ASTROBOOST

PUBLIC ENGAGEMENT WITH THE JAMES WEBB SPACE TELESCOPE

James Webb UK Space Telescope

Royal Astronomical Society

UKRI Science and Technology Facilities Council

Table of Contents

Introduction

This resource pack contains materials developed for the AstroBoost project:
https://jwst.org.uk/resource-network/articles/astroboost/

AstroBoost sought to support amateur astronomical societies in engaging local audiences with contemporary astronomy research by providing training, resources and equipment about the James Webb Space Telescope.

AstroBoost was created and managed by Dr Jenny Shipway on behalf of the Royal Astronomical Society. It was funded by a STFC Spark Award and run in partnership with the Webb UK campaign, Guildford and Newbury Astronomical Societies and Hampshire Astronomical Group.

For further information about the resources or the equipment referenced in the pack, contact the Webb UK campaign at: hello@jwst.org.uk

Prior knowledge

It's impossible to guess what people already know. This is true even for schools, who may be about to start a topic, or have just completed it. Individual pupils in a class will vary in their experience and knowledge. Interacting with the audience during the show is the only way to be sure you're talking at the right level.

Watch out though, there are traps:

- If you ask "do you understand", everyone will likely nod because it's socially difficult to say 'no'. Ask questions to test their understanding, ask 'which bits are still confusing?', or 'do you have any questions?'.
- Bright kids who have learned extra content from their parents will be the first to put their hands up. Wait a while for others to catch up and take answers from as many different people as possible.
- Children who are struggling are less likely to contribute. Remember you will always have a wide range of prior knowledge / abilities. These children especially will appreciate simple statements / repetition / recapping and contextualisation of concepts.
- Younger children might become over-focussed on asking questions if these are allowed throughout a talk, and so it's better to clearly identify times where these are appropriate (ideally at the end of each section).

Try to ask questions that don't require prior STEM knowledge. It's better to test whether they can understand what you've told them (or challenge them to work something out from information that you have provided).

You may otherwise find yourself rewarding the most privileged children, who have been given the most prior opportunities to learn (eg by a supportive family). Meanwhile less-experienced children may feel stupid for not already knowing something that they've simply never encountered before. It's better to reward people for effortful thinking about the subject matter.

Try to include some questions that anyone could answer (eg what is the brightest part of the image? What in the room do you think will look hot?). This helps include and give confidence to those who may otherwise be struggling with the content. Or ask questions that rely upon non-STEM experience (eg sport, or arts).

What they do at school

By the end of KS2 (yr6, 11yr), mostly in the final year of this period, they should have learned:

- Light is energy.
- Light appears to travel in straight lines.
- Shadows: what they are / why they make the shapes they do
- Light sources (eg the Sun) as compared to things that *reflect* light (eg the Moon)
- We see things because they give out / reflect light into our eye
- Light can be split into different *rainbow* colours of the *spectrum* using a *prism*.
- Light can *reflect* and *refract*.
- *Gravity* keeps the Earth in orbit around the Sun. More-massive things have more gravity.

By the end of KS3 (yr 9, 14yr), they should have also learned:

- Light travels really fast and can travel through a vacuum.
- *Luminous* things *emit* light.
- *Transparent* materials *transmit* light (*transmission*).
- *Translucent* things partly transmit light. *Opaque* things do not transmit light.
- Light can transfer energy from source to absorber (eg in eye/camera)
- Light is a wave. *Wavelength*, *frequency*.
- Use of ray model to show how mirrors, *convex lenses*, eyes work.
- *Heat* = the total amount of thermal energy in an object (kinetic energy of jiggling molecules)
- *Temperature* = a measure of the average kinetic energy in an object's molecules

For GCSE science (yr11, 16yr) they should also have learned:

- *The speed of light*.
- *Electromagnetic waves/spectrum - Gamma rays, X-rays, ultraviolet, visible light (colours), infrared, microwaves, radio waves and properties/uses of these.*

For GCSE physics, also:

- The pressure law: decompression decreases temperature; increasing pressure increases temperature. This is necessary when talking about how the space fridge works.

There is no problem with introducing concepts beyond what they may be currently doing in school. This can be a good opportunity to recap / reinforce concepts and jargon that is at their level. But do try to avoid introducing overly advanced jargon if you can avoid it.

Vocabulary

Jargon is *really* useful. But it needs to be used sparingly and with care.

Cognitive research has shown that working memory allows only a limited number of items to be considered at one time. Condensing a complex idea into a single word allows it to count as one item.

Think clearly about which jargon words you want to use during the presentation. They should be words that will be necessary/useful to use during this presentation, and which you will be actively using.

Each word should be clearly introduced in context, and then used a good few times. The first few times, remind people what it means (eg "So the wavelength – or colour – is related to …"). Be aware that people will need practice at recalling/interpreting (and preferably speaking) a word before it becomes defined in their brain in a way that allows them to use it as a single item in their working memory.

Physics of light, and heat transfer

There are many excellent places online to learn about the basics of electromagnetic radiation and heat transfer. Also some of you likely know this topic better than me, so I won't try to explain everything from scratch here. But here are some things to watch out for …

- Infrared includes a WIDE range of wavelengths. Many everyday uses of infrared (eg CCTV IR spotlights, TV remote controls) use wavelengths only just beyond the visible spectrum, aka shortwave-IR or near-IR. Near-IR can be seen using a mobile phone camera or hacked webcam, and behaves much like visible light. Webb's MIRI instrument and the Flir C2 camera detect longer, mid/far-IR wavelengths.

- Mid-infrared is easily absorbed by skin and so 'feels warm'. This is what radiant heaters emit. Near-infrared does not feel warm in the same way (it behaves more like visible light).

- *Heat* is a defined amount of energy, while *temperature* is a measure of the average energy per molecule in an object. A large, cool object may have more heat than a small, hot one.

- Mid-infrared is not the same as 'heat'. Heat is the kinetic energy of jiggling molecules, while infrared is energy in the form of electromagnetic radiation.

- The reason why mid-infrared is colloquially associated with 'heat' is that (i) everyday objects like our bodies are really good at absorbing/emitting mid-infrared and (ii) there's a lot of it around. (We absorb UV very well too, but there's a lot less of it in our environment.) So: mid-infrared is a form of energy which is significant for our *experience* of everyday heat *transfer*.

- Your skin does not directly detect mid-infrared in the way that your eyes directly detect visible light. Water in your body absorbs infrared, warming your skin. Your skin then detects the increase in temperature.

- If you stand behind glass you won't get any mid/far IR. But you'll still feel warmed by absorption of other (mostly shorter) wavelengths. About half the energy of sunlight is in the infrared.

- Snakes have tiny "heat pits", with temperature sensors inside. If they receive IR from one side, it heats the other side of the pit, giving them some directional sense. This type of structure is similar to that found in the early evolution of eyes, but these are NOT eyes because the IR is not directly absorbed by a light-reactive molecule. Also, the resolution is terrible! Generally, IR eyes aren't a thing because there'd be too much interference from your own body heat.

A trick to encourage questions

Sneaky trick: instead of asking "do you have any questions", try asking "what questions do you have?". Or, even more sneaky, "what questions do you think other people in the group might have?".

Why?

Using volunteers is a great way to break down the you/them glass wall. It shows that this is not a passive experience. It makes them relate to you as a real person, and you can demonstrate that you relate to them as real people too.

It can also be used for entertainment, humour, or just where you need an extra pair of hands.

Who?

Don't force people to participate! More likely though, you will have a number of people who are desperately keen to come up.

Sometimes you need someone who is super-confident, and a popular child can work well to engage the others' attention. But if you have multiple volunteers, then consider choosing the person your eye just subconsciously slid past – they are likely never picked. I used to like to pick the person sat next to the charismatic one who caught my eye.

Try to avoid giving someone a good appraising look but then rejecting them! Move your eyes quickly across the whole audience before making your decision.

Be sure to choose a mix of different groups / genders / ages / seating positions etc so that you are engaging with the whole audience and it doesn't look like you're playing favourites. Children like to see someone like them up there, and have a very strong sense of fairness. Beware picking the same person twice – if unsure, try saying "hands down if you've already volunteered".

If a school/group is going crazy with the hands up thing, getting up out of their seats, and behaviour is a bit sketchy generally, then saying "I'm going to pick .. someone who is sat nicely" is a good trick.

Ability and Disability

A friend of mine tells the story of calling a volunteer to the stage only to discover that the child had no hands. To their credit, they managed to adapt the demo so that the child could still help. (Flushed with success and relief, they then told the child to give themselves a big clap as they left the stage.)

Some people might have hidden disabilities. If you need them to have a particular ability, it is good to explain what this is before asking for volunteers. Eg "ok I need someone strong to help me hold this", "I need someone who has quick reactions", "I need someone to be my eyes".

Remember some people are unable to read or do simple maths. Again, just let them know what you'll be needing before they volunteer, and people can quietly choose not to put their hand up.

If there is a medical barrier to participation (eg magnets for pacemakers), again just say this up front. Never put someone in a position where they are asked to share medical information, even privately (they may have not shared such information even with their close families).

Welcome to the stage

It can be a scary place, stood up in front of your peers. Make sure they are confident of how to access the stage, and that you are there to give them a warm welcome with a smile and eye contact.

Getting everyone to join you in clapping them up (especially for larger audiences) is a useful way to fill the awkward gap while they make their way to you. The noise also gives you the chance to quietly give them a personal welcome / pep talk apart from that which the audience hears.

Always ask their name at the start – and do your best to use it.

You are now in a HUGE position of power over them, and responsible for their welfare. Monitor their happiness/confidence the whole time they're exposed on stage.

Help them by:

- Never making fun of their name / appearance / accent
- Avoiding turning your back on them or leaving them alone
- Ensuring they know exactly where to stand / what to do at all times
- Giving them positive feedback: "Great", "Exactly like that", "Perfect" etc
- Showing that you like them! You are impressed by them. Give them social kudos.

If they get a bit wobbly:

- Make eye contact and talk to them as if it's just the two of you, rather than talking to the audience.
- Cut the demo short if possible.

If they get very wobbly:

- Asking "are you OK to carry on" doesn't always work, as they may feel a social compulsion to say "yes". Try instead "Do you want to go back now?". If they nod then give them a big thanks/clap just as usual. Don't make a big deal of it or let them feel like they've let you down. If you need another volunteer to continue, be sure to pick them super quick. Don't make it a big deal.

Gender

Watch out for yourself preferentially choosing boys for physical roles, or girls for 'careful' ones.

It's really useful if you can train yourself to avoid using gendered language when referring to audience members. It's easy enough to say "pass them the ball", or "how do you think they did". This avoids a huge number of potential problems.

I have been *mortified* by my mis-gendering of a sturdy, short-haired female teacher as a man (and similarly a willowy long-haired boy as a girl). It can be genuinely hard to tell, even when you think you are sure!

Also of course using non-gendered language is also inclusive of people who are trans, or have other gender identities. The point is just not to make gender an issue, so that everyone can focus on the science

Avoiding gendered language also reduces stereotype fulfilment. This is a psychological phenomenon where people reminded of their identity will perform closer to the stereotype for that identity. This means that by reinforcing someone's female identity, you may well be reducing their ability in (stereotypically male) scientific thinking.

With that in mind, also avoid stereotyping your volunteers eg by admiring a young girl's dress/hair, or assuming that a boy likes cars. Let the interesting/valued thing about them be that they are individuals with scientific, enquiring brains.

The volunteer's task

Make sure they have something genuinely useful, and preferably interesting to do. If they have some agency over how the demo proceeds, that is ideal. If it's really boring but you genuinely need help, you can acknowledge this and make it humorous (eg "I need someone to help me with a really boring job!").

Take time to explain what you need very clearly. They are under stress and may not pick things up as quickly as they usually would. Speak clearly and while facing them – they may not be a native speaker, have a hearing impairment, and/or be partly lip-reading.

If at all possible, physically demonstrate/mime what you want them to do so they can copy your body position/movement.

If timing/precision is important, get them to demonstrate that they have understood by practicing / miming what they are going to do.

If they are doing something physically demanding such as holding something out straight in front of them, check periodically that they are ok with this. Think about whether you can give them a break during the demo to rest their arm.

Take time to pad out the demo to include a chance to talk to / involve them in what is happening.

Not like that ..!

Remember volunteers are not predictable and may not follow instructions! Consider this in risk assessment of all demos – what would happen / what would you do if they ignored your instructions?

If a volunteer is not following instructions because they didn't understand, don't make fun or otherwise embarrass/humiliate them for this. Communication is a two-way street and you're the one in the position of power. Just apologise for not making it clear (even if you think you did!) and take the time to explain more clearly.

If a volunteer is not following instructions even though they understand what you want, don't feel you need to tell them off. Parents can get super annoyed about other people telling their kids off, and anyway it's not appropriate to do so in front of the whole audience.

Instead, just explain clearly/directly that you need them to do it as you've asked, else you'll need to get someone else to help. If they continue messing around, then ask them to return to the audience and get someone else up. You can do all of this without being unfriendly. Smile as they leave, just as though it's the most natural thing in the world. Don't let it become an important/memorable moment compared to other parts of the show.

ON-STAGE VOLUNTEERS

Thank you!

When you are finished with a volunteer, let them take their seat as soon as possible.

There's nothing more awkward than a volunteer standing alone on stage unsure whether they should have already left, while a presenter addresses the audience to recap what happened in the demo. If you get stuck in that situation, include them in the recap so everyone knows you're aware they're still there.

Always make it really clear when you are finished with a volunteer. Leave them with eye contact and a thank you. Saying something like "Thank you very much. Everyone give a big hand to Fred. You can go back to your seat." makes it clear what they need to do. Be aware that young children may not realise that the social convention is that they should leave the stage at this point.

It's nice to spend a little time watching them leave while smiling and clapping them so it doesn't look like you've washed your hands of them the moment they left your immediate area. Or, in a small audience, to make more eye contact than usual with them in the minutes following their demo.

JIGSAW ACTIVITIES

Ideas for activities using the Webb mirror jigsaw pieces

Activities to help people learn about the size, design and function of the Webb telescope.
The jigsaw is sized so that, when assembled, it is the same size as one panel of the real Webb telescope mirror. The below activity suggestions assume you have already explained a bit about the telescope already, including its general structure and that the mirror is a light collecting surface.

Learning objectives:

1. The mirror is huge!
2. The multi-panel design allows the mirror to fold up to fit inside the rocket.
3. The mirror is gold because gold reflects infrared light (if you have already talked about infrared)

Common misconception 1: The pointy bit (secondary mirror) is beaming something out into space to 'see'.

Common misconception 2: The mirror is a detector.

Photo: Julia Gaudelli, Guildford Astronomical Society

Build the jigsaw

At its absolute simplest, you can just leave the pieces of the mirror out (on the floor works best for children), and let people assemble the hexagons into the right shape. They should then mix them up again for the next user. The mirror pieces are robust enough that this works fine so long as you or another sensible adult are in the general area to ensure they are not thrown about.

Be aware that a 10 year old child might be very quick to finish the jigsaw! If you need them to spend longer on this activity, you will need a plan for how to achieve this. Some ideas are given below.

The resources include a printable challenge sheet you could use to help guide them. This should print out fine in black and white. There is a picture of the telescope, but the lines between the segments have been removed to make the puzzle more challenging.

Photo: Alastair Bruce, AstroBoost 1 training day

The guide sheet includes some questions as an activity extension. If doing the activity as a round robin, you may want to discuss the answers to the questions at the end in case anyone was unsure.

This could also give them the opportunity to show off their new knowledge, an act that will help them recall it again in future.

f they haven't already been given the information required to answer the questions, just delete them.

With enough adults, it can be assembled in mid-air. This gives more of a challenge, involves more people, takes longer, and you can talk about the overall shape and how individual segments move.

Paper Pentagons / Hexagons

There are printable pentagons that you could cut out and provide to help them to answer the first question. There is a sheet to store the pentagons.

There is a matching sheet of printable hexagons provided too, just in case this is useful for something!

How Big is Webb's Real Mirror?

There is an explanation sheet for this activity, but it will still probably need a leader to ensure people understand what they are meant to do. (People are not good at reading instructions!)

I suggest you let them measure the jigsaw using a string that you have provided (in which case make sure it's much longer than needed, not exactly the right length), or maybe just have them pace it out. They can then multiply this length x4 to measure out how wide the real mirror is. If it's too big to fit in the room, that is not necessarily a bad thing, as it will show just how huge it really is.

I would suggest avoiding using a tape measure or ruler because the maths and numbers could distract from the emotional impact. Having a feel for the size is much more useful than remembering a number without the associated meaning. You want them to be imagining it in the room, like they were stood next to it.

Photo: NASA/ NASA/Desiree Stover
Licence: https://creativecommons.org/licenses/by/2.0/

Extra background information

The mirror segments are primarily made from **Beryllium** which is very strong, and a relatively lightweight material considering its strength. It also has excellent thermal stability. For these reasons, it is commonly used in spacecraft manufacture.

The gold layer is very thin. Gold is used as it is highly reflective to infrared. The gold is added to the highly-polished segments by vacuum vapour deposition, which achieves a layer just 100 nanometres thick (that's about 600 atoms thick). Altogether, the gold would make a **cube about 1.5 cm wide**, weighing just 48 grams.

Using hexagons is good because they pack nicely into a roughly circular shape, but also because in terms of **symmetry** there are only three types of segment position that need to be calculated for.

Find lots of nice mirror information and interesting videos at:

https://www.jwst.nasa.gov/content/observatory/ote/mirrors/index.html

Demo ideas

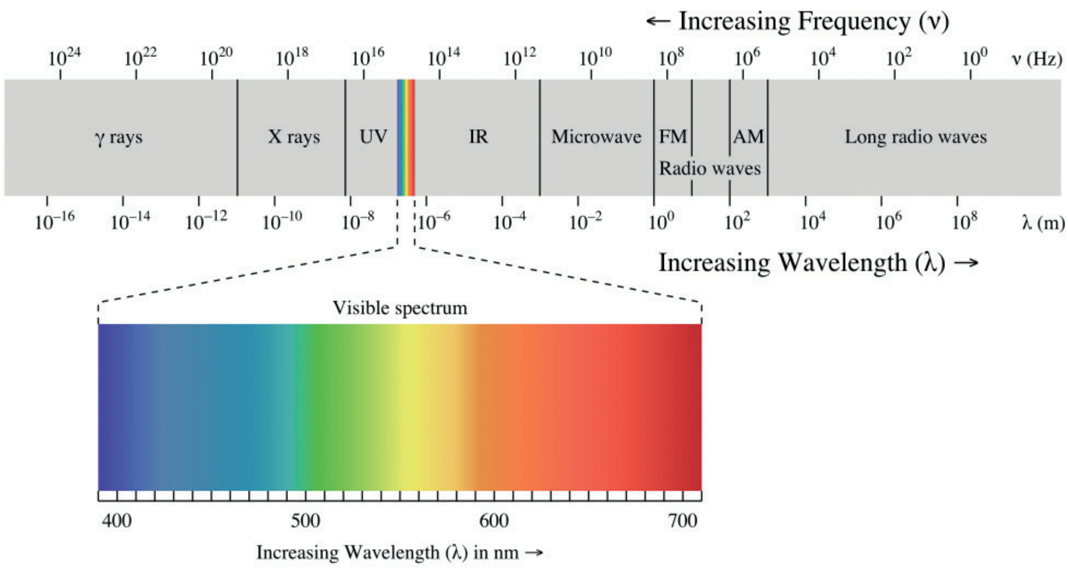
For more camera-related but mostly non-astronomy educational demos, see
https://www.techknow.org.uk/wiki/index.php?title=Infra_Red_Camera

INFRARED (IR) CAMERA

Just like a normal digital camera, the Flir C2 creates its images by detecting light focused through a lens. The difference is that it does this both for normal (visible) light AND for mid-infrared (invisible) light.

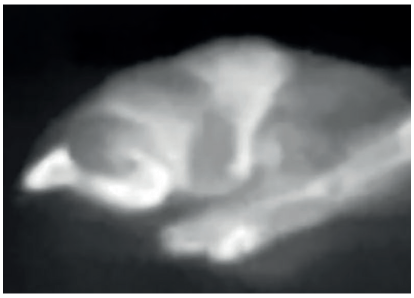
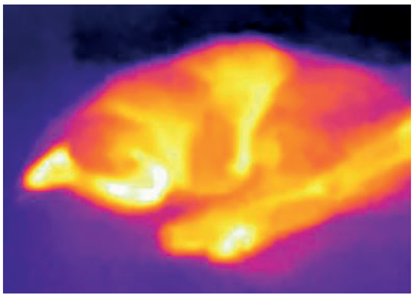
Very hot objects might glow in visible light. Pretty much all objects glow in mid-infrared (this requires less energy than visible light). Generally, the hotter they get, the more IR they emit.

Objects can also reflect IR, but you will find that these signals are usually overwhelmed by emissions.



Just as a normal black-and-white camera doesn't distinguish between colours (i.e. wavelengths), the C2 doesn't distinguish between different IR wavelengths. It just measures the total intensity of light between wavelengths of 7.5-14µm. Effectively it takes a black and white picture of the infrared world.

That said, you will find that most IR images have the IR intensities colour-mapped. This means that the different grey tones from the black and white image are shown as different colours.

Louis the Cat in (i) visible light (black/white), (ii) infrared (black/white), and (iii) infrared (colour-mapped).

Colour mapping does not add any information. It does not tell you anything about the wavelength of the IR. It just makes the differences in IR intensity clearer for the human eye. Colour choice is arbitrary, and usually chosen depending on which information is intended to pop out. Many people find this step a bit confusing, so it needs careful explanation.

Most people find it intuitive to use red/bright for "warmer" and blue/dark for "colder", so it is suggested to use this type of colouring by default. It's best to avoid rainbow colour maps as it's likely at least one person in your audience will be colour blind and unable to interpret these.

Physics info: emission and reflection

People often think the camera is measuring the object's temperature. But this isn't quite right:

- How much IR an object emits depends on its temperature AND how good an emitter it is
- Objects can reflect IR from other sources (e.g. the Mylar sheets act like IR mirrors)
- IR is absorbed by the air, so distant objects appear to emit less. And air can also emit IR!

The Flir C2 camera can be set for specific types of object to adjust for their distance and properties to allow more accurate temperature estimates. They are designed for use on building sites, so they might expect settings to allow for the different IR-reflectivity of e.g. metal struts, plaster wall etc.

Note that even cold things like ice will emit some IR radiation as they still have some heat (they are not at absolute zero).

Camera info: including a note about night vision tech

The camera by default will overlay information from the visible-light image to help outline objects in the IR image. You will see this mode when using the display on the camera's back.

Be careful that you don't present this type of image as being purely IR!

Using the software, you can switch to displaying IR-only. Be sure to use IR-only mode to avoid confusion.

Some CCTV cameras and/or night vision set-ups use an IR spotlight/floodlight to 'light up' a scene. These IR-reflection images (aka active illumination) look very different to the images the C2 produces, the C2 images being dominated by IR-emission.

But before you rush out to buy yourself an IR torch, be aware that these active illumination set ups use near-IR, which is shorter wavelength than the C2 can detect. If you want to make near-IR images, you can do this by using a hacked webcam (remove the IR filter) to detect the reflected light. Else trying using a smartphone: these usually have some detection in the near-IR.

RIGHT: Possum lit by near-IR spotlight. See how the warm possum looks darker than the cool pathway, because this camera is picking up reflected near-IR rather than emitted thermal/mid-IR.

Night vision goggles work by detecting very low levels of visible light plus near-IR, and multiplying up these tiny signals. They create an image that looks very similar to a normal black and white visible light picture. Such images are often colour-mapped to green because the human eye is more sensitive to green light.

Demo ideas

For more camera-related but mostly non-astronomy educational demos, see https://www.techknow.org.uk/wiki/index.php?title=Infra_Red_Camera

Ideas for activities using the Flir-C2 infrared camera

Activities to help demonstrate how the camera works and how to interpret the images.

Learning objectives:

1. Like Webb, the camera uses infrared light to reveal information not visible to our eyes
2. Infrared is like visible light in some ways
3. Infrared is different from visible light in other ways
4. Familiarity with the words "infrared", and (for ages 11/12yr+) "emitting" and "wavelength".

Photo: Julia Gaudelli, Guildford Astronomical Society

Common misconceptions:

If someone holds a misconception, it can be very hard for them to replace this idea in their mind, even if you explain it clearly. You will need to tackle these head-on if they are to try to change their prior beliefs.

Common misconception 1: That the camera measures the temperature of the object (not true, although if you calibrate it to the correct material then the data it collects can be used to give a good estimate of temperature).

Common misconception 2: That eyes/camera are emitting something that collects information from the seen object.

Common misconception 3: 'infrared is heat'. It is not; infrared is electromagnetic radiation, just like visible light. It just so happens that mid-infrared is easily absorbed by everyday objects/bodies and so is good at heating things up (transferring energy from one object to another). So our most familiar experience of it is that it makes us feel warm

Break down the concepts:

Take it one step at a time - it's a lot to process for people who are new to the concept of infrared. Avoid getting into reflection or good/bad emitters until they are confident with the general idea of what the camera is detecting.

Separated concepts to tackle one at a time (not necessarily in this exact order):

1. The camera shows a view of the world different from that which we see with our eyes.
2. Hot objects appear bright/different colours when using the camera.
3. Both our eyes and the camera work by detecting light that happens to shine into them from outside (many people, especially children, think that the eye sends light/something out to capture the image).
4. The camera detects *infrared light*, in contrast to a normal camera, or your eye, which detect *visible light*.
5. Infared is a type of light that is invisible to eyes. It's next to red on the rainbow.
6. Infrared light is going from the object into the camera.

7. Objects give out (emit) infared. (This is difficult to grasp; they are glowing with invisible light).

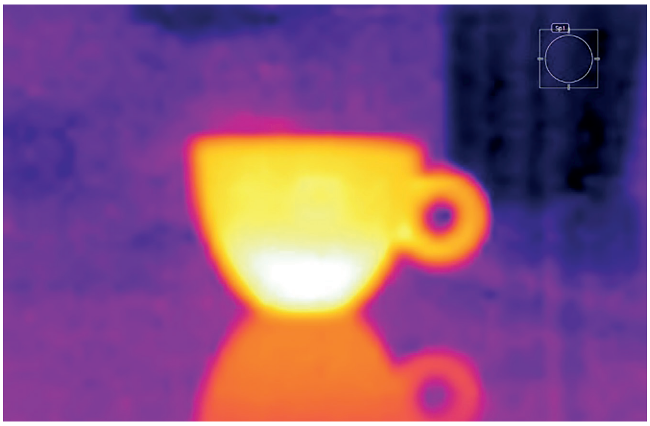
8. The hotter a thing gets, the more infrared light we see coming from it.

9. Infrared light doesn't always behave exactly like visible light. Different materials can reflect/absorb it.

10. By detecting infrared light, we get information that we cannot access just using our own eyes.

The last item is the key for understanding why the Webb Telescope uses infrared

Warming objects - Head pad



We've provided a heat pad as a way to safely warm objects without need for a complicated risk assessment. Keep the pad opened up flat and it will not overheat (if it does overheat, only the manufacturer can reset it!). Be aware it turns off periodically if left for a long time. Remember to tuck the cables out of the way, and don't use if damaged.

If you use other methods to heat things, just be careful with risk assessment for anything that gets over 40°C. Remember escapee toddlers won't read warning signs, and always have a plan for in case anything did go wrong.

Suggested activities

Attention Grabber: see yourself on screen!

This works very well on a drop-in display stand. People love to see themselves and to try different things, including taking photos of themselves. It's an effective way to attract visitors. You can then offer them different materials to experiment with, or give them ideas for things to try, depending on their ability to direct their own investigations. This gives an easy way to start a conversation.

During a Powerpoint talk, you can point the camera at the audience. Make sure you give them some time to enjoy waving their arms around etc before you start trying to explain what they are seeing as they won't be listening to you at first! With younger/excitable audiences you might need to turn the camera away to recapture their attention before continuing.

Humans are great to observe as they have both hot and cold bits, and people are (mostly) familiar with which are which. Also people enjoy looking at humans! This makes people a good thing to look at while talking about how the camera detects infrared, and that hotter things tend to give out more infrared and so appear brighter.

Top tips:

- Be ready to move the camera to preserve people's modesty if necessary! Bras may be visible through thin tops, and it's best to avoid the groin area.
- Do not ask people to undress or lift clothing (even if it's just a school jumper). However, be aware they may choose to do this! If they do, you will need to dynamically assess whether their behaviour is appropriate and safe for the context you're in (e.g. an unaccompanied child vs a child with their adult are very different).

Decoding the images: Relating camera image to heat of objects

The following activities give you the excuse to repetitively explain what the camera does, in different ways, using the scientific language you want them to become familiar with.

It's expected that you should have to explain things a few times before people understand; repetition is required for formation of memory. Also, different people will 'get it' from different types of explanation.

Things to try:

1. **Rub hands** together or rub feet along the floor. (Friction; kinetic energy transformed to heat energy.)

2. **Press hand** against magazine or other object, then remove it and look the handprint. The magazine demo goes down very well with primary age pupils, especially if it goes through to the other side. (Conduction.)

3. **Walk** without shoes across the floor, and look for footprints. (Conduction.)

4. **Spray compressed air** onto book / hand to rapidly cool it. (Decompression.)

5. **Suck air** in through clenched teeth (this will cool them).

6. **Free exploration** by a small group – the camera is robust and easy to use even for young children. They will talk to each other about what they're doing, which is great for cementing understanding and learning new language. Teenagers may be more confident to chat to each other when you aren't close by.

7. **Ice War Paint**: let people draw on their faces/arms with pieces of ice. Beware this will quickly get messy!

In my tests, the Flir C2 didn't appear to have good enough resolution for the mixing of hot water / ice to give a good result, but it'd be worth experimenting with this yourself to see if you can make it work.

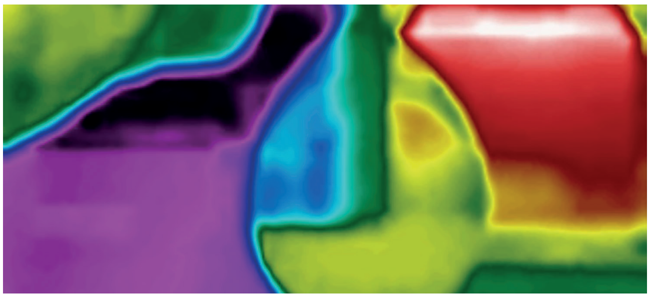
Things to try outdoors:

1. Look at **cars!** You can see the hot engines (or spot electric cars), and see their wheels heating as they brake. Can you spot those cars which have started their journeys recently? Or recently parked cars?

2. Smoke – if you are at an event with a fire or barbecue, you could try looking through the smoke with the camera. This would be a perfect demonstration of how Webb will look through nebulae. Careful risk assessment required if you are to try this!

Top tip: you may want to fix the colour-mapping on the camera to a specific temperature range, to make temperature changes easier to track. This especially where an object is the hottest or coldest thing on screen. By default the camera will dynamically change the mapping to the range of temperatures currently in view.

Infrared properties (vs visible light)



Infrared behaves like visible light in some ways, but differently in others. Once people understand what the camera is showing, you can use it to demonstrate these differences.

Jargon words:

Opaque, translucent, transparent, transmit, transmission, absorb, reflect

1. Bin-bag material: nearly-opaque to visible light; transparent to infrared.

You'll to test this on your particular bags to be sure; cheap-ish bags are great, thick rubble-sacks will not work! Bin bags can be used to represent a 'nebula' hiding interesting objects that Webb will be able to observe. For demonstrations the material can held up in front of a person, who is still visible to the camera. (Do not let anyone put the bag over their head.) When using the bin bag to screen objects from view, ensure they are not touching the bag, else the heat will conduct through.

It's weird that Bin Bags have this properly as they are black. Black is usually good at absorbing infrared! However, this material has been specially designed to be transparent to infrared so that any heat from decomposition of the contents can escape (rather than getting trapped and speeding decomposition).

2. Glass: transparent to visible light and near-infrared; opaque to mid-infrared.

Visible/near-infrared sunlight can get into a greenhouse and be absorbed, heating the contents, but infrared radiation emitted by the heated objects cannot escape. Try looking at people who are wearing glasses. Do you think the infrared camera lens could be made of glass? *(Why not?*)*

3. Mylar (e.g. emergency blanket): reflects both visible and infrared light.

This can be a nice surprise and a good way to recall that infrared is a type of light. Webb's sunshield material similarly reflects infrared light to keep it cool. Why are emergency blankets made of Mylar?

4. Water Balloon: water is opaque to infrared; the stretched balloon is translucent.

It is possible to fill a balloon half with air and half with water to show that the water is absorbing the infrared. Else have one with water and a similarly-sized one full of air. Make sure you have something hot that you can look at through the balloon(s) to make the difference clear.

This demo can be used to explain why the water-laden atmosphere ruins our view of the infrared universe. Nb raindrops don't absorb all of the Sun's infrared and so rainbows do still have a mid-infared band.

I tried to fill a balloon with CO_2 from an acid/base reaction to see if you could talk about CO_2 absorbing infared re climate change, but I couldn't get this to work (I'm pretty sure you'd need a lot more CO_2).

Health & Safety tip: some people are allergic to latex

** This is one of the reasons these cameras are expensive (another being their specialised detector).*

Activities for older audiences

Best for secondary school age (11/12yr+) and adults, after they are confident with the concepts discussed above.

1. Why does the mirror need to be SO big

Webb's mirror is a lot bigger than that of Hubble, but its resolution is similar.

Infrared light has a longer wavelength than visible light.

2. Do all room-temperature objects look the same on camera?

They will observe that objects can look different. This happens if one is a better *emitter* than the other.

This is an excellent entry to reinforce the fact that the camera does not show temperature! The camera can only detect infrared, and different objects give out different amounts of infrared depending both on temperature AND how good an emitter it is.

Good emitters are also good absorbers, so things that heat up more easily in the sunshine are also better emitters – e.g. black things tend to be better emitters than white things. Can you find any examples of this? Are there counter-examples (e.g. shiny black things)? Can you predict which of two objects is the better emitter before looking with a camera?

3. How does the Webb space fridge work?

Demo requires a bicycle pump with value, and a compressed air cannister (you can buy the latter for cleaning electronics/keyboards). It is best to fix the colour-mapping on the camera before doing these demos, so that the temperature changes are clearer.

Concepts to demonstrate:

Depressurisation cools things down. Show the cannister is room temperature, then spray it onto an object (e.g. your own hand). As the gas escapes, it depressurises, and cools.

Pressurisation heats things up. Use a bicycle pump with nozzle and show it heating when pumped. This is a bit of a tricky demo so make sure you practice in advance especially re how to hold it so that conduction from your warm hand does not confuse the demo.

How do fridges work:

The space fridge works like a domestic fridge. Fluid circulates. On the telescope side of Webb, the fluid is depressurised, so that it gets VERY cold and is able to absorb any tiny bit of heat from the instruments. Then on the sunward side of Webb, the same fluid is pressurised, heating it up so that it can radiate the collected heat away into space.

Webb on the Web: selected resources relating to Webb science

AstroBoost provides a selection of Powerpoint Slides to help you build your own presentation. You can find useful information and images in the following places:

- The WebbUK campaign website at: https://jwst.org.uk provides an overview of Webb science and engineering. Further resources can be found at: https://jwst.org.uk/resource-network
- NASA provides selections of images at: https://jwst.nasa.gov/content/multimedia/images.html and at: https://webbtelescope.org/resource-gallery/images

You'll need to check copyright. But almost all of these should be free to use, maybe just requiring a credit.

- The NASA website at: https://webbtelescope.org/ have a very cool animated slideshow landing page which would look great as an attractor on a drop-in stand.
- There are some great animations and time-lapse videos which could be useful to flesh out a talk or to play at a stand at: https://svs.gsfc.nasa.gov/Gallery/JWST.html

Photo: NASA/Chris Gunn;
Licence: https://creativecommons.org/licenses/by/2.0/

Hands-on Activities:

There are a variety of Webb resources available online, albeit of very variable quality. Here are some of the best:

- A template for making small, cut-out card mirror panels: https://www.jwst.nasa.gov/content/forEducators/ballActivity1.html
- A picture of Webb for young children to colour in: https://jwst.nasa.gov/education/D1899JWSTcoloringpage.pdf
- Print/make paper models of Webb (watch out some are quite challenging): https://www.jwst.nasa.gov/content/features/educational/paperModel/paperModel.html The website also has a gallery showing different ways that people have constructed models.
- There is a pack of activities relating to colour available in English and Welsh from https://www.stem.org.uk/resources/elibrary/resource/34400/colour-chaos Most of the activities are not relevant to Webb, although teachers (KS2-3) may be interested if they are planning wider work around the topic of colour.

  They also offer this way to make a spectrum:

  "Place a [small] mirror in a glass of water at an angle. Put this on the [sunny] windowsill and turn the glass so that the mirror is directly facing the Sun. Next, hold the paper at a slant in front of the glass. Move the paper around until you see the rainbow"

Useful resources you could mention to teachers:

Words and pictures: Teachers planning for children to investigate practical uses of infrared light on Earth (e.g. by vets, geologists, or firefighters) might be interested in: https://coolcosmos.ipac.caltech.edu/infrared_world

Six minute video for KS2-3: a team of children learning about differences between infrared and night vision, and choosing an infrared camera to 'rescue' someone in a dark, smoke-filled building: https://www.bbc.co.uk/teach/class-clips-video/science-physics-ks2-ks3-seeing-through-smoke-the-heat-camera/z4pw2sg This could be a nice thing for the children to watch BEFORE you visited a school, to help them learn the basics and to get them interested to see and use the camera.

Primary school resource book: The Deep Space Diary is a free primary STEM programme based around the James Webb Space Telescope including 25 curriculum-linked classroom activities and teacher notes. Some activities are also ideal for one-off workshops, and all can be downloaded for free at: https://www.discoverydiaries.org/diary/deep-space-diary/

Secondary school data project: Teachers of children aged 14yr+ (yr8+) might be interested in the Institute for Research in Schools (IRIS) Cosmic Mining project. Young people collaborate with researchers to carry out spectral analysis of Spitzer Space Telescope data to select potential targets for Webb, with the opportunity to present their research at an IRIS conference: https://researchinschools.org/projects/cosmic-mining/

People profiles and animations: The WebbUK campaign has developed profiles of scientists and engineers involved in the Webb mission which would be suitable jumping-off points for discussions about STEM careers. They can be found, along with animated videos about Webb, at: https://vimeo.com/user96759035

AstroBoost

These resources are adapted from the Royal Astronomical Society's original AstroBoost project, which was funded by a STFC Spark Award. The project was managed and developed by Dr Jenny Shipway.

Notes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