Introduction to Astrophysics

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- 6 lectures - **Introduction and basic definitions**
  - Astronomical measurements
  - Introduction to stars and the Universe
- 8 lectures - **Astronomical systems and their physics**
  - Stars and their evolution
  - Galaxies
  - Cosmology and the Universe
- Recommended text "Universe" (7th or 8th Ed.) by Freedman & Kaufmann - buy it!
- Course web site contains additional guidance: (www.sr.bham.ac.uk/~tjp/ItA/)

How to approach this course

- Delivered as a set of Powerpoint lectures
- Key slides available for download from course web site as pdf files - print these out, or download to your computer
- During lectures, make terse notes to complement these pdf files
- Lectures will include discussion topics and Concept Tests - participate to develop your understanding
- Read "Universe" to clarify any points you are unsure about
- Weekly assessed problems will test your grasp of the subject
- Look at course web site for some further material

Lecture 1: Introduction and astronomical coordinates

- Introduction: astronomy as an observational science
- The sky
  - Constellations
  - Diurnal and annual motions
  - The celestial sphere
  - Coordinates: celestial and galactic

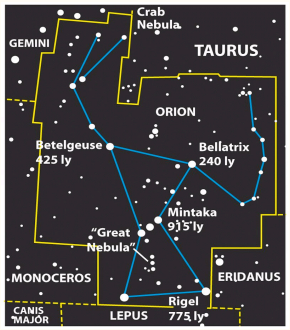
Astronomy - an observational science

Scientific method

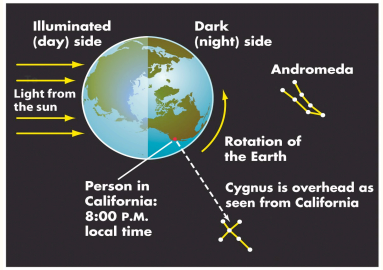
- Identify a problem or phenomenon to be explained
- Introduce a hypothesis or model to explain it
  - A hypothesis is generally rather specific, whereas a model is more wide ranging
- Make predictions for further phenomena which should be seen if the model is correct
- Conduct observations or experiments to test the model (in astronomy we cannot usually experiment)
- Reject or revise the model, or accept it provisionally
- Note: theoretical and observational work must be published, so it can be checked and criticised

Constellations

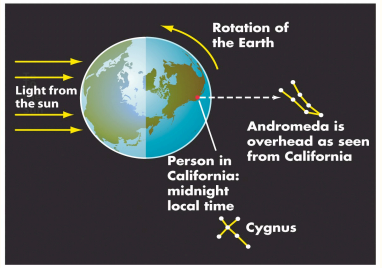
- On modern star charts, the entire sky is divided into 88 regions
- Each is a constellation (from the Latin for "group of stars") with names originating from the patterns they create on the sky
- Most stars in a constellation are nowhere near one another in space
- They only *appear* to be close together because they are in nearly the same direction as viewed from Earth



The appearance of the sky changes during the course of the night



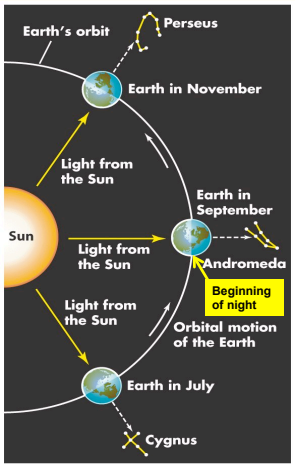
(a) Earth as seen from above the North Pole

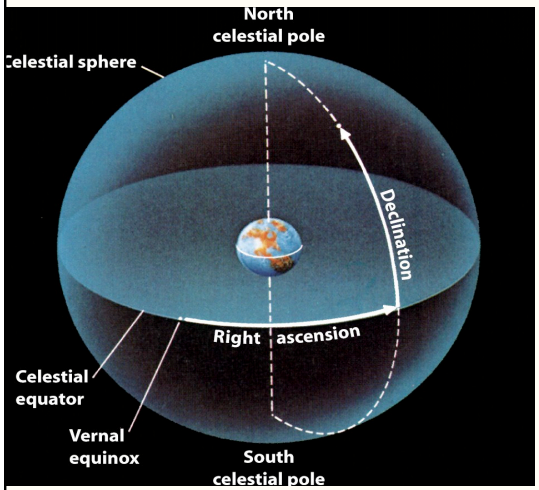


(b) 4 hours (one-sixth of a complete rotation) later

Annual Motion

- The stars also appear to slowly shift in position throughout the year
- This is due to the orbit of the earth around the sun
- If you follow a particular star on successive evenings, you will find that it rises approximately 4 minutes earlier each night, or 2 hours earlier each month

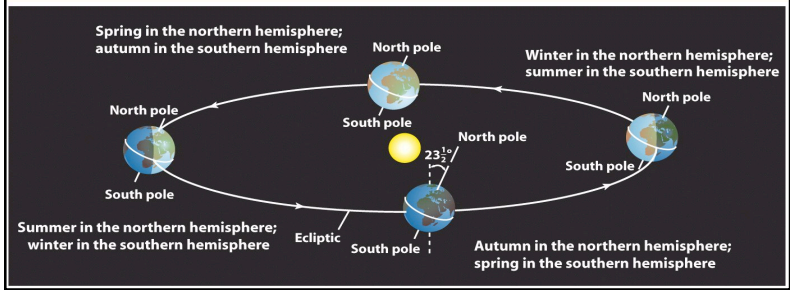




- Celestial equator divides the sky into northern and southern hemispheres
- Celestial poles are where the Earth's axis of rotation would intersect the celestial sphere
- Polaris is less than 1° away from the north celestial pole, which is why it is called the North Star or the Pole Star.
- Point in the sky directly overhead an observer anywhere on Earth is called that observer's zenith.

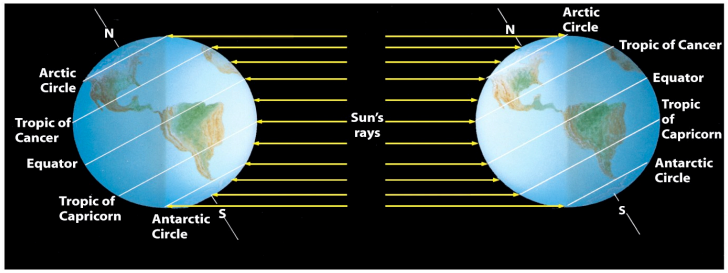
The seasons are caused by the tilt of Earth's axis of rotation

- The Earth's axis of rotation is not perpendicular to the plane of the Earth's orbit (the ecliptic)
- It is tilted about 23½° away from the perpendicular
- The Earth maintains this tilt as it orbits the Sun

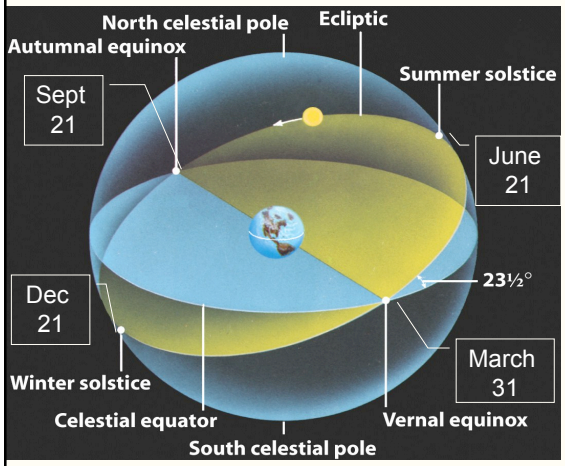


Seasons

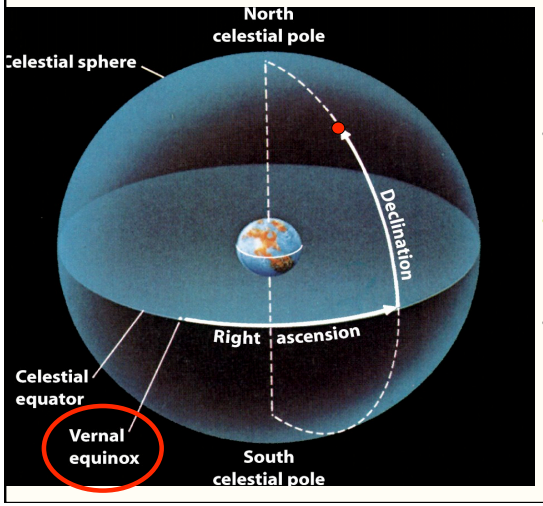
- The northern hemisphere of the Earth is tilted toward the Sun during our summer
- Days are long and the nights are short, and the ground is warmed more effectively by the sun's rays which strike the ground more perpendicularly than in winter



(a) Earth at winter solstice (b) Earth at summer solstice



- The Sun appears to trace out a circular path called the **ecliptic** on the celestial sphere, tilted at 23 ½ degrees to the equator
- The ecliptic and the celestial equator intersect at only two points, known as the **equinoxes**
- The **vernal equinox** (also known as the first point in Aries, and denoted ♈) serves as the zero-point for measurement of RA round the celestial equator. This is the celestial location of the sun at the spring equinox



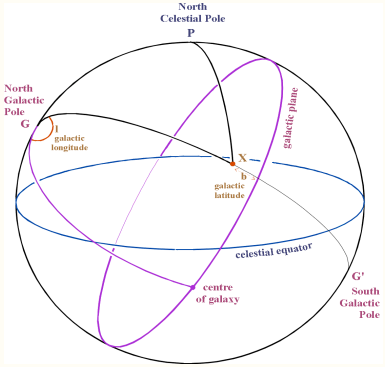
- The **Declination** of a point on the sky is effectively its celestial latitude - i.e. the angle measured from the celestial equator towards the North celestial pole
- Hence declination is negative for a point in the south
- **Right Ascension** is the celestial longitude, measured eastward from a zero point at the vernal equinox
- Rather than being measured in degrees like declination, it is conventional to measure RA in hours, minutes and seconds. 24 hours=360° (so that 1 hour=15°)

Galactic coordinates

The disk plane of our own Galaxy defines a great circle on the sky (the band of the Milky Way) which does not coincide with either the celestial equator or the ecliptic.

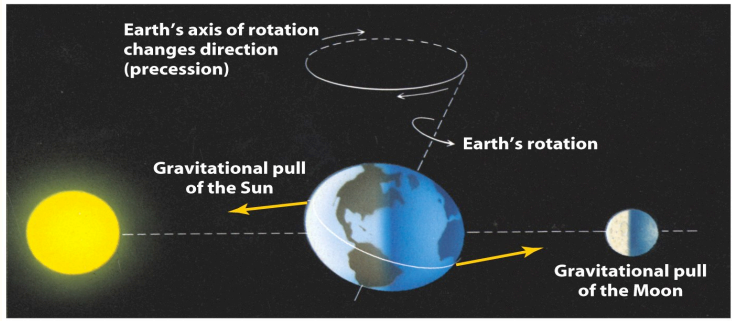
The North Galactic Pole lies at RA=12h49m, Dec=+27º24′, so the galactic plane is inclined by almost 63º relative to the celestial equator.

Any point on the sky can be defined by its galactic latitude and longitude. Latitude (b) is measured northward from the galactic plane, and longitude (l) eastward around the galactic equator from the galactic centre.



Precession of Earth's axis of rotation

The Earth's rotation axis slowly changes its orientation in space, due to the torque exerted by the moon and the sun. It describes a circle on the celestial sphere with a period of approximately 26,000 years.

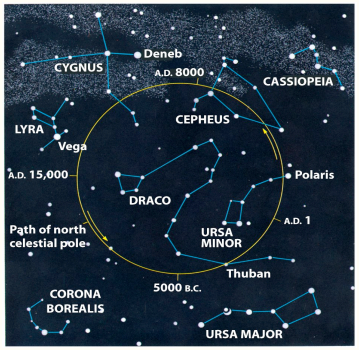


Precession of Earth's axis of rotation

This has two main effects:

i. The location of the celestial pole describes a circle on the sky, so that Polaris will no longer be close to the pole in a few thousand years.

ii. The position of the vernal equinox moves on the sky. In fact the "first point in Aries" is no longer in Aries (but in Pisces). This is a great nuisance for astronomers, since it changes the zero point for RA, which is currently fixed at the value for the year 2000 (but you may encounter some old "equinox 1950" celestial positions).



Problem - precession

(a) If the Earth's axis takes 26,000 years to complete one precession cycle, roughly how much should the RA of a star change between 1950 and 2000 coordinates?

(b) Will there be any accompanying change in declination?

(a) The vernal equinox will take 26,000 years to make a full circuit around the ecliptic, hence in 50 years it will travel $360^\circ \times (50/26000) = 0.69^\circ$. This corresponds to 0.69/15 hours of RA, or ΔRA=2.8 minutes. (The direction of the precession is such that the RA of objects *increases* from equinox 1950 to 2000.)

(b) Yes, the whole celestial coordinate system is shifting relative to the stars, so in general the declination of objects will also change. The position of the poles moves, and declination is (90°-angular distance from the N. celestial pole).