Just Going Through the Motions
Winter 2019 – 2020 Calendar Issue

Yes, after what seems like a year-long wait, the new AAAZ Calendar Issue is back. Well, that's just silly; this is an ANNUAL calendar, so it makes perfect sense that we wait a year, right? And, as with all my winter newsletters, we'll go through some astronomy info and upcoming events before we get to the long-awaited, afore-mentioned calendar! You just knew there had to be a catch…

Before getting into the scheduled astronomical events, and some interesting 2020 calendar anomalies, in this newsletter I'd like to address the subject of ***celestial motion***. Whether we think of ourselves as seasoned astronomers, keenly interested observers, or just casual sky watchers, the ***"apparent"*** versus ***"actual"*** movement of objects in the sky (day or night) has challenged us and caused confusion from the beginning of time. Confusion can manifest itself in several ways; it can come from something as simple as an accepted use of language, such as a ***"rising sun"*** or a ***"setting moon"*** – neither of which is technically accurate. Or, we may not be cognizant of every single factor that causes an apparent movement. For example, if the moon constantly moves east-to-west, why does it move west-to-east when observed at the same time from one night to the next? Finally, if a person is put in a new or unfamiliar setting, with no obvious reference points, it's much easier to think something is happening that cannot happen. This is particularly true, if we are not firmly rooted in what we know to be true, things that can't be challenged; there are, in fact, ***physical laws*** that are not up for debate!

Ancient cultures believed that the "rising" and "setting" of objects in the sky proved we were at the center of the universe and everything revolved around us – I call it ***"teenager mode"***. We now understand that this movement is caused by the Earth's daily rotation. So, before we are flung off into space, let's review some actual celestial conditions that cause apparent motion, and some other astronomical oddities. To prepare for this journey, let's set some concrete guidelines and definitions that will give us a reference point, to help us navigate through the fog of misunderstanding:

Rotation- Most celestial bodies "rotate" around their poles. The Earth rotates once in 24 hours. Sunspots show that even the Sun rotates, every 25 to 35 days about its poles.

Revolution- Planets and stars also tend to "revolve" or orbit about something. Planets typically orbit stars, and stars in a galaxy can orbit a supermassive black hole at the galaxy's center.

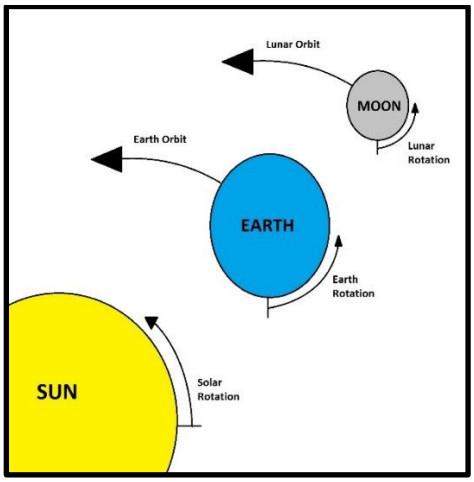
Ecliptic- The relatively flat "plane" of the solar system. Viewed from a distance, our solar system is shaped like a big pancake, with the Sun at the center. Most bodies that orbit our sun do so within a few degrees of this "plane of the ecliptic".

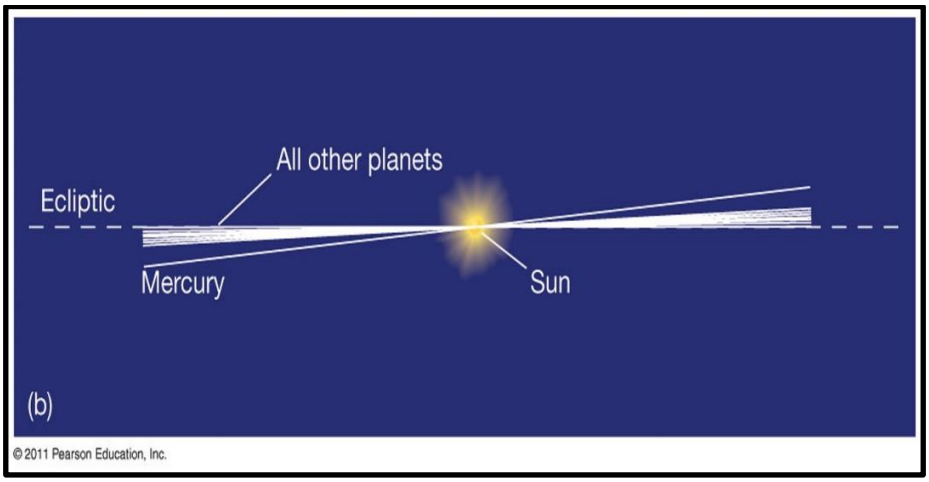
Tilt- The angle of a celestial body's pole to the ecliptic. Earth is "tilted" at about 24-degrees to the ecliptic. Venus' tilt is about 177-degrees; it's almost exactly upside-down!

With just these few "bedrock" assumptions, and a couple more physical laws and properties, we can explain many of the motions we observe in the sky. Remember, the above are set in stone…we'll not question the validity of these definitions, lest we lose ourselves in a never-never-land of metaphysics!

First, an easy one, we'll start with The Moon. We already know that it doesn't actually "rise" in the east; but, as Jack K. used to say when we worked on "The Mountain", that's a lot easier than saying, "At dusk on the night of a full moon, the Earth's west-to-east prograde rotation causes the eastern horizon, from our vantage point, to drop below the moon, making the fully illuminated lunar disk appear to rise in our eastern evening sky." Yeah, let's just go with "moonrise". From this, you can figure out the fiasco that would describe "moonset"! And this goes for all the stars, and the planets, even the sun, and every-other-natural-thing in the sky. When viewed "from above", the Earth is rotating "normally" about

its axis in a counter-clockwise direction…west to east…so everything ***APPEARS*** to rise in the east, move slowly across the sky, until whatever-it-is sets in the west. The Moon always moves this way – never question this – wherever you are, moonrise happens more-or-less in the east!



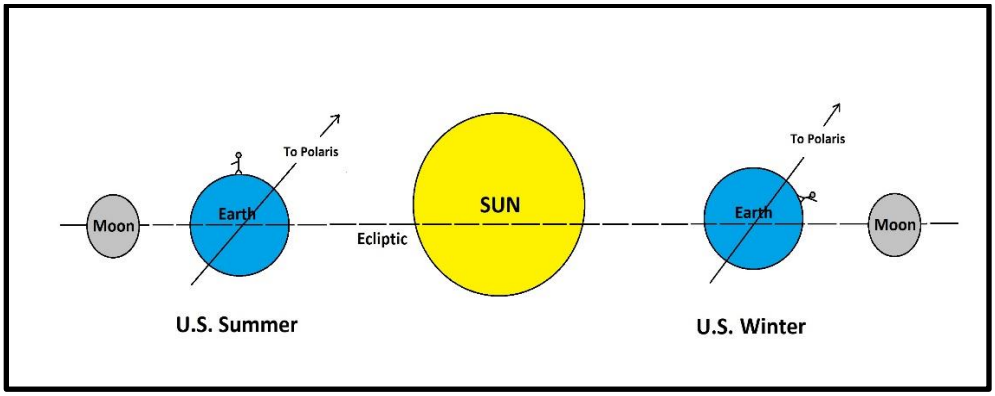


The images above depict our assumptions. At left, we see both ROTATION and REVOLUTION (orbit). We're viewing "from above", so everything moves right-to-left (west-to-east). In the right image are the orbits of the planets shown from the side. Notice how almost everything is within a tight sliver – except for Mercury. A good "pancake view" of the "plane of the ecliptic".

Simple. Then why is it, if you check the moon at the same time each night, it seems to "backup" a bit toward the east from day to day? Doesn't everything in our sky appear to move east to west? If Earth's rotation was the only motion, that would be true, but now we must expand to the next level. The Moon also moves; it orbits the Earth. And, if you once again take up your ***"God's-eye view"*** from above the solar system, you would see that our moon, like all the planets and most of their moons, orbits in a counter-clockwise direction…just like the Earth's rotation, and orbit around the Sun! You would also see the moon orbit the Earth once every 28 days. So, that little daily moon-jump from west to east, is one day's amount (about 1/28th) of the Moon's ***ACTUAL*** movement as it orbits the Earth. In 28 days, with 28 little jumps, the moon will be right back to where it started, moving west to east each night.

Well, now we know about the apparent motion of the moon due to Earth's rotation, and the moon's actual motion as it orbits the Earth…now let's go REALLY NUTS! I watched recently as someone explained how the moon moves up and down in a ***sine-wave type of motion*** during the year, and I saw the scrunched faces of many in the audience as they grappled with this. Does the moon move like a buoy in the ocean, with a wavy-up-and-down type of orbit? Do you think that's actual motion or apparent motion, and what would explain it, either way?

To answer this, we must consider two additional factors – the ecliptic, and the tilt of a celestial body…in this case, the tilt of the Earth. From the definition, we know that our planet is tilted toward the ecliptic by about 24-degrees; in fact, it's the tilt, and not our elliptical orbit around the sun, that causes our seasons. This slight inclination also puts the summer ecliptic (the sun's path) higher in the sky, while during winter it tracks lower toward the southern horizon. In summer then, our northern hemisphere is pointed more directly toward the sun. Likewise, in winter, we're pointed an equal amount away from the direct rays of the sun's path. At night, however, wherever you are, you've rotated opposite the sun to the night-side of the planet, so everything is reversed! The ecliptic sits LOW during U.S. summer nights, and it's HIGH in our winter night-time skies. And, like most solar system bodies, the moon follows closely to the ecliptic. Thus, at night, Luna's position over the horizon is opposite Sol's daytime position, making summer moons ride lower in the sky, while winter moons take the high road. This explains the apparent "moving-up-and-down" motion of the moon's path.

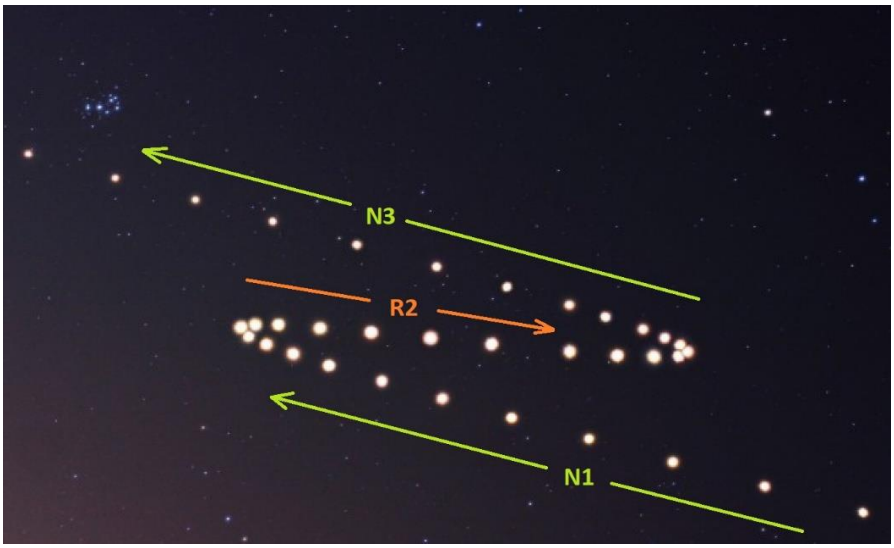


In the image at left, we see summer and winter moons as viewed from the U.S.A. The angles and sizes are not to scale, but the Earthling is standing in the U.S. on the "night side". Notice how high the moon is over her head on winter vs. summer nights!

So, thanks to scientists like ***Copernicus, Kepler, and Newton***, we know that most planets, moons, asteroids, and comets actually move in a flat elliptical path. The apparent "wavy-up-and-down" motion against the background stars, is explained mostly by a "tilt" toward the ecliptic.

Now we are finding our celestial "sea legs"! And we're going to need them, because it's time to tackle an oddity of celestial motion that helped to give "planets" their name. Let's first nail down the stars' motion in our earthly skies. We know that the Earth's daily rotation is what makes the stars rise and set each day. If you observe the stars carefully however, you'll see that, at the same time each night, all the stars have shifted 1-degree toward the western horizon! Our buddy, Copernicus, long ago pointed out that stars do not orbit the Earth, but the Earth does orbit the Sun! As our home planet treks west-to-east in its annual do-se-do around our host star, each day the other stars appear to move a tiny fraction in the opposite direction, east-to-west. That is why our ***summer constellations*** stay summer constellations; after a year, we are right back in our orbit, where we started.

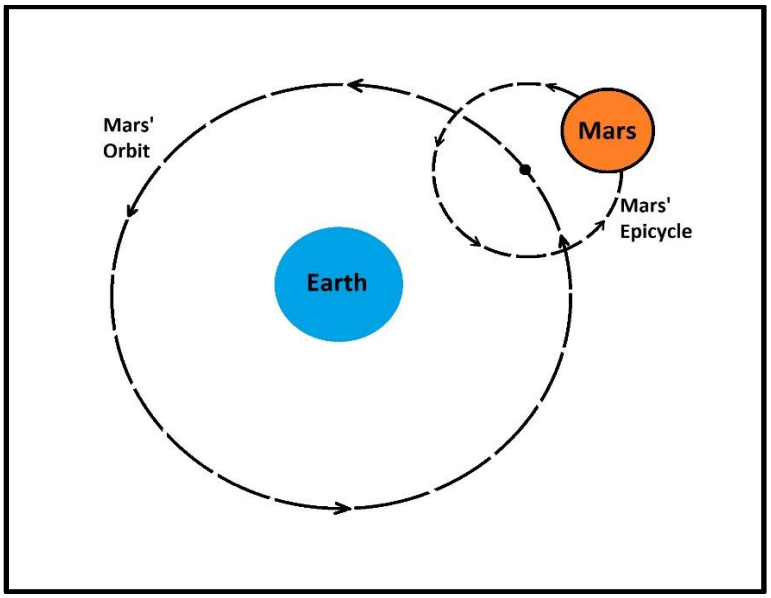
Our ancestors though were excellent sky-watchers, and they noticed that a handful of stars didn't shift along with all the other stars. Instead, these ***"wandering stars"*** shifted a bit eastward each night; the word "planet" means "wanderer". But there was a problem – every now and then, the wanderers started to walk back the other way! For a short time, they moved westward in the sky, until eventually they reversed again and took up their "normal" path. We call this, ***retrograde motion***, and it caused all kinds of havoc with ancient astronomers and astrologers, as you can well imagine.



In the image at left, we see normal planetary motion vs. retrograde motion. Astro-imager Tunc Tezel, imaged Mars weekly in an 8-month time lapse against background stars in 2005 (note the Pleiades in the upper left corner). The God of War approaches the Seven Sisters, west-to-east, during the normal segment (N1). It then turns east-to-west during the retrograde session (R2), before resuming its normal path (N3), later in the year.

As we've already established, each planet moves in a nice, normal, flat ellipse – no waves, no wobbles, and certainly no backing-up is allowed! We understand this is apparent motion, and we also know that our sky-watching ancestors went through all kinds of machinations and contortions to explain it.

The most “creative” explanation for this wild motion was that planets not only orbited the Earth, but they also orbited some unseen object or force near them. From this we got the ***“epicycle”***, and this is not some super cool bike, but a really crazy second orbit that each planet goes through.



Knowledge of “the wanderers” predates recorded history, but later astronomers attempted to explain and model what they observed in the heavens. It was Ptolemy in the 2nd century A.D. who introduced the concept of “the epicycle” to help explain the odd retrograde motion of the known planets. In the image at left, Mars not only orbits the Earth, as was accepted at the time, but it also orbits an imaginary point on the orbital path. This mechanism helped explain the occasional backward motion of the planets and worked surprisingly well to help predict their positions in the sky.

Copernicus resuscitated the even-at-that-time-ancient concept of a ***Sun-centered system*** in which all the planets, including the Earth, orbit the Sun. Kepler expanded on this to explain planetary motion with his “laws”, and one of them states that planets orbiting closer to the Sun move faster, while those further out orbit at a more leisurely pace. You could argue that the outer planets have bigger orbits and just have further to travel; maybe they don’t really move “slower”, they just take longer. The chart below shows that YES, outer planets travel further…and YES, they actually do move slower.

	Distance from Sun (radius in million miles)	Orbital Period (days)	Orbital Miles Traveled (2 x 3.14 x r)	Speed (miles/hr)
Mercury	36	88	6.28 x 36 = 226m	226/88/24 = 107k
Venus	67	225	6.28 x 67 = 420m	420/225/24 = 78k
Earth	93	365	6.28 x 93 = 584m	584/365/24 = 67k
Mars	142	687	6.28 x 142 = 892m	892/687/24 = 54k
Jupiter	484	4332	6.28 x 484 = 3039m	3039/4332/24 = 29k

Apart from being incredibly picky about details, why do we care? Well, this arrangement of the planets, and their speed around the Sun explains the head-scratching concept of retrograde motion. From our third position in the solar system family, the outer planets typically move to the east in our sky. However, Earth moves faster than Mars and the other outer bodies. So, every once in a while, Earth catches up with the slower objects and passes them up…like slower moving cars on the freeway. Just as the slower car next to us seems to move backward, slower moving planets appear to back-up in the sky; they move east-to-west for a time. As Earth makes its turn around the Sun, the slower planets reverse again, resuming their normal motion. You can see a more visual explanation here: https://www.scienceabc.com/nature/universe/what-is-retrograde-motion.html. Or, view a great video here: https://www.scienceabc.com/wp-content/uploads/2019/07/Apparent_retrograde_motion_of_Mars_in_2003.gif

So, that’s enough cosmic motion for now. I apologize for this slightly more “technical” newsletter, but I wanted to provide some info for readers who might want a bit more “meat on their astronomical bones!”

Now, for some fun in our skies, and on the calendar. First, up are the Geminid Meteors, peaking on December 13 – 14. While hampered by a nearly full moon this year, Geminids are bright, big, often colorful, and sometimes slow moving, so they're always a great meteor shower…moon or no.

Next, be sure to get your last looks at Jupiter and Saturn right now as they make up a beautiful triad with a nearly half-phase Venus low in the southwestern sky immediately after sunset. By the New Year, only Venus will remain high in the sky at dusk, as it races toward a smaller but brighter crescent phase.

And, speaking of planets, in 2020 Mars returns to our evening skies, with opposition set for early October. The Red Planet, however, starts the year with a Bang! Before dawn on February 18, the Moon will ***occult*** Mars. At 4:30am, in Tucson, the light side of a sleek crescent Moon will cover the planet, approaching from the west. An hour later, the God of War charges from the "dark side" of the moon's southwestern limb. Given the early-morning timing, you'll have to work for this one, but for those who make the effort, it will be a rare and wonderful sight! Fore knowledge of this type of event could surely have made you a wizard, or maybe even a demi-god, in ancient cultures.

A Lunar occult of Mars will begin soon after moonrise on 2/18, in Tucson, AZ. In the image at left Mars is below and left of the Moon. In the right image, Mars pops out as the Moon moves a bit further along in its orbit. The view from the east coast is obscured by daylight, while in the west, it's already started at moonrise.

The new year 2020 also provides some "interesting dates" that don't come up all the time. As an example, my first big telescope came as a gift from my wife, Helen. I soon took it to my local astronomy shop to be "signed and dated" by ***David Levy***; my 'scope is dated 9-9-99. That one won't come up again anytime soon. And, my son, Nick got his first telescope from us as a Christmas gift. It was signed on 02-02-02! Now, we're on the doorstep of 2020, and February offers some "dating possibilities". My first thought is February 2nd, which could be written as 02022020…a very nifty ***palindrome***! If you come up with other interesting dates, please let me know.

Finally, this year I'll be sending out the calendar as a separate document, and it will be coming very soon. In the meantime, I hope you all find this Winter issue of the Quarterly Newsletter timely, informative, and entertaining. If you have any questions or comments, please feel free to email or call me – it's a pleasure to hear from readers. As always, I hope you enjoy the skies wherever you are!

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