The Moon and Eclipses

ASTR 101 September 14, 2018

- Phases of the moon
- Lunar month
- Solar eclipses
- Lunar eclipses
- Eclipse seasons

Moon in the Sky





An image of the Earth and the Moon taken from 1 million miles away. Diameter of Moon is about ¼ of the Earth.

- Moonlight is reflected sunlight from the lunar surface. Moon reflects about 12% of the sunlight falling on it (ie. Moon's **albedo** is 12%).
- Dark features visible on the Moon are plains of old lava flows, formed by ancient volcanic eruptions
 - When Galileo looked at the Moon through his telescope, he thought those were Oceans, so he named them as Marias.
 - There is no water (or atmosphere) on the Moon, but still they are known as Maria
 - Through a telescope large number of craters, mountains and other geological features visible.

Moon Phases	
Sunlight	Sunlight
full moon	New moon
Sunlight	Sunlight
Quarter moon	Crescent moon

• Depending on relative positions of the Earth, the Sun and the Moon we see different amount of the illuminated surface of Moon.

Moon Phases





Earth in lunar sky is about 50 times brighter than the moon from Earth.

Earthshine

Moon

light reflected from the Earth



Sun

"old moon" in the new moon's arms

- Night (shadowed) side of the Moon is not completely dark.
- sunlight reflected off the Earth weakly illuminates the night side of the Moon (albedo of Earth ~35% and 4 times the diameter of Moon.)



- Moon is the only celestial object that moves around the Earth.
- It completes one orbit around the Earth in 27.3 days :

Sidereal month (relative to stars) 27.3ays (27d 7h 43m)

- But the length of the lunar phase cycle (lunar month, from full moon to full moon or new moon to new moon etc.) is 29.5 days
- Because Earth is also moving on its orbit around the Sun, Moon has to move little more than one orbit to come to the same alignment with the Earth and the Sun:

Synodic month (relative to Sun) 29.5 days (29d 12h 44m) also called the Lunar month

Where is the Moon in Sky



At the full moon: The moon rises at sunset (~6PM) and sets at sunrise sets (~6 AM)

- The time Moon rises, sets or visible in the sky depends on the relative positions of the Earth, Moon and the Sun.
- It changes throughout the lunar cycle

Where is the Moon in the Sky

First quarter moon: rises around 12PM and sets around 12AM





Sunlight

<u>Where is the Moon</u> <u>in the Sky</u>



Moon rises/sets ~50 min later than the previous day (on average).

Only one side of the Moon is visible to us

If the Moon is not rotating at all, all sides of it will be visible as it moves around the Earth Moon rotates with the same period as its orbital period. So it always faces the same side to the Earth.

- Due to "tidal locking", gravitational pull on the Moon by the Earth had slowed down and synchronized its rotation to orbital motion. (more after learning gravitation)
- The length of a lunar day is same as a Synodic month 29.53days
- In the lunar sky Earth is always visible at about same location.



First image of the far side of the Moon(Luna 3 spacecraft Oct.7 1959)



A modern image of the far side of the Moon (NASA)

We were able to see the far side of the Moon only after spacecrafts took images from the other side.

Less "dark features" \Rightarrow less volcanic activity in the past.



at perigee

- Since Moon's orbit is elliptical, its distance to earth changes as it goes around the earth.
 - So its angular size also changes depending on the location on the orbit

- by 13%

Perigee: the point in its orbit when the Moon is nearest to the Earth angular size is largest 34' (super moon)
 Apogee: the point when the Moon is farthest from the Earth angular size is smallest ~30' 12

Moon looks bigger when rising/setting- an illusion

- Moon looks bigger when it is near the horizon (at rising or setting) than when it is higher up in the sky.
 - It is an illusion, due to how the visual perception works.
 - If its angular diameter is measured or take images (with the same instrument), it shows the same size when near the horizon or higher up in the sky.
 - It happens with any other object, the Sun or constellations near the horizon.

Read more at :

http://www.skyandtelescope.com/observing/moon-illusionconfusion11252015/

http://blogs.discovermagazine.com/badastronomy/2010/05/13/why -does-the-moon-look-so-huge-on-the-horizon

http://news.nationalgeographic.com/2016/12/moon-illusionexplained-horizon-size-supermoon-space-science/



http://en.wikipedia.org/wiki/Moon_illusion



Moon looks flattened when it is rising/setting





- The Moon (and the Sun) looks flattened when it is near the horizon.
 That is real:
 - Light from the Moon is refracted in vertical layers of air (with changing densities), different from the horizontal direction.
 - Light from the bottom portion of the Moon bends more than the light from the top since density of air decreases with altitude.
 - this causes the apparent flattening.

Eclipses

An eclipse happens when the Moon or the Earth is in the shadow of the other.

A Shadow has two parts:

Umbra: Innermost part of the shadow, not getting any light from the source. Completely dark. If the source is larger, it has a finite length.

Penumbra: Outer part of the shadow. Only part of the light from the source is blocked.

Light source (Sun)

> occluding object (e.g. Moon)

Umbra – all of the light from the source is blocked

Eclipses

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A Shadow has two parts:

Umbra: Innermost part of the shadow, not getting any light from the source. Completely dark.

Penumbra: Outer part of the shadow. Only part of light is obscured Gets some light, not completely dark.



Total Solar Eclipses

Solar corona

A total solar Eclipse, Sun is completely covered by the moon



moon

A partial solar eclipse Only a part of the Sun is covered by moon

- Solar Eclipse occurs when Moon's shadow falls on Earth.
 - Moon is in between the Earth and the Sun.
 - A Solar eclipse happens on a new Moon day.
- A solar eclipse could be full, partial, annular.
- Angular diameters of moon and sun are about the same (~1/2°),
 - so a total solar eclipse lasts only a few minutes.
 - Only the solar photosphere is occulted and the "solar corona", which is much fainter and larger becomes visible.



Solar eclipse September 21, 2017

https://www.facebook.com/media/set/?set=a.1798750403472975.1073741 839.100000140985966&type=1&l=cff1ea7a60



May 20, 2012 solar eclipse (partial) from San Jose CA. https://www.flickr.com/photos/stoneymonster/7239382688/



Umbra ends before it reaches the Earth

- Since the Earth-Moon distance is changing, sometimes the angular size of the Moon is smaller than the angular size of the Sun.
 - (the length of the umbra is shorter than the Earth-Moon distance.)
- If a solar eclipse happens in a such situation, only middle of the Sun is covered by the Moon. Sun appears as an annular ring.



May 20, 2012 annular solar eclipse (from Japan)



Shadow of the Moon on Earth during the total eclipse August 11, 1999 both Umbra and penumbra (From Mir space station)



Shadow of moon on earth, during the May 20, 2012 annular eclipse only penumbra (From the International space station)

• Size of the shadow of moon on Earth is rather small (about 300 km).



September 21, 2017 solar cclipse captured by the NASA Deep Space Climate Observatory satellite from a million miles out in space <u>https://www.nasa.gov/image-feature/goddard/2017/nasas-epic-view-of-2017-eclipse-across-america</u>



- Due to combination of Moons orbital motion and Earth's rotation, shadow of moon travels on the earth surface at a speed exceeding 1700 km/h (1000 miles/h)
- So the totality of a solar eclipse visible from a given location is very short, 7.5 minutes at most.



Total lunar eclipse: Moon is in umbra

Penumbral eclipse : Moon passes only is in penumbra

- In a lunar eclipse Earth's shadow falls on the Moon.
 - The Sun, Earth and the Moon are aligned, with the Earth in the middle:
 - A Lunar eclipse happens on a full moon day.
- A lunar eclipse could be a total, partial or penumbral eclipse.
- Size of the Earth's shadow on the Moon (12000km) is larger than the Moon (2.5 x), a total lunar eclipse could last ~ 1.5 hours.
- Visible from anywhere on the night side of the Earth, so we see lunar eclipses more often.

Red Moon in totality



- Earth's shadow is not totally dark.
- Some of the light is refracted from the Earth atmosphere, and enters the shadow.
- Since most of the blue light is scattered • off in the atmosphere only red light remains.
- As a result during a total lunar eclipse • Moon is not going totally dark, it shines in a red-orange hue ("blood moon")



When there is a lunar eclipse on Earth there is a Solar eclipse on the Moon (an illustration)





- Orbit of the Moon is inclined by 5.2° to the orbital plane of the Earth.
- Moon and Sun are not always aligned when full or new moon occurs,
- Most of the time moon passes too far above (north) or below (south) the Earth's orbital plane and an eclipse won't happen.



- For a total eclipse to occur, Moon must be located very close the Earths orbital plane at a full moon or a new moon.
- An **Eclipse Season** is the period when the moon is close enough to the Earth's orbital plane, so that an eclipse could occur.
 - An eclipse season is about 34 days long (31-37 days).



- This could happen at two locations on the Earth's orbit (two times a year)
- Time between two eclipse seasons is about 173 days
 - (less than 1/2 year = 182.5 days)
- Up to three eclipse seasons in a calendar year, but usually two
 - In 2017: one in February other in August.



14-15 days later a solar eclipse

Eclipse can happen in this region (~34 days)

Earth's orbit

- During an eclipse season usually two eclipses occur.
 - But up to 3 can happen
- In 173 days another eclipse season, again 2-3 eclipses and so on...
- Up to seven eclipses can happen in a calendar year, but usually there are four eclipses 2 solar and 2 lunar

Eclipses 2014- 2017

Eclipses in 2017

February 11: penumbral lunar February 26: annular solar

August 07: partial lunar August 21: total solar

Eclipses in 2018

January 11: total lunar February 15: partial solar

July 13 partial solar July 27: total lunar August 11 partial solar Season

Eclipses in 2019

January 5: partial solar January 20: total lunar

July 2 total solar July 16: partial lunar

December 26: Annular solar



2019 July 2 total solar eclipse path

-Three seasons per calendar year.

Eclipses in History



Peruvians terrified during lunar eclipse, A 19th Century painting (Giulio Ferrario, 1827. Italy,)

- Solar and lunar eclipses were usually regarded as a disturbance in the natural order in ancient cultures.
- Eclipses have caused fear, and have been associated with myths, legends and superstitions throughout history.



Few Historical eclipses

<u>Solar eclipses</u> have caused fear, inspired curiosity and have been associated with myths, legends and superstitions throughout history.

Ancient Chinese view of a solar eclipse

- Earliest written record of a total solar eclipse is from China. According to a legend, in 2134 BCE two Chinese royal astronomers (astrologers), Hsi and Ho were executed for failing to predict a solar eclipse.
- The ancient Chinese believed that solar eclipses occur when the celestial dragon swallow the Sun. So they made loud noises during eclipses to frighten the dragon away and save the Sun.
 - Hsi and Ho, were drunk and failed to inform the emperor of the forthcoming eclipse. When the eclipse took place emperor was caught unprepared. He was unable to organize teams to beat drums and dispatch the archers to frighten the dragon devouring the Sun.
 - Sun survived the eclipse but Hsi and Ho lost their heads.

- Thales of Miletus, (first Greek philosopher/scientist) said to have predicted the solar eclipse of 585 BC ending a five-year war between the Medes and Lydians.
- Christopher Columbus had used the lunar eclipse on February 29, 1504 to persuade native Jamaicans to provide them with supplies.
- Predicting eclipses many years ahead is complicated. (possible only in 17-18th centuries)
 - But it may be possible to predict an eclipse few days ahead by observing of the movement of the path of the Sun and Moon in the sky .
 - The Sun, the moon and the Earth come to the same configuration every 18 years 11 days and 8 hours.
 - So eclipses repeat after that time interval (known as a Saros cycle)
- Early observers may have discovered this fact through observations and used it to predict eclipses.
- On the history of eclipses:
 - <u>http://eclipse.gsfc.nasa.gov/SEhistory/SEhistory.html</u>
 - <u>http://eclipsewise.com/extra/SEhistoryReis.html</u>



Babylonian clay tablet listing eclipses between 518 and 465 BC

http://sunearthday.nasa.gov/2006/lo cations/babylon.php



Review Questions

- What are the dominant features visible on the Moon?
- What are the dark features visible on the Moon
- What is the length of the lunar phase cycle?
- What is Earthshine?
- Why do we always see only one side of the moon.
- Why does the Moon look larger on the horizon than it does overhead?
- Where do you expect to see the Moon on a full moon day around midnight?
- If you see the Moon is rising at 3AM, what would be the phase of the moon?
- If the Moon is directly overhead at 3AM, what would be the phase of the moon?
- What is umbra and penumbra of a shadow?
- What is the phase of the moon on a day of a solar eclipse?
- What is the phase of the moon on a day of a lunar eclipse?
- What is an annular solar eclipse? When does it happen?
- Why don't we see an eclipse on every full moon or a new moon day?
- How many eclipses could happen in a calendar year?
- Why are solar eclipses rarer than lunar eclipses?
- Why does the Moon look red during a lunar eclipse?