Young Stellar Objects in the Low-Metallicity Small Magellanic Cloud

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The method of identifying YSO candidates used in this work is based on a combination of successful methods developed by Whitney, Sewilo et al. (2000), Governor & Chu (2000), and Sewilo et al. (2010) to search for the YSO candidates in the Large Magellanic Cloud. Additional modifications were made to further improve the YSO identification process.

(1) Color-Magnitude Selection Criteria

The initial selection of the YSO candidates was based on a combination of photometric data from the SAGE-SMC point source catalogs and IRAC and MIPS 24 μm images. We used the list of all IRAC catalogs as sources, as well as MIPS 24 μm sources with no IRAC counterparts. We selected sources with colors that are indicative of YSOs (as indicated by the YSO models; Robitaille et al. 2006), and less so by other stellar populations and galaxies.

Figure 1. An example of an isochronal (is. i) vs. (is. II) (24) CMD: the distribution of the SAGE catalog source (in greyscale) is compared to the position of the stars (left), the young stars (middle), and the YSO models (right). The region around the blue line was selected.

The models show that due to our selection criteria that avoided regions occupied by the galaxies and evolved stars, our YSO list is biased towards younger evolutionary stages and intermediate to high-mass sources.

(2) Image Inspection and SED Modeling

We performed a visual inspection of ~5000 color-selected sources. We carefully examined the environment of the sources at all available images (Figure 2), simultaneously with their spectral energy distributions (SEDs), supplemented by the optical photometric data available, and their location in the color-magnitude space. The SEDs were fitted with the YSO models using the model grid (~200,000 pre-computed 2-D YSO models; Robitaille et al. 2006, 2007). We removed sources with non-YSO characteristics, unreliable sources, etc., and fit with a model (solid line) with a fairly massive envelope.

Figure 2. CMDs (same as above) from a grid of YSO models scaled to a standard IMF and SAGE sensitivity limits. Three colors represent three stages of evolution (left) and three mass ranges (right) as indicated in the legends. The models show that due to our selection criteria that avoided regions occupied by the galaxies and evolved stars, our YSO list is biased towards younger evolutionary stages and intermediate to high-mass sources.

We have developed a method of calculating the likelihood of a source being a YSO: “the score”. The score ranges from 0 to 10, with higher scores indicating a greater confidence that the source is a YSO. The score is calculated based on where the source is located in the color-magnitude space with respect to the evolved stars, galaxies, and massive stars in the CMDs used for the source selection, and scaled by a fraction of CMDs the source appears in. We are more certain of the classification of the source that has more photometric measurements since we can gather more evidence by inspecting its location in more CMDs.

Our list of the YSO candidates includes previously known sources:

1) all spectroscopically confirmed YSOs
2) ~99% of the previously identified YSO candidates that are in the SAGE-SMC catalog and fulfill our color-magnitude criteria
3) ~10 sources that were identified as non-YSOs in other studies

Comparison to Gas Tracers

The YSO candidates are spatially correlated with the gas tracers.

Using the SAGE-SMC photometry and images combined with the near-infrared and optical data, we identified a population of massive YSOs in the SMC. Our methods involved color-magnitude selections, inspection of the multi-wavelength images, and fitting of the spectral energy distributions of the YSO candidates using the 3D radiative transfer models. The Figure below shows the distribution of ~1286 newly discovered YSO candidates, along with previously known YSO candidates and confirmed YSOs.

Figure 4. The distribution of scores for all the sources we inspected (blue) and those we determined are YSOs (the final list; red). All spectroscopically confirmed YSOs have high scores.

Figure 5. The distribution of the YSO candidates with respect to the H I, Hα, and CO gas.

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Figure 6. Pixel value histograms of the H I (left) and CO (right) images:

The histograms show that the YSO candidates are preferentially located in the regions of high HI column densities and high CO surface brightness.

References

Tremblay, E. et al. 2010, AJ, 139, 71