THE DRAKE EQUATION

& THE SEARCH FOR EXTRATERRESTRIAL LIFE IN THE MILKY WAY GALAXY

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THE DRAKE EQUATION

Figure 1: The Drake Equation. Retrieved from https://noirlab.edu/public/images/Drake_Equation/

Purpose

An equation developed by Frank Drake in 1961 to estimate the number of active extraterrestrial civilizations in the Milky Way capable of communication.
(The Editors of Encyclopaedia Britannica, 1998 & Ithy - Is Drake's Equation Solvable?, n.d.)

Limitations

1. Lack of empirical data
2. Big uncertainty
3. Anthropocentric Bias
4. Philosophical and Methodological Concerns
5. Ignorance of Sociopolitical Factors
6. Alternative Models and Equations

(Nse, 2023)

STAR FORMATION RATE

01

In the Milky Way

1. The current SFR is estimated to be about 1.5–2 solar masses per year, meaning that this amount of gas is turned into stars annually
2. Since most stars formed are less massive than the Sun, this corresponds to the formation of approximately 6–7 new stars per year in our galaxy

(Staff, 2023 & Roche, 2024)

02

Cosmic Star Formation History

1. The global star formation rate peaked about 10 billion years ago and has declined by approximately 97% since then (Siegel, 2024)
2. This decline is attributed to the depletion of molecular gas and other regulatory factors such as feedback from supernovae and active galactic nuclei

03

Factors Influencing SFR

1. The amount of molecular gas available
2. The timescale over which the gas reservoir is depleted by converting it into stars

(*How Nearby Galaxies Form Their Stars*, 2020)

Figure 2: Sh 2–106 is one of many star-forming regions in the Milky Way. Retrieved from https://www.astronomy.com/science/ask-astro-how-many-stars-are-born-each-year-in-the-milky-way/

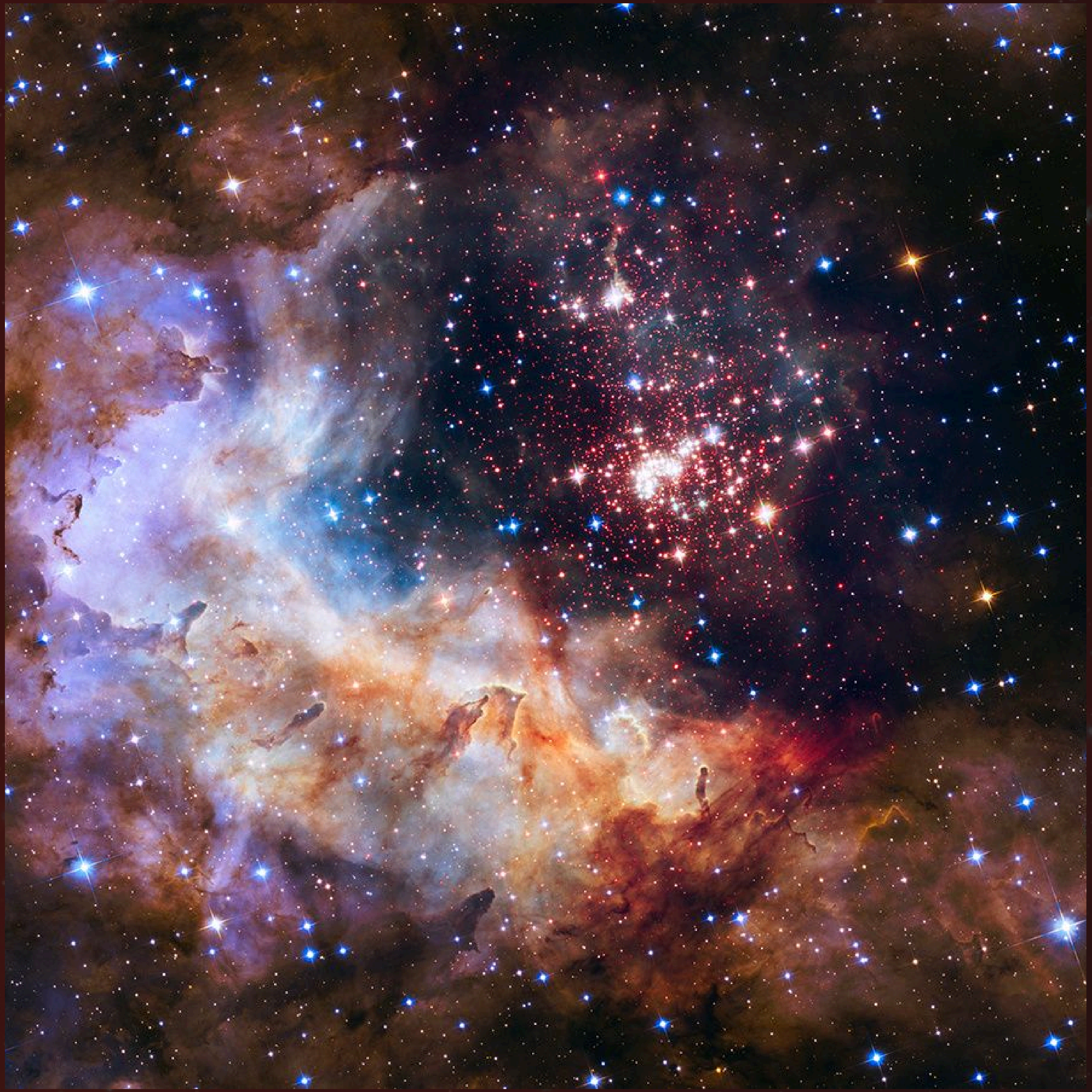
FRACTION OF STARS WITH PLANETS

01

- What we can see is very limited
- Greg has estimated that around 1% of stars' systems are the correct orientation

02

- Most stars have planets - Greg
- Planets are SMALL and DARK which makes them hard to see



METHODS OF EXOPLANET DISCOVERY

- Direct Observation
- Astrometry
- Radial Velocity
- Transit Photometry
- Gravitational Microlensing

Between 25 and 100% of stars have planets

(Lineweaver and Grether, 2003)

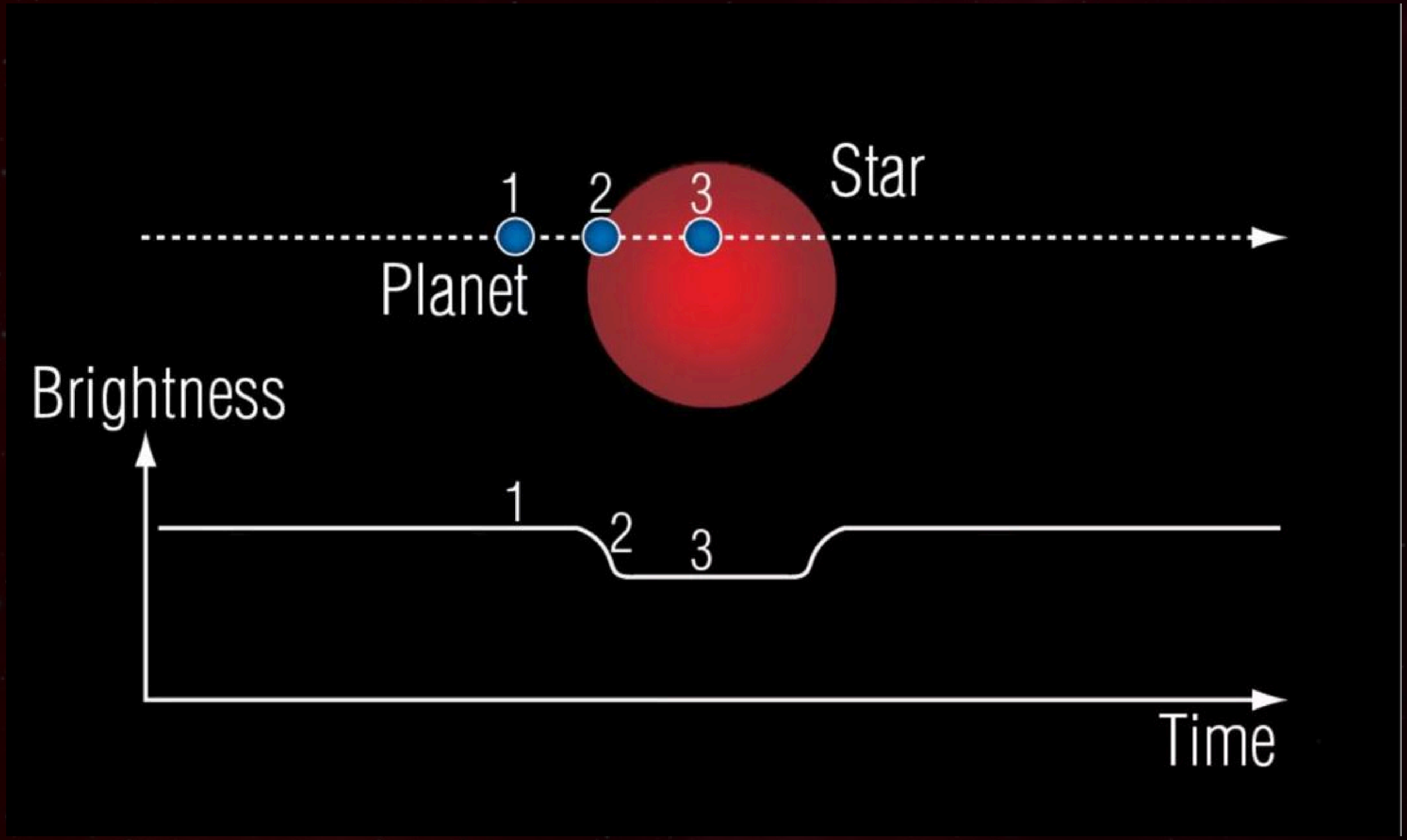
TRANSIT PHOTOMETRY

01 Detecting planets with relatively short orbital periods when solar system is in the correct orientation compared to the Earth

02 Telescopes with large field of view allow us to monitor the spectra of many stars at once

03 Method was implemented in 1999 and we still use it today

(The Planetary Society, 2002)



(Figure 3: The Planetary Society, 2002)

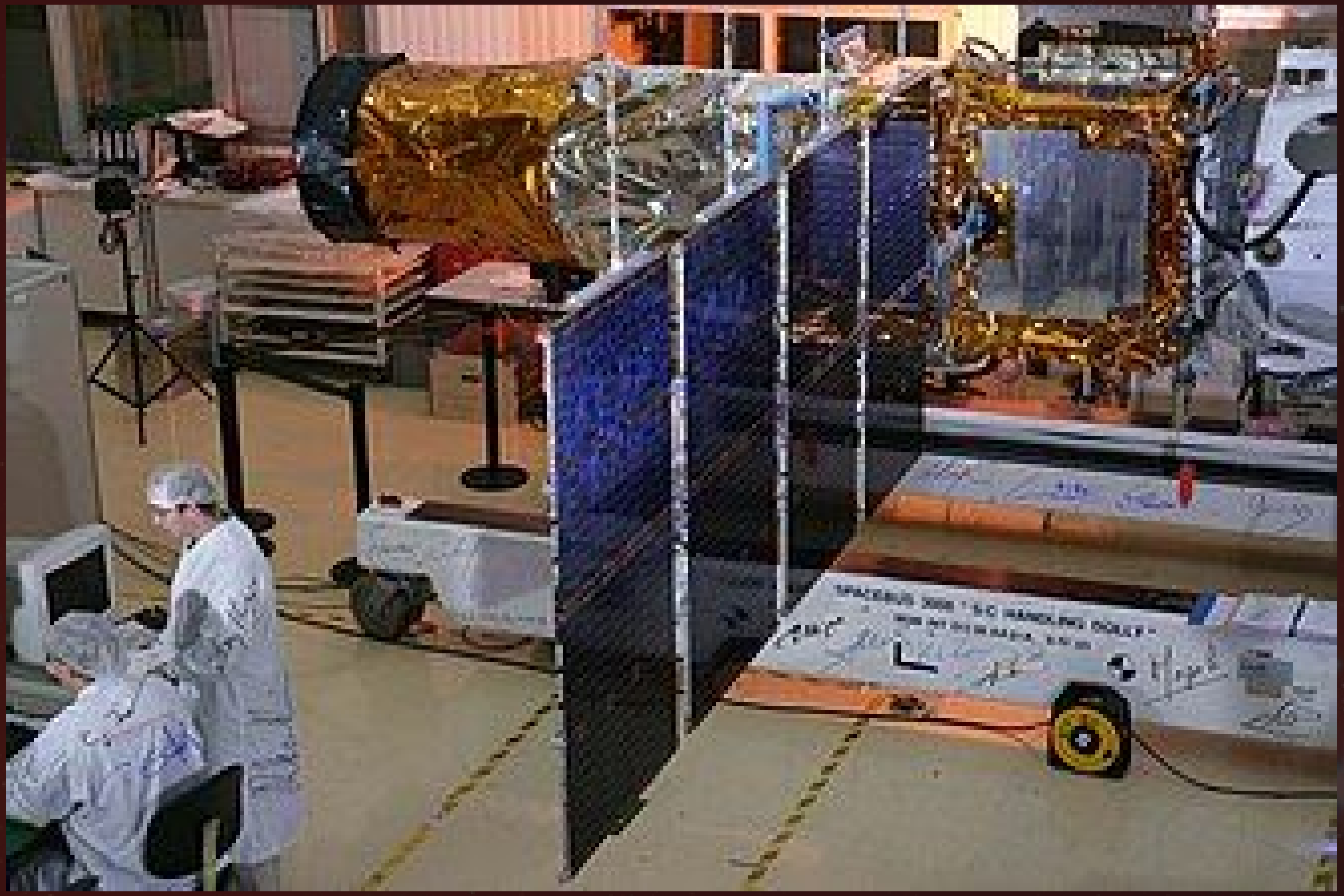
(Figure 4: COROT Telescope, ESA, 2025)

FINDING EARTH-LIKE PLANETS

Some methods are biased to finding only large planets - Direct Observation, Astrometry, and Radial Velocity (Exoplanet Detection, Dai et. All, 2021)

- Improve current methods
- Come up with new methods

COROT SPACE MISSION



(Figure 5: COROT Space Telescope, Wikipedia, 2025)

2006 - French Space Agency CNES

- Observing rocky planets orbiting red dwarf stars
- First transit photometry mission launched into space

Observed 5 different frames split between the galactic center and anticancer

27 cm telescope ~900 km altitude, 3.5 deg^2 field of view (Borde et. All, 2003)

Aperture photometry: “the flux collected during an elementary exposure of 32 s is measured by summing all pixels in a fixed mask encompassing the star” (summing the brightness of pixels in the appearance of a star over 32 seconds and measuring how it changes over time)

- Decommissioned in 2014

(Borde et. All, 2003)

2M1207B

01 First exoplanet found by direct imaging - 2004

- Very Large Telescope - Chile

02 Orbits a brown dwarf star 2M1207

- first planet we have found orbiting a brown dwarf
- 5x mass of Jupiter - is a gas giant
- Orbits at 55 AU from its sun

03 2M1207 is located in constellation of Hydra (Southern Hemisphere)

- 230 light years from Earth

NASA, 2024c

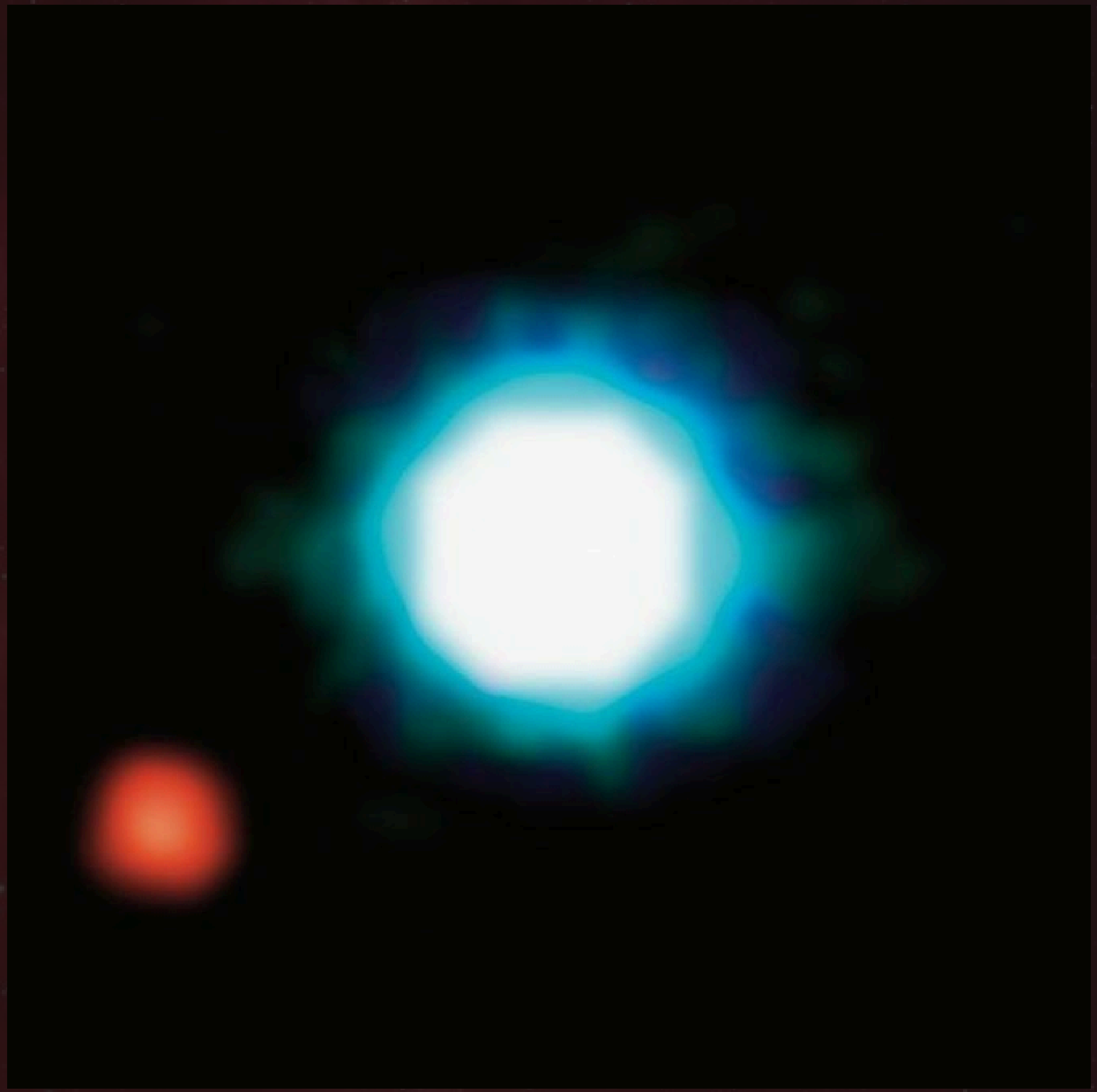


Figure 6: NASA, 2024d

OGLE-2005-BLG-390L B

01

Neptune-like planet
- Discovered in 2005 by microlensing

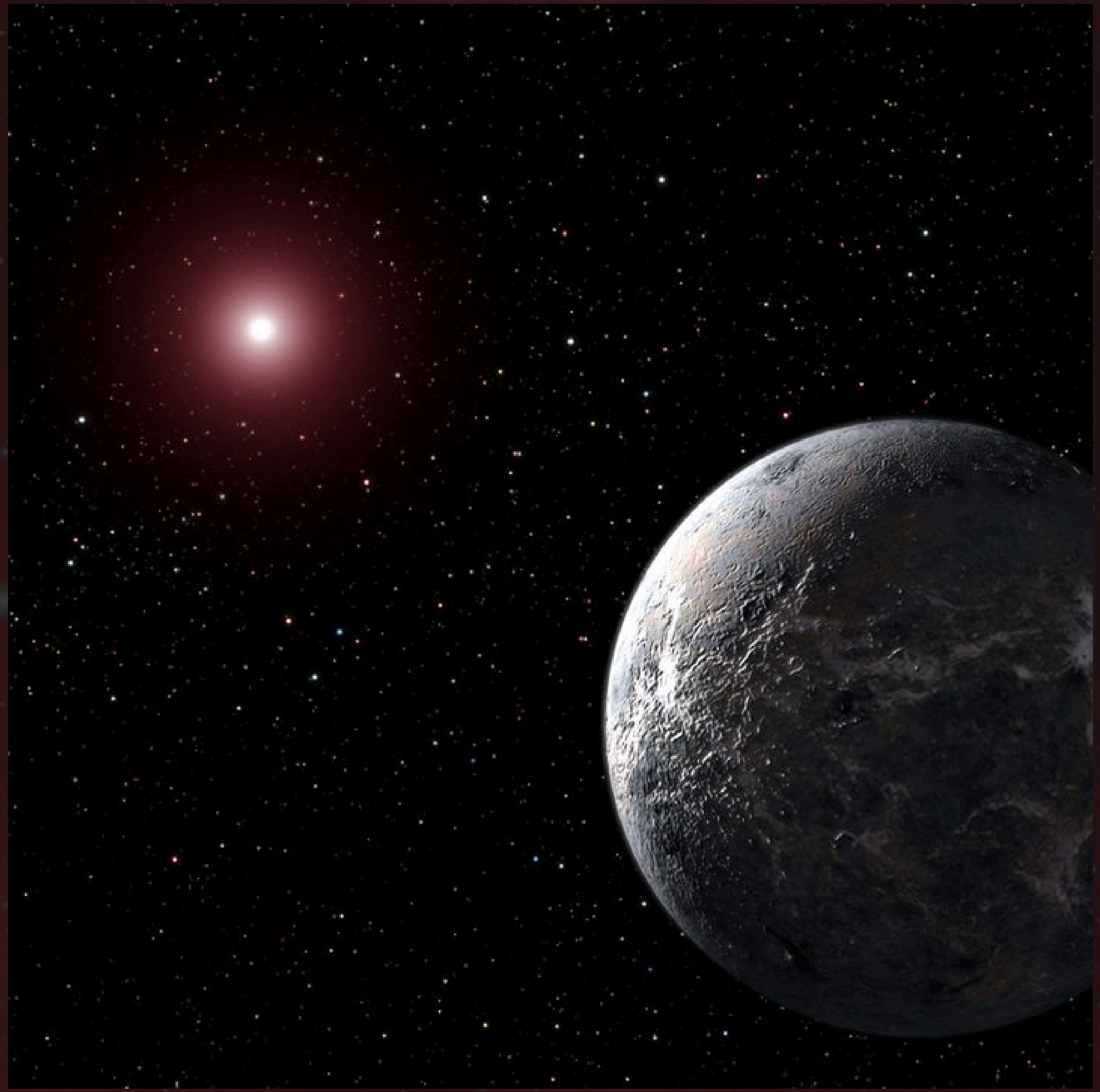
02

- 5.5x size of Earth
- 2.6 AU from its sun
- 9 Earth years to complete 1 orbit

03

Orbits an unkown type of star
- Constellation of Scorpius
- 21,500 lightyears from Earth

(NASA, 2024)



(Figure 7: NASA, 2024c)

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

THE FRACTION OF PLANETS THAT HAVE ENVIRONMENTS SUITABLE FOR LIFE

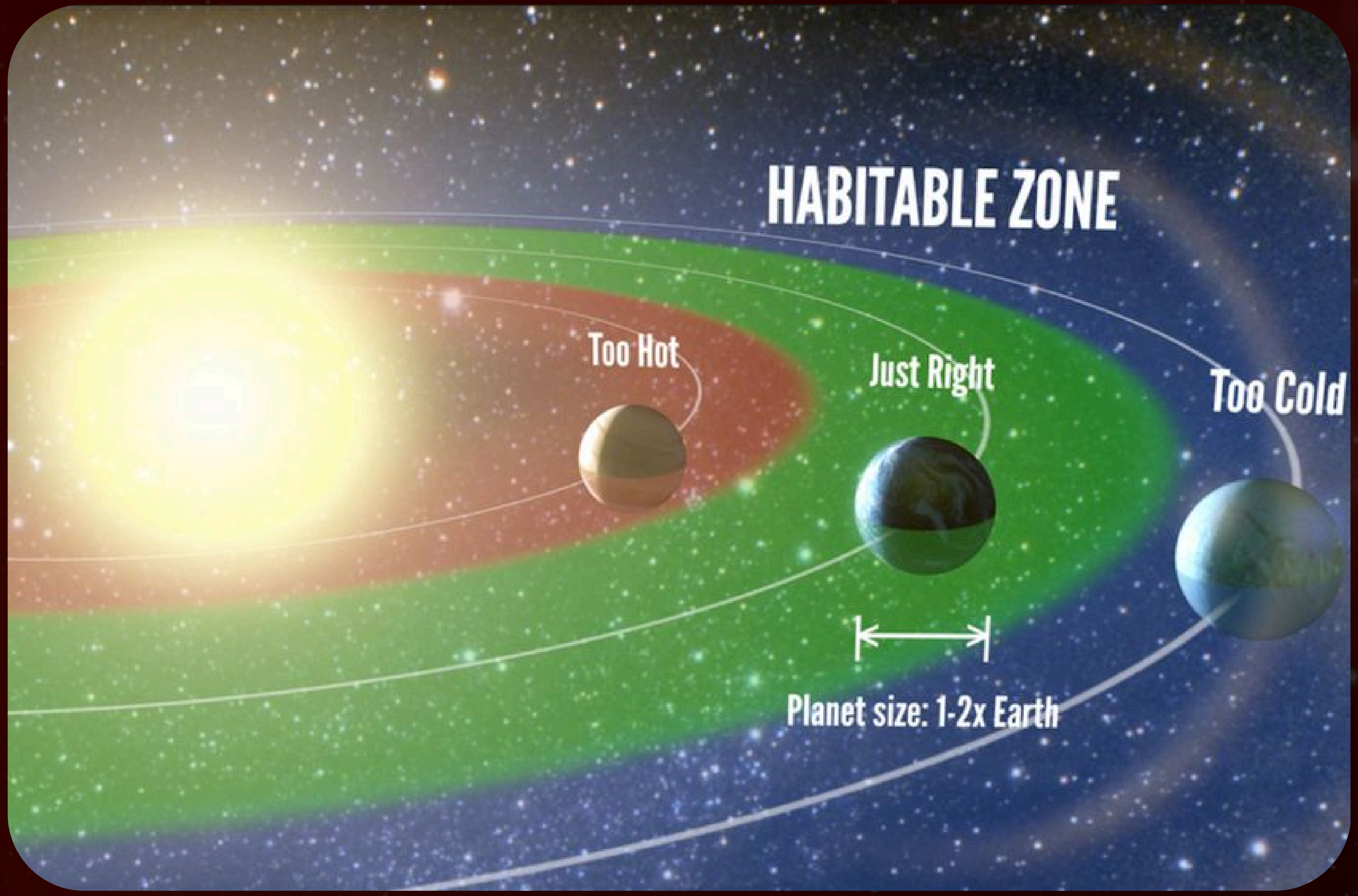


Figure 8: Habitable Zones (Thompson, 2013)

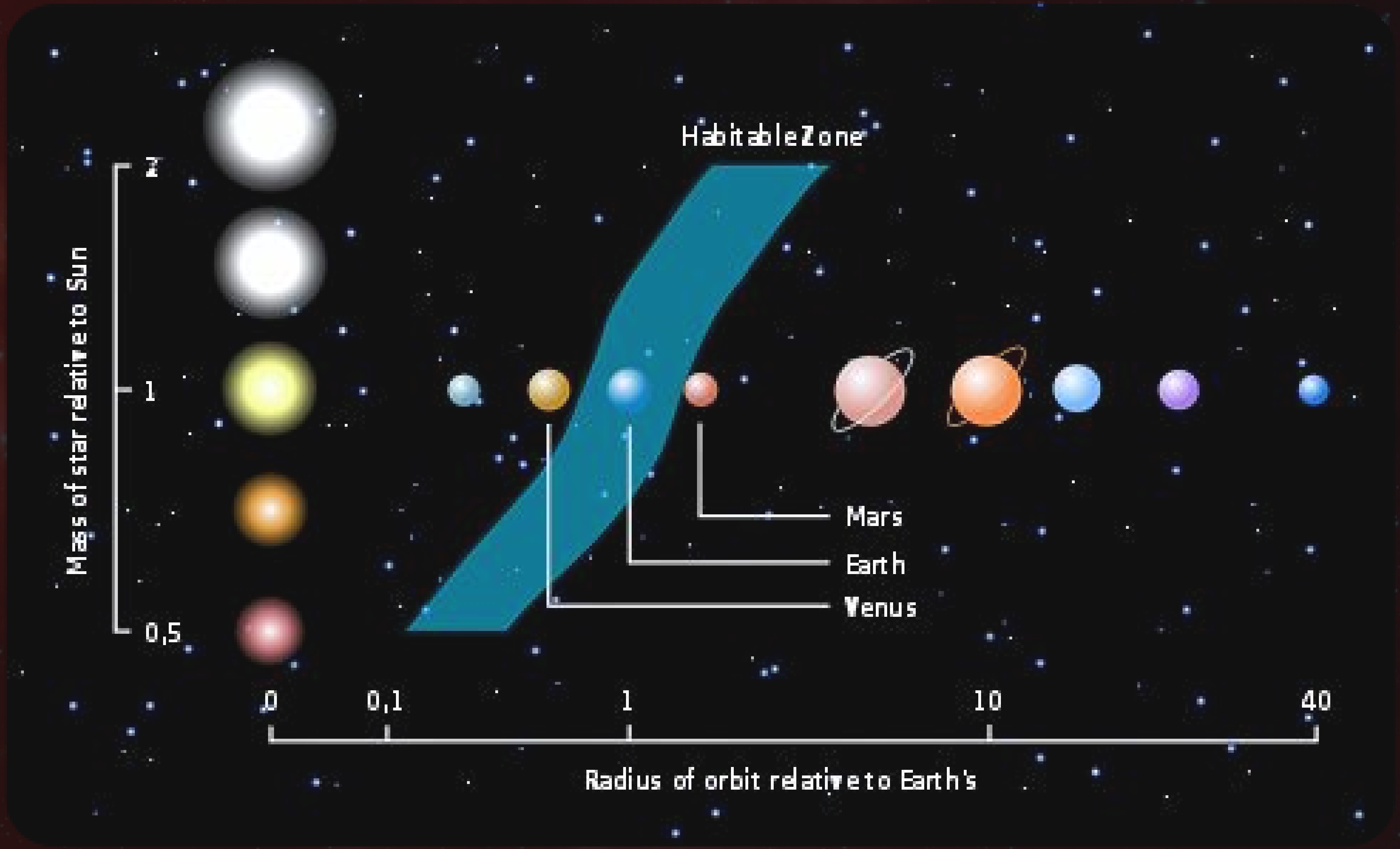


Figure 9: Habitable zones for different star types. Our solar system is used for comparison. (Tillman, 2011)

HIDDEN LIQUID WATER

TITAN

SATURN'S LARGEST MOON

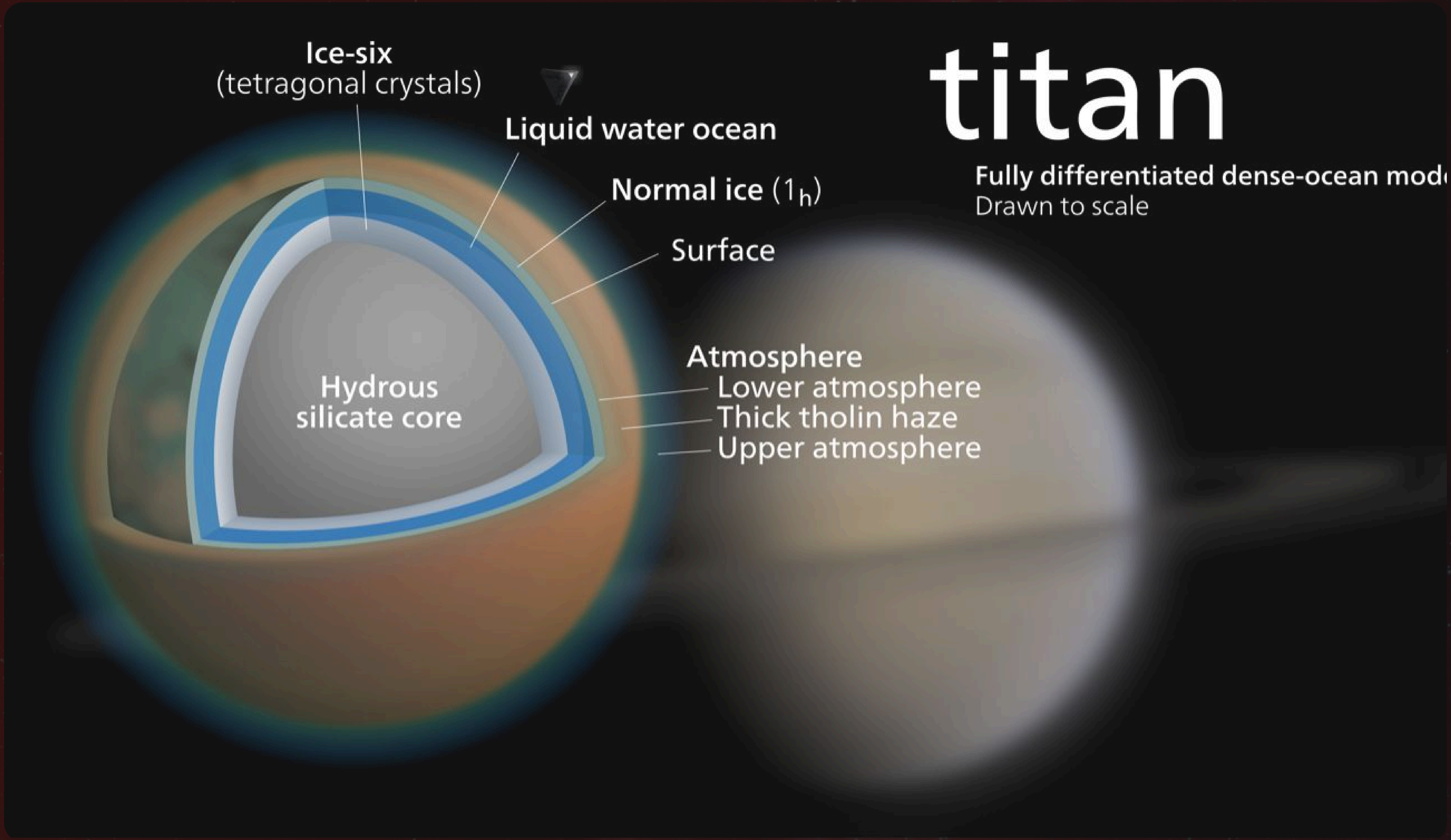


Figure 10: A model of Titan's internal structure showing ice-six layer. Retrieved from https://en.wikipedia.org/wiki/Titan_(moon)

HIDDEN LIQUID WATER

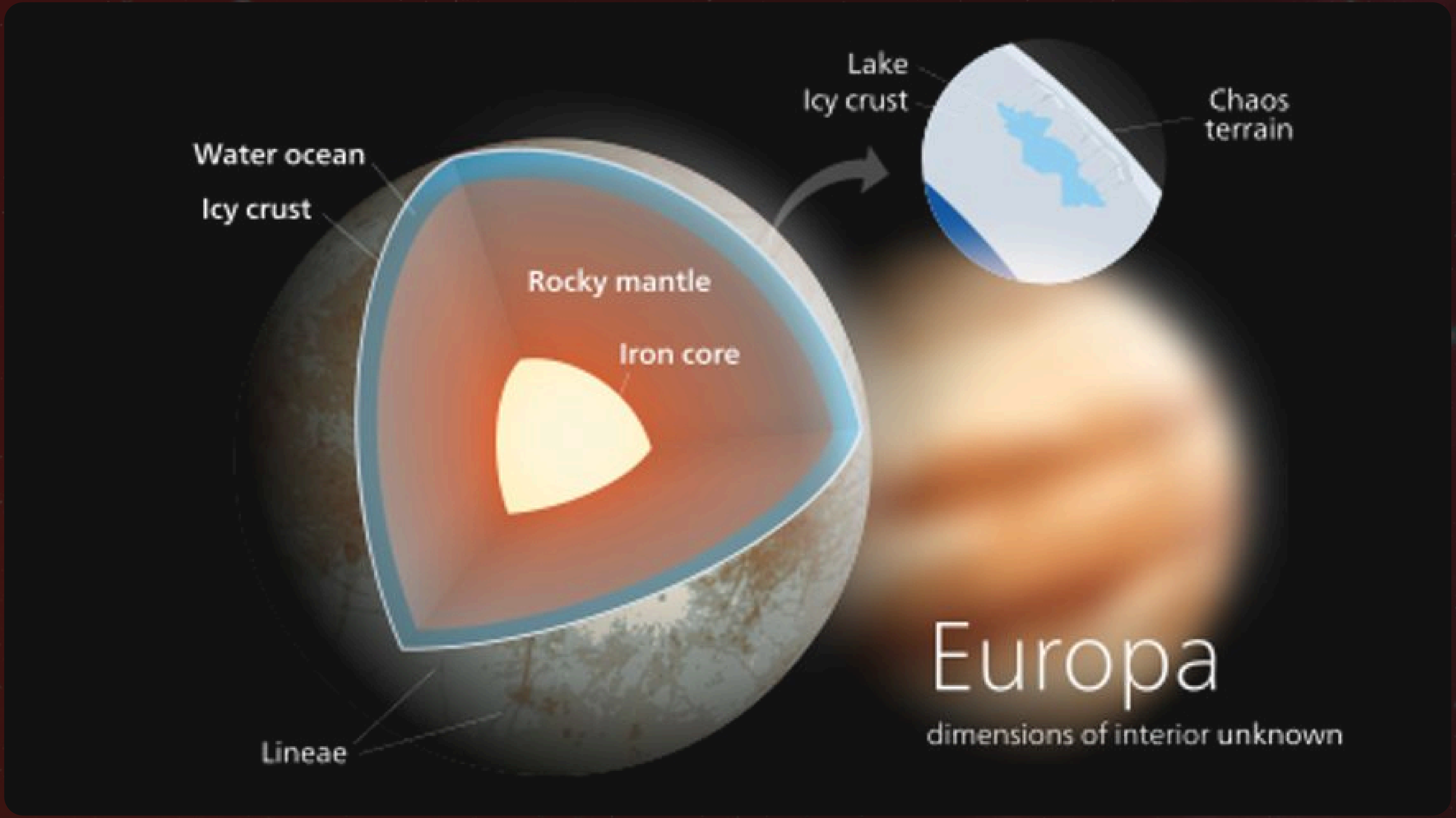


Figure 11: Model of Europa's possible interior structure, with a thin ice crust and a subsurface ocean atop a rocky mantle and metallic core. Retreived from https://en.wikipedia.org/wiki/Europa_%28moon%29

EUROPA

JUPITER'S FOURTH LARGEST MOON

THE GALACTIC HABITABLE ZONE

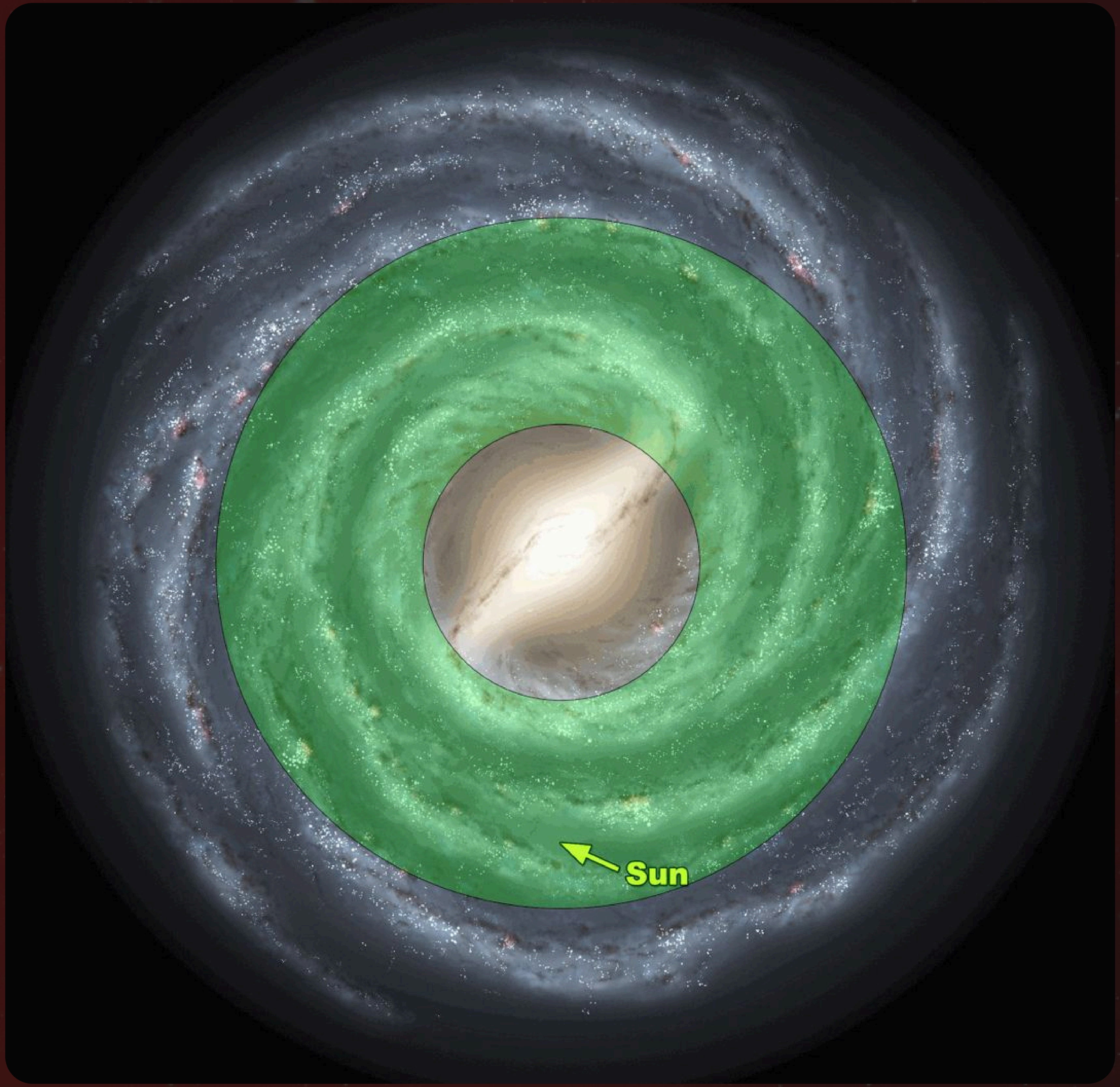


Figure 12: The galactic habitable zone.
Retreived from https://en.wikipedia.org/wiki/Galactic_habitable_zone

The GHZ is where conditions are stable enough for life to develop

Too close to the galactic center?
You get deadly radiation and supernovae.

Too far out?
Not enough heavy elements to form rocky planets.

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

HOW DOES LIFE BIOLOGICLALY AND CHEMICALLY EVOLVE?

01 How did life begin on Earth?

02 How does life biologically and chemically evolve under different conditions?

03 Does complex or intelligent life form under various circumstances?

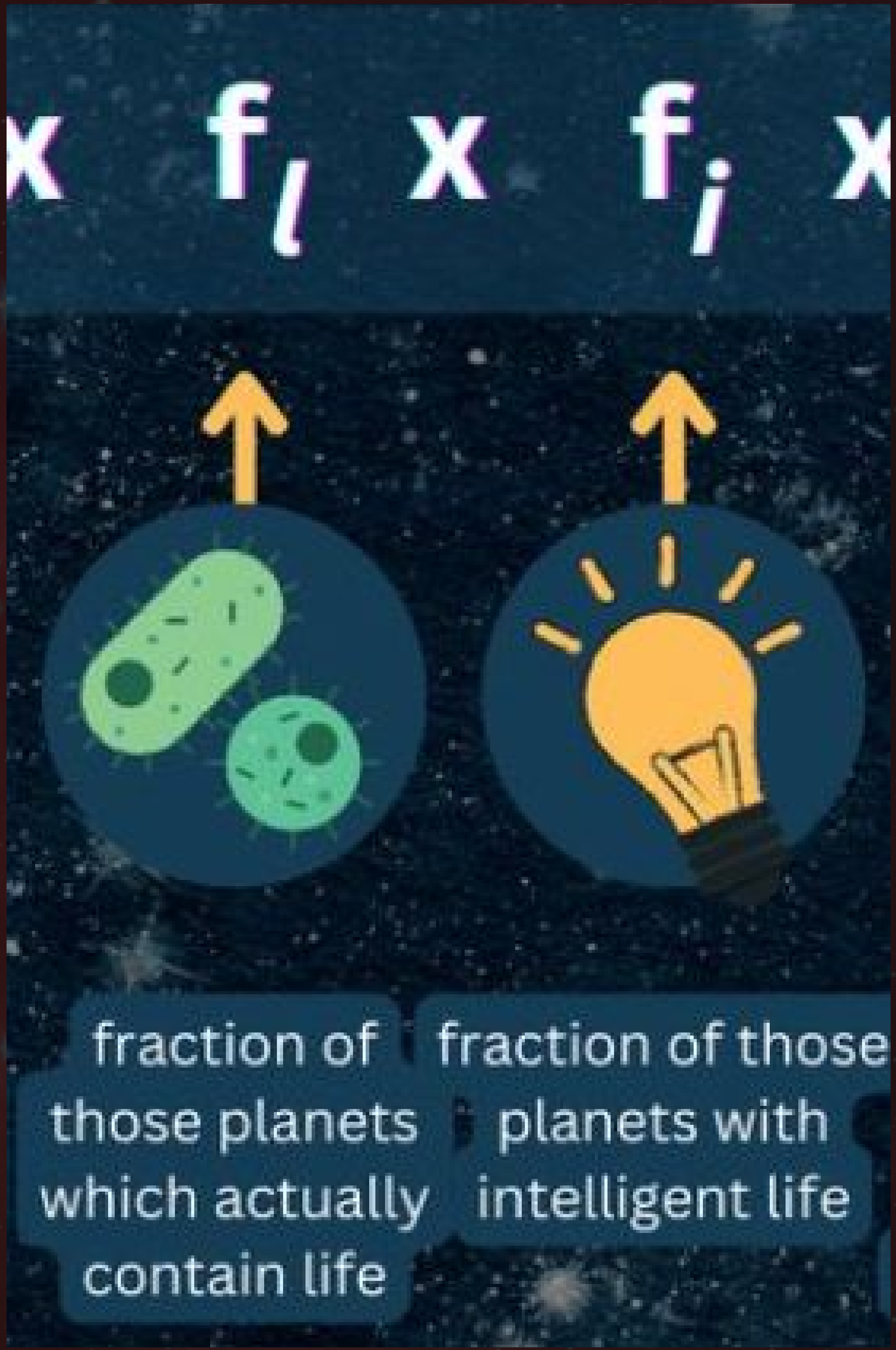


Figure 13: The Drake Equation. Retrieved from https://noirlab.edu/public/images/Drake_Equation/

THE FORMATION OF EARTH'S ATMOSPHERE

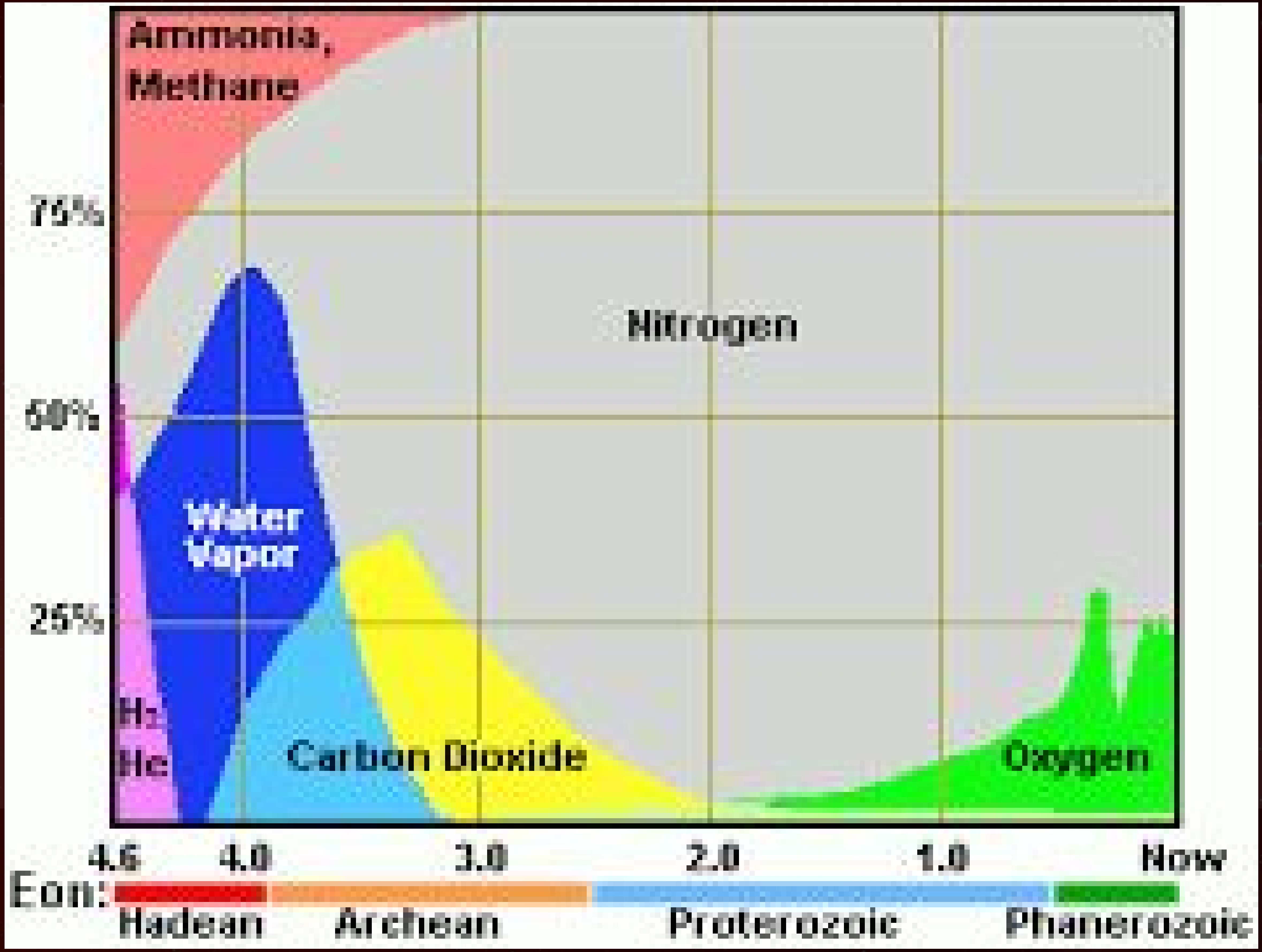
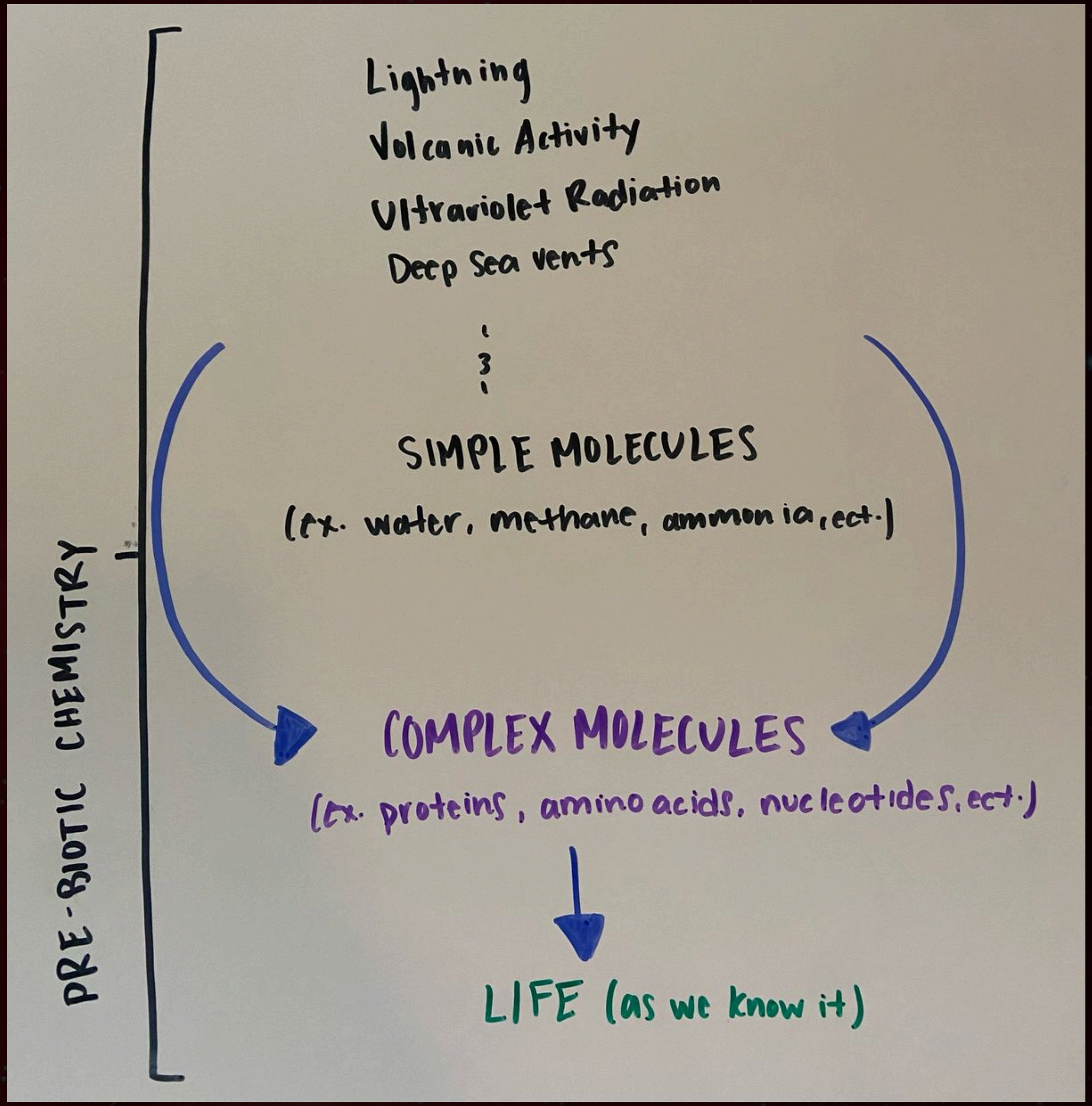


Figure 14: Composition of Earth's Atmosphere. Retrieved from https://www.youtube.com/watch?v=j0evKCTVh2I



KEY THEORIES OF PREBIOTIC CHEMISTRY

Figure 15: Lightning. Retrieved from https://www.usatoday.com/story/news/weather/2023/08/01/what-causes-thunderstorms/70389145007/

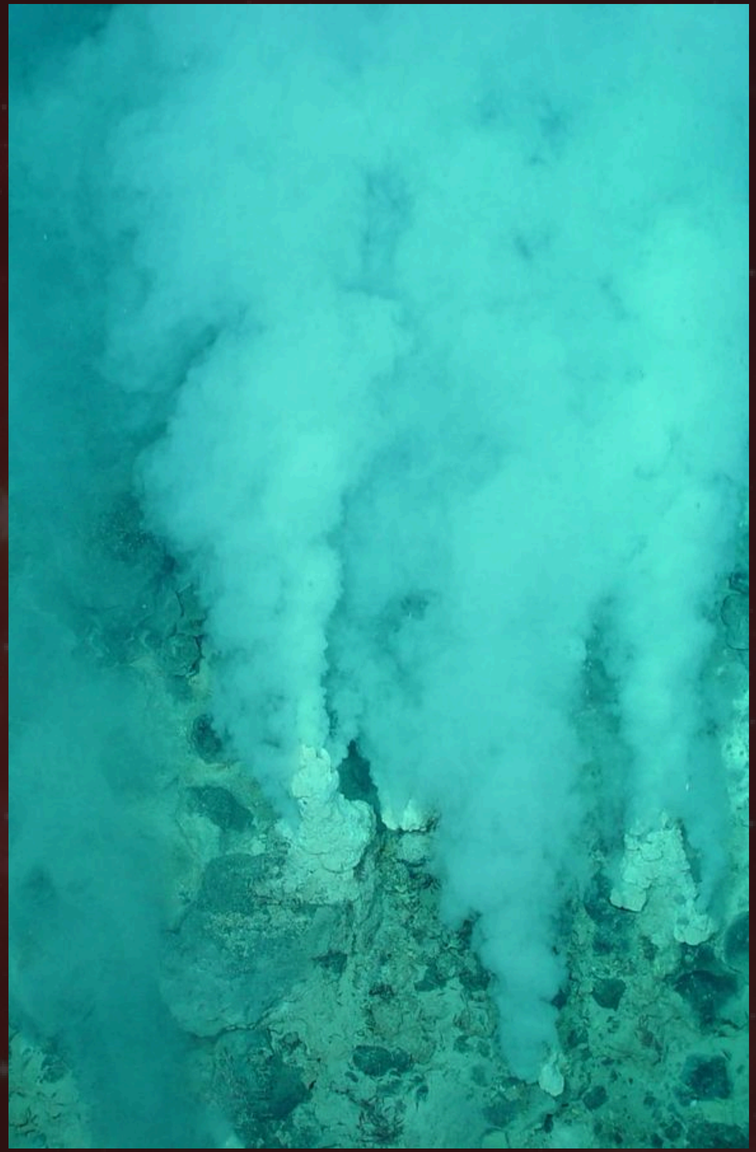


Figure 16. Deep-sea vents. Retrieved from https://nubeowatches.com/blogs/the-aquanova-journal/hydrothermal-vents-discovering-unique-deep-sea-environments

One popular idea is that lightning or UV radiation (from the Sun) could have acted as energy sources to help simple molecules form more complex ones.

Another theory is that deep-sea vents (underwater hot springs) might have created the right conditions for life to start, offering heat and chemicals that could help form the building blocks of life.

(Cleaves et al., 2008)

THE ROLE OF WATER

01 Water is thought to be crucial in the process of forming life.

02 It acts as a solvent helping different chemicals mix and react to form complex molecules.

03 Moons like Europa may offer similar conditions that could support prebiotic chemistry.

(Cleaves et al., 2008)

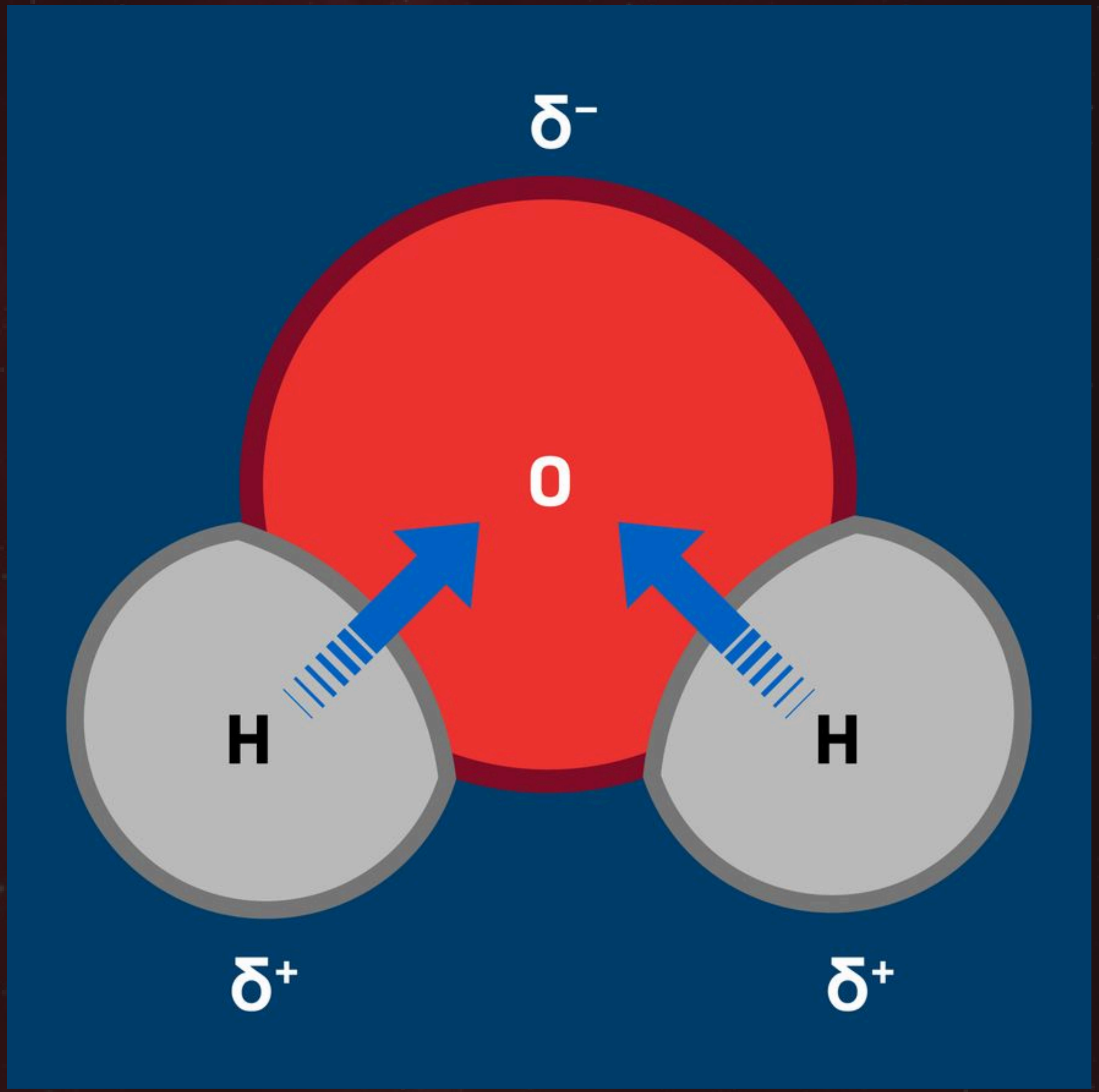


Figure 17. Water Molecule. Retrieved from https://www.labxchange.org/library/pathway/lx-pathway:7f5a47e2-2741-450c-8167-598ce43a3051/items/lb:LabXchange:005b0ca7:html:1/102577

UNCERTAINTIES & IMPLICATIONS FOR LIFE ELSEWHERE IN THE UNIVERSE.

01 We still don’t know for sure how complex molecules actually formed.

02 Can life evolve in completely different environments than we see on Earth?

THANK YOU.

QUESTIONS?

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IMAGE REFERENCES

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Figure 10: https://en.wikipedia.org/wiki/Titan_(moon)

Figure 11: https://en.wikipedia.org/wiki/Europa_%28moon%29

Figure 12: https://en.wikipedia.org/wiki/File:Milky_Way_galactic_habitable_zone.gif

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