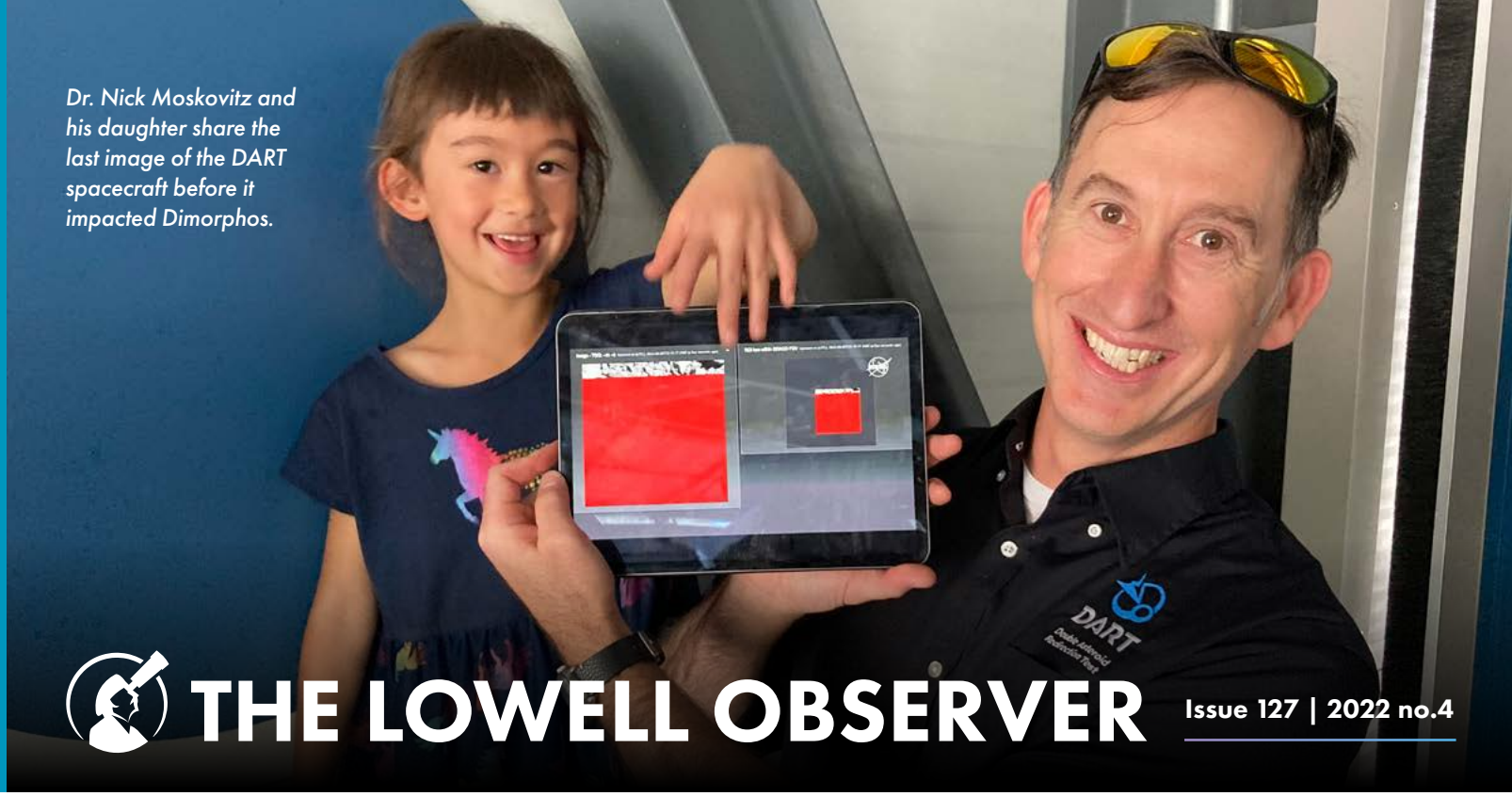

Dr. Nick Moskovitz and his daughter share the last image of the DART spacecraft before it impacted Dimorphos.

THE LOWELL OBSERVER

Issue 127 | 2022 no.4

DART Mission is a Success

By Dr. Nick Moskovitz, Assistant Astronomer

At 4:14pm MST on September 26, 2022, NASA's DART (Double Asteroid Redirection Test) spacecraft met a spectacular end when it intentionally impacted the asteroid moon Dimorphos. This was the world's first planetary defense test experiment and was designed to measure how much a controlled impact could deflect an asteroid in its orbit.

DART's target was the 160-meter moon Dimorphos, which orbits a larger body called Didymos. To enable this experiment, decades of observations were collected and analyzed to precisely determine where Dimorphos would be on Sept. 26. These observations relied on the fact that this binary system undergoes eclipses and occultations, collectively referred to as mutual events. At specific times in its orbit, Dimorphos passes in front of and behind Didymos (and in and out of Didymos' shadow). During these events a fraction of the reflected sunlight from the asteroids is blocked and thus, when viewed with telescopes from Earth, appears as a drop in overall brightness of the system. These brightness

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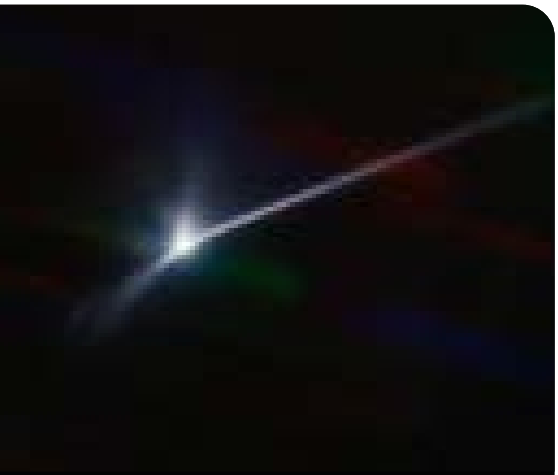

Analyzing DART's Ejecta

By D. Teddy Kareta, Postdoctoral Associate

The DART experiment's primary goal was to detectably change the orbit of an asteroid's moon, Dimorphos, around its parent asteroid, Didymos, by smashing a spacecraft into it. Unlike playing billiards, you can't just predict what will happen by comparing the masses and velocities of the two – the impact can excavate a large amount of ejecta from the surface, which can enhance the amount of momentum the spacecraft gives to the moon. The momentum enhancement factor Beta is directly related to how much ejecta was kicked off the surface

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EXECUTIVE DIRECTOR'S UPDATE

For years, I have kept the covers of my laptop computers festooned with stickers, always including the Lowell Observatory name and logo, as well as others such as NASA, NSF, Kitt Peak, and the Daniel K. Inouye Solar Telescope. They are always conversation-starters in airports and airplanes and hotel lounges when I'm working on email or other exciting things like budget spreadsheets. Sometimes they work a little too well! But it's always fun to talk with folks who are genuinely excited when they figure out I'm connected with astronomy. (Have you ever had a chat about exoplanets with a TSA officer during a pat-down? Been there done that!)

On my travels this year, DART has been the #1 topic: everybody thought giving an asteroid a wallop was the neatest thing ever. The jaw-dropping images from JWST have been a close second. And there are the other things that come up regularly: is Pluto a planet (yes), can JWST really look for markers of life on planets quadrillions of miles away (yes), how does relativity work (we're gonna need a longer flight).

I always get back from these trips reminded of how wickedly cool astronomy is, and how lucky we are to practice it. As 2022 rolls into 2023, we'll keep at our mission of bringing the coolness to professional audience and public audiences alike.

All the best to you for a wonderful holiday season and a great 2023. •

TRUSTEE'S UPDATE

The articles in this issue speak to an interesting situation that keeps happening at Lowell Observatory. Because of the dedicated work done by so many people over the past 128 years, there is a lot of history associated with the institution. But at the time they were doing that work, no one was thinking about the history. They were excited about the research and, at the time, the new discoveries they were uncovering. And so, in this issue, you see articles about the telescope Clyde Tombaugh built and used for 60 years along with Nick Moskovitz's article about the recent DART mission that is humanity's first step towards a possible defense against large meteors. That combination of the past and the current are uniquely Lowell and provide lots of storytelling material for our educators to share with the public.

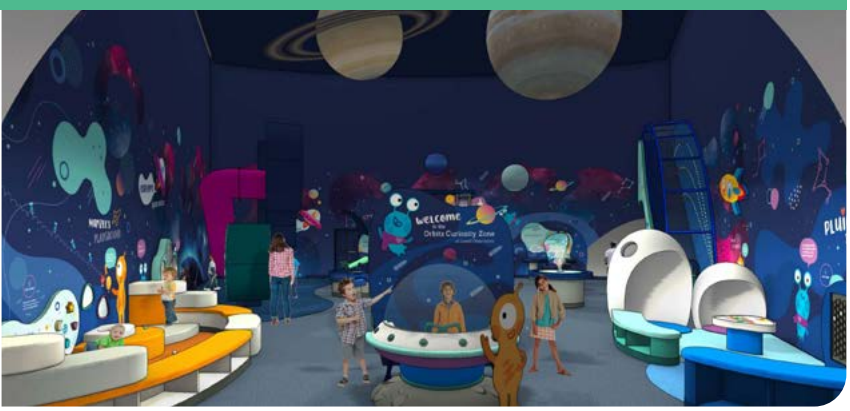
During this holiday season, please accept my thanks to you and your families for your support of Lowell Observatory and best wishes for the year ahead! •

ADC Construction Update

By Dave Sawyer, Technical Project Manager

Structural steel erection is exceeding expectations thanks to excellent engineering, fabrication, and field construction teams. Due to high quality of workmanship all around, the steel structure is flawlessly fitting together with the concrete footings and masonry walls that were built ahead of time. As of November, the east stairway along with second-floor beams in many areas have been completed and are ready for installation of the steel decking needed to pour the second-floor concrete slabs. The steel erection and upper-level concrete slab construction will continue through the winter.

View from the Origins Gallery looking into the Astronomy Gallery (right) and the children's Curiosity Zone.



Learn about ways to support the Astronomy Discovery Center's children's gallery exhibits: lowell.edu/support/curiosity-zone

Your Gifts Make a Difference!

By Lisa Actor, Chief Philanthropy Officer

Lowell Observatory is an independent, nonprofit organization. That's why your contributions are so important to us, and why we are profoundly grateful for your support. Thank you!

Because of COVID-19 closures and related issues, it has been a rough few years. We could not have made it without your support. Thank you!

In 2022, your gifts helped Native American students learn about our galaxy. They provided critical technology for our Lowell Discovery Telescope, helped us purchase display cases to show off historic artifacts, allowed us to acquire Clyde Tombaugh's early, hand-made telescope, and sponsored exciting hands-on exhibits for the future Kemper and Ethel Marley Foundation Astronomy Discovery Center. Thank you!

At the end of each year, we ask your support to fill in our budget gaps. This year is different. With a slow summer visitor season, our budget gap is bigger than normal. Your gifts of all sizes—via check, credit card, donor advised fund, IRA qualified distribution, stock, or good, old-fashioned cash—will help us complete 2022 in the black. Thank you!

Contact our Philanthropy team if you need help donating. Write to donate@lowell.edu or call 928.268.2924. •

Shop on Amazon, Benefit Lowell Observatory

When you use AmazonSmile for purchases, Lowell Observatory gets a donation from Amazon. There is no cost to you. You just sign up and select us as the organization that you would like to support.

- **Go to smile.amazon.com**
- **Enter "Lowell Observatory" as your charity**
- **Use smile.amazon.com when you shop**

Amazon donates 0.5% of eligible purchases to Lowell Observatory.

Miriam Robbins Heads MSA Western Chapter

Visitor Experience Manager Miriam Robbins is now president of the Western Chapter of the Museum Store Association (MSA). The MSA is an organization dedicated to advancing the nonprofit retail industry and the professionals engaged in it. Through advocacy, education, and collaboration, MSA provides the tools and community to help cultural institutions, vendor members, and their commercial partners to expand the visitor's experience, enabling them to take a piece of that experience home.

Miriam Robbins (5th from left) and other leaders of the Western Chapter of the Museum Store Association at a recent meeting in Denver.

Now Accepting Gifts of Cryptocurrency

Your gift of cryptocurrency will further research and inspire visitors to love astronomy as much as you do.

Lowell Observatory now has a system in place to accept your gift through Our Change Foundation. It is a safe and easy way for you to make your tax-deductible donation of cryptocurrency. Visit: **lowell.edu/support/donate-cryptocurrency**

If you have any questions regarding cryptocurrency gifts, please contact Rachel Edelstein at redelstein@lowell.edu or 928.255.0229.

CLYDE TOMBAUGH'S REMARKABLE 9-INCH TELESCOPE

By Kevin Schindler, Historian/PIO

Ingenuity, plus courage, plus work, equals miracles.
- Bob Richards

In 2023, Lowell Observatory will display a telescope that at first glance looks like it came from the windmill laboratory of Caractacus Potts, the fictional inventor who turned a broken-down racing car into the "fine four-fendered friend" that he and his kids named Chitty Chitty Bang Bang. Except for maybe a handful of amateur astronomers, not many people will recognize this telescope. Yet it boasts a rich history and, as the title of this article suggests, is remarkable.

Clyde Tombaugh stands by his recently completed 9-inch telescope on the family farm in Burdette, Kansas, ca. 1928.

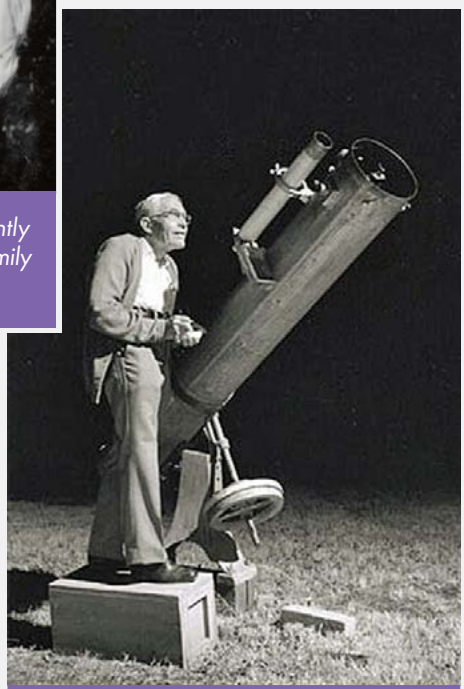
Clyde Tombaugh built the telescope between 1927-1928 while living on his family farm in Burdette, Kansas. He was passionate about astronomy and had built two telescopes prior to this one. His telescope-making skills improving with each effort, he was anxious to build a third telescope. But how could he pay for it? His family had little money, certainly not enough to spend on such a non-essential item as a telescope. So, to build the telescope, Clyde relied not on money but on his God-given ingenuity.

After his initial foray into telescope making, Clyde realized he needed a place with a stable temperature to properly figure the telescope mirrors that he ground by hand. So, with his farmer ethic of arduous work, he toiled away to build a cement-lined cellar that not only served as a haven for the family during storms, but which also provided Clyde with a temperature-stable environment to work on his mirror.

As for the telescope structure itself, Clyde scoured the farm and collected old pieces of farm machinery. He used part of a cream separator for the base, a steel shaft from an early-model Buick for the polar axis, 20-gauge galvanized iron as used in grain augers for the tube, and a spark lever arc from an old car for the worm gear. The result was a pieced-together creation that would have made another fictional character, Dr. Victor Frankenstein, proud.

Not surprisingly, the intrepid self-taught scientist was less interested in how the telescope looked than how it looks. He wanted a telescope with excellent optical quality that would allow him to explore celestial bodies in exquisite detail. And he was not disappointed. He clearly saw the belts and zones of Jupiter and gaps in Saturn's rings (but alas, not Percival Lowell's Martian canals), and made drawings of each.

Clyde became so proficient that he decided to send his handiwork to professional astronomers at Lowell Observatory to see how his work rated. In a splendid example of perfect timing, observatory Director Vesto Slipher was just then looking for someone to help with the reenergized search for Percival Lowell's predicted ninth planet. Slipher liked Tombaugh's drawings and hired the 23-year-old farmer. Within a year, Clyde Tombaugh discovered Pluto with the 13-inch telescope financed by Percival Lowell's brother, Abbott Lawrence Lowell.

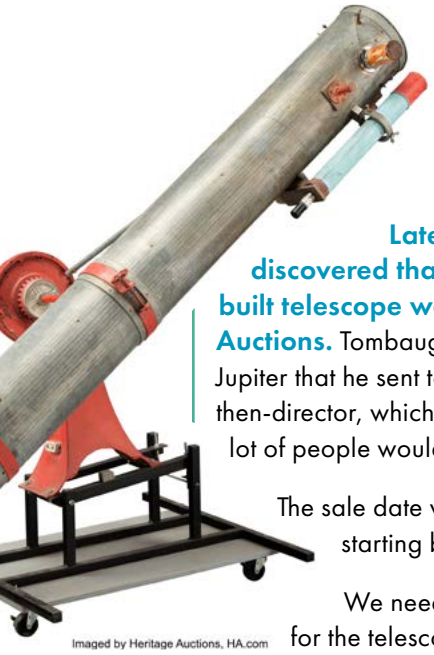


Tombaugh poses with the 9-inch telescope at his home in Las Cruces, New Mexico, more than six decades after he built it, ca. 1993.

The 9-inch telescope is thus significant because it provided a vital step along Tombaugh's pathway to the discovery of Pluto. While the 13-inch Pluto Discovery Telescope is the tool that Tombaugh used to make the discovery, the 9-inch helped pave his way to getting hired at Lowell in the first place. And while the 13-inch captures the spirit of the discovery itself, the 9-inch captures the spirit of the man who made the discovery. •

The Exciting Journey of the Tombaugh Telescope to Lowell Observatory

By Sherry Shaffer, Philanthropy Manager



Imaged by Heritage Auctions, HA.com

Late on July 7, Lisa Actor discovered that Clyde Tombaugh's 1927 hand-built telescope was being sold through Heritage Auctions. Tombaugh used it to make the observations of Jupiter that he sent to V.M. Slipher, Lowell Observatory's then-director, which resulted in a job offer. We thought a lot of people would agree that it belonged at Lowell.

The sale date was Saturday, July 16 and the starting bid was already $60,000.

We needed at least $100,000 to even try for the telescope as there was a 25% buyer's premium plus tax and shipping. Thankfully, two board members jump-started us with generous matching gifts. We fretted over the email to potential donors – this was a one-shot opportunity.

The first emails went out on July 9 to people who had given to Lowell's historic preservation. By the following Tuesday we realized we should contact everyone connected to Lowell. Every pledged dollar was important. Besides, that rustic jumble of parts was seriously cool. Who wouldn't want to be a part of that?

The pledges came pouring in. Each day we got emails and phone calls and by the end of Friday, we'd raised more than $140,000!

On the 16th, Lisa and I met in my office to watch the auction online. The items up before the telescope were things like sheet music hand written by Mozart and an elven family tree drawn by Tolkien. Many were selling for hundreds of thousands of dollars. I got nervous. What if we lost the Tombaugh Telescope?

Then it was our turn. We bid against one other person and the price went up and up. At our bid of $85,000 there was a pause. I held my breath while the auctioneer urged the other bidder to go higher. Then he said, "Going once, going twice...SOLD!"

Lisa and I whooped and jumped over the victory. I sent "We did it!" emails to everyone who pledged. Many quickly responded with congratulations and questions about the telescope's arrival.

If you've had a large item shipped you understand how frustrating the next weeks were. Pricing the rate and building the packing crate took weeks. The shippers didn't inform me when it went on the road, despite promises of an email.

I got the call at 8 a.m. on August 18. I was, of course, out of town. The driver was at Lowell and wondering where I was. After frantic calls to our facilities manager and COO, the huge wooden crate was deposited safely in our warehouse.

I returned for the "unboxing." We scanned the telescope, gleeful over every quirk. We then handed the telescope over to Ralph Nye, the genius behind the restoration of the Clark and Pluto telescopes. It will remain with him for a few months while he gets it back into shape.

The Tombaugh telescope will get its grand unveiling in the Slipher Rotunda during the I Heart Pluto Festival in February. You'll see me there. I'll be the one with the ear-to-ear smile watching the conclusion of the craziest and most fun project of my fundraising career. •

Left: Ralph Nye prepares to haul the telescope to his workshop in Lake Montezuma, where he will restore the instrument.

Right: The Executive Committee of the Lowell Observatory Advisory Board stand with the 9-inch telescope soon after its arrival.

ASK AN EDUCATOR: ENDURING THE COLD

By Resi Baucco, Public Program Supervisor

If you were to visit Lowell Observatory late into the long winter nights, just before close, you would find our enthusiastic public programs educators outside, queuing in their own line at the Giovale Open Deck Observatory to get a look through the telescope at their favorite winter sky objects.

The winter sky is a favorite of many of our educators, but the season does not come without challenges. Here at almost 8000 ft elevation in Flagstaff, winter nights can be brutal. Temperatures are usually well below freezing, snow can come without warning, and the gusty mountain winds make it difficult to keep warm.

Educator Juan R. prepares for the chilly night ahead at the Giovale Open Deck Observatory

Is it worth it? We think so! The winter sky is filled with bright stars that make it easy to learn and identify major constellations like Orion and Gemini. Some of our favorite telescope objects are winter objects: each year we see the Orion Nebula, Crab Nebula, the Pleiades, and many other winter classics. This year we also have excellent views of Jupiter and Mars through the coldest months of the year.

The winter sky is beautiful, but the challenge of enduring the cold still remains. We asked the Lowell Observatory educators for their best advice: who better, after all, to ask? Our educators often brave the cold outdoors for hours each night to share their enthusiasm for the stars with guests from all over the world. We've included some of that advice here, for you, so that you, too, can stay up late this winter and enjoy the bright winter sky.

The name of the game in winter is **layers**. Inner layers provide insulation to hold on to body heat, outer layers provide a shield against the wind to keep body warmth from being carried away. Many of our educators swear by **fleece** in their layers- fleece lined hats, leggings, socks, gloves. Fleece is a great, affordable way to stay warm, but many educators double up with thermal underwear and thick, water and wind resistant outer layers.

Often our educators must use their hands to make fine adjustments to our telescopes, which means traditional gloves can be a nuisance to wear during a shift at the observatory. Rather than using gloves we have to take off over and over again, **flip mittens** have gained a loyal following amongst observatory educators. These mittens cover the palm of the hand, but have a flap over the fingers that can be removed to allow you to adjust a telescope focus knob or move the scope to a new object.

Handwarmers are also a winter must at the observatory. There are a few different types: some use a chemical reaction to slowly warm up in your pockets and can only be used once, others are electric and can be recharged. Each educator has their own preference, but in asking the educators for their cold weather advice, we found some rather creative uses for these handwarmers. A few educators mentioned that they put handwarmers in their hats, one even said she places them in her socks.

Finally, our educators emphasize that **practice** is essential. One educator jokingly called it exposure therapy, but many of our educators agreed that with the proper layers and a little help from flip mittens and handwarmers, staying out in the cold gets easier the more often you do it. With a winter sky as clear and beautiful as the sky over Flagstaff, that part is easy: simply bundle up, look upwards, and let yourself be carried away by awe and curiosity (while your layers do the rest of the work). •

STAR STUFF
A LOWELL OBSERVATORY PODCAST

Season 2: Moving to Video!

After a successful Season 1 of Star Stuff, now crowned the #3 astronomy podcast according to GoodPods and #13 astronomy podcast on iTunes, we are happy to welcome Season 2 in January 2023! This time, we will also be airing episodes on YouTube–but don't worry, everything will still be available on all your favorite streaming platforms.

Thank you to everyone who has listened, shared, and supported Star Stuff. By the end of this season, Star Stuff will have published 56 episodes and hosted over 40 guest speakers. Catch up on Season 1 at lowell.edu/starstuff, and help us welcome Season 2 on YouTube at the start of the year!

I Heart Pluto Festival Set for February 18-20, 2023

by Kevin Schindler, Historian/PIO

Lowell Observatory is teaming with Flagstaff community partners to host the 4th Annual I Heart Pluto Festival, which will run from February 18-20, 2023. This year's festival will include the Night of Discovery keynote event at the Orpheum Theater, VIP tours, art displays, science demonstrations, family activities, virtual science presentations, a downtown pub crawl, and more. Activities will take place in-person at Lowell Observatory, the Orpheum Theater, and other Flagstaff venues. Lowell Observatory will also host a series of virtual science presentations. Stay tuned to iheartpluto.org for details. •

During the 3rd Annual I Heart Pluto Festival in 2021, VIP guests had the opportunity to tour the archives and visit several people with strong Pluto ties, including (left to right): Al & Cherylee Tombaugh and Charlene & Jim Christy.

Sarah Gilbert
Senior Creative Specialist

by Madison Mooney, Content Marketing Specialist

STAFF PROFILE

Sarah Gilbert joined Lowell staff as a Graphic Designer in January of 2013. She graduated from Northern Arizona University with a degree in visual communication and an emphasis in graphic design in 2011, as well as a minor in fine art. As Senior Creative Specialist, Sarah's responsibilities include overseeing and deploying Lowell's brand. This includes designing logos, creating graphics, finalizing the quarterly *Lowell Observer* (including this issue!) and yearly Annual Report, and much more. She's the brains behind the look and feel of every piece of Lowell branding you see both on and off campus.

Sarah designed the current Lowell Observatory logo, which was unveiled during the 2021 Advisory Board Meeting, as well as the 125th Anniversary logo that was used before that. She says that these logos are her proudest achievements, as they are a very visible and vital part of Lowell's history. Her favorite part of working at Lowell is collaborating with the other members of the Marketing and Revenue Team.

Sarah will celebrate 10 years of employment at Lowell in 2023. Recently, she had an asteroid named after her in recognition of her time at Lowell. Outside of work, she enjoys spending time with her husband Brad, their daughter Skyler, and their dog Piper.

Members-Only Facebook Page

The Membership Office is pleased to host a members-only Facebook group. This is a place where members can meet and discuss things of shared interest, as well as stay up to date on events. At the time of writing, topics have included telescope operation, the May lunar eclipse, and a shared article from astrobiology.com. Join now to become an engaged part of the Lowell Member Community!

facebook.com/groups/lowellobservatorymembers

The Exploration Fund

By Stephen Riggs, Senior Philanthropy Manager

Seven years ago, the Lowell Observatory Foundation (LOF), an independent non-profit organization, was created to manage and grow endowed funds that support the observatory's various operations. At present, the LOF houses 16 endowed funds, the total value of which is close to $10 million. One of the most important of these funds is the Exploration Fund. This endowed fund supports astronomical research and researchers at Lowell Observatory.

Credit: Harun Mehmedinovic/SKYGLOW Project

With a current valuation of $1.8 million, it is the third largest of the funds managed by the LOF Board of Trustees. Like all the LOF's endowed funds, four percent of the corpus each year is used for the endowment's purpose. Any remaining earnings are added back into the principal to increase the size of the fund...and create even more earnings over time. In the case of the Exploration Fund, approximately $72,000 is added to the science and research budget each year, an important offset to the observatory's operating expenses.

Payouts from the Exploration Fund have helped our astronomers understand how stars are formed in dwarf galaxies, characterize the atmospheres of exoplanets, and study properties of asteroids and comets—among many other uses. The funds are also used to partially offset salaries of research assistants, particularly student assistants.

Gifts to the Exploration Fund, or to any of the Lowell Observatory Foundation's endowed funds, are gratefully accepted, and gifts will certainly help to grow the funds at a faster pace than earnings alone. For more information about the Lowell Observatory Foundation and for a full list with description of its endowments, please go to the LOF website at foundation.lowell.edu. •

Lowell Observatory Hosts Event in Southern California

By Bruce Kosaveach, Philanthropy Manager

On September 21, 2022, Lowell Observatory organized a dinner event for Lowell members at the Old Ranch Country Club in Seal Beach, California. The occasion was hosted by long-time and generous Lowell Observatory supporters Mike Beckage and his wife Bridget Spanier-Beckage and was well received by all in attendance!

Opening remarks were made by Dr. Jeff Hall, Executive Director at Lowell Observatory.

Lowell planetary astronomer Dr. Nick Moskovitz is a co-investigator on NASA's Double Asteroid Redirection Test (DART) program and presented Earth Strikes Back: NASA's First Planetary Defense Experiment. This is a space-based experiment to deflect the course of an asteroid as a means of protecting Earth from future major impacts. DART then was within five days of impact, and since then the spacecraft has directly crashed into the asteroid Dimorphos as intended (see cover stories).

Professor Tarek Elsharhawy and Michael Pham, Student Program Director from Cal Poly Pomona, plus students Megan Beck and Zachary Gaines presented Bronco Space - A Cal Poly Pomona Student-led Undergraduate Space Program. Bronco Space is staffed and operated by pre-college and undergraduate students and their mission is to develop Cube Satellites and execute tests for systems programs. Samples of their Cube Satellites were on hand for everyone to see.

After the presentations Mike Beckage set up his telescope for everyone to view Jupiter and Saturn.

Dr. Nick Moskovitz discusses the DART program.

The Sun

Find as many words as you can!

N C A R N O N O E E P C N I
P O T S I N P A S C R P O R
H N P F C O T N I N O N O A
O V U L O S P M M E N E I D
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O C T O E S C E R I F O A A
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P N H O E O P I E O E O U N
T E N N R O U C N O D T E E

PLASMA
SUNSPOT
CORONA
FUSION
PROMINENCE
PHOTOSPHERE
CORE
CONVENTION ZONE
RADIATIVE ZONE
FLARE

Eclipse Over Texas: Live From Waco to Celebrate April 8, 2024 Total Solar Eclipse

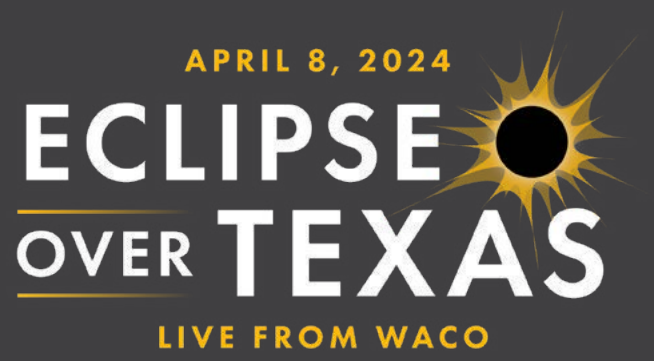
By Kevin Schindler, Historian/PIO

On April 8, 2024, a total solar eclipse will be visible from a narrow path running from Mexico to Canada. Texas will be an ideal viewing spot, and Lowell Observatory is teaming with The City of Waco, Baylor University, and Discovery on a public event, *Eclipse Over Texas 2024: Live from Waco*. This will include an onsite celebration at Baylor University's McLane Stadium in Waco, as well as virtual programming that people around the world may view.

Eclipse Over Texas 2024: Live from Waco will consist of a full day of presentations by astronomers and educators, interactive activities, and telescope viewing. Discovery will broadcast the event on their linear and digital networks. All of this will center around the eclipse: the Sun will begin to be eclipsed at 12:20pm CDT. The Sun's surface will gradually be covered until totality sets in at 1:38pm CDT. This will last for four minutes and 11 seconds, at which point the Sun will begin its gradual move out of the Moon's shadow.

Waco sits in the middle of the path of totality. This, combined with typically excellent weather in April, as well as easy accessibility, makes Waco an ideal location for an eclipse event.

For information, see **eclipseovertexas2024.com**.



Supporter Feedback

Compiled by Heather Craig, Marketing Operations Specialist

An unexpected treasure almost right in downtown Flagstaff... They stay open most nights until 10pm, and we had the chance to look through the old Clark telescope at Saturn, and then using smaller outdoor scopes saw Jupiter and other stars and galaxies... This place is a winner for both adults and kids. An amazing experience.

Trip Advisor

Google Review

This is one of my favorite places on planet earth. I recommend going an hour before sunset and staying until they close at night. The Flagstaff sky is unreal and I could not stop staring into the sky full of stars. Such kind and smart people work there. The location is easy to get to, only a five-minute drive from downtown. Plenty of parking but it does get full so beware! There are stairs and ramps for accessibility. The gift shop is awesome. I'm in love with this place and I want to come back during every season. You will learn so much and see so much amazing history. It's amazing that you can step into the observatory that discovered Pluto! So worth it.

Recent Publications

Jackman, J., Shkolnik, E., Million, C., Fleming, S., **Richey-Yowell, T.**, Loyd, P., 2022, MNRAS, Extending optical flare models to the UV: results from comparing of TESS and GALEX flare observations for M Dwarfs.

Schmidt, T., Treu, T., Birrer, S., ... **Kuehn, K.**, et al., 2022, MNRAS, STRIDES: Automated uniform models for 30 quadruply imaged quasars.

del Ser, D., Fors, O., del Alcazar, M., Dyachenko, V., Horch, E., Tokovinin, A., Ziegler, C., **van Belle, G.**, Clark, C., Hartman, Z., 2022, MNRAS, TFAW survey II: 6 newly validated planets and 13 planet candidates from K2

Dr. Stephen Levine has created a listing of research utilizing the 4.3-meter Lowell Discovery Telescope. It is based on the Astrophysics Data System (ADS) and is updated regularly: **www2.lowell.edu/users/tac/bio/dct_ref_pubs_etal.html**

Dr. Levine has also put together a list of work by Lowell Observatory staff: **www2.lowell.edu/users/tac/bio/Lowell_Annuals.html**

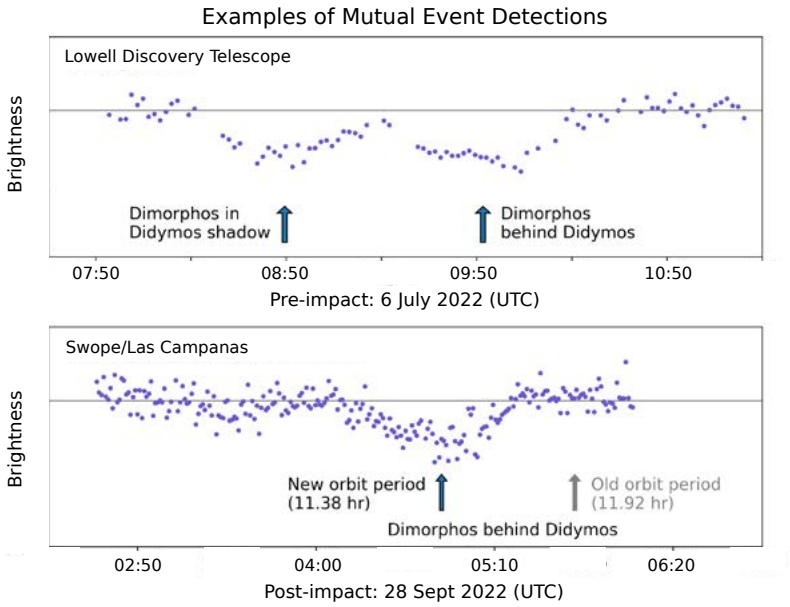
DART MISSION IS A SUCCESS | CONTINUED FROM PAGE 1

dips appear periodically, twice for every revolution of Dimorphos around Didymos, thereby providing a means to measure the time is takes Dimorphos to complete an orbit.

Lowell made significant contributions to the mission through regular monitoring of mutual events. In fact, over half of the few dozen mutual events detected since 2015 that informed mission planning were measured with the Lowell Discovery Telescope (LDT). These data refined the pre-impact orbit period of Dimorphos to a precision of 65 milliseconds — a factor of ten times better than was needed for the spacecraft to successfully impact.

Following impact, measuring mutual events had to start anew. We knew that DART would change the orbit period from a pre-impact value of 11.92 hours, but by how much? Unfortunately, it was expected that ejecta from the impact would obscure Didymos for several weeks before mutual events could be measured again. Thus, it was a great surprise when data from the 1-meter Swope Telescope in Chile taken just 27 hours after impact revealed the first post-impact mutual event. Even more surprising was the new orbit period. The timing of this mutual event showed that the new orbit period of Dimorphos is now 11.38 hours, representing a period change of over 30 minutes! While this was within the range of predictions simulated by the mission team, it was three times larger than baseline expectations. In the subsequent weeks this post-impact orbit period would be confirmed and refined to a precision (at the time of writing) of about one minute.

Working to fully understand the DART impact will keep the mission team busy for many months. For now, results are preliminary but are already providing new insights. For example, the new orbit of Dimorphos suggests that the impact imparted a velocity change of roughly 100 km/year. This is an important benchmark that will serve to inform impact mitigation strategies should an asteroid ever be discovered on an impacting trajectory with Earth. •



Measured mutual events before (from LDT) and after DART impact reveal a Dimorphos orbit period change of >30 minutes. The post-impact mutual event timing is clearly offset with the new orbit period.

ANALYZING DART'S EJECTA | CONTINUED FROM PAGE 1

of Didymos. The more material kicked back, the more the asteroid is pushed forward. The goal is to figure out what DART did and why—we can thus get a different view by studying the material ejected from the system by the impact.

It was apparent within minutes of the impact on September 26, 2022, that it wouldn't just be a tiny amount of dust—there was much more material ejected than most people on the team would have expected. I was extremely excited though—I had a pile of telescope time lined up at the SOAR observatory in Chile and at the Lowell Discovery Telescope just for this scenario. What I wanted to do with my colleagues was to look at two aspects of the ejecta: how it evolved spatially (e.g., where it was in relation to the asteroids and how it moved in the days and weeks after impact) and how it reflected light as a function of wavelength. (Some of what we saw from SOAR is shown as a figure.) To do this, we "just" needed access to a lot of time at large telescopes with large fields of view and modern high-quality cameras and filters. Easy! (Just kidding, I haven't slept well in months.)

Science Reporter Melissa Sevigny interviews Drs. Teddy Kareta and Nick Moskovitz right after the DART impact.

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What exactly do we learn by taking these kinds of images, and what preliminary things have we learned so far? The spatial distribution and reflectivity of the ejecta is primarily driven by the distribution of sizes of particles in and the composition of the ejected material. Previous telescopic characterization of Didymos has shown it is compositionally similar to ordinary chondrite meteorites—one of the most common and best-studied kinds of meteorites—so the size frequency distribution is the only big "unknown" standing between us comparing our observations against predictions for what DART did to that poor little asteroid moon.

Preliminarily, we can see the ejecta moving and reflecting light about how we might expect—we can see smaller (micron-sized!) dust spread out and begin to form the tail just hours after the impact, but by a week after DART met its demise most of the fine grains are all gone and even the bigger dust particles in the ejecta cone are starting to get pushed away from the sun by radiation pressure. This is good news: it means that we will be able to use our observations to understand what the ejected material says about the DART experiment rather directly. Stay tuned—by the time the next Lowell Observer comes out, we'll have learned a lot more. •

(Front Cover): Teddy Kareta leads the team that captured this multi-color image of the Didymos system about 53 hours after the DART impact onto Dimorphos. The long streak towards the right side of the image is the dust tail, over 10,000 kilometers long by the time we started observing. The bright material towards the left of the bright central area is the ejecta cone. Credit: CTIO/NOIRLab/SOAR/NSF/AURA/T. Kareta (Lowell Observatory), M. Knight (US Naval Academy). Image processing: T.A. Rector (University of Alaska Anchorage/NSF's NOIRLab), M. Zamani & D. de Martin (NSF's NOIRLab).

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