The Royal Institution
Science Lives Here
Masterclass network

Session Leader Notes

Primary OTS Masterclass: Satellite Vision

Thank you very much for leading this Masterclass. We hope that you enjoy working with this material as much as we enjoyed putting the activities together. We do appreciate all the effort that our volunteers put into bringing inspirational Computer Science Masterclasses to students around the country.

Inspiration for this topic:

In this session, students will explore how digital images are made, how resolution affects what we see, and how colours are assigned to reveal hidden detail in space. By becoming image processers themselves, they will uncover how telescopes like the James Webb Space Telescope (JWST) transform invisible light into breath-taking cosmic portraits. This session also introduces real-world computing applications in astronomy, showing students that science isn't just about looking – it's about decoding the universe, one pixel at a time!

Overview of Activities:

1. Guess what the image is activity – students guess what the image is as resolution increases
2. How do we create an image activity – students role play as light and electrons (optional)
3. Worksheet 1 – Pixel Bingo
4. Worksheet 2 – A Message from Space
5. Light Spinner activity – students make their own light spinner (optional)
6. Guess the RGB colour activity – students use RGB colour picking to make different colours
7. Worksheet 3a – Making a space image – AstroLab
8. Extension: Worksheet 3b – Making a space image – Observing with NASA

General Masterclass resources needed:

- Register of children
- Consent forms and emergency information to hand
- Stickers and markers for name badges
- Adult register
- Ri child protection policy
- Paper and pencils
- 2 different coloured post-it notepads (for feedback at the end)
- Drinks and biscuits

Specific resources needed (tailor to the number of students attending):

- 1 copy of Worksheets 1 and 2 per student
- 1 copy of Worksheet 3a per pair
- Laptops, computers, or tablets with internet access (Google Chrome and Safari are currently both supported), 1 per student ideally

Optional:

- 1 copy of Worksheet 3b per pair
- Coloured light filters (3D glasses also work well)

If students will be making their own light spinner:

- 1 copy of Light Spinner instructions per pair
- 1 copy of the Light Spinner template per student
- Scissors
- Glue sticks
- String (enough for 60cm per student)
- Card or cardboard
- Colouring pencils (red, light blue, blue, green, yellow, and purple colours required).

Support resources:

- PowerPoint slides
- Session Script

Things to prepare in advance

- Gather the complete list of resources as detailed above
- Print worksheets, additional information, and any other resources as needed
- You may wish to set the following webpages to be bookmarked on the students' devices or have the links easily accessible for the students. Alternatively, the instructions for accessing these webpages are in Worksheet 3a and Worksheet 3b.
    - Image Processing software – AstroLab - https://www.schoolsobservatory.org/astrolab/?lvl=0
    - Space Images for downloading from the Schools Observatory - https://www.schoolsobservatory.org/get-started/view-images/egimages
    - Image Processing software – Observe with NASA - https://waps.cfa.harvard.edu/eduportal/js9/software.php
- You may wish to prepare the light spinners in advance, or pre-cut the templates for the students.

Ask the Ri

Don't forget to collect any questions which arise, and email them to the Masterclass team at the Royal Institution: masterclasses@ri.ac.uk

Feedback

We would very much welcome your feedback on this session. If you have time, please collect feedback from the students at the end of the Masterclass and send it through to us. We would also appreciate feedback on how you have used the session, what you think worked well and what improvements would be useful.

Time plan of Masterclass:

Slides & Time	**Overview**	**Activity (see script for further details)**
Slides 1 - 3 5 minutes (5)	**Satellite Vision: What is an image?** Introduction	Welcome students to the masterclass. Ask if they have any guesses what the pixelated image on the first slide shows? Go to slide 2, and increase the resolution of the image, starting with a 10 x 10 pixel grid image, then click to add more pixels in. Ask if they have any new guesses each time. After 4 clicks the image should show the full resolution of the image. Explain that this is an image of the Dumbbell Nebula – a cloud of gas and dust that is the remnants of a dying star. Explain that at the end of the session, the students will make their own images of the Dumbbell Nebula. Ask why we cannot see space like this with our own eyes, and how we might get images of space. Explain that objects in space are much too far away for our eyes to get any detail from, and so we can use telescopes on the ground and satellites in space to take detailed images for us. Introduce the idea that resolution is the measure of how much detail you can see in an image, the higher the resolution the more detail you can see. Go to slide 3, and explain that an image is a visual representation of something that is stored in a computer as data, with numbers telling us what each part of the image looks like. Explain that there a lots of different ways images can be taken, with different equipment and different types of light forming the images. Give the examples of an x-ray, MRI, and thermal imaging. Explain that we can use these types of light to image when exploring space.

Slides & Time	Overview	Activity (see script for further details)
Slide 4-6 5 minutes (10)	**Pictures from space**	Ask the students if they can identify anything in the space images. Explain that the top left image is of the Sun, using x-rays and ultraviolet light, and shows us where the most bright, energetic regions of the Sun are. The image below this is of the Andromeda galaxy seen in ultraviolet light, and the bright spiral sections are areas of new star formation. Explain that the image on the right is of Jupiter, taken in infrared light. We can see Jupiter's rings, which we are not able to see in optical light. Explain that this image of Jupiter was taken by a telescope, called the James Webb Space Telescope. Go to slide 5 and introduce the James Webb Space Telescope, explaining that it images stars, galaxies and planets using infrared light. Ask why they think telescopes might take images of stars and galaxies in infrared light. Explain that infrared can see through clouds of gas and dust, unlike visible light. Relate the use of infrared light to students lives, by explaining that they use infrared every time they change the channel of the TV, using a remote. Go to slide 6 to showcase some of the infrared images taken by JWST of the Carina Nebula (top left), Eagle Nebula (bottom left), and Horsehead Nebula (right). Explain that you could say that all of these images have been photoshopped, since the colours of the images have been chosen in order to display the different features. Explain that we are now going to look at how an image is actually created.
Slide 7-9 5 minutes (15)	**How do we create an image?** Student role play as electrons and light. Video optional in place of role play activity.	Explain to students that imaging equipment has detectors in them that detect light. When the light hits the detector, it releases an electron, which can still be stored in a specific place in the detector, called a pixel. You may wish to demonstrate this by getting volunteers to demonstrate. Line some students up as electrons, and label the other students as light, and have the 'light' students vibrate into the 'electron' students, so that the 'electron' students take a step forward into a 'pixel'. Explain that the number of electrons for each pixel represents how bright or dim a specific part of the image is. If not demonstrating with the students, play the video from the 2014 Royal Institution Christmas Lectures, by Professor Danielle George (4:33) - https://youtu.be/h57pH5rbLgw?si=F4csXhG0dIjhtd3Z. Showcase how an image of a dog is actually made up of lots of pixels, by clicking to zoom in to see a close up of the dog's eye, then click to show an even closer shot that shows a grid of coloured pixels, then click to showcase one specific pixel within the image. Explain that a pixel is also called a picture element, because it is the smallest element that makes up a picture.

Slides & Time	Overview	Activity (see script for further details)
Slides 10-19 10 minutes (25)	**Worksheet 1 - Pixel Bingo**	**Hand out Worksheet 1: Pixel Bingo** – *1 per student* Explain to students that they are about to create their first image like a computer. They will be presented with a code of ten 1s and 0s, that represent whether a pixel needs to be shaded in or not, in order to create the image. Each number in the code represents a different pixel in the grid. The first number corresponds to the first pixel, the second number to the second pixel, and so on. If a pixel is assigned a 0, then it needs to be kept white. If a pixel is assigned a 1, then it can be shaded in. Go through the practice round, showing the code for each row of the image and giving them a few moments to shade in the squares before clicking to show the answer and moving on to the next row. The students can guess what the image is showing after each row, and the final result should be a smiley face. Explain that they are now going to play pixel bingo. The image they will be creating is 10 pixels x 10 pixels. After each row, they can guess what the image is, by shouting bingo. After the end of the 10th row, the whole image will be present, and show a rocket. Ask what would happen if we had less pixels and tried to show this image. Click onto slide 16, and explain that we are going to divide the number of pixels in the image by 4, by making the 10x10 grid into a 5x5 grid. Explain that in order to work out what colour the pixel should be, we will need to look at the information in all of the four pixels, and decide what colour they will be, depending on how many of the four pixels are light. Click onto slide 17, and ask the students how many of the four pixels within the first new pixel are light – 4! Continue this with the rest of the pixels in the first row, clicking to reveal the answer each time. The next four rows will reveal with each click, and then click again to reveal the colour gradient key. Click onto slide 18 to show the new 5x5 pixel image, with each pixel's colour mapped Ask what they think it looks like? Click onto slide 19 and ask them to compare the two images. They both have the same information within it, however the one on the left has less pixels, and so the image is not very representative of what we expect to see.
Slides 20-21 5 minutes (30)	**What happens when we increase the number of pixels?**	Ask if we lose details when we reduce the number of pixels, what might happen if we have more pixels available when creating an image? We can gain more details! Use the example of the character Mario's evolution over time, as versions of him were created with more pixels. Ask what details we can see in the newer versions, compared to the older versions. You may wish to mention that there are some AI algorithms that can predict and artificially create more pixels in an image, to improve the resolution and make them less pixelated/blurry. Click onto slide 21 to show how detail in space imagery is important for us to identify key features. Explain that the images here were taken by NASA's New Horizon spacecraft, on its approach to Pluto in 2015. As it approached Pluto, the detail in the image becomes clearer and clearer. Explain that the final image has twice the resolution than the previous image before it.

Slides & Time	Overview	Activity (see script for further details)
Slides 22-23 10 minutes (40)	**What else can satellites see?** Discussion on what things on Earth satellites can image. Worksheet 2 - A message from space	Discuss what things satellites can see on Earth, besides what they can see out in space. Take in contributions, and then click to display some of the ideas given. The bottom left image shows a wildfire in Salamanca, Spain in July 2022. The top right image shows a whale spotted from space, in a technique used by the British Antarctic Survey to count whale populations in remote locations. The bottom right image shows Hurricane Irma in the Bahamas in 2017. **Hand out Worksheet 2: A Message from Space** – *1 per student* Explain that they will need to identify the letter in the low-resolution images, by matching them to their high-resolution counterpart. Once they have done this, they will have a location matched to a letter. On the reverse of the worksheet they will need to match up the travel guide descriptions to one of the images, in order to spell a space-themed word they have come across in this session. The word they will find should be JWST. There is also an extension to write their own description of one of the leftover images. Once they have completed the tasks, ask if they found it difficult to identify the features in the images, and if so why? Explain that because the images are in greyscale, some features are harder to spot, such as green fields and trees, and sandy beaches. Ask how we could improve the images – by adding colour.
10 minutes (50)	**Break**	**Drinks and biscuits and comfort break.**
Slides 24-26 5 minutes (55) (15 minutes – optional)	**Lets add colour!** Discussion on light mixing and paint mixing **Create a Light Spinner Activity** Light Spinner Instructions and template	Explain that to get a colour image, we actually need to take three separate images using different colour filters. Explain that the filters only allow certain types of light through. Use a light filter or 3d glasses to demonstrate this to the students. Ask what happens when you mix red, green and blue paints together. Usually some dark brown colour. Explain that light actually does the opposite, when you mix red, blue and green coloured light together, you get white light! Explain that when we merge the individual-coloured images, we get a much more colourful and lighter image. **(***Optional***) Hand out Light Spinner instructions**– 1 per pair Hand out Light Spinner templates, card, string, glue, scissors, and colouring pencils for each student. Ask students to follow the instructions on the worksheet. They will need to cut out the paper spinner template and card if this has not been prepared in advance. They also require assistance in poking holes through the centre of the spinners and threading the string. If you have pre-made light spinners, explain the significance of the colours on the spinner, and demonstrate how to make the spinner turn by winding up the string and pulling it apart. Ask what happens when the spinner turns. The colours merge to form a white/grey blur. Explain this is because the colours are moving so fast our eyes cannot distinguish them, so they merge the light together to form white light. Go to slide 27. Explain that colour in a pixel can be represented by the RGB model, where each pixel contains three values: red, green and blue. Each of these colours has a value from 0 to 255, meaning 256 different possible intensities. Ask how many total possible colours there would be (256x256x256 = 16,777,216). Ask how many colours humans can see – 10 million! We see fewer colours than the RGB model gives us.

Slides & Time	Overview	Activity (see script for further details)
Slides 27 - 31 10 minutes (65)	**Guess the RGB colour** Activity creating different colours using RGB colour fill.	For each of the following slides, ask the students to guess the colour from the RGB values shown. The first number in the string relates to the red channel, the second number relates to the green channel, and the third relates to the blue channel. You may wish to get the students to practice making these colours digitally – RBG colouring is available through software such as Microsoft Word and Paint, where the students can create shapes like a circle and colour them in using the fill tool. The Digital Colour Meter app available as standard on Mac operating systems also allows you to find the RGB value of any pixel on your screen, which you may wish to let students explore. For slide 28, the correct colour shown is Blue, as only the blue channel has a value in. This is the maximum value, and so this is the purest blue you can get using the RGB colour model. You may wish to ask the students what they think the values for the red and green colours might be. The red is (255, 0, 0), and the green is (0, 255, 0). Continue with the rest of the examples on the subsequent slides – the correct answers are yellow, turquoise, white, and orange.
Slide 32 20 minutes (85)	**Turning space data into an image** Worksheet 3a: Making a space image – AstroLab Worksheet 3b: Making a space image – Observing with NASA	**Hand out Worksheet 3a: Making a space image – AstroLab** – 1 per pair. Explain that they are going to uncover an image taken from a satellite in space, by processing and adding colour to it. Students follow the tutorial of how to uncover an image of the Dumbbell Nebula. They can then try to choose the RGB ranges of the pixels, and see what they can find by making a 'real colour' image. If they have completed this successfully and there is time left in the session, they can then choose their own image to process, or move onto the more advanced software **(Hand out Worksheet 3b: Making a space image – Observing with NASA** – 1 per pair.) Students can download their images to be printed, or share their images with the rest of the group, and describe what they found when processing them. There are questions for them to think about when processing their images on the worksheet, including what the brightest and dimmest part of the images are, and what detail is visible in the different colour filters?
Slide 33 (last slide) 5 minutes (90)	Further activities Feedback, tidy up, questions time Ask the Ri	Introduce the extension material – Worksheet 4b: Making a space image – Observing with NASA; NASA's Astrophoto challenge; NASA Space Archaeology activity; ESA's Pixel your Space resource. Don't forget to collect any questions which arise, and email them to us: masterclasses@ri.ac.uk. We will send you answers as soon as possible. Then these can be reported back to the students at their next Masterclass session. We are also very grateful for any feedback you can provide us on the use of the resources, and we would love to hear your stories of how your masterclasses went!
Extension Activities		NASA's Astrophoto Challenge - https://mo-www.cfa.harvard.edu/OWN/astrophoto/ NASA Space Archaeology activity - https://earthobservatory.nasa.gov/blogs/eokids/wp-content/uploads/sites/6/2018/08/EOKids_SpaceArchaeology508.pdf ESA's Pixel your space activity – www.esa.int/Education/Teachers_Corner/Pixel_your_space_Geometry_behind_science_and_art_images_Teach_with_space_PR03