, cool stars, cosmic dust, and more!

**Chandra**
- **Wavelengths:** x-ray
- **Special powers:** barrel-shaped mirror captures tremendously fast x-rays before they know what happened! Real x-ray vision (we mean it this time)!
- **Sees:** black holes, supernovae, dark matter, and more!

**Webb**
- **Wavelength:** infrared
- **Special powers:** tremendous size, enormous mirror, continues to operate at extremely far distances and severe temperatures, folds for storage.
- **Sees:** the universe's earliest stars and galaxies, warm objects hidden by clouds of gas and dust, atmospheres of other worlds... and more!

**Coming soon!**
**Explore**

There’s a universe of information online! Scan these links to start learning even more about Webb, telescopes, and astronomy.

### More about the Webb Space Telescope

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<th>See Webb telescope developments for yourself on NASA's clean room “Webb-cam,” get pictures, and learn more about the science and technology.</th>
<th>The <em>Behind the Webb</em> video podcast gives a behind-the-scenes look at the people and places involved in building the Webb Telescope.</th>
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### Want to dig deeper?

Learn more about telescopes in *Telescopes from the Ground Up*, an online exploration that traces the 400 years of telescope development from Galileo’s refractor to NASA's Great Observatories.

Read about the milestones of telescope development within “eras” and “telescope pages.” Explore the basics of telescope optics, light, and color in the “Get to the Root of It” section. Get to know the inventors and astronomers behind the telescopes as well.

[http://amazing-space.stsci.edu/go/groundup](http://amazing-space.stsci.edu/go/groundup)

### Educators

Amazing Space is an online space science resource where you can explore the universe through images, activities, and more. Designed for both the public and educators, the Amazing Space website includes standards-based activities and resources related to telescopes, the electromagnetic spectrum, and light and color. Educator Overviews and Teaching Tips are included on the “For Educators and Developers” side of the site.

[http://amazing-space.stsci.edu](http://amazing-space.stsci.edu)
Watch the video!

See this story come to life, and find more great information online

WebbTelescope.org/go/beyond

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