Astronomy in Antarctica

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Abstract  Antarctica provides a unique environment for astronomers to practice their trade. The cold, dry and stable air found above the high Antarctic plateau, as well as the pure ice below, offers new opportunities for the conduct of observational astronomy across both the photon and the particle spectrum. The summits of the Antarctic plateau provide the best seeing conditions, the darkest skies and the most transparent atmosphere of any earth-based observing site. Astronomical activities are now underway at four plateau sites: the Amundsen-Scott South Pole Station, Concordia Station at Dome C, Kunlun Station at Dome A and Fuji Station at Dome F, in addition to long duration ballooning from the coastal station of McMurdo, at stations run by the USA, France/Italy, China, Japan and the USA, respectively. The astronomy conducted from Antarctica includes optical, infrared, terahertz and sub-millimetre astronomy, measurements of cosmic microwave background anisotropies, solar astronomy, as well as high energy astrophysics involving the measurement of cosmic rays, gamma rays and neutrinos. Antarctica is also the richest source of meteorites on our planet. An extensive range of site testing measurements have been made over the high plateau sites. In this article, we summarise the facets of Antarctica that are driving developments in astronomy there, and review the results of the site testing experiments undertaken to quantify those characteristics of the Antarctic plateau relevant for astronomical observation. We also outline the historical development of the astronomy on the continent, and then review the principal scientific results to have emerged over the past three decades of activity in the discipline. These range from determination of the dominant frequencies of the 5 min solar oscillation in 1979 to the highest angular scale measurements yet made of the power spectrum of the CMBR anisotropies in 2010. They span through infrared views of the galactic ecology in star formation complexes in...
1999, the first clear demonstration that the Universe was flat in 2000, the first detection of polarization in the CMBR in 2002, the mapping of the warm molecular gas across the $\sim 300$ pc extent of the Central Molecular Zone of our Galaxy in 2003, the measurement of cosmic neutrinos in 2005, and imaging of the thermal Sunyaev Zel’dovich effect in galaxy clusters in 2008. This review also discusses how science is conducted in Antarctica, and in particular the difficulties, as well as the advantages, faced by astronomers seeking to bring their experiments there. It also reviews some of the political issues that will be encountered, both at national and international level. Finally, the review discusses where Antarctic astronomy may be heading in the coming decade, in particular plans for infrared and terahertz astronomy, including the new facilities being considered for these wavebands at the high plateau stations.

Keywords Methods: observational · Telescopes · Site testing · Atmospheric effects · Astroparticle physics · Cosmic background radiation

1 Why astronomy in Antarctica?

1.1 The Antarctic continent and its high ice plateau

The Antarctic continent is the highest, driest and coldest of the continents on the Earth. It is the end of the Earth, literally as well metaphorically. As with all endeavours in Antarctica, it was the last continent where humans began to conduct astronomical observations from. The first astronomical discovery was made less than a century ago, and it has only been in the past two decades that major ventures in the discipline have taken place. Yet, with current technology, astronomy is no longer difficult to undertake in Antarctica, given appropriate resources and fore-planning. Moreover, the potential Antarctica offers for furthering a wide and diverse range of frontier investigations in astronomy is unmatched, in comparison with any other location on our planet.

Antarctica is the fifth largest continent, with a land area of 14 square million kilometres. The amount of exposed land is, however, tiny, about 2% of the total and confined almost entirely to the coastal fringe. As a continent, Antarctica is dominated by ice, with the area covered virtually doubling between the summer and winter extremes; the ice sheets extend up to 1000 km over the Southern Ocean from the coast at their September peak. From an astronomer’s perspective, it is the ice mass of the Antarctic plateau that draws the attention. For while the continent is crossed by one of the world’s great mountain ranges, the Trans Antarctic Mountains that stretch nearly 5,000 km from the Weddell Sea to the Ross Sea, all but its highest peaks (the nunataks) are obscured from view, buried under the ice sheet that makes up the Antarctic plateau.

The land itself lies under up to 4 km of ice, with the ice surface very gradually rising from the coast, over a distance of several hundred kilometres, to reach over 4,000 m at Dome A (though the peaks of some of the mountains rise higher than this, for instance, the Vinson Massif in West Antarctica is 4,897 m high). The area of ice over 3,000 m elevation is almost as large as the continent of Australia. This is the Antarctic plateau.