Naked Eye Astronomy, Day 5: Moon Phases and Eclipses

1. Review
   (a) Please ask questions at ANY TIME.
   (b) Web page with resources for the course: `https://osp.berry.edu/SeniorScholars`.
   (c) Recall our observations of the stars and Sun.
      i. The stars appear as though they are stuck to a celestial sphere that rotates around an axis through the Earth once every 23 hours 56 minutes.
      ii. The Sun generally moves along with this daily rotation but also drifts eastward relative to the stars along a circular path called the Ecliptic (which is tilted by 23.5 degrees relative to the celestial equator), completing its motion in 365.25 days.
   (d) Now we will observe the Moon's motion relative to the stars, its changing appearance, and its role in eclipses (both lunar and solar).

2. Phases and Motions of the Moon (Stellarium)
   (a) Turn off atmosphere and ground. Find Moon and center it. Note the day. Advance by day and watch how the appearance of the Moon changes. Discuss names of phases: New, Waxing Crescent, First Quarter, Waxing Gibbous, Full, Waning Gibbous, Third Quarter, Waning Crescent, New. Note day that the Moon returns to New phase. Total time for cycle of phases: about 29.5 days (one synodic month).
   (b) Is the cycle of phases related to the Moon's apparent motion? Show the ecliptic and celestial equator. First let's check the motion relative to the stars. Get the Moon near a bright star, note the day. Advance time by days until the Moon returns to the same star. Note the day again - the Moon's motion relative to the stars is generally (but not exactly) along the ecliptic and it takes about 27.3 days (one sidereal month).
   (c) What about the motion of the Moon relative to the Sun? Line the Moon up with the Sun (note New phase). Advance time until Moon is back with Sun (New phase again). This is the same time period as the synodic month, so the Moon's phases are related to its motion relative to the Sun in the sky.

3. Modeling the Phases (Phases of the Moon simulation)
   (a) The Ancient Greeks understood that the phases of the Moon could be explained if the Moon was spherical and shined by reflecting sunlight. They thought the Moon and Sun both orbited Earth, but the geometry works the same if the Moon orbits Earth while both orbit the Sun.
   (b) Simulation shows orbit of Moon around the Earth. The Sun is held in a fixed location far to the right (of course really the direction to the Sun changes, but we can always rotate our view to put it back toward the right).
   (c) Note that it is always the right side of the Moon that is lit, because that is the side facing the Sun. However, the portion of the Moon that is visible to Earth changes as the Moon orbits.
   (d) Move the Moon through its orbit and make sure it is clear why the phase of the Moon as seen from the Earth changes as it does.

(e) Discuss how we can use this model to predict approximate rising and setting times for the various phases.

(f) Note simplifications: assumes that the Moon is in the plane of the ecliptic, but we have seen that it is not always. Also assumes our observer is on the equator and ignores the tilt of Earth's axis, so our times are only approximate.

(g) This simplified model suggests that when the Moon is in New phase it would block sunlight from reaching Earth (a solar eclipse). It also suggests that a Full moon would be in the shadow of Earth (a lunar eclipse). While it is true that eclipses only occur during these phases, they do not ALWAYS occur. Why not?

4. Solar and Lunar Eclipse Simulation

(a) Show simulation view of Earth orbiting the Sun and Moon orbiting the Earth.

(b) Note that the Moon's orbit is tilted slightly (about 5 degrees) relative to the Earth's orbital plane (the ecliptic). Therefore, sometimes the Moon is seen above the ecliptic, sometimes below the ecliptic.

(c) There are two points where the Moon's orbit crosses the ecliptic. These points are called nodes (ascending and descending).

(d) Show that in order for an eclipse to occur the Moon must be at a node as well as in New phase (for a solar eclipse) or Full phase (lunar eclipse). If it is a bit off of the node we may get a partial eclipse.

(e) Time for Moon move from node back to the same node is about 27.2 days (draconic month). Since this period is different from the synodic month of the phases, these two cycles go in and out of sync. If there is a lunar eclipse during Full moon one month, there won't be one the next several months. Likewise for solar eclipses.

(f) In general there are a few lunar and solar eclipses per year. However, although a lunar eclipse will be visible to anyone who can see the Moon, a solar eclipse is visible only at certain locations on Earth. The shadow of the Moon on Earth is only a couple hundred miles wide and that shadow spot moves across the Earth's surface during the eclipses. If you are just outside that path you will see a partial eclipse. Further outside and you will see no eclipse at all. So solar eclipses are more rare form any particular location than lunar eclipses.

(g) For Rome: partial lunar eclipse on Nov 19, total lunar eclipse on May 15 2022, partial solar eclipse on Oct 14 2023.

5. Questions and conversation