Lec #6: 5 SEP 2011 Time & Calendars; Long-Term Cycles; Position Measurements

- LAST WEEK: Layout and Apparent Motions of Sky
  - Appearance of Sky; Spherical Earth
  - Celestial Sphere; Local Solar Time
  - Diurnal and Annual Motion of Sky
- TODAY: Measuring Time and Position
  - Local Sidereal Time; Hour Angle; Calendars
  - Long-Term Variations (precession, nutation)
  - Cataloging Properties. I. Position (RA and Dec)
- Wednesday: Cataloging Stellar Properties. II.
  - change in position (parallax, proper motion)
  - apparent brightness and true brightness

READ 1.2 - 1.4 before Wednesday

Sun's Apparent Annual Motion

- Even though Sun's motion around us is East->West, it appears to move Eastward w.r.t. the stars. ~1° or 4 min/day [demo]
- Stars rise ~4 min earlier each day (~2 h/month) [solar/civil time]
- Sun's apparent motion along ecliptic, which is tipped by 23.5° w.r.t. celestial equator, and velocity is not constant [analema:]
- Sun north of celestial equator March -> Sep
  - day > 12 h
  - meridian altitude > 57° (from Charleston)
- Sun south of celestial equator Sep -> Mar
  - day < 12 h
  - meridian altitude < 57° (from Charleston)
- Tropics: Sun at Zenith at least 1 day each year
- Arctic: Sun never rises at least 1 day each year
- Intensity of sunlight ~ altitude above horizon

Time and Celestial Longitude

- Solar Day: time between successive transits of Sun = 24 h
- Siderial Day: ... successive transits of a star ≈ 23 h 56 m
- RA measured *eastward from vernal equinox*
- Hour Angle = angle from meridian (in time units)
- Local Siderial Time: time since last meridian passage of vernal equinox
  - LST gives RA of the meridian
  - Stars rise and set at same LST every day
  - Telescope clock drive is a siderial clock
- RA can be determined from meridian transits, but accuracy governed by timing (not altitude)

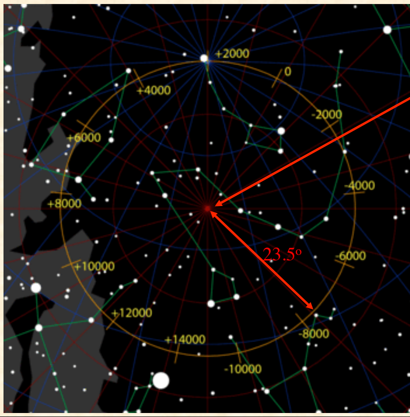
Some Interesting Factoids

- Lunar Calendar (13.4 orbits; 12.4 phase cycles)
- Year tied to our orbit; not integral # of rotations
  - leap years every 4 y
  - no leap year at millenia unless divisible by 4
  - still have to add leap seconds ~ once each year
  - goal to keep seasons in synch w/ calendar
- Sky motions do not all proceed at constant rates
  - e.g. b/c Earth's orbital velocity not constant
- Positions and time depend on location of <u>observer</u>
  - e.g., heliocentric v. geocentric
  - a few classic examples...

1. Observed eclipse/transit times of Jovian satellites
   - up to 16 minutes difference in time of flight between Jupiter and Earth (conjunction v. opposition)
   - Romer's classic measurement of speed of light
2. Ephemeris times for binary stars, pulsars, etc.
   - must convert to heliocentric Julian date
3. Location of galactic center
   - use variable stars to measure distance to globular clusters; combine with α and δ converted to l and b
   - geocentric 3-d map of globular clusters; not spherically symmetric w.r.t. Earth
   - center of this distribution is galactic center

Longer Term Variations of the Sky

- Precession
  - our coordinate grid tied to our angular momentum vector
  - rotation axis tipped 23.5° compared to ecliptic pole
  - rapid rotation should keep this fixed in space (gyroscope)
  - gravitational perturbations from Sun, Moon, and planets causes precession of the axis direction (but not angle; to 1st order)
  - north celestial pole traces out 47° circle on sky
  - entire sky rotates around grid with ~26,000 year cycle
  - vernal equinox moves 50"/year in ecliptic longitude
  - correlation with climatic cycles?
- Nutation
  - relative position of Sun and Moon; angle of axis wobbles
  - ~18.6 year cycle is largest; less than 1 arc minute
  - but the motion is more complex than that



What is this point?

The Earth's axis moves in space with a period of about 25 750 years, a phenomenon known as precession. Hence the celestial equator and poles also move. The positions of the stars therefore slowly change with time. Catalogues of stars customarily give the date, or epoch, for which the stellar positions that they list are valid. To obtain the position at some other date, the effects of precession must be added to the catalogue positions

$\Delta\delta \sim \cos(\alpha)$:

$$\delta_T = \delta_E + (\theta \sin \varepsilon \cos \alpha_E)T \qquad (5.1.4)$$

$\Delta\alpha \sim \alpha$ & δ :

$$\alpha_T = \alpha_E + [\theta(\cos \varepsilon + \sin \varepsilon \sin \alpha_E \tan \delta_E)]\,T \qquad (5.1.5)$$

where α_T and δ_T are the right ascension and declination of the object at an interval T after the epoch E, α_E, δ_E are the coordinates at the epoch and θ is the precession constant

$$\theta = 50.40'' \text{ yr}^{-1}. \qquad (5.1.6)$$

ε is the angle between the equator and the ecliptic—more commonly known as the obliquity of the ecliptic

$$\varepsilon = 23^\circ\ 27'\ 8''. \qquad (5.1.7)$$

Commonly used epochs are the beginnings of the years 1900, 1950, 2000 etc. Other effects upon the position, such as nutation, proper motion etc, may also need to be taken into account in determining an up-to-date position for an object.