Infrared Light and Infrared Astronomy

Learning Plan Days 7 and 8:
How do astronomers use spectra to investigate objects in the Universe?

Targeted Ideas: Optical devices can break light into its component parts called spectra. Every substance has its own unique spectral signature; finding the signature means that substance is present in the object being examined.

Overview of Days 7 and 8:

Astronomers use a variety of tools to examine the light from objects in the Universe. One essential tool in astronomy is the diffraction grating, which has been modified and improved over time. Gratings split (diffract) light into a spectrum by sending light of different wavelengths into very slightly different directions. Astronomers study the spectra of objects to look for the presence of a particular substance - each one has a known signature.

Students start this day by tying up some lose ends from Day 6. They begin by discussing the CircumNuclear Ring Case Study, using the Case Study Focus questions as a guide. They are then asked to consider the similarities and differences in how the astronomers used the image data.

The students are reminded of the wavelength model of light introduced on Day 2. The students are asked to recall (and consult) the data that they collected on Day 1 (the blue filter let through light that was green, not blue). They are given a green LED and white LED with a blue filter. They are asked to collect more data by observing blue-filtered green light and blue-filtered white light through the spectroscopes.

They students are also asked to review data depicting the spectrum of the filters as a graph. The data show light emitted from the green light and passing through the blue filter actually includes some green light. The data show light emitted from the white light and passing through the blue filter actually includes some green and red light. Students add to their explanations with model and evidence, to illustrate how we "see" infrared images and how we see white light through a blue filter and spectroscope. This includes viewing infrared images through an IR camera, and the GAM Filter Spectra Data sheet.

The students observe a spectrum from an incandescent lamp and emission spectrum from a CFL lamp with spectroscopes and record their observations. They use these data, in combination with solar and planetary atmosphere spectra, to make evidence-supported statements about the chemical composition of the atmospheres of the Sun, Mars, Earth, and Venus. In preparation for homework and activity on Day 9, students are presented with a Crosscutting Concepts (CCCs) guide.

Middle School Performance Expectations (PEs) and Disciplinary Core Ideas (DCIs) relevant to Days 7 and 8:

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.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 are building their understanding toward these High School DCIs in Days 7 and 8:

PS4.B.1 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 ~~while the particle model explains other features~~.

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.

PS4.B.4 Electromagnetic Radiation
Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities.

ESS1.A The Universe and Its Stars
The study of stars' light spectra and brightness is used to identify compositional elements of stars ~~their movements, and their distances from Earth~~.

Students are building their skills in / understanding of these Science and Engineering Practices (SEPs) and Cross Cutting Concepts (CCCs) in Days 7 and 8:

<u>**SEPs**</u>

Asking Questions

- Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
- Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.

Developing and Using Models

- Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria.

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.

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.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

<u>**CCCs**</u>

Patterns

- Empirical evidence is needed to identify patterns.

<table>
<tr><th>Instructional Materials</th><th>Resources</th></tr>
<tr><td>Handouts:
• GAM Filter Spectra Data Day 7
• Absorption Spectral Data Day 8
• Student Sample Model B
• Student Support Guide to examine Science Case Studies for Crosscutting Concepts

Materials:
• Spectroscope for each student
• Incandescent lamp
• CFL lamp
• Light base with rheostat
• Blue filters and green and white LEDs
• Button batteries for the LEDs
• Colored pencils, crayons, or markers
• Chart paper</td><td>• Day 7 and 8 PowerPoint</td></tr>
<tr><th colspan="2">DAY 7</th></tr>
<tr><th>Teacher Role:</th><th>Student Role:</th></tr>
<tr><td>• Prepare materials for emission tube and spectra demonstrations.
• Distribute materials.
• Summarize the puzzling phenomenon about blue filters and LEDs from Day 1, but do not tell students how to interpret this phenomenon with the new spectra in- formation. Clarify the CCCs as needed
• During the discussions, circulate and listen to conversations, making note of key student thoughts.
• Ask questions to help guide students.
• Share a few good examples overheard during discussions.
• (If time allows) Facilitate a gallery walk.</td><td>• Share thoughts and notes about both Case Studies.
• Contribute to group discussions.
• Listen to peer ideas.
• Admit areas of uncertainty.
• Make notes in preparation for sharing.
• Review observations and new data</td></tr>
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Steps to follow:

1) *Share Homework:* Ask the students to discuss the CircumNuclear Ring Science Case Study using the Focus Questions as the guide for conversation.
   - Who completed the study?
   - What object was being studied? Why was that object selected?
   - How the object was observed? (With what instruments? At what wavelengths?)
   - Describe some of the data collected and how that was used to construct an explanation of the scientists' results.
   - Why was this result important?
   - What were things you didn't understand or questions you had?
2) Today, we will use a new tool to help us understand light: spectroscopes. This tool "breaks apart the light" to let us look at the components that are not noticeable to us (because our eyes blend all of the colors together). Spectroscopes work like a prism or the holographic grating used to generate spectrum on Day 5. Notice the holographic diffraction grating slide on one end of the spectroscope. We can use this tool to collect more data around the mystery from Day 1 (the green LED light partially passed through the blue filter, suggesting it was not all green light).

3) *Elaborate:* Distribute spectroscopes, blue filter, green and white LEDs, batteries, and pencils or crayons. (The spectroscope will show that green LED light is really made up of green, as well as some blue light.)
   - Observe the green LED light with and without the spectroscopes.
   - Is the green light truly completely green?
   - Carefully record observations, including any drawings, thoughts, and questions.

4) Distribute blue filters. (The spectroscopes will show that blue filter really lets through light that is blue, as well as some green and red light.)
   - Observe the green LED light through the blue filter with a spectroscope.
   - Observe the white light with a spectroscope, and also view the white light through the blue filter with a spectroscope.
   - Does the blue filter truly block all wavelengths except blue?
   - Carefully record observations, including any drawings, thoughts, and questions.
5) Distribute the GAM Filter Spectra Data. Students compare their findings to the handout, and discuss how the blue filter spectrum curve explains their observation that the blue filter allowed more than just blue light to reach the eye. The filters in scientific instruments perform in the same manner. While a filter might be called a 37 micron filter, it allows a range of wavelengths around 37 microns to reach the detector.

6) Astronomical observing overview.

- The FORCAST instrument on SOFIA was used in the Jupiter, M2-9 planetary nebula, and CircumNuclear Ring studies. FORCAST (*Faint Object InfraRed CAmera for the SOFIA Telescope)* took photos of faint objects with different wavelength filters. The astronomers then produced images of the objects at different wavelengths, and these could be combined into a composite (combined) image.
- The Pluto Occultation research used HIPO (*High-speed Imaging Photometer for Occultations).* It measured the brightness of an object over a period of time and produced a light curve.
- Observatory flexibility: the scientific instrument can be changed depending on which kind of data the astronomers need for their research (images, spectra).
- One of the MOST important tools for any astronomer is **Spectra**, so we are going to look at what Spectra can tell us about the Universe next.

7) In groups add to the Group Explanation with Model and Claim – Evidence –Reasoning (CER).
   a) How we see a blue filtered light through a spectroscope (grating), and b) how we "see" an infrared image. Add more paper to the original explanation if needed. The explanation now illustrates how we see filtered light, IR light, and spectra. These models include both a drawing and a written description.

8) Distribute the last Science Case Study: Water in Sunlit Lunar Soil.

9) *Evaluate: Assign homework:* Students read the Case Study for homework and complete the usual questions on the Graphic Organizer, but also to *notice how the collected data differs from the type of data they have seen up to this point.*

Day 8	
Teacher Roles:	**Student Roles:**
• Prepare materials for emission tube and spectra demonstrations. • Distribute materials. • Summarize the puzzling phenomenon about blue filters and blue lights from Day 2, but **do not tell** students how to interpret this phenomenon with the new spectra information. • During the discussions, circulate and listen in on conversations, making note of key student thoughts. • Ask questions to help guide students. • Facilitate a gallery walk if time allows.	• Carefully make and record observations. • Participate in discussions and listen to peer ideas. • Admit areas of uncertainty. • Record group thoughts on chart paper. • Make notes in preparation for sharing. • If facilitated, respectfully observe and comment on the work of peers during gallery walk.

Steps to follow:

1) *Engage:* Set-up the light base at the front of the room. Turn on incandescent bulb at a low setting.
    - Students observe the light through spectroscopes - what colors does it actually contain?
    - What do they notice?
    - As you slowly turn the setting up, increasing brightness, the temperature increases. What do students notice? Turn the setting up and down slowly so students can observe the diminishing of the blue at the low setting.
    - Students turn to a partner and discuss: How do spectroscopes help us observe light?

2) Place the CFL lamp in the base. Turn the setting to highest setting. Students now observe an emission spectrum.
    - We can use diffraction gratings as a tool to understand the Universe.
    - Every time I turn on the CFL in, it shows the same emission lines (characteristic bars/wavelengths) of light.
    - If I observed a star, and I saw the same lines of light emitted, then I would know Mercury vapor is present.
    - The wavelength of light emitted or absorbed, the unique signature of that

element. In this manner, we can identify hydrogen, helium, oxygen, and etc.

3) Use PowerPoint slides to illustrate the following:
   - Emission vs. absorption spectra
   - Elemental spectra examples. The signatures are the same.
   - **Absence of signature does not mean that there is none of the substance; there could some present that we cannot detect with our current instruments.**
   - Compounds often have complex absorption "features." The darkness of absorption lines is often shown in a plot. The y-axis is brightness or intensity. The darker and wider the absorption line, the lower and wider the dip in brightness. Absorption means less light in that particular part of the spectrum.

4) *Explain:* Distribute Absorption Spectral Data. Use PowerPoint Slides
   - How can we know what we know about the atmospheres of planets that we have never traveled to? (Hopefully students will reply: We use spectra!)
   - Use the data on the handouts to make statements about the chemical composition of the Sun and the atmospheres of Mars, Venus, and Earth.
   - Give time for students to work in groups.
   - Ask one representative from each group to share their analysis of the data.
   - Allow other groups to respond or add.

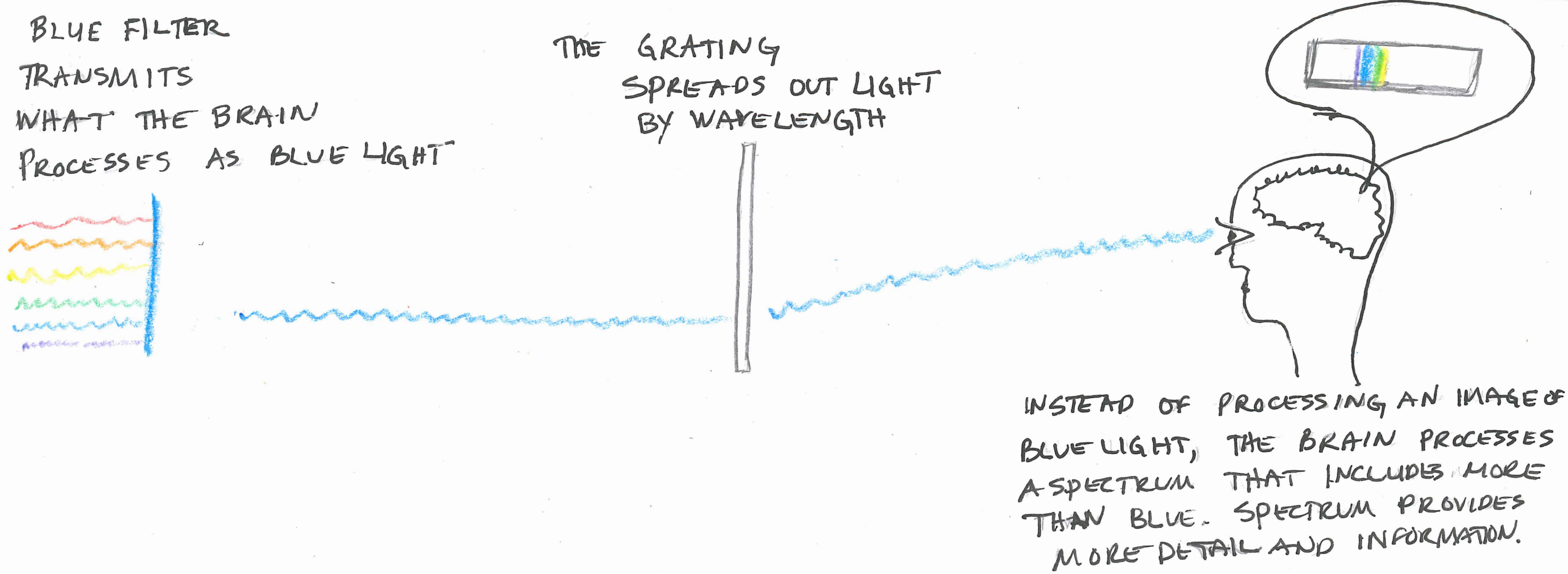
5) Wrap Up: Scientists can use diffraction grating instruments to help them to decipher the chemical composition of almost everything in the Universe: from nearby planetary atmospheres and surfaces, to stars, nebulae, the interstellar medium, and galaxies. The spectral lines extend beyond visible wavelengths, so when astronomers observe IR light through a diffraction grating, they can find spectral signatures that aren't detectable at visible wavelengths.

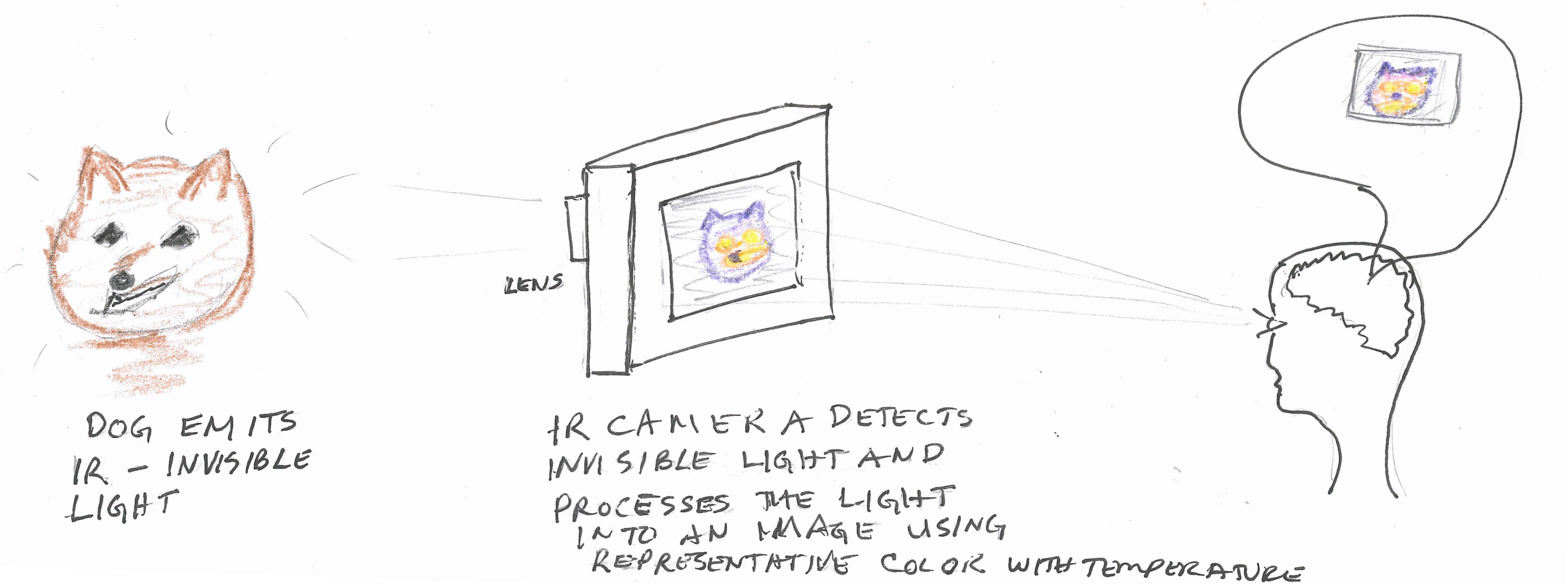
6) Using PowerPoint slides and the Student Support Pages for Crosscutting Concepts, provide a brief review of CCCs and how they are helpful.
   - A CCC is the lens that a scientist may use to view problems, or the approach they take when deciding how to study an object.
   - For example, if a scientist is trying to determine if something (x) affects (y), then they are viewing their phenomenon as a Cause and Effect problem.
   - Or if a scientist looks at many objects at once to search for similarities or form groupings, they are using the CCC of Patterns.
   - CCCs are reoccurring themes in the way scientists think about and solve problems.

7) If time allows, conduct a gallery walk of the Explanations with model and CER.

8) *Evaluate: Assign Homework:* Divide class into 5 groups, and assign each group a Case Study. Within each group, the students choose a CCC from the Guide: Patterns, or Stability & Change. Make sure that within each group, both CCCs are being

investigated. The homework assignment is to re-read the Case Study with CCCs in mind, and answer as many of the questions in the guide as possible for their selected CCC.

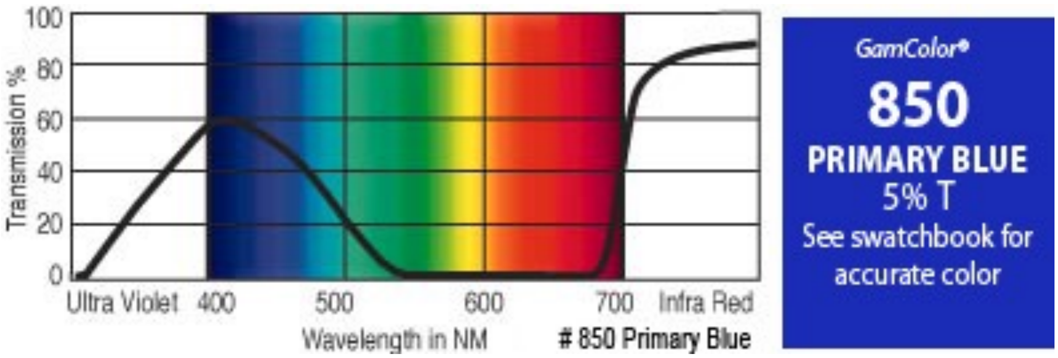

BLUE FILTER TRANSMITS WHAT THE BRAIN PROCESSES AS BLUE LIGHT
THE GRATING SPREADS OUT LIGHT BY WAVELENGTH
INSTEAD OF PROCESSING AN IMAGE OF BLUE LIGHT, THE BRAIN PROCESSES A SPECTRUM THAT INCLUDES MORE THAN BLUE. SPECTRUM PROVIDES MORE DETAIL AND INFORMATION.

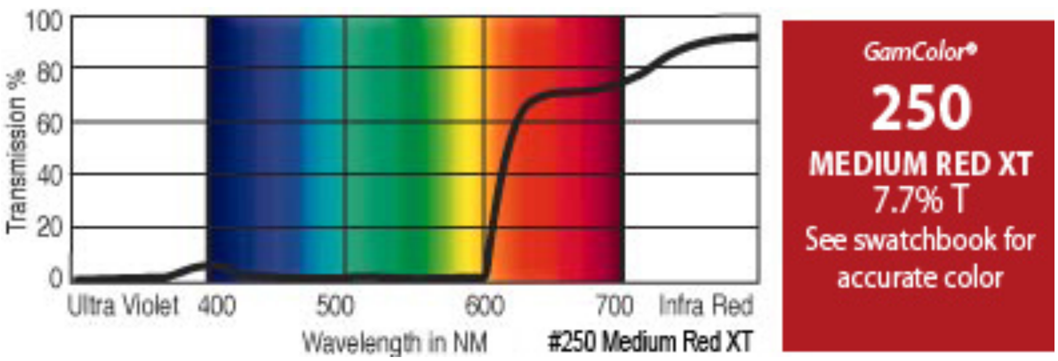

LENS
DOG EMITS IR - INVISIBLE LIGHT
IR CAMERA DETECTS INVISIBLE LIGHT AND PROCESSES THE LIGHT INTO AN IMAGE USING REPRESENTATIVE COLOR WITH TEMPERATURE

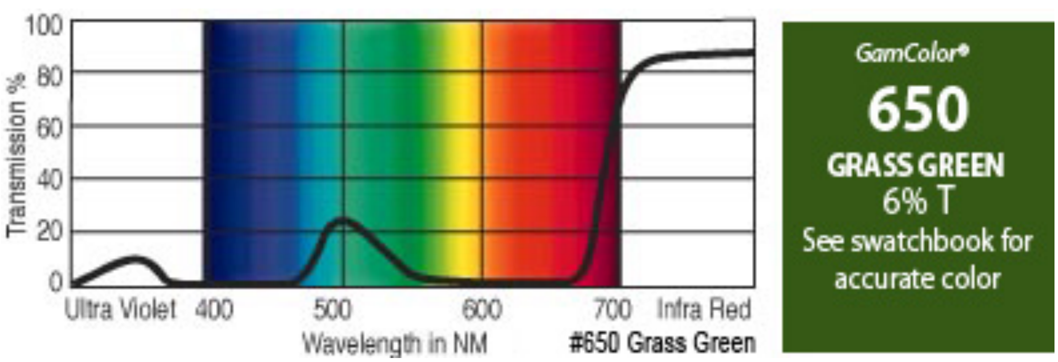
GAM Filter Spectra Data

Graphics from http://www.gamonline.com/catalog/gamcolor/numeric.php

The graphs below represent a simplified spectrum of each of the filters.



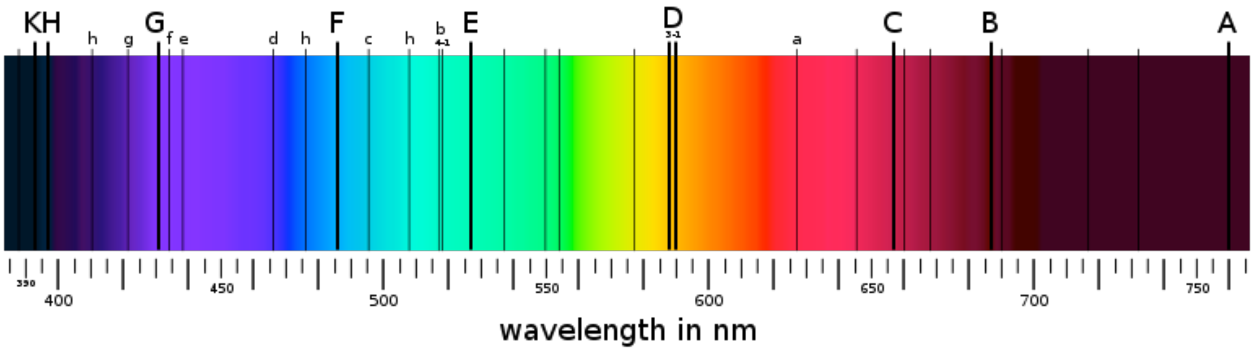


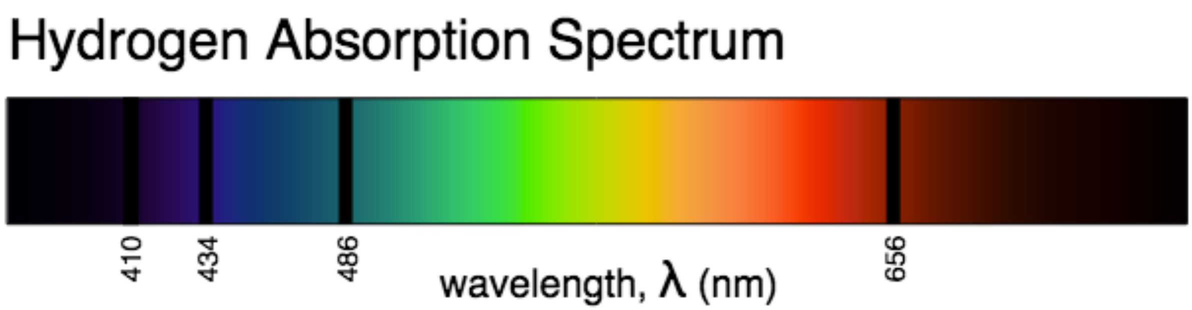


Day 8 – Spectral Data

Part 1: Use the following data to make statements about the chemical composition of the Sun:

Solar Absorption Spectrum

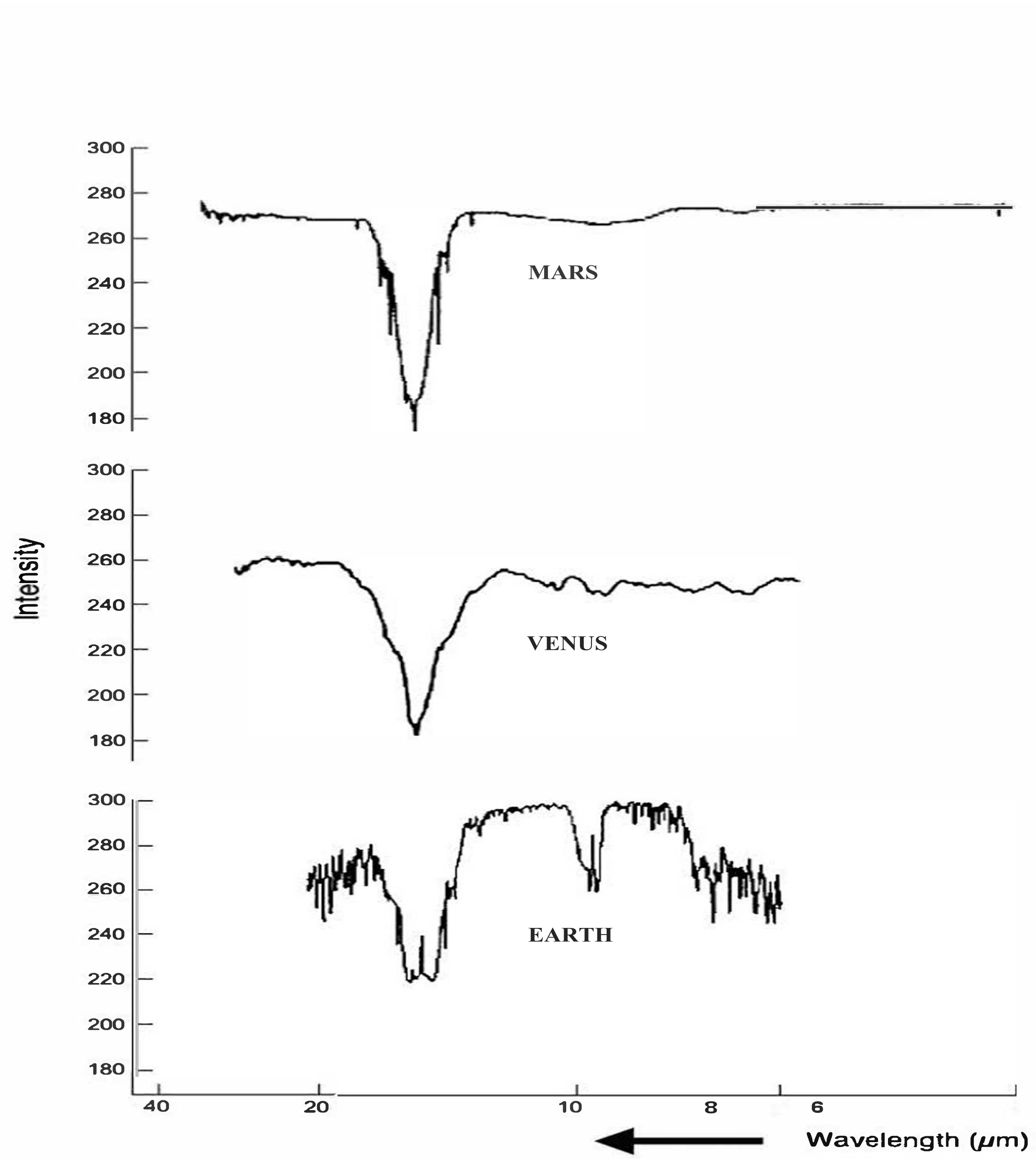




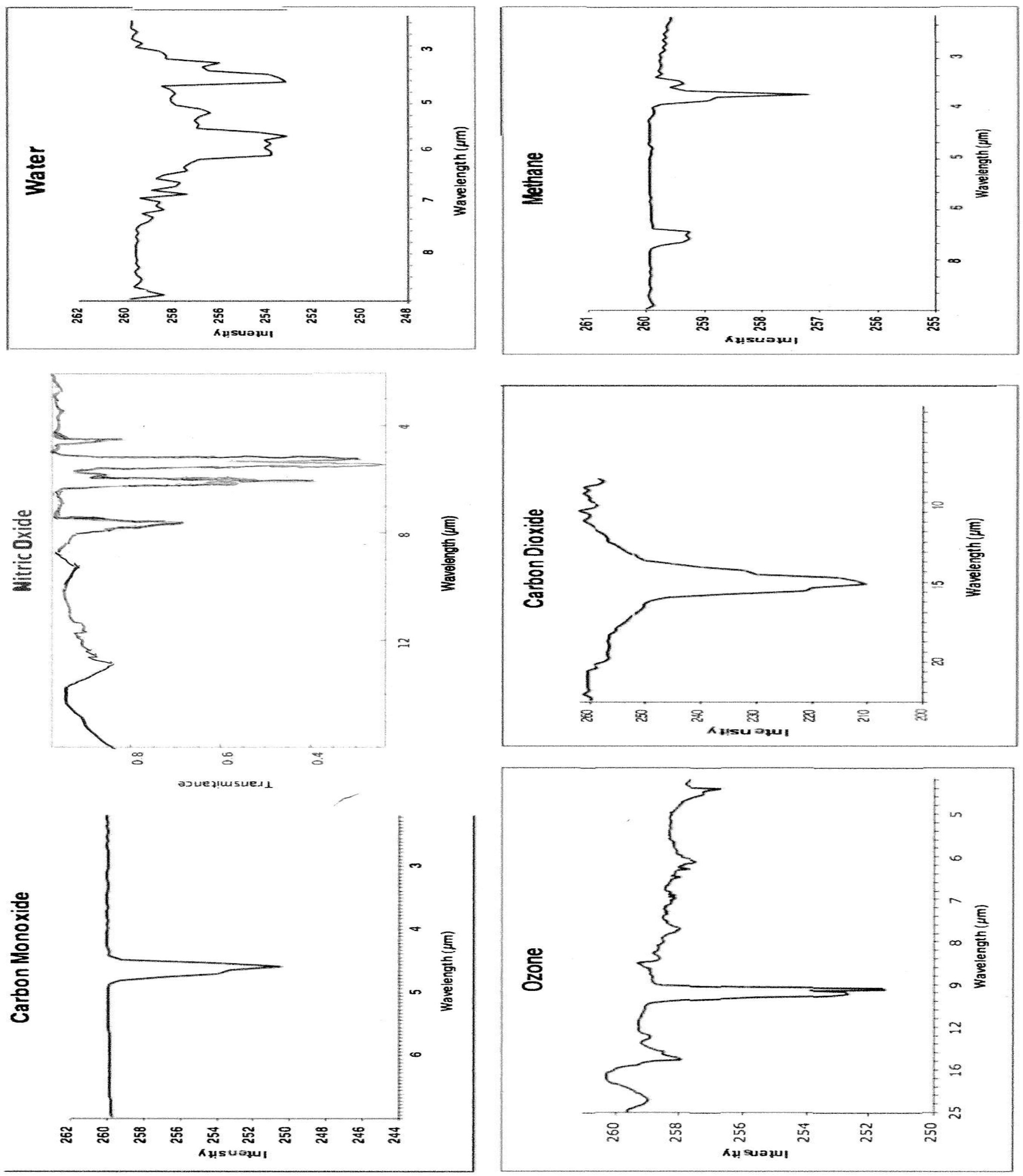
A cool, transparent gas in front of a hot, opaque body produces an absorption (dark-line) spectrum.

Part 2: Use the data on the following two pages to make statements about the chemical composition of each planet's atmosphere. What makes Earth unique?

Top: Spectrum of Mars taken by the Mariner 9 spacecraft in the 1970s.
Middle: Spectrum of Venus taken by the Venera 15 spacecraft in the 1980s.
Bottom: The spectrum of Earth taken by the Nimbus 4 spacecraft in the 1970s.



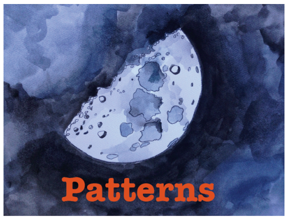
Known spectra of six atmospheric gases.
(Be sure to look carefully at the plot wavelength scales!)



Materials adapted from Project SPECTRA!: Goldilocks and the Three Planets.
Nitric Oxide spectrum is from the NIST WebBook © 2018 U.S. Department of Commerce.

Student Support Guide to Examine Science Snapshots for Crosscutting Concepts
Adapted from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. NRC 2012*, and http://crosscutsymbols.weebly.com Images Copyright 2013 Peter A'Hearn/Crosscut Symbols

PATTERNS



Patterns exist everywhere—in regularly occurring shapes or structures and in repeating events and relationships. For example, patterns are discernible in the symmetry of flowers and snowflakes, the cycling of the seasons, and the repeated base pairs of DNA. Noticing patterns is often a first step to organizing and asking scientific questions about why and how the patterns occur.

One major use of pattern recognition is in classification, which depends on careful observation of similarities and differences; objects can be classified into groups on the basis of similarities or on the basis of similarities of function. Once patterns and variations have been noted, they lead to questions; scientists seek explanations for observed patterns and for the similarity and diversity within them.

The ways in which data are represented can facilitate pattern recognition and lead to the development of a mathematical representation, which can then be used as a tool in seeking an underlying explanation for what causes the pattern to occur. For example, biologists studying populations can plot data for several different species on the same graph to look for patterns (e.g. every time the fox population increases, the rabbit population decreases).

Questions that Scientists might be asking themselves if they are viewing their question/problem through the lens of Patterns:

Is there a pattern in the data?
What is the evidence for this pattern?
Do similarities and differences reveal a pattern?
Is this pattern real or imagined?
What predictions can I make based on this pattern? Can I test them?
Is there a cause for this pattern?
How does this pattern compare to other patterns I have studied?

Identify which Science Case Study or Studies represent(s) examples of scientists looking for Patterns, and explain the patterns they were looking for or the patterns they found.

STABILITY AND CHANGE

Scientists are constantly trying to build their understanding of changes occurs in nature, or examine systems that remain stable. Stability can represent a system that is unchanging, or one that is in a repeating pattern of change—such as the Moon orbiting Earth.

A system can be stable on a small time scale, but on a larger time scale it may be seen to be changing. For example, when looking at a living organism over the course of an hour or a day, it may appear stable; yet over longer periods, the organism grows, ages, and eventually dies. For the development of larger systems, such as the variety of living species inhabiting Earth, the movement of tectonic plates, or the formation of a galaxy, the relevant time scales may be very long indeed; such processes occur over millions or even billions of years.

Questions that Scientists might be asking themselves if they are viewing their question/problem through the lens of Stability and Change:

What causes change in this system?
What causes stability in this system?
Is this system experiencing regular intervals of change, followed by stability?
Are there feedbacks that make this system more or less stable?
What is the time scale for this system to remain stable or change?
How quickly will this system return to being stable after it is disrupted?
If the system is stable, what would cause it to change?
If the system is changing, what would make it become stable?
How does stability or change in this system compare with other systems I have studied?

Identify which Science Case Study or Studies represent(s) examples of scientists looking at Stability or Change, and explain what they were looking for or what they found.