Introduction to Astronomy and Astrophysics I

Lecture 4

Yogesh Wadadekar

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Characteristics of Multiplanet Systems

- Over 800 known multiplanet systems
- Provide insights into planetary formation and evolution
- Often show compact orbital configurations (selection bias)
- Exhibit orbital resonances and dynamical interactions

Notable Multiplanet Systems

- TRAPPIST-1: 7 Earth-sized planets, 3 in habitable zone
- Kepler-90: 8 planets, mirroring our Solar System
- HD 10180: Possibly up to 7 planets
- Gliese 581: 3 confirmed planets, potentially habitable

Defining Earth-like Planets

- Size: 0.8 to 1.25 Earth radii
- Mass: 0.5 to 2 Earth masses
- Composition: Primarily rocky
- Orbit: Within the habitable zone of its star
- Atmosphere: Presence of an atmosphere (ideally with biomarkers)

Promising Earth-like Candidates

- Proxima Centauri b: Nearest known exoplanet (4.2 light-years)
- TRAPPIST-1e: Similar size to Earth, potentially habitable
- Kepler-442b: Super-Earth in its star's habitable zone
- TOI-700 d: First Earth-sized habitable-zone planet found by TESS

Challenges in Identifying Earth-like Planets

- Detection limits of current technologies
- Confirming planetary mass and composition
- Characterizing atmospheres of small, rocky planets
- Determining surface conditions and potential habitability

Upcoming Space Telescopes

- James Webb Space Telescope (JWST)
  - Launched in 2021, now operational
  - Capable of detailed atmospheric characterization
- PLAnetary Transits and Oscillations of stars (PLATO) from ESA
  - Planned launch: 2026
  - Focus on detecting and characterizing Earth-sized planets
- Habitable Worlds Observatory (HWO) - proposed NASA mission
- Large Ultraviolet Optical Infrared Surveyor (LUVOIR) - proposed

Advanced Detection Techniques

- Direct Imaging Improvements
  - Coronagraphs and starshades for better contrast e.g. Roman Space Telescope
- Extreme Precision Radial Velocity
  - Aim: 10 cm/s precision to detect Earth-mass planets
- Improved long and short cadence
  - Rubin/LSST will monitor 1 billion stars for 10 years.

The Search for Biosignatures

- Atmospheric biomarkers
  - Oxygen, methane, nitrous oxide
- Surface features
  - Vegetation's red edge - reflectance of plant leaves changes at 700 nm
- Technosignatures
  - Artificial atmospheric pollutants
  - Light pollution

PARAS

The Physical Research Laboratory (PRL) in Ahmedabad, India has a 1.2 m telescope at its Gurushikhar Observatory in Mount Abu that is equipped with the PRL Advanced Radial-velocity Abu-sky Search (PARAS) spectrograph. PARAS, developed by Abhijit Chakraborty, is an optical fiber-fed spectrograph that can measure the mass of planets orbiting stars, and was the first of its kind in Asia when it was developed in 2008. The PRL uses PARAS to search for exoplanets around F, G, and K dwarfs using the Radial Velocity (RV) technique. They have discovered several new exoplanets.

Conclusion and Future Prospects

- Exoplanet science: A rapidly evolving field
- Technological advancements driving new discoveries
- Potential for finding habitable worlds and signs of life
- Interdisciplinary collaborations: Astronomy, planetary science, biology
- The next decade: Exciting prospects for exoplanet exploration

Encyclopedia of exoplanetary systems

https://exoplanet.eu/home/
For a spectacular talk on Exoplanets watch the talk by Anjali Tripathi at https://www.youtube.com/watch?v=WTanfFgR7WU as part of An evening with NASA at the IAU GA 2024.

Solar Time

- Local time

Solar Time

- Local time
- Standard time

Solar Time

- Local time
- Standard time
- Greenwich time

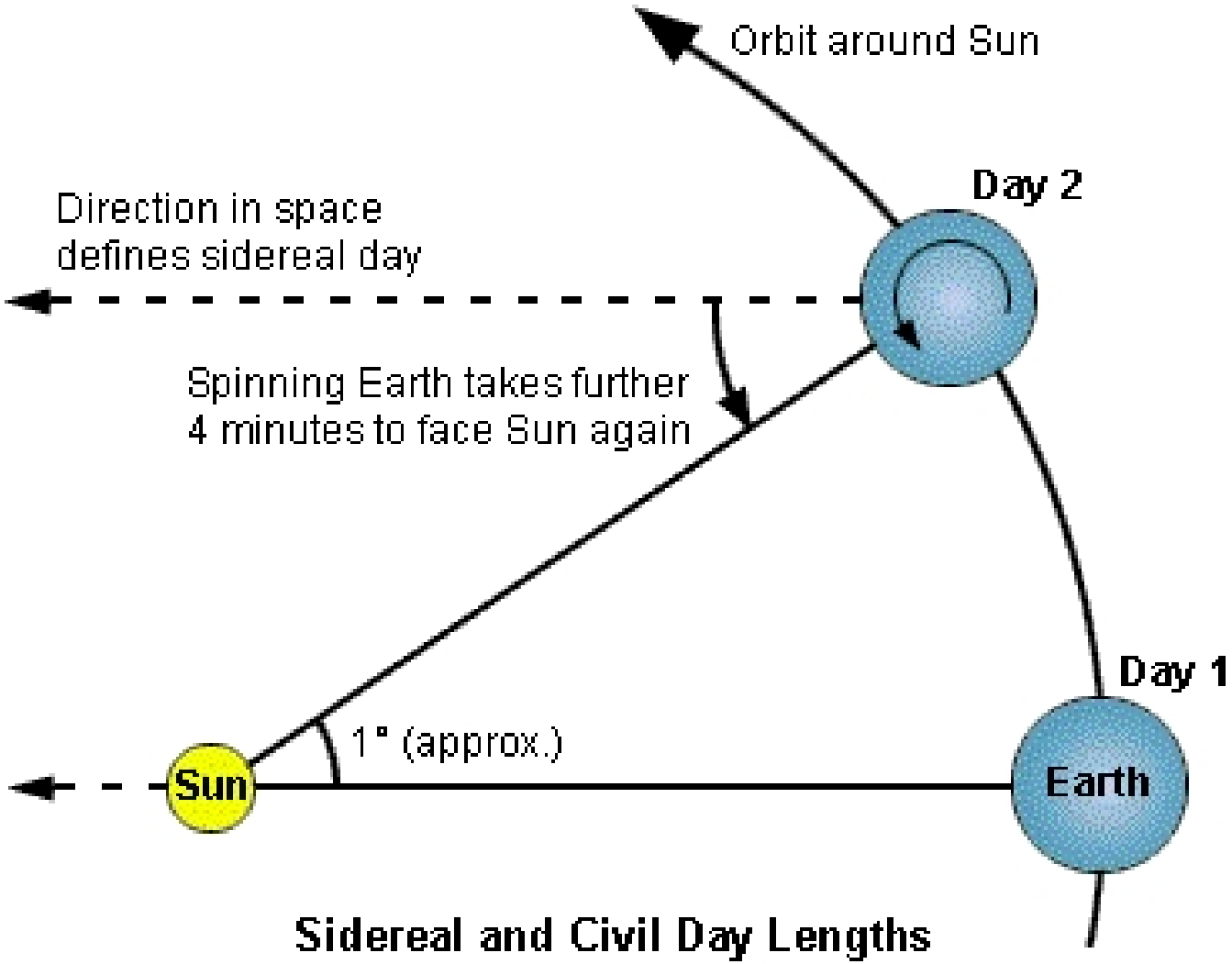
Solar Time

- Local time
- Standard time
- Greenwich time
- Universal time

Universal time

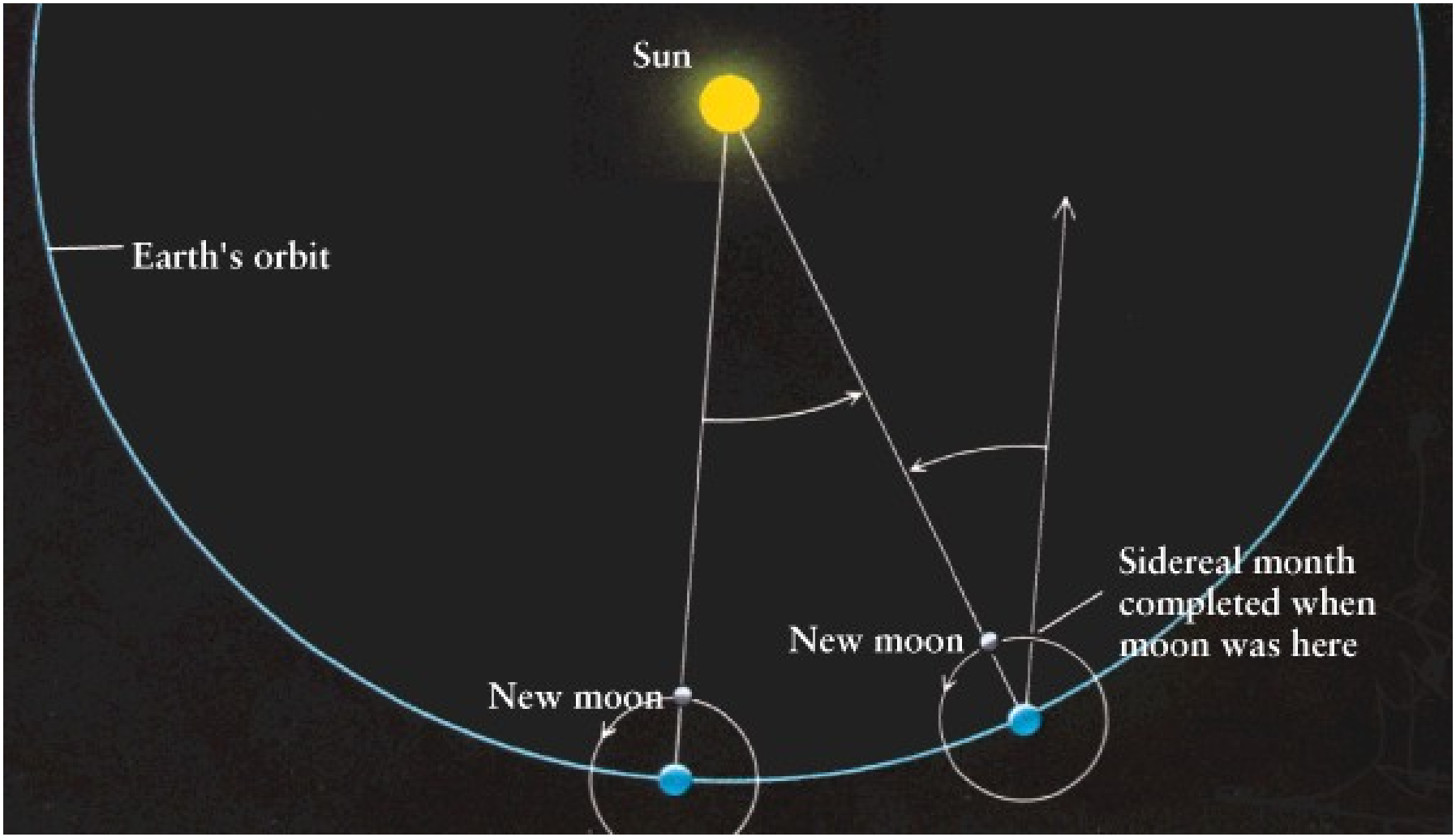
a generic reference to one of several time scales that approximate the mean diurnal motion of the Sun; loosely, mean solar time on the Greenwich meridian (previously referred to as Greenwich Mean Time). In current usage, UT refers either to a time scale called UT1 or to Coordinated Universal Time (UTC). UT1 is observationally determined by the apparent diurnal motions of celestial bodies, and is affected by irregularities in the Earths rate of rotation and needs correction. UTC is an atomic time scale but is maintained within 0s.9 of UT1 by the introduction of 1-second steps when necessary. Generally, leap seconds are added at the end of June or December as necessary, but may be inserted at the end of any month. Although it has never been used, it is possible to have a negative leap second in which case the 60th second of a minute would be removed.

Sidereal versus Solar Day



Could the sidereal day have been longer than a solar day?

Sidereal versus Synodic Month

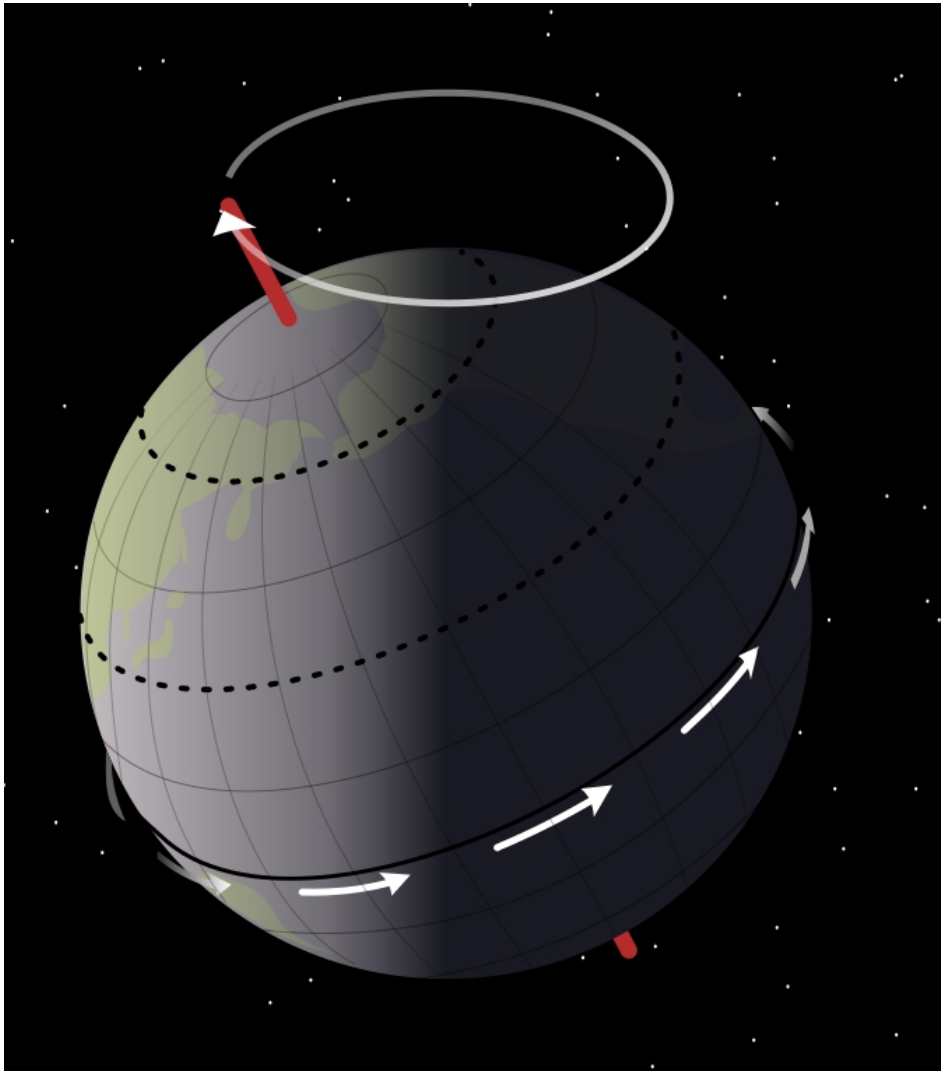


Most lunar calendars use the Synodic month

Julian Day

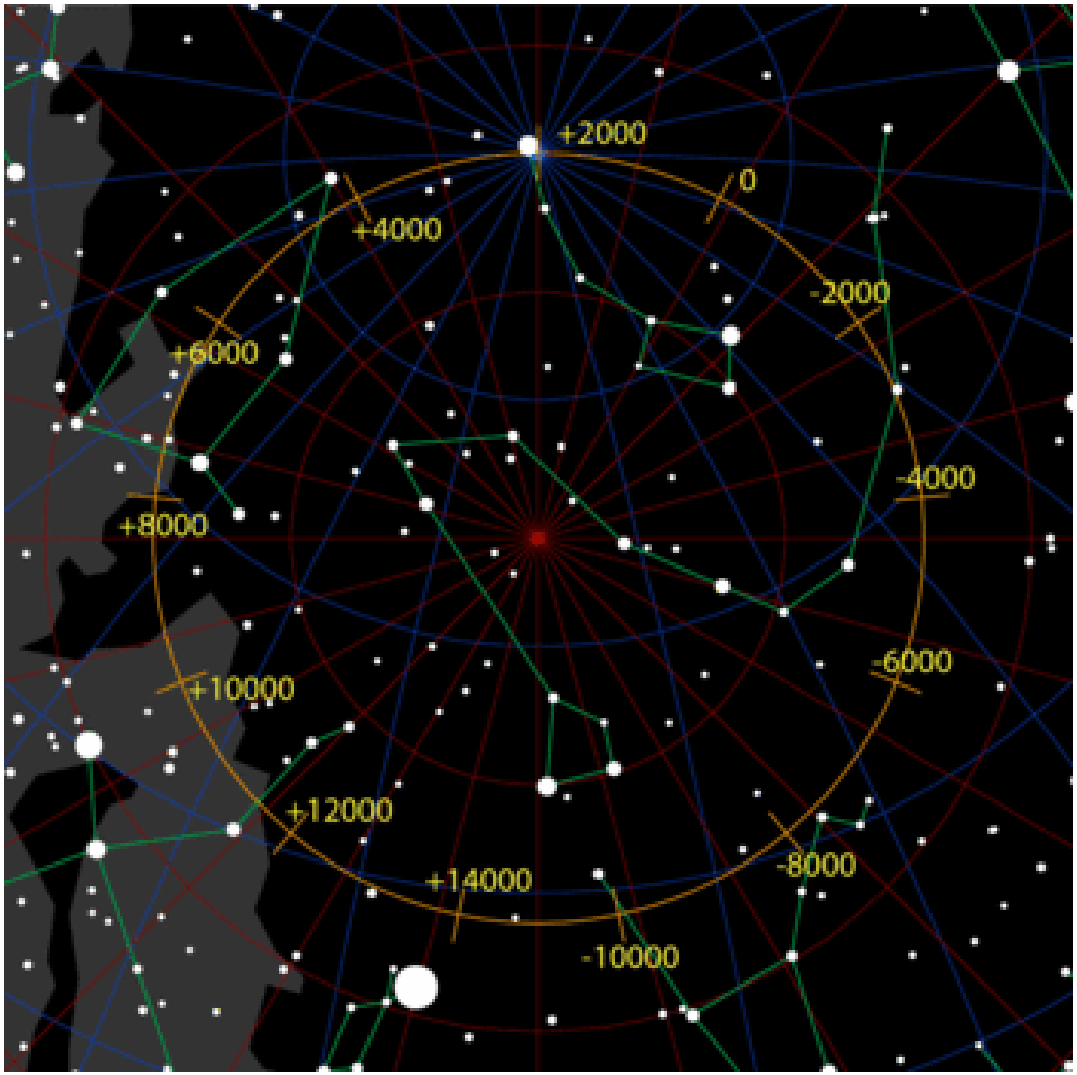
- the interval of time in days and fractions of a day, since 4713 B.C. January 1, Greenwich noon.
- note that Julian day starts at noon. Why?
- Astronomers often use modified Julian day (MJD; starts at midnight!) or reduced Julian day (RJD)

Earth precession - 25800 year cycle

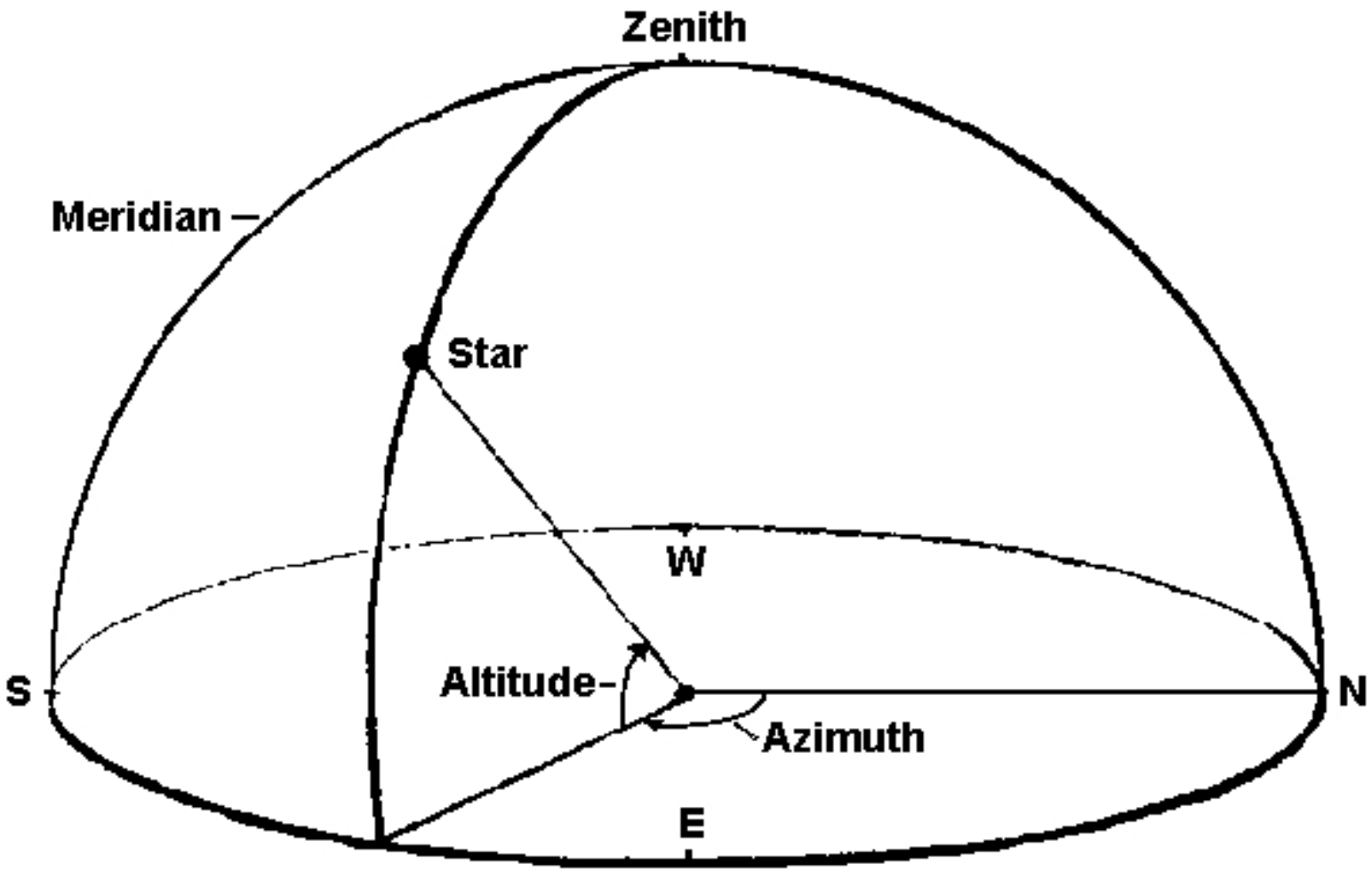


Note direction of precession

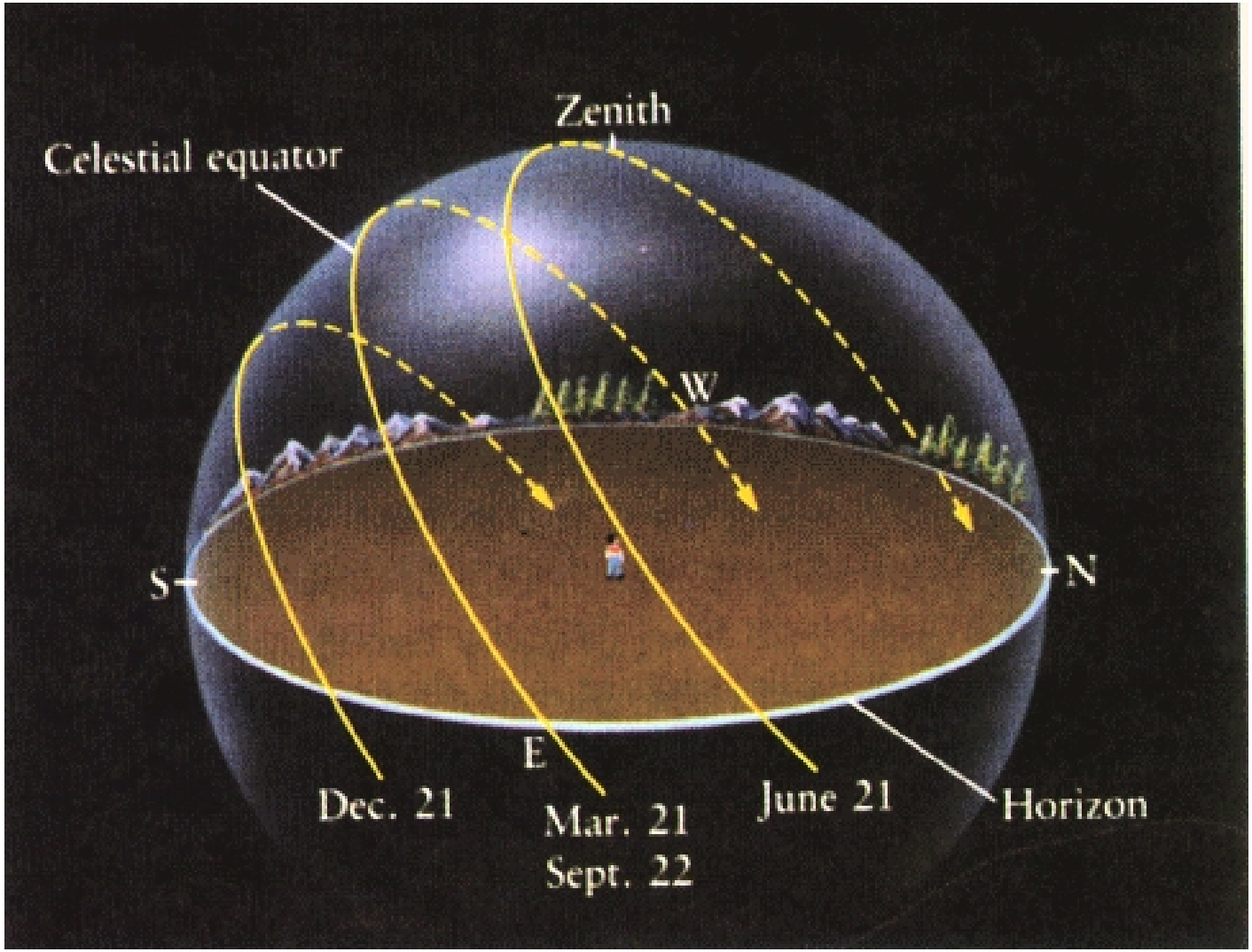
Earth precession changes the pole star



Altazimuth coordinates

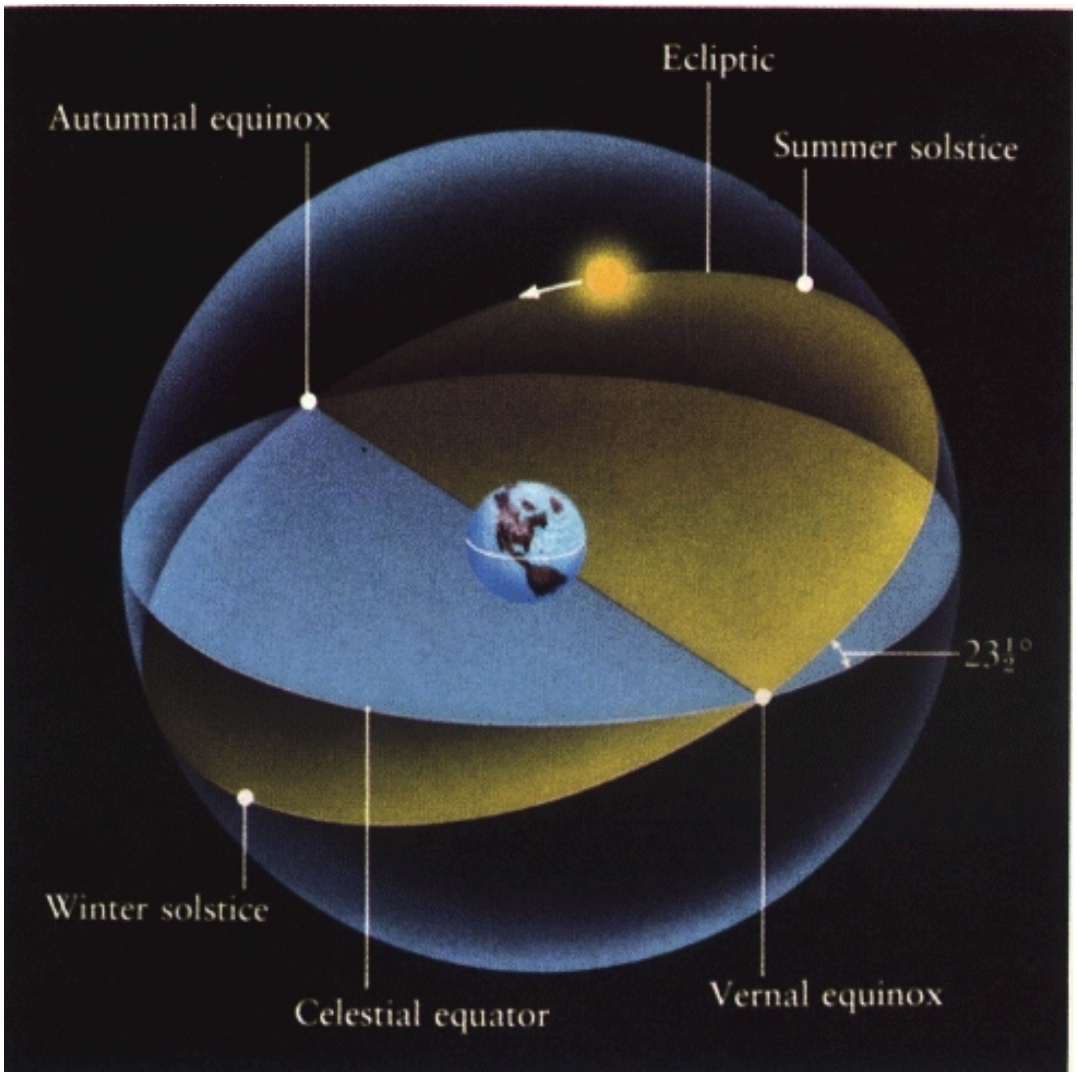


How does the sun move?

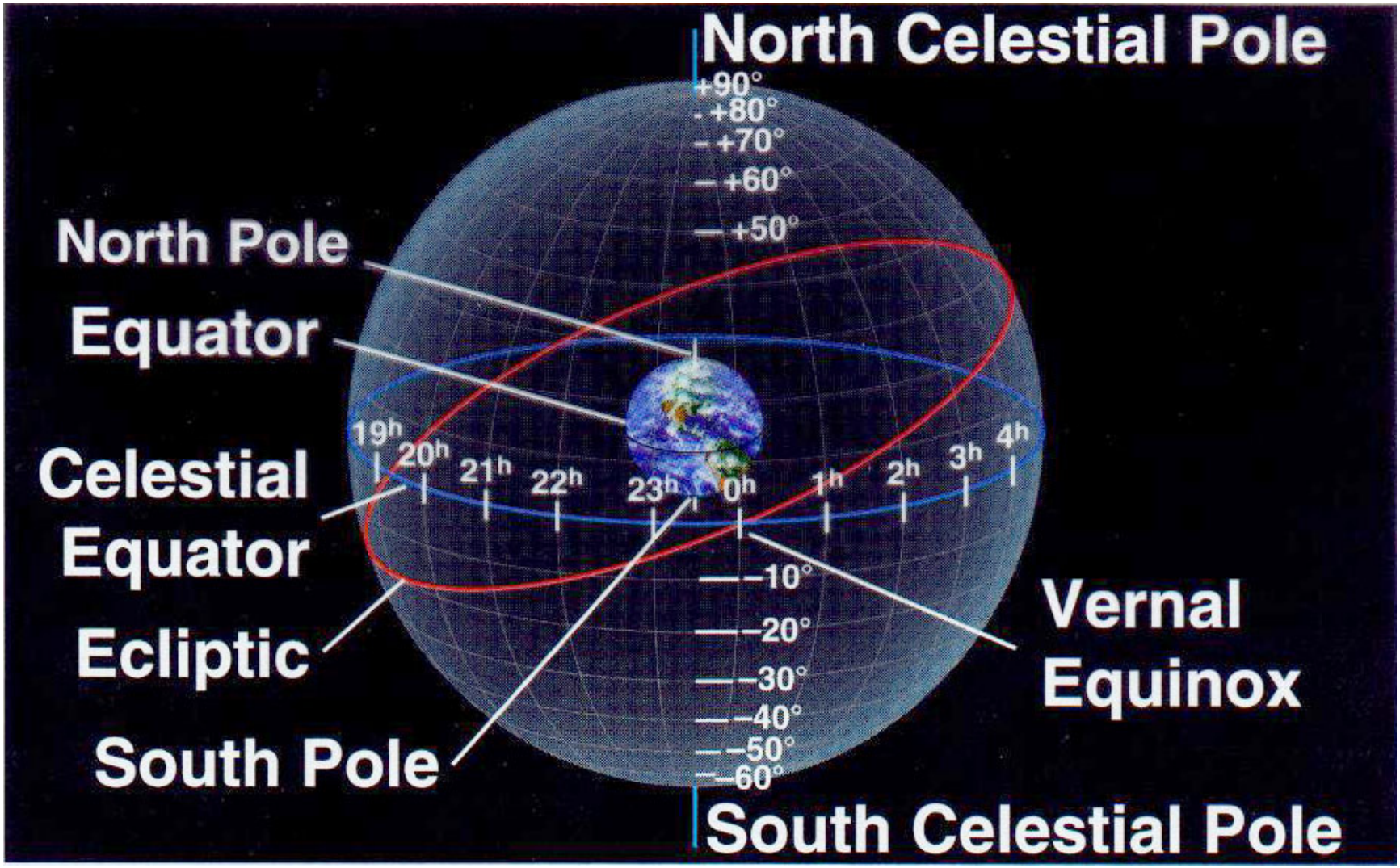


How do stars move in the sky?

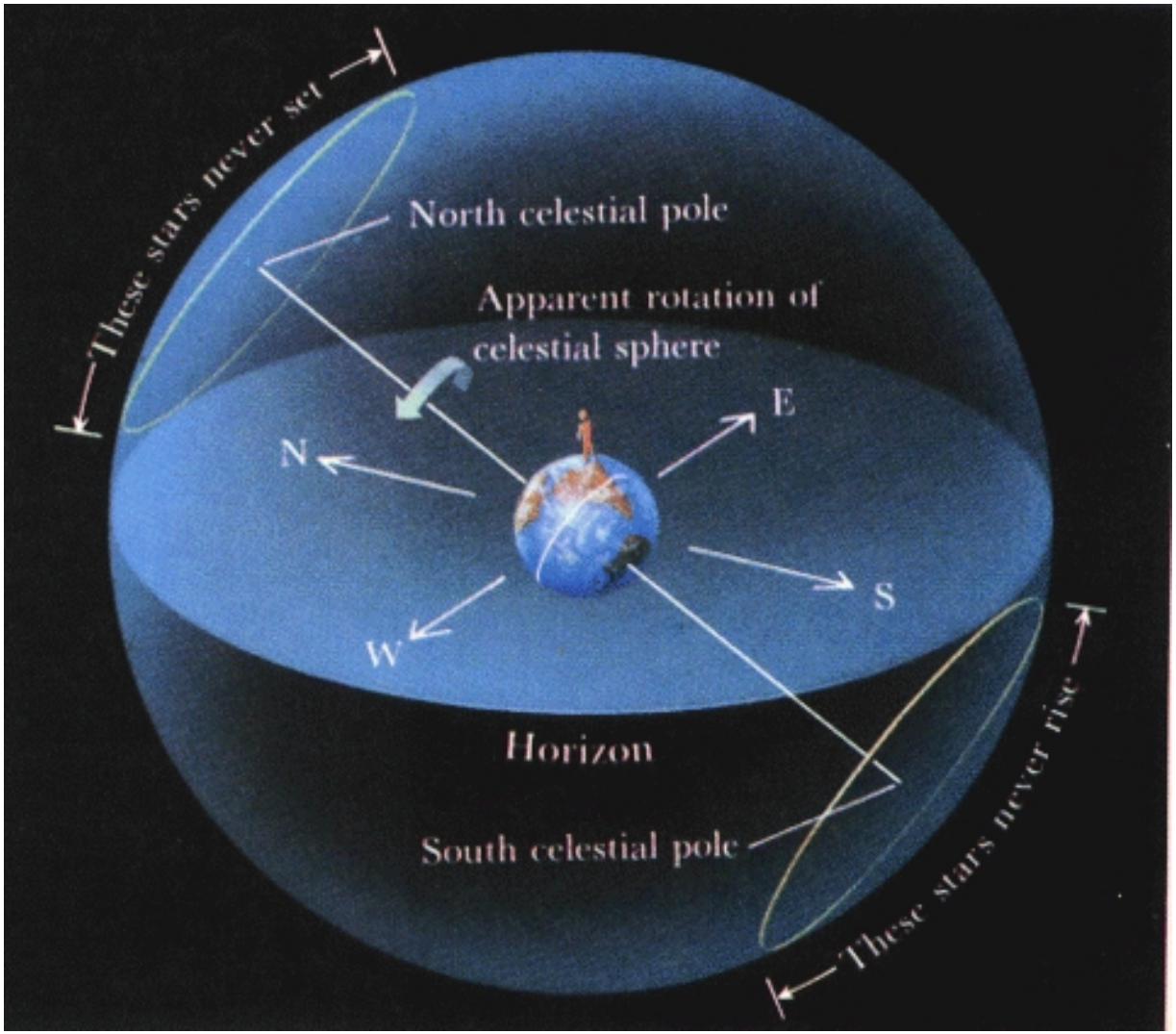
Celestial sphere



Celestial sphere - definitions

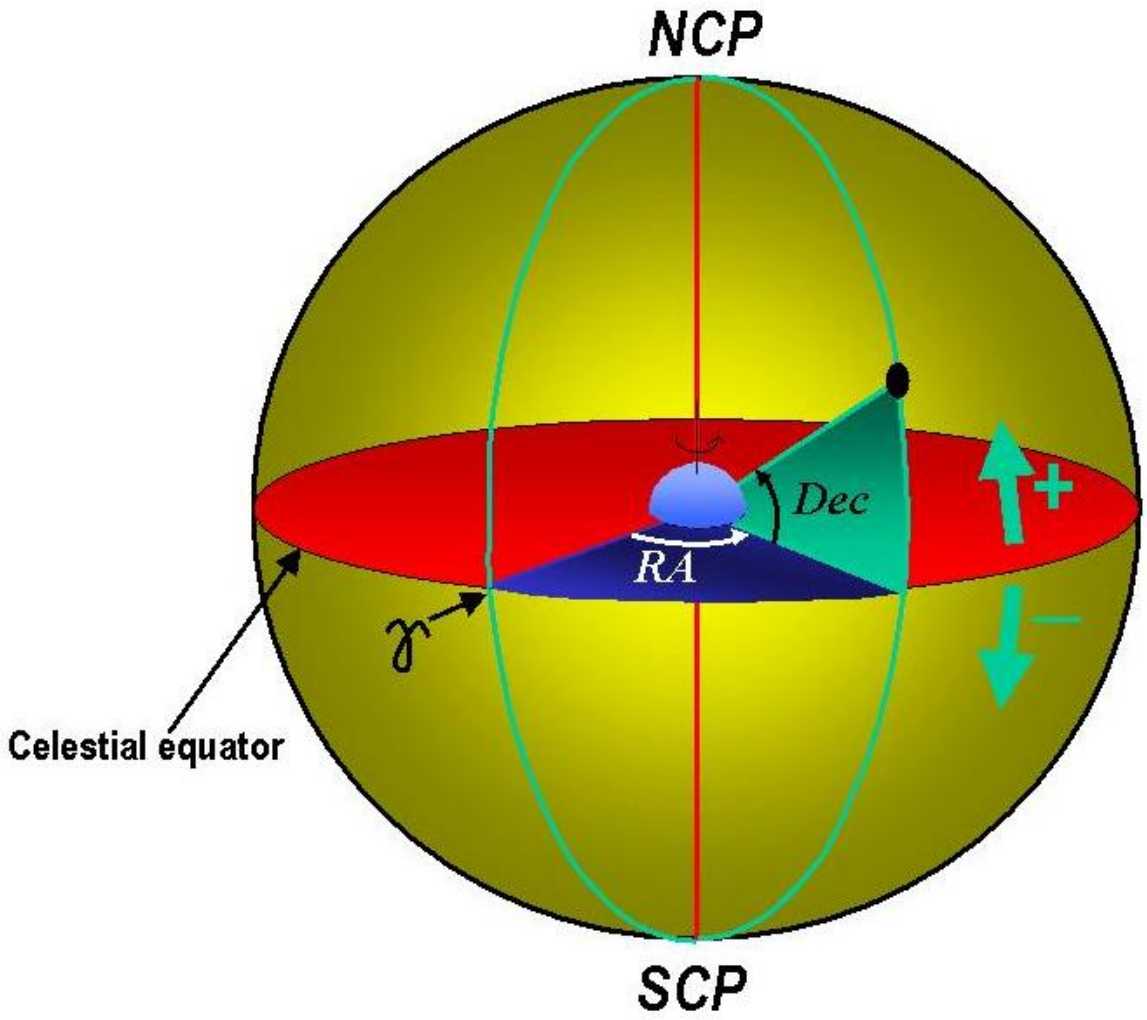


Circumpolar stars



Circumpolar stars

Right ascension (α) and Declination (δ)



Right ascension (α) and Declination (δ)

- RA measured in hours, minutes and seconds or decimal degrees.
- Dec measured in degrees, minutes and seconds or decimal degrees.

tidal friction and longer days

There is a secular increase in length of day of about 2.3 milliseconds per century which mostly results from slowing of the Earth's rotation by tidal friction. How much longer before we have 48 hour days?

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$86400/2.3 \times 10^3 \times 10^2 = 3800$ million years