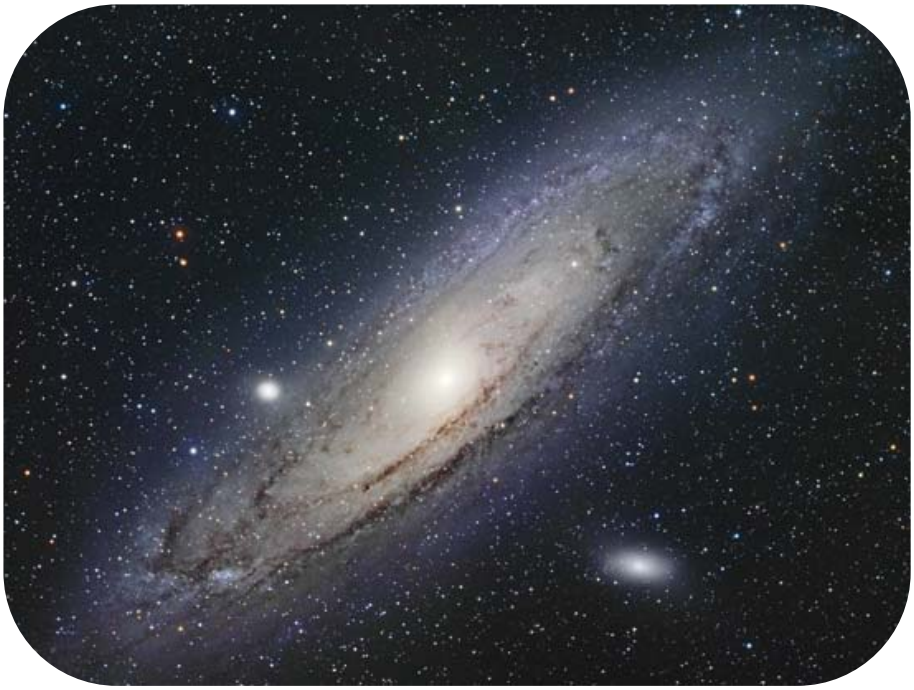
The Secrets of Galaxies

Student's Guide – Basic Level

CESAR's Science Case



Introduction

Galaxies are fundamental building blocks of the Universe. Some are simple, while others are very complex in structure; some have enormous sizes and contain trillions of stars, while others are very small and contain only hundreds of thousands of stars; some are yellowish and other display a variety of colours, from red to blue.

In this activity, you will use *ESASky*, a portal for exploration and retrieval of space astronomical data, to study the properties of galaxies. You will get a list of galaxies and will have to classify them according to their shapes. Then, you will investigate if there is a relation between the shape of a galaxy and its colour.

After doing the activity, or if your teacher tells you so, you're highly encouraged to take a look at the CESAR Booklet and read the "Galaxies" chapter, as most of the concepts that you'll learn in this lab are extensively discussed there. You can also read the chapters "The Electromagnetic Spectrum" and "Stellar Evolution" for further information that will help you to better understand the ideas behind this activity.

Material

What will you need?

- This student's guide
- CESAR Booklet
- Computer with web browser and internet connection
- List of galaxies (.txt file)
- Paper and pen

Background

One century ago, astronomers believed that the whole Universe was comprised within the Milky Way. There was a big controversy in the 1910s and early 1920s over whether the so-called (at the time) 'spiral nebulae' (milky patches of light with a spiral shape that were seen scattered among the stars) were outside the Milky Way or were part of it. Until work by Edwin Hubble (1889-1953) and Milton Humason (1891-1972) in the 1920s established that each of the spiral nebulae was a huge star system, called a *galaxy*. They were able to measure the distance to some of these galaxies, proving that the Universe was much vast than previously thought, and that our Galaxy is just one of billions of galaxies in the Universe.

Since then, astronomers have learned a lot about galaxies: how many they are, what types of galaxies exist, and the stars that they contain. They have also started to figure out how galaxies formed and how they evolve. And all this thanks to the light coming from those galaxies, emitted by the thousands to trillions of stars within them.

Activity Execution

To begin the activity, load *ESASky* in your browser by entering:

http://sky.esa.int

If you had not worked with it before, take a few minutes to get familiar with the tool. You may find the *Beginners' Guide* provided with the activity material very useful for that.

Upload the galaxy list you have been given by clicking on the *Upload target list* button on the left menu. The list of objects will be displayed as shown in Figure 1. You can move to any object in the list by clicking on its name. Below the list, some text will appear with a brief description of the selected object (see below for a transcription of this file), and the application will automatically load the image of it.

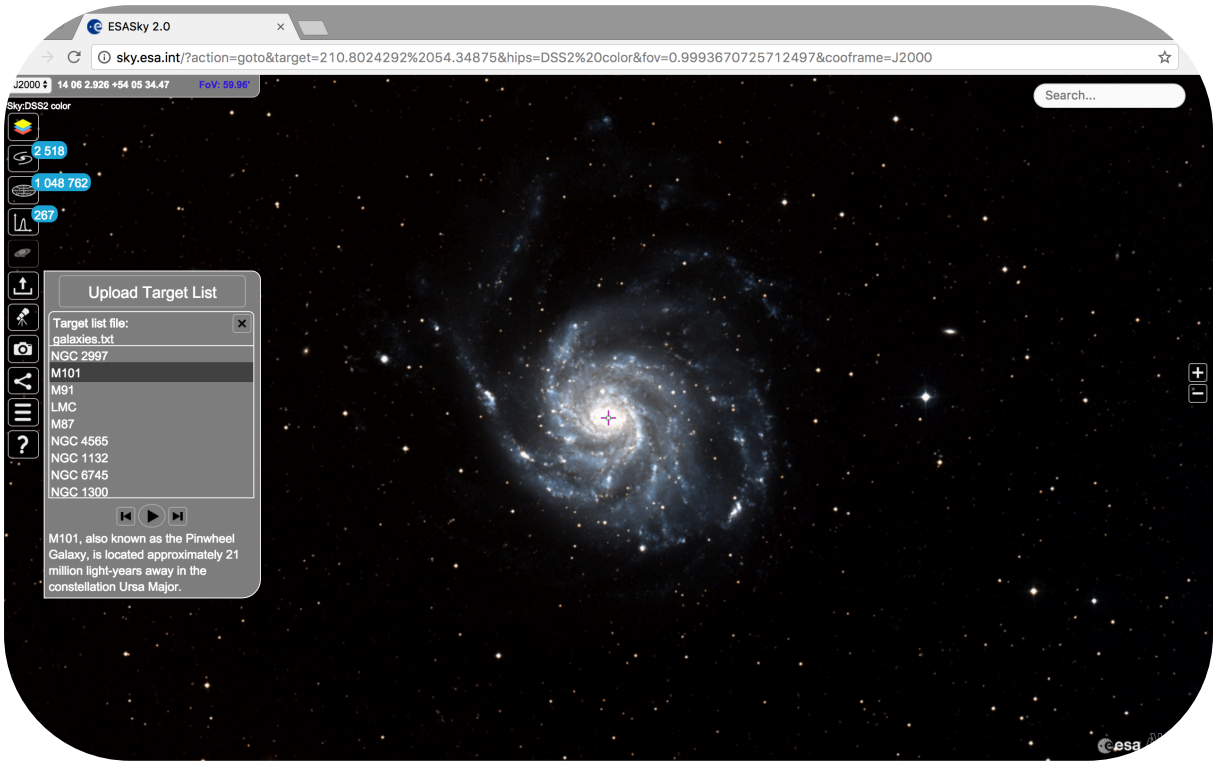


Figure 1: *The ESASky interface with its Target List functionality. A list of galaxies is loaded, and a description of the displayed object (which is highlighted) appears below the list. (Credit: ESA/ESDC)*

Transcription of the .txt file

- ***NGC 2997****: NGC 2997 is located approximately 25 million light-years away, in the constellation Antlia.*
- ***M101****: M101, also known as the Pinwheel Galaxy, is a spiral galaxy approximately 21 million light-years away in the constellation Ursa Major.*
- ***M91****: M91 lies approximately 63 million light-years away in the Coma Berenices constellation. It is part of the Virgo Cluster of galaxies.*
- ***Large Magellanic Cloud (LMC)****: The Large Magellanic Cloud (LMC) is the largest satellite galaxy of the Milky Way, and the fourth largest galaxy in the Local Group. At a distance of about 163,000 light-years, the LMC is the third-closest galaxy to the Milky Way, after the Sagittarius Dwarf and the putative Canis Major Dwarf Galaxy.*
- ***M87:*** *M87, located near the center of the Virgo Cluster, is one of the most massive galaxies in the Local Universe.*
- ***IC 5152:*** *IC 5152 is a dwarf galaxy in the Local Group, the group of galaxies our Milky Way belongs to.*
- ***NGC 1132:*** *NGC 1132 is located approximately 320 light-years away, in the constellation Eridanus.*
- ***NGC 1073:*** *NGC 1073 is about 55 million light years from Earth. and about 80,000 light years across. This galaxy is found in the Cetus constellation, also called the Sea Monster.*
- ***NGC 1300:*** *NGC 1300 is located approximately 61 million light-years away, in the constellation Eridanus. The galaxy is about 110,000 light-years across (about 2/3 the size of the Milky Way). It is a member of the Eridanus Cluster, a cluster of 200 galaxies.*
- ***M60:*** *M60, also known as NGC 4649, is located approximately 55 million light-years away in the constellation Virgo. Together with NGC 4647, it is part of a pair of galaxies known as Arp 116.*
- ***NGC 4449:*** *NGC 4449 is a galaxy in the constellation Canes Venatici. It is located about 12 million light-years away, part of the M94 Group (the Canes Venatici I Group), a galaxy group relatively close to the Local Group containing the Milky Way.*
- ***M31:*** *The Andromeda Galaxy, M31, is located about 2.5 million light-years (780 kiloparsecs) away in the constellation Andromeda. Being approximately 220,000 light years across, it is the largest galaxy of the Local Group, which includes the Milky Way, the Triangulum Galaxy and about 44 other smaller galaxies.*

Step 1: Your own classification of galaxies

Browse through the different galaxies, paying attention to shapes and colours. They look very different from one another!

Your first task will be to inspect all the galaxies from the list in the initial optical map (DSS-2 color), and to provide a classification for them based on their shapes and colours (you may need to play with the zoom levels to see the details). Group the galaxies that have something in common. How

many different types can you recognise? Give a name to each of the types, explain their properties, and list the galaxies that belong to that type in a table like the one below:

Galaxy type	Properties	Galaxies belonging to this type

Compare your classification with those of other groups. Do you agree in your grouping? Which are the differences between their classifications and yours?

Step 2: Hubble's classification

In 1926, Edwin Hubble proposed a classification scheme based entirely on the visual appearance of a galaxy on a photographic plate. His system has three basic categories: elliptical, spiral, and irregular galaxies. The elliptical and spiral galaxies are subdivided further, as illustrated in the diagram in Figure 2. This diagram is known as the 'Hubble Tuning Fork'.

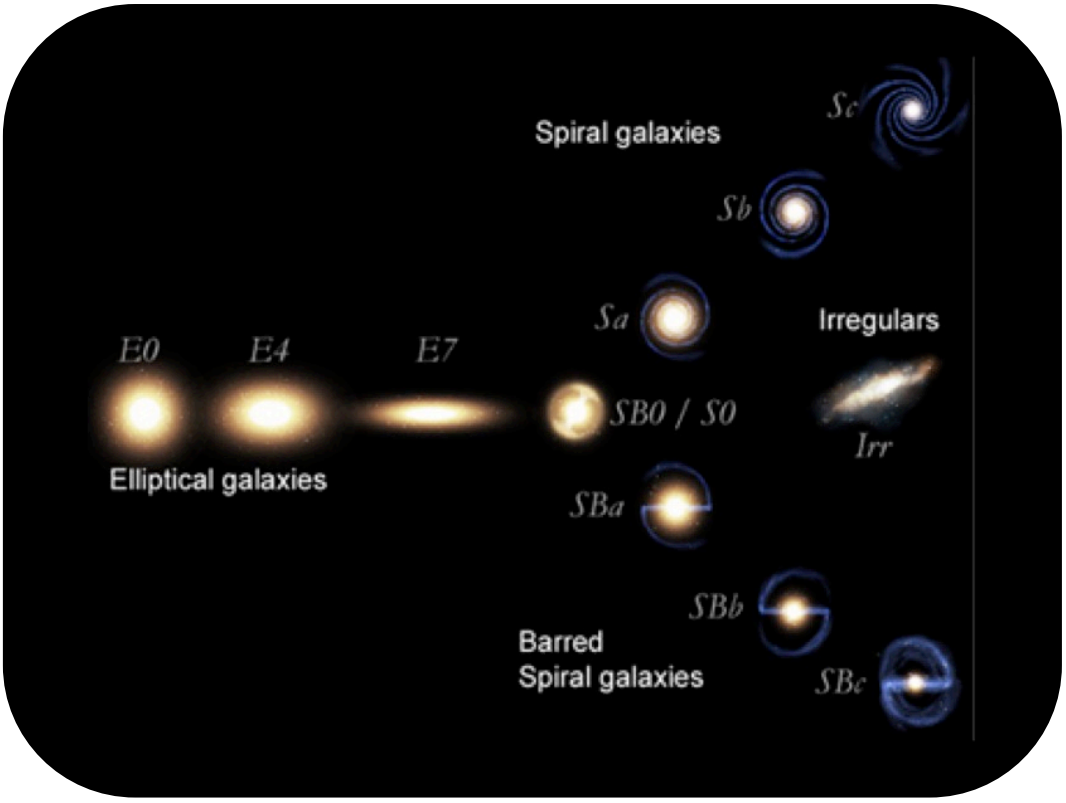


Figure 2: *The Hubble Tuning Fork. (Credit: NASA/ESA)*

Study Figure 2 and compare Hubble's classification with your own. What are the properties of the different types of galaxies according to Hubble? What are the differences with your own classification?

Once you are familiar with the Hubble Tuning Fork, use it to classify the galaxies in your list as Hubble himself would have done. Summarise your investigation in a table like this:

Hubble type	Properties	Galaxies belonging to this type
Spirals		
Barred spirals		
Ellipticals		
Irregulars		

Sometimes the type of galaxy will be very evident, but others it will be less clear, and it may happen that your classification does not agree with the classification from another group –this is like real science. To solve this type of discrepancies, astronomers make other observations to get more detailed views of the galaxy features, or to see how the galaxy looks like in wavelengths other than visible, so that they can learn more about the contents and shape of the galaxy.

After you have discussed your classification and compared it with the rest of the groups, your teacher will tell you the 'official' classification –that is, the type assigned to each galaxy by astronomers based on their current knowledge of the objects.

Step 3: The colours of galaxies

Now that you know the type of each galaxy, go through the gallery again and pay attention to the colours of the galaxies. Do you see some relation between the shape and the colour of a galaxy? Can you think of a reason for that? Your teacher will help you find the answer to this question.

Conclusions

In this activity, you have learned how astronomers classify galaxies. Now summarise your conclusions: How many different types of galaxies exist? What are the differences between them?