SPA613M: Introduction to Celestial Observational Techniques

Lecture 2

Prashant Pathak

SPASE IITK

08/08/2024

Summary

- Historical measurements: Earth's circumference and distance to the Sun and Moon.
- Kepler's Laws –qualitatively–.
- What is parallax and how to find distances of nearby stars.
- Different motions of Earth.
- Equatorial coordinate system.
- Positions of stars using RA and Dec.

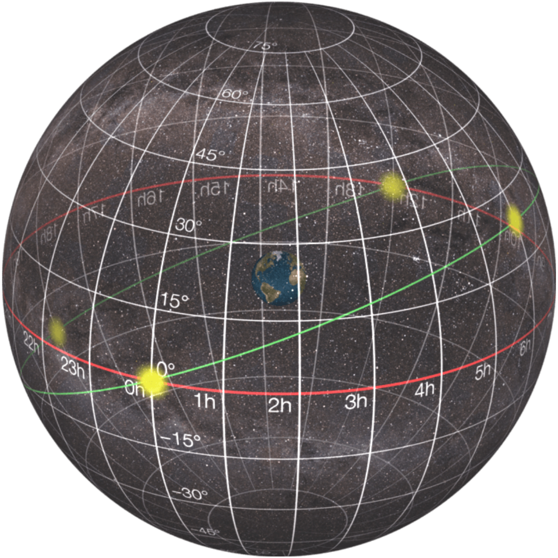
RA and Dec of some Stars

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?

RA = number of hours behind the Sun on March 21 (Vernal Equinox)

Equatorial Coordinate System



Epoch

- The fundamental plane and the fundamental direction for equatorial coordinates are tied to the axis of rotation of the Earth.
- Changes in Earths axis of rotation: (1) Precession and (2) Nutation (Tilt).
- The effects of precession and nutation causes the equatorial coordinates of celestial objects to change over time. This leads to moving of vernal equinox position over time.
- The First Point of Aries has a backward movement of about 50 arc seconds per year.
- This means that it isn't enough to just specify the coordinates, we must also specify the date or epoch for the coordinates.
- One of the most common epochs used today is the so called J2000 epoch. J2000 refers to 12h GMT on January 1st, 2000.

Julian Date

- In 1054 Chinese astronomers reported the discovery of a "guest star" in the constellation Taurus. Today with modern telescopes we know its a supernova remnant (Crab Nebula).
- Suppose as an astronomer you wished to accurately determine the interval of time between the supernova event and today.
- If you were given the calendar dates you would have to first count the number of years between the events and multiply by 365, then add the appropriate number of leap days, count the number of days in the any additional months and finally count any additional hours.
- In 1582, the system of Julian Day Numbers was introduced to avoid this sort of calculation.

Julian Date

- In this system, the time of an astronomical event is specified as the decimal number of days since noon UTC on January 1, 4713 BC.
- For example, the Julian date for 0 UT August 15, 1997 is 2,450,675.5.
- A more convenient, but related, system is the Modified Julian Day system. The modified Julian date (MJD) is the JD minus 2,400,000.5. At 0 UT on January 1, 1997 the MJD was 50,448.0.
- It is common for astronomers to use the Julian date to specify the epoch for the equatorial coordinates of a celestial object. For example, the Julian epoch 2000.0 is denoted J2000.0 and refers to January 1.5, 2000. The Julian date for January 1.5, 2000 is JD 2,451,545.0 or is the MJD 51,544.5.

Change in Coordinates

Most of the change in coordinates is due to precession and a good approximation is given by the equations;

$$\alpha = \alpha_0 + (m + n \sin \alpha_0 \tan \delta_0) N \tag{1}$$

$$\delta = \delta_0 + (n' \cos \alpha_0) N \tag{2}$$

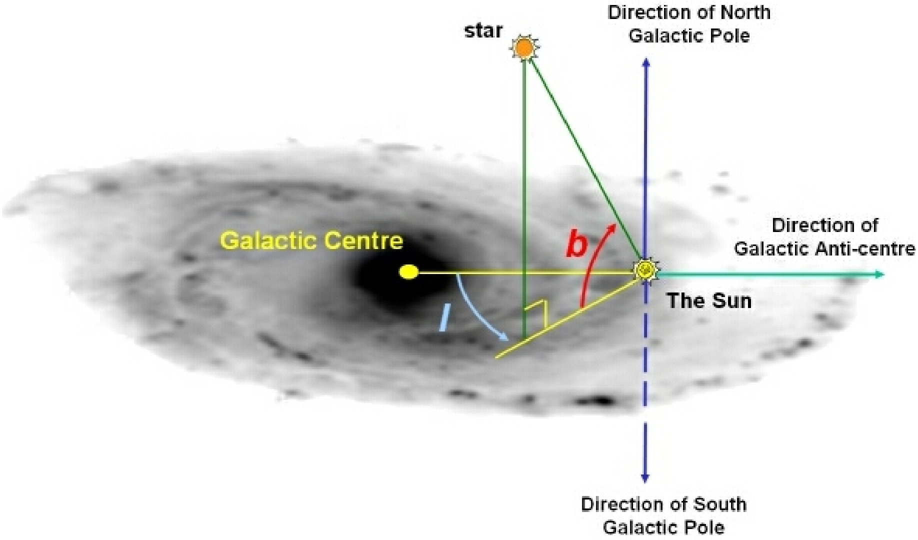
where α and δ are current-day coordinates and N is the number of years since the reference epoch.

Change in Coordinates

Example: The star Sirius has coordinates α(J2000) $=$ 6h45m8.9s and δ(J2000) $= -16°42'58''$. What are the coordinates on June 5, 2013?

Epoch	m (seconds)	n (seconds)	n' (arcsec)
1900.0	3.07234	1.33645	20.0468
1950.0	3.07327	1.33617	20.0426
2000.0	3.07420	1.33589	20.0383
2050.0	3.07513	1.33560	20.0340

Galactic Coordinates



Galactic Coordinates

- When studying the galaxy it makes sense to specify the positions of objects with respect to the center and the plane of the galaxy.
- The origin of galactic coordinates is the Sun.
- The fundamental plane coincides with the galactic plane and the fundamental direction points toward the center of the galaxy in the constellation Sagittarius.
- The galactic latitude, b, is the angle for the object above the galactic plane.
- The galactic longitude, l, is the angle in the galactic plane from the center of the galaxy.
- By convention, both angles are measured in decimal degrees with $-90^\circ \leq b \leq 90^\circ$ and $0^\circ \leq l \leq 360^\circ$.

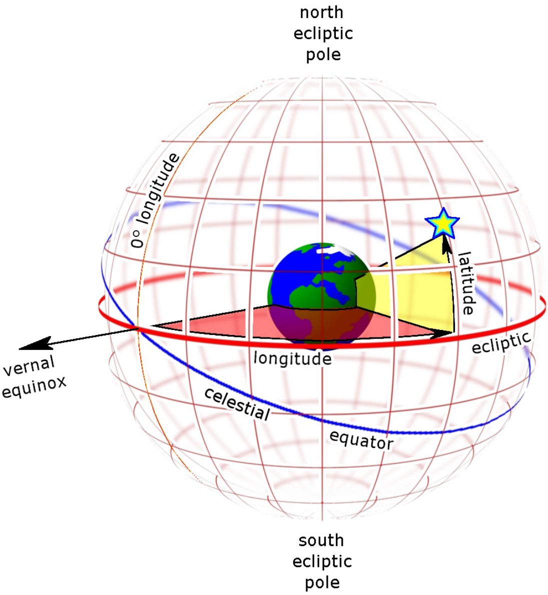
Galactic Coordinates

The transformation from equatorial to galactic coordinates for J2000 is,

$$\sin b = \sin\delta\cos 62.87^\circ - \cos\delta\sin(\alpha - 282.86^\circ)\sin 62.87^\circ \tag{3}$$

$$\cos b cos(l - 32.93^\circ) = \cos\delta\cos(\alpha - 282.86^\circ). \tag{4}$$

Ecliptic Coordinates



Ecliptic Coordinates

- It is convenient to use ecliptic when specifying the positions of solar system objects; planets, minor planets, comets, etc.
- Ecliptic coordinates have the Earth as the origin, but the fundamental plane is coincident with the ecliptic plane.
- Like equatorial coordinates the fundamental direction is toward the First Point in Aries.
- The ecliptic latitude, β, is the angle from the fundamental to the object. The ecliptic longitude, λ, is the angle in the ecliptic plane from the First point of Aires.
- It is a right-handed coordinate system and by convention, both angles are measured in decimal degrees with $-90^\circ \leq \beta \leq 90^\circ$ and $0^\circ \leq \lambda \leq 360^\circ$.

Ecliptic Coordinates

Ecliptic coordinates by are related to equatorial coordinates by a simple rotation around the fundamental direction by an angle equal to the obliquity/tilt, ϵ

$$\tan \lambda = (\sin \alpha \cos \epsilon + \tan \delta \sin \epsilon) / \cos \alpha \tag{5}$$

$$\sin \beta = \sin \delta \cos \epsilon - \cos \delta \sin \epsilon \sin \alpha. \tag{6}$$

Electromagnetic Spectrum

EM speed in vacuum is the product of its frequency and wavelength:

$$c = \lambda\nu$$

Table 1.1. *The electromagnetic spectrum. Region boundaries are not well-defined, so there is some overlap. Subdivisions are based in part on distinct detection methods*

Band	Wavelength range	Frequency range	Subdivisions (long λ–short λ)
Radio	>1 mm	<300 GHz	VLF-AM-VHF-UHF
Microwave	0.1 mm–3 cm	100 MHz–3000 GHz	Millimeter–submillimeter
Infrared	700 nm–1 mm	3×10^{11}–4×10^{14} Hz	Far–Middle–Near
Visible	300 nm–800 nm	4×10^{14}–1×10^{15} Hz	Red–Blue
Ultraviolet	10 nm–400 nm	7×10^{14}–3×10^{16} Hz	Near–Extreme
X-ray	0.001 nm–10 nm	3×10^{16}–3×10^{20} Hz	Soft–Hard
Gamma ray	<0.1 nm	$>3 \times 10^{18}$ Hz	Soft–Hard