Planetary Wonderings

December Focus: Winter Solstice Surprises

By Mary-Frances Bartels, NASA Solar System Ambassador

What and when is the winter solstice? The winter solstice is the day of the year with the least amount of daylight, and when the sun is the lowest in the sky. It also marks the start of winter, which this year occurs at 1:08 AM EST on December 22.

Did you know that the day of the solstice, which has the least amount of daylight, has ***neither*** the latest sunrise ***nor*** the earliest sunset? At first, this seems to make no sense. But, when examined in more detail, one can see why the "shortest day of the year" has neither the latest sunrise, nor the earliest sunset of the year. In fact, these three events occur on three different days! Two phenomena conspire to make the latest sunrise and earliest sunset on different days than the solstice; the Earth's tilt on its axis and location in its orbit around the sun, particularly with respect to perihelion and aphelion.

Let's start with the easier part of the sunrise/sunset/solstice quandary. As everyone knows the earth's tilt on its axis is what causes our seasons. Scientists call this tilt *obliquity*. The sun's rays are most direct and high in the sky on the summer solstice, while the opposite is true on the winter solstice. Daylight starts to lengthen on the winter solstice and shorten on the summer solstice. The speed of the sun with respect to the equator throughout the year changes because of the tilt. It travels faster (along an east-west line) at the time of the solstices. The rest of the year it travels northward (heading from winter to summer solstice) or southward (heading from summer to winter solstice) in addition to its eastward movement. At the equinoxes the sun's northward or southward travel is the greatest. (A way you can check this out for yourself is by observing where the sun rises and sets each day throughout the year. You will find that it rises and sets around the same place for a few days around the solstices, but changes considerably more around the time of the equinoxes.) This accounts for the change in the length of daylight around the solstices to be practically zero (discussed in *PW*, Dec. 2005) and to be greatest at the equinoxes. Because the sun's eastward movement is not at a constant "speed" this causes "local noon," the time when the sun is highest in sky on a given day, to be either later or earlier depending on the season (technically the switch would occur at the midpoints of the seasons). At the latitude of central Ohio the earth's tilt is primary in determining sunrise, local noon, and sunset times from June 28 until December 8, and from January 5 until June 14. These dates can vary depending on latitude of the observer.

Next, let's examine the problem presented by the earth in its orbit around the sun. Scientists call this *ellipticity*. If the earth's orbit were circular with the sun at the center, our planet would travel at the same speed in this orbit throughout the year. The orbit is not a perfect circle, however, but is an ellipse with the sun at one of the ellipse's foci. Kepler discovered that objects in orbit travel faster when they are closer to the sun (or whatever body the satellite is orbiting) and slower when farther from the sun. It just so happens that the earth is closest to the sun around the time of the solstice. The next perihelion occurs January 2 at 7:00 PM EST. So, what does that have to do with the length of a day? Usually when people think of the length of a day they, possibly unconsciously, count it as the time it takes for the sun to return to about the same place in the sky from one day to the next, for example from one local noon to the next. Throughout the year, this time **averages** about 24 hours. However, when the earth is near perihelion, since it is traveling noticeably faster in orbit, it has to rotate further before the sun is back to nearly the same point in the sky. In reality the length of day near perihelion is greater than 24 hours, as much as 30 seconds longer by late December. Since we do not correct for this on our clocks, this keeps pushing the sunrise and local noon times later and later, even past the winter solstice. Ellipticity pushes local noon later from October to April (the half year the earth is closer to the sun) and earlier from April to October.

As you can see, the reasons for the difference in latest sunrise and earliest sunset with respect to the solstice are based on the fact that our clocks run on a constant 24 hours per day basis. This works out fairly well for living everyday life, but not so well when understanding apparent contradictions such as this one. Here's a brain-buster question: If we told time using a sundial, would the latest sunrise and earliest sunset ever occur on one day? If so, what day would that be? Feel free to e-mail me your answer and how you arrived at that conclusion.

Times in table are for Centerburg, OH and in Eastern Standard Time

Date	**Sunrise Time**	**Sunset Time**	**Local Noon**	**Sunrise Position**	**Sunset Position**	**Hours Daylight**	**Comment**
Dec. 8	7:41 AM	5:04 PM	12:23 PM	120°	240°	9:24	Earliest Sunset
Dec. 22	7:50 AM	5:08 PM	12:29 PM	121°	239°	9:18	Solstice
Jan 5	7:54 AM	5:18 PM	12:36 PM	120°	240°	9:24	Latest Sunrise

Earliest "local noon" is November 2 - 4 at 12:14 PM EST
Latest "local noon" is February 11-12 at 12:46 PM EST

Resource of the Month: *Windows to the Universe* e-newsletter, dedicated to Earth and Space science education. It is sponsored by NCAR (National Center for Atmospheric Research), NASA, CISM (Center for Integrated Space Weather Modeling), National Earth Science Teachers Association, CMMAP (Center for Multi-Scale Modeling of Atmospheric Processes). Explore the Windows to the Universe website at http://www.windows.ucar.edu/ . Information on subscribing to the newsletter may be found in the middle of the page at "Newsletter for Teachers."

Activity of the Month: My explanation of the sunrise/sunset/solstice problem is a bit oversimplified. If you feel so inclined, examine this issue further. Find out what the following terms mean and how they relate to this phenomenon: analemma, angular distance, apparent motion, celestial equator, sidereal time, equation of time, declination, sun transit, azimuth, ecliptic, and conservation of angular momentum. How much closer is the earth to the sun during perihelion than at aphelion? More advanced students might want to find the actual equations that are used to determine sunrise time and the graph showing the equation of time throughout the year. Discover the time differences between mean local noon and clock noon as contributed by ellipticity or obliquity separately. From the information given in this article, can you determine how many minutes central Ohio is from the center of the Eastern Time Zone?

Suggestions, questions, and comments about "Planetary Wonderings" are welcomed and may be directed to stargazer @ keeplookingup.net (remove spaces). Past columns may be found at www.keeplookingup.net (all past columns, click on "Planetary Wonderings" on the right side of opening screen) and at http://www.freelists.org/archives/astronomyed/ (columns from Jan. 2007 to the present).

Remember to *keep looking up!*

Sources (not already mentioned): http://www.chiff.com/home_life/holiday/winter-solstice.htm
www.usno.navy.mil US Naval Observatory
http://www.arachnoid.com/lutusp/sunrise/ Solar Computer
http://curious.astro.cornell.edu/question.php?number=208
Kaluach 3 calendar software from www.kaluach.org