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

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☐ Asian
☐ Black or African American
☐ Native Hawaiian or Other Pacific Islander
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List of Suggested Reviewers or Reviewers Not To Include (optional)

SUGGESTED REVIEWERS:

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REVIEWERS NOT TO INCLUDE:

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

PROGRAM ANNOUNCEMENT/SOLICITATION NO./CLOSING DATE/if not in response to a program announcement/solicitation enter NSF 04-23 **NSF 05-608** **11/15/05**	FOR NSF USE ONLY
FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) (Indicate the most specific unit known, i.e. program, division, etc.) **AST - ASTRNMY & ASTRPHYS RES GRANTS**	NSF PROPOSAL NUMBER **0606750**

DATE RECEIVED	NUMBER OF COPIES	DIVISION ASSIGNED	FUND CODE	DUNS# (Data Universal Numbering System)	FILE LOCATION
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TITLE OF PROPOSED PROJECT **A Systematic Study of Supernova Host Galaxies**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ **284,451**	**36** months	**07/01/06**	

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☐ BEGINNING INVESTIGATOR (GPG I.A)
☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C)
☐ PROPRIETARY & PRIVILEGED INFORMATION (GPG I.B, II.C.1.d)
☐ HISTORIC PLACES (GPG II.C.2.j)
☐ SMALL GRANT FOR EXPLOR. RESEARCH (SGER) (GPG II.D.1)
☐ VERTEBRATE ANIMALS (GPG II.D.5) IACUC App. Date ____________
☐ HUMAN SUBJECTS (GPG II.D.6)
Exemption Subsection __________ or IRB App. Date __________
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PI/PD DEPARTMENT **Department of Physics**	PI/PD POSTAL ADDRESS **Eugene, OR 97403** **United States**
PI/PD FAX NUMBER **541-346-5861**	

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CERTIFICATION PAGE

Certification for Authorized Organizational Representative or Individual Applicant:

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

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

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

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(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 ☒

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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.

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

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

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

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

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

AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME **Kent Hardin**	**Electronic Signature**	**Nov 9 2005 7:29PM**

TELEPHONE NUMBER	ELECTRONIC MAIL ADDRESS	FAX NUMBER
541-346-3139	**Kent_Hardin@orsa.uoregon.edu**	**541-346-5138**

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To date, Supernova (SN) of all types have been discovered in 1833 galaxies with redshift less than 0.1. Also, to date, no thorough and systematic study of this sample has been undertaken in order to provide a good characterization of a) the properties of SN Host galaxies and b) the local environment within that host galaxy in which the SN occurred. With the tremendous activity in the area of detecting and measuring distant SN as cosmological probes, it is incumbent to better determine if the environments or hosts of these distant SN are similar to that of the nearby sample. Any systematic differences could potentially produce calibration errors which could either mask or artificially enhance any cosmological signal. In this proposal we aim to a) determine the average color and surface brightness of the stellar population on the 0.1-2 kpc scale that defines the environment in which the SN occurred; b) better characterize the environment for relatively large percentage of SN that have been detected well beyond the traditional optical radius of the host galaxy; c) through a Monte-Carlo analysis, better determine the SN selection function used by Earth observers over the last 100 years to produce the current catalog of nearby SN and d) to use that selection function to re-evaluate SN rates and galactocentric radius of occurrence as a function of global host galaxy properties. From that study should emerge a set of statistical attributes of SN host galaxies which we can then map onto the more distant Universe to critically probe if we are, in fact, observing the same local phenomenon at these distances.

This study has broad impact the area of science literacy and the American public. To wit, the public's fascination with cosmology has been recently re-invigorated with the apparent discovery of "Dark Energy" and the realization that the Universe may be accelerating thus verifying Einstein's "Biggest Blunder". In both professional and lay publications and/or press releases, many teams have claimed that the observed dimming of distant SN have provided direct evidence of the accelerating Universe. Yet, at some level, all of these results are making the tacit assumption that these distant SN represent the same physical process as is occurring locally. This has yet to be rigorously demonstrated which shows the overall scientific importance of the concepts of proper calibration of a technique and the need to ensure that one's assumption set used to generate scientific conclusions (or proclamations) is valid. Until we have a better understand of the SN rate in the nearby Universe as well as the galactic environments that produce SN, we can not rest so easily that the distant Universe is so similar.

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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.

Results of Prior NSF Support: LSB Galaxies

The PI has had two recent NSF Grants. One is related to Curriculum Development and is therefore not terribly relevant to this particular research based proposal. The other one centered on the discovery and measurement of the properties of Low Surface Brightness (LSB) galaxies. The existence of LSB galaxies and their likely large space density (at all galactic masses) clearly shows the severity of observational selection effects. As a result of this work, the PI may have a pretty good track record on properly identifying selecting effects and correcting samples for those effects. Simply put, the degree of surface brightness bias that exists in the standard detection and cataloging of galaxies has been greatly underestimated. The same set of strong biases that apply to galaxy selection may well apply to the selection of extragalactic supernova and so this current proposal represents a nice complement to the expertise gained under the previous proposal.

In the following I will briefly summarize the highlights of the research on LSB galaxies:

- Over the period 1995-2004 this research has resulted in at least 25 peer reviewed publications as well as a couple of popular articles. This research was also the direct basis for at least 5 Ph.D. students: S. McGaugh, K. O'Neil, D. Sprayberry, T. Pickering, and W. de Blok.

- It is safe to now say that LSB galaxies represent a legimitate sector of the galaxy population and research on these enigmatic objects has now become part of mainstream extragalactic astronomy. This was not the case prior to the NSF funded research so in that sense the impact of this work on the community was relatively large.

- LSB galaxies have, as a class, shown to be relatively unevolved systems compared to more normal galaxies of similar mass. Their overall gas contents are higher than other systems, their mean ages appear to be younger, their metal abundances are low, their current star formation rates per unit mass are considerably lower, and their dust and molecular gas contents appear to be deficient. Yet, these systems have managed to produce the same number of stars over a Hubble time as more normal spirals of the same mass. This is quite curious. The nature of star formation in LSB galaxies therefore remains elusive as its unclear whether star formation is stimulated by a sparse population of molecular clouds in these systems or is it occurring in the more plentiful diffuse atomic H I medium.

- LSB galaxies have very interesting dynamical properties. Rotation curves that are fit with standard dark matter halos invariably result in baryonic mass fractions of LSB disks that are 5-10 times lower than galaxies of higher surface brightness. Thus they appear to be considerably more dark matter dominated at all radii. This potentially makes them physically different objects than disk galaxies that define the Hubble sequence. On the other hand, LSB disks occupy the same locus of points on the

Tully-Fisher diagram as normal galaxies which is manifestly impossible if their baryonic mass fractions are systematically lower because this results in systematically lower dynamical mass-to-baryonic light ratios. LSBs should therefore define a different TF relation. A possible resolution to this dilemma invokes Modified Newtonian Dynamics as an explanation for their rotation curves. MOND indeed fits all the LSB rotation curve data extremely well. There may well be something very interesting going on here.

- A family of very large LSB disks (e.g. Malin 1 like) has been discovered and characterized. These objects are extremely enigmatic structures and seem to violate most of the standard rules for star formation and evolution of disk galaxies. Some of them are the most massive galaxies ever discovered and the most recent aspect of this project (e.g. O'Neill etal 2004) has now tripled the numbers of these objects.

- While the space density of LSB galaxies is still difficult to accurately determine (because of very strong selection effects against their detection) application of reasonable selection functions to go from observed space density to intrinsic space density produces the plausible scenario that most of the missing baryons are contained in LSB disks galaxies of baryonic mass approximately $10^{10} – 10^{11}$ solar masses.

In sum, the NSF funded study of the properties of LSB galaxies has been a highly productive area of investigation and has helped upon up a new window of inquiry in extragalactic astronomy. The field has been the basis of several Ph. D theses. The overall research in this field has elevated LSB galaxies from idiosyncratic individual objects to a major component of the extragalactic background. No theory of galaxy evolution can therefore be complete unless it includes these objects

A New Proposal: A Systematic Study of Supernova Host Galaxies

Background and Motivation:

Selection effects and bias continually plague extragalactic samples. In general, selection effects make obtaining a complete, unbiased, and representative sample of extragalactic objects difficult and challenging. The discovery of large numbers of LSB galaxies shows that observational selection effects can be severe. If the selection function is not properly accounted for, significant bias can result. In general, however, many extragalactic investigations make the tacit assumption that these selection effects, while likely present at some level, are not sufficiently strong so as to cause serious bias. This appears to be the standard operating procedure that is currently followed for the case of detected supernova (SN) at high red shift. To quote from Benjamin etal (2003), based on an HST imaging study of a sample of 18 high red shift SN host galaxies:

> ***These similarities support the current practice of extrapolating the properties of the nearby population of SN host galaxies to those at high red shift.***

It is the overall intent and focus of this project to thoroughly investigate the validity of this current practice by performing a comprehensive statistical analysis of the properties of the entire low red shift (**z < 0.1**) sample of historical extragalactic supernova. As of late 2005, there are 1833 SN that occurred in 1693 unique hosts with known red shifts less than z =0.1 and 1541 with red shifts less than z = 0.033. This forms our basic sample. In this proposal we outline, in detail, the kinds of analysis that can be performed on this sample. This analysis is guided by two principle questions:

1. **Is the galactic environment that produces SN (of all types but mostly SN Ia) likely to be the same environment that produces the detected sample of SN at higher red shift?**
2. **What is the selection function that Earth based observers have used to detect 1833 nearby SN in the last 100 years?**

Providing definitive answers to these questions will a) either validate or cast doubt on the voracity of the current and standard practice of directly mapping the properties of nearby SN Ia to those that occur in more distant galaxies and thereby assuming that nothing is evolving in time and b) produce the most robust estimate for the actual SN rate in the nearby Universe. This latter aspect is important to nail down in order to determine the expected yield of distant SN as a function of red shift/survey volume as well as to provide independent confirmation that we are selecting SN in distant galaxies that have “normal” rates.

As an anecdotal illustration of the rate problem, consider this situation. Suppose that one wanted to measure the evolution of the star formation rate (SFR) in the Universe by measuring the integrated SFR within co-moving volumes of radius 10 Mpc. The reliability of this measurement depends upon the degree to which the SFR is determined by the contributions of many galaxies, rather than just a few extreme ones. If one considers the integrated FIR luminosity (a reasonable proxy for SFR) of our local volume within this radius, one finds that approximately 90% of the total FIR luminosity can be accounted for by just three galaxies in this volume: NGC 253, M82 and M83 (although the former 2 dominate). An analogous situation potentially holds for the detection of distant SN. A single imaging frame may contain hundreds, if not thousands of distant galaxies each capable of producing a SN. Is it reasonable to expect, in this situation, the detected SN to come from a galaxy with a normal rate or one with an elevated rate? As discussed below, this basic point remains ambiguous with evidence available to support either case. Indeed, the general deficiency in our current understanding of the systematic properties of SN host galaxies is simply that all analysis has been confined to specific samples or sub-samples – the total nearby population has not yet been analyzed, en masse, in any systematic manner**. We propose to do that exact analysis.**

At the moment, there are two curious attributes about the nature of the sample of distant SN (presumed to be SN Ia) compared to the nearby sample:

1. Detected distant SN (Ia) have significantly bluer colors
2. Detected distant SN (Ia) are located at larger galactocentric radius in their hosts

Indeed, the very Benjamin etal (2003) paper that claims its okay to extrapolate the properties of nearby SN to a more distant population, also reveals, in their small sample of 18 hosts, a significant correlation between the observed V-R color (of the host galaxy) and distance residual with respect to some cosmological fit. Benjamin etal, however, simply dismisses this result by arguing that it is specific to their particular sample and not a potential host bias.

Clearly the current use of SN (Ia) as cosmological probes (e.g. Tonry etal 2003; Stogler etal 2004) motivates a more intense scrutiny of the properties of nearby SN and their environments. Any attempt to use the properties of nearby SN as a calibration template for the properties of distant SN requires some kind of test or certification that the physics of SN formation has not evolved over cosmic time and that the galactic environment which produce SN has also not strongly evolved. In order to perform this certification, it is necessary to thoroughly characterize the environments of local SN for which we can study that environment in more detail. In particular, assessing the true variance in the properties of SN hosts and the SN producing environments within those hosts is essential in understanding the probability of selecting a similar environment in any survey of distant galaxies.

Of direct relevance to the application of SN as cosmological probes is the amount of internal extinction that is typical for the SN environment. Of course, the larger the galactocentric radius of the SN event, the smaller this reddening is likely to be. However, for most distant SN it is not possible to cleanly determine if the SN has occurred in the inner or outer parts of the host galaxy. This is why a measurement of the broadband color of the local SN environment (i.e. the color of the underlying stellar population) in comparison with the color of the SN in its evolving light curve is so important. If it can be shown that the typical SN Ia environment is one of low reddening then we can gain confidence that extinction effects are not statistically biasing the distant sample. Larger than assumed extinction would dim the SN from its expected brightness which would therefore produce a larger distance modulus and hence generate a false signal for a particular cosmology. This is clearly a non-trivial problem and, as detailed below, the current published literature is ambiguous on this point. However, for the nearby sample, no thorough assessment has yet been made concerning the micro location (e.g. spiral arm, inter-arm, bulge, above the plane) and stellar population environment of the SN Ia event. Rather, this assessment has been made on particular sub-samples of objects (usually small) or on just individual objects themselves. **Its time to gain a more complete and thorough understanding based on the analysis and photometric measurements of the local SN environment of hundreds of hosts instead of just a few.**

The other issue of the reliability of SN as cosmological probes revolves around any possible dependencies between SN Ia peak luminosity and the properties of the host galaxies. An early foray into this question can be found in von Hippel etal (1997) who suggested that, since progenitors of SN Ia are white dwarfs in binary systems, then there may be a dependence of SN Ia peak luminosity on the white dwarf mass function (wdmf) of the host galaxy and that the wdmf is a function of the mean age of the galaxy. Indeed, it is well established (see Hamuy etal 1996) that among SN Ia, those that occur in E/S0 hosts are 0.3 mag fainter than those that occur in spiral hosts. The essential difference between an E/S0 galaxy and a spiral galaxy lies in the mean age of the stellar population (E/S0 being significantly older). The wdmf models of von Hippel etal correctly predict this observed difference. If the SN Ia formation mechanism is related to binary mergers and if the binary population depends upon host galaxy type as well as the range of local environments within that galaxy (a plausible scenario– Ruiz-Lapuente etal 2004), then there may well be important evolutionary corrections to SN Ia luminosity since **local galactic environments do evolve.** Such evolutionary corrections need to be properly accounted for in calibrating the SN Ia luminosity scale. Other groups (e.g. Umeda etal 1999; Reindl etal 2005) offer different explanations for this observed 0.3 mag difference. However, the origin of the difference, at this point, is not important. What matters is that the difference exists and that 0.3 mag of dimming is an appreciable fraction of any cosmological signal that the dimming of distant SN might be providing. These results point to two potential problems which need substantially more data analysis to resolve:

1. **Is there any statistical evolutionary correction to SN Ia peak luminosity that is based on the mean age of the stellar population in the host galaxy**.

2. **Is there any dependence of SN Ia peak luminosity on other host galaxy properties which is significant enough to require knowledge of these properties for galaxies at high redshift?**

The fact that both of these questions can be raised should be regarded as evidence that we should not be so secure in our assumptions that we can analyze the peak brightness of distant SN without any knowledge of the properties of the host galaxy.

Overall, this project is large and ambitious and, as such, forms the basis for an original and competitive Ph. D. thesis. University of Oregon graduate student, **Elsa Johnson**, has already begun work in this area and if this proposal is successful, the funding will be sufficient to support her to completion. Moreover, this project will be a successful manifestation of performing original research through data mining and analysis of a large, multi-parameter, astronomical database.

Meta-Analysis Questions:

What makes this study so intriguing and interesting is the multiple ways that the cumulative database of historical SN can be interrogated and analyzed. Ideally the components of this database are the following:

- Year of Discovery
- Type of SN
- Catalog ID of the host galaxy (e.g. NGC, UGC, anon)
- Redshift of Host Galaxy
- Environment of Host galaxy (e.g. isolated, interacting, group, cluster)
- Location of SN within the structural components of the host galaxy (e.g. spiral arm, inter-arm, bulge, above the plane, halo, etc)
- Luminosity/Mass of the Host Galaxy
- Broad Band color of SN (at maximum)

- Broad Band color of Host Galaxy
- Broad Band color of local region of the Host in which the SN occurred (supplemental data to be acquired at the Pine Mountain Observatory)
- Galactocentric Radius of the SN position
- FIR Luminosity and 60/100 micron flux ratio (to serve as proxies for the SFR)
- Metallicity of Host galaxy (through V-K colors mostly)

With the public releases of the SDSS and the 2MASS surveys, most all of this data can be acquired through ON line interrogation of the relevant data bases and through the NED resource. Furthermore, there is now very good completeness (about 97%) for redshift availability of the Host galaxy for these historical SN. Reliable photometric data also exists now for most of the sample and the release of the 2MASS data has greatly increased the available V-K data base for SN host galaxies.

The following list contains the objectives of our analysis. The section immediately after this one describes our plan of attack for tackling each objective. In that section we will also summarize relevant work done by other groups, to date, on that particular issue. As stated before, this other work is concentrated to much smaller samples of SN hosts and it remains unclear whether those specific results can properly be generalized

Objectives of this Study:

- What is the distribution of galactocentric radius as a function of SN type? Does this distribution show residual correlations with host galaxy luminosity, metallicity, color, or integrated SFR?

- Is their a dependence of SN color (at maximum) on galactocentric radius or host galaxy color or luminosity? That is, do most SN (especially SN Ia) occur in a preferentially un-reddened environment.

- Do SN occur where most of the stars are in the Universe?

- Is their a preferred meta-galactic environment for the production of SN or is this production more a function of the properties of the individual host?

- Is there a preferred local galactic environment (e.g. spiral arms) for the production of SN within an individual host?

- What is the range of local colors of the stellar population (on the 0.5-2 kpc scale) in the region that produced the SN?

- Is there an a priori combination of SN + Host galaxy broadband colors that strongly favor a candidate SN as being SN Ia?

- Is there a correlation between SN Ia peak luminosity and *any* other properties of the host galaxy?

- What is the local environment of the relatively large percentage of SN that are known to have occurred well outside the nominal optical radius of the Host?

- Has a SN of any type ever occurred in a Low Surface Brightness Galaxy?

- What is the nature of the local environments in those few galaxies which have produced multiple SN over the last 100 years (e.g. NGC 5253, M100, NGC 6946)?

- What is the observational selection function used by earth observers that has resulted in the current list of extragalactic SN?

- What is the revised SN rate that results when this global selection function is used? How does that rate vary with type of SN or with host galaxy properties? Is that rate consistent with the rate that we infer from the detected distant SN?

We emphasize that the primary goal of this work is to search for dependencies of SN type, SN Ia peak luminosity, and SN rate on the local and global properties of the host galaxy as well as the environment of that host galaxy and to assess whether or not these same conditions are likely to apply at higher redshift. Achieving this goal requires analysis of all attributes of the host galaxy as well as a robust Monte Carlo technique for determining the SN rate from the sample of 1833 catalogued SN with red shifts less than z = 0.1.

Plan of Attack:

The SN Producing Environment:

One set of objectives relates to the physical location of the SN occurrence within a host galaxy and the properties of the local stellar population at that location. We plan to measure this environment using archival ground based and HST images as well as acquiring new ground based data to supplement the archival data. We note that approximately 400 galaxies with historical SN have now been imaged by HST, although most of these images are only through one filter. The overall issue of SN location in host galaxies has received some scrutiny by others to date. Historically, the Sternberg Astronomical Institute Supernova Catalogue compiles SN photometric data in order to study SN frequency in galaxies as well as the radial distribution of SN within galaxies (see Tsvetkov etal 2004 for the latest analysis). One of their outstanding results is to document the relatively high preponderance of detected SN that occurred in galaxies at positions well outside the optical radius where the density of progenitors is rather low. The analysis of the Sternberg data also show that SN Ia tend to have a significant concentration in spiral arms (i.e. locally dusty environments), but not necessarily in H II regions where SN Ib/c or SN II are often found. We certainly plan to improve upon these results by utilizing the higher angular resolution data of the HST image archive will more properly define the galactic environment in which the SN occurred compared to ground based images.

Two striking examples of SN occurring at large galactocentric radius are shown below for SN 2003gd which occurred in NGC 628 (left) and SN 2000ch occurring in NGC 3432.

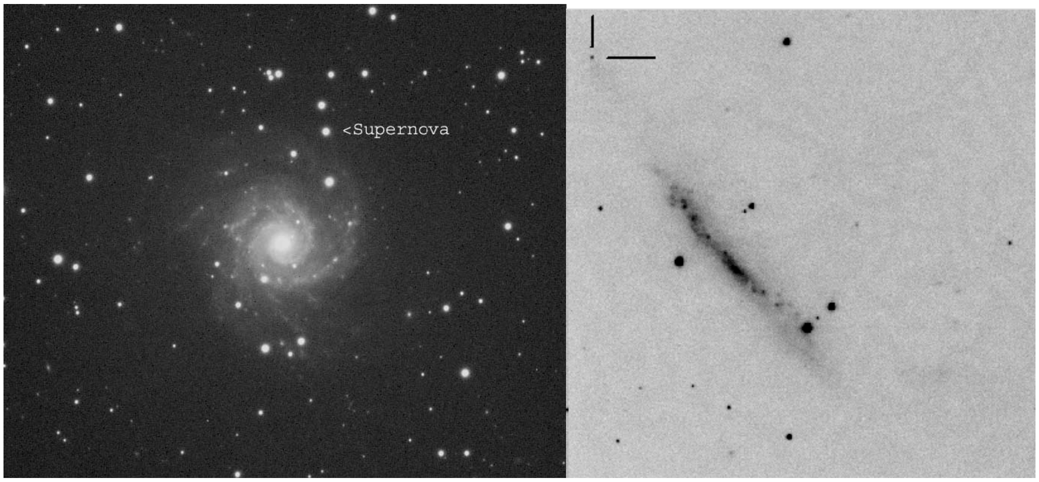

Figure 1: Examples of the occurrence of SN at large galactocentric radii

Using the broadband imaging capabilities of the Pine Mountain 32-inch telescope (described in more detail in the facilities section of this proposal), we plan to image the environments of these curious cases of distant galactocentric SN to determine mean colors and surface brightness in those regions. We also plan (and have already acquired the data for NGC 6946) to perform UBVRI imaging of those nearby galaxies which have had multiple (3 or more) SN detected in the last 100 years to study in detail the local environments of those SN events.

An earlier similar study is that of Hole etal (1996) who did V-I imaging of 50 SN host galaxies to determine the approximate mean age of the local stellar population. Their overall result was a wider variation in V-I colors associated with Type Ia events compared to Type II events. However, V-I by itself is not a good indicator of stellar population mean age (due to its dependence on giant branch effective temperature which depends on metal abundance – see Bothun etal 1984) and a proper analysis requires construction of color-color diagrams. Another benefit of this approach will be to further the work of Shella and Crotts (2004) who find that the use of the host galaxy B-V color in combination with the B-V or V-R color of the SN at maximum produces a relatively clean separation of types Ia from Ib, Ic and II. Their sample size was only 37 hosts so we wish to verify this separation with a much larger sample. If verified, this photometric determination of supernova type will be very helpful in correctly identifying probable distant SN Ia candidates without the need for very telescope time consuming direct spectroscopy.

The study of Wang etal 1997 has also produced a fairly alarming result which requires better investigation with a larger sample. That group studied the correlation between galactocentric distance and SN properties in a relatively small sample (less than 50 hosts). They find that SN which occurred at a distance of more than 7.5 kpc from the respective galactic centered showed 3-4 times smaller scatter in peak brightness than those SN which occurred closer to the center. To first order, this implies that SN events which occur at larger galactocentric radius form a more homogenous sample, which is good for the reliability of distant SN. Howell etal 2000 also performed an analysis of projected distances. They find that **photographically** discovered SN are preferentially discovered at larger galactocentric distances compared to those that have been discovered with more modern CCD imaging. They also find that SN located at large galactocentric radius are 0.3 magnitude fainter than near the center (but they integrate all types of host galaxies together to make this determination). Importantly, Howell etal calculate the probability that any high Z sample of selected SN coming from the same parent population as defines the local sample to be less than 0.1%. While this probability has clearly not been taken seriously by the current high redshift supernova teams, it nonetheless reinforces the overall concern of this proposal – namely that the SN occurring in distant hosts come from a different parent sample than the local SN. More recently, Ivanov etal 2000 studied the properties of 62 Sne Ia as a function of radial distance from host galaxy center. They find no radial dependence of the distribution of peak brightness for E/S0 hosts but do find that spiral hosts show a larger range in the peak brightness distribution, supporting the general idea that the mean age of the stellar population is a factor that determines the overall brightness distribution**. Clearly, stellar populations at high redshift have younger mean ages than stellar populations at z=0**.

On the issues of intrinsic reddening in the SN environment and the dependence of SN Ia peak luminosity on host galaxy properties, there is considerable ambiguity. Studies of distant SN generally assume relatively low amounts of reddening which may be wishful thinking rather than a proven physical situation (see Farrah etal 2004). A study of archival HST R and I images of 22 z=0.6 SN Ia host galaxies by Farrah etal (2002) finds that a) projected distances from galaxy centers range from 3-30 kpc and b) the variation in the broad band colors is large suggesting that extinction is important and is highly variable from host to host. Furthermore, they find no evidence that high red shift detected SN Ia events preferentially occur at radii larger than 10 kpc, where extinction might be expected to be low. In contrast to this, Sullivan etal 2003 show that Hubble diagram of type Ia SN as a function of host galaxy morphology reveals no evidence for dust effects in their overall sample but instead the scatter in peak brightness correlates with morphology (and is lowest in early type galaxies). This result is consistent with an attempted direct measure of dust content of 14 z=0.5 Ia hosts by Clements etal (2005). Using the sub-mm flux to define dust content, Clements etal find little evolution in mean dust content from z =0 to z =0.5 but do note that two objects in their sample of 14 appear to have quite large dust contents. Finally, Pennypacker etal 2004 argue that no convincing evidence for a "dust" bias can be found.

Other authors suggest, sometimes strongly, that potentially unknown and variable extinction within the host precludes the usefulness of distant SN as reliable cosmological probes. For instance Rowan-Robinson (2002) claims that dust extinction has been so seriously underestimated that the observed distribution of SN Ia peak brightness carries with it no cosmological implication. Totani and Kobayashi (1999) show that a simple model in which the optical depth of dust is proportional to gas column density and gas metallicity yields an average B-band extinction at z =0.5 which is 0.15 mag larger than the extinction at z=0. The difference between an open universe cosmology and a cosmology dominated by dark energy amounts to only 0.2 B magnitudes at z=0.5 so this issue of extinction is potentially extremely important. Riello and Patat (2005) are engaged in a more detailed modeling of extinction effects on the estimation of SN Ia rates and peak brightness. Their preliminary results suggest that the total dust content of the host as well as the size of its Galactic bulge have a greater effect than the particular spiral arm geometry in that host**.**

Clearly, extinction effects may be quite important, For instance, Prieto etal 2005 show that when multi-color broadband data is used to better estimate the host galaxy extinction, a significantly lower scatter is produced in the Hubble diagram based on SN Ia peak brightness. Adding to the complexity is the study by Reindl etal 2005 who claim that the extinction law for SN in distant galaxies is governed by a different extinction curve than that which holds for the Galaxy. As the form of the extinction law depends upon the distribution of grain sizes, this proposition may not be unreasonable as SN shocks have the potentially for altering the grain size distribution locally (see Contini 2004). Reindl etal 2005 go so far as to state that the observed difference in brightness (e.g. 0.3 mags) between SN Ia in E/S0 hosts compared to spirals is a manifestation of these different extinction curves as opposed to the mean age differences suggested by von Hippel etal (1997).

From these considerations we pose the following question: **What is the mean surface brightness and mean color of the underlying stellar population on the local scale (size ~1 kpc) environment of the SN?** This question has not yet been satisfactorily addressed by any investigation, primarily due to the lack of quality imaging of the host galaxies. For galaxies of angular size larger than 1.5 arcminuts, we can quickly acquire multicolor CCD data or access SDSS/HST archival images to make this determination but this restricts that sample to generally having velocities less than 5000 km/s. Still, several hundred galaxies become available. These measurements directly bear on the issue of local reddening in the SN **environment.** For instance, is there a typical local stellar population color that produces a SN Ia event? If, as seems likely, there is a large variation in this environment, then that variation must be mapped out properly in order to build some kind of probability density function on the expected level of internal reddening in more distant host galaxies where the micro position of the SN within the galaxy can not be easily measured. A thorough set of measurements of the local SN environment in nearby host galaxies seems crucial if we are to better map this local population on to the population of distant detected SN. **Are all SN really occurring in the same environments, independent of redshift/age of the Universe?**

Combes (2004) has explored this issue in a cursory manner to determine if evolution and extinction as a function of host morphology can help explain the result that high z SN Ia tend to have bluer observed colors than a local sample. She concludes that the current sample of selected high z SN Ia suffers from a reverse obscuration selection effect - namely distant SN are being preferentially selected in extinction free areas of their host galaxies (although the study by Farrah etal 2002 contradicts this view). That may or may not be the case for distant SN but we argue that this is not really known for the nearby sample. **Our analysis of the local colors of the SN producing environment should produce a robust statistical estimate for the a priori probability that a SN will be detected in a relatively low extinction region of a galaxy** (either because it occurs at large galactocentric radius or because the dust content in the galaxy is low or because it occurred in a low dust content region of the galaxy).

The other important calibration question relates to whether or not the peak brightness of SN Ia is dependent upon any other property of the galaxy. Recently, van den Bergh et al 2005 attempt to show that host galaxy morphology must be considered. They analyzed the morphologies of 604 recent SN hosts with specific focus on the types of galaxies that tend to produce “anomalous” SN. These SN usually are either sub-luminous or have non standard light curves. For convenience, these types are referred to by some prototypical case (e.g. the 1991bg family or the 1991T family). van den Bergh etal find that 1991bg family preferentially occurs in early type hosts while the 1991T family occurs in intermediate (e.g. Sb) hosts. However, they also find that SNe Ia occur in all Hubble types, with almost equal probability, and therefore in a variety of systems with different mean ages. While our study is not one that will concentrate on morphology, we are aiming to better determine the relation between different SN types and host galaxy broad band color and metal abundance.

Evidence that SN Ia peak brightness depends upon host galaxy metallicity has also surfaced. Theoretically, Umeda etal (1999) have shown that the variation in fractional carbon abundance among the heavy elements is important in the sense that environments with low fractional carbon abundance will produce fewer bright Ia events. Those progenitors located in old stellar populations (e.g. E/S0) or in low metallicty environments will preferentially produce fainter SN Ia events. This explanation may also be the origin of the observed 0.3 mag decrement in mean brightness for Ia events occurring in E/S0 hosts. Observationally, Hamuy etal 2000 show that, for a sample of 44 SN Ia events, the brightest events occur in the least luminous galaxies. This is contrary to the theoretical expectation. However, they also find that the brightest events occur in the youngest stellar environments (consistent with the expectation of von Hippel etal 1997). This ambiguity shows the importance of dis-entangling age and metallicity effects. With the release of the 2MASS data, V-K colors are now available for hundreds of SN hosts so that, in combination with broad band UBVRI data, we can make a more reliable separation between age and metallicty to study these overall dependencies more directly. **This will be a major component of our comprehensive study.** Finally we note that a recent recalibration of the Cepheid distance scale, based on a re-formulation of the Galactic metal abundance correction, by Allen and Shanks (2004) ultimately shows that for the 8 nearby SN Ia hosts with a Cepheid based distance, there is now an observed correlation (although its weak) between SN Ia peak luminosity and metal abundance. In contrast, Gallagher etal (2004) have used integrated spectra of 57 host galaxies to study the dependence of SN Ia light curve shapes on global metallicty or star formation rate and see little strong dependence and that the range of host galaxy metallicities is normal. We therefore consider this question as still unanswered.

Finally, our study will also focus on the meta-galactic environment of the SN host galaxy itself. The most thorough study of this to date comes from Navasardyan etal 2001. Their sample consists of 18 “isolated” SN hosts, 40 SN hosts distributed in 37 individual galaxy pairs, and 211 SN in 170 distinct hosts in 116 individual groups. Their principal conclusion is that the host galaxy environment has no direct influence on SN production. However, the question of meta-galactic environment bears on a more fundamental issue: **Do detected extragalactic SN trace the stars?** The current answer to this question is unclear as the topic hasn’t been adequately studied. The figure below shows our preliminary analysis of this question on the course scale of 1 degree spatially projected on the sky. This spatial projection is less clustered than that of catalogued galaxies in the NGC or the Zwicky catalogs and suggests, to first order, that SN are not effectively tracing where the stellar mass is in the nearby universe (but for a counter opinion see Radburn-Smith etal 2004).

The next logical step in this analysis is a counts-in-cells comparison between detected SN hosts and the galaxy distribution in redshift space. As sufficient red shift data now exists for the bulk the SN hosts we should be able to perform a robust analysis.

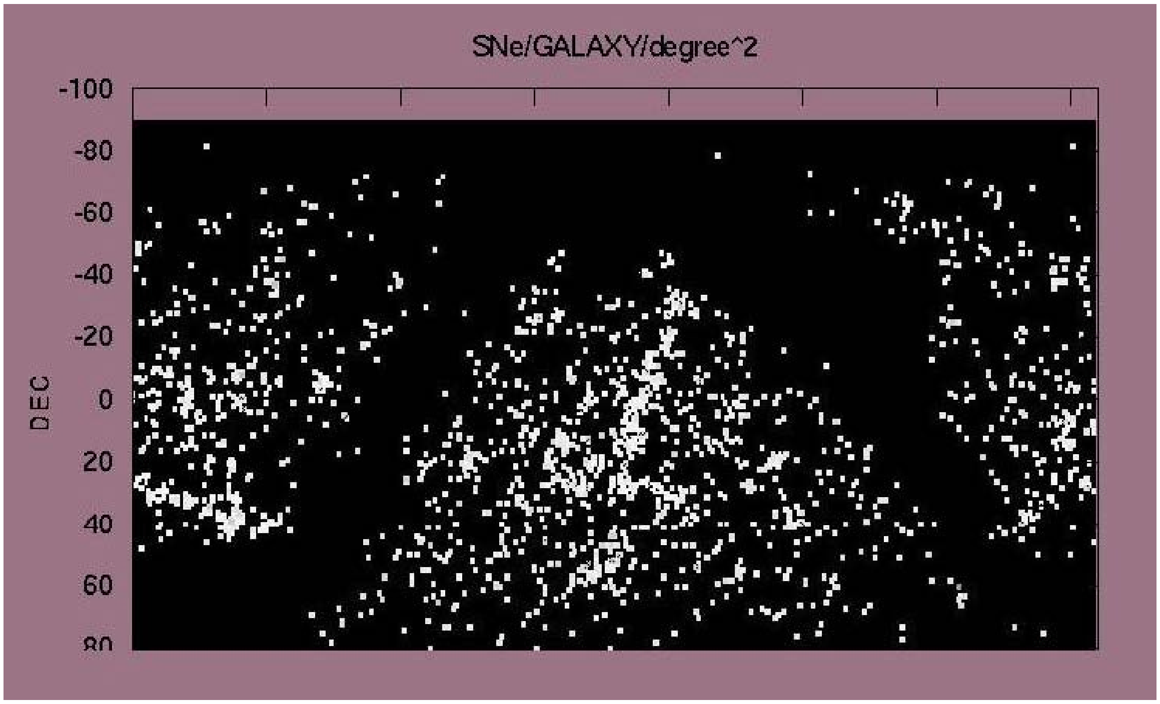

Figure 2: Spatial distribution of SN hosts on the sky binned in 1 square degree intervals

This aspect of our overall investigation is relevant to the issue of using SN as tracers of the intergalactic stellar population or the diffuse light in clusters and/or groups (see Gal-Yam etal 2003; White etal 2003). We wish to examine this question in more detail, using the spatial and redshift distribution of anonymous (i.e. uncatalogued galaxies) SN hosts as a guide. Currently several methods are used to trace the potential intergalactic star population (mostly in Virgo) including Planetary Nebulae, Tip of the Red Giant Branch stars, X-ray binaries, surface brightness fluctuations, etc. If it can be shown that SN are good tracers of where stars are (not necessarily the same thing as where galaxies are), then statistical detections of nearby SN may be able to better constrain the amount of intergalactic light that is present. Overall, however, the question of the frequency of true intergalactic SN has not been thoroughly investigated and evidence for the intergalactic SN is sporadic at best. The most promising case is probably 1980L whose position is 2-3 galaxy diameters away from either NGC 4374, NGC 4387, or NGC 4406 and hence really maybe a case of a SN being a tracer of diffuse light within a group (see also Gal-Yam etal 2003).

The Recalibrated SN Rate:

Supernova rates are expressed in terms of SNUs where 1 SNU is equal to one supernova event every 100 years per 10^{10} blue solar luminosities of stars. This is equivalent to one SN event per year per 10^{12} stars. To properly derive the intrinsic SN rate in the nearby Universe, the selection function for SN must be known. This has never been attempted before for the entire sample of historical SN and **this attempt represents the second main focus of our project.**

Instead, small and well defined samples are used to derive the rate in which the selection function is supposedly easier to derive. However, it is by no means clear that such small samples are representative.

To give an idea of the severity of the selection biases (or alternatively on our very low selection efficiency) consider the following global case: For the current cosmology (h=0.7 and $\Omega_{\_M}$=0.3), the volume out to z = 0.1 is 10^8 Mpc^3. Taking the current galaxy luminosity function and correcting it for the presence of LSB galaxies (e.g. O'Neil and Bothun 2000; O'Neil etal 2004) indicates that this volume contains approximately 3 million galaxies each capable of a 1 SNU of production. Over a 100 year period then, 3 million SN have occurred within this volume yet we have catalogued, at most, 2000 events (in about 1800 unique hosts). Thus our raw detection efficiency averaged over this time is approximately 0.1% (of course our efficiency is highly time dependent –see more below). Efficiency this low necessarily carries with it a very large and uncertain selection function.

The rapid rise in SN detection efficiency by the community of Earth observers in the last few years (where we now typically detect 200-300 SN per year instead of order 50) significantly complicates the selection function because the selection function is clearly time dependent. Monte Carlo techniques are the best approach to recovering this selection function and have been proven to work on smaller samples. The best case is the study of Hardin etal (2000) They used the detection of 8 SN in an 80 square degree area of blind sky whose hosts' redshift range from z = 0.02 to z=0.2 to derive an average SN rate at z ~0.1 of 0.5 SNU. While the universality of this result can be called into question, the approach that they used is largely correct. Of course, this small sample was uniform in detector properties and sensitivity as a function of time. Our proposed task is much more difficult. For instance, one clear selection effect can be ascertained just by looking at detected SN hosts as a function of galaxy catalog. Both the UGC and NGC sample galaxies out to a similar volume (approximately z = 0.04), yet 803 out of approximately 7850 NGC galaxies have had detected SN but only 373 out of approximately 7500 non NGC galaxies in the UGC catalog have had recorded SN. Clearly, earth based telescopes spend more time pointing at NGC galaxies than UGC galaxies. This is but one input in to the Monte Carlo simulation. Other inputs include flux limits evolving over time using better detectors, areas of sky surveyed, duty cycle of clear weather, etc. All the potential observing/detector components that are relevant to how SN are detected must be factored in to perform simulated observations of the sky resulting in 1833 SN discovered in the last 100 years with z < 0.1.

The largest sample to date for which the SN rate has been derived is that of Cappellaro etal 1999 (see also Hamuy and Pinto 1999). Those authors correct for biases against SN detection in the inner regions of galaxies and in inclined spirals (other components of our Monte Carlo simulation). From that sample, they derive a z=0 SN rate of 0.16 SNU. A reality check on their method is that they do find the expected correlation between core-collapse SN rate and integrated galaxy color. They do not find any dependence of SN Ia rate on galaxy properties. Estimates of the SN rate at higher red shifts are prone to even larger selection effects. Pain etal 2002 derive a SN Rate at average z = 0.55 of 0.65 SNU based on 38 SN with z = 0.25 – 0.85. In deriving this rate, they assume zero evolution in the SN rate with redshift even though they end up with a rate at z = 0.55 which is 4 times higher than the z=0 rate! In addition, a recent study by Dahlen etal 2004 finds a SN Ia rate at z~1 that is 3-5 times higher than the local rate. These high rates are similar to the rate of 0.7 SNU derived for active and starburst galaxies by Richmond etal 1998 with all detected SN in that sample coming from outside the dense stellar nucleus. While it seems obvious that detected distant SN hosts will be biased towards those that have the highest rates, the degree of this bias can't be properly known unless we have a secure measure of the local SN rate as a function of galaxy type and properties. If indeed it can be shown that the SN Ia rate in distant samples is significantly higher than in the detected nearby samples, this would again call into question the implicit assumption that the two samples are the same.

Recently, two examples of how selection effects may be masking reality have been published. Using the raw data or just simple selection functions, it has never been possible to re-produce the most simple and basic expectation: the number of detected SN should scale with the luminosity of the host galaxy. For a small sample, Melchior etal 2004 show that after selection biases have been identified, this expected trend emerges. More alarming is the recent (and frankly somewhat unbelievable) result of Mannucci etal 2005. They used the 2MASS database as a resource for correlating SN rate as a function of color and type. They find that the SN Ia rate is 20 times higher in late type spirals compared to E/S0 galaxies which is completely inconsistent with specific surveys, like the CTIO SN survey, which finds that the fraction of SN Ia hosts that are spiral is about 70% while 30% are elliptical. Moreover, Mannucci etal find that galaxies with B-K bluer than 2.6 have a rate which 30 times (!) higher than redder galaxies. They conclude that a significant fraction of SN Ia events must occur in late type spirals/irregulars which have relatively young stellar components. This is not at all consistent with the general makeup of the detected hosts of SN Ia as documented by van Den Bergh etal (2005). We mention this study here as it shows the power of how applying selection functions (most likely erroneous ones in this case) can fundamentally alter our view of the intrinsic nature of both SN host galaxies and the frequency of occurrence of SN in various types of galaxies. Our overall goal is therefore to produce a Monte Carlo simulation to effectively measure the SN detection efficiency so as to get a more robust **estimate of the actual SN rate in galaxies as a function of their stellar content, luminosity, metallicty, surface brightness and morphology**.

Anecdotal Oddities:

Finally we would like to draw attention to some curious occurrences in the overall nature of detected SN and host galaxies. This is meant to provide an indication of how incomplete our knowledge may well be about the nature of SN and the events that trigger them. In the following it will be helpful to remember that 1 SNU = one SN event per year per 10^{12} stars:

- **SN deficiency in the Coma Cluster**: The core of the Coma cluster contains at least 10^{14} stars yet the last detected SN in this core was done by Fritz Zwicky! However, there have been 4 SN detected in the general vicinity of NGC 4874 (in the more diffuse Coma supercluster and two of these (1968H and 1985K) occurred in anonymous galaxies.

- **NGC 5253**: This wimpy little galaxy with approximately $10^{9.5}$ stars has had 3 detected SN since 1895.

- **NGC 6946**: This semi-starbust, nearby, heavily reddened galaxy has had 8 detected SN occur since 1917. As this galaxy is very nearby, we can image it at a spatial resolution of just a few 10s of parsecs and therefore get good detail on the stellar populations in the 8 regions that produced a SN in this host with $10^{11.5}$ stars.

- **Very Large Disk Galaxies**: As pointed out initially by Romanishin (1983) there exists a class of very large spiral galaxies which contain 10^{12} stars and hence should have a supernova occurrence every 1-2 years. Canzian (1998) has more formerly produced a list of the 40 largest galaxies which basically meet this criteria and which have red shifts less than 0.04. Of the 1833 SN detected, 15 of these 40 hosts have had detected SN and 3 of these galaxies (e.g. NGC 772, NGC 1961, NGC 5172) have had 2 SN detected within a 3 year period. These multi SN hosts have all been detected since 1998 and NGC 772 had its 2 SN occur in the year 2003 (hl and iq). This is an important constraint on our Monte Carlo simulation because it indicates that our detections of nearby supernova now does include galaxies which potentially have very high intrinsic SN rates. If those kinds of objects are missing from previous samples, then clearly this would bias the determination of the overall SN rate.

SUMMARY:

In this proposal we have outlined our strategy for analyzing the large data base of extragalactic SN and for supplementing that data based with additional ground based multi-color imaging. Our goals in this study are to a) better characterize the local galactic environment that produces SN and to determine if there is any correlation between SN type and SN Ia peak brightness with the characteristics of that local environment and b) to use the entire historical SN database to derive the selection function that Earth observers have used to populate that database in order to recalibrate the intrinsic SN rate as a function of SN type, and host galaxy properties. Using a combination of ground based and HST archival data we will be able to characterize the nature of the stellar populations in the SN producing regions on physical scales of 0.1 to 2 kpc. We will also explicitly explore the environments of SN that have occurred at large galactocentric radius.

Overall we expect to produce several hundred examples of a local environment. Since we know that galaxies evolve, one might expect at least moderate evolution in the local environments of galaxies over cosmic time and thus evolutionary corrections may need to be applied to distant SN. To get a handle on the possible role of extinction, we will measure the local colors in the general area of the SN event via the method of grid photometry as outlined in Bothun 1986 and White and Bothun 2003. Our goal here is to fully explore the stellar populations and local morphology in the host galaxy that produced the SN event in order to establish norms and the range of deviations from those norms as well as to establish the SN rate as a function of those environments. Only after this baseline is established can we then more critically examine the question of whether or not the environments that produce the detected distant SN are likely to be the same as those that produce SN in the nearby Universe.

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BIOGRAPHICAL SKETCH

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Education:

- Undergraduate: University of Washington -- B.S. in Astronomy, June 1976
- Graduate: University of Washington -- Ph.D. in Astronomy, August 1981

Current Employment:

- Professor of Physics and Environmental Studies, University of Oregon, September 1995 - present

Past Employment:

- Associate Professor of Physics, University of Oregon, July 1990 - September 1995
- Assistant/Associate Professor of Astronomy, University of Michigan, 9/86-7/90
- Bantrell Fellow, California Institute of Technology, 9/83-9/86
- Center Fellow, Harvard-Smithsonian Center for Astrophysics, 10/81-9/83

Professional Awards/Activities:

- Center Fellowship (CFA), 1981-1983
- Bantrell Prize Fellowship (Caltech), 1983-1986
- Phi Beta Kappa Visiting Scholar, 2001-2002
- Scientific Editor, Astrophysical Journal 1996-2003
- Inaugural Member of ISI Highly Cited Astronomer over the period 1980-2000

Related Publications/Activities:

1) The Intrinsic Color and Structure of IC 342 from CCD Observations *Publications of the Astronomical Society of the Pacific* 2003 115, 1135
2) Star Formation in H I Selected Galaxies: H II Region Properties, *The Astrophysical Journal* 2005 630, 824
3) Far-Ultraviolet and H-alpha Imaging of Nearby Spiral Galaxies: The OB Stellar

Population in the Diffuse Ionized Gas *The Astrophysical Journal* 2001 559, 878

4) The Luminosity of SN 1999by in NGC 2841 and the Nature of ``Peculiar" Type Ia Supernovae *The Astrophysical Journal* 2004 613, 1120
5) The Pine Mountain Observatory Outreach Program *Bulletin of the American Astronomical Society* 2000 1971, 2005

Other Recent Publications:

1) Companions to Isolated Elliptical Galaxies: Revisiting the Bothun-Sullivan Sample *The Astrophysical Journal* 2004, 607 810
2) Extraordinary Diffuse Light in Hickson Compact Group 90 *The Astrophysical Journal* 2003, 585 739
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5) The Discovery of Cepheids and a New Distance to NGC 2841 Using the Hubble Space Telescope *The Astrophysical Journal* 2001 559, 243

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Advisors:

Graduate: Woodruff T. Sullivan III

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of Oregon Eugene**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Gregory D Bothun**	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. **Gregory D Bothun - Professor**	0.00	0.00	0.67	$ 6,400	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.67	6,400	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.00	0.00	0.00	15,000	
3. (**1**) GRADUATE STUDENTS				18,000	
4. (**0**) UNDERGRADUATE STUDENTS				0	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (**0**) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				39,400	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				8,674	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				48,074	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **Flat Field High Intensity Lamps** $ 5,000 **VRI 3x3 custom filters** 7,500					
TOTAL EQUIPMENT				12,500	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				1,500	
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				3,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				3,000	
4. COMPUTER SERVICES				500	
5. SUBAWARDS				0	
6. OTHER				9,100	
TOTAL OTHER DIRECT COSTS				17,600	
H. TOTAL DIRECT COSTS (A THROUGH G)				79,674	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 48.5000, Base: 58074)**					
TOTAL INDIRECT COSTS (F&A)				28,166	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				107,840	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 107,840	$

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

PI/PD NAME **Gregory D Bothun**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kent hardin**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

	FOR NSF USE ONLY		
ORGANIZATION	PROPOSAL NO.	DURATION (months)	
University of Oregon Eugene		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR	AWARD NO.		
Gregory D Bothun			

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. **Gregory D Bothun - none**	**0.00**	**0.00**	**0.67**	$ **6,720**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	**0.00**	**0.00**	**0.00**	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	**0.00**	**0.00**	**0.67**	**6,720**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL ASSOCIATES	**0.00**	**0.00**	**0.00**	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	**6.00**	**0.00**	**0.00**	**15,000**	
3. (**1**) GRADUATE STUDENTS				**18,900**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**40,620**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,108**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**49,728**	
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)				**1,500**	
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				**500**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**3,000**	
4. COMPUTER SERVICES				**500**	
5. SUBAWARDS				**0**	
6. OTHER				**9,555**	
TOTAL OTHER DIRECT COSTS				**15,555**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**66,783**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 48.5000, Base: 57228)**					
TOTAL INDIRECT COSTS (F&A)				**27,756**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**94,539**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **94,539**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME	FOR NSF USE ONLY		
Gregory D Bothun	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG
Kent hardin			

***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of Oregon Eugene**					**FOR NSF USE ONLY** PROPOSAL NO. / DURATION (months): Proposed / Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Gregory D Bothun**					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. Gregory D Bothun - none	0.00	0.00	0.00	$ 0	$
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.00	0	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.00	0.00	0.00	15,000	
3. (1) GRADUATE STUDENTS				19,845	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				34,845	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,165	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				41,010	
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)				1,500	
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				500	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				2,000	
3. CONSULTANT SERVICES				3,000	
4. COMPUTER SERVICES				500	
5. SUBAWARDS				0	
6. OTHER				10,035	
TOTAL OTHER DIRECT COSTS				16,035	
H. TOTAL DIRECT COSTS (A THROUGH G)				58,545	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 48.5000, Base: 48510)**					
TOTAL INDIRECT COSTS (F&A)				23,527	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				82,072	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 82,072	$
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Gregory D Bothun**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kent hardin**	Date Checked	Date Of Rate Sheet	Initials - ORG

***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Oregon Eugene**	FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Gregory D Bothun**	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. **Gregory D Bothun - none**	0.00	0.00	1.34	$ 13,120	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.34	13,120	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL ASSOCIATES	0.00	0.00	0.00	0	
2. (3) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	18.00	0.00	0.00	45,000	
3. (3) GRADUATE STUDENTS				56,745	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				114,865	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				23,947	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				138,812	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 12,500					
TOTAL EQUIPMENT				12,500	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				4,500	
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				4,000	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				6,000	
3. CONSULTANT SERVICES				9,000	
4. COMPUTER SERVICES				1,500	
5. SUBAWARDS				0	
6. OTHER				28,690	
TOTAL OTHER DIRECT COSTS				49,190	
H. TOTAL DIRECT COSTS (A THROUGH G)				205,002	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				79,449	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				284,451	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.C.6.j.)				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 284,451	$

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

PI/PD NAME **Gregory D Bothun**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kent hardin**	Date Checked	Date Of Rate Sheet	Initials - ORG

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

Budget Justification Page

Senior Personnel: We request 2/3 of a month of Summer Salary for the PI for the first 2 years of this award

Graduate Students: We request 12 months of stipend support (at $1500 per month) plus annual graduate student insurance. Annual increases are factored in at the rate of 5% per year

Technian: We request partial salary support for the remote data observer/technician, Allan Chambers, at the Pine Mountain Observatory. The remainder of this salary comes from some University funds. Continued funding of this position is crucial for data acquistion.

Fringe Benefits: Are calculated as 41% of the PI summer salary, 20% for the technician's salary and 1% for Graduate Student stipend.

Equipment: During the first year we request funds to upgrade our existing VRI filters (the U and B filters are fine). As we have an incoming F3 beam to a thin CCD, focus tolerance is just a few microns and hence we require very optically flat filters. Previously these have been manufactured at a unit cost of approximately $2500 each. In addition, although our CCD detector, luckily, is intrinsically quite flat, we are constructing a dome field flat system. The current limitation is the acquisition of sufficiently high intensity lamps so that we get reasonable signal in the U-band. We request $5000 for the acquistion of those lamps

Travel: We request a modest travel fund each year to support travel to and from the observatory (330 miles round trip) as well as to attend an annual meeting to present the results of this project.

Other Direct Costs: During the first year we request money in the materials and supplies section to acquire another dedicated Linux machine to run IRAF. In each year of the budget we request $3000 for support/consulting services associated with maintaining that platform. We also request $2000 per year for nominal publication charges. Finally, we request approximately 10K per year to cover graduate student tuition expenses. This item is not included in the overhead calculation.

Current and Pending Support

(See GPG Section II.C.2.h for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: **Gregory Bothun**

Other agencies (including NSF) to which this proposal has been/will be submitted.

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Using Technology to Transform Teaching and Learning: Data Driven Inquiry and Collaborative Learning**

Source of Support: **NSF CCLI Program**

Total Award Amount: $ **475,000** Total Award Period Covered: **09/01/02 - 08/31/06**

Location of Project: **Univ of Oregon, Univ. of Colorado, Univ. of Arizona, CWRU**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.50**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Pine Mountain Observatory Outreach Grant**

Source of Support: **NASA Space Grant**

Total Award Amount: $ **10,000** Total Award Period Covered: **07/01/05 - 12/31/05**

Location of Project: **Pine Mountain Oregon**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.00**

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title: **Tillamook School District Highly Qualified Science Teacher**

Source of Support: **Oregon Department of Education**

Total Award Amount: $ **90,000** Total Award Period Covered: **07/01/05 - 06/30/08**

Location of Project: **Pine Mountain Oregon, Tillamook Oregon**

Person-Months Per Year Committed to the Project. Cal: **0.00** Acad: **0.00** Sumr: **0.67**

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Summ:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

USE ADDITIONAL SHEETS AS NECESSARY

FACILITIES, EQUIPMENT & OTHER RESOURCES

FACILITIES: Identify the facilities to be used at each performance site listed and, as appropriate, indicate their capacities, pertinent capabilities, relative proximity, and extent of availability to the project. Use "Other" to describe the facilities at any other performance sites listed and at sites for field studies. USE additional pages as necessary.

Laboratory: **Image processing laboratory available for graduate student use.**

Clinical:

Animal:

Computer:

Office:

Other:

MAJOR EQUIPMENT: List the most important items available for this project and, as appropriate identifying the location and pertinent capabilities of each.

The Pine Mountain Observatory has a 32-inch telescope with a Prime Focus CCD system and a set of UBVRI filters. The pixel scale is 2.1 arc seconds per pixel with a total field size on the 1024 x 1024 rear illuminated thin CCD of 36 x 36 arcminutes. While this system was designed for survey work, it can provide the necessary imaging data for measurements of local SN environments in galaxies that are bigger than 1.5 arcminutes. The PI is the director of the facility and data for this project can be acquired

OTHER RESOURCES: Provide any information describing the other resources available for the project. Identify support services such as consultant, secretarial, machine shop, and electronics shop, and the extent to which they will be available for the project. Include an explanation of any consortium/contractual arrangements with other organizations.

FACILITIES, EQUIPMENT & OTHER RESOURCES

Continuation Page:

MAJOR EQUIPMENT (continued):

(remotely) anytime its clear. The observatory is located approximately 165 road miles from Campus.

Supplementary Information on the Pine Mountain Observatory:

The Pine Mountain Observatory, owned and operated by the University of Oregon has been quite active in educational outreach programs as well as K12 science teacher research partnerships over the last few years (e.g. Kang 2002, 2004). The summer visitor season typically attracts 2-3000 visitors to participate in Friday/Saturday evening viewing sessions which are run by expertly trained amateur volunteers. Internet connectivity to the site was established in 1997 and for many of these initial visitors this was their first contact with the Internet as a means of accessing scientific data and explanations. With the completion of a high quality, wide field prime focus CCD imaging system in June 1999 competitive research ability has been re-acquired by the observatory. However, to date, the research scope of the Observatory has been compromised by severe budget limitations. Therefore, the primary mission of the observatory has been public outreach and education together with K12 classroom activities and K12 science teacher training.

Current funding for the observatory is limited and comes via the following components:

- Basic funding for maintenance of the grounds and buildings and electricity to the site is provided for by Facilities Services at the University of Oregon. This budget provides for an on site caretaker who does assist with public tours but there is no University budget available for scientific operations.
- Revenue generated by sales of Tee shirts and cups as well as visitors donations during the summer visitor season helps to sustain that activity. The Friends of Pine Mountain Observatory (FOPMO) are an active group of amateur astronomers that help conduct tours in the summer and visit classrooms at other times of the year.
- A small endowment for research in astronomy (about $20K per year is used to pay for a part time remote observing/data technician as well as internet connectivity (although some of the latter has now been picked up via University cost-share)
- One time allocations made by the UO Research office, The College of Arts and Sciences and/or the Physics department are used to perform needed repairs on the telescope or domes.
- Approximately 10-12 K per year comes from NASA space grant to support our K12 classroom activities program, which is large in scope (250 classroom visitations around the state per year)
- PI generated grant money has been used to acquire some parts of the CCD camera, the focusing mount, the current filter system and data analysis machines.

Background and History of the Pine Mountain Observatory

a) 1967 – 1990:

The Pine Mountain Observatory (PMO) is located at an elevation of 6500 feet approximately 165 road miles due east of the University of Oregon campus. The University operates the facility but leases the land from the US Forest Service. The nearest large city is Bend (population 50,000 and growing very fast) which is 27 driving miles. The last 9 miles of this drive is on an unimproved road, irregularly "maintained" by the US Forest Service. The Observatory is located 50 linear miles from the Cascade crest and therefore is located in the prevailing dry climate of Eastern Oregon. Clear weather can occur throughout the year but is most prevalent in the period May 1 through Nov 15. Access to the observatory from Jan 1 – April 15 usually requires a robust 4 Wheel drive vehicle or snowmobile. The Pine Mountain observatory was founded by E. Ebbighausen, I. Nolt and R. Donnelly. PMO had first light in 1967 with the commissioning of the 15 inch reflector (see Ebbighausen and Donelly 1968) . Shortly thereafter a 24-inch Boller and Chivens was constructed. The largest telescope, constructed by Sigma Research (long out of business), is the 32-inch telescope which was completed in 1977. PMO has always been operated by the

Physics Department at the University of Oregon. of the department.

b) 1990 – Present

Important developments towards the present day state of the Observatory are summarized below:

1993: Bothun obtained a small NSF ILI grant to purchase commercially available CCDs (early ones from SBIG) to use on small telescopes as well as the Cassegrain focus of the 24 inch/f13.0 telescope. This helped introduce undergraduate students, FOPMO and the public to the concept of digital imaging.

1994: The Electronic Universe Project (http://zebu.uoregon.edu) started up on Feb 9, 1994. This is likely the very *first* Web server that was devoted to the delivery of digital astronomical images and scientific explanations to the public. Funding for that project was secured with State of Oregon development funds. In addition, I started to produce (and continue to do so) digital materials for introductory astronomy courses that were available for free to anyone that wanted to use them.

1995: A startup grant from the Oregon Community Foundation titled *Public Education Program at Pine Mountain Observatory* provided the basis for the transformation of FOPMO into an effective outreach unit with classroom visitation involving the use of SBIG CCD cameras attached to a laptop (this is 1995 remember!) to introduce K12 students to the science of digital imaging.

1996: A 90,000 dollar academic equipment grant from Sun Microsystems allowed for the deployment of a UNIX server at PMO as well as additional servers on campus to serve various digital documents images, and the budding enterprise of JAVA applets as a data reduction front end to astrophysical images.

1997: In 1994 significant funds from NASA came to the state of Oregon to build the Network for Education and Research in Oregon (NERO: www.nero.net). The activities at PMO figured prominently in this emerging network and by 1997 the PMO facility, through a frame relay circuit, achieved connectivity to the Global Internet.

1998: An HST Ideas was award to PMO to support the training and continuing education of K12 science teachers. This resulted in the creation of (a now annual occurrence) 2 week teacher workshop, held each summer in Bend, with a substantial component of work done at PMO. The goal of the workshops are to have teachers develop astronomy curriculum or lesson plans, based on the analysis of real digital imaging data acquired at PMO, to be used in their actual classroom
.

1999: The CCD Camera was finished by Spectra Source instruments. It houses a thin, rear-illuminated Tex 1024 x 1024 CCD with 24 micron pixel size. When placed at the prime focus of the f3.0/32-inch telescope the field size is 36 x 36 arcminutes, with a scale of 2.1 arcseconds per pixel. This is fairly large field size that lends itself to a wide variety of imaging projects.

Education and Outreach:

For many consecutive years, PMO and FOPMO have been offering K12 science teacher workshops. These workshops are taught mostly by Rick Kang, the education office for FOPMO, with supplemental help/teaching being provided by K. Carr and G. Bothun. These workshops are primarily supported through NASA Funding, although occasionally the State of Oregon provides some funding. Our training programs are unique and intensive and center around the delivery of real CCD pixel data to

K12 science teachers. In addition, we are also actively engaged in the development of astrophysical image reduction programs (supported by an NSF CCLI grant) that can in the Web environment. This requires the use of JAVA as the programming language. Specifically, we had to find a way that the teachers could actually reduce and view the FITS images that the camera produces. If we were only interested in delivering images to the teachers then this could have been accomplished through simple format conversions from FITS to JPG. However, such conversions will lose all calibration information. The prime goal of our outreach program is for K12 science teachers to directly analyze the real data. To accomplish this we have written a quite extensive FITS analyzer in JAVA which has most of the functionality of IRAF's Ximtool. With this tool, teachers can perform photometry, find stars automatically, measure brightness profiles of objects, determine the sky background, construct color-magnitude diagrams, measure the size of lunar craters, and even make true color CCD images from individual R,G and B frames. These tools help make the PMO educational outreach program somewhat unique and quite robust.

The intent of this educational program is to develop an interactive astronomy curriculum for K12 science teachers, based on the analysis of CCD data acquired at the Pine Mountain Observatory, to facilitate inquiry based activities. The overriding teaching strategy of this project is to get real data and analysis tools into the hands of students. Hopefully, this will kindle the excitement and spirit of adventure that is the very core of scientific research but which is rarely, if ever, communicated to students. Specific exercises and tools have been developed that will allow the students to effectively duplicate the steps of the professional scientist. We only need to train interested teachers in how to use these tools. Partial support is therefore requested in this proposal to continue these summer training workshops. Indeed, some graduates of these workshops are now experienced CCD observers and serve as expert tour guides during the summer visitor season. In some cases extended projects involving analysis of stellar populations in M33 or looking for distant red giant/carbon stars in M31 were supported by the Murdoch foundation partners in science program. These teachers obviously experienced very strong professional development.

The public outreach and education mission of PMO takes two forms:

1 Unstructured informal guided tours and naked eye viewing opportunities through either small amateur telescopes (some summer nights there can be 20 different amateur scopes deployed on the observatory grounds) as well as the 15 and 24 inch telescopes. Digital imaging is introduced to the visitors when they visit the 32-inch telescope + dome. The mountain also has wireless coverage making it possible for a digital image just obtained with the 32-inch telescope to be broadcast to a tour guides laptop screen somewhere else on the mountain. Most visitors think this is pretty “cool”.

2 Structured classroom visits that emphasize digital imaging reduction/ analysis of digital data, astrophysical concepts through visualization, etc, and remote observing projects in some cases. Our extensive statewide outreach program for grades K12 is the vanguard of our efforts to promote data acquisition from PMO; 2004-20045has been our 15th school year.

We now visit over 250 classrooms per school year (over 10,000 students and 500 teachers at over 100 different schools) mostly in Oregon and occasionally in Washington and California.

`The observatory’s web site is http://pmo-sun.uoregon.edu`