Galaxy Evolution – Intermediate Module

Program overview

Lessons required – 4

In this sequence of lessons students will learn about some factors that can enact change on galaxy structure. This unit will focus on environment being a determining factor for galaxy structure, and galaxy interactions. It includes two Science inquiry cycles and can be shortened to one at the teacher's discretion. Before beginning the program, students should understand how galaxies are classified, and the scientific terms used. e.g., barred-spiral, spiral, elliptical and irregular.

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

Skills focus:

- Evolution of celestial objects over time
- Coding (optional- only if using live viewing)
- STEM skills
  - Critical analysis
  - Independent thinking
  - Digital literacy
  - Creativity
  - Communication

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)

If you are choosing to process your images:

FITS liberator – (free software- converts FITS files to TIF files to use in photoshop)

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

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**

ATAR Physics- **year 12,** unit 3- Gravity and electromagnetism

<table>
<tr><td colspan="2">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

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 7-10
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 research
Stellarium downloaded
My viewing plan or investigation planner photocopied, if using.</td><td>1. Review Edwin Hubble's Classification Scheme https://tinyurl.com/y33m3bun and the names given to different galaxy classifications.
Questioning and Predicting
2. In small groups, brainstorm what factors could affect the structure of galaxies, or change its morphology e.g. gravity, just made that way, being near other galaxies, dark matter.
3. Focus on gravity. Discuss: What is gravity? How would it work on a large scale? Play https://gravitysimulator.org/misc/when-galaxies-collide to see what can happen when galaxies are close to each other. Before pressing play, ask students to make a detailed prediction:
What will happen to the disk or bulge?
Will the galaxies completely combine?
What might the particles we see floating around at the beginning signify?</td></tr>
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Teachers should have some experience using Stellarium and SPIRIT to help students conduct their viewing plan.	Change factors in the game, or simply play it again to get a different scenario and students can predict each time. Discuss how each interaction effects the structure of a galaxy. Is it still a spiral galaxy or has it changed? A quick summary of what can happen when galaxies collide can be watched here: https://www.youtube.com/watch?v=eWqETkudZXo **Planning and conducting** 4. Students are going to look for evidence of galaxy interactions. They can begin by researching some galaxy interactions independently. A good place to start is: https://hubblesite.org/images/gallery/19-interacting-galaxies/page/5 Alternatively, students can choose from this list: NGC 1532 (also called Woomera in Indigenous astronomy- https://tinyurl.com/t9xft32y) NGC 2937 NGC 3169 NGC 6872 NGC 5679 NGC 4038 5. Individually or in groups, students should use Stellarium to check if the chosen interacting galaxies are visible with the SPIRIT telescopes at an appropriate time. They made need to change the object they are viewing to suit the time of year. Information on using Stellarium can be found here. 6. Fill out *My Viewing Plan* or *Investigation Planner*. Only a clear filter needs to be used to see the interaction between galaxies. 7. 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. **Extra Activities** a) View this simulation of what may happen in 4 billion years when Andromeda and the Milky Way collide: https://www.youtube.com/watch?v=4disyKG7XtU b) Science as a human endeavour: Create a timeline of important galaxy related discoveries including astronomers such as; Immanuel Kant, William Parsons, William Huggins, Edwin Hubble and Maarten Schmidt
Lesson 2 (60 minutes) **Prequisites:** • Internet connected laptop or computer for students • Filezilla downloaded 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. Teachers should check that the images are ready to be viewed.	**Processing and Analysing Data and Information** 1. Students should use FTP to access their images. Instructions on how to use Filezilla are found here. On their image, label the two galaxies that are interacting, using an image editing software. 2. Ask students to attempt to find the two original bulges of the galaxies that are interacting and make an inference about what has happened between the two galaxies. How might the galaxies have evolved with their interaction? How might they continue to evolve? 3. Watch this video: https://vimeo.com/133402723 to explain how these interactions effect star formation. (A short video highlighting research by Dr Luke Davies, a Western Australian Senior Researcher) **Evaluating** 4. Use the *Investigation Planner* or *Image Evaluation* form. Students should reflect on how to improve their image e.g., exposure time. **Communicating** 5. Ask students to examine their image and prepare for a round table discussion in a small group. Discussion questions: -How are the two galaxies interacting? (e.g., colliding, merging) -How do you think the interactions have affected the structure of the two galaxies? -Where are the two bulges on your image? -What force is at play in this interaction? -What do you think might happen in the years to come? 7. Complete round table discussion and allow groups to share any interesting findings with the class.

	Extra activities: a) Students can read this article on WA about Dr Luke Davies' research on what happens when giant galaxies interact with dwarf galaxies: https://www.icrar.org/what-happens-when-cosmic-giants-meet-galactic-dwarfs/ b) Science as a human endeavour: investigate the work of Dr Alar Toomre, who was one of the first people to simulate galaxy interactions on a computer. He also developed the Toomre Sequence, which demonstrates the sequence of a galaxy merger.
Lesson 3 (60 minutes) **Prerequisites:** • Internet enabled devices or printed out information for research • Post-it notes • Stellarium downloaded • SPIRIT Galaxy Clusters Investigation Planner photocopied Teachers should have some experience using Stellarium and SPIRIT to help students conduct their viewing plan.	**Background knowledge- teachers:** Galaxies are most often found in gravitationally bound clusters, and these clusters can be a part of larger superclusters. The closeness and movement of these galaxies through space means that interactions are common. Gravity can change and morph these galaxies as they move through the cluster. Although the exact correlation between environment and galaxy structure is unknown, it is clear that there is a relationship. Galaxy clusters tend to have a high concentration of elliptical (including lenticular) galaxies close to the middle where galaxy distribution is denser and often have a large elliptical galaxy in the centre. Galaxies that are away from clusters or further from the centre, tend to be spirals or barred -spiral galaxies most of the time. This shows us that something must be happening in clusters that effects the structure of galaxies. This lesson requires students to image two clusters and look at the morphology of the galaxies contained within. There is also an opportunity to look at recent research by astronomers on this topic. It is important to note that Science is an ongoing human endeavour, and the unknown nature of galaxy clusters highlights that astronomy is a scientific area that we are continuing to learn about. **Questioning and predicting** 1. Revisit the brainstorm on galaxy changes from lesson 1 and see if students have anything else to add. 2. Watch https://www.youtube.com/watch?v=FEpX-H8vHu4 3. Give students a post it note and ask them to write down one question they have about galaxy clusters. If necessary, guide them to ask questions about galaxy structure within the cluster.

	4. Highlight the part of the video that discusses how isolated galaxies are mainly spirals and within clusters galaxies are mostly elliptical. On the back of their post it notes, students should make a prediction of why this might be the case. **Planning and conducting** 5. Explain to students that they are going to investigate whether clusters do influence the structure of the galaxies within it. They should get into small groups and brainstorm how they might find this out. 6. Using the *SPIRIT Galaxy Clusters Investigation Planner*, students can plan to image different clusters. Although students can research and choose their own clusters, Hydra and Fornax Clusters are both good clusters to image. The groups need to plan exposure times. (They may want to experiment with different amounts of time.) Only a clear filter will be needed to see the galaxy structures. *7.* Students should use Stellarium to check that their chosen cluster is visible at night time. They should also make note of the coordinates of the cluster to enter into the SPIRIT web interface. *They are not searchable on the catalogues of the SPIRIT interface.* 8. 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.** **Extra activities:** a) Using their knowledge of galaxy structures, students should write a guide of clues to look for to classify the galaxies in their images in the next lesson. E.g. spiral galaxies have tightly wound spiral arms. b) Students draw their own sequence of colliding/merging galaxies based on what they have learnt.
Lesson 4 (60 minutes) **Prerequisites:**	**Processing and Analysing Data and Information** 1. Students should use FTP to access their images. Instructions on how to use Filezilla are found here.

• Internet connected laptop or computer for students • Filezilla downloaded Teachers should check that the images are ready to be viewed. 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.	2. Before analysing their pictures, students need to come up with a plan in their group for how they are going to record the number of different galaxy structures in their images. They may choose a tally, graph, pictograph, or any other way to process and display their data. 3. Once they have a plan students should examine their image and record their data. **Evaluating** 4. Student/group self-reflection questions: -Was their chosen data collection method successful? -What would they change next time? - How could they make their data collection more reliable? -Was their image easy to collect data from? -How could they improve their image next time? 5. In their groups, students discuss their findings. Was there more of one galaxy type than the others? Why might that have happened? What do they think might be happening in their cluster to make this occur? 6. Fill out the evaluation section of the *SPIRIT Galaxy Clusters Investigation Planner* **Communicating** 7. Students should create an infographic about their cluster/s, including information about the cluster, their data collection process and results. This can be done digitally or in a hard copy format. **Extra activities:** a) For students wishing to take on a challenge: https://arxiv.org/abs/2104.02193 A paper released in July 2021 in Western Australia by Luca Cortese, Barbara Catinella and R. Smith. It discusses gas stripping that may effect galaxy structure. b) Write a simple glossary for the following words: tidal tail, red giant, orphan star, halo, central bulge, disk, dark matter.
What next: Using SPIRIT, students can undertake more astronomy research projects including photometry. 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	