CONTEMPLATING THE SUN AND MOON

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Some musings about our winter sunrises and sunsets, the fourteenth zodiacal constellation, high and low full moons, upcoming eclipses and the lunar tetrad

The December Solstice typically arrives on December 21 or 22. At this time the Sun reaches its southernmost point on the sky for Earth's Northern Hemisphere. Nights now begin to shorten and days begin to lengthen for people living in this hemisphere. In 2013 this moment arrives on December 21 at 17:11 UT or 12:11 p.m. EST.

Winter's Earliest Sunsets and Latest Sunrises for the Northern Hemisphere

But, did you know earliest sunsets can occur weeks before this solstice date and latest sunsets weeks after? (Actual dates depend on latitude.)

For example, North Florida has its **earliest sunsets** during the last few days of November until the end of the first week in December. So, by the time of the solstice date, the Sun has already begun to set later. For example, earliest sunset in Gainesville is 5:30 p.m. EST at the beginning of December but becomes 5:35 p.m. EST by December's solstice date three weeks later.

Likewise, North Florida will not see its **latest sunrise** until after the first of the New Year—not until about January 10 in Gainesville when the Sun rises at 7:26 a.m. EST, or about six minutes later than it does on the December solstice date.

See the **First Graph** at the end of this article showing **2014 Gainesville Sunrise and Sunset Times** (computed for Powell Hall on the University of Florida campus).

Note: If you wish to print any of the graphs included with this article, *landscape mode* is recommended for better clarity.

The Obliquity Effect All this is a consequence of two effects. The first, the "obliquity effect," involves Earth's axis tilt (*obliquity*), which causes the Sun to trace an annual path on the sky (the *ecliptic*) tilted to the *celestial equator* by approximately 23.4 degree. This allows the Sun to reach both higher and lower elevations (*altitudes*) at noon during the year depending on whether the Sun has moved north or south of the celestial equator. Therefore, the Sun is not running directly east on the sky but along the ecliptic.

This journey takes the Sun both north and south of the celestial equator during the year so the Sun's motion on the sky is not constant toward the east.

The Eccentricity Effect The second effect, the “eccentricity effect,” is a consequence of the nonuniform rate of the Earth in its non-circular (*elliptical*) orbit about the Sun. This causes the Sun to move fastest on the sky with respect to the stars in early January when Earth is nearest the Sun (*perihelion*) and slowest when farthest away (*aphelion*) in early July. Earth’s perihelion in 2014 is January 4. (Yes, Virginia, we have winter in the USA when closest to the Sun!)

Both effects cause the Sun to drift eastward on the sky with respect to the stars at a non constant rate during the year. This phenomenon can place the Sun either behind or ahead of uniform clock time, which marks time by a fictitious (average or mean) Sun that runs at a constant rate eastward along the celestial equator.

The Equation of Time Consequently, sundials that track the actual Sun on the sky and read “real sun time” differ from clocks using an “average” or “mean” sun. Astronomers call the difference between usual “mean clock time” and “real sun time” (called *apparent time)* the *Equation of Time.* Interestingly, the obliquity and eccentricity effects cancel (add to zero) four times a year so the real sun and apparent sun are together on these dates. This includes the end of December, nearly on Christmas Day!

See the **Second and Third Graphs** showing the **Equation of Time,** the difference between mean time and apparent time, during the year. The odd looking “sinusoidal” shape of the Equation of Time in the second graph results from the superposition of both the obliquity and eccentricity effects shown separately in the third graph.

The Fourteenth Zodiacal Constellation (or More)?

Meanwhile, a member of the Alachua Astronomy Club, Mike Toomey, raised an interesting point about the Sun’s path on the sky in response to a question I asked at the club’s holiday party 2013 December 7. This question asked which of four stars could not be *occulted* (hidden) by the Moon as the Moon wanders along its own monthly path on the sky, a path that is nearly the same as the ecliptic. The answer was *Betelgeuse* in Orion since the ecliptic does not pass through Orion. Therefore, Orion is not normally included as a “zodiacal constellation.”

The *astrological zodiac*, usually considered to be 8–9 degrees on each side of the ecliptic, contains twelve zodiacal signs, each 30 degrees wide. However, the ecliptic, which runs centrally through the zodiac, actually crosses through a thirteenth constellation, *Ophiuchus* (“Serpent Bearer”) using the boundaries officially defined by the **I**nternational **A**stronomical **U**nion or **IAU** (1930).

Still, Mike wondered if the Moon (not the Sun) could possibly pass through Orion since the Moon does not exactly move along the ecliptic during each lunation. After some research, Mike correctly concluded that the Moon, in fact, can sometimes move through the northern part of this constellation.

So, I also did some further checking. Sure enough, the Moon occasionally enters Orion but only at the very *extreme northern part of this constellation.* Still, the Moon cannot occult

Betelgeuse, which lies about 10 degrees south of the Moon's closest possible approach to this bright star.

Although the ecliptic does not go through Orion (missing the northernmost edge of Orion by approximately one half degree), the Moon can sometimes pass through the extreme northern section of this constellation. This results from the deviation of the Moon's path to the ecliptic by 5.1 degrees due to its orbital inclination to the Earth's equatorial plane.

So, should we count Orion as the fourteenth "zodiacal constellation"! (You decide.)

But that is not all! The planets (including Pluto) can also travel several degrees north and south of the ecliptic. Hence, they can move through additional constellations. For example, Venus can move nearly nine degrees north and south of the ecliptic although its orbital inclination is less than four degrees. (Can you explain this?) In fact, the Moon and the planets Mercury through Neptune can pass through twenty-two constellations. Adding Pluto, which has an orbital inclination of 17 degrees, increases the number to twenty-six!

The twenty-six "zodiacal constellations" include the following: **Aquarius, Aries,** Auriga, Bootes,* **Cancer, Capricornus,** Cetus, Coma,* Corvus, Crater, Eridanus,* **Gemini,** Hydra, **Leo, Libra,** Ophiuchus, Orion, Pegasus, **Pisces, Sagittarius, Scorpius,** Scutum, Serpens,* Sextans, **Taurus** and **Virgo.**

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The original 12 constellations of the zodiac are in **bold face.**

*Constellations added due to Pluto.

(Reference: Jean Meeus, *More Mathematical Astronomy Morsels,* 2002.)

In 2013 the Moon's path is currently south of the ecliptic near Orion. This situation will remain for the next several years. However, this condition will change over time as the Moon's crossing points with the ecliptic (*nodes)* retrogrades with an 18.6 year period. So, eventually the Moon's path will be too far north of Orion for the Moon to enter Orion. Then this situation will eventually reverse.

Note that during a given year the Moon does not stay north of the ecliptic for the entire year or south of the ecliptic for the entire year. The Moon's path is south of the ecliptic for half its path and north for half its path *during a given lunar cycle*. Presently the Moon's path takes the Moon south of the eclipse into Orion when near full. However, on the other side of the sky the Moon's path is north of the ecliptic.

The 2013 December 17 Full Moon. On this date, for example, when coincidently the lunar phase is full, the Moon will be about 4.2 degrees **south** of the ecliptic at moonrise, enough to put it within Orion by nearly three degrees! (See Figure 1 which shows the boundaries of Orion as defined by the IAU.) It is also noteworthy that the 2013 December 17 full moon will also be approximately two days before *apogee* (farthest from Earth) making this the **smallest full moon of 2013.**

However, three weeks later, the first quarter moon will be **north** of the ecliptic (in Aquarius) by nearly two degrees.

So, go out and wave at the Full Moon in Orion if you read this before Dec. 17, 2013!

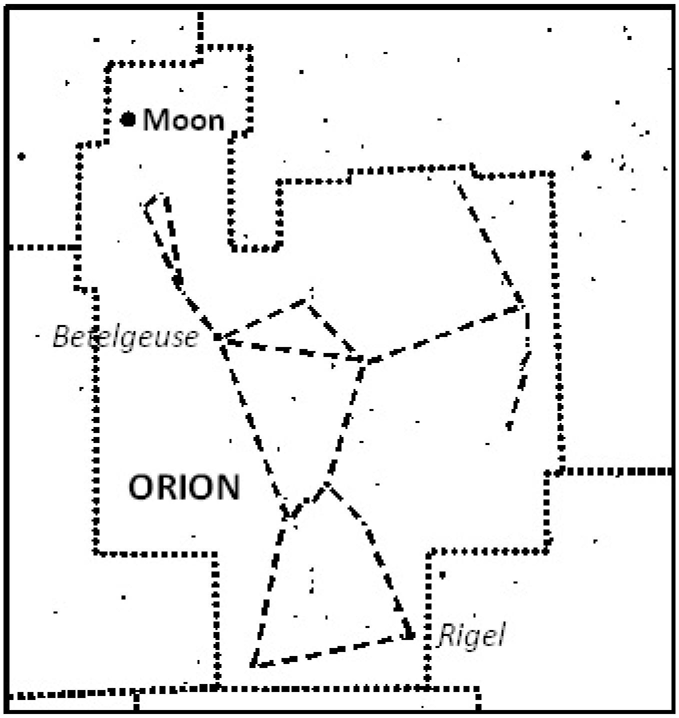

Fig. 1. The 2013 Dec. 17 Full Moon in Orion. The full moon lies within the upper regions of this constellation. (Constellation boundaries are defined by the IAU). Coincidently this is also the smallest full moon of 2013.

Likewise, the next full moon (January 15 in Gainesville) will be the smallest of 2014. The Moon will not be full in January when it again passes through Orion, but will still do so two days before but as a waxing gibbous.

Finally, the largest full moon of 2014 will arrive during summer, on August 10 when the Moon will rise at sundown in Capricornus about four degrees north of the ecliptic.

High and Low Full Moons

Most people in mainland USA probably know the summer sun rides high during the day reaching its maximum altitude above the horizon at midday. Likewise the winter sun rides much lower through the sky but its maximum altitude at midday is, however, much lower than in summer—about 47 degree less in fact!

But what about full moons during summers and winters?

Full moons occur when *opposite the Sun* on the sky. Thus, if the Sun is near its December solstice position (winter for Northern Hemisphere), the Sun is about 23.4 degrees *south* of the celestial equator (due to the Earth's axis tilt). Therefore, full moons occupy positions near the opposite solstice, 23.4 degrees *north* of the celestial equator. Consequently, a winter full moon in the USA will ride high through nighttime skies in contrast to a low sun.

In summer, the situation is therefore reversed and summer full moons ride low through the night sky.

If you add in the Moon's 5.1 degree deviation from the ecliptic, a winter full moon can move through the night as much as 28.5 degrees (23.4°+5.1°) above the celestial equator. (The actual value can sometimes be as much as 28.7 degrees.)

Likewise summer full moons can be as much as 28.5 degrees south of the equator. Consequently, the total variation of a full moon's altitude in the middle of the night could be as much as 57 degrees between a winter and summer full moon!

For example, in Gainesville (latitude 29.6°N), "midnight" full moons can appear nearly overhead during winters. But during summer months, full moons will only appear about one-third of the way from horizon to overhead.

Note: The full moon of 2017 December17, being more than four degrees south of the ecliptic, will still travel high through our winter sky but slightly lower than in other years.

I have always told people that "mother nature" has arranged this act so high winter full moons can make up for some sunlight lost during our colder, shorter daylight hours!

Looking Ahead for Lunar and Solar Eclipses

For those wishing to look ahead, the year 2014 brings four eclipses: **two total lunar eclipses**, an **annular solar eclipse** and **one partial solar eclipse**. *Three of the four eclipses are visible from Florida* including both lunar eclipses and the partial solar eclipse!

Eclipses in 2014

Apr. 15:	**Total Lunar Eclipse***	(entire eclipse visible)
Apr. 29:	**Annular Solar Eclipse**	(S. Hemisphere eclipse *not visible in the Americas*)
Oct. 8:	**Total Lunar Eclipse**	(first 60 percent of eclipse visible)
Oct. 23:	**Partial Solar Eclipse**	(first part visible; sun sets about 40 min. later)

The Tax Day Eclipse!

In addition, **2015 brings two more total lunar eclipses.** *Both are at least partly visible from Florida!* The first, **2015 April 4,** has the Moon unfortunately setting about one half hour before totality begins. Still, the beginning partial phases should be visible if skies are clear. However, the second lunar eclipse **(2015 September 27/28)** will be entirely visible in Florida although it comes during a more rainy season.

The Tetrad and a Plethora of Lunar Eclipses

Four successive total lunar eclipses are known as a ***tetrad*** and occur at intervals of six lunations (177 days). However, the frequency of tetrads is very variable. For instance, no tetrad took place for more than three centuries, in the years 1582 to 1908.

However, sixteen occur from 1909 to 2156 with **eight in the 21st century!**

The last tetrad was ten years ago, 2003-04, with three of the four total lunar eclipses visible in Gainesville. The next tetrad is now imminent, 2014-15.

We should be thankful that North Florida will see (weather permitting) all or part of the four upcoming total lunar eclipses during the 2014-15 tetrad! *This is likely the last tetrad that many of us will experience since the next tetrad is not until 2032-33.*

Recently, AAC president, Andy Howell, asked about this tetrad when he wrote, "What do you think of the "red blood moon tetrad" that is happening 2014-2015?"

Red Blood Moon Tetrad? Coincidently the four total lunar eclipses of the next tetrad coincide with the Jewish festivals of Passover and Sukkoth (each lasts seven or eight days), and a partial solar eclipse on Rosh Hashana.

Eclipse Date	Jewish Date	Jewish Festival	Eclipse Type
2014 Apr. 15	Nisan 15	Passover	Total Lunar
2014 Oct. 8	Tishri 15	Sukkoth	Total Lunar
2015 Apr. 4	Nisan 15	Passover	Total Lunar
2015 Sep. 13	Tishri 1	Rosh Hashana	Partial Solar
2015 Sep. 27	Tishri 15	Sukkoth	Total Lunar

Therefore, the four eclipses of this tetrad coincide with two important Jewish festivals, and a solar eclipse with Rosh Hashana, the beginning of the “High Holy Days.” Hence, religious fanatics may hype this tetrad.

However, eclipses will occasionally occur on some religious holidays since the Jewish calendar is based on lunar months of 29 or 30 days. Hence, holidays that fall on the first or fifteenth day of the Jewish month will always fall on or near new or full moons respectively, times when solar or lunar eclipses are possible. Both Passover and Sukkoth occur on the 15th day of their respective lunar months, close to or on dates of full moons. And the 2015 September solar eclipse also coincides with Tishri 1, a new moon date.

Moreover, Passover and Sukkoth are separated by six lunar months of 29 and 30 days, a period of 177 days or six lunations, a period similar to the separations of successive lunar eclipses.

Finally, it can be shown that the first eclipse in a tetrad always falls between mid-February and mid-June, an interval that includes the beginning date of Passover.

So, eventually, it is interesting that some tetrads will have all lunar eclipses coincide with these religious holidays as it will happen in 2014-15 on the holidays of Passover and Sukkoth (full moon holidays).

Therefore, some religious fanatics may hype this tetrad and declare bad omens are forthcoming even pointing to past disasters seeming to occur during a tetrad.

Unfortunately, the mentality of many people has not evolved much past the early stages of human evolution so much of the world remains mired in superstitious nonsense. So it will always be possible to cherry pick tetrads that may have some “historical events” on or near tetrad years. (Also who is going to define what events are historical or not?) It seems that every time some interesting astronomical event occurs, doomsayers come out of the wall. Enough said.

And so the world turns. ☼

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