Pre-HEAT: First Submillimeter Site Testing & Astronomical Spectra from Dome A
A Unique Mission of Opportunity for the International Polar Year

At the summit of the Antarctic ice plateau, Dome A is receiving international acclaim as the best site for ground based THz astronomy in the world (Lawrence et al. 2004). While at optical & near-infrared wavelengths the atmospheric image quality at Dome A is not yet demonstrated, at submillimeter and far-infrared wavelengths the measured extreme cold and dryness **already** sets Dome A apart from all other sites on the planet. Over the past 3 years our team has been pursuing the concept of a small (0.5 m), automated THz observatory for Dome A. This work has culminated in an NSF-funded design study of `HEAT`: the High Elevation Antarctic Terahertz Telescope. A MRI proposal to build `HEAT` for deployment to Dome A in the 2008-9 timescale is currently under consideration at NSF. The `HEAT` project (through the AstroPoles program, M. Burton-PI, UNSW) has been endorsed by the IPY Joint Committee (see attached letter).
An exciting and timely opportunity has arisen that allows us to perform important, pathfinding research *this year*, in advance of `HEAT`. Our Chinese and Australian partners in `HEAT` will be installing the first base Plateau Observatory (PLATO) on Dome A this coming Austral summer (2007-8). They have given us the opportunity to field a submillimeter radiometer as part of this expedition. This instrument, entitled `Pre-HEAT`, is a 450 μm (660 GHz) tipping radiometer coupled with a FFT spectrometer. Many of the key components for `Pre-HEAT` already exist in our lab. The goals of `Pre-HEAT` are to (1) Measure the submillimeter sky opacity as a quantitative demonstration of the exceptional conditions of Dome A, (2) Perform strip maps of the Galactic Plane in the ^{13}CO J=6-5 line at 661 GHz, constituting the first astrophysical measurements from Dome A, and (3) Field-test many of `HEAT`'s key technologies. `Pre-HEAT` will pioneer new capabilities for ground-based astronomy and is an opportunity for the US to play a major role in a landmark International Polar Year (IPY) project.

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1 The Scientific Importance of Dome A

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, 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!* 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 [CII], the brightest spectral line in the Galaxy.

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, including one providing access to the [CII] line. Such observations are imposssible from more established submillimeter sites such as Mauna Kea and the high Atacama desert in northern Chile (Figure 2). The extreme cold (-100F), high elevation (14,000 ft), and dryness of Dome A are what make it unique.

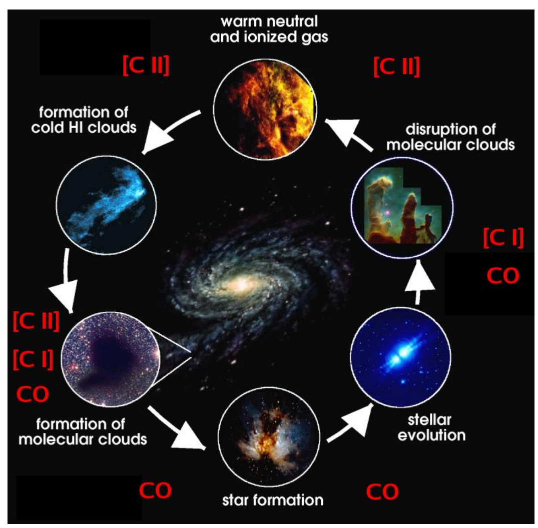

Figure 1: `HEAT`, with its forerunner `Pre-HEAT`, will be the first dedicated instruments to study the entire life cycle of interstellar clouds from which stars and planets are formed.

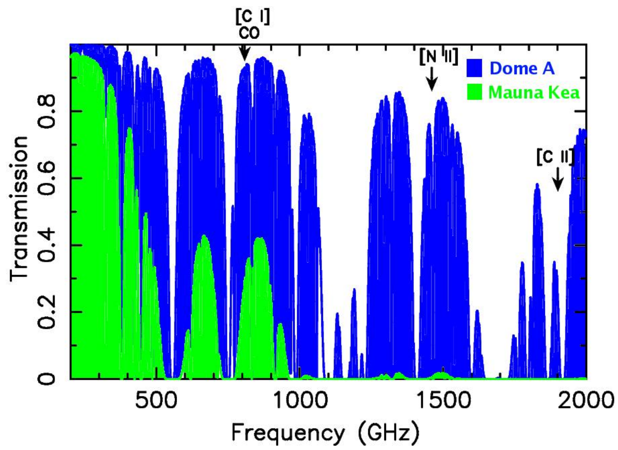

Figure 2: The atmospheric transmission from Mauna Kea allows efficient operation at frequencies below 1 THz, but the extraordinary conditions at Dome A open up entirely new atmospheric windows of crucial importance.

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). Finally, these surveys would be "finder charts" that would enable productive focused studies with future submillimeter and Terahertz observatories like ALMA, Herschel, and SOFIA.

In this SGER proposal, we are requesting funds to construct the forerunner of such a dedicated survey telescope. Since the survey telescope is named "`HEAT`" (the High Elevation Antarctic Terahertz Telescope), this forerunner will be referred to as "`Pre-HEAT`".

2 Pre-HEAT: A Unique Mission of Opportunity for NSF-SGER

`Pre-HEAT` will provide the first direct submillimeter observations of the atmospheric opacity from Dome A and the first astronomical spectra from this unique site. A block diagram and 3-D CAD rendering of `Pre-HEAT` is provided in Figure 3 and

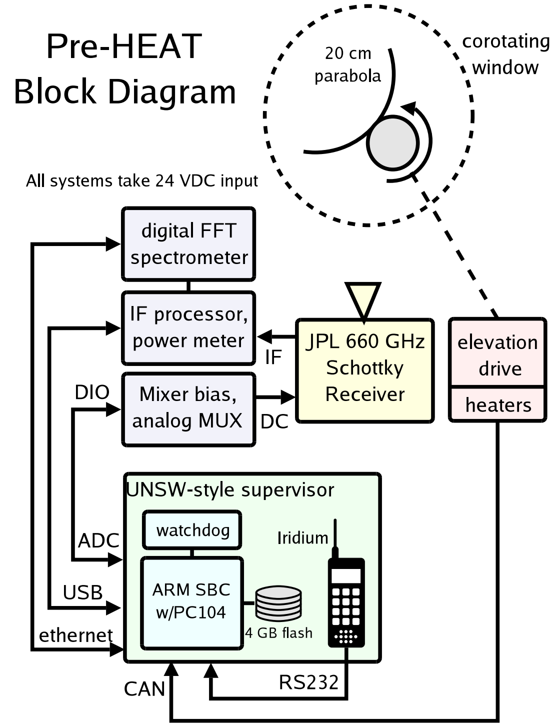

Figure 3: Block Diagram of the `Pre-HEAT` installation.

Figure 4. A rotating 20×28cm parabolic primary mirror illuminates an ambient temperature Schottky mixer receiver at 661 GHz (454 μm). The Schottky receiver (Siegel et al. 1998) has been graciously provided to the project from Peter Siegel's team at the Jet Propulsion Laboratory (JPL). The total power in the downconverted (4-12 GHz) Intermediate Frequency (IF) signal produced by the receiver at a series of elevation angles will be used to compute the atmospheric transmission. With 180 degrees of elevation travel and a simple fixed-azimuth mount, `Pre-HEAT` will also be able to observe the Galactic

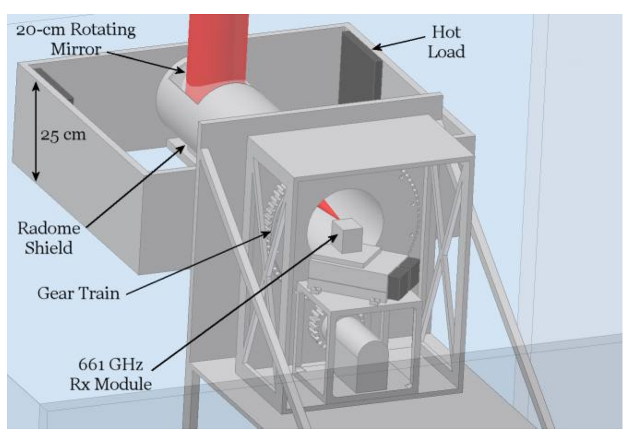

Figure 4: 3D mechanical diagram of `Pre-HEAT`.

Component	Readiness Level	Estd. Cost
660 GHz Schottky RX	Works in lab, requires mount	\$1000
IF processor	(From Supercam) Works in lab; needs packaging	\$500
Digital FFT spectrometer	(From Supercam) Works in lab; needs packaging	\$500
Analog (mixer) Bias Box	(From Supercam) Works in lab, needs packaging	\$500
20x28 cm mirror	Identified; need to purchase	\$1500
External Telescope Mount	Designed; need to fabricate	\$7000
Worm gear/Drive system	Parts identified; need to purchase	\$2000
Thermal Sensors/Heaters	System designed; need to fabricate	\$500
Single Board Computer	Prototype works in lab w/ partial software	\$500
Supervisor Module	UNSW design; need to fabricate and test	\$1000
Iridium Communication	Purchase sat. phone, integrate into Supervisor	\$1000

Table 1: Deployment Readiness of `Pre-HEAT` components. Total direct cost of fabrication and labor for telescope construction is approximately \$16,000.

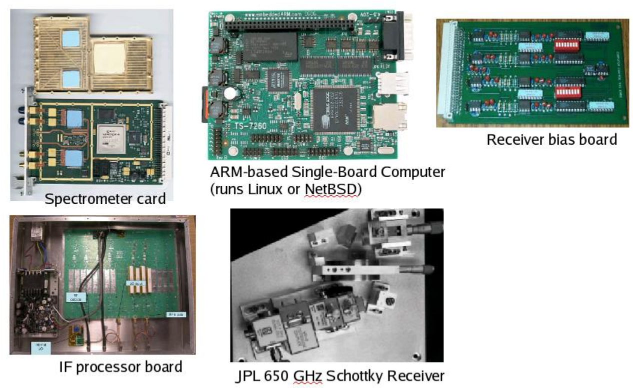

Figure 5: Major components of `Pre-HEAT` that are already fully tested and are now in the PI's lab.

Plane for 4 hours per day. During this time, spectral strip maps through the Galaxy at the pretuned frequency of the 661 GHz ^{13}CO J=6-5 line will be performed. These maps will be constructed by the technique of drift scanning (i.e. On-the-Fly mapping) as the Earth rotates. The IF signal is passed through a Fast Fourier Transform (FFT) Spectrometer which accumulates a power spectrum of the ^{13}CO J=6-5 line every 5-10 seconds. Over time, the S/N of the Galactic Plane strip maps will rival the sensitivity and angular resolution of the landmark CfA/Columbia CO J=1-0 maps of the sky (Dame et al. 1987, 2001). A total of 100 square degrees of the southern Galactic Plane will be observed in 2008. **Such a survey at submillimeter wavelengths has never before been performed.** The data set will complement the THz observations that will be performed by HEAT and be of immediate use to the larger astronomical community.

The site testing data and ^{13}CO J=6-5 survey results will be provided to the scientific community through the HEAT web site at the University of Arizona, in accordance with the spirit of the International Polar Year (IPY).

3 Pre-HEAT Instrument Implementation and Schedule

The PI's team has a decade-long experience building submillimeter instruments for the AST/RO telescope at the South Pole. Several of these instruments were built through collaborations with multi-institutional (including international) partners. The culmination of this collaborative expertise will be brought to bear on both HEAT and `Pre-HEAT`.

The aggressive schedule in which `Pre-HEAT` must be completed is set by the deployment dates of the Chinese 2007-8 traverse to Dome A: `Pre-HEAT` should be integrated into the PLATO module at UNSW by the end of August, 2007. Meeting this schedule within tight budgetary constraints is made possible by the technological foundation laid by the PI's NSF-funded *SuperCam* 64-beam heterodyne array (2004-7) and the NSF-funded design study for the HEAT telescope (2006-7). The Deployment Readiness of `Pre-HEAT` components is described in Table 1, and pictures of assembled components are shown in Figure 5. All components of the receiver system exist in the PI's lab. Only the integration of these components into the scanning mirror assembly is needed. The remaining items to be procured have been identified and can be assembled rapidly.

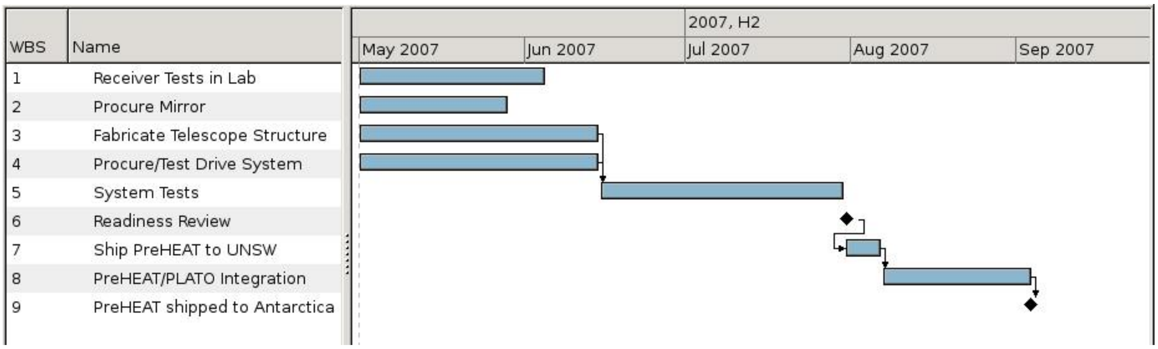

Figure 6: A working schedule for `Pre-HEAT` predicated on funding beginning May 1, 2007.

A schedule for `Pre-HEAT` integration and deployment is highlighted in Figure 6. A detailed budget and budget justification is provided on the pages that follow.

4 Next mission: the HEAT Observatory

With `Pre-HEAT` deployed, all systems will be in place to prepare for the deployment of the full `HEAT` telescope in 2008-9, pending funding from NSF/MRI. `HEAT` will be a 0.5-meter telescope with three sets of Schottky receivers that will simultaneously observe 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 an interstellar cloud's life cycle. The plan is for `Pre-HEAT` to remain in operation after the deployment of `HEAT`, extending the baseline of site testing data and providing valuable atmospheric calibration for the `HEAT` observations.