Researching habitable exoplanets

And writing a research paper

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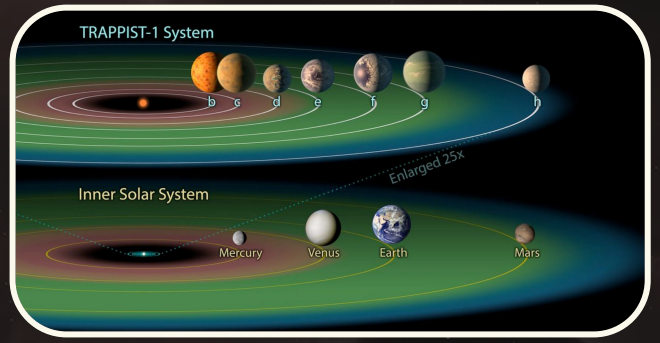
My project

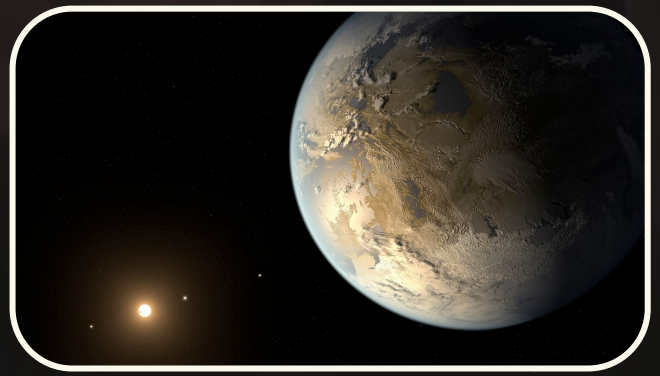
- For my IMPp project this year, I have decided to study and research potentially habitable exoplanets (planets outside our solar system)
- Exoplanets are planets outside our solar system
- Habitable exoplanets are planets we consider potentially suitable for life
  - They have the right conditions for life as we know it to develop
- The end product of this project will be a research paper, which I'm currently in the process of writing
  - The title of the paper is *Finding and distinguishing Habitable Exoplanets*

What are exoplanets?

- Exoplanets are planets outside our solar system
- There are different types, such as gas giants like Jupiter and Saturn and rocky worlds like our own
- Some are considered habitable, and my project is to study how we determine this and what are the factors that deem them potentially habitable



The TRAPPIST system has 5 of its planets in the HZ

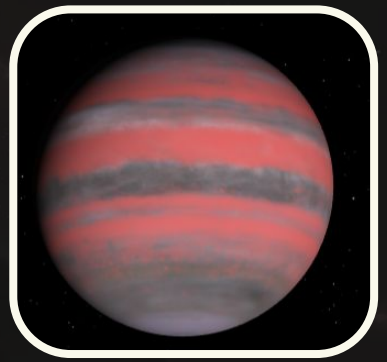


An artist's rendition of Kepler 186-f, an Earth sized planet in the HZ

HD 28185 - The first exoplanet discovered in the HZ

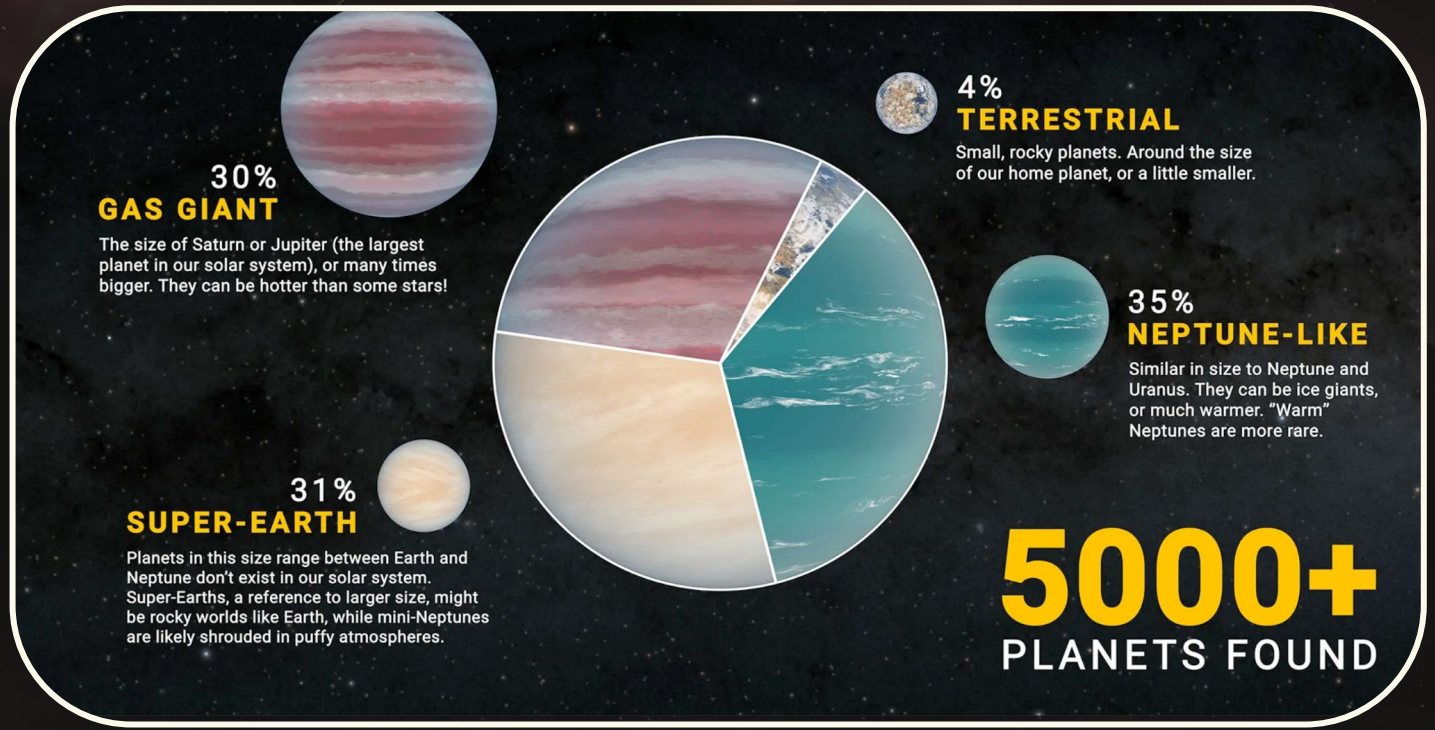
Radius	Mass	Planet Type
1.14 X Jupiters	5.837 X Jupiters	Gas Giant

Orbital period	Orbital Radius	Distance From Earth
385.5 days	1.035 AU	128 light years



Discovered on April 4, 2001, HD 28185 b was the first exoplanet discovered to be found in the habitable zone of its star. HD 28185 b is a gas giant that orbits a G-type star, it takes 385.5 Earth days to complete a single orbit, and its radius is about the same as Jupiter's radius but its mass is a lot more than Jupiters, indicating that it is denser than Jupiter.

Exoplanet statistics



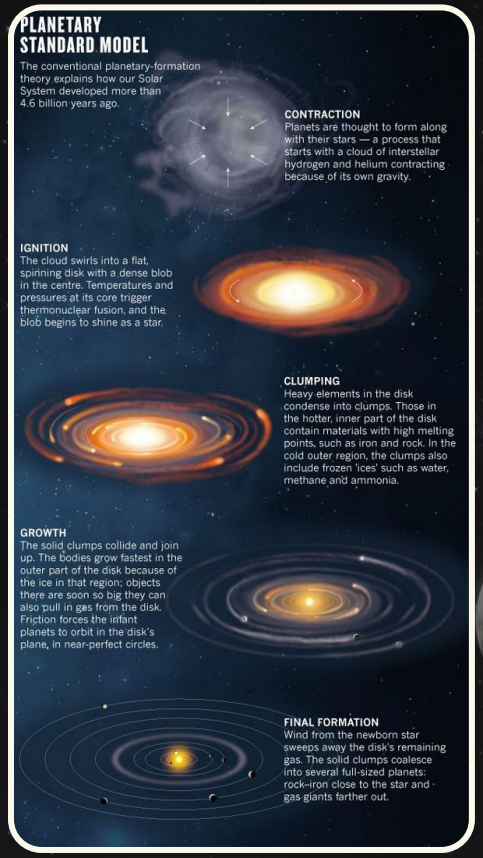
As show in the pie chart, there are more Super-Earths than rocky world like our own. However, this does not mean potentially habitable planets are only part of the 4%, in fact many habitable exoplanets are Super-Earths

Project phases

- ***1*** Determining exactly what I'm going to be researching since habitable exoplanets are a very broad topic
- ***2*** Make a preliminary outline – I went through every point that was on it with Ms Alexis to be sure it was doable with the time I had and corresponded with the overall goal for my paper
- ***3*** Start the research process
  - I first used and Astrobiology textbook for methods used for finding
  - Then I switched to scientific articles since they convey the precise information I need for the different topic for my paper
  - For the final phase of my research (which is specific things I look up as I'm writing) I use URL and website because they are easier to understand and way shorter
- ***4*** Start the writing process
  - I used my outline as a guide for writing, and the notes I took from the book and articles

Topics researched

- **Methods of finding**
  - How we find exoplanets, what are the different methods
  - What are we able to determine of the planet? (such as size or mass from their density, which can tell you what it's composed of)
- **The Habitable Zone**
  - The habitable zone is the distance from a star at which liquid water could exist on orbiting planets
- **The Planetary System**
  - How planetary interaction in the early stage of the system affect the habitability
  - How the eccentricity affects the planets orbit in the HZ



A diagram of how systems are formed

The Hubble Space Telescope, which has discovered hundreds of exoplanets

ARTIFACTS

HABITABLE PLANET FORMATION IN BINARY PLANETARY SYSTEMS

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Notes on *Calculating the habitable zone of binary star systems (close binary systems)*
Detecting binary star systems → ESA - How Gaia detects binary stars

- There has to be a maximum semi major axis (amax) of the planet given eccentricity, mass-ratio of the two stars, and semi major axis, beyond which the effect of the secondary star will make the orbit of the planet unstable
  - $a_{Max} = a_{Bin}(0.464 - 0.38\mu - 0631e_{Bin} + 0.586\mu\, e_{Bin} + 0.15e^2_{Bin} - 0.198\mu\, e^2_{Bin})$
    - This equation relates the semimajor axis of the planet (the eccentricity of the orbit with its star) to the semimajor axis of the two stars and the eccentricity. What max value can the eccentricity of the planet have to maintain a stable orbit in the HZ.
  - $\mu = m_2(m_1 + m_2)$ where m_1 is the mass of the primary star and m_2 the secondary.
- Binary eccentricity and stellar flux
  - Has to stay within a range to prevent strong interactions between the secondary star and the planet (chaos), to allow the planet to maintain a stable orbit in the HZ (see above)
  - Estimating the HZ by calculating the min and max flux of the secondary star at its closest and furthest points from the planet ***if*** you don't know the exact orbital configurations of the planet
    - It overestimates the shift of HZ from the primary stars to the binary (because of the secondary star) dua to the fact that the atmosphere of the planet can temporarily buffer the radiation →flux.

Notes from article (above) on binary stars

Astrophysical Conditions for Planetary Habitability

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James Kasting
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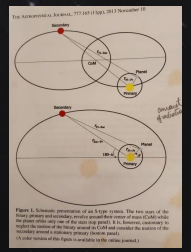
With the discovery of hundreds of exoplanets and a potentially huge number of Earth-like planets waiting to be discovered, the conditions for their habitability have become a focal point in exoplanetary research. The classical picture of habitable zones primarily relies on the stellar flux allowing liquid water to exist on the surface of an Earth-like planet with a suitable atmosphere. However, numerous further stellar and planetary properties constrain habitability. Apart from "geophysical" processes depending on the internal structure and composition of a planet, a complex array of astrophysical factors additionally determine habitability. Among these, variable stellar UV, EUV, and X-ray radiation, stellar and interplanetary magnetic fields, ionized winds, and energetic particles control the constitution of upper planetary atmospheres and their physical and chemical evolution. Short- and long-term stellar variability necessitates full time-dependent studies to understand planetary habitability at any point in time. Furthermore, dynamical effects in planetary systems and transport of water to Earth-like planets set fundamentally important constraints. We will review these astrophysical conditions for habitability under the crucial aspects of the long-term evolution of stellar properties, the consequent extreme conditions in the early evolutionary phase of planetary systems, and the important interplay between properties of the host star and its planets.

One of my main sources, it's long but it has a lot of information

Outline

- Methods of finding - 2
  - What kinds of methods we use, how do they work
    - Spectroscopy
    - Density of the planet, etc
  - What we are able to determine of the planet
- The habitable zone - 1
  - Start types (see below)
    - What are the properties of stars? Size, temperature, luminosity, etc
  - Even if a planet is not in our definition of the habitable zone, could life still exist in say a deep ocean under a layer of ice?
  - Definition of the habitable zone (how this affects the search for habitable exoplanets)
  - How does the radiation output of a star determine the habitable zone? Is there an equation associated with the luminosity of a star and the extent of the habitable zone
- The planetary system
  - Star types – life expectancy of the star, habitable zone shifting, what kind of stars have the most habitable planets, highest chance of habitable planets, radiation
  - Binary star systems
  - Big planets that cleared out the area of asteroids
  - Effect of a moon on the planet
  - How do planetary systems form?
- Characteristics of the planet
  - Size, density, magnetic field, plate tectonics, etc.
    - Is a magnetic field essential to the habitability of the planet?
  - The orbit, period of the orbit, tidally locked, length of 'day'.
  - Atmosphere



(Top) My outline
(Bottom) An important diagram from an article

Challenges

Deciding what areas I was going to focus on

Habitable exoplanets are broad topic, and I had to decide what I was going to focus on to write a concise topic

Reading and understanding scientific articles

There was a lot of complex math and difficult concepts

Finding non-scientific articles

I needed easy to understand, short, and detailed articles/URLs, which were sometimes hard to find

Acknowledgements

Thank you to Ms Alexis, my mentor,
for guiding me through my project,
for answering all my questions,
even the ones I asked three times.


Thank
You!