27. ANTARCTIC ASTRONOMY - INTRODUCTION AND SUMMARY OF INTERNATIONAL DEVELOPMENTS AFFECTING AUSTRALIA

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ABSTRACT

The extremely dry and cold atmosphere above the highest part of the Antarctic plateau presents opportunities for astronomical observations at infrared (IR) and mm wavelengths substantially better than from anywhere else on earth. Contrary to the popular conception of Antarctica, the climate high on the plateau features low wind speeds, mostly clear skies and relatively little snow fall. Many nations have already done astronomical work in Antarctica, some producing very good science, and in the last few years there has been a substantial quickening of interest. Several US institutions have collaborated to set up a Center for Astrophysical Research in Antarctica and this group has plans for greatly increasing the power of IR and mm instruments at the South Pole. A new international observatory sited for optimum astronomical performance has also been proposed. Australian and French astronomers, meeting in 1991 to discuss future collaboration, placed developments in Antarctica as their highest priority and a follow-up meeting on this topic will be held in 1992. At its triennial General Assembly in 1991, the International Astronomical Union adopted a resolution urging the establishment of an international high altitude observatory in Antarctica and set up a Working Group to encourage this.

27.1 INTRODUCTION

It is prophetic that the Australian $100 note features Douglas Mawson and Antarctica on one side, John Tebbutt and astronomy on the other. The next decade should see a blending of these two fields, in each of which Australia already has an enviable reputation, to produce valuable new scientific results. In this and the following papers, we shall explain why astronomers are becoming so interested in Antarctica and why we believe that Antarctic astronomy offers a particularly fruitful and appropriate field for Australian science.

Figure 1 shows some of Antarctica's key features from an astronomer's point of view. It is the high plateau and particularly its highest part, reaching nearly 4300 m altitude, that especially excites interest. Whereas the coastal sites, exemplified by the Australian stations at Mawson, Davis and Casey, suffer extremely high winds and much cloud, the high interior is very different. This is largely due to the systematic pattern of air flow that persists over much of the continent. Far from the ocean, surface winds are almost entirely the result of air, being cooled by the ground, flowing downhill. The velocities increase until, near the coast, they are very high. But near Dome A, the wind speeds are very low and the air flow is predominantly a slow settling from the stratosphere.

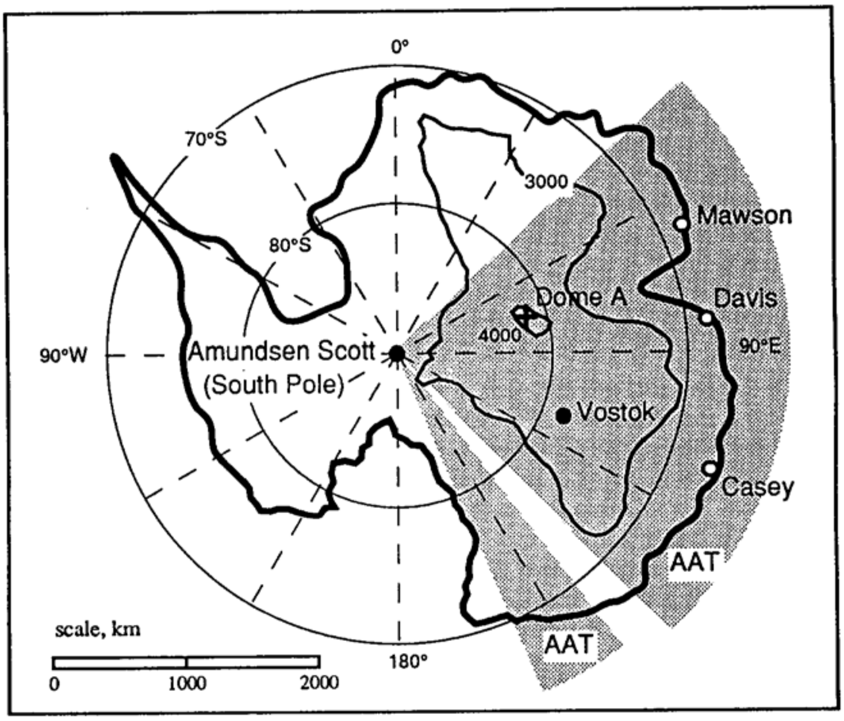

Figure 1. Antarctic stations, sites of special astronomical interest, Australian Antarctic Territory (AAT) and contours at 3000 and 4000 m altitude.

The outstanding attractions of a very high Antarctic site to astronomers working at wavelengths from the near-IR to a few mm results from the very dry, tenuous and cold atmosphere. Over much of this wavelength range, the main source of absorption in the earth's atmosphere is water vapour; at Dome A, the water vapour typically should be less than one tenth as great as at the best high altitude temperate sites (e.g. the summit of Mauna Kea on the island of Hawaii). The extremely low temperatures, down to below -80°C in winter, lead to very beneficial reductions in the thermal radiation from the atmosphere and telescope that is the major hindrance to detecting faint celestial sources, even at wavelengths where the atmosphere does transmit well. Note that nearly all the plateau above 3500 m altitude is in Australian Antarctic Territory.

27.2 ANTARCTICA'S CLIMATIC AND GEOGRAPHICAL ATTRACTIONS

Of the high inland sites, most work has been done at the South Pole where the USA operates the Amundsen-Scott base. The altitude there is about 2800 m. For the 18 year period 1957 - 75, the highest wind speed recorded was 24 m/s and there were many months for which the maximum was less than 15 m/s. The highest manned base, Vostok, at about 3500 m, has lower winds (a year round average of 5.1 m/s, with a very consistent direction) and less cloud (0 to 2/10 cloud for 61% of summer and 56% of winter observations, with 80% of the cloud being high cirrus). The year round average air temperature at Vostok is -55.3°C while it is -49.3°C at Amundsen-Scott (Burdyuzha 1992). Dome A, at 4300 m, will have more favourable wind speeds and cloud cover and lower temperatures than either the South Pole or Vostok.

Continuous observations for several days can be crucial in observing some time-dependent phenomena. For the more typical astrophysical observations for which time variations are not of interest, continuous access is still desirable, especially for observing very faint objects, when many consecutive hours may be needed to accumulate the required signal to noise ratio. The sky is astronomically dark (i.e. the solar zenith distance is greater than 108°) round the clock at mid-winter for latitudes south of -84.5° and nautically dark (solar ZD >102°) south of -78.5°.

For some relatively rare and short-lived events (such as bright super-novae) within a particular range of celestial positions, an Antarctic site could be the only one on earth from which the phenomenon was observable at a reasonable altitude in a dark sky. Importantly, this applies to the region of the Large Magellanic Cloud.

27.3 PLANS FOR MAJOR OBSERVING FACILITIES IN ANTARCTICA

Over the last few decades, many nations have made astronomical observations of one kind or another from Antarctica. The most notable scientific results have come from studies of seismological oscillations of the sun and from mm wavelength measurements of the uniformity of the cosmic background radiation. In the last few years, technological advances in astronomical detectors, especially the advent of very sensitive IR arrays, have pushed the performance of these detectors close to that theoretically attainable. Concurrently, several projects to build much larger optical telescopes have begun and one, the 10 m diameter Keck telescope on Mauna Kea, is nearing completion. Once these new telescopes are operational, one of the few ways to substantially improve sensitivity will be to exploit sites which give better transmission and lower background. Space, including the moon, offers ideal performance but placing telescopes of even modest aperture and therefore restricted (diffraction-limited) resolution into orbit or on the moon is very expensive. The Antarctic offers many of the attractions of space at a small fraction of the cost, especially for very large aperture instruments.

The most comprehensive set of projects currently planned are those under the aegis of the new NSF financed Center for Astrophysical Research in Antarctica (CARA) with its base at Yerkes Observatory, Wisconsin. Members include several US universities and a couple of industrial corporations. Their currently planned research includes the following projects (Harper and Bally 1992):

1. Antarctic Sub-millimetre Telescope and Remote Observatory (ASTRO) will use a 1.7 m diameter telescope to survey the galactic plane, the galactic centre, and the Magellanic clouds at wavelengths of 609 µm and 650 µm;
2. The Cosmic Background Radiation Anisotropy (COBRA) experiment will search for and map anisotropies in the cosmic background radiation on angular scales ranging from 15 arcmin to 20° at sufficient sensitivity to place stringent constraints on current theories of the origin of the universe;
3. South Pole Infrared Explorer (SPIREX) will use a near-IR telescope and IR array detectors to explore the potential of the Antarctic Plateau as an IR site and to make deep 2.4 µm continuum

surveys for faint sources including primeval galaxies, brown dwarf stars and dust-obscured objects in regions of star formation.

CARA researchers and collaborating astronomers from the United States and other countries will conduct experiments to measure environmental parameters including sky brightness, atmospheric transmission and seeing. They will also discuss and develop plans for more powerful telescopes which could be built in the future at the South Pole or other Antarctic sites.

Another important US initiative (Lynch 1989, 1992) has been the proposal for a new international base sited for optimum astronomical performance (at Dome A). Such a base, at an altitude above 4000 m and having a winter time pressure altitude equivalent to over 5000 m, would probably require pressurised living and working enclosures. It would then closely emulate a base on the moon and would provide very valuable logistic, scientific and political lessons on the path to an international lunar observatory. At its biennial meeting in 1990, the ICSU Scientific Committee for Antarctic Research (SCAR) adopted a resolution recommending serious international consideration be given to establishing such a station. At its meeting in June 1992, a session specifically to discuss astrophysical plans is scheduled.

27.4 INTERNATIONAL COLLABORATION INVOLVING AUSTRALIA

Following a meeting on Antarctic Astronomy at its General Assembly in 1991, the International Astronomical Union (IAU) passed a resolution 'encouraging international development of Antarctic astronomy' and created a Working Group (chaired by the author) 'to encourage international cooperation in site testing and in designing and constructing new Antarctic astronomical facilities'.

As part of a binational colloquium sponsored by the Australian Department of Industry, Technology and Commerce to encourage future scientific collaboration, French and Australian astronomers met in Sydney in April 1991. They rated cooperation in Antarctic astronomy as their first priority and recommended that a workshop specifically on this topic be held in 1992. This is to occur in Paris in May. A probable field of early collaboration is in developing critical tests of site quality, especially of seeing, to quantify the gains achievable in Antarctica and to help choose the very best site (Gillingham 1992). The director of CARA has indicated that they are very willing to provide logistic support for operating test equipment, developed by an Australian-French collaboration, at the Amundsen-Scott base. Good contact has also been established with Russian astronomers, who, following the 1991 IAU General Assembly, formed an Antarctic working group within their astronomical society. This contact is likely to lead to collaborative site-testing at Vostok.

A first meeting of some potential members of the IAU Working Group on Antarctic astronomy will be held in conjunction with the French-Australian meeting in May 1992.

An application has been made to the Australian Research Council for a grant to cover an initial investigation of the best ways for Australia to contribute to developing Antarctic astronomy, concentrating on the questions of how best to test site quality. The nominated chief investigators are at University of NSW, Anglo-Australian Observatory and Australian Defence Force Academy and the University of NSW would administer the grant.

27.5 CONCLUSION

In this decade and, even more so, in the 21st century, Antarctic observatories are likely to contribute very significantly to the advancement of astrophysical science. With our proximity to Antarctica, our long experience there in engineering and research, our strengths in astronomy and the technology of its instrumentation, and our claim to all that part of the Antarctic plateau most suited to astronomy, we in Australia should commit ourselves to playing a leading role in this very promising new field.

REFERENCES

Burdyuzha, V. (1992). Soviet Experience at Vostok and Plans for Antarctic Astronomy. *Highlights of Astronomy as presented at the 21st General Assembly of the International Astronomical Union.*

Gillingham, P.R. (1992) Super seeing from the Australian Antarctic Territory. In: Burns, G.B. *and* Duldig, M.L. (Eds). *ANARE Research Notes Number 88.* Australian Antarctic Division.

Harper, D.A. *and* Bally, J. (1992). CARA – The Center for Astrophysical Research in *Antarctica. Highlights of Astronomy as presented at the 2lst General Assembly of the International Astronomical Union.*

Lynch, J.T. (1989). A proposal for an International Station in Antarctica. *American Institute of Physics Conference Proceedings 198, Astrophysics in Antarctica.*

Lynch, J.T. (1992). An International Research Station in Antarctica. *Highlights of Astronomy as presented at the 21st General Assembly of the International Astronomical Union.*