Astronomy in Antarctica

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In their continual quest to understand the Universe around us, astronomers have always to work at the edge of current technology, and to bring together the best people in the fields of engineering, optics, electronics and computing to achieve their goals. Three limiting factors affect our ability to detect and record electromagnetic radiation arriving at the Earth from space; the size of our telescopes, the efficiency of our detectors, and the quality of the site where we perform the observations. As the end of the 20^{th} century grows near, astronomers are nearing the limits achievable for the first two factors. For instance engineering constraints limit the size of any ground-based optical telescope to little more than the 8m-class of telescopes currently being built. Detectors are getting close to 100% efficiency, which means they record nearly every photon they collect. The third limitation is the site from which observations are conducted, and here there is still room for considerable improvement.

Although it is of course essential to the continued well-being of life on the Earth, the atmosphere is a considerable source of disruption to many types of astronomical observation. Ideally astronomers would like to place their telescopes outside it. Major observatories today are built on high mountain tops on volcanic islands, such as Mauna Kea in Hawaii, or on desert mountain ranges, such as around the Atacama desert in Chile, where the air is extremely dry and stable. These still suffer many debilitating affects from the atmosphere, and a space-based platform, such as an orbiting space station or a Moon base, makes the ideal location for an astronomical observatory. While the engineering requirements for such an undertaking are just about within our capabilities, economic factors currently preclude it on the grounds of cost and competition for other resources. There is an alternative, however, which comes close to offering many of the advantages of space for a fraction of their cost. It is the Antarctic Plateau. The vast Antarctic Plateau, larger in area than the continent of Australia and most of it over 3000m high, makes Antarctica the highest continent on the Earth, as well as being the coldest and the driest place. Temperatures can fall to -90°C in the middle of winter, and the amount of water vapour in the air is typically one third to one fifth the amount of even a dry place like Mauna Kea. The height makes the air extremely thin, and because the atmospheric circulation patterns are centred around the Antarctic Plateau, the average wind speed is very low, unlike the Antarctic coast. This combination of extremely cold, dry and tenuous air makes the Antarctic Plateau the preeminent location for observing the heavens from the surface of the Earth. Of course, this has to be tempered against the technical and logistical challenge of constructing and operating an observatory in such a location, but this surely must be easier than doing the same job in space!

Australia lays claim to 40% of Antarctica, as the Australian Antarctic Territory (AAT), most of which consists of the Antarctic Plateau. The highest location, Dome A, at over 4,200 m elevation, is in the middle of the AAT, and is the optimal site for conducting astronomical observations on the surface of the Earth. Development in this, the most isolated region of the Earth, has been extremely limited. The USA operates the Amundsen–Scott base at the South Pole, 2800m high, and Russia also operates a base at Vostok, 3400m high in the AAT. France, in collaboration with Italy, are planning the construction of a base at Dome C, another high point within the AAT, but so far Australia has not established any permanent presence on the Plateau.

Given the tremendous difficulties that will be faced in conducting astronomical observations, it is necessary to consider carefully those areas where the gains will be unmatched elsewhere on the Earth. This leads us to four areas where the scientific potential is at its greatest, arising from the cold temperature, the dry air, the tenuous air, and the high southerly latitude. Taking these points in turn:

- The cold air benefits observations in the near-infrared (2-5μm) most, where the thermal background from the atmosphere ('noise') is vastly reduced compared to a mid-latitude site. Infrared radiation can loosely be described as heat, and by cooling a body down you reduce the amount of heat it radiates. When observing in the infrared both the telescope and the atmosphere contribute unwanted 'heat' radiation to the signal we are trying to measure. By reducing this 'heat' we improve the sensitivity of our observations. Dropping from 0°C to -60°C, a typical mid-winter temperature at the South Pole, reduces this 'heat' flux by about a factor of 200 times at a wavelength of 2μm.

- Water vapour in the Earth's atmosphere absorbs much of the radiation reaching us from space, especially in the far-infrared to millimetre wavelength regime (100μm to 1mm). Even from a superb site like Mauna Kea, much of this radiation is undetectable, and even for those wavelengths which can get through, the transmission is poor and patchy. Accurate observations are virtually impossible. Although the Antarctic Plateau won't open up the far-infrared and sub-millimere entirely to observation, it will open up new windows to ground based observation for the first time, and greatly improve the transmission through some of the existing windows.

- The tenuous and stable air above the Plateau is expected to promote conditions of extraordinary clarity for astronomical observation. In particular the "seeing", the twinkling of the stars we see at night, is expected to be much better than anywhere else on the Earth. Thus images could be obtained with higher spatial resolution than possible elsewhere.

- At the South Pole, although no astronomical sources in the Northern sky can be seen at all, every source in the Southern sky can be seen at all times. A star never sets! Thus continuous or very long time period observations are possible of a source. For some kinds of objects this is essential if we are to understand what is going on. For instance a radio telescope could observe one source continuously, as part of an intercontinental network. In the optical we have to worry about bad weather interupting the observations, but at the South Pole continuous periods of good weather of up to 150 hours have been recorded, much longer than the $\sim$ 12 hours of dark time available from a mid-latitude site.

There is now considerable international interest in the possibilities of an Antarctic Observatory. In 1991 at the congress of the International Astronomical Union, a resolution was adopted recognizing the importance of the Antarctic Plateau for astronomy and setting up a working group to promote international co-operation. It is chaired by an Australian, Peter Gillingham, the operations director of the Keck Telescope on Mauna Kea (the world's largest optical telescope). Several astronomy projects are now underway in Antarctica, with the most developed plans from the US group, the Center for Astrophysical Research in Antarctica (CARA), who are building a South Pole Observatory. Three telescopes are now under construction; a sub-millimetre telescope (ASTRO), a near-infrared telescope (SPIREX) and a cosmic background experiment (COBRA). There are also four other astronomical experiments run by the USA at various stages of development at the South Pole; a gamma-ray telescope (GASP), a cosmic ray monitor (SPASE, in collaboration with the UK), a neutrino telescope (AMANDA, also in collaboration with the UK) and an optical telescope (SPOT, in collaboration with China). Outside the Pole, both Germany and Japan run radio telescopes, though their prime purpose is geodetic rather than astronomical. Italy operates a sub-millimetre telescope, and the UK plans to relocate a radio telescope to Antarctica. Australia has a cosmic ray station at Mawson, the largest and most sophisticated of its kind in the Southern Hemisphere. It is part of a network of 10 neutron monitors in the Antarctica, operated by seven countries (Australia, Chile, France, Japan, Russia, South Africa and the USA). France has ambitious plans to construct an observatory at Dome C, in conjunction with an ice-core drilling program that is proposed for that site. Italy has also expressed interest in this project. Russia has conducted a number of site testing experiments at Vostok, and both Argentina and India have made some preliminary site testing measurements.

Aside from the cosmic ray work at Mawson, Australian astronomers from the Department of Astrophysics at the University of New South Wales have recently initiated two collaborations with the USA (CARA) and with France (Université de Nice) to conduct site testing measurements at the South Pole. The Antarctic Division has offered technical support in the design of experiments to survive Antarctic conditions, but are not in a position to support ventures into the Plateau itself. Thus we are relying on the goodwill of our US collaborators for transport to these regions in the AAT. The purpose of these experiments is to obtain quantitative information about the conditions on the Antarctic Plateau that affect the conduct of astronomical observations. This will yield essential information needed prior to the construction of a major observatory, giving us the experience in logistics and engineering will we require, as well as telling us exactly what kind of science we can perform best. The first experiment involves converting an infrared photometer originally used on the Anglo Australian Telescope for Antarctic conditions. This is being undertaken by Michael Ashley and a team of students from the department. The photometer will be taken to the South Pole in December 1993 by an Australian astronomer and make measurements of the brightness of the near-infrared sky through the following Antarctic winter. The second experiment is to determine the "seeing" conditions at the South Pole by making measurements of micro-turbulence in the atmosphere. This experiment will be installed at the South Pole at the end of 1994. A UNSW PhD student, Rodney Marks, is currently in Nice learning the necessary techniques with our French collaborators, lead by Dr. Jean Vernin. Following these experiments at the Pole it is planned to move them to higher locations on the Plateau where we believe the conditions for astronomy will be even better. This includes the Russian base at Vostok, the proposed French base at Dome C, and eventually to the highest part, Dome A itself. There we eventually hope to build an international astronomical observatory.

Australia has an enviable record in astronomy, with both one of the finest optical/IR telescopes (the Anglo Australian Telescope) and one of the finest radio telescopes (the Australia Telescope) anywhere in the world. As the end of the 20^{th} century approaches, our radio astronomy community is well positioned to retain its renowned reputation, but the lack of a truly exceptional site for optical and infrared astronomy within the mainland of Australia is starting to compromise the position of our optical/IR community. As 8m-class telescopes are constructed elsewhere in the world in the next decade on exceptional sites, the Anglo Australian Telescope will no longer be able to remain truly competitive. There are several ways to maintain our international position, one of which is to attempt a project for which we are uniquely capable of achieving. Our record not only in astronomy, but in Antarctic science and exploration, is outstanding. We can combine the two, to play a lead role in the construction of an international observatory at the highest point of the Antarctic Plateau, Dome A, in the Australian Antarctic Territory. This is the preeminent observing site for astronomy on the surface of the planet. The construction of such an observatory will be a supreme challenge to our finest engineers and scientists, and the bringing together of their skills and talents will be of inestimable value to our nation in the years to come. As Australia approaches her centenary of nationhood in 2001, and to celebrate our coming of age as a technological nation, the construction of such a *Federation Telescope* on the Antarctic Plateau is an enterprise worthy of our great country.

PRESS ANNOUNCEMENT

In order to quantify the potential of the Antarctic Plateau for astronomy, and to gain the experience needed to run an Antarctic observatory, Australian astronomers have initiated two collaborations aimed at measuring the conditions at the South Pole which affect astronomy. The astrophysics group at the University of New South Wales, lead by Drs. Michael Ashley, Michael Burton and John Storey, are collaborating with the US group, the Center for Astrophysical Research in Antarctica (CARA), to measure the near-infrared sky brightness at the South Pole. They are adapting an instrument originally used on the Anglo Australian Telescope, the Infrared Photometer Spectrometer (IRPS), for Polar conditions. They plan to take it to the South Pole at the end of this year and conduct observations over the following Antarctic winter, controlling the instrument remotely through electronic-mail communications. In addition, in collaboration with French scientists at the Université de Nice (leader Dr. Jean Vernin), and with CARA, they plan to make measurements of micro-turbulence in the air above the South Pole from balloons. This will determine the clarity of the sky for astronomical observations. This experiment will be deployed at the end of 1994. A UNSW PhD student, Rodney Marks, is currently in Nice working with Dr. Vernin on this project, under the support of the France–Australia scientific collaboration fund.

A national working group has been set up, with membership drawn from the Australian astronomical community, to study the scientific potential of an Antarctic observatory. It is being chaired by Dr. Burton. It will report at a special joint session of the Astronomical Society of Australia and the Royal Astronomical Society of New Zealand annual meetings, being held in Christchurch, New Zealand, in July. Professor Al. Harper, director of the US Center for Astrophysical Research in Antarctica, and Mr. Peter Gillingham, chairperson of the International Astronomical Union working group on Antarctic astronomy and operations director for the Keck Telescope, will attend.

Bibliography of Michael Burton

Michael Burton spent his undergraduate days at the University of Cambridge studying mathematics (1979-1982), and obtained his PhD in astrophysics from the University of Edinburgh (1983-1986). Following completion of his thesis, he worked briefly as a telescope operator at the UK Infrared Telescope on Mauna Kea, Hawaii, before taking a postdoctoral fellowship at NASA Ames Research Center in California (1987-1988), where he observed with the Kuiper Airborne Observatory. He followed this position with postdoctoral fellowships at the University of California at Irvine and at Berkeley (1989-1990), before taking up a position as staff astronomer at the Anglo Australian Observatory, where he worked from 1990-1992. In 1993 Michael began a lectureship in the department of astrophysics at the University of New South Wales. He is an infrared astronomer, studying star formation and the interstellar medium. His specific research interests are on how shock waves and ultra-violet photons excite molecular clouds. He is chair of the Australian Working Group on Antarctic Astronomy.

Bibliography of Michael Ashley

Michael Ashley obtained his BSc from the Australian National University in 1981, an MSc from California Institute of Technology in 1982 and a PhD from Mount Stromlo and Siding Springs Observatories in 1988. In 1987 he was a consultant for Auspace on the Endeavour space project, in 1988 he spent a year at the Anglo Australian Observatory, and joined the School of Physics at the University of New South Wales in 1989. Michael is an astronomer with research interests in planetary nebulae, open cluster photometry, astronomical instrumentation and in designing algorithms for astronomical computation.