Star Formation in High Redshift Clusters with Spitzer

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We request 2.5 hours of Director's discretionary time to involve six high school teachers and select students in the study of star formation rates in three high redshift galaxy clusters. Scientific and educational justifications for this proposal are addressed separately, below.

I. Scientific Justification

We propose to study the evolution of star formation in galaxy cluster environments by making measurements at epochs between $0.54 < z < 0.63$. We will measure the integrated SFRs for three optically selected galaxy clusters from the ESO Distant Cluster Survey (EDisCS) using MIPS 24μm photometry (Table 1). We will measure total past SFRs, i.e. stellar masses, from rest-frame near-infrared (near-IR) photometry obtained with IRAC. Two of the three galaxy clusters already have IRAC data. We propose taking new IRAC data for CL1232.5-1250 to complete the set. We have found that Hα-derived star-formation rates depend on both cluster mass and redshift (Finn et al. 2004, 2005a), demonstrating the necessity of sampling a large range in mass to disentangle evolutionary trends from trends in mass. Our three targeted clusters span the range in mass from near-group environment to the most massive cluster in the EDisCS sample. This mass range fills the gaps in existing studies, which are dominated by studies of field environments or of very massive clusters.

The Spitzer MIPS 24μm observations are needed to make a comprehensive measurement of the star formation rates in galaxies, because extinction by dust can completely obscure

the majority of star formation in galaxies. The IRAC observations will determine if AGN activity is present in individual galaxies, which would bias our measures of the SFR based on the 24μm flux since the AGN could also heat dust seen at 24μm. The IRAC data will also provide robust stellar masses to quantify the total past star formation.

We will observe the central 5'x5' of each cluster with MIPS in 24μm and with IRAC in all four channels. Our 24μm observations will reach a sensitivity of one solar mass per year and our IRAC depth is chosen to match the same SFR sensitivity. The exposure times from the AORs (including overheads) is given in Table 1. Our total time request is 2:33:50.

Extensive ancillary data are already in hand, i.e. deep VRIJK imaging, 8-meter telescope spectroscopy, HST I-band imaging for all three clusters, and IRAC data on two of the clusters. This ancillary data will help to isolate cluster members and interpret the derived SFRs. The mass and redshift range of our targets serves as an important complement to other Spitzer studies of low and intermediate-redshift clusters and will provide a more comprehensive picture of the evolution of star formation in galaxy clusters from $z \approx 1$ to $z \approx 0$.

Table 1:

Cluster Name	RA	DEC	z	Instrumentation	exp. time. [hours]
CL1037.9-1243	10:37:51.2	-12:43:27	0.58	MIPS(24μm)	0.64
CL1227.9-1138	12:27:58.9	-11:35:13	0.63	MIPS(24μm)	0.79
CL1232.5-1250	12:32:30.5	-12:50:36	0.54	MIPS(24μm)	0.54
CL1232.5-1250	12:32:30.5	-12:50:36	0.54	IRAC(Ch1-4)	0.38

Relevant Publications

- Finn, Balogh, Miller, Nichol, & Zaritsky, *Integrated Star-Formation Rates for C4 Galaxy Clusters*, 2006, in preparation
- Finn, et al., *Hα-Derived Star-Formation Rates for Three z ~0:8 EDisCS Galaxy Clusters*, 2005, ApJ, 2005, ApJ, 630, 206
- Finn, Zaritsky, & McCarthy, *Hα-Derived Star-Formation Rates for the z = 0.84 Galaxy Cluster CLJ0023+0423B*, 2004, ApJ, March 20

II. Educational Rationale

Literature and anecdotal evidence strongly suggest that the United States is lagging in the education and preparation of students in scientific, engineering, and technical fields[1]. This is reflected in the number of university graduates[2], but certainly begins before they enter college. Along the K-12 education pipeline, few students are interested in pursuing a science or engineering major in college. For underrepresented groups, the situation is even worse. The same observation can be made for the number of students interested in becoming science teachers. Even those certified to teach science in high school leave the profession in alarming numbers, with many leaving in their first five years[3].

Large numbers of adults lack the basic scientific education they require to be able to understand specific scientific advances and issues. The danger is that they will develop uninformed opinions, or perhaps in many cases make no decision at all about important issues that involve the economic and technical success of our country.

Education is the vital link to improving both situations: the lack of trained scientists and science teachers and a better-informed populace. Both students and teachers need a vision of the benefits of choosing a career path in scientific and engineering fields. The challenge is to communicate the excitement of science, the necessity of science and engineering to our technological society, and the tangible and intangible rewards associated with a career in science.

The Spitzer Space telescope observing opportunity provides a unique chance to convey a number of these aspects to teachers, and to a number of talented students. In addition, aspects of the training that the teachers receive as a result of this program will be communicated in both formal and informal educational settings to a much larger number of educators and students. In this way the program will reach a much larger number of students and teachers, and will also reach the general public through media outlets.

Below are specific details describing the activities of the six teachers who will be involved at the "first tier" level of developing the proposal, reducing and analyzing the data, and publishing the results. Each teacher will, in addition to their classroom activities with the Spitzer research project, complete specific outreach activities designed to educate other teachers and the public on the Spitzer telescope, infrared astronomy, instrumentation and techniques for measuring infrared radiation, and the nature of scientific research.

John A. Blackwell
Director Grainger Observatory at Phillips Exeter Academy, Exeter, NH.

John teaches three college level research-based astronomy courses and manages the school's research observatory. Phillips Exeter Academy is a boarding preparatory school with approximately 1030 students, 33% of whom receive full financial aid packages and/or scholarships to attend. Over 90% of the students receive some form of financial aid.

John's intent is to use the Spitzer experience as a method to teach authentic scientific research while allowing the students full access to the data to accomplish their own research goals. Students involved in the more advanced Astronomy-II & III courses will be taught about observing in the different wavelengths with an emphasis on the infrared using ground based and Spitzer observations. Experiments using the NASA-developed infrared kits will be done in the classroom to allow students to gain a familiarity with infrared light. Night time labs will be done at the observatory using both photometers and CCD imagers to capture photometric data in U, B, V, R, and IR bands with emphasis on what the data means when observing stars and galaxies. These labs will then be compared to this Spitzer project to study similarities and differences in data and data collection.

John intends to perform the following outreach activities:

•Evening lectures and presentations at the Christa McAuliffe Planetarium to the general public about this specific project and infrared astronomy in general: Attendance is expected to reach 90 people for the first event scheduled for August 18, 2006;

•Day-long teacher education seminars at the Christa McAuliffe Planetarium. John will contact the Director of Education, David McDonald, at the planetarium and schedule a teacher workshop to present infrared astronomy and this Spitzer project. The NASA-developed infrared kits will be used. The audience will be high school teachers in southern New Hampshire, eastern Vermont and all of Massachusetts. This has the potential to reach over 50 teachers. Teachers will be presented with lesson plans, lab routines and an extensive bibliography for use at their schools. Timing for these events has yet to be determined, but will likely be in the autumn of 2006 or winter of 2006-2007;

•The Annual Math and Science Colloquium at Phillips Exeter Academy (June 25th – 30th 2006): This annual event is a series of intensive training seminars for high school and college teachers which is hosted by the Academy and taught by academy and external teachers. Topics range across all disciplines. John has scheduled a one week seminar for this August about multiwavelength astronomy and astronomy with small telescopes. Infrared astronomy will be a two-day topic in which teachers learn about the Spitzer Space Telescope, this project specifically, and infrared astronomy in general. Teachers will be presented with lesson plans, lab routines and an extensive bibliography for their use at their schools. Over 25 teachers are expected to register for this course;

•At least one lecture to the New Hampshire Astronomical Society, which has over 120 members. The first is tentatively scheduled for the autumn of 2006. The primary topic will be the Spitzer research project, infrared astronomy, galaxies and cosmology;

•A two-hour presentation to amateur astronomers has been planned for September 2006 at the annual River's Camera Astronomy Day Celebration in Dover, New Hampshire. Over 150 people typically attend and include teachers, amateur astronomers and students.

Velvet Dowdy
Graves County High School, Mayfield, KY

Velvet teaches Earth, Space, and Physics (ESP), ESP Accelerated, and Astronomy courses. As a TLRBSE alumnus, Velvet has required all students in her ESP and Astronomy classes to complete a research project in astronomy since the 2003-2004 school year. She plans to use the Spitzer experience to develop additional research project ideas to use with her classes. The initial plan is to use IR images from the Cool Cosmos website and an IR camera from the local fire department to get students to ask questions about the IR spectrum. Then students would be trained to use the Spitzer archives to search for usable data—images and spectra. Students could then generate their own

research questions based on their explorations in the archive. Additional project ideas not only would give students increased opportunities for research questions, but also would allow them to use and analyze IR data, thereby broadening their experiences and understanding of astronomical phenomenon beyond the visible data provided through TLRBSE.

Kentucky's Core Content for assessment will change in the 2006-2007 school year. The changes add additional content at each grade level but more importantly, they define the specific skills and depth of understanding students must possess with respect to each content statement. Teachers at each level, particularly elementary and middle school teachers will be required to provide activities and assessments to deliver and assess the new content requirements. One of the new content and depth of knowledge requirements will be for the electromagnetic spectrum. These changes will especially impact science teachers in grades 4 and 7, but has implications for science in all grade levels 4-11. In addition, the state of Kentucky must address two major gaps with regard to students meeting the state standards in science—the gap between African American children and Caucasian children, and the gap between children receiving free and reduced lunch services and children who do not. In the Western Kentucky area where Velvet teaches, African American children are seven times less likely to meet state standards in science than their Caucasian counterparts and children in poverty are two times more likely to fall below standards.

To address these concerns, Velvet plans to offer three sessions to help teachers at the impacted grade levels adequately address this content at the Kentucky State Teachers Association Convention in November of 2006. One session will be geared toward elementary, one for middle, and one for high school teachers. Additional workshops for local and regional teachers will focus on activities and assessments for the relevant content at each level. Teachers will be provided with hands-on activities and education materials using the NASA-developed infrared kits and other sources.

Preliminary contact has also been made to offer a session on the electromagnetic spectrum as a component of the Kentucky NEED (National Energy Education Development) program. Kentucky NEED is designed to help elementary, middle, and high school science teachers incorporate energy education into the classroom using an interdisciplinary approach. All of these sessions are tentatively planned for the summer of 2006, with the exception of the KY NEED program. This is traditionally offered in the fall of each school year. Also, teachers from schools with significant populations of African American children and children in poverty (as determined by the state's criteria) will be more heavily recruited to participate in Professional Development opportunities—particularly at the regional level. Teachers in these targeted schools would have priority for access to free materials and resources, although Velvet plans to seek funding and support to provide these to all teachers who attend her local and regional workshops.

Finally, Velvet intends to write an article about her Spitzer experience using IR data and activities in the classroom for the Science Teacher, a National Science Teachers Association publication for high school science teaches. With a circulation of

approximately 18,000 teachers in 98 different countries, an article written for this professional trade journal has the potential to affect thousands of classrooms.

Rosa Hemphill
Oregon Episcopal School, Portland, OR

Rosa teaches chemistry and research classes in grades 10-12. A number of students in each class are second-language students. The primary route for bringing educational information about the Spitzer project and infrared astronomy into the classroom will be through labs and through independent student research projects. In chemistry classes, infrared activities will be integrated into the labs introducing spectra, spectral lines and some of the images taken from an infrared thermal imaging camera. For instance, students will be asked how "seeing" the world in optical wavelengths might give a different view than seeing the world in the infrared (or X-ray or radio) wavelengths. Rosa has arranged to borrow a FLIR (Forward Looking Infrared) FLIR camera for a science course March 17-23, 2006 during which a FLIR Systems representative will train ~ 16 high school students in the use of the camera; students will then use the camera to test "seeing" in the infrared and will demonstrate the use of the camera to three classes of elementary school students. This can be used to introduce the role of Spitzer in astronomical observations. Rosa will also serve as group representative to see if additional cameras or other FLIR Systems Inc. resources may be made available to the Spitzer teachers.

Rosa will invite a current chemistry student to participate in the research part of this program. She will learn how to locate and use the Spitzer data archive and will encourage chemistry/research students to pursue astronomy-related projects. Rosa will introduce students in a small introductory organic class to the infrared spectrometer during a Saturday field trip to Clackamas Community College (Oregon City) in April. *Student Spartan* (Wavefunction, Inc) is a molecular modeling program that can generate spectra. Students will use *Spartan* to generate IR spectra for models of hydrocarbons, including polyaromatics.

Rosa plans two 2-hour after-school workshops for teachers and specialists at her school (~10) and for 10-15 teachers from local schools on the electromagnetic spectrum and the use of a FLIR camera in inquiry activities during March; teachers will learn how to request and use a FLIR camera and download camera images for use in their lessons. In April, she will hold a 4-hour hands-on workshop for 10-20 local-area teachers, including teachers from a rural Canby school district, to make materials for lessons using SOPHIA kit materials on the electromagnetic spectrum and infrared activities. Rosa will present a workshop on the electromagnetic spectrum and on infrared teaching activities at the Oregon Science Teacher Association Conference October, 2006, Grants Pass, OR. Through teachers attending workshops, the outreach could reach potentially 800-1000 students. She will write an article for the The Oregon Science Teacher (~800 readership) on bringing inquiry-based IR activities into classrooms.

Rosa has arranged for an astronomer to make a presentation on galaxies (including the use of Spitzer for research) to 20 students during one of her class periods and to meet and talk to 40 elementary school students. Rosa has also invited the astronomer to make a presentation on galaxies at the February meeting of the Rose City Astronomers (estimated 150-175 attendance). At the same meeting Rosa will introduce the Spitzer educational program to RCA members and set up a table of materials from the Spitzer program.

Ardis Herrold
Grosse Pointe North High School, Grosse Pointe, MI

Ardis teaches Chemistry and Astronomy classes and is director of the district's planetarium. In addition she is the advisor of the school Radio Astronomy Team.

Students will work on components of the Spitzer research in Astronomy and Advanced Astronomy classes. This will reach a target audience of approximately 70 students over the next year. The use of comparative multiwavelength imaging, infrared spectra and the niche of infrared in the electromagnetic spectrum will be explored. In addition, some individual students will work on their own research projects using Spitzer data. As they are able, and as resources permit, they may also join in on this current teacher research effort. Using these data and being able to communicate firsthand to students the experience of real research is an excellent motivational tool and gives a more realistic view of science and research than what can be gained from textbook and internet reading.

The outreach components will involve teacher workshops on infrared astronomy, the Spitzer Space Telescope, authentic research experiences for teachers and students, and the electromagnetic spectrum. Activities will involve hands-on experiences of doing demonstrations and experiments in the infrared, offer take-home materials (some from the SOFIA kit) and will be correlated to the state science objectives. The audience will include some teachers who teach a large percentage of urban and minority students. The first of four target venues will be a school district workshop this spring for teachers of grades 6-9. Arrangements for this workshop are currently being made with Jane Nutter, staff development director of Grosse Pointe Schools. A Saturday workshop sponsored by the Michigan Earth Science Teachers Association will be held March 25th entitled "Stalking the Infrared Universe". This is one of a regular series of Saturday workshops offered by MESTA called "Stalking the Wild Quarry". Workshops will also be conducted at the fall conferences of the Metro Detroit Science Teachers Association on October 21st and the Michigan Earth Science Teachers Association on October 7th.

In the realm of informal education, Ardis has arranged to talk about Spitzer and infrared astronomy at meetings of the Student Astronomical Society of the University of Michigan and Eastern Michigan University astronomy club (memberships approximately 80 and 30 in these clubs) this spring. The EMU talk will be on April 6th. Ardis will also speak at the Great Lakes Star Gaze near Clare, MI (a regional star party with an attendance of 300) on October 23rd. Arrangements are pending to speak at the

Astronomy at the Beach event (attendance 800-1000) at Kensington Metropark in Milford, MI on September 30th.

Thomas Loughran
Saint Joseph's High School (SJHS), South Bend, IN

Tom teaches chemistry and leads a research community for high school students, grades 10-12. Two SJHS students will devote up to three semesters of their efforts in the context of their two-year Science Research course to every aspect of the Spitzer Teacher Research project, from participating in proposal development, data analysis, to collaborating in dissemination of results, including publication. These students (Matt Pellegrino and Vinay Patel) have already spent seven hours in public relations activities on behalf of Spitzer, leading some 500 children in hands-on activities with a thermal IR camera at Science Alive! (See below.) As they climb the learning curve, they will establish milestones connected to web resources in an attempt to ease the ascent for first-year participants in the research course next year who will join with them in this Spitzer research project. The hope is to make these milestones and resources available together with data and data analysis tools on the web in an e-Lab format (for a prototype, see http://quarknet.fnal.gov/grid) to serve a much broader community of student researchers. Tom is an education specialist on the staff of I2U2 (http://www.interactions.org/sgtw/2005/1207/20051207.pdf), the NSF-sponsored program responsible for e-Lab development. The resulting on-line resource will be submitted to the Merlot site (http://www.merlot.org/Home.po) for review and dissemination, publicized on the QuarkNet listserve reaching some 500 high school physics teachers, the Modeling listserve reaching a community of 800 physics teachers, and at the Computational Science Educational Reference Desk (http://www.shodor.org/refdesk/index.php), part of the National Science Digital Library (http://nsdl.org/).

Three other students in this same research class are currently using Photoshop with ESA/ESO/NASA Photoshop FITS Liberator v.2.0 to learn astronomy image processing, using .fits images taken from the WIYN .9m telescope at Kitt Peak by members of the 2004 Cohort of the NOAO's TLRBSE program. These students hope to create presentation-quality images from the photometry data taken in this proposed Spitzer observing project, which would be available for presentations of the project at AAS and other venues. They also plan to submit their methodology and results for publication in the RBSE Journal, to post their photos on the Saint Joseph's High School web site, and to create a series of large posters for display in school hallways and in the art gallery. Moreover, two of the students involved in this imaging project are filmmakers. They would like to make a 2.5 - 5 minute film documenting the research experience of their colleagues Matt and Vinay: a student-produced film on student involvement in Spitzer research, to be broadcast over the SJHS morning video assembly and submitted for broadcast on the Channel One network: (http://www.channelone.com/exchange/guidelines/video/.)

Public presentations of Spitzer and multiwavelength astronomy will include annual participation in Science Alive! (http://www.sjcpl.org/science_alive/default.html), a program which draws some 4000-5000 elementary and middle school students and families into the Saint Joseph County Public Library for hands-on science learning opportunities. In the first of these presentations, over 1500 Spitzer images were distributed to some 1000 mostly elementary students and their families, from 9am to 4pm on February 4th, 2006 in the Notre Dame Department of Physics display area. At that event, at least 500 children experienced face painting with ice in front of an IR camera on loan from the Indiana University Department of Astronomy. Spitzer images were also used as a lead-in to discussion of nuclear synthesis and to an invitation to weeklong summer science camps for middle school students sponsored by the Joint Institute for Nuclear Astrophysics at Notre Dame (http://www.jinaweb.org/).

Professional development workshops for teachers will take place in cooperation with Research Experience for Teachers (RET) programs at the University of Notre Dame (http://ret.nd.edu/pages/projects-physics.shtml). The focus of these workshops will be using e-Labs to bring a variety of research experiences, including this one with Spitzer, into workable curricular contexts. Tom has contacted Beth Marchant, the director of the Notre Dame Physics RET effort, to arrange for a presentation to 24 South Bend RET teachers. On the basis of the experienced gathered in this Notre Dame RET context, similar workshops (ranging 20 minutes to one hour in length) will be submitted to the 2006-07 national meetings of the American Association of Physics Teachers and the National Science Teachers Association.

Dwight Taylor
South Anchorage High School, Anchorage, Alaska.

Dwight teaches Astronomy and Advanced Placement Biology. Dwight plans to ask the local fire department to bring one of their IR cameras to his and other science classes at his school, South Anchorage High School, for a presentation of how infrared wavelengths can be observed. In his astronomy classes, after a multiwavelength project (based on the Cool Cosmos Multiwavelength Gallery) and learning about galaxies, students will work on the Active Galactic Nuclei Spectroscopy project from TLRBSE to give experience of real research. Students will then work on components of our Spitzer research project in Astronomy. They will analyze the data making the same calculations, where possible, that we as a team have used.

A presentation on the Spitzer Teacher Research project and infrared astronomy will be given at the fall in-service training of the Anchorage School District science department in August. The fire department will again be asked to participate by demonstrating their infrared camera. The Anchorage School District has 50,000 students and more than 3,000 teachers. A workshop class on infrared astronomy and the Spitzer Project (15 hours) will be offered in Anchorage during the fall of 2006. Continuing education credit will be sought for the workshop through the University of Alaska Anchorage. The SOFIA infrared teacher materials will be used along with other astronomy resources. In

addition a one-hour presentation on the Spitzer Teacher Research project and infrared astronomy will be offered at the biennial Alaska Science and Math Conference in October 2006, held in Fairbanks, Alaska. This is the statewide conference of math and science teachers usually attended by over 500 teachers.

References:

[1]*2003 Trends in International Mathematics and Science Study (TIMSS) results.* http://nces.ed.gov/timss/Results03.asp?Quest=4

[2]*2003 College Graduates in the U.S. Workforce: A Profile*, from the National Science Foundation report 06-304, December 2005. http://www.nsf.gov/statistics/infbrief/nsf06304/

[3]Ingersoll, Richard. **"**Turnover Among Mathematics and Science Teachers in the U.S.", *Science Educator*, Spring 2003.

III. Summary

The Spitzer Space Telescope is an important tool in uncovering the history of the Universe. While the Spitzer science legacy belongs to all human beings, the public is substantially removed from its impact, since they are under-informed about the universe, about the role of science, and particularly about the Spitzer Space Telescope in revealing it to us. This proposed project to involve six high school teachers in the study of star formation rates in three high-redshift galaxy clusters makes a substantial contribution toward closing that gap. Over the next several years thousands of teachers, tens of thousands of their students, and about as many members of the general public will come to better understand Spitzer's role in revealing the history of our universe and thus our own story to us. The teachers responsible for spreading this story of Spitzer's role will have learned of it not second hand but through primary interaction with the telescope and the research community responsible for using it well. They will have been involved in the crafting of a research proposal, joining efforts already in progress, as does every scientist. They will have contributed to the analysis of Spitzer data. They will have contributed, finally, to the dissemination of results, both to the scientific community and to the general public, inviting them to make the results of this research part of our common story which science reveals. The unique position of these teachers in the early educational system will allow them to directly reach students at a crucial stage in the development of their scientific awareness, and to introduce the importance of research with facilities like the Spitzer telescope. This proposal to study star formation rates in three high red shift galactic clusters will thus not only help uncover the story of galactic evolution for the scientific community, but also for a great many citizens who fund Spitzer and thus have a right to be told its story.