I BET YOU DIDN'T KNOW...

We have telescopes out in space studying the universe

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In December 2021 the James Webb Space Telescope (JWST) was launched using an Ariane 5 heavy-lift launch vehicle (Figure 1) from the European Space Agency's Kourou Launch Centre in French Guiana. The JWST is the replacement for the Hubble Space Telescope (HST) and is a joint project between The National Aeronautics and Space Administration (NASA), The European Space Agency (ESA) and The Canadian Space Agency (CSA).

Figure 1. ESA's Ariane 5 heavy-lift rocket is used for carrying satellites into Low Earth and geostationary transfer orbits.

The scale of the mission

As with all missions into space, the JWST mission has involved 1000s of scientists across the world working to achieve success over the past 32 years. The idea of an infrared telescope being set up a long way from Earth was first discussed in 1989; even before the HST was launched. Construction started in 2004 after a long planning and development phase. Much of the technology was 'borrowed' from existing space telescopes but other technologies had to be developed specially for the mission.

For many of the scientists and engineers working on the JWST mission, this has been their life's work, and for many of the scientists who will study the collected data and draw conclusions, their life's work is about to begin. There are thousands of scientists who are relying of the JWST to be a success.

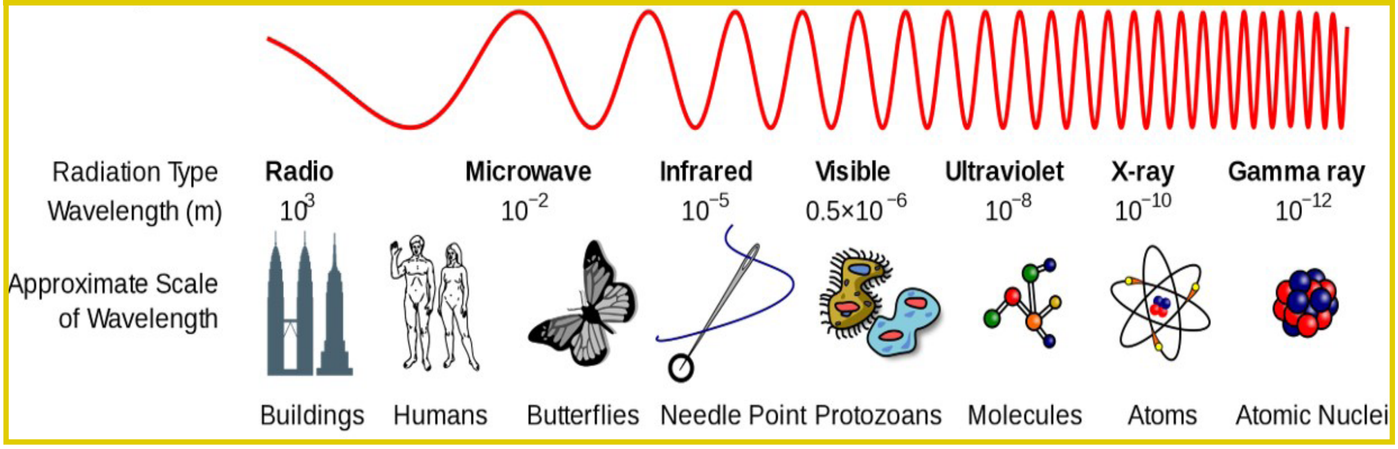
This scale of mission is not unusual for space exploration. The International Space Station (ISS) took over 30 years from planning to completion, although it is still being added to now. The HST was first proposed in the 1940s and construction took place from 1979 until its launch in 1990. Space exploration is also not cheap. The ISS cost $150 billion to build and the JWST mission has cost $10 billion so far.

Whereas the HST collected visible light, the JWST collects infrared light (explained below) and is designed to be able to explore the oldest *galaxies* in the *universe*. It will also allow scientists to study closely the process of star formation inside *stellar nebulae* and to do more detailed observations of *exoplanets*.

Questions children might like to consider:

- What does a telescope do?
- Why is it better to have telescopes in space rather than on the Earth's surface?

Figure 2. The electromagnetic spectrum showing infrared light in relation to visible light.



What is infrared light?

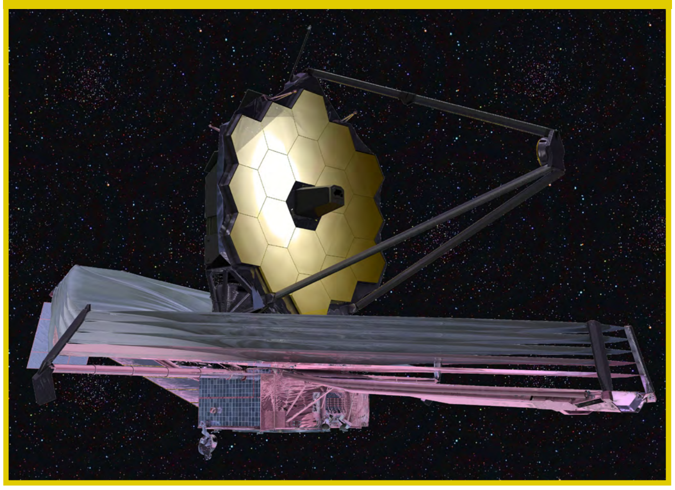
All light is a form of *energy*. We can see *visible* light but there are other similar waves of energy that together are known as the *electromagnetic spectrum*. Infrared is a part of this electromagnetic spectrum that we can't see, but we feel it as heat. The electromagnetic spectrum is a continuous range of wavelengths of light from radio waves (long wavelength) at one end to gamma rays (very short wavelength) at the other end. It includes the visible spectrum, which are the colours we can see, ultraviolet radiation that we also get from the sun and other sources, x-rays and microwaves (Figure 2).

Infrared is emitted by anything that gives off heat, including humans and the infrared from planets, stars and other objects in the universe can be *detected*. Because these waves can travel through clouds of dust and gas, it will allow the JWST to make observations of much deeper space objects than HST could.

Question for children to consider:

Have a look at the electromagnetic spectrum. Can you describe how some of the waves are used in everyday life?

Figure 3. The JWST has a 3m wide gold-plated mirror and a heat shield the size of a tennis court.



The design of the JWST

The JWST (Figure 3) carries a series of infrared detectors on board which all detect at slightly different wavelengths, from 0.6µm to 29µm (µm = micrometre; there are 1000 micrometres in 1mm). Because the JSWT basically detects heat, it needs to be kept very cold (about -230°C); this is mostly achieved by positioning the telescope a very long way from other large bodies (such as the Earth and the Moon which hold on to large amounts of heat from the Sun) and could warm the telescope. However, that's not quite enough to keep it cold enough so there is also a tennis-court-sized heat shield that will *deploy* once the JWST is in position.

As well as its huge heat shield, the JWST also has a $25m^2$ mirror made up of 18 hexagonal segments that form a tricontagon (30-sided polygon) when unfolded. The 18 mirror segments are made of a material called beryllium and coated with gold. The 6.2m diameter mirror is almost 3 times wider than the HST mirror that preceded it.

Positioning the JWST

The HST was launched in 1990 using the Discovery Space Shuttle. It is in a low orbit at about 540km above the Earth's surface, about 100km further away from the Earth than the ISS. When it was deployed and its mirror was discovered to be faulty and all the images were out of focus, but NASA astronauts were able to visit it and carry out repairs.

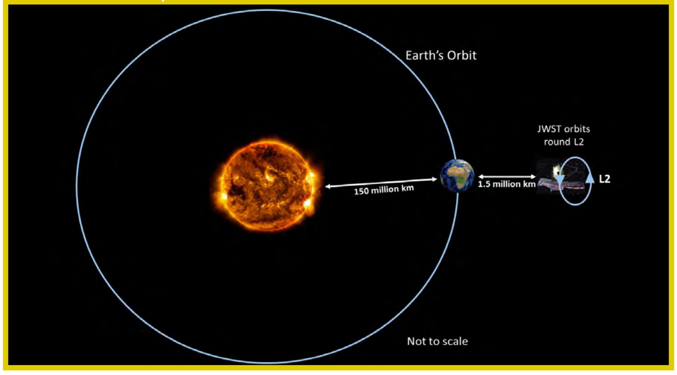
Repairing the JWST will not be an option, as it will be positioned about 1,500,000 km away from Earth. That's more than 3 times the distance from the Earth to the Moon! It is going to be positioned in a region of space called L2*, which will allow it to use the Earth to shield against the sun's heat while never fully entering the Earth's shadow, so it can generate power with solar panels.

*The L stands for Lagrange point, areas of space that were calculated by 18th century Italian astronomer and mathematician Joseph-Louis Lagrange to be good for space observation.

From L2 the JWST can observe 35% of the sky at one time and its orbital path round the sun, with Earth, means that over a 6 month period it will be able to observe the whole sky. Being in a *heliocentric orbit* with Earth (Figure 4) also means communication with JWST will be consistent allowing for 485Gb of data to be transferred every day. This is a lot of data - a 2-hour long high-definition movie would be 4Gb of data.

The JWST will take 100 days to reach L2 from its launch.

Figure 4. The JWST will orbit the Sun with the Earth at L2 observation point.



Deploying the JWST

The JWST's 6.5m diameter mirror and tennis-court-sized heat shield are specially designed to fit within the 5m diameter nose cone of the Ariane 5 rocket. So how do you fit something the size of a tennis court (approx. 23m by 8m) into something not much bigger than a transit van? The answer is by using *origami*.

NASA has been exploring the potential of origami to fold satellite components since about 2014 and the technology has been successfully used to fold large structures such as solar panels and solar sails that then deploy once in space. Both the heat shield and mirror will be carefully folded for launch and then opened up once JWST is in position (Figure 5).

The full deployment process involves 40 deployable structures and 178 release mechanisms, and it will take 14 days to fully deploy. This is being dubbed the '14 days of terror', as every step must work perfectly for the telescope to be operational.

Figure 5. An artist's impression of what the JWST will look like folded to fit in the Ariane 5 nose cone.

What will the JWST do while in space?

When the HST's first images were released, it was immediately obvious that it was going to change our understanding of the universe. From images of distant galaxies to detailed studies of planets in our Solar System, the HST has had an enormous scientific impact over the last 30 years. It is anticipated that the JWST will take our understanding of the origins of the universe to a whole new level.

Questions for children to consider:

- Why might scientists benefit from being able to 'see' distant objects more clearly?

The observations it makes will be based on recommendations from the international astronomical community and all suggestions will be 'peer reviewed' before being accepted. This means that every suggestion will have to be agreed on by other experts in astronomy before being passed. Primarily, the JWST will explore the origins of the universe, by looking in more detail at the first galaxies that formed. It will collect infrared data that will be processed into images that will give far more detail than those from the HST.

A Teacher Guide with links to appropriate NASA webpages and describing activities for children is available.

GLOSSARY

deploy
to move something into its correct position to work

detect
discover or identify the presence or existence of something

electromagnetic spectrum
a range of waves of energy of different sizes, for example x-rays, microwaves and visible light

energy
the ability to do work, energy can be stored or transferred from one thing to another

exoplanet
any planet beyond our Solar System

geostationary transfer orbit
a satellite's temporary orbit round Earth until it uses its own thrusters to reach its eventual orbit

galaxy
a huge collection of gas, dust, and billions of stars and their solar systems, all held together by gravity

heliocentric orbit
an orbit round the Sun (Helio means 'of the Sun'), the Earth has a heliocentric orbit

micrometre (µm)
one millionth of a metre, there are 1000 micrometres in 1mm

origami
the Japanese art of paper folding

stellar nebula (pl. nebulae)
a giant cloud of dust and gas in space where new stars are created

universe
all existing matter and space including planets, stars, galaxies and all other forms of energy

visible
able to be seen by humans

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This resource contributes to XAIDA – a project supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003469.

The paper that inspired this article was:
The James Webb Space Telescope: Mission Overview and Status

By Mathew Greenhouse[1].

Published in 2019 IEEE Aerospace Conference, 2019, https://ntrs.nasa.gov/api/citations/20090026783/downloads/20090026783.pdf Last accessed 8.12.21

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