Title: Young Stars in IC 2118

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I. Project Description

A. Goals

Stars form in large dense regions within the interstellar medium (ISM). The process of stellar formation in these clouds of molecular gas and dust is believed to be triggered by a passing shockwave, with the densest regions of the cloud contracting under the pull of their own gravity and eventually fragmenting to form protostars. These protostars begin as large cool objects, but as the fragment collapses the temperature increases. At a temperature of 1,000,000 K, hydrogen fusion begins in the core and a star is born. The newly formed star then begins shedding off its cocoon. With these young stars deeply embedded in their cocoons, it is difficult if not impossible to view them in visible light. However, they can easily be detected in the infrared because longer wavelength photons can escape the surrounding gas and dust. Thus, the Spitzer Space Telescope (SST) is an essential tool in unlocking the secrets of these star formation regions.

IC 2118, the Witch Head Nebula (~210 parsecs), is one such region located near the supergiant star Rigel in the constellation Orion. Kun et al. (2004, A&A, 418, 89) have determined that IC 2118 is on the near side of the Orion-Eridanus Super Bubble and that stellar winds and supernova from the Orion OB1 association may be triggering new star formation in the nebula. We propose using IRAC and MIPS to reexamine a small dense region of this nebula where Kun et al. have spectroscopically identified three 2MASS sources as T Tauri stars embedded in the cloud. Previous all-sky surveys, including both IRAS and 2MASS, have included this region, but not to the resolution that Spitzer can provide, and there are few studies of this particular region in the literature. Our team proposes to use IRAC and MIPS observations to (1) investigate star formation, (2) look for likely cluster member stars with infrared excesses, and characterize this young star population by obtaining their colors and therefore estimates of masses and ages (see, e.g., Allen et al., 2004, ApJS, 154, 363), (3) study the distribution of stars, their relationship to the ISM, and the possibilities of triggered star formation, (4) compare the young star population, distribution, and age to other similar sites of star formation, e.g., IC 1396

(Reach et al., 2004, ApJS, 154, 385) and (5) produce a dramatic image of the interstellar medium in the region surrounding IC 2118. Since this region is in the Orion constellation near the bright star Rigel, it provides additional appeal to students and the general public.

B. Data Analysis Methods

Once the data has been collected, the team plans to visit the Spitzer Science Center (SSC) to work with Dr. Rebull in the reduction of the data. The team will use MOPEX to create a mosaic and a list of band-merged sources. The source list data table will include 2MASS (J, H, and K band), IRAC (3.6, 4.5, 5.8, 8 μm), and MIPS (24 and possibly 70 μm) fluxes in both magnitudes and Janskys.

The reduced data will be accessible by programs available on our home institutions' computers. We plan to section the images into fits files suitable for use with the Hands-On Universe Image Processing (HOU-IP) software. HOU-IP is a user-friendly data analysis tool that runs in both Windows and Mac operating systems, and is currently used by many high school astronomy students. Although it may not be possible to extract accurate flux values using HOU-IP, it can be used for visual observation and spatial analysis within the images. The data tables can be imported into spreadsheet programs such as Excel and students can generate color-color plots with the data to test hypotheses related to how infrared wavelengths can be used to classify young stars.

In reaching the stated goals, the mosaics, data tables, and fits images will be shared with our students, as well as other teachers. It is hoped that all participants will assist in the data analysis process.

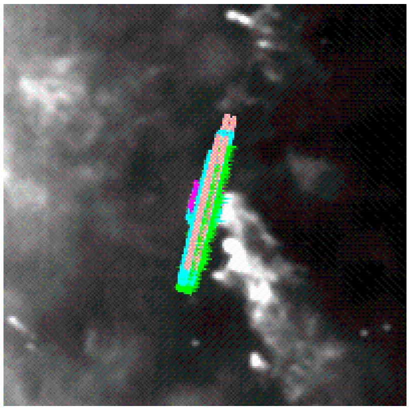
C. How the involved teachers developed this topic.

From the beginning of this process the team had a strong interest in protoplanet and star formation. Our initial ideas included imaging stars with known protoplanetary disks to further analyze IR spectra, examining our own Oort cloud for indication of PAH's, and identifying new protoplanetary disk candidates.

Early information took us in the direction of studying young type A stars for protoplanetary disks. Dr. John Stansberry from Steward Observatory suggested several newly identified nearby stars that we hoped to follow-up with Spitzer observations. However, upon viewing the Reserved Observation Catalog (ROC), we discovered the stars we had hoped to observe were already included in approved AORs.

Continuing with our interest in protoplanets and star formation, we met with Spitzer scientist Dr. Luisa Rebull to discuss studying star formation in a region of IC 2118. Following these discussions, the team made the decision to pursue the project and develop an observing proposal. A ROC analysis showed no current AORs for the proposed region, so we developed observations using Spot. Being limited by the amount of Spitzer time available, we identified several potential target areas in the cloud. We selected an area of the cloud containing a known IRAS source and the potentially new sources identified in Kun et al (2004).

II. Target



The image on the left shows the region of IC 2118 (in IRAS 100 microns) selected for observation by IRAC and MIPS (with the proposed observations overlaid). The region was selected because IRAS identified one source in the area, and a recent study by Kun et al (2004) identified three new classical T Tauri stars in this region using objective prism plates. The target center coordinates are RA 05h 07m 21s, DEC –6d 18m 04.5s (J2000).

We propose to use two instruments, IRAC and MIPS. Generally, IRAC will detect stars in this region, and MIPS will be more sensitive to the ISM. By using IRAC and MIPS-24, we will be able to identify more young stars via infrared excesses than by using IRAC alone (see, e.g., Allen et al, 2004, ApJS, 154, 363 and Muzerolle et al, 2004, ApJS, 154, 379). Spectral Energy Distributions (SEDs) constructed using IRAC+MIPS (combined with 2MASS) will enable us to discriminate between cluster members and background extragalactic objects. MIPS-70 will largely reveal the structure of the ISM, though it will also help with identifying cluster members because it will enable us to identify young stars with large mid-IR excesses. Although data will be obtained at 160 um with MIPS, we do not require it; any ancillary data obtained at MIPS-160 will further enhance our understanding of the interstellar medium in this region.

With IRAC we will make a 4 X 5 frame map at 3.6, 4.5, 5.8, and 8.0 microns with 3 dithers (cycling dither pattern) in the high dynamic range mode, each exposure 12s. This will cover a 20 x 20 arcmin area which will include both previously identified targets in this area of the cloud. The total duration for IRAC will be 1819 seconds.

With MIPS we will do a fast scan at 24, 70, 160 microns, four legs, stepping by half an array each time. This will cover a 20 arcmin strip through the center of the target, including most of the IRAC map. Because the MIPS scan covers a long, thin region compared to the IRAC map, an ancillary data area will be obtained that covers a larger portion of the cloud at the three MIPS wavelengths. The total duration for MIPS will be 1902 seconds, bringing the total project time to 3721 sec (62 min).

III. Scientific Merit

This study will characterize the young star population in a region of IC 2118 never before studied at the wavelengths and resolution proposed. With the exceptional spatial resolution of Spitzer and the sensitivity of IRAC and MIPS, we anticipate that it will be possible to classify hundreds of young members of the association. We will use IR color-color diagrams as tools to classify the age of stars (see, e.g., Allen et al., 2004, ApJS, 154, 363; Reach et al., 2004, ApJS, 154, 385). Our findings will enable us to characterize the process of pre-main-sequence stellar evolution in this cluster, examine the influence of the density of the molecular cloud on this process, and compare it to processes in other clusters also being studied with the Spitzer Space Telescope.

IV. Educational/ Public Outreach Merit

Students will have access to the image files in four IRAC and three MIPS wavelengths as well as three 2MASS and three (lower spatial resolution) IRAS wavelengths. Students will be able to combine images at different wavelengths to produce pseudo-color images that enhance the features of young stars and the interstellar cloud. Through these tasks, students will learn about the physical properties of light such as wavelength, intensity, emission, and absorption. Students will gain experience in measuring size and distance. They will be able to compare the images obtained by IRAC, MIPS, and IRAS to learn about spatial resolution. Students will also view evidence that the universe is changing, learn about the current models of stellar evolution, and learn that new stars and planets are still forming.

In addition to the image data sets, students will also have the extracted data tables of sources and fluxes at each wavelength. Using spreadsheet and graphing programs, students will be able to generate color plots with this authentic numerical data. They will be able to access the data sets already available in the Spitzer archive to compare the plots of this cluster with other clusters. Students will also be able to test their own ideas for color plots that could be useful in determining stellar age.

Students will be exposed to authentic scientific inquiry. They will be part of the process of developing ideas, working in teams, collecting and analyzing data, and interpreting and presenting results. They will learn about the instrumentation used in IR astronomy, controlling a space telescope, and the value of having a telescope in space. These experiences will help teachers and students meet the goals outlined in state/national science and technology standards. Specifically, this project is aligned with teaching standards to support inquiry-based work, working in teams, and providing resources for authentic inquiry. The content standards addressed are the structure and properties of matter, interactions of energy and matter, the origin and evolution of the Earth system, and the abilities of technological design.

The dramatic images that will be produced by this group and their students will be excellent vehicles for gaining public and administrative interest and support for science and educational initiatives. The data and experiences collected by this group of Spitzer teachers will be shared with other teachers via workshops and presentations. The lessons developed by the Spitzer teachers will address science and math skills and concepts with current scientific problems and original data. They will promote inquiry-based learning and disseminate interest in science, technology, and space research.

AOR

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