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Special Session 7
Astronomy in Antartica

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Abstract. The high, dry and stable climatic conditions on top of the Antarctic plateau offer exceptional conditions for a wide range of observational astronomy, from optical to millimetre wavelengths. This is principally on account of the greatly reduced thermal backgrounds, the improved atmospheric transmission and the supurb seeing, in comparison with conditions at temperate latitude sites. The polar plateaus in the Arctic may also offer excellent conditions for astronomy, though these have yet to be quantified. We briefly review the history of astronomy in Antarctica and outline some of the activities now taking place on the polar plateaus, and plans for the future.

Keywords. Antarctica, site testing, infrared, optical, millimetre, neutrinos, meteorites

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1. A brief history of antarctic astronomy

Antarctica is the highest, driest and coldest continent, facets which all offer gains for observational astronomy. The field goes back as far as 1912 with the discovery of the 'Adelie Land Meteorite' during Douglas Mawson's Australasian Antarctic Expedition (see Indermuehle, Burton & Maddison 2005). It was to be another 60 years, however, before this investigation advanced further, with the discovery in Antarctica, by Japanese scientists, of a number of different meteorites in close proximity – an event which could not have happenned by chance (Nagata 1975). More meteorites have since been discovered on the continent than the rest of the world put together, a result of the favourable conditions for their collection.

Cosmic ray detectors were installed in the Australian base of Mawson in 1955 and the US base of McMurdo during the International Geophysical Year of 1957, and are now widespread around the continent, taking advantage of the high geomagnetic latitude to detect lower energy particles than reach the ground at mid-latitudes.

The modern era in Antarctic astronomy began in 1979 with measurement of solar oscillations using an 8 cm optical telescope at the South Pole by a team led by Martin Pomerantz (see Grec *et al.* 1980). The field began in earnest with the establishment in 1991 of the Center for Astrophysical Research in Antarctica (CARA) at the South Pole, led by Al Harper. Experiments were begun in infrared, sub-millimetre and CMBR astronomy, together with an extensive site testing program to quantify the conditions for observation. Particularly successful were the sub-mm observations pursued with the 1.7 m AST/RO telescope (resulting in nearly 50 refereed publications; see Stark *et al.* 2001), and a series of increasingly precise measurements of fluctuations in the cosmic microwave background (e.g., the first measurement of its polarization – Kovac *et al.* 2002).

An extensive bibliography of publications relating to Astronomy in Antarctica can be found at the JACARA website `<www.phys.unsw.edu.au/jacara>`. Papers by Burton

(2004), Ashley *et al.* (2004), and Storey (2005) provide further background on conducting astronomy in Antarctica and some of the current activities taking place.

2. The South Pole

The South Pole suffers from a turbulent boundary layer, approximately 200 m thick, driven by the katabatic wind flowing off the summit of the Antarctic plateau (i.e., from Dome A). The seeing at ice level is thus modest, and so optical and infrared observations have not been pursued there beyond using modest-sized telescopes (e.g., the 60 cm SPIREX; see Rathborne & Burton 2005 for a review), where the diffraction limit is comparable to the seeing. Nevertheless, extremely deep thermal IR images have been obtained. For instance, it was only in 2004 that the 8 m VLT achieved deeper (ground-based) images at 3.5 μm than those obtained with SPIREX in 1998 of the 30 Doradus star forming complex in the LMC (see Maercker & Burton 2005).

Conditions for millimetre astronomy are, however, supurb, as they are for neutrino detection (making use of the vast quantities of pure ice to track the Cerenkov radiation following extremely rare interactions with nuclei). Astronomy at the South Pole is today dominated by two experiments being built to exploit these conditions. These are the 10 m South Pole Telescope (SPT, Ruhl *et al.* 2004), designed to measure the SZ-efect towards galaxy clusters in the sub-millimetre, and IceCube, a 1 km^3 neutrino *telescope*, designed to locate neutrino sources in the northern skies (Ahrens *et al.* 2004). A new station has been constructed at Pole by the US in order to meet the required infrastructure needs.

3. Dome C

Concordia Station, at the 3,200 m Dome C (one of the 'summits' along the ridge of the Antarctic plateau), is the newest scientific station on the continent. Run jointly by France and Italy, the Station's first 'winter' occurred in 2005. Already the median visual seeing, above an $\sim$ 30 m thick boundary layer, has been shown to be $\sim 0.''25$, and to fall below $0''.1$ on occassion (Lawrence *et al.* 2004; Agabi *et al.* 2006). Amongst the gains that have been quantified for optical and infrared astronomy are an isoplanatic angle 2–3 times smaller than at good temperate sites, coherence times 2–3 times longer, IR sky backgrounds 20–100 times lower, image sizes 2–4 times smaller (when using the same size telescope), and scintillation noise 3–4 times smaller.

An 80 cm prototype mid-infrared telescope (IRAIT) is shortly to be commissioned at Dome C (Tosti *et al.* 2006), in order to provide a first demonstration of the science potential, as well as to conduct a range of science programs. This may be followed by the 2.4 m optical/IR PILOT (Storey 2006; Burton *et al.* 2005). PILOT would be large enough to have comparable IR sensitivities as temperate latitude 8 m-class telescopes (on account of the low background), but be able to obtain high angular resolution (on account of the supurb seeing) over wide fields of view.

Beyond this, there are several possible options for telescopes under active discussion. These include optical/IR interferometers (API, Swain *et al.* 2003; and KEOPS, Vakili *et al.* 2005), as well as large (8 m++) telescopes (e.g., LAPCAT, Storey *et al.* 2006; and GMTA, Angel *et al.* 2004). Whether these are built at Dome C, or eleswhere, will depend on when other high plateau sites are opened for astronomy.

4. Dome A and Dome F

There are other sites along the summit ridge of the Antarctic plateau that will provide comparable conditions to Dome C, and possibly be superior in some respects. These are

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the highest point, the 4,200 m Dome A, and the 'northern' end of the summit ridge, the 3,800 m Dome F. Dome F is already the site of a Japanese ice-core drilling station ('Fuji') and has wintered over, though no measurements have yet been made of the astronomical site conditions. Dome A ('Argus') was visited for the first time by humans in January 2005 on a Chinese traverse, and is the subject of expeditions for the International Polar Year of 2007–08. Compared to Dome C, the most significant gain may be the lower water vapour content of the atmosphere, opening up windows in the terahertz regime, and possibly a slightly lower IR background (colder) and thinner boundary layer (even lower katabatic winds).

5. The Arctic

The polar plateaus of the Arctic also offer some promise for observational astronomy, though no site testing has yet been carried out. In particular, the summit ridge of the Greenland icecap (including the 3,200 m Summit Station) and northern Ellesmere Island in the North-West territories of Canada (reaching 2,600 m) warrant investigation. While not as cold or as dry as the Antarctic plateau, conditions should still be favourable for infrared and sub-millimetre astronomy. However it is possible that higher winds (storms?) and greater cloud cover may limit their use for astronomy?

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