Far Out!

Celestial Motions

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STARSociety

South Texas Astronomical Society

Editorial

Whence things have their origin, Thence also their destruction happens, According to necessity; For they give to each other justice and recompense For their injustice In conformity with the ordinance of Time.

The only surviving quote of Anaximander of Miletus, preserved and transmitted to us by Simplicius of Cilicia, is profoundly telling of some of our earliest theories of the changing universe. Anaximander created a cosmological theory involving *aperion* (ἄπειρον), the concept of a limitless and eternal universe that, through the principle of duality, continually creates and destroys all things. Through cosmological frameworks such as this, philosophers and physicists have sought to explain the motion of the stars and planets seen overhead night after night. With our increasing technological sophistication, telescopes and other astronomical instruments have revealed a universe full of unexpected beauty and wonder - as well as unexpected motion. Who knew astronomers would go beyond explaining the seasons, the annual and diurnal cycles, and the order of the planets? We would go beyond these discoveries to reveal unexpected motion: the pull of the Moon, the consequences of special relativity, the parallax of our shifting orbit around the Sun, and even the motions of planets in *other* star systems.

In this winter issue of FFO, we bring to you one of the oldest tales of the night sky, a tale about a hunter, love, and the gods. In the depths of the snowy cold, there is a fire. That fire is the phoenix, a mythological bird symbolizing rebirth and the eternal cycle of life. We explore the historical development of our understanding of the changing night sky and discuss some of the major sources of celestial motion. We delve into the science of exoplanet detection, the discovery of new worlds through the motion of their host star and the interaction of light. We discuss international relations in space, and we discover the worldview of Mexican pre-Hispanic cultures. We explore the global and climate impacts of light pollution, something that threatens our access to the night sky. Finally, we introduce some stellar jokes in our Cosmic Comedy, and bring you some fantastic artwork in Space Ranges to enjoy during your holiday season.

Wishing you clear skies,

Richard Camuccio
Editor-in-Chief

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Carol's Corner of the Cosmos

Carol Lutsinger

Welcome to winter, y'all. December brings the Geminid meteor shower at mid-month, with the peak set for December 12th. The New Moon will make it more likely to see meteors streaking across the sky. A team of friends out together watching makes an even more enjoyable event. December evenings bring so many beautiful constellations into view as darkness sets in.

Although winter does not officially begin until December 21st, we can expect more of our winter constellations to be visible in the east after sunset since the stars "rise" four minutes earlier until the winter solstice. On that day we will have about nine hours and twenty minutes of daylight. Perhaps you have noticed that the Sun is not as high in the sky and that it is not in your eyes as you drive to and from work. Just wait a while and it will be! From this point, the Sun will rise a few minutes earlier each day and set a few minutes later until mid-June. This amazing pattern continues to repeat itself because Earth travels at mathematically predictable speeds and in a predictable path. This would be an interesting science fair project, tracking the height of the Sun for the next several months, or graphing the times of official sunrise and sunset over a period of weeks.

Season's greetings, whatever day this month is one of special significance in your culture! People around the globe celebrate several religious observances and cultural events during the winter which date back to prehistoric times. The short dark days of winter were fearful to ancient people and bringing bonfires and as much light as possible during those long lonely weeks of little Sun were a vital part of early cultures.

As you have a bit of family time during the next couple of weeks, you may think about the guiding star that is part of the Christmas story. Scientists may debate what it was, people of faith accept that it WAS. We can enjoy the same regular stars that shone over Bethlehem and think about that one star that announced the special baby born 2000 years ago and exult in the wonder of it all. In fact, the very fact that a star and astronomers figures so prominently in the observance of Christmas is one reason I enjoy the science of astronomy so much.

Star patterns in the sky year-round include circumpolar constellations Ursa Minor and Ursa Major [1] in the north, along with Cassiopeia [2] and Cepheus circling about Polaris in Ursa Minor. As darkness sets in, the 'W' or 'M' of Cassiopeia's stars is high in the northwest quadrant of the sky and the Big Dipper asterism is circling Polaris in the low northeast. The two forward stars of the bowl of the Big Dipper point directly to Polaris; I call them the Pointer Sisters [3].

The unique position of Polaris in the sky helps navigators to find their way in the Northern Hemisphere because Polaris is as many degrees above the horizon as the latitude of the viewer. Those ancient astronomers who figured out geometry gave math students something to stress over and explorers something to get home by. If you are a geometry teacher, show your students those angles using astronomy and open new vistas for each of you.

If you are teaching an astronomy class at your local high school we would be interested in hearing from you since a few of our local high schools have teachers who have volunteered their after-school time to support astronomy clubs. Helping each other might make a stronger presence for each of you.

With Orion standing tall in the southeast as twilight begins, the full splendor of those stars that mark his shoulders and knees becomes apparent in the deepening night. The right shoulder is deep scarlet because this star is old and cooling as it burns its hydrogen into helium. Its name is Betelgeuse. About 15° to the right is another star; this one is blue and young, named Bellatrix. Each night Orion will be a few degrees closer to the zenith as it emerges through the dusk of early evening. This wonderful constellation has a most incredible astronomical object within its boundaries. The Great Orion Nebula [4] is home to the spectacular Horsehead Nebula [5] which has enchanted astronomers since it was first observed through telescopes.

Showing someone where to look for space objects developed during Babylonian's rule. They used their fists and fingers to mark off degrees of a circle. Your fingers spread in a "Hook 'em Horns" position stretched out at arm's length will measure 15°. The Full Moon measures your pinky finger, .5°; your clenched fist measures 10°.

February brings another opportunity to join the GLOBE project. The GLOBE at Night project is asking for your assistance February 12-21 to assess light pollution around the globe. You are asked to observe and record the magnitude of visible stars in the constellation Orion between 8-10 p.m. local time. Details are available at [6]. On the GLOBE at Night website there are activities for classroom teachers to use with their students.

If someone is interested in participating and wants local information I would be glad to share if you contact me. Participating in this activity would be a perfect parent/student event for a campus as well as a unique science fair project because of all the data that will be available.

Until next time, KLU. ★

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Biography
Carol Lutsinger is the founder of the South Texas Astronomical Society. She spent 40 years as a teacher, serving students from Pre-K through college. Carol attributes her astronomy enthusiasm in part to her experience in the American Astronomical Society's AASTRA program from 1994-96, and her space excitement from serving as a Solar System Educator, and later Ambassador, for the NASA/JPL program. She has been writing the Stargazer newspaper column since 1998, which is carried in the Brownsville Herald and the Valley Morning Star. Retired from formal education since 2020, she still makes every opportunity to share meteorites which she carries in her purse and to ask folks in parking lots if they know what that point of light is.

Phoenix

A mythological bird. It regenerates and is reborn from its predecessor‘s ashes, making it an immortal creature.

Celestial Motion

Richard Pomeroy

In the Beginning

Ever since the first humans became conscious and attained an awareness of their surroundings, they undoubtedly began to question their place in the universe and have naturally looked up at the sky. Unmarred by the light pollution which blights modern day man, ancient cultures around the world used the sky as a backdrop, a rich canvas on which their stories and mythologies were writ large and could be retold over generations. These myths were societal stories used to explain the biggest questions, to which we still search for answers, such as the origin of humans and the universe, but also to provide explanations for periodic and natural events.

Figure 1. The Milky Way, as viewed by some of its inhabitants. Credit: David Wilson, NCJ.

The Ever Changing Sky

It would have been obvious to early humans that the sky was very changeable, from the motion of the Sun across the sky during the day, to the passage of familiar star groupings across the firmament at night. They would also have seen the Sun's sister, the Moon, appearing on a regular basis, changing her shape as she made her progress across the sky, leaving the Sun behind as a small sliver and over many days growing to a bloated globe at the top of the night, before gradually disappearing a few nights later to meet the Sun once again. They would quickly have identified star groupings, or constellations, shaped as different characters they could use to narrate their mythology, perhaps one shaped like a bear and another as a swan floating serenely along a milky river (see Figure 1), and yet another as a memory of a mythological hunter. The hunter would slowly move from night to night, chasing his quarry stealthily across the heavens for six months, before disappearing for another six months only to reappear again and restart the cycle. They would also have noticed that groupings of stars in certain parts of the sky were visible constantly, but seemed to rotate around a single point, a static point which allowed the nomadic hunter-gatherers to navigate. In their travels, they may also have noticed that in moving toward that stationary point about which the stars rotated, it became steadily higher in the sky.

The nomadic tribes would have been able to relate to the bright 'stars' in the sky which moved faster than the others, seemingly meandering through the background of stars with a less predictable path. Two of these 'wanderers' (from the Greek *planete*) seemed to accompany the Sun, either heralding its arrival early in the morning or following in the wake of its departure late into the night. Three others were sometimes visible throughout the night, taking many months to peak in brightness. These wanderers were sometimes seen to reverse their passage across the sky for a brief period before slowly continuing their inexorable dive to the horizon over several more months.

Occasional Visitors

As if the motion of the planets was not strange enough, there were other occasional visitors projected onto the celestial sphere whose presence was less predictable still, and whose appearance was often synonymous with disasters, omens of bad luck and portents of doom. In fact, comets, the icy messengers from the outer reaches of our Solar System, were often seen as full of awe (instead of awful) and even ancient man appreciated their beauty. Other unpredictable events in ancient times include novae and supernovae – the appearance of 'new', but temporary, stars in the sky, such as the supernova of 1054 AD, recorded by the Puebloan astronomers in Chaco Canyon, NM (see Figure 2) and by Chinese astronomers of the time, and which we now know was the event that instigated the Crab Nebula.

Figure 2. The 1054 Supernova with a (faded) possible depiction of Halley's comet in its 1066/1145 apparition, in Chaco Canyon, NM. Credit: Peter Faris.

While today we can accurately predict the return of periodic comets such as Halley's Comet, based on relatively simple physics derived by Kepler, Galileo, and Newton, we still cannot predict the first appearance of comets or when stars are going to go supernova – current forecasts for the end of life of the red supergiant Betelgeuse in Orion give a 'window' for the event occurring from any time in the next week to several thousand years!

Figure 3. The Antikythera mechanism, discovered in a shipwreck off the coast of Greece, and generally referred to as the first known analog computer (circa. 200 BCE), was used to calculate the positions of the Sun and Moon, the Moon phase, eclipses, and calendar cycles. Credit: National Archaeological Museum, Athens. No. 15987.

Ancient Knowledge

Eclipses of both the Moon (where the Moon moves into the shadow of the Earth) and the Sun (where the Moon moves between the Sun and the Earth) are seen to have a similarly rich symbolism in historical records, but ancient cultures were also better at predicting these events than we might at first suspect. Mayan, Aztec, Egyptian, and Babylonian astronomers followed the lunar cycle and were able to predict the occurrence of lunar and solar eclipses with a high degree of certainty.

So, without necessarily understanding why, the ancient observers were able to read the signs, and through the cyclic nature of the Solar System, were able to predict many things essential to the very survival of their tribes, such as when the Moon was going to be best placed for night hunting, when the changing weather would start producing new fruits on the trees or cause animal migrations to occur, and when the days would become longer allowing the best chance of success for a wandering tribe to find a new home.

As the nomadic lifestyle diminished and the first farming communities were established, this knowledge was essential to ensure the success of the new paradigm. At the start of the first agricultural revolution around 12,000 BCE, it allowed humans to be able to predict the future. Astronomy, the oldest science, has been key to the success of humans for many millennia.

This knowledge of the motions of the Sun, Moon, and planets has remained important throughout history. For example, in the case of seafaring nations, knowledge of the positions of objects in the sky would have assisted in navigation, prediction of tides, and would not only have given traders a competitive advantage, but more importantly would potentially have improved the safety of what were dangerous voyages at the best of times. Around 200 BCE, the Greeks had what is believed to be the first analog 'computer' to predict lunar phases, and from Sun and Moon positions, could determine time of day and date. Eclipses, and possibly positions of the five known planets of the time, were also predicted. Known as the 'Antikythera mechanism' (see Figure 3), this device was a manually driven orrery (model of the Solar System) and had perhaps as many as 37 bronze gears in its computing mechanism. Although incredibly complex for over 2000 years ago, it illustrates the importance of determining the positions of prime celestial objects to the culture of the time, but also how the mysteries of celestial

Figure 4. A 2,000-year-old sundial unearthed in the ancient city of Laodicea in southern Turkey. Credit: Sebahatdin Zeyrek / AA.

motion can largely be reduced to a 'simple' clockwork mechanism.

The Sun moves across the sky rising in the east and setting in the west. In northerly latitudes, a stick placed in the ground will cast a shadow which traces out the daytime portion of a rudimentary clock. Sundials, such as the early example shown in Figure 4, were the first and most eco-friendly solar powered time-telling devices ever invented! The 'apparent' motion of the Sun across the sky is in a clockwise direction - no surprise there, given the connection between the Sun and timekeeping. The projection of the Sun's shadow also moves in a clockwise direction. However, as we now know, it is that incandescent orb of gas we call the Sun that is static in the center of our Solar System, and the Earth that is rotating anticlockwise beneath us at (about) one revolution per day, whisking us around, along with a few thin miles of atmosphere, on a journey that started many billions of years ago, and will likely last a few billion more... (but that is a story for another day!)

The one revolution per day of the sphere of the Earth

Figure 5. A time-lapse exposure pointing toward the 'celestial pole', illustrating the apparent motion of the stars due to the rotation of the Earth. Credit: Yuri Beletsky Nightscapes.

on which we are firmly positioned is responsible for the apparent motion of the stars across the sky. Within the bounds of human perception, it is also responsible for the motion of the Sun, the Moon, and the planets across the face of the celestial sphere, that is, the 'fast' motion which we experience on a daily basis - referred to as *diurnal motion*.

The Dynamic Heavens

As it is the Earth that spins on its axis, the north and south points of rotation are more familiar to us as the poles. These poles, when extended up into the sky onto the celestial sphere above us, mark the celestial pole positions about which the stars seem to rotate (see Figure 5). The inhabitants of the northern hemisphere are lucky enough to have the star *Polaris* in the tail of *Ursa Minor* (the little bear) almost coincident with the north celestial pole. Navigators ancient and modern have used this lucky alignment to north to affirm their direction of travel with a star whose light set out to us over 300 years ago.

As the celestial poles are related to the Earth's poles, one might wonder what happens to the apparent motion of the stars as we travel north or south. For example, if we don our arctic gear and travel until we are standing at Earth's north pole, then, spinning on top of the world, the North Star, Polaris, will be directly overhead, at the zenith. At that point on Earth, all the stars we observe would neither rise nor set, but merely rotate serenely around the Pole star, like children on a merry-go-round. Stars that are always visible from a particular location, that never set, are called *circumpolar*. From our arctic adventure, if we now journey south toward the equator, Polaris will always be at our back but will steadily reduce in altitude behind us as we traverse the surface of the globe. Shedding layers of Goretex and Thinsulate as we move to more temperate climes, eventually we would find that Polaris meets the horizon. The north celestial pole is on our northern horizon, and the south celestial pole is on our southern horizon. We are on the equator, equidistant from both of the poles. At this point, and any point on the equatorial line, we would see all the stars traversing a fictitious north-south line during the night, rising on the eastern horizon and setting on the western horizon. On the equator, we note there are no circumpolar stars. While on the Earth's equator, if we draw a line through all the stars which pass directly overhead, through the zenith, we have a new reference line. This is the *celestial equator*, and as one would expect, it marks a line on the celestial sphere of stars above us, which is midway between the north and south celestial poles

Heliocentricity

After our long journey south from the pole, we may decide to stay a while in one place and inspect the stars from night to night. As we are scientists, we want a point of reference, and for this we use our fictitious line, the *meridian line*, drawn from north to south on the face of the celestial sphere above us. We would, however, notice something strange - the stars we see are passing across the meridian earlier

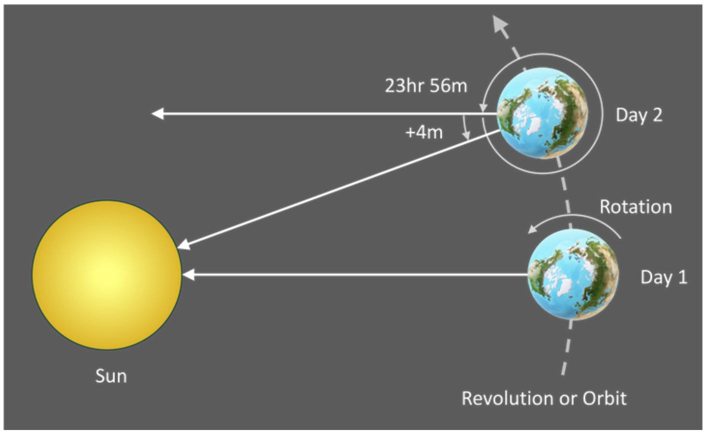

Figure 6. Cartoon showing the difference between sidereal and solar days. Credit: Author.

every night.

We have accounted for the diurnal motion of the stars on a daily basis due to the rotation of the Earth, but at the same time every day, the stars are a little further ahead. It is almost as if the Earth is performing a little more than one full rotation on its axis every day. This, of course, is exactly what is happening! The Earth is not static in space, but is revolving around the Sun at the center of the Solar System - this is the *heliocentric* model of the Solar System. As it moves in its journey around the Sun, the Earth has to rotate a little further every day, in order to bring the Sun to the same position in the sky, our north-south meridian line at midday. The Sun is, after all, the celestial object that we use to keep mean time on the Earth.

As shown in the cartoon of the Earth/Sun system above (Figure 6), the Earth takes 23 hours and 56 minutes to rotate once on its axis about its poles, and this is known as a *sidereal* day (from the Latin *sidus* meaning 'star') because it is the time it takes the stars to come back to the meridian position. The Earth revolves about the Sun, also referred to as its orbit, and during the 23 hours and 56 minutes it has been rotating on its axis, it has also been revolving around in its orbit. From the perspective of the Earth, the Sun is no longer where it was the previous day, and the additional time required for the Sun to reach our north-south meridian line is four minutes. Thus the length of a solar day is the familiar 24 hours. After 365 ¼ mean-solar days, or one year, this annual cycle will repeat as the Earth returns to the same point on its orbit.

The Seasons and Axial Tilt

We have talked about the daily rotation of the Earth on its own axis, and also its annual revolution in its orbit about the Sun, which explains the motion of the stars throughout the year. We are now in a position to look at the combined effect of these motions, although, the situation is rather more complicated that it first appears due to the tilt of the Earth's axis and the ellipticity of its orbit.

Figure 7. A characteristic *figure-eight* Analemma from San Pedro Garza García, Mexico. The motion of the Sun throughout the year, shown by taking an image at the same time on a weekly basis Credit: Cesar Cantu Quiroga.

We can illustrate the effect of these additional factors by taking an image of the Sun every day at the same time. If it were not for these factors, the Sun would return to the same position in the sky every day, year on year. However, as it is, the Sun traces a beautiful pattern on an annual basis known as an analemma as shown in Figure 7. This stunning slender, figure-of-eight depiction is created by these two characteristics of celestial motion. The first, *axial tilt*, is a measure of the tilt of the Earth's axis of rotation relative to the plane of its orbit about the Sun. This is also referred to as the *ecliptic* as it marks the path the Sun follows through the background stars throughout the year. The second, the *ellipticity* of the Earth's orbit around the Sun is more subtle.

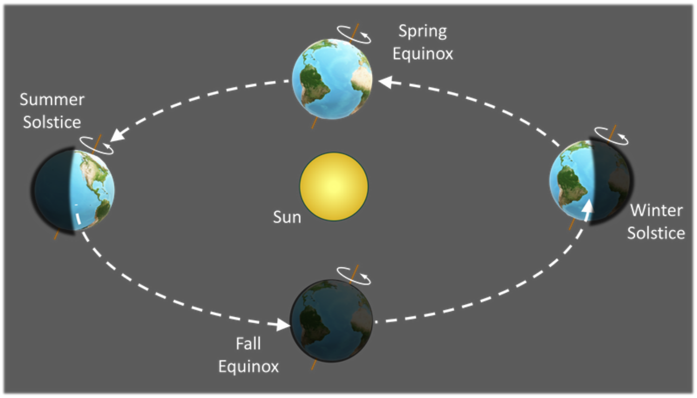

Figure 8. Seasons in the northern hemisphere are determined by the tilt of the Earth's axis of 23.5°. Credit: Author.

The tilt of the Earth's axis is 23.5° to the plane of its orbit about the Sun, and it is ostensibly fixed (in reality the Earth's axis precesses like a spinning top, but this occurs over many thousands of years). Here again we need a reference point in the orbit of the Earth around the Sun, and for this we use the point in the Earth's orbit where the days and nights are of equal length. This occurs in the Earth's orbit when the axis of rotation is neither pointing toward the Sun nor away from the Sun (see Figure 8). The axis is at right angles, or perpendicular, to the Sun. In the northern hemisphere, this is the vernal or spring *equinox*, (from the Latin for 'equal-night') and occurs around March 21st, when the Sun enters the constellation sign *Aries* (the ram) - which is the reason our reference point is known as the *first point of Aries*.

As the Earth continues in its anticlockwise orbit around the Sun, we find the Earth's axis will eventually be aligned directly with the Sun. Inhabitants of the northern hemisphere will notice this is the point where the Sun reaches its highest point in the sky, and this can be seen in our analemma image. It is the point (in the northern hemisphere) where the days are the longest and also the hottest, due to the radiant energy from the Sun being spread over as small an area as possible at a given latitude. This is the summer *solstice* which occurs around June 21st each year. The word 'solstice' comes from the Latin *sol* ('sun') and *sistere* ('to stand still'), as for a few days the Sun appears to linger at its highest annual point in the sky before reducing in altitude on subsequent days.

The inexorable journey of the Earth around the Sun continues, and as the days become shorter, the nights become longer. The Sun's light is spread over a greater area so the temperatures also become cooler. Eventually, we pass through another point of 'equinox' around September 21st known as the autumnal or fall equinox.

Our journey through the year, along the Earth's orbit about the Sun, progresses to the point where the Earth's axis is once again aligned with the Sun, but this time in the northern part of the globe, it points away from the Sun. This is the winter solstice which occurs around December 21st. The Sun is at its lowest point in the sky, the days are their shortest, and the light that does reach from the Sun is spread over as wide an area as possible for a given latitude. Most ancient and pagan cultures noted the point where the Sun starts to rise in the sky after this date as a time of celebration, and today Christmas is the most widespread contemporary holiday associated with the winter solstice.

After a further three months, the Earth, arcing through space, traverses another ¼ orbit to return to the spring equinox, where the rising Sun, longer days, and increasing solar illumination all combine to increase the temperatures, and influence the growth of plants, blossoming of trees, and birth of animals as we start another cycle through the ever-changing seasons on Earth.

Elliptical Orbits

In our analemma image, the Earth's axial tilt accounts for the 'up/down' (north/south) motion of the Sun's position throughout the year. To account for the east/west movement we need to look into the ellipticity of the Earth's orbit around the Sun, but first let us take a step back.

It was in the early 17th century that German Johannes Kepler was grappling with data from observations made by the Danish astronomer Tycho Brahe. At the dawn of the age of telescopes, Kepler was trying to find the rules which tied together the motions of the planets in the sky. Up to this point in time, all models of the Solar System had used *epicycles*, or circles on circles, to explain this motion. Even Ptolemy's model, which had prevailed for 1,500 years, used this technique, and the Antikythera mechanism, mentioned above, had gears which meshed in a epicyclic way to model planetary orbits. The genius of Johannes Kepler was that he used *ellipses* rather than circles to explain planetary orbits, and at a stroke, the need for the nonphysical epicycles was removed. Kepler, in his application of scientific formalism to explain observation, rather than just *saving the phenomena* – in other words, using what had always been used – opened the door to the modern scientific era. His contemporary, the Italian Galileo Galilei, and later the English Isaac Newton (see Figure 9), famously used the same scientific formalism in their own pursuits to describe the physical world.

Figure 9. Tycho Brahe, Johannes Kepler, Galileo Galilei, and Isaac Newton – some of the contributors to the modernization of astronomy and physics in the late 16th and 17th Century. Credit: Kean Collection/Getty Images.

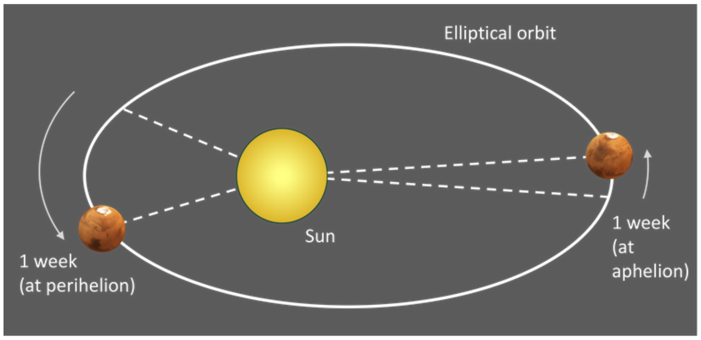

Figure 10. Exaggerated elliptical orbits of the planets, illustrated for Mars. Ellipses have two *foci* and the Sun sits at one of them. When closest to the Sun (*perihelion*) a planet moves faster in its orbit than when at its farthest point (*aphelion*). Credit: Author.

So why is this important? Kepler was concentrating on accurately explaining the motion of Mars, which had always proved problematic to predict. As it turns out this is because of Mars' *orbital eccentricity* which is a measure of how much the orbit deviates from a circle. In the end Kepler's three laws of planetary motion are

- *The orbit of a planet is an ellipse with the Sun at one of the two foci*
- *A planet covers the same area of space in the same amount of time no matter where it is in its orbit*
- *A planet's orbital period is proportional to the size of its orbit (its semi-major axis)*

and from the first law we surmise that the Earth's orbit is also an ellipse. The second and third laws state that the orbital velocity of a planet varies with its distance from the Sun. If that distance varies, as it would for an elliptical orbit as depicted in the cartoon above (Figure 10), then so does the orbital velocity. The planet's velocity will vary during differing portions of its orbit.

This then is precisely what occurs for the Earth. In early January in the northern hemisphere, the Earth reaches *perihelion*, its closest point to the Sun, and so its orbital velocity increases above average. In early July, the Earth reaches *aphelion*, its farthest point from the Sun, so its orbital velocity will be below average. Our clocks measure time based on the average position of the Sun in the sky. This is called *mean solar time*. In our analemma image (Figure 7), the east-west discrepancy between the actual position of the Sun in the sky, and the position of a (fictitious) 'mean' Sun, which we use to time each exposure, reflects the orbital velocity variations of the Earth during the year.

The Wanderers

Earlier we described how the stars would look from the Earth's equator and defined the *celestial equator* as midway between the north and south celestial poles. We also touched on another crucial reference line, that of the *ecliptic*. This is the plane of the Earth's orbit about the Sun, but from a human perspective on the moving Earth, it is also the path the Sun follows throughout the year. The figure below shows the celestial equator, the plane of the ecliptic, the vernal equinox (or first point of Aries), and the celestial poles in relation to each other.

We now have in place reasonable models to explain the motion of the stars and the Sun, but we will need a little more thought to determine the motion of the other planets, what the Greeks referred to as *the Wanderers*.

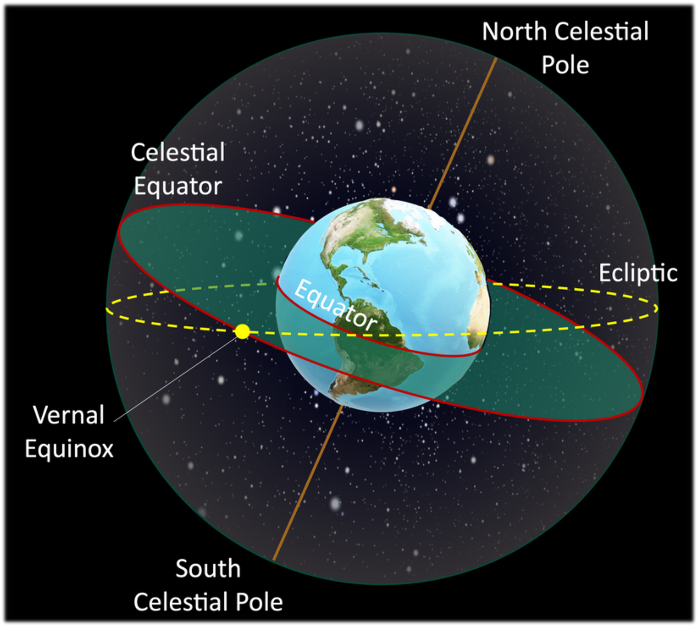

Figure 11. The celestial equator, plane of ecliptic, vernal equinox, and celestial poles in relation to each other. Credit: Author.

The ecliptic, as shown in Figure 11 above, is the plane through the path that the Earth takes around the Sun, and it is a useful reference for other measurements. For instance, the other planets which orbit the Sun have slightly different inclinations to the ecliptic, but (excluding Pluto as a minor planet) the other seven planets have orbital inclinations less than 7° from the ecliptic. You might be curious as to why the orbits of the planets all lie within such a narrow range of each other, and this is simply due to the way that gravitationally-bound material contracts to form disks when they are first forming. The rotation of the planets about the Sun is a 'fossil' record of the gas cloud from which the Solar System condensed 4.5 billion years ago. Due to their narrow range of inclinations about the ecliptic, the planets remain close to the plane of the ecliptic, and so from our perspective on Earth, we observe their motion will also always be close to the path followed by the Sun across the sky. Nevertheless, all the celestial motions that we have considered so far have effectively been due to the motion of the Earth, either its rotation on its axis or its revolution about the Sun. When we consider the motions of the planets, we need to account for an additional effect – the motion of the planet itself. Just like the Earth, all planets orbit the Sun, and so we can again use Kepler's laws to realize that the closer a planet is to the Sun, the faster its average orbital velocity will be.

Inferior Planets

No surprise then that the innermost of the planets, closest to the Sun, is named after the Roman winged messenger of the Gods, *Mercury*, and is often depicted with wings on both his helmet and his shoes to speed his passage across the sky. *Venus*, named after the Roman goddess of love and beauty, is the other planet which sits inside the orbit of the Earth. These two planets are referred to as *inferior* planets, not because they are of less importance, but rather that their orbits are smaller than that of the Earth. However, their inferior positioning introduces an additional observational facet. As illustrated in Figure 12, from our perspective on Earth, there is a maximum distance away from the Sun these planets can attain before they 'turn the corner' on their own orbits and they dive back toward the Sun. The diagram below illustrates the point. Mercury is small and close to the Sun, so is often difficult to spot in the dawn or evening twilight, but Venus, with its highly reflective atmosphere, often shines brightly

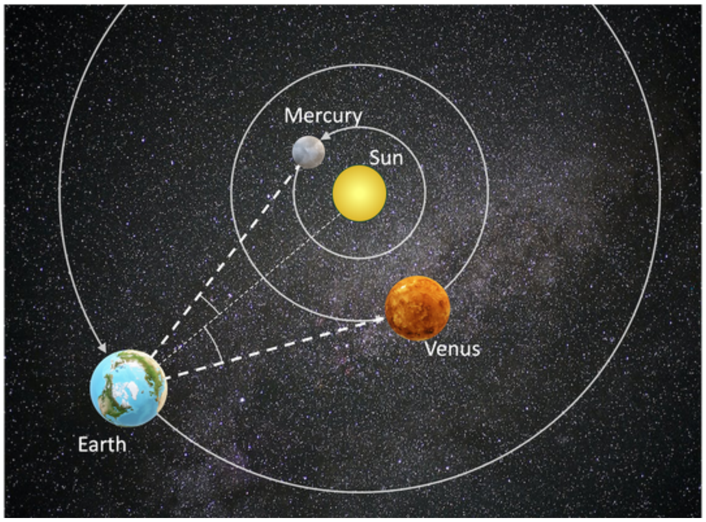

Figure 12. The *inferior* planets are always in attendance with the Sun. Their maximum angular displacement on the sky from the Sun is related to their orbital radius. Credit: Author.

just after the Sun has set or equally as brilliantly in the morning just before the Sun rises, earning it the additional monikers *evening star* (or *evenstar*) and *morning star*.

Superior Planets

For the planets outside of the Earth's orbit, you might think things would be simpler, and to a certain extent you would be right. The *superior* planets are named as such in relation to their larger orbits compared to the Earth, but of the five we now know, four of them are significantly larger than the Earth, so you could be forgiven for thinking they had been named for their size. Unlike the planets inside the Earth's orbit, the superior planets have the potential to be observed throughout the night, depending upon where the planet and Earth happen to be in their orbits. These superior planets, outside the orbit of the Earth, are

- *Mars*, named after the Roman God of War, because of the distinct red hue it shows even to the naked eye

- *Jupiter*, after the Roman King of the Gods, the largest and often the brightest in the night sky
- *Saturn*, after the Roman God of Agriculture
- *Uranus*, after the Greek God of the Sky (discovered in 1781)
- *Neptune*, after the Roman God of the Sea (discovered in 1846)

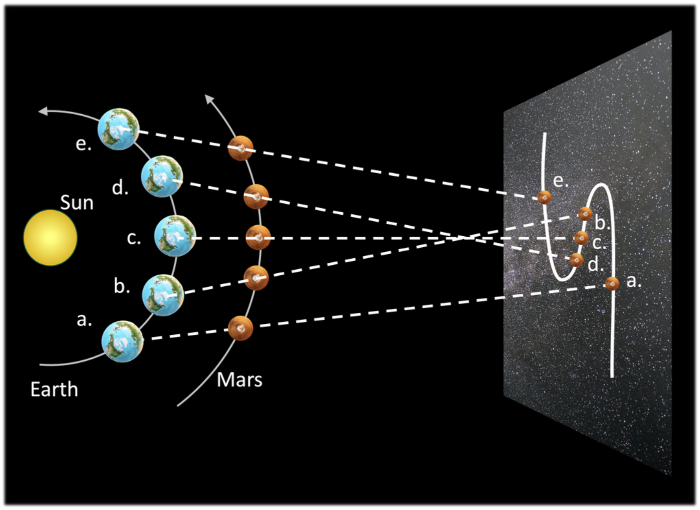

Figure 13. Illustration of the effect of apparent retrograde motion. This is due to the combination of planetary motion and Earth's motion in its orbit. Credit: Author.

As these planets move slower in their orbits than the Earth, when the Earth 'overtakes' the planet on its smaller orbit, we would notice an interesting effect. As shown in Figure 13, Mars, which we would have observed moving in a westerly 'normal' (*direct* or *prograde*) direction with respect to the background stars (point *a*), will suddenly start to move briefly backward (*retrograde*) over a few nights with respect to the fixed stars (points *b*, *c*, and *d*). After a few days it will return to its normal motion in a westerly direction as if nothing untoward had happened (point *e*). It this strange behavior that caused the ancient Greek observers to dub these objects wanderers, as no other visitors to the night sky exhibited this kind of motion. Retrograde motion is also the reason the inclusion of epicycles was required in the models which ancient astronomers created to represent the physical reality of their universe.

The retrograde motion is not limited to the superior planets and is also observed in the inferior planets as well. However, for Mercury and Venus, it occurs when the planet is between the Earth and the Sun, when we see the side of the planet in shadow during the daytime, and therefore is difficult to observe.

The frequency with which the planets show themselves in the night sky is highly dependent on their orbital periods. For example, the fleet-footed Mercury orbits the Sun in about three months, but Venus takes a slightly more sedate 7 ½ months in its orbit. Clearly, the inner planets spend a lot of time close to the glare of the Sun. Mars is interesting, as it takes nearly two years to orbit the Sun, which means that the Earth orbits twice for each single orbit Mars makes. This is the reason we only see Mars in the night sky every other year (Mars oppositions are about 26 months apart). The outer planets are more regular visitors, appearing in the night sky every year, as the Earth's faster orbit allows it to catch up with the more serene pace of Jupiter, Saturn, Uranus, and Neptune, which take about 12, 29, 84, and 165 years, respectively, to orbit the Sun. Interestingly, Neptune only recently (2011) completed its first orbit since its discovery.

The Motion and Phases of the Moon

We could not explore the mechanics of the Solar System and the motion of objects across the celestial sphere without looking into the motion of the Moon, the closest body to the Earth, and along with the Sun, the object which has the greatest effect on us.

Undoubtedly the most noticeable facet of the Moon's journey through the night sky is its changing phases, as shown in Figure 14. The eight named phases of the Moon denote the observable face of the Moon in its different orbital positions, when illuminated by the Sun. The 'new Moon' occurs with the Moon directly between the Earth and the Sun where its illuminated portion is not visible. As it revolves around in its orbit the illuminated portion increases, from a crescent, through a half illuminated first quarter after 7 days, to a bloated 'gibbous', before finally reaching full Moon, when at opposition to the Sun. The two-week period where the illuminated fraction is growing day on day, is referred to as a *waxing* Moon. The cycle continues with the *waning* of the Moon as the illuminated portion reduces over two-weeks to the next new Moon, when the cycle starts again.

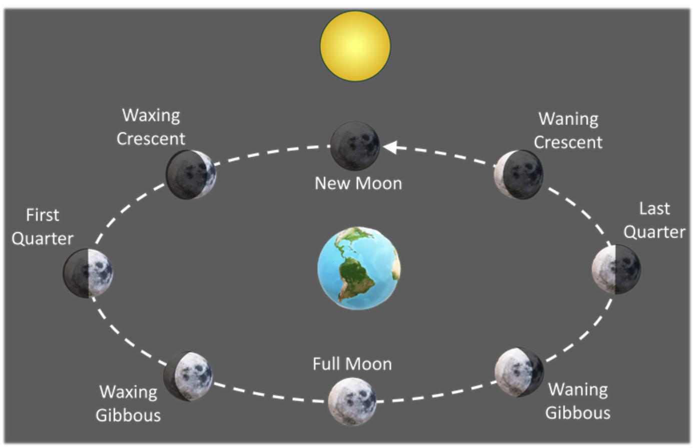

Figure 14. The phases of the Moon due to the changing illumination from the Sun, as the Moon revolves counterclockwise around the Earth. Credit: Author.

Due to the fact that the Moon always presents the same face to the Earth, what we are also observing throughout almost a month it takes the Moon to orbit the Earth is the 'day/night' cycle of the Moon. In other words, the Moon rotates on its axis in the same amount of time it takes to revolve around the Earth. This is not a coincidence, as the Moon is *tidally locked* to the Earth - quite a common occurrence for moons and exoplanets close to their stars. It is also no coincidence that our calendar weeks are seven days, about a quarter cycle of the Moon, and that our months are just over 28 days. As we noted earlier, the Earth moving in its orbit gives us two reference points (the Sun and background stars) and it is no different for the Moon. The Moon's sidereal period (a *sidereal month*) is about 27 days, 8 hours, and is the time it takes the Moon to rotate once on its axis against the fixed background stars. The Moon's *synodic month* is about 29 days, 13 hours, and is the period between consecutive new Moons.

Eclipses

When discussing the phases of the Moon, we mentioned that a new Moon occurs when the Moon is between the Earth and the Sun. A solar eclipse occurs when the shadow of the Moon traverses the face of the Earth and implicitly this is when the Moon is between the Earth and the Sun, so you might be wondering why we don't have an eclipse every month!

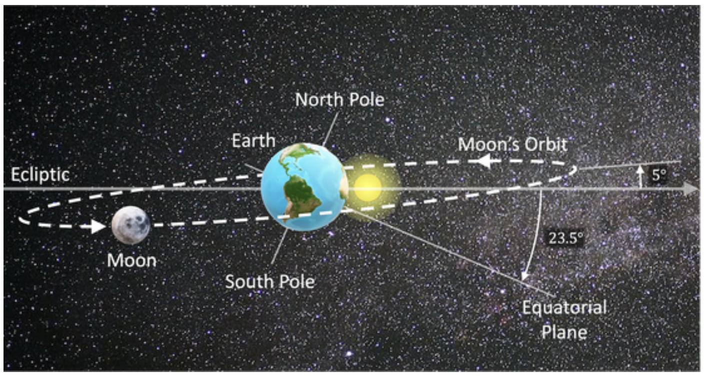

Figure 15. The inclination of the Moon's orbit and Earth's equatorial plane, with respect to the ecliptic, the plane of the Earth's orbit about the Sun. Credit: Author.

As with the planets, the Moon's orbit about the Earth is elliptical. It is also inclined to the ecliptic by 5° as shown in Figure 15. This means there is a very narrow range of circumstances associated with the alignment of the Earth's equatorial plane, the ecliptic plane, the Moon's orbital plane, and the position of the Moon in its orbit required for the alignment of the three bodies to be perfect. The association with the alignment of the equator and ecliptic planes is the reason eclipses are more likely to occur within a few weeks of the equinoxes (March 21st and September 21st), when the Earth's equator crosses the ecliptic (in alignment with the Sun). However, there is also an effect known as *apsis precession* to take into account, where the long axis of the Moon's orbital ellipse rotates with a period of just under nine years, and the upshot of all this is the required combination of alignments is such that eclipses, while entirely predictable, are infrequent events.

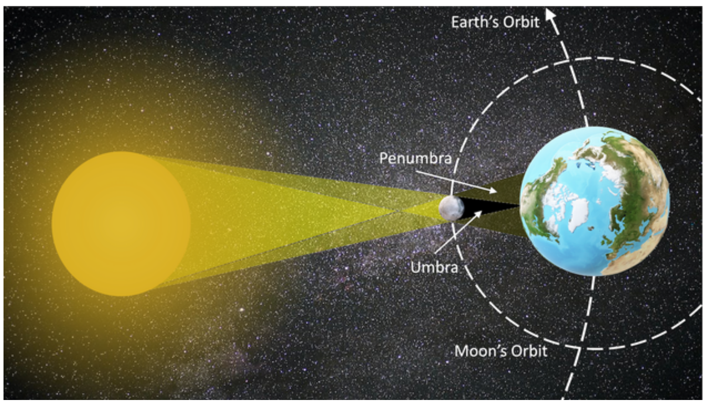

Figure 16. A total solar eclipse occurs when the Moon passes directly between the Earth and the Sun. The *path of totality* is defined by the *umbra*. Areas in the *penumbra* will experience a partial solar eclipse. (Not to scale!) Credit: Author.

Having said that, the USA has been particularly spoiled for eclipses in the last few years, with the total solar eclipse of 2017, the annular eclipse of 2023, and the upcoming total solar eclipse on April 8, 2024.

The eccentricity of the Moon's orbit affects the distance of the Moon from the Earth, and a solar eclipse which occurs when the Moon is at its farthest point is known as an annular eclipse, or a ring of fire, as the Moon's diameter is not big enough to cover the full face of the Sun. This occurred recently (October 14th), with the path of annularity passing through south Texas. Our journey of discovery into the world of celestial motion has taken us to the edge of the Solar System and beyond. We have explored the apparent motion of the stars in the night sky and the Sun in the daytime sky on both a daily and annual basis. We have looked at the meandering path the planets follow, close to the path traced out by the Sun throughout many years. We have also explored the motion of the Moon in its orbit around the Earth and its regularly changing face during its cycle. ★

Biography
Richard Pomeroy, from the United Kingdom, originally trained as an Electronics Engineer, but spent many years both managing teams and developing application software for industries as diverse as defense, telecoms, and finance, most recently as associate director of application systems for the European Bank for Reconstruction and Development. He changed career five years ago, following a lifetime passion for the stars, having completed a bachelors degree in astronomy, and a masters in astrophysics. He is currently an assistant instructor and Physics and Astronomy PhD student at the University of Texas, Rio Grande Valley.

Relaciones internacionales en el espacio

Yazmin Alessandra Castro Adame

La Estación Espacial Internacional es el ejemplo perfecto de las relaciones internacionales en el espacio, es una cooperación internacional que ha unido hasta 15 países que en el pasado estaban en guerra, o tuvieron algunos conflictos políticos y han decidido unirse y construir este increíble proyecto, dejando de lado las diferencias entre ellos, este proyecto tardó más de 20 años en construirse y más de 150 mil millones de dólares en crearse. Tenga en cuenta que ningún país ha hecho una estación espacial por sí solo, ni siquiera los Estados Unidos ni Rusia.

Estos países básicamente dijeron, trabajemos juntos y encontremos una manera de mejorar la humanidad en lugar de destruirnos unos a otros, veamos hasta dónde podemos llegar en el espacio y empujemos nuestros límites, esto va de la mano con el aprendizaje sobre el cuerpo humano y cómo reacciona y cuánto podemos probar en términos de ciencia y tecnología, es sorprendente ver a los representantes de dichos países ver que el espacio tiene el mayor efecto en términos de escala, velocidad y capacidad, y ha creado lo que la humanidad siempre ha prosperado, que es la paz, el avance y la sostenibilidad.

Mientras Vladimir Putin y Joe Biden discutían entre ellos, la NASA y su contraparte rusa (Roscosmos), estaban colaborando en una misión de rescate para tres miembros de la tripulación atrapados en la Estación Espacial Internacional, el astronauta estadounidense Frank Rubio y los cosmonautas Dmitry Petelin y Sergey Prokopyev fueron los que se quedaron atrapados debido a un mal funcionamiento, esto demostró que la humanidad es por encima de todo.

La Estación Espacial Internacional es un proyecto internacional en el que participan muchos países, incluyendo México. México ha contribuido a la Estación Espacial Internacional con su participación en la Agencia Espacial Mexicana, que ha colaborado en proyectos de investigación y tecnología en la estación, es muy importante que México se involucre en este tipo de proyectos para que se desarrolle mas y directa o indirectamente tiene muchos beneficios, y oportunidades, lo podemos ver con Katya Echazarreta la primera mujer mexicana en viajar al espacio.

Este proyecto internacional en el que participan muchos países, y su éxito depende de la colaboración y el trabajo en equipo de todas las naciones participantes. Las relaciones internacionales entre los países participantes son muy importantes para mantener la cooperación y la comunicación necesarias para el éxito del proyecto. Los países trabajan juntos para establecer objetivos comunes, compartir recursos y conocimientos, y colaborar en proyectos de investigación y tecnología. En general, las relaciones internacionales han sido muy importantes para el éxito de este proyecto.

En resumen, la EEI es un logro impresionante de la humanidad y es un ejemplo de lo que podemos lograr cuando trabajamos juntos. La estación ha sido utilizada para llevar a cabo investigaciones y ha permitido a los astronautas vivir y trabajar en el espacio durante largos períodos de tiempo. ★

Biografía

Mi nombre es Yazmin Alessandra Castro Adame y tengo 17 años. Soy de Matamoros, Tamaulipas, en México. Actualmente, soy estudiante en Saint George Prep School. Además de enfocarme en mi educación, disfruto de jugar vóleibol.

Spectrophotometry: An Intersection of Planetary Motion and Starlight

Andrew Maurer

The movement of celestial bodies has been significant throughout human history. From agriculture, to navigation, and even to spiritual significance, how the stars move and align give us insight into the larger mechanisms of how the universe functions. As humanity's ability to peer clearer and further out into the cosmos improves, a deeper understanding of these mechanisms has coincided. This expanding knowledge has also fed humanity's innate creativity and curiosity. The concept of exotic lifeforms living on alien worlds has existed since antiquity across numerous cultures, but it has been especially vivid since the discovery of other planets in our Solar System and beyond. Today, astronomers estimate the number of stars in the Milky Way galaxy alone to be in the billions, with each star estimated to have at least one exoplanet in its orbit [3, 15]. Through careful observation of starlight, astronomers can detect the presence of exoplanets. Moreover, the same observations may reveal the atmospheric composition of those exoplanets and possible biosignatures such as oxygen, ozone, and other products from biologically relevant redox reactions [4, 14]. This is possible through spectrophotometric analysis of electromagnetic radiation as an exoplanet transits its host star through the transit method or direct observation of the exoplanet itself.

Exoplanet detection is primarily indirect. Through observations in fluctuations of starlight frequency and luminosity, astronomers can infer the presence of an exoplanet. The methods most associated with these parameters are the radial velocity and transit methods. Radial velocity detections occur when the frequency of starlight periodically shifts into higher and lower wavelengths, otherwise known as blueshifts and redshifts, respectively. Periodic shifts occur when the target star wobbles toward and away from Earth because of the presence of an orbiting mass. Though not with light, we experience this phenomenon whenever an ambulance approaches and subsequently leaves; the pitch of the siren gets higher on approach and then lowers as it leaves. This phenomenon is an example of a Doppler shift, the same physical mechanism that radial velocity operates upon to find potential exoplanets. The intensity of the redshift and blueshift directly corresponds to the mass of the orbiting body or bodies.

The Transit, or Transit Photometry, method is when an observed exoplanet transits its parent star, lowering the luminosity, or brightness, of the star for a fixed interval. From the change in luminosity, astronomers can determine the diameter of the potential exoplanet [9, 10]. In combination with radial velocity data, the mass and diameter determine the density of the potential exoplanet:

$$\text{density} = \text{mass} \div \text{volume}$$
$$\text{volume} = (4 \div 3) \times \pi \times (\text{diameter} \div 2)^3$$

The density of the exoplanet is a cornerstone datapoint for identifying Earth-like exoplanets. The first observed exoplanet by the transit method is HD 209458 b, a gas giant that orbits the star HD 209458 in the Pegasus constellation [7]. Although originally discovered through the radial velocity method, the nature of HD 209458 b's transit was fundamental to how astronomers would later gain insight into the atmospheric composition of exoplanets. HD 209458 b orbits so close to its parent star that its atmosphere evaporates, like how a comet leaves a trail due to evaporation and sublimation of its surface. Thus, astronomers were able to deploy spectrophotometric analysis via the Hubble Space Telescope to determine the gas composition trailing the exoplanet; the primary element detected was hydrogen gas [7]. Although most exoplanet transit detections do not include such a dramatic display, this event marked an important complement between transit photometry and spectroscopy.

A general definition of spectroscopy is the study of how different matter interacts with different frequencies of electromagnetic radiation. The specificity of the matter ranges from pure elemental forms to complex mixtures of molecules, and the entire electromagnetic spectrum is implemented depending on what characteristic the scientist wants to research. For example, at frequencies of visible light, material will absorb most of the radiation and emit some electrons at an elevated energy level, corresponding to a specific frequency [11]. Take light from a light bulb and focus it through a prism, or a spectrometer, and one would observe the entire spectrum of visible light as a rainbow. Now, take an element like hydrogen gas, heat it to the point of the gas glowing or run an electric current through the gas, and then observe the subsequent light with a spectrometer. One would not observe the entire rainbow, but rather certain frequencies of light as columns of distinct colors, and those columns being of a certain width and brightness. Those columns are called emission lines [11]. Its inverse is an absorption line spectrum, a continuous spectrum that has dark columns at certain frequencies and with certain widths of darkness [11].

Emission and absorption lines are like fingerprints for people – each element has a unique set of lines that is crucial in the analysis of exoplanet atmospheric composition [11]. Therefore, potential biosignatures like oxygen and ozone will have predictable spectra on exoplanets whose atmospheres are Earth-like in composition. This principle expands into other frequencies of electromagnetic radiation, especially into relevant frequencies for atmospheric analysis like visible light and infrared frequencies. That said, not all elements have emission lines at all frequencies, emission line strength depends on the abundance of the element present, and the presence of other elements and compounds will add complexity to the final spectrum. Thus, it is important to be aware of which compounds or elements may or may not present themselves spectrographically due to the frequencies of radiation being collected. Biosignature detection is dependent upon the electromagnetic radiation originating from the exoplanet, and that presents a unique challenge, considering its host star is billions of times brighter than the exoplanet. How do astronomers ensure they are collecting data about the exoplanet, not its host star? The answer is partially inspired by another type of transit, an eclipse, and a clever inference about transiting orbital bodies.

Invented by French astronomer Bernard Lyot in 1939, the coronagraph is an apparatus that blocks the bulk of starlight through a shade or filter in the center of a telescope, while allowing light to enter from peripheral sources mostly undisturbed, as shown in Figure 1 [12, 16]. The purpose of this instrument is to reveal the corona, the outermost layer of a star's atmosphere, under normal conditions. Otherwise, an astronomer would have to wait until the next total solar eclipse to study the corona of the nearest star, the Sun. In conjunction with other filters like the Lyot stop, adaptive optics, and computer programs, the coronagraph has been deployed to not only reveal the coronae of stars, but to directly detect light from exoplanets in both ground and space telescope observations. This is possible through the same mechanisms that allow observation of the Sun's corona under normal conditions. The coronagraph is crucial for future direct imaging of exoplanets for further spectrophotometric analysis because it ensures the incoming radiation analyzed is from the exoplanet with a high level of confidence.

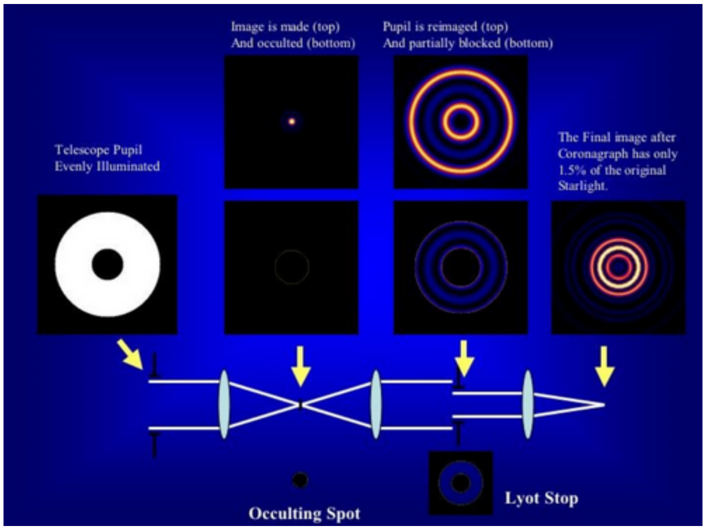

Figure 1. A simplified diagram of a coronagraph, adapted from Sivaramakrishnan et al. (2001). Credit: Ben R. Oppenheimer (2003).

Direct imaging of an exoplanet has occurred only a few times so far, primarily through near-infrared imaging on space telescopes like the Hubble and Spitzer Space Telescopes. In 2004, a team at the Very Large Telescope (VLT) in the Atacama Desert in Chile is credited for imaging the first exoplanet, 2M1207 b, orbiting its parent star through near-infrared observation as shown in Figure 2 [1]. Coincidentally, this event also marks the first time an exoplanet is found in-orbit around a brown dwarf [1]. Though ideal, the direct observation of an exoplanet is currently tedious and uncertain, and this is doubly true for an accurate spectrophotometric evaluation of its atmosphere. This is where the transit method can be redeployed.

As mentioned prior, the observation of HD 209458 b's transit involves the evaporation of its atmosphere, but that is not the only way astronomers deciphered its atmospheric composition. The star HD 209458 has been the subject of extensive observation, so information about the star like luminosity and chemical makeup was established prior. If the astronomer knows the spectrum of the star that the exoplanet transits, the atmospheric composition of the exoplanet can be inferred through the difference in spectra as the exoplanet transits the observational path, both directly in front and directly behind the star. Not only has the Hubble Space Telescope been deployed for such observations, but the Spitzer Space Telescope has also observed HD 209458 b's transit, collecting more information about the exoplanet's temperature, and further refining the chemical composition of its upper atmosphere [5, 8]. The Spitzer Space Telescope observation of HD 209458 b was the first to directly observe an exoplanet itself spectrophotometrically, a feat that continues to be accomplished through technological advancements in telescope instrumentation and computational power [5].

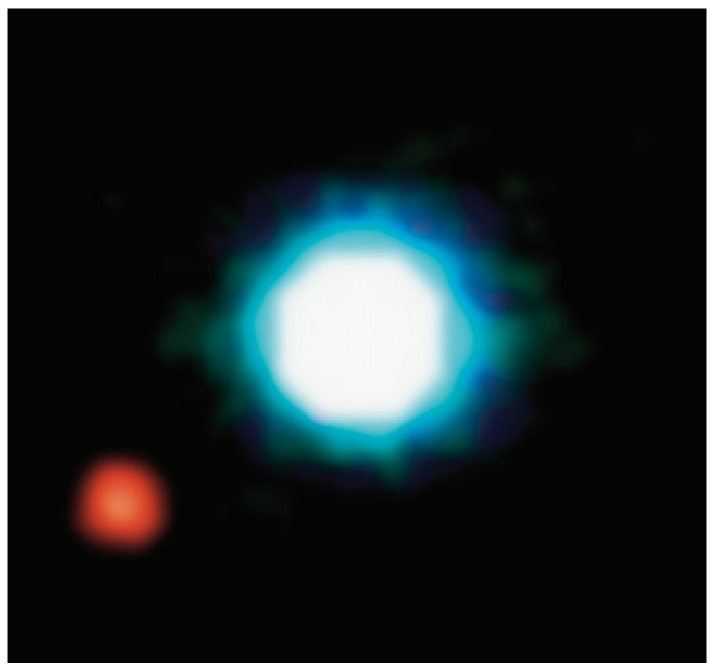

Figure 2. The composite image of exoplanet 2M1207 b (lower left red spot), orbiting around its parent star (center), the first sighting of an exoplanet in-orbit around a brown dwarf star. Credit: ESO.

Observing orbiting exoplanets and the subsequent change of starlight hints at the exoplanet's nature. Through transit photometry and direct imaging, astronomers can deploy spectrophotometry to identify the chemical composition of the exoplanet's atmosphere with the possibility of detecting a biosignature such as oxygen or ozone. These unprecedented observations have first occurred within the past two decades; exoplanet analysis is a nascent field with massive potential for growth and refinement. Growth has taken the forms of solely observational missions for exoplanet detection and in the number of detected exoplanets. NASA's Transiting Exoplanet Survey Satellite (TESS) and James Webb Space Telescope are currently active and continue the legacy established by missions like Hubble, Spitzer, and Kepler. The Nancy Grace Roman Space Telescope will participate in conjunction with TESS by the end of this decade, and whose function takes full advantage of how transits reveal the nature of the very celestial bodies passing by through transit, direct imaging, and microlensing methods for exoplanet detection and follow up analysis [13]. The number of confirmed exoplanets is currently about 5000 and will only continue to rise.

Refinement comes in-tandem with growth through improvements in exoplanet detection and in establishing consistent spectra for both stars and exoplanets for further analysis. In addition to more transit detections, other methods are being developed and used like microlensing and astrometry to increase the pool of detected exoplanets for future research candidates. Just like with radial velocity and transit photometry detection methods, microlensing and astrometry use the movement of stars and exoplanets within the observer's line of sight to glean information about the moving celestial body. Although these advancements are exciting, a diagnostic model that accurately determines the atmospheric composition of alien worlds, let alone whether one has a biosignature present, is far from truly realized. Spectrophotometric inferences ideally would be followed up with concrete observations, but that is truly a herculean task considering the many light years these targets tend to be. And so, the best astronomers can do in the present is compile and refine more information about target exoplanets through painstaking observation and finding more Earth-like exoplanets. Though with the progress seen within the past two decades is any indication, the sky's the limit. Although, in this case, the possibilities go well beyond our own atmosphere. ★

Biography

Andrew Maurer is a graduate of the University of Pittsburgh, where he received a bachelor of science in biology in 2016. He has keen interests and future goals of research in paleobiology, genetics, and zoology. Andrew currently works with the clinical molecular laboratory at MicroGen DX, and has previous clinical experience in the veterinary field.

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Culturas prehispánicas mexicanas: Su cosmovisión y el paso del tiempo

Daniela González

Nos encontramos en una era donde hay descubrimientos, avances e inventos en la ciencia y tecnología de manera gigantesca, esto a partir de nuestro punto de vista y obviamente de científicos que cada día se dedican a encontrar soluciones para nuestra vida cotidiana. A menudo, olvidamos que, aunque, necesitamos resolver estos problemas de forma práctica y rápida, también debemos saciar nuestra curiosidad de ver más allá de lo que se encuentra en el planeta tierra.

Desde el norte y centro del continente americano, entre los años 2500 a.C. Hasta el año 1521, los antepasados mexicanos tenían una inmensa curiosidad sobre el cosmos y como este tenía reglas específicas para moverse: ciclos e intervalos de tiempo. Esto le otorgó a las culturas prehispánicas una herramienta de suma importancia para saber en qué épocas del año podrían hacer actividades como cazar y cosechar alimentos.

Con el paso del tiempo estos individuos pudieron darse cuenta de que la relación del periodo de luz (día) y periodo de oscuridad (noche) tenían que ver con el astro más cercano, que es el sol, aunque también para ellos sería una interpretación de un ente superior, no le quita mérito que con el tiempo fueran desarrollando modelos de calendarios astronómicos que incluyeran el año, además de su relación con el cambio de clima y movimiento de especies alrededor del globo.

Desde la época de las culturas prehispánicas, la conquista y la historia moderna se ha transmitido el conocimiento de manera que, al día de hoy, seguimos recordando la cosmovisión de aquellos antepasados. "En el centro de México, en el momento de la conquista española, se realizaba la cuenta del año solar de 365 días, dividido en 18 veintenas más 5 días (*xiuhpohualli*). Ésta se combinaba con un ciclo ritual de 260 días compuesto por 13 veintenas (*tonalpohualli*). Los elementos de este sistema calendárico implican un conocimiento exacto del año solar, así como de los ciclos de Venus y de las Pléyades."

El conocimiento que actualmente se tiene del uso de la astronomía para la observación de movimientos celestes en las épocas antiguas, se obtuvo principalmente de la investigación arqueológica. Además, que es importante mencionar que, en su mayoría, las estructuras construidas en ese periodo estaban relacionadas con posiciones de los astros y actualmente se puede notar esto en lo que son sus ruinas o puntos de turismo, como es el caso de las pirámides de Chichén Itzá que su orientación está dirigida a la trayectoria de venus.

Finalmente, podemos tener en cuenta que el punto de vista desde la astronomía de nuestros ancestros está presente en todos los avances que, como humanidad hemos logrado, a partir de que sabemos cómo está constituida la dinámica universal de los astros y del desarrollo del calendario por consiguiente de las culturas prehispánicas mexicanas. ★

Biografía

Daniela es una chica de 20 años, originaria del estado de Aguascalientes, que busca incursionar en el ámbito aeroespacial y la física.

Consultas

SCrónicas, *Los astros y los fenómenos celestes*, Portal UNAM, Ciudad de México, EU.: Toda la UNAM en línea (2018)
https://blogs.acatlan.unam.mx/scronicas/2016/09/06/los-astros-y-los-fenomenos-celestes-i/

Orion the Hunter

An Updated Myth Retold by Carol Lee

My story begins long ago, during the beginning of time, when people on the Earth were trying to learn about the place they lived and called home. There was so much to learn and to think about, and children were always asking "Why" about everything, exactly like you do today, but there was no internet to search for answers then, only wise people who thought a lot about the "Why" of things.

In those days people believed there were many unseen beings they called gods and goddesses who made things happen. They had fire gods, river gods, elephant gods, sun gods, and a few females tossed in as goddesses to keep things fair and balanced.

One of their most important gods was the one they called Apollo who lived in a faraway place they called Mount Olympus with his sister, Diana. Apollo had a very important job that no one else could do. He drove the chariot of the Sun across the sky each day, traveling across the sky from east to west, bringing daylight, warmth, and cheer. His sister drove the chariot of the Moon across the sky following her brother's chariot at a safe distance so the chariot would not catch fire and fall out of the sky. Diana enjoyed hunting and running races when she was not busy driving her Moon chariot across the sky and fate had some interesting things about to happen because of this.

During this time, there were people living along the shores of ancient Greece and Italy who made their livings by fishing or farming. It was important to them that the Sun and Moon kept to their regular traveling schedules across the sky because that controlled the tides for the fishermen and the times for the farmers to plant their seeds in the spring and then to harvest their crops in the fall.

Each day the parents would work hard either in the house or fields, or out on the sea and river fishing. At night everyone would gather together to eat fish and bread, have a little olive oil for dipping the bread into for a delicious treat, and talk about the day's work and plan for tomorrow's tasks.

Sometimes a bold and bragging young man named Orion the Hunter would join different families for supper around the fire. Then it was extra exciting. Orion was a great hunter and he went all over with his two large dogs hunting wild goats, antelope, wild boars, deer, and any other animals that were tasty. After a successful hunt Orion would visit the nearest village and share his bounty with the folks of the village. There was always a party when Orion came. The mothers spent the late afternoon cooking while the men sat around the campfire telling hunting stories and making up tall tales. The children loved this special time and listened as the talk flowed around them of monsters, battles, adventures, and more. Everything was going well until...

One day Orion was stalking a deer in the woods. At the same time Diana had finished her trip taking the Moon through the sky. Diana had driven her chariot down to the Earth to go hunting. And she just happened to be hunting the same deer that Orion was. Each of them, unknown to the other, saw a chance to get the deer and took an arrow out of their quivers, nocked an arrow into the bowstring, pulled back the string and *whang*...out flew two arrows in opposite directions that hit that deer in each side. Dinner would soon be taken to the village thought Orion. And Diana was thinking her brother was going to enjoy venison on the table at Mount Olympus that night.

As each of them approached the deer they realized brother's request. Orion was left behind to remember all the pleasant dreams and plans he and Diana had been sharing.

Early the next morning, Apollo took the Sun chariot across the sky very fast and very low which made the day exceedingly hot which made Orion decide to take his dogs and go swimming while waiting for Diana to return.

When Apollo saw Orion in the sea he hurried home and called Diana to bring her bow and a few arrows and show him a private archery exhibition before the guests arrived. When Diana was ready Apollo said, "See that blockhead, I mean, that block of wood floating down there? Let's see if you can hit it."

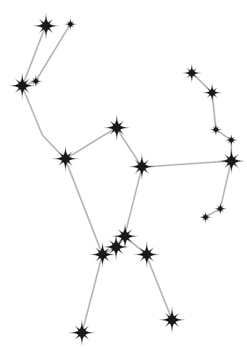
Now Diana was nearsighted which means she had a hard time seeing things that were far away. No one had invented glasses yet, so Diana didn't know that was Orion down there, not a block of wood. She put an arrow in the bowstring, pulled back with all the strength of her young arms, and let that arrow fly! *Smack!* It went right into Orion's chest, killing him instantly.

Seeing her success, Apollo shrugged and said she could go on back down to Earth and continue her hunting. Filled with excitement, Diana headed back down to tell Orion about the great shot she had made.

When she got to the place where they usually met she called, "Orion. Orionnn. Orriiionnn." But there was no answering call. She did hear his dogs barking so she followed her ears until she reached the beach. There were the dogs barking and jumping around a dark lump on the shore. As she ran closer, Diana realized it was her sweetheart on the beach. She fell into the sand sobbing as though her heart would break. Her cries brought her brother Apollo to see what was going on.

He was filled with regret for what he had done, but he did not have power over life and death on Earth. He carefully lifted Orion's body and placed it in his chariot of the Sun. Then he called the two faithful dogs to jump in as well. Apollo took Orion and the dogs into the sky and set them just above the path Diana would take when she traveled across the sky. And from that day to this you can see Diana happily visiting her sweetheart Orion each winter night in the sky.

And that is the end of my story. ★

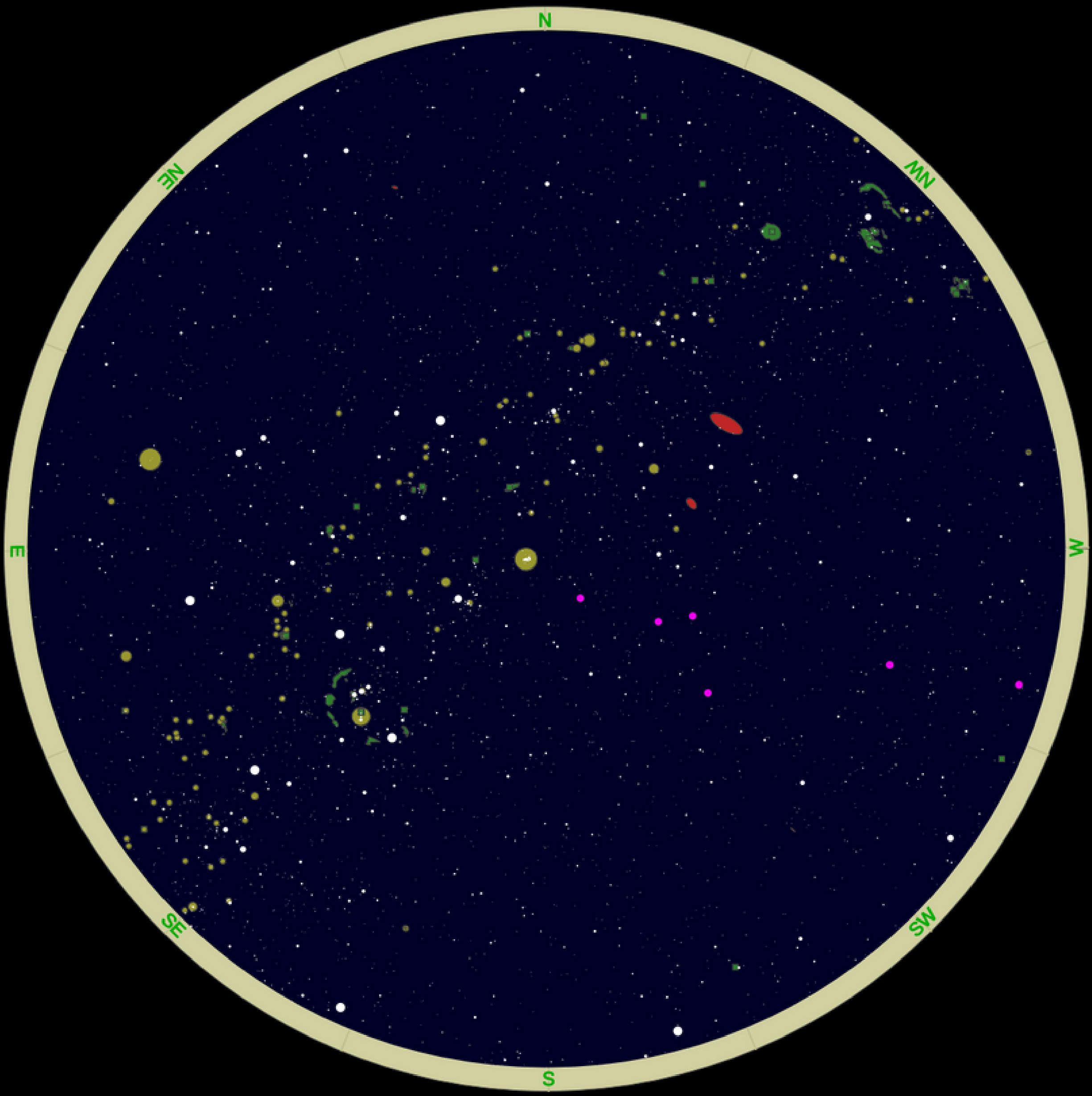


Biography

Carol Lutsinger is the founder of the South Texas Astronomical Society. She spent 40 years as a teacher, serving students from Pre-K through college. Carol attributes her astronomy enthusiasm in part to her experience in the American Astronomical Society's AASTRA program from 1994-96, and her space excitement from serving as a Solar System Educator, and later Ambassador, for the NASA/JPL program. She has been writing the Stargazer newspaper column since 1998, which is carried in the Brownsville Herald and the Valley Morning Star. Retired from formal education since 2020, she still makes every opportunity to share meteorites which she carries in her purse and to ask folks in parking lots if they know what that point of light is.

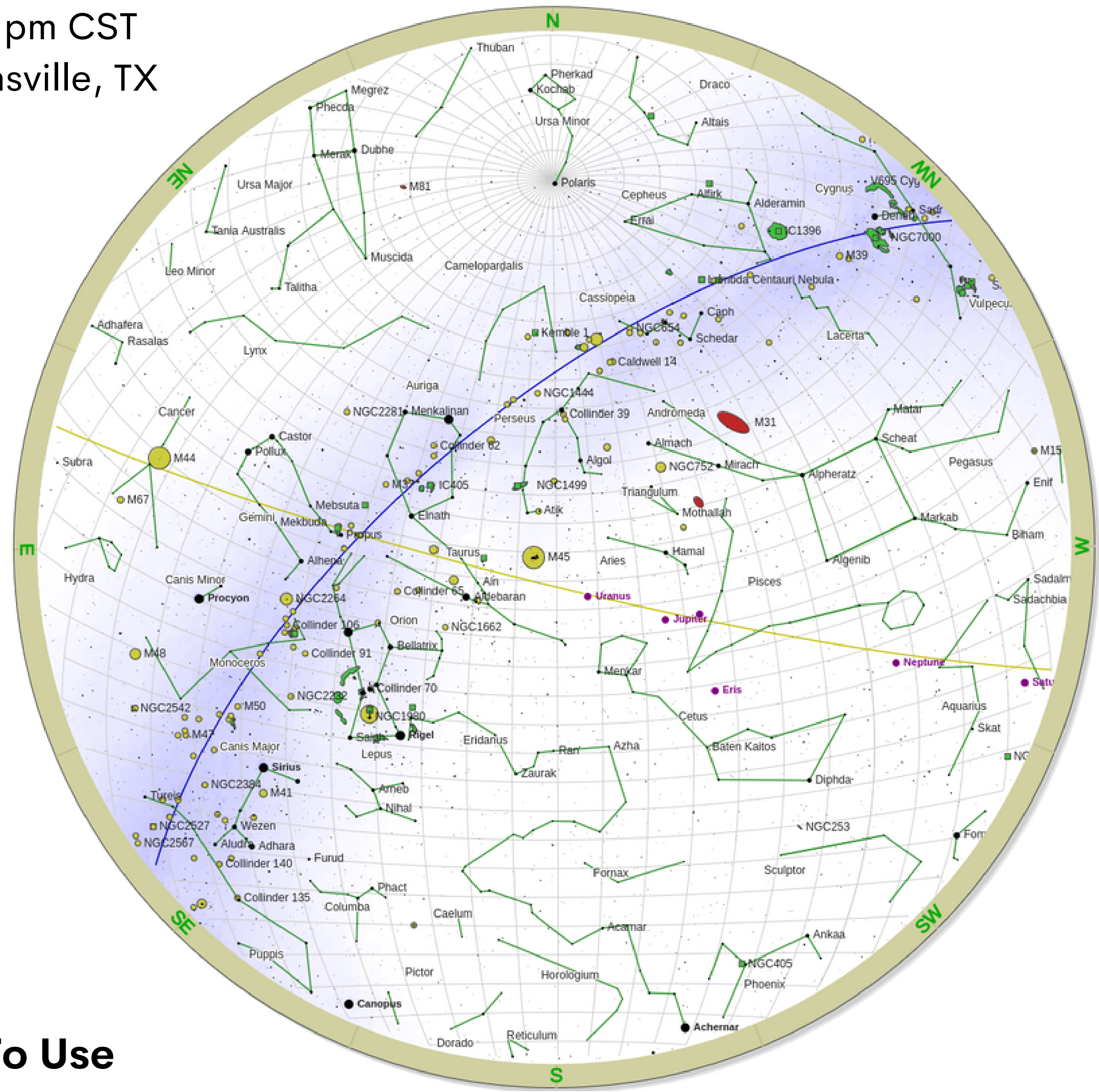
Cosmic Coordinates

Winter 2023-2024



Sky Map

21 December 2023
10:00 pm CST
Brownsville, TX



How To Use

Here is your own guide for celestial navigation: your very own sky map, allowing you to select and observe the finest of cosmic objects. If you find yourself within the Rio Grande Valley, this map will be accurate to help you along your celestial journey. Good luck, and clear skies! [Credit: Dominic Ford, In-The-Sky.org]

Sky Map Legend

- The Equator
- Ecliptic Plane
- Galactic Plane
- Galaxy
- Bright nebula
- Open cluster
- Globular cluster

Sky Events

Fall 2023

Appulses

Dec 09, Moon and Venus
Dec 17, Moon and Saturn
Dec 22, Moon and Jupiter
Dec 24, Moon and M45

Jan 14, Moon and Saturn
Jan 18, Moon and Jupiter
Jan 20, Moon and M45
Jan 27, Mercury and Mars

Feb 15, Moon and Jupiter
Feb 16, Moon and M45
Feb 22, Venus and Mars

Apsides

Dec 20, Mercury at Perihelion
Dec 25, 62P/Tsuchinshan at Perihelion

Jan 02, Earth at Perihelion

Feb 02, Mercury at Aphelion
Feb 14, C/2021 S3 (PANSTARRS) at Perihelion

Conjunctions

Dec 09, Moon and Venus
Dec 13, Moon and Mercury
Dec 17, Moon and Saturn
Dec 22, Moon and Jupiter
Dec 22, Mercury at Inferior Solar Conjunction

Jan 08, Moon and Venus
Jan 09, Moon and Mercury
Jan 10, Moon and Mars
Jan 14, Moon and Saturn
Jan 16, Venus and Ceres
Jan 18, Moon and Jupiter
Jan 20, Pluto at Solar Conjunction
Jan 27, Mercury and Mars

Feb 05, Mercury and Pluto
Feb 07, Moon and Venus
Feb 08, Moon and Mars
Feb 08, Moon and Mercury
Feb 10, Moon and Saturn
Feb 15, Mars and Pluto
Feb 15, Moon and Jupiter
Feb 17, Venus and Pluto
Feb 22, Venus and Mars
Feb 28, Saturn at Solar Conjunction
Feb 28, Mercury at Superior Solar Conjunction

Dichotomies

Dec 08, Mercury

Jan 07, Mercury

Earth

Dec 21, December Solstice

Elongations

Dec 04, Mercury at Greatest Eastern Elongation
Dec 07, Mercury at Highest Evening Altitude

Jan 09, Mercury at Highest Morning Altitude
Jan 12, Mercury at Greatest Western Elongation

Moon

Dec 04, Last Quarter
Dec 12, New Moon
Dec 19, First Quarter
Dec 26, Full Moon

Jan 03, Last Quarter
Jan 11, New Moon
Jan 17, First Quarter
Jan 25, Full Moon

Feb 02, Last Quarter

Feb 09, New Moon
Feb 16, First Quarter
Feb 24, Full Moon

Occlusions

Dec 19, Neptune
Dec 25, Elnath (Beta Tauri)

Jan 08, Antares (Alpha Scorpii)
Jan 15, Neptune
Jan 22, Elnath (Beta Tauri)

Feb 04, Antares (Alpha Scorpii)
Feb 12, Neptune
Feb 18, Elnath (Beta Tauri)

Oppositions

Dec 21, 4 Vesta
Dec 22, 9 Metis
Dec 27, 5 Astraea

Jan 19, 354 Eleonora

Retrogrades

Dec 06, Neptune Ends Retrograde
Dec 30, Jupiter Ends Retrograde

Jan 27, Uranus Ends Retrograde

Definitions

Appulse – the minimum apparent separation in the sky of two astronomical objects.

Apsis – the farthest (*apoapsis*) or nearest (*periapsis*) an orbiting body gets to the primary body. Plural is *apsides*. Special terms are used for specific systems: *aphelion* and *perihelion* are used for any object with respect to the Sun; *apogee* and *perigee* are used for any object with respect to the Earth.

Conjunction – when two astronomical objects or spacecraft share the same right ascension or ecliptic longitude as observed from Earth. For superior planets, conjunction occurs when the planet passes behind the Sun (also called *solar conjunction*). For inferior planets, if the planet is passing in front of the Sun, it is called *inferior conjunction*; if behind, it is called *superior conjunction*. Solar conjunctions are the most difficult periods to view a planet with a telescope.

Dichotomy – the phase of the Moon, or an inferior planet, in which half its disk appears illuminated.

Elongation – the angular separation on the sky between a planet and the Sun with respect to the Earth. When an inferior planet is visible in the sky after sunset, it is near its *greatest eastern elongation*. When an inferior planet is visible in the sky before sunrise, it is near its *greatest western elongation*.

Occlusion – when one astronomical object passes in front of the other. An *occultation* is when the foreground object completely blocks the background object. A *transit* is when the background object is not fully concealed by the foreground object. An *eclipse* is any occlusion that casts a shadow onto the observer.

Opposition – when two astronomical objects are on opposite sides of the celestial sphere. Opposition only occurs for superior planets and objects. Solar opposition is the best time to view a planet with a telescope.

Retrograde – when a planet reverses its direction of motion on the sky. A planet entering retrograde motion is an apparent phenomenon caused by the relative motion between the Earth and the object (like a slower car appearing to move backward on a highway as you overtake it).

Light Pollution has GLOBAL IMPACTS

Light emissions from the continents represents **246,238** gigawatt-hours of energy

Representing 1% of global emissions, or the equivalent of

38 MILLION vehicle miles

80 ROUNDTRIPS from Earth to the Moon

Source: Alejandro Sanchez de Miguel, University of Exeter, 2021
https://doi.org/10.3390/rs13163311

International Dark-Sky Association
www.DarkSky.org

Light Pollution drives CLIMATE CHANGE

U.S. outdoor lighting creates about **228 MILLION** metric tons of CO_2 emissions every year

Which is the same as **49 MILLION** passenger vehicles driven for a year

And would take **3.8 BILLION** tree seedlings growing 10 years to offset

Source: U.S. Environmental Protection Agency, GHG Equivalencies Calculator
https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results

International Dark-Sky Association
www.DarkSky.org

This Winter 2023, we present to you…

COSMIC COMEDY

(Don't space out on our jokes… you know they're absolutely stellar.)

COSMIC COMEDY

Winter 2023

Protons have mass?
I didn't know they were catholic!

A man walks into a library, and says to the Librarian, "I'm looking for a book that's been recommended to me... It's about Pavlov's Dogs and Schrödinger's Cat... Do you know it?"

The Librarian answers, "Well, that rings a bell, but I'm not sure if it's here or not".

How come the space mafia never come to Earth?

We're all making too much smoke.

-Matthew Swaykus

Space Rangers

Winter 2023

🚀 Welcome Space Rangers! 🚀

Time to use your creative skills and put them to the test!
We hope you enjoy our featured coloring page, word search, some fantastic eclipse artwork!
Your adventure awaits!

Exciting contents include:

1. Coloring
2. Word Scramble
3. Word Search
4. Crossword Puzzle
5. Artwork

Space Rangers Word Scramble

1. LNEIHOAP		The point in the orbit of a celestial body, such as a planet or a comet, where it is farthest from the Sun
2. ENTIOALCNLTSO		A group of stars that form a recognizable pattern or shape in the sky
3. UONTNTAI		A small, irregular motion in the Earth's axis of rotation.
4. LTNPAE		A is a celestial body that orbits around a star, is spherical in shape, and has cleared its orbit of other debris
5. CEOSRPESIN		The slow, circular motion of the Earth's axis of rotation.
6. OTERARERGD		The apparent backward motion of a planet in its orbit as observed from Earth
7. ADELSRIE AYD		The time it takes for a planet or any celestial body to complete one full rotation on its axis relative to the stars.
8. RVAEOPUSEN		Powerful and explosive events that occur at the end of a star's life cycle
9. CNSDYOI IRPEDO		The time it takes for a planet to return to the same position relative to the Sun and Earth
10. ENTTNASRI		A celestial object or event that appears suddenly and then disappears or changes over a relatively short period of time

Space Rangers Word Search

R	E	L	P	E	K	M	N	B	A	V	C
X	A	Z	L	K	J	H	D	G	R	F	D
E	A	T	S	A	P	O	I	I	C	S	U
X	S	Y	S	T	R	E	L	W	S	U	Q
P	T	M	N	S	B	V	C	C	E	P	X
A	R	Z	L	K	D	J	U	H	C	E	G
N	O	I	T	O	M	R	E	P	O	R	P
S	M	F	D	S	A	P	A	O	N	N	I
I	E	U	G	A	I	A	Y	N	D	O	T
O	T	R	E	W	Q	M	N	B	R	V	V
N	R	C	X	X	A	L	L	A	R	A	P
Z	Y	T	I	D	A	L	T	A	I	L	B

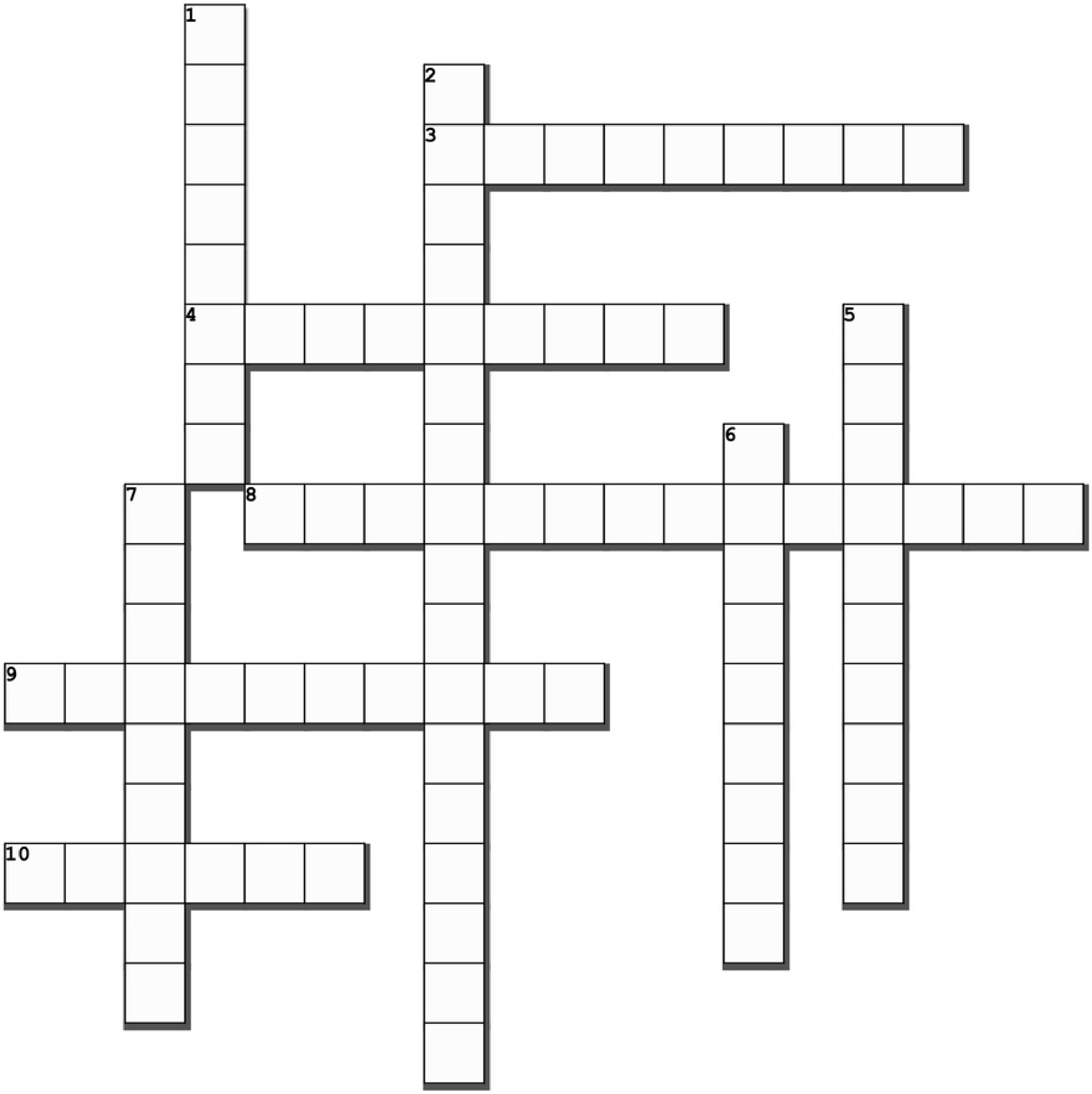
Use your space exploration skills to search for terms about the movement of celestial bodies in the night sky!

Space Rangers Word Search
Solutions

R	E	L	P	E	K				A		
	A						D		R		
E	A	T					I		C	S	
X	S		S				L		S	U	
P	T			S			C		E	P	
A	R				D		U		C	E	
N	O	I	T	O	M	R	E	P	O	R	P
S	M						A		N	N	
I	E		G	A	I	A		N	D	O	
O	T								R	V	
N	R			X	A	L	L	A	R	A	P
	Y	T	I	D	A	L	T	A	I	L	B

(1) ASTROMETRY – study of the position and movement of celestial bodies
(2) GAIA – a spacecraft tasked with tracking the motion of the stars in the Milky Way
(3) PROPER MOTION – when a star moves sideways across the sky
(4) ARC SECOND – unit of measurement used in astronomy
(5) PARALLAX – a method astronomers use to measure the distance between stars
(6) BARNARD'S STAR – known to be a fast-moving star
(7) EXPANSION – said to be happening to the universe
(8) EUCLID – new space telescope able to capture images of galaxies billions of light years away
(9) TIDAL TAIL – a trail of stars
(10) SUPERNOVA – explosion of a star at the end of its life cycle
(11) KEPLER – 17th-century astronomer famous for the three laws of planetary motion

Space Rangers Crossword



Across

3. A complete lighting unit that usually includes the light source, the electrical driver for the source, the optical reflector

4. An optic that achieves control of light by means of refraction using lenses

8. The portion of the electromagnetic spectrum that is visible to the human eye, i.e., from about 380 nm to about 760 nm

9. The measurement of light

10. The components of a luminaire, such as reflectors and refractors, that make up the light emitting section

Down

1. A unit of wavelength often used in astronomy, equal to 10-10 meter or 0.1 nanometer

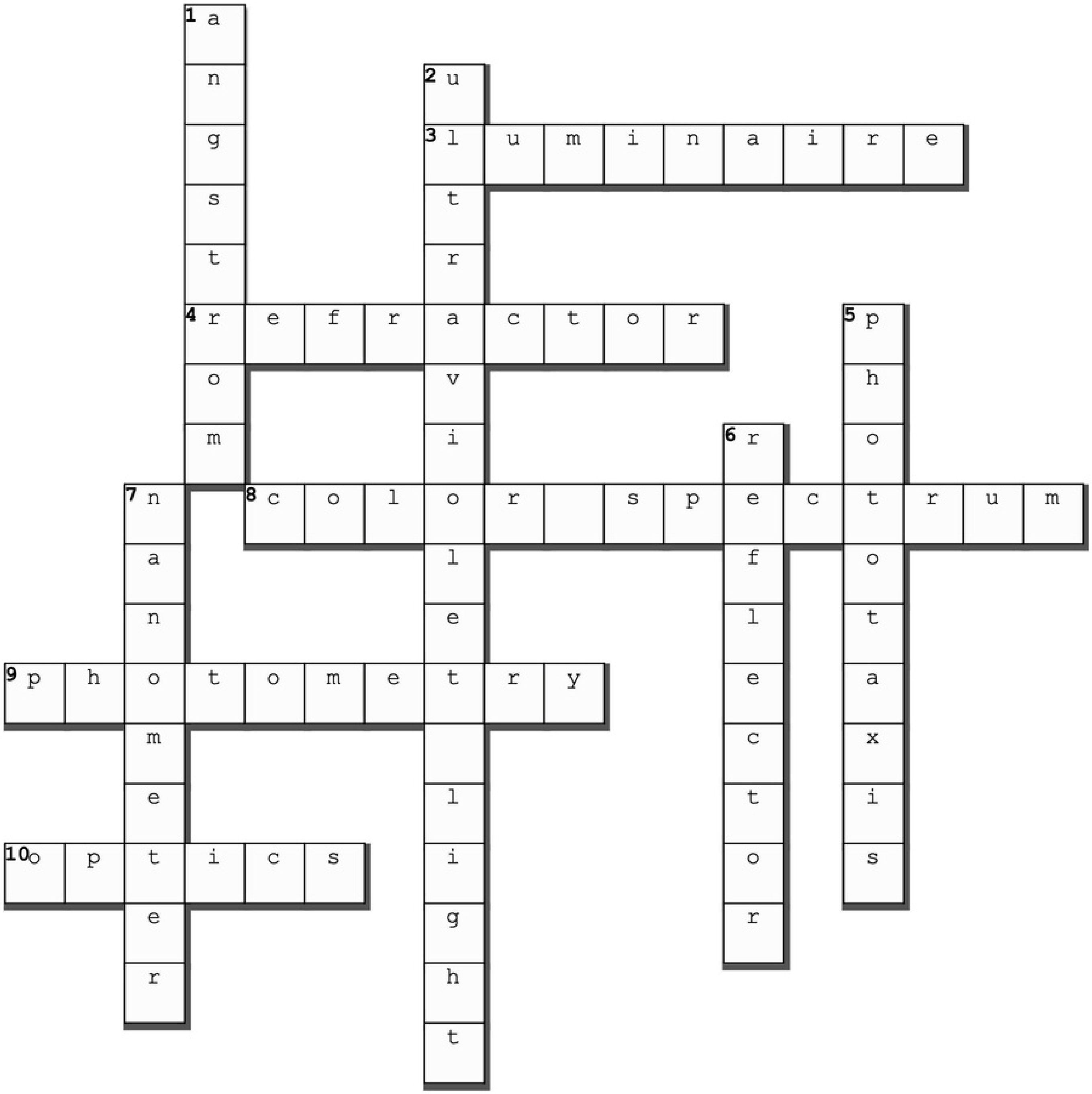
2. Electromagnetic radiation with wavelengths from 10 nm to 400 nm

5. The movement or direction of a living organism toward a light source as a behavioral response to changes in illuminance

6. An optic that achieves control of light by means of reflection using mirrors or other highly polished surfaces

7. 10-9 meter. Often used as the unit for wavelength in the electromagnetic (EM) spectrum

Space Rangers Crossword
Solutions



Across

3. A complete lighting unit that usually includes the light source, the electrical driver for the source, the optical reflector (**luminaire**)
4. An optic that achieves control of light by means of refraction using lenses (**refractor**)
8. The portion of the electromagnetic spectrum that is visible to the human eye, i.e., from about 380 nm to about 760 nm (**color spectrum**)
9. The measurement of light (**photometry**)
10. The components of a luminaire, such as reflectors and refractors, that make up the light emitting section (**optics**)

Down

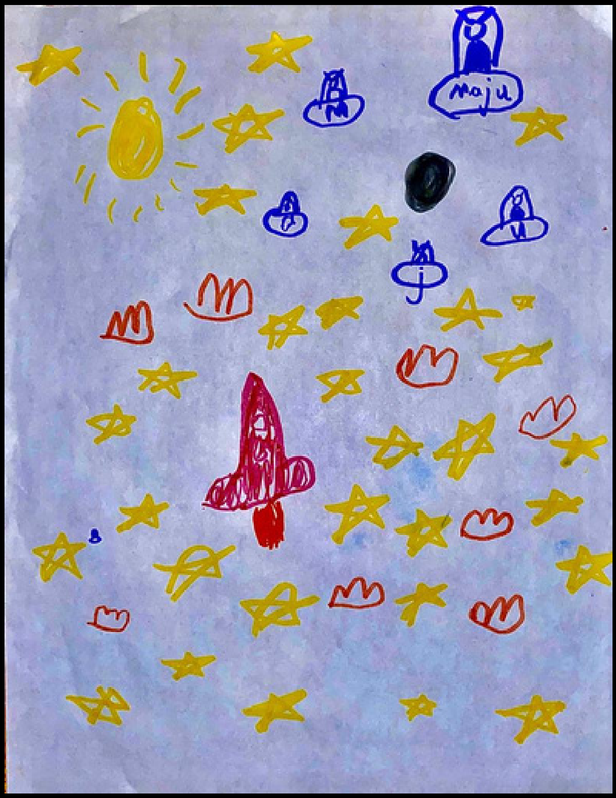
1. A unit of wavelength often used in astronomy, equal to 10-10 meter or 0.1 nanometer (**angstrom**)
2. Electromagnetic radiation with wavelengths from 10 nm to 400 nm (**ultraviolet light**)
5. The movement or direction of a living organism toward a light source as a behavioral response to changes in illuminance (**phototaxis**)
6. An optic that achieves control of light by means of reflection using mirrors or other highly polished surfaces (**reflector**)
7. 10-9 meter. Often used as the unit for wavelength in the electromagnetic (EM) spectrum (**nanometer**)

Ivan Garcia
1st Grade
Episcopal Day School
"Rocket Space"

Alexa Menchaca
2nd Grade
Jubilee Academy
"Outer Space"

About the Artist

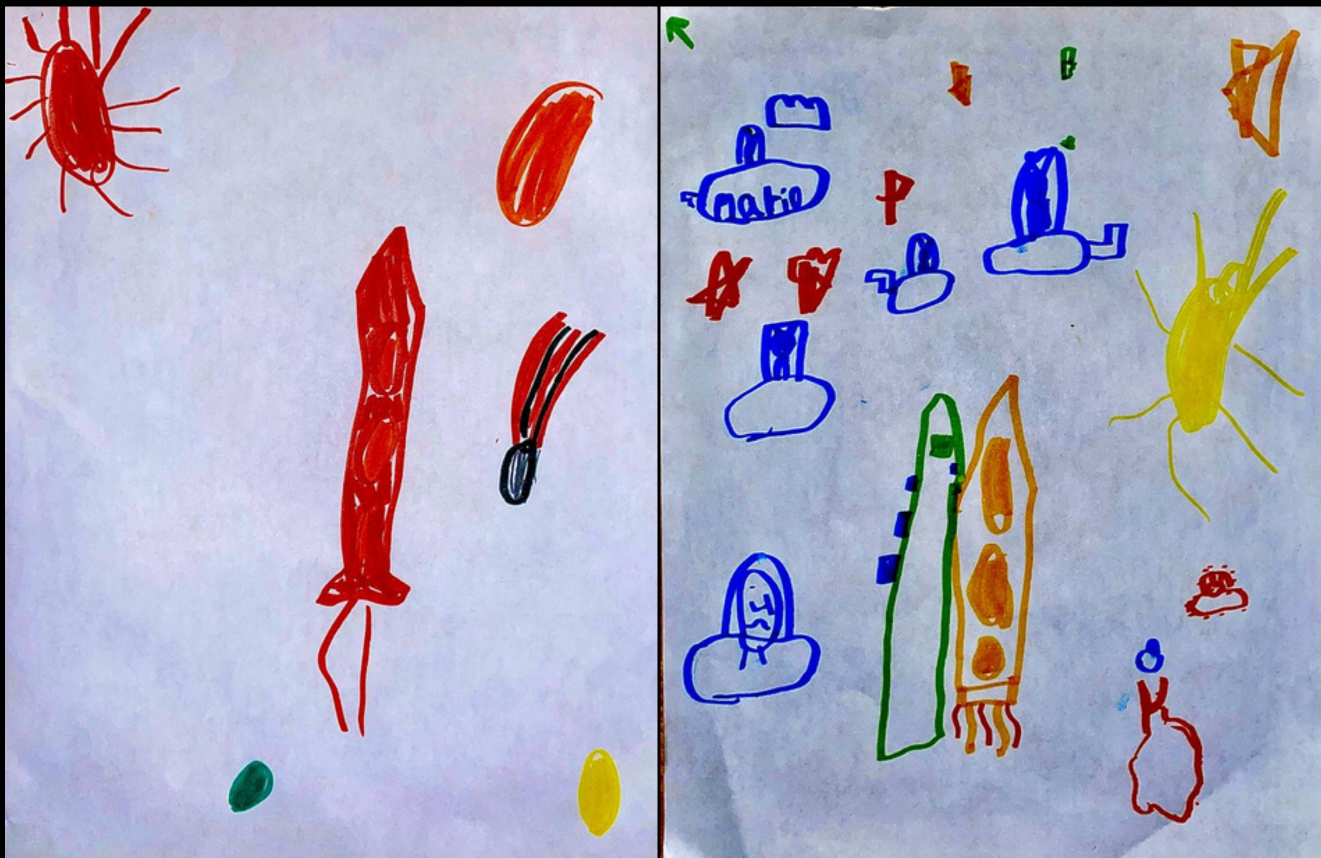
Alexandra Menchaca is a second grader with a passion for art, basketball, math, soccer, and science. She excels in art, enjoys playing basketball and soccer, and has a keen interest in math and science.



MariaJulieta Elizondo
1st Grade
Episcopal Day School

About the Artist

MariaJulieta Elizondo, affectionately known as MaJu and MJ. She is a first-grade student at Episcopal Day School. Her hobbies include drawing, reading, and playing basketball. When she grows up she aspires to become a zoologist. With her compassionate heart and vibrant personality, MaJu is destined to make a positive impact on the world and help needy animals through her future endeavors.



Mario Alejandro Elizondo
Kindergarten
Episcopal Day School

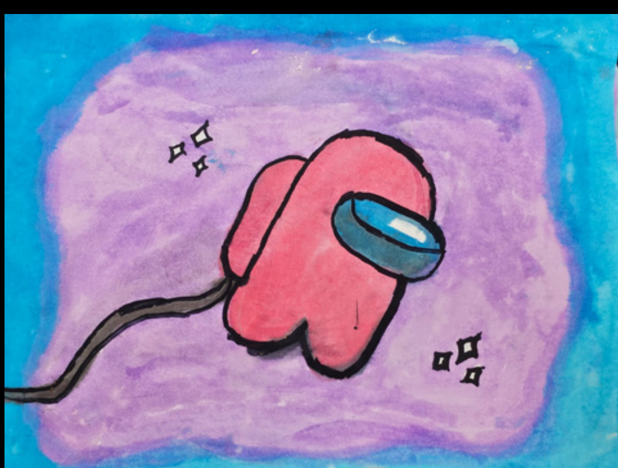
About the Artist

Meet Mario Alejandro Elizondo, a 5-year-old boy currently enrolled in kindergarten at Episcopal Day School. Affectionately known as Pollito, Bunny, and BunBun. Mario is a young enthusiast with an unwavering passion for science and space. He dreams of one day becoming an astronaut and embarking on a journey to Mars. Mario has actively engaged with the South Texas Astronomical Society, attending various events that have only served to deepen his love for all things celestial. Aside from his extraterrestrial ambitions, Mario enjoys a range of hobbies that keep his young mind active and creative. From playing baseball to building intricate Lego structures, he has a diverse array of interests that reflect his boundless energy and insatiable thirst for knowledge. With his infectious enthusiasm and determination, Mario is undoubtedly on a trajectory to reach for the stars and beyond.

"Space Fox"

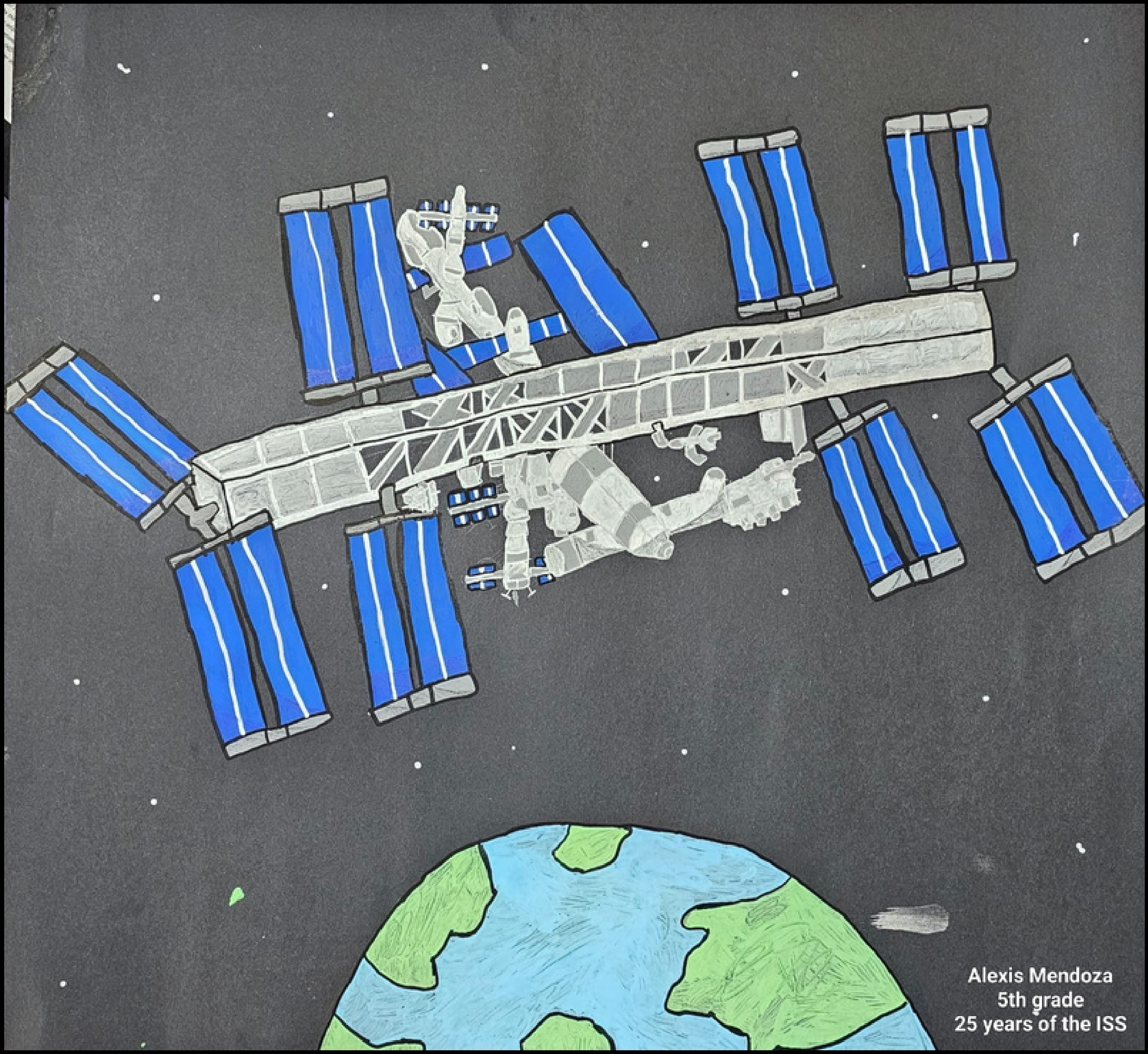
"NASA"

"Disco Saturn"



Maritza Manzanares
5th Grade
Canales Elementary
"Space Among Us"

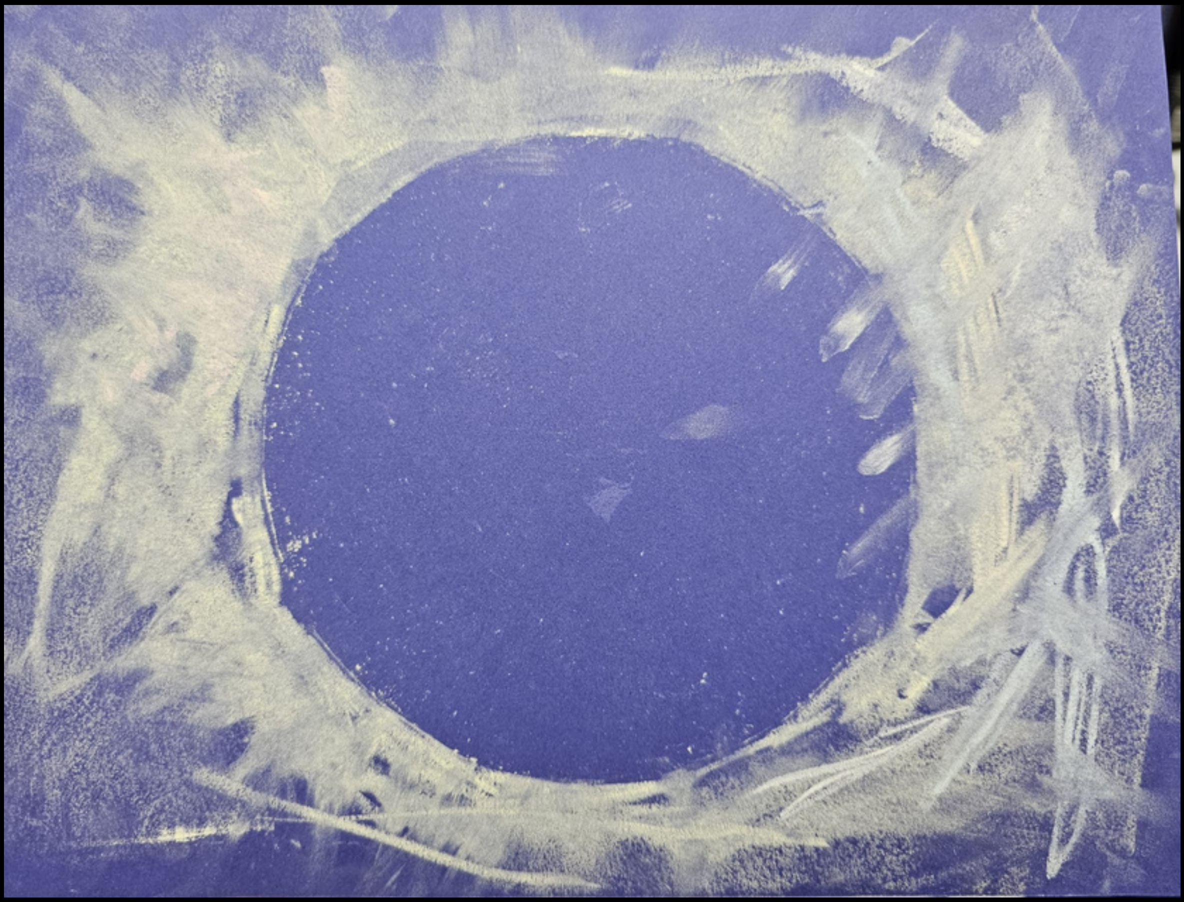
"Our Earth"



Alexis Mendoza
5th Grade
Canales Elementary
"25 Years of the ISS"

Rene Villafranca
5th Grade
Canales Elementary
"Alien Contacting"

Kayle Garza
5th Grade
Canales Elementary
"Dreaming of Space"



Madahlia Castillo-Martinez
2nd Grade
Canales Elementary
"Solar Eclipse"

Colophon

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Submissions
We encourage submissions from anyone interested in contributing to our newsletter. Any readers with ideas for our newsletter, or who are interested in submitting their own articles, illustrations, or other content, please contact the Editor-in-Chief at: richard.camuccio01@utrgv.edu

The South Texas Astronomical Society (STARS) is a nonprofit organization connecting the Rio Grande Valley community to space and science.

Our Mission is to ignite curiosity in the RGV through space science education, outreach programs, and by serving as a liaison between community members and space organizations and resources.

Our Vision is that STARS nurtures the innate human desire for exploration and discovery by fostering connections to science and the cosmos across the RGV.