Frontiers for Young Minds
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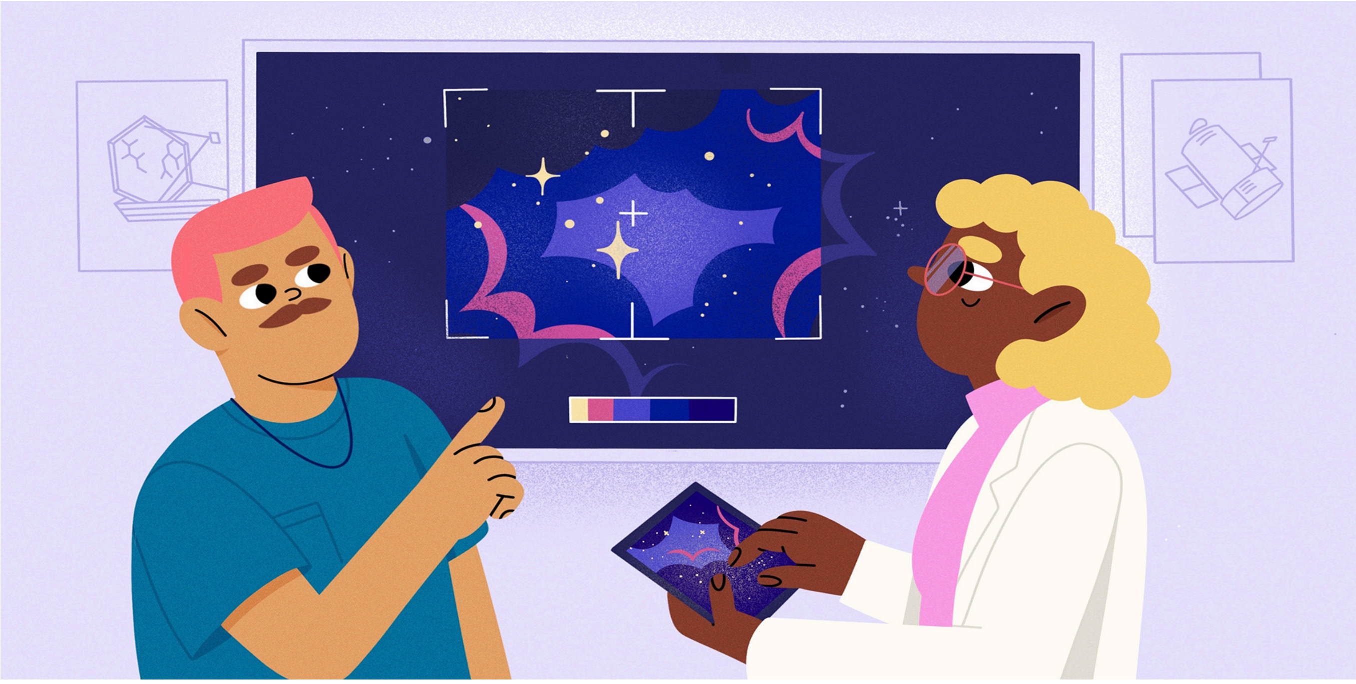

HOW TO COLOR THE UNIVERSE

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AGE: 12

Although we can see thousands of stars in the night sky with just our eyes, we know there are millions of other objects out there. To see these other stars, galaxies, nebulas, and more, we need telescopes that are not only more powerful than the human eye, but that can see types of light that our vision cannot process. Each of these telescopes specializes in seeing a certain type of light and provides unique information. By combining images from multiple telescopes, we can get a big-picture understanding of objects across the cosmos. In this article, using the center of our Milky Way Galaxy, the Tarantula Nebula, and the Tycho supernova remnant as examples, we explore how different telescopes, such as NASA's Chandra X-ray Observatory, James Webb Space Telescope, Spitzer Space Telescope, and Hubble Space Telescope, work together to produce beautiful and informative images of our Universe.

THE "INVISIBLE" UNIVERSE

Looking up at the night sky, you can see lots of black, with the stars appearing as simple white dots. But if we look deeper and with various kinds of telescopes, space and the stars that live there have a lot more to offer.

You may have heard the term **visible light**. This is what we call the range of colors that humans can see. Visible light, however, is just a tiny portion of all light. If you think of a piano keyboard, visible light would be the middle C key and a few keys on either side. The rest of the keys would represent the other kinds of light out there—**infrared**, **X-ray**, gamma ray, and ultraviolet, just to name a few.

VISIBLE LIGHT

The small range of types of light that human eyes can see.

INFRARED

Type of light associated with detecting heat with less energy and longer wavelengths than visible light.

X-RAY

Type of light with more energy and shorter wavelengths than visible light, typically associated with bone scans at the doctor.

Scientists know that objects in space give off all these kinds of light, but they are mostly invisible to the human eye. To solve this problem, astronomers build telescopes and place them on the ground or launch them into space, to detect the types of light we cannot see with our own eyes. Some types of light are absorbed by the Earth's atmosphere, so telescopes that detect those types must be put into space. Other telescopes are put into space to get a better view.

TRANSLATING LIGHT

Perhaps you are might be wondering how objects in space emit different types of light. Before we go any further, we should explain that light travels as a wave. Just like on the ocean, you can measure the distance between the peaks of waves of light. This is called the **wavelength**, and scientists use this measurement to put light waves into categories such as radio waves (longer wavelengths), visible light (medium wavelengths), X-rays (shorter wavelengths), for example.

WAVELENGTH

The length difference between two neighboring peaks of a wave or the length of one complete repetition (or cycle) of a wave.

Many things emit one or more kind of light, including people and non-living objects. People do not give off visible light (although we reflect visible light from the Sun and other sources), but we *do* give off infrared light. This is how thermal cameras, and some night vision goggles, pick up people in the dark. Just as we use different kinds of tools to see things here on Earth, astronomers have different kinds of telescopes to see a variety of phenomena out in space.

Once the data from telescopes are back on the ground, scientists can rearrange those data so our limited human senses can pick them up. They layer together various types of light using different colors of visible light, like red, orange, yellow, green, blue, or purple [1].

You might be thinking, "Wait a second! Is that cheating? Did you not just say we cannot see these other kinds of light? Is this all made up?" The answer is a big NO! This is not magic or a trick: it is a **translation**. If

TRANSLATION

Using imaging tools to correspond visible colors (red, green, purple, etc.) to invisible light values to produce a picture visible to your eyes.

you have ever visited a foreign country or spoken with someone who speaks a different language than you do, you have had to translate from whatever language you speak to the other language. The overall meanings do not change—just the words. The same idea is true for data. We translate data from invisible kinds of light into colors our eyes and brains can see [2].

SEEING THE CENTER OF THE OUR GALAXY

To demonstrate, let us explore the center of our Galaxy, the Milky Way. From some parts of Earth, you can see the Milky Way stretching across a big part of the night sky. In the view shown in Figure 1, we are zooming in on a relatively small part of the "downtown" of our Galaxy. Buried at its center is a giant black hole, weighing about 4 million times as much as the Sun, which astronomers have named Sagittarius A*. While we cannot see beyond the edge of the black hole itself, we can see stars, gas, dust, and more that surround it. In this figure, you can see the center of the Milky Way Galaxy in three different light filters (**near-infrared**, infrared, and X-ray).

NEAR-INFRARED

Specific type of infrared light with slightly less energy and longer wavelengths than visible light, sits in between visible and infrared light on the light spectrum.

To capture the image in Figure 1, of Sagittarius A* some 26,000 light-years (about 150,000,000,000,000,000 miles) away, astronomers used three different NASA telescopes in space. Each telescope looks at specific kinds of light and gathers important information about this region of the Galaxy. Taken together, however, they paint a more complete picture than any one telescope can get alone.

Here is what each color shows:

- Yellow: This layer contains observations in near-infrared light from the Hubble Space Telescope. The Hubble data show regions where stars are being born as well as hundreds of thousands of individual stars.
- Red: The Spitzer Space Telescope, which is now retired, was another space telescope that looked at infrared light. This layer has cooler kinds of infrared light than the Hubble layer, and it reveals radiation and winds from stars that create glowing dust clouds and complex structures.
- Blue and violet: X-rays are not only important at your doctor's or dentist's office. In space, objects give off X-rays when they are very hot or energetic, which the Chandra X-ray Observatory can see.

WHAT ELSE CAN WE SEE?

OK, so Figure 1 shows one image of one place in space. Does the same technique work for other areas? The answer is absolutely yes. Figure 2 shows another example of a very different kind of object in space. This

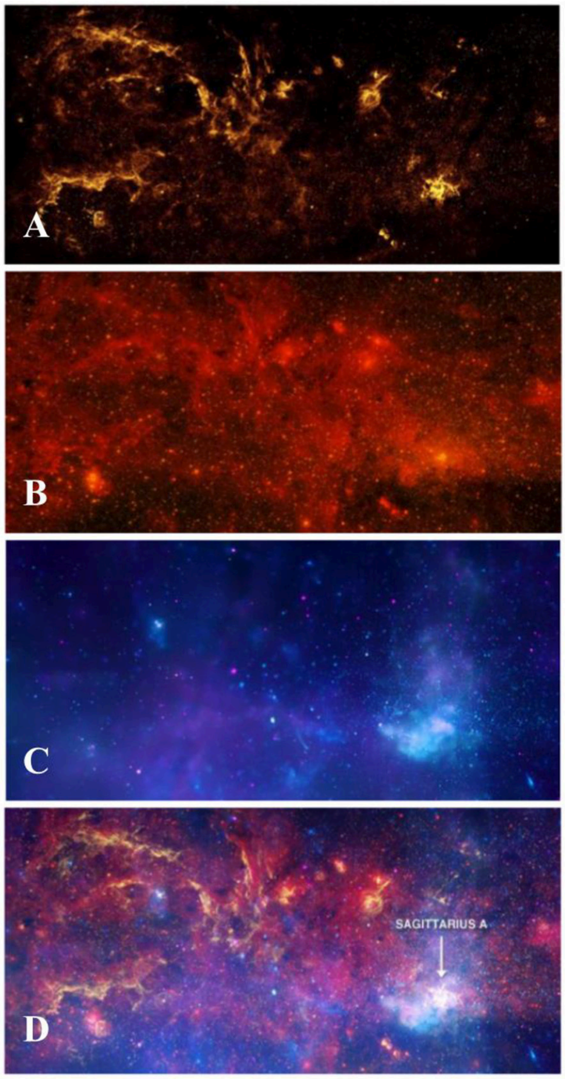

Figure 1

Figure 1

Three telescopes can use different light filters to capture some of the types of light emitted by the center of our galaxy: **(A)** near-infrared, from the Hubble Space Telescope; **(B)** infrared, from the Spitzer Space Telescope; and **(C)** X-rays, from the Chandra X-ray Observatory. Astronomers turned telescopes' data into visible light, using the colors you see here. **(D)** All the filters layered together, with an arrow pointing to the black hole at the center of our Galaxy, Sagittarius A*. The width of this image is about the same size on the sky as from Earth as the Full Moon (Credits: https://chandra.si.edu/photo/2009/galactic/).

NEBULA

General term used for any "fuzzy" patch on the sky, either light or dark; a cloud of interstellar gas and dust.

is a giant cloud where stars are forming. Astronomers call it a **nebula**. The image shows you what happens when astronomers combine X-ray data from Chandra with one of NASA's newest telescopes in space, the James Webb Space Telescope (JWST).

Like Spitzer and Hubble, JWST detects infrared light. However, the mirrors on JWST are much, much bigger, its instruments are much newer, and the telescope itself is located about a million miles away from Earth, where it is very cold and dark. You may have heard about the JWST or seen some of the new images it has released over the past year.

Astronomers can use the translation technique for an image of this nebula, just like they did for the center of the Galaxy. The infrared light from JWST shows us dusty parts of the Tarantula Nebula where stars are forming. In Figure 2, the infrared light is colored orange and brown.

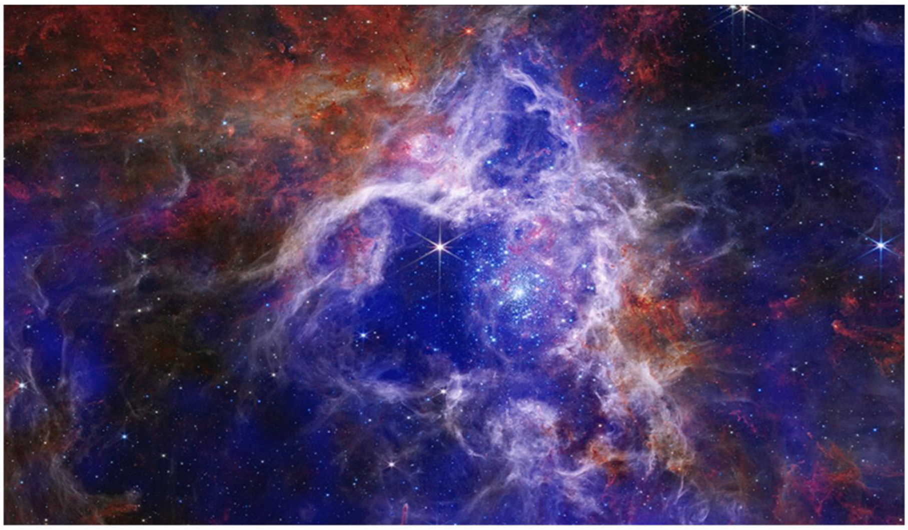

Figure 2

Figure 2

The Tarantula Nebula is located 161,000 light years away and is one of the closest and brightest nebulas to our Milky Way. To create this image, astronomers translated X-ray data from the Chandra X-ray Observatory and infrared data from the JWST into colors of visible light. You can see swirling, colorful gas clouds that look like the legs and body of a spider against a bright star field (Credit: https://chandra.si.edu/photo/2023/30dor).

X-rays from Chandra show gas that has been superheated by young, hot stars. We have made those data blue and purple. So, although the two telescopes tell a different story about what they see, they are both telling the truth. This image gives us a unique view of the Tarantula Nebula (though do not worry if you have a fear of spiders, this nebula is far, far away from Earth).

SUPERNOVA

Explosive death of a star, caused either by the star burning up or collapsing then imploding from being too heavy.

Another example of a sneaky object only appearing in certain kinds of light is the Tycho **supernova** remnant, shown in Figure 3, which is the remains of an exploded star. When we look at Tycho through a visible light telescope, we just see a star field. Nothing too interesting. However, when we turn our Chandra X-ray Observatory to the same area, we see an explosion (literally!) of colorful gas from a dead star. Supernovas are important to study because they are the birthplace of many of the heavier chemical elements in our Universe and they teach us about the life cycle of stars. Without colorful, multiwavelength images, we would not know nearly as much of our Universe as we do today!

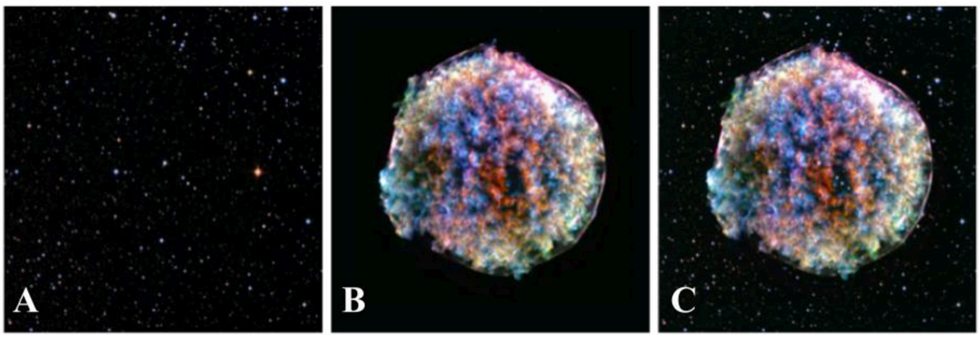

Figure 3

Figure 3

A supernova is the remains of a star that exploded at the end of its life. These are images of the Tycho supernova, which is in the constellation Cassiopeia. **(A)** If we view only the visible light from this supernova, we only see this star field, where the supernova is "invisible". **(B)** However, in X-ray light, we can see the striking debris field from this exploded star. **(C)** If we overlay the two images, we can see all the objects in the field of view, including both the optical star field and the X-ray supernova remnant (Credits: https://chandra.si.edu/photo/2019/tycho).

DO YOU WANT TO KNOW MORE?

There are countless other examples of how combining data from multiple telescopes that observe different kinds of light can help us learn more about our Universe [3]. The important thing to remember when you see these images online or in a book or even in a music video (see Ariana Grande, who is a big space fan) is that they are almost always translations from something invisible to us into colors we can see. While these images of our Universe are gorgeous, there is even more beauty when you dig a little deeper to learn what science and wonders they represent.

If *you* are interested in learning more, you can check out the Chanda X-ray Observatory website for young astronomers and students (https://chandra.si.edu/index_kids.html and https://chandra.si.edu/index_students.html). Here, you will find articles about the different objects you can see through a telescope that we have mentioned (black holes, supernovae, stars, galaxies, etc.). There are also fun activities and games (https://chandra.si.edu/make/ and https://chandra.si.edu/corps/) to give you hands-on experience with some of these astronomy ideas!

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YOUNG REVIEWERS

ABYAN, AGE: 12
Hi, I am Abyan! I like science, specifically space related science, and physics! I also like Mathematics and English. I would say that I am an independent person who loves new challenges. An example would be that I just recently started playing competitive tennis. I have a pet cat named Astro and I love spending time with him! In my free time, I play and interact with my friends and read about new space discoveries.

AUTHORS

KIMBERLY ARCAND
Kim was working in molecular biology and public health when she was hired for NASA's Chandra X-ray Observatory at the Center for Astrophysics in 1998. Since she always wanted to be an astronaut when she was little, this opportunity got Kim close to the cosmos but without the long-distance commute. Today, Kim uses data to tell stories about science, whether in the form of a 3D print of an exploded star, a sound from a black hole, or an augmented reality application of a stellar nursery.

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Taylor is a first-year graduate student at Caltech and starting toward a Ph.D. in astrophysics. Her research looks at the physics behind merging black holes with the LIGO collaboration. Outside of physics, she is passionate about the history of science and loves to be outside and craft! *tknapp@caltech.edu

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Megan has been communicating the wonders of the cosmos for decades. After earning an undergraduate degree in astrophysics, she went onto a graduate program in science journalism. She has been the press officer for NASA's Chandra X-ray Observatory at the Center for Astrophysics | Harvard & Smithsonian since 2000.