02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

Submit only ONE copy of this form **for each PI/PD and co-PI/PD** identified on the proposal. The form(s) should be attached to the original proposal as specified in GPG Section II.C.a. Submission of this information is voluntary and is not a precondition of award. This information will not be disclosed to external peer reviewers. ***DO NOT INCLUDE THIS FORM WITH ANY OF THE OTHER COPIES OF YOUR PROPOSAL AS THIS MAY COMPROMISE THE CONFIDENTIALITY OF THE INFORMATION.***

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

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:
Hispanic or Latino. A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race.
Race Definitions:
American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
Asian. A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
Black or African American. A person having origins in any of the black racial groups of Africa.
Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
White. A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

WHY THIS INFORMATION IS BEING REQUESTED:

The Federal Government has a continuing commitment to monitor the operation of its review and award processes to identify and address any inequities based on gender, race, ethnicity, or disability of its proposed PIs/PDs. To gather information needed for this important task, the proposer should submit a single copy of this form for each identified PI/PD with each proposal. Submission of the requested information is voluntary and will not affect the organization's eligibility for an award. However, information not submitted will seriously undermine the statistical validity, and therefore the usefulness, of information recieved from others. Any individual not wishing to submit some or all the information should check the box provided for this purpose. (The exceptions are the PI/PD name and the information about prior Federal support, the last question above.)

Collection of this information is authorized by the NSF Act of 1950, as amended, 42 U.S.C. 1861, et seq. Demographic data allows NSF to gauge whether our programs and other opportunities in science and technology are fairly reaching and benefiting everyone regardless of demographic category; to ensure that those in under-represented groups have the same knowledge of and access to programs and other research and educational oppurtunities; and to assess involvement of international investigators in work supported by NSF. The information may be disclosed to government contractors, experts, volunteers and researchers to complete assigned work; and to other government agencies in order to coordinate and assess programs. The information may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records", 63 Federal Register 267 (January 5, 1998), and NSF-51, "Reviewer/Proposal File and Associated Records", 63 Federal Register 268 (January 5, 1998).

02 INFORMATION ABOUT PRINCIPAL INVESTIGATORS/PROJECT DIRECTORS(PI/PD) and co-PRINCIPAL INVESTIGATORS/co-PROJECT DIRECTORS

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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 ☒

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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 13-1 **NSF 12-589** **11/15/13**	**FOR NSF USE ONLY** **NSF PROPOSAL NUMBER**
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **AST - ASTRNMY & ASTRPHYS RES GRANTS**	**1410368**

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
11/13/2013	1	03020000 AST	1678	806345617	11/19/2013 8:01pm S

EMPLOYER IDENTIFICATION NUMBER (EIN) OR TAXPAYER IDENTIFICATION NUMBER (TIN)	SHOW PREVIOUS AWARD NO. IF THIS IS	IS THIS PROPOSAL BEING SUBMITTED TO ANOTHER FEDERAL AGENCY? YES ☐ NO ☒ IF YES, LIST ACRONYM(S)
742652689	☐ A RENEWAL ☐ AN ACCOMPLISHMENT-BASED RENEWAL	

NAME OF ORGANIZATION TO WHICH AWARD SHOULD BE MADE **University of Arizona**	ADDRESS OF AWARDEE ORGANIZATION, INCLUDING 9 DIGIT ZIP CODE **TUCSON, AZ 857210001** **US**
AWARDEE ORGANIZATION CODE (IF KNOWN) **0010835000**	
NAME OF PRIMARY PLACE OF PERF **University of Arizona**	ADDRESS OF PRIMARY PLACE OF PERF, INCLUDING 9 DIGIT ZIP CODE **University of Arizona** **933 N. Cherry Ave** **Tucson ,AZ ,857210001 ,US.**

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

TITLE OF PROPOSED PROJECT **A Submillimeter Spectroscopic Galactic Plane Survey using Supercam at the HHT**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 339,569	36 months	09/01/14	

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

- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
- ☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.D, II.C.1.d)
- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ EAGER* (GPG II.D.2) ☐ RAPID** (GPG II.D.1)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ________
  PHS Animal Welfare Assurance Number ________
- ☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ________
  Exemption Subsection ______ or IRB App. Date ________
- ☐ INTERNATIONAL COOPERATIVE ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
  ____

PI/PD DEPARTMENT **Astronomy**	PI/PD POSTAL ADDRESS **933 N. Cherry Ave** **Tucson, AZ 85721** **United States**
PI/PD FAX NUMBER **520-621-1532**	

NAMES (TYPED)	High Degree	Yr of Degree	Telephone Number	Email Address
PI/PD NAME **Craig A Kulesa**	PhD	2002	520-621-6540	ckulesa@email.arizona.edu
CO-PI/PD **Christopher K Walker**	PhD	1988	520-621-8783	cwalker@as.arizona.edu
CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant 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 conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide,Part I: the Grant Proposal Guide (GPG). 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).

Conflict of Interest Certification

When the proposing organization employs more than fifty persons, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Conflict of Interest:
By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the organization has implemented a written and enforced conflict of interest policy that is consistent with the provisions of the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Section IV.A;
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 organization's expenditure of any funds under the award, in accordance with the organization'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 Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 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 Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 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.

Certification Regarding Nondiscrimination

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is providing the Certification Regarding Nondiscrimination contained in Exhibit II-6 of the Grant Proposal Guide.

Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant located in FEMA-designated special flood hazard areas is certifying that adequate flood insurance has been or will be obtained in the following situations:
(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

Certification Regarding Responsible Conduct of Research (RCR)
(This certification is not applicable to proposals for conferences, symposia, and workshops.)

By electronically signing the Certification Pages, the Authorized Organizational Representative is certifying that, in accordance with the NSF Proposal & Award Policies & Procedures Guide, Part II, Award & Administration Guide (AAG) Chapter IV.B., the institution has a plan in place to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students and postdoctoral researchers who will be supported by NSF to conduct research.
The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

Certification Regarding Federal Tax Obligations

When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

Certification Regarding Unpaid Federal Tax Liability

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

Certification Regarding Criminal Convictions

When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Criminal Convictions:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has not been convicted of a felony criminal violation under any Federal law within the 24 months preceding the date on which the certification is signed.

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Mary Gerrow**	**Electronic Signature**	**Nov 13 2013 12:36PM**

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

* EAGER - EArly-concept Grants for Exploratory Research
** RAPID - Grants for Rapid Response Research

PROJECT SUMMARY

Overview:

In recent years, a multitude of infrared and (sub)mm continuum surveys have provided a rich census of interstellar clouds and star formation in the Galaxy. However, the corresponding spectroscopy needed to transform these surveys into a comprehensive understanding of Galactic structure and dynamics remains an urgent need. Here, funds are requested to operate Supercam, the world's largest, most powerful submillimeter-wave heterodyne array receiver for use at the 10-meter Heinrich Hertz Telescope (HHT), in support of a Galactic Plane Spectroscopic Survey in CO J=3-2 and HCO+ J=4-3. Indeed, this key project was the scientific foundation for Supercam's design and construction through NSF's MRI program. This 64-beam imaging spectrometer operates in the astrophysically rich 850 micron atmospheric window, where the HHT has high aperture efficiency and good atmospheric transmission more than 50% of the winter season. With Supercam's successful engineering runs at the HHT in May 2012 and 2013, the promise of rapid, large-scale spectroscopic mapping at submillimeter wavelengths is now realizable.

Intellectual Merit :

The high throughput, mapping speed, and good angular resolution achievable with Supercam at the HHT uniquely probes the evolution of the interstellar medium in our Galaxy. This effort, the northern portion of the Galactic Plane Survey, will span from l=0 to 90 degrees with |b|<1 degree, with targeted observations spanning an additional 60 square degrees in the Outer Galaxy. In these regions, Supercam will map every major star forming complex, infrared dark cloud, star(less) cloud core, and sense the complex kinematics associated with Galactic rotation, cloud dynamics, collisions, and protostellar outflows. Supercam's surveys will dramatically improve our understanding of interstellar matter and the relationship between stars and gas in the Galaxy; they will explore the life cycles of molecular clouds -- how they form, evolve and are disrupted, and how material cycles between the phases of the ISM. They will relate how and under what conditions molecular clouds form stars, and how outflows, shocks, turbulence and radiation regulate star formation. To put Galactic observations into broad extragalactic context, a template of Milky Way star formation will be constructed. These observations, combined with existing CO and HI data, will help establish the use of the Milky Way as a ‘‘Rosetta Stone’’ for understanding the large-scale interplay (feedback) between stars and gas, which can then be applied to distant galaxies.

Broader Impacts :

The proposed surveys with Supercam are especially timely. They build on the massive legacy of continuum surveys from Spitzer, Herschel, 2MASS, BGPS and UKIDSS. They will provide a crucial spectroscopic counterpart; definitive spectral maps of the Galaxy will be compared to terahertz observations from Herschel and SOFIA, and serve as ideal ’finding charts’ for high-resolution follow-up with ALMA. These data therefore are highly complementary and have broad applicability. To maximize their impact, the Supercam surveys will be broadly disseminated to the astronomical community without a proprietary period. Supercam will also be available as a PI instrument at the HHT; the existing outside observer program provides access. Finally, constructing the Supercam array has been a interdisciplinary, team effort involving students from astronomy, optical sciences, and electrical engineering. Operating and optimizing such instrumentation for science is similarly complex, requiring the talents of many individuals to bring them to fruition. Providing students with technical and scientific training, and team-work experience increases their probability 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.B.2.

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

1.1 High Elevation Antarctic Terahertz (HEAT) telescopes for Ridge A

In 2010, the PI initiated an NSF-funded (ANT-0944335, 10/2010-9/2014) program to build two 60 cm terahertz telescopes for robotic operation at the summit of the Antarctic high plateau with the dual purpose of site testing and performing leading edge terahertz astronomy. These High Elevation Antarctic Terahertz (HEAT) telescopes operate from 150 to 600 microns wavelength and observe the brightest and most diagnostic far-infrared lines in the Galaxy. An international collaboration with Australia's University of New South Wales provided the PLATeau Observatory for Ridge A (PLATO-R), a platform for power and satellite communication. In January 2012, PLATO-R and the first HEAT prototype were successfully deployed to Ridge A and have performed admirably. A servicing mission to Ridge A in which the second-generation HEAT telescope will be installed is scheduled for January 2014. HEAT is the world's first robotic THz telescope. It has the first cryogenic receiver system in the deep field that operates for a full year between servicing missions. HEAT is showing that the Ridge A site is the best site on the planet from which to perform terahertz observations, with 10× more observing days suitable for 200 μm observations than Chajnantor (e.g. ALMA). Already, a preliminary public data release of 809 GHz (370 μm) data of atomic carbon J=2-1 line emission returned via Iridium satellite has been made available at `http://soral.as.arizona.edu/heat/`. Incremental followup data releases are expected 1-2 times per year for the duration of the program.

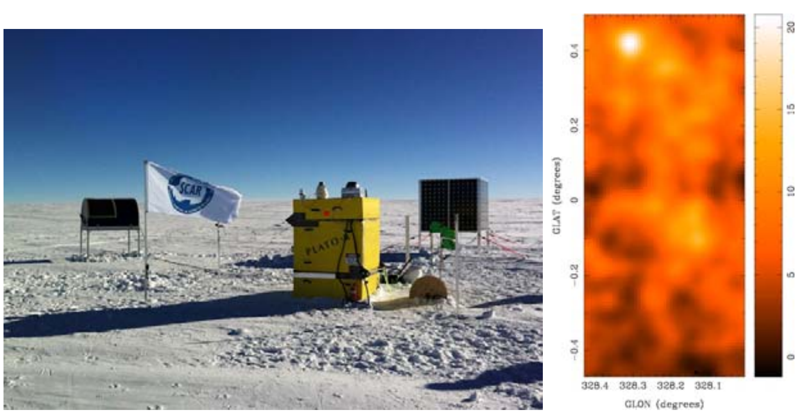


Figure 1: (left) The PLATeau Observatory and 60 cm HEAT telescope at Ridge A, Antarctica installed in January 2012. (right) The first 0.6 sq.deg. integrated intensity map in 370 μm [CI] emission returned by HEAT via onboard data processing and Iridium satellite downlink. The highly extended emission observed directly probes the *dark molecular gas*, i.e. H_2 clouds with little CO emission.

1.2 Supercam: A 64-beam Heterodyne Array Receiver at 850 μm

In 2005, this team initiated an NSF-funded (AST-0421499, 1/2005-12/2009, PI: C. Walker) program to design and construct the first integrated heterodyne focal plane array at submillimeter wavelengths: 64 beams in the astrophysically important 850 μm atmospheric window. Supercam was designed to be used at the Arizona Radio Observatory (ARO) 10-meter Heinrich Hertz Telescope (HHT) on Mt. Graham, Arizona to conduct its key project, a Galactic Plane survey in the ^{12}CO J=3$\rightarrow$2 line (the purpose of this proposal). Each component of Supercam has been modularized in units of 1×8 rows of the full heterodyne array (Figure 2). Thus, the mixer blocks, bias electronics, IF processors, and digital FFT spectrometers are quantized into modules that provide 8 detector "pixels" each. This one-dimensional integration is crucial to the realization of large format heterodyne arrays and has been successfully completed by the Supercam team (Figure 2).

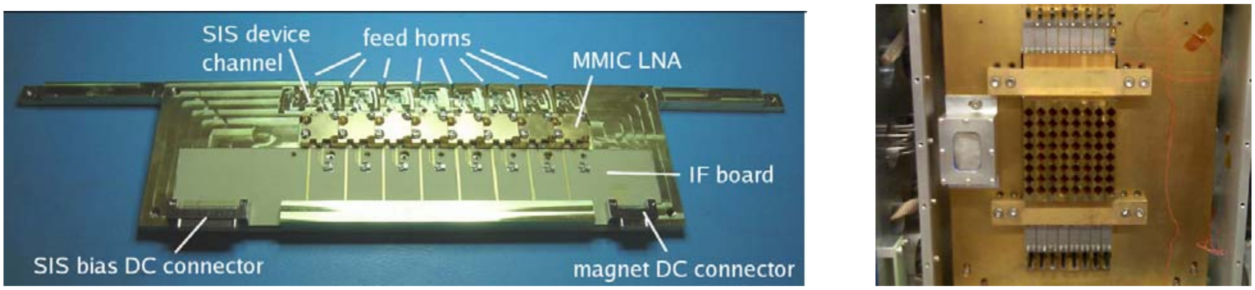


Figure 2: Left: The centerpiece of the Supercam heterodyne array is the integrated mixer block; comprised of 8 feedhorns, SIS mixers, MMIC low noise amplifiers, and nano IF & DC connectors. The final 64-beam focal plane consists of 8 such mixer modules. Right: Zoom-in on the opened Supercam cryostat, showing the fully populated 64-beam focal plane.

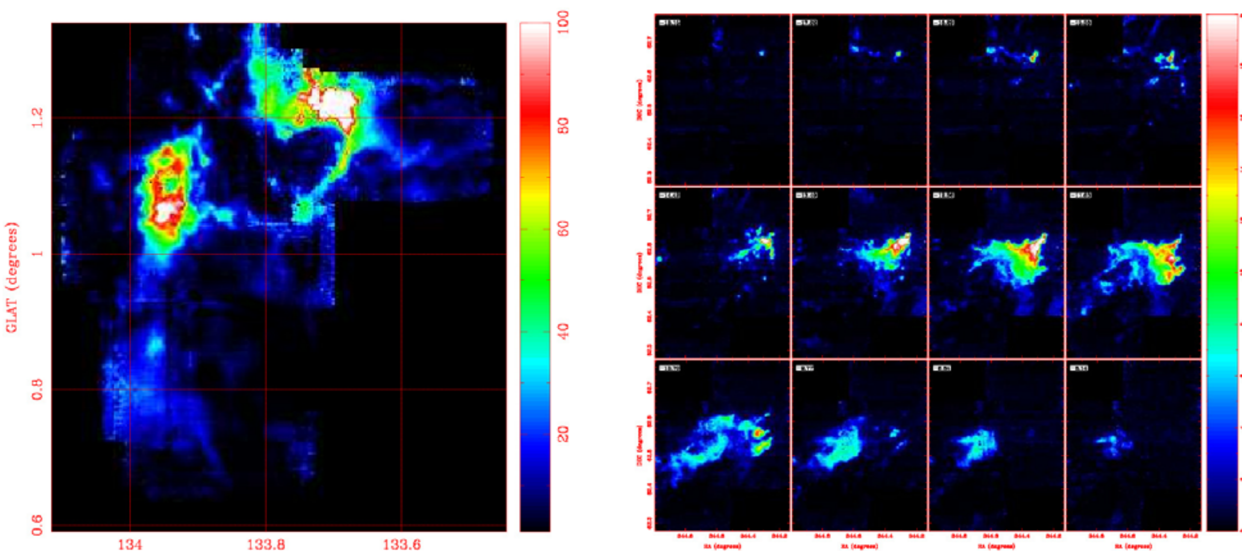


Figure 3: A sample of first light maps at 345 GHz made with Supercam at the HHT in late May 2012. Left: Integrated intensity map of CO J=3-2 line emission over 40'x40' of the W3 molecular cloud. Right: Channel maps spanning 24'x30' of the Cepheus A molecular cloud show complex kinematics. Each image represents the emission in 1 km/s bins from V_{LSR} = -18 to -6 km/s. Despite the poor early-summer weather and a reduced pixel count, these large-scale maps were made in a few hours each.

The full Supercam instrument was successfully installed on the HHT in May 2012. Despite the comparatively poorer weather near the end of the observing season, Supercam achieved first light and delivered more than 1 million spectra per day. Supercam's relay optics delivered a 23" diffraction-limited beam and 60% beam efficiency in nearly every pixel. Two sample maps from that engineering run are shown in Figure 3. The yield of pixels with good sensitivity ($T_{rec} < 100$K DSB) during the engineering run was approximately 55%. Optimization of devices in the focal plane took place in Fall 2012 and Spring 2013, and the focal plane now achieves the desired uniformity and sensitivity. Only the few (8) remaining bad 'pixels' will be replaced before the proposed work effort begins. The current instrument performance is shown in Figure 4(left) and the corresponding mapping speed is shown as a function of frequency in Figure 4(right), dominated by the atmospheric transmission in the 350 GHz band. At the frequencies of interest, near CO J=3-2 and HCO^+ J=4-3, the mapping rate is approximately 4-5 hours per square degree, or **5-6 square degrees per day**. This sharply contrasts to the 4-5 days per square degree that is typically expended at (easier) mm wavelengths using the ALMA Band 6 (1.3mm) prototype receiver at the HHT. *This is the specific enabling result which motivates the Galactic Plane survey proposed here.*

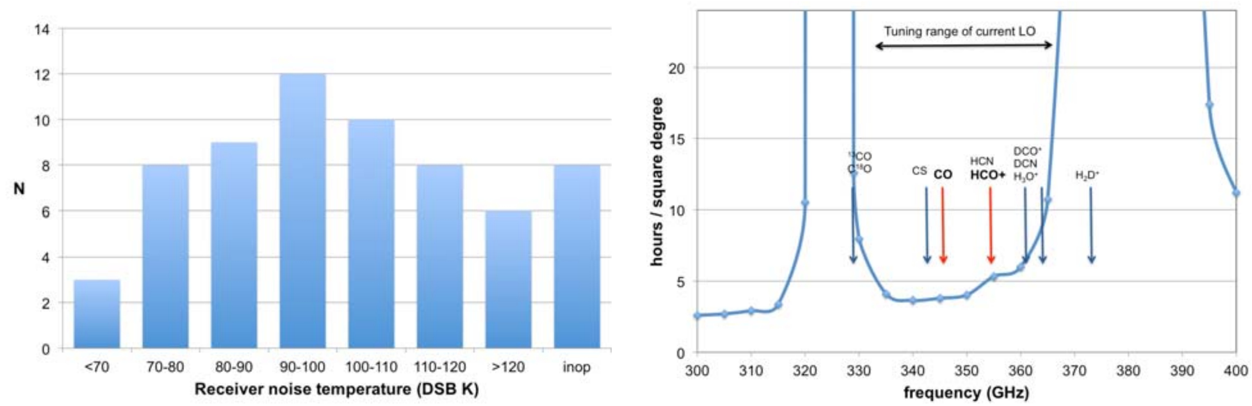


Figure 4: (left) Expected performance of Supercam based on laboratory receiver testing. The mean noise temperature of working devices is 90K DSB and the focal plane yield of good devices is projected to be 75%. (right) Corresponding mapping speeds at the HHT, assuming an rms noise level of 0.2 K km/s in median winter weather at a zenith angle of 30^o. Near the spectral lines of interest, the mapping speed will be approximately 5 square degrees per day.

2 Research Activities

Supercam will enable innumerable astronomical research opportunities as an available PI instrument at the HHT, open to all users. However, its high angular and spectral resolution, coupled with an exceptional field of view makes it *a truly exceptional Galactic Survey instrument*, which provided the primary motivation for its construction. Here, we outline a first Supercam "key project", a submillimeter CO and HCO^+ survey of the Galactic Plane observable from Arizona.

2.1 Introduction: Critical questions this proposal will address

The evolution of (the stellar population of) galaxies is determined to a large extent by the life cycles of interstellar clouds: their creation, star-forming properties, and subsequent destruction by both natal and dying (massive) stars. The need to understand the evolution of interstellar clouds as they directly relate to star formation and galaxy evolution has become acute. The most recent decadal survey, "Astro2010: New Worlds, New Horizons", specifically identifies the questions "*What controls the mass-energy-chemical cycles within galaxies*", "*how do stars form*", "*what determines the star formation rates and efficiencies in molecular clouds*", and "*what determines* *the properties of pre-stellar cloud cores and what is the origin of the stellar mass function*" as among the key questions for radio and (sub)millimeter facilities in this decade. Further, the specific recommendation is made: **"A large-field mapper operating at millimeter and submillimeter wavelengths is required to pave the way for follow-up observations with ALMA"**. Supercam is a direct answer to this recommendation **and is ready now**.

This project aims to increase our understanding of the interactions between stars and the molecular clouds which form them. Stars affect their environments through the direct input of kinetic energy and by radiation which ionizes or heats adjacent molecular gas. This proposed survey will yield major new results targeted at answering specific questions about molecular clouds, star formation, and stellar feedback:

(1) How do molecular clouds form, evolve, and get disrupted? How do typical atoms and grains cycle through the ISM; in particular, how do molecular clouds relate to the atomic hydrogen component of the ISM? Is there statistical evidence that molecular clouds may be formed by colliding streams or filaments of HI as has been shown in hydrodynamical models (Heitsch et al., 2006)?

(2) How and under what conditions do molecular clouds form stars? What role does the underlying physical structure of molecular clouds and their dense cores have on the mass function of stars that result?

(3) What are the effects of HII regions on their associated molecular clouds? To what extent does cloud compression caused by expanding HII regions trigger the formation of dense cores and subsequent star formation? To what extent do the dynamical, heating and ionization effects of OB stars and their HII regions destroy associated molecular clouds?

(4) What is the evolutionary and dynamical state of molecular cloud cores?

(5) How does the Galactic environment impact the formation of clouds and stars? What are the specific roles of spiral arms, central bars, and infall and other influences from outside the Galaxy? Can star formation in the Milky Way be synthesized into a "template" to help interpret star formation in distant, unresolved galaxies?

We will use Supercam, the aforementioned state-of-the-art 64-beam heterodyne array to map a large, 240 square degree region of the Galactic Plane in the J=3-2 transition of CO and the J=4-3 transition of HCO^+ from the HHT. The proposed observations exploit the unique capabilities of Supercam, namely efficient, rapid, high-fidelity spectral mapping over large angular scales. The survey angular resolution, 23", will yield maps superior in resolution and sensitivity to any other imaging data yet presented over comparably large areas of sky. We will also employ other available data to form as comprehensive a picture as possible of the ISM and the stellar content of Galactic interstellar clouds. With detailed kinematic analyses, it will be possible to compare our data with predictions of numerical hydrodynamical models of the ISM and thereby to constrain the physical mechanisms resulting from stellar energy injection and the resulting feedback which regulates the star formation process. We emphasize that these properties can only be determined from well-sampled large-area maps that cover a wide range of spatial scales. **Single-dish telescopes are key to making high-fidelity images of the ISM with high spectral resolution and spatial dynamic range**. With the advent of ALMA, sensitive, high resolution imaging of relatively small regions is now possible. However, large-scale imaging with ALMA is prohibitively time consuming; this is a task most effectively performed by precision single-dish telescopes outfitted with multi-beam receivers like Supercam.

2.2 *Properties of the Proposed Survey*

The following properties represent a definitive survey that would not only provide the clearest view of the star forming clouds in the Galaxy, but also serve as the definitive reference for focused follow-up studies with the SMA, CARMA and ALMA interferometers and LMT.

2.2.1 *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 BOLOCAM at the CSO, both techniques have performed large area maps of molecular material. In the past decade, continuum surveys at mid-infrared (GLIMPSE & MIPSGAL; Benjamin et al. 2003), submillimeter (Hi-GAL; Molinari et al. 2010), and ATLASGAL; Schuller et al. 2009, Contreras et al. 2012), and millimeter wavelengths (BGPS, Aguirre et al. 2011) have cataloged dense star forming clumps throughout the Galaxy. The Bolocam Galactic Plane Survey (BGPS) has discovered over 8400 sources in the Galactic plane (Rosolowsky et al. 2010). 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. Supercam will make it feasible, for the first time, to obtain a complete spectral map of the Galactic plane in a moderate (CO J=3-2) and dense (HCO^+ J=4-3) gas molecular tracer, for direct comparison with these surveys.

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 of 1 km s^{-1} or better, a cloud's kinematic location can be distinguished from other phenomena that alter the lineshape, such as turbulence, rotation, and local phenomena 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.

Supercam resolves the intrinsic profiles of Galactic CO and HCO^+ lines, with a per-channel resolution of 0.2 km s^{-1}. Supercam's IF center frequency will be adjusted to allow simultaneous observations of both lines, CO 3-2 in the lower sideband and HCO^+ 4-3 in the upper sideband. Supercam's mixers are optimized for double sideband operation, with a sideband ratio of $\sim$1. The spectral bandwidth will scale with the known CO velocity dispersion (Dame, Hartmann, & Thaddeus, 2001): ($l > 20^o$), all 64 pixels will observe both spectral lines simultaneously, with 110 km s^{-1} of bandwidth each. In the Inner Galaxy ($l < 20^o$), all 64 pixels will observe CO J=3-2 and HCO^+ in separate OTF maps to give each line the full 220 km s^{-1} of bandwidth each (comparable to the Galactic disk rotational velocity). Local Oscillator (LO) doppler tracking will ensure that the Galactic emission profiles stay within their spectral bandpasses.

2.2.2 *A Submillimeter Survey in CO and HCO^+*

CO is second only to H_2 as the most abundant molecule in the ISM, and it remains the most accurate, most sensitive tracer of H_2 on large scales. Molecular line surveys have been performed over the entire sky in the light of the 2.6 millimeter $J = 1 - 0$ line of ^{12}CO, and have been used to synthesize our best understanding of the molecular content of the Galaxy. Still, our understanding of Galactic molecular clouds is incomplete. Early results were obtained with large beams (Dame et

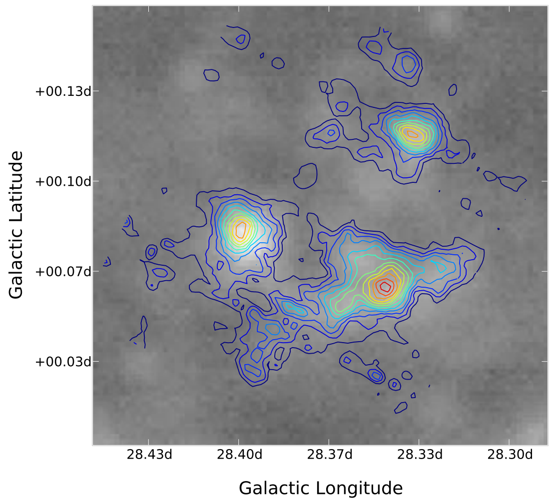


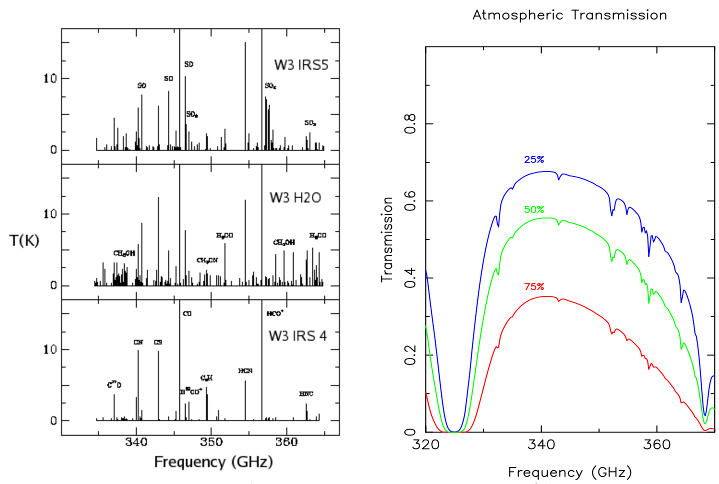
Figure 5: Integrated intensity maps ($\int T_{mb}\,dv$, 3σ contours) of G28.37+0.08 in HCO^+ J=3-2 obtained with the HHT overlaid on greyscale 1.1mm images (Battersby et al. 2010). Since the excitation conditions for HCO^+ J=4-3 are not drastically different from HCO^+ J=3-2, we expect the J=4-3 emission to be extended and mappable.

al., 1987; Dame, Hartmann, & Thaddeus, 2001), were undersampled (Solomon, Rivolo, Barrett, & Yahil, 1987; Scoville et al., 1987); or had limited areal coverage, e.g., the early FCRAO surveys – (Carpenter, Snell, & Schloerb, 1995; Stark & Brand, 1989; Bally, Langer, & Liu, 1991; Miesch & Bally, 1994). The Galactic Ring Survey (GRS) at FCRAO is by far the most comprehensive survey of the inner Galaxy to date (Simon et al., 2001). However, this survey traces only the $J = 1 - 0$ line of ^{13}CO, which is less sensitive to warm, low-opacity, high velocity gas such as produced by outflows, photodissociation regions (PDRs), and shocks.

A more comprehensive view of molecular clouds can therefore be gleaned from measurement of the submillimeter lines of CO and its isotopes, in combination with existing millimeter-wave observations. The gas probed by higher-J transitions is best suited to addressing the proposed survey's driving questions– it is the *energetic* 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. Higher-J line surveys like Supercam's are also needed to properly interpret basic properties of clouds derived from existing CO J=1-0 observations.

The CO J=3-2 transition at 345.8 GHz ($n_{crit} = 1.5 \times 10^4$ cm^{-3}) yields the lowest-lying line that significantly departs from the behavior seen in J=1-0 emission at 2.6mm, making it an ideal probe of the denser, more energetic portions of clouds. Similarly, HCO^+ J=4-3 is among the best tracers of high density gas ($n_{crit} = 2 \times 10^6$ cm^{-3}). In the 350 GHz atmospheric window, it has more accessible excitation characteristics than CS J=7-6 or HCN J=4-3. It is expected to be often subthermally-excited and optically-thick; radiative trapping reduces its effective excitation density to $n \sim 10^5$ cm^{-3}. HCO^+ also has a straightforward chemistry that is closely connected to CO. Observing both species is therefore highly synergistic.

While HCO^+ emission will be more concentrated than CO, bright BGPS sources such as those shown in Figure 5 clearly show that HCO^+ emission is often extended (Battersby et al. 2010). Based on the brightness of HCO^+ 3-2 emission and the typical gas kinetic temperature measured with NH_3 observations toward BGPS clumps ($< T_k >\sim 15$ K; Dunham et al. 2011), we expect to map extended HCO^+ $4 - 3$ emission in ~1600 individual clumps in a first quadrant survey alone. The MALT90 survey (Foster et al., 2011) in HCO^+ J=1-0 will provide a significant lever arm to



a) b)

Figure 6: a) The 345 GHz spectral line survey toward three positions in the W3 molecular cloud by Helmich & van Dishoeck (1997) shows a rich diversity of spectral diagnostics. b) Modeled submillimeter atmospheric transparency for the HHT on Mt. Graham in 75 percentile (top), median (middle), and 25 percentile (bottom) atmospheric conditions, derived from 24 hour 225 GHz radiometer measurements over the last 10 years.

constrain physical conditions in dense clumps that both surveys share in common.

The design of a 350 GHz spectroscopic survey is attractive; at this frequency the HHT has high aperture efficiency and good atmospheric transmission more than 50% of the winter (Figure 6-b).

2.2.3 Large Area Mapping: A Galactic Plane Survey

A complete picture for how star formation proceeds throughout the Galaxy can only be accomplished through Galactic plane surveys. Studies of star formation in other galaxies have derived a fundamental relationship between the surface density of dense gas and the star formation rate (i.e. the Kennicutt-Schmidt Law, Kennicutt 2007, Gao& Solomon 2004a,b, Bussmann et al. 2008, Baan et al. 2008, Juneau et al. 2009, Lada et al. 2012, Kennicutt & Evans 2012). The most recent molecular extragalactic surveys have pushed the spatial resolution of observations of CO to scales of 0.1 kpc in nearby galaxies (Bigiel et al. 2011). Over the next few years, ALMA observations will probe smaller scales and also trace the more relevant dense gas from which stars form with high efficiency using molecular tracers such as HCO^+ and HCN. A simultaneous effort is needed within our own Galaxy to build-up to the scales probed by extragalactic observers to determine a star formation relationship within the Milky Way. Galactic plane surveys in dense molecular gas tracers can provide the needed information on the surface density and fraction of dense molecular gas throughout the Galaxy. When combined with infrared surveys, they can constrain the global star formation relation in the Milky Way. No complete survey of the first quadrant of the Galactic plane currently exists in a submillimeter-wave, dense gas tracer.

Figure 7 shows the proposed sky coverage of the SuperCam submillimeter-wave Galactic plane survey. 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 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 the $l = \pm 100^o$ tangent arms 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 Arizona ($0 < l < 240^o$). Below $l = 90^o$, a *completely unbiased survey* will be undertaken, covering 180 square degrees ($-1^o < b < 1^o$). This "inner" Galaxy survey will coincide with several synergistic surveys (Section 3.2), such as the FCRAO-BU Galactic Ring Survey

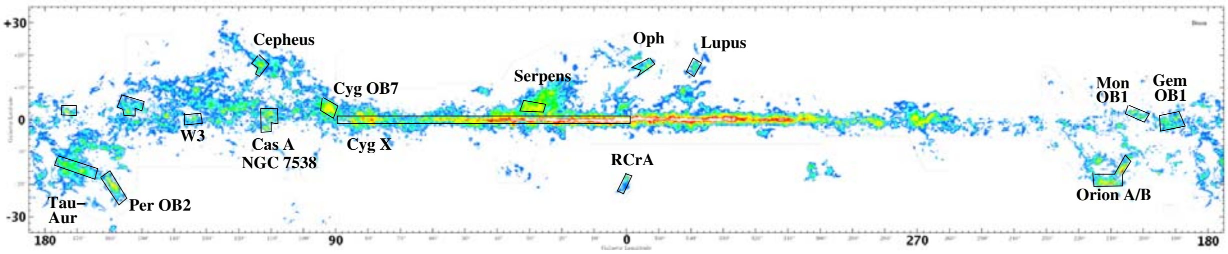


Figure 7: The power of SuperCam: a definitive chemical and kinematic survey of star forming clouds in ^{12}CO J=3-2 and HCO$^+$ J=4-3 over 240 square degrees of the sky can be performed in 4 months of observing in median winter weather. A corresponding survey with a single pixel receiver would take 100% of the HHT's observing time for 5 years.

(GRS), GLIMPSE, a Spitzer Space Telescope (SST) Legacy Program (Benjamin et al., 2003), and Hi-GAL (Molinari et al., 2010). Above $l = 90^o$, most of the CO emission is located at higher Galactic latitude; 60 square degrees will be distributed according to the Dame, Hartmann, & Thaddeus (2001) survey to follow the CO J=1-0 distribution, while maximizing synergies with the C2D and GLIMPSE(360) Spitzer programs (Evans et al., 2003), cloud cores seen by BGPS, and and other Spitzer & Herschel programs (Figure 7). Further discussion of the survey regions may be found in Section 2.3.1 and the data management document.

2.2.4 High Angular Resolution

Angular resolution is a critical aspect to the science return of a new Galactic plane survey. Figure 8 depicts a synthetic model cloud projected to distances of 500 pc and 5 kpc. Clearly, disentangling different clouds and cloud components can only be accomplished with sub-arcminute angular scales. The angular resolution of Supercam in CO J=3-2 on the HHT is 23$''$, equivalent to 0.9 pc at the distance of the Galactic Center.

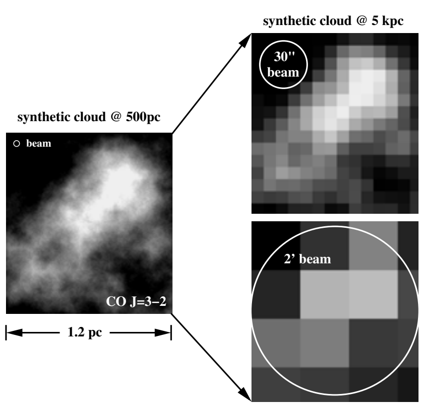


Figure 8: **The need for high angular resolution:** A synthetic model cloud seen in the ^{12}CO $J = 3 - 2$ transition at a distance of 500 pc (left) and at 5 kpc, with beam sizes of 30$''$ (top) and 2$'$ (bottom). The structure of the cloud is essentially lost in the larger beam. In order to probe cloud structure and excitation over the entire Galactic disk, high angular resolution is vital.

2.2.5 High Sensitivity

CO survives in the ISM in part because of the UV shielding from dissociation provided by H_2; thus CO's survivability depends upon a molecular, H_2-dominated environment. For typical molecular clouds, the sharp transition from H to H_2 occurs by a visual extinction of $\sim$1 magnitude in the local interstellar radiation field, N(H)=1.8×10^{21} cm^{-2}. We therefore aim to detect all CO down to this hydrogen column density limit. This corresponds to a 5σ detection limit of N(CO)=10^{15} cm^{-2}, which implies an integrated intensity for cold gas (T_{kin}=10-50K) of 1 K km s^{-1} in the $J = 3 \rightarrow 2$ transition at a gas density of $n_H = 10^4$ cm^{-3}. This sensitivity limit is achievable (at 5σ) within 12 seconds of integration time per independent beam in *median* atmospheric conditions (T_{sys} ~700K) at the HHT, or 5 hours per square degree, with 10" spatial pixels. Detection (or limits) on J=3→2 in that time would constrain the gas density, based upon the line brightness of millimeter wave transitions. In the same period of time, Supercam would also reach a 5σ limit of 1 K km s^{-1} in HCO^+ J=4-3, which would detect around 65% of the BGPS clumps observed by Schlingman et al. (2011) in HCO^+ J=3-2. Targeted follow-up HCO^+ observations with Supercam toward sources with a wide range of evolutionary stages are expected in year 3 of the proposed effort.

2.3 Survey Activities

2.3.1 Supercam Survey Mapping Strategy

The most efficient mode of data collection with a focal plane array that produces high 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 sufficent rate to eliminate aliasing and beam smearing. The primary advantage of OTF mapping with an array is that a given position on the sky is observed by all pixels in the array. This redundancy removes any noise and gain inhomogeneities between pixels and reduces the degree to which the data are correlated, as a singular off-source measurement is distributed to on-source data. Mapping projects at the HHT routinely and efficiently use the OTF technique.

The broad coverage of the Galactic Plane Survey lends itself naturally to efficient, 24-hour/day mapping. Only the regions defined by $0 < l < 40^o$ enters the 30^o Sun-avoidance circle in December, and $150 < l < 210^o$ during May-June. With 64 pixels, SuperCam can reach the requisite sensitivity of 1σ=0.2 K km/s over a full square degree in 5 hours (Section 2.2.5). A visibility diagram (Figure 9) shows the nominal observing strategy in which the entire survey can be accomplished in 4 months of observing time– total; two month-long campaigns in each of two years. A corresponding survey with a single pixel receiver would take 100% of the HHT's observing time for 5 years. The observing time required for the proposed survey was guaranteed by Steward Observatory in the original Supercam MRI proposal (see letter from P. Strittmatter). The Arizona Radio Observatory (ARO) that operates the HHT has supported multi-week engineering runs on the telescope with Supercam (in 2012 and 2013) for the purpose of enabling precisely these large-scale observing programs.

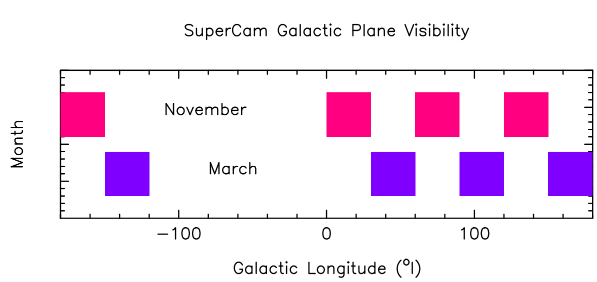


Figure 9: The entire Galactic Plane survey can be accomplished in 4 months of observing time total; two month-long campaigns in each of two years. This visibility diagram denotes how the Galactic Plane will be partitioned for efficient observing.

2.3.2 *Ancillary data: Direct Measurement of Cold H_2 & CO via Absorption Line Spectroscopy*

While molecular hydrogen (H_2) is the dominant constituent of molecular clouds, it has no accessible emission lines at the prevailing cold (10-50K) temperatures of dark clouds. However, contrary to popular belief, it is not invisible! It can be directly measured, albeit with some difficulty, through *absorption* line measurements in the near-infrared K-band (2.0-2.4 μm) (Lacy et al., 1994; Kulesa & Black, 2002); most interestingly, H_2 can be detected simultaneously with full ro-vibrational bands of CO and ^{13}CO. This would allow the H_2 to CO ratio in dark clouds to be directly measured with high accuracy, a "holy grail" of interstellar astronomy. More importantly, it would allow 4 decades of observations using CO line emission, far-infrared continuum emission, and near-infrared extinction mapping, to be properly calibrated. Contention in the literature over the best way to determine gas column density can finally be comprehensively tested relative to "ground truth" measurements of CO and H_2 toward lines of sight where these other methods are already used.

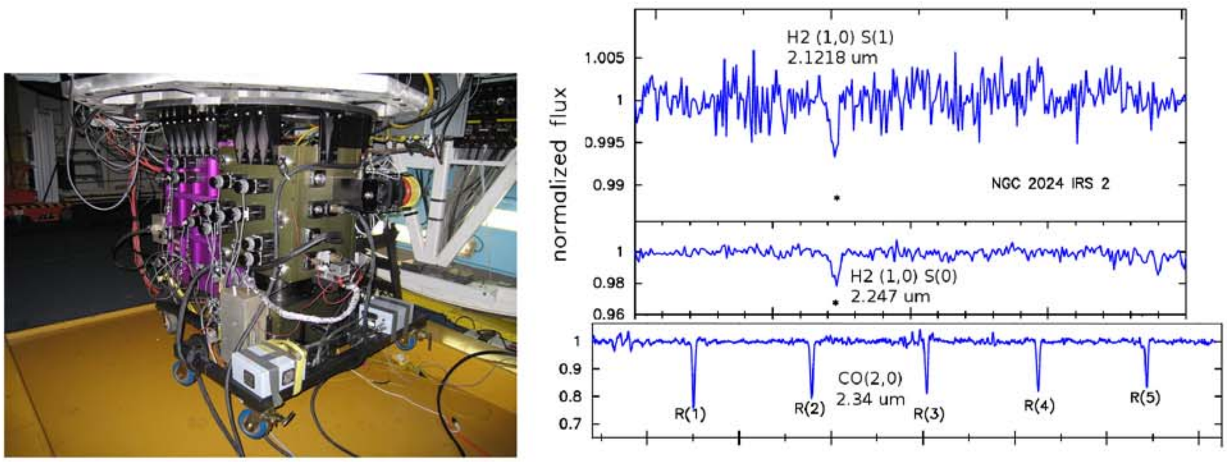


Figure 10: The ARIES AO imager and echelle spectrometer, installed at the 6.5m MMT telescope. Developed in part by the PI, the instrument has improved upon the landmark observations of cold H_2 and CO absorption of Lacy et al. (1994) in a test run, and will enable large scale surveys of H_2 absorption in dark clouds analogous to those performed in the vacuum ultraviolet toward diffuse clouds by *Copernicus* and *FUSE.*

In collaboration with D. McCarthy (Arizona), the PI has developed the high resolution cross-dispersed echelle spectrometer portion of the ARIES instrument (`http://aries.as.arizona.edu/`) for the AO system at the 6.5-meter MMT telescope on Mt. Hopkins, Arizona. The AO imager half of the ARIES instrument was partly funded from **NSF program AST-9623788**. Now fully operational from 1-2.5 microns wavelength, with an extension to 5 microns expected in 2014, ARIES has the unique blend of high spectral resolution (6-10 km/s), high angular resolution, and wide instantaneous spectral coverage needed to perform a valuable survey that complements Supercam perfectly: **a modest pencil-beam absorption-line survey of the Galaxy in H_2 and CO**. Early measurements with ARIES have reproduced the landmark Lacy et al. 1994 results with much higher accuracy and in less observing time (Figure 10). We detected both para and ortho forms of H_2, accounting for all of the ground-state molecular hydrogen and established the CO/H_2 abundance to 10% accuracy for the line of sight toward NGC 2024 IRS 2: 1.5 $\times 10^{-4}$. We propose to establish, toward more than 3 dozen lines of sight in the Supercam survey, the column and temperature of H_2 and CO, with spectral resolution that comes close (few km/s) to that delivered with Supercam. We will first target the Galactic Plane regions also observed by the Herschel GOTC+ program (Langer et al., 2010) in the 158 micron line of ionized carbon, [CII]. The GOTC+ program has measured the so-called "CO-dark H_2 gas" by using other principal reservoirs of gas phase carbon – namely C^+ and in some cases, atomic carbon (Pineda et al., 2013). We can compare the total carbon budget observed in [CII], [CI] and CO, in comparison to our measured hydrogenic column, to assess the amount of "dark gas" missing from CO surveys directly. We will also observe regions where the utility of CO line emission and near-infrared extinction mapping has been compared (and contested); e.g. Taurus and Perseus (Padoan et al., 2006; Goodman et al., 2009). We will be able to shed direct light on when certain indirect tracers of the total gas column are valid, and when they are not.

The PI will request total of 12-15 bright-time nights on the MMT during this proposed period of performance to accomplish this ancillary survey. An engineering run has already provided proof of concept (Figure 10). Arizona has a 44% share of the MMT, with little bright-time competition with ARIES. The PI therefore has excellent access to the instrument and telescope facilities needed to perform these uniquely powerful observations – which will add substantial value to not only the proposed Supercam Galactic Plane survey, but all other infrared continuum and infrared extinction-mapping surveys as well.

2.3.3 Science Products and Dissemination

The primary challenge of OTF mapping is data management, which becomes particularly acute with an array for which the data rates are typically 100x larger than typical. We have adopted the strategy developed at FCRAO for OTF mapping with the 32 pixel SEQUOIA array, whereby coadded and regridded data are written as a FITS cube, and headers for each scan are written into a SQL relational database. This approach facilitates efficient logging and retrieval of the data. Our storage requirements for a 240 square degree map, gridded to $10''$ spacing, with 1024 spectral points per grid position, is $\sim$100 GB. The total disk requirements for the raw data will be about 6 TB. This volume is readily handled by a single computer (`soral.as.arizona.edu`) with a redundant disk array for data integrity. This computer already exists as a byproduct of the PI's efforts developing the HEAT telescope and data system. Open access to these data products after calibration, with no proprietary period, will be provided through a web browser interface that will parse the SQL database and FITS data cubes. Standard Virtual Observatory (VO) services will be enabled in this interface.

All science tools, packaged reduction software, primary and ancillary data products and science products will be made available from the Supercam survey's web page, at `soral.as.arizona.edu/supercam`

2.3.4 Survey Science Analysis Strategy

To extract physical information from the Supercam survey data, in combination with copious ancillary data already available, we will employ a variety of analysis tools and integrative activities.

1) Coupled escape probability (CEP) (Elitzur & Asensio Ramos, 2006) and Monte Carlo (MC) (Bernes, 1979) **radiative transfer models** will be used to constrain kinetic temperature, hydrogen (molecule) particle density, and total column density. Observed line ratios and intensities can be

compared to CEP model grids that can be used to estimate the average physical conditions of each observed point. For HCO^+ J=4-3, application of Monte Carlo radiative transfer will be used to check the CEP solutions when applicable. Applicable codes have already been developed by the proposing team (CEP: Kulesa, MC: D. Narayanan).

2) **Photodissociation region (PDR) models** aim to reproduce the physics, chemistry, and emergent spectra of the surfaces of molecular clouds exposed to energetic stellar radiation. PDR codes were originally developed to model the interstellar clouds subject to intense UV fields, like those in massive star forming regions (Tielens & Hollenbach, 1985; van Dishoeck & Black, 1988). We will use modified versions of CLOUDY (Ferland, Korista & Verner, 1998) and the Meudon PDR code (Le Petit et al., 2012) in combination with the radiative transfer models cited above, to derive physical models of the observed regions, allowing the radiative impact on any cloud to be derived.

3) **Dynamical analyses.** Besides the effects of their radiation, stars influence clouds by depositing kinetic energy in protostellar outflows, stellar winds, and shocks from supernovae. This energy input is expected to drive turbulent linewidths in clouds, but the nature of this link is poorly established. To extract this kinematic information from the data set, we will first perform moment analyses of the CO and HCO^+ spectral line profiles. Centroid maps outside the line cores constitute the standard technique for finding high velocity gas such as shocks and outflows (Walker, Carlstrom, & Bieging, 1993; Groppi et al., 2004). The line width provides a measure of the velocity components coincident within a telescope beam and sets an upper limit on the turbulent velocity field. Secondly, we will extract kinematic information through a principal component analysis (PCA), a statistical approach that emphasizes the underlying patterns and regularities within complex data sets while minimizing inferences derived from incidental features (Heyer & Schloerb, 1997). Brunt & Heyer (2002) have demonstrated that PCA can recover the true 3-dimensional statistics of the velocity field, distinguishing incompressible, eddy-like flows from strong compressible motions that create shocks and generate density enhancements like cloud cores. These analyses will allow us to define the inertial range in molecular clouds and the variation of turbulence within molecular clouds and dense cores.

4) **Development of a Milky Way Template**. At high-redshift, (sub)mm-observations of molecular gas in galaxies are typically restricted to higher-rotational quantum number transitions ($J \geq 3$). Because the ground state transition is the principal tracer of star-forming molecular gas (H_2), some assumption invariably has to be made regarding the excitation of CO. This can dominate the error budget in determining the gas mass of the galaxy, driving uncertainty in baryonic gas fraction determinations of high-z galaxies. In the era of ALMA, these quantities are routinely being measured in galaxies from z=0-6 in order to understand the baryon cycle in galaxies that governs gas accretion from the intergalactic medium, conversion into stars, and subsequent expulsion due to stellar feedback. Our high-resolution CO (J=3-2) survey of the Galactic plane will reduce this uncertainty. By comparing Supercam data to the FCRAO CO and ^{13}CO J=1-0 surveys of the Milky Way, we will be able to construct CO (J=3-2)/(J=1-0) line ratio maps across the Galaxy at parsec scales. Comparisons of this data to young stellar object counts for nearby clouds will allow us to parameterize the excitation in terms of the star formation rate surface density, the observable quantity most likely to correlate with molecular excitation, and most readily observable for high-z galaxies. This comparison will also establish the Galactic Kennicutt-Schmidt Law. We will compute Star Formation Rate to the surface brightness of CO J=3-2 and HCO^+ J=4-3 relation for gas in a large range of physical conditions, determining the most complete estimate of the Milky Way's

molecular luminosity in a dense gas tracer. This strongly connects the Milky Way to observations of other galaxies. These templates will allow our team to not only inform future observations, and help constrain the cosmic evolution of the baryonic gas fraction in galaxies. With observations and cosmological simulations showing dramatic differences in the predicted gas fractions of high-z galaxies (Narayanan, Bothwell & Dave, 2012), the construction of these templates will be timely.

Participant	**Affiliation**	**Partipation Activity**
Craig Kulesa	U. Arizona	PI: Reviews & approves operations plans and execution Reviews and approves science data products Coordinates followup Supercam & ARIES observations.
Chris Walker	U. Arizona	Co-PI (Supercam PI): Leads science advising effort with students Responsible for instrument viability Shares responsibility for science operations, & data products
Yancy Shirley	U. Arizona	Advisor: dense gas mapping in HCO^+ Shares student advising effort
John H. Bieging	U. Arizona	Integration of SuperCam data with existing 1.3mm HHT survey
Ed Churchwell	Wisconsin	Advisor: Synergy with GLIMPSE survey
Paul Goldsmith	JPL	Advisor: Synergy with Herschel $GOTC^+$ survey
Alyssa Goodman	Harvard	Advisor: Synergy with C2D & COMPLETE surveys
Chris Groppi	Arizona State	Participates in science operations & instrument upgrades
Mark Heyer	U. Mass	Advisor: Synergy with GRS survey, PCA analysis
Desika Narayanan	U. Arizona	Theoretical modeling, construction of Milky Way template
Gopal Narayanan	U. Mass	Advisor: Galactic Surveys & Star formation regions

Table 1: Activities of the Supercam Science Team

2.3.5 Roles of the Collaboration Participants

Senior personnel who will use the Supercam instrument in this first "key" program at the HHT are listed in Table 1. *In addition, numerous students will participate in the science development at the University of Arizona and participating organizations.*

3 Project Impact

3.1 Educational Impact

The training of students in the development and use 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 occuring 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 team's lab (SORAL: Steward Observatory Radio Astronomy Laboratory), we have been fortunate to have had a number of talented students pursue their research. Over the past 10 years the lab has produced 9 Ph.D.'s and numerous undergraduate senior projects. The PI is in fact a byproduct of this educational facility! Most of the Ph.D.'s 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. It is interest in astronomy and the interdisciplinary nature of the research that attracts them to the SORAL lab. In an effort to reach this population of students, the Co-PI's and fellow faculty members in other departments are seeking to establish an interdisciplinary program in astronomical instrumentation. Two of Co-PI Walker's past Ph.D. students have received majors and minors in different departments. Co-PI Walker currently has 4 graduate and 2 undergraduate students participating in interdisciplinary studies.

In the proposed budget, funds for only one graduate student are requested. The use of Supercam on the HHT will be the focus of the student's research. However, as is customary in the SORAL lab, many other students will also participate in making the program a success. Indeed, one of the most important aspects of training students is the experience gained in working in teams. Astronomical science and 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.

3.2 Global Impact: Survey Synergies

The proposed Galactic Plane survey with Supercam will serve as a "finding chart" for future, focused surveys with ALMA and markedly enhance the value of numerous contemporary surveys. These data will be released openly to the astronomical community, with no proprietary period.

3.2.1 BGPS and ATLASGAL continuum surveys

The 1.3mm Bolocam Galactic Plane Survey and 850 μm ATLASGAL survey from APEX represent the most comprehensive long-wavelength continuum surveys of high column density, cold dust in the Galaxy. As previously described in Section 2.2.3, we will map the kinematics and column of HCO^+ toward $\sim 10^3$ cold dust condensations, and expect to map extended HCO^+ emission towards many of them. With Supercam's survey of dense gas, a linewidth-size relationship can be computed, which is critical to studies of turbulence and basic scaling laws for star formation. Approximately 12% of HCO^+ detections from Schlingman et al. (2011) showed a self absorption profile (Figure 9) indicating that we will also identify many potential infall candidates (see Reiter et al. 2011). Collaborator Shirley will provide advice to maximize the scientific return from Supercam's dense gas surveys in combination with the BGPS.

3.2.2 GLIMPSE, MIPSGAL, and Hi-GAL

The Spitzer Space Telescope Legacy program GLIMPSE, headed by E. Churchwell, provided 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. MIPSGAL extended the wavelength coverage to Spitzer's 24 μm band, and Herschel's Hi-GAL program is mapping 720 sq.deg. of the Galactic Plane in 5 bands from 60 to 600 μm. Supercam's Galactic Plane survey will provide the best corresponding molecular 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. Collaborator E. Churchwell will provide guidance in interpreting Spitzer data for comparison with the Supercam survey.

3.2.3 Probing the "Missing Gas" in CO surveys: Herschel's GOTC+ program

As previously described in Section 2.3.2, Herschel's GOTC+ open time key project measured 158 μm line emission from C^+ to ascertain the properties of the diffuse ISM and measure a probe of molecular gas that is missed in CO surveys (because the carbon is either neutral or ionized instead). Supercam provides a more robust measure of CO by providing a more comprehensive measure of its excitation, and the proposed ancillary data products in the infrared provide a reliable, direct measure of H_2. We will compare both data products with the results of Herschel's GOTC+ survey, and collaborator Paul Goldsmith (JPL) will help provide guidance as a member of the GOTC+ team.

3.2.4 Galactic Ring Survey

The FCRAO Galactic Ring Survey led by J. Jackson provided the most sensitive study of the inner Galaxy to date, but only mapped the ^{13}CO $J = 1 \rightarrow 0$ line. This proposed study will improve upon the GRS resolution by up to a factor of 4 in area and yield the crucial higher-J lines that make proper interpretation of existing CO surveys possible. Collaborator Mark Heyer (U.Mass) is a member of the GRS team and will provide guidance interpreting the GRS & Supercam data.

4 Project Management

Transitioning Supercam from an instrument development to a scientific workhorse is an exciting prospect that our team has been working towards for years. Collectively the Supercam team members represent many years of successful instrument development and observing experience. As related by Table 1, the main components of the organization are the PI, who has overall responsibility for the project and coordinates the activities of the participants; Co-PI Walker who shares in these responsibilities and lead the student advising efforts; and the distributed members of the science team who act as an advisory council to the PI and Co-PIs to ensure that the project stays on course. A schedule of key project milestones and tasks is provided in Figure 11. Routine communications between project participants is essential. There will be monthly science team telecons to monitor progress and provide insight into solutions to emerging problems, and redefine priorities as needed. A Supercam wiki at Arizona will provide a resource for team communications and documentation.

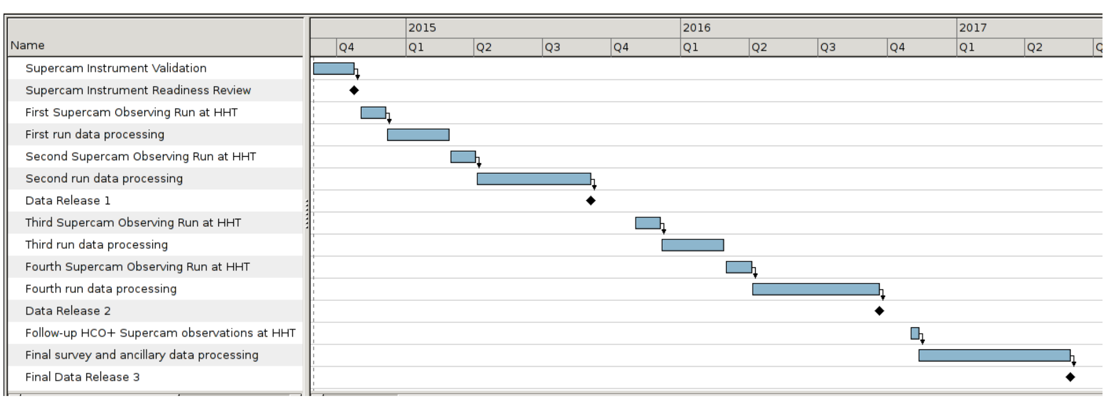


Figure 11: Supercam Science Operations Timeline

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Professional Preparation

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

Appointments

2012-	Associate Astronomer University of Arizona
2006-	Assistant Astronomer University of Arizona
2003-2006	Assistant Staff Scientist 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., 2005, 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. "Exceptional Terahertz Transparency and Stability Above Dome A, Antarctica", Yang, H. & Kulesa, C. A., et al. 2010, PASP, 122, 490
5. "Abundances of H_2, H_3^+ & CO in Dark Molecular Clouds", Kulesa, C. A. & Black, J. H. 2013, ApJ, submitted

Selected Related Papers

1. "Pre-HEAT: Submillimeter Site Testing and Astronomical Spectra from Dome A, Antarctica", Kulesa, C.A, et al., Proc SPIE 7012, 545 (2008).
2. "Deep Near-Infrared Observations of L 1014: Revealing the Nature of the Core and its Embedded Source", Tracy L. Huard et al., 2006, ApJ, 649, 391.

3. "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.
4. "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.
5. "SuperCam: a 64-pixel heterodyne imaging array for the 870-micron atmospheric window", Groppi, C., Walker, C., Kulesa, C., Puetz, P., Golish, D., Gensheimer, P., Hedden, A., Bussmann, S., Weinreb, S., Kuiper, T., Kooi, J., Jones, G., Bardin, J., Mani, H., Lichtenberger, A., Narayanan, G., 2006, Proc. SPIE, vol 6275, 62750O.

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

Instrumentation Experience Relevant to this Proposal:

1. PI of *HEAT*, an automated 0.6-meter terahertz telescope with 0.5-2 THz heterodyne receivers deployed in January 2012 to Ridge A, Antarctica, the best site on Earth for far-IR astronomy.
2. Deputy-PI of the *Stratospheric Terahertz Observatory* (STO), a balloon borne experiment to explore the life cycle of the ISM.
3. Deputy-PI of *Supercam*, a 64-beam, 345 GHz heterodyne receiver to be deployed at the 10-meter HHT telescope in Arizona. Responsibilities focus on the I&T of IF processor and spectrometer, system level testing, telescope integration, data system.
4. Constructed *ARIES*, the Arizona Infrared Imager and Echelle Spectrometer, for the adaptive optics secondary at the 6.5-meter MMT. Aside from NIRSPEC at Keck, ARIES is the only cross-dispersed NIR echelle spectrometer in the northern hemisphere.

Collaborations, 2011-2013:

J. Bieging (Arizona)	S. Brittain (Clemson)	D. Chuss (NASA/GSFC)
C. Groppi (Arizona)	D. Hollenbach (NASA-Ames)	T. Huard (CfA)
A. Lane (Harvard/CfA)	D. McCarthy (Arizona)	G. Narayanan (UMass/Amherst)
G. Novak (Northwestern)	T. Rettig (Notre Dame)	T. Simon (Hawaii)
A. Stark (Harvard/CfA)	C. Walker (Arizona)	M. Wolfire (Maryland)

Ph.D. Advisors:

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

Ph.D. Advisees:

Abigail Hedden (2007, Univ. of Arizona)
Desika Narayanan (2007, Univ. of Arizona)

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

Education

B.S.: Electrical Engineering, Clemson University, 1980
Graduated with Honors
M.S.: Electrical Engineering, Ohio State University, 1981
Advisor: John D. Kraus
Thesis: "Upgrading the Ohio State Radio Observatory"
Ph.D.: Astronomy, University of Arizona, 1988
Advisor: Charles J. Lada
Thesis: "Observational Studies of Star Forming Regions"

Experience

- Professor of Astronomy and Optical Sciences, Associate Professor of Electrical Engineering, University of Arizona, 2003-
- 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

Publications

5- Recent Closely Related Publications

Bussmann, R. S., Wong, T. W., Hedden, A., Kulesa, C., and Walker, C. K., 2007, *A CO (J=3-2) Outflow Survey of the Elias 29 Region, Ap.J.,* 657, Issue 1, pp. L33-L36.
Hedden, A. S., Walker, C. K., Groppi, C. E., and Butner, H. A., 2006, Star *Formation in the Northern Cloud Complex of NGC 2264*, *Ap.J.*, **645**, p.345.
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.
Stark, A., Martin, C., Walsh, W., Xiao, K., Lane, A., and Walker, C., 2004, "*Gas Density, Stability, and Starbursts near the Inner Lindblad Resonance of the Milky Way*", *Ap.J.*, **614**, Issue 1, pp. L41-L44.
Martin, C., Walsh, W., Xiao, K., Lane, A., and Stark, A., 2004, *The AST/RO Survey of the Galactic Center Region. I. The Inner 3 Degrees, Ap.J.S.,* **150**, 239.

5- Additional Publications

Narayanan, D., Kulesa, C., Boss, A., and Walker, C. K., 2006, *Molecular Line Emission from Gravitationally Unstable Protoplanetary Disks, Ap.J.*, **647**, Issue 2, pp. 1426-1436
Narayanan, D., Cox, T., Robertson, B., Dave', R., Di Matteo, T., Hernquist, L., Hopkins, P., Kulesa, C., and Walker, C. K., 2006, *Molecular Outflows in Galaxy Merger Simulations with Embedded Active Galactic Nuclei*, *Ap.J.*., 642, Issue 2, pp. L107-L110.
Groppi, C., Kulesa, C., Walker, C., and Martin, C., 2004, *Millimeter and Submillimeter Survey of the R Coronae Australis Region*, *Ap. J.,* **612**, 946.
Narayanan, G., Moriarty-Schieven, G., Walker, C.K., and Butner, H.M. 2002, *Detection of Infall Signatures Towards SMM4, Ap.J.*, **565**, 319.
Melia, F., Bromley, B., Liu, S., and Walker, C.K. 2001, *Measuring the Black Hole Spin in Sag A**, *Ap. J. Letters*, **554**, 37.

Synergistic Activities

1) Prof. Walker's lab the led efforts to construct the world's first 810 and 345 GHz heterodyne array receivers and helped developed one of the first 1.5 THz HEB receiver systems for radio astronomy.
2) Instruments developed by Prof. Walker's team have served as primary facility instruments at the Heinrich Hertz Telescope and the AST/RO telescope at the South Pole for over a decade.
3) Funded by the NSF, Prof. Walker has led the effort to design and build the world's largest (64 pixels) submillimeter-wave heterodyne array receiver (SuperCam).
4) He is PI of the NASA funded long duration balloon project ``The Stratospheric THz Observatory (STO)''.
5) Prof. Walker has served as dissertation director for nine Ph.D. students (7-Astronomy and 2-Optical Sciences).

Recent Collaborators (48 Months)

Pietro Bernasconi (JHAPL), Christopher Groppi (ASU), Karl Jacobs (U. Cologne), Craig Kulesa (UofA), Arthur Lichtenberger (UVa), Carey Lisse (JHAPL), David Neufeld (JHU), Gordon Stacey (Cornell), Paul Goldsmith (JPL), William Langer (JPL), David Hollenbach (SETI Institute), John Kawamura (JPL), Christopher Martin (Oberlin College), Antony Stark (SAO), Jeffrey Stern (JPL), Juergen Stutzki (U. Cologne), Sander Weinreb (CIT/JPL), Mark Wolfire (U. Maryland), Harold Yorke (JPL), Eric Young (USRA).

M.S.E.E. Graduate Advisor: John D. Kraus, OSU
Ph.D. Advisor: Charles J. Lada, SAO
Postdoctoral Advisor (Millikan Fellowship in Physics): Thomas G. Phillips, CIT

Ph.D. Advisees: Grace Wolf (Hansen Planetarium), Jason Glenn (UC Boulder), Gopal Narayanan (U. Mass), Craig Kulesa (UofA), Christian d'Aubigny (Teravision Inc.), Christopher Groppi (UofA), Desika Narayanan (CfA), Abigail Hedden (SAO), Dathon Golish (Teravision Inc.)

SUMMARY PROPOSAL BUDGET

YEAR 1

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

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. Craig A Kulesa - Associate Astronomer	0.50	0.00	0.00	2,227	
2. Christopher K Walker - Professor	0.00	0.00	0.50	5,333	
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	0.50	0.00	0.50	7,560	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	1.75	0.00	0.00	9,706	
3. (1) GRADUATE STUDENTS				30,175	
4. (2) UNDERGRADUATE STUDENTS				2,400	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				49,841	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				22,858	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				72,699	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
IF processor filter set for dual-spectral-line mode $ 9,600					
TOTAL EQUIPMENT				9,600	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,605	
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				620	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,640	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				10,900	
TOTAL OTHER DIRECT COSTS				14,160	
H. TOTAL DIRECT COSTS (A THROUGH G)				98,064	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
MTDC base (Rate: 51.5000, Base: 73376)					
TOTAL INDIRECT COSTS (F&A)				37,789	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				135,853	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				135,853	

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

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION University of Arizona				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Craig Kulesa				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. Craig A Kulesa - Associate Astronomer	0.50	0.00	0.00	2,301		
2. Christopher K Walker - Professor	0.00	0.00	0.50	5,509		
3.						
4.						
5.						
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	0.50	0.00	0.50	7,810		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.50	0.00	0.00	2,949		
3. (1) GRADUATE STUDENTS				31,170		
4. (2) UNDERGRADUATE STUDENTS				2,479		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				44,408		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				21,861		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				66,269		
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)				1,658		
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				637		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,727		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				0		
6. OTHER				413		
TOTAL OTHER DIRECT COSTS				3,777		
H. TOTAL DIRECT COSTS (A THROUGH G)				71,704		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC base (Rate: 51.5000, Base: 56119)						
TOTAL INDIRECT COSTS (F&A)				28,901		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				100,605		
K. RESIDUAL FUNDS				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				100,605		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME Craig Kulesa				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

YEAR 3

ORGANIZATION University of Arizona			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Craig Kulesa			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. Craig A Kulesa - Associate Astronomer	0.50	0.00	0.00	2,377	
2. Christopher K Walker - Professor	0.00	0.00	0.50	5,690	
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	0.50	0.00	0.50	8,067	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.50	0.00	0.00	3,047	
3. (1) GRADUATE STUDENTS				32,199	
4. (2) UNDERGRADUATE STUDENTS				2,561	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				45,874	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				22,582	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				68,456	
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)				1,713	
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				120	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,817	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				427	
TOTAL OTHER DIRECT COSTS				3,364	
H. TOTAL DIRECT COSTS (A THROUGH G)				73,533	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) MTDC base (Rate: 51.5000, Base: 57433)					
TOTAL INDIRECT COSTS (F&A)				29,578	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				103,111	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				103,111	

M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME Craig Kulesa	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 **University of Arizona**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Craig Kulesa**				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. **Craig A Kulesa - Associate Astronomer**	1.50	0.00	0.00	6,905	
2. **Christopher K Walker - Professor**	0.00	0.00	1.50	16,532	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (2) TOTAL SENIOR PERSONNEL (1 - 6)	1.50	0.00	1.50	23,437	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (5) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	2.75	0.00	0.00	15,702	
3. (3) GRADUATE STUDENTS				93,544	
4. (6) UNDERGRADUATE STUDENTS				7,440	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				140,123	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				67,301	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				207,424	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 9,600					
TOTAL EQUIPMENT				9,600	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				4,976	
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				1,377	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				8,184	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				11,740	
TOTAL OTHER DIRECT COSTS				21,301	
H. TOTAL DIRECT COSTS (A THROUGH G)				243,301	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				96,268	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				339,569	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				339,569	

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

PI/PD NAME **Craig Kulesa**	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

A. SENIOR PERSONNEL

0.5 calendar month of salary per year is requested for PI Craig Kulesa. His base salary is $58,131 per 12-month fiscal year.

0.5 summer month of salary per year is requested for Co-PI Christopher Walker. His base salary is $92,582 per 9-month academic year.

0.5 calendar month of salary per year is requested for Software Lead, William Peters. His base salary is $74,517 per 12-month fiscal year.

1.0 calendar month of salary in year 1 is requested for Operations Manager, Brian Duffy. His base salary is $65,918 per 12-month fiscal year.

B. OTHER PERSONNEL

0.25 calendar month of salary in year 1 is requested for Cryogenics Engineer, Jack Cochran as temporary staff at a rate of $45/hour.

Full funding for 3 years is requested for one graduate student (base salary $30,175) engaged in Ph.D. thesis research under this project.

200 hours of undergraduate student research support is requested each year (base rate $12/hour).

C. FRINGE BENEFITS

The following university-approved fringe benefit rates were applied to each labor category:

- Faculty/Appointed Personnel: 30.0%
- On Call/Temporary Staff: 10.0%
- Graduate Students: 59.5% composed of:
  - 9.5% for health/dental/life insurance
  - 50.0% for tuition remission (exempt from indirect cost charges)
- Undergraduate Students: 3.5%

D. CAPITAL EQUIPMENT

A 64-element RF filter set, used to shape the bandpass inside the IF processor system, will be purchased to replace the filterset that is currently used for CO J=3-2 currently. The new filterset will allow simultaneous observations in CO J=3-2 and HCO^+ J=4-3, which is critical to this proposal. Vendors for the filterset are derived from the acquisition of the original set of filters. We have provided the relevant vendors (Lorch and Tiger) with detailed specifications and they in turn have provided preliminary costing information that is reflected in the budget. Once project funding commences, bids and purchase orders will be issued as appropriate.

E. TRAVEL

Domestic

Funds are requested for one domestic AAS conference for one graduate student for five days each year. Travel funds requested include roundtrip airfare (@ $400/trip), lodging (@

$100/night), and per diem (@ $49/day). Conference registration fees are detailed under 'Other Direct Costs' in accordance with University of Arizona cost classification practices.

To support observations made with Supercam during observing campaigns, rental vehicle support for 14 days of on-site observations at the HHT is requested at $40/day.

F. OTHER DIRECT COSTS

Funds are requested in each year for research supplies and work-flow/data capture and telecommunications expenses required for the conduction of this investigation. These operational items represent the material costs of creating, replicating, archiving, distributing and presenting all project related data, documentation, reporting, and analysis that are directly related to this project. Such material costs include external disk drives, poster printer costs, and analysis and presentation software.

Funds are requested in year 1 for new IF processor LO units, to allow both HCO+ J=4-3 and CO J=3-2 to be observed simultaneously, a requirement of this proposal effort.

Funds are requested for minor electronics repairs to the Supercam instrument. Costing is estimated from the replacement costs of repairs during Supercam's laboratory testing over the past two years, including replacement of instrument control computers, hard drives, solid state storage, power supplies, and cooling fans.

Funds are requested in year 1 for the refurbishment of Supercam's two closed-cycle refrigerators (Sumitomo and CTI-350 cold heads), which are a basic maintenance requirement. The costs listed are based on actual costs incurred over the last two years of Supercam testing in the laboratory.

Instrument transport and installation at the HHT is budgeted in year 1 to allow observations to begin as early as possible in the program. The $2500 total estimate is based on the costs incurred in the previous two engineering runs at the telescope – including multiple rental vehicles, including a box truck for the transport of the instrument itself; rigging and lifting equipment, vacuum and electrical spares for support of those subsystems at the HHT, and other minor integration costs.

Funds are requested for one graduate student AAS conference registration per year.

Funds are requested for publication of findings in professional journals each year; estimated at 3 papers of 8 pages per year @ $110/page (Astrophysical Journal).

G. INDIRECT COSTS

The university-mandated indirect cost rate of 51.5% was applied to all costs except capital equipment and 50.0% of the graduate student fringe benefit rate, which is for tuition remission and exempt from IDC.

*A cost inflation rate of 3.3% per year is applied to all eligible costs for years 2 and 3.

CRAIG A KULESA, PI
The University of Arizona, Steward Observatory

CURRENT AWARDS as Principal Investigator

Project Title:	High Elevation Antarctic Terahertz (HEAT) Telescopes for Dome A and Ridge A
Source of Support:	NSF 0944335
Project Location:	The University of Arizona
Total Award Amount:	$1,480,000
Start and End Date: (MM/DD/YY)	10/01/2010 – 09/30/2014
Months Committed to the Project:	6 months per year

CURRENT AWARDS as Co-Investigator

Project Title:	Reflight of the Stratospheric Terahertz Observatory (STO-2)
Source of Support:	NASA APRA
Project Location:	The University of Arizona
Total Award Amount:	$4,400,000
Start and End Date: (MM/DD/YY)	1/01/2014 – 12/31/2017
Months Committed to the Project:	3 months per year

PENDING AWARDS as Principal Investigator

Project Title:	A Submillimeter-Wave Spectroscopic Galactic Plane Survey using Supercam at the HHT (THIS PROPOSAL)
Source of Support:	NSF AAG
Project Location:	The University of Arizona
Total Award Amount:	$339,569
Start and End Date: (MM/DD/YY)	9/01/2014 – 08/31/2017
Months Committed to the Project:	0.5 months per year

Project Title:	Continuing operation of the HEAT telescope at Ridge A, Antarctica
Source of Support:	NSF AAG
Project Location:	The University of Arizona
Total Award Amount:	$273,715
Start and End Date: (MM/DD/YY)	10/01/2014 – 09/30/2016
Months Committed to the Project:	6 months per year

CHRISTOPHER K. WALKER, Co-PI
The University of Arizona, Steward Observatory

CURRENT AWARDS as Principal Investigator

Project Title:	10 meter Sub-Orbital Large Balloon Reflector (LBR)
Source of Support:	NASA
Project Location:	The University of Arizona
Total Award Amount:	$99,898
Start and End Date: (MM/DD/YY)	8/12/13 – 5/11/14
Months Committed to the Project:	1 summer month

Project Title:	Reflight of the Stratospheric TeraHertz Observatory: STO-2
Source of Support:	NASA
Project Location:	The University of Arizona
Total Award Amount:	$4,180,531 (UA Portion: $1,081,269)
Start and End Date: (MM/DD/YY)	1/1/14 – 12/31/16
Months Committed to the Project:	1 summer month per year

CURRENT AWARDS as Co-Investigator

Project Title:	High Elevation Antarctic Terahertz (HEAT) Telescopes for Dome A and Ridge A (PI: C. Kulesa)
Source of Support:	NSF 0944335
Project Location:	The University of Arizona
Total Award Amount:	$1,511,020
Start and End Date: (MM/DD/YY)	10/01/2010 – 09/30/2014
Months Committed to the Project:	1 summer month per year

PENDING AWARDS as Principal Investigator

Project Title:	Investigation of the Meissner Effect Transistor
Source of Support:	NSF
Project Location:	The University of Arizona
Total Award Amount:	$350,535
Start and End Date: (MM/DD/YY)	5/1/14 – 4/30/17
Months Committed to the Project:	1 summer month per year

PENDING AWARDS as Co-Investigator

Project Title:	A Submillimeter-Wave Spectroscopic Galactic Plane Survey using Supercam at the HHT (PI Craig Kulesa) – THIS PROPOSAL
Source of Support:	NSF
Project Location:	The University of Arizona
Total Award Amount:	$339,569
Start and End Date: (MM/DD/YY)	9/1/14 – 8/31/17
Months Committed to the Project:	0.5 summer month per year

Project Title:	Continuing Operation of the HEAT telescope at Ridge A, Antarctica (PI Craig Kulesa)
Source of Support:	NSF
Project Location:	The University of Arizona
Total Award Amount:	$273,715
Start and End Date: (MM/DD/YY)	10/1/14 – 9/30/16
Months Committed to the Project:	0.5 summer month per year

FACILITIES, EQUIPMENT & OTHER RESOURCES

University of Arizona: Steward Observatory

Steward Observatory (SO) has a large technical staff 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) to millimeter/submillimeter wavelengths, such as the Heinrich Hertz Telescope (HHT). This expertise will be augmented by Instrument Team members with extensive experience in the development and deployment of terahertz instrumentation during the science operations of Superca at the HHT. Given that Supercam has already successfully operated at the HHT, no difficultities in integration and operation are expected.

In 1992, Co-PI Walker established a laboratory (the Steward Observatory Radio Astronomy Laboratory, SORAL) for the development of state-of-the-art submillimeter-wave receiver systems. The PI-Kulesa, was trained in this group. SORAL possess all the equipment (spectrum analyzers, network analyzer's, vacuum pumps, cryogenic support facilities, etc.) needed to maintain Supercam. In addition, the Arizona Radio Observatory utilizes similar equipment both at the 10-meter HHT and in the university ARO laboratory. We also have ^{4}He, ^{3}He, and closed-cycle cryostats, a full receiver testbed, local oscillator sources (including a Coherent/DEOS FIR laser), and an antenna test range which allows us to characterize a wide range of receiver systems. A Kern micromilling machine with 5 micron machining accuracy was purchased for Supercam and is available for precision machining work.

SORAL has licenses for CST Microwave Studio, Solidworks, and Altium Designer, should they be necessary for the support of Supercam. These programs are used to accurately model and optimize mixers and other crucial receiver components, produce solid models of mechanical structures, and design and simulate electronic circuits. In addition, we have licenses for optical design packages such as Zemax. All of these were used in the design and construction of Supercam and can be brought to bear on optimizing Supercam's science operations, as needed.

Data Management Plan

Supercam's extensive 3D FITS spectral line data cubes of the Galactic Plane, and targeted deep surveys will be acquired, reduced, analyzed, and distributed to the broader astronomical community via publications and permanent data archives.

Data Pipeline

The rate at which raw (Level 0) data is collected from the spectrometer is substantial in OTF mode (see Project Description, for a description of the mapping strategy) and not in the form desired for scientific distribution; therefore data processing is performed on the Supercam data computer. The data flow is depicted in Figure 1 and can be operated autonomously after basic verification. The steps undertaken in each data processing level are described as follows:

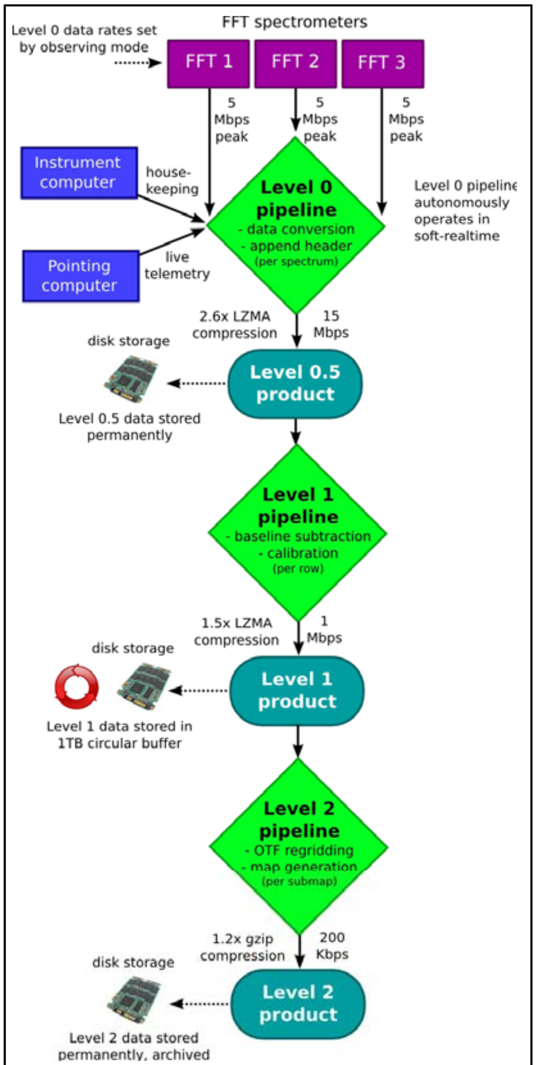

Figure 1: Supercam's demonstrated data pipeline

Level 0.5 (**data conversion, header tagging**) Each of the spectrometer data files is time-tagged upon being written to a RAM disk on the Supercam data computer. A data header is synthesized from streamed data from the HHT tracker and instrument control computers, which together deliver telescope telemetry, and instrument housekeeping data. The data payload is rescaled from 64-bit words to 32-bit integers and written as a single-dish FITS file. The archival disk storage holds the LZMA-compressed (.xz) file, while a 'scratch' disk maintains the uncompressed file for follow up processing for a limited time. After validation, the 'raw' level 0 files are removed from memory.

Level 1 (baseline subtraction and calibration): After the conclusion of a single OTF scan, the map data can be preliminarily processed. The reference scan is subtracted from the source scans acquired during drift mode. If poor results are obtained, the best adjacent reference scan is used instead. Residual artifacts are masked from the resulting spectrum, and the data are flux calibrated using the ambient temperature chopper wheel method. Based on the antenna pointing and the time, the spectra are frequency calibrated onto a V_{LSR} velocity scale.

Level 2 (OTF regridding & map production): Once a submap has been repeated a sufficient number of times that the desired sensitivity has been achieved, the highly oversampled data are regridded and convolved to 23" resolution with 10" pixels. Optionally, spectral smoothing and additional spatial smoothing can be applied at this stage. The numerical methods used during regridding follow that used by the 32-beam Sequoia array used at FCRAO to deliver outstanding high fidelity maps of CO emission in the first Galactic quadrant. These level 2 FITS cubes represent the baseline science products that Supercam will deliver. Thus, the highest priority for the observer is to continuously validate the level 2 processing using quicklook versions of the level 0.5 and level 1 data.

This data processing pipeline strategy has demonstrated heritage in the form of the baseline pipeline used with the PI's robotic High Elevation Antarctic Terahertz (HEAT) telescope, and was used with the appropriate changes in the May 2012 Supercam engineering run at the HHT. Relatively few changes are foreseen to the data pipeline; those changes will be managed by PI Kulesa and software lead B. Peters.

Ancillary Products

In addition to the standard level 2 data cubes and calibration data, important ancillary science products include a catalog of spatial and spectral correlated "clumps" in the data, using standard clump-finding routines, and a catalog of all detected outflows, with estimated energy input to the ISM computed. All data analysis tools, stand-alone pipelines, and cloud models will be provided. PI Kulesa is currently performing a systematic calibration of the dataset using high resolution infrared absorption line spectroscopy of CO and H_2 using ARIES at the 6.5m MMT, which will serve to provide precisely measured column densities of the two species. These data will also be provided.

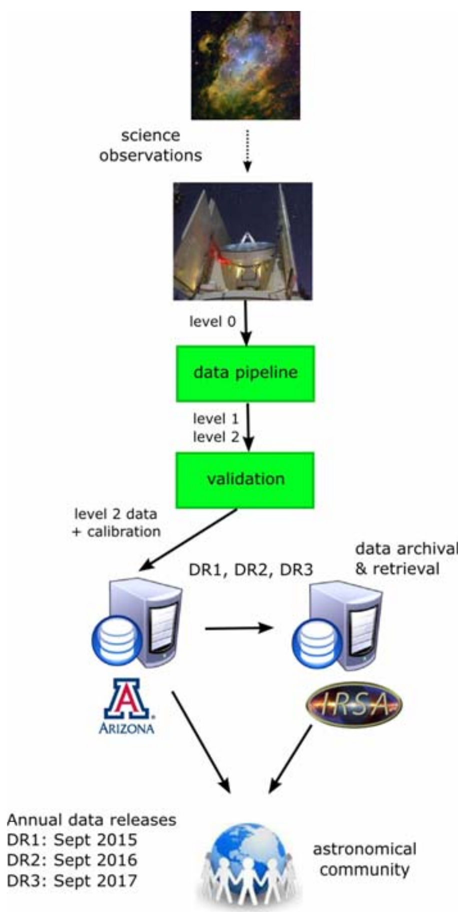

Figure 2: Archival data flow.

Data Archive

The Supercam data products will be in the form of FITS data cubes provided to the community from the University of Arizona and registered to the National Virtual Observatory (NVO). The data will be released annually in September of 2015, 2016, and 2017 as Data Release 1, 2, and 3 (DR1, DR2, DR3) as soon as calibration and formatting is complete, with **no proprietary period**. The archival data flow is diagramed in Figure 2. The maximum data volume is expected to be 100 GB in total, including all calibration datasets. The large FITS cubes will be developed within the Supercam team and hosted both at the University of Arizona and at the Infrared Science Archives (IRSA) at the Infrared Processing and Analysis Center (IPAC), as was done with the BGPS survey. The FITS headers will be stored in a SQL database to make a web-based relational queries of Supercam data and extraction of data subsets easy from the astronomer's perspective. PI Kulesa and software lead B. Peters will lead the development of the web interface to the data.

Postdoctoral Mentoring Plan

Not applicable: no postdoctoral researchers are supported under this proposal.

Steward Observatory
Director's Office

THE UNIVERSITY OF
ARIZONA®
TUCSON ARIZONA

Tucson, Arizona 85721
Telephone: (520) 621-6524
Telefax: (520) 621-7852

January 21st, 2004

Major Research Instrumentation Program
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230

Dear Selection Committee,

This letter is intended to convey our strong and enthusiastic support for the NSF MRI proposal entitled "Development of a Submillimeter-wave Superheterodyne Camera (SuperCam) for the Heinrich Hertz Telescope." SuperCam will be the first large-format, high resolution imaging spectrometer at submillimeter wavelengths. It will increase the mapping speed in many important astrophysical emission lines by more than an order of magnitude, making possible observational studies that until now have been intractable. We believe SuperCam will revolutionize spectroscopic studies in the same way the advent of SCUBA revolutionized observations of thermal dust emission in the far-infrared. Once SCUBA became operational, it dominated the observing programs on the JCMT. We expect the same will happen with SuperCam on the HHT. In anticipation of this we plan to dedicate at least two months a year, one in the fall and one in the spring, to the types of survey programs outlined in this MRI proposal. We believe SuperCam will make excellent use of the HHT and have a lasting impact on the field.

Sincerely,

Peter Strittmatter

Peter A. Strittmatter, Director
Steward Observatory