

Exploring the Interstellar Medium

Student's Guide – Intermediate Level

CESAR's Science Case



Introduction

Many people imagine outer space to be completely empty, but there is matter between the stars. Astronomers call this matter *the interstellar medium*, or ISM for short. It mainly consists of gas and dust, sometimes forming big clouds, or “nebulae”.

In this activity, you will use real telescope images to study all these properties of the Interstellar Medium. Your task will be to inspect several regions in the sky in order to identify the signs that tell us the presence of ISM. You will use *ESASky*, a portal for exploration and retrieval of space astronomical data, to compare images of the same object in different wavelength ranges, or ‘colours’, in order to figure out how we can tell there is ISM present and how it affects our observations.

Before you keep reading, **you’re highly encouraged to take a look at the CESAR Booklet and read “The Electromagnetic Spectrum” and “The Interstellar Medium”** chapters, as most of the concepts you’ll need to successfully complete your task are extensively discussed there.

Material

What will you need?

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

Background

The ISM is very cold and much less dense than any vacuum created in a lab. About 99% of it is gas, with about 90% of it in the form of hydrogen, 10% helium, and traces of other elements; the other 1% is in the form of dust grains, mostly made of iron, silicates, carbon and dirty ice.

There are two means for astronomers to study the ISM:

- By detecting and analysing the light directly emitted or reflected by the interstellar clouds.
- By studying the effect of the ISM in the light from stars within or behind it.

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 (with temperatures of about 100 K), is observed in the far-infrared (the part of the infrared whose wavelengths are closer to radio), while gas, which is extremely cold (with typical temperatures of about 10 K), 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*.



Figure 1: Types of nebulae: dark (Barnard 68), emission (Orion Nebula, centre) and reflection (Pleiades, right). (Credits: ESO/AAO/ROE)

In addition, we can see other effects of the ISM in optical images. Even if it makes a very small fraction of the ISM, at visible wavelengths 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 and scattering visible light:** Visible light (in particular, blue light) gets easily absorbed and scattered 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. Sometimes we see the blue light scattered and reflected by a dust cloud; this is called a *reflection nebula*.

- **Interstellar reddening:** Because blue light gets absorbed, scattered and reflected by dust grains, it is mostly red light what gets through them. As a consequence, a star placed behind a cloud of 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.

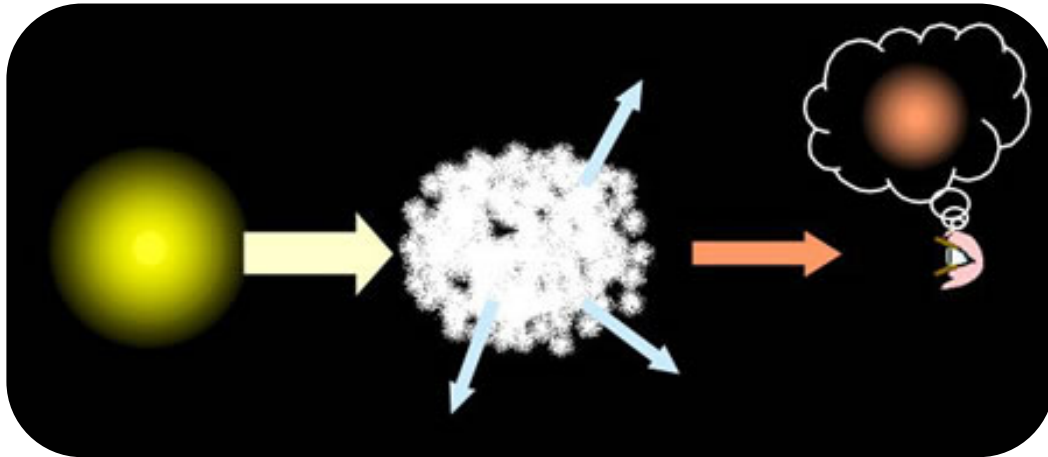


Figure 3: Effects of the ISM: A star behind it will look redder and fainter than it really is.
(Credit: COSMOS, the SAO Encyclopedia of Astronomy)

To unveil the stars hidden behind a cloud of dust, astronomers use near-infrared telescopes. Near-infrared light has longer wavelengths than visible light, and thus the dust grains no longer absorb it.

Activity Execution

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 laboratory material very useful for that.

Use the *Skies* menu to create a stack with the following sky maps: Optical – DSS2 color; Near-infrared – 2MASS color; Far-infrared – Herschel PACS RGB (see Figure 4). To do so, click on the colourful *Manage skies* button on the top left. Add several maps to the stack using the “+” button, and select the maps to be displayed from the drop-down menus. You can switch between maps manually or using the video-style buttons.

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.

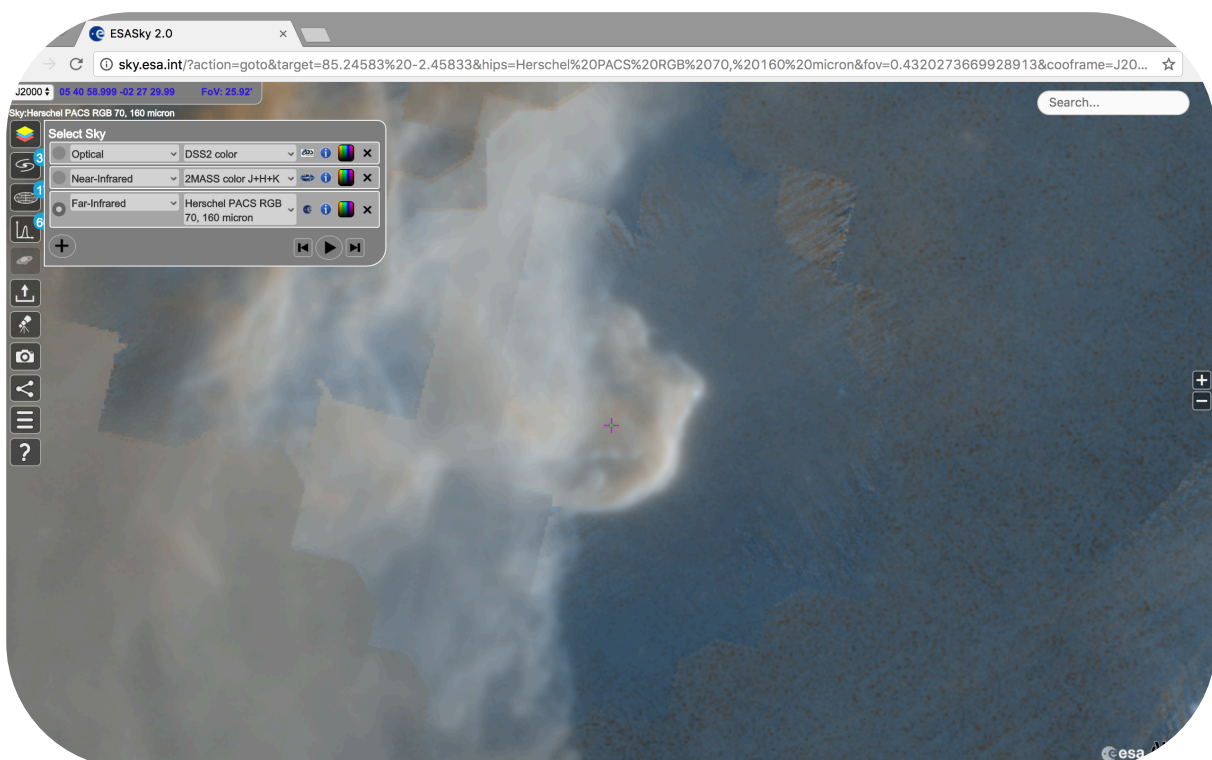


Figure 4: The ESASky Skies menu, with a stack of several maps. (Credit: ESA/ESDC)

Upload the target list you have been given by clicking on the *Upload target list* button. The list of objects will be displayed as shown in Figure 5. 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 below for a transcription of this file).

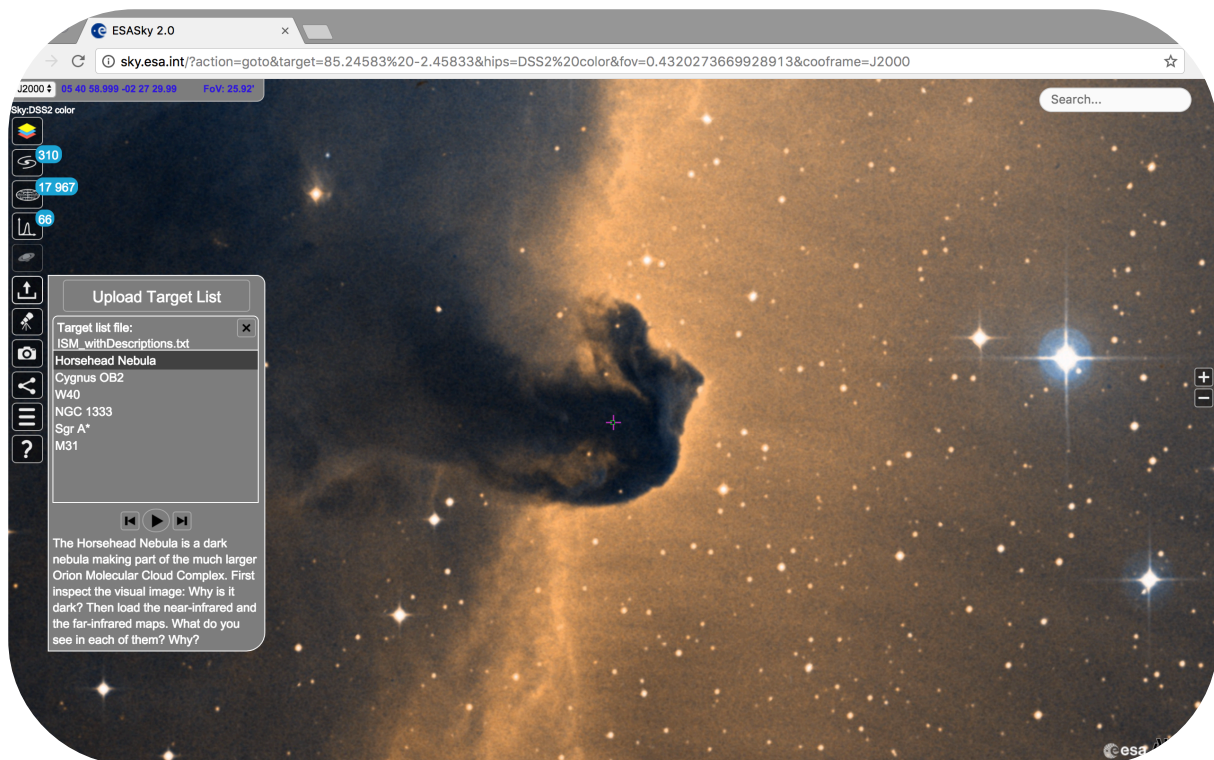


Figure 5: The ESASky Target List functionality. A list of objects is loaded, and a description of the displayed object (which is highlighted) appears below the list. (Credit: ESA/ESDC)

Now it is time to apply what you have learned about the Interstellar Medium.

Let's start by observing the ISM itself. You will investigate how the view of a region rich in ISM changes depending on the type of telescope (observing a different type of light). To do this, go to the first object in the list, the Horsehead Nebula, and browse through the sky maps in the stack to see how it looks like in the different images. Inspect the visual ("optical") image first: Why is it dark? Then have a look at the near-infrared and the far-infrared maps. What do you see in each of them? Can you explain the differences?

Similarly, inspect each region in the list in the different maps, going through the questions in the attached worksheet. Always start with the optical map, paying attention at the signs in that image that may hint that there is ISM in that region. How is the ISM affecting the way stars are observed? How are the stars affecting the ISM? Compare the near- and far-infrared images with the optical image. What differences do you see? What may be the reasons for these differences? Which image tells you more about the properties of the ISM itself, and why?

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. Are they different? Why? What do you see in each of them?
- **Cygnus OB2:** Cygnus OB2 is an association of young massive stars. Look at the visual image: How are the stars you see? Now switch to the near-infrared. What are the differences with the visible image? Can you see any evidences of the presence of ISM here? How would check this?
- **W40:** Compare this region of massive star formation with the previous region, Cygnus OB2. Check the optical image first. Do you see any evidences of the presence of ISM in W40? Now inspect it in the near-infrared. What is hidden within the dust?
- **M78:** Easily found in small telescopes as a hazy patch, M78 is the brightest of a group of nebulae belonging to the Orion Molecular Cloud Complex, about 1,600 light years distant from Earth. Comment on the optical colours of the cloud: What is causing them? How does this cloud look like in the infrared? What type of stars do you see? How is the presence of these stars affecting the cloud?
- **NGC 2174:** Also known as the Monkey Head Nebula, this cloud on the border between the constellations Gemini and Orion is located about 6,400 light years away from Earth. Inspect this region and the following ones trying to answer the same questions as in M78.
- **M17:** M17 has many names: The Omega Nebula, the Swan Nebula or the Horseshoe Nebula, among others. Its size and brightness make it one of the first nebulae to be discovered, which occurred in 1745.
- **NGC 1977:** The group of nebulae seen in this region (NGC 1977, NGC 1973, NGC 1975, M42 and M43) is sometimes collectively called the Running Man Nebula or the Ghost Nebula.
- **NGC 1333:** A mere 1,000 light-years distant, the NGC 1333 region lies on the edge of the large Perseus Molecular Cloud.
- **NGC 7635:** Also known as the Bubble Nebula, this cloud is seen toward the constellation Cassiopeia, and it is bright enough to be observed with a small telescope.
- **Sgr A*:** This is the region in the centre of our Galaxy. Until the central decades of the past century, this region was completely unknown to astronomers. To find out why, load the optical map, and zoom out until the field-of-view is about 12° (the size is indicated in the upper part of the screen). How does this region look like in the optical? Why was the Galactic Centre so difficult to observe? Make a guess: What do you expect to find if you observe it in the near and far-infrared?

Conclusions

In this activity, you have explored the properties of ISM and how it affects and is affected by nearby stars using images of different sky regions and in different wavelength ranges.

Now 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 is the ISM affecting the way stars are observed? How are the stars affecting the ISM?

If you want to learn more, you can now research about the relation between the ISM and the formation of stars.