Naked Eye Astronomy, Day 3: Models of the Sun's Motion

1. Recap of last week
   (a) Please ask questions at ANY TIME.
   (b) Web page with resources for the course: `https://osp.berry.edu/SeniorScholars`.
   (c) The stars look like they are stuck on a sphere with us at the center, and this sphere rotates on an axis through a point near Polaris once every 23 hours, 56 minutes. On the other hand, the Sun goes around the sky in exactly 24 hours, so the Sun must drift very slightly eastward relative to the stars.
   (d) Over the course of a single day the Sun seems to follow a path much like a single star, but at different times of year the path of the sun is different.
   (e) The sun rises and sets farthest north, is up the longest (about 14 hours), and transits highest in the sky, on the summer solstice (June 21). The sun rises and sets farthest south, is up the shortest (about 10 hours), and transits lowest in the sky, on the winter solstice (December 21). On the spring and fall equinoxes (March 21 and September 21) the Sun rises due east, sets due west, is up for exactly 12 hours, and transits at a middling altitude.
   (f) This cycle of changes takes about 365.25 days, what we call a (tropical) year. These changes can easily be tracked using shadows cast by a gnomon.
   (g) The local noon altitude of the Sun on the equinoxes is about 56 degrees (90 degrees minus the latitude of Rome). On the summer solstice it is 78.5 degrees and on the winter solstice it is 32.5 degrees, which is a variation of 23.5 degrees above and below the equinox values.
2. Ancient Greek Model for the Sun's Motion
   (a) Show Celestial Globe simulation.
   (b) Ancient Greek model: the sun moves around us, drifting eastward relative to the stars along a circular path (known as the ecliptic) that is tilted 23.5 degrees relative to the celestial equator.
   (c) Demonstrate motion of Sun over a single day (fall equinox). Pretty much tracks with a star on the equator. Fits observations.
   (d) Repeat for winter solstice. Acts like a star 23.5 degrees south of the equator. Fits observations.
   (e) Repeat for summer solstice. Acts like a star 23.5 degrees north of equator. Fits observations.
   (f) Show spiraling motion of Sun over several days.
   (g) Demonstrate motion of Sun over a year (with time of day held fixed). Sun moves along ecliptic, sometimes north, sometimes south of equator. Show how this alters the daily motion (rise/set locations, length of day, altitude).
   (h) This model reproduces everything we have seen about the motions of both stars and the Sun.
   (i) Repeat but this time trace Sun's motion to display the analemma. Talk about why this happens: Sun doesn't move uniformly along the ecliptic, and motion is not parallel to equator. These effects cause the length of a (solar) day to vary a tiny bit from one day to another, so the Sun gets behind (or runs ahead of) the "mean Sun."

3. Copernicus' model for the Sun's motion
    - Now switch to Earth Orbit simulation.
    - Copernicus: Earth orbits around the Sun while maintaining a fixed axis or rotation relative to the celestial sphere. As Earth orbits sometimes the axis is tilted toward sun (summer in N hemisphere) sometimes away (winter), etc.
    - Show location of Earth on AE, WS, VE, SS. Discuss how it is the orientation of Earth's rotational axis relative to the Sun that determines the seasons. Distance is not a factor.
    - Now show the motion but trace the poles. What is going on? The north celestial pole does not move around during the year, it is always near Polaris. How can we fix this?
    - Answer: the model is not to scale. To scale it correctly we must either shrink Earth's orbit or increase the size of the Celestial Sphere.
    - Copernicus' model does just as well as the Ancient Greek model, but no better, and it forces the stars to be VERY far away. (In the Greek model the Earth must be like a point in comparison to the celestial sphere. In Copernicus' model the Earth's orbit around the Sun must be like a point in comparison to the celestial sphere.
    - Copernicus' contemporaries could not believe in a moving and rotating Earth, or could they accept such a greatly enlarged universe. As a result, most astronomers and natural philosophers rejected Copernicus' ideas at the time.
4. Questions and conversation.