CLUB LEADER

STEM Club

LET'S EXPLORE THE UNIVERSE TOGETHER!

ACTIVITY DETAILS

RESOURCE LISTS

LEARNING OUTCOMES

PROUD TO BE PART OF

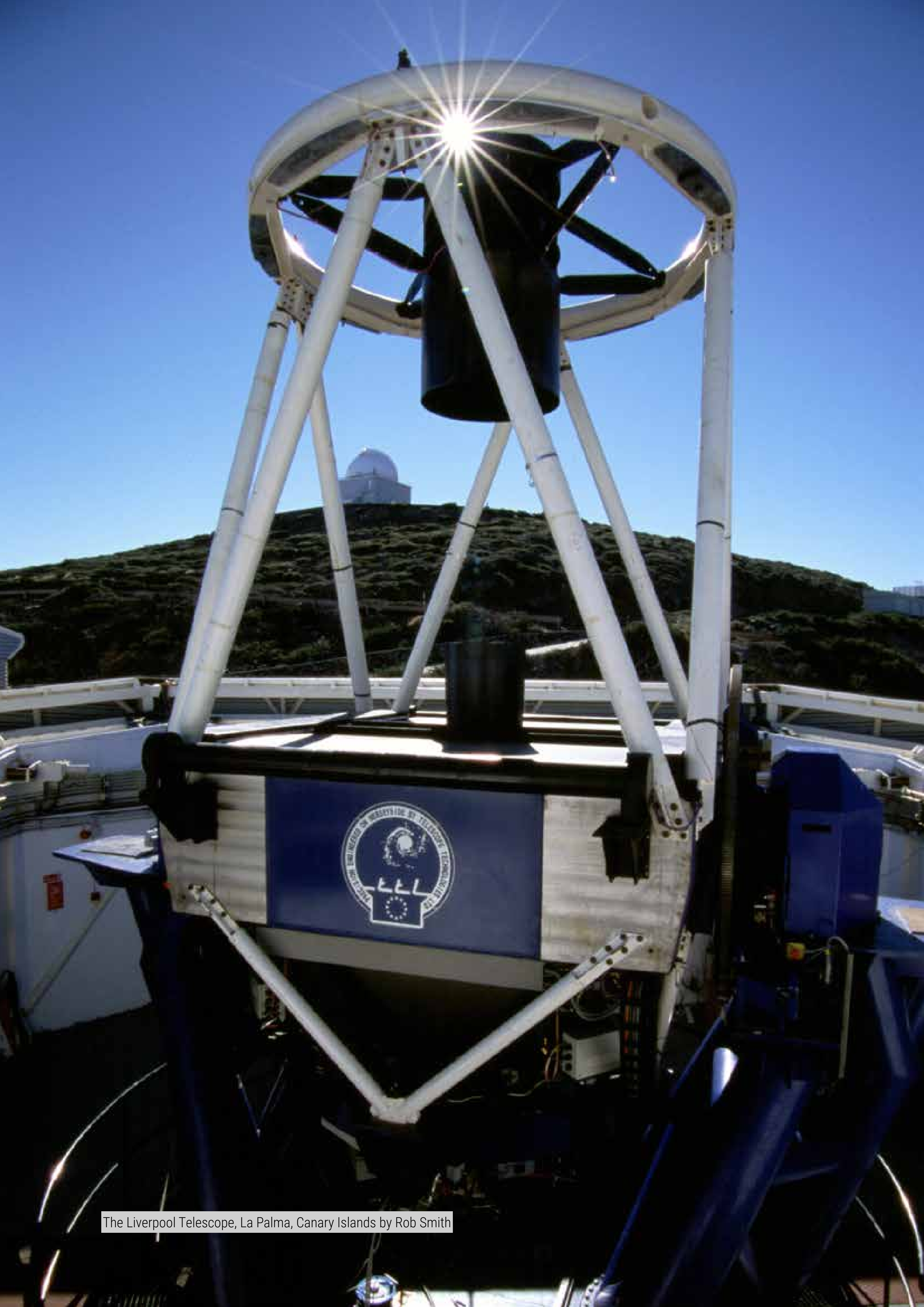
LIVERPOOL JOHN MOORES UNIVERSITY

Crab Nebula by Goran Nilsson & The Liverpool Telescope

SILVER

SECONDARY EDITION

THE SCHOOLS' OBSERVATORY



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

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Secondary STEM Club - Silver Award - Club Leader Edition

Messier 66 by The Schools' Observatory

Full moon by The Schools' Observatory

Messier 107 by The Schools' Observatory

INTRODUCTION

The Schools' Observatory (TSO) is passionate about inspiring the next generation of scientists, programmers, engineers and mathematicians. We provide free access to the world's largest fully robotic telescope, and use the wonders of space to excite and amaze students of all ages and develop their love of STEM education.

What is The Schools' Observatory STEM Club Programme?

This STEM Club programme provides three levels of activities; Bronze, Silver and Gold, with each level taking six weeks to complete. The activities are designed to take around an hour each week and can be run by someone with little-to-no science background, making them ideal for a parent, teaching assistant or even an older student.

The programme includes two resource booklets and a series of supplementary documents, hosted on www.schoolsobservatory.org/stem-club. The STEM Club Leader booklet (this booklet) provides guidance notes on the activities, and details the resources and knowledge needed to successfully and easily run each session. The student booklet contains step-by-step instructions for each activity and spaces for students to record their work throughout the programme. The student booklet forms their individual record of achievement as they progress through the levels.

How To Use This Booklet:

This booklet contains six sessions. Each session will briefly explain the pupil activities, list the necessary resources you'll need and contains additional useful information, such as facts or web links. It will also give learning objectives for the session and provide any answers if relevant.

It would be useful to have your own copy of the student booklet to help you plan and deliver the sessions.

What Happens On Completion?

Once you have finished this STEM Club level you can download a certificate for your pupils from our website. Full details can be found on page 23 of this booklet.

ABOUT THE BOOKLETS

Both the STEM Club Leader and student booklets use the same style and formatting. This page contains a full set of examples.

1. Activity steps are numbered like this

Interaction with the booklet comes in the form of questions like this, with room for the student to write their answer.

Full resource lists are included. The tables refer to materials needed per group e.g.

REQUIRED RESOURCES
☆ One piece of A4 paper
☆ One pencil

WARNING

Warning notices are used to remind students to be careful when completing the activity.

IMPORTANT

Important information is always highlighted in this way so hopefully the student will not miss anything vital to the activity.

It would be great if you tagged us on any social media posts **@SchoolsObs.**

This is a tip. Useful information will be written like this to help it stand out from the activity steps.

SESSION 1: SPEED OF LIGHT

In this first session the students will be creating waves and measuring the Speed of Light using a microwaves and a chocolate bar.

Learning Objectives, students will learn:

1. that the speed of light is a constant
2. about frequency and wavelength
3. that microwaves are light waves
4. about standing waves
5. to use speed of light to determine astronomical distances in light-years

* You will need to know the frequency of the microwave oven, check the label on the back.

**The chocolate bar needs to able to lay flat on the plate. We recommended size 150 -300g or similar of milk/dark chocolate)

Each group will require the following:

REQUIRED RESOURCES
☆ 2m length of rope
☆ Microwave*
☆ Microwavable Plate or Dish**
☆ Ruler
☆ Bar of chocolate

WARNING

Make sure there is only food in the microwave and no foil wrappers! Check the guidance of microwave.

Before the session:
You might find this video useful (We The Curious) www.youtube.com/watch?v=kpB1wezpJeE

Locate a microwave. It needs to be one that uses a rotating mechanism, even though we are going to remove the rotating plate.

Find the power output frequency of the microwave – it is usually written on a label like in the picture.

Power Input: 230-240v ~ 50Hz 5.1A

Power Output: 2450MHz 850W

Depending on the level of your students you can give it in Hz or let them convert it.

Example from label: 2450 MHz = 2,450,000,000 Hz

Example conversions:

1 kHz	1000 Hz
1 MHz	1,000,000 Hz

1 GHz	1,000,000,000 Hz
2.5 GHz	2,500,000,000 Hz

During the session:
Allow the students some time to read through the information in their workbooks about light: its ability to travel as a wave, the different wavelengths of light (and how they also represent colours), and that light travels at the same speed in a vacuum – no matter what its wavelength.

ACTIVITY 1: WAVES

Introduce the idea of waves to students using a rope:

First create a **travelling wave**:
1. Get two volunteers from the club.
2. Have each volunteer hold one end of the rope. Ensure that the rope is taut.
3. Have one of the students create a wave pulse by quickly moving the rope up and down a single time.
4. This wave pulse will travel down the rope to the other student and represents a travelling wave – it moves from one person to the other.
5. You can ask the students to repeat this – or send the wave back in the opposite direction – so long as there is a clear pause between each pulse you will have the desired effect.

Next create a **standing wave**:
1. Get two more volunteers from the club.
2. Have each volunteer hold one end of the rope. Ensure that the rope is taut.
3. Have one of the students move the rope up and down continually.
4. Ensure that the other student remains holding the rope still.
5. A pattern should appear on the rope of equally spaced peaks and troughs – this represents a standing wave.
6. Explain to the students that the points on their standing wave which appear not to move are called 'nodes' – these should be at the centre line of the rope.
7. Explain that the rope which constantly moves from peak to trough (highest to lowest point) are called 'antinodes'. These will appear between each node.
8. Allow the students to count the number of antinodes and note this in their workbooks.

ACTIVITY 1: CHOCOLATE HOT SPOTS

Calculate the speed of light using a microwave oven and some chocolate.

1. Follow the instructions in the student workbook to start to melt the chocolate in the microwave.
2. Once the hotspots start to appear have the students measure the distance between two neighbouring ones using a ruler.

WARNING

Melted chocolate can be extremely hot. Make sure your students do not touch the chocolate once it has been melted.

3. The students should note down this distance in their workbooks and convert it into metres.
4. Students should then calculate the wavelength of the microwave light by doubling this distance. Again ensure they note this value in their workbooks.
5. Provide the students with the frequency of your microwave (make sure they know this value in Hz which is equivalent to 'per second').
6. Using the equation $c=f\lambda$ your students should calculate the speed of light from their measurements.

Talk about why their answers are different. The following list can affect the accuracy of their answers;

- Chocolate is not a very precise measuring tool
- We are not in a vacuum
- The microwave may be old and less accurate
- Even something as small as millimetres does not provide an accurate enough measurement

The scientific notion value for the speed of light is $3\text{x}10^8$ m/s.

It is unlikely that your students will get the exact speed of light (299,792,458 m/s), if your students get an answer within the range of 290,000,000 and 310,000,000 consider this a correct answer.

ACTIVITY 3: DISTANCES IN SPACE

Use the speed of light to work out how far one light year is.

1. Remind your students about the speed=distance/time equation.
2. Students should rearrange the equation to make distance the subject.
3. Students should then work out how many seconds are in a year using the equation in their workbooks.
4. Students can then use the speed of light they calculated in activity 2, and the time they have just calculated to work out what 1 light year is in metres.
5. Have the students use this value to calculate how far away Alpha Centuri is in light years (using the information in their workbooks).

The answer is: 4.37 light years (there may be a small range depending upon whether leap years have been included for example).

Note that the distance the students are given to Alpha Centauri is in 'trillion km' so they need to convert this into metres. Remember trillion = 10^{12} and km = 10^3 m.

IMPORTANT

Your students may have come across the term light year in the past but confuse it as a unit of time rather than distance – clarify that a light year is a distance and is defined by how far light can travel in a year.

SESSION 2: LIFE CYCLE OF STARS

In this session students will use balloons to replicate the stages of a star throughout its lifetime. They will then use the balloon star timeline to match the cards in the sorting game.

Learning Objectives, students will learn:

1. that not all stars are the same
2. how stages in the life cycles of stars differ
3. that the life of a star is dependent on its mass

Activity 1 requires each student to inflate a balloon. We have listed required resources based on a group of 16 students. If your group is larger you should increase the number of yellow and red balloons.

You can have as many red and yellow balloons as you need. This helps to show that the most massive and hottest stars (white and blue) are much rarer and that black holes and neutron stars are less likely to occur.

There should never be more than 1 blue and 2 white balloons.

You can skip the red balloon and its associated timeline if you have a very small group.

Each group will require the following:

REQUIRED RESOURCES
☆ Red balloons (8 minimum)
☆ Yellow balloons (5 minimum)
☆ Ping pong balls (13 minimum)
☆ White balloons (2 maximum)
☆ Marbles/grapes (2 maximum)
☆ Blue balloon (1 maximum)
☆ Ball bearing/tic tac (1 maximum)
☆ Pin to pop the balloons

Before the session

Read through the Activity 1 instructions. Work out the best location to place your timeline (page 13). You will need enough space for 8 stops in the timeline and enough space for all the students to stand at each point in the timeline.

ACTIVITY 1: BALLOON GAME

Ask this question before the balloon game:

Q. Are all stars the same?

A. They are all different but some can be grouped together by: (some examples) mass, heat, colour, size, age, death

WARNING

Check for any latex allergies before anyone handles the balloons.

Balloon game:

1. Draw a timeline (page 13) of the main times on a board or along a wall. Make reference to the timeline being the top line of the balloon table where it goes from 10 million to 100 billion years.

2. Give each student a balloon (remember just 1 blue and 2 white) and ask them to blow up each balloon to about 8 cm diameter. They should hold the neck of the balloon closed, but should not tie it off.

   These balloons represent the creation of new stars. They form when gas and dust clump together through gravity. Once the pressure inside the clump is high enough, hydrogen atoms combine to form helium through nuclear fusion, and a star is born. The colour represents the surface temperature of the star.

   Nuclear fusion is the process by which lighter elements combine to form heavier elements. This process releases energy.

3. Guide the students to move along the timeline in stages using the times and instructions on the next page. When students arrive at each stop in the timeline, they should carry out the action listed for their colour of balloon. Ask the students to predict what will happen to their balloon as they move along the timeline.

   The remaining ball (ping pong/marble/ball bearing etc.) represents the core of the star and is all that remains at the end of its life. Show the relevant ball once the balloon is popped/deflated. There are additional supporting science notes and questions to support discussion below.

Notes:
10 Million Years + Blue Stars: When hydrogen begins to run low, the star becomes a red giant. The outer shell of the star expands (up to 100 times the size of the original star) and cools.

11 Million Years + Blue Stars: A supernova is a tremendous explosion that occurs when lighter elements in a star's core have been converted into iron. A black hole forms when the core of a star collapses in on itself to create an object so dense that even light cannot escape its gravitational attraction.

55 Million Years + White Stars: A neutron star is only about 10 miles in diameter, but has a mass about 1.4 times that of the Sun and a magnetic field a trillion times stronger than the Earth's.

12.5 Billion Years + Yellow Stars: Planetary nebulae are the expanding shells of gas that are ejected by some stars. A white dwarf is a slowly cooling core of a star. One unusual property is that the more mass the white dwarf has, the smaller it is.

After all the stars are "dead", review the sequence you have just covered:

Questions to ask:

Which stars died first?
Which stars died last?
Which stars deflated?
Which stars exploded?
What is the main difference between the stars that exploded and deflated?
How common are the really massive stars that become black holes?

Which colour balloon was the Sun? **Yellow**

How will the fate of our Sun affect the fate of the Earth? **About 5 billion years from now, the Sun will turn into a red giant, with its outer surface expanding to about the radius of the Earth's orbit.**

Balloon game answers for student workbook:
What colour are stars that are hottest? **Blue**.
What colour are stars that are coldest? **Red**.
Which stars will live the longest? **Red.**

ACTIVITIES 2 AND 3: CARD SORTING GAMES

Copy the images on the next page and ask the students to cut them out. Remember to keep the name on top of each image.

The students must arrange the images in their booklets to correspond with the correct description.

Activity 2 - Answers

Stage 1	Molecular Cloud
Stage 2	Protostars
Stage 3	Main Sequence (yellow)
Stage 4	Red Giant
Stage 5	Planetary Nebula
Stage 6	White Dwarf
Stage 7	Black Dwarf

Activity 3 - Answers

Stage 1	Molecular Cloud
Stage 2	Protostars
Stage 3	Main Sequence (blue)
Stage 4	Red Supergiant
Stage 5	Supernova
Stage 6a	Neutron Star
Stage 6b	Black Hole

ACTIVITY 4: CROSSWORD (ANSWERS)

ACROSS:
4. Supernova
5. Red giant
8. Main sequence star
9. White dwarf
10. Protostar

DOWN:
1. Neutron star
2. Black hole
3. Molecular cloud
6. Nuclear fusion
7. Black dwarf

There are no spaces represented in the crossword grid.

Card Sorting Games: copy this page, give one to each group. Ask them to cut out the images below (ordered alphabetically). They need to match each title and image with its description in activities 2 and 3 in their workbook. There are 7 for each activity.

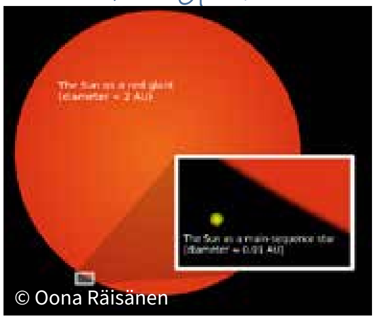
Black Dwarf

© Black dwarf - TSO

Molecular Cloud

© NASA/ESA/STScI

Red Giant



© Oona Räisänen

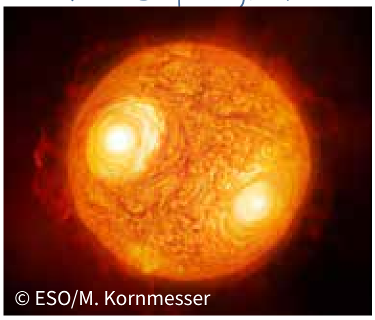
Black Hole

© Event Horizon Telescope et al.

Neutron Star

© Neutron Star - ESA/ATG medialab

Red Supergiant



© ESO/M. Kornmesser

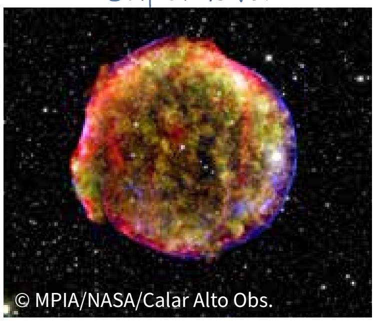
Main Sequence (yellow)

© NASA/SOHO

Planetary Nebula

© NASA/Andrew Fruchter (STScI)

Supernova



© MPIA/NASA/Calar Alto Obs.

Main Sequence (blue)

© Main sequence (blue) - NASA

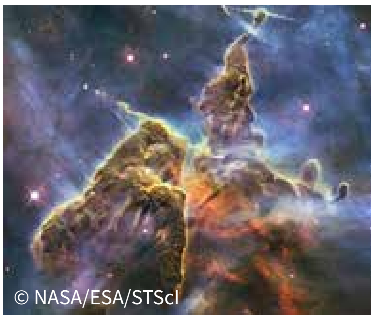
Protostars

© The Spitzer Space Telescope

White dwarf

© White dwarf - Sephirohq

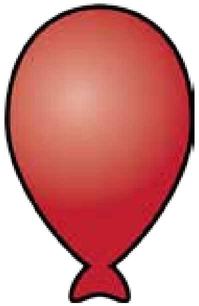
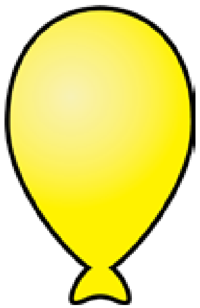
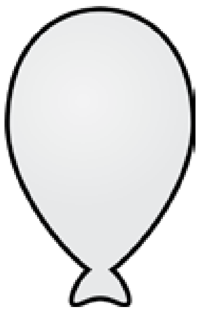
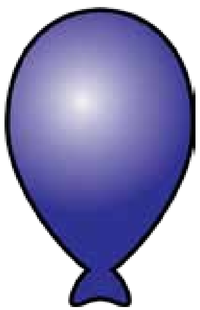
Molecular Cloud



© NASA/ESA/STScI

Protostars

© The Spitzer Space Telescope

Timeline:	10 Million Years	11 Million Years	50 Million Years	55 Million Years	10 Billion Years	12 Billion Years	12.5 Billion Years	100 Billion Years
	Wait. Do not change the diameter of the balloon.	Keep waiting.	Keep waiting.	Keep waiting.	Keep waiting.	Keep waiting.	Keep waiting.	Deflate balloon. **This star has become a white dwarf** (show ping pong ball as remains).
	Wait. Do not change the diameter of the balloon.	Keep waiting.	Keep waiting.	Keep waiting.	Blow up a little bit more. **This star is becoming a red giant.**	Blow up more. **This star is a red giant.**	Deflate the balloon. **Star releases its outer layers as a planetary nebula and becomes a white dwarf** (show ping pong ball as remains).	Still white dwarf.
	Wait. Do not change the diameter of the balloon.	Keep waiting.	Blow slightly more air into balloon. **This star is becoming a red giant.**	Quickly fully inflate balloon. Pop balloon. **This star exploded in a supernova and became a neutron star** (show marble/ grape as remains).	Still a neutron star.	Still a neutron star.	Still a neutron star.	Still a neutron star.
	Blow slightly more air into balloon. **This star is becoming a red giant.**	Quickly fully inflate balloon. Pop balloon. **This star exploded in a supernova and became a black hole** (show ball bearing/tic tac as remains).	Still black hole.	Still black hole.	Still black hole.	Still black hole.	Still black hole.	Still black hole.

SESSION 3: ENGINEERING TELESCOPES

In this session students will learn about different telescopes. The design and build of telescopes is very important to their success at making discoveries in space. First students will play the Telescope Game, then they will work in groups to build a stable structure from spaghetti. Finally, students will create an origami sunshield based on the design of space telescopes.

Learning Objectives, students will learn:

1. problem solving skills
2. to recognise that engineering is an important part of the space industry
3. about team work
4. about the iterative process (design, test, improve, reapeat)

Each group will require the following:

REQUIRED RESOURCES
☆ Telescope Game*
☆ Spaghetti
☆ Marshmallows
☆ Origami template

* The game is available to download from our website: www.schoolsobservatory.org/stem-club

ACTIVITY 1: TELESCOPE GAME

Aim of the game: win all the cards to end the game

Read the rules to the students:

- ☆ Shuffle the deck and deal an equal number to each player face down.
- ☆ Each player holds their cards face up to themselves. Only look at the top card.
- ☆ The person with the longest hair goes first!
- ☆ The starting player chooses one of the categories from their top card and reads it out loud to their opponent(s). The other players then read out their own values for the same category.
- ☆ The player with the winning value for the chosen category keeps all the cards from that round.
- ☆ The winner of that round gets to choose the next category.
- ☆ In the event of a draw, the cards are shuffled back into the players' decks and the starting player chooses another card.
- ☆ The winner of the Telescope Game is the person who has all the cards at the end.

Categories:

- ☆ MIRROR SIZE: largest wins.
- ☆ ALTITUDE: highest wins (but radio beats everything else!)
- ☆ FIRST LIGHT: oldest wins.
- ☆ WAVELENGTH: shortest wins (e.g. $10^{-2} = 0.01$ versus $10^{-4} = 0.0001$ (10^{-4} wins)

The students have extra questions to answer as part of the Telescope Game:

Questions	**Answers**
1. Which telescope has the widest diameter?	Arecibo Telescope
2. Which telescopes are in space?	James Webb Space Telescope Hubble Space Telescope Spitzer Space Telescope Swift Observatory X-ray Newton Telescope Chandra Observatory
3. Which telescopes have the longest wavelength?	Radio telescopes (Lovell)

ACTIVITY 2: MARSHMALLOW AND SPAGHETTI WEIGHT HOLDERS

Give each group (2-4 students) a handful of spaghetti (approximately 20 sticks) and 10-15 marshmallows. Give students 18 minutes total for this activity, including designing their structure. Remind them to think about what shapes are strong (e.g. triangles) and to evaluate throughout the 'build phase'.

The rule for each structure:

- ☆ Be at least 15 cm tall
- ☆ Hold a weight for at least 10 seconds
- ☆ Only made of marshmallow and spaghetti

End of activity: get group to discuss what they could have done differently. Was their planning successful? Did they try multiple designs and improve on it as they progressed or did they use one design and only test it at the end?

ACTIVITY 3: ORIGAMI

Before the session:
Photocopy the sunshield template on the next page. Rulers or retracted pens might be useful for scoring along the fold lines.

Extension activity: if any students finish early, you can ask them to try and design their own origami folding sunshield.

WARNING

Do NOT use your sunshield model to attempt to block the light of the Sun!

(Activity from:
www.jpl.nasa.gov/edu/learn/project/space-origami-make-your-own-starshade)

Space Origami: Make Your Own Starshade

Make a model of this NASA space technology designed to help capture images of planets outside our solar system! Full instructions at: **go.nasa.gov/2m1QT6B**

Materials

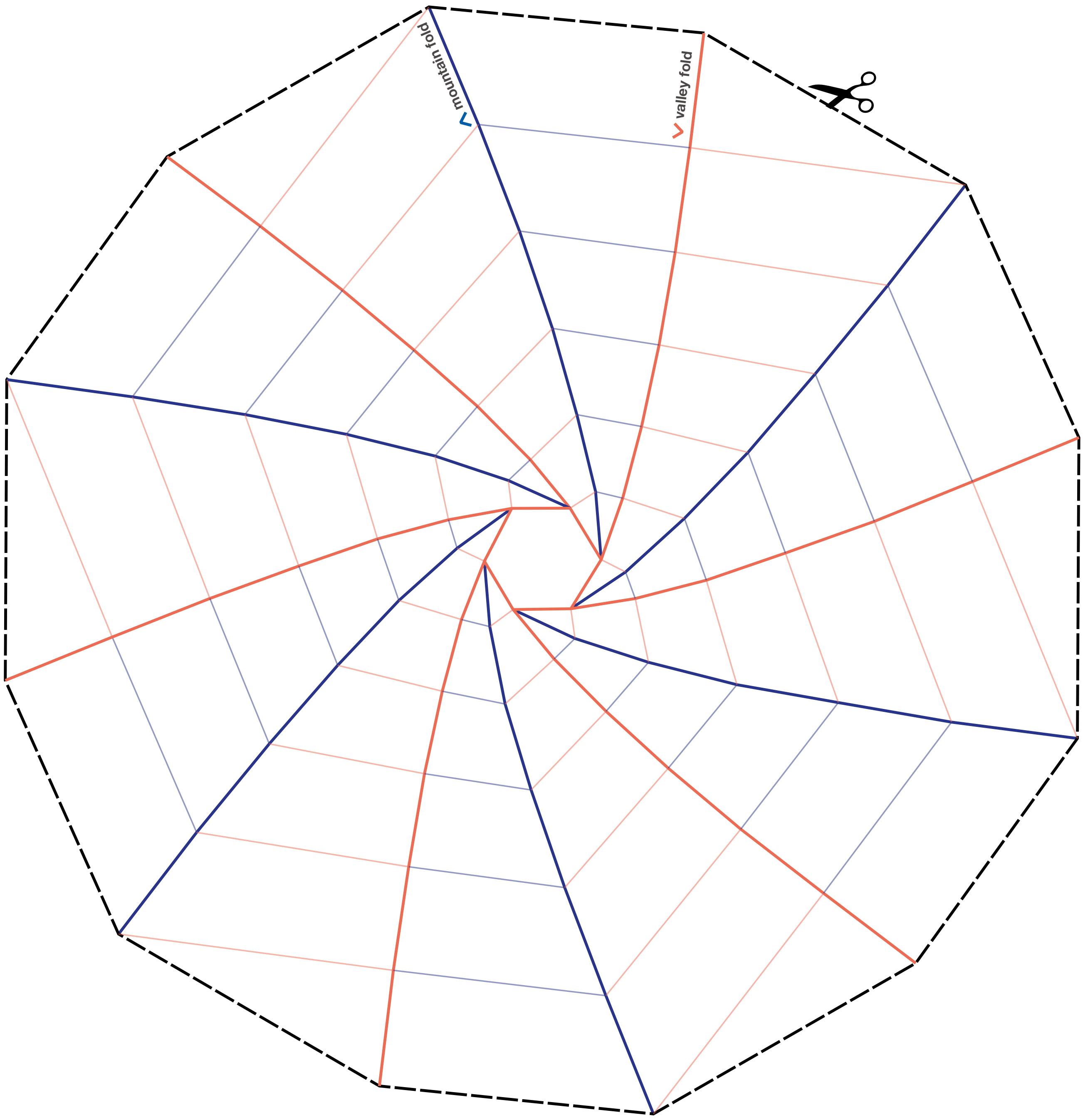
- Starshade Template
- Scissors
- Empty ballpoint pen or stylus (optional)

1. Cut it out: Carefully cut along the exterior (black) lines to remove the Starshade model.

2. Score and crease the darker fold lines: Crease each fold, individually, as follows: Blue lines are mountain folds that point up. Orange lines are valley folds that point down, as viewed from the printed side of the paper. You may use a tool – like a stylus, retracted mechanical pencil, or empty ballpoint pen – to lightly score the fold lines for easier creasing. Be careful not to tear the paper.

3. Score and crease the lighter fold lines (optional): The minor fold lines, printed in lighter colors, do not need to be creased; however, creasing them will produce a more satisfying origami

4. Fold it: After all lines have been creased, carefully fold the major fold lines, moving from the center outwards. The major fold lines will fold 180 degrees. You may hold the central hexagon flat while rotating it, gathering the folds in a spiral wrap.



SESSION 4: PLANNING OBSERVATIONS

During this session students will learn how to plan for astronomy observations. They will use Stellarium to work out what objects will be in the night sky on a particular date and time.

Learning Objectives, students will learn:

1. how to plan an evening of naked-eye observing
2. the importance of efficient planning for observing
3. the way that computer simulations can be useful to improve planning

Each group will require the following:

REQUIRED RESOURCES
☆ Stellarium software*
☆ Access to computers
☆ Student instructions**
☆ Leader guide**

* Stellarium is free, open-source software and runs on most computers (Windows, Mac, Linux). It is available to download from stellarium.org

There is also a web-based version, but that works slightly differently from the main software and so is not ideal for this activity. Smartphone and tablet apps are also available, but these are not always free.

** These are available to download from our website for you to print or display on screen: www.schoolsobservatory.org/stem-club

Before the session:
You will need to download Stellarium onto each computer for students to use. Instructions to download can be found in the 'Leader guide' for this session. You may find it useful to play with Stellarium before the session to familiarise yourself with the software.

During the session:
Provide the students or groups with a copy of the 'Student instructions' for the session. After following the Stellarium instructions, students should answer the questions in their booklet. They will imagine they are planning for a specific observing session at a particular date and time. It is up to you to decide if you want to plan for a real night of observing! If you choose not to it will not affect future sessions in the booklet.

Students will set up Stellarium and select the desired location for observing – usually the nearest city. Then they will choose a time and date for observing. This can be anytime in the future and can be for an imaginary session. They can explore the sky by moving around or searching for particular objects they might know like 'Mars' or 'Saturn'.

not all objects you can think of will be visible in the sky at the same time.

SESSION 5: COSMIC CLUES

In this session students will be investigating stars using light and colour.

Learning Objectives, students will learn:

1. that colour is an effect of light
2. to experiment with colour by using a variety of filters
3. to understand that stars' spectra can tell us what their surface temperature is

Before the session:
Make sure you have all the listed resources ready.

If you are running a short session or working with young students, we recommend making colour photocopies of the wheel printed on page 19. Students can cut out and use the photocopies, rather than creating their own.

Don't worry if you don't have access to all three colours of cellophane. The experiment can be done with only one of the colours, but will be shorter.

At the start of the session:
As a group, read the introductory text in the student booklet, 'Why are things different colours?' and 'How does the Liverpool Telescope (LT) record colour?'.

Each group will require the following:

REQUIRED RESOURCES
☆ Coloured pens/ pencils
☆ Paper or card
☆ Protractor and ruler
☆ Scissors
☆ Blu Tak or similar adhesive putty
☆ Pencil or pen
☆ Red, green, and blue marker pens
☆ Green, red, and blue cellophane

ACTIVITY 1: MAKE A COLOUR WHEEL

The students will work individually or in pairs to make a colour wheel and spin it to see what happens.

During the activity:
As they spin the wheel rapidly, students should observe that the colours blend into each other. This creates the illusion that the wheel is white. Students should notice that this only happens when they spin the wheel rapidly enough. At lower speeds they will still be able to distinguish the different colours.

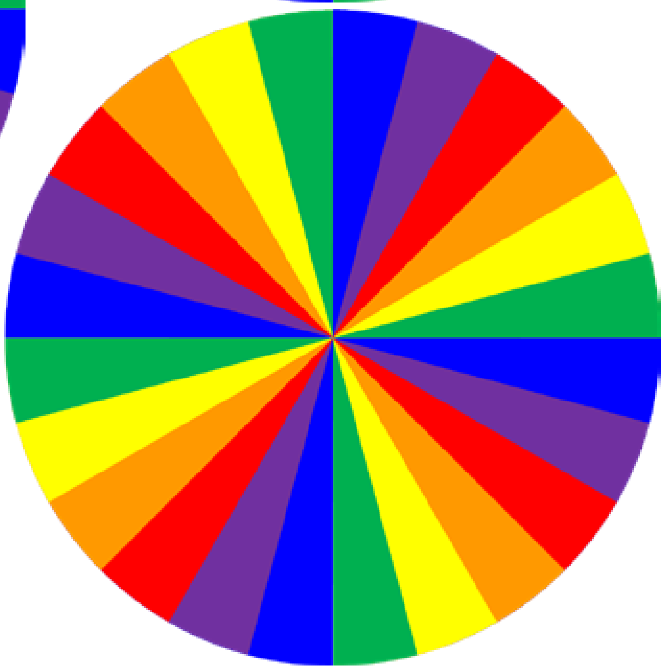
The illusion occurs because white light contains all the colours of the rainbow. When the wheel spins at the right speed, the colours blend to recreate white light. Students will see a white wheel because their eyes cannot keep up with the rapid rate the colours are spinning.

Possible answers to the question on page 22 of student booklet:
'A rainbow' or 'Using a prism' or 'In an oil or soap bubble'.

This happens because the different wavelengths (colours) of light are refracted (or bent) as they move from the air into the other material (e.g., water/oil/glass etc.). The amount the light is refracted depends on its wavelength and so the colours are separated out.

IMPORTANT

If the students are creating their own circles, make sure that they split their circle into equal parts and use the same order of colours shown in the booklet.



ACTIVITY 2: MAKE A MESSAGE DISAPPEAR!

The students will work in pairs or small groups and look through pieces of different coloured cellophane (red, green, and blue) to discover what coloured filters do to light before it reaches their eyes. They will then try to hide messages using different coloured ink and filters.

During the activity:
When looking through a coloured filter, students should notice that some of the colours disappear, whilst others remain.

Students should notice that the part of their message or drawing that is hidden when they look through a filter, is the same colour as the filter.

IMPORTANT

Have a look at the diagram on page 19 of the student booklet to understand what's happening during the experiment. This will help you support the students with any questions or problems they have.

Colour pigments (paints, dyes, or inks) display colour by absorbing certain parts of the visible spectrum and reflecting the parts that remain. Colour filters work in a similar way, absorbing certain wavelengths of light (or colours) and transmitting the other wavelengths. Red filters let through red light; blue filters let through blue light; green filters let through green light etc.

Answer to question on page 22 of student booklet:
Astronomers need colour images to get information about objects in space, including stars. Colours can tell astronomers about the elements an object is made of, the temperature of its surface, or even how far away it is (this involves something called red-shift). Colour pictures also look pretty!

ACTIVITY 3: STELLAR FORENSICS

The students will match up absorption spectra from stars to spell out code words. If there is time, they can also make up their own pneumonic device to remember the stellar classification sequence.

At the start of the activity:
"As a group, read the first four paragraphs about 'stellar forensics' on page 23 in the student booklets and familiarise yourselves with the reference spectra image.

During the activity:
Ensure the students understand that they are trying to match up the patterns of dark absorption lines in the spectra. It may be helpful for younger students to liken the patterns to barcodes.

Answers to question on page 24 of student booklet:
1. OAK
2. MOB
3. FOAM
4. AMOK

The scale at the top of the spectra tells students the wavelength of the light in nanometres. They can use it to help them match up the dark absorption lines in the spectra. One nanometre is one millionth of a millimetre (1×10^{-9} m).

SESSION 6: 3-COLOUR IMAGES

In this session, students will learn how to make a colour image of M51 using an observation taken by the Liverpool Telescope. M51 is also known as Messier 51, NGC5194 or the 'Whirlpool Galaxy'. It is a spiral galaxy interacting with a dwarf galaxy. The students will use our free image processing software to combine three images of M51 (a red, a green, and a blue image) to make a colour picture. They will use the software to combine, align and scale the images.

Learning Objectives, students will learn:

1. to understand how filtered images combine to make full colour images
2. to use astronomical software
3. to produce a 3-colour image

*If your room does not have internet access, download the files and copy them on to the students computers. In this case, you may want to download LTImage in advance.

Each group will require the following:

REQUIRED RESOURCES
☆ Computer
☆ Internet access/downloaded files*
☆ Student usernames & passwords

Before the session:

1. Register for The Schools' Observatory:
   Prior to the session you will need to create a teacher account and accounts for your students on our website. With a teacher account you can quickly and easily create multiple student accounts for your group. You might have done this already in the Bronze level STEM Club. It is a quick and easy process:
   - ☆ Go to www.schoolsobservatory.org/register and follow the instructions
   - ☆ A full video tutuorial of the process can be found here: www.schoolsobservatory.org/help/myaccount
   - ☆ Keep a note of the student usernames and passwords
2. We recommend that you check that the software works on your machines, have a play with the nebula data in advance to save time during the session. The file names are shown on the next page (M51_red.fits etc.).

   The software is available from this webpage on our website:
   www.schoolsobservatory.org/get-started/view-images

   The files can be downloaded from here:
   www.schoolsobservatory.org/teach/activities/3_colour_imaging

At the beginning of the session:
Introduce the session and read through the introductory information at the top of the student's booklets with the students. The step-by-step instructions for the students can be found here:
www.schoolsobservatory.org/stem-club

LOG IN TO OUR WEBSITE

The students will be asked to log in to our website. There is space in their booklet to write down their username and password.

GET THE IMAGES

The students will download one set of image files - 3 files in total that include red, green and blue files.

If your STEM Club does not have internet access or poor download speeds, you can download these files in advance for the students to copy onto their computers.

M51 (Whirlpool Galaxy)

M51_red.fits
M51_green.fits
M51_blue.fits

OPEN AND COMBINE THE IMAGES

If required, demonstrate how to load images into our free software. Make sure the students follow the instructions in their books carefully and open the files in the correct order, Image selection 1 = red, Image selection 2 = green, Image selection 3 = blue.

If the files are not in the correct order, their image won't look quite right in the later steps.

Students will use a fourth window to combine the files into a 3-colour image. When the students first make their images, they will probably be mostly black. This is normal at this stage, so no need to worry. The students will scale the image to reveal the colours later.

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 won't have done it perfectly. The students can correct any misalignment in this activity. Encourage them to carefully check the alignment of the image by following the instructions in their booklets.

If students cannot find a suitable "dot" to use to check the alignment, they can move on to the next step, and come back and align the images later.

SCALE THE IMAGE

Up until this activity, the software is only showing the very brightest parts of the image. Students will now 'scale' their image to reveal more of the galaxy.

Encourage students to use trial and error during this activity. There is not one correct solution. They should change the red, green and blue values in turn, checking the result in both the preview and image windows until they are happy. They can save any versions as they go along.

Here you can see a finished image. The 'Pixel values' have been reduced as follows; Red: from 64873.3 to 2600.0, Green: from 64747.3 to 2000.0, Blue: from 65265.3 to 1600.0.

At the end of the session:
As a class, look at a selection of the images produced. Are they all the same? Why not? Discuss the subjectivity involved.

Extension:
Students can have another go at the session but with a different observation. They could also use Go Observing on our website to request their own sets of 3-colour data from the Liverpool Telescope. Remember, they will not get the data immediately.

NEXT STEPS...

Congratulations on completing the Silver level of The Schools' Observatory STEM Club!

We hope your students have enjoyed the last 6 weeks and are proud of their completed workbooks. You will notice that the final page of their workbooks contains a space for a certificate. To obtain your certificates, please complete this short online form:

www.schoolsobservatory.org/stem-club/certificates

Once you submit the form, you will be able to download your certificate.

You can access the Gold level booklets here: www.schoolsobservatory.org/stem-club

Thank you for being part of The Schools' Observatory STEM Club!

JUST FOR FUN

We love to see the images that pupils have created from their observations! On page 28 of the student booklet there are details on how to share students' astronomical observations with us. The images you share with us may be showcased in our Galleries on The Schools' Observatory website.

You can share students' images with us by:

- ☆ Tagging @SchoolsObs on Twitter or Instagram

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

FEEDBACK

We love to hear from our users about how we can improve our services. If you or your students have ideas about how we can improve these booklets please email SchoolsObs@ljmu.ac.uk

THE SCHOOLS' OBSERVATORY

For more lesson ideas and interactive workshops visit the 'Things to Do' section of our website.

WWW.SCHOOLSOBSERVATORY.ORG/THINGS-TO-DO

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