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PI/PD Name: Christopher K Walker

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

REQUIRED: Check here if you are currently serving (or have previously served) as a PI, co-PI or PD on any federally funded project ☒

Ethnicity Definition:
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Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
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PI/PD Name: James H Burge

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
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- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
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- ☒ None

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PI/PD Name: Craig A Kulesa

Gender: ☒ Male ☐ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White

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- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
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- ☒ None

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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:
Not Listed

REVIEWERS NOT TO INCLUDE:
Not Listed

COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 04-23		FOR NSF USE ONLY
NSF 07-510	01/25/07	NSF PROPOSAL NUMBER
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) ANT - MAJOR RESEARCH INSTRUMENTATION		0723230

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
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EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS ☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
866004791		

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE
University of Arizona	888 N Euclid Ave TUCSON, AZ 85721-0001
AWARDEE ORGANIZATION CODE (IF KNOWN) 0010835000	
NAME OF PERFORMING ORGANIZATION, IF DIFFERENT FROM ABOVE	ADDRESS OF PERFORMING ORGANIZATION, IF DIFFERENT, INCLUDING 9 DIGIT ZIP CODE
PERFORMING ORGANIZATION CODE (IF KNOWN)	

IS AWARDEE ORGANIZATION (Check All That Apply) (See GPG II.C For Definitions)
☐ SMALL BUSINESS ☐ MINORITY BUSINESS
☐ FOR-PROFIT ORGANIZATION ☐ WOMAN-OWNED BUSINESS
☐ IF THIS IS A PRELIMINARY PROPOSAL THEN CHECK HERE

TITLE OF PROPOSED PROJECT **HEAT: the High Elevation Antarctic Terahertz Telescope**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 1,985,459	24 months	09/01/07	

CHECK APPROPRIATE BOX(ES) IF THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW

- ☐ BEGINNING INVESTIGATOR (GPG I.A)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.B, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.1)
- ☐ VERTEBRATE ANIMALS (GPG II.D.5) IACUC App. Date ______
- ☐ HUMAN SUBJECTS (GPG II.D.6) Exemption Subsection ______ or IRB App. Date ______
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j) ______
- ☐ HIGH RESOLUTION GRAPHICS/OTHER GRAPHICS WHERE EXACT COLOR REPRESENTATION IS REQUIRED FOR PROPER INTERPRETATION (GPG I.G.1)

PI/PD DEPARTMENT	PI/PD POSTAL ADDRESS
Department of Astronomy	Steward Observatory 933 N. Cherry Avenue Tucson, AZ 85721 United States
PI/PD FAX NUMBER 520-621-1532	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Electronic Mail Address
PI/PD NAME Christopher K Walker	PhD	1988	520-621-8783	cwalker@as.arizona.edu
CO-PI/PD James H Burge	Ph.D.	1993	602-621-8182	jburge@as.arizona.edu
CO-PI/PD Craig A Kulesa	PhD	2002	520-621-6540	ckulesa@as.arizona.edu
CO-PI/PD				
CO-PI/PD				

Electronic Signature

CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

By signing and submitting this proposal, the individual applicant or the authorized official of the applicant institution is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding debarment and suspension, drug-free workplace, and lobbying activities (see below), as set forth in Grant Proposal Guide (GPG), NSF 04-23. Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U. S. Code, Title 18, Section 1001).

In addition, if the applicant institution employs more than fifty persons, the authorized official of the applicant institution is certifying that the institution has implemented a written and enforced conflict of interest policy that is consistent with the provisions of Grant Policy Manual Section 510; that to the best of his/her knowledge, all financial disclosures required by that conflict of interest policy have been made; and that all identified conflicts of interest will have been satisfactorily managed, reduced or eliminated prior to the institution's expenditure of any funds under the award, in accordance with the institution's conflict of interest policy. Conflicts which cannot be satisfactorily managed, reduced or eliminated must be disclosed to NSF.

Drug Free Work Place Certification

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Drug Free Work Place Certification contained in Appendix C of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the NSF Proposal Cover Sheet, the Authorized Organizational Representative or Individual Applicant is providing the Debarment and Suspension Certification contained in Appendix D of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, ''Disclosure of Lobbying Activities,'' in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements and that all subrecipients shall certify and disclose accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by section 1352, Title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Mary Gerrow**	**Electronic Signature**	**Jan 25 2007 6:37PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
520-626-6433	**maryg@u.arizona.edu**	**520-626-4130**

*SUBMISSION OF SOCIAL SECURITY NUMBERS IS VOLUNTARY AND WILL NOT AFFECT THE ORGANIZATION'S ELIGIBILITY FOR AN AWARD. HOWEVER, THEY ARE AN INTEGRAL PART OF THE INFORMATION SYSTEM AND ASSIST IN PROCESSING THE PROPOSAL. SSN SOLICITED UNDER NSF ACT OF 1950, AS AMENDED.

PROJECT SUMMARY

HEAT: the High Elevation Antarctic Terahertz Telescope

Based upon the results of a design study funded by NSF-OPP in 2006, we propose to develop and deploy an automated, 0.5-meter THz observatory for remote operation at the summit of Dome A, the highest point on the Antarctic plateau. The High Elevation Antarctic TeraHertz Telescope (HEAT) is will operate from 158 to 370 μm, and observe the brightest and most diagnostic spectral lines from the Galaxy. The HEAT telescope will be integrated onto a University of New South Wales Plateau Observatory (PLATO) and transported to Dome A in Austral summer 2008-9. Together, HEAT and PLATO will operate autominously from Dome A for up to a year at a time, with commands and data being transfered to and from the experiment via satellite daily. At Dome A, HEAT will see excellent atmospheric transmission at 200+ μm during much of the winter, and good transmission in the pivotal 160 μm window for $\sim$20% of the winter. The HEAT heterodyne instrument package will utilize established mixer, local oscillator, amplifier, cryogenic, and digital signal processing technologies. Funds for conducting the HEAT science program will be requested through a separate proposal to the Office of Polar Programs. HEAT is the Dome A component of the multinational 'AstroPoles' program which has been offically endorsed by the Joint Committee for the upcoming International Polar Year (IPY).

What is the intellectual merit of the proposed activity?

HEAT will forge entirely new capabilities for ground based infrared and submillimeter astronomy which otherwise would be unachievable except via expensive airborne or space-based platforms. HEAT (with PLATO) is a new generation of polar instrumentation that permits the excellent conditions available from remote sites like Dome A to be harnessed without the costs and hazards associated with manned operations. The unparalleled stability, exceptional dryness, low wind and extreme cold make Dome A a ground-based site without equal for astronomy at infrared and submillimeter wavelengths. HEAT will operate in the atmospheric windows between 158 and 370 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. In particular, through large-scale Galactic surveys, the measurement and **impact of the Galactic environment** on the **life cycles of interstellar clouds** and their **relation to star formation** will finally be realized. The receiver system itself serves as a flexible testbed for heterodyne Terahertz components. Future upgrades of mixer, local oscillator, low-noise amplifier, cryogenic, and digital signal processing technologies are planned and will play essential roles in future Terahertz observatories. This pioneering mission will pave the way for future astronomical investigations from Dome A.

What are the broader impacts of the proposed activity?

HEAT's key project is to map with great sensitivity and precision, the Southern Galactic Plane in the spectral light of the dominant coolants of the interstellar medium. Definitive and comprehensive science products from the survey and its many synergistic collaborations will be made available to the astronomical community via the Web in a timely manner. These survey products will enhance the value of numerous contemporary surveys. Beneficiaries include the GLIMPSE and "C2D" Legacy programs from the Spitzer Space Telescope, the most recent HI and CO surveys of the Galactic Plane, and the 2MASS infrared sky survey. HEAT will serve both as a scientific and technological pathfinder for future suborbital and space-based missions. Finally, the design and fabrication of HEAT will be an interdisciplinary team effort involving students from astronomy, optical sciences, and electrical engineering. Astronomical instrumentation is becoming ever more complex, requiring the talents of many individuals to bring them to fruition. Providing students with both technical training and team-work experience increases their probability of of success not only within astronomy, but society as a whole.

TABLE OF CONTENTS

For font size and page formatting specifications, see GPG section II.C.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

Project Description

1 Results from Prior NSF Support

Over the past few years, the PI's group at the University of Arizona has constructed two spectroscopic heterodyne array receivers; *PoleSTAR*, a 4 pixel 810 GHz receiver that operated at the 1.7 m AST/RO telescope at the South Pole, *DesertSTAR* and a 7 pixel 345 GHz array receiver for the 10-meter Heinrich Hertz Telescope (HHT) on Mt. Graham, Arizona. Both instruments are the very first of their kind. *PoleSTAR* was completed in 2000 and offers excellent ($T_{\rm rec}$=600-800K) receiver performance on all 4 pixels (Kulesa et al., 2005). *DesertSTAR* went into routine operation on the HHT with an initial complement of 3 pixels in October 2003 and has recently been expanded to the final hexagonal array of 7 pixels (Figure 1). Both instruments were funded by NSF programs; work on *PoleSTAR* was funded by the NSF Office of Polar Programs (A. Stark–PI: OPP-0126090), and *DesertSTAR* development has been a joint effort between the University of Arizona, the University of Massachusetts, and the University of Virginia with partial funding through the NSF ATI program (AST-9622569).

More recently, a multi-institutional team led by the PI was awarded an NSF MRI grant (AST-0421499) to construct *SuperCam*, a 64 pixel, heterodyne array for the Heinrich Hertz Telescope (Groppi et al 2006). *Supercam* represents the cutting edge of heterodyne array development technology in terms of integrated mixer and low noise amplifiers (Puetz et al 2006), and scalable IF processor and spectrometer technology. It represents the first steps towards cost-efficient scalability that will enable very large format heterodyne spectrometers arrays to be practical in the near future. *Supercam* will be completed in the PI's lab by the end of 2007 and commissioned at the HHT in 2008.

Finally, in 2006 funding was obtained through NSF/OPP (ANT-0538665) to develop a design study for HEAT. The following proposal is based upon the design study funded by this award.

The experience and heritage gained through these unique efforts will be instrumental in making HEAT a reality.

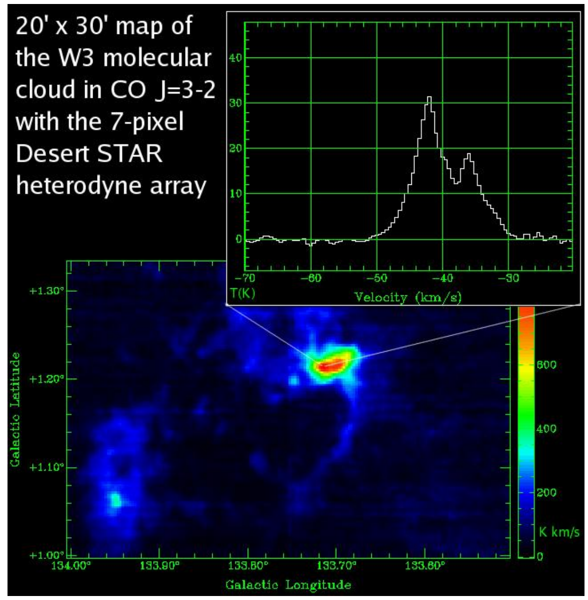

Figure 1: Large scale map of CO J=3-2 from the W3 star forming region taken by DesertSTAR, the PI's 345 GHz 7-beam array receiver at the Heinrich Hertz Telescope. The "cavity" seen in the center of the map represents the location of an OB association and its radiative feedback on its parent cloud, indicative of the phenomena that HEAT will reveal clearly. Furthermore, as shown in the inset, every imaged point in a heterodyne map also represents a high-resolution ($\lambda/\Delta\lambda \approx 10^6$) spectrum.

2 Research Activities

The proposed High Elevation Antarctic Terahertz Telescope (HEAT) will forge entirely new capabilities for ground based infrared and submillimeter astronomy, by providing a window on the Universe which otherwise would be unavailable except via airborne or space-based platforms. The pioneering surveys to be performed by HEAT will be made available to the entire astronomical community. HEAT represents a true international pioneering effort (US, Australia, China and the Netherlands) in keeping with the spirit of the International Polar Year (`www.ipy.org`: 2007-2009). Here, we outline HEAT's "key project", a THz survey of the Galactic Plane observable from Dome A, Antarctica. HEAT is the Dome A component of the multinational 'AstroPoles' program which has been officially endorsed by the Joint Committee for the upcoming IPY (see attached letter).

2.1 *Introduction*

From the Milky Way to high redshift protogalaxies, the internal evolution of galaxies is defined by processes closely related to their interstellar contents:

1. the transformation of neutral, molecular gas clouds into stars & clusters (star formation).
2. the interaction of the interstellar medium (ISM) with the young stars that are born from it, a regulator of further star formation.
3. the return of enriched stellar material to the ISM by stellar death, eventually to form future generations of stars.

The evolution of galaxies is therefore determined to a large extent by the life cycles of interstellar clouds: their creation, star-forming properties, and subsequent destruction by young (hot) stars.

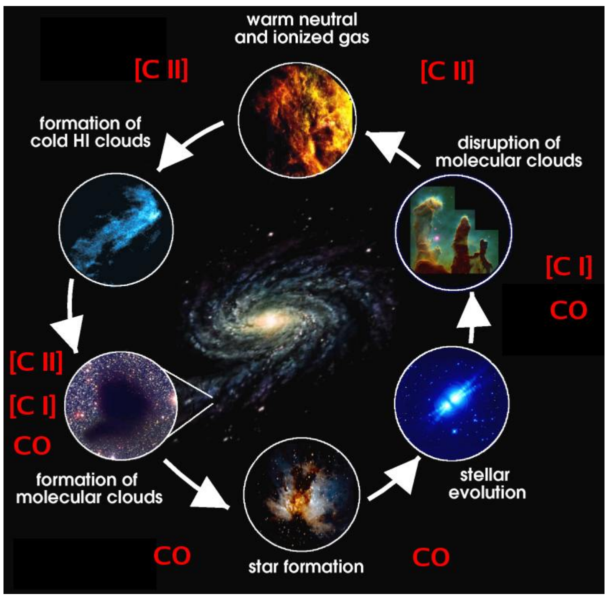

Figure 2: HEAT will observe the fine structure lines of N^+, C^+, C, and CO that probe the entire life cycle of interstellar clouds.

The life cycle of interstellar clouds is summarized pictorially in Figure 2. These clouds are largely comprised of atomic & molecular hydrogen and atomic helium. These species are notoriously difficult to detect under normal interstellar conditions. Atomic hydrogen is detectable via the 21 cm spin-flip transition and provides the observational basis for current models of a multiphase Galactic ISM. Its emission is insensitive to gas density and does not always discriminate between cold (T$\sim$70K) atomic clouds and the warm (T$\sim$8000K) neutral medium that is thought to pervade the Galaxy. Furthermore, neither atomic helium nor molecular hydrogen (H_2) have accessible emission line spectra in the prevailing physical conditions in cold interstellar clouds. Thus, it is important to probe the nature of the ISM via rarer trace elements. Carbon, for example, is found in ionized form (C^+) in neutral clouds, eventually becoming atomic (C), then molecular as carbon monoxide (CO) in dark molecular clouds.

Although we are now beginning to understand star formation, the formation, evolution and destruction of molecular clouds remains shrouded in uncertainty. The need to understand the evolution of interstellar clouds in the context of star formation has become a central theme of contemporary astrophysics. The National Research Council's most recent *Decadal Survey* has identified the study of star formation as one of the key recommendations for new initiatives in this decade.

A new, comprehensive survey of the Galaxy must address the following questions to make significant progress toward a complete and comprehensive view of Galactic star formation:

- How do molecular clouds form, evolve, and become disrupted? How do typical atoms and grains cycle through the ISM?
- How and under what conditions do molecular clouds form stars?
- How do the energetic byproducts of stellar birth, UV radiation fields and outflows regulate further star formation in clouds?
- How does the Galactic environment impact the formation of clouds and stars? What are the specific roles of spiral arms, central bars, infall and other influences from outside the Galaxy?

2.2 *HEAT Science Goals*

Via resolved C^+, C, CO, and N^+ line emission, HEAT uniquely probes the pivotal formative and disruptive stages in the **life cycles of interstellar clouds** and sheds crucial light on the **formation of stars** by providing new insight into the relationship between interstellar clouds and the stars that form in them; a central component of **galactic evolution**. A detailed study of the ISM of the Milky Way is used to construct a template to **interpret global star formation in other spiral galaxies**.

The **minimum science mission** of HEAT is to make significant contributions to achieving the three major science goals described below. Using the proposed instrument and observing methodology, the minimum mission is expected to be achievable in a single season of survey operation from Dome A. Note that funds for conducting the HEAT science program will be requested through a separate proposal to the Office of Polar Programs.

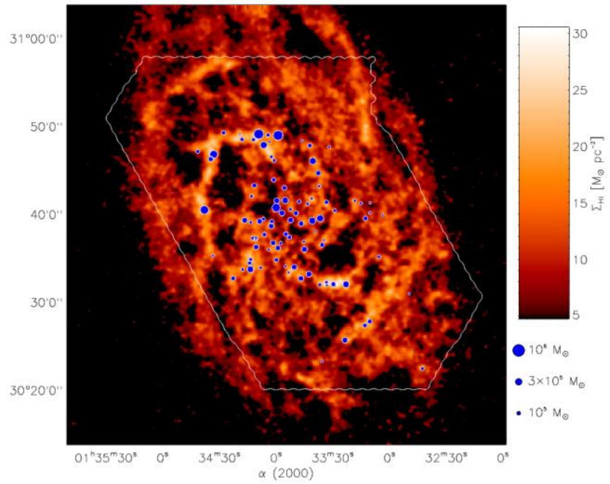

Figure 3: The location of GMCs in the nearby spiral galaxy M33 are overlaid upon an integrated intensity map of the HI 21 cm line (Engargiola, Plambeck, Rosolowsky, & Blitz, 2003). These observations show that GMCs are formed from large structure of atomic gas, foreshadowing the detailed study of GMC formation that HEAT will provide in the Milky Way.

Goal 1: Observing the Life Cycle of Interstellar Clouds

The formation of interstellar clouds is a prerequisite for star formation, yet the process has not yet been observed! HEAT is designed with the unique combination of sensitivity and resolution needed to observe atomic clouds in the process of becoming giant molecular clouds (GMCs) and their subsequent dissolution into diffuse gas via stellar feedback.

Theories of cloud formation are guided and constrained by observations of the atomic and molecular gas components. Based primarily on HI and CO observations, several mechanisms have been proposed to consolidate gas into GMC complexes (Figure 3). HEAT can distinguish these processes by:

1. Accounting for the entire H_2 mass (including H_2 clouds with little CO) when computing global measures of the interstellar medium.
2. Making a more complete & characterized catalog of interstellar clouds than CO or HI surveys alone.
3. Constructing spatial and kinematic comparisons of sufficient resolution, spatial coverage and dynamic range to probe a wide range of interstellar phases and environments.

Since the C^+ (and C^0) line emissivity barometrically selects clouds of atomic gas and H_2 clouds with little CO, regions of GMC formation may therefore be tracked by a large density of clouds per beam, or regions with individual clouds with higher than average columns or pressures. With HEAT's superlative spectral resolution, these regions can be identified with superrings or spiral arms or convergent parts of a turbulent medium. With guidance from 2MASS extinction mapping and existing CO and 21 cm HI surveys, HEAT will follow cold HI clouds and H_2 clouds as they transit the spiral potential, and will witness the process of cloud formation directly from the atomic substrate or small H_2 clouds. These clouds will be identified by C^+ and C line emission by HEAT. Similarly, N^+ observations of ionized gas survey the location and rate of star formation in the Galaxy. The rate of star formation is determined by using the N^+ luminosity to determine the ionizing luminosity of OB stars, a standard metric for the star formation rate.

HEAT's high spectral resolution enables crucial kinematic studies of the Galaxy to be made. HEAT will determine the kinematics and thermal pressures of most supershells, fossil superrings, and new molecular clouds condensing via gravitational instability of old superrings and supershells. HEAT can determine the role of OB association-driven supershells and superrings in the production of molecular clouds and the cycling of gas between the various phases of the ISM. Since N^+ measures the flux of ionizing photons, and C^+ measures their impact upon neighboring cloud surfaces, HEAT will measure the resolved photoevaporating atomic or ionized gas driven from clouds with UV-illuminated surfaces, thereby determining the rate of mass loss from all cataloged clouds, and their destruction timescales. HEAT's survey will correlate the star formation rate in a given OB association with the rate of destruction of any nearby (within 30 pc) natal GMC. Such measurements are crucial for models of star formation feedback and galactic evolution.

Goal 2: Measuring the Galactic Star Formation Rate

HEAT will probe the relation between the gas surface density on kpc scales and the N^+-derived star formation rate, so that we might be able to better understand the empirical Schmidt Law used to estimate the star forming properties of external galaxies.

Star formation within galaxies is commonly described by two empirical relationships: the variation of the star formation rate per unit area with the gas surface density (Schmidt, 1959; Kennicutt,

1998) and a surface density threshold below which star formation is suppressed (Martin & Kennicutt, 2001). The Schmidt Law has been evaluated from the radial profiles of HI & CO emission for tens of galaxies. The mean value of the Schmidt index, n, is 1.4 ± 0.15 (Kennicutt, 1998), valid for kpc scales. This empirical relationship is used in most models of galaxy evolution with surprising success given its simplicity. Oddly, there has been little effort to evaluate the Schmidt Law in the Milky Way owing to the difficulty in deriving the star formation rate as a function of radius within the plane.

The HEAT survey of CO, C, C^+ and N^+ emission provides the optimum set of data to calculate the Schmidt Law in the Galaxy. The N^+ line is an excellent tracer of the star formation rate as it measures ionizing luminosity with unmatched sensitivity, angular and spectral resolution, and is unaffected by extinction. The C^0 and C^+ lines, in conjunction with HI 21cm and CO line emission, provide the first coherent map of the neutral interstellar gas surface density and its variation with radius. HEAT's high spectral resolution allows one to assign a radial location of any emission feature assuming a rotation curve. The Schmidt Law is constructed from the radial profiles of the star formation rate derived from N^+ emission and the gas surface density. The column density threshold is inferred from the absence of star formation activity in the outer radii of galaxies where there is still a significant reservoir of gas (Kennicutt, 1998). Alternately, a threshold-less relation can be constructed by eliminating the HI gas that is inert to star formation (Blitz & Rosolowsky, 2006). Accounting for the H_2 clouds seen only in C^+ emission provides a far more detailed test of such a Schmidt Law formalism than do the CO clouds alone. The velocity-resolved star formation rate indicators provided by HEAT will be invaluable in interpreting more traditional indicators, like the far-infrared continuum. With its resolution and ability to gauge thermal ISM pressure, HEAT evaluates this critical, regulatory process in the Milky Way.

Goal 3: Constructing a Milky Way Template

C^+ and N^+ will be the premier diagnostic tools for submillimeter studies of external galaxies with large redshifts (e.g. with ALMA). In such spatially unresolved galaxies, however, only global properties can be measured. Detailed interstellar studies of the widely varying conditions in our own Milky Way Galaxy serve as a crucial diagnostic template or "Rosetta Stone" that can be used to translate the global properties of more distant galaxies into reliable estimators of star formation rate and state of the ISM. The HEAT mission covers a broad range of density and UV intensity, establishing the relationship between physical properties, C^+, C, CO, N^+, HI, FIR emission, and star formation. This relationship can be tested by application to nearby galaxies in the SINGS Spitzer Legacy Survey (Kennicutt et al., 2003), for which a large amount of ancillary optical, infrared and submm data exist.

2.3 *Properties of the Proposed Survey*

HEAT's science drivers represent a definitive survey that would not only provide the clearest view of interstellar clouds and their evolution in the Galaxy, but would also serve as the reference map for contemporary focused studies with Herschel, SOFIA, APEX, and the ALMA and SMA interferometers. The following properties define the science needs for HEAT.

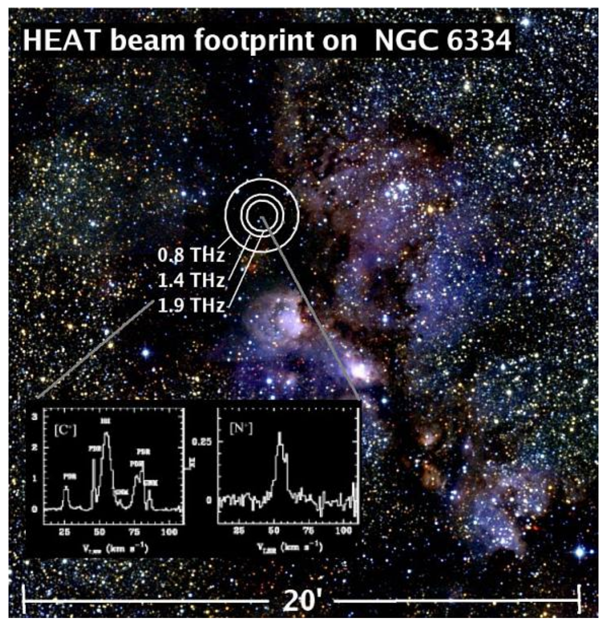

Figure 4: The power of HEAT: Each of the 3 heterodyne beams of HEAT are overlaid upon a 2MASS infrared image of NGC 6334. The beams will measure high-resolution spectra in the 0.81, 1.46, and 1.90 THz bands respectively, a small portion (25%) of each is shown as synthetic spectra of NGC 6334.

2.3.1 *High Resolution Spectroscopic Imaging*

Techniques commonly used to diagnose the molecular ISM include submillimeter continuum mapping of dust emission (Hildebrand, 1983) and dust extinction mapping at optical and near-infrared wavelengths (Lada, Lada, Clemens, & Bally, 1994). Large format detector arrays in the infrared are now commonplace, and with the advent of bolometer arrays like SCUBA at the JCMT and SHARC at the CSO, both techniques have performed degree-scale maps of molecular material. However, these techniques have limited applicability to the study of the large-scale evolution of molecular clouds due to the complete lack of kinematic information.

The confluence of many clouds along most Galactic lines of sight can only be disentangled with spectral line techniques. Fitting to a model of Galactic rotation is often the only way to determine each cloud's distance and location within the Galaxy. With resolution finer than 1 km s^{-1}, a cloud's kinematic location can be even distinguished from other phenomena that alter the lineshape, such as turbulence, rotation, and local effects such as protostellar outflows. These kinematic components play a vital role in the sculpting of interstellar clouds, and a survey that has the goal of understanding their evolution **must** be able to measure them. **HEAT will easily resolve the intrinsic profiles of Galactic interstellar lines, with a resolution of $<$0.4 km s^{-1} over up to 370 km s^{-1} of spectrometer bandwidth, comparable to the Galactic rotational velocity.**

2.3.2 *A Terahertz Galactic Plane Survey*

Molecular line surveys have been performed over the entire sky in the light of the 2.6 mm J=1-0 line of ^{12}CO, and have been used to synthesize our best understanding of the molecular content of the Galaxy. Still, our understanding of the evolution of Galactic molecular clouds is woefully incomplete. The CO J=7→6 line measured by HEAT is a better probe of the energetic gas that plays a role in stellar/interstellar feedback mechanisms. It probes gas that 1) participates in molecular outflows, 2) senses radiation fields at the photodissociated surfaces of clouds, and 3) is warmed by star-formation in cloud cores. It will help us interpret even basic properties of clouds derived from existing mm-wave observations by constraining excitation conditions.

As already described in Section 2.2, the dominant spectral lines of the Galaxy are the fine structure far-infrared and submillimeter lines of C, CO, C^+ and N^+. They probe and regulate all aspects of the formation and destruction of star forming clouds. They will provide the first barometric maps of the Galaxy, and illuminate the properties of clouds and their life cycles in relation to their location in the Galaxy. They will highlight the delicate interplay between (massive) stars and the clouds which form them, a critical component of galactic evolution.

2.3.3 *Angular Resolution and Fully Sampled Maps*

Good angular resolution is a critical aspect of improvement for a new Galactic survey. Previous surveys of [N II] and [C II] were limited to very small regions (KAO, ISO) or had low angular resolution (COBE, BICE) (Bennett et al., 1994; Nakagawa et al., 1998). HEAT will fully sample both species over large regions of sky to their diffraction limited resolution of 1.7′ and 1.3′, respectively. Arcminute resolution with proper sampling is crucial to disentangling different clouds and cloud components over large distances in the Galaxy. For example, the Jeans length for star formation in a GMC is approximately 0.5 pc. This length scale is resolved by HEAT to a distance of 500 pc at CO J=7→6 & [C I], and 1200 pc at [C II]. Warm and cold HI clouds and GMCs can be resolved well past 10 kpc.

2.3.4 *High Sensitivity*

HEAT's high sensitivity is owed mostly to the superlative atmospheric conditions above Dome A, Antarctica. The extreme cold and exceptional dryness allow ground-based observations into the otherwise forbidden THz windows. A plot of the expected atmospheric transmission for excellent winter observing conditions at Dome A versus the comparable opacity at the South Pole is plotted in Figure 5. **The high elevation, cold atmosphere and benign wind conditions at Dome A definitively open the Terahertz windows to ground-based observatories and cannot be matched anywhere else on Earth.** The implications for the sensitivity to each spectral line is discussed below.

CO $J = 7 \rightarrow 6$

We aim to detect all CO to A_V=1.5, where most hydrogen has formed H_2 and CO is just forming. This extinction limit corresponds to N(^{12}CO)$\sim 5 \times 10^{15}$ cm^{-2}, or an integrated intensity ($T_k \sim$ 70K) of 3 K km s^{-1} in the J=7→6 transition at $n_H = 10^5$ cm^{-3}. This sensitivity limit is achievable (3σ) within 100 seconds of integration time at 806 GHz in *median* winter atmospheric conditions (T_{sys} $\sim$10,000K) on Dome A. Limits on J=7→6 in that time would constrain the gas density, based upon the line brightness of millimeter wave transitions.

Atomic carbon $J = 2 \rightarrow 1$

The same extinction limit (A_V=1.5 mag) set for CO will also be applied to the J=2→1 fine structure

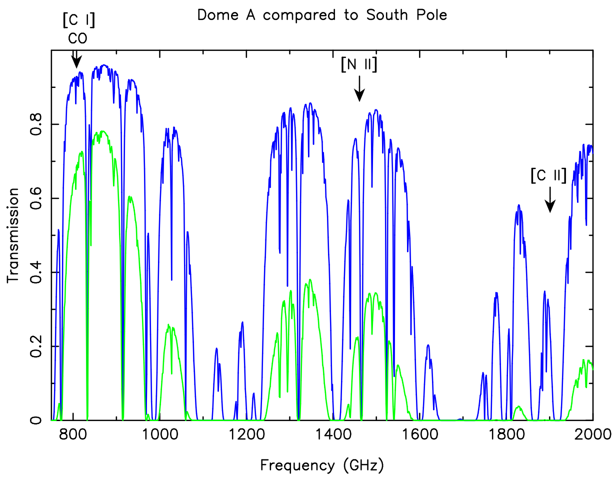

Figure 5: Terahertz atmospheric transmission for good (∼25th percentile) winter conditions for South Pole (bottom) and Dome A (top), derived from PWV measurements at Pole, atmospheric models from Lawrence (2004) and **actual Automatic Weather Station (AWS) data collected during 2005 from Dome A**. The PWV content for each model atmosphere is 220 and 70 microns respectively, Arrows indicate the wavelengths of the [N II], [C II], and CO/[C I] lines.

line of atomic carbon at 809 GHz. The corresponding column density of atomic carbon is $N(C) = 1.6 \times 10^{16}$ cm^{-2}, yielding a line intensity of 1.8 K km s^{-1} at $T_k = 50$K and $n_{\rm H} = 10^4$ cm^{-3}, achievable (3σ) in 5 minutes of integration time with HEAT during winter on Dome A.

N^+ and C^+

The fine structure lines of ionized carbon and nitrogen represent the dominant coolants of the interstellar medium of the Galaxy and starforming galaxies. Indeed, the integrated intensity of the 158 μm C^+ line alone represents 1% of the bolometric luminosity of the Galaxy! As such, these lines are relatively easy to detect in the ISM. Our most demanding requirements for detection of C^+ and N^+ lie in the search for the formation of giant molecular clouds (via C^+) and the measurement of the diffuse warm ionized medium in the Galaxy (via N^+). A flux limit of 2 K km s^{-1} will detect N^+ in warm HI as far away as the Molecular Ring, achievable in good winter weather in 3 minutes with velocity smoothing to 2 km s^{-1}, appropriate for hot ionized gas. Similarly, the accumulation of GMCs from many cold neutral clouds of atomic hydrogen occurs at low relative column densities of $\sim 5 \times 10^{20}$ cm^{-2}. Since essentially all carbon in such clouds is ionized, $N(C^+) \sim 10^{17}$ cm^{-2}. At the $T = 70$K common in cold atomic clouds and $n_{\rm H} = 10^3$ cm^{-3}, the expected C^+ line emission would be 2.5 K km s^{-1}, detectable in 10 minutes in excellent winter weather on Dome A. The 3σ limit achievable with deep integrations (2 hours) with HEAT would reach $n_{\rm H} = 10^2$ cm^{-3}. This *pressure* limit would readily determine whether interstellar material causing significant infrared extinction but without CO is gravitationally bound and likely to be a forming molecular cloud, or is simply a line of sight with numerous overlapping diffuse HI clouds.

2.3.5 Mapping Coverage of the Galactic Plane

From previous CO surveys it is known that the scale height of CO emission toward the inner Galaxy is less than one degree (Dame et al., 1987; Dame, Hartmann, & Thaddeus, 2001). The BICE experiment demonstrated that the C^+ distribution is more extended, but still is confined to $|b| < 1$. Interstellar pressure, abundances, and physical conditions vary strongly as a function of Galactocentric radius, so it is necessary to probe the inner Galaxy, the outer Galaxy, and both spiral arms and interarm regions, to obtain a statistically meaningful survey that encompasses the broad dynamic range of physical conditions in the Galaxy. We propose therefore to probe the entire Galactic plane as seen from Dome A ($0 > l > -120^o$). A *completely unbiased survey* will be undertaken, ultimately covering up to 240 square degrees ($-1^o < b < 1^o$); however 90 square degrees in 3 years will be targeted by the Schottky receiver system proposed here. Figure 6 demonstrates the sky coverage of HEAT's survey of the Inner Galaxy, with the first season coverage highlighted in yellow. It will probe three crucial components of the Galaxy; the Molecular Ring, the Crux spiral arm and the inter-arm region. The remaining sky coverage will be provided by a future, upgraded instrument package from SRON, featuring a cryocooled 4K SIS and HEB system (see SRON support letter). The "inner" Galaxy survey will coincide with GLIMPSE, a Spitzer Space Telescope (SST) Legacy Program (Benjamin et al., 2003). Above $l = 90^o$, most of the CO emission is located at higher Galactic latitude, so l and b "strip mapping" will locate the best regions to map, generally following the outskirts of CO J=1→0 distribution(Dame et al., 1987; Dame, Hartmann, & Thaddeus, 2001) and the best characterized star forming regions in the Galaxy – while maximizing synergies with the "Cores to Disks" SST Legacy program (Evans et al., 2003), and other SST GTO programs.

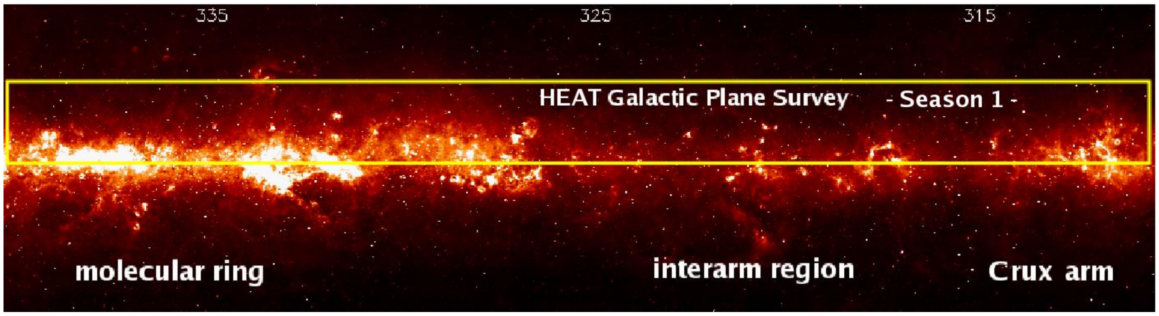

Figure 6: Midcourse Space Experiment (MSX) 8.3 μm map of the Galactic Plane from the Molecular Ring through the Scutum-Crux Spiral Arm ($-20^\circ > l > -55^\circ$). The yellow rectangle highlights the region to be explored by HEAT in its **first season** at Dome A. A definitive chemical and kinematic survey of star forming clouds in C^0 J=2-1, ^{12}CO J=7→6, and [N II] of 30 square degrees (∼10 square degrees in [C II] emission) can be performed in a single season. No other site on Earth allows routine access to both far-infrared lines.

HEAT exceeds all of these needs and constitutes an exceptional Galactic survey instrument.

2.4 *Survey Activities*

2.4.1 *Mapping Strategy*

The most efficient mode of data collection which produces the highest fidelity images is On-the-Fly (OTF) mapping. In this mode, the telescope continuously scans back and forth across a field while the backends are read-out at a sufficient rate to eliminate aliasing and beam smearing.

The broad coverage of the HEAT survey and the circumpolar nature of the sky rotation over Antarctica lends itself naturally to efficient, 24-hr/day mapping. HEAT can reach the requisite sensitivity of 1σ=0.2 K km s^{-1} per beam at 810 GHz (1σ=0.9 K km s^{-1} at 1.4 THz) over a fully sampled square degree in 7 days, assuming median winter conditions of τ_{810} ∼1. 30 square degrees from $-20 > l > -60^o$ will be mapped in ≈210 days. Mapping of the Inner Galaxy with $-1 < b < 0$ (30 sq degrees) will follow in Season 2, and targeted observations (30 sq. degrees) in the Outer Galaxy in Season 3 (with the SRON 4K HEB receiver upgrade if available). When the atmospheric opacity at 1.9 THz drops below ∼1.5, focused surveys including C^+ will begin. Of the best 35 days of winter weather, 3-4 weeks will be devoted to a medium-sensitivity C^+ survey (1σ ∼1.5 K km s^{-1}), with each square degree of mapping requiring about 2 days each, for a total of up to 10 square degrees of coverage per season. 10 days will be devoted to deep C^+ surveys of selected regions guided by 2MASS and GLIMPSE for the formation of molecular clouds – a total of 0.4 square degrees will be mapped to $1\sigma \sim 0.4$ K km s^{-1} per season.

HEAT's wide IF bandwidth, coupled with chopping OTF techniques, allows detection of the 158, 205, and 370 μm dust continuum emission. Thus, we will also simultaneously record total power scans and construct dust continuum maps.

2.4.2 *Science Products and Dissemination*

A primary challenge of OTF mapping is data management. We therefore plan to adopt a scheme akin to that developed at FCRAO, whereby coadded and regridded data is written as FITS & CLASS files, and headers for each scan are written into a MySQL relational database, which facilitates efficient logging and retrieval of the data. The most demanding storage requirements for the final 90 square degree maps, regridded to 50″ spacing, with 1024 spectral points per grid position, is <4 GB. This volume can be readily handled by embedded computers with disks of nonvolatile flash memory.

Access to these data products to the greater scientific community will be provided through a web browser interface that will interface with MySQL and the FITS data cubes. Preprocessed data cubes will be transferred over Iridium satellite. Raw data will be collected from the telescope annually during maintenance, and hopefully earlier with an occasional downlink from NASA's TDRSS-1 satellite using a portable field antenna. There will be biannual data products – a preliminary release midseason, and a final release in January. The final release will be fully calibrated and will include all science products.

All science tools, packaged reduction software, data products and science products will be made available from the HEAT web page.

Participant	Team	Affiliation	Participation Activity
Christopher Walker	I, S	Univ. Arizona	Project PI
James Burge	I	Univ. Arizona	Optical systems: opto-mechanics, testing and metrology
J. R. Gao	I	TU Delft/SRON	Future 4K mixer package upgrade of HEAT
Paul Goldsmith	I, S	JPL	THz instrumentation, space flight hardware, ISM physics
Jeffrey Hesler	I	Virginia Diodes, Inc.	Schottky mixer development and LO technology
Jon Lawrence	I	UNSW	Antarctic instrumentation, site testing & astronomy
Craig Kulesa	I, S	Univ. Arizona	Deputy PI, software+electronics integration, ISM physics
Chris Martin	I, S	Oberlin College	Antarctic Astronomy and Instrumentation
Michael Schein	I	Univ. Arizona	Optical systems design, pointing & tracking, cryocoolers
Peter Siegel	I	Caltech/JPL	THz Schottky mixer development
Gordon Stacey	I, S	Cornell	Far-infrared Instrumentation & spectroscopy
Antony Stark	I, S	SAO/CfA	Telescope Optics & Systems; Synergy w/ AST/RO
John Storey	I, S	UNSW	PLATO Systems, Site testing, Polar Operations
Sander Weinreb	I	JPL	IF amplifiers & processors, backend spectrometers

Table 1: Activities of the Science (**S**) and Instrumentation (**I**) Teams

2.4.3 *Synergies with Spitzer, ALMA, SOFIA and Herschel*

HEAT is timely. The Spitzer Space Telescope Legacy program GLIMPSE, headed by E. Churchwell, provides a thermal infrared survey of the Galactic plane that provides a complete census of star formation, the stellar structure of the molecular ring, will map the warm interstellar dust, constrain extinction laws as a function of galactocentric radius and will detect all young embedded O and B stars. HEAT will provide the best corresponding interstellar cloud survey that will account for the dense cloud material that forms stars, cloud interaction with formed stars, and kinematic disruption by mass ejection, outflow, and supernova remnants.

HEAT naturally complements the capabilities of heterodyne receivers on SOFIA and Herschel. The higher angular resolution afforded by larger telescopes necessarily reduces their field of view and mapping speed. **The HEAT survey would require many months of dedicated observing time on either Herschel or SOFIA, inconsistent with their use as general purpose observatories.** In contrast, HEAT is a dedicated mapping instrument with a focused mission and a lifetime that exceeds the grasp of long duration balloons. HEAT will provide ideal reference maps of THz line emission for more detailed followup with SOFIA and Herschel. Indeed, the HEAT data distribution and databasing system will be aligned as much as possible with that of Herschel/HIFI.

Similarly, the small field of view of the ALMA interferometer (8-25") makes such large scale surveys untenable. However, HEAT's Southern survey in atomic carbon and CO emission will be an ideal survey for active star forming clouds and cores and represents an exceptional reference map for detailed followup with ALMA when it becomes available.

2.4.4 *Roles of the Collaboration Participants*

Personnel who will initially develop and use HEAT comprise the Science (S) and Instrument (I) Teams tabulated in Table 1. They are also represented in an organization chart, Figure 12 in Section 4. *At least 2 graduate students and 2 undergraduates will participate in the instrument development alone.*

3 Research Instrumentation and Needs

3.1 Overview

HEAT will be a fully automated, state-of-the-art THz observatory designed to operate autonomously from Dome A in Antarctica. The combination of high altitude (4,200 m), low precipitation, and extreme cold make the far-IR atmospheric transmission exceptionally good from this site. In Figure 5 we present a plot of the expected atmospheric transmission above Dome A as a function of wavelength (Lawrence, 2004), indicating that winter weather at Dome A approaches (to order of magnitude) the quality of that achieved by SOFIA. The wavelengths of several important astrophysical lines are indicated with arrows. HEAT is designed to take advantage of these unique 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 conceptual drawing of HEAT is shown in Figure 7. For robustness and efficiency, the tele-

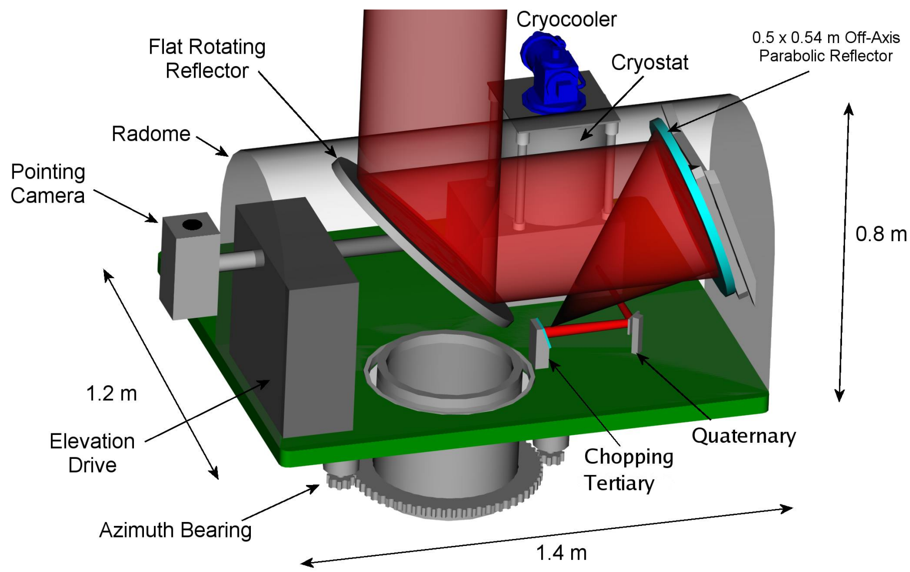

Figure 7: HEAT concept: The telescope has an effective collecting area of 0.5m. Elevation tracking is accomplished by rotating the $45°$ flat reflector. The entire telescope structure rotates for azimuth tracking and is warmed well above ambient by waste heat from the PLATO module below. The Schottky mixers used in the instrument package are efficiently cooled to $\sim$ 70 K using reliable off-the-shelf closed-cycle cryocoolers.

scope and instrument are integrated into a common optical support structure (OSS). HEAT will be mounted on top of a University of New South Wales Plateau Observatory (PLATO), a successor to the AASTINO (Automated Astrophysical Site-Testing InterNational Observatory) deployed to Dome C in 2003. The PLATO provides power and communications for the HEAT telescope and instrument. The total power budget for HEAT (including cryogenics, telescope drive system, and instrument control system is maximally 600 W, which is readily provided by efficient, high reliability generators within the PLATO. Data transfer and command and control of HEAT will be done via satellite and is described in more detail in Section 3.3.7. The University of New South Wales will construct a PLATO for HEAT and participate in all aspects of design, integration, deployment, and operation (see Support Letter from J. Storey). The HEAT/PLATO facility is functionally equivalent to a space-based observatory. A 3D rendering of HEAT mounted atop PLATO is shown in Figure 8.

3.2 *Telescope*

The telescope is designed to have maximum efficiency and the minimum number of optical components. Its design is similar to that of Kraus (1966) and utilizes an off-axis, Gregorian configuration. Incoming light is reflected horizontally off a 45°, 0.5×0.7 m flat reflector to an f/2.2 off-axis parabolic mirror. The converging beam is intercepted by a hyperbolic tertiary mirror that directs it to a flat quaternary and into the receiver. The tertiary mirror can chop the incoming beam between source and reference positions (Δaz $\sim$ 10′) at a rate of 0 to 4 Hz. The mirrors are fabricated from aluminum on a numerical milling machine and have a surface roughness $\leq 3\,\mu$m rms. Elevation tracking is achieved by rotating the first flat reflector. Azimuth motion is achieved by rotating the OSS on a bearing attached to the roof of the PLATO. Mapping will be typically performed in drift-scanning ("on-the-fly") mode with the azimuth drive locked and tracking only in elevation. In fact, some of the Galactic Plane can be mapped purely with sidereal-rate scanning, using no tracking whatsoever! The absolute pointing accuracy will be 15″, 1/5 of the smallest diffraction-limited beam. The slew speed will be 1°/sec. The University of Arizona has a long history of building state-of-the-art telescopes and, with oversight from members of the Instrument Team, has the expertise required to optimize the telescope for operation in a Polar environment. The telescope cost estimate, which includes detailed design, fabrication, and testing of the telescope and drive system, is provided in the budget.

To prevent ice accumulation, the telescope is enclosed and warmed to -10°C by ducted waste heat forced up through the azimuth bearing from the PLATO. A small radome made of a low-loss dielectric (e.g. Goretex or polyethylene) encircles the first flat reflector. This optical configuration provides an unobstructed view of the sky. A near-IR camera (provided by UNSW) is mounted just outside the radome on an extension of the elevation axis. The camera will provide pointing and site testing data.

3.3 Receiver

3.3.1 Design Approach

Heterodyne receivers are needed to achieve the sensitive, high spectral resolution ($R = \lambda/\Delta\lambda > 10^6$) observations of [N II], [C II], and CO/[C I] required for the proposed Galactic plane survey. The key components of a submillimeter-wave heterodyne receiver are the mixer and local oscillator (LO). There are 3 types of mixers in common use; the Schottky diode mixer, the SIS mixer, and, more recently, the Hot Electron Bolometer (HEB) mixer. The Schottky diode mixer is somewhat less sensitive than either SIS or HEB mixers and requires more LO power, but is exceptionally stable in operation and **can operate at ambient temperature**. In contrast, SIS and HEB receivers require cooling to LHe temperatures (4K). HEAT's aggressive development schedule combined with the critical need for robust technologies that will work at low power and in a harsh environment leads us to select Schottky mixer systems for the initial deployment of HEAT. Virginia Diodes, Inc. has a long history of delivering submm-wave Schottky mixer systems and has demonstrated sub-harmonically pumped Schottky mixers using lower frequency LO sources (see Support Letter from J. Hesler). Virginia Diodes will deliver one such mixer at 1.9 THz and another at 1.46 THz. Two sub-harmonically pumped 810 GHz mixers (one for each polarization) will be provided to increase sensitivity and redundancy. Though the system will function well at ambient temperatures, we plan to improve HEAT's sensitivity to within a factor of ~3 of demonstrated THz HEB systems by cooling the mixer blocks to ~70K using economical, low power, commercial Stirling-cycle cryocoolers such as those sold by Qdrive and Sunpower, Inc. In this manner we will achieve a solid blend of good sensitivity and experimental robustness. A future 4K cryocooled SIS and HEB receiver system for HEAT is now in development at the Space Research Organization of the Netherlands (SRON, see K. F. Wakker, Director, support letter), with an initial 600,000 Euros of institutional support.

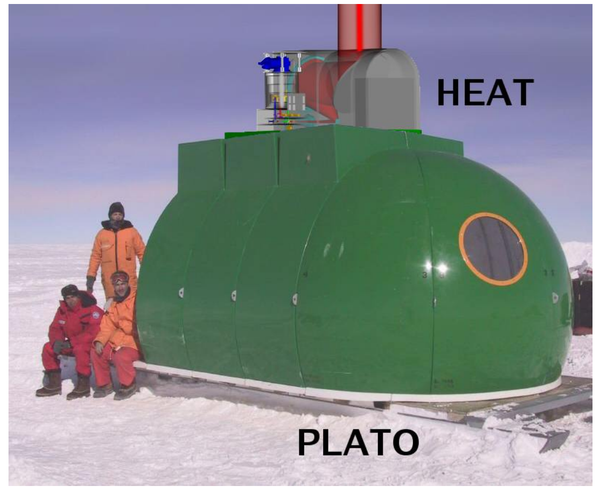

Figure 8: Rendering of HEAT atop a UNSW Plateau Observatory (PLATO)

3.3.2 Receiver Optics and Cryostat

A close-up of the receiver optics is shown in Figure 9. The incoming beam from the quartenary encounters two bandpass filters, the first centered on the [N II] (1.459 THz) line and the second on the [C II] (1.9 THz) line.

Outside of their nominal passband, the filters are highly reflective. Therefore, when the incoming beam encounters the first filter, all but a narrow range of frequencies around the [C II] line are reflected to the [N II] filter. The light reflected off the [N II] filter contains the CO J=7→6 and [C I] lines. The three emerging beams are collimated and directed into the instrument cryostat.

Sub-harmonic LO pumping of the Schottky mixers eliminates the quasi-optical injection of the LO signal and simplifies the optical layout of the cryostat. Wire grids direct the horizontal and vertical polarization components of the incoming light into the two 0.8 THz mixers.

The vacuum vessel and cryocooler integration will be consigned to Universal Cryogenics of Tucson, Arizona (see attached quote), who delivered a cryostat with a 4K cryocooler for the PI's Supercam heterodyne array, and has recently delivered a 70K cryocooled vacuum vessel to another Steward Observatory project. The 10″ diameter, 5″ tall vacuum vessel, complete with Antarctic coldproofing and its integration with a 70K cryocooler will be a straightforward application for Universal Cryogenics.

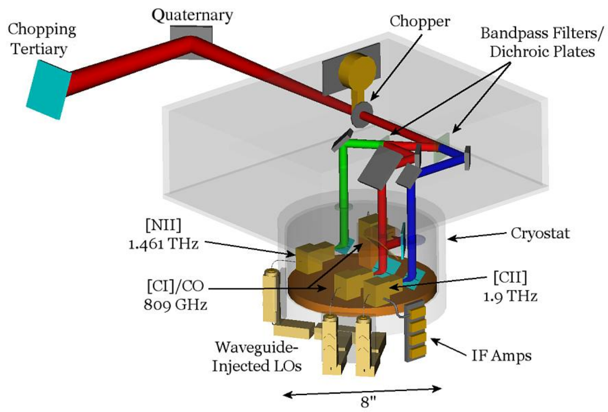

Figure 9: Optical subsystem for HEAT's Schottky mixers.

3.3.3 *Mixer Performance*

Virginia Diodes will provide Schottky mixers subharmonically-pumped using integrated, synthesizer-driven LO chains with competitive receiver noise performance even when warm (see attached quote from VDI and Support Letter from J. Hesler). With 5 watts of thermal load, both Qdrive and Sunpower cryocoolers will deliver a detector temperature of 70 K, sufficient to increase the sensitivity of the Schottky mixers by a factor of 2 (Hesler et al., 1997). We anticipate delivered cooled DSB receiver noise temperatures in the vicinity of 1500K at 0.8 THz, 3000K at 1.4 THz and 5000K at 1.9 THz. These receiver noise figures were used in defining the scope of the science program discussed in Section 2.3.

3.3.4 *IF Processors*

The entire IF processing and spectrometer system will be leveraged from the successful design currently implemented in the 64-beam Supercam 345 GHz array receiver in final development in the PI's lab. Funds will only be needed to fabricate additional amplifiers, IF processor modules, and spectrometer boards for HEAT. The 5 GHz-centered IF output of the THz mixers is first amplified by a low-noise MMIC amplifier designed by Sander Weinreb's group at Caltech for the Supercam project. In order to simultaneously detect the CO J=7→6 line in the lower sideband and the [C I] line in the upper sideband, the 0.8 THz mixer will have an IF center frequency of 1.5 GHz, be initially amplified by a commercial Miteq amplifier, and then upconverted outside the cryostat to 5 GHz in order to match the other channels for subsequent IF processing.

The 5 GHz IF signal emerging from the cryostat must be filtered, downconverted to baseband (0-1 GHz) and amplified to 0 dBm to be properly conditioned for the input of the digital spectrometer system. We will use the same IF processor boards designed by Sander Weinreb and his students at Caltech for the Supercam project to fulfill the IF processing needs for HEAT. The IF processor board provides each IF with an initial 48 dB of gain, a variable digital attenuator, a 1 GHz bandpass filter, a mixer conversion to baseband, a low pass filter and then 50 dB of baseband gain. An additional circuit provides total-power measurements of the IF power for telescope pointing and continuum measurements. A picture of a rack-mountable 8-channel IF processor module and a sample 0.5 GHz bandpass (from Supercam) is shown in Figure 10.

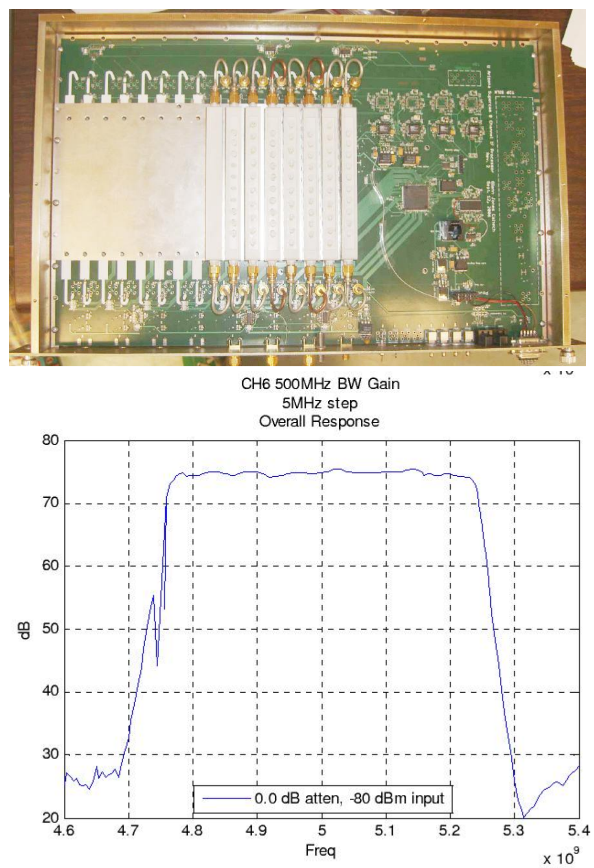

Figure 10: 8-channel Supercam IF processor module and sample 0.5 GHz bandpass

3.3.5 *FFT-in-FPGA Spectrometer*

Science drivers for the HEAT spectrometer stipulate two principal requirements. Sufficient kinematic resolution of molecular cloud components in

C^+C/CO emission will only be achieved with frequency resolution of finer than 2 MHz per channel, with 1 MHz preferred. The divergence of the velocity field of the inner Galaxy requires a bandwidth of 1 GHz or greater. **Recent gains in high-speed ADCs and FPGAs have made such a wide bandwidth direct-digitization spectrometer economically feasible.** The baseband output of the IF processors is fed into two direct digitization spectrometer boards each featuring 2-IF inputs each with 1 GHz of bandwidth (Figure 11). These spectrometer units perform 8-bit digitization of the input signal using dual 1 Gs ADCs in combination with a Xilinx Virtex4 FPGA which performs a real-time FFT power spectrum which is stored on the instrument computer(s). The spectrometers will each have 1 GHz of instantaneous bandwidth and 1 MHz resolution. They provide velocity coverage up to 370 km/s at a resolution ≤ 0.4 km/s, enabling all three lines to be resolved and observed throughout the Milky Way while only needing to Doppler-track in frequency. Omnisys Inc. has already been consigned to design and deliver 8 of these boards for the Supercam 64-beam array receiver being completed in the PI's lab. The prototype was delivered in mid-2006 and performs admirably. Allan variance (stability) times are 650 seconds using a 5 GHz noise source, downconverted through the Caltech IF processor board! Funds are requested in this proposal to consign Omnisys to fabricate and test three additional boards for HEAT (2 for deployment, 1 as a spare; see quote from Omnisys).

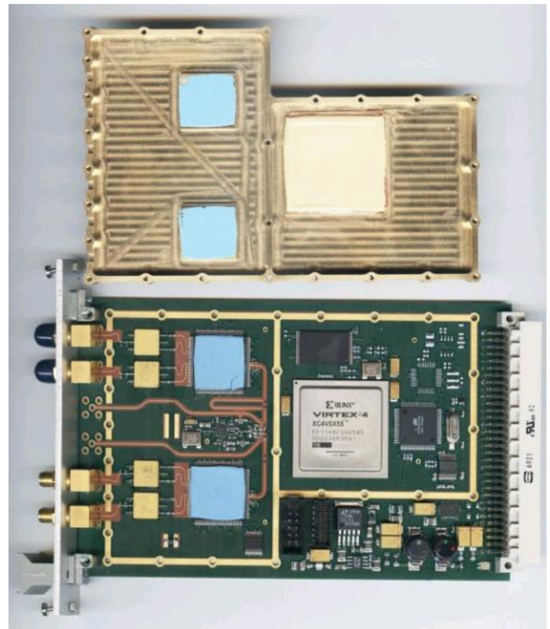

Figure 11: SuperCam spectrometer card as constructed by Omnisys Inc. The board features 2 GHz of bandwidth.

3.3.6 *Calibration*

HEAT will be able to calibrate observations through several means. 1) A vane with an ambient temperature absorbing load will be located at the cryostat entrance window, allowing standard chopper wheel calibration to be performed. 2) HEAT will routinely perform sky-dips to compute the atmospheric optical depth in each of its three wavelength bands. 3) HEAT will regularly observe a standard list of calibration sources. 4) The PLATO will host a submillimeter tipper that will measure atmospheric transmission throughout the FIR. These measurements will be coordinated with HEAT spectral line observations to provide cross calibration.

3.3.7 *Control System and Communication*

The HEAT control system will consist of a distributed computer control system where the telescope drive system, receiver frontend (*e.g.* mixers, LOs, and cryostat) computer, backend (spectrometer) computer, and the PLATO communicate via Ethernet. The prototype system is based on Technologic Systems TS-ARM embedded computers that draw less than 2 watts of power, runs Linux or NetBSD, and have been field-tested to survive the cold. These systems provide digital I/O, analog-to-digital conversion, serial I/O, and CAN, SPI and I2C bus interfaces for control of the various electronic subsystems in HEAT. These single-board computers are slave to a UNSW-designed "supervisor" power control board that contains a watchdog circuit that will reset the system in case of a software or hardware malfunction and cycle tasks to the next available embedded computer. HEAT will be designed to work autonomously for up to a week at a time, performing pre-programmed observational programs and storing astronomical and housekeeping data on non-volatile memory. Preprocessed sample data will be uploaded to control centers at the Universities of Arizona and New South Wales via dedicated Iridium satellite channels located on each "supervisor" board. Raw data will be recovered from HEAT each year during maintenance and processed into the released data products. We aim to also integrate a portable field antenna for NASA's TDRSS-1 satellite for routine downlink of raw data well in advance of annual maintenance, however financial support for this capability is not included in this MRI request.

3.4 *Integration and Testing*

The use of developed or commercial subsystems in HEAT allows for a significant and necessary program of integration and testing even on the abbreviated timescale for the delivery of the observatory. A testing schedule is provided for in Figure 13.

1. **Cold component testing** will be used to determine limiting temperatures for reliable operation of constituent components in each subsystem – for example, drive motors of the telescope, nonvolatile (flash) memory for storage, or the flexibility of interconnects and cabling at -60^{o}C. These component tests will define a process by which the telescope can be nominally operated in a range of highest reliability, or safely resurrected from an idle state in which all components have been thoroughly cold-soaked.
2. **Subsystem testing** will demonstrate the proper functionality of large components of the HEAT system, such as the assembled telescope drive system or the Schottky instrument package and control electronics, or the spectrometer and data system.
3. **Integrated system testing** involves the interplay of subsystems in the actual collection of data, such as performing on-the-fly mapping observations with active receivers, spectrometers, data system, while monitored over a Iridium satellite connection; i.e. normal astronomical operation at Dome A.
4. **Failure Mode testing** involves the intentional disabling of a component to observe the fault handling and interplay of the hardware and software systems. A Failure Mode Effects Criticality Analysis (FMECA) will be generated to determine system robustness to component failure. System reliability will then be enhanced through application of redundancy, increased reliability rated components, and improved operational design where indicated.

3.5 *Survivability and Robustness*

The applicability of Murphy's Law to remote observatories means that one must design an experiment to survive despite component failures or unexpected conditions. The adoption of Schottky diode receivers with dual polarization at 810 GHz, redundant and interchangable instrument and telescope computers and Iridium links on robust watchdog circuits, diesel power generation with solar panel backup, eliminating the need for the telescope drives to track for most observations, and adopting a largely fixed, stable, and simple optical system – all contribute to a highly redundant and robust system. For example, in the extreme instance of a PLATO power failure during the winter, HEAT will be designed to auto-boot using solar panels when the Sun reappears in September. Remote access to the instrument allows a wide range of system modification even in the event of a major failure; even a complete software reprogramming is possible should the need arise. **HEAT represents an exceptionally robust experiment optimized for remote operation under the environmental conditions of Dome A.**

4 Project Management

4.1 *Organization*

HEAT is an exciting, challenging project that requires the coordinated participation of scientists and engineers from several academic institutions and leading-edge companies to succeed. We have developed an organizational structure (shown in Figure 12) to meet this task. Collectively the HEAT team members represent many years of successful telescope and instrument development in Antarctica. The organizational structure of the HEAT project provides effective control of the project while allowing the delegation of authority to be made at the proper level within the organization. The main components of the organization are (1) the PI, who has overall responsibility for the project and coordinates the activities of the participants, (2) the DP-I (Kulesa) who assists the PI and is responsible for instrument control, system integration, and data products, (3) Co-I Burge who is responsible for the HEAT telescope design, fabrication, and testing (4) the Project Manager (PM-McMahon) who oversees the fiscal realities of the project, and (5) the Science and Instrument Teams who will provide scientific and technical guidance throughout the course of the project. Table 1 provides a listing of the roles and responsibilities of each member in the organization. Endorsement letters from members of the Science and Instrumentation committees are provided in the Supplementary Documentation section.

A schedule of key project milestones and tasks is provided in Figure 13. Based upon the 2006 design study funded by NSF-OPP the project will begin with a design review by the instrument and science teams. Procurement of key components will begin

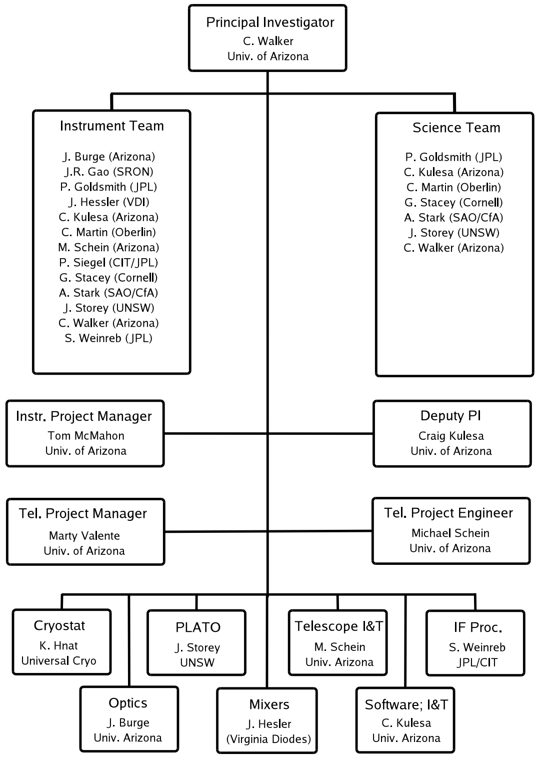

Figure 12: HEAT Organizational Chart

soon after following the spending profile outlined in the budget. Integration and test of the receiver system will take place at the Univ. of Arizona in the PI's lab in March 2008. Acceptance tests of the telescope will take place in June 2008. The receiver and telescope will then be shipped to the University of New South Wales, where an extended period of integration and testing with the PLATO module will occur, including system evaluation in a -80°C environmental chamber (see Support Letter from J. Storey). HEAT will then ship in October 2008, with deployment on Dome A in January 2009.

Routine communications between project participants is essential. There will be quarterly telecons between Science and Instrument team members to monitor progress, provide insight into solutions to emerging problems, and redefine priorities as needed. There will be weekly telecons and quarterly meeting (primarily through teleconferencing) between the PI, D-PI, Co-I, PM, and Technical Leads (Storey - PLATO, Burge - Telescope, Hesler - Mixers, Weinreb -IF amplifiers and processors, and Kulesa - spectrometers, data system, software).

The ability to meet the proposed schedule is made possible by the heavy leveraging of IF processor and spectrometer technology funded through NSF-ATI for Supercam, the PI's 64-beam heterodyne array receiver, in combination with commercially-available mixer and cryogenic hardware. The simplicity of the telescope design and operation in combination with the expertise of the Optical Sciences College at the University of Arizona in developing optical systems for ground and space is a solid match. *Indeed, the HEAT instrument team officially formed over a year ago and has been optimizing component technologies and system designs for HEAT since.*

4.2 Logistics: Deployment to Dome A

Although no logistical support is requested in this instrument proposal, it is nonetheless important to highlight how HEAT will be deployed to Dome A. The Antarctic science has reached a level of maturity where several options exist for fielding instruments on remote sites. For Dome A, these include:

1. **(Chinese) Traverse from Zhongshan to Dome A**: UNSW has recently signed a Memorandum of Understanding (provided in the Supplementary Documentation) with the Polar Research Institute of China and the National Astronomical Observatories of China for Chinese deployment of a UNSW PLATO to Dome A in 2007-8. An attractive option would be to simply install HEAT atop this PLATO unit in 2008-9. It could be installed as part of a 2008-9 Chinese traverse or combined with alternative transport options described below.
2. **CASA 212** (Australian Antarctic Division): J. Storey (see Support Letter) will be requesting one CASA 212 cargo flight directly from South Pole to Dome A for transport of the HEAT experiment, with subsequent flights to support fuel and personnel for the HEAT installation.
3. **LC-130 or Twin Otters from South Pole**: Raytheon Polar has developed a flight plan to deploy the HEAT experiment on Dome A using an LC-130 flight from McMurdo (put-in) and Twin Otter flights from Pole (personnel). If a Chinese traverse brings PLATO and HEAT to Dome A, Twin Otter air support would allow personnel to be flown in from South Pole to participate in the HEAT installation.
4. **IPY Traverse from Dome C** (Multinational): There is considerable interest amongst the international community in exploring the astronomical potential of Dome A by deploying a set of experiments to monitor site conditions there. HEAT is included in the international IPY proposal for the Dome A traverse.

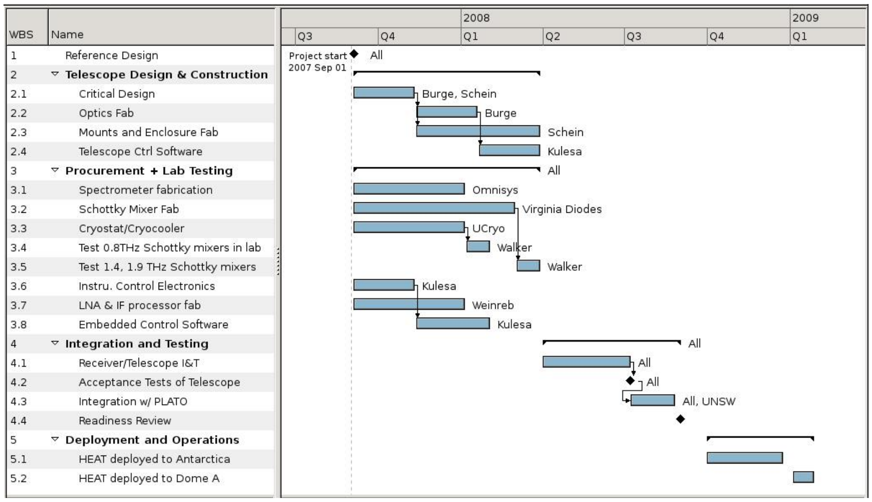

Figure 13: Timeline: two years of development, integration and testing (through the proposed MRI grant) is followed by three years of survey work at Dome A (funded separately through the OPP grants program). Leverage of technologies both from commercially available mixers and IF technologies from the PI's SuperCam instrument development makes this timeline achievable.

5. **Traverse from Pole**: By the IPY it is expected that the overland route from McMurdo to the South Pole will be well established, and the necessary infrastructure such as tractors and sleds will be routinely available at South Pole. A single overland expedition from Pole to Dome A could bring in all the equipment and supplies needed for the HEAT experiment.

The HEAT team will continue to work closely with the NSF, Raytheon Polar, and the International Community to implement an optimal plan for deployment to Dome A during the IPY.

5 Educational Impact

The development and establishment of the first astrophysical observatory on Dome A offers many opportunities to tap into the imagination of students of all ages. Below we highlight two examples.

Instrument Development Experience

The training of students in the development of state-of-the-art instrumentation is essential to the future of science. This is particularly true in mm/submm astronomy where technological advances are happening so rapidly. Ironically, there are only a handful of laboratories in the world where students gain hands-on experience in the design, fabrication, and fielding of radio astronomy instrumentation. In the PI's lab we have had a number of students (both graduate and undergraduate) participate in the development of submm-wave instrumentation for Antarctica (i.e. AST/RO) and the Heinrich Hertz Telescope (HHT) on Mt. Graham, Arizona. This work, and the astronomy that has come from it, has been a major component of 5 Ph.D. dissertations and numerous undergraduate research projects. HEAT is a natural extension of these research efforts. In the proposed budget for HEAT, funds for two graduate students are requested. However, as is customary in the PI's lab, many other students will also participate in making the program a success. Indeed, one of the most important aspects of training students in instrument development is experience in working in teams. Astronomical instrumentation is becoming ever more complex, and requires the talents of many individuals. Providing students with both technical training and team-work experience increases their probability of success.

K-12 Outreach: A Student Radio Telescope

In support of education and public outreach activities the PI and his students have constructed a remotely operable, steerable, 3.5 m Student Radio Telescope (SRT) for observing the HI line in the Milky Way. The SRT has been used as a instructional tool in undergraduate courses (both major and non-major). Students from on and off campus will soon be able to monitor and control observations with the SRT. Unlike optical telescopes, the SRT can be used day and night, making it ideal for classroom instruction. Like HEAT, the SRT is a spectroscopic Galactic Plane survey telescope. During the course of developing and operating HEAT we will develop instructional modules for various age groups that focus on the science and technology of HEAT and use the SRT as a "hands-on" laboratory with the goal of providing students with an intuitive understanding of underlying physical concepts.

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Thesis: "Observations Studies of Star Forming Regions".
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- Associate Professor of Astronomy, Optical Sciences, and Electrical Engineering, University of Arizona, 2002-2003
- Associate Professor of Astronomy & Optical Sciences, University of Arizona, 2000-2002
- Associate Professor, Steward Observatory, University of Arizona, 1997-2000
- Assistant Professor, Steward Observatory, University of Arizona, 1991-1997
- Millikan Research Fellow in Physics, Caltech, 1988-1991
- Graduate Research Assistant, Steward Observatory, 1983-1991
- Research and Development Engineer, Jet Propulsion Laboratory, 1983
- Electrical Engineer, TRW Aerospace Division, 1981-1983

Five Closely Related Publications (Refereed Journal)

Kulesa, C., Hungerford, a., Walker, C., Zhang, X., and Lane, A., 2005, *Large-Scale CO and [CI] Emission in the Rho Ohiuchi Molecular Cloud*, *Ap. J.*, **625**, 194.
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Synergistic Activities

The training of students in the development of state-of-the-art instrumentation is essential to the future of science. This is particularly true in mm/submm astronomy where technological advances are happening so rapidly. Ironically, there are only a handful of laboratories in the world where students gain hands-on experience in the design, fabrication, and fielding of radio astronomy instrumentation. In the PI's lab we have been fortunate to have had a number of talented students pursue their research. Over the past 10 years the lab has produced 6 Ph.D.'s and numerous undergraduate senior projects. All the former Ph.D. students are still pursuing astronomical research and a number of the undergraduates have gone on to receive Ph.D.'s at other institutions. In recent years research in the lab has drawn an increasing number of students from other departments, particularly optical sciences and electrical engineering. Many students in science and technology have an interest in astronomy. It is this interest and the interdisciplinary nature of the research that attracts them to the PI's lab. In an effort to reach this population of students, the PI and fellow faculty members in other departments are seeking to establish an interdisciplinary program in astronomical instrumentation. Two of the PI's past Ph.D. students have received majors and minors in different departments. The PI currently has 7 graduate and 5 undergraduate students participating in interdisciplinary studies.

Collaborators and Other Affiliations

Gordon Chin (GSFC), Neal Erickson (U.Mass), Eyal Gerecht (NIST), Dave Glaister (Ball Aerospace), Martin Harwitt (SAO), Carl Heiles (UC Berkeley), Mark Heyer (U.Mass), David Hollenbach (NASA ARC), Jonathan Kawamura (JPL), Jacob Kooi (Caltech), John Kraus (OSU), Adair Lane (CfA), William Langer (JPL), Christopher Martin (CfA), Imran Mehdi (JPL), Arthur Lichtenberger (U.Va), Gopal Narayanan (U.Mass), Gordon Stacey (Cornell), Antony Stark (CfA), Mark Swain (JPL), Rodger Thompson (UofA), Sander Weinreb (JPL/Caltech), Erick Young (UofA), Sigfrid Yngvesson (U.Mass) Harold Yorke (JPL)

Graduate/Postdoctoral Advisors

John D. Kraus (OSU) for MSEE, Charles J. Lada (Harvard) for Ph.D., T.G. Phillips (Caltech) for postdoc

Thesis Advisor/ Post Graduate Sponsor

Past Ph.D. Advisees: Christian Drouet d'Aubigny (U Az), Jason Glenn (UC Bolder), Craig Kulesa (U Az), Gopal Narayanan (U. Mass), Grace Wolf-Chase (Adler Planetarium), Chris Groppi (U Az)

Total Number of Graduate Students Supervised: 6 current, 7 past
Number of Postdoctoral Sponsorships: 3 current

Dr. James H. Burge
Associate Professor
College of Optical Sciences and Astronomy
University of Arizona
Tucson, AZ 85721, USA
jburge@optics.arizona.edu

Education:

Ph. D. Optical Sciences, University of Arizona, 1993

M. S. Optical Sciences, University of Arizona, 1991

B. S. Engineering Physics, Ohio State University, 1987

Professional Employment:

1997 – present Assistant, now Associate Professor Optical Sciences and Astronomy, University of Arizona,

- Lead projects that develop and implement advanced technologies for large optical systems, including ground and space based telescopes.
- Participate on technical and programmatic review panels for NASA and government programs.
- Supervise students carrying out research projects in optical engineering.
- Teach graduate and undergraduate courses in Optical Engineering

1991 – 1997 Project Scientist for Mirror Testing, Steward Observatory Mirror Lab ,University of Arizona,

- Developed testing technologies and led the development of hardware for measuring large concave and convex mirror for astronomical telescopes
- Provided optical engineering support for development of telescope instruments
- Developed methodology and software for large computer controlled polishing machines

Honors and Awards:

- Fellow of SPIE (Optical Engineering Society.)
- Panel member *Product Integrity Committee* responsible for overseeing NASA's James Webb Space Telescope (2003 -)
- Chair of subcommittee on infrastructure for NASA's roadmap development for Advanced Telescopes and Observatories. (2004-2005)
- Associate Editor, *Optics Express* (2004 -)
- Battelle Memorial Fellowship 1988

Some Recent Publications: (over 165 publications in all)

- E. E. Sabatke, J. H. Burge, and P. Hinz, "Optical design of interferometric telescopes with wide fields of view," Appl. Opt. **45**, 8026-8035 (2006).
- Y. Chang, P. Zhou, J. H. Burge, "Analysis of phase sensitivity for binary computer generated holograms," Appl. Opt. **45**, 4223-4234 (2006).
- J. H. Burge, "An easy way to relate optical element motion to system pointing stability," Proc. SPIE **6288**, 62880I (2006).
- J. H. Burge, L. B. Kot, H. M. Martin, C. Zhao and R. Zehnder, "Design and analysis for interferometric testing of the GMT primary mirror segments", Proc. SPIE **6273** (2006).
- J. H. Burge, T. Zobrist, L. B. Kot, H. M. Martin and C. Zhao, "Alternate surface measurements for GMT primary mirror segments", Proc. SPIE **6273** (2006).
- P. C. V. Mallik, R. Zehnder, J. H. Burge, and A. Poleshchuk, "Absolute calibration of null correctors using twin computer-generated holograms," Proc. SPIE **6292**, 62920H (2006).
- H. M. Martin, J. H. Burge, S. D. Miller, B. K. Smith, R. Zehnder and C. Zhao, "Manufacture of a 1.7-m prototype of the GMT primary mirror segments", Proc. SPIE **6273** (2006).
- R. Zehnder, J. H. Burge and C. Zhao, "Use of computer-generated holograms for alignment of complex null correctors", Proc. SPIE **6273** (2006).
- P. Su, J.H. Burge, R. Sprowl, J. Sasian, "Maximum Likelihood Estimation as a General Method of Combining Sub-Aperture Data for Interferometric Testing**,"** Proc. SPIE **6342** (2006).
- C. Zhao, D. Kang, and J. Burge, "Effects of birefringence on Fizeau interferometry that uses a polarization phase-shifting technique," Appl. Opt. **44**, 7548-7553 (2005).
- C. Zhao, R. Zehnder, J. H. Burge, "Measuring the radius of curvature of a spherical mirror with an interferometer and a laser tracker," Optical Engineering **44**(9) 090506 (2005).
- E. Sabatke, J. Burge, and D. Sabatke, "Analytic diffraction analysis of a 32-m telescope with hexagonal segments for high-contrast imaging," Appl. Opt. **44**, 1360-1365, (2005).
- C. Zhao, R. Zehnder, J. H. Burge, H. M. Martin, "Testing an off-axis parabola with a CGH and a spherical mirror as null lens," Proc. SPIE **5869,** 58690X (2005)
- P. C. V. Mallik, C. Zhao, and J. H. Burge," Measurement of a 2-meter flat using a pentaprism scanning system," Proc. SPIE **5869,** 58691A (2005)
- R. Angel, J. Burge, and S. P. Worden, "Testable lightweight telescopes for space," Proc.SPIE **5899,** 58990X (2005).
- F. Y. Pan, J. Burge, **"**Efficient Testing of Segmented Aspherical Mirrors by Use of Reference Plate and Computer-Generated Holograms. I. Theory and System Optimization," Appl. Opt., **43**, 5303-5312, (2004).
- T. Kim, J. H. Burge, Y. Lee, S. Kim, "Null test for a highly paraboloidal mirror," Appl. Opt., **43**, 3614-3618, (2004).
- F. Y. Pan, J. H. Burge, R. Zehnder, and Y. Wang, "Fabrication and alignment issues for segmented mirror telescopes," Appl. Opt. **43**, 2632-2642 (2004).
- J. H. Burge and J. R. P Angel, "Wide field telescope using spherical mirrors," Proc. SPIE **5174**, 83-92 (2004).
- G. G. Williams, E. W. Olszewski, M. P. Lesser, and J. H. Burge, "90prime: a prime focus imager for the Steward Observatory 90-in. telescope," Proc.SPIE **5492,** 787-798 (2004)
- P. D. Koudelka, J. H Burge, "Fabrication of cube beamsplitters for white light interferometry," Proc. SPIE **5252,** 17-25 (2004).
- D. Baiocchi, J. H. Burge, B. Cuerden, "Metrology results and lessons learned from the Univ. of Arizona NGST mirror system demonstrator," Proc. SPIE **5180**, 220-227 (2004)
- B. L. Stamper, J. H. Burge, W. J. Dallas, "Measurement of bulk refractive index inhomogeneity," Proc. SPIE **5180**, (2004**)**
- D. Baiocchi and J. H. Burge, "Optimized active, lightweight space mirrors," Proc. SPIE **5166**, 49-57 (2004).

Craig A. Kulesa

Steward Observatory
University of Arizona
Tucson, AZ 85721

Telephone: (520) 621-6540
FAX: (520) 621-1532
Email: ckulesa@as.arizona.edu
http://loke.as.arizona.edu/∼ckulesa/

Professional Preparation

Ph.D., Astronomy	December 2002	The University of Arizona
B.S., Physics	June 1993	Miami University (Ohio)

Appointments

2006-	Assistant Astronomer University of Arizona
2003-2006	Assistant Staff Scientist Steward Observatory University of Arizona
1998-2002	Research Assistant (Science and Instrumentation) University of Arizona
1994-1996	Research Assistant (Science) University of Arizona

Selected Papers

1. "Large Scale CO and [CI] Emission in the Rho Ophiuchi Molecular Cloud", Kulesa, C.A., Hungerford, A.L., Walker, C.K., Zhang X., & Lane, A., ApJ, 625, 194

2. "Warm, Dense Molecular Gas in the ISM of Starbursts, LIRGs, and ULIRGs", Narayanan, D., Groppi, C. E., Kulesa, C. A., & Walker, C. K. 2005, ApJ, 630, 269.

3. "Millimeter and Submillimeter Survey of the R Coronae Australis Region", Groppi, C. E., Kulesa, C., Walker, C., & Martin, C. L. 2004, ApJ, 612, 946

4. "CO Emission from Disks around AB Aurigae and HD 141569: Implications for Disk Structure and Planet Formation Timescales", Brittain, S. D., Rettig, T. W., Simon, T., Kulesa, C., DiSanti, M. A., & Dello Russo, N. 2003, ApJ, 588, 535

5. "Abundances of H_2, H_3^+ & CO in Molecular Clouds and Pre-planetary Disks", Kulesa, C. A. & Black, J. H. 2002, Chemistry as a Diagnostic of Star Formation, 60

Selected Related Papers

1. "Deep Near-Infrared Observations of L 1014: Revealing the Nature of the Core and its Embedded Source", Tracy L. Huard et al., 2006, ApJ, in press (accepted Sept 12 2005)

2. "The Youngest T Tauri Star - the Sudden Appearance of Mcneil's Nebula", Rettig, T. & S. Brittain, E. Gibb, T. Simon & C. Kulesa, 2005, ApJ, 626, 245.

3. “CO Line Emission and Absorption from the HL Tau Disk - Where is all the dust?”, Brittain, S., T. Rettig, T. Simon & C. Kulesa, 2004. ApJ, 2005, 626, 283.

4. “Scientific results from the MMT Natural Guide Star Adaptive Optics System”, Kenworthy, M. et al., 2004, SPIE, 5490, 351.

5. “Infrared H_3^+ line absorption toward LkHα101”, Brittain, S., T. Simon, C. Kulesa & T. Rettig, 2004. ApJ, 606, 911.

Synergistic Activities:

- Dissemination of research results to the wider public by lectures and presentations, e.g. through Steward Observatory programs, student organizations, and primary/secondary schools.
- Development of new techniques for molecular cloud modeling of physical structure, chemistry, radiative transfer and dynamics.
- Development of infrared and submillimeter survey data and science products for ecological studies of the Milky Way

Collaborations, 2004-2006:

J. Black (Onsala)
S. Brittain (Clemson)
M. DiSanti (Goddard)
N. Dello Russo (Goddard)
E. Gibb (Missouri)
C. Groppi (Arizona)
D. Hollenbach (NASA-Ames)
T. Huard (CfA)
A. Lane (Harvard/CfA)
P. Myers (CfA)
G. Narayanan (UMass/Amherst)
T. Rettig (Notre Dame)
T. Simon (Hawaii)
A. Stark (Harvard/CfA)
C. Walker (Arizona)
M. Wolfire (Maryland)
X. Zhang (NRL)

Ph.D. Advisors:

Christopher K. Walker (Arizona)
John H. Black (Onsala Space Observatory)

Ph.D. Advisees:

Sean Brittain (2003, Univ. of Notre Dame)
Abigail Hedden (estd. 2007, Univ. of Arizona)
Desika Narayanan (estd. 2007, Univ. of Arizona)

SUMMARY PROPOSAL BUDGET — YEAR 1

FOR NSF USE ONLY	
PROPOSAL NO.	DURATION (months) Proposed / Granted
AWARD NO.	

ORGANIZATION
University of Arizona

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Christopher K Walker

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher K Walker - PI	0.00	0.00	1.00	$ 9,755	$
2. James H Burge - Co-PI	0.00	0.00	1.20	11,144	
3. Craig A Kulesa - DPI	12.00	0.00	0.00	54,814	
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	12.00	0.00	2.20	75,713	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (2) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	7.00	0.00	0.00	32,926	
3. (2) GRADUATE STUDENTS				58,964	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				167,603	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				54,767	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				222,370	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Buildup table (included in Optics Cost Estimate) $ 10,000					
Dewar/Cryocooler 40,000					
IF Amplifiers (6) 30,000					
Others (See Budget Comments Page...) 592,000					
TOTAL EQUIPMENT				672,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				20,025	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				496,403	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,500	
5. SUBAWARDS				50,000	
6. OTHER				1,000	
TOTAL OTHER DIRECT COSTS				548,903	
H. TOTAL DIRECT COSTS (A THROUGH G)				1,463,298	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC - Tuition Remission - Capital - 25K = TDC (Rate: 51.0000, Base: 750142)					
TOTAL INDIRECT COSTS (F&A)				382,572	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				1,845,870	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 1,845,870	$

M. COST SHARING PROPOSED LEVEL $ 0 — AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Christopher K Walker

ORG. REP. NAME*
Mary Gerrow

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

** D- Equipment
IF Processor Boards (2) (Amount: $ 50000)
PLATO (Amount: $ 102000)
Schottky Mixers - 2x 810 GHz, 1x 1.4 THz, 1x 1.9 THz (Amount: $ 340000)
Spectrometer System - 3 x 2 GHz (Single Component) (Amount: $ 100000)

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION University of Arizona			FOR NSF USE ONLY		
			PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Christopher K Walker			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher K Walker - PI	0.00	0.00	1.00	$ 9,950	$
2. James H Burge - Co-PI	0.00	0.00	0.00	0	
3. Craig A Kulesa - DPI	6.00	0.00	0.00	27,955	
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	6.00	0.00	1.00	37,905	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	1.00	0.00	0.00	7,652	
3. (1) GRADUATE STUDENTS				17,393	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				62,950	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				18,878	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				81,828	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				4,225	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				6,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				1,000	
5. SUBAWARDS				0	
6. OTHER				1,000	
TOTAL OTHER DIRECT COSTS				8,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				94,053	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC - Tuition Remission - Capital = TDC (Rate: 51.0000, Base: 89287)					
TOTAL INDIRECT COSTS (F&A)				45,536	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				139,589	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 139,589	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME Christopher K Walker	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* Mary Gerrow	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET — Cumulative

ORGANIZATION	FOR NSF USE ONLY		
University of Arizona	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Christopher K Walker	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Christopher K Walker - PI	0.00	0.00	2.00	$ 19,705	$
2. James H Burge - Co-PI	0.00	0.00	1.20	11,144	
3. Craig A Kulesa - DPI	18.00	0.00	0.00	82,769	
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (3) TOTAL SENIOR PERSONNEL (1 - 6)	18.00	0.00	3.20	113,618	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	8.00	0.00	0.00	40,578	
3. (3) GRADUATE STUDENTS				76,357	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				230,553	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				73,645	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				304,198	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 672,000					
TOTAL EQUIPMENT				672,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				24,250	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				502,403	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				2,500	
5. SUBAWARDS				50,000	
6. OTHER				2,000	
TOTAL OTHER DIRECT COSTS				556,903	
H. TOTAL DIRECT COSTS (A THROUGH G)				1,557,351	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				428,108	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				1,985,459	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 1,985,459	$

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $	
PI/PD NAME: Christopher K Walker	FOR NSF USE ONLY — INDIRECT COST RATE VERIFICATION	
ORG. REP. NAME*: Mary Gerrow	Date Checked / Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification

HEAT will be the world's first automated THz observatory. Here we request funds to design, build, and test the HEAT telescope and instrumentation. Optimized for operation from the highest point on the Antarctic plateau, HEAT will routinely access one of the least explored regions of the electromagnetic spectrum and provide new, fundamental knowledge about the distribution and state of matter in the Galaxy. The high degree of automation within HEAT will significantly reduce operation costs and increase efficiency. To succeed, HEAT must be robust and capable of remote, low-power, operation for a year at a time. The target date for the deployment of HEAT to Dome A (November 2008) coincides with the International Polar Year. The HEAT project is budgeted for a 2 year period and can be divided into development and integration/test phases. Funds for science operations of HEAT on Dome A will be requested through a separate proposal to the NSF Office of Polar Programs. The total 2 year project cost is $1,985,459.

Personnel
Senior Personnel include PI- Walker, Co-PI Burge, Co-PI Kulesa, and Project Manager (PM)- McMahon. The PI and Co-PI Burge request one month's salary for each year of the project. Their academic year salary of the PI is provided by the University of Arizona. Co-PI Kulesa will be responsible for the HEAT instrument control system, software development, and system integration. Full funding is requested for him during the first year of the project and half time in year 2. PM-McMahon will be responsible for monitoring project related expenditures, establishing and maintaining purchase orders, and tracking all equipment purchases. One month of salary is requested for him for each year of the project.

Other Personnel include two full-time graduate students in the first year and one in the second. One graduate student will focus on the telescope development and the other on the receiver system. A half-time electronic technician is budgeted during the hardware build up phase in the first year.

Operations
Funds are requested to cover basic, annual operating costs of the project including communications, computer networking technical support, licenses & software directly related to this project. To make a fully functional system, the HEAT telescope/receiver will be integrated on the University of New South Wales PLATO module in the summer of 2008. The costs associated with this trip are reflected in the travel budget.

Equipment Purchases
All major expenditures are related to the creation of the observatory and its instrumentation. These expenditures and target vendors/sources are:

1) *Receivers:* vendors- Virginia Diodes Inc.: A world leader in millimeter-wave/THz Schottky based receivers/components.
2) *Spectrometer System:* vendor- Omnisys Inc. has successfully delivered spectrometers of the type being used for HEAT to the University of Arizona for the SuperCam project. .
3) *Cryogenic system (cryocooler + cryostat):* vendor- Universal Cryogenics has successfully delivered complete closed-cycle cryogenic system to the University of Arizona for the SuperCam project.
4) *PLATO module:* vendor- University of New South Wales: will serve as a `spacecraft bus' for HEAT while on Dome A. They are the only builder of such modules.

We have provided the above vendors/sources with detailed specifications of each item and they in turn have provided quotes (see attachments) used in the budget. (Please note the PLATO quote provided by the University of New South Wales is in Australian dollars.) Additional components to be procured are listed below. Their costing is based on previous procurements for the SuperCam project.

5) *IF amplifiers:* the first amplifier after the mixer
6) *IF processor:* used to translate mixer IF output to the frequencies and power levels needed by the spectrometer system

Once project funding commences and vendor selection has been completed, purchase orders will be issued to suppliers.

Fabricated Equipment

In support of the HEAT project the University of Arizona will fabricate the HEAT telescope in the Optical Sciences Center Workshop. The total direct cost of the telescope design, fabrication, and testing is $746,818 (a detailed cost breakdown is attached). Fabrication costs associated with the HEAT receiver system include the mixer plate, receiver optics, and associated machining.

Project Title:	*A High Elevation Antarctic TeraHertz Telescope (HEAT)*	
PI and Co-PI:	*Christopher K. Walker and Craig Kulesa*	
Period of Performance:	*September 1, 2007 - August 31, 2009*	**Amount Requested:** *$1,985,460*

	Labor Hrs.	*Labor Rate*	**YEAR 1** *1-Sep-07 31-Aug-08*	**YEAR 2** *1-Sep-08 31-Aug-09*	**TOTAL YEARS**
SENIOR PERSONNEL					
C. Walker, P.I. - 1 su. mo per year @ $87,708/AY	166	58.76	$9,755	$9,950	$19,705
C. Kulesa, DPI - 12 months in Y1, 6 months in Y2 @ $54,814/FY	2080	26.35	$54,814	$27,955	$82,769
J. Burge, Co-PI - 1.07 months in Y1 @ $93637/AY	177.63	62.74	$11,144		$11,144
Program Manager, 1 mo. in Y1 and Y2 @ $90,025/FY	173.33	43.28	$7,502	$7,652	$15,154
OTHER PERSONNEL					
Electronic Tech Sr. @ $50,848/FY	1040	24.45	$25,424		$25,424
2 Graduate Research Assistant, 9-AY months each in Y1; 1 GRA in Y2	1760	19.38	$34,104	$17,393	$51,497
2 Graduate Research Assistant, 3-summer months each in Y1	1088	22.85	$24,860		$24,860
Labor Subtotal			*$167,603*	*$62,950*	$230,554
FRINGE BENEFITS					
Sr. Personnel, 26.7% 7/1/07 and beyond		26.7%	$22,218	$12,164	$34,382
Staff, 38.5% effective 7/1/07 and beyond		38.5%	$9,788	$0	$9,788
Graduate Student, 11.2% effective 7/1/07 and beyond		11.2%	$6,604	$1,948	$8,552
Graduate Student, 27.4% (tuition remission) effective 7/1/07 and beyond		27.4%	$16,156	$4,766	$20,922
Fringe Subtotal			*$54,767*	*$18,877*	$73,644
PERSONNEL SUBTOTAL			**$222,370**	**$81,828**	**$304,198**
FABRICATED EQUIPMENT					$0
Optics costing for design, fabrication and testing			$446,403		$446,403
Mixer Plate			$4,000		$4,000
Receiver Optics			$20,000		$20,000
Machining, miscell.			$10,000		$10,000
FABRICATED EQUIPMENT SUBTOTAL			**$480,403**	**$0**	**$480,403**
OPERATIONS					
Instrument Control Computers and supervisor modules (4)			$4,000		$4,000
Iridium L-band transceivers (3)			$3,000		$3,000
Communications			$1,000	$1,000	$2,000
Computer Network Support, Licenses, & Software			$1,500	$1,000	$2,500
Materials & Supplies			$6,000	$6,000	$12,000
Misc. Electronic Components (connectors, cables, etc.)			$3,000		$3,000
OPERATIONS SUBTOTAL			**$18,500**	**$8,000**	**$26,500**
SUBCONTRACT					
EOS Technology, Inc. (included in College of Optical Sciences Optics Cost Estimate)			$50,000		$50,000
SUBCONTRACT SUBTOTAL			**$50,000**	**$0**	**$50,000**
TRAVEL					
Foreign			$20,025	$4,225	$24,250
TRAVEL SUBTOTAL			**$20,025**	**$4,225**	**$24,250**
CAPITAL EQUIPMENT					
Dewar/Cryocooler (Universal Cryogenics Inc.)			$40,000		$40,000
IF Processor Boards - 2			$50,000		$50,000
IF amplifiers - 6			$30,000		$30,000
Spectrometer System - 3 x 2GHz (Omnisys Inc.)			$100,000		$100,000
Schottky Mixers - 2x 810 GHz, 1x 1.4 THz, 1x 1.9 THz (Virginia Diodes Inc.)			$340,000		$340,000
PLATO (UNSW)			$102,000		$102,000
Buildup table (included in College of Optical Sciences Optics Cost Estimate)			$10,000		$10,000
CAPITAL EQUIPMENT SUBTOTAL			**$672,000**	**$0**	**$672,000**
TOTAL DIRECT COSTS			**$1,463,298**	**$94,053**	**$1,557,351**
Less Graduate Tuition Remission			*$16,156*	*$4,766*	*$20,922*
Less Capital Equipment			*$672,000*	*$0*	*$672,000*
Less first $25K of subcontract			*$25,000*		
			$713,156	***$4,766***	***$717,922***
BASE			**$750,142**	**$89,287**	**$839,429**
INDIRECT COSTS (MTDC rate 51%)		51%	$382,572	$45,536	$428,109
TOTAL PROJECT COSTS			**$1,845,871**	**$139,589**	**$1,985,460**

College of Optical Sciences
THE UNIVERSITY OF ARIZONA®

Proposal to: NSF

Title:

PI: James Burge

		Design Phase	Fab. & Test	Total
SALARIES & ERE				
James Burge		$0	$0	$0
Drafter @ $20/hour	240 hrs	$4,800	$0	$4,800
Undergraduate Student @ $10/hour		$5,000	$10,000	$15,000
	TOTAL SALARIES & ERE	**$9,800**	**$10,000**	**$19,800**
OTHER DIRECT COSTS				
Optics Shop Support @ $78.44 per hour	1720 hrs.	$41,573	$93,344	$134,917
Engineering Support @ $78.44 per hour	2150 hrs.	$97,266	$71,380	$168,646
University Instrument Shop @ $55 per hour	520 hrs.	$0	$28,600	$28,600
Materials		$0	$94,440	$94,440
Subcontract	(Included in Section G.5 Subawards of NSF Year 1 Budget)	$25,000	$25,000	$50,000
	TOTAL OTHER DIRECT COSTS	**$163,839**	**$312,764**	**$476,603**
EQUIPMENT				
Buildup Table	Included in Section D. Equipment of NSF Year 1 Budget)	$0	$10,000	$10,000
	TOTAL EQUIPMENT	**$0**	**$10,000**	**$10,000**
TOTAL DIRECT COSTS		**$173,639**	**$332,764**	**$506,403**
F&A COSTS @ 51% MTDC		**$88,556**	**$151,860**	**$240,415**
TOTAL COSTS		**$262,195**	**$484,624**	**$746,818**

QUOTE from Universal Cryogenics

JOB CODE	Date	Quote #
UACL20K	1/18/2007	235

UNIVERSAL CRYOGENICS
1815 W. Gardner Ln.
Tucson, AZ. 85705
520-622-6277 ph
520-623-3167 fx
www.ucryo.com
kirby@ucryo.com

QUOTE VALID FOR 30 DAYS.

SHIPPING WILL BE ADDED TO FINAL INVOICE.

PROGRESS PAYMENTS MAY APPLY WITH PO.

Ship To

The University of Arizona
Central Receiving
1145 South Warren Ave.
Tucson, AZ 85721-0458
Attn CHRIS WALKER

Customer Name / Address

The University of Arizona
Accounts Payable
P.O. Box 3607
Tucson, AZ 85722-3607

Customer Contact	Customer Contact Ph	Rep	Project
CHRIS WALKER			

Line	Item	Description	Qty	Rate	Total
1	Dewar	Southpole Dewar based on Closed Cycle System. -10-inch case section -Dewar stand and handles located around cold head for handling. -External case holes TBD for interface with customers system. -Case split at critical location for ease of dewar assembly with array. -Cold plate details to allow install of customers instrument. -System assembly and Stack up.	1	6,500.00	6,500.00
2	Cryo-Cooler	Sunpower CryoTel CT Series cooler. -RTD Temp sensor feedback. -Electronics contol box mounted in rack mount enclosure with cooling fan. -KF50 welded bellows interface mount. -SunPower cooling tube with heat exchange fins and high flow cooling fan to allow in lab testing. -Gold plated thermal bus bar interface from cold tip to cold plate. -Thermal radiation shield. -System design and integration.	1	22,000.00	22,000.00
3	Rad-Shield	Radiation shield attached to cold plate. -Allows flange mount at both ends.	1	1,000.00	1,000.00
4	Rigid-Supp-A	Internal Rigid Support System fixed between cold work regions.	1	650.00	650.00

UNIVERSAL CRYOGENICS TERMS AND CONDITIONS 2005 APPLY
THANK YOU, FROM UNIVERSAL CRYOGENICS!

Total

QUOTE from Universal Cryogenics

JOB CODE	Date	Quote #
UACL20K	1/18/2007	235

UNIVERSAL CRYOGENICS
1815 W. Gardner Ln.
Tucson, AZ. 85705
520-622-6277 ph
520-623-3167 fx
www.ucryo.com
kirby@ucryo.com

	Ship To
QUOTE VALID FOR 30 DAYS.	The University of Arizona Central Receiving 1145 South Warren Ave. Tucson, AZ 85721-0458 Attn CHRIS WALKER
SHIPPING WILL BE ADDED TO FINAL INVOICE.	
PROGRESS PAYMENTS MAY APPLY WITH PO.	

Customer Name / Address

The University of Arizona
Accounts Payable
P.O. Box 3607
Tucson, AZ 85722-3607

Customer Contact	Customer Contact Ph	Rep	Project
CHRIS WALKER			

Line	Item	Description	Qty	Rate	Total
5	Electrical Connectors	Electrical Connector hermetic Pin and Plug for instrument wiring. -18 and 26 pin connectors. -Blank flange for each connector. -Machine details in case. -Heat sink details pass thru radiation shield.	1	1,575.00	1,575.00
6	Dewar	Upgrade all vacuum seals to indium metals seals. -Tongue and groove with oring combination seals. -Indium wire for qty-2 seals for each interface.	1	1,500.00	1,500.00
7	Electrical Connectors	Electrical Connector Pin and Plug. -Housekeeping hermetic connector and plug installed on dewar. -Includes blank flange.	1	475.00	475.00
8	Temp-Sensor	Silicon diode installed in dewar.	1	350.00	350.00
9	Wiring	Dewar wiring. -Wire temp sensor.	1	250.00	250.00
10	SMA-COAX	SMA brass flange installed on dewar. -Solder hermetic SMA feedthrus to brass flange, qty-3. -Install qty-3 SMA UT-085-SS coax into dewar. -Strain relief on cold plate for SMA coax.	1	1,500.00	1,500.00
11	GETTER-STYLE-B	Charcoal getter installed on cold plate.	1	350.00	350.00
12	Window-detail-A	Window mounting Detail on dewar case. Indium and/or Oring sealed, TBD window OD, CA, THK.	1	475.00	475.00

UNIVERSAL CRYOGENICS TERMS AND CONDITIONS 2005 APPLY THANK YOU, FROM UNIVERSAL CRYOGENICS!	**Total**

QUOTE from Universal Cryogenics

JOB CODE	Date	Quote #
UACL20K	1/18/2007	235

UNIVERSAL CRYOGENICS
1815 W. Gardner Ln.
Tucson, AZ. 85705
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Central Receiving
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Tucson, AZ 85721-0458
Attn CHRIS WALKER

Customer Name / Address

The University of Arizona
Accounts Payable
P.O. Box 3607
Tucson, AZ 85722-3607

Customer Contact	Customer Contact Ph	Rep	Project
CHRIS WALKER			

Line	Item	Description	Qty	Rate	Total
13	baffle-filter-hldr	Baffle with filter holding on radiation shield cover.	1	375.00	375.00
14	Blank-Flange-A	Blank mounting Flange mounted to dewar. -Location TBD based on design. -Allows access to array install to match customers instrument design.	1	1,000.00	1,000.00
15	Design	Dewar Mechanical Design of system. -Design meetings and presentation at UofA.	1	1,000.00	1,000.00
16	Dewar-Test-A	Dewar Leak Checking, Vacuum and Cryogenic Testing of Dewar with Documentation.		1,000.00	1,000.00
17	DELIVERY TERMS	DELIVERY OF SYSTEM IS 16 - 18 WEEKS ARO.			

UNIVERSAL CRYOGENICS TERMS AND CONDITIONS 2005 APPLY
THANK YOU, FROM UNIVERSAL CRYOGENICS!

Total $40,000.00

PLATO budget (cost AUD)

		Unit cost	qty	total	spares
POWER				***56880***	
Engine	Hatz 1B30	3370	4	13480	
Alternator	e-cycle	3000	4	12000	
Engine mounts	vibration damping	500	4	2000	
Fuel tanks	3000 lt			6500	
Fuel lines				2000	
Fuel filters		250	4	1000	500
Oil tanks and lines		250	4	1000	
Air filters		200	4	800	400
Exhaust system		800	4	3200	
Thermal control				2000	
Batteries	Gel 12 V 100 Ahr	600	4	2400	
Solar panels	BP2150 (150W)	1000	8	8000	
Solar panel mounts				1500	
MPPT	AERL Maximizer	1000	1	1000	1000
COMPUTER				***19920***	
PC104 processor	DSP TPP3	730	3	2190	730
PC104 multi-com	Parvus	220	3	660	220
PC104 power supply	D104-PCS20	190	3	570	195
PC104 components		400	3	1200	400
Flash memory	2 GB FDHD	1300	6	7800	2600
Iridium	L-band transiever	1200	4	4800	
Computer cases		500	3	1500	500
USBHD	Maxtor GB	300	4	1200	300
COMMS				***4100***	
Ethernet hub	16 port	500	1	500	500
RS232 multiplexer		800	1	800	800
USB multiplexer		800	1	800	800
USB hub	8 port	400	1	400	400
Webcams	Watec	400	4	1600	400
Electronics				***5200***	
Power distribution PCB			1	800	800
ADC/DIO PCB		400	2	800	800
Super WW PCB		200	4	800	
Wiring/ cabling				2000	
Rack housing		800	1	800	
PLATO				***33000***	
Structure				25000	
Mechanical				4000	
Toolkit				4000	
TOTAL				**119100**	**11340**

VIRGINIA Diodes Inc.

QUOTATION: QTC111006UAz

TO: Chris Walker
University of Arizona
e-mail: cwalker@as.arizona.edu

November 10, 2006
Total Pages = 1

We are pleased to offer the following budgetary quotation for Schottky diode receivers.

Item	Description	Unit Price	Delivery
1	**810 GHz Subharmonic Mixer + LO** Ambient Mixer Noise Temperature: 4000 K (DSB) Expected System Configuration: {PLO} + {Amplifier} + {D50 Doubler} + {D100 Doubler} + {D200 Doubler} + {D400 Doubler} + {WR-1.2SHM} RF Input Port: WR-1.2 Diagonal Feedhorn, 25 dB gain typical DC Power: 16 W expected DC Requirements: 11.4V @ 0.4A, 9V @ 1.2A, <25V @ 0A (four times)	**$65,000**	**14 Weeks**
2	**1.45 THz Subharmonic Mixer + LO** Ambient Mixer Noise Temperature: 10,000 K (DSB) Expected System Configuration: {PLO} + {Amplifier} + {D60 Doubler} + {D120 Doubler} + {D250 Doubler} + {T750 tripler} + {WR-0.65SHM} RF Input Port: WR-0.65 Diagonal Feedhorn, 25 dB gain typical DC Requirements: Similar to Item 1	**$85,000**	**14 Weeks**
3	**1.9 THz Subharmonic Mixer + LO** Ambient Mixer Noise Temperature: 20,000 K (DSB) Expected System Configuration: {PLO} + {Amplifier} + {D90 Doubler} + {D90 Doubler} + {D180 Doubler} + {D375 Doubler} + {T830 tripler} + {WR-0.51SHM} RF Input Port: WR-0.5 Diagonal Feedhorn, 25 dB gain typical DC Requirements: Similar to Item 1	**$125,000**	**20 Weeks**

NOTES:
All VDI components offered use planar diode technology and have no mechanical tuners.
This quote is valid for sixty days beyond date given above.
Delivery: Delivery dates shown are the expected maximum, VDI will add cost of shipping and insurance to invoice. Please include shipping instructions with the PO.
Terms: Net 30 days, VDI Terms and conditions apply.

Authorization:

Thomas W. Crowe, President
Virginia Diodes, Inc.

Quotation

FPGA based spectrometer system

Quotation reference: Q070112A
Dr. Anders Emrich
Tel: +46 31 7343401
Email: ae@omnisys.se
Omnisys Instruments AB
Gruvgatan 8
SE-421 30 Västra Frölunda, Sweden

Dear Sir,

We are hereby offering a spectrometer system based on 4 spectrometer boards in one single height 19” EuroRack crates with the following specification:

Size:	1 x single hight 19” crates
RF I/O:	4x4=16 SMA connectors (as for SuperCam)
Main clock:	Synthesized on board
Data I/O:	1 x 100 MBit/s Ethernet
Power:	110 V
Configuration:	8x1000 MHz *Tested with white noise and CW source for radiometer applications.*
Integration time:	0.1-10 seconds
FPGA:	Xilinx Virtex-4 SX-55
Cost:	$120 000 plus shipping and tax
Delivery time:	6 months after order
Payment plan:	50% at order 50% 30 days after delivery
Note:	$20 000 will be deducted if one board is excluded, i.e providing 6 x 1 GHz processing. The system will be shipped with a spare parts kit, such as an extra power supply and embedded control computer.

Dr. Anders Emrich

SUMMARY PROPOSAL BUDGET

YEAR 1

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
Electro-Optical Sciences Inc

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
James H Burge

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. James H Burge - PI	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				0	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				0	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				50,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				50,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				50,000	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) (Rate: , Base:)					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				50,000	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 50,000	$

M. COST SHARING PROPOSED LEVEL $ 0 | AGREED LEVEL IF DIFFERENT $

PI/PD NAME
James H Burge

ORG. REP. NAME*
Mary Gerrow

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION Electro-Optical Sciences Inc				**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR James H Burge				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. James H Burge - PI	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				0	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				0	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				0	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				50,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				50,000	
H. TOTAL DIRECT COSTS (A THROUGH G)				50,000	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				50,000	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 50,000	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME James H Burge	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* Mary Gerrow	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Current and Pending Research Support
Investigator: Christopher K. Walker

CURRENT SUPPORT:

Project title: Development of a Submillimeter-wave Superheterodyne Camera (SuperCam) for the Heinrich Hertz Telescope
Source of Support: NSF MRI Program AST-0421499
Total Award Amount: $1,742,356 Total Award Period Covered: 09/01/04 - 08/31/07
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 1.0

Project title: Coherent THz Sources Using Carbon Nanotubes - PI: C. d'Aubigny
Source of Support: NSF - 05-557 SBIR/STTR Phase I
Total Award Amount: *$34,220 Total Award Period Covered: 01/01/06 - 03/31/07
*UA awarded amount
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: .50 Sumr:

Project title: A High Elevation Antarctic TeraHertz Telescope -HEAT-
Source of Support: NSF- OPP Antarctic Aeronomy & Astrophysics
Total Award Amount: $79,695 Total Award Period Covered: 07/15/06 - 06/30/07
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 1.0

Project title: Computing a Universe of Galaxies (Co-I)
Source of Support: NSF 05-627 DMS Infrastructure Program
Total Award Amount: $99,681 Total Award Period Covered: 08/01/06 - 07/31/07
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 0

Project title: Hazal: A Portable System for Detecting Hazardous Materials Using Terahertz Absorption Line Spectroscopy
Source of Support: Teravision, Inc.
Total Award Amount: $323,253 Total Award Period Covered: 11/26/06 - 12/31/07
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 1.69

PENDING SUPPORT:

Project title: Hazal: Development of a Submillimeter-wave Superheterodyne Camera (SuperCam) for the Heinrich Hertz Telescope (Supplement)
Source of Support: NSF
Total Award Amount: $395,124 Total Award Period Covered: 03/01/07 - 12/31/07
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 1.0

Project title: Hazal: Identification of hazardous Materials Using High Resolution Spectroscopy Between 0.14 and 0.9 THz
Source of Support: Air Force Office of Scientific Research - DURIP
Total Award Amount: $235,000 Total Award Period Covered: 04/01/07 - 03/31/08
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: 0.36 Sumr:

Current and Pending Research Support
Investigator: Christopher K. Walker

PENDING SUPPORT (Continued):

Project title: Mapping the Connections Between Molecular Clouds, Star Formation and Stellar Feedback (Co-I)
Source of Support: NSF - 05-608 AARG
Total Award Amount: $282,553 Total Award Period Covered: 07/01/07 - 06/30/10
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: 0.24 Sumr:

Project title: HEAT: the High Elevation Antarctic TeraHertz Telescope (THIS PROPOSAL)
Source of Support: NSF- 07-510 - ANT - MRI
Total Award Amount: $1,985,459 Total Award Period Covered: 09/01/07 - 08/31/09
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 1.0

Current and Pending Research Support
Investigator: James Burge

CURRENT SUPPORT:

Project title: Optical Desigen and Analysis to Support Optical Testing for
James Webb Space Telescope Project
Source of Support: NASA Goddard (POC: Ritva Keski-Kuha)
Total Award Amount: $240,000 Total Award Period Covered: 02/15/2004 - 02/14/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project Cal: Acad: 0.45 Sumr:

Project title: Space Surveillance Telescope
Source of Support: MIT Lincoln Laboratory (POC: Jefferson Kommers)
Total Award Amount: $7,365 Total Award Period Covered: 09/01/2005 - 11/30/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: 0.72 Acad: Sumr:

Project title: Solar Power Initiative
Source of Support: Raytheon (POC: Devon Crowe)
Total Award Amount: $6,093 Total Award Period Covered: 11/28/2006 - 01/14/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: 0.12 Acad: Sumr:

Project title: Concepts for Scalable Lightweight Space Telescopes (Co-I)
Source of Support: National Reconnaissance Office
Total Award Amount: $1,230,000 Total Award Period Covered: 05/01/2004 - 04/11/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr:

Project title: A Deep Field Infrared Observatory Near the Lunar Pole (Co-I)
Source of Support: NASA
Total Award Amount: $396,612 Total Award Period Covered: 09/01/2005 - 02/28/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr:

Project title: Fabricating DCT 4.3 Meter Primary (Co-IP)
Source of Support: Lowell Observatory (POC: Byron W. Smith)
Total Award Amount: $3,160,327 Total Award Period Covered: 09/01/2006 - 07/31/2009
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: 0.60 Sumr:

Project title: Hobby-Eberly Telescope Wide Field Corrector Study (Co-I)
Source of Support: University of Texas, Austin (POC: John Booth)
Total Award Amount: $96,266 Total Award Period Covered: 12/06/2006 - 04/30/2007
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: 0.60 Sumr:

PENDING SUPPORT:

Project title: HEAT: the High Elevation Antarctic Teraherz Telescope (Co-I) THIS PROPOSAL
Source of Support: NSF - 07-510 - ANT - MRI
Total Award Amount: $1,985,459 Total Award Period Covered: 09/01/2007 - 08/31/2009
Location of Project: The University of Arizona
Person-Months Per Year Committed to the Project: Cal: Acad: Sumr: 0.60

Craig Kulesa

Current & Pending Support

Title ***Program Name***	***Agency***	***Performance Period*** ***Budget***	***Total Commitment*** (calendar months)
Development of a Submillimeter-wave Superheterodyne Camera (SuperCam) for the Heinrich Hertz Telescope	NSF/MRI	09/2004 - 08/2007 $1,742,356	6
HEAT: The High Elevation Antarctic Terahertz Telescope	NSF/OPP	07/2006 – 06/2007 $80,000	5
PENDING: Mapping the connections between molecular clouds, star formation, and stellar feedback	NSF/AST	07/2007 – 6/2010 $282,553	1
PENDING: Identifying molecular cloud formation in the Galaxy	NSF/AST	7/2007 – 6/2010 $224,175	5
PENDING: (this proposal) HEAT: The High Elevation Antarctic Terahertz Telescope	NSF/OPP	09/2007 – 08/2009 $1,985,536	18

FACILITIES, EQUIPMENT & OTHER RESOURCES

University of Arizona: Optical Sciences Center & Steward Observatory

The Optical Sciences Center (OSC) and Steward Observatory (SO) have large technical staffs with many years of experience in the design and construction of state-of-the-art telescopes and instrumentation for use from optical (e.g. MMT, Magellan, and Large Binocular Telescope (LBT)) to millimeter/submillimeter wavelengths (e.g. Heinrich Hertz Telescope (HHT)). This expertise will be augmented by Instrument Team members with Polar experience and utilized during the development of the HEAT telescope and its associated instrument package. The mirror fabrication and metrology systems available at OSC can easily accommodate the HEAT telescope mirrors. The control system specifications can be readily met. An environmental chamber will be constructed to test the telescope optics and drive system components under conditions similar to that expected at Dome A.

In 1992 the PI established a laboratory (the Steward Observatory Radio Astronomy Laboratory, SORAL) for the development of state-of-the-art submillimeter-wave receiver systems. SORAL possess all the equipment (spectrum analyzers, network analyzer's, vacuum pumps, cryogenic support facilities, etc.) needed for the development of receivers. We also have 4He, 3He, and closed-cycle cryostats, a full receiver testbed, local oscillator sources (including a Coherent/DEOS FIR laser), and an antenna test range which allow us to characterize a wide range of receiver systems. In addition, the receiver systems built by the PI's group in collaboration with the University of Cologne for AST/RO (a 492/810 GHz receiver and PoleSTAR a 4 pixel 810 GHz receiver) was returned to SORAL after AST/RO was decommissioned last year. Recently, a HEB THz test receiver has been built for SORAL in a collaborative effort between SRON and the PI's group. These systems and their components will directly benefit HEAT instrument development.

SORAL has licenses for Hewlett Packards High Frequency Structure Simulator (HFSS) and Advanced Design System (ADS) software packages, as well as Agilent HFSS and CST Microwave Studio. These programs are used to accurately model and optimize mixers and other crucial receiver components. In addition, we have licenses for optical design packages such as Zemax and Code V.

THE UNIVERSITY OF
NEW SOUTH WALES

School of
PHYSICS

Professor Chris Walker
University of Arizona
933 North Cherry Ave
Tucson, AZ 85721

18 January 2007

Dear Chris

Australian participation in HEAT proposal

This is to confirm that the Antarctic Group at the University of New South Wales is an enthusiastic and committed partner in the HEAT collaboration. The key Faculty personnel are:

- Professor Michael Ashley
- Associate Professor Michael Burton
- Professor John Storey

In addition, postdoctoral fellow Dr Jon Lawrence and several of our students will also contribute at various levels.

The deployment of HEAT on an AASTINO at Dome A forms part of the *Astropoles* IPY project. Building on our experience with the AASTINO at Dome C (and, prior to that, the AASTO at South Pole) we will provide the HEAT project with a new, remote laboratory including power generation, heat, and a Command, Control and Communication system based on the Iridium satellite network. I note that you will be requesting funding from the NSF for the component items, and we will provide our expertise and experience to the design, construction and integration of the system including the shelter itself, solar panels, batteries and power distribution.

UNSW will also assist in the development of an Automated Weather Station that will accompany the HEAT experiment to Dome A. This weather station will provide valuable data for future scientific experiments, as well as helping to provide quality control for the HEAT data. In addition, by monitoring wind speed, visibility and other basic meteorological parameters the station will assist aircraft movements and planning.

UNSW has recently signed a Memorandum of Understanding with the Polar Research Institute of China and the National Astronomical Observatories of China, for Chinese deployment of a site-testing AASTINO (called *"PLATO"*) to Dome A as part of their *"PANDA"* IPY program in 2007 – 8. An attractive option for HEAT would be to simply install it on this PLATO laboratory during the 2008 – 9 season. We will work with you to explore this option with the newly formed Chinese Center for Antarctic Astronomy. Some other options are discussed below.

We will take delivery of the HEAT telescope and receiver from you in June 2008, and integrate it in our laboratory at UNSW during the following months. The complete facility will then be ready to deploy to Dome A during the 2008 – 9 season, for operation there throughout 2009 and beyond. I would like to take this opportunity to invite you, and other members of your team, to spend the northern summer periods of 2007 and 2008 at UNSW. This would be an excellent opportunity for us all to work together on any remaining technical issues prior to deployment.

The Australian Antarctic Division (AAD) has recently commissioned two ski-equipped CASA 212 aircraft. These will be used over the coming decade to provide air transport within Antarctica, including to green-field sites such as Dome A. In discussions with AAD logistics

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ABN 57 195 873 179

personnel I understand that the CASAs could be able to deliver a payload of approximately 1500 kg to Dome A in a single flight. I will be applying to the AAD for logistic support on behalf of the HEAT collaboration. As is the case with the NSF, all logistic support is provided on the basis of peer review of the scientific merit of the proposal. I will be requesting one CASA flight directly from South Pole to Dome A for transport of the HEAT experiment. In addition, I will ask for a flight (from Mawson or Pole) to bring in personnel for installation of the experiment, and a third flight a few days later to bring in the remainder of the fuel and to retrieve the science team from Dome A.

Using the Australian CASAs is just one of several feasible options for deployment. The most attractive possibility, as discussed above, is to incorporate HEAT into the PLATO laboratory. We will explore all such possibilities before choosing the most cost-effective option for deployment. Other options include:

- Traverse from Pole (NSF). By 2007 we expect that the overland route from McMurdo to the South Pole will be well established, and the necessary infrastructure such as tractors and sleds will be routinely available at South Pole. We would apply for a single overland expedition from Pole to Dome A to bring the HEAT experiment in, supported by one or two Twin Otter flights to bring in personnel and to prepare the site.
- LC-130/Twin Otters (NSF). A Twin Otter would bring in the Automatic Weather Station and the personnel who would prepare the surface prior to field deployment of the LC-130 with the AASTINO and HEAT.
- IPY Traverse from Dome C (Chinese/French/International). There is currently considerable interest amongst the international community in exploring the astronomical potential of Dome A by deploying a set of experiments to monitor site conditions there. HEAT will make a major contribution to this international effort, providing a wealth of data on terahertz transparency and sky brightness. Should the planned IPY traverse from Dome C to Dome A go ahead, we could include HEAT as part of that overall instrument package.

Our site testing work over the past decade has led to the inescapable conclusion that the Antarctic plateau offers quite exceptional observing conditions, particularly in the far-infrared and sub-millimetre. Of all the potential sites, Dome A – which is the highest region of the plateau – will offer conditions that are unrivalled anywhere else on the planet. HEAT is an extremely well thought-out experiment that will take maximum advantage of the conditions, and deliver some very exciting science. We look forward to making an essential contribution to this project.

Sincerely,

Professor John Storey

cc: Associate Professor Richard Newbury, Head of School.

MEMORANDUM OF UNDERSTANDING

BETWEEN

THE UNIVERSITY OF NEW SOUTH WALES

AND

NATIONAL ASTRONOMICAL OBSERVATORIES OF CHINA,

POLAR RESEARCH INSITUTE OF CHINA

UNSW Research Services
The University of New South Wales
Sydney
UNSW 2052
Telephone: (02) 9385 7230
Fax: (02) 9385 7238

THIS MEMORANDUM OF UNDERSTANDING IS DATED the day of 200

1. Parties

1.1 The parties to the Memorandum of Understanding are the Polar Research Institute of China ("**PRIC**"), National Astronomical Observatories of China ("**NAOC**") and The University of New South Wales a body corporate established under *The University of New South Wales Act 1989* (NSW) through its School of Physics Sydney 2052 in the State of New South Wales Australia ("**UNSW**").

1.2 The parties are aware and agree that this Memorandum of Understanding is not legally binding.

2. Aim of this MOU

2.1 The aim of the agreement is to explore the potential of Dome A, in Antarctica, as a site for a future astronomical observatory.

3. Areas and Mode of Collaboration

3.1 This research collaboration aims to:

- Add value to the Chinese-led expedition to Dome A by the contribution of additional intellectual and financial resources from Australia,
- Ensure that the results of site testing are distributed throughout all of the partners in China, Australia, USA and elsewhere as fast and as fully as possible.

3.2 UNSW will provide an AASTINO as described in Annex 1.

3.3 UNSW will deliver the AASTINO to Fremantle by November 1 2007.

3.4 UNSW will provide resources to ensure that operation of the AASTINO is monitored from UNSW and that the facility is kept operating.

3.5 PRIC will transport the AASTINO to Dome A in the austral summer of 2007 – 8, deploy it and the associated instrumentation, and set it in operation.

3.6 UNSW will contribute the fuel that the AASTINO itself will use, and part of the fuel for transportation of AASTINO. The amount of the fuel that can be transported is limited by the transportation capability of PRIC.

3.7 Instrumentation for the AASTINO will be provided by Australia, China, USA and other countries. Decisions on which instruments will be supported will be made by a committee that includes representatives from Australia, China, and third countries. NAOC will be the leading organization and coordinator of the international astronomical activities at Dome A connected with PRIC and the Chinese–led expedition to Dome A. In this way, the cooperation on AASTINO is included in the PANDA project – a Chinese key international program of IPY.

3.8 All site-testing data acquired within this program by UNSW will be shared promptly with the PRIC and the other partners.

3.9 Wherever possible, publications that result from scientific collaboration between UNSW and the PRIC may include at least one author from each of:

- The Polar Research Institute
- The relevant Chinese astronomical institutes

- UNSW.

The parties will use all reasonable endeavours to ensure that publications arising from the scientific collaboration are issued jointly.

Except the first paper on site testing results, in which the first author should be the PI of PANDA Project of PRIC provided that the parties agree that the PI of PANDA: (1) fulfils the criteria for authorship in accordance with the Vancouver Protocol; and (2) has provided the primary contribution to the paper, each of the institutes involved in this collaboration will have an equal opportunity to contribute publications on which a member of that institute is the first author.

All publications, conference posters and other publicity form this work will fully acknowledge the Polar Research Institute of China.

3.10 It is acknowledged by all parties that this is an experimental collaboration and that it may not be possible for one or both sides to fulfill its part of the collaboration.

4. Intellectual Property Rights

4.1 This clause does not affect the ownership of Intellectual Property in any pre-existing material owned by either Party as at the date of signing this Memorandum of Understanding, however expertise with respect to the operation of the AASTINO and site testing instruments in Antarctica gained by the Parties as a consequence of this collaboration will be freely shared between the Parties.

5. Term and Termination

5.1 This MOU will commence on the date of execution of this MOU and will continue for a period of three (3) years or such other term as may be agreed by the parties.

5.2 Either Party may terminate this Memorandum of Understanding upon issuing the other Party with one (1) month's written notice of that Party's intention to terminate the Memorandum of Understanding.

5.3 Each party is responsible for its own expenses in relation to any activities undertaken pursuant to this Memorandum of Understanding, and any actions taken by the other party in reliance on any preliminary agreements expressed in this Memorandum of Understanding will be at that party's own risk.

6. Negation of Employment, Partnership and Agency

6.1 PRIC agrees not to represent itself, and will ensure that its employees or sub-contractors do not represent themselves as being an employee, partner or agent of the UNSW, or as otherwise able to bind or represent the UNSW.

6.2 UNSW agrees not to represent itself, and will ensure that its employees or sub-contractors do not represent themselves as being an employee, partner or agent of PRIC, or as otherwise able to bind or represent PRIC.

7. Variation and Renewal

7.1 This agreement may only be varied by the written agreement of the parties.

8. Governing law and jurisdiction

8.1 This agreement is governed by and must be construed in accordance with the laws of New South

Wales.

8.2 Each party:

(a) irrevocably and unconditionally submits to the non-exclusive jurisdiction of the courts of New South Wales and all courts which have jurisdiction to hear appeals from them; and

(b) waives any right to object to proceedings being brought in those courts for any reason.

9 Entire agreement

This agreement constitutes the entire agreement between the parties in relation to its subject matter and supersedes any previous agreement of the parties, or any other communication or representation made, in relation to its subject matter.

SIGNED for and on behalf of)
THE UNIVERSITY OF NEW SOUTH WALES)
on the day of 2006)
in the presence of:)

Signature of Authorised Officer

James Walsh Director Research Services
Name of Authorised Officer (Please Print)

Signature of Witness

Name of Witness (Please Print)

SIGNED for and on behalf)
of **NAOC**)
on the day of 2006)
)
in the presence of:)

Signature of authorised delegate

Signature of Witness

Name of Witness (Please Print)

SIGNED for and on behalf)
of **PRIC**)
on the day of 2006)
)
in the presence of:)

Signature of authorised delegate

Signature of Witness

Name of Witness (Please Print)

30 November 2005

Dear Associate Professor Michael Burton

On behalf of the ICSU/WMO Joint Committee for the International Polar Year 2007-2008 we wish to thank you for submitting a proposal entitled 'Astronomy from the Polar Plateaus' for consideration as an IPY activity. Success of the IPY depends fundamentally on excellent research and support and on a high level of international coordination, derived from the talents and energy of groups such as yours.

At its November meeting in Geneva the Joint Committee completed evaluations of all proposals received up to 30 September 2005 for scientific or educational significance, for consistency with the IPY themes, regions and time frames, for evidence of international collaboration, and for development of effective management plans covering communications, operations, data, and education and outreach. In addition, the Joint Committee examined each proposal for evidence of involvement by scientists from non-polar nations, for indications of interdisciplinarity within the proposal and of linkages to other IPY activities, and for evidence that activities proposed would contribute to an IPY legacy. The Joint Committee evaluated more than 200 coordination proposals and expects to evaluate one additional set of coordination proposals submitted by 31 January 2006.

The Joint Committee considers that your proposal as submitted includes very strong scientific, education and outreach components and demonstrates a high level of adherence to IPY themes and goals. The Joint Committee therefore endorses your proposal as a prominent and valued part of the IPY program. The Joint Committee intends that these endorsements will provide assistance as IPY participants seek funding for the work proposed.

The IPY International Programme Office will shortly provide additional guidance for project coordinators and steering groups, including description of initial IPY information management processes. As part of that information exchange, we will expect project coordinators to keep the IPO informed about funding status of their projects and about substantial changes from the projects as proposed. In all cases, we wish you enormous success with your component of the IPY.

Yours sincerely

Co-chairs of Joint Committee

Ian Allison   Michel Béland

cc: Dr Lucio Piccirillo

c/o British Antarctic Survey, High Cross, Madingley Road, Cambridge
CB3 0ET, United Kingdom

Tel: +44 (0)1223 221468   Fax: +44 (0)1223 221270   Email:ipyipo@bas.ac.uk

SRON

Netherlands Institute for Space Research

Prof. Ch.K. Walker
University of Arizona
Department of Astronomy
Steward Observatory
933 North Cherry Avenue
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USA

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Our reference: SRON D-07/006

Direct dialling: +31 (0)30 253 5732
E-mail: k.f.wakker@sron.nl
Date: January 19, 2007

Re: High Elevation Antarctic THz Telescope (HEAT)

Dear Professor Walker,

SRON Netherlands Institute for Space Research enthusiastically supports the "High Elevation Antarctic THz Telescope (HEAT)" proposal being submitted to the NSF MRI program and acknowledges its role in the project. The HEAT project is of high interest to SRON and the Dutch space science community both scientifically and technologically.

SRON is planning to take the lead in developing the high sensitivity cryogenic (4 K) HEB receiver system that will ultimately be used on HEAT. This work serves as a technological and astronomical pathfinder for future ESA/NASA space science missions.

Towards this end, SRON is investing significantly (>600 k€) in the design and development of HEAT instrumentation. In addition, a proposal has been submitted by SRON to NWO, the Netherlands Organisation for Scientific Research, to further support the HEAT instrumentation development.

Yours sincerely,

Prof. Karel F. Wakker
General Director

College of Optical Sciences
1630 E. University Blvd.
Tucson, Arizona 85721-0094
http://www.optics.arizona.edu

James H. Burge
(520) 621-8182
(520) 621-9613 FAX
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College of Optical Sciences
THE UNIVERSITY OF ARIZONA®

January 24, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Chris,

I am writing to enthusiastically support your proposal "The High Elevation Antarctic THz Telescope (HEAT)" being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

As Co-Investigator, I will take responsibility for the engineering, manufacture, and testing of the telescope hardware. This system fits well within the capabilities and interests of the Optical Engineering and Fabrication Facility at the College of Optical Sciences.

Sincerely,

James H. Burge

Steward Observatory
933 North Cherry Avenue
Tucson, Arizona 85721-0065

THE UNIVERSITY OF
ARIZONA®
TUCSON ARIZONA

Telephone: (520) 621-2288
Telefax: (520) 621-1532

25 January 2007

Prof. Christopher K. Walker
Steward Observatory University of Arizona
Tucson, AZ 85721
USA

Dear Prof. Walker,

I acknowledge that I am identified by name as a Co-Investigator to the investigation "*HEAT: A High Elevation Antarctic Terahertz Telescope*" that is being submitted to the NSF Office of Polar Programs (OPP) and that I intend to carry out all responsibilities identified for me in this proposal.

This is a strong collaborative effort that builds on a heritage of many prior successful projects. As DP-I, my organizational portion of this effort will focus on assisting the PI (Walker) and be responsible for instrument control, electronics, all software and overall system integration. Scientifically, my work will will involve the intepretation and modeling of spectral line data derived from the observations, the construction of data and science products, and ancillary programs at optical/IR telescopes in Arizona that will serve to calibrate the Polar dataset.

HEAT represents a bold new advance in the capabilities of ground based astronomy, and will lead the way for new capabilities at Antarctica's Dome A. I look forward to the opportunities and challenges that HEAT will provide.

Best regards,

Craig Kulesa

Dr. Craig A. Kulesa
Assistant Astronomer
Steward Observatory
The University of Arizona

Harvard−Smithsonian Center for Astrophysics

AST/RO Project
60 Garden St. Mail Stop 12
Cambridge, MA 02138

tel: 617−496−7648
FAX: 617−384−7830
email: aas@cfa.harvard.edu

23 January 2007

Professor Christopher K. Walker
Steward Observatory
University of Arizona
Tucson, AZ 85721

Dear Prof. Walker:

I am writing this letter in support of your proposal ‘‘A High−Elevation Antarctic TeraHertz Telescope (HEAT)’’ being submitted to the NSF Office of Polar Programs Major Research Instrumentation (MRI) program. I am aware of my role in the proposed research and realize it will be considered in the review process. My interest in the project stems from my long−standing interest in the interstellar medium of the Milky Way and in Antarctic instrumentation. This instrument is the next step to higher frequencies and automated operation, beyond what we accomplished with the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) project during the past decade.

Yours truly,

Antony A. Stark
Principal Investigator
AST/RO Project

Antony A. Stark
Harvard-Smithsonian Center for Astrophysics
60 Garden Street, MS-78
Cambridge, MA 02138
(617) 496-7648
aas@cfa.harvard.edu

Education:

1975	B.S. with Honors, Physics and Astronomy, California Institute of Technology
1977	M.A., Astrophysical Sciences, Princeton University
1979	Ph.D., Astrophysical Sciences, Princeton University

Professional history:

1991–	*Astronomer*, Harvard-Smithsonian Center for Astrophysics
1989–2007	*Principal Investigator*, Antarctic Submillimeter Telescope and Remote Observatory
1980–1992	*Visiting Lecturer*, Department of Astrophysical Sciences, Princeton University
1979–1991	*Member of Technical Staff*, Radio Physics Research Department, Bell Laboratories, Holmdel, NJ
1976	*Physicist*, Lawrence Livermore National Laboratory
1975	*Summer Student*, Lawrence Livermore National Laboratory
1974–1975	*Programmer*, Space Radiation Laboratory, Caltech
1973	*Observing Assistant*, Owens Valley Radio Observatory, Big Pine, CA
1972–1973	*Research Assistant*, Kellogg Radiation Laboratory, Caltech

Proposal-related publications:

Stark, A. A. 2003, “AST/RO: A Small Submillimeter Telescope at the South Pole”, in ”The Future of Small Telescopes in the New Millennium, Vol. II”, ed. T. D. Oswalt, (Kluwer Academic Publishers: Dordrecht), pp. 269-284.

Stark, A. A., Bally, J., Balm, S. P., Bania, T. M., Bolatto, A. D., Chamberlin, R. A., Engargiola, G., Huang, M., Ingalls, J. G., Jacobs, K., Jackson, J. M., Kooi, J. W., Lane, A. P., Lo, K.-Y., Marks, R. D., Martin, C. L., Mumma, D., Ojha, R., Schieder, R., Staguhn, J., Stutzki, J., Walker, C. K., Wilson, R. W., Wright, G. A., Zhang, X., Zimmermann, P., and Zimmermann, R. 2001, “The Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)”, PASP, 113, 567.

Stark, A. A., Chamberlin, R. A., Cheng, J., Ingalls, J. G., and Wright, G. A. 1997, “The Optical and Mechanical Design of the Antarctic Submillimeter Telescope and Remote Observatory”, Rev. Sci. Instr., 68, 2200.

Stark, A. A., Davidson, J. A., Harper, D. A., Pernic, R., Loewenstein, R., Platt, S., Engargiola, G., and Casey, S. 1989, “Far Infrared and Submillimeter Photometric Mapping of Spiral Galaxies in the Virgo Cluster”, ApJ, 337, 650.

Miller, R. E., and Stark, A. A. 1986, “SIS Mixer Having Thin Film Wrap-Around Edge Contacts”, U. S. Patent 4,610,032.

Other significant publications:

Stark, A. A., Gammie, C. F., Wilson, R. W., Bally, J., Linke, R. A., Heiles, C., and Hurwitz, M. 1992, “The Bell Laboratories H I Survey”, ApJS, 79, 77.

Lee, Y., Stark, A. A., Kim, H. G., and Moon, D. 2001, “The Bell Laboratories ^{13}CO Survey: Longitude-Velocity Maps”, ApJS, 136, 137.

Miller, R. E., and Stark, A. A. 1986, “SIS Mixer Having Thin Film Wrap-Around Edge Contacts”, U. S. Patent 4,610,032.

Binney, J., Gerhard, O. E., Stark, A. A., Bally, J., and Uchida, K. I. 1991, “Understanding the Kinematics of Galactic Centre Gas”, MNRAS, 252, 210.

Stark, A. A., Davidson, J. A., Harper, D. A., Pernic, R., Loewenstein, R., Platt, S., Engargiola, G., and Casey, S. 1989, “Far Infrared and Submillimeter Photometric Mapping of Spiral Galaxies in the Virgo Cluster”, ApJ, 337, 650.

Examples of Synergistic Activities:
PI of AST/RO Project; Chair of South Pole User’s Committee; supervised graduate and undergraduate students in Astronomy and Engineering at Boston University, Northeastern University, and Harvard University; supervised students as part of CARA REU program; contributed to development of antenna-measuring holography instrumentation and software; designed all and constructed some of the sub-systems of the AST/RO telescope; member of telescope design advisory panel of Paul Allen Telescope; developed millimeter and submillimeter-wave cryogenic detector systems.

Collaborators in past 48 months:
T. M. Bania (Boston U.), J. A. Carlstrom (U. Chicago), R. A. Chamberlin (Caltech), G. Engargiola (Berkeley), W. Holtzapfel (Berkeley), J. G. Ingalls (IPAC), K. Jacobs (U. Koeln), J. M. Jackson (Boston U.), J. W. Kooi (Caltech), A. P. Lane (CfA), A. Lee (Berkeley) Y. Li (Korea Astronomical Observatory), K.-Y. Lo (NRAO), C. L. Martin (Oberlin), R. Ojha (UNSW), R. Schieder (U. Koeln), J. Staguhn (NASA), J. Stutzki (U. Koeln), C. K. Walker (U. Arizona), R. W. Wilson (CfA), X. Zhang (NASA), P. Zimmermann (Radiometer Physics), R. Zimmermann (Radiometer Physics).

Graduate Advisor: Arno A. Penzias (New Enterprise Associates)

Student Advisees:
H. Hsieh, senior honors thesis at Harvard University; Northeastern U. students E. Walters, K. Farinaella, D. Atkins, and C. Tran, capstone design project; also played a major role advising Boston U. students A. Bolatto (Berkeley) and J. Ingalls (IPAC), and Princeton U. student G. Heiligman (Lincoln Labs).

Postdoctoral scholars sponsored:
M. Yan (industry), K. Xiao (industry), N. Tothill (Exeter), A Loehr (CfA), W. Walsh (U. New South Wales), J. I. Harnett (NRAO).

CORNELL

Department of Astronomy

Prof. Gordon J. Stacey
Center for Radiophysics & Space Research
Cornell University
230 Space Sciences Building
Ithaca, NY 14853-6801

Telephone: 607 255-5900
Fax: 607 255-5875
E-mail: Stacey@astro.cornell.edu

January 24, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Chris,

I am writing to enthusiastically support your proposal ``The High Elevation Antarctic THz Telescope (HEAT)'' being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

As you know, my group had excellent success using our Fabry-Perot Spectrometer (SPIFI) on the AST/RO telescope, detecting the [NII] (205 μm) and CO(13-12) (200 μm) lines, and mapping the [NII] emission from the Carina star formation region and the Galactic Center. The detection of the [NII] line was the first reported detection of this line from the ground and demonstrated the utility of the South Pole site for THz spectroscopy. Extensive testing indicate that Dome A is an even better site than South Pole, thereby permitting access to additional spectral lines that are of great astrophysical interest. The HEAT experiment takes advantage of this site, and promises very exciting new science.

Sincerely,

Gordon J. Stacey

Gordon J. Stacey
Department of Astronomy
Cornell University
Ithaca, NY 14853
(607)-255-5900
gjs12@cornell.edu

Professional Preparation

Undergraduate Institution	Grinnell College	Physics and Mathematics	BA 1979
Graduate Institution	Cornell University	Astronomy	MS 1982
	Cornell University	Astronomy	PhD 1985
Postdoctoral Institution	UC Berkeley	Infrared Astronomy	1985-1991

Appointments

2001-present	Professor of Astronomy, Cornell University
1996-2001	Associate Professor, Cornell University
1991-1996	Assistant Professor, Cornell University.
1988-1991	Assistant Research Physicist, Level 1-4, U. C. Berkeley.
1985-1988	Postdoctoral Research Physicist, U. C. Berkeley
1984-1985	Postdoctoral Research Associate, CRSR, Cornell University.
1981-1984	Research Assistant, CRSR, Cornell University.
1979-1981	Teaching Assistant, Department of Astronomy, Cornell University.

Proposal Related Publications

1. "The 157 Micron [CII] Luminosity of the Galaxy II: The Presence of Knotlike Features in the [CII] Emission", G. J. Stacey, P. J. Viscuso, C. E. Fuller & N. T. Kurtz, Ap. J., 289, 803 (1985).
2. "158 μm [CII] Line: A Measure of Global Starformation Activity in Galaxies", G. J. Stacey, N. Geis, R. Genzel, J. B. Lugten, A. Poglitsch, A. Sternberg, & C. H. Townes, Ap. J., 373, 423 (1991).
3. "Infrared Space Observatory Measurements of a [CII] 158 μm Line Deficit in Ultraluminous Infrared Galaxies", M. L. Luhman, S. Satyapal, J. Fischer, M. G. Wolfire, P. Cox, S.D. Lord, H. A. Smith, G.J. Stacey, & S. J. Unger, S. D. Lord, Ap.J. 504, L11 (1998).
4. "CO(7→6) Observations of NGC 253: Cosmic Ray Heated Warm Molecular Gas", Bradford, C.M., Nikola, T.N., Stacey, G.J., Jackson, J.M., Bolatto, A.D., Davidson, J.A., Savage, M.L., & Higdon, S.J., ApJ 586, 891 (2003).
5. "Infrared Space Observatory Measurements of [CII] Line Variations in Galaxies", S. Malhotra, G. Helou, G. Stacey, D. Hollenbach, S. Lord, C.A. Beichman, H. Dinnerstein, D.A. Hunter, K.Y. Lo, N.Y. Lu, R.H. Rubin, N. Silbermann, H.A. Thronson Jr., & M.W. Werner, Ap.J. 491 L27 (1997).

Other Significant Publications

1. "Detection of the 205 μm [NII] Line from the Carina Nebula" T.E. Oberst, S.C. Parshley, G.J. Stacey, T. Nikola, A Löhr, J.I. Harnett, N.F.H. Tothill, A.P. Lane, A.A. Stark, & C.E. Tucker, ApJ 652, L125 (2006).
2. "Warm Molecular Gas Traced with CO J = 7→6 in the Galaxy's Central 2 Parsecs: Dynamical Heating of the Circumnuclear Disk", Bradford, C.M., Stacey, G.J., Nikola, T.N., Bolatto, A.D., Jackson, J.M., Savage, M.L., & Davidson, J.A, ApJ 623, 866 (2005).
3. "SPIFI: the First Direct - Detection Imaging Spectrometer for Submillimeter Wavelengths", C.M. Bradford, G.J. Stacey, M.R. Swain, T. Nikola, A.D. Bolatto, J.M. Jackson, M.L. Savage, J.A. Davidson, & P.A.R. Ade, Applied Optics 41, 2561 (2002).

4. "158 μm [CII] Mapping of NGC 6946: Probing the Atomic Medium", S. C. Madden, N. Geis, R. Genzel, F. Herrmann, J. M. Jackson, A. Poglitsch, G. J. Stacey, & C. H. Townes, Ap. J. 407, 579 (1993).

5. "Infrared Space Observatory Long-Wavelength Spectrometer Spectroscopy of Star-forming Regions in M33", Higdon, S.J.U., Higdon, J.L., van der Hulst, J.M., and Stacey, G.J., ApJ 592, 161 (2003)

Synergistic Activities

I typically employ 3 undergraduates in my research lab at any given time. Over the past 6 years, 23 different undergraduates have worked in my lab, 11 NSF REU students, and 12 others supported by NSF grants outright. Ten of these were female students, and 4 were minority students. These students engage in many activities in the lab including building and testing cryogenic Fabry-Perot interferometers (FPIs), optics, filters, filter wheels, and laser alignment systems. At present there are two graduate students working in my lab towards their PhD. These students, and the postdoctoral scholar have worked towards creating two submillimeter direct detection spectrometers, SPIFI and ZEUS, that employ bolometer at very low (sub Kelvin) temperatures. These activities are vitally important to training the next generation of "hands-on" scientists and engineers.

There is a great deal of knowledge transfer between my research group and S.H. Moseley's group at GSFC. The GFSC group delivered thermister sensed bolometer arrays for SPIFI and ZEUS, and a engineering grade 1×32 pixel SQUID multiplexed TES array for ZEUS. We have worked closely both in hardware and software development. Cornell graduate student Tom Oberst has made several journeys to GSFC to learn how to test and run the new arrays. We have ties to K. Irwin's group at NIST, as they supply the SQUID MUXs. We will work closely with them in the design and test of components of our new large format TES array. The PI believes that it is vitally important to maintain instrumentation groups at major universities to train the next generation of "hands-on" scientists and engineers.

I created the course "Observational Astronomy" at Cornell, and teach it every year. This course is a "hands-on" observing and lab course designed for non-science majors. Among the labs I created we measure the diameter of the earth, the distance to the sun, the mass of Jupiter, and the latitude of Ithaca. I believe this course is very useful in keeping non-science people aware of how much one can learn with simple tools. Examples from my research are often brought into the lecture, including slide show of polar activities with SPIFI.

I also regularly give astronomy talks at the local public schools, and hold observing sessions for these classes. I am also the Director of Undergraduate studies in Astronomy at Cornell, so not only am I the primary contact for Cornell Astronomy class students and majors, I also have quite a bit of interaction with high-school students who are thinking of attending Cornell University.

Collaborators over the past 48 months include A.D. Bolatto (UC Berkeley) D. Benford (GSFC), J.A. Davidson (USRA), T.L. Herter (Cornell), S.U. Higdon (Cornell), K. Isaak (Cambridge), J.M. Jackson (Boston U), S.H. Moseley (GSFC), J. Staguhn (GSFC), AA Stark (CFA) Adair Lane (CFA)

Graduate and Postdoctoral Advisors: Thesis Advisor: M. Harwit (Cornell), Postdoctoral supervisors: C.H. Townes (UC Berkeley) and R. Genzel (MPE, Germany)

Thesis Advisor and Postgraduate-Scholar Sponsor: Thesis Advisor for H. Latvakoski (Industry), C.M. Bradford (Caltech), L. Hall (Cornell), S. Hailey-Dunsheath (Cornell), T. Oberst (Cornell), Danette Fitzgerald (Cornell), and James Ledoux (Cornell)

Postgraduate Sponsor: M.R. Swain (JPL), and T. Nikola (Cornell)

OBERLIN

Oberlin College
Department of Physics and Astronomy
Wright Laboratory
110 North Professor St.
Oberlin, OH 44074-1088
440/775-6730

January 23, 2007

Prof. Christopher K. Walker
Steward Observatory
933 N. Cherry Avenue
University of Arizona.
Tucson, AZ 85721

Dear Dr. Walker:

I am writing to express my enthusiastic support for your proposal "The High Elevation Antarctic THz Telescope (HEAT)" being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

As a former winter-over scientist for the Antarctic Sub-mm Telescope/Remote Observatory, I have developed substantial expertise in telescope construction, instrumentation, maintenance, and operation under the most extreme of Antarctic environments, winter on the polar plateau. During the academic year of 2007-08, I will be on leave from my current position at Oberlin College and intend to spend this time at the Univ. of Arizona working on this and related projects.

I'm confident that the team you have assembled brings together the necessary range of experience and qualifications to successfully accomplish the construction of this worth instrument. My students and I are tremendously excited by this project and we look forward to working with you.

Sincerely yours,

Christopher L. Martin

Curriculum Vitæ

Christopher L. Martin

Education

1994–1999	Ph.D. in Physics University of California Santa Barbara, CA Thesis Advisors: Robert L. Sugar & Douglas Scalapino

Professional Experience

2004–	Asst. Professor, Oberlin College
2004–2006	Principal Investigator, NSF Grant ANT-0338150 studying the dynamics of the middle atmosphere using data from radio telescopes.
2002–2004	Astronomer, Harvard-Smithsonian Center for Astrophysics. Winterover scientist with the Antarctic Sub-millimeter Telescope / Remote Observatory (AST/RO), responsible for all aspects of telescope operation and maintenance while performing observations for myself and others.
1999–2002	Smithsonian Postdoctoral Fellow, Harvard-Smithsonian Center for Astrophysics. Post-doctoral advisor: Antony A. Stark

Honors

2001	NSF Antarctica Service Medal with Gold Winterover Bar

Publications

A. A. Stark, C. L. Martin, W. M. Walsh, K. Xiao, A. P. Lane, and C. K. Walker, "Gas Density, Stability, and Starbursts near the Inner Lindblad Resonance of the Milky Way," Astrophysical Journal, Letters **614**, L41 (2004).

C. L. Martin, W. M. Walsh, K. Xiao, A. P. Lane, C. K. Walker, and A. A. Stark, "The AST/RO Survey of the Galactic Center Region. I. The Inner 3 Degrees," Astrophysical Journal, Supplement **150**, 239 (2004).

C. E. Groppi, C. Kulesa, C. Walker, and C. L. Martin, "Millimeter and Submillimeter Survey of the R Coronae Australis Region," Astrophysical Journal **612**, 946 (2004).

C. L. Martin, W. M. Walsh, K. Xiao, A. P. Lane, C. K. Walker, and A. A. Stark, "The Inner 200pc: Hot Dense Gas," Astronomische Nachrichten Supplement **324**, 93 (2003).

S. Kim, C. L. Martin, A. A. Stark, and A. P. Lane, "Antarctic Submillimeter Telescope and Remote Observatory Observations of CO $J = 7 \rightarrow 6$ and $J = 4 \rightarrow 3$ Emission toward the Galactic Center Region," Astrophysical Journal **580**, 896 (2002).

Jet Propulsion Laboratory
California Institute of Technology

4800 Oak Grove Drive
Pasadena, California 91109-8099

(818) 354-4321

JPL

January 24, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Chris,

I am writing to enthusiastically support your proposal ``The High Elevation Antarctic THz Telescope (HEAT)" being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

I anticipate being involved in the instrument/facility planning and the scientific utilization of the new facility. My experience with high frequency receiver systems and as co-Principal Investigator on the Submillimeter Wave Astronomy Satellite (SWAS) is relevant for planning and utilizing an observatory that will have to function largely like a spacecraft. I am very interested in exploiting the submm spectral lines of key molecular and atomic probes of the interstellar medium to investigate conditions in dense clouds particularly those associated with formation of massive stars.

Sincerely,

Paul F. Goldsmith
Senior Research Scientist
Jet Propulsion Laboratory
MS 169 506
818 393-0518

PAUL F. GOLDSMITH
1121 Charles Street
Pasadena CA 91103
tel. (626) 793–2276
email Paul.F.Goldsmith@jpl.nasa.gov

Curriculum Vitae

Citizenship: USA

EDUCATION

American School of Paris, France	High School Dipoma 1965
University of California, Berkeley	A.B. (Physics) 1969
University of California, Berkeley	Ph.D. (Physics) 1975

POSITIONS HELD

2006 -	Senior Research Scientist, Jet Propulsion Laboratory, Calif. Inst. Technology, Pasadena
2005 - 2006	Principal Scientist, Jet Propulsion Laboratory, Calif. Inst. Technology, Pasadena
2005 -	Professor Emeritus of Astronomy, Cornell University
2000,2001,2004	Professeur Invité, Ecole Normale Supérieure, Paris, France
1999 - 2005	James Weeks Professor in the Physical Sciences, Department of Astronomy, Cornell University
1993 - 2002	Director, National Astronomy and Ionosphere Center
1993 - 2005	Professor, Department of Astronomy, Cornell University
1986 - 1992	Professor, Dept. of Physics & Astronomy, University of Massachusetts, Amherst
1982 - 1992	Vice President of Research and Development, Millitech Corporation
1981 - 1986	Associate Professor, Dept. of Physics & Astronomy, Univ. of Massachusetts, Amherst
1980 - 1992	Associate Director, Five College Radio Astronomy Observatory
1977 - 1980	Consultant, Lincoln Laboratory, Lexington, Massachusetts
1977 - 1979	Resident Visitor, Bell Laboratories, Holmdel, New Jersey
1977 - 1981	Assistant Professor, Dept. of Physics & Astronomy, Univ. of Massachusetts, Amherst
1975 - 1977	Member Technical Staff, Bell Laboratories, Crawford Hill Laboratory, New Jersey
1971 - 1975	Research Assistant, Dept. of Physics, University of California, Berkeley
1969 - 1970	Research Physicist, Lawrence Radiation Laboratory, Berkeley, California

HONORS AND AWARDS

Fellow, Insitute of Electrical and Electronics Engineers, 1991
IEEE Microwave Theory & Techniques Society - Distinguished Lecturer, 1992
James Weeks Professor in the Physical Sciences, Cornell University, 1999

NATIONAL &INTERNATIONAL COMMITTEE SERVICE

Joseph Weber Award for Astronomical Instrumentation Committee, American Astronomical Society, 2003-2005

Chair, Scientific and Technical Advisory Committee for Large Millimeter Telescope (LMT) University of Massachusetts, Amherst, and INAOE (Mexico), 1994 -

PUBLICATIONS

Articles

"Collisional Excitation of Carbon Monoxide in Interstellar Clouds," Goldsmith, P.F., Ap.J., 176, 597, 1972.

"Measurement of Atmospheric Attenuation at 1.3 and 0.87 mm with an Harmonic Mixing Radiometer," Goldsmith, P.F., Plambeck, R., and Chiao, R., IEEE Trans. Microwave Theory Tech., MTT-22, 1115, 1974.

"Observations of the J = 2–1 Transition of Carbon Monoxide in Interstellar Clouds," Goldsmith, P.F., Plambeck, R., and Chiao, R., Ap.J., 196, L39, 1975.

"Observations of the $^{12}C/^{13}C$ Ratio in Four Galactic Sources of Formaldehyde," Matsakis, D., Chui, M., Goldsmith, P.F., and Townes, C.H., Ap.J. (Lett.), 206, L63, 1976.

"A 230 GHz Radiometer System Employing a Second Harmonic Mixer," Goldsmith, P.F., and Plambeck, R., IEEE Trans. Microwave Theory Tech., MTT-24, 859, 1976.

"Rotational Excitation of Molecules by Electrons in Interstellar Clouds," Dickinson, A.S., Phillips, T.G., Goldsmith, P.F., Percival, I.C., and Richards, D., Astron. Astrophys., 54, 645, 1977.

"Comparison of J = 2–1 and J = 1–0 Spectra of CO in Molecular Clouds," Plambeck, R., Williams, D.R.W., and Goldsmith, P.F., Ap.J. (Lett.), 213, L41, 1977.

"Isotopic Abundance Variations in Interstellar HCN," Linke, R.A., Goldsmith, P.F., Wannier, P.G., Wilson, R.W., and Penzias, A.A., Ap.J., 214, 50, 1977.

"A Quasioptical Feed System for Radioastronomical Observations at Millimeter Wavelengths, B.S.T.J., 56, 1483, 1977.

"Molecular Cooling and Thermal Balance of Dense Interstellar Clouds," Goldsmith, P.F. and Langer, W.D., Ap.J., 222, 881, 1978.

"Carbon Monoxide Mixing Ratio in the Mesosphere Derived From Ground-Based Microwave Measurements," Goldsmith, P.F., Litvak, M.M., Plambeck, R.L., and Williams, D.R.W., J. Geophys. Res., 84, 416, 1979.

"Microwave Radiometer Blackbody Calibration Standard for Use at Millimeter Wavelengths," Goldsmith, P.F., Kot, R.A., and Iwasaki, R.S., Rev. Sci. Instrum., 50(9), 1120, 1979.

"Tunable Submillimeter Sources Applied to Excited State Rotational Spectroscopy and Kinetics of CH_3F," Blumberg, W., Fetterman, H., Goldsmith, P.F., and Peck, D., Appl. Phys. Lett., 35(8), 1979.

"Evidence for Isotopic Fractionation of Carbon Monoxide in Dark Clouds," Langer, W.D., Goldsmith, P.F., Carlson, E.R., and Wilson, R.W., Ap.J. (Lett.), 235, L39, 1980.

"Observations of Interstellar Carbon Monosulfide – Evidence for Turbulent Cores in Giant Molecular Clouds," Linke, R.A. and Goldsmith, P.F., Ap.J., 235, 437, 1980.

CALIFORNIA INSTITUTE OF TECHNOLOGY
ELECTRICAL ENGINEERING/MS 136-93
1200 E. California Blvd.
Pasadena, CA 91125

January 23, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Chris,

I enthusiastically support your proposal ``The High Elevation Antarctic THz Telescope (HEAT)'' being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

We have extensive experience at Caltech with the development of low noise amplifiers and microwave down-conversion equipment and look forward to supplying these items for the HEAT project.

Sincerely,

Sander Weinreb
Faculty Associate

Curriculum Vitae - Dr. Sander Weinreb

Present Position

Principal Staff Member, Section 385 Caltech Jet Propulsion Laboratory and Faculty Associate, Caltech Electrical Engineering Department.

Education

Ph.D., Electrical Engineering, M.I.T., 1963. Thesis: "A Digital Spectral Analysis Technique and Its Application to Radio Astronomy"
B.S. , Electrical Engineering, M.I.T., 1958

Summary of Major Technical Accomplishments

1. Developed coarse-quantization, digital correlelation techniques that have been widely used in radio astronomy systems for past 30 years.
2. Co-discoverer of the first radio molecular line, OH, observed in radio astronomy (1963)
3. Introduced cooled field-effect transistor and HEMT amplifiers to radio astronomy.(1980)
4. Led the electronics design of the Very Large Array.

Experience

U. of Massachusetts (1996-1998) - Research Professor in the Five College Radio Observatory, Department of Physics and Astronomy.

Lockheed Martin Laboratories (1989-1995): Principal Scientist and Leader of the Millimeter-Wave Design and Test Group. Provided expertise in the areas of millimeter-wave system and component design. He designed or led the design of a radar seeker, a prototype IFF system, two phased-array receiver systems, a radiometric focal plane array system, several high sensitivity radiometer modules, a W-band power amplifier module, and MMIC amplifiers, mixers, multipliers, phase-shifters, detectors, and switches.

U. of Virginia (1988-1989) and U. of California (1976-1978): Taught courses in microwave theory and techniques as a visiting professor.

National Radio Astronomy Observatory (1965-1988): Head of the Electronics Division (1965-1985) and Assistant Director (1985-1988). Led a team of 30 to 70 engineers and technicians and was responsible for the design, construction, operation, and maintenance of radio astronomy receivers at the Green Bank, WV, and Kitt Peak, AZ observatories. Led the design of the $17M electronics system of the Very Large Array, Socorro, NM, on schedule and in-budget. He led the addition of 8.4 GHz cooled HEMT receivers to of the VLA to augment the DSN and receive images from the NASA Voyager Neptune encounter mission; this was successfully accomplished within budget.

Publications

Over 135 publications in the areas of digital correlation techniques, array receivers, low-noise amplifiers, and millimeter-wave receivers. Key publications are:

1. S. Weinreb, "A New Upper Limit to the Galactic Deuterium-to-Hydrogen Ratio," Nature, 195, 367, 1962.
2. S. Weinreb, A. H. Barrett, M. L. Meeks, and J. C. Henry, "Radio Observations of OH in the Interstellar Medium," Nature, 200, 829-831, 1963.
3. S. Weinreb and A. R. Kerr, "Cryogenic Cooling of Mixers for Millimeter and Centimeter Wavelengths," IEEE J. of Solid-State Circuits, vol. SC-8, Feb. 1973.
4. S. Weinreb, R. Predmore, M. Ogai and A. Parrish, "Waveguide System for a Very Large Antenna Array," Microwave Journal, vol. 20, no. 3, March 1977.
5. S. Weinreb, M. Balister, S. Maas, and P. J. Napier, "Multi-Band, Low-Noise Receivers for a Very Large Array," IEEE Trans.MTT, vol. MTT-25, no. 4, April 1977.
6. S. Weinreb, "Low-Noise Cooled GASFET Amplifiers," IEEE Microwave Theory and Techniques, vol. 28, no. 10, October 1980, pp. 1041-1054.
7. S. Weinreb, M. Pospieszalski, and R. Norrod, "Cryogenic, HEMT, Low-Noise Receivers for the 1.3 to 43 GHz Range", S. Weinreb, M. Pospieszalski, and R. Norrod, IEEE 1988 MTT-S Digest

National and International Activities

Visiting Committee, National Radio Astronomy Observatory, Charlottesville, VA, 2001-2004

Fellow of the IEEE (1978) - Elected for "Contributions to Instrumentation in Radio Astronomy

U. S. Delegate to the Soviet Space Research Institute Radioastron Technical Committee, 1986-1987

U.S. Delegate to International Radio Science (URSI) meetings - 1966, 1969, 1972, 1978, and 1995.

Member of Advisory Committee - NASA Search for Extraterrestrial Life Program - Moffett Field, CA, 1991-97.

National Lecturer, 1984, IEEE Microwave Theory and Techniques Society (35 lectures in U.S., Canada, Australia, and New Zealand)

Member of Visiting Committee - Nat. Astronomy & Ionospheric Center (Arecibo),1970-72; Chairman, 1972

Member of Visiting Committee - Netherlands Foundation for Radio Astronomy - 1971 - 1974

Member of Visiting Committee - M.I.T. Haystack Observatory, 1993-1995. Chairman, 1995

Review Papers for IEEE Transactions on Microwave Theory and Techniques and Proposals for NSF

Nominated to Army Science Board, 1991 (Nomination by Assistant Secretary of the Army)

Jet Propulsion Laboratory
California Institute of Technology

4800 Oak Grove Drive
Pasadena, California 91109-8099

(818) 354-4321

January 23, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Professor Walker,

I am submitting this letter in enthusiastic support of your proposal titled “The High Elevation Antarctic THz Telescope (HEAT)” being submitted to the National Science Foundation Major Research Instrumentation (MRI) Program. I fully acknowledge my role as described in the proposal and understand that my participation will be considered during the review process. I am truly excited about the possibility of contributing both device and instrumentation support to this bold and exciting program. Our whole team of submillimeter wave engineers has been fired up by this exciting program and we are all hopeful of its success. We feel that our experiences in developing and delivering state-of-the-art submillimeter wave sensors for four space flight programs to date, will help insure our successful contribution to HEAT.

Yours truly,

Peter H. Siegel
Senior Research Scientist & Technical Supervisor: Submillimeter Wave Advanced Technology team, Jet Propulsion Laboratory
Senior Scientist, Beckman Institute, California Institute of Technology

PETER H. SIEGEL (BS Colgate Univ., 1976, PhD Columbia Univ., 1983) has been involved in the analysis and development of millimeter-and submillimeter-wave sensors for over 30 years. From 1975-1983 he worked on millimeter wave receiver development at the NASA Goddard Institute for Space Studies in NYC, New York under Dr. Patrick Thaddeus and Dr. Tony Kerr. Afterwards he spent three years at the Central Development Laboratory of the National Radio Astronomy Observatory in Charlottesville, Virginia run by Dr. Sandy Weinreb. He came to JPL in 1987 to work on superconducting array receivers for astrophysics applications under Dr. Margaret Frerking. In 1993 he founded the JPL Submillimeter Wave Advanced Technology (SWAT) team, a group of more than 25 engineers and scientists working on the development of submillimeter-wave technology for NASA's near and long term astrophysics, Earth remote sensing, and planetary mission applications. In 2002 Dr. Siegel joined the staff at Caltech as a Senior Scientist at the Beckman Institute, Division of Biology, where he is working on biomedical applications of THz technology. He also maintains a joint appointment as the Technical Group Supervisor for SWAT at JPL, where he continues to propose and work on space and ground-based applications of THz technology.

Dr. Siegel's research team has won numerous JPL awards for their technical achievements and are internationally recognized as leaders in THz technology development. Dr. Siegel has published more than 200 articles on millimeter and submillimeter wave technology and applications, has been PI or co-I on more than 60 programs totaling more than $50M and has received 40 NASA certificates of recognition, four NASA group achievement awards, a NASA Space Act award and is a three time recipient of JPL's award for technical excellence. Dr. Siegel is a member of AAAS, chair of IEEE MTT Committee 4 - Terahertz Technology, an acting IEEE Technical Program Committee member, Vice-Chair of the international organizing committee of the Int. Conf. on Infrared and Millimeter Waves (IRMMW) and an elected Fellow of the IEEE.

POSITIONS HELD

1975-1976	Staff Scientist, Sigma Data Corp., New York City, NY
1976-1983	Graduate Fellow, Columbia Radiation Lab., New York, NY
1976-1983	Research Fellow, Goddard Institute for Space Studies, New York, NY
1983-1984	National Research Council Fellow, Goddard Institute, New York, NY
1984-1987	Member Technical Staff, National Radio Astronomy Obs., Charlottesville, VA
1987-1993	Technical Group Leader/Member of Technical Staff, JPL, Pasadena, CA
1993-	Technical Group Supervisor/Principal Staff, JPL, Pasadena, CA
2002-	Senior Research Scientist, Beckman Inst., Div. of Biology, Caltech, Pasadena, CA
2006-	Senior Research Scientist, Jet Propulsion Laboratory

INVITED PRESENTATIONS:

More than 50 invited talks at universities, industry facilities and conferences including, Caltech, Stanford, MIT, University of Virginia, University of Massachusetts, Arizona State, UCLA, UC Santa Barbara, UC Davis, Univ. of Rochester, Texas A&M, RPI, Occidental College, Cornell Univ., Univ. of Lille, France, Riken Univ. Japan, Helsinki Univ. of Technology, Finland, Tech. Univ. of Denmark, Copenhagen; National and Industry Labs: Lincoln Labs, National Radio Astronomy Observatory, Charlottesville, National Institute of Standards, Gaithersberg, National Institute of Standards, Boulder, Northrop Grumman, Litton, Lockheed Martin, AIL, United Technologies, MPB Canada, Sumitomo Heavy Industries, Japan, Hughes Research Labs, Malibu, Stanford Linear Accelerator, Palo Alto, JPL Board of Gov's, NASA Goddard Space Flight Center, NASA Headquarters, DARPA Headquarters, Rutherford Appleton Labs, UK.

PROFESSIONAL ACTIVITIES:

1984- Reviewer IEEE Trans. Microwave Theory and Tech., Microwave and Guided Wave Let., Electronics Let., IEEE Microwave and Wireless Comp. Let., IEEE Trans. Electron Devices, IEEE Trans. Nanotechnology, many others.
1990-4 Technical Review Board – University of Michigan Center for Space THz Technology.
2002/4 IEEE Microwave Theory & Techniques Committee 4: THz Technology - Co-chair
2002 IEEE Int. Microwave Sym.: Session organizer and chair: THz Technology
2003 DARPA: SWIFT Workshop, Session organizer and chair
2003 IEEE Int. Microwave Sym.: Session organizer and chair: THz Applications
2003 THz Technology Forum of Japan: Inaugural Speaker
2004 DOE: Workshop on THz Science - Session Leader
2004 IEEE Int. Microwave Sym.: Session organizer and chair: THz Technology and Biology
2005 IEEE Int. Microwave Sym.: Session organizer and chair: THz Imaging
2006 IEEE Int. Microwave Sym.: Session organizer and chair: THz Integrated Circuits
2007 IEEE Int. Microwave Sym.: Session organizer and chair: Submillimeter Wave Imaging
2007 IEEE Int. Microwave Sym.: Session organizer and co-chair: THz Astronomy
2005/7 IEEE Microwave Theory and Techniques Committee 4: THz Technology: Chair
2005/7 Int. Org. Committee: Int. Conf. on Infrared and Millimeter Waves: Vice-Chair

RECOGNITION:

1974 Harvey Picker Physics Prize, Colgate University
1978 Eta Kappa Nu, Columbia University
1983 National Research Council Fellowship, NASA
1989- NASA Certificates of Recognition for Technical Work - 40 since joining JPL
1994 Technology and Applications Program commendation for Exceptional Performance - JPL
1997 Nova Award for Excellence – Submillimeter Wave Advanced Technology Team, JPL
1998 Indium Phosphide and Related Materials, Best Paper of Decade Award, (co-author)
1998 Award for Excellence: Exceptional Leadership, JPL
1999 Award for Excellence: Level B Cross Directorate, JPL
2000 Who's Who in Science and Engineering
2000 Award for Excellence: Technical Excellence - MOMED Development Team, JPL
2001 Award for Excellence: Technical Excellence – SWAT Local Oscillator Dev. Team, JPL
2001 Fellow of the IEEE
2002 Featured Interview: Chem Matters magazine
2003 Team Award: SWAT Herschel HIFI LO Development, JPL
2003 Team Award: SWAT MLS Tripler Development, JPL
2004 NASA Space Act Award
2005 IEEE Distinguished Microwave Lecturer
2005 NASA Goddard Space Flight Center- Aura Team Award

PUBLICATIONS AND PROGRAM INVOLVEMENT:

200 articles in conferences and refereed journals including one book chapter.
40 New Technology Reports (NASA Tech Briefs), 3Patents
PI or Co-I on 60 research and development programs totaling $50M.
Four supervised theses: 2 Bachelor's (Caltech), 1 Masters (MIT), 1 PhD (Univ. of Paris).
Significant involvement in four space flight programs: NASA Upper Atmospheric Research Satellite, NASA Aura, ESA Rosetta, ESA Herschel Space Telescope.

January 24, 2007

Prof. Christopher K. Walker
Steward Observatory
University of Arizona
933 N. Cherry Ave.
Tucson, Arizona 85721

Dear Chris,

I am writing to enthusiastically support your proposal "The High Elevation Antarctic THz Telescope (HEAT)" being submitted to the NSF Major Research Instrumentation (MRI) Program. I acknowledge my role as described in the proposal and realize my participation will be considered during the review process.

I believe that with my extensive experience in the design of Schottky-based submillimeter systems, including both sources and mixers, that I will be able to benefit the Instrument Team. Of particular relevance for this proposal is the experience I gained as the P.I. on a NASA SBIR Phase II grant ("Compact Terahertz Heterodyne Receivers," NAS5-02107) which involved the successful design and implementation of a series of state-of-the-art Schottky receivers up to 1 THz. These receivers are now being used in an airborne platform for monitoring the properties of ice-clouds in the atmosphere. The technical requirements of these receivers were similar in many ways to those needed for the HEAT program, including high sensitivity, ruggedness, stability and low DC power requirement. In addition, I have worked on the design of a wide variety of local oscillator systems for astronomical receivers (typically based on SIS or HEB cryogenic technology) at frequencies ranging from 100 GHz to 1.9 THz, experience which will also be quite relevant to this proposal.

Sincerely,

Jeffrey L. Hesler
Vice-President, Virginia Diodes, Inc.
(434) 297-3257

Visiting Assistant Research Professor
University of Virginia
Dept. of Electrical & Computer Engineering

Jeffrey Lee Hesler

Vice President
Virginia Diodes, Inc.
Charlottesville, Virginia
e-mail: hesler@vadiodes.com

Visiting Research Assistant Professor
Department of Electrical & Computer Engineering
University of Virginia
Charlottesville, Virginia

Overview

Dr. Hesler's career is focused on the creation of new technologies that are making possible the full exploitation of the terahertz frequency band for scientific, defense and industrial applications. Over the past fifteen years his efforts have focused on developing terahertz components and systems, including frequency multipliers and mixers, frequency selective surfaces, receivers, local oscillators, spectrometers, etc. Terahertz systems based on his innovative designs are now used in research laboratories throughout the US, Europe, Asia and the Middle East. These often unique systems are enabling ground-breaking scientific measurements in diverse fields such as astronomy, chemical spectroscopy, plasma and accelerator diagnostics, weather and environmental monitoring, imaging, antenna test ranges, and THz radar characterization.

As a faculty member at the University of Virginia Dr. Hesler led the development of advanced THz components and systems for compact range radars and environmental sensing. He served as the PI on several research grants from NASA and supervised two Master of Science theses and two Doctoral dissertations. He has also published over 70 technical papers in refereed international conferences and journals.

In 2001 Dr. Hesler joined Virginia Diodes Inc. (VDI), where he serves as a member of the Board of Directors, a shareholder, and Vice-President of the corporation. At VDI Dr. Hesler is a leader in the development of THz components and systems, with emphasis on THz receivers, spectroscopy systems, and broadband high sensitivity transceivers. A specific example of his efforts was the invention of a new, broadband frequency tripler design that has yielded exceptional broadband (tunerless) performance and is remarkably easy to fabricate in large volume. This new design is now an enabling component in the local oscillator systems of Atacama Large Millimeter Wave Array; a large (~$500M) international project to build an array of 50+ astronomical antennas for the frequency range 100-1000 GHz.

Employment History

Vice President (April 2001 to present) Virginia Diodes, Inc., Charlottesville, Virginia.

- Development of novel THz components including broadband triplers, quintuplers, mixers, detectors, harmonic mixers, and frequency selective surfaces.
- THz system development, including broadband sources, receivers, spectrometers, transceivers, and phase measurement systems.
- P.I., SBIR Phase II "Compact Terahertz Heterodyne Receivers," NAS5-02107. Contract resulted in the successful design and implementation of a series of state-of-the-art Schottky receivers up to 1 THz. Project completed successfully in 2005, and the receivers are now being used in airborne measurements.
- P.I., SBIR Phase II "Metal Mesh Filters for Terahertz Receivers," NNC06CB68C. Project is in progress, and has already resulted in the development of novel methods to economically fabricate large mesh filters at center frequencies up to 2 THz.

Visiting Research Assistant Professor (November 1997 to present) University of Virginia Department of Electrical & Computer Engineering, Charlottesville, Virginia. Status was changed to "Visiting" in 2004.

- High efficiency heterostructure-barrier-varactor frequency multipliers with state-of-the-art performance.
- Development of novel THz phase-shifting components for use as modulators and frequency upconverters.
- Development of subharmonic mixers at submillimeter wavelengths for space-based applications.

Education

University of Virginia, Charlottesville, VA, **Doctorate of Philosophy** in Electrical Engineering, Jan. 1996
Dissertation: *Planar Schottky Diodes In Submillimeter-Wavelength Waveguide Receivers*
University of Virginia, Charlottesville, VA, **Master of Science** in Electrical Engineering, May 1991
Thesis: *Noise Measurement of Schottky Diodes*
Virginia Tech, Blacksburg, VA, **Bachelor of Science** in Electrical Engineering, *cum laude*, May 1989

Selected Journal Publications

H. Xu, Y. Duan, J.L. Hesler, and R.W. Weikle, "Subharmonically Pumped Millimeter-Wave Upconverters Based on Heterostructure Barrier Varactors," *IEEE Trans. Microwave Theory Tech.*, Vol. 54, pp. 3648 - 3653, Oct. 2006.

H. Xu, Z. Liu, C.H. Smith, J.L. Hesler, B.S. Deaver, and R.M. Weikle, "A Non-Contacting Tunable Waveguide Backshort for Terahertz Applications," 2006 IEEE MTT-S International Microwave Symposium Digest, pp. 1919-1922, June 2006.

J. Hesler, W. Bishop, and T. Crowe, "Multiplier Development for the Upper ALMA Local Oscillator Bands", Proc. 17th Intl. Symposium on Space Terahertz Technology, May, 2006, Paris, France.

T. Crowe, W. Bishop, D. Porterfield, J. Hesler, R. Weikle, "Opening the Terahertz Window With Integrated Diode Circuits," IEEE Jrnl. Of Solid State Circuits, Vol. 40, No. 10, October 2005, pp. 2104-2110.

Xiao Q., Duan Y., Hesler J.L., Crowe T.W., and Weikle RM, "A 5 mW and 5% efficiency 210 GHz InP-based heterostructure barrier varactor quintupler," Microwave and Wireless Components Letters, Volume 14, pp. 159 – 161, April 2004.

D.S. Kurtz, J.L. Hesler, T.W. Crowe, R.M. Weikle, "Submillimeter-Wave Sideband Generation Using Varactor Schottky Diodes," *IEEE Trans. Microwave Theory Tech.*, Vol. 50, pp. 2610-2617, Nov. 2002.

Roland Feinäugle, Heinz-Wilhelm Hübers, Hans Peter Röser, and Jeffrey L. Hesler, "On the Effect of IF Power Nulls in Schottky Diode Harmonic Mixers," *IEEE Trans. Microwave Theory Tech.*, Vol. 50, pp. 134-142, Jan. 2002.

J.L. Hesler, K. Hui, T.W. Crowe, R.M. Weikle, C.M. Mann, and R. Dahlstrom, "Analysis of an Octagonal Micromachined Horn Antenna for Submillimeter-Wave Applications," *IEEE Trans. on Antennas and Propagation*, Vol. 49, pp. 997-1001, June. 2001.

K. Hui, J.L. Hesler, D.S. Kurtz, W.L. Bishop, and T.W. Crowe, "A Micromachined 585 GHz Schottky Mixer," *IEEE Microwave Guided Waves Lett.*, Vol. 10, no. 9, pp. 374 -376, Sept 2000.

Kurtz, D.S.; Hesler, J.L.; Crowe, T.W.; Weikle, R.M., II, "Millimeter-wave sideband generation using varactor phase modulators," *IEEE Microwave Guided Waves Lett.*, Vol. 10, no. 6, pp. 245 -247, June 2000.

J.L. Hesler, D. Kurtz, and R. Feinäugle, "The Cause of Conversion Nulls for Single-Diode Harmonic Mixers," *IEEE Microwave Guided Waves Lett.*, Vol. 9, no. 12, pp. 532-534, Dec. 1999.

T.W. Crowe, J.L. Hesler, R.M. Weikle, and S.H. Jones, "GaAs Devices and Circuits for Terahertz Applications," *Infrared Physics and Technology*, Vol. 40, pp. 175-189, June 1999.

J.L. Hesler, W.R. Hall, T.W. Crowe, R.M. Weikle, II, B.S. Deaver, Jr., R.F. Bradley, and S.-K. Pan, "Fixed-Tuned Submillimeter Wavelength Waveguide Mixers Using Planar Schottky Barrier Diodes," *IEEE Trans. Microwave Theory Tech.*, Vol. 45, pp. 653-658, May 1997.

D.W. Porterfield, J.L. Hesler, R. Densing, E.R. Mueller, T.W. Crowe, and R.M. Weikle, "Resonant Metal Mesh Bandpass Filters for the Far-Infrared," *Applied Optics*, Vol. 33, No. 25, pp. 6046-6052, Sept. 1994.

S.S. Gearhart, J.L. Hesler, W.L. Bishop, T.W. Crowe, and G.M. Rebeiz, "A Wide-Band 760-GHz Planar Integrated Schottky Receiver," *IEEE Microwave Guided Waves Lett.*, Vol. 3, pp. 205-207, July 1993.