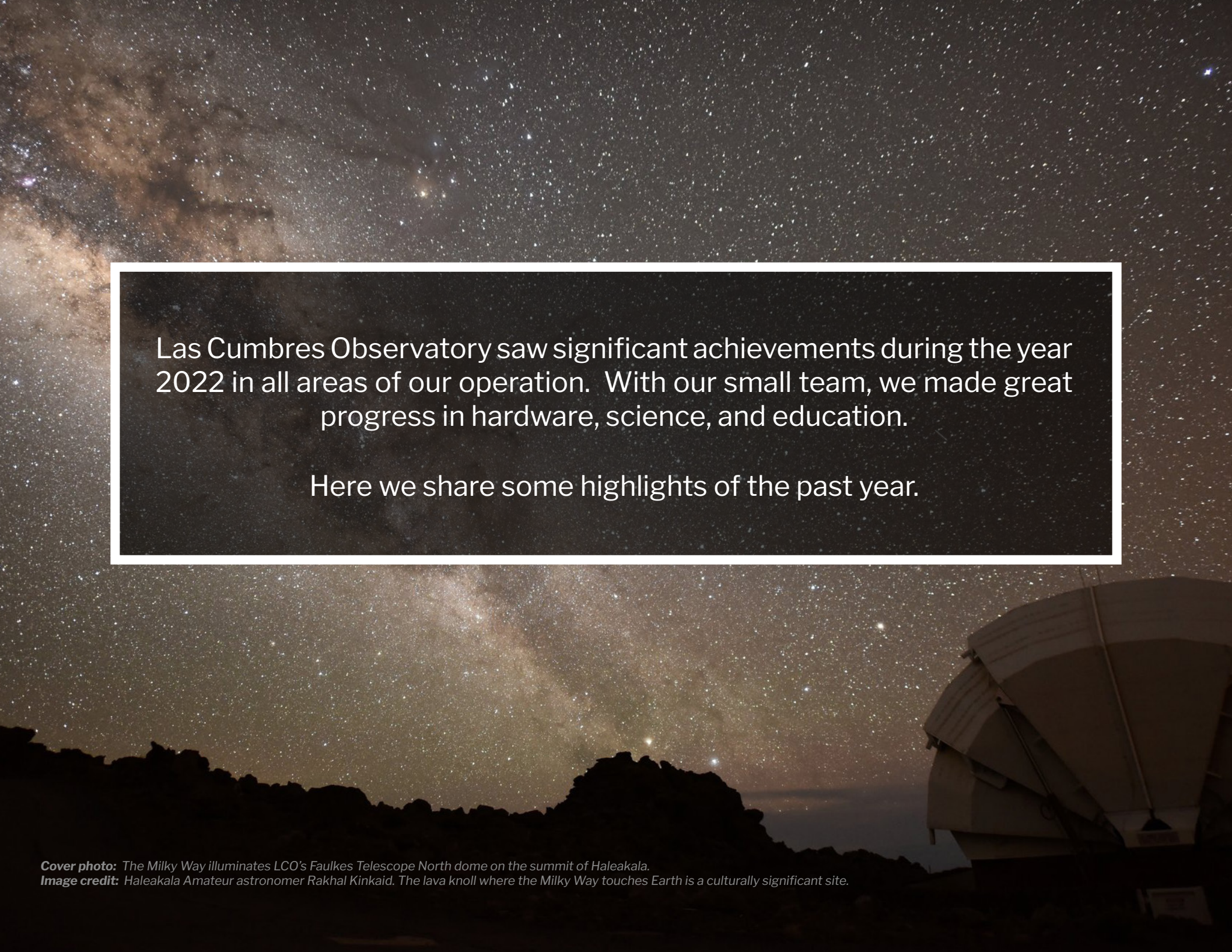
2022 Annual Report

Las Cumbres Observatory LCO

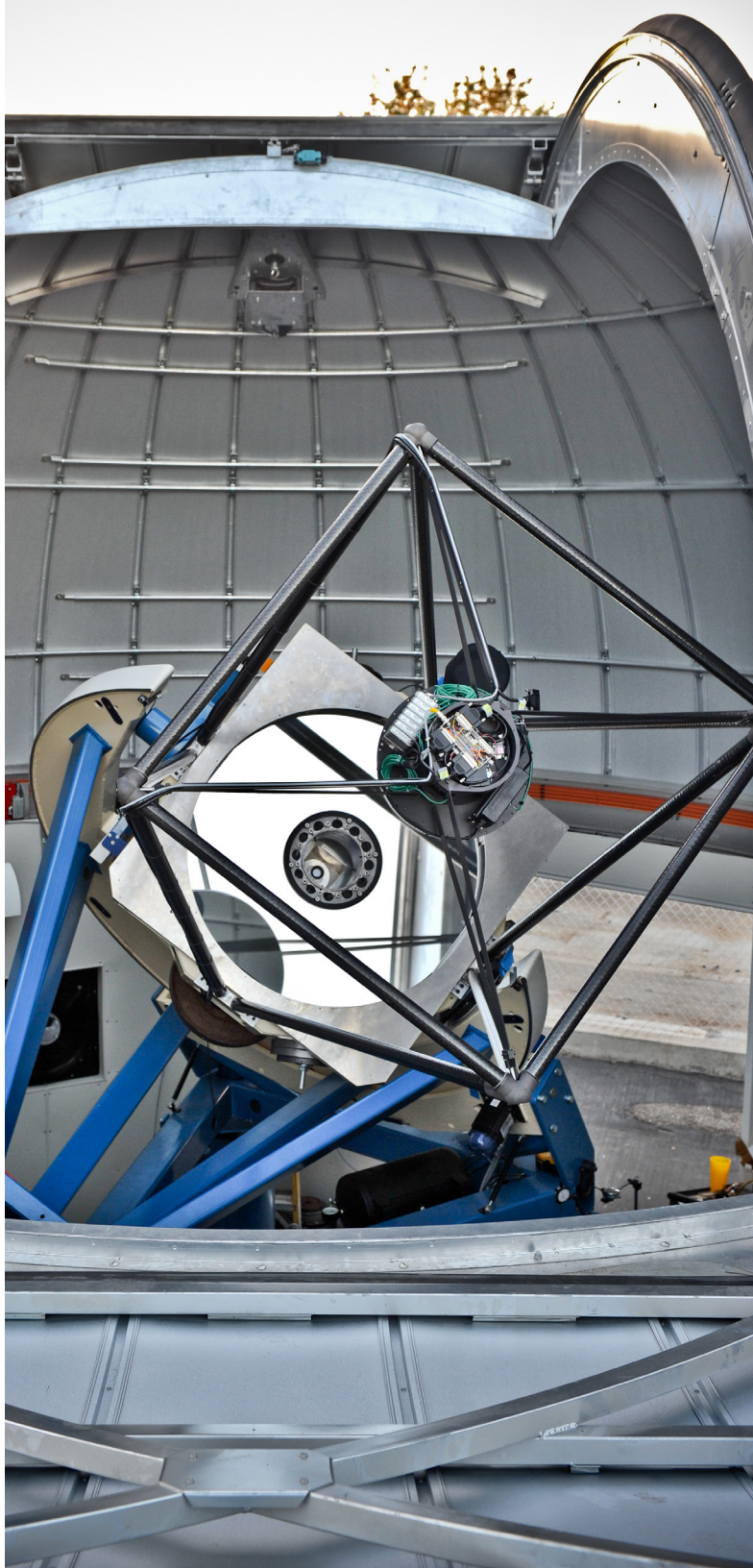


Las Cumbres Observatory saw significant achievements during the year 2022 in all areas of our operation. With our small team, we made great progress in hardware, science, and education.

Here we share some highlights of the past year.

Cover photo: *The Milky Way illuminates LCO's Faulkes Telescope North dome on the summit of Haleakala.*
Image credit: *Haleakala Amateur astronomer Rakhal Kinkaid. The lava knoll where the Milky Way touches Earth is a culturally significant site.*

Telescopes



Heising-Simons Foundation Grant Funds New Instrument

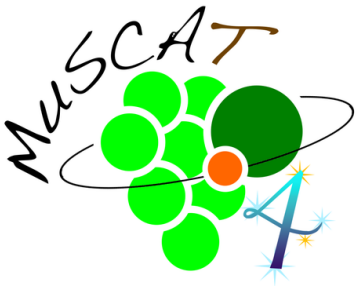
The Heising-Simons Foundation is investing in the future of astronomy with a grant of $1.6 million that provides funding for a new multichannel imager. The award is managed by the Las Cumbres Observatory, a global robotic telescope network dedicated to time domain astronomy. The instrument, called MuSCAT4, will be installed on the 2-meter Faulkes Telescope South at Siding Spring Observatory in Australia in late 2023. LCO is thrilled to be able to offer this enhanced capability to astronomers around the world.

MuSCAT (**Mu**lticolor **S**imultaneous **C**amera for studying **A**tmospheres of **T**ransiting exoplanets) is a four-channel optical simultaneous imager. Observing in four channels at once dramatically improves the effective throughput of the telescope, benefiting all science observations. MuSCAT4 will be the fourth instrument in a series of multi-channel imagers designed and constructed by a team led by Dr. Norio Narita at the University of Tokyo and the Astrobiology Center in Tokyo, Japan. MuSCAT3 was installed in 2020 on LCO's 2-meter Faulkes Telescope North at Haleakala Observatory. The installation of MuSCAT4 will provide LCO observers with identical imaging instrumentation in the northern and southern hemispheres.

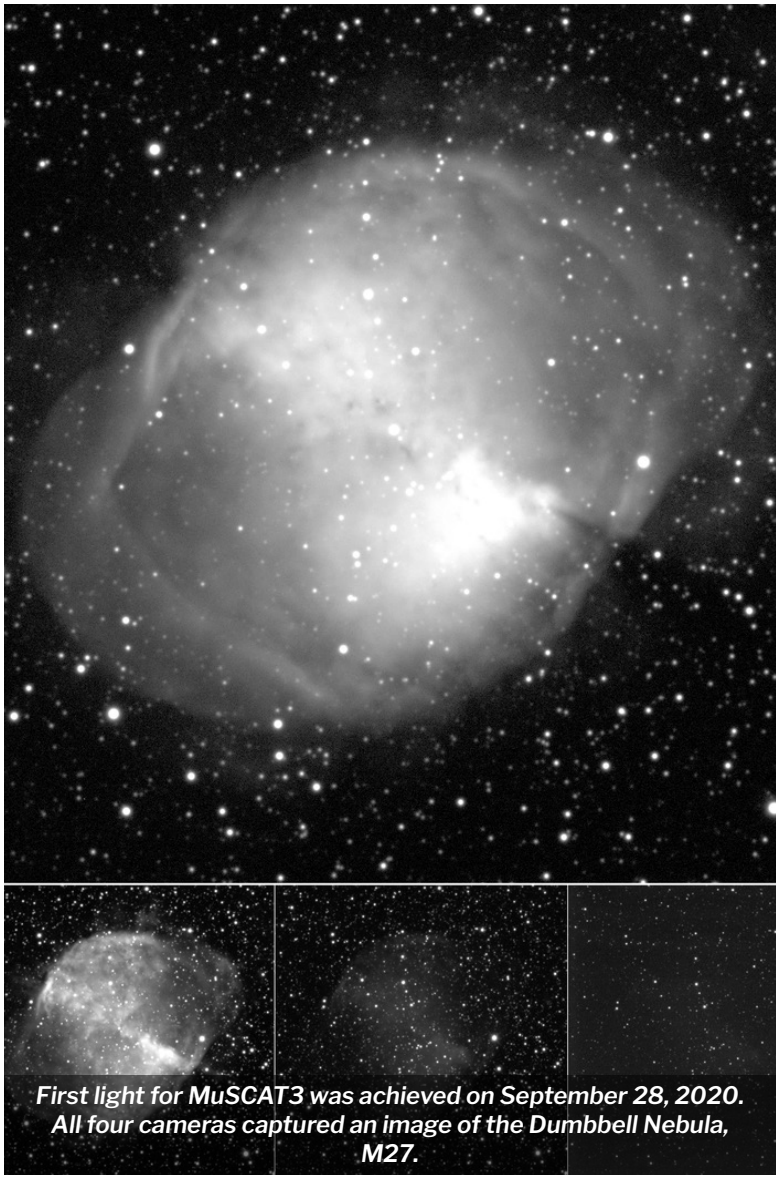
The Heising-Simons Foundation, in recognition of the unique research capabilities of LCO, has provided funding for the construction and commissioning of the new instrument.

"LCO's value to the time domain astronomy community is very clear ...The Foundation is happy to support the MusCAT4 instrument and LCO's efforts to expand their capabilities in the Southern hemisphere."

- Jochen Marshall
Science Program Officer,
Heising-Simons Foundation

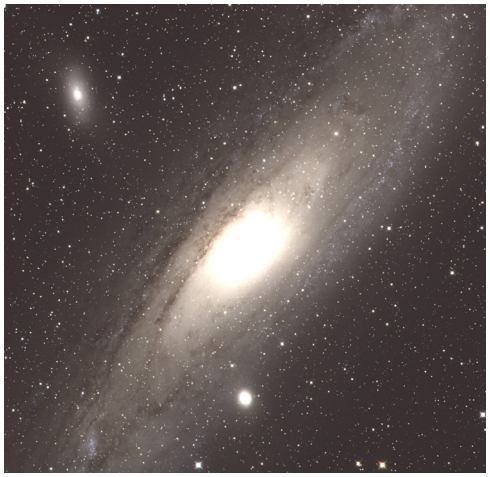


The new logo for MuSCAT4, designed by the MuSCAT team, incorporates the Southern Cross in recognition of the instrument's future home in Australia.



First light for MuSCAT3 was achieved on September 28, 2020. All four cameras captured an image of the Dumbbell Nebula, M27.

New Delta Rho Imagers on the 0.4-meter Telescopes

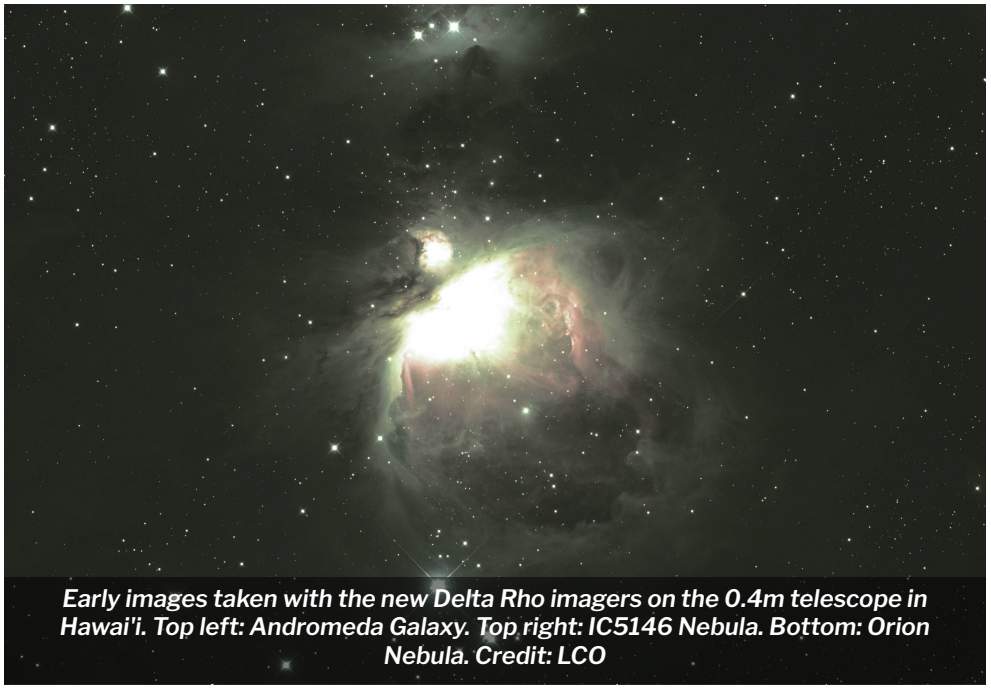


LCO's education program, Global Sky Partners, makes telescope time available to students, particularly from underrepresented communities and the developing world, via partner organizations.

Our network of ten 0.4-meter telescopes is the backbone of this program. Over 1300 hours of telescope time were provided in 2022.

With a grant from the Moore Foundation, the 0.4-meter telescopes are being upgraded , which will improve the reliability of the network and the quality of the images. The telescopes are being replaced with Planewave Delta Rho 35cm instruments.

A prototype in Hawai'i has been successfully commissioned and installation of the other units will continue over the next year. The image quality is vastly improved.



Early images taken with the new Delta Rho imagers on the 0.4m telescope in Hawai'i. Top left: Andromeda Galaxy. Top right: IC5146 Nebula. Bottom: Orion Nebula. Credit: LCO

The upgraded telescope. The previous Meade 40cm has been replaced with a Planewave Delta Rho 35cm instrument. Credit: LCO

Science

LCO Telescopes Capture DART Asteroid Impact

Image of asteroid Didymos taken on Oct 1 from the 2-m LCO Faulkes Telescope North on Maui, Hawaii showing the extended tail produced by the impact. Credit: Helen Usher, Comet Chasers, Tim Lister / LCO, Faulkes Telescope Project.

The NASA DART spacecraft impacted the asteroid Dimorphos on September 26 at 4:14pm PDT. The images from the LCO 1-m telescope in South Africa show the expanding cloud of ejecta, twelve and fifteen minutes after the moment of impact. Credit: Tim Lister, Joseph Chatelain, Rachel Street, Edward Gomez, Joseph Farah / LCO.

The NASA Double Asteroid Redirection Test mission — the first test mission for NASA's Planetary Defense Coordination Office — launched a spacecraft last November aimed to crash into the binary near-Earth asteroid system Didymos. The DART impact with the smaller asteroid Dimorphos occurred on September 26.

LCO is pleased that its 1-m telescopes in South Africa captured the moment of impact and the resulting debris plume. The video of this event is available on the LCO YouTube channel.

Las Cumbres Observatory, along with other ground-based observatories, is contracted to make observations of the near-Earth objects during the mission. The work conducted at LCO is under the direction of Dr. Tim Lister, who heads the group studying Near-Earth Objects, that includes Solar System scientist Dr. Joey Chatelain and Education Director Dr. Edward Gomez.

"We are very pleased to be a part of the DART project. The unique capabilities of the LCO network are providing invaluable data that are an essential element to the protection of our planet. We are pleased that our telescopes in South Africa allowed us to be some of the first people to see the impact of DART and its after effects. We were surprised by the size of the effects, which were much bigger than predicted, but this shows why we should run these tests."

- Dr. Tim Lister
Senior Staff Scientist, LCO

Astronomers Reveal First Image of the Black Hole at the Heart of our Galaxy

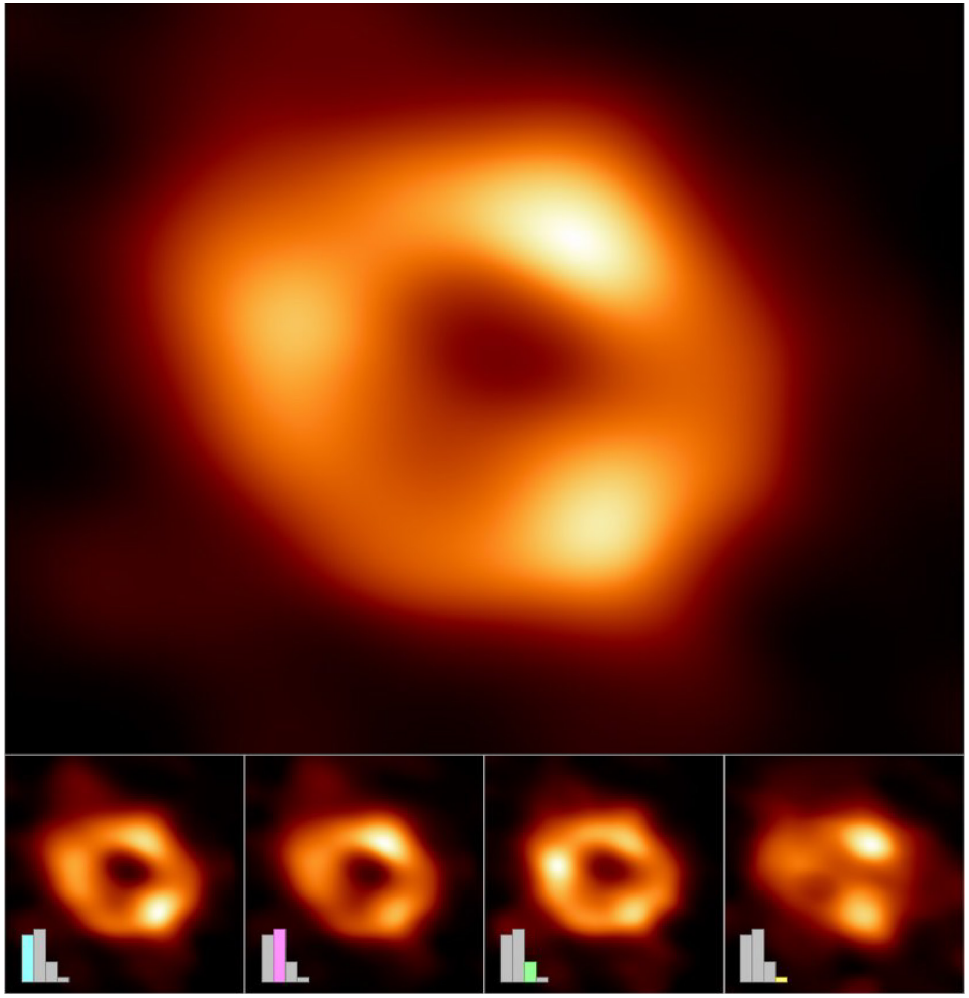
Joseph Farah, a graduate student at UC Santa Barbara and Las Cumbres Observatory, participated in a press conference in Washington D.C. last May where astronomers unveiled the first image of the supermassive black hole at the center of our own Milky Way galaxy. This result provides overwhelming evidence that the object is indeed a black hole and yields valuable clues about the workings of such giants, which are thought to reside at the center of most galaxies. The image was produced by a global research team called the Event Horizon Telescope (EHT) Collaboration, using observations from a worldwide network of radio telescopes.

Mr. Farah devised a new technique for producing a dynamical movie representation of the black hole Sgr A*. He is the lead author on the paper released today, *Selective dynamical imaging of interferometric data*, in the special issue of *The Astrophysical Journal Letters*. Now a member in the lab of UCSB/LCO astronomy professor Andy Howell, Farah conducted much of the work for this project as an undergrad at University of Massachusetts, Boston.

Mr. Farah is grateful to the National Science Foundation for supporting his work through a Graduate Research Fellowship.

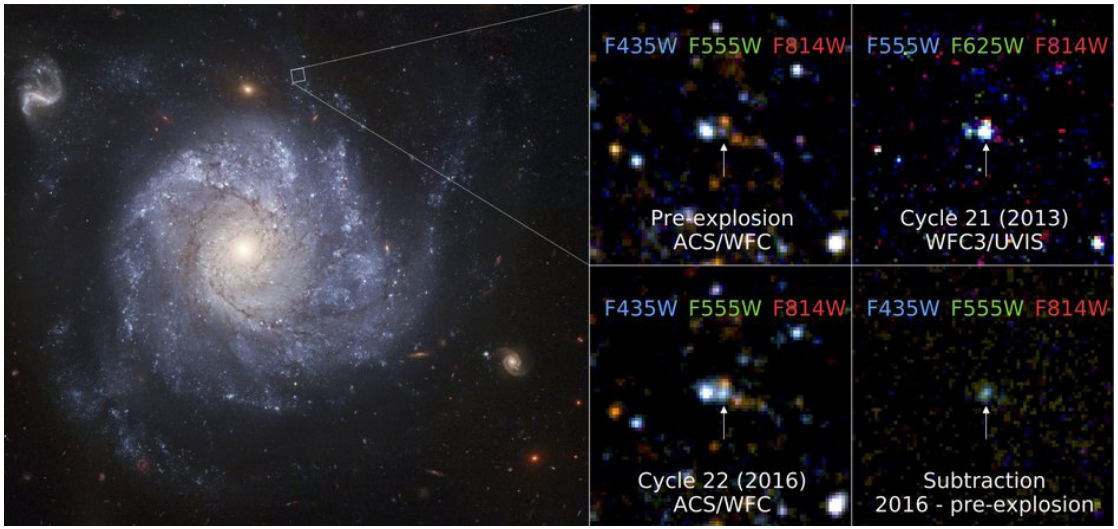
"I can't believe how quickly the project grew from analyzing the exciting-but-preliminary initial datasets to seeing the beautiful shadow reconstruct before our eyes. It's the only thing that seems to evolve faster than Sgr A! What a privilege it has been to be a part of this wonderful project, with all of our wonderful collaborators."*

- Joseph Farah
Graduate Student, UCSB and LCO



Making of the image of the black hole at the center of the Milky Way. Credit: EHT Collaboration

The Star that Survived a Supernova



Color images of NGC 1309 both before and after SN 2012Z. The left panel shows the Hubble Heritage (pre-explosion) image of NGC 1309. The top-middle panel shows a zoom in on the position of the supernova from the pre-explosion image. The top-right shows SN~2012Z from the 2013 visit. The middle-bottom panel shows the location of SN~2012Z in the latest observations in 2016. The bottom-right panel shows the difference image between the pre-explosion images and the observations from 2016. The source at the location of SN~2012Z is still significantly brighter in 2016 than in the pre-explosion images. Image from McCully et al. 2022, ApJ, 925, 138.

"The implications for Type Ia supernovae are profound. We've found that supernovae at least can grow to the limit and explode. Yet the explosions are weak, at least some of the time. Now we need to understand what makes a supernova fail and become a Type Iax, and what makes one successful as a Type Ia."

- Curtis McCully
Astrodata Scientist, LCO

A supernova is the catastrophic explosion of a star. Thermonuclear supernovae in particular signal the complete destruction of a white dwarf star, leaving nothing behind. When a team of astronomers led by Dr. Curtis McCully, Senior Astrodata Scientist at Las Cumbres Observatory, went to look at the site of the peculiar thermonuclear supernova SN 2012Z with the Hubble Space Telescope; they were surprised to find that the star had survived the explosion. These findings were presented in an article in The Astrophysical Journal and featured in a press conference at the 240th meeting of the American Astronomical Society. The scientists were shocked to find that the star was even brighter after the supernova than it had been before it exploded. The puzzling results give us new information about the origins of some of the most common, yet mysterious, explosions in the universe.

For decades scientists thought Type Ia supernovae explode when a white dwarf star reaches a certain limit in size, called the Chandrasekhar limit, about 1.4 times the mass of the sun. That model has fallen somewhat out of favor in the last few years as many supernovae have been found to be less massive than that and new theoretical ideas have indicated that there are other ways to cause them to explode. Astronomers were not sure if stars ever got near the Chandrasekhar limit before exploding. The study authors now think that this growth to the ultimate limit is exactly what happened to SN 2012Z.

LCO Scientists Observe Lone Black Hole

Astronomers announced the first discovery of an isolated compact object, likely to be a black hole in the Milky Way. Astrophysics theory has predicted the presence of solo black holes and ten years of observations made by the Hubble Space Telescope, confirmed by ground-based observatories, have made the identification.

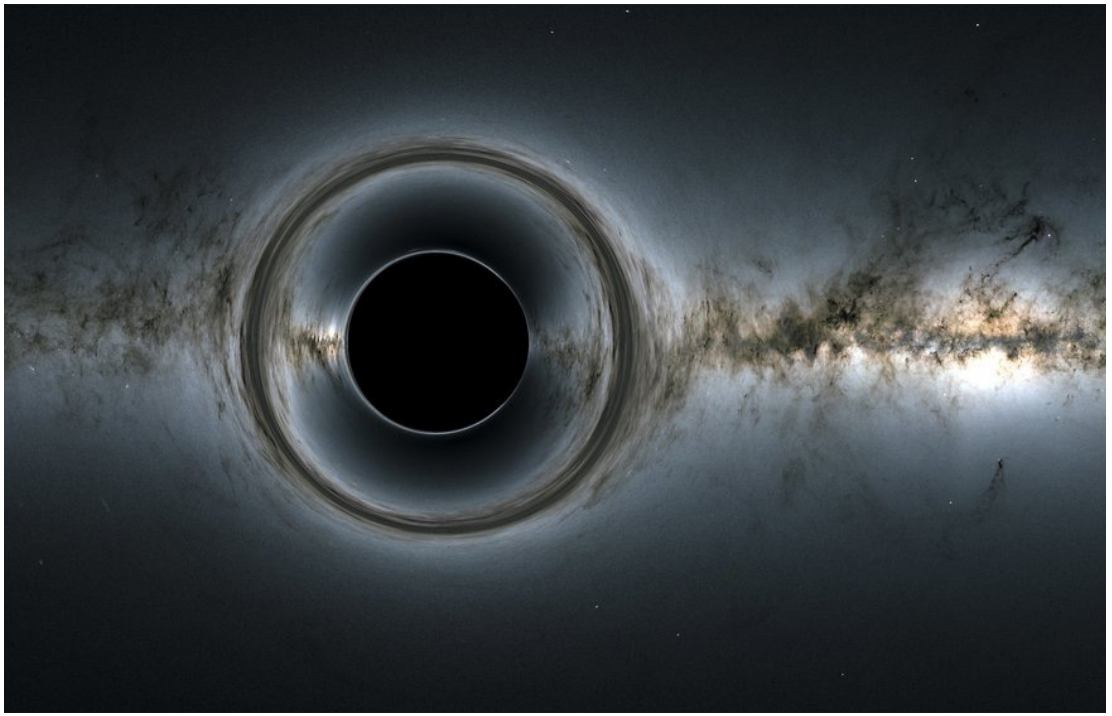
Las Cumbres Observatory was part of the team that made this great discovery. Under the direction of Dr. Rachel Street, postdoctoral fellow Dr. Etienne Bachelet modeled all of the data and confirmed the exciting result.

"This is a groundbreaking find because compact objects are an important part of stellar evolution but intrinsically hard to study. Microlensing is a unique tool that allows us to find isolated black holes and explore these hidden populations for the first time."

- Dr. Rachel Street
Senior Staff Scientist, LCO

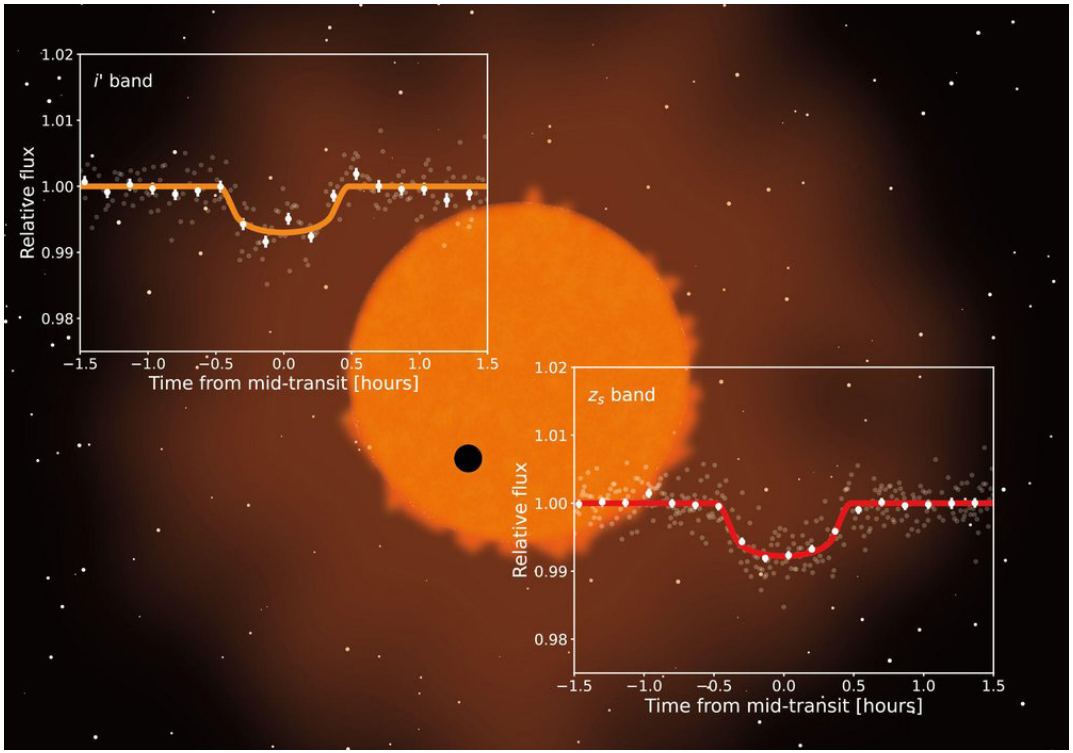
The discovery is reported in these two papers:

- An isolated mass gap black hole or neutron star detected with astrometric microlensing.
- An Isolated Stellar-Mass Black Hole Detected Through Astrometric Microlensing.



This simulation of a supermassive black hole shows how it distorts the starry background and captures light, producing a black hole silhouettes. Credit: NASA's Goddard Space Flight Center; background, ESA/Gaia/DPAC.

LCO Instrument Vital to the Discovery of Two Super-Earths



Artist's rendition of exoplanet discovery. Credit: Astrobiology Center/MuSCAT team.

The discovery of two "Super-Earth" temperate exoplanets orbiting a small cool star was announced in September 2022 by the National Astronomical Observatory of Japan. This exciting discovery involved follow-up optical telescope observations to transits observed by NASA's Transiting Exoplanet Survey Satellite (TESS). TESS found a periodic dimming of a star and announced it as a transiting planet candidate in July 2021.

This discovery was made possible by international collaboration between ground-based telescopes and a Japanese TESS follow-up team from the University of Tokyo and Astrobiology Center.

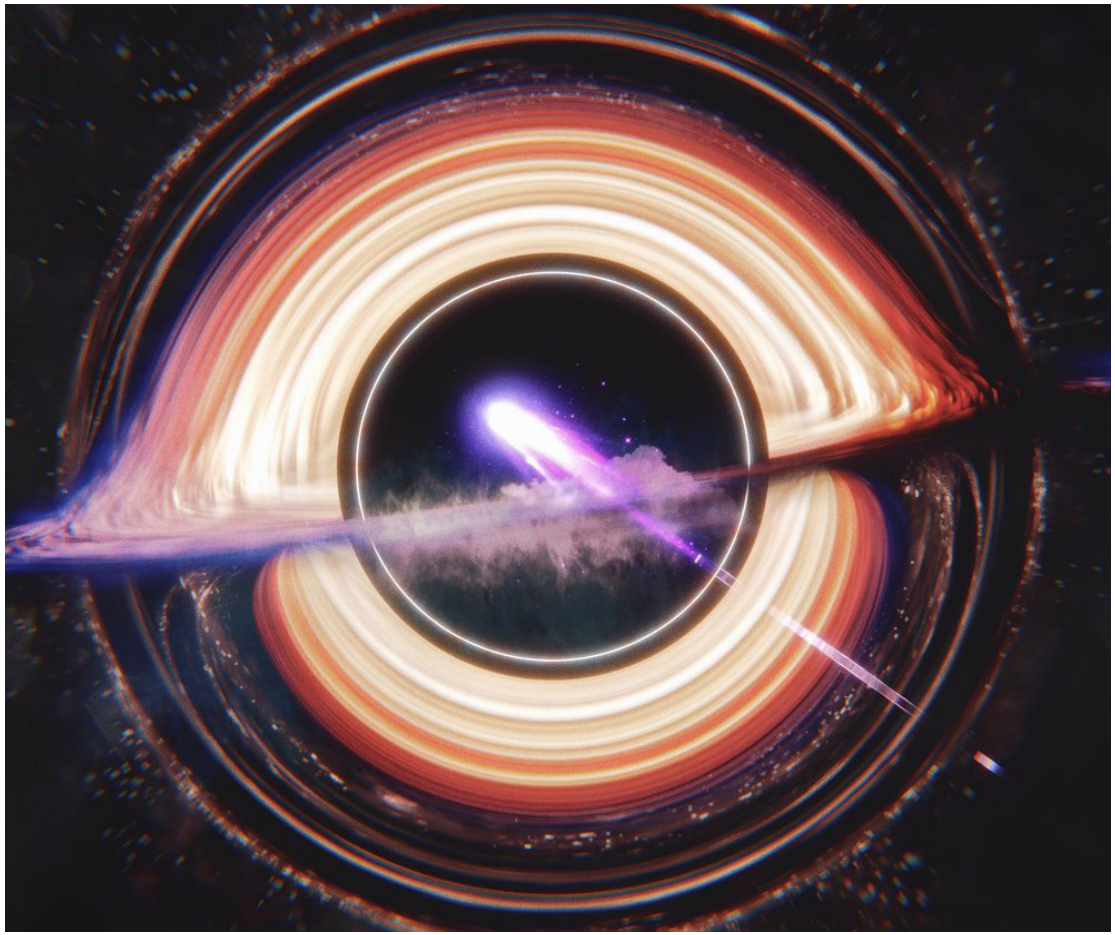
The Japanese TESS follow-up team led by Norio Narita observed one exoplanet with the 4-color simultaneous camera MuSCAT3 installed on the Las Cumbres Observatory 2-m Faulkes Telescope North at the Haleakala Observatory, Maui, and the InfraRed Doppler instrument (IRD) installed on the Subaru Telescope on Maunakea, Hawai'i Island, and confirmed the discovery by October 2021.

The MuSCAT3 multi-channel camera, shown before it shipped from Tokyo in the summer of 2020, was installed on the LCO 2-m telescope at Haleakala Observatory.

LCO Graduate Student Assists in the Discovery of a Gas Bubble Orbiting Black Hole Sgr A*

In September of this year, a team of scientists led by Maciek Wielgus at the Nicolaus Copernicus Astronomical Centre in Poland announced the discovery of a hot gas bubble orbiting the supermassive black hole at the center of the Milky Way galaxy. The existence of the black hole — known as Sagittarius A* (Sgr A*, pronounced "sadge-ay-star") — was confirmed in May when the images of the object were published. Further observations of the black hole and its characteristics are pushing the boundaries of astronomy and physics.

LCO and UCSB graduate student Joseph Farah was part of the original team of the Event Horizon Telescope that imaged Sgr A*. As part of the science team that continues to observe the black hole, he played a role, along with the principal investigators, in the discovery of the hot gas bubble.



Artist's rendering of a hot gas bubble orbiting Sgr A, the black hole at the center of our galaxy. Credit: Joseph Farah, LCO*

Education

LCO Education Partners Recognized by the International Astronomical Union

In spring of 2022, the International Astronomical Union hosted a conference for projects funded in 2021 by the Office of Astronomy for Development. The Office supported 21 educational projects with an emphasis on high-quality astronomy programs in the developing world.

Five of the 21 programs recognized were LCO Global Sky Partners, supported with free telescope time and mentoring in the application of astronomical data to educational projects. LCO is pleased that our worldwide education work is recognized for its quality, reach, and educational value — particularly in the developing world and among underserved communities.

The education partners recognized were:

- AstroLab
- Pan-African School for Emerging Astronomers (PASEA)
- Shristi Astronomy (AstroSprint)
- Interactive Elementary Astronomy for Students in Uganda (Knowledge access and sharing through Cultural Astronomy in Uganda's refugee settlements and host communities)
- PeTER (Amanar)

The attendees of the 2019 PASEA workshop in ABUJA, NIGERIA, hosting an outreach event for 3 local schools. Credit: PASEA.

"All of the inspirational projects selected by the Office of Astronomy for Development have made a huge impact on people in the developing world. Underserved communities are a key audience for the LCO education, therefore I am delighted that we could support these projects."

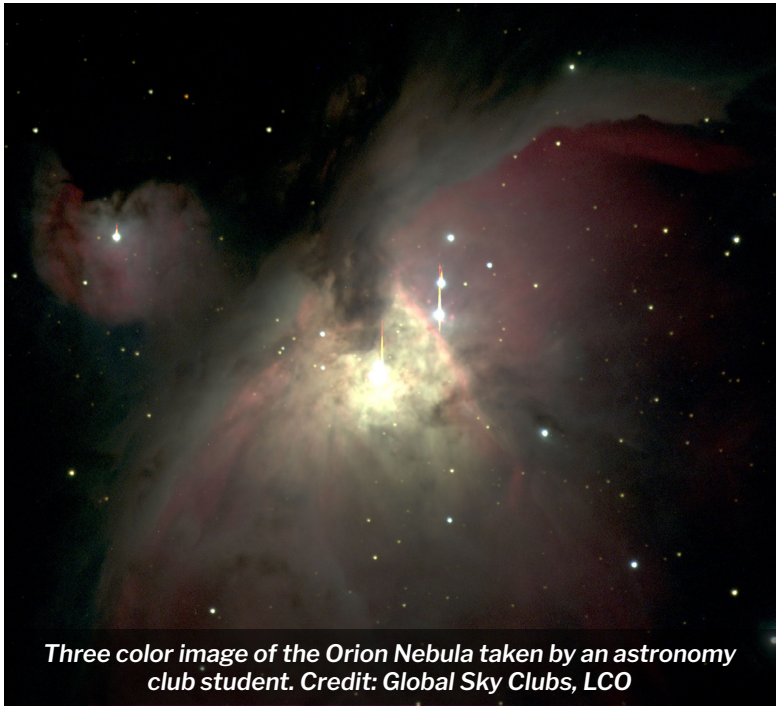
- Dr. Edward Gomez
Director of Education, LCO

Global Sky Clubs - Robotic Telescopes for Astronomy Clubs

Astronomy clubs in school are often a place where young people have their first experience of astronomy. In 2022, we piloted a new program for school-based astronomy clubs, called Global Sky Clubs. We offered access to LCO's global network of robotic telescopes and our world class, award winning educational resources.

This program is targeted at clubs who have some experience making astronomical observations and would like to start an investigation or research project.

In August 2022, we had 12 astronomy clubs join our Global Sky Clubs program. Each astronomy club was provided with 10 hours of telescope time on our 0.4-meter robotic telescope network for a 6 month period. With this amount of time they are able to investigate deep sky objects like star forming nebulae, variable stars and even exoplanets.



Three color image of the Orion Nebula taken by an astronomy club student. Credit: Global Sky Clubs, LCO

Moon Over Us astronomy club students from India, showing their certificates. Credit: Moon Over Us

LCO Offers the World's Largest Astronomy Lesson in India

Mission Platinum, a member of LCO's Global Sky Partners program, set itself high aims: to host the world's largest astronomy lesson. It was timed to coincide with HM Queen Elizabeth II's Platinum Jubilee celebrations in 2022. The program had two key components: using robotic telescopes in classrooms in India and an astronomy talk for the students.

Initially 25 schools were selected to use the LCO network from their classrooms and over 1,000 students participated in making astronomical observations. The students and their teachers took more than 4,000 images using the LCO 0.4-meter telescopes over a period of 3 days. The students generated images of the most impressive astronomical objects.

In August 2022, these original schools and 100 more from the Bulandshahr district of India took part in an astronomy talk presented by Prof Carole Mundell (University of Bath, UK). Prof Mundell showcased some of the best examples of the images taken by the schools earlier in the year.

Mission Platinum was a great success in achieving its goal by hosting over 7,000 students (including virtual participation by Zoom) in the world's largest astronomy lesson. Each student was awarded with a certificate of achievement for being involved in this citizen science project.

In the village of Mukundgarh, an extra-special presentation was made by the Chief Minister of Uttar Pradesh, Yogi Adityanath. Student Bhoomika (aged 10) and her grandfather Hansroop (75) both were awarded for their involvement in Mission Platinum. Bhoomika for her contributions to citizen science and Hansroop for his contributions to amateur astronomy.

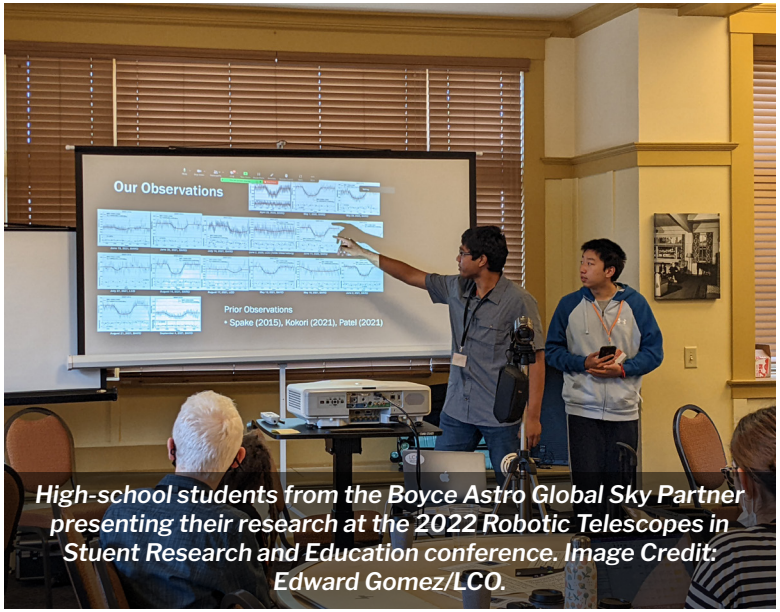
All the images taken by the students can be viewed on the Mission Platinum gallery.

Mission Platinum was supported through the **Global Sky Partners** program, by the **UK High Commission in India** and by the **Bulandshahr District Education Authority**.

Students from one of the Mission Platinum schools at the UK High Commission in India, after a talk and demo by LCO Education Director Dr. Edward Gomez.

Students from a school in Bulandshahr, India, joining the world's largest astronomy lesson via Zoom, with Mission Platinum.

Global Sky Partners



High-school students from the Boyce Astro Global Sky Partner presenting their research at the 2022 Robotic Telescopes in Stuent Research and Education conference. Image Credit: Edward Gomez/LCO.

The primary aim of the Global Sky Partners program is to inspire, educate and provide authentic scientific experiences through the use of the LCO robotic telescope network. Through this opportunity, LCO aims to inspire audiences in underrepresented communities and the developing world, reaching audiences who would not normally be able to take part in programs involving professional scientific equipment. In 2022 we supported 30 Global Sky Partner projects which had an impact in 45 countries across the globe.

From Partners offering mentoring, workshops and training programs, with a total audience size of ~21,500 individuals:

- **58%** of the audience were from disadvantaged or underrepresented communities or developing world countries with a further 37% being from mixed representation
- **31%** of the audience were mentored in publication quality research projects
- **64%** of the audience took part in workshops and teacher training
- **71%** of the audience were high-school students
- **19%** of the audience were teachers.

Students in these projects published 19 papers in peer reviewed journals, and presented 13 talks at professional astronomy conferences.

The programs these partners led directly served a total audience of over 22,000 individuals, which increases to over 100,000 individuals when you include students whose teachers were involved. The program used 1380 hours of observing time on the LCO educational network of 0.4-meter telescopes.

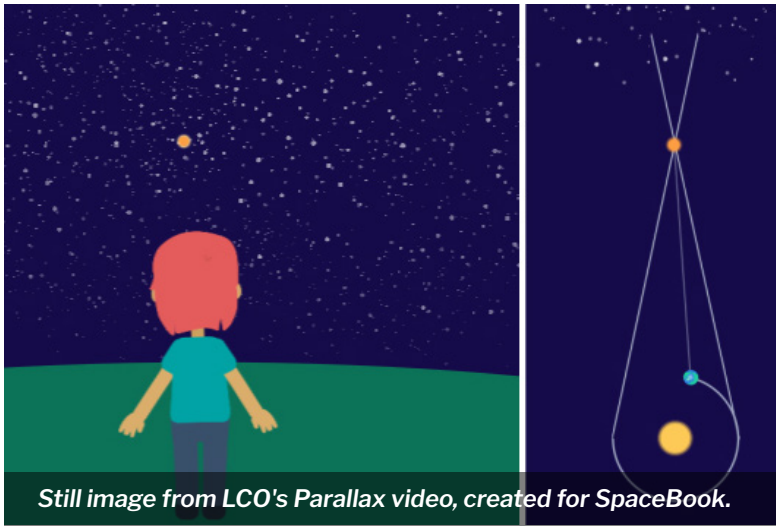
Global Sky Partners is supported by the Simons Foundation and the Gordon and Betty Moore Foundation.

Educational Resources

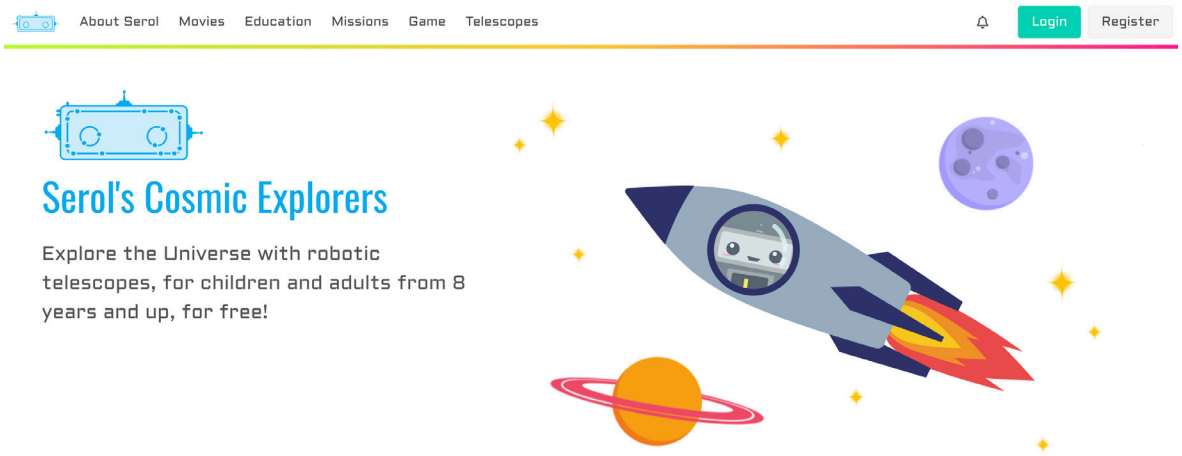
Our in-house education team produces and supports educational resources for the wider community. SpaceBook is one of our most used resources, containing information on a whole range of topics within astronomy. We have added videos to some of the most popular pages to further engage with that audience. The Stellar Parallax page now includes a video which has been watched over 180,000 times.

We developed Serol's Cosmic Explorers as an interactive web adventure for children and young people aged 8 and up. There are 3 missions which allow the audience to explore the Universe using LCO's 0.4m telescopes in a highly intuitive way. As well as these missions, there are educational resources and a video game. Serol's Cosmic Explorers is free for anyone with computer and internet access.

Ada's Adventures in Science is a comic book series which tracks the life of an aspiring young scientist called Ada, written by our Education Director, Edward Gomez, and illustrated by the artist Laura Sorvala. These stories promote the idea that anyone can be involved in the excitement of science, they just need to ask questions. In 2018, 15,000 copies of Ada's story have been delivered to 20 countries. During 2022 we have continued creating new translations of this comic book, which is now available in 17 languages, and is completely open access.



Still image from LCO's Parallax video, created for SpaceBook.



Serol's Cosmic Explorers website.

Multiple language versions of Ada's Adventures in Science comic books preparing to be shipped around the world.

About LCO

Las Cumbres Observatory (LCO) is a nonprofit corporation based in Goleta, California, dedicated to advancing worldwide understanding of the Universe through science and education with its global network of fully robotic optical telescopes. LCO began its mission in 2005 and has been operating a global network continuously since May of 2014. The network currently consists of twenty-five telescopes, located at seven sites of high astronomical quality, which together serve as a single integrated observatory. The observatory is leading the future of time domain astronomy with observations that capitalize on the network's unique capabilities.

To learn more about our observatory, please visit our website.