2021 Annual Report

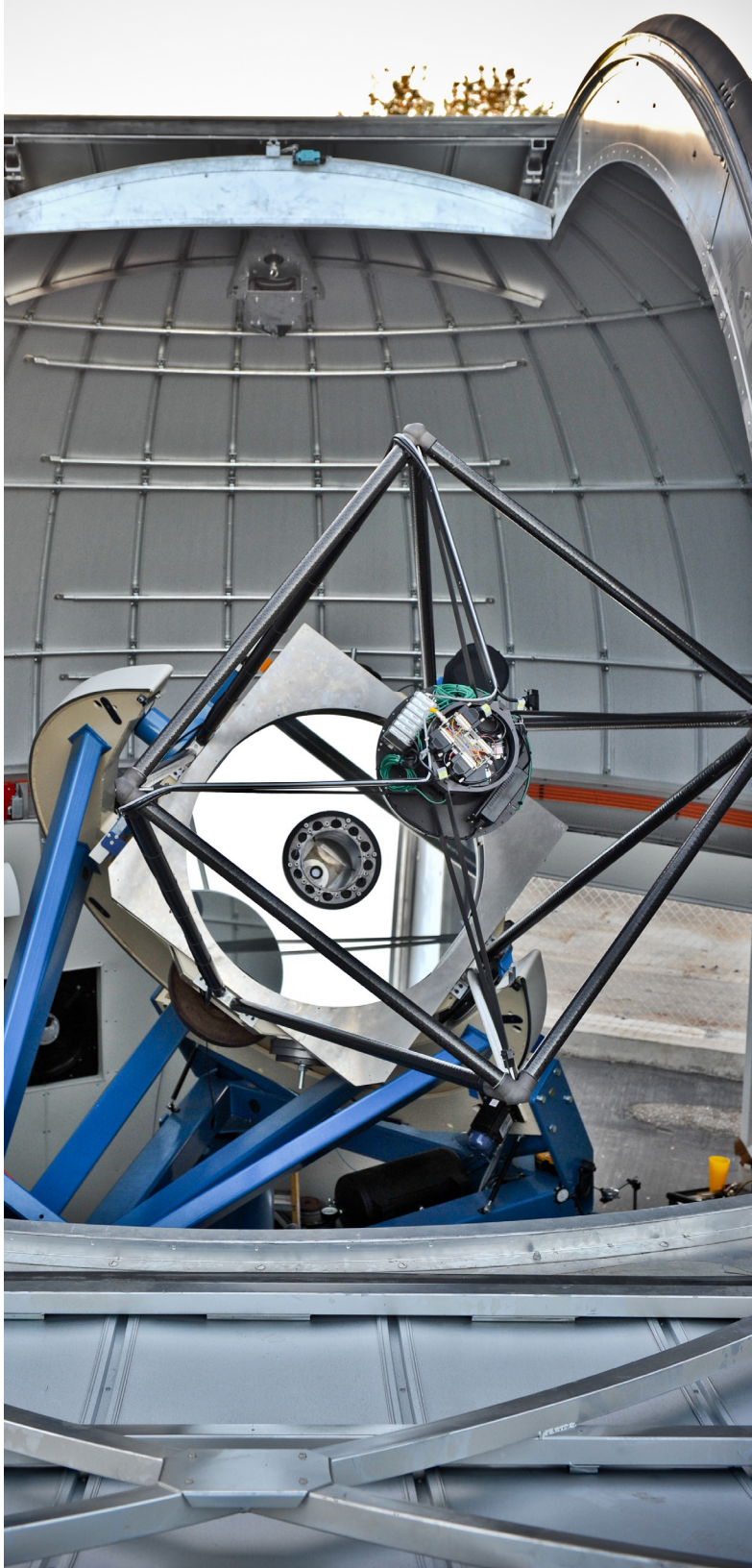
Las Cumbres Observatory LCO

Las Cumbres Observatory saw significant achievements during the year 2021 in all areas of our operation. With our small team, many still working remotely, we made great progress in hardware, science, outreach, 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



Two New Telescopes See First Light in Tenerife

We were thrilled to accomplish the installation and commissioning of two new 1-m telescopes at Teide Observatory in Tenerife.

The two new 1-meter telescopes on Tenerife are strategically important to the LCO network and provide several critical capabilities. The most significant impact is that they have greatly increased the ability to observe objects in the northern sky. These telescopes are a vital part of LCO's northern ring, which includes observatory sites in Hawai'i, Texas, and Israel. The LCO network provides 24-hour continuous monitoring in the northern skies and this essential feature enables unique data for scientific discoveries.

Astronomers around the world use the LCO telescope network for a variety of research projects and the new instruments at Teide are already making great contributions. The ASAS-SN program is using the telescopes for the follow-up observations of supernovae. Three Key Projects supported by LCO have made observations on the new 1-m instruments: the OMEGA project for microlensing events, the Global Supernova Exchange, and the follow-up of TESS exoplanet candidates.

The two new domes at Teide Observatory housing the LCO 1-m telescopes. Image Credit: LCO.

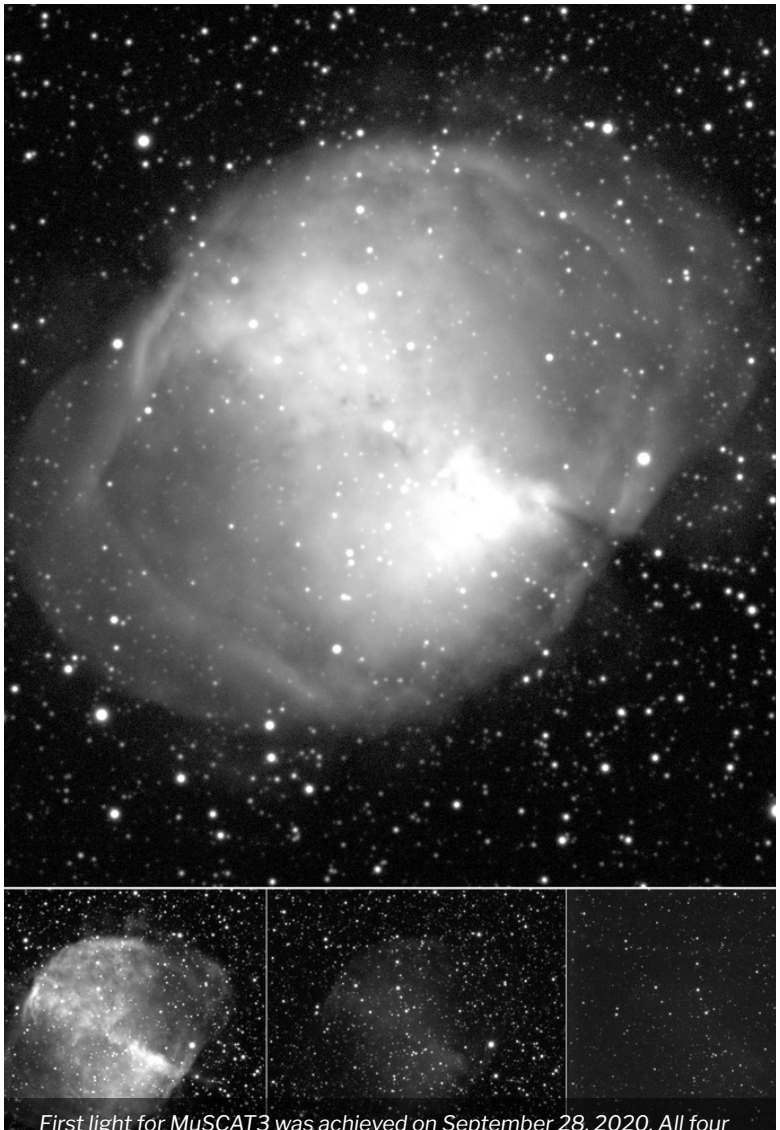
"The new telescopes have doubled our 1-meter imaging capacity in the northern hemisphere. It was very exciting to watch the schedule for these instruments fill up immediately when they went online ...The additional sky coverage and observing time available in the north could be particularly valuable in following rare multi-messenger sources."

- Dr. Lisa Storrie-Lombardi, President and Director of LCO

The two new 1-meter telescopes were funded by the **Gordon and Betty Moore Foundation**.

A Night View of the New 1m Telescope from its Dome at Teide Observatory. Image Credit: LCO.

Commissioning a New Instrument in Hawaii



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

Las Cumbres Observatory was pleased to announce that it has commissioned a new multichannel imager on the 2-m Faulkes Telescope North at Haleakala Observatory.

MuSCAT3 (**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. The new instrument is critical for use during exoplanet transits, when simultaneous observations in multiple passbands can reveal information about planetary atmospheres.

MuSCAT3 is the third instrument in a series of multi-channel imagers designed and constructed by the Astrobiology Center in Tokyo, Japan. MuSCAT instruments were already installed on the 1.9m telescope at Okayama Astrophysical Observatory and the 1.5m Carlos Sanchez Telescope at Teide Observatory in Tenerife. LCO entered discussions with the Astrobiology Center of Japan in the summer of 2019 to form a partnership regarding building multicolor imaging cameras for the network.

The new instrument was constructed and tested in Tokyo and arrived in Maui in September of 2020. First light was achieved on September 28, as shown in the image of M27, on the left. On November 4, LCO made MuSCAT3 available to the astrophysics community for science observations.

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

Las Cumbres Observatory is grateful to the Astrobiology Center of Japan for building this fine instrument. LCO also recognizes the efforts that enabled the instrument to be installed and commissioned during the pandemic. The science, engineering, and software teams of LCO and the Astrobiology Center came together via video conferencing to support the team of three people who performed the work on site. LCO is proud of the staff who enabled this instrument to serve the global community of astronomers.

Las Cumbres Observatory is working to secure funding for MuSCAT4, to be installed at the 2m telescope at Siding Spring Observatory in Australia.

Project Underway to Upgrade the 0.4-meter Education Network

Las Cumbres Observatory was pleased to announce that it received a three-year grant of $1.2m from the Gordon and Betty Moore Foundation that will support our award-winning education program and pay for an upgrade to the telescopes in our education network.

Ten 0.4-meter telescopes comprise the portion of LCO's global network dedicated to education and they are located in both the northern and southern hemisphere rings. Hardware upgrades to the ten 0.4m telescopes will provide an education-focused telescope network that will deliver high operational reliability and the highest image quality for the next decade.

Las Cumbres Observatory launched the award-winning Global Sky Partners education program in 2017 with the goal of inspiring students, teachers, and the public around the world to engage in astronomical and scientific endeavors. Global Sky Partners are a diverse group of educators and scientists who run their own fully-supported education projects and investigations using LCO telescopes. The LCO program provides over 1,250 hours of telescope time per year, mentoring and support tailored to each Partner, and a global forum for the Partners to learn from and support each other. Many student projects from the program are presented at astronomy conferences and published in scientific journals.

"We were drawn to LCO's dual goals of advancing science and science education through their global telescope network. Use of this global network as an educational resource enables LCO and the organizations with whom they collaborate through the Global Sky Partners program to provide youth, teachers, and the broader public with compelling science learning experiences, including exciting opportunities to engage in authentic astronomical research. We are excited to learn from LCO and their partners as they expand the depth and breadth of their programming."

- Dr. Janet Coffey
Program Director for Science Learning of the Moore Foundation

The new grant from the Moore Foundation will allow LCO to continue to support 30 Global Sky Partners per year and will also allow us to give multi-year status to the stronger Partner programs. With these funds, we will be able to increase outreach to Partners in our most underrepresented communities and in the developing world.

Undergraduate physics students from South Africa attending a workshop in South Africa using LCO data, hosted by Global Sky Partner AstroLab. Image credit: AstroLab

Grade 8 students from Roggeveld primary school in Sutherland, South Africa, using the LCO resource Agent Exoplanet as part of the outreach program from South Africa Astronomical Observatory. Image Credit: LCO.

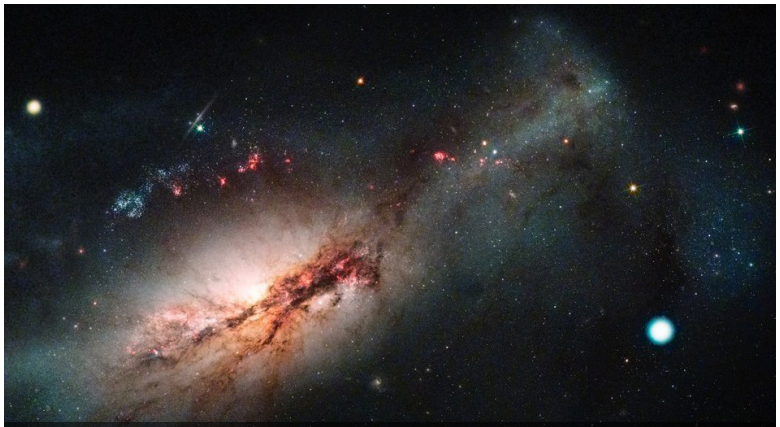
Science

Discovery of the Electron-Capture Supernova

A worldwide team led by scientists at Las Cumbres Observatory has discovered the first convincing evidence for a new type of stellar explosion -- an electron-capture supernova.

While electron-capture supernovae have been theorized for 40 years, real-world examples have been elusive. They are thought to arise from the explosions of massive super-asymptotic giant branch (SAGB) stars, for which there has also been scant evidence. The discovery also sheds new light on the thousand-year mystery of the supernova from A.D. 1054 that was seen all over the world in the daytime, before eventually becoming the Crab Nebula.

The new study, published in Nature Astronomy, is led by Daichi Hiramatsu, a graduate student at the University of California, Santa Barbara (UCSB), and Las Cumbres Observatory (LCO). Hiramatsu is a core member of the Global Supernova Project, a worldwide team of scientists using dozens of telescopes around and above the globe. The team found that the supernova SN 2018zd had many unusual characteristics, some of which were seen for the first time in a supernova.



Las Cumbres Observatory and Hubble Space Telescope color composite of the electron-capture supernova 2018zd and the host starburst galaxy NGC 2146. Credit: NASA/STScI/J. DePasquale; LCO

It helped that the supernova was relatively nearby — only 31 million light-years away — in the galaxy NGC 2146. This allowed the team to examine archival images taken prior to the explosion from the Hubble Space Telescope and to detect the likely progenitor star before it exploded. The observations were consistent with another recently identified SAGB star in the Milky Way, but inconsistent with models of red supergiants, the progenitors of normal iron core-collapse supernovae.

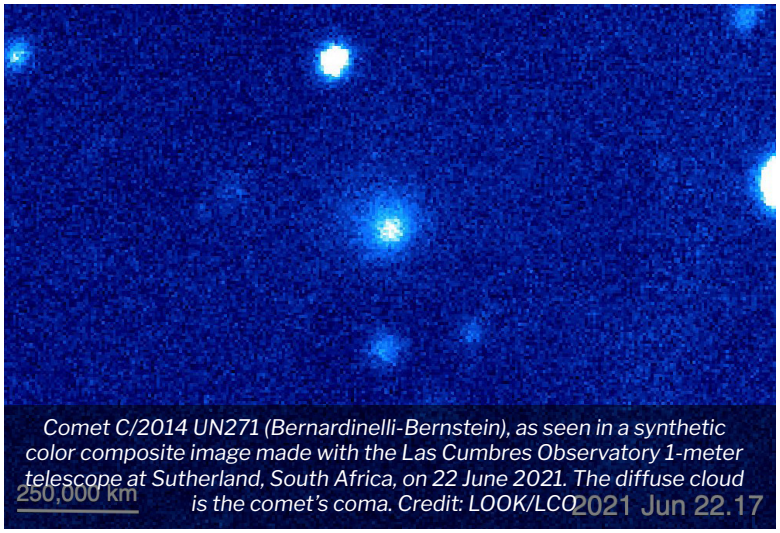
The study looked through all published data on supernovae, and found that while some had a few of the indicators predicted for electron-capture supernovae, only SN 2018zd had all six - an apparent SAGB progenitor, strong pre-supernova mass loss, an unusual stellar chemical composition, a weak explosion, little radioactivity, and a neutron-rich core.

"We started by asking 'what's this weirdo?' Then we examined every aspect of SN 2018zd and realized that all of them can be explained in the electron-capture scenario. It was such a 'Eureka moment' for all of us that we can contribute to closing the 40-year-old theoretical loop, and for me personally because my career in astronomy started when I looked at the stunning pictures of the Universe in the high school library, one of which was the iconic Crab Nebula taken by the Hubble Space Telescope."

- Daichi Hiramatsu
Graduate Student, UCSB and LCO

The new discoveries also illuminate some mysteries of the most famous supernova of the past. In A.D. 1054 a supernova happened in the Milky Way Galaxy, and according to Chinese and Japanese records, it was so bright that it could be seen in the daytime for 23 days, and at night for nearly two years. The resulting remnant, the Crab Nebula, has been studied in great detail. It was previously the best candidate for an electron-capture supernova, but this was uncertain partly because the explosion happened nearly a thousand years ago. The new result increases the confidence that the historic SN 1054 was an electron-capture supernova. It also explains why that supernova was relatively bright compared to the models: its luminosity was probably artificially enhanced by the supernova ejecta colliding with material cast off by the progenitor star as was seen in SN 2018zd.

LCO Discovers Activity on Largest Comet Ever Found



Comet C/2014 UN271 (Bernardinelli-Bernstein), as seen in a synthetic color composite image made with the Las Cumbres Observatory 1-meter telescope at Sutherland, South Africa, on 22 June 2021. The diffuse cloud is the comet's coma. Credit: LOOK/LCO

"Since the new object was far in the south and quite faint, we knew there wouldn't be many other telescopes that could observe it. Fortunately LCO has a network of robotic telescopes across the world, particularly in the Southern Hemisphere, and we were able to quickly get images from the LCO telescopes in South Africa. There are now a large number of surveys, such as the Zwicky Transient Facility and the upcoming Vera C. Rubin Observatory, that are monitoring parts of the sky every night. These surveys can provide alerts if one of the comets changes brightness suddenly and then we can trigger the robotic telescopes of LCO to get us more detailed data and a longer look at the changing comet while the survey moves onto other areas of the sky. The robotic telescopes and sophisticated software of LCO allow us to get images of a new event within 15 minutes of an alert. This lets us really study these outbursts as they evolve."

- Dr. Tim Lister
Senior Staff Scientist, LCO

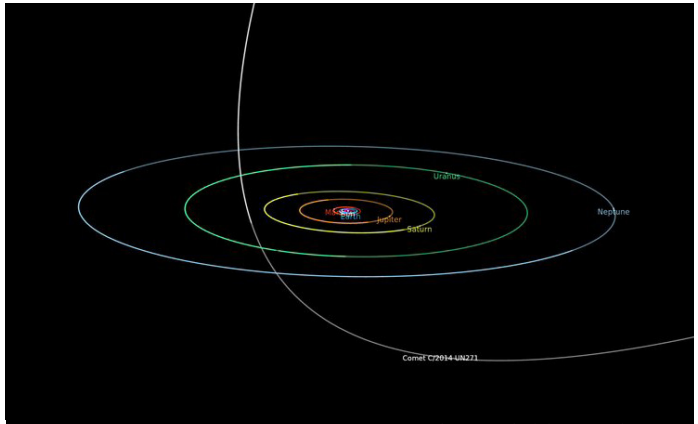
A newly discovered visitor to the outer edges of our Solar System has been shown to be the largest known comet ever, thanks to the rapid response telescopes of Las Cumbres Observatory.

The object, which is named Comet C/2014 UN271 Bernardinelli-Bernstein after its two discoverers, was first announced on Saturday, June 19th, 2021. C/2014 UN271 was found by reprocessing four years of data from the Dark Energy Survey, which was carried out using the 4-m Blanco telescope at Cerro Tololo Inter-American Observatory in Chile between 2013 and 2019. At the time of the announcement, there was no indication that this was an active world. Anticipation was immediately high among astronomers. C/2014 UN271 was inbound from the cold outer reaches of the Solar System, so rapid imaging was needed to find out: when would the big new-found world start to show a comet's tail?

Las Cumbres Observatory was quickly able to determine whether the object had become an active comet in the three years since it was first seen by the Dark Energy Survey.

The images from one of LCO's 1-meter telescopes hosted at the South African Astronomical Observatory, came in around 9pm PDT on Monday night June 22. Science team members in New Zealand were the first to spot the comet in the images.

The comet is estimated to be over 100km in diameter, which is more than three times the size of the next biggest comet nucleus we know, Comet Hale-Bopp, which was discovered in 1995. This comet is not expected to become naked-eye bright: it will remain a telescopic object because its closest distance to the Sun will still be beyond Saturn. Since Comet C/2014 UN271 was discovered so far out, astronomers will have over a decade to study it. It will reach its closest approach to the Sun in January of 2031.



An orbital diagram showing the path of Comet C/2014 UN271 (Bernardinelli-Bernstein) through the Solar System. The comets' path is shown in gray when it is below the plane of the planets and in bold white when it is above the plane. Credit: NASA

SCIENCE

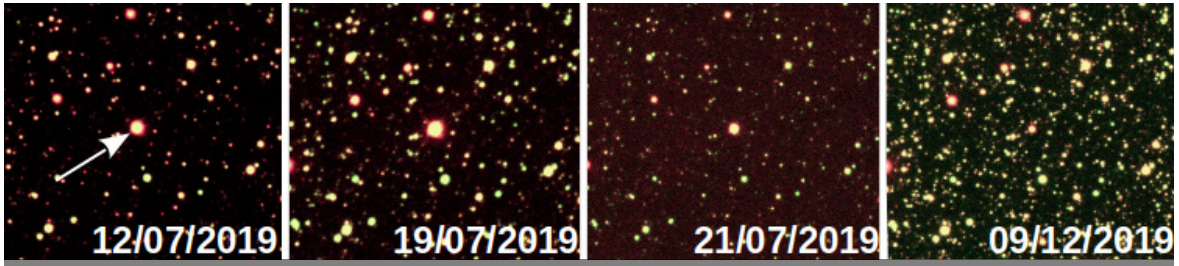
LCO Scientists Confirm the Discovery of the First Moving Microlensing Arcs

Observations performed by LCO instruments enabled the determination of the mass of the microlens object Gaia19bld to an unprecedented accuracy.

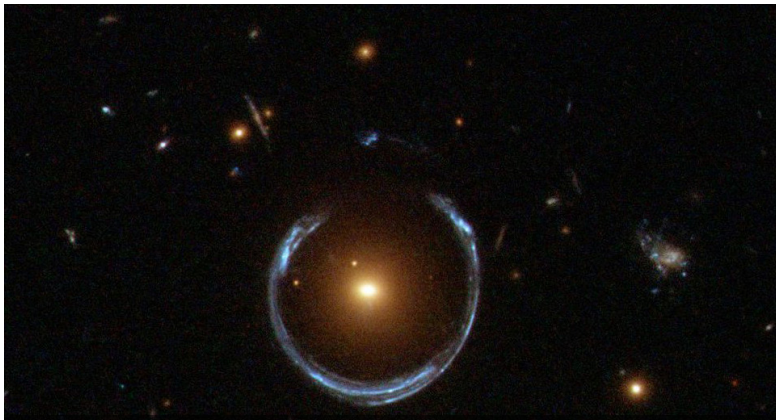
On April 18, 2019, the European Space Agency's Gaia Mission alerted astronomers worldwide to an unusually bright but fleeting celestial event: the gravitational microlensing event Gaia19bld. The temporary, chance alignment between two unrelated star systems produced twin images of the background star and gave scientists their first opportunity to actually observe the arc-shaped images move in real time, unlocking key information. Follow-up photometric and spectroscopic observations performed by LCO instruments gave the angular separation between the arcs.

In a recent paper published in Astronomy & Astrophysics, LCO postdoc Dr. Etienne Bachelet details the use of spectroscopic and imaging observations from LCO for the calculation of the mass and distance of the Gaia19bld lens. Both low- and high-resolution spectroscopy from multiple sites around the world were obtained during the event.

This work demonstrates the potential of the spectroscopic follow-up of microlensing events. It allows the precise characterization of the source star stellar parameters, which are critical to unlock the physical characteristics of the hidden lensing system.



These images are observations of the microlensing event Gaia19bld. The four images are color-composites made from the LCO data collected during the event. The white arrow indicates the position of Gaia19bld. The first three images were collected when the source was magnified, i.e. when the star looked artificially brighter. The last image was collected several months after the peak brightness of the event, when the source was no longer magnified. Image credit: LCO



An image of the Large Red Galaxy 3-757, an example of a galaxy's light that is distorted and magnified by gravitational lensing. The image shown above is an observation taken with the Hubble Space Telescope. Image credit: ESA/Hubble/NASA

"For the first time, we saw the motion of the two images created by the gravity field of the microlens! More importantly, these interferometric observations allow an independent estimation of the properties of the microlens, which was in perfect agreement with the measurements made with other telescopes."

- Dr. Etienne Bachelet
LCO Postdoctoral Fellow

Outreach

Major Grant will Fund Equity and Excellence in Science

The Heising-Simons Foundation is investing in the future of astronomy with a grant to LCO that will provide researchers around the world with the opportunity to kickstart scientific research programs in time for the opening of the Vera C. Rubin Observatory.

Twilight at Rubin Observatory, April, 2021. Cerro Pachón, Chile. Image Credit: Rubin Observatory / NSF / AURA

Under the title "Leveling the Playing Field", this project will enable all astronomers to explore the potential of Rubin Observatory for Galactic, stellar, and Solar System science, through the work of Science Collaborations that are dedicated to these topics.

The new Rubin Observatory Legacy Survey of Time and Space is planned to start nightly survey operations in 2024. The highly-anticipated groundbreaking survey will transform many areas of astrophysics by delivering high cadence, multi-color, optical lightcurves for a vastly larger population of objects than it has ever been possible to observe. The Observatory will survey the southern sky more efficiently than ever before, probing all types of time-domain phenomena, and it will take advantage of modern data processing capabilities to generate alerts of new discoveries in real-time. This revolutionary facility will open up new opportunities to study a wide variety of transient and variable astrophysical phenomena.

The scientific community is laying the groundwork necessary to fully exploit the survey datastream from Day 1. The community is organized through the Rubin LSST Science Collaborations, eight groups with international memberships specializing in distinct scientific subjects.

The Rubin LSST Science Collaboration Coordinator, Prof. Federica Bianco of the University of Delaware, recognized that there is a need for a significant, regular, funding stream to support the work necessary to prepare for the new survey data. "The Science Collaborations, that today include nearly 2,000 scientists across six continents, have worked alongside Rubin to prepare the scientific community to capitalize on the LSST data for years, working largely on a voluntary basis. This grant will help three of the Science Collaborations make the final steps toward survey start and be ready to enable the scientific discoveries that the Rubin LSST is capable of, and to include all scientists in this discovery process."

"This program gives us a much needed and timely opportunity to kickstart research programs, ready for the start of Rubin operations. I hope it will encourage researchers from a wide range of backgrounds to get involved, and I'm excited to see the science they will do!"

- Dr. Rachel Street
Senior Staff Scientist, LCO

Program Lead Dr. Rachel Street of Las Cumbres Observatory shares the leadership of this grant with Prof. Bianco and the chairs of the participating Science Collaborations.

This grant will ensure that all researchers have an equitable opportunity to participate in laying the groundwork for the age of the Rubin Observatory and will enable a broader community to more fully harness its enormous scientific potential. Preparatory research is especially critical for time-variable and moving object observations and thus the community must be ready before the survey starts. Through this program, the whole community will have the chance to kickstart research programs to maximize the scientific return of the Rubin Observatory.

Education

Global Sky Partners

Our award-winning program to support high quality education projects using LCO's unique telescope network, particularly amongst underserved communities, served over 66,000 people in 66 countries in 2021, 21% of which were from disadvantaged or underrepresented communities.

The primary aim of this 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 2021 we supported 29 Global Sky Partner projects which had an impact in 66 countries across the globe.

From Partners offering mentoring, workshops and training programs, with a total audience size of ~3900 individuals:

- **21%** of the audience were from disadvantaged or underrepresented communities or developing world countries with a further 31% being from mixed representation
- **14%** of the audience were mentored in publication quality research projects
- **68%** of the audience took part in workshops and teacher training
- **47%** of the audience were high-school students
- **41%** of the audience were teachers.

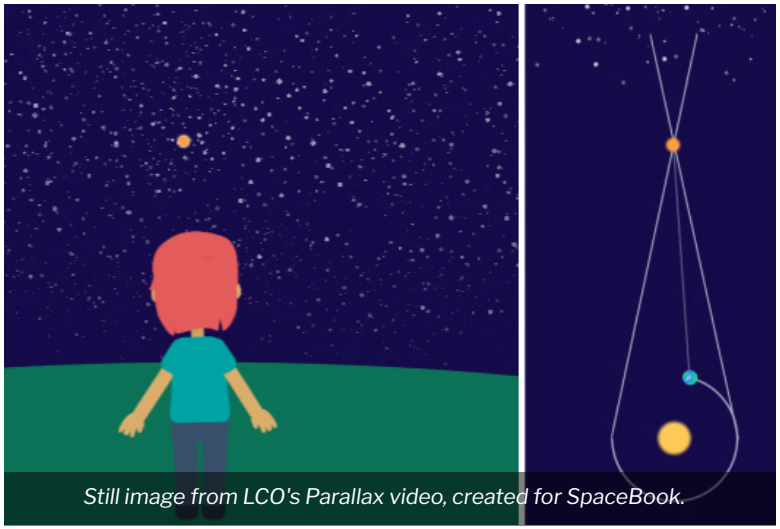
Students in these projects published 21 papers in peer reviewed journals, and presented 7 talks at professional astronomy conferences.

The programs these partners led directly served a total audience of over 24,000 individuals, which increases to over 66,000 individuals when you include students whose teachers were involved. The program used over 2000 hours of observing time on the LCO educational network of 0.4-meter telescopes. Despite the global pandemic the audience of the Global Sky Partner program is over twice the size, more diverse and has a larger geographic reach than in previous years.

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

High-school student, Beatrice Miller, from the Stanford Online High School Global Sky Partner. Beatrice is presenting her project on double star observations using LCO at a NASA conference for professional astronomers. Image Credit: Kalee Tock/LCO.

Educational Resources



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

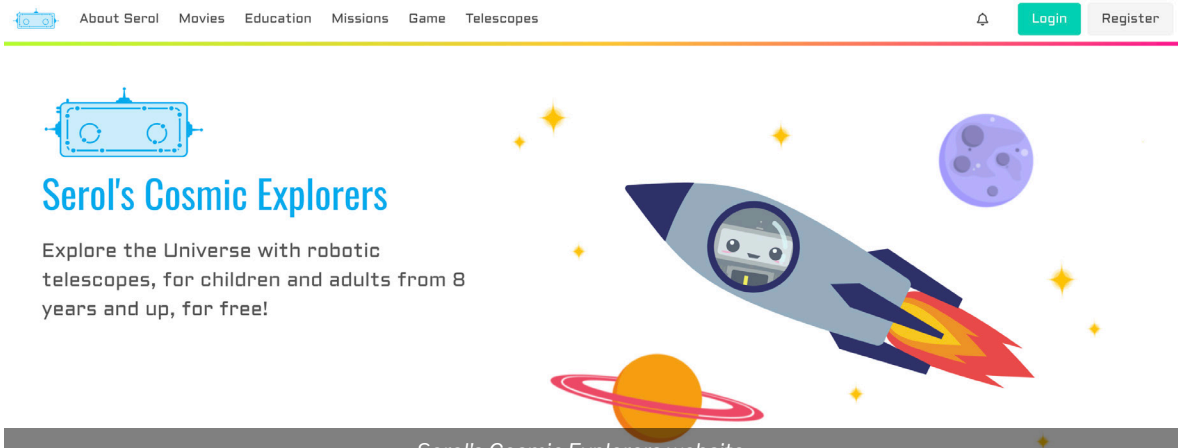
A major component of LCO's education program is the wealth of educational resources, developed in house and made available for free.

Our in-house education team produces and supports educational resources for the wider community. During 2021 we saw over 500,000 unique visitors to our open access astronomy textbook SpaceBook. We have added videos to some of the most popular pages to further engage with that audience. For example the Stellar Parallax page now includes a video which has been watched over 150,000 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. During 2021 we have been creating new translations of this comic book, which is now available in 13 languages, and is completely open access. So far over 15,000 copies of Ada's story have been delivered to 20 countries.

Ada's Adventures in Science comic book series in Simplified Chinese.



Serol's Cosmic Explorers website.

About LCO

Las Cumbres Observatory (LCO) is a nonprofit corporation based in Goleta, California, dedicated to advancing worldwide understanding of the Universe through science 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.