Are we alone in the Universe?

Class 4.

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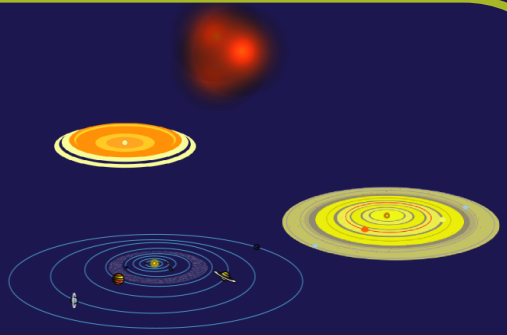
Our Map:

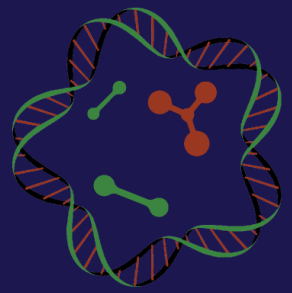
What are there in the Universe?
Scales involved in describing Universe

Our planet and Solar system



How did the Solar system form?
Is it unique?

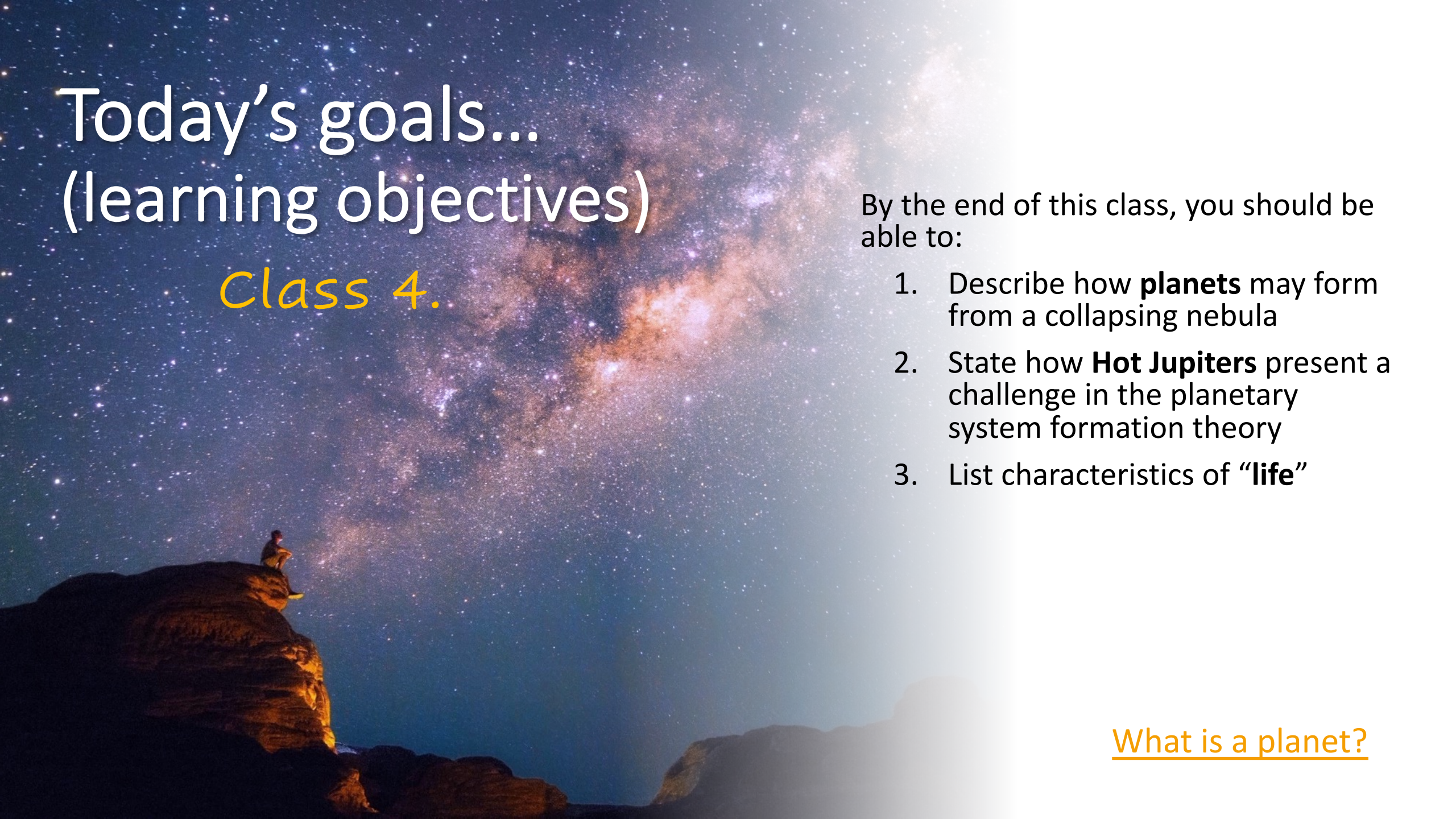
Are we alone in the universe?



What is life?
How did life on Earth begin? Building blocks of life, first form of life on Earth.

How can we look for ET life?
Atom and EM spectrum.

What form of life would you look for and how? Possibility of life on other planets.



Today's goals… (learning objectives)

Class 4.

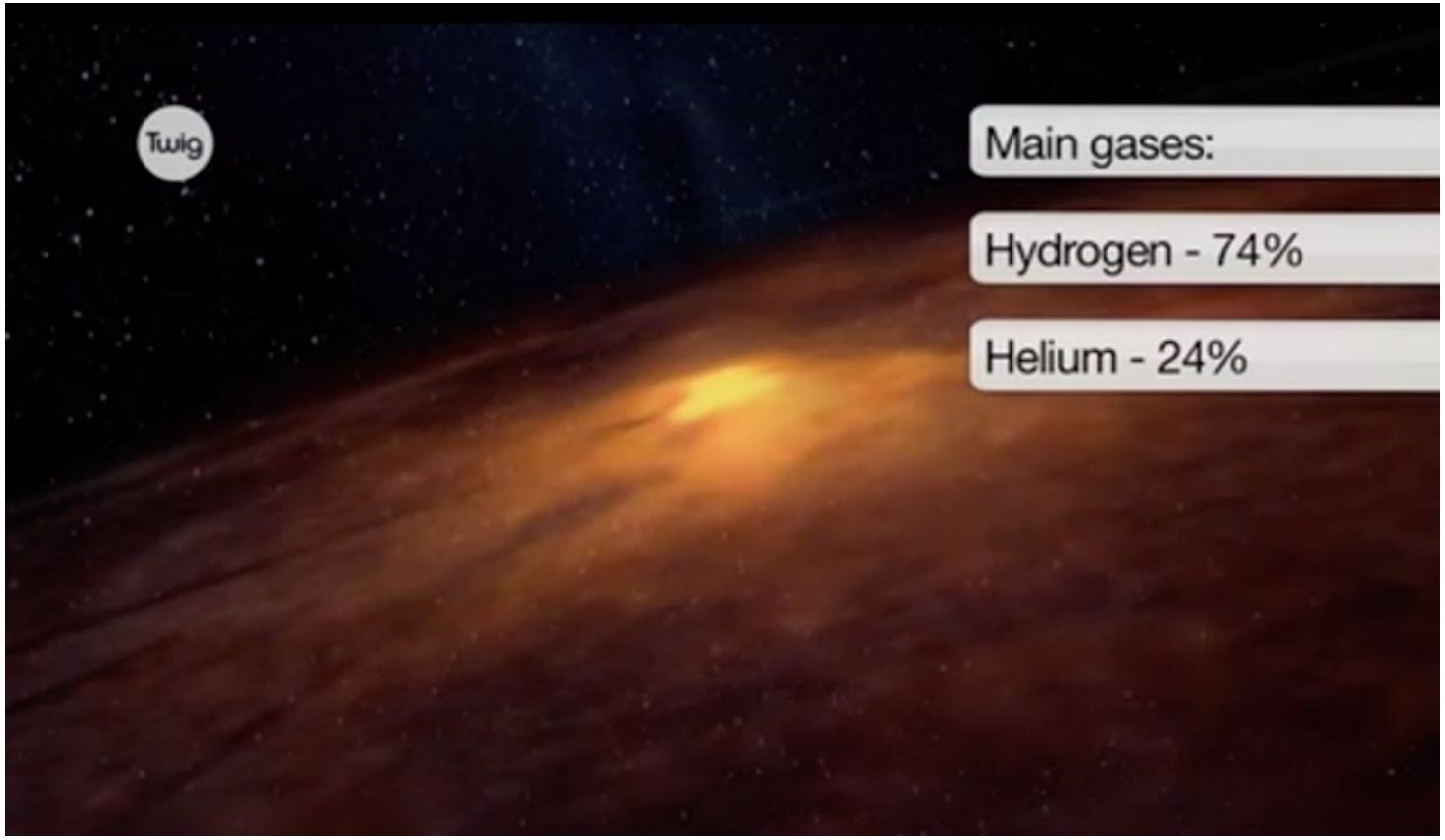
By the end of this class, you should be able to:

1. Describe how **planets** may form from a collapsing nebula
2. State how **Hot Jupiters** present a challenge in the planetary system formation theory
3. List characteristics of "**life**"

What is a planet?

Birth of the Solar System

Why are the inner planets rocky and the outer planets gaseous?



https://www.stem.org.uk/elibrary/resource/26893

Nebular theory of Solar system formation

- **Hypothesis**: Our Solar system formed out of a nebula which collapsed under its own gravity (This is the basis of nebular theory of star formation)
- **Supporting Observation:** Newly forming stellar systems are observed to be inside dense interstellar gas clouds.

Nebula: a large cloud in space consisting of gas and dust

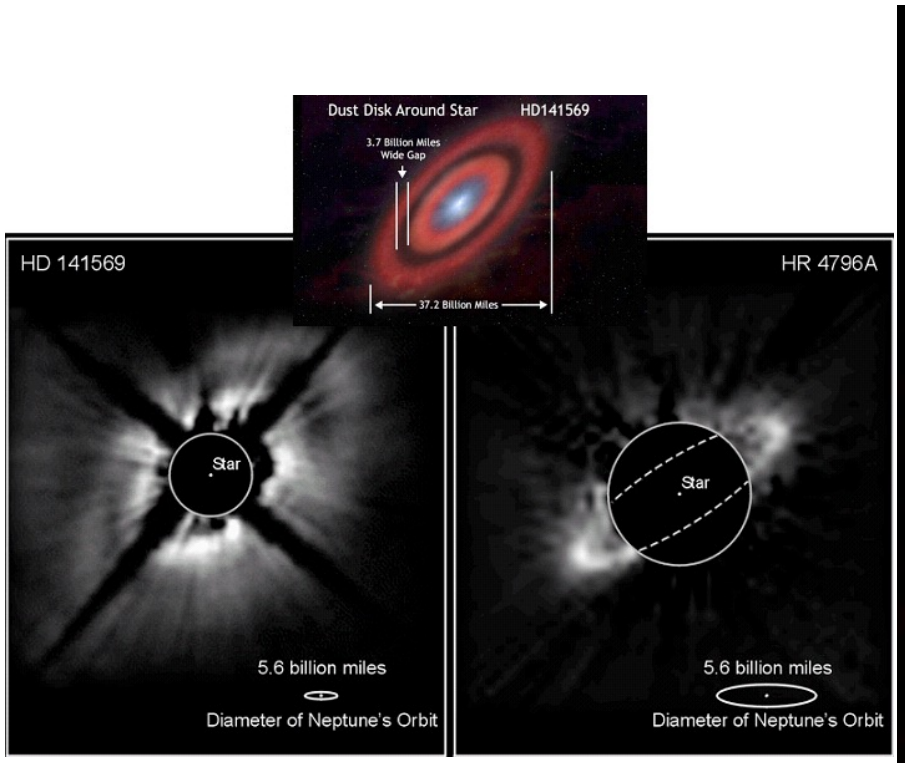
"Star-forming" nebulae

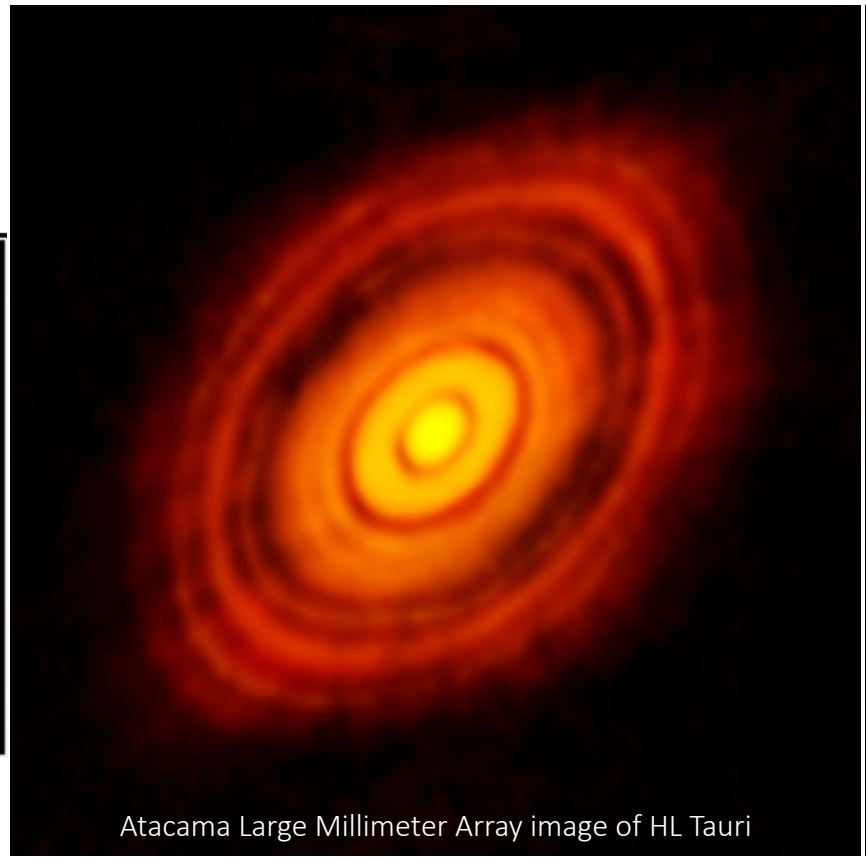
Trifid nebula

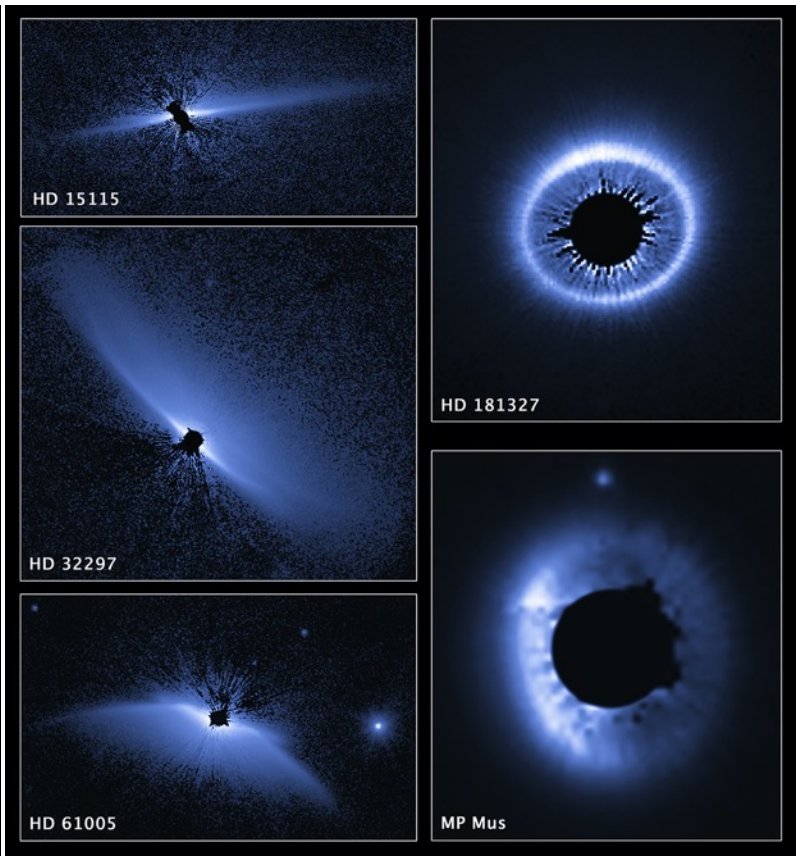
Orion nebula

Eagle nebula

Disks around stars (Observations)




Atacama Large Millimeter Array image of HL Tauri



https://www.eso.org/public/archives/images/large/eso1436a.jpg

Planets occupying same orbit in PDS 70b

A planet may be forming in the region where gravitational pulls of the planet and the star are similar (trojan planet)

https://www.space.com/two-exoplanets-same-orbit-trojan-planet
https://www.youtube.com/watch?v=T7-cp8Om_qU

https://www.nobelprize.org

The Nobel Prize in Physics 2019

New perspectives on our place in the universe

The Nobel Prize in Physics 2019 rewards new understanding of the universe's structure and history, and the first discovery of a planet orbiting a solar-type star outside our solar system. This year's Laureates have contributed to answering fundamental questions about our existence. What happened in the early infancy of the universe and what happened next? Could there be other planets out there, orbiting other suns?

Read the press release
Read the scientific background
Learn more in the popular information

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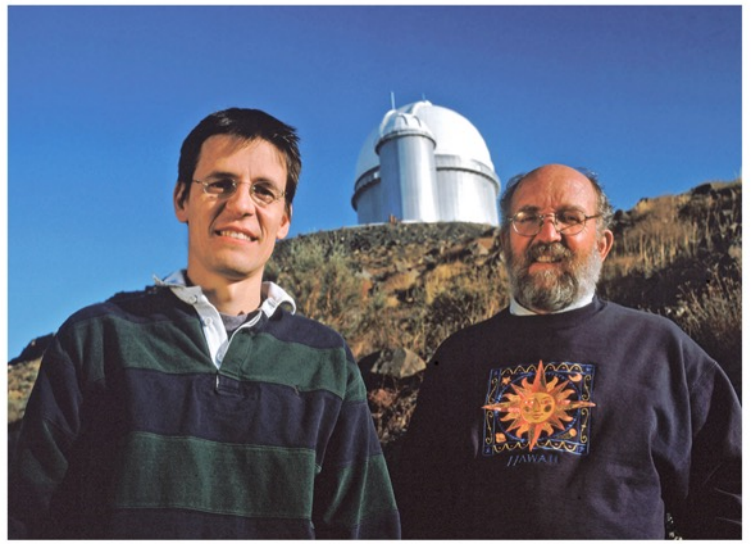
The 2019 Physics Laureates

The 2019 Nobel Prize in Physics are awarded "for contributions to our understanding of the evolution of the universe and Earth's place in the cosmos", with one half to James Peebles "for theoretical discoveries in physical cosmology" and the other half jointly to Michel Mayor and Didier Queloz "for the discovery of an exoplanet orbiting a solar-type star."

Ill. Niklas Elmehed. © Nobel Media

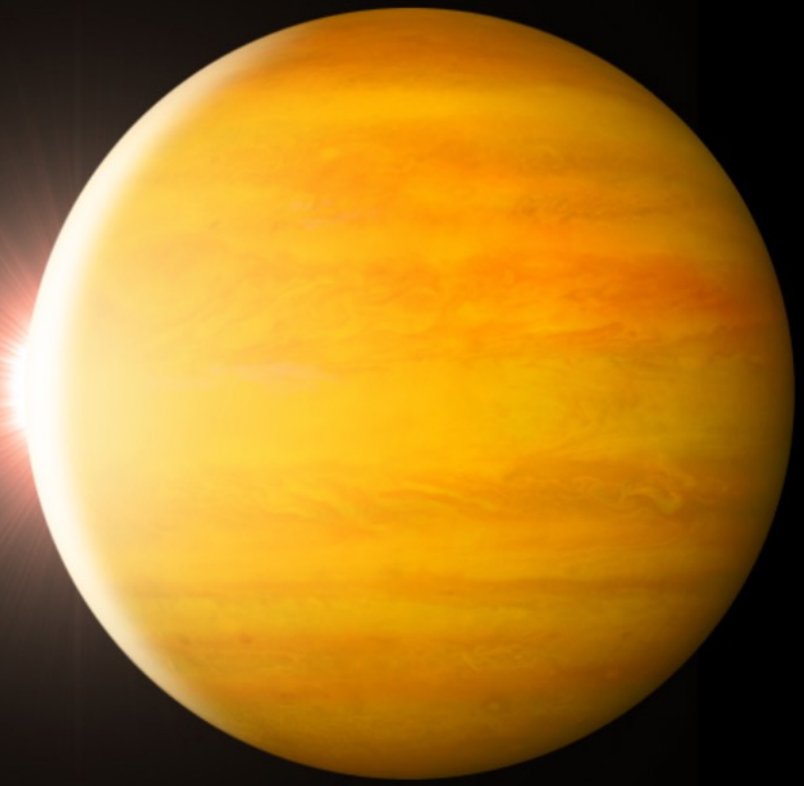


Swiss astronomers Didier Queloz and Michel Mayor in front of La Silla Observatory in Chile. The pair discovered 51 Pegasi b in 1995, the first planet found orbiting a star like our sun. Credit: L. Weinstein/Ciel et Espace Photos

https://exoplanets.nasa.gov/what-is-an-exoplanet/about-exoplanets/

CELEBRATING 20 YEARS OF EXOPLANET DISCOVERIES

THE FIRST PLANET DISCOVERED AROUND A SUN-LIKE STAR



51 Pegasi b

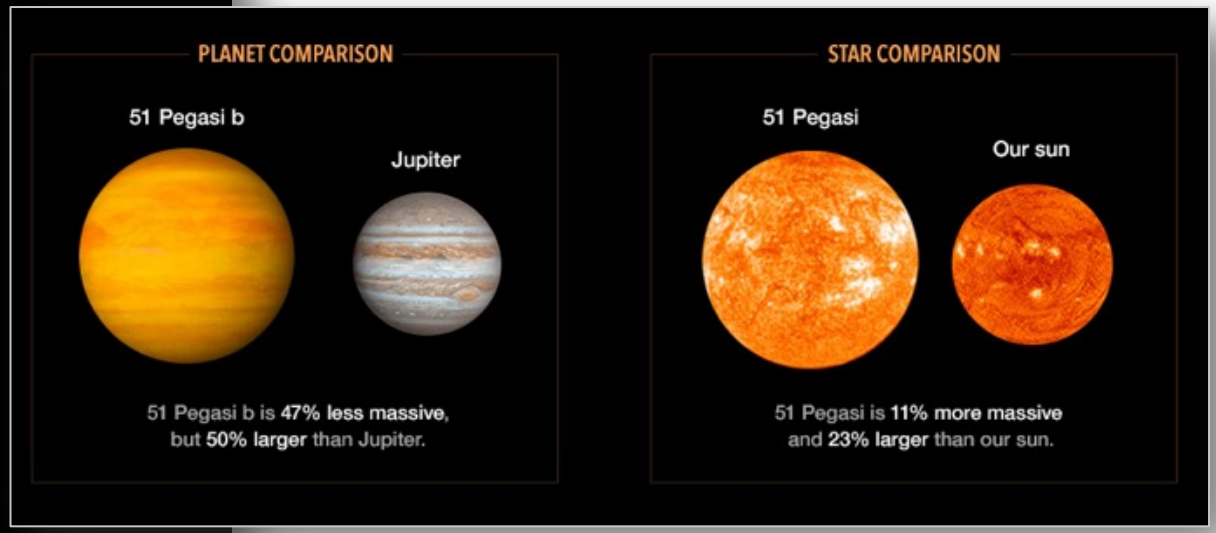
Discovered October 6, 1995

This year we celebrate the discovery of 51 Pegasi b in October, 1995. This giant planet is about half the size of Jupiter and orbits its star in about 4 days. '51 Peg' helped launch a whole new field of exploration.

TEMPERATURE
51 Pegasi b has a temperature of **1000C°/1800F°.**

ORBITAL PERIOD
51 Pegasi b orbits its host star **every 4 days.**

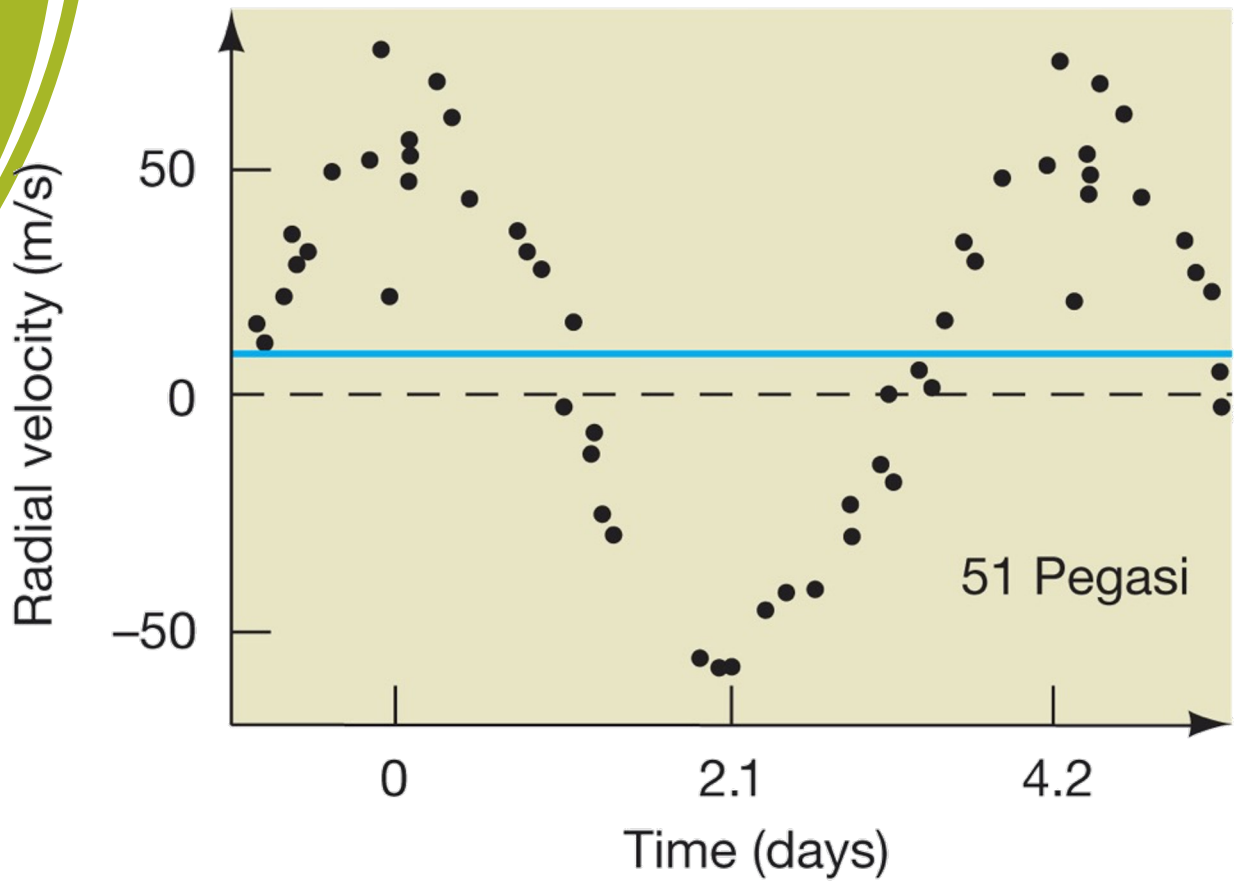
DISTANCE FROM EARTH
51 Pegasi b is **50 light-years** from Earth.



Full version:
https://exoplanets.nasa.gov/resources/289/infographic-profile-of-planet-51-pegasi-b/

51 Pegasi: Planet Detection

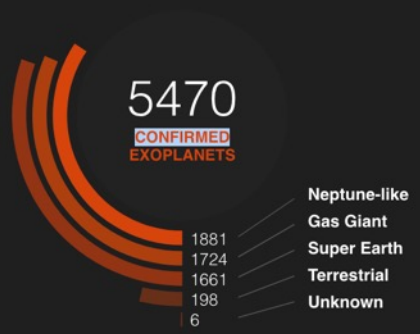
https://en.wikipedia.org/wiki/51_Pegasi_b



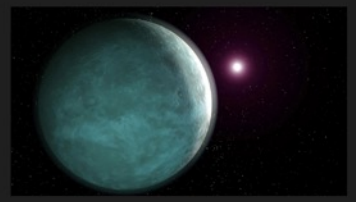
The blue lines show the maximum possible signal produced by Jupiter orbiting the Sun.

"Doppler shift" measurements of the star 51 Pegasi with a planet mass of at least half the Jupiter mass

Planet Types



New Discovery

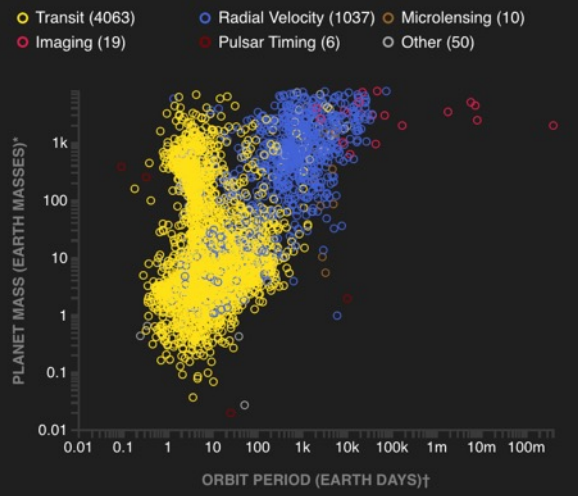


PLANET NAME	PLANET TYPE
TOI-908 b	Neptune-like
DISCOVERY DATE	DETECTION METHOD
2023	Transit

› More about this planet

Exoplanet Census

Display limited to planets with both measured or estimated orbital period and mass



YEAR **2023** | DISCOVERIES‡ **5470**

1989 — 2023

By Method

74.8%	Transit
19.2%	Radial Velocity
3.7%	Microlensing
1.2%	Imaging

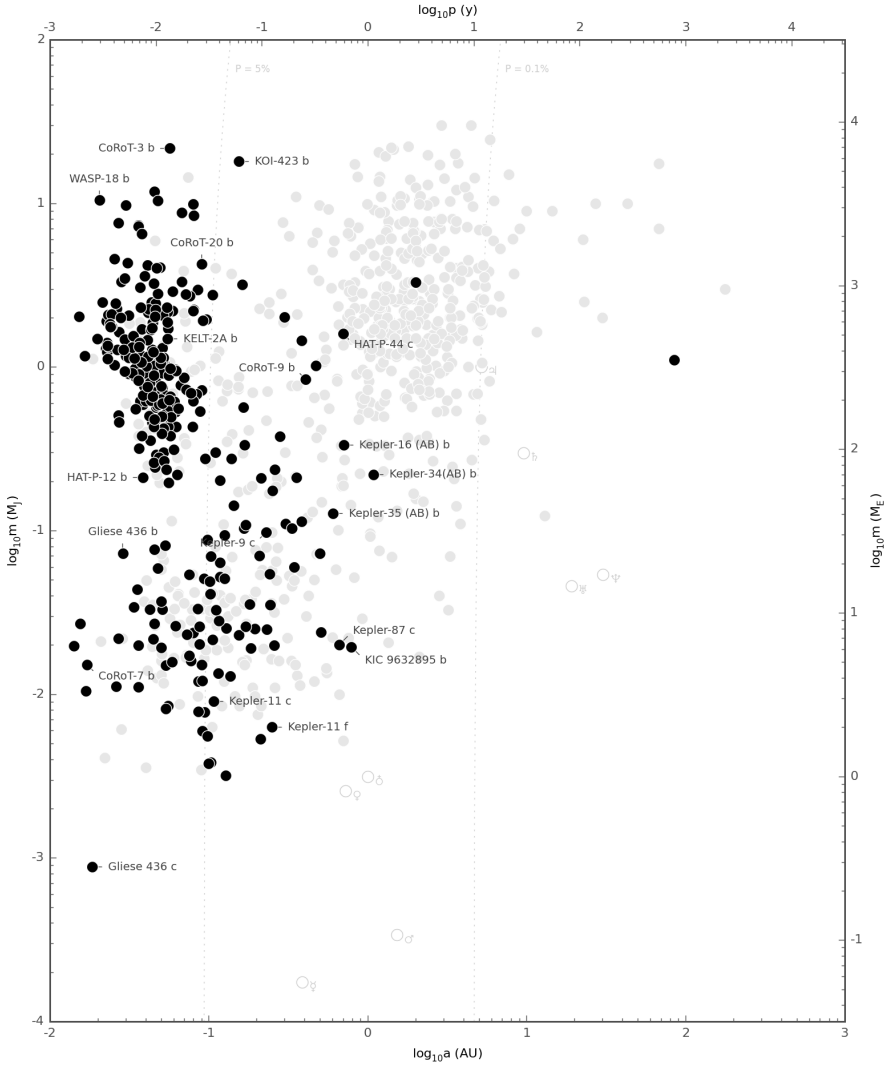
0.46% Transit Timing Variations, 0.31% Eclipse Timing Variations, 0.16% Orbital Brightness Modulation, 0.13% Pulsar Timing, 0.04% Astrometry, 0.04% Pulsation Timing Variations, 0.02% Disk Kinematics

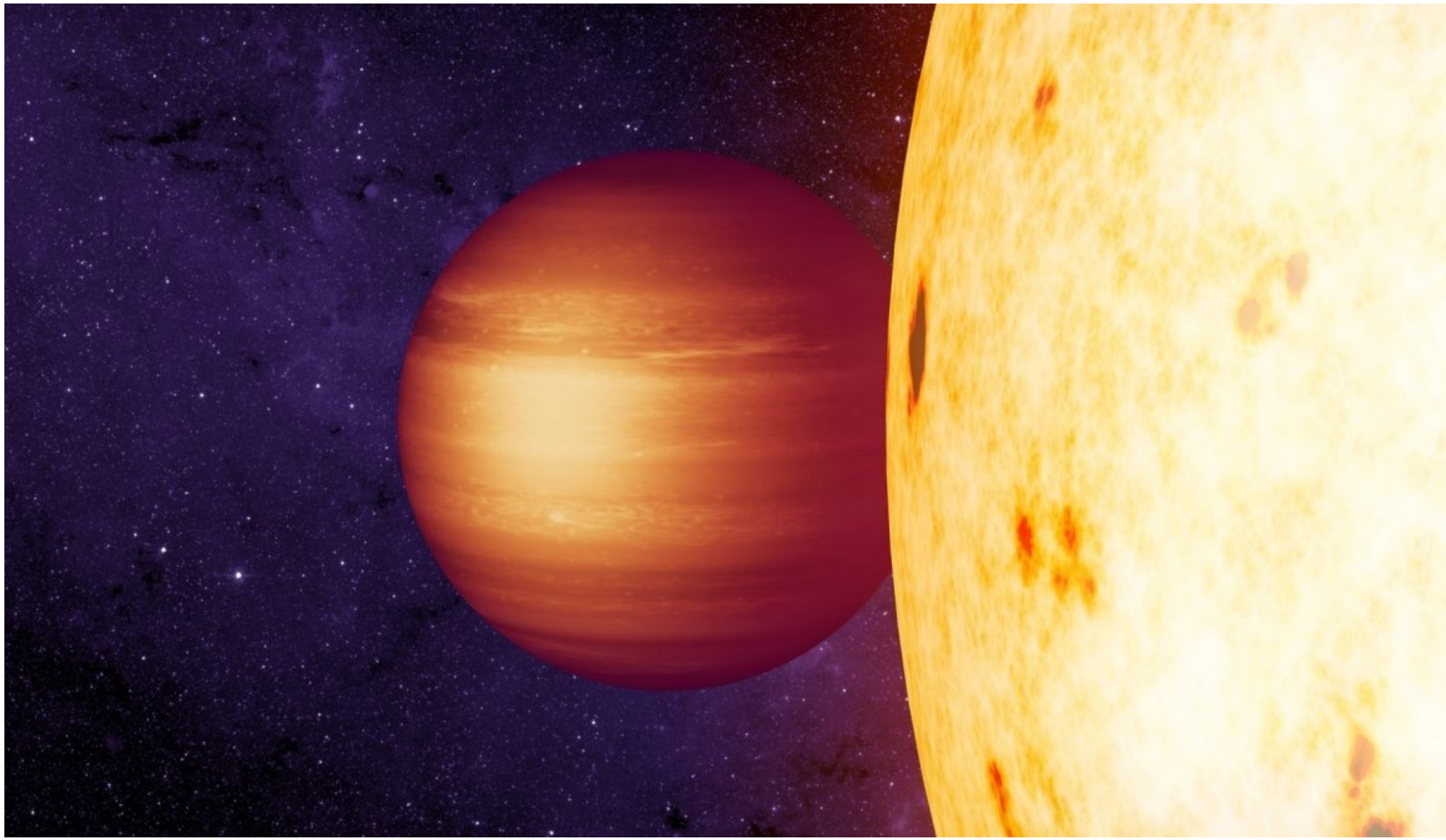
› More about planet-hunting methods

https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/

https://exoplanets.nasa.gov

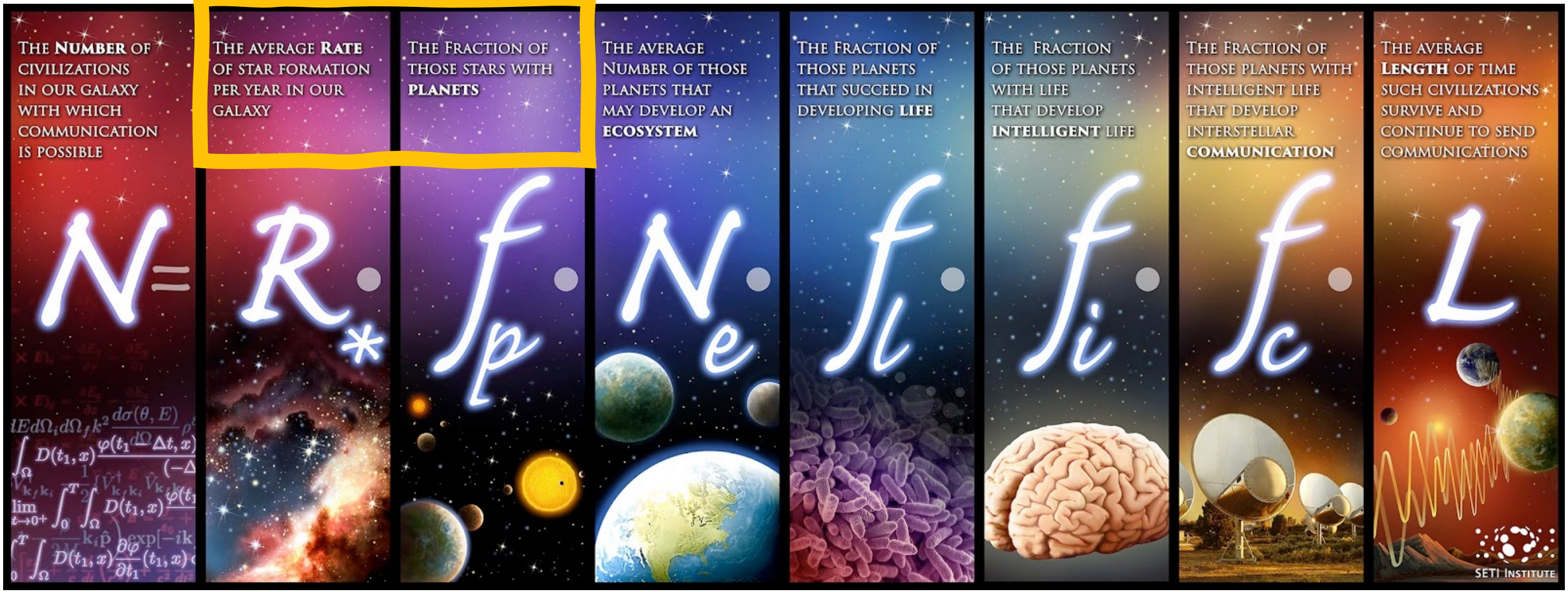
HOT JUPITERS?





https://www.informationisbeautiful.net/visualizations/the-drake-equation/

Drake Equation



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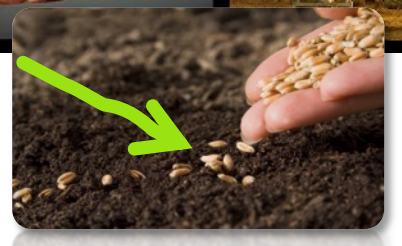
Drake Equation

Question: Is a seed of a plant alive?



OUR Criteria of Life?

Living organisms have all of the following traits:

1. **Organization:** Exhibit complex but ordered organization (cells → tissues → organs)
2. **Regulation:** Regulate their internal environment to maintain the conditions needed for cell function (e.g., body temperature)
3. **Response to environment:** Change properties reacting to environment / stimulus (mimosa plant)
4. **Growth and Development:** Information carried by genes controls the pattern of growth and development
5. **Energy utilization:** Use energy to function (chemical reactions = "metabolism")
6. **Reproduction:** Reproduce to carry on their own kind
7. **Evolution:** Capacity of populations to change (evolve) over time for the survival of the species

But also see: https://astrobiology.nasa.gov/research/life-detection/about/

Assignment

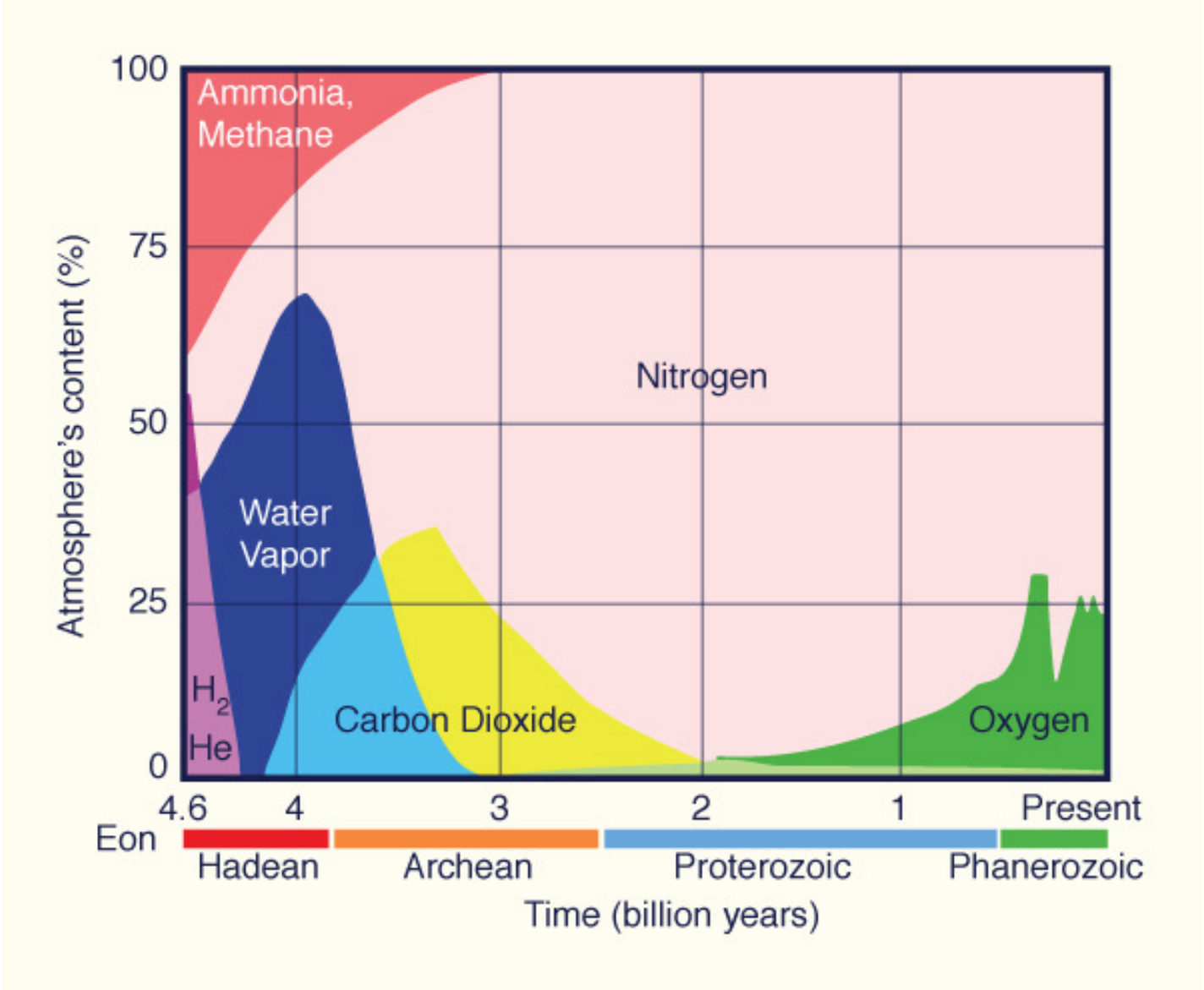
- Based on the criteria of life presented in class, would you call a CYBORG operated by artificial intelligence as a living organism?

Going back to the planet formation….

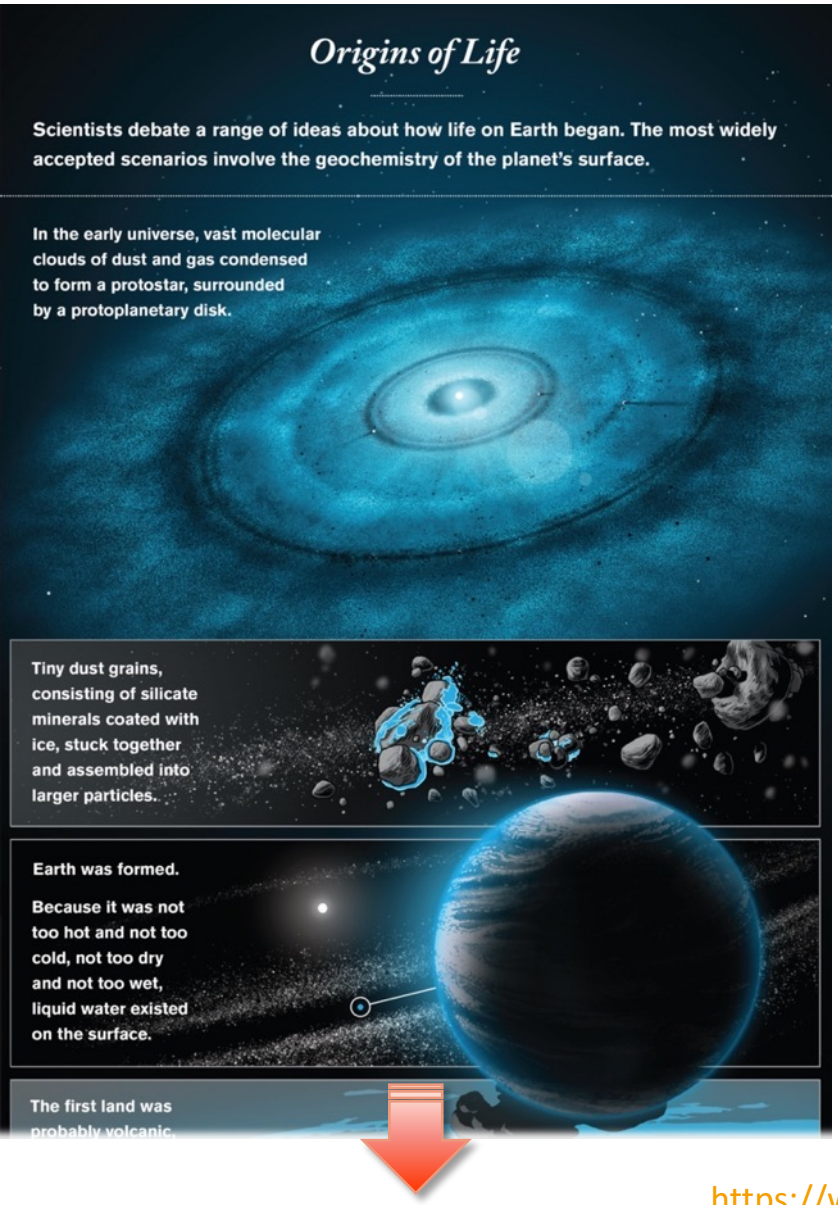
- How did life start on Earth?
- What were the conditions of Earth?
- What observational evidences do we have for the “origin of life”?

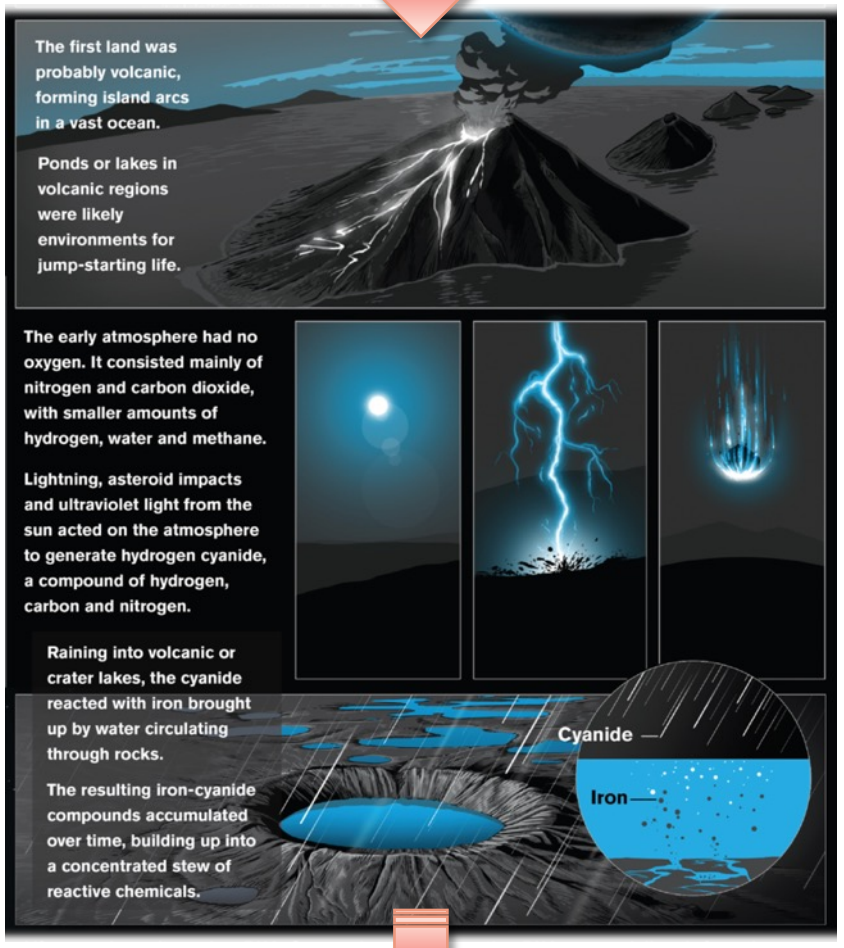
Atmospheric composition

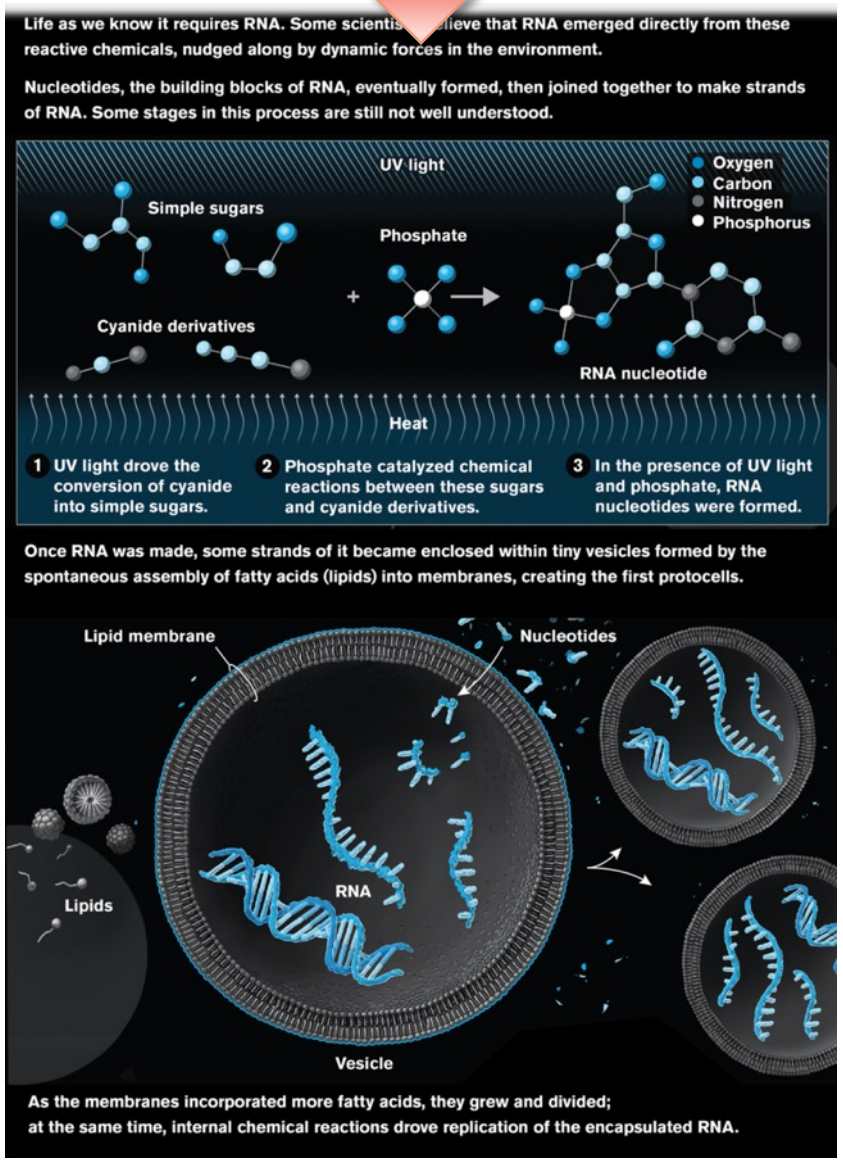
- When did the first life emerge?



(Possible) Origin of Life in a Nutshell







https://www.scientificamerican.com/article/how-did-life-begin1/