

# SPITZER OBSERVATIONS OF YOUNG STARS IN THE WITCH HEAD NEBULA (IC 2118)

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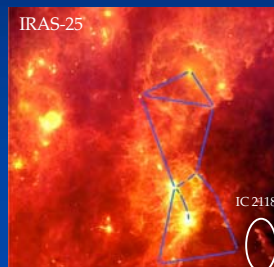
## ABSTRACT

IC 2118, the Witch Head Nebula (~210 parsecs), is a molecular cloud that is experiencing star formation, thought to be triggered by Rigel and the rest of Orion OB I (Kun et al. 2001). Kun et al. (2004) found 5 new T Tauri stars in this region. We recently observed ~2 square degrees of the cloud with Spitzer/IRAC (Infrared Array Camera; 3.6, 4.5, 5.8, and 8 microns) and MIPS (Multiband Imaging Photometer for Spitzer; 24, 70, and 160 microns). Our pilot project last year in a 15x15 arcminute region at the head of the cloud (where there were 3 previously-known T Tauris from Kun et al. 2004) approximately quadrupled the number of suspected young objects in this region. In this poster, we present initial results from our larger map. These observations were obtained as part of the Spitzer Space Telescope Research Program for Teachers and Students, and involves high school teachers (and their students) from across the United States.

## OBSERVATIONS AND ANALYSIS

Observations were obtained with Spitzer/IRAC and MIPS in March 2005 and March 2006. We created the mosaics and extracted the photometry using MOPEX, the package designed by the Spitzer Science Center (SSC) for use with Spitzer data. Almost 34,000 point sources are detected in at least one Spitzer band (~32,000 seen at IRAC-1, 3.6 um, and ~2500 seen at MIPS-1, 24 um). The data were bandmerged with JHKs data from 2MASS. Due to variations in instrument sensitivity, there are ~3000 objects seen at all 4 IRAC bands and MIPS-24.

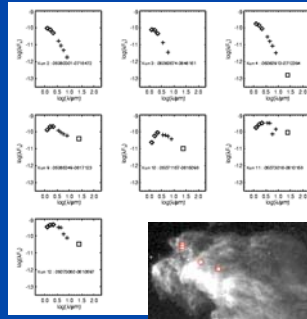
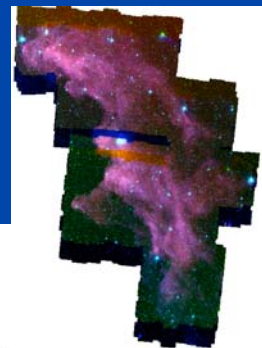
Following other investigations of star-forming regions where the only data available are JHKs through MIPS photometry (e.g., Joergensen et al. 2006, Rebull et al. 2006), we constructed several color-magnitude and color-color diagrams to assess how many young stellar object (YSO) candidates we have found; see below. There are about 100 YSO candidates selected based on IRAC colors, about 150 selected based on a combination of IRAC and MIPS colors, and about 25 selected based on MIPS-24 and Ks. Nine objects meet all three of these criteria for candidate YSOs, 3 of which are already known YSOs.



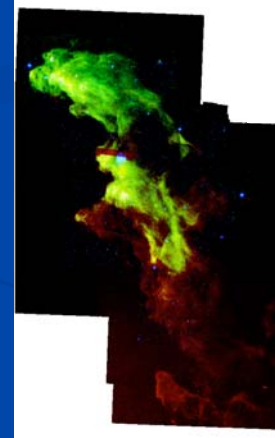
## WHERE IS IC2118?

IC 2118, also known as the Witch Head Nebula, is a reflection nebula located in projection towards the Orion star-forming complex. It is easily visible in IRAS images (left); at about 210 pc away, it is thought to be illuminated by Rigel. Kun et al. (2001, 2004) have found 6 molecular clouds totaling ~140 Mo of material here, as well as at least 7 likely young stars. Numerous lines of evidence point to triggered star formation occurring here (see Kun et al. 2001, 2004).

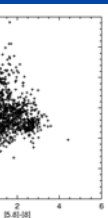
**RIGHT:** IRAC (3.6 [blue], 4.5 [green], 8 [red] um) mosaic of IC 2118. Most of the emission is in 8 um, suggesting PAHs at the origin.



Kun et al. (2004) studied 11 stars in this region, 7 of which overlap with our map (right) and whose SEDs are shown above. They concluded based on Halpha and Li that the objects #2 and 4 above are foreground stars, and the SED for obj #3 also resembles a photosphere. The remaining SEDs show clear evidence of circumstellar material.



**LEFT:** IRAC (3.6 um [blue], 8 um [green], and MIPS 24 um [red]) mosaic of IC 2118. The redder gradient towards the bottom of the nebula (before the end of the IRAC data) is real.



**LEFT:** Sample color-color and color-magnitude diagrams used to select candidate YSOs. **Upper left:** photospheres are near (0,0) and red objects are towards the upper right. **Lower left:** photospheres again have colors near 0, and galaxies extend redder; to avoid contamination from galaxies, we take YSO candidates to be redder than  $K_s-[24] \sim 1$  and brighter than  $K_s \sim 14$ . Additional similar diagrams are used to attempt to separate YSO candidates from foreground/ background stars and galaxies.

**RIGHT:** Spectral energy distributions (SEDs) for several objects in this region. Diamonds=2MASS, crosses=IRAC, squares= MIPS-24. **Upper right:** SEDs for objects discussed by Kun et al. (see caption above). **Lower right:** SEDs for 9 YSO candidates (6 new) meeting 3 color criteria for circumstellar material. All of them are located in the "head" of the nebula, and three are "rediscoveries" of the Kun objects above.

## FUTURE WORK

- Based on additional analysis, refinement of selection of YSO candidates.
- Palomar 200" observing run scheduled for January 2007 for optical spectroscopy to obtain spectral types of candidate YSOs.
- Ongoing optical monitoring to look for variability in candidate young stars using a variety of small telescopes including Perth Observatory, New Mexico Skies, Oil Region Astronomical Observatory, and the Faulkes Telescope.
- Ongoing development of lesson plans and materials using these data to share with the rest of the world.

