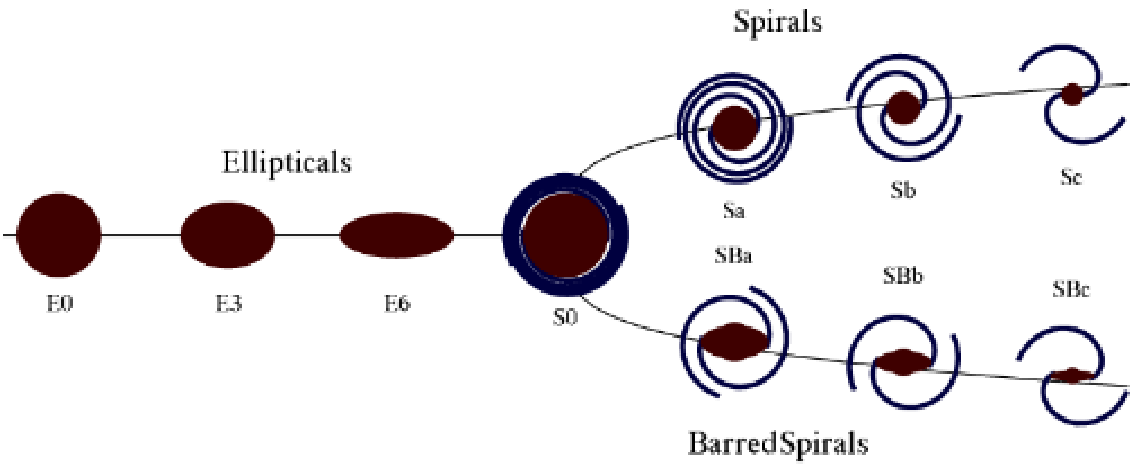
Report to Find the Luminosity and Colour of Galaxies and Plot them on a Colour-Magnitude Diagram

**Introduction and Background**

There are many different types of galaxy that can be identified by using a tuning fork. The types that will be mentioned in this report are elliptical, spiral and irregular.




Elliptical galaxies are named due to their stretched spherical appearance based on the two dimensions we can observe them from. They are classified by the letter 'E' followed by a number between 0 (S0 is also known as lenticular) and 8 that indicates the degree to which the galaxies are elongated.

The appearance of spiral galaxies resembles a disk shape with a bulge in the centre that generally consists of dust and young stars being pulled into a supermassive black hole. There may also be a bar present extending horizontally through the bulge to the inner edges of the spiral. Spiral galaxies are designated by the letter 'S' with letters 'a', 'b', 'c' or 'd' to denote the brightness of the spiral. 'SB' is used to address barred spiral galaxies and uses an identical system to represent spiral intensity.

Irregular galaxies fall under no known category and generally have no distinct structure. They are categorised based on their surroundings and what types of stars are present. Ir I galaxies are primarily composed of young stars with high surface temperatures and are amongst regions of hydrogen gas. Not as much is known about Ir II galaxies are their distinguishing feature is that they are surrounded by large amounts of dust, obscuring our view of most of the stars present. [1]

Galaxy Colour-Magnitude Diagrams (GCMDs) are graphs to show the magnitude of one colour filter of an image subtracted from the magnitude of another colour filter against the absolute magnitude of images from one filter (we used the Sloan r' filter as the r-band has a lower light-mass ratio than the g-band so there is less variation). GCMDs are useful for spotting trends in large quantities of galaxies and are generally used to identify the size and age of a galaxy by comparing their relative colours. The first description of the diagram was made by Eric F. Bell. [2] The diagram is bimodal, with a red sequence group and a blue cloud group.

In this report, we will be creating our own GCMD using pictures with Sloan g' and r' filters of 32 galaxies as well as a multitude of other graphs in the hope of identifying trends within the given galaxies and what they show.

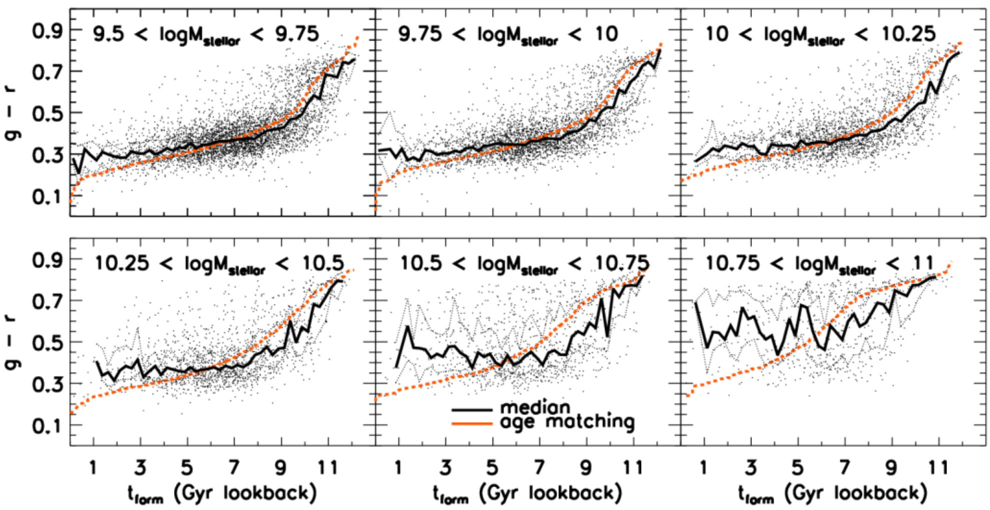
**Target and Dataset** [3]

Our target was to use the data given to us to produce a colour-magnitude diagram of the sample of galaxies. A Galaxy Colour-Magnitude diagram shows the apparent magnitude on the x-axis, and the colour of the galaxy on the y-axis, and can be used to identify trends in the relative colours of different types of galaxies. We were given a spreadsheet with the distances to each galaxy, and also two pictures from the Liverpool telescope of each galaxy, one with a Sloan r' filter and one with a Sloan g' filter. We used these, by processes described in the methods section below, to get information about apparent and absolute magnitudes and the luminosity of the galaxies.

We aimed to classify the galaxies by eye, using a Hubble Tuning Fork diagram, and then identify any trends in the types of galaxies, their colour and their luminosity, and the location of these on the colour-magnitude diagram, then use this to explain their features.

We expected to see that the younger spiral galaxies are bluer than the older spirals and the elliptical galaxies (which should be redder). We also expect the red galaxies to be brighter than the blue galaxies because the red ones tend to be older, so they have accreted more stellar mass so they are bigger than the bluer galaxies.

We expected to see this as it would be consistent with the results of the study by Aaron D. Bray and his colleges on the paper "Modeling Galactic Conformity with the Color–Halo Age Relation in the Illustris Simulation." In the paper we were able to find a diagram that illustrated what it was we should be seeing in our results. (The below has been lifted from the aforementioned paper)

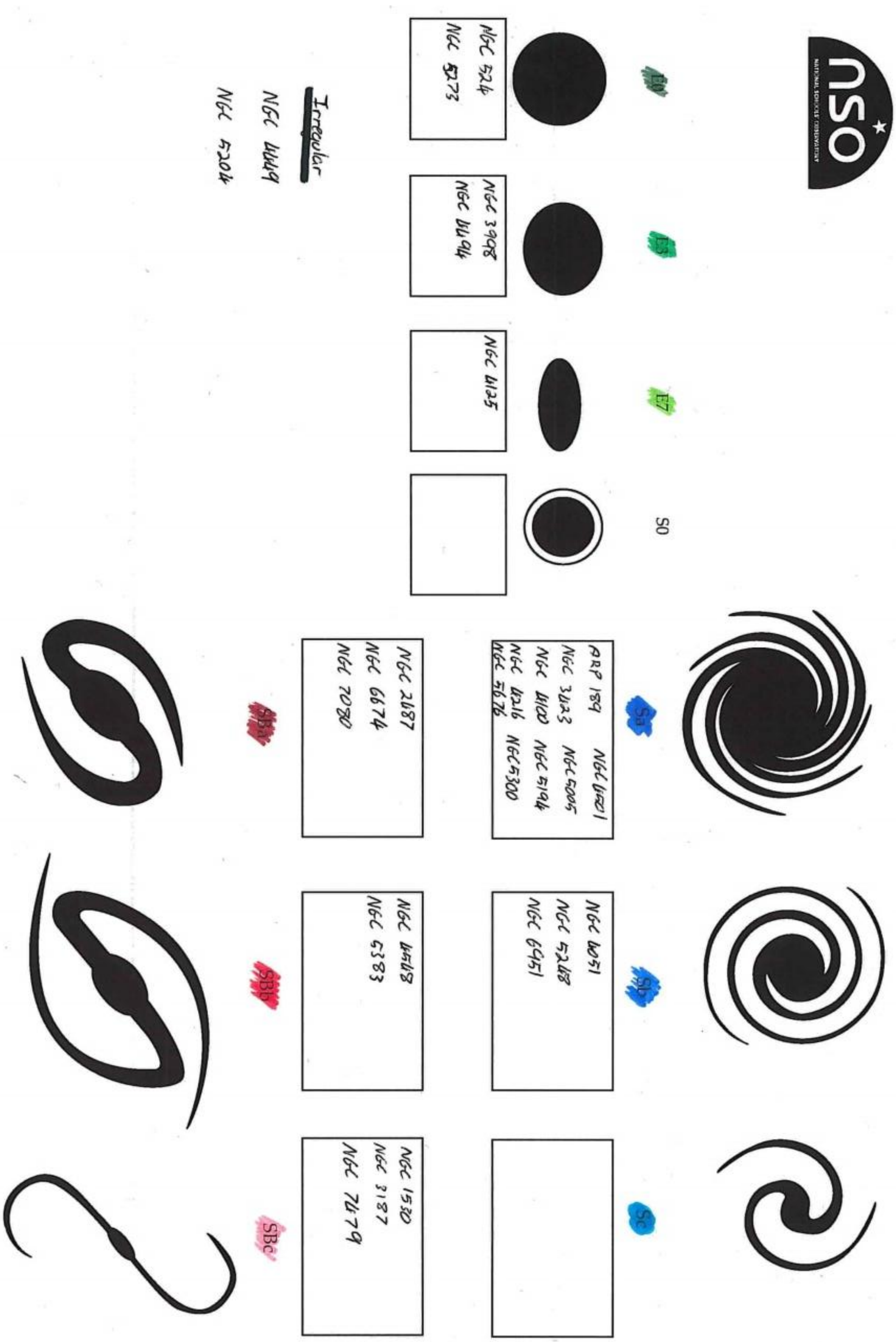



The image shows simulations run by the teams of groups of galaxies classed by weight. It presents a clear correlation between the age of the galaxy in giga-years and its colour (the older being redder).

**Method of Analysis**

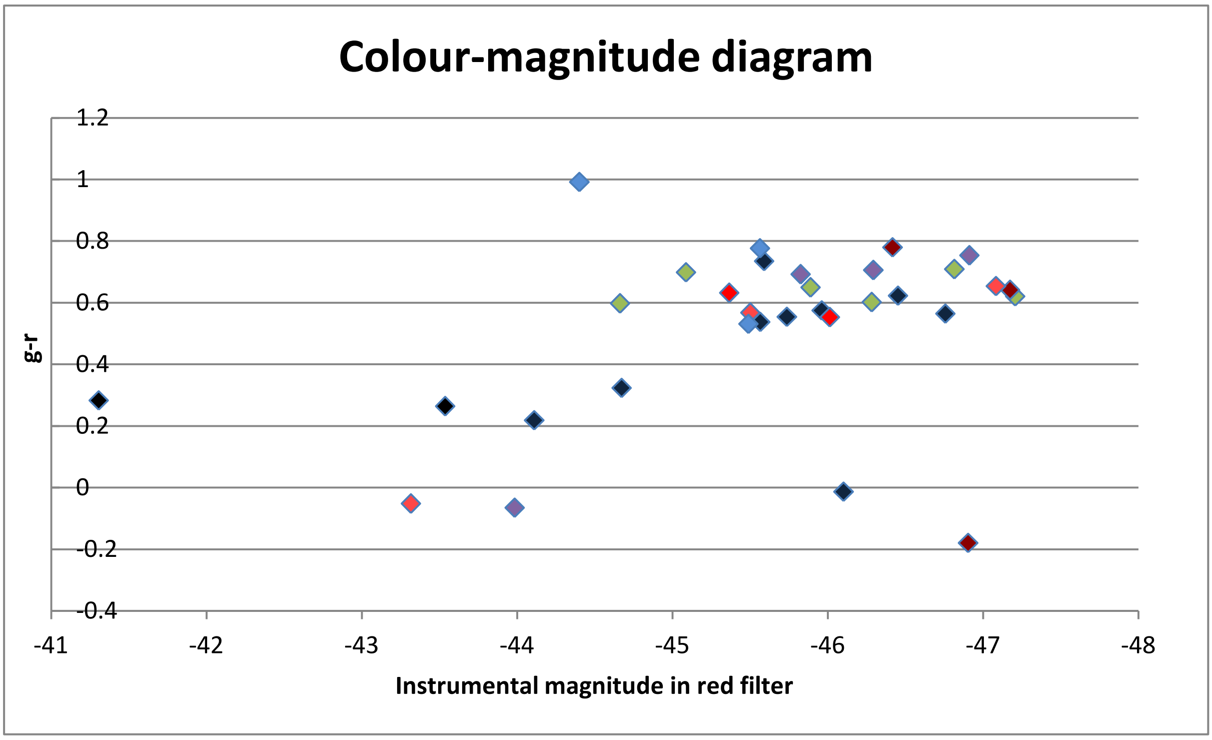
To get the data from the images provided by the Liverpool Telescope we used LTImage to find the apparent and absolute magnitude of both the red and green images of each galaxy. To do this, we first adjusted the scaling to be able to see the galaxy more clearly, then we used the brightness measurement tool under the astro tab to measure the counts of photons received by the telescope of the image. We then found the counts per second by dividing the counts by the exposure time. For each filter we applied the equation "$M_{app}$ = -2.5 x $Log_{10}$(counts/sec)" to give the apparent magnitudes. We then used the distances to each galaxy that we had been given, and the equation "$M_{abs} = M_{app} + 5 - (5 \times Log_{10}(d))$" where "d = distance to galaxy" to find the absolute magnitude of the galaxy in each image.

We created a scatter graph of our results to show trends in the data. To create the y-axis for the colour-magnitude graph we subtracted the values of the red absolute magnitudes from the green absolute magnitudes. The x-axis was created by plotting the absolute magnitude of the Sloan r' filter for each galaxy. It did not matter which filter we used to plot the x-axis because it would show the same distribution either way.




The Hubble Tuning Fork of our classified galaxies

This is the galaxy colour-magnitude diagram we obtained from our calculations.



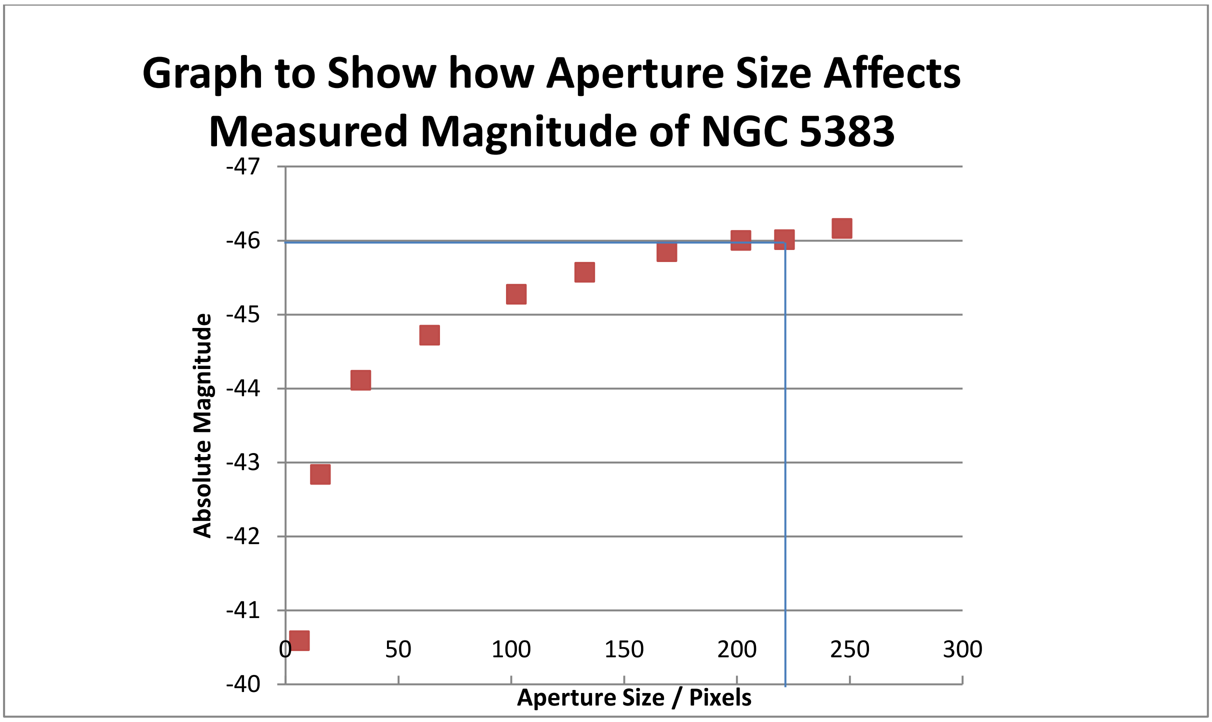

**Key:**

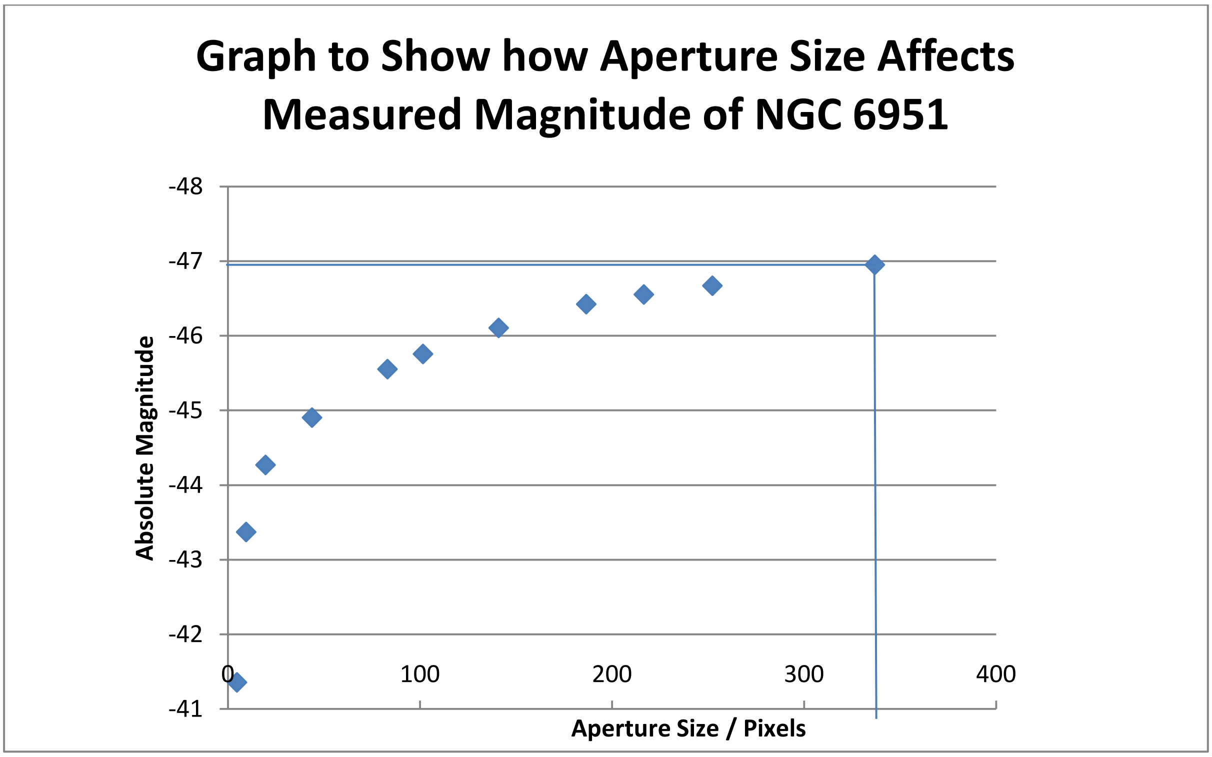
| | |
|---|---|
| Irregular | Black |
| Sa | Dark blue |
| Sb | Medium blue |
| Sc | Light blue |
| SBa | Dark red |
| SBb | Medium red |
| SBc | Light red |
| Elliptical | Green |
| unknown | Purple |

**Results**

We found that, in general, the red galaxies were brighter than the blue galaxies, with lower absolute magnitudes. The irregular galaxies, which are represented by black data points, did not follow the trend of the rest of the galaxies, being dimmer (examples of such galaxies are NGC 4449 and NGC 5204). Galaxies NGC 7080 and ARP 189 are brighter than the other blue galaxies. When we colour-coded the types of galaxies after classifying them, there was a clear trend that all of the elliptical galaxies in our data set were red, and were brighter galaxies. Of the spiral galaxies, the Sa galaxies were bluer, and the Sb galaxies were redder. None of the given images appeared to be Sc galaxies. There was no pattern in the spiral bar galaxies.

We also created four graphs to demonstrate how aperture size and brightness affected absolute magnitude to ensure that we used the correct aperture size when gathering the data. To show this, we drew lines from each of the original measurements to both of the axis. The graphs were expected to portray a decreasing curve that eventually flattens out.




The graphs above compared aperture size with absolute magnitude for NGC 5383 and NGC 6951 respectively

**Conclusion**

From our results, we can conclude that the red galaxies are brighter than the blue galaxies, which we think is because they have more stellar mass, as they are older. This is supported by the result that the elliptical galaxies are redder, because it is thought that elliptical galaxies are older since they are no longer forming stars and have no interstellar mass. [4]

The graphs for aperture size against absolute magnitude and brightness against absolute magnitude turned out as we expected with each of the original points following the predicted trend as well as the newly calculated ones. This ultimately shows that our original aperture constructions on LTImage were correct.

Some factors that affected our project were out of our hands so we were not able to alter them. An example of which is that that we were unable to capture the images from the Liverpool Telescope at the same time and under the same conditions. This may have affected the quality of the images we used as the relative magnitude would be impacted.

If we were to do this research task again, we would take multiple readings for the apertures so we would be able to calculate an average size for each image under each filter. For this task we merely estimated the area of pixels that the galaxy takes up. Therefore, we would also create an aperture/absolute magnitude graph for each image in order to enable us to select the optimal area of aperture.

Our diagram was not clearly bimodal, because we only used 32 galaxies, whereas to get a clear pattern thousands of galaxies are needed. It would have been ideal to be able to use more galaxies to get a wider range of data.

**References**


1. http://www.astro.cornell.edu/academics/courses/astro201/galaxies/types.htm
2. *Nearly 5000 Distant Early-Type Galaxies in COMBO-17: A Red Sequence and Its Evolution since z=1*, The Astrophysical Journal, 608:752–767, 2004 June 20.
3. http://arxiv.org/pdf/1508.05393v2.pdf?
4. https://www.cfa.harvard.edu/~ejchaisson/cosmic_evolution/docs/fr_1/fr_1_gal1.html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