Notes on Space – Student Pack

A musical enrichment activity for Key Stage 3 science

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Science & Technology Facilities Council

Contents

Pre-evaluation

Name:		Class:	

How many different astronomical objects can you name?

What do astronomers use to study space?

Can you name any telescopes?

Us & the Universe

Lyrics and questions

It's extraordinary to think that the nursery rhyme Twinkle Twinkle Little Star was only written two hundred years ago. "How I wonder what you are" – just two hundred years ago, we had no idea what stars actually were. But we did have theories. Likewise, there were theories about everything else we see in the night sky. Now that we've worked a lot of it out, it's time the nursery rhyme got a little update.

Of all of the creatures who've lived on this Earth
The ones we call humans seem to be the first
To ponder their place in the Universe.

Twinkle twinkle, little star,
How we used to wonder what you are.
Were you fixed to a heavenly plane?
Could you help us predict the rain?
Did you chart our past and future?
Could you help us find our suitor?
Twinkle twinkle little star,
Now we know much better what you are.

The idea that the stars were literally fixed to the inside of a vast 'celestial sphere' or 'firmament' was very common since ancient times, and was first challenged by Giordano Bruno in 1584.

Of course, some people still believe that the position of the stars can predict future events here on Earth. But they can't.

Twinkle twinkle little planet,
Oh how we endeavoured to understand it.
Was your shine divine and godly?
Were you a star that twinkled oddly?
Why did Mars sometimes reverse its direction?
What happened to celestial perfection?

The link between the planets and the gods lives on in their names: all the planets except Earth are named after Greek or Roman gods or goddesses.

Twinkle twinkle big round Sun,
How a total solar eclipse would stun.
What did this baffling occurrence portend?
Was the world soon about to end?
Was the Sun being eaten by a beast?
Did it represent a warning, at least?

Mythological beasts who ate the Sun during a solar eclipse include a Vietnamese giant frog, Norse wolves, a Chinese dragon, a Native American bear, and the decapitated head of the Hindi god Rahu.

We now know stars
Are all suns much like ours,
And a planet is a sphere
Like this Earth we've got here,
And total eclipses
Happen when ellipses
Lunar and solar
Fleetingly cross over.
As for the strange path of Mars, it's explained by the fact that the Earth's not the centre of our Solar System.
Those old superstitions have been superseded as peer reviewed science has lately replaced received wisdom.
But so many questions remain.
There is still so much left to explain.

As the Earth passes Mars on its orbit round the Sun, Mars will briefly appear to travel in the opposite direction across the sky. This is called 'apparent retrograde motion'.

Twinkle twinkle distant sun,
By alien lifeforms are you overrun?
Why is space missing so much of its matter, and
What explains the mountain chains
On the moons of Saturn?
At the end, will it just disappear?
Why is the Universe here?
Twinkle twinkle distant glow
The simple fact is that we do not know.

There's something extremely puzzling about the amount of matter in the Universe. There doesn't seem to be nearly enough stuff out there to explain the way galaxies behave. The missing stuff (which should account for 85% of all matter) is termed 'dark matter'. And then there's also the mystery of 'dark energy', but don't get me started.

Collect the words you are unfamiliar with here.

Us & The Universe Questions – to be answered while you listen to the song

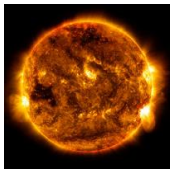
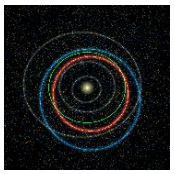
1. What weird thing does Mars sometimes do?

2. What is the difference between The Sun and other stars?

3. How does the song explain eclipses? (Either in your own words or using the song's words)

Astronomical objects – Matching activity

Connect the matching name, picture, example, and explanation of these different astronomical objects. You can use different coloured pencils to help tell the lines apart!

Galaxy		**The Sun**	Huge clouds of gas, many light years wide. These are the birthplace and graves of stars.
Nebula		**Milky Way**	Ball of gas that is so massive that gravity forces nuclear fusion to happen. Often come in pairs.
Planet		**Jupiter**	Groups of millions, to 100s of billions of stars, with a supermassive black hole at their centres.
Planetary System		**The Solar System**	Collection of planets, asteroids and other satellites gravitationally bound to a star or star system.
Star		**The Pillars of Creation**	A body that is large enough to be spherical due to its gravity, but not large enough for nuclear fusion to happen, and usually orbits a star.

Write down the objects in ascending size order (starting with the smallest).

Tools & Technology

Lyrics and questions

It is often very difficult to know exactly when certain types of tool were invented, especially a long time ago. There is also lots of debate about how to define certain eras in tool-making history. However, by and large, all the inventions mentioned in this song are listed in the order that we think they first appeared.

As far as toolkits go, there is no older one
Than the stone age toolkit called the Oldowan.

The Oldowan Toolkit was widespread between 2.6 and 1.7 million years ago, and consisted of simple stone tools made by chipping off flakes with another stone

The Stone Age is split into the Paleolithic,
The Mesolithic and the Neolithic,
And the stuff that they came up with was utterly terrific.
Knock knock knock with a fist-sized rock.
Scrape scrape scrape with a sharp flint flake.
Whack whack whack with a rough hand axe
Boom boom boom, it's the world's first spoon.

'Paleo–' means ancient, 'Meso–' means middle, and 'Neo–' means new. The exact dates of these eras were different in different places.

Tool, tool, tool me up.
I'm fashioning a tool and I just can't stop.
From the first sharpened stick to the conquest of space
Tools are a trait of the human race.

Then came the time when we started to engage
With the smelting of metal alloys. It was all the rage.
First came the Bronze Age and then the Iron Age.
Oh how exciting! It's the first recorded writing!
I just can't cope! We've now got soap!
Woah man, for real! It's the first spoked wheel!
It's harder to harm a soldier in armour!

Most useful metals can't be found in the ground in pure form (gold is an exception), and therefore need to be smelted. This process was invented over 8000 years ago.

Then, with our own age getting nearer and nearer,
Comes the start of the historical era
When the dating of inventions is a lot lot clearer,
Wow, that's ace!
It's the spiral staircase!
Wow, that's brill!
It's the first windmill!
Yes yes yes!
It's the printing press!
There's still hope!
It's the telescope!
This must be a dream!
Things are running off steam!

The 'historical era' is defined as the period about which we have a reliable written record. The inventions listed here span the period 480BCE – 1710CE.

Tool, tool, tool me up.
I'm fashioning a tool and I just can't stop.
From the first sharpened stick to the conquest of space
Tools are a trait of the human race.

The invention of electricity was a magical
Turning-point in making the world more practical.
This is the era electromechanical.
Night time's solved! It's the first light bulb!
This is fantastic! We're making stuff with plastic!
Woah, what a trip! It's the world's first zip!
This is blowing my brain! It's the first aeroplane!

Now mankind is really on a roll
And the speed of progress is taken to a whole
New level. Things are spiralling out of control!

Personal computers! Chemotherapy for tumours!
Manned space flight! The LED light!
Infrared lasers! Rechargeable razors!
Mp3s! DVDs!
The International Space Station!
CRISPR Cas-9 gene manipulation!
A vaccine against COVID-19!
What are the next
Technological steps?
A telescope that sees even further galaxies?
Will we integrate technology into our biology?
Will we live in space?
Have the power to erase
Humanity at the press of a key?
What new toolkits do we want to see?

Tool, tool, tool me up.
I'm fashioning a tool and I just can't stop.
Without apology, I think technology is ace,
For I am a member of the human race.

People have known about the existence of natural forms of electricity for thousands of years – such as electric eels, lightning and the related phenomenon of magnetism. However, it wasn't until the late 1700s that electricity was well-enough understood for its power to be harnessed.

The rate of technological growth really has been speeding up over the past decades and centuries. One reason for this is that new inventions are not only based on older inventions but are actually designed *using* those inventions. For example, there's no way we'd have found a COVID-19 vaccine so quickly without computers.

Collect the words you are unfamiliar with here.

Tools & Technology Questions – to be answered while you listen to the song

1. Circle which invention in each of these pairs came first, according to the song.
    a. Wheel or soap?
    b. Telescopes or printing press?
    c. Aeroplanes or zips
    d. Mp3s or the International Space Station?

2. What invention mentioned in the song is used to look at galaxies?

How big is a telescope's eye?

We have included a maths activity. This is to calculate aperture area from the telescopes' main mirror's radius, including opportunities for them to practice rearranging equations.

Two examples of next generation telescopes that the UK is involved in are the James Webb Space Telescope (JWST) and the Extremely Large Telescope (ELT). To focus the light they receive these telescopes use huge mirrors.

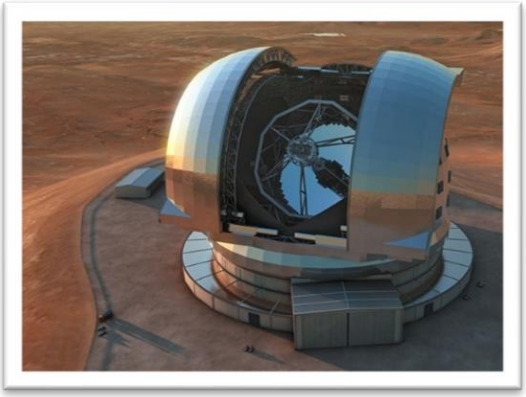


Figure 1: The ELT is currently being built. Note the cars in the foreground - this telescope will be **extremely** *large! Credit: ESO/L. Calçada*

Figure 2: The JWST's sunshield is as big as a tennis court. Credit: European Space Agency/ATG medialab

Using the equation for area of a circle: $A = \pi r^2$

Object	Diameter (m)	Radius (m)	Total area ( )
Pupil of human eye (think about how many you have)	0.0050		
James Webb Space Telescope		3.25	
Extremely Large Telescope			1213

Students can discuss which would be able to collect the most light and why this is important.

Homework Task – Write your own song!

Now that you've had a listen to two of my songs about science, it's time for you to write your own. Here are the steps I go through when I'm settling down to write a science song, and I'd like you to follow them.

1. What is your song about?

The list of possibilities is almost endless, so I'll make it a bit easier for you. Your song is going to be about a telescope. Specifically, it'll be about either the James Webb Space Telescope (JWST) or the Extremely Large Telescope (ELT). What? You don't know anything about them? Don't worry! We have infographics!

a) **Split into groups**
While I generally write my lyrics alone, it can help to write them in pairs, especially when time is limited. Threes can work too. But I wouldn't really recommend many more than that.

b) **Each group gets one infographic**
These infographics were made by the Science & Technology Facilities Council, who part-funded the JWST, and also part-funded the activity pack you're currently reading (thanks for the money!).

Each group (of 1 to 3 people) gets one sheet, which is about one aspect of one of the Telescopes. Read it. Read it again, and if you don't understand anything, ask or look it up.

2. Mindmap the topic

Write down the main theme of your infographic in the middle of a bit of paper. It is up to you if you want to have one bit of paper for the group and designate a scribe, or have one each.

Spread out over the rest of the bit of paper, write down words that are related to the topic you wrote in the middle, and draw a line from the middle to those words. For example, if the topic was "Mars", subtopics might include geology, atmosphere, orbit, human colonisation, the Roman God of War, why it's red…

Some of the related words may have related words of their own (for example, human colonisation might be further split into SpaceX, NASA, space food…).

You can use the words that appear on your infographic, but it might be nice if you find words of your own to describe what you've found out.

3. Rhyme!

Ideally in a different colour, write down words that rhyme with the words on the page in front of you. The most useful rhymes are ones that are also in some way related to the topic (for example, if your topic was "Horses", and your related word was "Ride", then an excellent rhyming word would be "astride", since that is a word you also use in relation to horses). Write as many possibly-useful rhyming words for each word that you can think of.

A note on true rhymes and half rhymes: "Ride" and "astride" are known as true (or perfect) rhymes, because both the vowel (the "i") and the final consonant ("d") sound the same when you say them. "True" and "crew" are also true rhymes, even though the ending is spelt differently, because in songs it's the sound that's important. There is also something called a half-rhyme, which is where either the vowel or the consonant don't sound exactly the same. An example is "ride" and "wild". Or "horse" and "house". The important thing is that **half rhymes are absolutely fine!** When you listen to a song, you hardly notice when a rhyme is not perfect. So, for this exercise, do use half-rhymes and don't let anybody tell you off for it!

Remember to find a rhyme or two for the topic that's written in the centre of your bit of paper too.

4. Expand the rhymes in to couplets

The next step is to try to communicate the information that's on your infographic to everyone else but using rhyme rather than just telling them the information.

So, try to flesh out the rhyming pairs you've already found into full lines that convey the information as accurately as possible. You are allowed a bit of poetic license, such as adding your own opinion, or introducing metaphors or wordplay. But what you're not allowed to do is get any of the science wrong!

Ideally, the lines should have the same rhythmic meter (the same number of stressed beats per line), but don't worry too much about this. Here are two examples, with the stressed beats underlined, and both of which add a personal opinion to the information:

I like to sit astride
My horse and have a ride.

Mars missions have been planned by SpaceX and NASA,
But personally I put more trust in the latter.

(Notice the half-rhyme – "NASA" and "latter" almost rhyme but not quite, and **that's fine**.)

If you've got time, write more couplets. Don't worry if they seem bad to you at the moment – it's best just to write them down, because once they're down you may spot a way to improve them, or someone else might. Don't censor yourself while you're creating – write it all down.

5. Verses

There are lots of different parts to a song – there's the intro, the outro, the middle-8, the bridge, the instrumental… but for the moment, let's just concentrate on the chorus and the verses.

We're going to say that what you've been writing so far are verses. Everyone whose infographics were about JWST were writing verses of one song, and everyone whose infographics were about ELT were writing verses of another song.

Share the verses – read them out to each other. Then do your best to put them in an order. It could be that two groups' couplets might go together into the same verse, or it may be that they should go in different verses. There's no right or wrong and it's not like the 'best' verse should go first or last or somewhere in between, it's just a question of what seems to make sense. If there's a disagreement, teacher decides!

And now it's time to write the chorus!

6. Chorus

This may be your homework task. Now that you know a fair bit about the particular telescope you're writing about, write a catchy, rhyming chorus that can be repeated again and again between each verse, and that kind of sums up the essence of the telescope, or maybe addresses some other aspect of it that isn't covered by any of the infographics. You may need to do some more research for this task.

7. What next?

Well, it'll need a tune (unless it's spoken word). Then you'll need to pick up an instrument (or lay down some beats). Then form a band and I look forward to seeing you on tour ☺

If you fancy hearing some of the hundreds of other science songs I've written, search YouTube or Spotify for "Ensonglopedia".

Post Evaluation

Name:		Class:	

What is the JWST?

Give one benefit and one drawback of having a telescope in the following locations

On the ground

Benefit

Drawback

In space

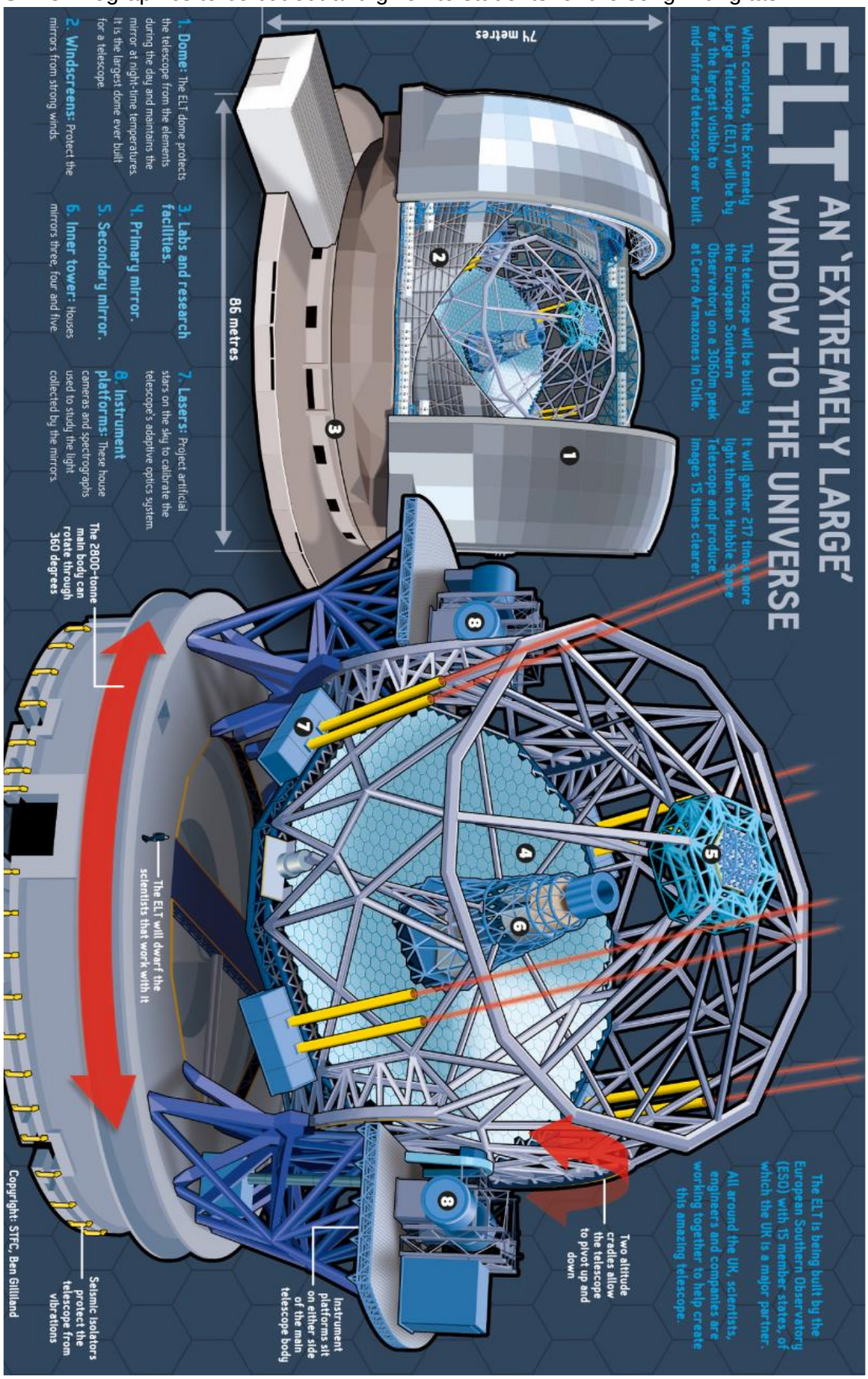
Benefit

Drawback

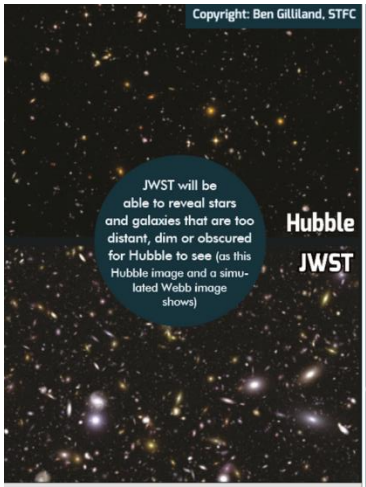
How many different astronomical objects can you think of?

Appendix – STFC infographics for JWST and ELT.

STFC infographics to be cut out and given to students for the songwriting task.

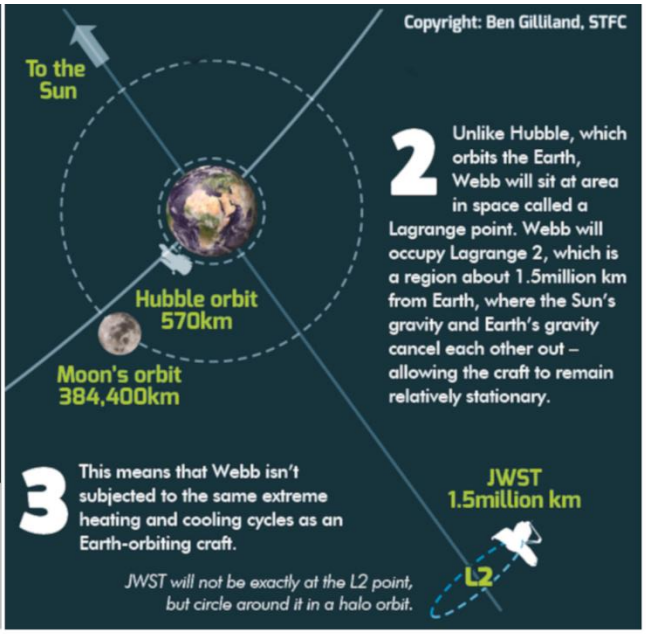


JWST information

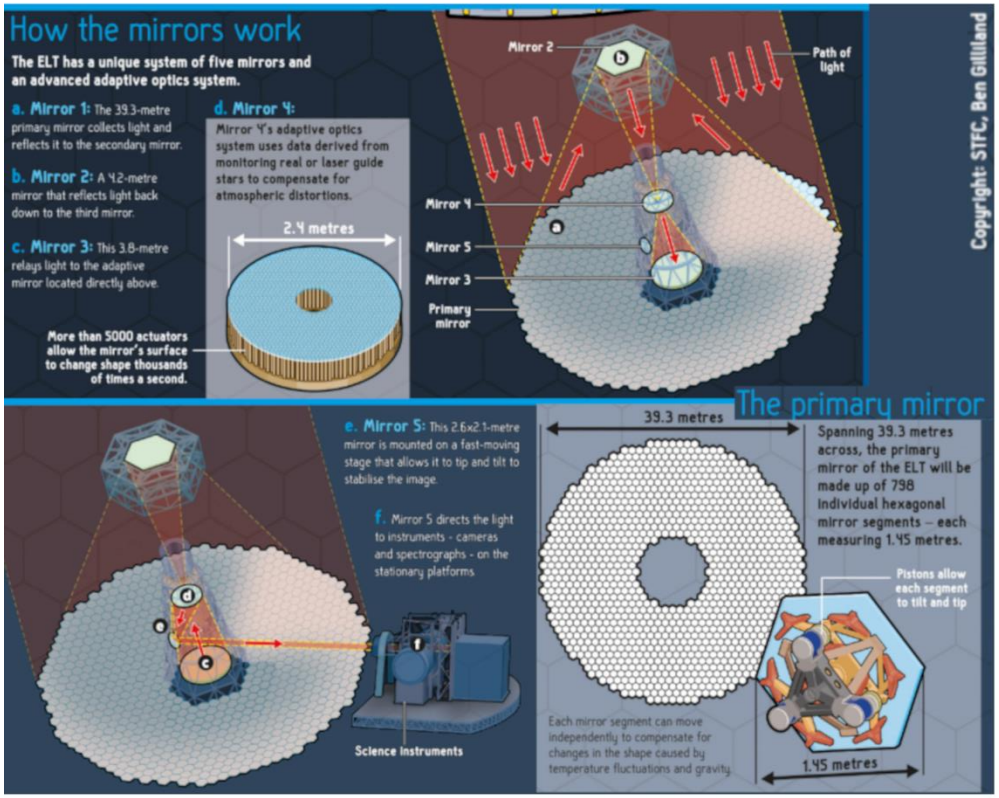


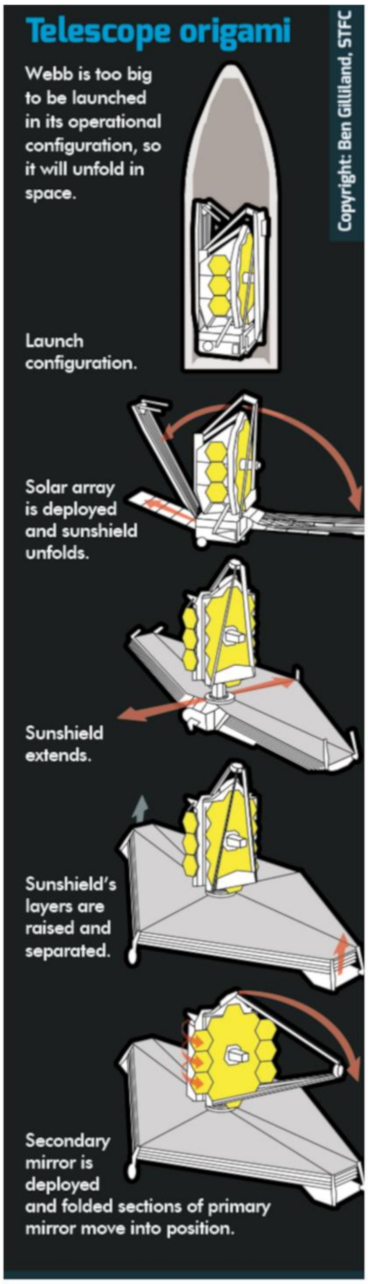
Looking back in time

Light travels very fast, but its speed is finite and can take a long time to reach us. As a result, the more distant an object is, the further back in time we looking. Hubble can see back to the 'toddler' stage of the universe when it was barely 1 billion years old. Webb will be able to capture light from universe's 'baby' stage when the first stars were born after the Big Bang.

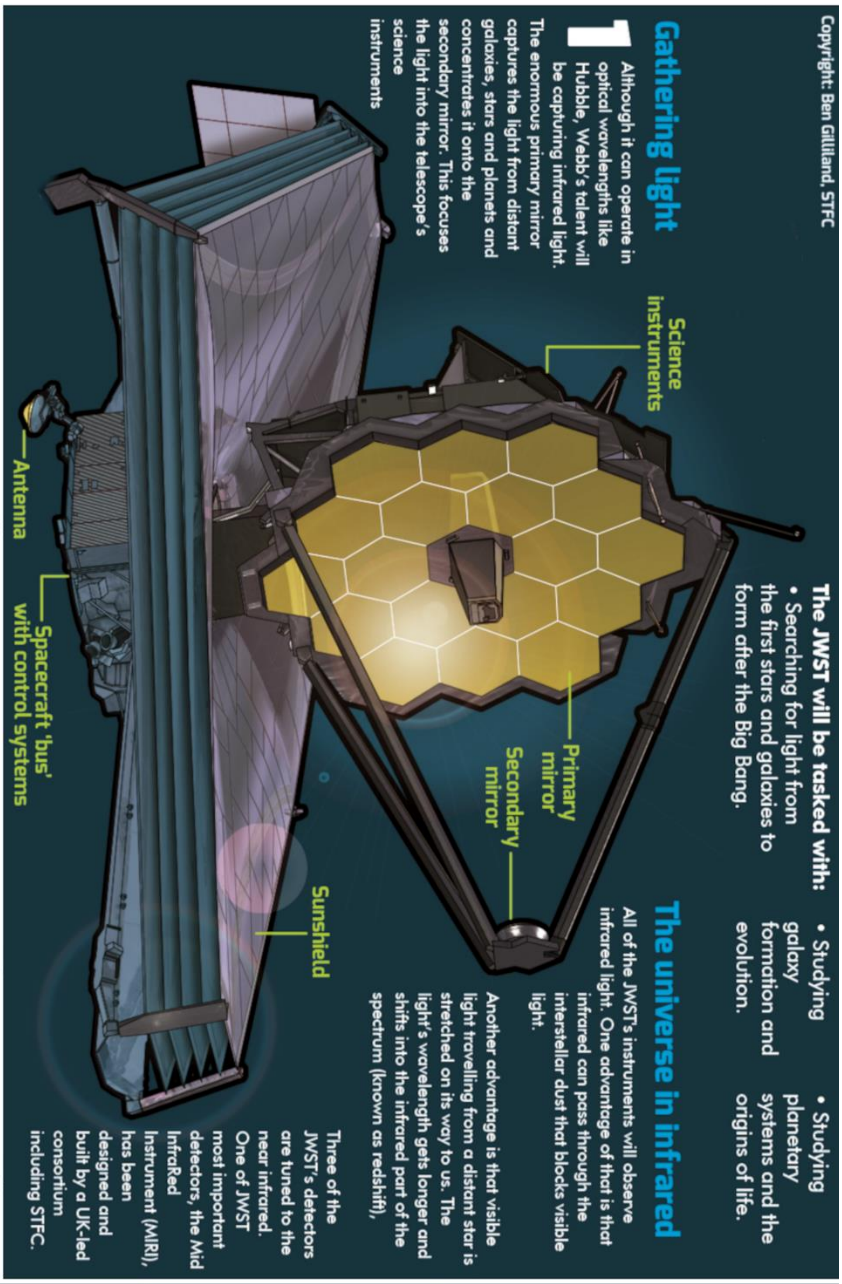


ELT information

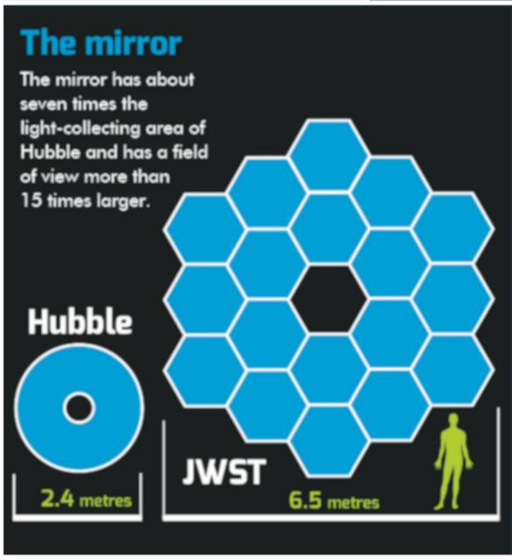




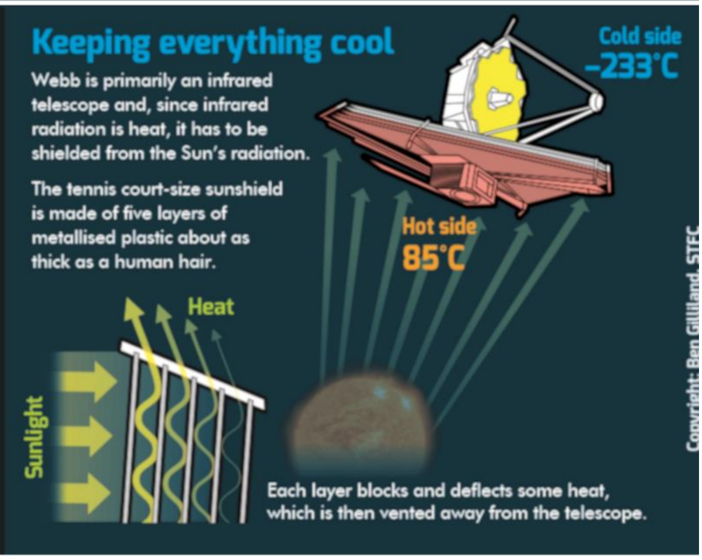
Telescope origami
Webb is too big to be launched in its operational configuration, so it will unfold in space.
Copyright: Ben Gilliland, STFC
Launch configuration.
Solar array is deployed and sunshield unfolds.
Sunshield extends.
Sunshield's layers are raised and separated.
Secondary mirror is deployed and folded sections of primary mirror move into position.



Copyright: Ben Gilliland, STFC
Gathering light
Although it can operate in optical wavelengths like Hubble, Webb's talent will be capturing infrared light. The enormous primary mirror captures the light from distant galaxies, stars and planets and concentrates it onto the secondary mirror. This focuses the light into the telescope's science instruments
Science instruments
Antenna
Spacecraft 'bus' with control systems
Primary mirror
Secondary mirror
Sunshield
The JWST will be tasked with:
• Searching for light from the first stars and galaxies to form after the Big Bang.
• Studying galaxy formation and evolution.
• Studying planetary systems and the origins of life.
The universe in infrared
All of the JWST's instruments will observe infrared light. One advantage of that is that infrared can pass through the interstellar dust that blocks visible light.
Another advantage is that visible light travelling from a distant star is stretched on its way to us. The light's wavelength gets longer and shifts into the infrared part of the spectrum (known as redshift).
Three of the JWST's detectors are tuned to the near infrared. One of JWST most important detectors, the Mid InfraRed Instrument (MIRI), has been designed and built by a UK-led consortium including STFC.



The mirror
The mirror has about seven times the light-collecting area of Hubble and has a field of view more than 15 times larger.
Hubble
2.4 metres
JWST
6.5 metres



Keeping everything cool
Webb is primarily an infrared telescope and, since infrared radiation is heat, it has to be shielded from the Sun's radiation.
The tennis court-size sunshield is made of five layers of metallised plastic about as thick as a human hair.
Cold side
−233°C
Hot side
85°C
Heat
Sunlight
Each layer blocks and deflects some heat, which is then vented away from the telescope.
Copyright: Ben Gilliland, STFC