**Lecture 3: rotation and orbit of Earth**

* 1. Comments on lecture questions
     1. Best to put down SOME answer for everything
     2. Please EXPLAIN your answer; this is part of my evaluation
     3. Remember your UNITS!
     4. One key thing: HA = 0 hr at transit, which is highest point in sky
  2. Rotation of Earth
     1. The Earth rotates once every 23h 56m (not 24 hours): the sidereal day
     2. If I am at a particular position on the Earth, my Zenith is indicated by the arrow
     3. Say I start at noon on a particular day: my Zenith is towards the Sun
     4. A star will return to its original position in exactly 23h 56m
     5. **Can you guess why we define the day to be slightly LONGER than the time it takes the Earth to spin once?**
  3. Orbit of the Earth
     1. Why does this happen? Because the Earth is orbiting the Sun because as it moves gravity pulls it to the left here; bends its motion just enough at any given time to keep it in a circle.
     2. It orbits around this way, and rotates in the same sense
     3. One sidereal day later, my Zenith is pointing this way still, but the Earth has moved with respect to the Sun. So my Zenith isn’t pointing to the Sun anymore
     4. Another way of putting this is that it is 11:56am
     5. In 4 more minutes, one solar day, my Zenith will be pointing to the Sun and it will be noon again.
     6. Because humans define time with respect to the SUN not the STARS
  4. Universal time, time zones, and daylight savings time
     1. Local standard time is useful: essentially set so noon is when Sun transits in about the “middle” of the time zone
     2. Local “mean” time at a given place is set so noon is when Sun transits right there; it is always about +/- half an hour from standard time, so we hardly worry about it for this course
     3. Universal time (UT) is standard time in Greenwich, England (longitude zero)
     4. Universal time is +5 hours from EST; useful for astronomical events, which are usually listed in UT (e.g. in Peterson you’ll find full moon times or eclipse times listed in UT)
     5. Daylight savings time differs from locality to locality, even state-by-state in the US in some cases; basically it is 1 hour ahead of standard time, and we switch to it sometime in the Spring, and back to standard sometime in the Fall; don’t blame me!
     6. Thus, UT is +4 hours from EDT; again, it is important when trying to catch events occurring at particular times!!
  5. Consequences for how stars are viewed
     1. Rotation means stars move across sky
     2. Orbit means that at a given TIME of night (solar), the stars we see are a bit different; they advance 4m across the sky
  6. Local Siderial Time
     1. The way we keep track of this is through the local siderial time
     2. This is the RA along the meridian at a given time and place
     3. You can see that with time the LST advances forward at 24h in RA per sidereal day
     4. Note that an object's hour angle increases with LST; HA = LST - RA
     5. If a star is west of the meridian, it has a lower RA than the current LST
     6. If a star is east, it has a higher RA
     7. **What is HA of this object? that object?**
     8. This makes the LST a useful quantity, because it tells you where any object is NOW
     9. If you go to a professional telescope, there are clocks all over the place with the LST
     10. Remember, the LST advances a little bit faster than normal time! (24h of siderial time in 23h56m of solar time)
  7. Effect on what is visible over time
     1. Clearly the orbit of the Earth has a profound effect on what is observable at a given time of year
     2. Let’s take a closer look at the configuration
     3. Looked at from the side, the Earth’s rotation axis is tipped relative to its orbital axis by the ecliptic angle of 23.5 deg. The brown arrow shows the direction of the North Pole.
     4. **As shown, what time of year is this configuration?**
     5. As shown, this would be the configuration in late June
     6. At midnight clearly there is only a certain range of stars you can see in RA, wherever you are
     7. In December, the Earth is on the other side of the Sun, so at midnight in December you can see a different set of stars
     8. Note that for standard time, these statements are roughly independent of where you are on the globe: that is what we MEAN by standard time, and why we have time zones.
     9. Of course, there is also the effect of latitude which we have already discussed
     10. **Which direction is Dec = 0? Dec = 90? Dec = -90?**
     11. Horizon only reaches so far south
     12. So at a particular latitude, throughout the year there is only a certain range of Decs which are visible
  8. RAs visible over time and RA of Sun
     1. More quantitatively, we can consider what RA values are visible as a function of month
     2. Recall that at any given time and place, some RA value corresponds to HA=0
     3. In other words: at any given time and place, some RA value is transiting
     4. **At what point on Earth is it midnight here?**
     5. E.g. midnight on Jun 20 (summer solstice), RA of 18h is transiting
     6. Meanwhile, Sun is at RA = 6h
     7. Midnight on Sep 23 (autumnal equinox), RA of 0h is transiting
     8. And Sun is at RA = 12h
     9. Etc for the Winter Solstice and the Vernal Equinox
     10. This works out to about 2 hours per month that the RA transiting at midnight advances
  9. Decs visible over time and RA of Sun
     1. Declinations visible over the year do not change
     2. However, the Dec of the Sun does change, because of the ecliptic angle
     3. From Dec = 23.5 in summer to -23.5 in winter
  10. Seasons and regions on Earth
      1. **Why do seasons occur?**
      2. Of course, this means the Sun remains above the horizon longer in Summer than in Winter in Northern Hemisphere
      3. This is a major component to explaining the existence of seasons on the Earth
      4. The other reason is that the angle of incidence of light is steeper in the Winter
      5. Note that this can mean different things at different latitudes
      6. E.g. Dec of Sun is always between -23.5 and +23.5
      7. So Sun can ONLY pass through Zenith in the latitudes between -23.5 and 23.5: these regions of the Earth are called the tropics; Sun actually only passes directly overhead two days a year in a given place in the tropics
      8. Similarly, when Sun is at +23.5 deg, than at latitude +66.5 deg, it is ALWAYS visible: it is a circumpolar star (recall circumpolar stars are those above 90-latitude)
      9. Regions at latitude > 66.5 deg are called Arctic, because in those places there are at least one day with 24 h of Sun, and one day with 24 h of darkness
      10. Similarly for latitude < -66.5 deg: the antarctic
      11. Regions in between are the “temperate” regions: divided from tropics at -23.5 by the tropic of Capricorn, and +23.5 by the tropic of cancer
      12. So the ecliptic angle has a profound effect on the weather and climate on the Earth
  11. Ecliptic
      1. This path of the Sun is called the ecliptic
      2. It is a Great Circle on the sky
      3. If we look through this path, all the planets are close to the ecliptic
      4. This is because the planets are all very close to orbiting in the same 2D plane as Earth does
      5. Because they formed in a disk-like structure (e.g. we see this in young nearby stars, e.g. in Taurus, a region you will become familiar with)
      6. The ecliptic also goes through the 12 constellations of the Zodiac (plus Ophiuchus)
      7. The “meaning” of the astrological sign is the constellation that the Sun is in on a particular date (note that this isn’t what you see in the newspapers, which are wrong, as we will see later in the course)
  12. Practical example: using the Edmund atlas
      1. all the Edmund atlas pages come with a marking on the top
      2. E.g. here is the first page, which is a map of the North Celestial Pole
      3. RA, but also by date
      4. the RA is obvious, it just is marking the RA so you can figure out the coords of the star
      5. the date is telling you the day of the year that each RA transits at 8pm local mean time
      6. so in this case, I should read this as saying: if I step outside and look North at 8pm standard time on August 20, this is about what I should see
      7. as time goes on, the Earth rotates, and the RA transiting increases
      8. so the stars rotate counter-clockwise around the pole
      9. So at 8 pm, the LST is about 18h, but at 10pm, it will be about 20h
      10. Similarly, as the months progress, the RA at 8pm standard time increases; also moves counterclockwise
      11. You see here again: the RA transiting changes by about 4 min per day, or about 2 h per month
      12. E.g. let’s take a look at the distribution of stars from the roof of 715 Broadway
      13. On Feb 5 or so at 8pm this is what it will look like
      14. as the night goes on, the sky rotates; Cassiopeia falls and the Big Dipper rises
      15. Or, if you come out night after night at 8pm and look up, you will see the same progression
      16. Learning how to interpret these charts, and getting a “sense” of what the local siderial time means and how it changes throughout the year is a major goal of this course; knowing this will allow you to understand a lot more about astronomy and make it easier to become an amateur (or professional) astronomer