The Search for Life on Exoplanets: Spectroscopic Evidence

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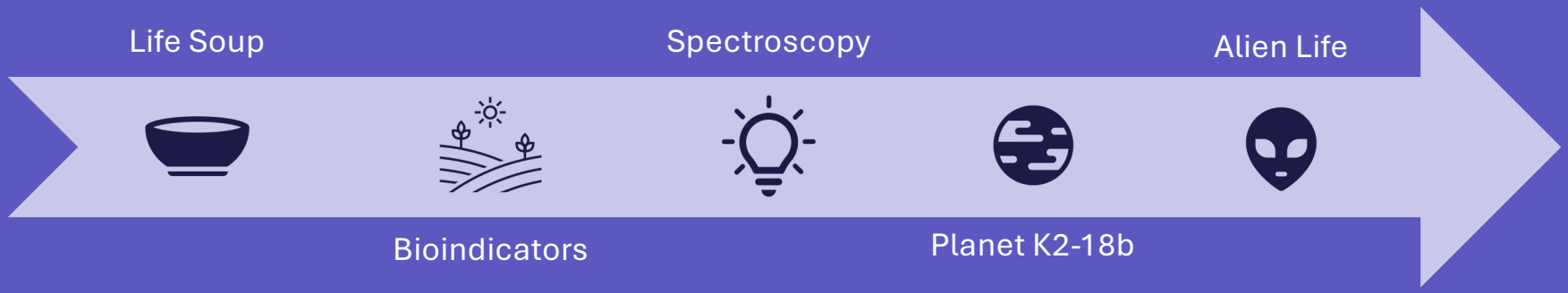
ASTR 312

Overview


Life Soup
Bioindicators
Spectroscopy
Planet K2-18b
Alien Life

Introduction

Exoplanet: Planet that exists outside of our solar system

When we look for life in space, we tend to look for exoplanets that share similarities with earth

We use technologies, such as the James Webb Space Telescope (JWST) to examine exoplanets for signs of life

Life Soup

- **POT**: Stability & protection = pressure & atmosphere
- **BROTH**: Water
- **MEAT & POTATOES**: Carbon (backbone)
- **SEASONING**: Oxygen, hydrogen, phosphorous, sulfur, nitrogen[1] (DNA, fats, proteins, carbs)
- **HEAT**: Sunlight

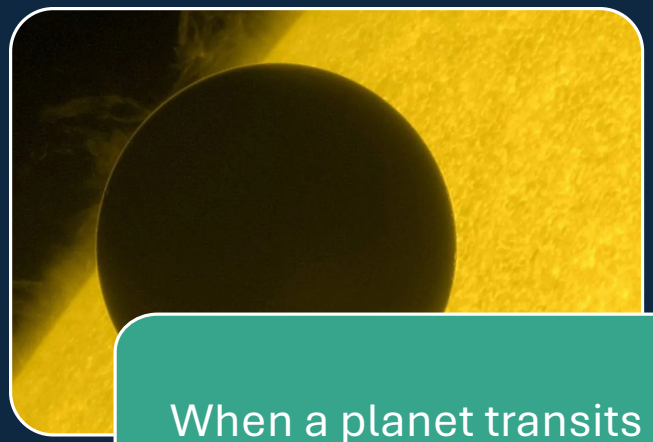
Bioindicators

Bioindicators are clues or signs that life may exist on another planet

- Life leaves behind “fingerprints”, such as atmospheric gasses that are hard to produce otherwise
  - Oxygen (O_2): Produced by photosynthesis
  - Methane (CH_4): Produced by microbes
  - Dimethyl Sulfide (DMS): Produced by marine phytoplankton[2]

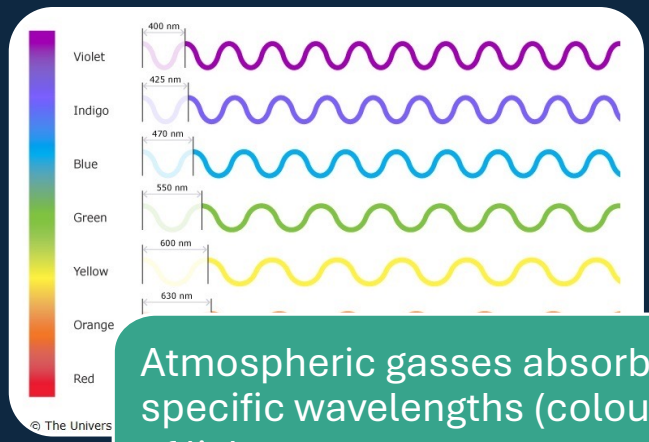
Detecting Bioindicators

(NASA, 2023)



When a planet transits in front of its star, light shines through the planet's atmosphere

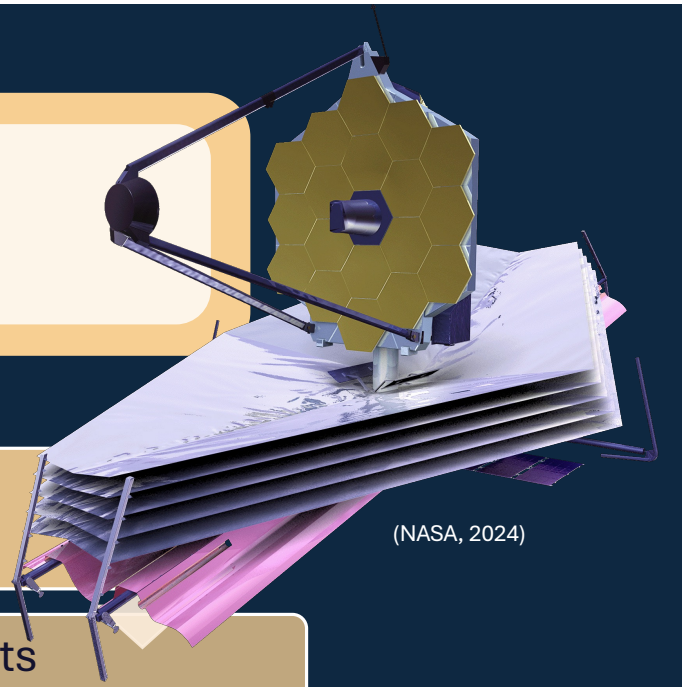
(Science Learning Hub, 2012)



Atmospheric gasses absorb specific wavelengths (colours) of light

- Oxygen: absorbs visible light[3]
- Methane & DMS: absorb infrared[4, 5]

Spectroscopy



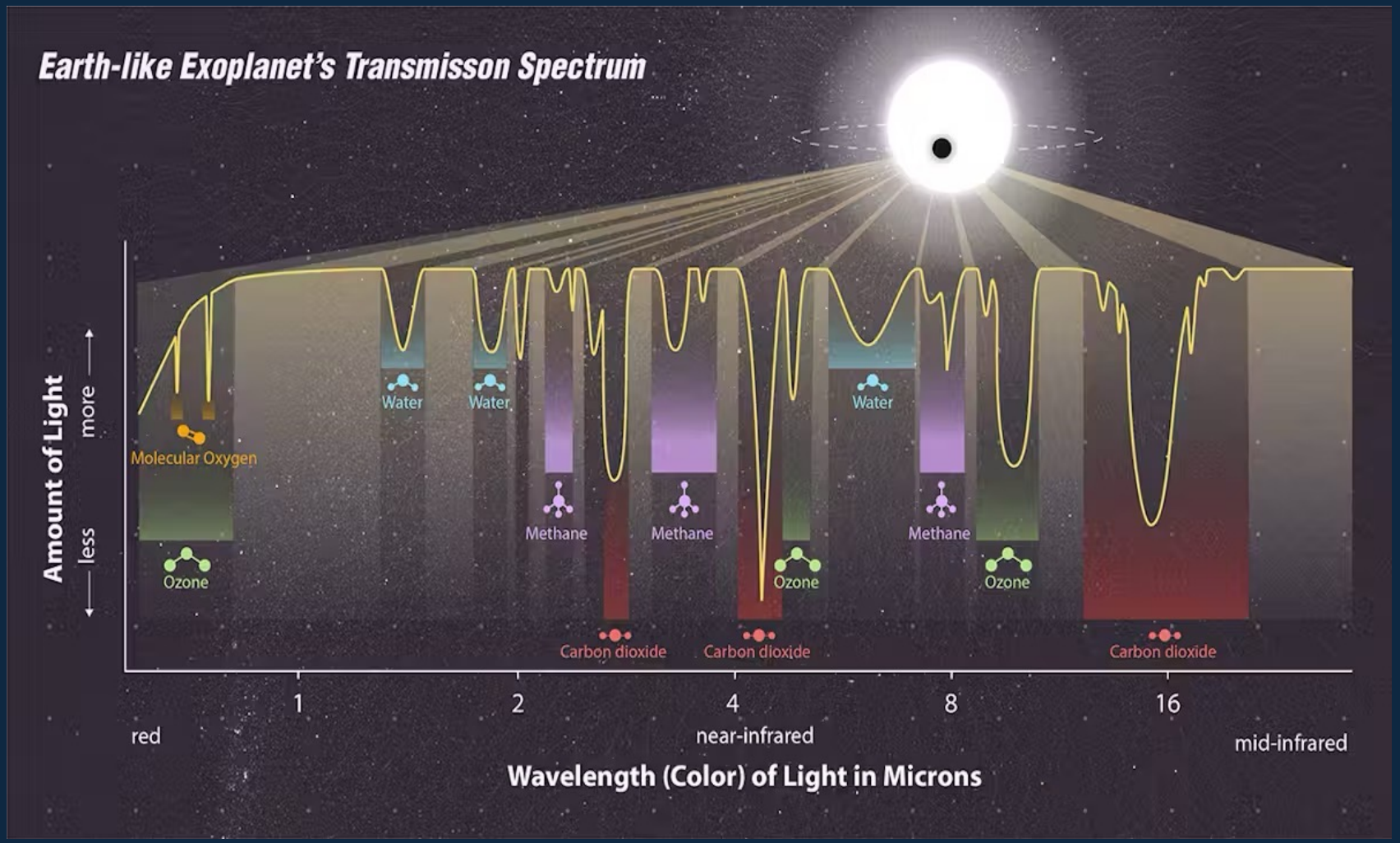
(NASA, 2024)

Spectroscopy is the science of breaking light into its component colours to study how it interacts with matter

When a telescope observes a planet's transit, it collects light that passes through the planet's atmosphere

Instruments split the light into its wavelengths and measure which parts of the spectrum are dimmer

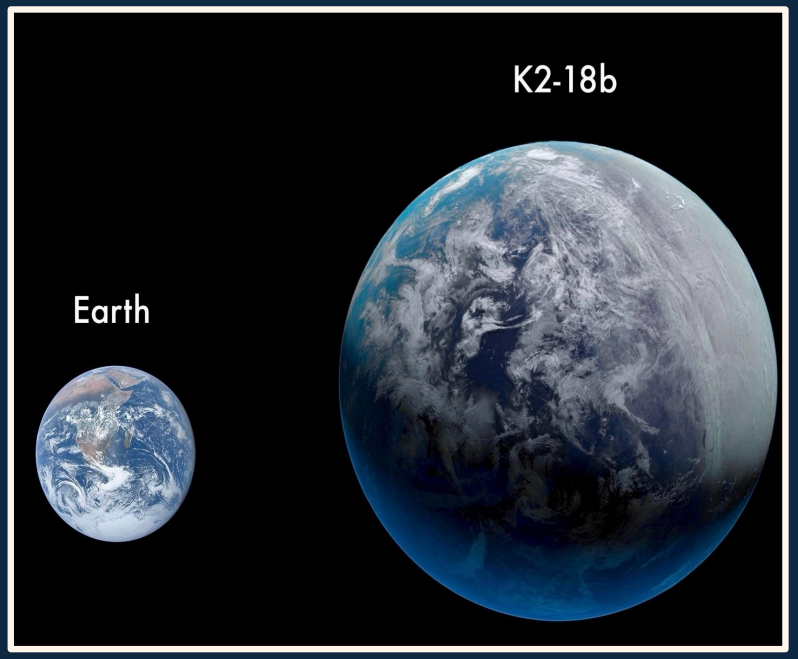
Dimmer areas indicate absorption by gasses[6]



(Space.com, 2023a)

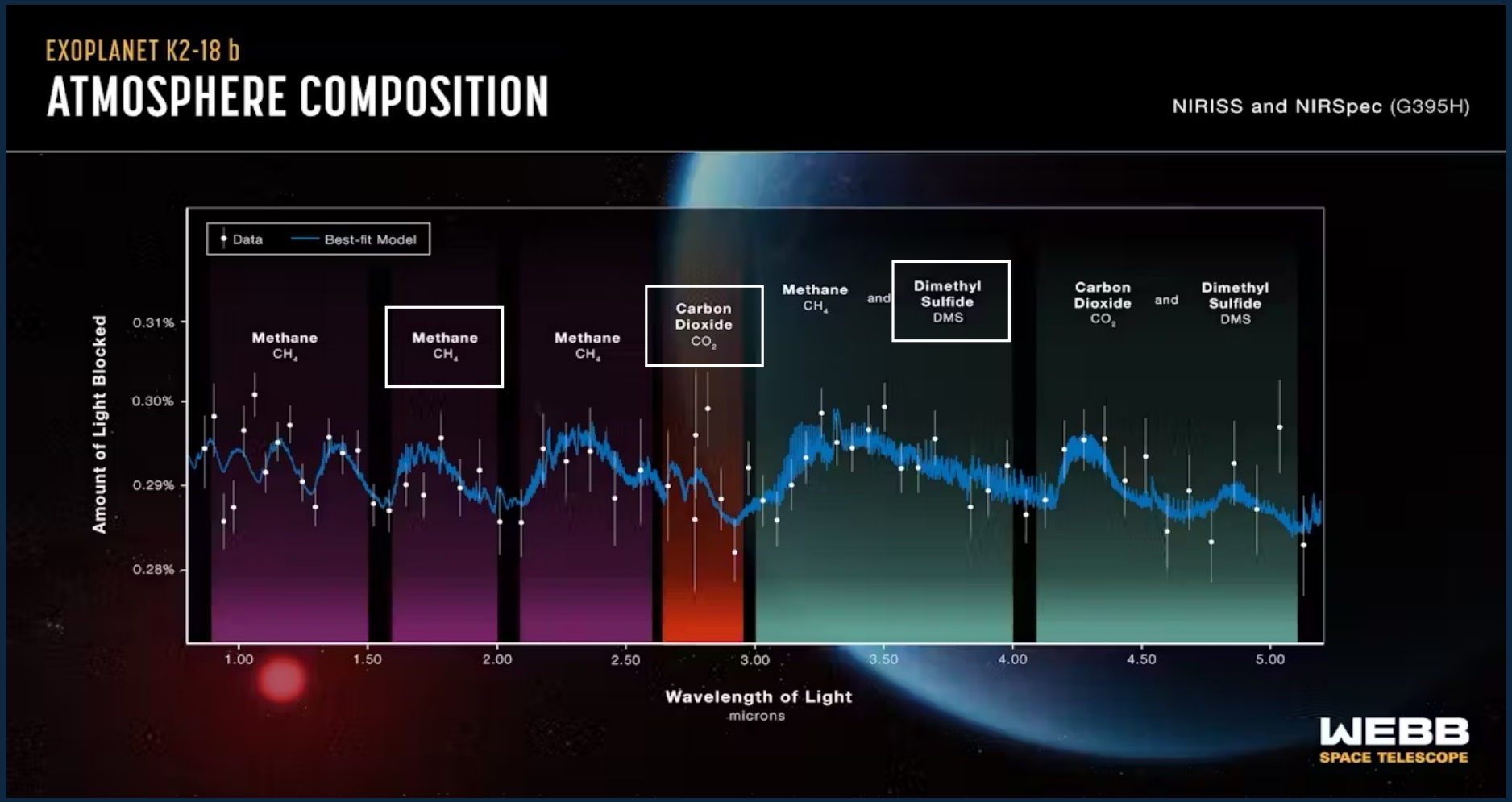
K2-18b

- An exoplanet in the constellation Leo, about 124 lightyears away (9.5 trillion km)
- Classified as a sub-Neptune
  - 2.6 times the size of Earth
  - 8.6 times Earth's mass, indicating a dense, rocky core[7]



K2-18b

- Located in the habitable zone of red dwarf star K2-18
  - Habitable zone: distance from the sun where liquid water can exist[7]
- Possible Hycean world
  - Hy (hydrogen) – cean (ocean): an exoplanet with a rich hydrogen atmosphere and liquid ocean[8]



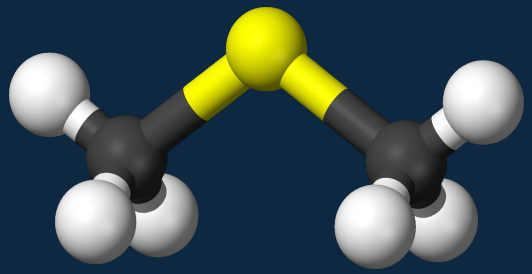
(Space.com, 2023b)

Proof of Alien Life?

We currently don't know of a way DMS can be naturally created without life

If DMS is accumulating to detectable levels, something would have to be producing it at 20 times the rate found on Earth[9]

DMS signals overlap with methane



Current instrumentation can't conclusively separate the two[10]

Proof of Alien Life?

- Detection of DMS by the JWST was not very strong & inconclusive
- More observations using better instrumentations is required to know for sure what K2-18b's atmosphere is comprised of[10]

New Recipe?

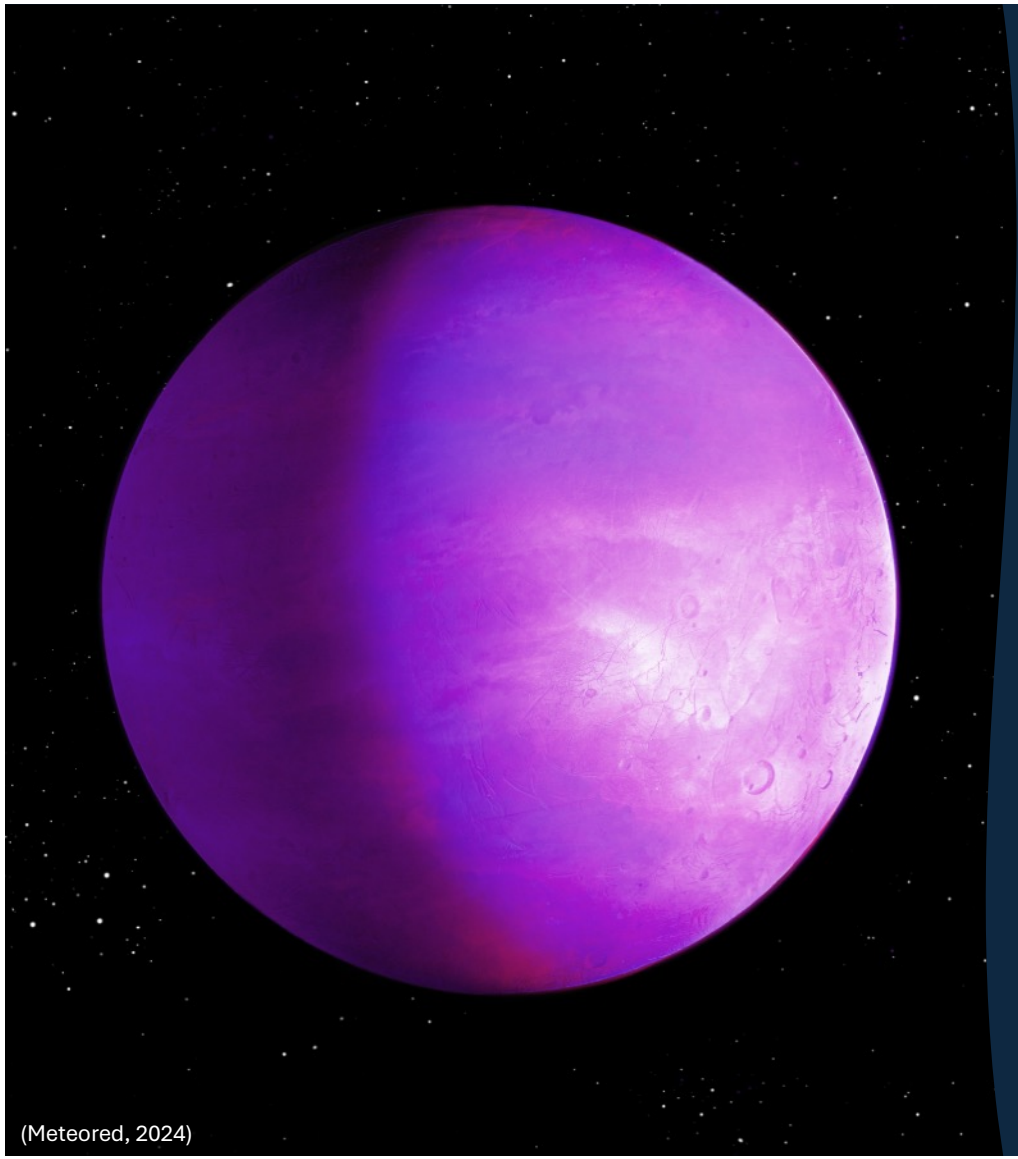
- We know that we can apply the laws of physics and chemistry known on earth and apply them elsewhere in the universe
- Would life be possible if they used a different recipe for their life soup?
- Hypothesized that silicon performs similar biochemical functions as carbon when liquid water isn't present[11]

Bioindicator Diversity

The atmosphere of a planet determines what organisms can survive there and what bioindicators they create

Green plants and bacteria that use photosynthesis NEED oxygen

What happens in a low-oxygen environment?



(Meteored, 2024)

No Oxygen? No Problem!

Prior to photosynthesis on Earth, microorganisms generated energy using a purple molecule called retinal[12]

The current search for alien life is biased towards looking for green pigments[13]

In reality, life could be purple!

Conclusion

- Bioindicators like DMS are critical clues for finding life on other planets
- Spectroscopy allows us to “read” a planet’s atmosphere
- Life on other planets may not resemble Earth’s
  - It could be purple, thrive in a hydrogen-rich atmosphere, or rely on chemistry we haven’t even discovered
- As our technology improves, finding alien life is becoming less of an “if” and more “when”

"Why do we keep exploring the cosmos for signs of life?" Tsai asked rhetorically.

"Imagine you're camping in Joshua Tree at night, and you hear something. Your instinct is to shine a light to see what's out there.

That's what we're doing too, in a way."[14]


Questions?

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