# Discovering the Universe For Yourself






## Describing Positions

- Representing position with coordinates:
  - Flat surface: 2 dimensions
    - coordinate system of this room
    - coordinate system of Rocklin
  - Surface of a sphere: 2 dimensions
    - coordinate system of Earth
    - coordinate system of the Sky






## Positions on the Earth

- The Terrestrial Coordinate System
  - Points of reference: north pole, equator
  - Two angular coordinates: latitude, longitude
  - Zero point of longitude: prime meridian

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## Angle Measures

- Measuring Positions of Objects on Spheres
  - Angular separation, measured from the observer, is the angle between two objects in the sky
  - A minute of arc (or arcmin or ′) is one-sixtieth (1/60) of a degree of arc
  - A second of arc (or arcsec or ″) is one-sixtieth (1/60) of a minute of arc
  - A fist held at arm's length yields an angle of about 10°
  - A little finger held at arm's length yields an angle of about 1°
  - Angular separation and its relationship to an object's distance




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## Position in the Sky - I

- The **Horizon System**
  - Points of reference: horizon, north point on horizon
  - Two angular coordinates: altitude, azimuth
  - Other reference points: zenith, nadir
  - Reference Line: meridian stretches from north horizon point to zenith to south horizon point
  - But this won't work as a permanent designation!!!! Why?




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## Position in the Sky - II

- The Equatorial Coordinate System
  - The Celestial sphere is the sphere of heavenly objects that seems to center on the observer.
  - Points of reference: **north celestial pole, celestial equator**
    - In North (South) Hemisphere one can see the north (south) celestial pole directly above the North (South) Pole
  - Two angular coordinates: declination, right ascension
  - Other references: Ecliptic and vernal equinox
  - Altitude of the celestial pole = observer latitude

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## Motions in the Sky

- Diurnal Motion - General
  - Stars are fixed on the celestial sphere, which rotates from east to west (on a minute-by-minute basis) completing one full turn each sidereal day – this is called diurnal motion
  - For northern hemisphere observers
    - The circular region around the north celestial pole in which stars never set is the North Circumpolar Region.
    - The circular region around the south celestial pole in which stars never rise is the South Circumpolar Region.




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## Motions in the Sky

- Diurnal Motion – Northern Observer Details
  - East: stars rise, altitude increases, azimuth increases
  - South: stars rise and set, altitude increases and decreases, azimuth increases
  - West: stars set, altitude decreases, azimuth increases
  - North: stars neither rise nor set, but rotate around a pole (circumpolar motion); altitude and azimuth both alternately increase and decrease




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## Patterns in the Sky

- Constellations
  - A constellation (from the Latin, meaning "stars together") is an area of the sky containing a pattern of stars named for a particular object, animal, or person.
  - The earliest constellations were defined by the Sumerians as early as 2000 B.C.
  - The 88 constellations used today were established by international agreement.
  - Asterisms are unofficial arrangement of stars. (Ex: Big Dipper, Summer Triangle, Teapot)

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## The Sun's Motion

❖Motion of the Sun

- The Sun appears to move constantly eastward relative to the background stars and along the ecliptic on a day-to-day basis.
- The ecliptic is tilted 23.5° to the celestial equator.
- The band of constellations that lies about 10° on either side of the ecliptic is referred to as the zodiac.
- The time the Sun takes to return to the same place among the stars is about 365.26 days - consequently, the stars rise about 4 minutes earlier each day.




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## The Sun's Motion

❖ Motion of the Sun - Details

- As the Sun marches on the ecliptic it encounters 4 special points.
- Equinoxes: The 2 intersections of ecliptic and celestial equator
  - Vernal (March 20)
  - Autumnal (Sept 22)
- Solstices: The 2 extremes in declination of ecliptic
  - Summer (June 21)
  - Winter (Dec 21)
- The seasons occur as a result of the ecliptic's tilt relative to the celestial equator
  - In summer, Sun is above the horizon longer than winter
  - In summer, Sun is more directly over the north than in winter
  - No significant effect due to Earth's distance from Sun




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## A Day on Earth

❖The Day

- Sidereal Day – The length of the day with respect to the stars. It is 3 min. 56 sec. SHORTER than the solar day.
- Solar Day – The length of the day measured with respect to the sun. It varies from day to day and is about 24 hours.
- All clocks measure the day as a 24 hour period. This is called the mean solar day.

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## The Moon's Phases

- Motion and Appearance of the Moon
  - Elongation is the angle of the Moon (or planet) from the Sun in the sky.
  - Phases of the Moon - The changing appearance of the Moon during its cycle are caused by the relative positions of the Earth, Moon, and Sun (different elongations).
  - The phases follow the sequence of new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, third (or last) quarter, waning crescent, back to new Moon.




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## Phase and Time of Observation

- The Moon and Time
  - The Moon is bright enough to be seen easily in the daytime
  - When and where the Moon is in the sky is completely determined by phase.
    - Example: A first quarter moon should be crossing the meridian at around sunset
    - Example: At midnight, a rising Moon must be in third-quarter
  - There are certain phase combinations that cannot be seen at certain times
    - Example: A waxing crescent high cannot be seen at 1 AM
    - Example: A full Moon cannot be seen at noon




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## Sidereal and Synodic Moon Periods

- Sidereal Period
  - The amount of time required for one revolution (or rotation) of a celestial object with respect to the distant stars.
  - A sidereal revolution of the Moon takes about 27 1/3 days.
- Synodic Period
  - The time interval between successive similar alignments of a celestial object with respect to the Sun.
  - A synodic revolution of the Moon takes about 29 1/2 days
  - Lunar month is the Moon's synodic period, or the time between successive phases (e.g. new moon to new moon): $29^d12^h44^m2^s$.
- Phase Age
  - The number of days past new Moon
  - For example: 1st Quarter ≈ 7.5 days etc

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## Eclipses and Shadows

❖**Eclipse Basics**

- Eclipses occur when the shadow of one celestial object falls on the surface of another celestial object (solar and lunar eclipses).
- The Umbra is the portion of a shadow that receives no direct light from the light source.
- The penumbra is the portion of a shadow that receives direct light from only part of the light source.




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## Lunar Eclipses

❖Types of Lunar Eclipses

- Penumbral lunar eclipse is an eclipse of the Moon in which the Moon passes through the Earth's penumbra but not through its umbra.
- Partial lunar eclipse is an eclipse of the Moon in which only part of the Moon passes through the umbra of the Earth's shadow.
- Total lunar eclipse is an eclipse of the Moon in which the Moon is completely in the umbra of the Earth's shadow.




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## Lunar Eclipses

❖Why is a totally Eclipse Moon Visible?

- A total eclipse of the Moon is never totally dark because some light is refracted toward the Moon by the Earth's atmosphere.
- Most of this refracted light reaching the Moon is red; the blue portion has been scattered out.

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## Solar Eclipses

- Types of Solar Eclipses
  - A total solar eclipse is an eclipse in which light from the normally visible portion of the Sun (the photosphere) is completely blocked by the Moon (the Sun's corona will be visible).
  - A partial solar eclipse occurs when a part of the Sun's disk is covered by the Moon.
  - An annular eclipse is an eclipse in which the Moon is too far from Earth for its disk to cover that of the Sun completely, so the outer edge of the Sun is seen as a ring or *annulus*.




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## Eclipse Frequency

- When To Expect an Eclipse
  - Eclipses do not occur at each full and new Moon because the Moon's orbital plane is tilted 5° to the Earth's orbital plane.
  - An eclipse season is a time of the year during which solar and lunar eclipses are possible.
    - Only during the two (or three) eclipse seasons that occur each year are the Earth and Moon positioned so that the shadow of the Moon or the Earth falls on the other to create an eclipse.
    - 1 or 2 solar eclipses may occur during an eclipse season, whereas 0 or 1 lunar eclipses are possible.
    - Viewing of eclipses is dependent on observer location.




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## Future Eclipses

- Upcoming Lunar Eclipses
  - Total: 2019 Jan 21 (22:15 PST)
  - Partial: 2019 Jul 16 (14:30 PDT)
  - Penumbra: 2020 Jan 10 (11:10 PST)
  - Penumbra: 2020 July 4 (21:30 PDT)
  - Penumbra: 2020 Nov 30 (1:45 PDT)
- Upcoming Solar Eclipses
  - Partial: 2019 Jan 06 (ne Asia, n Pacific)
  - Total: 2019 Jul 02 (s Pacific, S. America)
  - Annular: 2019 Dec 26 (India, Indonesia)
  - Annular: 2020 Jun 21 (s Asia)
  - Total: 2020 Dec 14 (s Pacific, S. America, s Atlantic)
  - Total: 2024 Apr 08 (Mexico, US, Canada)

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## Observations of the Planets

- Planetary Motion - Definitions
  - Opposition: when a planet and Sun appear in the opposite part of the sky (Elongation = 180°)
    - Only happens for outer planets
  - Conjunction: when the planet and Sun appear together in the sky (Elongation = 0°)
  - Greatest Elongation: when Mercury or Venus reaches a maximum elongation angle during a particular apparition
  - The time it takes a planet to return to a particular configuration (*e.g.* conjunction, opposition) is called the synodic period.




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## Observations of the Planets

- Planetary Motion
  - Five planets are visible to the naked eye: Mercury, Venus, Mars, Jupiter, Saturn.
  - Planets lack the simple, uniform motion of the Sun and Moon.
  - These planets always stay near the ecliptic.
  - Mercury and Venus never appear very far from the position of the Sun in the sky. Thus their elongation is small.
  - Planets sometimes stop their eastward motion and move westward against the background of stars. This is called retrograde motion.




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## Earth-Centered Solar System Models

- Some History
  - 400 years before Ptolemy (circa 150 A.D.), the Greek philosopher Aristarchus proposed a moving-Earth solution to explain celestial motions.
  - Ptolemy discredited Aristarchus's model using the lack of stellar parallax as proof.