SPA613M: Introduction to Celestial Observational Techniques

Lecture 1

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Topics Covered

- **Introduction:** Night sky, celestial sphere, Stellarium, motion of planets, moon and comets, constellation, sidereal time, calendars, precession, proper motion and parallax, eclipses and transits, brightness, intensity, flux, luminosity, magnitude scale, filters, Atmospheric transmission windows on Earth, atmospheric seeing, extinction.
- **Tools:** Observing tools in ancient astronomy, modern optical and infrared telescopes, equatorial and alt-az mounts, space observatories, detectors in X-ray, UV, optical and IR.
- **Measurement Techniques:** - Photometry, spectroscopy (doppler shift, spectral resolution, FWHM, convolution) fast imaging and timing of photon arrivals, speckle, adaptive and active optics, calibration.

Astronomy: Techniques and Technology

- Astronomy is defined as the study of the objects that lie beyond our planet Earth and the processes by which these objects interact with one another.
- Astronomy answers big questions: stars, galaxies, planets, how big is universe, what it is made off, what kind of matter, etc.
- Astronomy is challenging: observe with tools at hand.

The Biggest Challenge in Astronomy

- How far things are?
- How big things are?
- How bright things are (Absolute / Apparent magnitude)?

Some numbers in Astronomy

- 1 arcminute = 1/60 deg (').
- 1 arcsecond = 1/60 arcminute (").
- Moon and Sun subtend about an angle of half degree.
- Astronomical Unit (AU): distance between Earth and Sun: $\approx$ 150,000,000 km.
- Jupiter is about 5.2 AU.
- Light Year: distance light travels in a year (8 min 20 sec from Sun to Earth) = $9.461x10^{12}$ km.
- 1 parsec = 3.26 light years. But how its defined?

Aristarchus 310-230 BC

Greek astronomer, came up with first known heliocentric model that placed the Sun at the center of the universe, with the Earth revolving around the Sun once a year and rotating about its axis once a day.

Estimated size of the Moon and Sun relative to Earth.

Size of the Earth?

Eratosthenes (276 - 194 BC)

- Measurements: Syene to Alexandria distance $\approx$ 5000 stadia,
- Angle $= 7.15^{\circ}$
- 1 stadia $\approx$ 185 m
- Circumference $=$ 46640 km
- Actual $=$ 40075 km

Johannes Kepler 1571-1630

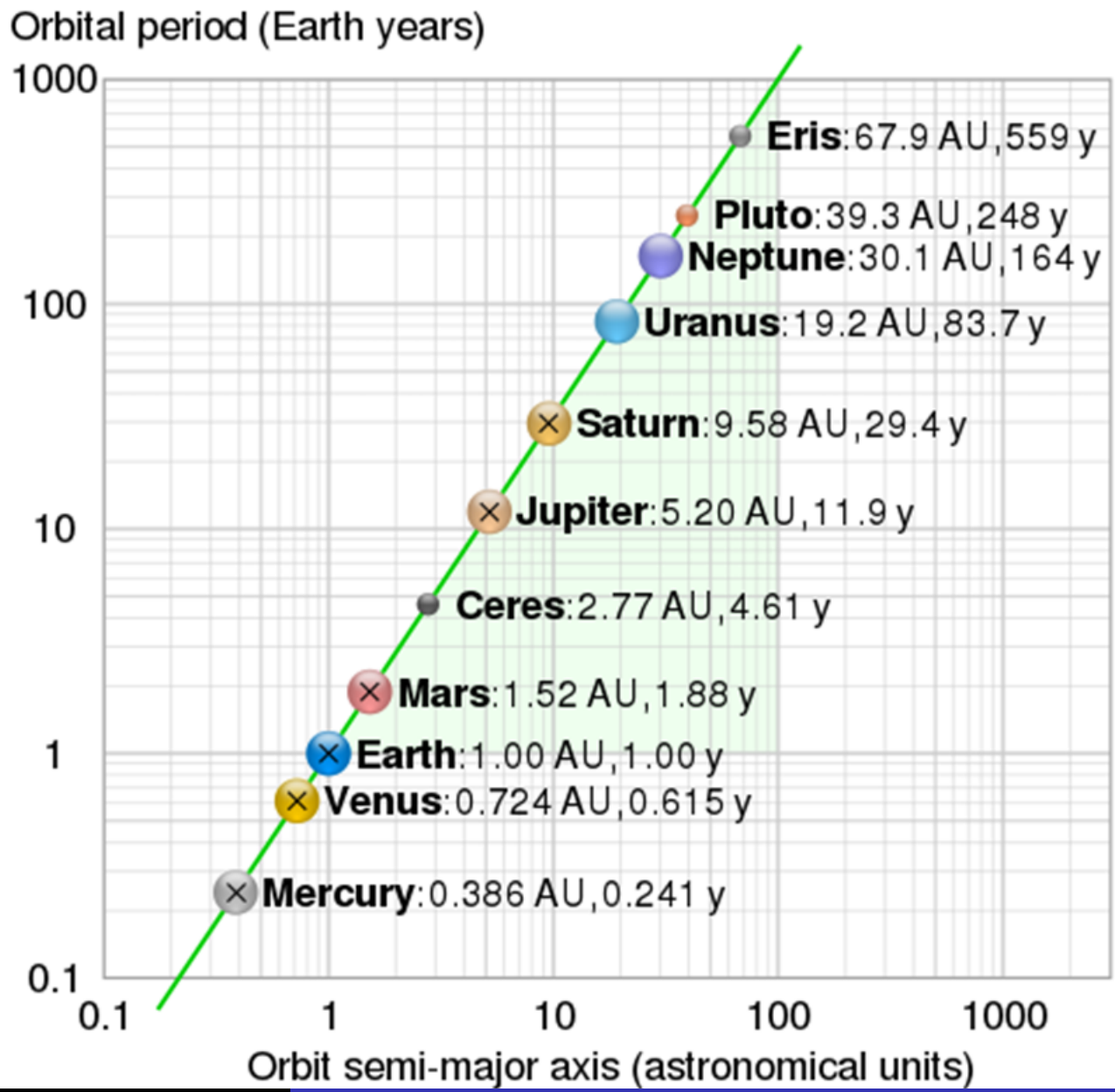
- Tycho Brahe (1546-1601): spend 20 yrs to compile the most accurate (one arcminute) naked eye measurements ever made of planetary positions.
- Kepler first tried to match Tycho's observations with circular orbits.
- But an 8 arcminute (1/4 of the Moon's apparent size on the sky) discrepancy led him eventually to ellipses.
- **1st Law:** The orbit of every planet is an ellipse with the sun at one of the two foci.
- **2nd Law:** Area swept is equal for a given time.

Kepler's 3rd Law

$D^3 = P^2$

D is distance from Sun.

P (period) = time for one orbit around the Sun.



Distance to the Sun

- Jeremiah Horrocks – 1639.
- Brilliant idea of using transit of Venus.
- His estimate 95 million km, 40% error.
- Christiaan Huygens in 1659 using Transit of Mercury, 6.8% error.
- In 1771, the French astronomer Lalande used the combined 1761/1769 transit data to derive a distance of 153 ± 1 million km, 2.3% error.

How to determine distance to stars?

- Stellar parallax is the apparent shift of position of any nearby star against the background of distant stars.
- To avoid very large numbers for r, the **parsec (pc)** is defined such that, **it is the distance of an object whose parallax is one second of arc**.
- Astrometry data from Hipparcos and GAIA satellites have been used to calculate parallax.
- To find distance of stars, $D_{parsec} = \frac{1\ parsec}{\theta\ ('')}$
- How to differentiate between proper motion and parallax?

Understanding the Night Sky: Motions of Earth

Six different motions of Earth:

- Rotation: 23 hrs 56 min (Sidereal) and 24 hrs (Solar).
- Revolution: 365 days.
- Precession: like a top, 26,000 yrs for one cycle.
- Earth Moon Barycenter: Both the Moon and the Earth orbit a common center of gravity.
- Milankovitch cycles: Earth orbit goes from elliptical to circular, 1,00,000 yrs (causes ice age).
- Tilt: changes from 21° to $24\frac{1}{2}^\circ$ cycle 41,000 yrs.

Solar vs Sidereal Day

- Sidereal means "related to the stars"; note that you'll measure the same time no matter what star you choose.
- For practical purposes, the sidereal day is Earth's precise rotation period.
- The solar day is indeed 24 hours on average, although it varies slightly (up to about 25 seconds longer or shorter than 24 hours) over the course of a year.

Understanding the Night Sky: Celestial Sphere

- The celestial sphere is an imaginary sphere on which the astronomical objects appear to be located. We can specify any point on the sphere, by specifying two angles.
- In order to specify any coordinate system we need to choose an origin for the coordinates. In astronomy this is usually taken to be at the center of the Earth or the Sun.

RA and Dec of some Stars

Star	RA	Dec
Sirius	6 hr 45 min	-16° 42'
Betelgeuse	5 hr 55 min	$+7^\circ$ 24'
Vega	18 hr 36 min	$+38^\circ$ 48'
Alpha Centauri	14 hr 40 min	-60° 50'

How RA is defined?