Planets, stars, and galaxies

Extract from SCIENCE to GCSE, Stephen Pople, Michael Williams,
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1) Énoncer l'objectif de la séquence:

To start with astronomy, I suggest you to explain what the Solar System is and what place it has in the Universe.

2) Aborder le document dans son ensemble:

Look at the document and answer my questions:

- **What is the document composed of?**

It is composed of a text, pictures and charts.

- **What is the title of each paragraph?**

The Solar System
Stars and galaxies
Exploring space
Models of Universe

- **In which direction do we go in space by reading the text?**

We go from the Solar System to the rest of the Universe.
We go out of the Solar System

- **Do we follow the same progress, the same direction, by looking at the pictures? Say why.**

Yes: firstly, we have one planet, secondly the Solar system, thirdly our galaxy, and finally, another galaxy much farther than ours.

3) Aborder le texte par morceau, en rentrant de plus en plus dans les détails:

Now read the <u>first page</u> by yourself: <u>the Solar System</u>

Laisser du temps.

Let's read it together now.

Interroger les élèves pour lire quelques phrases chacun, corriger les plus grosses erreurs de prononciation, mais pas toutes, pour ne pas rompre le fil de la lecture.

Is there any word you do not understand?

S'assurer de la maîtrise du vocabulaire : expliquer le terme non compris soit en donnant un synonyme, soit en donnant un antonyme, soit en employant le mot dans un contexte bien connu de l'élève, dans une expression toute faite, ou en dernier recours, en le traduisant.

To give off = to emit = to produce
Tiny = very very small
Whether = if
Bits of = little pieces of
Iron = Fe
Dwarf = an adult with little size, who will never grow
Minor = not very important

Now focus on the first paragraph and answer my questions:

- What are the different celestial bodies mentioned in the text?
Planets, moons, comets, asteroids, dwarfs, giants
- What other celestial bodies do you know?
Stars, pulsars, satellites, meteorites…
- What does the Solar System consist of?
The Solar system consists of a star that is the Sun, eight planets (Pluto does not belong to the Solar System anymore), asteroids and satellites.
- What is the difference between planets and stars, like the Sun?
The stars produce their own light (by thermonuclear reactions) *whereas planets only reflect light.*
- Is it easy to distinguish planets from stars to the naked eye? Why?
No, because they look like tiny dots.
- What is the motion of the planets around the Sun?
They have circular motion.
- Does their orbit belong to the same plane?
Yes, this is called the ecliptic plane *(See fig 7 of the document "Space observation")*
We can see that Pluto's orbit is not on the same plane as the other planets. That is one of the reasons why it is not supposed to belong to the Solar System anymore.
- What are the moons of planets, what are they called?
They are called satellites.
- The Moon is the natural satellite of the Earth, but do you know other satellites?
Jupiter has four large satellites. They are named Io, Europa, Ganymede and Callisto.
Except its rings Saturn has a famous satellite, called Titan.
- What are the comets made of?
They are made of ice, gas and dust.
- What trajectory do they have?
They have an elliptical trajectory.
- Do they belong to the Solar System?
No, they come from far away and go far out of the Solar System (See fig 10 of the document "Space observation")

4) Exploiter un schéma et un tableau

Now, let's look at the picture and the chart below:

- What does the picture stand for?

The picture represents the Solar System with the Sun on the left and the planets on the right.
They are aligned to figure the order but the distances are not to scale.

Try to classify the planets by filling the following table:

Laisser du temps, interroger plusieurs élèves au tableau pour corriger.

the name	**inner planets**	**asteroids**	**outer planets**
the nickname	**rocky dwarfs**	**asteroid belt**	**gassy giants**
the size	**small**	**very small**	**large**
the structure	**dense, made of rock and iron**	**rock and iron**	**made of gas**

We can explain the difference in structure by the process of formation of the Solar System. We'll see that next time.

- What are the pieces of information given by the chart?

The average distance from the Sun in million km = the orbit's radius = r
Time for one orbit in years = period of revolution = T
Diameter in km = size
Average surface temperature in Celsius degrees
Number of moons = number of satellites

- Comment on the way the period varies according to the distance from the Sun?
The greater the distance from the Sun is, the longer the period.

- How to check if it is proportional?

Comprendre qu'une fonction croissante n'est pas forcément une relation de proportionnalité.

We calculate T/r and if the ratio is constant, it means that T is proportional to r.

Let's calculate! (Take care about the significant figures) **Respecter les chiffres significatifs.**

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune
r = orbit's radius in million km	**58**	**108**	**150**	**228**	**778**	**1427**	**2870**	**4497**
T= period in years	**0.24**	**0.62**	**1.00**	**1.88**	**11.86**	**29.46**	**84.01**	**164.8**
T/r	*4.1E-3*	*5.7E-3*	*6.67E-3*	*8.24E-3*	*1.52E-2*	*2.064E-2*	*2.927E-2*	*3.664E-2*
T^2/r^3	*2.9E-7*	*3.1E-7*	*2.96E-7*	*2.98E-7*	*2.99E-7*	*2.99E-7*	*2.98E-7*	*2.99E-7*

The ratio is not constant, thus the period is not proportional to the radius of the orbit.

- In the 17th century, a German astronomer, Johannes Kepler stated that the square of the period is proportional to the cube of the orbit's radius.
- Which ratio do we have to calculate to verify this statement?
We must verify that $\frac{T^2}{r^3}$ *is constant.*

Complete the last line of the table. **Savoir utiliser sa calculatrice avec les puissances.**

5) Enrichir sa culture scientifique

- The previous law found by Kepler experimentally was used by Newton to calculate the mass of the Sun.

- Indeed, Newton used his law of gravitation to demonstrate that this ratio was equal to $4\pi^2/GM$, that

is: $\boxed{\frac{T^2}{r^3} = \frac{4\pi^2}{G \times M}}$ **where M is the mass of the Sun**

and G, the universal constant of gravity: G = 6.67 x 10^{-11} SI

Let's calculate the mass of the Sun as Newton did!

- Express the mass of the Sun thanks to the previous formula: $M = \frac{4\pi^2 \times r^3}{G \times T^2}$

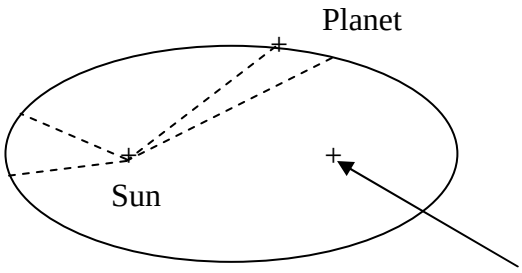
- Take a couple of data in the chart and: **Savoir convertir.**
- Convert r into metre, using the power of ten: **r** = 150 x 10^6 x 10^3 m
- Convert T in second: **T** = 365 x 24 x 3600 s

- Replace in M = $\frac{4\pi^2 \times (1.5 \times 10^{11})^3}{6.67 \times 10^{-11} \times (1 \times 365 \times 24 \times 3600)^2}$ *= 1.99 x 10^{30} kg* *the mass of the Sun*

The previous law was not the only one stated by Kepler, actually it was the third. Two others describe the motion and the speed of the planets around the Sun:

The first law states:
A planet moves in an ellipse, with the Sun at one focus.

The second law states:
The closer to the Sun a planet is, the faster it goes.



Or: the line from the Sun to a planet sweeps equal areas in equal times.

Back to the table of data:

-What about the average surface temperature of the planets according to the distance from the Sun? How does it vary? Can you notice anything about the figures?

The average surface temperature of the planets seems to decrease with the distance, except for Venus. The farther the planet is, the colder. The closer the planet is, the hotter, except Venus.

Indeed, the atmosphere of Venus is mainly made of CO_2 (and sulphuric acid), so that there is a very important greenhouse effect. This effect warms the planet up and increases its temperature abnormally.

6) Construire une réalisation personnelle pour ancrer son savoir et travailler sa représentation dans l'espace.

Homework: **Savoir choisir et utiliser une échelle.**

- Build a frieze which represents the Solar System. Use a piece of paper 5cm wide and 50cm long.
- Draw an axis, with the Sun at its origin. Represent the planets (except Pluto) by coloured dots at their respective distance from the Sun.
- Which scale do you have to choose? Write down your calculations!

7) Travailler les grands nombres et utiliser l'année lumière.

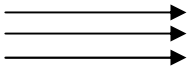
Let's look now to the second page of the document: Stars and galaxies.

Interroger des élèves pour lire la première partie du texte.
S'assurer de la compréhension du vocabulaire:

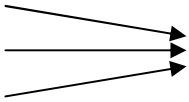
Find a synonym for:

huge: *enormous*
a beam of light : *rays of light,*

examples: **parallel** beam of light:



converging beam of light:



bright: *luminous, full of light*
a cluster: *a group*
major: *very important*

S'assurer de la compréhension du texte:

Questions about this part:

- Which galaxy do we belong to?
We belong to the Milky Way.
- Where is our Sun in the galaxy?
It is on an arm of the galaxy which is a spiral galaxy. It is on the edge of the Milky Way.
- What is the origin of the nickname "Milky Way"?
When we look at a starry night, we can see a bright band across the night sky just like a white way.
- Where does it come from? Give an explanation.
When we see this band, it means we are looking towards the centre of the galaxy that is in the direction of most of the stars, that is why it is so bright.
- Which other galaxy is "close" to ours?
The Andromeda galaxy is another galaxy which belongs to the same cluster as ours.
- How far is it from us?
It is 2 million light years away.
- What does it mean?
It means that the light takes 2 million years to cover the distance between Andromeda and us.

Exploiter les données pour aller plus loin:

- Is that a great distance? Could you be able to convert it in km?
- What would you need to make this conversion?
We need the speed of light.
- What is the speed of light according to the text?
300000 km/s

Work out the light year into km and prepare yourself to justify.

Laisser du temps aux élèves pour faire le calcul et pour réfléchir à la manière de l'expliquer oralement. Suivant l'aisance des élèves, on peut leur demander de travailler seul ou par deux.

Interroger les élèves au tableau. Et demander la participation de la classe si nécessaire.

The light covers 300 000 km in one second. To know how many km it travels in one year, we must convert one year into seconds.

1 year = 365 × 24.0 × 3600 = 31.5 × 10^6 s

Thus a light year = 300 000 × 31.5 × 10^6 = 9.45 × 10^{12} km

- What is the order of size in km?
That is about 10^{13} km

- What does it correspond to, in billions of km? **Travailler l'expression des grands nombres.**
10 000 billion km or 10 000 billions of km

Manipuler les grands nombres et les puissances de 10.

Let's read the paragraph: Exploring space

Expliquer le vocabulaire nouveau par des synonymes ou des dessins:

Unmanned: with nobody.
Spacecraft: same as aircraft (airplane) but for space.
Space **probes**: a device which is able to test, to analyse soil and atmosphere.
To rely: to be dependent on.

What are the different steps of the space exploration?
→ *Men on the Moon (1969)*
→ *Unmanned spacecraft on Mars and Venus*
→ *Space probes next to the most of the outer planets*

What is the main problem of travelling through space?
→ *It takes too much time.*

Find out what time it takes in light time to go to …

- **Alpha Centauri** → *4 years*
- **The Pleiades** → *400 years*
- **Andromeda galaxy** → *2 million years*