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ASTRONOMY IN BRAZIL

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ABSTRACT. Survey of the progresses of Brazilian Astronomy from its begining, around 1960, till nowadays. It is shown the important role played by the Physics Departments of Brazilian Universities in these progresses. The survey is preceded of a short historical introduction.

I. HISTORICAL INTRODUCTION

The history of Astronomy in Brazil has its origins in the colonial period, with the astronomical observatory of G. Markgraf functioning between 1639 and 1643, in Olinda (Pernambuco). It has been the first in the American Continent and in Southern Hemisphere (Cajori, 1928), being equipped with a 30-cm quadrant for meridian observations, a telescope and a pendulum. The National Observatory and the Astronomical and Geophysical Institute of the University of Sao Paulo, the two oldest Brazilian astronomical institutions, have their origins in the 19th century. The National Observatory created in 1827 by the Imperial Government has been actually installed in 1846 and began to work out effectively in 1852 in Morro do Castelo, Rio de Janeiro. It was equipped with a mural arc, a refractor, a meridian telescope and auxiliary equipments. The Astronomical and Geophysical Institute of the University of Sao Paulo (USP) is the result of several administrative transformations in Sao Paulo Observatory. It was installed in Sao Paulo, in 1912, endowed of a meridian instrument, a refractor and a Time Service, and assembling the meteorological, geophysical and astronomical observation services which were held in the Geographical and Geological Comission of Sao Paulo State. Some of these services were working in this Comission since its creation in 1886.

Untill the mid 20th century, the National Observatory was the only institution to carry out researches of importance in astronomy. In the 19th century there were numerous works by E. Liais and L. Cruls, comprising a great number of subjects favoured at that epoch such as comet photometry and polarimetry, Mercury and Venus transits through the sun disk, meridian observations and systematic observations of double stars, eclipses, zodiacal light, planetary surfaces (Moraes, 1955). In the 20th century, new themes were added. Among the contributions of National Observatory the study by Lélio I. Gama of the latitude variation in Rio de Janeiro in the period 1924-1931, which involved 33,000 star transit observations with a zenithal telescope, deserves to be emphasized.

2. ASTRONOMY AND THE PHYSICS DEPARTMENTS

Yet, in the first half of this century, the flow of ideas, which had begun in Imperial times, was interrupted. As a consequence, the Brazilian Astronomy of today has no other link with the old times than some equipments and the rich heap of old publications in the libraries. While for some writers the occupation of a same physical space and an administrative continuity are enough to make sure that one thing is the continuation of another, for the scientist, what matters are the ideas and their spreading. And the totality of the researches that constitute the astronomical activity in Brazil today, derives from the interests generated from the contact with the astronomy practiced in great centers through 25 years of continuous interchanging of graduate students and visiting researchers.

This new Brazilian Astronomy was born from the physicists' increasing interest towards Astronomy and was developed narrowly associated with the Physics Department of Brazilian Universities, and even inside them.

At the University of Sao Paulo (USP), Professor Abrahão de Moraes, from the Physics Department, was called in 1955 to lead the Astronomical and Geophysical Institute and he started its modernization. He accomplished researches on Celestial Mechanics, installed a Moon camera and a Danjon's impersonal astrolabe; he encouraged the formation of astrophysicists and built a modern astrometrical observatory in Valinhos, 60 km distant from Sao Paulo.

In 1960, Mackenzie Radio Astronomy Group (GRAM) was created in the Physics Department of Mackenzie University in Sao Paulo. Under the direction of P. Kaufmann, GRAM installed, in 1964, the Umuarama Radio Observatory in Campos do Jordão (Sao Paulo State), equipped with a solar radiotelescope and a radiotelescope with mobile parabolic reflector, both in 300 MHz, as well as some equipments for the study of the effects of solar activity on the low ionosphere.

The Physics Department of the Aeronautics Institute of Technology (ITA), in Sao Jose dos Campos, had, since 1963, a small observatory functioning with a 52-cm telescope built in the very Institute. In 1966 the Astronomy Department was created and allowed, in 1968, the functioning of the first post-graduate courses in Astronomy in Brazil. ITA's telescope was, for a long period, the only one operating in Brazil, having been used in several programmes of variable stars photometry.

Radio Astronomy was also developed in the Physics Institute of the Federal University of Rio Grande do Sul, the observational work being executed in Argentinean Radio Observatories. Afterwards, a 50-cm telescope was installed in Porto Alegre, offering opportunities of researches in several other fields of astrophysics.

In the Physics Department of Federal University of Minas Gerais, astronomy has been implanted firstly as a support activity for the site testing of the Brazilian Astrophysical Observatory. Lately, the University has installed a small telescope in Serra da Piedade, near Belo Horizonte.

Other Physics Department have included, recently, astronomical research in their plans. The Physics Department of Federal University of Rio Grande do Norte has installed an impersonal astrolabe in Natal and supports the existence of a research group in Astrophysics. In the Physics Department of Federal University of Espirito Santo, in Vitoria, there is a group interested on Relativistic Astrophysics. In the Physics Department of Federal University of Paranã, in Curitiba, researches on Space Physics and Orbital Dynamics are being carried out.

3. NATIONAL OBSERVATORY

In the last decade, while the Brazilian Astrophysical Observatory (OAB) was being built (see next section), National Observatory increased its staff employing astronomers from ITA, CRAAM and USP and hiring others from abroad. At the end of the decade, National Observatory had already a modern Astronomy Department.

The main activities of the National Observatory Astronomy Department are grouped in four areas. 1. Fundamental Astronomy; 2. Stellar Astrophysics; 3. Extragalactic Astronomy; 4. Instrumentation.

The works on Fundamental Astronomy are centered on the operation of a Danjon's impersonal astrolabe and of photographic cameras installed in OAB 1.6-m telescope and in National Observatory 6-m-focus refractor.

The works on astrophysics are mostly focused on the operation of OAB coudē and Cassegrain spectrographs and, since 1982, of a detector Reticon. Besides that, researches on Stellar Astronomy are making use of data obtained through IUE satellite as well as photopolarimetric data gotten in the Cassegrain focus of the 1.6-m telescope. The studied objects include Be stars, optical pulsars, cataclismic variables, BY Dra, variables stars, novae, etc. In Extragalactic Astrophysics, besides OAB data, plates obtained from ESO and data acquired with the millimetric radio telescope of CRAAM are being used. An image analysis laboratory equipped with a PDS 1010 A coupled to a SISCO computer is held by National Observatory for plate analysis. The accomplished works include quasars, galaxies and clusters of galaxies. Since the begining of Reticon functioning, a survey of radial velocities of Southern Hemisphere galaxies is being done.

Theoretical researches include, among others, the following subjects. Coronae and cromospheres in cold stars, expanding envelopes, Be stars and planetary nebulae.

In the instrumental domain, the construction of a spectrophotometer-spectropolarimeter and of a fast photometer has just been accomplished. This last instrument is already functioning. A low frequency interferometer to be installed in Vassouras, near Rio de Janeiro, is under construction.

4. BRAZILIAN ASTROPHYSICAL OBSERVATORY (OAB)

The Brazilian Astrophysical Observatory is a national laboratory under management of National Observatory. It is located in Pico dos Dias (1860-m high), municipality of Brazópolis in the South of Minas Gerais State. This observatory was funded by the Federal Government after a joint request made by National Observatory, Aeronautics Institute of Technology, the University of Sao Paulo and Federal University of Minas Gerais. Under coordination of Professor Luiz Muniz Barreto, a Boller & Chivens, Ritchey-Chretien/coudé telescope of 1.6-m aperture was acquired. This is the main OAB instrument, operating since 1980. Besides this reflector, since 1983, a Cassegrain parabolic Zeiss-Jena 60-cm telescope is also in operation.

The peripheric instruments available to the user are 1. coudé spectrograph; 2. Cassegrain spectrograph; 3. photographic camera; 4. photometers.

The coudé spectrograph is composed of a group of high reflectivity mirrors and works with a dispersion of ~18.2 Å/mm in 1st order and ~19 Å/mm in 2nd order. The Cassegrain spectrograph is constituted of two networks, one of 1,200 line/mm (40-Å/mm dispersion). and another of 300 line/mm (193-Å/mm dispersion).

The photographic camera, has been built to work in the Cassegrain focus, with effective focal relation f/10 and has a field corrective lens of 2 elements that produces a field with corrected images and without vignetting of diameter 22 cm. The scale in the plate is 12.9 arcseconds per millimeter. The photographic laboratory is equipped for plate hipersensibilization.

The available photometer is a 1-channel 4-filters fast photometer which can be utilized in the two OAB telescopes. A ultrafast photometer, with 0.5-msec resolution and with several ways of operation controlled by a microprocessor, is also under operation.

The Boller & Chivens 60-cm telescope of the Astronomical and Geophysical Institute, of high mechanical accuracy, presently installed in Abrahão de Moraes Observatory, will be transfered soon to OAB.

5. ASTRONOMICAL AND GEOPHYSICAL INSTITUTE (IAG-USP)

The Astronomy Department of University of Sao Paulo has been created in 1972, almost at the same time as the inauguration of Abrahão de Moraes Observatory, in Valinhos. It assembled the astronomical activities of the Astronomical and Geophysical Institute. Under the direction of J.A. Freitas Pacheco, it had a fast grown and in a few years has reached its present size. In 1982 part of the Radio Astronomy Department of National Observatory was transfered to it. Today, the Department of Astronomy of IAG-USP is the biggest nucleus of astronomical researches in Brazil, assembling more than 30 researchers as its permanent staff, several visiting researches and more than 30 graduate scholarship students. The Astronomy Department activities may be grouped into several areas. 1. Fundamental Astronomy; 2. Mathematical and Dynamical Astronomy; 3. Solar System Astronomy; 4. Interstellar Medium; 5. Cold-Stars; 6. Hot Stars; 7. Galaxies and Quasars; 8. Clusters of Galaxies; 9. Instrumentation.

The works on Fundamental Astronomy are done in Abrahão de Moraes Observatory, in Valinhos. There functions a meridian circle AM-190 equipped with photoelectric readers of the graduate circles, and a Danjon's impersonal astrolabe. This last has been modified to permit observations at 45° zenithal distance. These instruments are utilized in catalog work. The results of solar observation with astrolabe have been obtained before the ones in Northern observatories.

The astrophysics researches are divided in equal proportions between theoretical and observational areas. Observational works made use of the 1.6-m telescope of OAB and the 60-cm telescope of Abrahão de Mores Observatory, besides the observations done in ESO and CTIO (Cerro Tololo), and in the Itapetinga Radio Observatory. The Department has been concentrating great activity in the development of detector systems. It owns a photopolarimeter operating effectively in the band 0.3-0.9 μ. A CCD camera and an infrared photospectropolarimeter are under construction. A millimetric radio telescope of 2.4-m diameter is being installed in Sao Paulo and will operate firstly in 115 GHz. Abrahão de Moraes Observatory telescope is working since 1982 with a K-band photometer developed in Meudon Observatory and has already allowed the detection of more than 1,000 sources brighter than m_K=4.5 in the South Galactic plane.

The observed objects were quasars, galaxies active nuclei, cataclysmic variables, Be stars, infrared sources, population-II stars, X-rays binary sources, clusters of galaxies, optical pulsars, reflection nebulae, etc...

Theoretical researches have included among many other subjects: cosmic-ray origin, acretion disks and X-rays sources, plasma acceleration mechanisms, detection of cosmic and solar neutrinos, emission line models for active nuclei of galaxies, molecular astrophysics, planetary nebulae, and H II regions.

6. CRAAM AND ITAPETINGA RADIO OBSERVATORY

In 1968, the Radio Astronomy Group working in the Physics Department has changed into Mackenzie Center of Radio Astronomy and Astrophysics (CRAAM), an autonomous laboratory in Mackenzie University. It became a federal institution in 1977 and is functioning today in the Space Research Institute (INPE).

In 1970, CRAAM has built the Itapetinga Radio Observatory, in Atibaia, near Sao Paulo, transfering the whole equipment from Campos do Jordão. Later on, it has installed a great accuracy radio telescope for millimetric waves, of 13.7-m diameter. The radio telescope is operated in 10.7 GHz, 22 GHz, 30 GHz and 44 GHz. Some measurements have been executed in 90 Hz, showing a 25% efficiency. Recently, an acustic-optical spectrometer of high resolution has been completed.

The 13.7-m radio telescope is used by astronomers from several Brazilian institutions and has been serving for researches on solar, galactic and extragalactic radio astronomy. In the case of solar radio astronomy, this antenna presents the advange of remaining pointed out at the Sun during long periods as it is closed in a plastic radome which protects it from distortions caused by an overheating; it also allows measurements with a sensibility 2 orders of magnitude greater than those of solar-patrol radio telescopes.

CRAAM solar physics program is directed towards the following study areas. 1. Solar bursts; 2. Evolution of active regions; 3. Quiet and disruptive filaments; 4. Quiet regions and coronal holes; 5. Sun-Earth relationship. The conjugation of the millimetric observations and the high-energy measurements with SMM (solar Max), Hinotori and ISEE 3 satellites, as well as the measurement done in other radio observatories, have been permiting a better knowledge of the impulsive phase of solar bursts.

CRAAM researches in the galactic and extragalactic domain have included the discovery of several sources of water vapour in the galactic level as well as in the Magellanic clouds. Ammonia sources, SiO-maser sources, explosions in water vapour masers, have been also found out.

The radio telescope has also been used in experiments of VLBI in baselines with the Radio Observatory of Owens Valley (USA) and National Radio Astronomy Observatory (USA). Next year, these experiments will be part of NASA crustal dynamics program and of the VEGA program of Meudon Observatory and France's National Center on Space Studies.

7. ITA ASTRONOMICAL OBSERVATORY

ITA Astronomical Observatory was utilized, from 1967 to 1973, for variables stars photometric studies. From initial eclipsing binary studies it went to Cepheids, and in the period 1971-1973 it has been employed in an extense program of red dwarf stars observation for

periodicity research. Ninety stars have been observed. Thirteen of them have exhibited variation and 7 have been suspected. All variable stars (or suspected) have Balmer or ionized Calcium lines in emission.

The programs developed in this period have been the first observational ones in optical astrophysics conducted by a Brazilian observatory. Particularly, red dwarf observation program lead to the first full Brazilian papers in astrophysics to deserve international recognition and to be widely cited in the scientific litterature. The observational work has been continued in some observing missions at Cerro Tololo that helped to relate BY Dra variables to flare stars. Many among the discovered variable stars were lately observed in other observatories and with the satellite IUE and they have shown peculiarities that made them important objects in the stellar family. The most noticeable was the discovery of Lithium lines in the spectrum of V 1005 Ori, indicating its extreme youth.

8. UFRGS PHYSICS DEPARTMENT

The Physics Institute of Federal University of Rio Grande do Sul (UFRGS) owns an Astronomical Observatory with a 50-cm aperture Zeiss-Jena telescope installed in Morro de Santana, in Porto Alegre. The main equipment used is an automatic 6-filter photoelectric photometer with two systems of data acquisition allowing 0.01 to 100 seconds integration times. The Institute also disposes of a Zeiss MD 100 microdensitometer for the quantitative analysis of photographic plates.

The first researches on Astrophysics have been based on observations of the 21-cm line of neutral hydrogen accomplished together with the Argentinean Institute of Radio Astronomy. Presently the researches are concentrated in the optical domain. The 50-cm telescope has been used for photometry in the systems UBV and/or DDO (David Dunlap Observatory) of a great number of objects as globular clusters, red giants in open clusters, G and K stars in the solar neighborhood, semi-regular red variables, and Mira variables. The system ubvyβ was also used for absorption studies in the solar neighborhood.

The OAB 1.6-m telescope, the CTIO (Cerro Tololo) and Bosque Alegre (Argentina) station telescope have been used to several studies on extragalactic astronomy. Theoretical models of H II regions have been developed and compared to data obtained through observation.

9. THE ASTROPHYSICS DEPARTMENT OF THE SPACE RESEARCH INSTITUTE

Since its begining in 1968, the activities on high-energy Astrophysics of the Space Research Institute (INPE) have been developed aiming at an improving in the technology of payloads for space research using stratospheric baloons as vehicles. The payloads developed have included X- and Gamma-ray detectors. The first flights aimed at the measurement of radiations in the 0.03 to 10 MeV range present in the atmosphere, determining the spectrum of this radiation in magnetically calm and perturbed times. Once understood the flow of atmospheric origin, the studies were enlarged to the components of solar, galactic and extragalactic origin. The following step consisted in the construction of detectors using Germanium-Lithium diodes that were used for flow measurements in 0.511 MeV arising from the direction of the galactic center.

The Baloon Launching Center of INPE, allows the launching of loads of 2,000 kg to 40 km altitude for 20 hours.

10. FEDERAL UNIVERSITIES

Astronomy exists as department or research group in several Federal Universities. Besides the Federal University of Rio Grande do Sul, whose activities have been already described, astronomical installations exist at the Federal Universities of Minas Gerais, Rio de Janeiro and Rio Grande do Norte. In Minas Gerais, the Serra da Piedade Observatory, near Belo Horizonte, contains a 60-cm Zeiss-Jena reflector. In Rio de Janeiro, Valongo Observatory has a 40-cm Zeiss astrograph which is being installed in Campinas (Sao Paulo State), assigned to continue astrometrical and photometrical studies of comets and asteroids. In Rio Grande do Norte, the Federal University's Center of Exact Sciences maintains at work, in Natal, a Danjon's impersonal astrolabe; it has also a 73-MHz radio interferometer and a simple photometer for usage with a little

telescope.

11. MATHEMATICAL AND DYNAMICAL ASTRONOMY SEMINAR

The theoretical researches on Celestial Mechanics in Sao Paulo area has an organization different from the one adopted in other domains. The Mathematical and Dynamical Astronomy Seminar assemble researchers from the Astronomical and Geophysical Institute of the University of Sao Paulo, Aeronautics Institute of Technology and from two Mathematics Departments of Sao Paulo State University: the Institute of Geosciences and Exact Sciences of Rio Claro and the School of Engineering of Guaratinguetá.

The works done by the Seminar fellows cover several areas: Multiple resonance and non-integrable systems, resonances in the Solar System, planetary satellites and applied Celestial Mechanics. The most ancient research domain in the seminar is the study of planetary satellites. Many works related with Jupiter Galileans, Saturn and Uranus satellites have been already published.

12. BRAZILIAN ASTRONOMICAL SOCIETY (SAB)

Brazilian astronomers met in the Brazilian Astronomical Society, a scientific society formed in 1973 having 110 full members. Annual meetings of scientific discussion and Colloquia are promoted by this Society. In 1984, SAB promoted its 11th Annual Meeting, in which more than 50 papers have been presented. SAB also publishes a quarterly information bulletin containing general subjects related to the astronomical community and to the development of Astronomy in Brazil.

13. CONCLUSIONS AND ACKNOWLEDGEMENTS

I am indebted to my colleagues for the privillege of being invited to give this lecture. However my great satisfaction has been the possibility to stop and evaluate the progresses of Brazilian Astronomy in less than one generation from its begining, around 1960, till nowadays. To sum up today's Brazilian Astronomy and its evolution is a difficult problem. The solution given here is a mere approach, and surely affected of a personal equation. I thank the colleagues who answered my information requests and apologize for some non-linearities which I could not escape from. Many points considered in this article deserve more attention and a handfull of them certainly a specific study.

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Cosmología
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