STUDYING ASTEROIDS

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In this activity, students will learn about asteroids and where they can be found in our Solar System. They will spot an asteroid through real images from the Faulkes robotic telescopes and calculate the speed of an asteroid.

EDUCATIONAL CONTEXT

AGE

13-18

DURATION

2 school hours

PREREQUISITES

Pythagorean theorem, trigonometry (sin), velocity, inertial and non-inertial frame of reference

EDUCATIONAL OBJECTIVES

WHAT DO YOU AIM FOR YOUR STUDENTS TO LEARN THROUGH THIS ACTIVITY

COGNITIVE OBJECTIVES

To define what asteroids are and where they can be found in our Solar System.
To use math to calculate the speed of an asteroid.
To explain why it is important to study asteroids.
To explain how an asteroid can be spotted in telescope images.
To recall that astronomers use coordinated to define the position of a celestial body.

AFFECTIVE OBJECTIVES

To share his/her thoughts and ideas with the rest of the classroom.
To increase his/her interest about science, astronomy and space exploration.
To enjoy the activity.
To be intrigued to find out more about the topic.

CONNECTION TO THE CURRICULA (GREECE)

- Physics 2nd Grade of Junior High School(Velocity)
- Physics 2nd Grade of Junior High School (Describing a motion)
- Math 3rd Grade of Junior High School (Trigonometry)
- Physics 1st Grade of High School (Circular motion)
- Math 2nd Grade of High School (Trigonometry)
- Skills Lab

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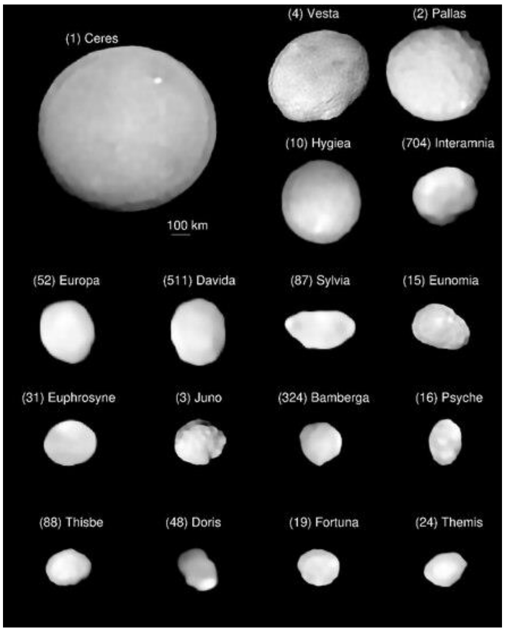
StAnD

ORIENTING & ASKING QUESTIONS

- **What are asteroids and where are they located?**

There is no official definition for asteroids. They can be defined/described as «an irregularly shaped rocky body orbiting around the Sun that does not qualify as a Planet or Dwarf-Planet». Asteroids are **rocky** remnants from the formation of our solar system that orbit the Sun. Sometimes they are called minor planets, and they can **range in size** from a few meters to hundreds of kilometers in diameter. The largest asteroid (Vesta) is about 530 kilometers in diameter while the smallest asteroids are less than 10 meters across. The total mass of all the asteroids, in our Solar System, combined is less than that of the Earth's Moon.



Examples of asteroids with their names. (P. Vernazza et al. (2021) "VLT/SPHERE imaging survey of the largest main-belt asteroids: Final results and synthesis." A&A 654, A56. doi.org/10.1051/0004-6361/202141781)

The area with the most asteroids in the Solar System is the Main Asteroid Belt. It is located at approximately 2.1 – 3.3 AU from the Sun and it contains the vast majority (90%) of known asteroids.

The main asteroid belt is a vast, ring-shaped region located between the orbits of Mars and Jupiter. While often depicted as a densely packed field of space rocks, the asteroid belt is actually quite sparsely populated. The average distance between asteroids is hundreds of thousands of kilometers.

Despite the vast area of the main asteroid belt, millions of asteroids inhabit this region. They vary significantly in size, from small rocks to objects several hundred kilometers across. The largest asteroid, Ceres, is so massive it has been reclassified as a dwarf planet.

The asteroid belt is believed to be a remnant of the early solar system, where the formation of a planet was prevented by the gravitational influence of Jupiter. Instead of coalescing into a planet, the material in this region remained as countless smaller bodies.

Close to the main asteroid belt are the Trojan asteroids that share Jupiter's orbit around the Sun and they are distributed in two elongated, curved regions. They can be distinguished, based on these two regions, to the leading Trojans (they orbit ahead of Jupiter) and to the trailing Trojans (they orbit behind Jupiter).

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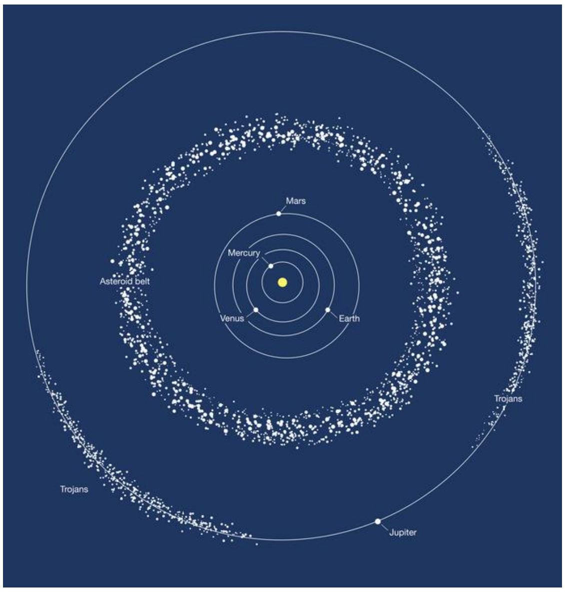

Main asteroid belt and Trojan asteroids in the Solar System (© ESA-HUBBLE https://sci.esa.int/web/hubble/-/59582-asteroid-belt).

- **Why should they be studied?**

Studying asteroids can help reveal information about the formation of our Solar System and the creation of its Sun and planets. Discovering, cataloging and monitoring asteroids can be also proven extremely helpful for the planetary defense efforts that are globally organized.

Can an asteroid hit the Earth? Can humanity do something to prevent it?
https://www.youtube.com/watch?v=r-OCcFnp2RA

HYPOTHESIS GENERATION AND DESIGN

- **How can you spot an asteroid? How was the first asteroid discovered?**

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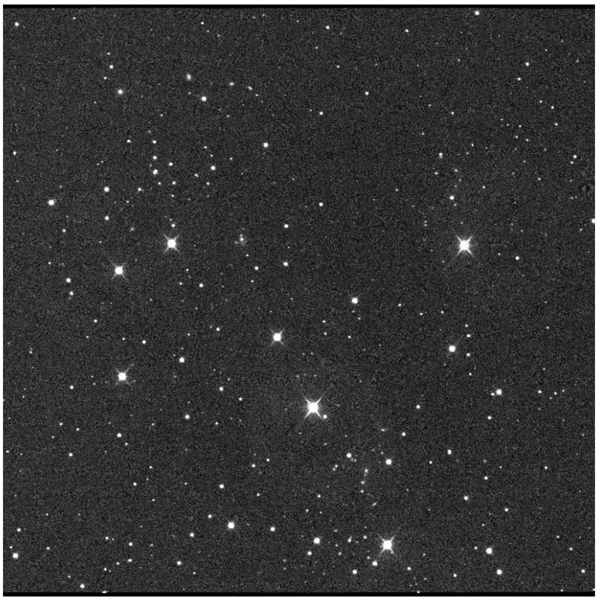
………

Can you spot the asteroid in the following image? What would help you?



Asteroids move differently compared to the stars we see on the sky. To spot them we need to see them moving compared to background stars. The same phenomenon can be observed with other celestial objects as well (like planets).

- **How can you calculate an asteroid's speed? How fast do you think an asteroid revolves around the Sun?**

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- **What do you need in order to calculate the speed of a moving body?**

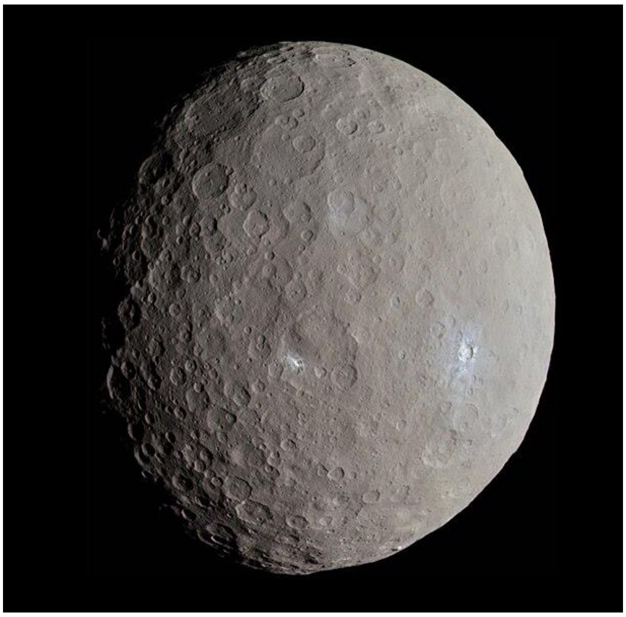
………
………
………

PLANNING AND INVESTIGATION

How was the first asteroid ever discovered?

In the 18th century, astronomers were intrigued by Bode's law, a mathematical formula that seemed to predict the locations of known planets. However, there was a discrepancy as Bode's law suggested a planet should exist between Mars and Jupiter. The discovery of Uranus in 1781, at a distance predicted by Bode's law, fueled excitement about the formula's accuracy.

A group of astronomers, known as the "Celestial Police," formed to search for the missing planet using the Lilienthal Observatory in Germany, owned by Johann Hieronymous Schröter. Giuseppe Piazzi discovered Ceres in 1801 from the Palermo Obseratory, beating the "Celestial Police" in this race. Initially, Giuseppe Piazzi believed the small object he observed was a faint star not listed on his star chart. However, upon revisiting it the next day, he realized its movement indicated it was not a star. Due to illness and unfavorable weather, Piazzi couldn't continue his observations for a few nights. By January 24, 1801, through careful tracking of its movement against the star background and calculating its distance, he confirmed that the object belonged to our solar system.



Dwarf planet Ceres (© NASA / JPL-Caltech / UCLA / MPS / DLR / IDA / Justin Cowart)

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Asteroids were (and are) discovered in the same planets were discovered. The astronomer(s) discover an object that overtime has a different position compared to the starry background. Then, through precise measurements they are able to determine the object's orbit/distance and identify it as 'planet-like' body. The difference is that asteroids are much smaller than planets.

Though initially thought to be a planet, Ceres was later classified as a minor planet due to its small size. Over the next few years, astronomers identified three more minor planets in the same region: Pallas, Juno, and Vesta. The realization of a "belt" of asteroids between Mars and Jupiter emerged, dispelling the notion of a single large planet. Since then, asteroid discoveries have been ongoing, with new ones found almost annually. Telescopes and campaigns specifically designed to identify near-Earth asteroids, which could potentially pose a threat to Earth, have become crucial tools in astronomical research.

Finding images of asteroids from telescopes

You can find images of asteroids taken from the Faulkes robotic telescopes in the STAND website:https://projectstand.eu/asteroids-with-robotic-telescopes/. In this activity we will be using the images from the Asteroid (47144) Faulkes.

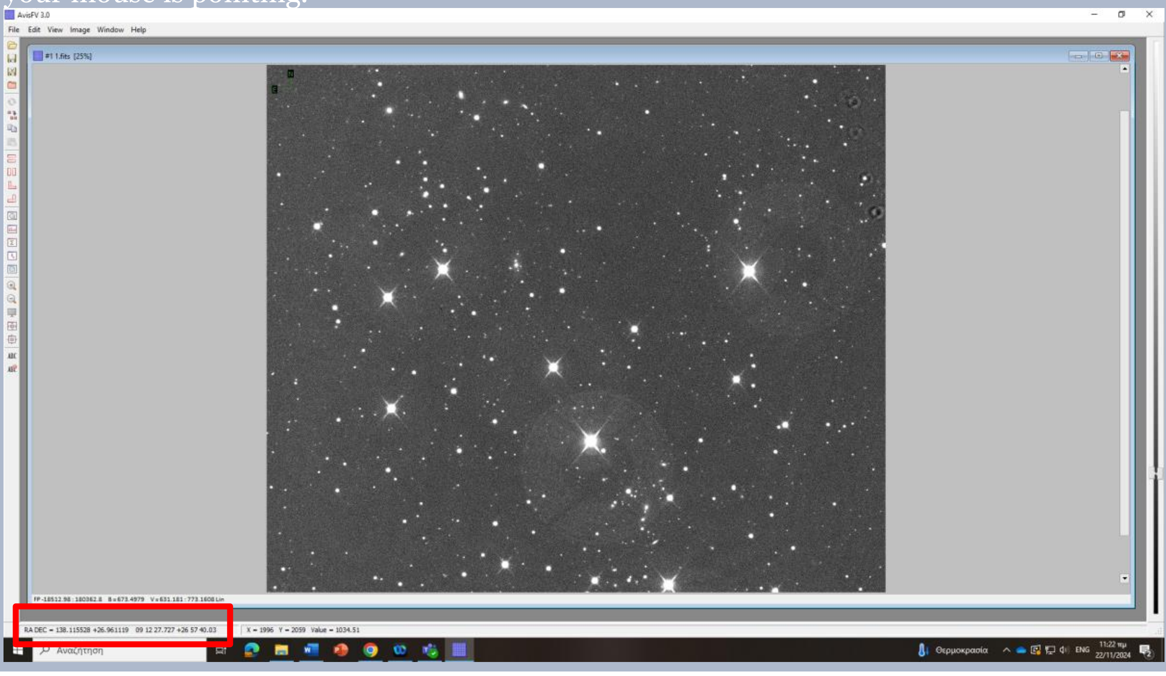
Look at the images or blink between two images or create a video with the images to spot the asteroid more easily. You can have the students do it or you can create the video for them and discuss it in the classroom.

Can you spot the asteroid now?

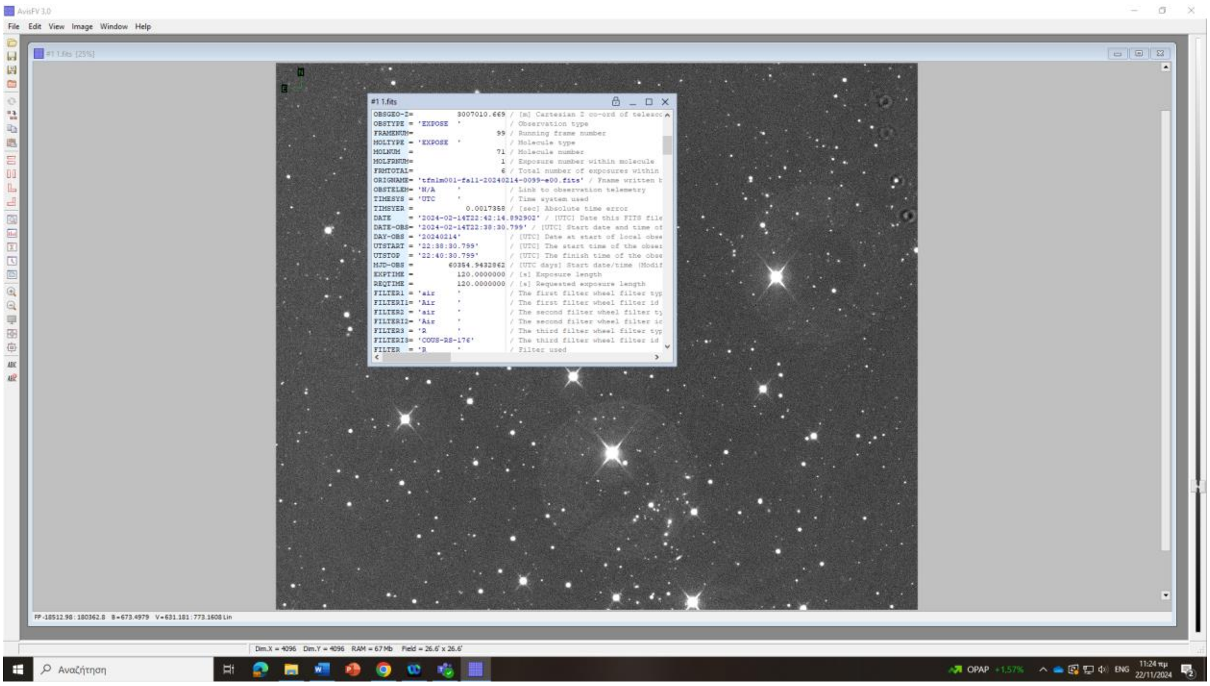
To calculate the asteroid's speed you need to know how much it moved and how long it took.

You can download a free FITS file viewer here: https://www.msbsoftware.it/avis/

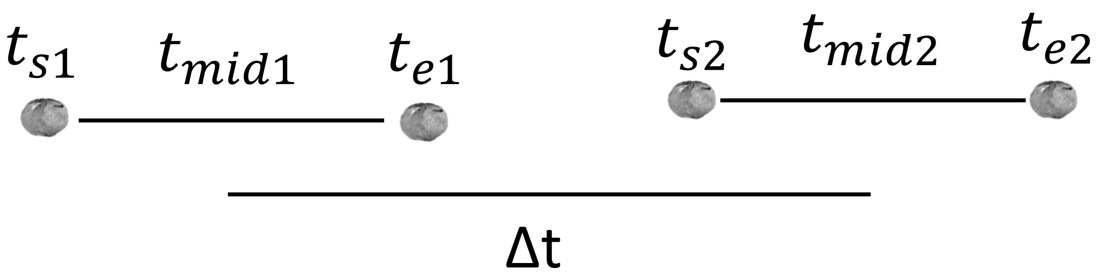
You can have the students open the files and find the coordinates or you can show them on your computer/projector if you do not have enough computers available. The coordinates appear on the bottom left of the screen and change as you move your mouse over the image. Each time the coordinates that are shown correspond to the coordinates of the location your mouse is pointing.



Open the first and last (6th in this case) image of the asteroid. On the FITS viewer click View→FITS header. The header includes many information concerning the observation parameters of the image you are looking at. Let's find the time at which the images were taken. Astronomical images are not taken instantly. This means that the camera stays open for an amount of time, called exposure time, collecting light in its pixels. Since we want one number for when the image was taken, we consider that this time is the middle of the exposure time.



For example, image 1 exposure began at 22:38:30 (UTSTART) and ended at 22:40:30 (UTSTOP) (on 14th of February 2024). So, we consider that the time this image was taken was at 22:39:30.



Similarly, the last (6th) image exposure began at 22:50:55 and ended at 22:52:55 (on 14th of February 2024), so the time it was taken was at 22:51:55.

Calculate the amount of time that the asteroid was moving in these images.

Δt=12 min 25 sec=745 sec

To calculate how much the asteroid moved we need to know where it was and where it went. To mark the position of a celestial body Astronomers use coordinates like we do to point a location on Earth. They are celestial coordinates and you can find them by placing the cursor at the asteroid on each image. The coordinates are written on the bottom left part of the app and they are angles as shown in the following image.

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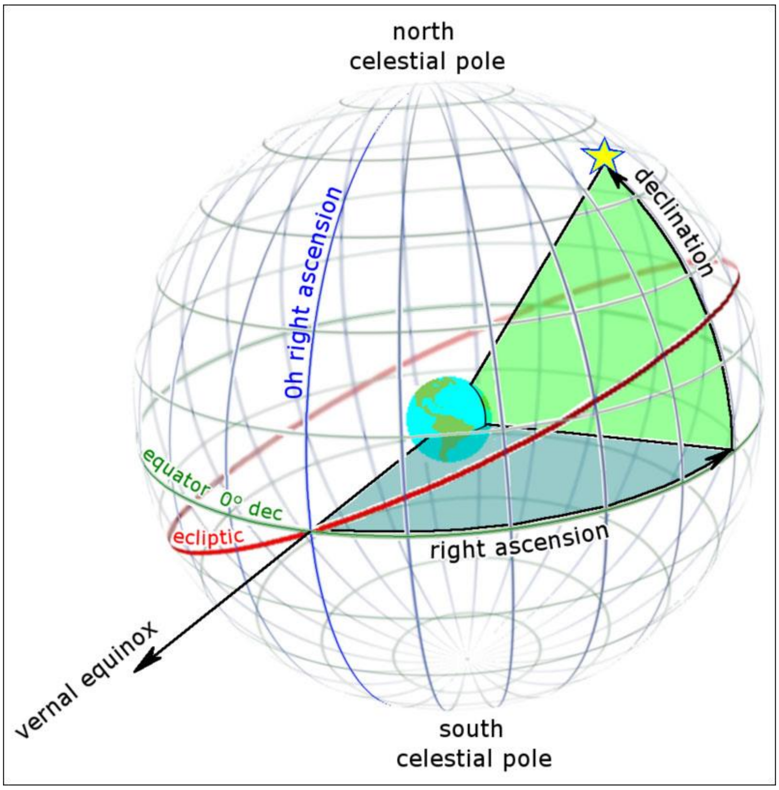
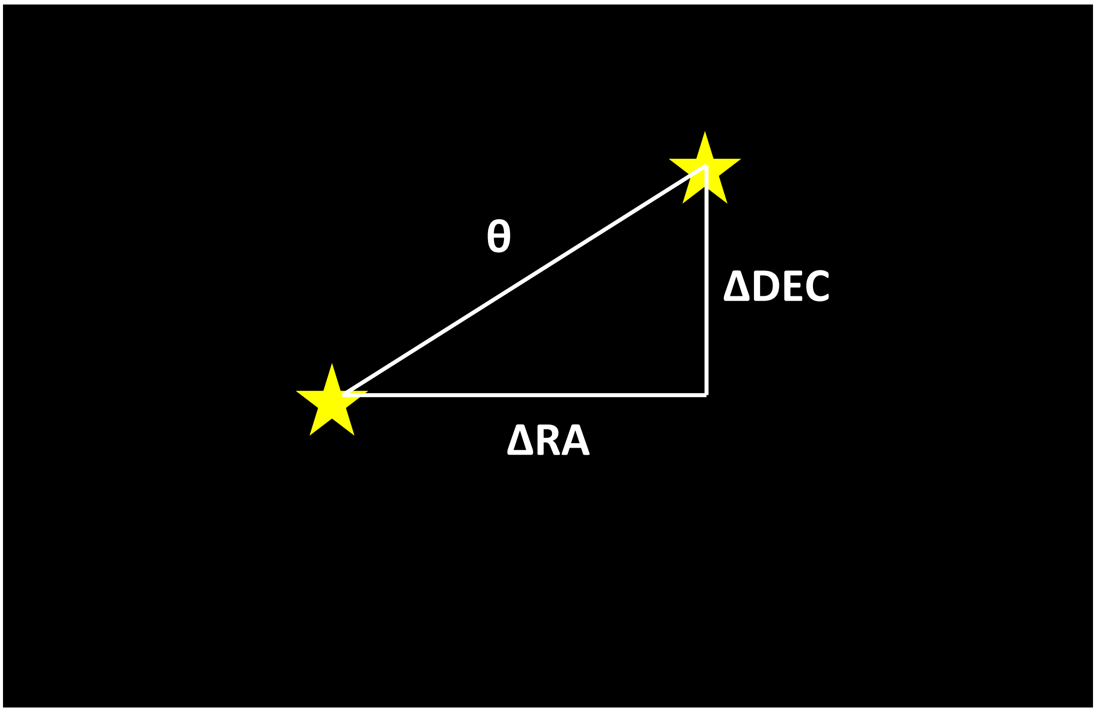
	RA (right ascension)	DEC (declination)
1st image	138.115285	+26.961118
6th image	138.112830	+26.961639



Learn more about right ascension and declination here: https://www.youtube.com/watch?v=oMZdYPJHE8s

To find the total distance (angle) that the asteroid moved through during this time you need to use the Pythagorean theorem.

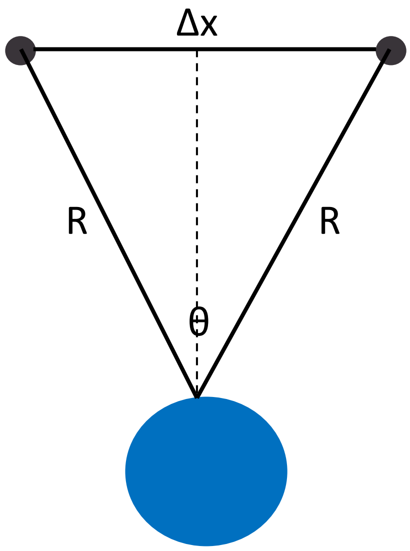


$$\theta = \sqrt{\Delta RA^2 + \Delta DEC^2}$$

$$\theta = \sqrt{(138{,}112830 - 138{,}115285)^2 + (26{,}961639 - 26{,}961118)^2} = 0{,}00245153\ deg$$

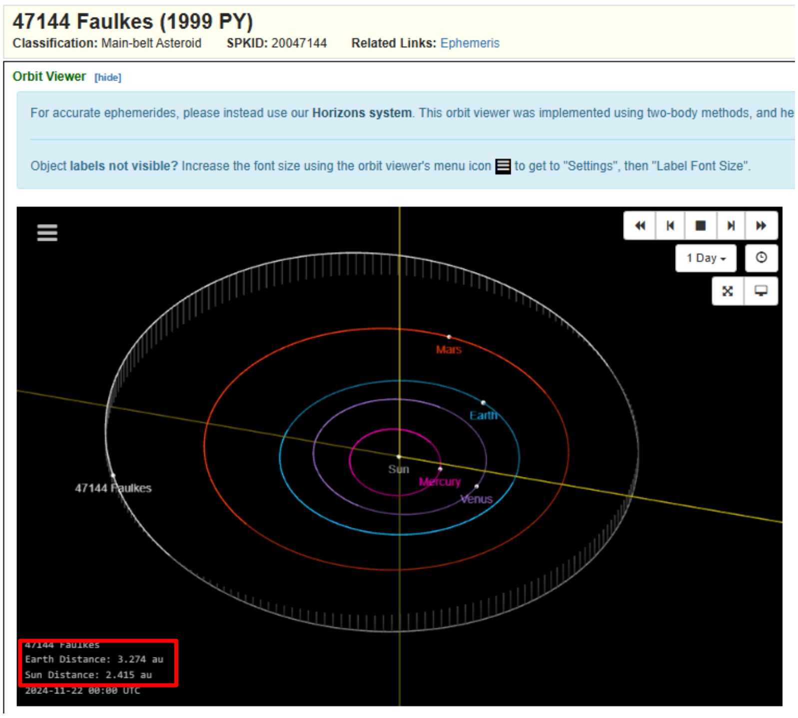
So far we could calculate the angular velocity of the asteroid. But in order to find the linear velocity we need the distance that the asteroid travelled in kilometers and not degrees. How can we do that?

ANALYSIS & INTERPRETATION



$$\sin\frac{\theta}{2} = \frac{\frac{\Delta x}{2}}{R} = \frac{\Delta x}{2R} \leftrightarrow \Delta x = 2R\sin\frac{\theta}{2}$$

You can find the distance R between the asteroid (47144) and the Earth at the time of the observation using this app.
https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=47144&view=VOP



It is equal to 1.518 AU (the Astronomical Unit is the average distance between the Earth and the Sun and is equal to 149,597,871 kilometers). So:

R=227,089,568 kilometers

Now you can calculate the distance that the asteroid travelled in kilometers (Δx).

$$\Delta x = 2 \times 227{,}089{,}568 \times 0.00002133635 = 9{,}690.525\ km$$

And the linear velocity of the asteroid.

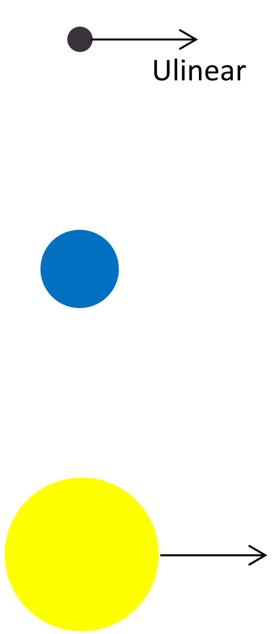
$$U_{linear} = \frac{\Delta x}{\Delta t}$$

$$U_{linear} = 13\frac{km}{s} = 46{,}800\frac{km}{h}$$

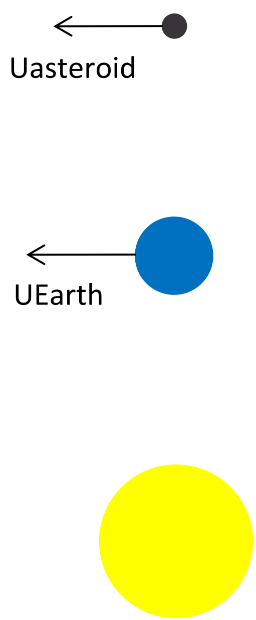
But is this the true velocity of the asteroid?

We have to take into consideration that we are on Earth and the Earth is revolving around the Sun. So, the velocity you calculated is not the real velocity of the asteroid. It is like you are in a moving car. Luckily during the observations, the asteroid, Earth and Sun are almost aligned, so we can consider them aligned and make our calculations much simpler.

From the Earth



From the Sun



You can also use the app (https://ssd.jpl.nasa.gov/tools/sbdb_lookup.html#/?sstr=47144&view=VOP) to help you image the positions and the motion of the celestial bodies. Be careful as not all velocities in the following equation have the same direction. If you consider positive the real direction of the asteroid's velocity, then the linear velocity you calculated is negative and the other way around.

$$U_{linear} = U_{asteroid} - U_{Earth} \leftrightarrow U_{asteroid} = U_{linear} + U_{Earth}$$

Now calculate the real velocity of the asteroid.

$$U_{asteroid} = -46{,}800\frac{km}{h} + 107{,}000\frac{km}{h} = 60{,}200\frac{km}{h}$$

CONCLUSION & EVALUATION

- Why do you think it is easier to spot asteroids today compared to the past?

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- Do asteroids go fast (revolving around the Sun)? With what everyday thing can you compare their speed?

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Would you like to do more?

Now that you know how asteroids are spotted through telescope images would you like to be part of a scientific project? Would you like to analyze real images and help scientists discover more unknown asteroids?

Visit the Zooniverse project called **The Daily minor planet** and start looking!

https://www.zooniverse.org/projects/fulsdavid/the-daily-minor-planet

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