



CESAR Scientific Challenge

The mass of Jupiter

*Calculate the mass of a planet from
the motion of its moons*

Teacher Guide

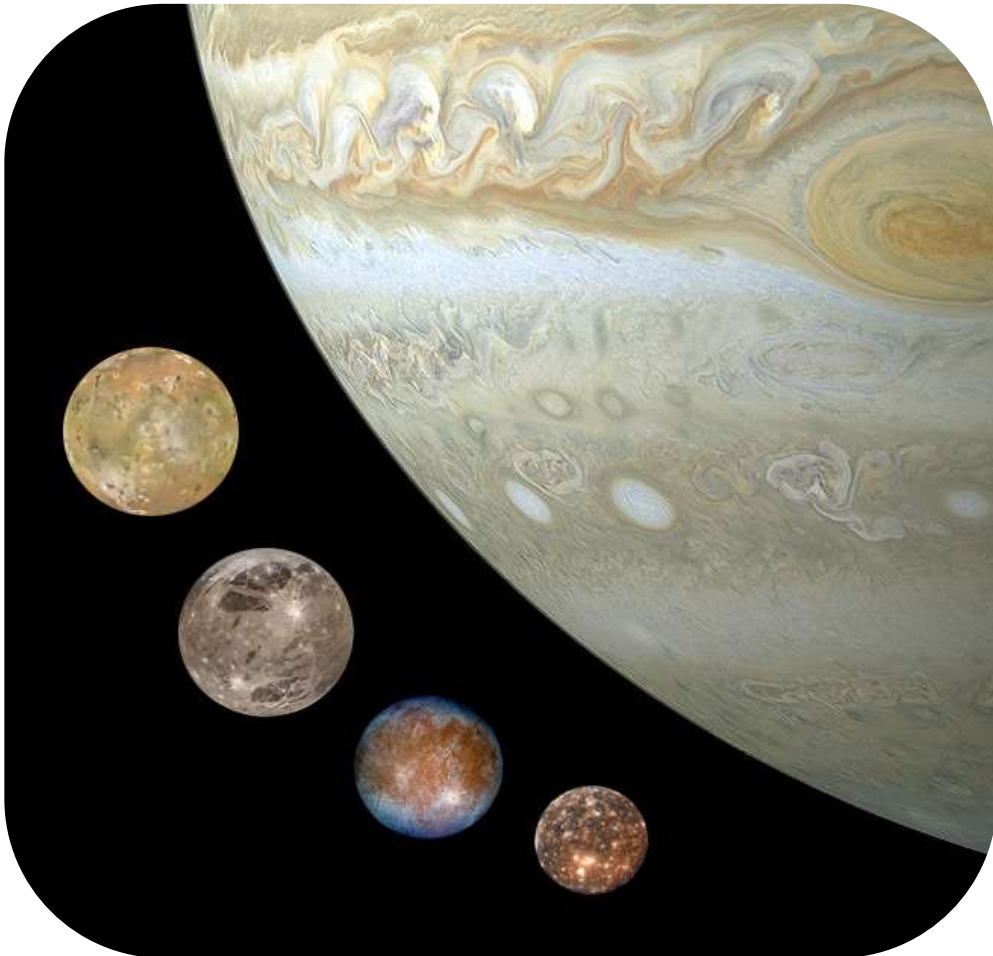




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Didactics

Learning objectives



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

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 **analyzing** events).

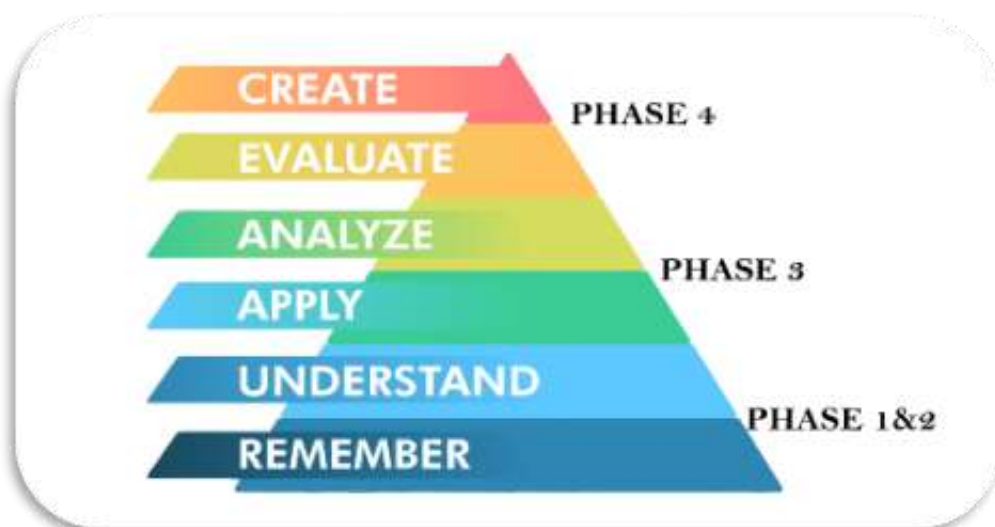


Figure II: Bloom's Taxonomy diagram. (Credits: <https://medium.com/@ryan.ubc.edtech/>)



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** their center in Spain (European Space and Astronomy Centre, ESAC) as well as the CESAR Team. (in videos)
 - **Nowadays 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 until the moment in what students have just learnt. At this stage, students had already become “experts” on the topic of the Challenge .
- **Phase 3: *applying*** the already known concepts following a methodology (procedures) for ***analyzing 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.

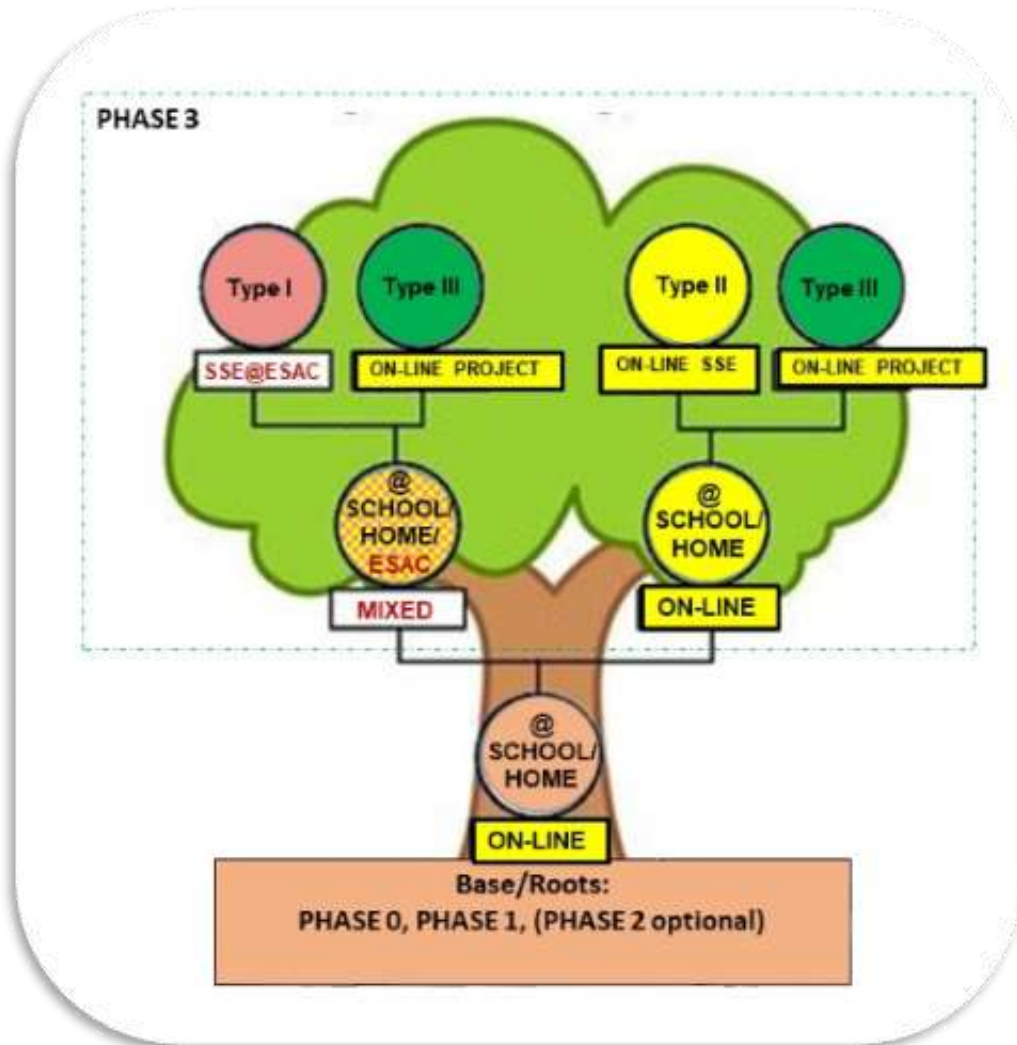


Figure III: Decision tree of the CESAR Experiences according to Phase 3 (Tipo I @ESAC, Tipo II y III, on-line). In yellow are indicated those paths that can be run completely on-line. (Credits: teacherspayteachers.com)

Teachers are the best ones in assessing the Type of Experience (Challenge) for their classroom and school year conditions. **Per each Type of Experience we propose you 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 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, II 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, 3 and 4	6	7, 8.1, 8.2 y 5	9	12 and 13	3h
ACTIVITIES (Adventure 2)	3 videos	1, 3 and 4	(6)	7,8 and 9	8.3 and 5,	12 and 13	3h
ACTIVITIES (Adventure 3)	3 videos	1, 3 and 4	(6)	7, 8.1 and 11	5 and 10	12 and 13	3h
ACTIVITIES (Adventure 4)	3 videos	1, 3 and 4	(6)	7, 8.1, 10	5 and 11	12 and 13	3h

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

PHASES	0	1	2	3 (@school)	4	Minimum duration
ACTIVITIES (Adventure 1)	3 videos	1,3,4 y 5	6	7, 8.1, 8.2, y 9	12 y 13	3h
ACTIVITIES (Adventure 2)	3 videos	1,3,4 y 5	(6)	7, 8, 9, y 8.3	12 y 13	3h
ACTIVITIES (Adventure 3)	3 videos	1,3,4 y 5	(6)	7, 8.1, 8.3 y 10	12 y 13	3h
ACTIVITIES (Adventure 4)	3 videos	1,3,4 y 5	(6)	7, 8.1, 10 y 11	12 y 13	3h

• **Table III: Research Project: All Activities**

PHASE	0	1	2	3 (@school)	4	Minimum duration
ACTIVITIES	videos	1,2,3,4 and 5	(6)	7, 8, 9, 10 and 11	12 y 13	4h

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

Recommended target age range: (16-18) years old

Recommended academic course: (1-2) Bachelor's degree

Type: Student activity

Complexity: Medium

Teacher preparation time: (1-2) hours

Lesson time required: (1h – several days), depending on the activities requested by the teacher.

Location: Indoors

Includes use of: Computers, internet

Outline

In these Activities students compare Jupiter and the Earth. They will get to know about Jupiter and its moons, as well as their space exploration. Students will choose one of the Galilean moons and measure their main orbital parameters (rotational period and radius).

Considering a 2 body-system (a massive fixed object with another one, neglectable in mass, orbiting around it in circular orbits at a constant speed - with no friction), students will derive the mass of Jupiter.

Students will also access to the Hubble Space Telescope archive and explore the images of the transit of Europa in front of Jupiter. From previous calculations of Europa's orbital period

Curriculum relevance

Physics and Chemistry

- The need of strategies in the scientific activity, the use of ICT and communication skills. Research project.
- Force as an interaction. The 2-bodies system. Dynamics of the circular uniform movement. Kepler laws. Universal Gravitation Law.
- History and composition of the Universe.

Maths

- Planning of the problems solution process. Generation and presentation of scientific forms. Mathematical studies of daily life concepts.
- Approach to basic equations. Trigonometry. Calculations of angles, distances, areas and volumes.

Scientific culture

- Use of ITC for seeking information. Research and exploration of the Universe. Working in teams. Debates.

Students should already know ...

- Orbital Mechanics (velocity and period)
- Kepler's Laws
- Trigonometry
- Units conversion

Students will learn...

- How to apply theoretical knowledge to astronomical situations.
- The basics of astronomy software.
- How to make scientific measurements.
- How to predict astronomical events.
- The easy access to ESA scientific data/archives through ESASky.

Material

- Paper, pencil, pen and a computer with Stellarium software installed

Students will improve ...

- Their understanding of scientific thinking.
- Their strategies of working scientifically.
- Their teamwork and communication skills.
- Their evaluation skills.
- Their ability to apply theoretical knowledge to real-life situations.
- Their skills in the use of ICT.

To know more...

- CESAR Booklets: [Stellarium](#), [El Sistema Solar](#)



Summary of Activities:

Phase	Activity	Material	Results	Requirements	Time
Phase 0	Putting things into context	a) This is ESA b) ESAC: ESA's A window on the Universe c) Presentation to ESA/ESAC/CESAR by Dr. Javier Ventura	Students will get familiar with <ul style="list-style-type: none"> • ESA • ESAC • The CESAR Team • The influence of astronomy in culture 	None	30 min
Phase 1	1. Refresh concepts	a) Mass & weight b) Gravity (ESAKids , NASAKids) c) orbital period d) Kepler's laws (introduction & simulator)	Students refresh: <ul style="list-style-type: none"> • The difference between mass and weight • The concept of gravity • The concept of orbital period • Kepler's laws 	None. This Activity is necessary to refresh the curriculum relevance contents.	30 min
Phase 1	2. Compare Jupiter and the Earth	Table 1	Students improve their skills to: <ul style="list-style-type: none"> • work scientifically in teams. • communicate themselves. • assess their background knowledge. Students improve their knowledge about Jupiter		15 min



Phase	Activity	Material	Results	Requirements	Time
Phase 1	3. The Jovian system	<p>Select your option (time permitting)</p> <p>(PDFs):</p> <p>a) CESAR booklet: The Solar System (Jupiter)</p> <p>b) CESAR booklet: The Solar System</p> <p>ESA VIDEOS:</p> <p>c) The Solar System</p> <p>d) Diverse worlds: The Moon and Titan</p>	<p>Students improve their knowledge about:</p> <ul style="list-style-type: none"> Jupiter, its moons and their role in the Solar System. Other visited moons in the solar system (the Moon and Titan) <p>Students will compare their hypothesis (in Activity 2) with the facts here.</p>	<p>It is recommended to have executed Activity 2.</p>	30 min – 1 h
Phase 1	4. The space exploration of Jupiter by the European Space Agency	<p>Select your option (time permitting)</p> <p>VIDEOS:</p> <p>a) Unlocking the secrets of Jupiter icy moons.</p> <p>b) JUICE's Jovian odyssey trip</p> <p>WEB</p> <p>c) The Jupiter system (JUICE)</p> <p>d) Missions to Jupiter</p> <p>3D MODEL:</p> <p>e) ESA scientific fleet</p>	<p>Students improve their knowledge about:</p> <ul style="list-style-type: none"> The discoveries of Jupiter and its moons performed by Space Agencies (NASA & ESA) The ESA scientific fleet dedicated to explore Jupiter, in particular, the JUICE mission 	<p>It is required to have executed Activity 3.</p> <p>It is recommended to have executed Activity 2.</p>	30 min - 2 h
Phase 1	5. Evaluate what you have learnt until now	.	<p>Students improve their skills for:</p> <ul style="list-style-type: none"> evaluating working scientifically handling ICT tools 	<p>It is required to have executed Activities 1, 3 and 4.</p> <p>It is recommended to have executed Activity 2.</p>	5 min



Phase	Activity	Material	Results	Requirements	Time
Phase 2	6. Ask for a video-call with CESAR Team if needed	a) http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=17&ChangeLang=en	<p>For teachers: [options a) & b)] Teachers will have access to talks given by ESA scientist for the CESAR teacher's workshop sessions related to Jupiter and a tailored class about orbital parameters.</p> <p>For the classroom: [options b & c)] Teachers and students have the chance to watch tailored class about orbital parameters and of having a video call with the CESAR Team</p>	<p>It is required to have executed Activities 1, 3 and 4.</p> <p>It is recommended to have executed Activities 2 and 5.</p>	(30-40) min
Phase 3	7. Choose your favourite Galilean moon.	questionnaire	<p>Students improve their skills for:</p> <ul style="list-style-type: none"> evaluating working scientifically handling ICT tools 	It is recommended to have executed Activities 1 to 6.	10 min
Phase 3	8. Calculate some orbital parameters of your moon. 8.1. orbital radius 8.2. orbital period	Stellarium installed	<p>Students improve:</p> <ul style="list-style-type: none"> Their knowledge of working scientifically and how astronomers make calculations ICT skills Their understanding about how the trigonometry is used in problems solution 	<p>It is necessary:</p> <ul style="list-style-type: none"> To have Stellarium installed (basic guide) To have executed Activities 1 and 7. <p>It is recommended to have executed Activities 5 and 6.</p>	45 min
Phase 3	9. Calculate the mass of Jupiter	Stellarium installed	<p>Students improve their skills for:</p> <ul style="list-style-type: none"> Working scientifically Applying theoretical knowledge to solve problems Handling ICT 	<p>It is necessary :</p> <ul style="list-style-type: none"> to have Stellarium installed (basic guide) to have completed Activity 8 	30 min



Phase	Activity	Material	Results	Requirements	Time
Phase 3	10. Inspect data of a transit in ESA archived data	<p>ASTRONOMICAL DATA:</p> <p>Needed:</p> <ul style="list-style-type: none"> Data set: HSTdata.tar <p>Optional:</p> <ul style="list-style-type: none"> Search and download data from: ESASky <p>ASTRONOMICAL SOFTWARE:</p> <ul style="list-style-type: none"> SalsaJ installed SalsaJ tutorial SAODS9 installed 	<p>Students learn:</p> <ul style="list-style-type: none"> The easy access to the ESA archives through ESASky (search and download astronomical data). To handle astronomical data (FITS format) The basics of astronomical software for data analysis (SAODS9 and/or SalsaJ) <p>Students improve:</p> <ul style="list-style-type: none"> Thinking and working scientifically ICT skills 		1 h
Phase 3	11. Predict the next transit		<p>Students will improve their skills to:</p> <ul style="list-style-type: none"> Work scientifically Make predictions based in findings To handle ITC 	<p>It is necessary to have completed Activity 7.1.</p> <p>Be sure that Activity 8.2</p>	25 min
Phase 4	12. Evaluation	questionnaire	<p>Students will check whether they have had a meaningful learning process.</p> <p>Students improve their team work and communication skills.</p>	Necessary to have completed Activities 1,3, 4,6, 7, 8, 9,10 and 11.	15 min
Phase 4	13. Present your results	Open format (ppt, youtube, Word)	<p>Students improve:</p> <ul style="list-style-type: none"> Their application of theoretical concepts to real life situations. Their teamwork and communication skills. <p>Their knowledge about the Jupiter system and the solar system in general.</p>	<p>Depending on the work identified by the teacher to be done by their class.</p> <p>Necessary to have completed Activities 1,3, 4,6, 7, 8, 9,10, 11 and 12.</p>	30 min – 2h



Your Scientific Challenge

How to get in contact with our unknown neighbours?

Jupiter is the largest planet in our Solar System and from the analysis of their data, scientist consider that life could be found under the water of some of their Galilean moons. Whether we will find them and how will they look like is still an open question.



Figure 1: The movie Contact. (Credit: Warner Bros)

The JUICE - JUpiter ICy moons Explorer - mission is planned for launch in 2022 and arrival at Jupiter in 2029, it will spend at least three years making detailed observations of Jupiter and G anymede, Callisto and Europa.



Figure 2: The JUICE mission (Credit: ESA, <https://www.quora.com/In-which-comic-does-superman-pull-planets>)

In order to plan our travel to the Jovian System, we must know how much is the Mass of Jupiter , **will you help us to do so?**



Phase 0



In order to put into context, we recommend students to watch these videos:

- [This is ESA](#) (10 min)
- [ESAC: ESA's A window on the Universe](#) (3 min)
- [Presentation to ESA/ESAC/CESAR by Dr. Javier Ventura](#) (15 min)
- Here there is another complementary set of [videos](#).

We recommend to **work in teams**, of (4-6) people, with a clear role in their team, assigned per profession. Students will fill Table 1 for the coming Challenge with a name for their Team and the name of the team members after having agreed among themselves on their role in the team.








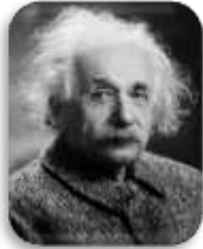
Challenge ID				Team number (1-6):
Names				
Profession	Mathematician/ Software engineer	Astrophysics	Engineer	Biologist
Roles	Lead the correctness of the calculations	Lead the use of telescope and the understanding space missions.	In charge of finding the optimum strategy agreed among the team members and its correct execution.	Lead the more detailed research about the scientific understanding of the energetic processes and composition of the celestial objects.
Reference	Katherine Johnson	Vera Rubin	Samantha Cristoforetti	Marie Curie
(female)				
(male)	Steve Wozniak	Matt Taylor	Pedro Duque	Albert Einstein
				

Table 0: Define the working groups for solving this Challenge.

Note: The documentation makes use of [the International System of Units](#).



Phase 1

Activity 1: Refresh concepts

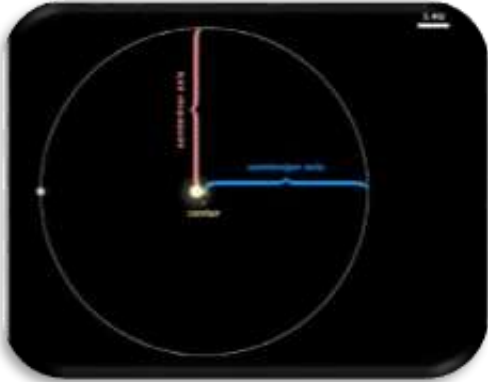

Mass & weight	Gravity: ESAKids & NASAKids	orbital period
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Table 1: Concepts to be refreshed before facing this Scientific Challenge.

Kepler's Laws

Kepler's Laws, published between 1609 and 1619, led to a huge revolution in the 17th century. With them scientists were able to make very accurate predictions of the motion of the planets, changing drastically the **geocentric model of Ptolomeo** (who claimed that the Earth was the centre of the Universe) and the **heliocentric model of Copernicus** (where the Sun was the centre but the orbits of the planets were perfectly circular). These laws can also explain the movement of other Solar System bodies, such as moons, comets and asteroids.

Kepler's laws can be summarised and tested with the [Kepler laws' simulator](#) as follows:

Kepler Laws	Simulator to test that Law
<p>First Law: The orbit of every planet is an ellipse, with the Sun at one of the two foci.</p>	
<p>Second Law: A line joining a planet and the Sun sweeps out equal areas during equal intervals of time</p>	

Third Law: The square of the orbital period of a planet, T , is directly proportional to the cube of the semi-major axis of its orbit, R :

$$T^2 \propto R^3$$

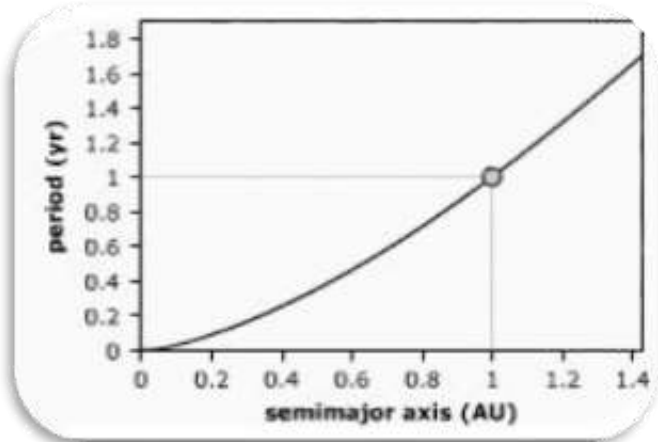


Table 2: Introduction to the Kepler Laws and the simulator where to understand them. (Credit: astro.unl.edu)

How to calculate the mass of Jupiter?

We will derive the equation that we will apply to calculate the mass of Jupiter from the movement of one of its moons, orbiting around it.

For this, we consider the case of Figure 4, where a small body, like the Earth with a mass (m), orbits around another body of higher mass (M), like the Sun. For simplification, we assume that this movement is in a circular orbit, without friction, at a constant speed. The Earth would be in equilibrium, because the gravitational force (F_g) equals the centripetal force (F_c):

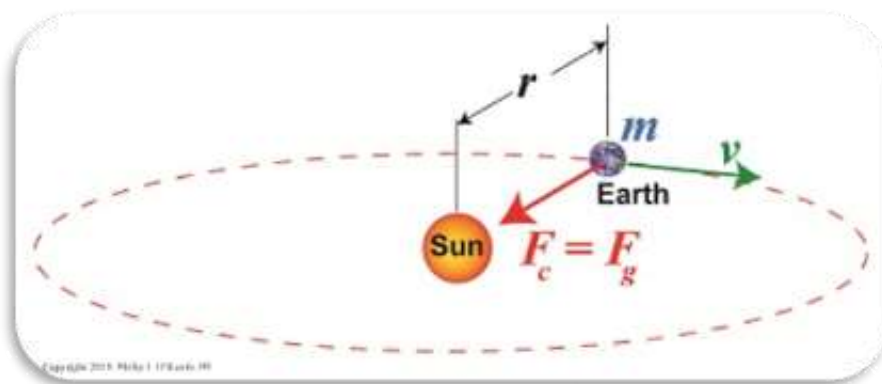


Figure 4: Second Law of Newton (Credit: <https://www.toppr.com>)

$$F_g = F_c$$

$$F_g = \frac{GMm}{R^2} \quad \text{and} \quad F_c = m a_c$$

$$\text{as } F_g = F_c \quad \rightarrow \quad \frac{GMm}{R^2} = m a_c$$



$$\text{as } a_c = \frac{v^2}{R} \quad \rightarrow \quad \frac{GMm}{R^2} = m \frac{v^2}{R}$$

$$\text{and as } v = \omega \cdot R = \frac{2\pi}{T} R \quad \rightarrow \quad \frac{GMm}{R^2} = m \frac{4\pi^2}{T^2} R \quad \rightarrow \quad \frac{GM}{4\pi^2} = \frac{R^3}{T^2}$$

The same situation could be applicable is the massive object (M) is Jupiter (or another planet) and the less massive object (m), one of its moons.

In the equation of the movement, v , is the linear velocity (in metres per second), R , is the radius of its orbit (in metres), ω , is the angular velocity of the moon (expressed in radians per second), T , is the orbital period (in seconds) and, G , is the Universal Gravitational constant, with a value of $G = 6.674 \cdot 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$.

Therefore we can deduce the Third Law of Kepler, for a constant mass, M , (or M_J , in the case of the mass of Jupiter in our Jupiter-moon system) and say "that the square of the orbital period of a planet, T^2 , is directly proportional to the cube of the semi-major axis of its orbit, R^3 ":

$$\text{cte} = \frac{GM}{4\pi^2} = \frac{R^3}{T^2} \quad \rightarrow \quad \boxed{T^2 \propto R^3}$$

From the same equation, we can derive M , or M_J , the mass of Jupiter as follows:

$$\frac{GM}{4\pi^2} = \frac{R^3}{T^2} \quad \rightarrow \quad (\text{Eq. 1}) \quad \boxed{M_J = \frac{4\pi^2 R^3}{G T^2}}$$

Equation 1 will be used in this Scientific Challenge to calculate the mass of Jupiter. We see that by measuring the orbital period and radius of one of the moons, and knowing at the time the distance between Jupiter and the Earth we can estimate the mass of the planet. The measurements are going to be made using the astronomical software Stellarium (<http://stellarium.pdf>)

Figure 5: Stellarium logo. (Credit: Stellarium)



Activity 2: Compare Jupiter and the Earth.

Fill in Table 3 after comparing some properties of Jupiter and the Earth.

	Earth	Jupiter
Radius	6 300 km	69 000 km (11 times Earth radius)
Density	5.5 g/cm ³	1.3 g/cm ³
Average temperature	20° C	-145° C
Distance to the Sun	1 AU	~ 5 AU
Moons	1	79
Type of planet	Rocky	Gas giant
Composition	<ul style="list-style-type: none"> • Silicates mantel, metal core & crust • Atmosphere: nitrogen, oxygen, argon. 	<ul style="list-style-type: none"> • Mainly Hydrogen & helium • Atmosphere: methane, water vapor & ammonia.
Magnetic fields	yes	yes

Table 3: Comparison of some properties from Jupiter and the Earth.

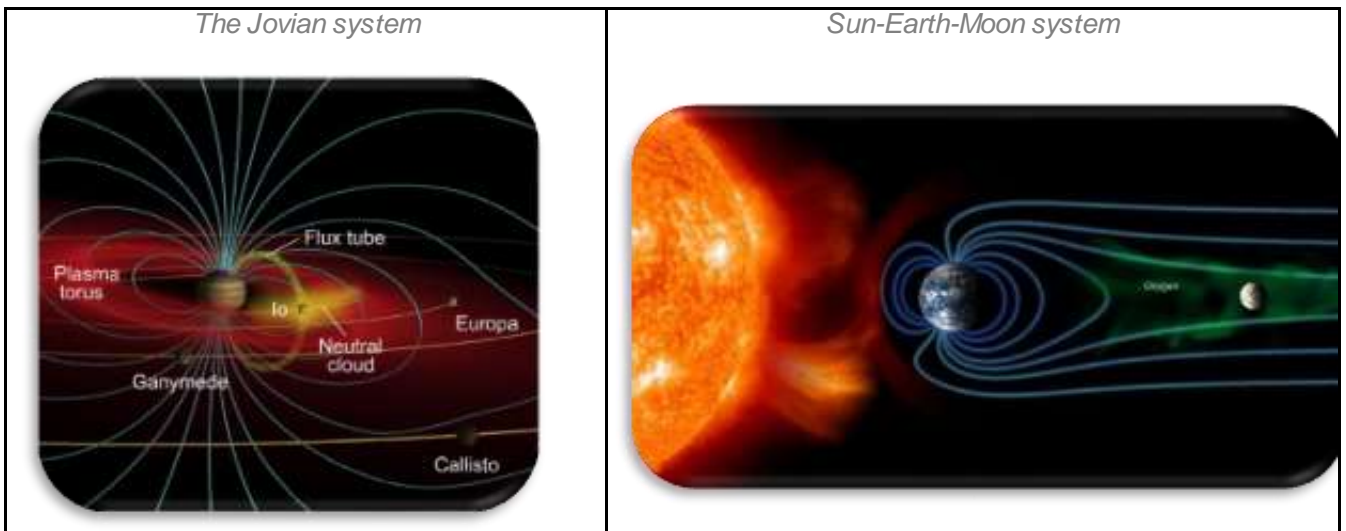


Figure 6: Magnetic fields around the (Credit: http://www.esa.int/Observing_Jupiter)

Activity 3: The Jovian system

The gas giant Jupiter is the largest planet in our Solar System. It doesn't have a proper surface and is made up of swirling clouds of gas and liquids that are mostly hydrogen and helium. Jupiter is so large that about 11 Earths could fit across it. Its mass is more than twice the mass of all the other planets in the Solar System combined.

Jupiter has [79 moons](#) (as of 2020) – the highest number of moons in the Solar System. This number includes the **Galilean moons**: Io, Europa, Ganymede, and Callisto. These are Jupiter's

largest moons and were the first four to be discovered beyond the Earth by astronomer Galileo Galilei, in 1610.

The Galilean moons are distinctive worlds of their own and of high scientific interest. We provide in Table 4 an overview of their appearance and most relevant characteristics.



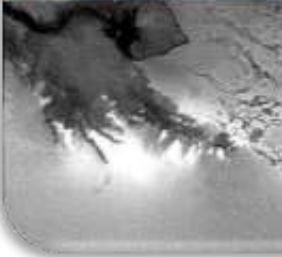









  	  	  	  
<p>The most volcanically active object in all the Solar System due to the inward gravitational pull from Jupiter and the outward pull from other Galilean moons.</p>	<p>A cold world that might have a liquid water ocean beneath a thick layer of surface ice. Of Jupiter's moons, Europa is the one scientists believe is more likely to be habitable.</p>	<p>The largest known moon. There is evidence that it conceals a liquid water ocean under its icy shell; potentially an environment suitable for life.</p>	<p>Has an old and heavily cratered surface, therefore providing a window to explore the early formation of the moons. Also, thought to have an ocean beneath the surface.</p>

Table 4: A modified version of the montage of Jupiter's four large Galilean moons as imaged by NASA's Galileo spacecraft. Image (Credit: NASA/JPL/DLR)

For completeness, time permitting, see some other of the contents provided for this Activity in the Table "Summary of Activities", such as [CESAR booklet: The Solar System](#)

Occasionally we could see the **transit**¹ of its moons in front of Jupiter, as shown in Figure 7.



Figure 7: Image of a transit caused by Io and Europa in front of Jupiter (Credits: Stellarium & CESAR)

Activity 4: The space exploration of Jupiter by the European Space Agency

Jupiter has always been a very interesting astronomical object to study. Since the first observations were made by Galileo using an early version of the telescope huge advancements in technology have been achieved.

Several space missions have flown by close to Jupiter, including **Pioneer 10**, **Pioneer 11**, **Voyager 1**, **Voyager 2** and **Cassini-Huygens**. In addition, other missions have been developed to specifically study Jupiter and its moons. However it was not until 1995 when the NASA's **Galileo** spacecraft became the first to orbit Jupiter and in 2016 the NASA's **JUNO** spacecraft arrived at the jovian system.

ESA is currently working on the JUpiter Icy moon Explorer (**JUICE**), see Figure 8, that is scheduled to be launched in 2022 and arrival at to the jovian system close to 2030. The mission observing targets are Jupiter, Ganymedes, Callisto and Europa, for being the moons that could contain water (and maybe host life?). The [JUICE science objectives](#) are to characterise the conditions that may have led to the emergence of habitable environments among the Jovian icy satellites.

For completeness, time permitting, we recommend you to watch some of the videos provided for this Activity in the Table "Summary of Activities", such as [The Solar System](#), [Unlocking the secrets of Jupiter icy moons](#), [JUICE's Jovian odyssey trip](#), [Diverse worlds: The Moon and Titan](#)

¹In [astronomy](#), a **transit** (or **astronomical transit**) is a [phenomenon](#) when a [celestial body](#) passes directly between a larger body and the observer. The transiting body appears to move across the face of the larger body, [covering](#) a small portion of it.^[4]

[https://en.wikipedia.org/wiki/Transit_\(astronomy\)](https://en.wikipedia.org/wiki/Transit_(astronomy))

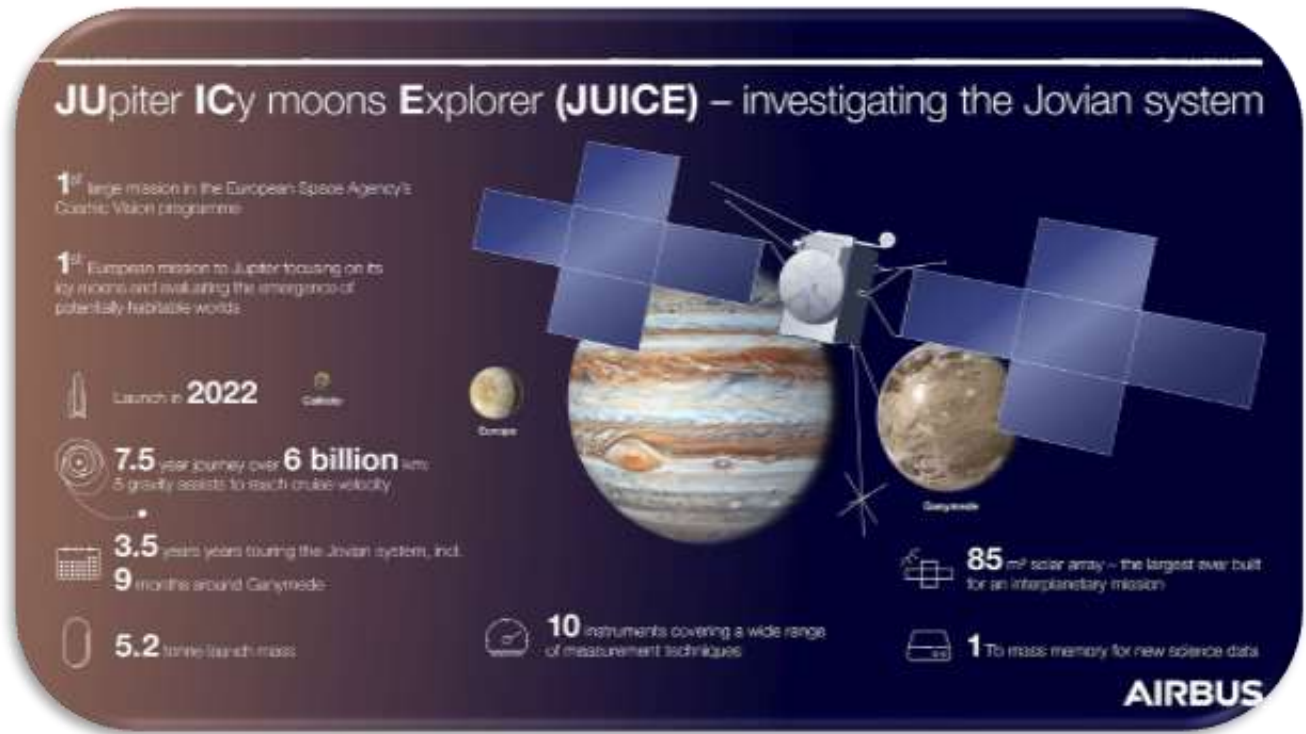


Figure 8: Infographic about the JUICE mission (Credits :AIRBUS)

Activity 5: Evaluate what have you learnt until now

Check what you have learnt so far 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) **using this extra material**

Here the complementary material: (http://cesar.esa.int/index.php?Section=Scientific_Cases&Id=17&ChangeLang=en)	
Expert talks given at CESAR Teacher workshops (pdf and/or videos) ESA dedicated videos CESAR Monographics (booklets) Simulators/websites	

→ **Go to PHASE 3**

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

Activity 6: Ask for a video-call with the CESAR Team if needed

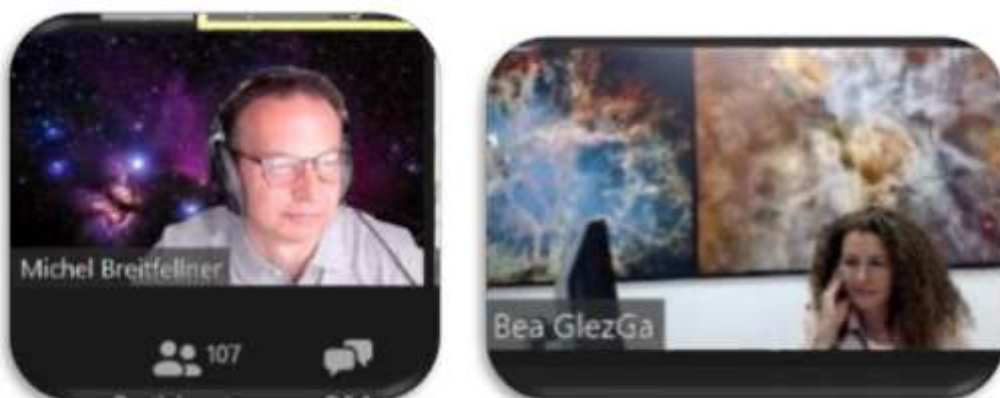


Image of the CESAR Team making a video call (Credits: ESA)



Note: Per scientific challenge you have the opportunity to ask for a 30 min video call

- With your class (in PHASE 2) to clarify concepts
- Teachers only (in PHASE 3) in case you are stuck with software



Phase 3

Activity 7: Fill in information about the Galilean moons. Choose your favourite moon.

In this activity students should fill in Table 5 some of the various properties of the Galilean and select their moon which parameters (orbital period and orbital radius) will be used in Activities 8 and 9 to calculate the mass of Jupiter.

			
<p>The most volcanically active object in all the Solar System due to the inward gravitational pull from Jupiter and the outward pull from other Galilean moons.</p>	<p>A cold world that might have a liquid water ocean beneath a thick layer of surface ice. Of Jupiter's moons, Europa is the one scientists believe is more likely to be habitable.</p>	<p>The largest known moon. There is evidence that it conceals a liquid water ocean under its icy shell; potentially an environment suitable for life.</p>	<p>Has an old and heavily cratered surface, therefore providing a window to explore the early formation of the moons. Also, thought to have an ocean beneath the surface.</p>

Table 5: A subset of Table 4 with the main properties of the Galilean Moons.

If the students do not know which moon to use, keep in mind that Europa will be used for the Activities 10 and 11.

IMPORTANT:

- If you do not want to do many calculations, you can introduce your results from Stellarium into the following Excel table (with formulae). Please make a copy of it and use this copy if desired.
- This [Excel sheet](#) will serve you to make all the calculations of Activity 8 and 9

Activity 8: Calculate some orbital parameters of your favourite moon.

In this Activity students require the use of **Stellarium** to calculate the orbital period and the orbital radius of your favourite Galilean moon. ([Basic guide of Stellarium](#)).

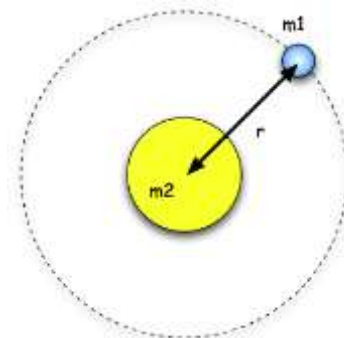


Figure 10: Representation of an orbital radius, r .
(Credits: Wikipedia)

Activity 8.1: Calculate the orbital period of your moon



From Wikipedia:


“The orbital period is the time a given astronomical object takes to complete one orbit around another object, and applies in astronomy usually to planets or asteroids orbiting the Sun, moons orbiting planets, exoplanets orbiting other stars, or binary stars.”

Procedure

- **Step 1: Open Stellarium.** You will be located on a green path in a day or night view, depending on your local time. If the location is active on your device, you will be placed there.



Figure 11: Starting window for Stellarium when opened at a location place where is daytime. (Credits: Stellarium & CESAR)

- **Step 2: Travel to Jupiter.** You may choose any of these two modes:
 - **MODE 1: By using a set of instructions written in a programming language (script)**
 1. **Open a console in Stellarium by pressing F12** (on your keyboard)
 2. **Copy and paste the script from Figure 12 in your console** (Note: You may use CTRL-C & CTRL-V).
 3. **Click on the play button** ().

```
core.setObserverLocation("Madrid, Spain");  
  
LandscapeMgr.setFlagLandscape(false);  
LandscapeMgr.setFlagAtmosphere(false);  
LandscapeMgr.setFlagFog(false);  
  
core.selectObjectByName("Jupiter", true);  
core.setMountMode("equatorial");  
core.setTimeRate(3000);  
StelMovementMgr.setFlagTracking(true);  
StelMovementMgr.zoomTo(0.167, 5);
```

Figure 12: Script to copy into the Stellarium console to view Jupiter close up. (Credit: Stellarium)

4. Check that the view on your screen looks similar to Figure 13. (Note: You can toggle to and from Full view using F11)

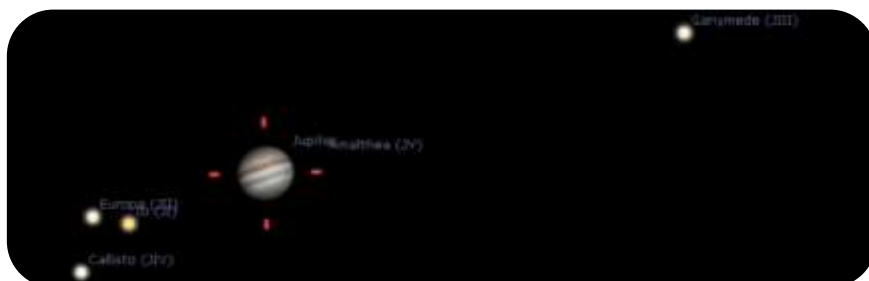


Figure 13: Stellarium view, after running the script. (Credit: Stellarium)

5. **Find your chosen moon in the [Activity 7](#) and watch how it orbits around Jupiter.** We are especially interested in studying and ensuring that the moon is following a



periodic motion. (Note: The movement of the moon will be about 3000 times faster than real, as so is requested in the script).

- a. You need to calculate how long your moon takes to make a complete orbit

○ **MODE 2: By using Stellarium control commands.**

1. Click on this search icon and type in Jupiter, as shown in Figure 14.



Figure 14: Search command in Stellarium (Credits: Stellarium & CESAR)

2. In case Jupiter is not above the horizon or in daylight, in order to observe it, it is required to disable the ground and afterglow (atmospheric) effects, as shown in Figure 15 (the little trees and the cloud will be unselected after that).

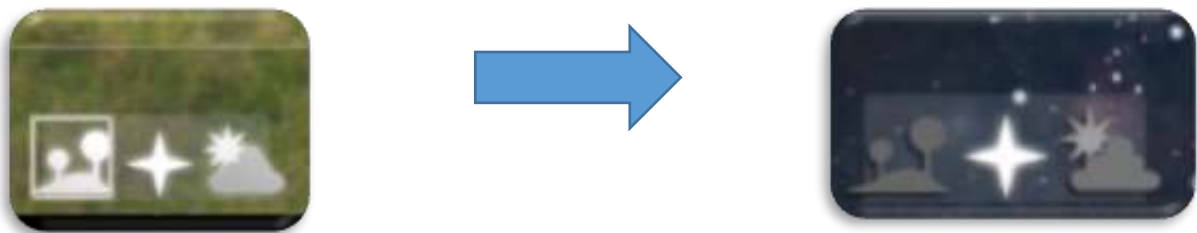



Figura 15: Stellarium control commands to enable (left image) and disable (right image) the ground and the atmosphere effects (Credits: Stellarium & CESAR)

3. With the mouse wheel, you can zoom in on Jupiter and its Galilean moons until they are in your center of vision as shown in Figure 13.
4. In order to follow the movement of the Galilean moons in an horizontal plane, it is recommended to from a simulated telescope with alta-azimuth mount to another one with an equatorial mount. This can be done by enabling this option ()

Note 1: In the following [video](#) (and in Figura 15), we can watch the apparent movement of the night sky, as seen from a particular place on Earth. By changing from the Earth reference system to a fix position outside the Earth, we see the stars as dots almost fixed in position, this is why they are used as references in the field of view of the satellites. The position of the stars tend to be given in the equatorial coordinates system (RA: right ascension and DEC: declination). For example, the star Vega has the coordinates (RA: 18 35 14.66578, DEC: +38 44 09.7806) – check

[Wikipedia](#) and the astronomical database [Simbad](#).

Equatorially mounted telescopes, which we place on the ground, can move in both right ascension and declination. One of their axes is aligned with the North Star. During a night we will see a star moving - due to the Earth's rotation - parallel to the plane of the equator (movement on the axis of right ascension, due to the Earth's movement) and not in declination (angle formed between the equator and the poles), so observing it during the night (or "tracking" it) will require constant movements in right ascension.

High azimuthal telescopes, which we place on the Earth, can move on the height and azimuth axis. Over the course of a night, a star will be seen to move - due to the Earth's spin - in both altitude and azimuth, so observing it at night (or tracking it) will require constant motion on both axes

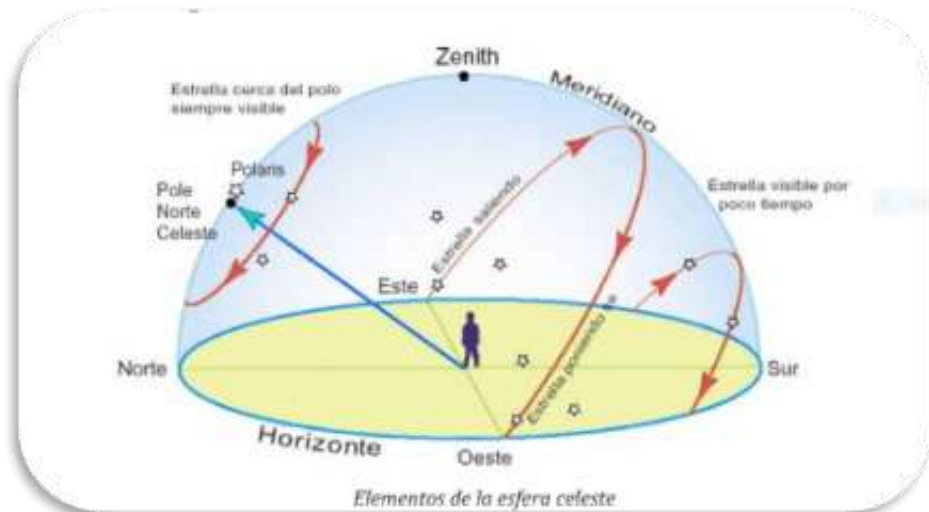


Figura 15: Apparent movement of a star as seen by an observer at a certain location on Earth. (Créditos: <https://www.uv.es/fabregaj/apuntes/AstronPos.pdf>)

Depending on the Earth's latitude where an observer is located will have one or another horizon. Only those stars with a declination above $(90 - \text{latitude})$ degrees could be observe for that observer (if they are visible at night). In the case of Madrid, with latitude of about 40 degrees, only those stars with declination above $(90 - 40) = 50$ degrees could be visible.

Note 2: [Basic ideas for selecting your own telescope](#)



- **Step 3: Calculate the orbital period of your Galilean moon**

To study the orbital movement of the moons, you need to know how to use the basic time setting, which is located at the bottom cursor of the screen:







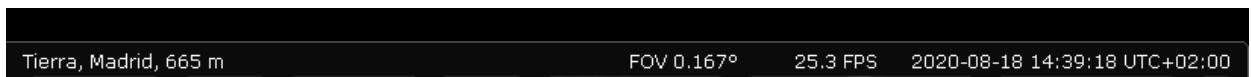
Button	Shortcut key	Description
	J	Decrease the rate at which time passes
	K	Make time pass as normal
	L	Increase the rate at which time passes
	B	Return to the current time & date

Figure 16: Control commands dedicated to moving the time in Stellarium. (Credits: Stellarium & CESAR)

If Step 2 was executed with a script (Mode 1), slow down the movement of the moons by pressing twice the rewind icon.	
If Step 2 was executed by control commands (Mode 2), move the time forward faster by pressing twice the forward icon.	

1. Pay attention to the **“date” and “time”** parameters in the lower part of the display.



2. **Select a starting point** (when the moon is further from the planet) **and write down the date and time in Table 6**. Information of time is given in the format *YYYY-MM-DD hh:mm:ss*, where *YYYY* stands for year, *MM* for month, *DD* for day, *hh* for hours, *mm* for minutes and *ss* for seconds.
3. **Watch the moon make one complete orbit** (what means passing by the starting point once) **and note down the date and time** when the moon returns to the same position. (Note: Use the same time format of *YYYY-MM-DD hh:mm:ss*)
4. **Write in Table 6 the orbital period of your moon (in days and hours)**. (Note: the orbital period is the difference between these two dates calculated)



Example for the moon Europa

Initial date (YYYY-MM-DD hh:mm:ss)	Final date (YYYY-MM-DD hh:mm:ss)
2018-09-01 03:05:00	2018-09-04 15:25:00
<p>Calculate the time difference here</p> <p style="text-align: center;">Same year and month</p> <p style="text-align: center;">(4 – 1) day= 3 days; (15–3) h = 12 h ; (25-5) min = 20 min</p> <p style="text-align: center;">Because 1h = 60 min → 20 min = 0.3 h</p> <p>Nota: This result has an error caused by the uncertainty of a hand-made measurement. The correct value can be found in Table S.1</p>	

Table 6: Initial and final date when your Galilean Moon period is counted.

Period	3 days	12 . 3 hours
--------	--------	--------------

The periods of all the Galilean moons can be found in Table S.1.

Moon	Orbital Period
Io	1 day 18.45 hours
Europa	3 days 12.26 hours
Ganymede	7 days 3.71 hours
Callisto	16 days 16.53 hours

Table S.1: Period of the Galilean moons.

Note: In *Stellarium* we see Jupiter as it is seen from the Earth. However, the orbital motion of the moons is actually circular, we are simply viewing 2 dimensional projections






Figure 18: Visualization of the Jupiter moons (Credit: CESAR)



Activity 8.2: Calculate the orbital radius of your favourite moon

We can consider the orbital radius for our Galilean moon as the furthest distance between Jupiter and the moon, assuming that the moon moves in a circular orbit around Jupiter. Let's calculate it by following the steps in the procedure.

Procedure:

- **Step 1: Configure the plugin "Angle measurement".**
 1. **Open the configuration menu**  (or F2 in your keyboard).
 2. Check in Plug-ins that the functionality "Angle Measure" is enabled
 - If this is not the case,
 - Select the box next to 'Load at start-up' at the bottom of the window.
 - Restart Stellarium
- **Step 2: Identify the orbital radius**
 1. **Stop the movement of the moons around Jupiter** by clicking on  in the menu at the bottom of the screen (or K on your keyboard)
 2. In the same menu, click on  (or press Ctrl + A) to enable the "Angle Measure" plugin.
 3. **Measure the distance between Jupiter and your moon:**
 - Click on the centre of Jupiter and then without releasing drag the cursor to the centre of your chosen moon (as shown in Figure 19). (**Note:** The calculations are only valid if the measurements are made from the centre of both objects. Repeat your measure as many times as needed to be sure that you are comfortable with it).

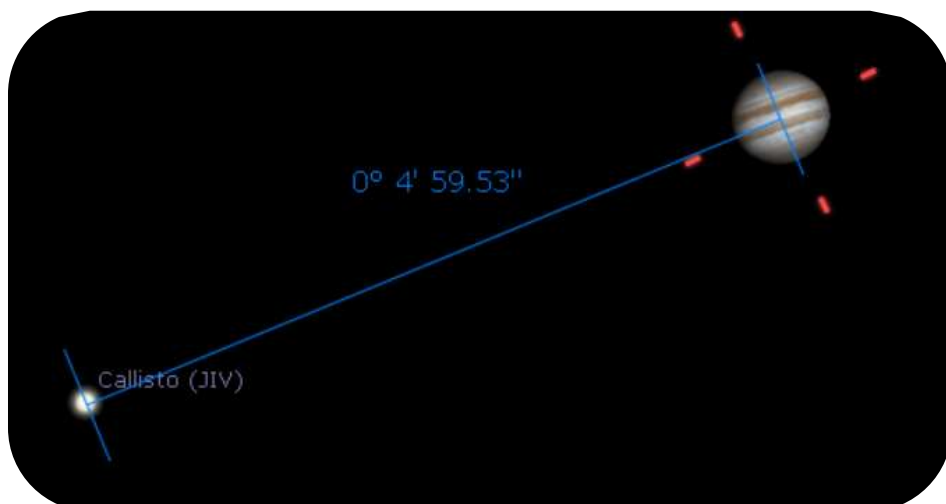


Figure 19: Using Angle Measure plugin. (Credit: CESAR)



4. Record in Table 7 your measurement of the distance between Jupiter and the moon, using the units, degrees, arc minutes, arc seconds, as given in *Stellarium*.

Maximum Distance of your Moon to Jupiter (i.e. Moon = Europa)	0 ° 2 ' 40.31 "	0.0445 °
---	-----------------	----------

Write your calculations here 1° = 3600 "	Remember: 1° = 60' and 1' = 60" →
---	-----------------------------------

Table 7: Calculate the distance between Jupiter and your moon

5. Record in Table 8 the distance from the Earth to Jupiter, d_{JE} , in Astronomical Units and kilometres

Note 1: The **distance** Jupiter-Earth is available in Stellarium by clicking on Jupiter. This information is given in Astronomical Units, as requested by this step.

Note 2: Be aware that the distance (d) in Stellarium represents the distance Jupiter-Sun.

Note 3: As we are also requested to provide the Earth-Jupiter distance in kilometres, you should apply the conversion AU to km. **The distance of 1 AU is the Earth-Sun distance, of 150 000 000 km (149 584 372 km)**

Note 4: The Earth-Jupiter distance is not a constant value along the year.

Convert the distance between Earth and Jupiter from astronomical units into kilometres. Write your calculations here

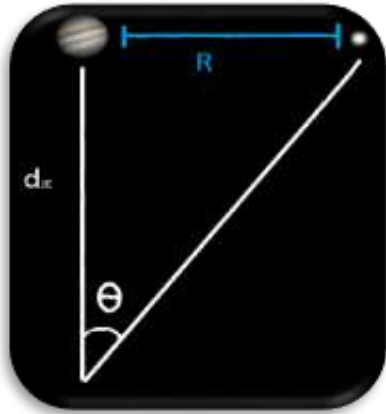
$d_{JE} =$	5.72 au	$8.55 \cdot 10^8$ km
------------	---------	----------------------

Table 8: Distance between the Earth and Jupiter for a particular time (time dependent)

• **Paso 3: Apply your knowledge about trigonometry**

1. Use the diagram shown in Figure 20 to help you with your calculations, where θ represents the angular distance between Jupiter and the moon, d_{JE} , the distance between Jupiter and the Earth and R the orbital radius of the moon around Jupiter.

Note: Remember that for very small angles, as it is the case for the angular radius moon-Jupiter, the value of the tangent of the angle is comparable with the sinus of the angle or even the value of the angle itself.



$$\tan \theta = \frac{R}{d_{JE}}$$

$$R = d_{JE} \cdot \tan \theta$$

$$\tan \theta \approx \sin \theta \approx \theta$$

$$R = d_{JE} \cdot \theta \text{ (Equation 2)}$$

Figure 20: View to calculate the Jupiter-moon distance

2. Use the Equation 2 to calculate the radius of the orbit of the moon, R , (in kilometers) and fill in Table 9 (with its value in meters). Use the values of Stellarium:

- θ : angular radius between Júpiter and the moon (from degrees to radians)
- d_{JE} : Jupiter-Earth distance

$R = d_{JE} \theta$ $R = 8.55 \cdot 10^8 \times 0.0445^\circ \times \left(\frac{2\pi \text{ radianes}}{360^\circ}\right) =$ $8.55 \cdot 10^8 \times 0.00077667151 = 664\,054.15 \text{ km}$		
$R =$	$664\,054.15 \text{ km}$	$6.64 \cdot 10^8 \text{ m}$

Table 9: Results for the orbital radius of the moon Europa

• **Step 4: Calculate the velocity of your moon**

Once you have the radius of the orbit you can calculate the velocity of the moon using the Equation 3

$$v = \omega \cdot R = \frac{2\pi}{T} R \text{ (Equation 3)}$$

where, v , is the linear velocity, ω , is the angular velocity, T , is the period of the moon (in seconds) and R , is the orbital radius of your moon (in metres).

1. Complete Table 10 with the value of the lineal velocity (**Note: In this calculation we are using the value of the period obtained by Stellarium, the correct one is in Table S.1**)



$$T = 3 \text{ d } 12.3 \text{ h} = 3 \times 24 + 12.3 \text{ h} = 84.3 \text{ h} = 84.3 \text{ h} \times \frac{3600 \text{ s}}{1 \text{ h}} = 303\,480 \text{ s}$$

$$v = \frac{2\pi}{303480} 6.64 \cdot 10^8 = 13\,747.31 \text{ m/s} = 13\,747 \text{ m/s}$$

$v =$	$13\,747 \text{ m/s}$
-------	-----------------------

Table 10: Results for the orbital velocity of the moon Europa

Moon	Orbital radius (km) (Semi-major Axis)	Orbital velocity (m/s)
Io	421 700	17 334
Europa	670 900	13 740
Ganymede	1 070 400	10 880
Callisto	1 882 700	8 204

Table S.2: Chart with orbital radius and velocity for each Galilean moon

Note: No solution is provided for the angular distance, θ , since it will depend on the distance from the Earth to Jupiter, which is not always the same.

Activity 8.3: Estimate the relative measurement errors

1. To check the relative errors in calculations students must compare their results with those values after some searching on internet or checking them in Table S.2.
2. To calculate the relative error for any measurement students can make use of Equation 4.

$$E_R = \frac{| \text{Measured Value} - \text{Real Value} |}{\text{Real Value}} \cdot 100 \quad (\text{Equation 4})$$

$$\rightarrow E_R = \frac{| 664\,054 - 670\,000 |}{670\,000} \cdot 100 = \frac{5\,946}{670\,000} \cdot 100 = 0.887\%$$

Table 11: Estimation of relative error for the orbital radius of Europa

Note 1: A negative value for the relative error will probably mean that the absolute value of equation (2) has not been applied.

Note 2: An error of less than or equal to 5% is acceptable.



Activity 9: Calculate the mass of Jupiter

As explained in Phase 1, the mass of Jupiter can be derived from Equation 1.

(Equation 1)

$$M_J = \frac{4\pi^2 R^3}{G T^2}$$

1. Make use of the following area, putting the values for the orbital radius and orbital period obtained from Activity 8 in Table 12:

$$M_J = \frac{4\pi^2 R^3}{G T^2} = \frac{4\pi^2}{6.674 \cdot 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}} \cdot \frac{(6.64 \cdot 10^8 \text{ m})^3}{(303460 \text{ s})^2} = 1.8805066 \cdot 10^{27} \text{ kg}$$

Table 12: Calculate the mass of Jupiter derived from Europa's movement around Jupiter

Activity 10: Inspect data of a transit in ESA archived data.

Hypothesis

1. What do you see in Figure 21?

In Figure 15 we can see the shadow of the Galilean moons projected on the surface of Jupiter. The observer, on a different planet, has to be behind the transiting planet to be able to see it pass. That is, any celestial body behind the observer's one cannot be seen.





Figure 21: Io and Europa transit, using Stellarium. (Credit: Stellarium)

2. Do you think that is correct to say that we can see transits of Galilean moons in front of Jupiter?

3. May we predict these transits? How?

Experiment

- Video tutorial: <https://youtu.be/EbcBJGD1RDw>

Activity 10.1: Getting familiar with ESASky and access to the scientific data of your favourite target

1. Click on ESASky (<https://sky.esa.int>) and select the option “Science”.



Figure 22: Welcome page to ESASky (Credits: ESA)

2. **Search for “Jupiter” in ESASky:** Write the name of “Jupiter” in the search window, at the top right part of ESASky and press “Enter”.

- Access to the observations of “Jupiter” in the ESA archives with scientific images. For this click on the top left second icon (identified in Figure 23, with the shape of a galaxy). This will display a menu similar to the one in Figure 23, where we see squares in green and in purple, that represent:
 - In size:** the amount of imaging observations of Jupiter within the Solar System Objects (SSO) catalogues, stored in the [Hubble Space Telescope \(HST\)](#) and the archives.
 - In colour:** The wavelength at which those observations were collected by their scientific instruments, being green the optical range (for HST) and purple the UV/X-ray (for XMM-Newton).

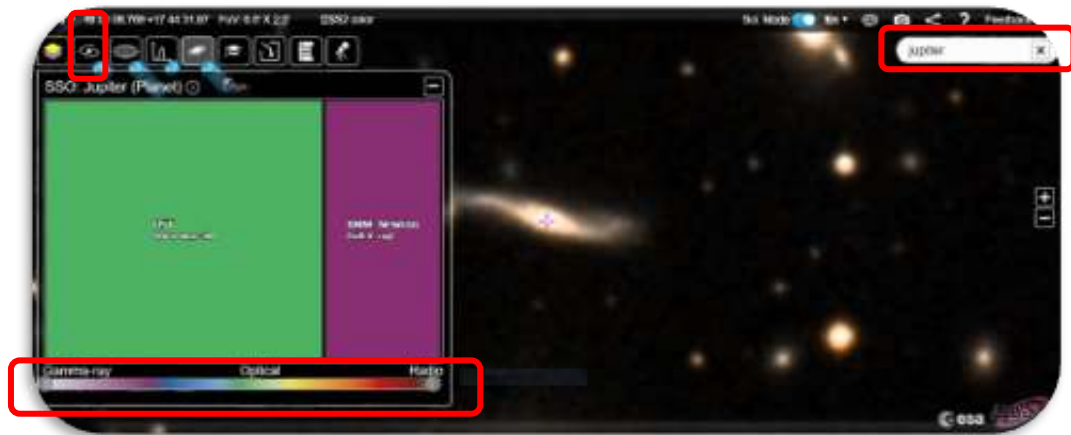


Figure 23: Explore image observations for a selected region (Credit: ESA)

4. Explore the HST data of Jupiter:

- Click on the green square and this will display a table, as shown in Figure 24. The table will display, in slots of 50 observations, the HST images with Jupiter in their field of view.

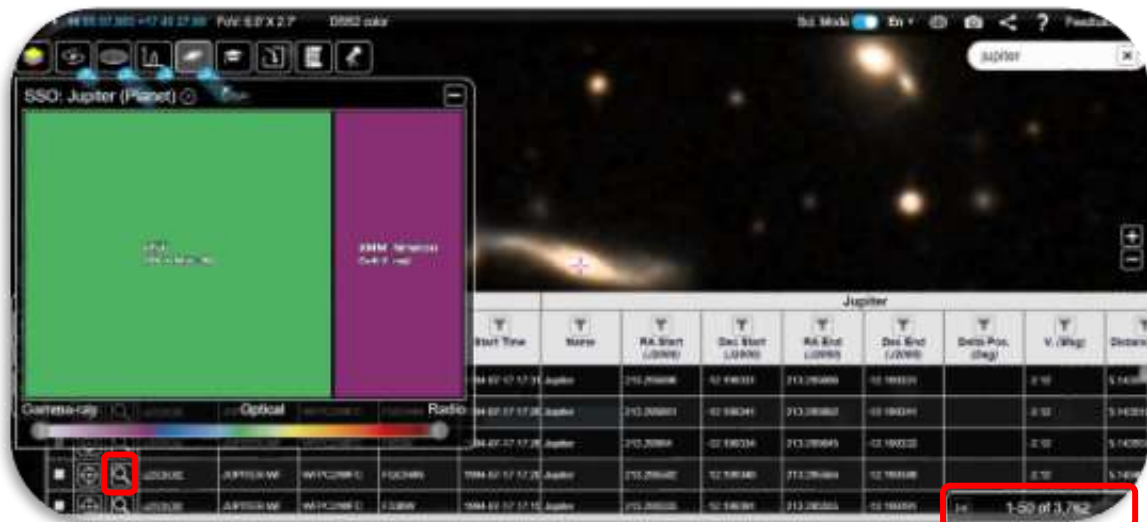


Figure 24: HST imaging observations of Jupiter (Credit: ESA)

5. Inspect images of Jupiter collected by HST:

- Click on the magnifier, as shown in Figure 25.
- By double clicking on the image of Jupiter you will be able to see it better. Resize the image (CTRL+ or CTRL-) as it is shown in Figure 26.

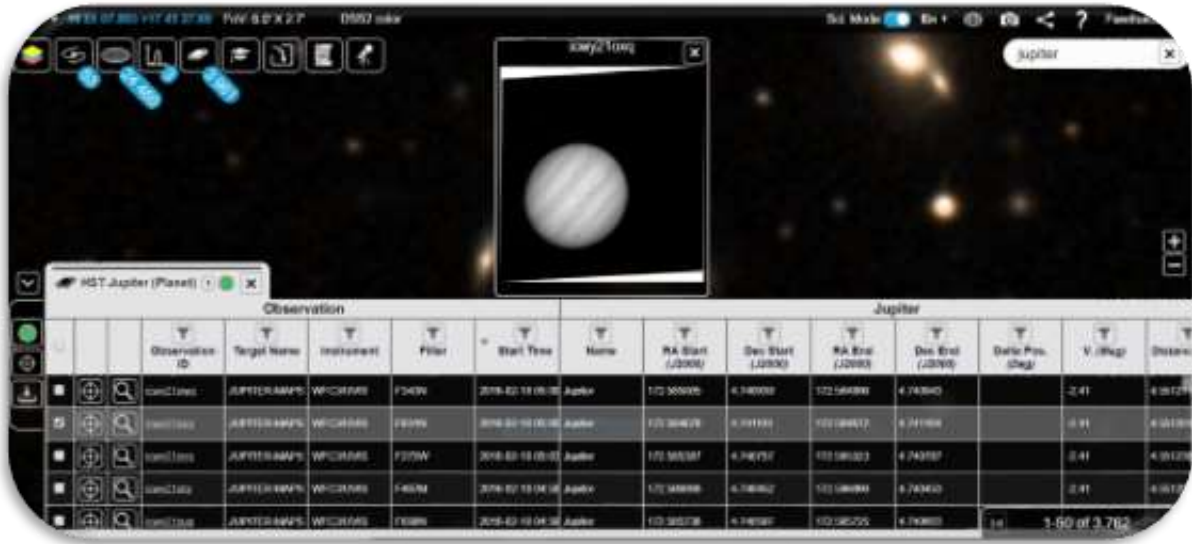


Figure 25: Selection of one of the HST observations of Jupiter (Credit: ESA)

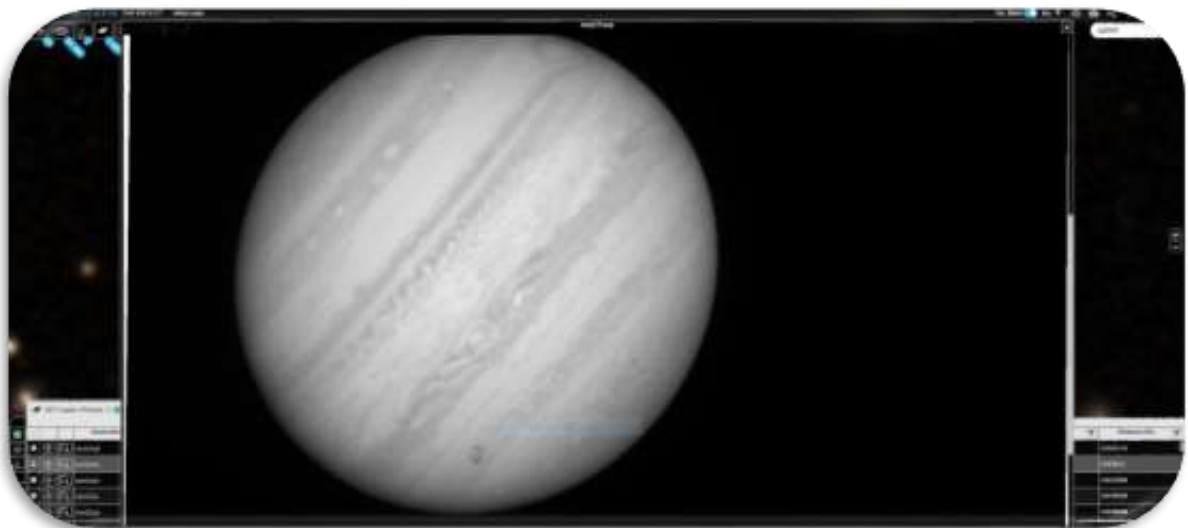


Figure 26: HST image of Jupiter obtained from the image selected in Figure 18 (Credit: ESA)

Activity 10.2: Identify the transit of Europa in the ESASky data of Jupiter

1. After the execution of [Activity 10.1: Getting familiar with ESASky and access to the scientific data of your favourite target](#), let's inspect our list of Jupiter images and search for a transit of Europa.
2. Let's find the HST image collected in 2013-12-29, that means 29th of December in 2013.
3. Organize your table by time. For this you can click at the top part of the column "start time", indicated in Figure 27



Figure 27: Jupiter images collected by HST on 2013-12-29. (Credit: ESA)

4. Once identified, by time, your observation, have a look at the magnifier and inspect it, as shown in Figure 28.



Figure 28: View of one of the Jupiter images collected by HST on 2013-12-29. (Credit: ESA)

We do not know in advance which one the Galilean moon(s) create(s) the transit effect

Why could we know that the transit is caused by a Galilean moon?

The first easiest answer is that this is what the Activity said, that at this time there was a transit of Europa

The second easiest answer could be that because these are the biggest moons in Jupiter it is more probable that we see their transits

The third possible answer is because the name of the target in the observation table said "EUROPA".

Activity 10.3: Analyse data of a transit of Europa as scientist do

Activity 10.3.1 : Inspect HST scientific data with SalsaJ

1. Download the **set of images** ([attached](#)) of a transit of Europa in front of Jupiter collected by [the Hubble Space Telescope](#).
2. Download [SalsaJ software package](#) and install it
3. Open the data (1 dimension FITS format, PNG format, JPG format) in Salsa J ([SalsaJ tutorial](#))

File -> Open -> [select data]

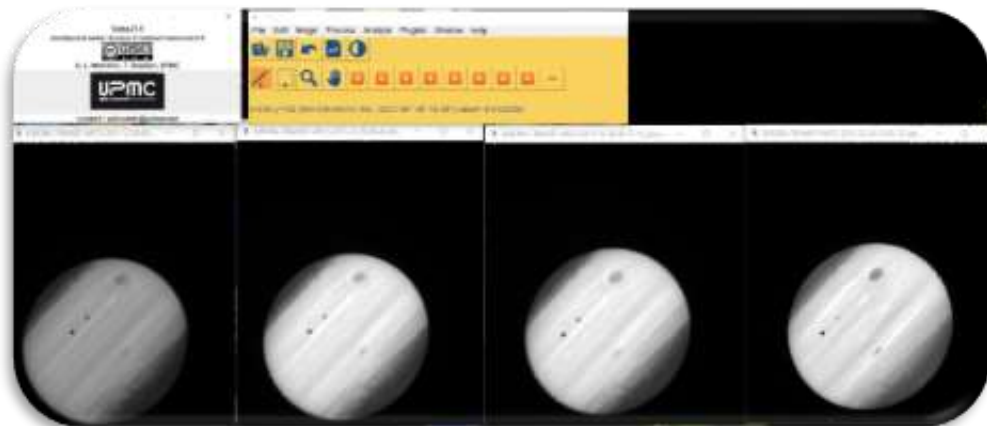


Figure 29: Inspection in SalsaJ of the set of data provided for this challenge. (Credit: ESA/ SalsaJ/ CESAR)

Activity 10.3.2 : Inspect HST scientific data with SAODS9

We are going to inspect HST data of the transit of Europa in front of Jupiter during the time period.

1. Download the **set of images** ([attached](#)) of a transit of Europa in front of Jupiter collected by [the Hubble Space Telescope](#).
2. Install [SAODS9](#) software package
3. Watch [video 3](#) to see how to do so and replicate Figure 24.

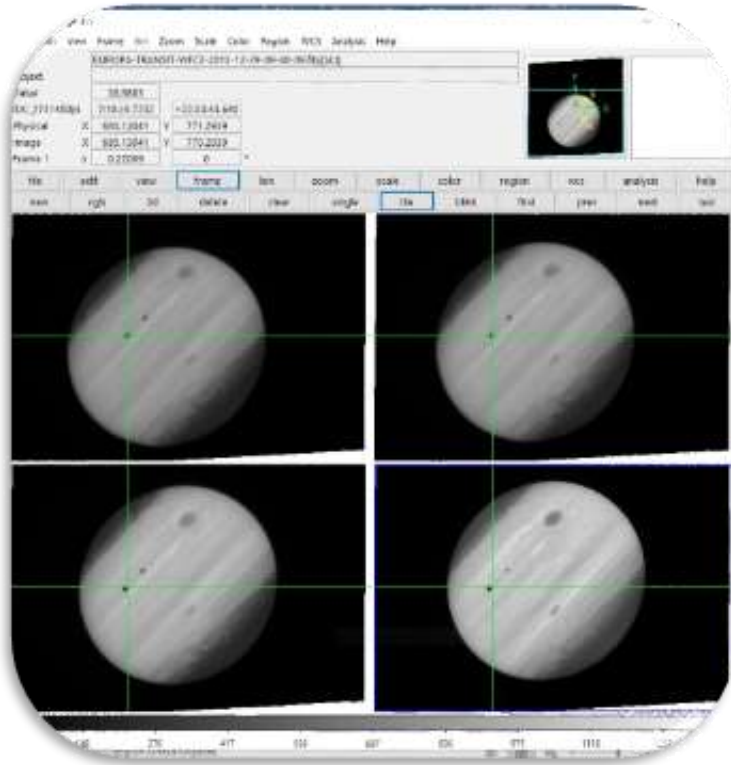


Figure 30: Inspection in SAODS9 of the set of data downloaded from ESA archives for this challenge (HST data of the Transit of Europa observed on 2013-12-29) .
(Credits: ESA/ SAODS9/ CESAR)

Activity 11: Predict a consecutive transit.

Activity 11.1: Predict a consecutive transit with Stellarium

Note: To solve this Activity we need to know the orbital period of Europa around Jupiter.

- If you have calculated the orbital period of Europa (in Activity 8.1), execute the following Procedure.
- If not, return to [Activity 8.1](#) and calculate the orbital period of Europa and afterwards, execute the Procedure.

Procedure:

1. **Open Stellarium**
2. **Travel in location:** search for Júpiter and “go to” it (Use [Activity 8.1](#) as reference)
3. **Travel in time:** search for the date of 2013-12-29T09:40 (edit the Stellarium menu for it)
4. **Do you see the planet Jupiter and the moon shades?**
 - If the answer is YES
 - If the answer is NO, travel in time until you see this picture
5. Predict the following transit as it is shown in this [video](#)



Note: Each time they press the “forward icon” the speed rate is multiplied by 10, therefore just touching this button two or three times the motion will be adequate for this Activity.

Activity 11.2: Other methods to predict a transit

1. Access to the web by clicking on https://skyandtelescope.org/wp-content/plugins/observing-tools/jupiter_moons/jupiter.html

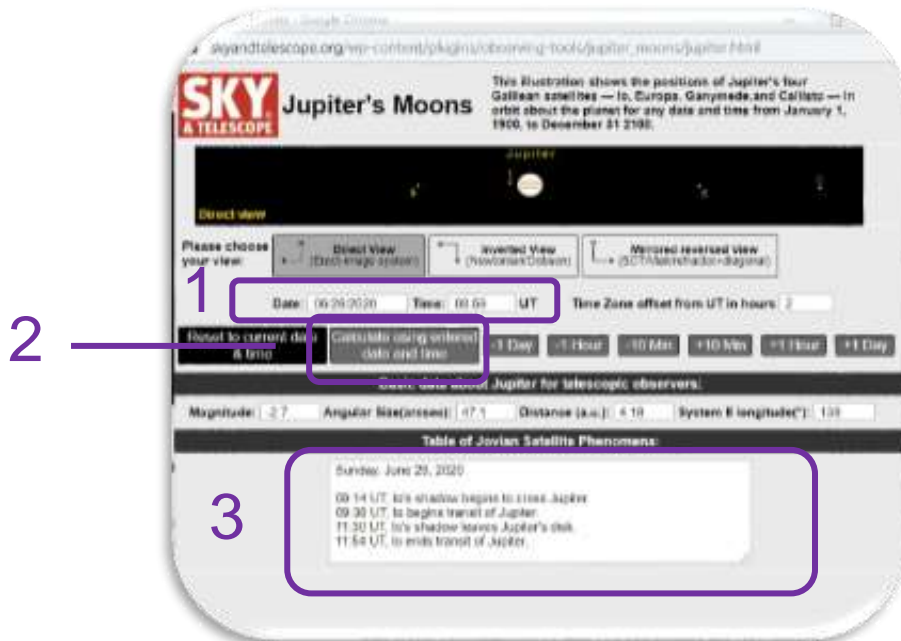


Figure 31: Sky Telescope Jupiter's transits predictor

2. How do I use this web?

- Enter the predicted **date and time** of the transit in the text boxes labelled number 1 in Figure 30.
- Click on “**Calculate using entered date and time**” labelled 2, to have a representation of the moons position at that time.
- All the information will be displayed in the textbox labelled 3.

Conclusions

When was the following transit of Europa, in front of Jupiter after the one detected in 2013-12-29T09:40?





Phase 4

Congratulations!
You have completed your Science Challenge!
Tell us your story!

Stop to think about the Experience with your Team and teacher and complete these Activities.

Activity 12: Evaluation

- **Teams:** Fill in this [questionnaire](#) so that you can check what you have learned in the Challenge.
- **With your teacher:** Give us your feedback

IMPORTANT NOTES

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



Activity 13: Present your results

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

- <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
- <http://cesar.esa.int/index.php?Section=Multimedia&Id=63>
- <https://ingemecanica.com/tutoriales/unidadesdemedida.html>.

Phase 1

- <https://www.youtube.com/watch?v=Y8-T8RouhPA>
- <https://www.pinterest.es/pin/293226625732878538/>
- http://cesar.esa.int/upload/201905/jupiter_moons_booklet_pdf.pdf (Jupiter)
- http://cesar.esa.int/upload/201905/jupiter_moons_booklet_pdf.pdf
- <http://astro.unl.edu/classaction/animations/renaissance/kepler.html>
- <http://stellarium.pdf>
- [http://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_7_Exploring_our_backyard_the_Solar_System/\(lang\)/es](http://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_7_Exploring_our_backyard_the_Solar_System/(lang)/es)



- [https://www.esa.int/ESA_Multimedia/Videos/2013/07/Science ESA Episode 10 Diverse worlds The Moon and Titan/\(lang\)/es](https://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_10_Diverse_worlds_The_Moon_and_Titan/(lang)/es)
- [El sistema solar.](https://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_10_Diverse_worlds_The_Moon_and_Titan/(lang)/es)
- [https://www.esa.int/ESA_Multimedia/Videos/2013/07/Science ESA Episode 10 Diverse worlds The Moon and Titan/\(lang\)/es](https://www.esa.int/ESA_Multimedia/Videos/2013/07/Science_ESA_Episode_10_Diverse_worlds_The_Moon_and_Titan/(lang)/es)
- <https://www.youtube.com/watch?v=gDWftjNUKqk>
- https://youtu.be/tjOn-N_cu0
- <https://sci.esa.int/web/juice/-/50068-science-objectives>
- <https://sci.esa.int/web/juice/-/59908-juice-s-secondary-target-the-jupiter-system> (JUICE)
- [https://sci.esa.int/web/juice/-/59334-exploring-jupiter\(en inglés\)](https://sci.esa.int/web/juice/-/59334-exploring-jupiter(en%20ingl%C3%A9s))
- <http://scifleet.esa.int/#/>
- <http://cesar.esa.int/form.php?id=4&k=&ChangeLang=en>

Phase 2

Phase 3

- <https://drive.google.com/file/d/17yJ25ne0kONn4tje12o3OT-sz3iP7dAa/view?usp=sharing>
- [ESASky](#)
- [SalsaJ installed](#)
- [SalsaJ tutorial](#)
- [SAODS9 installed](#)

Phase 4

- <http://cesar.esa.int/form.php?id=4&k=&ChangeLang=en>
- http://cesar.esa.int/index.php?Section=SSE_Contest&ChangeLang=en

Credits:

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Initial version: http://cesar.esa.int/index.php?Section=SSE_The_Mass_of_Jupiter