STEM Club

LET'S EXPLORE THE UNIVERSE TOGETHER!

DESIGN A TELESCOPE

COMPARE GALAXIES

THROW A STAR PARTY!

AND MORE...
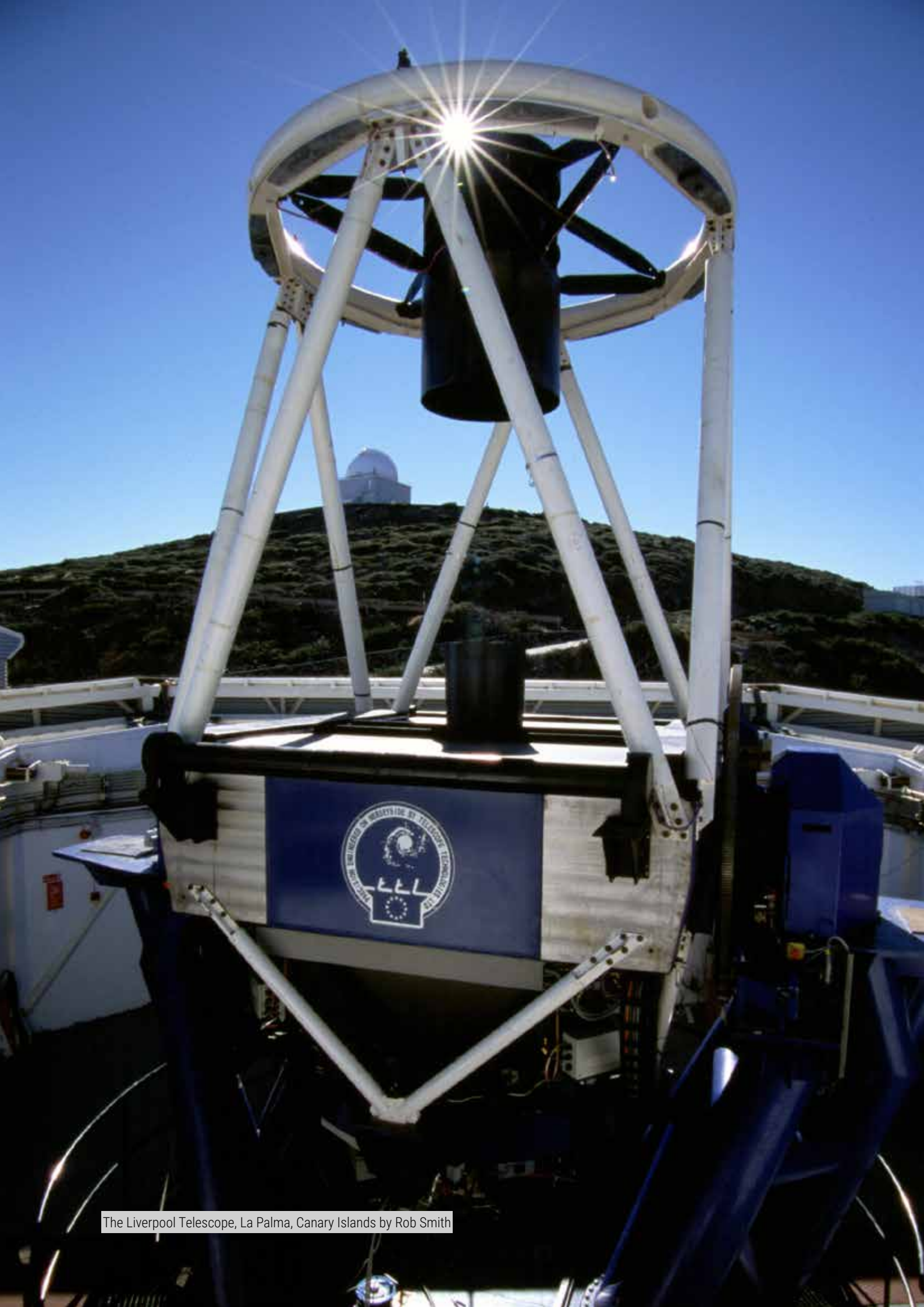
PROUD TO BE PART OF

LIVERPOOL JOHN MOORES UNIVERSITY

GOLD
SECONDARY EDITION

THE SCHOOLS' OBSERVATORY

The Liverpool Telescope, La Palma, Canary Islands by Rob Smith

CONTENTS

Secondary STEM Club - Gold Award

Your Name: _____   Age: _____

Rose Galaxy by The Schools' Observatory

NGC 7129 by The Schools' Observatory

GC 2261 by The Schools' Observatory

SESSION 1: DESIGNING A TELESCOPE

Astronomy is driven forward by always asking new questions. When we get to a question that we can't answer, it usually means that we don't have the technology, or the knowledge, to get to the bottom of the problem. This drives technology forward, and there are constantly new telescopes in development.

When deciding upon what new telescope to build, the primary driver is the science – what questions are we trying to answer and what technology do we need to answer them?

In this session you will work in groups to design a new telescope to try and detect sources of gravitational waves!

In 2015 the first detection of a gravitational wave was recorded. A gravitational wave is a ripple which travels through the fabric of space (often called space-time) much the same as a ripple travels through water when you drop a stone. They were first predicted by Einstein in 1916 with his theory of relativity. They are made when very massive objects move quickly in space. For the ripples to be strong enough to be detected on Earth, the movement of these objects has to be very fast. The following events are likely to lead to gravitational waves:

- ☆ Black holes colliding together
- ☆ Huge supernova explosions
- ☆ Neutron stars colliding together
- ☆ Neutron star merging with a black hole

Gravitational wave detectors on Earth 'listen' out for these events. They can measure the size of the waves and then try to figure out what event caused them. To learn more about this new area of astronomy it is useful to also 'see' the events with telescopes. If the source of the waves includes a neutron star or a supernova explosion, then we should be able to see an optical source alongside the gravitational wave detection. This will help scientists to answer questions like:

- ☆ Where did the event take place?
- ☆ Do gravitational waves travel at the speed of light?
- ☆ What is going on inside a neutron star?
- ☆ How do stars actually explode?

Your budget for your telescope is £150 million and you must decide:

- ☆ Where to build it
- ☆ What mirrors to use
- ☆ What material to build the telescope structure from

Name your telescope: _____

ACTIVITY 1: OBSERVING SITE SELECTION

In order to detect the maximum number of gravitational wave sources it is important for the observing site to be close to the equator, from which both the northern and southern hemispheres can be observed.

Your STEM Club Leader will give you a map of potential observing sites and locations fact files. Use these to choose a first-choice site for your telescope and a backup. Fill in the pros and cons for each site below:

Primary-choice location: _____

Pros	Cons

Budget required: £_____ (cost per square metre)

Backup-choice location: _____

Pros	Cons

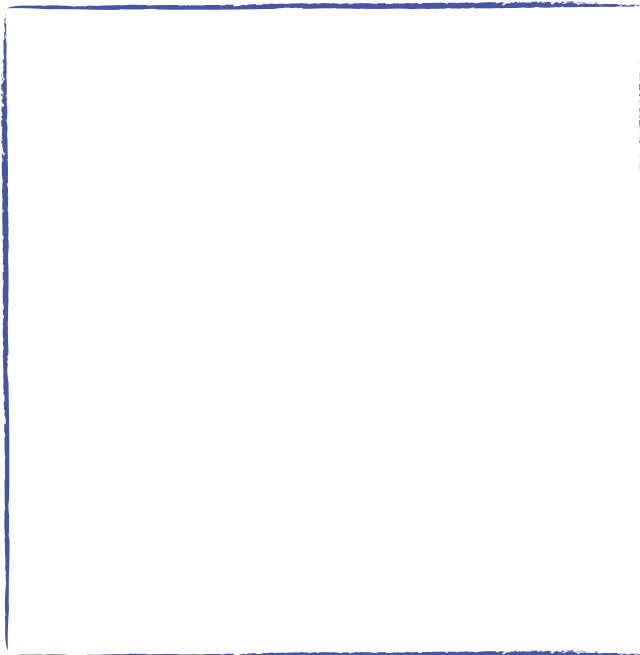Budget required: £_____ (cost per square metre)

ACTIVITY 2: MIRROR SELECTION

Gravitational wave sources can come from very distant objects. In order to be able to see these distant sources, astronomers must use telescopes with as large a mirror as possible. The bigger the diameter of the mirror, the more light can be collected, enabling you to see fainter objects. The **minimum diameter** of mirror which can **detect** gravitational wave sources is **8 metres**.

Use the mirror information page provided by your STEM Club Leader to decide upon the mirror set up for your telescope. You can combine several mirrors of different sizes. Draw the design for your Primary and Backup mirror choice below and note the mirror diameter, weight and cost of each choice.

Primary Mirror:

Design:
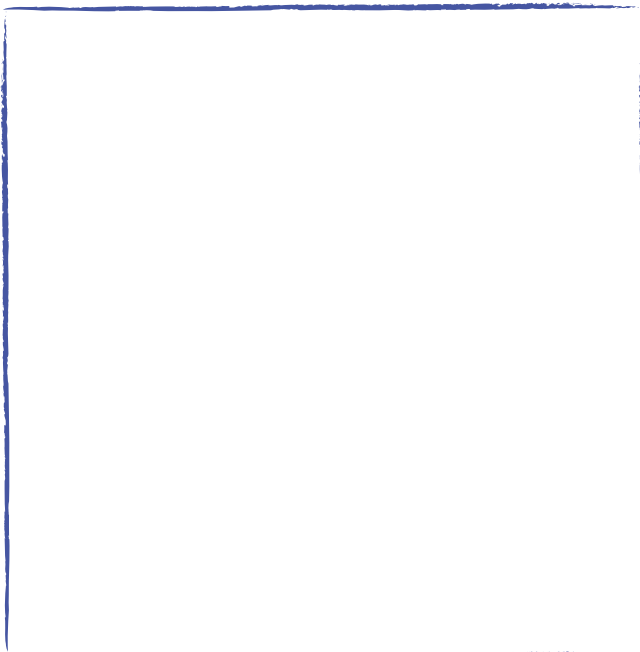
Effective diameter: _____

Widest diameter: _____

Weight: _____

Cost: £ _____

Backup Mirror:

Design:

Effective diameter: _____

Widest diameter: _____

Weight: _____

Cost: £ _____

ACTIVITY 3: TELESCOPE STRUCTURE MATERIAL SELECTION

Gravitational wave sources are also likely to emit flashes of optical light, which appear and then fade very quickly. This means that the telescope needs to move very quickly to see the light before it disappears. The materials need to be strong enough to support the mirror, but light enough to move at speed.

Use the Material Selection table provided by your STEM Club Leader to decide upon which material to use to build your main telescope structure. You need to consider the weight of your mirror in your decision. Your material MUST be strong enough to hold up the mirror.

Fill in the pros and cons for each selected material below:

Primary-choice material: _____

Pros	Cons

Budget required: £_____   Weight limit: _____

Backup-choice material: _____

Pros	Cons

Budget required: £_____   Weight limit: _____

ACTIVITY 4: REACHING A DECISION

Total up the cost of your **primary telescope choices**:

Site: cost per square meter x mirror diameter x10 = £ _____

Mirror: £ _____   Material: £ _____

Total: £ _____

It's usually not possible to build the absolute best telescope for your science. There are often compromises which need to be made to ensure that you stick to your given budget. Considering your budget of £150 million, you must now choose between your primary and backup choices for each aspect of your telescope design to reach a final decision on your set up:

Final build: £ _____

Site: cost per square meter x mirror diameter x10 = £ _____

Mirror: £ _____   Material: £ _____

Total: £ _____

Telescopes are expensive to build. Below is a table of some of the best telescopes in use today, or soon to be launched. The costs skyrocket if astronomers want to put the telescope in space!

Telescope	Location	Mirror size	Cost	First Light
Hubble Space Telescope	Space (low Earth orbit)	2.4m	£3.4 billion	1990
Very Large Telescope	Paranal, Chile	4 x 8.2m	£300 million	1998
Subaru Telescope	Hawaii, US	8.3m	£275 million	1999
Liverpool Telescope	La Palma, Canary Islands	2m	£7 million	2003
James Webb Space Telescope	Space (Lagrange Point 2)	6.5m	£7.5 billion*	2022*
New Robotic Telescope	La Palma, Canary Islands	4m	£24 million*	2026*
Extremely Large Telescope	Cerro Armazones, Chile	39m	£1.1 billion*	2025*

The year of 'First Light' refers to the first time it is used to take an astronomical image. For space telescopes we have used their year of launch.

*These telescopes have not yet been completed and the costs and first light dates might change.

Extra Activity:
If you have enjoyed this activity you may want to try a more advanced version – designing and launching a space telescope: chrisnorth.github.io/design-a-space-telescope

You might also like the computer game: www.kerbalspaceprogram.com

SESSION 2: COMPARING STARS

Graphs and charts are essential tools in science. Scientists use them to make sense of data and to spot patterns and trends. Charts can show if two different quantities are related, or demonstrate that the data is random.

One of the most useful and powerful charts in astrophysics is the Hertzsprung–Russell Diagram, which plots the brightness of a star on a graph against its surface temperature. It was created by astronomers Ejnar Hertzsprung and Henry Norris Russell about 1910. Astronomers use the chart to infer information about the life and evolution of stars.

In this session you will work together to create a Hertzsprung–Russell Diagram using data from different stars.

The Pleiades star cluster by NASA, ESA and AURA/Caltec

ACTIVITY 1: WHO AM I?

You may recall that stars are not all the same and they don't last forever. Stars come in different sizes and have different temperatures. Each star goes through stages in its lifetime which depend on how massive it is.

Challenge someone in your STEM Club to play 'Who am I?' - use the information in the table on the next page to help you. The aim of the game is to guess the star life-stage stuck to your head.

Instructions and rules:

☆ Chose a **star life stage** from the table (this is only a selection of all possible stages). Write it on a sticky note and stick it to your partner's forehead, gently! Make sure they don't see the answer!

☆ The person wearing the sticky note asks questions about the star life stage using the information in the table, for example, "Am I more massive than the Sun?"

☆ They are NOT allowed to just ask which star life stage they are, for example, "Am I a Red Giant?"

☆ Take it in turns until everyone in your group has had a go or two

Star Life Stage	Information
Main Sequence	A star spends about 90% of its lifetime in this stage.
	Nuclear fusion of hydrogen within the star's core releases energy.
	The Sun is currently in this life stage.
Red Giant	A middle-aged star that has run out of hydrogen in its core but is fusing hydrogen in its shell – making it expand.
	It can grow up to 100 times the size it was as a Main Sequence star.
	Its colour reflects its cooler surface temperature.
Red Supergiant	A massive star that has run out of hydrogen in its core but begins to fuse heavier elements in shells surrounding the core.
	It expands up to 1000 times the size of the Sun.
	Its surface temperature remains cool, and its colour reflects its temperature.
White Dwarf	The dense compact core of a low-mass star that has come to the end of its lifetime.
	Although nuclear fusion has ended, the surface of the star remains very hot, such that it shines a bright blue/white.
	They can appear quite faint from a distance because they are so small.
Black Hole	The infinitely dense compact core of a high-mass star that has come to the end of its lifetime.
	The core is so dense that not even light can escape it making it appear black.
	They can be hard to find because they don't emit light.

ACTIVITY 2: CREATE A HERTZSPRUNG–RUSSELL DIAGRAM

You are going to work as a team to create your own Hertzsprung–Russell Diagram. Your leader will give you a labelled empty chart and some star circles. You will use the information on your star circles to place them in the correct place on the chart.

The information on your stars circle includes:

☆ The **name** of star

☆ The **temperature** of star in Kelvin

☆ The **brightness** (or luminosity) of the star in number of Suns

☆ The **colour** of the star

Carefully look at the scale on each axis.
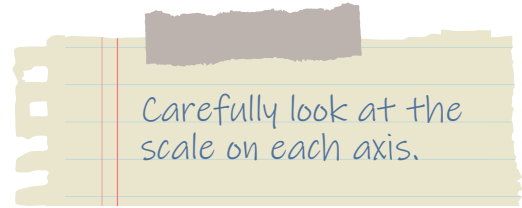
Instructions:

1. Take turns to add your star circles data to the chart.

2. Share any observations or questions you have about the data with the rest of your group.

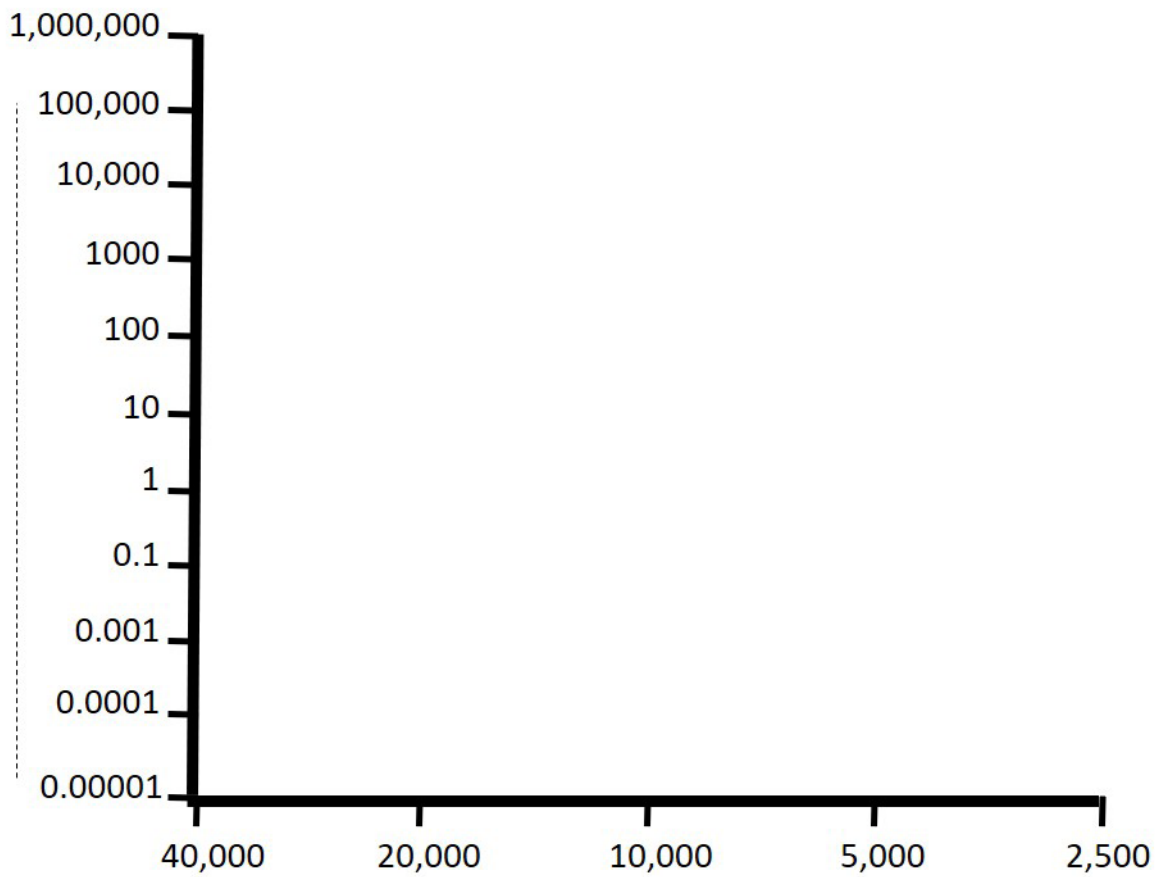3. Keep going until all the data is plotted.

ACTIVITY 3: USING THE HERTZSPRUNG–RUSSELL DIAGRAM

Most stars, including the Sun, can be found in the main sequence of stars - a band running from the top-left to the bottom-right of the diagram. White dwarfs, giants, and supergiants fall outside of the main trend.

Use your club's chart and the blank template on the next page to complete the following:

1. Label the variables on the x-axis (horizontal axis) and the y-axis (vertical axis) using the dotted lines on the next page.

2. Draw a rough sketch of your club chart onto your blank template on the next page.

3. Label the areas on the template where you expect to find the following types of stars: main sequence, giants, supergiants, white dwarfs.

4. Next to the labels on the horizontal axis, indicate the corresponding star colour.

Your Hertzsprung-Russell Diagram:

1,000,000				
100,000				
10,000				
1000				
100				
10				
1				
0.1				
0.001				
0.0001				
0.00001				
40,000	20,000	10,000	5,000	2,500

? Explain in 1 or 2 sentences what the Hertzsprung-Russell Diagram shows:

_____

_____

_____

SESSION 3: THE SHAPE OF GALAXIES

Galaxies are vast collections containing many billions of stars and planets, and giant clouds of gas, dust and ice. Understanding galaxies is an important part of astronomy. One key tool to understanding them is classifying them – grouping them into a small number of different categories.

There are more than 100 billion galaxies in the observable Universe, but they can all be classified by their shape into a small range of different types.

Elliptical Galaxies

Roughly half of all galaxies are ellipticals. They look smooth, are shaped like squashed circles, and fade away towards the edges.

They are old, with very few new stars being made inside them.

They can look anywhere from nearly circular to quite oval:

Credit: ESA/Hubble & NASA, P. Cote

Credit: ESA/Hubble & NASA

Spiral Galaxies

Spiral galaxies are almost as common as ellipticals but look much more interesting. They have sweeping spiral "arms" with new stars forming inside them, and long streams and clouds of darker dust.

The centre of the spiral looks quite like a small elliptical galaxy and is called the bulge.

Barred Spiral Galaxies

Rather like normal spiral galaxies, barred spirals have arms full of new stars, and an older bulge. The biggest difference is rather than the arms connecting directly to the bulge, they twist down to join a long bar that joins them to the bulge.

Credit: NASA/ESA

Credit: ESA/Hubble & NASA

Lenticular Galaxies

Lenticular Galaxies get their name from their lens-like shape. They are half-way between Ellipticals and Spirals, with a fairly flat disk surrounding the central bulge, but they have no obvious spiral shape.
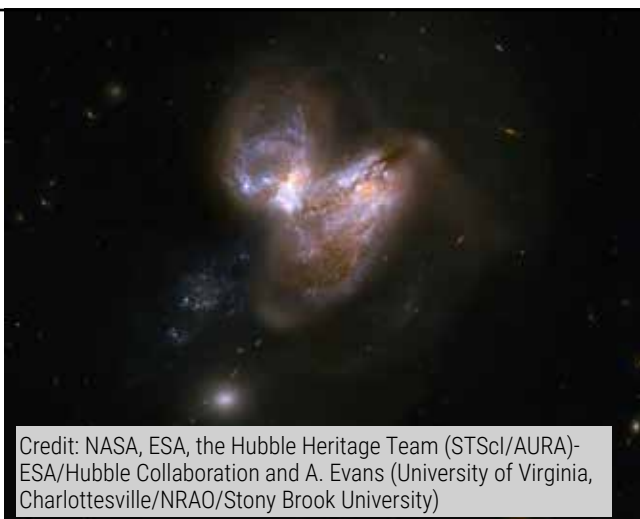
Irregular Galaxies

Some rare galaxies do not fit any of the main groups and are a bit of a mess.

Sometimes called "peculiar galaxies", these irregular ones are often caused by two galaxies getting very close together, or colliding. The gravity pulling between them causes them to stretch and distort.

Credit: NASA, ESA, the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration and A. Evans (University of Virginia, Charlottesville/NRAO/Stony Brook University)
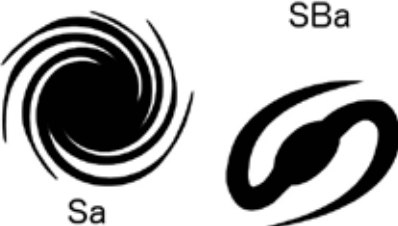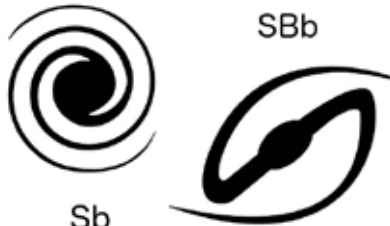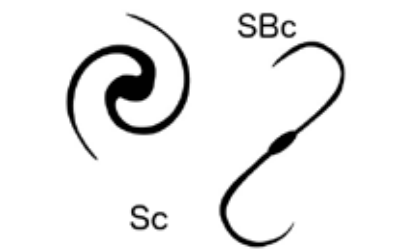
ACTIVITY 1: THE HUBBLE CLASSIFICATION SCHEME

In 1936, an astronomer called Edwin Hubble created a way of sub-dividing the main galaxy types so that it was possible to learn even more about them.
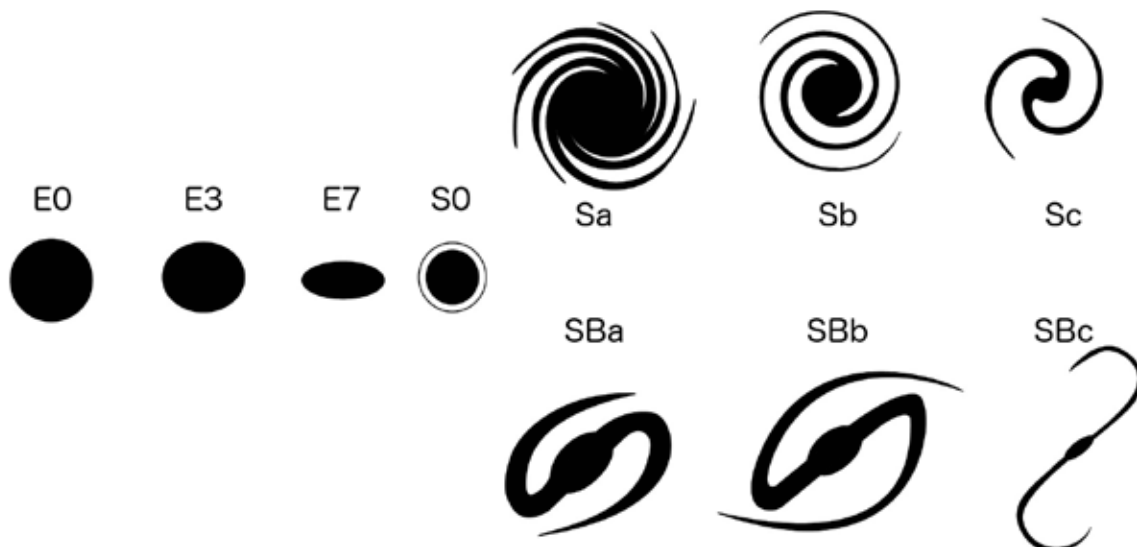
Elliptical Galaxies	**Lenticular Galaxies**
Elliptical Galaxies are given the letter E followed by a number. The number describes how circular or flattened the galaxies look, with E0 being almost circular, through to E7, which are very oval shaped, being about twice as wide as they are high.	Lenticular Galaxies sit between ellipiticals and spirals and are called S0 galaxies.

E0 E3 E7   S0

Spiral Galaxies

Spiral galaxies are split between simple spirals called Sa, Sb or Sc, and barred spirals SBa, SBb and SBc. In both cases, the final letter (a, b or c) describes how tightly wound the spiral arms are.

Sa and SBa galaxies have tightly wound spirals and a large central bulge.	Sb and SBb are less tightly wound and have a less obvious bulge.	Sc and SBc are loosely wound and have a very faint, small bulge.
SBa / Sa	SBb / Sb	SBc / Sc

Hubble's scheme is often drawn as a diagram and called the **Tuning Fork Diagram**:

E0   E3   E7   S0   Sa   Sb   Sc

SBa   SBb   SBc

Your STEM Club Leader will give you some pictures of actual galaxies. Use the Hubble Tuning Fork Diagram to try and settle upon a classification for them.

Start by deciding whether the galaxy is an elliptical (E), lenticular (S0), spiral (S) or barred spiral (SB), or whether it can only be described as irregular (Irr).

Then where appropriate, look at the subgroups (0-7 for ellipticals, a-c for the two kinds of spiral).

When you have decided, write down the galaxy's number (or name) and your classification in the table below. You may want to add some notes to explain your decision, or if there is anything odd about the image.

Galaxy Number	Classification	Notes

DISCUSSION

When you have finished, you may want to compare your results with other peoples. Have they looked at the same galaxies as you, and did you agree? If not, why not? After discussing them, do you agree with your classmate?

ACTIVITY 2: OUR GALACTIC NEIGHBOURHOOD

When we look at galaxies in space a couple of things become clear:

☆ Galaxies do not exist alone – they live in small groups. Often these groups are part of a larger cluster of hundreds of thousands of galaxies.

☆ There are small – or dwarf – versions of all of the types of galaxy. These are indicated with a 'd' in front of the rest of the classification. E.g. dSc would be a dwarf spiral galaxy with the subgroup c.

Our own Milky Way galaxy lives in a group we call the 'Local Group', which we will now sketch out.

Use the information below to draw each galaxy in our Local Group on to the grid below using the correct symbol – for a dwarf galaxy just make the symbol a little smaller!

Key

Elliptical:

Lenticular:

Barred Spiral:

Spiral:

Irregular:

Dwarf: Smaller version of one of the 5 icons

Name	Classification	Grid Position
Milky Way	SBc	B5
Sculptor	SBc	A4
Fornax	dE0	A2
Large Magellanic Cloud	dIrr	B6
Small Magellanic Cloud	dIrr	B6
NGC147	dE5	F2
NGC185	dE3	G2
Andromeda	Sb	H3 and H4
Messier 33	Sc	H5
IC1613	dIrr	H7
Messier 110	E5	G4

SESSION 4: 3-COLOUR IMAGE PART II

In this session you will create a 3-colour image of an object of your choice, using archive data from the Liverpool Telescope.

The Liverpool Telescope takes pictures using different 'filters'. Use our free software to combine three filtered images of M51 (a red image, a blue image and a green image) to make a colour picture.

ACTIVITY 1: SEARCH THE ARCHIVE

1. Go to the archive of observations on our website:
   www.schoolsobservatory.org/obs/arch

2. Use the webform to search the archive for observations using '...**Taken for this Observing Programme:'.** You can select any of these options: '3-colour galaxy', '3-colour nebula', or '3-colour observation'.

Archive of Observations

You can use this form to search the **Go Observing Archive** for particular observations.

You can fill in as many or as few of the boxes as you want - the more you fill in, the fewer observations you will have to choose from.

Only search for Observations...

...Of Objects with names like this:		Help
...Taken for this Observing Programme:	--Select--	Help
	--Select--
	3-colour galaxy
...Requested by this User:	3-colour nebula
	3-colour observation
...That were taken after:	A Galaxy	Help
	Classifying Galaxies
...That were taken before:	Counting Stars	Help
	Crater Counts
	Galaxy of Stars

You will now see a list of all observations that met your search criteria. There are 3 image files for each 3-colour observation: a red file, a green file and a blue file.

The **red images will have '000'** at the end of their filename, the **green images will have '001'**, and the **blue images will have '002'**. All three will have the same numbers at the beginning of the filename. For example, 10308F000.fits is the red image and 10308F001.fits is the green image from the same observation.

3. Choose an observation and download the 3 data files. To do this, click on the observation code number and then click on 'Download Image Data File'. Repeat for each of the 3 image files for your chosen observation.

4. Save the files somewhere you can find them again.

Not sure which search result to choose? Click on the 'i' button in the object column to find out more about the object.

ACTIVITY 2: LOAD AND COMBINE THE IMAGES

1. Double click on 'LTImage' (it may be called 'LTImage.exe') to launch the software. Your STEM Club Leader will tell you where this is on your computer.

In the bottom right of the LTImage window there is an 'Image Selection' panel with four boxes. You are going to open your red, green and blue files in the first three 'Image Selection' boxes. You will create your false-colour image in the fourth box.

2. In LTImage click on 'File', then 'Open Data Image', find the location of the saved files from 'Activity 1' and click on the red data file that ends '000', then click 'Open'.

3. Click on Image Selection 2 in the bottom right corner. Click on 'File', then 'Open Data Image', and click on the green data file that ends '001', then click 'Open'.

4. Click on Image Selection 3 in the bottom right corner. Click on 'File', then 'Open Data Image', and click on the blue data file that ends '002', then click 'Open'.

5. Click on Image Selection 4 in the bottom right corner.

6. Click on 'Colour' in the main menu, then click '3-Colour Image'.

7. Now click on the 'Make new image' button at the top of the tool that appears to the right of the main image panel.
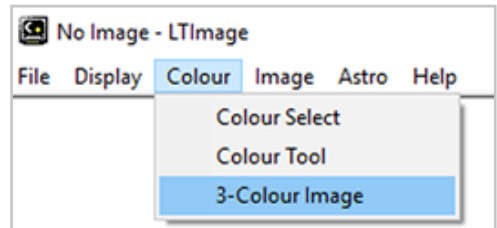
You should now have a first-guess version of the 3-colour image displayed in the main image panel. Don't worry if this looks very dark - it will often just show black with perhaps a couple of small 'dots', but this is quite normal at this stage.

ACTIVITY 3: ALIGN THE IMAGES

The software has done its best to line up the red, blue and green images on top of each other. But it might not have done it perfectly. You need to correct this. There is a panel on the right that contains the '3-Colour Image' tools. You will use the 'Zoom Preview' window, the 'Working Colour' buttons and the 'Alignment' buttons.

1. Click on the circle next to the word 'Red' in the 'Working Colour' panel. You are now working on the red image.

2. Try moving your mouse pointer over one the bright 'dots' in your main image panel and then "click" with the left mouse button. The 'Zoom Preview' window will change to show the small piece of the image under your pointer.

3. You should see that the red, green and blue 'dots' are slightly separate and not on top of each other. Use the 'Alignment buttons' to nudge the red image up, down, left and right until it is under the blue one. This will make the 'dot' look more purple.

4. Next, move the green image so it is on top of the others. To do this, click the circle next to the word 'Green' in the 'Working Colour' panel. You should see the background colour of the tool change to green. Use the 'Alignment buttons' to nudge the green image so it is on top of the red and blue images. Your 'dot' should end up as a smaller and whiter point. It's actually a star!

5. Click on the 'Make a new image' button in the top-right panel to save your progress and see your new aligned image in the main window.

ACTIVITY 4: SCALE THE IMAGE

Don't worry if you are still a bit disappointed with your image – your image looks dark because the software is only showing you the very brightest parts of the image. You are now going to change the 'Pixel values' so you can see more of your image.

You now need to select 'Pixel values' to bring out the stars and colourful regions of the image.

About half-way down the panel on the right side of the window, you will find a line that says 'Colour from: X to Y' (your numbers will be different depending on which files you have loaded).

1. Reduce 'Y' (the larger number) by a factor of 10, e.g. if it was '20000' reduce it to '2000', then click 'Make new image' at the top.

2. Repeat step 3 for the 'Green' and 'Blue' sections in the 'Working Colour' area of the panel.
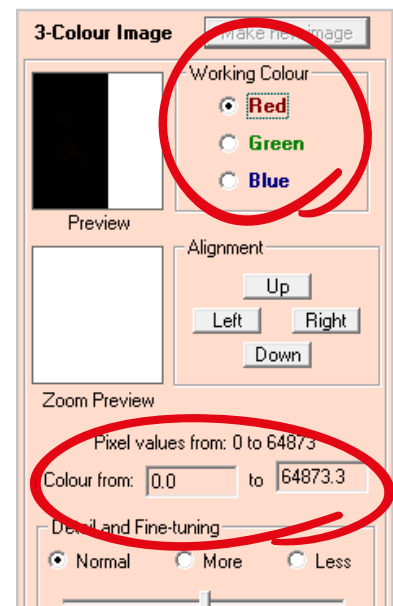
It is worth playing around a bit with these values to bring out exactly what you want. Don't forget that you can use the 'Display' menu tools to 'Zoom' in and out on the main picture, and the 'Zoom Preview' to explore in detail.

ACTIVITY 5: SAVE THE IMAGE

When you have an image that you like, you can save it to your computer.

1. Click 'File', then click 'Save picture'.

2. Choose a location on your computer and give your file a suitable 'File name'

3. Click 'Save'.
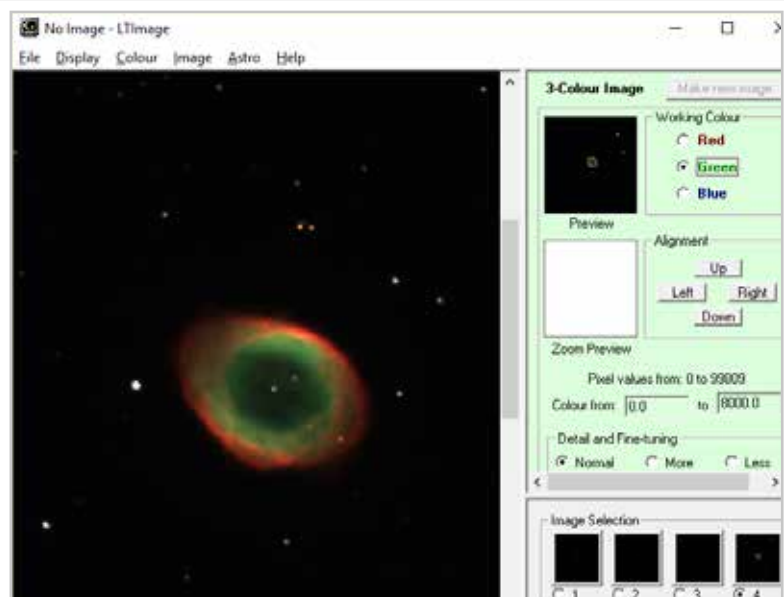
SESSION 5: CAREERS IN SPACE

We, as humans, have been exploring space since we first looked up at the night sky. We have successfully sent satellites to the edge of the Solar System, put people on the Moon, built an International Space Station, landed probes on other planets and used telescopes in space to study galaxies far away. To achieve this took took lots of different kinds of experts and skilled people.

The space industry is made up of governments, international groups and some private companies. Space Agencies are large organisations that are responsible for developing science and technology related to space. Examples of Space Agencies are the UK Space Agency, the European Space Agency and NASA.

Generally speaking, many roles in the space industry require a background in science and engineering, but this isn't always a necessity. For example, the space industry also needs lawyers, fitness instructors and spacesuit costume designers!

ACTIVITY 1: MANAGING A SPACE AGENCY

You are the manager of a space agency.

What is the name of your agency?

_____

Researchers have recently discovered a new dwarf planet in the outer Solar System and you want to plan a crewed mission to visit. Using a newly developed rocket engine, it will only take 2 years to get there.

Your Mission: Scope out the planet's surface for potential future base camp locations. You need to assemble a team of people. What job roles do you think are important for this mission?

1. _____   6. _____

2. _____   7. _____

3. _____   8. _____

4. _____   9. _____

5. _____   10. _____

If you were a part of this crew which role would you most like to fill:

_____

ACTIVITY 2: CAREER FOCUS

Choose one of the jobs to focus on. What type of person do you think would be needed to do this role? Think about what they studied at school, what their skills are and what they do for fun. Create a CV for this person – be as imaginative as you like or you can base it on your own interests.

The CV will need the following sections:

Name:

About me:

Education:

Skills/Expertise:

Experience:

ACTIVITY 3: JOB TASKS

What are the main tasks your chosen person will have to do as part of their mission to the new dwarf planet? List them and explain why the tasks are important to the mission.

Extra Activity:
Go to schoolsobservatory.org/careers to explore the careers profiles of some real people working in the space sector – you may want to concentrate on the 'Exploring' and 'Spaceflight' sections to find people who might make it onto your mission crew.

Or maybe you are more interested in influencing people or managing the space agency? What about numbers and data? Many careers in space and astronomy rely heavily on maths. Are you interested in making things? What about rocketry? Or working on some of the biggest telescopes on Earth?

There are a wide range of careers in this sector. One of them could be right for you!

SESSION 6: STAR PARTY

This week your club will have a Star Party to celebrate completing The Schools' Observatory STEM Club! Congratulations!

Find some time during your Star Party to answer these four questions. Think about what you have done during your STEM club sessions. Look back through your booklet to help you remember.

1. What is the most important thing you've learned?

    _____

2. What surprised you the most?

    _____

3. What do you want to learn more about?

    _____

4. How could you share what you have learned with others?

    _____

Star party photo:
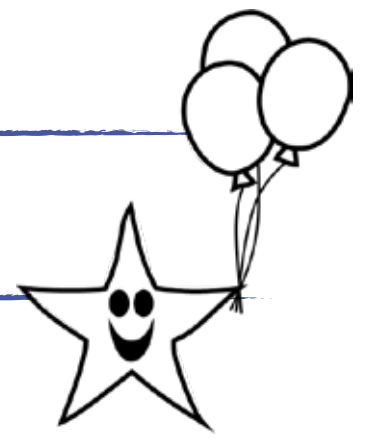
JUST FOR FUN!

SHARE YOUR IMAGES WITH US

We love to see the images you have created from your observations! Share your images with us.

Ask your STEM Club Leader to share your images with us by:

☆ Tagging @SchoolsObs on Twitter or Instagram

By James from St George's School

By AstroStace via Instagram

By Guy Wells via Facebook

By Bradley Young of Forres Academy

By Dundee and Angus College

By Bexhill Academy

By Andy Newsam

By TardigradeOfDoom

By Hichingbrooke School
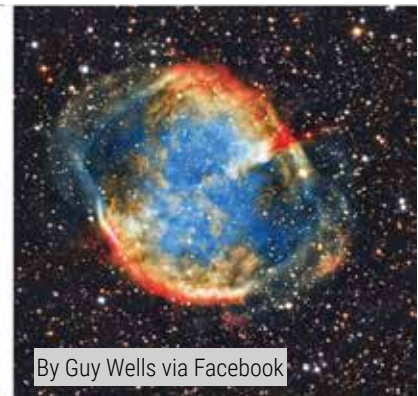
By sharing your images with us, you consent for The Schools' Observatory to use your image on our website and social media accounts and/or for publicity.

WORD SEARCH

Can you find all the space words in the puzzle below?

```
T  Q  S  T  L  B  Z  E  S  X  O  W  G  W  C
X  B  B  A  R  R  E  D  K  E  P  B  Q  R  G
M  Z  U  F  T  E  L  E  S  C  O  P  E  A  R
F  H  E  K  L  A  L  U  D  F  B  S  V  L  A
G  M  C  O  S  O  E  L  W  O  S  P  O  F  V
S  P  D  N  O  S  N  W  A  V  E  A  G  T  I
G  P  H  X  C  T  T  M  X  K  R  C  P  P  T
L  K  I  U  K  A  I  L  O  U  V  E  K  E  A
E  I  Q  R  B  R  C  G  A  L  A  X  Y  Z  T
C  M  G  E  A  B  U  T  S  U  T  D  F  I  I
T  P  I  H  E  L  L  I  P  T  I  C  A  L  O
A  T  R  R  T  O  A  E  M  A  O  K  J  T  N
T  R  U  P  R  M  R  J  W  A  N  W  F  L  A
U  K  M  T  R  O  R  L  F  B  G  K  H  I  L
H  I  H  E  H  A  R  H  Q  E  O  E  O  A  K
```

BARRED	GRAVITATIONAL	LIGHT	SPIRAL
DATA	HUBBLE	MIRROR	STAR
ELLIPTICAL	IMAGE	OBSERVATION	TELESCOPE
GALAXY	LENTICULAR	SPACE	WAVE

Answers - page 26

ABOUT THE SCHOOLS' OBSERVATORY

The Schools' Observatory (TSO) is proud to be part of Liverpool John Moores University (LJMU). We are part of LJMU's Astrophysics Research Institute (ARI). LJMU has a robotic telescope, called the Liverpool Telescope, which is located at the top of a very high mountain on La Palma in the Canary Islands. LJMU is one of the few UK Universities that owns and operates a professional telescope.

We were created to help young people across the UK and Ireland use the Liverpool Telescope. You can read all about our team here: www.schoolsobservatory.org/about/team

Congratulations! You have now finished the Gold STEM Club booklet! We hope you have enjoyed yourself and learnt a few things along the way.

If you want to know about other topics that are not already on our website, ask your Stem Club Leader to email us and let us know! SchoolsObs@ljmu.ac.uk

WORD SEARCH - ANSWERS

```
T  Q  S  T  L  B  Z  E  S  X  O  W  G  W  C
X  B  B  A  R  R  E  D  K  E  P  B  Q  R  G
M  Z  U  F  T  E  L  E  S  C  O  P  E  A  R
F  H  E  K  L  A  L  U  D  F  B  S  V  L  A
G  M  C  O  S  O  E  L  W  O  S  P  O  F  V
S  P  D  N  O  S  N  W  A  V  E  A  G  T  I
G  P  H  X  C  T  T  M  X  K  R  C  P  P  T
L  K  I  U  K  A  I  L  O  U  V  E  K  E  A
E  I  Q  R  B  R  C  G  A  L  A  X  Y  Z  T
C  M  G  E  A  B  U  T  S  U  T  D  F  I  I
T  P  I  H  E  L  L  I  P  T  I  C  A  L  O
A  T  R  R  T  O  A  E  M  A  O  K  J  T  N
T  R  U  P  R  M  R  J  W  A  N  W  F  L  A
U  K  M  T  R  O  R  L  F  B  G  K  H  I  L
H  I  H  E  H  A  R  H  Q  E  O  E  O  A  K
```

[PLACE YOUR CERTIFICATE HERE]

THE SCHOOLS' OBSERVATORY

If you enjoyed these STEM Club Booklets you can continue your space adventure by visiting our website, where we have lots more activities to discover.

WWW.SCHOOLSOBSERVATORY.ORG

PROUD TO BE PART OF

LIVERPOOL JOHN MOORES UNIVERSITY

Triangulum galaxy by The Schools' Observatory

STEM Club

SECONDARY EDITION