An In Depth Look at the Reach of Infrared, Further than Greenhouses and TV Remotes, at Pierce College and Beyond
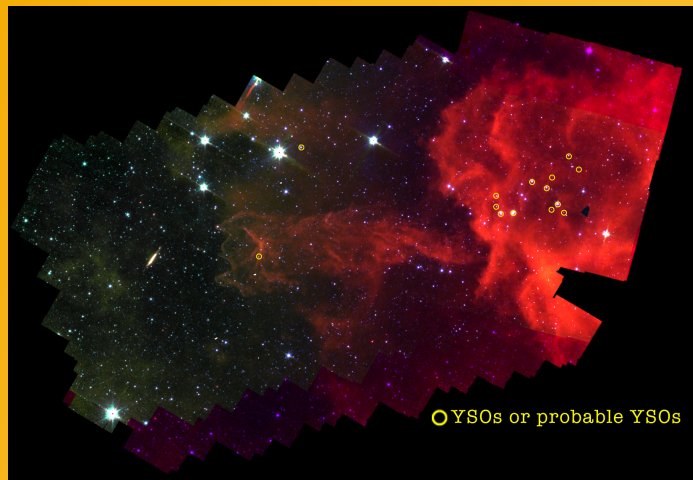
C. R. Mallory, N. Mahmud, T. Silic (Pierce College, CA),
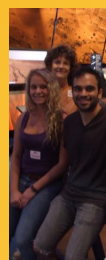L. M. Rebull (Spitzer Science Center)

Two students from Pierce Community College, Woodland Hills, CA and their instructor participated in the NASA/IPAC Teacher Archive Research Program (NITARP) in 2010. Our team worked with archival Spitzer and Two-Micron All-Sky Survey (2MASS) near- and mid-infrared data and optical data from Cerro Tololo to look for young stars in the greater CG4 region, part of the Gum Nebula. Some of our science and education results are described below.

We integrated our NITARP experience into the Pierce College environment through programs given at our large Astronomy Club, team presentations before individual classes, and instructor inclusions into lectures. Through the NITARP experience, students honed scientific thinking skills and ability to analyze data. Our analysis of multiple IR sources revealed what is going on in the CG4 region. NITARP is one of several active learning programs at Pierce College.

Program facilitated by the NASA/IPAC Teacher Archive Research Program (NITARP) and was funded by IPAC Outreach and NASA Astrophysics Data Program.

○ YSOs or probable YSOs

This 3-color image displays the locations of some of the studied objects. The image was created using data from Spitzer Infrared Array Camera (IRAC) channels 2 (4.5 microns, blue), 3 (5.8 microns, green) and 4 (8 microns, red). This is a powerful, penetrating IR look inside a nebula.

Early student attempts at generating spectral energy distributions (SEDs). Plots use all the data we have, optical through mid-infrared wavelengths. These objects are YSO candidates because they have an infrared excess visible here.

These are preliminary color-color and color-magnitude plots. The black points are sources which could be YSOs. The red triangles are polycyclic aromatic hydrocarbon clouds or active galactic nuclei according to the recommendations of Gutermuth et al. (2008, 2009). These plots represent a subset of our final entire catalog.

Purpose
Using Spitzer and other data, Pierce Community College (Woodland Hills, CA) students attempted to answer the questions: Are there young stars in the CG4 region of the Gum Nebula? If so, what SED class are they? Did a whole cluster of stars form and if so does this indicate triggered star formation? The answers to these important questions are fundamental to the understanding of why/ how stars develop, which are essential components of the galaxies and the Universe!

Programs and Databases We Used
Students were excited to use many databases: SHA, 2MASS, IRSA, ADS, SDSS, and Goddard Sky View Virtual Observatory. Software used included Excel, APT, Python, and DS9 (for use with FITS files). Just learning how to *use* these programs, actually *seeing what info these programs reveal*, was a new, unique experience and a great reward for our NITARP participants. Our students were the first NITARP students ever to use Python successfully!

Analyses Students Performed
Students harvested data directly from the Spitzer Archive, and analyzed 3.6, 4.5, 5.8, and 8 micron (from IRAC) and 24 micron data (from MIPS). Further data analysis included creation of color-color graphs to select YSOs, SEDs of suspected YSOs to show IR excess, and determination of SED slope to determine their YSO class. YSOs, with equatorial discs of gas and dust, typically show IR excesses. Please see our companion science poster, Johnson et al. (340.08), for more results.

Students utilized critical thinking skills, and ability to organize their data analysis into a mental big picture, pursuing understanding of what is actually happening in the Gum Nebula.

Pierce College, enrollment 23,000 students, is a highly respected Community College and transfer institution. This student-friendly school offers high-quality and challenging education that prepares students for University. Pierce offers an affordable means of obtaining the first two years of a college education. The Pierce Astronomy Program in particular is being improved and enhanced by a subset of Astronomy Instructors.

NITARP partners astronomers with small teams of educators to complete an original research project within a calendar year.
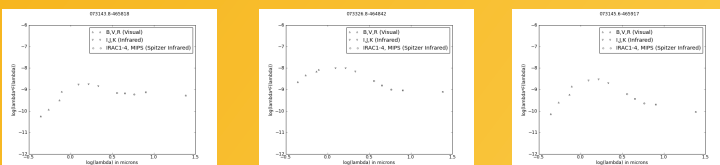
Impact of Research Activity on Pierce College
Our NITARP CG4 team visited Caltech in June; right after the visit, Professor Mallory made a Power Point presentation of students during the visit, and circulated it widely around the college. Immediate support for the program and students emerged, school and local newspapers interviewed them, the story was featured on the college home page, and the students were guests of honor at local astronomy club meetings. The program was solidly embraced by our college physics department, as a form of 'Active Learning'. Professor Mallory passed knowledge learned on to students in her classes. This program has enriched the college.
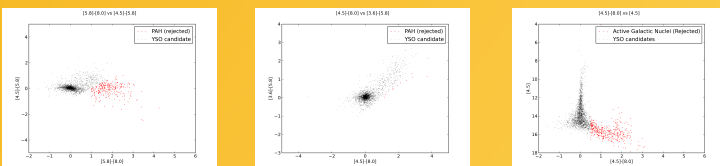
I feel privileged to have been granted this opportunity to expand my astronomy knowledge through hand-on research with an incredible team. -Tiffany Silic

It may be naïve, but texts and TV shows always made it seem like Astronomy was all figured out from the beginning to the end of the universe. Now I realize how much is still left to discover. -Niyaz Mahmud

Here is a portion of the table in which we kept notes on an early assessment of each suspected YSO, in multiple near and mid IR bands.

```
07 31 44.1,  -47 00 08    IRAC,  3.6  um, star       binary, xcss IR fringe
2MASS Flux=5.6E+02        2MASS,  2.17 um, star       nice! bright, bluish
                          IRIS,  25 um, no star       nebulosity
                          IRIS,  12 um, no star       nebulosity

07 31 45.6,  -46 59 17    IRAC,  3.6 um,  yes-star    bright star, fringe xcss IR
2MASS Flux=7.5E+02        2MASS,  2.17 um, none        Nearby bright star:co-ords off?. 25 um SEE Gum Neb! 12 um
                                                            none.
                          IRIS,  25 um, none
                          IRIS,  12 um,

07 33 37.6,  -46 42 46    IRAC,  3.6 um,  nothing     empty space at 3.6 um
2MASS Flux=6.14E+02       2MASS,  2.17 um, star        fat, IR excess fringe
                          IRIS,  25 um, none           none
                          IRIS,  12 um, none           none

07 34 06.9,  -46 58 05    IRAC,  3.6 um, tiny star    spherical, no fringe or xcs
2MASS Flux=9.8E+04        2MASS,  2.17 um, no          Lovely star not in Gum.
                          IRIS,  25 um, none           Nebulosity only.
                          IRIS,  12 um, none           Nebulosity only.
```

The Educational Merit of NITARP, and A Few Pitfalls

The National Standards and Benchmarks include standards that address science as inquiry. The methods used to find answers to the questions we posed epitomize inquiry, as well as the scientific method!

It's necessary to keep the instructor and students tightly associated during the research process, because students so easily misunderstand reasons for performing some tasks, or fail to understand the scientific principles underlying the processes. Students are great on computer applications, though! In the college setting, with classes distributed through a range of day and night timings, students may have less ability to fulfill the research project they previously committed to doing. College students have jobs (often full-time), and independent lives; faculty have less over-arching control than the secondary teachers (which have been the primary audience for NITARP and its predecessor). College faculty themselves may collaborate less than secondary teachers.

The Pierce Astronomy Instructor who guided these students has worked for the last six years to bring advanced science opportunities, high-quality and challenging information programs, advanced technology, and the fun and beauty of astronomy to the Pierce setting. Enrollment, retention, and enthusiasm advanced significantly in this time period!