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Australian plans at Concordia

J.S. Lawrence, M.C.B. Ashley, M.G. Burton, and J.W.V. Storey

School of Physics, University of New South Wales, NSW 2052, Australia
e-mail: jl@phys.unsw.edu.au

Abstract. Astralian astronomers have proposed the construction of a 2 m infrared telscope — the Douglas Mawson Telescope — as an international collaborative project. Such a telescope would have comparable wide-field sensitivity to an 8 m telescope at a temperate location, but could be built for a fraction of the cost. The Douglas Mawson Telescope would also be able to do unique science from the visible to the sub-millimetre regions by expoiting the unique atmospheric conditions at Dome C — particularly the excellent atmospheric transparency and the absence of high altitude turbulence. In addition, the DMT could form the first element of a multi-telescope interferometer, an instrument which would have unrivalled power as a ground-based "planet finder".

Key words. site testing – Antarctic astronomy – infrared astronomy

1. The Dougals Mawson Telescope

The Douglas Mawson Telescope is a proposal initiated by the University of New South Wales in Sydney, Australia, to build a 2 m class infrared telescope for operation at Dome Concordia station (Candidi and Lori 2003), on the Antarctic plateau.

There are several motivations for this choice of telescope size. A 2 metre class telescope is small enough to be readily achievable in terms of budget and logistics, and large enough that it can do internationally competitive science, particularly when the advantageous site qualities of Dome C are considered. The relatively small collecting area implies that a wide field of view can be provided inexpensively, and a 2 metre telescope can be expanded to make an interferometer.

The approach adopted for the DMT proposal is to design the instrumentation suite around a commercially available telescope, mount, and control system, with modifications neccessary to withstand the extreme winter conditions. The company EOS Technologies Inc. manufactures telescopes in the 1.8–2.5 m size. This class of telescope comes standard with a fully autonomous and remote control system, a 100 Hz tip-tilt secondary mirror, and costs on the order of 3 million USD. The initial instrument will be capable of wide field (20 arcmin) imaging in the near infrared (optimised for the 3–5 micron band). Future instrument design options include a mid-infrared and submillimetre imager, and a low resolution near-infared spectrometer.

Send offprint requests to: J.S. Lawrence
Correspondence to: jl@phys.unsw.edu.au

2. Benefits to Australia

Australian astronomers are uniquely placed to benefit from a significant involvement in the development of Antarctic astronomy and the DMT proposal in particular. The geographic proximity gives Australia an advantage in terms of logistic support. Australia has a tradition of Antarctic exploration, and Antarctic exploration and science has a high public profile within the country. Through the Australian Antarctic Division, there is an on-going, major, national Antarctic program with a continuity of funding. Australia has no national participation in other international infrared telescope facilities (eg, SOFIA, SIRTF etc), and so Australian astronomers have more to gain than those of most other countries. Australian researches have demonstrated a high degree of commitment through previous Antarctic site testing and the development of cold-rated instrumentation and remote software, from the SPIREX/Abu telescope at the South Pole and remote site testing laboratories at South Pole (AASTO) and Dome C (AASTINO).

Astronomy is a science for which Australia has a very strong reputation — both internationally and locally. There are over 160 professional astronomers employed at universities and observatories, with citation rates amongst the highest in Australian science. There are several major observatories in Australia (such as the Anglo-Australian Telescope, the Mopra millimetre telescope, the Australia Telescope Compact Arrray, and the Parkes radio dish), and links to many international institutions, for example, Australia has recently joined the Gemini partnership.

Several factors, however, limit infrared capabilities. Australia has only a 6.5% share of Gemini — corresponding to only a few observing nights per year. Of primary importance for future major developments in infrared or optical astronomy is a good quality site. Australia has no high mountains, and existing sites have poor optical/infrared qualities. Future developments will therefore be necessarily offshore. Additionally, Australia presently has no sub-mm or far-infrared capability.

3. Logistics

Currently logistic support for Dome C station is provided via a number of routes. Twin Otter aircraft are used to support Dome C from the coastal bases (McMurdo, Terra Nova Bay, and Dumont d'Urville). Many flights per season are available, however the cargo capacity of this aircraft is limited. Any heavy machinery or equipment must come via overland traverse (four rotations leave each year from DdU). Support of the coastal stations is via ship from Hobart (the Astrolabe to DdU, and the Italica to TNB) and a limited number of LC130 flights from Christchurch (to TNB early in the season and McM later).

An important new development is that the Australian Antarctic Division is currently initiating air links to all Australian bases via Hobart. This is in the form of a Falcon 900EX aircraft from Hobart to Casey, and a ski-equipped CASA 212 for inter base supply. The Falcon does not have the capacity of the LC130 but can supply the coastal stations with personnel in just over 4 hours from Hobart. The CASA 212 is a significant improvement in cargo capacity to the Twin Otter, and is twice as fast.

4. Technology

An extensive site testing campaign has been carried out at the South Pole station from the AASTO (Storey et al. 1996) over the last decade and is now being extended to Dome C via the AASTINO (Lawrence et al. 2003). These studies have shown that an Antarctic plateau site is superior to mid-latitude sites for several reasons.

Because of the very low water vapour content, the transmission of the Antarctic plateau atmosphere is higher than at any other site. While the largest benefits are obtained in the far infrared and submillimetre regions where water vapour absorption dominates the transmission spectrum (Calisse et al. 2003), there are still significant benefits in the near and mid- infrared. Because of the low temperature of the Antarctic atmosphere, the sky background in the thermal infrared is up to two orders of magnitude lower than found at good quality temperate sites (Phillips et al. 1999). These factors combine such that the sensitivity for some observations of a 2 m telescope located at Dome C is equivalent to that of an 8 m telescope located at a temperate site. Additionally, the wide field of view of the DMT gives a dramatic improvement to the speed or sky coverage of a wide field sky survey.

While the ground level seeing at the South Pole is poor compared to good temperate sites, it has been shown that because of the absence of a high altitude jet stream above the Antarctic plateau, there is very little high altitude turbulence; this results in a large isoplanatic angle. This is important for the DMT because a simple tip-tilt correction can remove most of the atmospheric turbulence effects in the near infrared over a wide field (Lawrence 2003). It is important for larger telescopes with high-order adaptive optics because such systems will work over a wide field, which avoids the necessity for multi-conjugate systems or laser guide stars. The large isoplanatic angle also dramatically improves the performance of an infrared astrometric or nulling interferometer, for which the DMT could readily be expanded to form a component. While more data are needed for a quantitative comparison with Dome C, preliminary data indicates that, with a lower integrated seeing and larger isoplanatic angle (Travouillon et al. 2003b), this site is significantly better than the South Pole (Travouillon et al. 2003a).

Preliminary data from Dome C indicates very low cloud cover; skies are cloud free for better than 80% of the time (Ashley et al. 2003). The high latitude of the site also indicates that continuous observation is possible over much of the sky — a feature only found in the polar regions.

5. Science

The technological benefits which arise from the exceptional site qualities result in a number of specific areas for scientific research with the DMT that cannot be accomplished with the same efficiency as any other planned or existing infrared facility.

1/ Star formation: The enhanced sensitivity of the DMT in the near and mid-infrared wavebands (as a result of the the low sky background) coupled with the wide field of view of this telescope leads to the capability of performing low resolution imaging surveys at least an order of magnitude quicker, deeper, or wider than any existing infrared survey telescope. The extreme stability and low magnitude of the sub-millimetre atmospheric opacity also allows spectral line studies to be performed with much greater efficiency and in spectral regions unobservable elsewhere. Such surveys and spectral line studies are important for the analysis of star formation environments (through the molecular, neutral, and ionised gas spectral features), and the statistics of star formation regions (through a complete population census, and the identification and determination of abundancies of young stars and stellar discs) (Burton et al. 2001).

2/ Extra-galactic studies: The site characteristics important for star formation studies are also important for extra-galactic studies. An extensive wide field near infrared survey could target the identification of proto-galaxies (through the spectral signatures of the galaxy's visible emission at high redshift). Submillimetre observations of redshifted molecular lines (such as CO) and dust continuum emission of distant galaxies can add to our understanding of the star formation history of the universe. The observations of individual molecular clouds in nearby galaxies is important to understand the effects of star formation on the interstellar medium, and on the chemical evolution of galactic disks.

3/ Asteroseismology: The benefit of a continuous observation of a given source and reduced scintillation noise will allow studies of stellar spectral oscillations important for the understanding of stellar interiors, determination of stellar mass with high accuracy, and stellar rotational dynamics. A single telescope at Dome C could produce data that currently requires a large number of dedicated telescopes at positions around the world (Fossat 2003) (Kurtz 2003).

4/ Microlensing: The high surface density of stars readily observable from Dome C, the possibility of long time period continuous observations, the low sky brightness (particularly in K band), and the high photometric accuracy (because of the low scintillation) indicates that the identification and probability of incidence of secondary gravitational microlensing from planetary systems would be an important scientific goal for the DMT.

5/ Interferometry: The DMT would be an important technological demonstrator (for the site) and could be designed as a component of a future interferometer, such as the Antarctic Planetary Interferometer (Swain 2003) which intends to use nulling or astrometric interferometry to search for exo-planets. The potentially very large isoplanatic angle of the Dome C atmosphere implies a dramatic reduction in astrometric error, which means the performance of such an interferometer could approach that of future space missions.

6. Conclusions

Data obtained so far indicate that Dome C is potentially the best site on the planet to place an infrared telescope. The Douglas Mawson Telescope is one of several proposals to build and develop a 2 m class telescope at this site. Other such projects include the AIRO (Jackson 2003) and the IRAIT (Busso et al. 2002). As a result of the site qualities several areas of important astronomical research are possible with the DMT that cannot be done at any other ground-based site with the same efficiency. The full potential of this site will not be realised until a large (6–10 m) class telescope, or an interferometrically combined series of smaller telescopes (2 m) is in operation. The DMT is an important first step necessary to demonstrate required technologies for the development of this site.

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