ASTROEDU

Peer-reviewed Astronomy Education Activities

Chasing the Moon

Let's observe the Moon and learn how to measure its motion with simple observations and tools!

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KEYWORDS

moon, star-chart, star-gazing, coordinate, observation

CATEGORY

<QuerySet [<SciCategory: Observational astronomy>, <SciCategory: Scientific instrumentation>, <SciCategory: The Solar System>]>

AGE

14 - 19

LEVEL

<QuerySet [<Level: Middle School>, <Level: Secondary>]>

TIME

multiple days

SKILLS

<QuerySet [<Skills: Analysing and interpreting data>, <Skills: Asking questions>, <Skills: Constructing explanations>, <Skills: Developing and using models>]>

TYPE OF LEARNING

<QuerySet [<Learning: Guided-discovery learning>, <Learning: Observation based>]>

MATERIALS

- a cross-staff (you can also build one with the students using the activity The Sky at your fingertips)
- star charts (in attachment)
- goniometer or compass
- sheet of paper
- pen or pencil

GOALS

Students will learn how to collect data and analyse their measurments, showing that it is possible to determine some characteristics of the Moon's motion around the Earth with these simple measurements.

LEARNING OBJECTIVES

Students will learn:

- How to measure with angles the position of celestial bodies.
- The movement of the Moon across the sky and in space, it's orbit.

BACKGROUND

The Earth orbits around the Sun and its motion lies on a plane that is called "ecliptic".

At the same time, the Moon orbits around the Earth on a complex path that does not lie on the plane of the ecliptic. There are two different ways of measuring the period of time taken by the Moon to orbit around the Earth. They use two different reference systems: the position of the Sun and the position of the stars, which are typically called "fixed" as they seem not to change their position across the sky.

We call "sidereal period" the time interval needed for the Moon to orbit around the Earth and to return to its initial position relative to the fixed stars (i.e., as observed from some fixed point outside the Solar System). We call "synodic" period, instead, the time interval needed for the Moon to orbit around the Earth and return to its initial position relative to the Sun, as seen by an observer on Earth. This corresponds to the time interval between two recurrences of the same lunar phase (e.g., between full Moon and full Moon).

We can determine the duration of the sidereal and the synodic periods by carefully observing the night sky for a short period of time. In this way we can discover that the two periods have a different duration as a result of the motion of the Earth around the Sun.

If we measure the position of the Moon in the sky over a longer period of time we can also discover that the motion of the Moon is not uniform and that its orbit is tilted with respect to the plane of the ecliptic. This is the reason why we do not have eclipses every full Moon or new Moon.

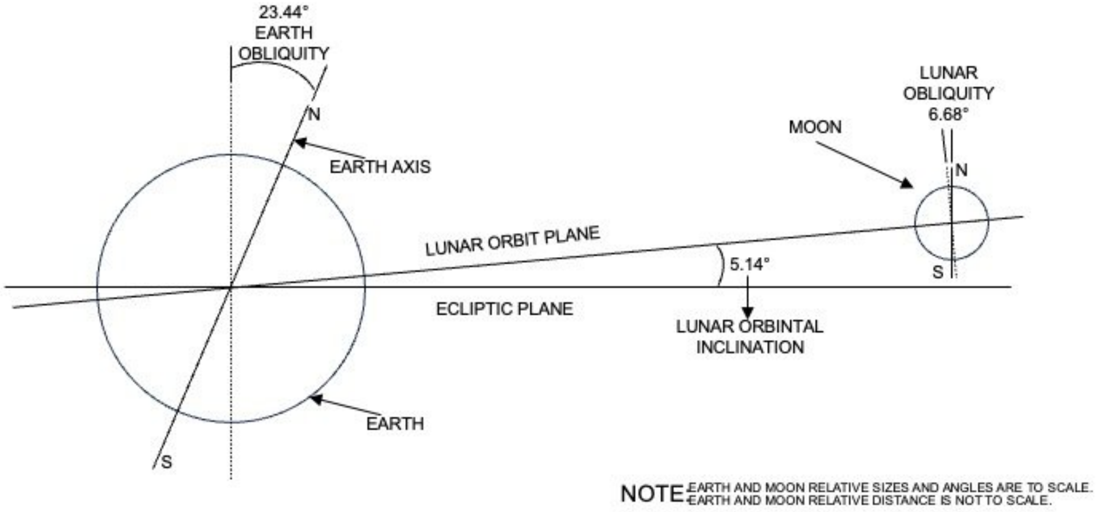

Figure 1- orbits of Earth and Moon

FULL DESCRIPTION

Measuring the position and phases of the Moon in the sky, we can determine its synodic and sidereal periods. These measurements will be done over different nights, using a Cross-staff (you can also build one with the students with the activity "The Sky at your fingertips").

Of course, there will be large errors in these measurements, but the pedagogical purpose of the observations will still be achieved.

Activity 1 - Determining the sidereal period of the Moon

In a clear night, observe the position of the Moon with respect to the fixed stars. You could use the attached star charts to identify constellations. Using the cross-staff, measure the angular distance between the Moon and the stars of observable constellations. Draw the position of the Moon on the sky chart and note down the date and the time of your observations.

The position of the Moon on the sky chart is determined as follows. Adapt the compass to the measured angle between the stars and the Moon with the angular scale on the map. Put one leg with the spike into the first star on the map and inscribe the first arc. Then repeat for all other measurements. The intersection of the arcs is the position of the Moon on the sky chart. As we have two intersects notice which intersection corresponds to the position of the moon in the sky. Also notice that it is better to choose stars located at an angle of about 90 ° with respect to the Moon than to be in the same direction that passes through the Moon. With three stars mutual angles of about 120 ° would be appropriate.

Repeat the measurement the next night, around the same time, and draw again the position of the Moon on the sky chart.

To determine the sidereal period a minimum of two consecutive measurements (i.e., two consecutive nights) are required. In order to achieve better results, the measurements can be carried out over a longer period of time and over several evenings.

After taking the measurements and reporting them on the sky chart, note down the longitude of the Moon by reading it on the sky chart itself. it is then possible to estimate the apparent angular speed (omega_sid) of the Moon around the Earth using the following equation:

$\omega_{sid} = (l2 - l1) / (t2 - t1)$

where:

- ω_{sid} - apparent angular speed of the Moon around the Earth (in degrees per day)
- $l1$ - longitude (in degrees) at moment $t1$ (in days), corresponding to the first measurement
- $l2$ - longitude (in degrees) at moment $t2$ (in days), corresponding to the second measurement

If ($l2 - l1$) < 0 then add 360deg to that difference in longitude.

In turn, the sidereal period of the Moon, P_{sid} (in days) can be estimated as:

$P_{sid} = 360 \text{ deg} / \omega_{sid}$

Activity 2- Determining the synodic period of the Moon

As the Moon orbits the Earth, it changes its phases as a result of the change in the mutual position of the Earth, the Moon and the Sun. By measuring the change in the phase of the Moon over a certain period, the synodic period of the Moon can be determined. The Moon phase, namely the ratio between lit section and diameter of the Moon, corresponds to the angle between the Earth and the Sun as viewed by the Moon, called “phase angle”. During a clear night, observe what is the Moon phase. On a paper sheet draw a circle and report on it the Moon phase (top panel of Figure 1), such that the white part indicates the illuminated portion of the Moon and the grey part indicates the dark portion of the Moon which is not visibile. The full Moon would be a completely white circle, while the new Moon would be a completely dark circle. The Moon phase can be estimated with the following equation:

$phase = x/d$

where

d - diameter of the drawn circle, representing the diameter of the Moon

x - maximum width of the white portion of the circle, representing the illuminated portion of the Moon

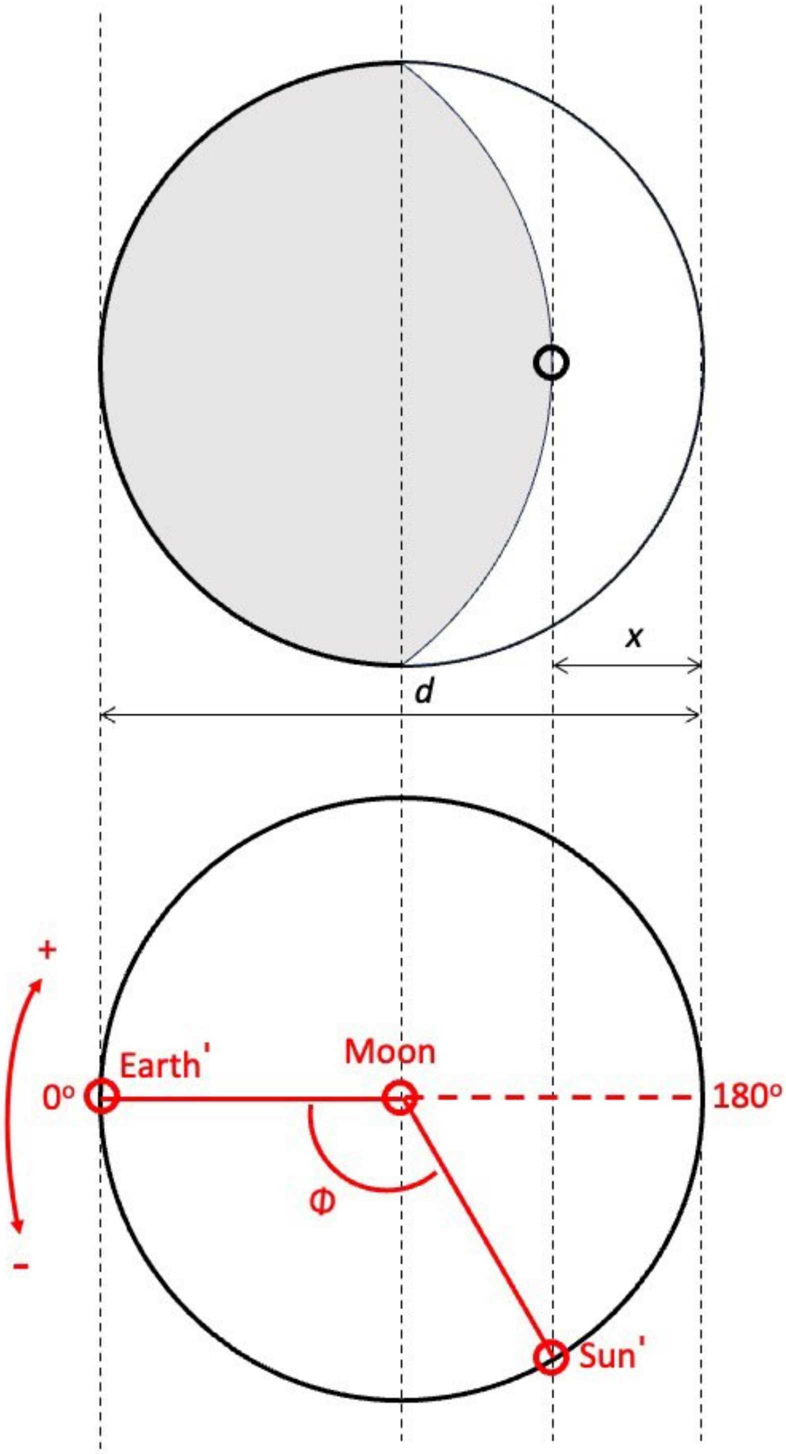

Figure 2- How to measure the synodic period of the Moon. Notice that on the bottom panel, the actual relative positions of the Sun and the Earth are rotated 90 ° in the counter clockwise direction wtr shown Earth' and Sun' positions.

We can then measure the phase angle corresponding to the observed Moon phase by drawing a second circle on the piece of paper, below the first one and aligned with it, as shown in the sketch reported in Figure 2 (bottom panel). We measure the phase angle (Φ) from the Earth - Moon direction to the Moon - Sun direction.

On the bottom circle, draw an horizontal line that crossed half of the circle along its diameter, from left to right. This identifies the Earth' - Moon direction, rotated by 90° of actual relative Earth - Moon direction.

From the top circle, draw a vertical line so to report the length x on the bottom circle. Draw a line connecting this point with the center of the circle. This line identifies the Moon - Sun′ direction rotated by 90° of actual relative Moon - Sun direction. The phase angle is the angle between the two red lines that you can measure with a goniometer. The values of the phase angle range between -180 deg and 180 deg.

Note that:
phase = 0 (new moon) -> $\Phi = -180$ deg (or 180 deg);
phase = 0.5 (first quarter) -> $\Phi = -90$ deg;
phase = 1 (full moon) -> $\Phi = 0$ deg;
phase = 0.5 (last quarter) -> $\Phi = 90$ deg.

Repeat the measurement of the phase angle after some time, when the lunar phase is different. You need at least two measurements to estimate the synodic period. You can estimate the apparent speed of the Moon with respect to the Sun as:

$\omega\_syn = (\Phi 1 - \Phi 2) / (t2 - t1)$

where:

ω_syn - apparent angular speed of the Moon around the Earth with respect to the Sun (in degrees per day)

$\Phi 1$ - phase angle (in degrees) at moment $t1$ (in days), that corresponds to the first measurement

$\Phi 2$ - phase angle (in degrees) at moment $t2$ (in days), that corresponds to the second measurement

If $(\Phi 1 - \Phi 2) < 0$ then add 360 deg to that difference in phase angle. Note that between phases of the new and full Moon the absolute value of the phase angle is decreasing over time and during this period we put a negative sign on the value of a measured phase angle (i.e., the phase angle of the first quarter is -90 deg).

The synodic period of the Moon, P_syn (in days) is then:

$P\_syn = 360 \text{ deg} / \omega\_syn$

Activity 3- Determining the inclination of the Lunar orbit around the Earth with respect to the Ecliptic

You can measure the position of the Moon with respect to the stars using the same method of Activity 1. However, measurements taken over a longer period of time (at least 15 days) are needed. Each time you measure the position of the Moon relative to the stars, report it on the star charts. When at least 15 measurements have been collected, draw a curve connecting all the points, indicating the orbit of the Moon with respect to the fixed stars. The curve should have a sinusoidal shape.

The provided sky maps are in the Mercator ecliptic projection that make it possible to easily determine the inclination of the lunar orbit around the Earth with respect to the ecliptic as follows. Measure the amplitude of the sinusoidal curve that you have drawn and this will give you the inclination of the orbit of the Moon with respect to the ecliptic.

EVALUATION

Evaluation could be performed both with a quiz or with a guided class discussion. Some of the questions that could be asked concern what are the sidereal and synodic periods of the Moon and how long they are based on the measurements that each student determined. A discussion on why different students obtained slightly different results (depending on measurements errors, instrumental settings, and other possible biases) could also be performed.

CURRICULUM

This activity can be employed in several curricular subjects, such as: Science, Physics, Technology, and Mathematics.

ADDITIONAL INFORMATION

For more information about the STEAM-Med co-design project : Read this Link

This activity is available in other languages: Link (to be provided soon).

CITATION

Andrej Guštin; Damir Hržina; Dunja Fabja, 2024, *Chasing the Moon*, astroEDU, 2402