Idea413

Astronomical Site Testing at Dome A

The world's pre-eminent site for viewing the cosmos

An Expression of Interest for an IPY Programme from the AAA Expert Group

The Antarctic plateau has long been realised as having great potential for the conduct of astronomical observations, largely on account of the extremely cold, dry and tenuous air above it. This allows for more sensitive observations to be made of the radiation arriving on Earth from space of many parts of the electromagnetic spectrum than from any other location on our planet. The South Pole has, for over two decades, proved to be an exceedingly promising site, and been used in particular for measurements of the microwave radiation resulting from the formation of the universe in the "Big Bang", over 13 billion years ago. The conditions on the plateau, however, should also permit exceedingly sensitive measurements to be made of the processes of formation of planets, stars and galaxies, in addition to the microwave background, through a range of observations conducted from the optical to millimetre wavebands.

The South Pole is on the flank of the Antarctic plateau. Turbulence generated by air flow in the surface boundary layer there can disrupt observations made at optical and infrared wavelengths (i.e. from 0.4 to 3μm). The first site testing measurements have just been made from Dome C, one of the summits of the plateau. They meet the high expectations held for that site on account of the greatly diminished wind speeds in the surface boundary layer. The astronomical seeing (the blurring of star images) at Dome C has been found to be as low as 0.1" (both in daylight and dark-time conditions), and to consistently average below 0.3". These values are around two to three times lower than measured at the best temperate-latitude sites. They include the lowest seeing values *ever* recorded since Galileo first applied a telescope to astronomical observations nearly 400 years ago! They offer an extraordinary opportunity for astronomical telescopes to make observations of the cosmos with unprecedented clarity and sensitivity.

Yet there remain sites in Antarctica that may offer even better conditions than Dome C. Dome C lies at a 3,260m summit of the plateau, whereas Dome A is at its highest point, 4,080m. The temperature there likely falls as low as –90°C at times, the precipitable water vapour content to ~100μm (i.e. perhaps half that at Dome C), and the surface winds are likely to be even lower than at Dome C. If so, Dome A will provide the best observing conditions on the planet for a wide range of astronomy, from the near-UV to millimetre wavelengths. We do not yet know, however, if this is indeed the case as yet, for no measurements have yet been made. It is necessary to obtain the requisite data to answer this question before plans to develop new facilities at any site on the Antarctic plateau can be fully realised. On the other hand, it is possible that the conditions at Dome A will not be sufficiently better than those at Dome C to justify the cost of a new station there sometime in the future. Either way, it is necessary to find out what the conditions are like at Dome A and the IPY provides an opportunity to do so. We thus aim to characterise the conditions at what is expected to be the pre-eminent astronomical observing site on the planet as part of the IPY.

The timing of the IPY also comes just as humanity has reached the position where it can conduct such an experiment. The logistical capability to support an expedition to Dome A, by both traverse and by plane, now exists. The ability to make the necessary measurements has also been proved, through the example of the AASTINO (Automated Astrophysical Site Testing International Observatory) that has operated, completely autonomously, at Concordia Station during the past two winters, while over 1,200 km from the nearest human. For example, the seeing measurements that demonstrate the superb characteristics of the site were obtained this current winter, while the remote operation and data transfer capability has allowed them to be directly prepared for publication – they will appear in Nature in October; i.e. in the same season (Lawrence et al, Nature, 2004, in press) as the data were obtained.

An expedition to Dome A might also be extended to cover two other potential sites which are also likely to provide exceptional conditions for astronomical observation, the 3,500m high Vostok and the 3,800m high Dome F. Both sites already have stations at them. Obtaining site testing data from all these high plateau sites is also the task which the AAA Expert Group has charged the PASTA (Plateau Astronomical Site Testing in Antarctica) Action Group. By doing so, PASTA will complete the task for which it was formed.

An astronomical site testing expedition to Dome A meets IPY Themes 4 (investigate unknowns at the frontiers of science) and Theme 5 (unique vantage point of the polar regions to develop observatories studying .... the Sun and [the cosmos] beyond). It also contributes to Theme 1 (determine present state of polar environment), through the characterisation of the atmosphere that site testing requires. The programme also fits into two of the observational initiatives: (iv) (launch of international expeditions into new scientific frontiers) and (v) (implementation of polar observatories to study important facets of Earth and beyond). Astronomical programmes are also easily amenable to outreach activities and for providing inspiration to the next generation of scientists. In addition, they take advantage of new technology and logistic capability. The programme we propose can also readily be structured to meet all the mandatory and desirable characteristics specified for IPY activities.

The potential for developing outreach programmes are particularly potent with this project. Our expectations of the site conditions on the high plateau are such that it should one day be possible to build telescopes there capable of pursuing perhaps the most challenging and exciting programme in science, the detection of other Earth-like planets in our Galaxy. How it might be possible to develop facilities for such projects is now a question being given consideration by several national and international bodies, including space agencies. It may be that Antarctica provides the only environment where such observations are feasible, or at least where they can be conducted for much lower costs than the alternative of developing an equivalent space-based observatory. Whether this will prove to be the case or not remains to be determined, but it is only through the pursuit of programmes such as that proposed here that one can find out.

This programme is best accommodated as an Associated Project within the IPY, complementing and adding to a Core Project. There are also synergies with other projects being proposed for the IPY, in particular the work of the AGCS (Antarctic and Global Climate System) Programme within the Physical Sciences SSG. This

latter programme seeks to obtain short ice cores along the ridge of the Antarctic plateau in order to investigate topographic effects on ice core variability. These would be obtained by a traverse through the Antarctic plateau. The AASTINO could be added as a separate trailer to the traverse (it weighs about 4 tonnes). A Dome A expedition can most readily be accommodated through a traverse from Dome C (as is being considered by France and Italy), but it may also be undertaken through traverses being planned by the Chinese, Swedish and/or Japanese programmes. Use of multiple traverse routes may also allow site testing to be conducted at other high plateau sites, such as Vostok and Dome F. An astronomical site testing expedition complements and adds an interdisciplinary nature to the activities being planned for these traverses. The programme may, however (or additionally), be serviced through direct air support to Dome A, possibly via the support of the US, French, Italian and/or Australian programmes. The use of air transportation would then mean that only the AASTINO needs to be carried on a traverse, with the scientists who deploy the facility being flown direct to the site (preferably having acclimatised at another, slightly lower altitude site, such as Dome C or South Pole, first). Indeed, it is also possible to bring a cut-down version of the AASTINO to Dome A by air, with only the fuel needing to be transported by traverse.

The nature of the logistic support needed for this programme is clearly the province of national Antarctic programmes, and it should be organised so as to fit in with the plans being made for other IPY programmes on the plateau. The funding to provide the facility, i.e. the AASTINO and associated experiments, would be obtained through application to science funding agencies within partner countries. For instance, we envisage seeking funding for 2 AASTINO units, which provide the power (about 2 kW is available, continuously through the winter), warm environment, control and communications systems for the observatory. The AASTINOs would be equipped by a range of site testing instruments able to measure the properties of the atmosphere that affect the conduct of observational astronomy. This would be instrumentation already adapted for use in the AASTINO and including measurements of the seeing (MASS instrument), turbulence (SODAR instrument), and infrared and millimetre sky brightness (NISM, MISM and SUMMIT instruments). It may also be feasible to equip an AASTINO with a facility able to make direct astronomical measurements in sub-millimetre bands that are opaque from any other site on the Earth (e.g. the HEAT experiment – the High Elevation Antarctic Terahertz telescope)?

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(on behalf of the AAA Expert Group of the SSCAR Standing Science Committee for Physical Sciences)