Brazil's Route to ESO Membership

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On 29 December 2010, in a ceremony held at the Ministry of Science and Technology in Brazil´s capital, Brasília, the then Minister, Sergio Machado Rezende and the ESO Director General Tim de Zeeuw signed the accession agreement by which, pending ratification by the Brazilian Congress, Brazil becomes the 15th ESO Member State and the first non-European member. An overview of the historical background, the current state of astronomy in Brazil, and the motivation that made Brazil apply to become an ESO Member State is presented.

History

The signature of the accession agreement to ESO (see de Zeeuw, 2011) is the latest highlight in Brazilian astronomy's very long and distinguished history, which goes back much further than most non-Brazilian astronomers are aware. Long before Brazil was established as a state, at a time when various European powers still disputed dominion over its vast expanses, Brazil hosted the first astronomical observatory, not just in the Americas, but also in the southern hemisphere. In 1639 the German naturalist and astronomer Georg Marcgrave founded an observatory in Recife (Prazeres, 2004), which was then the capital of a Dutch colony. The probable appearance of this observatory is shown in Figure 1. Should we consider this as the first "European Southern Observatory"?

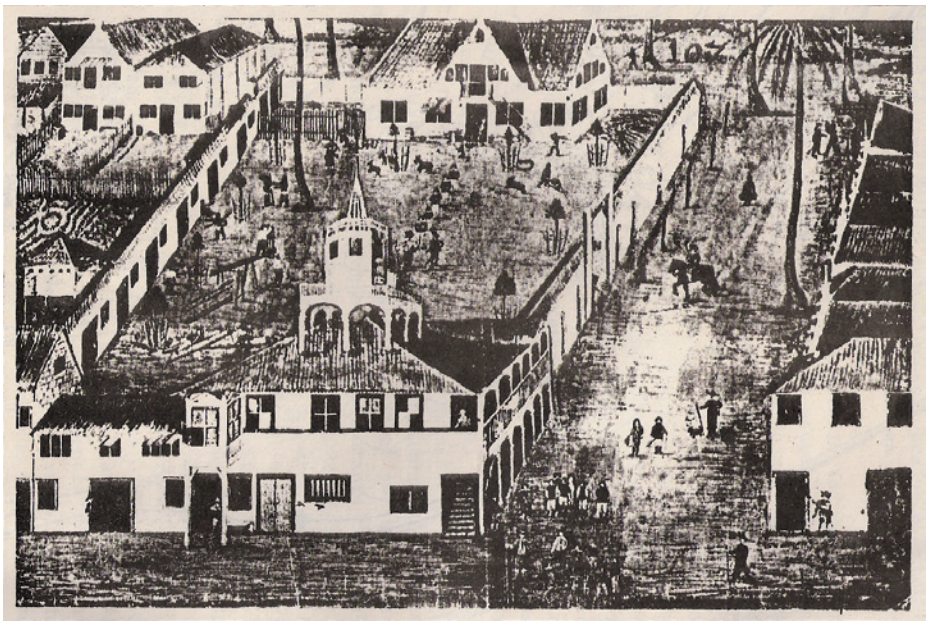

Figure 1. A contemporary engraving by Zacharias Wagener of a building in 17th century Recife that may have hosted the first astronomical observatory in the Americas.

However, troubled times and warfare between the countries disputing hegemony over the rich Brazilian colonies impeded the long-term survival of these initial astronomical activities and astronomy only took firm root in Brazilian soil after the country became an independent empire in 1822. On 15 October 1827, the Emperor Dom Pedro I established the institution that has now evolved into the Observatório Nacional (ON) in Rio de Janeiro (Videira, 2007), and is shown in Figure 2. It was originally meant to provide essential services to the newly founded state such as time-keeping, and fundamental scientific research in astronomy only gradually became part of its activities. Arguably the observatory's most notable scientific achievement was the organisation of the expedition to observe the solar eclipse of 1919 in Sobral, Ceará, which contributed decisively to the first observational proof for Einstein´s theory of general relativity.

Astronomy began to establish itself in other Brazilian institutions in the late 19th century and this progressed, primarily in the universities, and most notably in São Paulo and in Porto Alegre, at a rather modest pace during much of the 20th century. Astronomy in Brazil has only really taken off during the past three or four decades. The three main factors that have contributed to this substantial and very successful increase are:

MAST

Figure 2. The early home of the Observatory Nacional in Rio de Janeiro, photographed in 1921, which today hosts the Museum of Astronomy and Related Sciences.

1. New funding lines that permitted promising Brazilian students to receive their professional education abroad, mainly in Europe and in the USA.
2 Newly created graduate courses in astronomy, meaning that scientists could be trained in Brazil, taking advantage of the expertise brought back by others who had obtained their degrees in foreign countries.
3. The creation of the Observatório do Pico dos Dias (OPD) and the installation of a medium-sized (at the time) telescope which gave the growing astronomical community access to a competitive observational infrastructure for the first time.

The above-mentioned factors resulted in the dramatic growth of Brazilian astronomy, both in terms of the number of scientists, as well as in scientific output. It quickly became evident that the available instruments were insufficient to satisfy the rapidly growing demand and that there is no really good site for a modern optical observatory in Brazil. So, instead of enlarging the existing facilities at a location that is far from ideal for astronomical observations, and following the modern trend towards the globalisation of science, it was recognised that international collaborations were the right way forward for the further development of astronomy in Brazil.

Infrastructure for astronomical research

So as to make telescopes and instruments with a wide range of apertures, characteristics and capabilities available to Brazilian astronomers, Brazil became a partner in the Gemini Observatory, the SOAR Telescope and finally entered into a Cooperative Agreement with the Canada–France–Hawaii Telescope (CFHT), giving Brazilian astronomers access to a range of facilities besides the Brazilian OPD.

Brazilian observational optical astronomy takes place primarily at the OPD (shown in Figure 3). When the observatory was planned in the 1970s, logistical considerations demanded that the observatory was built within easy reach of the big population centres where most astronomers were located. A site within the triangle formed by the cities of São Paulo, Rio de Janeiro and Belo Horizonte was chosen as a compromise between easy accessibility and good observing conditions. The observatory is operated by the National Astrophysical Laboratory (Laboratório Nacional de Astrofísica [LNA]), based in Itajubá, Minas Gerais, which is a research institute of the Ministry of Science and Technology, and is responsible for providing the optical astronomical infrastructure to the entire scientific community. Today the OPD hosts three telescopes with apertures between 1.6 metres and 0.6 metres, and it is equipped with an instrument suite that is tailored to serve its users well. An effort to upgrade the observatory is underway to keep it competitive, despite the increasing light pollution and the growing number of other facilities that are now open to Brazilian astronomers.


LNA

Figure 3. Aerial view of the OPD, the principal observatory on Brazilian territory, located in the Serra da Mantiqueira in the southern part of the State of Minas Gerais, operating a 1.6-metre telescope (main building) and two 0.6-metre telescopes.

The Gemini Observatory operates two 8-metre-class telescopes on Hawaii (Mauna Kea) and in Chile (Cerro Pachón) on behalf of a consortium of seven countries. Although very well used by Brazilian astronomers, and extremely important for the development of optical astronomy in Brazil, the rather small share of Gemini that Brazil was able to purchase has proved to be a severe limitation. Brazil currently owns 2.5% of Gemini. In 2010 it purchased additional observing time from the United Kingdom, increasing its access to the telescopes by a factor of two and it is anticipated that Brazil will increase its share in Gemini to about 6% after 2012, when the UK leaves the partnership.

With abundant access to rather small telescopes (OPD) and limited access to big telescopes (Gemini), the Brazilian astronomical community felt the need for something in between: a decent amount of time at an intermediate-sized telescope. So Brazil joined forces with three US institutions (NOAO, University of North Carolina and Michigan State University) to build and operate the SOAR Telescope (Southern Astrophysical Research Telescope), located next to Gemini South on Cerro Pachón (see Figure 4). SOAR is a 4.1-metre telescope that is optimised for high image quality. Brazil entered this consortium as the majority shareholder with a stake of about 34%. Brazilian astronomers also have access to the 4-metre Blanco Telescope at CTIO through an agreement with NOAO about the exchange of observing time, which complements the services and instruments offered by SOAR.

The cooperative agreement with the CFHT, which is located on Mauna Kea, Hawaii, is meant to provide access to a

SOAR Inc.

Figure 4. The 4.1-metre SOAR Telescope on Cerro Pachón, Chile.

José-Williams Vilas-Boas

Figure 5. The dome of the Itapeninga Radio Observatory (ROI) in Atibaia, São Paulo.

highly productive wide-field 4-metre-class telescope with competitive instruments in the northern hemisphere. The agreement is limited in time and will be reviewed, with the aim of potentially renewing the contract, in 2012.

Brazilian participation in all these international observatories is managed by the LNA, which thus exercises a key role in optical astronomy in Brazil. Apart from these installations, which are open to the entire astronomical community, some institutions operate their own facilities on a more modest scale, and these either serve a specific scientific purpose or concentrate on education and outreach. The most recent and arguably most important (and certainly the biggest) of these is IMPACTON, a robotic one-metre telescope for observations of near-Earth objects, which is currently being commissioned by the Observatório Nacional, and is located in the interior of Pernambuco State.

Other areas of astronomical research have also benefitted from Brazil's contributions to international projects and collaborations. These include space astronomy (Brazil is a partner in the CoRoT space mission, and it is also engaged in the PLATO mission), high energy astrophysics (through the participation of Brazil in the Auger experiment), and cosmology (Brazilian institutions are members of the International Center for Relativistic Astrophysics Network [ICRA-Net]).

The growing importance of large surveys and the exploitation of data banks for astronomical research has been recognised and has led to the recent creation of the Brazilian Virtual Observatory (BraVO), as the national branch of the International Virtual Observatory Alliance. BraVO unites researchers from various institutions in a coordinated effort to create infrastructure and tools for data-mining and to disseminate the concept of the Virtual Observatory in Brazil. In parallel, the LIneA (Laboratório Interinstitutional de e-Astronomia) collaboration is formed by scientists working at three research institutes of the Ministry of Science and Technology (MCT) to develop the infrastructure and software to store and process large astronomical datasets.

LNA

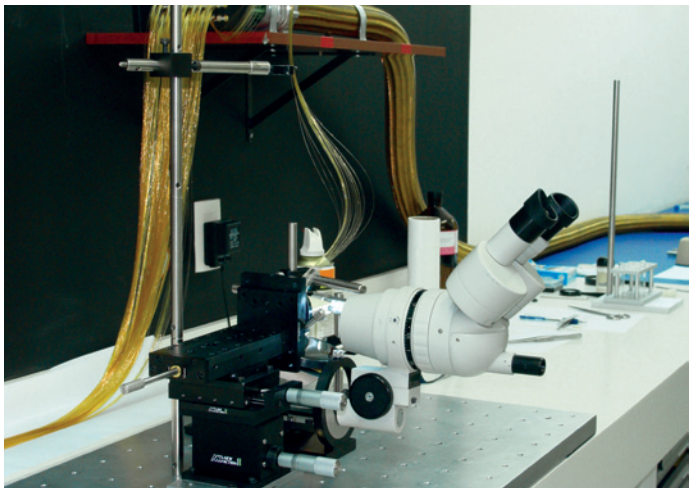

Figure 6. Mounting the 1300 optical fibres of the SOAR Integral Field Spectrograph at the LNA Optics Laboratory.

Radio astronomy, which was already comparatively well developed before the steep increase in optical astronomy activities began, has not followed the same steeply rising path. Apart from some modest investments in specialised instruments operated by small groups, no major effort has been made to provide access to a competitive infrastructure for the general community. The Itapeninga Radio Observatory (ROI; Figure 5), located in Atibaia, some 50 kilometres from São Paulo, and operated by the Nacional Space Research Institute (Instituto Nacional de Pesquisas Espaciais [INPE]) is the only instrument available to all astronomers. This 18–90 GHz, 14-metre antenna has not had a major upgrade since it was built in 1974. Access to more modern equipment would be very much welcomed by the radio-astronomy community.

Instrumentation

The desire to participate in both scientific research in astronomy and in technological development has led to the implementation of the necessary infrastructure to build astronomical instruments for use at international observatories, such as SOAR. These efforts are concentrated at the LNA and INPE, in collaboration with the universities and other scientific institutions.

While most of the activities in instrument development at INPE are related to fields other than astronomy (e.g., observation of the Earth from space), a group at INPE is currently building MIRAX, a small survey satellite to observe the spectral and temporal behaviour of a large number of transient X-ray sources. Moreover, INPE is collaborating with the LNA and the Instituto de Astronomia, Geofísica e Ciências Atmosféricas (IAG) of the University of São Paulo to develop the Brazilian Tunable Filter Imager (BTFI), which is an innovative camera and integral field spectrograph for the SOAR telescope. Other long-term collaborations between INPE and LNA on instrumentation for the OPD are also ongoing.

In the past, instrumentation development at LNA was rather modest and restricted to immediate OPD needs. But during the past decade much effort has been invested in turning such activities into one of the fundamental pillars of the institute. The LNA has built laboratories and workshops, and provided them with state-of-the-art equipment, with a special emphasis on optical metrology and the handling of optical fibres for astronomy (see Figure 6 as an example). In collaboration with the IAG and other university institutes, the LNA has built SIFS, a 1300-channel integral field spectrograph (currently being commissioned at the SOAR Telescope). It is also constructing the SOAR Telescope Echelle Spectrograph (STELES) and is planning a similar instrument for the OPD. The LNA was a member of the winning team in an international competition for the detailed design study of the Wide Field Multiple Object Spectrograph (WFMOS) for Gemini, where it was responsible for the fibre feed between the telescope and the bench spectrograph (although, unfortunately, through lack of funding the instrument was never built). In a successful attempt to find a place on the international market for astronomical instrumentation, the LNA has also built the fibre feed for the Frodospec spectrograph at the Liverpool Telescope on La Palma.

Independent efforts in instrument development are ongoing at the Observatório Nacional, which, in collaboration with the IAG, is building a camera for the J-PAS (Javalambre Physics of the accelerating Universe Astrophysical Survey) project in Spain. Facilities for instrumentation development are also being installed at the Federal University of Rio Grande do Norte in Natal.

Size of the Brazilian astronomical community

According to a census (updated in 2010), there are 341 fully trained and active astronomers (i.e. with a PhD) in Brazil (up from no more than a handful some 40 years ago). This workforce is complemented by 313 postgraduate (Master's and PhD) students. Thus, more than 650 scientists are active in astronomical research. While there is a concentration of astronomers in a few universities and federal research institutes, the number of groups in other places is rapidly increasing as a result of the policy of the federal government to strengthen science and higher education in less well-developed parts of the country. In consequence, astronomy is being pursued today in 46 institutions (… and counting), which are widely spread across Brazil. While many of the smaller groups are part of physics or other related university departments, postgraduate education in astronomy is offered in 19 institutes.

There is not enough room here to characterise all these institutes in detail. However, it may be worthwhile to briefly enumerate the most important. With the IAG (see Figure 7), the University of São Paulo hosts the dominant research institute in astronomy in the country. It is home to about 20% of the total workforce mentioned above. This is twice

Figure 7. Urania, the Muse of Astronomy, from a picture window in the library on the former campus of the Institute of Astronomy and Geophysics of São Paulo University.

as many as the second most important, the venerable Observatório Nacional in Rio de Janeiro. Strong astronomy groups can also be found at INPE, located in São José dos Campos, the Federal University of Rio de Janeiro (distributed between the Observatório do Valongo and the Department of Physics), the Federal University of Rio Grande do Sul in Porto Alegre and the Federal University of Rio Grande do Norte in Natal. While all these astronomy centres carry out research in many fields, the Brazilian Centre of Physical Research (Centro Brasileiro de Pesquisas Físicas [CBPF]), Rio de Janeiro, which hosts the Brazilian branch of ICRAnet, focuses mainly on cosmology.

Administratively, the numerous astronomy groups are distributed between government institutions, which are directly subordinated to the federal Ministry of Science and Technology (CBPF, INPE, LNA, ON), entities belonging to federal or state universities, and (increasingly) private universities.

The community founded the Brazilian Astronomical Society (Sociedade Brasileira de Astronomia [SAB]) in 1974. The Society currently has 678 members.

As measured by the number of publications in refereed journals, scientific productivity was all but non-existent until the end of the 1960s, but as the number of active astronomers has increased, a steep and continuing rise in the number of published papers has been observed (Figure 8). The role of Brazil as a significant producer of scientific papers was recognised when it became a member of *Astronomy and Astrophysics*, the leading astronomical journal in Europe.

Although optical and infrared observational astronomy is predominant, Brazilian astronomy embraces a wide range of special fields. There are at least 16 major areas of astronomy that are being actively pursued by astronomers in Brazil and that have recently been identified in the context of a National Plan for Astronomy[1]. The relative importance of the various disciplines can be gauged from the number of publications that they have generated. Table 1 gives the percentages of papers by Brazilian authors in refereed journals by area in 2008.

Funding

Brazilian astronomy is largely publicly financed. Operating costs for facilities open to the entire community are borne exclusively by the Federal Government, normally through MCT research institutes. Funds for the development of new projects and capital investments (instrument development among them), come from the same sources, including the government funding agency FINEP (Financiadora de Estudos e Projetos), as well as from Brazilian state funding agencies, which normally do not fund the operation of astronomical infrastructure. While other states also contribute, FAPESP, the funding agency of São Paulo state, plays a dominant role.

CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico), a branch of the MCT, is extremely important as a provider of stipends for students and grants for established scientists. A similar role is played by CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), a branch of the Ministry of Education. Apart from stipends and grants, CNPq also finances smaller scale projects for individual scientists, scientific meetings, etc. (as do the state agencies).

Specific funding by the federal and state governments, such as PRONEX (Programa a Núcleos de Excelência) and the Millennium Institutions (Institutos do Milênio) in the past, and the current (virtual) National Institutes of Science and Technology (INCT) has also greatly benefited Brazilian science. Two astronomy-related National Institutes have been created: INCT-A (A for astrophysics), which focuses on preparing the astronomical community for the challenges and opportunities of the future, and INCT-E (E for *espaço* [space]) which focuses on space technology and astronomy from space.

Direct personnel costs are, of course, carried by the employers, who are, in most cases, the federal or the state governments. However, the private sector is also involved through private (in general, non-profit) universities with research and higher education interests in astronomy.

Long-term strategic outlook

Brazil's young and vigorous community feels that it has gained an international reputation as a respected player in global astronomy. It is not seen as an accident that Rio de Janeiro was chosen to host the IAU General Assembly in 2009, but rather as recognition of the achievements of Brazilian science. The community is

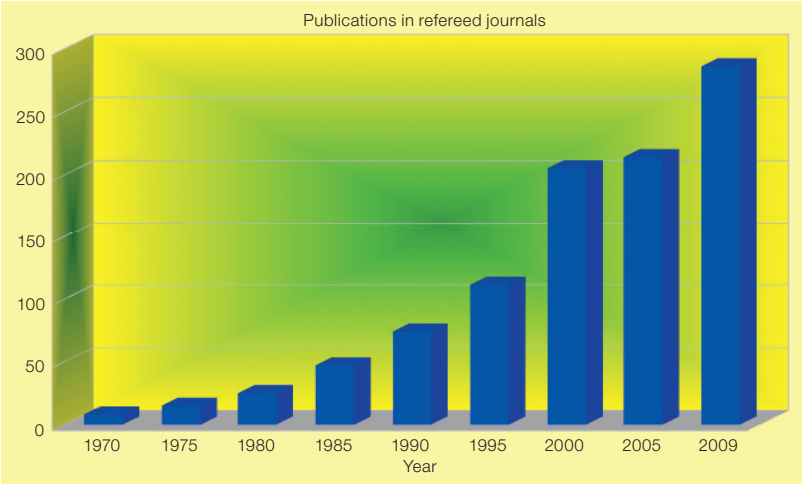

Figure 8. Evolution of the number of publications by Brazilian astronomers in refereed journals over the past decades.

aware that worldwide astronomy is characterised more than ever by international collaborations. Consequently, success for a national community depends decisively on its participation in the international community.

Moreover, it is understood that the growing necessity for international collaborations, the numerous scientific opportunities that present themselves in the worldwide scenario, combined with the elevated costs for large-scale scientific projects, call for a medium- and long-term strategic plan for astronomy to direct and coordinate the further development of the field in Brazil. Therefore, with the active support of the Ministry of Science and Technology, in 2010 the community elaborated a National Plan for Astronomy[1] as a guideline for the future of astronomy in the country, aligned to the general policy for science and technology of the federal government.

Among many other issues, this document emphasises the need to maintain access to a competitive observational infrastructure, on penalty of losing the respected position gained by Brazilian astronomers. Different ways of achieving this purpose have been studied by the INCT-A and a special commission created by the MCT. Based on these results the broad majority of the astronomical community came to the conclusion that the association of Brazil with ESO would be the most effective of all the available options. More than any other alternative, the association with ESO benefits the country in many ways, the most important advantages being that:

– it gives Brazil immediate access to ESO's existing telescopes, fostering scientific collaboration (and competition!) with scientists of other member states, and enlarging the scope of instruments already at the disposal of Brazilian astronomers significantly, thus eliminating some limitations felt by parts of the community;
– it meets one of the main recommendations of the National Plan for Astronomy by guaranteeing access to the future generation of giant telescopes, i.e. the European Extremely Large Telescope, and opening up opportunities for Brazilian industry to take part in its development and construction;
– it provides access to ALMA, satisfying and fostering the development of a community of radio astronomers who have not benefited from significant investments similar to those made in optical astronomy during the past three decades;
– it opens up a wide range of opportunities for the participation in technological development as part of the instrumentation programme for ESO telescopes.

Optical and infrared stellar astronomy	28.8 %
Theoretical cosmology	17.4 %
Optical and infrared extragalactic astronomy	11.9 %
Physics of asteroids	5.8 %
Theoretical stellar astrophysics	4.3 %
Chemical evolution of stellar systems	4.3 %
Dynamical astronomy	4.3 %
Solar radio astronomy	3.2 %
Instrumentation	3.2 %
Exoplanets	2.7 %
Other	13.2 %

Table 1. Percentage of papers published in refereed journals by area in 2008.

It is felt that the development model for optical astronomy which Brazil has followed in the past, i.e., offering its scientists a suite of instruments with diverse characteristics on small and medium-sized telescopes up to to the 8-metre-class Gemini giants, although with limited access in the case of the larger instruments, has lifted the astronomical community to a level of maturity. This progress now permits the next step — or rather leap — in its evolution: the ascent to a new and higher level in scientific, technological and instrumental terms, which is expected to be the natural consequence of Brazil's association with the strongest organisation in ground-based astronomy in the world. We are confident that not just optical astronomy will be strengthened, but that the fertile environment of partnership with ESO will benefit Brazilian astronomy as a whole, as well as related technological fields.

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Links

[1] National Plan for Astronomy: http://www.lna.br/PNA-FINAL.pdf