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OBSERVATIONAL ASTRONOMY IN THE SOUTHERN HEMISPHERE IN THE NEXT DECADE

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RESUMEN. Los grandes desarrollos en astronomía observacional del hemisferio Sur durante los últimos 10 años se revisan y se hace un esfuerzo para proyectar el curso al que nos guía la nueva instrumentación y las técnicas de observaciones disponibles. Se pone énfasis en la necesidad de incrementar las fuentes observacionales desde tierra en el Hemisferio Sur para apoyar a futuros telescopios espaciales. Se hace especial mención de la importancia del estudio de las Nubes Magallánicas y de la necesidad de aumentar la investigación de binarias y estrellas múltiples.

ABSTRACT. Major developments in observational astronomy in the southern hemisphere over the last 10 years are reviewed and an effort is made to project the course along which the newly available instrumentation and observing techniques are leading us. Emphasis is given to the need for increased based support in the southern hemisphere for future space telescopes. Special mention is made of the importance of Magellanic Cloud studies and of the need for further work on binary and multiple stars.

Here in the southern hemisphere we have a privileged view of the Universe. For example, the center of our Milky Way system passes overhead at 30° S and the disk form of our Galaxy is seen clearly on a dark winter night away from city lights. The globular cluster system concentrates strongly about the galactic center in Sagitarius. The Magellanic Clouds, the nearest of the external galaxies can only be studied from the south. Other important objects are the nearest of the giant radio galaxies (NGC 5128) and the great Carina nebula within which is one of the most luminous and massive stars known (η Carinae).

In trying to project the course of observational astronomy here in the southern hemisphere during the next decade, I believe, it is important first to look back 10 years, to recall what we were doing then and to note how things have altered. There have been two really major changes. First, we can now observe over a far greater range of wavelength. Ultraviolet observation with IUE from space has become almost routine for bright stars. A major impact has come from the results of X-ray satellites, for example, with the Einstein Observatory. In the infrared, detectors have become more sensitive and mm-wave telescopes like the small Columbia telescope on Cerro Tololo are giving us a first look at the giant molecular clouds of the southern Milky Way.

Ten years ago, the first of the large 4m telescopes was still under construction at Cerro Tololo. First light came in 1974 and shortly after, it was joined by two similar telescopes, the AAT and the ESO 3.6m telescope. These 3 telescopes have contributed much to astronomy in the last decade. However, it is important to emphasize that many of the new discoveries are a result of developing new instruments, especially new detectors for telescopes. In 1973, the Kodak IIIa-J emulsion had recently come into use together with the similar IIIa-F emulsion. Photographic plates are still unsurpassed for wide-field imagery as the publication of the ESO-SRC sky atlas has shown us. Apart from low quantum efficiency, the photographic plate suffers from

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non-linear response which makes calibration difficult. An improvement which has served us well is the image intensifier tube. This has been used both as a detector for spectrographs and also in a direct manner to electronically intensify images before recording them on photographic plates. On the 1m telescope at Cerro Tololo, for example, we have an image tube camera with a field of 12'. For certain applications, such as interference filter photography, it can do things which cannot be achieved with the 4m telescope. Image tubes still have calibration problems associated with photographic plates and more recent detectors rely on electronic detection and registration completely.

At CTIO, the SIT vidicon has been in use for some years. Here, as well as high sensitivity we have a linear response of the output signal to input light intensity. Spectrophotometry has become much more fast and more accurate now that we can obtain absolute intensity measurements over a whole spectral range. Most recently, new gains are coming from CCD detectors. The CCD detector has unprecedented sensitivity, its dynamic range is large and its linear response sufficiently good that a precision of a few hundredths of a magnitude can be obtained with stellar photometry. A new era is coming as these new detectors are applied to smaller telescopes (e.g. precision photometry to 20 mag with a 1m telescope). However, it is important to realize that along with the CCD cameras, we need to provide object acquisition techniques at the telescope as well as some on-line data reduction. For example, for faint objects which cannot be seen at the telescope, a good integrating TV system is necessary for centering the object. CCD fields are small, 3' x 5' is typical. Centering cannot be done by position alone with the most telescopes. Bright stars, which can introduce undesirable saturation effects on the CCD must be avoided. The CCD detectors presently in use at Cerro Tololo typically have 500 x 300 picture elements with a distance of 0.4-0.6 arc sec between each pixel. Each of these image elements provides a number proportional to the intensity of the light and photometry is carried out by integrating under the star image and subtracting the sky measured in a surrounding annulus or other sampling area. For faint star work there is a great advantage over traditional photoelectric photometry in that the sky is recorded *at the same time* as the star image. Crowding from other stars can be taken into account by refining the measuring procedure. The price we must pay is the additional computational complexity and for the techniques to work routinely with small telescopes we must have some degree of on-line computing power to carry through the reductions at least partially at the time when the observations are made. One problem with CCD photometry is that time resolution is not good and for observations where high time resolution is required, (e.g. cataclysmic variables and flare stars) we will continue to use the traditional methods.

An especially important application of CCD photometry has been to the globular clusters in the Magellanic Clouds. These clusters are very important because, while visually similar to those in our own Galaxy, there are many outstanding differences. Early work by Gascoigne (1966) and others showed that some clusters have color-magnitude diagrams similar to those of the Galaxy but others are very different. Color magnitude diagrams are important because they provide a very good inter-relation between theory and observation. From a comparison with theoretical models of evolving stars it is possible to estimate age and chemical abundances for the stars in a cluster. Investigations have shown that Magellanic Cloud globular clusters are found with a wide range of age, there are blue clusters with about 10^7 years old and red clusters with ages about 10^{10} years. Until recently, photometry of cluster stars has been difficult because of large random and systematic errors in photometry as well as problems in separating cluster stars from stars in the field. A difficult case has been the cluster Hodge 11 which has been thought to be both an intermediate age cluster (600 million years) and an old cluster (10,000 million years). Recent CCD work by Stryker, Nemec, Hesser and McClure (1984) demonstrates the new technique well and gives a good idea of the errors encountered. In this work the importance of careful field subtraction is emphasized even for this cluster which is far from the center of the Large Magellanic Cloud. The new work shows that, without doubt, Hodge 11 is a very old, metal poor cluster with a very blue horizontal branch, so blue that the characteristic RR Lyrae variables are not present in this case. Studies of this sort are of the highest importance. Globular clusters are also seen around more distant galaxies and it is clear that these contain many clues about the origin and evolution of the parent galaxies. However it is only in the Galaxy and the Magellanic Clouds that we can resolve them into individual stars and where we have hope for understanding how they are formed.

CCD detectors are already being used for spectroscopic work at Cerro Tololo. As an example, I mention some of my work in progress with Dr. Roberta Humphreys. This is a study of the red supergiants in the nearby galaxy NGC 300. From visual and infrared photographs, Dr. Humphreys selected apparently red stars seen near the Galaxy. These stars are of two types, faint stars belonging to the Milky Way seen in front of NGC 300 and stars intrinsically bright

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which belong to NGC 300. To distinguish between the two we are observing the strength of the Ca II triplet at λ 8500 Å. This is a good luminosity criterion for red stars. The 3 lines are strong in supergiant but weak in dwarf stars. Observing spectroscopically at λ 8500 Å has been very difficult until recently. Photographic plates are insensitive in the infrared and most detectors become inefficient at about λ 7500 Å. The GEC CCD used at Tololo is very sensitive out to about 1 micron and we were able to use the 4m telescope to reach our stars (19th mag visual, 17th mag infrared) in one hour with a spectral resolution of about 10 Å. About 50% of our candidate stars are supergiants. A similar CCD is presently being tested on the spectrographs at the 1.5 meter and 1 meter Yale telescopes. We expect that it will soon be available for routine use on stars down to magnitude 15-16.

Several major new telescopes are being planned, designed or are under construction. Some will make a major impression on observational astronomy in the southern hemisphere in the next decade.

Most outstanding is, of course, the Space Telescope. The launch date is expected to be in 1986 or 1987. It is a 2.4m telescope which will be fitted out with a variety of instruments for imaging spectroscopy and photometry. Initially it will cover the wavelength range of ultraviolet (1000 Å) to infrared (11,000 Å). From above the atmosphere, it will be able to observe at very high spatial resolution. The optics are designed so that details as small as 0.1 sec arc can be resolved. Prime objects for observation will be the globular clusters in the Magellanic Clouds and nearby galaxies. Sharp resolution is important both for going faint and for observing crowded objects. At a good site like Cerro Tololo, seeing of 1 arc sec is considered good. With space telescope we expect a resolution 10 times as high.

Other ground based instruments are going to transform our knowledge of the southern skies. The southern hemisphere has found itself behind in the construction both of a large mm wave telescope and a synthesis radio telescope. Plans are underway to construct a 15 meter mm wave telescope on La Silla. This is a joint Sweden-ESO project which will give very high sensitivity and resolution. One important application will be for studying in detail the regions where star and planet formation are presently occurring. Work is also going ahead on the construction of a large radio synthesis telescope in Australia. This instrument will consist of 7 22-meter antennas and will operate in conjunction with the Parkes 64 m disk. The maximum baseline will be 300 km and by distributing the antennae in various configurations, detailed images of the sky will be made in frequency bands from 405 MHz- 50,000 MHz. The antennae are being designed so that simultaneous observations in more than one frequency band will be possible. Data processing is a major factor here, much more so than anything we are accustomed to handle in optical astronomy. For the compact array configuration alone there will be up to 6,000 million bits of information reaching the control room each second. The telescope is expected to be operating for the Australian bi-centennial in 1988.

Optical astronomers also have plans. We realize that time on Space Telescope will be very precious and observing programs will demand much preparation and much follow-up work. The number of ground-based telescopes is far greater in the north and we astronomers in the southern hemisphere expect great pressure on our smaller number of telescopes. We have had some experience of this with the Einstein X-ray Observatory. X-ray sources also concentrate towards the Galactic Center and we have received many requests for telescope time to make more detailed observations of the new X-ray identifications. This work alone has accounted for almost 1/4 of the visitor use of the CTIO 4 m and 1.5 m telescopes during the last 10 years. Use on X-ray projects continues even though Einstein Observatory stopped functioning 3 years ago. In anticipation of the increased demands from Space Telescope and other satellite observatories such as IRAS, Cerro Tololo is presently soliciting support for a second large telescope with an aperture of the order of 5 m. By taking advantage of new telescope technology we believe we can build this telescope for about $10 million. We feel strongly that such an instrument should complement as well as support Space Telescope. There are some projects such as high dispersion spectroscopy and detection of faint, resolved sources, where the relatively small 2.4 m aperture of Space Telescope is a limiting factor. We can do better on the ground with a bigger (and much cheaper) 5 m telescope. We plan to optimize the telescope to work in the infrared at wavelengths where there will be initially no high-resolution capability in space.

We also look forward to the completion of Argentina's 2.1 meter telescope. One field of investigation which is going to have increasing importance in the coming years is the study of multiple stars. Many talks at this meeting, such as those by our hosts Dr. Levato and Dr. Sahade indicate the activity of this field. We sometimes forget as much in observational work as in theoretical work that more than 50 percent of stars may be double or multiple. The evolution of the magnitude and color of a close binary system can depend on the degree of interaction of the component stars. Some stars become X-ray sources by this mechanism. Integrated

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colors of stellar systems are probably influenced by this effect. It is important, too, I believe, that theory and observation of star formation in molecular clouds take into account this very common multiplicity of stars.

With new telescopes and instruments we shall be able to push fainter and observe spectroscopic binaries in the Magellanic Clouds, for example, to check whether the relation between stellar mass and luminosity determined for stars in the solar neighborhood is also valid in more distant galaxies.

The next ten years will be exciting ones for astronomers and there will be certainly enough work for the participation of all of us here at this meeting. Working together, I believe that we can look forward to solving some of the most exciting problems in astrophysics today and thereby to being able to understand a little better our Universe as a whole.

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