

Scanning Across the Spectrum KEY

Overview: We're going to use some software developed by the European Space Agency (ESA) to view data of distant galaxies. We'll be able to switch between different wavelengths to see different parts of the galaxy light up. At first your goal will be to explore two galaxies using different kinds of wavelengths and take notes and photos of what you find. In the second half of the assignment, you'll be tasked to summarize your findings as you describe the two galaxies, and then compare and contrast what makes the galaxies different. Part of the goal today is to deliberately practice your writing skills, so expect to put in effort to write a couple paragraphs today.

Part 1: We are going to use software made by the ESA to view different galaxies using photographs from a variety of types of telescopes. We will focus on two Galaxies today: M 31 (young galaxy) and M 87 (old galaxy) to see how the galaxies have different shapes, but also because of their age difference they have different types of stars spread throughout them. **For each galaxy you will use a variety of types of light to investigate what stars make up the galaxy and record this using a screenshot and a description.**

1. Open up this link here: <https://sky.esa.int/esasky/>
2. Then click **EXPLORER**
3. Use the table below to help you make sense of what you see in the photographs.

Types of Light and Objects that Produce Them		
Type of Light	Temperature (K)	Typical Sources
Gamma Rays	$> 10^8$ K	Matter falling into Black Holes
X-rays	$10^8 - 10^6$ K	Supernovas
Ultraviolet	$10^6 - 10^4$ K	Very Hot (and young) Stars
Visible	10000 - 1000 K	Cool (medium to old) Stars
Infrared	200 - 1000 K	Cool Dust and Stars Forming
Microwaves	10 - 200 K	Cosmic Microwave Background
Radio	< 10 K	Extremely Cold Dust

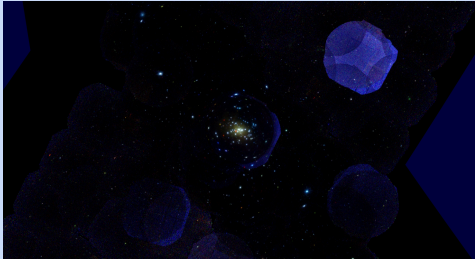
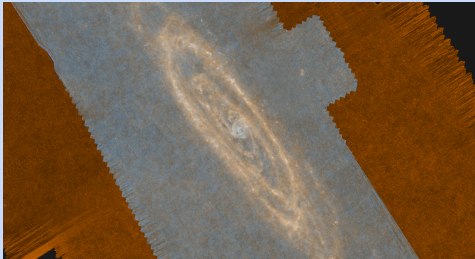
4. For Both galaxies use the software to view the galaxies using the following types of light. Switch between the types of light by clicking the icon in the top left corner which is three colored diamonds. Click the drop down menu on the left and select the light setting you are looking for.

Light Setting in Software	Part of EM Spectrum
Optical	Visible Light
Ultraviolet	Ultraviolet
Soft X-ray (M87 will need to zoom out)	X-rays (lower energy)
Far Infrared	Infrared (lower energy)

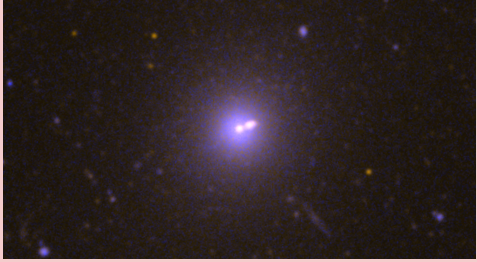
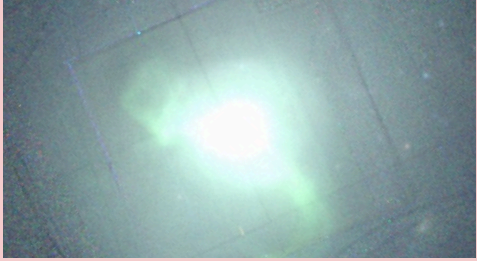
5. For each galaxy and type of light:

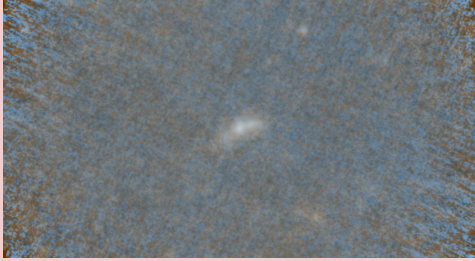
- Get a screenshot with the camera icon (like this ) in the top right corner. **And then upload it into this document.**
- Describe with your words where that type of light is showing up in the galaxy
- Describe with your words what type of objects are the likely source of the light (table above to help)
- **And in the visible light section**, describe the shape and overall look of the entire galaxy

M 31 - Spiral Galaxy - Younger galaxy		
Type of Light	Screenshot of the Galaxy	Description
Visible		Describe the Galaxy and where this light is coming from. The Galaxy is a flat disk shape, with a bright central bulge and then darker rings / arms spiralling out from the center. The outer edges are a mix of dark dust sections that block light and bright section where light escapes to the telescope. The central bulge is a yellow-ish color while the outer rings are more white to blue colored. Describe what kinds of objects are a source for this light. Most stars make visible light, but it is the best way to see relatively cool stars that are not blocked by dust. You can see there is a lot of light coming from the central bulge but also plenty of more spaced out stars around the outer rings.

Ultraviolet		Describe the Galaxy and where this light is coming from. The UV light is mostly coming from spiraling bands that start near the middle and extend out towards the outer edges. Some the UV streaks appear to match the Visible bright parts of the outer areas of the galaxy. Describe what kinds of objects are a source for this light. UV sources tend to be very hot young stars, so this photo is indicating that most of the young stars are forming in streaks near the mid center to the outer edges. While Visibly the center was very bright, this image seems to indicate very few new stars are near the center of the galaxy.
X-rays		Describe the Galaxy and where this light is coming from. The X-rays are coming from random little bright spots around the galaxy. Most of them are near the center of the galaxy, but there are a couple random spots in the outer areas of the galaxy. Describe what kinds of objects are a source for this light. Supernovas are a source of X-rays, this points to the idea that there are not many supernovas happening in this galaxy. However, they are more likely near the center rather than clustered to the outside edges. I wonder if more stars there go supernova, or if there are just more stars near the center and thus more supernovas are forming as a consequence.
Infrared		Describe the Galaxy and where this light is coming from. The infrared light is mostly coming from swirls that originate near the center and spiral outwards. If you look closely, you can see the IR tends to overlap with the locations where there are dark swirls in the Visible image, hinting to the idea that dust clouds that block visible light are the main source. These IR swirls also line up relatively well with where there are UV-young stars indicating they are forming in / near the dust. Describe what kinds of objects are a source for this light. IR is mostly produced by relatively cool objects like nebula dust, however this dust is too cool to glow in visible or other colors so it often looks dark in other images.

M 87 - Elliptical Galaxy - Older galaxy

Type of Light	Screenshot of the Galaxy	Description
Visible		Describe the Galaxy and where this light is coming from. The Galaxy looks like a relatively round ball shape of bright light. It's honestly kind of a featureless ball. I could see a person assuming it's a star. Yellowish-orange color overall. Describe what kinds of objects are a source for this light. Most stars make visible light, but cool stars tend to show up best in visible light. The yellow-orange color indicates that most of the younger blue hot stars have died. I wonder if the UV will confirm this and show fewer objects.
Ultraviolet		Describe the Galaxy and where this light is coming from. This galaxy makes a lot less UV light than Visible light. Like the visible picture the image is a mostly blurry ball shape. While the UV is concentrated near the center it's not as bright as the visible light overall. Describe what kinds of objects are a source for this light. UV light is made by young hot bright stars, the lower presence of UV light seems to indicate that most of the young hot stars have died out at this point.
X-rays		Describe the Galaxy and where this light is coming from. This object makes a LOT of X-rays. Way more than the first galaxy. The X-ray light looks even brighter than the visible light as it extends farther out from the center and seems to have blurry arms reaching out from the center. Describe what kinds of objects are a source for this light. X-rays are produced by supernova remnants so this galaxy either has a lot of supernovas happening (which would show up in visible as well) or they had many in the past that are still producing X-rays, which is my bet.

Infrared		Describe the Galaxy and where this light is coming from. Like UV, there is very little infrared coming from this galaxy. The small amount is clustered near the center, unlike the other galaxy which had most of its IR coming from outer areas. This indicates that the IR sources are rare and in different places than the first galaxy. Describe what kinds of objects are a source for this light. IR is made mostly by dust clouds, and the small amount of IR in this galaxy hints to the idea that most of the dust in this galaxy has either been blown away or sucked up by objects by this point. So there is way less free dust left compared to the young galaxy.
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Part 2: In this section you will write about three paragraphs. I want you to summarize with your words what you found above about each galaxy. So one paragraph per galaxy. Then in your third and final paragraph compare and contrast what makes the two examples different. Try to show what appears to change as a young galaxy (M 31) ages into an old galaxy (M 87). At this point you have all the data you need to start, you just have to summarize what you have found and explain what makes the galaxies different.

Before I start, we have not focused on galaxies yet in class, so most of my students know very little about their organization nor development. That means I am assuming they will mostly report what they found and not why things are where they are. Some students might come into class already knowing that dust turns into stars, and that blue / hot stars finish quickly, but I doubt they will mention anything more about the progression of stars or their placement within the galaxies.

Paragraph 1 - M31 young spiral galaxy - Students should mention the following:

- The center of the galaxy has a lot more visible light, this is coming from cooler stars. (I hope they mention that the center is more yellow while the outer parts are more blue, but I'm not expecting it)
- The outer parts of the galaxy are where most of the ultraviolet is coming from. This light comes from new hot stars, so new stars are mostly forming in the outer rings.
- Very little of the galaxy glows in X-rays. Only a few stars make X rays, and they are mostly clustered near the center of the galaxy. These X-rays are coming from supernovas. (I am hoping but not counting on students to know what supernovas are or how they formed at this point in the year.)
- Most of the infrared is coming from the outer rings of the galaxy. This light comes from dust too cool to glow in visible light. This dust is forming into new stars. (I am hoping they connect the IR image to the UV image and notice how there is

significant overlap of the two, hinting to the idea that the IR dust is turning into the UV young stars.)

Paragraph 2 - M87 old elliptical galaxy - Students should mention the following:

- The galaxy looks like a solid round yellow object. The galaxy has few features or parts to it. It looks really simple. The visible light tells us there are a lot of older stars in this galaxy.
- The UV light is centered on the core of this galaxy. However, there is a lot less UV light than visible light. This tells us there is a lot fewer new stars than old stars in this galaxy.
- M87 is very bright in X-rays. It's the brightest type of light coming from this galaxy. This tells us there are a lot of supernovas and their remnants within this galaxy.
- The IR is quite dim for this galaxy. It is roughly centered on the galaxy, but less IR implies there is less dust left and few stars forming in this older galaxy.

Paragraph 3 - Compare and contrast old vs new - Students should mention some of the following:

- Shape: As the galaxies get older they become more round and lose their outer rings / arms to become more simple.
- The older galaxies still have plenty of old stars at their core.
- The young galaxy has a lot more IR dust and UV young stars, especially around the outside edges. While the older galaxy has very little of both. (This implies the dust has been used, turned into young stars, then they aged / died already.)
- The young galaxy has much less X-rays than the older galaxy, this means that it has / has had fewer supernovas than the older galaxy.