CORNELL ASTRONOMICAL SOCIETY NEWSLETTER

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LETTER FROM THE EDITOR

Greetings readers! I hope you're all enjoying your summer, while in Ithaca or elsewhere. I know it's been a while since the last regular edition of the newsletter, which means there's a lot of Fuertes activities to catch up on. CAS had a moon-filled March and April, with a shockingly clear Lunar Eclipse with some of the busiest crowds this year. Our last lecture series of the academic year was held on April 11th to celebrate Yuri's Night, with Professor Mason Peck lecturing on How to Thrive on the Moon. CAS also made journeys to Cherry Springs State Park and the Finger Lakes National Forest for stargazing and campfire activities. We celebrated graduation and reunion as well, providing a final send-off to our wonderful seniors and giving tours for alumni of all ages.

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Speaking of alumni, CAS ‘24 alumna Justine Singleton returns to the newsletter with another moon article! Additionally, we also have guides on giving sky tours and doing astrophotography in this edition, along with two farewells from former presidents Gillis Lowry and Erik Payton.

Additionally, Fuertes will be open for much of the summer for open houses! It’ll be undergoing renovations sometime later this summer, so keep an eye out for more details.

I’d like to thank all of our newsletter contributors for allowing us to continue publishing new editions, and to all you wonderful readers for continuing to read them. It’s been a joy being your newsletter editor.

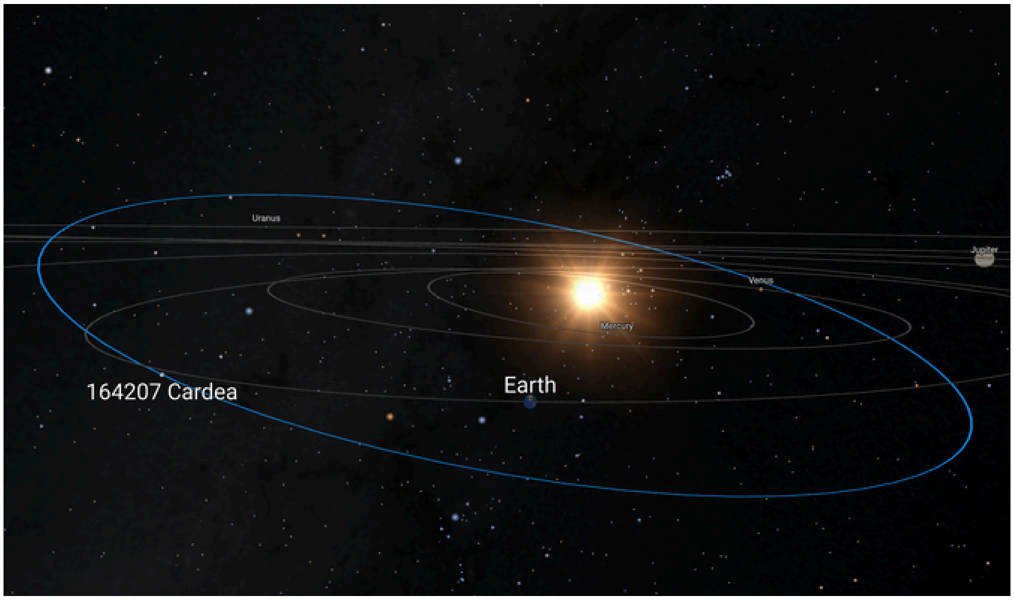
Fare thee well,
Shane Kuo, Editor-in-Chief

Fuertes during the Lunar Eclipse
Credit: Shane Kuo

AND INTRODUCING...CARDEA

BY JUSTINE SINGLETON

Picture this: You are in an introductory astronomy class in college. One day, your professor announces an extra-credit assignment. The science podcast Radiolab is holding a contest to name one of Earth's quasi-moons, asteroids that appear to orbit Earth from a certain point of view, but are actually orbiting the Sun. After some research, you decide on a name. Cardea.



Unlike moons, quasi-moons, including Cardea, orbit the sun. Its orbit with respect to other Solar System bodies is shown above.
Credit: [ESA/GAIA/DPAC]

Clayton Chilcutt, a student at the University of Georgia, found himself in this exact situation. His astronomy professor, Prof. Hina Sheikh, announced the contest in her class during a unit on small Solar System objects. From June through September 2024, participants around the world were able to submit their names of choice for quasi-moon 2004 GU9. Each name submission had to follow the International Astronomical Union (IAU) rules and guidelines for naming near-Earth asteroids, which meant it had to be a mythological name unrelated to creation myths or the underworld, written in Latin script, with a maximum length of 16 characters. Chilcutt's proposed name, Cardea, was a Roman goddess of doorways – specifically, hinges. After researching names from Greco-Roman mythology, Chilcutt decided on "Cardea" because of her association with transitions and thresholds and the poetic parallels to the quasi-moon's orbit.

In October 2024, judges, including astronomers, journalists, students, actors, artists, and Cornellian Bill Nye, narrowed down the list to seven finalists. Coincidentally, Chilcutt was not the only finalist in his class; his classmate Samuel Lashley's submission, Tarriaksuk, also made the list. In December 2024, the public was able to vote on which name would become the official name of a near-Earth object. And once voting closed at midnight on New Year's Day, Cardea was ultimately chosen as the new name for this quasi-moon, which the IAU officially announced on January 13, 2025.

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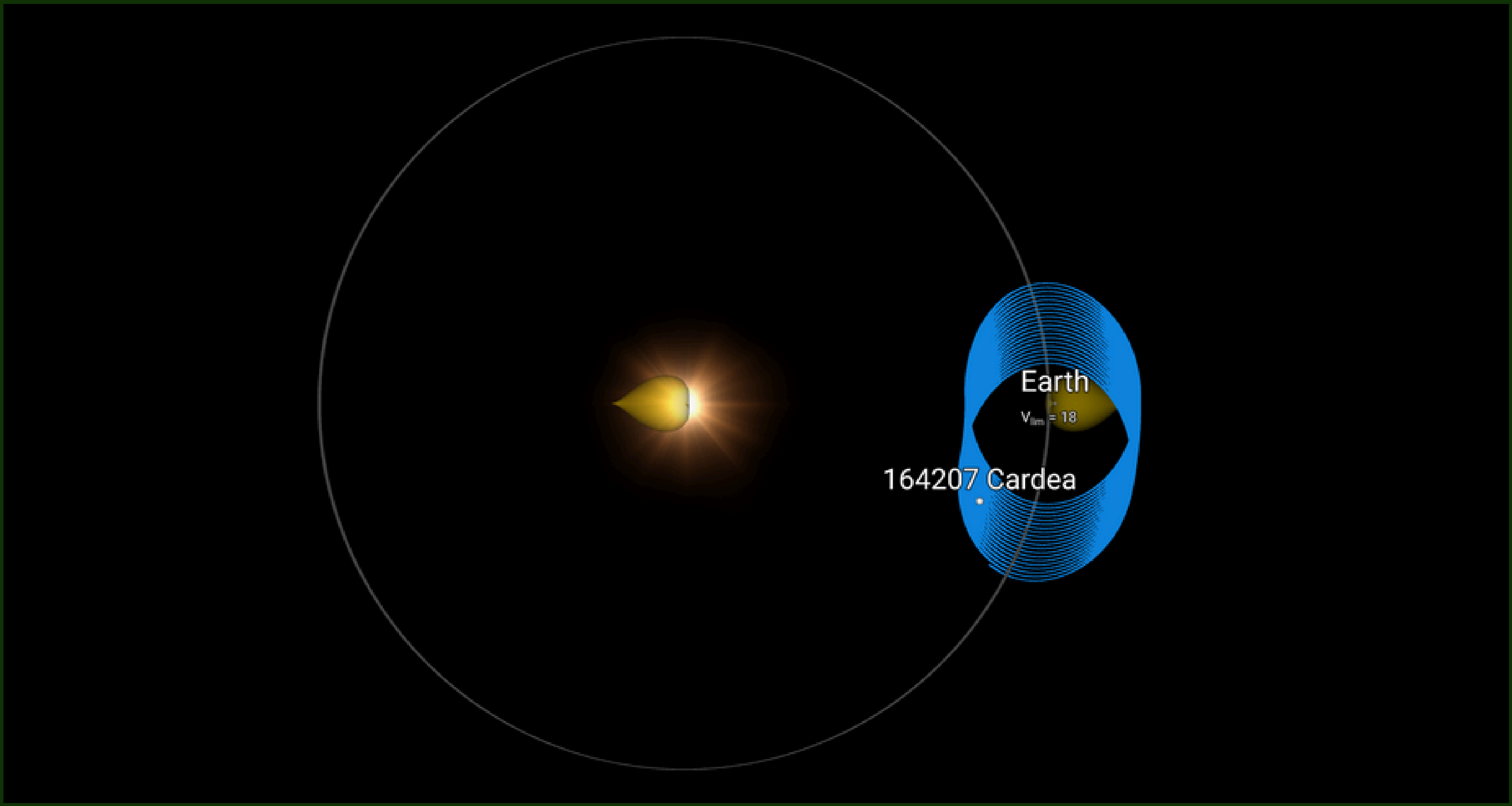

Cardea's orbit with the Sun and Earth fixed; it appears to orbit Earth in this render.
Credit: [ESA/GAIA/DPAC]

A Partial Lunar Eclipse
Credit: Elina Stengle

But Cardea itself is far from new. This quasi-moon was discovered in 2004 and has been near Earth since 1900. Interestingly, its next "close approach" is in October 2026. However, what is "close" for a quasi-moon isn't necessarily close on a human scale. At that time next year, Cardea will be about 18.5 million miles from Earth, over 77 times the average distance between Earth and the Moon.

So why should we care about what we call an asteroid not much longer than a football field? Perhaps Latif Nasser, Radiolab's co-host, put it best: "We hope that this quasi-moon name continues to inspire people to learn more about space and science in general, to look up together to remember the universal things we all share."

HOW TO GIVE A CONSTELLATION TOUR

BY JILLIAN EPSTEIN

So you want to give a constellation tour. As someone who has given many constellation tours, both paid and for free, I hope to impart some wisdom on how to give a good constellation tour for those who hope to continue carrying on what is, in my opinion, one of the best crowd-management strategies on the deck.

Before you start, orient yourself. Locate the Big Dipper, the Little Dipper, and at least four other constellations. That's a good place to begin. Don't try to start talking before you figure out where things are. Pull out your star map and confirm you know what's going on in the sky before you draw attention to yourself.

To begin, I usually climb up on a ladder and just start talking. People will quiet down if they are interested. However, I am rather vertically challenged, so standing on a ladder may not be necessary for everyone. Standing on a ladder does have the benefit of clearing all your sightlines, and makes lasing across the sky notably safer, as you are well above everyone's heads.

Right when you first point the laser, someone will likely ask about it. At this moment, the best thing to do is just to say "it's a special astronomy laser," and push further conversation for later. You're here to do a constellation tour, not discuss the dangers and details of a laser pointer.

Once everyone's attention is on the stars, start with the Big Dipper. Always start with the Big Dipper. It's bright, it's big, and it's always in the sky. Unfortunately, during winter, it may be hidden behind the glare of North Campus. There is no secret to finding it. You just need to search for it until it catches your eye.

A busy night on the deck at the Fuertes Observatory
Credit: Shane Kuo

Now, reveal that the Big Dipper is not a constellation. It is an asterism. The constellation is Ursa Major. There are 88 official constellations, which is why this distinction is important. Point at the second star from the end of the handle. Ask if anyone can see two stars. If anyone says yes, I usually make a joke about how they could be an archer in the ancient Roman military. Tell them how it was an ancient eye test. Call it Alcor and Mizar. Or Mizar and Alcor, whichever you prefer.

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Dramatically reveal that it is actually six stars all gravitationally bound. Unfortunately, it is physically impossible to discern more than two of them with the naked eye because of how close together they appear. You can get up to four with a telescope. However, every time, there is a little kid who claims they can see three with the naked eye. There is no need to crush their dreams.

Take the pointer stars of the Big Dipper and point out Polaris. Ask the crowd to guess the angle between the horizon and Polaris. They won't say 42°, but they will probably be close. Reveal that this is the latitude of Ithaca. Make a joke about sailors of the past. Or pirates. Up to you. You can also discuss how Polaris would be directly overhead at the North Pole, and right on the horizon on the equator.

Point out the vague shape of the Little Dipper. Mention Ursa Minor. You won't be able to see more than three stars unless it is a very clear night. It's too dim. A good trick to figure out where the remaining stars would be is to remember that the Little Dipper pours into the Big Dipper.

If Cassiopeia is high enough, move onto Cassiopeia. Tell about how it is a throne on which a woman sits. Unless it is upside down (looks like an M), then she is clinging on for dear life. Poseidon stuck her up there because she said her daughters were prettier than his. You know how the Greek gods were.

Constellations and Asterisms in the Northern Sky, including the Big Dipper, the Little Dipper (Ursa Minor), and Cassiopeia
Credit: Stellarium

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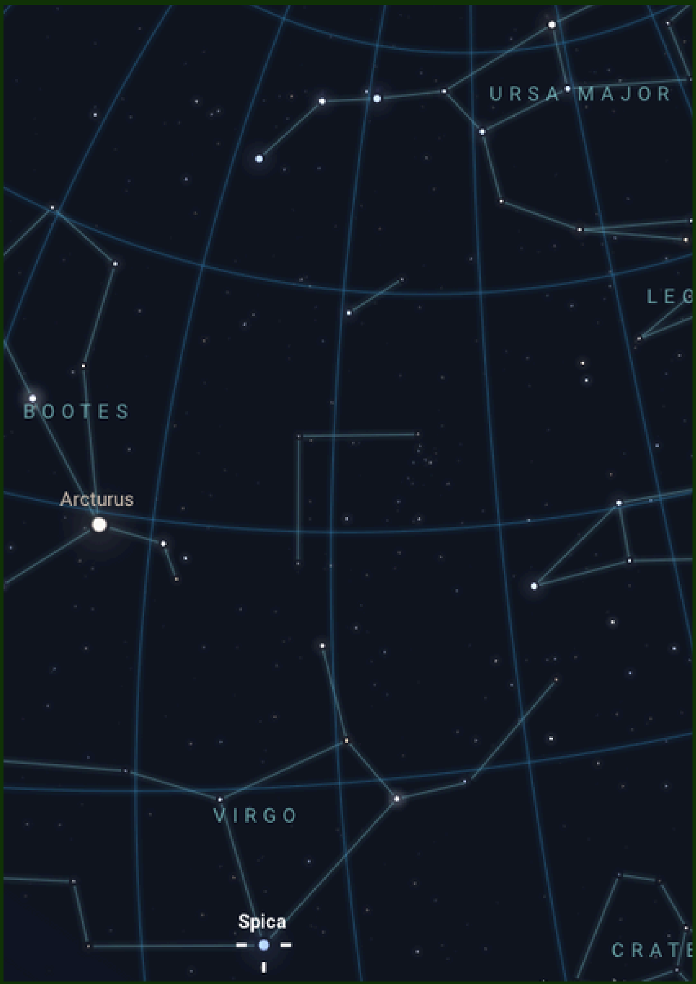
If it is up, point out Orion. Show them the belt and the Orion Nebula. End with Betelgeuse. Pronounce it however you want, but if you say “Beetlejuice,” don’t say it three times. (With certain crowds, a joke about this lands well.) Talk about how it may go supernova. When discussing supernovas, you can also talk about the Crab Nebula, which is located in Taurus. Note that the Crab Nebula went supernova in the 11th century and was bright enough to be visible in daytime. Various ancient civilizations across the globe recorded this, including the Chinese, Arabs, and Native Americans, but not the Europeans, who were too busy dying of the plague. (In reality, they likely noticed it, but the records did not survive.)

If it’s winter or spring, point out the winter triangle, which contains the stars Sirius, Betelgeuse, and Procyon. If it’s not, be glad it is not cold out!

The Winter Triangle of Betelgeuse, Procyon, and Sirius, along with their respective constellations.
Credit: Stellarium



Arcturus and Spica with respect to the Big Dipper.
Credit: Stellarium

Move back to the Big Dipper and follow the handle to “arc to Arcturus”, provided that it’s in the sky. Point out that it is a red giant, and Bootes if you’re feeling confident. (It can be a little tricky to know exactly which stars are correct without a star chart, in which case I often gesture vaguely in the right direction.)

Then, provided that it’s spring or summer, you can “spike to Spica.” Say that Spica is in Virgo. Note that Virgo is extremely difficult to find except on a clear night. Even if Virgo isn’t up or is too dim to see, point out other visible Zodiac constellations, though. Highlight the planets as you go. Mention that the Zodiac constellations are extremely dim. You can typically only get the heads of the Gemini twins (Castor and Pollux), Leo, Spica from Virgo, Scorpio, the teapot of Sagittarius, and a bit of Taurus. If you can see the Pleiades, also mention Subaru. Their logo has seven stars, corresponding to the seven brightest stars in the Pleiades. The rest are difficult. However, do explain the ecliptic! My go-to joke is that “if the flat earthers just thought a little bigger, they’d at least be right, since the solar system is flat.”

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Various constellations on the Ecliptic, such as Leo, Gemini, and Taurus, alongside some planets.
Credit: Stellarium

If Sagittarius is visible, mention how the center of the Milky Way is over there. This is a great time to discuss galactic centers and black holes if you feel up for it, since the center of the Milky Way is, of course, a black hole! Finally, if Scorpio is in the sky, point out Antares. Explain how that translates to “not Mars,” since, because of its color and location on the ecliptic, Mars can end up close to it.

Prepare yourself to be asked about all 12 Zodiac signs, so know which ones are up that night. However, know that the current Zodiac dates are over a thousand years out of date, and fudged a little bit so that each constellation has equal time.

If it’s summer or autumn, move to Cygnus, the swan. Say that the Milky Way band is there, as Cygnus flies along it. There are some beautiful myths that work this into the story. If the body of Cygnus is visible, it’s plausible that the Milky Way is too, but don’t count on it, especially with the light pollution on North Campus. Also, point out the summer triangle, which consists of Vega, Altair, and Deneb. It can be fun to explain how Vega will be the north star in 10,000 years, due to the way Earth wobbles when it orbits, like a top. When the ancient Egyptians were building the pyramids, Thuban was the North Star. If you’re feeling really fancy, point it out in Draco. Thuban is very dim, so feel free to make a joke about how lucky we are to have a reasonably bright North Star, and how lucky future navigators will be to have Vega.

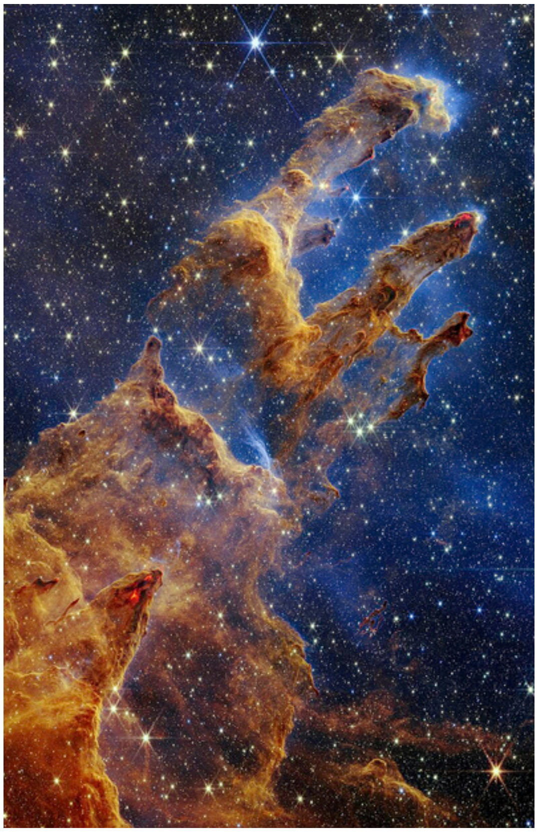
The Summer Triangle, consisting of Vega, Altair, and Deneb, along with the constellations for each of its parts.
Credit: Stellarium

Open the floor to questions. Be confident, but be prepared to say ‘I don’t know.’ Make sure to have a favorite constellation, because someone will probably ask. Don’t be afraid to pull out your star map if you need to. However, star maps are more like paper maps than GPS’s, even if they use your phone’s gyroscope, so sometimes it will still be difficult to find. If you can’t find something, blame the light pollution, clouds, or moon.

ASTROPHOTOGRAPHY: AN OVERVIEW

BY SHANE KUO

For myself and many of the members of CAS, one of the first things that comes to mind when thinking about space are the pictures: the humbling Pale Blue Dot image taken by Voyager 1 on its journey out of the solar system and the breathtaking views taken by Hubble and JWST of distant nebulae and galaxies, are but a few examples. Photography, which is the art of taking pictures and is derived from the Latin “writing with light”, is a great way to capture the wonders of the cosmos. Here at Fuertes, we’ve been doing a lot of astrophotography, or photography of astronomical objects, over the past few months. With our newest DSLR, we’ve been imaging various objects in the springtime sky through Irv by attaching the camera body to it. Throughout our astrophotography sessions, we’ve learned about processing these astrophotographs, as well as taking them. Of course, we’ll be showing some of our astrophotographs, but first, I’d like to provide some background on how these pictures were processed.



The Pillars of Creation through JWST
Credit: [NASA, ESA, CSA, STScI, Joseph DePasquale (STScI), Anton M. Koekemoer (STScI), Alyssa Pagan (STScI)]

To better understand how to take astrophotographs, tracing photography to its roots often helps. Scholars have understood the principles of the pinhole camera, also known as the camera obscura, since antiquity. A pinhole camera is essentially a hole poked in a dark container, which projects a mirrored version of the scene outside the hole onto the opposite wall. Since the only light rays that can enter the dark room must come through the hole, the light shining on one particular part of the room can only come from one line; the line connecting that point and the hole. In comparison, sunlight entering a windowed room is diffused across the entire wall, as are the shadows of any obstructions, because light hitting any point on the opposite wall could come from many different rays. A lens inside the pinhole can also modify the field of view. However, pinhole camera photographers drew the image projected onto the darkroom themselves.

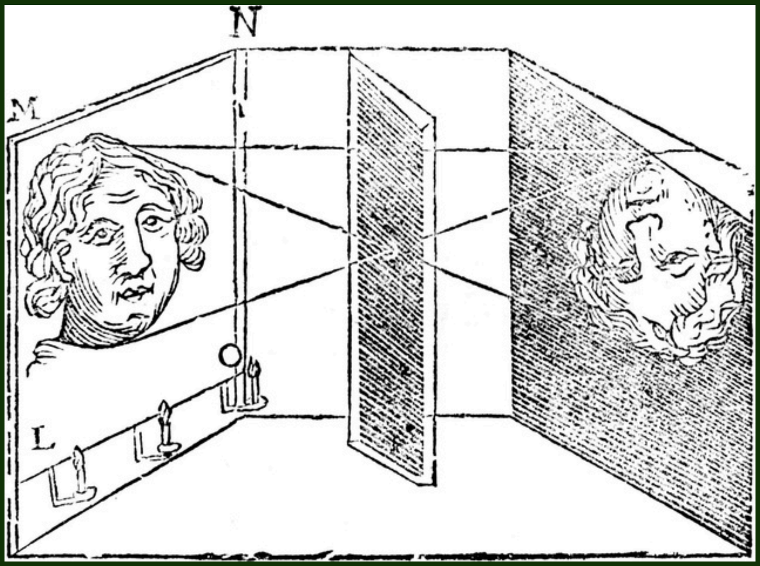


Illustration of the principle of the camera obscura, 1671.
Credit: Encyclopedia Britannica

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Photography, as we know it today, could not begin until Johann Heinrich Schulze demonstrated that silver salts were sensitive to light in 1727. Techniques for recording images of silver salts were developed and rapidly improved throughout the mid-1800s. During this time, black-and-white pictures could be stored on photographic plates with ever-improving quality and speed, culminating in the development of the wet collodion process. The wet collodion process, also known as wet-plate photography, involves adding iodine salts to collodion, a liquid similar to flash paper. To take a photo, silver salts would be added to a glass plate coated with collodion, exposed to light, and developed by adding acid. However, wet-plate photography was never widely used because of the restrictive picture-taking process and the need for the camera to be mounted on a tripod for sharp images. The dry-plate process, proposed in 1871 by Richard Leech Maddox and popularized by George Eastman and the Kodak camera and film, resolved these issues. The dry plates were more sensitive to light while exposed and less sensitive when not, allowing film to be exposed using a handheld Kodak camera, and the entire roll to be shipped to Kodak facilities in Rochester, New York, and elsewhere for processing. Compared to wet-plate photography and its precursor techniques, using a Kodak camera was extraordinarily convenient. The popularity and enhanced light sensitivity of film cameras let astrophotography take off starting in the early 1900s; many of the pictures on Fuertes' slide wall are from this era as well.

Quarter page advertisement for the Kodak Camera inside front cover of "The Outlook" (weekly magazine), Vol. 65, No. 15, August 11, 1900. New York.
Credit: Eastman Kodak Company

Kodak's stranglehold on the film market lasted until the late 1900s, with the rise of the DSLR, or Digital Single-Lens Reflex Camera. The DSLR contains almost a century's worth of improvements over the first Kodak dry-plate cameras and is even more convenient. The Single-Lens Reflex design allows photographers to see a preview of the picture through the viewfinder. The digital sensor, typically a CCD or CMOS, can display the picture instantly after taking it, or even show a live preview of what the camera sees instead of having to develop the film afterward. DSLRs can also change the camera's sensitivity to light with the push of a button, another advantage they have over older film SLRs. They can also save pictures in various file formats, take videos, and automatically tune certain camera settings for convenience or better quality. Ironically, Kodak itself was at the forefront of DSLR research and development for many decades, but its reluctance to completely reorient itself around this new technology led to its decline.

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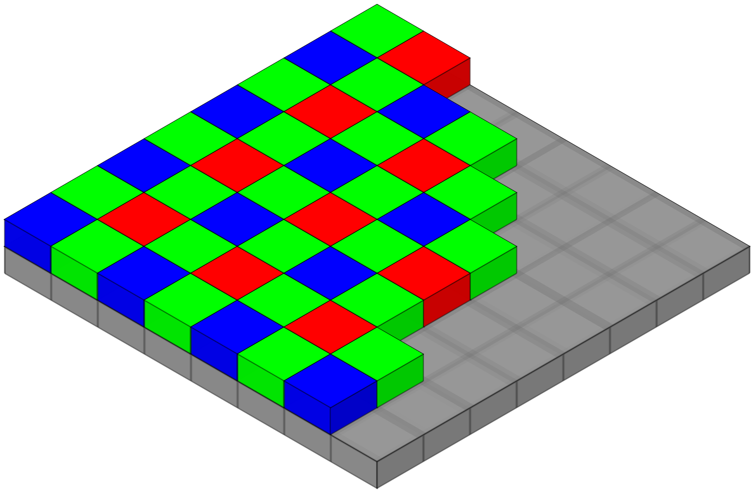
Many of the DSLR's advantages over Film SLRs depend upon its sensor. These sensors come in two main forms: the CCD (Charged Coupled Device) and the CMOS (Complementary Metal Oxide Semiconductor). Both technologies contain pixels, which are small pieces of light-sensitive material that convert incoming light to charge. Color sensors add red, green, and blue color filters above each pixel, then combine the colors recorded by each group of pixels into one final color.



The Bayer arrangement of color filters on the pixel array of an image sensor
Credit: [Colin M.L. Burnett, Wikipedia]

The Canon EOS 6D MKII, an example of a DSLR and the model that the Cornell Astronomical Society uses
Credit: [Negawa Ohsaki, Wikipedia]

The main difference between these comes in how they read out data. CCD pixels trap electrons in a potential well and shift rows of them out to be amplified and then stored as data. In comparison, CMOS pixels convert the excess charge that light hitting them creates directly into voltage, which can then be interpreted directly as data. CMOS sensors, because each pixel converts light into a voltage, can be read much faster than CCDs and with less power consumption.

Very fitting for a discipline named after "writing with light", the most important settings on a camera are intimately connected to the light it receives. These settings are ISO, shutter speed, and aperture. ISO, short for the International Organization for Standardization, represents a standard developed for film and adapted to DSLRs that measures the sensitivity of the film or digital sensor to light. In the days of film, ISO was related to the density of light-sensitive materials on the film, with more light-sensitive silver chemicals corresponding to a film with a higher ISO. Nowadays, the ISO instead reflects how much the CCD/CMOS sensor and the chip in the camera amplify incoming electrical signals; a larger ISO means that incoming light is more amplified. However, larger ISOs also amplify the noise, or unwanted artifacts in the image, caused by certain imperfections in the camera system, as well as the actual image. Images shot with higher ISOs tend to have more grain and image artifacts. This makes the image look worse by adding random speckles or striped patterns to it. ISO is approximately linear, meaning that doubling ISO roughly doubles the sensitivity to light. However, sensors are not perfect, and there can be some slight errors with this rule of thumb. Additionally, if a pixel is saturated, or reading the maximum value possible, further increasing the ISO will not increase the pixel's brightness.

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The left image uses a low ISO, likely because it risked washing out the image. The right image doesn't have this risk because of different lighting conditions and thus uses a higher ISO. The right image shows more details of the surface, but also more noise, caused by the higher ISO.
Credit: [Ernest White]

Shutter speed controls how long the camera sensor is exposed to light. A faster shutter speed means that the camera is exposed for a shorter time and thus picks up less light, and vice versa for a slower shutter speed. However, making the shutter speed slower comes with the drawback of worsening motion blur. Because the camera adds all the light it receives throughout the entire exposure to produce the final image, an object that appears to move is smeared out across the image. Objects in view can move for longer with longer shutter speeds, which worsens the smear. In the context of astrophotography, this motion blur often arises from no or inaccurate tracking of astronomical objects. Objects in the sky appear to move throughout the night, and this is readily visible in the field of view of a telescope. Since astrophotography occurs in low light, minute-long shutter speeds are often required for detailed images. Most walk-around photography does not use shutter speeds slower than 1/20th of a second, because of limitations in holding the camera still. With shutter speeds this long, even tiny inaccuracies in tracking can be seen in the final image. Vibrations caused by people walking around the telescope mount can also propagate to the telescope, which causes motion blur. Shutter speed is also linear; doubling the time the shutter is open doubles the light entering the camera.

The effects of changing Shutter Speed on image brightness while keeping other settings constant
Credit: [Ernest White]

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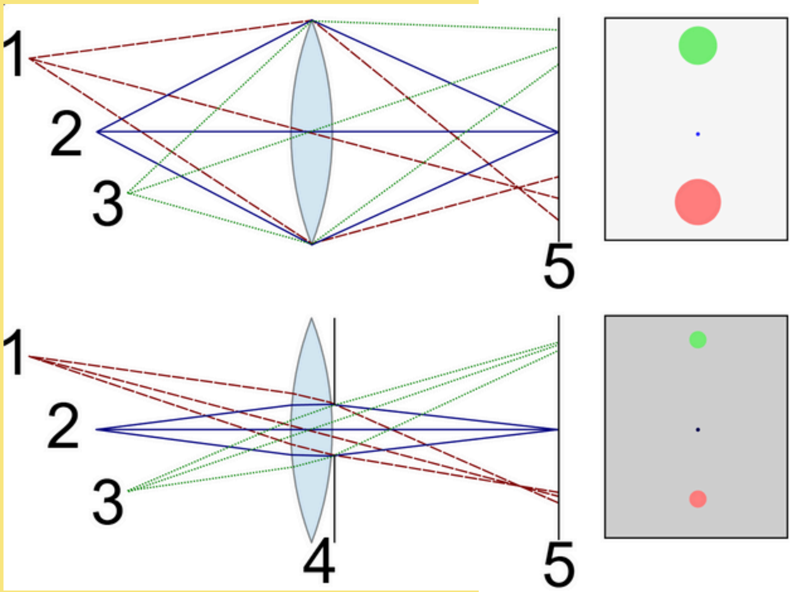
Aperture is measured by the F-number, which is the ratio of the focal length of the camera to the size of the opening that lets in light. This typically depends on the properties of the lens, not the sensor. When doing astrophotography with a DSLR, the telescope itself acts as a lens with an aperture itself. Thus, the aperture of the camera system is fixed at the aperture of the telescope; f/15 for Irv here at Fuertes, as is the focusing of the image. A smaller F-number represents a larger aperture compared to the focal length of the camera, meaning more light can enter the camera, and a larger F-number represents the opposite. However, there's a drawback here, too.



The effects of changing the aperture on an image.
Credit: Ben Dale, Wikipedia

Remember the Pinhole Camera? A pinhole camera acts like a camera with an infinite F-number, because the hole is infinitely small. One property of the pinhole camera is that everything appears in focus because any light ray that enters the camera must go through the pinhole and can only ever hit one specific point on the camera. However, a room with a window acts like a small F-number because the hole, or aperture, is large compared to the length of the room.

If you look at sunlight streaming into a room, however, light coming from one point can pass through the entire window and thus gets spread out across the room. A similar effect happens in a camera, albeit a bit more complicated. The camera contains lenses and can focus light rays from an object at a specific distance by changing the distance between these lenses. For objects that aren't at this distance, light coming from a point on the focal plane gets spread out, causing blurriness. With a larger F-number, there is less spread because the light rays that would deviate the most from the center are blocked. Thus, a higher F-number enables more of the image to be in focus, but results in less light entering the camera. Note that the F-number has an inverse square relationship with light; doubling the F-number quarters the amount of light entering the camera.

Pinhole Camera effect with tree leaves on the 2024 Total Solar Eclipse. Note that this effect doesn't occur in broad daylight right before the eclipse, showing how aperture affects focus.
Credit: NASA/Emma Friedman

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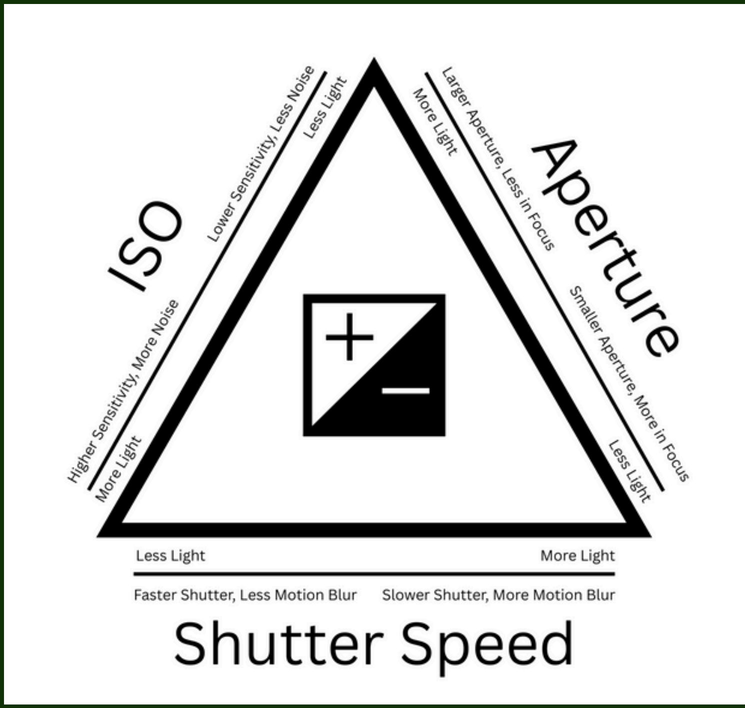

The Exposure Triangle
Credit: Shane Kuo

Photography involves writing with light, but a scene only has so much light to work with. In other photographic disciplines, this restriction can be dealt with by changing the lighting and viewpoint, but in astrophotography, this is essentially impossible. The Exposure Triangle summarizes this tradeoff between ISO, shutter speed, and aperture, and how you can use the light entering the camera to create the image you want. Decreasing the noise level, motion blur, or defocus requires increasing one or more of the others. With more light entering the camera, photographers can be more selective with the light and have lower ISO, faster shutter speeds, or a larger depth of field. With less light, some aspects of the image must be sacrificed. Exactly how this tradeoff is made is often an art form, and many choices can produce beautiful images. However, it is still important to keep in mind the tradeoff between noise level and motion blur.

Noise is an inescapable part of any sensor technology, including DSLRs and telescopes, and understanding its components and reducing it is critical for taking the best astrophotographs. One of the most powerful tools for reducing noise is called “stacking”. Stacking essentially artificially lengthens the exposure time of the image by combining multiple images with short exposure times. This is extremely useful because it reduces the effect of motion blur on each image compared to taking a single, long exposure, and can help protect the camera against overheating. The effect of noise that is random between different pictures and gets added to them can usually be reduced with stacking. This includes the random grain that high ISO causes, as well as many other unwanted artifacts. However, anything that’s shared between all images will be brought out more by stacking. This includes the image we want, a helpful property, but also some aspects of noise that all images have in common, such as any dust on the camera sensor or fixed patterns that the camera system adds.

Stacked 40x (Bottom) vs Unstacked (Top) images
Credit: Ben Jacobson-Bell, Shane Kuo, and Andrew Lewis

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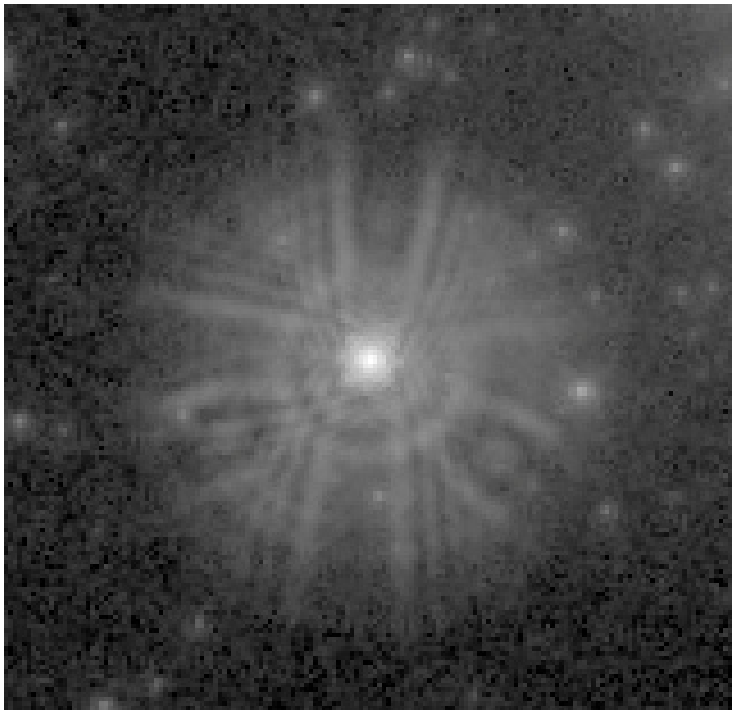
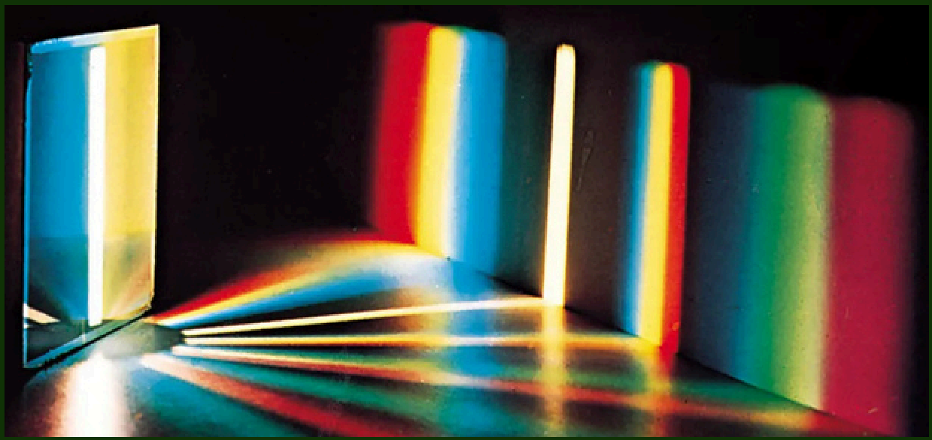
One source of noise that all images share is the Point Spread Function (PSF). It's especially noticeable in astrophotography because pictures of stars often show them much larger than they should appear based on their actual angular size. Their light, which approximately comes from a point source, has essentially been spread across the image under the PSF. The PSF itself comes from many different sources as well. CCD and CMOS sensors are comprised of many millions of pixels; even if light enters the camera at one exact point, the most the camera can resolve is that one pixel receives light, which already puts an upper limit on how much detail the camera can see. Even worse, if this light hits the edge of two pixels, the camera will see two pixels with brightness depending on the fraction of the light they received instead of one point with all the brightness, which further reduces detail.



An extreme example of a Point Spread Function, taken from the Hubble Space Telescope before correction.
Credit: [NASA, ESA and the COSTAR Team]

Furthermore, if the telescope-camera system is not in focus, then the light coming from a single point won't land on a single point on the camera sensor. Instead, it lands across an entire circle and spreads the detections further. There's no escaping this defocusing either; physics itself prohibits it. If you've ever heard a car drive by on the road blasting music, you may have noticed that the bass is much louder than the treble, if you can even hear the high notes at all. Diffraction, the ability of waves to bend around obstructions based on their wavelength, causes this effect. Since light acts like a wave, it can diffract off the edges of the aperture, which means it will spread out and create a minimum amount of defocus for a particular optical system. This also explains why cameras don't have extremely high F-numbers and why the pinhole camera can't produce a perfectly sharp image in real life; diffraction will cause a minimum level of blurriness regardless of how small the aperture is.



Spectrum of white light split by a diffraction grating, showing how light gets redirected when passing through small openings.
Credit: [Encyclopedia Britannica]

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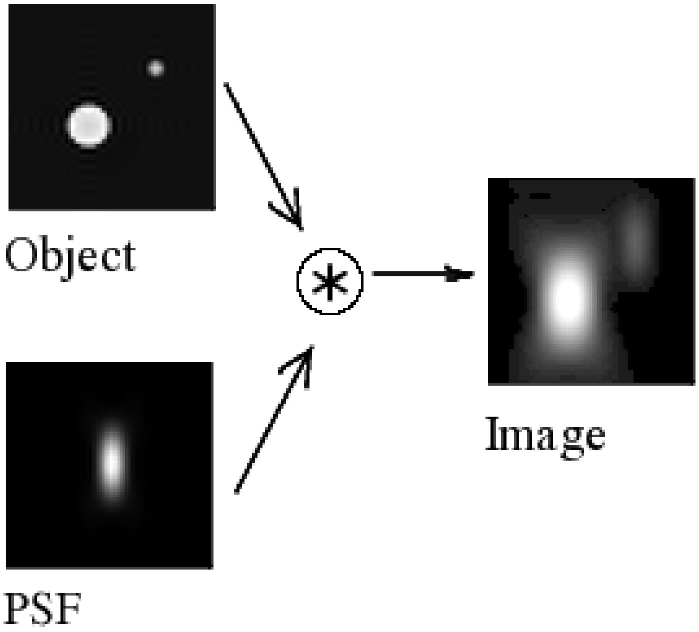
Star Trails caused by Motion Blur at Cherry Springs National Park
Credit: Erik Payton

The properties of the CCD and CMOS pixels themselves also contribute to this noise. Because these sensors have many closely packed wires, each wire induces electromagnetic interference in neighboring wires. This causes crosstalk in pixels, where a signal in one pixel creates magnetic fields that induce signals in its neighbors. Another component of the PSF is caused by the motion of the camera or telescope. Vibrations around the camera can worsen the PSF and cause it to spread out, as the same light source ends up hitting different groups of pixels as the camera moves. Systematic errors from motion blur can also contribute to this, as light sources that gradually move across the sensor cause streaking in the final image.

The action of the PSF on the image, the "spreading" of light from one specific pixel onto its neighboring pixels for every single pixel on the sensor, is called a "convolution". To reduce noise, the image can be "deconvolved", a process that tries to undo this convolution. However, deconvolution has issues because the act of spreading this light around loses information about the exact source of the light. Additionally, because the "convolution" takes the light from one pixel and adds a very small fraction of it to some neighboring pixels, the "deconvolution", if taken at face value, would take some part of the neighboring pixels and multiply it by a huge value. Any noise in this pixel would then get amplified massively and drown out any signal that deconvolution could recover. Thus, it's impossible to fully recover the original image from the blurry one. Again, we have run into tradeoffs here; reducing the blurriness from the Point Spread Function would force an increase in blurriness caused by noise amplification. A general guideline for making this tradeoff is to decrease the noise with the biggest impact, but the details are highly subjective and often an art form as well.



The effect of a convolution on an image
Credit: [Random007, Wikipedia]

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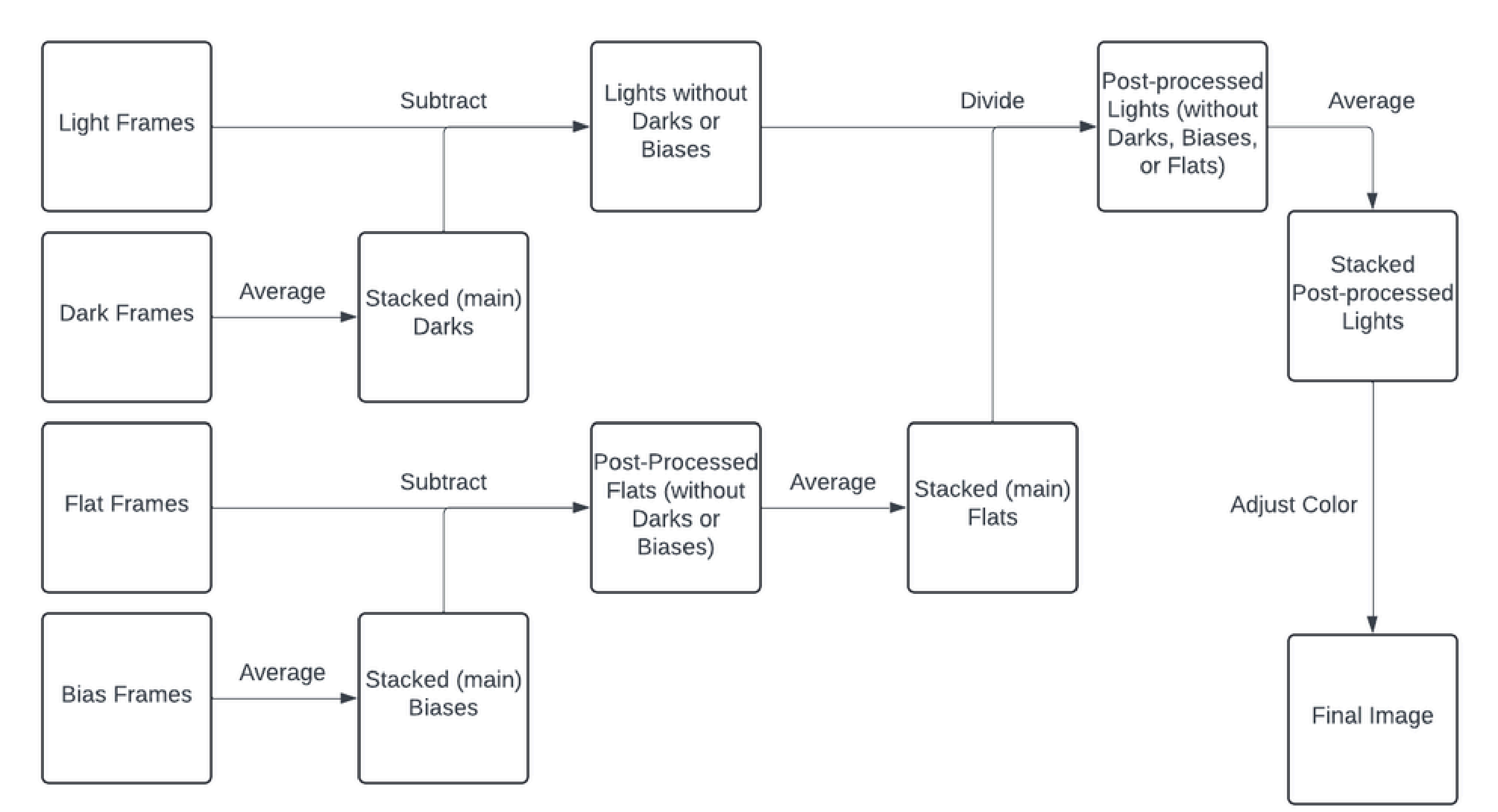
Besides the PSF, other sources of noise contribute to reduced detail in the final image. Light is comprised of small chunks of energy called photons, and the randomness of the photons themselves can contribute to noise. This is called photon shot noise. The actual number of photons per pixel can vary from the average number of them (brightness) over time, which introduces random offsets to the brightness across the photograph. Additionally, CCD or CMOS sensors add noise to the image when reading the data itself. This is called Read-Out Noise or the Bias Level and usually contains a fixed pattern inherent to the camera, plus some random noise. Additionally, the camera's internal heat can also make dark current noise, with higher temperatures creating more baseline noise. Another source of noise is that each pixel on the CCD or CMOS sensor may be unequally sensitive to light, effectively multiplying a sensitivity pattern on top of the image. One way to see this sensitivity pattern is by taking a picture of an evenly illuminated field, or flat field.

Some of these types of noise, such as photon shot noise and the random noise component of the read-out noise, dark current noise, and flat field noise, can be reduced by stacking. However, some aspects of read-out, dark current, and flat field noise are unaffected by stacking and will remain in the image. These types of noise must be specially accounted for by taking and stacking multiple "bias frames", "dark frames", and "flat frames" for each set of "light frames", which are the raw astrophotography images. Bias level, the noise generated by default for taking a picture, can be found by taking pictures with the lens covered, the ISO kept the same as the light frames, and the shutter speed set to maximum, so there's no time for the CCD or CMOS to pick up any other signal. These typically don't change much and can be reused between different shots with the same ISO. Biases can be stacked to find the bias common to all pictures. If this isn't done, the random variations in the biases themselves will add more noise if they are used.



Simplified Processing Flowchart
Credit: Shane Kuo

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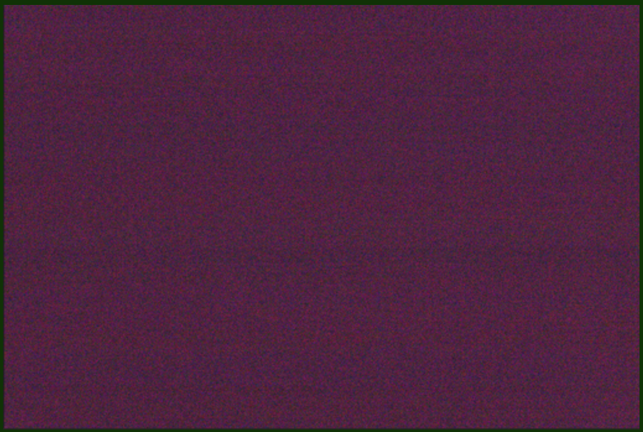
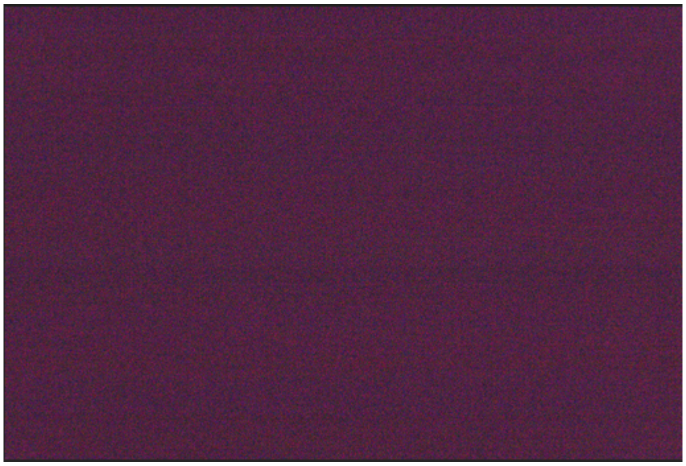


Examples of Lights (Top) and Biases (Bottom)
Credit: Erik Payton, Ben Jacobson-Bell, Andrew Lewis, and Shane Kuo

The dark current noise depends on both the temperature of the camera and the shutter speed; this means darks should be taken with the same shutter speed and ISO as the lights, with the lens cap covered. The average effect of dark current noise can be found by removing the bias and stacking them. The flat frames, because they quantify the sensitivity pattern multiplied onto the image itself, should be taken with an average brightness somewhere in the middle of the camera's sensitivity range for the best color resolution. Their ISO is the same as the darks and biases, and the shutter speed is adjusted to tune the brightness. They can reuse the same biases, but the darks should be retaken at the shutter speed of the flats. The flats need to have their own biases and darks subtracted and stacked as well. Because the sum of the darks and biases is actually the unprocessed darks, stacking the unprocessed darks together and subtracting them from the lights and flats saves time and works just as well. However, since the flats have higher shutter speeds than the lights, the dark flats tend to have little effect. Once the lights and flats are found and their darks and biases removed, the last step is to divide them to remove the sensitivity differences.

After all this noise reduction, further techniques to improve the image quality include subtracting the background from the image, balancing the color either manually or automatically, removing green noise, and modifying the light histograms. This helps make the colors in the image more accurate and vivid, and blackens the background for better contrast. Cropping the image also helps a lot and can make the subject pop out better or remove unwanted artifacts near the side of the image. More adjustments can be made using the wavelet transform, which can emphasize or de-emphasize patterns of different sizes and adjust the levels of fine detail and noise.



Examples of Darks (Left) and Flats (Right)
Credit: Erik Payton, Ben Jacobson-Bell, Andrew Lewis, and Shane Kuo

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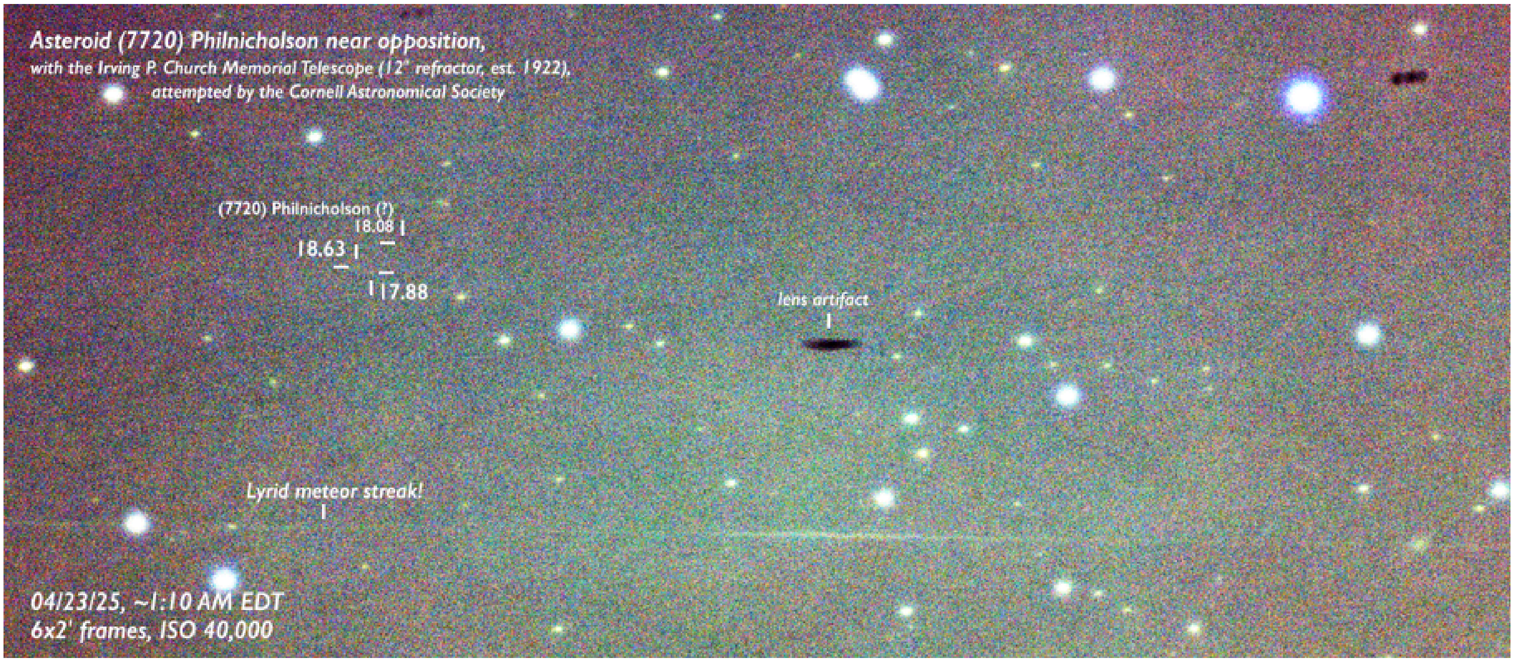
I've promised astrophotographs, and I hope that with this bit of context, you're able to try taking some of your own! From solar system objects to Messier objects, from open clusters to galaxies, we've had a wonderful time taking these pictures at Fuertes this semester (although a less wonderful time the following morning), and I hope you enjoy them. Without further ado, here are the results!



CAS's attempted detection of Asteroid 7220 Philnicholson, named after our very own CAS advisor! (4/23/25)
Canon EOS 6D Mk II, 6x 120s exposures
Credit: Erik Payton, Ben Jacobson-Bell, Shane Kuo, and Andrew Lewis

M29, the Cooling Tower Cluster (6/2/25)
Canon EOS 6D Mk II, 66 x 30s exposures
Credit: Ben Jacobson-Bell, Andrew Lewis, and Shane Kuo

M39, the Pyramid Cluster (6/4/25)
Canon EOS 6D Mk II, ??? x 30s exposures
Credit: Ben Jacobson-Bell, Gillis Lowry, Marquice Sanchez-Fleming, Andrew Lewis, and Shane Kuo

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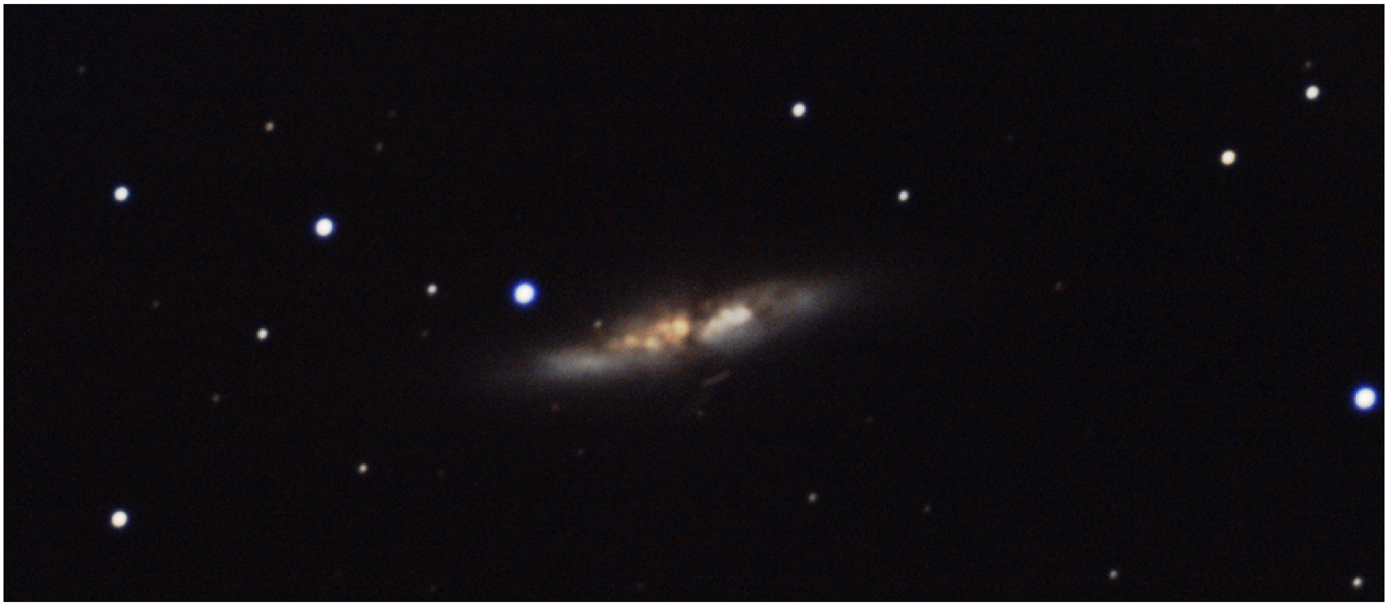
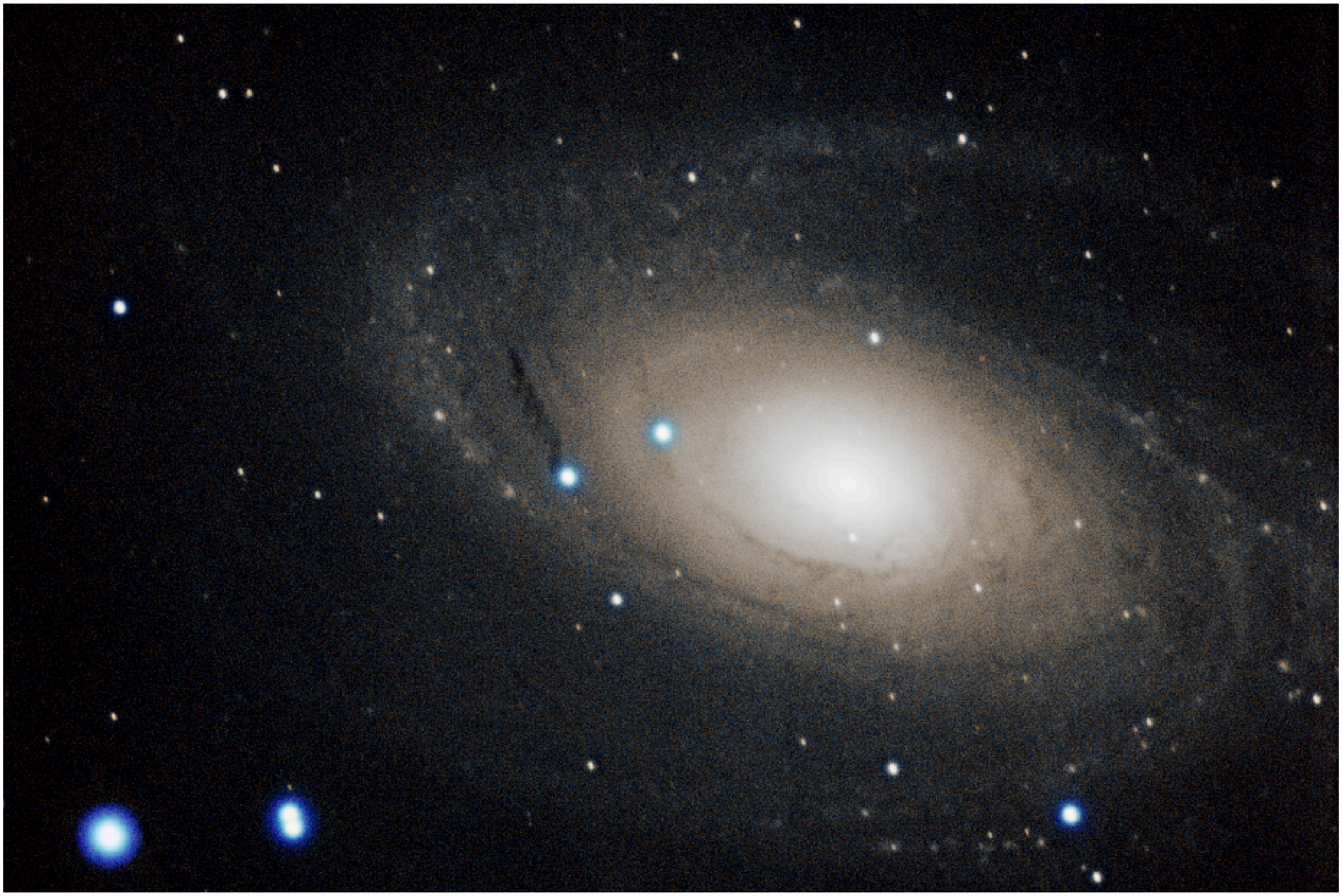


M82, Cigar Galaxy (4/20/25)
Canon EOS 6D MkII, 12x 180s exposures
Credit: Erik Payton, Ben Jacobson-Bell, Shane Kuo, and Andrew Lewis



M81, Bode's Galaxy (4/22/25)
Canon EOS 6D MkII, 21x 180s exposures
Credit: Erik Payton, Ben Jacobson-Bell, Shane Kuo, and Andrew Lewis

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M36, Pinwheel Cluster (4/20/25)
Canon EOS 6D MkII, 50x 30s exposures
Credit: Erik Payton, Ben Jacobson-Bell, Shane Kuo, and Andrew Lewis

M92 (5/15/25)
Canon EOS 6D MkII, 30x 60s exposures
Credit: Erik Payton, Ben Jacobson-Bell, Gillis Lowry, and Ella Mansfield

M27, Dumbbell Nebula (5/26/25)
Canon EOS 6D MkII, 19x 90s exposures
Credit: Ben Jacobson-Bell, Gillis Lowry, Marquice Sanchez-Fleming, and Andrew Lewis

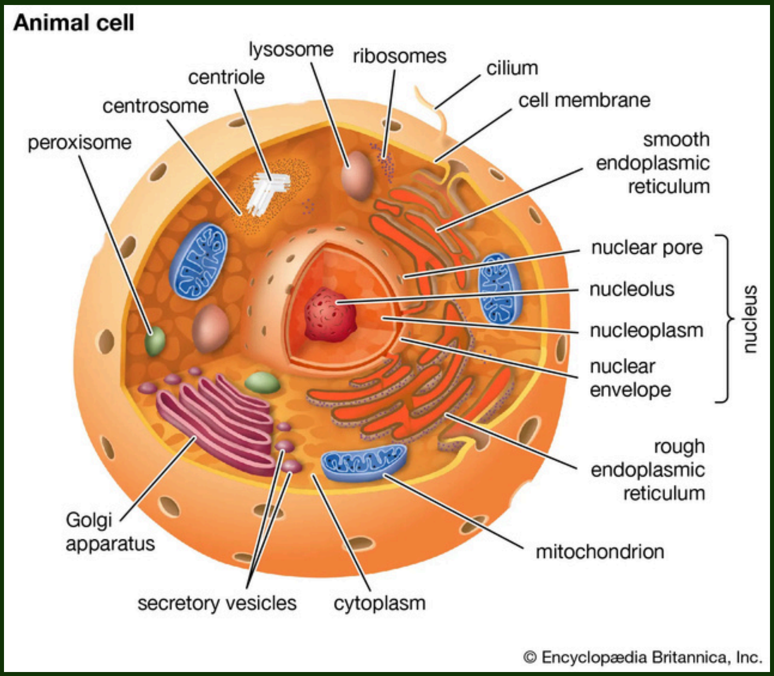
THE MICROSCOPICALLY SMALL IN THE UNIVERSE

BY TREYTON GRAHN

Just as we were able to zoom out an unfathomably large amount in the December issue of the CAS Newsletter, we can zoom in to discover the microscopically small in the universe. Along the way, we will discover truly how small atoms are, whether or not there is anything smaller than atoms, and maybe even discover some parallels between the small and the large in the universe.

Let's begin our journey in the same place we began last time: Earth, wherever you are reading this. I chose to start here because it is a place so familiar to all of us, every waking moment of your life has been spent here (unless you are an astronaut). Ironically, our next destination just may be the one thing in the universe you are most familiar with: yourself. You are one of 8.062 billion people on Earth (as of 2025). Just like last time, that is just like filling 8 cubes with 1-meter long sides entirely, where each cube will have about 1 billion grains of sand. Each one of those grains is a person, each who is living out their own lives, with different thoughts, experiences, morals, and views on life. Each one of them with a happiest memory and a moment that changed them forever. Each person, just as infinitely complex as yourself.

Time to zoom in a little bit, well quite a lot actually. Let's go to the microscopic realm. You may remember learning about the cell and what it does. Cells are considered quite universally as the basic building block of life as we know it. Think of cells like a workshop. They store your nutrients, they produce your energy, they store your DNA and proteins, and much more. Cells die after some time, so they can duplicate themselves in a process called mitosis. Cells are incredibly complex and incredibly small as well. There are so many cells that it is quite unfathomable. The best estimates of today put the number of cells at 30 trillion in the average human body. That is 30,000 billion. In other words, if you wanted to represent each cell in your body as a person, you would need roughly 4,000 Earths to fit them all.



Anatomy of an Animal Cell
Credit: [Encyclopedia Britannica]

How big are they? Well, on average, they are about 25 micrometers, or 25 millionths of a meter! Each of these cells plays a role in keeping you alive. These cells come in many shapes and play many different roles. This is not a biology lesson, so I will not get into the details, but these cells are incredibly small compared to you. Let's zoom in some more.

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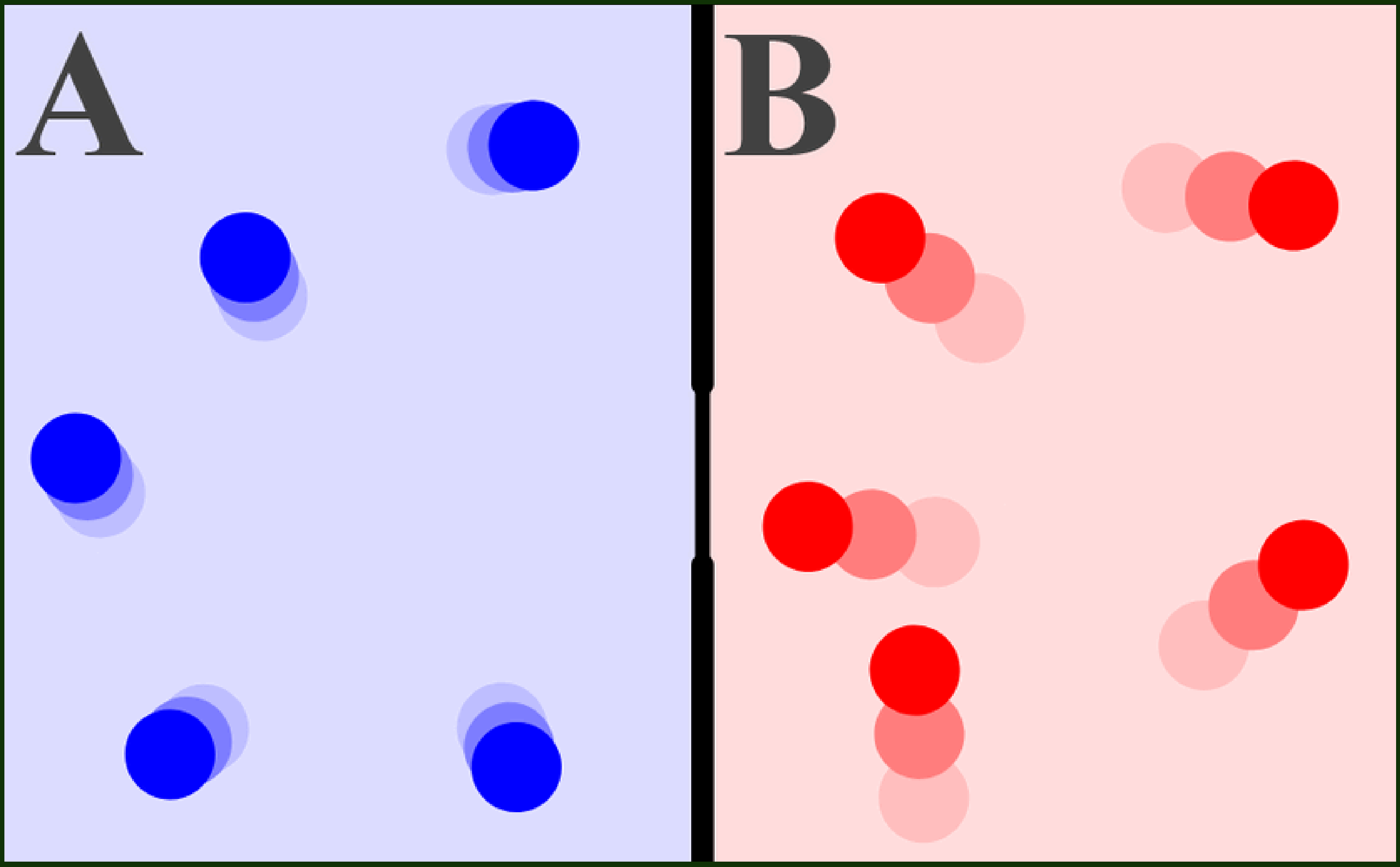
We are now in the atomic realm. Cells are tiny, but atoms are even tinier. They measure around 0.1 nanometers. Take each person on Earth to be the size of an atom and line them up side by side, and everyone together would not even stretch to be one meter long. What are atoms good for? In the same way that cells are the building blocks of life, atoms are the building blocks of matter; they come in different shapes and sizes, just like cells. With these different shapes and sizes, atoms can bond together to form molecules, which are the smallest unit of many things you know. Some examples are water, oxygen, carbon dioxide, methane, carbon monoxide, and so many more. These molecules are what give rise to temperature and heat. At the human scale, we experience temperature as something being hot or cold, but what does this mean? Fundamentally, hot and cold come from the difference in energy between two sources. This could be your body and the surrounding air, where if the air has less energy, energy flows from your body to the air, giving you the sensation of feeling cold. The more energy there is, the faster the molecules move. Temperature is really a measure of how fast these molecules move. The more energy there is, the faster the molecules will move. Higher temperature and something being perceived as "hot" are two completely separate things. Imagine it is much colder outside than room temperature, like winter in the northern United States. Your friend had been outside while you were inside a house at room temperature. When your friend comes in, their hand is going to feel quite cold to the touch, even though the temperature of their hand is still rather high compared to the temperature of the air outside. What is happening when you feel something as being cold is energy transferring from your hand to their hand. Since your hand has higher energy, it will flow to your friend's, which has lower energy.



Visualization of hot (side B) and cold (side A) molecules. Note that the hot molecules move faster than the cold ones.
Credit: [Htkym, Wikipedia]

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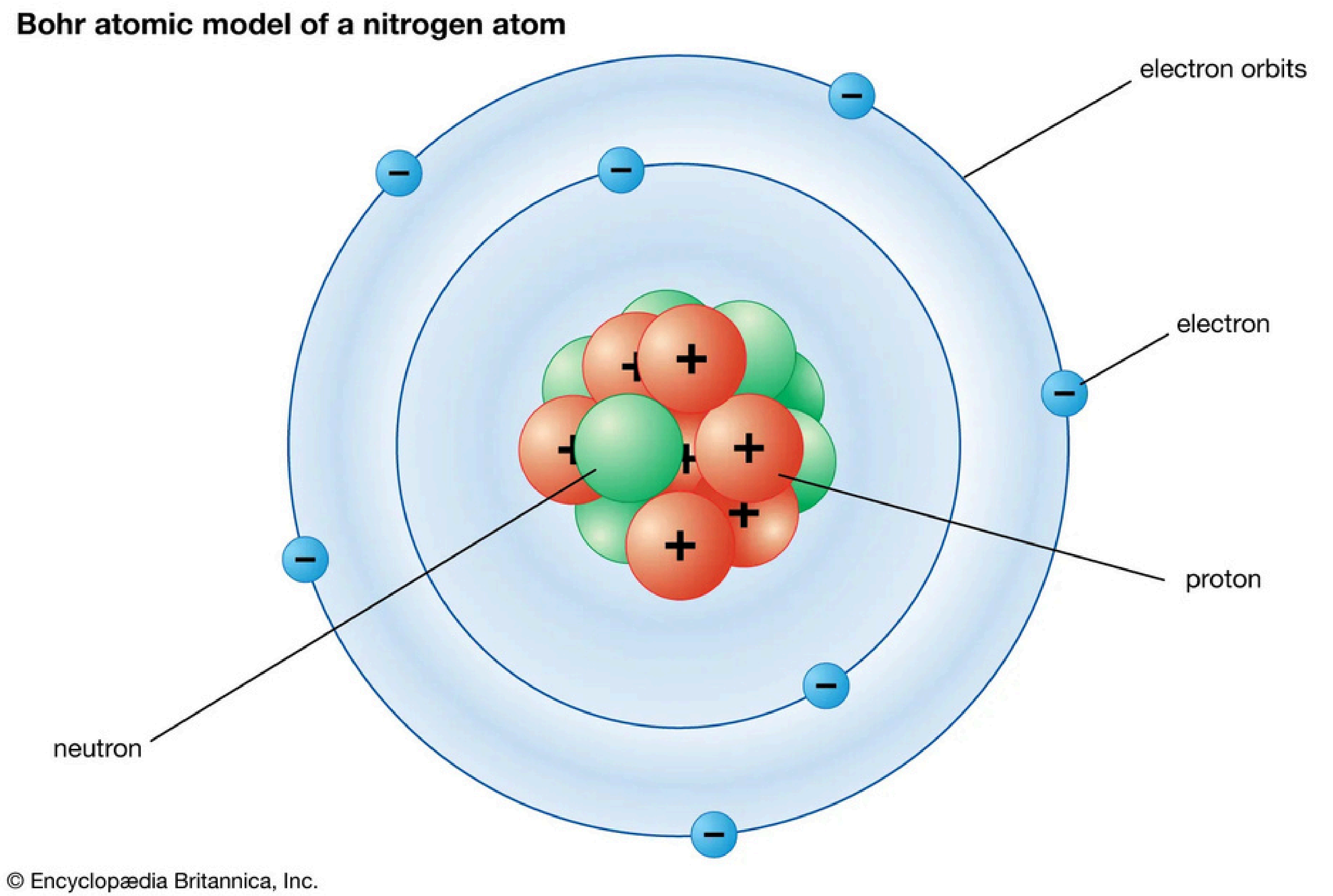
So is this the end? Is there anything that is smaller than a molecule or an atom? Well, yes there is. Let's zoom into the subatomic realm. Here we answer the question, “What are atoms made of?’ Atoms are made up of three subatomic particles, called protons, neutrons, and electrons. These particles play important roles in how the atoms behave. Protons and neutrons live in the nucleus of the atom, the number of protons determines the element of the atom, and the number of neutrons and protons together determines whether the atom is stable or unstable. The electrons are much smaller than the protons and neutrons orbiting the nucleus. These three subatomic particles and the amount of each in the atom lead to all sorts of properties unique to the combination of them that the atom has. Physics as we know it begins to break down here in the atomic realm, and a different set of rules begins to take over: quantum physics. The picture here is how the atom is commonly depicted, the truth is that this is vastly oversimplified, and the effects of quantum physics make the structure of the atom far more complex. Quantum physics is strange, unintuitive, and seemingly impossible, but it works. From electrons not having a definite position (superposition), to not being able to measure a particle’s position and momentum at the same time (Uncertainty Principle), and so much more, reality in the atomic realm is weird and fully understood by no one.



A diagram with a model of the atom, with protons and neutrons in the nucleus and electrons surrounding it.
Credit: [Encyclopedia Britannica]

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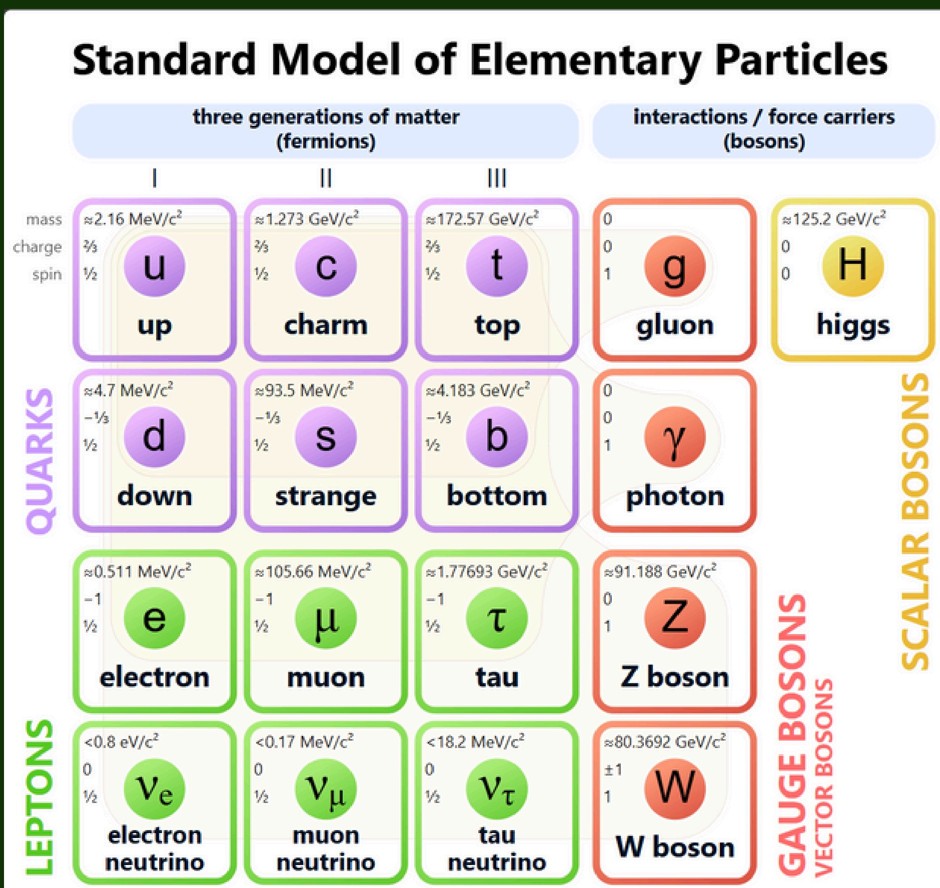
So are these three particles: protons, neutrons, and electrons, fundamental to nature? Can we still go smaller despite the weird things that go on here? Yes we can. Our final stop is the world of the fundamental particles. One of the crowning achievements in all of physics is the Standard Model of particle physics, which classifies all known fundamental particles and describes three of the four fundamental forces, being the electromagnetic force, the strong interaction, and the weak interaction. The one force that is not described in the Standard Model is gravity. It is an incomplete theory, but it is the most complete theory of fundamental interactions that physicists have produced. This is the scale where cutting-edge particle physics is being done. Many questions are still unanswered here, and it is the smallest we can go on our journey. Particles at this scale are so small that size is not a really meaningful measurement. Experimental evidence suggests that some of these particles are as small as 1 billionth of a billionth of a meter. There are theories of smaller objects existing, but I am choosing to omit those as there has been no experi-mental evidence of their existence as of 2025.



The Standard Model of Particle Physics.
Credit: Cush, Wikipedia

The end of the last journey that explored the vastness of the universe at the largest scales came with it a sense of feeling small. This journey was one where we explored some of the smallest things that the universe has to offer, and through that, I hope that the feeling of tininess was washed away. One of the wonderful things about physics and astronomy is that the most interesting phenomena happen at the extremes: the limits of what the universe has to offer. The closer to the limits you go, the more bizarre the phenomena. I hope throughout this adventure and the last, you were able to gain an appreciation for what exists at the limits of our universe and the bizarre things that can happen there.

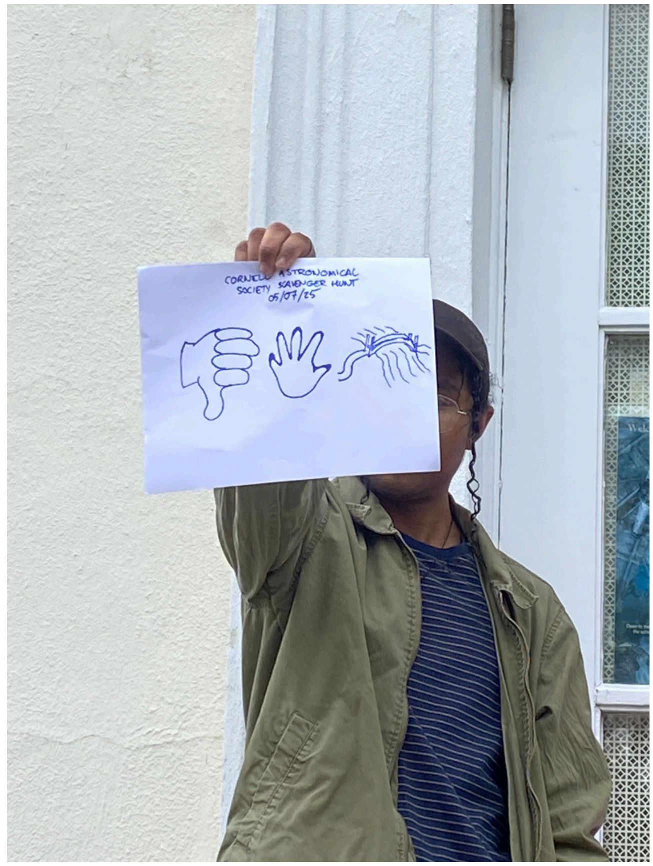
CAS SCAVENGER HUNT REVIEW

BY GILLIS LOWRY

My extra year at Cornell has granted me many things. I gained more research experience; I helped design events honoring Carl Sagan's 90th birthday; I learned the joys of clocking out at 5 PM. But as my time in Ithaca drew to a close, I knew I must appease the tantalizing final huzzah that had been sitting in the back of my brain since my wee freshmen days: designing another of my signature scavenger hunts.

Thus, the great CAS Co-Presidential Scavenger Hunt was born, with Erik, Ben, and me at the helm. The terms were simple: CAS must find and solve ten riddles. Only then could they thwart Marquice Sanchez-Fleming and his dastardly plot to steal our beloved Irv. Some clues were simple. Others… near impossible. What I expected to be a five-hour gallop became a ten-hour marathon across all of Ithaca. But with the power of friendship and well-timed hints, our two valiant teams visited Martha's weather machine at Bradfield Hall, mourned the original Fuertes Observatory at Barton Hall, and even fought a chicken jockey in Minecraft Fuertes.

In the end, a single ice bucket challenge vanquished Marquice Sanchez-Fleming. Irv was saved, and the secret boss (me) was defeated for now. I set myself up neatly as a villain for the sequel, if President Ella continues the tradition…!



The aforementioned near-impossible starting clue
Credit: Ella Mansfield

Andrew Lewis's scavenger hunt path
Credit: Andrew Lewis

The final sprint!
Credit: Abigail Bohl

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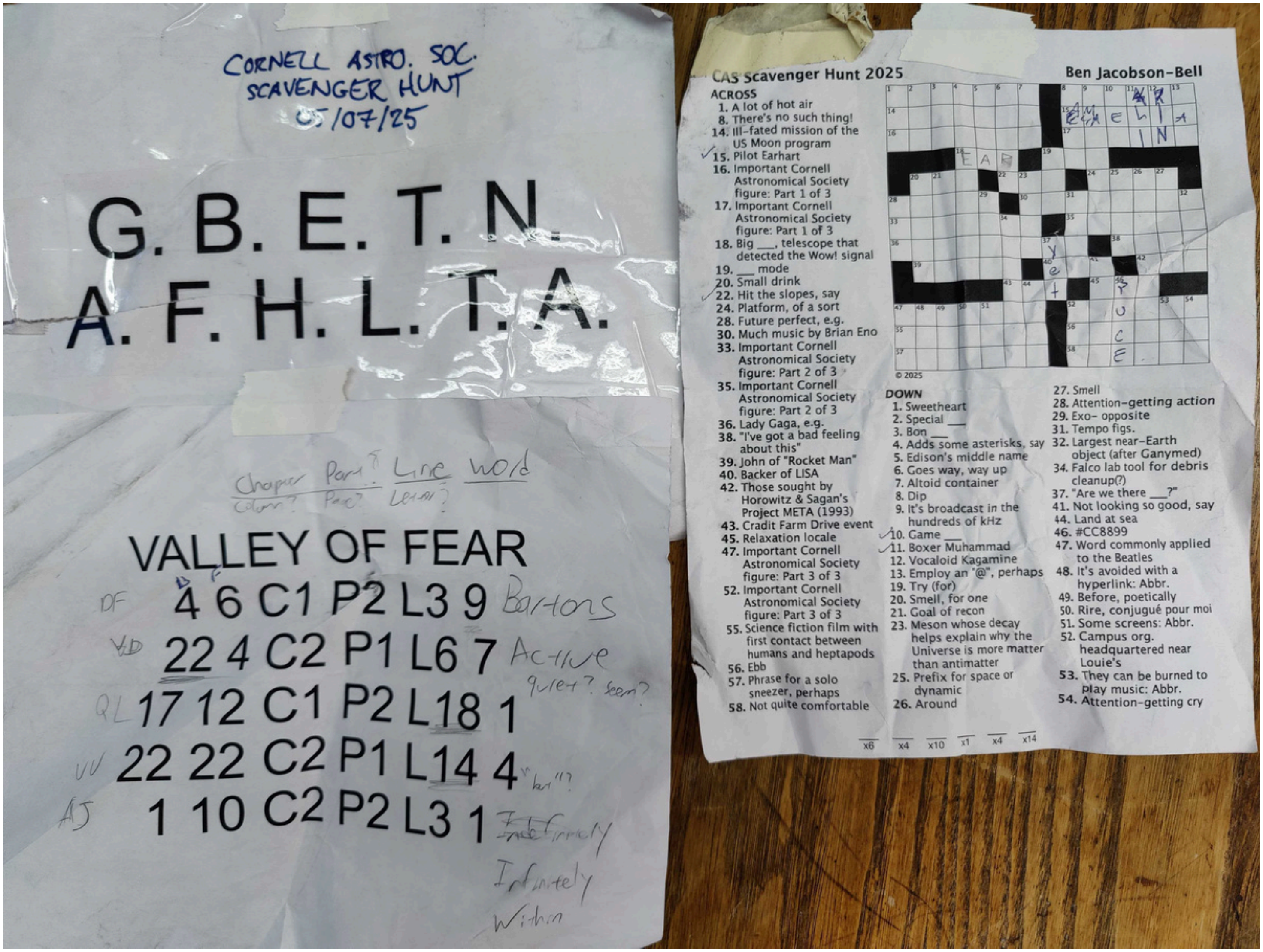

A collection of clues for the scavenger hunt!
Credit: Gillis Lowry, Erik Payton, and Ben Jacobson-Bell

This marks my 10th-or-so goodbye to CAS. No matter how many times I say farewell, I can never say it enough: I’m always going to miss this place and its people. There will be more observatories, more friends for every one of us, but nothing quite like this.

Come November—and for many years down the line—I’ll find my road back home again.

Love,
Gillis

FAREWELL FROM THE PRESIDENT

BY ERIK PAYTON

I remember the first time I stepped into Fuertes. It was sometime in my freshman fall, I don't remember exactly when. I was looking for something to do on a Friday night, and I stumbled across the observatory. I remember going up to that dome for the first time, looking through Irv and seeing Jupiter. That was the first time that I remember seeing Jupiter through a telescope in my adult life. If you told freshman Erik how much this observatory, the telescope, and most importantly the people would have changed his time at Cornell, well, I doubt he would have believed it.

If I have not had the privilege of talking to any of you, I am not an astronomy or physics major, but rather a mechanical engineer. I will be pursuing a career in aerospace engineering after graduate school, and that is in large part due to this club. In Fall 2021, I had an interest in space, but also renewable energy and robotics. Sometime that fall, I was walking to the observatory under a full moon. I remember just looking up at it and thinking that I have the opportunity to study that, and help design spacecraft to go explore the unknown of space. It was in that moment that I made my decision to pursue aerospace engineering. Fuertes gave me that, and for that I will be forever grateful.

A MechE Moment! Erik Payton and Claire Cahill repairing the C14!
Credit: Andrew Lewis

Congratulations to our newly graduated seniors!
Credit: Ben Jacobson-Bell

Following my sophomore year, I was fortunate enough to spend the summer in Ithaca and at Fuertes. If there were one piece of advice I could give to the younger CAS members, it is to spend a summer in Ithaca. It's so beautiful, and a truly enriching experience. The people you will meet will inspire you, and you will treasure the memories you make forever. I was fortunate to have three incredible years being closely involved with CAS, and it was not nearly long enough. There is so much more I want to see with Irv, so many more pictures I want to take, and so many more shanties to sing.

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Serving as President and leading this club along with the rest of the outstanding 24-25 officer team has been one of the best -if not the best- parts of my time at Cornell. I am so proud of all we've accomplished and am so excited to see how this summer's renovations turn out (thank you Andrew for all you did communicating with the department and the student assembly). Though my time at Cornell as a student has finished, I will never stop being a CAS member. I will be coming back to this observatory next year, and long past when no one remembers my time in the club. Irv, Fuertes, the deck, the anti-deck, the basement, the office, the clock drive, all of it. It has all made my time at Cornell so full and meaningful, and I will keep coming back.

To the officer team of next year (Pres. Ella Mansfield, Vice Pres. Andrew Lewis, Treasurer Treyton Grahn, Outreach Coordinator Elina Stengle, and Editor-In-Chief Abigail Bohl), treasure this time leading the club. It all goes by so fast, and I know you will all do incredible things. To the rest of CAS, keep stargazing, keep shanting, keep having tea parties, and keep that special type of "CAS randomness" alive. I will be back before too long—but until then, (and I know this is copying former Pres Gillis), it's not the leaving of Ithaca that grieves me, but my dear CAS when I think of thee.

Wishing you all clear skies and dark nights,
Erik, lifelong president and Irv enjoyer

Outgoing and incoming officers. Front row, left to right: Ella Mansfield, Elina Stengle, Abigail Bohl, Treyton Grahn. Middle row, left to right: Erik Payton, Jillian Epstein, Shane Kuo, Christopher Brown. Back row: Andrew Lewis
Credit: Ben Jacobson-Bell

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Jillian Epstein, Outreach Coordinator
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Ben Jacobson-Bell

Sources for “And Introducing...Cardea”

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Sources for “Astrophotography: An Overview”

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Sources for “The Astronomically Large in the Universe”

1 - 2 - 3 - 4 - 5 - 6 - 7

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

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