Infrared Light and Infrared Astronomy

Learning Plan
Day 6: How do astronomers use images in research?

Targeted Idea: Images provide a great deal of information about objects in the Universe.

Overview of Day 6:

Astronomy is unlike other sciences in that investigators cannot change the variables of an experiment or collect physical materials to measure properties of the objects under study (with a few exceptions, such as the Moon and Earth). Astronomers are almost entirely dependent on studying the light from celestial objects. A variety of tools are used to collect this light, to receive the data from these instruments, and to process the data. After those steps, investigators can analyze and interpret the images. Astronomers can compare the images to other similar objects to look for patterns; other times, they make measurements on the photos and plot the brightness data. Investigators can maximize the study of objects by collecting data in multiple wavelengths of the electromagnetic spectrum.

In this activity, students examine a variety of astronomical images. They practice respectfully providing critiques on the scientific arguments of peers. In groups, they make and defend a claim based on evidence. They begin with easy to interpret optical images, and eventually move toward examining IR images, both printed images and images from the IR camera.

Students will build upon these prior Middle School Performance Expectations (PEs) and Disciplinary Core Ideas (DCIs) in Day 6:

PE MS-PS4-2 Waves and their Applications in Technologies for Information Transfer
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.]

DCI MS-PS4.A Wave Properties
A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

DCI MS-PS4.B Electromagnetic Radiation
When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.

Students will build their understanding toward the following High School DCIs during Day 6:

PS4.A Wave Properties
Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory ~~and sent over long distances as a series of wave pulses~~.

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.

Students are building their skills in / understanding of these Science and Engineering Practices (SEPs) and Cross Cutting Concepts (CCCs) in Day 6:

SEPs

Engaging in Argument from Evidence
- Evaluate claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.
- Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Constructing Explanations
- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, 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.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

CCCs
Patterns
- Empirical evidence is needed to identify patterns.

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<table>
<tr><th>Instructional Materials</th><th>Resources</th></tr>
<tr><td>Handouts:
Science Case Study: Milky Way CircumNuclear Ring (CNR)
Orion lithograph
Materials:
Color copies of photos (suggestion: laminate or put into protective sleeves)
IR camera</td><td>Day 6 PowerPoint
Day 6 Teacher Support Notes</td></tr>
<tr><th>Teacher Role</th><th>Student Role</th></tr>
<tr><td>Emphasize student use of evidence and reasoning. Model this for the first few images, so that students see how to push each other for more evidence and reasoning.
If disagreements happen, encourage students to have respectful, evidence-based discussions.
Embrace that this is an opportunity for students to disagree and engage in scientific argumentation.
Remember that more the participants respectfully push each other to cite evidence to support their claims, the more they will be engaged in this practice.</td><td>Carefully observe images, and state claims that are supported by evidence.
Contribute to group discussions.
Listen to peer ideas.
Respectfully challenge peers when they make unsupported statements.
Add supporting evidence to peer claims to improve strength of their claim.
Be willing to change mind if there are stronger arguments presented.</td></tr>
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Steps to follow:

1) Briefly discuss homework writing assignment.

2) *Engage:* Project Image #1 (Gruyeres, Switzerland). Ask students to imagine that they are sitting around the table with fellow planetary scientists trying to make sense of a planetary surface image they are seeing for the first time.

3) Together as a class, ask for a few students to share what they are seeing in the image. Challenge unsupported statements, and model how to do this respectfully, by asking questions such as:
   - How do you know that?
   - Where have you seen another example of that?
   - What is it about the color, shape, orientation, etc. that leads you to say that?
   - Can you support that statement with some additional evidence or experience?
   - What might be another example of what you are describing?

Teacher note: Do not allow groups to make statements like "that is snow on the mountains" or "that is a graveyard". They must give detailed reasoning to support these claims. An example might be: "We are seeing snow on the top of a mountain, and green valley below. The white at the top of the peaks is snow. Temperature decreases with increasing altitude- this supports the idea that it is colder in places that are higher in the image. There is a point lower in altitude where the green coloration ends and the snow begins. This also supports the idea that it is colder at the higher elevations, and (if the green is vegetation) trees do not grow above this. I have seen this "tree line" in other mountain areas." Stop participants anytime they make assumptions, asking "how do you know that is Ice? Water? Clouds? A man-made structure?" Push them to describe what it is about the item's shape, placement, color, orientation, and other details that can provide a clue about the nature of the object.

4) Ask students to make more detailed observations as a small group (3 or 4) of what they are seeing in the image.
   - Students should talk at their tables and discuss what they think they are seeing in the image, and to use evidence and reasoning to support a claim of image's location.
   - Share out.

5) Remind students:
   - We/scientists must be able to justify our interpretations with sound, logical explanations.
   - Sometimes the images are extremely challenging, strange or hard to interpret. First instincts may be completely incorrect.
   - We/scientists must keep an open mind, be willing to hear alternate arguments and change our minds if we hear stronger, more complete explanations.

6) *Explore:* Today, we will act as planetary scientists: receiving new images, examining those images, asking questions about what we see, generating possible explanations, and ultimately deciding which are the strongest arguments.

- Distribute visible images (images 2-5) to the group.
- In your group, discuss the photos of objects in the Solar System.
- One team member should start by describing what they observe, then state one claim, and end with citing as much evidence as they can to support their claim.
- The other members in the group should follow the teacher's model of questioning, probing for more explanation, evidence, and examples.
- Switch roles during the discussion so each student has a chance to make a claim.
- Based on their observations and discussions, groups should make a claim of the Solar System object shown in each image. They should try to be as specific as possible in their claim.
- Groups should then place the images in order of their confidence in their claims.
- Share out. Allow time for other groups to challenge, ask questions, and share additional/ different observations/explanations to add. Use the Day 5 CER structure.

Teacher note: At this point, students may begin to ask for the "right answer". You may wish to share what is stated on the image summary page, but stress that for scientists, there is no "right" answer, but rather, a "best" answer- the one that is supported by the most data/evidence, and soundest logical reasoning. There is no book of right answers for scientists to consult!

7) *Extend:* Remind the students that they have been practicing their skills of image interpretation and constructing an evidence-based explanation of the new data. This is even harder when the data collected extend into wavelengths that our eyes can't detect. We are now going to try the same approach with images from different wavelengths. Give a short overview of representative color.
    - Distribute the infrared images (Images 6, 7, 8) to the group.
    - In your group, discuss the photos.
    - One team member should start by describing what they observe, then state one claim, and end with citing as much evidence as they can cite to support their claim.
    - The other members in the group should follow the teacher's model of questioning, probing for more explanation, evidence, and examples.
    - Switch roles during the discussion so each student has a chance to make a claim.
    - Based on their observations and discussions, groups should make a claim of the objects shown in each image. They should try to be as specific as possible in their claim.
    - Groups should then place the images in order of their confidence in their claims.
    - Share out. Allow time for other groups to challenge, ask questions, and share additional/ different observations/explanations to add.

8) What sort of additional information can we gain from looking at two or more wavelengths? Use the Day 5 Claim Evidence Reasoning (CER) structure.

9) Spend remaining time demonstrating IR images with the IR camera. Encourage students to suggest objects in the classroom they would like to see in the infrared. (e.g.- cups containing hot and cold water, sprayed mist, on Plexiglas, computer behind garbage bag.) (Alert: Rayon clothing tends to be transparent in infrared. Use caution when

showing images of students.)

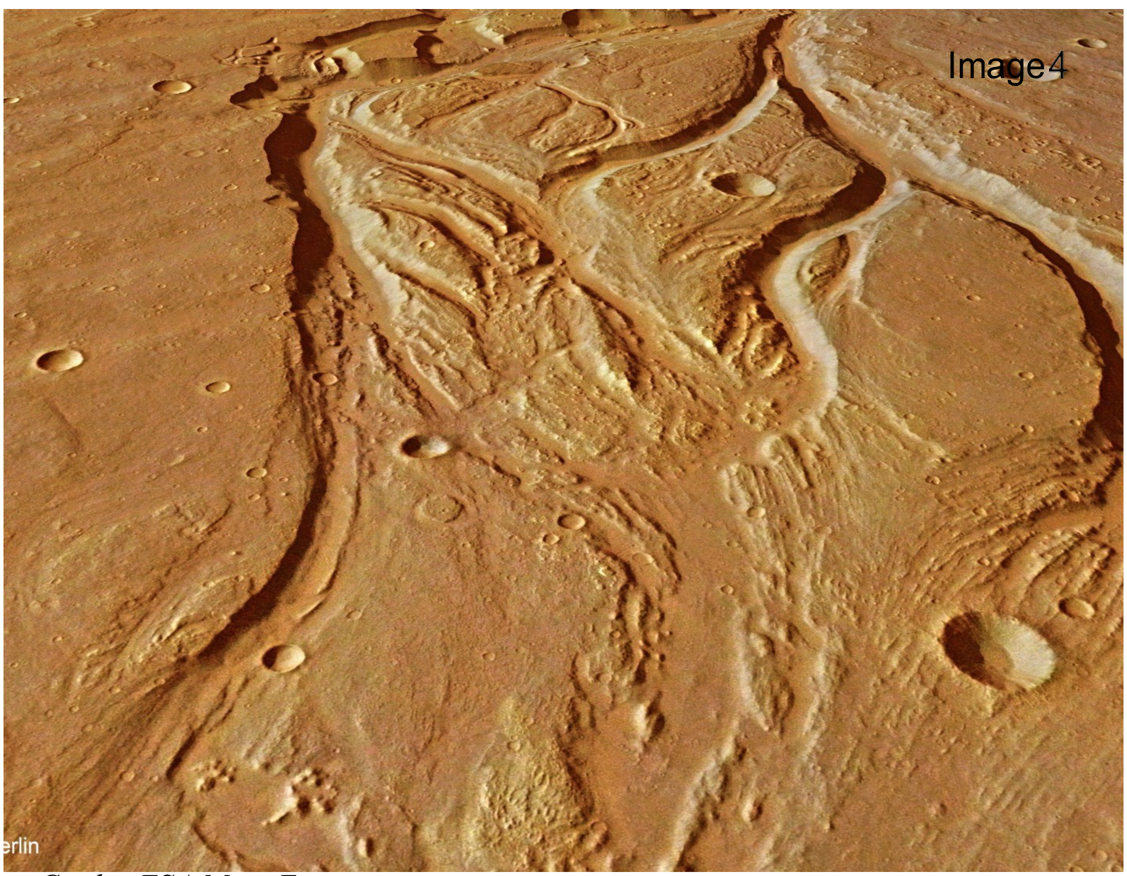
10) Distribute Science Case Study (CircumNuclear Ring) and Orion lithograph.

11) *Assign Homework:* Read the Case Study, add to the Case Studies graphic organizer, and read the back of the Orion lithograph.

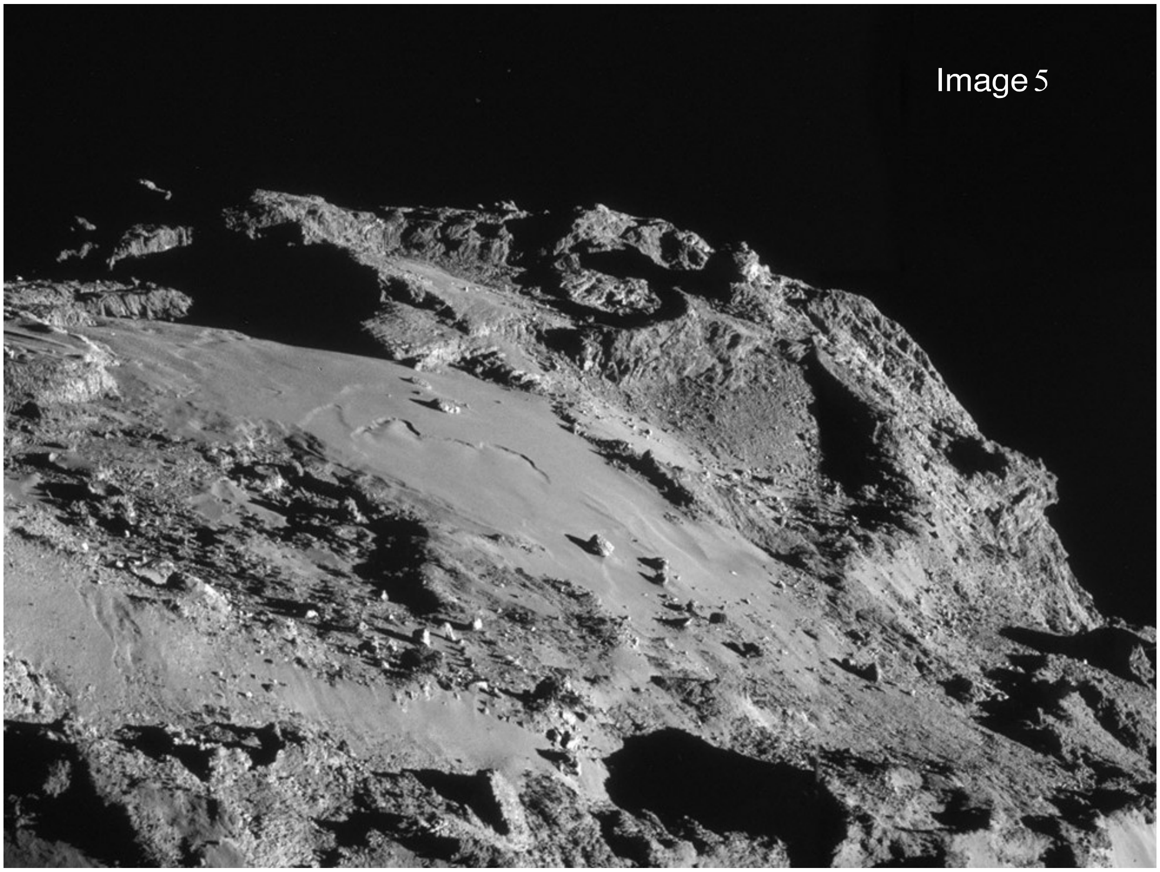
Credit: Theresa Moody

Credit: Theresa Moody

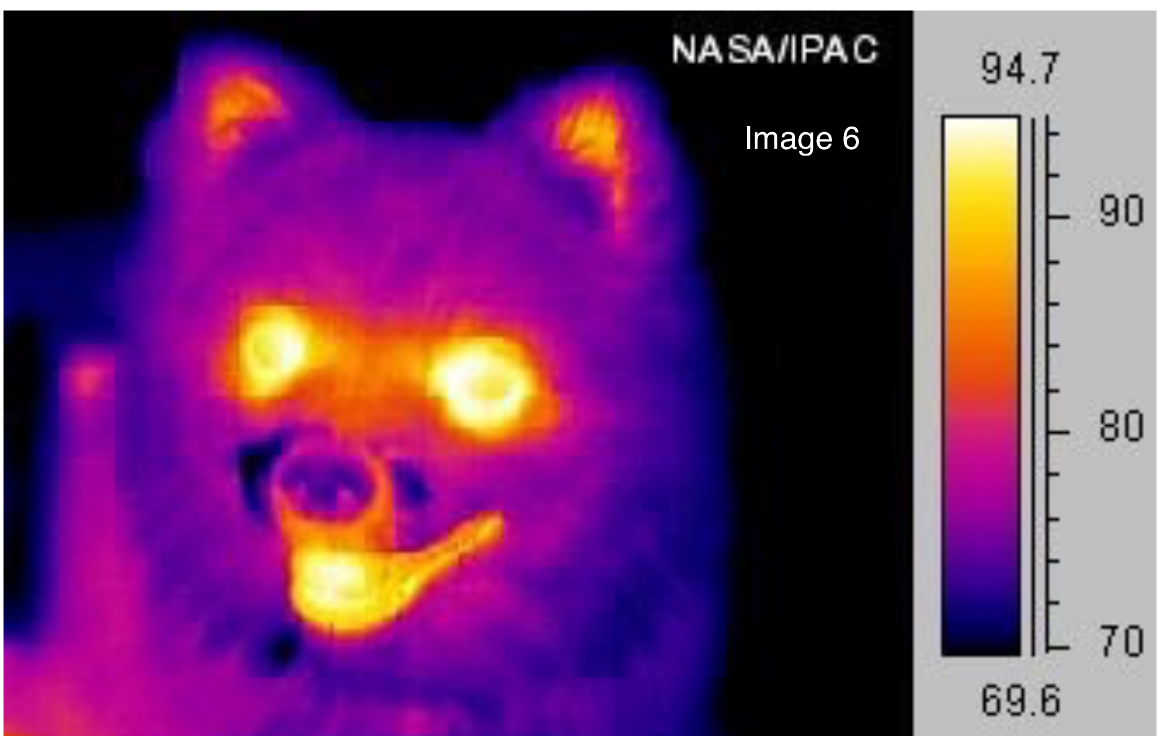
Credit: NASA MSL



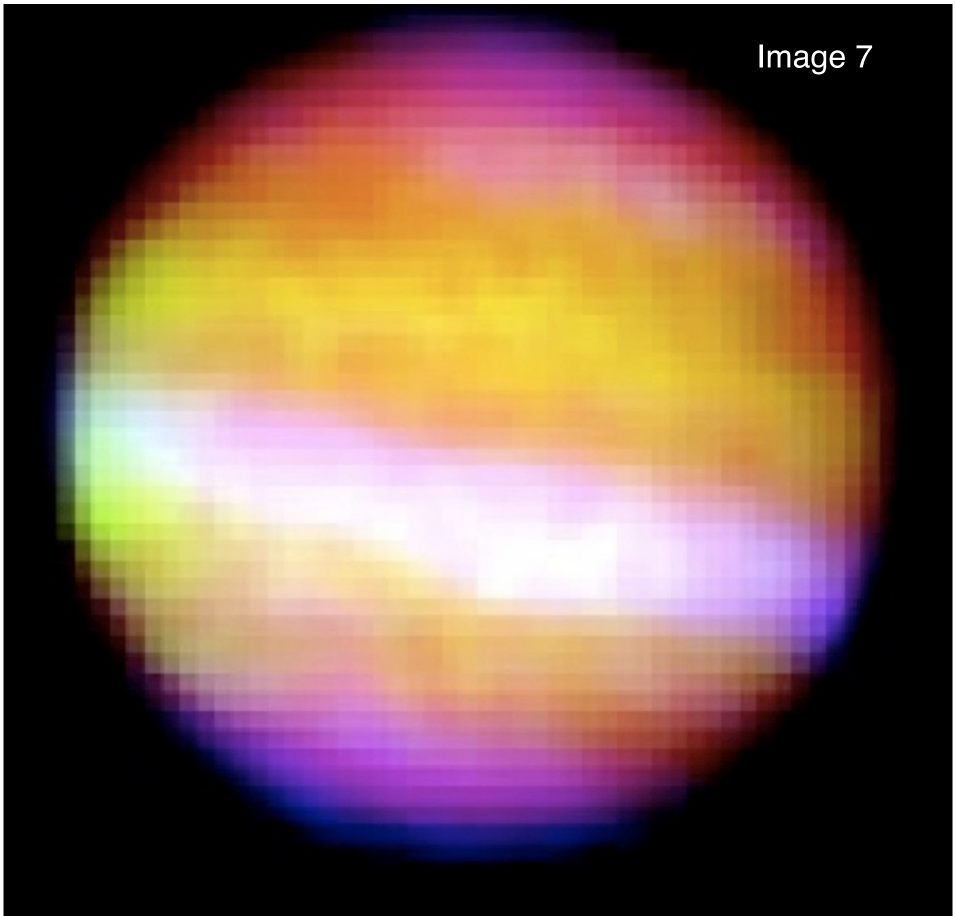
Credit: ESA Mars Express



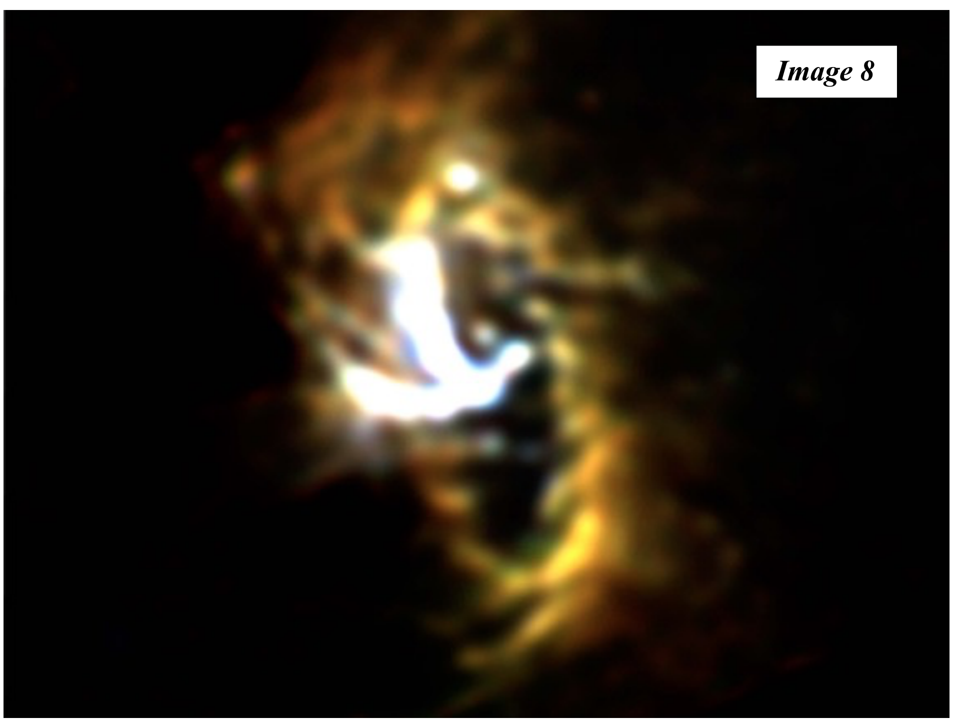
Credit: ESA Rosetta mission



Credit: IPAC Caltech

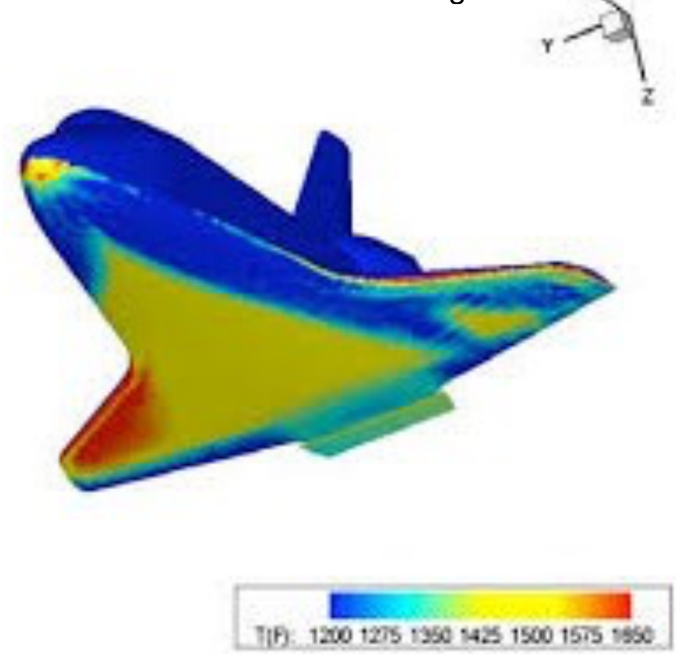


Credit: NASA/SOFIA/USRA/FORCAST Team/James De Buizer



Credit: NASA/DLR/USRA/DSI/FORCAST Team/Lau et al. 2013

Image 9



Credit: NTRS NASA

Credit: IPAC Caltech

Support Document - Teacher Notes to accompany the PowerPoint
Day 6: How do astronomers use images in research?
These notes are only for the teacher, and **not** intended as a handout for students to be given 'the right answer'!

Photo Descriptions and Credits:

Image 1:
Gruyères, Switzerland
Cathedral and Pre-Alps
Credit: Theresa Moody

In the foreground, there is a church and graveyard, and in the distance, a valley with buildings and roads, flanked by mountains topped with snow. Looking closely, one can see sheep, and a river at the bottom of the valley. Students can identify the man-made structures by looking at their shape, straight lines, repeating pattern of window shapes. The valley bottom is green and then loses this color with altitude. Students can cite the presence of snow at altitude as a common pattern seen as temperature is known to decrease with increasing altitude. The tree line is quite visible in the photo, just below the edges of visible snow/ice.

Image 2:
Ice, water, sand, pebbles, glacier and clouds
Jökulsárlón Glacier Lagoon, and Breiðamerkurjökull Glacier, Iceland
Credit: Theresa Moody

In the foreground, we see rounded pebbles and rocks of every size, and a slightly rippled pool of water reflecting the image of the floating iceberg. The iceberg contains streaks of grey dirt and debris in flat layers, that are no longer oriented horizontally. Regions/bands of the ice are melting at different rates. In the distance we see a glacier, mountain and clouds.

Image 3:
Cross bedding on Mars
http://www.jpl.nasa.gov/spaceimages/details.php?id=PIA19076
Credit: NASA MSL

This view from the Mast Camera (Mastcam) on NASA's Mars Rover Curiosity shows an example of cross-bedding that results from water passing over a loose bed of sediment.
The cross-bedding -- evident as layers at angles to each other -- reflects formation and passage of waves of sand, one on top of the other. These are known as ripples, or dunes. The direction of migration of these small ripples and dunes was toward the southeast. That direction is toward Mount Sharp and away from the area where Curiosity found evidence of delta deposits where a stream entered a lake. The directional flows recorded in the sediments are interpreted to have formed by currents moving down the deltas and into deeper lake water. The color has been approximately white-balanced to resemble how the scene would appear under daytime lighting conditions on Earth.

Image 4:
Water erosion features and impact craters on Mars
Credit: ESA Mars Express

The heavily eroded Osuga Valles with streamlines around the islands in the valley indicate that the direction of flow; and sets of parallel, narrow grooves on the floor of the channel suggest that the water was fast flowing. Differences in elevation within the feature, along with the presence and cross-cutting relationships of channels carved onto the islands, suggest that Osuga Valles experienced several episodes of flooding. Impact craters are evidence of more recent events.

Image 5:
Comet 67P/Churyumov-Gerasimenko
https://www.esa.int/ESA_Multimedia/Missions/Rosetta/(result_type)/images
Image credit: ESA Rosetta mission
An image of part of Comet 67P/Churyumov-Gerasimenko that was visited in 2014 by the European Space Agency's *Rosetta* spacecraft and *Philae* lander. The *Rosetta* mission was the first to do extended observations of this comet. Astronomers sometimes call comets "dirty snowballs," but this comet is more accurately described as a"snowy dustball" because it contains more dirt than snow. This image was captured by Rosetta in orbit around the comet at a distance of about 16 km (10 miles).

Image 6:
Dog in IR
Credit: IPAC Caltech
http://coolcosmos.ipac.caltech.edu/image_galleries/ir_zoo/dog.html

This warm-blooded dog is covered with a thick coat of fur which prevents much of the heat generated by his body from escaping. In the infrared we can see how areas of the dog which are covered by thicker fur are cooler, while areas not covered by much fur, like the eyes, ears and mouth (when open) glow brightly in the infrared. Notice how cool the dog's nose is!

Image 7:
Jupiter in IR
Credit: NASA/SOFIA/USRA/FORCAST Team/James De Buizer

SOFIA, the Stratospheric Observatory for Infrared Astronomy, captured its "First Light" images on May 26, from an altitude of 35,000 feet. While flying above most of planet Earth's infrared- absorbing water vapor, SOFIA's premier infrared views of the cosmos included this remarkable false-color image of Jupiter. The image shows the bright white stripe below Jupiter’s equator where infrared radiation from the planet was most intense at wavelengths of 5.4, 24, and 27 microns. Other locations on Jupiter were not emitting infrared radiation as intensely as that latitude stripe below the equator.

As noted above, astronomers already knew that Jupiter put out more energy than it received from the Sun. That glow from Jupiter was understood to be energy coming from Jupiter's interior that has a very high temperature because of heat trapped there when Jupiter formed. Astronomers expected that most of Jupiter's interior heat would 'leak' out pretty much evenly all over the planet.

Image 8:
Circumnuclear Ring
Image Credit: NASA/DLR/USRA/DSI/FORCAST Team/Lau et al

SOFIA/FORCAST mid-infrared image of the Milky Way Galaxy's nucleus showing the Circumnuclear Ring (CNR) of gas and dust clouds orbiting a central supermassive black hole. The nucleus of the Milky Way is inhabited by a black hole with 4 million times the mass of the sun that is orbited by a large disk of gas and dust. The CNR is the inner edge of that disk. The bright Y-shaped feature is understood to be material falling from the ring toward the black hole that is located where the arms of the "Y" intersect.

Image 9:
Space shuttle during re-entry
Image Credit: NTRS NASA

Infrared image of a space shuttle heated by atmospheric friction to temperatures as high as 1650°F.

Image 10:
Crab Nebula
Image Credit: IPAC Caltech
https://coolcosmos.ipac.caltech.edu/infrared_gallery/5

The Crab Nebula is an expanding remnant surrounding the site of a supernova explosion that was noted by Chinese astronomers in 1054 AD. In this infrared view we see both the cloud of hot electrons that are whirling around inside the dead star's magnetic field (symbolized by blue color), and extraordinary hot, gassy filaments seen at many wavelengths (red).