



Final Discover the COSMOS Demonstrators

Open Clusters

Name of your Institution:	University of Glamorgan
Title of the educational scenario template:	Inquiry-based teaching
Title of your educational scenario:	Investigating Open Clusters

Educational problem:

How do we know how massive stars are? How can we study the lifecycle of a star, given that it will be millions or billions of years?

To answer these questions, we need to study a coherent group of stars under “controlled conditions” – or at least as controlled as the Universe will allow. Astronomers observe groups of stars called open clusters (relatively young stars, mainly in the early phases of their lifecycles) and globular clusters (very ancient groups of stars, containing many in the end stages of their lives).

Open clusters are loose groups of 10s or 100s of stars that were born from the same initial cloud of gas (mainly hydrogen) and dust.

Cluster stars are very useful as they are all at about the same distance from us (although as a group they are typically hundreds or thousands of light years away). By observing a group of stars in a cluster, we can assume they are all the same age, made of the same material, and that they are all the same distance away from us – so any observed differences in brightness between them are really caused by their different mass (and not by the effects of distance).

By analyzing digital images of open clusters, students can investigate the lifecycle of stars and produce their own version of the theoretical Hertzsprung-Russell diagram (HRD), on which they can identify stars at different stages of their lives. The HRD is a fundamental tool of astronomy, and the production and analysis of such a plot teaches students a great deal about measurement (using techniques known in astronomy as photometry and astrometry) and the lifecycle of stars of different masses.

Textbook teaching of this subject is inherently limited and lacks the possibility of active investigations by the students. Also, the lack of sophisticated telescopes in schools makes direct observations of open clusters a very difficult task.

This scenario aims to fill these gaps and enable students to understand the lifecycle of stars.



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Educational scenario objectives:

During this scenario, students will:

1. Learn about clusters of stars
2. Learn about the lifecycle of stars
3. Get acquainted with making and studying astronomical observations
4. Learn how to analyse telescope data with specific software packages

Characteristics and needs of students:

The scenario helps students understand the lifecycle of stars by using real astronomical data and requiring them to perform their own analysis. Students will be shown how to use Faulkes Telescope data (<http://faulkes-telescope.com>) to measure the intensity of light from the stars in a cluster as observed through different filters (a process known as photometry), and plot the measured colours of the stars on a 'colour-magnitude diagram' (an observational version of a HRD).

Once a measure of both how bright and how "red" (or "blue") the stars are has been made, more information about them can be obtained – massive stars are usually blue (hot), intermediate mass stars (like the Sun) are yellow, and the very lowest mass stars are red (cool). This gives students the possibility to draw a conclusion about the types of stars in the cluster, and also identify any foreground/background stars (i.e. not associated with the cluster, but in the same line-of-sight in the sky) which may be visible in the images.

Students are introduced to the SalsaJ software package which is used to open and analyse real data from astronomical instruments.

The measurements will also allow students to interact (e.g. by working in pairs) and develop social and collaboration skills, allowing them to see that science can be a group activity and not only a solitary one. The experience from working like a "real scientist" (using real research data) may trigger an increased awareness of science in many of them, and possibly an interest in future science careers.



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Rationale of the Educational approach and Parameters guaranteeing its implementation:

This scenario is structured upon the phases prescribed for inquiry-based learning and allows students to make their own discoveries, albeit in a structured and guided way. During the scenario the students assume the role of a scientist and work with real data from scientific experiments and real scientific instruments, thus gaining a first-hand understanding of scientific inquiry.

For the implementation of this scenario students must have access to PCs (which should also be connected to the Internet). The software package SalsaJ must also be downloaded onto each machine and can be accessed here

<http://www.euhou.net/index.php/salsaj-software-mainmenu-9/download-mainmenu-10>

Learning activities:

Phase 1: Question Eliciting activities

Exhibit curiosity

You may begin your lesson with a presentation or video on the Faulkes robotic telescopes, to introduce the students to the professional-grade instruments which they will be using, and analyzing the cluster data from. Then trigger a conversation with your class by asking your students what they know about stars in general. You can then let your students know about what they will do during this exercise:

- Learn how to use SalsaJ to measure the brightnesses of stars in telescope data
- Plot the data in Excel and study their plot
- Investigate the lifecycle of stars

Define questions from current knowledge

During your discussion with your students make sure that you ask them some of the following questions. This will both engage them further and check how much background knowledge they have on the subject.

- a) How do stars form?
- b) Where do stars live?
- c) How long do stars live for? What determines this?
- d) Are there different types of stars?



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- e) How do we classify stars?
- f) Why are stars important to us?

Phase 2: Active investigation

Propose preliminary explanations or hypotheses

In the early 20th century, after investigating the effects of an object's temperature and of the colour of its radiation, scientists reasoned that there should be a relationship between the temperature of a star and its luminosity. If all stars were alike, those with the same luminosity would have equal temperature and hotter stars would be brighter than cooler ones.

In 1911, Ejnar Hertzsprung (Denmark), plotted a graph of star's magnitudes against their colour. Independently in 1913, Henry Russell (USA), constructed a plot of star's magnitudes against their spectral class, confirming that indeed, there did seem to be some sort of relationship between a star's luminosity and its temperature, and the stars fell into distinct groups. Such a plot was thereafter named the Hertzsprung-Russell (or H-R) diagram.

A star on a HR diagram is represented by a dot. Since a large number of stars are usually represented on a HR diagram, there are a large number of dots on the diagram. The y axis on a HR diagram represents the star's luminosity (brightness) and the x axis represents the temperature of the star (with high temperatures plotted to the left, for historical reasons).

In order to plot a HR diagram, the temperature and luminosity of the stars need to be known. The simplest indication of a star's temperature is its colour. A star's colour is simply a measure of the amount of light from the star in one filter compared to another. The most common colour system is B-V, which is simply an object's magnitude as measured through the B (blue) filter, minus its magnitude as measured through the V (visible) filter.

The luminosity of a star can be determined from its magnitude and distance. However, if you do not know the distance to the star then you cannot find the luminosity. To overcome this problem, astronomers commonly use a colour-magnitude diagram, which is effectively a simple form of the HR diagram.

Students will put themselves in the position of a scientist, and produce and analyze the colour-magnitude diagrams of selected open clusters of stars. Their project includes two main tasks:

- 1) They will initially use archive data to analyse the well-studied open cluster NGC957 and produce a colour-magnitude diagram
- 2) They will then either (a) search the data archives for additional suitable open cluster images, or (b) use a robotic telescope to observe a star cluster of their choice, then analyse the data and produce a colour-magnitude diagram for this cluster



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Show your students pictures of different star clusters and ask them whether they can tell which stars are younger/older, nearer/further away, hotter/colder. Ask them if they can come up with an idea on what they could measure from the pictures to determine any of the properties above. Make sure that the students keep notes of their ideas.

After the students have discussed their ideas, mention the H-R diagram and ask them whether they are acquainted with it. Discuss the HR diagram with them and compare it with their suggestions on how they could measure the properties of the stars in a cluster.

Plan and conduct simple investigation

In order to prepare for the exercise, ask your students to study the 'Background Information' and 'Photometry of Star Clusters With SalsaJ' documents which are available here

http://faulkes-telescope.com/files/faulkes-telescope.com/archive/photometry/Lifecycle_stars/LCS_Bkgrd_Info.pdf

http://faulkes-telescope.com/files/faulkes-telescope.com/archive/photometry/Lifecycle_stars/photometry_salsaj_SR_points_feb10.pdf

These pdf files can also be accessed from the FT clusters weblink at the end of this paragraph. You may divide your class into working groups. Inform your students about the two main tasks of this exercise. In the first part, students will be directed to the area of the Faulkes Telescope website containing the telescope data files for NGC957.

<http://resources.faulkes-telescope.com/course/view.php?id=81>

Divided into groups, students will analyse the data using the information given in the documents listed above and the SalsaJ software package, and produce a colour-magnitude diagram.

In the second part, students will choose one of the open clusters listed and either download archival data or make an observation using a robotic telescope from the Faulkes Telescope website. After they retrieve their observation they will conduct photometry on the data and produce a colour-magnitude diagram.

The steps below outline what the students will need to know to achieve the two tasks above:

1. Teach the students how to use the SalsaJ software package, or let them discover how it works by reading through the instruction documents and 'playing' with simple data files.
2. Train the students to carry out photometry on the NGC957 data files – a step-by-step document to explain this process can be found on the Faulkes Telescope website. Then either :
 - 3a. Teach the students how to access astronomical data from online archives,



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or,

3b. Teach the students how to use a robotic telescope – a simulator of the Faulkes robotic telescopes can be found here:

<http://lcogt.net/files/flash/rti-demo/index.html>

Phase 3: Creation

Gather evidence from observation

For the first task of analysing and producing a colour-magnitude diagram of NGC957, the steps below should be undertaken:

Students work in pairs on PCs. They will use the software package SalsaJ to analyse real telescope data of NGC957

All material for the measurement, including the data files for NGC 957 and spreadsheet for results can be found in here

<http://resources.faulkes-telescope.com/course/view.php?id=81>

Further data from the Faulkes Telescope archive is available here

<http://lcogt.net/observations/search>

If you are planning on accessing the data archive, the three clusters below are recommended:

1. **NAME:** Berkeley27

COORDINATES OF CLUSTER (RA; DEC): 06:51:18; +05:46:00

FILTERS: Bessel B and Bessel V

EXPOSURE TIME: 30s B and 30s V

2. **NAME:** NGC7510

COORDINATES OF CLUSTER (RA; DEC): 23:11:00; +60:34:00

FILTERS: Bessel B and Bessel V

EXPOSURE TIME: 10s B and 10s V



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3. **NAME:** Berkeley 100

COORDINATES OF CLUSTER (RA; DEC): 23:26:36; +63:45:00

FILTERS: Bessel B and Bessel V

EXPOSURE TIME: 60s B and 60s V

Searches on names such as Berkeley 27 may provide different results depending on whether the observer types 'Berkeley 27' with a space or 'Berkeley27' without a space. Other users may misspell an object's name or call it 'Daves object'. For this reason, it is sometimes easier to search for an object using its RA and dec in the form as shown in the co-ordinates field.

If you are using a robotic telescope to obtain your own open cluster images, in addition to the aforementioned clusters, the two clusters below are also recommended:

1. **NAME:** Berkeley 85

COORDINATES OF CLUSTER (RA; DEC): 20:18:51; +37:43:00

FILTERS: Bessel B and Bessel V

EXPOSURE TIME: 20s B and 20s V

2. **NAME:** Berkeley 90

COORDINATES OF CLUSTER (RA; DEC): 20:35:18; +46:48:00

FILTERS: Bessel B and Bessel V

EXPOSURE TIME: 10s B and 10s V

The best exposure times can depend on weather conditions and moon phase so the above should be taken as recommendations only. Increasing or decreasing the exposure time by a factor of ~ 2 can often produce better results.

The information above is suitable for making observations using the robotic telescopes of the Faulkes Telescopes Project via the Faulkes Telescope website. The Faulkes Telescopes are free to use for all UK based schools, however all data and resources mentioned in this document are freely available worldwide without requiring a password.



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Phase 4: Discussion

Explanation based on evidence / Consider other explanations

Ask students to answer the following questions in their pairs/teams. Students will find the 'Background Information' document of particular use here.

1. How do your colour-magnitude diagrams look compared with other's in the class?
2. Are the various regions of the lifecycle of a star, apparent in your colour-magnitude diagram (e.g. main sequence, red giant branch, white dwarf stars etc.)?
3. Are there any stars which seem to stand out in your diagram? Are they redder/bluer than the others?
4. What could be the possible cause of these stars standing out in your plots (e.g. a mistake in the measurement/plot, or a real difference from the other stars)?
5. Based on your colour-magnitude diagram, do you think you have obtained data for a fair sample of stars in the open cluster, or do you have a lot of contamination from stars outside the cluster?



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Phase 5: Reflection

Communicate explanation

Make an overview of what has been discussed in the classroom during the exercise. You may focus on the following issues:

- a) Did you face any difficulties when analysing the data? How did you deal with them?
- b) How does your analysis differ from the way astronomers analyse open cluster data?
- c) How does your colour-magnitude diagram differ from the Hertzsprung-Russell diagrams shown in textbooks?
- d) How do you think the colour-magnitude diagrams of globular clusters would appear? Would it differ to that of an open cluster, or generally look similar?
- e) Can you think of any difficulties you might find if you were carrying out photometry on globular clusters?

Ask your students to present the colour-magnitude diagrams they made and produce a report with the information about the measurements and the results/conclusions. The students should try and comment on the accuracy of the method they followed and make suggestions for further work which they could carry out based around their observations.

Participating roles:

In this scenario students are introduced to robotic telescopes, and start by talking about stars and what they know about them. After an introduction to the subject, they are acquainted with the Faulkes Telescope website to learn how they can use robotic telescopes, and how to analyse data with the SalsaJ software package. They then use archive telescope data of NGC957 to produce a colour-magnitude diagram, and finally either choose archival open cluster data or make their own observations of a chosen cluster, to perform analysis on that object.

The teacher is a facilitator. He/she introduces students to the relevant concepts, directs them to the task by asking questions and shows them how to use Salsa J. Then he/she allows them to perform their own measurements, and discusses the results with them.



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Tools, services and resources:

The scenario requires the use of:

1. Computers with internet connection and the SalsaJ software package installed
2. The Faulkes Telescope website