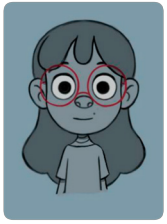
BEYOND THE SUN

In search of a new Earth


May the stars light your dreams.

Hi! My name's Celeste.

I'm sure glad to see you reading these pages because I need your help.

There is nothing I like more than exploring, discovering new things, understanding and being amazed by everything that happens on Earth... and beyond. Because you know what? Things happen in the universe... thousands of things! And even if we can't see them with our eyes, we can see them with the eyes that science gives us...

So this year I've decided to become an EXPERT PLANET HUNTER. That's right, exxxxxpert. And to do that, I have to read, play, and answer the questions in this guidebook.

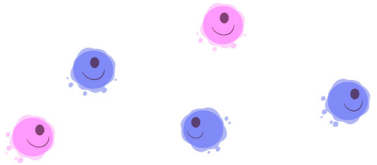
If you lend me a hand, we can discover incredible stuff...

Will you join me?

Hi! I'm Moon.

I'm a small particle of light from a star very far away. I'll guide you and train you to become an exoplanet hunter.

Ah, and these are my helpers!



They'll be flying around here whenever you need help.

Good luck!

This Diary belongs to:

Name:.....

Age:.....

School:.....

Class:.....

My best friend's name is .....

What I like best in the world is .....

My favorite animal is .....

Welcome!

The first thing every planet hunter should know by heart is:
THE EIGHT PLANETS IN THE SOLAR SYSTEM.

Celeste wanted to show that she already knows them all, but my helpers interrupted her with their giggling.

Celeste: "I know all the planets!"

Celeste: "Why are they laughing?"

Let's see how much you remember.
Ready?
Let's go!

1. The planet that is closest to the Sun and that looks like the Moon is called MERCURY

2. The planet that is full of clouds is : V____

3. The E___ H is the one that has oceans, forests, and lots of animals.

4. ____ is red.

5. The biggest planet is called __P____

6. S_T__N... has rings.

7. URANUS ... Also has rings and is on its side!

8. And finally, NEPT__E ... is very cold because it is very far from the Sun.

YOU KNOW WHAT? Hunting a planet means to discover it, to detect it. That's why we say that an exoplanet hunter is someone who looks for and, if they're lucky, finds planets beyond the Solar System!

Always remember that the **Sun** that we see each day is not a planet, but rather a **star**. And yes, almost all the bright little points of light you see at night... ARE ALSO STARS! The big difference between the Sun and the ones you see as bright little points of light at night is that our **star** (the **Sun**) is much, much, much closer to us than the rest of the stars...

¡But careful! Not all the things in the **Solar System** are planets and the Sun. What else is there? Choose the correct answers.

Comets – Stars – Dwarf planets – Galaxies – Moons – Supernovae – Asteroids

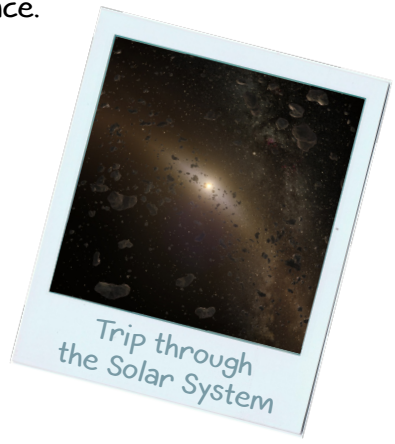
1 _____ 2 _____ 3 _____ 4 _____

Remember: You must know the words that planet hunters use.
Use the dictionary at the end of the guidebook to learn everything about these words!

On the trip that we make through the Solar System
in Beyond the Sun, we pass through an area
with thousands and thousands of "rocks" that float in space.
Do you remember what they are called?

A_T____D

B__T


Trip through the Solar System

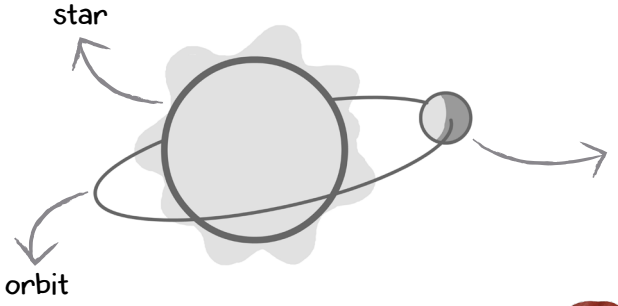

Mars

And... do you remember which two planets it lies between?

1. MARS
2. J_____R

BRAVO! You just passed to the next level. You are no longer a beginner, and you earned it all on your own. Now pay close attention and get your memory working because... we're going hunting!

Do you remember what planet hunters call a world that revolve around another **star** than **Sun**?



E__P__N_T

That looks like Jupiter!

That's true, but this planet is very far away from the **Solar System.** It's **Dimidium**, an enormous, gassy planet that orbits very close to its star, which is very similar to our sun. It's classified as a **hot Jupiter.**

Did you know that some **exoplanets** have two names? For example, **Dimidium** is known to exoplanet hunters as **51 Pegasi b.**

Why? I'll explain it to you:

- **51** Pegasi because that's the Latin name for the **star** that **Dimidium** revolves around.
- And he letter "b" because it is the **exoplanet** discovered around that star.

It's time to use your imagination. What name would you give these **exoplanets**?

1 _____

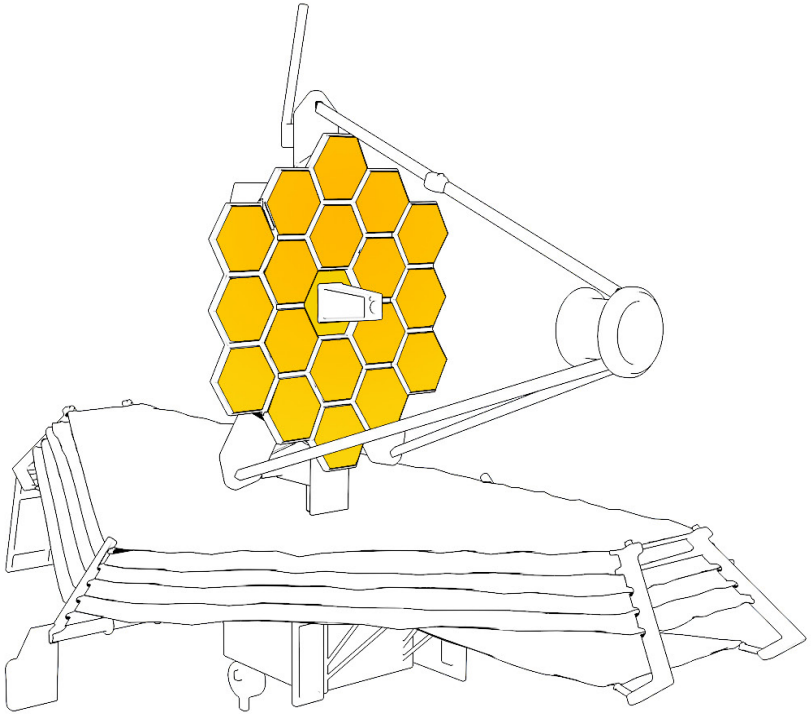
2 _____

3 _____

DID YOU KNOW THAT? There are international competitions to name exoplanets. Dulcinea, Quijote, Poltergeist and Saffar are some of them.

What do you say if we take a break and play for a while?

Color this great exoplanet hunter!



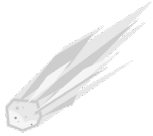
JAMES WEBB SPACE TELESCOPE

DID YOU KNOW THAT? With this space telescope, planet hunters hope to take the first picture of an Earth-like planet.

WORD SEARCH.

You have already learned a bunch of words that planet hunters use.
Find the **5** that are hidden in this word search.

E S C L H J D U W A P A M K
S D U W T F F I D N X B Z A
T C C B F T A G W E R Y C S
A O T N E I M A N S U B L T
R A R J F M G L R W B O N E
L W E X O P L A N E T P L R
F U F S E M V X P A T T W O
A D U E T F F Y D I T N X I
R E N D E R H A S M J S P D
C O M E T V D R R A E P K W

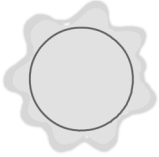


COMET

ASTEROID

GALAXY

EXOPLANET



STAR

I want to be
an exoplanet hunter!

Great!
Because you're on the right path to become one.
You're doing a good job. Shall we continue?

No, no, even better,
I want to hunt
a new Earth!!

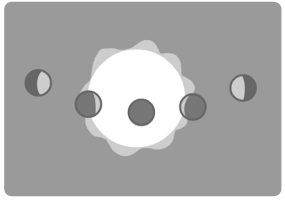
Hunting **exoplanets** isn't easy... You can't see most of them even with the biggest and most precise telescopes. But planet hunters have learned ways to detect them.

The ones they use most are:

- **Transit photometry.**
- **Radial velocity.**

TRANSIT PHOTOMETRY:

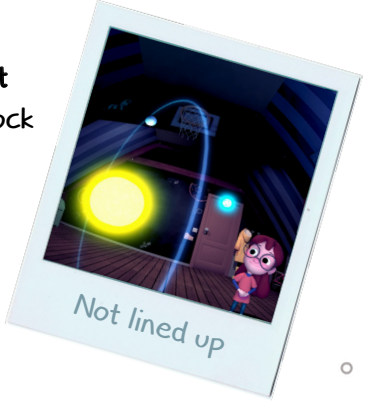
This method consists of measuring the decrease in the brightness of a **star** when an **exoplanet** passes in front of it, and that is what we call **transit**.



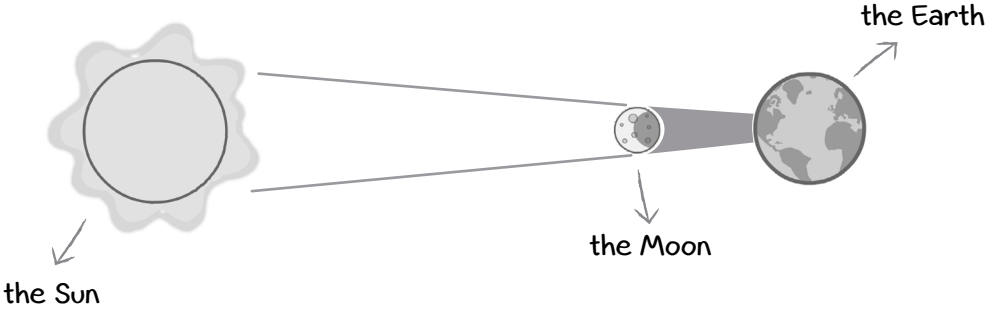
Let's refresh our memories.

But careful! For this method to work, the **star**, the **exoplanet** and we ourselves all have to be lined up... like when you stand in line at school!.

If we aren't lined up, then the exoplanet will never cross in front of us, it won't block part of the **STAR** and so its brightness won't change.



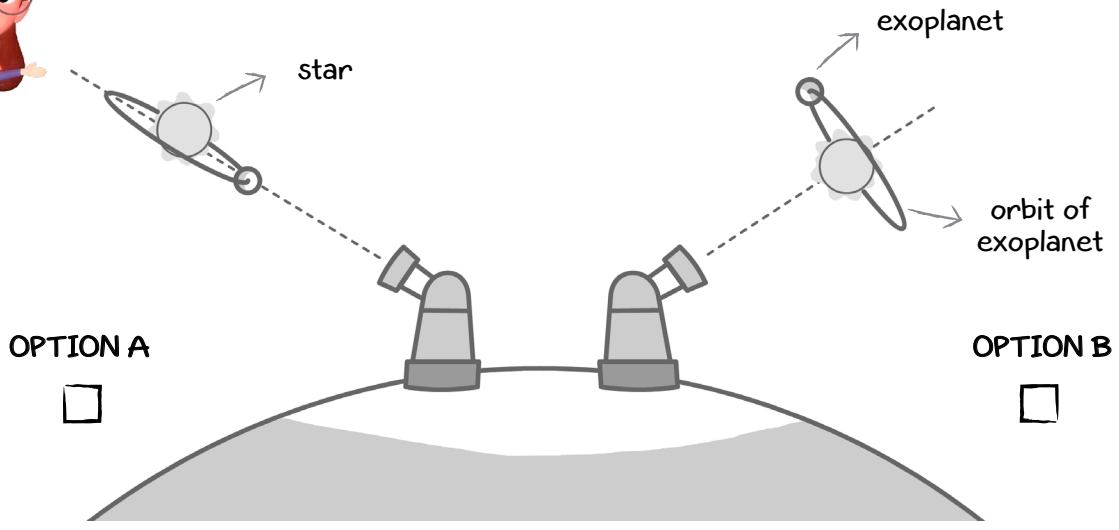
Oh! I think I understand now. Something similar
happens during an eclipse, right?



Exactly!
But our moon is so big
and is so close to us that it can block out
the Sun completely when they all line up.

ACCEPT THE CHALLENGE

Which of these exoplanets could we discover with transit detection?
Mark the right option.



Amazing, isn't it? It turns out that you can't see the vast majority of **exoplanets** even with the most powerful telescopes, but **exoplanets** hunters are still able to discover if they are there. And they do that with two methods: transit photometry and radial velocity. Wow...!

I've decided that I'm going to explain this to my friends,
but I want to be sure to do it right...
Will you help me to complete the sentences?

• The **Earth** takes approximately _ _ _ DAYS to complete its **orbit around the Sun**.

• **And the time that an exoplanet** takes to complete its **orbit** is the **exoplanet** Y _ A _.

• **To be able to discover an exoplanet** with the T_ _ _S_T PHOTOMETRY detection method, the **exoplanet**, the **star**, and we ourselves have to be in line.

Terrific... It's been a great day.
I learned that "to complete the **orbit**"
means to revolve all the way around a **star**
and that the **Sun** is a **star** that is very close to the **Earth.**

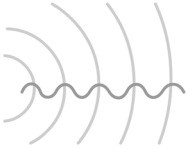
What did you learn?

We have arrived at the second method
that exoplanet hunters use to look for new planets:
RADIAL VELOCITY DETECTION.

If you've made it this far, then you've got a really big chance of becoming
an exoplanet hunter. Remember that this is something super complicated,
something that even a lot of adults aren't able to understand. So take your time,
read it as many times as you need to, and ask for help if you need it. Now close your eyes,
take a deep breath, count to ten, and... let's continue!

The first thing that we need to understand is the **DOPPLER EFFECT. Remember that?**

Sound is transmitted in the form of waves



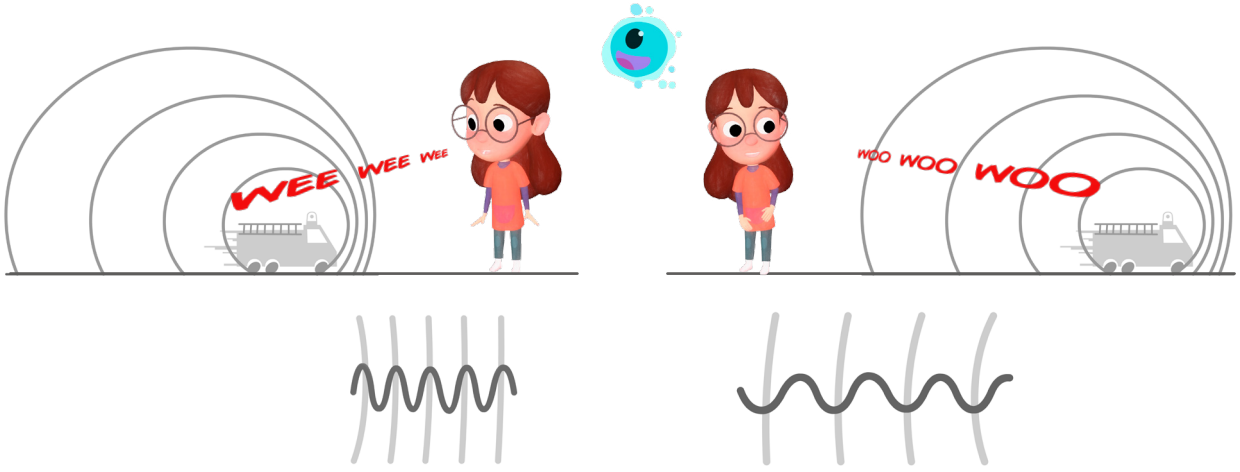
Like the waves that you make when you through a stone in a pond?

Exactly, but because the sound travels through air, we can't see the waves.

Now watch what happens when this fire engine that is making the sound approaches us and moves away from us.

You see? As the fire engine approaches us, the sound waves are shorter in the direction that the truck is traveling.

And as the sound moves away from us, the sound waves that reach us are longer.

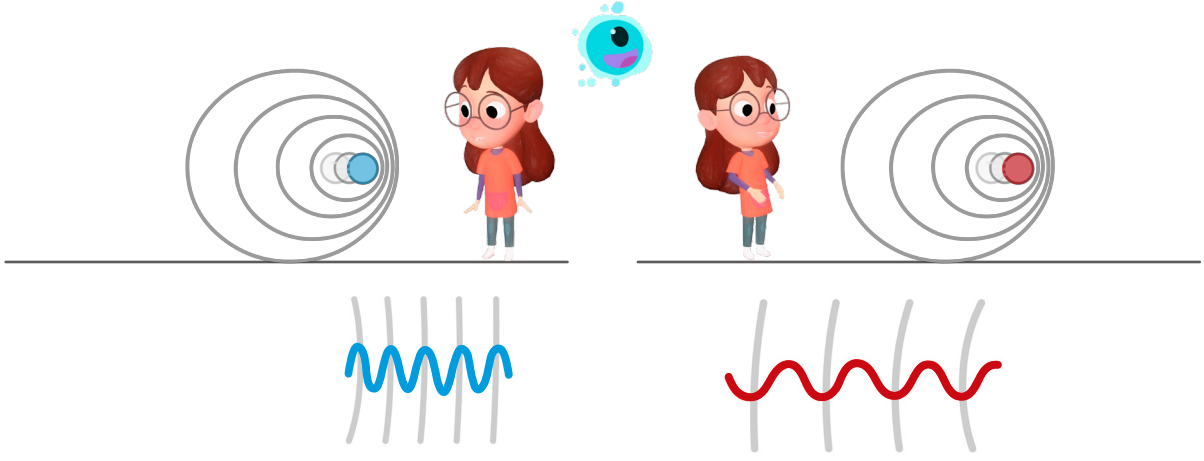


When the shape of the sound wave that reaches our ears changes... THE SOUND CHANGES. It becomes higher-pitched when the sound wave gets shorter, and lower-pitched when the sound wave gets longer. This is what's known as the **Doppler effect.**

And that colored light?

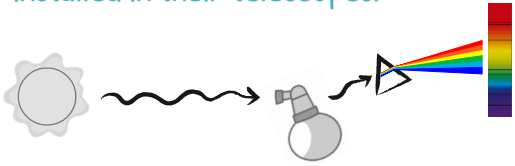
It's a star. Because it's traveling towards where we are, we see a change in the color of the light it gives off.

Just like sound, light also travels in the form of waves. The light from the star turns blue when the star approaches us and it turns red when the star that is giving off the light moves away from where we are.



Well... I don't understand. I've never seen stars change from red to blue and I've never seen them whizzing around, either. I always see them fixed in the same place in the sky!"

I'll explain it to you. Let's go little by little!
The changes in the light from stars are so small that planet hunters can only see them analyzing the light using super-special instruments installed in their telescopes.



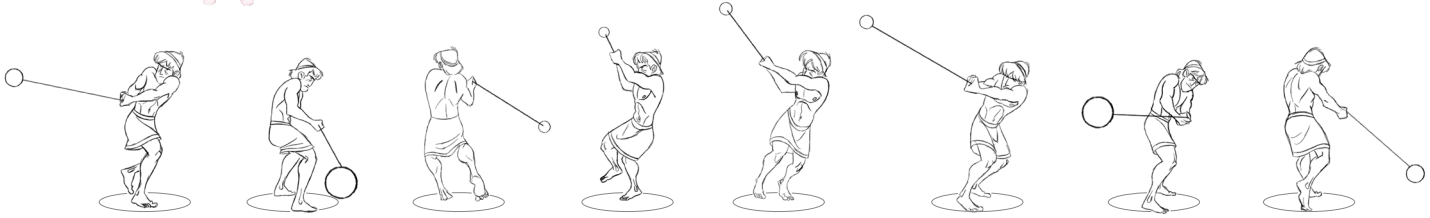
And you can't see how they move, either... because it's impossible to see that with the naked eye! Stars are so far away that we can't see their movement even with the most powerful telescopes... but if we observe their light for a while and we see that it gets bluer and then redder again and again... then we know that that star is moving, even if we can't see its movement.

And for a star to move... there has to be an exoplanet revolving around it. And that is exactly what planet hunters are looking for!

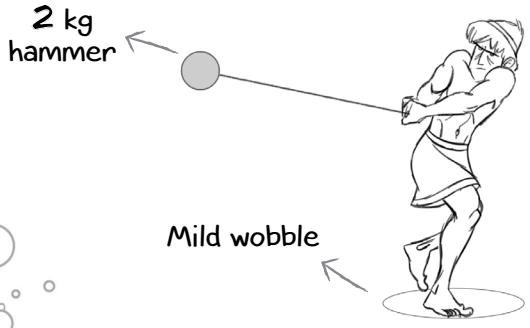
But do you know what is more important than seeing it? UNDERSTANDING IT.

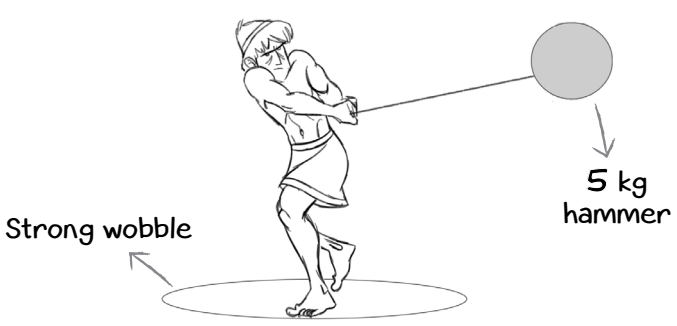
So... here we go. Do you remember the athlete?

The weight of the hammer influences
the athlete and makes him wobble.

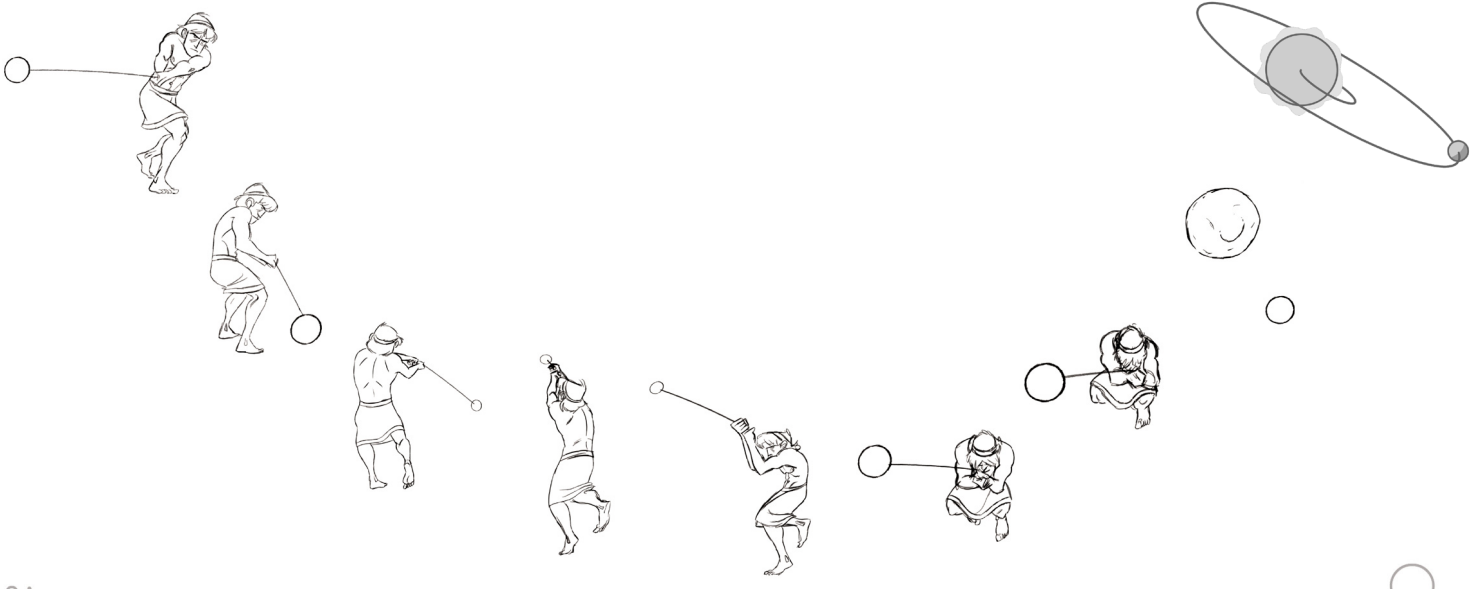


The more the hammer weighs, the more the athlete wobbles.



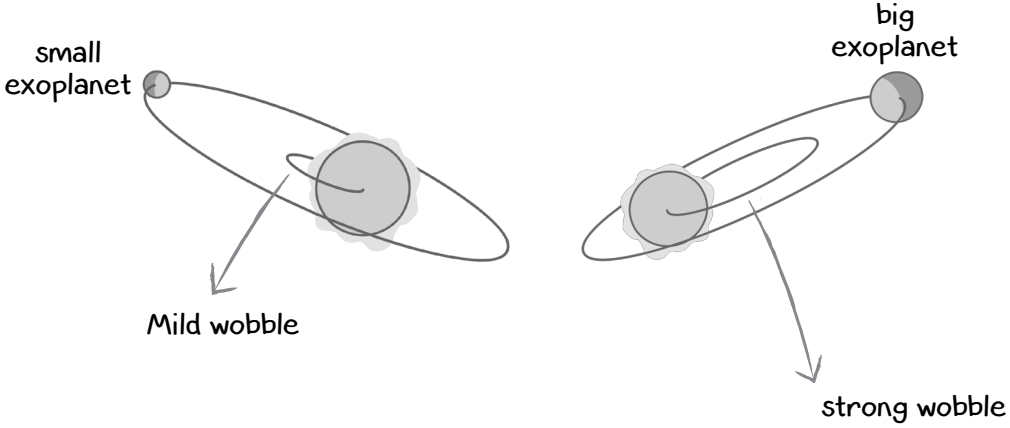


Exactly the same thing happens with a star
when an exoplanet orbits around it.



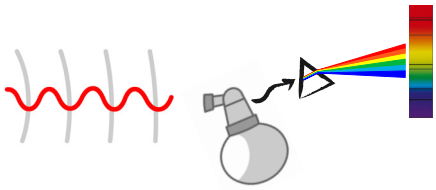
Remember! What exoplanet hunters can measure with their telescopes is the changes in the light from the **star**.
If the star gets BLUER AND gets REDDER then there's an **exoplanet around it.**

And the bigger the changes in the light are... the bigger the planet revolving around it is, even though WE CAN'T SEE IT!



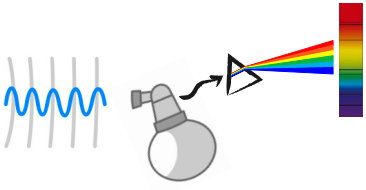
The exoplanet makes the star wobble.

When the star is moving away from us...



the light we receive gets redder

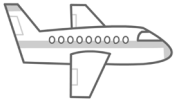
When the star is moving toward us...



the light we receive gets bluer

Did you know that Dimidium...?

It's so big that more than **2000** Earths could fit inside this planet.



It moves at **500.000** km/hour.! That´s **500** times faster than an airplane.

Its surface temperature is over **1.000** Celsius. That's so high that it would melt almost all metals. That's why it's called a hot Jupiter!

Its year lasts less than **5** Earth days.

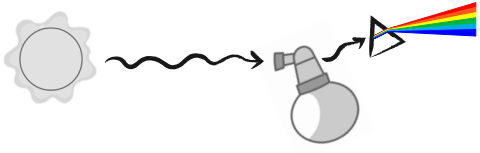
In which of these two options do you think we could discover an **exoplanet**?

Celeste is still thinking about her answer...

What can a planet hunter learn if, when she observes a star for a while, the star doesn't turn red or blue?

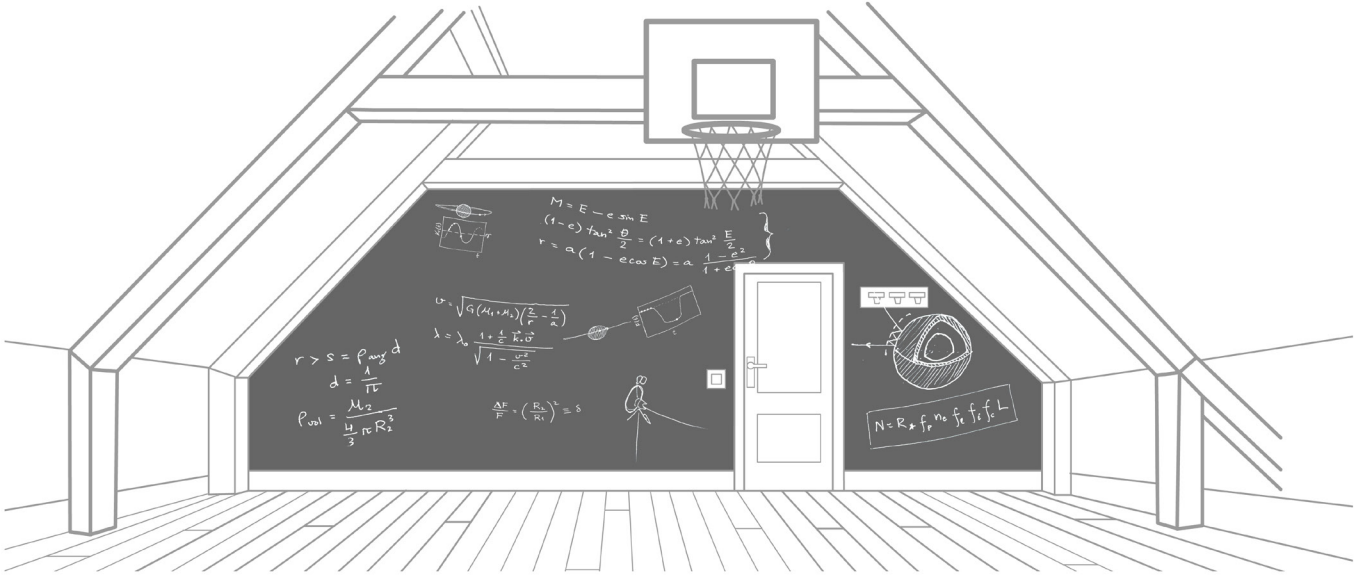
☐ That there isn't an **exoplanet** revolving around that star. Since there isn't an **exoplanet**, the **star** doesn't wobble and so the light doesn't change.

☐ That there is a giant **exoplanet**, an exoplanet so big that it immobilizes the star.



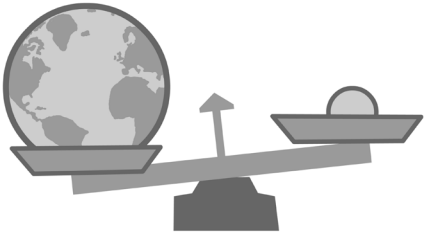
Now I know that only planet hunters
are able to find exoplanets by studying with
their telescopes how the light of the stars changes.

If you don't understand what is on this blackboard, don't worry...
Not even the grown-ups, nor your teacher, nor your parents are able to!
Only exoplanet hunters are able to understand
it after they have studied for many, many years...



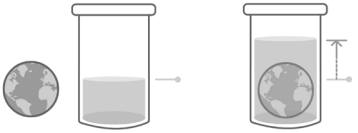
This formula is also for grown-ups,
but we can try to understand it. If you manage to do
that, you'll remember it your whooooole life.

$$\rho = \frac{M}{V}$$



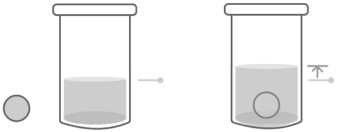
- All the objects around us have two things in common:
  mass and volume. And everything that has mass and volume is MATTER.

- The **mass (M)** of an object is a measurement of the amount of matter that it contains.
  The more matter an object has, the greater its mass is.



- The **volume (V)** of an object is a measurement of the space it takes up.
  So the more space it takes up, the greater its volume is.

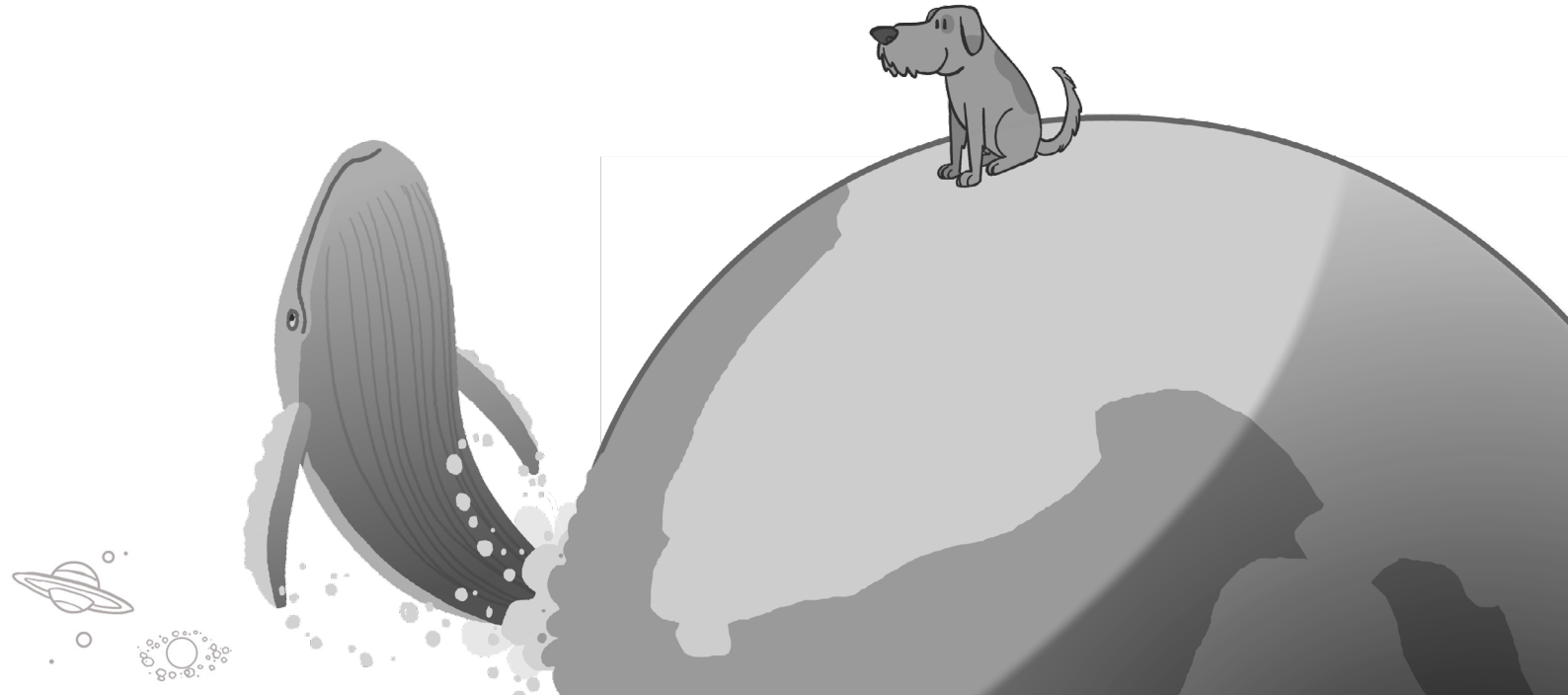
We know the **density (rho)** of an object by dividing the mass of that object by the volume it takes up.



DID YOU KNOW THAT? When it freezes, water takes up more space: its volume is bigger.
This decreases its density and that is why ice cubes float in water.

If there are super-Earths, then there must be super-whales, super-dogs...!

In reality, we still don't have proof that there is life on other planets...
For the moment, we can only discover if an **exoplanet**
that we've found is in its **HABITABLE ZONE.**

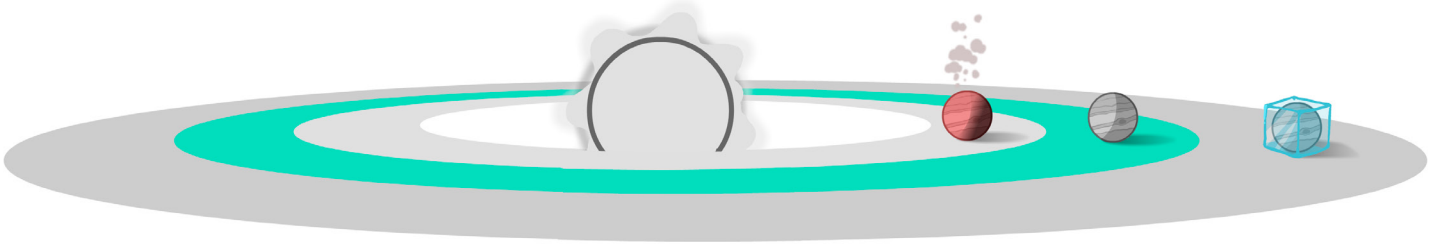


Do you know what that means?
To inhabit means to live in a place.

So for a planet to be HABITABLE, that is, to be able to have life on it,
it needs to meet certain conditions.

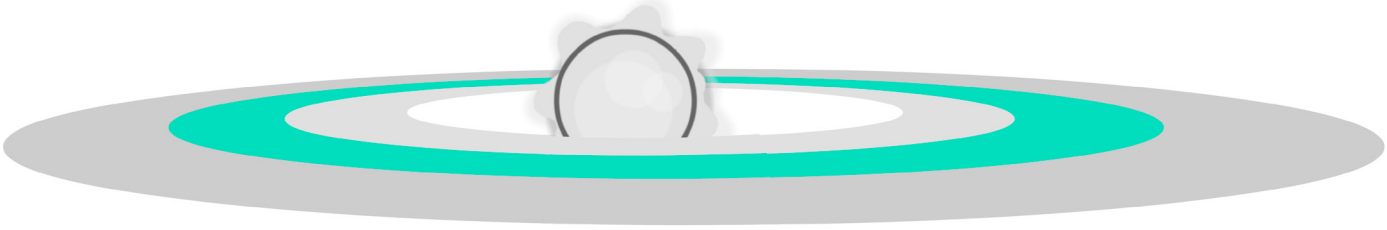
And the most important one is for it to be able to have LIQUID WATER ON ITS SURFACE.

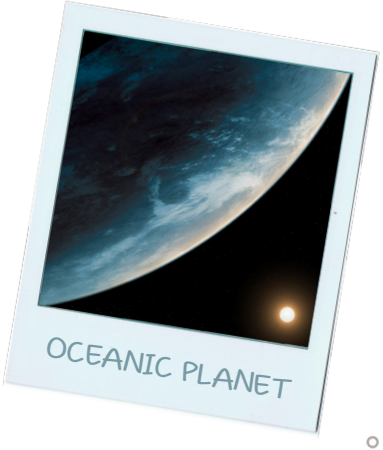
If it is too close to its star, the water will turn into steam because of the heat,
but if it is too far away, it will freeze into ice!



DID YOU KNOW THAT? It would take us more than 300 years to count, one by one, the ten billion habitable planets that may exist in the Milky Way.

Where would you put the frozen planet? Draw it in its position!
And the oceanic planet? Can you also draw the hot Jupiter where it should be?

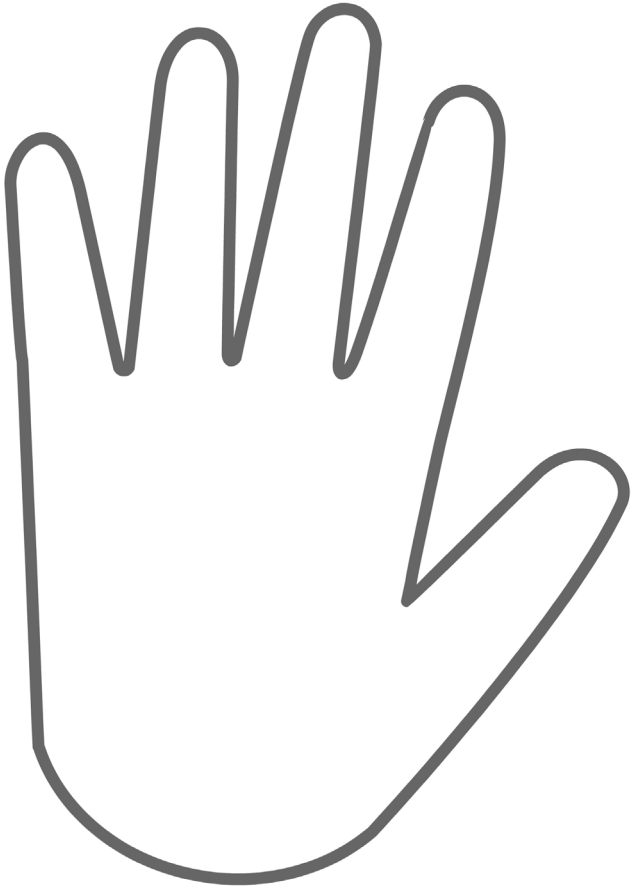




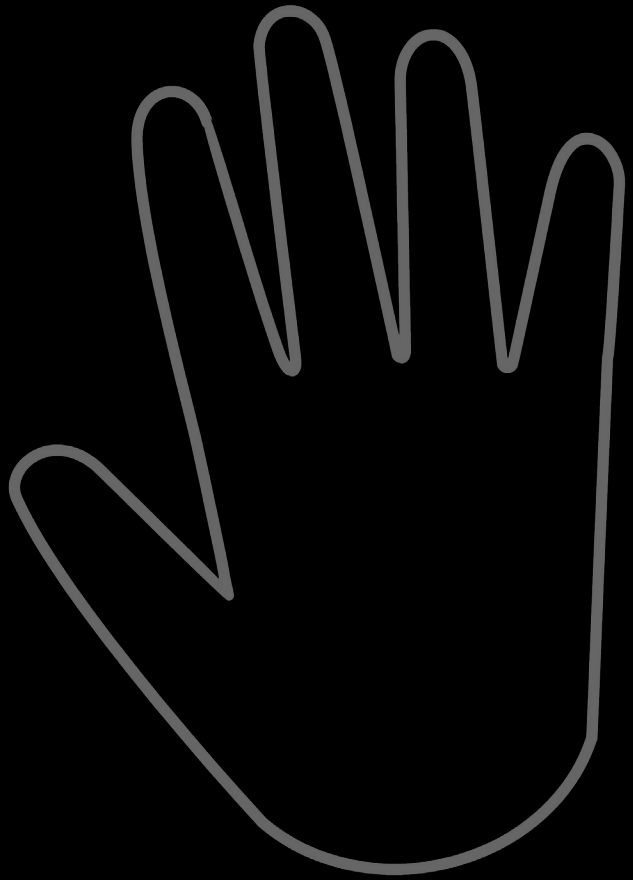
But the amount of light that the exoplanet is able to reflect
is also essential. Do you remember the **ALBEDO**. . .?

Now you've got the chance to experience it yourself so that you'll never forget it.

Open your diary and let the sunlight heat up the two pages.
Two minutes should be enough to heat them. Then place each of your hands on a page.
Close your eyes to feel better which of the two pages is hotter.



High albedo: The white paper reflects a lot of the light.



Low albedo: The black paper absorbs a lot of the light.

Which page is hotter?
Well, the same thing happens with exoplanets!

Which of these planets has the higher albedo?

Which will be hotter?

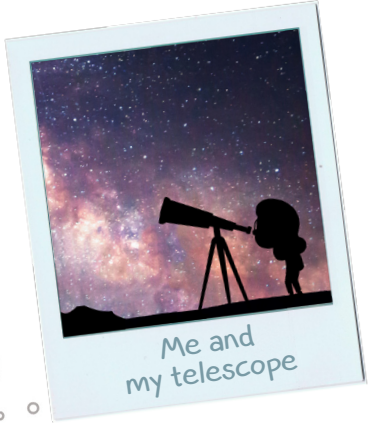
But in addition to liquid water and the albedo, there are many other factors that can influence the existence of life on an exoplanet.
That's why finding an exo-Earth is such an amazing challenge!

DID YOU KNOW THAT? It would take us about unos **5.000.000** years to reach the exoplanet closest to the Earth if we traveled at the speed of an airplane.

Earth is so pretty! And it's got loads of lights!

The Earth

So many that we suffer
what's called light pollution.



Me and
my telescope

Why do you think that all the lights that we have on Earth prevent us from seeing the lights in sky well?

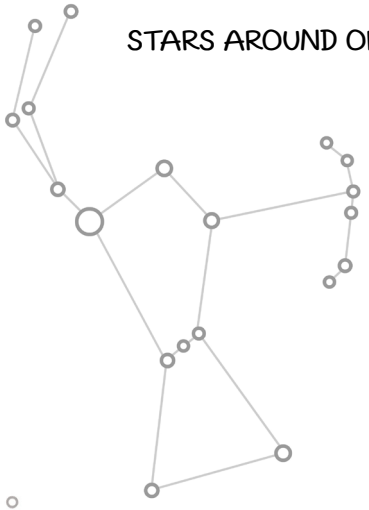
Now, so you can have some fun and remember what you've learned here,
I want you to experience for yourself how light pollution affects us.

The experiment is very simple: Accompanied by someone from your family, try to count the stars that you see at night in your town. The best thing would be to identify a constellation (like, for example, Orion) and count the stars that you see around it, but if you don't find a constellation, it doesn't matter. Simply count all the stars that you're able to see.

STARS AROUND ORION seen from my town
on a well-lit street.

When you have a chance, do the same thing again, but this time look for someplace where there isn't much light. It might be on the outskirts of a town or in the country.

STARS AROUND ORION seen from the outskirts of my town or in the country.



You'll be surprised by the difference!
And you will experience how big an affect
light pollution can have when we look at the stars.

You've done an excellent job.
And don't forget... out there, there may be a star
like our Sun, and orbiting around it,
at the same distance as ours,
a planet that has oceans, jungles,
and – who knows? – civilizations...

DICTIONARY OF PLANET HUNTERS.

Let's see... Every aspiring exoplanet hunter
needs to learn the meaning of certain words.
Ah! And don't forget to write down the ones that you discover for yourself.

- **Earth**: The third planet in the Solar System. The world where you live.
- **Universe**: The place that contains everything that exists.
- **Orbit**: The path that a planet follows around its star. It has an almost circular shape.
- **Albedo**: The amount of light that a planet reflects.
- **To orbit**: To revolve around a star (or around a planet in the case of a moon)
- **To complete the orbit**: To go all the way around.
- **Year**: The amount of time that a planet takes to revolve all the way around its star. The Earth's year lasts 365 days approximately.
- **Transit**: The passage of a planet in front of its star.
- **Transit photometry**: The method to discover exoplanets by analyzing if the star's brightness decreases.
- **Radial velocity detection**: The method to discover exoplanets by analyzing if the star's color changes.
- **Galaxy** : An enormous collection of stars, dust, and gas grouped together.
- **Star**: An enormous ball of gas that is hot and very bright.
- **Sun**: The Sun is a star. It looks much bigger and brighter than the other stars that we see at night because we are very close to it.

- **Supernovae**: The super-powerful explosion of a star.
- **Dwarf planet**: A small world that revolves around a star.
- **Comet**: An object that looks like a big ball of dirty snow. When it approaches a star, the ice evaporates and it forms an extremely long tail.
- **Moon**: A small world that orbits around a planet. Also called a satellite. The Moon is the Earth's satellite.
- **Asteroid**: A rocky or metallic object similar to a big rock that floats in space.
- **Habitable zone**: The distance that an exoplanet should be at from its star in order to be able to have liquid water on its surface.
- **Exo-Earth**: A planet just like the Earth.
- **Super-Earth**: An oceanic or rocky exoplanet that may be twice as big as the Earth.
- **Jupiter**: The fifth planet in the Solar System. It is famous for having a big, red spot.
- **Hot Jupiter**: A giant exoplanet that revolves very close to its star.
- **Asteroid belt**: The region of the Solar System which has thousands and thousands of asteroids that revolve around the Sun.
- **Exoplanet**: A planet that revolves around a star other than the Sun.
- **Dimidium**: The first exoplanet ever found. Also known a *51* Pegasi b.
- **Solar System**: That is what we call the place that includes all the planets, moons, asteroids, and comets that revolve around the Sun.

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