Terahertz Astronomy From The Coldest Place on Earth

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Abstract

Many atoms and molecules have emission lines that occur at THz frequencies. These emission lines can be used to probe the conditions in Giant Molecular Clouds (GMCs) throughout our galaxy. From studying the star formation process in GMCs we will gain a better understanding of the origin of planetary systems like our own. The high Antarctic plateau offers unique opportunities for observatories optimized for this important wavelength regime.

Introduction

All stars and planets originate in cold clouds of gas and dust that permeate interstellar space. The original clouds contained only hydrogen and helium with trace amounts of lithium and deuterium. Indeed the first generation of stars contained only these elements. Over the lifetime of the Universe many generations of high mass stars have come and gone depositing the products of nucleosynthesis (C, N, O, Si, P, etc.) into the interstellar medium. Within the shielded environments of Giant Molecular Clouds (GMCs) these elements are able to combine to form a plethora of molecules. Through radiative transitions, these molecules play an important role in determining the energy balance within star forming clouds and the interstellar medium as a whole. They partially regulate the formation of stars and planets and can be used to diagnose the physical conditions (composition, temperature, density, velocity fields) within these regions.

Most of the dominant atomic and molecular features are found at submillimeter wavelengths (>0.3 THz, see Figure 1), one of the last largely unexplored wavelength frontiers in modern astronomy. The extreme dryness and cold of the Antarctic plateau make it the best location for conducting infrared and submillimeter astronomy from the ground. Sites of particular astronomical interest on the plateau are shown in Figure 2.

The Antarctic Submillimeter Telescope & Remote Observatory

Over the past decade the Antarctic Submillimeter Telescope & Remote Observatory (AST/RO, see Figure 3) has been in operation at the Amundsen-Scott South Pole Station. AST/RO was conceived as a submillimeter-wave survey instrument and a prototype telescope for automated winter operations in Antarctica. It is designed to carry out large-scale mapping of the southern Galactic plane, the Galactic Center, nearby galaxies, and selected star-formation regions using a wide variety of submillimeter-wave heterodyne receiver systems. Principal targets are the 0.5 THz fine-structure line of atomic carbon and rotationally excited lines of carbon monoxide (CO) from 0.46-0.81 THz. The 1.7-meter aperture yields a beamsize of 1-2 arcminutes at these frequencies, large enough to permit large-scale mapping programs, yet small enough to map distant clouds in the Galaxy [1].

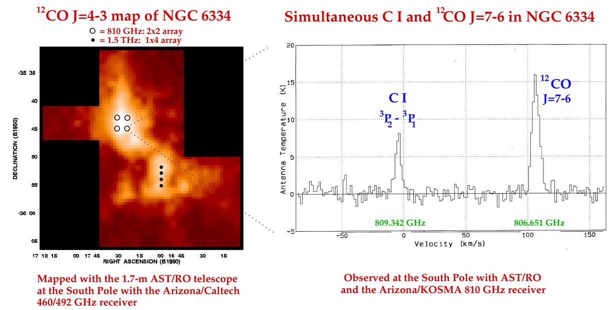

Figure 1: *Left): The southern giant molecular cloud NGC 6334 imaged in the light from the J=4-3 rotational transition (0.46 THz) of CO with the AST/RO telescope. Right): A sample 0.81 THz spectrum of neutral atomic carbon and the J=7-6 rotational transition of CO observed toward a star forming region.*

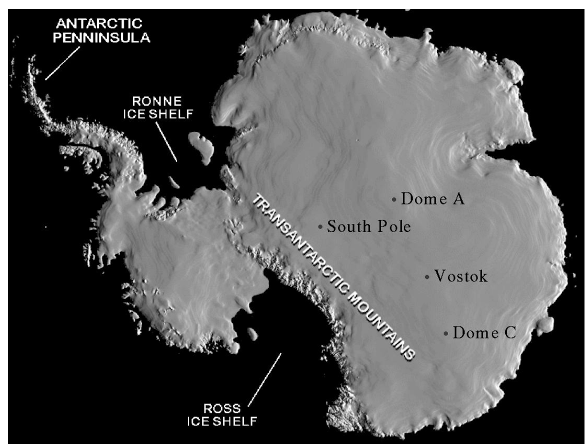

Figure 2: *Map of the Antarctic continent showing the locations of South Pole, and the high-elevation sites of Dome A, Dome C, and Vostok station.*

Figure 3: *The 1.7-meter Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) has been in continual operation at the Amundsen-Scott South Pole Station since 1994.*

The South Pole Telescope

Based upon the success of astronomical experiments at the South Pole, new submillimeter facilities are being conceived and constructed. The largest of these, the 10-meter South Pole Telescope (SPT) is now under construction and is scheduled for completion in 2007 (Figure 4). It will be used to study the formation and evolution of the early Universe as well as the interstellar medium in our and other galaxies [2].

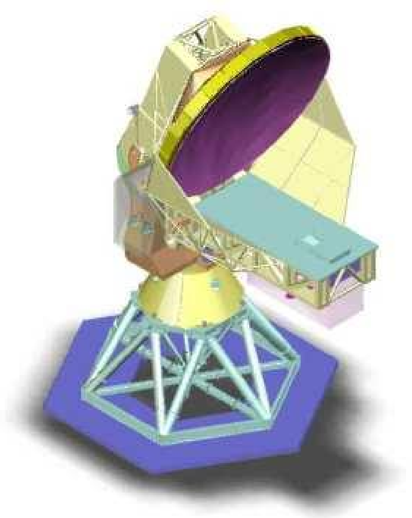

Figure 4: *Conceptual drawing of the 10-meter South Pole Submillimeter Telescope.*

HEAT: A Terahertz Observatory for Dome A

Building upon the heritage of AST/RO, a new 0.5-meter observatory, the High Elevation Antarctic Terahertz Telescope (HEAT), is being proposed for Dome A in Antarctica (Figure 5) [3]. Dome A is the highest (4.1 km), driest, coldest site on the ice plateau. From its summit, observations of the astrophysically important 1.46 and 1.9 THz lines from N^+ and C^+ should be routinely possible. From remote sites such as Dome A, the next generation of THz instrumentation can be field tested, providing an invaluable dress rehearsal for future space missions.

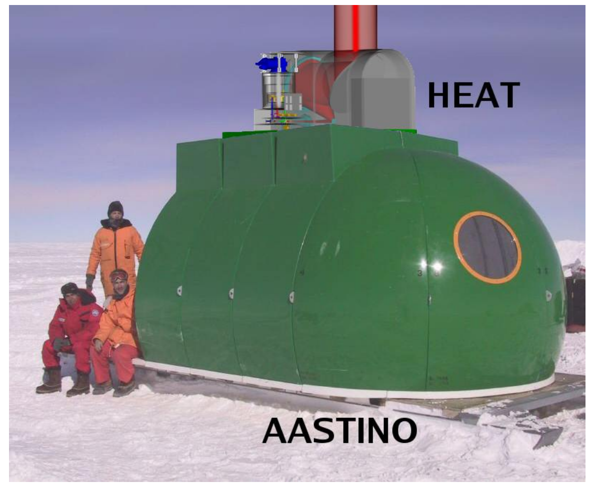

Figure 5: *The High Elevation Antarctic Telescope will be a dedicated observatory for astronomical investigations at THz frequencies. It will rest atop an Automated Astrophysical Site-Testing InterNational Observatory (AASTINO), built by the University of New South Wales. Equipped with sensitive SIS and HEB receivers, HEAT is designed to perform an automated survey of the southern Galactic Plane from Dome A, the highest point on the Antarctic plateau, starting in 2008.*

References

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[2] Ruhl, J., et al. 2004, "The South Pole Telescope", Proc. SPIE, 5498, 11

[3] Walker, C. K., et al. "Forecast for HEAT on Dome A, Antarctica: the High Elevation Antarctic Terahertz Telescope", 2004, Proc. SPIE, 5489, 470