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REPORT ON THE FIFTH UNITED NATIONS/EUROPEAN SPACE AGENCY WORKSHOP ON BASIC SPACE SCIENCE: FROM SMALL TELESCOPES TO SPACE MISSIONS, HOSTED BY THE ARTHUR C. CLARKE CENTRE FOR MODERN TECHNOLOGIES ON BEHALF OF THE GOVERNMENT OF SRI LANKA

(Colombo, 11-14 January 1996)

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INTRODUCTION

A. Background and objectives

1. The General Assembly, in its resolution 37/90 of 10 December 1982, decided, upon the recommendation of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE 82), that the United Nations Programme on Space Applications, *inter alia*, should promote greater cooperation in space science and technology between developed and developing countries as well as among developing countries.

2. The Committee on the Peaceful Uses of Outer Space at its thirty-seventh session, held at Vienna from 6 to 16 June 1994, endorsed the programme of United Nations workshops, training courses, expert meetings and seminars proposed for 1995, outlined by the Expert on Space Applications in his report (A/AC.105/555, paragraph 62). Subsequently, the General Assembly, in its resolution 49/34 of 9 December 1994, endorsed the United Nations Programme on Space Applications for 1995.

3. In response to General Assembly resolution 49/34 and in accordance with the recommendations of UNISPACE 82, the Fifth United Nations/European Space Agency Workshop on Basic Space Science: From Small Telescopes to Space Missions was organized, within the framework of the activities of the Programme for 1995, particularly for the benefit of countries in the region of the Economic and Social Commission for Asia and the Pacific.

4. The Workshop was organized jointly by the Office for Outer Space Affairs of the Secretariat, the European Space Agency (ESA) and the Arthur C. Clarke Centre for Modern Technologies at Colombo.

5. The objectives of the Workshop were: (a) to inaugurate the astronomical telescope facility at the Arthur C. Clarke Centre; (b) to examine research and education programmes for small telescopes; (c) to address robotic telescopes and telescope networking; (d) to review telescope projects; (e) to discuss new research results on the Sun, binary stars and cosmology; (f) to focus on international cooperation in basic space science; and (g) to review astronomical software and databases that could be accessed on the World Wide Web.

B. Organization and programme of the Workshop

6. The Workshop was held from 11 to 14 January 1996 at Colombo. The Workshop continued a series of annual United Nations/ESA workshops on basic space science, which had been held in India in 1991 for Asia and the Pacific (A/AC.105/489), in Costa Rica and Colombia in 1992 for Latin America and the Caribbean (A/AC.105/530), in Nigeria in 1993 for Africa (A/AC.105/560/Add.1) and in Egypt in 1994 for Western Asia (A/AC.105/580).

7. The Workshop was attended by 74 astronomers and space scientists from 25 countries: Austria, Canada, China, Colombia, Czech Republic, Egypt, France, Germany, Honduras, India, Indonesia, Japan, Malaysia, Morocco, Pakistan, Philippines, Russian Federation, South Africa, Spain, Sri Lanka, Oman, Thailand, United Kingdom of Great Britain and Northern Ireland, United States of America and Viet Nam. Financial support to defray the cost of air travel and living expenses of 32 participants was provided by the United Nations and ESA. The expenses for other participants were defrayed by the Institute for Space and Astronautical Sciences of Japan; The Planetary Society; the German Space Agency (DARA); the University of Arizona in the United States; Swarthmore College in the United States; the National Astronomical Observatory of Japan; the Bisei Astronomical Observatory of Japan; and the Observatoire Midi-Pyrénées of France. Facilities, equipment and local transportation were provided by the Government of Sri Lanka.

8. The programme of the Workshop (see the annex to the present report) was developed jointly by the Government of Sri Lanka, the Office for Outer Space Affairs, ESA and the Arthur C. Clarke Centre for Modern Technologies.

9. The present report, which covers the background, objectives and organization of the Workshop, in addition to presenting the observations and recommendations of the Workshop and a summary of the technical presentations, has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants reported on the information that they had acquired and the work conducted during the Workshop to the appropriate authorities of their Governments, universities, observatories and research institutions. Selected papers presented during the Workshop will be part of a technical study entitled "Developing astronomy and space science worldwide", to be published by the United Nations in 1996. The technical study will also contain the materials for the assessment of the United Nations/ESA workshops on basic space science organized in the period 1991-1996.

I. OBSERVATIONS AND RECOMMENDATIONS

A. World Space Observatory

10. It was stated that, considering the increase in the participation of the developing countries in astronomy and space science and taking into account the foreseeable rapid increase of participating professionals in the developing countries, it was important to establish the tools for their participation at the most advanced scale. Since access to smaller telescopes and the use of archival data in astronomy would result in an expanding and professionally competent astronomical community in the developing countries, it should be recognized that access to front-line facilities would be required for many scientists. As the costs associated with major ground-based facilities would often pose excessive economic burdens for the developing economies, such conditions would give rise to an unproductive conflict cycle in which many of the best trained scientists would tend to travel elsewhere for their professional lives, which would remove an important asset for their countries: highly trained people.

11. In a world where concentration of first-scale astronomical facilities was an unstoppable trend, a technologically attractive solution could be supplied by a World Space Observatory. That would also stimulate industrial development, enhance and improve the communications infrastructure and allow independent local access to a prime astronomical facility.

B. Inauguration of the telescope facility at the Arthur C. Clarke Centre for Modern Technologies

12. The Arthur C. Clarke Centre for Modern Technologies was established in 1984 with the objective of accelerating the introduction and development of modern technologies in Sri Lanka in the fields of computers, communications, space technologies, robotics and energy. The Arthur C. Clarke Centre had been planning to combine activities related to space communications and satellite remote sensing since its establishment and to launch a practicable programme in the field of space technologies. That programme was only confined to scientific and technical work within the geostationary orbit. Following the introduction in 1994 of an action plan based on the Beijing Declaration on Space Technology Applications for Environmentally Sound and Sustainable Development in Asia and the Pacific, which had been adopted by the ministerial conference on space applications for development in Asia and the Pacific, held at Beijing from 19 to 24 September 1994, the Arthur C. Clarke Centre established a space applications centre in 1995. Following the decision to accept the donation of a telescope to the Arthur C. Clarke Centre, plans were made to commence astronomical programmes in the space applications centre.

13. In the early 1960s, the Universities Commission in Sri Lanka, established by the Governor General, identified the importance of astronomical education and research and recommended that a separate Department of Astronomy should be set up and provided with the necessary equipment and facilities. That recommendation did not materialize. Sri Lanka currently has a Zeiss planetarium that contributes to the astronomical education in the country.

14. The few other small telescopes available in the country were primarily used for amateur observation purposes. However, many organizations and individuals were keen to acquire knowledge in astronomy, despite the limited facilities available.

15. At the first United Nations/European Space Agency Workshop on Basic Space Science, held at Bangalore, India, in 1991 (A/AC.105/489), a team of scientists representing Sri Lanka indicated the importance to their country of acquiring an astronomical telescope. At the Workshop, the United Nations recommended the establishment of an observatory in Sri Lanka. Subsequently, the Office for Outer Space Affairs made a request to the Government of Japan to consider donating a telescope to Sri Lanka. The Government of Japan, after having considered the request, offered a 45-centimetre Cassegrain reflecting telescope to the Government of Sri Lanka.

16. A team of officials from the Government of Japan and the United Nations visited Sri Lanka in 1992 and a meeting was held at the Sri Lanka Association for the Advancement of Science at Colombo. Owing to the large expenditure for the infrastructure required for the telescope and considering the technical capabilities of the Centre, it was requested to take over the project. It was decided to instal the telescope on the fourth floor of the new building of the Arthur C. Clarke Centre, which was under construction at the time.

17. It was also decided to construct the telescope room with a sliding roof instead of a dome due to the high costs involved. The Board of Governors of the Arthur C. Clarke Centre established in 1994 a Steering Committee comprising astronomers, scientists and engineers to prepare an action plan to implement the project.

18. The first meeting of the Steering Committee was held in September 1994. The Minister of Science, Technology and Human Resources Development of Sri Lanka took a keen interest in the project and obtained the necessary approval to accept the 45-centimetre reflecting telescope from the GOTO Manufacturing Company of Japan. The telescope arrived in Sri Lanka in 1995.

19. The Steering Committee identified certain areas to be considered for future activities under the telescope project. It was decided to make the facility available for the following activities: (a) facilitating research work of undergraduate and postgraduate degree programmes related to astronomy in the universities of Sri Lanka; (b) linking up with international astronomical observation programmes; (c) conducting routine observation programmes with the assistance of the astronomers and the staff of the Arthur C. Clarke Centre; (d) maintaining a database at the Arthur C. Clarke Centre and linking it up with other countries through Internet; and (e) promoting astronomical education in Sri Lanka and assisting amateur astronomical associations.

20. In the telescope project the Arthur C. Clarke Centre will act as the host and help the scientists and astronomers in Sri Lanka to obtain the optimum usage of the telescope. The telescope facility was inaugurated during the Fifth United Nations/ESA Workshop on Basic Space Science (see session 5 in the annex to the present report).

II. SUMMARY OF PRESENTATIONS

A. Small telescopes: research

Russian/Former Soviet Union experience in small telescope usage for professional astronomy and education

21. It was stated that astronomers in the Russian Federation never had enough large optical telescopes and traditionally used small ones (mirror diameters up to 1 metre) to carry out classical and more modern astronomical observations. Russian astronomical facilities were briefly described. The following issues were discussed: small optical (stellar) telescope usage for photometry of variable stars and active galactic nuclei (AGN), including the participation in programmes for monitoring bright variable stars and AGN; radial velocity of star measurements aimed to study the Galaxy (i.e. the Milky Way) structure; registration of optical components of gamma-bursts; registration of microgravitational lensing etc.; and small instrument usage for astronomical education.

Small astronomical telescopes for research and education at Helwan, Egypt

22. It was stated that the Helwan Observatory had been constructed in 1903 on a limestone plateau 25 kilometres south of Cairo. At that time, Helwan had been a village of about 5,000 inhabitants characterized by sunny days and nights with clear skies and high atmospheric transparency. Astronomical observations at Helwan had started in 1905 using a 30-inch reflecting telescope. The observatory had participated in various international activities and projects such as the observation of Halley's comet in 1910; the observation of planets and their discovery; the observation and studies of some galaxies and nebulae south of latitude 30° north; the photographic observation of the Moon and planets; and the total eclipse of the Sun in 1952 in the Sudan and the discovery of the spectral lines of the inner corona in cooperation with the Meudon Observatory in France.

23. Owing to the expansion of Helwan, currently the centre of heavy industry in Egypt, and the effects of light and atmospheric pollution, the quality of astronomical observations had been greatly affected and a new site had been chosen at Kottamia in the north-eastern desert, 80 kilometres from Helwan on the Cairo-Suez Road on a hill 476 metres above sea level. The Kottamia Observatory, which had been built and started functioning in 1962, housed a 74-inch reflecting telescope manufactured in England. Since 1964, the Helwan observatory had specialized in solar observations by Coude refractor with a 6-inch lens manufactured by Carl Zeiss Jena. The daily routine observations for sunspots covered three solar cycles (20, 21 and 22), and the monthly reports on solar photospheric aspects had been sent to the world's solar data centres for more than 30 years. In the preceding 10 years, solar observations had been developed to become photographic, for studying proper motions of the sunspots. Also, hydrogen alpha and calcium-II II K-line filters manufactured at Ondrejov observatory near Prague, connected with a 6-inch Coude refractor, were used for studying chromospheric phenomena. In addition, a 25-centimetre horizontal Coelostat equipped with an auto-collimating spectrograph with a high dispersion had been erected in 1957 at Helwan observatory for solar spectroscopy. There was a programme for using it to study the terrestrial lines for air pollutants at Helwan. There were also small astronomical refracting telescopes that had been installed in 1965 at Helwan, for visual and photographic tracking of artificial Earth satellites. The station was developed to use laser tracking through a programme with the Czech Republic and the United States and had been operating for more than 10 years. There were programmes for developing the 30-inch reflecting telescope at Helwan and equipping it with a charge-coupled device (CCD) camera for observing the geostationary artificial satellites. The 6-inch Coude refracting telescope, 25-centimetre horizontal Coelstat, 30-inch reflecting telescope and photographic and laser station for artificial Earth satellites were all used in the experimental and practical university courses for undergraduate and postgraduate students from the Department of Astronomy at Cairo University and Al-Azaher University at Cairo. They had also been in training courses for research assistants at the National Research Institute of Astronomy and Geophysic, and for training courses and international summer schools

in astronomy for young astronomers held in 1981 and 1994 in cooperation with the International Astronomical Union.

Astronomy with small telescopes: the Indian experience

24. It was stated that modern astronomy had been institutionalized in India in 1790 as a British colonial aid. A number of telescopes in the aperture range of 6-15 inches had arrived in India during the period 1837-1907. Of those, scientifically the most productive had been the 6-inch and 8-inch telescopes in use at Madras during the nineteenth century and the 8-inch Cooke astrograph at Nizamiah Observatory at Hyderabad, used for Carte du Ciel work. The Madras telescopes, since remodelled, were still in use at Kodaikanal; the 6-inch telescope was used for taking white-light pictures of the Sun, while the 8-inch telescope was used for public viewing and cometary studies when needed. A number of small telescopes had been purchased and a couple had been built after India had become independent in 1947; they were used for research, mostly stellar photometry. In addition, small telescopes, especially the C14 Celestron model, had been acquired by a number of organizations for purposes of research, education and public viewing. A particularly productive small telescope for night-time astronomy was a locally made 15-inch reflector (placed on a mounting vacated by an old 6-inch telescope) at Vainu Bappu Observatory at Kavalur. It had been used for building a valuable uniform database, extending over 15 years, for selected RS CVn-type binary stars.

On the importance of astronomical photometry of variable stars with small telescopes in the Asian region

25. It was stated that variable star research was one of the most important branches in astronomy and astrophysics. The stars changed their radiative intensities with time. In order to catch such changeable phenomena precisely, they should be observed continuously and successively from various observatories in different countries. The significance of the participation of Sri Lanka in such international cooperative observations was also reviewed.

Spacewatch experience applied to the new telescope in Sri Lanka

26. It was stated that "Spacewatch" was the proper name of a programme at the University of Arizona in the United States to study statistics of the various populations of comets and asteroids in the solar system. The new telescope in Sri Lanka could be used for astrometrical studies of the brightest objects, including perhaps near-Earth asteroids, provided the limiting magnitude 19 was reached. Astrometry software packages were readily available. Previous studies of astrophysic possibilities in Sri Lanka were described in *Fundamental Studies and Future of Science*,[1] a book based on presentations at the dedication of the Institute for Fundamental Studies in Sri Lanka.

Astrometry of near-Earth objects using small telescopes

27. It was stated that, with the availability of cheap CCD detectors over the past few years, together with the personal computers and software necessary to analyse the images, it had been possible for a wide variety of interested astronomers - professional and amateur alike - to make observations of near-Earth objects (NEO), i.e. asteroids and comets that crossed, or came close to, the orbit of planet Earth. Such observations had been important in defining the heliocentric orbits of recently discovered NEO, for which immediate follow-up was needed. The necessity of immediate follow-up astrometry militated against the use of large telescopes since those were generally scheduled months ahead of time, usually for quite different astronomical topics. Thus, small, suitably equipped telescopes with enthusiastic observers were proving to be invaluable in ensuring that NEO were not discovered and then immediately lost because the ephemeris uncertainty was large in the absence of a sufficiently long observation arc (arc being defined as the orbital distance separating two points). Those objects were important for a number of reasons, and not just because they were potential impactors of planet Earth. They were also spacecraft targets (several NEO would be visited by spaceprobe missions over the next decade), and in the twenty-first century they would be the economic sources of raw

materials for building large structures in space. In discussing the situation worldwide, examples were given of different groups and individuals who had made important contributions over the past year or so, and the detailed operations using several small telescopes at the Siding Spring Observatory in Australia.

Searching for and monitoring supernovae

28. It was stated that the study of supernovae had significant implications for many areas of astrophysics, ranging from stellar evolution to cosmology. The variation in the photometric evolution of supernovae was an important clue to their progenitors' life histories. Type Ia supernovae, in particular, had been widely used as distance indicators to determine the Hubble constant and, most recently, to measure the motion of the Galaxy (i.e. the Milky Way) relative to distant galaxies. For those and many other studies, it was necessary to have a large sample of supernovae with accurate multi-colour light curves. A supernova search had just commenced in the nearby Abell clusters using a CCD camera on a 1.2-metre telescope on Mount Hopkins, Arizona, United States. Other searches were being carried out at Berkeley, California (United States), Mount Stromlo (Australia) and Cerro Tololo (Chile). There was an unprecedented opportunity (and need) for small telescopes around the world to contribute to those research efforts either by complementing the current search programmes or, perhaps even more importantly, by making careful follow-up observations of the newly discovered supernovae.

The 15-cm refractor telescope of the astronomical observatory in the Philippines

29. The 41 years of observational functions of the 15-centimetre refractor telescope of the astronomical observatory of the Philippine Atmospheric, Geophysical and Astronomical Services Administration were described. Some of the problems faced by the observatory and the prospects for their solution were also discussed.

New technologies to produce small telescopes with apertures smaller than 1 metre for routine astronomical observations and education

30. It was stated that numerous astronomical observatories had been established in all parts of the world. Large installations were the drivers of technology, not only for astronomy, but also for other engineering problems. Those installations required excellent viewing sites, preferably as large as possible; alternatively, space-borne telescopes were used to overcome the atmospheric barriers of Earth. Huge costs were involved, with requirements constantly growing. Time-sharing and guest observation at a large installation was one way of overcoming the problems, but not sufficiently. To develop the necessary background and infrastructure locally, a series of small high-quality telescopes was necessary for routine observation, education and research to contribute substantially to an international network of information. The telescope should have sufficient aperture with good optical quality and professional computer control with adequate flexibility for different applications. The experiences from large instrument design and manufacturing might be used in realizing such telescopes. Based on the traditional larger telescopes up to 3.6 metres in diameter, for instance, a 530-millimetre telescope featuring a Cassegrain and a Coude focus had recently been established in Malaysia at an Islamic college, mainly for Moon and planet observations. The telescope had a professional computer control system that was able to compensate positioning for atmospheric refraction influences and mechanical deformation of the tube under different observation conditions. The electronics system and the optical technology employed were derived from instruments such as those at the new ground station of ESA at Tenerife for satellite communication and space debris observations. Other technologies to be employed were CCD imagers and active and adaptive optics. The design of optical components had also taken a tremendous developmental step forward with modern testing technology equipped with CCD cameras and up-to-date interferometers. The computer-controlled design control, that is, local design correction at various surfaces, resulted in better image quality and the most effective use of the telescope. A special field in astronomy was the observation of the Sun, Moon and the planets. Solar telescopes required a particular design. Recently, an educational unit had been installed in the Republic of Korea providing a 150-millimetre

apochromatic objective particularly suited for solar observations. The unit was equipped with a number of special peripheral accessories for solar imaging, such as filters and trackers. The unit was equally capable of night-time observation.

B. Small telescopes: education

The role of public observatories in astronomical observations

31. It was stated that the number of public observatories in Japan equipped with moderate to large telescopes (60-100 cm), having high observational capabilities, was rapidly increasing. Those observatories, mostly established in the 1990s, had started their astronomical observations in collaboration with amateurs and research institutes. Whereas most of them were working in CCD imaging and/or CCD photometry, some observatories were carrying out spectroscopic observations of stars and galaxies. That was a new trend in public observatories in Japan, and they were working as local centres in their own districts, both for astronomy popularization and astronomical observations. Although they were still faced with many problems similar to those of the research observatories, such as limited staff and insufficient budgetary resources, their observation efforts would in the near future provide a new epoch of domestic as well as international network observations. Some examples of public observatories, together with their expected roles, were briefly discussed.

C. Robotic telescopes and telescope networking

The oriental robotic telescope network

32. It was stated that the scientific objective of the oriental robotic telescope (ORT) network was non-stop observation of variable stars, by complementing automated networks operating at specific longitudes and latitudes. As selected from archives of meteorological satellites, sites in the Arab world had high-quality astronomical conditions. Photometric 1.30-metre diameter telescopes, extended for use in spectroscopy in the future, could be fully automated. The data collected by each station would be simultaneously transmitted by telecommunication satellites to all the scientific centres of the network. Included in the project were schemes for teaching and training in the technical use of the equipment, basic courses in astronomy and astrophysics and opportunities for student practice on a fully equipped small-diameter telescope.

Robotic astronomical telescopes as ground-based support for satellite projects: the Ondrejov robotic telescope

33. The design, development and current status of the Ondrejov robotic telescope, based on commercially available parts (Schmidt-Cassegrain telescope, CCD cameras and personal computers), were discussed with emphasis on the satellite projects (gamma ray observatory - Burst Allert Coordinates Distribution Network (BACODINE), High Energy Transient Explorer (HETE) and International Gamma-Ray Astrophysics Laboratory (INTEGRAL). Explanations of the software solution for remote control of appropriate instruments via electronic mail (e-mail), Telnet and file transfer protocol (FTP) connections were provided. The software solution was based on Universal Internet Shell (UIS), which drove the telescope, CCD cameras and communication with local and remote servers. UIS received e-mail messages, prepared lists of targets to be observed with a specific level of priority, provided those observations and transmitted observation data to remote users. Although the main scientific goal of the Ondrejov robotic telescope was to provide follow-up observations of optical counterparts of gamma-ray bursts, there were also plans to use it in other areas of astronomy where automatization was required. The whole system was based on inexpensive parts, so that such systems could be easily duplicated at other observation sites.

D. Telescope projects

The large sky area multi-object fibre spectroscopy telescope project

34. It was stated that China had proposed to build a new spectroscopic survey telescope. A special reflecting Schmidt telescope configuration was put forward for that project. The optical system was horizontal. The primary mirror was spherical and segmented. It faced towards the northern sky. In its spherical centre there was a segmented plane mirror. The clear aperture was 4 metres and the *f*-ratio was 5. The angular field of view covered 5.0 square degrees and 4,000 objects could be observed simultaneously by using optical fibre. The scientific goal was to make a 20,000 square degree spectroscopic survey, including galaxies, of up to 20.5 magnitude with about 1 million galaxies in that sky area, 1 million quasars and many variable objects, and to identify numerous objects found by radio, X-ray, infrared and other surveys in that sky area.

Status of the upgrade of the Kottamia telescope in Egypt

35. It was finally decided in 1994 to contract the refurbishment of the Kottamia telescope after the evaluation of several submitted tenders. The National Research Institute for Astrophysics and Geophysics (NRIAG) at Helwan and the Ministry for Science and Education of Egypt had entered into a contract financed completely by the Egyptian Government. The task included the design and manufacture of a new optical system for the 1.88-metre telescope tube. The mirror materials were made from Schott Zerodur to ensure superb optical quality in the respective temperature range for observations. In order to achieve a high-quality optical surface in working conditions, i.e. in all applicable positions of the telescope, a new support or mirror cell for the primary mirror would be necessary. Therefore a new 18-point support instead of the old 9-point support was proposed and would be part of the project. The new optics would be integrated in the nearly 30-year-old Kottamia telescope and first light would be expected early in 1997. In July 1995 the representatives of NRIAG had accepted the test results of the blanc for the primary mirror at a factory in Germany. The mirror was still being ground and polished, resting on an 18-point support just as in the future telescope cell. The procedure would take several months, first creating a spherical surface of already high surface quality and then gradually approximating the required spherical shape. Preliminary tests of the mirror shape showed excellent results, and the preliminary acceptance tests would be accomplished according to schedule in 1996.

The astronomical observatory of Honduras: a project for permanent international cooperation

36. It was stated that it took considerable effort to establish an astronomical observatory in any country of the world; however, to do so in a developing country was a major challenge. In Central America, the first astronomical observatory had been initiated in Honduras at the beginning of the 1990s. The first step in the establishment of the research centre had already been taken, following a strategy based on regional cooperation involving national universities in Central America, at an international level, making contact with astronomers and prestigious astronomical research centres. Since 1994, an astronomical observatory had operated at Tegucigalpa, at the Universidad Nacional Autónoma of Honduras. That academic unit had been equipped with a 42-centimetre computerized telescope and other supporting facilities. In 1995, the observatory had hosted the first Central American course in astronomy and astrophysics and, jointly with other European and Latin American universities, was currently promoting a regional training programme for astronomers of Central America. Several important cooperation agreements were in the process of being signed in order to contribute to the development of basic space science in the region. The main activities and project of the Astronomical Observatory of Honduras were discussed.

The establishment of an astronomical observatory in Colombia

37. It was stated that the Andean equatorial region, where Colombia was located, offered a combination of geographical attributes that had great scientific potential for a certain class of observations. Its equatorial latitude and presence of high peaks (above 4,000 metres) opened up many scientific opportunities. Observations of the galactic disc (in the radio part of the spectrum) and observations that required simultaneous access to both celestial hemispheres were favoured by characteristics of the sites in Colombia. Other classes of experiment, such as automated supernova searches, complemented existing efforts in sites on the northern or southern hemisphere. The scientific opportunities and the feasibility of establishing an astronomical observatory in Colombia had been discussed.

E. The Sun

Solar neutrinos: short history and present-day situation

38. It was stated that the first solar neutrino experiment performed by the group of R. Davis Jr. at the Homestake mine with C_2Cl_4 had shown discrepancies with theoretical predictions. The decisive experiment, showing that the main cause of the discrepancies was due to the properties of neutrinos, had been performed with a gallium target in the Soviet American Gallium Experiment (SAGE) and in the European Gallium Experiment (GALLEX). Interesting results had been achieved by analysing the correlation of the ^{37}Ar production in Davis' experiment and magnetic field strength on the surface of the Sun measured at the Stanford University magnetometer. Recent calculations for the interior of the Sun had also reduced the discrepancies between experimental findings and theory. New generations of solar neutrino detectors (Superkamiokande, SNO), as well as theoretical work, would result in further discoveries and bring astronomy closer to the final solution of the problem.

The solar neutrino problem

39. Four operating neutrino observatories confirmed the long-standing discrepancy between detected and predicted solar neutrino flux. Among those four experiments, the Homestake experiment had been gathering data for almost 25 years. The reliability of the radiochemical method for detecting solar neutrinos had been tested by the GALLEX experiment. All efforts to solve the solar neutrino problem by improving solar, nuclear and neutrino physics had so far failed. That might also mean that the average solar neutrino flux extracted from the four experiments might not be the proper quantity to explain the production of neutrinos in the deep interior of the Sun. It had been emphasized occasionally that the solar neutrino flux might vary over time. The presentation focused on the periodic variation in the number of solar neutrinos detected on Earth.

Outer planets in the solar system in relation to solar activity

40. It had been demonstrated recently that the brightness of Neptune was anti-correlated to sunspot numbers for the period 1972-1989, but the anti-correlation suddenly had broken down in 1990. The visibility of the Great Red Spot of Jupiter, another outer planet, had been shown to be correlated to sunspot numbers between 1892 and 1947, and the correlation had broken down in 1947. The years 1947 and 1990 both corresponded with epochs of unusually high sunspot numbers, a manifestation of high solar activity. It was stated that the purpose of the paper was to investigate, using updated data, whether the abnormal behaviour of the two outer planets and solar activity might have a common cause, such as density variation of the local interstellar medium.

Some results on the solar corona during the solar eclipse of 24 October 1995 at Phan Thiet, Viet Nam

41. It was stated that remarkable results had been obtained by optical and radio astronomers in the investigation of the Sun in Viet Nam. The observation of the solar eclipse of 24 October 1995 at Phan Thiet, Viet Nam, and the possibility of developing optical and radio astronomy in Viet Nam were discussed.

Properties of neutrinos from supernovae

42. Calculated limits on the form factors of neutrinos emitted from supernovae were presented. Those limits were compared with the theoretical calculations of the properties of neutrinos in hot and dense backgrounds.

F. Binary stars

Cooperative observing programme in binary star research

43. Most of the binary systems were complex and observational studies were required to provide insight. There were many cases where collaboration among astronomers was needed in obtaining the data. The following types of systems that required attention were discussed: (a) systems requiring continuous monitoring; (b) systems having periods of integer day(s); (c) systems requiring times of minimum study; (d) systems with apsidal motions; (e) systems requiring multi-wavelength study during a discrete period of time; (f) long period atmospheric eclipsing binary systems; and (g) lunar occultation from different geographical locations.

Anomalous gravity darkening and mass loss in semi-detached close binary systems

44. From a quantitative analysis of the observed photometric elliptically periodical effect, values of gravity darkening could be empirically deduced for the distorted components of close binary stars. That research had revealed that the empirical gravity darkening determined for the main sequence components was generally consistent with existing theories of radiative and convective stellar atmospheres. Alternatively, the empirically deduced gravity darkening values were significantly greater than unity for Roche lobe-filling secondary components of semi-detached binary stars. That was interpreted by the enthalpy transport associated with the mass outflow from the secondary components filling the Roche lobe.

International cooperation in RS CVn binary system research

45. Photometric and spectroscopic research on RS CVn binary systems had been established through international cooperation between Chiang Mai University, in Thailand, and the Beijing Astronomical Observatory, in China, with the support of the National Research Council of Thailand and the National Natural Science Foundation of China during the period 1995-1997. The following research on RS CVn binary systems had been carried out by both institutes: photometric observations for the determination of the basic parameters and the long-term variations of starspots in RS CVn binary systems; and spectroscopic observations for the measurement of spot temperatures by the titanium oxygen (TiO) bands for RS CVn binary systems.

G. Cosmology

Cosmological challenges

46. The current dilemma in cosmology was discussed wherein the age of the universe (assuming that it had started with a big bang) was not sufficient to accommodate old stars and galaxies. Other problems with the big bang cosmology were also highlighted. Some alternative ideas proposed by the quasi-steady state

cosmology were described, and observational tests for distinguishing between the two models were proposed. There was hope that the forthcoming telescopes would provide an answer to those questions.

X-ray detections of quasars associated with low redshift, active galaxies

47. Archival data from the X-ray Roentgen Satellite (ROSAT) showed that in a sample of the 26 brightest galaxies with active nuclei (Seyferts), there were more than 54 X-ray sources within a degree on the sky that were physically associated with those galaxies. Almost all of those X-ray sources were quasars or related objects of much higher redshift than the central galaxy. The strong tendency for those quasars to pair across the galaxies confirmed evidence going back 30 years that quasars were intrinsically redshifted objects that were ejected from nearby, active galaxies. The current expanding universe and big bang creation paradigms then became untenable because the observations required extragalactic redshifts not to be expansion velocities and also required new matter and new galaxies to be continually created. Because the largest telescopes, in the range of 4-10 metres, were locked into programmes based on conventional redshift assumptions, the only remaining possibility was that telescopes in the range of 1-3 metres could use the opportunity to investigate a more viable cosmology.

The galactic emission mapping project: an international collaboration to survey the galactic radiation emission

48. It was stated that synchrotron radiation from relativistic electrons moving inside the magnetic field of the Galaxy (i.e. the Milky Way) was the main component of diffuse galactic emission at low frequencies (from 300 MHz to a few GHz). At higher frequencies (greater than 50 GHz) free-free emission from ionized hydrogen started becoming the dominant component. Accurate and complete maps of the diffuse galactic emission in the range of 0.5-10 GHz were required in order to study cosmic ray electrons in the galactic disk and the galactic magnetic field. The galactic signal was also the most relevant foreground contamination in cosmic microwave background radiation (CMBR) experiments. Improving the understanding of galactic emission at long wavelengths was therefore an essential task for extracting cosmological information contained in present and future generations of CMBR experiments. An international collaboration (Colombia, Italy, Spain, United States) had been formed with the aim of designing and building a dedicated system (the galactic emission mapping (GEM) project) for carrying out observations from a number of sites at different latitudes. The instrument consisted of a 5.5-metre parabolic reflector and receivers at 408, 2,300 and 5,000 MHz. Taking data at several frequencies allowed for the determination of spectral indexes of the different emission processes. Preliminary analysis and prototype tests indicated that a substantial improvement over the existing maps could be achieved within a few years from the beginning of the observing programme. A first observing campaign from the White Mountain Research Station in California, United States, had been completed in November 1994. Observations from an equatorial site in Colombia had started in February 1995. Preliminary results of those observations were presented.

Stability of galactic discs

49. Based on observations by Kennicutt published in 1989, which showed that star formation in galactic discs was closely correlated to the stability properties of the interstellar gas (ISG), models of chemical evolution of galactic discs were developed whose main features were the inclusion of thresholds on star formation and infall with and without radial flows. Kennicutt showed that star formation in disc galaxies was only active in regions where the surface density of ISG was above a critical value determined from the Toomre parameter, Q. Using that observational result, it had been assumed that star formation started only when the gas surface density reached its critical value in a differentially rotating disc formed out of infall inside a spherical halo of non-baryonic dark matter. The predictions of those models had been satisfactorily compared to the observed properties of the Galaxy (i.e. the Milky Way) in the solar neighbourhood. Among other investigations, the ability of those models to predict the age of the Galaxy using the method of cosmochronology had been analysed.

H. Presentations on selected topics

The importance of archival research from data of modern observatories: evolution since the first United Nations/European Space Agency Workshop (1991-1995)

50. The impact of the distribution and access to scientific archives of space agencies in developing countries was discussed, and usage and distribution viewed in that context. That was discussed in the overall context of the advancement of participation in basic space science. An attempt was made to identify future directions in which the impetus of progress could be maintained, avoiding the typical up-and-down course owing to fluctuations in economic development. The utilization of archives for the definition of future activities, both from space alone, as well as in the context of the use of small telescopes for participation and definition of joint space and ground-based observational programmes, was discussed.

Alternative astronomical software packages

51. It was stated that, at a time when the United Nations, in collaboration with a research company, had been using the Mathematica software package to inform developing countries about the available scientific tools, it was important to review other choices of software being used by active scientists around the world. For observational astronomers with large volumes of digital data to be analysed, the main challenges were data reductions, image handling, model comparisons, interactive fits, data simulations and visualizations etc. There were several good alternative software packages such as: Astronomical Image Processing System,* Image Reduction and Analysis Facility,** Munich Image Data Analysis System*** and Interactive Data Language.**** The first three packages could be obtained free of charge by contacting the sponsoring institutions. Interactive Data Language was a commercial package that could be used in all kinds of computer platforms and was extensively used in space astronomy (it was the main language of software reduction packages for astronomical satellite missions such as ROSAT). All of those packages were able to handle some of the most common commercial and scientific data formats (Flexible Image Transport System, Common Data Format and Hierarchical Data Format). Those software packages provided general tools for image processing and data reduction with an emphasis on, although not limited to, astronomical applications. All of the packages had active customers' support strategies, the most useful ones being periodic newsletters, related meetings (e.g. the annual meeting on astronomical data analysis software and systems), software user groups, bulletin board discussions and frequently asked questions. The relative usefulness, available platforms, associated libraries and related resources of the four software packages were presented, as well as the many already existing and potential astronomical applications.

Emission-line stars in the Orion region

52. It was stated that, under a cooperative programme between Indonesia and Japan, a search for hydrogen alpha emission-line stars in the Orion region had been conducted using the Kiso Schmidt telescope. In an area of 300 square degrees (12 Kiso sky areas), about 1,200 emission stars and several emission objects had been detected, of which more than 800 were newly detected. The limiting magnitude was around V=17. Most of the stars lay in the magnitude range V=14-16, implying that they were mostly T Tauri-type stars. Although the limiting magnitude of the survey of the outer region was not as deep as that in the inner region, the boundary of the distribution of emission-line stars was roughly determined.

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*Developed by National Radio Astronomy Observatory (http://www.cv.nrao.edu/aips/).

**Developed by National Optical Astronomy Observatories (http://iraf.noao.edu/).

***Developed by the European Southern Observatory (http://www.eso.org/midas-info/midas.html).

****Developed by Research Systems Incorporated (http://sslab.colorado.edu:2222/projects/IDL/idl_ssl_home.html).

Remote spectral reflectance of selected lunar grounds

53. A study of the variation of the spectral relative ratio of reflectivity of southern upland lunar regions was presented for values between wavelengths 4,000 and 8,000 angstrom.

54. The peak transmission of the five narrow pass band filters used in the measurements were 4,035, 4,765, 5,538, 6,692 and 7,922 angstrom, respectively. The intensities at different wavelengths of each region were corrected for angles of illumination and viewing. They were scaled to unity at λ = 5,538 angstrom. A comparison was made between the spectral relative ratios of reflectivity of different types of grounds, as well as between the present and the previous deduced results.

Notes

[1]C. Wickramasinghe, ed., *Fundamental Studies and Future of Science* (University College Cardiff Press, 1984), pp. 377-385.

Annex

PROGRAMME OF THE WORKSHOP

Date/Time	*Subject*	*Speaker/Country/ Organization*
11 January 1996		
0800-0850	Registration	
	Opening session	
0900-0910	Welcoming address by the Chairman of the Board of Governors of the Arthur C. Clarke Centre for Modern Technologies	K.K.Y.W. Perera
0910-0925	Address by the Deputy to the Director-General of the United Nations Office at Vienna and Director of the Office for Outer Space Affairs	N. Jasentuliyana
0925-0930	European Space Agency address	V. Hood
0930-0945	Address by the Minister of Science, Technology and Human Resources Development of Sri Lanka	B. Soysa
0945-1000	Keynote address by the Patron of the Arthur C. Clarke Centre for Modern Technologies	A. C. Clarke
1000-1030	Theme address by the Director-General of the Institute of Space and Astronautical Science: Space activities in Japan	R. Akiba
1030-1100	**Break**	
	Session 1. Small telescopes: research	
	Chairman: B. Warner (South Africa)	
1100-1130	Russian/Former Soviet Union experience in small telescope usage for professional astronomy and education	N. Bochkarev (Russian Federation)
1130-1200	Small astronomical telescopes for research and education at Helwan, Egypt	M. A. Mosallam Shaltout (Egypt)

Date/Time	*Subject*	*Speaker/Country/ Organization*
1200-1230	Astronomy with small telescopes: the Indian experience	R. K. Kochhar (India)
1230-1300	On the importance of astronomical photometry of variable stars with small telescopes in the Asian region	M. Kitamura (Japan)
1300-1400	**Lunch**	
1400-1430	Spacewatch experience applied to the new telescope in Sri Lanka	T. Gehrels (United States of America)
1500-1530	Astrometry of near-Earth objects using small telescopes	D. Steel (Australia)
1530-1600	Multi-site small-telescope studies of pulsating variable stars	P. Martinez (South Africa)
1600-1615	**Break**	

Session 2. Small telescopes: research (continued)

Chairman: B. Hidayat (Indonesia)

1615-1645	Searching for and monitoring supernovae	R. Jayawardhana (United States of America)
1645-1715	The 15-cm refractor telescope of the astronomical observatory in the Philippines	B. M. Soriano (Philippines)
1715-1745	New technologies to produce small telescopes with apertures smaller than 1 metre for routine astronomical observations and education	P. Koehler (Germany)
1800-1900	Working Group session: Astronomy in Sri Lanka Chairmen: T. Gehrels (United States of America) D. de Alwis (Sri Lanka) Rapporteur: K.P.S. Chandana Jayaratne (Sri Lanka)	

Date/Time	*Subject*	*Speaker/Country/ Organization*
12 January 1996		
	Session 3. Small telescopes: education	
	Chairman: J. S. Mikhail (Egypt)	
0900-0930	The role of public observatories in astronomical observations	T. Kogure (Japan)
0930-0950	Popularization of astronomy and the general knowledge of the public	B. Hidayat (Indonesia)
0950-1010	Astronomy teaching in a networked world	A. K. Bagchi (Oman)
1010-1020	Use of electronic and print media in Sri Lanka to educate the public and school children on astronomy from grass-root level	K.P.S. Chandana Jayaratne (Sri Lanka)
1020-1030	Basic Space Science education in developing countries	M. Ilyas (Malaysia)
1030-1045	**Break**	
	Session 4. Robotic telescopes and telescope networking	
	Chairman: S. Karunaratne (Sri Lanka)	
1045-1115	The Oriental Robotic Telescope (ORT) Network	F. R. Querci (France)
1115-1145	Robotic astronomical telescopes as ground-based support for satellite projects: the Ondrejov robotic telescope	J. Soldan (Czech Republic)
1145-1215	Asteroseismology with a network of small telescopes	B. Warner (South Africa)
1215-1315	**Lunch**	
1315	Departure to the Arthur C. Clarke Centre for Modern Technologies	
1450	Arrival at the Arthur C. Clarke Centre for Modern Technologies	

Date/Time	*Subject*	*Speaker/Country/ Organization*
	Session 5. Inauguration of the telescope facility at the Arthur C. Clarke Centre for Modern Technologies	
1505	Welcoming address by the Chairman of the Arthur C. Clarke Centre for Modern Technologies	K.K.Y.W. Perera
1515	Speech by the Deputy to the Director-General of the United Nations Office at Vienna and Director of the Office for Outer Space Affairs	N. Jasentuliyana
1525	Speech by the Ambassador of Japan	Y. Noguchi
1535	Speech by the Minister for Science, Technology and Human Resources Development of Sri Lanka	B. Soysa
1545:	Presentation of the telescope to the Minister for Science, Technology and Human Resources Development of Sri Lanka by the Ambassador of Japan	
1555	Vote of thanks by the Director of the Arthur C. Clarke Centre for Modern Technologies	S. Karunaratne
1600	**Break**	
	Session 6. Telescope projects	
	Chairman: N. C. Wickramasinghe (United Kingdom of Great Britain and Northern Ireland)	
1615-1645	The large sky area multi-object fibre spectroscopy telescope (LAMOST) project	Y. Chu (China)
1645-1715	Status of the upgrade of the Kottamia telescope in Egypt	P. Koehler (Germany)
1715-1745	Observing facilities of the Max-Planck-Institut für Radioastronomie under the aspect of international cooperation	R. Schwartz (Germany)
1745-1815	The astronomical observatory of Honduras: a project for permanent international cooperation	M. C. Pineda de Carias (Honduras)

Date/Time	*Subject*	*Speaker/Country/ Organization*
1815-1845	The establishment of an astronomical observatory in Colombia	S. Torres (Colombia)
1845-1915	**Break**	
1915	Working Group session: observations and recommendations	
	Chairman: W. Wamsteker (European Space Agency)	
13 January 1996		
	Session 7. The Sun (parallel session)	
	Chairman: H. J. Haubold (United Nations)	
0830-0900	Solar neutrinos: short history and present-day situation	G. T. Zatsepin (Russian Federation)
0900-0930	The solar neutrino problem	H. J. Haubold (United Nations)
0930-1000	Outer planets in the solar system in relation to solar activity	D. Basu (Trinidad and Tobago)
1000-1015	**Break**	
1015-1045	Some results on the solar corona during the solar eclipse of 24 October 1995 at Phan Thiet, Viet Nam	N. Van Nha (Viet Nam)
1045-1115	Properties of neutrinos from supernovae	S. Masood (Pakistan)
	Session 8. Binary stars (parallel session)	
	Chairman: T. Kogure (Japan)	
1115-1145	Cooperative observing programme in binary star research	K. C. Leung (United States of America)
1145-1215	Anomalous gravity darkening and mass loss in semi-detached close binary systems	M. Kitamura (Japan)

Date/Time	*Subject*	*Speaker/Country/ Organization*
1215-1245	International cooperation in RS VCn binary system research	B. Soonthoornthum (Thailand)
1245-1400	**Lunch**	

Session 9. Cosmology (parallel session)

Chairman: Y. Chu (China)

0830-0900	Cosmological challenges	J. V. Narlikar (India)
0900-0930	X-ray detections of quasars associated with low redshift, active galaxies	H. Arp (Germany)
0930-1000	The quest for the chemical identity of interstellar dust	N. C. Wickramasinghe (United Kingdom of Great Britain and Northern Ireland)
1000-1015	**Break**	
1015-1045	The slow unveiling of active galactic nuclei (AGN)	W. Wamsteker (European Space Agency)
1045-1115	The Galactic Emission Mapping (GEM) project: an international collaboration to survey the galactic radiation emission	S. Torres (Colombia)
1115-1145	Stability of galactic discs	K. Chamcham (Morocco)
1245-1400	**Lunch**	

Session 10. Presentations on selected topics

Chairman: H. J. Haubold (United Nations)

1400-1430	The importance of archival research from data of modern observatories: evolution since the first United Nations/ESA Workshop (1991-1995)	W. Wamsteker (European Space Agency)
1430-1500	Alternative astronomical software packages	M. R. Perez (United States of America)

Date/Time	*Subject*	*Speaker/Country/ Organization*
1500-1515	Observation of huge globular shape regions of subatomic particles churned up by the Jupiter Shoemaker-Levy 9 impact using the 28 cm reflector telescope and a video camera	K.P.S. Chandana Jayaratne (Sri Lanka)
1515-1530	The Cassegrain telescope at the Department of Meteorology of the University of Moratuwa	G.H.P. Dharmaratna (Sri Lanka)
1530-1545	**Break**	
1545-1600	Star/Sun observations for finding positions in survey and geodesy	S.D.P.J. Dampegama (Sri Lanka)
1600-1615	Emission-line stars in the Orion region	S. D. Wiramihardja (Indonesia)
1615-1630	Remote spectral reflectance of selected lunar grounds	J. S. Mikhail (Egypt)
1630-1730	Working Group session: Adoption of the report Chairman: W. Wamsteker (European Space Agency)	
1730-1800	Closing session S. Karunaratne (Sri Lanka) and N. Jasentuliyana (United Nations)	

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