ASTRONOMY IN ARGENTINA

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Abstract. This article analyses the current state of Astronomy in Argentina and describes its origins. We1 briefly describe the institutions where astronomical research takes place, the observational facilities available, the training of staff and professionals, and the role of the institutions in scientific promotion. We also discuss the outreach of Astronomy towards the general public, as well as amateur activities. The article ends with an analysis of the future prospects of astronomy in Argentina2.

1. Introduction

Argentina has an important scientific tradition, in which astronomy has been one of the pioneering areas. There are interesting documents recording astronomical observations carried out at the beginning of the 18th century, but systematic studies of astronomy in Argentina began with the creation of the Observatorio Nacional Argentino (ONA, National Argentine Observatory, today the Observatorio Astronómico de Córdoba, see Fig. 1) in Córdoba on 14 Oct 1871. The President, Domingo Faustino Sarmiento, entrusted the study of the southern skies to the renowned US astronomer Benjamin Gould (who was the founder, among other projects, of The Astronomical Journal). With ONA’s foundation, Sarmiento’s intention was

1Hernán Muriel was President of the Argentinian Astronomical Society for the period 2008-2011.
2Although we have tried to be as objective as possible, some statements inevitably contain some personal views.
to send a clear message to the country and to the world, as he declared on the occasion of the inauguration of the new observatory: “We should renounce our standing as a Nation, or our title as a civilized people, if we do not take our part in the progress and development of natural sciences”. Some historians assign such importance to ONA’s creation, and particularly to Benjamin Gould’s presence, that they consider that moment as the introduction of modern science in Argentina.

The second milestone in the history of astronomy in Argentina was the creation of the Astronomical Observatory of La Plata in 1883 (see Fig. 2). This institution was the cradle of the first school of astronomy, founded in 1935, where the first Argentinian astronomers were formed, including local pioneer astronomers such as Jorge Sahade, José Luis Sérsic and Carlos Cesco.

In spite of these strong beginnings, the growth of science in Argentina has not been easy, as it has been always complicated by the to-and-fros of the country’s politics, with periods of great impetus mixed with other, very dark times, which resulted in a significant exodus of Argentinian scientists, who found positions in research centres all over the world. Amid this constant flux, one undeniably positive fact has been the creation of the
Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET\(^3\), National Council for Scientific and Technical Investigation) in 1958; nowadays, together with the universities, CONICET provides essential support to the development of science and particularly to astronomy in this country. Currently, one hundred and forty years after ONA’s foundation, there are a variety of Argentine astronomical institutions, where about two hundred researchers work on a wide range of topics.

2. Astronomical Institutions in Argentina

There are approximately a dozen institutions where astronomical research is taking place in Argentina. In spite of having started with a defined research profile in one specific area, most of these nowadays have scientists doing research in a great diversity of topics (see Tables 1a and 1b), including the most conventional fields along with novel ones.

Since the second half of the last century, a series of research institutes depending from CONICET have been created, some of which function within the observatories, and in most cases depend on the universities as well. From a geographical point of view, the vast majority of astronomical research in Argentina is centred in three provinces: Buenos Aires, Córdoba and San Juan, located in the east-centre, centre and west-centre of the

\(^3\)http://www.conicet.gov.ar/
Table 1. Principal research areas per institution.

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<th>FCAGLP &amp; IALP</th>
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<td>Interstellar Medium and Galactic Structure</td>
<td>Astronomy, Instrumentation and observational techniques</td>
<td>Planetary Systems</td>
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<td>Dynamics of Stellar Systems</td>
<td>Stellar Astrophysics: Stellar Systems, Stellar Atmospheres, Stellar Formation, Stellar variables and binaries</td>
<td>Galactic Structure</td>
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<td>Astrophysics of Open Clusters</td>
<td>Interstellar medium and Galactic Structure</td>
<td>Astronomical Reference Systems</td>
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<td>Stellar Astrophysics: Stellar Evolution; massive stars; Peculiar Stars; Binaries and Symbiotic Systems</td>
<td>Extragalactic and Cosmological Astronomy: Systems of Galaxies, Active Nucleus, Large-Scale Structure of the Universe, Galaxies</td>
<td>Solar Physics</td>
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<td>Cosmology</td>
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<th>IAPE</th>
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<td>High energy astrophysics</td>
<td>High energy astrophysics and compact objects</td>
<td>Galaxies</td>
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<td>Astrophysics of the interplanetary medium</td>
<td>Clusters of galaxies and active galactic nuclei</td>
<td>Solar Physics</td>
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<td>Stellar Astrophysics</td>
<td>Circumstellar Disk</td>
<td>Stellar Astrophysics, theoretical and observational</td>
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<td>Numerical Astrophysics</td>
<td>Interstellar medium and Early Stars</td>
<td>Cosmochemistry</td>
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<td>Planetary Science</td>
<td>Large radioastronomical database</td>
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<tr>
<td>Planetary and Stellar physics</td>
<td>Planetary Systems</td>
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<td>Solar Physics and Astrophysical Plasma</td>
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<td>Supernova Remnants and interstellar medium</td>
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<td>Quantum, Relativity and Gravitation</td>
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country, respectively (see Fig. 3); however, in the future, more groups may well consolidate in other regions where incipient activity is occurring.

The following is a summary of institutions whose main activity is astronomical research:
Figure 3. A map of Argentina showing the location of observatories (in red), institutes of CONICET where the main activity is astronomy (in green), institutes of CONICET where astronomy is a secondary activity (in light blue), astronomical facilities in the mountains (in yellow), planetariums (in black), characterized sites for astronomical facilities (in orange), and Universities where Astronomy or related sciences are taught (in brown). (graphics by Victor Renzi)
As mentioned, astronomy in Argentina began with the creation of the National Argentine Observatory (Observatorio Nacional Argentino) in 1871. After going through several changes in its institutional status, it finally became part of the National University of Córdoba (UNC), the oldest university in the country (almost four hundred years old), and its second largest.

The scientific profile of the institution was defined by the celebrated Benjamin Gould, who initiated various astronomical projects, among which the *Uranometry of Córdoba* was a pioneer work, cataloguing the position and brightness of all stars visible to the naked eye from Córdoba. The star survey *Córdoba Durchmusterung* was by no doubt one of the greatest astronomical achievements in Córdoba during the nineteenth century. Argentina later also participated in the international *Carte du Ciel* project at the beginning of the 20th century.

Astrophysics arrived at the NAO with its director, Charles Perrine, who also proposed and initiated the foundations for the construction of a big reflector telescope. The project was completed with the help of Enrique Gaviola, and inaugurated, in 1942, in the Astrophysical Station of Bosque Alegre, 40km from the city of Córdoba. This 1.54m reflecting telescope enabled Córdoba Observatory to position itself as a pioneer in astrophysical studies in the southern hemisphere, and to give a strong impulse to extragalactic astronomy, led by José Luis Sérisc, who later published the renowned *Atlas of Southern Galaxies* in 1968. In 1956, Gaviola initiated the foundation of the Institute of Mathematics, Astronomy and Physics within Córdoba National University, which in 1983 would become the Faculty of Mathematics, Astronomy and Physics (FaMAF), in which a considerable number of astronomers have been formed.

The Astronomical Observatory of the UNC is today one of the most important astronomical centres in the country, with approximately sixty professors, who carry out research in varied areas of Astronomy. They are also responsible for the teaching and training of graduate and postgraduate astronomy students studying at the FaMAF.

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4Astronomical Observatory of the National University of Córdoba (http://www.oac.uncor.edu/).
5Institute for Theoretical and Experimental Astronomy (http://www.iate.oac.uncor.edu/).
6Published by the Astronomical Observatory of the UNC.
7http://www.famaf.unc.edu.ar/
Within the OAC, and under the auspices of the UNC and CONICET, the Institute of Theoretical and Experimental Astronomy (IATE) was created, as a continuation of the Extra-Galactic Studies group founded by Sérsic more than three decades earlier. In spite of having started merely as an extra-galactic research project, other areas have been incorporated since then, such as solar physics, extra-solar planets and the search for new astronomical sites. The IATE nowadays has more than thirty post-graduate researchers, many of whom are also professors in the OAC.

Observatorio Astronómico de La Plata (OALP)
Instituto de Astrofísica de La Plata (IALP)

The creation of the Astronomical Observatory of La Plata was related to Argentina’s participation in the transit of Venus observations in 1882, together with the need to endow the new city with public buildings. Among the aims of founding the OALP was the realisation of mapping studies, for which reason its first activities were basically of services. As from the thirties, systematic astronomical observations have been made of occultations, eclipses, asteroids and comets.

It is important to note that the Observatory is older than the University of La Plata (UNLP), which, founded in 1905, is nowadays one of the most important in the country. The insertion of the OALP into the UNLP, together with Félix Aguilar’s special interest, led to the creation of the first School of Astronomy in the country in 1935, which was to have a strong impact on the future of astronomy in Argentina. With its first graduates, some of whom had completed further studies abroad, and the presence of Livio Gratton, the Observatory of La Plata initiated its astrophysical studies, as well as the idea of developing a large telescope. This idea would be materialized some decades later by Jorge Sahade, with the creation of the Astronomical Complex of “Leoniceto” (CASLEO) in the province of San Juan.

In 1982, the OALP School of Astronomy became the Faculty of Astronomical Science and Geophysics (FCAGLP), permitting it to recover from the harsh decade of the seventies and to begin a period of growth, which has been sustained up to the present. The Observatory of La Plata has traditionally offered the study of varied astronomical areas such as Astrometry and Stellar Astrophysics, though nowadays research is carried out in most areas of contemporary astronomy. The FCAGLP today has more

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8 Astronomical Observatory of La Plata, nowadays the Faculty of Astronomical Sciences and Geophysics of La Plata (Facultad de Ciencias Astronómicas y Geofísicas de La Plata, FCAGLP (http://www.fcaglp.edu.ar/).
9 Institute of Astrophysics of La Plata (http://www.fcaglp.unlp.edu.ar/~gladys/ialp/).
than fifty professors in astronomical fields, and is one of the most important astronomy institutions in Argentina.

In 1999, the Institute of Astrophysics of La Plata (IALP) was created, housed in the FCAGLP and under the UNLP and the CONICET. In the IALP, research is carried out in areas such as Dynamics, Stellar and Planetary Evolution and Formation. Most IALP researchers are also professors at the FCAGLP, and its staff of more than fifty includes graduate students and postdoctoral fellows.

Observatorio Astronómico Félix Aguilar (OAFA\textsuperscript{10}, San Juan)

The Félix Aguilar Astronomical Observatory (OAFA), now under the Faculty of Exact, Physical and Natural Sciences of the National University of San Juan (UNSJ), was inaugurated on September 28th, 1953 by a small group of professors from the Engineering School (nowadays a Faculty) of the National University of Cuyo, led by Carlos Cesco, with the aim of forming geographers. Its main astronomical facilities are in the Andes Range in the province of San Juan, in the locality of Calingasta, named Estación de Altura (Altitude Station) Carlos Cesco. Over the years, and thanks to international cooperation, the OAFA has consolidated a strong profile in the field of Positional Astronomy, which still distinguishes it nowadays.

Fundamental in the history of the institution has been its agreement with the University of Yale. Between 1973 and 1974, as the University of Columbia had withdrawn from its agreement with Yale, an agreement was signed between the newly created National University of San Juan and the University of Yale. This Yale Southern Observatory-OAFA agreement is still current today, and its main scientific objective is linked to the study of Proper Motion of more than thirty million stars. At present, there is also an agreement with the Chinese Academy of Sciences to operate a Satellite Laser Ranging station. Other current activities in the OAFA focus on Planetary Systems and the study of the sun, activities which are mostly performed by engineers.

Instituto Argentino de Radioastronomía (IAR\textsuperscript{11}, La Plata)

The Argentine Institute of Radio Astronomy (IAR) was created in 1962, only 22 years after the publishing of the first radio astronomical observation, which proves the highly pioneering character of Argentinian Astronomy in the mid-twentieth century.

The idea behind IAR first emerged as a project for the creation of a regional Radio Astronomy Observatory in South America, as an initiative

\textsuperscript{10}\textit{Félix Aguilar Astronomical Observatory} (http://www.oafa.fcefn.unsj-cuim.edu.ar/).

\textsuperscript{11}\textit{Argentine Institute of Radioastronomy} (http://www.iar.unlp.edu.ar/).
of Merle Tuve of the Carnegie Institution of Washington. The project began with the installation of a 30 meter antenna, with the active participation of Carlos Varsavsky. Later, a second antenna of similar characteristics was assembled, allowing important surveys of neutral hydrogen to be carried out. Neither antenna is operating nowadays, although there are plans to have one of them running again as a School Telescope. As is the case with other institutions in Argentina, the IAR has suffered from the political and economic turbulence of the country, affecting its initial growth.

As from 2002, the IAR started to perform assignments related to technology transfer for the National Commission of Space Activities. Nowadays, the IAR is strongly committed to technology transfer and continues to perform astronomical research, for which it has an active scientific staff of ten researchers in a variety of fields, being particularly productive in the area of High Energy Astrophysics.

Instituto de Astronomía y Física del Espacio (IAFE\textsuperscript{12}, Buenos Aires)

The Institute of Space Astronomy and Physics (IAFE) is under CONICET and was created in 1969 as a result of a restructuring of the Centro Nacional de Radiación Cósfnica (CNRC, National Centre for Cosmic Radiation). The institute included members from the CNRC, the Faculty of Exact and Natural Sciences, and astronomers from the OALP, among which was the first director of IAFE, Jorge Sahade. The IAFE emerged as a pioneer institute in experiments in cosmic radiation, in $\gamma$, X and infra-red rays, with a strong observational profile, taking great advantage of technological developments carried out in the country.

At present, the IAFE has more than seventy researchers in different astronomical subjects, some of which have started in recent years as a result of the migration of researchers from other national institutions. Due to its location in the city of Buenos Aires and within the University of Buenos Aires, which is the biggest in the country, the IAFE has experienced steady growth.

Complejo Astronómico El Leoncito (CASLEO\textsuperscript{13}, San Juan)

During the sixties, the OALP purchased a Ritchey-Chrétien optical reflector telescope, with a 215cm mirror. The installation carried out in cooperation with the Universities of Córdoba and San Juan, together with CONICET, as a national observation facility. After a process of searching and characterization of potential astronomical sites, an area was chosen close to the OAFA altitude station, in the province of San Juan.

\textsuperscript{12}Institute of Space Astronomy and Physics (http://www.iafe.uba.ar/).
\textsuperscript{13}Leoncito Astronomical Complex (http://www.casleo.gov.ar/).
For budgetary problems, it was not possible to set up the telescope at the site selected, and it was installed nearby, but at a lower altitude, with astronomical conditions inferior to those of the first site. Nowadays, the agreement between the universities and CONICET in relation to the CASLEO has expired, and a new agreement is being negotiated.

Despite having started as a services institution, over the years CASLEO acquired a small astronomical staff. However, with the creation of the Institute of Earth and Space Astronomical Sciences (ICATE) in 2009, these astronomers became part of the new institution, and so CASLEO has returned to its original format, with a staff mainly consisting of engineers and technicians.

Although this telescope has lost its competitiveness, due mainly to its age, it is still in high demand by the astronomy community in Argentina, especially by stellar astronomers. Numerous PhD theses have been produced in the last twenty years with data obtained through this telescope, and it is still the astronomical instrument most widely used by the astronomy community in Argentina.

Besides the 215cm Jorge Sahade telescope (named after the outstanding Argentinian astronomer), CASLEO also has other instruments: the Helen Sawyer Hogg 60cm telescope, in Cerro Burek (the site originally chosen for the 215); the Solar Sub-millimeter Telescope, built by international collaboration with the Mackenzie Centre for Radio Astronomy and Astrophysics of Brazil; and finally, the Astograph for the Southern Hemisphere, also installed in Cerro Burek in collaboration with the Astrophysical Institute of Andalucía, Spain.

Instituto de Ciencias Astronómicas, de la Tierra y del Espacio (ICATE\textsuperscript{14}, San Juan)

Founded in 2009, the Institute of Earth and Space Astronomical Sciences (ICATE) is the youngest astronomical institute in the country, and its members are mostly former scientific staff from CASLEO. Nowadays it has about ten researchers, who carry out studies in areas such as Galaxies, Solar Physics, Stellar Physics and Cosmochemistry. Some members of ICATE are also professors at the Faculty of Exact, Physical and Natural Sciences at the University of San Juan, teaching in the Licenciatura\textsuperscript{15} and PhD in Astronomy.

Among other institutions where astronomical research takes place are the Institute of Physics of Rosario (Rosario), the Institute of Geological Correlation (Tucumán), the Regional Centre of Scientific Research (Men-

\textsuperscript{14}Institute of Earth and Space Astronomical Sciences \texttt{(http://www.icate-conicet.gob.ar/)}.

\textsuperscript{15}Licenciatura is a five-year first degree obtained in Argentinian Universities. The following degree would be a PhD.
doza) and the Institute of Detection Technologies and Astroparticle Physics (Buenos Aires and Mendoza).

3. Observational Facilities

*Gemini*\(^{16}\)

Since its beginnings, Argentina has participated in the International Gemini Partnership, which operates two eight meter diameter optical/infrared telescopes, one in Chile and the other in Hawaii, USA. Despite having a small share in the partnership (approx. 2.5%), this infrastructure is highly regarded by the Argentinian astronomy community, since it offers a concrete possibility to access the latest generation of telescope.

The participation of Argentina in this project has not always been constant or easy. In the past, two factors constituted an obstacle to the normal development of the project. Firstly, the project arrived here as an initiative of the United States, instead of being suggested by the local community. Secondly, during several years the project did not have decisive support from the national institutions responsible for its financing and management. As a consequence, there was not only scant participation of Argentina in the political, technical and scientific discussions regarding the project, but also the loss of actual telescope time between the years 2003 and 2008.

In 2009, the *Ministerio de Ciencia, Tecnología e Innovación Productiva* (MinCyT\(^{17}\)) took over the project; this, together with the commitment of numerous astronomers, led to the gradual normalization of Argentinian participation in the partnership. Nowadays, Argentina has its payment contributions up to date, has adhered to the renovation of the international partnership, and it actively participates in the different international committees.

Argentina is eligible for a total of forty hours observation-time per semester in both telescopes. On average, the demand is fifty percent higher than the time actually available.

*CASLEO*

As mentioned above, CASLEO includes a series of operating instruments. For most of these, telescope time allocation depends on a scientific committee made up of representatives from the three Universities involved and CONICET. Time is assigned each semester, and in most cases the demands for observation time are satisfied.

\(^{16}\)http://www.gemiarginentina.mincyt.gov.ar/

\(^{17}\)Ministry of Science, Technology and Productive Innovation (http://www.mincyt.gov.ar/).
The Jorge Sahade Telescope, with a 215cm diameter primary mirror, contains a variety of instruments: direct CCD of 1340 × 1300 pixels; two spectrographs, one of which is Échelle type, and two photopolarimeters, one of which was designed and built in CASLEO.

*High Altitude Station “Carlos U. Cesco”*

The main astronomical facilities of the OAFA are found in the locality of Barreal, San Juan. Some of the operating instruments are: Photoelectric Astrolabe; Double Astrograph Telescope (in agreement with Yale Southern Observatory); Automatic Meridian Circle (in agreement with the Royal Observatory of the Spanish Navy). There are also two instruments for the study of the sun: MICA (Mirror Coronograph for Argentina) and HASTA (Hα Solar Telescope for Argentina).

*Bosque Alegre*

The 154cm diameter telescope of the OAC, located in the Córdoba hills, had been out of use for many years. At the end of 2008 it was decided to put it back into operation as an educational telescope and for scientific uses, and this project received a major boost during 2011. It is expected that it will soon be possible to invite proposals for observation.

*Pierre Auger Observatory*

The Pierre Auger Observatory, the result of the collaboration of nineteen countries including Argentina, is located in the province of Mendoza and is studying ultra-high energy cosmic rays. Although a correlation has been suggested between cosmic rays and extragalactic objects, these results have not been confirmed, and therefore the participation of astronomers in the field is still limited. The positive results of Argentinian collaboration in this project are commonly used as an example of the capability of our country to successfully host scientific projects of great magnitude.

4. Computational Resources

In Argentina there are diverse groups with significant experience in the utilization and undertaking of simulations and of numerical models. Consequently, there has been a need to acquire high performance computational resources. Nowadays, the computational infrastructure available at Argentinian institutions is somewhat obsolete, so that they have to recur to the infrastructure of other countries through international collaborations. Recently, the MinCyT created the High Performance National Computation System, which aims to integrate computer clusters throughout the country into one distributed calculation facility, which will enable an optimal use of

[18](http://www.auger.org.ar/)
this technology. This is a tentative project in formation, which, if successful, will allow the Argentinian astronomical community to access significant computational resources.

In 2009, with the involvement of most Argentinian astronomical institutions, the Nuevo Observatorio Virtual Argentino (NOVA19) was created, aimed at the national and international coordination of resources relating to data-centres, software tools and information about inter-operational standards. Recently, the International Virtual Observatory Alliance20 accepted NOVA’s membership; the new virtual institution is now studying the first projects to be run, as well as searching for sources of funding to permit sustained medium-term operation.

5. The Argentinian Astronomical Society

The Asociación Argentina de Astronomía (AAA21), which has recently turned fifty years old, brings together the vast majority of Argentinian astronomers, with the main objective of the promotion and progress of astronomy and its related activities in the country. Its specific functions are: to provide appropriate spaces for discussion and promotion of research activities in astronomy and in related sciences; supply institutional back-up to initiatives in the area; organize scientific meetings where astronomers may exchange information; give support to young astronomers by means of scholarships and work-contracts; act as a contact between astronomers and organizations which support science in Argentina and the world; and finally, the outreach of astronomy among the general public.

The AAA is economically sustained by its members’ fees, and is administered by a Board elected by the member’s general Assembly, renewed every three years. The Assembly also votes for the National Committee of Astronomy, which is responsible for liaison with the International Astronomical Union (IAU22).

The AAA also has an important publishing role. The Boletín de la Asociación Argentina de Astronomía (BAAA) is produced annually by an editorial committee, which is independent of the Board. Following a refereeing process, the BAAA publishes the papers presented during the annual meetings, where numerous astronomers and undergraduates get together, creating a good environment for scientific and policy discussions. Special debates or sessions on specific topics are held. The AAA also publishes the

19New Virtual Argentinian Observatory (http://www.nova.org.ar/).
20http://www.ivoa.net/
22http://www.iau.org/
Workshops and Books series, as well as a newsletter. As from 2006, the AAA holds annual workshops related to a variety of topics. Among the recent have been Observational Astronomy, Theoretical Astronomy, the outreach of Astronomy, History of Argentinian Astronomy, the Gemini Project and Computational Astronomy.

The Argentinian Astronomical Association grants three prestigious awards: the Carlos Varsavsky Award for the best Doctoral Thesis, the José Luis Sérsic Award for the outstanding Senior Researcher and the Jorge Sahade Award for Scientific Trajectory. The first two awards are granted every two years, and the latter, every three.

6. Education in Argentina

Argentina has historically had a very high literacy level among its population, and a great level of achievement of its University graduates. Nevertheless, there are nowadays some warning signs, especially as regards Elementary and Middle education levels. Clearly reflecting the problem is the noticeably low achievement of Argentinian secondary students in the last PISA (Programme for International Student Assessment\(^\text{23}\)), an exam for 15-year old middle school students, which located Argentina in the 58th place. Secondary school education, of course, affects studies at university, which has led to the creation of preparatory courses in order to bring students’ knowledge and training to the level of the new demands they need to face at university.

Traditionally, the educational system in Argentina has been public and free, including universities. Moreover, the highest academic levels and achievements are well known to have originated and been found in public universities, despite the rapid growth in the private education sector nowadays. Free education in Argentina at all levels has permitted unlimited access to higher education for all social levels, with a strong presence of the middle class.

The vast majority of Argentinian astronomers studied for their degrees in Argentina, and a large number have undertaken postdoctoral studies abroad. Most researchers who nowadays carry out astronomy studies in our country were formed and trained in the Universities of La Plata, Córdoba and San Juan, although some have graduated in Physics.

In Argentina, about ten students per year obtain their PhD with an astronomical orientation, in one of the following institutions:

\textit{Facultad de Ciencias Astronómicas y Geofísicas de La Plata}\(^\text{24}\) (FCAGLP), \textit{La Plata}

\(^{23}\)http://www.pisa.oecd.org/
\(^{24}\)Faculty of Astronomical and Geophysical Sciences
As mentioned above, this was the first School of Astronomy in the country. Here students work towards the Licenciatura and PhD in Astronomy, the latter having the highest category given by the Comisión Nacional de Evaluación y Acreditación Universitaria (CONEAU). Although the average duration of a Licenciatura is of five years (containing 30-35 subjects), it is taking students longer lately.

**Facultad de Matemática, Astronomía y Física (FaMAF), Córdoba**

This is the second School of Astronomy founded in the country, and this and the one in La Plata are the two most traditional ones. Although FaMAF is independent of the Astronomical Observatory, the professors of the Observatory are in charge of the academic formation of astronomy students in these specific subject-areas. FaMAF students work towards the Licenciatura and PhD in Astronomy, and the latter has the highest category given by the CONEAU. As in La Plata, the average period of studies for the Licenciatura has extended, possibly due to its demanding level, which may be compared to a Master studies in Universities abroad.

**Faculty of Exact, Physical and Natural Sciences of the UNSJ, San Juan**

Since 1995, students can work for the Licenciatura in astronomy in San Juan. This was originally a four-year degree, but nowadays it has been extended to the same period as in other Universities. Not long ago, there was no possibility of completing a PhD in astronomy or in related sciences in San Juan; consequently, most graduates then migrated to other national or international universities, to complete their postgraduate studies. Some of these researchers are now returning to San Juan, presaging a powerful growth for local astronomy. In 2009, a PhD program in Astronomy was started, specializing in Observational Astronomy.

An important contribution to research in the area of Astronomy has come from doctors in physics, mainly from the University of Buenos Aires (UBA). Thanks to its strategic location and joint dependency on the UBA and CONICET, IAFE attracts physics students from the Faculty of Exact, Physical and Natural Sciences, who are interested in astronomical topics.

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25National Commission of University Evaluations and Accreditations
(http://www.coneau.edu.ar/).
26Faculty of Mathematics, Astronomy and Physics.
28http://www.uba.ar/
7. Institutions and Resources for the Promotion of Science

According to the 2010 UNESCO Science Report, Argentina has the third largest gross domestic product (GDP) in Latin America, after Brazil and Mexico (2009 figures), while its Gross Expenditure on Research and Development (GERD) represents 0.51% of the GDP, setting Argentina again in the third place, after Brazil and Chile (2007 figures). Compared to other countries of the region, Argentina has a low percentage of funds provided by the business sector, while a high percentage of the scientific activity carried out in Argentina is financed by the State.

In 2007, the Argentine government transformed the previous Secretary of Science and Technology into the Ministry of Science, Technology and Productive Innovation (MinCyT), with CONICET as one of its most important agencies for the development of science. The national universities are the other pillar sustaining the Argentinian Science System. Other institutions which provide resources for the promotion of science are the National Agency for the Promotion of Science (also dependent on the MinCyT), as well Secretariats and Ministries dependent on the provinces.

Perhaps as a result of the constant crises the Argentinian scientific system has been subject to, its astronomical community has acquired great experience in obtaining funds abroad, in many cases as a result of international scientific collaboration programs. Contributions from private national funds in Argentina are hardly existent. Nonetheless, a great part of the Argentinian scientific community remembers with gratitude the Antorchas Foundation, which before disappearing in 2006, financed numerous astronomical projects.

**CONICET**

CONICET is, no doubt, one of the main driving forces behind scientific development in Argentina. Since its creation more than half a century ago, CONICET has implemented the so-called “career of scientific researcher” (Carrera del Investigador Científico y Tecnológico, CIC), by which it hires researchers to enable them to carry out their activities in one of the national scientific institutions. Nowadays, CONICET has 6350 researchers, of which 114 are in the area of astronomy (2010 figures).

The CIC has a scale of five categories, access to which includes peer evaluation; except for the first category (assistant researcher), permanency in the career is guaranteed by merely achieving a passing mark in the biannual evaluations. Following long decades of scarce income and a lack of senior researchers, a radical change in the last decade has provided CONICET with approximately 500 annual positions for all areas of research.

which allows, within the range of the exact sciences at least, inclusion in the CIC of a large proportion of those who qualify for it.

Currently, around ten astronomers qualify to enter the CIC annually, which has resulted in the sustained growth of Argentinian astronomy in all its aspects. The qualification criteria to enter the CIC are basically having graduated as a PhD and having published internationally refereed articles in first level journals. However, one drawback of this policy is the limited mobility of researchers who, in many cases, obtain a permanent position without undertaking previous postdoctoral activities. CONICET, aware of this complication, has implemented scholarships for researchers who are interested in working abroad, though this measure has not yet been shown to be successful.

Another important input of CONICET in the human resources area is the award of doctoral scholarships. Most doctoral theses in astronomy undertaken in Argentina are funded by CONICET scholarships, with a duration of five years. CONICET also contributes funds for research projects which are quite accessible for most researchers. Nevertheless, these funds only cover the basic expenses of a group of researchers and part of their travel expenses, thus limiting their presence and participation in international scientific events or scientific visits to other research centres. The typical ratio between funds in research grants and salaries ranges between 0.1 and 0.3, significantly lower than international standards.

CONICET promotes research by creating and financing scientific institutions. At present, most researchers in the area of astronomy work in one of the following institutions: IAFE, IALP, IAR, IATE, ICATE, CASLEO, IFIR\(^30\), CRICYT\(^31\), INSUGEO\(^32\), ITEDA\(^33\). The present policy of CONICET is that the institutes will ideally work in co-management with the National Universities, as is the case of several of the institutions mentioned above. CONICET also provides funding for organizing scientific meetings and, particularly as regards astronomy, for the Argentinian membership of the IAU and for the *Astronomy & Astrophysics* journal.

**National Universities**

Universities are undoubtedly the principal actor in Argentinian scientific development. They are responsible for undergraduate and graduate studies, without which there would be no science in Argentina. It is important to

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\(^{30}\) Instituto de Física de Rosario (http://www.ifir-conicet.gov.ar/).

\(^{31}\) Centro Regional de Investigaciones Científicas y Tecnológicas (http://www.mendoza-conicet.gob.ar/).

\(^{32}\) Instituto Superior de Correlación Geológica (http://www.insugeo.org.ar/).

\(^{33}\) Instituto de Tecnologías en Detección y Astropartículas (http://www.iteda.org/).
remember and point out that the public university is free of charge in Argentina and in some cases, low-income students may get some financial help.

The universities in Argentina are autonomous and so it is difficult to generalise about them. However, the most relevant aspects of all the universities are as follows: universities provide an important number of jobs for researchers in astronomy; these may be full-time (“exclusive”) or part-time (“semi” or “simple”) posts; in the first two categories, undertaking scientific research is compulsory. At present, very few new posts are being created, and thus the possibilities for entering the university system are mainly limited to vacancies. Usually, researchers may qualify for these posts through a selection committee, and this process may be renewed periodically.

Universities also finance doctoral scholarships and provide grants for basic expenses of research projects. It is important to point out that universities support the running of Observatories and co-finance CONICET institutes with double dependency. In fact, a large number of professors are also CONICET researchers.

Agencia Nacional de Promoción Científica y Tecnológica (ANPCT)\textsuperscript{34}

Dependent on the MinCyT, the ANPCT has as one of its central goals the funding of large-scale research projects; however, in our case, these are hard to obtain due to the fact that the area of astronomy is not considered a priority.

8. Scientific Meetings

The Argentinian astronomical community has a long tradition of holding scientific events. The most traditional one is the annual meeting of the AAA, which brings together more than 300 students and graduates in a different part of the country every year. For the 2011 series, and for the first time, the event was jointly organized with the Chilean Society of Astronomy.

Numerous international scientific meetings have taken place in Argentina in the last fifty years. In 1991, Buenos Aires hosted the 21\textsuperscript{st} IAU General Assembly; in the years 1983 and 2001, two IAU Latin American regional meetings were held, the third in Buenos Aires and the tenth in Córdoba, respectively. Since 1969, eight IAU Symposia have taken place: The Problem of the Variation of the Geographical Coordinates in the Southern Hemisphere (IAUC 1, La Plata 1968); Spectral Classification and Multicolour Photometry (IAUS 50, Córdoba 1971); Wolf-Rayet and High-Temperatures Stars (IAUS 49, Buenos Aires 1971); Solar Gamma-, X-, and

\textsuperscript{34}National Agency for the Promotion of Science and Technology.
EUV Radiation (IAUS 68, Buenos Aires 1974); Evolutionary Processes in Interacting Binary Stars (IAUS 151, Córdoba 1991); Eruptive Solar Flares (IAUC 133, Iguazú, 1991); Jets at All Scales (IAUS 275, Buenos Aires 2010); and Comparative Magnetic Minima: Characterizing quiet times in the Sun and Stars (IAUS 286, Mendoza 2011). There is currently a special emphasis on the organization of scientific meetings: during 2011, at least nine events of different features and topics were organized.

9. Promoting Astronomy within the Society at Large

The outreach of astronomy to the general public in Argentina has grown significantly in the last few years. Historically, it was an activity reserved for only a few and, even though the traditional institutions carried out related activities, these were not innovative and were mainly related to specific astronomical events or to the systematic attention to observatory visitors.

Nowadays, a great part of the astronomical community is seen to be clearly committed to performing extension activities for the general public. No doubt, the International Year of Astronomy in 2009 gave a mighty impulse to the development of these activities, which were not limited to traditional institutions such as the OLP or OAC, but expanded to the vast majority of astronomical institutions, as well as to others not devoted directly to scientific investigation, but which also took on a great role in the promotion of astronomy.

OAC, OALP, and OAFA have their own museums, while there are two traditional planetariums, in Rosario and, the most emblematic one, the Galileo Galilei Planetarium in the city of Buenos Aires, which has recently been refunctionalized to include full-dome digital technology. In the city of Malargue, in the province of Mendoza, there is a high technology digital planetarium; in San Luis, the University of La Punta also operates one. Moreover, the National University of La Plata is building a large digital planetarium, while in Córdoba an opto-mechanical planetarium is being built, based on an instrument donated by the city of Nantes in France, and the possible construction of a digital one is being studied. Three examples of astronomical promotion at non-traditional sites are the La Punta Astronomy Park35 in the city of San Luis, the Sky Plaza36 in the city of Esquel and the awi Puna Observatory in the small locality of Tolar Grande (150 inhabitants), Salta, 3500m above sea level in the middle of the Andean Puna.

35http://www.palp.edu.ar/
10. Amateur Astronomy

The fascination astronomy has always evoked has not escaped the Argentinian people, and that is why there are numerous Friends of Astronomy associations, reflecting a long tradition of interest in astronomy in the country. The most important of these groups is the Argentinian Association of Friends of Astronomy (AAAA\textsuperscript{37}), which dates back 81 years and is thus older than the professional association AAA, and is the oldest of its kind in Latin-America.

On some occasions, amateur astronomers also engage in scientific projects, for example devoted to precision astrometry of minor bodies of the Solar System. The Association of Argentinian Observatories of Minor Bodies\textsuperscript{38} groups the amateur observatories accredited by the Minor Planet Centre\textsuperscript{39}. At present, there are fourteen amateur observatories which hold a certification of the Minor Planet Center of the IAU.

11. Future Astronomical Projects

Except for Gemini, it is noticeable how far behind Argentina is in terms of latest generation observational infrastructure. For this reason, the Argentinian astronomical community has an agenda of numerous new astronomical infrastructure projects, some of which are national projects, while others are international collaborations. Recently, the National Ministry of Science and Technology has created a committee of Astronomy and Sciences of the Universe, with the purpose of evaluating projects in these areas. After inviting the scientific community to present possible projects, and a prior evaluation process, the committee has selected and ranked four greatly varied projects for possible funding.

The projects are the following:

\textit{Long Latin American Millimeter Array (LLAMA)}

This is a bi-national project in collaboration with Brazil, for the installation of one or two antennas in the millimeter/sub-millimeter wavelengths in the northwest of Argentina at a height of 4600m. The project includes the possibility of setting up a Very Long Baseline Interferometer by means of integration with projects such as ALMA\textsuperscript{40}, ASTE\textsuperscript{41} and/or APEX\textsuperscript{42} in the Chilean northeast. The Argentinian side is led by IAR researchers.

\textsuperscript{37}http://www.asaramas.com/
\textsuperscript{38}http://www.ao ACM.com.ar/
\textsuperscript{39}http://www.minorplanetcenter.net/iau/mpc.html
\textsuperscript{40}http://www.almaobservatory.org
\textsuperscript{41}http://www.ioa.s.u-tokyo.ac.jp/~kkohno/ASTE
\textsuperscript{42}http://www.apex-telescope.org
Cherenkov Telescope Array (CTA)

This project consists of a mega-international collaboration to build and operate the next generation of ground-based very high energy gamma-ray instruments to provide a deep insight into the non-thermal high-energy universe. CTA is made up of 25 countries and is considering the building of different types of telescopes in both hemispheres. Some of the Argentinian institutions involved in the project are IAFE, IAR and ITEDA. One of the main reasons for Argentina to participate in this project is its possible location within Argentinian territory, probably in the northwest or at sites close to CASLEO in the province of San Juan.

Doubling the Time at Gemini

This project consists in doubling Argentina’s time in the international Gemini partnership, which would be possible due to the withdrawal of Great Britain. This proposal is not led by any particular institution, but has the support of numerous astronomers and institutions at national level.

Argentina-Brazil Astronomical Centre (ABRAS)

This is a bi-national project which consists in the joint installation of a 1m/1.2m infrared robotic telescope with a medium size field of view in the Macon site, Salta Province at 4600m above sea level where an 8m-diameter dome is under construction. The Argentinian side is led by the IATE.

12. Human Resources

As mentioned, the national universities and CONICET are responsible for almost all astronomical posts available in Argentina. If we take into account teaching and research positions, the number amounts to approximately 250 scientists (considering that many of them depend on both these institutions). Table 2 shows the number of CONICET researchers by category (2010 figures). If we assume that, from the category of “Independent” and upwards, we are looking at senior researchers, we may conclude that the population pyramid is reasonable, which has been achieved during recent years thanks to the steady entry of young researchers.

Most PhD students undertake their studies with some kind of scholarship, the most numerous being those of CONICET. There is also a possibility of access to university scholarships, or ANPC grants. The present number of postgraduate students and postdoctoral fellows from CONICET in the area of astronomy is 62, which indicates that the human resources of astronomy will continue growing in Argentina.

Nowadays, approximately half the astronomical community in Argentina are women, and these are expected to become the majority in the medium term, taking into account that women are already a majority among un-
dergraduate students. It is important to point out as well that Argentina has the highest percentage of women members in the IAU\textsuperscript{43}, 48 out of 131.

Although Argentinian astronomy was initiated by citizens of other countries, with Benjamin Gould being NAO’s first director, and that this tradition lasted many years, nowadays almost all scientific posts are held by Argentinian citizens. One of the reasons for this is the policies of the institutions for the promotion of science, which do not have easy procedures for the incorporation of foreign citizens into the system; it is currently not possible to enter the CIC of the CONICET without Argentine residence, while the entry of foreign citizens to universities is by means of exception. In the case of postgraduate student scholarships, there is a CONICET program aimed specifically for Latin American citizens. Although most postdoctoral fellows are Argentinian as well, there are programs suited for foreigners.

The history of salaries in the scientific sector in Argentina is complex, with extreme ups and downs. Nowadays the situation may be qualified as fairly good, although there is a noticeable difference with other countries of the region, Brazil or Chile for instance, where scientific activity is much better paid.

Due to successive economical and political crises, as well as to the search for new scientific horizons, a great number of Argentinian astronomers reside in foreign countries, many of whom have gained international prestige. Nowadays, most astronomers migrate to attain training and expertise, and with the hope of coming home after completing their postdoctoral activities. It is important to point out that many Argentinian astronomers living abroad maintain ties with their local peers, and that this is supported by national subsidies devoted specifically to this kind of interchange, as in the case of the PICT-Raíces (Roots) grant of the ANPCT and the Cesar Milstein\textsuperscript{44} grant of the MinCyT.

\textsuperscript{43}http://www.iau.org/administration/membership/individual/distribution/
\textsuperscript{44}http://www.raices.mincyt.gov.ar/aplicar_milstein.htm

Table 2. Number of CONICET researchers per category.

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assistant</td>
<td>32</td>
</tr>
<tr>
<td>Attached</td>
<td>32</td>
</tr>
<tr>
<td>Independent</td>
<td>40</td>
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<tr>
<td>Principal</td>
<td>14</td>
</tr>
<tr>
<td>Superior</td>
<td>4</td>
</tr>
</tbody>
</table>
13. Scientific Production

The Digital Library for Physics and Astronomy for the Astrophysics Data System (ADS\textsuperscript{45}) shows that about 300 articles\textsuperscript{46} with at least one author from an Argentinian institution were published during 2010. If we assume that the number of active astronomers, including postgraduate students, is approximately 250, the result is a little more than one article for each researcher, similar to all other sciences in Argentina. If we consider only the four non-specialist publications used, *The Astrophysical Journal (ApJ)*, *The Astronomical Journal (AJ)*, *The Monthly Notices of the Royal Astronomical Society (MNRAS)*, and *Astronomy & Astrophysics (A&A)*, the total of publications in the same period is 105, distributed as follows: A&A (38), MNRAS (35), ApJ (22) and AJ (9), which shows a clear preference of the Argentinian astronomers for publishing in European journals.

This may be explained principally by the high costs per page in North American publications, which are hard to afford with the limited grants given in Argentina. Needless to say, Argentinian astronomers do not pay for publication in A&A, due to Argentinian membership in the A&A partnership since 2004; actually, Argentina was the first non-European country to be incorporated to the A&A.

14. Technological Development

From its beginnings, Argentinian astronomy brought about and has been associated with promising instrumental development. It is sufficient to remember Charles Perrine, who built a 76cm reflecting telescope in the OAC at the beginning of the twentieth century. Nonetheless, with the passing of the years, this activity has lost competitiveness and support. There is a general consensus that this situation should be reversed, but to date there is no certainty regarding the possibility of making it happen in the short term. One of the paths being explored is to encourage high technology companies, such as INVAP\textsuperscript{47}, to participate, in conjunction with astronomers and astronomical institutions, in the development of future instruments for Gemini.

The IAR is also an institution of great potential; although the advanced technological development carried out there is mainly aimed at the satellite area, the necessary tools and expertise exist there to reorient it to the development of radio-astronomical instruments.

\textsuperscript{45}http://www.adsabs.harvard.edu/

\textsuperscript{46}This number should be taken only as an approximate figure due to the possible incompleteness of ADS as well as the techniques used to choose the articles, which may include thematic contaminations or omissions.

\textsuperscript{47}http://www.invap.com.ar/
15. Argentina as a Site for Large Astronomical Facilities

The western border of Argentina lies on the high summits of the Andes Range, which extends over 4000km. Moreover, between the central region and the northern border there are significant peaks and great plains at considerable altitude, such as the Puna which, 150km wide and 350km long, and an average of about 4000m in altitude, constitutes one of the major highlands in the world. The climatic characteristics of this region are of a very dry area with a high percentage of clear nights, similar to those in the north of Chile.

All these features of the region have generated numerous initiatives from the astronomical community to attract important international projects to Argentina. Since the year 2000 there has been intense activity, aimed not only at selecting potential sites, but also advancing in their characterization. Probably the work with the greatest breadth in this direction has been undertaken by researchers of the IATE, who were in charge of the astronomical characterization of the Cerro Macón, in the Province of Salta. This study was carried out in agreement with the European Southern Observatory\(^{48}\) within the framework of site selection for the European Extremely Large Telescope\(^{49}\). Though Argentina was not finally chosen for the installation of the telescope, the region has been thoroughly characterized in all its aspects, which has given rise to new projects such as ABRAS, mentioned above. Under the IAR’s responsibility, this site was studied in reference to its vapour content, as well as other regions of the Puna, such as Alto Chorrillo, which is being considered for the LLAMA project. The region has also been studied for high-energy projects. The central region of the Andes, especially the zone close to CASLEO, has also been proposed for international projects, particularly the Square Kilometre Array\(^{50}\). Led by researchers of the IAFE and the IAR, Argentina actively participated to establish this project in the region. Although Argentina was not selected for this project either, the Argentinian astronomical community has proved its strong vocation to encourage such initiatives. What is more, it has been demonstrated that there are sites of great potential, and thus it is only a matter of time before a project of great magnitude, as in the case of the Pierre Auger Cosmic Rays Observatory, is attracted.

\(^{48}\)http://www.eso.org/
\(^{49}\)http://www.eso.org/sci/facilities/eelt
\(^{50}\)http://www.skatelescope.org/
16. Future challenges

Astronomy in Argentina may be considered as one of the foundational areas of science in our country. It has a long tradition as well as significant regional and international recognition. Despite repeated periods of crisis, nowadays it is experiencing sustained growth, especially in terms of human resources. Astronomical research is carried out in traditional institutions as well as in novel ones, in at least ten scientific centres. As long as no more local or international crises interfere, this tendency of constant growth should consolidate in the forthcoming years.

Yet the Argentinian astronomical community, together with the institutions for the promotion of science, have a series of challenges ahead of them: to update the observation infrastructure, improve young researchers’ mobility, improve scientific production and its impact, recover high-technology development of astronomical instruments, raise the amounts of grants destined to research, encourage astronomical research in more regions of the country, enable greater inclusion of foreign researchers and, last but not least, attract international astronomical projects of great magnitude to be set up in the country.

Acknowledgments

This work would have not been possible without the collaboration of numerous colleagues who contributed important data and precision regarding a diversity of topics. I would like to thank Mario Abadi for his contributions and advice, and Galit Shani and Joss Heywood for their help with the manuscript.

I am also grateful to anonymous referees for their suggestions and linguistic improvements brought to the paper.

Bibliography

One of the main sources used for the historical institutional aspects was the book Historia de la Astronomía Argentina (History of Argentinian Astronomy), AAABS 2 from the Book Series of the Argentinian Association of Astronomy. The other important sources of information were the web pages quoted in this article, as well as colleagues whom I consulted.

Abbreviations

AAA The Argentinian Astronomical Society
ANPCT The National Agency for the Promotion of Science and Technology
BAAA Journal of the Argentinian Astronomical Society
CASLEO The Leoncito Astronomical Complex
CIC Career of the scientific researcher of the CONICET
CONEAU The National Commission of University Evaluations and Accreditations (Comisión Nacional de Evaluaciones y Acreditaciones Universitarias)
CONICET The National Council for Scientific and Technical Research (Consejo Nacional de Investigaciones Científicas y Técnicas)
CRICYT Regional Centre for Scientific and Technical Research (Centro Regional de Investigaciones Científicas y Técnicas)
FaMAF Faculty of Mathematics, Astronomy and Physics
FCGALP Faculty of Astronomical Sciences and Geophysics
IAFE The Institute of Space Astronomy and Physics
IALP Institute of Astrophysics of La Plata
IAR Argentinian Institute of Radioastronomy
IATE Institute of Theoretical and Experimental Astronomy
IAU International Astronomical Union
ICATE Institute of Earth and Space Astronomical Sciences
IFIR Institute of Physics of Rosario
INSUGEO Superior Institute of Geological Correlation
ITEDA Institute of Technologies in Detection and Astroparticles
MinCyT Ministry of Science, Technology and Productive Innovation
NOVA New Virtual Observatory
OAC Astronomical Observatory of Cordoba
OAFA Félix Aguilar Astronomical Observatory
OALP Astronomical Observatory of La Plata (nowadays the Faculty of Astronomical Sciences and Geophysics)
NAO The National Argentinian Observatory (nowadays OAC)
UBA University of Buenos Aires
UNC National University of Cordoba
UNSJ National University of San Juan

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