Lithic Letters from the Gods

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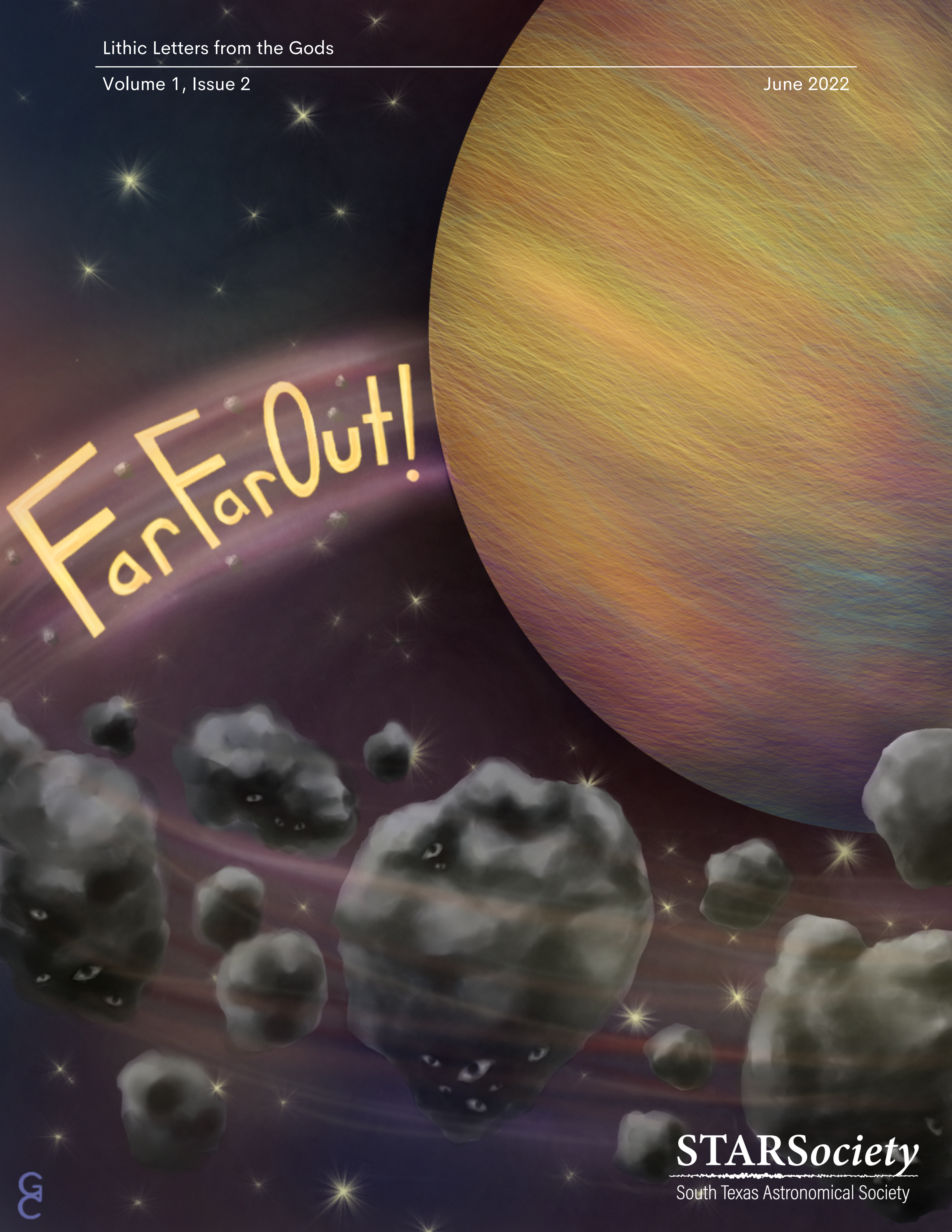

STARSociety
South Texas Astronomical Society

Editorial

Asteroids, rocky wanderers between the stars, carry messages from the distant past and implications for our near future. Herschel borrowed from the Greeks to derive their name, meaning "star-form," but they are far from stars. They are the shattered remains of planetesimals that hearken back to the formation of our stellar system.

We can learn a great deal of our history, all the way back to the birth of the Sun, by studying asteroids. Piazzi discovered the first, Ceres, in 1801. As of 2020, we know of at least one million. And there is more. From afar, telescopes measure the reflected light from asteroid surfaces, providing information about their motion, shape, and composition. Up close, with spacecraft, we can conduct a more precise analysis by studying the monoliths in detail and mining them for their virtually limitless worth.

Our fate is linked to the study of asteroids. Ovid told us Phaeton, son of Helios, was struck down by Zeus and fell into the mouth of the Eridanus. Critias told Socrates about Solon's encounter with a priest in Sais, who told Solon that Phaeton is not a myth, but rather a tale of the actual past, and one which resulted in the destruction of Atlantis and resetting of humanity. Perhaps there have been many resettings of civilization, but that is a myth that can only be answered by discovering our past and preparing for our future.

In this issue, we present a mission to a sea of metal, prospecting for precious and rare material in our Solar System. We discover the possibility of the ingredients of life - or living wanderers - hitchhiking a ride on a rock bound for Earth. We will face the implications of destruction by rocks from above on the scale of Tunguska, Chelyabinsk, or Barringer. We tell the story of an asteroid hunter and future astronaut in our Rio Grande Valley. And we hear the tales of the Rainbow Crow and our summer night sky.

Wishing you clear skies,

Richard Camuccio
Editor-in-Chief

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Summer 2022

As of this issue, there are around 1.2 million observed minor objects in the Solar System. More than half have been confirmed discoveries, with the majority existing within the Main Asteroid Belt, and the rest being near-Earth objects, Mars-crossers, Trojans, Centaurs, and Trans-Neptunian Objects. There may be 10 trillion one-meter-sized objects within Jupiter's orbit, and one trillion objects in the Kuiper Belt. Beyond, at the frontier of the Solar System, lies the Oort Cloud - and who knows what objects it contains?

Carol's Corner of the Cosmos

Carol Lutsinger

Summer will officially arrive June 21! And if you are thinking, "So what?" I don't blame you. For those readers who are interested, then this column is for you. The summer solstice occurs when the sun reaches its highest point, standing overhead on the Tropic of Cancer in the western Pacific Ocean. It is also the number of degrees the sun has moved along the horizon farther north of east at its rising and farthest north of west at its setting. In the Northern Hemisphere, we experience the longest day and shortest night of the year during the two weeks on either side of this event. The earliest sunrise occurred a week earlier for the mid-northern latitudes and the latest sunset will occur June 28. As you make your trek to work and home again, notice where the sun is in relation to the direction of the E-W stretches of highway.

An hour after the sun sets, look for golden Arcturus gleaming high overhead the NE, look for Vega (VEE-ga), the brightest star in the constellation Lyra, the Harp. Compare the colors of these two beauties. As the Earth rotates on its axis throughout the night, other stars of the summertime appear in the eastern sky. By midnight, all three stars of the Summer Triangle asterism, which is the three brightest stars from three different constellations, Lyra the Harp, Cygnus the Swan, and Altair the Eagle, will be visible if light pollution or clouds are not an issue.

Imagine a large triangle, with Vega at the apex, Deneb to the left vertex, and Altair to the right. Deneb is the brightest star in the constellation called the Northern Cross, or the Swan, Cygnus. This arrangement of stars does look like a cross. With an active imagination it can also appear to be a swan with its graceful neck outstretched toward the center of the triangle, and its strong wings spreading out on either side of the body. Deneb marks the tail. The swan's head is marked by an exquisite pairing of stars named Albireo, a match of a 3rd magnitude yellow star and a 5th magnitude blue star, considered by many to be the most beautiful double-star in the sky. Deneb itself is a massive supergiant star pumping energy/light equal to 60,000 suns. Cygnus is located in the Milky Way, and if your summer travel takes you to the Alpine area and the McDonald Observatory, be sure to look at those velvety really dark skies and enjoy the sights. This massive grouping spreads across the E-NE sky and spans 75% of the sky from horizon to the zenith. WOW! And it is all ours to enjoy.

Around the northern circle, in the NNE, look for Cepheus. This constellation looks like a crooked little house to the right of the Big Dipper. Cepheus is the king who was married to Cassiopeia, of "Clash of the Titans" fame. She will look like a letter W or M stretched out. As midnight passes, you may be able to spot her in the NNE.

If your summer nights include watching for fireworks on the 4th of July, keep an eye out for the graceful curve of Scorpius. This constellation is massive and resembles a fishhook or the letter J in manuscript. There are three stars at the leading edge of the group that mark the pinching claws outstretched toward Ophiucus. At the opposite end are two faint stars known as the "stingers" asterism. In between is a gorgeous reddish star named Antares, or the rival of Mars, who is called Aries by Greek mythologists. Often Mars is found in the same general vicinity and the two can be compared as to color and brightness - competition is ingrained in humans it seems.

Ophiucus is another massive constellation visible throughout the summer months in the southern skies. Connecting the star dots reveals - well, you decide. Either a 1950s-era coffee percolator, or a modified C-3PO Star Wars robot. He is holding a serpent that he has cut in half after finding it lurking in his herb garden. Ophiucus in myths is the first physician. After cutting the serpent in half with his hoe, another serpent came from the garden and placed an herb on the two halves, which immediately healed the first serpent and they crawled off together. Then Ophiucus decided he would use that herb to cure all his patients. That led to no one dying and creating havoc with Pluto...well, that is a story for another myth.

Following Scorpius is the Teapot asterism, or Sagittarius, the Archer. Under clear dark skies away from the ubiquitous light pollution the teapot is definitely identifiable. There is a triangle for the lid, another one for the spout, and a third one for the handle. Those of us of a certain age might remember the nursery rhyme tune of "I'm a little teapot, short and stout..." and hum it while searching for Sagittarius which is surrounded by stars of the Milky Way arm that harbors our solar system.

Weather permitting, summer skies are a delight to share with family and friends, and visiting other locations may reveal some interesting stargazing experiences. Check your vacation destinations for astronomy groups who may be hosting star parties, especially if you are heading out to dark sky locations.

Have a safe summer and do let some stars get in your eyes. ★

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.

CLEO: A Mission to a Sea of Metal

Olivia Lincoln & Jaqueline Peña

CLEO is a mission design project created by two high school juniors aiming to create a method of cataloging asteroids by their composition through infrared spectroscopy. CLEO brings us a step further in the path to asteroid mining, which can provide us with resources that are finite on Earth and the primordial remnants of planetary formation. CLEO wants to address the hindrances to asteroid mining by designing a new-age orbital satellite within a solutionary framework. The projected innovation will possess the process of mission design and testing of a satellite body, which includes analyzing the composition of asteroid 1982 DV (also named 3288 Seleucus).

Why Asteroid Mining?

The sampling and mining of asteroids will play an essential role in the future of space exploration. Asteroids can provide us with an abundance of information and resources, as they are composed of primordial material and numerous precious elements such as iron, nickel, and cobalt. Since multiple resources on Earth are classified as finite, different celestial bodies containing specific metallic ores have the potential to provide access to a tangible source with an almost unlimited yield of precious metals. As settlements in space develop, humans can turn to asteroid mining to gain access to necessary resources for a functioning society. In view of the fact that Earth's resources are finite, celestial bodies containing ores and pure elements can therefore enable larger-scale solar system exploration by providing these future societies with access to an almost unlimited reserve. Furthermore, C-type asteroids, or carbonaceous asteroids, contain elemental tracings of H_2O which can actually be harvested for rocket propellant. Due to the given prospects, there is a tremendous amount of capital to be found on the asteroid belt, which will overall contribute to Earth's economic growth.

Asteroids, often considered the building blocks of the planets, are scientifically invaluable as they hold remnants from the formation process of our inner solar system. This primordial material sits within the rocky mantles of these asteroids, so, if we sample this material, we can gain more insight into how the planets were structured and the history of the solar system itself. This is actually why we adopted the name CLEO. Cleo is a spelling adaptation of the Greek muse Kleio (Κλειω), who is the Greek goddess of history. We chose the muse of history because asteroids, containing this primordial material, are practically physical pieces of history floating in space!

The National Space Society (NSS) compiled a Roadmap to Space Settlement with asteroid mining being appointed a major milestone. The roadmap states the benefits of asteroid mining as access to volatiles like water/ice and high mineral wealth. However, to eventually accomplish asteroid mining, the technologies necessary for the research and actual mining will need to mature vastly. The NSS Roadmap lists the main barriers to the robotic characterization and utilization of asteroids as the following:

1. Lack of information on the composition and physical structure of individual asteroids
2. Lack of machinery that can rendezvous with/analyze asteroids
3. Lack of machinery dedicated to spectral analysis of asteroid composition

Now, this is where we begged the question: How can a mission be designed in regards to addressing all these barriers?

Creating CLEO

Initializing this project included the selection and research of an ideal asteroid trajectory point or otherwise specifying: How can we find the essential Goldilocks zone for this objective?

A targeted area was researched to locate a range tangible for CLEO whilst simultaneously reaching the prosperous frostlines of the rock belt. Utilizing the Asterank Database, 1982 DV (3288 Seleucus) was chosen as a reference celestial body by meeting satisfactory composition, value, and apogee/perigee. To calculate a projected range of movement, the use of orbital mechanics, or, more specifically, Newtonian/Keplerian dynamics, led the team to calculate a simulated Homann transfer. This launch operation was segmented into three stages: (i) Launch from Earth, (ii) Calculating Semimajor Axis from Earth to Asteroid Orbit, and (iii) Adjusting for Speed of 1982 DV. Furthermore, the project took into account the amount of propellant necessary for take-off and travel; the Tsiolkovsky rocket equation was used to calculate the modular specifications, allowing for an estimated wet and dry mass.

This design is composed primarily of new-age technologies. Previous satellite missions using infrared such as OSIRIS-Rex, Lucy, Rosetta, Dawn, and Galileo were researched in the development of CLEO. CLEO's design was made with the intention to travel far within the asteroid belt, calling for higher efficiency in power systems, larger integrated solar arrays, precise autonomous navigation, and far-reaching data transfer. The primary focus of the satellite is oriented toward compositional analysis using infrared instrumentation. A notable feature of CLEO is its hexagonal solar arrays which utilize the NASA Origami method for assembly (in which the center is pinched to a fold and opens up like origami practices).

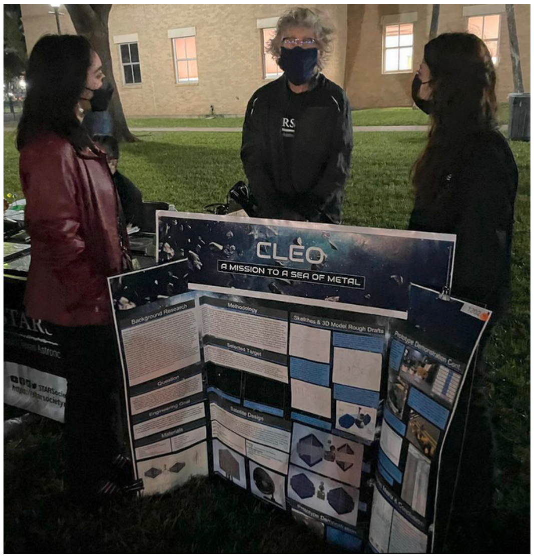
In a sector of tangible development, prototype assembly followed suit. Using VEX robotics, a robot was programmed for sensor detection in a simulation of scientific instruments on an orbital plane. The team constructed a mock asteroid terrain consisting of plastic blocks and colored sticky notes spaced with enough room for a satellite pathway and initiation of spectroscopy. This 1′ by 1′ boxed machine was able to detect the color signatures and proximity measurements of these plastic bodies.

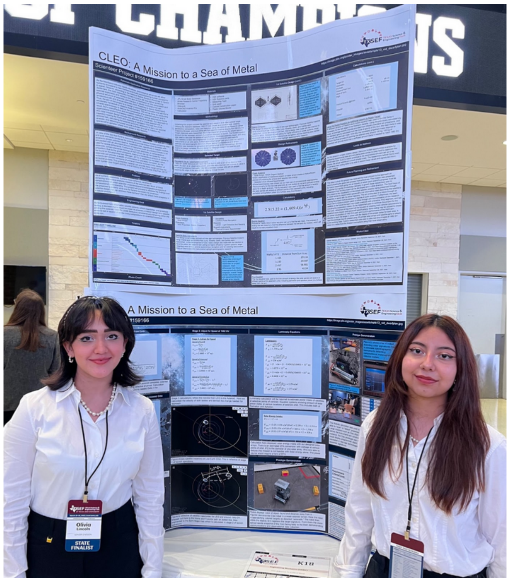
Following an industry review and refinement, a large criticism on which we evaluated ourselves lands within the scope of "How can we communicate this more effectively?" We present this mission as future researchers going into an industry in which each scientific proposal must be supported by a guide of knowledge demand. In growth, we wish to understand how far we can develop this project and in what direction. We want to focus next on visualization of this satellite - perhaps creating a trailer or informative video describing the satellite's assembly in space and its orbital trajectory. The aim of this step is to follow through on altering our project to be more accessible in regions of public science. Furthermore, our team would really like to create a mission patch to follow through with our publication of this research satellite. We have been looking at creating a website with a timeline and FAQ segment.

We competed with CLEO in our local science fairs and SkillsUSA contests, and almost every judge we've received has asked how we came up with this project. As avid lovers of astronomy, more than anything we wanted to create a project that had the potential to contribute to a developing aspect of space exploration. So, after asking a former teacher really knowledgeable in astronomy who suggested space mining, we were most intrigued by asteroid mining and settled on centering the project on asteroid composition.

CLEO has evolved and matured tremendously since first planning and choosing the asteroid, and we owe our utmost gratitude to the directors of the STARSociety and their support in this ambitious project.

And, as of recent, CLEO has advanced to state finals in both Texas' Science & Engineering Fair and SkillsUSA. ★



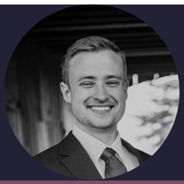


Biographies

Olivia Lincoln is a junior at James Pace Early College High School and is an ambassador for the South Texas Astronomical Society. She will be starting an astronomy club for her school with STARS in the fall. After high school she wishes to study astrophysics and pursue research in gravitational wave astronomy.

Jaqueline Peña is a junior at James Pace Early College High School. She is president of the school's SkillsUSA Drafting chapter and an ambassador for the South Texas Astronomical Society. She wishes to pursue a career in aerospace engineering.

The Seeds of Life: Panspermia and Meteor Impacts



Andrew Maurer

The origin of life on Earth is still one of the most profound mysteries ever. The specific mechanisms by which life on Earth arose are still largely unknown. However, the general scientific consensus is that *abiotic* elements like hydrogen, oxygen, and carbon chemically interacted to form basic organic molecules. Given particular environmental conditions, these simple molecules further transform into complex organic molecules like *glucose, triglycerides, proteins,* and *nucleotides*. This process is called *abiogenesis*. These four organic molecules are foundational for life on Earth. Without these molecules, life on Earth would be fundamentally different, or may not even be able to exist. Keeping with the discussion of asteroids, comets, and meteors: how do these cosmic fragments of ice, metal, and rock interact with life on Earth? Other articles in this issue discuss the more obvious outcome of asteroid or cometary interactions with Earth (destruction), but some space rocks may harbor something else - the potential for new life. There is a name to such a phenomenon, and it is *panspermia.*

Imagine - microscopic (or even macroscopic) life hitchhiking its way across the galaxy on an asteroid or comet, and eventually plummeting onto Earth's surface. A scene like this is commonplace in a science fiction novel or film. However, is this realistic? Are extraterrestrial visitors able to travel from one celestial body like Mars to another, or even from a planet outside our solar system? What is described here is called *lithopanspermia;* the distribution of organic life imbedded in rock from one planet to another, and a subset of panspermia. Lithopanspermia is a highly contentious subject for several reasons, a major reason being the inability for scientists to properly test or observe lithopanspermia. While it is unlikely to directly observe the effects of lithopanspermia, there is indirect evidence that the phenomenon may be plausible.

There is mathematical support for intact rock to be ejected from a celestial body's surface due to a meteor or asteroid impact [4]. This phenomenon is called *spallation*, and is the reason why Lunar and Martian fragments have been found on Earth's surface [4]. This information is crucial, because microorganisms are abundant and thrive in the soil. Moreover, many microorganisms are able to transition into a metabolically catatonic state or have a spore-form as part of their life cycle. The scene is set: a meteor strikes a planetary surface, sending a large plume of debris into the air, and some sizable chunks with living microorganisms imbedded in the rock escape the planet's atmosphere and travel into outer space. In this stage, if the microbes are still alive, they now face the extreme environment of space. Remarkably, there are organisms that can withstand the hard vacuum of space for some time [1,3]. An excellent example is *Deinococcus radiodurans,* an *extremophile* bacterium that is able to thrive in highly radioactive areas. Several experiments through NASA, the European Space Agency (ESA), and other space-related programs have revealed how *D. radiodurans* and other microorganisms respond to exposure to outer space-like environments [1,3]. Overall, microorganisms have a higher survival rate if properly shielded from high frequency radiation (UV, gamma, cosmic, etc.), high temperatures (> 40℃), form multiple layers of cells in a colony, and have glucose present [3]. A hard-vacuum environment does lower survival rate if exposed for a signifcant amount of time on the order of months [3]. One experiment even mixed the bacterium *Bacillus subtillis* in a clay mixture as a means to simulate Martian soil [3]. When exposed to a hard-vacuum environment for approximately 11 months, no *B. subtillis* spores were viable [3]. Also, it is highly unlikely for naturally wandering meteors to visit our solar system from another galaxy, primarily due to Jupiter's placement in our solar system [5]. Even within our solar system, the exchange of viable life among planetary bodies is unlikely, but the relationship between life and meteors does not end here.

Again imagine - a meteor makes landfall onto a planet's surface, but instead of alien ooze or even extremophiles, it carries with it something even more foundational to complex life: amino acids. This describes a scenario called *pseudo-panspermia*, or *molecular panspermia*. Unlike the scenario described prior, organically-rich meteorites have been recovered from impact sites on Earth as recent as 2019 [7]. The key difference between the two impact events is that with pseudo-panspermia, carbon-rich compounds are deposited instead of living organisms. This does mean abiogenesis still needs to occur on the planet itself for life to develop. Organically-rich, primordial bodies are theorized to have contributed to the prebiotic chemistry on Earth in the Hadean eon [6,7]. In support of this theory, *carbonaceous asteroids* (*C-class asteroids*) are plentiful in the asteroid belt between Mars and Jupiter, and C-class asteroid impacts are commonplace throughout Earth's history [6,7]. *Murchison* and *Aguas Zarcas* are two prominent examples of *carbonaceous chondrites,* C-class asteroids composed of more organic compounds than a typical C-class asteroid, making landfall onto Earth's surface [7]. Aguas Zarcas made landfall in April 2019 just outside of the Costa Rican district of the same name. Significant compounds found within the meteorite include *Calcium-aluminum-rich inclusions* (*CAIs*), *calcite, chondrules,* and a dark matrix that holds the organic compounds [7]. The properties of this meteorite are crucial in understanding the *astrochemistry* involved in solar system formation [7]. Chemical analysis of the Aguas Zarcas meteorite is similar to that of another carbonaceous chondrite, Murchison, that landed in an Australian cattle town of the same name in 1969 [7]. Murchison is significantly more massive, contains an array of amino acids of varying rarity, and *nucleobases*, the nitrogenous component of a nucleotide (i.e. adenine, thymine, guanine, or cytosine). Furthermore, carbonaceous chondrites are not the only source of essential organic compounds found in the cosmos.

Complex, carbon-based chemicals are also found in the interstellar medium, primarily forming on ice grains in interstellar clouds, remnants of solar system formations [2]. *Polycyclic aromatic hydrocarbons* (*PAHs*), other hydrocarbon compounds, and nitrogen- and oxygen-containing complex chemicals are examples of biochemically fundamental substances being forged in extremely low temperature (5 K or -268.15℃) environments [2]. There are space expeditions tasked to traverse the cosmos to specific asteroids to collect samples and send them back to Earth for analysis, a prominent one being like Hayabusa2 from the Japan State Space Agency [6]. One such location was to an asteroid, Ryugu, another C-class asteroid [6]. Samples from Ryugu were recovered in the Australian Outback in December 2020 [7]. Hayabusa2 continues to operate and will rendezvous with another asteroid by 2031 [7]. NASA has a similar mission, OSIRIS-Rex, that made contact with and collected samples from the asteroid Bennu, and is set to return to Earth by 2023 [7].

Ultimately, there is no definitive evidence that either lithopanspermia or pseudo-panspermia are actively altering Earth microbiomes. However, that does not mean that the universe is devoid of life. If anything, it is full of potential for life to sprout and prosper. Missions like Hayabusa2, OSIRIS-Rex, and others will continue to scour the rock and ice of the cosmos to find the potential for life. And we hope that every so often, life will find a way. ★

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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.

Averting (Accidental) Armageddon

Miles Hartl

Even the smallest of asteroids have the potential to unravel life as we know it. Here's how to keep the risk from going nuclear.

On the morning of February 15, 2013, the skies over Chelyabinsk, Russia were illuminated by a flash brighter than the sun. A previously undetected meteorite, measuring no more than 19 meters in diameter, exploded against the atmosphere with the force of four hydrogen bombs. The blast sent shock waves rippling through the air, damaging over 7000 buildings across six cities and resulting in 1500 casualties.

News of the disaster received immediate, worldwide media coverage, aided by an abundance of video footage and eyewitness accounts. The incident renewed discussion over threats posed to human society by near-Earth objects (or NEOs) and was quickly dubbed "a wake-up call" by scientists and activists [1]. Yet despite the initial tally of carnage, final accounting chalks this disaster up to a near miss. Had the object entered straight down (as opposed to moving on a tangent relative to the atmosphere) the resulting force would have dispersed vertically instead of horizontally, leveling buildings for miles and resulting in thousands of deaths.

Chelyabinsk, while unusual in its drama and visibility, is far from an isolated incident. Thirty years of NASA records document over 886 fireball impacts occurring with chilling regularity, ranging from explosive blasts equivalent to 92,000 hand grenades (1) to city-obliterating holocausts equivalent to 10 atomic bombs [2]. Most remain confined to the atmosphere and remote regions. However, future collisions with settled land are a question of "when" and not "if." Nearly every single object escaped prior detection, and no coordinated or efficient system exists to spot and intercept bolides of concern. As such, human society stands wholly unprepared as the Earth stumbles blindly through a constant, unceasing bombardment of shrapnel, bullets, and cannon fire from outer space. The clock is ticking down to disaster.

Since the vindication of the Alvarez-Smit hypothesis (2), a wealth of scientific research and planetary defense fundraising has focused on the consequences of collisions with so-called "doomsday" asteroids. The most recent data suggest that this term may encompass many more possibilities than previously imagined. We simply do not need a rock the size of Manhattan Island to reset the clock on civilization. Under the right circumstances, we need little more than a rock the size of a Greyhound bus. One misplaced collision with a ~20 to several hundred meter long object could shatter the beating heart of the modern world overnight, plunging society into chaos and unleashing an irrevocable collapse of organized human life.

Such a scenario remains, like for all major impact events, statistically unlikely within any given century. Nevertheless, it is *far more likely* than the potential for a collision with a Chicxulub-sized rock so dominant in popular imagination, and no comprehensive and effective planetary defense campaign can exist without addressing it.

A disaster of this magnitude could unfold through several avenues. The primary threat involves unforeseen consequences of asteroid strikes over populous regions. Hydrogen bomb equivalence is useful not just for conveying the extent of bolide damage. It also provides some of our best analogies for how asteroid impacts appear to any surviving witnesses and the evidence they leave behind. Indeed, outright confusion of meteorite collisions with nuclear attacks is not without historical precedent. Engineer and science fiction author Aleksander Kasantsews, upon comparing photographs of the damage wrought by Hiroshima and Nagasaki side-by-side with surveyance photographs of the 1908 Tunguska impact site, theorized that the latter event resulted from a nuclear explosion caused by an alien spacecraft. Debate continues to the present day as to whether the Prince Edward Islands impact of 1963 was a bolide or undisclosed nuclear test (3).

Such mistakes, while sometimes humorous in retrospect, illustrate an important point about the limits of perception regarding this tier of destruction. Amid the chaos, confusion, and incomprehensible devastation of a meteorite strike, surviving witnesses may simply not know what they're looking at. The first instinct in the minds of many is not "rocks from outer space" but rather "nuclear attacks from enemies abroad." The same holds for panicked government agencies responding to reports of city-sized explosions and blast radii resembling atomic tests, coupled with ionizing radiation and nuclear fallout (4).

It is a mistake with potentially apocalyptic consequences in the era of mutually assured destruction. Current risk of nuclear conflict between the United States and Russia stands at its highest point since the Cold War, prompting the Bulletin of Atomic Scientists to move the Doomsday clock to 100 seconds to midnight in 2020. Consensus among nuclear experts suggests that the danger of annihilation lies less in a deliberate act of aggression and more in the potential for launches brought about by mistakes and miscommunication.

The cosmic shooting gallery has wasted no time in testing our margins of error. As recently as 2018, a meteorite detonated close to an American Ballistic Missile Early Warning Site in Thule, Greenland. Hans Kristensen, director of the Nuclear Information Project at the Federation of American Scientists, cited the incident as an example of a "freak accident" that "could potentially trigger an alert that caused the United States to overreact" [3]. While relatively lower international tensions likely contributed to a calm and collected diagnosis, the ongoing Russo-Ukrainian conflict has radically altered the state of hostilities. Indeed, it is no exaggeration to suggest that a repeat of Chelyabinsk at this very moment could easily trigger a shooting war between the world's foremost nuclear-armed powers, absent any clear warning or diffusion of tensions.

Even barring the possibility of World War III, the economic impacts of a bolide collision over a major inhabited area would have irrevocable consequences on its own merits. Awakening to a world where London, Shanghai, or New York City was destroyed overnight would instantly rewrite history - extinguishing millions of human lives and vaporizing trillions of dollars in economic assets in an instant (5). Worse still, impacts in *remote* regions may paradoxically prove more severe than impacts in populous regions. An ocean-based impact from a ~200-500-meter-wide NEO several miles off the coast of the Acela Corridor (for just one example) holds the potential to flood several major US cities simultaneously (6). Loss of life may be contained with enough advance warning, but very little could be done to mitigate resultant economic damage. At bare minimum, such a scenario risks a worldwide depression and collapse of multiple supply chains. At worst, it may serve as the proverbial "straw that breaks the camel's back" to a society exponentially strained by climate change and deteriorating political infrastructure. It is a risk that our precarious future simply cannot afford to allow.

The scenarios outlined above are as bleak as they are neglected in the public consciousness, yet all remain mitigable. Almost no small asteroid capable of this kind of damage lies outside current means of detection, and technological advances promise more and more time to react to incoming threats. Unfortunately, recognition of danger inherent to even the smallest of NEOs means that the detectives' workload has increased exponentially. Existing resources are stretched impossibly thin for the task at hand, and the tools required to complete it stand as scarce, underfunded privileges reserved for a small minority of researchers.

This is not to say the foundation for an effective planetary defense network is entirely absent. Smaller observatories (those with telescopes having diameters less than one meter) constitute most currently active stargazing facilities. They are ideal for following up on known, but ill-defined, asteroids and hazardous candidates. Small scopes hold additional advantages for spotting objects several kilometers in size given optimal viewing conditions.

Nevertheless, detection remains challenging for objects below one kilometer in length. Here, we must turn to the cutting edge of astronomical science. The PanSTARRS observatory, created and maintained by the Institute for Astronomy at the University of Hawaii, offers a look into the future of defense. Its 1.8-meter diameter telescope boasts a 24th magnitude limit (7), offering approximately 26 days' notice for objects ~20 meters in diameter and approximately 130 days' warning for objects ~100 meters in diameter (8).

The tradeoff for acquiring such a data set is processing time - upward of several weeks to complete a single scan of the entire night sky. For a reduced magnitude limit, the as-yet-unfinished Asteroid Terrestrial-Impact Last Alert System (or ATLAS) promises a useful alternative. Once fully operational, ATLAS will require only half a night to complete a full survey (at the cost of 100x less depth of vision than PanSTARRS's scope). It will also be able to detect ~20 meter-sized objects several days out, and ~100 meter-sized objects several weeks out.

This remains terrifyingly short notice. It is also far from nothing. At bare minimum, successful detection provides a window for evacuations and some attempt to brace for impact. The time gap also continues to improve as research and development progress. The Simonyi Survey Telescope, set to open with the Vera C. Rubin Observatory in 2023, promises to detect a million transient events per night. This amounts to a deeper survey of the night sky than ATLAS or PanSTARRS *every four days*. Apart from being a necessary investment, it is also a reasonably priced one - clocking in at roughly $500 million per observatory (or roughly 24 for the cost of a single USS Gerald R. Ford aircraft carrier) (9).

These results are encouraging, though it is vital to remember that no technical innovation is complete without an organized deployment. Likewise, no science can continue to advance without steady sources of funding. The planetary defense movement remains frustratingly stagnant in the realms of public awareness and legislation, which remain critical to advancing these goals. In response, this article proposes four major suggestions.

First, the astronomical community must clearly communicate an unspoken truth about NEOs - that their existential threat goes all the way down to the smallest of rocks that make it past our atmosphere. It must emphasize that bolides which may be confused with weapons of mass destruction hit *all the time*, and that the good fortune of near misses cannot continue indefinitely. Emphasis should stray away from Cretaceous-Paleogene-tier extinction events (which are low probability and remain abstract in the minds of many) and toward the cornucopia of devastation provided just within the last hundred years. Tangible examples produce tangible concerns, which in turn provide the best change at provoking awareness and action. An alliance with nuclear nonproliferation movements is also strongly encouraged.

Second, the astronomical community must push for massively expanded research and development regarding NEO detection. Despite advances in recent years, blind spots and razor-thin margins of error continue to plague our best technology (10). More of what already exists would certainly help detect dangerous NEOs, but more and *better* resources remain our best chance for averting disaster. Planetary defense activists must clearly communicate gaps remaining for small asteroid detection, along with potential avenues for fixing them.

Third, another R&D push must focus on interception strategies for small bolides of concern. Currently, options for destroying or redirecting Chelyabinsk to Tunguska-tier asteroids remain strictly hypothetical. This is a gaping hole in our defenses. The best detection methods available may provide time to minimize casualties in the event of incoming fire. But without a plan to *prevent* such impacts from occurring in the first place, progress will be stalled at reducing "accidental obliteration of civilization" to "unprecedented economic and social disruption." In the short term, this may save our lives. In the long term, this is incompatible with living.

Fourth, all existing observatories must renew efforts to centralize and share NEO data. The Minor Planet Center offers an established network for recording all known asteroid and comet observations in the world. Despite this, far too few small observatories are linked in - lacking necessary codes, knowledge, and training. The result relegates threat detection on a handful of overworked and underfunded facilities. This is a critical handicap for a task demanding sustained, worldwide vigilance and impeccable organization. Small observatories are an essential component of any effective global defense network. More eyes on the sky means more chances for success. With an all-hands-on-deck approach, Earth defense stands to consolidate into a well-oiled machine, predicting cosmic flack as easily as meteorologists predict the weather.

On every front, NEO impact assessment reveals a picture that is more damaging, more disruptive, and more frequent than the most morose estimates of cynics' past. Yet the science of counteroffensives offers reasons for conditional optimism. Despite an unending interstellar assault - with even the smallest projectiles carrying potentially lethal risks - we have been handed the gift of second chances. We have also been handed the kind of case studies that win hearts and minds, advancing the conversation beyond literally unfathomable horrors from prehistory. All that remains is action, and the courage to confront the unthinkable. Now more than ever, planetary defense activism must take its rightful place, in an era desperate for "sustainability," as a mainstream political cause devoted to preserving our continued existence.

We have everything to lose, and everything to gain. ★

Notes

(1) Using the definition of one ton of TNT equaling 4.184 gigajoules of energy, with one Mk2 hand grenade filled with 52 grams of TNT.

(2) Postulating a six-mile-wide asteroid as the cause of the Cretaceous-Paleogene (dinosaur) extinction event, centered on Chicxulub, Mexico.

(3) See Silber et al. (2009), *An Estimate of the Terrestrial Influx of Large Meteoroids from Infrasonic Measurements*. The PEI 1963 impact was only observed with infrasound, unlike other recorded events which included other reliable observations in tandem with the infrasound measurements. For this reason, we cannot rule out a nuclear test. It was an unusually high energy event and is unique for not being recorded as reliably as other bolide impacts. "The nature of this one bolide remains a mystery; no other reports exist of the effects of this large impact (as may be expected of an event occurring far from land this time period), and unlike most other events in the AFTAC database, this one did not have independent confirmation from other techniques. It remains possible that this event was not a bolide but rather another source."

(4) Differentiation of asteroid strikes with nuclear attacks is possible within minutes via satellite readings, but not every country has access to said technology. See remarks from Air Force Brig. Gen. Simon P. Worden to the House Science Subcommittee, October 2002

(5) A readjusted Chelyabinsk impact would cause catastrophic damage. Total destruction of a major metropolitan area could be achieved by rocks 100-140 meters in diameter.

(6) Estimates of tsunami effects vary, given a lack of recorded examples. General consensus nevertheless cites ~200-500 meters as the threshold for significant wave activity. See Crawford and Mader (1998), *Modeling Asteroid Impact and Tsunami*, Science of Tsunami Hazards, Volume 16, pp. 21-30; S. N. Ward and E. Asphaug (2003), *Asteroid Impact Tsunami of 2880 March 16*, Geophysical Journal International, Volume 153, Issue 3, F6-F10

(7) In layman's terms, the capacity to view objects 10 billion times fainter than Saturn at its brightest.

(8) Assuming an albedo of 0.1, observed distance from the sun of 1 AU, and speed of 20 km/s for each object. For standard baseline estimates, see http://astro.physics.uiowa.edu/ITU/labs/professional-labs/introduction-to-impact/part-3-the-size-of-an-earth/

(9) See Vera C. Rubin Observatory cost estimates at: https://nsf.gov/about/budget/fy2021/pdf/34g_fy2021.pdf
https://www.nsf.gov/about/budget/fy2022/pdf/58g_fy2022.pdf

(10) The Chelyabinsk asteroid came from the direction of the sun, which blocks visibility using conventional telescopes. This is how it escaped detection. Developments in infrared observation, championed by the University of Arizona's NEO Surveyor and NEOWISE missions, offer a potential solution (see https://neos.arizona.edu/).

References

[1] The EarthSky Team (2013), *Russian Meteor Was a Wake-up Call, Says Scientist*, EarthSky

[2] *Fireball and Bolide Data*, Center for Near Earth Object Studies, NASA Jet Propulsion Laboratory, https://cneos.jpl.nasa.gov/fireballs/

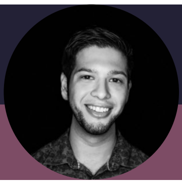
[3] J. Hamill (2018), *An Asteroid Exploded Near a US Early Warning Radar Base and We're Lucky It Didn't Spark Nuclear Armageddon*, Metro

Biography

Miles Hartl is a music producer and researcher for the City of Philadelphia Law Department. A former intern for Marine Corps Base Quantico History Division, he received a BA in history from Temple University in 2014 and a certificate in paralegal studies from Villanova University. His debut album, "Punching Up," is slated for release in mid-2023. He lives in Philadelphia, Pennsylvania.

RGV Highlight: Wendy the Asteroid Hunter

Victor De Los Santos



In the first issue of *FarFarOut!* we took a deeper look into the Cristina Torres Memorial Observatory (CTMO), an astronomical facility in the Rio Grande Valley that captures cosmic light from celestial objects light years away. Though the observatory and its magnificent 17-inch telescope are cosmically awesome in their own right, the real stars are the people behind the camera; the ones who operate this astronomical machinery and translate the images into meaningful science.

In this issue, we highlight a unique astronomer who thoroughly embodies the concept that anything is possible if you are willing to put in the work required: Wendy Mendoza.

Wendy was born in a small town called Willmar, Minnesota, about two hours away from the city of Minneapolis. In the earlier part of her life, Wendy and her family were migrant workers in the agricultural industry, and so for the majority of her childhood, she moved from state to state to harvest crops alongside her parents and sisters. By her teenage years, Wendy's family had lived and worked in Minnesota, Illinois, Louisiana, and Texas.

Looking Up

On many occasions during Wendy's childhood, she would listen in on discussions between others working alongside her in the fields. "I met a lot of people and heard a lot of stories about other migrant workers trying to build better lives for themselves - some of them would fail, some would succeed; some would make it out of the migrant fields, some wouldn't." Amongst the telling and retelling of stories, there was one name that would consistently come up: Jose Hernandez.

Jose Moreno Hernandez is a Mexican-American engineer and former NASA astronaut. As a child, he too grew up working with his family as a farm worker and moving from city to city in California. When he was 10 years old, Jose witnessed the Apollo 17 mission, the final mission in NASA's Apollo program, on television. This inspired him to pursue an education in electrical engineering which would put him on a path to becoming an astronaut. In 2004, after 11 rejections over three years, Jose was approved for astronaut training. In 2009, Jose Hernandez achieved his goal of going to space as part of NASA's STS-128 mission to the International Space Station, where he spent more than 13 days. (Fun fact: He also became the first person to tweet in Spanish from space!)

After learning about Hernandez's journey, Wendy came to the realization that would determine the course of her own life: "If he can make it to space, I can do it, too."

When Wendy was about 10 years old, her family moved to Brownsville, Texas, where she embarked on her own journey to becoming an astronaut.

Journey to the Stars

As of 2022, Wendy Mendoza is a graduate student of physics at the University of Texas Rio Grande Valley (UTRGV), assistant director of CTMO, and astrophysics researcher for the university's Time Domain Astronomy Group.

Wendy's entrance into the world of physics began at Texas Southmost College (TSC) in 2015 and then continued within the UTRGV Department of Physics and Astronomy in 2017. After getting in contact with

Dr. Mario Díaz, Professor of Physics at UTRGV and Director of CTMO, Wendy became interested in becoming a part of the university's optical astronomy research group. At this point in time, Wendy could not drive, nor did she have a car, so she had no way of getting herself to the observatory at Resaca de la Palma State Park. Using the potential position as an astronomy researcher as motivation, she learned how to drive and saved up enough money to purchase her own car within one year.

Wendy went on to receive her Bachelor of Science in Physics from UTRGV in 2020. In 2021, she completed a summer internship program with the Space Telescope Science Institute (STScI), where she programmed machine learning code into software that will be launched aboard NASA's Nancy Grace Roman Space Telescope in 2027. Over the course of her professional career at UTRGV, Wendy has participated in a number of academic science symposiums and presented her work in conferences across the country.

Though her upbringing was far from easy, Wendy persisted on the path of most resistance and continues to persevere through all obstacles.

Space Rocks!

Although Wendy's position as Assistant Director of CTMO includes training observatory staff members and managing time-domain astronomy projects, Wendy's primary interest at the observatory lies in the study of peculiar and potentially hazardous celestial objects: asteroids.

Asteroids are rocky bodies that orbit our Sun. They range in sizes from diameters of less than 50 feet (about the size of a semi-truck trailer) to more than 300 miles (about the distance from Brownsville to San Antonio), and consist mostly of leftover pieces from the early formation of our Solar System [1]. Asteroids are classified as "near-Earth objects" (or NEOs) by astronomers if their orbit brings them closer than 1.3 AU (1 AU = 93 million miles, the average distance between the Earth and Sun). To optical astronomers like Wendy, near-Earth asteroids are the target of most interest.

Wendy: "With an optical telescope, we can determine the size and shape of certain near-Earth asteroids. There are also other tools we can use to get even more information about the asteroids. For example, with a spectrometer, we can determine the composition of the asteroid - what they're made of. If we're lucky, we can even discover asteroids that have not been recorded yet.

At CTMO, we track brightness of objects in space over time. Asteroids don't emit their own light, so we can tell how far away they are from Earth by their brightness. Basically, the brighter the asteroid is, the closer it is to Earth; the darker the asteroid, the further away it is."

Astrogeology, also called "planetary geology," is the study of physical structures outside the boundaries of our own planet such as asteroids, moons, and comets. As humans continue to progress in our ability to successfully reach celestial bodies - from Apollo astronauts stepping foot on the Moon to rovers treading across the landscapes of Mars - scientists are becoming increasingly interested in the information to be discovered on the surface of other worlds.

Wendy's initial curiosity in these space rocks (asteroids) stemmed from an interest in geology.

Images of asteroid 7482 1994PC1, a stony Apollo near-Earth asteroid, observed on 17 January 2022 by Wendy Mendoza and Monica Rosas at CTMO. This asteroid has a diameter of 1.1 kilometers and was discovered in 1994 at Siding Spring Observatory in Australia. Each image was taken using a PlaneWave CDK17 telescope and Finger Lakes Instrumentation PL16803 CCD camera, unfiltered, and with an exposure time of 10 seconds.

Wendy: "When my family and I would do migrant work in Minnesota, we would sometimes need to pick rocks of all sizes out of the fields so that the crops could grow. It was really difficult, but I enjoyed it. It was fun just being with my family. When we'd find a unique rock, we'd say things like 'hey, look at this one!', 'I found an even bigger one!', or 'this one has a cool design on it!'. The rocks were all different sizes and shapes and colors, and looking at them so closely on the fields is how I got interested in rocks. It was really hard, but it was fun. It was a beautiful experience."

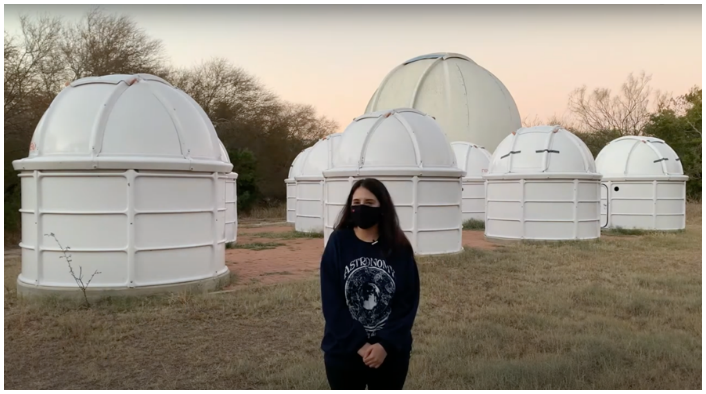
Wendy knew early on that she was interested in outer space and becoming an astronaut, but for a while, she was not sure exactly what she wanted to focus her research on. There were many different projects (time-domain objects in space) to choose from, including variable stars, supernovae, exoplanets, and more. Ultimately, Wendy's natural interest in geology combined with her growing passion for space and turned her toward the exciting field of astrogeology.

Looking to the Future

Though Wendy's ultimate mission is to reach space as an astronaut, her short-term goal for the near future is to discover her own asteroid from CTMO in Brownsville. After her experience with the Space Telescope Science Institute, she also aspires to learn more about the intersection of machine learning and astronomical observation.

When asked what she would respond to someone who was in a similar position as she was - interested in space science, but unsure of a specific path to take - Wendy said the following:

"Explore any fields you're interested in - even if it's not directly related to space, anything can be connected to it. Nursing, communications, art, even psychology - astronauts need psychologists! Just try anything you like, and if you don't want to pursue it, move on to something else. It doesn't really hurt to try. It may be hard, but if you really want it, it can happen." ★



Wendy Mendoza at the CTMO main dome and telescope farm in Resaca de la Palma State Park.

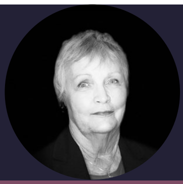
References

[1] https://spaceplace.nasa.gov/asteroid/en/

Biography

Victor De Los Santos is Executive Director and Chair of the Board for the South Texas Astronomical Society. Victor graduated from Hanna High School in 2013. He earned a bachelor of science in business from Texas A&M University - College Station in 2016. He has worked as a software development project manager since 2016.

Rainbow Crow: A Story of Friendship and Sacrifice



An Ancient Astronomers' Tale Retold by Carol Lee

Now it is night; it is time for the telling of tales from the days of long before now. Sit and listen; learn about what it was like in the days of before, when there were no humans upon the face of our earth and the creatures lived in harmony with one another.

In those days the crow was not wearing his splendid black feathers. There *were* feathers all over Rainbow Crow's body; feathers made from the colors worn by the rainbow that danced with the sun when rain fell from the sky: red, orange, yellow, green, blue, indigo, and violet. Rainbow Crow was exceedingly proud of that fact and chose his very name because of it. Sometimes, sad to say, Rainbow Crow would even laugh to himself at the drab colors worn by most of the other creatures that lived nearby.

As if having those beautiful feathers was not enough, at the same time Rainbow Crow was the bird that had the most musical songs to sing. Each day Rainbow Crow would spend hours in the top of a shade tree singing his beautiful songs while other creatures went about their business of living. It seemed to the other creatures that everyone's work was easier to do if they listened to his song drift into their ears.

One cloudy cold morning, while Rainbow Crow was singing in the oak tree, Mouse, Deer, and Fox were sitting underneath the tree resting and listening to the song their friend was singing and something soft, white, wet, and cold began to drift slowly down from the sky. After a while Fox looked over at Mouse and all that could be seen was a small black nose peeking up from a pile of that soft, white, wet, cold stuff that was coming out of the sky.

"Oh! Mouse," exclaimed Fox, "you are covered in soft, white, wet, cold stuff that is falling from the sky. All I can see is your little button nose! Climb on my back and get out of it so you can keep on listening to the song Rainbow Crow is singing."

And Mouse did just that, carefully scampering up along Fox's beautiful silver tail, up on his shoulders, and then sat perched between Fox's pointed ears, safe and warm. But the soft, white, wet, cold stuff kept falling from the sky. After another while Deer looked down and all she could see was the shiny black nose of Fox and the tiny button nose of Mouse sticking up out of the soft, white, wet, cold stuff that was coming out of the sky.

"Oh, Fox. You are covered in the soft, white, wet, cold stuff now! Climb on my back so you and Mouse can keep listening to Rainbow Crow's beautiful song." And so Fox leaped up on Deer's back and sat there to listen while Mouse was perched between Fox's pointed ears, listening too.

That soft, white, wet, cold stuff kept falling out of the sky and finally Rainbow Crow came to the end of his song. He looked down to see three black noses sticking up from a mound of soft, white, wet, cold stuff. "What has happened to my friends? They are in danger from that soft, white, wet, cold stuff. I will fly and get some fire from the Sun!" And off he flew as fast as his wings could take him, far to the west where Sun went each night to rest from his travels across the sky.

Rainbow Crow flew farther and faster than he had ever flown before and when he reached the Western Mountain he was exhausted. He fell onto the rocks outside the cave where Sun was sleeping.

"Sun! Sun! Wake up! I am Rainbow Crow and I need some of your fire to save my friends from the terrible soft, white, wet, and cold stuff that has covered them like a blanket back in the woods," called Rainbow Crow.

Now Sun was not happy to be awakened in such a manner and he opened one eye and glared at Rainbow Crow. "Go away. I am not going to share my fire with you, no matter what. Leave me to my rest!" snarled Sun.

Desperate to save his friends, Rainbow Crow waited silently while Sun wrapped himself up in his bright yellow blanket and went back to sleep. Then Rainbow Crow crept ever so carefully to the edge of the blanket.

"Perhaps I can grab a small ember from Sun's fire with my beak and take it back to warm my friends," thought Rainbow Crow. Stretching his neck as far as possible, he succeeded in picking up a very small, faintly glowing twig and immediately flapped his wings to get out of the way as Sun leaped up shouting, "Stop! Bring back my fire! I told you I was not willing to share any part of my warmth with you."

A desperate Rainbow Crow flew out of the cave and away from the blazing angry Sun as fast as his wings could take him. Faster flew Rainbow Crow, but faster still came Sun. As Rainbow Crow flew, the winds of the air fanned the ember until it began to blaze and send smoke swirling around his head. Feeling as though he was choking, Rainbow Crow kept on flying, but his throat was hurting and he was getting very tired; he was not sure he would be able to reach his friends who needed that fire. Still, as he thought of his friends, he knew that he must keep going if they were to survive, so with his feathers being scorched and his throat in pain from the flames from the ember, on he flew, with the furious Sun hot on his tail.

Just as he thought he could not stay in the air one more minute, Rainbow Crow saw the oak tree his friends were sitting under. He used his last bit of strength and made one last tremendous effort to reach them just as the ember fell from his beak onto the mound of soft, white, wet, cold stuff (I am sure you have guessed this is snow) with a soft *hissssssss* as the snow melted and Sun turned back to return to his secret cave.

The three friends, Mouse, Fox, and Deer, slowly stretched their cramped legs and warmed themselves by the ember while they looked around for Rainbow Crow. But all they saw in the oak tree was a bird with tattered feathers that looked as though it had been scorched with a fire. "Who are you? What are you doing sitting in this tree? What have you done with our friend Rainbow Crow? This is his tree and you are trespassing!" shouted the three friends.

Poor Rainbow Crow tried to answer the loud trio but all that would come out was a harsh CAAAWWWWWW from his painful throat. The three angry creatures shouted at the strange bird and threw rocks and sticks at him until he flapped his wings and flew away to the top of the tallest mountain and into the branches of a tall bare pine tree where he sat and felt sorry for himself. He felt as though his heart was breaking in two.

After all that he had tried to do, the three creatures he had counted as friends had rejected him because he was no longer beautiful and no longer able to sing his songs. From the rain clouds in the sky came a soft voice on the breeze. It was the Great Spirit who asked, "Ah, Little Brother, why are you sorrowing? I tell you that you are more fortunate than your brothers. My rascally two-legged ones are about to appear on the face of this planet and those rascals are going to be nothing but trouble for all of the creatures. Mouse they will catch in traps. Fox they will trap for his fur to wear on their ugly bare skins, and Deer they will hunt for food and coverings for their offspring. Other birds will be caught and placed in cages forever, to never fly freely, so that their songs will delight the two-legged ones; their feathers will be plucked to decorate the two-legs' hair and coverings. No one will want to eat you because you will now taste like smoke. No one will want to hear you sing except me, because I alone hear you, friend. So you will be able to fly to the top of the tallest trees and call out a warning to the other creatures when humans walk into the forest and your fellows will know it is time to hide from those two-legged ones. And I will cause Sun to be the one that reveals the rainbow in your feathers so that those who know to look beyond the obvious will see the beauty hidden in the darkness of your feathers."

And from that day to this, it is so. Look carefully at the crow and his cousins and you will see the rainbow hidden there. Watch to see which birds people keep in cages to sing forever behind bars. And remember the faithful friend and try to be a friend like Rainbow Crow.

And that is the end of the story. ★

Summer 2022

Night Sky Bulletin
Rio Grande Valley, Texas

Saturn Enters Retrograde
Sat, 04 Jun 2022, 16:35 CDT, Capricornus

29 Amphitrite at Opposition
Mon, 06 Jun 2022, 14:10 CDT, Scorpius

Moon at First Quarter
Tue, 07 Jun 2022, 09:49 CDT, Leo

Conjunction of Venus and Uranus
Sat, 11 Jun 2022, 08:14 CDT, Aries

Full Moon
Tue, 14 Jun 2022, 06:51 CDT, Ophiuchus

Moon at Perigee
Tue, 14 Jun 2022, 18:23 CDT, Sagittarius

Moon at Aphelion
Tue, 14 Jun 2022, 22:34 CDT, Sagittarius

Mercury at Greatest Western Elongation
Thu, 16 Jun 2022, 16:21 CDT, Taurus

Conjunction of Moon and Saturn
Sat, 18 Jun 2022, 07:22 CDT, Capricornus

Mercury at Peak Morning Altitude
Mon, 20 Jun 2022, Taurus

Moon at Last Quarter
Mon, 20 Jun 2022, 22:11 CDT, Pisces

June Solstice
Tue, 21 Jun 2022, 04:08 CDT, Taurus

Conjunction of Moon and Jupiter
Tue, 21 Jun 2022, 08:35 CDT, Pisces

Mars at Perihelion
Tue, 21 Jun 2022, 09:01 CDT, Pisces

Mercury at Dichotomy
Wed, 22 Jun 2022, 05:40, Taurus

Conjunction of Moon and Mars
Wed, 22 Jun 2022, 13:15 CDT, Pisces

Lunar Occultation of Mars
Wed, 22 Jun 2022, 14:07 CDT, Pisces

Lunar Occultation of Uranus
Fri, 24 Jun 2022, 17:15 CDT, Aries

Conjunction of Moon and Venus
Sun, 26 Jun 2022, 03:11 CDT, Taurus

Conjunction of Moon and Mercury
Mon, 27 Jun 2022, 03:20 CDT, Taurus

Neptune Enters Retrograde
Tue, 28 Jun 2022, 01:19 CDT, Pisces

Moon at Perihelion
Tue, 28 Jun 2022, 13:57 CDT, Gemini

New Moon
Tue, 28 Jun 2022, 21:53 CDT, Gemini

Moon at Apogee
Wed, 29 Jun 2022, 01:08 CDT, Gemini

Earth at Aphelion
Mon, 04 Jul 2022, 02:10 CDT, Pisces

Moon at First Quarter
Wed, 06 Jul 2022, 21:14 CDT, Virgo

Mercury at Perihelion
Sun, 10 Jul 2022, 17:10 CDT, Gemini

Moon at Perigee
Wed, 13 Jul 2022, 04:05 CDT, Sagittarius

Moon at Aphelion
Wed, 13 Jul 2022, 07:14 CDT, Sagittarius

Full Moon
Wed, 13 Jul 2022, 13:37 CDT, Sagittarius

Conjunction of Moon and Saturn
Fri, 15 Jul 2022, 15:16 CDT, Capricornus

Mercury at Superior Solar Conjunction
Sat, 16 Jul 2022, 14:44 CDT, Gemini

Conjunction of Moon and Jupiter
Mon, 18 Jul 2022, 19:59 CDT, Cetus

134340 Pluto at Opposition
Wed, 20 Jul 2022, 04:46 CDT, Sagittarius

9 Metis at Opposition
Wed, 20 Jul 2022, 06:58 CDT, Sagittarius

Moon at Last Quarter
Wed, 20 Jul 2022, 09:19 CDT, Pisces

Lunar Occultation of Mars
Thu, 21 Jul 2022, 10:55 CDT, Aries

Conjunction of Moon and Mars
Thu, 21 Jul 2022, 11:46 CDT, Aries

Lunar Occultation of Uranus
Fri, 22 Jul 2022, 01:11 CDT, Aries

1 Ceres at Solar Conjunction
Fri, 22 Jul 2022, 01:23 CDT, Cancer

192 Nausikaa at Opposition
Fri, 22 Jul 2022, 16:34 CDT, Sagittarius

Moon at Apogee
Tue, 26 Jul 2022, 05:21 CDT, Gemini

Conjunction of Moon and Venus
Tue, 26 Jul 2022, 09:12 CDT, Gemini

New Moon
Thu, 28 Jul 2022, 12:56 CDT, Cancer

Jupiter Enters Retrograde
Thu, 28 Jul 2022, 15:32 CDT, Cetus

Moon at Perihelion
Fri, 29 Jul 2022, 12:53 CDT, Leo

Conjunction of Moon and Mercury
Fri, 29 Jul 2022, 16:08 CDT, Leo

Conjunction of Mars and Uranus
Mon, 01 Aug 2022, 04:22 CDT, Aries

Moon at First Quarter
Fri, 05 Aug 2022, 06:07 CDT, Libra

Moon at Perigee
Wed, 10 Aug 2022, 12:08 CDT, Sagittarius

Moon at Aphelion
Wed, 10 Aug 2022, 16:54 CDT, Capricornus

Full Moon
Thu, 11 Aug 2022, 20:35 CDT, Capricornus

Conjunction of Moon and Saturn
Thu, 11 Aug 2022, 22:55 CDT, Capricornus

Saturn at Opposition
Sun, 14 Aug 2022, 12:02 CDT, Capricornus

Conjunction of Moon and Jupiter
Mon, 15 Aug 2022, 04:41 CDT, Cetus

Lunar Occultation of Uranus
Thu, 18 Aug 2022, 09:14 CDT, Aries

Moon at Last Quarter
Thu, 18 Aug 2022, 23:36 CDT, Taurus

Conjunction of Moon and Mars
Fri, 19 Aug 2022, 07:17 CDT, Taurus

Mercury at Peak Evening Altitude
Sat, 20 Aug 2022, Virgo

4 Vesta at Opposition
Mon, 22 Aug 2022, 06:58 CDT, Aquarius

Moon at Apogee
Mon, 22 Aug 2022, 16:52 CDT, Gemini

Mercury at Aphelion
Tue, 23 Aug 2022, 16:33 CDT, Virgo

Uranus Enters Retrograde
Wed, 24 Aug 2022, 08:40 CDT, Aries

Conjunction of Venus and Ceres
Wed, 24 Aug 2022, 14:13 CDT, Cancer

Conjunction of Moon and Venus
Thu, 25 Aug 2022, 15:58 CDT, Cancer

New Moon
Sat, 27 Aug 2022, 03:18 CDT, Leo

Mercury at Greatest Eastern Elongation
Sat, 27 Aug 2022, 04:47 CDT, Virgo

Moon at Perihelion
Mon, 29 Aug 2022, 03:18 CDT, Virgo

Conjunction of Moon and Mercury
Mon, 29 Aug 2022, 05:51 CDT, Virgo

Mercury at Dichotomy
Mon, 29 Aug 2022, 11:31 CDT, Virgo

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* is for anything orbiting the Sun; *apogee* and *perigee* is for the Moon orbiting 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

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--- Major Meteor Showers (Class I) ---

Southern Delta Aquariids (SDA)
Peak: Jul 30
Activity: Jul 12 – Aug 23
Radiant: (α = 22:42, δ = -16:18)
Speed: 40 km/s
ZHR: 20

Perseids (PER)
Peak: Aug 13
Activity: Jul 14 – Sep 1
Radiant: (α = 03:13, δ = 58:00)
Speed: 59 km/s
ZHR: 100

--- Minor Meteor Showers (Class II) ---

July Pegasids (JPE)
Peak: Jul 11
Activity: Jul 04 – Aug 08
Radiant: (α = 23:11, δ = 10.48)
Speed: 64 km/s
ZHR: 5

Alpha Capricornids (CAP)
Peak: Jul 30
Activity: Jul 03 – Aug 15
Radiant: (α = 20:26, δ = -09:06)
Speed: 22 km/s
ZHR: 4

Kappa Cygnids (KCG)
Peak: Aug 18
Activity: Aug 01 – Aug 27
Radiant: (α = 19:05, δ = 50:12)
Speed: 22 km/s
ZHR: 3

--- Variable Meteor Showers (Class III) ---

June Bootids (JBO)
Peak: Jun 27
Activity: Jun 25 – Jun 29
Radiant: (α = 14:48, δ = 47:54)
Speed: 14 km/s

Beta Hydusids (BHY)
Peak: Aug 17
Activity: Aug 15 – Aug 19
Radiant: (α = 02:25, δ = -74:30)
Speed: 23 km/s

--- Weak Meteor Showers (Class IV) ---

Daytime Arietids (ARI)
Peak: Jun 10
Activity: Apr 14 – Jun 24
Radiant: (α = 02:46, δ = 23:42)
Speed: 41 km/s

June Iota Pegasids (JIP)
Peak: Jun 25
Activity: Jun 25 – Jun 27
Radiant: (α = 22:06, δ = 29:18)
Speed: 59 km/s

Phi Piscids (PPS)
Peak: Jun 25
Activity: Jun 13 – Jul 05
Radiant: (α = 00:40, δ = 21:24)
Speed: 67 km/s

Microscopiids (MIC)
Peak: Jul 06
Activity: Jun 25 – Jul 16
Radiant: (α = 21:13, δ = -27:00)
Speed: 40 km/s

July Chi Arietids (JXA)
Peak: Jul 07
Activity: Jun 26 – Jul 22
Radiant: (α =02:11 , δ = 07:48)
Speed: 68 km/s

Phi Piscids (PPS)
Peak: Jul 10
Activity: Jul 02 – Jul 22
Radiant: (α = 01:23, δ = 27:54)
Speed: 67 km/s

c-Andromedids (CAN)
Peak: Jul 12
Activity: Jun 21 – Jul 28
Radiant: (α = 02:10, δ = 48:18)
Speed: 57 km/s

Northern June Aquilids (NZC)
Peak: Jul 15
Activity: Jun 26 – Jul 22
Radiant: (α = 21:18, δ = -02:24)
Speed: 38 km/s

Zeta Cassiopeiids (ZCS)
Peak: Jul 16
Activity: Jul 07 – Jul 22
Radiant: (α = 00:30, δ = 50:54)
Speed: 57 km/s

July Gamma Draconids (GDR)
Peak: Jul 28
Activity: Jul 23 – Aug 03
Radiant: (α = 18:42, δ = 50:36)
Speed: 27 km/s

Piscis Austrinids (PAU)
Peak: Jul 29
Activity: Jul 15 – Aug 10
Radiant: (α = 23:53, δ = -20:12)
Speed: 43 km/s

Eta Eridanids (ERI)
Peak: Aug 06
Activity: Jul 10 – Sep 10
Radiant: (α = 02:44, δ = -13:00)
Speed: 64 km/s

Northern Delta Aquariids (NDA)
Peak: Aug 12
Activity: Aug 02 – Aug 17
Radiant: (α = 23:02, δ = 00:54)
Speed: 39 km/s

August Xi Draconids (AXD)
Peak: Aug 15
Activity: Aug 04 – Aug 28
Radiant: (α = 18:26, δ = 53:36)
Speed: 20 km/s

Beta Hydusids (BHY)
Peak: Aug 17
Activity: Aug 15 – Aug 19
Radiant: (α = 02:25, δ = -74:30)
Speed: 23 km/s

August Beta Piscids (BPI)
Peak: Aug 21
Activity: Aug 17 – Sep 08
Radiant: (α = 23:30, δ = 04:24)
Speed: 38 km/s

Zeta Draconids (AUD)
Peak: Aug 26
Activity: Aug 12 – Sep 05
Radiant: (α = 17:16, δ = 62:48)
Speed: 21 km/s

August Gamma Cepheids (AGC)
Peak: Aug 29
Activity: Aug 17 – Sep 06
Radiant: (α = 23:57, δ = 76:54)
Speed: 44 km/s

Definitions

Activity – the range of expected dates over which a meteor shower event is observable.

Class – an intensity scale for meteor showers developed by Robert Lunsford

Major Meteor Shower (Class I) – annual, stronger meteor showers with ZHRs of 10 or greater

Minor Meteor Shower (Class II) – consistent, weaker meteor showers with ZHRs between two and 10.

Peak – the date on which the highest ZHR for a meteor shower is expected.

Radiant – the point from which a meteor shower appears in the sky. Here it is defined as two sky coordinates: right ascension (α, hh:mm) and declination (δ, dd:mm).

Speed – average speed of meteors as they enter the atmosphere.

Variable Meteor Shower (Class III) – inconsistent, yet potentially spectacular meteor showers

Weak Meteor Shower (Class IV) – weakest meteor showers reserved for observers seeking a challenge, with ZHRs less than two.

Zenith Hourly Rate (ZHR) – the expected number of observed meteor events per hour if the radiant of the shower was at zenith and observed under ideal conditions (limiting magnitude of +6.5).

References

2022 Meteor Shower List, American Meteor Society

D. Ford (2011-2022), In-The-Sky.org

Colophon

Contributors
Andrew Maurer
Carol Lutsinger
Jaqueline Peña
Miles Hartl
Olivia Lincoln
Victor De Los Santos

Illustrators
Gabrielle Camuccio

Production and Layout
Richard Camuccio
Victor De Los Santos

Editor-in-Chief
Richard Camuccio

Website
www.starsocietyrgv.org

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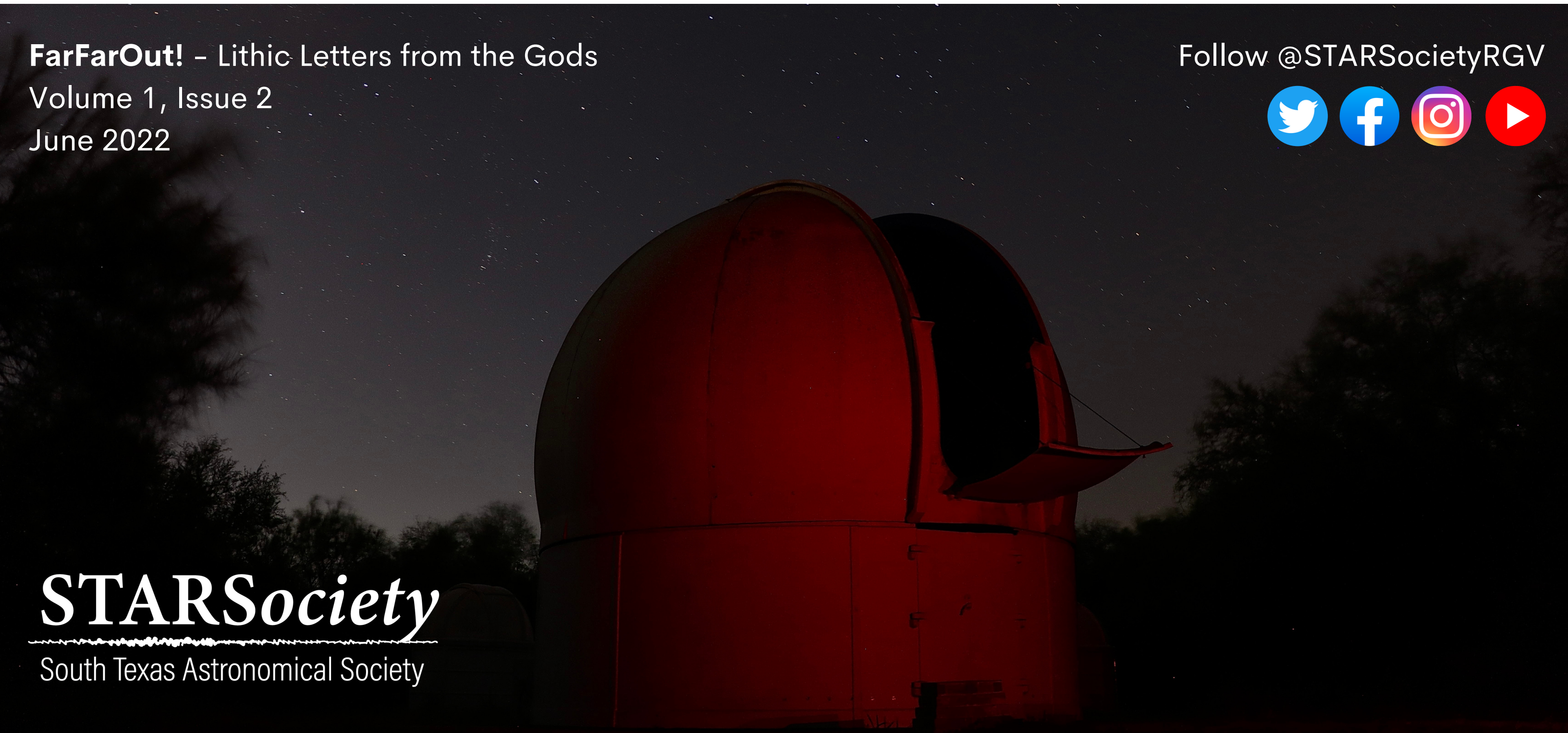
The South Texas Astronomical Society (STARS) is a nonprofit organization connecting the Rio Grande Valley community to space and science.

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.



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