A Starry Multi-Messenger

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Editorial

When Galileo pointed the "spyglass" at the night sky in 1609, his published observations the following spring (*Sidereus Nuncius – Starry Messenger*) ushered in a new era of astronomy. Over four centuries later, we follow his practice of collecting photons from the starry heavens with our telescope buckets – now situated all over the hills, in the valleys, and in the space above our heads.

On August 17, 2017, two neutron stars outside our Galaxy collided and merged in an event that was observed unlike any previously seen in the history of astronomy. The merger produced gravitational waves, ripples in spacetime, that were felt by detectors on Earth. The detectors sent alerts to a network of telescopes, and following the initial detection, over 70 independent observations were made of the event in the sky. What was seen was spectacular – a spacetime disturbance, a burst of gamma rays, and an afterglow of nuclear material that was seen for weeks and months later. We are now in the era of *multi-messenger astronomy*, where we have a plethora of tools available for observing the heavens, building on the legacy first set forth by the practice of turning spyglasses to the sky.

In this issue, *A Starry Multi-Messenger*, we explore the exciting frontier of multi-messenger astronomy with a collection of the finest articles I have edited – and which I am absolutely proud to share. We will learn what it's like to work for a gravitational wave (GW) observatory, and how to become a GW astronomer; listen to thunderclaps and other noise sources that plague GW detectors on the ground and in space; investigate the multi-tools of Perseverance as it searches the deserts of Mars; learn about the newly-launched James Webb Space Telescope, which will give us information about the earliest of messengers; discover how a small observatory on the ground can bring its tools to bear on exciting problems, such as tracking rocks in space and finding optical counterparts to GWs; learn how to join in on celebrating the World Space Week in October; listen to ancient tales of the Sun; learn about the Fall night sky in southern Texas.

Wishing you clear skies,

Richard Camuccio
Editor-in-Chief

Contents

Carol's Corner of the Cosmos

Carol Lutsinger

Are you a moon watcher? The Full Moon of September is the famous Harvest Moon on the 10th. The Moon, just barely clearing the horizon, will rise just a little bit later now due to the angle of the ecliptic and the Moon's position nearly on it during this time of the year. If you aren't sure what the ecliptic is, imagine two hula hoops intersecting, with an acute angle and an opposite obtuse angle, with one being the horizon, the other the ecliptic. Regular readers may remember the ecliptic is the apparent "path" along which the Sun, Moon, and planets' motions occur.

Summer is winding down to autumn this month. As our spacecraft Earth takes us on our daily adventures rotating and revolving, we have been drawing closer to the autumn equinox. On September 22 our planet reaches the three-quarters mark on its annual trek around the Sun. Earthlings will be experiencing nearly equal amounts of daylight and darkness on our world. Official sunrise time at the point of the vertices of the ecliptic and the equator, imaginary circles we use to geometrically describe and locate positions on Earth and in space, is the starting point of the change of seasons that mark the equinoxes. Our hometown time for officially being in autumn will be at 8:03 PM September 22.

You might consider this to be a perfect time to do a family or classroom astronomy activity and measure the shadow cast by flag or light pole or some other upright standard. Plan to take another measurement during the winter solstice, again on the vernal equinox, and the summer solstice. You may be surprised at what you discover.

You may have already noticed the earlier nightfall and the smallest bit of cooler air in the morning as you leave for work. As our blue planet circles about the Sun, when we reach this point of the orbit our Sun appears in the morning directly over the equator, and sets directly over it as well. This gives us nearly equal hours of day and night, hence the term "autumnal equinox." Throughout autumn, the Sun will appear along the horizon just a bit farther south of east each day and disappear into the western horizon just a little bit farther south of west. Some western indigenous peoples had wonderful stories to tell about this phenomenon.

It isn't your imagination; it is darker earlier so we can see stars earlier since darkness will fall earlier. We can still enjoy our faithful summer constellations. The Summer Triangle is overhead by full dark. If you are standing facing west and looking up, then Vega (the Lyre) is low, Deneb (in Cygnus the Swan) is to your right, and Altair (the eye of Aquila the Eagle) is to the left. Bring your gaze down toward the horizon to enjoy the gleam of Arcturus in Boötes, the Herdsman. To the right of Arcturus, you may be able to discern the stars of the handle of the Big Dipper in the northwest.

Look between Vega and Arcturus to see if you can locate Hercules. It looks like a keystone of the arch of an old stone bridge. Below Hercules you may also be able to see a small delicate curve of stars known as the Corona Borealis. Below Boötes and a bit to the north (right), look for an inverted triad of stars known as the Coma Berenices.

If you turn about and face east, then you will see the Great Square of Pegasus has risen up from the horizon about halfway to the zenith. Imagine you are facing a baseball diamond layout with home plate at the top, then first base to the left, etc. At first base is where Andromeda trails off to the NE. Look below third base to see if you can see a pentagon shape that is one of the fish of Pisces.

If you are a regular star gazer then try to find the delicate constellation Delphinus just to the upper left of the bright star Altair in the Eagle (Aquila). Beginning sky watchers may think this group is the Little Dipper asterism, not realizing the Little Dipper is always in the northern part of our sky in this hemisphere. The Dolphin is a cluster of five stars in a small kite shape. There is a Y shape of stars just above Altair that is Sagitta, the Arrow. You need fairly dark skies to locate these small, delightful constellations.

If you like puzzles, you might like to know that the names of two stars in Delphinus are named Sualocin and Rotanev, the name of the Italian astronomer Nicolaus Venator at the University of Palermo observatory who placed the name in the first catalog of stars compiled at that university!

What other wonders have you discovered as you star gaze? You might want to start keeping a list of the heavenly discoveries you make. Did you know we can still see pages from journals kept by Galileo? Your records might inspire a future generation's interest in what YOU discover.

Until next time, Keep Looking Up, and DO let some stars get in your eyes. ★

Figure 1: The Moon as seen by the Cristina Torres Memorial Observatory. The image is a one-second exposure taken in the SDSS u band with a CDK17 astrograph and PL16803 camera. Image taken on 1 July 2020 by Wahltyn Rattray and Richard Camuccio.

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.

Thunderclaps and Gravitational Wave Transients

Brina Martinez

It is easy to learn and accept many of the things we learn growing up, such as how the planets revolve around the Sun, how the Moon revolves around the Earth, and how we can use a telescope to view the untouchable with our own eyes. But it is not as easy to accept the things that aren't fully understood or yet discovered, but they are, in my opinion, the most fun things to bring to light.

Let's begin by breaking down the phrase "Gravitational Waves." We have the word "Gravitational," given by the definition - "relating to movement toward a center of gravity," and the word "Waves," where most of us would think of the ripples produced by the motion of water moving in the ocean, given by the scientific definition - "a propagating dynamic disturbance of one or more quantities." Now that we defined those two words, what do we think gravitational waves "look" like? Or, should I say, what do they "sound" like?

Detecting gravitational waves is not easy. Although they are produced from some of the most eventful collisions, they are invisible to the eye, and occur so far away that by the time they reach Earth, the effects are minuscule and require extremely sensitive machines to record them. Although we cannot see gravitational waves or the objects that create them, such as black holes, due to lack of light, we can hear such collisions by using light, specifically laser light. And that is exactly what LIGO does. LIGO stands for the Laser Interferometer Gravitational-Wave Observatory. There are currently two ground-based detector sites in the United States: one in Livingston, Louisiana and another in Hanford, Washington. The LIGO detectors are built in an "L" shape, where each arm of the detector spans roughly four kilometers long. LIGO's construction is based on a Michelson interferometer. LIGO collaborates with other ground-based detectors such as GEO600 in Germany, Virgo in Italy, and eventually KAGRA in Japan. On September 14, 2015, LIGO was the first experiment to directly detect and prove the existence of gravitational waves.

Although the first gravitational wave detection was discovered in 2015, it wasn't until I was a Junior in college that I learned about LIGO, what interferometers were, and the detection of gravitational waves. I attended a conference for undergraduate women in physics in 2019, where I met Dr. Gabriela González and listened to a presentation she gave about LIGO and gravitational waves. I instantly thought she was the coolest person ever, I thought interferometers were amazing, and LIGO data was something I wanted to work with. A few months later I managed to get into a Research Experience for Undergraduate Students (REU) at Louisiana State University (LSU) to work under Dr. Gabriela González and Dr. Guillermo Valdés on LIGO-related projects.

At LSU I worked with the Detector Characterization (DetChar) group, primarily at the Livingston, Louisiana site. Since LIGO is such a sensitive instrument, it often picks up unwanted signals from terrestrial sources. For example, noise from ground motion due to extreme weather can show up in the detector data. Scientists working in the DetChar group monitor the status of the detector, verify common and new noise sources, and correlate data to reassure that we are looking at an actual gravitational wave signal. Louisiana is subject to multiple thunderstorms throughout the year which lead to disturbances in the detector in the form of acoustic noise from thunderclaps. Located inside

LIGO are many different types of monitoring sensors, and a few examples are accelerometers, seismometers, and microphones. Since thunderclaps result in both vibrational and acoustic noise, we used data from microphones inside the detector to determine the effect on the detector data. To correlate data from thunderclaps in the detector we took a look at dates and times in which thunderstorms occurred near the detector site and gathered microphone data. We then created a machine learning algorithm that used known thunderclap noise to identify unknown noise data into "thunderclap" and "not thunderclap" categories. My work was part of a three-step process, where we identified thunderclap noise, located where in the LIGO detector it showed up (which showed us how close/far the thunderstorm was), and allowed us to determine the effects it had on the detector data at different frequencies and areas.

After completing my REU at LSU, I returned back to my university but continued to work on DetChar projects related to mitigating environmental noise that affects the Livingston detector. The next summer I was fortunate enough to land a Summer Undergraduate Research Fellowship with the California Institute of Technology's (Caltech) LIGO Lab. I was still working with the DetChar group, but instead of analyzing acoustic noise data, I worked on analyzing different data quality veto methods used in a program called PyCBC. PyCBC is a pipeline written in Python (Py) that uses previously simulated gravitational waveforms to search for potential gravitational wave signals produced from compact binary coalescences (CBC). CBCs occur when two compact objects such as black holes or neutron stars coalesce and experience an inspiral (where they spin around each other), a merger (when they come into contact), and a ringdown (where the chaotic event settles down). PyCBC uses a signal-to-noise ratio (SNR) statistic when determining if a signal is a gravitational wave. If we ran a set of obtained data across waveform templates and saw a high SNR, that would mean we came across a potential gravitational wave signal. The pipeline uses what are called "flags" to remove data it believes are correlated to some type of physical coupling, such as noise mentioned before from thunderstorms or other terrestrial disturbances.

Although the pipeline was successful in determining some gravitational waves, the way it flagged and removed data was not the best. It worked by completely removing chunks of data that carried noise, which could remove a potential gravitational signal completely if it is covered by the noise. To mitigate the effects of this issue a new veto method was introduced. I worked on programming an efficient veto method that did not remove any flagged data, but instead re-ranked flagged data so that it became less significant compared to any potential signals in the same data (and which increased the sensitivity of the program and increased the possibility of finding signals).

The current ground-based detectors we use have already told us so much about the universe, but there is still a lot more we can discover. Although ground-based detectors continue to improve in sensitivity, there are limits on the performance of current detectors from noise, how large a ground-based detector can be, and how well they can detect certain frequencies of gravitational waves.

Next-generation detectors will focus on frequency bandwidths not yet achieved in ground-based detectors, and one way to mitigate the limits we have seen so far in ground-based detectors is to go to space, where there is no limit to how loarge the observatory can be, and there is effectively much less noise. LISA, which stands for the Laser Interferometer Space Antenna, is a large-scale space-based gravitational wave observatory. Unlike the LIGO detectors, which consist of an interferometer with two arms creating an "L" shape, the LISA observatory will consist of three spacecraft, creating an equilateral triangle constellation, each separated by roughly 2.5 million kilometers.

I am currently a graduate student in Aerospace Engineering at Texas A&M University. Although working with data analysis was very fun, I always like to learn new skills, and I now focus on developing optomechanical accelerometers that could potentially be used for future gravitational wave detectors. I work on the design, modeling, fabrication, and readout of compact optomechanical resonators. Resonators are devices that experience a resonant motion at a given frequency. Accelerometers work by tracking the oscillations of a test mass such as one on a resonator, and though there are currently many versions of optomechanical accelerometers, in most cases they operate at high frequencies or are large in size for lower frequencies. The current models I developed are roughly 1.2 inches in size and have a relatively low frequency (20-35 Hz range) which is not common. I develop models using multiphysics software such as Solidworks and COMSOL, and use simulations to understand how the models act, what resonant frequency they achieve, and how the effects of stress look on the system (since we do not want our devices to break easily). Once I have a design that matches our requirements, I am able to fabricate them at my university's nanofabrication facility. The two materials we focus on are fused silica, which is currently used in gravitational wave observatories, and silicon, which has been found to perform better than fused silica at cryogenic temperatures (which future detectors plan to operate at). At the nanofabrication facility I am able to fabricate resonators in silicon using silicon wafers, which are cryogenically etched. Once we have fabricated resonators, I set up a fiber-based Fabry-Pérot cavity to test the sensors' performance, where we measure a displacement that is turned into acceleration, eventually creating an accelerometer.

The detection of gravitational waves not only opened a new perspective of the universe, but generated curiosity that will potentially lead to other amazing scientific endeavors. I personally cannot wait to see how future gravitational wave detectors operate, what new devices will arise for these experiments, and what kind of information we will get from new detections. ★

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https://lisa.nasa.gov

Biography

Brina Martinez is an aerospace engineering student at Texas A&M University. She obtained a bachelor's degree in physics from the University of Texas Rio Grande Valley. Her research has primarily focused on areas related to gravitational physics through programming and experimental physics/engineering. Brina also works with STARS as a board member.

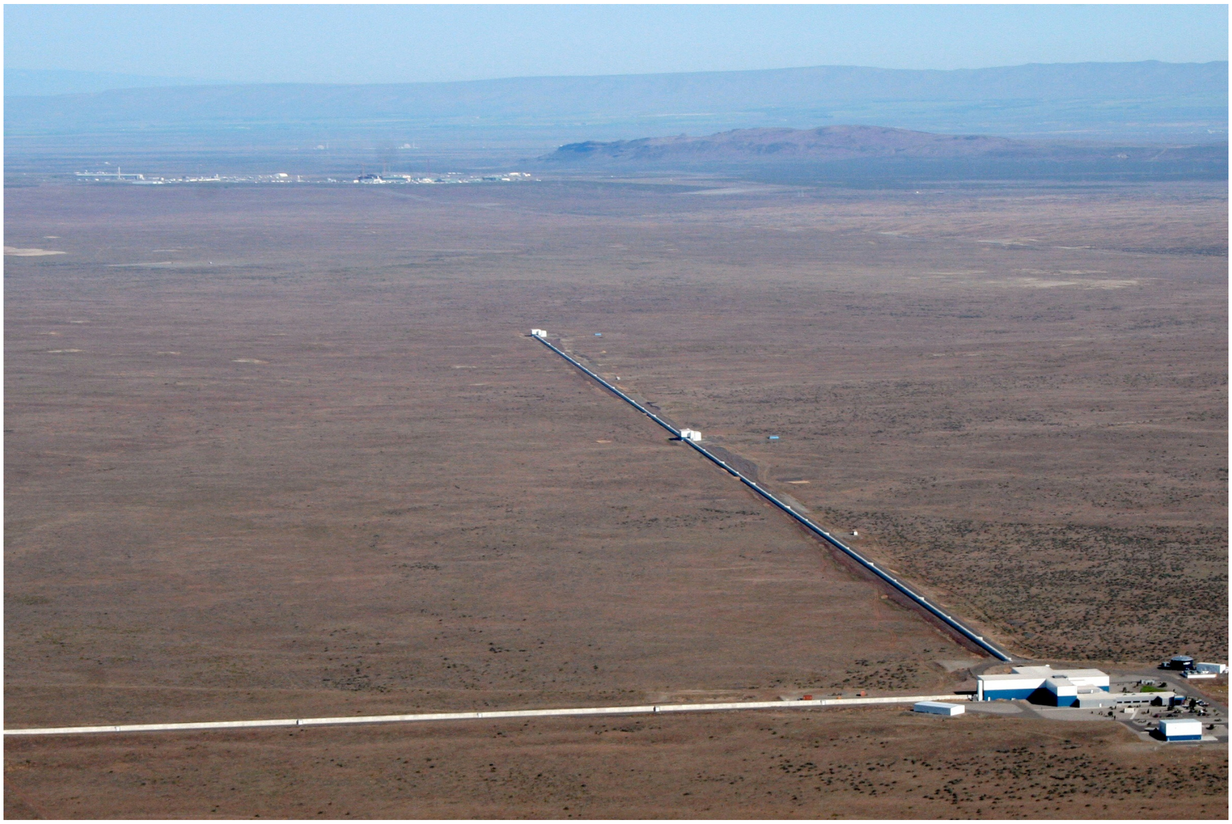

Figure 1: The LIGO Hanford Observatory in Hanford, Washington. For scale, each arm is four kilometers long, and the detector measures relative changes less than one ten-thousandth the diameter of a proton. An identical observatory exists in Livingston, Louisiana, and together they form a network of ground-based gravitational wave detectors. Image credit: The LIGO Scientific Collaboration (2008).

What Is It Like to Work as a LIGO Scientist, and How Do I Become One?

Dr. Guillermo Valdés

It was the morning of September 14, 2015; everything seemed normal at the Laser Interferometer Gravitational-Wave Observatory (LIGO), a couple of days before the first observation phase scheduled for September 18, 2015, would formally begin. At the time, I was an intern researcher at LIGO. Little did I know that this day would become one of the most exciting days of my life.

And it is because that day, while we were sleeping (at 4:40 am CT time) in this part of the globe, the LIGO detectors had observed for the first time a signal of gravitational waves generated by one of the most violent events in the universe: the collision of two black holes with masses about 30 times the mass of the Sun, and which happened 1.4 billion light-years away from Earth! (For comparison, one light-year equals more than 63 thousand times the distance from the Earth to the Sun.)

However, we saved the celebrations for a few months since we had a lot of work to do before giving the formal announcement on February 11, 2016. But what is the relevance of this detection that made it worthy of the Nobel Prize in Physics? And what is it like to work as a LIGO scientist, and how do I become one?

What are gravitational waves and how do we detect them?

Gravitational waves are distortions in **space-time** generated by the acceleration of objects, like the waves formed in a lake when we throw a stone. But only massive events such as colliding **black holes** (BH) or **neutron stars** (NS) generate gravitational waves large enough that we can detect with our current technology. From now on, I will refer to gravitational-wave detectors as simply *detectors*, and to gravitational waves as *GW*.

We use ground-based detectors such as those in LIGO in the USA (one in Hanford, Washington, and another in Livingston, Louisiana), Virgo in Italy, and KAGRA in Japan to observe GWs. Each detector consists of an L-shaped interferometer with arms several kilometers long. As their name implies, interferometers measure interference and are ideal devices for measuring tiny length changes. When GWs pass through the detector, one arm of the L contracts while the other lengthens, producing patterns in the data that are proportional to the wave's amplitude. These detectors can measure amplitudes on the order of 10^{-23}, which is thousands of times smaller than the diameter of a proton!

The detection of GWs on September 14, 2015 (so-called GW150914) generated by two BHs colliding opened a new window in astronomy, capable of verifying the existence of invisible events for other types of observatories. Since BHs do not emit light, we do not expect these events to emit light waves, making them difficult to observe by conventional observatories. This detection also confirmed Einstein's theory (formulated a hundred years ago) about the existence of GWs, but even he doubted we could detect them one day. The GW150914 detection was a joint achievement in which more than a thousand scientists worldwide participated, and three members of the LIGO Scientific Collaboration received the 2017 Nobel Prize in Physics. Still, the rest of the Scientific Collaboration was also recognized with the Breakthrough Prize in in Fundamental Physics (my favorite because it included all the scientists that made this possible, we received a medal and some monetary retribution) and a few other awards.

Figure 1: With the Nobel Prize Medal given to one senior member of the LIGO observatory. Very proud because my work helped with the detection of gravitational waves.

What Is It Like to Work as a Gravitational-Wave Astronomy Scientist?

Reporting the detection of a GW requires great effort, and we can achieve greater goals when working in teams.

There are teams dedicated to:

- Keeping the correct functioning of the detectors. This work requires lots of hands-on activities inside and outside the vacuum chambers enclosing the mirrors and lasers. It requires knowledge in physics, optics, electronics, robotics, and expertise in the operation of the observatory.
- Maintaining the algorithms identifying the GW signals and the source parameters. The detectors record tons of data containing the GW signals buried in noise. These computer programs trigger an alarm every time they find a signal with the waveform of a GW in one or more of the detectors. Then, other algorithms calculate the parameters of the source (for example, the masses of the two BHs colliding and the location in the sky). This task requires expertise in physics, astronomy, and a passion for coding.
- Analyzing the data recorded by the detectors and hundreds of auxiliary sensors, such as **accelerometers** and **magnetometers**, to verify the GW is genuine and not a sporadic noise. These scientists love data analysis and pattern recognition. They use **machine learning** and many other techniques to create automated tools that help improve the performance of the observatory. It requires knowledge about the observatory and the newest developments in data analysis and **artificial intelligence**.

Finally, the Scientific Collaboration chooses a group of people (around ten persons) to write the article that will bear the name of more than 1400 authors in some of the world's best scientific journals. Some time ago, when I was part of the article writing team, I realized how demanding this task was. One barely sleeps because you must meet remotely with people in Europe, Asia, and Australia with very different time zones. At some point, you receive hundreds of comments daily from the world experts in gravitational-wave astronomy, which one must address as soon as possible. But, in the end, it is a great feeling to know you are part of an article close to perfection.

How Did I Become a Gravitational-Wave Astronomy Scientist?

In short, with effort, perseverance, and patience. But let me tell you more about how an electronics and communications engineer participated in one of the most important discoveries in the history of astronomy. When I finished my degree, I moved to the Rio Grande Valley to study the M.S. in physics, because Mario Díaz (who later became my advisor and mentor) convinced me that physics is fun, there are plenty of scholarships and opportunities for STEM careers, and I could use my signal processing knowledge in the astronomy field. Spoiler alert: he was right in everything.

Once in the master's program, I helped with the CTMO - Cristina Torres Memorial Observatory [1] construction, learned about GWs, and began my journey characterizing the LIGO detectors and their noise. Working as a detector characterization scientist requires expertise in the observatory's functioning and state-of-the-art data analysis techniques. We communicate our findings to others who will implement improvements to eliminate the noise.

I continued my work on detector characterization for the physics Ph.D. at the University of Texas Rio Grande Valley. I focused on applying data analysis techniques to study the noise in LIGO. I employed signal processing methods such as Kalman filters and the Hilbert-Huang transform, used in navigation, economics, tracking objects, analyzing sea level heights, and electroencephalography. I used these same methods to study the noise generated by the laser heating the mirrors and to locate sporadic noise that can be confused with GW signals.

One of the things that I love the most in working as a scientist in the LIGO collaboration is the variety of investigations you can perform. You can work on-site or remotely, do coding or hands-on experiments, be responsible for current technologies' correct functioning, or design new devices for future generations of observatories.

Figure 2: Guillermo on the right of the picture, helping with the CTMO construction in 2007 (then the Nompuewenu Observatory).

How Can You Become a Gravitational-Wave Astronomy Scientist?

The best way is by studying physics, astronomy, or being related to any of the 120 institutions belonging to the LIGO, Virgo, and KAGRA scientific collaborations. Your options increase by completing a graduate degree and expanding to institutions involved in space-based GW observatory missions, future generations of ground-based GW observatories, and **multi-messenger astronomy**.

But, if you think that after 90 GW detections, including those coming from binary systems (like BH-BH, NS-NS, and NS-BH), a Nobel Prize, a Breakthrough Prize, and a Princess of Asturias Prize, there is not too much left to do in GW astronomy - think twice. There are other types of GW sources we haven't detected yet. For example, there are **continuous** GWs produced by a massive spinning object like a neutron star with any imperfections in its spherical shape; **burst** GWs coming from exploding stars known as supernovae; **stochastic** (fancy word for "random") GWs originated in the Big Bang. You could help detect them when writing your thesis on the improvements in the existing observatories and the development of space-based observatories like LISA - Laser Interferometer Space Antenna [2], and the next generation of ground-based observatories like the ET - Einstein Telescope [3]. Additionally, you could work at observatories like CTMO and observe the electromagnetic counterpart of a GW detection.

And your work might not be limited to the study of GWs. You could develop instruments necessary to ensure the correct functioning of the observatories, as I do at the Department of Aerospace Engineering of Texas A&M University. Here, we design and fabricate instruments (also called sensors) to measure vibrations. Our sensors use non-conventional technologies and materials such as interferometers and glass pieces. Our interferometers are a couple of centimeters, very tiny compared to the kilometers-long interferometers used in GW detectors. We use glass because it is lighter and introduces less noise in the measurements than the metallic pieces used in conventional sensors.

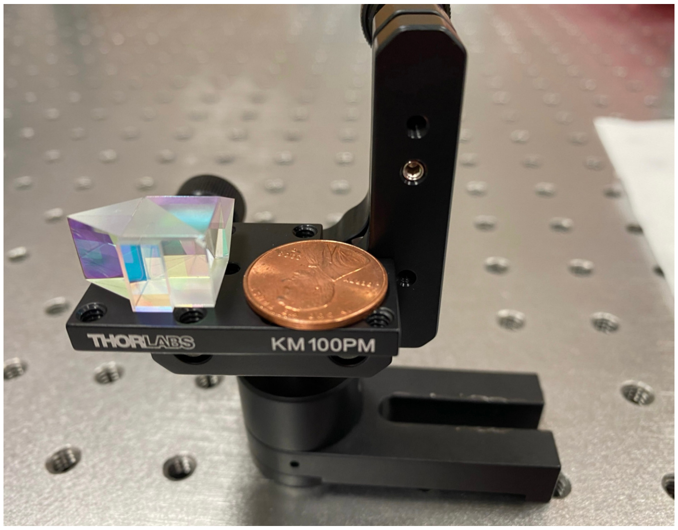

Figure 3: Our vibration sensors consist of small pieces made of glass called resonators and interferometers. This photo is an interferometer, very small compared to LIGO's kilometers-long interferometers.

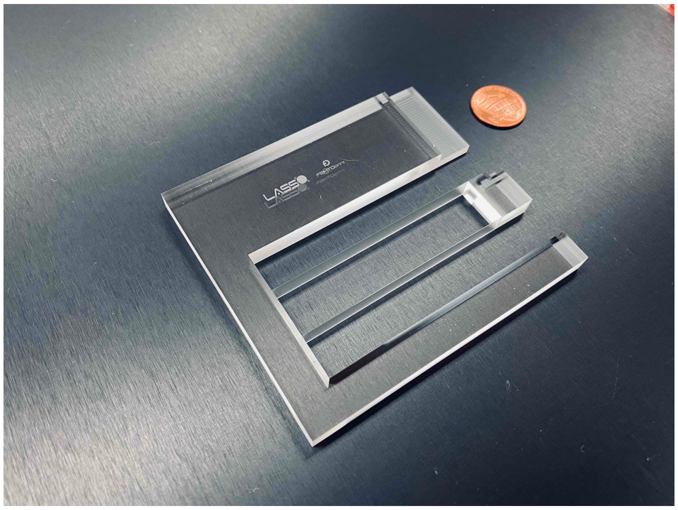

Figure 4: This photo is a resonator, another part of our sensors that move according to the vibration of the body under test.

Finally, I will give you some advice that has worked for me. Listen to others' experiences and share yours. I knew about the graduate program and scholarships at the University of Texas, thanks to my cousin. Very important: take advantage of the opportunities you encounter on the road, and don't be afraid to try new things. You never know what you will eventually discover. ★

Figure 5: With Neil deGrasse Tyson at the LIGO observatory control room.

Glossary

- *Accelerometer*: A tool that measures acceleration.
- *Algorithm*: A procedure for solving a problem or performing a computation.
- *Artificial intelligence*: Refers to the general ability of computers to emulate human thought and perform tasks in real-world environments.
- *Binary system*: A system with two objects in orbit around one another.
- *Black hole*: A region of extremely warped space-time caused by a highly compact mass where the gravity is so intense it prevents anything, including light, from leaving.
- *Characterizing*: A description of the distinctive nature or features of something.
- *Interference*: The net effect of combining two or more waves moving on intersecting or coincident paths.
- *KAGRA*: An underground gravitational-wave detector situated near Toyama, Japan. It is also a laser interferometer, but with three-kilometer-long arms and cryogenically-cooled mirrors.
- *LIGO*: A US-based pair of gravitational-wave detectors. One is situated near Livingston, Louisiana, and the other near Hanford, Washington. Both detectors are large-scale laser interferometers with two perpendicular four-kilometer-long arms that attempt to measure any changes in the relative arm length caused by a passing gravitational wave.
- *Machine learning*: Refers to the technologies and algorithms that enable systems to identify patterns, make decisions, and improve themselves through experience.
- *Magnetometer*: An instrument for measuring the strength and direction of magnetic fields.
- *Multi-messenger astronomy*: The practice of synthesizing various messengers (like electromagnetic radiation, gravitational waves, neutrinos, and cosmic rays) from violent

astronomical events.

- *Neutron star*: A relic of a massive star. When a massive star has exhausted its nuclear fuel, it dies in a catastrophic way that may result in the formation of a neutron star. These stars are about as massive as our Sun, but with a radius of about ten kilometers.
- *Space-time*: A conceptual model combining the three dimensions of space with the fourth dimension of time. It can be thought of as a 'fabric' in which the objects of the universe are embedded.
- *Virgo*: A gravitational-wave detector situated near Pisa, Italy. It is also a laser interferometer, but with three-kilometer-long arms.
- *Waveform*: A representation of how a gravitational-wave signal varies with time.

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Biography

Guillermo Valdés is a Postdoctoral Researcher and Lab Manager at the Laboratory of Space Systems and Optomechanics at Texas A&M University, member of the LIGO Scientific Collaboration, and a public outreach enthusiast that has been invited to National Television to share his expertise.

World Space Week: Join In On the Worldwide Celebration

Deborah Camuccio

The vastness of the universe and your understanding of it may seem inconceivable. But during World Space Week, you may find the cosmos isn't quite as far out of reach as you think.

With the aim of encouraging excitement about the fields of science, technology, engineering, and math (STEM); supporting space programs; and educating people about the benefits of space, the United Nations launched World Space Week in 1999 to be celebrated each year on October 4th through 10th.

With this year's theme, "Space and Sustainability," World Space Week will address how space plays a role in sustainability on Earth. Here are some ways you can join in the celebration:

Bring the universe right to your fingertips. Download a stargazing app to your phone. Their virtual maps - for beginners or pros - can help you discover constellations, planets, and stars and learn about astronomy. Some charge a nominal fee but many have a free version. Check out the list of stargazing apps at Space.com and choose the right one for you [1].

View an out-of-this-world photo gallery. Behold astounding images of galaxies, exoplanets, and more, captured by the James Webb Space Telescope [2].

Check out a book at your local library. Your local library has a wealth of interesting content for reading or viewing for kids and adults alike. Books, such as *A Is for Astronaut: Blasting Through the Alphabet*, by Clayton C. Anderson, are a fun way to fascinate a young, budding astronaut. And for those of you who are looking for an accessible explanation of the universe, check out *A Brief History of Time*, by Stephen Hawking.

See the stars up close. Participate in a local observation. Check out this publication's sponsor, STARSociety, for a listing of fun and informative events [3].

Envision your future. For anyone thinking of a new career - or changing careers - learn about exciting opportunities in the field of space science, including astronomers, meteorologists, technicians, engineers, and media and communications specialists [4].

Learn more. Find out more about the mission and theme of World Space Week and ideas for holding your own event at their website [5].

If you've ever had a sense of wonder about what's out there but didn't feel connected or weren't sure how to interact with it, remember the words of Christa McAuliffe - astronaut and teacher - who said, "Space is for everybody. It's not just for a few people in science or math, or for a select group of astronauts. That's our new frontier out there, and it's everybody's business to know about space." ★

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https://www.worldspaceweek.org/

Biography

Deborah Camuccio is a writer and editor covering such topics as anxiety, depression, addiction, and other aspects of mental health for a global employee assistance program. She is also an independent contractor providing transcription services for a family medical practice. In her free time, Deborah enjoys reading mystery and suspense novels and spending quality time with her family and friends. She lives in the Greater Philadelphia region of Pennsylvania.

Postcards from Eternity

Dr. Mario Díaz

When Richard, our esteemed editor, asked me to prepare a column for this issue of FFO (this was several months ago) I did not hesitate. I planned to write about the first picture ever taken of the "gentle giant" lodged at the center of the Milky Way, as it was called by Dr. Feryal Özel of the University of Arizona at the National Press Club in Washington, D.C. on May 12 of this year [1]. Back then and on that occasion, the Event Horizon Telescope collaboration released an image taken of a faint source of radio called Sagittarius A* (pronounced A star). Since 1974, the center of the Milky Way has been known to coincide with this source and there was clear evidence that it was a supermassive (about four million times heavier, more massive, than our Sun) black hole. This was the first image of the event horizon surrounding the huge black hole at the center of our own galaxy. It was indeed big news.

But just a few weeks after I made my commitment, another big astronomical announcement made the front page news all over the world. And, to make it clearly outstanding, at the press release conference communicating it, the news was introduced by the president of the USA himself! On July 10, 2022 President Biden, in a brief event at the White House, unveiled an image taken by the James Webb Telescope, representing our deepest view ever on our past universe.

The James Webb Space Telescope (JWST) is the largest space telescope ever built. The JWST is operated primarily by NASA, which is providing the largest portion of the funding, with the European Space Agency (ESA) and the Canadian Space Agency (CSA) as partners. The telescope is named after one of NASA's past administrators, James E. Webb, who oversaw the creation of the Apollo program in the 1960s.

The image showed a very far away and tiny speck in the sky. It was displaying extremely young galaxies, groups of stars in their "infancy" just 600 million years after the Big Bang.

President Biden said: "This is the oldest documented light in the history of the universe from 13 billion - let me say that again, 13 billion - years ago."

Barely two weeks after this announcement, our society, STARS, organized jointly with the UTRGV Cristina Torres Memorial Observatory - for the first time after the long pandemic hiatus - Astronomy at the Park. This is a star party gathering open to the public at the UTRGV astronomical site located in Resaca de la Palma State Park, here in Brownsville. More than four hundred people showed up (paying the $4.00 entrance fee) at the event. All of them had their astronomical curiosity turned on by the recent announcement from the JWST. Very clearly, I needed to change the original subject of this column.

The JWST was launched aboard a NASA spacecraft on Christmas Eve last year. It was going to take about a month for the spacecraft to reach the second Lagrange point, or L2, about a million miles from Earth. The Lagrange points, also called libration points, are points in space between two celestial bodies where the gravitational pull from one (in this case the Sun) balances out the attraction of the other (in our case the Earth). For any two given celestial bodies there are five Lagrangian points. Any small object (small compared with the Earth or the Sun) located at that point will require very few corrections to be maintained in the desired orbit. Three of the points are located on a line joining the center of the two bodies. The other two formed the outside vertex of a triangle where its base are the two bodies. The JWST is located on the second Lagrangian point, quite suitable to keep it orbiting the Sun with the telescope mirror pointing opposite to it all the time.

But even after reaching its designed position in the sky, the JWST had also to carefully turn on four main scientific instruments. It took several months for the Mid-Infrared Instrument, or MIRI, to be cooled to minus 447 degrees Fahrenheit. Only then its scientists could perform the final commissioning of the JWST instrumentation and initiate a new series of discoveries in astronomy. Many things could have gone wrong at each and every step of this process.

The JWST's primary mirror is 6.5 meters in diameter, almost three times larger than its predecessor, the Hubble Space Telescope (launched into space also by NASA more than 30 years ago), which is 2.4 meters. The JWST can gather seven times more light than Hubble and thus it can see farther out in space. And in space, to see farther away, because of the light travel time (it takes one second for it to make almost 200,000 miles), it also means seeing farther into the past.

Additionally, the JWST is equipped with infrared sensitive cameras. The expansion of the universe causes the light frequencies to become lower and their associated wavelengths longer. This means that normally visible wavelengths have become shifted to longer infrared wavelengths which are invisible to human eyes.

One of the most ambitious missions of the Webb telescope is to study the stars and galaxies at a very early stage in the development of our universe, as close as possible in time to the Big Bang in which our universe exploded into being 14 billion years ago.

The snapshot presented by President Biden might not have been that old, but it showed the potential of the telescope's scientific instruments, and the exquisite precision obtained by its scientists and engineers at each stage of its long development and deployment process.

The tiny speck in the sky showed by President Biden is a region named J0723.3-7327, commonly referred to as SMACS 0723. SMACS is an acronym for Southern MAssive Cluster Survey. SMACS 0723 is a cluster of galaxies about four billion light years from Earth within the southern constellation of Volans. It is a patch of sky visible from the Southern Hemisphere on Earth and it had already been observed by Hubble and other telescopes in search of the deep past. This cluster exerts an enormous gravitational pull which also acts as a lens, distorting and magnifying the light from galaxies behind it in a manner similar to an optical lens. This makes possible to gather the light from a celestial region that would otherwise be too feeble and remote to be observed.

The JWST will also be studying the atmosphere of extraterrestrial planets and other celestial objects, but one of its main scientific goals is indeed the early universe. Scientists hope that the JWST will see all the way back to when the first galaxies formed and shed light on how the initial fireball, into what our universe was born, became the stars and groups of stars of today. It will be truly sending us news from the beginning of time, postcards from eternity. ★

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Biography

Mario Díaz is Director of the Center for Gravitational Wave Astronomy and a Professor of Physics at UTRGV. He is Director of Cristina Torres Memorial Observatory, principal investigator of the Transient Robotic Observatory of the South Collaboration, and a member of the LIGO Scientific Collaboration. He received a PhD in general relativity and gravitation from University of Cordoba, Argentina.

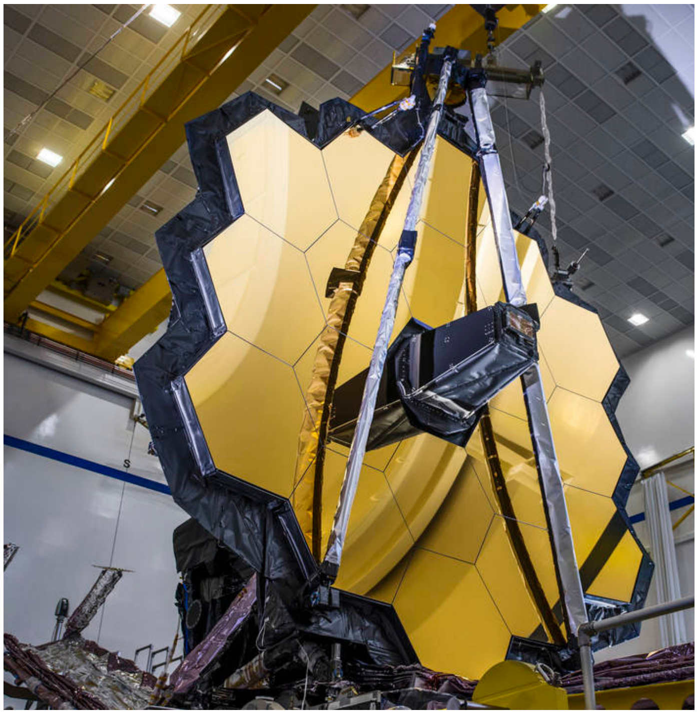

Figure 1: The JWST's primary mirror segments, measuring 6.5 meters in diameter at full deployment. Image credit: NASA

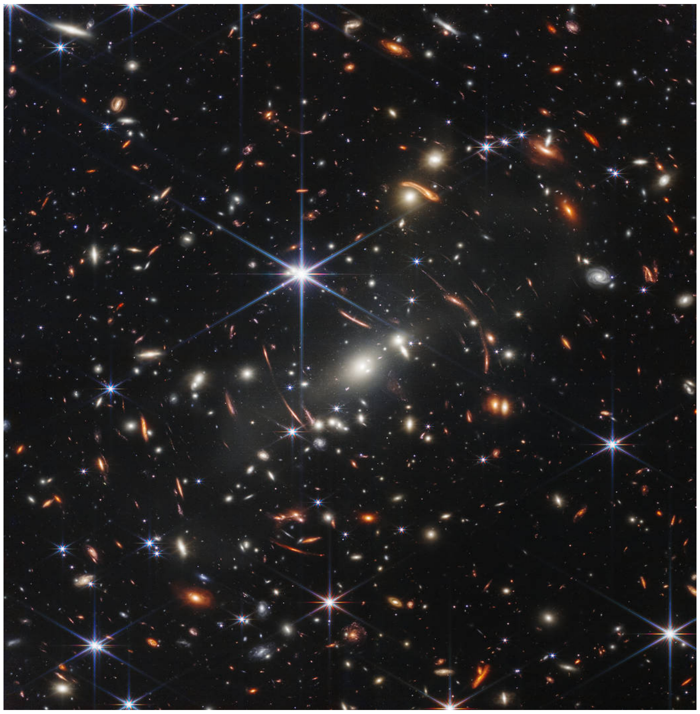

Figure 2: The JWST's first deep-field image of SMACS 0723. Image credit: NASA

Observing a Stone-Faced Story

Jaqueline Peña

Some might account the idea of asteroids being possible cataclysmic world-enders as a singular notable act. For that, tracking their moving bodies as threats to our fundamental existence seems obvious and almost a given.

We watch, stationed at dome-shaped watch towers, and look directly at these solid, giant, dull bodies. Armed and eager, only now do we question insight into the target.

Now, there is some truth to this statement. However, it does not exist in isolation. Scientists track asteroids, particularly Near Earth Asteroids (known as NEAs) for the purpose of determining their size, shape, rotation, brightness, possible rings, and, most importantly, for gaining an understanding of compositional tellings [2].

All of these observed parameters serve as lookout data, invaluable to priorities such as planetary defense. We watch, yes, but we also take the part of reading a story between lines of light.

Strategies of Observation

In the gatherings of scientific data, ground-based optical observations prove revealing to asteroid analysis. Using a strategy known as light curve photometry, sunlight reflected off the rocky body is recorded by astronomers and read on CCD imagers (charge-coupled devices).

Short Intersection on CCD Background (for Funsies)!

A background on CCD application is fundamental to understanding operations and characteristics of this astronomical work. CCDs operate on the interactive handling of electrons coupling with positive potential wells [1]. For explanatory imagery purposes, the well-known "Rain-bucket" analogy can be used to showcase the works of these CCDs. Picture a grid arrangement of buckets lined up. These will represent pixels on a CCD array. When photons fall onto a CCD chip, the photons are counted in a process called integration. One can envision this process as rain droplets falling and pooling together in the buckets, then the total amount of collected rainwater being counted by a computer at the end of collection. These buckets are then drained and read collectively. The amount of rain collected within these buckets would reflect photons captured by the CCD chips, therefore more rain would equate to more light. While this oversimplified analogy may be simple to grasp, it essentially mirrors the process in which photons are absorbed by silicon in pixels that can be input and read as analog-to-digital units (ADUs) [1].

Recording a light curve requires the method of tracking brightness variations of an object over time. That's the focus of the Cristina Torres Memorial Observatory (CTMO) in Brownsville, TX: time domain astronomy, a study of transient astronomical events.

Shape, Size, and Rotation

When looking for an asteroid's size and shape, multiple recordings of light curves must be noted at varying positions as we make our way around the Sun (this is also known as aspect angles). For optimal results on must track an asteroid through months as it spins through the scope's field-of-view [2].

As input data is collected, an inversion process of varying amplitudes is done to determine pole orientation and body curvature. As the object spins, light is reflected differently on its higher points as it is to its dips and bumps. Think of the way shadows and highlights reflect off of a human face. Various points of detection are called maxima and minima, for maximum reflection on high points and minimum on the low points, respectively [2].

This inversion technique was presented by scientists M. Kaasalainen and J. Torppa, by which they produced an effective means to render a 3D image of an asteroid through using light curves. The inversion of these parameters in light curves also gives insight into an asteroid's sidereal period and poles [3].

H and G Values

When observers state they are looking for the H value, it indicates searching for the absolute magnitude of an object. This, in definite terms, is the brightness of an asteroid at a distance of one astronomical unit (or 149.6 million kilometers) and with zero phase angle [4].

Accuracy of an H value, in combination with an asteroid's physical shape and size, are factors often used to determine taxonomic class [2]. The albedo appearance (brightness variation) of an asteroid is also telling of its composition, with different reflections of sunlight corresponding to different compositions.

G value, on the other hand, reflects the phase angle, or slope parameter. This is the monitoring of brightness at various angles [2]. This number is used in calculations for finding the factors mentioned above.

Occultations

The process of observing an object at the precise moment it aligns with a star and is illuminated from behind is called an occultation. This method of observing asteroids is practical in that it can be done by amateur astronomers with portable equipment and referenced in accuracy for size and shape measurements [5].

As the object passes in front of a light source, factors of observation previously mentioned can be determined. However, on a more explorative note, these backlit phenomena can reveal light curves telling of asteroid rings. As the photometric readings display a dip in brightness, it is picking up on the rings of a body blocking photons from entering the telescope [6].

Discovery and Wonder

Picking apart an asteroid's makeup can aid in theories of Solar System origin. These pieces of rocky history are ancient to the beginning of planetary formation. Cataloging compositional values can reveal substances present for Earth's core as well as give an image to collisional events.

Although, if you're more interested in the future prospect of a timeline, a bright-looking-future-over-past type of answer, understanding these compositions can also provide motivation for futuristic outer space mining of asteroids. Of course, to each its own on the geological aspect of these celestial threats.

Staring at space rocks from a distance at ground-based scopes is exciting, thrilling almost. A bold statement to pronounce after explaining scientific technicalities. If, in case I did not lose you after the phase values, I restate: these solid gray masses hold a goldmine of discovery. May we soon see the evolution of the rock-watching, or at the very least, a curious, cautious sight, turn into a storybook of stone. ★

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Biography

Jaqueline Peña is a senior 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.

Optical Transients: How CTMO Studies the Oldest Nuncius in MMA

Olivia Lincoln

The first scientific study based on telescopic observations was published by Galileo Galilei in a document titled *Sidereus Nuncius*, which translates to *Sidereal Messenger* or *Starry Messenger* in English. In this document, Galileo chronicles his discoveries of Jupiter's moons, various constellations, and mountainous ranges on Earth's moon. Galileo accredited the scope for these astounding discoveries to light - according to him, the light emitted from heavenly bodies is the *nuncius*, or messenger, of the stars. Thus far, throughout the extensive history of observing celestial messengers at different wavelengths, light does remain the supreme *nuncius* in the observable universe.

Flux is Fruitful

From Hipparchus to Hubble, humans have been surveying the night sky through photometry for decades. Flux, or the amount of energy we receive from a luminous object, is the most basic data we can derive from light sources like stars. With instrumentation and data analysis, astronomers can calculate the star's distance from Earth and use photometry to help calculate parameters such as size, temperature, mass, and luminosity. From a single light source, astronomers can even deduce if a star has powerful magnetic fields, if it possesses large sunspots, and if gas and/or dust surrounds it [5] Henceforth, as scientists expand observation into more wavelengths, optical counterparts still remain an important source of data for extreme astronomical events.

Small Optical Observatories: the Underdogs

When beholding the vast study of multi-messenger astronomy, we can allegorize the types of signals to pieces in a puzzle: each observation of an extreme astronomical event is a puzzle piece in a collective understanding of the event and how it happened. Having multiple mediums of observation for this event can equip a more comprehensive view of the physics behind it, which would otherwise not be feasible for a single type of instrument. Every detection of every observable wavelength can be seen as a brush stroke in a painting, further and further building a clearer image of how the phenomenon works. While many of these observations are made possible by the sensitive instrumentation from high-tech observatories, smaller optical observatories can very well be a puzzle piece or brush stroke in this growing picture.

When compared to smaller observatories, larger optical observatories can be more efficient at quickly covering larger areas and greater depths, but despite their advantages, these systems are often constrained by the amount of telescope time that can be used for long-term transient surveys. The participating astronomers may not have a schedule that permits longer periods of observations amidst a major event detection, and time is crucial because optical transients can vanish quickly, most notably in the event of a gravitational-wave detection from LIGO or a neutrino detection from IceCube. Because smaller observatories have more time available and can undertake longer-term measurements, they can therefore hold these observations and obtain integral data in these transient witch hunts. Of course, there are limitations to these small observatories, which include instrumentation quality and site/environmental conditions. Regardless, these observatories (including CTMO) are notable assets in time-domain astronomy.

Method

After seeing a small observatory's importance in time-domain astronomy, we can start to explore the process behind capturing optical counterparts in the event of a major detection.

The astrophysical event will behave like a trigger on a map of the sky, after which the trigger's region on the map is searched by telescopes for counterparts of different wavelengths. The following description of CTMO's reactionary method would follow the hypothetical case of a gravitational wave (GW) trigger. GW events that LIGO and other ground-based detectors can spot are the effect of merging compact objects (e.g. black holes and neutron stars - a.k.a. my favorite things in space) or by gargantuan explosions, all of which could potentially leave behind a trace in other channels of *nuncius* (electromagnetic radiation, gamma rays, radio waves, or particles like neutrinos). If we catch the optical messenger, the event's data and comprehension can drastically increase.

The notice of events and relative targets will come from NASA's Gamma-ray Coordinates Network & Transient Astronomy Network (GCN/TAN). According to GCN, counterparts are recorded through the following timeline [4]:

- A transient happens and is detected by some transient-detecting instrument.
- The location of this trigger is distributed to the world community by GCN.
- Some person/group/instrument makes a follow-up observation (possibly through a different parameter) in search of the transient.
- They identify a counterpart to that trigger.
- They submit that counterpart location to GCN.

Observatories like CTMO get involved in the second step, after which the notice is formatted into a Virtual Observatory Event (VOE) file and sent out. CTMO is part of the Transient Robotic Observatory of the South (TOROS) Collaboration and receives this file from their alert robot. In the alerts, they describe parameters like event identification, detection times, alert type, probability of neutron star involvement, probability of remnants, and a rapid localization skymap through an algorithm [2]. Additionally, TOROS' robot generates a list of relative targets (usually nearby galaxies) specific to CTMO. Observed targets are often chosen based on three factors: i) localization uncertainty, ii) target visibility at the time of the event based on geographical information, and iii) cuts on parameters like distance, magnitude, and luminosity [1].

After a target is selected, the observers at CTMO will proceed with their standard routine for a nightly observation - which includes captures of the target, darks, and flats. Here's a mini description for those unfamiliar with the terms:

- Dark frames are used to remove the thermal noise within the CCD chip. These frames are usually taken with the telescope covered and exposure and temperature set the same as the light frames or target image. Several raw dark frames are then averaged out and combined into a single image (master dark).
- Flat fields help correct uneven illumination on the surface of the CCD as well as errors in the optical path like dust on filters, variations in pixel sensitivities, or vignetting. They are taken out of focus after observations as a normally exposed image, uniformly lit [6].

After the observing session, data are obtained and saved. Next, raw data must be reduced - this is where the flat and dark frames come into play. The master darks and flats are applied to the raw object image, and additional routines are used to clean the image (e.g. detecting transient artifacts like cosmic rays and subtracting the background). Finally, the frames are aligned, stacked, and undergo a process called plate solving - a technique that matches the stars in the image to an astronomical catalog and makes it possible to calculate the celestial coordinates of any object in the image. The resulting stacks are then ready to compare with reference images and be scientifically measured [2].

When looking for a transient near or within the target, CTMO can use multiple methods, including the comparison of the source's positions in the image with reference to one in archives, a process called "cross-matching." After following a process like this one, we may be able to subtract the source and ultimately see the GW event's remnant. We can also begin with measurements like flux and calculations involving magnitude.

Lastly, an ideal phase in this method would include lightcurve photometry to graph the receding brightness of the object. A lightcurve is the plot of magnitude or flux versus time (or other parameters), so if we graph the brightness of the transient (albeit faint and rapidly fading), we can see a total decline as time progresses. This data is integral because it can further demonstrate the explosion (and even the aftermath like nucleosynthesis).

Capturing (and Fangirling Over) GW170817

GW170817 was the first plausible binary neutron star merger detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO for short) and is also the name of my future pet cat (Gwen for short). I am infamous for babbling about this merger at every possible opportunity, but many other astronomers and astronomy-lovers would agree to define this event as the paramount milestone in multi-messenger astronomy. The merger was extremely important to scientific research because it was i) observed by both gravitational and electromagnetic waves, ii) the first GW observation that was confirmed by non-gravitational means, and iii) was a completely global effort - the papers were co-authored by over 4000 astronomers, and observations involved over 70 observatories on all seven continents (and in space!) [3].

GW170817 was the ideal case for CTMO's focus in time-domain astronomy - the event reveals that binary neutron stars merged, their collision produced a gamma ray burst, and optical/infrared light was produced from explosion of radioactive elements. At CTMO, relative time-series photometry was performed on the optical counterpart, after which its light curve revealed a rapidly fading transient source!

Our editor-in-chief, Richard, was one of the observers involved in TOROS' optical observations for this merger. As he recounts, the observers were notified late at night and drove to CTMO (after getting some snacks). Doing the usual routine, they spent the rest of darkness observing the selected target. Once dawn fell, they concluded the long night by buying breakfast tacos from Stripes at 6 am - an arguably perfect way to wrap up the important occasion.

The visceral curiosity of what lies beyond the night sky is indiscriminate. The witch hunts for ephemeral transients of extreme astronomical events is a global effort, so it is always comforting to know that, with help from TOROS and CTMO, we can be a part of the hunt right here, in Brownsville, Texas. ★

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Biography

Olivia Lincoln is a senior at James Pace Early College High School. She is an intern and ambassador for the South Texas Astronomical Society, and she has established an astronomy club for her school under STARS. After high school she wishes to study astrophysics and pursue research in gravitational wave astronomy.

Perseverance: The Multi-Faceted Rover Harnessing the Power of the Electromagnetic Spectrum

Andrew Maurer

Multi-messenger astronomy uses the "messengers" of the universe to better understand the universe itself. Messengers are classified as follows: electromagnetic radiation, neutrinos, gravitational waves, and cosmic rays. All four messengers have distinct sources, and their study leads to a better understanding of their respective sources, and therefore the universe. Although it does not detect neutrinos, cosmic rays, or gravitational waves, Peseverance uses electromagnetic radiation in a number of ways to understand the geologic history of Mars.

For those not familiar, Perseverance is the latest Martian rover that made landfall on Mars on February 18, 2021 in the Jezero Crater. The Perseverance mission contributes to the overall scientific mission of NASA's Mars Exploration Program - to search for signs of life [3]. In addition, Perseverance has four primary objectives: to evaluate the potential of the Martian rock at Jezero for biosignature preservation; to study the geologic processes and history (the **petrology**) of Jezero Crater and a nearby, ancient river delta system; to collect lithospheric samples for future extraction and transport to Earth; to help prepare for future human exploration on the Red Planet's surface [3]. The specifics of Martian sample caching and future in-person exploration preparation are for another article. The focus here will be how Perseverance harnesses the electromagnetic spectrum to gain insight into Martian petrology, minerology, and identify potential biosignatures.

Perseverance comes equipped with seven scientific

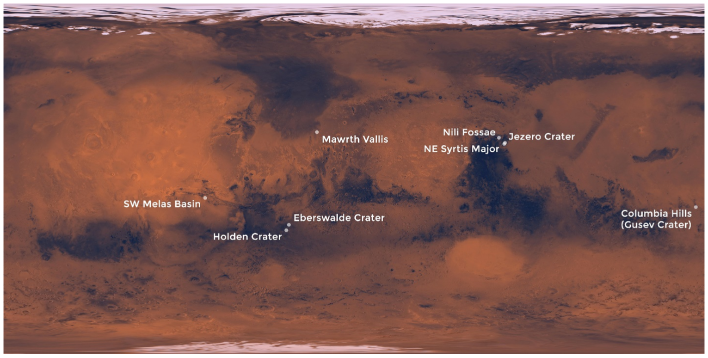

Figure 1: A global map of Mars with the location of Jezero Crater and other candidate landing sites for the Perseverance rover. Note that all candidate landing sites are relatively near the Martian equator to increase the likelihood of encountering biosignatures because the historic presence of liquid water at or near the equator. Image credit: NASA/JPL-Caltech

instruments to accomplish its mission objectives. Although (partially) locked onto Mars' surface, Perseverance uses the electromagnetic spectrum to its fullest advantage, from low frequency infrared to high frequency X-ray. The instruments that chiefly use electromagnetic radiation to assess the Martian terrain include **PIXL** (Planetary Instrument for X-ray Lithochemistry), **SHERLOC** (Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals), **SuperCam**, **MEDA** (Mars Environmental Dynamics Analyzer) and **Mastcam-Z** [3]. Each piece of technology manipulates specific ranges of electromagnetic frequency to gather a more comprehensive, high-definition image of the Martian surface. For example, MEDA uses a suite of meteorological sensors to detect environmental characteristics like atmospheric pressure, relative humidity, and atmospheric and ground temperature, while PIXL emits X-rays to detect lithospheric florescence and therefore identify different elements in the Martian rock [5,6]. Each device has a scientific team dedicated to its development and support, and even has their own specific scientific objectives.

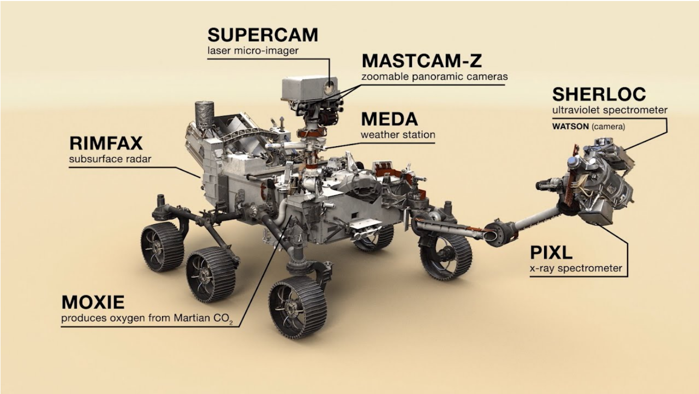

Figure 2: A model of Perseverance with its seven instruments from various laboratories labeled. Note that not all use spectroscopic tactics to interact with the Martian environment. Image credit: NASA/JPL-Caltech

Unlike Perseverance's older counterpart, Curiosity, there is an emphasis on sub-millimeter resolution with UV- and X-ray-emitting instruments such as PIXL and SHERLOC. These two sets of instruments implement an analytical strategy called **spectroscopy**, the study of how materials absorb and emit radiation. As mentioned prior, PIXL emits an X-ray beam that induces fluorescence on a target material at such a resolution that the chemical constitution of the material can be equivocated to the target material's texture [6]! This is done through its proprietary software and with data comparison with other instruments, specifically SuperCam and SHERLOC. The geochemical insights gained from these precise measurements relate to the petrology at Jezero Crater and its ancient river delta with a fidelity that has yet to be seen with any Martian mission at this point. The ultimate hope is that these nuanced, petrological discoveries may uncover biotic interactions with the Martian rock: a biosignature.

The likelihood of the Perseverance rover encountering viable microorganisms is practically zero. However, ancient microorganisms leave evidence of their existence on how certain rocks present themselves, like **stromatolites**, and the chemical composition of the rock that they inhabited. This is why high-resolution cameras like Mastcam-Z and onboard spectroscopic equipment like SHERLOC, PIXL, and SuperCam are crucial for the environmental evaluation for biosignature preservation and detection. For example, SHERLOC can detect organic material via UV radiation. SHERLOC uses a spectroscopic technique called **Resonance Raman spectroscopy** to identify potential organic material by emitting a deep UV-induced (DUV) laser with a wavelength of 248.6 nm [7]. Large, organic compounds with ring structures (**aromatic**) and long, hydrogen-saturated branches (**aliphatic**) are especially sensitive to radiation at this particular wavelength; SHERLOC can detect these molecules from the wavelength differences between the DUV laser and the received radiation. The wavelength differences correlate to the type and size of organic compounds present, and therefore proper identification of the molecules is able to occur. SuperCam is also capable of this kind of spectroscopy, but at a slightly different wavelength, 532 nm, and in tandem with other spectroscopic techniques such as visible and near-infrared spectroscopy, or **VISR**, and Time-Resolved Fluorescence (**TFR**) spectroscopy [8]. The culmination of precise, individual measurements of the chemical composition of Jezero reveals its broader geologic history, and after a year and a half of operation, this is what Perseverance has discovered.

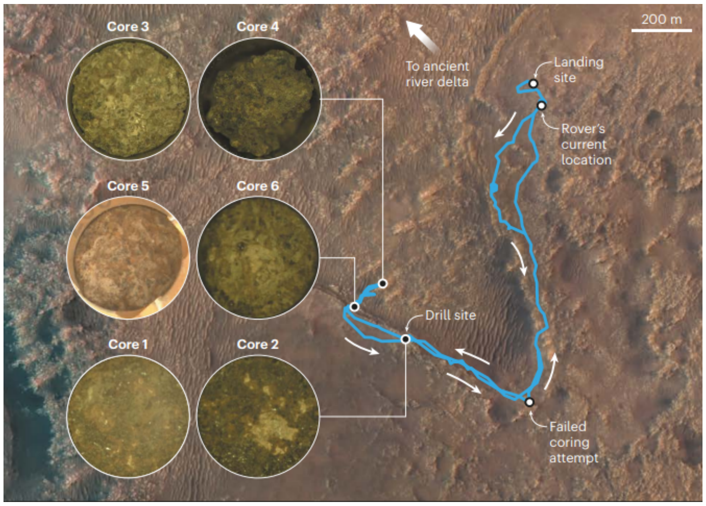

Figure 3: The Perseverance rover's journey as of one years after landing. Core samples are extracted in pairs to increase the likelihood of future extraction and delivery back to Earth. Image credit: NASA/JPL-Caltech

At the time of writing, Perseverance has traveled over three kilometers (over 1.8 miles) of rugged Martian terrain [9]. Its route is primarily localized to the floor of Jezero Crater; a proper visit to Jezero's ancient river delta is still in order. However, significant findings were revealed at the crater floor and in the proximate, sand dune-dense area called Seitah [2,9]. Both regions' rock composition is determined to be igneous because of the presence of the mineral, **olivine**, encased inside another mineral, **pyroxene** [2,9]. On Earth, pyroxene-encased olivine is commonplace in rock formations that formed from large bodies of magma that have gradually cooled [1]. This discovery surprised scientists because both landscapes appear more akin to landscapes on Earth predominantly composed of sedimentary rock. If Jezero Crater was composed primarily of sedimentary rock, it would support the model of active, substantial water flow from the delta, depositing sediment onto the crater floor as a result. The strong presence of pyroxene-encased olivine suggests ancient lava flows constructed the region Perseverance rolls upon more so than extensive water flow [2].

With that said, liquid water presence is not out the question. Prior to the first attempt to cache a sample, Perseverance burrowed into a rock of interest, and imaging revealed the freshly-ground rock to appear similar to an igneous rock on Earth with salt-rimmed holes inside of it [9]. Generally, a salt forms when solid solutes precipitate in an aqueous solution; when the solvent evaporates or is absent, a solid residue is left behind. Thus, the scenario that aqueous water interacted with nascent igneous rock billions of years ago is plausible. Moreover, if this scenario is true, then the presence of organic molecules being in the rock is significant because of the combination of igneous rock chemical composition and the environmental conditions present at the junction of water and magma being a theoretical wellspring for complex, organic molecule formation. With that said, more traditional biosignatures are more likely present near the mouth of Jezero’s delta system, in addition to sedimentary rock being formed as a result of water deposition from active water flow.

Perseverance's operation deadline is just under another year, and there is still much more to be done [9]. Another two dozen core samples need to be secured for future delivery and the aforementioned river delta system needs to be explored. Perseverance will deliver crucial information on the chemical composition of the rock of the delta, just as it did at the crater floor and Seitah. Another Mars mission will prioritize sample extraction from the Martian surface and delivery of the cached samples back to Earth [9]. From there, those samples will undergo more extensive analysis. As sophisticated as the instruments mounted upon Perseverance are, scientists have immediate access to the powerful equipment houses in the laboratories on Earth, utilizing our most familiar messenger to the extent we know best. As Perseverance nears the mouth of the delta, a more nuanced image of the ancient environment at Jezero Crater will come into focus, and humanity will hopefully learn whether our planetary neighbor once harbored life at this curious location on the Red Planet. ★

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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.

Why Sun Rises Cautiously

An Ancient Astronomers' Tale Retold by Carol Lee

Now it is night, time to sit and talk about the world in which we live, time to share the tales of those who have gone before; time to listen and think about the reasons for things to be as they are.

In the beginning of time, each morning very early, while the animals were trying to sleep, Sun would leap suddenly into the sky, shine in their faces, and rouse them from their dreams. He would dance around the sky all day, leaping and shouting, and making things so very hot that the animals began to complain loudly:

"My fur is too hot!" howled Coyote.

"My feet are burning!" grumbled Horned Lizard.

"I am thirsty and cannot find water!" chattered Cactus Wren.

All of this complaining was too much for Rabbit! He was a loud and boastful fellow and liked to make all the noise and do all the grumbling by himself. He stood up in front of the Council of the Tribe and bragged thusly:

"Tomorrow I myself will go and teach that Sun a lesson! No longer will he dare show his face so early in the sky. No longer will he *singe* our flesh and take away our water!" vowed Rabbit. Then he marched right out of the Council House to his hogan and began to remove from his quiver all but the most straight and true-flying arrows.

That night as the Sun disappeared into the Land of the Dead, Rabbit sat watching and planning just how he would teach the Sun to respect The People. As he sat, his friends Coyote, Horned Lizard, and Cactus Wren came and sat beside him, also thinking thoughts to help their friend. Together they decided to rise early the next morning and stand on the mesa where the Sun came leaping into the sky. Rabbit was to be ready with his best arrow nocked in the bow and let it fly just as Sun leaped.

And so it was, as the Moon and his sister, Morning Star, were the only things in the sky, Rabbit and Coyote climbed to the mesa top to wait. Carefully, Rabbit placed the base of the arrow against the tough sinew bowstring and he p-u-l-l-e-d back the string v-e-r-y s-l-o-w-l-y and carefully, holding it taut against his right ear until...THERE; there were the fingers of the Sun! Rabbit let go the bowstring and the arrow flew straight toward where he had seen Sun rising the day before!

And the arrow flew right on by Sun, while Sun laughed because he had come into the sky just a little bit to the side of where he had come up the day before.

The next morning the four friends again went to the mesa to wait. Rabbit took out another arrow and placed it in his bow, ready to shoot. He carefully aimed his arrow toward the spot where Sun had leaped into the sky the day before. Just as the Sun leaped, Rabbit let his arrow fly! Coyote howled his encouragement, Wren sang a warrior's song, and Horned Lizard danced a straight-flying dance, but this time the arrow fell again to Earth without striking Sun.

Rabbit was very embarrassed and angry as well. He jumped up and down in his anger. Coyote howled in frustration; Wren chattered loudly; Horned Lizard raced away to sit under a cool rock and collect his thoughts. But Rabbit was not discouraged. He vowed to try again the next morning.

Now the friends had been watching while Rabbit was shooting and they noticed that the Sun moved just a bit farther along the horizon this day as well. When they told Rabbit what they had seen, he decided to aim just a little bit ahead of Sun to see what would happen.

The next morning the friends again rose early and walked in the cool morning breeze to the mesa. Once again Rabbit took an arrow from his quiver and nocked it into the bowstring, slowly pulling back on the bowstring and holding it taut, and aiming just a bit ahead of where the Sun had risen the previous morning. At the exact moment that Sun leaped, Rabbit let the arrow fly, and true it flew, right SMACK into the right side of the Sun!

At once fire began to spread from Sun and fall toward the Earth, and Rabbit! Rabbit began to run for his life across the mesa! Frantically he called to Yucca Tree, "Help me! Hide me! Save me! I have shot the Sun and Fire is chasing me!"

"Oh, no," sighed Yucca Tree. "I cannot help you, for if I do that fire will burn me too!" And Yucca Tree kept herself straight and tall.

Rabbit raced on, with fire close on his heels. In the distance he saw a creosote bush and called out desperately, "Creosote! Creosote! Help me! Hide me! Save me! I have shot the Sun and Fire is chasing me! It will surely burn me if you don't!"

"Oh, no, Rabbit," whispered Creosote Bush, "for if I do that fire will burn me too!"

And Rabbit raced on, with Fire close on his tail. As Rabbit was nearly exhausted, he saw, far away, a small cactus plant rising out of the sand. He managed to gasp out, "Cactus! Help me! Hide me! Save me! I have shot the Sun and Fire is chasing me! It will surely burn me if you don't!"

Now Cactus was a kind-hearted soul, even if he was prickly with thorns all over him, and he called out, "Come quickly! I will protect you with my thorns! Dig a hole at my feet and Fire will not find you!"

Gasping in exhaustion, Rabbit used his last ounce of energy to dig furiously at the base of Cactus to make just enough space for himself. Rabbit managed to get in, just as Fire raced over the top of Cactus, not seeing Rabbit under the thick green feet of Cactus. As Fire raced on across the prairie looking for Rabbit, he burned it into desert that is still desert today after all this time.

Rabbit crawled shakily out from the hole at Cactus' feet and thanked Cactus for rescuing him. Modestly, Cactus replied, "That is what kind beings are for, to help people in need. Even though I did not know you and you did not know me we are still friends in this place and our children will be friends forever."

That is why, from that day to this, Rabbit has become a shy, timid fellow, hiding from danger, often under a cactus. If one looks closely, the dark streaks where Fire singed Rabbit can be seen between his ears because the hole was not quite deep enough for all of Rabbit to hide in.

And that is why Sun carefully lifts his head above the horizon and slowly peeks around the edge of the Earth before lifting himself into the sky where he slowly makes his way across the *safe* path in the sky. ★

Figure 1: High-definition image of the Sun rising above Earth's horizon on 11 June 2011. Captured by astronaut Ron Garan aboard the International Space Station. Image credit: NASA

Night Sky Bulletin
Rio Grande Valley, Texas

--- **September Events** ---

Moon at First Quarter
Sat, 03 Sep 2022, 13:08 CDT, Ophiuchus

Venus at Perihelion
Sun, 04 Sep 2022, 21:10 CDT, Leo

Moon at Perigee
Wed, 07 Sep 2022, 13:18 CDT, Capricornus

3 Juno at Opposition
Wed, 07 Sep 2022, 14:10 CDT, Aquarius

Conjunction of Moon and Saturn
Thu, 08 Sep 2022, 05:31 CDT, Capricornus

Appulse of Moon at Saturn
Thu, 08 Sep 2022, 07:35 CDT, Capricornus

Moon at Aphelion
Thu, 08 Sep 2022, 07:40 CDT, Capricornus

Full Moon
Sat, 10 Sep 2022, 04:58 CDT, Aquarius

Conjunction of Moon and Jupiter
Sun, 11 Sep 2022, 10:16 CDT, Pisces

Appulse of Moon and Jupiter
Sun, 11 Sep 2022, 11:41 CDT, Pisces

Lunar Occultation of Uranus
Wed, 14 Sep 2022, 17:26 CDT, Aries

Appulse of Moon and Mars
Fri, 16 Sep 2022, 19:16 CDT, Taurus

Conjunction of Moon and Mars
Fri, 16 Sep 2022, 20:43 CDT, Taurus

Moon at Last Quarter
Sat, 17 Sep 2022, 16:52 CDT, Taurus

Moon at Apogee
Mon, 19 Sep 2022, 09:43 CDT, Gemini

September Equinox
Thu, 22 Sep 2022, 19:58 CDT, Virgo

Mercury at Inferior Solar Conjunction
Fri, 23 Sep 2022, 01:45 CDT, Virgo

New Moon
Sun, 25 Sep 2022, 16:55 CDT, Virgo

Jupiter at Opposition
Mon, 26 Sep 2022, 14:25 CDT, Pisces

Moon at Perihelion
Wed, 28 Sep 2022, 01:57 CDT, Virgo

Neptune at Opposition
Fri, 16 Sep 2022, 17:12 CDT, Aquarius

--- **October Events** ---

136472 Makemake at Solar Conjunction
Sat, 01 Oct 2022, 15:28 CDT, Com

Moon at First Quarter
Sun, 02 Oct 2022, 19:14 CDT, Sagittarius

Moon at Perigee
Tue, 04 Oct 2022, 11:33 CDT, Capricornus

Conjunction of Moon and Saturn
Wed, 05 Oct 2022, 10:51 CDT, Capricornus

Appulse of Moon and Saturn
Wed, 05 Oct 2022, 13:02 CDT, Capricornus

Mercury at Perihelion
Thu, 06 Oct 2022, 15:57 CDT, Virgo

Moon at Aphelion
Fri, 07 Oct 2022, 09:30 CDT, Aquarius

Mercury at Dichotomy
Sat, 08 Oct 2022, 03:53 CDT, Virgo

Conjunction of Moon and Jupiter
Sat, 08 Oct 2022, 13:11 CDT, Pisces

Mercury at Greatest Western Elongation
Sat, 08 Oct 2022, 13:52 CDT, Virgo

Appulse of Moon and Jupiter
Sat, 08 Oct 2022, 14:48 CDT, Pisces

Mercury at Highest Morning Altitude
Sun, 09 Oct 2022, Virgo

Full Moon
Sun, 09 Oct 2022, 15:54 CDT, Pisces

Lunar Occultation of Uranus
Wed, 12 Oct 2022, 01:11 CDT, Aries

Appulse of Moon and Mars
Fri, 14 Oct 2022, 22:40 CDT, Taurus

Conjunction of Moon and Mars
Fri, 14 Oct 2022, 23:31 CDT, Taurus

Moon at Apogee
Mon, 17 Oct 2022, 05:20 CDT, Gemini

Moon at Last Quarter
Mon, 17 Oct 2022, 12:15 CDT, Gemini

136199 Eris at Opposition
Mon, 17 Oct 2022, 23:30 CDT, Cetus

Venus at Superior Solar Conjunction
Sat, 22 Oct 2022, 16:49 CDT, Virgo

Saturn Ends Retrograde Motion
Sat, 22 Oct 2022, 22:36 CDT, Capricornus

136108 Haumea at Solar Conjunction
Sun, 23 Oct 2022, 00:43 CDT, Bootes

New Moon
Tue, 25 Oct 2022, 05:49 CDT, Virgo

Moon at Perihelion
Thu, 27 Oct 2022, 07:43 CDT, Scorpius

Moon at Perigee
Sat, 29 Oct 2022, 09:35 CDT, Sagittarius

Mars Begins Retrograde Motion
Sun, 30 Oct 2022, 08:21 CDT, Taurus

--- **November Events** ---

Moon at First Quarter
Tue, 01 Nov 2022, 01:37 CDT, Capricornus

Conjunction of Moon and Saturn
Tue, 01 Nov 2022, 16:08 CDT, Capricornus

Appulse of Moon and Saturn
Tue, 01 Nov 2022, 18:25 CDT, Capricornus

Conjunction of Moon and Jupiter
Fri, 04 Nov 2022, 15:23 CDT, Pisces

Appulse of Moon and Jupiter
Fri, 04 Nov 2022, 17:19 CDT, Pisces

Moon at Aphelion
Sun, 06 Nov 2022, 03:29 CST, Pisces

Total Lunar Eclipse
Tue, 08 Nov 2022, 05:00 CST, Aries

Full Moon
Tue, 08 Nov 2022, 05:02 CST, Aries

Lunar Occultation of Uranus
Tue, 08 Nov 2022, 06:39 CST, Aries

Mercury at Superior Solar Conjunction
Tue, 08 Nov 2022, 10:56 CST, Libra

Uranus at Opposition
Wed, 09 Nov 2022, 02:18 CST, Aries

Appulse of Moon and Mars
Fri, 11 Nov 2022, 07:14 CST, Taurus

Conjunction of Moon and Mars
Fri, 11 Nov 2022, 07:46 CST, Taurus

27 Euterpe at Opposition
Sat, 12 Nov 2022, 10:46 CST, Aries

Moon at Apogee
Mon, 14 Nov 2022, 00:39 CST, Gemini

Moon at Last Quarter
Wed, 16 Nov 2022, 07:27 CST, Leo

115 Thyra at Opposition
Sat, 19 Nov 2022, 05:58 CST, Perseus

Mercury at Aphelion
Sat, 19 Nov 2022, 14:35 CST, Scorpius

324 Bamberga at Opposition
Tue, 22 Nov 2022, 05:58 CST, Perseus

New Moon
Wed, 23 Nov 2022, 16:58 CST, Scorpius

Jupiter Ends Retrograde Motion
Wed, 23 Nov 2022, 17:15 CST, Pisces

118P/Shoemaker-Levy at Perihelion
Thu, 24 Nov 2022, Cancer

Moon at Perihelion
Fri, 25 Nov 2022, 00:19 CST, Ophiuchus

Moon at Perigee
Fri, 25 Nov 2022, 19:31 CST, Sagittarius

Conjunction of Moon at Saturn
Mon, 28 Nov 2022, 22:40 CST, Capricornus

Appulse of Moon and Saturn
Tue, 29 Nov 2022, 00:57 CST, Capricornus

30 Urania at Opposition
Tue, 29 Nov 2022, 03:34 CST, Taurus

Moon at First Quarter
Wed, 30 Nov 2022, 08:37 CST, Aquarius

♂ **Mars at Perigee**
Wed, 30 Nov 2022, 20:11 CST, Taurus

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 called *superior conjunction*. Conjunctions are the worst time to view a planet with a telescope.

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

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 is the best time to view a planet with a telescope.

Meteor Shower Bulletin
Rio Grande Valley, Texas

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

Orionids (ORI)
Peak: Oct 21 (Sep 26 - Nov 22)
Radiant: α = 06:21, δ = 15:36
Speed: 66 km/s
Maximum ZHR: 23

Leonids (LEO)
Peak: Nov 18 (Nov 03 - Dec 02)
Radiant: α = 10:17, δ = 21:36
Speed: 70 km/s
Maximum ZHR: 15

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

Aurigids (AUR)
Peak: Sep 01 (Aug 26 - Sep 04)
Radiant: α = 06:04, δ = 39.2
Speed: 65 km/s
Maximum ZHR: 6

September Epsilon Perseids (SPE)
Peak: Sep 10 (Sep 02 - Sep 23)
Radiant: α = 03:10, δ = 39.5
Speed: 64 km/s
Maximum ZHR: 5

Southern Taurids (STA)
Peak: Oct 18 (Sep 23 - Nov 12)
Radiant: α = 02:36, δ = 10.5
Speed: 28 km/s
Maximum ZHR: 5

Epsilon Geminids (EGE)
Peak: Oct 19 (Sep 27 - Nov 08)
Radiant: α = 06:45, δ = 28.2
Speed: 69 km/s
Maximum ZHR: 2

Leonis Minorids (LMI)
Peak: Oct 21 (Oct 13 - Nov 03)
Radiant: α = 10:35, δ = 37.2
Speed: 61 km/s
Maximum ZHR: 2

Southern Taurids (STA)
Peak: Nov 05 (Oct 11 - Dec 08)
Radiant: α = 03:35, δ = 14.4
Speed: 28 km/s
Maximum ZHR: 5

Northern Taurids (NTA)
Peak: Nov 05 (Oct 11 - Dec 08)
Radiant: α = 03:55, δ = 22.8
Speed: 28 km/s
Maximum ZHR: 5

November Orionids (NOO)
Peak: Nov 30 (Nov 13 - Dec 12)
Radiant: α = 06:06, δ = 15.4
Speed: 42 km/s
Maximum ZHR: 3

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

Draconids (GIA)
Peak: Oct 08 (Oct 08 - Oct 09)
Radiant: α = 17:32, δ = 55.7
Speed: 21 km/s

Alpha Monocerotids (AMO)
Peak: Nov 22 (Nov 13 – Nov 27)
Radiant: α = 07:50, δ = 00.7
Speed: 62 km/s

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

Nu Eridanids (NUE)
Peak: Sep 11 (Aug 31 – Sep 21)
Radiant: α = 04:33, δ = 00.7
Speed: 66 km/s

September Lyncids (SLY)
Peak: Sep 11 (Aug 30 – Sep 20)
Radiant: α = 07:15, δ = 55.8
Speed: 59 km/s

Chi Cygnids (CCY)
Peak: Sep 13 (Sep 08 – Sep 17)
Radiant: α = 20:00, δ = 31.0
Speed: 19 km/s

Daytime Sextantids (DSX)
Peak: Oct 03 (Sep 22 – Oct 13)
Radiant: α = 10:27, δ = -03.3
Speed: 32 km/s

October Camelopardalids (OCT)
Peak: Oct 06 (Oct 05 – Oct 07)
Radiant: α = 11:09, δ = 78.6
Speed: 45 km/s

A Carinids (CRN)
Peak: Oct 14 (Oct 13 – Oct 14)
Radiant: α = 06:27, δ = -54.3
Speed: 32 km/s

October Ursae Majorids (OCU)
Peak: Oct 16 (Oct 10 – Oct 20)
Radiant: α = 09:41, δ = 64.2
Speed: 55 km/s

Tau Cancrids (TCA)
Peak: Oct 21 (Sep 23 – Nov 12)
Radiant: α = 09:13, δ = 29.6
Speed: 67 km/s

October Zeta Perseids (OZP)
Peak: Oct 25 (Oct 25 – Oct 25)
Radiant: α = 03:53, δ = 33.7
Speed: 48 km/s

Lambda Ursae Majorids (LUM)
Peak: Oct 28 (Oct 18 – Nov 07)
Radiant: α = 10:32, δ = 49.4
Speed: 61 km/s

Southern Lambda Draconids (SLD)
Peak: Nov 04 (Oct 29 – Nov 08)
Radiant: α = 10:46, δ = 68.2
Speed: 49 km/s

Chi Taurids (CTA)
Peak: Nov 04 (Oct 24 – Nov 13)
Radiant: α = 04:16, δ = 27.2
Speed: 40 km/s

Kappa Ursae Majorids (KUM)
Peak: Nov 05 (Oct 28 – Nov 17)
Radiant: α = 09:37, δ = 45.6
Speed: 65 km/s

Andromedids (AND)
Peak: Nov 06 (Oct 24 – Dec 02)
Radiant: α = 01:23, δ = 28.0
Speed: 18 km/s

Omicron Eridanids (OER)
Peak: Nov 13 (Oct 23 - Dec 02)
Radiant: α = 03:54, δ = -01.0
Speed: 28 km/s

November Sigma Ursae Majorids (NSU)
Peak: Nov 24 (Nov 17 - Dec 02)
Radiant: α = 09:56, δ = 59.0
Speed: 55 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.

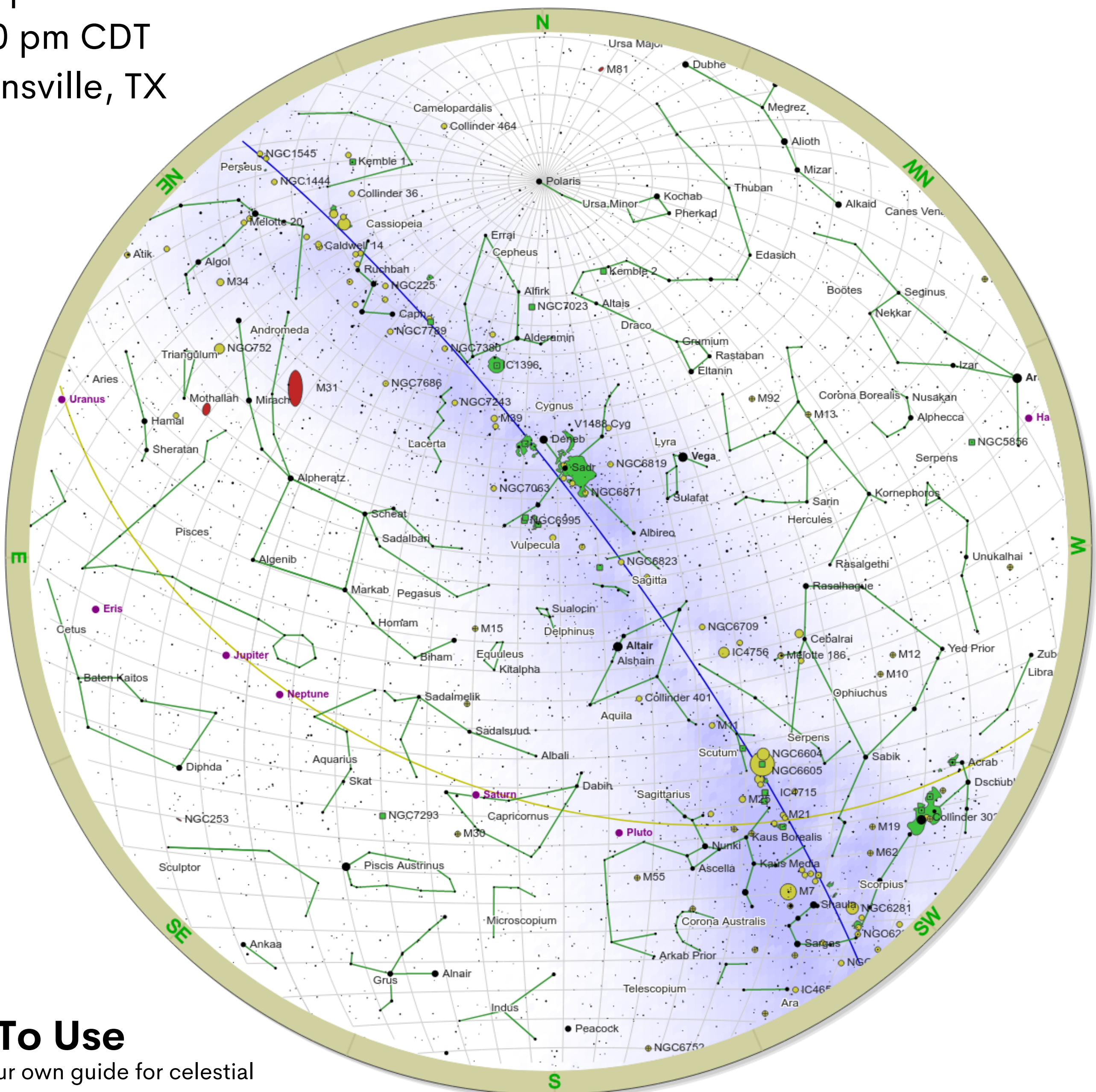
Zenith Hourly Rate (ZHR) - the expected number of observed meteor events per hour if the radiant of the shower was at zenith and observed under ideal conditions (limiting magnitude of +6.5).

Sky Map

22 September 2022

10:00 pm CDT

Brownsville, TX



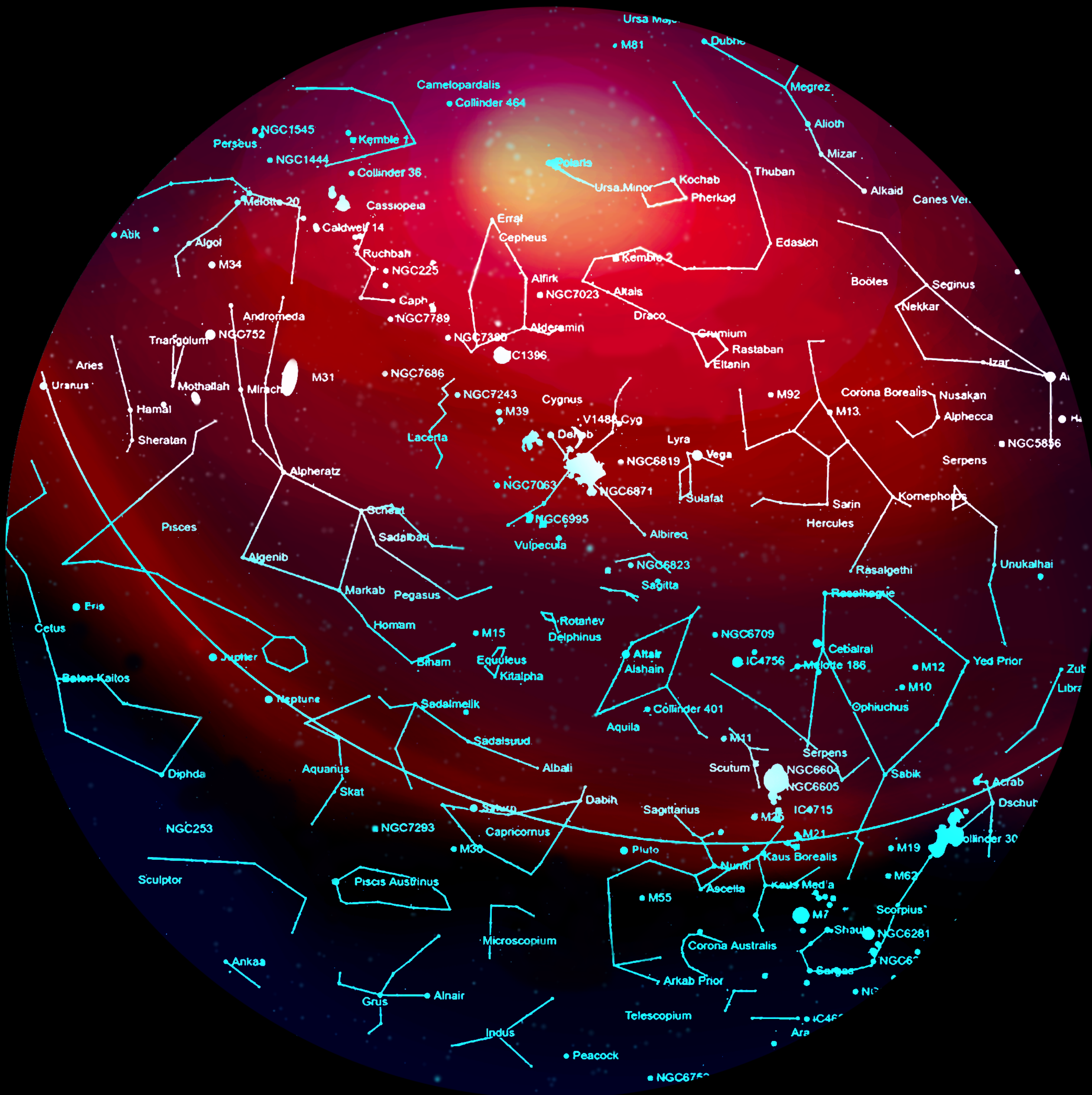
Sky Map Legend

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

How To Use

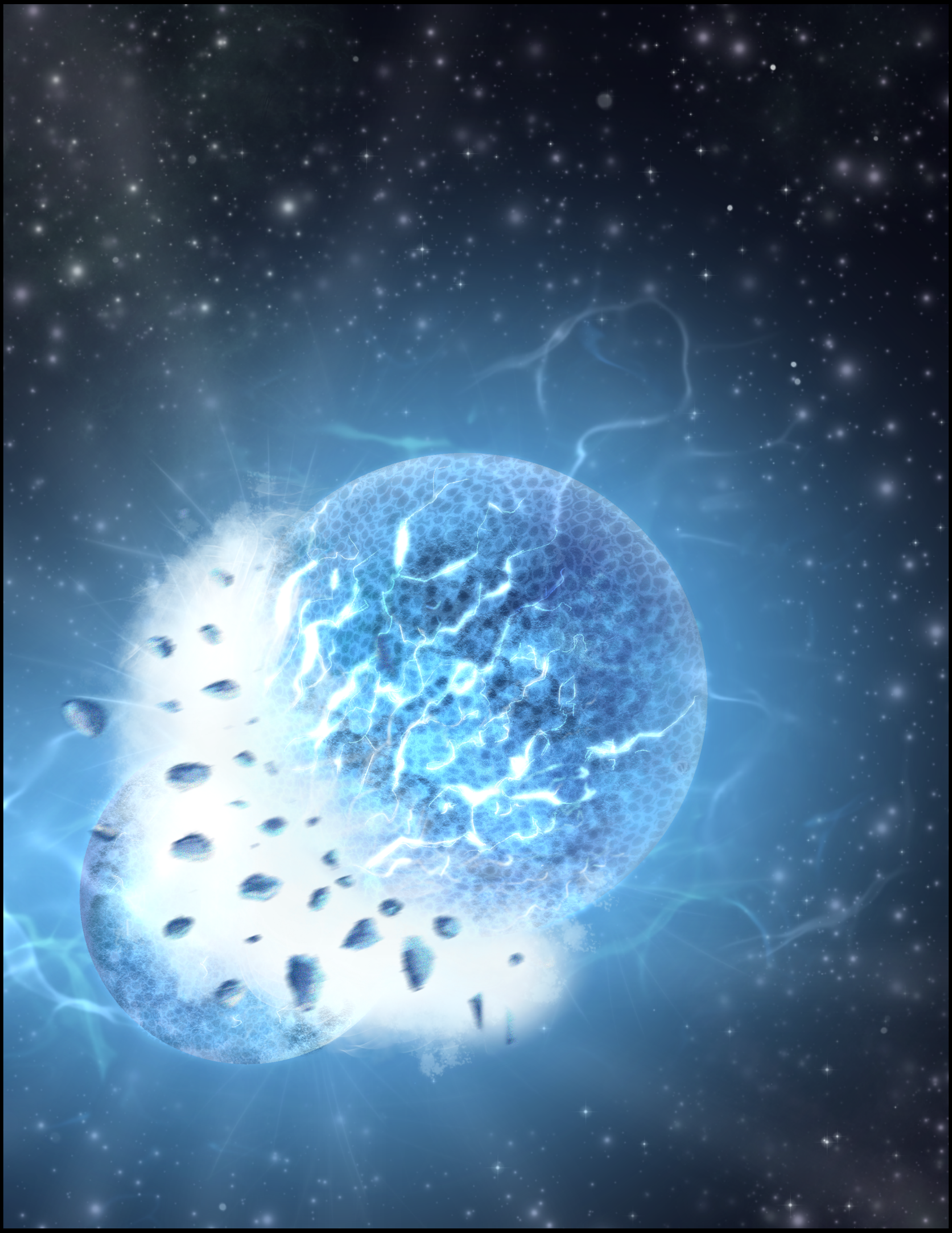
Here is your own guide for celestial navigation: your very own sky map, allowing you to select and observe the finest of cosmic objects. If you find yourself within the Rio Grande Valley, this map will be accurate to help you along your celestial journey. Good luck, and clear skies! [Source: In-The-Sky.org]

Those who first invented and then named the constellations were storytellers. Tracing an imaginary line between a cluster of stars gave them an image and an identity. The stars threaded on that line were like events threaded on a narrative.



Imagining the constellations did not of course change the stars, nor did it change the black emptiness that surrounds them. What it changed was the way people read the night sky. – John Berger (2014)

Sky map artistically rendered by Gabrielle Camuccio, gabriellecamuccio.com



Artist rendition of a binary neutron star (BNS) merger. Image credit: Laurence Datrier, https://ldatrier.github.io/gallery/

Colophon

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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.

FarFarOut! – A Starry Multi-Messenger
Volume 1, Issue 3
September 2022

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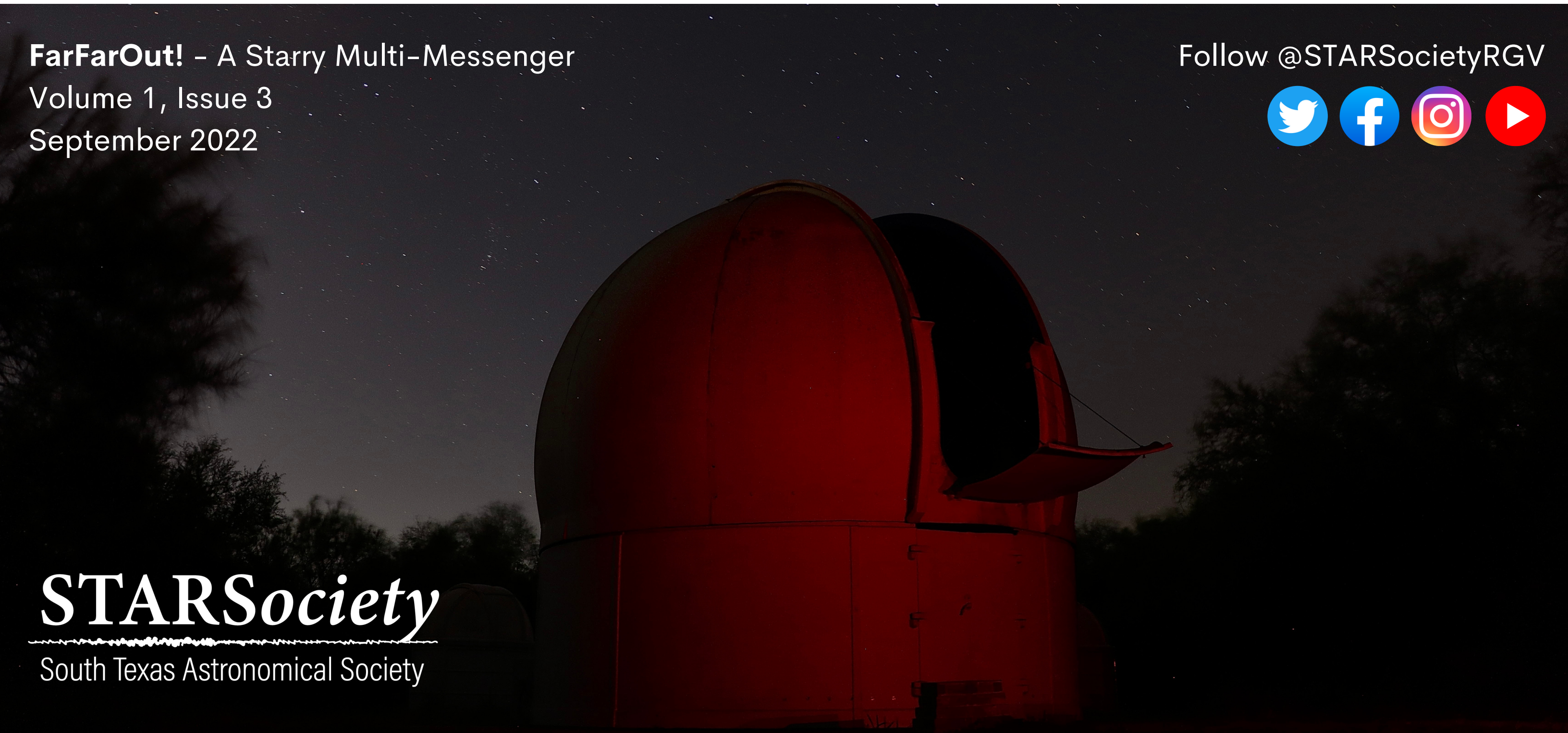

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