Abstract

This paper describes the Australian astronomy program on the Antarctic plateau, which has been conducted in close collaboration with the USA and particularly CARA. This collaboration has culminated in the commissioning this year of a thermal infrared camera, SPIREX/Abu. Since 1994 a site testing program has been underway at the Pole. An automated observatory has been constructed in order to test the suitability of the high plateau for astronomy. Plans for future development within the International Antarctic Observatory are outlined.

Australia's Astronomy Program on the Antarctic Plateau

M.G. Burton, M.C.B. Ashley & J.W.V. Storey
Joint Australian Centre for Astrophysical Research in Antarctica and
School of Physics, University of New South Wales, Sydney, NSW 2052, Australia.
(email: M.Burton@unsw.edu.au)

1 Why Astronomy in Antarctica?

The Antarctic plateau offers the promise of the best site conditions on the surface of the Earth for a wide range of astronomical observations. This is a result of the unique combination of cold, dry and tenuous air that is only found there. The Plateau reaches an elevation of over 4,000 m, has average winter-time temperatures of -60°C and has a precipitable water vapour column which can fall below 100 μm. Winds are generally light, with the katabatic wind, originating on the highest parts of the Plateau, not reaching its full fury till near the coast. Weather conditions are stable, with minimal diurnal temperature fluctuations. This environment provides superlative conditions for measurement of the photon fluxes incident on the Earth from space, particularly in the near-infrared and sub-millimeter regimes.

This has provided the rationale driving the US astronomy program at the South Pole over the past decade, resulting in the now extensive facilities of CARA. Several European nations have shown considerable interest in the prospects of Antarctic astronomy, with a French/Italian base at Dome C under construction. Australia has also developed a program, closely entwined with that of the US, which we now describe further.

2 Why Australia's Interest?

Astronomy is a major science in Australia, and its astronomical facilities are world class. Particularly significant are the Australia Telescope, the only radio interferometer in the southern hemisphere, and the Anglo–Australian Telescope, a 4-m optical/IR facility. However, Australia lacks the really high, dry mountain tops demanded of leading observatories today for their superior viewing conditions. As a result the Australian astronomy community has been seeking opportunities abroad to ensure its healthy future. Australia also has strong historical ties and extensive interests in Antarctica, a result of our relative proximity to the continent. It currently supports three year-round coastal stations, at Casey, Davis and Mawson, and bases on two sub-Antarctic islands, Macquarie and Heard Islands. With this heritage it is natural that the high Antarctic plateau, offering the potential of the best observing conditions on the planet, should be appealing to the Australian astronomy community. Indeed, the recent review of Australian astronomy by the Australian Academy of Science rated the development of Antarctic astronomy as the equal highest priority for major new facilities in the coming decade.

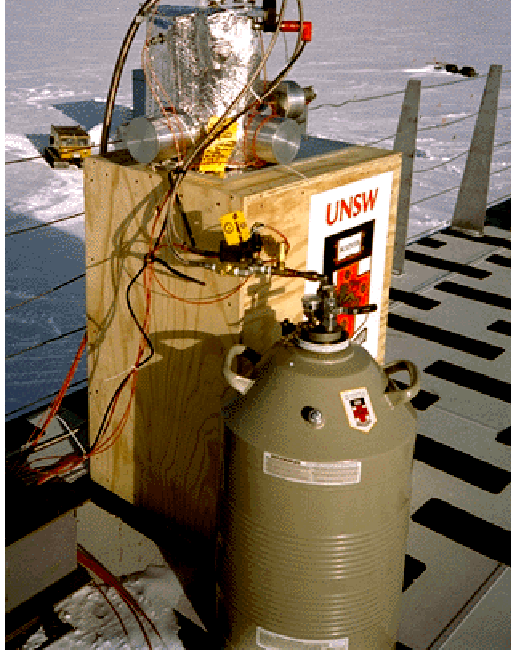

Figure 1: The IRPS, on top of the MAPO building at the South Pole.

3 What is Australia Doing?

Australia has been working closely with CARA at the South Pole since 1994. National interest first crystallized with the formation of the 'Australian Working Group for Antarctic Astronomy' in 1993, which produced a detailed scientific case on the opportunities afforded by the Plateau for astronomy (Burton et al. 1994). After a successful first season at the Pole, JACARA was formed in 1994. The 'Joint Australian Centre for Astrophysical Research in Antarctica', modeled shamelessly on CARA, is developing instruments and facilities. Two Australians have now wintered at Pole as part of our collaboration, Jamie Lloyd in 1995 and 1996, and Rodney Marks now in 1998.

3.1 Site Testing

In 1994 the University of New South Wales initiated two experiments with CARA. The first was a near–infrared sky monitor, the 'IRPS', measuring the brightness of the sky emission from 2 to 4μm over the winter. The IRPS was modified from the Anglo Australian Observatory's first infrared photometer of the early 80's. Working in parallel with CARA's SPIREX telescope, it demonstrated both the existence of the postulated 'cosmological window' at 2.4μm, and also of a window from 3–4μm where the sky background is 20–40 times lower than at temperate sites (see Fig. 2; Ashley et al. 1996).

The second experiment also involved the Université de Nice from France, and measured the level of microthermal turbulence in the atmosphere. From this the 'seeing', or blurring of star light by the air, can be determined. The experiment lasted two years. It used a set of sensors tied to the meteorological tower the first year and a series of balloon launches the second. The results were remarkable (Marks et al. 1996, 1998): while the ice-level seeing was only moderately good ($\sim 1.5''$) it is almost entirely produced in the lowest 100 m of the atmosphere. Above that altitude the contribution is virtually neglible. The nature of the seeing is thus quite different from other observatory sites, where high altitude contributions from the jet stream dominate. Antarctica thus offers an outstanding opportunity

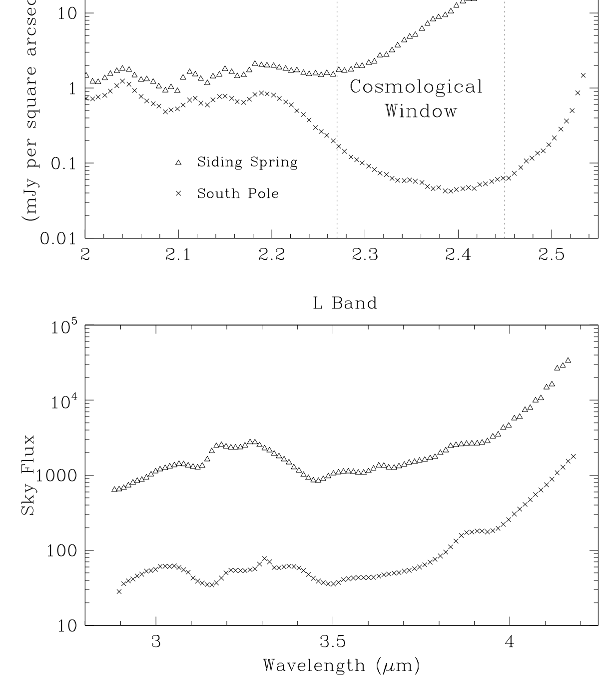

Figure 2: Results from the IRPS measurements of the infrared sky brightness at the South Pole (crosses), comparing it to Siding Spring (triangles), the site of the major observatory in Australia.

for near-diffraction limited viewing over wide angles, if the contribution from the surface layer can be removed.

A third experiment, undertaken in 1996, made daytime measurements of the mid-infrared sky brightness (from 10–20μm) (Smith & Harper 1998). At 11.5μm a particularly clear window was found where the emission is 10–30 times less than at temperate sites. This is better than expected from simply the drop in temperature, with the superb clarity of the atmosphere and its increased transmission both contributing significantly to the gain.

3.2 The AASTO

Acquiring site-testing data from uninhabited sites is always difficult—nowhere more so than from the high plateau of Antarctica. Fortunately, the geophysical community have for many years been developing the 'Automated Geophysical Observatory', or AGO (Doolittle 1986). There are now six AGOs deployed across the Plateau.

The AASTO, or 'Automated Astrophysical Site Testing Observatory' is, in effect, the seventh AGO and incorporates several small improvements over that design. It was built by Lockheed–Martin under contract to the University of New South Wales and the Australian National University (Storey et al. 1996, Storey 1998). Like the AGOs, it is designed for field deployment from a ski-equipped LC–130 Hercules transport plane. It is a self-powered, self-heated autonomous laboratory. It is currently operational at South Pole station, and will later be deployed to remote, uninhabited sites on the high plateau. It is being fitted with a suite of astronomical site-testing instruments, so that potential observatory sites can be fully characterized over a wide range of wavelengths. The AASTO was formerly opened by Senator Robert Hill, Australian minister for the Environment and leader of the Senate, in January 1997.

Figure 3: The AASTO at the South Pole. The shelter is to right and the fuel supply to left. The tower, at centre, supports a 30-cm telescope. The two insert pictures show three of the experiments, a UV/optical fibre-optic spectrometer to left (attached to the 30-cm telescope) and near– and mid–infrared sky brightness monitors to right.

3.3 SPIREX/Abu

SPIREX, the 'South Pole InfraRed EXplorer', is a 60-cm telescope built in 1994 by CARA in order to conduct observations in the 2.4 μm 'cosmological window' (Harper 1989, Hereld 1994). An agreement between the Universities of Chicago and Ohio State, NASA Goddard, the US National Optical Astronomy Observatory and the University of New South Wales has resulted in a project to upgrade SPIREX and install a state-of-the-art IR focal plane array. UNSW's contribution includes the thermal control, design and installation of new optics, and the addition of a CCD fast guider and tip-tilt secondary mirror to improve the tracking and pointing. This upgrade has taken place during the 1997/98 summer season at the Pole.

The system has been optimised for the thermal infrared, from 3–5μm. For wide-field surveys at these wavelengths SPIREX/Abu is, despite its modest 60-cm diameter mirror, the most powerful instrument on Earth. With it we aim to survey the Large Magallenic Cloud for sites of massive star formation.

4 The Future

4.1 Site testing

The South Pole is not the optimal site for astronomy on the Plateau. It is directly under the auroral circle and also experiences a steady katabatic wind of 5–10 m/s. The best observing sites are expected to lie at the high points of the Plateau, the 4,000 m Dome A and 3,200 m Dome C, where this wind is absent and the depth of the inversion layer thinner. How much better these sites are remains to be seen. This is the goal of the AASTO program, to quantify what the gains are. After field testing the AASTO at the Pole in the 1998 and 1999 winters, it is planned to bring it first to Dome C, and then to Dome A. We aim to know how good the best observing site on the planet is by 2001.

4.2 SPIRIT

The NSF is upgrading the Pole station so that is capable of supporting some of the more ambitious scientific plans for it. One of these is the 'International Antarctic Observatory' (IAO). Australia is particularly interested in contributing to the development of intermediate-scale infrared facilities for the IAO, and has formulated plans for the 'South Pole Infrared Imaging Telescope', or SPIRIT. This is envisaged as a 2-m class infrared optimised telescope capable of yielding near-diffraction limited images at 2.4μm. It will be a wide-field telescope, instrumented with large format focal plane arrays, and operate primarily from 2–5μm and 10–30μm. The first programs would involve surveys of star forming regions in these bands, to make a complete census of their embedded populations.

Further Information

The JACARA and AASTO web pages, at URL http://www.phys.unsw.edu.au/~mgb/jacara.html and http://www.phys.unsw.edu.au/~mcba/aasto.html, provide further information on the Australian Antarctic astronomy program.

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