The High Elevation Antarctic Telescope (HEAT):
Opening New Windows to Ground-Based Astronomy

We propose to develop an automated, 0.5-meter Terahertz (far-infrared) observatory for remote operation at the summit of "Dome A", the coldest, highest, and driest point on the central Antarctic plateau. From this extraordinary site, the High Elevation Antarctic Terahertz Telescope (HEAT) will operate in the atmospheric windows between 150 and 400 μm, in which the most crucial astrophysical spectral diagnostics of the formation of galaxies, stars, planets, and life are found. HEAT will answer timely and fundamental questions about the evolution of the interstellar medium and star formation: through large-scale Galactic surveys the **impact of the Galactic environment** on the **life cycles of interstellar clouds** and their **relation to star formation** will finally be realized. HEAT will pioneer new capabilities for ground-based astronomy, Terahertz instrumentation technologies, and will deploy during the landmark International Polar Year (IPY). The HEAT project is driven by the University of Arizona but also brings with it a rich and diverse worldwide collaboration with unique opportunities for future development of ground, sub-orbital, and space-based missions and technologies.
The HEAT project (through the AstroPoles program, M. Burton-PI, UNSW) has been endorsed by the IPY Joint Committee (see attached letter) and received funds from the NSF Office of Polar Programs (NSF-OPP) to conduct a detailed design study. The NSF-OPP recognizes the importance and pioneering spirit of HEAT and it is with their encouragement that we submit this proposal.

Scientific Justification

The far-infrared (Terahertz) portion of the electromagnetic spectrum contains answers to fundamental questions concerning the origin and evolution of the Universe, galaxies, stars, and planets. For example, far-infrared spectroscopy will fill glaring gaps in our understanding of the life cycle of interstellar clouds (Figure 1), the "nurseries" from which all stars and planets (and life?) are born. *It is astonishing that the formation and destruction of these clouds remains unobserved given their importance to our own cosmic origins!* However, all far-infrared spectroscopy has come from limited operation of airborne and space observatories. Less than 0.01% of the Galaxy has been surveyed with high spectral resolution in the pivotal 158 μm line of ionized carbon, the brightest spectral line in the Galaxy! Yet no present or planned observatory will significantly increase that figure despite improvements in detector sensitivity.

Exciting new developments offer promise that such observations can be performed from the ground! A 2005 Chinese expedition to "Dome A", the summit of the Antarctic ice plateau, installed an Australian Automated Weather Station (AWS) that still operates today. A plot of the atmospheric transmission based on this data shows that entirely new windows onto the Universe are opened in the skies above Dome A versus established submillimeter sites such as Mt. Graham and the high Atacama desert in northern Chile (Figure 2). These data confirm that Dome A is the preeminent site on the planet for submillimeter and far-infrared (THz) astronomy owing to its extreme cold (-100F), high elevation (14,000 ft), dryness, and near-absence of weather or wind.

A small, dedicated survey telescope at Dome A would benefit astronomy enormously; its large-scale coverage of the Galaxy would provide a timely study of the ecology of the Milky Way and how the evolution of interstellar gas relates to the evolution of stars. It could witness for the first time the formation of interstellar clouds from which all stars and planets are created. By revealing the full life cycle of interstellar clouds, a meaningful template of the Milky Way can be constructed – a "Rosetta Stone" which can be used to translate future observations of distant galaxies into reliable indicators of their respective histories (Figure 1). These surveys would be "finder charts" that would enable productive focused studies with future submillimeter and Terahertz observatories like ALMA, Herschel, and SOFIA.

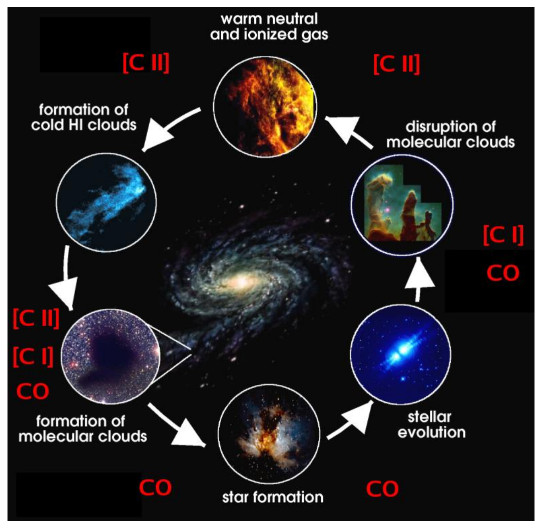

Figure 1: HEAT will be the first dedicated instrument to study the entire life cycle of interstellar clouds from which stars and planets are formed.

The decade-long experience of the PI's team in building submillimeter instruments for the AST/RO telescope at the South Pole puts the UofA in a unique position to carry Terahertz instrumentation and astronomy to the next stage of evolution. The culmination of this collab-

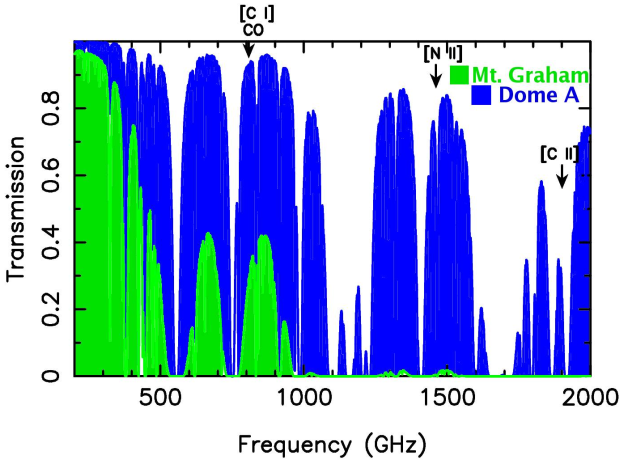

Figure 2: The atmospheric transmission from Mt. Graham allows efficient operation at frequencies below 1 THz, but the extraordinary conditions at Dome A open up entirely new atmospheric windows of crucial importance.

orative expertise will be brought to bear on HEAT: the High Elevation Antarctic Terahertz Telescope, an automated 0.5-meter telescope for Dome A, Antarctica.

Instrument Description

HEAT will be a fully automated, state-of-the-art THz observatory designed to operate autonomously from Dome A in Antarctica. HEAT is designed to take advantage of Dome A's unparalleled atmospheric conditions and observe simultaneously in [C II](158 μm), [N II](205 μm), and CO J=7$\rightarrow$6/[C I] (370 μm) – a combination that probes every stage of a cloud's life cycle!

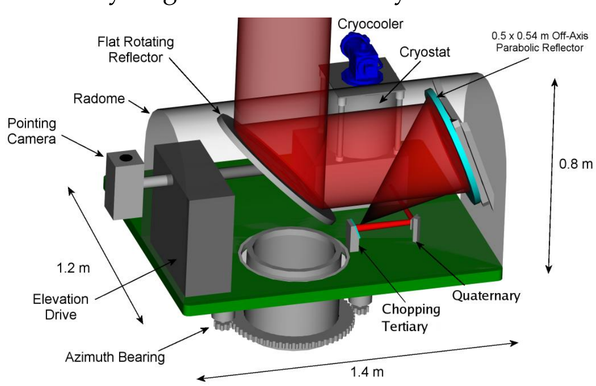

Figure 3: Concept drawing of the HEAT telescope

For robustness and efficiency, the telescope and instrument are integrated into a common optical support structure (Figure 3). HEAT will be mounted on top of a University of New South Wales AASTINO (Automated Astrophysical Site-Testing InterNational Observatory, Figure 4). The AASTINO provides power and communications for the HEAT telescope and instrument. The total power budget for HEAT is 600W, readily provided by solar cells and/or generators within the AASTINO. Data transfer and command and control of HEAT will be done via Iridium and TDRSS-1 satellites. The University of New South Wales will participate in all aspects of design, integration, deployment, and operation (see Support Letter from J. Storey).

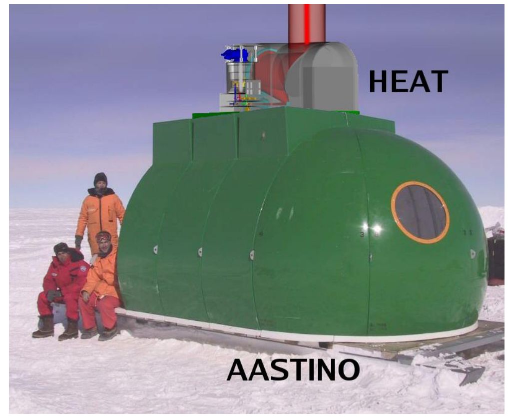

Figure 4: 3D rendering of HEAT mounted on its AASTINO

The telescope will be built at the College of Optical Sciences. Its off-axis, Gregorian configuration is designed to have maximum efficiency and the minimum number of optical components. Incoming light is reflected horizontally off a 45°, 0.5×0.7m flat reflector to an f/2.2 off-axis parabolic mirror. The converging beam is intercepted by a hyperbolic tertiary mirror, to a flat quaternary and into the receiver. The detector system will employ Schottky diode mixers with subharmonically-pumped Local Oscillators that can operate effectively at ambient temperature. The mixers and amplifiers will be housed in a closed-cycle cryostat with a 200 watt free-piston Stirling engine cryocooler that can reduce the operating temperature to 60K, improving sensitivity by a factor of 2-3. Other components, such as the IF amplifiers and processors, digital FFT spectrometer, and bias electronics, will be identical to that developed for SuperCam, a 64-beam imaging spectrometer for the HHT on Mt. Graham. The receiver system will be constructed by the PI and his UofA team who have extensive experience designing, building, deploying, and using state-of-the-art submillimeter-wave/THz receiver systems.

The 3-year budget for the HEAT project (including telescope, instrument and personnel) is $1,875,000, well within the cost cap of the MRI program.

With the implementation of HEAT, the UofA will have a unique capability for exploring the origins and ecology of galaxies, stars and planetary systems like our own. It will play a visible role in the landmark International Polar Year with a telescope that is a pioneer in absolutely every regard! During the last IPY in 1957, the U.S. established a science station at the geographic South Pole – this time, the UofA could pioneer an observatory at Dome A! HEAT (with its accompanying AASTINO module) is tentatively scheduled to be taken to Dome A by a joint Chinese/Australian/US expedition during the 2008-2009 austral summer. We look forward both to the exciting science that HEAT will perform and to the unique challenges of making it a reality.