Classifying Galaxies – Intermediate Module

Program overview

Lessons required – 4

In this sequence of lessons students will learn how galaxies are classified into different types. After learning about the different types of galaxies, students will then image and process at least one galaxy of each type. The last lesson focuses on Science as a Human Endeavour, using an example of galaxy classification

It is assumed teachers have a background knowledge of using Stellarium and SPIRIT in order to guide their students through it.

Skills focus:

- Classification of celestial objects
- Coding (optional- only if using live viewing)
- STEM skills
  - Critical analysis
  - Independent thinking
  - Digital literacy

Required digital resources:

Device (laptop, computer, tablet) with internet access

Stellarium – (free software) http://stellarium.org

A FTP program (recommended free software Filezilla https://filezilla-project.org)

FITS liberator – (free software)

https://noirlab.edu/public/products/fitsliberator/

If you are choosing to process your images:

Photoshop or a free photo processing software such as GIMP

Curriculum links:

Science

The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe (ACSSU188) **Year 10**

Scientific knowledge has changed peoples' understanding of the world and is refined as new evidence becomes available (ACSHE134 and ACSHE119) **Year 7 and 8**

Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157 and ACSHE191) **Year 9 and 10**

<table>
<tr><td colspan="2">Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158 and ACSHE192) Year 9 and 10</td></tr>
<tr><td>Science Inquiry Skills – year 9-10
Questioning and Predicting
Planning and Conducting
Processing and Analysing Data and Information
Evaluating
Communicating
Digital Technologies – year 7 – 10
Collecting, managing and analysing data
Digital implementation
Creating solutions</td><td>General capabilities:
Numeracy
ICT capabilities
Critical and creative thinking
Literacy</td></tr>
<tr><td>Lesson 1 (60 minutes)
Prequisites:
Internet enabled devices or printed out information for rapid research
Printed out Galaxy Classification Activity- enough for small groups</td><td>1. Brainstorm objects that can be found within the universe, focusing on objects outside of our solar system. Share your ideas as a class.
Questioning and Predicting
2. Focusing on galaxies, create a KWL chart, and encourage students to question the structure of galaxies, and whether they are all the same. E.g. Do all galaxies look the same? What parts do galaxies have?
3. Rapid research: Individually or in groups, see which students can identify the types of galaxies the fastest. (elliptical, spiral, barred-spiral, irregular, lenticular)
4. Watch https://www.youtube.com/watch?v=BO9KBZaCn28 and introduce the Hubble Classification Scheme (sometimes also called the tuning fork). This can be seen here: https://tinyurl.com/y33m3bun (image credit ESA/NASA)
5. Complete Galaxy Classification Activity- students need to sort the images of galaxies into different types. (elliptical, spiral, barred-spiral, irregular)
Discussion points: Why did some people have different ideas of where to sort the galaxies?
What features of galaxies are used when using the Hubble Classification Scheme?
What might be some issues scientists might run into when using Hubble’s Classification Scheme?</td></tr>
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	What are some other features of galaxies that scientists could use to classify galaxies? Hubble's Classification Scheme is based on visual aspects of galaxies only. Some people may classify galaxies differently based on the features that stand out to them e.g. how big a 'bar' appears, or how round a galaxy appears. Galaxies may also be classified wrong based on the view we get on Earth. If we can only view a galaxy from its' side on Earth then it can be difficult to classify. **Extra activities:** a) Research Edwin Hubble and his work in astronomy. How have scientists been able to build on his work? E.g. the tuning fork, evolution of galaxies, redshift, universe expansion b) Look at other popular classification systems for galaxies: the de Vaucouleurs system, the DDO system and the Yerkes system.
Lesson 2 (60 minutes) **Prequisites:** • Internet connected device for students • Stellarium downloaded • Investigation Planner/ My Viewing Plan photocopied Teachers should have some experience using Stellarium and SPIRIT to help students conduct their viewing plan. Teachers need to choose between live viewing, scheduling or a mixture of both.	**Planning and Conducting** 1. Review what was covered in the last lesson. Ask students to recall the names we use for classifications of galaxies. 2. Individually or in groups, students should use the *Galaxy Viewing Guide*, or their own research, to choose at least one galaxy from each classification. 3. Use Stellarium to check when the best viewing time is for their galaxy. Information on using Stellarium can be found here. Students may need to adjust their chosen galaxies if they are not visible at that time. 4. Fill out *My Viewing Plan* or the *Investigation Planner* for the chosen images. A clear filter will be sufficient to see the structure of the galaxies but encourage students to experiment with exposure times to get the clearest image. 5. Use SPIRIT to get images by: *a) Live viewing- If you are using live viewing and would like students to create a plan to practice their coding skills use the information here.* **Please note: If using live viewing teachers need to book the appropriate time on SPIRIT 2. Students or teachers will need to log in at the requested time to complete their viewing plan and live viewing.** *b) Scheduling- If you are using the scheduler then students should follow the instructions here.* **Please note: Students or teachers will need to include an email address in the schedule browser section of the web interface to make sure they get notified when the images are ready.**

	6. Visit https://esahubble.org/images/heic0406a/ for information on the Hubble Ultra Deep Field. Read the information and then click on 'zoomable' on the right-hand side to open the zoomable image. 7. Have students explore the image to find any interesting features. Students can attempt to identify different types of galaxies based on Hubble's Classification Scheme. **Extra activities:** a) Students can take part in some Citizen Science by helping to identify galaxies at https://astroquest.net.au b) Using the galaxy pictures from the last lesson, students come up with their own way of classifying galaxies following a set of rules they develop.
Lesson 3 (60 minutes) **Prerequisites:** • Devices with Filezilla installed • Photo processing software if using • SPIRIT image evaluation form or SPIRIT investigation planner photocopied if using. Teachers will need to be familiar with how to use Filezilla to access the FTP where SPIRIT files are kept. Please contact us for FTP information.	**Processing and analysing data and information:** 1. Students should use FTP to access their images. Instructions on how to use Filezilla are found here. 2. Examine the images for features that match its classification. E.g. long and distinct spiral arms, large or small bulges, haloes. 3. Students choose one of their galaxies and research it. This could include the classification, when the galaxy was discovered, it's approximate distance from Earth, its position in the night sky and any interesting features it may have. **Evaluating:** 4. Ask students to rate their images using the *SPIRIT image evaluation form, SPIRIT investigation planner* or both. Focus on critical thinking and ideas on how to improve their imaging. They may ask group members or other peers for feedback. **Communicating:** 5. In small groups or to the whole class, students should present the information on their chosen galaxy. Alternatively they could turn the information and the image into a poster or digital presentation. 6. At the teacher's discretion students can publish their photos for the wider astronomy community. Some places to do so are: ICRAR's SPIRIT photo of the year competition (watch www.spirit.icrar.org for more information) Astrofest Astrophotography exhibition and competition (watch www.icrar.org for more information) Astronomy.com's community gallery (http://cs.astronomy.com/asy/m/default.aspx)

	NASA's Astronomy Picture of the Day website (https://apod.nasa.gov/apod/lib/apsubmit2015.html) 7. Revisit the KWL chart from the beginning of the program to fill in new information learnt and see what questions were answered. **Extra Activities:** a) Working together, students make their own Edwin Hubble's classification scheme using the images they took on SPIRIT. b) Play 'Messier Bingo' https://messierbingo.lco.global/# where students identify types of celestial objects including galaxies.
Lesson 4 (60 minutes) **Prerequisites:** • Teachers should have read and have a background understanding of both classifying images (Hubble Classification Scheme and the Angular Momentum – Mass Plane) • Copies of images available	**Teachers - Background knowledge** Science as a human endeavour- Science is an ever-growing and changing base of knowledge. It is common for Scientists to build on and add to earlier discoveries, as they learn more. This is especially the case in astronomy, as technology changes so does the amount and type of knowledge Scientists are able to gather. For example, when telescopes first started to be used in the early 1600s we were able to learn so much more about the universe that lay beyond our own solar system. Since then, advances in astronomy have continued to expand our knowledge. An example of this is the work being undertaken on the Square Kilometre array, an endeavour to build the world's largest radio telescope, part of which will be right here in Western Australia. (For more information visit here: https://www.icrar.org/our-research/ska/) This lesson presents an example of Scientists building on another's knowledge. The Hubble Classification Scheme is widely used but it does have flaws, such as the subjective nature that is used to decide which classification a galaxy falls into. It relies almost entirely of the visual aspects of the galaxy, which can be misleading. The classification of a galaxy using this scheme depends on the view we have of it from Earth, and allows for confusion when deciding on a galaxy. Look at NGC 3109 and NGC 5195 that have disputed classifications. It uses **qualitative** measures. The Angular Momentum-Mass Plane allows us to understand the Hubble sequence from a physical point of view. It gives us a **quantitative** measure to classify galaxies. It uses a quantitative measure of angular momentum and mass to classify galaxies to provide a physical interpretation for the Hubble sequence. High angular momentum means that orbits are ordered and circular along the plane of the galaxy, low angular momentum means that orbits are more random and do not follow a circular pattern. Put in other

	words, at fixed mass, the angular momentum tells us how much of the global energy of the system goes into rotation. So, the fact that different morphological types follow parallel sequences in the Angular Momemtum-Mass plane shows that the different morphological types in Hubble sequence are equivalent to galaxies that have different degrees of rotational support. The Angular Momentum-Mass Plane shows the correlation between the angular momentum a galaxy has, it's mass and the morphological type on the Hubble Classification Scheme. The Angular Momentum-Mass Plane is an important component of our current theory of galaxy formation and was first investigated in 1983. More recently, thanks to the improvement in optical telescopes, astronomers have been able to further characterize this plane. This includes work by Luca Cortese, Luca Cortese, an astrophysicist that works in Western Australia in observational extragalactic astronomy, with a main interest in the study of the physical properties of galaxies. Find out more about Luca here. **Questioning and Predicting** 1. Revisit the Hubble Classification Scheme (referred to as HCS) from earlier in the program. (https://tinyurl.com/y33m3bun) Complete a five-minute brainstorm on the benefits and drawbacks of the HCS. Share as a class. 2. Discussion: Based on the drawbacks of the HCS, what kind of things could be done to improve a new classification scheme? **Planning and Conducting** 3. Introduce and explain the Angular Momentum-Mass Plane (referred to as AMMP). A simple explanation on angular momentum can be found here: https://www.youtube.com/watch?v=iWSu6U0Ujs8 4. Read this article to get more information on the AMMP. Explain to students that they are going to present a small discussion point on the use of both schemes. They may want to jot down some preliminary thoughts as a group. 5. Investigate galaxies where a consensus on morphology has not been reached e.g. NGC 3109 and NGC 5195. **Processing and analysing data and information**

	6. Complete a T-Chart of different properties and features of HCS and AMMP. Possible discussion points: • Do these classification schemes cater to different audiences? • Why would Scientists continue to work on a classification scheme when one already exists? • What features/characteristics does the HCS use to classify galaxies? • What features/characteristics does the AMMP use to classify galaxies? **Evaluating** 7. In groups, students should devise one or two discussion points on the use of the classification schemes. They may want to discuss: the different uses of each system, the effectiveness of other systems mentioned in lesson 1, what information is important to know before using each system. **Communicating** 8. Groups share their ideas with the class. Allow students to present their discussion point and have a conversation as a class on agreements or disagreements. **Extra activities:** a) Create a timeline that shows significant discoveries and inventions in astronomy, e.g. the invention of the telescope, the discovery of planets, the launch of the Hubble telescope, the advent of radio astronomy. The timeline may need to be broken down in smaller parts to make it more manageable. b) Ask students to investigate one astronomical foundation and how ideas were developed to our understanding today. E.g. that the Earth is round and its circumference, the phases of the moon, the size of the universe, the length of an astronomical unit, the distance of objects in deep space. How many people contributed to this understanding?
What next: Now that they have an understanding of galaxies, students could move onto a research project to investigate how galaxies change and evolve by imaging galaxy mergers and interactions. If you are looking for ideas or support on how to use SPIRIT in your classroom, please contact us at any time at: spirit@icrar.org	