Celestial Motions, Timekeeping and Navigation:  I. Intro

A. How do we keep track of celestial motions
   1. Coordinate systems
   2. Clocks
B. How do we use this knowledge
   1. Astronomy
   2. Calendars
   3. Navigation

Celestial Coordinates - a coordinate system fixed to the (unchanging) stars

I. Declination

A. Similar to latitude
B. Any star on the celestial equator has 0 DEC
C. North star has 90 degrees
D. South celestial pole is -90 DEC
E. Determining latitude in the northern hemisphere
   1. Find angle from horizon to N. star
   2. That is your latitude
   3. On N. Pole, see it at 90°
   4. On Equator, see it at ?
   5. In Boston, ?

II. Right Ascension

A. Similar to longitude
B. Does not spin with Earth
C. Need a reference point for 0 - arbitrary
D. Choose the Sun at spring Equinox - draw a line from the center of the Earth - through the center of the sun.
E. 0RA 0DEC lies in the constellation Pices toward aquarius.
F. Measured in hours, minutes and seconds, 24hr=360° ⇒ 15°/hr

III. Sun’s motion

A. What is the RA and DEC of the sun exactly at spring equinox?
B. Sept 23 (Autumnal equinox) 12hr 0°
C. Summer Solstice? 6hr +23.5°

IV. Celestial Navigation

A. Principle purpose of this coordinate system

B. Latitude is easy - lost at sea
   1. Measure N. star at 40°? LATITUDE?
   2. Cloudy in N but can see Vega and a compass telling us
      N. Star chart tells us Vega is +38°44’
      Draw it:
      N is 90 – 38°44’ + 70° = 121°22’
      Subtract from 180 = 58°44’

C. Longitude is much harder.
   1. Boston is \(-71°\frac{15^\circ}{12}\) = 4.7 hr
   2. So it is solar noon 4.7 hr after it is in Greenwich
   3. Solar noon is when the sun is highest if you are above the
      tropic of Capricorn - How about if you are on the equator?
   4. If you leave Greenwich with a good watch then if you
      determine when solar noon is, you can look at your watch
      and know your location.
   5. At night you can use a star
   6. Takes a little calculating or a chart
   7. Vernal equinox it is easy. If we spot Vega which has RA
      18hr 37min, then
   8. Today how is it done?

Story of the Clock:

I. 1707 Adm. Shovell Shipwrecks -
   A. Hangs man - why?
   B. 4 - ships and 2000 men lost 20 miles from GB
   C. Shovell is killed on the beach
   D. Need clock - Pendulums don’t work at see
   E. Parliament offered a 20,000 lb prize to determine Latitude to
      within 1/2 a degree
   F. Astronomical clock - location of Saturn’s moons
   G. Harrison worked from 1730 - 1767 produced the first clock
      accurate to 1 min/year
   H. 8 man years of labor/ watch
   I. Collected prize in 1773 after decades of intrigue

2
II. Astronomer’s use celestial coordinate system
   A. Large observatory have a custom clock
      1. Set so that when it reads 0hr, Star’s with a RA of 0 is on the meridian
      2. At this time, where is a star with a RA of 3hr.
      3. At any other time, one need only subtract the RA of the item from the clocks reading.
      4. How long is a “day” on this clock? 23hr 56”

Slow motions of the Earth

I. Precession
   A. The N. Star will not always be the N. star
   B. The Earth is not just rotating around its axis, it also wobbles
   C. Precession - demonstrate with top
   D. Result is every 23,000 years the Earth completes a circuit -
   E. Show motion of Polaris.
   F. The tilt remains unchanged.
   G. Star charts must be updated.
   H. Cause: Torques from the sun and moon on the not perfectly round Earth.
      I. Demonstrate with bike wheel.

II. Slower motions - Nutation over many millions of years the 23° angle changes.