Student's guide

CESAR Science Case – Exploring the Interstellar Medium

Name _____ ***Date*** _____

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 other properties such as its colour or content in stars and gas. You will also get introduced to the topic of galaxy formation and evolution.

Theoretical background

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 Figure 1. This is known as the 'Hubble Tuning Fork'.

For a time, this scheme was thought to be an evolutionary sequence, with galaxies progressing from left to right across the diagram as they evolve from one type into another. We now know that this is not the case; galaxy evolution is much more complex than Hubble imagined, and it depends on the conditions at the galaxy's birth, collisions with other galaxies, and the ebb and flow of internal star birth.

Material

1. CESAR Booklet
2. CESAR List of Galaxies (.txt file)
3. Computer with Internet browser
4. Paper, pencil or pen

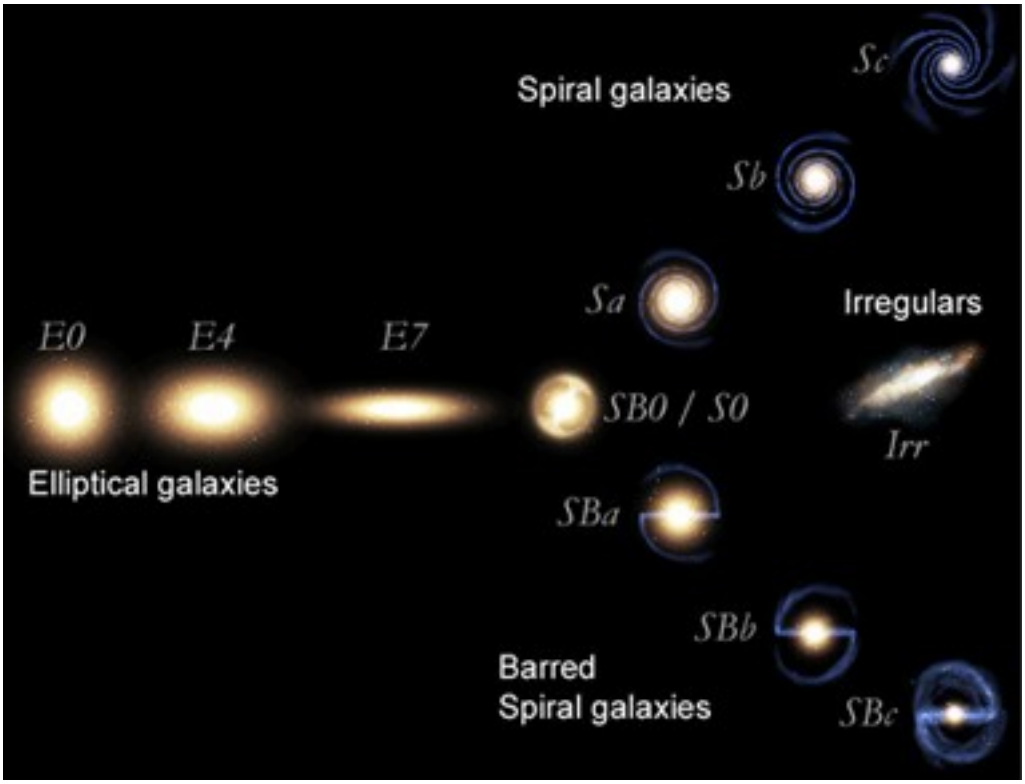

Figure 1: *The Hubble Tuning Fork.* ***Credit:*** *NASA/ESA*

Laboratory description and purpose

The main purpose of this laboratory is to get familiar with the main types of galaxies that exist (according to their shapes) and to investigate the relation between the shape of a galaxy and its content, as well as to get some very basic understanding of the way galaxies evolve.

Laboratory execution

Before starting the laboratory, you should have read the Booklet carefully and made sure you understand the main ideas.

Load *ESASky* in your browser. 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 laboratory material very useful for that.

Upload the galaxy list you have been given by clicking on the *Upload target list* button right below the *Skies* button. The list of objects will be displayed as shown in Figure 2. 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 displayed object (see next section for a transcription of this file).

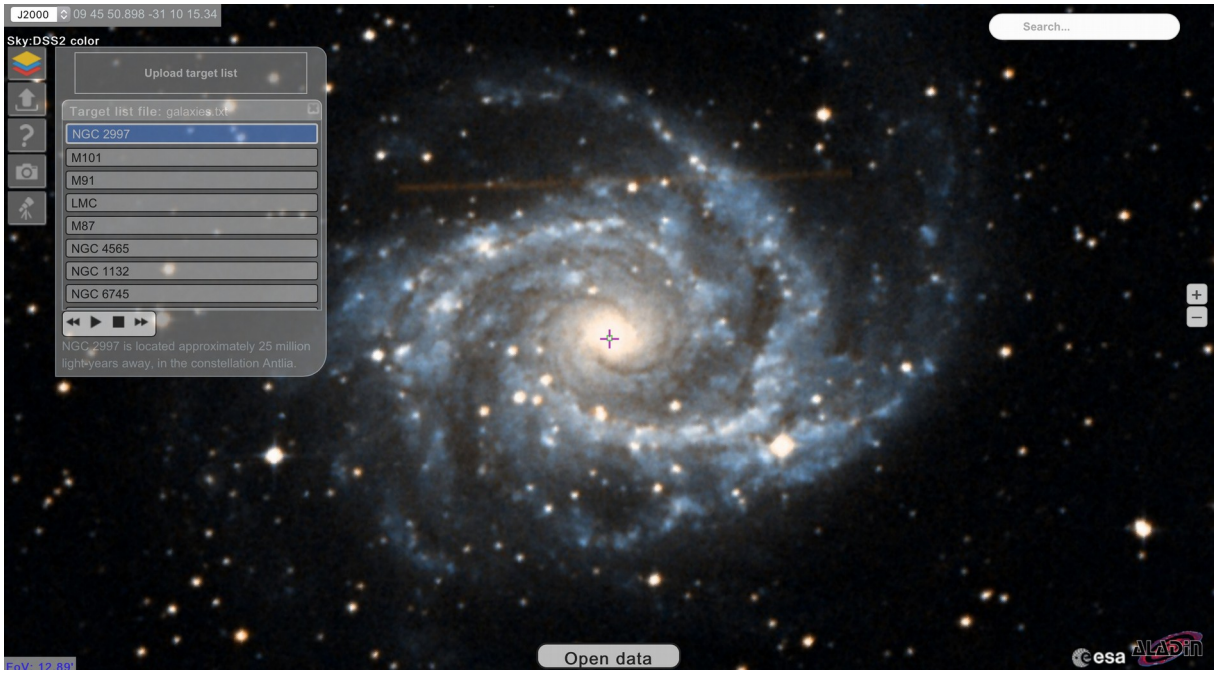

Figure 2: *The ESASky interface with its Target List functionality. A list of galaxies is loaded, and a description of the displayed object (which is highlighted) appears below the list.* ***Credit:*** *ESA/ESDC*

Your first task will be to visualise each galaxy from the list in the initial optical map (DSS-2 color), and to classify it according to the Hubble Tuning Fork (you may need to play with the zoom levels to see the details). Is it a spiral galaxy, a barred spiral, an elliptical or an irregular galaxy? 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.

Now that you know the type of each galaxy, go through the list again to answer the questions in the attached worksheet. Comparison with other wavelength ranges may be useful to confirm your hypotheses on the properties of the galaxies. You can create a stack of different maps to easily switch between ranges and compare the images.

The final questions in the worksheet refer to the way galaxies evolve and interact. You have to discuss if the Hubble Tuning Fork represents an evolutionary sequence for galaxies. Then, with a high-resolution image from NGC 6745, you will investigate what is happening in this galaxy.

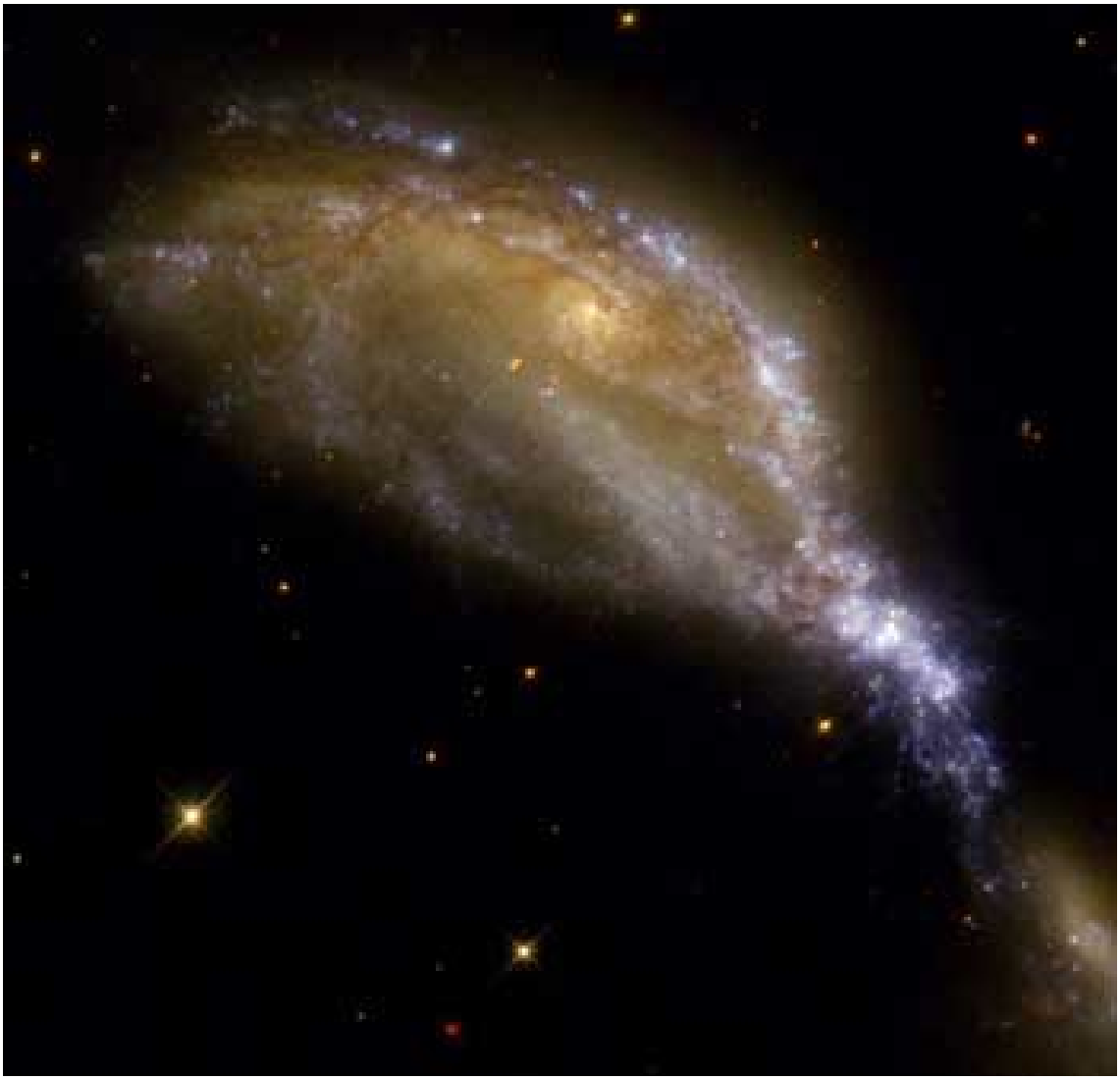

Figure 3: *A high-resolution image of galaxy NGC 6745 taken with the Hubble Space Telescope.*
Credit: *NASA/ESA*

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.*
- ***NGC 4565:** NGC 4565, also known as the Needle Galaxy for its narrow profile, is located about 30 to 50 million light-years away, in the constellation Coma Berenices.*
- ***NGC 1132:** NGC 1132 is located approximately 320 light-years away, in the constellation Eridanus.*
- ***NGC 6745:** NGC 6745 is a galaxy about 206 million light-years away in the constellation Lyra.*
- ***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.*

Exercises

1. *Classify the galaxies in the list according to the Hubble scheme:*

Hubble type	Galaxies
Spirals	
Barred spirals	
Ellipticals	
Irregulars	

2. *Do the colours of galaxies seem related to their shapes? Explain.*

3. *Look at the spiral galaxies. Why are the colours of the bulge and the colors of the spiral arms so different? Suggest an explanation. (Note that only the most luminous stars are observable at these large*

distances.)

4. *Compare the bulges of spiral galaxies to elliptical galaxies. In what sense are they similar?*

5. *Do you expect spiral galaxies to be rich in gas and dust? And elliptical galaxies? Where do you expect most of this dust to be located? How would you check?*

6. *Hubble thought that his tuning fork diagram displayed an evolutionary sequence for galaxies. According to his hypothesis, galaxies would initially have a spherical shape, and would flatten and develop their spiral arms with time, until they become very disrupted and irregular. Based on what you have been discussing, do you think that this hypothesis is plausible? Explain your answer.*

7. *Have a closer look at galaxy NGC 6745.*

   a. *What may be the cause of its peculiar shape?*

b. *Inspect the high-resolution image of this galaxy. Comment on the colours of NGC 6745. What are the blue patches? Why aren't any other parts of that galaxy so blue?*

c. *Provide a hypothesis that explains what is happening in this galaxy, taking into account its shape and colours.*