Getting to Know SOHO

Studying the Sun

Classroom Activity

Material List:

- Internet Access (not essential)
- Pen/pencil
- Paper
- Calculator

Outline

In this activity, you are introduced to the ESA/NASA joint mission, SOHO. Learning about the different instruments on board the satellite and how they observe in different wavelengths of the electromagnetic spectrum in order to study different regions of the Sun.

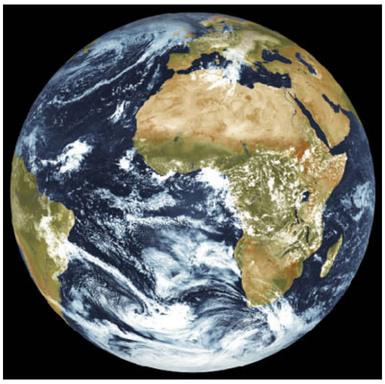
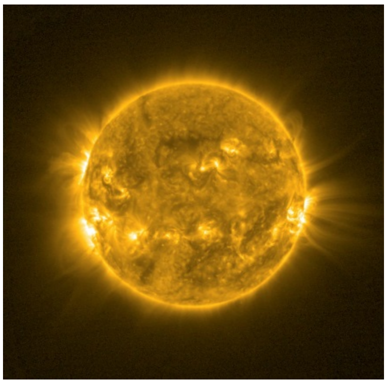
You look into SOHO's orbit and its position in the Solar System relative to the Sun and Earth and perform mathematical calculations and apply scientific concepts. develop your understanding of concepts such as speed and distance calculations and gravitational potential energy.

Procedure:

1. Read through the 'Getting to Know SOHO Background' document.

2. Take a look at images 1a, 1b and 1c. Name the objects you see in these images.

The online observatory collaboration consists of the following partners:
Baldone Observatory, Brorfelde Observatory, Cardiff University, Harestua Solar Observatory, Helsinki Observatory

3

Answer the following questions:

What differences do you notice about these objects?

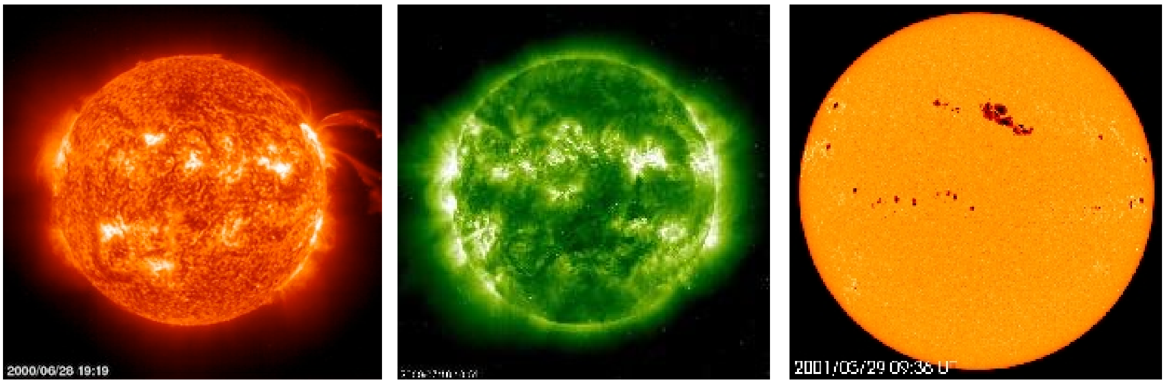
Do you think they all have the same brightness?

What is the source of their light?

Are these objects all the same size?

Are these objects all of the same composition? How might they be different?

4 Look at figures 2a, b and c. Do you know what these objects are?



5 Answer the following questions:

What differences do you notice?

What do you think is the reason for these differences?

6

Take a closer look at figure 2c.

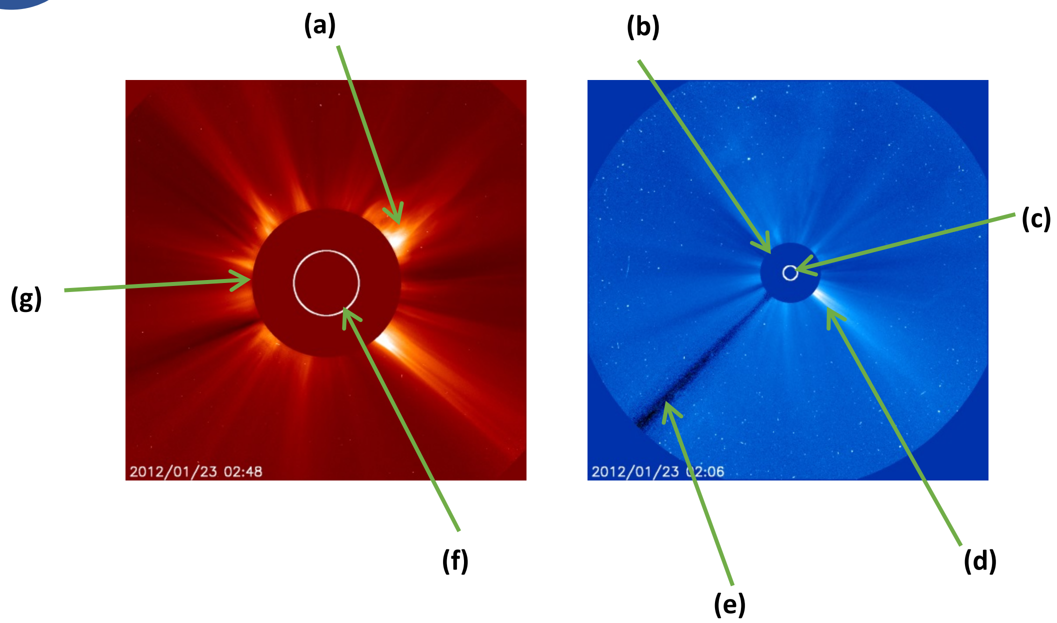
What features do you notice? Do you know what they're called?

Can you think of why they might be a different colour to the rest of the object in the image?

Hopefully you will have recognised that Figures 3b, 4a, b and c are all the Sun. The Sun is our closest star which means scientists can study the Sun in order to help develop our understanding of all other stars in the Universe.

7

Take a look at the images taken with different LASCO filters



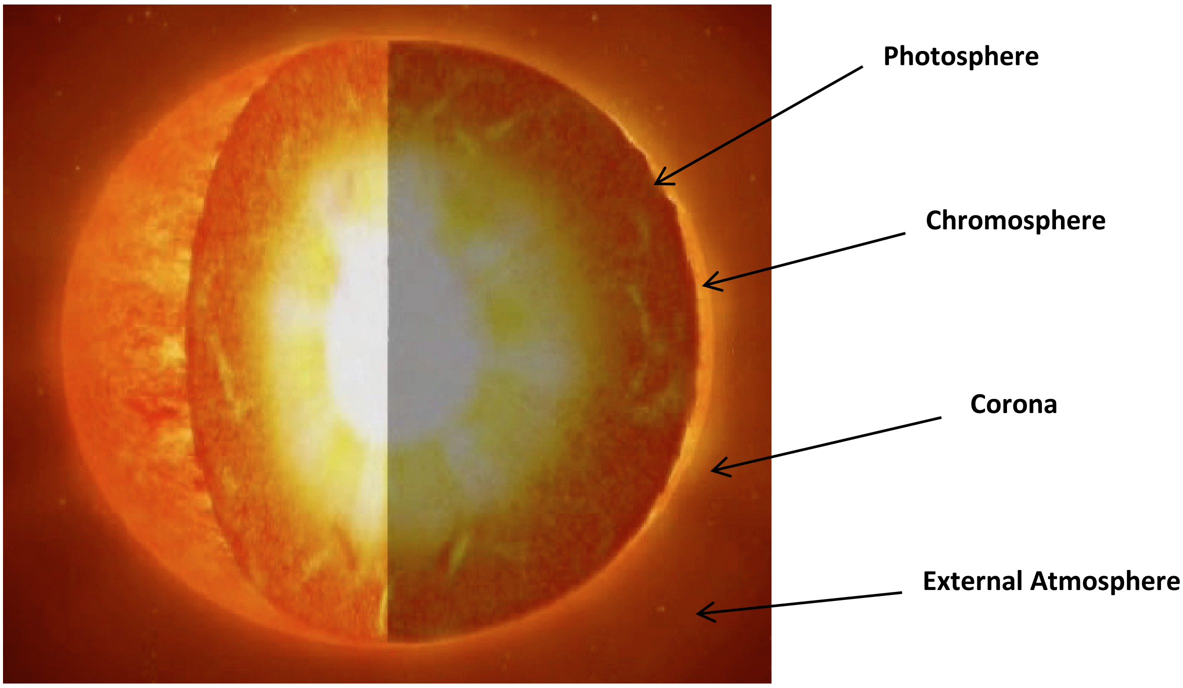
What do you think are the differences between these two filters?

Why do you think they might be different colours?

Can you identify what the labels (a), (b), (c), (d), (e), (f) and (g) point to?

8

Match the equipment on SOHO with the part of the image it would be used to observe



9

Given what you have learnt about the wavelengths the different instruments use. What wavelength of light would you choose if you wanted to observe the following regions of the Sun?

The Low Corona:

The Solar Wind:

The Photosphere:

What particular tool would you need if you wanted to study solar prominences (a feature that extends out from the surface of the Sun) or coronal mass ejections?

Earth Orbits and Lagrange Points

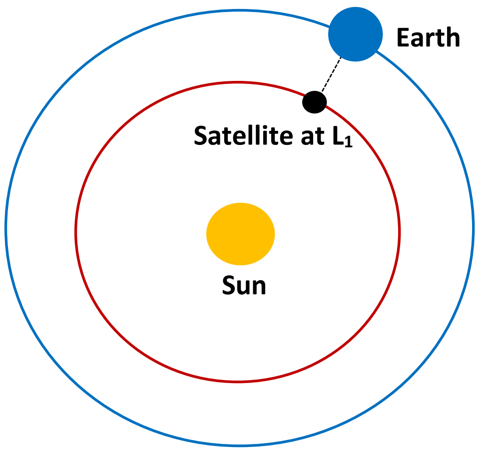
Satellites can be launched into a number of different orbits depending on their objectives and what they are observing. Many satellites are launched into an orbit in which they circle around the Earth as they orbit the Sun (the Moon also does this). However, this is not the only viable orbit for a satellite.

Stable orbits are also possible at special locations known as Lagrange points. At these orbital locations, satellites do not circle the Earth but rather orbit the Sun in sync with it.

The five Lagrange points, named after the astronomer and mathematician, Joseph-Louis Lagrange, are positioned at locations which are made **stable** for satellite observations due to a balance of **gravitational forces** and **orbital motions** of the Earth and the Sun. Let's take a look at each of the points individually.

10

Lagrange point 1 (L_1) follows an orbital path that is closer to the Sun than Earth's orbit. Show how the Newton (N) is the unit of measurement for the gravitational force that is calculated between two objects in Equation 1:



Equation 1: $F_g \frac{G\, m_1 m_2}{r^2}$

Where:

- F_g = force due to gravity
- G = gravitational constant
- m_1 = mass of central body
- m_2 = mass of orbiting body
- r = distance between the two bodies

What gravitational influences would you expect an object located in the L_1 position to experience?

What is the definition of a centripetal force?

Using Equations 1 and 2, how would the orbital velocity of an object differ from Earth's if located closer to the Sun?

Equation 2: $$F_c = m\frac{v^2}{r}$$

Where:

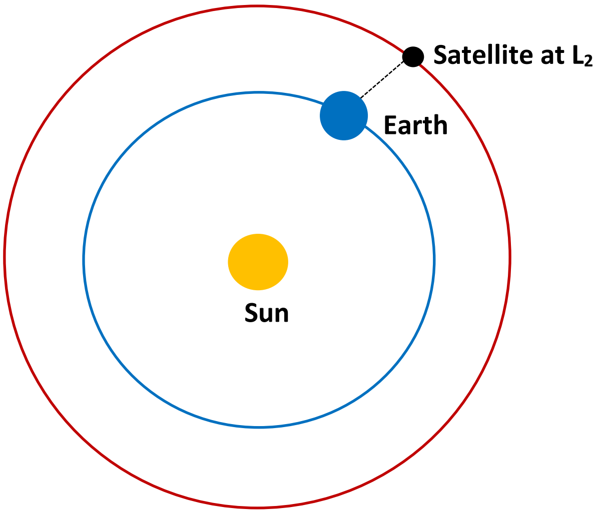
F_c = centripetal force (N)
m = mass of orbiting body (kg)
v = orbital velocity (m s^{-1})
r = distance between the two bodies (m)

However, an object on an L_1 orbit does not overtake the Earth on its orbit. L_1 is positioned at a specific distance of 1.5×10^6 km from the Earth so that the extra influence of gravity that the object should experience from the Sun is cancelled out by the gravitational pull from Earth in the opposite direction.

As a result, the object's orbital speed is **reduced** and therefore stays in pace with the Earth.

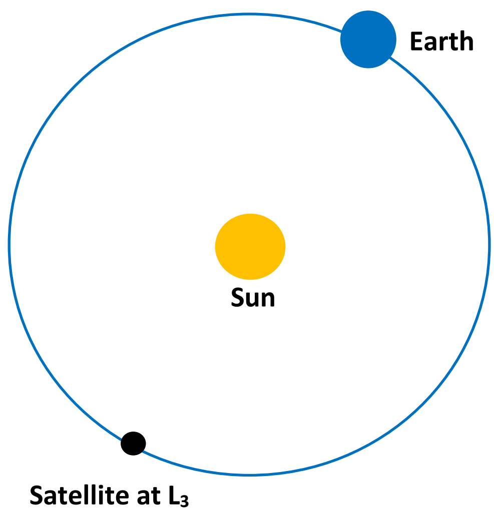
11

Like L_1, **Lagrange point 2 (L_2)** is also located 1.5×10^6 km away from Earth. However, L_2 lies **further** from the Sun, placing it outside Earth's orbit rather than inside like L_1. For an object located further away from the Sun, how would you expect its orbital velocity to differ from Earth's?



12

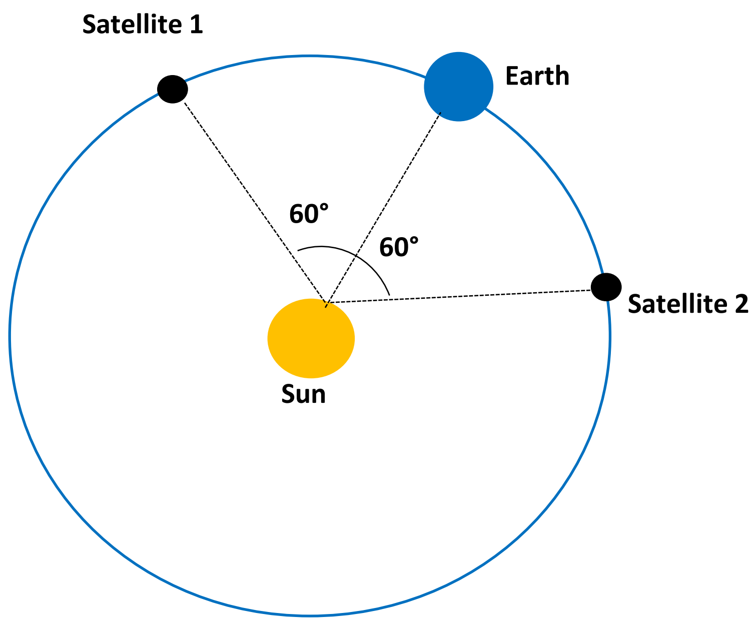
Lagrange point 3 (L_3) is located at much greater distance from Earth, positioned behind the Sun, directly opposite Earth's orbital position. A satellite located here would follow the same orbit as Earth just on the opposite side of the Sun.



For an object positioned at the L_3 point, how would you expect its orbital velocity to compare to that of Earth?

13

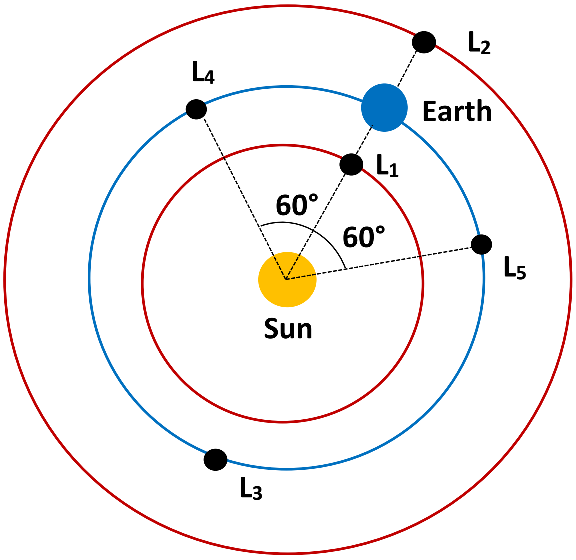
Lagrange points 4 and 5 (L4 and L5) are positioned at **60 degrees** ahead (L4) and behind (L5) of Earth's orbit. The Earth is orbiting the Sun in an anti-clockwise direction. Which Lagrange points do satellites 1 and 2 correspond to?



To take a look at some animations of orbits on the Lagrange points, follow the link below:
http://www.esa.int/Our_Activities/Operations/What_are_Lagrange_points

14

Now you are familiar with the different orbital positions on the Lagrange points, we can apply them more specifically to SOHO.



Given what you know about the SOHO satellite and what its mission objectives are. Which of the Lagrange points do you think would be the most suitable for SOHO's position? Justify your answer.

Which of the Lagrange points do you think would be most suitable for a satellite built to observe more distant objects in the Universe, outside of our Solar System?

Why do you think an orbit on Lagrange point 2 would not be suitable for SOHO?

15

Now that you are familiar with the SOHO mission, its place in the Solar System and its mission objectives, we can see how this all applies to some of the scientific concepts and mathematical formulae in your curriculum.

Work your way through the following questions and record your answers as you proceed.

1. Use the information provided and Equation 1 to calculate the force of *gravitational attraction* between SOHO and the Sun.

Equation 1: $F_g \frac{G\, m_1 m_2}{r^2}$

Gravitational Constant = 6.67×10^{-11} m^3 kg^{-1} s^{-2}

SOHO – Sun Distance = 1.481×10^{8} km

Mass of Sun = 1.99×10^{30} kg

Mass of SOHO = 1,850 kg

2. SOHO is positioned at a distance of *1.5×10^6 km* from Earth inside its orbit. What is the total distance covered by SOHO in one orbit around the Sun? (State your answer to 4 significant figures).

Earth's Distance from the Sun = 1.496×10^8 km

3. SOHO orbits the Sun in approximately the same time as the Earth does. Use this information and your answer from Question 3 to calculate the *orbital speed*. Give your answer in *$km\ s^{-1}$*.

4. Use Equation 2 and your answer in Question 3 to calculate the *centripetal force* on SOHO's orbit around the Sun.

Equation 2: $F_c = m\frac{v^2}{r}$

5. How does the centripetal force you calculated in Question 4 compare with the value you obtained for Question 1?

6. Assume the average running speed of a human is $4.0\ m\ s^{-1}$. How does this compare with the velocity of SOHO's orbit around the Sun?

7. If you were to run the distance of SOHO's orbit at *4.0 m s⁻¹*, how long would it take you to complete one orbit? Give your answers in *years*.

Hint: You will need to use your answer from Question 2.

8. What is the corresponding *frequency range* of the following instruments?

Speed of Light = 3.00×10^8 m s^{-1}

a). VIRGO

b). SWAN

/. The **Atlas-IIAS** launch vehicle that sent SOHO into orbit has a total mass of **236,268 kg.**

9. The launch is made up of two stages. The first stage involves two boosters that each deliver **2,093 kN** (kilonewtons) of thrust and four boosters delivering **478 kN** each. The second stage then delivers **174 kN**.

a). Calculate the vertical *acceleration* of Atlas-IIAS.

Acceleration due to gravity on Earth = 9.81 m s^{-2}

b). What *percentage* do the two stages contribute to the total thrust of Atlas-IIAS?

Now you have learnt about some of SOHO's key features and the mathematical and scientific concepts involved, let's see what you can conclude from the activity.

10. What considerations need to be made when deciding on an orbit for a satellite?

11. How is SOHO able to look at so many different regions of the Sun?

Further Work:

Once you have carried out the activity and completed the Student Worksheets, you can discuss some of the reasons for why scientists study the Sun and why it is important.

Below are some suggested points you may want to raise:

- Weather
- Global climate change
- Satellites, communication and navigation systems
- Electric power stations
- Radiation hazards for satellites
- Radiation hazards for astronauts