

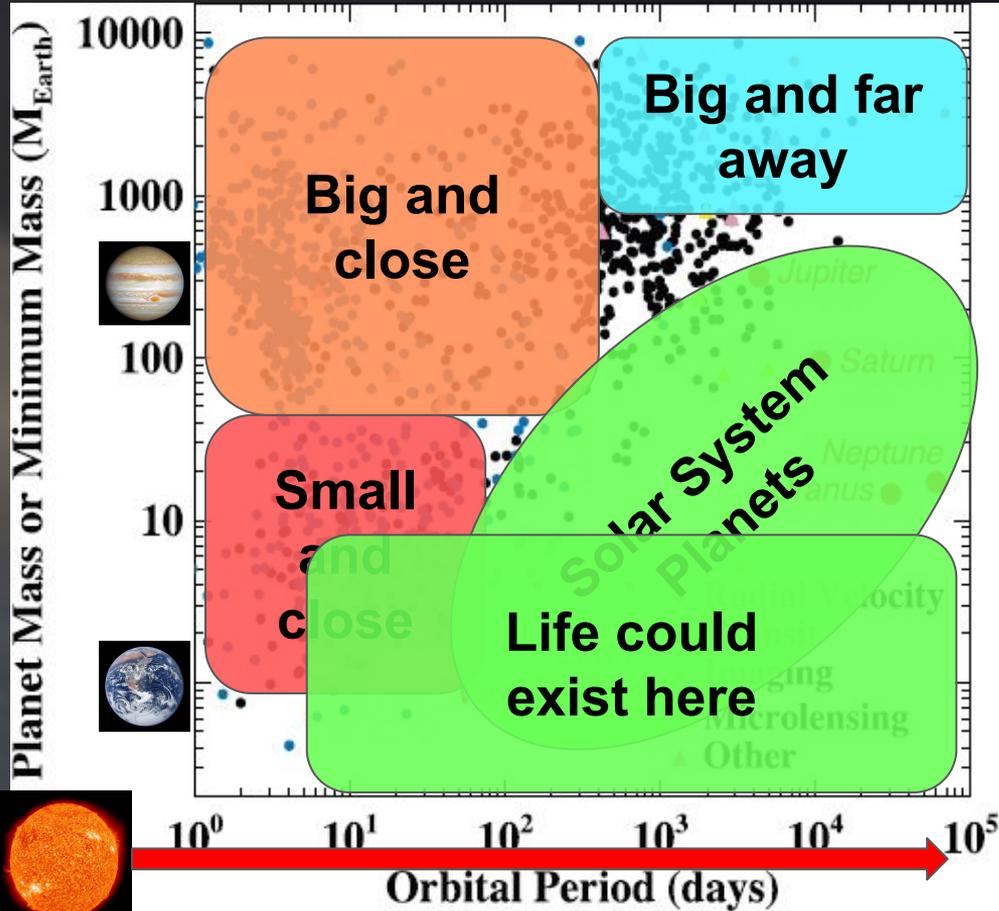
Exoplanets and Life Beyond Earth

Lecture 5

Recap from last week:

**Types of exoplanets
outside the solar system**

Types of Exoplanets



Planets are sorted from close to far away (x-axis) and small to large (y-axis).

Most exoplanets found are big and close because of how we observe them.

Far away planets we only found if they are big. These planets are colder because they receive less light.

Small planets we only found if they are small. These planets are very hot because they receive a lot of light.

Hot Jupiter

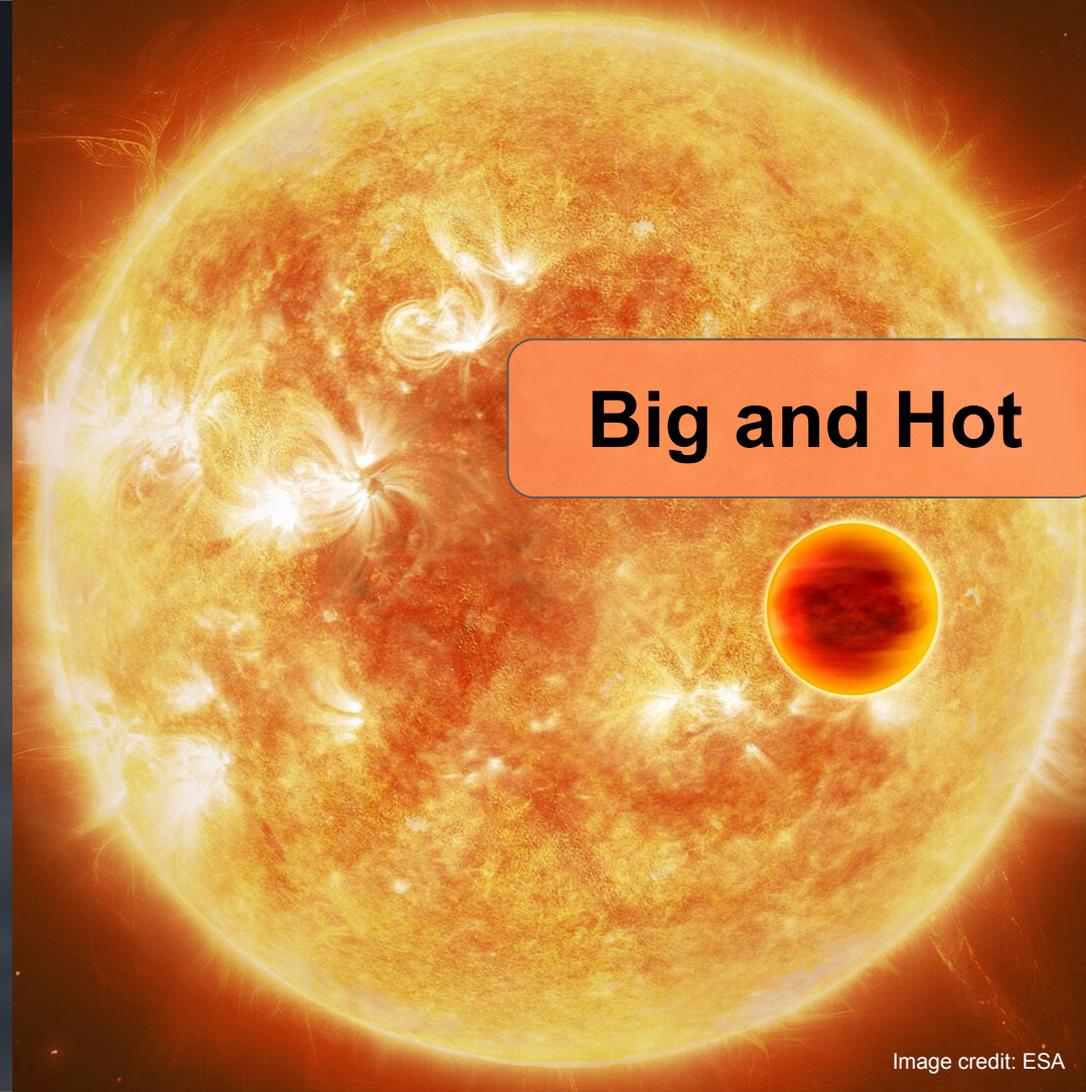
The same size as Jupiter, but closer to the Sun than Mercury!

Made from gas.

Does not have a rocky surface.

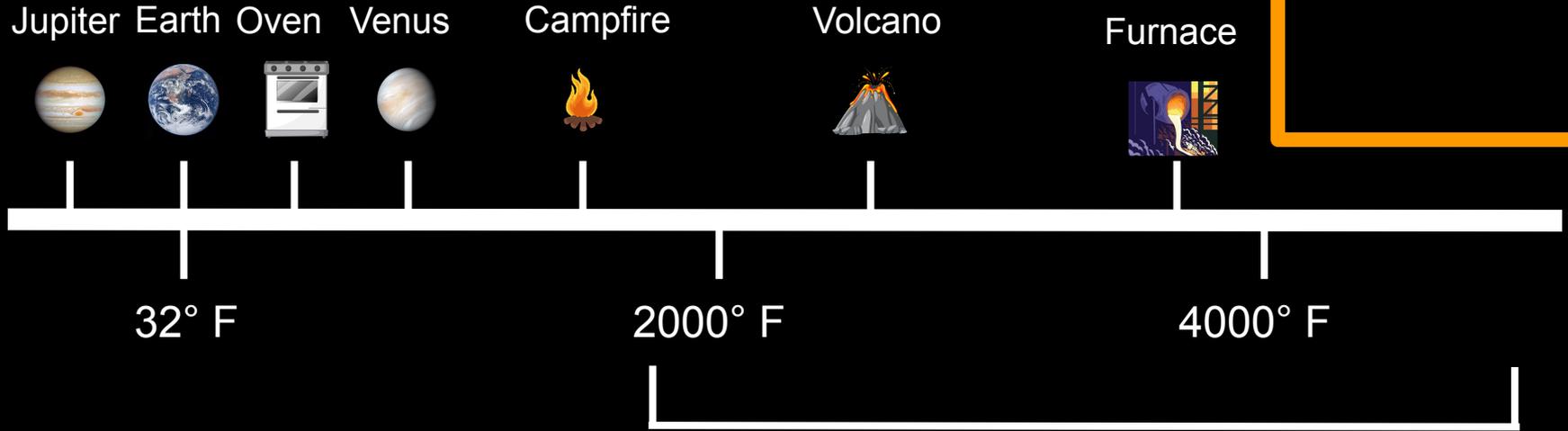
Can we find life on a hot Jupiter?

- **No!**
- **No solid surface**
- **They are too hot, but how hot are they?**



Big and Hot

How hot are hot Jupiters?



Hot
Jupiter

Lava Worlds

They are also closer to their star than Mercury is to our sun.

They have a rocky surface.

They are very hot.

Can we find life on a Lava World?

- **No!**
- **No atmosphere**
- **They are too hot, up to 3000°F!**

**Small,
close**



Super Earths

Planets that are bigger than Earth but smaller than Neptune.

They have a rocky surface.

They have a thick atmosphere.

Can we find life on a Super Earth?

- Maybe!
- But it needs to be in the right spot

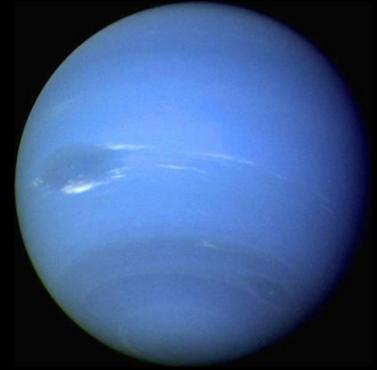


Too hot

Just right
for a
Water
World

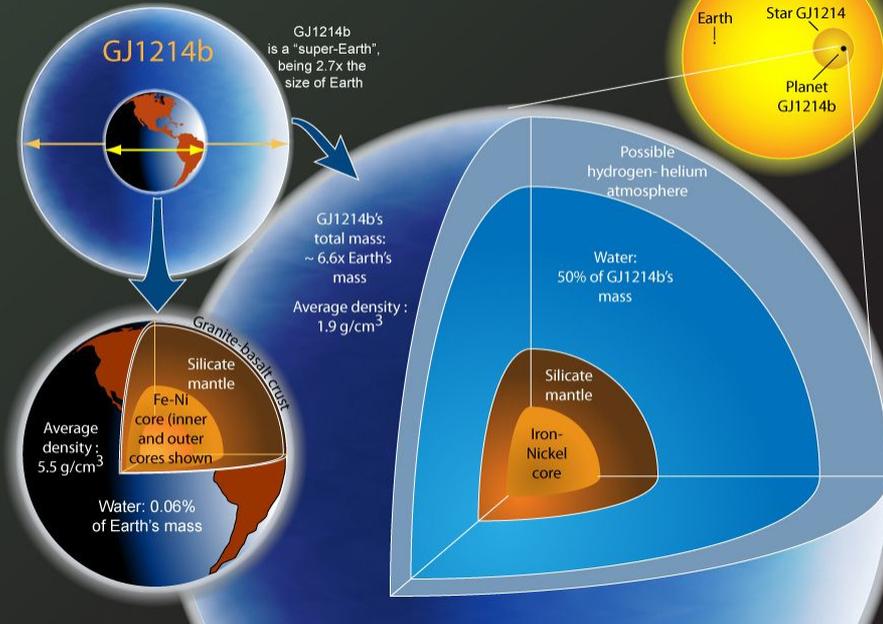
Too cold

Image credit: Wikipedia/Aldaron and NASA



Water World: Exoplanet GJ 1214b

From Nature 17 Dec. 2009; Review by Marcy; Letter by Charbonneau et al.
Illustration © copyright John Garrett



Tidally locked planets

Only planets around small stars (e.g. M-dwarfs) can be tidally locked and habitable.

Only a small strip of the planet has liquid water. The night side is frozen, the dayside is a desert.

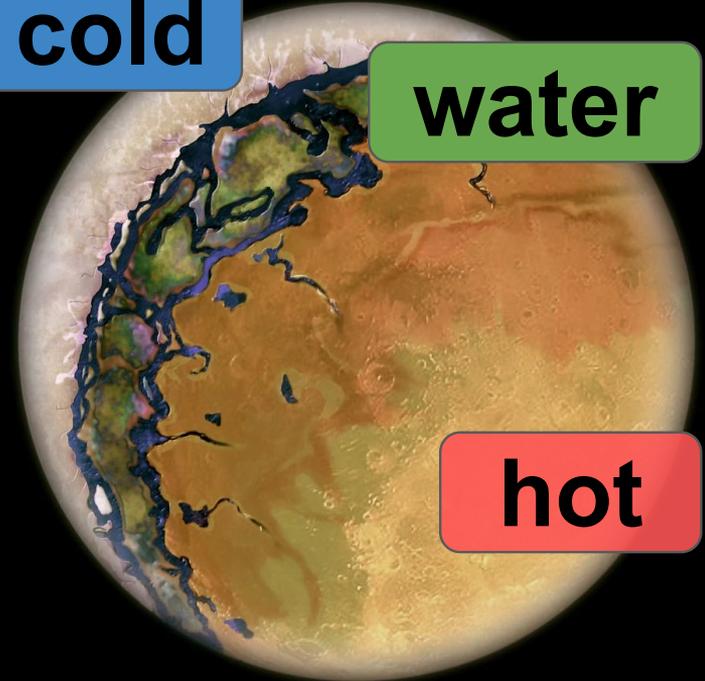
We have found tidally locked planets in the habitable zone but they have no atmosphere.

M-dwarf



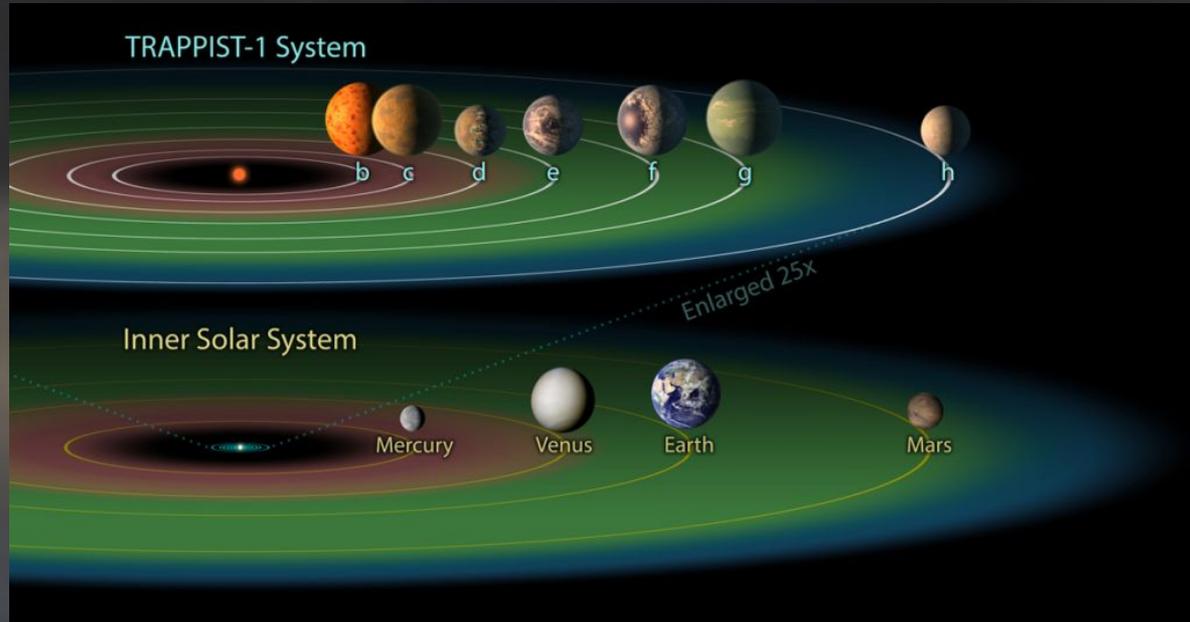
cold

water



hot

TRAPPIST-1 System



The trappist system has 3 planets in the goldilock zone.

All planets are tidally locked.

So far we have not found an atmosphere on any of the 7 planets. And we have tried very hard!

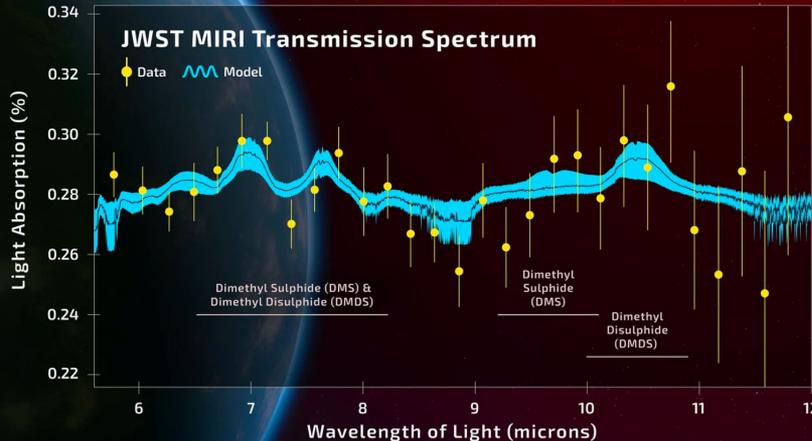
K2-18b

K2-18b is a super Earth.

It might be a water world.

Some researchers think they found signs of life on this planet.

So far, we don't know if there is life on K2-18b.



Homework

EXOPLANETS AND LIFE BEYOND EARTH

LECTURE 4 WORKSHEET

COULD THERE BE LIFE?

Circle the planets which could host life on its surface.

**Hot
Jupiter**

**Super-
Earth**

**Tidally
locked
rocky
planets**

**Lava-
world**

TRUE OR FALSE

T | F : Planets in the Goldilock zone can have water oceans.

T | F : Lava-worlds are far away from their host stars.

T | F : The Star Wars planet Tatooine could be real.

T | F : The Trappist-1 system has 3 planets in the Goldilock zone.

THE GOLDILOCK ZONE

- 1) Highlight the region where water could exist in liquid form.
- 2) Draw a planet that could have liquid water oceans



392°F



212°F



32°F



-148°F

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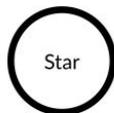
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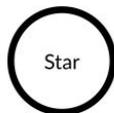
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This Week's Topic:
Finding Life on
Exoplanets

How could we find life on other planets?

- 1) Find biosignatures in planet atmospheres
- 2) Find intelligent life signals (such as radio communication)
- 3) Find techno signatures



What is a biosignature?

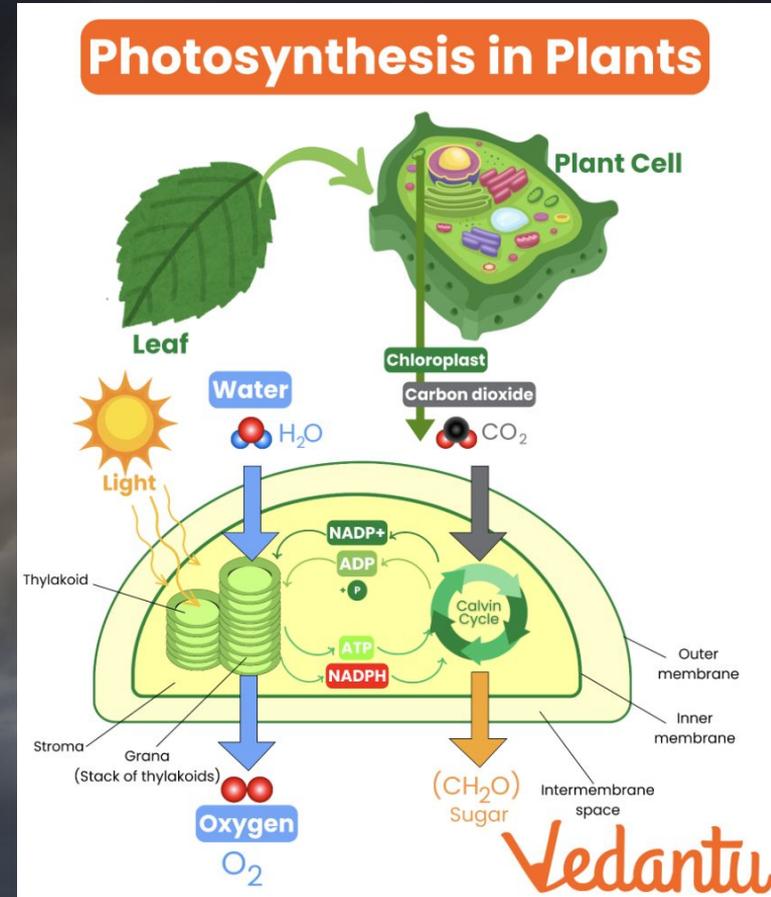
- A feature in the planet's atmosphere that can be made from life

- 1) Gases produced by life: molecular oxygen (from plants), methane (from animals), ozone (from plants + UV light)
- 2) Planet surface information (e.g. reflection off of vegetation)
- 3) Seasonal (changes in atmospheres or surfaces due to changing seasons on planet)



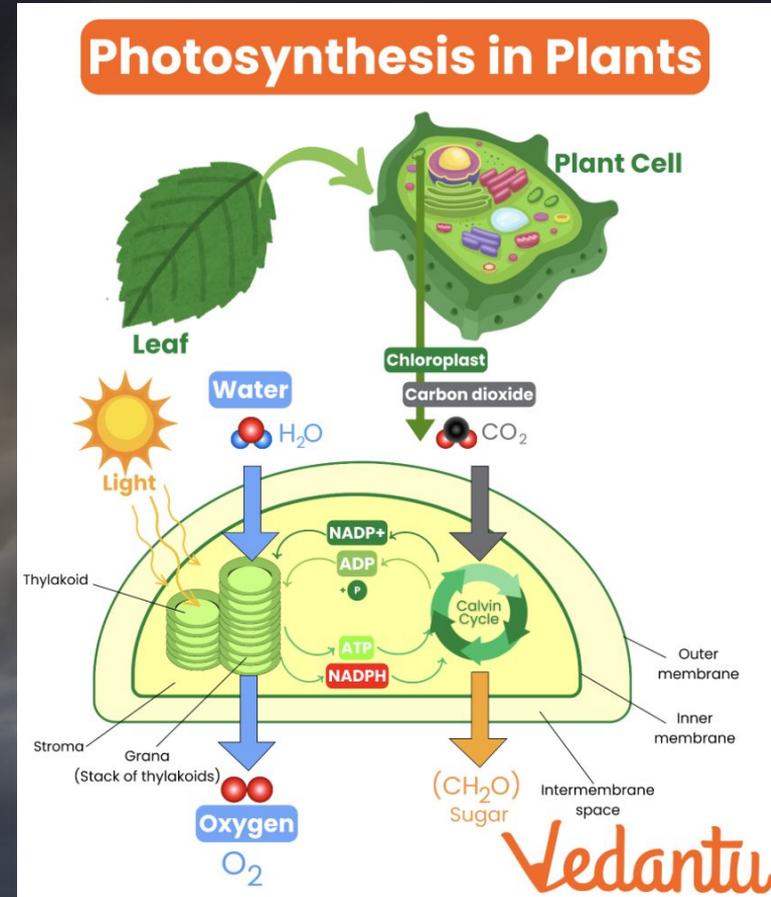
Gaseous biosignatures

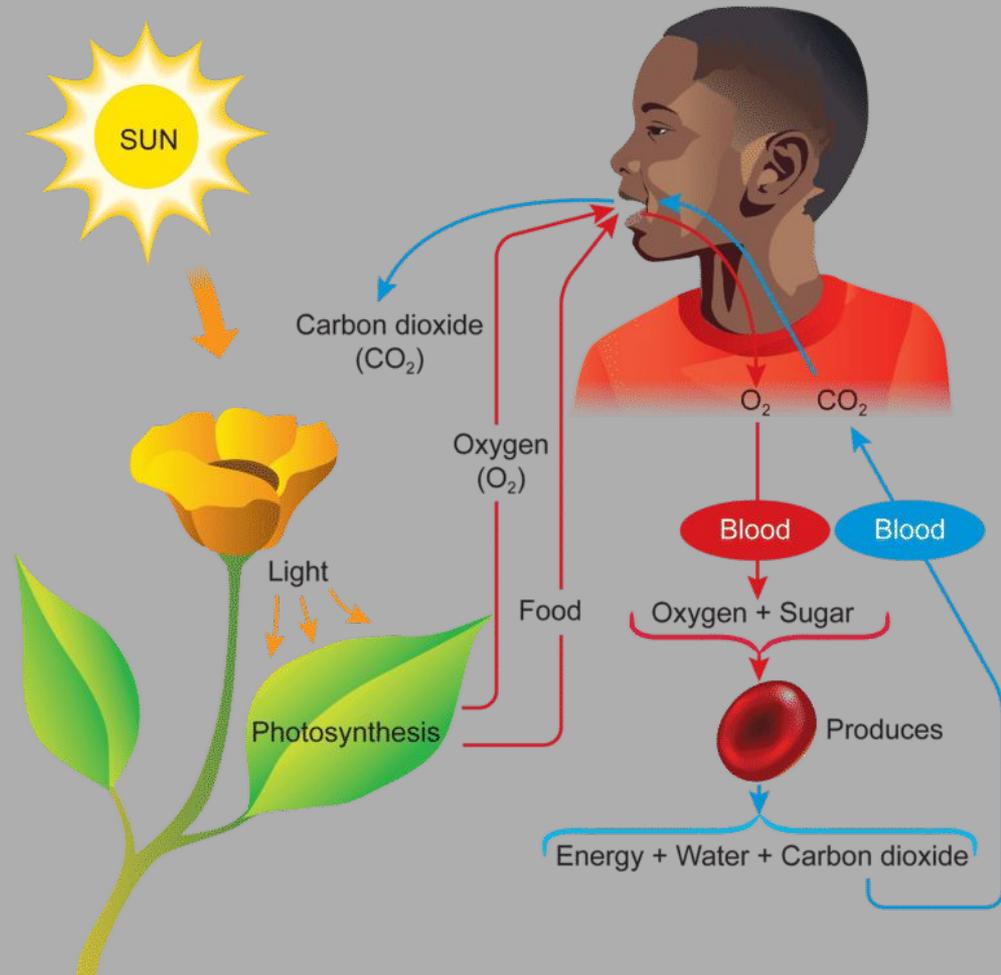
- Molecular oxygen (O_2)
- Plants use water and carbon dioxide to make energy and molecular oxygen
- Carbon dioxide is commonly produced around stars and star forming regions



Gaseous biosignatures

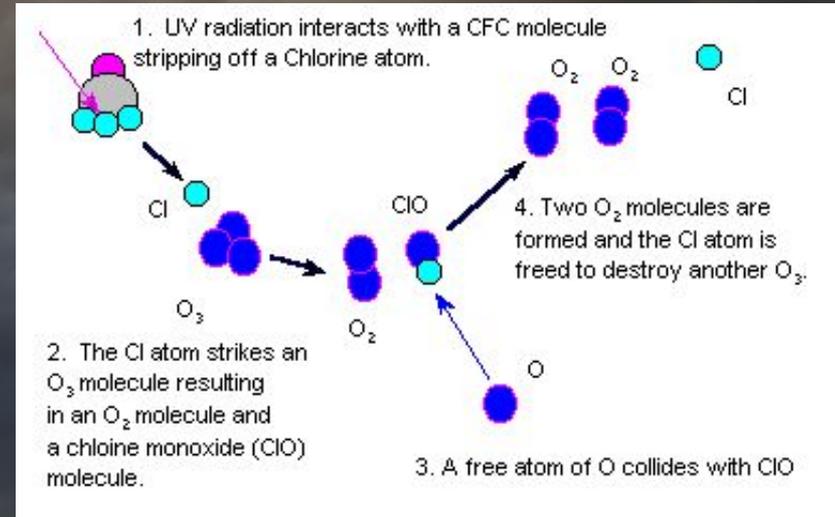
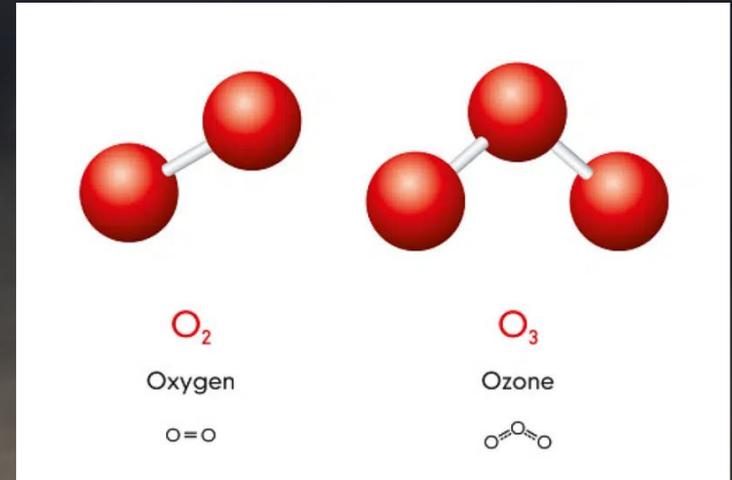
- Carbon dioxide is commonly observed in many exoplanet atmospheres
- If we found carbon dioxide and molecular oxygen, that would be a strong indicator that plant life exists on that planet





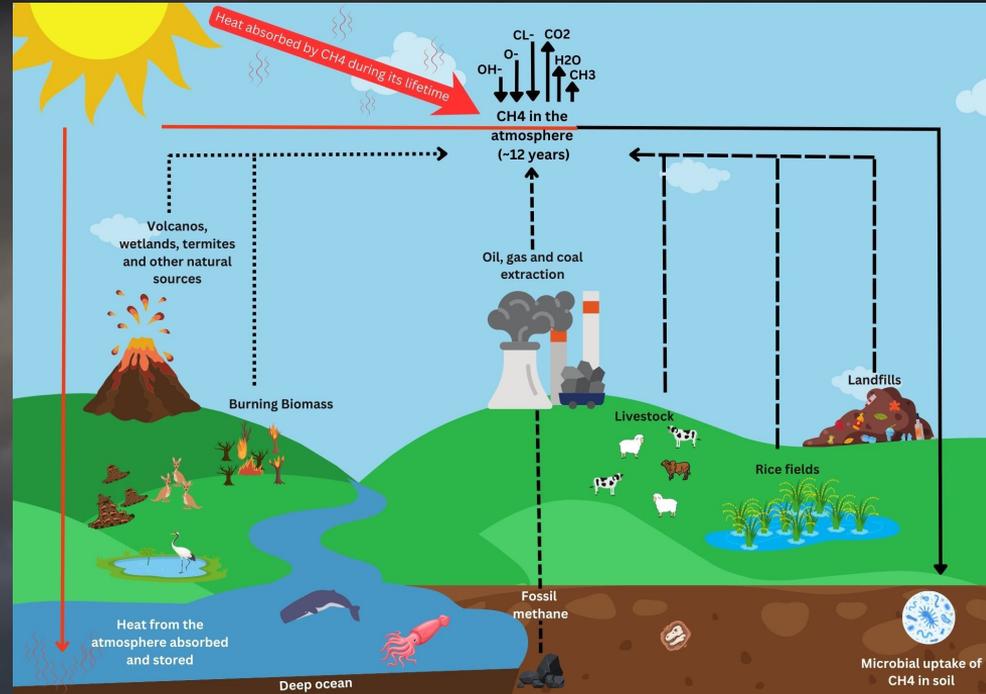
Gaseous biosignatures

- Ozone (O_3)
- Produced from O_2 reacting with UV light
- Because it can breakdown easily, if we see ozone, that means something on the planet must be making O_2 consistently

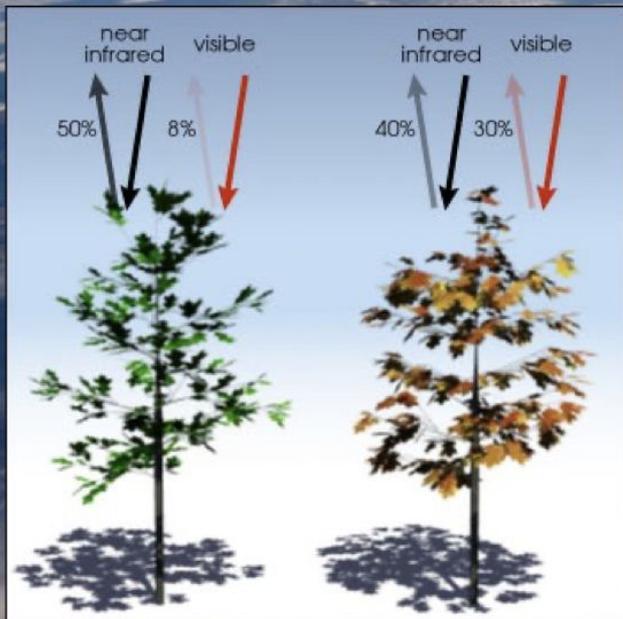


Gaseous biosignatures

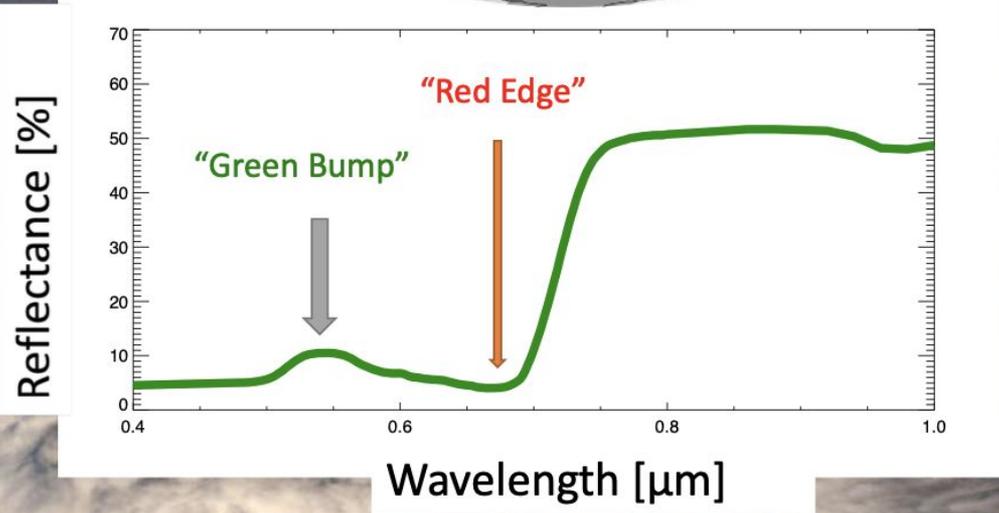
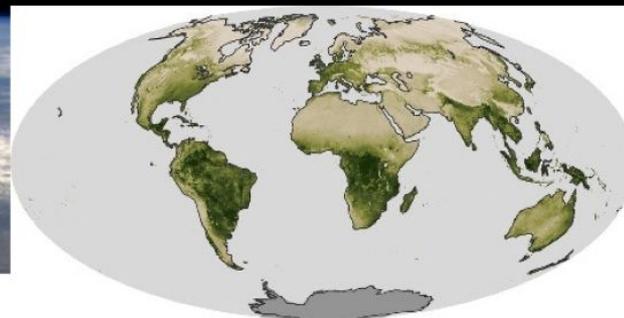
- Methane (CH_4)
- Methane has a short lifetime so if it is present in an atmosphere, it may be continuously replenished by life
- Animals, burning plants, and industry release methane
- But can be made from non-life processes, like volcanos



Surface Biosignature: Vegetation “Red Edge”



NASA Earth Observatory

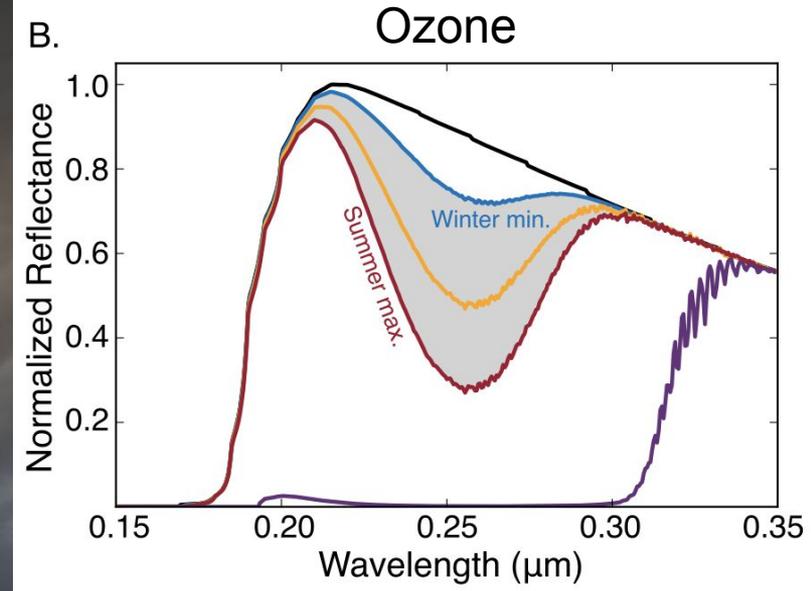
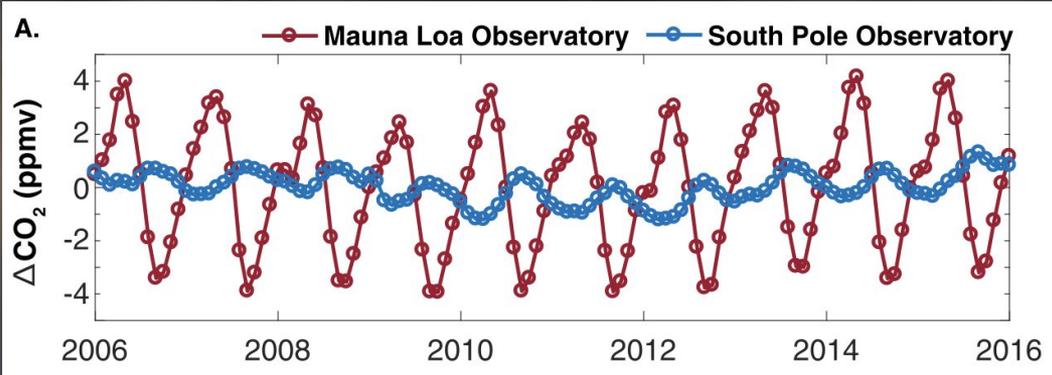


Seasonal Biosignatures

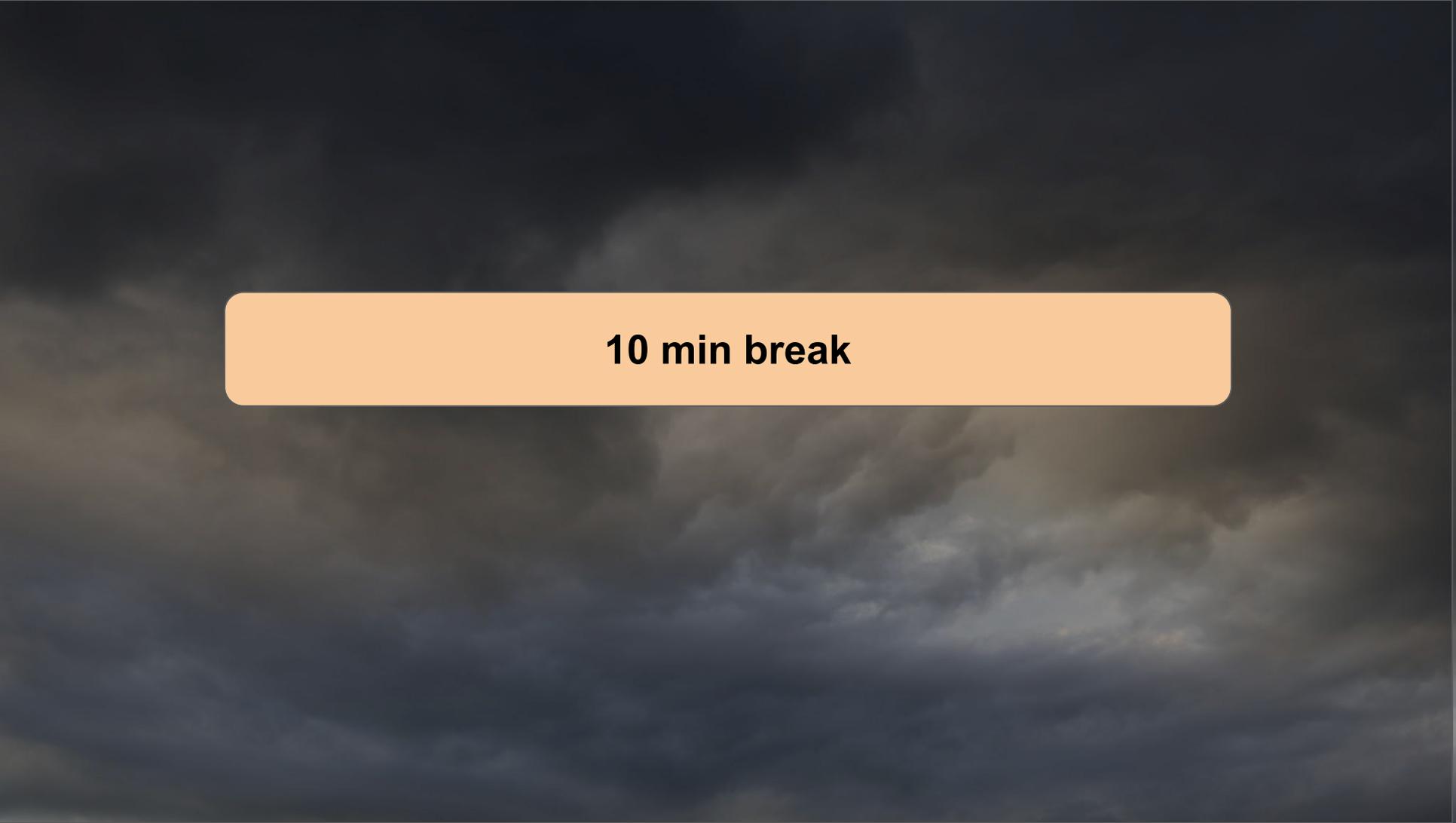
- In summer, there is more molecular oxygen
- In winter, there is more carbon dioxide
- This is from the plant life cycle



Seasonal Biosignatures



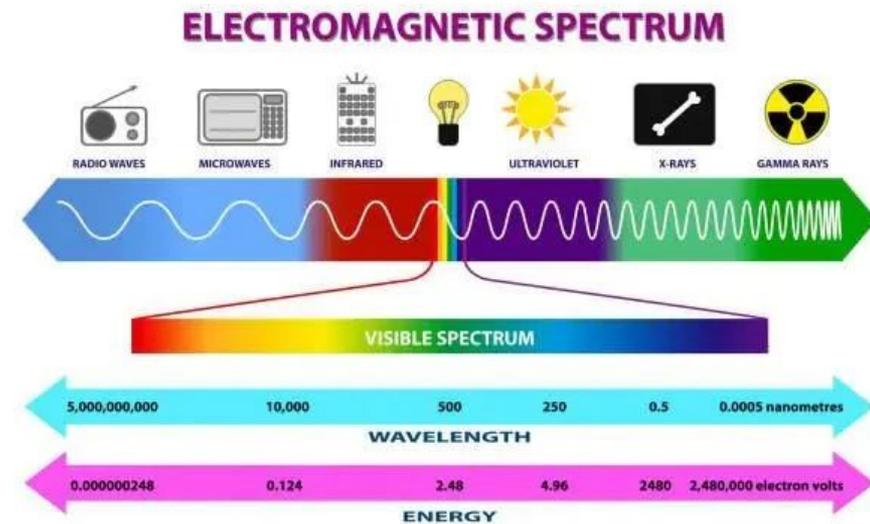
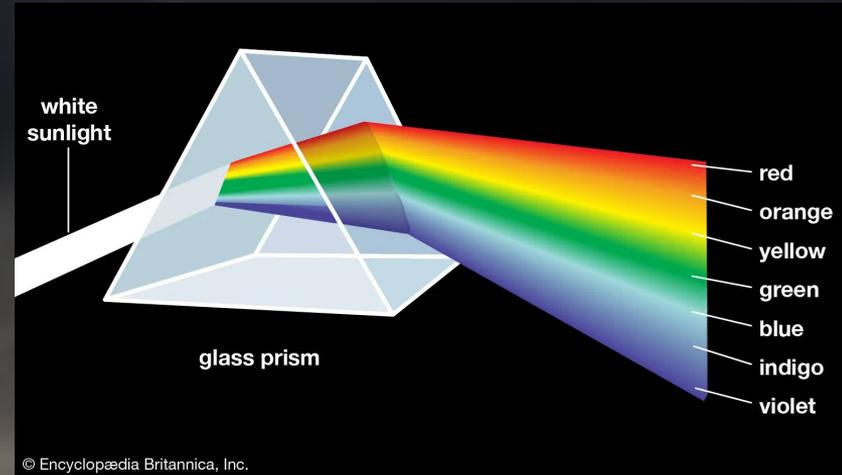
Olson+18



10 min break

How can we find biosignatures on other planets?

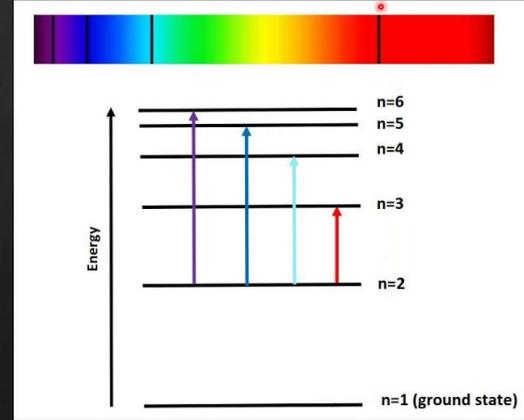
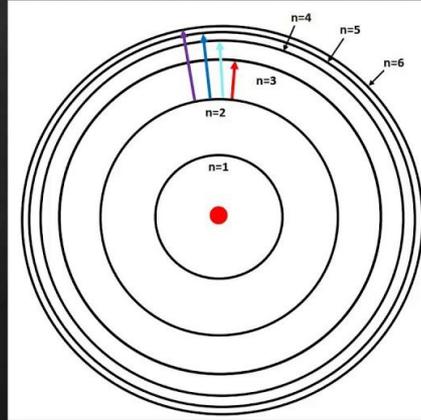
- We must look at the light coming from these planets
- They will retain the signal of their atmospheres
- Their light covers a lot of different colors (also called wavelengths)
- We spread this light out into a “spectrum”



How can we find biosignatures on other planets?

- Light emitted from the planet will pass through its atmosphere
- The molecules in the atmosphere will absorb light so that specific energy will not be seen in its spectrum

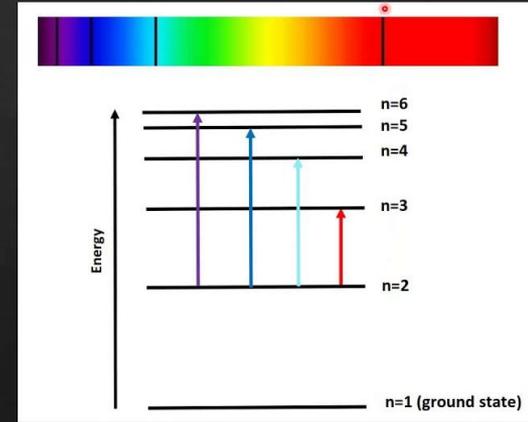
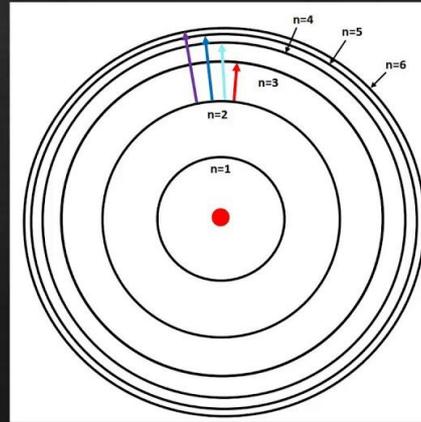
Absorption spectrum



How can we find biosignatures on other planets?

- What's really happening is the electrons in the atoms are moving to different energy levels when they absorb light
- Hydrogen is the easiest example because it has one electron

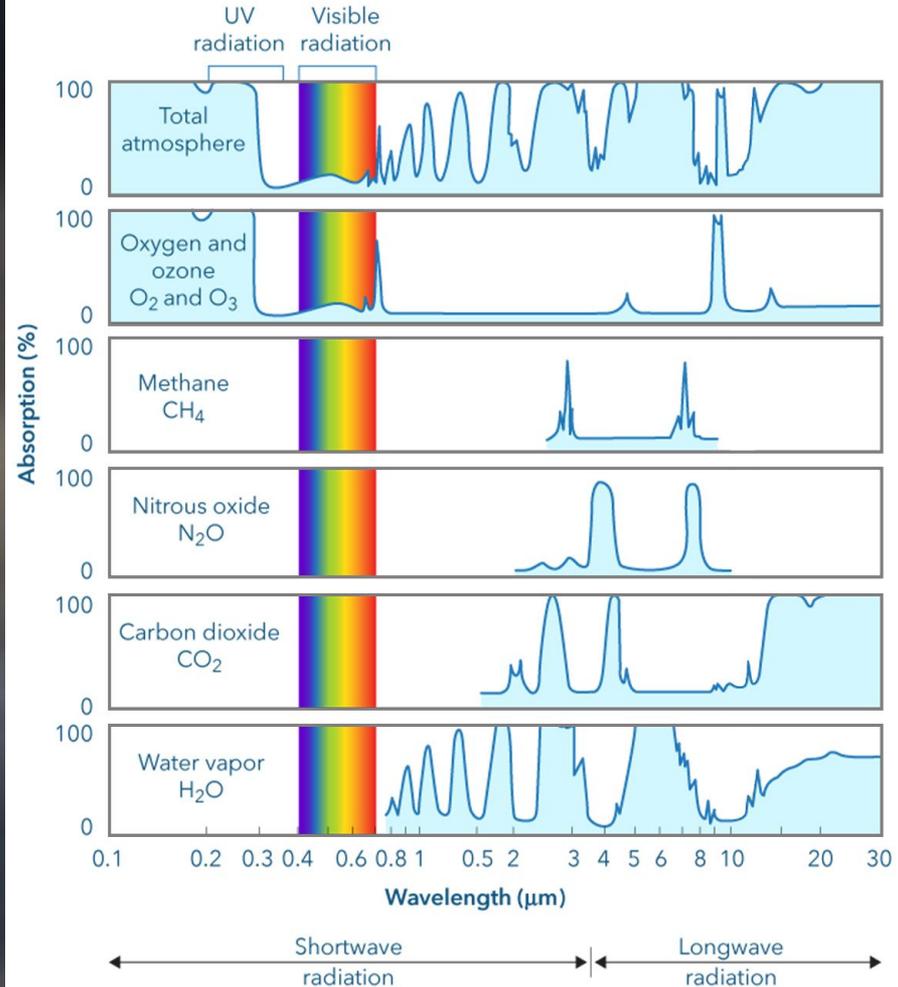
Absorption spectrum



Earth's "Atmospheric Windows" to Solar Energy

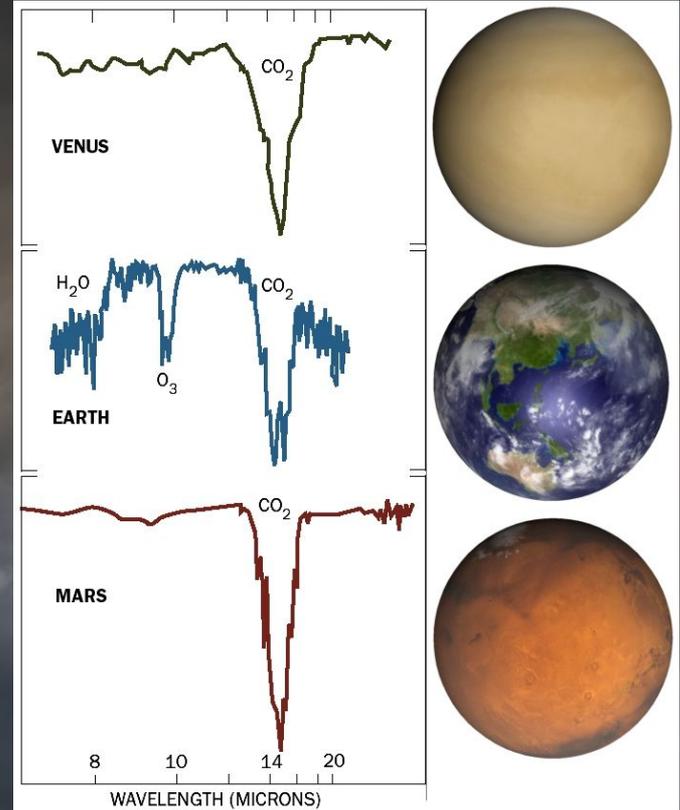
How does this look for Earth?

- Molecules have really funky absorption features because their electrons can move to many different energy states
- Different molecules result in different absorption features



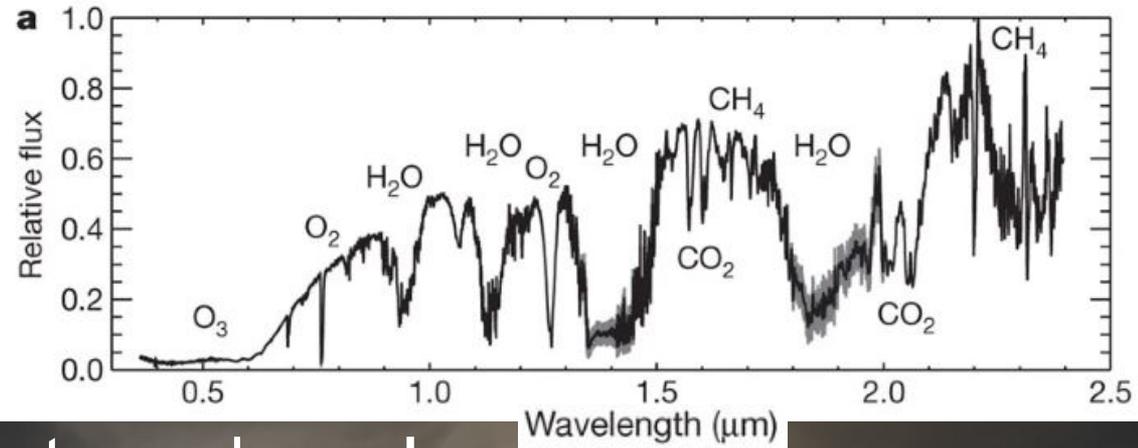
The atmosphere of Planets with life look different

- Venus and Mars only have a single feature from carbon dioxide (CO₂).
- Earth has multiple features from Water, Ozone (O₃) and also carbon dioxide (CO₂).



We cannot see directly onto other planets to find life.

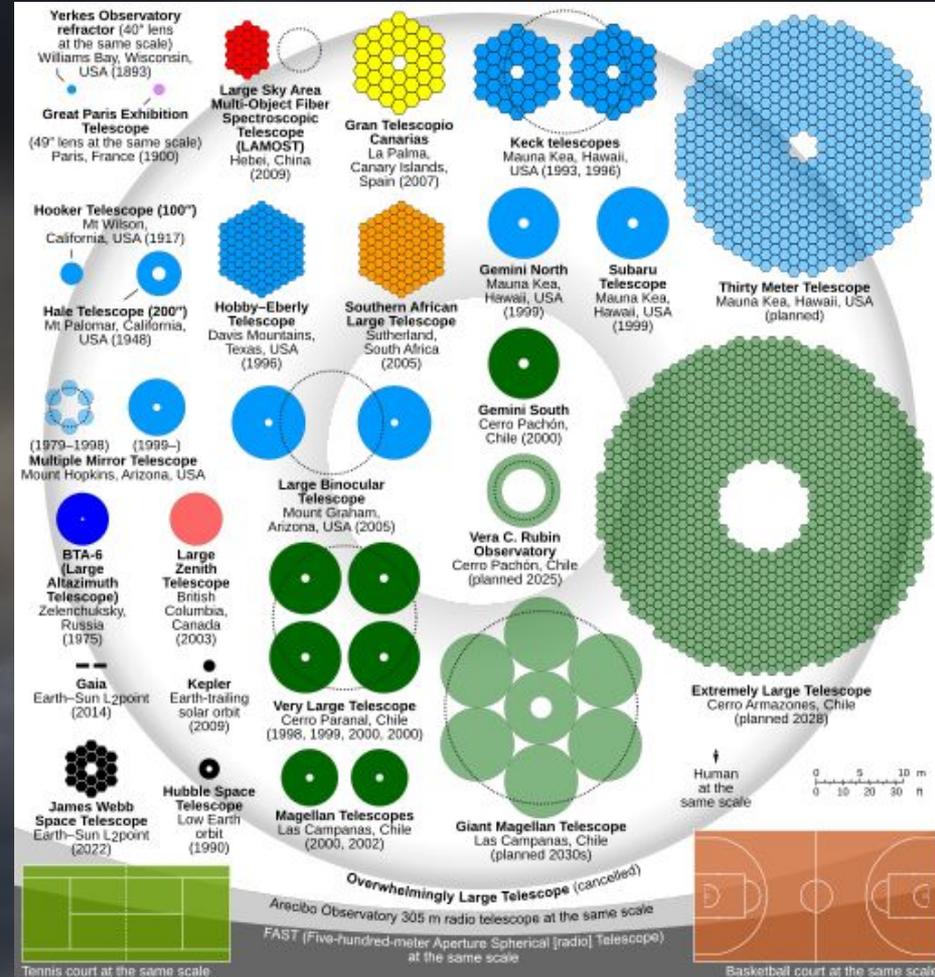
Figure 1: Earth's visible and near-infrared transmission and reflection spectra.



- But we can see their atmospheres!
- Earth's atmosphere has molecules that may be signatures of life.
- Molecular oxygen, ozone, water, methane, carbon dioxide, etc.
- We need very big telescopes to be able to see these molecules around other planets.

Thirty Meter Class Telescopes

- Will be the biggest optical/infrared telescopes ever created.
- Will look for molecules in planets as tracers of life.
- Extremely Large Telescope (ELT)
- Giant Magellan Telescope (GMT)
 - UT is a partner
- Thirty Meter Telescope (TMT)



The Fermi Paradox

**If life is common in the universe,
where are all the aliens?**

The Fermi Paradox

- Where are all the aliens?
- The Milky Way Galaxy is 13 billion years old
- There are 100 billion stars in our galaxy
- ~ 20% have rocky planets in the Goldilocks Zone
- If intelligent life forms on 0.1% of those planets, there should be 20 million planets in our Galaxy alone that has intelligent life
- **WHERE IS EVERYBODY?**

Breakout Activity: The Drake Equation

$$N = R_* \times f_p \times n_e \times f_l \times f_i \times f_c \times L$$



The **number** of technologically advanced civilizations in the Milky Way Galaxy



The **rate** of formation of stars in the galaxy



The fraction of those stars with **planetary** systems



The number of planets per solar system with an **environment** suitable for life



The fraction of suitable planets on which **life** actually appears



The fraction of life-bearing planets on which **intelligent** life emerges



The fraction of those planets with intelligent life that develop interstellar **communication**



The **length** of time such civilizations release detectable signals into space

Signals from Intelligent Life

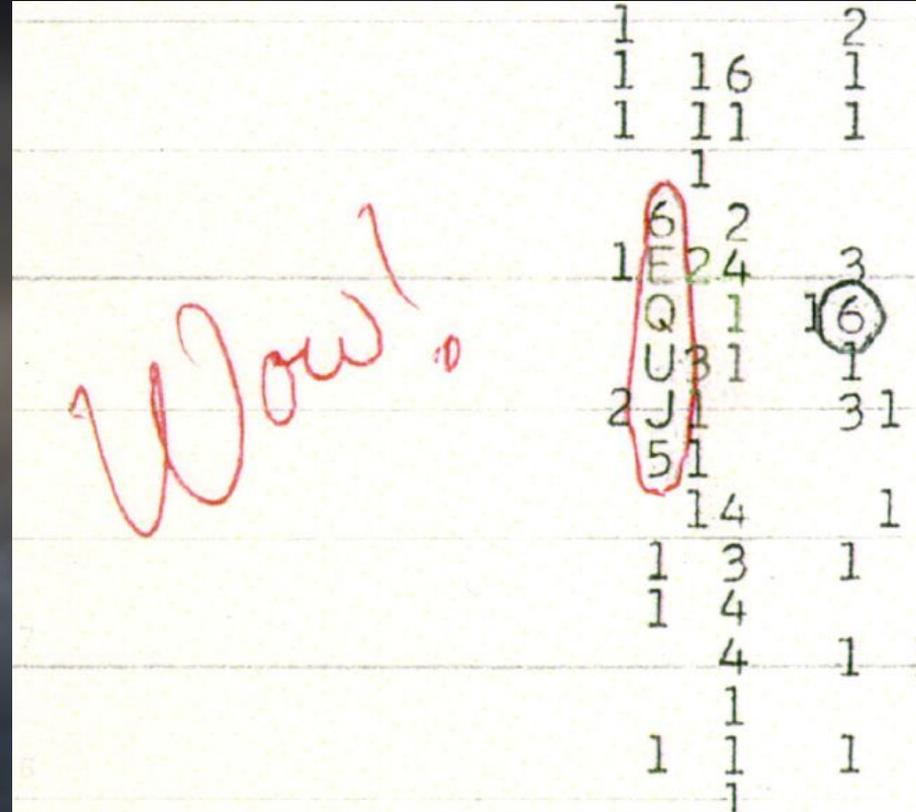
- Humans communicate using radio waves
- Like your cell phone, the radio, the television, the internet, and many other ways
- Aliens could also communicate this way
- We can search for alien communication using giant radio dishes that could collect signals from other planets

Signals from Intelligent Life - The WOW signal

The WOW signal was a very strong radio signal coming from the center of our galaxy that lasted for 72 seconds in 1977.

We did not find the signal again after observing the same part of the sky later.

It is unclear if this signal was really from an alien. Most likely it is of natural origin.



Search for Extraterrestrial Intelligence (SETI) - Breakthrough Listen

Breakthrough listen observes the closest 43 stars to our sun and over 1,000,000 other stars in total.

They also observe 100 nearby galaxies like the andromeda galaxy.

So far, no signs of intelligent life has been found.

This is the andromeda galaxy



Image credit: Brody Wesner

This is a telescope with which we search for intelligent life.

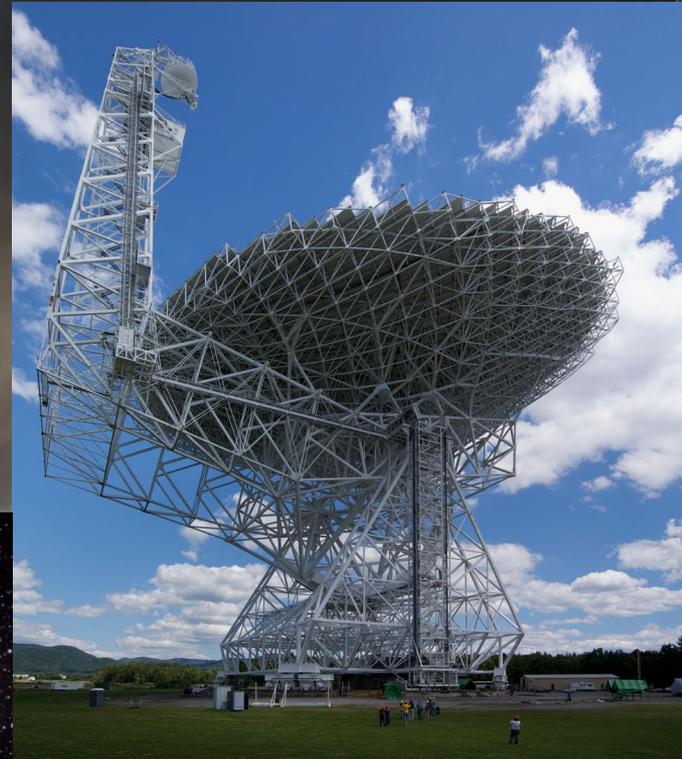
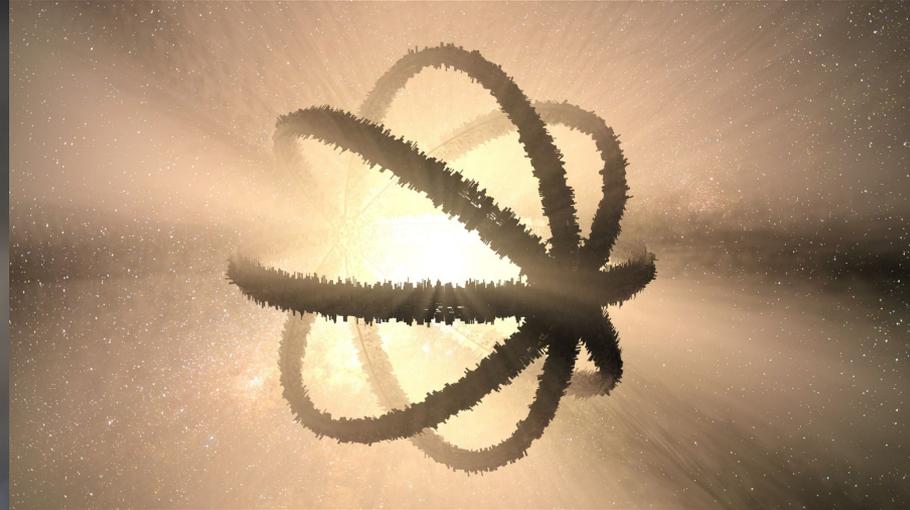


Image credit: Wiki/Geremia

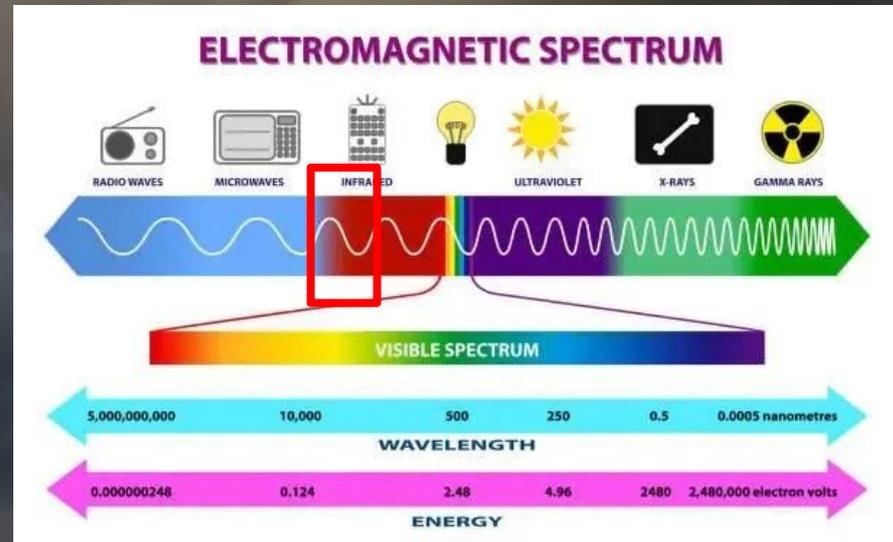
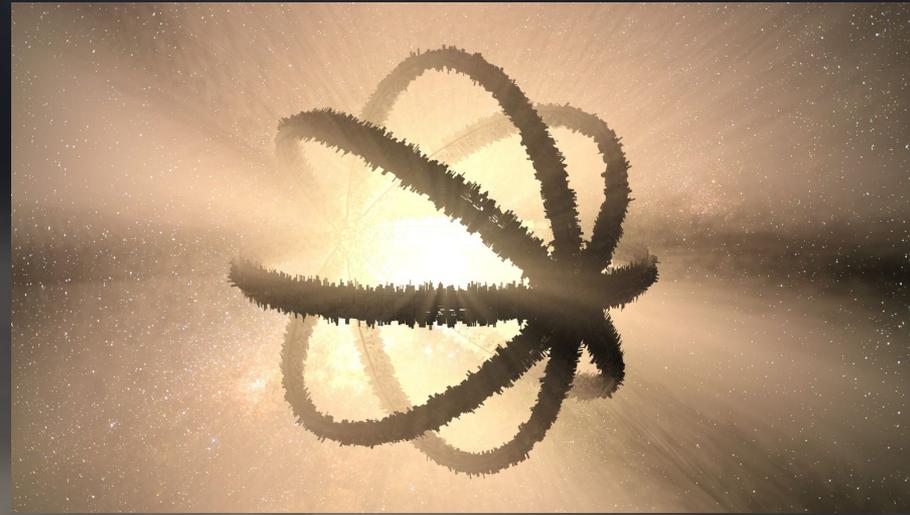
Technosignatures from Intelligent Life: Dyson Spheres

- Large objects that surround a star
- They collect light from the star that we can use as energy
- Stars make much more energy than we could ever produce
- Dyson Spheres would collect more energy than we could ever produce



Technosignatures from Intelligent Life: Dyson Spheres

- Because Dyson spheres collect energy, they are hot and radiate in the infrared
- We could find candidates if we find object that only emit light in the “mid-infrared”



Technosignatures from Intelligent Life: Dyson Spheres

- They could also cause dips in the star's light if it only covers a portion of the star
- Unusual dips or fluctuations in the star's light that happen repeatedly could be candidates for Dyson Spheres

