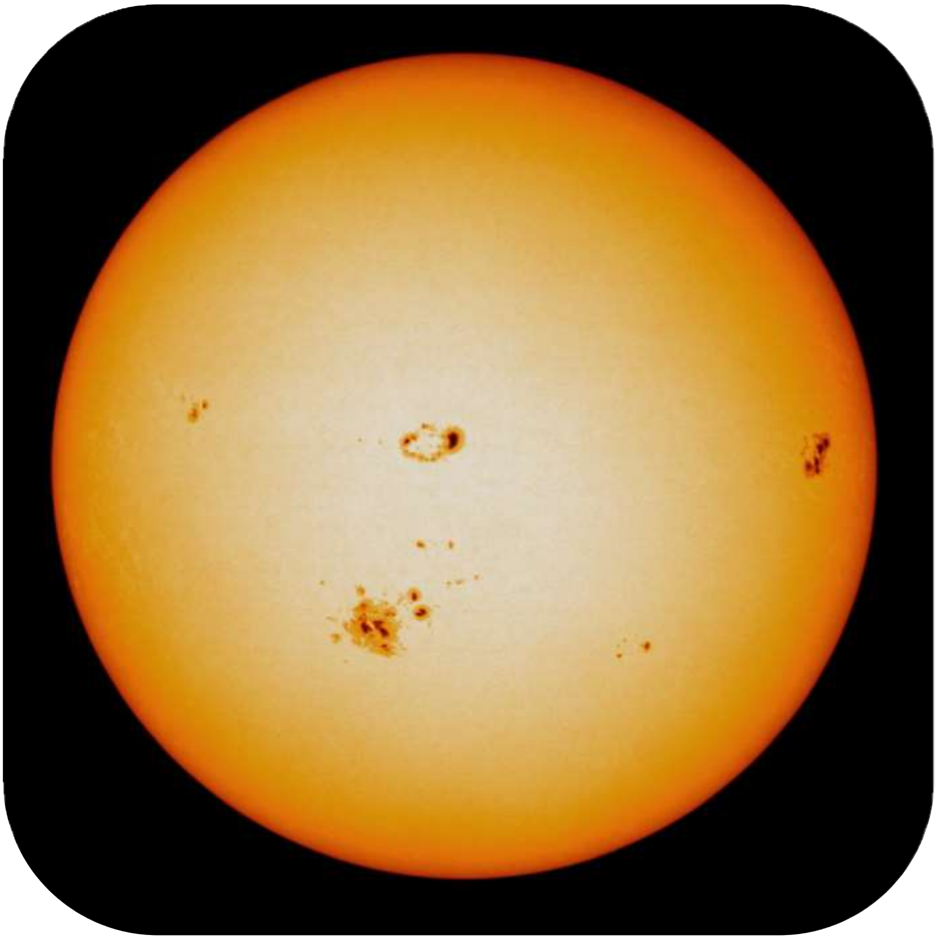
CESAR Scientific Challenge

# Following Sunspots

*(Calculate the Sun rotation with the HELIOS Telescope)*

## Teacher Guide



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# Didactics

# Learning objectives


***Figure I:*** *The considered top 10 skills in the 2020. (Credits: Refthinking).*

The CESAR Team generates activities for students to develop the considered top 10 skills in the 2020, where problem solving requires critical thinking and creativity. Our proposal is to execute these activities in teams. Students will find the environment where to develop their communication skills, managing different opinions and approaches, and making use of their emotional intelligence.

The CESAR scientific challenges aim to follow the thinking skills order established by the Bloom's taxonomy diagram, from a low order thinking skills (**remembering, understanding)** to a high order thinking skills (**evaluating, creating**), passing through mid-order thinking skills (**applying** methods and concepts for **analysing** events).


***Figure II:*** *Bloom's Taxonomy diagram. (Credits:* https://medium.com/@ryan.ubc.edtech/*)*

# Teaching Techniques:

In order to achieve the previously mentioned Learning Objectives, the CESAR Team recommends the use of some techniques like, ***flipped-classroom, solution of daily life problems (using the scientific method) and collaborative work.***

In this activity students will make use of the *flipped classroom* for Phases 0 and 1 to get ready for the problems solution of their Challenge during Phase 3. Phase 2 is optional and consist on a video call with us. In Phase 4, each team will evaluate their Experience and share it with the Scientific Community (their class/center and us, the CESAR Team). All phases are recommended to be executed as collaborative work (using **forum and blogs**). Here we detail the process:

- **Your Scientific Challenge:** We introduce the Challenge to students and ask for their support
- **Phase 0: Putting things into context**
  - The role of the **European Space Agency** and their center in Spain (European Space and Astronomy Centre, ESAC) as well as the CESAR Team. (in videos)
  - **Role models** for students to build the **Teams for their Challenge**. We recommend that Teams are formed by 4-6 people, each one of them with well-defined tasks. When possible, try to balance them in gender and diversity of capabilities.
- **Phase 1 and Phase 2:** ***remembering and understanding*** using different sources:
  - **Phase 1**: scholar cv material & new concepts (videos, documents, games)
  - **Phase 2 (optional)**: learn from an expert
    - For the teachers: talks provided by experts on the topic in previous CESAR teacher workshops.
    - For the classroom: A video call with the CESAR Team to solve doubts that may have appeared. At this stage, students have already become "experts" on the topic of the Challenge .
- **Phase 3:** ***applying*** the already known concepts following a methodology (procedures) for ***analysing*** *data* and *solving daily life problems* (their Scientific Challenge).
- **Phase 4:**
  - ***evaluating*** their learning process during the Challenge (self and co-evaluation)
  - ***creating*** a final product to show to the Community (class/school/us) their learning process. With this you could participate in the CESAR Scientific Challenge contest.

**As Figure III shows, the CESAR Scientific Challenges should execute all mentioned Phases.** Phase 0 and 1, are the roots for all the Scientific Experiences, always to be done in the classroom/home. Phase 2 (video call executed from the classroom to us) is optional.

**Depending on the type of Phase 3, there are various CESAR Experience Types:**

- **Type I: Space Science Experience(s) @ESAC**: At ESAC, (as always in the past), completely run by the CESAR Team. Total duration 1.5 hours, with 45 minutes for the Activity and another 45 minutes the tour around the ESA spacecraft models.

1. **Type II : On-line Space Science Experience(s)**: In the classroom/home, (Type I but completely guided by the teacher). Total duration 1h (MIXED when combined with Type I/III)
2. **Type III: On-line Research Project**: In the classroom/home, completely guided by the teacher. Total duration several days. (Type II but executing more or all the Activities of the Guide).

Phase 4 is always executed in the classroom/home to evaluate the learning process per Team as a whole.

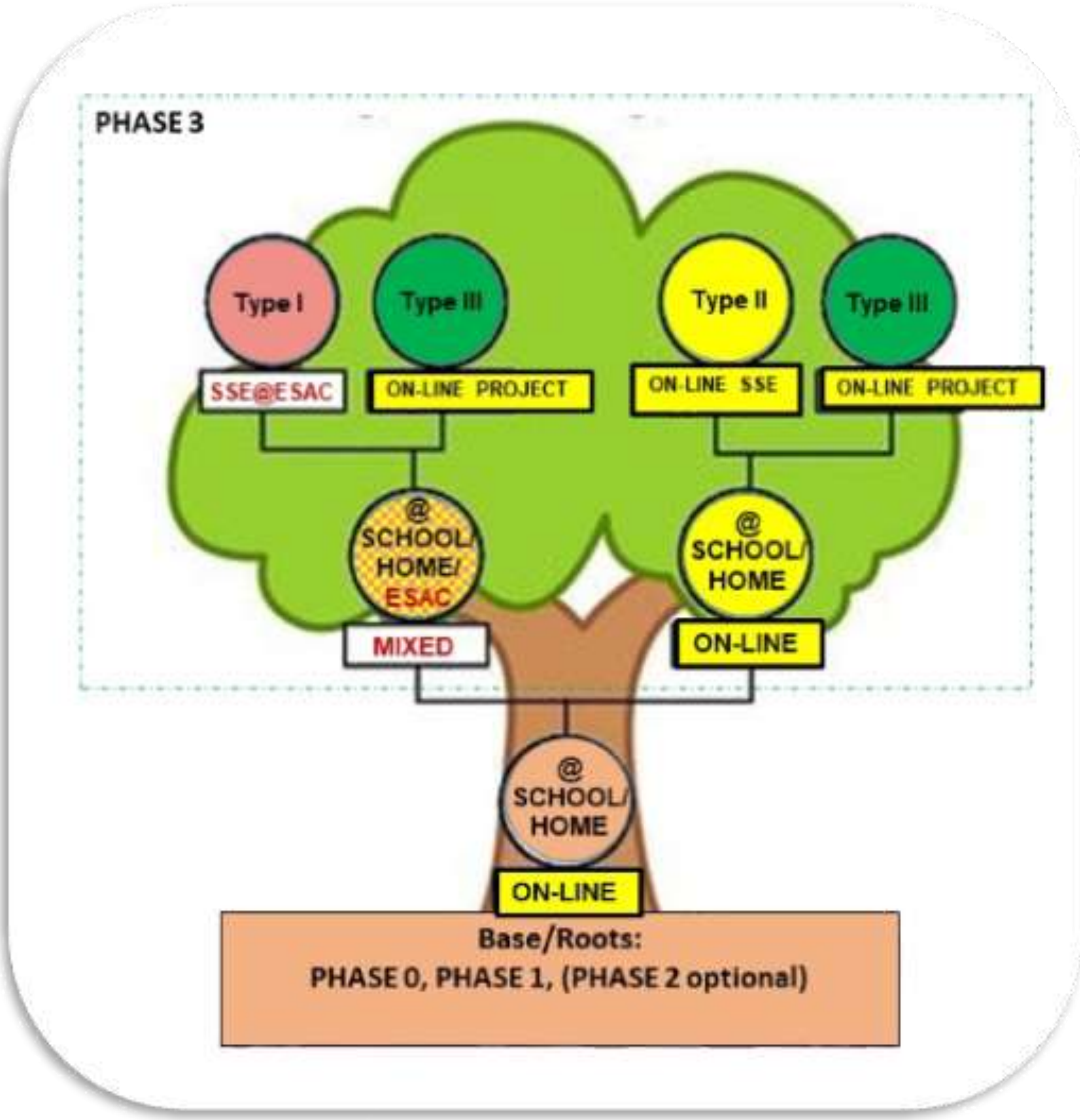



*Figure III: Decision tree of the CESAR Experiences according to Phase 3 (Tipo I @ESAC, Tipo II y III, on-line) .In yellow are indicated those paths that can be run completely on-line.(Credits:teacherspayteachers.com)*

Teachers are the best ones in assessing the Type of Experience (Challenge) for their classroom and school year conditions. **For each Type of Experience we propose different Adventures. The teacher decides if each Team in the class execute an Adventure and once finish they put them in common or whether all the Teams execute the same Adventure(s) at the time (see Tables I, II and III).** Teachers can also decide whether they want to execute some Activities on-line, and when it became feasible, to ask for the already well known an SSE @ESAC (Type I), for the same Challenge but different Adventure or another Challenge (see Figure III).

The CESAR Team recommends you to follow the phases in order (for an optimum learning process) and do not start one before closing the previous one. The Table Summary of Activities will mention when the execution of a previous Activity is required.

The CESAR Team can be contacted once per Scientific Challenge in phase 2 (with the class) and in phase 3 (only for the teacher). For that, dedicated slots of 30 minutes are scheduled.

➢ For the Scientific Challenge, the Fast Facts section provides the information regarding the school curriculum and the contents of each of the Activities (by Phase) can be found in the Table "Summary of Activities". The flavors of Adventures, per each Type of Scientific Experience are in Tables I, III and III.

**Table I: Space Science Experience @ESAC (SSE @ESAC):**

| PHASES | 0 | 1 | 2 | 3 (@ESAC) | 3 (@school) | 4 | Minimum duration |
|---|---|---|---|---|---|---|---|
| ACTIVITIES (Adventure 1) | 3 videos | 1,2,3,4,5 | 7 | 8.1 | | 9 and 10 | 3,40h |
| ACTIVITIES (Adventure 2) | 3 videos | 1,2,3,4,5 | 7 | 8.2 | | 9 and 10 | 3,40h |
| ACTIVITIES (Adventure 3) | 3 videos | 1,2,3,4,5 | (7) | 8.2 | 8.1 | 9 and 10 | 3,55h |
| ACTIVITIES (Adventure 4) | 3 videos | 1,2,3,4,5 | (7) | 8.1 | 8.2 | 9 and 10 | 3,55h |

**Table II: On-line Space Science Experience (On-line SSE):**

| PHASES | 0 | 1 | 2 | 3 (@school) | 4 | Minimum duration |
|---|---|---|---|---|---|---|
| ACTIVITIES (Adventure 1) | 3 videos | 1,2,3,4,5 | (7) | 8.1 | 9 and 10 | 3,40h |
| ACTIVITIES ( Adventure 2) | 3 videos | 1,2,3,4,5 | (7) | 8.2 | 9 and 10 | 3,40h |

- **Table III: On-line Research Project:** All Activities

| PHASE | 0 | 1 | 2 | 3 (@school) | 4 | Minimum duration |
|---|---|---|---|---|---|---|
| ACTIVITIES | videos | 1,2,3,4,5 and 6 | (7) | 8 | 9 and 10 | 4,45h |

**REALLY IMPORTANT**

✓ As a teacher, **register as part of the CESAR Community here** (If you approach us for the first time, it may take some time – a non-automatic process -, but you will not regret ;o))

✓ **Once you have been confirmed as part of the CESAR Community** ask for the CESAR Scientific Experiences to live with your class **and you will be guided in the process:**
   - Click here to request an on-line experience – Type II & III
   - Click here to request a combined experience - Type I (Only for schools in the Comunidad de Madrid and close cities)

✓ **Guides are very long (many possible tools) to build your Experience but also very flexible**

**It is your time! Choose your Adventure!**

# Fast Facts

## FAST FACTS

**Age range:** 12-16 years old

**Recommended academic courses:** (3-4) ESO

**Type:** Student activity **Complexity:** Medium

**Preparation time:** 30 minutes - 2 hours

**Required time:** 1 hour - several days, depending on the chosen activities

**Location:** Indoors

**Includes use of:** Computers, internet

## Abstract

In this activity, students will measure the Sun's rotation period by following the movement of sunspots at different latitudes. They will use images taken with CESO (CESAR ESAC Solar Observatory) to measure the position of sunspots and estimate the rotation speed of the Sun. By comparing different measurements, you can see how this speed depends on the solar latitude.

## Curriculum relevance

### Physics and Chemistry

- The scientific method. Research Project. Errors in measurement. Use of new technologies.
- Speed
- The periodic system of elements. Quimic reactions

### Mathematics

- Ability to carry out small mathematical investigations and present the results.
- Interpretation of a phenomenon by means of a statement, table, graph or analytical expression

### Scientific Culture

- The investigation and exploration of the Universe. The solar system.

### Geography

- The movements of the Earth. Representation of the Earth. Latitude and longitude.

## Students should know…

- The rotation period concept.
- longitude and latitude.
- Speed concept
- Angles measurement
- Time units conversion.

## Students will learn...

- To get information from astronomical images (positions).
- To calculate speed and periods of rotating object, in this case the Sun, from fix reference points (sunspots) in its surface.

## Students will improve…

- Their understanding of scientific thought.
- Their ability to work in group and communication skills.
- Evaluation competences.
- Their ability of apply theoritical concepts to practical activities..
- Their ability in the use of TIC.

## You will need…

CESARtool
webhttp://cesar.esa.int/tools/14.differential_rotation/index.php

## More information…

CESAR Book "The Sun"

# Activity Summary

| Phases | Activity | Material | Results | Requirements | Time |
|---|---|---|---|---|---|
| Phase 0 | *To put into context* | VIDEOS:<br>a) This is ESA<br>b) ESAC (3<br>c) ESA/ESAC/CESAR by Dr. Javier Ventura | Students will become familiar with:<br>• ESA<br>• ESAC<br>• CESAR Team | None | 10-20 min |
| Phase 1 | *1. Refresh concepts* | The solar system<br>States of matter<br>Latitude, longitude<br>Rotatory speed and period<br>the physics of soccer | The students will refresh some concepts:<br>• Object in the Universe<br>• States of matter.<br>• Coordenates system | None | 15 min |
| Phase 1 | *2. Compare the Son with The Earth* | Students will compare the Son with The Earth | Students will improve::<br>• Their understanding of the scientific method.<br>• Their team work stratergies..<br>• Their evaluation skills. | You need to have done Activity 1 and we recommend Activity 2. | 10 min |
| Phase 1 | *3. The Sun*<br>*3.1. The Sun structure*<br>*3.2. The Quimic of the Sun* | Dependnd on the time to spent:<br>(PDFs):<br>a) Activity The Sun<br>b) Th estructure of the Sun<br>c) The solar system<br>d) The evolution of stars | Students will compare their hypotheses (Activity 2) with known data about the Sun. | It is necessary to have done Activity 1 and 2. | 10-50 min |

| Phases | Activity | Material | Results | Requirements | Time |
|---|---|---|---|---|---|
| Phase 1 | *4.The magnetic activity of the Sun*<br>*4.1. Sunspots*<br>*3.3. The influence of the Sun on the Earth* | e) The Sun magnetics (top) | Students will improve::<br>• Their knowledge aobut tyhe origen of the solar magnetism.<br>• the influence of solar magnetism on the earth. | It is necessary to have done Activity 1 and we recommend Activity 3. | 15 min |
| Phase 1 | *5. The Exploration of the Sun by the European Space Agency*<br>*5.1. SOLO*<br>*5.2 HELIOS* | Depending on the time spent,<br>WEB:<br>• Exploring the Sun<br>• The Sun in 2018<br>• El estudio del Sol por el Equipo CESAR<br>VIDEOS:<br>• Solar Orbiter (<br>• ESA missions to the Sun.<br>• The electromagnetic spectrum and its study by ESA missions<br>3D:<br>• Fleet of ships of the European Space Agency.<br>• SOLO<br>COSMOGRAPHy:: (30 min demo video) | Students will learn:<br>• What is like to work at the European Space Agency.<br>• Space exploration.<br>• To recognize thye processes that happen in the Sun..<br>• How scientifics get information.. | It is advisable to have done Activities 3 and 4 | 15-50 in |
| | *6.Evaluate what you have learntd so far* | questionnaire | Students will evaluate in a fun way what they have learned so far | Have done Activities 1 to 5 | 5 min |

| Phases | Activity | Material | Results | Requirements | Time |
|---|---|---|---|---|---|
| Phase 2 | *7..Ask for a video-call with CESAR team if needed* | http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=19&ChangeLang=en | Students will have first-hand information from experts<br>• on-line CESAR lectures<br>ESA experts talks given in CESAR teacher courses<br>• video call with an expert.con un experto. | It is convenient to have carried out Activities 1 to 6 | 30 min-1 h |
| Phase 3 | *8.Calculate the Sun rotation* | *Explanation of the web tool (video)* | Students will learn:<br>• How astronomical images look like.<br>• How identify patters in real images (sunspots)<br>• How to analyze variations in actual image patters (stain)<br>• The varaition of Sun rotations at defferent latitudes.<br>Students will improve::<br>• TIC skills<br>• Their Knowledge of the seasons<br>• Their scientific thought. | It is recommended that you have executed the Activities 1, 3, 4, 5 y 6 | 30 min |
| Phase 4 | *9. Evaluate your learning* | questionnaire | Students will check to see if they have internalized the concepts.<br>Students will improve:<br>• Their understanding of scientific method.<br>• Their stratergies to work as a scientific.<br>• Their educative skills.<br>• Their ability to apply their theoretical knowledge to real life. | It is necessary to have performed at least Activities 1,3,4,5,6,8 . | 15 min |
| Phase 4 | *10.Present your results* | Free student format (ppt, youtube, Word) | Students will improve::<br>• Their ability to work in teams and communication skills.<br>• Their knowledge about the Sun, the solar activity, sunspots and solar rotation. | It is necessary to have performed at least Activities 1,3,4,5,6,8, and 9. | 30 min – 2h |

# Your Scientific Challenge

# Following Sunspots

*We have received a message:*

***"¡ Solar storm to Earth detected! Take cover!"***

***Figure 1:*** *Coronal Mass Ejection (CME) (Credits: https://www.libertaddigital.)*

*In addition, the Solar Observatory HELIOS at ESAC, which was observing the Sun, has detected spots on the surface of the Sun where the SOHO satellite detected the coronal mass ejection.*

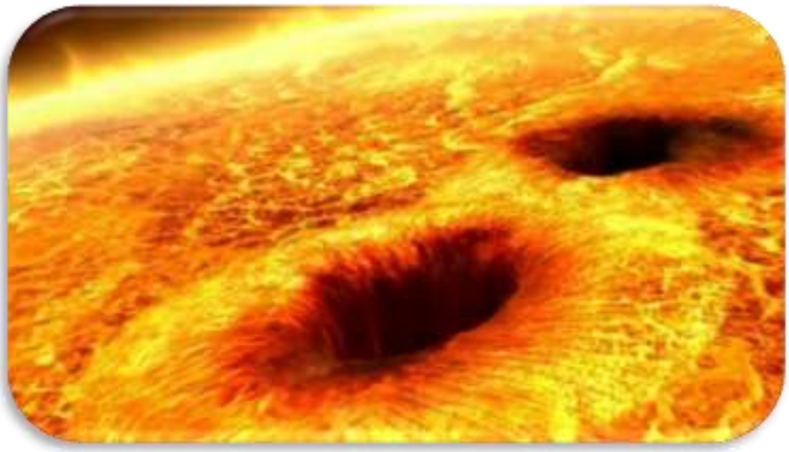


***Figure 2:*** *Sunspots (Credits: http://newsmobile.in/)*

*We need your help to protect Humanity.* ***Can we count on you?***

In this scientific challenge, we will follow the trail of the sunspots, in order to answer the following questions: Do the sunspots move? Does the sun break? And if so, does it do the same on its entire surface?

# Phase 0

**To put us in context** we recommend looking at these **videos**:

- This is ESA (5 min)
- ESAC: ESA's A window on the Universe (3 min)
- Presentation to ESA/ESAC/CESAR by Dr. Javier Ventura (15 min)
- Other videos about Space.

**You will work in Teams of (4-6) people**, each of you having an specific key role, unique and needed for the Team. Fill in Table 0 with the Identification for the Challenge, Number of the Team and Name of the Team members.

| **Challenge ID** | | | **Team Number (1-6):** | |
|---|---|---|---|---|
| **Members** | | | | |
| **Professions** | **Mathematics Software Engineer** | **Astrophysicists** | **Engineers** | **Biologists/ physicist** |
| **Roles** | Leads the correct execution of the calculations | She/he guides the solar telescope | She/he is in charge of finding agreements and leading the team. | She/he addresses the need for further research. |
| **References** (female) | Katherine Johnson  | Vera Rubin  | Samantha Cristoforetti  | Marie Curie  |
| (male) | Steve Wozniak  | Matt Taylor  | Pedro Duque  | Albert Einstein  |

***Table 0:*** *Write down the Identification of your Challenge (an unique number), the Number of your Team (1-6) and the name of the team members, one of them with a clear role (and assigned tasks), all needed.*

**Note**: The documentation makes use of the International System of Units.

# Phase 1

Activity 1 Remembering concepts

You can refresh concepts needed for the Scientific Challenge by clicking on the links in Table 2. These correspond to the contents of the school curriculum.

| | | |
|---|---|---|
| 10 curiosities of the solar system | The states of matter (TED-Ed ) | Latitude and longitude |
| Speed rotation and period | Discovering electromagnetism | How do nuclear reactions work? |

***Table 2:*** *Concepts that need to be refreshed before facing this scientific challenge.*

In this activity we are going to study the surface of the Sun. In the same way that we can know the time it takes for a ball to go around on itself by looking at some of the details (colors, lettering, stains) on its surface, we are going to do with the Sun. In this case we will look at what we call its **sunspots**, which we will explain later.

It is important to keep the concepts of **latitude and longitude** in mind when identifying the positions of the spots, just as you use **coordinates** to express what position on Earth you are in. Latitude is positive for the northern hemisphere and negative in the south. Longitude takes a meridian (Greenwich) as a reference and is positive for the east and negative for the west.
For example, if you are in Madrid, you will find yourself in some coordinates **(Latitude: 40° 25′ 0″, Longitude: 3° 42′ 12″),** however, someone who is in Santiago de Chile, will be in some coordinates close to (**Latitude: -33° 26′ 14″, Longitude: - 70° 39′** 2**″)**

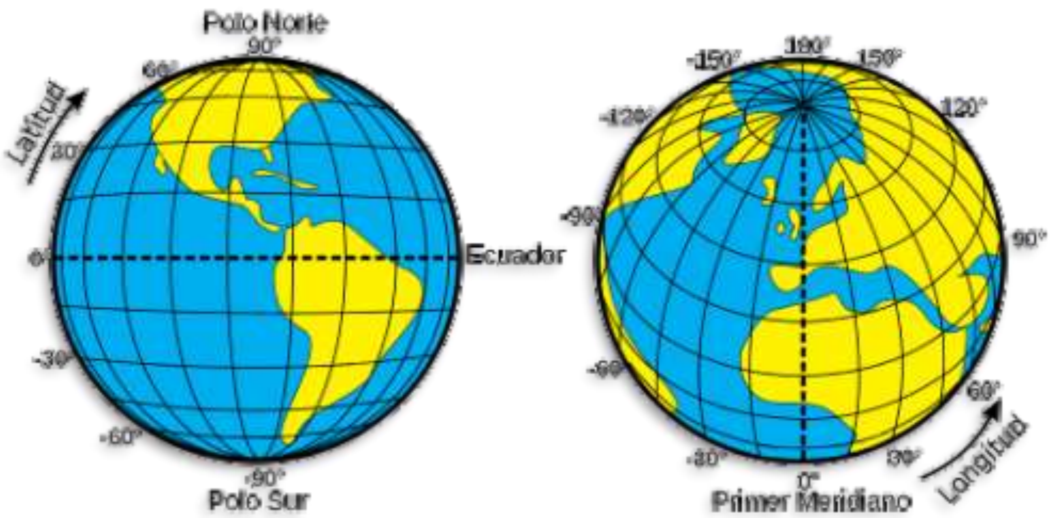



***Figure 3:*** *Concepts of latitude and longitude (Credits: Wikipedia)*

## Activity 2: Compare the Sun with Earth

Fill in Table 3 comparing the Sun and the Earth:

| Property | Sun Value | Value on Earth | Sun/Earth comparison |
|---|---|---|---|
| Type of object | Star | Planet | |
| State of most of the matter | Plasma | Solid | |
| Radio (km) | ~ 700 000 | 6 400 | ~ 110 |
| Mass (kg) | ~ 2 x $10^{30}$ | ~ 6 x $10^{24}$ | ~ 33 333 |
| Density (kg/m³) | 1 400 | 5 500 | ~ 0.25 |
| Surface temperature (ºC) | ~ 5 500 | 17 | ~ 20 |
| Most abundant elements | $H_2$, He, $O_2$ | $N_2$, $O_2$, Ar | |
| Age (years) | 4 650 000 000 | 4 550 000 000 | ~ 1 |

***Table 3:*** *Comparison of some of the characteristics of the Sun and the Earth.*

- *¿ How many Earths fit in the Sun? (Hint: volume of a sphere, V, is 4/3 πR³)*

$R_{sol}$= 700 000 -> $V_{sol}$= 4 π (700 000)³ = 1,436,755,040,241,732,107.72
$R_{Tierra}$ = 6 400 -> $V_{Tierra}$= 4 π (6 400)³ = 1,098,066,219,443.52

1 308 441.16 ~1 300 000 planetas Tierra caben en el Sol

## Activity 3: The Sun

The Sun is our closest star. It is a star of hot ionized gas or "plasma". It generates energy through nuclear reactions inside it, consuming about four million tons of hydrogen fuel every second. Figure 4 shows some of the Sun's properties.

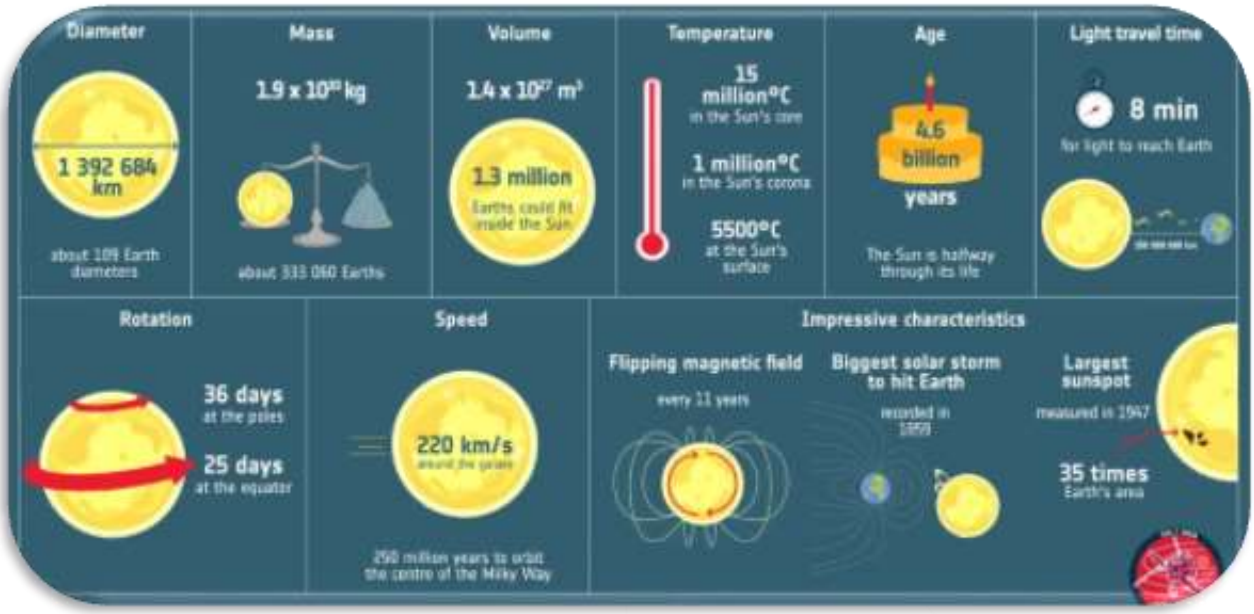



***Figure 4:*** *Meet the Sun (Credits: ESA)*

Despite its age, it is expected to shine for another five billion years. By then, though, it will have become a red giant. In Figure 5 we can see the different phases that the Sun will go through during its life. For more information about the Sun and how stars evolve, access the [CESAR booklet on the Sun and CESAR booklet on stellar evolution].


***Figure 5****: Life Cycle of the Sun (Credits: Wikipedia)*

1. Watch this video of The Sun and tell us what you have learned from the Sun.

| |
|---|
| |

## Activity 3.1: The Sun Structure

1. Draw what you think the structure of the Sun looks like.


*Figura S.1: The layers of the Sun (Credits: Talk by Benjamín Montesinos Comino for CESAR teachers' course, June 2018)*

2. Check what you have learned in this game. To do this:
   a. Click on this **[Link]**
   b. Press "play" or the upper right button "Again" if it is not the first time you play
   c. At the top you will be shown the name of a zone of the Sun, your mission will be to click on the number you think corresponds to that zone. The results appear in the upper left corner

      - If you hit the number it will turn green. If you fail the number will turn red.

Think carefully about what the area is and take into account the time shown on the top right.

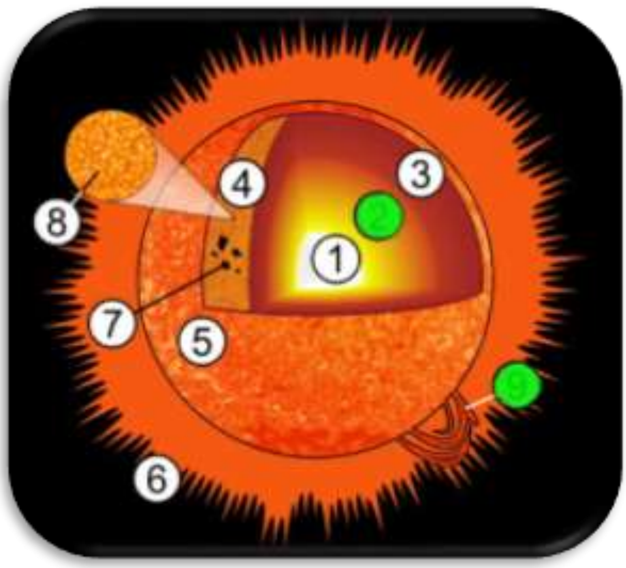



***Figure 6:*** *Simulation layers dollars. (Credits: https://www.purposegames.com)*

3. Write here the layers you remember in order from the inside to the outside of the Sun .

4. What layer(s) of the Sun do we see from the Earth?

**WARNING-Never look directly at the sun, it can cause serious damage to your eyes .**

When we look at the Sun from the Earth (with solar telescopes) we see what we call the photosphere or solar disk. Look at the table to understand the properties of the different outer layers of the Sun

| Tipo radiación | Temperatura | Grosor de la capa | Densidad |
|---|---|---|---|
| Fotosfera | 8000 – 4500 K | 500 km | $\sim 10^{-4}$ kg/ m$^3$ |
| Cromosfera | 4500 - 20000 K | 1600 km | $\sim 10^{-8}$ kg/ m$^3$ |
| Zona de transición | 20000 – $10^5$ K | 100 km | $\sim 10^{-10}$ kg/ m$^3$ |
| Corona | $10^6$ - $3x10^6$ K | >$10^7$ km | $\sim 10^{-13}$ kg/ m$^3$ |

The outermost layers (crown) can only be seen from the Earth with special glasses during solar eclipses .

*Figure S.2:Solar Eclipse (Credits: ESA Kids)*

## Activity 3.2: The Chemistry of the Sun

The nuclear reactions that take place in the Sun generate the energy that makes life possible on our Planet. During the most stable phase of the stars, chemical reactions take place in their nucleus that transform 4 atoms of hydrogen into one of helium, as shown in Figure 7.

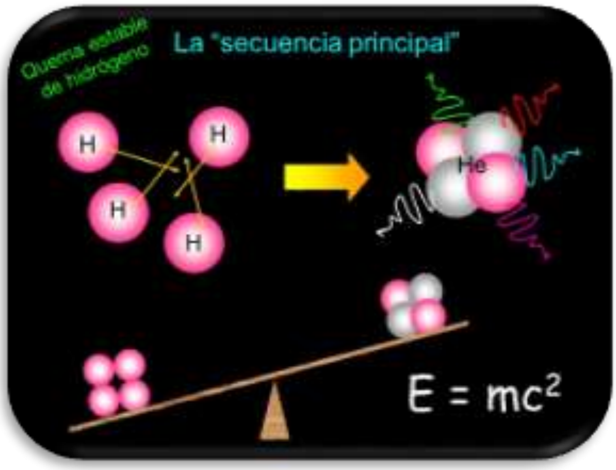



*Figure 7: Nuclear reaction of stars in their most stable phase (Credits: Talk by Dr. Benjamín Montesinos Comino in course of professors CESAR and June 2018).*

**Note 1:** Specifically 92 sextillions (92 000 000 000 000 000 000 000 000 000 000 000 000) of nuclear reactions occur every second in the Sun

**Note 2:** Every second 4 260 000 tons of matter are converted into energy, which is capable of providing a (standard) home with electricity for 9 500 billion years.

As shown in Figure 8, the Sun is composed mainly of hydrogen (H ~91%) and helium (He ~8.8%), plus other chemical elements in a much smaller percentage.

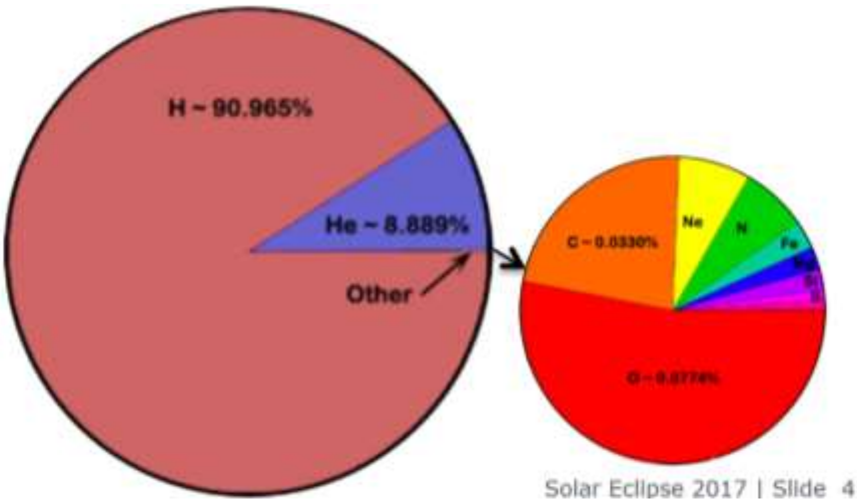



*Figure 8: Elements of the Sun (Credits: Presentation of Dr. Anik De Groof, in course of professors CESARr).*

1. Identify which group each of these chemicals belongs to by checking the [Dynamic Periodic Table](#) (figure 9) and fill in Table 4.


***Figura 9:*** *Tabla Periódica Dinámica (Créditos: PTable).*

| Proportion of that element (%) | Nomenclature | Chemical element | Group in the Periodic Table | Atomic number |
|---|---|---|---|---|
| 90.96 | H | Hydrogen | No metal | 1 |
| 8.89 | He | Helio | Gases | 2 |
| 0.07 | O | Oxigen | No metal | 8 |
| 0.03 | C | Carbono | No metal | 6 |
| < 0.1 | Ne | Neon | Gas | 10 |
| < 0.1 | N | Nitrogen | No metal | 7 |
| < 0.1 | Fe | Iron | Metal | 26 |
| < 0.1 | Mg | Magnesium | Metal | 12 |
| < 0.1 | Si | Silicon | Metal | 14 |
| < 0.1 | S | Sulfur | No metal | 16 |

*Table 4: hemical composition of the Sun.*

2. Repeat the previous activity for the case of the Earth. by checking the [Dynamic Periodic Table] and see Figure 10 for this.

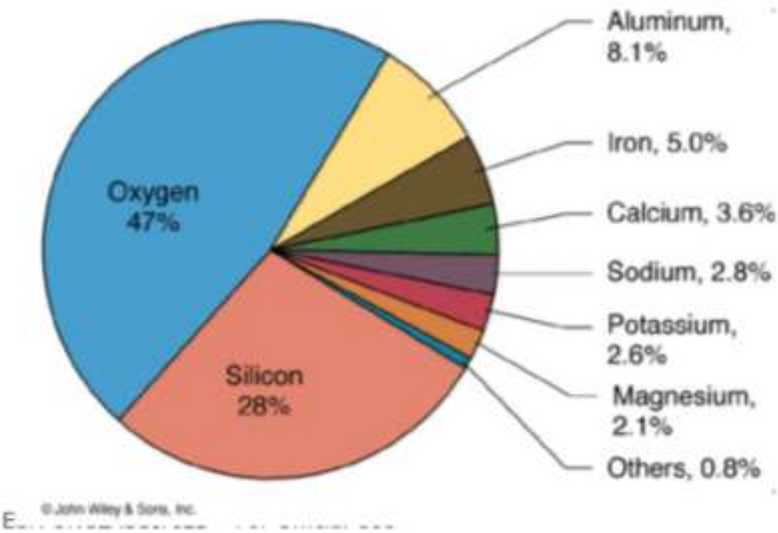



*Figure 10: Elements of the Earth (Credits: Presentation by Dr. Anik De Groof, in course of professors CESARr).*

| Proportion of that element (%) | Nomenclature | Chemical element | Group in the Periodic Table | Atomic number |
|---|---|---|---|---|
| 47 | O | Oxigen | No metal | 8 |
| 28 | Si | Silicon | Metaloides | 14 |
| 8.1 | Al | Aluminion | Metal | 13 |
| 5.0 | Fe | Iron | Metal | 26 |
| 3.6 | Ca | Calcium | Metal | 20 |
| 2.8 | Na | Sodic | Metal | 11 |
| 2.6 | K | Potassium | Metal | 19 |
| 2.1 | Mg | Magnesium | Metal | 12 |
| 0.8 | Otros | | | |

*Table 5: Chemical composition of the Earth*

3. Compare the composition of the Sun and the Earth.

| |
|---|
| |

Figure 11 shows the positions in the electromagnetic spectrum occupied by the transitions of the different elements found in the Sun.

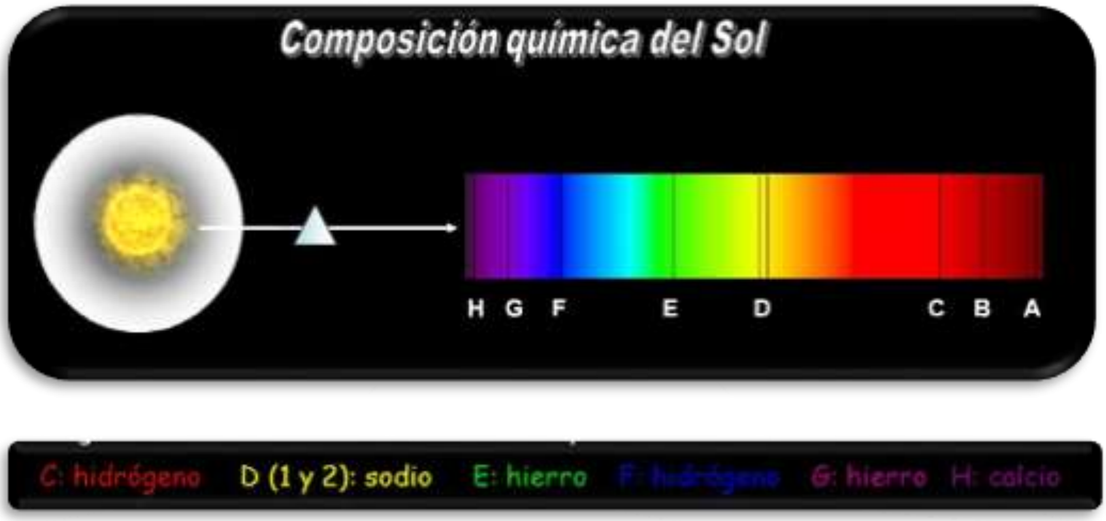



***Figure 11:*** *Chemical Composition of the Sun (Credits : [https://slideplayer.es](https://slideplayer.es))*

Perform the activity [CESAR " What are the stars made of?]() using the application [https://spectralworkbench.org/](https://spectralworkbench.org/)

## Activity 4: The Magnetic Activity of the Sun

As we commented in Activity 3, the sun is a large ball of gas at very high temperatures that is in a [plasma]() state, as seen in Figure 12

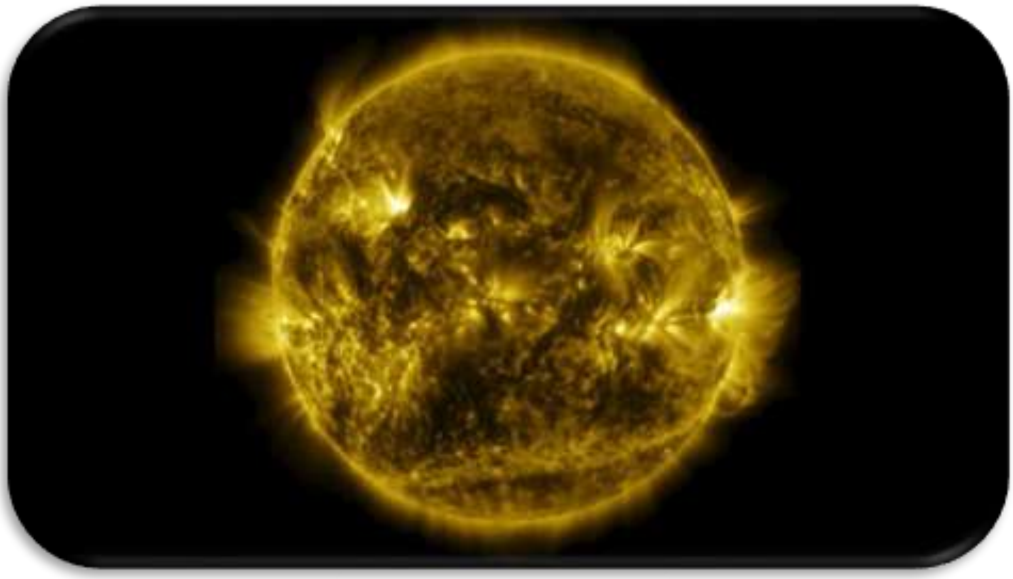


***Figure12:*** *Image of the Sun (Credits: Presentation by Dr. Benjamín Montesinos Comino for the CESAR teachers' course, June 2018)*

Due to this state, as the Sun rotates on itself, the equatorial and polar areas rotate at different speeds, twisting its magnetic fields and causing variations in its magnetic field, as shown in Figure 13.

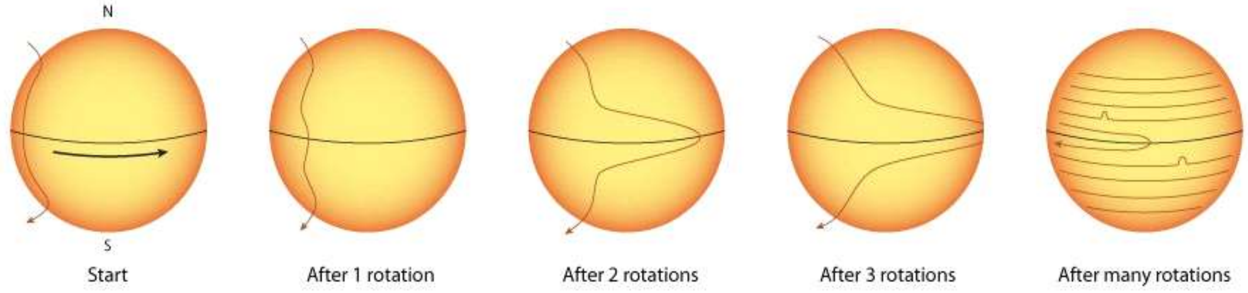



***Figure 13: Explanation of how the differential rotation of the Sun is generated over several days (Credits: NASA / IBEX)***

Our star is very active magnetically, because it has a very intense and variable magnetic field, which changes year by year. The orientation of its magnetic poles changes every time it reaches its maximum activity, which occurs once per cycle (every 11 years approximately), as shown in the data recorded in Figure 14.

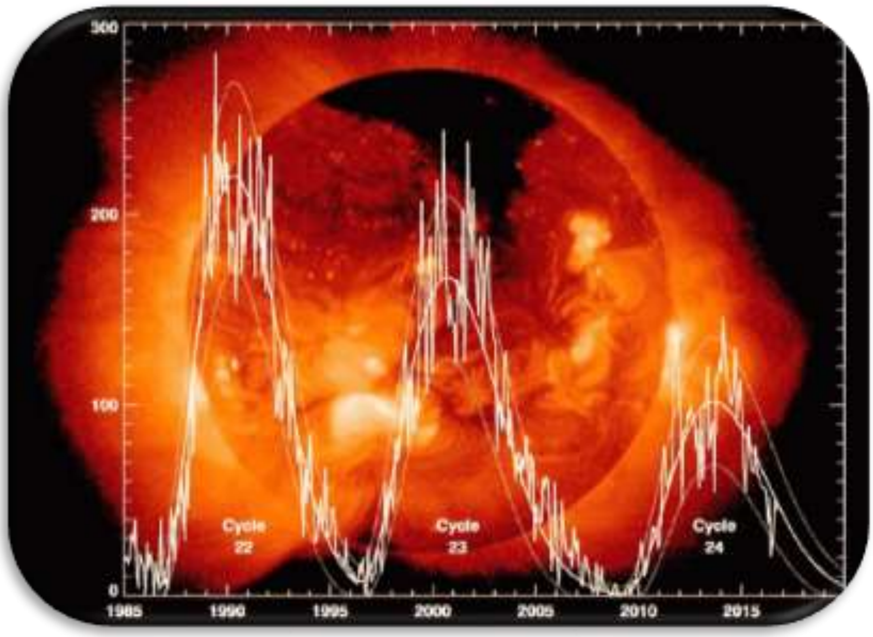



***Figure 14:*** *Cycles of activity of the Sun (Credits https://ciencia.)*

The magnetic activity of the Sun produces numerous effects, which together are known as solar activity. Figure 15 shows some of them as solar flares, erupting prominences, sunspots and coronal mass ejections of various types sent to the solar wind, among others.

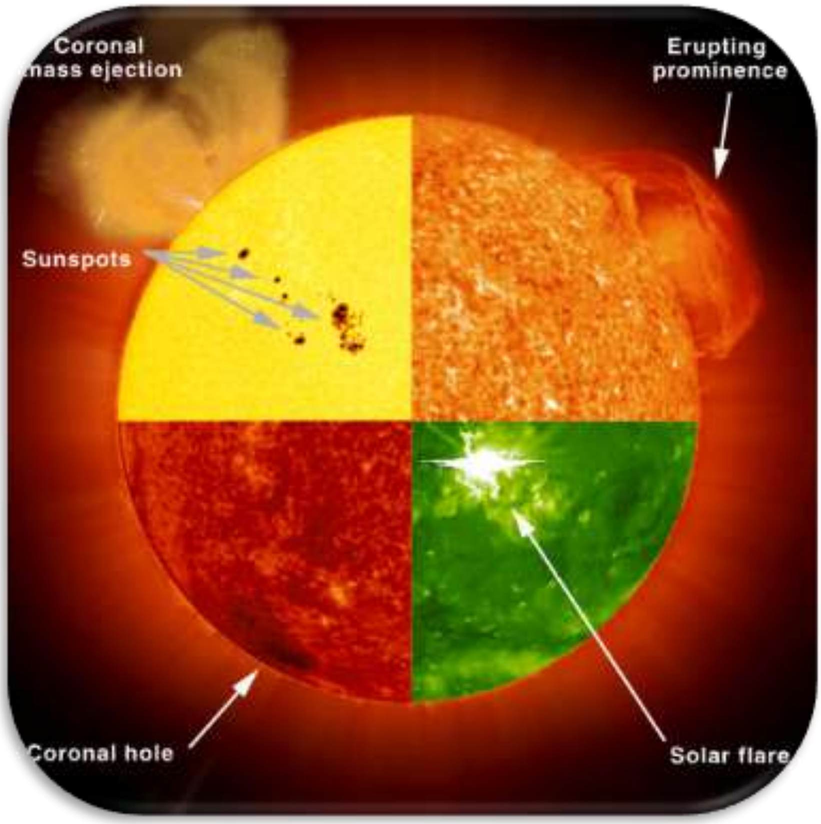



***Figure 15***: *Connection between the different effects of solar activity (Credits: geomag)*

For more information about the different effects caused by the magnetic field, we invite you to visit [CESAR's booklet on the Sun.](#).

## Activity 4.1: Sunspots

1. What do you think sunspots are and what causes them?

When we look at the Sun through a telescope adapted to observe the Sun (EYE: Never look at the Sun directly with a naked eye or telescope), sometimes darker areas can be seen forming pairs or groups. These constantly changing areas are called sunspots and are found in the photosphere (surface of the Sun).

We see them dark because their temperature is about 1 000 K lower than the temperature of the photosphere (which is about 5 780 K). This difference in temperature is due to the fact that the field lines through which the plasma circulates cross the surface, inhibiting its flow

2. In what layers of the Sun are sunspots visible? Draw an outline.

Sunspots are seen on the surface of the Sun, called the photosphere.

3. Do you think sunspots are related to the sun's magnetic field?

A sunspot is immersed in intense activity of the Sun's magnetic field. This activity makes the convective process, by which the hot material from below rises, stop. Consequently, the temperature of this region is lower than the rest. But the magnetic field in these areas is much greater than in the rest of the Sun and about 2 000 more intense than that of the Earth...see more in CESAR Booklet: The Magnetic Sun

Astronomers have observed that the sunspot cycle is intimately related to the activity of the Sun, including powerful coronal mass ejections, the size and extent of the Sun's outermost layers (the corona), and the intensity of light emitted by particles that the Sun emits throughout space, especially to the solar system. These particles can therefore affect the magnetic fields of numerous planets in the system, especially the Earth. The Northern Lights are a very representative example of this phenomenon.

**Sunspots** are a result of the Sun's magnetic activity, being regions where the Sun's magnetic fields exit (or enter) through the surface of the Sun (photosphere). They often appear in pairs, with one of the spots being created by the magnetic field line coming out of the photosphere and the other by the magnetic field line coming in. Therefore they often have magnetic poles (or polarity), resembling the north and south poles of a magnet.

They appear as dark patches on the surface of the Sun (known as the photosphere) because they are about 1000 K cooler than their surroundings and can vary in size, becoming as large as the Earth or Jupiter (see left image of Figure 16)

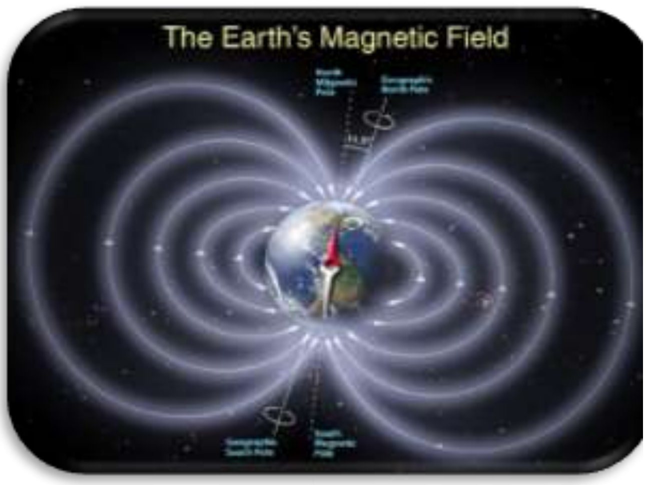

***Figure 16**: (Left image) Sunspot size comparison. (Right image) Comparison of sunspots with a magnet (Credits: ESA Solar Orbiter)*

## Activity 4.2: The influence of the Sun on the Earth

The Sun is the star that allows the existence of life (zone of habitability), as we know it on Earth, and the variations in its activity impact on Earth at many levels.

Most of the planets in the Solar System are surrounded by large magnetic envelopes. They are known as magnetospheres and are produced by activity inside the planet. These magnetospheres form the largest structures in the Solar System, being between 10 and 100 times larger than the planet itself.

The solar wind interacts with these "magnetic bubbles" and can move and deform them. They can therefore be induced by this interaction with the solar wind with its ionosphere (Venus and comets) or by a magnetic dynamo process (as occurs on Mercury, Earth or giant planets).



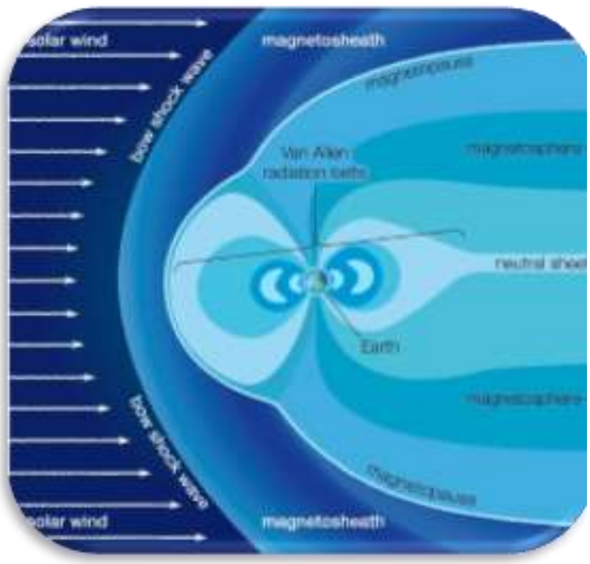




*__Figure17:__ Earth's magnetic field and the influence of the solar wind on it (Credits NASA, ESA )*

The Earth's magnetic field is very stable and does not change much over time, unlike the solar magnetic field. However, some of the ultraviolet radiation manages to pass through the atmosphere and so we must protect ourselves. Watch this [TED-ED video] to see the effect of the sun on people and the need to use sunscreen.

1. Draw how you think it might affect the Sun's magnetic activity on Earth


***Figure S.3: Example of how not all ejections impact the Earth (Credits: CESAR)***

.


***Figure 18:*** *Earth's magnetic field and its effect on the Sun and satellites (Credits : ESA)*

2. Do you think there is any relationship between the Sun and the Northern Lights?

***Figure 19:*** *Auroras Boreales Training (Credits :* [www.meteorologiaenred.com)](www.meteorologiaenred.com)

| |
|---|
| The Earth is protected by a magnetic field, which is the union point between the Earth and Space, and the charged particles, emitted by the Sun, can produce very impressive visual effects, such as the Northern Lights. |

- **The following video explains the appearance of the Northern Lights as a cause of the Sun's influence on the Earth's magnetic field video**

3. What other influence can solar activity have on the Earth?

The Sun also has a magnetic field, but this changes constantly (Solar Activity), this can cause large explosions in the outer layers of the Sun, which are known as Coronal Mass Ejections.

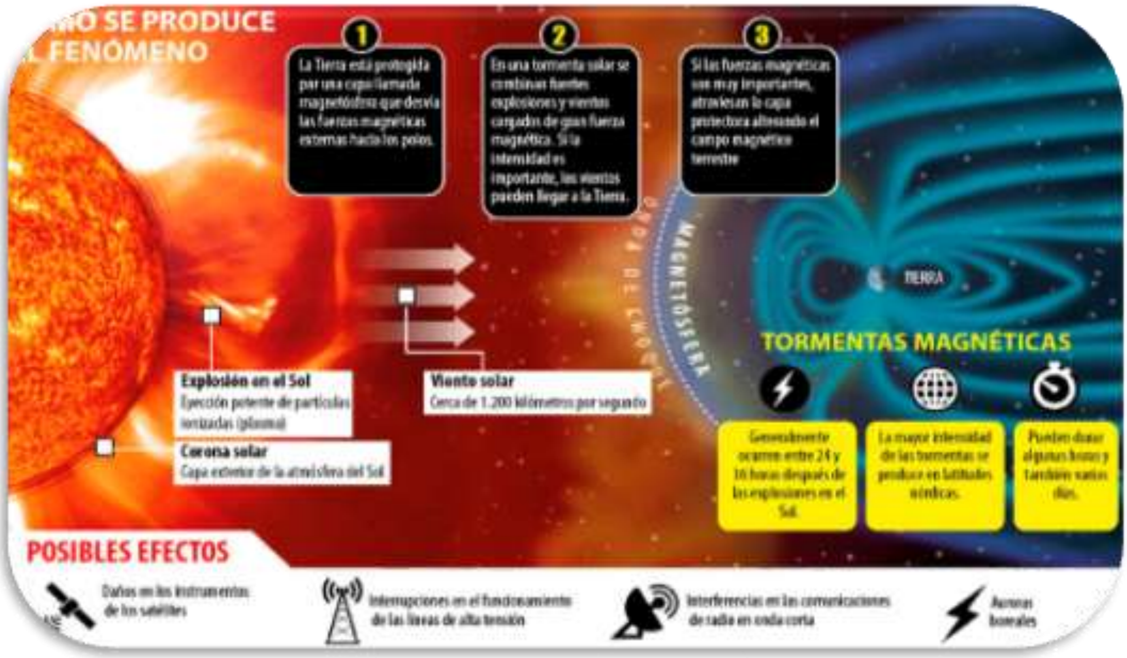



***Figure S.4:*** *The influence of the Sun on the Earth's magnetic field (Credits: www.capasdelatierra.org))*

It is important for scientists to monitor solar activity, because if the ejection is powerful enough, when it reaches Earth, it can damage telecommunication satellites and even surface electrical installations.

Another important effect of Solar Activity is also its impact on the Earth's climate history. Some research in the Northern Hemisphere has proven that the more sunspots detected on the Sun's disk, the warmer the climate on Earth has been, and conversely the more icy it has been when these sunspots were smaller in number and/or size


***Figure S.5: The Little Ice Age***

## Activity 5: The Space Exploration of the Sun by the European Space Agency (ESA).

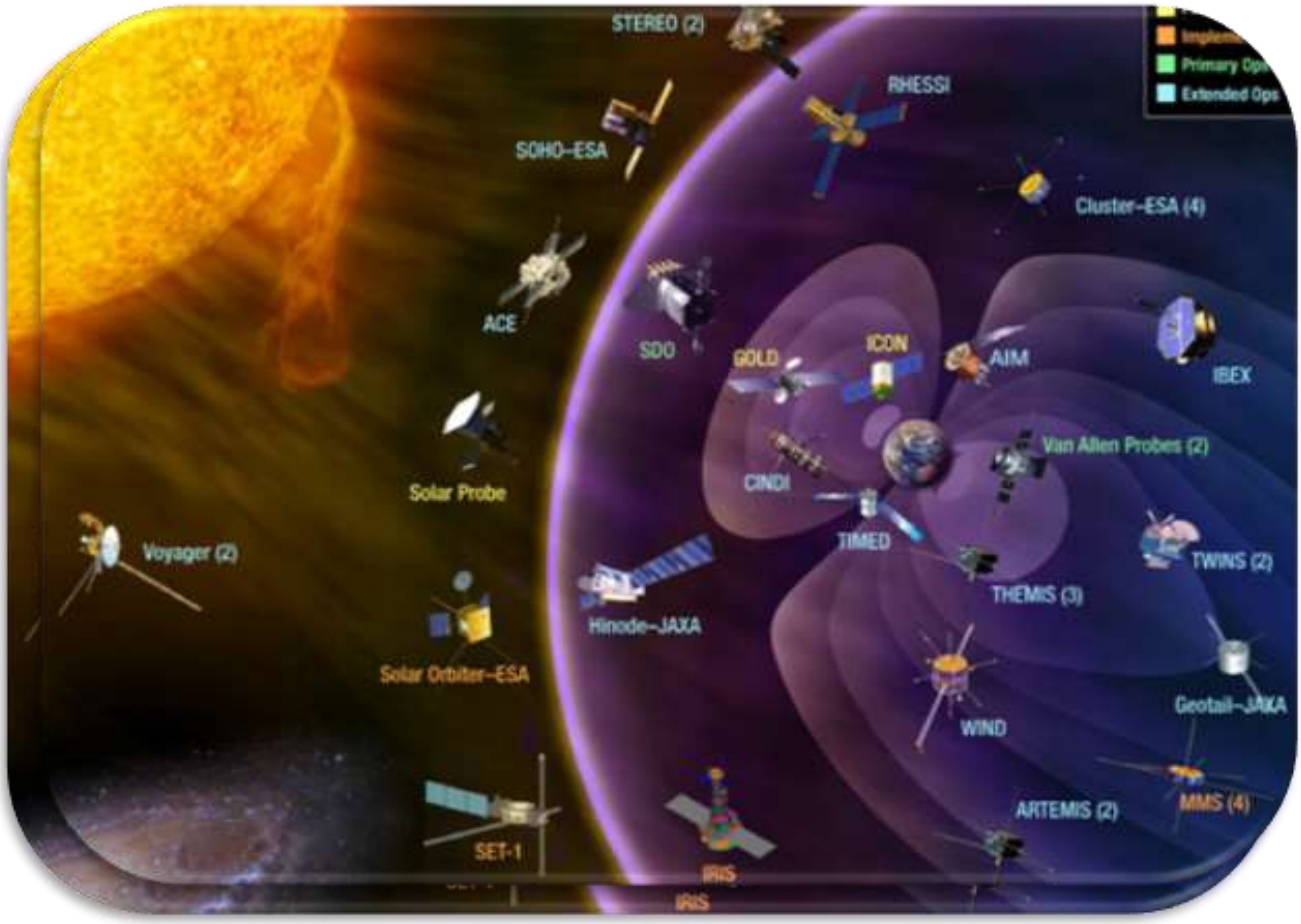



***Figure 20:*** *European Space Agency mission fleet. (Credits: www.fidefundacion.es)*

For more than two decades, the European Space Agency, together with the US Space Agency, has been studying the Sun, as its variations can significantly affect the Earth. Figure 20 shows all of them and Figure 21 those with a high European contribution (PROBA-2 , SOHO y Solar Orbiter). The field of physics that studies the Sun is called **Heliophysics.**

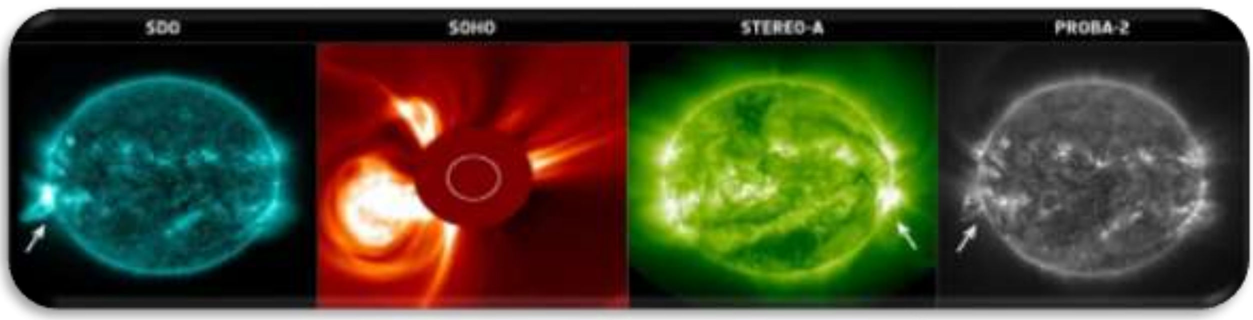



***Figure 21:*** *The Sun observed in different filters (credits: kiri2ll.livejournal.com)*

## Actividad 5.1. Solar Orbiter. SOLO

***Figure 22:*** *Simulation SOLO, ESA. (credits www.esa.int)*

ESA's Solar Orbiter mission was launched in 2020, with the main objective of closely studying the Sun, its poles and in particular to analyze the behavior of its magnetic fields, in order to predict the behavior of the star on which our lives depend.

***Figure 23:*** *SOLO launch, ESA. (Créditos: ESA–S. Corvaja)*

Discover the travel blog and educational activities created by SOLO mission scientist Dr. Anik de Groof to chronicle her journey to see the mission launch in February 2020. Here is a video of the launch of the SOLO mission..

The following links are extra resources to know the missions in charge of the study of the Sun:

o ESA mission to the Sun
o 3D Simulators of the European Space Agency mission spacecrafts fleet
o The ESA SWARM mission studies the variations of the Earth's magnetic fields.
**The mission ESA SWARM studies the variations of the Earth's magnetic fields.**

## Activity 5.2: Solar telescope CESAR (HELIOS)

The HELIOS telescope, as shown in Figure 24, is a solar telescope belonging to the CESAR Team and has been installed at ESAC since 2012. Its main objective is to observe the Sun's disk every day (in the visible and H-alpha range) as shown in the calendar created with the images of the Sun taken in 2017 in Figure 25.

***Figure 24: Solar*** *Observatory HELIOS (Credits: CESAR*

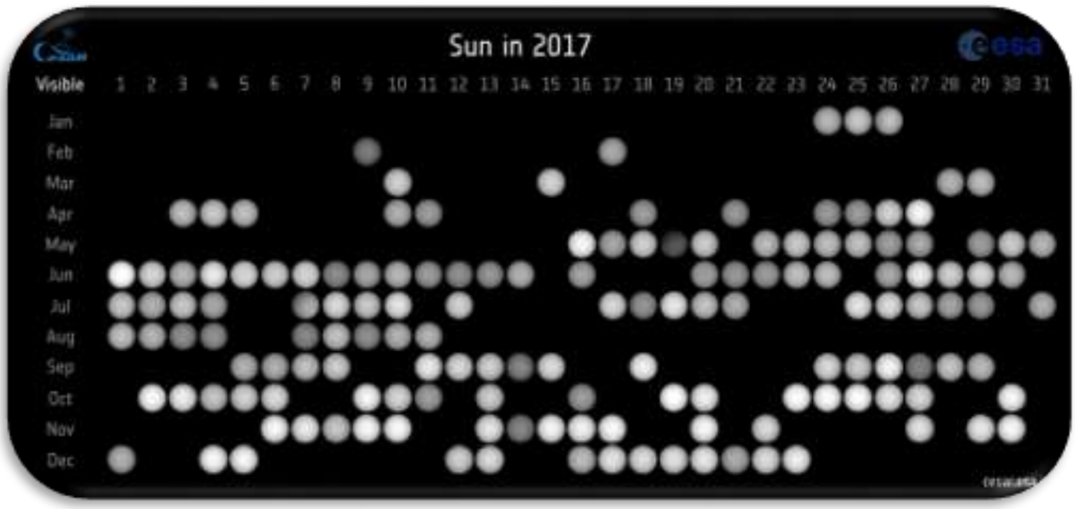



***Figure 25:*** *ESA solar observatory (Credits www.esa.int)*

From this scientific data the CESAR Team creates educational material such as "The Study of the Rotation of the Sun.

If you want to see the last image taken by this telescope Access to "The Sun live"”

- For more information about this ground-based telescope access the ESAC SOLAR OBSERVATORY, in the following link.

## Activity 6: Evaluate what you have learnt so far

Check all what you already know with this questionnaire

# Phase 2

How to proceed in this Phase depends on the results obtained in the latest Activity of Phase 1 (questionnaire)

- **Case 1:** Your students replied quite well to the quizz
  - ➔ **Go to PHASE 3**
- **Case 2:** Your students did not reply very well to the quizz or they have many questions related to the topic of the Scientific Challenge
  - ➔ **Review PHASE 1** (see below) **and use this complementary material**

| http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=19&ChangeLang=en | |
|---|---|
| • Expert talks given at CESAR Teacher workshops (pdf and/or videos)<br>• ESA dedicated videos<br>• CESAR Monographics (booklets)<br>• Simulators/websites |  |

➔ **Go to PHASE 3**

- **Case 3:** You can not make it alone and you need interaction with the CESAR Team

## Activity 7: Ask for a video-call with CESAR team if needed


***Figure 27:*** *Image of the CESAR Team in a video call with teachers (Credits: ESA)*

**Note:** Per scientific challenge you have the opportunity to ask for 30 min video call
- with your class (in PHASE 2) to clarify concepts
- with the teachers only (in PHASE 3) in case you have issues with the software/answers

# Phase 3

This activity is structured according to the scientific method. First you will make a **hypothesis**, then an **experiment** (procedure) and finally you will come to your own **conclusions**.

**Are you prepared to think like a scientist?**

## Hypothesis

1. How long do you think it takes the Sun to go around itself?

The Sun is a ball of hot, ionized gas, called a plasma (not a rigid body), and therefore the gas on its surface does not move in a block but will vary.

The Sun rotates faster near the equator, where the radius is greater and therefore the linear velocity, v, is proportional to the angular velocity, w, and the radius of rotation, r, through the equation:

$$v = w \, x \, r$$

This is why we talk about the differential rotation (different speeds of rotation) of the Sun. The time it takes for the Sun to go around itself, or what we call the rotation period, is 25 days around the equator, while near its poles (+/- 90 degrees latitude) it rotates more slowly, reaching a rotation period of about 35 days.

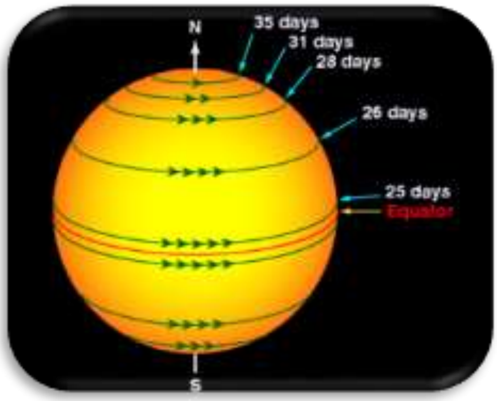



***Figure S.6: Diagram showing how the rotation period of the Sun on its surface varies (Credits: http: //www.star.bris.ac.uk/bjm/solar/solarrot.html)***

2. Do you remember what a sunspot was? (Hint: Check Activity 4.1 to remember)

When we look at the Sun through a telescope adapted to observe the Sun (EYE: Never look at the Sun directly with a naked eye or telescope), sometimes darker areas can be seen forming pairs or groups. These constantly changing areas are called sunspots and are found in the photosphere (surface of the Sun).

We see them dark because their temperature is about 1 000 K lower than the temperature of the photosphere (which is about 5 780 K). This difference in temperature is due to the field lines through which the plasma circulates crossing the surface, inhibiting its flow ...

3. In what direction do you think a sunspot moves on the surface of the Sun? Draw a diagram that illustrates your answer. (Hint: Check Activity 4.1 to remember)

Since sunspots are the result of magnetic processes, they move in the direction of their magnetic fields.

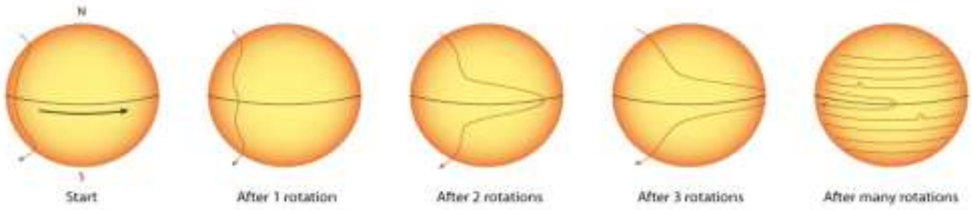



*Figure S.7: Explanation of how the differential rotation of the Sun is generated over several days. (Credits: NASA / IBEX)*

As shown in Figure S.7 the magnetic field lines of the Sun start perpendicular to the Sun's equator and wind in the direction of the Sun's rotation. Therefore, sunspots move mainly parallel to the equator. In this activity, the main position change for the Sunspot is on the x-axis or length.

4. Do you think sunspots only move in one direction?

Due to the rotation of the Sun we see the spots, which are visible phenomena on its surface, rotating in the direction of the Sun mainly, as shown in the previous question.

Sunspots are the result of the Sun's magnetic fields, which twist around the Sun, crossing the photosphere and inhibiting the flow. In a time range greater than days (which is what we analyze in our data) sunspots also move in latitude, going from higher to lower latitudes, as shown in Figure S.8.

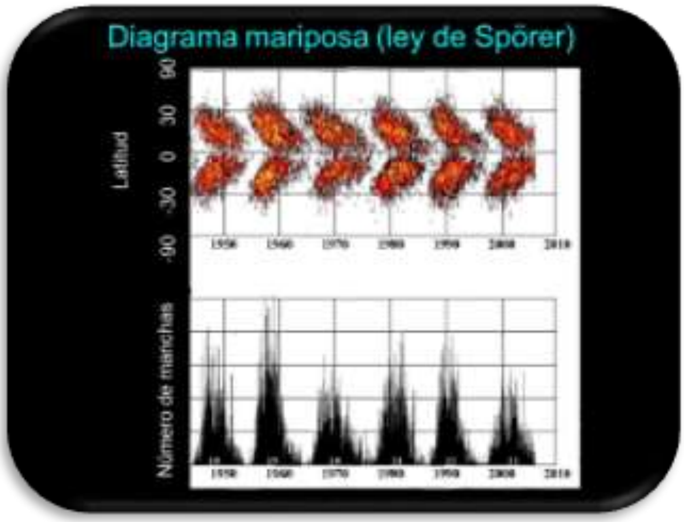



*Figure S.8: Representation of the variation in latitude of sunspots, related to the evolution of the solar activity cycle (Credits: Talk by Dr. Benjamín Montesinos Comino for the CESAR teachers' course, June 2018)*

## Activity 8: Calculation of the rotation of the Sun

In this activity, students will use images of the Sun taken by the [Solar Observatory HELIOS](), belonging to the CESAR Team and installed in ESAC. From these images, they will measure the movement of a sunspot over several days to calculate the rotation of the Sun.

### Actividad 8.1: Versión on-line

- **Data:** Images taken by the HELIOS solar telescope of the Sun's photosphere.
- **Tools:**
  - Web tool designed by the CESAR Team of "Study of the Differential Rotation of the Sun
  - Calculator
- **Video tutorial** https://youtu.be/6C5wirg9lQU
- **Recommendations:** It is convenient that different groups carry out the exercise with different sets of images and finally put their results in common so that the differential rotation of the Sun is more evident.

**Procedure**

- Watch the video tutorial and repeat the exercise for the set of images chosen in Option 3
- **Access the CESAR web tool for** the "Study of the Differential Rotation of the Sun".
- **Step 1/4:** Choose a set of images (for example, Option 3). These are consecutive images which allow us to study the evolution of sunspots

**If you choose Option 3:**

- They will access a predefined set of sunspots, observed between the dates 8-12 December 2017.

**If you choose Option 1:**

- Search for a date with available data (for example, by clicking on the arrow you can find data from the Sun taken in February-March 2020).
- Once you have found images of the Sun, look for images with sunspots (Note: you have to find 4 consecutive images where the same spot is visible in order to study its evolution).


*Figure 27: Step 1 of the web tool for calculating the rotation period of the Sun (Credits: CESAR)*

- **Step 2/4 (I):** Calculate the radius of the Sun to know the scale of the image.
  Click with the mouse in the center of the Sun (black cross) and then on the end of the disk. This will allow the tool to know internally how many kilometers from the Sun fit in a pixel of the image. The result is around 230 pixels representing 695,842 km.

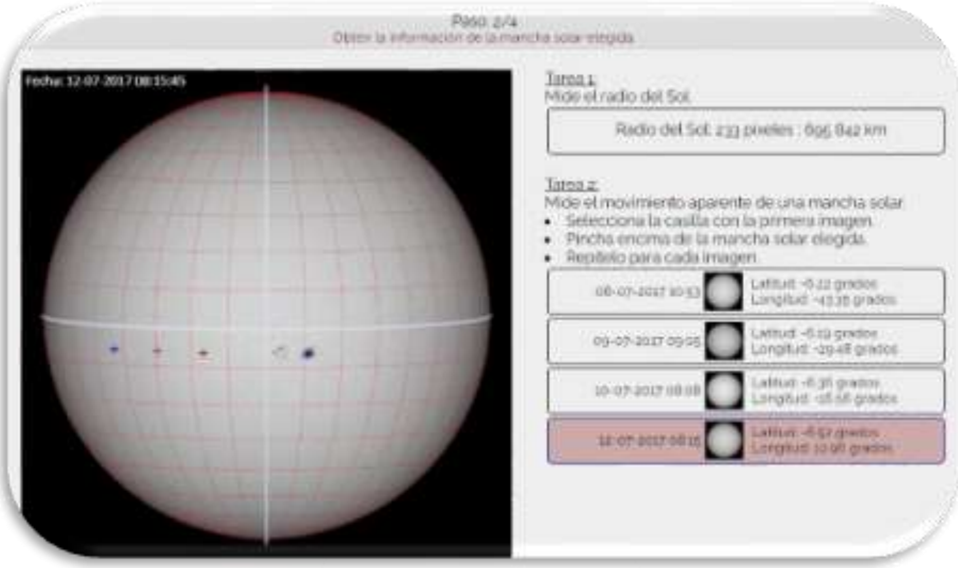



*Figure 28:* *Step 2 of the web tool for the calculation of the rotation period of the Sun (Credits: CESAR)*

- **Step 2/4 (II):** For each image select the position where the stain is.

- **Step 3/4 (I): Calcule the rotation period of the Sun:**
  - Fill in the time difference between the image(N) and the image(N-1), in days (e.g. XY days) in the numerator. (Note: The time the images were taken is given as DD-MM-YYYY hh:mm, with DD being the day, from month MM of year YYYY to hour hh and minutes mm).
  - Fills in the denominator the difference in length between the image(N) and the image(N-1), in degrees. (Note: Depending on whether the spot is in one area or another, it will have a positive or negative value. What the tool needs is the angle in absolute value).

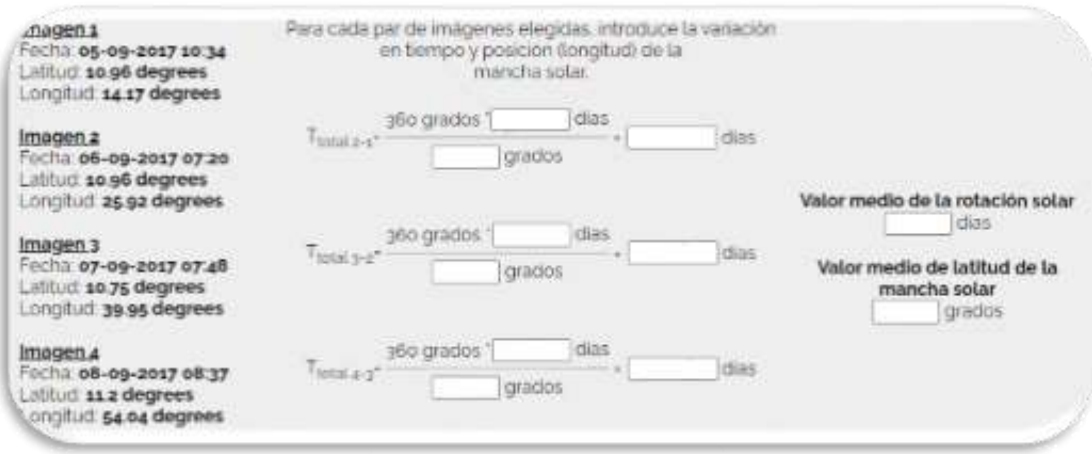



*Figure 29:* *Step 3 of the web tool for the calculation of the rotation period of the Sun (Credits: CESAR)*

**Note**: Calculations should be performed using external means which may be calculator, paper or mental calculations

- **Step 3/4 (II): Calculate the average value of the rotation period:**
  - Use the values of the three instantaneous rotation periods (calculated between pairs of images) and calculate the average value. (Note: This value should be calculated using external means which can be calculator, paper or mental calculation).

- **Step 3/4 (III): Calculate the average value of the stain latitude:**
  - Enter the average latitude of the spot from the latitude of the four images.

- **Step 4/4: Compare your result of the rotation period with that of the solar system planets**


***Figure 30:*** *Step 4 of the web tool for the calculation of the rotation period of the Sun (Credits: CESAR)*

Figure 30 shows a result for Option 3. Note that when choosing the center of the image by hand there is an error in the measurement. (Note: We give the periods of rotation of the planets of the solar system, taking into account that for the gas giants the value is average (link)).

1. Based on your observations, how long does it take for the Sun to turn on itself?

We have contrasted what the Phase 1 theory told us, that the movement of the spot is mainly parallel to the equator (in length). The time of rotation will depend on the latitude at which we calculate it, being less at latitudes close to zero. We saw that the reason is that since the Sun is not a solid body, it rotates faster to positions of greater radius (the equator) than to positions of lesser radius (the poles).

Note: The images available in the HELIOS database (accessible from the tool and this link) have detected spots at latitudes between 0 and 45 degrees because of the location of the telescope on the globe.

2. Do you give the same value to your colleagues? If this is not the case, analyze the reasons

## Activity 8.2: PDF Version

- **Data**: Images taken by the HELIOS solar telescope of the Sun's photosphere, with dates and distribution of parallels and meridians on it. We see the surface of the Sun (or disk) and sometimes dark spots on it (sunspots).
- **Tools:** The images bring superimposed the meridians and parallels of the Sun for that date.
- Calculator
- **Recommendations:** It is convenient that different groups perform the exercise with different sets of images and with different sunspots. The sharing of the results can give a different value to be analyzed according to the latitude of the sunspot used.
- **Possible solutions:** we present a result of possible solution that may or may not correspond with the one calculated by the teacher or the students. It is only intended to explain to the teacher the way of execution, in case any doubt arises.

Follow the **Procedure:**

- Download and print the sun disk images taken by the HELIOS telescope. There are two groups of images taken on two different dates, with spots at different latitudes:
  - **Option 1: Three images taken between 29/03/2001 and 02/04/2001** (link)
  - **Option 2: Three images taken between 31/12/2010 and 11/01/2011** (link)
- **Step 1 /4:** Inspect the images and choose the sunspot you will use for your measurements (Note: It is important that the same spot is visible in all 3-4 consecutive images)
- **Step 2/4 (I):** Measure how much your favorite sunspot has shifted in length

| Image | Date (DD-MM-YYYY hh:mm) | Latitude | Longitude |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |

***Table 5:*** *Table for the identification of sunspots in the study images (Credits: CESAR)*

  - Fill in Table 5 with the date, latitude and longitude information of your patch.
  - Repeat the exercise for the same spot in the other images.

- **Step 3 of 4 (I):** Calculate the rotation period of the Sun:
  - Fill in Table 6 with the time difference between the image(N) and the image(N-1), in days (e.g. X.Y days). (Note: The time the images were taken is given as YYYY/MM/DD hh:mm, with DD being the day, from month MM to year YYYY at hour hh and minutes mm.)
  - Fill in Table 6 with the difference in length between the image(N) and the image(N-1), in degrees. (Note: Depending on whether the spot is in one area or another, it will have a positive or negative value, check Activity 1. What the tool needs is the angle in absolute value).

- **Step 3/4 (II):** Calculate the average value of the rotation period:
  - Uses the values of the two instantaneous rotation periods (calculated between pairs of images) calculates the average value. (Calculations should be performed using external means which may be calculator, paper or mental calculations).

- **Step 3/4 (III):** Calculate the average value of the latitude of the spot:

o Enter the average latitude of the spot from the latitude of the three images.

| Pair of images | Variation in time (days) | Variation in longitude (degrees) | Rotation period (days) |
|---|---|---|---|
| 1 and 2 | | | |
| 2 and 3 | | | |
| Average value of the rotation period (days) | | | |
| Average latitude (degrees) | | | |

*Table 6: Table of sunspot movement variation (Credits: CESAR)*

**- Step 4/4:** Compare your result of the rotation period

*Table 7: Rotation periods of the planets of the Solar System.*

| Objeto | Periodo de rotación |
|---|---|
| Mercurio | 58.64 días |
| Venus | 243.02 días |
| Tierra | 1 día |
| Marte | 1.03 días |
| Jupiter | 0.41 días |
| Saturno | 0.44 días |
| Urano | -0.71 días |
| Neptuno | 0.67 días |

**Conclusions**

1. Is the value of the rotation period of the Sun what you expected? Compare your results with those of other colleagues, are they similar? If not, what do you think is the reason for these differences?

The different images of the Sun were taken on different days. When calculating the rotation period by comparing different pairs of images for the same sunspot, we must also consider the following sources of error

- The position of the stain. This was chosen by hand, and there may be an error in identifying the center of the spot between images as they are large images or several spots together and not well resolved by the image.

- We only considered the variation in longitude of the spot and not in latitude.

- Only two decimals were used for position identification (in longitude) and the unit used was degrees.

- Only two decimals were used for time identification and the unit used was days.

2. Did you expect the Sun to rotate more or less fast than the Moon? And more or less fast than the Earth?

We see that the Earth rotates much faster than the Sun, which we expected because it is a smaller body. However, in the case of Mercury or Venus, this does not happen. It might be interesting to discuss with students what different processes might influence the rotation of these planets to slow down. Table 4 shows a list of periods of rotation of more planets. It is interesting to see that the Moon and the Sun rotate at similar speeds

3. The following factors affect how the sunspot (and therefore the Sun rotates:):
   a) the hemisphere we are looking at?
   b) date?
   c) the latitud value?

Explain the reasoning behind your answers.

The database of images used in the activities covers a time interval of only 2 years, therefore for these images the main factor affecting the speed of rotation is the latitude of the sunspot. Solar activity is known to vary over an 11-year period (also called the "Solar Cycle"). During this cycle, different sunspots appear at different times.

4. Given the latitudes of the sunspots, at what latitude does the Sun rotate fastest? In other words, at what latitude is the Sun's rotation period shorter??

For latitudes near the equator, the rotation speed is higher, so the solar rotation period is shorter.

# Phase 4

## Congratulations!
## You have completed your Scientific Challenge!
## Tell us your story!

In Teams and with some support from the teachers, Recall the Experience about your Adventure and do these last Activities

### Activity 9: Self-assess and co-evaluation

- **Teams:** Fill in this questionnaire so that you can check what you have learned in the Challenge.
- **With your teacher:** Give us your feedbac

**IMPORTANT NOTES**

- Teachers will make sure that each Team performs the evaluations (quizzes)

### Activity 10: Tell us about your Adventure

Students will have to create a final product (an A0 poster in pdf format, using power point, for example) showing what they have learned in the different phases of the Scientific Challenge.

This poster is the ticket to participate in the CESAR international adventure competition.

**IMPORTANT NOTES:**

- It would be very interesting if you could present it to your schoolmates on a certain date, simulating a congress of scientists.
- Any document involving photos of your students can be published on the CESAR website or social networks. Therefore, please only attach those images for which you have explicit permission for publication, intellectual property and image. The CESAR Team is not responsible for their intellectual property and image.

**Congratulations teacher!**
**Thanks to your dedication your class will receive a CESAR Team Super Diploma**

# Links

# PHASE 0:

### VIDEOS:

- This is ESA: https://www.youtube.com/watch?v=9wdbNU7Pu8U&feature=youtu.be
- http://www.esa.int/ESA_Multimedia/Videos/2015/01/ESAC_ESA_s_Window_on_the_Universe
- Presentation to ESA/ESAC/CESAR by Dr. Javier Ventura: http://cesar.esa.int/index.php?Section=Multimedia&Id=63
- http://cesar.esa.int/index.php?Section=SSE_Videos_NEW&ChangeLang=es

### APPS:

- https://www.edumedia-sciences.com/es/media/112-cinematica

### WEBS:

- Katherine Johnson: https://kids.britannica.com/kids/article/Katherine-Johnson/628677
- Vera Rubin: https://www.nytimes.com/2016/12/27/science/vera-rubin-astronomist-who-made-the-case-for-dark-matter-dies-at-88.html
- Samantha Cristoforetti: https://www.nytimes.com/2016/12/27/science/vera-rubin-astronomist-who-made-the-case-for-dark-matter-dies-at-88.html
- Marie Curie: https://es.wikipedia.org/wiki/Marie_Curie
- Steve Wozniak: https://es.wikipedia.org/wiki/Steve_Wozniak
- Matt Taylor: https://www.famousbirthdays.com/people/matt-taylor-scientist.html
- Albert Einstein: https://es.wikipedia.org/wiki/Albert_Einstein

# PHASE 1:

### VIDEOS:

- http://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_8_The_Sun_our_local_star/(lang)/es
- https://www.youtube.com/watch?v=ZSJITdsTze0
- https://www.youtube.com/watch?v=1DXHE4kt3Fw
- Solar Orbiter https://www.esa.int/ESA_Multimedia/Missions/Solar_Orbiter/(result_type)/videos
- SOLO: https://www.esa.int/ESA_Multimedia/Videos/2020/02/Solar_Orbiter_launch_highlights
- https://www.esa.int/ESA_Multimedia/Missions/Solar_Orbiter/(result_type)/videos
- https://www.esa.int/Applications/Observing_the_Earth/Swarm/Highlights/Earth_s_magnetic_field
- https://dlmultimedia.esa.int/download/public/videos/2013/07/020/1307_020_AR_ES.mp4
- COSMOGRAPHIA: https://www.youtube.com/watch?v=VBO9MDt8Gvs

### APPS:

- https://www.purposegames.com/game/layers-of-the-sun-game
- https://www.ptable.com/?lang=es
- http://cesar.esa.int/index.php?Section=SSE_Composicion_de_las_estrellas_portada
- https://spectralworkbench.org/
- http://scifleet.esa.int/#/.
- http://scifleet.esa.int/#/model/sun

- SOHO: http://scifleet.esa.int/#/model/soho
- SOLO: http://scifleet.esa.int/#/model/solar_orbiter
- https://www.solarorbiterforkids.com/
- http://cesar.esa.int/form.php?Id=11&k=9gPSn9hqRN&ChangeLang=en

**WEBS:**

- http://cesar.esa.int/upload/201905/jupiter_moons_booklet_pdf.pdf
- https://www.esa.int/Space_in_Member_States/Spain/Explorando_el_Sol
- https://www.esa.int/Space_in_Member_States/Spain/El_Sol_en_2018
- http://cesar.esa.int/index.php?Section=News&Id=183

- http://cesar.esa.int/index.php?Section=Live_Sun
- http://cesar.esa.int/index.php?Section=Observatories_ESAC_Sun
- https://www.esa.int/kids/es/Aprende/Nuestro_Universo/El_Sol/Eclipses_solares

- http://www.esa.int/Our_Activities/Space_Engineering_Technology/Proba_Missions/About_Proba-2
- SOHO: http://www.esa.int/Our_Activities/Space_Science/SOHO_overview2
- Solar Orbiter: http://sci.esa.int/solar-orbiter/

## PHASE 2:

## PHASE 3:

**VIDEOS:**

- LASCO
  - https://www.esa.int/ESA_Multimedia/Keywords/System/SOHO_LASCO_coronograph/(result_type)/videos

**APP:**

- http://cesar.esa.int/tools/15.coronal_mass_ejections/index.php?ChangeLang=es

**WEBS:**

- https://es.wikipedia.org/wiki/Coron%C3%B3grafo

## PHASE 4:

**APP:**

- http://cesar.esa.int/form.php?Id=11&k=9gPSn9hqRN&ChangeLang=en

**WEBS:**

- SSE: http://cesar.esa.int/upload/202001/bases_concurso_sse_final.pdf

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- Previous guide: http://cesar.esa.int/index.php?Section=Differential_Rotation_of_the_Sun