U.S. Engagement in Chile: The Development of Chilean Astronomy

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ESO's La Silla Observatory, Atacama Desert, Chile/ European Southern Observatory/ Flickr/ Creative Commons License

By the end of this decade, over 70 percent of the world's astronomical viewing capacity will be concentrated in Chile; the country has indisputably become the "eyes of the world" in space, as expressed by Chilean President Sebastián Piñera (*Política Nacional Espacial 2014-2020*). Chile has emerged as the world's leading astronomical hub in large part because of a unique combination of geography, atmospheric conditions, and internal political factors. In particular, the deserts in the north of Chile offer exceptionally clear and dry skies at elevation, combined with low light pollution, allowing for pristine viewing some 330 days out of the year. In conjunction with the stability of Chile's economic and political environment and supportive tax and diplomatic policies for researchers, these factors have turned Chile into the leading destination for international astronomers (García-Huidobro, 2017).

The U.S. has played a vital role in the transformation of Chile into an astronomical hub: non-indigenous astronomy in Chile began in 1847 with the arrival of a scientific expedition of the U.S. Navy. The Chilean government bought the equipment from this expedition in order to found the National Astronomical Observatory in 1852, one of the first in Latin America. In the late 1950s, University of Chile Professor Federico Rutllant visited the U.S. to raise interest in building telescopes in Chile; in the 1960s, the Association of Universities for Research in Astronomy (AURA)[1] and the Carnegie Institute, along with the European Southern Observatory (ESO) purchased land to establish the first high-tech observatories in Chile (Barandiaran, 2015). The telescopes built during this period – the Las Campanas Observatory, run by the Carnegie

[1] AURA is a consortium of universities founded in the U.S. with support from the NSF. Today, the organization has 47 member institutions from the United States, as well as 3 international affiliate members, and operates in partnership with the NSF and NASA.

Institution, and the Observatory of Cerro Tololo, managed by AURA with support from the National Science Foundation (NSF) and the National Optical Astronomy Observatory (NOAO), among others – continue to provide significant research value, reflected by investments in each project totaling well into the hundreds of millions of dollars.

The success of these projects paved the way for a rapid expansion of international astronomy projects in Chile, with the active involvement of the U.S. government, academic institutions, and civil society. A brief review of large-scale observatory projects either led or supported by American investment illustrates the scope of U.S. involvement. The Gemini South Observatory, paired with its twin in Hawaii, provide almost complete coverage of the skies of the northern and southern hemispheres; the NSF is the largest funder and the controlling member; the remaining budget is split among the United Kingdom, Canada, Australia, Brazil, Argentina, and Chile. ALMA, the Atacama Large Millimeter/submillimeter Array, is managed by the U.S. National Radio Astronomy Observatory (NRAO), with European and Japanese partners, with an anticipated total investment of around $1 billion. The Vera C. Rubin Observatory (previously known as the Large Synoptic Survey Telescope, LSST), set to complete in 2023, will provide the deepest and widest available images of the universe. The project is managed by AURA with funding from NSF, the U.S. Department of Energy, and private funders, with a current total investment of around $450 million. Other projects with significant U.S. involvement include the Cornell Caltech Atacama Telescope, later renamed the Cerro Chajnantor Atacama Telescope, (CCAT), a large-scale submillimeter radio telescope, the Atacama Cosmology Telescope, which involves several U.S. universities, and the SOAR (Southern Astrophysical Research) Observatory, managed by AURA.

The push to expand Chile's astronomy infrastructure led by the U.S. along with other international counterparts, has had a significant impact both for the expansion of Chilean 'pure' sciences as well as for related industries, which have benefitted from the economic opportunities generated by massive international investments. By rule, Chilean researchers are guaranteed 10 percent of the observation time on all international telescopes established in Chile, a policy that AURA had voluntarily implemented since it began operations in Chile.[2] In addition to time allocations, the U.S. government has also directly supported Chilean astronomers as part of the agreement to establish the Gemini South observatory, which included a contribution of $9.3 million to CONICYT, the Chilean science agency. Furthermore, AURA funding contributes to an annual scientific scholarship fund that originated from the Gemini agreement, managed by the Agencia Nacional de Investigación y Desarrollo de Chile (AINID).[3] The U.S. Embassy and the NSF also support the Chile-US Astronomy Education and Outreach Summit, designed to promote collaboration and exchange on outreach work to young people in Chile (*Chile-US Astronomy Education and Outreach Summit*).

In addition to support from the U.S. government, interconnections with the American academy have played a vital role in building up the capacity of Chilean astronomy. AURA in particular has done significant work historically in building the partnership between U.S. and Chilean researchers. Following its decision to establish an observatory in Chile in the 1960s, AURA

[2] Hernan Bustos Binvignat, Personal Communication, 8/30/2021.

[3] Hernan Bustos Binvignat, Personal Communication, 8/30/2021.

brought in the University of Chile as a member of the organization and created opportunities for Chileans in the administrative and scientific operations of the organization, and intentionally sought to develop strong local ties with a public outreach office, the first of its kind from an observatory in Chile (Barandiaran, 2015). The academies of both countries continue to maintain deep ties. The University of Chile has established agreements with a host of American universities, including Yale, Princeton, MIT and Cornell, among others. The Universidad de Concepción has exchange programs with the University of New Mexico, Caltech and Cincinnati. Beyond student exchanges, these partnerships allow for exchanges of information, collaborative research, and the joint development of specific parts for observatories (Kobayashi, 2016).

Currently, a wide range of university laboratories work in direct partnership with U.S.-supported observatories, creating opportunities for joint work and technical exchange. The Millimeter Wave Laboratory of the University of Chile works in association with CalTech to develop advanced millimeter wave receivers and other high-tech equipment for the ALMA observatory. The Computer Systems Research Group at the Universidad Técnica Federico Santa María developed ALMA's common software framework. With the support of the NSF, the Radio astronomy Laboratory collaborates with MIT to develop ALMA's VLBI (Very Long Baseline Interferometry) processing, a technique that integrates data from multiple radio telescopes into a single observation. The Astro-engineering Center at the Pontificia Universidad Católica works with the Gemini Observatory to develop their adaptive optics and vibration mitigation instruments, in partnership with Harvard and other American universities (Addere Consultores, 2012).

The diverse range of support and opportunities for research and partnerships stemming from U.S. investments in astronomy in Chile have played a key role in the rapid expansion of Chilean astronomy capabilities. Within a decade following the shift to allocate 10 percent viewing time to Chilean researchers, four new astronomy departments opened, with funding from AURA, among other partners; PhD students increased from 5 in the early 1990s to 40 by 2005 (Barandiaran, 2015). Chile currently holds 8 universities with astronomy departments and ranks 11th globally in astronomy journal citations (*Política Nacional Espacial 2014-2020*, 2014). Nevertheless, there is still room for growth: Chilean scientists demand more access to observation time, in line with what host nations in Hawaii and Spain receive; and argue that there is still too much dependence on technologies and expertise from the North, which largely controls the research agenda (Leighton, 2014).

Beyond the opportunities it presents for Chilean researchers, U.S. involvement in astronomy in Chile has also meant the arrival of multi-billion-dollar investments, presenting important economic opportunities for a diverse range of Chilean businesses. The Chilean government estimates that about 10-20 percent of these investments enter into the Chilean economy, the majority of which are fixed-location goods and services: construction of roads, buildings, electricity, water and gas supply, hospitality, etc. (*Política Nacional Espacial 2014-2020*, 2014). The Gemini observatory provides employment to 80 Chileans; the Rubin Observatory estimates that for the construction of their Giant Magellan Telescope, $200-300 million will go towards Chilean construction and civil engineering companies, with down-the-line opportunities for advanced engineering projects for Chilean companies, as well as around 120 jobs in construction, logistics, maintenance, and other services (Arenas & Mieres, 2018).

However, the benefits to Chilean businesses are not limited to solely providing relatively unspecialized services. The Chilean government estimates that there are at least 15 Chilean companies that have provided advanced engineering and technology services to the observatories. AXYS Technologies, a Chilean company, provides a wide range of engineering services to the ALMA observatory; the fiber optics installation work they did for the observatory was groundbreaking in understanding how fiber optics operate at altitude. ARCADIS, a Dutch engineering company with Chilean subdivisions, has conducted a range of geological studies and construction consulting for the Rubin Observatory and for AURA's observatory in Cerro Tolar (Addere Consultores, 2012). AURA describes a "permanent interest" in building relationships with high-tech Chilean industry, and cites a history of working with Chilean companies and universities on fiber optics, cloud computing, machine learning and data management.[4]

The Chilean government sees this domestic involvement with international astronomy projects as the starting point for a significant long-term driver of Chile's economic growth. Ambassador García-Huidobro, director of the Technology & Innovation Division in Chile's Ministry of Foreign Affairs, calls the expansion of the professional scientific and engineering community as a "sine qua non for jump-starting development" (García-Huidobro, 2017). Likewise, the Ministry of Economy has created a liaison officer position to connect observatories with domestic industry and research centers, using the sector as a trigger for innovation and growth. One example of these potential spillover effects is the data science sector: the observatories require huge data processing and storage capacities; the experience generated in these spaces has the potential to position Chile as a player in big data management. To that end, Microsoft, Google, and Amazon are developing astro-data projects in Chile; furthermore, the NSF is funding a Data Science summer school at La Serena university to build connections with the future generation of Chilean data scientists (Arenas & Mieres, 2018).

[4] Hernan Bustos Binvignat, Personal Communication, 8/30/2021.

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Assessing the Cumulative Effects of U.S. Engagement in Uruguay and Chile

This research has been funded through a cooperative agreement between the Institute for War & Peace Reporting and the U.S. Department of State.

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