PROCEEDINGS

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OF

AMATEUR ASTRONOMERS

Perth 1984 April 20-23

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Edited by

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OBSERVING THE SOLAR ECLIPSE IN JAVA, 1983 JUNE

Byron W. Soulsby,
Canberra Astronomical Society

ABSTRACT

Two observing parties conducted separate observations from the main group of the PACTO expedition to Northern Java for the Total Solar Eclipse on 1983 June 11. Their purpose was to be in the vicinity of the Northern limit of the eclipse path to time Baily's Beads during totality. This particuclar expedition was highly successful and many bead-timings were obtained, the details of this special expedition are described and illustrated.

INTRODUCTION

Members of the Canberra Astronomical Society joined the PACTO expedition to Bali and Northern Java for a tour of this beautiful country and to time Baily Beads at the Northern Limit of the eclipse path. David Herald and myself had obtained sufficient surveying data to establish proposed sites for observation near the villages in the North, however details of knowledge of the area were limited — an unknown adventure was before us all, wives and one child included.

How we succeeded and obtained much useful data and at the same time enjoyed the spectacle of this my first successful solar eclipse will be related by illustrations and some technical discussion of the observing techniques and results obtained.

THE EXPEDITION

The morning of the eclipse was cloudy and raining as we approached our expected destination, the village of Palohwaru, near Pati in Central Java. Our driver and police escort understood some English but not our Australian accent.

Within minutes of establishing our first site several locals arrived, this swelled to hundreds later before the local police and Army intervened — a popular event, not the eclipse but foreigners visiting this remote area.

At totality my site was established and the area was deserted, all the villagers had retired to their hall to watch the event on television, Cathie and I were alone about to witness the awe inspiring sight of a perfectly clear sky and the eclipse.

OBSERVATIONS

Using a crystal timer previously and later synchronised with WWV, a tape recorder, my small camera and Unitron 10X-40 mm telescope mounted on a special fitting attached to a camera tripod I waited expectantly for the first Baily Bead as the surrounding area became still and ever darker.

Contact, a large bead forming, many others followed both above and below the first, I recorded furiously hoping against hope that all the equipment and preparation, weeks before this event, were in order. The water alongside my small camp stool erupted with small fish, the village elders moaned out their song warding off the giant demon named Kala Rau as he reared forward to swallow the Moon.

At totality I glimpsed the corona and streamers warning Cathie to use the filter I had prepared, immediately the chromosphere reappeared but, all this time I awaited the reappearance of the Sun to time more Baily Beads. A colour photograph was taken to capture this first reappearing bead, and indeed provided an accurate time for third contact not easily determined by observation.

The event was over, with a total observing time of 9 minutes 55 seconds including a magical 66 seconds of totality — it seemed as if a lifetime had come and gone in that all consuming minute, the wonders of an eclipse must be seen and felt to be fully appreciated.

RESULTS

Later the tape recordings analysed for six individual timings and these were averaged and the timer drift applied linearly to give true UT times for each of the 88 events recorded.

A lunar profile was constructed based on Watts Limb Charts and each bead timing identified in relation to the lunar limb. The method of analysis to obtain the lunar profile height for each bead and the associated Watts Angle, as given in the final results, is based on the overall analytical method developed by David Herald.

Of the forty two (42) Baily Beads observed, 57 limb data points have been established for further analysis by USNO for the determination of the solar diameter.

Comparison of observational techniques and instrumentation with personal equation of the two observers placed near the Northern Limit will also be possible.

CONCLUSIONS

The observation of the Java solar eclipse was indeed an astronomical highlight for me, the awe inspiring sight coupled with the capture of scientific observations made this expedition a huge success.

Future solar eclipse expeditions will be attempted and it is hoped that this, my first success in three attempts at the timing of Baily Beads, will be continued.

ACKNOWLEDGEMENTS

I should like to express our thanks to PACTO and to Ashgrove Travel for a magnificent tour as well as to the Indonesian Government for their assistance at the Palohwaru sites.

RADIO AND PHOTOGRAPHIC OBSERVATIONS OF THE SUN

M.H. Wilkinson, G. Sprott and T.B. Tregaskis,
Astronomical Society of Victoria

ABSTRACT

A programme including radio and photographic observations of the Sun and visual auroral observations was undertaken from 1981 Sepember to 1982 October. The aim of the programme was to establish if relatively simple radio measurements at metre-wavelengths could usefully supplement an existing solar photographic and auroral programme. The radio equipment consisted of a versatile meridian transit radio telescope which was designed to record the variability in solar radio flux by performing daily measurements at 228 MHz, radio spectral measurements at 228 MHz and 138 MHz and polarization measurements at 138 MHz. A Newtonian reflector of open tube design, using an uncoated 15-cm diameter primary mirror and a shock mounted camera were used to obtain high resolution white light photographs of the Sun. Visual auroral observations were carried out by a number of observers in Victoria, Tasmania and South Australia. From the data gathered over this period several types of radio bursts were identified: Type I emission associated with radio noise storms located in the corona above active sunspot regions, Type II radio bursts associated with magneto-hydrodynamic shock waves generated during large solar flares and Type III bursts generated during the rapid expulsion of electron streams from the solar surface during flares or sub-flares. From the daily measurements of solar radio flux estimates of 'Quiet Sun', coronal temperatures were made giving a value of 1.4 million Kelvin. The spectrometer measurements of Type III bursts gave an average electron stream radial velocity of 0.26 c for ten isolated bursts measured during the programme. Polarization measurements at 138 MHz showed only a small degree of polarization for these bursts whereas Type I storm bursts were often highly polarized with values exceeding 80%. It is concluded that radio observations can provide important information to aid in the prediction of aurorae since they give vital clues as to the high energy (invisible) phenomena occurring in the solar corona. When combined with visual and photographic observations a much more complete picture of Sun-Earth interactions can be established.

Although many amateur astronomers periodically observe the Sun, very few have mastered the difficult art of solar photography and fewer still have ventured into the intricacies of radio observations. However, within our Society, we were fortunate enough to have the expertise to make not only these types of observations but also auroral observations. These circumstances led us to consider a joint solar observing programme which would combine the facilities of the Solar, Radio and Auroral Sections of the Society.

During the programme which extended over the period 1981 September to 1982 September we recorded our optical observations photographically on a weekly basis, we recorded the 228 MHz radio flux levels daily and collected auroral observations as they became available. Our aim was to explore the temporal relationship between the appearance of sunspots, the day to day changes in the intensity and type of solar radio emission and the appearance of the aurorae.

Our equipment consists of a 15 cm Newtonian reflector with an effective focal length of 202 cm which was specifically designed for solar photography, and a multi-mode radio telescope designed to allow dual frequency observations of the radio Sun at 138 and 228 MHz, polarization measurements at 138 MHz, and interferometer operation at 228 MHz. Visual auroral monitoring is performed by observers in South Australia, Victoria and Tasmania who submit observations to the Society. As well as visual sightings some observers provide photographic records and use a short wave radio receiver to check for the presence of auroral flutter, which is a distinctive rapid fluctuation of radio signals caused by solar induced turbulence in the terrestrial ionosphere.

Conventional closed tube telescopes are generally unsuitable for solar photographic work for several reasons. Firstly, unless some form of filtering is used, the image of the Sun formed at the focal plane of the camera is so intense that the shutter can be damaged. Secondly, thermal effects generally attributed to the convective movement of the air immediately adjacent to the inside of the tube can cause image distortion due to anomalous refraction in the light path and thirdly, camera shutter vibration may be transmitted to the telescope mounting during exposure giving further image distortion. Of course this latter effect is a common problem with all astronomical photographic work.

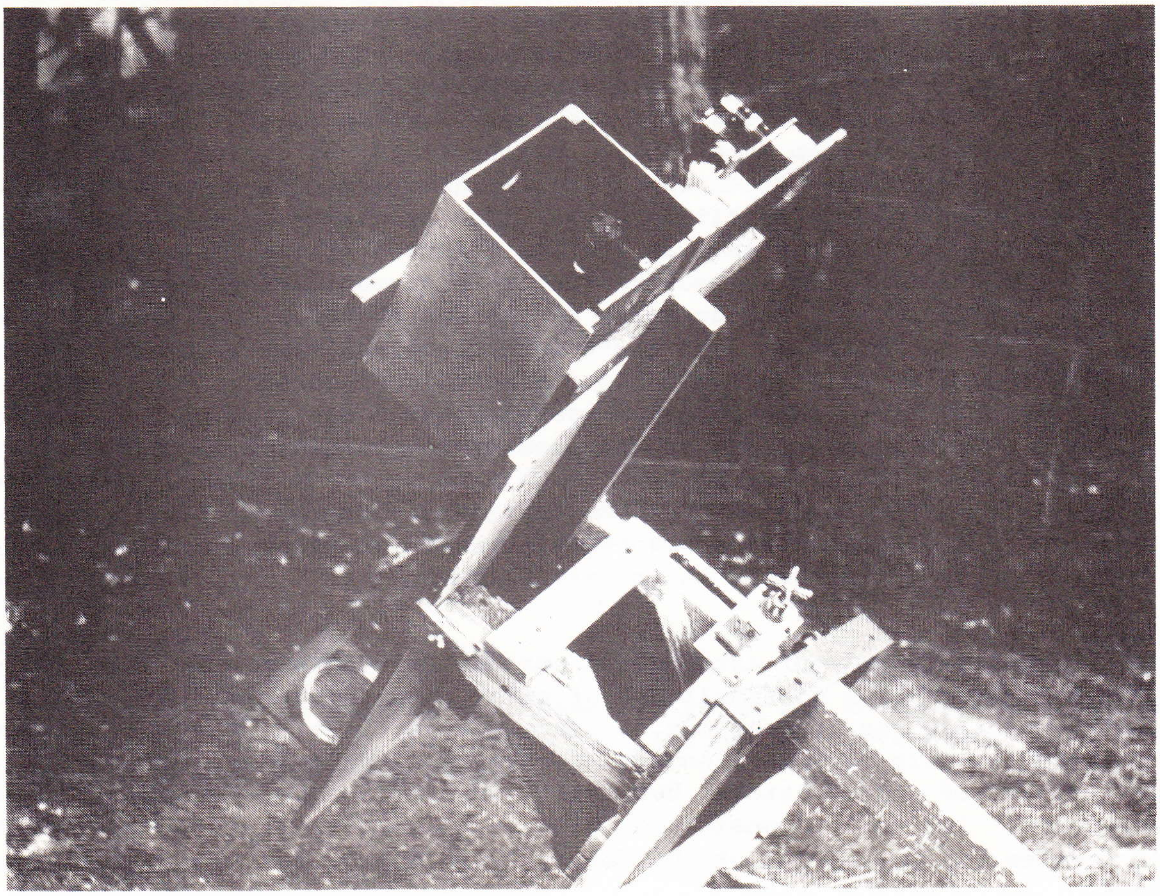

Fig. 1. The 15-cm open tube Newtonian reflector uses an uncoated primary mirror and a neutral density filter attached to the camera to reduce image brightness. The focal length of the primary mirror is 140 cm which is increased to an effective focal length of 202 cm by using a barlow lens mounted in the eyepiece holder. The camera mounting uses 4 sponge rubber supports to reduce the amount of shutter vibration transmitted to the tube.

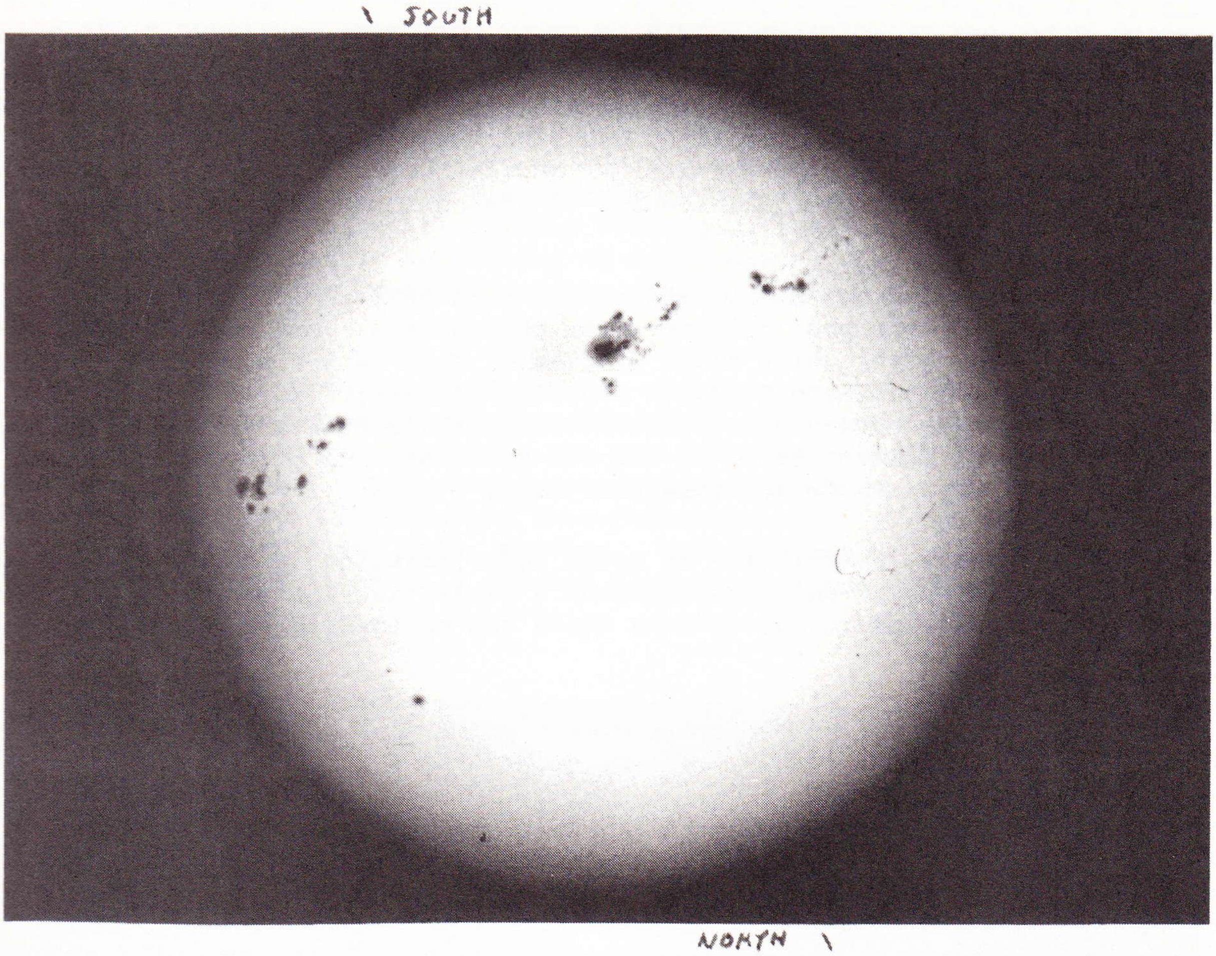

Fig. 2. This white light photograph of the sun was taken using the telescope illustrated in Fig. 1 on October 17 at 22 h 34 m UT. During this period of increased solar activity, several large active regions were present in the southern hemisphere. Limb darkening and photospheric faculae are clearly visible on this photograph taken using ILFORD Pan F film exposed 1/250th of a second and developed in KODAK D19 for 3.25 minutes.

The first problem was tackled by using an uncoated primary mirror and a neutral-density filter (density 2.9) attached to the camera. Only about 4% of the incident light is reflected from the surface of the mirror and the neutral density filter further reduces the light intensity at the focal plane, so that typical exposure times of 1/250th of a second can be used with fine grain films. Such short exposure times eliminate the need for tracking and also reduce the effect of air turbulence and telescope tube and mounting vibration.

Thermal effects can be reduced by using either an oversized tube, an open tube design or evacuating the air from the tube. In our case the open tube design was chosen and observations are made from a grassed location sheltered by trees which help to further stabilize the air around the telescope. We have found that the best results are achieved when photographs are taken two to three hours after sunrise, before appreciable heating of the telescope surroundings has occurred.

The amount of camera shutter vibration transmitted to the tube and mounting was considerably reduced by supporting the plate, to which the camera is attached, on four sponge rubber mounts. The success of this simple, but effective, technique for reducing tube shake is largely due to the removal of the rigid mechanical coupling between the eyepiece-holder and the camera. The only possible problem with such a system is that since the light path is open, extraneous light may enter the camera. This possibility is effectively eliminated by the neutral density filter, which reduces the extraneous light level to a point where it does not record on the film.

Using the telescope described we have been able to record consistently high quality photographs of the solar photosphere but we have never recorded a white light solar flare on film. This is not surprising since these events are extremely rare indeed. However, while the optical telescope is rather powerless to record solar flare-events without spcial (and expensive) filters tuned to the red spectral line of hydrogen alpha, the radio telescope can detect them with ease.

A comprehensive description of solar radio emission is beyond the scope of this article but at metre wavelengths a classification scheme has been developed by solar radio astronomers which can be used to categorize bursts into five main types.

TYPE I bursts are short duration highly polarized bursts which have a duration of the order of one second and occupy a relatively narrow bandwidth of typically two percent of the observing frequency. They are usually superimposed on enhanced broad-band emission which is polarized in the same sense. It is the combination of the type I bursts and the enhanced emission which is referred to as a noise storm. These storms may last for hours or several days and are thought to be generated in storm centres in the corona above sunspot groups. The remaining burst classifications, TYPE II, III, IV and V are all generally associated with solar flare activity. TYPE II and III are the so-called slow and fast drift bursts generated during the expulsion of proton and electron streams respectively during the flare. The description 'drift burst' arises from the fact that these particle streams (referred to as exciters) excite progressively lower frequency radio waves as they travel out through the corona. Since the frequency of the radio waves is uniquely determined by the coronal electron density and magnetic field intensity at the point of generation, frequency versus time recordings of these bursts can be used to deduce the velocity and apparent height of the exciters in the solar atmosphere. This information is useful in the study of flare mechanisms.

There is considerable variability in the form of flare related radio emission. The full orchestration of a large solar flare perceived at metre wavelengths commences with a group of fast drift TYPE III bursts (each several seconds in duration) generated during the expulsion of electrons at high speed (100,000 km/s) at the onset or flash phase of the flare. These are followed several minutes later by a TYPE II slow drift burst lasting perhaps 15 minutes which is generated by a slower moving proton disturbance that forms a shock wave as it passes through the corona. Finally these events may be followed by TYPE IV wide-band continuum emission lasting for several hours.

It is the X-rays generated by the intense heating of the chromosphere during the flash phase which cause the short wave fadeouts observed on Earth about 8 minutes later, and it is the slower moving shock wave and associated gas cloud which interact with the terrestrial ionosphere 1 to 3 days later causing auroral displays.

Occasionally the exciters which generate TYPE III radio bursts also generate a continuum afterglow known as TYPE V emission in the outer corona. This is generally confined to frequencies below 50 MHz.

The radio telescope was designed to allow identification of some of these types of radio emission and has three distinct modes of operation. The phase switched interferometer mode is used for overall monitoring of solar flux levels and burst activity, the dual frequency radiometer mode is used for identification and timing of drift bursts and noise storm bursts, and the polarimeter mode is used to measure the polarization of these bursts.

The phase switched interferometer operates at 228 MHz and employs two 11-element yagis spaced 10 wavelengths apart. It is similar in design to that described by G.W. Swenson Jr. in the 1978 May through October issues of *Sky and Telescope*. Two important differences are the use of a double balanced modulator (DBM) as the interferometer phase switch instead of the half-wave transmission line section, and the use of a varactor tuned television tuner instead of a crystal locked converter. These changes allow

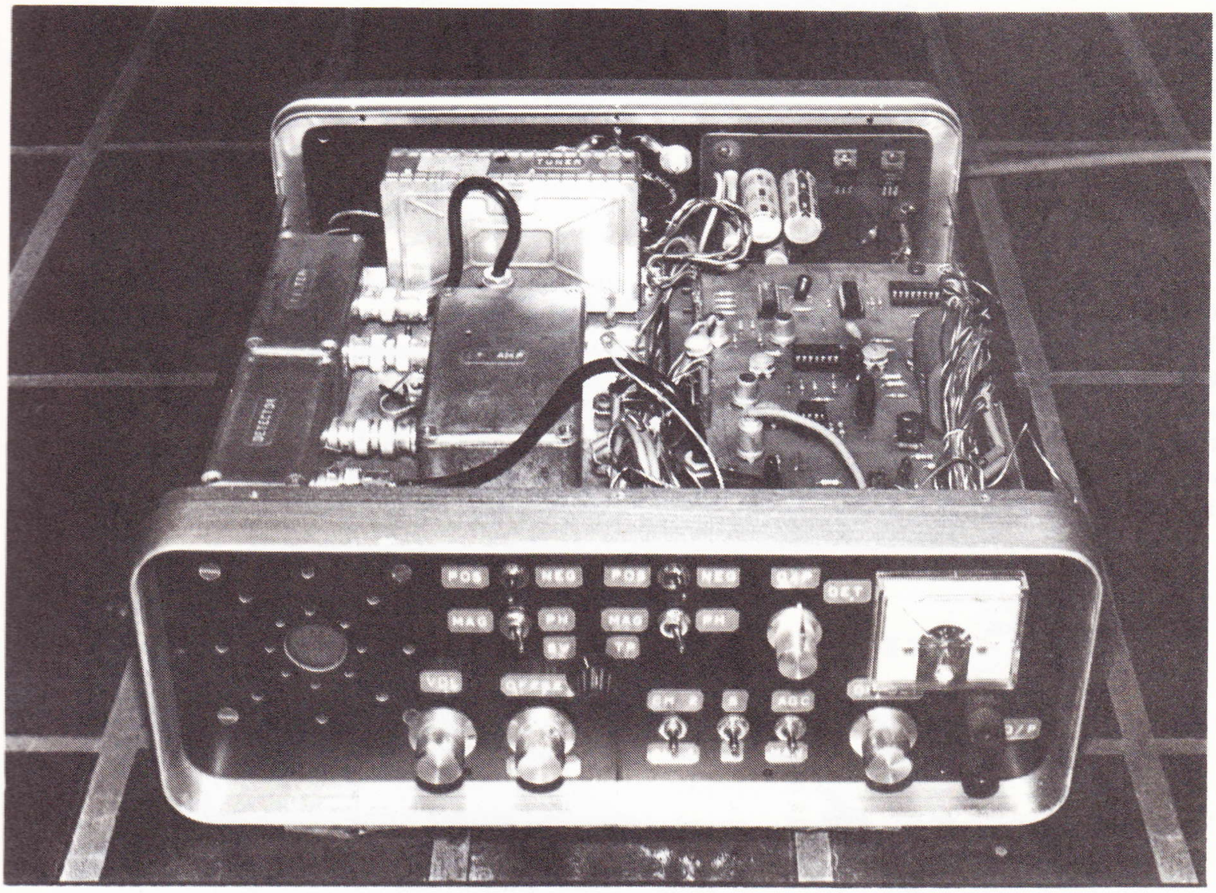

Fig. 3. The radio telescope receiver uses a varactor tuned television tuner (top left) to perform dual frequency or dual polarization observations of solar flare activity using a single receiver. It can also be used as an interferometer for daily flux level measurements. The radio frequency pre-detection circuitry (left) is of modular construction while the post detection circuitry (right) is assembled on a single printed circuit board. All aspects of telescope operation can be controlled from the front panel.

greater flexibility in the choice of operating frequency and make possible electronic switching of the receiver frequency. This feature is exploited in the second mode of operation — dual frequency radiometry.

In this mode the receiver is rapidly switched between 138 MHz and 228 MHz and at the same time the receiver input is switched between an 8 element 138 MHz yagi antenna (used in the polarimeter) and one of the 228 MHz yagis. This antenna switching function is implemented by using two DBM's in a changeover configuration (one of them is also used as the interferometer phase switch). The switching is carried out 125 times per second so that 125 samples proportional to the radio flux intensity at the two observing frequencies are available at the receiver detector each second. In effect the receiver is multiplexed to emulate the function of two separate receivers. Any number of receiving frequencies may be covered using this technique. The receiving frequencies used were chosen to suit readily available antennae and to allow drift rates for TYPE III bursts to be easily determined. The time delay was expected to be between 1 and 3 seconds at these frequencies.

The detector output is demultiplexed electronically and filtered to produce two separate outputs which are recorded on a reel to reel stereo recorder modified to accept low frequency data. The reason for using the tape recorder instead of a chart recorder for this mode is that high chart speeds would be required to achieve accurate time delay measurements which in turn requires a large amount of expensive recording paper. On the other hand, using a tape recorder, events can be selected from the tape for replay onto the chart recorder after the recording session. The chart speed can then be chosen to achieve accurate time delay measurements without wasting paper.

The polarimeter configuration uses an 8-element crossed yagi which consists of two identical linearly polarized yagis with the respective elements mounted at right angles. Equal length feedline connections are made to each antenna and one of the feedlines is extended by a quarter wavelength to provide the 90 degrees of phase shift required for the reception of circularly polarized radio waves. The interferometer phase switch supplies the additional 0 or 180 degrees of phase shift needed to alternately combine the antennae for the reception of either right or left

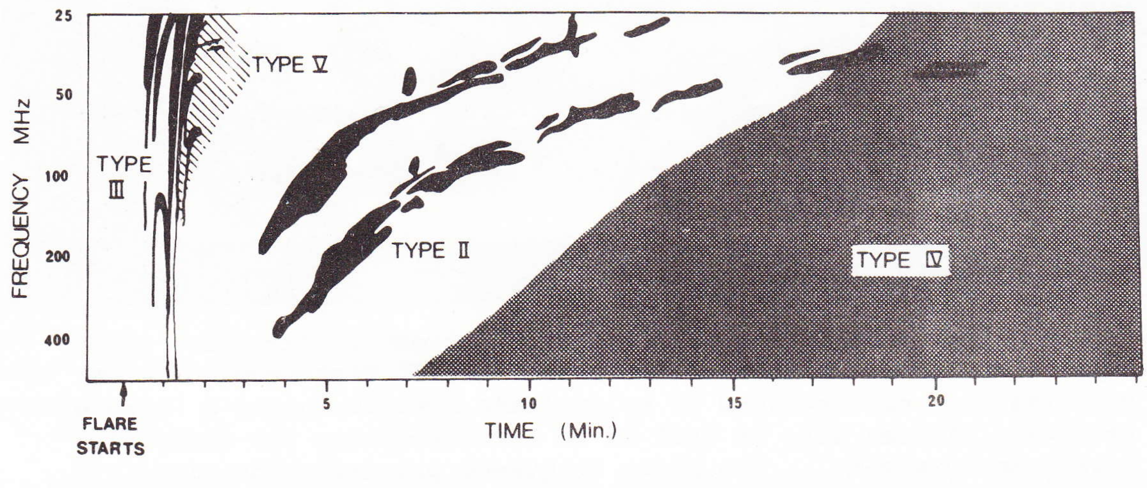

Fig. 4. The classical radio spectrograph of a large solar flare showing Type III and Type V (5) bursts followed by a Type II and Type IV burst. (Ref. Wild, J.P. et al., Solar Bursts, Ann. Rev. Astron. Astrophys., vol. 1, pp.291-366, 1963).

circularly polarized waves. The receiver detector output is demultiplexed using the same circuitry as in the dual frequency mode. However the two outputs are now proportional to the intensity of the two circularly polarized components of the 138 MHz radio waves incident on the antenna. The outputs are recorded on a dual channel chart recorder.

The radio telescope is switched on by a time clock for a total of four hours each day, two hours each side of local noon. The duration of the monitoring period is dictated by the beamwidth of the antennae which are not steerable in hour angle. The radio telescope can operate unattended for a week or more unless a mode change is required or time delay measurements are being made.

Our observing programme is controlled by the results of both the optical observations which are taken at least once per week and the trend in the daily radio flux values measured with the radio telescope. When active regions are visible or periods of enhanced radiation are detected,

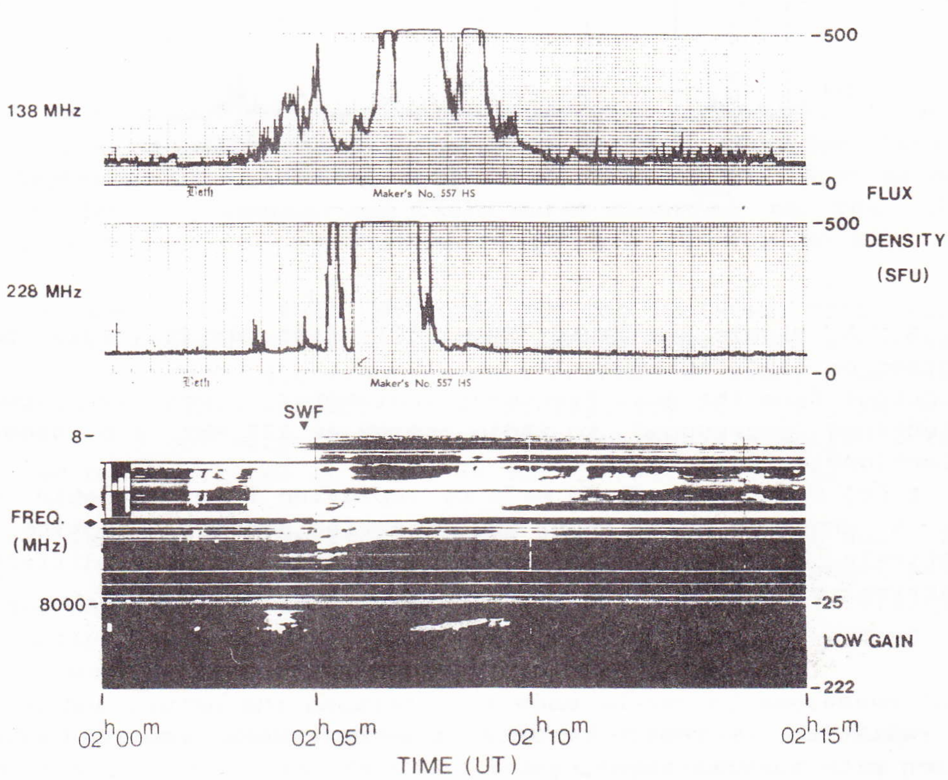

Fig. 5. The two top panels illustrate one of the authors' dual channel pen recordings of a solar radio outburst which occurred at 02 h 04 m UT on 1982 August 8, and was coincident with a solar flare. The bottom panel is a radio spectrographic record of the same event recorded at the CSIRO Solar Radio Observatory at Culgoora, N.S.W.. Intensity of radio emission is represented on a grey scale with white corresponding to the strongest solar emission. Notice the short-wave radio fadeout commencing at 02 h 04 m UT due to the effect of solar X-rays on Earth's ionosphere. The progressively delayed arrival of radio waves at lower frequencies — typical of a Type II radio burst — is clearly evident starting at 02 h 05 m UT. The two diamonds shown on the left hand frequency axis of the spectrograph indicate the authors' observing frequencies. The horizontal lines are fixed frequency signals generated by terrestrial transmitters. (Spectrograph courtesy of G. Nelson, Culgoora Solar Radio Observatory.)

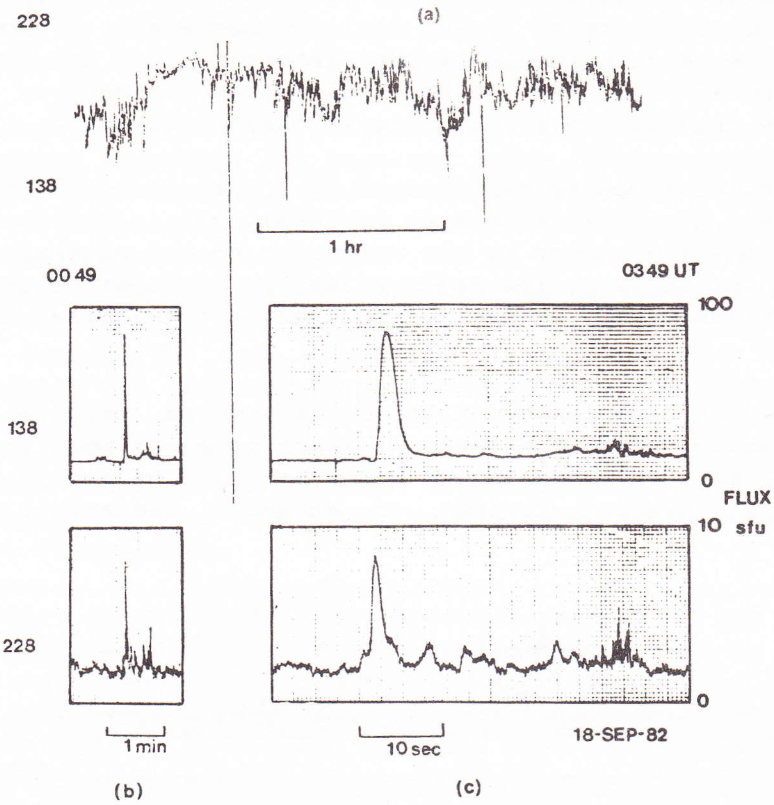

Fig. 6. A single isolated Type III fast drift radio burst recorded on 1982 September 18.
(a) Output from the dual frequency radiometer. Positive (upward) deflections correspond to radio energy at 228 MHz and negative deflections energy at 138 MHz.
(b) & (c) Chart recordings made by replaying from magnetic tape onto a chart recorder after the observing session. Notice the relatively high chart speed required to show the time difference in arrival of the burst at the two recording frequencies.

additional measurements can be made to determine the nature and polarization of the radiation. These results are carefully recorded for later correlation with auroral sightings.

Using this observing protocol many of the basic findings of early solar radio observers were 're-discovered'. We found an association between the presence of active sunspot groups and increased radio burst activity. We were able to infer a connection betweend large sunspots and solar radio noise storms. We found that while noise storm radiation was consistently highly polarized at 138 MHz, TYPE III bursts at the same frequency exhibited a much smaller degree of polarization. The difference in these measurements supports the currently held view that TYPE I bursts are generated in regions of high magnetic field intensity, whereas TYPE III bursts tend to be generated in magnetically neutral regions such as are found within coronal streamers.

TYPE III and TYPE I bursts were by far the most commonly recorded bursts. As many as five or six TYPE III's were sometimes recorded during a single four hour recording period and if a noise storm was in progress many hundreds of TYPE I bursts were occasionally recorded over the same priod.

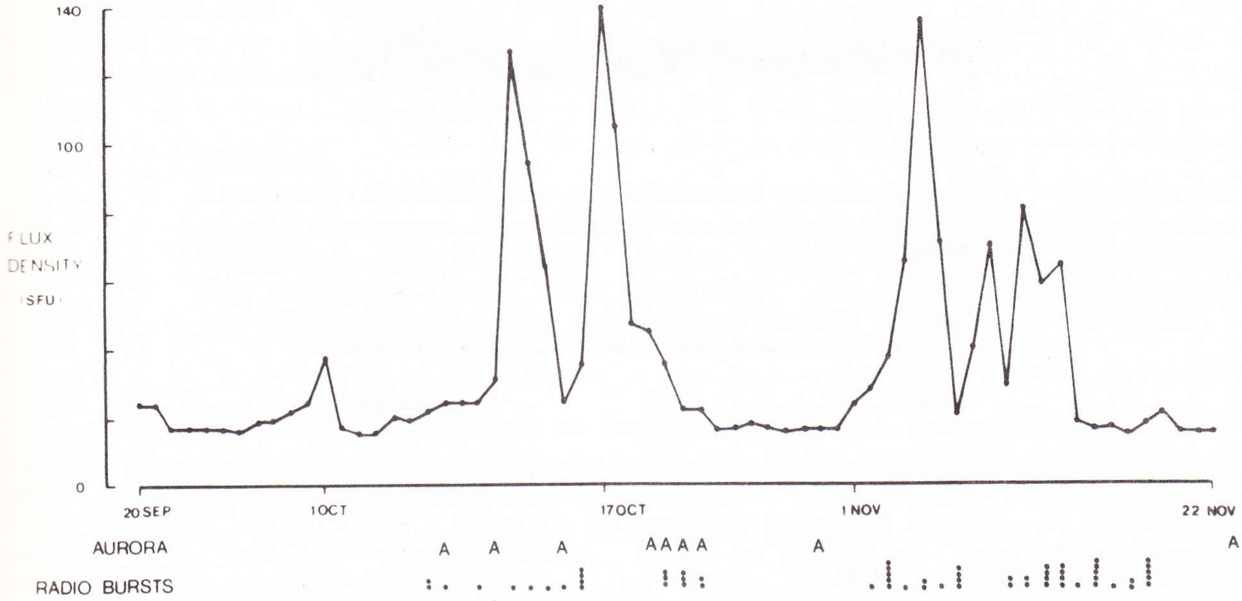

Fig. 7. Graph of Noon Solar Radio Flux data on 228 MHz (1 solar flux unit = 10 E-22 watts per sq. metre per Hz) recorded between 1981 September 20 and November 22. Radio bursts are shown as dots — each dot represents one radio burst observed on that day. Auroral sightings for a particular night are shown as an A.

The average drift rate measured for ten isolated TYPE III bursts recorded in 1982 September was 50 MHz per second. By using a suitable model of the electron density distribution in a coronal streamer, we used this drift rate to calculate an exciter radial velocity of 77,600 km per second (0.26 c). It is not surprising that these energetic electron streams have been detected by satellites at least as far as Earth's orbit.

On 1982 August 8 a TYPE II burst was recorded using the dual frequency radiometer. This event was accompanied by a five minute short wave radio fadeout and was preceded by a group of TYPE III bursts. Interestingly no TYPE IV activity was observed following the TYPE II burst and we did not receive any auroral sightings over the following three days.

1981 was a particularly noteworthy year for auroral sightings, some 35 being reported by our Auroral Section, the highest number for ten years. We noted that aurorae were more prevalent during times at which radio burst rates were high or noise storms were in progress, but the study of these correlations tends to be hampered by weather conditions which prevent auroral observations.

From the daily flux level measurements a baseline value was calculated* (this is referred to as the quiet Sun flux) and used to calculate the apparent temperature of the quiet Sun. These calculations gave a value of 1.38 million Kelvin, a value consistent with the known temperature of the corona (≈ 1 million Kelvin). Interestingly, fringe visibility measurements using the interferometer at different antenna spacings, gave a value of 0.85 degrees for the east-west solar diameter indicating that the radio waves being received at the observing frequency (228 MHz) were generated in the corona.

* The calibration was checked against the 245 MHz flux data provided by Learmonth Solar Observatory, Learmonth, Western Australia.

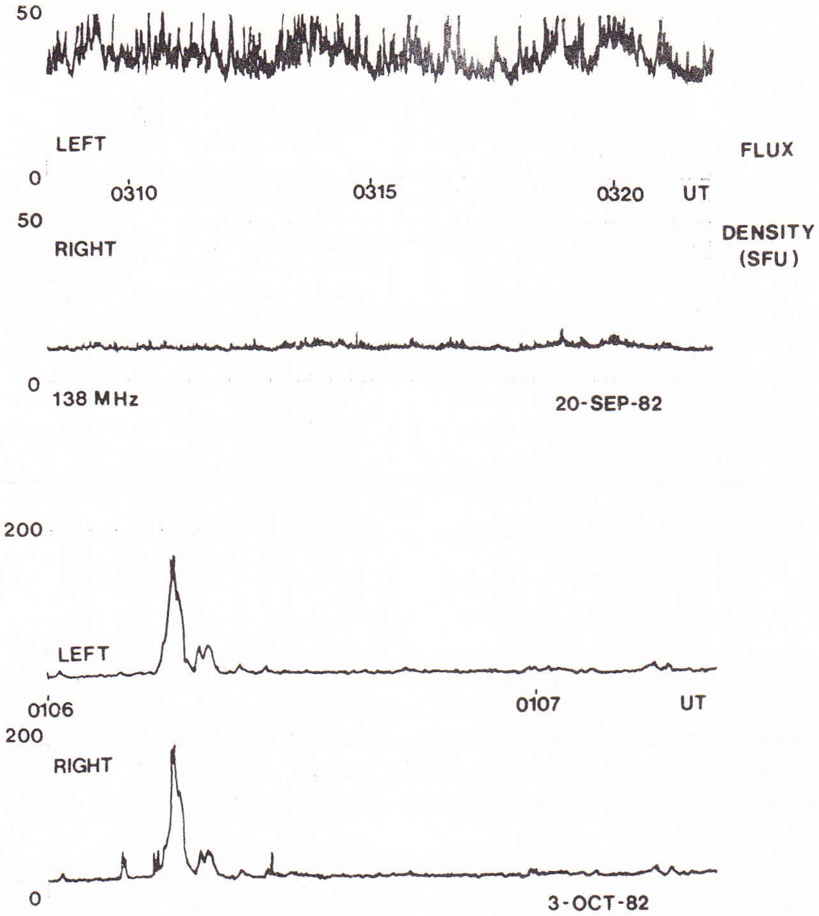

Fig. 8. These chart recordings show radio polarization measurements made with the 138 MHz polarimeter configuration. The top panel illustrates the high degree of circular polarization often present during solar radio noise storms at this frequency. This particular storm was recorded on 1982 September 20. The bottom panel shows the generally smaller degree of polarization associated with Type III radio bursts. (Unpolarized bursts can be thought of as being composed of equal amounts of uncorrelated left and right circularly polarized waves.)

In conclusion, the ability to make the variety of observations described has considerably extended our personal understanding of solar phenomena. The inclusion of radio observations into the programme significantly extended its scope by seemingly providing a missing link between the ever changing face of the visible sun and the terrestrial effects observed. These observations are a clear revelation of the fact that Earth is linked to the Sun by the invisible outflow of solar plasma appropriately termed the solar wind. The radio observations provide a 'window' into the corona making it possible to 'see' the normally invisible high energy phenomena which continuously modulate this wind.

JAVA ECLIPSE 1983: USING THE 2 BARREL SYSTEM

M.M. Wolf
Astronomical Society of South Australia

ABSTRACT

Planning for the trip is discussed together with a description of the equipment used during the eclipse. Details of the double telescope, 800 mm focal length, which fits into a lightweight box 30 x 60 x 13 cm, are described. An account of the eclipse and personal views and impressions of the whole trip are given.

About 10 years ago I decided to photograph a total solar eclipse. This spectacle of nature impressed me so much the first time that since then I seem to follow the eclipses whenever possible. Some people like to watch the eclipses only, but I like to photograph them and obtain a permanent record. In between the exposures, there is plenty of time to observe through the telescope and while exposing, naked-eye observations can be made as well.

Before going to describe the necessary equipment I shall state the type of photography I am doing. Photography is my hobby and over the last 25 years I have had my prints exhibited in national and international salons. Most of my prints are 40 cm x 50 cm and to achieve this, the equipment and processing techniques must be first class.

Most important is the image size on the negative — large enough to show plenty of detail of the flares and allowing up to three diameters of the Sun for the corona and streamers. This depends largely on the exposures. Short exposures will reduce the corona to a very narrow ring around the Sun and long exposures will produce a blur due to the Sun's movement of 15 seconds of arc per second, if the camera is stationary. This can be eliminated by driving the telescope at the solar rate, but all the portable telescopes are subject to vibrations due to wind and camera winding or release. Even small telescopes like Dynamax 6 proved to be a problem when travelling by plane, you cannot take them with you as personal luggage and when sent as normal luggage they would most likely arrive out of collimation.

The next source of drawbacks are the stands and tripods, which vibrate in the slightest breeze and when the shutter is rewound.

Having mentioned all the points to be considered, I shall give a brief description of equipment used in the past and how it all evolved into the 2-barrel system.

During the 1974 W.A. eclipse I used an 800 mm focal length, f/11 refractor, which was mounted in SRBF (single resin bonded fibre) collapsible tubes for transport purposes. The telescope was used on a photographic tripod. After each exposure there was about 20 to 30 seconds waiting time, before the telescope stopped vibrating. Two 35 mm SLR cameras were used, one with B&W film and the other with colour film. Changing of cameras during the eclipse is definitely not recommended.

An improved version was used in 1980 in Kenya, when two refractors were mounted in a yoke, but still situated on a tripod. This eliminated changing cameras with different films. The yoke-mount reduced vibrations — 15 to 20 seconds. But it took more than its share of space in the suitcase.

When planning a trip to Indonesia more emphasis had to be put on the weight of luggage, especially as we intended to be away for three weeks. Also the telescope had to fit into a suitcase. Aluminium tubing is the best for the telescope, but the sizes which were required were not available. So, the next best was PVC tubing.

Each telescope consists of two tubes (1,2), sliding into each other, Fig. 1. The two front tubes (1) are permanently attached to a wooden frame (3). Each leg (7) has an angle bracket (6), specially bent, so that the legs make an equilateral triangle when screwed to the frame (3). Each leg (7) is made out of two equal lengths of aluminium tubing 14 mm in diameter. A dowel (14,15) is pressed into one tube while allowing a sliding fit with the other tube. Both legs are also held together with a 'U' channel (11) for extra support and rigidity. Cameras (12,13) are screwed to the bracket (10) and at the same time attached to the rear tubes (2). Both telescopes are focused simultaneously and then locked with screws (5) which hold tubes (2). Between the rear tubes (2) there is a swivelling joint to which a short tube (8) is attached — this forms the third leg of the tripod. The third leg can also be varied in length and screwed to the bracket (10).

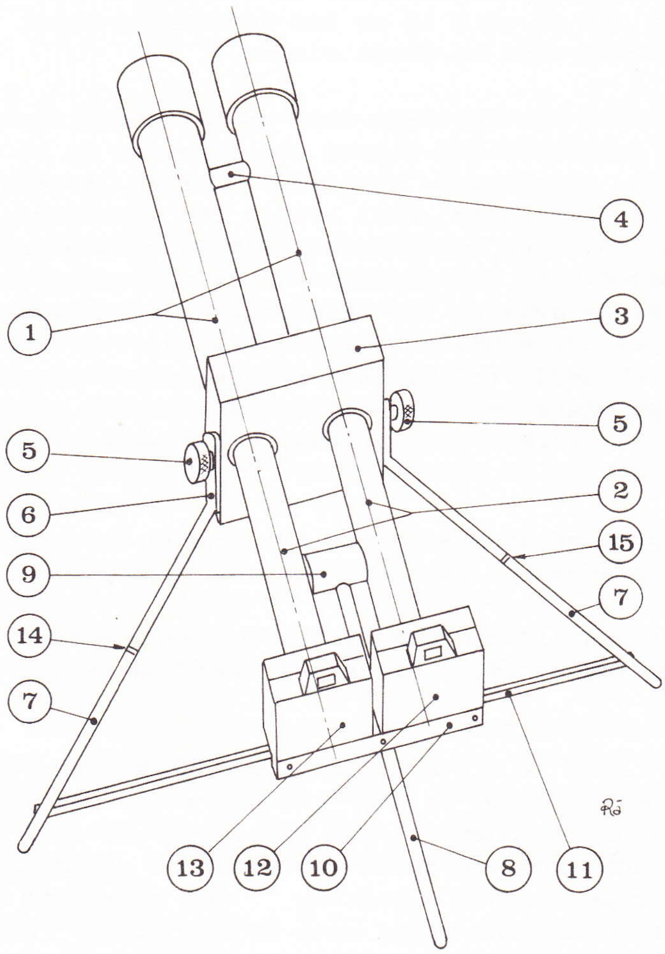

Fig. 1. The 2-Barrel System. 1,telescope front end tubes; 2, telescope rear end tubes; 3, wooden frame; 4, spacer; 5, locking screws, knurled; 6, angle bracket; 7, legs; 8, adjustment leg; 9, swivel joint; 10, camera bracket; 12, B&W - SLR camera; 13, colour - SLR camera; 14 & 15, dowel joint.

The tripod-like frame is aligned in such a way that only a small movement of the short leg (8) will follow the Sun. Less than 50 mm of horizontal movement will change the elevation by 1° for elevation of 60°. If the eclipse lasts 4 minutes the Sun moves 1°. The following of the Sun was found to be very easy, and the vibrations caused by winding the camera stopped within 5 seconds.

The setting up of the telescope takes under 10 minutes. The dismantling takes even less time and all the parts fit into a box 60 cm x 30 cm x 13 cm, which can be placed into a suitcase and should survive the roughest luggage handling. The total weight is 7 kg.

Cameras are extra, but they can be carried around the neck when boarding the plane. The main advantages of this 2-barrel system are light weight, two telescopes and camera operation and the unbelievable rigidity, due to the third leg, which, being an extension ofthe telescope, is embedded into the ground. The cost is less than 15 dollars.

The films used in Indonesia were XP1 - 400 for B&W, Fig. 2, and Fujichrome 100 for colour slides. The exposures ranged from 1/1000 to $^1/_2$ second. Longer exposures produce objectionable blur if the telescope is stationary

$$15 \times \text{exposure time (s)} \times \frac{\text{f.l.(mm)}}{200\ \text{(mm)}} = \text{blur}(\mu\text{m}),$$

for a 1 second exposure with the 800 mm lens, the blur is 16 μm.

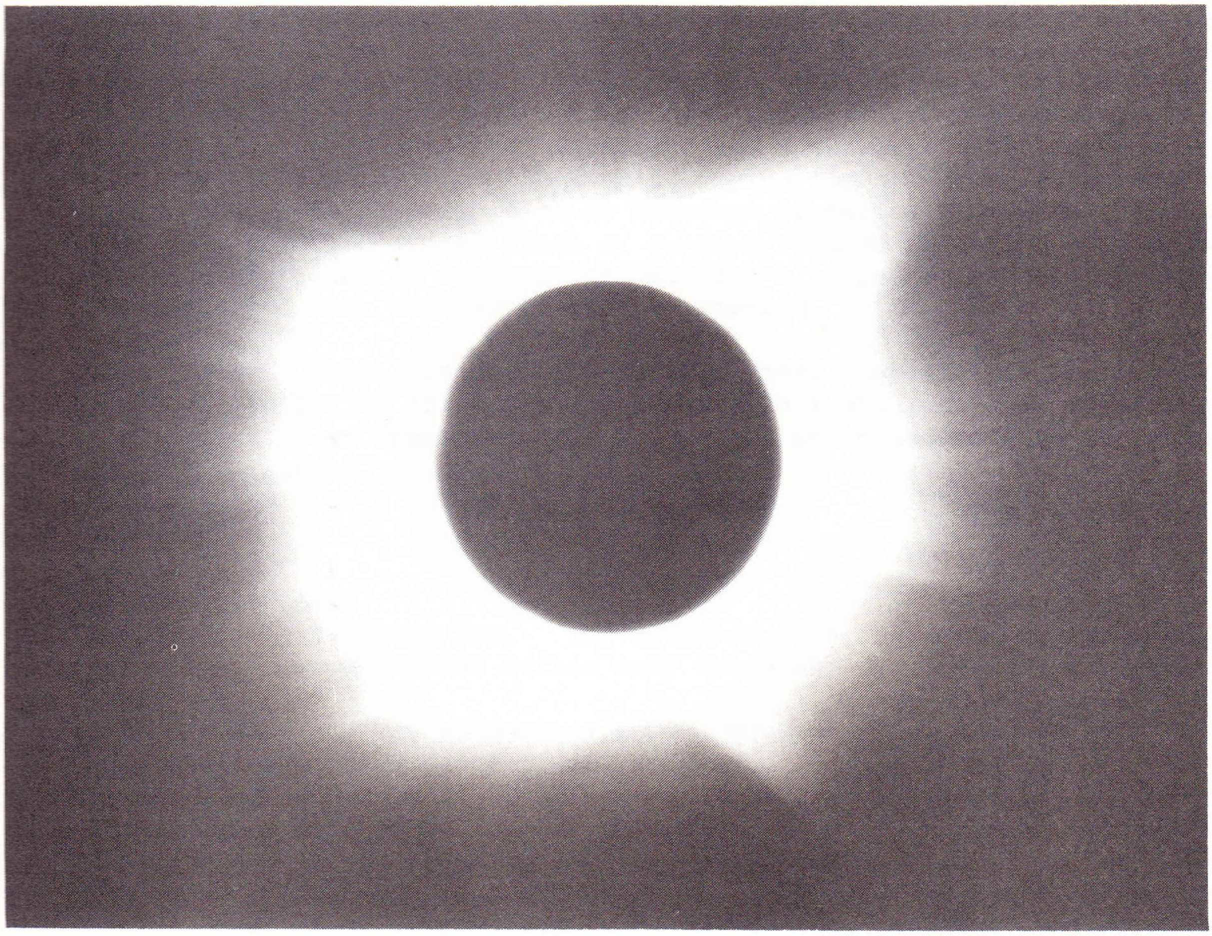

Fig. 2. Java eclipse, 1983 June 11, 11h 26m West Java Time.

I am so pleased with the 2 barrel system that I can recommend it to all. There is one improvement possible, a bit more expensive. The two refractors could be replaced with two Bausch & Lomb, 1-4 m zoom tele lenses, costing about $500 each and available in Australia since the middle of last year. The normal corona shots still would have to be taken with 1 m f.l., but some prominences and Bailey's beads taken with 4 m f.l. could be really outstanding.

DESIGN AND DEVELOPMENT OF A TRIAXIAL MOUNTING

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ABSTRACT

Definition of Triaxial Mounting and a brief look at the advantages and disadvantages of such a system are given. The Poncet mounting is described in detail and related to the first mounting built as an experimental model, together with the reasons behind its failure. The forces acting within this type of installation are examined. The above mounting was re-designed and re-built, developing some similarities to a split ring configuration. Tangential clock drive is considered.

This paper does not aspire to be a complete coverage of mountings that could be termed Triaxial, so much as an account of the development of one particular example. It is a tale of original conception and construction and of the inevitable faults that became apparent during the building and testing period.

First, however, let us define what is meant by Triaxial. Obviously as its name implies it has three axes, but there is more to it than that. The advantages of an old type Altazimuth mounting are well known and in an effort to preserve those advantages while at the same time exploiting the single axis tracking capability of an equatorial, it occurred to someone to mount an altazimuth unit on a polar axis. Thus the first triaxial unit was born. Many variations appeared, and among the most interesting was one credited to Adrian Poncet (Cox, 1977; Sinnott, 1980a; Sinnott, 1980b) which reduced the polar axis portion to a triangular table with the apex pointing away from the pole and supported on some form of universal joint or pivot. The other end of this horizontal triangle, facing the pole, was supported at its eastern and western extremities by bearings or Teflon pads that ran on a very carefully positioned base plate or running surface which *exactly* faced the pole and was tilted to *exactly* the observer's latitude. The altazimuth unit was installed near the centre of the triangle.

This Poncet form was selected for my first experiments in actual construction. It failed for several reasons wich I shall discuss later, but first I feel that an examination of advantages and disadvantages of three movements is warranted.

Advantages

1. Extreme stability.
2. Maximum comfort during use. The eyepiece of a refractor or compound telescope always remains within easy reach and close to the supporting pier.
3. No Polar Hassle. Try aligning a normal equatorial on an area near the pole and the problem becomes very evident.
4. Fairly easy construction of a reasonably accurate drive.
5. It possesses all the well known advantages of an altazimuth, coupled with the short term tracking ability of an equatorial.
6. Dobsonian operators will find that it is the only practical way of making their instruments capable of medium long exposure photography. (Short of computer controlling both existing axes.)

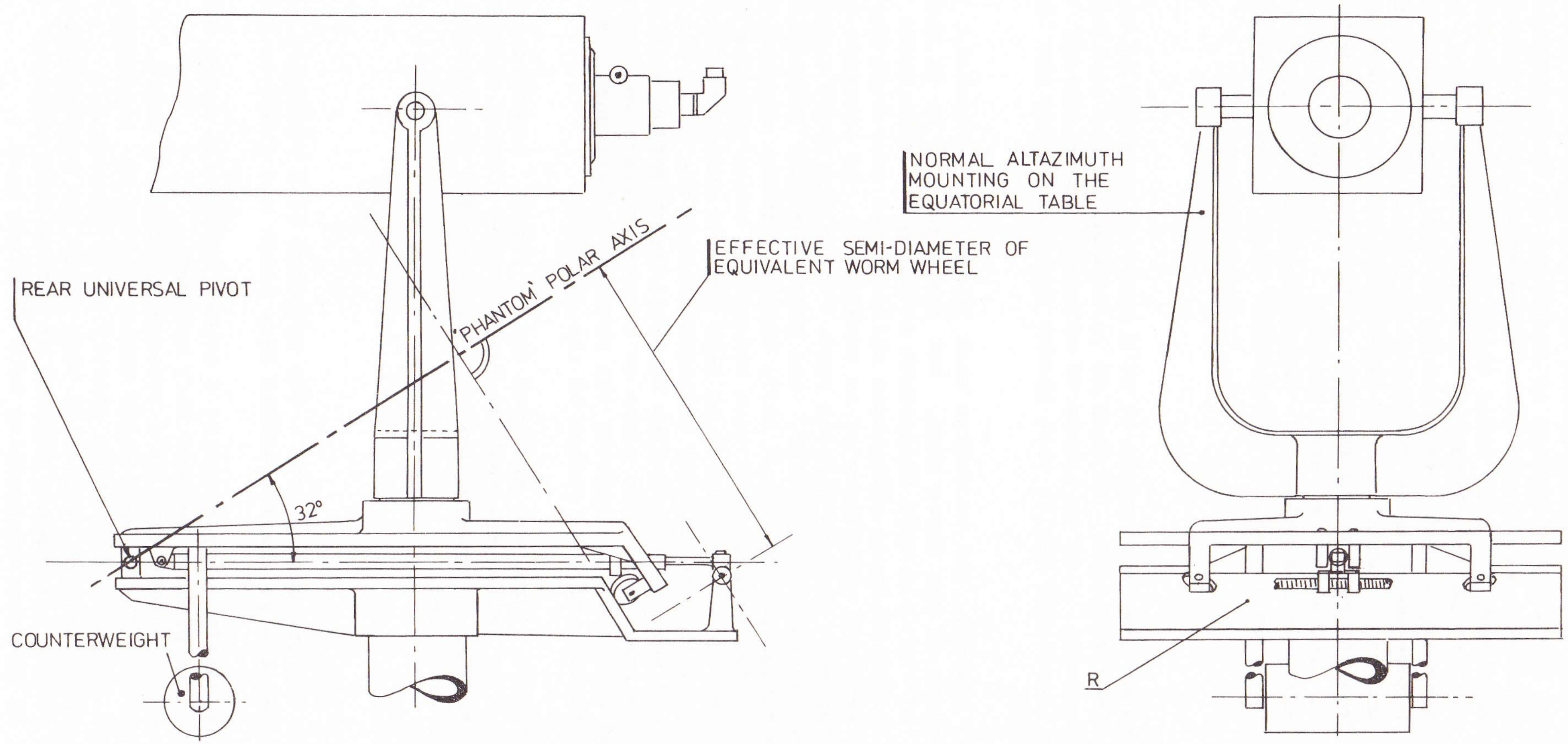

Fig. 1. General arrangement of the first (Poncet) form of the experimental mounting, showing the geometry of the supports and clock-drive linkage.

Disadvantages

1. Use of setting circles is precluded.
2. Only just over an hour of tracking is usually possible at any one setting and any re-setting of the table rotates the field.
3. The N/S line in the visual field can lie at any angle, varying with azimuth and altitude.
4. It is not possible to sweep along a preselected R.A. or Dec with a single axis movement.
5. There are undoubtedly extra complications involved when designing for three axis movements as against two in any traditional type of mounting.

The choice seems to become a completely personal one. Some fields of observational astronomy could welcome it while others might deem it completely impracticable.

Rather than embarking upon a lengthy description of my mounting in its first (Poncet) form, I have opted for a series of detailed annotated sketches which should be self-explanatory. One point however that does seem to give people a lot of trouble visualizing, is the total motion of the table section. It actually moves as though it were attached to the side of a cone who axis is co-incident with the Phantom polar axis. Thus as well as rotating around the rear pivot, it also twists at the rate of 15 degrees per hour. It follows therefore that the most suitable rear coupling should be either a free-turning universal joint or a self:aligning ballrace. A point or hemispherical support pin located in a matching depression would also serve, but provide very limited load bearing capabilities. It would therefore only be suitable for comparatively light and small instruments.

The instrument in its first form is detailed in Figs. 1 and 2. As previously stated the running plate, R, must very accurately face the south pole of the sky. Upon this and this only depends the accuracy of tracking. All other dimensions may be fair approximations, but not the alignment of the running surface. Contact between the moving table and running surface can be ballraces as illustrated (Fig. 2), or may be a non-rotating slidng contact between two low friction surfaces such as Teflon and metal.

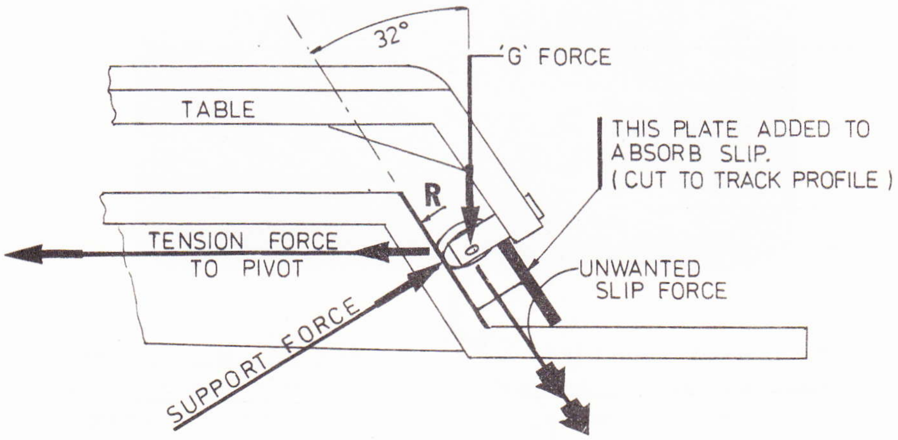

Fig. 2. Some forces acting within the mounting. The first modification as described in the form of an additional support plate is also illustrated.

A very serious defect became apparent when the pilot model was constructed. In its original form the Poncet was intended for use at high latitudes. It is probably quite efficient under those conditions, but the nearer one approaches the equator the more it becomes prey to a kind of sogginess. Theoretically it would at the equator actually suffer total failure. The cause is not hard to understand as is illustrated in Fig. 2. This shows that at any latitude there would be a lateral thrust across the running surface. At latitudes above 45/50 degrees it would probably not be a matter for much concern, but at our latitudes can give rise to disastrous effects. In a rigidly built table the movement is slight enough to be only visible through the eyepiece of any telescope mounted thereon. The worst feature of this effect is that the two southern supports do not necessarily oscillate together, producing a rather disconcerting effect of using a telescope mounted upon an unstable jelly!

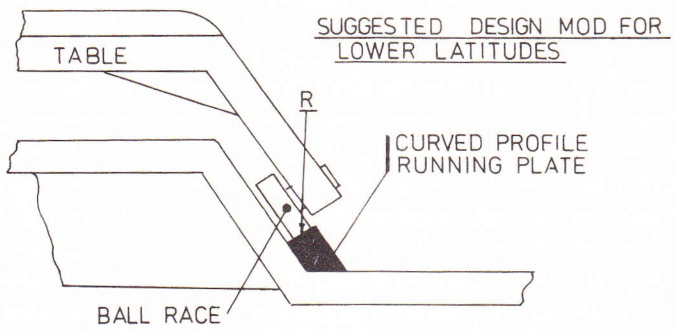

Fig. 3. One of the alternative designs considered but never built.

Some improvement was effected without resorting to major surgery. First to be tried was the addition of a 5 mm thick plate with a carefully tailored curve on its upper edge, mounted in the same plane as the running surface. By bearing against the bronze ballrace supports it absorbed most of the oscillation produced by lateral thrust, resulting in a much more rigid mounting, but still leaving something to be desired.

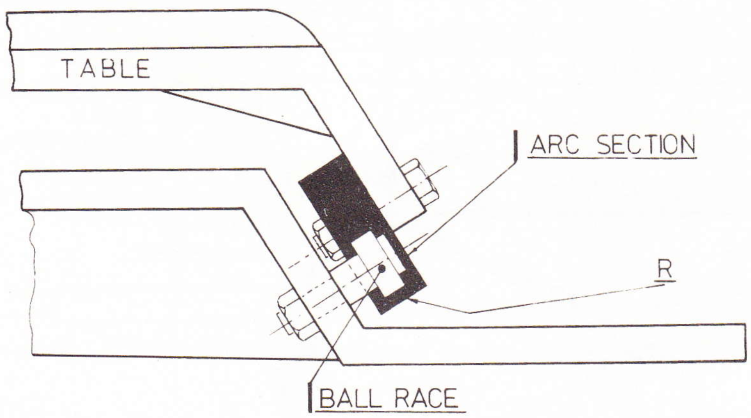

Fig. 4. The final solution.

Another partial solution would have been to rotate the axes of both ballraces through 90 degrees and allow them to run upon a heavier version of the above plate, Fig. 3. All thrust would then have been radial to the ballraces.

To understand the forces acting within such a frame, reference should be made to Fig. 2, which is completely self explanatory. The tendency for the ballraces to slip laterally across the running surface is the real cause of instability. (Marked with a double arrow.)

At this point it was decided to entirely re-design what was proving to be the Archilles heel of the mounting. In the new design both ballraces were removed from the moving table casting and replaced with a heavy 26 mm thick accurately machined steel arc section using HTS bolts through the 13 mm diameter holes previously housing the ballrace shafts, to hold the parts securely in alignment. Both ballraces were then mounted on the east and west extremities of what had been the Poncet running plate and in the same plane thus giving the table radial support via the new arc section, Fig. 4.

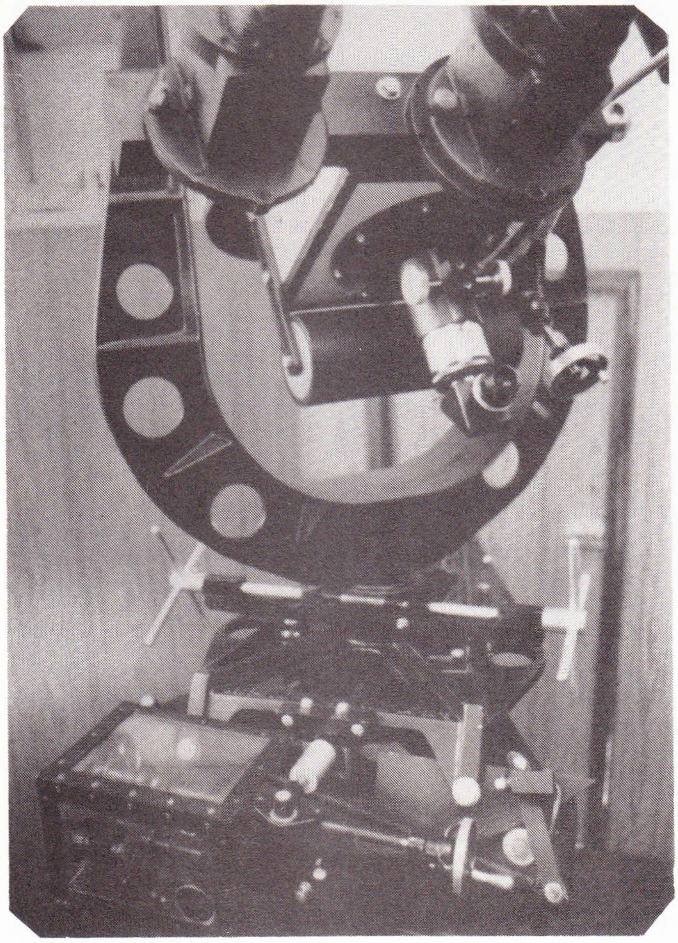

Fig. 5. Southern view of the table in its final form. To the left is the gearbox and clutch unit. The radius rod is visible in the centre making connection with the drive screw, to the right may be seen the electrical limit switch. Arc section and Eastern ballrace are also visible. Telescopes shown in the picture are 150 mm refractor (f/10), 120 mm refractor (ex Moonwatch apogee telescope) and 50 mm finder.

With these new features the system became very similar to that employed in a split-ring equatorial. Because of the spread between the now fixed ballraces a far more stable unit resulted. So much for the actual mounting.

To conclude I offer a few notes on applying a suitable tangential clock drive mechanism. Visible in both photographs, Fig. 5 and 6, is a 12 tpi brass screw of local hardware store origin, which while of nominal cost, has a very accurate thread due to its method of manufacture. It has a drive effect upon the movement of the table equal to that which would be produced by a worm and wormwheel (of the same pitch) whose diameter would be double the distance from the screwed rod to the phantom polar axis. In this type of mounting one is able to achieve the effect of using a wormwheel that would be far too large and costly for most amateurs to consider — see Fig. 1. In the case of the present mounting the equivalent wormwheel diameter worked out at 660 mm. It provides one of the smoothest drives that I have used. Particular mention should be made of the method of

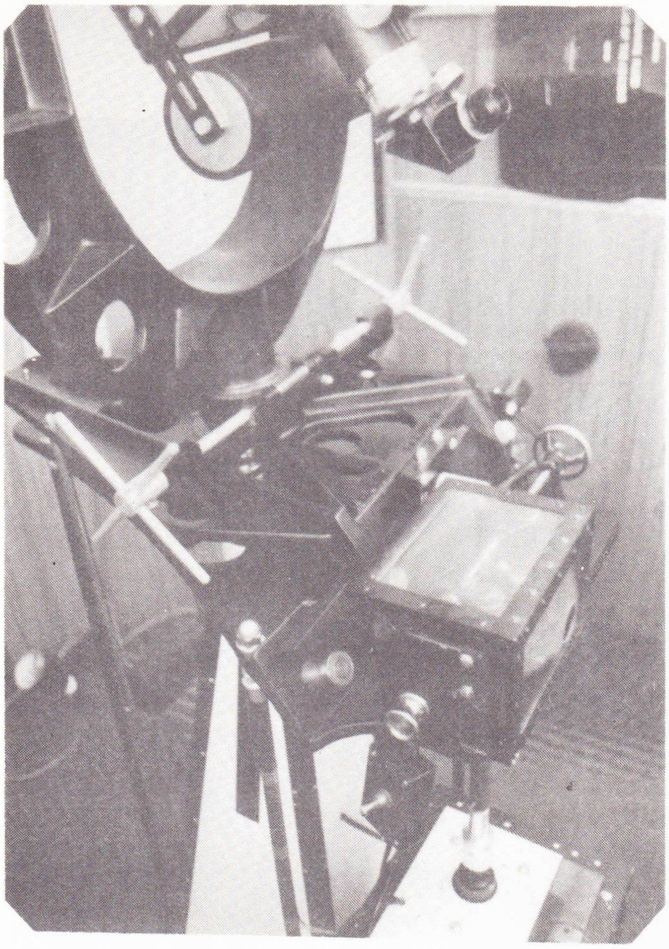

Fig. 6. Aspect of the unit from West side. Relationship of the three main aluminium castings (base, table and forks can be seen in this view. On the facing side of the gearbox is clutch conrol knob and hanging from it is the remote slow motion control paddle. Clock rewind wheel is at the further end of front section. The two large capstan wheels give slow motion in azimuth and can be easily reached from any possible position of the telescope eyepiece. At the extreme lower right may be seen the top of the clock drive motor housing, separately mounted and connected to the instrument by a vibration absorbing coupling.

transmitting motion from the screw to the main table. This is done through a radius rod anchored at the north end of the table and passing through a vertical slide arrangement at the southern end. Where the radius rod meets the screw thread the head must be free to turn on the radius rod, and to telescope in and out of the rod. Only by incorporating these three motions will a strain free coupling be achieved.

After an hour of tracking, which is all that is practicable with any tangential drive, the screw is disengaged from its motor by means of a clutch at the western end and wound back to its starting point by means of the handle visible at the eastern end. Pressure operated micro switching prevents any over-ride by turning off the electric drive before any mechanical jamming occurs. Slow motion in R.A. is achieved through an incorporated Sperry differential unit, electrically controlled.

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A TELESCOPE-DRIVE CONTROL SYSTEM USING A CRYSTAL OSCILLATOR

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ABSTRACT

Drive control systems are an important aspect of modern telescopes. This is particularly so in the case of telescopes which are used for astrophotography and photometry. For both these and other uses it is important that the drive control system be able to provide an accurate and stable drive frequency to the telescope and allow a user the capability of guiding in two axes. It is important that the drive rate is isolated from the frequency of the power supply mains (since this is not sufficiently stable) and, for portable telescopes, is capable of operation from battery supply. It is also important that the drive control system is reliable, easy to operate, efficient in its use of power, inexpensive and is accurate over wide ranges of temperature and supply voltage. This paper describes a new design of telescope-drive control system which meets all the above criteria and is significantly more accurate than many others. It makes use of recent advances in semiconductor technology which enable the inclusion of a number of attractive features. Two important aspects of the design are the inclusion of a new configuration of crystal oscillator (developed by the author and J.G. Hollow) and the use of power field-effect transistors in the output circuitry.

INTRODUCTION

The quality required of telescope drive control systems for amateur astronomers' telescopes is dependent upon their expected use. Some applications, for example low power visual observation, do not necessarily require automatic drive while for others, such as photometry and photography, it is essential.

This paper considers the accuracy required from telescope drive control systems for various applications, and means of eliminating errors due to the electrical drive system. The crystal controlled drive system described takes advantage of recent technological advances to obtain high performance, yet offers simplicity and low cost.

DRIVE CONTROL ACCURACY REQUIREMENTS

The accuracy required of telescope drive systems varies markedly with the application under consideration. Some applications can be achieved with no drive system at all whilst others may require stringent control. The following provides an evaluation of this requirement.

Low power visual observation

Where the magnification is low (say less than 100 times) and a reasonably wide field is available (say more than 0.5 degrees) there is generally no significant difficulty in manually adjusting the telescope position to track a particular object. This is frequently the case when the telescope is being used for 'general browsing' or low power observation of, for example, variable stars.

Medium to high power visual observation

When the magnification is sufficient to provide only a small field of view (say more than 100 times) it becomes increasingly desirable to have the telescope driven at an appropriate rate to track objects being observed. It is generally undesirable to have to touch the telescope in order to adjust its position because of consequential vibrations, particularly at very high magnifications (say more than 200 times). The drive system need not be of the highest standards of accuracy, since it is really only necessary to retain the object in question reasonably close to the centre of the area of good definition of the telescope for the duration of the observing time. For example:

Assuming:

- A magnification of 400 times.
- A requirement of retaining the image within the inner 20% of the field of view for, say, 20 minutes.
- An apparent field of view of 45 degrees.

It can be shown that the drive error should not exceed 45*60/400*5=1.35 minutes of arc per 20 minutes of time, that is, about 1 part in 220 variation from correct drive rate in right ascension (assuming little drift in declination).

Thus, for visual observation at medium to high magnification (for example as would be used for planetary observation, double star observation and some observation of variable stars) it is important to drive the telescope automatically rather than manually, however, the accuracy required is not great. The accuracy required should be readily obtainable using power supply company mains and synchronous motor drive, assuming no errors due to mechanical or atmospheric considerations.

Location of objects

Availability of accurate setting circles can be a significant aid in the location of either faint or unfamiliar objects. For the circles to be effective it is necessary for the object in question to be able to be centred, say, within the inner 50% of the field of a low power eyepiece. For example:

Assuming:

- A magnification of 100 times.
- A requirement of retaining the image within the inner 20% of the field of view for, say, 120 minutes.
- An apparent field of view of 45 degrees.

It can be shown that the drive error should not exceed about 13.5 minutes of arc per 120 minutes of time, that is about 1 part in 120 variation from correct drive rate in right ascension (assuming little drift in declination).

Thus, for ease of location of faint or unfamiliar objects using setting circles, it is important to drive the telescope automatically rather than manually; however, as previously, the accuracy required is not great. The accuracy required should be readily obtainable using power supply company mains and synchronous motor drive, assuming no errors due to mechanical or atmospheric conditions.

Planetary photography

Photography of planets generally requires the highest resolution obtainable from the telescope and atmosphere. Exposures are typically around 2 seconds but perhaps as long as 10 seconds.

Assuming:

- Resolution requirement of 0.2 seconds of arc.
- Exposure time of 5 seconds.

It can be shown that the drive error should not exceed about 1 part in 380. This is about the limit of possible performance to be expected from normal power supply company mains, assuming no errors due to mechanical or atmospheric considerations.

Deep-space photography

Photography of deep-space objects does not generally require the highest resolution obtainable from the telescope and atmosphere. It is usual for corrections to be made to the telescope position from time to time in order to obtain suitable guiding. In order to avoid this task becoming overly tiring for the observer it is best to ensure that the corrections do not have to be made too frequently.

Assuming:

- Resolution requirement of 1 second of arc.
- Time between drive corrections of 30 seconds.

It can be shown that the drive error should not exceed about 1 part in 450. This is above the limit of possible performance to be expected from normal power supply company mains. In addition to this it is necessary to be able to change the drive rate to enable guiding, further ruling out the use of mains supply.

Photometry

Photometry is becoming a particularly attractive technique for amateur astronomers, but it places some stringent demands upon the telescope drive accuracy. For example, it may be desirable to monitor the brightness of an object over a long period of time (without break to check alignment) such as for occultations. It may also be essential to use a small aperture in order to ensure that sky glow does not mask the object in question (particularly in suburban areas). Both these factors combine to produce stringent accuracy requirements. For example:

Assuming:

- An observation time of 15 minutes.
- An aperture of 10 seconds of arc.
- The object is maintained within the inner 50% of the aperture.

It can be shown that this implies that the drive error should not exceed about 1 part in 2,700.

Spectroscopy

Spectroscopy is not often undertaken by amateur observers. However, the drive error requirements can be readily examined. If it is assumed that a star image is to be retained on a slit, then the drive should not allow a drift of more than, say, 50% of the width of the image over the period between drive corrections. For example:

Assuming:

- An image size of 0.5 seconds of arc.
- Drive correction every 30 seconds.

It can be shown that the drive error should not exceed about 1 part in 1,800.

Summary

It can be shown that for all usual uses of telescopes other than low power visual observation it is advantageous to use some form of automatic drive system. The accuracy requirements are such that for medium to high power visual observation it is probably adequate to rely upon power supply company mains (assuming it is available) and synchronous motor drive. For photographic, photoelectric and spectroscopic use it is necessary to obtain greater precision.

CAUSES OF INACCURACY

A number of factors can lead to inaccuracies in telescope drive systems, all of which should be taken into consideration. These include the following (Sidgwick, 1979):

Atmospheric

The atmospheric refraction of light results in the required drive rate of a telescope varying according to the zenith angle of the object in question. This is most marked at large zenith angles. For small zenith angles it should not be a cause of difficulty.

Mechanical

Many mechanical aspects can result in significant drive errors in telescopes. It can readily be shown that these are most likely to be the limiting factor in drive accuracy. They include: polar axis alignment, regularity, concentricity and centring of drive gears, concentricity of bearings and flexure of telescope axes and optics.

Electrical

Assuming electrical signals of some controlled frequency or repetition rate are used to activate the telescope drive motors, the drive accuracy will depend upon both the initial frequency and drifts which may occur with time, temperature and supply voltage level to the drive control system.

Summary

In order to obtain a drive system of sufficient accuracy it is necessary to consider each of the possible contributing degradatory aspects. It is desirable, where possible, to ensure that the degradation from the majority of these causes is well below that required for the total system. In general, it is possible for electrical considerations to be removed as a source of degradation by suitable design (as will be shown below). The dominant remaining cause of degradation will, in most cases (certainly for the amateur astronomer), be mechanical.

DRIVE CONTROL SYSTEM

Requirements

A drive control system for the typical telescope used by an amateur astronomer should meet the following criteria:

Accuracy

As shown previously in the paper, the drive rate should be accurate to at least 1 part in 2,700. In order to ensure that the contribution from the electrical system to any errors is negligible it is desirable that the electrical system be significantly more accurate than that, say at least 1 part in 10,000. This accuracy includes both the initial setting accuracy and drifts with time, temperature and supply voltage. This level of accuracy is in excess of that which can be readily obtained, except by the use of crystal controlled oscillators. For example, typical RC oscillators will in general be limited by the temperature coefficient of the passive components to an accuracy of less than 1 part in 1,000 over the expected temperature range.

Crystal oscillators can be readily expected to achieve an initial setting accuracy of about 1 part in 100,000 and a drift with temperature change of about 1 part in 100,000 per 10 degrees. They will also generally be far less complex and cheaper to construct than high quality RC oscillators and require no precision components.

Efficiency

It is desirable to ensure that the efficiency of the drive control system is high for two reasons. First, this will maintain a lower temperature of the system. Second, it will consume less power from the power source — an important consideration if this is a battery.

Facilities

Many facilities can be provided in drive control systems. Those considered essential by the author are:

- Guiding capability in both axes. This implies that the output for right ascension must be variable in frequency, either by fixed step change or continuously. The author prefers fixed step variation, seeing no advantage to be gained from the other more complex implementation.

  Assuming that several fixed frequencies are to be generated and be switch selectable it is necessary to select these to be readily suitable to electronic implementation and suitable for the type of drive motor used. The most readily implementable frequencies are half and twice the nominal drive frequency, these being obtainable from simple divider chains. This is suitable for some motors although others will be likely to stall. The author has found that a suitable compromise is 3/4 and 3/2 nominal frequency. Few motors will stall at these drive rates, yet they are sufficiently different from the nominal drive rate to enable adequate guiding.

- Power supply from either mains or battery. This enables the telescope to be used at remote locations.

- Protection from damage due to external causes. This should include, at least, protection from output short circuits and incorrect polarity of battery supply power.

- Provision to control the drive system remotely, including at least: ability to stop the output, drive in both axes with the ability to reverse the control switches (in order to be able to have switches arranged so that their effect is in accord with their physical position, allowing the use of star diagonals).

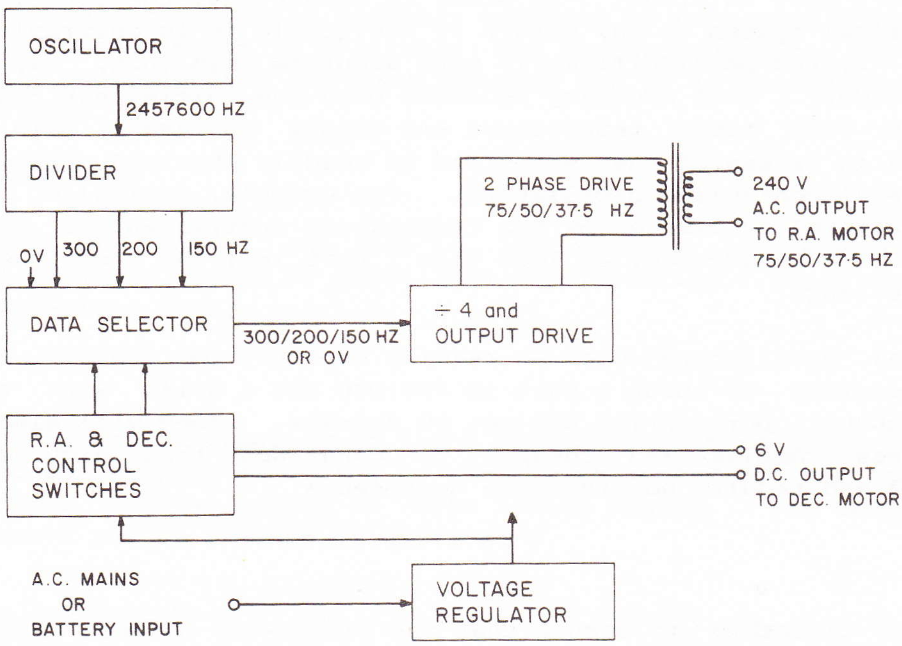


Fig. 1. Block diagram.

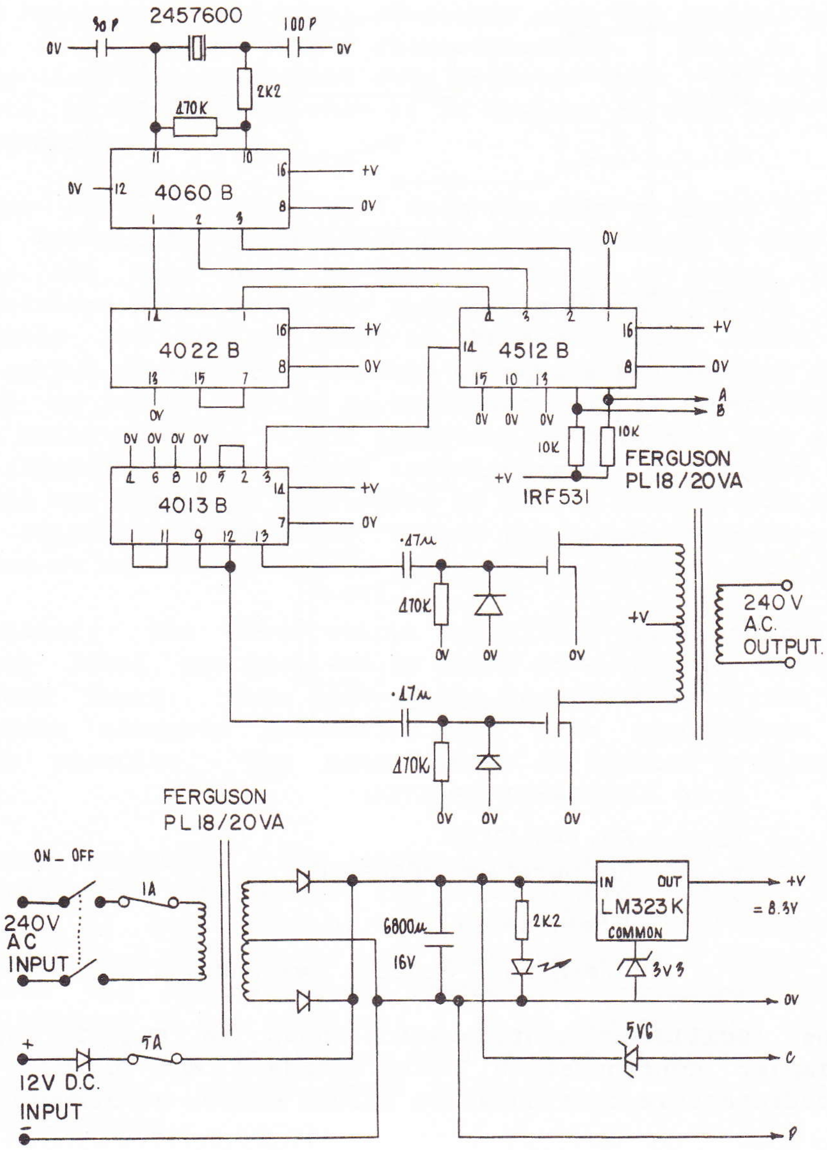


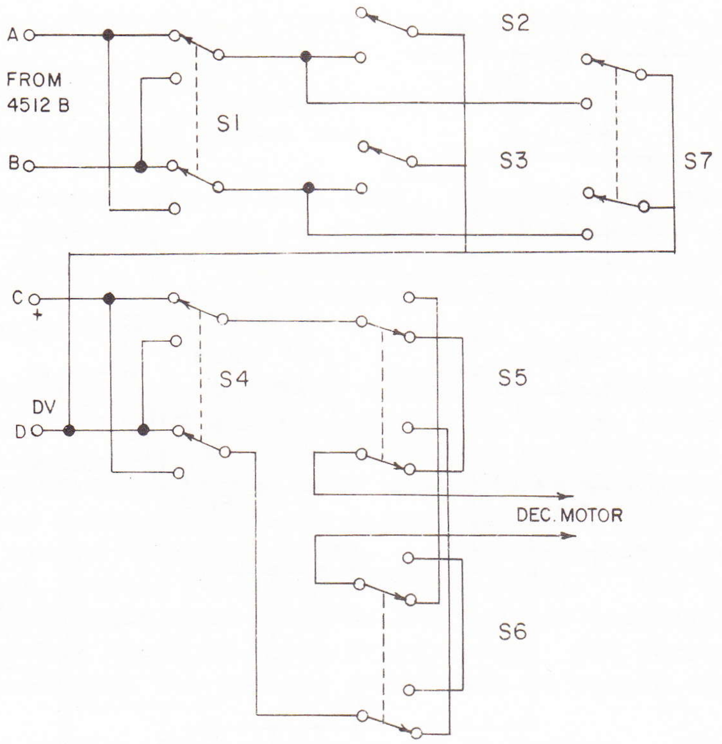
Fig. 2. Circuit diagram.

Block diagram and circuit

The block diagram of the drive control system is given in Fig. 1, the circuit diagram in Fig. 2 and the control switches in Fig. 3. The major components are as follows:

- Oscillator: This oscillator is crystal controlled, providing suitable drive accuracy as discussed in Section 2. The oscillator can be implemented in a number of ways. It is important to select a configuration which is tolerant of supply voltage and temperature variations, is guaranteed to start oscillating upon turn-on and is not prone to operate at erroneous frequencies. Many oscillator configurations do not meet all of these criteria.

  An alternative oscillator configuration is given in Fig. 4. This circuit is due to Hollow and Park and is superior to that shown in Fig. 2, having better accuracy and greater protection from erroneous operation. It should be used if greater accuracy is desired.



S1,S4 : MOVEMENT DIRECTION

S2,S3 : R.A. FAST/SLOW

S5,S6 : DEC. INCREASE DECREASE

S7 : R.A. OFF

Fig. 3. Control switches.

The oscillator configuration shown in Fig. 2 is, however, a simpler configuration using standard CMOS logic. While not as accurate this configuration allows easier construction.

- Divider: This block divides the output frequency of the oscillator to obtain suitable drive frequencies for the drive motor. The nominal output frequency is obtained by dividing the 2,457,600 Hz from the oscillator by 12,288 to give 200 Hz (which is further divided to give 50 Hz). The fast and slow drive rates are obtained by dividing the oscillator frequency by 8,192 and 16,384 to give 300 Hz and 150 Hz respectively (these being further divided by 4 to give 75 Hz and 37.5 Hz).

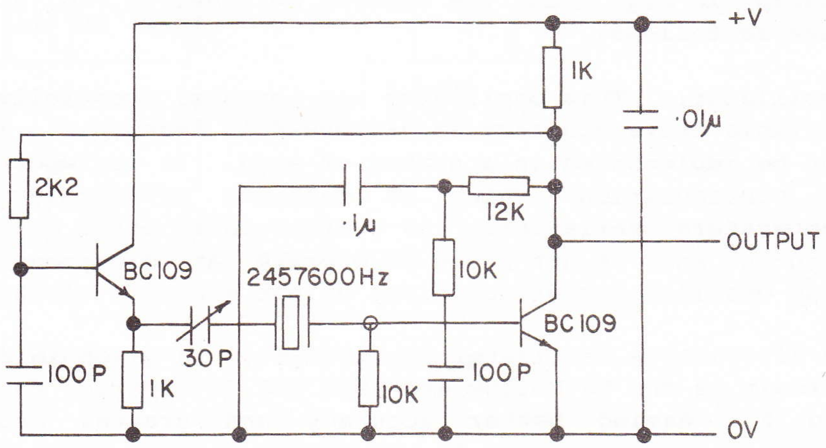


Fig. 4. Alternative oscillator.

- Data selector: This block, together with the control switches, is used to select the output drive frequency. This is implemented using an eight input CMOS data selector chip, one of the unused inputs being selected when it is desired to turn off the output momentarily.

- Output driver: The signal from the data selector is first split into two signals 180 degrees out of phase using a CMOS flip-flop. These are then used to drive a pair of power field-effect transistors which drive the output transformer. The transformer produces 240 volt AC power at the appropriate drive frequency. The output waveform is composed of square pulses with peak voltage equal to 240 V, giving an equivalent RMS value to that obtained from mains supply. It is important to note that the signals from the flip-flop to the output transistors are AC coupled in order to enable the output to be stopped by simply turning off the input to the flip-flop (otherwise, one of the output devices would remain turned-on and overheat when the output is turned off).

- Regulator: The power output capability limit and regulation of output level are provided by means of a voltage regulator with current limit. This adds to the inefficiency of the system but provides adequate protection from such occurrences as output short circuits. The output power is limited to a total of 15 Watt.

- Control switches: The control switches are usually remotely located from the rest of the drive control unit. They enable control of both axes of the telescope. The right ascension controls are so arranged that when the control switch module is removed the nominal output frequency is obtained (for example, when guiding is not required). It is important to note that the switches for the declination axis need to be arranged so as not to cause power supply short circuits if both are operated simultaneously.

Highlights

The major design innovations included in this drive control unit are:

- The crystal oscillator (discrete device version), invented by the author and Dr J. Hollow (to be published). The alternative use of a standard CMOS oscillator is satisfactory, though not as accurate.

- The use of power field-effect transistor output devices (Collins, 1979).

- The basic simplicity, yet high performance of the unit.

Important construction details

The use of switched mode output driving inherently involves very fast risetime waveforms with large amplitude. This is particularly the case when field-effect devices are used. Consequently, care should be given to the construction of the electronics (Park and Hollow, 1981). In particular, attention should be paid to earthing, power supply decoupling and the use of earth-plane construction.

Safety

It is important to note that drive control systems as described in this paper are potentially lethal in that they generate high voltage outputs with the capability of outputting some tens of Watts of power. Consequently, they are not the domain of unskilled tinkerers and appropriate measures must be taken to ensure that electrical safety is achieved. This is particularly important because of the fact that they may be prone to damp environments and rough treatment.

SUMMARY

It has been shown that in order to obtain sufficient accuracy it is necessary to use a crystal oscillator in telescope drive control units. The unit described in this paper provides excellent performance yet is not complex or expensive. Standard components are used throughout and no laboratory measurements or sophisticated facilities are necessary for its construction or calibration. It is fully protected and can supply sufficient output power to drive the majority of "amateur-size" telescopes. The adoption of power field-effect transistors for the output drive has enabled the use of CMOS devices and the attainment of low operating power requirements. At present-day prices, the approximate cost of construction is $100.

The use of a drive control system as described should eliminate electrical considerations as a source of drive error. The dominant remaining source of error for amateur telescopes will most usually be mechanical.

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TELESCOPE MOUNTINGS FOR GREATER EFFICIENCY IN COMET HUNTING

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Astronomical Society of South Australia

ABSTRACT
For horizontal sweeping of the sky with an altazimuth-mounted telescope, it is necessary to make an adjustment to the angle of elevation between consecutive sweeps to allow for the rising or setting of the star fields. The use of a motorized elevation axis can simplify the adjustments and eliminate the risk of missing out fields between adjacent sweeps. However, if the altazimuth mounting is carried on a polar axis which is driven at sidereal rate, duplicated coverage and omission of star fields can both be eliminated. Some mountings which have been constructed and used by the author are described. The procedure to obtain greater search efficiency with these mountings is discussed.

INTRODUCTION

The simplicity of an altazimuth mounting and the ease with which it can be used make it an attractive support for a comet-sweeping telescope. Unfortunately, the published statements on comet-hunting procedures are oversimplified on the detail of using the altazimuth mounting. The technique advocated (Norton,1957; Sidgwick,1971; Apsi,1975; Bortle,1981; Sherrod,1981; Seargent,1982) is to sweep horizontally, first in one direction and then, after an adjustment to the telescope elevation has been made, back in the opposite direction. this back-and-forth process is continued as the sweeps are progressively stepped upwards or downwards as required. The suggested adjustment has been given(Apsi,1975;Bortle,1981;Sherrod,1981) as half the field width, with the steps being made upwards in the western sky and downwards for sweeps in the eastern sky.

It may not be realised that the above procedures will usually result in an unnecessary amount of overlap of consecutive sweeps. The area of duplicated coverage can be reduced by:

(1) adopting a unidirectional sweep pattern instead of the back-and-forth method;

(2) selecting the sweep overlap according to the time taken to make a sweep.

Since the problems of using an altazimuth are primarily related to the motion of the star fields across the sweep path, this aspect needs examination.

MOTION OF THE STARFIELD

Figure 1 shows the western sky as seen from a latitude of 32° south (Perth), giving the trails of stars below an elevation of 60°. At all azimuths in the general westerly direction the star-motion is downwards. Except for the upper polar region, the motion is also towards the south.

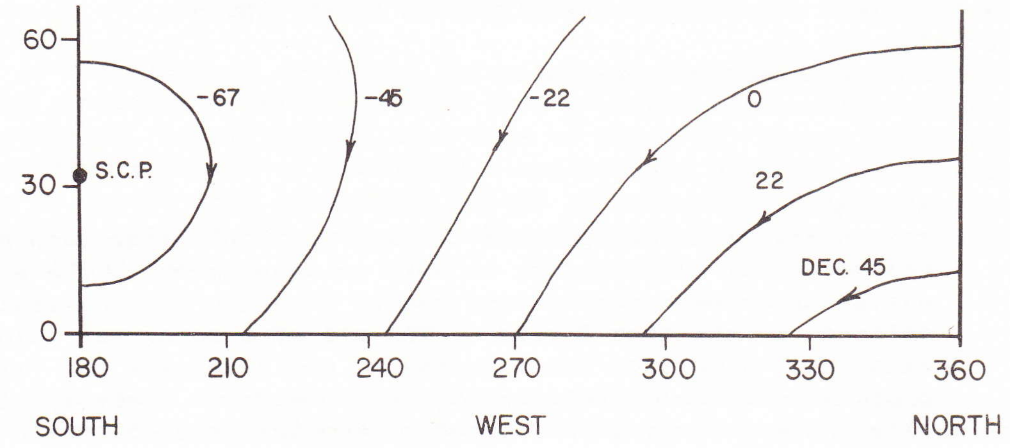

Fig. 1. Star tracks in the western sky.

The linear motion in degrees per minute of the stars across the celestial sphere as seen from all latitudes is a function of their declination and equals 0.2507 cos δ. A calculation using spherical trigonometry can be made to show that the instantaneous vertical component, V, of the linear motion, as observed from a given latitude, is

$$V = 0.2507 \cos L \sin A \ ^\circ\mathrm{min}^{-1},$$

where L is the latitude, and V is independent of the elevation of the star for a given azimuth, A. Figure 2 shows the sinusoidal variation of the vertical component of motion for various observer latitudes. The maximum vertical component occurs at due east and due west (for the maximum negative, downward motion).

For Perth (latitude 32°S) the vertical component of the linear motion is:

$$V_{PERTH} = 0.2126 \ (\sin A) \ ^\circ\mathrm{min}^{-1}.$$

COMPARISON OF UNIDIRECTIONAL SWEEPING METHOD WITH BACK-AND-FORTH METHOD

To show the benefits of unidirectional sweeping, an example of sweeping in the western sky is discussed. For simplicity, sweeping is restricted to a limited arc centred on azimuth 270°, so that the vertical component of

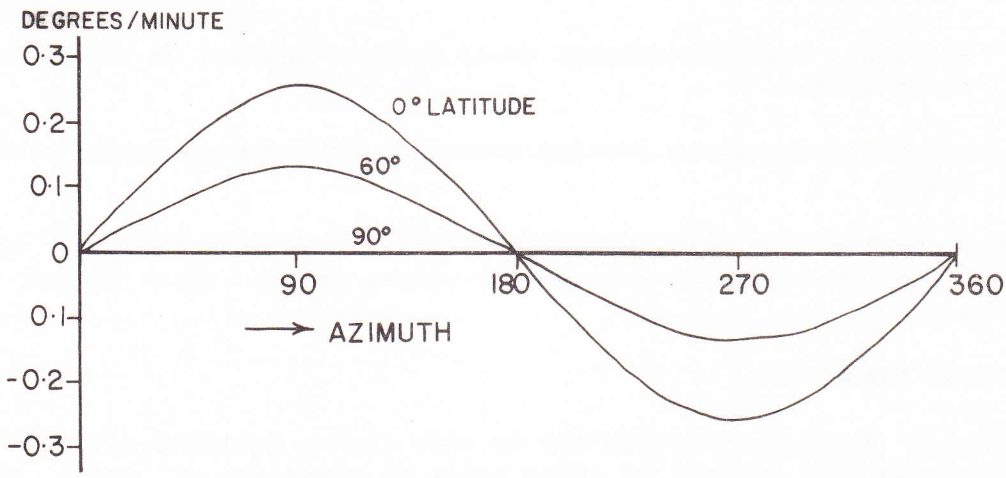

Fig. 2. Vertical motion of the celestial sphere.

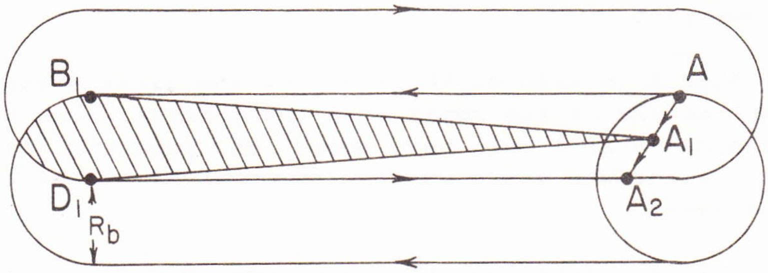

Fig. 3. Back-and-forth sweeping mode.

star-motion can be assumed to be constant for all azimuth points along the arc. The sweeping is a constant rate movement without interruptions and is slow enough for the observer to determine the nature of diffuse objects as they drift through the field of view. In Figs. 3 and 4, the width of the field of view is exaggerated in relation to the length of the sweep to help clarify the diagrams. Also, the direction of star-motion depicted in the field of view is the same as that seen when using a telescope fitted with a terrestrial eyepiece, to simplify the explanation.

Back-and-forth sweeping

In Fig. 3, star A is observed at the start of the first sweep at the top of the field. At the end of the sweep when the observer sees star B_1 at the top of the field, star A will have moved to position A_1. Line A_1B_1 then represents the line through all stars which were observed at the top edge of the field during the sweep.

The telescope is immediately elevated for the return sweep by the maximum possible amount which is consistent with ensuring that no star fields between the two sweeps escape unsearched. This adjustment must allow star A, at position A_1, to be seen at the bottom edge of the field at position A_2 at the end of the second sweep. Thus the telescope elevation needs to be increased by amount

$$R_b = F - 2TV,$$

where R_b is the step-up in elevation, degrees,
F is the width of working field, degrees,
T is the time of one sweep, minutes,
V is the vertical component of star-motion, degrees/minute.

At the beginning of the second sweep, line D_1A_1 represents the line through stars which are subsequently observed at the bottom edge of the field during the second sweep. Area $B_1D_1A_1$ is common to the two sweeps and it is this area which is unavoidably swept twice.

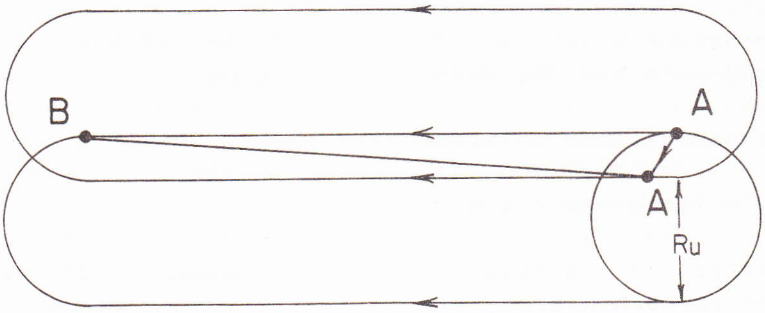

Fig. 4. Unidirectional sweeping mode.

Unidirectional sweeping

In Fig. 4, star A is seen at the start of the first sweep at the top of the field. At the end of the sweep when the observer sees star B1 at the top of the field, star A will have moved to position A1. Line A1B1 represents the line through stars which were observed at the top edge of the field during the sweep.

In unidirectional sweeping the telescope is quickly returned after completion of the first sweep to the starting point and adjusted in elevation for immediate commencement of a second sweep. The adjustment required is

$$R_u = F - TV$$

and places star A, at position A1, at the bottom edge of the field for the second sweep. Providing the sweeping rate for the second sweep is the same as that for the first sweep, all the stars observed at the bottom edge of the field during the second sweep will have been located along line A1B1 at the start of the second sweep. Thus no overlap area is formed between the two sweeps.

Comparison of performance

It is clear from the above that the unidirectional method is superior to the back-and-forth method for a restricted arc of sweep. In practice, the path swept will be much longer so that the vertical component of star-motion cannot be considered as constant along the sweep-path. The varying vertical component will create some small duplicated coverage in the unidirectional sweeping method, but in all cases this duplication will be much less than the duplicated coverage created by using the back-and-forth method.

An explanation of the mathematical analyses which take into account the variation of the vertical component of the star-motion with change of azimuth, will not be detailed here. In these analyses, the duplicated coverage between two sweeps can be expressed as a fraction of the area of one sweep-path by the relation

$$D = V_{max}\ d\ T/F$$

where D is the duplicated coverage fraction,

V_{max} is the maximum value of the vertical component encountered in the sweep-path,

d is a constant which is a function of the azimuth limits of the sweep-path and the method of sweeping,

T is the time of one uninterrupted sweep,

F is the working field width.

Some results of calculations for the example of sweeping between azimuth 270 and azimuth A are given in Fig. 5, where values of d are plotted as a function of A. The curves for the back-and-forth and unidirectional sweeping methods readily show the superiority of the unidirectional method.

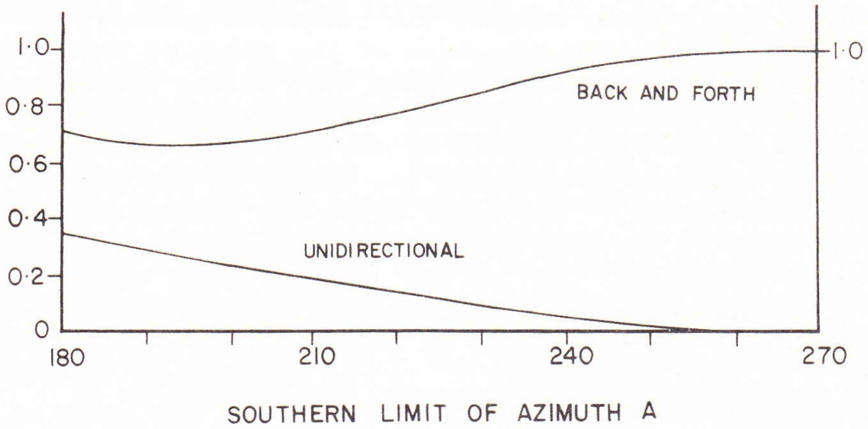

Fig. 5. A plot of d as a function of azimuth, A, for the back-and-forth and the unidirectional modes.

Effect of telescope aperture

If a larger aperture telescope is used to see fainter objects, not only will the field of view be smaller but the time to complete a fixed length of sweep will be proportionally larger. Thus for a fixed sweep-rate (expressed as fields covered per unit time) the duplication fraction will be proportional to the square of the time taken to complete one uninterrupted sweep. In using large aperture telescopes it is more imperative that unidirectional sweeping practices are used.

PRACTICAL ASPECTS

In practical sweeping there is a tendency to overlap sweeps excessively to ensure that no star fields are missed. This may be the reason why it may be easier for the beginner to follow the often quoted suggestion of adjusting the elevation by half the field width. However, high efficiency sweeping with altazimuth mountings can only be obtained if the overlaps are based on the actual time to complete uninterrupted sweeps. If the observer can establish his maximum sweeping rate which ensures consistent detection of diffuse objects, it is possible to standardize the sweep-time and hence the corresponding adjustment in elevation. The difficulty of achieving the maximum efficiency can be overcome without the need to monitor sweep-times by using a motorized drive on the elevation axis of the altazimuth mounting.

MOTORIZED ALTAZIMUTH MOUNTING

As comet sweeping involves sweeps mostly through the west or east azimuth points, adjustments to the telescope-elevation between succeeding sweeps must be related to the vertical component of the motion of stars at these directions. In providing a motorized drive for the elevation axis it is necessary to duplicate this motion. The stars further away in azimuth from the west point (or east point) will continue to drift across the sweep-path but at a very much reduced rate. After each sweep with the driven system, the telescope is returned to the starting point and adjusted by an amount equal to the full working field-width, regardless of the time taken to complete the sweep.

The mechanical arrangement used by the author for a 150-mm refractor consists of a lever which is driven at its free end about the telescope's elevation axis by a screw coupled via reduction gearing to an electric motor. By the appropriate selection of the pitch of the screw and the length of the lever, the required turning rate of the lever can be achieved. The lever motion is transmitted to the telescope body near the eyepiece end by an adjustable link. Adjustments of the elevation of the telescope after each sweep are achieved by changing the length of the link by means of a built-in rack and pinion. The motor drive and tangent screw assembly are mounted on the side of the fork mounting which supports the telescope on its elevation axis bearings. As in the conventional usage of altazimuth mountings for comet hunting, the telescope is turned in azimuth by hand. The A.C. synchronous electric motor is supplied from a D.C. to A.C. inverter connected to a 12 volt car battery. In the arrangement used by the author, the tangent screw gives a drive time of $1^{1}/_{4}$ hours and needs to be reset to give a further $1^{1}/_{4}$ hours.

Figure 6 gives a simplified layout of the system. As originally used, the column supporting the azimuth bearing can be raised or lowered in the telescope supporting stand to give comfortable stand-up viewing for all elevation angles of the refracting telescope.

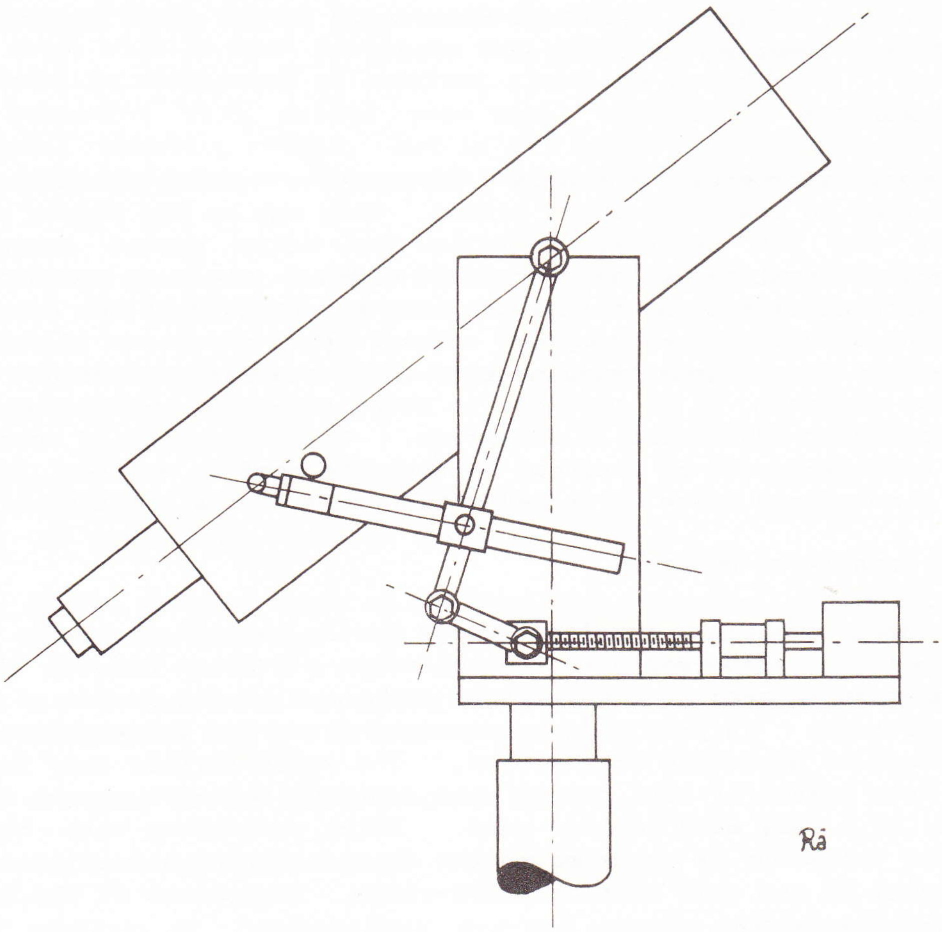

Fig. 6. Motorized altazimuth mounting.

ALTAZIMUTH MOUNTING FOR NEWTONIAN REFLECTOR

In 1981 October, a decision was made by the author to use a 250-mm aperture f/5.6 Newtonian reflector for some comet hunting operations. A mounting for the telescope to give comfortable viewing for the observer in the standing position was designed, built and used. The principal features are shown in Fig. 7 where the telescope is shown pointing to the zenith. Eyepiece viewing is in the horizontal direction, as the eyepiece axis is coincident with the elevation axis of the telescope mounting. Balance of the telescope about the elevation axis is given by a counterweight (a 6-brick cluster) mounted ahead of the telescope, so that the centre of gravity of the moving system coincides with the intersection of the elevation and azimuth axes. An adjustable link (not shown in the simplified diagram) is used to hold and adjust the elevation angle setting. A handle attached to the elevation bearing block is used to push the telescope about the azimuth axis in much the same way as by a submarine commander operating his periscope. Although the main structural supports for the telescope and its counterweight require a more massive system, the author constructed a version which could be broken down for transport and stowed as four main sub-assemblies in a station wagon.

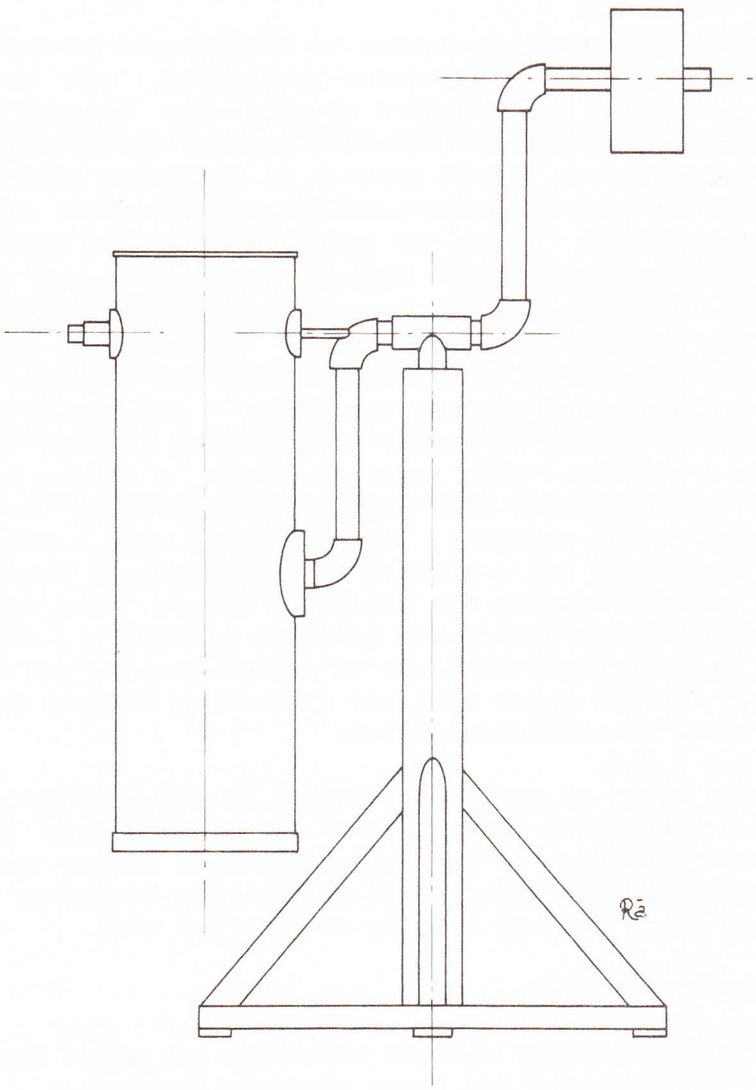

Fig. 7. Altazimuth mounting for Newtonian reflector.

THREE AXIS SYSTEM

The altazimuth mounting with the motorized elevation axis previously described gives a small but acceptable duplicated coverage of the star fields which are located away from the west (or east) azimuth points. This unavoidable duplication is increased substantially when using larger aperture telescopes. Complete elimination of all undesirable overlap across the whole range of azimuths including the polar regions can be obtained by mounting the simple altazimuth (without elevation axis drive) onto a platform which is driven about a polar axis at sidereal rate. There are many variations of platform based on the Poncet principle, but most of these have various undesirable features such as:

(a) centre of gravity of telescope removed from the equivalent polar axis so that the load on the polar axis drive varies as the platform tilts,

(b) limitation of the tilt of the platform,

(c) eyepiece position may vary considerably for various pointing directions of the telescope so that comfortable observing positions may not be always available.

These features prompted the author to investigate an improved system for the use of a 250-mm f/5.6 Newtonian reflector, and the altazimuth mounting shown in Fig. 7 was modified so that the azimuth bearing was mounted on the upper end of a polar axis shaft. The intersection of the two axes of this altazimuth was placed exactly on the polar axis so that the centre of gravity of the complete turning mass remained fixed for all positions of the telescope. With the eyepiece axis also directed to this intersection point, a comfortable viewing position could be obtained. However, when the altazimuth tilts over as a result of being driven at sidereal rate, the initial horizontal plane, representing movement of the eyepiece in azimuth, becomes a tilted plane where the eyepiece position can become lower or higher during part of the sweep. For higher positions of the eyepiece there is a need to stretch a little or arrange a low level ground platform as a step-up. With lower positions, a slight body crouch or a sideways tilt of the head will enable the observer to maintain a comfortable attitude at the eyepiece. Comet hunting with a 250-mm reflector was considerably simplified and a greater sky coverage was possible with the three axis system without missing out strips of stars. The scheme was more complicated than the simple altazimuth mounting of Fig. 7, but in portable form it was used to accumulate 48 hours of sweeping up to the discovery of comet 1984a. Drive for the polar axis was given by a tangent screw assembly providing over 3 hours of continuous drive.

Tilting of the plane of eyepiece-movement during an observing session can be less of a difficulty if the system is initially set in a tilted position opposite in direction to that which develops during the second half of the observing period. For example, in western sky sweeping, the axis can be initially tilted with its top leaning towards the east.

EQUATORIALLY MOUNTED TELESCOPES

The use of an equatorially mounted telescope for comet hunting should not be dismissed, particularly for large aperture telescopes, provided the change of eyepiece position during sweeping can be accepted. For portable equatorial telescopes there is no need to accurately align the polar axis as for astronomical photography. Sweeping should be conducted about the polar axis and steps between sweeps should be made by turning the telescope about its declination axis. The major difference between the equatorial and altazimuth modes concerns the interaction of sweeps with the western or eastern horizons. With the equatorial it is not possible at any one session to obtain the same coverage of near horizon stars as with the altazimuth; however, those star-fields which are examined with an equatorial will be examined under more favourable viewing conditions and fainter objects may be discovered.

CONCLUSION

The use of a motorized elevation axis altazimuth system for a 150-mm aperture telescope has been adopted by the author and provides a considerable advantage over the use of a simple altazimuth for comet hunting. Larger aperture instruments can only be satisfactorily employed if the problems associated with the smaller field and the rotation of the earth can be overcome. Solutions which include a polar axis are preferred but the extent of complexity which can be accepted with a three-axis mounting will depend on the achieved portability.

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MOUNT GUNGIN RADIO OBSERVATORY

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Astronautical Society of Western Australia

ABSTRACT

The Astronautical Society of Western Australia is developing a radio observatory at Mount Gungin, situated in the Darling Range close to Perth Observatory. Two activities are catered for, radio astronomy and reception of signals from artificial satellites. Three different types of antenna have been installed, and their design and construction are described. The various astronomical programmes that are planned are described, accompanied by the results of some preliminary trials. Whereas satellite applications is an expanding field in Western Australia, the science of radio astronomy has always been neglected. It is hoped that the Mt Gungin Radio Observatory will stimulate interest in this activity, which is presently confined to the south-east of Australia.

Mount Gungin Radio Observatory (MGRO) is owned and operated by the Astronautical Society of Western Australia. The Observatory is on a two-hectare site leased from the State Forestry Department, and is situated about 1 km north-west of Perth Observatory. The site is surrounded by hills, which provide useful screening against electrical interference from power-lines and nearby television transmitters.

INITIAL DEVELOPMENT

About ten years ago, enquiries made at the Physics Departments of the University of W.A. and the W.A. Institute of Technology revealed that no radio astronomy was conducted at either establishment, despite the fact that Australia has been a leader in this field since its commencement some 35 years ago. (It is worth noting that, today, there is still no professional radio astronomy carried out in Western Australia.) Consequently, Brian Sallur and another individual with similar interests decided to establish an observatory for radio astronomy studies, and the present site was acquired. A local amateur astronomer donated a ready-built antenna and the steel material to build another, and a small transportable hut was purchased to house the electronic equipment. Due to the difficult nature of the ground (densely-packed gravel and very hard rock), the task of burying cables to connect the antennae to the hut was very time-consuming and progress was slow. It was at this time that the Astronautical Society became involved.

PARTICIPATION BY THE ASTRONAUTICAL SOCIETY OF W.A.

Initial contact with the Society resulted in the Society taking over the management of the project. It was thought that this would benefit both parties — the greater number of individuals available would speed progress on development of the Observatory, and (hopefully) a number of members would become interested in taking up radio astronomy as a hobby.

A Radio Astronomy Division was formed, and a series of working parties was formed. These operated at weekends and, over a period of two years, resulted in a great deal of work being done. All the cabling was buried in plastic conduit, an annexe to the hut was built to enlarge the working area, and a third antenna, for the reception of radio signals from artificial satellites, was built.

Approaches were made to a number of companies, resulting in the donation of material to build the satellite antenna and much other needed equipment. A brochure was printed and distributed to a number of organizations, and requests for assistance with the design of the equipment were made to the CSIRO Division of Radiophysics.

RECENT DEVELOPMENTS

After some 2 to 3 years of intense activity, progress again slowed. There was a drop-off of interest by Society members, to the extent that there are now once again only two or three people involved. One setback has been several occurrences of vandalism at the site, resulting in damage to the hut, antennae and cables. The remoteness of the site, in a State Forest, makes it difficult to protect.

A further misfortune occurred during the winter of 1983 when the satellite antenna was damaged during a severe storm. These occurrences have resulted in the efforts of the few individuals still active being concentrated on protecting and repairing equipment, and on developing an interferometer antenna for radio astronomy, leaving the other antennae and all satellite work to a later time.

COMPARISON OF OPTICAL AND RADIO ASTRONOMY

There are several interesting similarities and differences between optical and radio astronomy. In a reflecting optical telescope, light-waves are reflected from the primary mirror to a secondary mirror or prism, then directed to the eye-piece or photographic plate. The magnification of the instrument is given by the ratio of the focal-lengths of the eye-piece and the primary mirror. In a radio telescope, such as a parabolic-dish instrument, radio waves are reflected by the dish to the antenna element at the focus, then directed to a receiver and then to a pen- or chart-recorder. The magnification of the instrument is given by the product of the electrical gains of the antenna and receiver. Just as an optical telescope is affected by light pollution and instrument leakage, so a radio telescope is affected by electrical interference and by electrical noise in the receiver.

The major difference between the two sciences is the wavelengths at which they operate, and the effect that this has on the design of the instruments. Optical astronomy is conducted at wavelengths, for white light, of around 6×10^{-7} metres. The angular resolution of a typical amateur telescope, with a 30 cm-diameter mirror, is given by wavelength divided by diameter:

$$\text{resolution} = \frac{6 \times 10^{-7}}{0.3} = 2 \times 10^{-6} \text{ radians}$$

Radio astronomy is conducted over a very wide range of wavelengths, Fig. 1, from below 10 mm to about 30 metres. For a radio telescope, operating at 1 metre, to have a resolution of 2×10^{-6} radians, as above, the diameter of its reflector would have to be $\frac{1}{2 \times 10^{-6}} = 5 \times 10^{5}$ metres, or 500 km.

Alternatively, for a typical amateur radio telescope with a reflector 5 metres in diameter, the resolution is only 0.2 rad, which is 100,000 times poorer than the optical telescope. Fortunately there are techniques available to overcome this apparently insurmountable obstacle.

The surface accuracy of a radio telescope reflector can be much less than that of an optical telescope. An accuracy of 1/20 of a wavelength is considered acceptable, so for an operating frequency of 300 MHz (wavelength = 1 metre), the required accuracy is 1/20 metre or 5 cm. It is therefore quite satisfactory to use coarse wire-mesh, or even parallel wires spaced 5 cm apart, to form the reflector. As the operating frequency is increased the wavelength becomes less, so the surface accuracy must be increased, but it is not until very high frequencies are reached that a solid-metal surface becomes necessary.

RADIO SOURCES

There are a number of celestial radio sources that are strong enough to be studied by the amateur.

TABLE 1. Some astronomical radio sources.

Source	Signal strength (Jansky) measured at	Frequency (MHz)
Sun (quiet)	$10^4 - 10^5$	50 - 500
Sun (active)	$10^7 - 10^8$	50 - 500
Jupiter	10^6 up	5 - 40
Milky Way (Sagittarius A)	1,000	178
Cassiopeia A	17,000	100
Cygnus A	8,000	178
Crab Nebula	1,500	100

Cosmic radio sources are extremely weak compared to terrestrial or satellite broadcast signals, and are frequently weaker than the background noise. Very high amplification and special techniques are necessary to extract the signals and display them on a recording instrument.

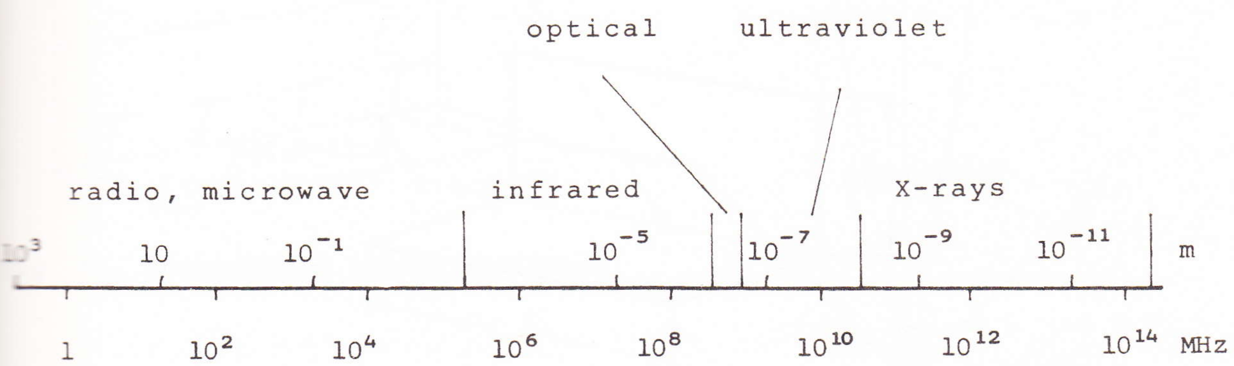

Fig. 1. The electromagnetic spectrum.

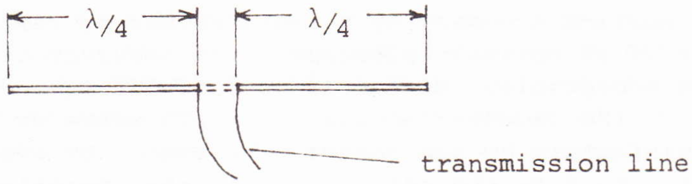

Fig. 2. The half-wave electrical dipole.

BASIC ANTENNA DESIGN

The most elementary radio antenna element is the HALF-WAVE DIPOLE, and it is the standard against which all other antennae are compared. It consists of two metal conductors, each a quarter-wavelength long, separated by a small space. There are two main types of antenna used for radio astronomy. One is the multi-element, consisting of a number of dipoles in a stack (looking like a fringe-area TV antenna); the second type is the large-area reflector, which employs a parallel-wire, mesh or solid-metal reflector. It is the second type which is used at MGRO and which will be described further. The simplest reflector-type antenna is the CORNER REFLECTOR, which consists of two flat metal reflectors at right-angles with a dipole mounted at the focus, Fig. 3.

If the antenna is mounted with its long axis in the east-west direction, then as the Earth rotates a region of the sky will pass in front of the antenna. Since the antenna is directional, a radio source in this region of sky will pass through the receiving beam and be detected. If the antenna is then adjusted vertically to scan a different region of sky, other radio sources will be detected. This technique is called DRIFT-SCAN operation. The pattern of the receiving beam, called a polar diagram, is shown in Fig. 4. The sensitivity or gain of the antenna is maximum in the forward direction, and falls away towards the sides, the lengths of the arrows denoting the sensitivity. The beam-width is the angle measured between the points on the polar diagram where the received power is half the maximum value (called the 'half-power points'). The beamwidth is given by:

$$BW = \frac{1}{\text{length in wavelengths}} \text{ radians} = \frac{57.3}{\text{length}} \text{ degrees}$$

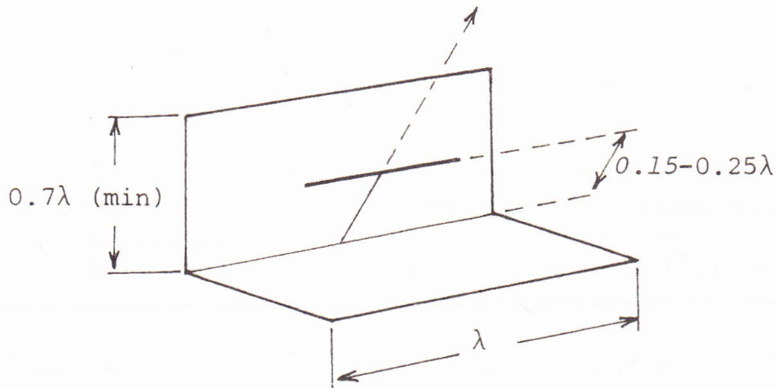

Fig. 3. Single-element corner reflector.

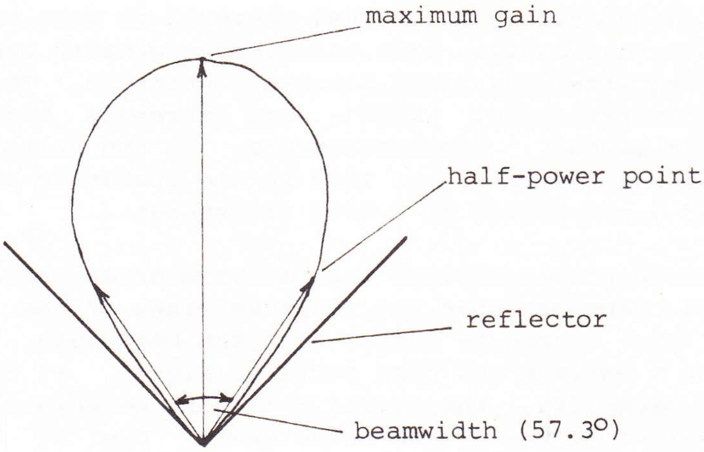

Fig. 4. Polar diagram for single-element corner reflector.

So a corner reflector one wavelength long has a beamwidth of 57.3°. The beamwidth (resolution) can be improved by increasing the length of the reflector and the corresponding number of dipoles. An antenna 4-wavelengths long has a beamwidth of $\frac{57.3}{4}$ = 14.8°, Figs. 5 and 6.

IMPROVING THE RESOLUTION

As stated earlier, radio telescopes of conventional design cannot match optical telescopes in terms of resolution. This is where the technique of **INTERFEROMETRY** provides a solution; this was first used by Michelson for optical astronomy, but is now used extensively for radio astronomy. A simple interferometer consists of two similar antennae, on an east-west baseline and separated by a minimum of 10 to 20 wavelengths, connected to the same receiver. The resultant polar diagram is called a fan-beam, consisting of a number of narrow beams whose width depends on the distance between the two antennae, Fig. 7. If two single-element corner reflectors, separated by 20 wavelengths, are used, the resolution is improved from 57.3° to $\frac{57.3}{20}$ =2.8°. Increased separation gives improved resolution, but at the expense of longer cables and resultant loss of signal.

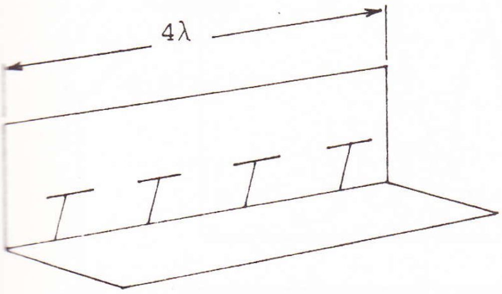

Fig. 5. Four-element corner reflector.

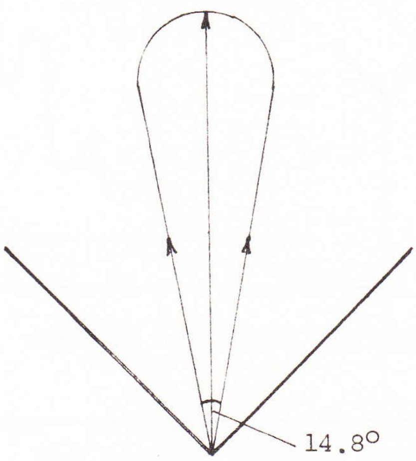

Fig. 6. Four-element polar diagram.

Eventually a separation is reached where it is more efficient to use radio links rather than cables; this allows much greater separation, even to the extent of using satellite links between continents. This is called Very Long Baseline Interferometry (VLBI), and extremely high resolution is possible by this method. Two instruments, in the United States and the Soviet Union, with a separation of 7400 km and operating at a wavelength of 1.35 cm, achieved a resolution of 0.0004 arcseconds.

When a radio source passes through the fan-beam of an interferometer, the resultant signal depends upon the relative sizes of the source and the beamwidth. If the source is larger than the beamwidth, the signal will gradually rise to a maximum and then decline, Fig. 8. If the source is much smaller than the beamwidth, the signal will vary between a series of maxima and minima determined by the system noise level, Fig. 9; and if the source is only a little less than the beamwidth, the signal will be as shown in Fig. 10.

REMOVING THE BACKGROUND NOISE

Although the Drift Interferometer provides greatly improved resolution, it does nothing to reduce the background noise. If a radio source lies close to another, stronger source, the wanted signal will be swamped by the unwanted signal. A technique developed by Ryle overcomes this problem; it is called the **PHASE SWITCHED INTERFEROMETER.**

Referring back to Fig. 7, it can be seen that as a source rises in the east, passes through the individual beams of the two antennae, and sets in the west, the difference between the two signal-path lengths (source-to-antenna) will vary, and will become zero when the source is overhead. Therefore, the signals received by the two antennae will arrive at different times, and will sometimes be in phase and sometimes out of phase. If the cables connecting the antennae to the receiver are of identical length, the signals arriving at the receiver will have the same phase relationship as

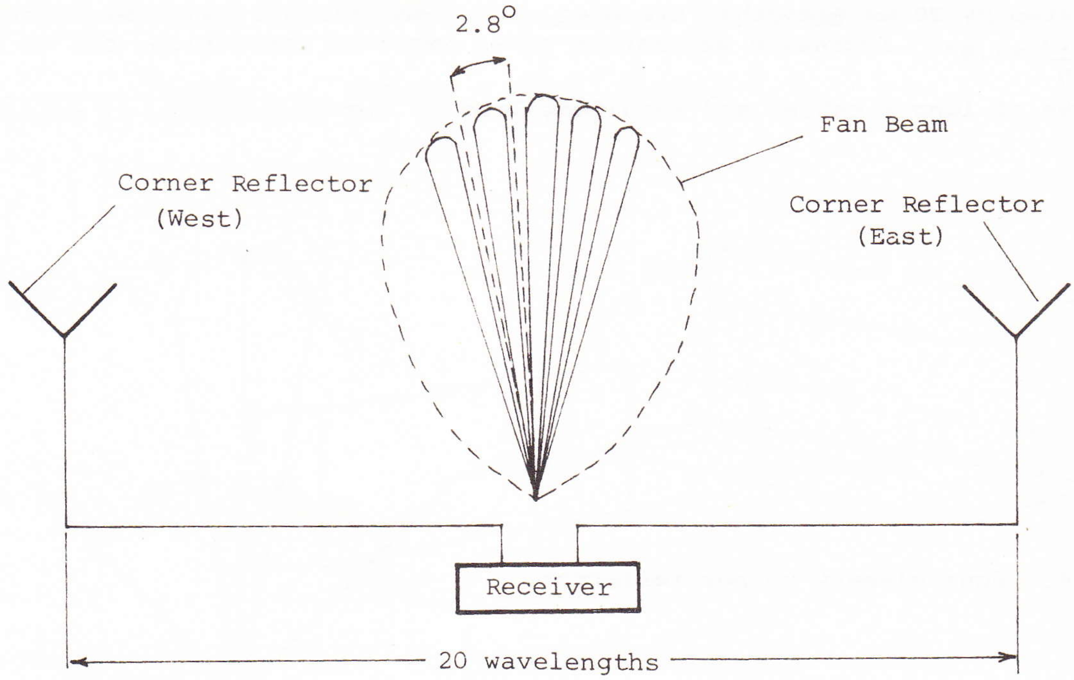

Fig. 7. Typical drift-scan interferometer.

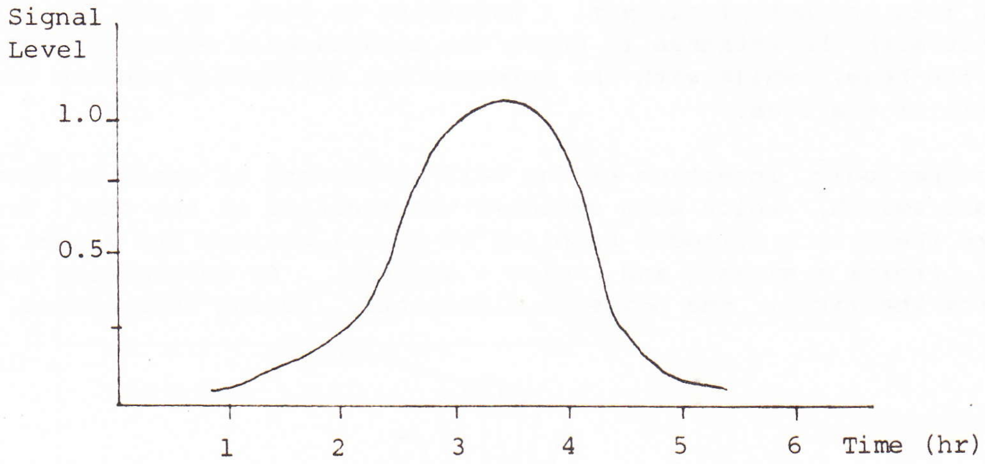

Fig. 8. Signal from a source with angular diameter greater than the beamwidth.

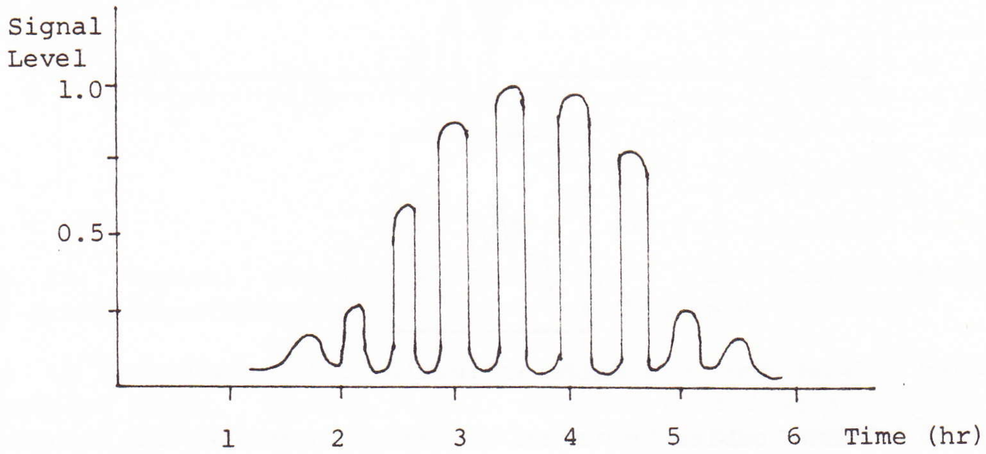

Fig. 9. Signal from a source with angular diameter much smaller than beamwidth.

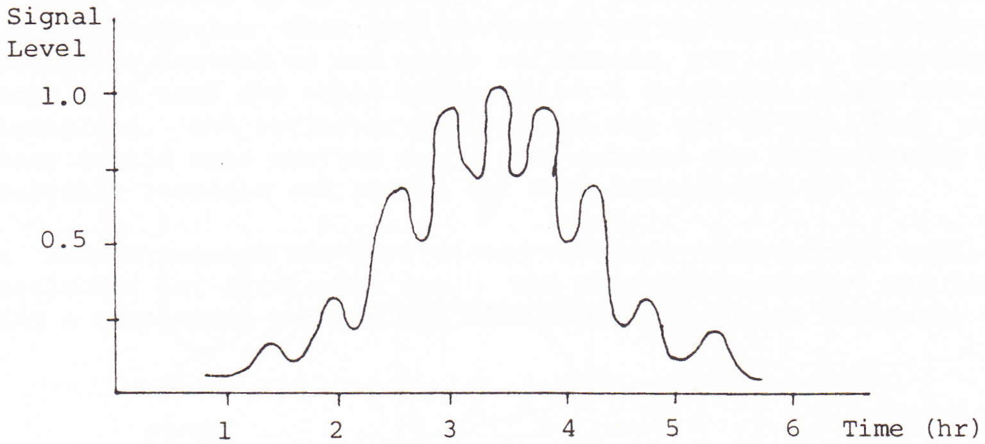

Fig. 10. Signal from a source with angular diameter slightly smaller than beamwidth.

when they arrived at the antennae. However, if one of the cables is made one half-wavelength longer than the other, the signals passing through that cable will arrive at the receiver one half-cycle later than before. This is the principle of **PHASE-SWITCHING**. A half-wavelength of cable is alternately switched into and out of circuit. Referring to Figs. 11 and 12, it can be seen that with the antennae in phase the maximum gain occurs at the centre of the fan-beam, while with the antennae out of phase a minimum occurs at the centre of the beam.

The periodic insertion of the half-wavelength of cable is done by an electronic switch, which also switches the receiver at the same frequency. Therefore there is a periodic sampling of signal maximum and signal minimum, that is, (noise + signal) and (noise - signal). By subtracting the second term from the first, the noise is eliminated. Using this method, it is

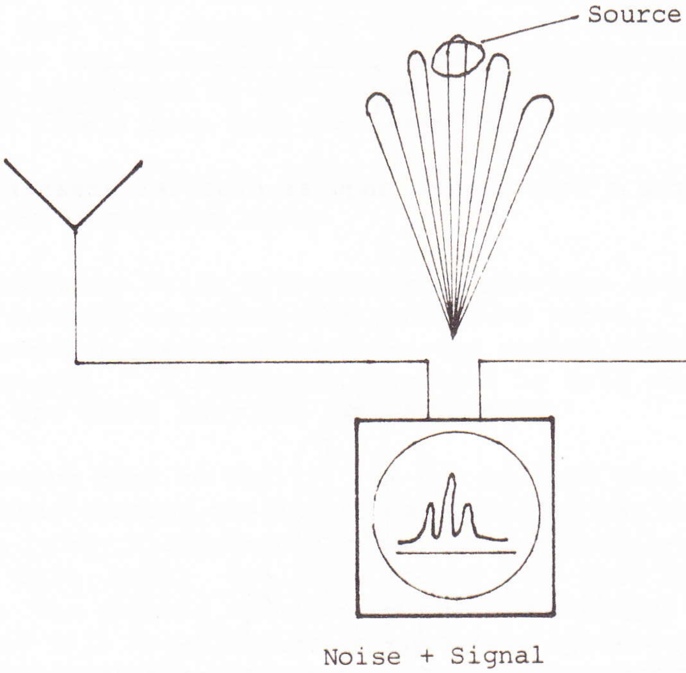

Fig. 11. With cables of equal length the antennae are in phase and the maximum signal occurs at the centre of the fan-beam.

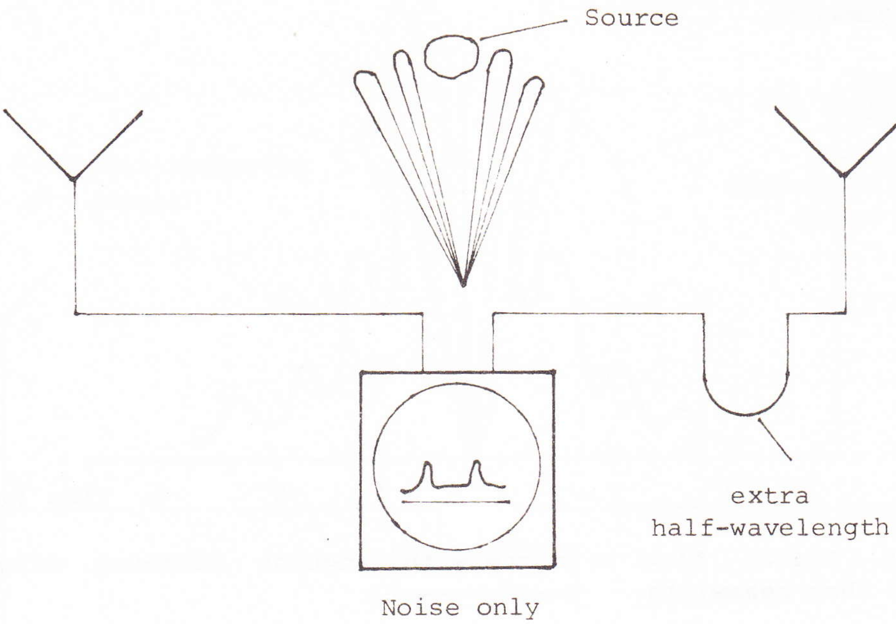

Fig. 12. With the cables of unequal length (a half-wavelength added to one) the antennae are out of phase and a minimum occurs at the centre of the beam.

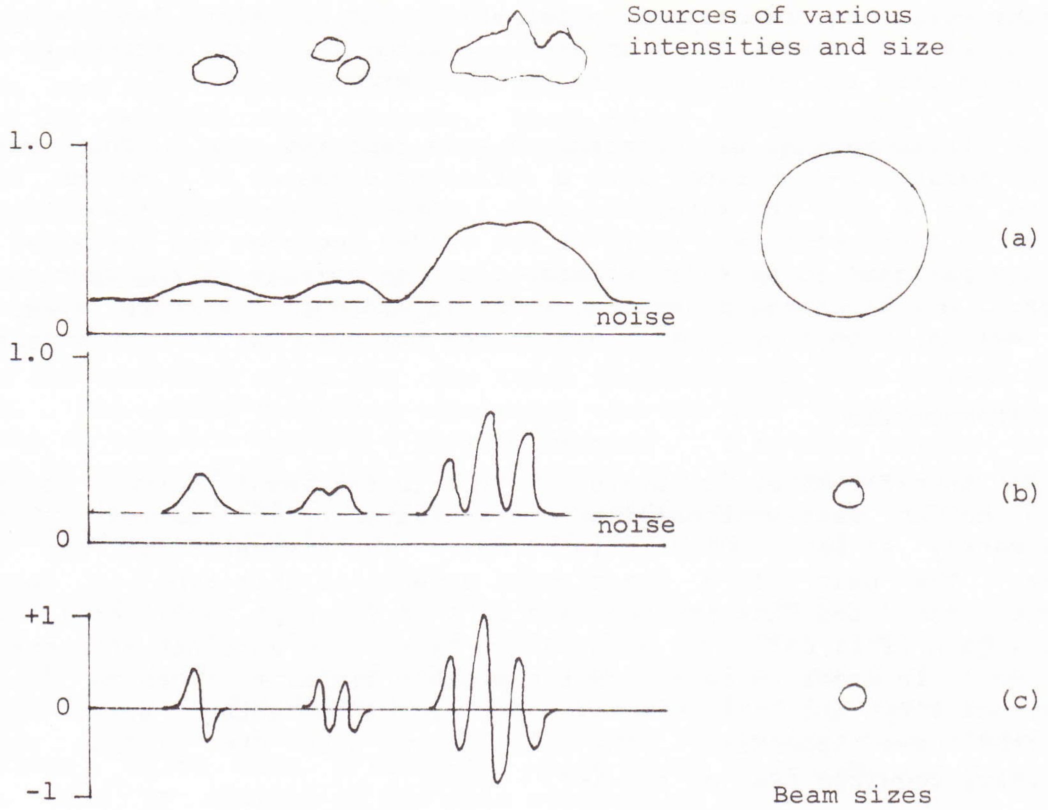

Fig. 13. Typical signals received by: (a) single antenna; (b) drift interferometer; (c) phase-switched interferometer.

possible to record signals from sources which are considerably weaker than the background noise. Typical signals received by a single antenna, a drift interferometer and a phase-switched interferometer are compared in Fig. 13.

THE M.G.R.O. ANTENNAE

The first antenna to be installed was a TROUGH PARABOLA, also known as a Cylindrical Parabola. This is a variation of the Corner Reflector, with a curved reflector instead of two plane reflectors, Fig. 14. This antenna had previously been used for radio astronomy at a frequency of 220 MHz. After being installed, the reflector was rewired for use at 500 MHz, and some preliminary trials were carried out. The antenna was subsequently moved to a more suitable location and it has not been reconnected yet.

The second antenna was constructed on-site; this was a multi-element corner reflector for drift-scan use. The selected frequency was 149.9 MHz, this being a compromise between the electronic components available to build

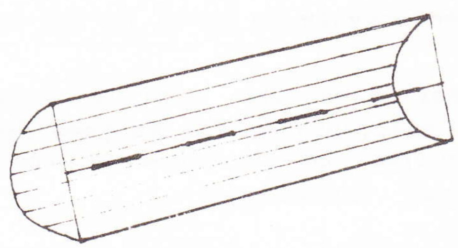

Fig. 14. The MGRO 4-element trough parabola.

the receiver, the resolution obtainable, and the flux density (signal strength) of the sources to be studied. Eventually it was decided to divide the antenna into two halves to form an interferometer.

The third antenna was constructed away from the site. This was the familiar parabolic-dish type, with a reflector diameter of 6 metres, and was intended to be used for satellite work. The reflector was transported to the site in four sections, where it was welded together and installed. The dish was designed to be fully-steerable and to operate at frequencies up to 500 MHz. Due to damage caused by vandalism and during a storm, some repair work remains to be done on it, and it has not been put into operation to date.

THE INTERFEROMETER

The interferometer consists of two four-element corner reflectors located on an east-west baseline and separated by 120 metres, which is approximately 61 wavelengths at 149.9 MHz. The elements used are Folded Dipoles. The gain of a one-element antenna of this type is about 12 decibels (dB), and this is increased by 3 dB for each additional dipole, giving a gain of 21 dB. The combination of the two antennae increases this to 24 dB. In order to calculate the minimum signal that can be detected, the directivity and the effective aperture of the antenna array must be calculated (see Appendix). The calculations give the minimum receiver sensitivity required (Pa) as 4×10^{-17} watts.

RECEIVER DESIGN

The minimum detectable antenna power is given by

$$Par = \frac{(0.11\Delta Sm \times Var)^2 \times 10^{12}}{No^2 \times Za}$$

where ΔSm is smallest detectable change in reading on the recorder, calculated to be 50 mV.
Var is receiver sensitivity in μV (0.1 μV).
No is normal output noise level (0.75 V).
Za is antenna impedance (50 ohms).

NOTE: ΔSm can be improved by up to 5 times as follows:

$$\Delta Sm' = \frac{\Delta Sm}{\sqrt{T \times N}}$$

where: $\Delta Sm'$ is adjusted minimum detectable change in reading.
ΔSm is minimum detectable change read directly.
T is the time constant in seconds.
N is the number of records averaged together.

Thus the increase in sensitivity is equal to the integration time of the system.

The equation for Par gives the minimum detectable antenna power as 1×10^{-22} Watts; the calculations for Pa (see Appendix) give the minimum receiver sensitivity required to detect a source of 100 flux units (100 Jansky) as 4×10^{-17} Watts. Therefore:

to observe source of 100 J, receiver must detect	4×10^{-17}W
10 J	4×10^{-18}W
0.1 J	4×10^{-20}W

So, operating as a simple Drift Interferometer, it should be possible to detect sources as weak as 0.01 Jansky. An average signal could be between 0 and 5, and very strong sources can reach as high at 10^6 — Table 1. It should be pointed out, however, that these calculations refer to a relatively simple interferometer, and they should be used only as a guide.

DESCRIPTION OF RECEIVING EQUIPMENT

The phase-switching receiver operates at a centre frequency of 149.9 MHz. It is a double-superhet receiver, with a first intermediate amplifier (IF) of 10.7 MHz and bandwidth of 500 KHz, and a second IF of 470 Hz and bandwidth of 25 Hz. The total receiver gain plus antenna gain is 160 dB. The phase-switching frequency is 470 Hz. The receiver time-constant is variable between 1 and 100 seconds. A battery supply provides several dc voltages and a 150 volt ac supply via an inverter. The recording instrument is a pen recorder with a dc-operated motor, and a small computer is available to operate the switching and recording of data.

The instrument hut was originally used by a geophysical exploration company, and when purchased was fitted with equipment racks, a battery compartment and interconnected wiring. The equipment rack contains 12 plug-in modules, with pre-wired sockets and a flexible interconnection system, Fig. 15. The two corner reflector antennae are fitted with wideband RF amplifiers, which have a receiving range of 40 to 860 MHz and a gain of 27 dB. The RF section of the main receiver is housed in a steel cabinet midway between the antennae, together with the cable terminations and the antenna phase-switching device.

CONCLUSION

Mount Gungin Radio Observatory has always been regarded as an on-going project, with continuous development taking place. At the time that the Astronautical Society became involved, it was decided that the MGRO

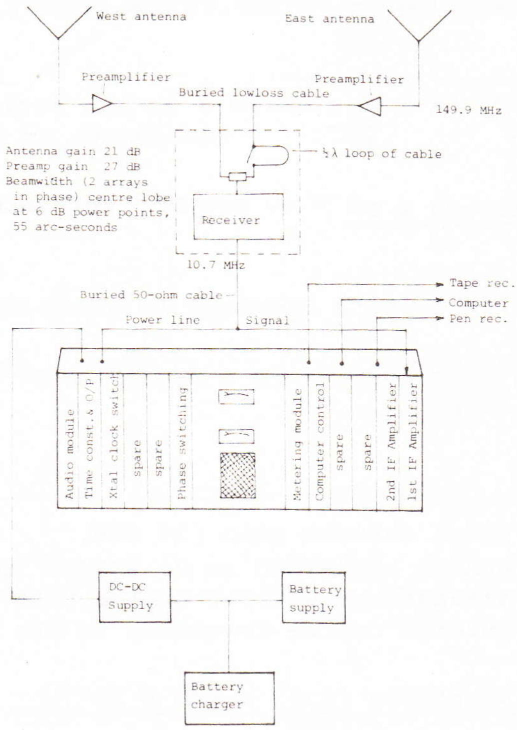

Fig. 15. Schematic diagram of the Mount Gungin Radio Observatory.

facilities would be made available to any persons who had a genuine interest in carrying out either radio astronomy or satellite reception. The site, being well away from habitation, is also ideally situated for carrying out optical astronomy. It is disappointing that, after many attempts to put the observatory into operation, it is still not functioning. As this paper is being prepared, vandals have struck once again, causing some damage to the equipment in the steel cabinet; this occurred at a time when the receiver and the recorder were about to be installed and tested. It is hoped that by the time of the Convention, MGRO will definitely be on the air. It is also hoped that MGRO will stimulate an interest in radio astronomy in Western Australia. Optical astronomy is a very popular activity in this State, but it appears that its radio counterpart is virtually unknown.

The Australia Telescope, which is a radio astronomy project, is planned to become operational in the Bicentennial year, 1988. Although there are no plans at present to do so, it has been suggested that, in addition to incorporating radio telescopes at Alice Springs and in Tasmania, the AT could be expanded even further to include an installation in Western Australia. This is unlikely to come about in the present situation, where there is no professional interest in radio astronomy here. Perhaps, as has occurred many times before in several scientific disciplines, it will be the amateurs who will lead the way.

APPENDIX

Calculation of Minimum Detectable Signal

In order to calculate the minimum signal that can be detected, we must first find the Directivity and the Effective Aperture of the antenna array.

a) Directivity, $D = \text{antilog}\left(\frac{Gp}{10}\right)$ where Gp is the power gain.

Therefore, $D = \text{antilog}\left(\frac{21}{10}\right) = 125.89$ (no units)

b) Effective Aperture, $Ae = \frac{D\lambda^2}{4\pi}$ where λ is the design centre-wavelength of the antenna

Therefore, $Ae = \frac{125.89 \times 2^2}{4\pi} = 40$ metres^2 per antenna

c) Minimum receiver sensitivity required is given by:

$$Pa = \frac{7.17 \text{ antilog}\left(\frac{Gp}{10}\right) \times 10^3}{F^2} \times FU \times Ae \times B \times 10^{-26}$$

where Gp is total antenna gain (24 dB9.
B is system bandwidth in Hz (500×10^3).
FU is strength of weakest source (100 J).
F is antenna centre frequency in MHz (150).

$$\text{Therefore } P = \frac{7.17 \text{ antilog } (2.4) \times 500 \times 10^{-18}}{150^2}$$

$$= 4 \times 10^{-17} \text{ watts.}$$

ANALYSIS OF CRATER TIMING VARIATIONS

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ABSTRACT

A poster paper presented at the 10th NACAA in Brisbane in 1982 described an improvement to the method of analysis for the Lunar Eclipse Programme. This new technique has now been fully developed and is known as Single Crater Timings. It has been used to further analyse timings made for five craters reported by twenty observers and to compare these with all other timings submitted to determine any pattern in their variations. Indeed some have shown consistency over the several eclipses examined and the technique shows promise.

INTRODUCTION

Since the time Link (1962) published Kosik's theory of analysis for estimating the umbra enlargement from timings made of the immersion and emersion of lunar craters from the shadow of Earth during a lunar eclipse as illustrated in Fig. 1, many astronomers have provided such observations for reduction.

Jiri Bouska (1950-1970) was one of the first astronomers to undertake such work and has published his estimates of umbra enlargement for ten lunar eclipses observed by him and fellow astronomers in Czechoslovakia from 1943 August 15 to 1968 April 13.

Various analysts (Ashbrook, 1957-1980; Watts, 1961-1962; Meeus, 1979; Sinnott, 1982-1983) have continued this study of observations by publication

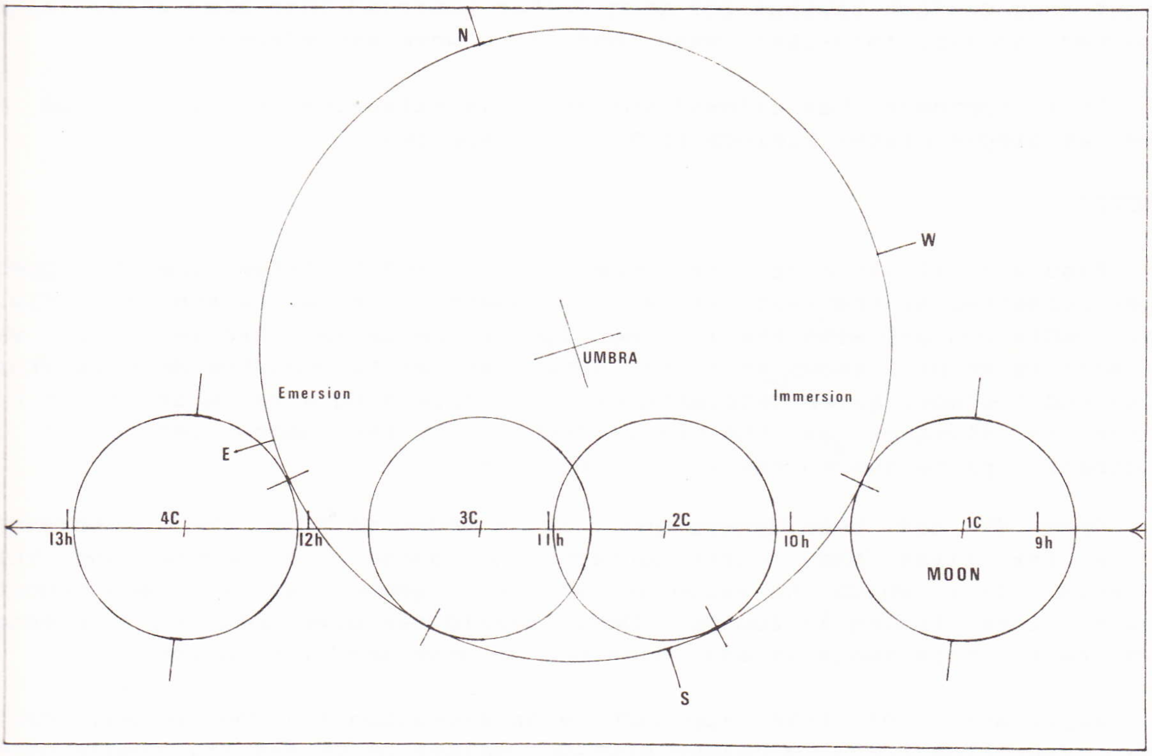

Fig. 1. Lunar eclipse circumstances 1979 September 6.

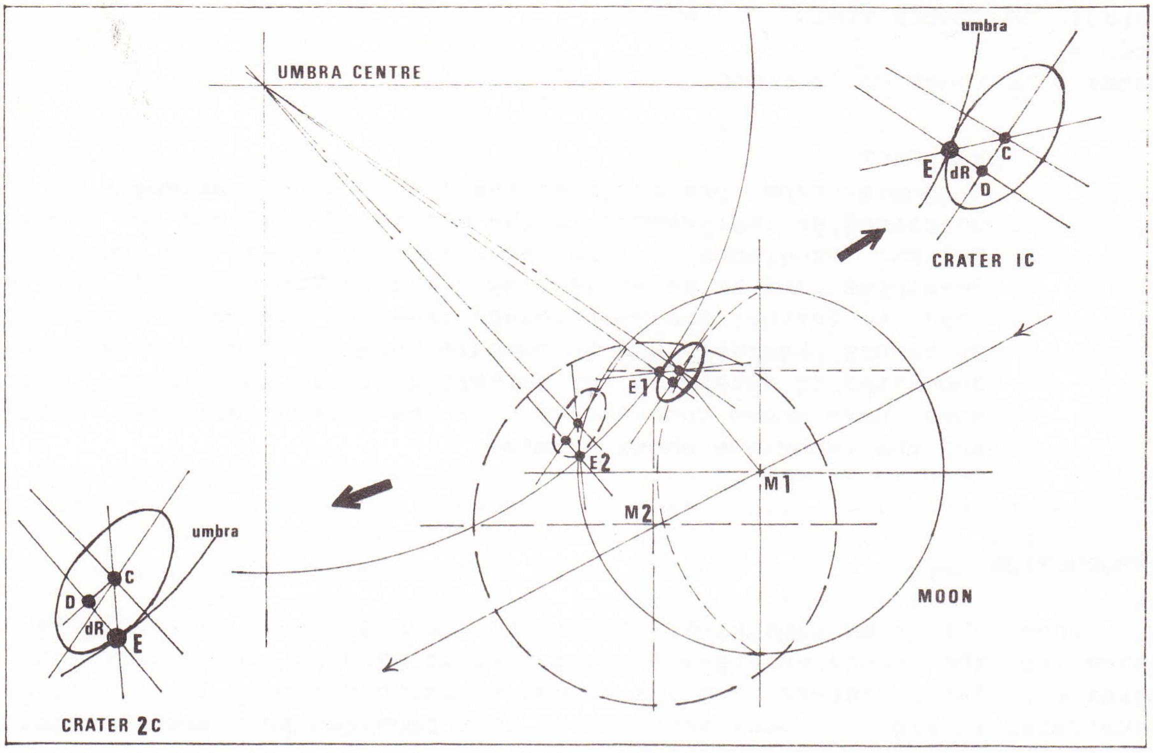

Fig. 2. Single crater timings.

in *Sky and Telescope* from the event on 1956 November 18 to the present and results for eighteen eclipses have been reported so far.

In 1972 the Canberra Astronomical Society Programme commenced and studies have continued in parallel with other programmes with eleven eclipses analysed to 1984. The CAS Programme is unique in that from the outset four contact timings for each crater observed have been attempted and reported (Soulsby,1978-1983) when conditions were satisfactory.

This approach has allowed the analysis extension described here and known as Single Crater Timings (SCT) to be applied.

CONCEPT

Figure 2 illustrates the concept of SCT and is taken from the poster paper presented at the Tenth NACAA in Brisbane. It can be seen from Fig. 2 that umbra contact with the leading edge of the crater observed at E1 when the Moon is at M1, known as First Contact and at E2 when the Moon is at M2 at second contact, gives circumstances for expressing a value dR as the true change in distance of the crater centre from the umbra centre on the fundamental plane due to the size of the crater.

Once dR has been determined, it is deducted from the crater-umbra radius for first and fourth contacts and added for second and third contacts, from which the value of umbra enlargement (%E) for each reported single crater timing is found. David Herald has developed the necessary formulae for this analysis and these can be provided if required.

Application of this approach as an extension to the normal crater timing reduction (CTR) technique provides values of %E for any single crater contact not possible with the Link method used by *Sky and Telescope*, Jiri Bouska and others.

METHOD

When four contact timings for any observed crater are reported a relationship between each can be drawn up as shown in Fig. 3. Here values of %E for each timing (and the average) can be plotted on linear axes against time to show observer variation.

In some cases (Observer 4 in Fig. 3) the reported mid-crater timing can deviate from the calculated mid-timing particularly noticeable here for 1C and 2C for the total eclipse of 1979 Sepember 6 for the crater Tycho. This illustrates the difficulty of observer estimates of the crater centre but does show consistent estimates of the crater edge or rim which is visible for all craters. This highlights the difficulty of estimating the centre of features many of which are without central peaks.

The comparison of observer's crater timings is considered further later in this paper to examine any patterns of consistency between observers.

DISCUSSION

In Fig. 3 where an observer's timings produce a near horizontal line between contacts it is considered that a reasonably consistent estimate of the umbra edge has been made for each crater rim, even if the %E value is not common with that of other observers. Observers 3, 7 and 9 for 1C/2C and observers 12 and 15 for 3C/4C show this for Tycho the crater results illustrated.

Each observer's results have been averaged and this value is shown as a dashed line in Fig. 3. When each observer's timings are compared with this average then an estimate can be made of the variation between observers.

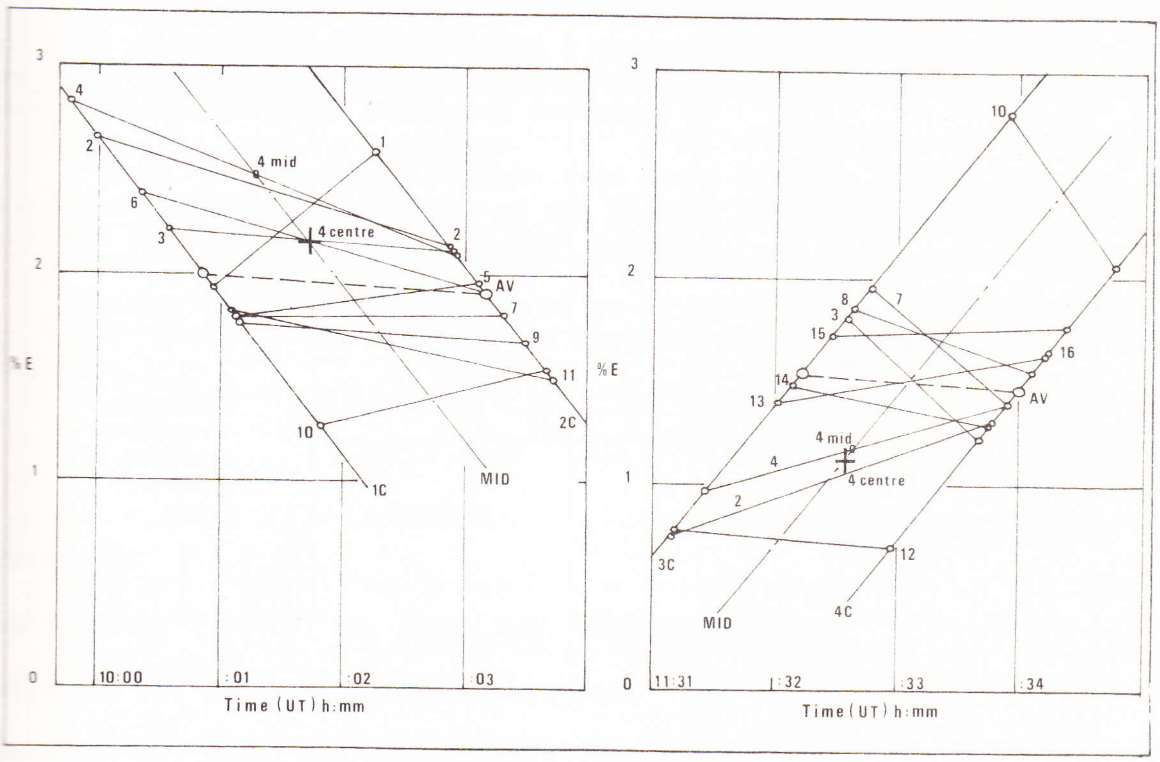

Fig. 3. Single crater timings for Tycho on 1979 September 6.

OBSERVER VARIATION

A survey has been made of all crater timings reported for several lunar craters for all lunar eclipses observed in the Southern Hemisphere or CAS Programme from 1974.

Five craters have been selected and variations from the mean of all timings for each feature for each event have been determined for twenty observers. The detailed examination was made using a simple linear regression fit computer programme to deduce a mathematical expression for the straight line relationship between %E and Observing Time on the basis of that found in Fig. 3. The observer's timing departures were determined as the difference between the projected regression mean and that observed for each crater contact timing. In all, some 587 single crater timings were reduced with about half this value again for corresponding mean %E values.

In Fig. 4 these departures from the mean values are shown for several consistent observers for each of the four contacts where reported and for the five craters considered. Fig. 4 illustrates the variation of this data over the full range of eclipses observed, but these results are not considered a good sample due to the gaps in the available data.

To appreciate the results presented in Fig. 4 it must be remembered that each observer's contact timing is based on his or her estimate of the most dense part of the umbra at contact with the crater edge. Hence, the deviation shown from the overall mean time for each of the four contacts illustrated represents each observer's best estimate of this umbra edge.

For emersion crater timings where the crater reappears from the umbra additional difficulty is experienced (compare stellar occultation disappearances with the more difficult reappearance timings) and hence third

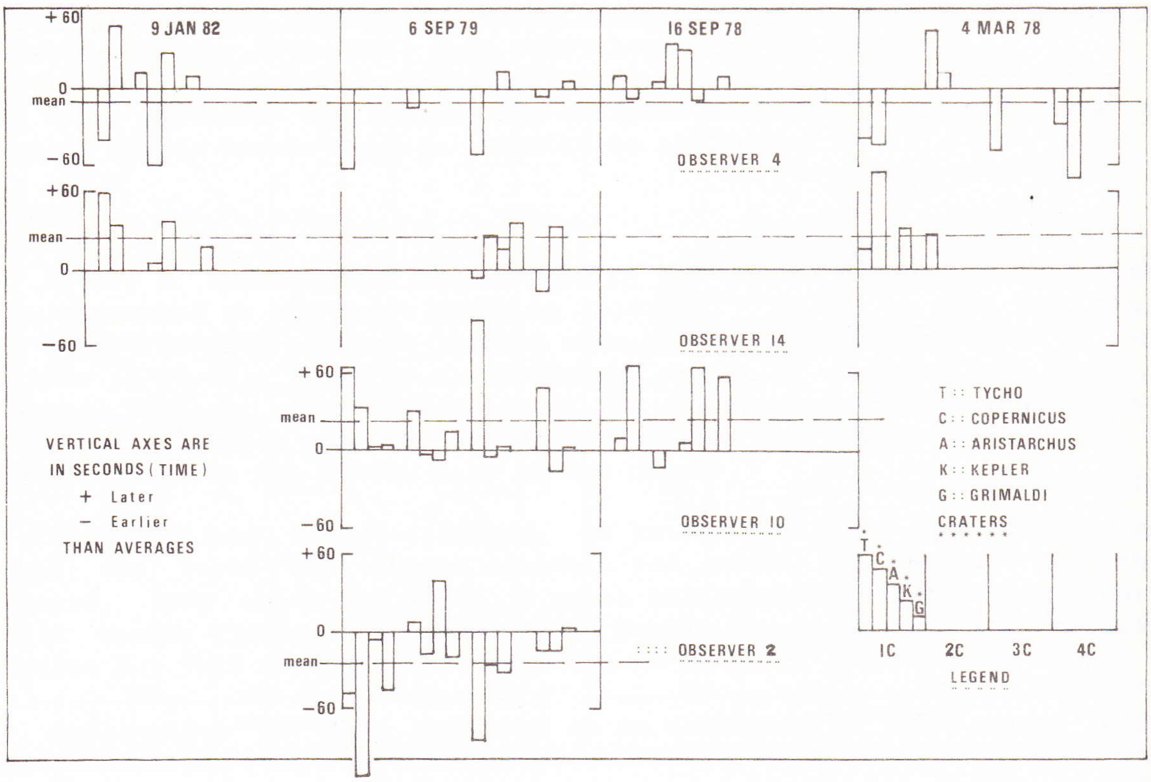

Fig. 4. Observer variations.

and fourth crater contact timings cannot be expected to be of the same accuracy as those for first and second contacts due to reaction time and other physiological factors.

Observer number 4 is shown for comparison, not as one of the consistent observers, but to indicate the spread possible when variations are shown for a longer period of time and for a greater number of events.

From the examination made it has been determined that wide fluctuations occur for most of the twenty observers studied; however, for the several shown in Fig. 4 who exhibit distinct trends, either early or late, when compared with the average of all observations, a consistency in their estimate of the umbra edge is evident. However, it must be remembered that the average used as a datum does change from event to event and from crater to crater and indeed for 1C/2C to 3C/4C and as such provides a major variable in all comparisons.

CONCLUSIONS

Comparison of each of the twenty observers' estimate of the position of the umbra edge on contact with five selected craters for six of the lunar eclipses observed in the Southern Hemisphere Programme does not provide any distinct trend except for the three consistent observers illustrated in Fig. 4 when using the method of comparison to a mean contact time.

However, it is intended to establish absolute contact times for several craters by photoelectric means in future eclipses in 1985 and this will stabilize the change in the datum used for observer variation comparisons with a view of providing improved umbra size and shape estimates and corrections or adjustments to the observational data held.

ACKNOWLEDGEMENTS

The many observers who have taken part in this programme have provided me with invaluable information and I owe all my debt of gratitude. There are too many to list individually but success in this programme has been most dependent on their continued interest.

I have also received support from David Herald, Roger Sinnot, Jean Meeus and Geoffrey Amery (1983) of the British Astronomical Association and to these fellow astronomers I am most grateful.

Finally, it would be remiss of me if I did not record my gratitude to my wife, Cathie, for her love and patience during my many hours of happy computing.

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THE PRINCIPLE OF ABSOLUTENESS IN ASTRONOMY AND COSMOLOGY

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THE PRINCIPLE OF ABSOLUTENESS IN ASTRONOMY AND COSMOLOGY

J. Callow

ABSTRACT

There is now firm unrefuted evidence that Earth has a velocity in the order of 300 km s^{-1} relative to a universal preferred frame of reference. To consider this phenomenon as absolute motion of Earth, as has been done by some physicists, is in direct opposition to Einstein's Special Theory of Relativity. A return to Newton's concepts of absolute rest, space and time resolves this problem, but the Principle of Relativity has to be replaced by the Principle of Absoluteness. 'The Laws of Physics have their simplest form in the unique frame of reference at absolute rest'. Such a change in the fundamental concepts of modern physics leads to quite a different picture of the universe to that seen by relativitists. Some of the alternative interpretations of physical phenomena in astronomy and cosmology are discussed and shown to give a consistent and understandable alternative to the generally accepted model of the universe.

INTRODUCTION

The history of astronomy and cosmology has not been a continuous development in man's understanding of the nature of the physical universe. It can be divided into periods by the theories believed at the time to describe reality. The long period dominated by the Ptolemaic theory ended with the acceptance of the Copernican theory. The Newtonian theory, with its concepts of absolute space and time, guided the thinking of astronomers and cosmologists during the eighteenth and nineteenth centuries. The early years of the twentieth century saw the switch to Einstein's theory of relativity with the rejection of the classical concepts of an aether and a unique frame of reference at absolute rest. In recent years physicists have revealed physical phenomena that are inconsistent with relativity theory. In future years it is likely that this will be seen as the beginning of the end of the Einstein era. We are now at the dawning of a new age.

Those who doubt this should ponder the following. Einstein has said of his special theory of relativity (Einstein, 1946) 'According to this theory there is no such thing as a "specially favoured" (unique) coordinate system to occasion the introduction of the aether-idea and hence there can be no aether-drift, nor any experiment with which to demonstrate it'. In his original relativity paper Einstein also claimed that the results of experiments "suggest that the phenomena of electrodynamics as well as of mechanics possess no properties corresponding to the idea of absolute rest". However, R.A. Muller (1978) has said "Absolute motion of the earth through space has been determined by measuring slight differences in the temperature of the three-degree cosmic background radiation reaching the earth from various directions... The new aether-drift experiment shows that the earth's net motion is space is about 400 kilometers per second". Professor Paul Davies (1982) said 'modern theories of "the vacuum" reveal that even empty space is seething with activity... Most people think of empty space as just that — vacuous, devoid of any physical content. Physicists, however, know better'. He closes his article by saying "James Clerk Maxwell and his colleagues ... would surely have been gratified to learn that in its modern quantum form the aether has materialised at last".

In conjunction with this they should also ponder Sir Henry Dale's (1954) statement on science, "And science, we should insist, better than any other discipline, can hold up to its students and followers an ideal of patient devotion to the search for objective truth, with vision unclouded by personal or political motive, not tolerating any lapse from precision or neglect of any anomaly, fearing only prejudice and preconception, accepting nature's answers humbly and with courage, and giving them to the world with an unflinching fidelity. The world cannot afford to lose such a contribution to the moral framework of its civilisation".

Is there no anomaly here? Are not nature's answers clear? There is an aether and a unique frame of reference at absolute rest. Astronomers and cosmologists are failing as scientists if they adhere dogmatically to special relativity theory, ignoring nature's answers. While Einstein was alive there was no clear exprimental confirmation of the existence of a unique frame of reference or an aether. Yet Bernard Cohen (1979), after interviewing Einstein late in his life tells us, "Looking back over all of Newton's ideas, Einstein said, he thought that Newton's greatest achievement was his recognition of the role of privileged systems. He repeated this statement several times and with great emphasis. This is rather puzzling, I thought to myself, because today we believe there are no privileged systems, only inertial systems". Could it be that Einstein, great scientist that he was, realized, without the evidence available to scientists today, that his own theory was not a true description of nature? With all Newton's great achievements how could Einstein possibly believe that his greatest achievement was his recognition of the role of privileged systems if Einstein himself still believed that not one such system existed.

The fact that there is now unrefuted experimental evidence for the existence of a unique frame of reference and an aether does not mean that Einstein should no longer be regarded as the greatest scientist of the twentieth century. We can still say of Einstein much the same as he said of Newton "you found the only way which, in your age, was just about possible for a man of highest thought and creative power".

The main purpose of this paper is to put forward a new principle, consistent with all the phenomena, that can replace Einstein's principle of relativity and more truly guide the thinking of astronomers and cosmologists in the age ahead.

ABSOLUTE MOTION

A superficial observation of the motion of the Sun and stars convinced men for generations that the Sun goes around Earth. This led most great thinkers before the seventeenth century to accept the Ptolemaic theory as a true description of nature. In a similar way in our time a superficial examination of the phenomena has convinced scientists that it is only relative motion that needs to be considered in kinetic energy calculations and collisions. Just as after a more careful and unbiased examination of the facts, people now readily accept as quite obviously true the Copernican idea that Earth and the other planets orbit the Sun, so thinking people, after a more careful and unbiased examination of all the known physical facts should realize it is equally obvious that absolute motion is important in mechanics and electromagnetic phenomena. It then follows that the principle of relativity must be false and should be discarded.

The one phenomenon, above all others, that makes the importance of absolute motion clear is the fact that kinetic energy has inertial mass. The relationship between mass and energy has been claimed as the most important outcome of relativity theory. The equation $E = mc^2$ will forever be associated with Einstein. The fact that radiation energy has momentum was a recognised part of electromagnetic theory before the turn of the century. Once it is accepted as true, that it is impossible to have momentum without mass, that energy has mass goes back at least to Maxwell. One way of putting $E = mc^2$ into words and figures is; one joule of energy has a mass of 1.11265×10^{-17} kilograms. It is just this that is one of the most important physical discoveries of all time. This is a fundamental constant of nature. It is this that is missing from classical mechanics. When the speed of light is fixed by definition at 299792458 metres per second what is really being done is to fix this important fundamental constant, the relationship between mass and energy, at $1.112650056 \times 10^{-17}$ kilograms per joule. This is so because $c = (E/m)^{1/2} = (1/1.112650056 \times 10^{-17})^{1/2} = 299792458$ metres per second. Although both equations are mathematically correct to maintain that $E = mc^2$ is just as fundamental and true as $c = (E/m)^{1/2}$ is similar to arguing that the statement, the Sun goes around Earth once each day is just as true and fundamental as the statement that Earth turns on its polar axis once each day.

Understanding the relation between mass and energy and its consequences is a prerequisite to understanding the nature of the physical universe. Einstein gave a central position in his theory to the speed of light as a fundamental constant and gave it the extraordinary property of having the same speed relative to all observers. Yet Peter Kapitsa (1964) tells us Einstein said to him, "I don't believe that God created the Universe without the speed of light being dependent on something". It should be realised by all scientists that the speed of light depends on just how much mass energy has. Nineteenth century physicists believed that the properties of the aether determined the speed of light. The aether that physicists have now found does exist does not have properties that determine the speed of light. In Appendix I, the application of Newton's laws of motion and mechanics show quite definitely that if kinetic energy has an inertial mass of $1.112650056 \times 10^{-17}$ kg J^{-1} then the greatest speed that can be given to mass is exactly 299792458 m s^{-1}.

Photons are also subject to these same laws and are limited to this same speed because their energy also has this same mass. This limiting speed must be the same throughout the universe because it does not matter from where particles or radiation come, or the motion of their source, they still have the same limiting speed as radiation and particles from sources on Earth. Thus, throughout the universe there must be one unique frame of reference at absolute rest in which mass at rest does not have any kinetic energy. If, in this unique frame of reference, a mass of one kilogram is accelerated from rest to a speed of 1.414 metre per second so that it has a kinetic energy of exactly one joule then it has a total mass of $1 + 1.112650056 \times 10^{-17}$ kg. If this was not so the speed of light from all sources in the universe would no always be exactly the same. Although this gives a new meaning to Newton's concept of absolute rest, it conflicts with not only Einstein's extension of the principle of relativity to the whole of physics, but also with Newton's principle of relativity in mechanics. The laws of mechanics are not the same in all inertial frames of reference. The equation for the total mass of a body and its kinetic energy,

$$m = m_o(1 - v^2/c^2)^{-1/2},$$

derived in Appendix 1, only holds in the unique frame of reference at absolute rest. A new principle in physics is required to express this fact and to replace the principle of relativity which is false and does not apply even in mechanics.

THE PRINCIPLE OF ABSOLUTENESS IN PHYSICS

The principle of absoluteness can be stated as, *The laws of physics have their simplest form in the unique frame of reference at absolute rest.* Anyone who has doubts about the truth of this principle should treat it as a postulate, just as Einstein did with his principle of relativity. They will then find that this new principle not only fits in with Newton's theory, but it unifies and extends it so that it can completely replace Einstein's special theory of relativity. The main consequences of this principle of interest to us now are as follows. The law of the absolute speed of light. The speed of light is c in all directions only in the unique frame of reference at absolute rest. In any other frame of reference having a velocity v relative to absolute rest the speed varies with direction from c - v to c + v. Appendix II shows the way this law leads to a quite different understanding of the null result of the Michelson-Morley experiment and also the Kennedy-Thorndike experiment, that is fully consistent with Newton's concept of absolute time.

The most important consequences for mechanics can be stated as follows. In the unique frame of reference at absolute rest all energy has an inertial mass of $1.112650056 \times 10^{-1}$ kilograms per joule. A body of intrinsic mass m_0 when at rest in this frame of reference always has an increased mass when in motion, due to the mass of its absolute kinetic energy. The total mass m is given by the equation, $m = m_0(1 - v^2/c^2)^{-1/2}$ where v is the absolute velocity of the body. It follows that any body at rest in an inertial frame of reference having an absolute velocity v has a total mass

$$m = m(1 - v^2/c^2)^{-1/2}.$$

When the body is in motion relative to this inertial frame of reference, its total mass may increase or decrease, depending only on whether its absolute speed is increased or decreased.

ABSOLUTENESS IN ASTRONOMY AND COSMOLOGY

The observed behaviour of radiation from double stars and binary pulsars has been claimed to confirm the truth of Einstein's relativity theories. However, not only is the observed behaviour consistent with this unified Newtonian theory, it is also easier to understand. Because the radiation, according to this theory, has a speed c only relative to the frame of reference at absolute rest, it does not have to have the extraordinary property, required by Einstein's theory, of having a speed of exactly 299792458 m s^{-1} relative to an observer on Earth, throughout the whole year. We know that the speed of the observer, relative to the rest of the galaxy changes by approxidmately 60000 m s^{-1} sinusoidally throughout the year because of its orbit around the Sun. When we consider the fact that the light is on its journey through space for perhaps thousands of years without changing its speed it seems fantastic that the photons always arrive at Earth with a relative speed of exactly c as is required by Einstein's theory. Before the advent of · radar one of the most accurate ways of determining the speed of Earth in its orbit around the Sun was to measure the Doppler change throughout the year of the light from a star lying in the plane of Earth's orbit. In accordance with the principle of absoluteness we can now understand this simply as a change in the speed of light relative to Earth due solely to the change in the absolute speed of Earth. Again, this is very simple compared to relativity theory which requires not only the frequency but also the wavelength to change in such a way that when multiplied together they give the speed c. In this new theory light not only has an absolute speed but also an absolute frequency and an absolute wavelength. Once the absolute velocity of Earth has been accurately determined the absolute frequency of starlight could be found.

Consider a high energy cosmic ray particle. It may have been generated millions of years ago in some distant galaxy. According to relativity theory it does not have a precise energy unless an observer somewhere observes it. Indeed some supporters of relativity theory maintain that it does not have any real existence until it is observved. In contrast, according to the principle of absoluteness it has a precise energy at every instant of its life, whether it is observed or not. Its energy may be changed by the action of gravitational fields or the interstellar medium, but at each instant it has one unique value. If it is adsorbed on impact with some body it is this absolute energy and mass that is involved, but, of course, the absolute velocity of the body with which it collides also has to be taken into account in considering the result of such a collision. In the collision of bodies on Earth the absolute velocity is so small that the effect of the mass of the absolute kintic energy can usually be neglected and is undetectable. However, at absolute velocities approaching that of light, the mass of the kinetic energy may be many times greater than the intrinsic rest mass and must be taken into account. In collisions involving fundamental particles accelerated to high energies, the mass of their absolute kinetic energy must always be taken into account. It is the absolute speed of the particles, not their relative velocity, that is important.

It is generally agreed that in physics the conservation laws are of fundamental importance. Although relativity theory embraces the conservation laws, the conservation only holds in a particular inertial frame of reference. The total mass of a body is not an invariant, it depends on who observes it. In this absolute theory, the conservation is absolute. The absolute speed, the total mass and the absolute kinetic energy are invariant, the same for all inertial observers. The total mass of the universe is an absolute invariant quantity, made up of the mass of matter and the mass of energy. In relativity theory, the total mass of the universe does not have a definite value, it changes with the speed of an observer relative to it. Two observers, moving relative to each other, could calculate a different total mass and, according to the theory, one is just as correct as the other.

This absolute theory sheds new light on the phenomena that have led to the acceptance of the Expansion of the Universe and the Big Bang theory as the standard cosmological model. Because in this absolute theory there is a frame of reference at absolute rest, an expanding universe must have a centre, a place at rest. Any other place in the universe would have an absolute velocity away from this centre with the velocity increasing with distance from the centre. Because the distant parts of the universe are believed to be receding from Earth with speeds approaching that of light and Earth has been measured to have an absolute speed in the order of one thousandth that of light, Earth and the Galaxy must be near the centre of the universe. While this is possible, it should be regarded as an unlikely coincidence unless there is other clear suppoting evidence. The now proven existence of a material aether calls for reconsideration of interpreting the observed red shifts in the spectra of distant cosmological objects as a true Doppler shift caused by speed of recession of the source. It is very unlikely that an aether pervading all space would have no effect whatever on light passing through it for billions of years. While the old classical aether was assumed to have properties that determined the speed of light, it is now clear that the aether shown to exist does not have to have this property. The speed of light, the limiting speed for all matter and energy, is determined solely by the fact that energy has just so much inertial mass. However, the results of experiments are consistent with a photon being a particle and this particle being accompanied by, and to some extent guided by, electromagnetic waves. These electromagnetic waves could be waves in the aether. If these waves accompanying a photon were to dissipate energy from the photon to the aether at a rate that caused a given photon to lose half its energy after travelling through the aether for twelve billion years, this would account for the same red-shift that is now interpreted as Hubble's constant having a value of 55 km s^{-1} Mpc^{-1}. This rate of energy loss from a photon is so low that it is unlikely that it could ever be measured in a laboratory on Earth.

The observed 2.7°K black body background radiation is asserted to be confirmation of the Big Bang theory, but if there is an aether, and it can absorb energy from photons, then it should have an energy content that could be revealed as a temperature. The observed microwave background radiation could be black body radiation from the aether. Although the aether would be losing energy by this radiation, its temperature could be maintained by energy absorbed from starlight and other forms of radiation.

The aether, to have the observed properties, must be made up of real particles, not just energy. It is unnecessary to postulate a new particle to fulfil this purpose. Electron-positron pairs having a binding energy of approximately 1.02 MeV have all the properties required. A seething sea of such particles, each with a fluctuating but average energy could be the source of the observed 'zero-point motion'. If a sufficiently strong electric field was applied to such an aether electron positron pairs should be *created*. This is just what has been reported (Greiner and Hamilton, 1980). It is also consistent with P.A.M. Dirac's prediction over 50 years ago that if an electron was plucked out of the 'vacuum' a positron would appear in its place. Moreover, although the strengths of the electric and magnetic fields of these minute dipoles could average to zero, on account of random orientations, they could be aligned to form electric and magnetic fields. In other words they could be the carriers of the electromagnetic field. This role has long been assigned to *virtual photons*. These virtual photons, these electron-positron pairs could have a variable energy depending on the extent to which the electron and positron merge together or are partially pulled apart by forces. Real photons would then be virtual photons that have been given a comparatively high kinetic energy. All real photons are known to have the same 'spin'. Both the electron and the positron are known to have a 'spin' of exactly half that of a photon. The spin of a photon which is one of its most fundamental properties, is therefore consistent with it being made up of an electron and a positron. The measured mass of an electron and a positron is known to reside in the electro-magnetic field surrounding the particle. When an electron and a positron come together the energy and mass in the electromagnetic fields are released but it is posible that the electron and the positron retain their identity and spin in the photon and that this could well have a very small but finite rest mass. This is consistent with observations (Goldhaber and Nieto, 1976). Thus when an electron jumps into a lower energy orbit in an atom it is not necessary for a photon to be *created* to carry away the energy, it is just transferred to one of the existing photons in the electromagnetic field or aether.

Experiments have shown that collisions between sufficiently high energy photons *or* electrons and positrons can produce all the known particles. This shows that it is possible that the whole universe consists of just electrons and positrons plus energy in different modes and combinations. The process of the formation of the universe could then start with the existence of a vast aether of photons or electron-positron pairs plus energy. The observed universe could then *evolve* by the concentration of energy in some photons producing protons, electrons, neutrons and other particles. The clumping together of these particles could lead to the formation of stars and in them all the elements. This basic sketch of the formation of the universe is a logical outcome of replacing the principle of relativity in physics by the principle of absoluteness. The beginning is almost the complete opposite of the now standard cosmological model of the Big Bang.

The ideas expressed in this paper are put forward for consideration by those interested in astronomy and cosmology in all seriousness and in the spirit of the search for objective truth. Dogmatic adherence to outmoded theories and concepts, however beautiful and satisfying, is not the way to make progress in understanding the true nature of the universe.

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APPENDIX I

DERIVATION OF THE EQUATIONS $E = mc^2$ and $m = m_o(1 - v^2/c^2)^{-\frac{1}{2}}$ IN A UNIFIED ABSOLUTE THEORY

In classical mechanics the momentum, p, of a mass, m, having a velocity, v, is $p = mv$. (1)
In Maxwell's electromagnetic theory electromagnetic radiation energy E has momentum p where $p = E/c$. (2)
This was confirmed by experiments prior to 1905. Simplicity and unity in physics suggests that this momentum, E/c, should have mass associated with it such that $p = mv = E/c$. (3)
The velocity of radiation is the propagation velocity, c, so substituting c for v we have $p = mc = E/c$ — i.e. an amount of electromagnetic radiation energy, E, should have a mass, m, associated with it so that,
$mc = E/c$ or $m = E/c^2$. (4)
As c has the value 299792458 m/s the mass of one joule of radiation energy should be $1.112650056 \times 10^{-17}$ kg. Experiments have confirmed that not only radiation energy but also other forms of energy have this mass.

Classical mechanics, as developed up to the end of the nineteenth century, did not take account of the fact that kinetic energy has mass. This can be done without making any change in Newton's concepts of absolute space and time and absolute rest or his Laws of Motion.

However, to do this the principle of absoluteness, not the principle of relativity, must be taken into account. To conform to the principle of absoluteness it is only the absolute kinetic energy, the kinetic energy of a body with velocity relative to absolute rest that has inertial mass. The kinetic energy of a body relative to any other inertial observer or frame of reference does not have a direct relationship with inertial mass. However, the absolute velocity of Earth is so low compared with that of light that in most cases it can be considered to be at absolute rest.

From classical mechanics the kinetic energy, E_k, of a mass, m_o, when it is accelerated from rest to a velocity, v, is given by the equation

$$E_k = \int_o^{m_o v} v\,d(m_o v) \qquad (5)$$

Because m_o is constant, i.e. it does not change with the velocity, this equation can be simplified to,

$$E_k = m_o \int_o^{v} v\,dv = \tfrac{1}{2}m_o v^2 \qquad (6)$$

If the mass, m_o, is accelerated from absolute rest to an absolute velocity, v, then each joule of this kinetic energy has a mass of 1.11265×10^{-17} kg, i.e. absolute kinetic energy $\frac{1}{2}m_o v^2$ joules has a mass of $\frac{1}{2}m_o v^2/c^2$ kilogram. This mass, which can be designated m_1, does increase with the velocity. To travel with the mass m_o at the velocity, v, this mass also has to be accelerated from absolute rest. This requires additional energy that has not yet been taken into account. As this additional energy will have a mass, m_2, that also has to be accelerated to the velocity, v, it requires more energy with a mass, m_3, and so on. So the total kinetic energy, E_{kt}, is not $\frac{1}{2}m_o v^2$ but an infinite series of terms, of which $\frac{1}{2}m_o v^2$ is the first, even though the mass, m_o, remains constant as Newton thought. The mass of this total kinetic energy does increase with velocity and is also given by an infinite series of terms which, when added to the mass, m_o, of the body, gives the total mass, m, which has to be accelerated to the velocity, v. i.e.

$$m = m_o + m_1 + m_2 + m_3 + m_4 + \ldots + m_\infty \qquad (7)$$

The value of each term in both series can be calculated from equation (5), the general equation for kinetic energy, in the following way.

When m is not constant, $E_k = \int_0^{mv} v\,d(mv)$, may be integrated by parts, i.e.

$$E_k = mv^2 - \int_0^v (mv)\,dv \qquad (8)$$

From this we get E_{kn}, the nth term of the energy series,

$$E_{kn} = m_{n-1}v^2 - \int_0^v (m_{n-1}v)\,dv \qquad (9)$$

where m_{n-1} is expressed in terms of m_o, v and c, as calculated in sequence from m_o. As an example we first recalculate E_{k1} by this method to show that we get the same result as in (6) because m_o is constant. n = 1 so,

$$E_{k1} = m_o v^2 - \int_0^v (m_o v)\,dv$$

$$= m_o v^2 - \tfrac{1}{2}m_o v^2 = \tfrac{1}{2}m_o v^2$$

Now m_n is obtained from E_{kn} by dividing it by c^2 to convert units of energy to units of mass. Therefore, $m_1 = \tfrac{1}{2}m_o v^2/c^2$

$$E_{k2} = m_1 v^2 - \int_0^v (m_1 v)\,dv$$

$$= (\tfrac{1}{2}m_o v^2/c^2)v^2 - \int_0^v (\tfrac{1}{2}m_o v^2/c^2)v\,dv$$

$$= \tfrac{1}{2}m_o v^4/c^2 - \tfrac{1}{8}m_o v^4/c^2 = \tfrac{3}{8}m_o v^4/c^2 \qquad (10)$$

$$m_2 = E_{k2}/c^2 = \tfrac{3}{8}m_o v^4/c^4 \qquad (11)$$

Using this method again we find $E_{k3} = \tfrac{5}{16}m_o v^6/c^4$ and $m_3 = \tfrac{5}{16}m_o v^6/c^6$.

In this way as many terms as desired can be calculated but the series can be simplified by the binomial theorem,

$$m = m_o + \tfrac{1}{2}m_o v^2/c^2 + \tfrac{3}{8}m_o v^4/c^4 + \tfrac{5}{16}m_o v^6/c^6 + \tfrac{35}{128}m_o v^8/c^8 + \ldots$$

$$m = m_o(1 + \tfrac{1}{2}v^2/c^2 + \tfrac{3}{8}v^4/c^4 + \tfrac{5}{16}v^6/c^6 + \tfrac{35}{128}v^8/c^8 + \ldots)$$

$$m = m_o(1 - v^2/c^2)^{-\frac{1}{2}} \qquad (12)$$

This equation shows that v cannot exceed c because at v = c the total mass would be infinite. This follows from Newton's laws of motion. Because energy has inertial mass it is subject to this limiting velocity in just the same way as all other mass. It should therefore be realized that c is not a fundamental natural constant. This limiting velocity is a consequence of one joule of energy, having a mass of 1.11265×10^{-17} kg. Because the inertial mass of energy is more fundamental than the velocity, c, it is preferable in this theory to express the relationship between mass, energy and the velocity of light as $c = (E/m)^{\frac{1}{2}}$ rather than as Einstein's famous equation, $E = mc^2$. In Einstein's theory c is fundamental, it has a central position and is postulated to have extraordinary properties.

APPENDIX II

THE CONTRACTION OF SOLID BODIES WITH ABSOLUTE VELOCITY

The distance between the atomic nuclei of any substance is in the order of ten thousand times the diameter of a nucleus. In solid bodies the distance between the nuclei is firmly maintained by the electromagnetic forces which are transmitted through the absolute space between the atoms. What has not been understood in detail is the mechanism of this two way force. Classical physicists thought that the dimensions of a solid body were not affected by acceleration or motion. The null result of the Michelson-Morley experiment showed that this notion was false. Modern physicists believe that the Lorentz contraction occurs with velocity relative to an observer. In this absolute theory any contraction must occur with absolute velocity. The simplest explanation consistent with experiments is that the forces between the atoms act in such a way that the time for a return trip at the speed c between two points on a body remains constant for all possible velocities.

The total time, T, for a signal, travelling at an absolute velocity, c, to make a return trip over a distance, D, on a body when it is at absolute rest is —

$$T = D/c + D/c = 2D/c \quad (1)$$

When the body has an absolute velocity, v, the velocity of the signal relative to the body is c - v in the direction of motion and c + v in the opposite direction, so that the distance D_p parallel to the motion over which a signal can make a return trip in the time T must satisfy the equation

$$T = D_p/(c - v) + D_p/(c + v) = 2D_p/c(1 - v^2/c^2) \quad (2)$$

The velocity of a signal relative to the body when travelling over a distance D_t transverse to the motion is $(c^2 - v^2)^{\frac{1}{2}}$ in both directions, so to make a return trip in the same time T, D must satisfy the equation,

$$T = D_t/(c^2 - v^2)^{\frac{1}{2}} + D_t/(c^2 - v^2)^{\frac{1}{2}} = 2D_t/c(1 - v^2/c^2)^{\frac{1}{2}} \quad (3)$$

When the time, T, is constant,

$$2D/c = 2D_p/c(1 - v^2/c^2) = 2D_t/c(1 - v^2/c^2)^{\frac{1}{2}} \quad (4)$$

$$D = D_p/(1 - v^2/c^2) = D_t/(1 - v^2/c^2)^{\frac{1}{2}} \quad (5)$$

So if a body contracts with absolute velocity, v, by a factor of $(1 - v^2/c^2)$ in the direction of motion and by a factor of $(1 - v^2/c^2)^{\frac{1}{2}}$ transverse to the direction of motion the time for a return trip at an absolute speed, c, between two points on the body remains constant for all speeds and orientations of the body. Because the time would remain constant these contractions are consistent with the results of all Michelson-Morley and Kennedy-Thorndike type experiments without any dilation of time.

J.F. SKJELLERUP: A FORGOTTEN NAME IN AUSTRALIAN COMETARY ASTRONOMY

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ABSTRACT

Australia has a proud history of cometary discovery, spanning nearly two hundred years. Well-known are the exploits of such greats as John Tebbutt and Walter Gale, and that contemporary giant Bill Bradfield. Less well-known are two Victorians, David Ross and Frank Skjellerup, and it is about the latter — whose tally of comets is second only to that of Bradfield — that this paper is concerned. Skjellerup, who was born in Cobden, Victoria, moved to South Africa in his mid-20's, and there developed a passion for astronomy. The appearance of Halley's Comet in 1910 sparked an interest in comet-searching, which Skjellerup pursued with great success; from 1912 until his return to Australia in 1927 he independently discovered five comets. After settling in Melbourne he added another two to his tally. Most of his comet-searching was accomplished with a 76 cm refractor, which was located in 1982 and brought back to Melbourne from New Zealand. In addition to his comet work, Skjellerup also engaged in variable star observing, and was a very active member of the Astronomical Society of Victoria for many years. He died in 1952. Although he spent two-thirds of his life in Australia, because of his early achievements while in Cape Town, many people assume that Frank Skjellerup was in fact a South African.

INTRODUCTION

Australian cometary astronomy

Australia has a long history of cometary astronomy, beginning with the pioneering efforts of Rumker and Dunlop at the Parramatta Observatory during the 1820's and 30's. Each discovered a comet, and Rumker was also responsible for the first recovery of Encke's Comet following the computation of its orbital period (Orchiston and Bhathal, 1984b). But Australia's links with comets date earlier than Parramatta Observatory, back to the initial European settlement of the continent. When the 'First Fleet' reached Sydney Cove in 1788, one of the newcomers, Lieutenant William Dawes, was charged with establishing an astronomical observatory in order to observe the predicted return of Halley's Comet later in the year. As it turned out, Neville Maskelyne's calculations were in error, and the comet did not appear until 1835.

During the 1850's Francis Abbott was actively involved in cometary observing in Hobart, and he was soon joined by John Tebbutt of Windsor (New South Wales). Tebbutt went on to become Australia's greatest amateur astronomer (see Ashbrook, 1972; Kimpton, 1980;Orchsiton, 1968; White, 1979), and comets were his major preoccupation (see Orchiston, 1982b). He was responsible for the discovery of two of the 'Great Comets' of last century (Orchiston, 1981), and tried to establish Australia's first astronomical society, an association of comet observers (see Orchiston, 1982a).

Tebbutt and Abbott provided the impetus which gave rise to a new generation of comet-observers and comet-searchers, the best known of whom were Walter Gale of Sydney, David Ross of Melbourne and Alfred Barrett Biggs of Launceston (see Orchiston, 1984a,b,c; Orchiston and Bhathal, 1984b).

Until the advent of Adelaide's remarkable Bill Bradfield, twentieth century Australian cometary astronomy was the almost exclusive domain of one man, J.F. Skjellerup, the discoverer of six different comets. Despite this impressive record, Skjellerup's name is virtually unknown in Australia, largely because his early work was carried out in South Africa. Through this paper, I hope to rectify this situation. After briefly reviewing Skjellerup's life we will examine his cometary work in detail, before discussing the significance of his discoveries, his publications record, and the fate of his telescope and comet-discovery medals.

J.F. SKJELLERUP

John Francis Skjellerup was born at Cobden, Victoria, on 1875 May 16, the tenth of thirteen children (Skellerup, 1961:28; Victorian Government, 1890:148). While still a small boy his father died in an accident, and the family grew up in a state of hardship (Skellerup, 1961:29). In 1889, just one day before his fourteenth birthday, young Frank (he preferred this name to John or Francis) went to work for the Post Master General's Department in Cobden as a messenger (Victorian Government, 1890:148), and subsequently trained as a telegraph operator. When the South African Government appealed to the Australian Government for trained telegraphists in 1900, Skjellerup was one of those selected (Skjellerup, 1912-48:107). Initially, he settled in Kimberley, but soon moved to Cape Town, and it was there that his interest in astronomy developed. Although he began observing in 1909, it was the appearance of Halley's Comet in 1910 that provided him with the inspiration for a full-scale commitment to astronomy (*ibid.*).

When the Cape Astronomical Association began in 1912, Skjellerup was appointed Foundation Secretary-Treasurer (Skjellerup, 1909-12), and during their first year addressed the membership on the subject of variable stars (*ibid.*). A year later, in 1914, he became a member of the British Astronomical Association (B.A.A. 1914).

In addition to his astronomy, Skjellerup assigned time to golf, which he pursued with a passion. He was a gifted player with a low handicap rating, and competed regularly for Rondebosch in local tournaments (Skjellerup, 1909-12).

Apart from six-month visits to Australia and England in 1914 and 1921 respectively, Skjellerup remained in Cape Town until 1927 when he retired and returned to Australia (op. cit.:52,80,93). He settled in the Melbourne suburb of Oakleigh and immediately turned to astronomy once more, although he waited until 1933 before joining the Astronomical Society of Victoria. In less than a year he had risen — with almost indecent haste — to the rank of Vice-President, and in 1942 began the first of three successive one-year terms as President. In 1943 he was appointed an Honorary Member of the Society (Moroney, 1941; Obituary, 1952). Two years earlier, a newspaper reporter had described Skjellerup as '..... a tall, slimly-built, quiet-spoken man, of the student type, who talks to you of his hobby with shy enthusiasm' (Skjellerup, 1912-4:107). His appearance somewhat earlier in life is shown in Fig. 1.

Later in the 1940's sickness in the family home kept Skjellerup away from Astronomical Society meetings, and also prevented him from pursuing his other major interest, bowls. For many years he had been a competition bowler with the Oakleigh Club, and served as President from 1934 to 1936 *op. cit.*:106). He died on 1952 January 6; there were no children from the marriage (Obituary, 1952; Skellerup, 1961:31).

SKJELLERUP'S COMETARY WORK

Introduction

Almost all our information on Skjellerup's observational astronomy derives from two fieldbook/diaries which I was fortunate enough to gain access to. One of these (Skjellerup, 1909-12) is mainly a scrapbook and notebook, but includes a diary of observations carried out between 1909 December 1 and 1910 November 17. Most of the entries relate to Halley's Comet. The second of these two volumes is a genuine fieldbook, with entries spanning the 1912-1948 period.

Skjellerup's first astronomical observation recorded in his fieldbook/ diary dates to 1909 December 6:

> Saw Saturn and rings. 2 Satellites visible E of Saturn The outer one very bright The inner one just visible. (Skjellerup, 1909-12).

Accompanying the description is a sketch showing the planet (and rings) and the position of the two satellites.

A perusal of the two fieldbooks immediately brings to light further observations of Saturn, as well as records of meteors, sunspots, Nova Aquila 1918, lunar occultations and lunar eclipses, Juno, and Jupiter, but it is soon apparent that his attention was mainly directed towards variable stars and comets. His principal instruments throughout the 40-year period when he systematically observed were two different 76 mm refractors and an excellent pair of Zeiss 8X binoculars. From 1917 until 1927 he also had the use of a 15.2 cm refractor at the Cape Observatory (see Skjellerup, 1912-48:72).

Let us now examine Skjellerup's cometary work in detail.

Fig. 1. Mr and Mrs Skjellerup in their garden at Rosebank, Cape Town (Jones Collection photograph).

A chronological narrative

The first mention of a comet in Skjellerup's fieldbook appears on 1910 January 15:

> Telegram from Reuters Correspondent ..... published in S.A. News on Monday 17th Jany "Large comet visible in East since Yesterday (Friday)". (Skjellerup, 1909-12).

This object was the celebrated Comet Halley 1910 II. Five mornings later Skjellerup went to Seapoint to view the comet, but although he arrived twenty minutes before sunset there was no sign of it. Further attempts to observe this comet on January 23 and 24 were likewise unsuccessful, and he had to wait another seven weeks before catching his first glimpse of the famous spectacle. His fieldbook entry on this occasion (April 15) reads as follows:

> Saw Halley's Comet at 5.40 am Tail just visible through field glass. At 6.5 AM got on to it with 3 in nucleus bright, tail not visible. Only just glimpsed with naked eye. (*ibid.*).

From this date until July 2 he followed the comet religiously, and recorded details of its appearance in his fieldbook. There are also sketches of its telescopic appearance on April 18 and 24. Accompanying these observations are seven pages of newspaper clippings on the comet, plus a full-page diagram by Skjellerup showing the orbits of Venus, Earth and Halley's Comet, and various positions of the comet between February 16 and June 25.

As Skjellerup pointed out to a newspaper reporter many years later (see Skjellerup, 1912-48:107), Comet Halley 1910 was the single most important factor that influenced and consolidated his burgeoning astronomical interests. It also prompted him to focus on cometary astronomy and to commence a regular comet-search programme. The latter involved morning and evening searches, generally with binoculars.

Skjellerup's first success came on 1912 September 11, and was reported in the *Cape Times* on the 13th:

> J.F.S. writes from Rosebank last night: A fairly bright comet was seen by me at 7.30 this evening in the constellation Centaurus, its position at that time being approximately: Declination, 32 degrees South; Right ascension, 13 hours 58 minutes. No tail was noticeable. During the previous 24 hours the comet had moved about one and a half degrees in an easterly direction and appeared last night to be a little brighter than on Wednesday evening. (Skjellerup, 1909-12).

He was disappointed to learn on the 14th that this comet had been detected several days earlier by fellow-Australian, Walter Gale of Sydney (see Orchiston and Bhathal, 1984a,b). The Cape Town newspapers also reported that Comet Gale 1912 II was independently discovered on the 11th by a staff member of the Santiago Observatory in Chile. For some unknown reason, neither of Skjellerup's fieldbooks contains any entries pertaining to this comet –– all we have to go on are the newspaper clippings.

The third comet to come under Skjellerup's scrutiny was Comet Tuttle 1912 IV. This first receives a mention on November 19, as too faint to detect, and was not observed until the evening of November 30/December 1:

> Waited up to see Tuttle's Comet (1912B). Seen at 1.0 am about 45°S 12H. 10M. Very faint not visible through zeiss binoculars. No tail noticeable in fact the comet could only just be seen and no more. (Skjellerup, 1912-48-6).

Accompanying the fieldbook entry is a sketch titled 'Position in glass' and a comment on the apparent motion of the comet. This was Skjellerup's only observation of the comet. Two nights later he searched unsuccessfully for another known comet (he refers to it as '1912c'), and on December 15 recorded a faint object near lamda Centauri. Its position had not changed by the following night, so he concluded that it was 'apparently [a] cluster of stars, not resolvable in 3'.

As with other comet-searchers, Skjellerup used indication of motion as the primary criterion for identification of a faint comet, and relied on a 17-page listing of clusters and nebulae in one of his fieldbooks to dismiss inappropriate suspect objects. The December 15 case, above, illustrates that this list was by no means definitive. Several more suspicious objects, thought initially to be comets because they were not recorded in his list, make their appearance in his 1913 fieldbook entries, but none showed signs of motion. The only comet observed in this year was Schaumasse 1913II. It was first detected on June 10:

> Looked for Schaumasse's Comet (1913a). Found it after the moon had set. Position at midnight (S.T.) N 40° 45' RA 15H 13M (approximate). Not quite as far west as given in the Ephemeris in BAA Journal P351. (Skjellerup, 1912-48:24).

It was also observed on the 11th, but moonlight prevented further searches until the 23rd, by which time it was beyond the range of Skjellerup's 76 mm refractor.

The next comet observed by Skjellerup was Delavan 1914V, which was located on 1914 February 14. It was just visible in the telescope, and was 'small and round [with] no sign of a tail'. It was subsequently observed on fourteen different evenings between February 16 and March 27, by which time it was very faint. The fieldbook contains little information on the comet throughout, other than its position (occasionally), and its apparent visual magnitude.

On 1914 August 7 Skjellerup left South Africa for a visit to Australia, and during his five months in Melbourne observed Comet Campbell 1914 IV on two occasions (September 24 and 25). On the latter date he recorded in his fieldbook:

> The above is the only observation of note made in Australia. The weather was not usually favourable. (Skjellerup, 1912-48:52).

As we shall see, in later years these less than ideal Melbourne skies were to yield further cometary discoveries for Skjellerup. Comet Campbell, meanwhile, was very much an antipodean affair, beng independently discovered by Dr Lunt at the Cape Observatory (in Skjellerup's home territory) and the New Zealand amateur, C.J. Westland (see Orchiston, 1983a).

The year 1915 was undoubtedly a record one for Skjellerup in terms of cometary astronomy, with no less than four objects under investigation. The first, Comet P/Tempel 1915 I, was detected on January 13, exactly one week after Skjellerup's return to Cape Town from Australia. Although it was, by then, a faint naked eye object, no tail was apparent (though Skjellerup conjectured that the prevailing moonlight may have been at least partly responsible for this). Skjellerup followed this object religiously until February 21, observing it on nine different evenings. By February 12 it had developed a small tail 1 to 1.25 degrees in length, and vestiges of this were still faintly visible on the 21st, by which time it had faded beyond naked eye range. His next observation of Comet P/Tempel 1915 I was on April 8 (by then the tail had disappeared), and he continued to observe it intermittently with the binoculars and telescope until June 11.

The April-June priod of 1915 must have been a busy one for Skjellerup, because in addition to Tempel's Comet he had Comet Mellish 1915 II to contend with. He first observed this object on April 16, when it was about magnitude seven and possessed a bright nucleus (Skjellerup, 1912-48:57). Skjellerup recorded this comet on twelve different evenings, through to June 11, and on many occasions noted its appearance, magnitude and position. For much of this interval it was a naked eye object, and by June 11 its tail had grown to 5-6 degrees in length. On June 15, he forwarded his observations of Comet Mellish 1915 II to the Director of the Comet Section of the British Astronomical Association. His next observation of the comet was not until August 12, by which time it had become a binocular object, and his final record of this comet dates to September 30.

The third comet observed by Skjellerup in 1915 is a very interesting affair. The account begins on October 31 when he writes in his fieldbook: '11.20 pm. Object seen near α Sagittarii, not shown in atlas'. Included are a field sketch showing the location of the 'object' relative to surrounding stars, and right ascension and declination estimates (obtained, as with all previous values, by interpolation, using known stars — Skjellerup's small telescope apparently lacked circles, and indeed probably had an altazimuth mounting). The following evening he noted that the object had moved significantly, thereby betraying its cometary nature, and so he immediately proceeded to the Cape Observatory. There, he and Dr Halm tried to find the object using the 30.5 cm refractor, but they were frustrated by intervening cloud. The following morning (November 2) Skjellerup sent a telegram to R.T.A. Innes, Director of the Union Observatory in Johannesbsurg and one-time amateur astronomer of Sydney (see Orchiston and Bhathal, 1984a). It read:

> Unknown comet observed Sunday Monday approximate position 19 hours 25 mts 38° South former increasing 5 mts daily eighth magnitude confirmation necessary. (Skjellerup, 1912-48:61).

That evening, Skjellerup returned to the Cape Observatory, at Halm's request, and they succeeded in finding the newcomer and recording its position.

The next day (November 3), Skjellerup was surprised to find an article in the *Cape Times* announcing his discovery of the new comet. It derived from Innes, apparently, and was titled 'Rosebank Amateur's Discovery'. He was even more surprised when Dr Lunt telephoned from the Cape Observatory the following day to point out that the 'discovery' was in fact Comet P/Pons-Winnecke 1915 III. Accordingly, Skjellerup wired Innes asking for confirmation, and this was received the same day. An annoyed Skjellerup writes in his fieldbook:

> Mr Innes should have discovered the identity of the comet before giving above particulars to the press. (Skjellerup, 1912-48:62). See also Innes, 1915a,b).

The last comet observed by Skjellerup in 1915 was P/Taylor 1916 I, which was discovered by his friend and fellow Cape Town amateur, C.J. Taylor. Skjellerup had visited Taylor's observatory a number of times over the years and used the 25.4 cm reflector housed there for general sky-browsing. He heard of Taylor's discovery on 1915 December 2, and located the comet that evening, using his 76 mm refractor. On the 4th an announcement of Taylor's discovery appeared in the *Cape Times* (the clipping is in Skjellerup, 1912-48:64). Skjellerup continued to observe the comet through to 1916 February 26 (when it was very faint), and on various occasions recorded its position.

The only other comet observed by Skjellerup in 1916 was P/Neujmin 1916 II, which he detected on May 6 at the ephemeris position published in *Nature*. No other observations of this comet were made. Later in the year, on June 19, he searched unsuccessfully for Comet Wolf 1917 III, and it again eluded him on 1917 January 21 and April 19. He finally met with success on August 11, and observed the comet again on the 12th, which represents his last fieldbook entry for 1917.

In the interim, his attention was drawn by a bright new comet, P/Mellish 1917 I, announced in the Cape Town newspapers on April 15 and 16. Clouds prevented observation of this early morning object until the 19th, by which time it was a spectacuclar sight:

> 5.30 am Tail of comet visible above trees on horizon. The nucleus cleared the horizon at 5.45 am tail about 10° long nearly straight up towards the zenith but with a slight curve towards the N. Nucleus very bright about 3rd mag Coma small and difused, Tail narrow but widened out a little towards the end. (Skjellerup, 1912-48:70-71).

Further observations of this interesting object were made on April 21, 25 and 26.

Only a single comet came to Skjellerup's attention in 1918, namely Reid 1918 III, discovered by a friend and fellow Cape Town amateur (see Brown, 1973:131). Skjellerup observed it on June 12 and 15, on both occasions recording the position. On the latter date he noted its magnitude at about 9.5, and commented on the absence of a tail.

By 1919, Skjellerup was an experienced observer of comets, with fourteen different objects in his fieldbooks, and although he could take credit for the independent discovery of Comet Gale 1912 II and the recovery of Comet P/Pons-Winnecke 1915 III, he had yet to claim a newly-found comet of his own. This situation changed on the morning of 1919 December 19 when he came upon a 'suspected comet' while searching for the variable star RS Librae. The following night its cometary nature was confirmed and the Cape Observatory advised. The apparent visual magnitude was about 8.5. Further observations followed, on December 21, of what was eventually designated Comet Skjellerup 1920I. On December 23 Innes (1919) wrote congratulating Skjellerup on the discovery.

Less than two months later, on 1920 February 8, Skjellerup began sweeping the western-southwestern horizon after sunset and immediately found a suspicious object which, upon subsequent examination of the ephemerides, turned out to be Comet Metcalf 1919 V. This object was observed again on February 16 and 17.

1920 December brought Skjellerup his second comet (which also happens to be Comet Skjellerup 1920 II). On the 11th he reported it in his fieldbook as a 'suspicious object', and the following night was able to report: 'Obviously a comet, has moved about 1° to N and slightly east'. (Skjellerup, 1912-48:77). The discovery was reported to both the Cape and Union Observatories, where photographs were taken and the orbital elements calculated. Meanwhile, Skjellerup continued to observe his new comet until 1921 January 3.

The next comets to gain Skjellerup's attention were two periodic comets, one of which he had sighted six years earlier. This was P/Pons-Winnecke 1921 III, which he first detected as a 7 to 7.5 magnitude object on 1921 July 12 several hours before dawn. Further observations followed on July 27 and 28 and August 27 and 30. The other periodic comet, P/Encke 1921 IV, was first seen on July 27 as a small round object of magnitude 9.5 to 10.0. Further observations were made on July 28 and 29 and on August 24, by which time it was diffuse, with no nucleus, and had faded to magnitude 12.5. These last three observations were made with the 15.2 cm refractor at the Cape Observatory, and positional readings were taken directly from the circles rather than by micrometry. This was a suitable method for establishing approximate position, but was less than satisfactory for orbital computations.

In 1921 October Skjellerup left on a six-month holiday that took him, amongst other places, to London, and whilst there he arranged the purchase of a new telescope, another 76 mm refractor. This altazimuth-mounted Cooke instrument cost twenty-five pounds, and when it reached Cape Town (in 1922 April) was immdiately put to work in comet-searching. Success quickly followed, with the discovery of a new comet on May 16. This find was made known to his friend Reid the next day, and was also reported to the Cape Observatory, where its position was determined with the 15.2 cm refractor. Skjellerup continued to observe the new comet on every opportunity, recording it on eight additional nights, up to and including May 28. At the bottom right hand corner of the relevant page of his fieldbook he recorded the following comments about his colleague and fellow comet-discoverer, William Reid:

> Mr Reid claims to have discovered this comet on same evening, but when asked on phone (follg day) if he had a comet in sight he reported in negative. He admits however my prior Discovery of object. (Skjellerup, 1912-48:81; his underlining).

Later this comet has shown to be the same object that a New Zealand astronomer named Grigg had detected in 1902. At 5.1 years, Comet Grigg-Skjellerup has one of the shortest periods of all known comets (see Marsden, 1982), and is also famous for the Puppids meteor shower, with which it is associated (Porter, 1952:92; Povenmire, 1980:21).

Early in the morning on 1922 November 26 Skjellerup discovered his fourth comet (Skjellerup, 1923 I), using the 76 mm refractor. It was a faint tenth to eleventh magnitude '..... diffuse nebulosity .... [with] no definite nucleus'. (Skjellerup, 1912-48:83). He reported the newcomer to the Cape Observatory later the same day, and the following night made further observations. Articles appeared in the local press on the 28th announcing the 'Discovery by Rosebank Observer' (see press clippings in Skjellerup *ibid.*). From this date until 1923 February 17, when it was only just visible in the 76 mm refractor, the comet was observed on thirteen different occasions. It reached a maximum magnitude of around 8 on December 23. A tail is not mentioned in any of the fieldbook entries.

After 1923 March 3, the next entry in Skjellerup's fieldbook dates to late 1927, following his return to Australia. After settling in the Melbourne suburb of Oakleigh he began comet-searching with the 76 mm telescope. Again December proved a lucky month, when on the 4th he was able to claim his fifth comet (Skjellerup-Maristany, 1927 IX). The way in which Skjellerup was led to this discovery clearly highlights the dual roles of luck and chance in the drama of cometary discovery: he reports in the Melbourne press (see the newsclippings in Skjellerup, 1912-48:93) that he was awakened by a strange noise early one morning, and found that the cat had knocked over something in one of the rooms. Noting that the sky was clear, he could not resist the temptation to take out the telescope and engage in a little comet-searching before slipping back to bed. He met with almost instant success! Despite this, he was not particularly overwhelmed by the discovery; the local press reports that although he was '..... tremendously excited when he discovered his first comet ..... repetition of the experience has blunted his zest'. (Skjellerup, 1912-48:91).

Skjellerup was only able to follow the comet for eleven days, but during that time it created a great deal of local interest, as a conspicuous naked eye object. It even inspired one writer to pen the following poem for the Melbourne newspapers:

> The comet that's known as the Skjellerup,
> At least cannot get one Fjellerup,
> In bed 'Oriel' lies,
> And won't watch the skies,
> And says he don't care who the Hjellerup.
> (Skjellerup, 1912-48:90).

On December 15 Skjellerup made an interesting series of daylight observations, as the comet approached the Sun. Let us quote from his fieldbook:

> 12.55 to 1.15 pm Lying on ground and using side of house and chimney as screen from direct rays of sun was able to pick up comet through binoculars watched it for 20 mts and again saw it at 2 pm 5.10 pm picked up comet through telescope (low power) about 1½ to 1¾ degs away from edge of Sun. Nucleus only visible. (Skjellerup, 1912-48:88).

In the margin, beside this fascinating entry, Skjellerup added the cryptic comment: 'Would astronomers believe this?'

Public interest in the comet was also heightened as a result of competition for its discovery from a contestant named Thomas Knox. Knox was a Melbourne nightwatchman, and claims to have first seen the comet five nights before Skjellerup, but he failed to advise Melbourne Observatory of its presence because he took its prior discovery by others for granted. Ultimately, Knox (like Skjellerup) received a bronze medal for his '..... joint discovery of the comet Skjellerup, December 4, 1927'. (see newsclippings in Skjellerup, 1912-48:96).

The next comet observed by Skjellerup was P/Crommelin 1928 III, which was first seen on 1928 November 24 as a ninth magnitude object. His second view of it was on the following morning. Moonlight then intervened and prevented further observations.

Comet Geddes 1932 VI, discovered by a New Zealand astronomer, was the next comet to claim Skjellerup's attention. He first located this telescopic object on 1932 June 25 and reported on it through a Letter to the Editor which appeared in *The Argus* (Melbourne) on June 28 (see Skjellerup, 1912-48:96). He observed the comet on ten more occasions between June 26 and July 27 (inclusive), though it never became a naked eye object. Later in the same year Forbes of South Africa and the South Australian Government Astronomer, G.F. Dodwell, shared in the discovery of a new comet (Dodwell-Forbes 1932 X), and this was first viewed by Skjellerup on December 26, shortly after the Director of Melbourne Observatory provided Victorian observers with its position. Skjellerup continued to observe 'The Adelaide Comet', as he called it, until 1933 January 17. It remained a telescopic object throughout.

Following a comet-sweeping entry for 1933 June, the next entry in Skjellerup's fieldbook is 1941 January 21, and reports the capture of what turned out to be his sixth and last comet:

> 3 am Up to see Cunningham's Comet. In few minutes saw a comet in Norma. Position plotted at 3.30 am RA 16^h6^m Dec 40°S Magnitude about 4.5 short, broad tail about ¾ degree long. Possibly a new comet (Skjellerup, 1912-48:97; my underlining).

The following morning the comet was found to be moving in the wrong direction for Comet Cunningham, and so Skjellerup was able to report a new discovery to Melbourne Observatory on the 22nd. On this same date he also wrote James Nangle, the Government Astronomer of New South Wales, mentioning that the initial observations were made with binoculars, and asking that the Donovan Trust be advised of the discovery (Skjellerup, 1941). The following day (January 23) the Melbourne *Age* ran an article announcing the discovery (see Skjellerup, 1912-48:99).

Other Melbourne newspaper accounts reveal that another Melbourne amateur astronomer named Barnes also detected this comet on January 21, just one hour after Skjellerup (see also, Moroney, 1941), but it was subsequently learnt that the comet was first discovered by De Kock in South Africa on the 15th, six days before Skjellerup ('Comet 1941a', 1941; 'The history .....', 1941). It was also independently discovered on January 23 by Paraskevopoulos in South Africa, and on the 25th by observers in New Zealand and South America. In his *Catalogue of Cometary Orbits*, Marsden (1982) lists this object as Comet De Kock-Paraskevopoulos 1941 IV, but the information at our disposal shows clearly that Skjellerup was the second person to independently discover and report it. It would seem, therefore, that there is a case for the official renaming of this comet as De Kock-Skjellerup 1941 IV.

Skjellerup observed the comet whenever sky conditions permitted through to February 6, on January 30 noting the tail as '..... 6 or 7 degrees long, slightly curved'. (Skjellerup, 1912-48:99). During the several weeks it remained a naked eye object, this comet created abundant popular attention, judging from the various press clippings in Skjellerup's fieldbook (1912-48:99-108).

The only post-1941 entries in Skjellerup's fieldbook date to 1948 November, when he observed the famous 'Eclipse Comet' (1948 XI) on two consecutive mornings. On the first (November 10), it was an easy second magnitude object and he noted that a star was visible through the seven degree long tail. The fieldbook record for the 11th represents Skjellerup's last known observation of a comet.

DISCUSSION

During thirty years of intermittent comet-searching John Francis Skjellerup independently discovered eight comets. One of these was assigned to another (Gale) on the basis of prior discovery, and a second turned out to be the periodic comet Pons-Winnecke. Thus, Skjellerup can claim six comets to his name, but his last, De Kock-Skjellerup 1941 IV, has yet officially to be assigned to him. Two other comets named after him (Grigg-Skjellerup and Skjellerup-Maristany 1972 IX) are also shared with other discoverers, although Grigg was not the co-discoverer of Grigg-Skjellerup in 1922. Skjellerup's remaining three comets (1920 I, 1920 II and 1923 I) bear his name only. If current rules of nomenclature had applied in 1912, Comet Gale 1912 II would also have gained Skjellerup's name, and he could have claimed it as a seventh legitimate find. Fate, and history, have decreed otherwise. Nevertheless, this is quite a remarkable tally, and amongst Australian astronomers is second only to that attained by the current co-world record holder, Bill Bradfield of Adelaide. Nor should we forget that in addition to his independent sighting of the aforementioned comets, Skjellerup was also responsible for the recovery of Comet P/Encke 1921 IV (along with his Cape Town colleague, Reid). We should not, incidently, make the mistake (see Bateson, 1972, for example) of confusing Australia's J.F. Skjellerup with the Danish astronomer H.C.F. Schellerup, who is also known in cometary circles and can claim the independent discovery of Comet 1862 III. Skjellerup himself (1912-48:107) was quick to point out that they were in no way related.

Of Skjellerup's six comets, only the last two (discovered in Australia) were major comets of naked eye prominence. Indeed, his 1927 find was so conspicuous an object that Seargent (1982:109, 133, 216) includes it in his listing of twentieth century 'Great Comets'. Skjellerup's other finds were all telescopic objects. At least two of these (there is no information on 1920 II in his fieldbook) were discovered during systematic telescopic comet-searches, as was P/Pons-Winnecke 1915 II, whilst three were fortuitous finds. Comet 1920 I was found by chance while variable star observing; 1941 IV appeared in the process of searching for a known comet (Cunningham); and 1927 IX resulted from the famous 'cat incident'.

Another interesting feature of all the discoveries is the prevalence of morning as opposed to evening sightings. Skjellerup discovered four of his six comets in early morning skies, indicating that the proportion of morning to evening searches must have increased dramatically after his earliest search years.

During the twelve months from 1912 November, for instance, he carried out systematic comet searches on 49% of all nights suitable for observation, and only 9% of all searches were conducted just before dawn. Moreover, the great majority of Skjellerup's early comet-searching was carried out with the Zeiss binoculars, but the telescope had become his principal search instrument by the time that success began to stalk him, in 1919.

Although it is tempting to engage in a statistical analysis of Skjellerup's 'success-rating', in terms of the number of hours of search time per comet discovery (see Kresak, 1982:66; Roemer, 1963:529), required data are lacking. There are numerous major gaps in Skjellerup's fieldbooks, particularly after 1923, and some of these undoubtedly represent periods when he did not bother to record all his comet-searching activities. There were also periods, as between 1914 and 1918, when he concentrated on variable stars at the expense of comets. Given these and other deficiencies, we are not even able to arrive at a figure for Skjellerup's average number of comets per year, although it must certainly have been lower than Bradfield's value of just less than one.

As a result of his cometary dicoveries, Skjellerup accumulated a collection of commemorative medals. By the date of his 1941 discovery he had already amassed four Donohoe Medals (awarded by the Astronomical Society of the Pacific for the comets he discovered in South Africa) and one Donovan Medal (presented by the Donovan Trust, Sydney, for his 1927 find) (Skjellerup, 1912-48:105:107). He subsequently received a second Donovan Medal for his 1941 comet (*ASV Bulletin*, 1942). After Skjellerup's death in 1952 the medals, together with his 76 mm refracting telescope, went to relatives in New Zealand. However, only five medals are mentioned in the family history (see Skellerup, 1961:34), so the fate of one medal is uncertain.

The five known medals were eventually distributed among the children of George Waldemar Skellerup, and two ended up at Mount John University Observatory (P.J. Skellerup, pers. comm., January 1983). In 1984 February the Skellerup Family kindly returned one of the medals to Australia, and it is now on long-term loan to Victoria College in Melbourne. This is the Donohoe Medal awarded for his very first discovery, Comet Skjellerup 1920I. Two medals are still held by members of the Skellerup Family in Christchurch.

In mid-1983 the Skellerup Family also saw fit to place the 76 mm refractor on long-term loan with Victoria College (see Garran, 1984), and it is now used there by undergraduate astronomy and post-graduate museology students (the latter for conservation and display purposes). It is a standard Thomas Cooke altazimuth-mounted refractor, with a focal ratio of about f/15, and comes complete with a finder and a number of eyepieces (there is not a full complement, as some have been mislaid over the last thirty years). The tube, mounting, and all attachments are in brass. The mounting is supported by a sturdy wooden tripod.

Given Skjellerup's outstanding records in comet discovery and variable star observing, his poor publications record comes as somewhat of a shock. Indeed, I have been unable to find any published papers by him on his cometary work, though he did make a practice of forwarding his observations to the Comet Section of the British Astronomical Association. As some small consolation, Skjellerup would sometimes lecture on astronomy to astronomical societies and other bodies. However, his talks rarely focussed solely on comets; rather he preferred to deal with the range of activities open to the amateur astronomer and to the contribution that amateurs could make to the discipline of astronomy (e.g. see Skjellerup, 1942, 1943, 1944). In these addresses, comets merely formed a part of the menu.

CONCLUSION

After Bradfield of Adelaide, J.F. Skjellerup must be classed as Australia's most successful comet-discoverer. Between 1912 and 1941 he discovered seven comets, five of which now bear his name. A case has been made for the renaming of another, to bring his tally to six. Of these six comets one (Comet Skjellerup-Maristany 1927 IX) turned out to be one of the Great Comets of the twentieth century. Meanwhile, another of his finds, Comet P/Grigg-Skjellerup, is a well known periodic comet associated with the Puppids meteor shower. In recognition of his discoveries, Skjellerup was awarded four different Donohoe Medals and two Donovan Medals. One of the former has recently been returned to Melbourne by relatives in New Zealand, along with the 76 mm telescope that Skjellerup used for much of his comet work.

In addition to his comet discoveries, Skjellerup was responsible for two recoveries. He also carried out regular observations of known comets, recording data on 21 different objects between 1910 and 1948 (see Table 1). Despite this impressive observational tally, he failed to publish any papers on his work and was merely content to forward his observations to the Comet Section of the British Astronomical Association where they could be used by others.

Although comets were his first love, Skjellerup also was addicted to variable star observing. Throughout his life he was active in astronomical societies, first in Cape Town and later in Melbourne.

This invaluable contribution to astronomy was brought to an end in 1952 when John Francis Skjellerup died at the age of seventy-five.

ACKNOWLEDGEMENTS

This project would have been impossible but for the continued assistance of Lady Marion Skellerup, and Messrs. C.V. and P.J. Skellerup of Christchurch, New Zealand, and Mrs Grace Jones of Lorne, Victoria. To them I extend my sincere thanks. I am also grateful to the following for providing information of relevance to this study: Mrs A. Herbert (Geelong), Mrs M. Friend (Ondit) and Mr Colin Duggan (Post Office Historian, Melbourne). Finally, I must thank Mrs Jones for permission to publish Fig 1, and my own institution for contributing towards the cost of this project.

TABLE 1. Comets observed by J.F. Skjellerup, 1910-1948

Year	Number Observed	Comet Name(s)
1910	1	Halley 1910 II.
1912	2	Gale 1912 II, Tuttle 1912 IV.
1913	1	Schaumasse 1913 II.
1914	2	Campbell 1914 IV, Delavan 1914 V.
1915	4	P/Tempel 1915 I, Mellish 1915 II, P/Pons-Winnecke 1915 III, P/Taylor 1916 I.
1916	2	P/Taylor 1916 I (continued), P/Neujmin 1916 II.
1917	2	P/Mellish 1917 I, Wolf 1917 III.
1918	1	Reid 1918 III.
1919	1	Skjellerup 1920 I.
1920	2	Metcalf 1919 V, Skjellerup 1920 II.
1921	3	Skjellerup 1920 II (continued), P/Pons-Winnecke 192 1III, P/Encke 1921 IV.
1922	2	P/Grigg-Skjellerup 1922 I, Skjellerup 1923 I.
1923	1	Skjellerup 1923 I (continued).
1927	1	Skjellerup-Maristany 1927 IX.
1928	1	P/Crommelin 1928 III.
1932	2	Geddes 1932 VI, Dodwell-Forbes 1932 X.
1933	1	Dodwell-Forbes 1932 X (continued).
1941	1	'De Kock-Skjellerup 1941 IV'.
1948	1	'Eclipse Comet' 1948 XI.

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SOLAR DIAMETER MEASUREMENTS FROM PAST ECLIPSES: THE TOTAL SOLAR ECLIPSE OF 1922 SEPTEMBER 22

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ABSTRACT
There has been much interest in recent years in measuring the diameter of the Sun to see if there have been any changes in its size. One of the more successful methods has been to make use of observations near the limits of the eclipse path of total or annular eclipses. This method has the advantage that it can potentially be compared with suitable observations made at 'historical' eclipses. This paper concerns investigations that I have made into the Total Solar Eclipse of 1922 September 22.

Research to identify historical eclipses at which suitable observations were made for the purpose of measuring the size of the Sun (that is, observations made from near the limits of the eclipse path) which has been carried out at the U.S. Naval Observatory has elucidated some suitable observations made at the eclipse of 1922 September 21. The nature of the reports published was such as to make this particular eclipse worthy of close investigation; however, some modern data, such as site coordinates, were required, and I was asked to assist in this matter. In Fig. 1 there is reproduced the map of the eclipse circumstances as published in the Nautical Almanac for 1922.

The reports of the eclipse, published in the *Memoirs of the Sydney Observatory* are fairly full. The major part of the report is devoted to the efforts made at Goondiwindi (on the NSW/QLD border) to perform the 'Einstein experiment' and other miscellaneous experiments. For the current investigations, these matters are of no interest. However, there are reported also two sets of observations, made by non-astronomers, which are of paramount importance. They are visual observations made at or near the towns of Grafton (NSW) and Beaudesert (QLD). Because of the quite different problems associated with the two sets of observations, I shall discuss them separately.

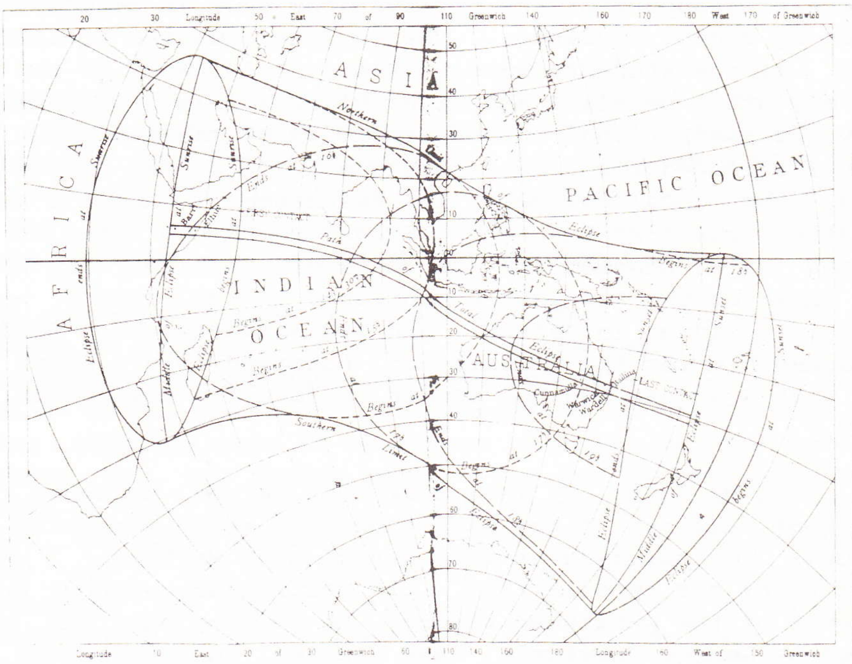

Fig. 1. Circumstances of total solar eclipse of 1922 September 22.

BEAUDESERT

The report of the observations made at Beaudesert is quite brief, and I quote it here in full:

> Beaudesert is a small town in Queensland, situated in Lat. 27d 59' long. 152d 56'. It does not possess a high school, but I interviewed Mr. Stanley, headmaster of the State School, who promised to place a number of his oldest and brightest pupils at distances a furlong apart along a road passing in a more or less north-south direction, the central point being the railway station through which passed the predicted position of the shadow-edge. Mr. Stanley was absent from Beaudesert at the time of the eclipse, but the observations were carried out as arranged, under the superintendance of Mr. George Crawford. All reports agree that the sun was not totally eclipsed within the limits of the string of observers: that is, that the shadow edge passed south of lat. 28d 0'. Two reliable youths went as far south as Mount Mahomet (Lat 28d 07', long 153d 01'), where the eclipse was total, the totality lasting for 1 min 10 secs.

When I went to modern maps to identify the site coordinates of Mount Mahomet, it was rather disturbing to note that the specified coordinates were for a location several kilometers away from the peak named Mt Mahomet, and could equally possibly be for another peak in the mountain range. However, correspondence with the Queensland Dept of Mapping and Surveying elicited the following:

> With due respect, the geographical coodinates mentioned in the 1922 report should today be used only as an aid to general positioning. A number of geodetic datum changes have occurred since the 1922 computations which would explain the difficulties you have experienced in positioning the feature on current map sheet series. The modern coordinates for the trig station on top of Mt. Mahomet are lat 28d 04' 49"24, long 152d 59' 32"41.

An interesting aspect of the observations made in Beaudesert is that they were made by school students. The eclipse occurred in 1922, that is, 61 years ago: if the students were in their early teens at the time, then perhaps some may still be alive and might be locatable. Of particular value would be any information that the observers on Mt Mahomet might recollect. To this end I arranged for a small article to be placed in the *Logan and Albert Times*, the local newspaper for Beaudesert. About a week later I received a letter from a Mr Dawson J. Bradshaw who has lived on a property on the slopes of Mt Mahomet for the whole of his life. He was able to recall the names of the two youths mentioned in the report — a Bernard Kennedy Yore, now living in Gatton, and Sid Rasmussen, now dead. I phoned Bradshaw, thanked him for the information, obtained Yore's phone number, and ascertained that Bradshaw had not spoken to Yore for some years. Bradshaw was of age 77.

I then rang Mr Yore. I feel sure that he was somewhat stunned to receive a phone call out of the blue inquiring about something he saw 60 years previous! On speaking at some length with Mr Yore, I was impressed with the clarity of his recollection. In particular, without any knowledge of the contents of the published report, he told me that the observations were organized by George Crawford, that Stanley, the Headmaster, was absent on long-service leave, and that a string of observers were located in Beaudesert centered on the railway station and spaced at furlong intervals

— he recalls them using a 66-foot tape-measure to space the observers. From the exact correspondence of these details with those of the published report, I concluded that he was able to accurately recall the circumstances of the event.

It turned out that at the time they all thought it was a 'bit of a lark', but they had a feeling of pride and responsibility as they had been specially picked to go to Mt Mahomet. He was able to confirm beyond any doubt that they observed the eclipse from the feature marked on modern maps as Mt Mahomet, and said that in fact there were four people at the site — himself, his father, someone by the name Gray, and someone else. He recalled that their prime mission was to observe the shadow on the landscape, that he himself would not have had a watch, but his father would have, and that his father would have done the eclipse timings. He described his father as being a 'very accurate' person, who was particularly interested in the eclipse. He also recalled writing a detailed report, as did the other observers in Beaudesert. (Nick Loveday tried to locate these at the Mitchell Library, with no success.) When I spoke with Yore, he was of age 75: he was thus 15 at the date of the eclipse.

Some days after speaking with Yore, I received a letter from a Mr H.E. Gray of Taringa. He also could recall the details of the sites around Beaudesert. Apparently he was asked to go to Mt Mahomet, but on the day of the eclipse he got sick and couldn't go to school: as a result they arranged for another boy to go in his place. Nevertheless he ended up going as well, together with Yore and Yore's father. In regard to the timings, he recalled that 'Mr Yore senior had a pocket watch, and I think the other man had one also. I seem to remember they had a bit of a difference, and it could have been a matter of a few seconds; these little things did not appear important at the time'.

It was most heartening that the two independent recollections of the eclipse were so close, and agreed so well with the published information. The recollections have removed most of the uncertainties associated with the published report of the eclipse as seen from Beaudesert.

GRAFTON

The observations that were made at the southern limit of the eclipse, at Grafton are of quite a different nature to the Beaudesert observations. All observations were made by adults, and there were many reports from throughout Grafton. Figure 2 is a map of Grafton, on a scale of 1:25000, to which it may be useful to refer. The following condensed report is sufficient to indicate the nature of the Grafton problems.

> An attempt was made to locate the edge of the moon's shadow on the earth at Grafton. A position on the locus of the shadow edge was computed from the Nautical Almanac, viz. 29d 41' 30" sth, long 152d 56'E. (through the grandstand at the Grafton Racecourse). Two separate sets of observers provided two distinctly different paths for the shadow edge. One set placed the observed shadow edge on the river itself, just south of the city, in lat. 29d 41' 35", the other placed it a little north of the grandstand, say 29d 40' 20". The disputed strip is a little over a mile, and just includes the whole city of Grafton. There is no doubt that the shadow did not reach the south bank of the river.
> Both parties agree on the following points: Throughout the disputed zone the black moon was completely visible, the corona was visible for the complete circle, though more pronounced on the

northern edge; and a bright spot of apparent sunlight persisted at the position of 11 o'clock. One additional observation seems to decide the matter, viz. that the actual edge of the shadow was plainly seen along the river, near its nothern bank, by people situated on both banks; that the portion near the city was dark, whereas that near South Grafton was quite bright all the time.

In interpreting the analysis of these observations, it is wise to remember that they did not possess the modern understanding of what happens at the times of eclipse contacts; nor could they predict, let alone analyse, Baily Bead phenomena. Indeed, reading the full report, one gains the impression that they expected the shadow edge to be extremely well defined — which it is not.

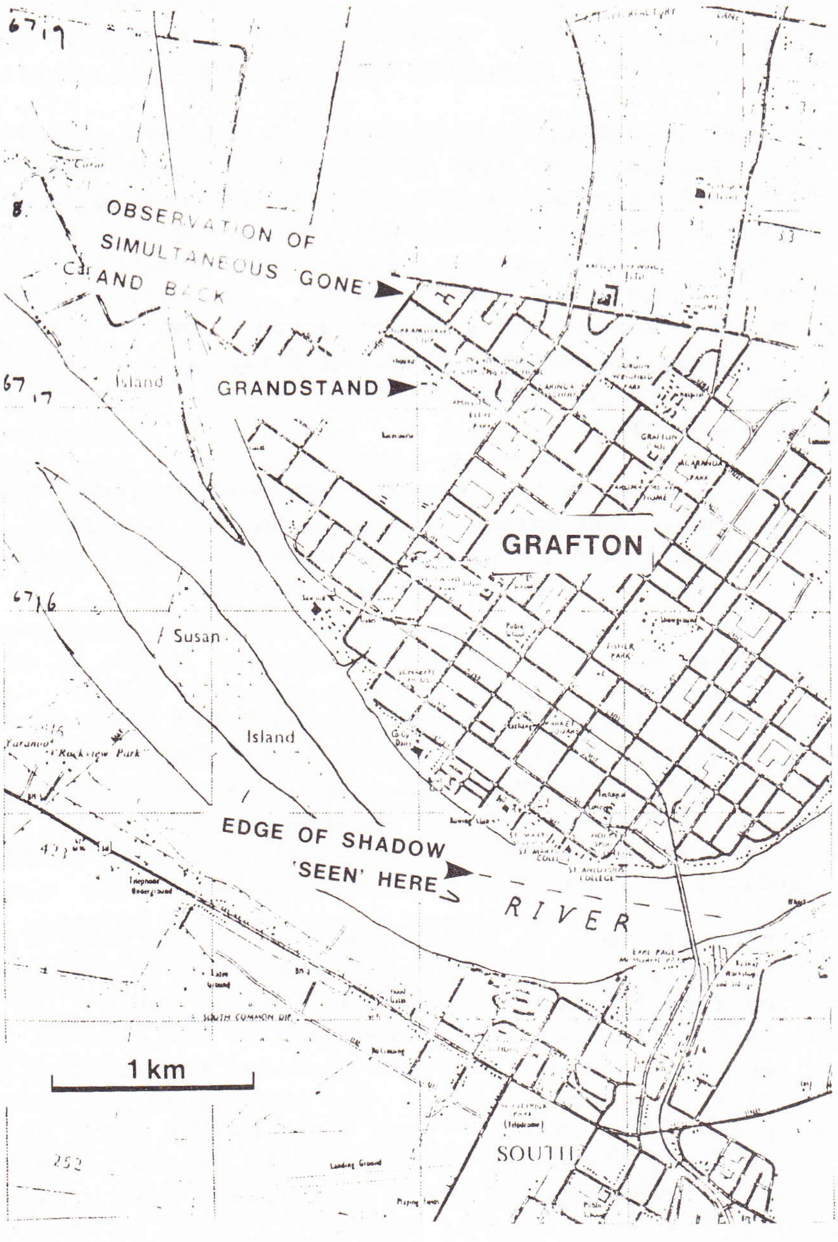

Fig. 2. Part of the town of Grafton, N.S.W., where the eclipse was observed.

The worrying aspect of the reports is the presence of the bright spot of light, which all observers from Grafton reported to be present throughout 'totality'. However, there are three reported observations, each from sites somewhat north of the racecourse which are quite interesting. One, at the racecourse grandstand, reports that the crescent of light 'shrank until it was a thin line, when it became a brilliant spark of light like Venus, got smaller, then increased in size and again became crescentic, but never entirely disappeared'. The other two observers' reports are similar, with one who was some 400 yd north of the grandstand reporting that the last spark of the Sun's glow disappeared and reappeared 'almost instantaneously'. The reporter of these observations also notes that having spoken with one of the observers who reported the visibility of the shadow edge on the water of the river, he was convinced that what was seen on the water was no more than a line of light reflected from ripples on the water.

How are these observations to be interpreted? The contemporary astronomers concluded that the weight of the evidence pointed to the shadow edge passing over the river, south of Grafton. However, the reported observations are ENTIRELY CONSISTENT with the occurrence of a large Baily Bead (which is to be expected at the southern limb of the moon), thus placing the southern limit of the actual eclipse path some 400 yd or so north of the racecourse grandstand.

CURRENT STATUS

Having investigated the reports of the eclipse, and come to some definite conclusions about what was seen, both at Grafton and Beaudesert, it has been possible to go to the computers and analyse the observations by comparing them with predictions of the eclipse path location using modern ephemeris data together with the now, substantially, known shape of the lunar limb. Of great encouragement is the fact that the modern data is entirely consistent with the eclipse limit as affected by the irregular lunar limb being somewhat north of the Grafton grandstand, and also predicts the presence of appropriately large valleys to form the observed Baily Bead. Unfortunately, it also puts the northern limit NORTH of Beaudesert, whereas the observations from there indicate that it was SOUTH. Making corrections to the ephemeris data so that the northern limit is south of the Beaudesert observers, and consistent with the Mt Mahomet observations, has the effect of moving the southern limit far too south in Grafton. At this stage, the cause of this inconsistency is unknown, and awaits further investigations. Unfortunately, until or unless the observations are somehow interpreted in a manner which is consistent with modern ephemeris data and its uncertainties, this particular eclipse may not be of much value for investigating the changes of the solar radius over historical periods.

ALFRED BARRETT BIGGS AND AMATEUR ASTRONOMY IN TASMANIA

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ABSTRACT

The second half of the nineteenth century saw the emergence of state observatories across the continent which, in addition to astronomical research, provided an assortment of astronomical and meteorological data, as well as a time service, for their local communities. In centres without professional observatories, it sometimes fell to serious amateurs to provide this public service. One such 'astronomical information centre' was established at Launceston by A.B. Biggs in 1880, and faithfully served the local community for twenty years. Alfred Barrett Biggs was introduced to the world of astronomy in 1874 when he assisted the American Transit of Venus party at Campbell Town where he served as a teacher. Soon after he obtained a 76 cm refractor, and upon moving to Launceston in 1880 added a 216 cm reflector to his repertoire. Operating from two observatories, he carried out regular double star and cometary work, and provided a time service for the local population with his home-made transit instrument. His early double star observations were made by means of a micrometer of his own construction. During the 1880's and 90's Biggs contributed a number of papers to professional journals in Australia and overseas; wrote numerous astronomical articles for the local press; and maintained a correspondence with Australia's leading astronomers. His interests also lay in areas other than astronomy. He was one of the founding fathers of seismology in Australia and is said to have been the first to build and use a telephone within this country. Biggs died in 1900.

INTRODUCTION

One area of astronomical history gaining increasing attention is the contribution made to the advance of the discipline by amateurs (e.g. see Inkster, 1980, 1982; Rothenberg, 1981; Stebbins, 1981, 1982; Williams, 1983). In Australia, despite earlier accounts by Baracchi (1914), Ellery (1902) and Russell (1889), we are still at the stage of documenting the achievements of the various notable amateurs, and except in the case of John Tebbutt, perhaps (see Ashbrook, 1972; Baracchi, 1941:351-354; Kimpton, 1980; McDonagh and Orchiston, 1961; Orchiston, 1968, 1981, 1982b,c; White, 1979), this work is still very much in its infancy. Recent detailed studies have been published on leading South Australian amateurs (Waters, 1980-1) and J.F. Skjellerup (Orchiston, 1984c), while research is currently in progress on the contributions of Bendigo's John Beebe and Leslie Jeffree (by D. Martin); David Ross (Orchiston) and R.W. Wigmore (Brewer), both of Melbourne; Sydney's Walter Gale (Bhathal) and R.T.A. Innes (Orchiston); Captain Henry Baker of Ballarat (Kay); Newcastle's Mark Howarth (Burke); and Drs McFarlane of Irvinebank, Queensland, and Bone of Castlemaine, Victoria (both by Orchiston), amongst others. Some preliminary information on Bone, Innes and Gale has already appeared in Orchiston (1982a,b,c) and Orchiston and Bhathal (1984), while Orchiston (1983b) provides a listing of notable Australian amateur astronomers.

The purpose of this paper is to add to this data bank by examining the role of Alfred Barrett Biggs in late nineteenth century Australian and

Tasmanian astronomy. A preliminary report on my 'Biggs Project' was presented at a Royal Society of Tasmania seminar in Launceston last November (see Orchiston, 1984a), and an exhaustive account is given in Orchiton (1984b).

Alfred Barrett Biggs (Fig. 1) was born in London on 1825 April 10, the second of twelve children. In 1833 he emigrated to Tasmania, and there gained an education through his father, a businessman turned school teacher. He, too, turned to teaching in 1845, and spent the next 30 years of his life in a number of posts in Tasmania and Victoria. He entered a new phase of life in 1880 when he accepted the position of accountant and head ledger keeper at the Launceston Bank for Savings in Launceston (Beever, 1972:96), and remained there until shortly before his death on 1900 December 19 (Obituary ..... 1900).

Biggs's interest in astronomy was awakened while teaching at Campbell Town (Historical Committee ..... 1966), with the advent of the 1874 Transit of Venus, but only blossomed following his move to Launceston and his appointment to the bank.

We shall now review the various instruments at Biggs's disposal before proceeding to an examination of his observational programmes and an evaluation of his place in Tasmanian and Australian astronomy.

Fig. 1. Alfred Barrett Biggs of Launceston, Tasmania (1825-1900).

INSTRUMENTATION

The first telescope that Biggs acquired was apparently the 51 mm refractor that he used in 1874 to observe the Transit of Venus (Biggs, 1881d)*. We have no description of this instrument. Some time during the period 1875-8 he obtained a 76 mm refractor, which he fitted out with an equatorial mounting complete with circles and drive (Biggs, *ibid.*; 1882b). At Launceston the telescope was mounted on a stone pier (A.W. Biggs, 1933) within a small octagonal domed observatory located in George Pullen's garden, 0.8 km from the bank where Biggs lived (Biggs, 1882d; 1886c). George Pullen was Biggs's brother-in-law, and was the actuary at the Launceston Bank for Savings (Beever, 1972:74-75; Biggs Family Tree).

Soon after moving to Launceston Biggs (1882b) also added a simple home-made transit telescope to his stable of instruments, and a reticle micrometer of his own design for the 76 mm telescope (Biggs, 1882a). Both proved inadequate and were subsequently replaced, the former by a transit instrument on loan from Melbourne Observatory, and the latter by a new home-made model, this time a bar micrometer (Biggs, 1889b; A.W. Biggs, 1933).

The most important instrument used by Biggs was a 216 mm Newtonian reflector given him by a Campbell Town friend, Mr John Taylor, in mid-1885 (Biggs, 1885b). In a letter to John Tebbutt dated 1885 July 31, Biggs describes this instrument as:

> ..... an 8½ inch Reflector — (Browning-With) ..... It is mounted equatorially (approximately) by its former owner, but without circles ..... It is provided with Browning's powers Nos 1,3,5, also G achromatic and a position spider-line eyepiece. Also Barlow-lens, and diagonal Sun-prism.

Biggs (1885c) modified the instrument to suit his observational needs, adding circles and an ingenius drive involving a water-clock (see A.W. Biggs n.d.). The new telescope was mounted in a newly-constructed roll-off roof observatory in Royal Park (as it is now known), adjacent to Pullen's property (The largest telescope ..... 1885; Scott and Scott, 1935). Three years later, Biggs (1888a) purchased the latest Troughton and Sims filar micrometer for use with the large reflector.

In addition to the above, a marine chronometer, sextent and master electric clock completed the range of instruments at Biggs's disposal (Biggs, 1882b; A.W. Biggs, 1933).

Let us now examine the use to which these instruments were put.

OBSERVATIONAL ASTRONOMY

Introduction

Although Biggs carried out his first observations in Campbell Town, assisting an American Transit of Venus party in 1874 (Raymond n.d.:383), he only turned seriously to astronomy after moving to Launceston. He continued to observe regularly throughout the 1880's and into the 90's, when advancing age and failing eyesight forced him to curtail his enthusiasm. By 1897 he had all but abandoned observational astronomy (Biggs, 1897).

* Henceforth, all text references to 'Biggs' relate specifically to Alfred Barrett Biggs.

Throughout his comparatively short astronomical life, Biggs's attention focussed primarily on two different types of objects -- comets and double stars -- though he also made a point of observing a range of 'current phenomena'.

Cometary astronomy

Biggs commenced his assault on cometary astronomy with one of the major comets of the nineteenth century, the Great Comet of 1880, which he followed assiduously for one and a half months (Biggs, 1881b). His next comet was also a Great Comet, that of 1881, discovered by John Tebbutt (see Orchiston, 1981). He obtained a number of positional readings directly from the circles, and sent these to Tebbutt (Biggs, 1881a), thereby establishing a friendship that was to last for the rest of his life. It was Tebbutt's comment that cometary orbital computations were only possible with positional measurements obtained with a micrometer which prompted Biggs to construct his own device. This was first applied to Schaeberle's Comet of 1881 (Biggs, 1881b,c), which proved too faint to detect. Instead, Biggs had to wait for Comet Wells (1882), by which time he had the use of his new bar micrometer. He recorded details of this comet on 18 different nights (Biggs, 1882c,d,e) and on eight of these also obtained micrometric positions. All these data were forwarded to Tebbutt.

Biggs had a second chance to pursue micrometric cometary astronomy later in 1882, with the arrival of the Great Comet of that year. Although a morning object, this did not stop Biggs from obtaining 25 observations — some with the micrometer — and he again forwarded all his measurements and notes, plus field drawings, to John Tebbutt (Biggs, 1882f,g; 1883a,b,c). On 1883 January 15 Biggs recorded an occultation of a nineth magnitude star by the comet's nucleus, which he thought was '..... of considerable scientific interest' (Biggs, 1883a).

The end of 1883 saw the reputed discovery of a naked eye comet by two Tasmanian laymen, Clevers and Thirlwall, but Biggs was convinced that the whole matter was a hoax (see Orchiston, 1983a). Despite a search, he could not locate this object.

The year 1884 featured another, less controversial, comet, discovered by the Melbourne astronomer, David Ross, while searching for Comet Pons. Comet Ross was a '..... very hazy, ill-defined object' (Biggs, 1884a) in the 76 mm telescope and so received relatively little attention. This was in marked contrast to Comet Pons which was observed both visually and spectroscopically. In 1884, Biggs's first astronomy publication appeared in the *Papers and Proceedings of the Royal Society of Tasmania*. It was titled 'Notes on spectroscopic observations of Comet 'Pons' .....' (Biggs, 1884c). This was followed later in the year by a shot paper in *Monthly Notices of the Royal Astronomical Society*, which reported the visual observations of this comet and Comet Ross 1884 (Biggs, 1884d).

With the arrival of the large reflector Biggs was able to pursue fainter comets for longer, and he immediately put this premise to the test in 1886 when three different comets were visible from Launceston (towards mid-year, all at the same time). Although Biggs forwarded a number of micrometric observations to Tebbutt (Biggs, 1886b), he did not write up any of this work for publication.

In contrast, 1887 brought Biggs only one observable comet, but this was yet another Great Comet, and was remarkable in that its head appeared to lack a nucleus. Biggs (1887b,c) noted this feature in his letters to Tebbutt, and also remarked on it in a short observational paper (Biggs, 1887a).

Further micrometric positions, this time of Comet Sawerthal, with the new ring micrometer, were obtained in 1888, and published in two short papers in *Monthly Notices* (Biggs, 1888b,c). The first of these also contained information on the head of the comet, together with magnitude estimates.

Australia's international reputation in cometary astronomy was boosted in 1889 when J.E. Davidson of Queensland discovered a new comet, and this was the only comet observed by Biggs during that year. All his observations were sent to Tebbutt (Biggs, 1889a), and were also brought together in a short paper (Biggs, 1889c).

About this time, over-exertion at both work and observatory caused Biggs's health to break down (see Biggs, 1890, 1891a), and he was only ale to resume comet-observing in late 1892, with a very few positional measurements of the 'Andromeda Comet' and Comet Brooks (Biggs, 1893a). No publications resulted, and these two comets marked the end of Biggs's comet-observing career.

One final aspect of Biggs's cometary work warrants our attention, and this is his involvement in comet-searching. Most of his searches were conducted under the auspices of the ill-fated Australian Corps of Amateur Comet-Seekers initiated by John Tebbutt in 1882. Since the history of this body, and Biggs's crucial role in it, have been dealt with in detail elsewhere (Orchiston, 1982b), we need only outline the major ingredients here.

The idea of a team of observers each charged with systematically searching their own sky-zones for new comets had its origin with the Boston Scientific Society, which suggested that Tebbutt establish a similar group in Australia to monitor the southern sky. Although a number of those approached indicated a willingness to become involved, Tebbutt and Biggs were in fact the only ones to commence systematic searches. Biggs persisted with his searches during June, July and August 1882, with Comet Wells actively competing for his time during much of this period. Cloudy skies and 'extra duties' at the bank plagued Biggs during September and into October, when his attention was directed to the newly-arrived 'Great Comet'. This spectacular object was followed until 1883 April 7, and must have taken up much of the time that Biggs would otherwise have allocated to comet-searching. He was also distracted in late 1882 by the December 6 Transit of Venue, spending a good deal of time renovating the Reverend Canon Brownrigg's transit instrument, with which he hoped to obtain accurate time.

All of the above activities merely served to reduce the frequency of Biggs's comet-searches, but what put paid to them once and for all was Barnard's accidental discovery of a new comet within Biggs's sky zone towards the close of 1882. Naturally Biggs was devastated, and wrote Tebbutt that 'There seems to [be] a fatality against my prosecution of the work I have undertaken' (Biggs, 1882h). When Biggs abandoned comet-searching the Comet Corps died a sudden death (much to Tebbutt's chagrin — see Tebbutt, 1887:16-17).

Non-cometary astronomy

After comets, the multiple star alpha Centauri was Biggs's major preoccupation. He carried out his first observations of the separation and position angle of the two main components of the system in 1878 and continued to record them from time to time through into the early 1890's. In 1887 he published an interesting paper on his observations, and drew also on the measurements of others to derive a new period of 83.7 years for the system. Two years later he published another paper (Biggs, 1889d), which detailed a long series of new observations carried out in 1888.

Biggs also made a point of observing Transits of Mercury and Venus. Indeed, his earliest astronomical observations were made during the 1874 Transit of Venue, when he served as the 'Recorder' in the 'Photographic House' set up by the American party at Campbell Town (Raymond n.d.:33). By the time of the 1882 Transit he was firmly established in Launceston, and teamed with Reverend Brownrigg to successfully time the various contacts. Instead of publishing their results in the traditional fashion, in an academic journal, Biggs (1882i) decided instead to write them up for the local newspapers.

In addition to the above events, Biggs also attempted to observe two Transits of Mercury. On 1881 November 8 he missed the ingress phase due to clouds, but was later able to view the Transit in progress from the bank with his little 51 mm telescope (Biggs, 1881d). As the time of egress neared he returned to his observatory to watch the spectacle through the 76 mm refractor, but

> ..... just as I got the Sun into the telescope, clouds obliterated it from view, and I saw no more of it. I could only 'gnash my teeth' (Biggs, 1881e).

He made amends ten years later, with the Transit of 1891 May 10, and published a brief account of his observations.

Biggs also observed two lunar eclipses, in 1885 March and 1891 May, and wrote short descriptive papers on both events (Biggs, 1885a, 1891b).

Finally, Biggs rounded out his programme with occasional observations of aurorae, sunspots, the variable star R Carina, and planetary conjunctions, oppositions and occultations. He wrote two short papers on this work (see Biggs, 1886a,c). In collaboration with Reverend Brownrigg he also contributed monthly meteorological reports to the *Launceston Examiner* (B. Underwood, pers. comm., January 1984), and made a special study of the mysterious 'sky glows' of 1883-4 (Biggs, 1884e), now thought to have been associated with the eruption of Krakatoa.

DISCUSSION

Alfred Barrett Biggs was a late-comer to astronomy, and his intensive involvement lasted a mere 15 years. During the 1890's ill health and failing eyesight progressively took their toll and kept him from the telescope. Eventually the walk from the bank to the observatories became too much, and in 1897 he reluctantly announced:

> I regret much that I have been compelled to almost lay aside my Observatory work, of late. I find advancing years telling .....

He was then 72 years of age.

Despite his comparatively short foray into the realm of astronomy, Biggs achieved a great deal. Over the thirteen years from 1880 to 1892 he followed 15 different comets (see Table 1), and published six short papers on this work. He also published his double star work and his observations of 'current phenomena'. Yet he remained insecure throughout, often questioning his own ability and the value of his work (e.g. see Biggs, 1882c, 1884b, 1893b). He keenly felt the 'tyranny of distance'.

Academic publishing was for him a painful process, but a necessary one if a serious commitment to astronomy was involved:

> However little my modest efforts may be estimated by the master minds who lead the way ..... there are times when locality has an important bearing ..... and I think my situation is almost unique. Under such circumstances, careful observations and notes from even a novice may be of some value. (Biggs, 1893a; his underlining).

And so this is what Biggs did: he published simple descriptive papers, and left it to others to make whatever use they wished of the data he provided (see Biggs, 1884c,e). Only very rarely did he try to take the data beyond this basic stage to an analytical or theoretical level — and even then somewhat unsuccessfully. In the case of his double star work he had to rely very heavily on John Tebbutt's assistance in order to come up with meaningful results.

But if Biggs felt ill at ease in the academic publishing arena he found his niche in popular writing for a lay audience. Perhaps this is not unexpected given his background in the teaching profession. To Biggs, astronomy was a wonderful hobby to be shared by all, and he actively promoted this viewpoint by writing up accounts of his various observational projects for the local Tasmanian newspapers. He was quick to point out to Tebbutt in 1891 that

> ..... in our little colony, which is so wofully [*sic.*] backward in the subjects I have discussed, these efforts are somewhat appreciated. (Biggs, 1891a).

These frequent newspaper articles were the most visible signs of Biggs's strong commitment to popular astronomy, but they were not the only ones. He lectured on astronomy from time to time, and made a point of operating his Royal Park observatory on an 'open house' basis, to all intents and purposes running it as a city observatory, just like the Victorian astronomers William Bone and James Oddie did in Castlemaine and Ballarat, respectively (see Orchiston, 1982a,c). The local populace responded magnificently, and flocked to their beloved 'Astronomer Royal' (see Scott and Scott, 1935) to look through the largest telescope in Tasmania.

To my mind, Biggs's greatest contribution to Australian and Tasmanian astronomy was not as a researcher, but rather as a popularizer. He was one of the first Australian astronomers — amateur or professional — to espouse the concept of popular astronomy and wholeheartedly pursue it. In some ways he was an anachronism, for his efforts would have been more in place in today's society with the current high public profile of astronomy, astronautics and astrophysics.

Despite this appraisal, we should not lose sight of the fact that Biggs also made a contribution to scientific astronomy. Although not in the league of Hobart's Francis Abbott (see Orchiston, 1984b; Rimmer, 1969), Biggs would have to rate as Tasmania's second most important nineteenth century astronomer (amateur or professional). Both Baracchi (1914) and McAuley (1902) list Abbott and Biggs as the only Tasmanian astronomers of last century who gained any degree of professionalism. Thus, Biggs's contribution easily eclipses that of other possible contenders, such as James Dear, the Reverend Canon Brownrigg, Captain Shortt and Lieutenant Kay.

Given the heightened public awareness of astronomy in Launceston achieved through Biggs's various activities, it is illuminating to ponder the fate of his observatories and instruments following his death in 1900. Contrary to the wishes of the family, Biggs bequeathed the large telescope to the Royal Society of Tasmania, and in 1901 it was shifted to Hobart (Royal Society of Tasmania 1901-2:21 February 1901 Minutes). In late 1902 the Society loaned this instrument to the Physics Department at the University of Tasmania (McAulay, 1902), and it remained there until 1918 when it was retrieved by the estate and subsequently sold in Melbourne (this whole episode is considered in detail in Orchiston, 1984b).

The 76 mm refracting telescope was bequeathed by Biggs to one of his nephews, and was mounted at Inveresk, Launceston, until the death of its new owner in 1946. Its current whereabouts, as with the large reflector, is unknown. This, unfortunately, is also the case for the 51 mm refractor and the original home-made transit telescope. The second transit instrument was returned to Melbourne Observatory (A.W. Biggs, 1933).

The fate of the two observatories is equally obscure. Both appear to have been demolished soon after Biggs's death and the removal of the telescopes. Currently, all that remains in Royal Park as a tangible reminder of these buildings is a stone monument (Meston, 1933), which bears the following inscription:

LAT. 41° 26' 1" S.
LONG. 147° 7' 49.5" E.
SITE OF THE OBSERVATORY OF
A.B. BIGGS, ESQ.
ERECTED BY THE
ROYAL SOCIETY OF TASMANIA
18TH SEPT. 1935.

As I have indicated elsewhere (Orchiston, 1984b), the current location of the monument does not correspond to the site of Biggs's Royal Park observatory building.

Finally, it is only fitting that we complete this paper by looking briefly at Biggs's non-astronomical achievements. The innate optical and mechanical genius that he brought to astronomy through his telescopes and micrometers was also channelled in other directions. He manufactured his own microscocpe, and was for a time actively involved in microscopy. Likewise, he constructed an electric master clock and a microphone (Obituary *The English Mechanic*, Biggs promptly constructed three telephones of his own and successfully tested them between Campbell Town and Launceston. These are reputed to be the oldest telephones in Australia, and in 1947 two of them were donated to the Queen Victoria Museum and Art Gallery in Launceston.

Biggs also made a major contribution to earthquake research, and is regarded as the founder of instrumental seismology in Australia (see Royal Society of Tasmania, 1984).

Throughout the later years of his life, Biggs was also involved in society activities. For many years he was a member of the Launceston Mechanics Institute, serving three sessions as President and three more as Treasurer (Whitfield n.d.:23-24). In about 1885 he was elected a Fellow of the Royal Society of Tasmania, and in 1895 joined the fledgling New South Wales Branch of the British Astronomical Association (BAA, 1894-5).

In addition to these scientific and mechanical pursuits, Alfred Barrett Biggs was an accomplished composer and choir-master, and a frequent commentator on political and community issues in the Tasmanian press (Obituary .... 1900).

CONCLUSION

Alfred Barrett Biggs of Launceston was one of a number of talented amateur astronomers operating in Australia during the second half of the nineteenth century, but what set him apart from his contemporaries was his extreme geographical isolation, and the fact that he came to astronomy very late in life and spent such a short time in the service of the discipline. Nevertheless, he was able to achieve a great deal. His interests lay in both scientific and popular astronomy, and his contribution in each was significant.

Biggs's research astronomy revolved around comets and the multitude star alpha Centauri, but he also found time to record a variety of current phenomena. Almost all his observations were carried out with a 76 mm refractor, a 216 mm reflector, and several different micrometers, some of which he made. These instruments were housed in two separate but adjacent observatories, some distance from his place of residence. In the course of his research Biggs enjoyed the friendship of that doyen of Australian astronomers, John Tebbutt, who provided abundant guidance and assistance. Partly through Tebbutt's influence, Biggs ended up publishing sixteen short astronomical papers in academic journals.

The second area of astronomy to which Biggs was devoted was popular astronomy, and he was one of Australia's most outstanding pioneers in this field. His constant efforts to bring astronomy to the average man were achieved through lectures, frequent newspaper articles and reports on astronomy, and by operating one of his observatories as a de facto city observatory.

When his combined astronomical activities are examined, it emerges that, after Francis Abbott of Hobart, Alfred Barrett Biggs was Tasmania's most important nineteenth century astronomer.

Nor were Biggs's scientific, mechanical and optical talents confined to astronomy. He is also recognized nationally as a pioneer in the fields of telephony and seismology. He was one of that rare breed, the multidisciplinary amateur scientist-engineer. But, on the basis of his astronomy, alone, Biggs rates a place in the history of Australian science.

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TABLE 1. Numbers of Comets Observed by A.B. Biggs, 1880–1892.

Year	Number
1880	1
1881	2
1882	2
1884	2
1886	3
1887	1
1888	1
1889	1
1892	2
Total:	15

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The following abbreviation is used for A.B. Biggs entries:
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A PORTABLE PHOTOELECTRIC PHOTOMETRY SYSTEM

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ABSTRACT

A photoelectric photometry system has been developed which is suitable for both (UBV) variable star work and occultation observations from a remote site. All the equipment is designed to be portable and battery powered (12 V). The system utilises a Meade 25 cm Cassegrain reflector and Hopkins photometer head kit, fitted with a current to frequency (I/F) converter. The photometer uses an EMI 9781R side window photomultiplier tube (uncooled) and the system limit set by the dark current of this tube is approximately m_V 12. Electronics for the data acquisition and display system have been designed and constructed to fit in a small box. This unit contains:- a) power supplies, b) a quartz oscillator for timing and c) electronics to count and digitally display the I/F converter pulses over a selected time interval. This unit also enables the signal, together with timing pulses, to be output to a chart recorder. An interface is also provided to enable data acquisition (every 1/10th s) by a computer. The latter is at present a Microbee 16K which has a battery back-up memory and can be operated from a 12 V DC supply. The system has successfully measured total lunar occultations and Jupiter satellite eclipse phenomena. Variable stars down to at least M_V 9 have also been measured.

INTRODUCTION

Previous experiments with a prototype photoelectric photometer (Bembrick and Daggar, 1982) encouraged us to develop the fully portable system described here. Elements of the previous system such as the I/F converter and the HT power supply have been incorporated in the newly completed instrumentation.

AIMS

Full portability and battery operation have been retained in the new system with the aim of operating from remote field sites for events such as minor planet occultations. The new system remains a pulse-counting instrument rather than the more sophisticated photon-counting designs. The detection of stellar diffraction patterns from lunar occultation events has not been contemplated in the design of this equipment as this would require millisecond sampling rates for the photometer readings.

No attempt has been made at this stage to introduce additional complexities such as a cooled photomultiplier tube.

THE EQUIPMENT

<u>The telescope</u>

The new system has been linked with a 25 cm, f/10, Schmidt-Cassegrain telescope which has a tripod mount and electric RA drive. The latter runs from 240 V AC supply or a 12 V DC car battery.

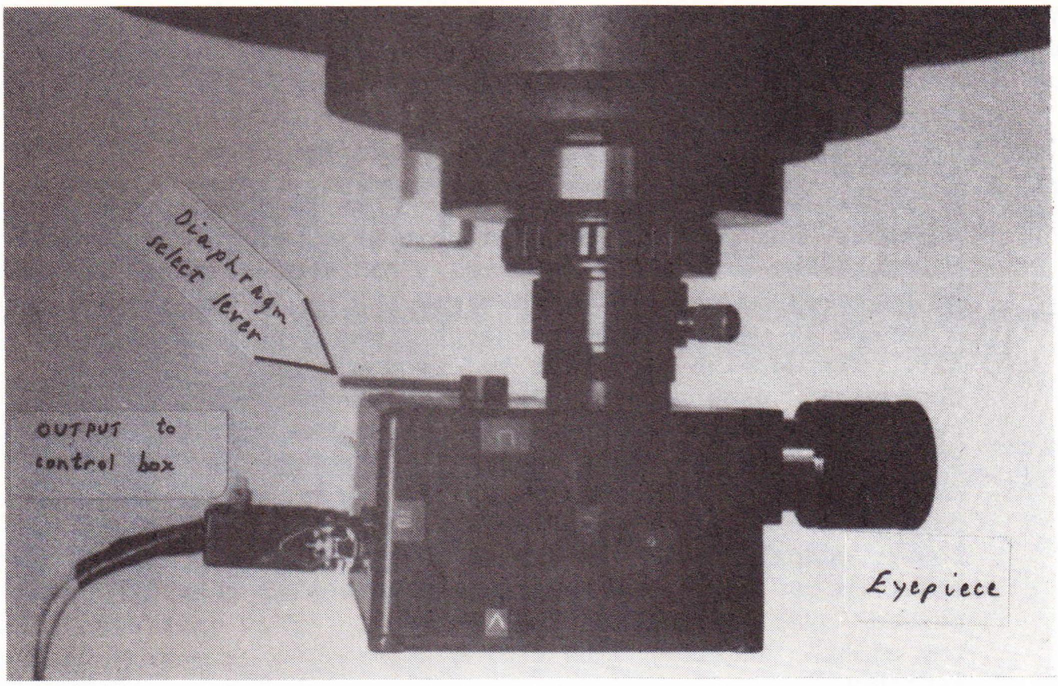

Fig. 1. The Hopkins photometer head attached to the 25-cm Meade.

This telescope has been fitted with a 50 mm guidescope of 600 mm focal length which is mounted in such a way that it can be offset from the main telescope optic axis. It can thus function as an offset guider when the photometer head is attached to the Cassegrain focus of the main telescope.

The other option for photometer guiding is an off-axis guiding unit, with a low power illuminated crosshair eyepiece, which is normally inserted at the Cassegrain focus immediately in front of the photometer head.

Guiding is at present accomplished by use of the manual slow motion controls of the telescope. If the telescope has been well aligned then little guiding is usually required in RA and intermittent adjustment in Dec is all that is required over a time period of a few minutes.

<u>The photometer head</u>

To speed the construction and development of the new system a commercial photometer head, including tube, was purchased, in kit form, from Jeffrey Hopkins in Phoenix, Arizona (Hopkins, 1982). This kit was purchased with an EMI 9781 R side window tube and standard UBV filters. The head is a small lightweight unit, Fig. 1, weighing less than 1 kg and we have incorporated our I/F converter circuitry (Bembrick and Daggar, 1982) within the head. The head, Fig. 2, incorporates a small flip mirror and high power eyepiece with illuminated crosshairs for viewing the starfield through the diaphragm. There are three diaphragms and a large viewing aperture 19 mm in diameter. The diaphragm sizes are:-

#	Diam (mm)	Diam. (arcsec)
1	1.0	80 (approx)
2	0.75	60 "
3	0.35	30 "

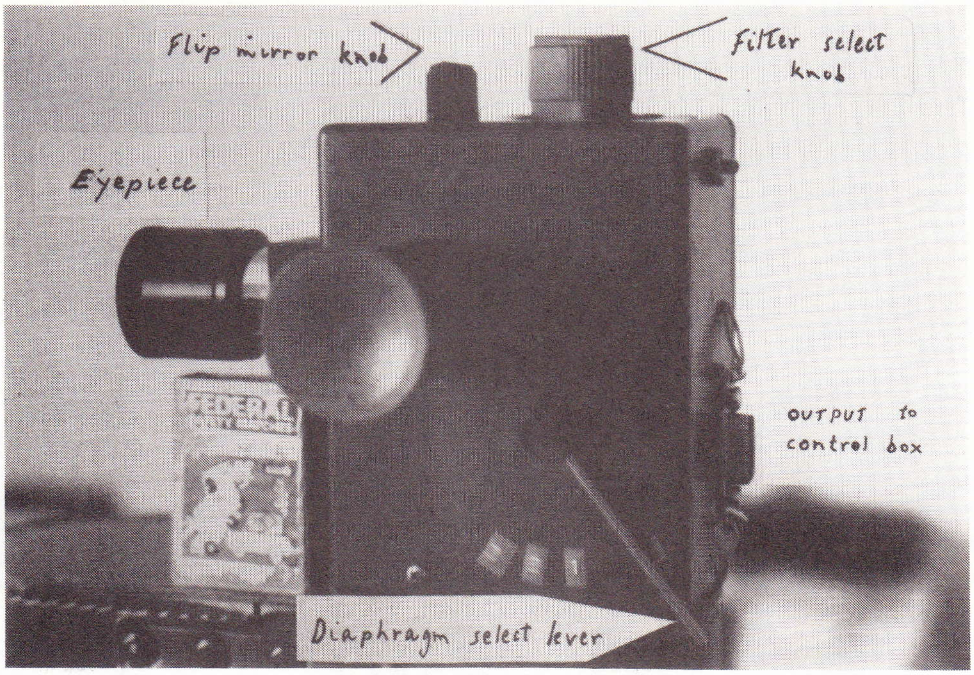

Fig. 2. The Hopkins photometer head.

The three filters and one dark slide are mounted on a small turret which encloses the side window PMT. Adjustable detents are used to define the filter wheel and diaphragm positions and thus these 'click stops' make the head easy to use in the dark.

The head has been modified so that it can screw directly into the back of the off-axis guiding unit, which in turn is screwed firmly to the telescope. The whole assembly is thus assured of adequate rigidity in coupling to the telescope.

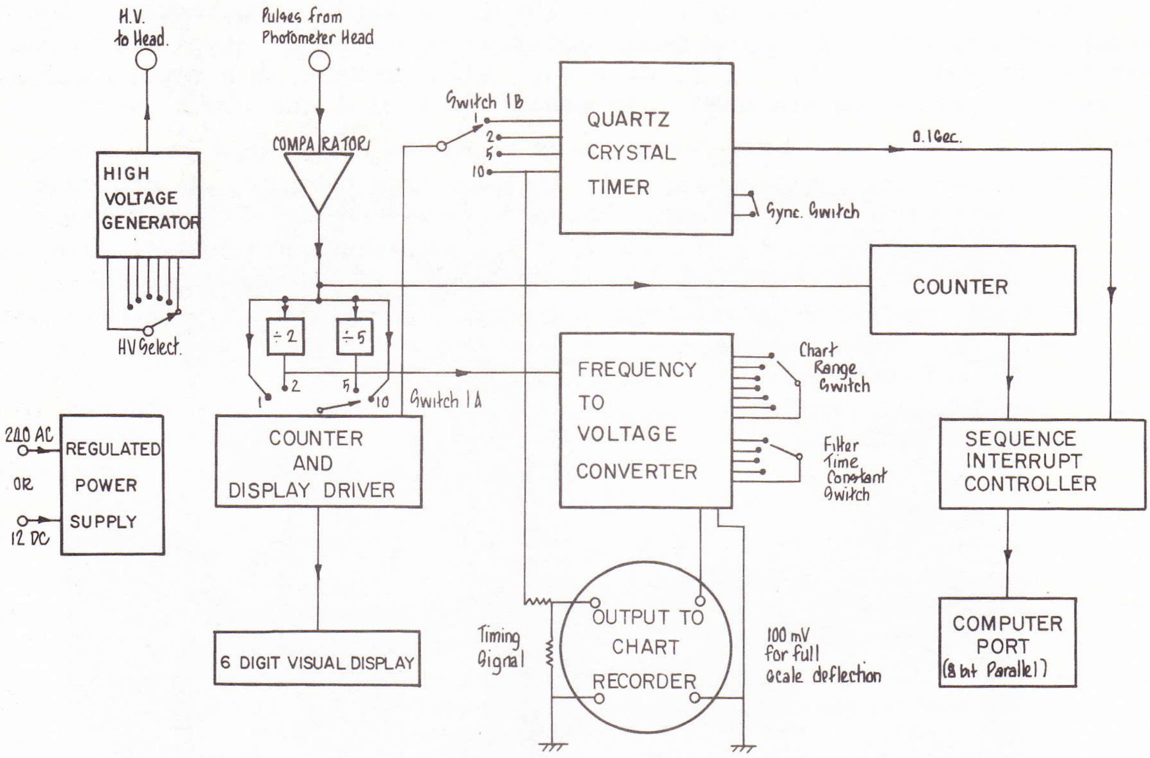

Fig. 3. Photometer control box components.

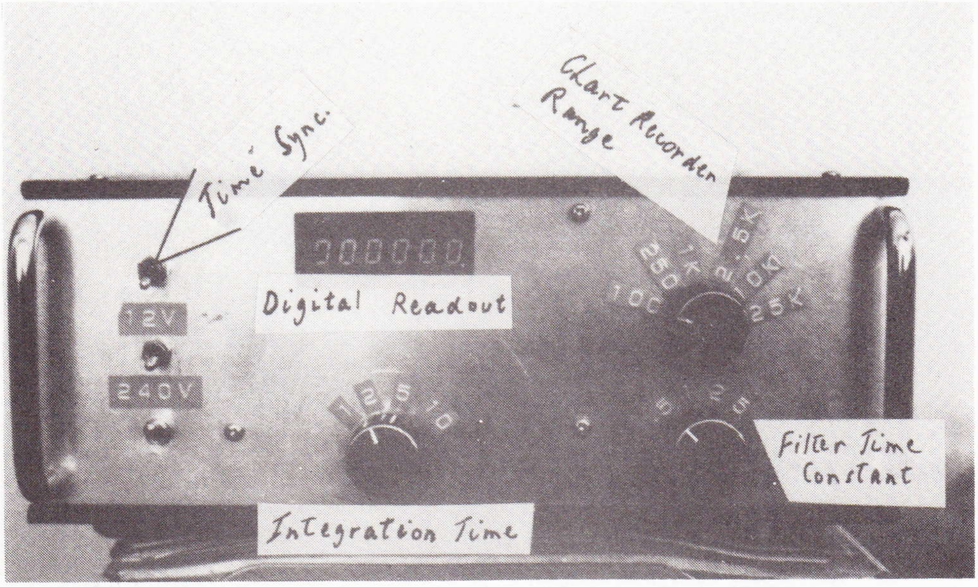

Fig. 4. The front panel of the control box.

Control box electronics

The control box supplies the head with high and low voltage power and receives back pulses whose frequency is proportional to the photomultiplier current. It presents the data obtained through three channels, see Fig. 3.

Firstly, a six digit (light emitting diode) front panel readout displays the average frequency of the head pulses, the average being taken over a time that is set by a front panel switch (1, 2, 5, or 10 seconds, Fig. 4.

Secondly, an output for a pen recorder which has a full scale voltage of 0.1 V. Full scale can be set with a panel switch to correspond to a count rate of 100, 250, 1000, 2500, 10000, or 25000. To reduce noise this output has been through a low pass filter with a time constant which can be selected by switch (0.5, 1, 2, or 5 s). Also present is a second signal, a 10 second period square wave, to assist in timing the chart record, see Fig. 5.

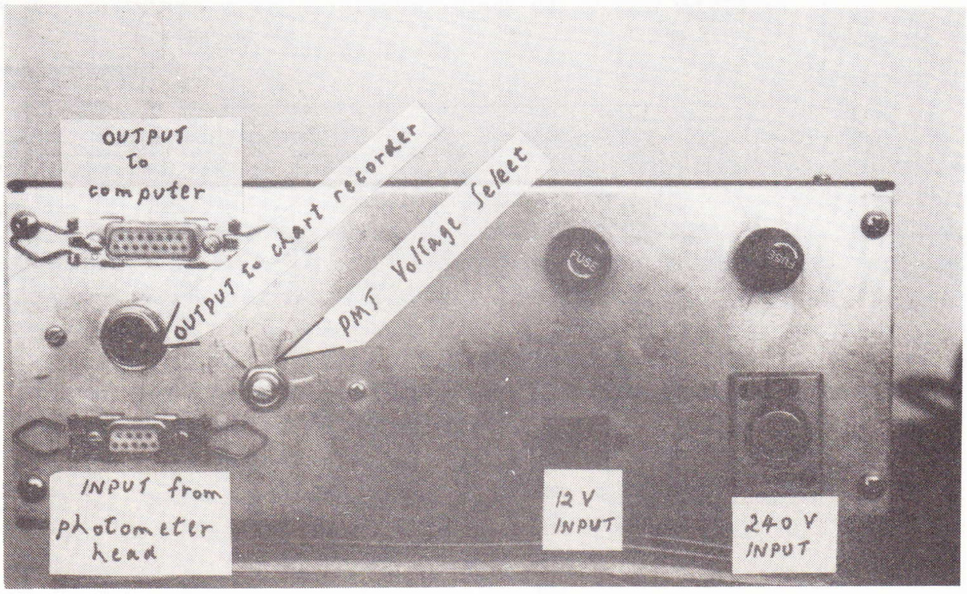

Fig. 5. The back panel of the control box.

Thirdly, there is an eight bit port for interfacing to a micro computer. The port supplies an interrupt to the computer every 0.1 s. The computer then reads via the port the number of pulses that have come from the photometer head since the last interrupt. All the control box functions are timed by an internal quartz crystal timing unit. This unit can be synchronised to an external reference by means of a reset and restart switch — see Fig. 4.

The control box can be run from the 240 V AC mains or from a 12 V battery. All its supplies are regulated and it has a regulated high voltage generator to supply the photomultiplier in the head. The high voltage can be selected in steps of 100 V from 1000 V to 1500 V.

It was decided that the front panel display would read in counts per second rather than total counts. This means the numbers are similar whether one selects a 1, 2, 5, or 10 second counting period. This was achieved by dividing the incoming head pulses by 2 on the 2-s range and by 5 on the 5-s range, while for the 10-s range the decimal point in the display was moved along one place. This causes the counter resolution on the 2-s and 5-s ranges to drop to 1 count/second rather than 0.5 and 0.2/second. As the head signals vary by more than 1 count the loss was not considered significant compared to the convenience and reduced chance of operator error. Any very high precision readings would in any case be made on the 10-s range where there is no loss of resolution.

The three channels (readout, chart recorder, computer) are totally independent on each other's settings.

The computer

The decision to interface a computer to the photometer was made when it was found that a reasonale quality portable 12 V chart recorder could cost up to twice as much as, for instance, a Microbee computer. The Microbee was chosen because it can be powered from a 12 V battery, has a parallel I/O port and has continuous CMOS memory with an internal sustaining battery. The continuous memory means that data can be stored in memory at an observing site and read out or processed at a later time. The Microbee is also compact and light.

There are additional benefits that result from the use of a computer. The data can be recorded with smaller time resolution than can be obtained with simple pen recorders. Also, the data can be recorded in raw form. The good time resolution means that if filtering has to be done it can be done with a digital filter that introduces no time lag in the results such as caused by a low pass filter in a chart recorder channel. The data does not have to be read off a chart and entered into a calculator for reduction. Furthermore it is versatile as to the format in which data can be collected and it enables information such as dates, times, conditions, star names, etc. to be combined with photometer data and used for presentation or for library use when saved on magnetic tape.

The interface

The choice of a Microbee computer did influence the design of the control box and slightly limited the performance of the photometer. This computer in standard form has a single parallel port that can be either 8 output bits or 8 input bits or a mixture of input and output bits. We chose the mixture as we wanted output bits from the computer to control the photometer and, of course, input bits to get back the raw data. The scheme used is as follows:-

BIT 7	Input	-	Interrupt to computer
BIT 6	Output	-	Acknowledge interrupt & freezes data
BIT 5	Output	-	High bit digit address
BIT 4	Output	-	Low bit digit address
BIT 3	Input	-	D3 M.S. bit of digit
BIT 2	Input	-	D2
BIT 1	Input	-	D1
BIT 0	Input	-	D0 L.S. bit of digit.

The control box interrupts the computer with 0 on bit 7 and the computer then replies with 0 on bit 6, which also prevents any further change to the data. The computer next places 0 on bits 4 & 5. Then the control box places the first digit of the reading on bits 0,1,2,3 and the computer reads it. Next the computer places 1,0 on bits 4 & 5. The control box then places the second digit on bits 0,1,2,3 and this digit is read by the computer, etc..

In this way the computer can read a 4 digit number from the photometer on every interrupt (every 0.1 s). This limits the counts we can read to 99,990 s^{-1}. This is not as bad as it seems because the current to frequency converter starts to become slightly non-linear at 100,000 counts s^{-1}. We could drop the interrupt period to 0.01 s to go to 999,900 counts or fit the head with a second, less sensitive range. Even as it stands, the counters in the control box fold around above 100,000 so that 120,000 reads as 20,000 counts. This means that results can still be meaningful so long as you 'tell the computer' on those rare occasions the photometer is pointing at a very bright object. This limitation does no apply to a computer having an 8 bit input and 8 bit output port.

The problem could have been solved by making the control box intelligent or by adding a second port to the Microbee. The first would have complicated the control box more than we desired and the second would probably have added a 'computer expansion box' to a system that we wanted to be compact and portable.

The software

When it was decided to use a computer we had to plan the software. It was realized that we would probably want different programmes for different types of observations and that these programmes would also be altered and developed. So it was decided that the best approach would be to write a number of acquisition modules or drivers that would obtain data from the photometer and leave it in a form that the main BASIC programme could access. The idea being that once they were developed these drivers would seldom be changed but that the main programmes that use them could be modified as much as desired. This means that anyone who can write BASIC can develop a programme for carrying out observations to his own liking without concern as to the details of how photometers and computers talk to each other. This point becomes very important when the drivers are written in assembler as is the case here. The drivers are written in assembler because the BASIC on most hobby computers cannot handle interrupts and we also wanted the speed of assembler. As it turned out the driver we wrote takes about one to two milliseconds to service each interrupt which leaves the computer plenty of time to be running a BASIC supervisory programme or perhaps plotting up results on its graphics screen. However we are getting ahead of ourselves! Back to the evolution of the software.

The Microbee uses a Z80 P.I.O. chip for its parallel port. We had no previous experience using this chip nor in setting up the Z80 microprocessor to service real time interrupts. So our first task was to write a small assembly language routine to test that we had read the manuals properly! The routine simply added 1 to a single digit number and displayed it on the screen. When interrupted the computer stops what it is doing, executes our little routine and then returns to what it was doing. The excitement was totally out of proportion to the cause when we shorted one of the port pins to ground (the interrupt) and a number flashed up on the screen! It was not long before we had the computer apparently doing two things at once by running a BASIC programme continuously printing message on the screen while magically a number at the top right of the screen counted whenever the port pin was shorted.

The clock

We had planned that the photometer would interrupt the computer every 0.1 second. This made the test routine that counted the interrupts an obvious candidate for expansion into a software clock especially as the computer has no built in clock and there is a need to record time along with the photometer readings. We had no difficulty in writing a 24 hour block (updated every 0.1 s) which displays HH:MM:SS. At this time it was realized that while the clock had to run all the time it could be a nuisance if the time kept flashing up on the screen. This was solved by having the clock routine display the time only if a location in memory (a flag) had the value 1. This flag can be set to 1 or 0 from a BASIC programme or the keyboard. This concept of CONFIGURABLE SOFTWARE was to have a great influence on the data acquisition software, see Fig. 6.

The acquisition routine

This software had its origins in a noble proposition — it's about time we wrote something to drag numbers out of the photometer to see if the idea works. As before, we wrote a test routine. It took numbers from the photometer and displayed them on the screen. This worked and confirmed that the photometer/computer interface was working.

We had thought it would be necessary to write several acquisition modules, each geared to the requirements of one type of observation. For example, one that averaged a number of readings to be used when taking a single measurement of a stellar magnitude; another to record continuously to be used for occultations, etc.. However as work progressed, it became clear that we could write a general module that could be configured by the BASIC programme using it.

Before describing the acquisition software we should define some terms. When the computer is interrupted it gets 4 digits from the photometer (the counts since the last interrupt). This we call a sample, to distinguish it from the number that is finally stored in memory which is called a reading. For example, we could sum ten samples to make a reading. This reading would be the number of counts from the photometer head over the last second and would be the same as the number read on the control box display.

The acquisition module has two fundamental modes of operation, FREE RUN and NON-FREE RUN. The mode used is selected by a flag that can be set from the BASIC language programme.

If non-free run mode a sample is taken on every interrupt. A number of samples are summed to form a reading. As readings are formed they are stored in a buffer in memory. When this buffer is full acquisition ceases. The module signals this fact to the BASIC programme by clearing the busy flag.

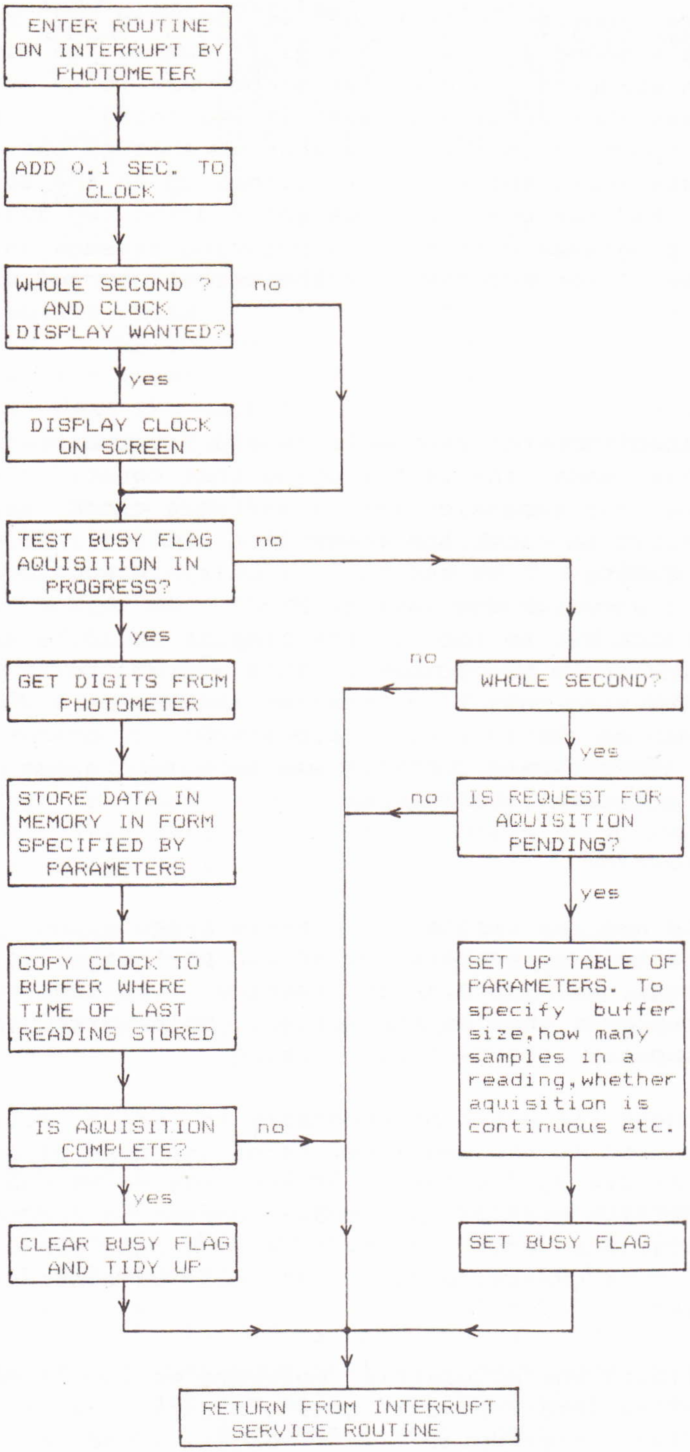

Fig. 6. Flow chart of interrupt service routine.

In free run mode samples are also formed into readings and stored in the buffer but when the buffer is full the module simply starts filling it again from the start, overwriting the oldest data in the buffer. This process only stops when the BASIC programme clears the busy flag. The free run mode can be used for recording occultations. The system is set running before the predicted time and stopped soon after the event. If the buffer is 1000 readings long it will contain the last 1000 readings taken and hopefully the record of an ocultation.

The non-free run mode can be used when one just wants a suite of readings, although it could be used to record an event with a certain prediction time. As well as the mode (free run or not) the module can be configured in other ways. The size of the buffer can be set and a parameter we call 'option' can be chosen. Option determines the way samples are made into readings. If option=0 then a reading consists of one sample. This means the buffer will be filled with readings taken every 0.1 s.

If option=1 then a reading consists of the sum of the last 10 samples. A reading is generated every second on the second and is the total counts from the previous second to the present second.

If option=N,N>1, then a reading consists of the sum of N samples. (N must be less than 100.)

The above description of the acquisition module is best summarized by saying that the one acquisition module can be used with tasks that range from recording the occultation of a relatively bright object with thousands of readings at 0.1 s intervals, to integrating the counts from dim objects for effective periods that could approach an hour. The buffer operation is outlined in Fig. 7. (A) shows the state immediately after acquisition has commenced, but no readings have been stored. The configuration parameters have been used to establish the base of the buffer (Bufbas). A pointer is kept to point to the last reading entered in the buffer. The busy flag is set as acquisition is in progress. The buffer full flag is not set as the buffer has not been filled and a time has not been saved. (B) shows the

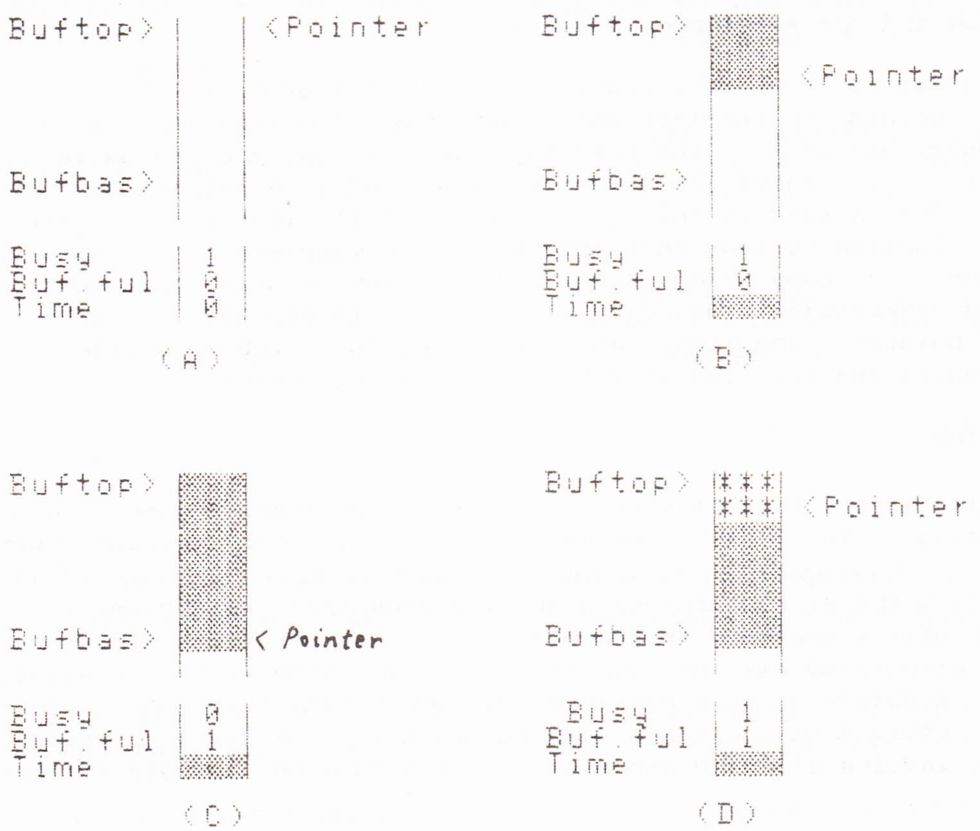

Fig. 7. Schematic diagrams of buffer operations.

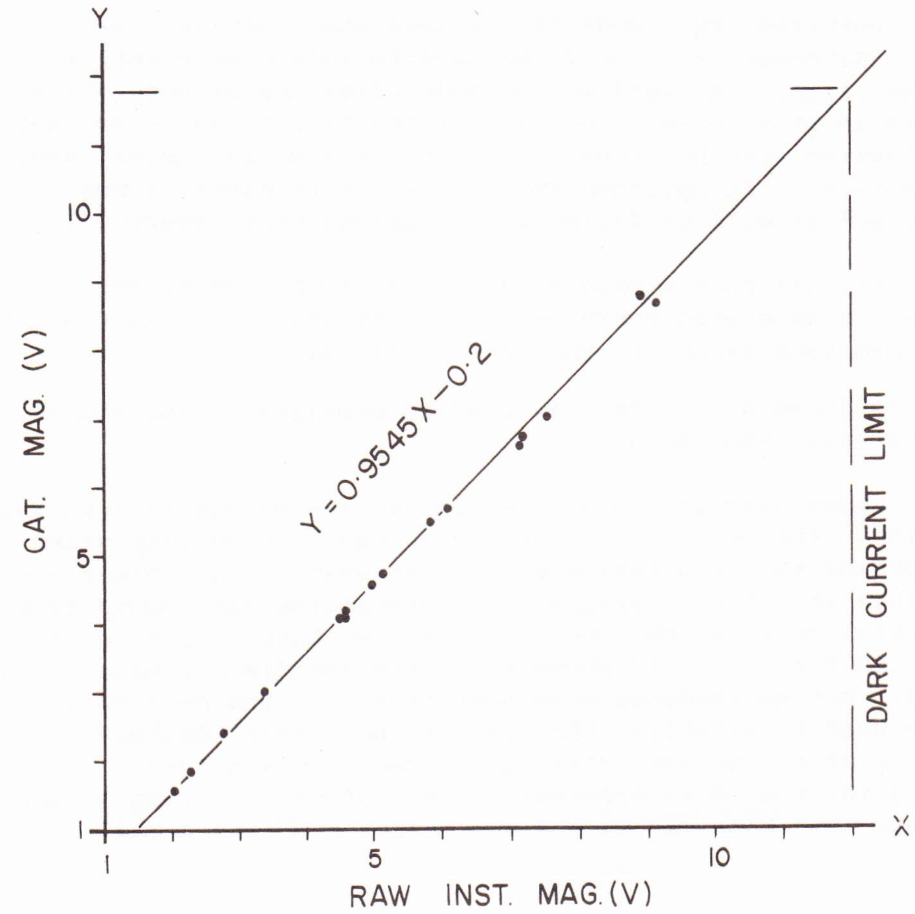

Fig. 8. A plot of best results, raw instrufment magnitudes (V) against catalogue magnitudes (V), using the 9781R photomultiplier tube and the 80 arcsec. diaphragm.

state after a number of readings have been stored in the buffer. The pointer points to the last entry and 'Time' contains the time at which the last entry was made. The busy flag is still set and the buffer full flag not set. (C) shows the state at the end of a non-free run acquisition cycle. The buffer is full so the buffer full flag is set. The busy flag has been cleared to show that acquisition is complete. In the case of free run mode the busy flag is not cleared and acquisition continues with readings overwriting previous data (D). It is necessary to know the value of the pointer, the Time, and the buffer full flag, in order to retrieve each reading and the time it was entered in the buffer.

DISCUSSION

Initial test results with the Meade and photometer combination are most encouraging. The 9781 R tube has commonly given dark current counts as low as 3 s^{-1}, corresponding to a raw instrumental magnitude (m_V) of approx. 12. Tests using the #1 (80 arcsec) diaphragm show that stars close to magnitude 9 can be easily measured in a moonlit sky. Further tests with the 60 and 30 arcsec diaphragms will be completed when improvements to the alignment and guiding accuracy of this portable instrument have been made. Some of the guiding options have already been described. The final solution will most probably involve electric motor slow motion guiding controls for both RA and Dec. axes.

The test results with the photometer, Fig. 8, show a very good linear relationship exists between raw instrumental (V) magnitudes and catalogue

(V) magnitudes These results encourage us to believe that acceptable rigorous transformation coefficients can be derived for this equipment to yield the standard Johnson (UBV) magnitudes (Johnson, 1963) used in photoelectric variable star work.

Theoretical considerations indicate that for an ideal transformtion from the system magnitudes to standard UBV magnitudes, the coefficient, ϵ_V, should be close to zero. This transformation relationship takes the form of --

$$V = v_O + \epsilon_V(B-V) + Z_V,$$

where V = standard Johnson V band mag.
v_O = system instrumental mag. corrected for extinction
$(B-V)$ = star's colour index
Z_V = zero point correction.

The colour-dependent term, $\epsilon_V(B-V)$, should ideally be zero if the PMT/filter combination shows a perfect match with the standard Johnson (UBV) system. Coefficients up to 0.1 are tolerable, but values larger than this indicate that the transformation relationship may not be linear. Preliminary results indicate that this system's V mag. transformation coefficient (ϵ_V) may be as low as 0.03 to 0.01, a most encouraging result.

CONCLUSION

A workable, portable photoelectric photometry system has been developed which has sufficient sensitivity and flexibility to be used for variable star and minor planet work and for occultation events.

The system has a theoretical limit of m_V 12, though this has yet to be achieved in practice and will require longer integration times, computer processing and reduction of data.

A linear relationship for this system has been demonstrated between raw instrumental (V) magnitude and catalogue (V) magnitudes. Preliminary results indicate a transformation coefficient (ϵ_V) of less than 0.1 between this system and the standard Johnson UBV system.

Further developments of this system will involve better guiding for the telescope, a better relay lens for the photometer postviewer eyepiece and more sophisticated software for data acquisition and reduction.

It is hoped to use this photometer to obtain some minor planet light curves in 1984.

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THE SPACE SHUTTLE AND ITS APPLICATION TO ASTRONOMY

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ABSTRACT

The paper traces the development of the Space Shuttle to the present day, and then explains the operational use of the Shuttle with an emphasis on its re-usability and versatility. The various applications of the Space Shuttle to astronomy are highlighted, with specific emphasis on:
(a) Hubble Space Telescope, a 13-metre long telescope which will be deployed in space and will, well above the turbulent atmosphere, look 7 times more deeply into space, detect objects 50 times more faint, and view them with 10 times better clarity than Earth-based observatories, thus expanding the universe visible to man 350 times; and (b) Starlab, a joint proposal by the United States, Canada and Australia for a one-metre aperture telescope which will be carried into orbit on a Spacelab pallet.

INTRODUCTION

During the three and a half centuries from Galileo to the birth of the space age, there have been some significant advances in astronomy: the reflecting telescope, the photographic plate, computer enhancement. But throughout this period one obstacle has remained: Earth's atmosphere. Despite observatories being built in desert regions or on mountain -tops, the distorting effect of this turbulent sea of gas and dust particles is always present.

With the launching of the first artificial satellite in 1957, the way was open for the next major advance — placing telescopes above the atmosphere. Not only did this benefit optical astronomy, it also made possible observations in those regions of the electromagnetic spectrum where the radiation does not penetrate to Earth's surface.

The first space telescope, for ultraviolet studies, was put into orbit in 1968, and there have been many others since for studies in the X-ray, gamma-ray, optical and infrared bands. Now that the Space Shuttle is available, a further major step is possible, a space telescope to be serviced or modified in orbit, and to be returned to Earth for overhaul and subsequent re-flight.

In this paper the authors confine themselves to a cursory description of the Space Shuttle, followed by summaries of the Hubble Space Telescope and Starlab. For detailed information on all these complex programmes, the reader should consult the specialist literature.

THE SPACE SHUTTLE

Concept

Ever since the United States became seriously involved in the possibilities of spaceflight, the idea of a winged re-usable space vehicle has been considered. It is obvious that the economics of such a vehicle, that can not only carry a payload into orbit but also do this repeatedly, are superior to those of building large rockets that can only be used once.

So, whilst in the 1960s and 1970s the American space programme forged ahead on expendable boosters, and in the process landed men on the Moon, sent probes throughout the Solar System and placed satellites in Earth-orbit, major U.S. aerospace companies studied the concept of re-usable space vehicles.

In 1970 the National Aeronautics and Space Administration (NASA) awarded contracts for feasibility studies into a two-stage re-usable space vehicle with the following features:

a) capability to undertake subsonic to supersonic flight in the atmosphere as well as spaceflight;
b) capability to carry a substantial payload into low Earth-orbit (185 to 1100 km altitude);
c) extensive use of computer-controlled systems with triple-redundancy;
d) a normal mission duration of seven days, with extension to 30 days by inclusion of additional facilities;
e) capability to make a controlled re-entry into the atmosphere permitting landing at an alternative runway if required; and
f) protection against the heat of re-entry by heat-resistant material instead of ablative material.

In 1972 the now-familiar design of a winged orbiter, an expendable external propellant tank, and two re-usable solid rocket boosters was selected, Fig. 1.

Design and operation

The current programme calls for the construction of four orbiters — Columbia, Challenger, Discovery and Atlantis, of which the first two are already in service. A fifth orbiter has not yet been funded. (Note that the 'orbiter' Enterprise was used for landing trials only and had no spaceflight capability.)

TABLE 1. Space Shuttle Characteristics

	Length (m)	Span/diameter (m)
Orbiter	37.19	23.77
Boosters	45.47	3.71
External Tank	46.80	8.40
Payload-bay	18.30	4.60

Gross Liftoff Weight	2,000,000 kg (approx)
Orbiter Liftoff Weight	94,800 kg (approx)
Maximum Payload Weight	29,500 kg

The orbiter has three main engines, which are used during launch and are supplied from the external tank. Once the tank is jettisoned some eight minutes after launch, the main engines can no longer be used. For operation in space, the orbiter is equipped with two Orbital Manoeuvring System (OMS) engines and 44 Reaction Control System (RCS) engines. The OMS engines are used for modifying the orbit and (after turning the orbiter through 180°) as retro-rockets for reducing velocity prior to re-entry. The RCS engines (16 at the front and 28 at the rear) are used for all other attitude manoeuvres in space.

The orbiter's large payload-bay is sealed for launch and re-entry by two longitudinal doors, which remain open throughout the orbital flight.

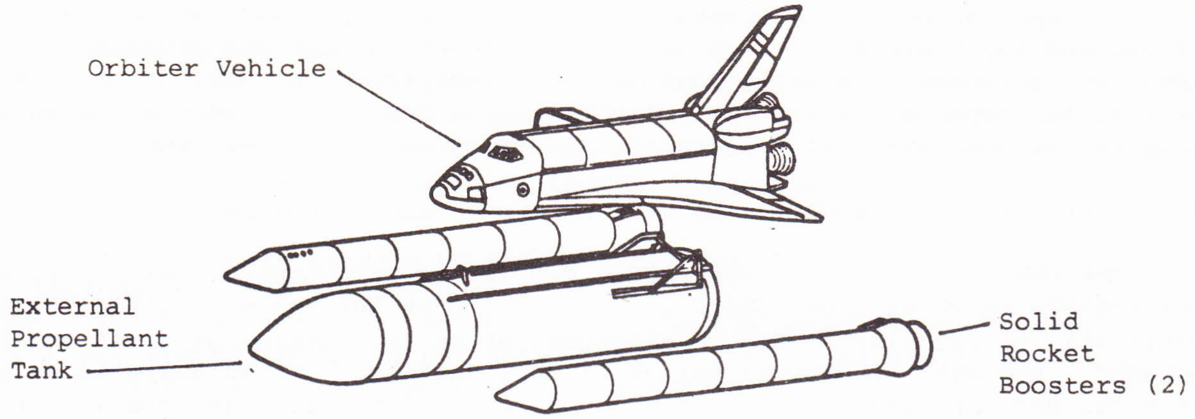

Fig. 1. Space shuttle main components.

The payload-bay can accommodate both fixed payloads and payloads intended to be placed in orbit, the latter being either ejected by springs or lifted out by the Remote Manipulator System (RMS) — a computer-assisted mechanical arm equipped with a grappling device and with TV cameras to allow it to be remotely operated from inside the crew-compartment. The RMS is also used for retrieving spacecraft which are to be serviced aboard the orbiter, or brought back to Earth.

The crew of up to seven consists of the Commander and Pilot, who are responsible for the orbiter operations; Mission Specialists, responsible for the launching of payloads and for interaction between the orbiter and mission activities; and Payload Specialists, who may be provided by customers whose payloads are particularly complex or require a lot of attention. All Shuttle launches are currently made from Kennedy Space Center in Florida, in an easterly direction, but from late-1985 launches will also be made into polar orbit, from Vandenberg, California.

The allowable directions of launch, see Fig. 2, are defined by the requirement that the flight-path during the launch-phase must be over water, to allow the recovery of the booster rockets from the ocean and to avoid any part of the external tank falling on populated areas.

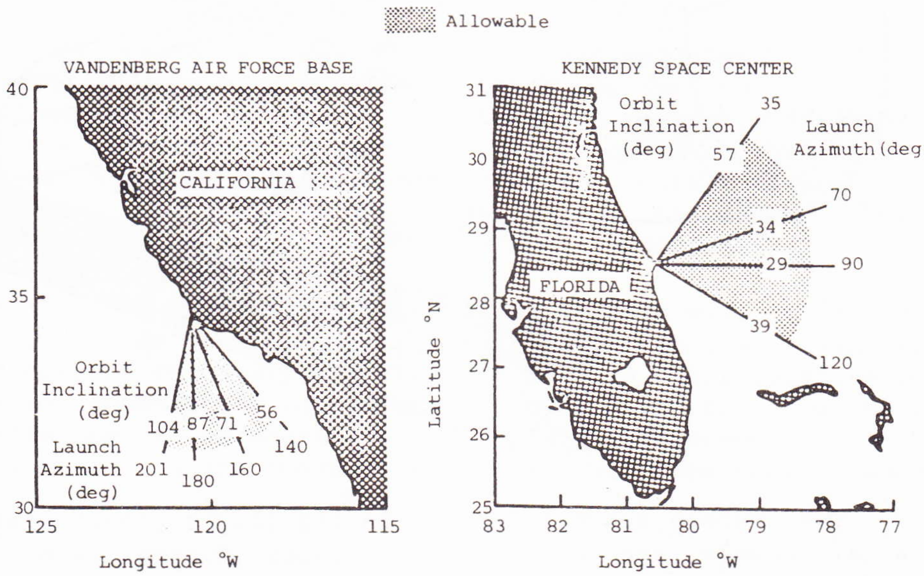

Fig. 2. Space shuttle launch facilities.

On completion of its mission, the orbiter's payload-bay doors are closed and the vehicle makes an unpowered descent through the atmosphere to land on a runway. After removal of equipment from the payload-bay, the orbiter is prepared for its next flight. It is designed to make at least 50 flights, with an eventual turnaround time of as little as two weeks.

THE HUBBLE SPACE TELESCOPE

The Hubble Space Telescope (HST), Fig. 3, is an unmanned, multi-purpose observatory which will be placed in Earth-orbit by the Space Shuttle. The orbit will be circular at 500 km altitude, at an inclination of 28.8° to the equator, and with an orbital period of 94.5 minutes. It is designed to be serviced and modified in orbit, and to be returned to Earth at intervals for major overhauls, thereby providing an expected lifetime of at least 15 years.

The instruments to be carried will enable observations to be carried out from the far-ultraviolet to the far-infrared, with a pointing stability of 0.007 arcseconds. The telescope will achieve 10 times better resolution and add 4 magnitudes (50x) to the capabilities of the best ground-based telescopes. Furthermore, it will more than double the observation time each year that is obtainable at the most favoured ground observatories.

Concept

It was at a workshop held by NASA in 1962 that the first proposals for a space telescope were made. In 1967 the U.S. National Academy of Sciences held a series of seminars to focus the attention of astronomers on the project, and in 1971 NASA commenced an advanced study for a 3 m-diameter instrument which was called the Large Space Telescope.

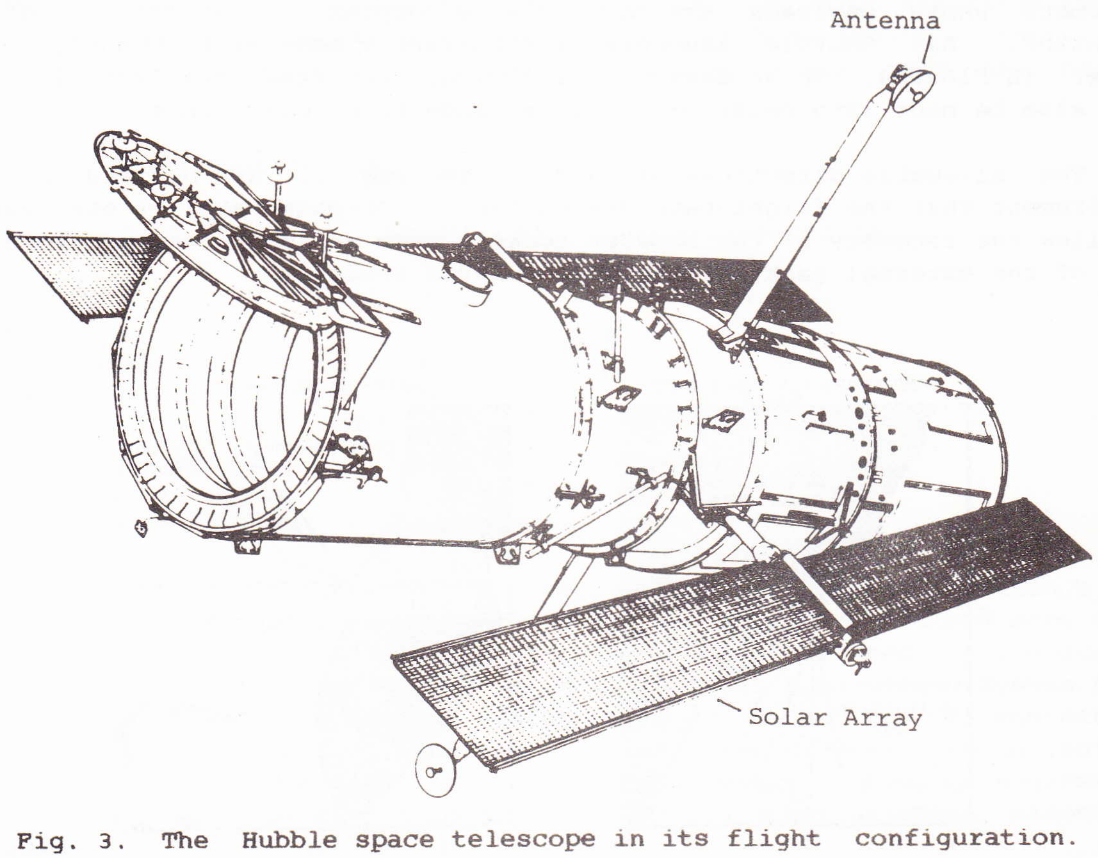

Fig. 3. The Hubble space telescope in its flight configuration. The solar panels are rolled up into tubes during launch and unfurled in space. Astronauts will be able to service or replace equipment through the panels in the rear.

The scientific definition was carried out between 1973 and 1976, when the mission objectives, modes of operation and scientific instruments were defined. It was at that time that, due to cost, the size of the miror was reduced to 2.4 metres and the project was renamed the Space Telescope. In 1976 the European Space Agency became a partner when it agreed to provide one of the instruments (the Faint Object Camera) and the solar panels, in return for 15 percent of the observing time on the telescope.

Contracts were awarded to Perkin-Elmer for the telescope assembly, and to Lockheed for the support module, and development commenced in 1977. At that time it was expected that the Space Shuttle would become operational in 1979 and the HST could be put into orbit in 1983, but due to delays in the Shuttle programme and to technical and management problems with the HST, the launch is now unlikely to occur before late-1986. In 1983 October the Space Telescope was renamed the Edwin P. Hubble Space Telescope. The HST consists of three major components: the Optical Telescope Assembly, the Support System Module, and the Scientific Instruments.

Optical telescope assembly

The telescope is a Cassegrain-type diffraction-limited Ritchey-Chretien instrument with an effective aperture of 2.4 metres. The spatial resolution is 0.1 arcsec, the limiting magnitude is 27-28, and the dynamic range covers the far-ultraviolet (121.6 nanometres) to the far-infrared (1 millimetre).

Light is reflected from the primary mirror to the 0.3 m-diameter secondary mirror located at the prime focus, then through a central hole in the primary mirror to a focus 1.5 m behind it, where the instruments are positioned. The telescope tube contains a series of baffles to suppress unwanted illumination from bright celestial sources and from the structure. The tube is 13.10 m long and 4.27 m in diameter.

The primary mirror blank, made of Ultra Low Expansion Glass, was supplied by Corning Glassworks, and consists of 25 mm-thick front and rear plates fused to a honeycomb interior. Manufacture commenced in 1977 October, and the blank was delivered to Perkin Elmer in 1978 December. The grinding and polishing took three and a half years, by which time the initial weight of 907 kg had been reduced to 748.5 kg. The final polishing (figuring) lasted nine months and was done on a unique machine called the Computer Controlled Polisher. On completion in 1981 May, the surface was calculated to be accurate to within 25 nm.

Coating of the mirror was done in a stainless-steel vacuum chamber. First a coating of pure aluminium 65 nm thick was applied, then a protective coating of magnesium fluoride 27.5 nm thick to prevent oxidisation of the aluminium. The specification calls for the mirror to be reflective from the 121.6 nm Lyman Alpha line for hydrogen to 1 mm, with at least 85 percent reflectivity at the neon-red resonance line of 632.8 nm. The smaller secondary mirror was also prepared to the same specification.

In orbit, the primary mirror's front surface will be at near-space temperature while the rear is maintained at 21°C. To ensure that the mirror retains its correct curvature, and the two mirrors their relative positions, special optical sensors are placed at the focal plane to allow the condition of the telescope to be monitored; also, the telescope's main internal structure is made of a low thermal-coefficient graphite-epoxy composite.

If any errors of the primary curvature are detected, the surface can be adjusted by 24 force-actuators mounted behind the mirror. If the secondary mirror is out of alignment, six precision motors can be used to move its support.

Support systems module

The Support Systems Module provides service systems to operate the HST. It is contained in a collar, which fits around the telescope tube, level with the primary mirror, and contains the electrical power distributors, communications and telemetry systems, thermal control system, and attitude-control gyroscopes. Electrical power is supplied by two deployable and retractable panels each 11.82 m long with a total area of about 50 m^2, carrying 48,760 solar cells. These will deliver 5 kilowatts at 34 volts, falling to 4 kW after two years in orbit due to the degradation of the cells. The solar panels supply storage batteries which will be used during the regular periods when the HST enters eclipse. The solar panels are supplied by the European Space Agency.

Attitude control is provided by reaction wheels which receive information from rate-gyros, star-trackers and fine-guidance sensors. The reaction wheels allow the telescope to be moved through 90° in no more than 20 minutes. The star-trackers will use bright stars to provide pointing accuracy to within 1 arcmin, which is sufficient to place the guide-star within the fields of view of the fine-guidance sensors. These three sensors, located around the primary mirror, use interferometry to provide error signals to the attitude-control system. Overall accuracy of the system provides pointing and stability to within 0.007 arcsec. The fine-guidance system was originally designed to lock onto 13th magnitude stars, data at the time showing that this would provide 95 percent sky-coverage. Later, it was found that many of these stars were in fact double-stars and that the sensors would either lock onto the wrong star or fail to lock on at all. Consequently the system was re-designed to operate on 14th magnitude stars.

All astronomical data will be converted to telemetry which will be transmitted to the ground. Ground-control will also receive 'house-keeping' data which will inform them of the operating condition of the HST.

Scientific instruments

The HST will accommodate five different instruments at its focal plane, but the flexible design allows these to be replaced, when desired, to incorporate advances in technology or to satisfy changes in observational requirements. Updating, repair or replacement can be carried out aboard the Space Shuttle or after returning the HST to Earth. Each instrument is mounted in a standard module which is completely independent.

Wide field/planetary camera (WF/PC)

This instrument, supplied by the California Institute of Technology, is used for the measurement of evolutionary changes and testing of models of the Universe, and to look for perturbations of nearby stars in a search for Jupiter-size planets. It consists of two cameras sharing the same housing and electronics. The Wide Field Camera is an f/12.9 instrument with a field of view of 160 sq.arcsec., and will be used for deep-sky surveys. The Planetary Camera is an f/30 instrument with a field of view of 68.7sq.arcsec. for high-resolution imaging of faint sources. The light which enters the WF/PC is directed by a movable mirror to either of the two detectors; both consist of four sets of Charge Coupled Devices cooled to -95°C and coated with Coronene, an organic phosphor. This coating converts ultraviolet photons into visible photons to increase the range of the detectors. The range is 115-1100 nm, with a visual magnitude of 8 to 28.

The minimum exposure time is 0.1 s and a typical long-exposure time is 3000 s, corresponding to half an orbital period of the HST. The WF/PC is equipped with a large number of filters, transmission gratings and polarisers.

Faint object camera (FOC)

Supplied by the Huygens Laboratory, The Netherlands, the FOC will use the full capability of the HST to study very faint objects at high angular resolution. It is complementary to the WF/PC, in having higher spatial resolution while the WF/PC has a larger field of view.

The FOC consists of two independent cameras operating at f/96 and f/48. When operated at f/48 the field of view is four times that at f/96, but of lower resolution. At short wavelengths, very high resolution can be obtained by inserting a compact Cassegrain assembly into the optical path, converting f/96 into f/288.

The detectors are based on the Image Photon Counting System, a very high performance image-intensifier which can count individual photons. By using integration-times of up to 10 hours during successive orbits, it should be possible to obtain a signal/noise ratio of 4 for objects down to 28th magnitude for point sources.

The f/48 mode provides a long-slit spectrograph for observing extended objects such as galaxies, comets and nebulae, which should be visible down to 22nd magnitude. In the f/96 mode a coronagraph can suppress bright objects in the field of the faint object being observed. The FOC is equipped with a variety of filters and polarisers, and has a dynamic range of 120 nm to 700 nm.

Faint object spectrograph (FOS)

This instrument, supplied by the University of California at San Diego, will determine the constitution, physical characteristics and dynamics of faint sources. It will be used for moderate and low resolution spectro-polarimetry and time-resolved spectroscopy at visible and UV wavelengths.

The FOS uses two magnetically-focussed, photon-counting Digicon sensors, one for UV and visible bands, the other for visible and near-infrared bands. The Digicon operates by re-imaging the detected photo-electrons onto an array of silicon diodes. Exposure times vary from 50 microseconds to 10,000 seconds or more. A continuous set of exposures, each 50 microsec. to 10 millisec. long, can be made at rates of up to 100 exposures per second.

The faintest stars that are visible will vary according to the wavelength studied and the resolution chosen, but are expected to be about 21st magnitude at high resolution and 25th magnitude at low resolution, for a 10,000 second exposure. The range of the FOS is 114 nm to 700 nm, with the polarisation analyser operable over the range 120-350 nm.

High resolution spectrograph (HRS)

This NASA instrument is supplied by Goddard Space Flight Center, and will enable scientists to determine the composition of the interstellar medium and the abundance of the elements. It can be operated in sunlight and therefore can be used at all times, to provide high-quality spectra at ultraviolet wavelengths between 110 nm and 230 nm.

The HRS can be operated in three resolution modes, but normally only the high and moderate resolution ranges will be used. At high resolution, the resolving power is about 100,000. Moderate resolution will be used for target acquisition, estimating exposure times for high-resolution spectra, and for coverage of the short wavelength region where the Optical Telescope Assembly is inefficient.

The HRS uses two Digicon detectors each with 512 diodes. Minimum exposure time is 25 milliseconds. Limiting visual magnitude varies with wavelength and mode, but for a 2,000-second integration time will be about 11 at high resolution, 14 at medium resolution, and 17 at low resolution.

High speed photometer (HSP)

This University of Wisconsin instrument will be used to study brightness fluctuations of a variety of rapidly-varying objects ranging from point sources to celestial fields of small angular size, over a dynamic range of 120 to 180 nm. It uses four image dissectors (photomultipliers with spatial resolution) and a red-sensitive photomultiplier; two operate at ultraviolet wavelengths, and two at visible and near-infrared wavelengths. Unlike a conventional photometer, which uses a stepping-motor to position various filters in the optical path, the HSP contains no moving parts; the choice of filter and aperture combination is made by positioning the image within the instrument by small movements of the telescope.

The HSP operates in any of three modes: star-sky photometry with a single filter, allowing the brightness of the local starfield and nebulosity to be subtracted from the stellar magnitude to improve accuracy; photometry or polarimetry with several filters used sequentially with small motions; and wide-field photometry over 10 arcsec. diameter area without a filter, requiring no special motion of the telescope. Limiting visual magnitude, with 1000-second integration time and a signal/noise ratio of 10, will be 24. Photometric accuracy is expected to be about 0.2 percent.

Astrometry

During normal operations, two of the three Fine Guidance Sensors (FGS) will be used for accurate telescope-pointing, leaving the third free for astrometric measurements. A University of Texas at Austin project will make use of the unused FGS and, with the aid of neutral-density filters, will measure stars of magnitudes from 4 to 20. The positions of ten stars should be able to be determined within 10 minutes. Possible targets, as well as distant stars, are satellites of the outer planets of the Solar System.

Management and operation

Overall direction of the HST Programme is carried out by NASA's Office of Space Science and Applications. Marshall Space Flight Center has management responsibility, while Goddard Space Flight Center is responsible for instrumentation and operation planning.

The data centre is the Space Telescope Science Institute (STSI), located at John Hopkins University in Baltimore, Maryland and established by the Association of Universities for Research in Astronomy. STSI will be the host for U.S. and foreign astronomers, who will use the facility as they would a conventional observatory.

The European Co-ordinating Facility (ECF) is located at the European Southern Observatory at Garching, Federal Republic of Germany. The ECF will

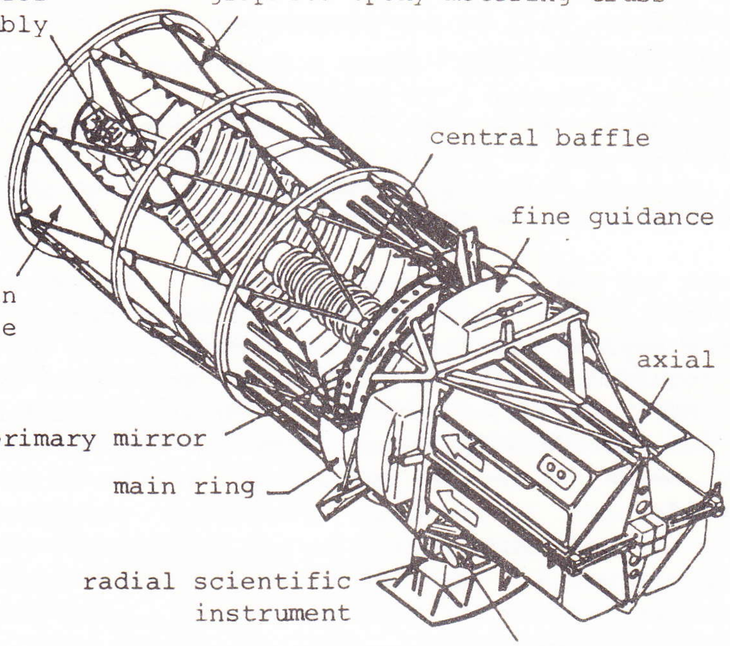

Fig. 4. Main features of the Hubble space telescope.

work in conjunction with STSI, and will co-ordinate work in Europe on data analysis, providing advanced computer facilities to European astronomers. Operationally the HST will be controlled from Goddard SFC, and all astronomical data will be sent by telemetry to Goddard via NASA's Tracking and Data Relay Satellite System, Fig. 5, which will consist of two TDRS communications satellites in geostationary orbit and a ground station in New Mexico. Goddard SFC will forward the data to STSI in Maryland. Due to demands on the TDRS network by other users, the HST will be able to use it for only about 20 percent of the time, so most observation programmes will

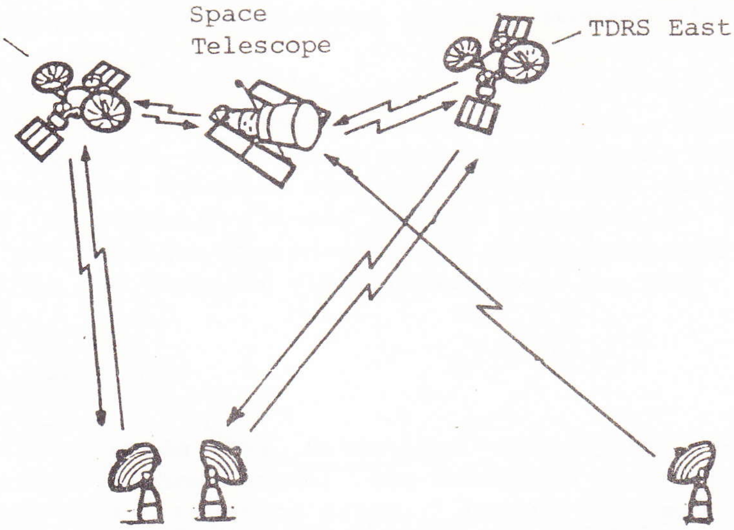

Fig. 5. Hubble space telescope communications links.

be stored on board the HST. For some observations of irregular or unusual sources, alternatives will be pre-programmed with the astronomer able to select his choice in real time.

'Quick-look data' will be sent direct to STSI, to enable early assessment of results and to enable programme changes to be made. Normally, however, data will be filtered to remove noise, then checked and reduced before being delivered to the scientist concerned.

After about two and a half years in orbit, the HST will be visited by the Space Shuttle. Its solar panels will be retracted and it will be brought into the payload-bay for routine servicing and for replacement of instruments if required. After a further two and a half years, it will be brought back to Earth for major overhaul; the mirrors and solar panels will be sent to the manufacturers for refurbishment, and new instruments will be installed. By means of regular servicing, a life of at least 15 years should be obtained.

STARLAB

Starlab is a one-metre space telescope being developed jointly by Australia, Canada and the United States. After initial proving flights aboard the Space Shuttle in 1990 and 1991, it will be mounted on a free-flying space platform for periods of six to twelve months at a time. Starlab will carry two instruments: a camera providing high-resolution imagery over a very large field of view; and a multi-purpose spectrograph for the study of extended or point sources. Starlab will form an ideal complement to the Hubble Space Telescope, operating in the same spectral range with similar spatial resolution, but having a field of view one hundred times larger. Due to its space environment, where the darker background is equivalent to an improvement of one to two magnitudes at optical wavelengths increasing to four to five magnitudes at about 1000 nm, Starlab will be a more powerful instrument than much larger ground-based telescopes.

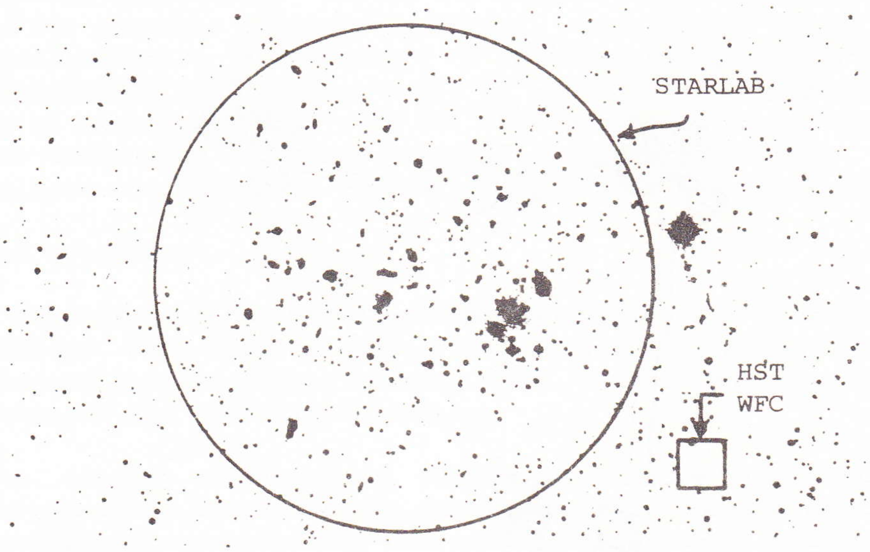

Fig. 6. Comparison of Starlab and Hubble space telescope data fields. The Hercules cluster of galaxies at a redshift of z=0.034. The Starlab data field at this distance corresponds to 1.8 Mpc diameter.

Evolution of Starlab

Because the HST represents a great leap forward in observational capability, it would, in the absence of a suitable companion, have to function as its own survey instrument. This would be very inefficient, due to the HST's very small field of view, Fig. 6. Even its Wide Field Camera has a field of view of only 2.7 arcmin., less than one-tenth the diameter of the full-Moon.

The U.S. National Academy of Sciences therefore recommended a one-metre, diffraction-limited space telescope as the 'prime complement' to the HST. In 1974 NASA commenced a programme for a Spacelab Ultraviolet Optical Telescope, later renamed STARLAB. Scientific studies commenced in 1975, but restricted funding led to suspension of the programme in 1978.

In 1979 Professor Mathewson, Director of the Australian National University's Mount Stromlo and Siding Spring Observatories (MSSSO), proposed to NASA that Australia participate in Starlab. A few months later, Canada made a similar proposal. These proposals led to Starlab being revived, and joint meetings were held in 1980, resulting in a greatly-modified specification. Originally, Starlab was intended to be a highly-versatile, general-purpose telescope which would remain in the Space Shuttle's payload-bay. However, the short-duration Shuttle flights (7-10 days) made this extremely expensive. Also, during the early Shuttle flights, it was found that the payload-bay was an unsuitable environment from the point of view of instrument-pointing accuracy and chemical cleanliness. These factors led to Starlab being redefined as mounted on a free-flying space platform, to be periodically visited and serviced by the Space Shuttle.

Features of Starlab

In addition to acting as a survey instrument for the HST, Starlab will be a powerful instrument in its own right. It will be of value to all branches of astrophysics, and could well become one of the world's most heavily-used astronomy facilities. The Direct Imaging Camera will survey entire galaxies with a single exposure to seek out unusual objects; it will survey distant clusters to discover the large-scale structure of matter and it will measure the explosions of dying stars to monitor the expansion of the Universe.

The second instrument, the Multimode Spectrograph, will be used to determine plasma densities, ionisation state and chemical composition and mass-loss of stars, the dynamics of galactic systems, the abundance of molecular species in comets, planets and the interstellar medium. Both instruments will use a unique photon-counting array developed by MSSSO to obtain data more than one thousand times faster that the HST.

Division of responsibilities

Australia will provide the Scientific Instrument Package, which consists of the Direct Imaging Camera, the Multimode Spectrograph, and the Ultra Large Format Photon Counting Array. Canada is responsible for the telescope structure, main optics, thermal control, fine guidance system, and integration and testing of the instrument. The United States will supply the space platform, Shuttle launch services, telemetry systems, and recovery facilities. The three nations will receive equal observing time.

The telescope

Starlab consists of a one-metre f/15 modified Ritchey-Chretien telescope followed by an instrument bay, Fig.7. It is approximately five metres in length and one and one half metres in diameter, and will weigh about 1800 kg. The nominal optical coating of the mirrors is aluminium protected by magnesium fluoride, giving a usable range from 115 nm to the near-infrared. By employing a special coating, the 90-120 nm range could also be covered. The total field of view is 0.8° and the limiting magnitude is 26. Stability of the optics is achieved by the use of a graphite-epoxy shell as the inner wall of the telescope.

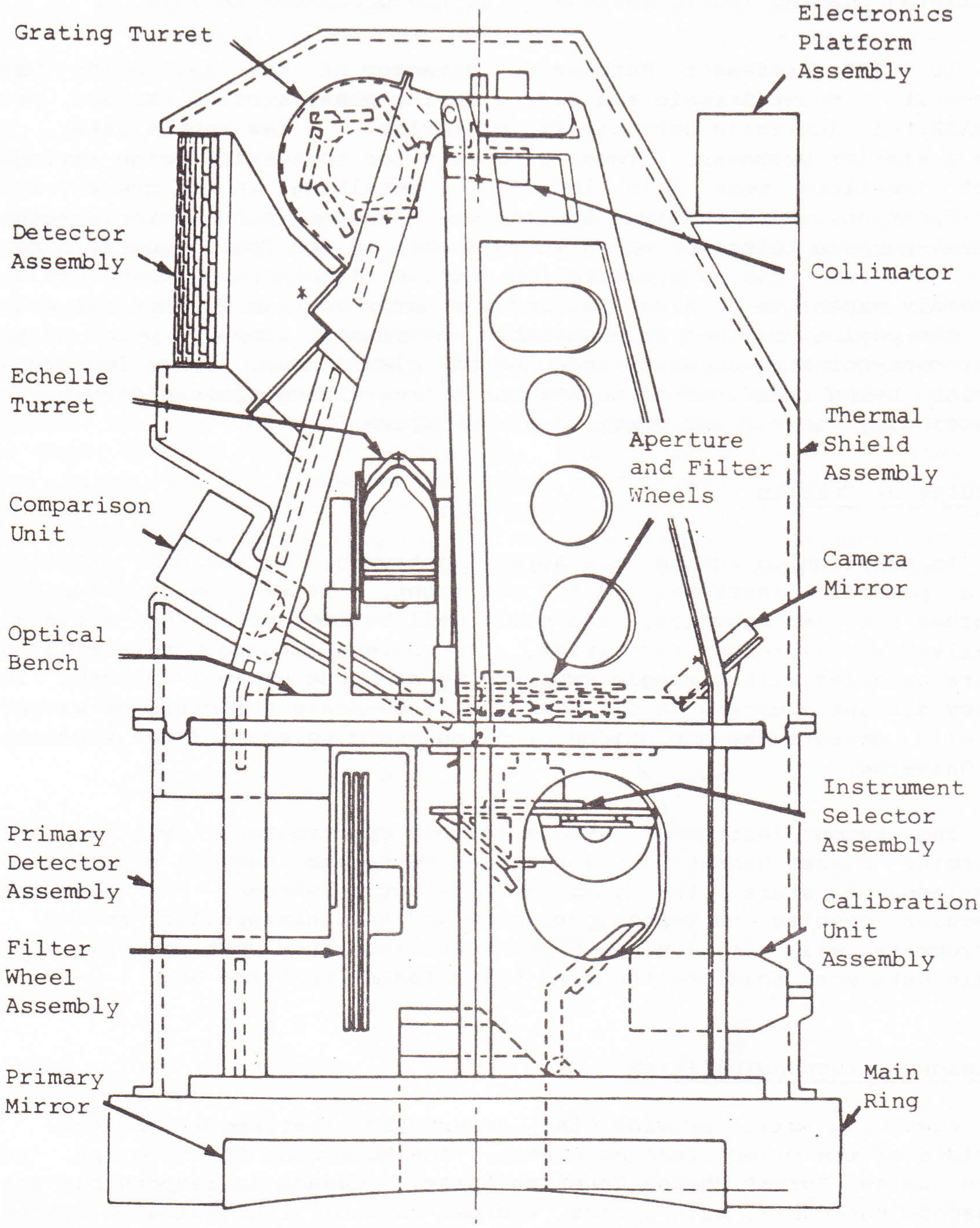

Fig. 7. Starlab instrument package.

Scientific instrument package

The *Direct Imaging Camera* is a wide-field, photon-counting instrument with diffraction-limited performance. It employs a reflective Gascoigne corrector, developed at MSSSO. The field of view is 30 arcmin., over the range 115—1200 nm.

The *Multimode Spectrograph* has three modes of operation:
a) low dispersion — maximum resolution of 5000, with a maximum slit-length of 8 arcmin. throughout the range 110-800 nm.
b) high dispersion — maximum resolution of 100,000, with a maximum slit-length of 30 arcsec. over the range 110-800 nm.
c) direct imaging — resolution up to 500, with a maximum field size of 8 x 8 arcmin. over the range 110-800 nm. In mode (a), with a single exposure, over 2300 independent spectral measurements can be made in each of 2500 spatial elements on the sky.

The *Ultra Large Format Photon Counting Array* will be used by both instruments. It consists of an image-intensifier which generates one million electrons per photon, which are focussed onto a phosphor coupled by fibre-optics to an array of Charge Coupled Devices (CCDs). The CCD array is scanned continuously at a rate of up to 15 MHz, and the output is digitised and stored in the memory of the instrument computer.

Operation

Starlab will be attached to a NASA-supplied pointing system, which will provide crude guidance by means of star-trackers. Fine guidance will be accomplished by moving the secondary mirror. Maximum movement is 5 arcsec. and the expected accuracy is 0.02 arcsec.

Starlab will be mounted on a Spacelab pallet, a U-shaped platform of modular design which is a component of the European-built Spacelab, Fig. 8. The pallet is designed to be carried in the payload-bay of the Space Shuttle orbiter vehicle. Initial proving flights will be carried out with the Starlab/pallet complex remaining in the orbiter payload-bay. On completion of the proving flights, the complex will be carried into Earth-orbit by the Shuttle and attached to a free-flying space platform.

One space platform being developed by NASA is the Science and Applications Space Platform (SASP). This is a free-flying platform that, placed in low Earth-orbit, will support payloads attached to it by providing electrical power, thermal control, attitude control, and high data-rate communications. SASP will weigh 14 tonnes and will be 12 metres in length, and its operational orbit will be 435 km at inclinations of either 28.5° or 57°. Communications with the ground will be via NASA's Tracking and Data Relay Satellite System, described earlier.

Starlab will remain attached to the free-flying space platform for periods of 6 to 12 months. It will then be retrieved by the Space Shuttle for servicing, modification or the installation of new instruments, and replaced in orbit. It is anticipated that at least ten flights can be unertaken by the year 2010.

Conclusion

In this paper the authors have reviewed two particular astronomical applications of the Space Shuttle. The Hubble Space Telescope, and the complementary Starlab, which due to its large-format light-detecting system

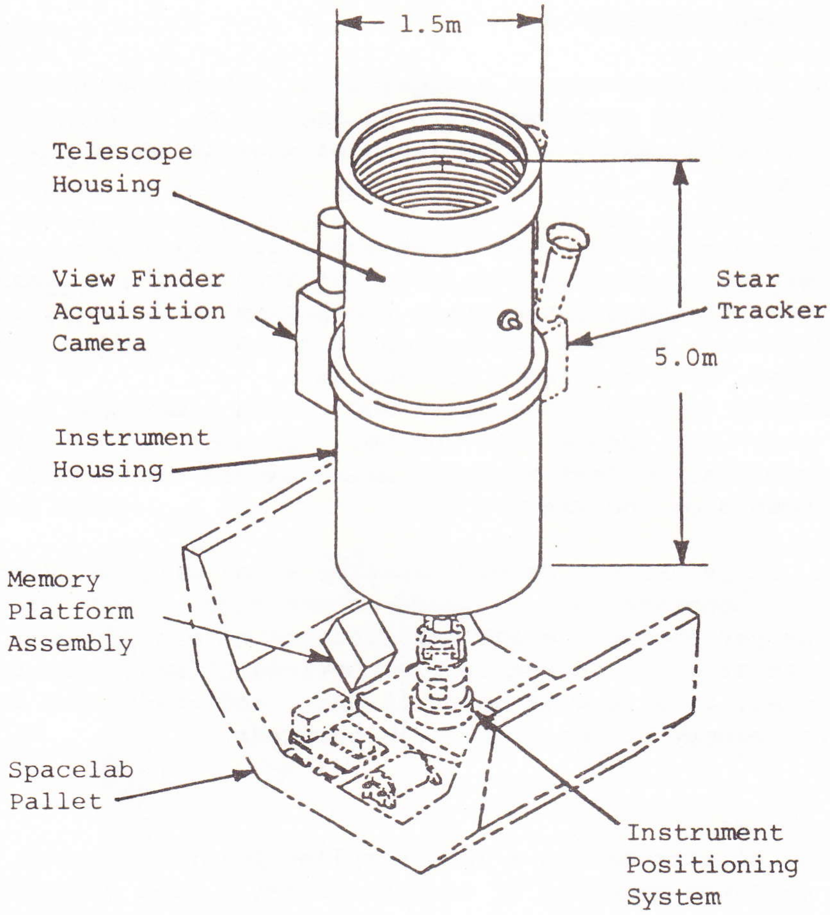

Fig. 8. General view of Starlab facility.

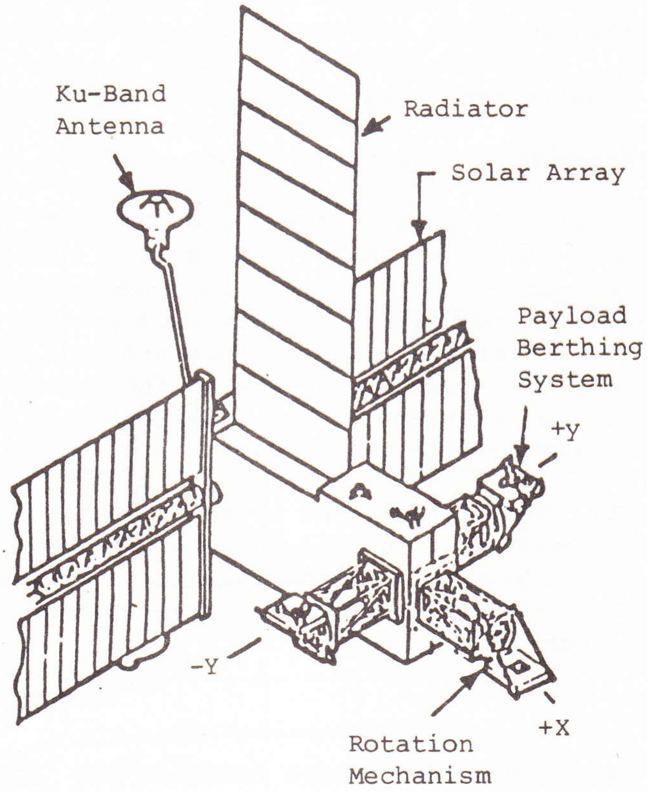

Fig. 9. Science and applications space platform.

is capable of making observations which the HST cannot, will together comprise the most powerful observatory in astronomical history. These instruments have also been highlighted because they will provide Australian astronomers with the opportunity to carry out their observations in space. Starlab will do this directly, through the guarantee of equal time on the telescope. Through Starlab, Australia will also gain access to the Hubble Space Telescope which might otherwise have been denied them. In addition to these two telescopes, however, the Space Shuttle offers many other astronomical opportunities. Not only will it carry a variety of astronomical observatories into space; it will also play a vital role in the construction of large space platforms and, later, of manned space stations which will probably house a great many observatories.

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ASTRONOMICAL SOCIETIES -- HOW SUCCESSFUL ARE THEY?

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ABSTRACT
An attempt is made, from the limited viewpoint of membership in two such societies and guest relationships with some others, to gauge the effect such societies have upon their immediate (and extended) environment. The apparently unavoidable stratification that occurs when groups form as a result of a stated or implied common interest, and the results of such segregation upon the aims and activities of scholarly corporate bodies is further discussed, largely subjectively. The paper also endeavours to give the author's viewpoint of the social responsibility of organized bodies in view of the conflict that can arise between a desire to concentrate on observational and data-productive activities and the need to promote what might be termed informational exercises aimed at a wider public.

It is quite conceivable, I think, that there may be a certain amount of 'eyebrow raising' among those good enough to attend this session, in that it would be natural to assume that a conference programme such as NACAA provides would comprise talks of a scientific or technical nature concerned with astronomy in general, and with those matters which are uniquely the stock in trade of the amateur astronomer in particular. The apparent irrelevance of my chosen topic did indeed, during the throes of composition, plague me with nagging doubts and uncertainty. However, resolutely adapting the policy of the deaf adder of scripture to the voice of self-denegration, I persisted with my self appointed task, with what success I leave to your judgement. As this literary effort progressed, it became increasingly obvious to me that firstly, because the approach I adopted is in some measure autobiographical, and secondly that the topic is dauntingly many-faceted, the paper tends towards the episodic and the anecdotal. This is regrettable, but in the circumstances unavoidable — one can only hope that the continuity is not thereby jeopardized and that the thematic thread is not lost.

I think it appropriate at this stage, and with your kind indulgence, to outline my personal experiences and affiliations as they seem applicable as a basis for this paper. They are as follows:-

I am a member of the Astronomical Society of South Australia, a member of the British Astronomical Association, and an associate member of the Australian Liaison Group for the Space Sciences and Astronomy. These are the astronomy-oriented group of bodies with which I am currently associated. I am also a Fellow of the Royal Socity of South Australia, a member of the Field Geologists Society of South Australia, and, until recently, a member of the Australian Museum of Natural History, and finally, of course, I held membership in those associations relevant to my professional life before retirement. In some of these groups I have held office of one sort or another, from President to Committee member. It is based upon these experiences that I presume to attempt the present task.

The business of involvement with a range of institutions has been an important feature of the later years of my life, partly because I developed a somewhat distorted view of learned societies from an early exposure to Dickens' 'Pickwick Papers', in which such institutions were lampooned in the archetypal Pickwick Club as pretentious, pompous and obsessed with the interminable minutiae of quite trivial matters, which effectively reinforced a natural proclivity as a loner. However, I eventually overcame my diffidence, and for many years now I have sought and enjoyed the company and stimulation of my peers, and I might add, it has been a most rewarding experience. I would like to add though, without embarrassing anyone by revealing identities, that I have sometimes, while engaged in association activities, observed behavioural characteristics that could only be described as Dickensian.

Having disposed of what it is that this paper is about, and of my own background as it applies to writing it, I think it would be a sound idea now to have a brief look at what may be termed the historical background and to try and reveal the evolutionary path, so to speak, of the type of corporate body we are discussing. I shall avoid devising at this stage a comprehensive personal definition of what I think a society is — so let us instead settle for talking about groups of individuals organizing themselves for a common purpose, and specify further that the common purpose shall be of a cultural nature. Let us pass quickly, however, over art-oriented groups, and examine more closely those bodies which have a preoccupation with scientific and technical objectives.

As religion and warfare became more efficiently organized and sophisticated, a process called civilization, there arose a priestly caste whose task it was (and still is) to preserve the religious and cultural concepts of the race, to order ritual observances in their due season, and to train acolytes to ensure preservation of their cherished beliefs. Once again, we have groups of individuals organized for a common, that is, specific purpose. Fascinating as these matters are, much of which is still in the realm of conjecture, we must take a leap forward to Greece of the eighth century B.C., when for the first time we become aware of collections of people of differing backgrounds attending upon individuals whose fame as thinkers and sages had spread widely. One may cite Thales, Anaxagoras, Anaximander and others. However, one such group founded by Pythagoras with the best of motives, became an esoteric brotherhood, in which all sorts of magical nonsense grew out of what was originally practical and useful knowledge, based upon geometry and manipulation of numbers. The Pythagorean brotherhood was founded in 530 B.C., and survived off and on for some 800 years. It is thought by some, however, that they preempted Aristarchus by postulating an Heliocentric cosmos. Here we have a society with an heirarchical structure, rules for activities and observances, and a common concern (mathematics and cosmology).

Moving along a little further, we come to the times of Socrates, Plato and Aristotle. The important features here are two institutions, Plato's Academy (actually founded by Socrates) and Aritotle's Lyceum, both teaching institutions, and both founded around the end of the fifth century and beginning of the fourth century B.C. The Lyceum barely survived the death of its founder, but the Academy continued until 529 A.D., when it was closed as a result of the purge of allegedly pagan institutions by Justinian.

It would be reasonable to argue that the Academy and the Lyceum were the progenitors of institutions of higher education rather than societies as we know them today, but as we shall see, there occurred later on a series of developments that places the Academy clearly on the ancestral line of societies, in addition to that of universities and other schools of advanced learning.

Once more we take a leap forward (I warned you that this paper is episodic in structure) and arrive at what is known as the Renaissance. This uniquely western phenomenon is hard to place precisely in time; all we can say is that around the end of the fourteenth and beginning of the fifteenth centuries A.D., the dark ages of feudalism, knight errantry and religious autocracy were beginning to display elements of geriatric decrepitude. However, the Church alone of these managed to survive by a system of strategic but limited withdrawals, and is still a feature of the modern world, and although some attitudes have become modified, archaic remnants of dress and of ritual still remain. Mention of the 'dark ages' immediately brings to my mind a picture of all those obscure monks in their scriptoria busily and patiently copying out by hand the remnants of learning that had escaped the ravages of pagan destruction and the selective purging of books by the Church.

The Renaissance, of course, was largely contemporary with another revolution, namely the invention by Gutenberg of the printing press. Ironically, we have here an early example of 'high technology' rendering obsolete a whole class of persons with more primitive skills no longer tenable in a changing world. I often wonder what became of those nameless dedicated scribes — did they find alternative employment in the church they had served so very well for such a long time? Not only did the printing press make increasingly available to a wider segment of the population cheaper books in ever larger editions, but the publishers were issuing them in the vernacular as well as the *lingua franca* of the scholarly world, Latin. To augment this heady mixture, a flood of material from Byzantium, after the Turks captured that city in 1453, comprising original texts or fair copies of the great names of classical Greece, became available in relatively cheap printed copies, often, as stated above, in the vernacular. All this meant that knowledge was becoming increasingly democratized. It was indeed a new and spectacular re-birth of learning.

All this may seem something of a digression, but the point I wish to stress is that all of us inherit the availability and understanding of knowledge, which in earlier times was the sole prerequisite of an elite minority. It is solely because we are able to have access to all the knowledge we can assimilate that some of us find ourselves making the logical next move, and congregate with others of similar tastes and interests — hence astronomical societies, typical of a whole range of such institutions.

To resume our investigations, we find that it was in Florence in 1442 A.D. that Cosimo de Medici, inspired by Renaissance fervour, and consequently affected by classical Greek ideals, founded the 'Platonic Academy', based obviously from its name on the institution closed by Justinian in 529 A.D. It was basically a literary academy, and it survived for fifty years. We next hear of the formation in 1582 of the Accademia della Crusa, again in Florence, and as its predecessor, a literary academy. It has the distinction of compiling one of the earliest language dictionaries. The work was performed by a committee selected from members of the academy. Does not this remind one of just such procedures inherent in modern society activities? Eleven years later in Rome, the Academy of St Luke was formed, its particular area of interest being the fine arts.

It began to be felt, however, that these bodies and many others similar in outlook but of lesser social standing, were all very fine, but, it was stressed, what about science and technology.

The idea of a scientific society or academy had many supporters, and, in fact, became endemic throughout Europe quite rapidly. In the precincts of the Academie Francaise in Paris, which came under the patronage of

Cardinal Richelieu in 1636, Mersenne, Descartes and Gassendi, and Kepler by correspondence, all interested in mathematics and astronomy and opposed to the cabbalistic and hermetic basis of much of contemporary and earlier science, created the intellectual environment which encouraged the holding of weekly meetings at the home of Habert de Montmor in 1648. This was formalized as the Montmor Academy in 1657. It finally ceased to exist in 1664.

A model for academies primarily concerned with scientific matters was the Accademia dei Lincei, founded in 1603 in Rome by Prince Federigo de Cesi. Gallileo was one of its earliest and most distinguished members. Although strictly limited in numbers of members, it exercised considerable influence on, for example, the formation and policies of the later Royal Society in England.

Back to Paris, and two years after the demise of the Montmor Academy, The Academie des Sciences was founded in 1666, which laid emphasis on research work, and in fact provided what were then excellent facilities for chemists, physicians, anatomists, astronomers and mathematicians. The Academy was under the direct patronage of Louis XIV, who held the institution in much higher regard than the opinion held by his cousin Charles II of England of the Royal Society.

This is our cue to leave the Continent and take a look at the situation in England. There had been a tradition there that a few of the more enlightened proprietors of stately homes would sometimes hold informal gatherings at their respective family seats, encouraging the attendance of neighbours and friends with similar interests in intellectual matters. There were no formal programmes, and very little cross-fertilisation of ideas with other such events. It should be understood that these were *ad hoc* meetings, and of comparatively rare occurrence. They did, however, serve to nurture the concept of the establishment of a formal society for the better understanding of science and natural philosophy, whereby regular meetings and discussions could be implemented.

Gresham College, London, founded in 1580 and funded from the estate of Sir Thomas Gresham, never achieved the fame of its older and wealthier rivals, such as Oxford and Cambridge, but did succeed in attracting to its teaching staff some illustrious names. We mention the college because it was the setting, in 1660, for a significant event. Following upon a lecture at that institution by Sir Christopher Wren, who was its professor of astronomy, but who is better known as the architect of St Paul's Cathedral, a meeting was held in the rooms of Laurence Rooke, professor of geometry at Gresham. At this meeting a formal resolution was passed to inaugurate 'a more regular way of debating things, and, according to the manner in other countries, where there were voluntary associations of men and *academies* for the advancement of various parts of learning' by meeting weekly, and inviting others to join them. Thus there came into being the Royal Society, although there had been other attempts to do so dating back to 1645 — unfortunately the Civil War and the Commonwealth, and the chaos inevitably concurrent with those events, discouraged further development until the return of the monarchy in 1660. It was not, however, until 1662 that the Society was granted its Royal Charter by Charles II, which in the end meant very little, as that parsimonious and indifferent monarch successfully evaded making any sort of financial grant — in fact, he was heard to refer to its members as 'Mes fous' ('my jesters').

This attitude, coupled with the fact that all scientific equipment in England at this time was privately owned (even Flamsteed, installed by the self-same Charles II as the first Astronomer Royal, was provided with an empty building only, and had to furnish it himself and instal his own private instruments), were the main reasons that the Royal Society became solely a discursive body, in which reports of experimental work and talks at a scholarly level were mixed with a great deal of conjecture and discussion of a more naive standard. Much of this less than scientific content has now mercifully passed into oblivion, due in no small measure to the careful editing of Henry Oldenberg, of which more will be said later. The fact that it even appeared was the result of the fact that the Society in its early formative years was open to all who professed any interest at all in science and allied topics, which resulted in quite a large body of what would now be calld popular or lay membership.

From the latter half of the seventeenth century onwards, learned societies proliferated, spreading northwards and eastwards through Europe, and later crossed the Atlantic to North America, although there the development was both later and slower, reaching its peak as late as 1848 with the estalishment of the Smithsonian Institute. This now famous and august body had its belated inception as a sequel to the strange and strongly contested will of a chemist named Smithson, a Scot who lived most of his life in Paris, and who had no identifiable contacts with America in his lifetime. Most of these later generation societies had a restricted membership, and were not very often open to what we would now term amateur ranks.

Two concomitant but seemingly unrelated phenomena became apparent during the eighteenth century. First of all, the social dichotomy of professional and amateur took place, over a period of time, it must be stressed. However, concurrently and with markedly greater rapidity, there emerged the society sponsored and edited publication. Reverting to the first matter, we note that both the professional and the amateur had a common origin in that class of individuals we can best designate as dilettanti (to use this rare form of the plural of dilettante), that is, those of compulsive curiosity who of their own volition, and often with no career inducements, experimented (perhaps dabbled is a better term) in scientific, or pseudo-scientific matters, *vide* Newton and alchemy or Kepler and astrology. They were invariably avid readers in their chosen enthusiasm, and did sometimes contribute to humanity's better understanding of nature.

The second interesting event, the society-produced publication, which made a rather sudden appearance and has gone from strength to strength ever since, certainly increasing in numbers and diversity, if not, unfortunately, uniformly in quality. The progenitor, so to speak, was a periodical called the 'Journal des Scavons', which first appeared in 1665 January for the Academie Francaise under the editorship of Denis de Sallo. Unfortunately, he was too liberal in his views for the comfort of church and state authorities, and so it was suppressed after three months. A process all too familiar in human history. The journal was reinstated early in 1666 under the editorship of the Abbe Jean Gallois, a safe, respectable, but incredibly dull editor. At the same time, 1666, the 'Philosophical Transactions' of the Royal Society commenced publication in the capable hands of Henry Oldenberg, the long-time and competent secretary of that body. It is still issued under the same title, and in Oldenberg's time was circulated to other European societies, either in a Latin or in a local vernacular translation.

Following, in succession, upon the 'Philosophical Transactions', which was greatly admired on the continent, there appeared the 'Giornale dei Letterati' in Rome in 1670, the 'Acta Eruditorium' in Leipzig in 1682 edited by Leibnitz, the 'Nouvelles de la Republique des Lettres' in 1684 in Paris, the 'Memoires des Trevoux' in 1706, again in Paris, a Jesuit publication, rigidly conservative and strongly anti-Newtonian, to name but a few early examples. In addition to periodicals, which eventually comprised bulletins, proceedings, transactions, journals, circulars, and newsletters for example, there were also issued books, of which we could cite Newton's 'Principia' (1687), 'Opticks' (1704), both of which the Royal Society published upon the recommendation of Edmund Halley, and which set a precedent which continues to this day. Darwin's 'Origin of Species' first appeared as a Royal Society publication in 1859. In the earlier days of society publications, they were quite often circulated to other bodies by means of the consular courier, as public mail services were then non-existent or most unreliable — dare I suggest that the last-named characteristic has hardly yet disappeared?

In view of the preceding, it seems most likely that at least some amateurs would seek to set up their own societies with little, if any, restrictions in the way of required academic qualifications. By their very nature, these groups tend to be ephemeral, and, in earlier times, rather haphazardly kept records would seldom reach any sort of archival authority for preservation. For these reasons, evidence from the earlier years of the nineteenth century of the existence of such parochial and low-activity level societies, is fragmentary indeed. In contrast with the scenario we have been at some considerable pains to establish, there are those who opine that the amateur scientific socity is purely and simply a by-product of the modern social environment, and the phenomenon manifested itself practically overnight, so to speak. Reminiscent, it would seem, of Botticelli's famous painting 'The birth of Venus', in which that lovely goddess is depicted emerging from the sea fully grown and delightfully unclothed. This last point, however, raises doubts in my mind as to the appropriateness of our allegory, because from what I remember of much older members of scientific societies (from the dimness of my long vanished boyhood), it would have been completely out of character for those persons ever to have appeared in public without correct dress, in or out of the sea!

However, ignoring the view that our sort of institution has no antecedents, let us agree that we have established there are indeed forms and structures inherent in our present time having clear, although sometimes tenuous, connections with the past. It would be apparent, I am sure you will agree, that the long surviving academies and societies can be seen as learned societies in the full sense of the term. They are rather fully engrossed in on-going research programmes, the presentation of scholarly papers, the publication of those papers, and the preservation of the status of titles such as 'fellow', which carry with them implicit evidence of competence. On the other hand, the amateur society, which is really what we are talking about, has a quite different purpose and motivation, and this seems a convenient time to leave our historical investigations and concentrate on the stated *raison d'etre* of this paper. I should like to point out, though, that the historical approach is for me a really fascinating topic, and in the limited space and scope here I have not been able to do it full justice.

To continue, the amateur society is rather difficult to define precisely. It is hardly a learned society in the sense of those mentioned by name above, nor is it simply a recreational club, although both elements do appear. Furthermore, in the multiplicity of such bodies now current, the activity fields and levels of attainment are very diverse indeed.

Those of you who have taken the trouble to attend this lecture would share with me, I have no doubt, a keen interest in, and indeed may I say, a love of the universe at large, its structure, contents, and dynamic phenomena, including its past and conjectural future, and be fully aware of is awesome beauty and wonder, of which we are a microcosmic, albeit conscious, part. Furthermore, I feel sure that you would also have a concern for the well being and survival of those corporate bodies designed to foster an interest in, and develop our knowledge of, the ancient discipline of which we are modern acolytes. It is this area, that of the function and management of individual societies, that I should like to talk about. The discussion is based upon a very small sample indeed, and clearly it would be foolish to derive any statistical assessment therefrom. However, I do consider that some statements can be made that would be relevant to other groups similarly situated and motivated.

Let us suppose, in order to begin at the beginning, that a society is in the process of foundation. One can reasonably infer that a group of interested persons have 'found' each other, an inaugural meeting is promulgated, and the business of existence as a formal society is established, either then or at subsequent meetings (remember the resolution passed at the 1660 meeting at Gresham College in London, as noted earlier). A constitution, a set of rules and policy matters are agreed upon and recorded. Any other legal matters, which will probably vary from one locality to another, are hopefully complied with, and the society then enters upon its period of existence, which its progenitors optimistically see as of very long duration.

In contrast with professional societies, which are invariably state-sponsored at least in part, and are often beneficiaries through bequests from deceased estates, the typical amateur group has to struggle along on very little, if anything, more than individual subscriptions, and these are often reluctantly and tardily paid, and, in any case, hardly cover the cost of bare survival. This somewhat discouraging situation is, unfortunately, all too familiar, and explains in part the rather high mortality rate of young amateur societies. Let us suppose, though, that our typical hypothetical body does succeed in weathering all the difficulties attendant upon its youthful period — what then?

To start with, its membership will undoubtedly be small, and it is unlikely to include much organizational and managerial skill in its limited membership (it is a matter of good fortune and augers well for its continued existence if it does). It is hardly likely to have its own meeting facility, such as club rooms, library centre, workshop, remote or incorporated observatory, nor such important items as books, instruments, A.T.M. stocks, or means of using them. All these, or some of them, may be available at the inception of the society, or soon after, but in the majority of cases, most certainly not.

The condition of chronic poverty which is endemic with many, particularly young, amateur societies, creates a set of constraints that materially limit activities in the particular subject interest that brought the society into being. It is often the case that some individuals who have, prior to joining a society, pursued a particular interest such as novae or comet searching, variable star observations, and so on, will undoubtedly continue these activities after joining, and will possibly thereby act as a catalyst for support for their own interest, and even stimulate the generation of interest in other fields of astronomy within the society. It is not necessarily the case, however, that such response will be forthcoming among other members, and pleas for support often appear to fall on deaf or uncomprehending ears, though oddly enough, I have noted, on occasion, that the seed has been sown (to mix metaphors) and at some later time one's recommended ideas are espoused and successfully promoted by the most unlikely of persons; which only goes to show that it is the total organism that thrives, the individual cell is expendable.

To return to the administrative aspects of running a society, and this applies to all institutions, whatever the motivating interest which brought it into being, there are functions which are sometimes ineptly and haphazardly formulated and performed, sometimes even inveighed against by those whom such systems are designed to protect. Administration comprises a series of functions demanding a high degree of skill and knowledge, the importance of which cannot be overstressed. In the very nature of these matters, unfortunate members of an institution who stub their toes on some point of law, and have their attention drawn to the fact, tend to denegrate the authority concerned as 'bureaucratic', and the point of order as 'red tape'. I must confess to being guilty of this sort of frustrated reaction to regulatory restraint myself. Now the structural format of society management and the procedures stemming therefrom, have evolved, as I hope I have shown in our historical excursus, over a long period of time, and though by now seemingly archaic, are generally acceptable. Those who would make sweeping changes to group administration systems and methods should heed the awful example of what has happened in the political arena with larger (national) groups. This by no means denegrates the attrition by time of those elements which have become redundant.

Astronomical societies come in a wide range of sizes and activities. Some activities are fundamentally subjective enthusiasms, and comprise, as has been mentioned earlier, such hobby-type pursuits as amateur telescope making, observational projects of, say, variable stars, double stars, occultations, eclipses, and searches for transient phenomena such as comets, novae, and so on — the list can be extended considerably, but enough has been given to categorise the sorts of things that are the stock in trade, to a greater or less extent, of all amateur astronomical societies, and can be carried on by individuals, often supported by sub-groups called sections. Such activities are self-contained within the society, and rarely, if at all, involve interaction with the public at large.

On the other hand, it may be that, if circumstances permit, the society may entertain ambitions to enlarge its horizons, and in addition to the normal activities listed above, can become involved in projects predominantly aimed at establishing the society as an integral and significant influence in the local social zone, be it city, suburb or district. The sorts of things that can be suggested here comprise public viewing nights, solar barbecues, demonstrations of society projects, star parties, and others which I am sure you can all suggest. Quite apart from these, however, or more possibly in addition, a society can become involved in what may be termed educational and public relations exercises. These projects require a good deal of time, effort and material, and can only successfully be prosecuted if the society includes in its membership persons with requisite qualities, and also has the capacity to support such schemes. In the educational field, the proposal is to supply to schools which request it, lectures and demonstrations, using prepared 'kits' of printed and audio visual material, with additional equipment for practical demonstrations. The whole thing being designed to complement any astronomy-based segment in the school curriculum.

Public relations activities, on the other hand, are best carried out by someone who is *persona grata* with the media, or who has the sort of personality that could foster such relationships. By gaining the cooperation of T.V., radio and press facilities, and winning their support for donating time and space (not an easy thing to do), it would be possible to develop three important areas. Firstly, alert the public to forthcoming astronomy spectaculars, e.g. eclipses and comets, and advertise the society's plans to offer public viewing and informational functions for these events. Secondly, to alert the public to political decisions to curtail funding for science and technology, and persuade those interested to promote lobbying campaigns to counter such matters. This could also be a matter for consideration by a national coodinating body, which will be mentioned at the end of this talk. Thirdly, to arrange a regular session (or sessions) to keep before the public notice the activities of the society, and the current astronomical phenomena (the changing sky at night, for example).

All these suggestion could be better implemented if the society that plans to become so involved could increase its committee, or council, to include a social secretary, an educational officer, and a public relations officer. Whether one, two, or three persons are elected is dependent upon the resources of the society concerned. Another matter that could conceivably involve the social secretary and the public relations officer is that of fund raising. Although in the past fund raising has been an *ad hoc* low profile activity, I feel that we now need to place it upon an organized and effective basis by implementing long-term objectives, and plan functions to achieve those objectives.

Before I leave this discussion of societies in general, and the individual society in particular, I should like to enter a plea for better consideration of the rank and file, that is, those who, though having less expertise and experience, nevertheless form a majority (and a full subscription paying majority too). There is a tendency to denegrate the interests and limited achievements of these people, and emphasise the feats of the elite few. No one would deny the significance and value of this elite group, and the necessity to give their work due prominence, but after all, we are members of an amateur society, and those better equipped have a responsibility to encourage the less advantaged, and to curb a natural impatience when called upon to listen to naive and elementary comments. After all, there was a time when all of us were also mere beginners, and it behoves us to remember that.

There is much, much more that I could talk about here, but time and space necessitate calling a halt, so let me conclude with firstly the hope that this pioneering attempt may not have been in vain, notwithstanding its shortcomings and inadequacies, and that it will generate further studies into this and allied topics. Secondly, I would like to propose that a national body be set up (a sort of NACAA with more muscle) with a permanent secretariat (possibly the Science Communication Unit of the CSIRO could be approached for assistance in this regard). This idea may seem somewhat serendipitous, but I personally do not think so. It could be achieved by application and dedication on the part of all of us.

Finally, let us make the most of what we have and create new directions with new purpose in our various societies, for better cooperation and exchange of ideas over and above that of our biennial conference. There ought not be any astronomical society, however small and inadequate, operating in isolation.

My grateful thanks go to my wife for carefully preparing the typescript and patiently correcting the many deficiencies in my original manuscript.

ASTRONOMICAL SOCIETIES' JOURNALS: ARE THEY WORTH IT?

J.L. Perdrix and R.J. Lawrence

ABSTRACT

At least 25 publications are produced by astronomical societies in Australia giving over 180 issues and 1800 A4 pages annually. A closer look is taken of this situation and a specicmen issue of an Australian Journal is produced and discussed.

During our 13 years as Editors of an astronomical journal it became obvious that the production of a journal on a regular basis is not an easy task. Occupying such a position gives the Editor an ideal forum for expressing his opinions, writing upon his favourite topics and publishing those subjects most dear to his heart. Of course sufficient material must be forthcoming and it must be of a suitable standard for the particular journal. But is the monthly or bi-monthly headache worth it?

In response to a questionnaire sent out at the end of 1983 to all, then known, astronomical societies in Australia we received 19 replies from 27 questionnaires, follow-up letters and telephone calls. However, answers to some of the questions were available without a reply and so the figures could be built up into something meaningful.

There are 29 astronomical societies in Australia with a total membership of over 2000. (There are also astronautical societies which have not been considered in this paper, but which may well add weight to our final recommendation.) Between them they produce some 25 publications ranging from annuals to monthlies giving over 180 issues per annum. Converting all the published material to A4-size pages, there are over 1800 pages of printed material produced annually. A staggering amount, half as much again as *Sky and Telescope* including all its advertisements.

It was reported to the Delegates' Meeting at the 7th NACAA (Sydney) in 1976 that there were 21 astronomical societies with a total membership of 1200 producing 17 publications. The present figures for societies and total membership are larger; however, neglecting those societies formed about or since that time, ten of the (1976) societies reported a decline in their membership since 1978. What do all these figures mean? One certain point is that a number of people are spending an awful lot of time producing these publications which are not always read by the members.

We should look at not only the quantity of printed matter produced, but also the quality (material and presentation) of the issues. For those members who are unable to attend meetings regularly, the journal is all they receive for their annual subscription. One recent issue from a society was 16 A5 pages produced on a reducing photocopier and six of them were totally unreadable. The content may have been excellent, but is it of use if it is unreadable. Other journals have extremely good reproduction, but the contents are not worth spending time on reading. We could go on looking at all the publications, but it would be time wasting.

The prime purpose of a society's publications is communication.

1. They are to advise and remind members of meetings and the main agenda item for the next meeting.

2. They are to give any recent up-to-date discovery details for members, so that they may observe the object.

3. They are to present some good articles (recent lectures, reviews or research results) for members to read.

4. They should be a forum for those observations of members worthy of reporting.

5. They should contain some local news of members or club's activities.

We are not proposing that all the Australian astronomical societies should cease producing publications. There is a very strong need for local publications; however, we believe that they should be restricted to the local content. Photocopying machines are the best things since sliced bread when they are working properly and they are copying from good, clean originals. In our view all astronomical societies should produce a newsletter to advise members of coming events. In addition, as part of their annual subscription members could receive issues of an Australian journal.

We have produced a specimen issue of such a journal for this Convention as an example of what could be expected. If you are expecting the quality of *Sky and Telescope* then we suggest that you subscribe to that magazine. Most of the articles have either been published before or would have been published in journals around Australia. This has been done to illustrate the types and quality of articles which are being produced, but seen by only perhaps 10% of the 2000 amateur astronomers who are members of societies, not to mention the many other Australians who would read them with eagerness if only they were available to them.

Three ingredients are necessary for such a journal to become a reality -- a publisher, acceptance of such a journal and cooperation from the executive members of the Australian astronomical societies. The first of these is the easiest to find and should produce no difficulty. A circulation of over 2000 would ensure a wide audience for advertisers, thus helping to keep costs down. Members of distant societies would learn about suppliers of astronomical goods and services which they did not realize were available in Australia.

It is hoped that acceptance by members of astronomical societies would be automatic. We do not believe that Yaraandoo is the ultimate in an Australian journal; however, with a dynamic Editor it would continue to grow and aim for even higher goals with each issue. Full acceptance would lead to the inclusion of colour pages. As circulation continued to grow, we would see specialty articles by professional astronomers appearing, bringing amateurs up to date with the latest discoveries.

The last of the ingredients is the one which we believe will be the most difficult to obtain. As that sixteenth century proverb says the road to a Yaraando is paved with good intentions. It was for this reason that we have produced this specimen issue, independent of any one astronomical society. It was the fear that one large society would take over that prevented the formation of an Australian National Astronomical Body (ANAB) 14 years ago. Once a few issues had been produced, we believe that the cooperation of the Australian astronomical societies would greatly improve, but then we could be wrong. It is the independence of such a journal which we believe would be its strength.

The prospect of writing up your lecture to the local society does not greatly inspire you if the circulation of your local publication is only in the tens or perhaps may approximate 200. This would be increased at least tenfold with an Australian journal and make the task of writing so much more rewarding. It is expected that each Society's Editor would take an interest in Yaraandoo and be responsible for vetting and forwarding suitable articles for publication. These Editors would also be expected to contribute news of their Societies for inclusion in a section devoted to Club's Activities.

We trust that you will enjoy Yaraando No. 0 and that it will provide a talking point amongst members of societies. Just as it would provide a forum for the exchange of views and ideas amongst readers in the future. We should greatly appreciate any comments or ideas which you may have regarding the idea, content, style, format, etc. of an Australian journal. Perhaps you do not like the name, it is the choice of one (JLP) for us, the legend is truly Australian* or did this and the Greek and Roman legends all have a common origin in the very distant past.

To iterate, we do not advocate the cessation of societies' publications. We are recommending that there should be an Australian journal as part of the subscription of every member of all societies and that these societies should produce their own newsletter. Whilst the journal would contain news of various activities of societies, production time would not always allow for announcements to be received in time for notification to reach members before certain events. This is the function of a newsletter.

What is the time scale of such a journal? To us, the obvious time to commence publication of Yaraandoo would be just prior to the appearance of Halley's Comet, when interest in astronomy must gain momentum. If there is no interest in this starting date, then the concept should be placed on the Agenda for the Delegates' Meeting at the 1986 NACAA in Hobart.

Whilst we have concerned ourselves in this paper with Australian astronomical societies, we do have close neighbours across the Tasman Sea who should have been included in this study. If, no not if but when, this type of journal becomes a reality, we should hope the New Zealand astronomical societies would be part of the venture and any other South Pacific societies.

We should like to thank all those Societies who replied to our questionnaire and provided us with the necessary information. Our special thanks go to the Editors of the Journals who allowed us to reproduce those articles in Yaraandoo which had been published before and to the authors of the other articles.

We are forwarding a copy of Yaraandoo, containing a copy of this paper, to all the Australasian Astronomical Societies.

***YARAANDOO**

To the Euahlayi tribe, Yaraandoo is the place of the white gum-tree or the Southern Cross. The legend of Yaraandoo is reproduced here from Australian Legendary Tales by K. Langloh Parker by kind permission of the publishers Angus & Robertson Publishers.

In the very beginning when Baiame, the sky king, walked the earth, out of the red ground of the ridges he made two men and a woman. When he saw that they were alive he showed them such plants as they should eat to keep life, then he went on his way.

For some time they lived on such plants as he had shown them; then came a drought, and plants grew scarce, and when one day a man killed a kangaroo rat he and the woman ate some of its flesh, but the other man would not eat though he was famished for food, and lay as one dead.

Again and agin the woman told him it was good and pressed him to eat.

Annoyed, weak as he was, he rose and walked angrily away towards the sunset, while the other two still ate hungrily.

When they had finished they looked for him, found he had gone some distance, and went after him. Over the sandhills, over the pebbly ridges they went, losing sight of him from time to time. When they reached the edge of the coolabah plain they saw their mate on the other side, by the river. They called to him to stop, but he heeded them not; on he went until he reached a huge yaraan, or white gum-tree, beneath which he fell to the ground. As he lay there dead they saw beside him a black figure with two huge fiery eyes. This figure raised him into the tree and dropped him into its hollow centre.

While still speeding across the plain they heard so terrific a burst of thunder they gazed wonderingly towards the giant gum-tree. They saw it being lifted from the earth and passing through the air towards the southern sky. They could not see their lost mate, but fiery eyes gleamed from the tree. Suddenly, a raucous shrieking broke the stillness; they saw it came from two yellow-crested white cockatoos flying after the vanishing tree. Mooyi, they called them.

On went the Spirit Tree, after it flew the Mooyi, shrieking loudly to it to stop, so that they might reach their roosting-place in it.

At last the tree planted itself near the Warrambool, or Milky Way, which leads to where the sky gods live. When it seemed quite still the tree gradually disappeared from their sight. They only saw four fiery eyes shine out. Two were the eyes of Yowi, the spirit of death. The other two were the eyes of the first man to die.

The Mooyi fly after the tree, trying always to reach their roost again.

When all nature realized that the passing of this man meant that death had come into the world, there was wailing everywhere. The swamp oak trees sighed incessantly, the gum-trees shed tears of blood, which crystallized into red gum.

To this day to the tribes of that part, the Southern Cross is known as Yaraan-doo, the place of the white gum-tree. And the Pointers are called Mooyi, the white cockatoos.

So is the first coming of death remembered by the tribes, to whom the Southern Cross is a reminder.