Astronomy at the Top of the World:
Educators experience why Chile is vital to astronomy

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Cerro Tololo sunrise. Photo by Jim O'Leary

Some of the ACEAP Team in front of the Blanco Telescope at Cerro Tololo (from left) Kadur Flores, Renae Kerrigan, Sarah Komperud, Michael Prokosch, Brian Koberlein, Shannon Schmoll, Jim O'Leary, and Charles Blue.

Those of us working in astronomy education know the great observatories of the world: Kitt Peak, Mauna Kea, and the mountains of Chile. And many of us have visited these remote locations to see the great instruments used to explore the universe.

Earlier this year, a new National Science Foundation-funded program brought nine U.S. astronomy educators to Chile to visit U.S.-supported observatories and to hear from Chilean-based astronomers and educators about their work. Known as the Astronomy in Chile Educator Ambassador Program (ACEAP), the initiative looks to spread the word about U.S. astronomy efforts in Chile and forge lasting links between the American and Chilean astronomy education communities.

Representing planetariums, schools, universities, and astronomy organizations, the nine of us visited the major NSF-supported observatories along the Chilean Andes: Cerro Tololo, Gemini South, the Southern Astrophysical Research Observatory, and the Atacama Large Millimeter Array.

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Other astronomy educators rounded out the group: Ryan Hannahoe (Monforton School, Montana), Brian Koberlein (Rochester Institute of Technology, New York), and Vivian White (Astronomical Society of the Pacific, California).

Why Chile?

Chile is one of the prime locations on the planet for astronomy research. The combination of climate, high mountains, dry air, clear skies, and stable government make it a mecca for ground-breaking research, new observing sites, and even a burgeoning astro-tourism business that brings thousands of visitors a year to this southern hemisphere nation.

Located along the western coast of South America, Chile is unique in shape. More than 2,600 miles north to south but only 215 miles at its widest east-west, it spans a wide variety of climates, landscapes, and ecosystems.

The regions that attract astronomical interest range from the area around La Serena in central Chile to the vast and arid Atacama Desert in the north. This is where the world's astronomy community has looked to build the largest and most innovative observatories.

Chile is home to more than 40% of the world's astronomy infrastructure, and by 2022 this number is expected to swell to 70%.

Chile experiences more than 300 clear nights a year on average, thanks to its geography. It's free from the atmospheric moisture surrounding it on both sides. The towering Andes Mountains to the east block moist Amazon air, and persistent high pressure over the Pacific Ocean and cold ocean currents prevent clouds and rain coming in from the west. The Andes are the world's longest continental mountain range, averaging about 13,000 feet in height, providing the ideal lofty setting for observatories.

The region from La Serena north leads into the harsh Atacama Desert, considered the driest non-polar desert in the world. Average rainfall across the Atacama is about 15 mm (0.6 in) per year, and some weather stations have never recorded rain. Records show that the Atacama may not have had any significant rainfall for 400 years prior to 1971. Dry air is ideal for astronomy research since water vapor in the atmosphere absorbs critical wavelengths of incoming light.

Away from major population centers, these sites offer the darkest skies possible. While population and development continue to grow and light domes are visible from some observatories, the government is working to reduce light pollution.

The Chilean government is another reason for the abundance of Chilean astronomy. Among the dozen countries on the continent, Chile is one of the most stable and prosperous nations and welcomes the international astronomical community.

Cerro Pachon

The first peak our ACEAP team visited was Cerro Pachon, home of Gemini South and the Southern Astrophysical Research Observatory (SOAR). It is also the future home of the Large Synoptic Survey Telescope (LSST).

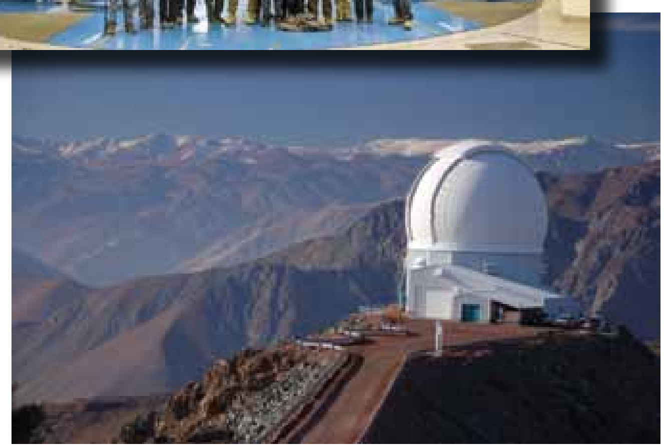
Gemini South

The only thing better than one great telescope is two, especially if the second one is located in the opposite hemisphere. This is the story of the Gemini twins, Gemini North on Mauna Kea in Hawaii and the twin we visited, Gemini South on Cerro Pachon. As we walked around the cavernous dome that houses the 8.1-meter telescope we were immediately impressed with the magnitude of the instrument and the cutting-edge technology it employs.

Huge segments of the dome's walls can open to help stabilize the inside of the dome with the outside air temperature. It uses the most advanced adaptive optics system of any telescope in the world. There are 120 hydraulic actuators changing the shape of the 20-cm-thick mirror to cancel out the effects of air turbulence. The adjustments to the mirror made by the actuators can be as fine as 1/1000th the thickness of a human hair, providing razor sharp images.

Three different camera systems are used, with the Gemini Multi-Object Spectrograph (GMOS) being the workhorse. The Gemini Planet Imager (GPI), an adaptive-optics imaging spectrometer, and FLAMINGOS-2, a wide-field imager and multi-object spectrometer, complete the instrument package.

Notice the word "spectrometer" in all of the cameras. This is because Gemini South sees the universe by looking at heat signatures in the near-infrared rather than visible light. The mirror has a coating of silver, which gives it a much better sensitivity to heat. There is more of this precious metal in two silver dollars than what is found on the Gemini mirror.



Top: The Gemini telescope with dome side ports open. Photo by Jim O'Leary. Center: The ACEAP ambassadors in front of the Gemini. Bottom: The SOAR Telescope as seen from Gemini on Cerro Pachon. Photo by Jim O'Leary.

The universe in these wavelengths allows us to see what is hiding behind those curtains of gas and dust in star-forming regions or permits us to reveal black holes at the centers of galaxies, but that is just the beginning. Observations with the Gemini telescopes can give us key insights into the history, structure, and evolution of the universe.

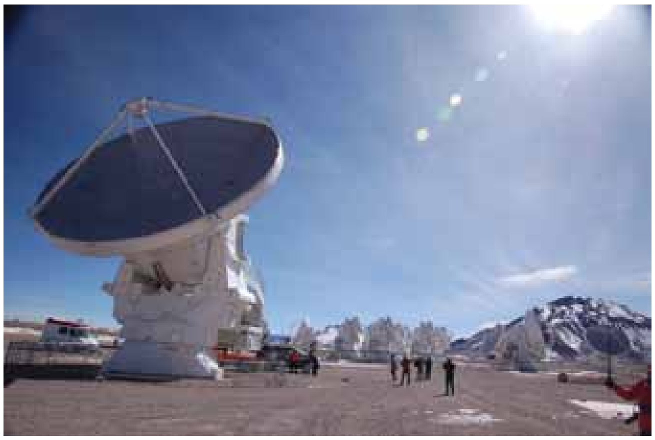
Interested in observing with Gemini? A successful online application for research is put into a scheduling queue. Your observing request is then programmed for time by the Gemini staff by matching conditions optimal for your research.

The days of having an astronomer travel to the facility with a set observing time only to discover that there is a problem with the weather or a camera are over at Gemini. The astronomer stays at home and collects the data when it is completed. This new philosophy of doing astronomy at a major observatory is now standard rather than the exception.

SOAR

Just a jaunt down the road from Gemini South is SOAR. At 4.1 meters it is half the diameter of Gemini South, but still impressive. This telescope is a collaboration of the National Optical Astronomy Observatory, Ministerio da Ciencia e Tecnologia of the Federal Republic of Brazil, the University of North Carolina at Chapel Hill (UNC), and Michigan State University (MSU).

SOAR can have up to nine instruments



Top: The Cerro Tololo "mushroom farm" at sunset. Bottom: The ALMA antennas. Photos by Jim O'Leary.

mounted at a time and observes in optical to infrared bands, requiring the high dry location of Cerro Pachon.

SOAR has public time, though astronomers from UNC, MSU, Chile, and Brazil do have guaranteed time on the telescope. The advantage of this is that astronomers from those locations are able to use their time on longer-term projects that require monitoring or scanning the sky.

For instance, Megan Donahue, a professor at MSU, and her student Tom Connor use SOAR to study the gas in the brightest galaxies in giant clusters. They are studying how active galaxies turn "on" and "off." Their time allows for many observations to show what is happening across multiple galactic clusters at different levels of activity.

Observers either travel to Cerro Pachon and work from the control room on site, or work remotely from several locations. These remote sites have identical set ups to the one in Cerro Pachon, but allow observers to skip the travel. That might seem baffling to those of us who want to visit these telescopes, but for those with guaranteed time, traveling monthly can get a bit tiring.

LSST

The Large Synoptic Survey Telescope (LSST) is the next major survey project by astronomers and will change the way we do science. It will have a 3.2-gigapixel camera that will take an image of the sky every 60 seconds while in operation. That equals nearly 15 to 18 terabytes of data each night. LSST will cover the entire visible sky from Cerro Pachon every three nights. All collected data will be freely available for anyone in the world to use.

Up until now, most astronomy has been driven by astronomers proposing observations they want to make to help answer a specific question. They collect the data they need to answer that question. In short, the question often precedes the data.

This is not so with LSST. The data will be collected, and it is up to astronomers to mine the data to find what is interesting. This requires new skills in computer science, physics, and mathematics to figure out how to meaningfully sift through so much information. LSST will not be fully operational until 2023, but current students are already starting to train and develop new skills and techniques required to deal with the science LSST will be bringing us.

Cerro Tololo

There is something indescribable about Cerro Tololo. It is a smell in the air—wind, dust, and the aroma of an herb that grows all over the mountain. It is the way telescope domes shine at the top of the mountain and the grasses seem to glow in the bright sunlight. It is the people who live and work on the mountain, and the foxes who gather around, hoping for a treat. It is the velvety dark night, the stars that glimmer brightly and the Milky Way leading you across the night sky. It is sunsets, scenery, and science. All of these things add up, until Cerro Tololo has imbedded itself in your heart.

A friendly fox at CTIO. Photo by Shannon Schmoll.

The ACEAP team spent two nights at the NSF-funded Cerro Tololo Inter-American Observatory (CTIO) campus, which houses many telescopes. There are so many domes clustered together on the hill that it is affectionately called the "mushroom farm." CTIO is part of the National Optical Astronomy Observatory (NOAO), and NOAO is managed by Association of Universities for Research in Astronomy (AURA).

Beginning in 1963, construction of CTIO was managed by AURA in partnership with the University of Chile. Work on the complex was completed in 1974 with the installation of the 4-meter Blanco Telescope.

Part of the charm of CTIO is the contrast between the vintage and modern. The furnishings and appliances are mostly original, but the equipment is about as high-tech as you can get.

The star of CTIO is the Victor M. Blanco 4-meter Telescope. This optical telescope has often been used for sky surveys, thanks to its wide field of view. In the mid 1990s, two teams of astronomers used the Blanco telescope to look for supernovae to try to prove that the expansion of the universe was decelerating.

However, both teams found that the data proved the opposite: the expansion of the universe was accelerating! In 2011, members of both teams received the Nobel Prize in Physics for the groundbreaking discovery.

The Blanco currently is outfitted with the Dark Energy Camera (DECam), a high-performance, wide-field CCD imager that photographs a large portions of the sky with a single image. This high-resolution survey allows astronomers to identify supernovae, weak gravitational lensing, galaxy clusters, and other evidence to probe dark energy.

While the study of the large-scale structure of the universe is the primary mission of the DECam, the images it takes are such high resolution that astronomers will be able to use the data it gathers for many other projects.

The ACEAP team had the privilege of being inside the Blanco's dome while it was observing, and hearing about the project from Dr. Chris Smith, astronomer and AURA head of mission in Chile and a member of one of the teams that discovered the expansion of the universe was accelerating.

The Blanco is in good company. There are about 13 telescopes on the top of the mountain. Astronomers and students from all over the world operate many of the scopes remotely. It was thrilling and slightly spooky to be out at night observing, and suddenly have a dome start rotating; you knew science was happening at that very moment!

ALMA

All along our journey we were allowed unbelievable and unparalleled access to the observatories and the people behind them. But nothing toped the access we were granted at

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the Atacama Large Millimeter Array (ALMA).

After a few days of acclimating to sites at approximately 8,000 feet, ALMA's Operation Support Facility tour, at 10,000 feet, felt easy. But the test was the high site. In order to be allowed to visit the high site at 16,404 feet, we had to pass a basic physical.

Although blood oxygen levels aren't something we typically worry about in our day-to-day lives, we do pay attention at 16,000 feet, where blood oxygen levels drop fast while blood pressure rises.

Those of us used to moving fast found that our bodies and brains didn't quite work the way we were used to. Asking questions and taking notes while on a tour of the second fastest supercomputer in the world, the ALMA Correlator, was like dredging through the shallows on a beach: able to be done, but slow work.

All that effort paid off once we got outside and were able to walk around the antennas. Scattered amongst the 12-meter antennas, the 7-meter antennas form a compact array. The limited snow sublimates at this altitude, and the reddish mountains make the scenery look like what you'd picture on the planet Mars. The sheer wow factor can't even be described.

Star Trails taken at CTIO with the Victor M. Blanco Telescope in the foreground. Photo by Peter Detterline

The antennas can be transported around the plateau with giant vehicles named Otto and Lore to change resolution for various research projects. At a maximum baseline of 16 kilometers, this gives ALMA the same resolution as the Hubble Space Telescope when all 66 antennas are working together as a single telescope.

This is easier said than done, since there are three different designs to the antennas, themselves each from partner country.

That's where the supercomputing correlator comes in, with its 32,768 chips performing 17,000,000,000,000,000 operations every second, equivalent to three million laptops. This combines the pairs of signals into data that can be used to study the universe in a whole new way.

The process of observing at ALMA is somewhat similar to that at an optical observatory. You fill out an online application and it goes through a peer review and selection process. If accepted, then a member of the software team writes a script for telescopes to collect your data based on the antenna configuration you need.

The software team oversees the observing run, making certain that everything goes according to plan. The astronomer can be present at ALMA during the observing run or can collect the data remotely.

Resource	Link
ALMA	
ALMA	www.almaobservatory.org
NRAO ALMA	public.nrao.edu/telescopes/alma
CTIO	
CTIO web site	www.ctio.noao.edu
Blanco Webcams	www.ctio.noao.edu/noao/content/ctio-external-webcam
Dark Energy Survey, Dark Energy Camera (DECam)	www.darkenergysurvey.org darkenergydetectives.org
National Optical Astronomy Observatory	www.noao.edu
Gemini	
Gemini Observatory	www.gemini.edu
SOAR	
SOAR Outside Webcam	www.ctio.noao.edu/soar/content/cerro-pachon-soar-outside-webcam
LSST	
LSST Public	www.lsst.org/lsst/public
LSST Education and Public Outreach Plans	www.lsst.org/lsst/public/outreach
LSST Construction Site Webcam	www.lsst.org/lsst/gallery/construction-webcam
Other	
ACEAP	public.nrao.edu/look-deeper/aceap/about-aceap
ACEAP Facebook page (links to all of our blog posts, news articles, etc)	www.facebook.com/AstronomyAmbassadorsProgram
Associated Universities, Inc.	www.aui.edu
AURA	www.aura-astronomy.org

Due to its sensitivity, ALMA can image galaxies in minutes, rather than hours. ALMA's targets include studies in astrochemistry, with astronomers looking for carbon and carbon monoxide in Milky Way-type galaxies. They can also do cosmological studies to calculate the high redshift of galaxies or observe galaxies being formed in the early universe.

ALMA does a lot in helping our understanding of star formation and viewing protoplanetary disks around newly-forming stars. A good example is HL TAU, a young star in the throes of planet building. In the image, we see these future worlds sweep out their orbits leaving dark lanes behind. This is the highest resolution image ever taken of a planet forming disk, and images like this show that ALMA is truly a revolution in astronomy. It is the case study model of where science is going.

Futures

So, where do we go from here? As fellow ACEPA ambassador Dr. Brian Koberlein put it, when we first met we were strangers, but now we are a family. We would like to see that family grow and prosper, but how?

First, we plan to get the word out and share it with others. ACEAP team members belong to GLPA, SEPA, MAPS, and IPS, and we will be presenting at upcoming conferences.

We also plan to create a planetarium show documenting our experience. We will use the hundreds of photos taken by all the members of the ACEAP family. This includes photospheres and ones taken with a macro fisheye lens to give images a natural curve. These images will also be made freely available for planetarians to use.

One of the many take aways for us from this trip was learning about the vast content available from the observatories we visited. For instance, ESO hosts a large library of full-dome images and video sequences on their website, including footage shot on location at La Silla, Paranal, and ALMA as well as some

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full-length planetarium shows. For a listing of where you can find educational content from these observatories see the table on page 32.

We encourage our fellow planetarians to teach about the southern skies as well to help spread the word about why observatories in places like Chile are so important. In our northern planetariums we celebrate the wonders of the night sky so that we can excite the imaginations of our audiences. Our hope is that they will look skyward with a new sense of curiosity, and the ability to locate some things on their own.

We can do more. We can take our planetarium audiences on a journey south to show them how astronomy is done at major observatories, and how the southern sky offers them a new perspective.

Imagine, as the dome view dips south, the audience watches as Polaris and the big bipper disappear from view. They notice how Orion rises feet first in the sky, beginning his journey across the heavens upside down.

The closest star system, Alpha Centauri, shines brilliantly in a dark patch of the Milky Way, with the familiar cruz del sur, the southern cross, right next door. The southern cross is the pathway to find the south celestial pole, conspicuously absent of an easily-visible star.

Instead of Sagittarius hugging the horizon, here it approaches the zenith to showcase the vast expanse of the Milky Way. Imagine the bulge of our galaxy overhead with arms extending outward from both sides. The Large and Small Magellanic Clouds make a ghostly glow in the south, and the Andromeda Galaxy is faintly visible toward the north.

We slowly bring the planetarium audience back from their vacation in the south, and the stars once again become the same familiar patterns that shine down on their homes. They are left with a better appreciation of our place in space, and the sense of a much bigger universe to explore.

The southern skies offer many celestial wonders for planetarium educators and our audiences, and the next year of ACEAP is just around the corner. Perhaps you can make the journey too.

The application window will open sometime in late November or early December, 2015, and close in late January, 2016. Interested applicants must be U.S. citizens or permanent residents who are amateur astronomers, kindergarten through college formal or informal educators who teach astronomy as part of their curriculum or program, or planetarium educators. Information about the application process can be found at public.nrao.edu/lookdeeper/aceap/about-aceap. ☆

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