

## Exploring Infrared with FLIR & JWST

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Eyes on Earth - Fall 2022

<b>Grade/Grade Band:</b> 10-12	<b>Topic:</b> Astronomy <i>Electromagnetic Spectrum - Infrared; Current Events - James Webb Space Telescope</i>	<b># of Lessons:</b> 3, 45-minute periods
<b>Brief Lesson Description:</b> Students will use FLIR Infrared cameras to make observations of objects around the classroom. From their investigations, students will learn how infrared and visible light may be transmitted through and blocked by different materials. Students will then complete an online exploration of the James Webb Space Telescope and relate what they've learned back to the FLIR activity to better understand infrared astronomy.		
<b>Performance Expectation(s):</b> HS-PS4-5. <i>Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.</i>		
<b>Specific Learning Outcomes:</b> Students will be able to: <ul style="list-style-type: none"><li>- Sketch the views of objects in both the visible and the infrared.</li><li>- Explain why some objects are 'visible' in infrared but not visible in visible light and vice versa.</li><li>- Identify the materials through which infrared can be transmitted, and the materials by which infrared is blocked.</li><li>- Identify the features of the James Webb Space Telescope that allow it to effectively observe in the infrared.</li><li>- Contrast and analyze images in both visible and infrared light.</li><li>- Explain why it is important for astronomers to observe objects in both the visible and infrared bands.</li></ul>		
<b>Narrative/Background Information</b>		
<b>Prior Student Knowledge:</b> At this point in the Astronomy curriculum, students will have gotten an overview of the Electromagnetic Spectrum. Students will be familiar with how 'light' is categorized by different frequencies and wavelengths, and how these categories have names such as infrared, ultraviolet, etc. Students will have learned that higher frequency light has higher energy, and that all forms of light travel at the same speed in a vacuum. Prior to this lesson, students will have completed an investigation of visible light using colored filters, prisms, etc. After exploring the visible band of the EM spectrum, students then completed a lesson about radio waves and radio telescopes such as the Very Large Array. That lesson re-introduced students to the idea that some forms of light are invisible to humans, and can travel through barriers such as dust, buildings, etc. This lesson continues students' journeys through the Electromagnetic Spectrum as an exploration of infrared light. Students will investigate sources of infrared in their everyday lives, and then learn about the James Webb Space Telescope, which observes celestial objects in the infrared.		

**SEPs:**

Constructing Explanations and Designing Solutions: *“Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future”* - HS-ESS1-2

Asking Questions and Defining Problems: *“Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design”* - HS-PS4-2

**DCIs:**

PS4.C: Information Technologies and Instrumentation: *“Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them”* - HS-PS4-5

PS4.B: Electromagnetic Radiation: *“Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features”* - HS-PS4-4

PS4.B: Electromagnetic Radiation: *“When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells”* - HS-PS4-4

**CCCs:**

Interdependence of Science, Engineering, and Technology: *“Science and engineering complement each other in the cycle known as research and development (R&D)”* - HS-PS4-5

Influence of Engineering, Technology, and Science on Society and the Natural World: *“Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks”* - HS-PS4-2

**Common Core State Standards:**

CCSS.ELA-LITERACY.RI.11-12.7: *“Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.”*

CCSS.ELA-LITERACY.RST.11-12.4: *“Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.”*

CCSS.ELA-LITERACY.RST.11-12.9: *“Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.”*

**Lesson Plan - 5E Model****Engage:**

Students will view Chromoscope (<http://www.chromoscope.net/>) to investigate the Milky Way galaxy in various wavelength bands. They will discuss their observations with a small group of classmates. The instructor prompts student thinking by asking: “What is it that we are looking at here? Does the object itself (the Milky Way) change as you change the slider to different wavelengths? Do certain features appear differently, or appear/disappear altogether, in different bands?” Allow a few minutes for students to view Chromoscope on their own chromebooks, and discuss their ideas with peers.

**Explore:**

Explain to students that they will be seeing objects in different wavelengths today too, just like they saw the Milky Way on Chromoscope. Instead of objects in space, they will be looking at items in the classroom to discover how infrared is emitted and/or blocked by certain objects and materials. Each small student group (<4 students, if supplies allow) will receive a FLIR camera attachment to use with the FLIR One app. (In my own classroom, student groups are also provided with old phones preloaded with the app to connect to the FLIR camera). The instructor should also set up stations – one with beakers of hot and cold water, one with power cords/adapters plugged into a wall outlet, and one with a desk lamp (or multiple lamps – ideally, it would be great to use both an LED and an incandescent bulb). Student groups will also need panes of glass (like from a picture frame - seal off sharp edges with tape), sheets of aluminum foil, and a piece of opaque black plastic sheeting (i.e., cut from a black trash bag).

Using the attached “Explore” worksheet to guide their exploration, students will make observations at the different stations, using colored pencils or crayons to sketch what they see in both visible and in infrared using the FLIR cameras. The “table tasks” section of the worksheet asks students to sketch the view of a mug of hot water through barriers (glass, plastic, aluminum foil) in both infrared and visible light.

As they work through the tasks on the worksheet, some questions will ask students to summarize their findings and connect what they are seeing to astronomical observations. The instructor will use this time to supervise students for safety (hot water, glass, etc.), answer student questions, prompt student thinking with questioning, and look at students’ sketches for formative assessment as students work through the tasks.

**Explain:**

During the “Explain” section, the class will come to a consensus about which types of radiation may travel through which materials, and which are blocked altogether. A combination of small-group and whole-class discussion will lead students to an understanding of what happens to both the visible and infrared radiation from, for example, the mug of tea when it hits the black plastic barrier. Students were asked to sketch this on the “Explore” section of the attached worksheet. During the ‘explain’ segment of the lesson, students can now go back and revise their sketches from before if necessary. Then, the instructor will re-introduce the photos from the “engage” section. Students will be given a few minutes to discuss with a partner how their new knowledge of visual and IR light applies to the images that they saw earlier. A class discussion can guide students toward the knowledge that some forms of light are blocked by barriers in space like dust and clouds, while other forms travel through these. The “Explain” worksheet, attached below, asks students to sketch this out.

**Elaborate:**

Explain that just as students needed a special tool, a FLIR camera, to make infrared observations of the objects around them, astronomers need special tools to make infrared observations of objects in space. Before introducing the James Webb Space Telescope, ask students to think-pair-share about the questions on the first section of the “Elaborate” sheet, attached below.

Then, the instructor will briefly introduce the James Webb Telescope, giving students an opportunity to share anything that they know/have heard about JWST. The instructor will provide a list of links to students (through a platform such as Google Classroom, as well as on the paper copy of the worksheet) so that they can explore at their own pace on their Chromebooks or phones. Students will aim to answer questions provided on the sheet, which will guide their exploration and help them relate what they are learning about the telescope to what they learned in the Explore section.

As students work, the instructor will rotate around the room to provide support and clarification, use questioning techniques to promote deeper student thinking and understanding, provide refocusing and redirection, and perform formative assessment.

**Evaluate:**

Evaluation happens throughout the entire lesson as students make observations, construct explanations, and answer questions on the materials provided. As a final check-in before students leave, they will be provided with an exit slip that allows them to demonstrate their understanding of the lesson. Please see “Evaluate” sheet attached below.

**Materials:**

- Worksheets - All included below.
- FLIR Cameras and compatible devices, such as smartphones, pre-loaded with the FLIR One app
- Mugs and/or beakers for cold and hot water
- Glass panes (such as from a photo frame, with sharp edges taped)
- Aluminum foil
- Black plastic sheeting (such as from a black trash bag)
- Colored pencils and/or crayons
- Chromebooks, laptops, cell phones – any internet-enabled devices for students to access links
- Informational links about the James Webb Space Telescope:

<https://webb.nasa.gov/>

<https://webbtelescope.org/>

<https://youtu.be/6VqG3Jazrfs>

<https://spaceplace.nasa.gov/james-webb-space-telescope/en/>

<https://webbtelescope.org/webb-science/the-observatory/infrared-astronomy>

<https://www.nisenet.org/webb>

<https://webb.nasa.gov/content/webbLaunch/whereIsWebb.html>

Name: \_\_\_\_\_

### Exploring Infrared with FLIR & JWST - **Explore**

With your partner(s), use the FLIR cameras to investigate objects around the room and at the labeled stations.

For each station, make a sketch (or paste a photo if electronic) of your view in both visible light and infrared light.

First, take a few moments to observe objects around the room. Follow your curiosity! Based on your observations, describe what the colors you see in the infrared images from the FLIR camera represent:

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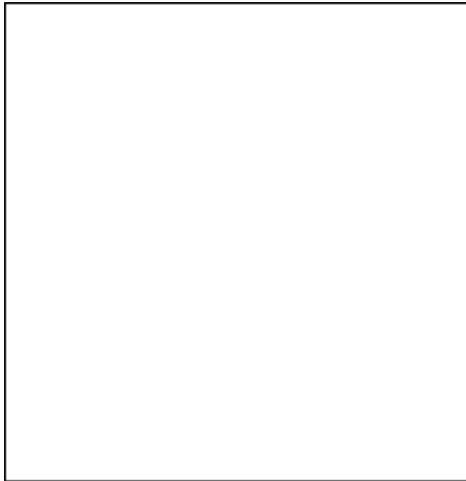
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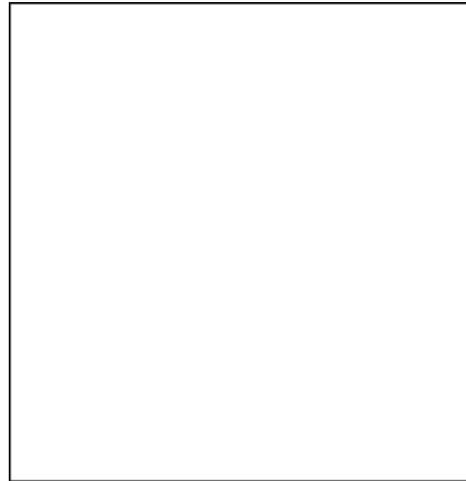
### **ROTATION STATIONS**

With your partner(s), visit the stations labeled #1-3. For each station, make a quick sketch of your view of the station in visible light (just with your eyes) and in infrared light (through the FLIR camera). Answer the questions that follow.

#### **Visible View of STATION 1**



#### **Infrared View of Station 1**



In Station 1, one beaker contains cold water and the other contains hot. In which view(s), visible and/or infrared, can you tell the difference? Explain.

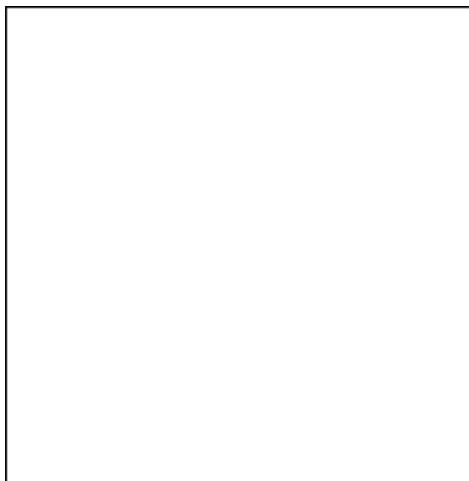
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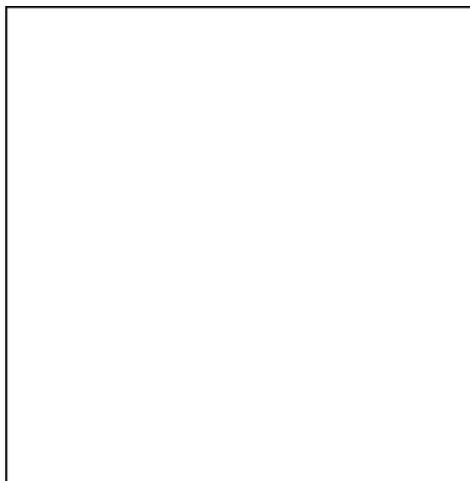
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**Visible View of STATION 2**



**Infrared View of Station 2**

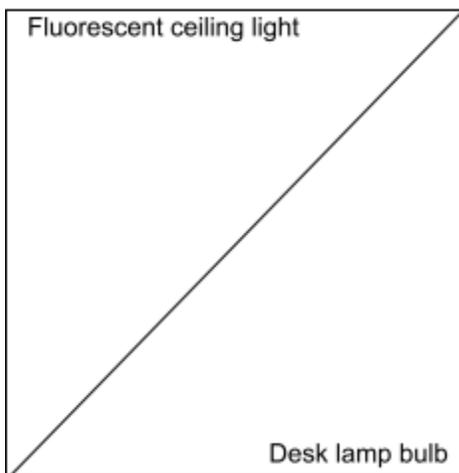


This station contains two power adapters (cords plugged into the outlet). Why do you think they might look the way they do in the infrared? What is causing this?

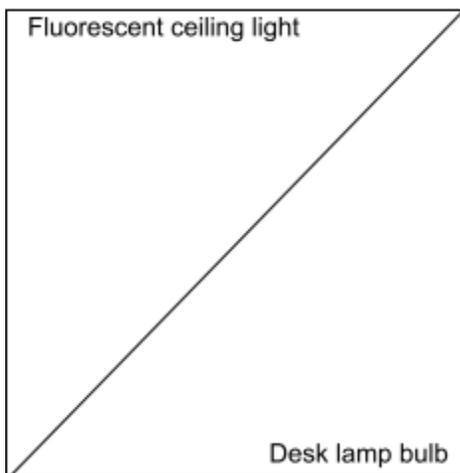
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**Visible View of STATION 3**



**Infrared View of Station 3**



At station 3, look first at the fluorescent ceiling lights. Then, look at the bulb of the desk lamp. How do the brightnesses of these two light sources compare in the visible? How do the 'brightnesses' of the two bulbs compare in the infrared? Explain.

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**Stations 1-3 Summary Questions:**

What kinds of information did you gain from viewing each of the stations in infrared? Would you have the same knowledge about each object if you were to view each station only in visible light? Explain.

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Thinking about objects in space, what kind of information might astronomers gain from viewing objects in infrared?

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**✨ TABLE TASKS: Investigating the transmission of infrared through materials**

Once you've completed the rotation stations above, go back to your own table with your group and work through the tasks below and answer the questions that follow.

**Task A**

Find someone in the room who wears glasses. With their permission, look at their face using the FLIR camera. In the IR image, what do you notice about their glasses compared to their face? Why do you think this might be? Explain.

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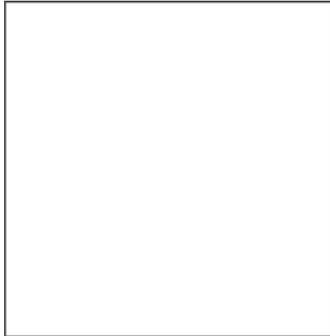
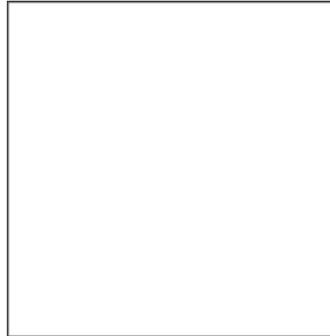
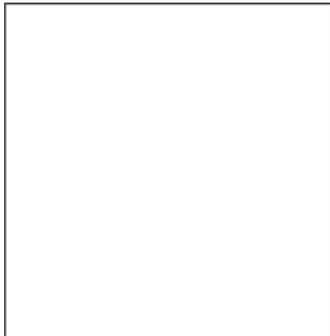
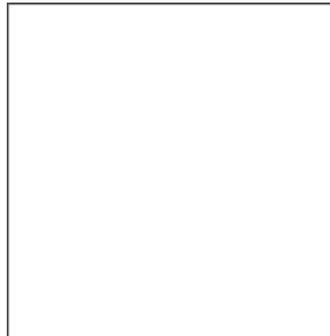
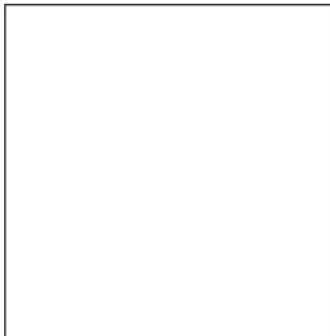
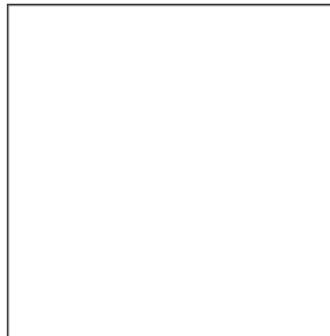
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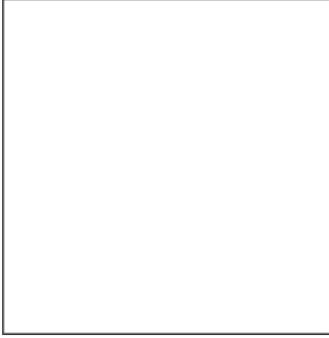
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**Task B**

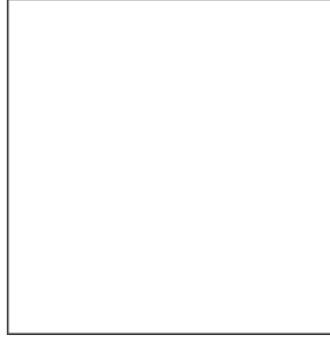
When your group is ready for this task, let your instructor know so they can provide materials. Once you have your materials, make sketches of your visible and infrared views of the mug behind each material, as listed.

**Visible view of mug (no barrier)****Infrared view of mug (no barrier)****Visible view of mug behind glass****Infrared view of mug behind glass****Visible view of mug behind aluminum foil****Infrared view of mug behind aluminum foil**

**Visible view of mug behind black plastic**



**Infrared view of mug behind black plastic**



Which material(s) were transparent to visible light? Opaque to visible light? Explain.

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Which material(s) were transparent to infrared light? Opaque to infrared light? Explain.

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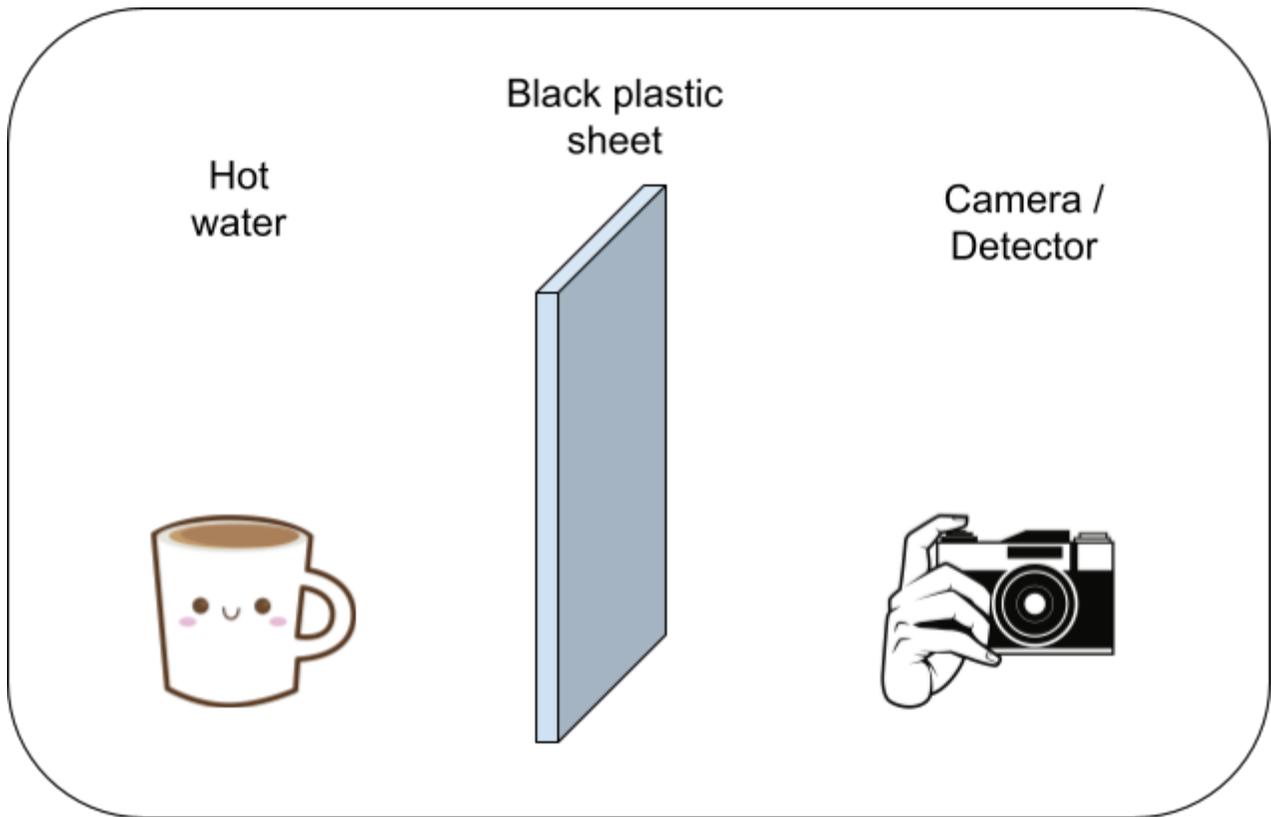
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Did any of your observations in this task surprise you? Explain.

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In the box above, sketch:

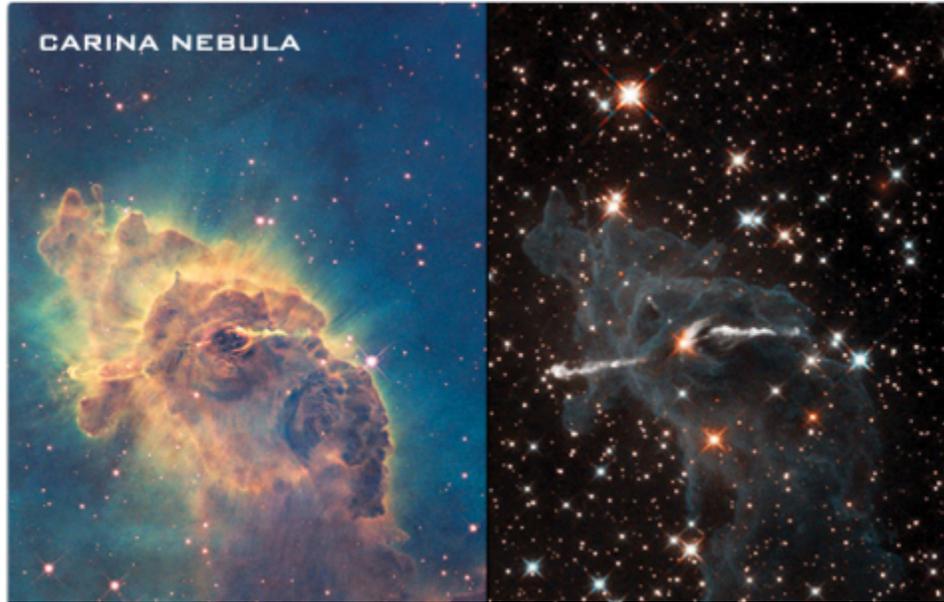
- (a) the path of visible light coming from the hot water mug (draw in green), and
- (b) the path of infrared light coming from the hot water mug (draw in red).

Which type(s) of light pass through the black plastic barrier? Which type(s) are blocked by it?

In your sketch, be sure to show the relative wavelengths of the visible and infrared light. (Which type of radiation has a shorter wavelength? Longer wavelength? Sketch accordingly!)

### Task C

The two images below show the exact same astronomical object, the Carina Nebula. However, each image shows the nebula in a specific band of the electromagnetic spectrum.



From [https://science.nasa.gov/ems/07\\_infraredwaves](https://science.nasa.gov/ems/07_infraredwaves)

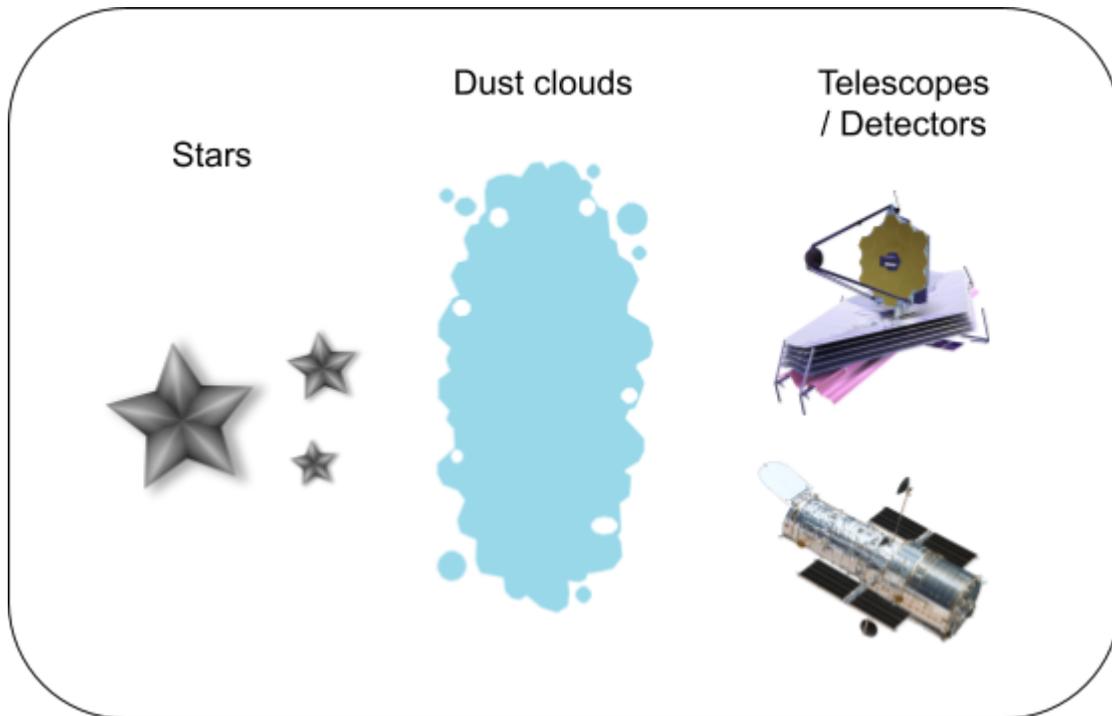
Compare and contrast the two images shown above. Which features are similar in each image? Which features are different in each? Are there any features that are shown in one image but not the other? Use the space below to list out any observations.

Which of the images above, left or right, do you think represents the visible image of the Carina Nebula? Which do you think represents its infrared image? Explain your answer below.

Name: \_\_\_\_\_

## Exploring Infrared with FLIR & JWST - Explain

After our mini-lesson and discussion as a class, demonstrate your understanding by responding to the prompts below.



In the box above, sketch:

- (a) the path of visible light coming from the stars (draw in green), and
- (b) the path of infrared light coming from the stars (draw in red).

Which type(s) of light pass through the dust cloud? Which type(s) are blocked by it?

In your sketch, be sure to show the relative wavelengths of the visible and infrared light. (Which type of radiation has a shorter wavelength? Longer wavelength? Sketch accordingly!)

Name: \_\_\_\_\_

## Exploring Infrared with FLIR & JWST - **Elaborate**

Before using the links provided on Google Classroom to learn about NASA's newest infrared telescope, discuss with your partner(s) and answer the following questions with your best guesses!

☀️ What types of astronomical objects (stars, planets, dust clouds, etc.) would you expect to emit lots of infrared radiation? Little infrared radiation? Explain why you think so.

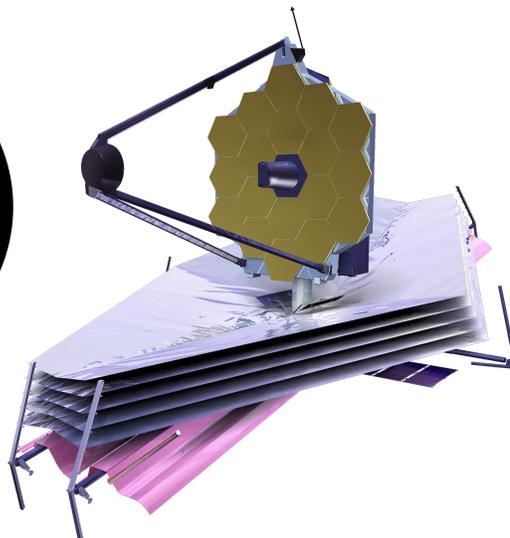
☀️ If you were to decide where to put an infrared telescope so that it was the most effective at observing objects in distant space, would you decide to put it:

- On the surface of the Earth, or
- Out in space?

Why? Explain your answer.

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## EXPLORE THE JAMES WEBB SPACE TELESCOPE!



Now, use the links provided below and embedded in the prompts (also posted on Google Classroom) to explore and answer the following questions about NASA's newest infrared telescope, the James Webb Space Telescope!

<https://webb.nasa.gov/>

<https://webbtelescope.org/>

<https://youtu.be/6VqG3Jazrfs>

<https://spaceplace.nasa.gov/james-webb-space-telescope/en/>

<https://webb.nasa.gov/content/webbLaunch/whereIsWebb.html>



Name: \_\_\_\_\_

## Exploring Infrared with FLIR & JWST - Evaluate



From <https://www.jwst.nasa.gov/content/about/comparisonWebbVsHubble.html>

☀️ The two images above show the exact same astronomical object. However, each image shows the nebula in a specific band of the electromagnetic spectrum. Which of the images above, left or right, do you think represents the visible view? Which do you think represents its infrared view? Explain your answer below.



From <https://abcnews.go.com/Technology/hubble-james-webb-telescope-images-difference/story?id=86763039>

☀️ Here's another set! Which image, left or right, represents an infrared view and which represents a visible light view? Explain why you think so.

☀️ Should astronomers rely solely on visible light telescopes to observe and learn about astronomical objects? Why or why not? Explain in a brief paragraph, using what you learned in the activities from yesterday & today. (Feel free to use the space on the back of this page if you need!)