- LAST TIME: RA & Dec; Daily Motion of the Sky
  - Spherical Earth
  - Latitude and Longitude
  - Right Ascension and Declination
- TODAY: Annual and Long-Term Motions of Sky
  - Daily Motion of Sky from any latitude on Earth
  - Apparent Annual Motion of Sun and Nighttime Sky
  - Putting it all together
  - Long-Term Variations: Parallax, ...
- FRIDAY: Practice, Review, Digest Coordinate Systems
- NEXT Week: Cataloging Stellar Properties. I.
  - how do we measure position accurately/precisely?
  - what can we learn from it?

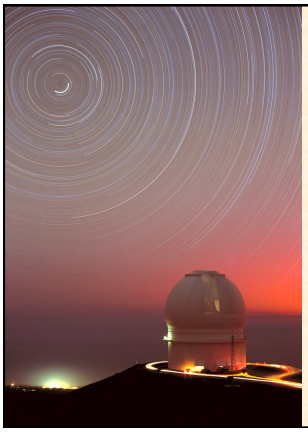
## The Sky Viewed from Charleston

- motion depends on where in sky you are looking
- some apparent paths are east-->west arcs
- some apparent paths are counterclockwise circles
- time from rise to set depends on declination:

$0^h$: < -57°; $<12^h$: -57 to 0°; $>12^h$: 0-57°; $24^h$ >57°

(a) At middle northern latitudes

- NCP elevation=33°
- CE from east through meridian elevated by 57° to west
- see all stars north of declination -57°



- all stars move in ccw circles around NCP
- stars with declination more than 90 minus your latitude (57 to 90 degrees for Charleston) are "CIRCUMPOLAR"
- for stars south of this, we only see a portion of their circular path, so they appear to move in an arc
- notice that stars farther from pole move farther in same amount of time

## The Sky From Different Places on Earth

- everyone on same longitude sees same "time" (i.e. Sun same distance east or west of meridian)
- everyone on *same latitude* sees the *same part of the sky* (e.g. 33° north latitude sees from -57° to +90° of declination) at the *same local time*, but local time depends on longitude
- e.g., at 11 PM Eastern Time in Washington, DC you see the same thing as someone in Denver, CO will see at 11 PM Mountain time (i.e. 2 hours later)
- different latitudes see different parts of the sky, or the same things but at different altitudes at the same time

## Local Solar Time

- when Sun is "on" the meridian, we call it "noon"
- one rotation (one day) corresponds to time it takes Sun to go all the way around and appear again on the meridian
- altitude of Sun increases from sunrise to noon (AM) and decreases from noon to sunset (PM)
- midnight corresponds to Sun on the meridian on the other side of the Earth (1/2 rotation or 12 hours after noon)
- in astronomy, we use local solar time, but it's not very practical for society...

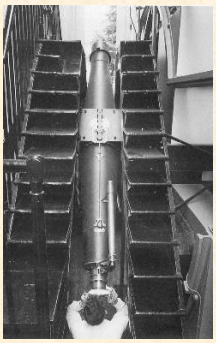
## Solar v. Civil Time

- Sun "on" meridian at *local solar noon*
  - only one longitude on Earth has solar noon at any given instant
- It would get very confusing if everybody had *different* clocks, but
  - it would be just as confusing if we all used the *same* time: it could be dark at "noon"!!
  - but astronomers, pilots, etc. use "Universal Time"
- So we split the difference and have 24 time zones, each about 15° wide (360°/24h=15°/h)
  - Sun (and stars) move 15° each hour = 1 hour of RA
  - "Civil Time" = "Solar Time" ± 1/2 hour

## Coordinate Systems & Diurnal Motion

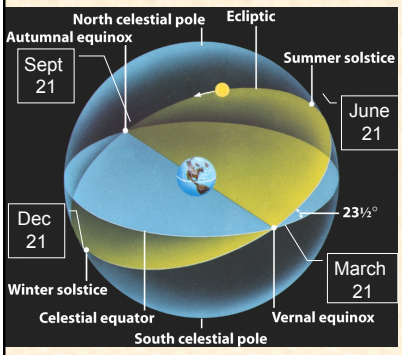
- Review:
  - Altitude, Azimuth, Zenith, Nadir, Meridian
  - Right Ascension, Declination
  - How are all of these measured? Units?
  - Apparent motion on sky depends on (1) object's declination and (2) your latitude
- Transit Altitude --> Declination
  - how do we use transits to measure RA?
- Thought experiment: Transit Altitude(s) of a Circumpolar Star
  - upper and lower culmination
  - can find meridian, NCP, equator, declination, latitude

## Transit Telescope at Royal Observatory in Greenwich and the "Prime Meridian"



## Apparent Annual Cycle of the Sun

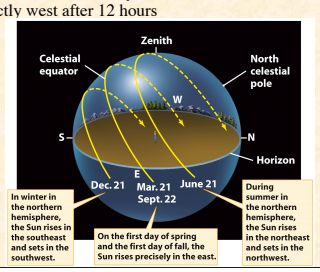
- Sun appears to go around us once per day, but it also *appears* to go around us once per year
- Over course of year, Sun's apparent path on the sky is called the ECLIPTIC
- Ecliptic passes through 12 constellations of the ZODIAC; multiple meanings of "ecliptic"
- Sun moves 360 degrees along the ecliptic in 365 days; ≈1°/day; ≈ 30°/month; ≈ 2 hours of rotational motion (at 15°/h) ≈ 4 m of time
- which direction? what can you infer?




- The Sun appears to trace out a circular path called the **ecliptic** on the celestial sphere tilted at 23.5° to the equator
- The ecliptic and the celestial equator intersect at only two points: Each point is called an **equinox**
- The point on the ecliptic farthest north of the celestial equator that marks the location of the Sun at the beginning of summer in the northern hemisphere is called the **summer solstice**
- At the beginning of the northern hemisphere's winter the Sun is farthest south of the celestial equator at a point called the **winter solstice**

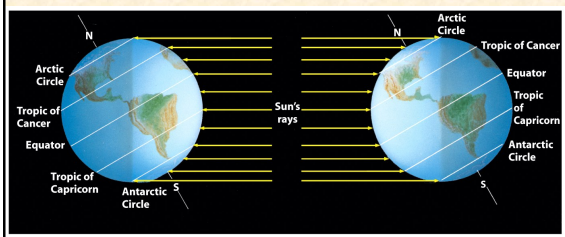
## The Sun's Motion Viewed From Charleston

- June: rise north of east; 57+23.5=80.5 degrees elevation on meridian at noon; set north of west > 12 hours later
- December: rise south of east; 57-23.5=33.5 degrees elevation on meridian at noon; set south of west after < 12 hours
- note: difference is 47°; no matter where you are
- March or September: rise exactly east; 57° above horizon on meridian at noon; set exactly west after 12 hours




## Sun Viewed from The Tropics and from "The Land of the Midnight Sun"

- Arctic Circle: 90-23.5 = 66.5° latitude
- Antarctic Circle: -66.5° latitude
- Tropic of Cancer: +23.5° latitude
- Tropic of Capricorn: -23.5° latitude



## 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

Anchorage Airport Sunset

How long until Sun dips below horizon?

15°/h --> 1/2° in 2 minutes

Where on horizon will it set?

10 minutes later...

Notice how the Sun is moving almost parallel to the horizon.