SpS3 – Astronomy in Antarctica

Special Session 3, IAU General Assembly XXVII
Rio de Janeiro, Brazil, August 6-7 2009

Preface

This was a 2-day meeting held during the XXVIIth International Astronomical Union General Assembly in Rio de Janeiro in 2009.
Antarctica offers a range of remarkable conditions that provide asuperlative environment for observational astronomy from visible to millimetre wavebands, as well as for high energy astrophysicsexperiments. This meeting discussed the current state of Antarctic astronomy, with winter-time facilities now operating at both the South Pole and Dome C on the high plateau, and activity underway at Domes A and F. The status offacilities at these sites was reviewed at the meeting and new science results presented, including from the International Polar Year of 2007/08.

Scientific Rationale

Antarctica provides unique conditions for a wide range of astronomicalobservations. The cold, dry air above the high Antarctic plateauprovides the best ground-based conditions for many observations at thermal infrared and sub-millimetre wavelengths. The stable air, low levels of high-altitude turbulence and narrow boundary layer over thesummits of the plateau provide for superb seeing in the optical. Thecircumpolar wind provides suitable conditions for long durationballoon flights. The vast quantities of pure ice, on a stableplatform, provide unsurpassed conditions for neutrino telescopes. The high geomagnetic latitude provides unique conditions for cosmic raydetection.Over the past decade Antarctica has seen a wide range of experiments designed to exploit these conditions for a variety of astronomical observations. Extensive site testing on the plateau has establishedthe great potential for observational astronomy from optical tomillimetre wavelengths. At the South Pole there have been infrared(SPIREX), sub-millimetre (e.g. AST/RO, Viper) and several CMBR (e.g. Python, DASI, ACBAR) telescopes operating. Particle physicsexperiments, particularly cosmic ray air shower arrays (e.g. SPASE)and neutrino telescopes (AMANDA), have been developed. Coastalstations, such as McMurdo, have hosted long-duration balloon flights,such as the BOOMERANG CMBR experiment. The high plateau site of DomeC has now completed its third season of winter-time operations, withthe first site-testing experiments deployed there demonstrating superboptical seeing conditions. The first expedition ever to Dome A, the summitof the Antarctic plateau, was undertaken in 2005. Initialinvestigations have also been undertaken regarding the suitability ofDome F for future astronomical observations.At the 2,900m US Amundsen-Scott South Pole station there are now twomajor facilities for astrophysics. These are the cubic kilometrecollecting volume IceCube neutrino telescope, and the 10m South PoleTelescope, to probe dark energy through for SZ measurements of distantgalaxy clusters. For the French-Italian 3,200m Concordia Station atDome C, the 80cm IRAIT mid-IR telescope is under construction, and adesign study completed for the 2.4m optical/IR PILOT telescope. Chinaconducted the first traverse to 4,200m Dome A, the highest pointon the Antarctic plateau, and returned there in 2008 in the PANDAprogram of the International Polar Year. At the Japanese base of Fujiat the 3,800m Dome F the first investigations on the suitability ofthis site for astronomical observations have begun.International involvement in these experiments is high. Internationalcollaboration in Antarctica has been productive and effective, withboth SCAR (the Scientific Committee

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for Antarctic Research) and theIAU sponsoring sub-committees to foster developments in astrophysicalresearch there. This meeting will further all these objectives.

Conference Programme

The meeting took place over 1.5 days, and followed the format of thesuccessful meetings held during the IAU General Assemblies in Sydney and Prague.The first day reviewed the experiments of the past few years.Speakers from the major facilities were invited to report on theirachievements. Highlights from the science conducted in the infrared,sub-millimetre, CMBR and particle astrophysics were presented. The openingsession also provided an introduction to the field ofAntarctic astronomy for the non-specialist, as well as the role of astronomy in SCAR.The second day featured discussion on plans for the development ofthe high plateau stations and the astronomical facilities they mightprovide in the near future.

Day 1, August 6, 2009:

- Session 1: An Overview of Astronomy in Antarctica
  - Astronomy in Antarctica: an overview *by Michael Burton*
  - The SCAR 'Astronomy & Astrophysics from Antarctica' Scientific Research Program *by John Storey*
- Session 2: The South Pole
  - BICEP: a cosmic microwave background telescope at the South Pole *by Yuki Takahashi*
  - The 10m South Pole Telescope *by John Carlstrom*
  - IceCube neutrino observatory at the South Pole *by Kirill Filimonov*
  - Observing the Universe from the South Pole *by Vladimir Papitashvili*
- Session 3: Dome C
  - ARENA, a roadmap for astronomy at Concordia Station (Dome C) *by Nicolas Epchtein and given by Hans Zinnecker*
  - Future plans for Dome C *by Vincent Coudé du Foresto*
  - The LUCAS program: detecting vegetation and traces of life in the Earthshine *by Danielle Briot*
- Session 4: Dome A
  - CSTAR and future plans for Dome A *Xiangqun Cui*
  - The PLATO observatory: robotic astronomy from the Antarctic plateau *by Michael Ashley*

Day 2, August 7, 2009:

- Session 5: Dome F
  - Solar cycles and supernovae embedded in a Dome F ice core *by Yuko Motizuki*
  - Plans for Dome F *by Takashi Ichikawa*
- Session 6: Other Sites
  - Site testing activities on the Greenland Ice Cap *by Michael Andersen*
  - The Stratospheric Terahertz Observatory (STO) *by Gordon Stacey*
- Session 7: Visions for Antarctic Astronomy
  - Science for the Antarctic plateau: what should we do? *by Hans Zinnecker*
- Session 8: Business Meeting
  - Matters for Discussion
  - Election of Chair for Working Group
  - The SCAR Scientific Research Program

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Most of the talks given at this meeting can be downloaded from the IAU Working Group for Antarctic Astronomy website, at URL http://www.phys.unsw.edu.au/jacara/iau.

Michael Burton, Chair SOC
Sydney, Australia, October 31, 2009

Scientific Organising Committee
Michael Burton (Chair, Australia)
Carlos Abia (Spain)
John Carlstrom (USA)
Vincent Coudé du Foresto (France)
Xiangqun Cui (China)
Sebastián Gurovich (Argentina)
Takashi Ichikawa (Japan)
James Lloyd (USA)
Mark McCaughrean (UK)
Gino Tosti (Italy)
Hans Zinnecker (Germany)

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Astronomy in Antarctica in 2009

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Abstract. This article summarises the subject matter of Special Session 3 at IAU General Assembly XXVII in Rio de Janeiro, Brazil, which took place on August 6-7, 2009. In it, we overview the state of Astronomy in Antarctica as it is in 2009. Significant astronomical activity is now taking place at four stations on the Antarctic plateau (South Pole, Domes A, C & F), as well as at the coastal station of McMurdo.

Keywords. Antarctica, Telescopes, Site Testing, Instrumentation.

1. Overview

As is now well known (e.g., Storey (2005)), Antarctica offers remarkable conditions for a range of astronomical observations across both the photon and the particle spectrum. This is especially so on the summits of the Antarctic plateau on account of the extremely cold, dry and stable atmosphere. The conditions enable measurements from optical to sub-millimetre wavelengths that would have greater sensitivity and/or sharper imaging quality than measurements made with equivalent facilities at temperate-latitude sites, as well as opening new windows for regular ground-based viewing in the mid-IR and THz spectral regimes. Furthermore, the pure ice provides a novel detector for the capture and detection of particles, in particular neutrinos. At coastal locations the circumpolar vortex provides opportunities for long duration balloon flights that might last several weeks. The ice flow off the plateau also concentrates meteorites that have fallen over the continent into a few locations where they can be readily collected. In the following section we briefly review some of the astronomy ventures taking place over Antarctica. International collaboration is an integral part of these activities at each of the locations. Astronomy is now also established within SCAR – the equivalent body to the IAU for Antarctic science – as a formal research program. Lack of space precludes referencing in this article; however further information on the activities mentioned below is to be found in the accompanying articles in this Journal.

2. Antarctic Stations conducting Astronomy

2.1. *South Pole: the US Amundsen-Scott Station*

The South Pole Station dates back to the IGY of 1957-58, with astronomical activity pioneered there by the late Martin Pomerantz beginning in 1979. The establishment of the "Dark Sector" in 1994 set the scene for what is a major Observatory today. Four astronomical experiments are currently funded; the AMANDA and IceCube neutrino observatories (the latter will comprise of a cubic kilometre detector 2 km beneath the ice surface), the 10m South Pole Telescope (SPT) measuring the SZ-effect in galaxy clusters to probe the equation of state for dark energy, and BICEP measuring the polarization of the cosmic microwave background emission in order to search for gravity waves from the inflation of the Universe.

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2.2. *Dome C: the French / Italian Concordia Station*

Concordia Station opened for winter operation in 2005. Noted for its ice core measurements of a column nearly 1 million years in depth, the principal astronomical activity so far has been site testing and instrument characterisation. It is clear that the surface boundary layer, for instance, is much narrower than at South Pole, and the average wind speed is lower. European interest in the station has been piqued through the European Union-funded ARENA network program, which has examined possible options for the site. Highest priority of these is a 2.5m class IR-optimised telescope (PILOT/PLT), a collaboration also including Australia. Interest in the sub-mm is also high, as are the prospects for long-time series measurements, CMBR experiments, solar astronomy and, in particular, an IR interferometer for studying exo-zodiacal emission.

2.3. *Dome A: the Chinese Kunlun Station*

The first humans only visited Dome A in 2005 with a Chinese traverse to the summit of the Antarctic plateau. No humans have yet wintered over at the site. During 2009 China began construction of a new station, Kunlun. The PLATO autonomous observatory operated through the winters of 2008 & 2009, gathering the first astronomical data from the site, as well as site testing data, including on the boundary layer and the atmospheric transparency in the sub-millimetre. These have shown that the boundary layer is exceedingly narrow (less than Dome C), and that the air is exceedingly dry. The Chinese Center for Antarctic Astronomy is now examining options for ambitious facilities, including a network of 0.5m telescopes, a 4m optical/IR telescope and a 15-30m sub-mm/THz telescope.

2.4. *Dome F: the Japanese Fuji Station*

The Japanese station at Dome Fuji has been used to collect ice cores (with one fascinating astronomical result reported by Motizuki at the meeting), and has operated through an Antarctic winter. No astronomical experiments have yet been conducted, but some site testing data has been obtained. The site would appear to offer comparable qualities to Domes A and C. The site testing program is being enhanced and there are plans for both optical/IR and sub-mm/THz facilities. Pilot studies for prototype facilities in these bands have commenced.

2.5. *McMurdo: the US Long Duration Balloon Facility (LDBF)*

Over the Antarctic summer season the circumpolar vortex provides an opportunity for long duration (several weeks) flights of balloons launched from coastal locations, providing the rational behind the LDBF at McMurdo station. Several astronomical experiments have been launched from here, perhaps the most notable being the BOOMERanG experiment which determined that the Universe was flat. In 2010-11 a 0.8m diameter THz spectral imaging telescope will be launched (STO – the Stratospheric Terahertz Observatory) with the aim of mapping large scale N^+ and C^+ emission over the southern Galactic plane.

References

Storey, J. W. V. 2005, Antarctic Science, 17, 555

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