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Technology and the emergence of X-ray astronomy

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Abstract
X-ray astronomy went through a decade of impressive growth within the decade following the discovery observations of bright X-ray sources in 1962. The beginning of the discipline had to do with development of military rockets during World War II and the subsequent high interest in both military and civilian applications. The first X-ray sensing instruments were rooted in early nineteenth century technology but scientists quickly developed powerful new instruments that have sustained the discipline and provide the basis for future observatories. Entirely new instruments have been emerging that may provide for impressive new capability. The discipline provides a classic example of how a science discipline can emerge rapidly following an initial discovery and then settle into long middle age.

1 INTRODUCTION

In 1960 astronomy was very much a classical topic by current standards. The world's most advanced telescope was the 200 inch on Mount Palomar for which development had begun during the 1930s. Film was still the workhorse medium for recording information; phototubes and photomultipliers were just coming into use for photometry and spectroscopy. Radio astronomy was coming of age and just leading to the recognition of the prevalence of high energy, non-thermal processes in the Cosmos. No one could predict what was to emerge in the coming decade. Within a short time, quasars (1962), cosmic background radiation (1965) and pulsars (1967) were discovered, all with ground-based optical and radio instruments. Space astronomy was meeting its promise of providing an entirely novel vista from which to make observations, yielding yet other discoveries, most prominent of which were the bright X-ray sources (1962), entirely unpredicted and unexplainable. It is X-ray astronomy that I will discuss in this paper. What was the technology employed in the emergence of the discipline, how has it evolved and where may it be going?

2 THE FIRST DECADE

Observations from balloons in the early 1900s, intended to study natural radioactivity, led serendipitously to the discovery of cosmic rays. During the 1930s serious considerations led to the recognition that the Sun had to be a powerful source of ultraviolet and X-radiation in order to sustain the ionized region found at several hundred kilometres altitude above Earth's surface. Direct analysis of solar radiation led to the realization that the Sun's atmosphere had gas with a temperature of a million degrees. At that time balloons were the only technical means for carrying instruments to high altitudes, but they could only penetrate the stratosphere at ten kilometres or so, far short of the altitudes needed to see X-rays. Nevertheless the stage was set and with the availability of sounding rockets after World War II, scientists were able to carry instruments well above the sensible atmosphere.

One of the principal objectives of the earliest rocket experiments was the short wavelength radiation of the Sun. But it was only with the greatest ingenuity that information could be obtained; for example, Herbert Friedman and his colleagues at the Naval Research Laboratory enlisted the aid of the U.S. Navy to fire rockets during a solar eclipse from the back of a ship in the South Pacific and were able to establish that the Sun consisted of both a hot, tenuous atmosphere and small, bright regions of activity associated with sunspots (Chubb, 1960a). Another landmark observation of the Sun obtained by Friedman and his group at NRL from a rocket in 1960 was the image shown in Figure 1 (Chubb *et al.*, 1960b). This figure illustrates the power of imagery and the limitations of the then current technology. The optics was a pin hole and the recording medium was film. The rocket was aimed at the Sun but still was spinning; thus the image rotated during the exposure. Nevertheless the image shows specific features of the solar emission – an overall hot atmosphere that is revealed at the limb and the concentrated emission associated with active regions. Thus this single image revealed what had required a naval expedition and a solar eclipse.

Figure 1. Pinhole image of the Sun obtained on film by NRL during a sounding rocket flight in 1960. This is first image of the Sun obtained from above the atmosphere at X-ray wavelengths. The image is smeared because of rotation of the rocket during the exposure.

By 1960, space science, having received a tremendous boost from the US-Soviet space competition, was well into its 'second' generation. NASA had been founded, sensors were being flown on orbiting satellites and new groups were being encouraged to pursue space observing. The study of X-ray emission was a natural choice. The fact that the Sun was an X-ray source led to the idea that stars generally would be observable in X-rays. From a totally different vista, the observation of cosmic rays in the vicinity of Earth and of radio emission from both galactic and extragalactic objects, led to the recognition that observable X-rays (and even more energetic radiation) should be generated through various physical processes. Thus it was not surprising that by 1960 three different US agencies, NASA, the Navy, and the Air Force, had independently made the decision to provide support for technical developments aimed at measuring cosmic X-rays from space, as distinct from solar X-rays.

This research support reached fruition in June 1962 when a large and unexpected flux of X-rays was detected from an Aerobee rocket experiment devised by Riccardo Giacconi and his colleagues at American Science and Engineering (AS&E) in Cambridge, Massachusetts (Giacconi *et al*., 1962), of which this writer was a member. The instrumentation consisted of three Geiger counters placed around the axis of the rocket. As the rocket spun, the counters scanned a swath of sky. Pointing consisted of waiting for the time when a given celestial location was in the right position with respect to vertical and firing straight up. Since the counters had a very broad field of view (about 60 degrees), it was hard to miss. The total collecting area was about 30 cm^2. These results were quickly confirmed and extended using similar, but larger instruments.

Aside from learning how to build larger instruments and how to plan experiments, there were two important innovations made within the first few years of the discovery flight. One was the switch to proportional counters from Geiger counters. The two are simple variants of gas detectors. Both work by arranging for a gas discharge upon the passage of a charged particle; however, proportional counters provide a signal proportional to the degree of initial ionization. This allows for measuring, albeit crudely, the energy of detected photons and allows for efficient background rejection techniques. Figure 2 shows a rocket payload developed by the AS&E group in 1967 that was used for scanning the Milky Way (Giacconi *et al*., 1967). The collecting area was now about 1000 cm^2 and the detectors were collimated to ½ degree using closely-spaced latex sheets.

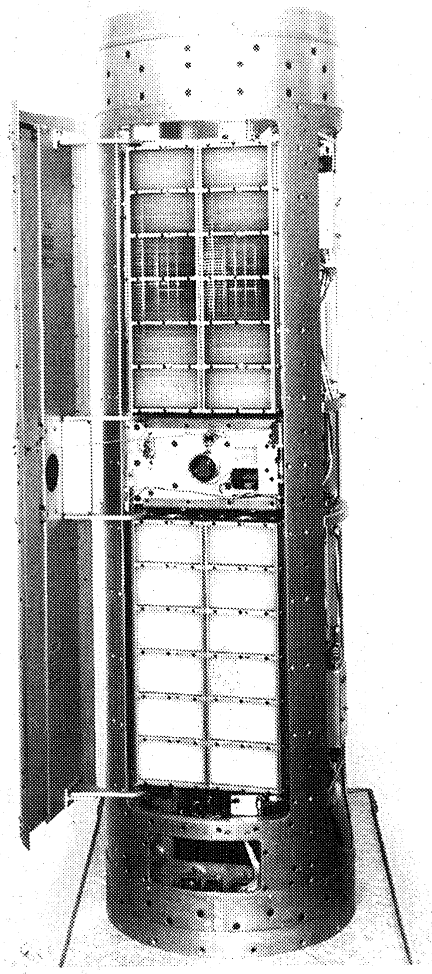

Figure 2. The sounding rocket payload used by the AS&E group to scan the Cygnus region of the sky in 1967.

The other innovation was the modulation collimator. The initial design consisted of two planes of wires with equal diameter and separation. Such collimators have multiple transmission directions. Following a proof of principle rocket flight, a modulation collimator instrument was used in 1966 to localize the bright X-ray source, Sco X-1, with arc minute precision, a landmark experiment that led to the optical identification of the bright X-ray source Sco X-1 and to the emergence of the recognition that binary systems with a collapsed companion star could be very luminous in X-rays. (Gursky *et al*., 1966). The data from that flight are reproduced in Figure 3 and show a few seconds of data with the source moving through the multiple fields accommodated by the collimator, each of 4 arc minutes width. Modulation collimators also introduced astronomers to the idea of spatial modulation and spawned a great variety of devices for mapping X-ray sources with high precision using relatively simple, mechanical elements.

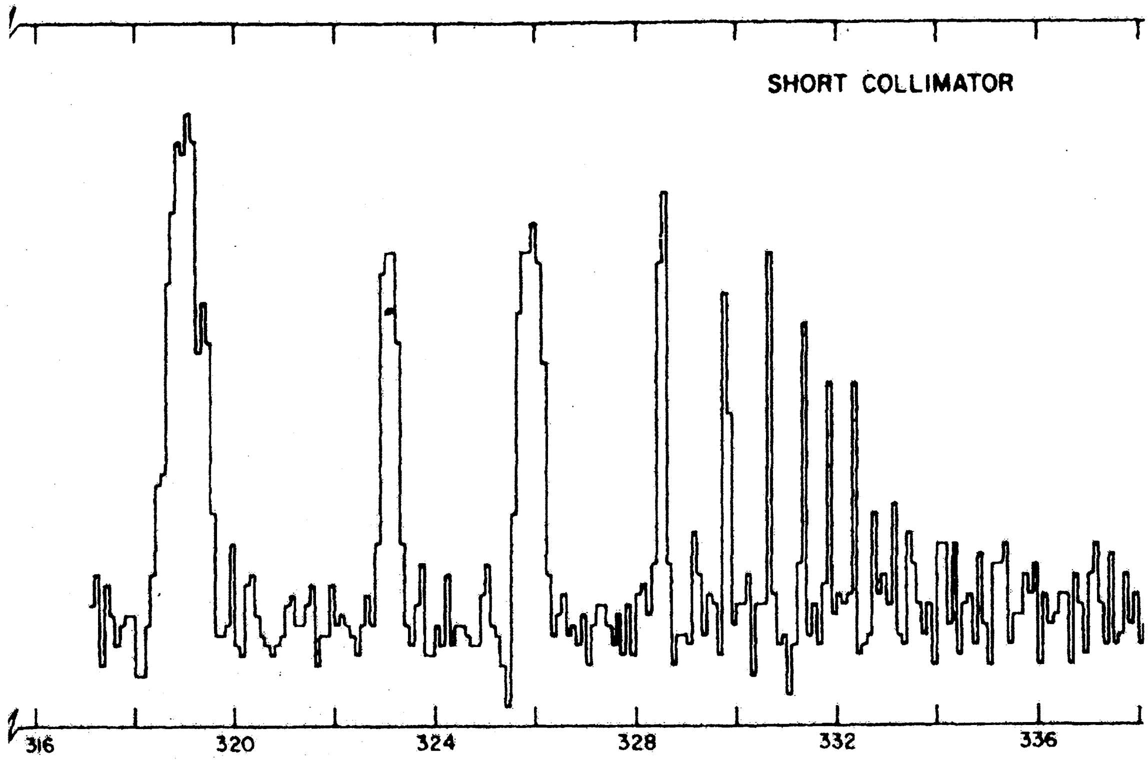

Figure 3. Data from the modulation collimator instrument flown in 1966 on a sounding rocket that led to a precise location for the bright source, Scorpius X-1, and its subsequent optical identification

The decade ended with the launch of the Uhuru satellite using instrumentation similar to that shown in Figure 2. The Uhuru data created a quantitative and qualitative change in the discipline. Each day in orbit, the satellite produced far more data than all the previous experiments to date and yielded important new discoveries, such as the pulsing, binary X-ray sources and the rich clusters of galaxy. The amount and quality of information produced by Uhuru brought X-ray observations into astronomy as a distinct discipline.

At the same time that astronomers were using rockets (and balloons) and gas counters to extend their knowledge of the X-ray sky, another development was taking place that would revolutionize the discipline; namely, that of X-ray optics and imaging detectors. Again the Sun was the key science driver and again there were independent trajectories, this time involving the Naval Research Laboratory, the Goddard Space Flight Center, and American Science and Engineering. I began this discussion by noting that the first information regarding the distribution of X-rays from the Sun came from rocket instruments flown during an eclipse and from a pinhole camera. During the 1960s the group at AS&E had begun to develop focussing optics that could produce proper images of X-ray emission, based upon the principle of total external reflection. The key ideas relating to X-ray optics were expressed by Giacconi and Rossi (1960) who noted the enormous improvement in point source sensitivity that resulted from the use of X-ray optics and by Wolter (1952) who described specific optical configurations that could yield images in X-rays.

The first X-ray optics were replicas taken from a steel mandrel and were used to observe the Sun from a sounding rocket. An example of an early image is shown in Figure 4. Except for the fact that the image was not smeared due to rotation of the rocket during the exposure, its quality was not much better than the one shown in Figure 1. However by 1968, high quality optics were obtained by AS&E using traditional polishing and figuring techniques on a glass blank. The same mirror technology was used in solar X-ray imaging experiments on NASA's SkyLab. The mirror blanks are shown in Figure 5; instead of flat discs that are the start of traditional astronomical mirrors, X-ray optics look like sections of large diameter pipe. Their inner surfaces become the figured mirror.

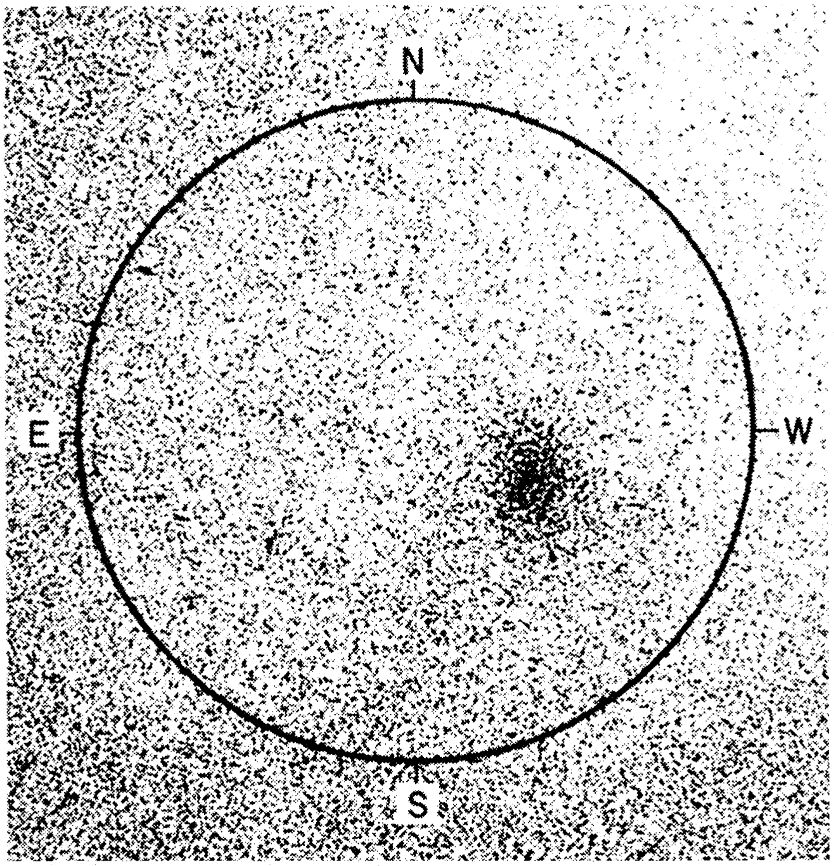

Figure 4. First solar image obtained with grazing incidence optics flown on a sounding rocket in 1967.

So for the purposes of solar investigation high quality X-ray optics had emerged. However the solar experiments, even Skylab, used film as the image-recording medium, totally unsatisfactory for the study of cosmic X-ray sources. Meanwhile, John Lindsey, who left NRL's solar research team when NASA was formed and started a solar research group at the Goddard Space Flight Center had introduced the idea of microchannel plate arrays as X-ray imaging devices. Each channel, and there are millions in the array, acts as an electron-multiplier when a voltage is applied across them. Thus a photon converting at or near the face of the array will produce a cascade of electrons. These devices do not provide any energy resolution. Leon Van Spoeybroek, Ed Kellogg and I employed such a device with the mirror used by the AS&E solar group, to image Sco X-1 from a sounding rocket in 1969. An image was formed by allowing the electron cascades from a multichannel detector to fall onto a scintillating screen, which was then photographed. Two camera frames from that flight are shown in Figure 6, each frame yielding a single event at the position of Sco X-1. A total of only four photons were detected during the flight. The result was reported at meetings but never published. Somehow I could never convince my colleagues that it was a very significant result.

The great power of telescopes was fully revealed with observations from the Einstein Observatory, the development of which was begun around 1970. Its point source sensitivity was a thousand times greater than that of Uhuru and other instruments using collimated proportional counters. Virtually every kind of astronomical object was seen as an X-ray source, including individual objects in external galaxies.

Thus within a few years after the discovery of cosmic X-rays with the simplest gas counters, astronomers had developed powerful new sensors and auxiliary devices for recording X-rays with very high sensitivity; including, proportional counters, modulation collimators, transmission grating spectrometers and microchannel plate detectors. However it is also the case that innovations in the technology of space access and NASA's expanding programme of space science drove X-ray astronomy in its first decade. Of special note was the technology relating to pointing rockets and spacecraft steadily at a fixed position in space.

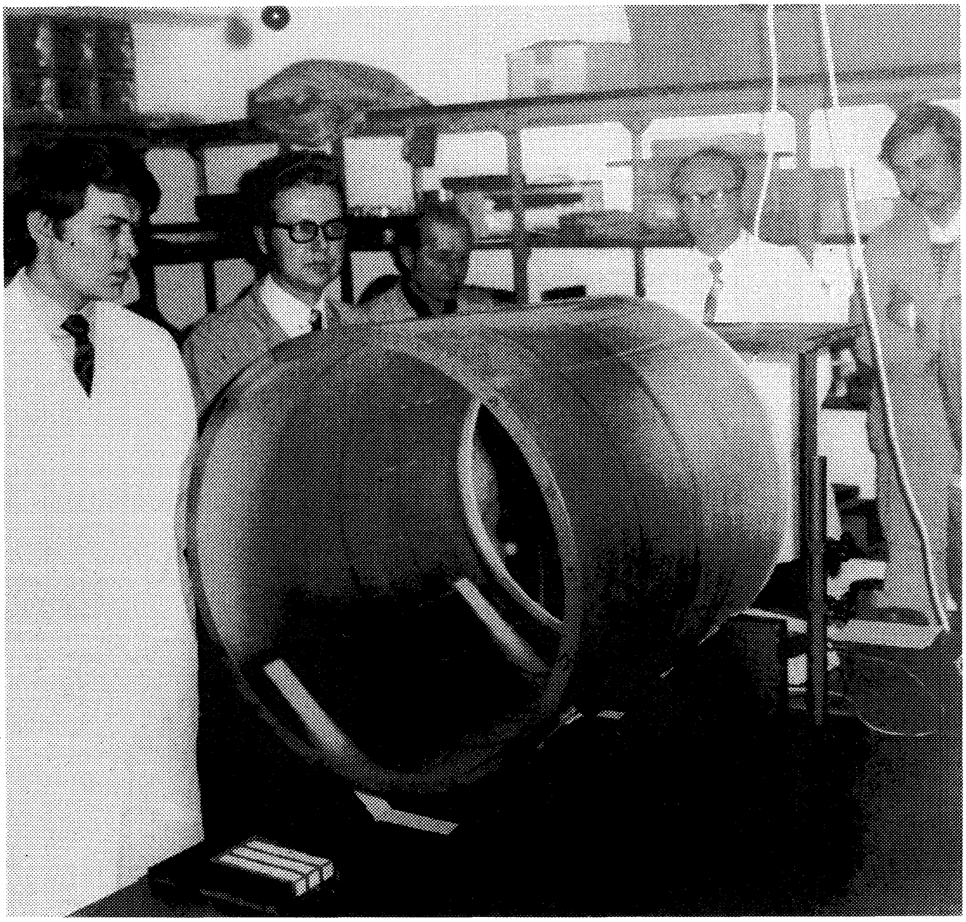

Figure 5. The blanks for one of the X-ray mirrors used on the Einstein X-ray astronomy mission.

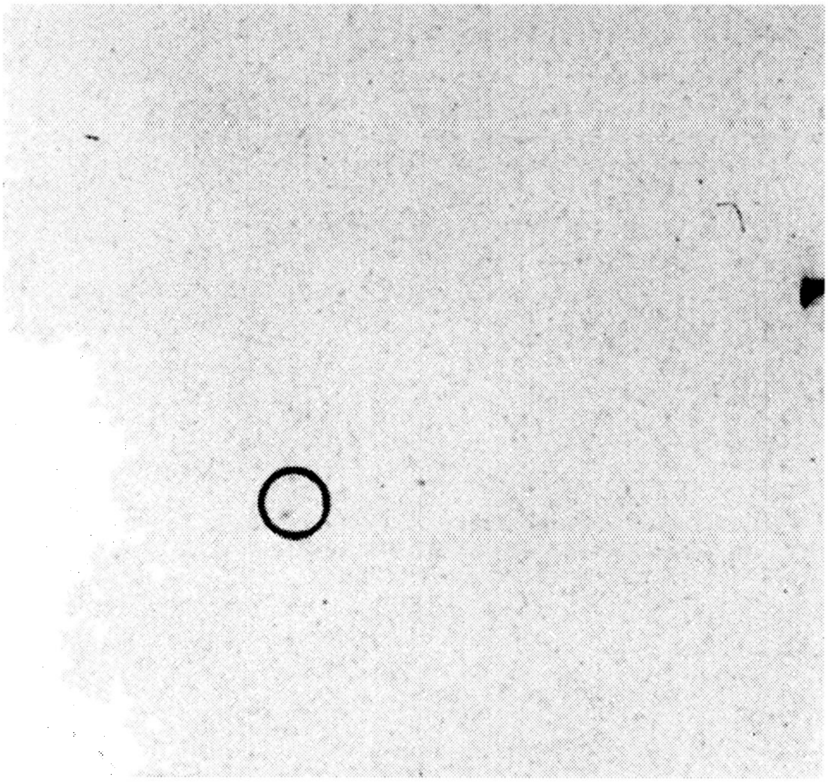

Figure 6. Photograph of a single photon obtained from Scorpius X-1 using grazing incidence optics flown on a sounding rocket.

3 MIDDLE AGE

These devices and their many variants would carry the discipline for the next two decades and down to the present time. This is revealed in Table I, which shows X-ray astronomy space missions that have both flown and are in the planning phase. The largest differences that are revealed in Table I are in the spacecraft themselves. The first space mission dedicated to X-ray astronomy, UHURU, used detectors identical to those flown in the 1967 rocket payload shown in Figure 2. The spacecraft was only spin stabilized, much like the first rockets used to study cosmic X-rays. The ANS satellite was the first to use inertial stabilization that allowed pointing continuously to single targets. By the 1980s all space missions were inertially stabilized. Another notable feature of this table is size growth of the missions. Uhuru was only a few hundred pounds and was flown on a SCOUT launcher; the recently-launched CHANDRA weighs over 10,000 pounds and took the entire bay of NASA's Space Shuttle. What has happened with the space missions is just what has happened with astronomical facilities on the ground; the development of larger and more sophisticated instruments in order to continue conducting state-of-the-art observations. The table reveals that space research is still a high-risk activity. Two recent missions, ABRIXAS and ASTRO-E, were total failures.

There were notable instrument developments that have provided a much different capability from their parents. One is the imaging proportional counter that was used in X-ray telescope systems for imaging. These devices were proportional counters in which the sensing wires were closely spaced, about 100 microns apart. The wires by themselves provide one dimensional data since the signal from photons converting in the gas would appear on a single wire; the second dimension was obtained by determining where along the wire the signal occurred, which was down by, for example, making the wire a delay line. Another advantage of imaging proportional counters was that they could be built large, or at least significantly larger than

Table 1. X-ray astronomy missions.

Programme	Nation	Launch Year	Instrumentation
Uhuru	US	1970	Collimated Proportional Ctrs, Spin Stabilized
ANS	Netherlands	1974	Collimated Proportional Ctrs, 3-Axis Stabilized
Ariel 5	UK	1974	Modulation Collimated Proportional Ctrs
HEAO A	US	1977	Collimated Proportional Counters
Einstein	US	1978	High Resolution Telescope
Hakucho	Japan	1979	Modulation Collimated Proportional Ctrs
Ariel 6	UK	1979	Collimated Proportional Ctrs
Tenma	Japan	1983	Gas Scintillation Proportional Counters
Exosat	Europe	1983	X-ray Telescope, High Elliptical Orbit
Ginga	Japan	1987	Collimated Proportional Counters
ROSAT	Germany	1990	High Resolution Telescope
ASCA	Japan	1993	High Throughput Telescope, CCDs
Rossi XTE	US	1995	Collimated Proportional Counters
BeppoSax	Italy	1996	Collimated Proportional Counters, Telescope
ABRIXAS	Germany	1999	High Throughput Telescope, Custom CCD
AXAF(Chandra)	US	1999	High Resolution Telescope, CCDs, High Elliptical Orbit
XMM	Europe	1999	High Throughput Telescope
ASTRO-E	Japan	2000	High Throughput Telescope, Bolometer
Constellation	US	Conceptual	High Throughput Telescope, Four Independent S/C
XEUS	Europe	Conceptual	High Resolution Telescope, Focal Plane, Mirrors are Separate S/C

microchannel plate detectors also used for X-ray imaging. As an example, the Einstein mirrors, with an eight-foot focal length required a detector almost ten inches in size to cover its one-degree field of view. The other variant was the high throughput telescope. The problem with X-ray telescopes as they were first developed during the 1960s was that they were massive and heavy. Each telescope only produced a small area and even though mirrors could be nested, only a small fraction of the frontal area could be utilized to collect photons. Thus the 'high throughput' variant emerged, mirrors designed so that large numbers, even hundreds, could be nested and much more collecting area achieved for a given frontal area. This was achieved by using thin metal or glass sheets as the collecting surfaces. But such surfaces cannot be manufactured or held to high mechanical precision; thus, their angular resolution has been limited to arc minutes compared to the arc seconds achievable with the more conventional mirrors.

The next substantially-new technology introduced into X-ray astronomy was the CCD as an imaging device for X-ray telescopes, which was first employed on the ASCA mission in 1993. X-ray astronomers have always counted photons with high efficiency devices, so the introduction of the CCD did not represent nearly the same shock as when optical astronomers switched from film to CCDs. CCDs have provided a substantial improvement over their predecessors since they provide for measurement of the energy of arriving photons with much higher precision than do imaging proportional counters, which means that some spectral features, especially the iron lines at 6 kev, can be cleanly recorded. Also CCDs offer superior spatial resolution to imaging proportional counters. The telescope missions, Einstein and ROSAT, used two different focal plane instruments, a microchannel plate detector for the highest spatial resolution and an imaging proportional counter for the best spectral resolution. On the Chandra Observatory, CCDs have replaced the imaging proportional counters.

It is in the area of spectral imaging that a spectacular new technology is emerging; namely, photon detectors that function by sensing individual phonons, which can be thought of as quanta of thermal vibration. Since energy resolution of single photon detectors is ultimately limited by the number of electrical carriers released per unit photon energy, the conversion of photon energy to phonons to charge carriers produces far more electrical carriers than do the processes in gas or silicon detectors which rely on ionization to produce carriers. Thus, instead of limiting energy resolution of kev of energy, these new detectors have the potential of producing energy resolution of ten electron volts or less (or spectral resolution of a few hundred, in terms commonly used by spectroscopists). For many objects, the combination of high temperature and opacity broadens spectral features to the point that higher resolution is not especially useful. These new detectors do not come without pain. They typically involve very small signals produced at very low temperatures; thus, the X-ray astronomers will suddenly have to deal with many of the technical problems that the space infrared astronomers deal with, at least in the focal plane.

The first of these new detectors to fly will be a bolometer developed by the University of Wisconsin and the Goddard Space Flight Center (Stahle *et al.*, 1993). This device measures directly the increase in resistance in a thermistor in thermal contact with a heat sink in which photons convert. Other devices make use of the changes in superconducting properties that accompany small temperature rises. The bolometer is scheduled for flight on the Japanese ASTRO-E mission. As with the first of anything, this detector is limited, comprising only a double strip of 16 detectors. However in principle large arrays of detectors can be constructed.

Other notable advances include advanced spectroscopic instruments. The US Chandra Observatory and the European XMM mission both include grating spectrometers. On Chandra they are of the transmission variety; and on XMM they are of the reflection variety at grazing angle.

4 THE FUTURE

Not surprisingly future X-ray astronomy missions are principally larger versions of current missions. In the US, the Constellation mission entails the launch of a number of independent X-ray telescopes, each with its own focal plane instruments. Common observing with each of the telescopes and co-adding data provides for the larger effective area. The use of independent telescopes allows for a shorter focal length compared to a single telescope with the same area. The Europeans have chosen a different approach; namely, eliminating the optical bench tying the telescope to the focal plane. Their future mission, XEUS, has the telescope and the focal plane on independent spacecraft and the alignment is maintained by station keeping between the two with laser beams and other aids. Thus the actual focal length of the mirror is not a factor in the development. Another feature of XEUS is maintenance by the International Space Station. The idea is that the focal plane spacecraft could rendezvous with the station on occasion for maintenance and refitting as needed. CCDs, bolometers, and other novel focal plane devices will further enhance the power of these new observatories.

The principal limitation for these new missions will be support from the funding agencies. These new missions are not particularly more complex than what has flown before, but they are much larger and will be more expensive than earlier ones. The world's major space science agencies, NASA, ESA, and ISAS, are under pressure to limit the cost of individual missions. NASA's new mantra – faster, cheaper, quicker – is not especially well suited to these super telescopes.

There is another kind of mission that is needed by the X-ray astronomers; namely, those like the Rossi XTE that are dedicated to observing the stronger sources. These can make do with traditional collimated detectors, although to some degree the same objectives can be met with missions like XMM where the mirrors are designed for maximum collecting area rather than the best possible angular resolution. It is also possible that new kinds of detectors based upon large sheets of silicon may become the detector of choice. NASA's proposed mission for energetic gamma ray observations, GLAST, will make use of 80 square metres of silicon strip detectors. For use with X-rays they will require cooling which will limit their applicability.

It is certainly possible that entirely new observing instruments may emerge of great power. One development is the use of multilayer coated optics that allow for normal incidence reflection in the soft X-ray range (Barbee, 1986). This is the same technology that is used to create very narrow pass band filters. The X-rays will reflect (and transmit) across each of the layers in the multilayer stack, allowing for constructive interference within a narrow pass band. Such multilayers have been used successfully in space solar instruments, the latest example being the instrument on NASA's TRACE satellite used to image the solar atmosphere at various temperatures. A portion of one of the TRACE images is shown in Figure 7 and shows how far the discipline has come in improving the quality of observing. The technique can also be used to create normal incidence reflection gratings of great power. Like other solar instruments, these are bound to find application in X-ray astronomy. However, because they currently function at 100 Å and longer, their cosmic span of vision is no more distant than about 100 parsecs or so. Interferometry may also find application in X-ray astronomy. It has already been demonstrated that fringes could be produced in X-rays using grazing incidence mirrors as a Michelson interferometer (Cash, 1999).

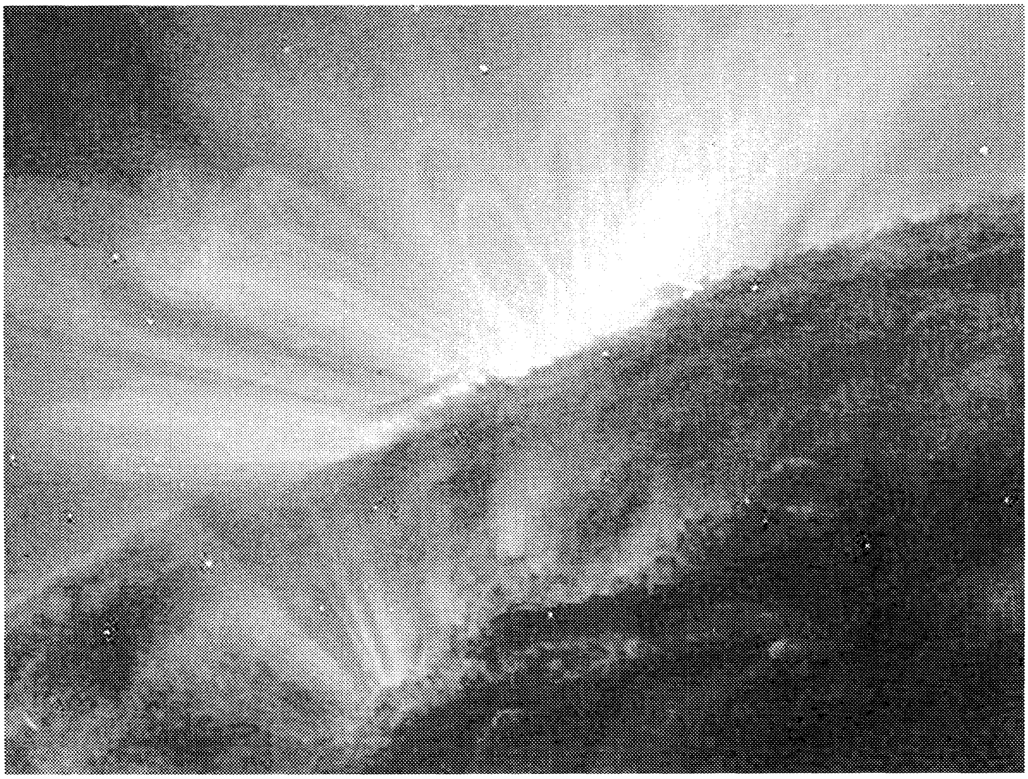

Figure 7. A portion of an image of the Sun in X-rays obtained from NASA's TRACE satellite.

5 SUMMARY

The principal factors relating to the emergence of X-ray astronomy were the rocket technology that developed during World War II and the interest in their continued development after the War. The technology that was utilized by scientists in the discovery observations was based upon concepts and instruments that had their origin early in the twentieth Century. In the decade after the discovery there was a period of intense development that yielded the devices that sustained the discipline for two decades. Only now are new devices in common use that did not exist in the 1960s.

The discipline is approaching a phase in which the next generation of major observing facilities being presented to the community are hardly novel, but are principally much larger versions of current facilities. These new facilities should provide significant advances in sensitivity over those that will be put into operation shortly, especially with the improved detectors and spectrometers now under development. However, if history is our guide, these more advanced concepts may have difficulty finding broad support; in particular, they will face tough competition with major facilities from other disciplines that offer novel concepts and new science.

I cannot leave a discussion of the history of one aspect of X-ray astronomy without commenting upon the human and social aspects of the discipline. As with the rest of astronomy, there was explosive growth during the 1960s. Indeed the CHANDRA mission had its origin then. One individual, Riccardo Giacconi, and the social environment in which he found himself in the early 1960s, can be credited with much of that growth; certainly with the development of large facilities based upon grazing incident telescopes. X-rays would have been discovered and the field would have developed without Giacconi and his colleagues – by 1960 there were too many people working on it and there was too much interest in exploiting space science for the field not to have emerged – however, not with the impressive pace that it did; certainly, not with the large, high quality, telescope missions such as Einstein. Several factors were present that provided for Giacconi's success. Firstly, it was the presence at MIT of a group of scientists and their collaborators, headed by Bruno Rossi, dedicated to studying cosmic rays; not just the particles but also the gamma rays. Secondly, it was the emergence of the Boston area as a breeding ground for scientists exploiting new technology, fed by MIT and Harvard and by military contracts. Thirdly, and in part due to the second, it was the attractiveness of the Boston area as place for scientists to work and live. Finally, it was the fact that much of the development took place in a private company, American Science and Engineering, which could pursue a range of applications, as opposed to the academic community that is frequently narrowly focussed. Giacconi stepped into this brew and exploited it for the benefit of his chosen discipline.

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Seeing the impossible: meteors in the Moon

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Abstract
Over the time span of a decade beginning circa 1940, numerous observers reported the apparent detection of luminous meteors in a supposed lunar atmosphere. These observations run counter to our present-day knowledge and it is now understood that the Moon has no gaseous envelope in which meteoroid ablation can occur. Before circa 1950, however, the presence of a tenuous lunar atmosphere, in which meteoroid ablation was theoretically possible, could not be ruled out by the available observations. It is argued here that the observers who reported the apparent detection of lunar meteors unconsciously 'molded' imperfect perceptions to fit a pre-existing, but flawed theoretical ideal. The term philosophical parallel is introduced to describe this phenomenon.

Key words: The Moon; lunar atmosphere; meteors; meteoroid impacts

1 INTRODUCTION

The light emission that results from vigorous meteoroid ablation may be potentially seen from any planet or moon with an atmosphere. While we are mostly familiar with the observation of meteors within Earth's atmosphere, they should also be observable in the atmospheres of Mars and Venus. The only planet, however, besides Earth on which a meteor trail has been observed, albeit with an *in situ* satellite camera, is that of Jupiter (Cook and Duxbury, 1981). The Moon is Earth's nearest large-body neighbour, and consequently it is the best place for Earth-based observers to look with the hope of recording extraterrestrial meteors – that would be, of course, if the Moon had a corporeal atmosphere.

To the modern observer it is well known that the Moon has no substantive atmosphere and that lunar meteors are an impossibility. Up until circa 1950, however, the situation was much less obvious, and indeed, several prominent observers did report observations of selenographic meteors. This is a remarkable situation. From our present-day advantage we might initially attempt to dismiss the claimed observations as absurd and hardly worthy of attention. This, however, would be too harsh a judgment on our predecessors and indeed, it is our contention that the situation is not so easily resolved. So, where does this leave us? We can, if nothing else, begin by ruling out the idea of fraud – essentially, the observers had nothing to gain by making the claims that they did. We are inherently left, therefore, with an interesting mystery: how can observers apparently 'see' something that is in reality physically impossible?

The human eye is not the most trustworthy of analytic instruments, and even the experienced observer will occasionally record something that is 'odd' – such as a flash or short-lived streak of light. Some of these 'odd' events are no-doubt real phenomena, but others (possibly the majority) are simply illusory. It is our contention that the solution to the lunar meteor problem lies in the process by which observers decide which of the 'odd' observational events to count as 'real' and which to dismiss as 'noise'. As we shall outline in detail below, the apparent observation of lunar meteors was a consequence of well-meaning observers being swayed by what we shall term the 'philosophical parallel'. That is, possibly illusory and certainly poorly-observed transient events, that under typical circumstances would have been ignored, were accorded a 'real' status because of a pre-existing theoretical ideal already known to the observers. In other words, observers sometimes 'witness' the things that they 'expect' to see. To understand how the philosophical parallel applies to the study of lunar meteors we have to first consider the development of ideas concerning the Moon's atmosphere.

2 THE MOON'S VANISHING ATMOSPHERE

If a planet or moon is to retain an atmosphere for any appreciable length of time, a balance has to be established between the diffusive effects of thermal molecular motion and the entrapping effect of gravity. To first order, the average velocity of the atmospheric gases must be less than the escape velocity. For the Moon the escape velocity is 2.4 kms^{-1} and its daytime temperature of about 350 K is sufficiently high that the escape-time for hydrogen and helium is just a matter of hours (Zeilik and Gregory, 1998). Heavier molecules of, for example, oxygen and carbon dioxide take longer to escape, but they still disperse in a time short compared to the age of the Solar System. What little exosphere the Moon does display is primarily produced through solar-wind implantation and subsequent release via sputtering and impact-driven vaporization (Potter and Morgan, 1988).

One of the earliest references to the possible existence of lunar meteors was made by the famed science fiction writer Jules Verne. In his fascinating book *Round the Moon*, published in 1870, Verne wrote, "... if the invisible disc [the Moon as seen by the explorers in their stranded spacecraft] had any atmosphere, the shooting stars would be seen passing through it" (Verne, 1870:101). Verne did not commit himself, or his fictional characters, to the detection of lunar meteors in his story, and indeed, at the time that he wrote *Round the Moon*, the idea of a substantive lunar atmosphere had been almost universally abandoned. Had the Moon's atmosphere, it was argued, been anything more than a mere wisp, one would have expected to observe twilight phenomena and possibly even clouds. In his *Unfinished Worlds*, Parkes (1887:152-153) described the Moon thus

> No quivering atmosphere, with swift moving clouds traversing its disc; no changing features on its rugged, broken-up surface, not any indications of life; but groups of conical elevations, and detached mountain ranges – as sharp and hard in outline as though they had been chiseled by the hand of some mighty sculptor – each one a silent record of the tragic history of a world now dead, but not destroyed.

While Parkes dismissed the Moon as an entirely 'dead' world, other astronomers felt that the presence of a lunar atmosphere had not been wholly ruled-out. John Herschel in his classic text *Outlines Of Astronomy* argued, for example, that "... we are entitled to conclude that the non-existence of any atmosphere at its edge dense enough to cause a refraction of 1 seconds of arc, i.e., having one 1980th part of the density of the earth's atmosphere" (Herschel, 1869: 358-359). American astronomer William Pickering also noted the absence of lunar refraction, and argued that his Jupiter occultation observations constrained any lunar refraction to be less than 0.5 seconds of arc. This value, Pickering continued, while extremely small still allowed for the Moon to have an atmosphere with a surface density 1/8000th that of Earth's at sea level (Pickering, 1892). At first glance Pickering's argument does not seem encouraging towards the possibility of lunar meteors, but as Pickering himself noted, meteors in Earth's atmosphere begin their luminous flight at an altitude where the atmospheric density is some 1/2 500 000th that at sea level (assuming ablation begins at 100 km). Pickering concluded, "... it will therefore be seen that the lunar atmosphere is quite sufficient to render luminous and destroy all the smaller meteors before they can strike the surface."

Pickering did not directly address the question as to why no lunar meteors had ever been unequivocally observed. This point, however, later became the focus of some interest. J W Gordon (1921), for example, raised the question of the non-detection of lunar meteors in the journal *Nature,* and his letter prompted a response from the well-known astronomer A C D Crommelin. While acknowledging that the surface density of the Moon's atmosphere must be small, Crommelin (1921) noted that because of the Moon's lower gravitational acceleration, the rate at which the Moon's atmospheric density decreased with height must be smaller than that found for Earth. Given this fact, Crommelin argued, even if the ratio of the lunar to Earth surface densities was as small as 1:10 000 then, all else being equal, the Moon's atmosphere would be denser than Earth's for heights above 40 miles (64 km).

Crommelin's argument concerning the variation in atmospheric density with height can be readily described by considering the properties of a hydrostatic, isothermal atmosphere. In such models, the atmospheric density, $\rho(h)$, at height h can be written as

$$\rho(h) = \rho_0 \exp(-g\,h / H_0) \qquad (2.1)$$

where ρ_0 is the surface density, g is the surface gravity and $H_0 = k\,T / \mu m_H$ (where k is the Stefan-Boltzmann constant, T is the temperature, μ is the mean molecular weight and m_H is the mass of the hydrogen atom). Since the Moon's gravitational attraction is about one sixth that of Earth's and assuming, as Crommelin did, that H_0 is the same in both atmospheres, the height at which the two are equal is

$$h = -H_0\,(5/6)\ln(\rho_{0M} / \rho_{0E}) \qquad (2.2)$$

where the M and E subscripts refer to the Moon and Earth respectively. Crommelin argued that $\rho_{0M} / \rho_{0E} \approx 10^{-4}$, and adopting a scale height of six kilometres for Earth's atmosphere, we find $h \approx 66$ kilometres.

It is important to note that Crommelin's assumption on the equality of H_0 in both atmospheres was, in fact, a forced assumption. The argument was necessitated since he knew nothing about the composition or temperature stratification of the supposed lunar atmosphere. Lincoln La Paz (1938:281) later picked up on this point and argued that

> It seems probable that the explanation of the efficacy of the rare lunar atmosphere as a shield against meteoritic bombardment as given by Pickering and Crommelin is the correct one; nevertheless, ... a final decision must await a recalculation of h [the height of equality given by equation (2.2)] on the basis of assumptions conforming more closely to the actual state of the lunar atmosphere, as revealed by modern observations and theory.

La Paz was, of course, correct in his summation, but it would appear that his reservations were largely ignored. For example, Ernst Öpik wrote to Patrick Moore in 1952, claiming

> Lunar meteors are quite probable. Considering the surface gravity of the Moon, which leads to a six times' slower decrease of atmospheric density with height, the length and duration of a meteor trail will be six times that on the Earth, if a thin atmosphere exists. (cited in Moore 1984).

That meteor trails would be six times longer, for the same initial meteoroid mass, in the supposed lunar atmosphere follows from a consideration of the classical theory of meteoroid ablation (Hughes, 1978). If the rate of meteoroid mass loss is considered to be proportional to the kinetic energy of the oncoming airflow, then the meteoroid mass at height h can be written as

$$m^{1/3}(h) = A - B\, H_0\, (\rho_0 / g)\, \exp(-g\, h / H_0) \tag{2.3}$$

where A and B are constants and the other symbols have their earlier meanings. In the derivation of equation (2.3) it has been assumed that the ablation takes place at constant velocity – to first order this is an acceptable approximation (ibid.). From equation (2.3) one can derive a correspondence between the heights h_E and h_M at which the same amount of mass has been ablated in Earth's atmosphere and in the assumed lunar atmosphere. We find,

$$h_M = (g_E/g_M)\, \{ H_0 \ln(g_E\, \rho_{0M} / g_M\, \rho_{0E}) + h_E \} \tag{2.4}$$

Once again, it has been assumed that H_0 is the same in each atmosphere. It follows from equation (2.4) that the meteor trail length, L, will be of order

$$L = h_{start} - h_{end} = (g_E/g_M)\, L_E \tag{2.5}$$

where L_E is the trail length in Earth's atmosphere and since $(g_E/g_M) \approx 6$, we obtain Öpik's result. In 1952, Öpik summarized the situation in his letter to Moore: "... the average duration of a meteor on the Moon will be two to three seconds. ... the average length of trail would be 75 miles [121 km] – and the meteors would therefore be very slow, short objects." (cited in Moore, 1984).

Equation (2.1) allows us to set a lower limit to the ratio (ρ_{0M} / ρ_{0E}) beyond which meteoroid ablation will not commence in any assumed lunar atmosphere. If $(\rho_{0M} / \rho_{0E}) < 10^{-7}$ then the density of the Moon's atmosphere will never exceed 10^{-7} kg/m^3, and consequently vigorous ablation will not occur. (Meteoroid ablation begins at a height of about 100 km in Earth's atmosphere, where the atmospheric density is of order 10^{-7} kg/m^3.) Most importantly, the lower limit to (ρ_{0M} / ρ_{0E}) establishes an observational constraint. If the observations reveal a ratio less than 10^{-7}, lunar meteors should not exist.

When Crommelin addressed the issue of lunar meteors in 1921, the available observations set a lower limit of about 10^{-4} to the ratio (ρ_{0M} / ρ_{0E}). Russell *et al.* (1926:170-171) state that, "... an atmosphere 10,000 times thinner than the earth's illuminated by full sunlight, would be more conspicuous than the dark part of the moon when lighted by the full earth." They did not suggest what the lower limit to (ρ_{0M} / ρ_{0E}) might be. In 1938, La Paz argued that an examination of the literature suggested $10^{-5} < (\rho_{0M} / \rho_{0E}) < 10^{-3}$. These early constraints were mostly based upon the non-detection of lunar atmospheric refraction, and from the supposed detection of twilight prolongations of the Moon's cusps (Pickering, 1892).

It was realized in the early 1940s that if the Moon actually had an atmosphere then the sunlight reflected to Earth, when the Moon was near first or third quarter phase, should be polarized. The presence, or not, of a lunar atmosphere could be established, therefore, upon the detection of a polarization component in the Moon's light. One of the first lunar polarization studies to be published was that by Fessenkoff (1943) where an upper limit of $(\rho_{0M} / \rho_{0E}) < 10^{-6}$ was established. The allowable upper limit to (ρ_{0M} / ρ_{0E}) was, however, pushed to lower and lower values by more and increasingly-refined polarization studies. In 1952 the French astronomer Andouin Dollfus was able to set an upper limit of $(\rho_{0M} / \rho_{0E}) < 10^{-9}$ and with this constraint he technically ruled-out the possibility of lunar meteors. Commenting upon the new results by Dollfus (1952), Öpik (1952) wrote, "... if this is correct, the lunar atmosphere would present no obstacle to the motion of meteors; these, including the smallest 'micro-meteors', would penetrate the lunar atmosphere un-hindered, and without perceptible luminous display before striking the ground." Interestingly, Öpik (1955) later argued that the upper limit to (ρ_{0M} / ρ_{0E}) could only be constrained to be less than 10^{-6}, allowing, once again, for the theoretical possibility of lunar meteors. In spite of Öpik's rather optimistic interpretation of the observations, subsequent studies have pushed the upper limit of the ratio (ρ_{0M} / ρ_{0E}) to less than 10^{-10}.

3 LUNAR METEORS

Many observers have reported seeing transient light phenomenon on the Moon. The compilation of anomalous lunar events collected by Corliss (1985) indicates that the majority of historic sightings involve the appearance of reasonably long-lived luminous 'spots'. Prior to the beginning of the twentieth century these transient lights were often interpreted in terms of volcanic activity.

It is interesting to note that Corliss finds a distinct dearth in the number of reported transient lunar events between 1902 to 1948. The reasons for the drop in apparent 'sightings' are probably many-fold. We speculate, however, that the decline in reports was related to the realization that the Moon was truly a geographically-dead world, and that its craters were not volcanic calderas. Corliss, however, is mistaken to say that no reports of 'strange' lunar events were made in the 46-year interval prior to 1948. Indeed, it was during the early 1940s that observers first reported seeing meteors against the Moon's disk. This observational activity coincides with the publication of the work of Lincoln La Paz (1938) in the widely-read magazine *Popular Astronomy*. It also coincides with the announcement of the first observational studies that suggested the Moon might, in fact, have a thin atmosphere.

During the early 1940s several members of the American Association of Lunar and Planetary Observers (ALPO) began conducting organized observational searches for lunar meteors. At that time the idea of such a study had great scientific merit; the unambiguous detection of lunar meteors would, for example, clearly indicate the presence of a lunar atmosphere. A null detection, on the other hand, would imply that the Moon had no or at least a very tenuous atmosphere. We note, however, that the null hypothesis is a rather vague one, given that it is not clear at what stage and at what level one could say it had been established.

The first published account of the sighting of a possible lunar meteor appears to be that by Walter Haas in 1943. Haas was then an observer at the University of New Mexico and editor of the *Strolling Astronomer*, the journal published by ALPO. Haas' account was based upon an observation made with a 6-inch telescope at near full Moon on 1941 July 10. His account reads: "I saw a tiny luminous speck move across the Moon's surface at a uniform rate ... The brightness was constant along the whole path, and the stellar magnitude was estimated to be +8. The duration was one second." By comparing the projected path across the Moon's disk with a lunar atlas, Haas estimated the trail length to be 63±10 miles (101±16 km).

After Haas' paper appeared in 1943, other sightings of lunar meteors followed. In 1948 Haas published a review and account of the lunar meteor statistics gathered by ALPO members (see Chant, 1948). Between 1941 and 1948 a total of ten lunar meteors had been recorded in 145 hours of observation. Haas wrote of the meteors observed that they, "... showed just the aspects which we would expect lunar meteors to exhibit" (cited in Chant, 1948). A summary of the lunar meteor observations is given in Table 1.

Of the 17 events listed in Table 1, three are described as flashes (all seen by the same observer) and these were interpreted as direct meteoroid impacts. The meteors that were recorded as moving had an average trail length of 52 ± 44 miles (we have excluded from this average the single observation by Schmidt since it is so discordant with the other estimates) and an average duration of 1.25 ± 0.75 seconds. The average visual magnitude of the observed meteors was +6.8 ± 2.7. We note that these averages

Table 1. Summary of candidate lunar meteors observed by ALPO members. The table is based upon data summarized by Haas (1947, 1952). The observer codes are 1: W. H. Haas. 2: R. G. Johnson. 3: C. P. Smith. 4: R. Schmidt. 5: L. T. Johnson. Note, L. T. Johnson reported a further three flashes, but gave no details as to their magnitude.

Year	Date (UT)	Trail Length (mile)	Duration (sec.)	Visual Magnitude	Observer
1941	July 10.24	63	1	+8	1
1942	Aug. 24.15	18	0.3	4	2
1943	Feb. 20.10	144	0.75	4	3
1943	Feb. 20.14	22	0.5	8	1
1944	May 5.17	15	1.5	7	1
1944	June 27.08	55	1	9	1
1944	Aug. 11.34	25	1.5	11	1
1946	June 10.10	500?	1	1	4
1946	June 22.10	35	1	8	1
1946	July 22.46	3	3	6	1
1951	Mar. 13.06	---	Flash	10	5
1951	Apr. 11.11	---	Flash	7	5
1951	May 9.07	---	1	---	5
1951	Sep. 28.46	80	---	---	5
1951	Oct. 26.37	---	Flash	6	5
1951	Oct. 26.40	110	2.5	---	5
1951	Nov. 4.99	---	2	---	5

do not tally with the numbers suggested by Öpik in his letter to Moore (see Moore, 1984), and we also note that Öpik appears to have either ignored or been unaware of the observations collected by ALPO.

The data collected between 1941 and 1946 were derived from 65.7 hours of systematic observing. The lunar meteors and flashes reported by L T Robinson in 1951 were recorded during 19 hours of lunar monitoring. The average detection rate for lunar meteors was apparently one event ever four hours. No month was favored for the sighting of lunar meteors, and only one lunar meteor was reported during the annual Perseid meteor shower (Haas; 1944, August 11). One might well expect, in fact, to see meteor flashes near the peak time of the Perseid shower since at that time the meteoroid flux is sizably enhanced at Earth and the meteoroid encounter velocity is high.

In his 1948 review of the available data on lunar meteors Haas argued that "... it is impossible to regard all the moving lunar specks as terrestrial meteors because of the extreme shortness of their paths" (cited in Chant, 1948). He also noted that "... the specks grow more common with decreasing brightness until we reach those so dim that most of them go unobserved. Our possible lunar meteors in this respect resemble terrestrial meteors" (ibid.).

At the outset of the lunar meteor programme Haas argued that the search would either reveal that the Moon had no atmosphere, in which case only impact flashes would be seen, or, that the Moon supported an atmosphere capable of producing luminous meteoric-streaks (Haas, 1943). By 1947, when he published his review in *Popular Astronomy*, Haas was faced with the potential problem that 17.5% of the observed events were flashes. In the observing time amassed by the ALPO observers, one would not expect to see so many 'face-on' meteors in the Moon's or, for that matter, Earth's atmosphere. Haas put a great deal of weight behind his own observations of luminous streaks – the indicators of a lunar atmosphere – and writing somewhat defensively in 1947, he commented (Haas, 1947),

> I feel as certain of the reality of the 7 specks that I recorded as I do of the reality of a third-magnitude terrestrial meteor observed with the naked eye under favorable conditions

Only one of the meteors that Haas recorded, however, was actually seen under conditions that were described as 'good'. The other observations were made when the conditions were described as being 'rather poor', 'poor' or 'fairly good'. The comments by Haas in 1947 are a far cry from those he made in 1943, when he pointedly noted, "... in seeking to explain such surprising appearances, one must bear in mind the possibility of illusion" (Haas, 1943:398).

Towards the close of the 1940s we begin to see a parallel developing between the apparent observation of lunar meteors and Percival Lowell's supposed and staunchly-defended observation of Martian canals (Sheehan, 1988), and with W F Denning's supposed detection of stationary meteor radiants (Beech, 1991). The parallel is one in which respected and experienced observers, who genuinely believed in the reality of their observations, continue to record events that were increasingly at odds with main-stream theory and practice. The adopted stance is essentially one of "I see it, therefore it is." This pragmatic, somewhat naïve approach can occasionally be a useful one to adopt, but it is also one that requires extra special examination. There is a fine distinction between the act of recording a genuinely-new phenomenon in low quality data and the act of unconsciously molding the observations, made under difficult conditions, to 'fit' some pre-supposed ideal. Indeed, Denning essentially realized this problem with respect to planetary observations, although he apparently did not see it as a problem when it came to meteor observations. For example, in discussing the supposed telescopic observation of faint surface features on the planet Saturn, Denning (1895) wrote:

> There is a distinct line of demarcation between what is absolutely seen and what is possibly seen or suspected. An object may only be glimpsed, and yet it is certainly seen. ... but with some objects the experience is different ... they flit about like an *ignis fatuus*, and are intractable to our utmost efforts. Obviously in such a case the observer has but one alternative, and that is to regard the objects as imaginary.

Denning is without doubt correct in his summation, but history appears to abound with observers who failed to follow his edict.

When the ALPO observers embarked upon their search for lunar meteors it was theoretically possible that they might actually record such events. And, indeed, by the close of their programme in the early 1950s the ALPO observers had recorded, all in good faith, a sizable number of lunar meteor candidates. In the meantime, however, the theoretical underpinning of their work had been completely eroded. The polarization studies conducted by Dollfus, and others, had placed such a low upper density limit on any possible lunar atmosphere that meteoroid ablation would not be expected. In short, lunar meteors were no longer tenable as reasonable theoretical entities by circa 1950. The collapse of the theoretical argument, however, does not explain why the ALPO observers actually 'saw' lunar meteors. We contend, however, that it was the philosophical parallel that distorted the observers' objectivity. From the outset of their study the ALPO observers knew that lunar meteors were theoretically possible, and consequently they started looking for events that resembled the theoretical expectation. In this way we contend the 'strange' and 'odd' sightings that would have been previously ignored (as presumably physiological in origin) were accredited the status of 'real' lunar events. And further, once one observer has reported seeing a certain phenomenon, it is then easier for other observers to believe that they are 'seeing' similar events. Sheehan (1988) describes a parallel situation with respect to Giovanni Schiaparelli's observation of Martian canals. Otto Struve, for example, is quoted as writing that it was a challenge to other observers to find them [Schiaparelli's canals] "... now that they knew they were there." (cited in Sheehan, 1988:124).

With the collapse of the 'theoretically possible' argument for the potential existence of lunar meteors, a second problem arose. The observers were left with a 'well-stocked' catalogue of events that had no apparent explanation. Under these circumstances one can either 'dig-in' and continue to claim that the events are real and "theory be damned" or one can just let the subject drop. It is this latter option that was ultimately adopted, but even so, sightings of lunar meteors were reported well into the 1950s.

4 DISCUSSION AND CONCLUDING REMARKS

The confusions of the philosophical parallel may flourish in any situation where theoretical precedent leads observation. It will especially flourish when the observations are difficult to collect and when they are made under less than idea conditions. This is the situation with respect to the apparent detection of lunar meteors.

Not only were the lunar meteor sightings made under mostly poor-observing conditions (according to the observers' notes), but initially at least the observers had two 'theoretical props' upon which to promote their work. Firstly, the Moon is continually subject to impacts by meteoroids – there is no question that this must be the case. And second, the available measurements could not rule out the presence of a lunar atmosphere in which luminous meteoric phenomena might be observed. Not only this, while it would seem that the motives of the observers were entirely genuine, it would appear that they did not expect to fail in their endeavours. In other words, they did not apparently allow for the possibility that no luminous events might be seen. As Haas (1943) argued, one would see either 'flashes' or 'luminous meteors.' There is no mention of the possibility of not seeing anything. Indeed, Haas addressed the question as to why so few observers had reported seeing lunar meteors and commented, "... an observer not mindful of the possibility of lunar meteors would be likely to attach little importance to their appearance" (Haas, 1947:272). This statement is, from our perspective, a pure distillation of the philosophical parallel.

Even when the theoretical support for the possible detection of luminous meteors was removed, the observers of lunar events could still cling to the unshakable argument that the Moon is continuously subject to meteoroid impacts. However, even then, their observations are not consistent with the measured meteoroid flux at one astronomical unit from the Sun. To see that this is the case we can make use of the flux model of Halliday *et al.* (1984). If we assume that the Moon encounters essentially the same meteoroid flux as Earth and consider a target area equal to half that of the Moon's surface (the visible area as seen from Earth), then the number N of meteoroids of mass greater than m(kg) that impact the Moon per year will be of order

$$\text{Log } N = -0.69 \text{ Log}(m) + 2.97 \tag{4.1}$$

In (4.1) we have simply adjusted the meteoroid flux derived by Halliday *et al.* (1984) to a surface area appropriate to the visible disc of the Moon. So, for example, we would expect 933 impacts per year on the Moon's visible disc from meteoroids of mass $m(\text{kg}) \geq 1$. We noted in section 3 that the implied lunar meteor event rate was 1 per 4 hours of observation. This rate is equivalent to the meteoroid flux at $m(\text{kg}) \geq 0.29$. In Earth's atmosphere a 0.29 kg meteoroid would produce a meteor of peak visual brightness of –5, assuming an initial atmospheric velocity of 20 kms^{-1}. Meteoroids of the same mass but with higher velocities will produce even brighter meteors. If the Moon had an atmosphere, a 0.29 kg meteoroid would produce a meteor of peak visual magnitude about +13 when viewed from Earth. The range of reported lunar meteor magnitudes varied from +10 to +1 (see Table 1), with an average of +7. Clearly, the implied large meteoroid flux at the Moon is much greater than that observed at Earth, and this is not what we would expect.

Direct evidence for meteoroid impacts upon the Moon's surface has been recorded with the Apollo lunar seismometer network. Duennebier *et al.* (1976), for example, have described the occurrence of 'meteor' storms on the Moon (signified by periods of enhanced meteoroid impact activity), while Oberst and Nakamura (1991) have discovered the existence of meteoroid impact clusters that coincide with the times of maximum of annual meteor showers on Earth. None of these impacts, however, was linked to optical transients, but this was no doubt because no one was looking for such a correlation. It should, in fact, be noted that optical transients resulting from large meteoroid impacts on the Moon's surface are to be expected occasionally, and indeed, may yet be unambiguously detected with video-tape recording equipment (Beech and Nikolova, 1999). In this respect, we also note that some of the 'flash' phenomena reported by L T Johnson (see Table 1) may have been genuine impact events.

Lunar meteors are not the only luminous phenomena to be reported by selenographers. Transient Lunar Phenomena (TLPs) have been reported on numerous occasions throughout history (Middlehurst and Moore, 1967), and while these remain a largely unexplained phenomenon they do represent a bona fide lunar mystery, distinct from that of lunar meteors (Hughes, 1980, and Cameron, 1991). Also, the observed rate and observational characteristics of TLPs make them quite distinct from the observational 'qualities' ascribed to lunar meteors.

In conclusion, the lesson to be learned from the 'observed' yet non-existent lunar meteors is a simple, yet important one. Indeed, the issue highlights an essential human quality in the often de-humanized workings of science. The lesson is this: biased by a priori theoretical argument, observers can in all honesty record the desired theoretical ideal, and, as the lunar meteor narrative illustrates, astronomers can sometimes 'see' impossible things. We suggest that this effect be called the 'philosophical parallel'.

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Note added in proof:

Observations of possibly six lunar impacts were reported during the 1999 Leonid meteor storm. Captured on video tape, the transient light flashes that accompanied the propounded meteoroid impacts lasted about one thirtieth of a second and two were as bright as magnitude three.

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Refining the astronomical unit: Queenstown and the 1874 transit of Venus

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Abstract
The 1874 transit of Venus was regarded as a major event which promised to produce an improved value for the solar parallax and hence the astronomical unit. As a result, the United States dispatched eight different observing parties to far northern and southern hemisphere locations. This paper documents the activities at the Queenstown transit station in the South Island of New Zealand and examines the scientific outcome of the overall American 1874 and 1882 transit programmes. It also mentions other New Zealand-based observations of the 1874 transit, and traces the early development of astronomical photography in New Zealand at a time when this innovative methodology was emerging internationally as a valid tool of the 'new astronomy', astrophysics.

Keywords: *1874 transit of Venus; solar parallax; astronomical unit; Queenstown; S Newcomb; W Harkness; C H F Peters*

1 INTRODUCTION

One of the fundamental yardsticks in astronomy is the astronomical unit (AU). During the eighteenth century, the opportunity to use transits of Venus to determine the AU prompted a number of nations to dispatch expeditions to the far corners of the globe (see Orchiston, 1998; van Helden, 1995; Woolf, 1959). The 1761 and 1769 transits produced conflicting results, with solar parallax values ranging from 8″. 28 to 10″. 60, and although a smaller spread characterized the latter transit (see Table 1), greater precision was desired. This led to a focus on the next pair of transits, in 1874 and 1882 (e.g. see Dick, Orchiston and Love, 1998; Forbes,1874; Grant, 1874; Janiczek and Houchins, 1974; Meadows, 1974; Proctor, 1874), and "Every country which had a reputation to keep or to gain for scientific zeal was forward to co-operate in the great cosmopolitan enterprise ..." (Clerke, 1893:289).

As a consequence, in 1874 the United States, England, France, Germany, and Russia dispatched observing parties to selected sites widely separated in latitude and longitude. In addition, Italy also funded three observing parties, and Holland one. These expeditions represented one of the first major international scientific collaborations, and occurred at a time when photography was beginning to impact on astronomy (Lankford, 1984, 1987; Norman, 1938), but they were plagued by controversy over instrumentation and methodology.

Table 1: Solar parallax values

Source	Date	Method	Parallax (")
Pingré	1770	1769 transit of Venus	8.88 ± 0.05
Lalande	1771	1769 transit of Venus	8.55 – 8.63
Encke	1835	1761 & 1769 transits of Venus	8.57116 ± 0.0371
Gillis & Gould	1856	Meridian parallax of Mars	8.495
Powalky	1864	1761 & 1769 transits of Venus	8.83
Hall	1865	Meridian parallax of Mars	8.842
Newcomb	1867	Meridian parallax of Mars	8.855
Stone	1868	1761 & 1769 transits of Venus	8.91
Todd	1881	U.S. 1874 transit of Venus	8.883 ± 0.034
Obrecht	1885	French 1874 transit of Venus	8.81 ± 0.06
Harkness	1889	U.S. 1882 transit of Venus	8.842 ± 0.0118
Newcomb	1891	1761 & 1769 transits of Venus	8.79 ± 0.051
Harkness	1894	ystem of constants	8.809 ± 0.0059
Newcomb	1895	System of constants	8.800 ± 0.0038
Spencer Jones	1941	Eros campaign	8.790 ± 0.001
IAU	1976	Radar	8.794148 ± 0.000007

Positional astronomy had long been the research focus of the U.S. Naval Observatory, and it is only natural that it was charged with overseeing the two nineteenth century American transit programmes. The 1874 programme involved eight different stations (Figure 1): Vladivostok in far eastern Russia; Nagasaki in Japan; Peking in China; the Chatham Islands (New Zealand territory to the east of the mainland); Queenstown in the South Island of New Zealand; Hobart and Campbell Town in Tasmania; and Kerguelen Island in the southern Indian Ocean. This paper is about the Queenstown station, its contribution to the overall American programme, and the place of the 1874 transit in the evolution of astronomy in New Zealand.

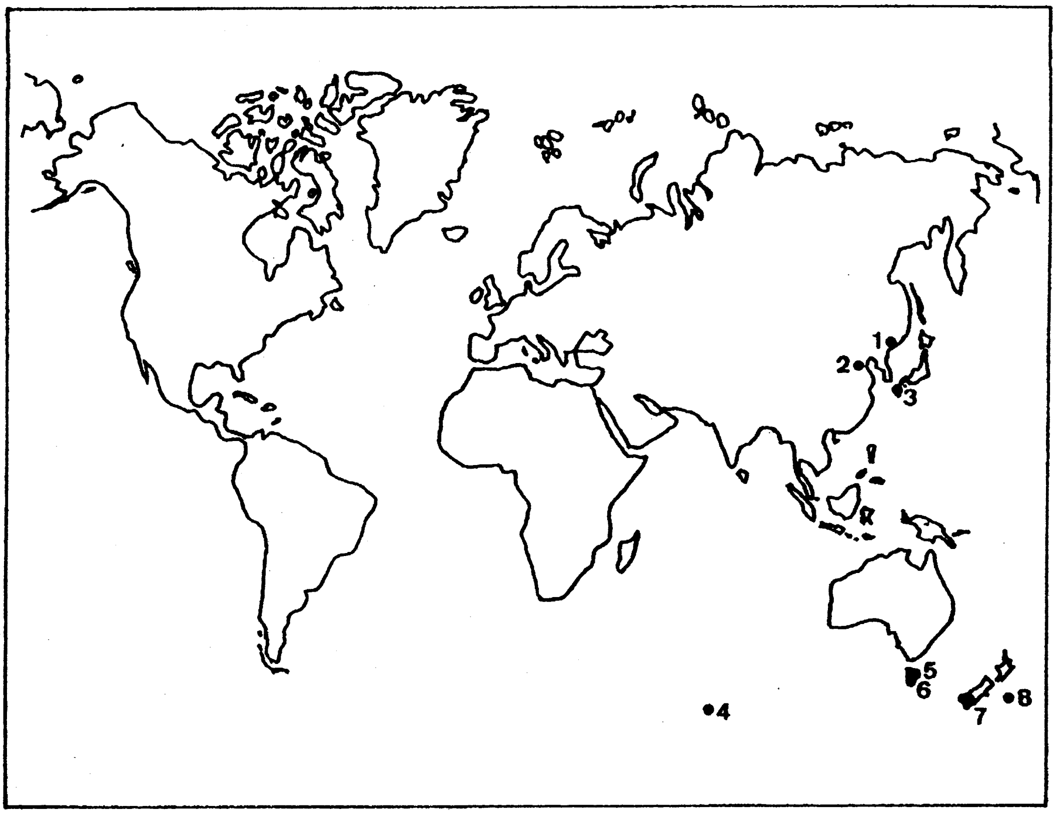

Figure 1. Locations of U.S. 1874 transit of Venus observing stations: 1 Vladivostok; 2 Peking; 3 Nagaski; 4 Kerguelen Island; 5 Campbell Town; 6; Hobart; 7 Queenstown; 8 Chatham Islands.

2 INSTRUMENTATION

The American transit of Venus programme was planned, initiated, and implemented by a special Commission which was created by Congress in 1871. Dominating the Commission were U.S. Naval Observatory personnel, one of the most influential of whom was Simon Newcomb, Professor of Mathematics at the Observatory. Newcomb was destined to become a leading figure in American astronomy (see Archibald, 1924; Newcomb,1903).

The first challenge of the Commission was to decide on the instrumentation, and for this they had to choose between visual and photographic observations. Although they decided to adopt both, photography was to play the leading role. It was then a matter of selecting the type of photographic telescope, and two basic designs were considered: the equatorially-mounted heliograph developed by de la Rue and used by the British transit parties, and the fixed horizontal solar telescope first conceived by Winlock and successfully used at the Harvard College Observatory. The Commission chose the latter, and Newcomb decided that two discrete series of photographs would be taken: of the ingress and egress contacts, and of Venus superimposed on the disk of the Sun during the transit.

The Commission then finalized the instrumentation to be issued to each observing party. It comprised: the photographic telescope, a standard refracting telescope, a transit telescope, a sidereal clock, three box chronometers, a chronograph, five thermometers, a barometer, and equipment for measuring terrestrial magnetism.

The principal research instrument was the photographic telescope, or photoheliograph (see Newcomb, 1880 for details). Vital was the 203-mm square brass photographic plate holder (Figure 2a), which was mounted on a solid metal pier. Permanently cemented into the plate holder was a transparent sheet of plate glass about 7.6 mm thick,

> ... divided into small squares by very fine [etched] lines about one-five-hundredth of an inch thick ... the sensitive plate goes into the other side of the frame, and when in position for taking the photograph, there is a space of about one-eighth of an inch between the ruled lines and the plate. The former are, therefore, photographed on every picture of the sun which is taken, and serve to detect any contraction of the collodion film on the glass plate. (Newcomb, 1887:189).

Also attached to the plate holder was a plumb line, which was used to indicate vertical on each of the photographs. A simple, prefabricated flat-roofed, wooden 'Photographic House' housed the plate-holder, and contained facilities for preparing and developing the photographic plates.

Twelve metres away from the Photographic House, in the open air, was a second metal pier supporting a 178-mm unsilvered glass heliostat mirror (which captured the rays of the Sun) and a 127-mm objective (which focussed the light on the photographic plate). The heliostat tracked the Sun with the aid of a weight drive (see Figure 2b). If it was deemed necessary, a temporary cover could be erected to shelter the heliostat and drive. Between the heliostat and the plate-holder was a measuring rod which was used to accurately determine the focal length of the telescope, a key element in establishing the plate scale. The measuring rod was supported by a wooden framework, and was protected by a narrow 'roof'. This roof also covered a tube which extended about 4 m from the Photographic House and through which the light from the heliostat passed. An image of the Sun about 108 mm in diameter was formed. Four thermometers and a barometer were generally housed in the Photographic House to monitor variations in environmental conditions. The overall arrangement of the photographic telescope is shown in Figure 3.

In order to visually monitor the transit and obtain precise micrometric measures of Venus on the Sun's disk, each transit party was supplied with a 127-mm (5-inch) *f*/14 refracting telescope manufactured by Alvan Clark, America's leading nineteenth

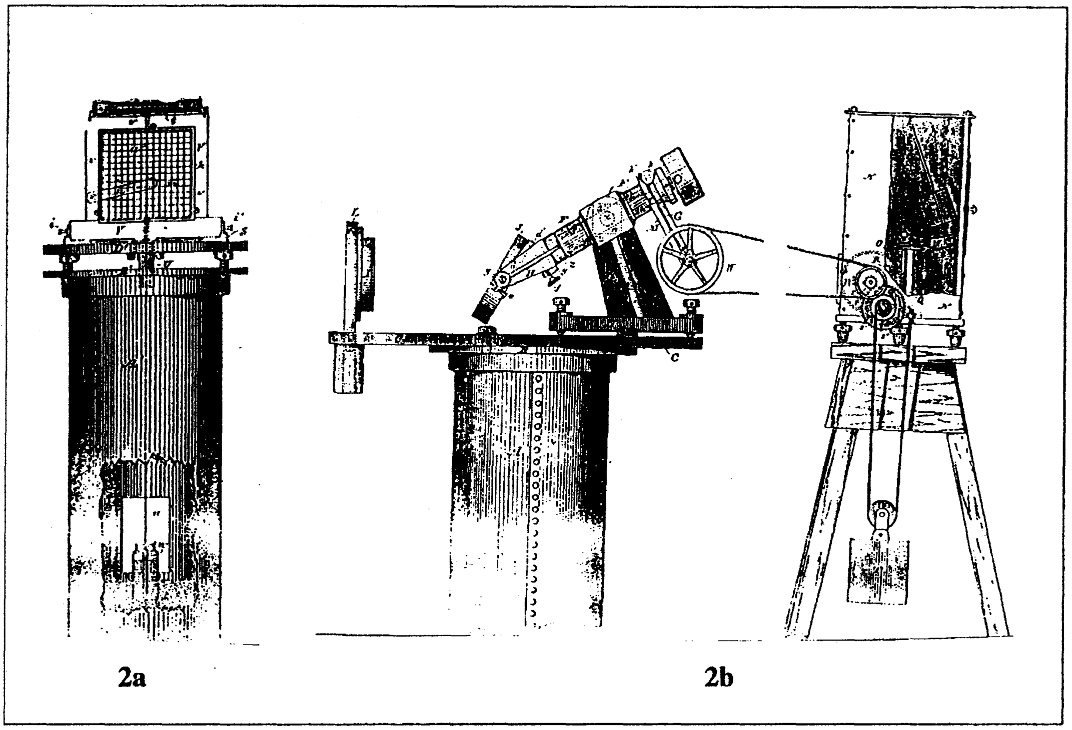

Figure 2. Photographic telescope design (2a: plate-holder; 2b: heliostat and drive)

century telescope-maker (see Warner and Arial, 1996). This instrument (Figure 4) was supported by a solid metal pier rather than a tripod, and was supplied with a German equatorial mounting, circles, a weight drive, slow-motion controls, and the all-important double-image micrometer. Protecting the refractor from wind and inclement weather was a prefabricated, wooden, octagonal observatory of 3 m diameter, with a rotating conical roof containing a single hinged shutter. Those involved in the transit expeditions generally referred to this observatory as the 'Equatorial House'.

Accurate time-keeping was paramount for the success of the venture, and so each transit station was supplied with an astronomical clock. All of the clocks were built by the Howard Clock Company of Boston, and because they were designed for long and difficult journeys to the observing stations they were not particularly elegant (Newcomb, 1880:14-15).

Each station also was provided with a transit instrument, which was used to regulate the clock. These transit telescopes had an aperture of 63.5 mm and were manufactured by Stackpole Brothers. They were of the 'broken tube' construction,

> ... a prism being placed in the center of the tube, by interior reflection from which the pencil rays is [*sic*] thrown along the axis; and the image is thus formed at the end of the latter... This form of instrument has the great advantages of convenience in observing and rapid and easy manipulation, but is still subject to the disadvantages of collimation varying with zenith-distance of the object observed. (Newcomb, 1880:14).

This unusual type of transit telescope is shown in Figure 5, and was mounted on a solid brick foundation capped by a stone slab. Protecting it from the elements was a simple, prefabricated, wooden 'Transit House', with a sloping roof and an observing shutter aligned north-south which could be readily removed to reveal a strip of sky. This building was located near the heliostat so that it could also be used to accurately

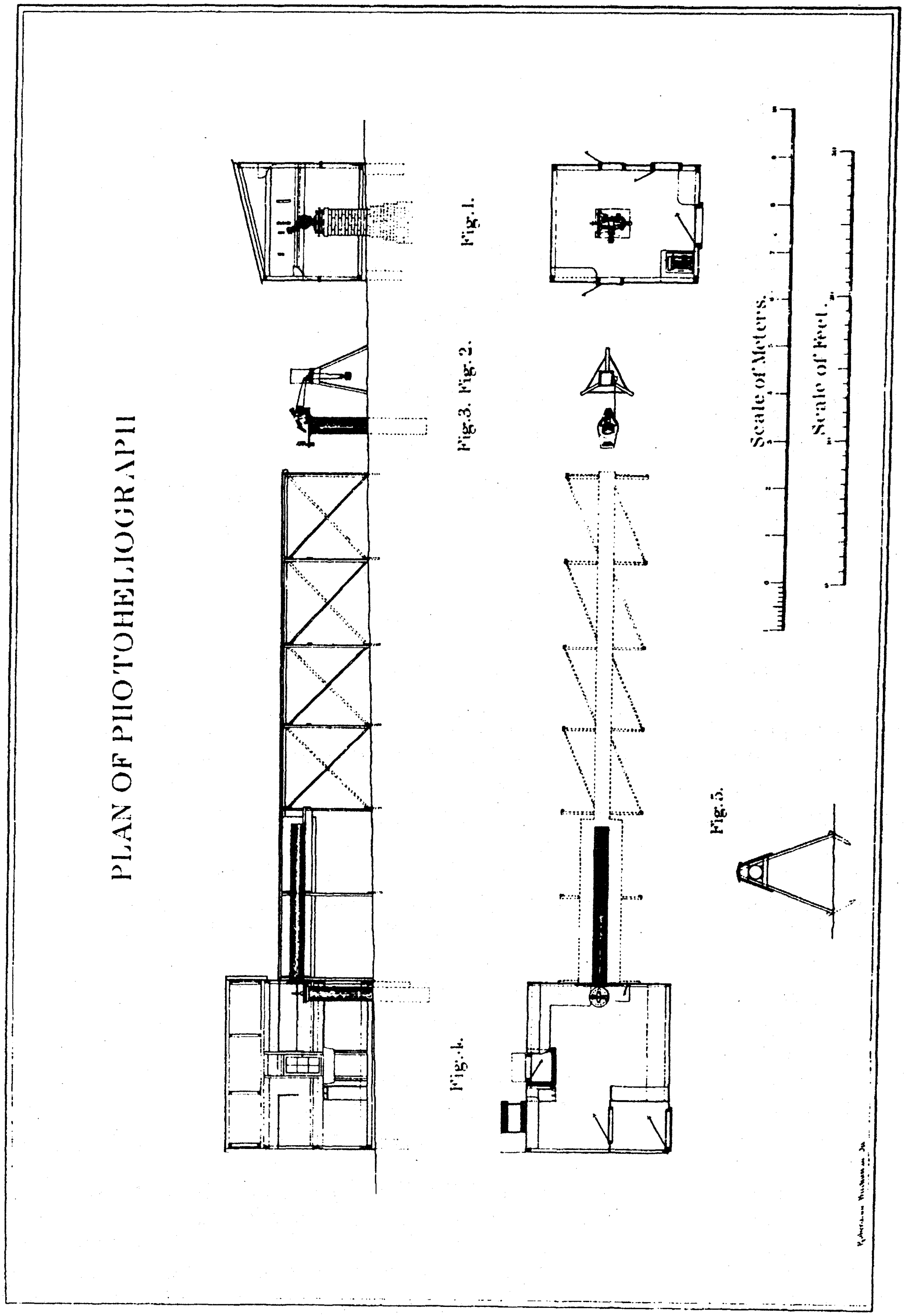

Figure 3. Overall arrangement of the photographic telescope (top: side elevation; bottom: plan)

align the photographic telescope north-south (see Figure 3). One thermometer was normally kept in the Transit House. In addition to its time-keeping role, the transit telescope was used for latitude and longitude determinations.

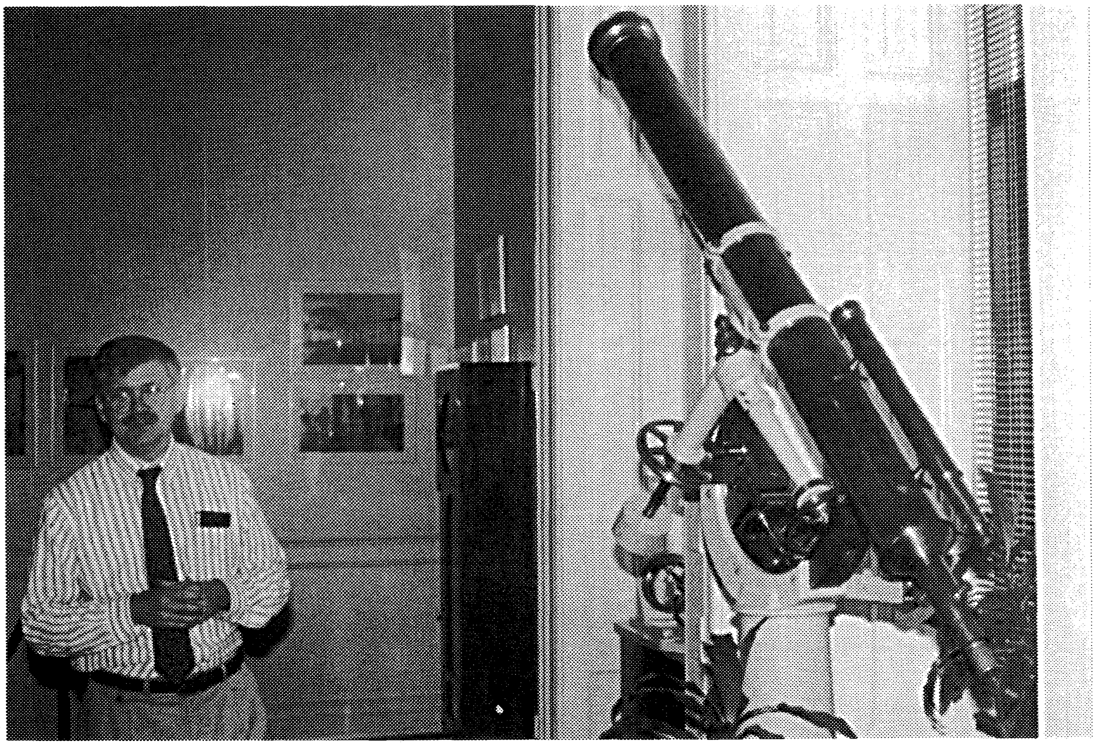

Figure 4. Steven J Dick with one of the 127-mm Alvan Clark refractors.

In order to accommodate these assembled instruments, a transit station required a nearly level north-south site about 25 m in length offering a firm foundation, protection from the winds, and a clear view of the Sun for the entire duration of the transit (Commission ..., 1874).

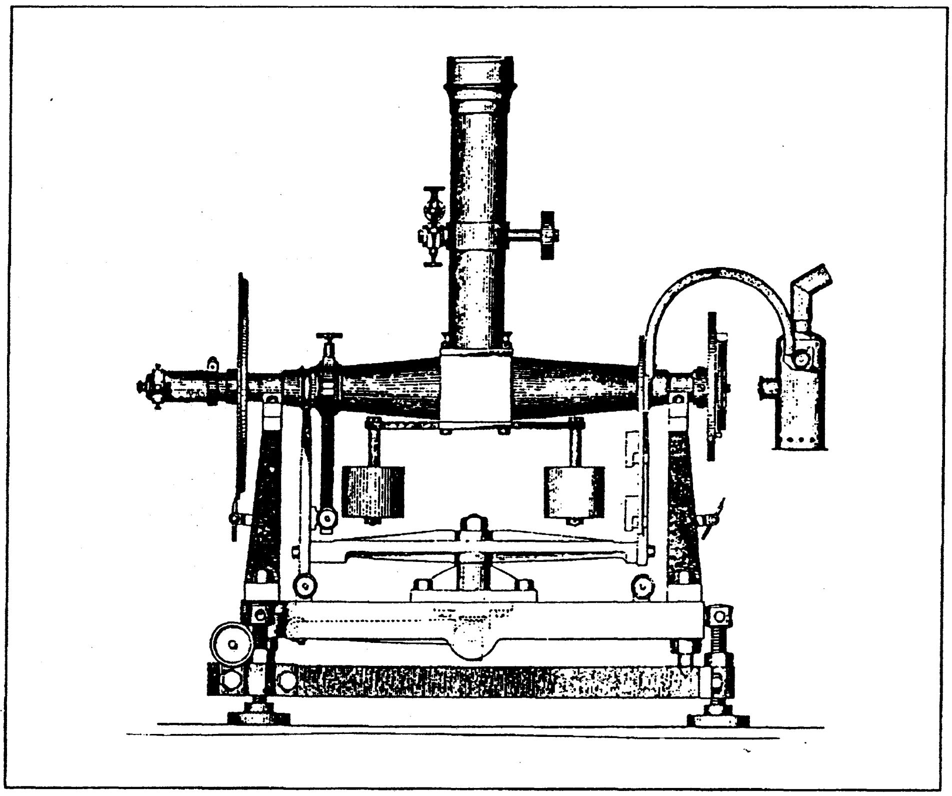

Figure 5. The 'broken tube' transit telescope

3 QUEENSTOWN, AND THE NEW ZEALAND OBSERVING PARTY

Each American transit party normally consisted of a Chief Astronomer and Assistant Astronomer, who were responsible for visual observations and the time-service, respectively, and three or four photographers (Herman, 1984:38). The Chief Photographer was always a professional photographer, while the Assistant Photographers were typically "... young gentlemen of education, recent graduates of different colleages, who had been practised in chemical and photographic manipulation." (Newcomb, 1880:16).

Leading the New Zealand party was C H F Peters (Figure 6), Professor of Astronomy at Hamilton College, New York, and Director of the College's Litchfield Observatory (Sheehan, 1998). Christian Heinrich Friedrich Peters was born at Coldenbüttel, Schleswig, in Denmark (now Germany) on 1813 September 19. He studied mathematics and astronomy at the University of Berlin, completing his Ph.D. in 1836. In 1854 he emigrated to the United States, and after working with the U.S. Coast Survey and at the Dudley Observatory he was appointed to the Hamilton College post in 1858. One of Peters' interests was solar astronomy, and he also searched – with considerable success – for new minor planets (see Ashbrook, 1984; Baum and Sheehan, 1997).

Figure 6. Christian Heinrich Friedrich Peters, 1813-1890
(Photograph courtesy Hamilton College)

The Assistant Astronomer was Lieutenant E W Bass from the U.S Corps of Engineers. After the voyage he was promoted to Lieutenant-Colonel, and became Professor of Mathematics at West Point. Peters was extremely happy with Bass' performance, as the following concluding remarks in his report indicate:

> ... it is my pleasant duty to mention still another circumstance that contributed not a little to the good work that the New Zealand party can show. The companionship of Lieutenant E.W. Bass (now lieutenant-colonel and professor of higher mathematics at West Point) was a most happy one. It is impossible to separate what in the work belonged to each of us, and when in the foregoing pages I have spoken in the plural I include the assistant astronomer. Our judgement agreed almost even in the minute particulars, so that we formed one head with four hands, and, if I may say so, a double brain. (Peters, 1881:548).

Completing the Queenstown party were four photographers: C L Phillippi (Chief Photographer), I Russell (First Assistant Photographer), E B Pierson (Second Assistant Photographer) and L H Aymé (Third Assistant Photographer). Phillippi was a professional photographer (from Philadelphia); Russell and Aymé were college students. Assisting the photographers was a local volunteer named Beckett, who just happened to be from the USA (Peters, 1881). Figure 7 shows members of the Queenstown party (minus Mr Beckett) assembled at the U.S. Naval Observatory prior to their departure for New Zealand.

On 1874 June 8 the U.S. man-of-war *Swatara* sailed from New York with the five southern hemisphere transit parties, and proceeded to the Indian Ocean, via Bahia in Brazil and Cape Town. On September 7 Kerguelen Island was reached, and the first of the observing parties was dropped off. Subsequently, two parties disembarked at Hobart (see Orchiston and Buchanan, 1991 for an account of one of these), and the *Swatara* then headed for New Zealand, anchoring at Bluff Harbour on October 16 (see Figure 8).

There Peters was met by Bass, who had arrived in New Zealand several weeks earlier in order to finalize a suitable site for the transit station. Initially, the Americans had planned to install their South Island transit station at Bluff, a convenient coastal location, but the Hon. J T Thompson (President of the Otago Academy) and James McKerrow (Chief Surveyor of the Province of Otago) counselled Bass against this. Instead, they suggested a site in central Otago, an elevated inland area known in summer for its warm temperatures and clear sunny skies (Peters, 1881:439). After considering various options, Bass selected Queenstown on the shores of Lake Wakatipu, 320 m above sea level (see Figure 9 for New Zealand localities mentioned in the text). In hindsight, this was to prove a particularly astute decision.

The New Zealand Government supported the US transit project by freighting the boxes of equipment free of charge to Winton. After being off-loaded from the train, they were taken to Kingston by wagon while the transit party travelled by stage coach. The last short leg of the journey from the southern tip of Lake Wakatipu to Queenstown was by steamer, and Peters' party reached its final destination on October 23 (Peters, 1874a), six and a half weeks before the transit. This may appear to be an unreasonably long lead-in period, but a great deal of preparation was necessary before the 'grand event' (see Bass, 1874; Newcomb, 1880; Peters, 1874a, 1881).

On October 24 the astronomers pinpointed a suitable observing site on an old terrace surface 408 m above the lake and about 0.8 km east of the centre of town (Figure 10). There were already a few houses scattered about in the general vicinity, and Peters (1881:516) noted that streets and sections had been laid out, anticipating the future growth of Queenstown. The transit party proceeded to mark out a 24.4 m by 12.2 m enclosure on Melbourne Street, and erect a perimeter fence.

Then began the busy schedule of setting up a functioning transit station. This involved assembling the prefabricated buildings they had brought; installing and adjusting the various scientific instruments; conducting observations for latitude, longitude and time; and practising the photographic procedures to be followed on the day of the transit. Fortunately Newcomb had provided the necessary detailed instructions for all of the observing parties (see Commission ..., 1874). On October

26, the *Otago Daily Times* (1874) reported that the station had been connected to the local telegraph. The first observations with the transit telescope were obtained on October 30, the Alvan Clark telescope came into operation on November 5, and the first experimental plates were exposed with the all-important photographic telescope on November 14. By November 24 the photographers were ready to commence their 'practice drill', in preparation for the December 9 transit. Peters (1881:472) noted that in the course of these preparations daytime temperatures were rather pleasant, but at night "... during observing hours, the air was sometimes very chilly."

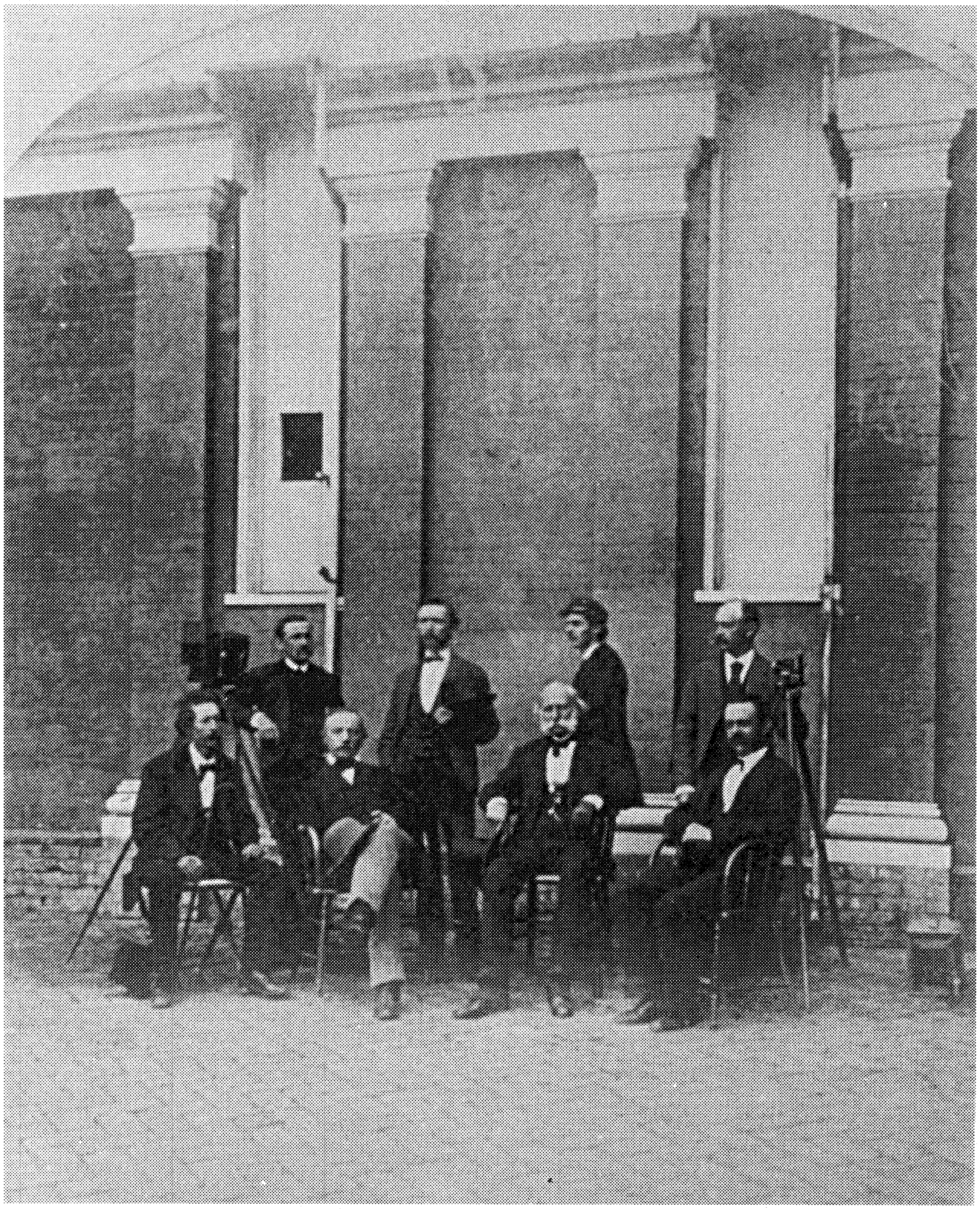

Figure 7. New Zealand transit of Venus observing party and *ex officio* members. Seated (left to right): C.L. Phillippi (Chief Photographer), Professor C.H.F. Peters (Chief Astronomer), Admiral C.H. Davis (President, U.S. Tranit of Venus Commission), Professor H. Draper. Standing (left to right): I. Russell (First Assistant Photographer), E.B. Pierson (Second Assistant Photographer), L.M. Aymé (Third Assistant Photographer), and Lieutenant E.W. Bass (Assistant Astronomer) (Photograph courtesy U.S. Naval Observatory)

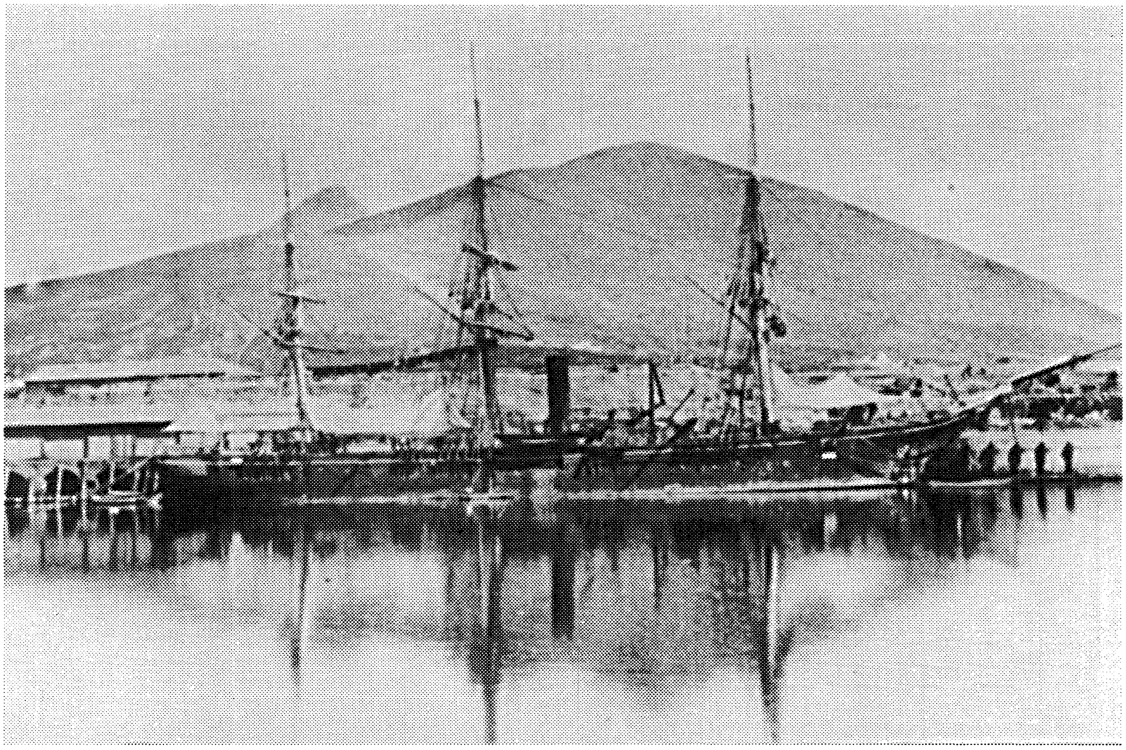

Figure 8. The *Swatara* anchored in Bluff Harbour (Photograph courtesy Hocken Library)

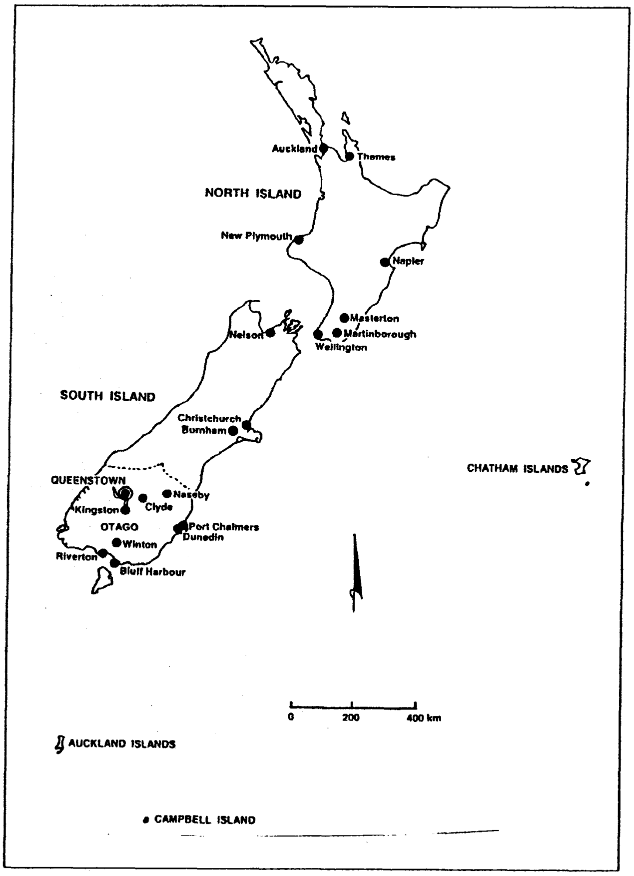

Figure 9. New Zealand localities mentioned in the text

Figure 11 shows part of the completed transit compound, and a plan of the total transit station is reproduced in Figure 12. The specific instruments assigned to the Queenstown transit party are listed in Table 2 (after Newcomb, 1880; Peters, 1881).

Knowledge of the precise location of the transit station was critical, and twenty pairs of stars almost equal distances from the zenith were used to determine the latitude. The first observations were made on November 12, and further observations followed on November 13, 14, 20, 21, 28, 29, and 30 (Peters, 1881:500-509). Meanwhile, the clock had been set up on November 18, and on the 25th time signals were exchanged with the British transit party at Burnham, near Christchurch, in order to establish the longitude of the Queenstown site. Further exchanges with Burnham took place on November 27 and 30, and on December 2. In addition, on December 5, 8 and 28 signals were exchanged with the Rockyside Observatory near Dunedin where McKerrow and Thompson were based; with the *Swatara* on November 2 and December 27, while it was temporarily anchored at Port Chalmers; and with the *Alexandrine* (the German Auckland Islands transit party's vessel) on December 17 and

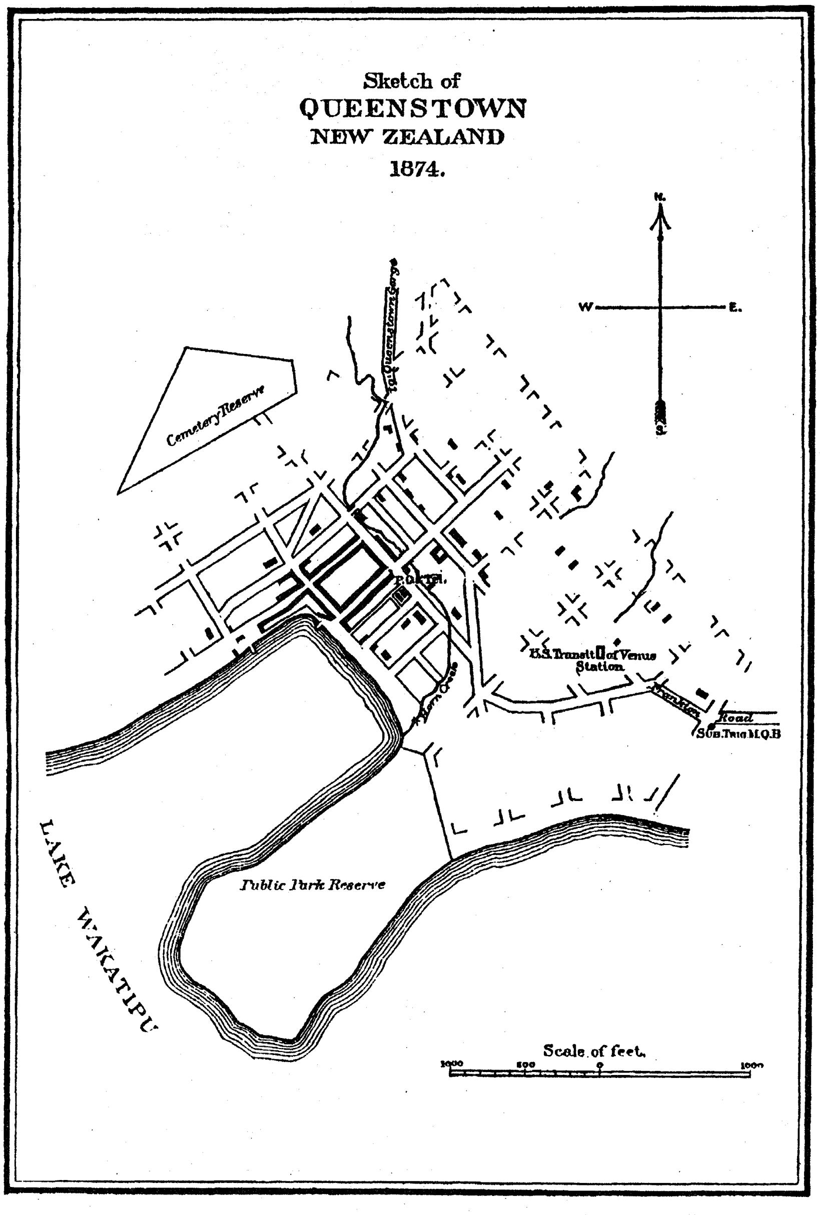

Figure 10. Location of the Queenstown transit station, east of the centre of town

19, while it was in Bluff Harbour (see Peters, 1881:479-499). Apart from the various telegraphic exchanges, Peters (1881:496) lamented that "... we were able to observe only a few occultations and no more than two moon culminations." The derived co-ordinates of the site (after Peters, 1881:499,550) were:

Latitude	45° 02′ 08″.10 ± 0.14 S
Longitude	$11^h\ 14^m\ 40^s.4$ E

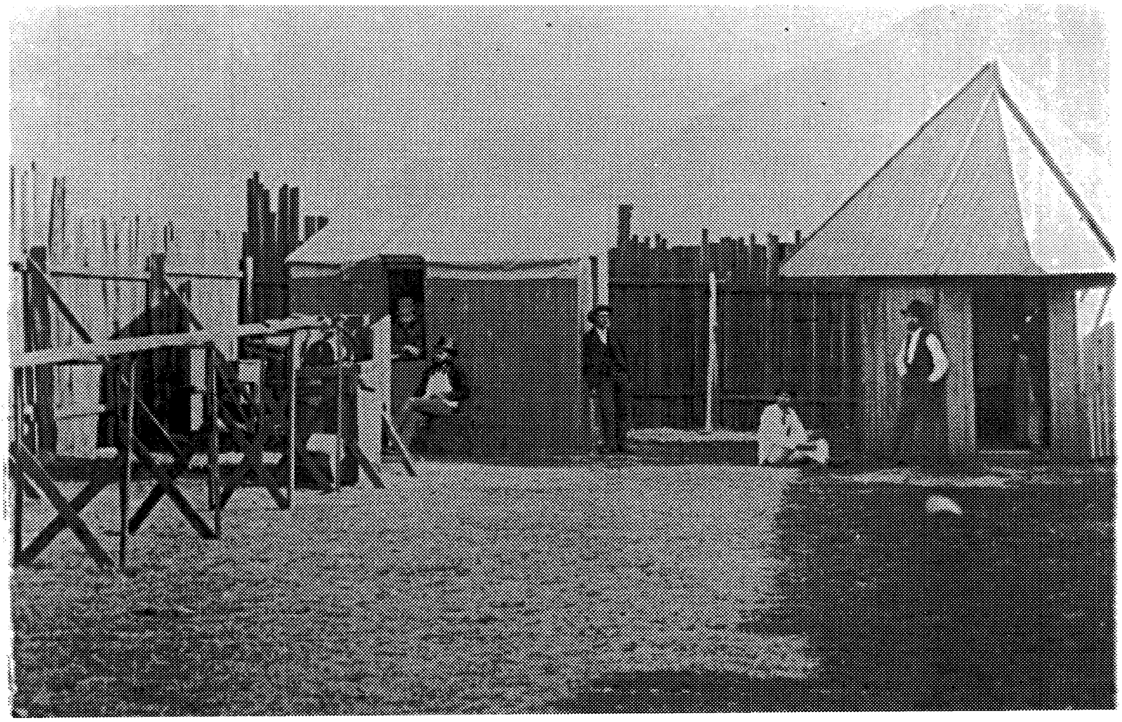

Figure 11. Part of the fenced-in Queenstown transit of Venus compound, showing the Transit House and heliostat (left) and the Equatorial House (right) (Photograph courtesy Hocken Library)

Table 2: Instruments used at the Queenstown 1874 Transit of Venus Station

Instrument/Component	Manufacturer	Number
Sidereal clock	Howard Clock Company	626
Mean time chronometer	T.S. & J.D. Negus	994
Sidereal chronometer	T.S. & J.D. Negus	1470
Sidereal chronometer	Bond	335
Transit telescope	Stackpole Bros.	1504
Refracting telescope	Alvan Clark & Sons	858
Heliostat mirror	Alvan Clark & Sons	II
Photographic objective	Alvan Clark & Sons	IV
Measuring rod	Alvan Clark & Sons	VIII
Plate holder	Alvan Clark & Sons	8
Engineer level	Alvan Clark & Sons	1489

4 OBSERVATIONS AND RESULTS

On December 9, the long-awaited morning of the transit, Peters (1874a) wrote in his journal: "The eventful day at 5 o'clock in the morning looked very ugly and black. The forenoon was cloudy and inclined to be stormy." Despite this far from promising situation, all the final adjustments were made to the instruments, and

> About 2 minutes before computed time of 1st contact the Sun came out, permitting observations of Equatorial and photographs to be made without interuption for 1¾

> hours about. After that only at intervals, up to within 16 minutes before computed time of 3ᵈ contact. The Sun then remained invisible until 30ˢ to 40ˢ after 4ᵗʰ contact. Attempts were made for reversed photographs at 6ʰp.m. but invain [*sic*]. (ibid.).

During the transit, Bass was in charge of the Photographic House. Phillippi exposed the different plates, Russell and Pierson developed them, and Aymé entered information on each plate in the photographic journal (see Bass, 1874). Becker took care of the heliostat and its drive (Peters, 1881:530).

In all, 237 photographs of the transit were obtained, 178 of the first and second contacts and 59 of Venus superimposed on the disk of the Sun (Peters, 1874b). The final photograph was taken 16 minutes before the commencement of egress (Peters, 1881). Regrettably, none of the Queenstown photographs has survived, but one of the images obtained at the Campbell Town transit station in Tasmania is shown in Figure 13 for reference purposes.

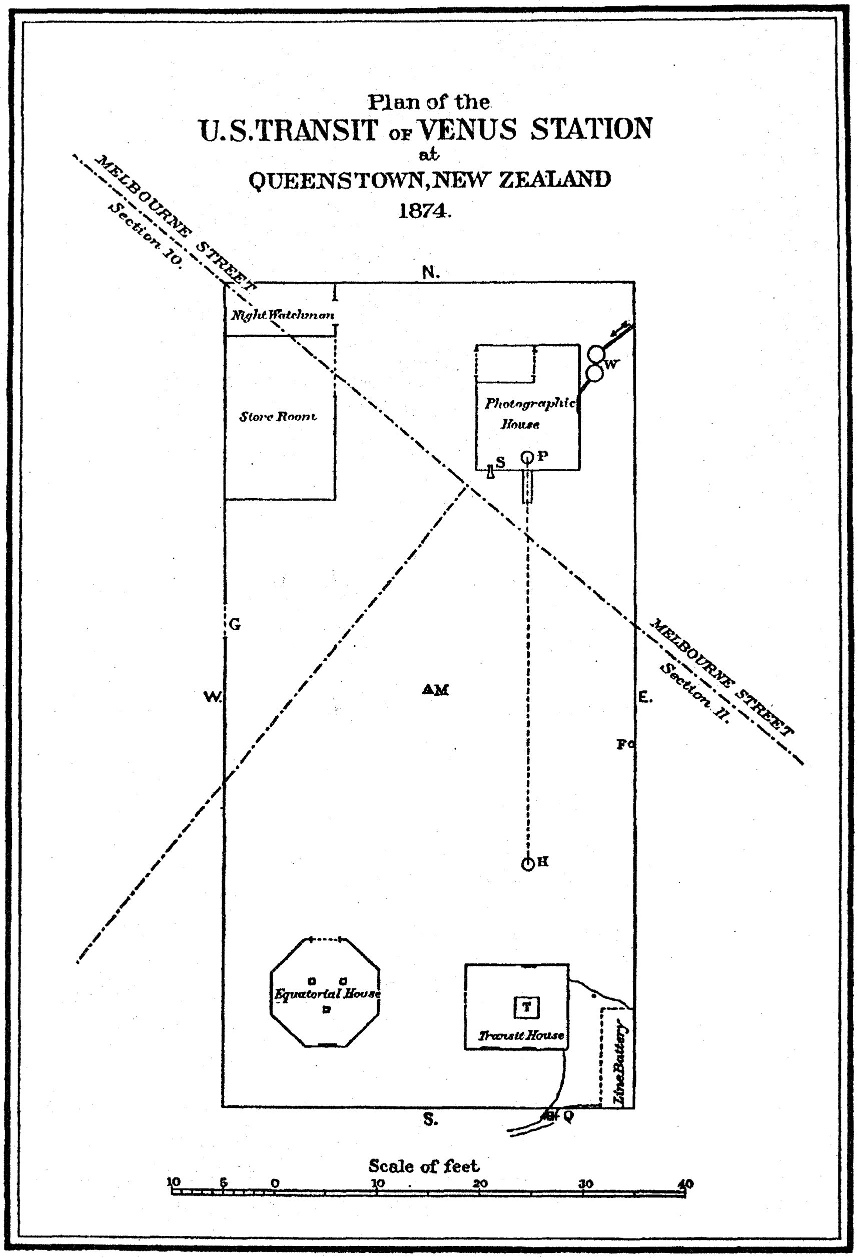

Figure 12. Plan of the Queenstown transit of Venus station (T = transit telescope; H = heliostat; P = photographic plate)

While Bass and the photographers were busy in the Photographic House, Peters was observing the first and second contacts with the 127-mm refractor, and he specifically noted the absence of the notorious 'black drop effect' (Peters, 1874a). He succeeded in obtaining fourteen measures of chords and cusps while Venus was on the Sun's limb (see Newcomb, 1880:135), and twenty-one measures of the distance of the planet from the limb while the transit was in progress. He also made ten determinations of the diameter of Venus. He remarked that during the transit

> ... perfect silence reigned in and around the station. Though my door [of the Equatorial House] was shut, whenever a picture registered itself in the photographic house the distant click was audible, and gave encouraging satisfaction and delight. (Peters, 1881:543)

All in all, Peters was pleased with the outcome of the programme and that "The instruments and appliances worked admirably, and everything passed off well." (*Lake Wakatip Mail*, 1874c). Despite the intermittent cloud cover, Queenstown proved to be one of the few 'successes' of the American transit programme. Global weather conditions were generally poor at the time (Janiczek, 1983) and although they were far from ideal in Queenstown, Peters' party did succeed in observing two of the four transit contacts and obtaining more photographs than at any of the other southern transit stations (see Dick, Orchiston and Love, 1998:Table 2). Peters (1881:548) was quick to acknowledge that their success at Queenstown was in part due to following the advice proffered by Thompson and McKerrow and selecting "... an inland station". Most other regions of New Zealand were clouded out at the critical time.

After the transit, Peters and his party dismantled the transit station and journeyed to Bluff Harbour where the *Swatara* was waiting at anchor. After loading the boxes of equipment, they sailed for the United States on 1875 January 20. Their route took them first to Hobart and Melbourne (Newcomb, 1880:19). Soon after their return Peters continued his regular research, and on 1875 June 3 he discovered two new minor planets which he promptly named after the Roman goddesses of journeyings and homecomings to commemorate his Queenstown successes (see Ashbrook, 1984).

For the Commission, the challenge now was to analyse the entire suite of observations from the expedition and produce a meaningful result. Newcomb believed that the visual observations from all the different transit parties (not just those of the Americans) would, when combined, "... give a value of the solar parallax of which the probable error will lie between 0".02 and 0".03." (*Annual Report*, 1875). He also felt that the American photographs alone would produce a result of comparable, if not better, accuracy.

In 1875 June the task of measuring these plates was assigned to William Harkness, and he subsequently reported that these yielded "excellent results" for the period when the planet was visible on the Sun's disk but that those taken during the four limb contacts were of "no value" because of the black drop effect (Harkness, 1883). Forty-five of the 59 disk photographs obtained at Queenstown were used in the final anlaysis.

Although all measurements on the photographs were completed by the end of 1877, the laborious task remained of determining the longitudes of the various transit stations. When this was accomplished, the official report of the American 1874 transit of Venus programme was to have been published in several volumes, but funding restrictions only allowed the appearance of the first volume (Newcomb, 1880). This comprised 157 quarto pages; the first 117 discussed the photographic work (without providing any conclusions) and the final 40 pages related to the visual observations. The planned Part II, in two volumes, reached the proof stage in 1881 and today exists as only a single copy in the Library of the U.S. Naval Observatory in Washington, DC. In the course of 564 pages, Part II provides detailed accounts of the eight different transit stations, including Queenstown (Peters, 1881), but does not report any results. Parts III and IV were supposed to contain the results, but did not even reach the proof stage.

Because of this unfortunate situation, D P Todd, an assistant at the Nautical Almanac Office, analysed some of the successful 1874 photographs, and obtained a provisional value of 8″.883 ± 0. 034 for the solar parallax. This result was published in 1881 (Todd, 1881), and although it differed significantly from some of the earlier values obtained (see Table 1), there was continuing concern about the quality of the photographic images – which showed some limb-darkening – and the difficulty of establishing plate scales (see Lankford, 1984). As a result, some astronomers then decided to turn to other methods in order to calculate the AU (including the night-time observations of minor planets, which appeared as point-sources).

Following what appeared to be a far from satisfactory outcome of the 1874 transit observations, scientists from 14 nations met in Paris in 1881 October to plan for the 1882 transit, and after some debate most nations decided to reject the use of photography. The United States was one of the few countries which determined to persevere with a photographic investigation, but for a time there was even doubt as to whether an international programme would be mounted. In the end it was agreed that eight different stations would be established, four in the United States itself and four at overseas localities. Parties were subsequently dispatched to South Africa, South America and New Zealand. The single New Zealand station was located in Auckland, and the leader of that party was Edwin Smith, Chief Astronomer of the United States Coast and Geodetic Survey. During the previous transit, Smith had led the Chatham Islands party.

This time it was William Harkness, another U.S. Naval Observatory astronomer, who was responsible for the overall U.S. programme:

> Although Newcomb had initiated American interest [in the nineteenth century transits], it was Harkness who had designed much of the equipment and personally led one of the parties, and it was Harkness who after Newcomb's abdication in 1882 would not only be the driving force behind the 1882 expeditions but also (in sharp

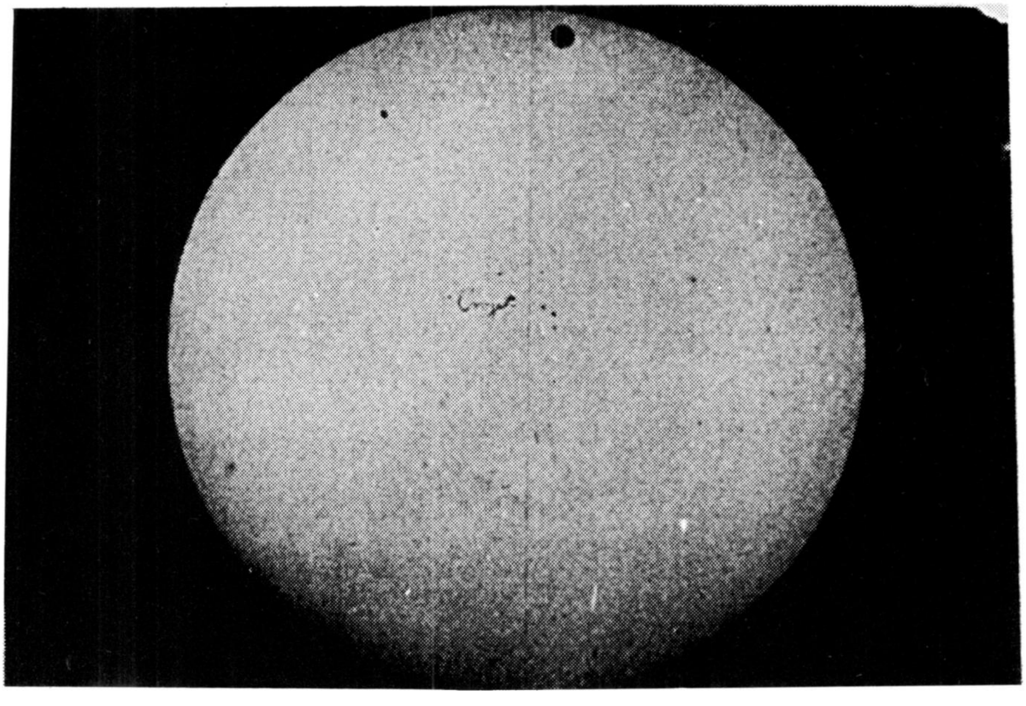

Figure 13. Photograph of the 1874 transit of Venus obtained at Campbell Town, Tasmania. (Photograph courtesy Queen Victoria Museum and Art Gallery, Launceston)

> contrast to Newcomb) produce a final result. Bringing the transit of Venus observations to fruition became a major goal of Harkness and a landmark in his career. (Dick, Orchiston and Love, 1998:242).

Six years after the 1882 transit Harkness reported a value of 8″.847 ± 0. 012 for the solar parallax based on his analysis of 1,475 photographs of the event (*Annual Report*, 1888:17-18), and just four months later he revised this to 8″.842 ± 0. 0118 (*Annual Report*, 1889:424-425).

5 DISCUSSION

Investigation of the astronomical unit did not end with the publication of the 1882 transit results. Harkness insisted that the solar parallax was intricately entwined with lunar parallax, the constants of precession and nutation, and parallactic inequality of the Moon, the masses of Earth and Moon, and the velocity of light, among others. By treating these constants as a system, he was able to produce what has been described as "... the crowning achievement of a lifetime of work ..." (Dick, Orchiston and Love, 1998:247), a monograph tilted *The solar parallax and its related constants* (Harkness, 1891). Three years later, Harkness (1894) published a 'best estimate' for the solar parallax of 8″.809 ± 0.0059, and Newcomb (1895) then produced a value of 8″.800 ± 0.0038, which was adopted as the international standard at the Conference Internationale des Étoiles Fondamentales in 1896. By way of comparison, the current value of the solar parallax (ratified by the IAU in 1976) is 8″.794148 ± 0.000007, equating to a mean solar distance of 149,597,870 km.

As one of the most visually-appealling of all sciences, astronomy has long enjoyed a high public profile, and the importance of the transit of Venus certainly was not lost on the good citizens of Queenstown back in 1874. Throughout their stay, amiable relations persisted between the Americans and the townsfolk, and when Peters gave a public lecture about the transit programme on November 26 this was well attended and was reported in the local newspaper, the *Lake Wakatip Mail* (1874b). The account ran to two and a half columns of detail, and summarized the history of astronomical distance measurement from antiquity through to the nineteenth century transits of Venus. Given Cook's intimate association with New Zealand, Peters made a point of labouring his exploits, to the obvious delight of the audience:

> To this astronomer, who had fought his way up, the highest credit was due, considering the instruments he had to work with. He had no time-piece that would exceed an ordinary American clock ... yet his efforts were, to this day, appreciable (Applause). He did not intend to flatter, but these were facts well known, and they were much indebted to Captain Cook (Renewed applause). He took his observations at Cape Venus, Otaheite. The observations of this memorable explorer were made in the year 1769. They should be proud of him who afterwards met his death in the South Seas Islands he loved so well (Applause). And to him, more than anyone else, was due the presence of the present expedition (Cheers).

On December 17, after the 1874 transit, there was a dinner in the Queen's Arms Hotel to farewell the visiting scientists, and the coverage in column inches assigned to this event in the *Lake Wakatip Mail* (1874d) outstrips by far the account of the transit itself! Yet the speeches, which were reported in detail, hardly touched on the transit or on science. Instead, they focussed on the glories of New Zealand in general and Queenstown in particular (to the frequent accompaniment of enthusiastic applause). In a diplomatic yet prophetic moment, Peters saw

> ... in the stars a large city here [at Queenstown] in the future; railways converging upon it; people coming from many other parts of the earth to enjoy its beautiful climate, and behold its grand scenery (Loud Cheers).

Finally, on 1874, Boxing Day, the transit party attended a picnic and dance given in their honour by the Masonic fraternity. All in all, the Americans were made to feel very welcome during their two month stay in Queenstown.

Nor did the Americans restrict their non-astronomical activities to socializing. On December 2 and 3 the photographers went on 'an excursion', in order to photograph Queenstown and the magnificent scenery offered by Lake Wakatipu and the surrounding countryside. Pierson and Phillipi subsequently published an album of New Zealand photographs which presents a unique record of Otago in the 1870s and is currently the subject of research by staff at the Hocken Library in Dunedin. Janiczek (1983:66) has reproduced some of the photographs from this album in one of his papers.

The transit party also extended its scientific interest beyond astronomy. In an interesting seismological diversion, Peters (1881:469,474) wondered whether some of the problems associated with the sidereal clock and the chronometers were caused by minor earthquakes – not that members of the transit party noticed any during their sojourn at Queenstown. Meanwhile, Russell (one of the photographic team) was always on the look-out for local 'curiosities', and in the course of their stay he succeeded in collecting seven Maori adzes, together with native birds, plants, insects, crustaceans, small vertebrates and moa bones. This collection found its way into the Smithsonian Institution, and the adzes, together with ethnographic specimens sourced from Riverton and the Chatham Islands, are documented by Keyes (1967). It is of interest to note that the adzes are stylistically and petrologically typical of those found in early prehistoric southern South Island New Zealand (Orchiston, 1974), and they reflect the important role that Central Otago (and the Queenstown area) played in early Maori life.

One of those living in Queenstown during the transit was a 10-year old girl, Sarah Cockburn, who had a passion for astronomy. In later years (under her married name of Salmond) she lobbied relentlessly for a monument to be erected on the site of the transit station, to mark what is arguably the most important venture in international science ever carried out at Queenstown. Her endeavours were finally rewarded in 1953 when at the age of 88 she had the honour of unveiling the monument (see Salmond, 1993). The plaque (Figure 14) reads:

> From this site a transit of the planet Venus across the solar disc was observed on 1874 December 9 by an American scientific expedition which came to Otago in the ship "Swatara".

In 1995 the monument was incorporated into the new multi-storey international Millennium Hotel which was constructed on the site of the transit station.

From an astronomical point of view, the 1874 transit was important because it also attracted British, French and German parties to New Zealand and its outlying islands, Campbell Island and the Auckland Islands, respectively (see Airy, 1881; Auwers, 1898; Bouquet de la Grye, 1882; Filhol, 1885), and Major Palmer at Burnham even had one of his party set up a 'satellite station' at Naseby, 300 km to the southwest (see Figure 9). As in Australia (see Orchiston and Buchanan, 1993), the transit served as a catalyst for the development of local astronomy as it was the first opportunity for local astronomers to become involved in a project of international importance. Observers in Auckland, Thames, Wellington, Nelson and Dunedin, among other centres, prepared for the event (see *Lake Wakatip Mail*, 1874a; The transit of Venus, 1874(a), 1874(b); Tomorrow's transit of Venus, 1882), and one of the Wellington astronomers, Archdeacon Arthur Stock, produced a small popular book about the transit (Stock, 1874). Unfortunately, cloudy skies prevented most observers from viewing the transit.

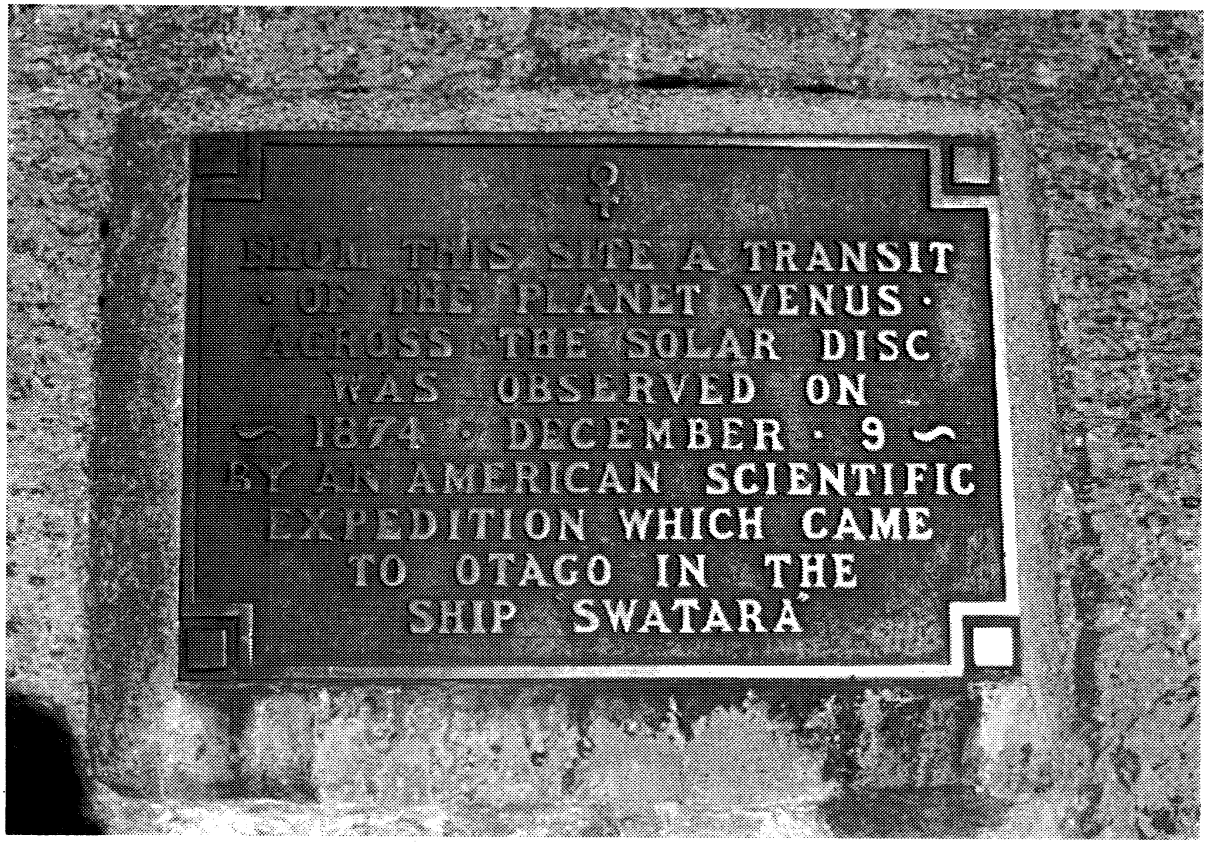

Figure 14. The Queenstown transit of Venus monument

This transit also was a milestone because it precipated the first attempts to apply photography to astronomy in New Zealand. However, the Americans in Queenstown were not the only ones to experiment successfully with this new technology, as a team from Auckland comprising Professor S J Lambert, FRAS, and Messrs Martin, Pond and Redfern obtained "A good many photographs of the first and second contact stages ..." of the transit (McIntosh, 1958a). Their pioneering spirit is to be applauded, even though the 'black spot' phenomenon prevented their images from having any appreciable research value.

There was even more New Zealand interest in the 1882 transit (e.g. see Hector, 1882; Stone, n.d.; Tomorrow's transit of Venus, 1882; Transit of Venus, 1882), with observers located in Auckland, Thames, New Plymouth, Martinborough, Wellington, Nelson, Christchurch, Dunedin and Clyde. A party under Professor Lambert was again successful, photographing the event through both 63.5-mm and 76-mm refractors (McIntosh, 1959), and Mr Foy, in Thames, obtained two photographs of the transit (McIntosh, 1958b). Meanwhile, the American transit party – situated in Auckland – was happy with its efforts, a total of 74 photographs (McIntosh, 1958a).

The year 1882 also appears to mark the start of non-transit astronomical photography in New Zealand. Just two weeks before the transit, an Auckland professional photographer and astronomy enthusiast, Josiah Martin (see Maitland, 1993), exhibited "... a very successful photograph of the sun ..." at a meeting of the Auckland Institute (McIntosh, 1959).

The 1885 September 9 total solar eclipse, provided yet another incentive for New Zealand astronomers to develop their photographic skills. At Masterton, within the band of totality, a Mr Humphries obtained good photographs of the event, recording Bailey's Beads, prominences and the corona (ibid.). In Auckland, where the eclipse was only 95% total, a Mr Cranwell "... climbed Mt Eden and secured a few photographs through gaps in a cloudy sky ..." (ibid.).

John Grigg of Thames was also active at about the same time, obtaining photographs of the Moon and of the partial solar eclipse of 1890 December 12. During the first decade of the twentieth century, he photographed the Moon, sunspots, star fields, and two comet: the Great Comet of 1901 (C/1901 G1) and Halley's Comet (1P/Halley) in 1910. Grigg's name is well-known today through his cometary discoveries, and he was New Zealand's leading amateur astronomer at the start of the twentieth century (see Orchiston, 1993, 1999). He was the first New Zealander to carry out astronomical photography systematically and over an extended period of time, and his pioneering efforts in this emerging field of astronomy have been reviewed by Orchiston (1995).

Early in the twentieth century, cometary photography also was pursued successfully by the Reverend Dr David Kennedy and his assistants Cullen and von Gottfried at the Meeanee Observatory near Napier in 1907 (Orchiston, 1996), and Grigg, Cullen and von Gottfried and C.J. Westland all obtained photographs of Halley's Comet in 1910 (some of which are reproduced in Mackrell, 1985). Westland (of Christchurch) went on to independently discover Comet C/1914 S1 (Campbell) in 1914, and he also took a number of successful photographs of this object (see Orchiston, 1983).

6 CONCLUSIONS

The 1874 U.S. transit of Venus programme was a expensive venture designed to refine that fundamental yardstick of solar system astronomy, the astronomical unit. It was a major logistical exercise, involving the transportation of extensive equipment (including prefabricated buildings) to eight different transit stations, five of which were in the southern hemisphere. One of these was situated at Queenstown, in the South Island of New Zealand.

While most other New Zealand sites were clouded out during the transit, those at the Queenstown station succeeded in observing both ingress contacts and obtaining a succession of photographs of these contacts and of Venus while it was visible on the disk of the Sun. Todd used the latter photographs and those from other U.S. transit stations to produce a value for the solar parallax that differs only 0″.089 from the currently-accepted figure, but because the reliability of photography was called into question at the time this result was not seen as improving on the value of the astronomical unit.

Despite this disappointing outcome, from a national perspective the 1874 transit did serve to introduce astronomical photography to New Zealand, and it provided an important impetus for the development of local astronomy.

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Under a tropical sky: a history of astronomy in Indonesia[1]

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Abstract
This paper reviews the birth of astronomy as a branch of natural science in the nineteenth and early twentieth centuries on Java, Indonesia, through the three and a half year period of the Japanese occupation during World War II. In the 1950s astronomy as a science received new impetus by incorporating the science into the higher education system in Indonesia. The newly-founded Faculty of Mathematics and Natural Sciences in Bandung was honourably charged to carry out the modern science education, including astronomy. The introduction of the Anglo-Saxon system of higher education in the late 1950s, which replaced the continental system of education, is briefly sketched to serve as background information for astronomy education in the later years in Indonesia.

1 INTRODUCTION

Simplistically, the relationship between Leiden and Dutch astronomers in the Dutch East Indies (present-day Indonesia) from the 1920s until the start of World War II can best be characterized as a love-hate paternalistic affair. Pyenson (1987) describes how this kind of tie was surrounded by an atmosphere charged with a metropolitan aspiration on the one hand and colonial endeavours on the other. The atmosphere only became neutral when a young, talented, Leiden astronomer, A de Sitter, ascended to the directorship of the Bosscha Observatory in the late 1930s. Unfortunately, by that time the long shadow of World War II had already started to creep into the Dutch East Indies. The ensuing years between 1942 to 1945 were filled with hardship for, and oppression of, Dutch subjects by the Japanese. In 1945, after the War, the national movement for independence in Indonesia practically stopped astronomical activities in the Indonesia, It was only in mid-1946 that the restructuring of the Bosscha Observatory was begun by C Hins of Leiden. But, reconstruction in earnest had to wait a little longer, until 1949, when G B van Albada was appointed Director. The rather unusual situation of the 1940s makes assessment difficult, and a simple line of judgment could create some bias against what was happening at the time.

It must be added, right at the outset, that this paper is not meant to belittle the contribution of Leiden astronomers in opening the southern skies to modern astronomy in Indonesia. On the contrary, it exposes the solid influence of this Dutch School of Astronomy. Already in the middle of the nineteenth century the influence of Leiden astronomers was felt in the colony, for the directive of F Kaiser, the then Director of the Leiden Observatory, formed the sole pillar of guidance for systematic astronomical observations in the tropics. It embodied the rule and procedure for the determination of longitude and latitude in the vast area of what was then called the Dutch East Indies. The measurements were meant to improve existing maritime charts of the new territory which, at the time (around 1850), were very much in demand. Impressive territorial expansion, dictated by the colonial economy of the day, required much better topographic maps and geographical knowledge in order to ensure the hegemony of power. A 27-year old naval lieutenant, de Lange, surveyed the difficult terrain under almost unbearable tropical conditions and managed to accumulate important data essential for positional determinations. Unfortunately psychological stress caused by on-going pressure from Leiden and the poor infrastructure for the work in the colony brought an abrupt end to his life at the very young age of 39 years.

The lifestyle of an explorer such as de Lange was not atypical in the days of territorial conquest. As an astronomer by training, he carried a very heavy dual mandate upon his shoulders. He was expected to produce utilitarian knowledge and at the same time advance pure learning, which could add to the crowning achievement of metropolitan astronomy. A similar dual role was also associated with the history of the Royal Magnetic and Meteorological Observatory in Batavia (now Jakarta). Bergsma, the geophysicist, worked under the wing of Buys Ballot of the Royal Netherlands Meteorological Institute in Utrecht, and had to prove his ability to serve the needs and ambitions of many masters, both in the motherland and in the colony. He found this situation very uncomfortable, and it took him twenty years to develop the Centre of Meteorological Science (now BMG) in Jakarta. In those days, a large part of science was surveys, and surveying work in biology as well as in geology could not be left untouched, regardless of the physical conditions.

I shall not go beyond this point as it would distract us from the track of astronomy. Instead, allow me to touch upon matters concerning the founding of the Bosscha Observatory here in Indonesia. It appears that at least two centres of science in the Netherlands were involved in formulating the decision to found an observatory for the southern hemisphere in the Dutch enclave. The involvement of the Leiden School of Astronomy was only natural in view of its status, but one cannot avoid the impression that the founding of the new observatory in the tropics also stemmed from the aspirations and needs of astronomers in Groningen and Utrecht. When a native son of the Dutch East Indies, J Voute, had the desire to found a new astronomical institute in Java, he sought advice from de Sitter, who was then Director of the Leiden Observatory. Voute believed that if figures like de Sitter and Kapteyn (who was about to head the new institution in Groningen) supported his plans, then the colonial government would come through with financing. Furthermore, Voute supplemented his rationale for an astronomical institute in the colony with the premise that it would respond to both 'disciplinary' and 'national' needs. 'Disciplinary' in the sense that new avenues for scientific research could be opened up, such as the study of the structure and dynamics of stellar systems. This was Kapteyn's anticipation, and his vision led him to propose a telescope of at least eight metres focal length in order that the motions of the stars could be effectively studied. The observatory, the argument continued, would also compensate for the domination of observatories in the northern hemisphere and would complement them. In this regard Voute was correct, because the southern sky in those days was almost a *terra incognita*, not only for modern astronomy but also for double star research (through which stellar masses could be directly determined).

Moreover it was clear that the southern sky, which first received attention from Europeans through the publication of a star catalogue by Frederick de Houtman[2] in 1603, was a much richer research resource than the northern sky[3].

2 THE APPEARANCE OF SCIENTIFIC ASTRONOMY IN THE DUTCH EAST INDIES

The catalogue of stars published by Frederick de Houtman in 1603 provided the basis for the renaming of many of the southern constellations. In a publication that was brought to the attention of European astronomers, de Houtman listed 303 stars in the southern sky and provided names for the major constellations

Disputes about who was responsible for the naming of the southern constellations abound. In 1917, Knobel used circumstantial evidence and arrived at some interesting inferences. One of these was that "... the whole catalogue and the formation of the twelve new constellations must be attributed to Pieter Dirksz Keyzer, and not in any way to Frederick de Houtman." Keyzer was also a member of the first voyage expedition, along with the de Houtman. Could this allegation be correct? If it were, then we should have to rethink the whole issue. Besides, there were many other voyages of exploration carried out by the Spanish, Portuguese, Italians, and others. But, Dekker (1987) was able to show convincingly that de Houtman deserves the credit for producing the catalogue and the sky atlas. Not only was he responsible for the catalogue but it appears that the act of the discovery was also in line with the scientific attitude of Dutch cartographers of that century. This, in turn, so Dekker emphasized, was "... instrumental in bringing about the general revival of scientific interest in the low countries of the Sixteenth Century onwards."

Looking back along the axis of time one comprehends that the act of reaching a far-away territory was a navigational achievement. With it, new ethics and values flourished. The feeling of confidence and success became a great incentive for the development of science in the Netherlands. Important as it was, serious astronomy in the Dutch East Indies had to wait for the presence of Pastor Johan Mauritz Mohr, who had studied theology at the University of Groningen and between 1737 and 1775 led the congregation of the Portuguese Church on the outskirts of Batavia. He made many astronomical observations, the results of which were communicated to the Dutch Society for Sciences in Haarlem. His observations included the two transits of Venus in the 1760s. Mohr also published his results in the *Philosophical Transactions of the Royal Society*, London. The street where his observatory existed could still be located in Batavia until the 1920s and was named "Gang Torong", a modification of the word "toren." Unfortunately, after Mohr's death scientific astronomy in Indonesia had to wait more than three generations before being taken up again in the second half of the nineteenth century (Voute, 1933).

The early and the middle parts of the nineteenth century witnessed many scientific activities in the Dutch East Indies, with the founding of scientific research centres and institutions. Notably, close to scientific astronomy was the founding of the first magnetic and meteorological observatory at Batavia. Although astronomical activities relating to trigonometrical surveying began in 1821, it was not until the 1850s that they really became a necessity. New economic and social order demanded the exact locations of sites in various parts of the archipelago be known. Although the scientific aspects of triangulation cannot be separated from observational astronomy, there were difficulties in developing pure astronomical science in the second half of the nineteenth century. Astronomy only persisted through its application to geodetic astronomy, and Dutch astronomers in the colony during that era strove to find a state of equilibrium between practical knowledge and pure learning. But it was also during this period that basic improvements to maritime charts of the archipelago were made, on the basis of astronomical observations (Haasbroek, 1977).

The East Indies Physical Society, which was founded in Batavia at the end of the nineteenth century, provided early publications about astronomy. Some of these were on the popular level in order to inform scientists in the archipelago about current trends in science back in the 'motherland', Holland. But quite a number of contributions were reports of astronomical activities, written mainly by engineers in the Geographic Institute or by naval officers in charge of geographical surveys. It was only in 1919 that a concept to develop astronomy as part of the natural sciences found support in Indonesia.

3 AN ERA OF SCIENTIFIC DEPENDENCY

Western European countries became the home of modern science during the seventeenth century. The Netherlands was one of those countries that entertained the philosophical viewpoint of the scientific revolution, experimental activities, and institutions of learning. All of these are attributes which we now identify as modern scientific enterprise.

The Bataafse Republic also enjoyed great economic progress during the eighteenth century which, in turn, catapulted science into an honorable place in the world. Historians would, of course, argue the simple correspondence between scientific ascendancy and economic prosperity, but many would agree that scientific institutions enjoyed material abundance to fuel their progression. Certainly there was more to it: what actually counted was the spirit and ethics of scientific thought which served as the agent to propel academic life to high levels of competence.

Thus, by the beginning of the twentieth century, three centres of higher learning were already invested with the research ethic. These were located in Leiden, Groningen, and Utrecht, and each had an institution of astronomy in its own right. Among these astronomy centres, Leiden was at the forefront and was the most privileged. Pyenson (1989) believed that the Leiden Observatory enjoyed the earliest government commitment to astronomy, and it effectively functioned as a member of the Dutch Naval Institute by training officers and calibrating optical and astronomical instruments. Some of the Leiden astronomers received financial support and opportunities to participate in major scientific expeditions to foreign countries and to the Dutch colonies.

During this time, Kapteyn at Groningen created and nurtured his 'laboratory' for measuring and analyzing stellar positions, while Oudemans at Utrecht followed rather different lines. Pyenson (1989) paid tribute to Oudemans as being the most successful person in using colonial ambitions to finance pure learning. Born in Amsterdam in 1827, Oudemans grew up in a scientifically-oriented family, and at the age of sixteen he enrolled as a student at the University of Leiden. There he attended the lectures of Frederick Kaiser, who convinced him to specialize in astronomy. Kaiser later became his mentor.

The chance for Oudemans to visit the Dutch East Indies came in 1857 when the Colonial Ministry, at the proposal of the ever-present Kaiser, sought to chart the topography of the Indonesian archipelago by astronomical means. Oudemans was then appointed by King William III to become the head engineer of the Geographical Service in the Dutch Indies, which prompted him to immediately marry his long-time girlfriend. With a starting annual salary of fl.7200, he set out to follow in the footsteps of his father, to work in the Dutch East Indies, and remained there for the next twelve years. His salary is of course small by present standards, but it was a huge sum in those days.

When he arrived in 'Indie' Oudemans saw before him two tasks which were equally compelling (Pyenson, 1989). The first was to produce detailed maps by the standard procedure of topographical triangulation, and the second was to verify the positions independently by astronomical means. One might have expected that the two calculations would be different due to the perturbing effect of mountain masses on the figure of Earth. The Amsterdam Academy of Sciences expressed interest in the general survey, and it also supported the astronomical side as an exercise in pure learning.

Unfortunately the two-sided nature of Oudemans' responsibilities were not always compatible. In his report to Kaiser in 1858 (Pyenson, 1989) he mentioned specifically that the military and agricultural authorities wanted good maps. The navy, however, gave a cool response to his appeal for astronomy programmes. If he were unable "... to obtain support for carrying out my goals of taking position readings in the archipelago ..." then he would resign himself to his fate and just continue with the routine problem of triangulation. The problem lay in the top-heavy bureaucracy, he said. Kaiser was not happy with the situation, and threw up his hands in despair. His negative opinion of Oudemans' task apparently derived from his experience with an earlier Dutch attempt to survey the Indies. In 1850 the Governor General had asked Sjuurd de Lange to make astronomical observations in the Indies in order to improve maritime charts. However, as was mentioned earlier, the situation in the colony was not conducive to support the project and far from accommodative for pure science.

Without knowing the real situation in the tropics, Kaiser in 1853 severely criticized de Lange for not devoting enough time to astronomical observation and discovery. On the other hand, as was testified to in a letter from Mrs de Lange to Kaiser in the 1850s (Haasbroek, 1977), de Lange had tried hard to do his best to fulfill the expectation of his mentor in Holland. The letter was a humanist document which indicated how different the situation in the tropics was from that in the metropole during the nineteenth century.

Returning to the astronomer Oudemans, we are impressed by his persistence to carry out what he had set out to do. He had a special ambition to devote his time to surveying the 'outer possessions', and throughout his stay in the tropics he continually sought to include them in his geographical mandate. In these enterprizes he received more than casual government support, because such mapping aided their interest in systematic exploration.

To implement such a task covering large areas of the Indonesian archipelago was not an easy undertaking. Fortunately, unlike in de Lange's case, Oudemans had a few more advantages, but his travels had to depend upon when naval gunboats could be spared from policing action. In 1859 he wrote to Kaiser:

> The Naval Deparment received approval of the government to use a steamboat for an expedition with regards to the defining of the already mentioned points, as soon as this would be feasible. Nothing has happened yet. Maybe after the expedition to Bone is finished, there was a revolution in Sulawesi, but then they will probably have to send troops to Palembang.

There was always an atmosphere of uncertainty!

Despite heavy burdens as a topographer, Oudemans determined to remain in contact with European astronomy where, he thought, he would find his place after the Indies assignment. His concern to finish the longitude calculations was related to his broader academic ambitions, and he never lost an opportunity to publish scientific results in Europe. Nobody could blame him for hoping to secure a chair of astronomy in his motherland.

This ambition unfortunately had to be abandoned when he saw H G van de Sande Bakhuyzen succeed Kaiser and move to the chair at Leiden Observatory. However, he soon after heard from his friend, Johannes Bosscha (the father of Karel Bosscha, the Indonesian tea magnate), who had recently been appointed Professor of Physics at the Technische Hogeschool in Delft, that Hoeks, the Director of the Utrecht Observatory, had died. Bosscha asked how Oudemans would feel about returning to Utrecht. The message from Bosscha created a spark of hope, as it also included the comment that "... some people feel that his place should be kept open until you get back from the Indies, a course that does not seem objectionable." Oudemans did return to Utrecht some time later, but unfortunately he encountered some uncomfortable situations which will not be elaborated upon here.

However, one aspect that should not be left untouched is the scientific part of the triangulation. This all began with the initiation of the Naval Commander in Batavia, Admiral Marie Isaac Brutel de la Riviera. In 1878 he wrote to Governor General Wilhelm van Lansberge that the whole program concerning mapping of the outer possessions could now be placed back on track – and should not be delayed – if Oudemans could be persuaded to supervise the final reduction and publication of the Javan data.

Oudemans was indispensable because of the peculiar way that pure science had become an essential part of the programme. The Geographical Service had to determine the figure of Earth by employing the results of true absolute latitude and longitude measurements. In the 1870s the scientific part of the triangulation became the inherent element of the Geographic Science. Controversy appeared only later when astronomical observations had received more serious attention. The Government then realized that accurate maps of Java did not depend on Oudemans' programme. About this Oudemans, understandably, replied reverently, and he stated in his retirement address (in 1898) that his Batavian stay was a digression, although he added that he had tried to apply a good part of the science of astronomy in his work (Pyenson, 1989).

The episode outlined above was not unique to the Indonesian case nor to astronomy, and portrayed the so-called Phases One and Two in the Basalla (1967) model of scientific diffusion. In this model Basalla treats science as a specific culture, and the spread of science as the transmission of that culture through a process which moves from cultural dependence to independence. Phase One coincides with the era when the 'nonscientific' society or nation provides a source for European science. Here the word 'nonscientific' refers to the absence of modern Western science, as was shown in the early epoch of exploration in Indonesia. With varying speed, depending upon the countries involved and the importance attached to a particular field of science, Phase One was followed by Phase Two. Phase Two is marked by a period of 'colonial' science. Sciences like biology and zoology would understandably not only enter Phase One earlier than astronomy but they would reach the second phase sooner, because of necessity. The Baconian principle was clearly heard by the Dutch colonists in Indonesia, as well as by British explorers in India and Australia. Bacon counselled "... look about (for) what kind of victual the country yields of itself ... [and then] ... consider ... what commodities the soil ... doth naturally yield, that they may in some way help to defray the charge of the plantation." This explains part of the phenomena which have just been described, namely the growth, the speed of progression, and the execution of astronomy in the Dutch East Indies theatre. In regard to colonial science in India, readers should refer to Kumar's 1993 and 1995 treatises on science and the Raj.

4 THE EMERGENCE OF AN INDEPENDENT ASTRONOMICAL TRADITION

Basalla (1967) categorizes the third phase of his diffusionist model as the phase where the process of transplantation takes place with a struggle to achieve an independent scientific tradition. Based upon a different starting point, MacLeod (1982) expounded the view of an "imperialist model" in which he treats scientific culture as an aspect of political hegemony. In his model, science transmission is regarded as an implementation of imperial policy. The transplantation of astronomy to the tropical Dutch territory during the first quarter of the twentieth century would hardly fit the scheme of MacLeod. It fits, in my opinion, that period included in the third phase of Basalla's model, except during the interregnum period of the Japanese occupational force.

According to Hins (1950) three main events blended together to give the impetus to found a powerful Dutch observatory in the southern hemisphere. The first, as already discussed, was the need to open up the southern sky for astronomical research. This had been stimulated by the research of J C Kapteyn at Groningen. During the first two decades of the twentieth century Kapteyn had convincingly shown the importance of statistical astronomy in order to study the structure of our Universe. His paper titled "First attempt at a theory of the arrangement and motion of the sidereal system" (Kapteyn, 1922) represents the culmination of his work. Here it was shown that the lack of understanding of the structure of our Universe was partly hindered by the relatively small amount of information that had been gathered from the southern hemisphere. Up to that time, a large number of observatories were found in the northern hemisphere, and it was seen as necessary to have more southern stations where modern astronomical observations could be carried out.

The second reason was the enthusiasm of Dr J G E G Voute, a civil engineer-turned-astronomer. He was Assistant at the Royal Observatory in Capetown before being invited by van Bemmelen to take charge of the time-keeping section of the

Meteorological Office in Jakarta. Voute had an interest in double-star astronomy, which had been aroused when he was associated with the Commission of Latitude Determination and had been appointed an observer at the Leiden Observatory. His six year stay at Capetown (from 1913 to 1919) not only allowed him to gain more experience in observational astronomy, but it also determined his outlook for the future. Upon his return to Indonesia he decided to follow a course which eventually led him to found an astronomical observatory.

Last but not least, is the stature of Mr K A R Bosscha, then the administrator of a flourishing tea estate in Java. His was the most influential non-astronomical factor that helped to shape and materialize the idea of an astronomical observatory in the tropics. When Voute approached him for help, Bosscha was already a legendary figure through his generous support of the scientific community in the colony. A detailed account of Bosscha was presented by van der Hucht and C L M Kerkhoven in 1982, but a few words about his involvement with the Technische Hogeschool (TH), which he founded in 1920, are warranted. He became head Curator of the TH, which was in Bandung, and showered it with his wealth and his energy. Included in the school was the Bosscha Physical Laboratory, where Professor C Clay studied cosmic rays.

These were the three factors that finally paved the way for the foundation of the Dutch East Indies Astronomical Association in 1920, the primary task of which was to build an observatory and, in the widest sense of the words, to promote the progress of astronomical science in the colony. Initiated by a telescope of 7 inches aperture donated by Professor de Sitter of Leiden Observatory, parallax observations were begun at Lembang in the early part of the 1920s at what is now the home of the Bosscha Observatory Figure 1). When the Observatory was still in *statu nascendi*, Professor van de Sande Bakhuysen (the retired Director of Leiden Observatory), at Bosscha's request, donated his fine and extensive collection of books. These were soon to become the core of the Bosscha Observatory library which, thanks to the Leids-Kerkhoven Bosscha Foundation, is still the prime astronomical library in Indonesia.

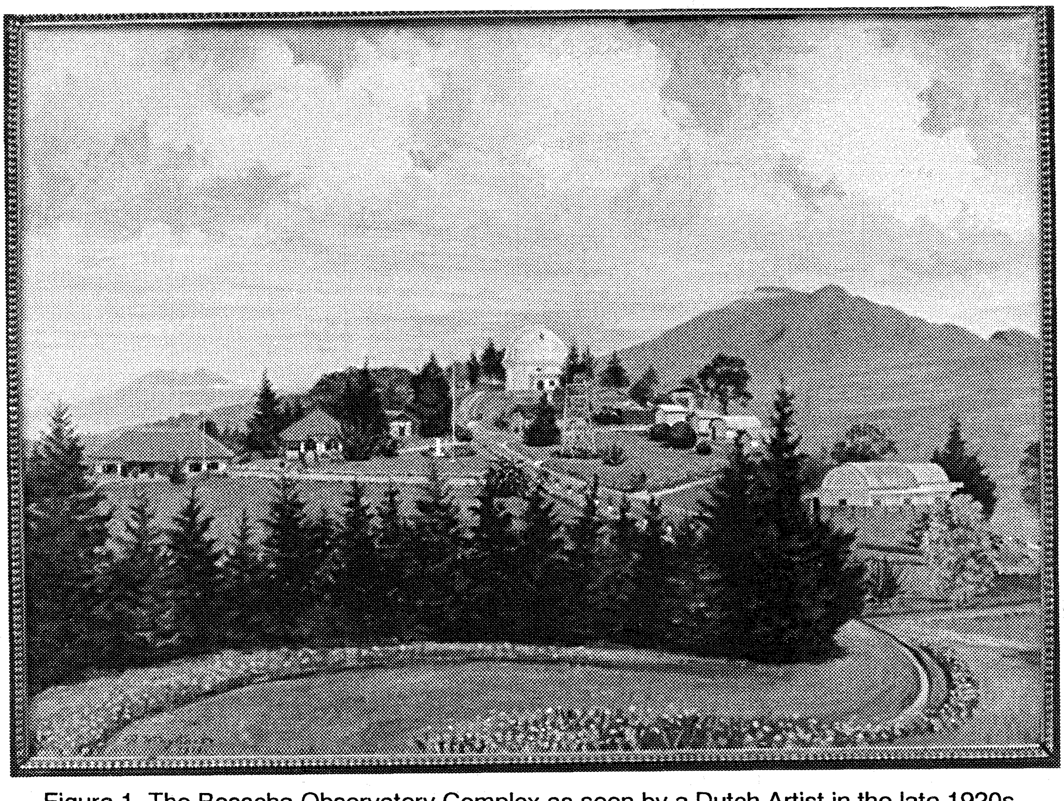

Figure 1. The Bosscha Observatory Complex as seen by a Dutch Artist in the late 1920s. From the original work to be found at the Leiden Sterrenwacht, The Netherlands).

In 1928, after five years of hard work, the main instrument was finished, a 60-cm double-refractor made by Carl Zeiss of Jena. As it has already been described by Voute (1933) and others, I shall not provide any technical details here, but it is worth noting that the completion of this telescope marked the beginning of 'modern' astronomical research in Indonesia.

Looking back at the founding process one could ponder the fact that the road to the establishment of an Indonesian observatory was not as smooth as it seems at first sight. The Director of the Royal Magnetic and Meteorological Observatory, Professor van Bemmelen, continually complained to de Sitter about the poor conditions for observing in Indonesia, even though they were far better than those of Leiden. Van Bemmelen seemed rather reluctant to see another scientific institution besides his own one faring well, and he also believed that it would be better if the new observatory could be part of his institute.

Another problem which arose during that period was caused by Voute's expectation that there would be an independent Director in the 'Indies', even though he saw no other alternative than to follow closely the research programmes pursued by Leiden. De Sitter did not actually object to this as he was not interested in a power-sharing arrangement with Groningen. In practice, he anticipated that the Director in Java would make all the local decisions and so "... it would be better to allow and recognize his power."

A third problem related to the fact that the Leiden-South Africa connection had become very strong by this time, and many Dutch astronomers had worked in South Africa and served in the observatories there. As a matter of fact, in 1923 de Sitter arrived at a bilateral exchange agreement with Dr Innes from the Union Observatory to make facilities at Johannesburg and Leiden open to astronomers from both institutions. These agreements allowed Dutch astronomers to observe the southern sky, but not from Java. Although the Leiden Professors de Sitter and Hertzsprung corresponded with Voute and with Bosscha during both the pre- and post-construction phases of the Javan observatory, the exchange had no spirit (Pyenson, 1989), and it is significant that not a single Leiden astronomer was at the opening ceremony.

Besides the photographic observation of visual double stars by Voute (1933), who served also as its first Director, several other interesting programmes were conducted at the new observatory, which was named the 'Bosscha Observatory'. In 1926 Professor Pannekoek of Amsterdam spent several months at the Observatory extending his work which was started earlier on the northern sky. This was to draw isophote brightness lines of the southern Milky Way, and many years later this monumental work was employed as a basis for the Milky Way sections of the well-known *Skalnate Pleso Atlas*, an indispensable tool for students of galactic structure. The Observatory honoured Pannekoek's visit by naming one of its observer houses "Rumah Pannekoek" (Pannekoek House), and in more recent times many visiting astronomers have stayed there when making observations at Lembang.

Other visiting astronomers early in the history of the Observatory were Dr Paul Ten Bruggencate of Göttingen (Germany) and Dr E A Wallenquist of Uppsala (Sweden). The first-mentioned astronomer studied globular clusters and carried out photometric and spectroscopic studies of variable stars, while Dr Wallenquist innitiated theoretical studies at the Observatory. He investigated some southern galactic clusters by means of their colors, and studied distributions of stars, particularly in the Sagittarius and Ophiuchus regions. A noted astronomer of the pre-War era was Dr E A Kreiken from the Amsterdam School of Astronomy, and his interests and contributions ranged from theoretical studies of physical double stars to the general distribution of stars in the Milky Way, but in particular in Scutum. Later, in 1950, Kreiken (1950) determined the Oort Constant and the potential energy of the galactic system.

Some notes on personal accounts may be relevant in this context. After a successful undertaking of ten years at Bosscha, Wallenquist returned to his native country to become Professor of Astronomy at Upsalla University. In his account, Wallenquist (1987) described the good weather condition prevailing at the Bosscha Observatory, where about 50% of nights could be used for observing. This percentage was of course higher, reaching about 80%, during the dry season (from April to October). Kreiken, who did not stay long at the Observatory, became a teacher in the HBS (school) in Central Java, and after World War II became head of the Department of Higher Education in Jakarta. According to E van Albada-van Dien (1994), he was instrumental in obtaining UNESCO's donation of the Schmidt telescope to the Bosscha Observatory. We shall return to this instrument later. *Annals* of the Observatory were published until the 1940s, and Volume IV (1940) contained the results of double star observations conducted by many astronomers. Besides Voute and the three scientists already mentioned above, Dr G Simonov participated in the observing programmes from 1936.

In 1939, Dr A de Sitter and later Dr Chr Martin, both from the Leiden School of Astronomy, came to join the staff of the Observatory, and stayed until the war broke out. Due to his age, Voute retired in this same year, and he was replaced as Director by Dr de Sitter.

Between 1943 and 1945 Indonesia was under the control of the Japanese military, and Professor Masasi Miyadi, a young Japanese army captain who later became Director of the Tokyo Astronomical Observatory, was in charge of the Bosscha Observatory. His presence saved the Observatory from improper treatment that might otherwise have taken place. According to his own account, Miyadi (1975) recognized Voute's administrative ability and was also responsible for putting him back to work in Lembang (instead of staying in a concentration camp). However, Miyadi's act was not unique as there were many other Dutch nationals in the occupied territory who were asked to continue administrative duties under the eyes of the military. This situation persisted at least until 1943 when the war situation became intolerable for employing Dutch nationals. Voute worked at the Observatory until the end of World War II, and it was he who received the official "transfer" of the facility back from Miyadi.

Despite Miyadi's efforts, the Second World War and subsequent conflicts were disastrous for the Observatory. Not only did three leading members of the staff perish, but many instruments were found to have deteriorated. After the War, Dr C Hins (1950) was sent to Indonesia from Holland to restore the Observatory, and he found the ground in a jungle-like condition. Discussions soon took place between Ir Poldervaart (Army Triangulation Brigade), Professor Dr H P Berlage (Director of Meteorology and Geodesy Office in Jakarta) and Hins to chart the steps necessary to put the Observatory into effective use once again. It took almost three years to rehabilitate the Observatory, and by August 1949 photographic observations could be resumed. Dr Elsa van Dien (later Elsa van Albada-van Dien) and Dr G B van Albada took charge of the Observatory, and they decided to continue the double star programme and laid down important plans for the 1950s. To the best of my understanding, the Lembang-Leiden connection was maintained in good condition by the van Albadas during this period. It was also during this period that Dr Iwan Nikoloff of Bulgaria joined the staff and conducted some double star observations, while Mr Santosa Nitisastro served as an assistant astronomer.

5 ASTRONOMY EDUCATION AND A NEW TELESCOPE

The importance of teaching astronomy at the university level was realized as far back as 1948, when it received attention from the Dean of the Faculty of Mathematics and Natural Sciences of the University of Indonesia, Professor M Th Leeman. He made the necessary arrangements to transfer the Observatory from a private institution (the

Dutch East Indies Astronomical Association) to the University, and in October 1951 it officially became part of his Faculty (which was later to become the Faculty of Mathematics and Natural Sciences of the Bandung Institute of Technology). In the process, Dr G B van Albada was made the first Professor in the Department of Astronomy. This was the beginning of an association with the University which would ensure a continuing supply of astronomers. It was also the first time that Indonesia incorporated an astronomy curriculum into its tertiary education programmes. Before that time, astronomy (in the guise of 'Cosmography') was taught at the secondary school level, and the classical text books by Visser or Raymond were used in high schools throughout Indonesia.

The model of astronomical education was derived from the Dutch university system, where the first three years leaned heavily on courses in physics and mathematics, with a relatively smaller amount of astronomy. Only after students passed successfully their first three years could they embark on real astronomy courses. The later part of their studies took between two and two and a half years. This system of education persisted until about 1965, when tertiary education in Indonesia became more oriented towards the Anglo-Saxon model, which made it possible for a student to follow a Bachelor's degree with a Masters or a Doctoral degree. Realizing the isolated position of Lembang as far as astronomy is concerned, young graduates are still encouraged to obtain their higher degrees in astronomy abroad. This practice allows younger colleagues to experience contact with a wider circle of astronomers, and hopefully will prevent 'in-breeding'. With this attitude in mind, Bosscha Observatory astronomers purposefully seek to establish co-operation with astronomers from other countries.

A new research direction was initiated at the Observatory in 1959 when a new 51-cm Schmidt-type $f/3.5$ telescope became available. This instrument telescope came into existence through a UNESCO project that was started in 1951, and involved the co-operation of astronomers, optical workers, and engineers from Indonesia, the Netherlands, and the United States. The optical parts for the telescope where donated by UNESCO and were prepared at the Yerkes Observatory (University of Chicago) under the supervision of Dr G P Kuiper, a former Leiden astronomer. The mechanical parts were contracted out by the Indonesian Government to the engineering firm of Rademakers (not the chocolade firm!) in Rotterdam, under the supervision of Ir B G Hooghoudt of Leiden. The assembly, adjustment, and testing were completed successfully by Dr V M Blanco from the Case Institute of Technology's Department of Astronomy (in Cleveland, USA) and Professor Pik Sin The, who is now at Amsterdam. Officially inaugurated on 1960 May 28, the telescope was used immediately to survey Hα emission-line stars in the direction of the galactic centre. Pik Sin The (1961) has already given an elaborate description of the new telescope and I shall, therefore, not repeat it here. Suffice it to say that an important feature of the telescope is its large field of view ($5^\circ \times 5^\circ$), which means that it is a good instrument for research into galactic structure. In addition, the telescope is equipped with a 6° objective prism, with which spectroscopic work can be carried out.

In 1994, at a conference on The Schmidt Telescope, van Albada-van Dien (1994) gave an interesting and a very personal account of the birth of the Bosscha Observatory's Schmidt telescope. Let me quote from her paper:

> UNESCO agreed to the change that involved a somewhat higher price, and contacted the government of Republic of Indonesia about the matter. The government was told that UNESCO was willing to donate the optical parts of a Schmidt telescope for Bosscha Observatory, on the condition that the government would guarantee in writing the cost of constructing the mounting and operating of telescope. Before accepting this obligation, the officials dealing with the project sought information

about the probable costs of mounting. Based on a completely inexpert estimate of US$16,000 the government accepted the offer from UNESCO and signed the contract, to our great satisfaction.

Van Albada was then asked to find a construction company for the mounting. He contacted various well-known telescope construction companies, who offered to build the mounting for a mere (*sic*!) US$150,000 to 200,000. Gone was our satisfaction ... Van Albada in his despair contacted Jan H. Oort, Director of Leiden Observatory Foundation, a foundation, however, that in no way could make up the difference. Oort discussed the problem with the company of Rademakers in Rotterdam, a factory of high-precision tools, among which were cog-wheels. The director of that firm took a great interest in astronomy, and the firm had worked for the Leiden Observatory and Mt. Palomar Observatory. In his explorations to reduce the cost of the mounting, Oort also contacted the directors of the Mt. Wilson & Mt. Palomar Observatories. Mt. Palomar just had at its disposal the "big S," at that time the largest Schmidt telescope in existence. Its director obliged us greatly by allowing Rademakers the free use some of the designs for the "big S," among which that of the plateholder. Rademakers for its part would not charge us for a variety of other designs. And thus the marvel materialized that in 1953 Rademakers made the offer to build the mounting for US$16,000, or a little more. In case the cost would exceed US$18,000, the Leiden Observatory Foundation would provide up to US$4,000 (in the end the Foundation had to provide only US$1,000), and UNESCO too promised an additional US$2,500.

All that remained to be done, in 1954, was for the Indonesian government to sign a contract with the firm of Rademakers for the construction of the telescope mounting. Each and every one of the officials at the Department of Education in Jakarta who was party to the contract expressed great satisfaction with the offer. But the signing of the contract did not come about. It took us years to find out why, and in 1955, after a leave-of-absence, we almost decided not to return to Indonesia unless the contract was signed by the Indonesian government. Finally one of the Bandung university assistants discovered why and how: two of the government officials in Jakarta who were supposed to sign the contract were not on speaking terms with each other! We then easily passed this bottleneck by carrying in person the contract from one to the other. Meanwhile it was June 1956.

Rademakers had already done much of the preparatory work, started the actual construction of the mounting in 1957, and finished it in March 1958. The large cases containing the mounting arrived by ship in Tanjung Priok, the harbour of Jakarta, in May 1958. Van Albada and his student, Santoso, personally went to Jakarta to oversee the careful handling of the precious shipment. It took them three or four days of custom formalities, bureaucracy and some friendly gestures to get the cases from the harbour. On the final stretch to Lembang all that could go wrong went wrong. Out of gas, the crane that was to unload the truck broke down, and it turned out that the large cases with the mounting could not pass through the door of the telescope building. But, as always, solutions were found.

6 INTERNATIONAL CO-OPERATION AND THE FUTURE

The participation of Indonesia in international co-operations may be represented by its readiness to organize meetings in the country. In 1963 an international symposium on 'Stellar Photometry and Spectral Classification' was hosted by the Institute Technology Bandung, the parent institution of the Bosscha Observatory. The meeting was under the general supervision of Professor Pik-Sin The. In 1973 the International Astronomical Union entrusted Indonesia to organize an IAU School for Young Astronomers, and twelve participants from five countries took part in this meeting. Similar activities were organized again in 1983, this time in conjunction with the 60th Anniversary of the Bosscha Observatory; twenty astronomers from six countries came to attend the School, and there were fourteen teaching staff from seven countries. Professor de Jager, in his dual capacities as an officer of the IAU and a Professor of Astronomy at Utrecht, has been very supportive of Indonesian astronomy.

Indonesia only became a member of the IAU in 1979, and the late Professor Edith Muller (Switzerland) and Professor A. Blaauw (Netherlands) are to be thanked for their support. Two years after that, the Second Regional Asia-Pacific Meeting on Astronomy was organized in Bandung. This meeting, which was attended by over 115 astronomers, discussed the problems of Galactic Structure, Extra-galactic Astronomy, Binary and Variable Stars, and Astronomy Education. Since this time, the topic of Astronomy Education has been an essential feature of these Regional Meetings.

The year 1983 commemorated the 60th Anniversary of Bosscha Observatory, and in order to celebrate the occasion the IAU sponsored a Colloquium (No. 80) on Double Stars, with emphasis on physical properties and generic relations. On this occasion, and on many others, the Leids-Kerkhoven Bosscha Foundation has stood ready to promote our astronomical endeavours, and for these gestures the community of Indonesian astronomers wishes to express its grateful appreciation.

Another aspect of international co-operation is the link between astronomy in Indonesia and Japan, which was started in 1978. The activities of this fruitful co-operation have been reviewed by Kogure and Hidayat (1985).

A revival of Dutch-Indonesian co-operation in astronomy has been established formally within the framework of 'Indonesian-Netherlands Astrophysics' (INA), which has operated under the cultural treaty between the Indonesian and Dutch governments. Four main research areas have been adopted in the co-operative work. They are:

- studies of visual binaries;
- studies of the spatial distribution of the hottest and coolest stars;
- high- and low-energy astrophysical studies of evolved massive binaries; and
- investigation of shock waves and particles in curved space time corresponding to plasma and condensed media.

Under this umbrella of co-operation, Indonesian students have had the opportunity to study in the Netherlands and obtain higher degrees in astronomy.

The Indonesian astronomical community is naturally looking forward to the realization of hardware projects, which would enable it to expand its activities and research. Since the Schmidt telescope of the 1960s, a new 45-cm telescope has been commissioned (in 1989). This instrument, which was obtained through the Indonesia-Japan collaboration, is dedicated to photometry of close binary stars. A versatile instrument, this telescope is also used to carry out spectroscopic studies.

An anticipated project is the acquisition of a large optical telescope. The original idea was launched by van der Hucht (1984), who suggested that a 2.5-m class telescope would be suitable for Indonesia. The idea has been received with great and sincere enthusiasm in Indonesia, and it is hoped to produce a more elaborate view on this project in the future. Another suggested project, which has been temporary shelved, is to establish a metre radio telescope in equatorial Sumatera (see Swarup, Sukumar and Hidayat, 1984).

7 IN RETROSPECT

Since its emergence in the Netherlands back in the seventeenth century, science has become a permanent engine of progress and a determining force in the pursuit of betterment. The hegemony, and to some extent exploration, of the West in general, the Dutch in particular, has brought the earth, meteorological, biological, and astronomical sciences into our oriental Indonesian domain. In principle we, in the east, accepted the message of modern science and technology. Of course we do realize that the implantation and the effective application of such concepts strike against some long-rooted traditions and, consequently, attitudes. Therefore, the existing social structure in Indonesia may affect the growth of science in our country.

When it proclaimed its independence in 1945, Indonesia inherited a set of good modern scientific institutions, in which we should rejoice. However it took us a reasonably long time to recover the manpower needed to steer the high and noble enterprise due to the disruption of World War II. In the meantime, during the same period, new avenues of activities and new priorities relating to social institutions and welfare have impacted on our working domain. All of these have to be solved simultaneously if the country is to survive the demands of the modern world.

Astronomy eventually found its place in Indonesia, thanks to the founding fathers and Dutch scientists after World War II. Of course many things still have to be done if we are to show ourselves on the plane of modern science. There is one maxim which I would like to reiterate, that I learned in 1951 from Minnaert's book, *De Sterrenkunde en de Mensheid* (Servire, Den Haag, 1946): "Van de universiteit moet zich de wetenschap geleidelijk over het gehele volk verspreiden, zoals het bevruchtende water van de hoogten der bergen daalt en valleien bevloeit." which tranlates approximately as: "From the university scientific knowledge should flow throughout the entire population, just as enriched water from the mountains fertilizes the valleys below." This is precisely what we are striving to do with our numerous seats of higher learning in Indonesia.

8 NOTES

1 Adapted from the 'Lustrum Lecture', given at University of Leiden, May 18, 1995.

2 Frederick De Houtman was the brother of Cornelis de Houtman who later became a high official in the Dutch East Indies Company and the Governor of the islands of Maluku.

3 When de Houtman arrived on the shores of Aceh, the study of stars in the Indonesian archipelago had already been the practice of seafarers and farmers since time immemorial. The main purpose of the practice was to construct a calendar system from which agricultural activities could be organized and religious ceremonies could be conducted. Inter-island voyages also required a knowledge of the sky. It is beyond the scope of this paper to describe in detail the practice of astronomy in ancient Indonesia, but for a recent review see Hidayat (2000).

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"The papers presented here ... are mainly the proceedings of the International Schall Symposium held in Sankt Augustin in May 1992." Seventeen of the 54 papers are in Chinese.

See particularly part III, "Johann Adam Schall von Bell – Astrology, Astronomy, and Calendar" (p. 369–616).

Zach, Franz Xaver, *Freiherr* von. Astronom, Weltbürger, Blasensteinpatient: Franz Xaver von Zachs Briefe an Rudolf Abraham von Schiferli, 1821–1832. Eingeleitet und hrsg. von Leo Gosteli, Urs Boschung, Peter Brosche. Basel, Schwabe, 1998. 382 p. illus., ports. (Gesnerus. Supplementum, 45)

Zuidervaart, H. J. Speculatie, wetenschap en vernuft. Fysica en astronomie volgens Wytze Foppes Dongjuma (1707–1778), instrumentmaker te Leeuwarden. Ljouwert/Leeuwarden, Fryske Akademy, 1995. 206 p. illus., facsims., map, ports. (FA, nr. 814) (Fryske histoaryske rige, nr. 12)

Contents: 1. Inleiding. – 2. De vorming van een 'wiskundig vernufteling.' – 3. Rekenmeester, instrumentmaker & natuurfilosoof. – 4. Astronoom. – 5. Kometen, planeten en een collectieve angst voor de eindtijd. – 6. Invloed, context en betekenis.

Zuidervaart, H. J. Van 'konstgenoten' en hemelse fenomenen; Nederlandse sterrenkunde in de achtiende eeuw. Rotterdam, Erasmus Pub., 1999. 663 p. illus., facsims., maps, ports. (Nieuwe Nederlandse bijdragen tot de geschiedenis der geneeskunde en der natuurwetenschappen, nr. 58)

Contents: d. 1. Inleiding en probleemstelling. – d. 2. Achtergronden. – d. 3. Het probleem van de loopbaan van kometen. – d. 4. Het probleem van de zonne-parallax. – d. 5. Epiloog.

Supplements include lists of astronomical observatories active in Europe, 1710–1750; Netherlands publications on eclipses, 1700–1750; observations in the Netherlands of comets, 1715–1770; Netherlands observers of transits of Mercury and Venus, 1736–1769; and astronomical observers in the Netherlands, grouped by educational background, 1715–1770.

"Dutch astronomy in the 18th century" (English summary): p. 415–422.

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Achar, B. N. Narahari. On an astronomical concept in Visnupur_na. Indian journal of history of science, v. 34, June 1999: 109–115.

Ackermann, Silke. Sun, moon and stars: telling the time with astronomical instruments from the British Museum. Antiquarian horology, v. 25, Sept. 1999: 31–46. col. illus.

Another illustration, showing three instruments, appears on the outside front cover of the issue.

Allison, Chantal. The Ifriqiya uprising horoscope from *On Reception* by Masha'alla, court astrologer in the early 'Abbasid caliphate. Culture and cosmos, v. 3, spring/summer 1999: 35–56. illus.

Altschuler, Eric. An astronomical whodunnit. Astronomy & geophysics, v. 40, Oct. 1999: 8. port.

Argues that the astronomical knowledge, or lack of it, in Shakespeare's plays supports the proposal of the Earl of Oxford as their author.

Aquilecchia, Giovanni. Bruno at Oxford between Aristotle and Copernicus. *In* Giordano Bruno, 1583–1585: the English experience/l'esperienza inglese. Atti del convegno (Londra, 3–4 giugno 1994) a cura di Michele Ciliberto e Nicholas Mann. Firenze, L. S. Olschki, 1997. (Istituto nazionale di studi sul Rinascimento. Atti di convegni, 20) p. 117–124.

Aricò, Denise. Les "yeux d'Argos" et les "étoiles d'Astrée" pour mesurer l'univers. Les jésuites italiens et la science nouvelle. Revue de synthèse, t. 120, avril/sept. 1999: 285–303.

Abstract in English.

"Comme la nova de 1604 et les trois comètes de 1618, qui engagèrent Galilée et les jésuites du Collège romain dans un long débat, la comète de 1664 a relancé la curiosité et l'attente des astronomes et des astrologues. L'article analyse quelques aspects de ce débat européen ..."

Armijo Canto, Maruxa. División medieval del día astronómico: la hora. *In* Jornadas Medievales, *5th, Mexico City, 1994*. Caballeros, monjas y maestros en la Edad Media. Actas de las V Jornadas Medievales. Editores: Lillian von der Walde, Concepción Company, Aurelio González. México, Universidad Autónoma de México, 1996. (Publicaciones de Medievalia, 13) p. 507–519.

Aveni, Anthony F. Astronomy in the Mexican Codex Borgia. *In* Archaeoastronomy. no. 24; 1999. Cambridge, Science History Publications. p. S1–S20. illus., facsims.

Aveni, Anthony F. The star of Bethlehem: was it a celestial event, a supernatural phenomenon, or a story made up by Matthew? Archaeology, v. 51, Nov./Dec. 1998: 34–42. col. illus., facsim.

Includes a box, "Dialogue With the Firmament" (p. 39), on the widespread practice in antiquity of looking to the stars for guidance regarding the future.

Another color illustration appears on the outside front cover of the issue.

See also comments by the editor in chief on p. 2.

Bakhouche, Béatrice. Musique et philosophie. Le De institutione musica de Boèce dans la tradition encyclopédique latine. *In* Association Guillaume Budé. Bulletin, oct. 1997: 210–232.

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Débarbat, Suzanne V. À propos des éclipses totales de Soleil en Europe, depuis le XV^{e} siècle. L'Astronomie, v. 113, mai 1999: 128–133. facsims., map.

A painting (artist unknown) of the scene at the Paris Observatory on the occasion of the last eclipse visible there (22 May 1724) is reproduced in color on both sides of the front cover of the issue. See also the color illustration of the total solar eclipse of 18 July 1860 on the outside back cover.

Débarbat, Suzanne V. Cassini et ses découvertes dans le système de Saturne. L'Astronomie, v. 113, oct. 1999: 248–257. facsims., map, port. (Histoire)

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Dimitrijević, Milan S. Life and scientific activity of Professor Ivan Atanasijević (1919–1998). Serbian astronomical journal, no. 158, Nov. 1998: 147–156. port.

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Fernie, J. Donald. The American Kepler. American scientist, v. 87, Sept./Oct. 1999: 398–401. col. illus., col. port. (Marginalia)

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Ferrari d'Occhieppo, Konradin, Rolf Krause, *and* Theodor Schmidt-Kaler. Die Gefilde der altägyptischen Unterwelt: Spiegelbild der Sonnenbahnen im Jahreslauf. Zeitschrift für ägyptische Sprache und Altertumskunde, Bd. 123, Heft 2, 1996: 103–110. illus.

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Grebe, Sabine. Die Astronomie (8.803–887). *In her* Martianus Capella, 'De nuptiis Philologiae et Mercurii.' Darstellung der Sieben Freien Künste und ihrer Beziehungen zueinander. Stuttgart, B. G. Teubner, 1999. (Beiträge zur Altertumskunde, Bd. 119) p. 494–616.

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See also, in the section entitled "Querverbindungen innerhalb des ganzen Werkes," the subsections entitled "Buch 8 und 9: Astronomie und Musik" (p. 744–755) and "Buch 6, 7 und 8: Geometrie, Arithmetik und Astronomie" (p. 755–767).

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"Fellow of the RAS, Senior Technical Officer of the Cambridge Observatories, constructor and operator of solar magnetograph."

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CLEA = Comité liaison enseignants/astronomes.

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See also the first section, "L'astrologie, victime de la restauration et de la raison en Angleterre (1660–1700)," in ch. 11, and treatment of the resurgence of astrology in contemporary life in ch. 16.

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"Insgesamt hat Pallas durch seine wissenschaftsorganisatorischen Aktivitäten und die Forschungsarbeit an der sibirischen Eisenmasse dazu beigetragen, den Boden für die Meteoritentheorie von E. F. F. Chladni zu bereiten, wofür er das Kommunikationsnetz der russische-europäischen Wissenschaftsbeziehungen genutzt hat."

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Witt, Volker. Zum 200. Geburtstag von Friedrich Wilhelm Argelander. Sterne und Weltraum, 38. Jahrg., Nr. 10, 1999: 898. port. (Geschichte)

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Zik, Yaakov. Galileo and the telescope. The status of theoretical and practical knowledge and techniques of measurement and experimentation in the development of the instrument. Nuncius, anno 14, fasc. 1, 1999: 31–67. illus.

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R. S. Freitag
Library of Congress
April 2000

Reviews

The Victorian Amateur Astronomer. Independent Astronomical Research in Britain 1820-1920, by Allan Chapman (Wiley-Praxis Series in Astronomy and Astrophysics, John Wiley & Sons, Chichester, 1998), xx + 428 pp., ISBN 0-471-96257-0, cloth £40, 245 x 172 mm.

The nineteenth century was a time of remarkable change in astronomy, particularly late in the century when "new astronomy", astrophysics, was beginning to eclipse positional astronomy. Amateur astronomers world-wide played a key role in these developments, and this book brilliantly portrays the role of Britain in all this.

Allan Chapman is well-known for his numerous research papers on the history of astronomy, and this sizable tome is an important contribution to the subject. In his Preface, Chapman explains that he is interested in "... tracing the history of a scientific movement within nineteenth-century British society ..." and that he has four inter-related factors in mind:

- to write primarily about astronomers rather than about astronomy *per se*;
- to relate these astronomers to the social and financial worlds in which they lived;
- to examine the development of ideas in nineteenth-century astronomy and see how amateur astronomers were involved in advancing understanding of the universe; and
- to chart advances in instrumentation.

Chapman then proceeds to assign his material to three different Parts.

Part 1, titled "Grand Amateurs", examines the contribution made by "... those independently wealthy individuals who took upon themselves the reform and advancement of British astronomy at the highest technical and intellectual level." After two introductory chapters which set the professional astronomical "scene" so to speak in Britain and Europe, we are introduced – in Chapman's easy writing style – to many familiar names, including Carrington, Cooper, Dawes, De La Rue, Groombridge, Lee, Sir John Herschel, Sir William Huggins, Lockyer, Pearson, W H Smyth and his son, Sir James South, and the telescope-makers, Common, Lassell, Nasmyth and William Parsons, the Third Earl of Rosse. Ending this account is a chapter about those oft-forgotten professional assistants to the Grand Amateurs. Part 1 occupies 157 pages of this book, and obviously a separate book could be written about each of the above astronomers and telescope-makers (and some already have been), but those seeking further information and wishing to follow up particular individuals or themes are well served with a detailed and copiously-referenced "Notes and references" section.

One of the things I found particularly refreshing about Chapman's approach was his decision to include Parts 2 and 3 of this book. Collectively they encompass a little over 140 pages, and are respectively titled "Poor, obscure and self-taught: astronomy and the working class" and "The rise of the leisured enthusiast".

In his Prologue to Part 2, Chapman explains that astronomy had a lively following among the working classes, but that "Because there were no social forums or journals to which they had easy access, and because their overall social position was one in which literary record was not necessary for daily survival ... [their] activities are extremely patchy in their documentary remains." After a chapter on "A penny a peep: the astronomical lecturers of the people", we are introduced to seven case studies of modest astronomers: a baker, a blacksmith, a cobbler, a ploughwright, a railway porter, a slate counter and a station master. The trials and tribulations of pursuing an amateur astronomical "career" within the context of limited means and opportunity certainly come through.

Part 3 deals with the late nineteenth century and what Chapman identifies as "... a new type of amateur astronomer... People of more modest fortune and ambition. They were what might be called the 'leisured enthusiasts'." Supplying this new breed of amateur astronomer with information were people like Ball, Proctor and Webb, while their instrumental needs were satisfied by Calver, Cooke and With, amongst others. To Chapman's way of thinking, Cooke and America's Alvan Clark "... barged as bulls into the optical china shop and brought in their wake those refreshing winds of change which shook up old monopolies, old technologies, and old pricing policies to bring the refracting astronomical out of the closet of exclusiveness." Also serving the burgeoning population of British amateur astronomers were the earliest formal groups: the Leeds, Liverpool, Manchester, Newcastle-on-Tyne and Ulster Astronomical Societies, the Astronomical Society of Wales and the British Astronomical Association. A notable feature of these societies was the admission of women to membership, and as a consequence the late nineteenth century saw increasing numbers of women amateur astronomers rising to prominence in Britain. In Chapter 14, titled "Now ladies as well as gentlemen", Chapman discusses the achievements of Elizabeth Brown, Agnes Clerke, Mary Evershed (neé Orr), Agnes Giberne, Lady Huggins, Annie Maunder and Mary Proctor, and a number of others whose names are not so widely known.

A concluding chapter succinctly brings us up to date by reviewing contemporary British amateur astronomy.

One of the things that makes Chapman's account of nineteenth century astronomy so entertaining is the inclusion of numerous quotations throughout the book. Some of these are simply delightful: imagine the unidentified sailor at a Tyneside barber's shop during the 28 July 1851 total solar eclipse who explains to a woman present: "Oh, its only the moon, ma'am, that broke adrift and got athwart the sun. It'll all be right by-and-by, if the old boy [God!] only puts the helm hard over" (page 172), or a London contemporary, Mr Tregent, describing the challenge of making telescope objectives: "Men have been known to go and throw their heads under waggon wheels, and have them smashed, from being regularly worn out with working an object glass, and not being able to get the convex right." (page 175). And on page 34 we read of Airy's destain for astronomical observation: "The lowest of all employments in the [Greenwich] Observatory is mere observation. No intellect and very little skill are required for it. An idiot with a few days' practice may observe very well". Hardly wanting to be branded an idiot himself, is it little wonder that the distinguished Astronomer Royal left the observing to others?

In addition to quotations, the book is well illustrated, with 80 different black and white plates. Although some are well-known images, there are others that I do not recall having seen in print previously. But if I have one concern – and it is only a slight one – it is with the placement of these plates. Rather than incorporating them within the text, they have been grouped in 8-page lots at four different places throughout the book. This was presumably done in the interests of cost, but I found it a little inconvenient.

It is to be expected that a book exceeding 400 pages will include some errors, but in this instance they appear to be few and far between. However, the first magnitude southern star, Alpha Centauri, could hardly be described as "visually dim" (p.42), and the Great Melbourne Telescope (known as the "GMT" in Australian circles!) was pressed into service at Melbourne Observatory in 1869 rather than 1874 (p.109).

Yet these are minor concerns, and I think this is an excellent book. Obviously, the focus is on England, but by using it in conjunction with other works (including Ashbook's *The Astronomical Scrapbook* and Clerke's *A Popular History of Astronomy During the Nineteenth Century*) one can quickly gain an international perspective, and at the same time come to appreciate the immense contribution that was made by the British amateur astronomer to positional astronomy *and* astrophysics during the period 1820-1920.

The final assessment? I thoroughly enjoyed reading this book, and recommend it to others. It is excellent value at £40, and deserves to be on the bookshelf of every astronomer with an interest in nineteenth century astronomy or the role of the amateur in world astronomy. I believe that this book will long remain a standard text for historians of astronomy.

Wayne Orchiston

Mapping and Naming the Moon: A History of Lunar Cartography and Nomenclature, by Ewen A Whitaker (Cambridge University Press, Cambridge, 1999), xix + 242 pp., ISBN 0 521 62248 4, cloth £37.50, , 253 × 195 mm.

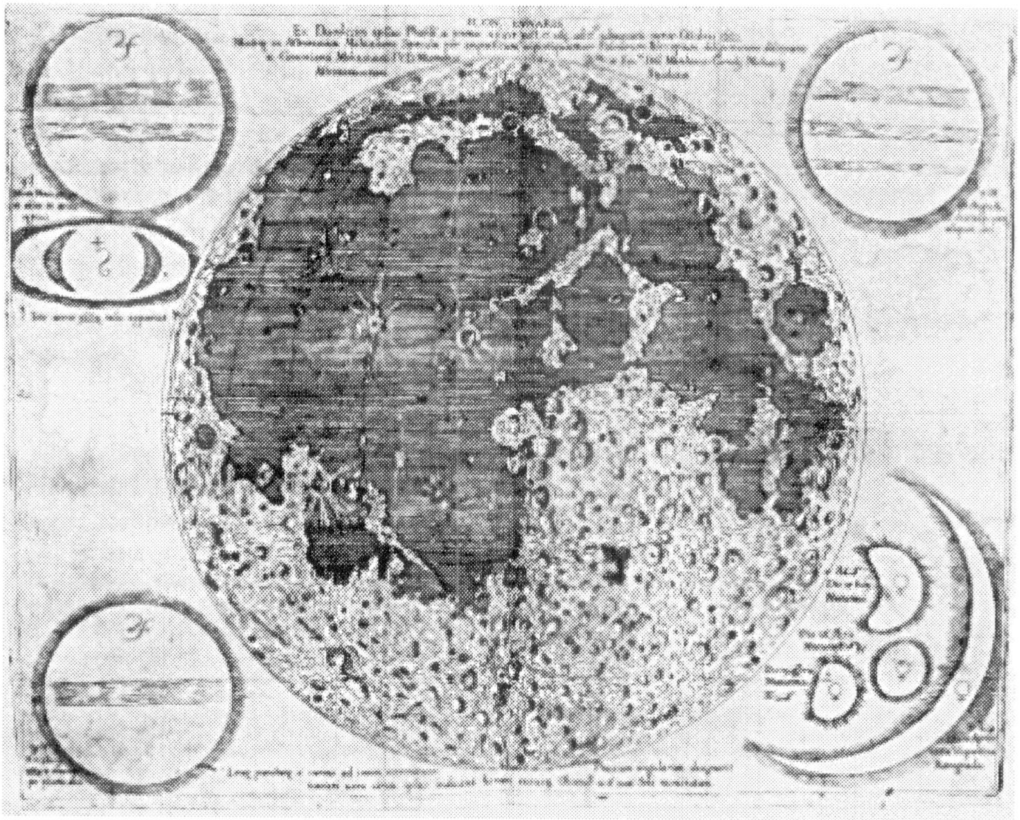
The markings on the face of the Moon are visible to the naked eye and have been known since antiquity. Telescopic study of the Moon and more recently its exploration by spacecraft have revealed ever more detail. There is a similarly long history of naming lunar features. *Mapping and Naming the Moon* tells the sometimes circuitous story of lunar mapping and nomenclature.

The treatment is chronological. It starts with the 'Man in the Moon' and other images traditionally seen in the lunar disc. There were a couple of pre-telescopic drawings by Leonardo da Vinci and William Gilbert. However, the first drawings from telescopic observations were made by Galileo Galilei and Thomas Harriot around 1610. Whitaker convincingly refutes the common idea that Galileo's original drawings were crude and that the features in them cannot be identified.

The first detailed lunar nomenclature was introduced by Van Langren in his map of 1645. Modification of his names was forbidden by Royal Decree under pain of incurring the 'indignation' of the King of Spain. Nonetheless, two entirely different systems of nomenclature appeared within six years. One was introduced by Helvelius in his *Selenographia* of 1647. The other was due to Riccioli and Grimaldi and appeared in the *Almagestum Novum* in 1651. These two different systems persisted in parallel for about one hundred and forty years and it is the Riccioli and Grimaldi names which form the basis of modern nomenclature.

Maps of increasing complexity and detail were produced by Mayer, Schröter and, in the nineteenth century Lohrmann, Beer and Mädler, Schmidt, Neison, and others. Most of these authors introduced additional names. By the start of the twentieth century lunar nomenclature had degenerated into chaos with many features enjoying multiple names and different authors applying the same name to different features. A determined effort at standardisation was made by *inter alios* Saunder, Turner, Müller and, in particular, the indefatigable Mary Blagg. This effort resulted in the *Named Lunar Formations* of 1935, a definitive list of standard names which was adopted by the IAU. Perhaps surprisingly, there was similar confusion during the late 1960s and 1970s when the nomenclature was extended to the far side and smaller features because of exploration by spacecraft. However, again standardization by the IAU ultimately restored order.

The author, now retired, was latterly a selenographer at the Lunar and Planetary Laboratory, Tucson, and was, for many years, heavily involved in American programmes to map the Moon. He is uniquely well-qualified to tackle the subject. The book is well written and produced. Detailed lists of the feature names used by different authors are given in appendices. Similarly, representative references for each chapter are listed in an appendix. This approach leaves the main body of text uncluttered and easy to read. The book is profusely illustrated and the figures chosen with care. They virtually all show the lunar maps and drawings being described and many would otherwise be difficult to find.



Map of the Moon published by Geminiano Montanari in 1662 (see *Mapping and Naming the Moon*. The drawings in three of the four corners show sketches of the cloud bands of Jupiter (see *Galileo's Planet*).

I suppose the book most similar to Whitaker's is *Mapping of the Moon* by Z Kopal and R W Carder (1974, D Reidel, Dordrecht). However, this latter is now over a quarter of a century old, and has a different emphasis; only its first chapter is really similar. It is pleasing to see the development in knowledge of early lunar mapping during the period between them: one of the drawings of the Moon by da Vinci which Kopal and Carder thought lost is reproduced by Whitaker. The book is detailed, comprehensive, authoritative and likely to become the definitive work on the subject. I enjoyed reading it and learnt a lot: it can be recommended to anyone interested in selenography or the history of lunar observation.

Clive Davenhall

Galileo's Planet: Observing Jupiter Before Photography, by Thomas Hockey (Institute of Physics Publishing, Bristol and Philadelphia, 1999), xvii + 217 pp., ISBN 0 7503 0448 0, cloth £29.95, US$49.50, 241 × 165 mm.

The cloud bands of Jupiter are visible through even a small telescope and are some of the most obviously variable phenomena in the solar system. *Galileo's Planet* is a survey of the historical observations of these features from the invention of the telescope until photography was applied to astronomy in the last few decades of the nineteenth century.

An introductory chapter sets the scene with a summary of what is now known about Jupiter and a description of the modern BAA nomenclature for the belts and zones. Thereafter the treatment is largely chronological. A short second chapter covers pre-telescopic observations. However, the story really starts with the application of the telescope to astronomy by Galileo Galilei in 1610. The disc and major bands were soon recognized, as were satellite shadows crossing the disc. Later the first isolated spots were discovered by Campani, Hooke, and Cassini. A chapter describes these important seventeenth century advances. The following chapter covers the eighteenth century, though there was little further progress: only a few astronomers were interested in Jupiter and the focus of astronomy was elsewhere.

Three chapters, about half the book, cover the nineteenth century. During this period knowledge of the morphology of Jovian atmospheric features increased greatly. A number of factors contributed to this progress: certainly there were better telescopes and more observers. Moreover, astronomers began to work co-operatively, sharing results through the new medium of single-discipline journals. As the century progressed it became apparent that isolated, intermittent observations were not adequate to understand the transient and time-varying phenomena occurring in the Jovian atmosphere. Systematic sequences of observations were required, ultimately leading to continuous monitoring programmes, the descendants of which continue to this day. Interest in Jovian atmospheric features was stimulated by the equatorial reddening around 1870 and the appearance of the Great Red Spot in 1878. The book's coverage ends at about 1880.

The penultimate chapter covers theories of Jupiter from the beginning of the seventeenth to the end of the nineteenth centuries. During this time models which saw Jupiter as broadly a 'large Earth' gave way to ones in which it was a 'small Sun'. The final chapter tidies up a few loose ends, including considering who the Jupiter-watchers were and where they worked. Before the introduction of photography the only ways of recording morphological features were drawings and written descriptions. A discussion brings out the strengths and limitations of each technique and is amply illustrated by the numerous figures throughout the book (all in black and white apart from the frontispiece, though this is no great detriment). One problem was that the planet was faster than the pencil: Jupiter's rapid rotation, coupled with foreshortening towards the limb, transported features out of view before all the detail visible could be recorded.

The author is an Associate Professor at the University of Northern Iowa and has written about historical observations of Jupiter for many years His book is well written and produced. It is comprehensive, detailed and thoroughly referenced. It complements the two modern syntheses of terrestrial observations of Jupiter: Peek's *The Planet Jupiter* (1958, Faber and Faber, London) and Roger's more recent *The Giant Planet Jupiter* (1995, Cambridge University Press, Cambridge). It can be recommended to both historians of planetary observation and Jupiter-watchers alike.

Clive Davenhall

Eyes on the Universe. The Story of the Telescope, by Patrick Moore (Springer, London, 1997), viii + 120 pp., ISBN 3 540 76164 0, paperback £9.95, 234 × 155 mm.

Patrick Moore is so well known to astronomers, amateur and professional alike, and many of us who are now in our fifties were inspired to pursue a career in this noblest of sciences as a result of reading *Guide to the Moon*, *Guide to the Planets*, and other "favourites". This is one of Patrick's strengths: his ability to produce readable astronomy books, on innumerable topics, decade after decade. *Eyes on the Universe* is his latest work on the history of optical telescopes, and was published to mark the fortieth anniversary of his world-record television programme, "The Sky at Night".

In just 120 pages we are taken on a chronological tour from pre-telescopic times, via familiar figures like Galileo, Newton, Sir William Herschel, and the Third Earl of Rosse, the "great refractors" of the nineteenth century, and reflectors associated with George Ellery Hale, to "recent" telescopes (including the 6-m Russian reflector, the Anglo-Australian Telescope, the Isaac Newton and William Herschel Telescopes, the various instruments at Cerro Parañal, La Silla, Cerro Tololo and Las Campanas in

Chile, and the two 10-m Keck reflectors and other telescopes on Mauna Kea). The final chapter takes us beyond the Earth, by introducing the Kuiper Airborne Observatory, satellite telescopes and the Hubble Space Telescope. Completing the book are two Appendices; the second of these is titled "Some Great Telescopes", and it is a sign of how quickly the state-of-play changes that most of the very large instruments listed there as "Telescopes in preparation" are now operational.

Obviously individual books could be written about many of the telescopes mentioned in this book (and some already have been), but Patrick has done a good job in producing a general introduction. Nor has he attempted to gloss over some of the controversies or uncertainties surrounding certain instruments and individuals, such as the roles of Robert Grosseteste, Leonardo da Vinci and Leonard Digges in the invention of the telescope. On the other hand, given the demands of brevity, there is no Bibliography, or even a list of "Further Reading".

One of the positive features of this little book is the large number of high quality colour photographs scattered through the text. But if I have one minor quibble it is that greater care was not devoted to checking the captions. Indeed, the very first one, on the Acknowledgements page, shows the author posing beside one of his smaller reflecting telescopes, not the 15 inch (38.1 cm) that is mentioned in the caption! On page 32, we read of Herschel's "40-foot refractor"(!), while on page 80 the lower photograph actually shows the dome of the Auckland Observatory's 50.8-cm Zeiss reflector and not "... the Mount John reflector in New Zealand".

These concerns aside, in an age when it is typical to pay more than £25 for an astronomy book, it is a pleasure to find a volume - albeit a slim one - at what can only be described as a "bargain basement price". *Eyes on the Universe* is good value, a good read, and yet another worthwhile product from the prolific pen of Patrick Moore.

Wayne Orchiston

Other books received

Seven Wonders of the Cosmos, by Jayant V. Narlikar (Cambridge University Press, Cambridge, 1999), x + 324 pp., ISBN 0 521 63898 4, paperback AU$34.95, ISBN 0 521 63087 8 cloth AU$110.00, 228 × 152 mm.

Using simple analogies and a wealth of illustrations, the author skilfully steers the reader through a cosmic journey of discovery from Earth to galactic distances. Each of the seven wonders represents a range of mysterious phenomena, a class of spectacular events, or remarkable cosmic objects which have challenged human curiosity.

The Cambridge Concise History of Astronomy, edited by M. Hoskin (Cambridge University Press, Cambridge, 1999), 362 pp., ISBN 0 521 57600 8, paperback AU$48.95, ISBN 0 521 57291 6, cloth AU$125.00, 250 × 175 mm.

Concise is the operative word for it appears to contain more material than the editor's *The Cambridge Illustrated History of Astronomy* of 1997. Each of the authors does a thorough job with their respective chapters.

The American Astronomical Society's First Century, edited by David De Vorkin (American Astronomical Society, Washington, DC, 1999), 350 pp., ISBN 1 563 96683 2, cloth US$45.95, 285 × 220 mm.

While not as old as the Royal Astronomical Society, this prestigious society celebrated its centenary in 1999 September. Both societies had humble beginnings with fifty astronomers meeting at Yerkes Observatory and today over a thousand attend the annual meeting. Well illustrated, this volume tells the story of people rather than science.

Worlds Without End, The Historic Search for Extraterrestrial Life, by Roger A. S. Hennessey (Tempus Publishing, Stroud, 1999), 160 pp., ISBN 0-7524-1450-X, cloth £18.99, 254 × 178 mm.

Covers the contributions of philosophers, theologians, and scientists over the past 2500 years, for example, Plato, Aquinas, Newton, Kant, Paine, Wells, Hoyle, and Crick. Well illustrated, the book reveals that much of what is considered new today turns out to be old and well worn.

Aiming for the Stars, The Dreamers and Doers of the Space Age, by Tom D. Crouch (Melbourne University Press, Carlton, 1999), xiii + 338 pp., ISBN 0 522 84885 0, cloth AU$45.00, 233 × 157 mm.

A history of the space age from sixteenth-century astronomers and philosophers to the present-day astronauts. It links the individuals of space travel with the political events and social currents which surrounded them, to paint a complete picture of four centuries of vision and action in space exploration.

Guido Horn d'Arturo e lo specchio a tasselli, edited by Marina Zuccoli and Fabrizio Bònoli (Cooperativa Libraria Universitaria Editrice Bologna, Bologna, 1999), 103 pp., ISBN 88-491-1292-0, paperback, 240 × 170 mm.

Reprints of nine of d'Arturo's papers relating to multi-mirror telescopes from 1932 to 1966 together with introduction and short biography (Un insigne maestro) make this an interesting read. A fuller story of his astronomical and cultural life was published by CLUEB in 1994, *Guido Horn d'Arturo, astronomo e uomo di cultura*.

From Galaxies to Turbines, Science, Technology and the Parsons Family, by W Garrett Scaife (Institute of Physics Publishing, Bristol, 2000), xvi + 579 pp., ISBN 0 7503 0582 7, hardcover £35.00 US$45.00, 240 × 160 mm.

Covering some 125 years, Scaife relates the story of the Parsons family and their roles from astronomy to shipbuilding during the industrial revolution. Considered a world expert on the Parsons family, Scaife covers the period in great detail without going into too much technology.

Science in Translation, movements of knowledge through cultures and time, by Scott L Montgomery (University of Chicago Press, Chicago, 2000), xi + 325 pp., ISBN 0-226-53480-4, cloth US$28.00 £18.00, 235 × 158 mm.

Examines the role of translation in handing down and recovery of scientific texts during written history. Many examples are given showing the power of the translator to include his own interpretation, sometimes good, sometimes not so good. One example given is the translation of Newtonian physics into Japanese from a Dutch text, which in turn was a translation of the Latin text by John Keill.

The Astrophysical Journal, American Astronomical Society Centennial Issue, edited by Helmut A Abt (University of Chicago Press for the American Astronomical Society, 2000), ix + 1283 pp., ISBN 0-226-00185-7, cloth US$50.00, 293 × 220 mm.

Fifty-two papers of this century from *The Astronomical Journal* and *The Astrophysical Journal* are presented. Each paper is accompanied by a commentary providing the scientific-historical context essential to comprehending its original impact.

The Irish Astronomical Journal

Founded in 1950

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The editor will consider for publication papers on all aspects of astronomy: observational, theoretical, technological and historical. Papers on related topics such as geophysics and climatology will also be considered.

A Cyclopaedia of Telescope Makers was published in the IAJ in seven parts from 1992 to 1997, with 368 illustrations. The *Cyclopaedia* consists of short biographical notes on telescope-makers, telescope-opticians, telescope-engineers, contemporary astronomers and natural philosophers, and retailers of optical scientific instruments of particular influence in their time. It is intended to provide some guidance to those seeking up-to-date information on telescope making, retailing and designing over the last four centuries.

The Editor welcomes communications of all kinds with subscribers worldwide. All correspondence and requests for further information regarding submissions for publication, subscription prices and advertising please contact the editorial office by letter or e-mail or visit the associate website (see below for details).

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Cover illustrations show a series of images of the η Carinae area beginning with a drawing by John Herschel published in 1847, a black and white photograph taken by Ben Gascoigne with the MSSSO 40-inch reflector at Siding Spring, a colour photograph taken by David Malin with the AAO 150-inch at Siding Spring, and a view taken with the Hubble Space Telescope, courtesy J Morse (U. CO), K Davidson (U. MN), and NASA.