The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)

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Abstract: The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) is a highly automated 1.7 m diameter telescope aimed at exploiting the superb submillimetre skies of the Antarctic Plateau for astronomy and aeronomy studies. It was recently installed at the Amundsen–Scott South Pole Station during the 1994/95 Austral season and is currently undergoing its first winter-over of operation. In this paper we briefly outline the capabilities of the instrument and describe some recent achievements culminating in the telescope's first observations of the South Polar submillimetre sky.

Keywords: telescopes — instrumentation: detectors — radio lines: ISM — ISM: atoms — ISM: molecules — stars: formation

1 Introduction

It is becoming increasingly clear that the Antarctic Plateau is an exceptionally good observing site for studies at submillimetre and infrared wavelengths due to its high altitude, low ambient temperatures, low atmospheric water vapour content and stable atmospheric conditions. Many measurements made at the South Pole over recent years have confirmed this view, including studies by Pajot et al. (1989) and Dragovan et al. (1990), which showed that the broad-band atmospheric opacity in the 650 μm window is typically τ ~ 0.2 in summer. Chamberlin and Bally (1994, 1995) measured the 225 GHz opacity throughout 1992 using a tipping radiometer, and found that the sky at this frequency is significantly better than at Mauna Kea, currently one of the best low-latitude observing sites, exceeding τ ~ 0.1 only fifteen days a year compared to half the year at Mauna Kea. When these measurements are extrapolated to submillimetre wavelengths, the situation becomes even more favorable.

Observations in the submillimetre region are of great importance as they trace the warm, dense component of the interstellar medium associated with star and galaxy formation, as well as the complex interface between atomic and molecular regions of molecular clouds. In this way it is possible to follow the ‘interstellar recycling’ process as molecular material is created and destroyed. Of particular use in tracing these mechanisms are the higher rotational states of the abundant interstellar molecule CO, such as the J = 4–3 line at 650 μm (462 GHz), and the fine-structure transition of neutral carbon atoms at 609 μm (492 GHz). Observations at these wavelengths are much more successful on the Antarctic Plateau than at lower latitudes.

Submillimetre telescopes can also be used to study molecules in the Earth’s atmosphere. Abundances for important atmospheric species like CO, O₃ and H₂O can be measured as a function of altitude; while these are not as accurate as balloon-borne measurements, they are most sensitive to species at the highest altitudes, beyond the reach of balloons, and can be monitored in different directions on the sky for continuous periods of time. Such studies are fundamental to our understanding of the dynamics of the atmosphere above the Antarctic Plateau.

2 Instrumental Details

The telescope, which has an alt–azimuth mounting, uses a 1.7 m diameter primary reflector made of carbon fibre and epoxy, with a vacuum-sputtered aluminium surface having a surface roughness of 6 μm and an rms figure of around 9 μm. This yields a beamsize of 96″/λ/600μm), which is large enough to allow large-scale mapping programs to be undertaken, yet small enough to detect nearby external galaxies.

All optics are offset for high beam efficiency and to avoid inadvertent reflections and resonances (Stark 1989). The Gregorian secondary is a prolate spheroid with its exit pupil at a flat tertiary mirror which can be chopped between different positions on the sky. The diffraction-limited field of view is 3° at 3 mm wavelength and 30' in diameter at 200 μm. A flat fourth mirror directs the beam to a coude focus below the telescope along the azimuth axis. This optical configuration is shown...
The telescope is offset along both the elevation and azimuth axes. The coudé focus is achieved using a total of four mirrors. The Nasmyth focus is achieved by removing the fourth mirror.

The offset primary is attached to the telescope with INVAR alloy truss rods which have a very low coefficient of expansion and hence help to maintain a constant primary-secondary distance.

The instrument also has a Nasmyth focus located where the beam passes through a 0.2 m hole in the elevation bearing. Access to this focus is made possible by removal of the fourth mirror (shown in Figure 1). This focus is almost identical in its optical properties to the bent Cassegrain focus on the Kuiper Airborne Observatory, except for having a larger field of view. Array detectors are planned to be used at this focus in the future.

The receivers and associated cryogenic systems are located in a coudé room below the telescope at room temperature. Up to four receivers can be placed on an optical table suspended under the telescope structure. Currently, four heterodyne receivers are being tested on the instrument: a 230 GHz SIS, 300 K SSB noise temperature receiver (built by J. Bally of the University of Colorado), a 470–500 GHz quasi-optical SIS receiver, 170 K DSB (Engargiola, Zmuidzinas & Lo 1994; Zmuidzinas & LeDuc 1993), 440–510 GHz SIS waveguide receiver, 340 K DSB (built by C. Walker of the University of Arizona) and a 460–500 GHz Schottky diode receiver, 950 K DSB (built by P. Zimmerman of Radiometer Physics GmbH). The last receiver is unique in not requiring a liquid helium supply. The backends are acousto-optical spectrometers (AOS); two 1 GHz bandwidth spectrometers and one high-resolution spectrometer are currently installed (Schieder, Tolls & Winnewisser 1989). The laboratory space also holds three racks of electronics which hold the AOS controllers, telescope drive boxes, control computer/data acquisition systems and various other electronics along with tools and workbenches. To improve the reliability of the system, there is a twofold redundancy in most of the vital components. The system was designed at the outset to be highly automated so as to reduce the need for operator intervention, and can be operated remotely over the Internet.

3 Recent Achievements

In 1993 January, AST/RO was lifted to its test site on top of the Physics Department at Boston University, where system integration and initial observations were performed. During early 1993 and early 1994 the telescope was successfully used for observations of the CO $J = 2 \rightarrow 1$ transition at 230 GHz and preliminary measurements were made at 492 GHz (Stark et al. 1995). These initial observations confirmed that the various components of the system were working correctly and that the telescope as a whole was operating satisfactorily.

In August of 1994 the telescope was shipped and finally installed on a custom-designed building at the Amundsen-Scott South Pole station during the 1994/95 Austral season. Although many logistical difficulties had to be overcome, the instrument is now operational and is undergoing its first season of winter-over observations. Figure 2 shows a preliminary 492 GHz neutral carbon spectrum of the galactic centre source Sgr A made by AST/RO at the South Pole using the University of Illinois quasi-optical SIS receiver in 1995 March.

The initial goals for the instrument are heterodyne spectroscopy of galactic molecular clouds and molecular lines in the Earth’s atmosphere at wavelengths near 600 μm. However, the telescope will eventually be developed into a general-purpose instrument for studies in the millimetre, submillimetre and far infrared. Although the first results are only starting to come in, it is already clear that AST/RO will make some very important contributions towards our understanding of the interstellar medium, and also help to establish the Antarctic Plateau as one of the world’s premier observing sites.

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Figure 2—A preliminary 492 GHz neutral carbon spectrum of the galactic centre source Sgr A taken at the South Pole by the newly installed AST/RO telescope in 1995 March, using the University of Illinois quasi-optical SIS receiver.

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