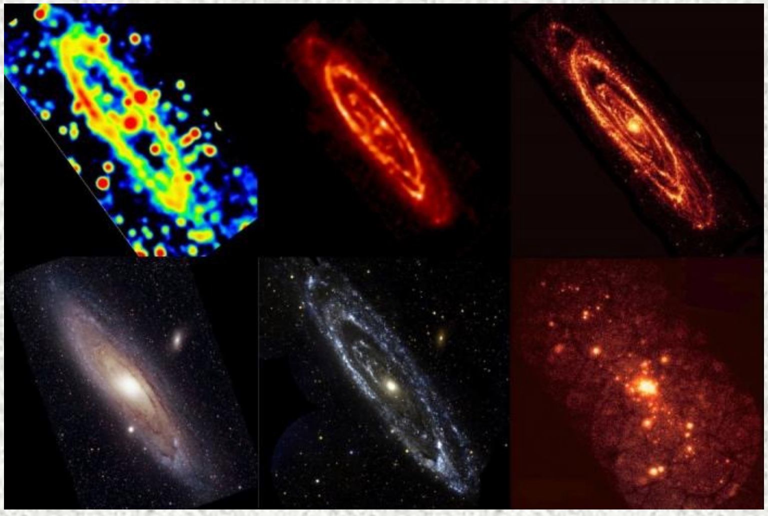
Electromagnetic Spectrum and Multi-wavelength Astronomy

Day 1

INITIAL PROBE



Wei: “I don’t think cameras can photograph different wavelengths of light. It’s just like one of those Instagram filters that changes colors around after you take the photo.”

Latoya: “These can’t be real photos. Galaxies don't produce microwaves, radio waves can only be heard and not seen, and the Sun is the only thing that produces UV light.”

Juan: “I think they used filters, so that the camera only recorded certain colors of visible light coming from the galaxy. When you combine them together, it makes a photo, just like what you would ordinarily see with your own eyes.”

Sofia: “I think each image is recording a different wavelength of light coming from the object. So, the camera must have a sensor that can detect those wavelengths, and then it shows that as different colors.

Jared: “Each image looks different because of the speed of the waves. For example, the radio images looks different because that light travels much slower than visible light, and the infrared light travels the fastest.”

Which student(s) do you agree with the most? _______________
Explain why you agree.

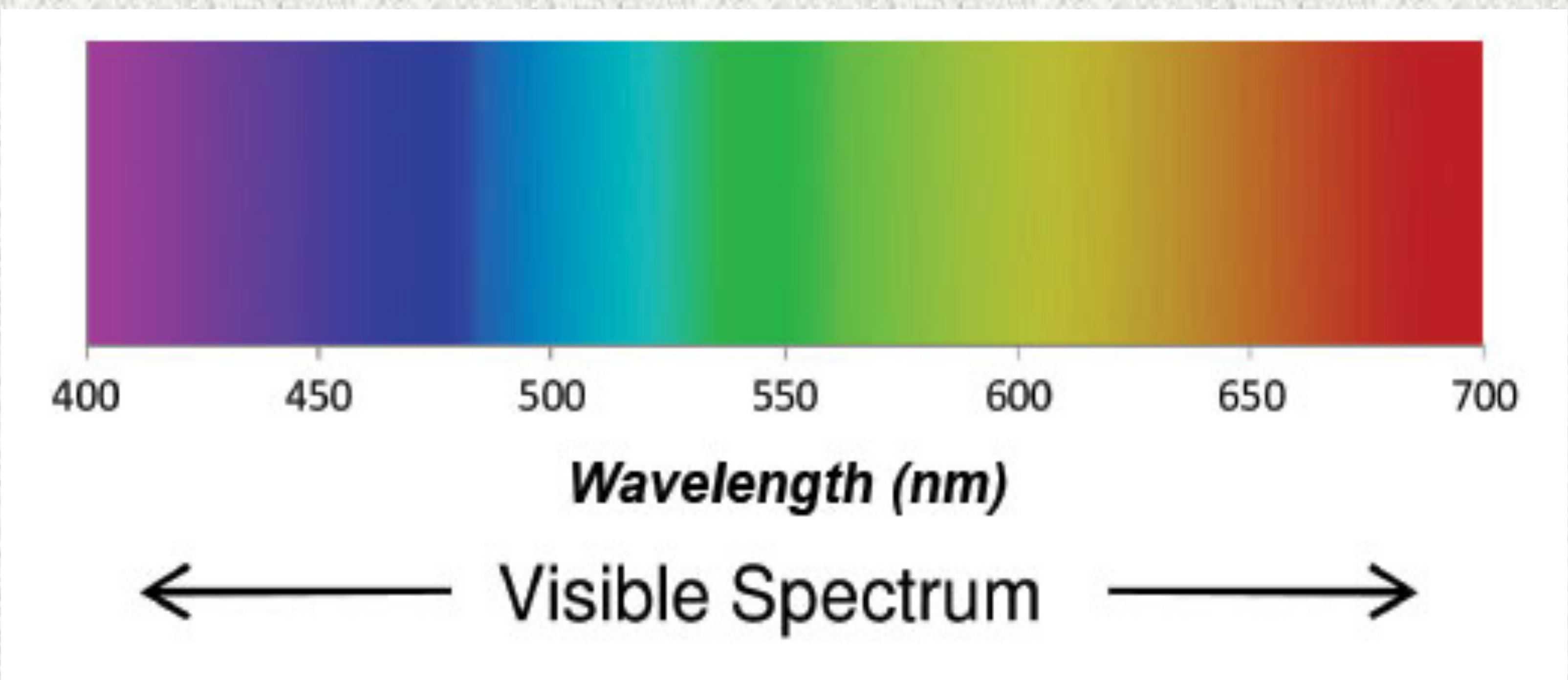
Science Case Study Focus Questions

- Who completed the study?
- What object was being studied? Why was that object selected?
- How was the object observed? (E.g., with what instrument(s)? At what wavelength(s)?)
- Describe one piece of data collected and how it was used to construct an explanation of the scientists' results.
- Why is this result important?

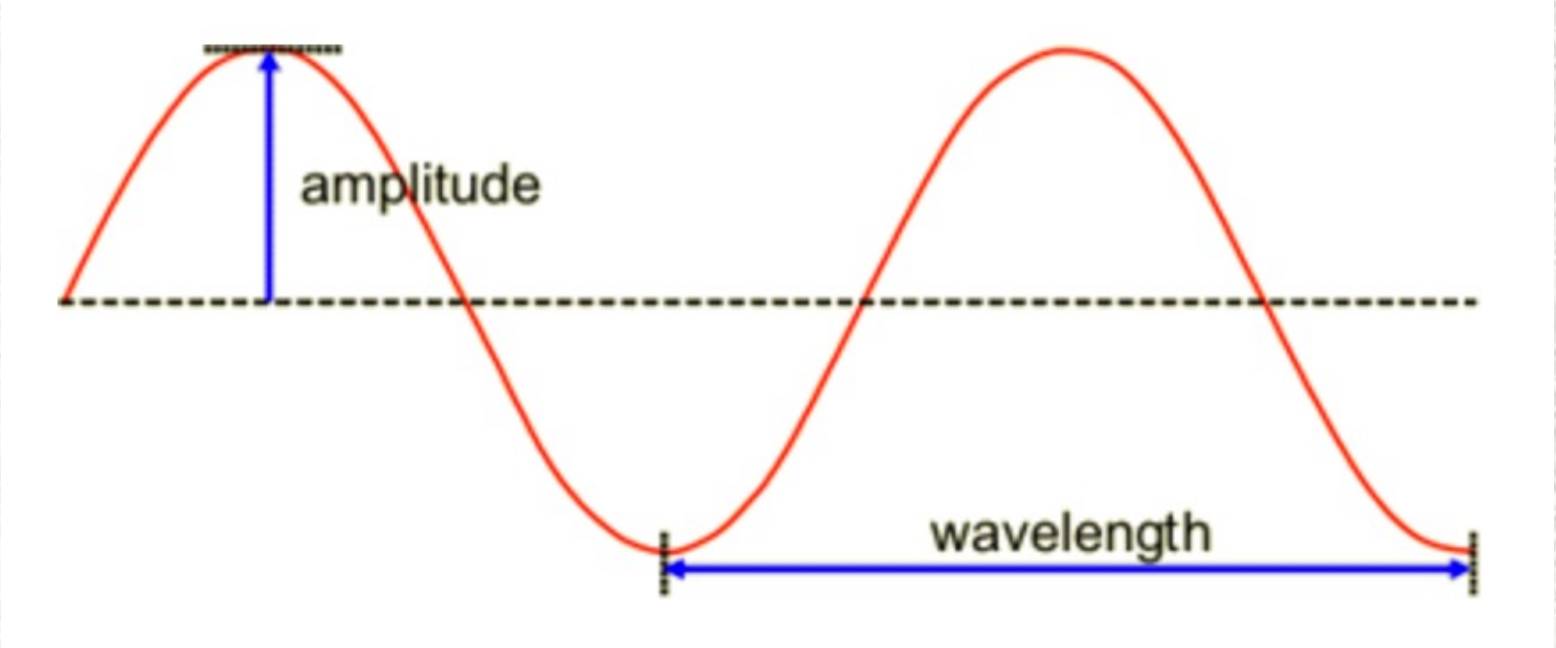
Day 2

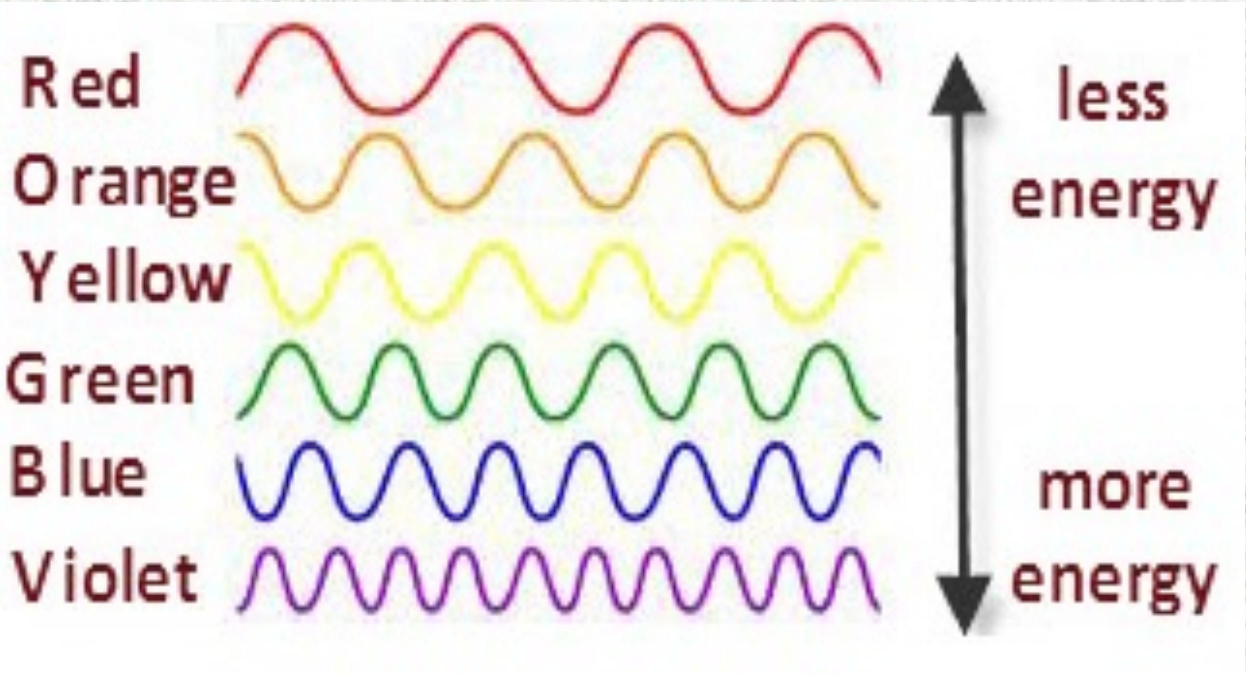
Visible Light Spectrum: Review (1)

Light within certain ranges of wavelength, frequency, and photon energy values can be seen by human eyes and is useful to us. The visible spectral region starts at red color and ends at violet color. From red to violet, the **wavelength decreases** and **energy per photon (particle of light) increases**. The speed of light is constant across the spectrum.

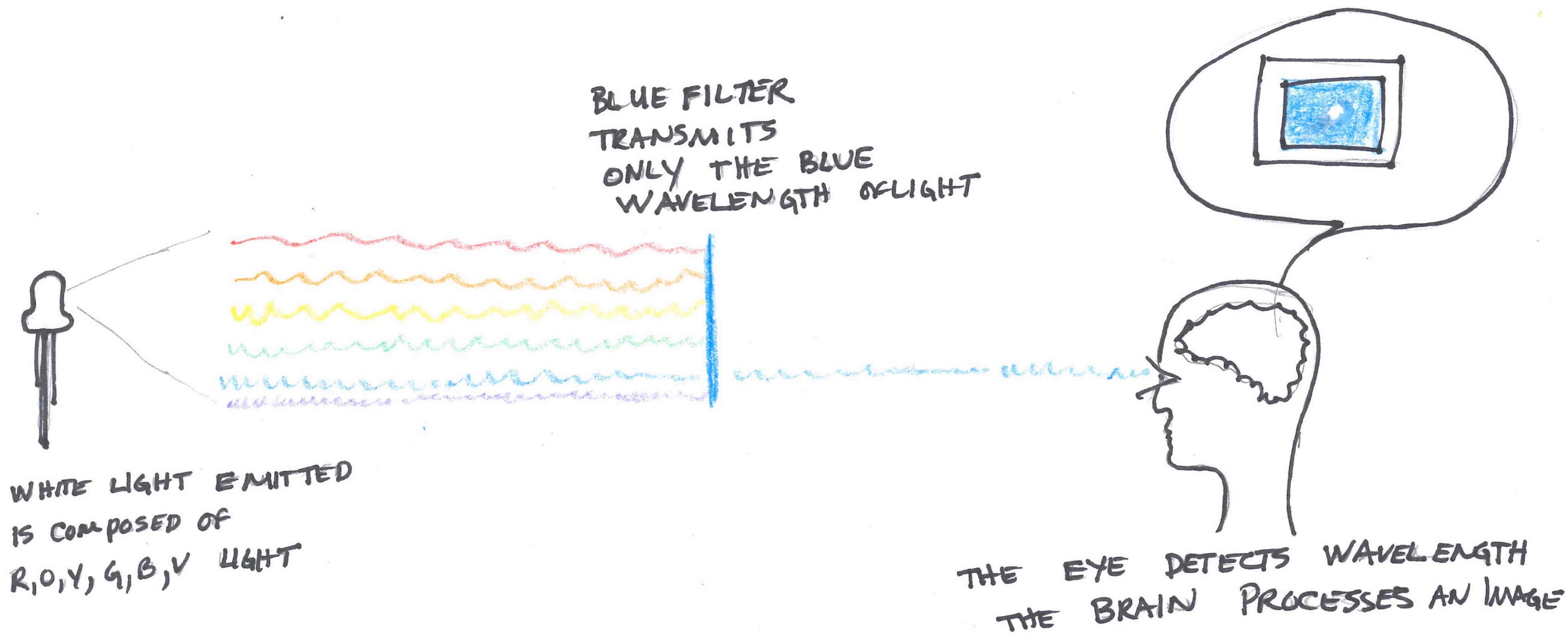


Visible Light Spectrum: Review (2)





Sample Student Model A



D2

Unit Organizer Questions

- What are some properties of visible radiation?
- What are some properties of infrared (IR) radiation?
- What can IR radiation tell us about objects in the Universe?
- How do we know (what is the evidence to support the idea) that there is more “light” beyond what our eyes can see?
- What are the different ways we can detect and record IR radiation data?
- What are the different scientific instruments used with the IRTF, SOFIA, and JWST? How do they collect information about objects in the Universe?

Day 3

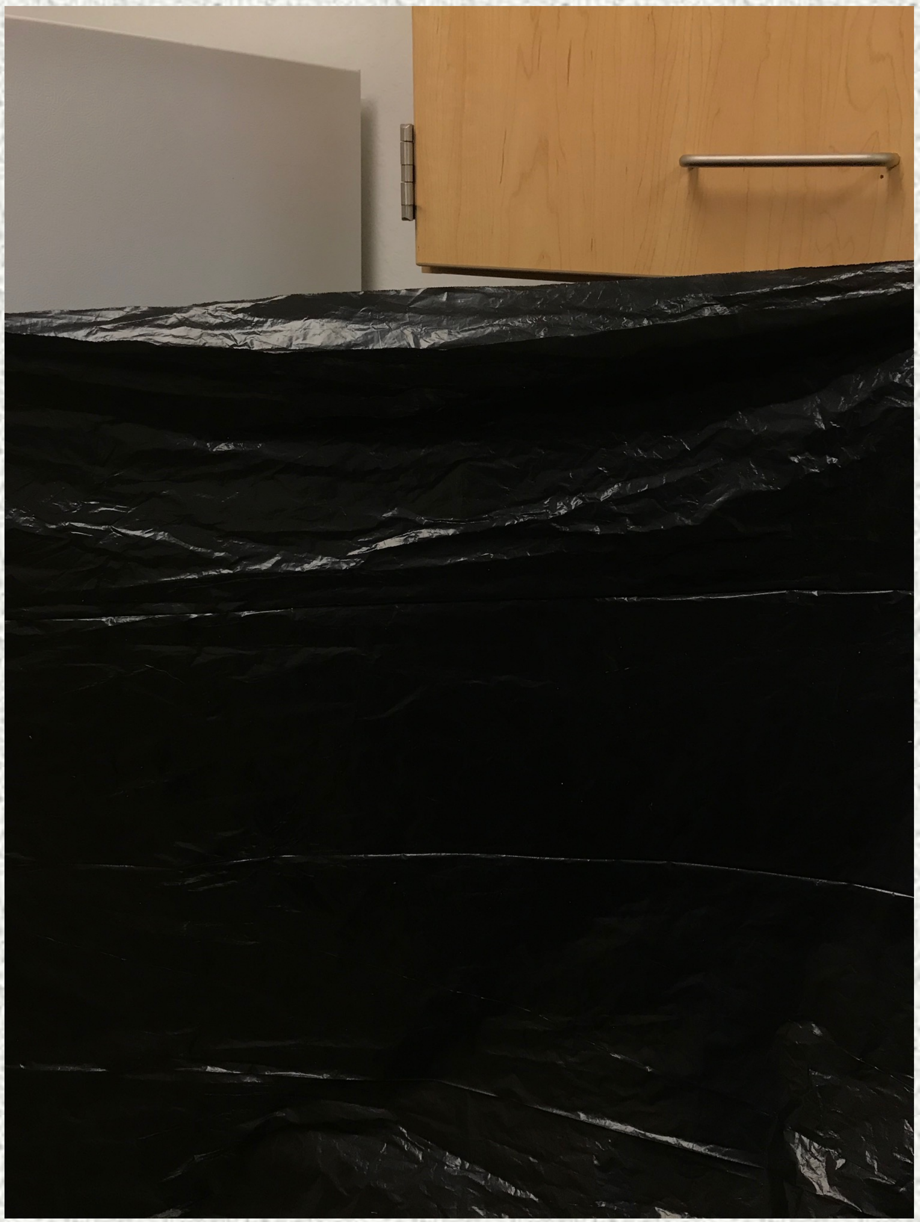
1. Can special cameras detect light that our eyes cannot see/detect?

2. Could the camera see through this object? (trash bag; plexiglass)

3. Is the object a filter or a blocker / absorber? (trash bag; plexiglass)

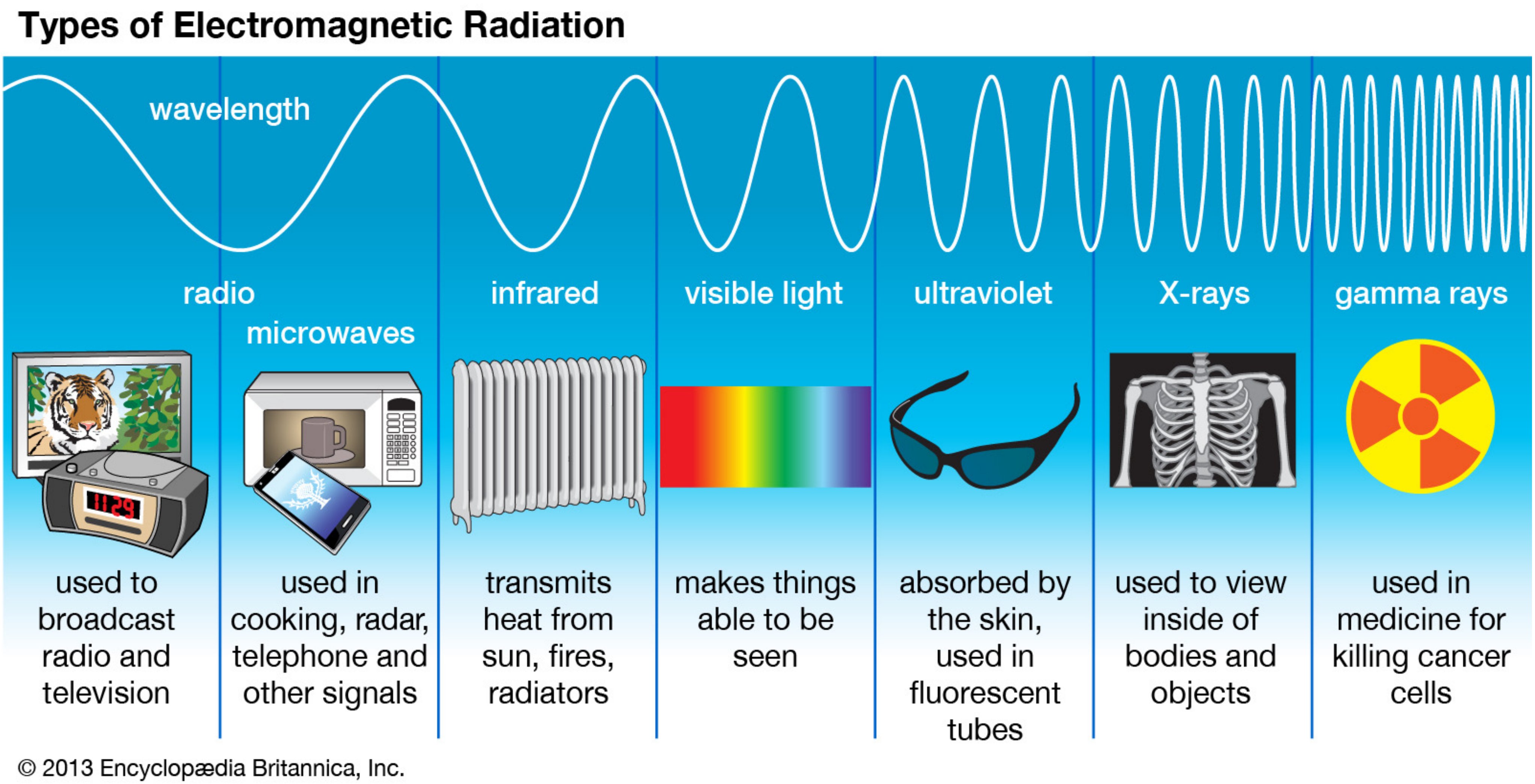
D3

Visible Light & Invisible Light

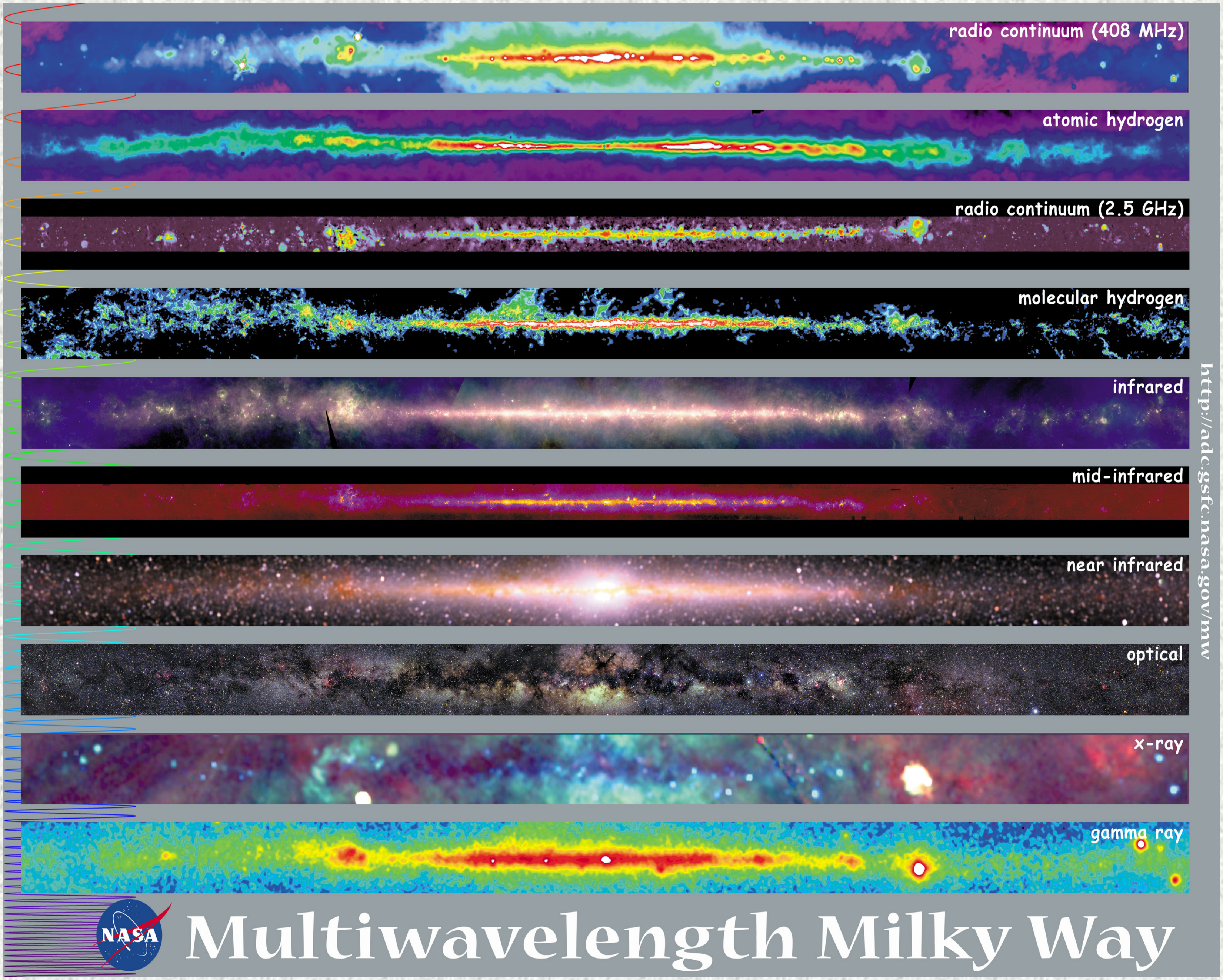


D3

EM Spectrum: Review (1)



EM Spectrum: Review (2)



EM Spectrum: Review (3)

NASA VIDEOS:

Introduction to the Electromagnetic Spectrum

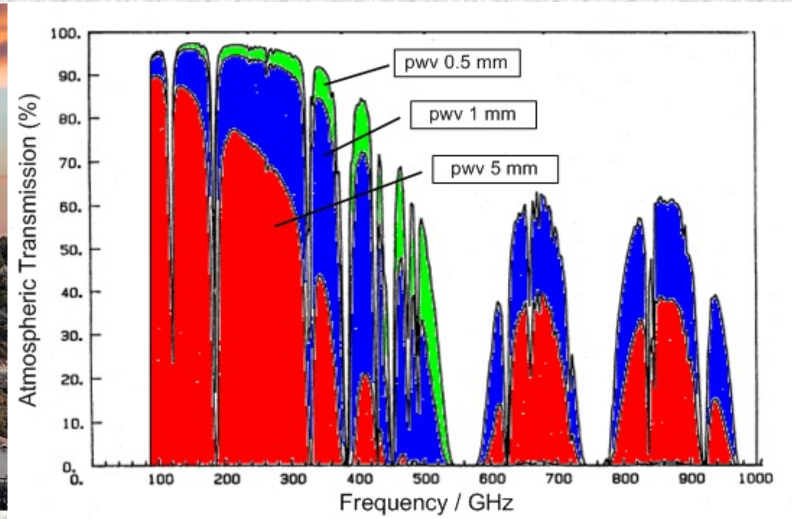
https://science.nasa.gov/ems/01_intro/

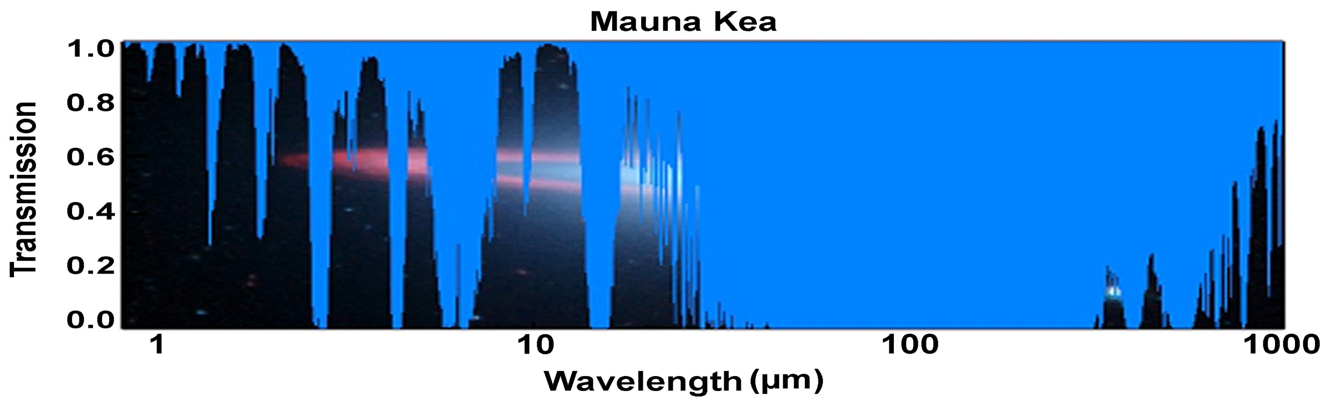
Infrared: More Than Your Eyes Can See

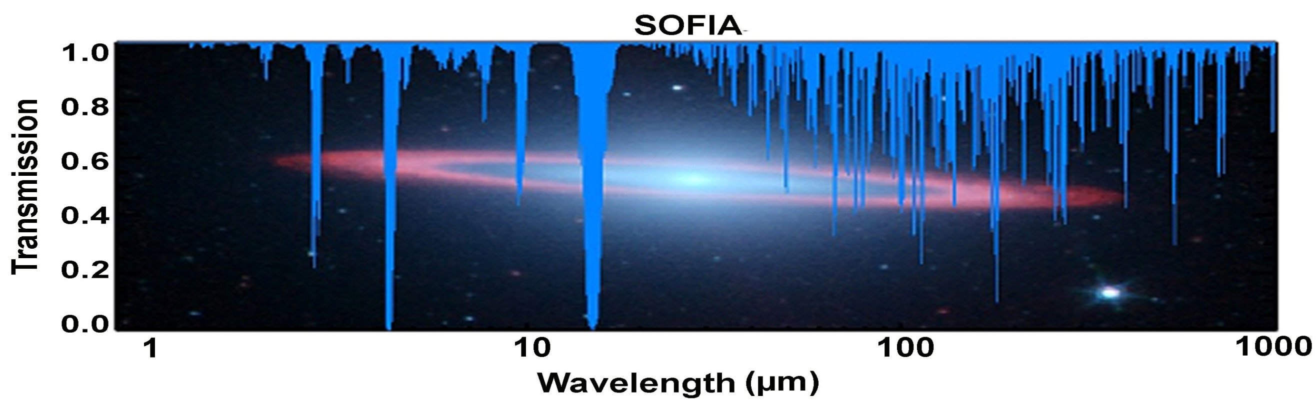
https://www.jpl.nasa.gov/video/details.php?id=180

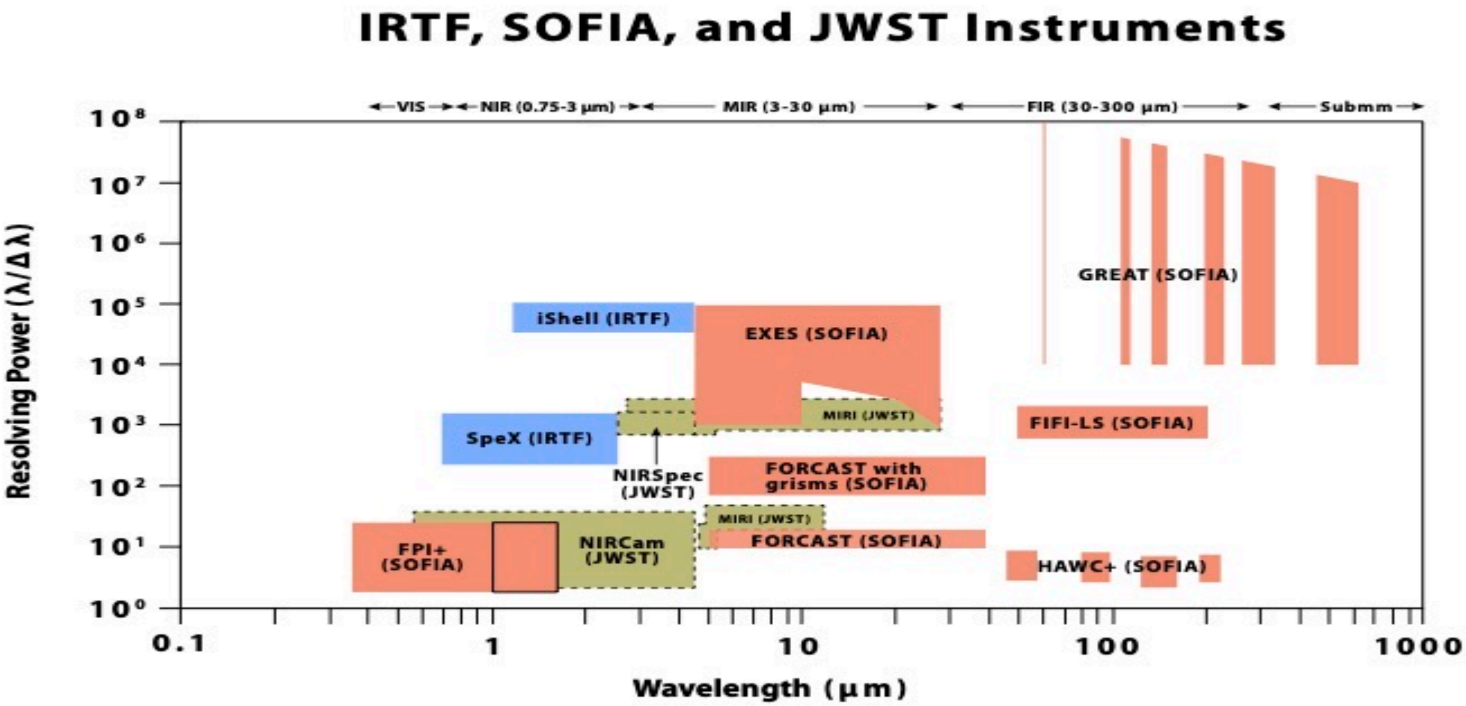
RIGHT PLACE AT THE RIGHT TIME (1)

Kitt Peak
h = 6900 ft

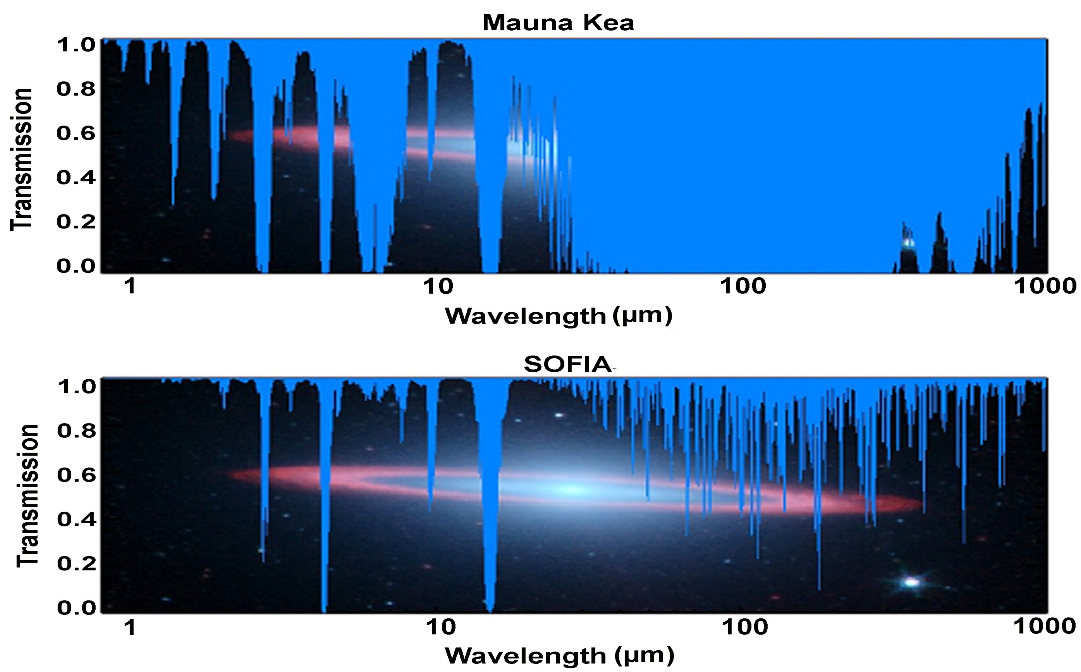








IRTF, SOFIA, and JWST Instrument ”footprints” = spectral resolution vs. wavelength



D3

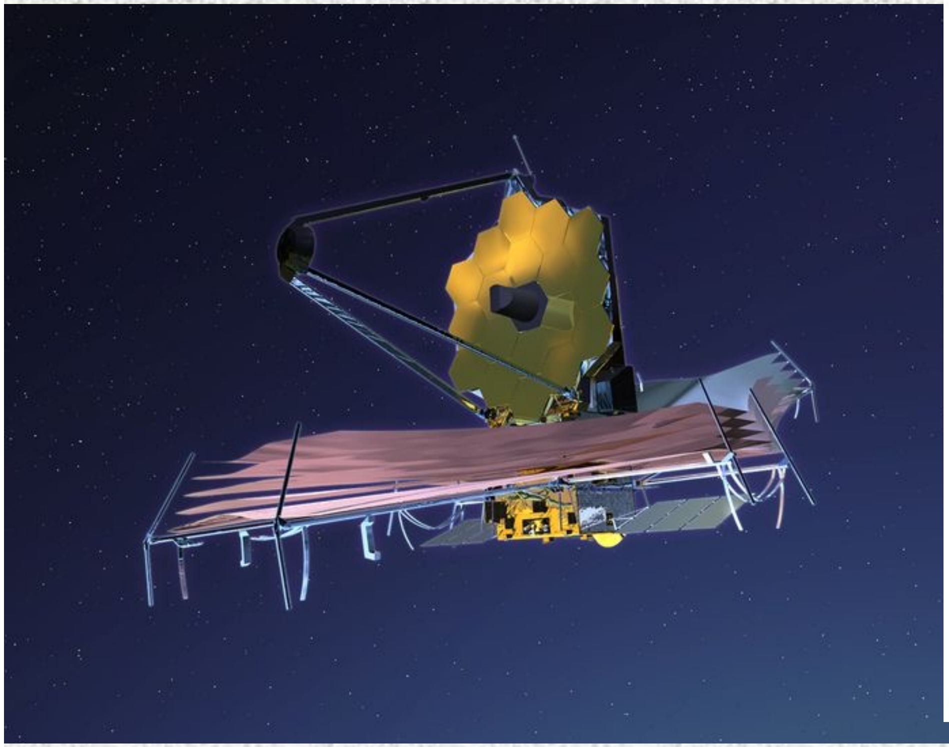
Support Resources Regarding NASA Infrared Observatories

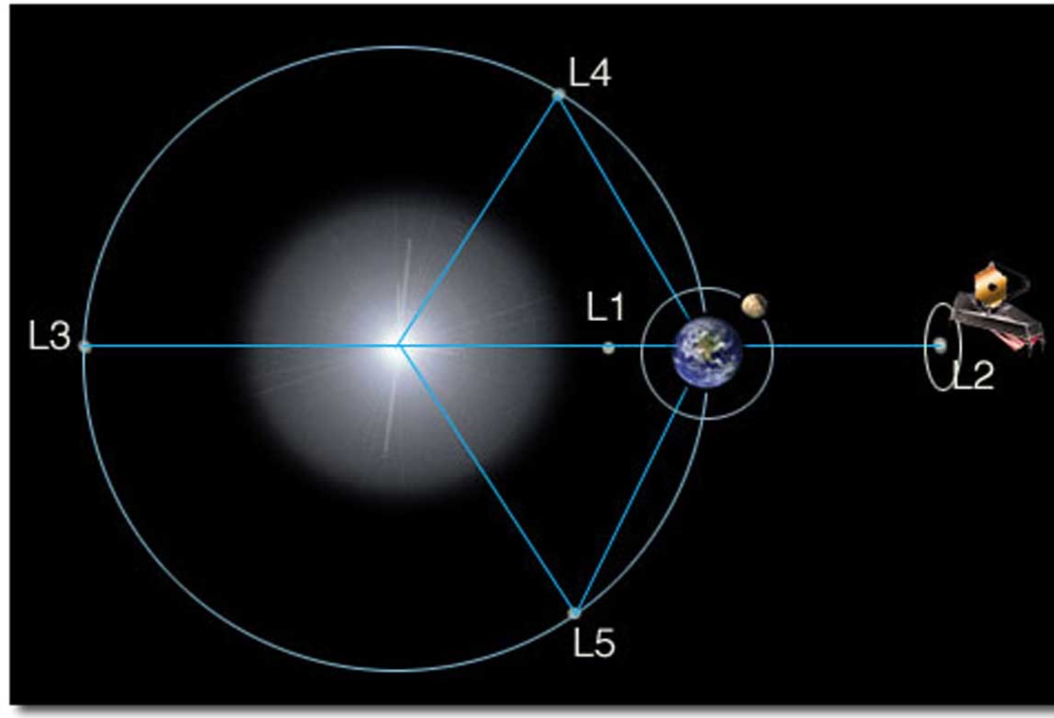
- NASA's Infrared Telescope Facility (operated by the University of Hawai`i): http://irtfweb.ifa.hawaii.edu/
- NASA's IRTF page: https://astrobiology.nasa.gov/missions/nasa-irtf/

- James Webb Space Telescope: https://webbtelescope.org/
- JWST Science: https://webbtelescope.org/webb-science

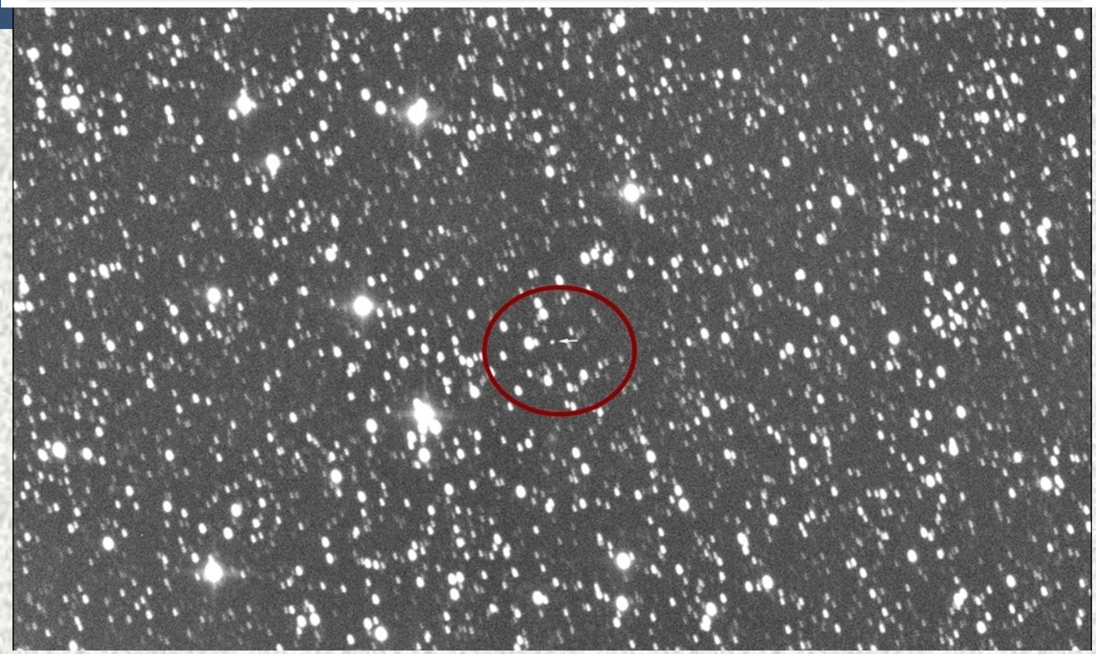
For historical reference:
NASA's SOFIA page: https://www.nasa.gov/mission_pages/SOFIA/index.html

RIGHT PLACE AT THE RIGHT TIME (3)





James Webb Space Telescope (JWST)



Day 5

CLAIM – EVIDENCE – REASONING: SCIENTIFIC EXPLANATIONS

Statement about the results of an investigation:

- A one-sentence answer to the question you investigated;
  - * It answers: **What can you conclude?**
  - * It should NOT start with **'Yes'** or **'No'.**
  - * It should describe the relationship between **dependent** and **independent** variables.

Evidence must be:

- **Sufficient** — Use enough evidence to support the claim.
- **Appropriate** — Use data that support your claim. Leave out information that doesn't support the claim.
- **Qualitative** — (using the senses / verbal), or **Quantitative** (numerical), or a combination of both.
- Shows **how** or **why** the data count as evidence to support the claim.
- Provides the justification for why **this** evidence is important to **this** claim.
- Includes one or more **scientific principles** that are important to the claim and evidence.

Scientific data used to support the claim tie together the claim and the evidence.

Day 6


Image 1
D6
Credit: Theresa Moody / SETI Institute

Probe for explanation and evidence!

- Ask one member to start with describing one observation, what they claim is in the image, providing as much data as they can find to support their explanation.
- Other members of the group should question them, probe them for more explanation, evidence, and examples.
- Switch roles regularly.
- Take notes!

Challenge Unsupported Statements

1) How do you know that?
2) Where have you seen another example of that?
3) What is it about the color, shape, orientation, etc. that leads you to say that?
4) Can you support that statement with some additional evidence or experience?
5) What might be another example of what you are describing?


Image 2
D6
Credit: Theresa Moody / SETI Institute


Image 3
D6
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Credit: ESA Mars Express

D6 *Credit: NASA MSL*

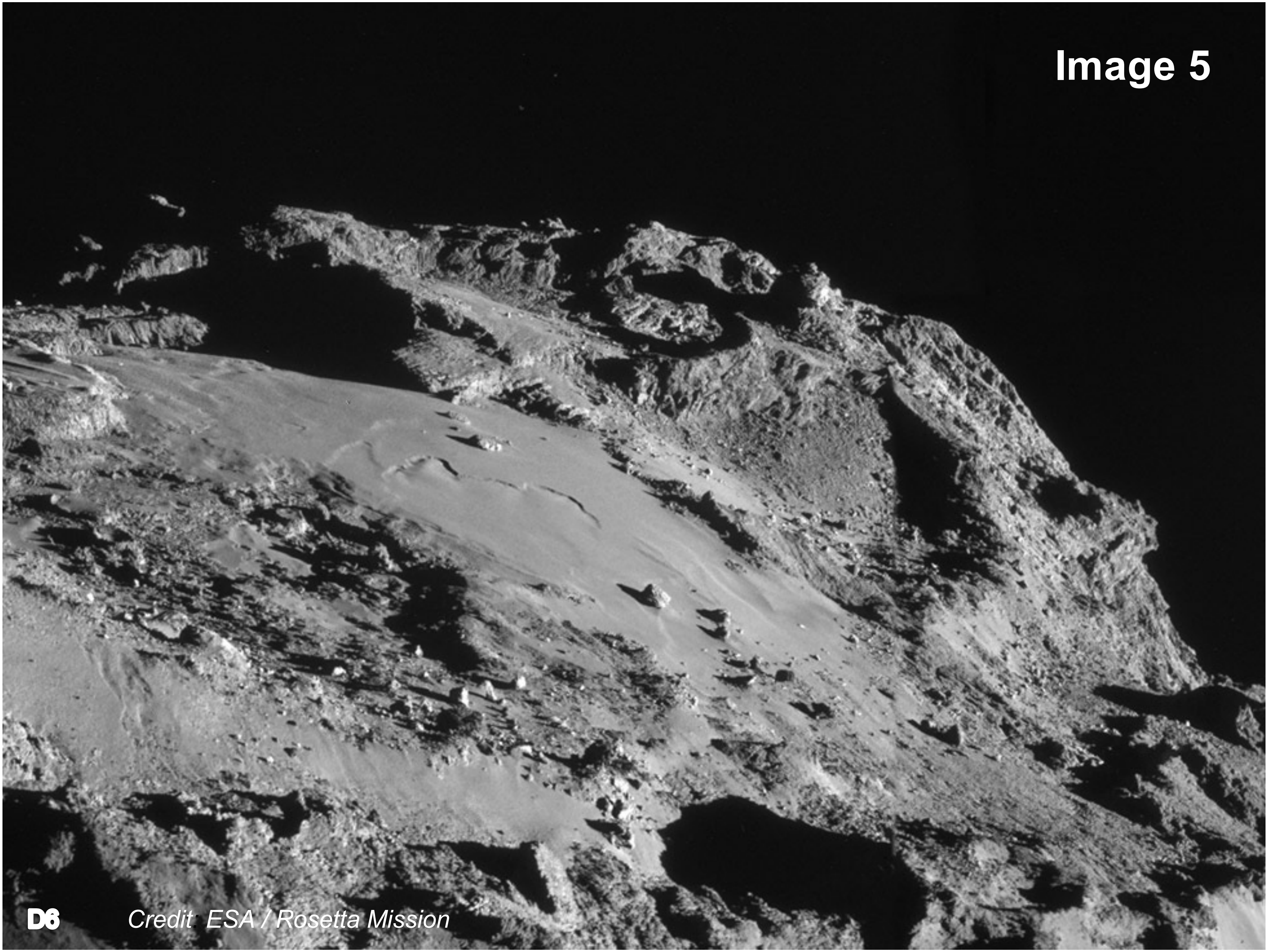


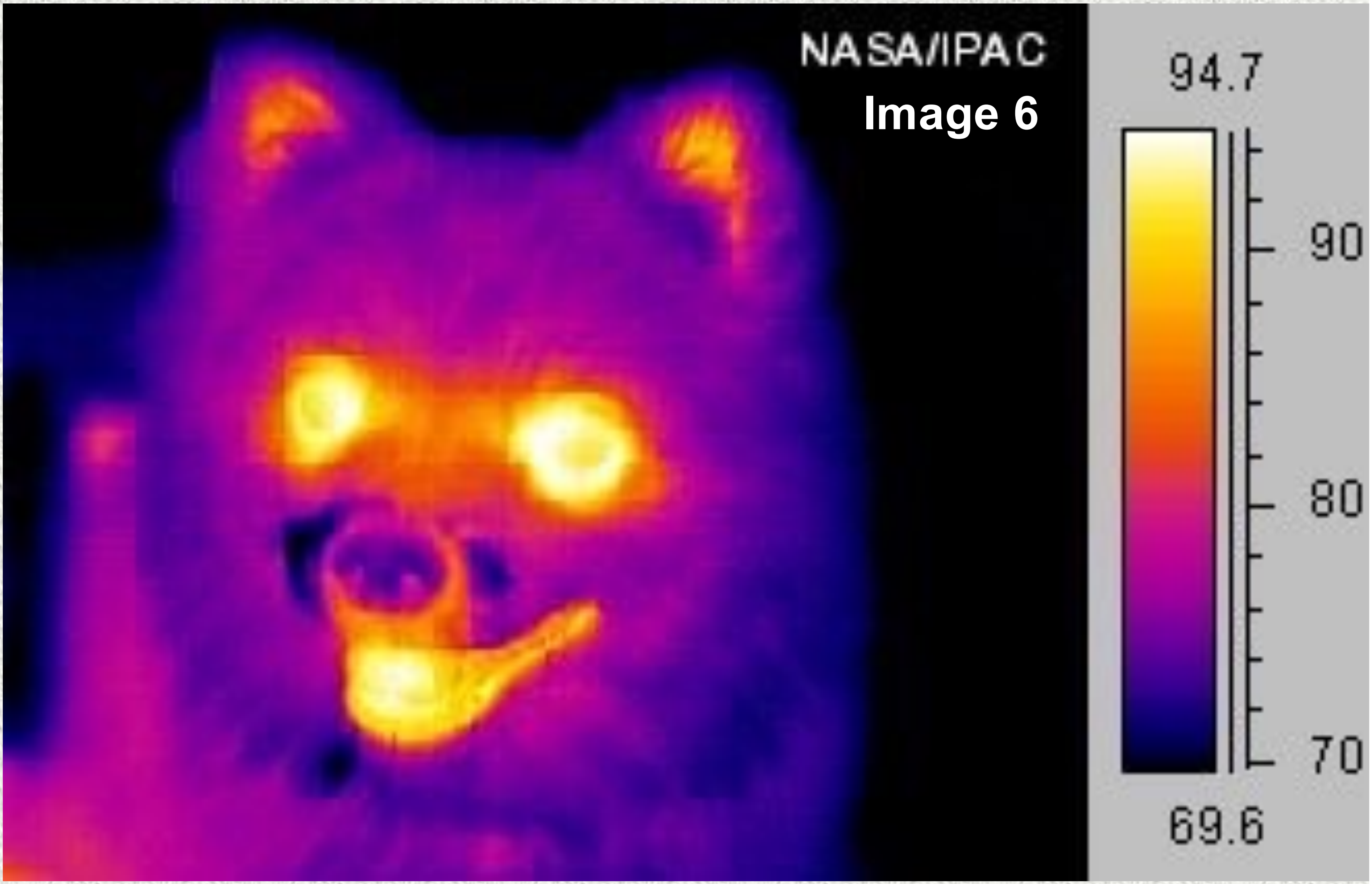
Image 5
D6
Credit ESA / Rosetta Mission

Observations & Explanations: In the IR

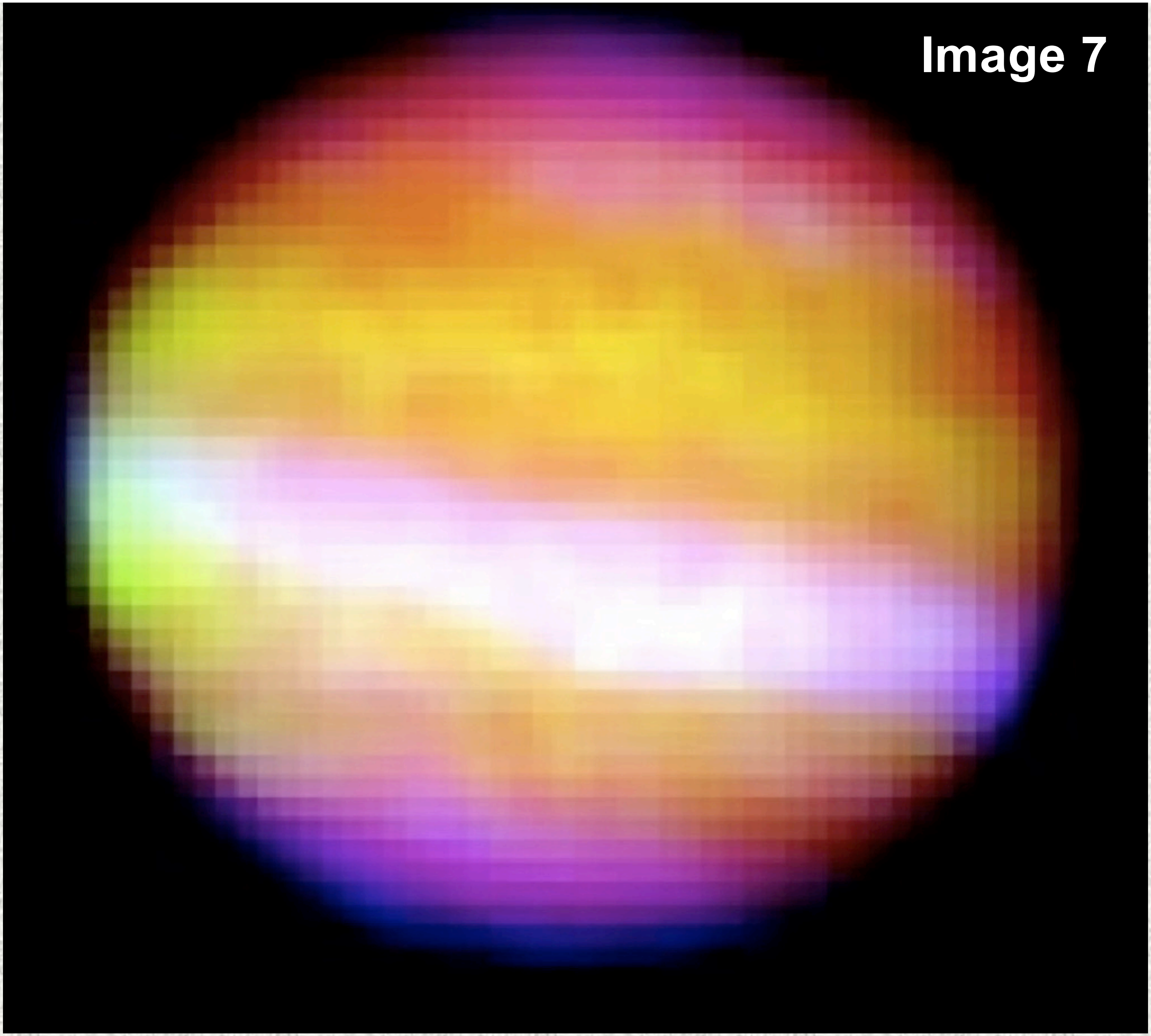
- You have been practicing your skills of image interpretation, and constructing an explanation based on your current knowledge.
- This becomes even harder to accomplish when we work outside of the visible spectrum.
- Observe the IR images.
- What do you notice? What statements can you support with data or experience?

Challenge Unsupported Statements

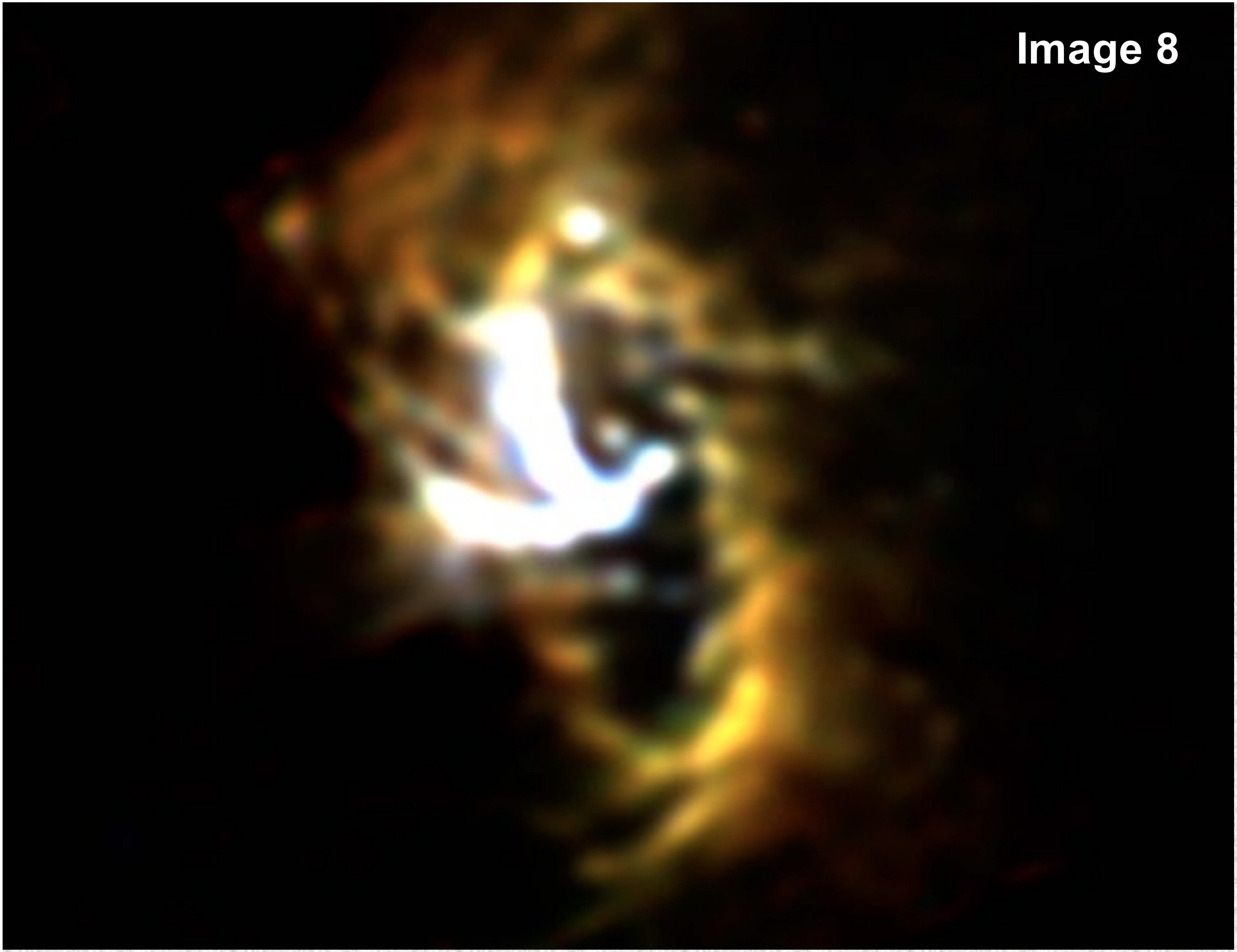
1) How do you know that?
2) Where have you seen another example of that?
3) What is it about the color, shape, orientation, etc. that leads you to say that?
4) Can you support that statement with some additional evidence or experience?
5) What might be another example of what you are describing?



Credit: NASA/IPAC/Caltech

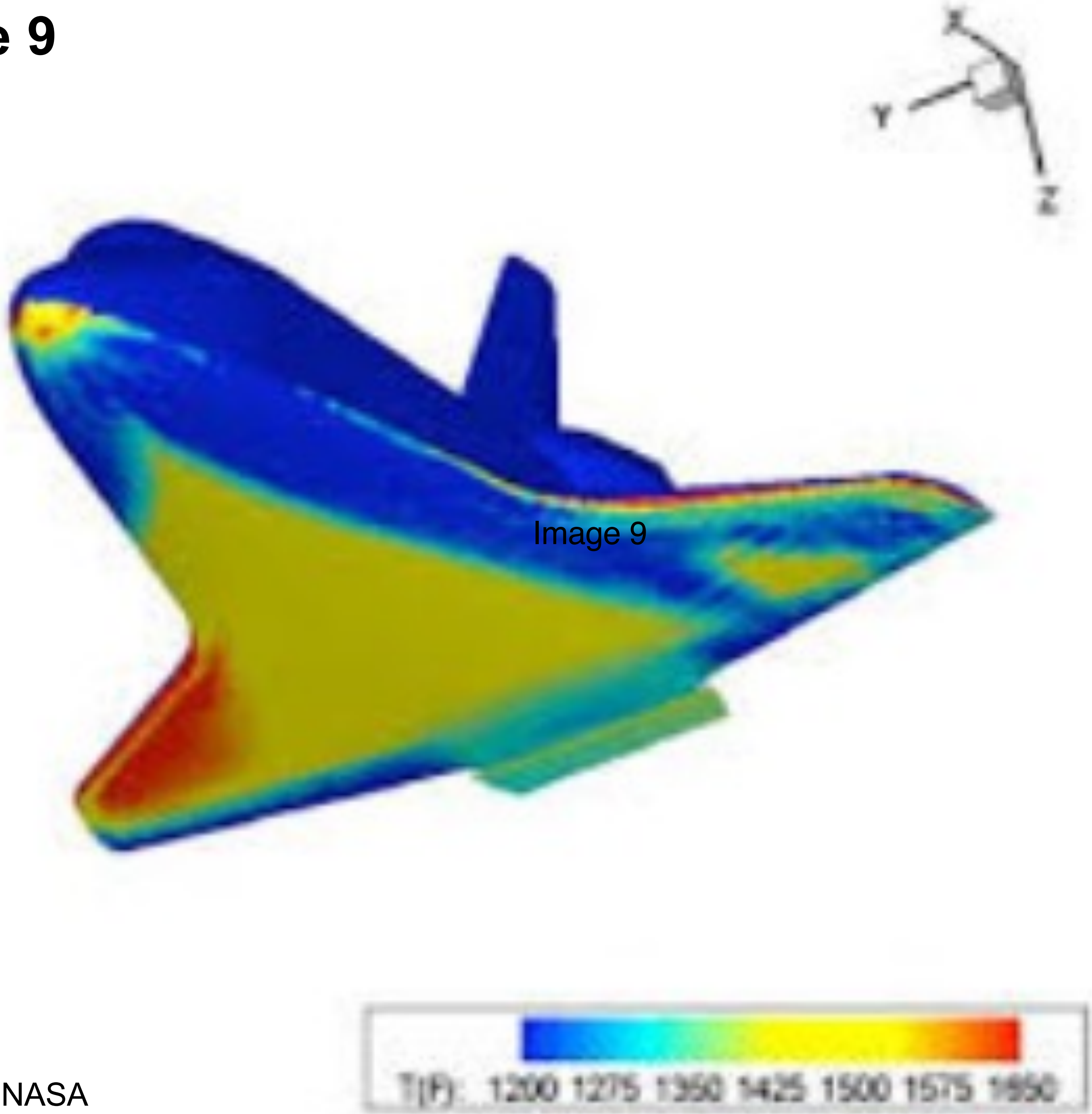


Credit: NASA/SOFIA/USRA/FORCAST Team/James De Buizer



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

Image 9



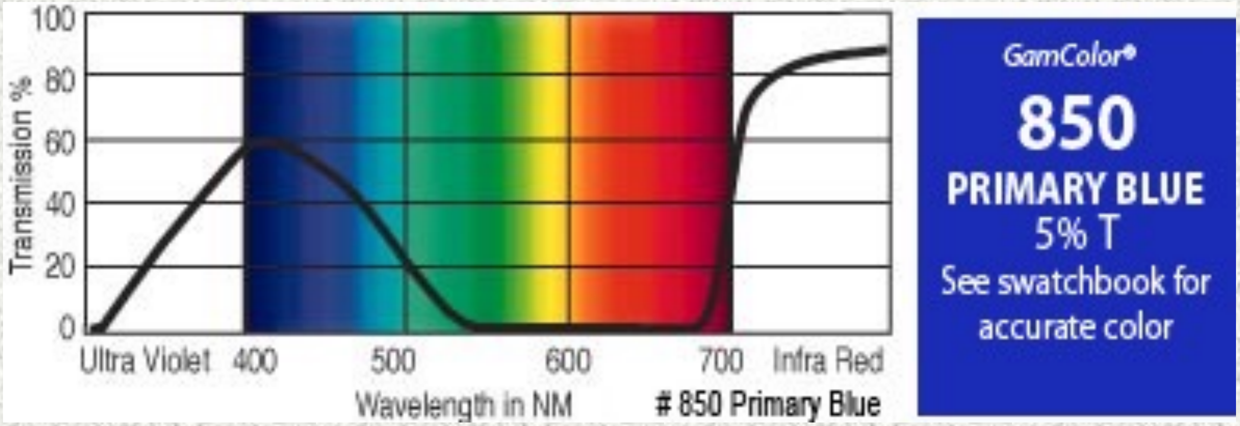
Credit: NTRS NASA

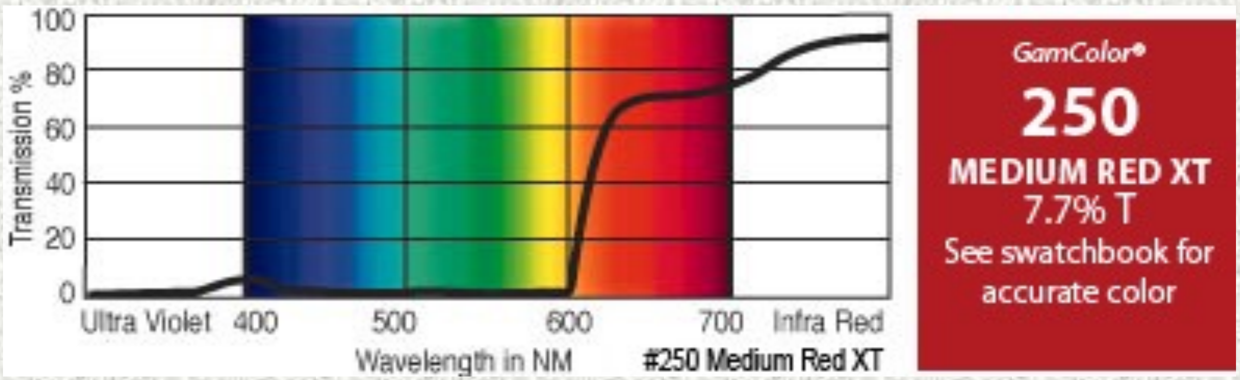
D6 Credit: IPAC / Caltech

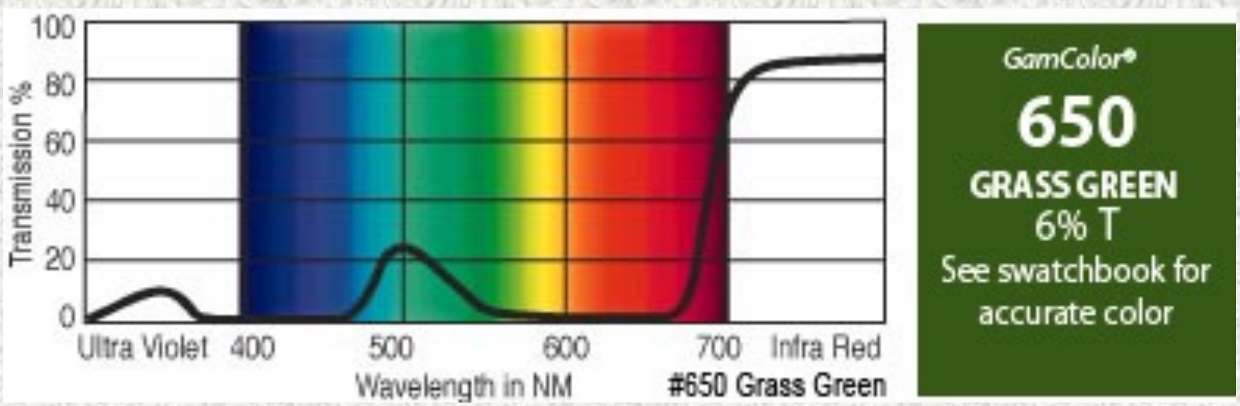
Day 7

Filter Spectral Response Curves

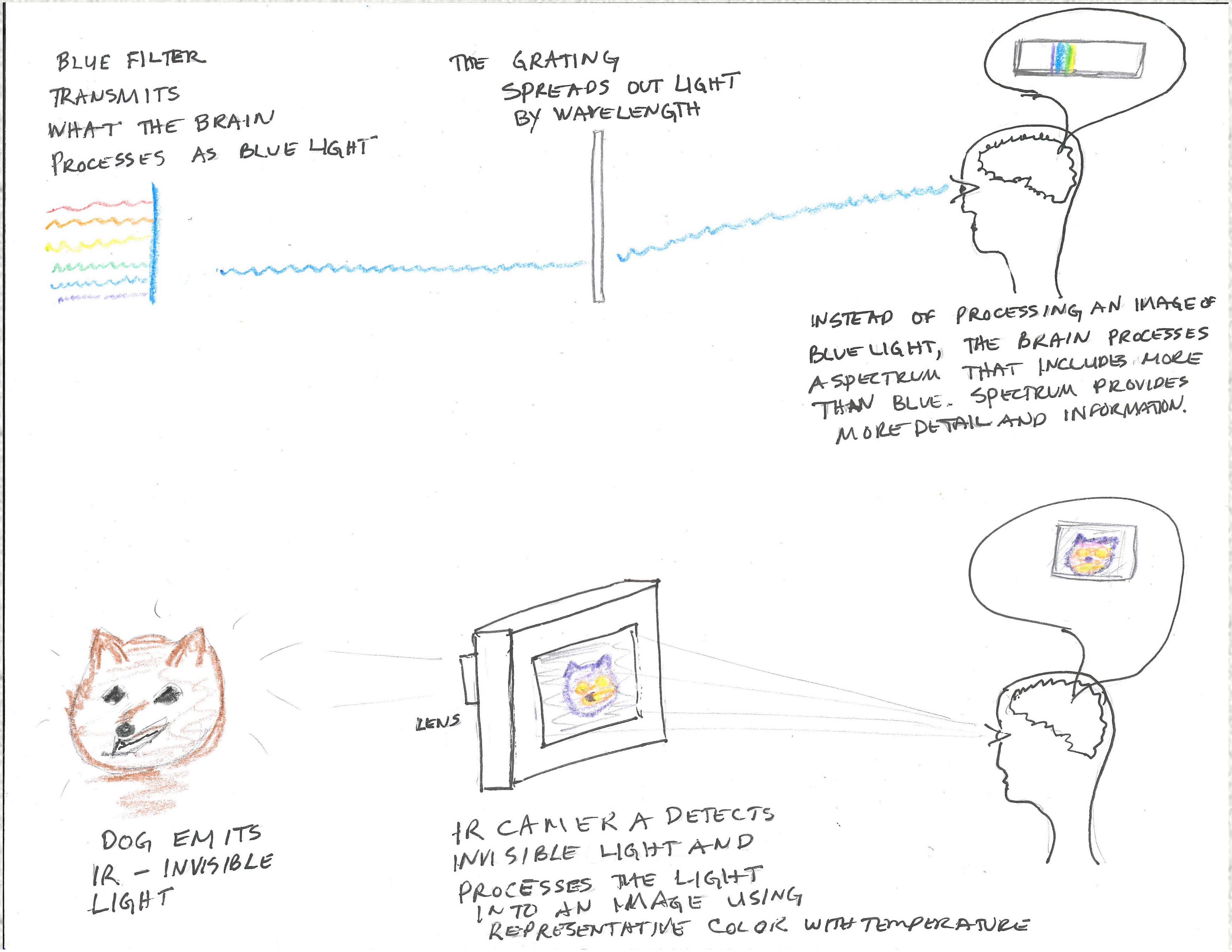
Credit: Gamnline.com





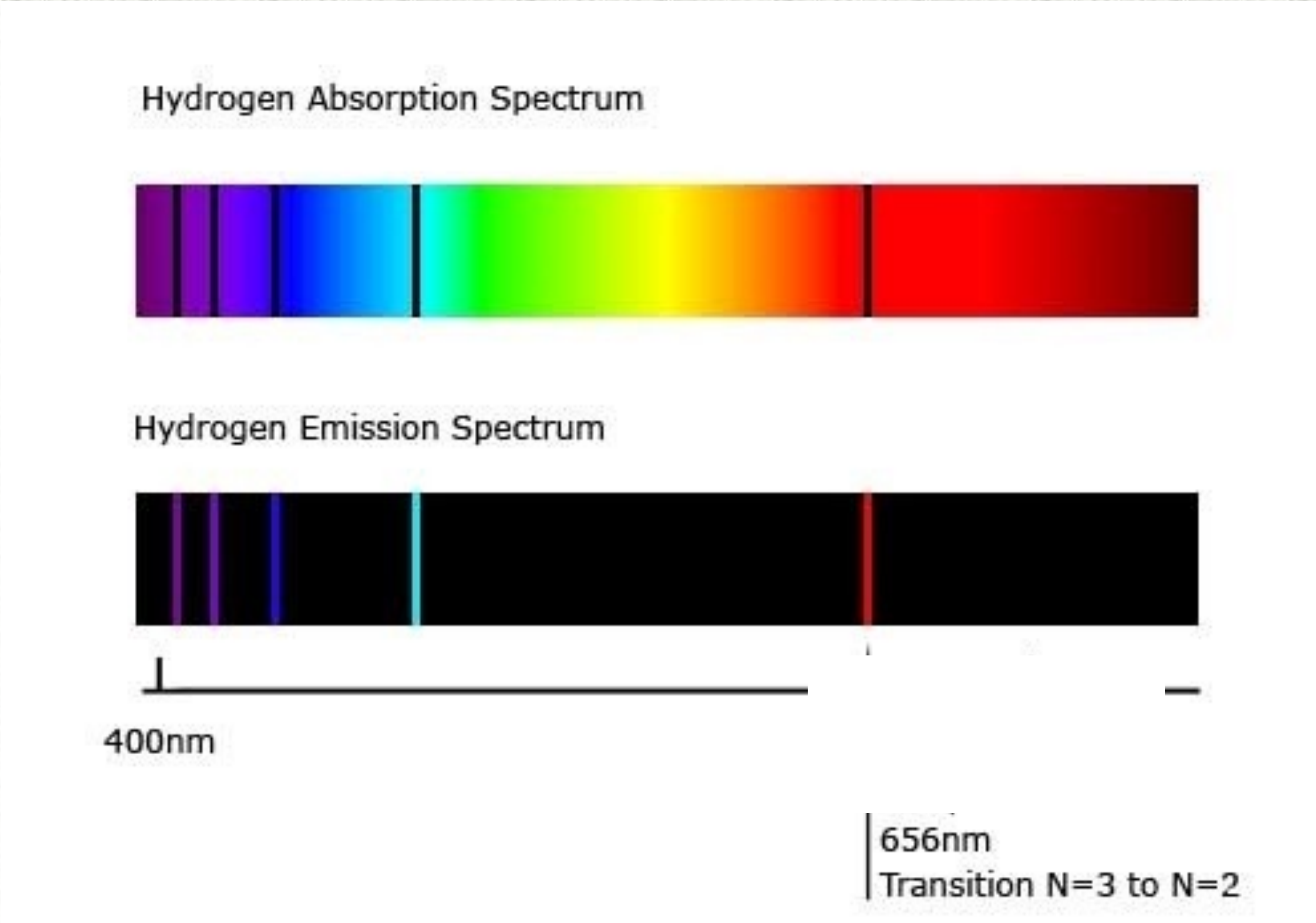


Sample Student Explanation B



D7

Day 8



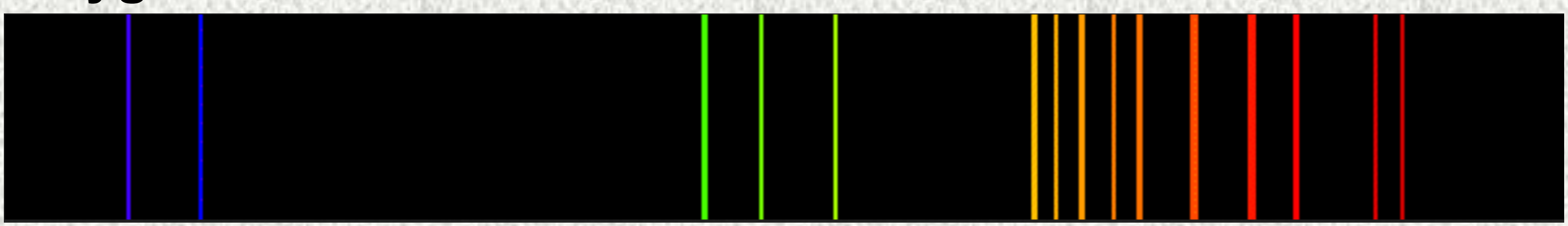
A hot solid body behind a cooler transparent gas produces an absorption spectrum.

A hot transparent gas with a cool / dark background produces a series of brightly colored lines that depend on its chemical composition - an emission spectrum

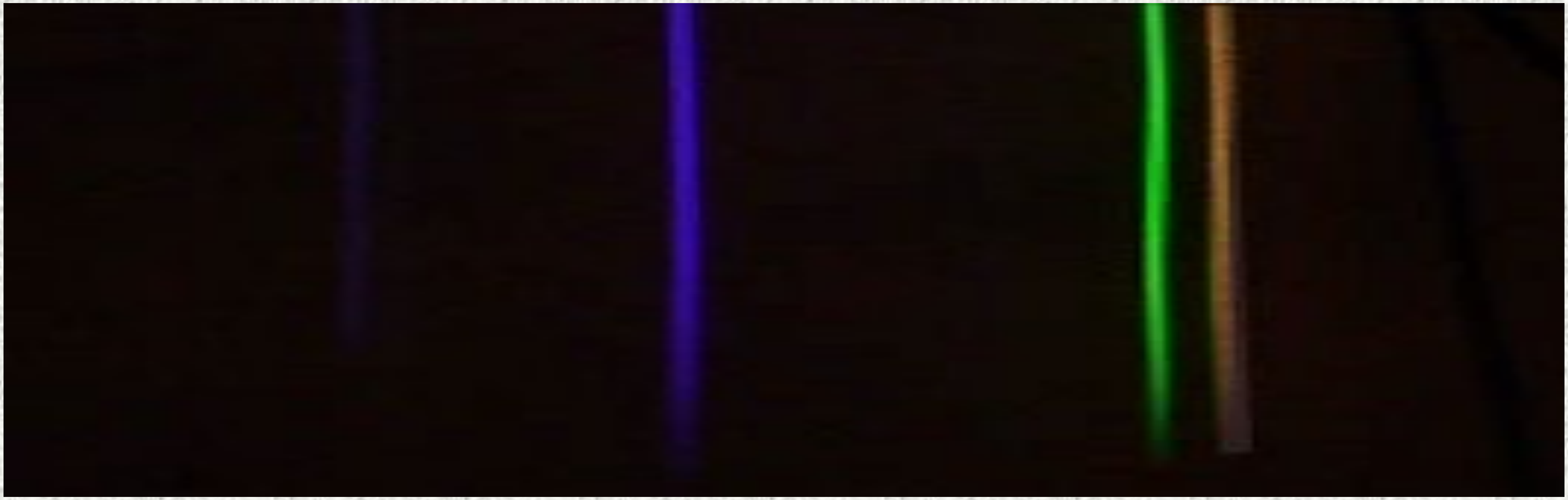
Helium

Carbon

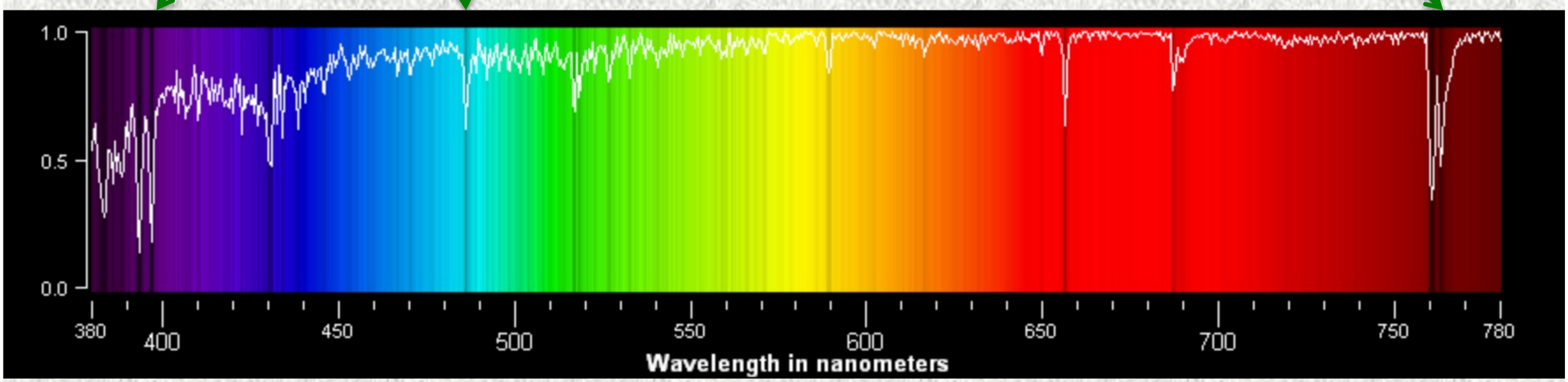
Oxygen



Mercury vapor



The darker and wider the absorption line, the lower and wider the dip in brightness. Absorption = less light in that particular part of the spectrum.

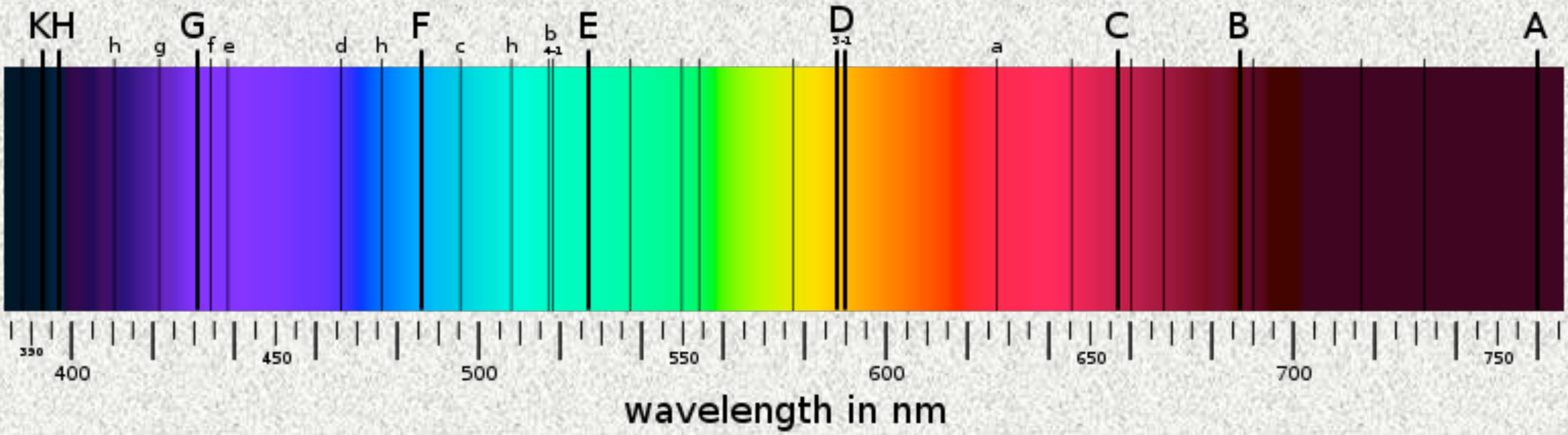


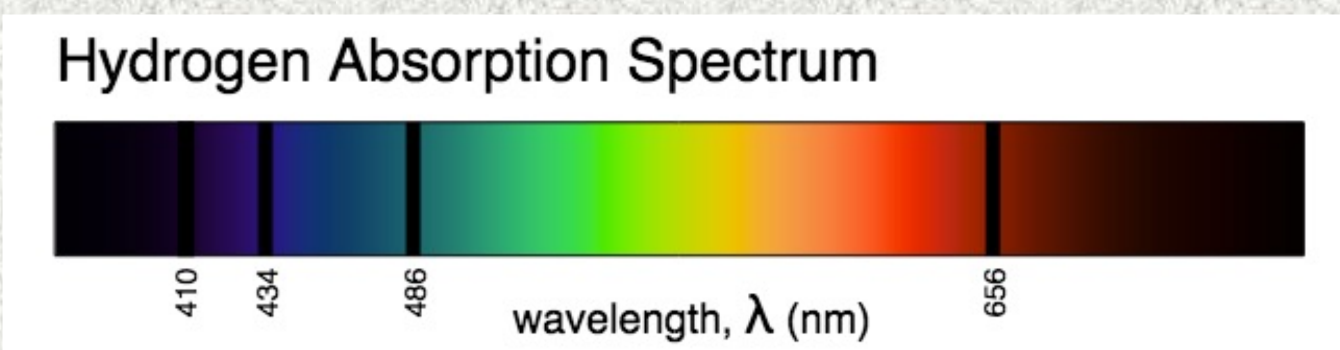
RGB Spectrum Generator R.L. McNish

Spectral Data (1)

Use the data to make statements about the chemical composition of the Sun.

Solar Absorption Spectrum

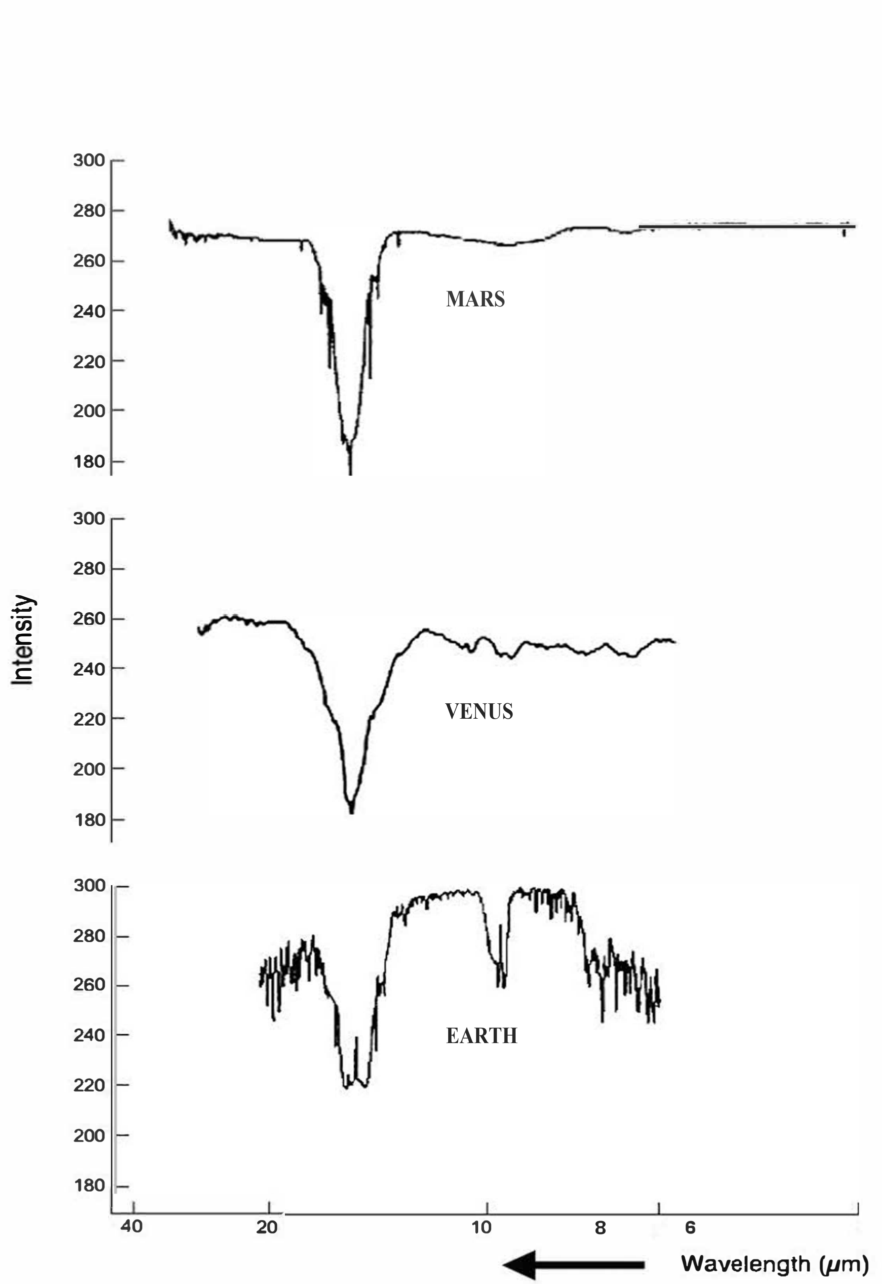




A cool, transparent gas in front of a hot, opaque body produces an absorption (dark-line) spectrum.

Spectral Data (2)

Use the following data to make statements about the chemical composition of each planet. What makes Earth unique?



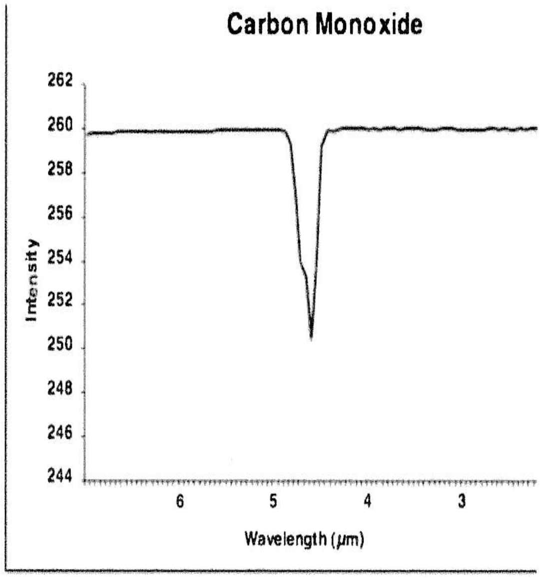
Mars mid-IR spectrum taken by the Mariner 9 spacecraft in the 1970s.

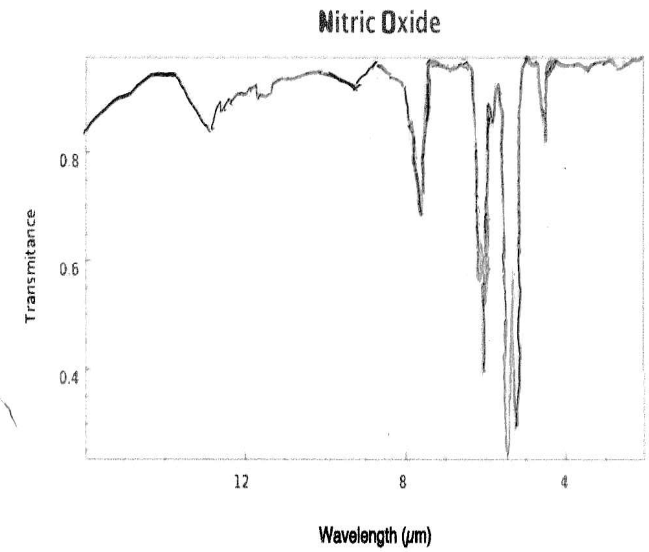
Venus mid-IR spectrum taken by the Venera 15 spacecraft in the 1980s.

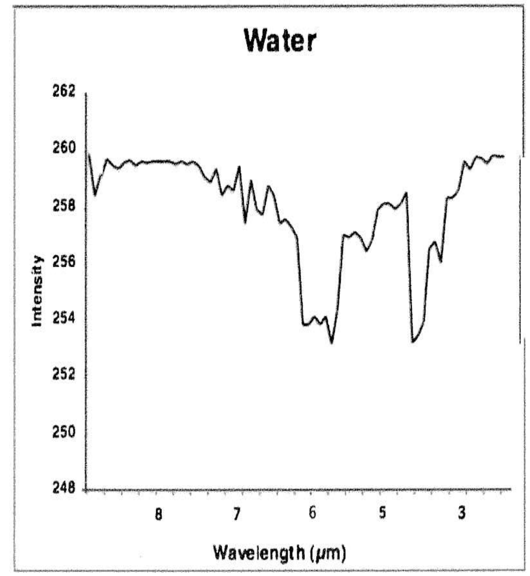
Earth mid-IR spectrum taken by the Nimbus 4 spacecraft in the 1970s.

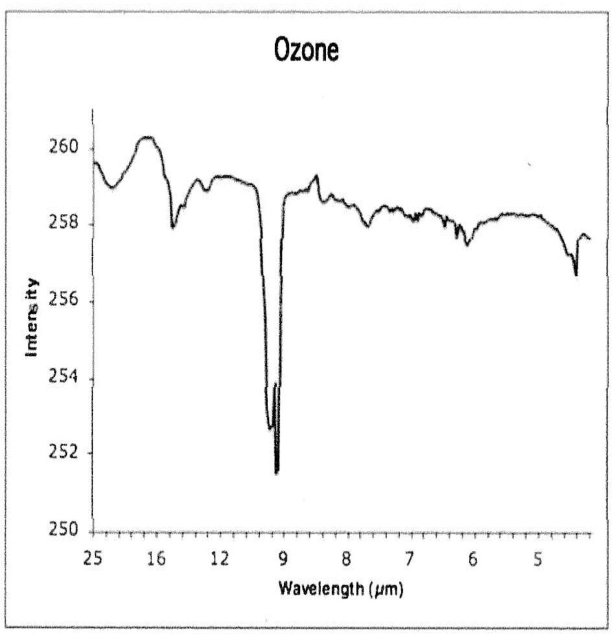
(Materials adapted from Project SPECTRA!: "Goldilocks and the Three Planets.")

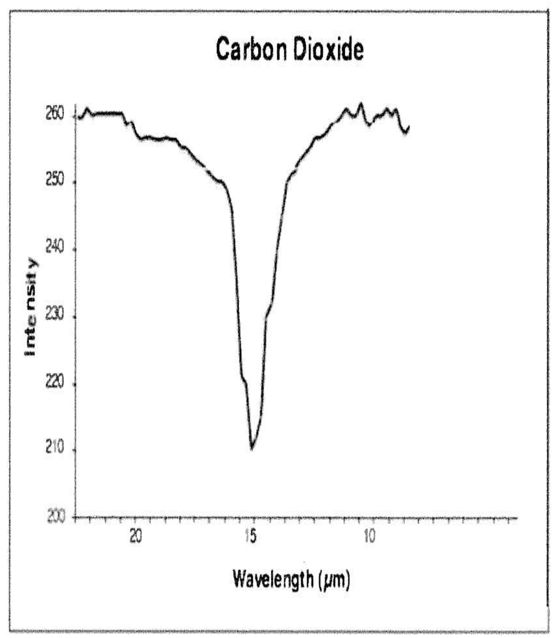
Known spectra of a few atmospheric gases
(be sure to look carefully at the plot wavelength scales!):

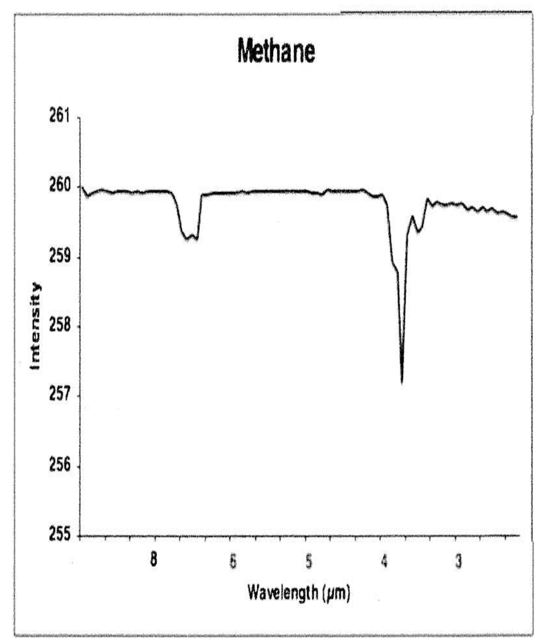




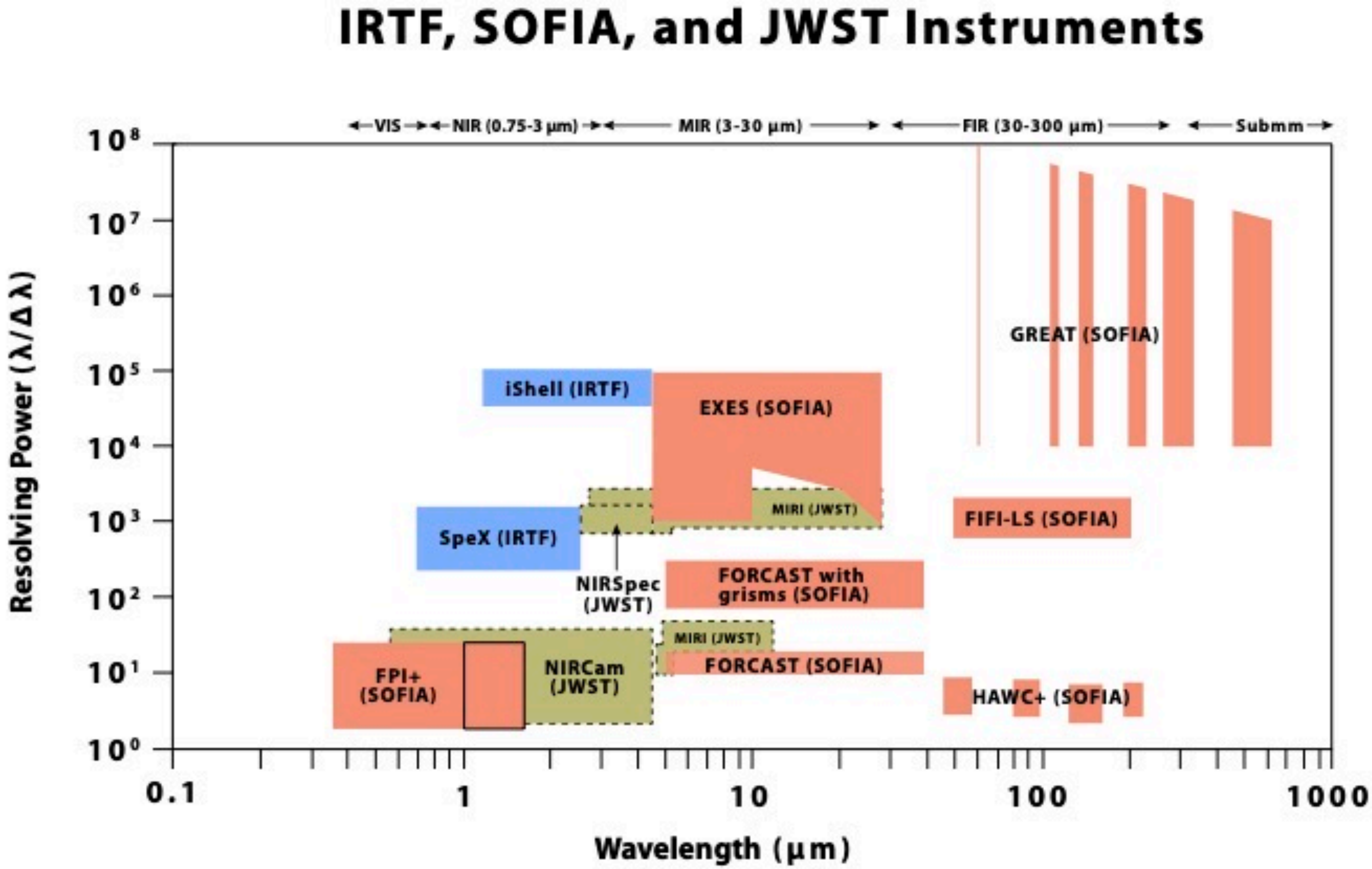








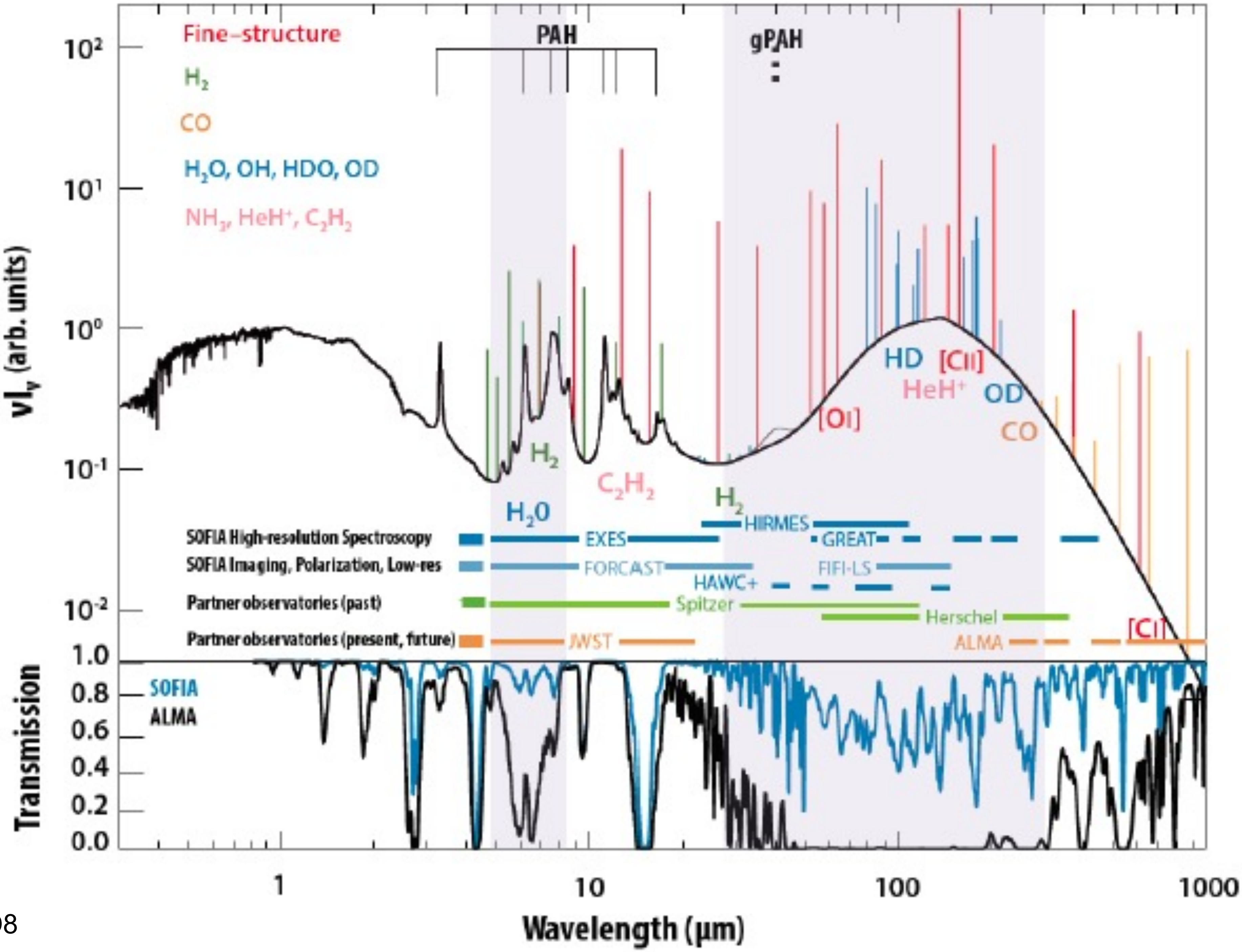
D8



IRTF Instruments: http://irtfweb.ifa.hawaii.edu/instruments/

JWST instruments: https://www.stsci.edu/jwst/instrumentation/instruments

Science Capabilities - Spectroscopy



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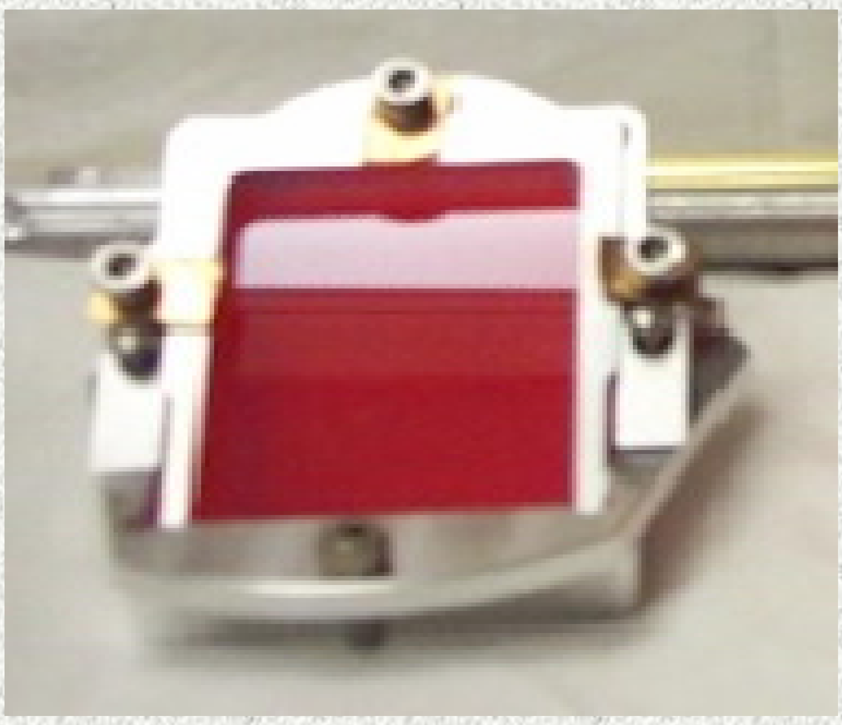


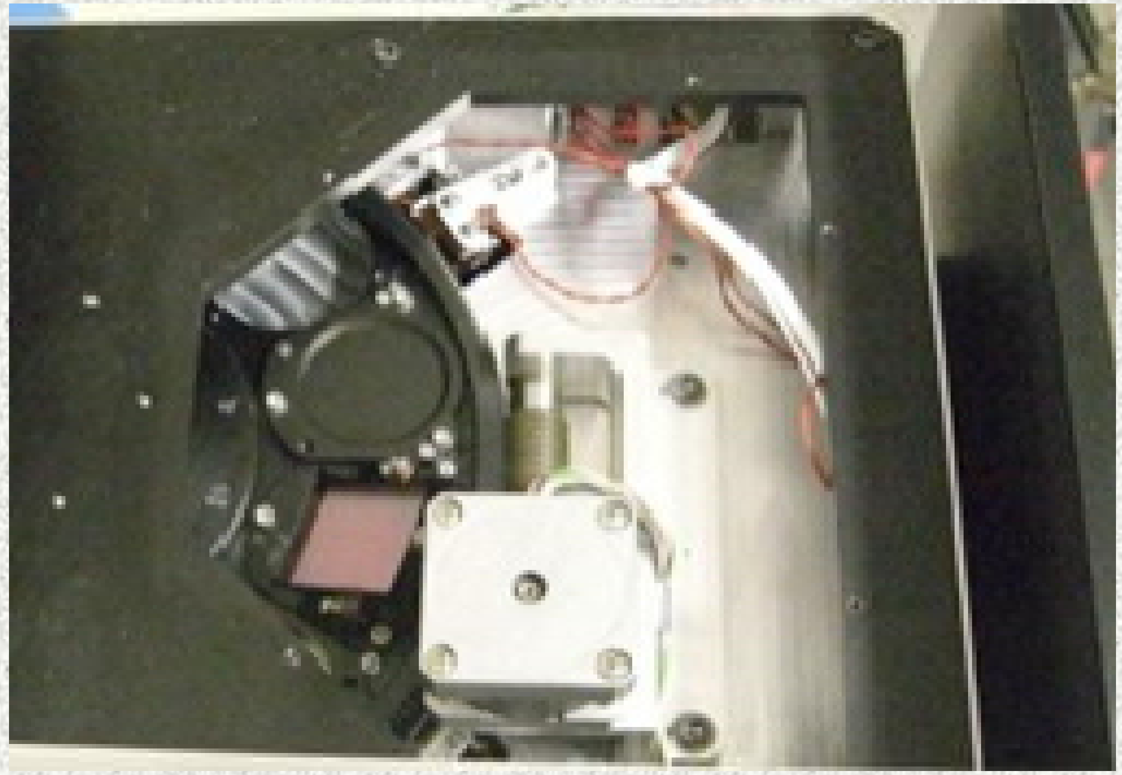
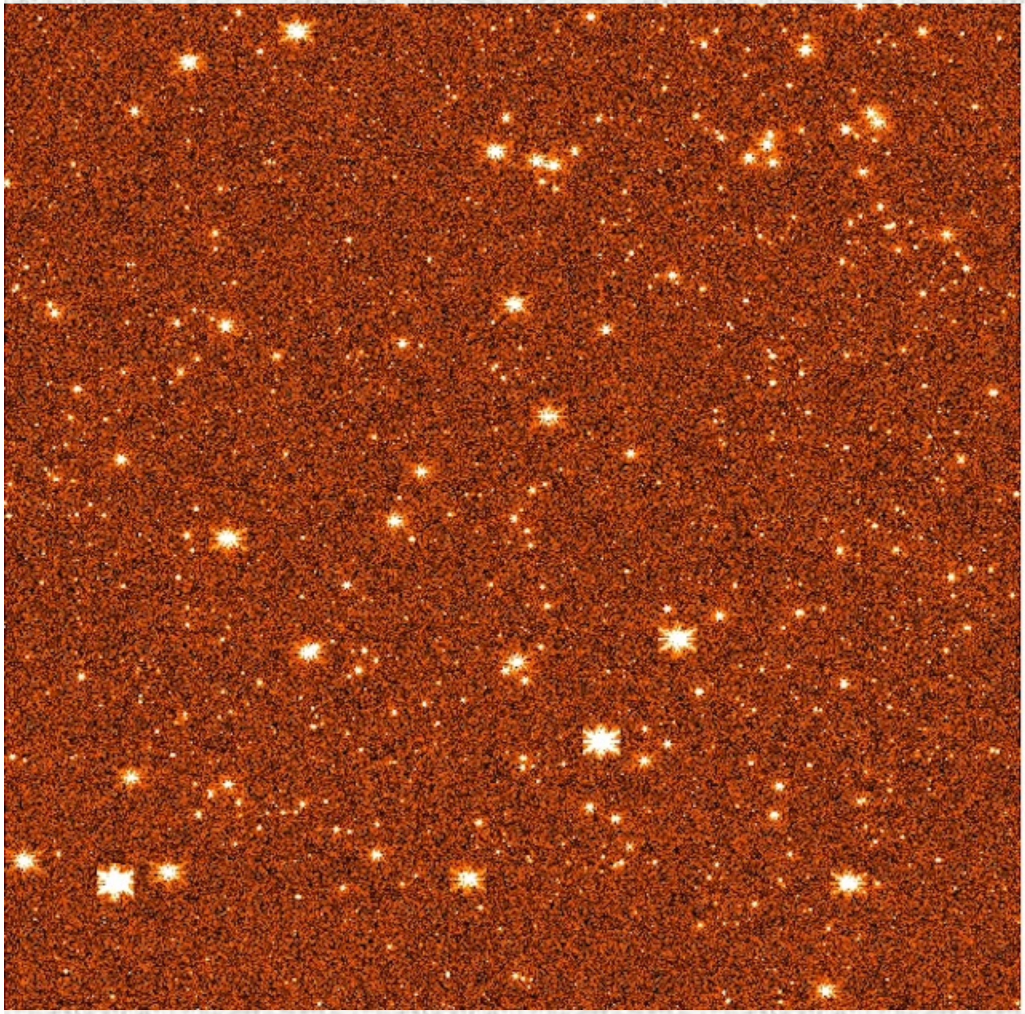
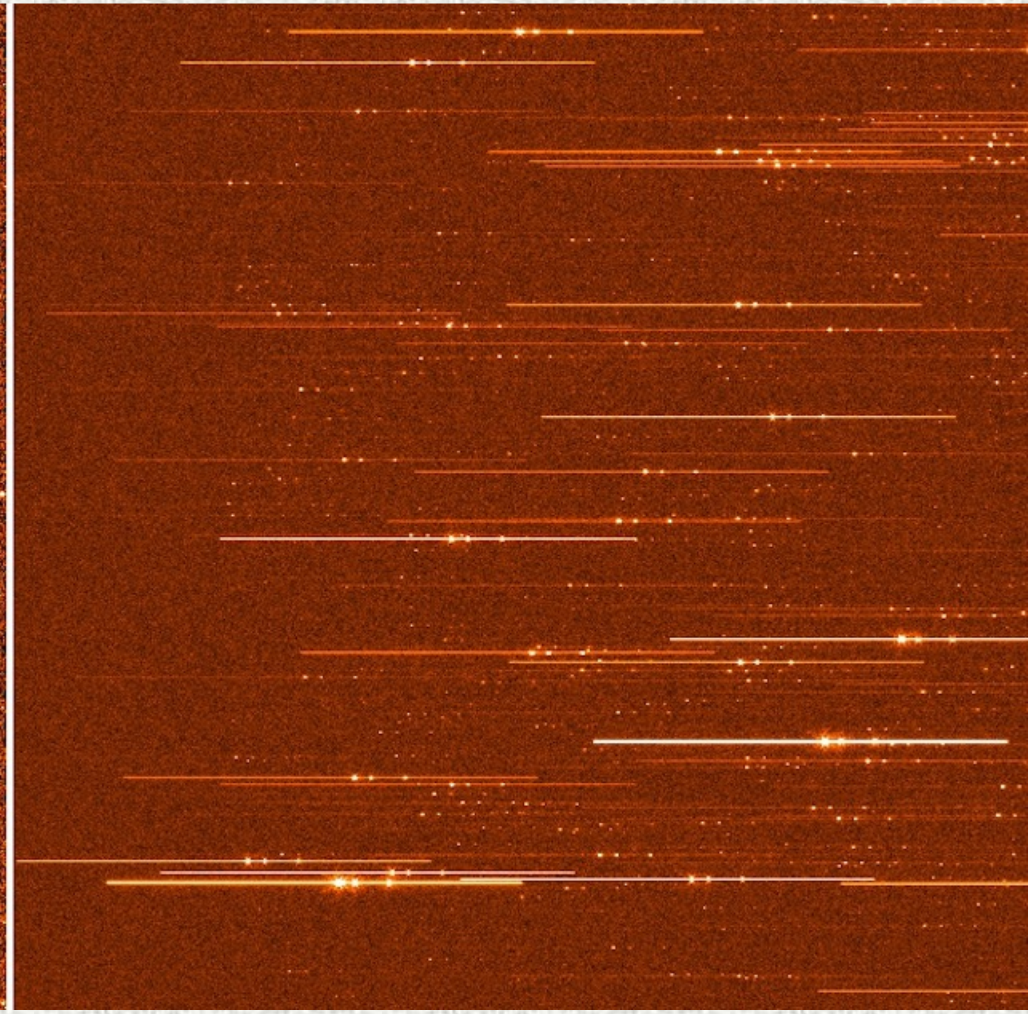


Fig. 7. Left: KRS-5 grism installed in its holder. Right: The grism installed in the FLITECAM filter wheel.

FLITECAM grism

(From E. Smith & I. McLean 2008, SPIE 7014, 11)



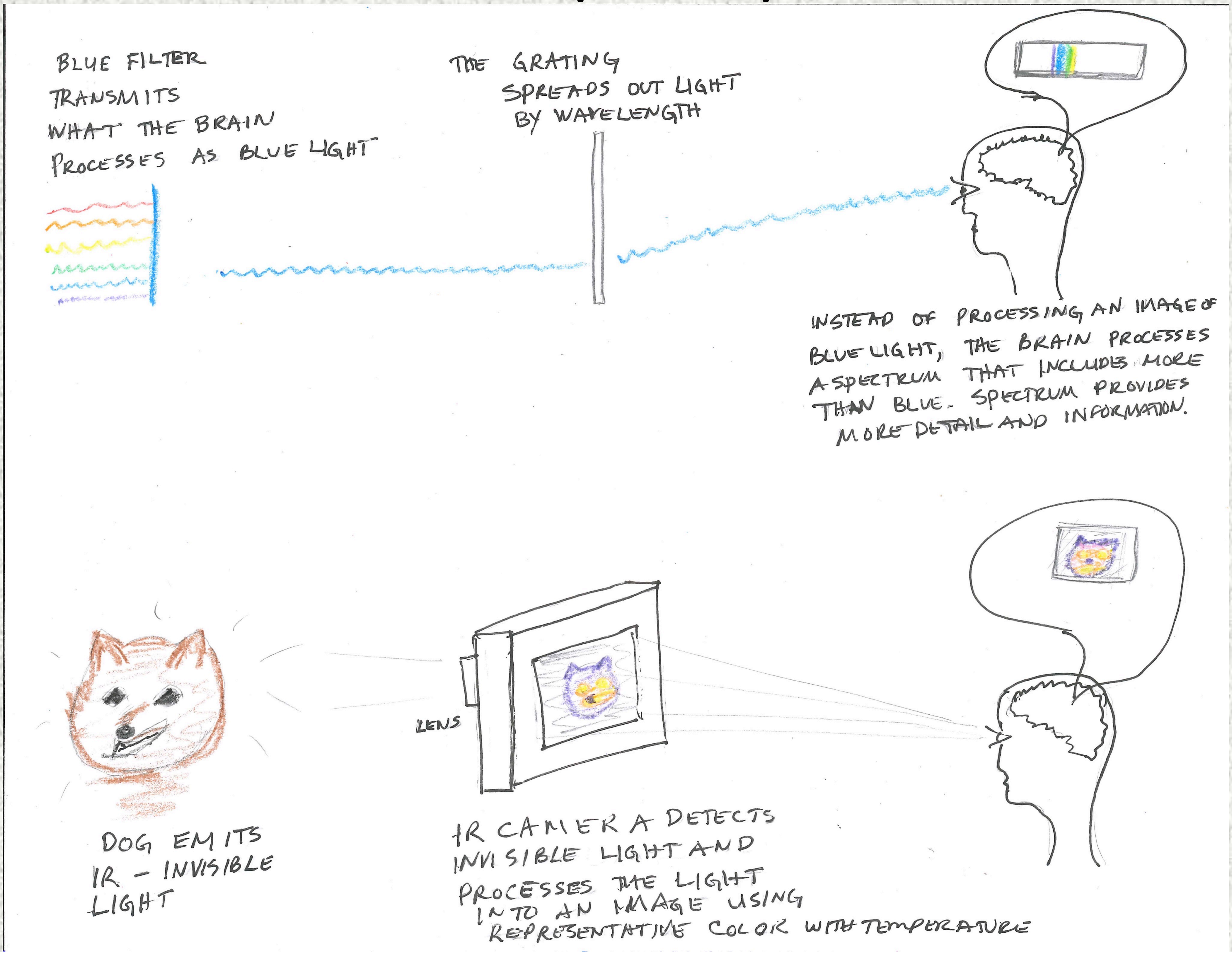


Ordinary image of a star field.

Grism spectral image of the same star field.

Substitute with IRTF spectroscopy info???

Student Sample Explanation B



D8

CCCs (Cross-Cutting Concepts)

– A CCC is a "lens" that a scientist can use to view a problems, or the approach taken when deciding how to study an object.

– For example, if a scientist is trying to determine if something (x) affects (y), then they are using the CCC of *Cause and Effect*.

– 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 recurring themes in the way scientists think about & solve problems and investigate nature.

Guide to CCCs (1)

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?

Guide to CCCs (2)

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?

Day 9

Final Assignment

1. Plan an astronomy investigation that would yield infrared spectra.

- What astronomical object would like to investigate? Why?
- What telescope and instrument would you use? Why?

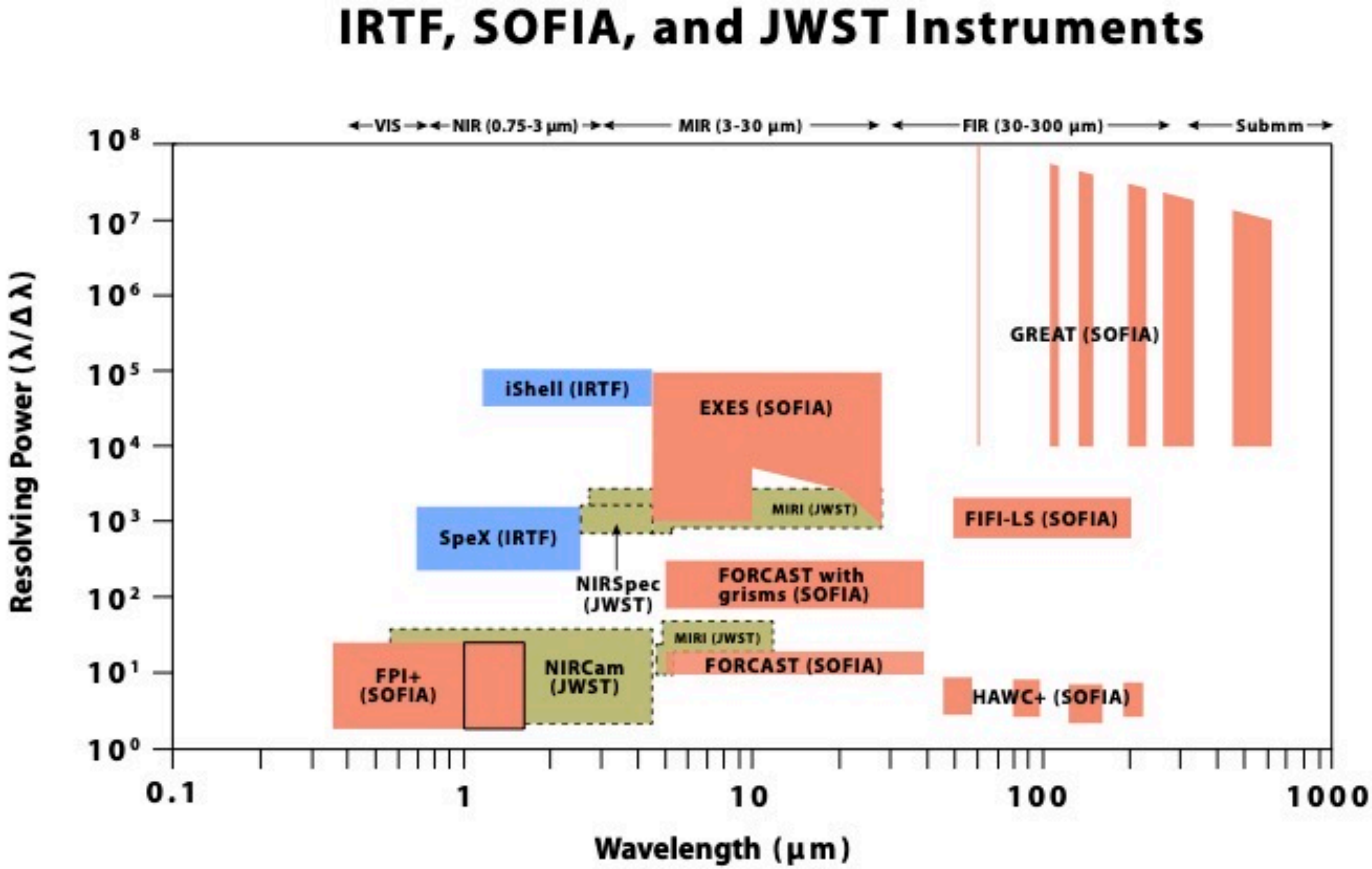
2. Explain how scientists know and understand a science research finding from data collected by a SOFIA instrument using a model; show reasoning in your response.

Include the following terms/items in your explanation:

- Infrared
- Emit
- Reflect
- Data
- Telescope
- Instrument
- Directional arrows

Optional terms/ labels

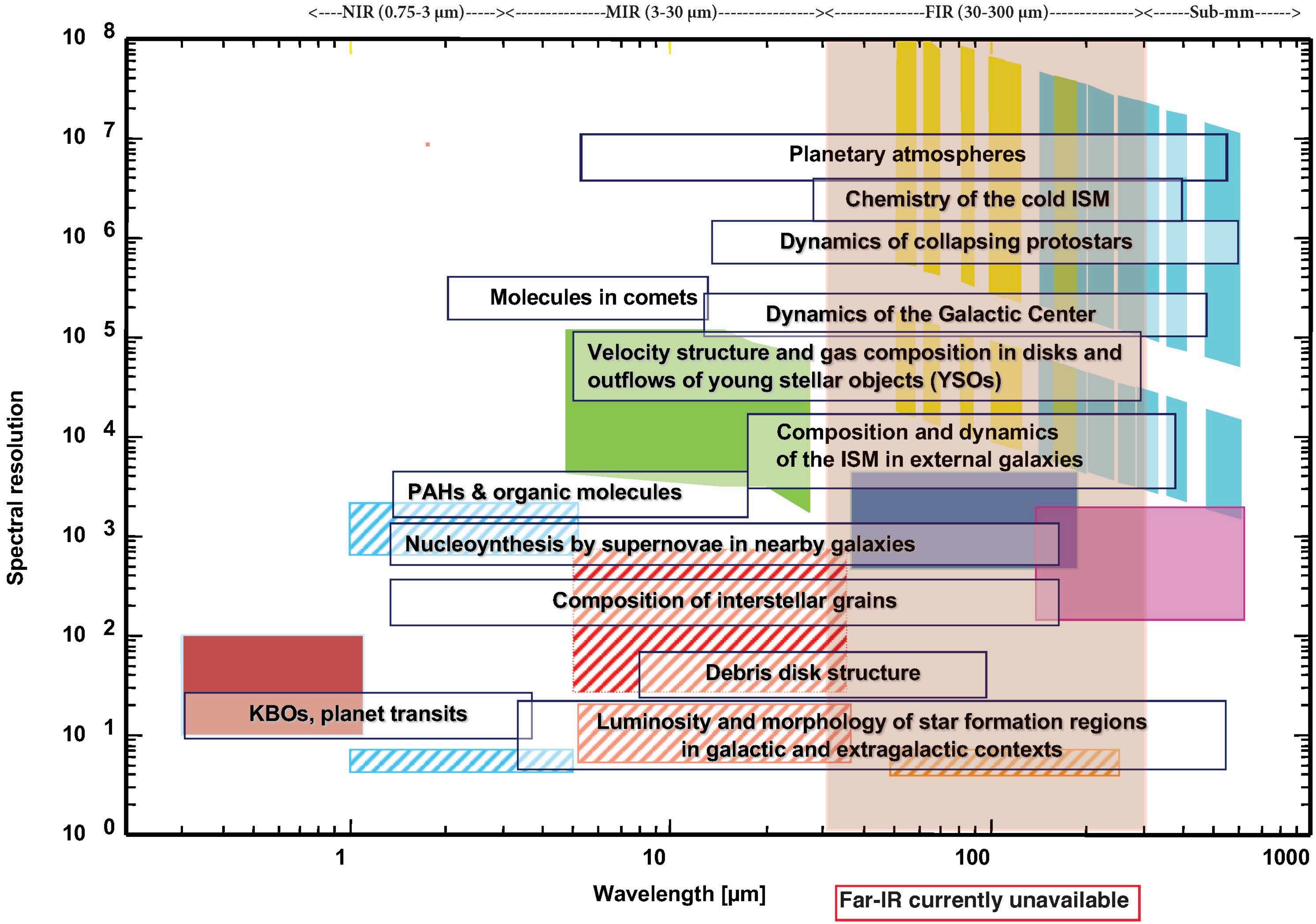
* Transmit
* Speed of light
* Your own ideas



IRTF Instruments: http://irtfweb.ifa.hawaii.edu/instruments/

JWST instruments: https://www.stsci.edu/jwst/instrumentation/instruments

Infrared Science for the Astronomical Community



IR Discovery Matrix

Wavelength range	Objects / systems	Prominent spectral features	Interesting to astronomers because ...
Visual to Near-IR	HII (ionized hydrogen) regions	Atomic and molecular emission lines	Raw material for new stars, excited by UV emission from nearby young stars
Visual to Near-IR	Cool stars: M dwarfs, red giants, and red supergiants	Molecular absorption lines and bands	Stellar evolution archetypes; chemical evolution of the Galaxy
Visual to Near-IR	Brown dwarfs	Molecular absorption lines and bands	Star and planet formation processes
Visual to Mid-IR	Planetary nebulae	Atomic and molecular emission lines	Late stage of solar-mass stellar evolution; recycling of chemical elements to the ISM
Near-IR to Mid-IR	Exoplanets	Atomic and molecular absorption lines during stellar transit	Composition and temperatures in exoplanet atmospheres
Near-IR to Mid-IR	Protostars	Atomic and molecular emission lines	Longest-lasting stage of star formation
Near-IR to Mid-IR	Protoplanetary disks	Atomic and molecular emission lines (and absorption lines, if seen edge-on)	Compositions, chemistry, and gas motions In forming planetary systems
Near-IR to Mid-IR	Planetary surfaces	Silicate and ice reflection absorption bands	Composition of planetary surfaces
Near-IR to Far-IR	Asymptotic Giant Branch (AGB) red giant stars and carbon stars	Molecular absorption lines & bands; maser emission lines	Late stages of stellar evolution; recycling of chemical elements to the ISM
Mid-IR to Far-IR	Planetary atmospheres	Atomic and molecular emission and absorption lines	Composition and gas motions in planetary atmospheres
Mid-IR to Far-IR	ISM dust	Near-IR ice and organic absorption and emission bands; Mid-IR silicate bands (usually absorption)	Composition of raw material for new stars and planets
Mid-IR to Far-IR	Debris disks	Atomic and molecular emission and absorption lines	Nearly-mature planetary system
Far-IR	Molecular cloud cores	Atomic and molecular emission lines	Earliest star formation processes, before protostar stage