Exoplanets and Life Beyond Earth

Lecture 4

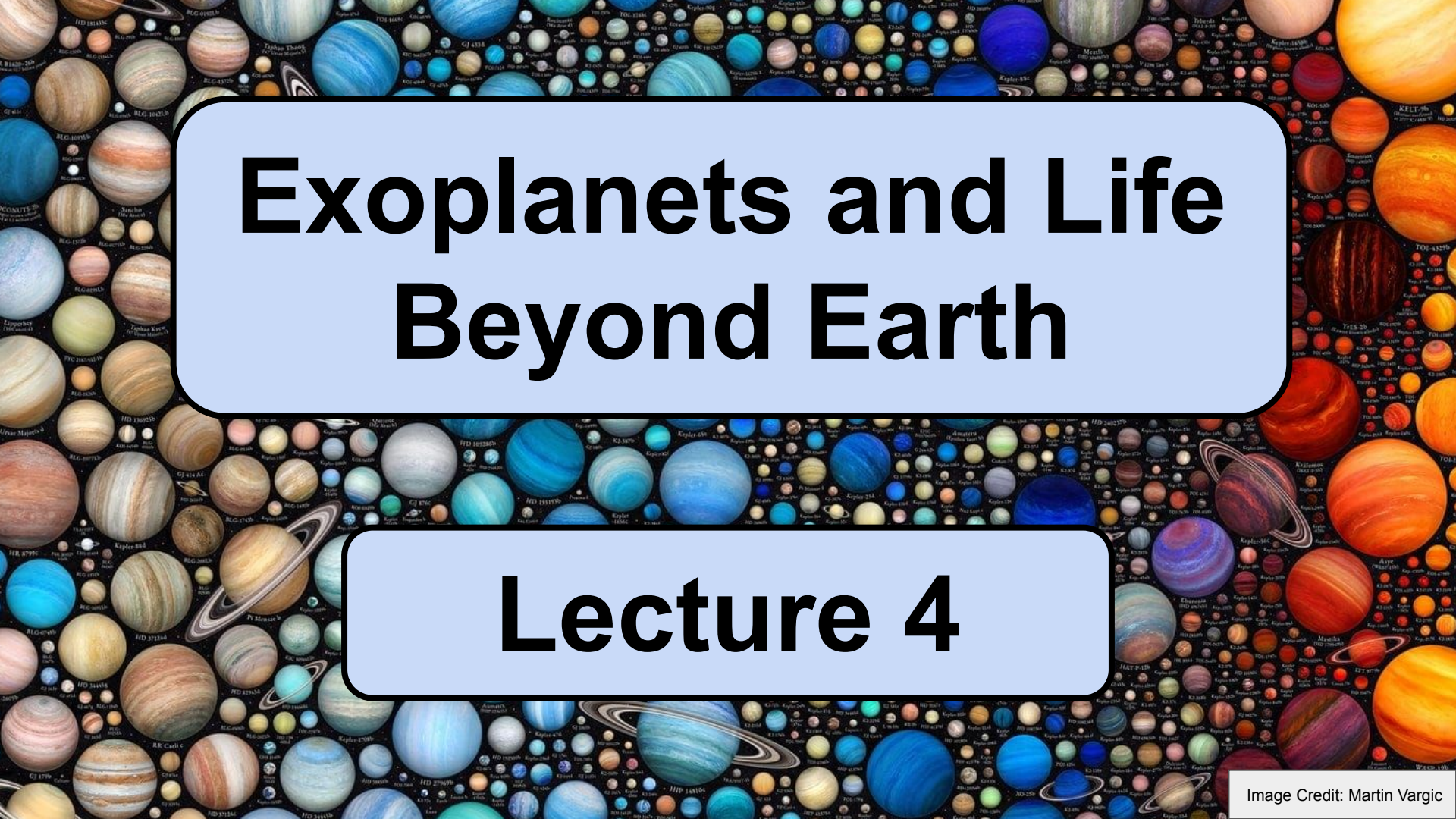


Image Credit: Martin Vargic

Recap from last week: Detection Methods of exoplanets

What are these detection techniques called?

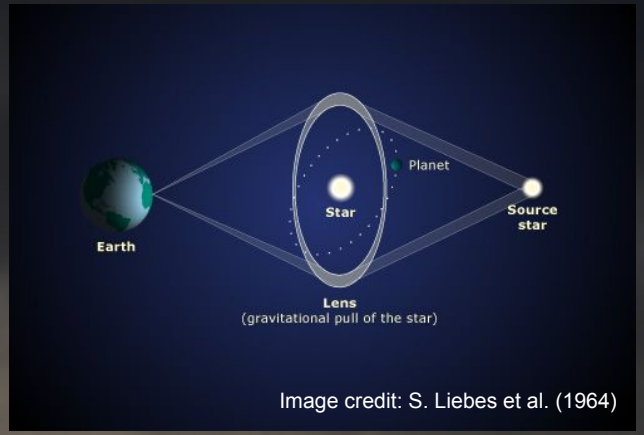


Image credit: S. Liebes et al. (1964)

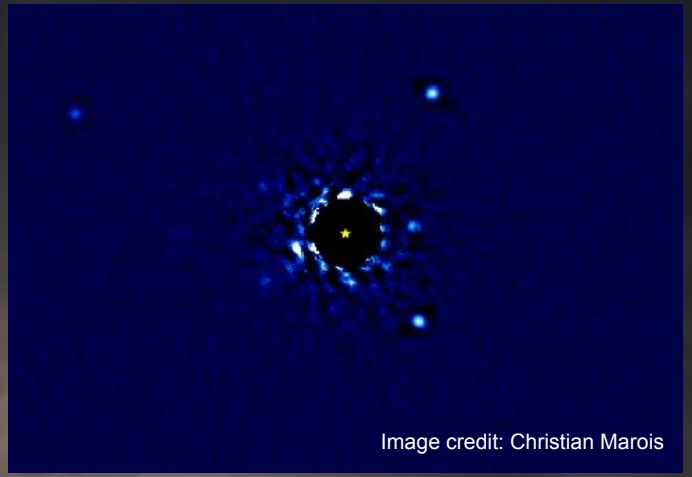


Image credit: Christian Marois

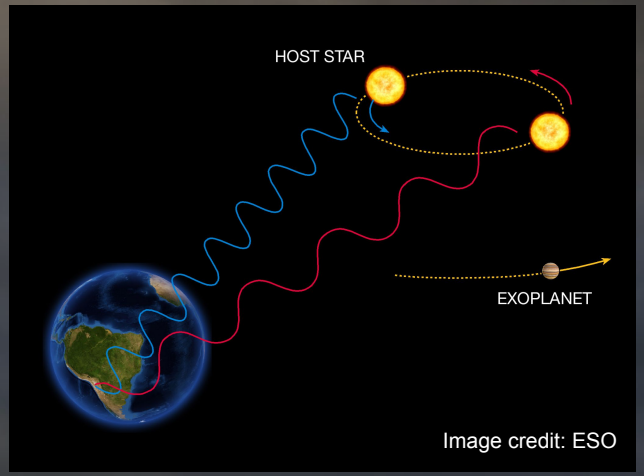


Image credit: ESO

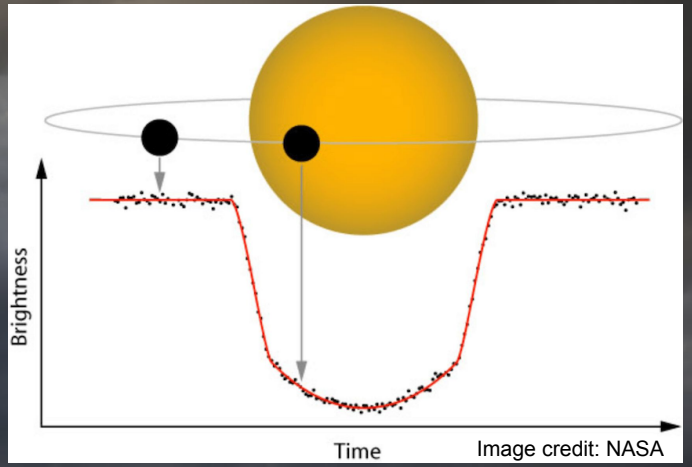
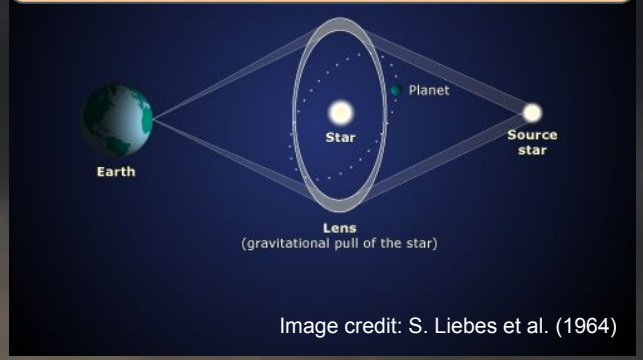


Image credit: NASA

What are these detection techniques called?

Microlensing



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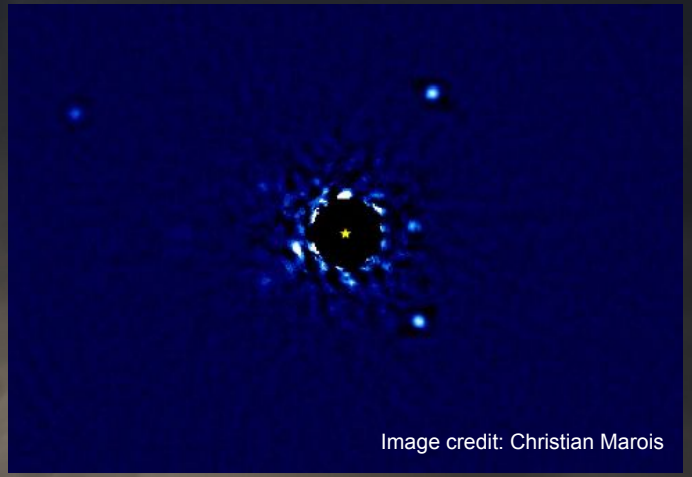

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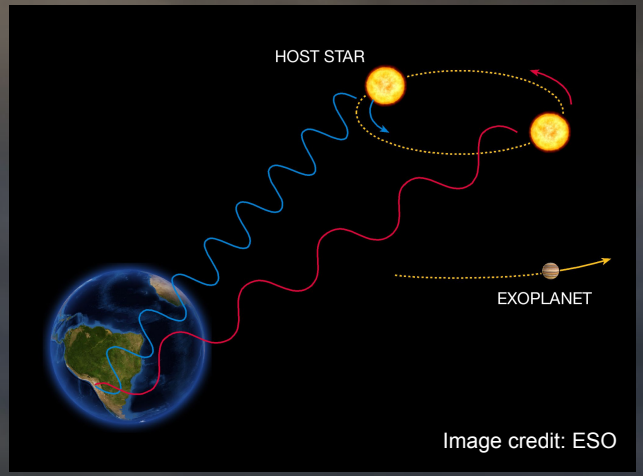

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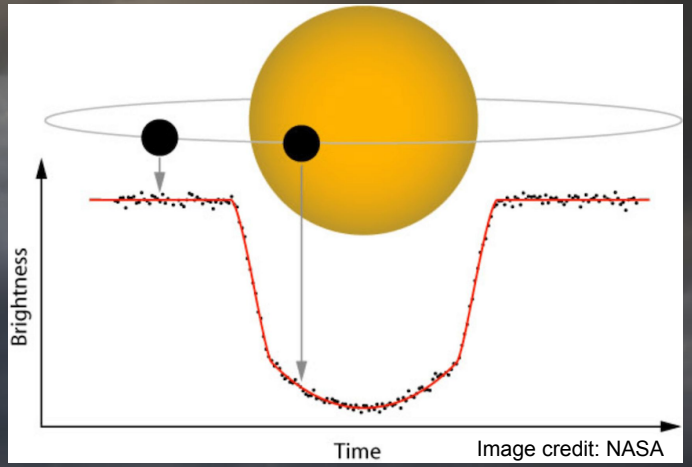

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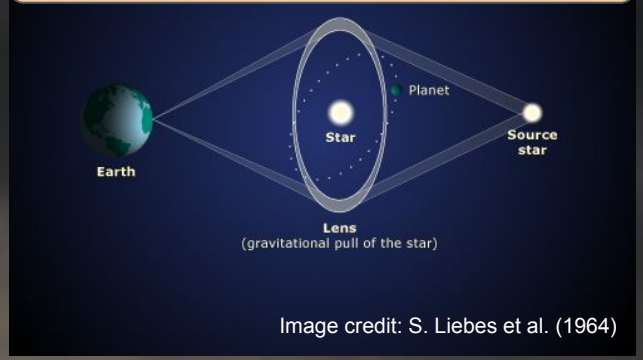

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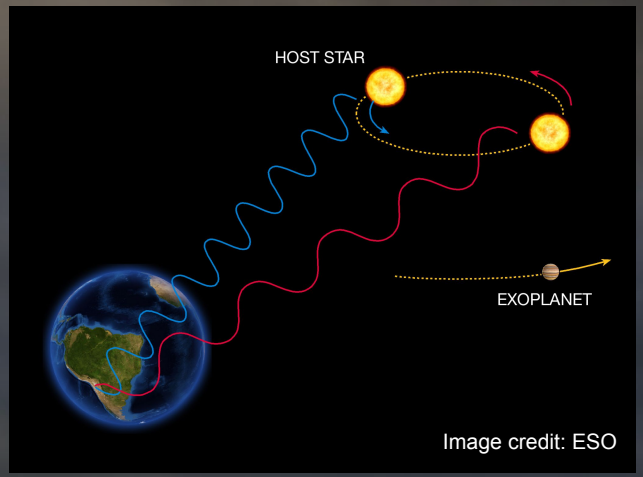
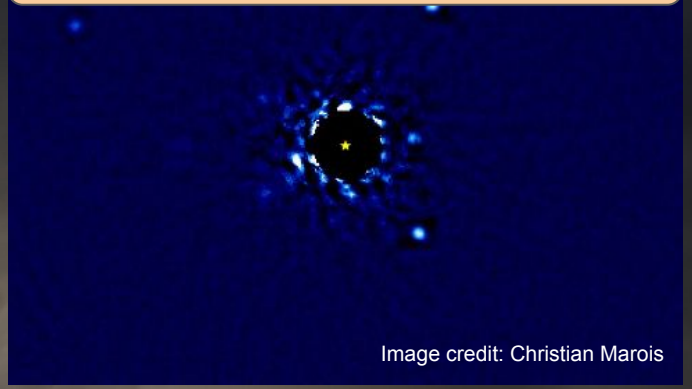


Image credit: ESO

Direct Imaging



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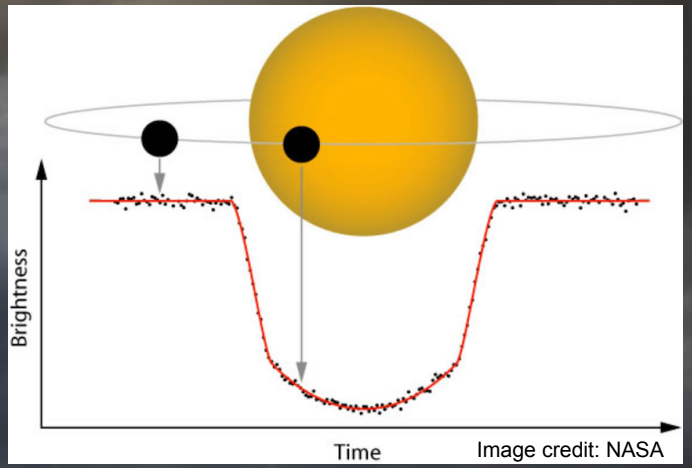

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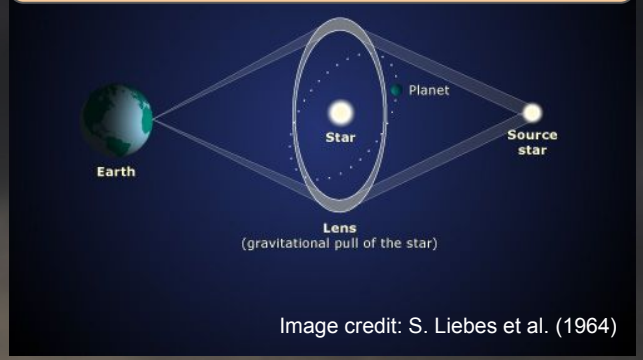

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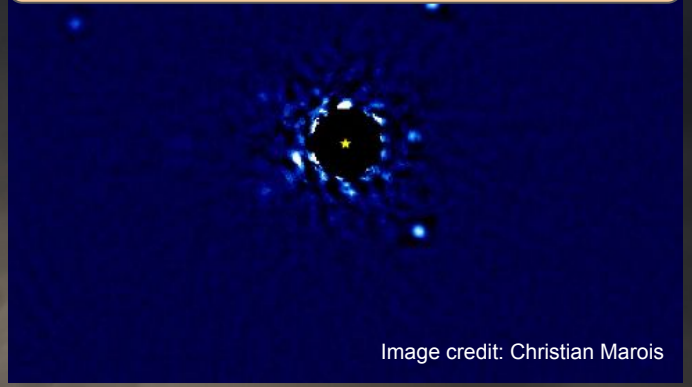

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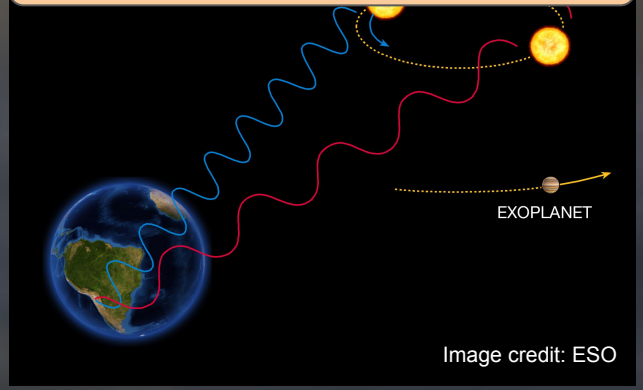
Doppler Method



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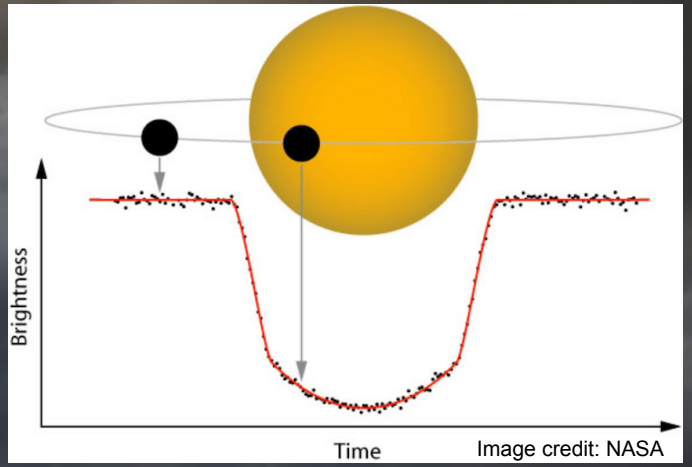

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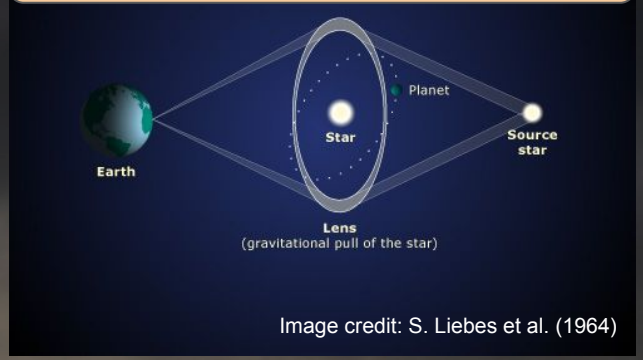

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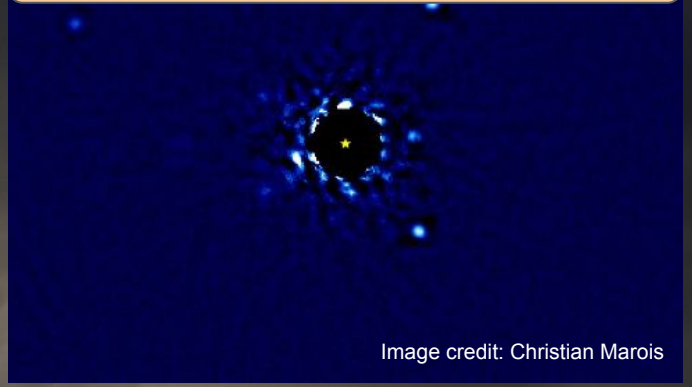

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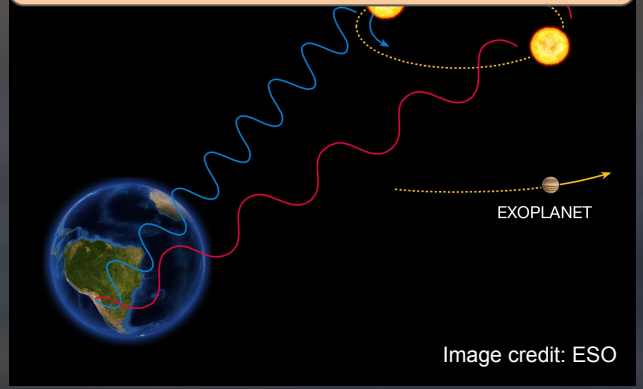

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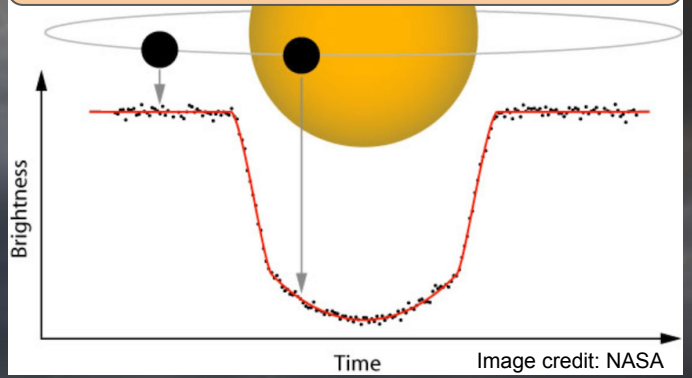
Transit Method



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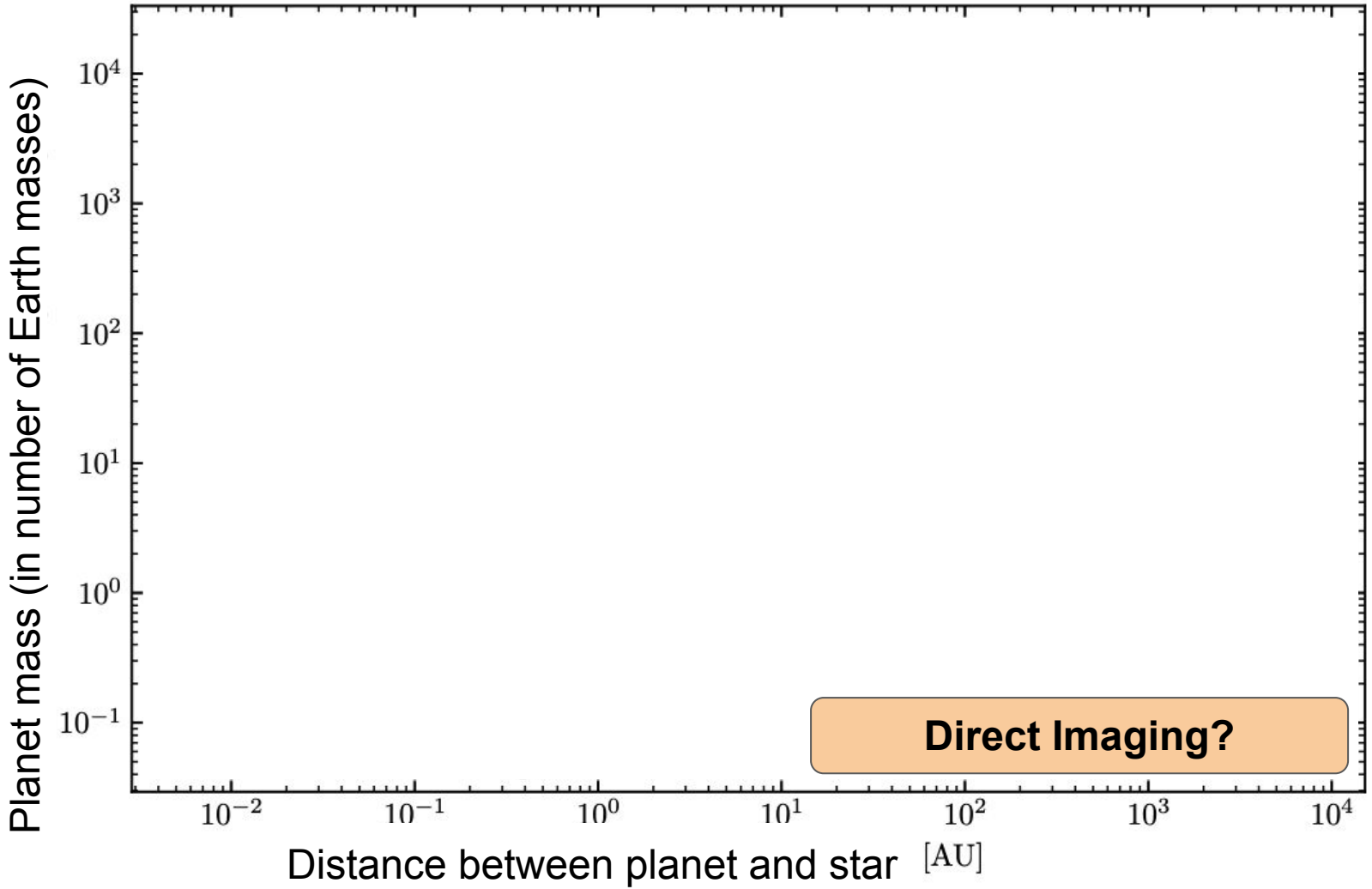
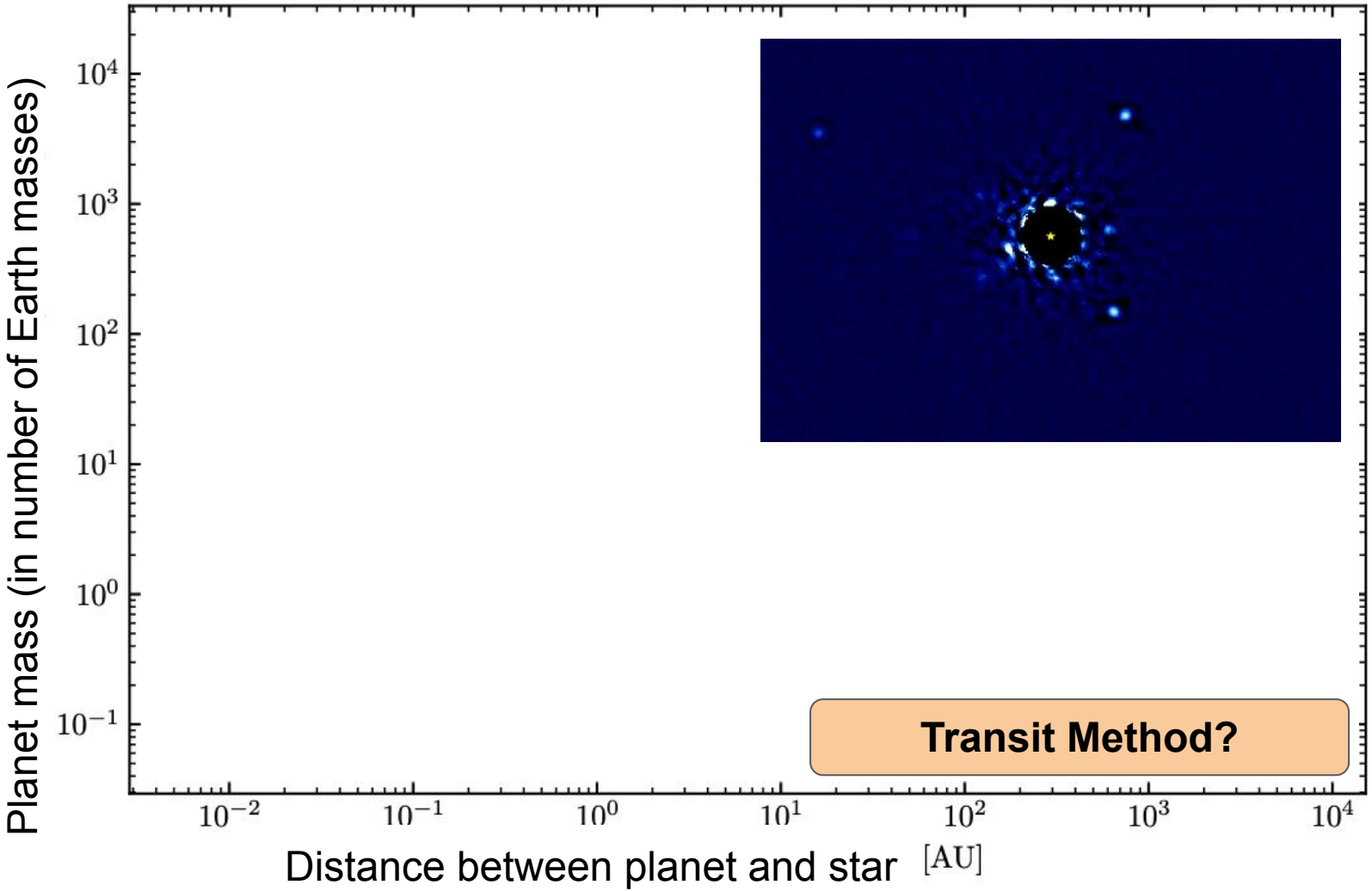

Planet mass (in number of Earth masses)
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
10^4
Distance between planet and star [AU]
Direct Imaging?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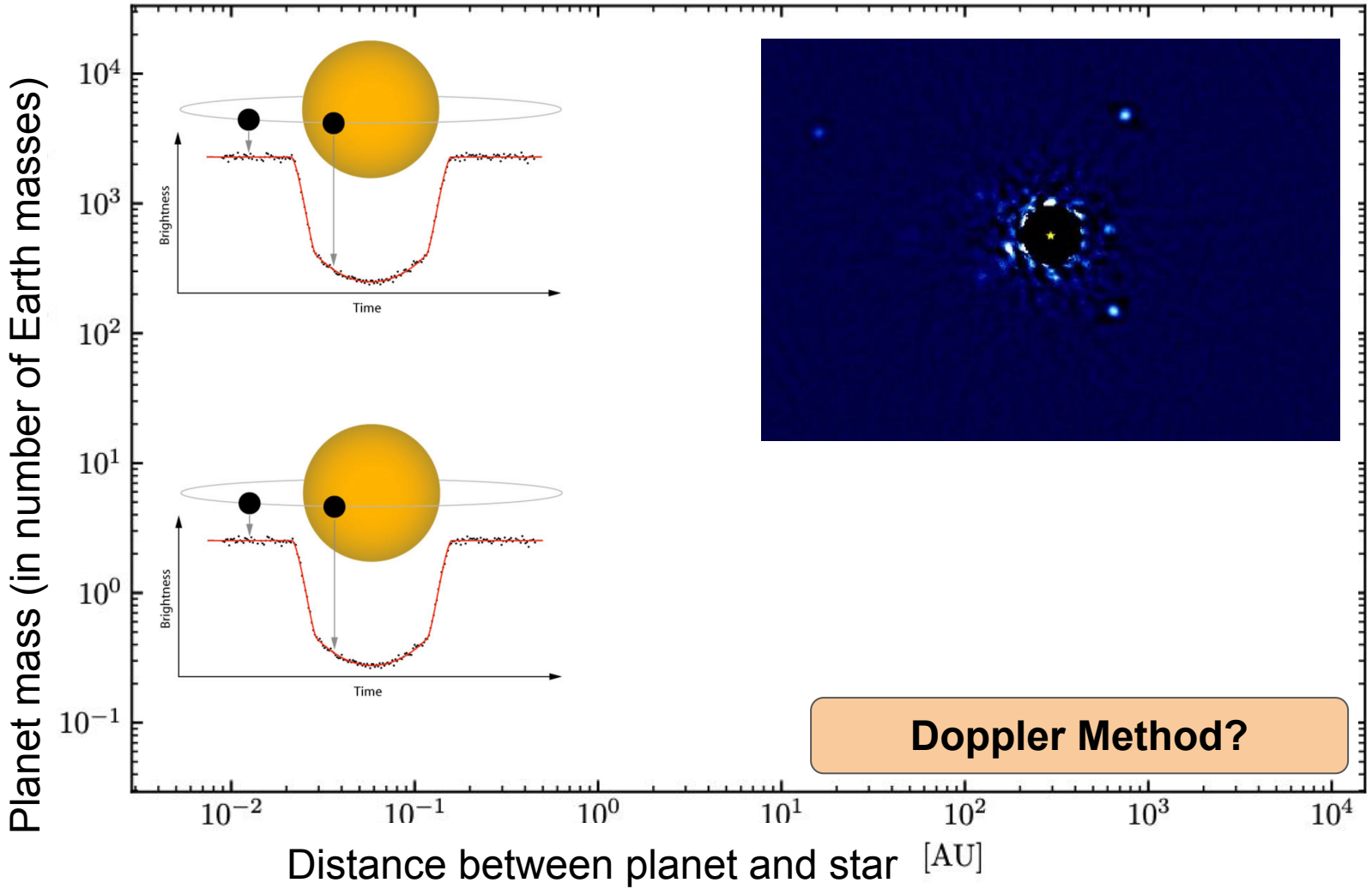
Planet mass (in number of Earth masses)
10^4
10^3
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10^1
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Brightness
Time
Brightness
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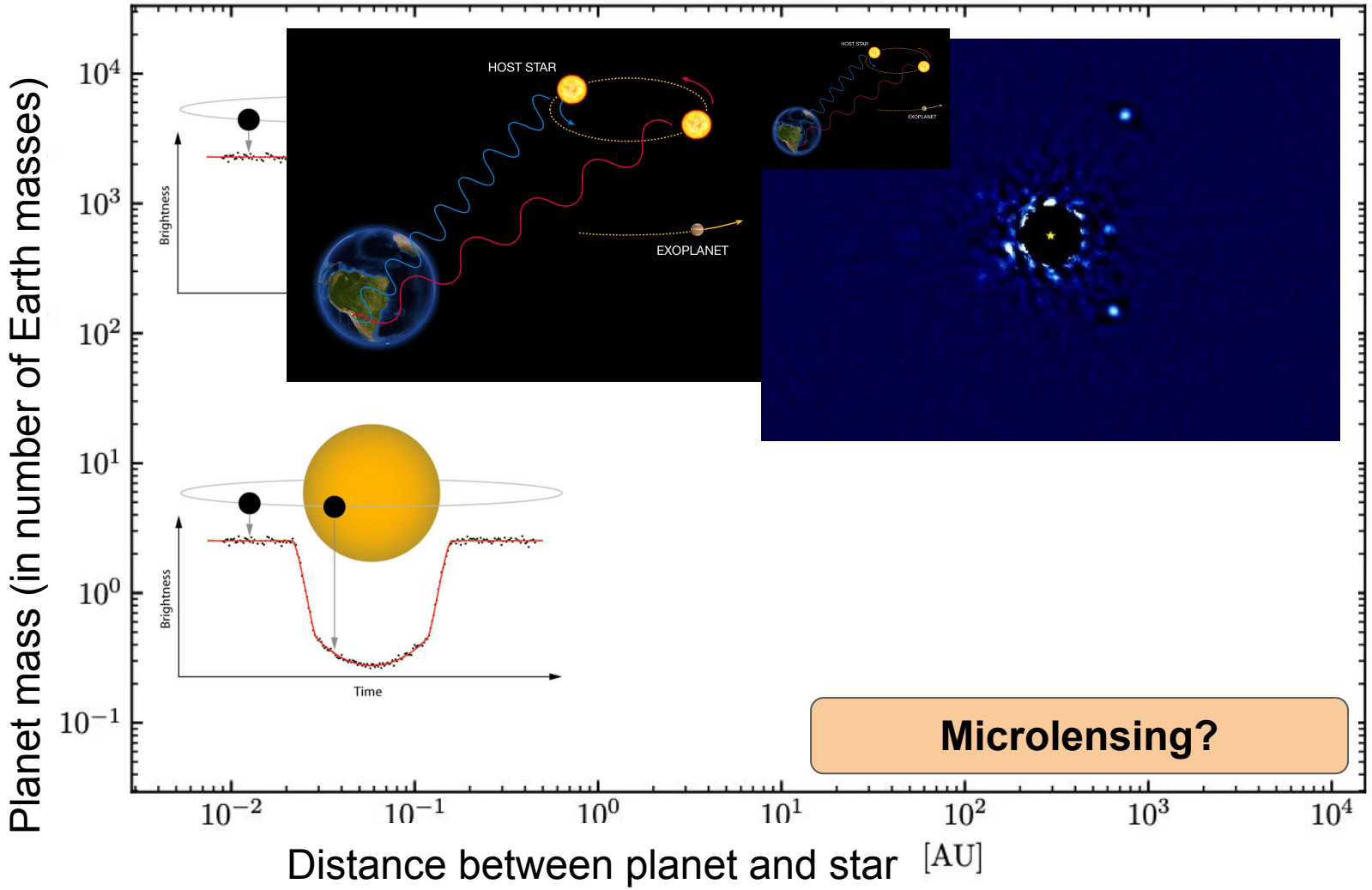
Planet mass (in number of Earth masses)
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10^3
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HOST STAR
EXOPLANET
Brightness
Time
Microlensing?
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
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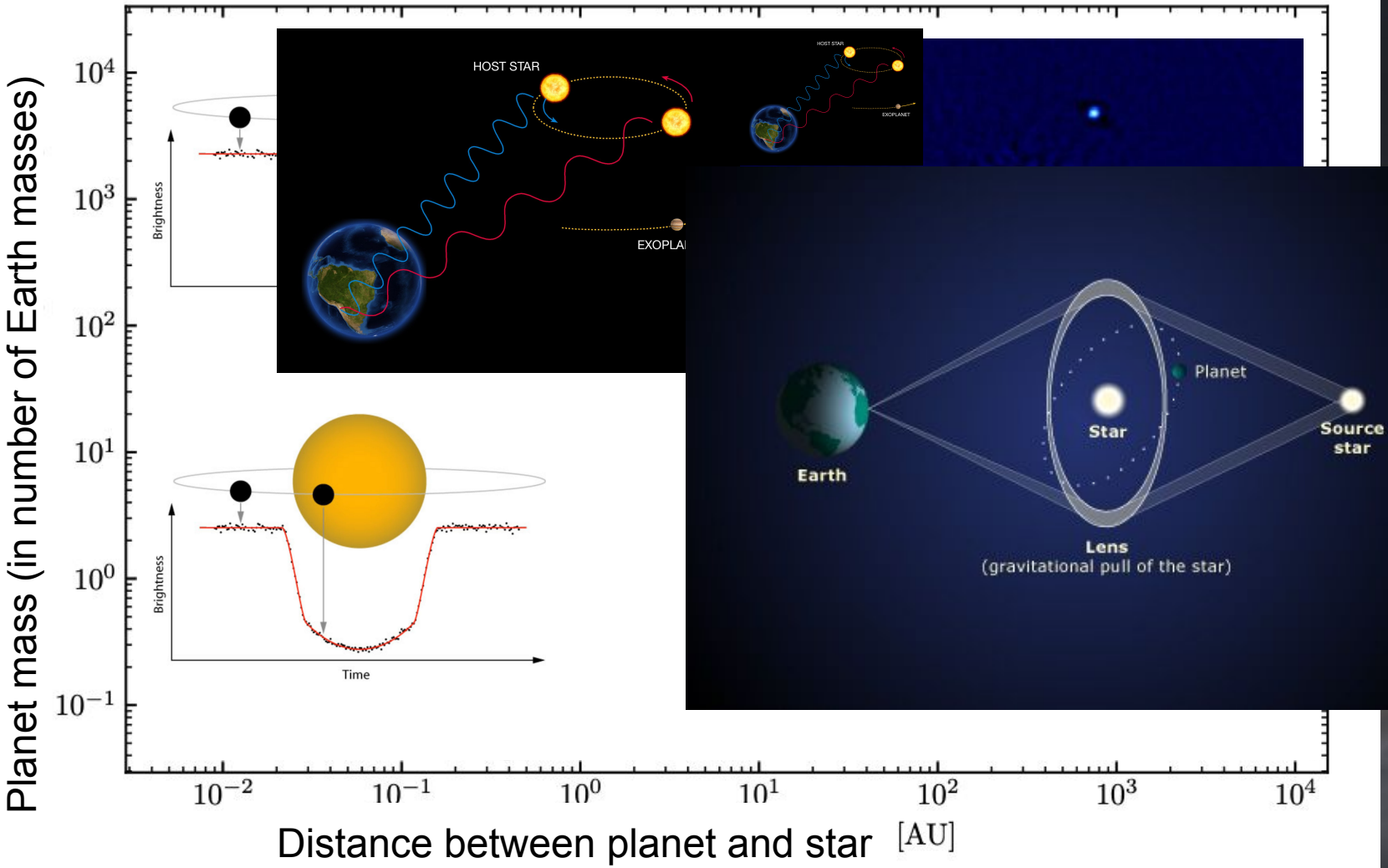
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Brightness
HOST STAR
EXOPLA
Brightness
Time
Earth
Star
Planet
Source star
Lens
(gravitational pull of the star)
10^{-2}
10^{-1}
10^0
10^1
10^2
10^3
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Last week's Homework

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The Sun has _ planets.

A. 11
B. 8
C. 9
D. 10

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The first exoplanet was found in _____ around a neutron star.

The first exoplanet around a Sun-like star was found in _____.

Most planets are found by the _____ _____.

_____ _____ is a main motivator for future 30m telescopes.

Word Bank

1992	Direct Imaging
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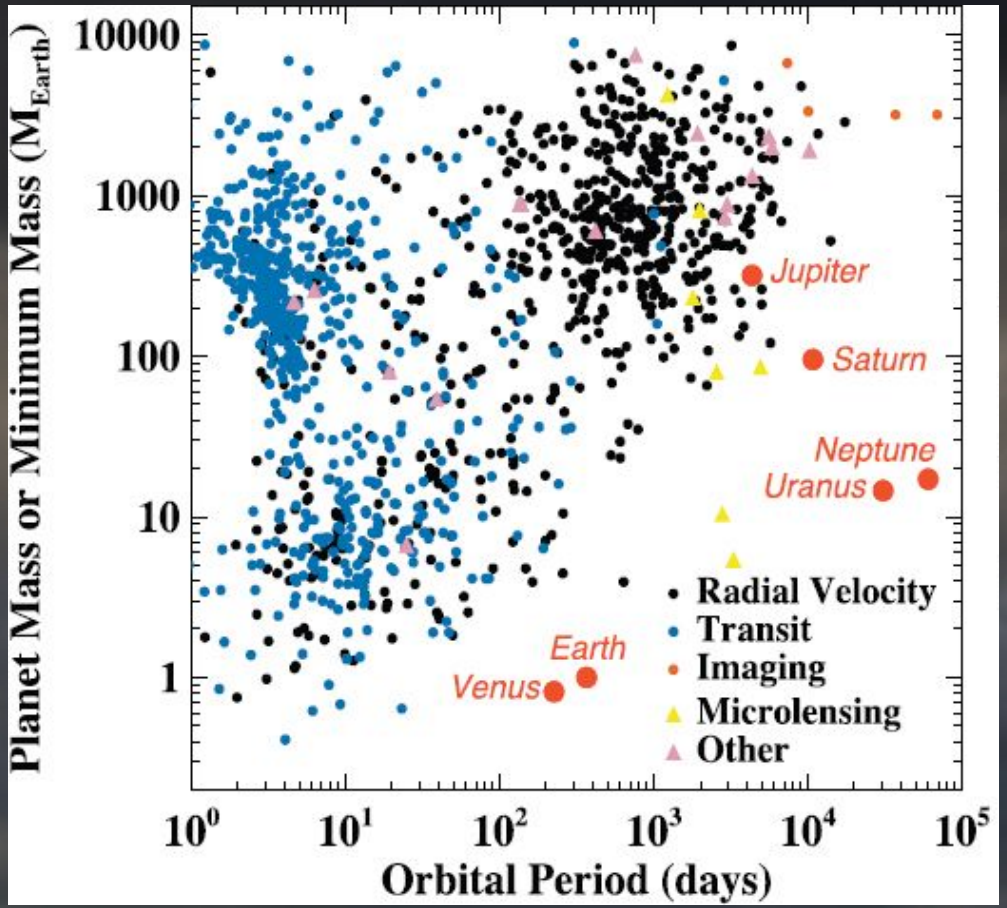
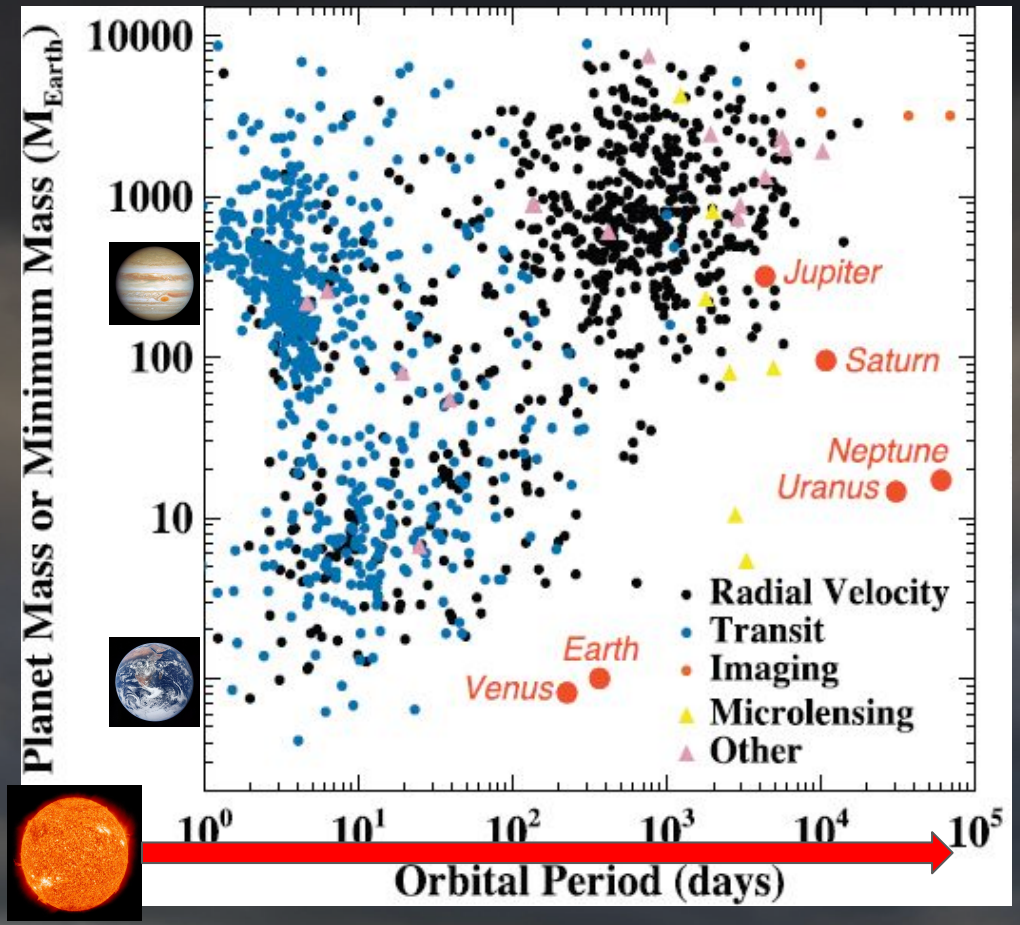
Types of Planets that don’t exist in our Solar System

Types of Exoplanets



Exoplanet Populations: NASA Exoplanet Science Strategy (2018)
Sun, Jupiter: NASA // Earth: Harrison Schmitt / Apollo 17

Types of Exoplanets



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

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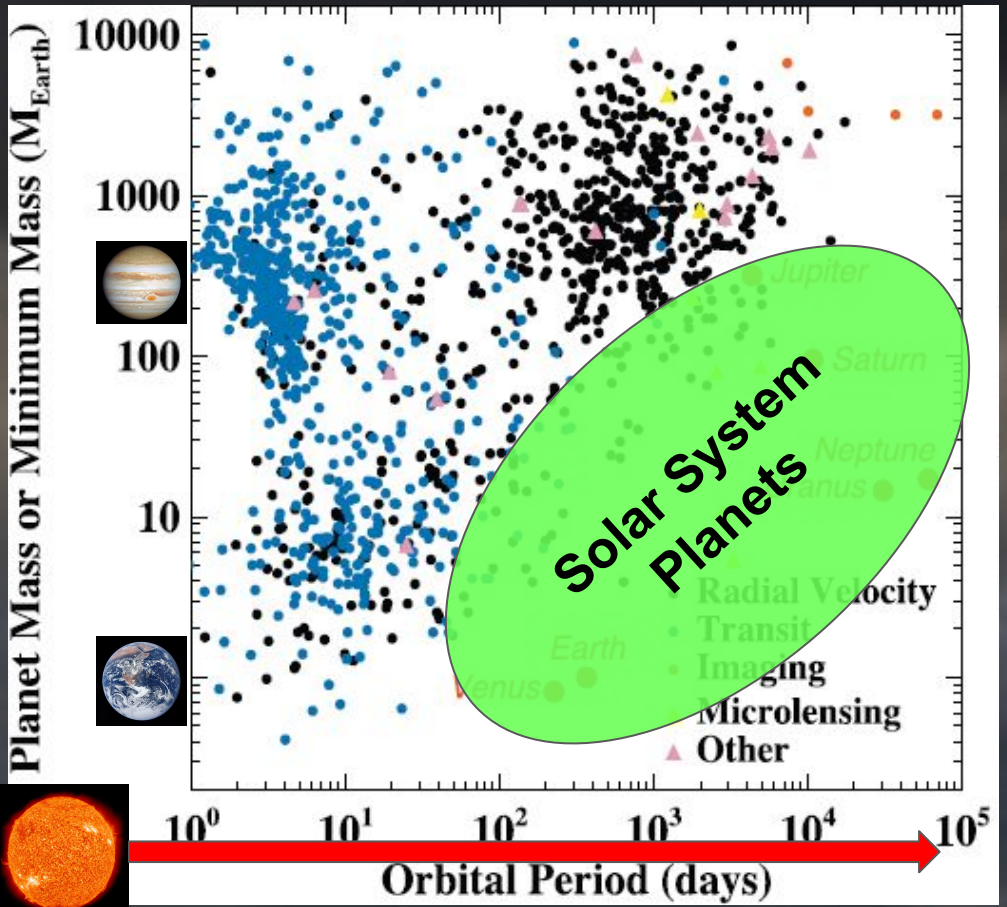

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Our solar system planets are here.

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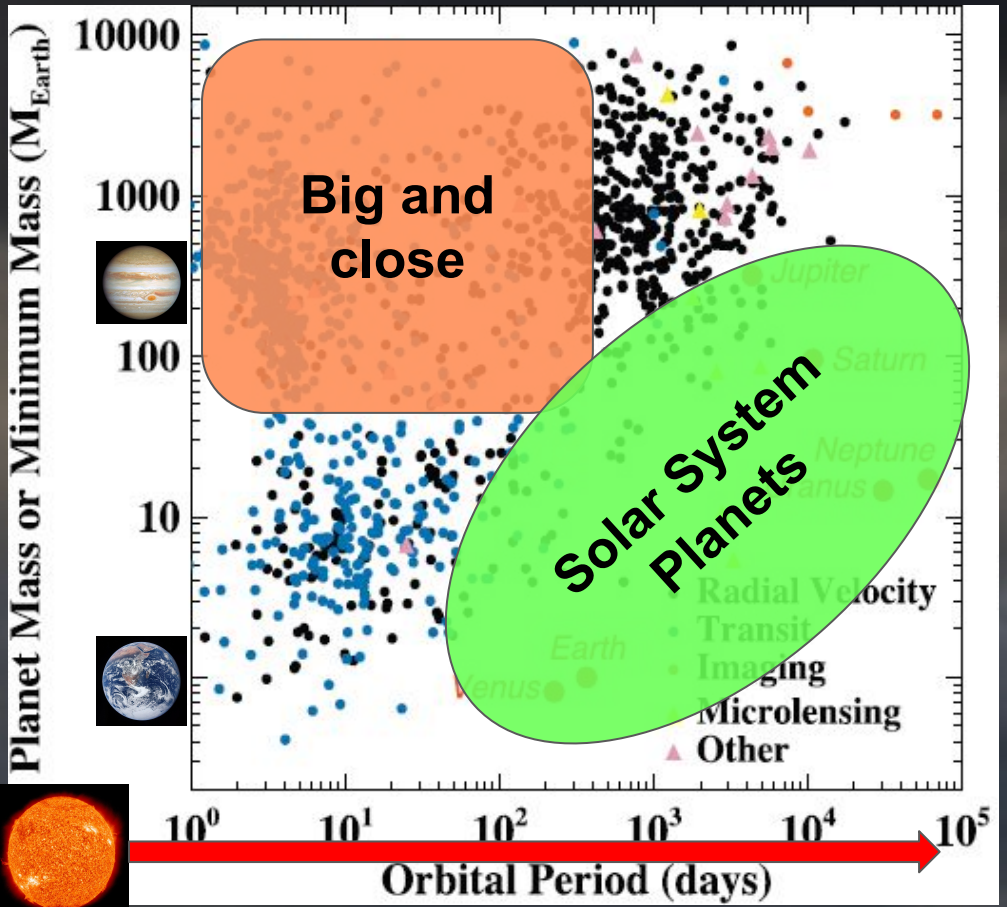
Types of Exoplanets



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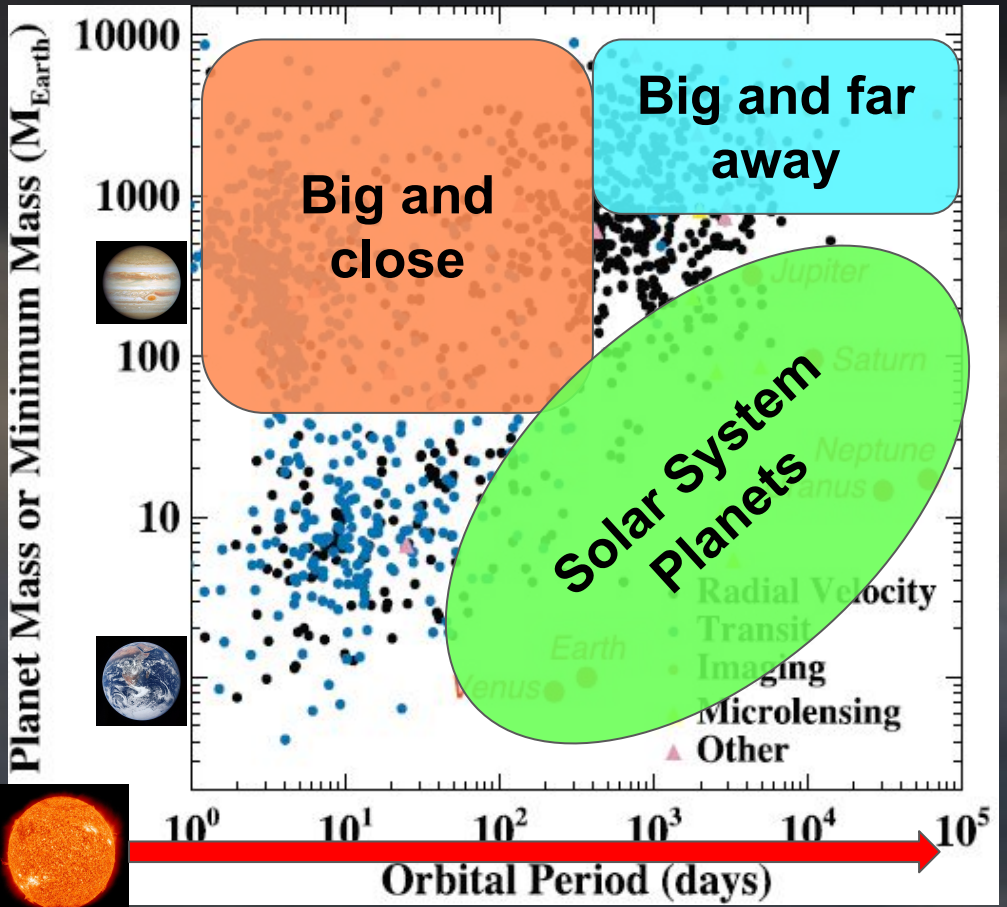

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Far away planets we only found if they are big. These planets are colder because they receive less light.

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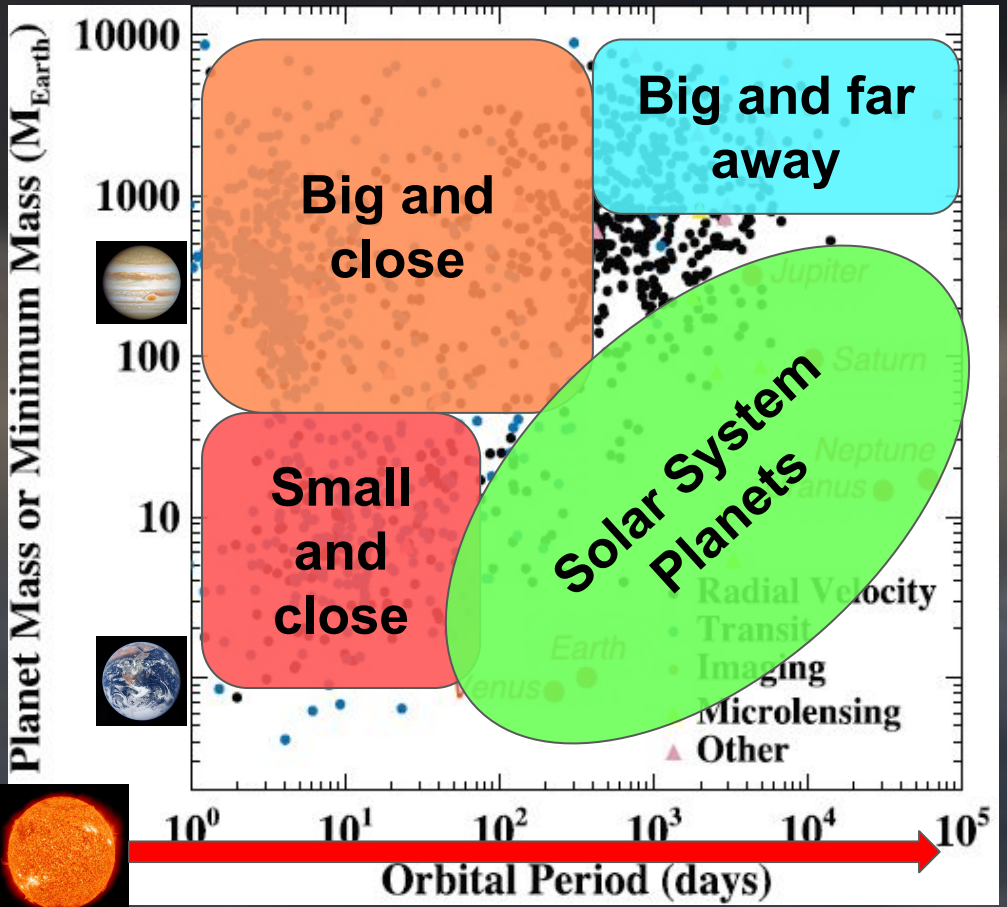
Types of Exoplanets



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

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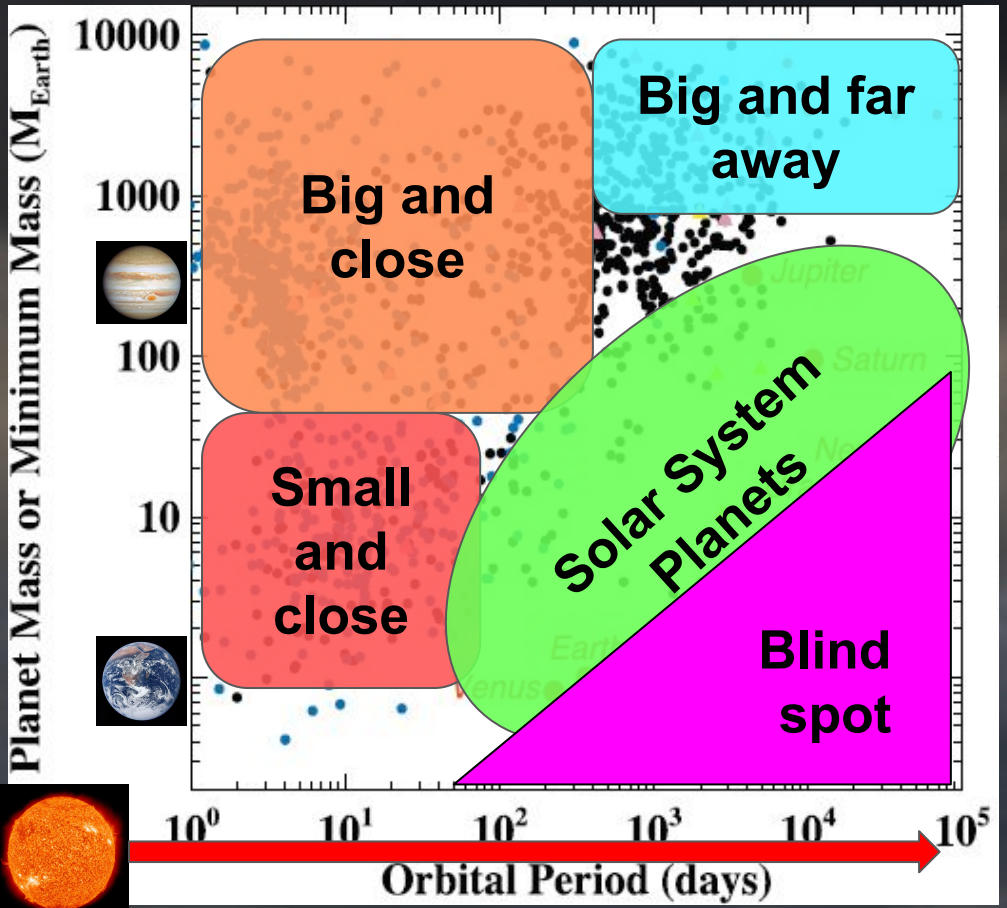
Types of Exoplanets



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Small and far away exoplanets are difficult to find and we have only found a few.

Exoplanet Populations: NASA Exoplanet Science Strategy (2018)
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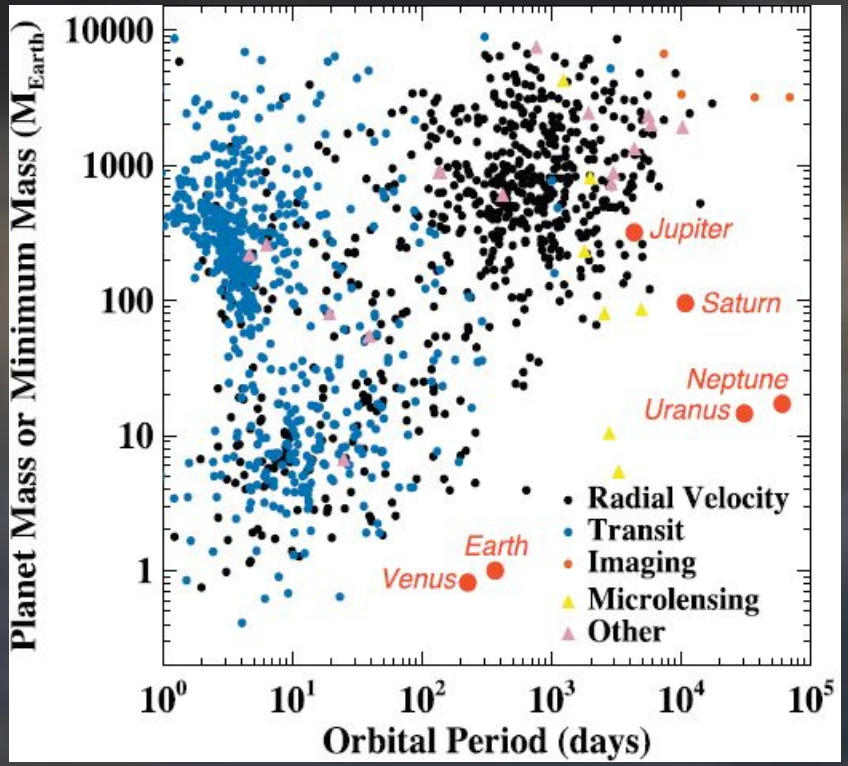
Where could life exist on this graph?



- Form groups
- Discuss where on this graph life could exist
- What current problem do we have to find life?

Exoplanet Populations: NASA Exoplanet Science Strategy (2018)

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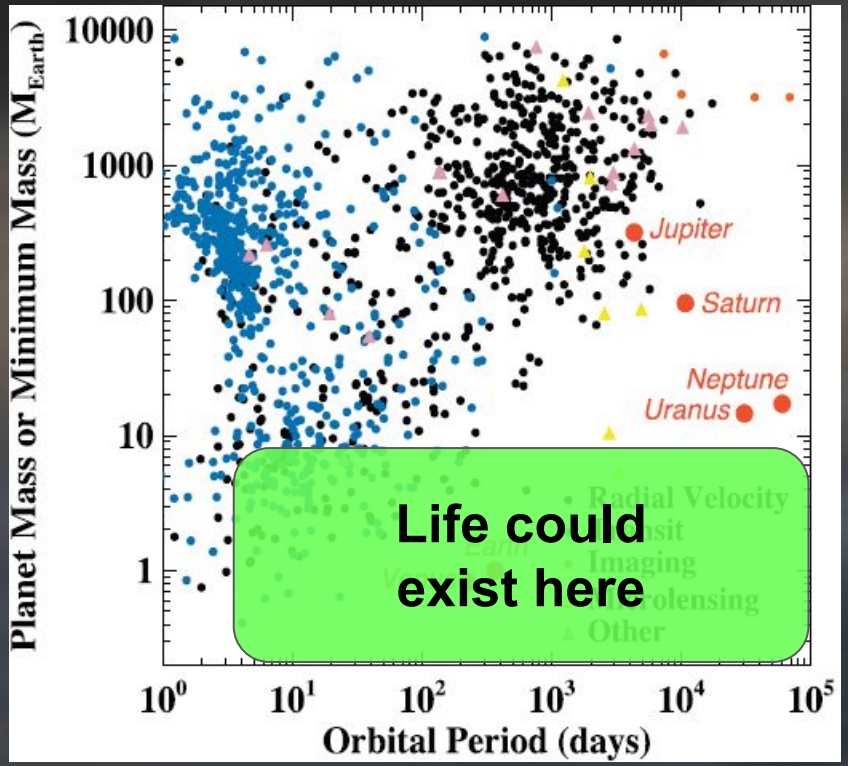


- Form groups
- Discuss where on this graph life could exist
- What current problem do we have to find life?
  - Planets which could host life are difficult to detect.
  - We have only found a few planets that could host life.

Exoplanet Populations: NASA Exoplanet Science Strategy (2018)

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?

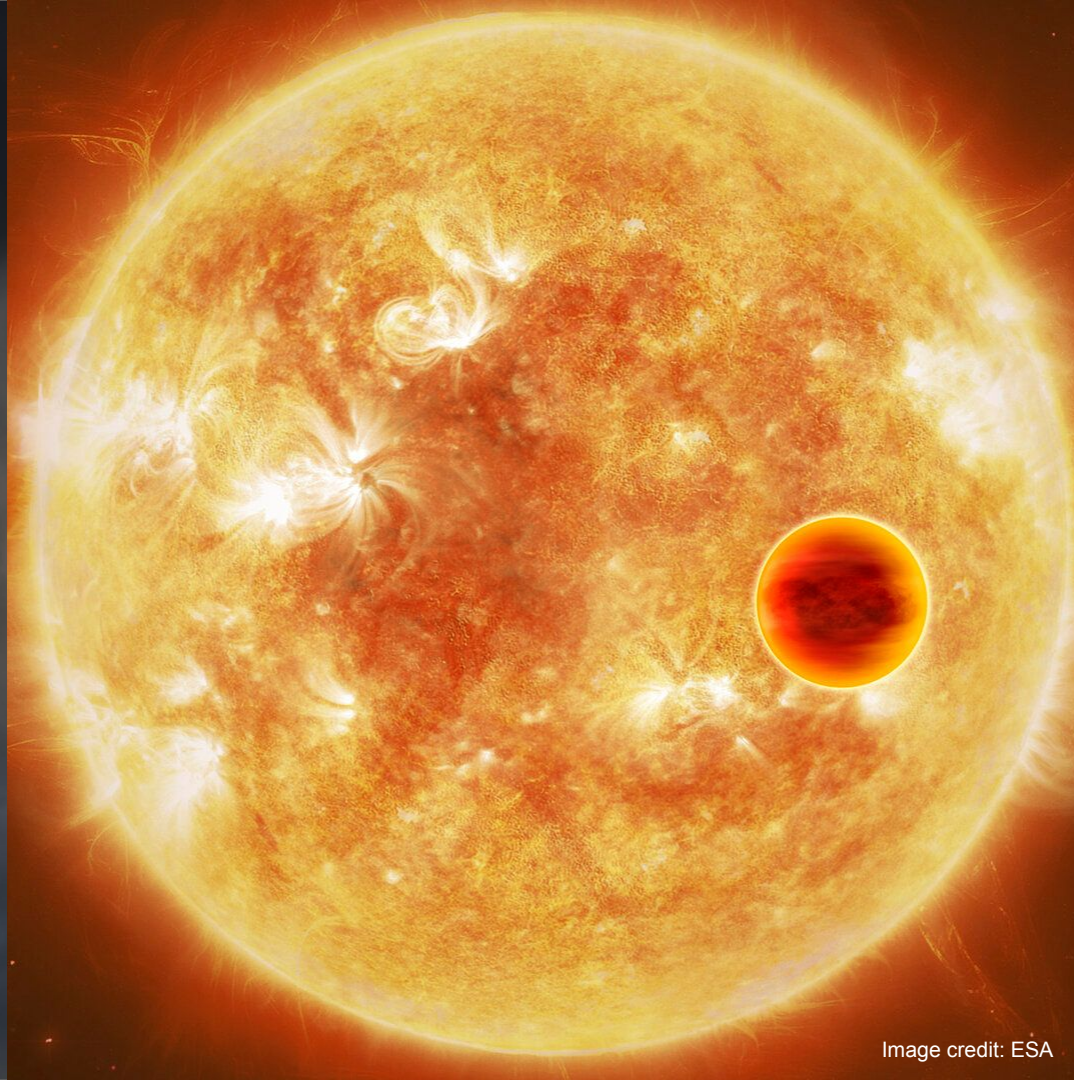


Image credit: ESA

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?

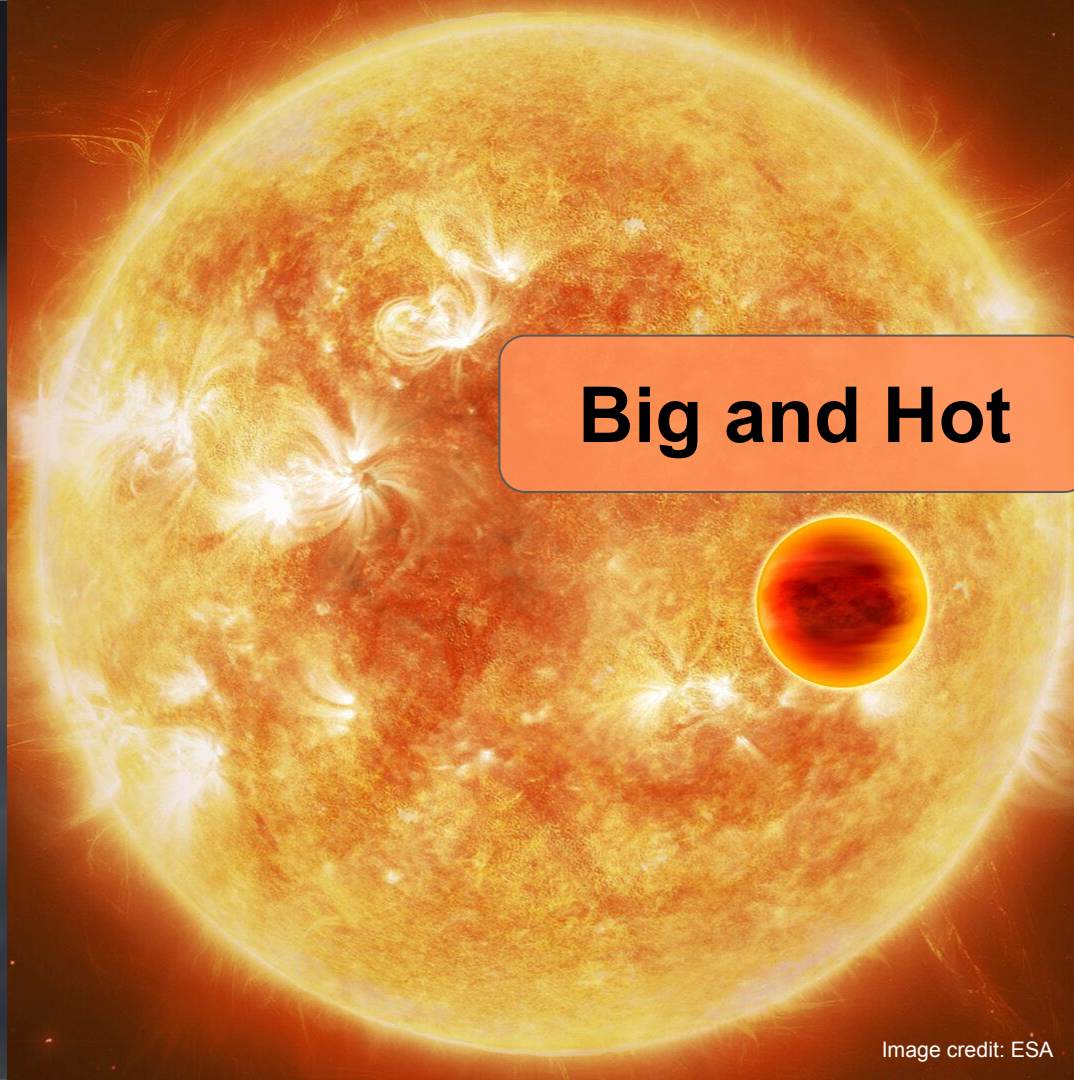


Image credit: ESA

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 to hot, but how hot are they?**

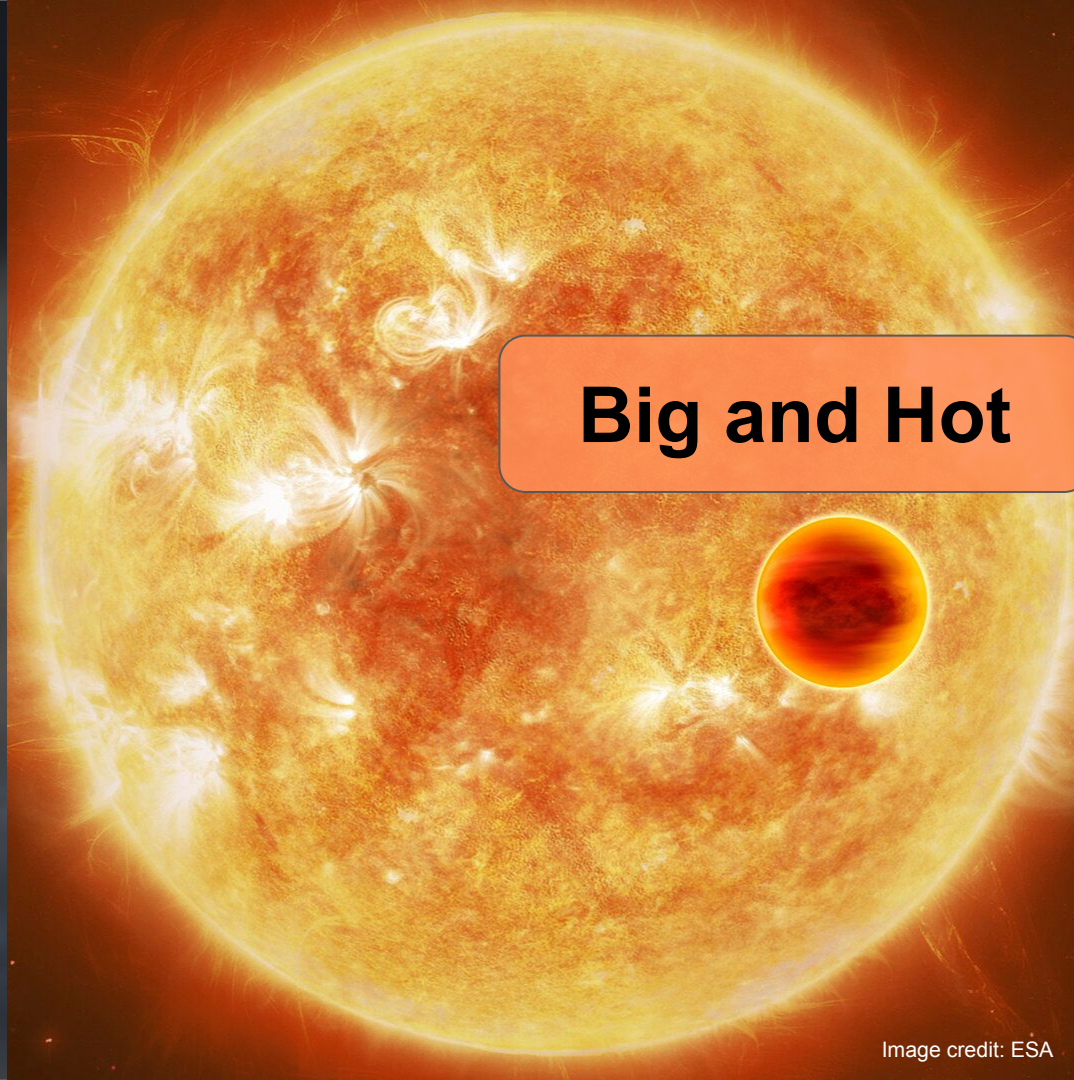
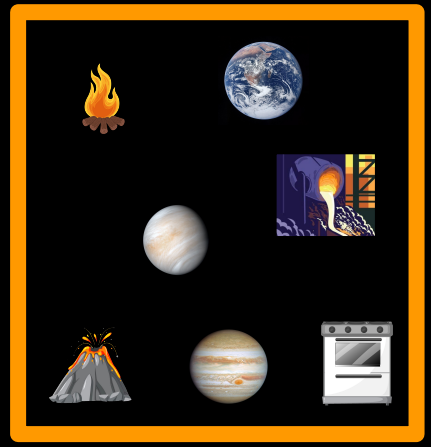


Image credit: ESA

Quick Excursion: How hot are hot Juptiers?



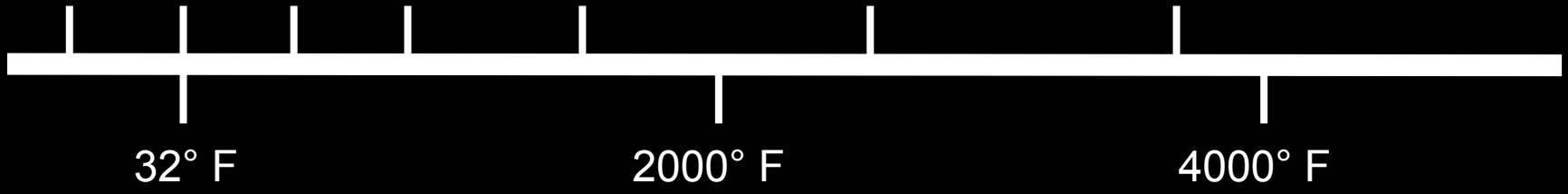


Image credit:
Jupiter, Venus, Hot juptier: NASA // Earth: Harrison Schmitt / Apollo 17
Oven, Fire, Volcano: Freepik // Furnace: globalenergymonitor

Quick Excursion: How hot are hot Juptiers?

Jupiter

Image credit:
Jupiter, Venus, Hot juptier: NASA // Earth: Harrison Schmitt / Apollo 17
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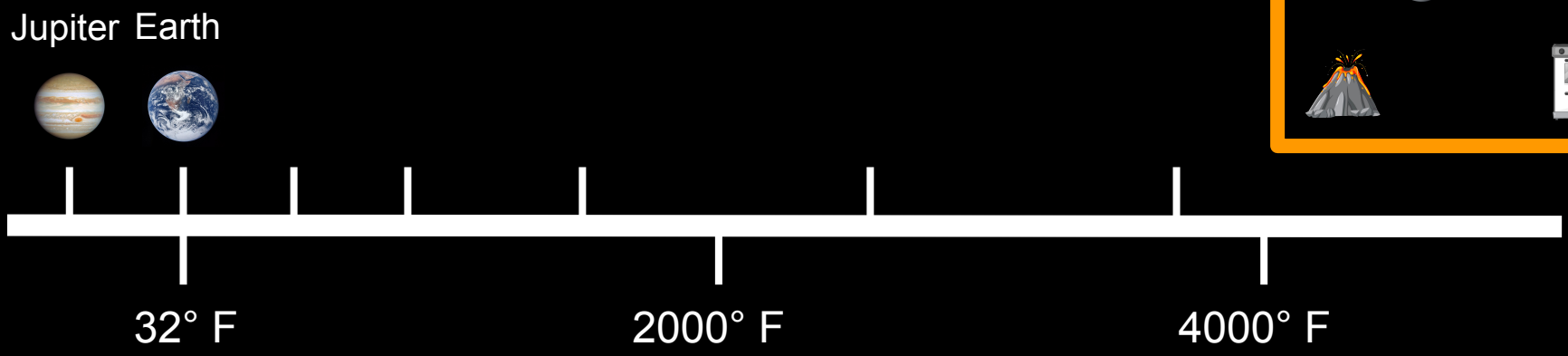
Quick Excursion: How hot are hot Juptiers?



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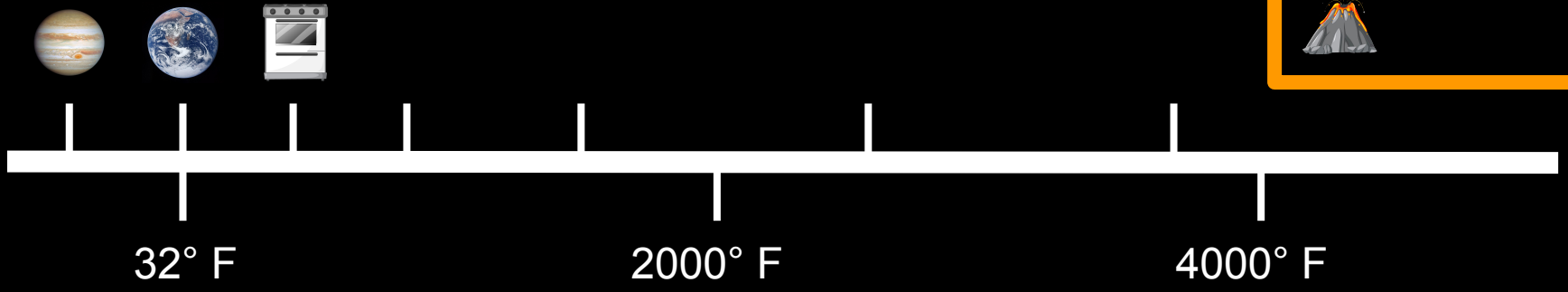
Quick Excursion: How hot are hot Juptiers?

Jupiter Earth Oven



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Jupiter, Venus, Hot juptier: NASA // Earth: Harrison Schmitt / Apollo 17
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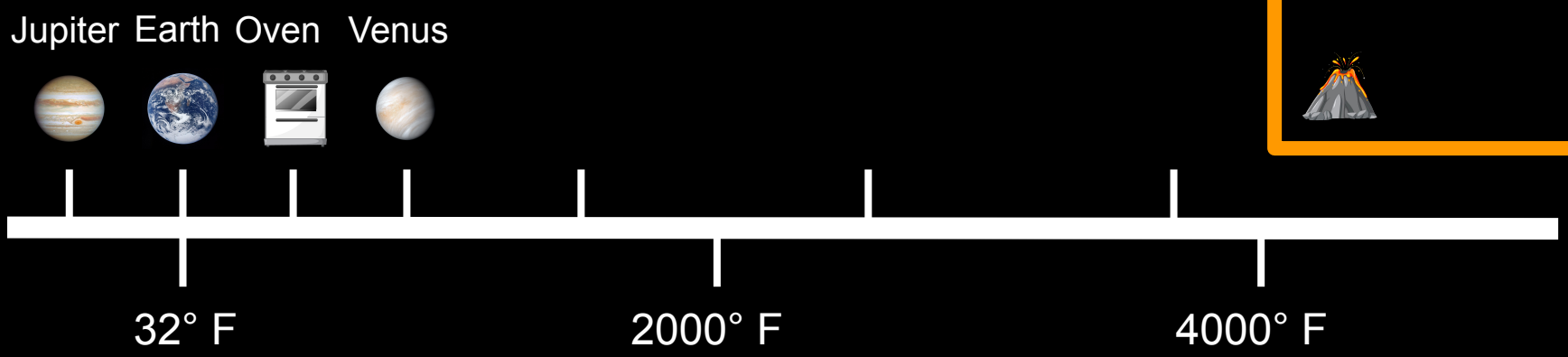
Quick Excursion: How hot are hot Juptiers?



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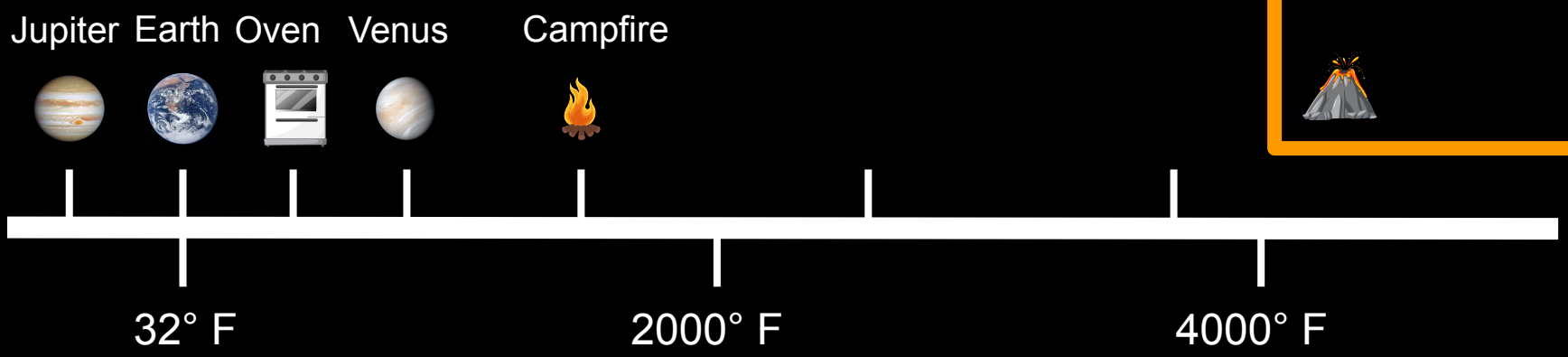

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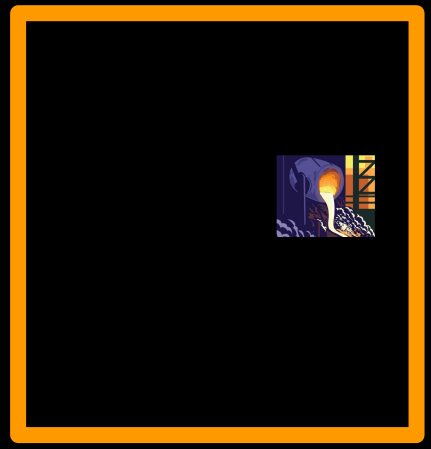
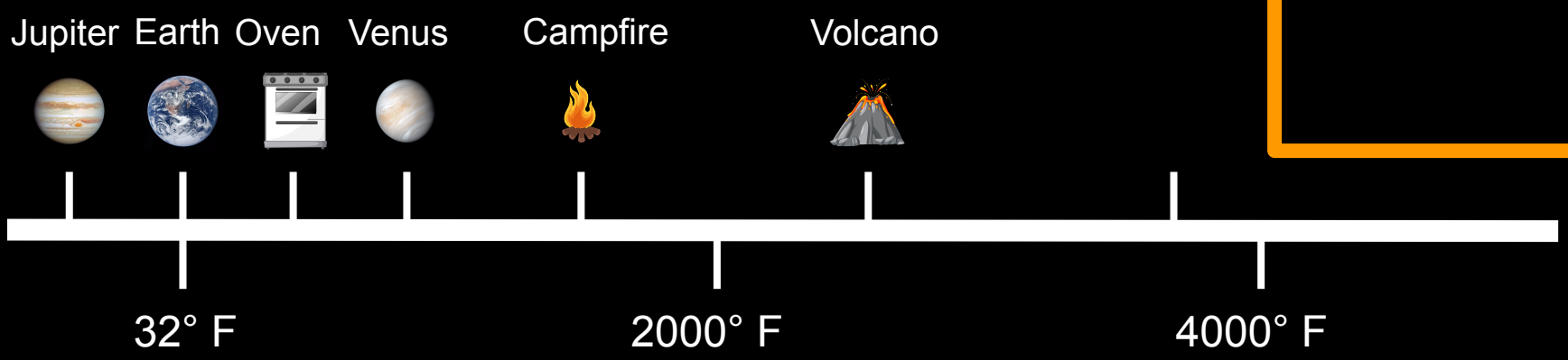
Quick Excursion: How hot are hot Juptiers?





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Jupiter, Venus, Hot juptier: NASA // Earth: Harrison Schmitt / Apollo 17
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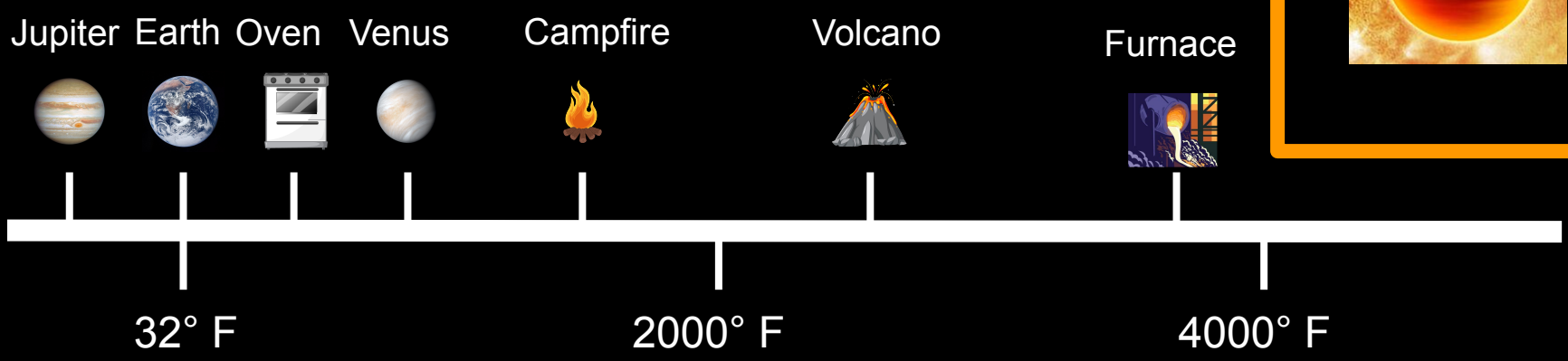

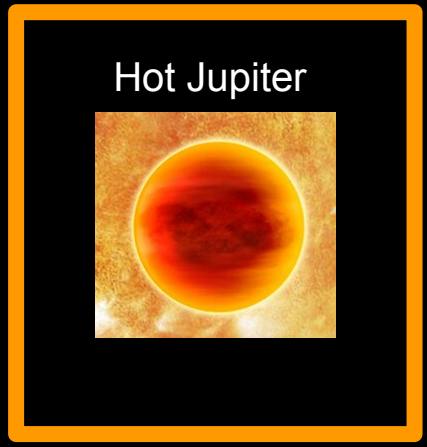

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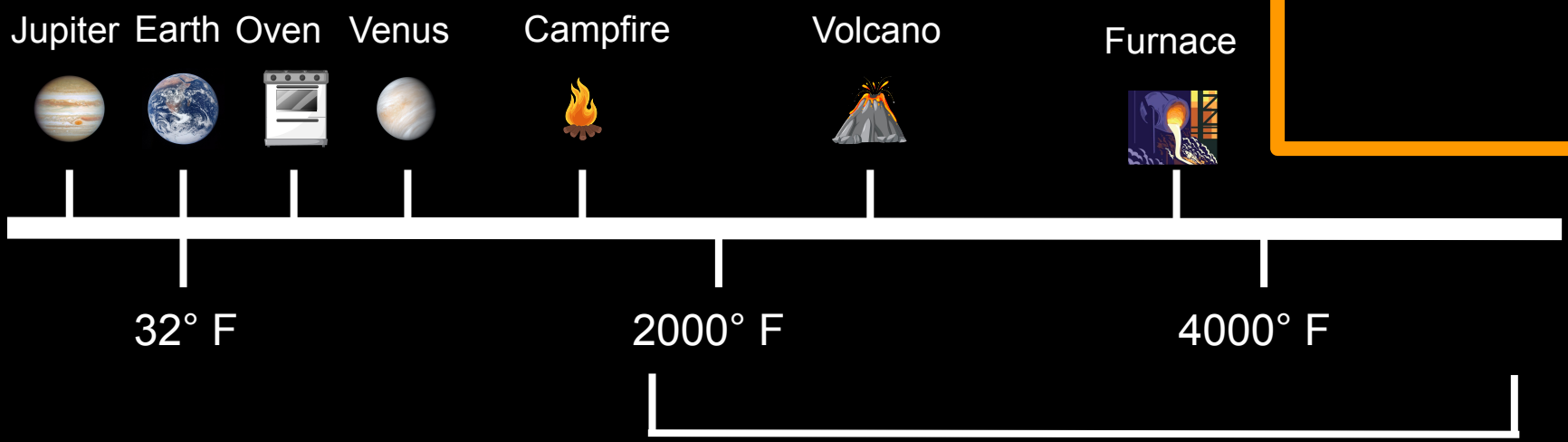
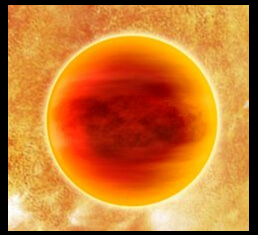
Quick Excursion: How hot are hot Juptiers?





Hot Jupiter

Image credit:
Jupiter, Venus, Hot juptier: NASA // Earth: Harrison Schmitt / Apollo 17
Oven, Fire, Volcano: Freepik // Furnace: globalenergymonitor

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 to hot, but how hot are they? Over 2000°F!**

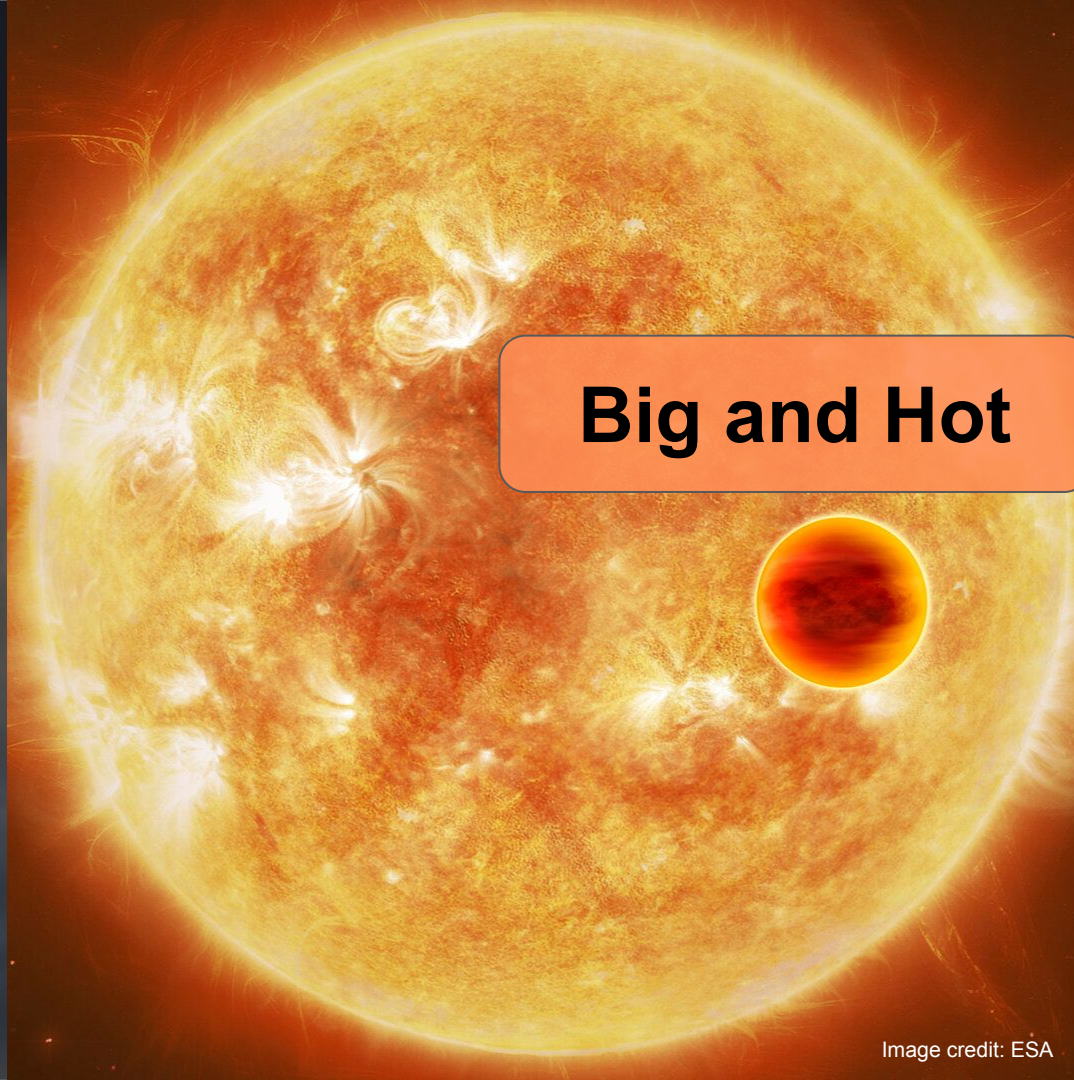


Image credit: ESA

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?

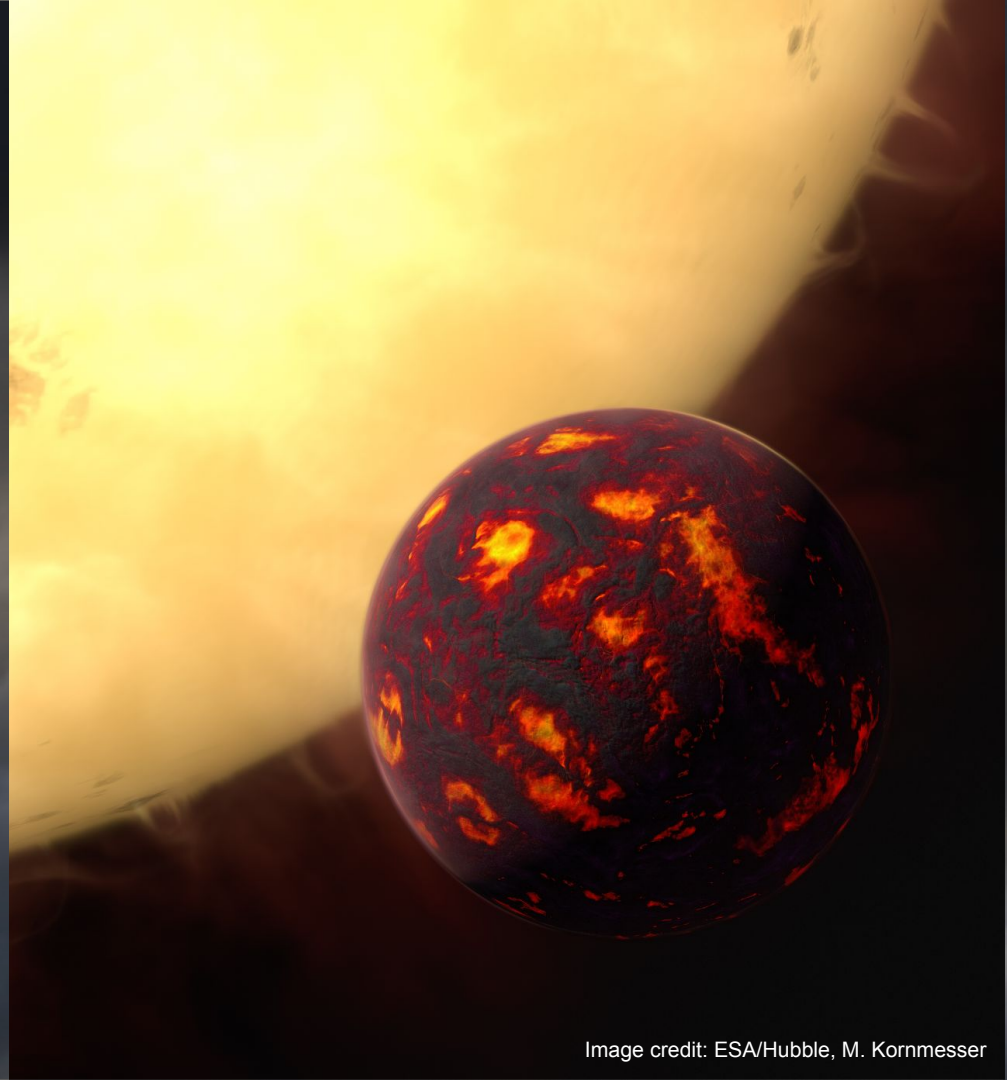


Image credit: ESA/Hubble, M. Kornmesser

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

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Can we find life on a Lava World?

Image credit: ESA/Hubble, M. Kornmesser

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 to hot, up to 3000°F!**

Image credit: ESA/Hubble, M. Kornmesser

Super Earths

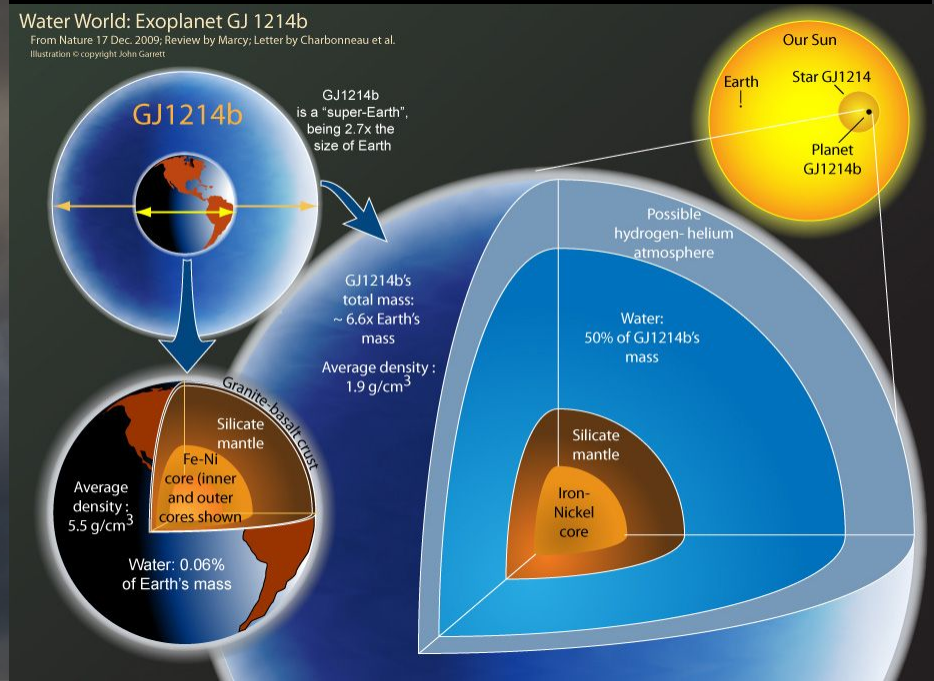
Planets that are bigger than Earth but smaller than Neptune.

They have a rocky surface.

They have a thick atmosphere.

Can we find life on a Super Earth?

Image credit: Wikipedia/Aldaron and NASA



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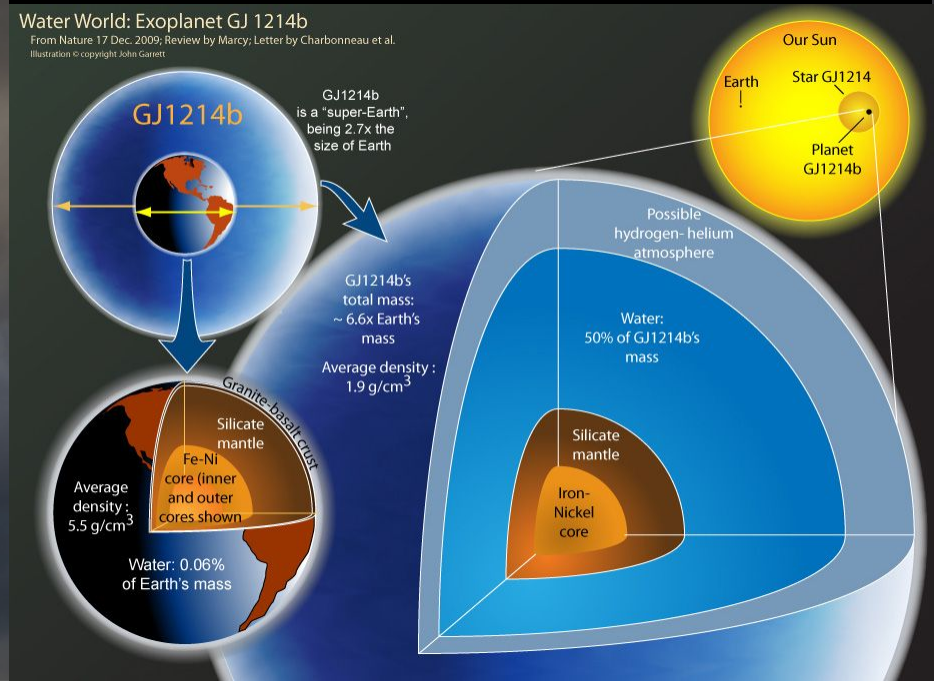

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Planets that are bigger than Earth but smaller than Neptune.

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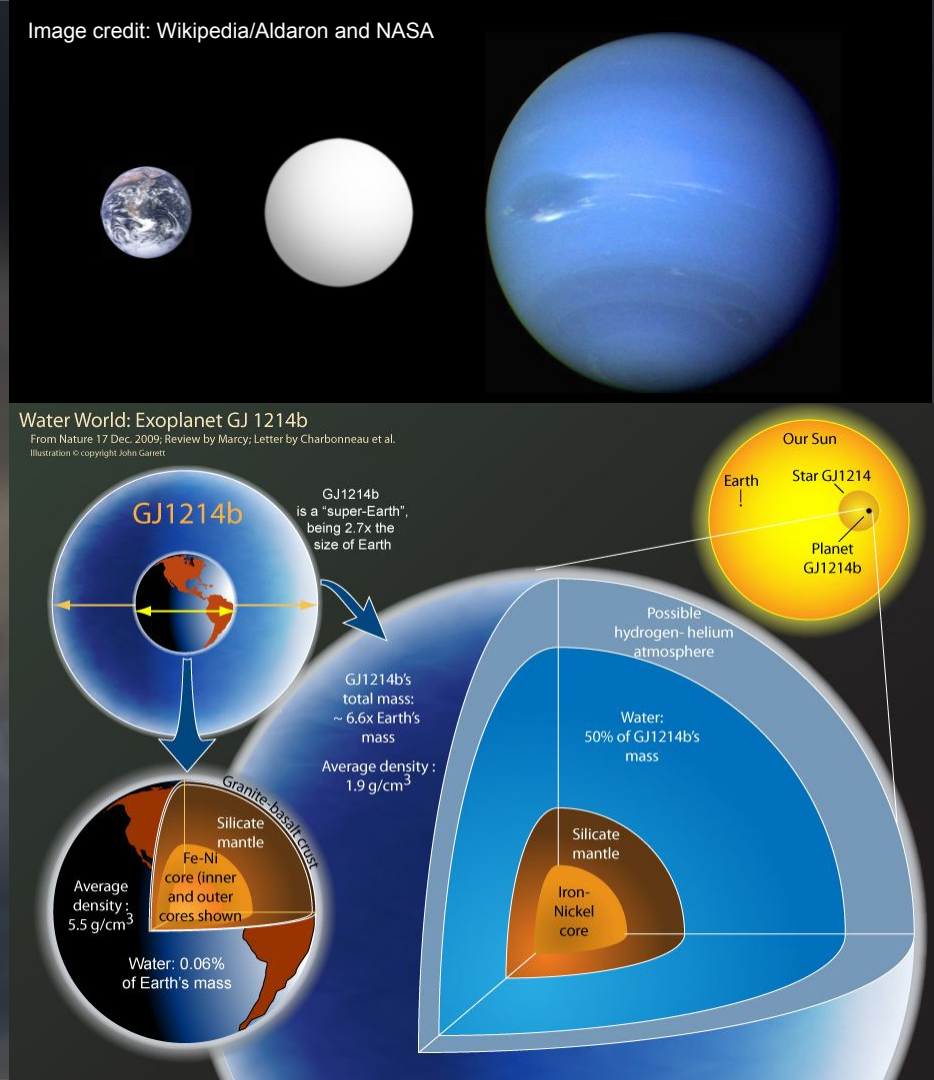
Can we find life on a Super Earth?

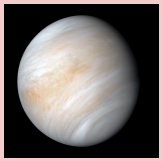
- **Maybe!**
- **But it needs to be in the right spot**

What does it mean to be in the right spot?

Image credit: Wikipedia/Aldaron and NASA



Quick Excursion: The Goldilocks Zone



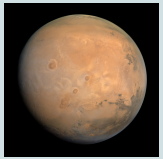
Venus is too hot

Close to the star it is too hot and water evaporates

This zone is also called the habitable zone

Earth is just right

The Goldilock Zone is where water can be liquid

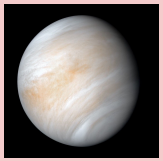


Mars is too cold

Far away from the star it is too cold and water freezes

Image credit:
Sun, M-dwarf, Mars, Venus, Exo-Earth: NASA
Earth: Harrison Schmitt / Apollo 17
Steam: tuttnauer // Ice: T.Tulic/Fotolia // T.Tulic/Fotolia

Quick Excursion: The Goldilocks Zone



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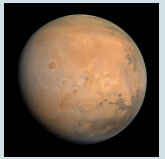

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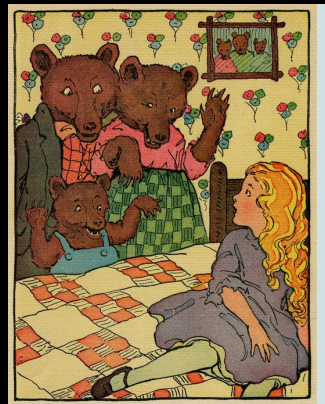

It's called Goldilock because of the fairytale!

Image credit:
Sun, M-dwarf, Mars, Venus, Exo-Earth: NASA
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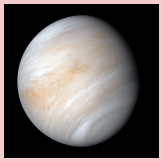
Quick Excursion: The Goldilock Zone



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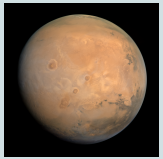


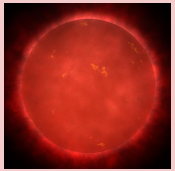
Mars is too cold

Close to the star it is too hot and water evaporates

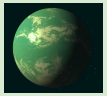
The Goldilock Zone is where water can be liquid

Far away from the star it is too cold and water freezes

M-dwarf



M-dwarf stars are smaller than our sun



Around smaller stars, the Goldilock zone is closer to the star.

It's called Goldilock because of the fairytale!

Image credit:
Sun, M-dwarf, Mars, Venus, Exo-Earth: NASA
Earth: Harrison Schmitt / Apollo 17
Steam: tuttnauer // Ice: T.Tulic/Fotolia // T.Tulic/Fotolia

Super Earths ?

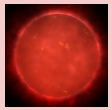
Planets that are bigger than Earth but smaller than Neptune.

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**

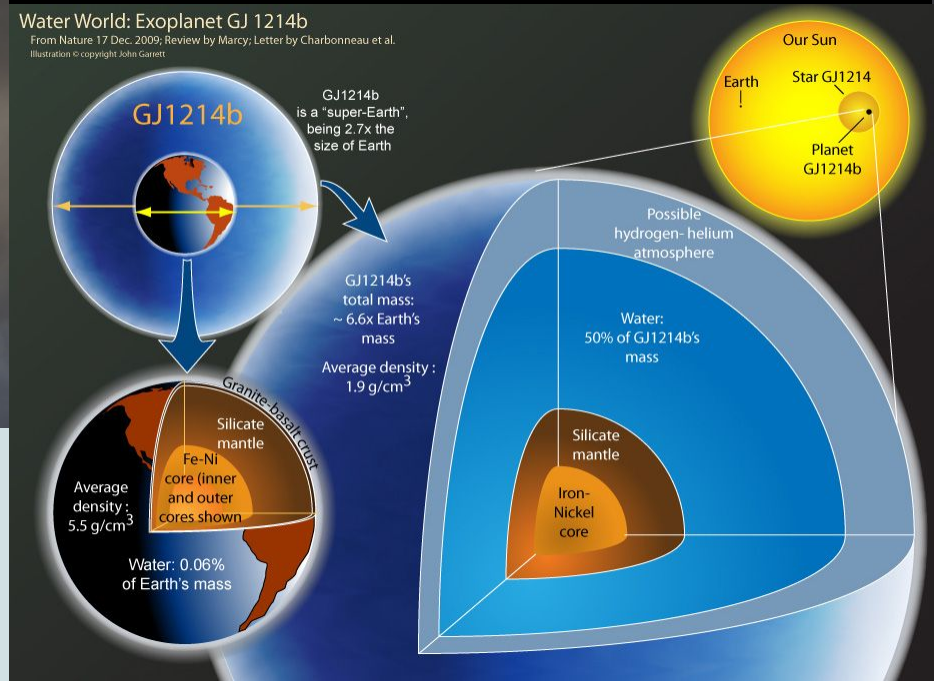


Too hot

Just right for a Water World

Too cold

Image credit: Wikipedia/Aldaron and NASA




INTERSTELLAR
EXTENDED CLIP

Super Earths ?

Planets that are bigger than Earth but smaller than Neptune.

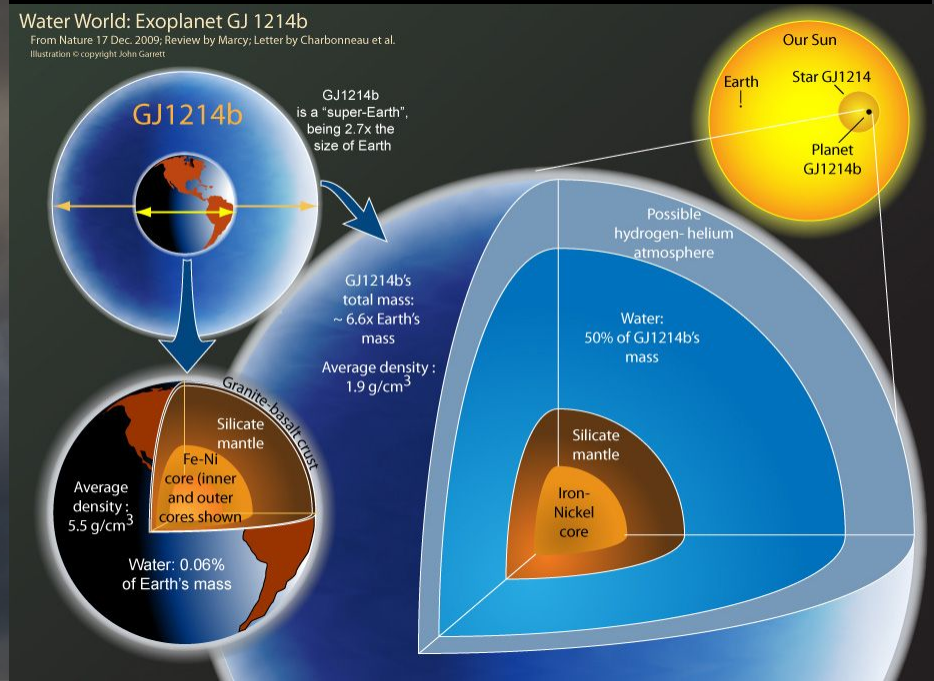
They have a rocky surface.

They have a thick atmosphere.

Can we find life on a Super Earth?

- **Maybe!**
- **But it needs to be in the right spot**
- **Water can be oceans, shallow or very deep.**

Image credit: Wikipedia/Aldaron and NASA



Tidally locked planets

A tidally locked planet has a permanent dayside and a permanent night side.

The day side gets all the sun light, the night side gets nothing.

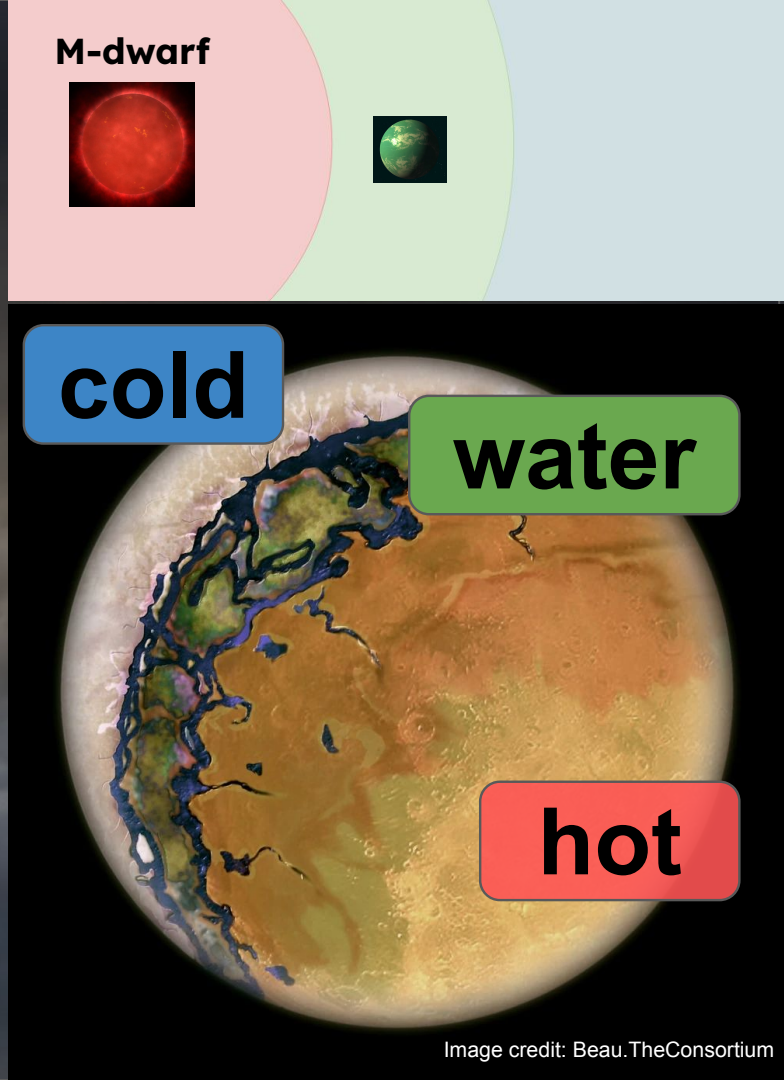
Video Credit: NASA

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 dessert.

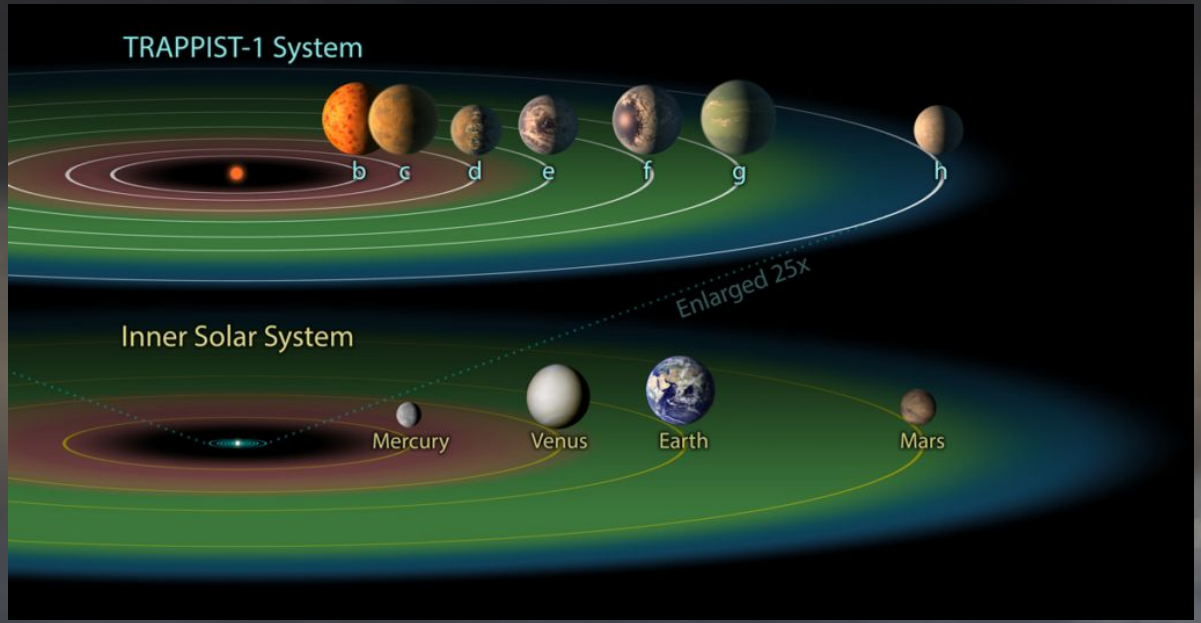
We have found tidally locked planets in the habitable zone but they have no atmosphere.



10 min break

Let’s meet the celebrities: Some famous exoplanets

TRAPPIST-1 System



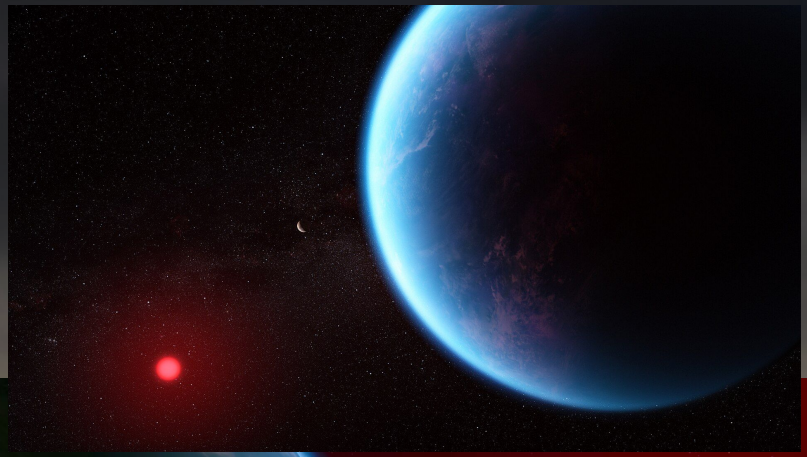
The trappist system has 3 planets in the goldilock zone.

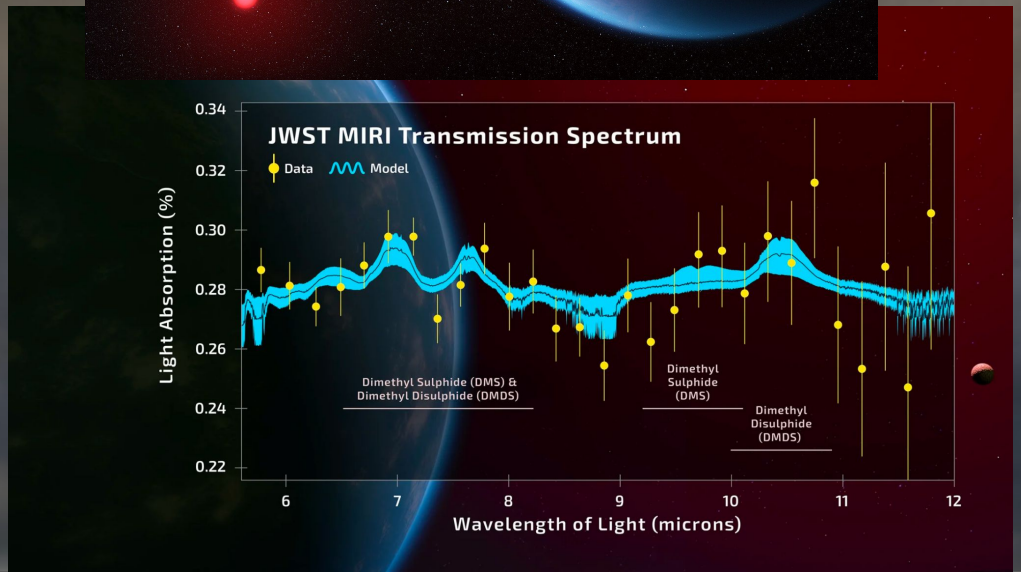
All planets are tidally locked.

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

Image credit: Nasa

K2-18b





K2-18b is a super Earth.

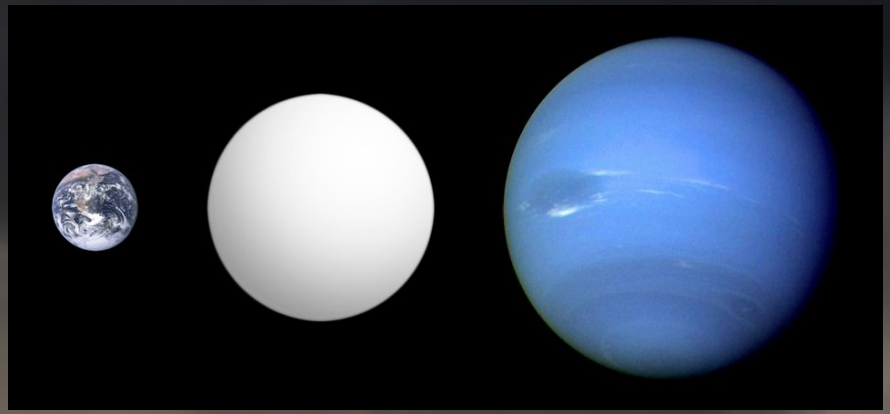
It might be a water world.

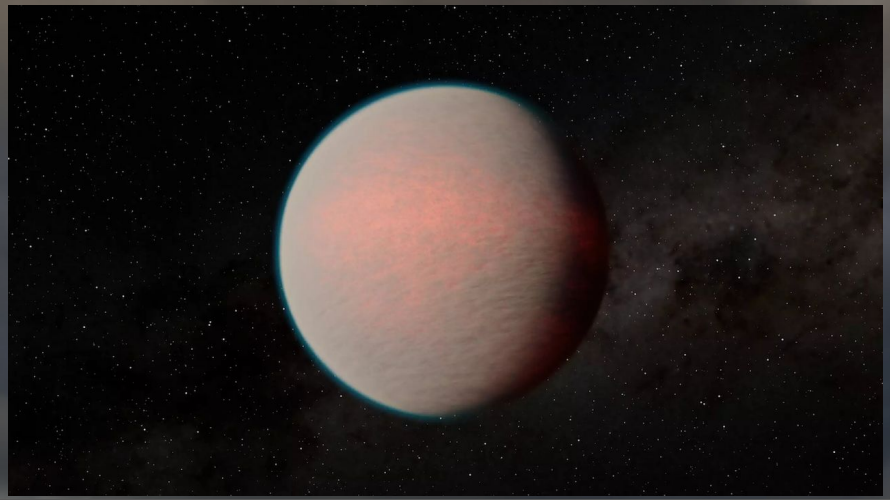
Some researchers think they found signs of life on this planet.

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

Image Top: Nasa
Image bottom: A. Smith, N. Madhusudhan

GJ-1214b





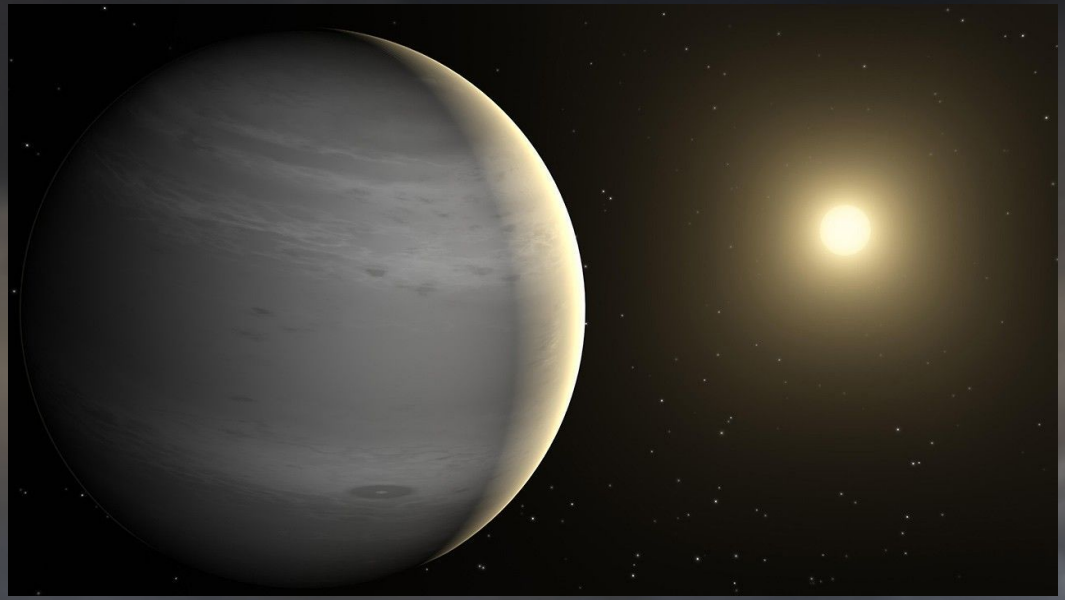
GJ-1214b is a sub-Neptune.

It might be a water world.

So far, we don’t know if there is life on GJ-1214b.

Image Top: Wikipedia/Aldaron
Image Bottom: NASA/JPL-Caltech/R. Hurt (IPAC)

51 Pegasi b



51 Pegasi b is a hot Jupiter.

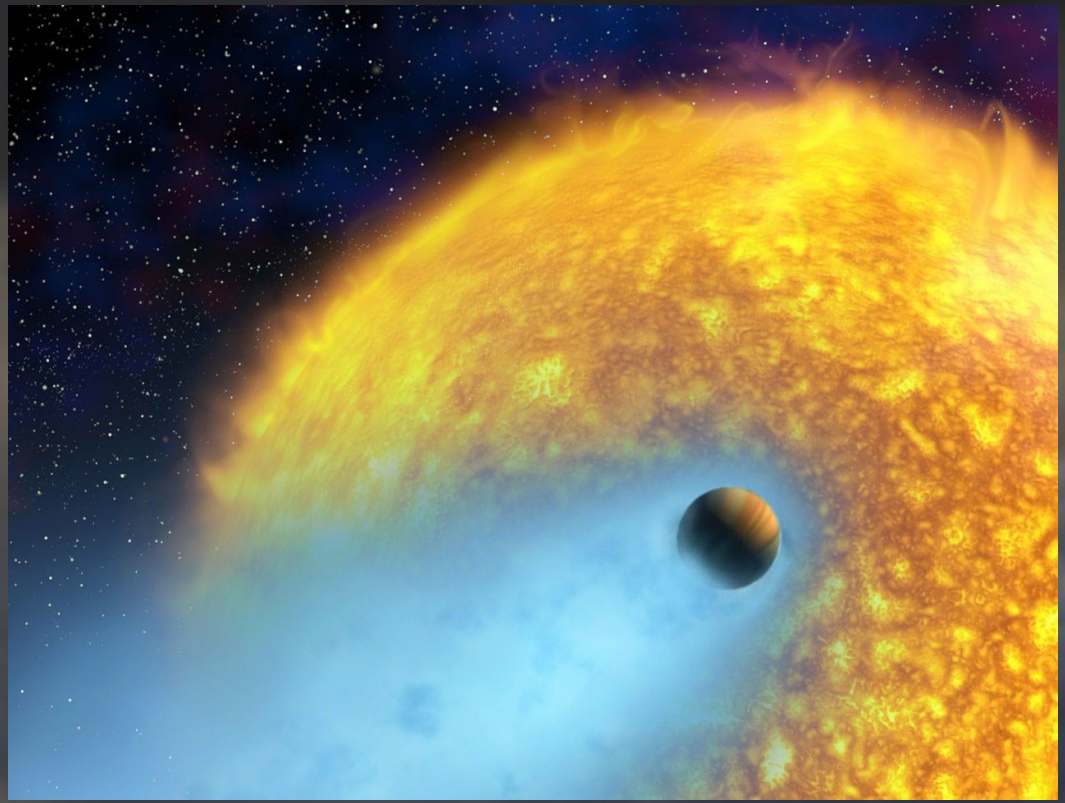
It is the first exoplanet discovered.

This planet cannot host life.

It was discovered with the doppler method.

Image Crdit: Nasa

HD 209458 b



HD 209458 b is a hot Jupiter.

It is the first exoplanet discovered with the transit method.

This planet cannot host life.

Image Credit: NASA

Breakout Activity: The Diversity of Exoplanets

- Go to https://science.nasa.gov/exoplanets/exoplanet-catalog/

- Checkout the different exoplanets. Look at their radius and how far away they are from earth.
  - K2-18 b
  - Trappist-1 b
  - Trappist-1 e
  - GJ 1214 b

- Could your favourite planet host life? Could we live there?

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- Go to https://science.nasa.gov/exoplanets/exoplanet-catalog/
- Checkout the different exoplanets. Look at their radius and how far away they are from earth.
- Could your favourite planet host life? Could we live there?

Let's Discuss: Which exoplanet is your favourite?

Game: Could this planet be real?

Planet #1:

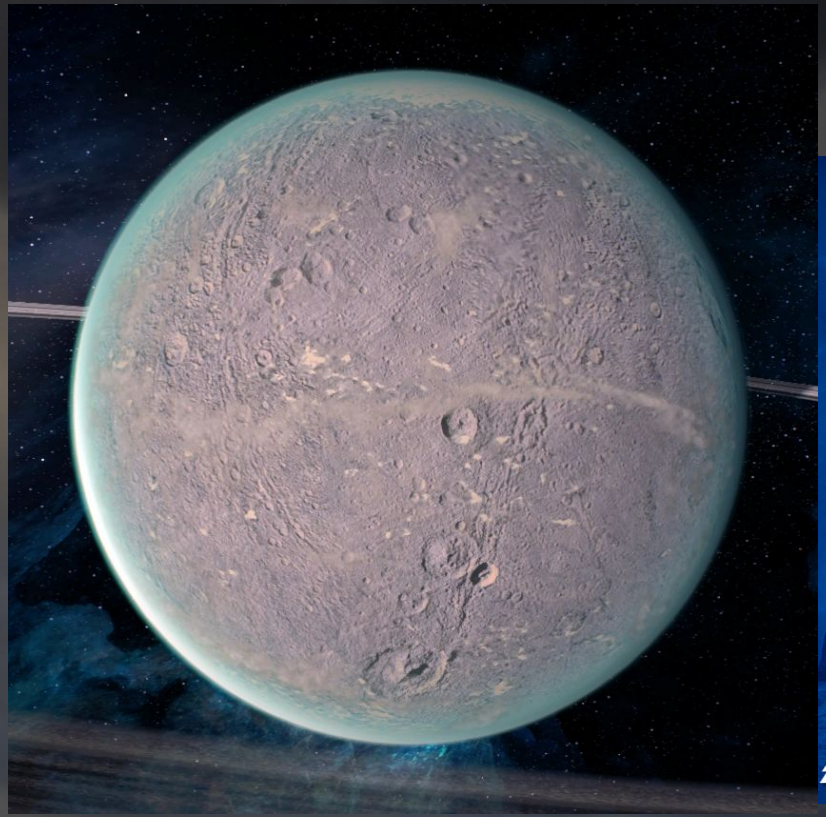
Planet #1: Tatooine, a planet around 2 stars!

Image Credit: Star Wars

Planet #1: Tatooine, a planet around 2 stars!

Image Credit: Star Wars

Planet #2:

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MASS
EFFECT
ANDROMEDA

Planet #2: Voeld, a planet covered in ice

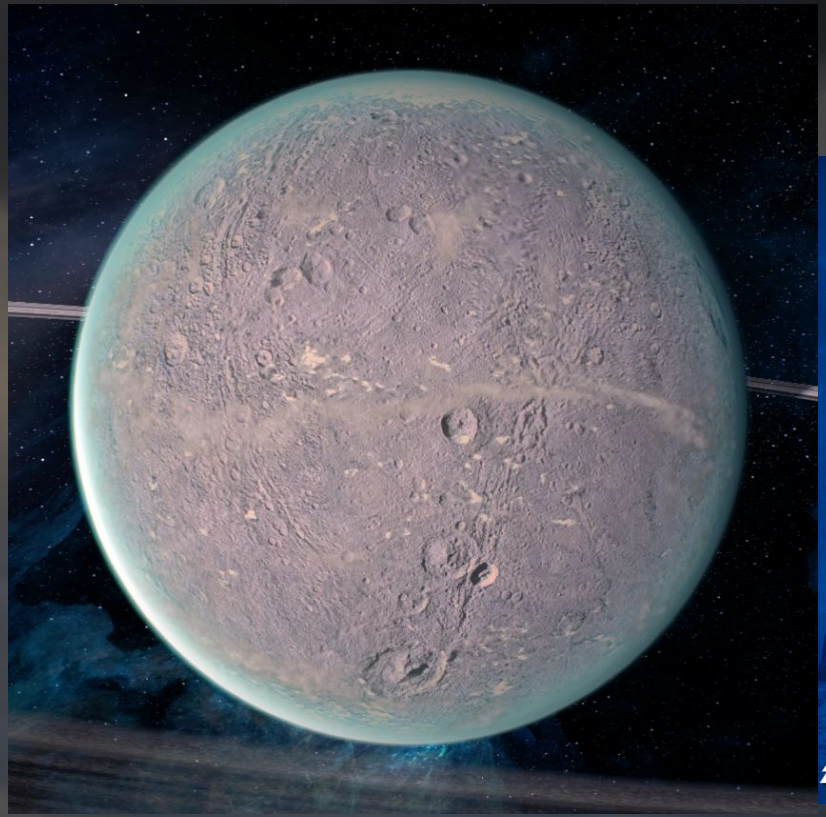
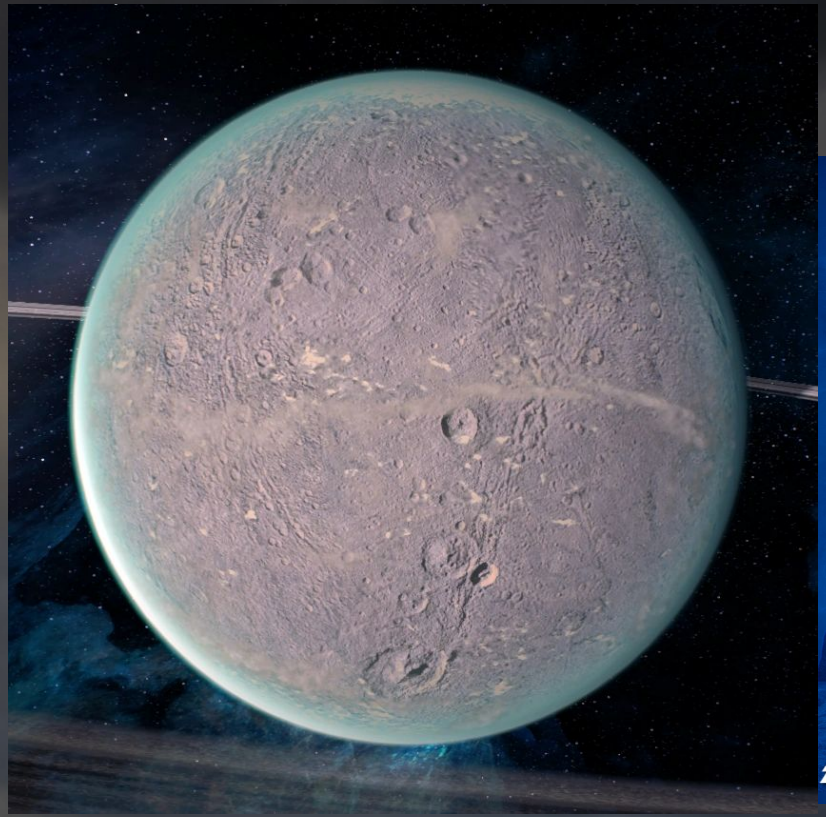


Image Credit: Mass effect

Planet #2: Voeld, a planet covered in ice



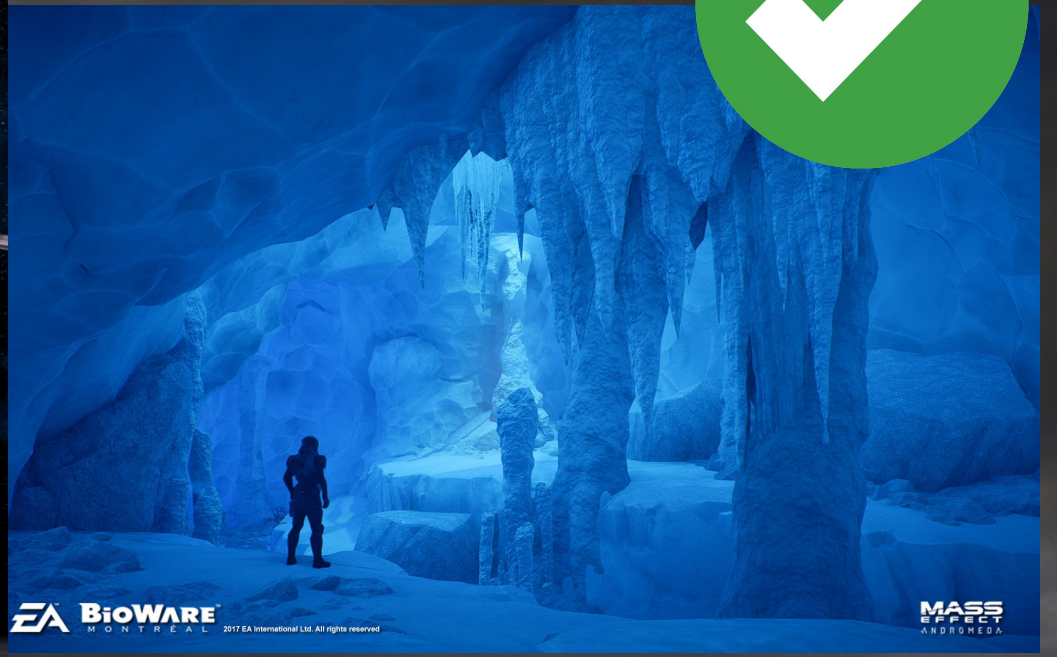


Image Credit: Mass effect

Planet #3:

Planet #3: Mann’s planet with frozen clouds

Image Credit: Interstellar

Planet #3: Mann’s planet with frozen clouds

Image Credit: Interstellar

Planet #4:

Planet #4: Pandora, a planet around a planet

Planet #4: Pandora, a planet around a planet

Planet #5:

Planet #5: Cybertron, a planet made from metal

Image Credit: Transformers

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Image Credit: Transformers

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