Student's guide

CESAR Science Case – Exploring the Interstellar Medium

Name ______________________________ ***Date*** ______________________

Introduction

Even though the space between the stars in our Galaxy is more devoid of matter than any vacuum created in a lab on Earth, there is matter in space. This so-called "interstellar medium" (ISM) mainly consists of gas and dust, sometimes forming big clouds, or "nebulae".

In this activity, you will use *ESASky*, a portal for exploration and retrieval of space astronomical data, to investigate the properties of the ISM. You will compare images of the same object in different wavelength ranges, or 'colours', to see how we can tell there is ISM present and how it affects our observations.

Theoretical background

About 99% of the ISM is gas, with about 90% of it in the form of hydrogen, 10% helium, and traces of other elements. At visible wavelengths, however, dust has a greater effect on the light than gas: Due to the size of dust particles (similar to blue wavelengths), they affect light in different ways:

- **Blocking visible light:** Visible light (in particular, blue light) gets easily absorbed by dust grains, because the size of these grains is approximately that of visible wavelengths. Sometimes the dust is so dense that visible light simply does not get through. We then see dark areas in the sky, where no stars are observed.
- **Interstellar reddening:** Blue light gets absorbed, scattered and reflected by dust grains, while red light gets through them. As a consequence, a star behind the dust will look redder than it really is.
- **Optical extinction:** Because part of the light from the star is scattered, it will also look dimmer than expected by just the effect of distance.

To directly observe the ISM, we have to use telescopes that are able to detect light at longer wavelengths than visible. The reason is that the ISM is so cold, that emits most of its light at these wavelengths. Dust, which is hotter than gas, is observed in the far-infrared (the part of the infrared whose wavelengths are closer to radio), while gas, which is extremely cold, is observed by radio telescopes.

There are however cases when we can observe the ISM in visible light: If a gas cloud contains young, hot stars, they can heat up the gas and make it glow red, creating what is known as an *emission nebula*. We can sometimes see the blue light scattered and reflected by a dust cloud; this is called a *reflection nebula*.

From the ground, we can only observe in visible light, near-infrared (the part of the infrared whose wavelengths are closer to the red colour), a small part of the mid-infrared, and part of the radio band of the spectrum. The Earth's atmosphere blocks the rest of light –luckily for us, because most of this radiation is dangerous to humans. This is one of the main reasons to place telescopes in space: to be able to observe astronomical objects across the full electromagnetic spectrum. The other main reason is to get images of better quality than from the ground, because the atmosphere also distorts the images.

Material

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

Laboratory description and purpose

The main purpose of this laboratory is to understand how astronomers study the ISM, and how it affects observations of other astronomical objects. You will compare images of the same objects taken with different telescopes and in different wavelength ranges (visible, near-infrared and far-infrared), discuss the differences between the images and look for evidences of the presence of ISM in them.

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.

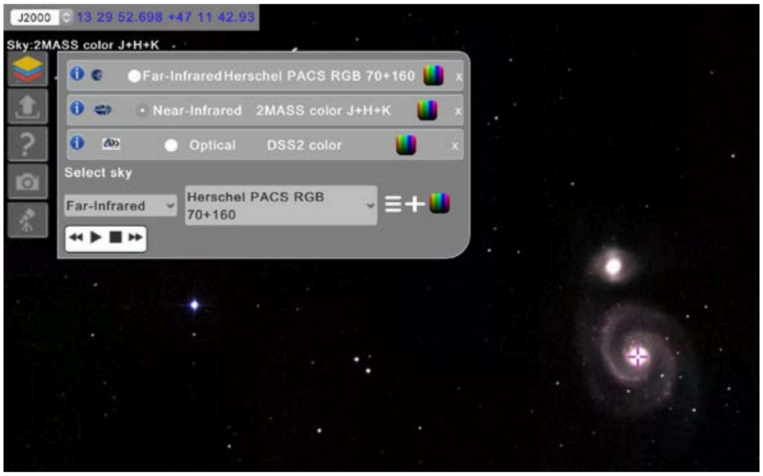

Figure 1: *The* ESASky *Skies menu, with a stack of several maps.* ***Credit:*** *ESA/ESDC*

Use the *Skies* menu to create a stack with the following sky maps: Optical – DSS2 color; Near-infrared – 2MASS color; Far-infrared – Herschel-PACS-RBG (see Figure 1). Each of these maps shows the sky as observed by a different telescope, in a different type of light. It is important to keep in mind that astronomical images do not display the real colours of the objects. In the case of the optical (visible light) images, colours approximately match what we would see with our own eyes (should we be close enough to the objects); but in those images taken with invisible light, the colours have been chosen in such a way that they best display the features of the objects. Also, the resolution (capability of separating two objects that are seen very close to each other) may differ greatly from one telescope to another; as a general rule, the resolution is best in the optical and gets worse as we move toward the two extremes of the spectrum (gamma rays and radio), but it also depends on the characteristics of the telescope and camera.

Upload the target 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 and some guidelines for discussion (see next section for a transcription of this file).

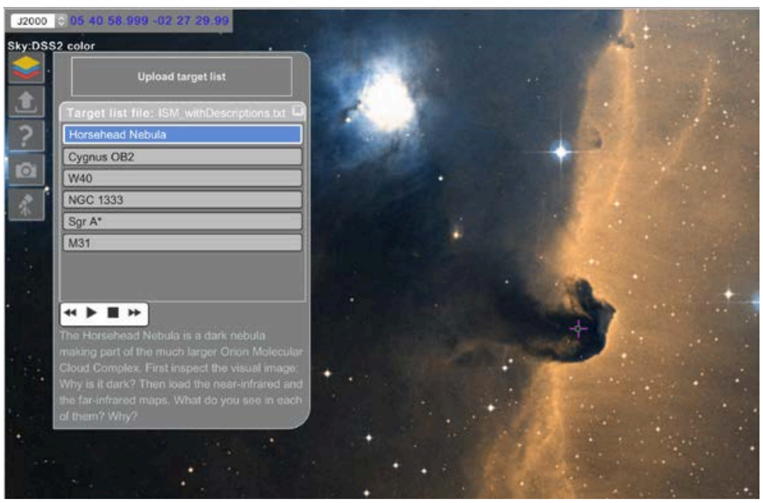

Figure 2:** The* ESASky *Target List functionality. A list of objects is loaded, and a description of the displayed object (which is highlighted) appears below the list.* ***Credit: *ESA/ESDC*

With the initial optical map ('DSS-2 color'), use the given guidelines to discuss with your partner the properties of the ISM as can be seen in the displayed sky region. (You may need to play with the zoom levels to see the full details.) Which evidences do you see for the presence of ISM?

Now explore how the region looks like in the near ('2MASS color') and far-infrared ('Herschel PACS RGB'), and compare these images with the optical image. What differences do you see? What may be the reasons for these differences? How is the presence of the ISM affecting the stars in the region? How are the stars affecting the ISM?

Go back to the optical map. Move to the next object by clicking on its name, or using the video-style buttons. Repeat the process with all objects. You can take snapshots to include in your final report by clicking on the *Snapshot* camera button.

Finally, summarise your conclusions: How can you tell the presence of ISM from an optical image? How can astronomers study the properties of the ISM itself? How are the ISM and the stars in a given region related?

Transcription of the .txt file

Horsehead Nebula

The Horsehead Nebula is a dark nebula making part of the much larger Orion Molecular Cloud Complex. First inspect the visual image: Why is it dark? Then load the near-infrared and the far-infrared maps. What do you see in each of them? Why?

Cygnus OB2

Cygnus OB2 is an association of young massive stars. Look at the visual image: Can you see any evidences of the presence of ISM here? How would check this?

W40

Check the optical image first. Do you see any evidences of the presence of ISM in this region? Now inspect it in the near-infrared. What is hidden within the dust?

NGC 1333

A mere 1,000 light-years distant, the NGC 1333 region lies on the edge of the large Perseus Molecular Cloud. How does this cloud look like in the optical and infrared? What type of stars do you see? How is the presence of these stars affecting the cloud?

Sgr A*

This is the region in the centre of our Galaxy (you will need to zoom out to a field of at least 12 degrees to fully appreciate it). How does this region look like in the optical? Make a guess: What do you expect to find if you observe it in the near and far-infrared?

M31

M31, the Andromeda Galaxy, is one of the nearest galaxies and the one of the largest member of the Local Group of galaxies, together with our own Galaxy, the Milky Way. Compare the observations of this galaxy in the optical and infrared. Do you think M31 is rich in gas and dust? Where is this ISM mostly located within the galaxy?