CORNELL ASTRONOMICAL SOCIETY NEWSLETTER

ISSUE 11 • MAY 2023

LETTER FROM THE PRESIDENT

Dear Lovely Readers,

On behalf of the wonderful team of CAS writers, I am honored to welcome you to the final newsletter edition of the semester! In this issue we travel to Europa, then hop over to take a stop by the ISS. This issue also features articles going into how spectroscopy works, and a little bit of the history and physics behind relativity.

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In regards to CAS, we recently held elections for the 2023-24 school year officers. I am excited to take this moment to announce next year's officers! Gillis Lowry will be taking on the role of President, with Ben Jacobson-Bell as Vice President! Next year's Treasurer will be Haonan Gong, with Ben Shapiro as Outreach Coordinator and Abigail Bohl (this semester's wonderful Newsletter Editor-in-Chief) taking on the newly official role of Newsletter Editor-in-Chief! Congratulations to our new officers! It has been an indescribable honor to have served as President of this most wonderful club in this past year, and I eagerly await the amazing work next year's officers will do!

Finally, I would like to end this letter by acknowledging our graduating seniors. Lucas, Alia, Kelly and Ethan, from myself and the rest of CAS, we love you and we will miss your presence next year. I am confident you will all go on to do wonderful things, and wherever you may go, your CAS family is here cheering you on. We love you, and congratulations!

Much Love,
Annika Deutsch, signing off as President

WHAT IS ISS AND HOW TO FIND ISS:

BY LUCAS LAWRENCE

When I was a sophomore, I drove up to Mt. Pleasant in Dryden with a few friends to do some stargazing away from Ithaca's bright lights. At one point, I noticed a bright, fast moving object which wasn't flashing like an airplane would. Having a hunch that I was looking at a satellite, I pulled up a night sky app with the real-time positions of most major man made satellites. I pointed my phone up at the speck of light flying across the sky and, to my surprise, learned that I was gazing right at the International Space Station.

International Space Station
Credit: [NASA]

The ISS likely needs no introduction, being one of the most famous engineering marvels of the modern age. However, while most of our readers are likely familiar with the ISS, not as many may know that you can actually see it with the naked eye. Be in the right place at the right time, and all you need to do is to look up and find a fast-moving dot of light.

Knowing when to look can be a challenge, but fortunately NASA has a website dedicated to helping anyone interested to know exactly when the ISS will be overhead. Go to https://spotthestation.nasa.gov/, search for your current location, and you will be given a list of upcoming opportunities to see the ISS with your own eyes.

According to the website, one of the best opportunities to see the ISS from Ithaca may be Saturday, May 13, when the ISS will be visible for 7 minutes. Of course, the weather in Ithaca is not always amenable to stargazing, so be sure to check the website on clear nights.

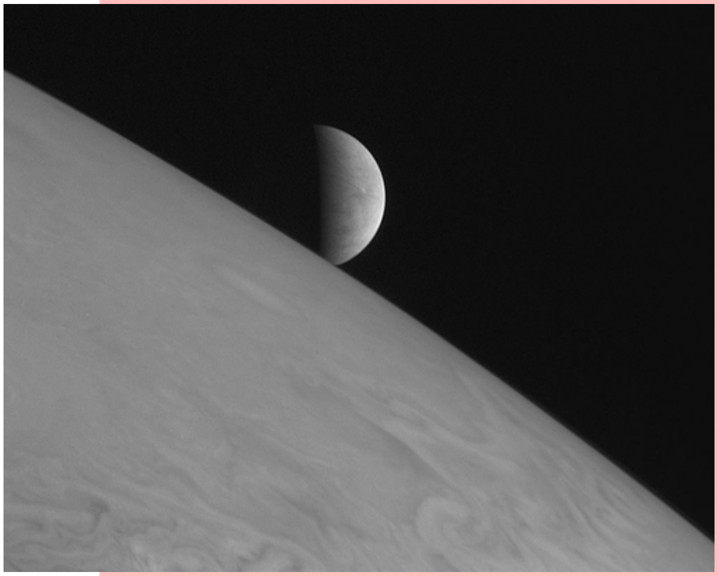
The International Space Station is seen in this 30-second exposure as it flies over Elkton, VA early in the morning, Saturday, August 1, 2015. | Credit: NASA/Bill Ingalls

EUROPA

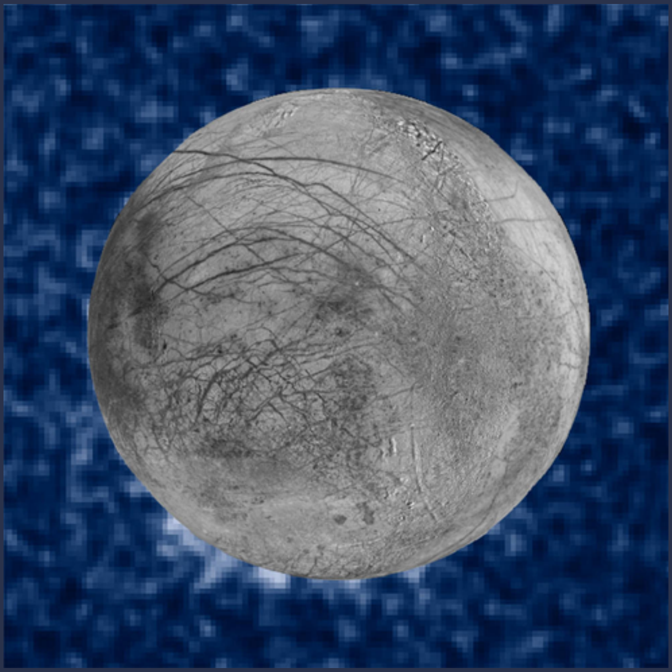
BY JUSTINE SINGLETON

Picture this: It is a cool day in spring, though not nearly as cold as it has been. The weather hasn't been this nice in a while, so you are out for a walk.

There are still patches of snow on the ground, but they are steadily melting away. If you look closely, you can see the tips of flower petals and leaves peeking through. Despite the long stretch of snow and cold, the life underneath still managed to survive. It reminds you of Europa.



Europa rising above Jupiter's cloud tops. Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute



Composite image of suspected water vapor plumes on Europa. Water vapor image taken by Hubble. Europa image superimposed on top is a combination of data from Galileo and Voyager. Credit: NASA/ESA/W. Sparks (STScI)/USGS Astrogeology Science Center

Scientists suspect that life might be able to survive beneath the icy crust of Jupiter's moon. It's part of the reason why two missions are being sent to Europa—Jupiter Icy Moons Explorer (JUICE), which was launched on April 13 and will arrive in July 2031, and Europa Clipper, which is planned to launch in April 2024 and arrive in April 2030.

The main feature that makes the Jovian moon a consideration for life is its subsurface ocean. Observations from the Hubble Space Telescope have shown signs of plumes spraying from Europa's surface. Afterwards, a team at the Keck Observatory studying the chemical composition of that moon's atmosphere found signs of water vapor. Since the only life we know of exists on a planet covered in water, an ocean world seems like a good place to search.

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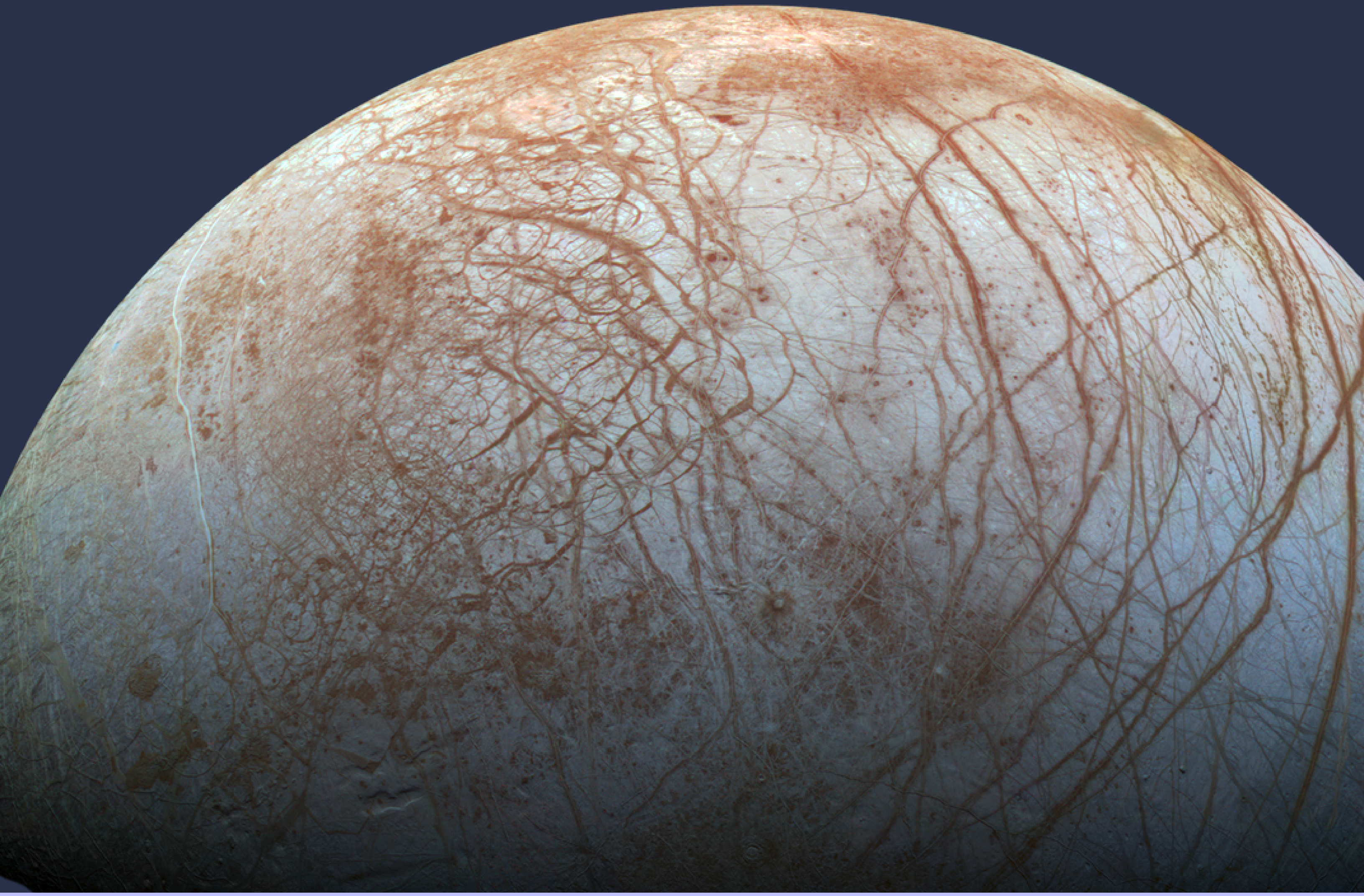
There is a chill in the air, and you grab the edges of your jacket. As you brace yourself against the cold, you remember another of Europa’s features. Tidal heating. Europa’s interior is kept warm by Jupiter’s gravitational pull. If there is any life there, you think, it must be very comfortable. Jupiter’s gravity might have also formed the cracks on the Europan surface. Alternatively, they may have formed from tectonic activity. If Europa does have plate tectonics, it might also have volcanoes on the ocean floor. The chemical processes from volcanic eruptions would also make good conditions for life. After all, there are animals on Earth that call undersea volcanoes their home.

As you pass by the remaining bits of snow and frost, you imagine yourself on Europa. What would you see if you could peek through the cracks on the surface? The idea that a moon about the size of our own could have life hidden inside is fascinating. What would it even be like? Crabs scuttling across the ocean floor, never having seen the light of day? Space urchins getting nutrients from underwater volcanoes? Or even just microbes? The possibilities are endless. In Earth’s oceans alone, there are so many varied forms of life. Who knows what we could find in a Europan ocean?

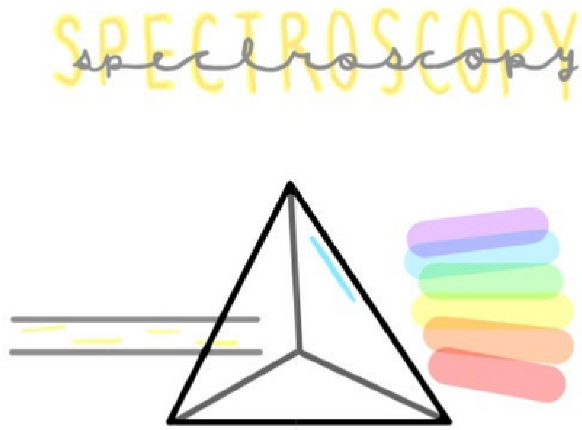
Your walk is over, and you decide to head back inside. In a few days or weeks, you hope, it will start to feel warm again. The life that’s been hidden beneath the snow all winter will emerge once more.



WHAT IS SPECTROSCOPY?

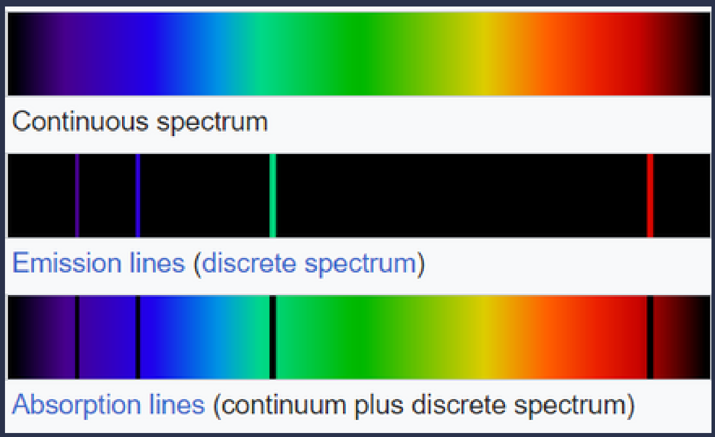
BY ABRA GEIGER

If you ever shine white light through a prism, you will notice that it disperses into a rainbow of colors. You will see this full rainbow pass from the prism because white light contains all visible wavelengths of the electromagnetic spectrum, and the prism separates the white light into its composing wavelengths. Astronomers use this optical phenomenon for spectroscopy, which is the study of light across the electromagnetic spectrum for the purpose of learning about the matter that it interacts with. Through spectroscopy, we can study distant astronomical objects such as planets, stars, and galaxies.



The wavelengths of light emitted from an object can reveal details about the object's chemical composition. For example, by analyzing the composite wavelengths of light emitted from a distant star, we can learn what elements it is made up of, its temperature, and more. A hot, solid body emits an approximately continuous spectrum across all wavelengths in the electromagnetic spectrum, whereas a hot solid body surrounded by cooler gas will emit a continuous spectrum with absorption lines.

Each element has specific wavelengths at which it prefers to absorb energy. Therefore, absorption lines correspond to the specific wavelengths at which the surrounding cold gas elements prefer to absorb energy. Additionally, hot gas will have *emission* at very specific wavelengths. These wavelengths are the same as the absorption wavelengths for a given element. This analysis is highly applicable to stars and can also be used to learn about exoplanets, their atmospheres, and more.

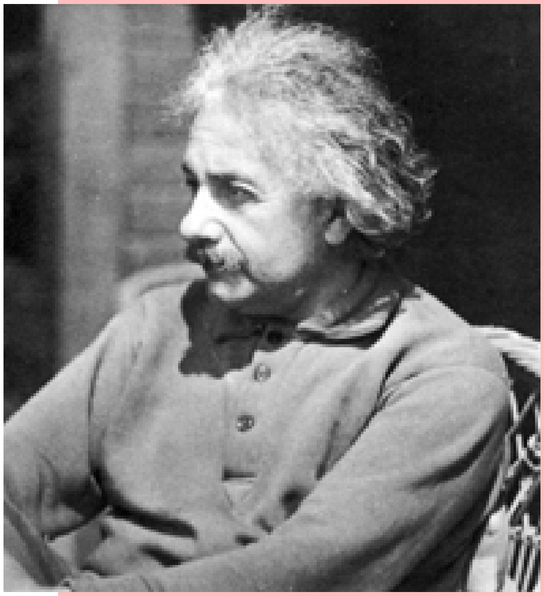


Spectroscopy can also be used to measure the motion of an observed object through the Doppler effect. The Doppler effect shows us that light from an object moving away from Earth will be shifted toward lower frequencies from our perspective. Similarly, light from an object moving *towards* Earth will be shifted toward *higher* frequencies from our perspective. Through spectroscopy, we can observe and measure the deviation of observed frequency of light from expected frequency for an astronomical body and determine its motion towards or away from us. Spectroscopy is an incredible tool for understanding the motion and composition of our observable universe!

SPECIAL & GENERAL RELATIVITY EXPLAINED

BY DYLAN JACKAWAY

Everyone's heard that space and time are "relative" and that "*E*" equals "*mc*-squared," but what do we mean when we say that? Known as one of Albert Einstein's founding contributions to what we know as modern physics, the theory of relativity has been recognized over the last century as an extremely accurate model of reality. While many of the actual equations Einstein used to build these models are far beyond the scope of this article (and are in fact taught in some classes by the Cornell Physics and Astronomy Departments), the concepts he used as inspiration through his signature thought experiments are fairly accessible.



Albert Einstein
Credit: NASA

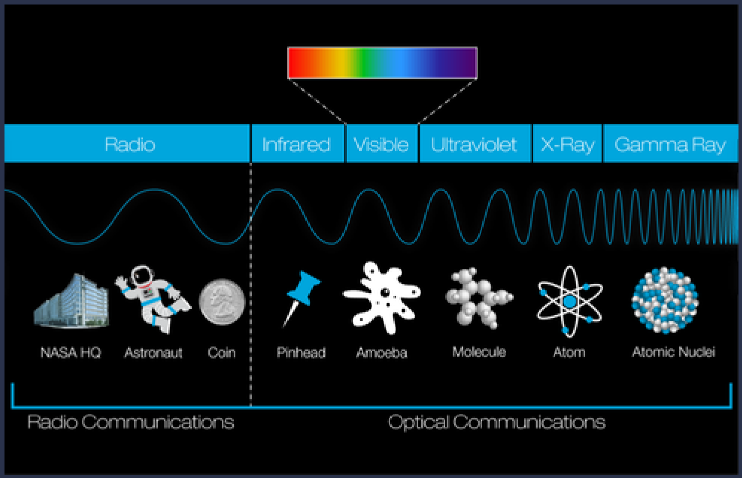


Image of the electromagnetic spectrum. Wavelength of each category of wave is compared to objects of similar size.
Credit: NASA

In the lead-up to the turn of the 20th century, scientific consensus had it that light was composed of electromagnetic waves, and just like sound waves in air or seismic waves in earth, there must be some material that served as their medium, referred to hypothetically as "the luminiferous æther."

As Earth moves in its orbit around the Sun, it would be moving through this æther, so any light emitted "forward" (in the same direction as Earth's motion) would move away more slowly, while light emitted "backward" (in the opposite direction from Earth's motion) would move away more quickly. But when Albert Michelson and Edward Morley attempted to measure just that in 1887, they found that the speed of light remained constant. It was later gradually confirmed that no such æther exists.

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In his spare time while working as a patent clerk in Switzerland, Einstein pondered the consequences of this apparent rule of nature keeping the speed of light unchanged. Assuming that the laws of physics remain the same in any possible environment (known as the "principle of relativity"), Einstein realized that if you could get in a car and drive away at close to the speed of light, you would still see the beams from your headlights moving away from you at the speed of light, but other people would see these beams barely managing to outpace you. (This also implies that it's impossible to ever reach the speed of light.) How to explain this discrepancy? When traveling close to the speed of light, time *literally* speeds up from your point of view. For every second that passes by for you, people back on Earth might experience minutes, days or even years. This is referred to as [time dilation].

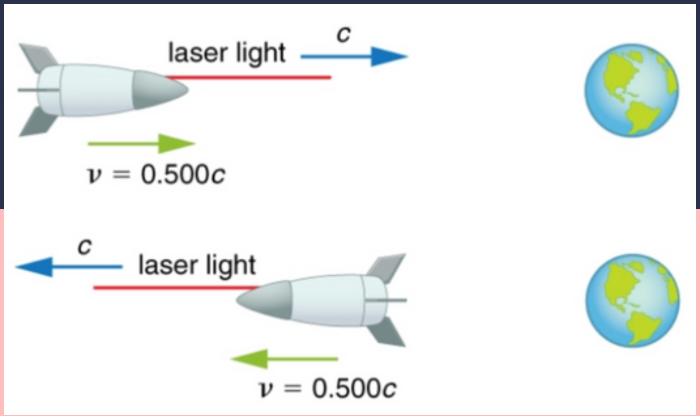

Diagram of light speed as a constant
Credit: [LibreTexts]

On the flip side, if you passed by a planet or star at this high speed, it would be squashed iinto an ellipsoid from your point of view, since an observer on that planet wouldn't agree with you about how long it took for you to pass by. This is referred to as length contraction.

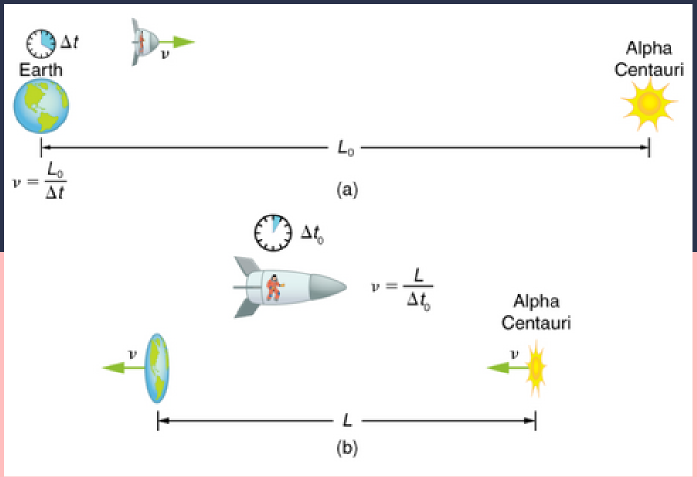

Diagram of length contraction | Credit [LibreTexts]

The top part of the diagram is from the perspective of a person on Earth. This person would measure a distance "L_0" between Earth and Alpha Centauri.

The bottom part of the diagram is from the perspective of a person moving inside the rocket. Due to length contraction, this person would see the distance between Earth and Alpha Centauri as shorter than the person on Earth.

These two effects are not optical illusions or any kind of sleight of hand, but real physical effects that make up the primary consequences of special relativity, published in September 1905. We never see these happen in our daily lives, due to the snail paces at which we tend to move compared to the speed of light (299,792,458 meters per second). Two months later, Einstein followed this up by examining inelastic collisions between objects at these "relativistic" speeds (i.e. where the two colliding objects, with a lot of kinetic energy, stick together). He found that they had to acquire an increased mass, leading him to realize that [mass and energy] must be on some level equivalent. In particular, his equation "*E* equals *mc*-squared", means that even small amounts of mass at rest contain enormous energy, due to the size of the "speed of light squared" conversion factor.

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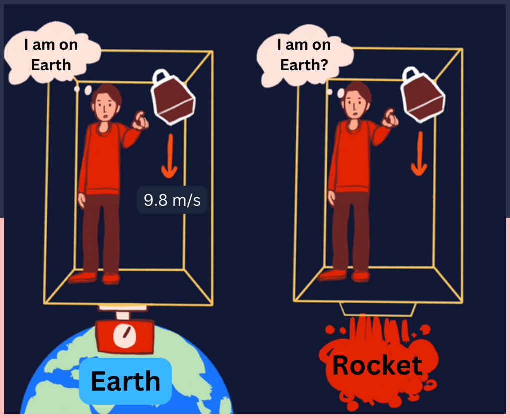
If we stop and think about it, we'd realize that according to the principle of relativity, the reverse should also hold, since from the planetary observer's point of view, your ship should be compressed in the direction of motion. This is indeed the case. But they'd also expect that you should experience minutes or years for every second experienced by them, and we can't have it both ways. This discrepancy arises from the fact that a spaceship can't instantaneously jump to a high speed, but requires time to accelerate, and special relativity only describes the experiences of observers traveling at a constant speed.

In order to generalize this model, Einstein pondered the nature of acceleration itself. When standing on the ground, we experience Earth's gravity pulling at around 9.8 meters per second per second. But if a spaceship in open space accelerated at this rate, its occupants would feel an identical "force" pressing them into their seats, despite the absence of any planetary-mass objects. Similarly, a person in freefall experiences no gravitational force, not unlike occupants of a spaceship with its engines off.

Einstein concluded that these seemingly unrelated phenomena must be one and the same, due to an observer's inability to meaningfully distinguish them. However, this still left open the question of what causes objects in a gravitational field to fall, since we've just questioned the reality of the force acting on them. (Newton himself had no explanation for what actually causes gravity, despite his description of its effects, which was accurate enough for NASA to send people to the Moon.)



On the right-hand side, the person sees a weight falling due to Earth's gravity.

On the left-hand side, the weight is "falling" because the rocket enclosing it is accelerating. This phenomenon is similar to when your car takes a sharp turn around a curve, and you sway to the side. Both the weight in the rocket and you in the car feel a "force" due to acceleration. To the observers, the reason why the weight is falling is indistinguishable, which is why they both are wondering if they are on Earth.

Einstein then considered the behavior of two objects dropped from space, both falling directly towards Earth's core. Despite the initial appearance of their trajectories as parallel lines, they gradually draw closer, not unlike two people walking towards the North Pole from different locations on the equator. Just as these two Arctic explorers never experienced a force bringing them together, neither do these two falling objects (assuming their own gravitational attraction to be negligible). This led Einstein to infer the nature of spacetime as a four-dimensional curved surface along which objects travel in "straight lines" that merely *appear* curved to us. As this curvature is caused by the presence of large masses, this principle is often summarized thus: "spacetime tells matter how to move; matter tells spacetime how to curve."

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Published in 1915, the theory of general relativity has generated a wide range of predictions that have passed every test scientists have come up with. The first of these was during a solar eclipse in 1919, which allowed stars located just next to the Sun to be observed without their light being drowned out. It was found that the Sun's gravity actually bent the path of these stars' light on its way to Earth, causing them to appear slightly off from their regular positions in the sky by the exact amount that Einstein's equations said they would. Another prediction expands on the already established phenomenon of time dilation: because it takes energy to "climb out" of a gravitational field, any light doing so would have its frequency reduced in the process (known as "redshifting").

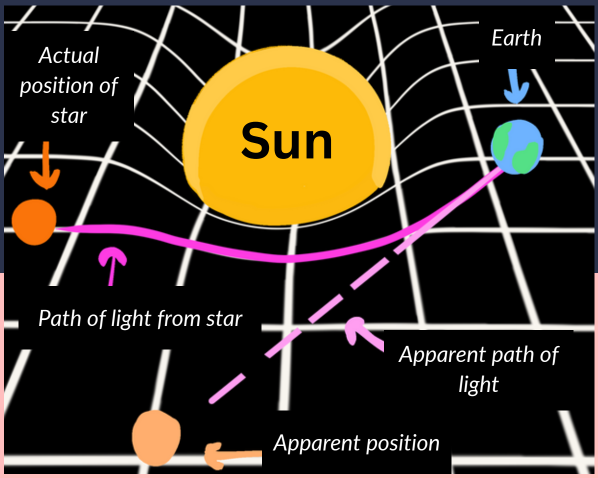


Diagram of spacetime curvature.

The Sun's large mass causes spacetime to curve around it, as noted with the grid curvature around it. This curvature appears to warp the path of light coming from a distant star, causing it to look like it is in a different position relative to Earth than it actually is. The effect is exaggerated in this diagram for visibility purposes.

The actual position of the star is compared against its apparent position.

But because light waves are really just oscillations in the electromagnetic field, an outside observer looking in would interpret this light to mean that these oscillations are occurring more slowly than an observer at the source would; in other words, time passes more slowly close to a gravity source, an effect which the GPS system relies on for its accuracy and a plot point that features prominently in the hit sci-fi movie *Interstellar* (2014).

Most recently, in 2016, researchers at the Laser Interferometer Gravitational-wave Observatory detected the merger of two massive black holes based on the spacetime ripple that they produced in the process, spreading out at the speed of light. They did this using an apparatus similar to that of Michelson and Morley, but instead of expecting the speed of light to change, they saw the length of the apparatus itself stretch and contract by a small fraction of the width of a proton as the wave passed by (a testament to the sensitivity of their measurements).

Although that's as much as we have room to discuss in this newsletter, it represents just a sample of Einstein's profoundly impactful career. While some hold Einstein and his "*E* equals *mc*-squared" equation responsible for the invention of the atomic bomb, Einstein was also an outspoken advocate for progressive ideals, world peace, and opposing authoritarianism. (And no, he didn't fail math class as a kid.) If you'd like to learn more about him, I'd recommend *Einstein's Greatest Mistake: The Life of a Flawed Genius*, by David Bodanis.

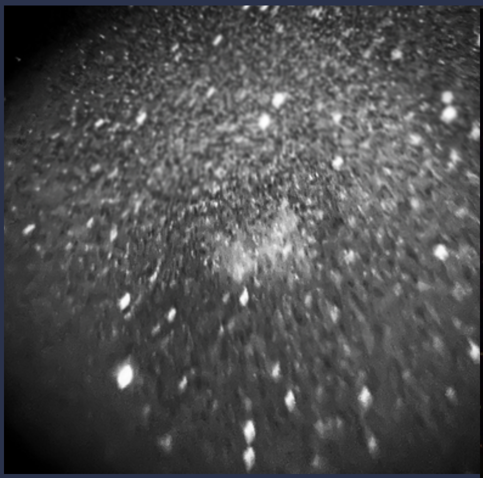
RETURN TO CHERRY SPRINGS

BY GILLIS LOWRY & BEN JACOBSON-BELL

Two years after CAS's last excursion to Cherry Springs State Park, an International Dark Sky Park near Coudersport, PA, we returned the evening of May 10 with two cars, two telescopes, and a keenness to observe deep-sky objects we rarely get to see through Ithaca's city lights.

On a tarp in the middle of the Overnight Astronomy Observation Field, we set up our 15" Obsession and one of our new 4.5" Orion tabletop scopes. Over the course of about two hours, we saw 19 Messier objects, a few additional galaxies and star clusters, and a beautiful dark sky with the Milky Way through Cygnus just beginning to rise in the east.

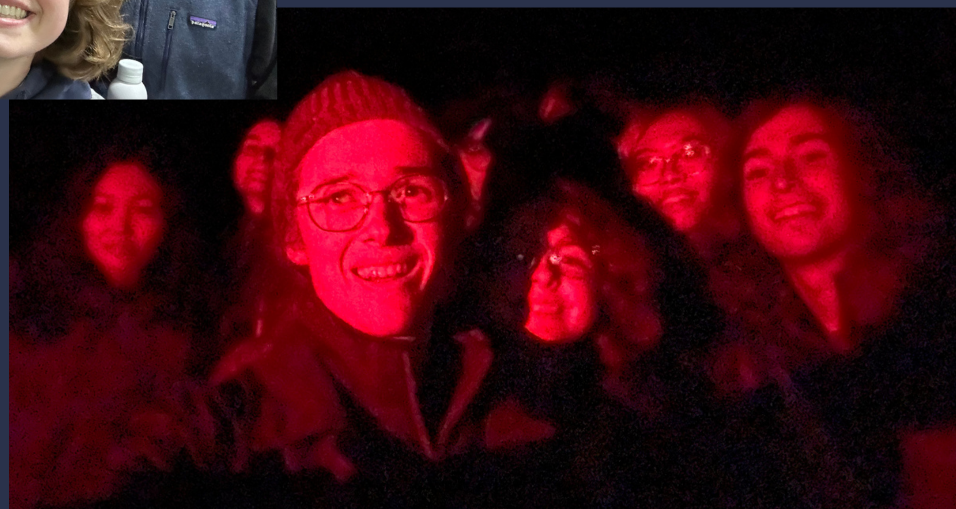
Our 19 Messier objects from Wednesday represent a new record for us in short-term observing, which we hope will lead to successful Messier Marathon attempts as soon as next year! A complete list of our Wednesday targets, including non-Messier objects, can be found on the following page.



We brought our trusty night vision goggles and Gillis's new iPhone (courtesy of the concrete she dropped the old one on) to take some pictures through the Obsession! At left is our photo of the Dumbbell Nebula (seen as a bright hourglass shape in the center), alongside a composite image by the Big Amateur Telescope community.

Don't forget the Ring Nebula! It's finally rising early enough in the night to be visible at open houses. At the far right is an improved photo from our HBO trip last spring! Looking closely at our image, you might even see the elongated gas on the top that gives the nebula an egg shape. Image credit: NASA

Back row, from left: Grant Whitman, Stella Dang, Annika Deutsch, and Warrick Ma.
Front row, from left: Ben Jacobson-Bell, Maggie Li, Gillis Lowry, and Dylan Jackaway.



Club photos of the 5/10/23 Cherry Springs crew — at the gas station just outside the park, above, and at the end of the night, at right.

List of Cherry Springs targets (5/10/23):

- Unidentified galaxy in Coma Cluster*
- M65, M66, & NGC 3628 (Leo Triplet; galaxies)
- M95, M96, M105, & NGC3384 (galaxies in Leo)
- M4 (globular cluster in Scorpius)
- M104 (Sombrero Galaxy)
- M57 (Ring Nebula)
- M13 (Great Hercules Cluster; globular cluster)
- M27 (Dumbbell Nebula)
- Albireo (double star in Cygnus)
- Second unidentified galaxy in Coma Cluster*
- M81 & M82 (Bode's Galaxy and Cigar Galaxy)
- M97 (Owl Nebula)
- M108 & M109 (galaxies in Ursa Major)
- M51 & NGC 5195 (Whirlpool Galaxy)
- M101 (Pinwheel Galaxy)
- M63 (Sunflower Galaxy)
- M94 (galaxy in Ursa Major)

(Objects are listed in order of observation. All were observed through the Obsession, though a few were also found using the 4.5" Orion scope. Venus, Mars, the Milky Way, and the Alcor/Mizar double were also observed without a telescope.)

** These galaxies were not intentional targets, but were found by simply pointing the Obsession in the general direction of the Coma Cluster. We did not take the time to identify them in our charts on Wednesday.*

CREDITS

CAS Officers

Annika Deutsch, President
Anthony Fine, Vice President
Ben Jacobson-Bell, Treasurer
Gillis Lowry, Outreach Coordinator
Phil Nicholson, Faculty Advisor

Contributors to this issue

Abigail Bohl, Editor in Chief
Claire Cahill
Annika Deutsch
Abra Geiger
Dylan Jackaway
Ben Jacobson-Bell
Lucas Lawrence
Gillis Lowry
Justine Singleton

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Cornell Astronomical Society (CAS) is a student-run non-profit organization founded in 1972.

Contact:
209 Cradit Farm Dr.
Ithaca, NY 14853
astrosociety@cornell.edu