Identifying Candidate Young Stellar Objects in the Spider Nebula (IC 417) Using Archival Visible and Infrared Data

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Abstract

- IC 417 (Spider Nebula) is ~2.3 kpc away in the direction of the galactic anticenter.
- The "Nebulous Stream" (NS) (see Figure 2) was identified by Jose et al. (2008), but has not yet been studied in detail.
- We selected young stellar object (YSOs) candidates from the literature and the NS.
- We assembled literature photometry from optical to mid-IR, including Gaia and PanSTARRS.
- We inspected images to ensure correct source matching, and created spectral energy density (SED), color magnitude diagram (CMD), and color color diagrams(CCD).
- We used this process to narrow down a list of ~650 to ~600 candidate YSOs.
- Future work will allow us to further refine the list.

Methodology

- We assembled a list of YSO candidates in this region from the literature, including work done by a previous NITARP team (2015).
- We selected additional sources from a polygon defined by us by position around the NS (outlined in blue in figures 1 and 2).
- We constructed SEDs for all candidate YSOs from optical to mid-IR bands, including PanSTARRS, Gaia, IPHAS, UKIDSS, 2MASS, Spitzer, and WISE.
- We visually inspected images across wavelengths and spatial resolutions to confirm (or fix) our initial position-based match.
- We removed objects that were deemed to be non-point sources, like nebular knots.
- We constructed CCD and CMD to further investigate the candidates.

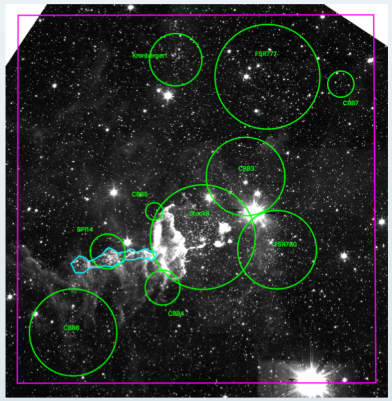

Figure 1. *The region we studied in IC417 (the Spider Nebula) is shown in IRAC-2 (4.5 μm), encompassed by the magenta square, which is ~0.7 deg on a side (North is up). The green circles are clusters identified in the literature from 2MASS star counts. The blue polygon is the NS (also see Fig. 2). Literature YSOs are found over the entire region; we added stars from the NS based on position within the polygon shown.*

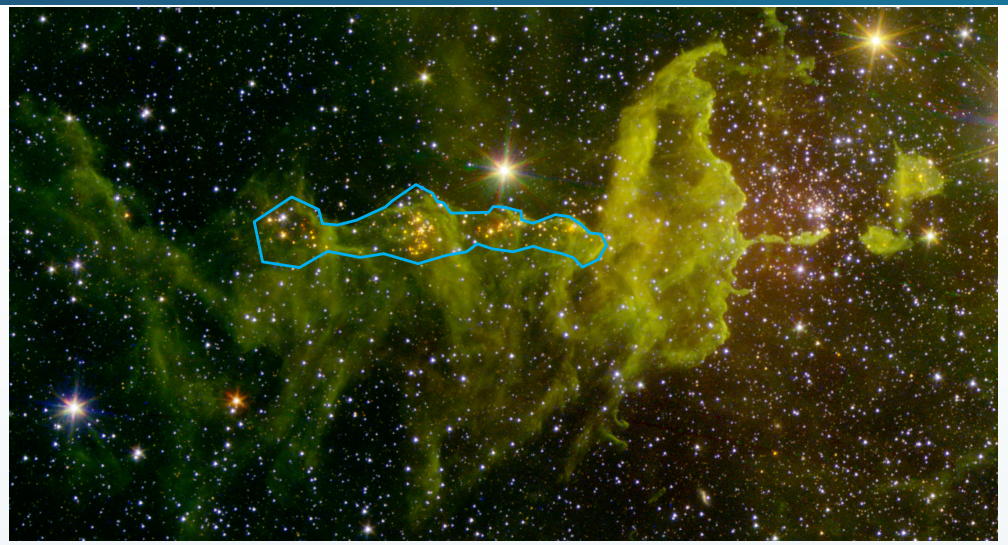

Figure 2. *Press release image from Spitzer (2016, NASA/JPL-Caltech) using 1.3 μm (2MASS, blue), 3.6 μm (IRAC, green), and 4.5 μm (IRAC, red). Many of the stars in the NS look red, even in this view, which is a driving reason why we chose to explore YSO candidates based on position in the NS.*

Plots

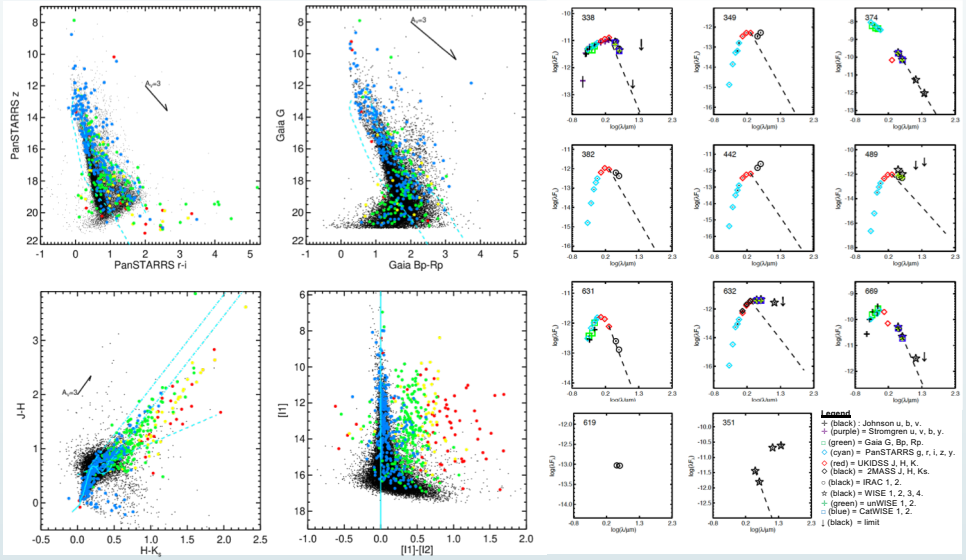

Figure 3. *CMD and CCD from the region. Bands used are noted in the plot. Key: blue = class III, green = class II, yellow = flat, red = class I, black points are other stars in the field. Redding vectors are shown (that in IRAC is negligible). In the optical CMDs, blue dashed lines are PARSEC isochrones for 6 and 9 Myr. Solid line in the other plots is the main sequence. In the JHK diagram, blue dashed line is CTTS locus, and dot dashed lines delineate where reddened main sequence stars lie. Most of our candidate YSOs have colors consistant with YSOs.*

Figure 4. SEDs for selected YSO candidates from the NS. Symbols defined on the left. Dashed line is a Rayleigh-Jeans line extended from Ks to guide the eye as to where the photosphere is expected to be, assuming that Ks is unaffected by dust. Plots are log λ Fλ in cgs units (ergs/s /cm^2) against log λ in microns.

Results

We have identified 616 candidate YSOs. Within these candidates, we have determined the SED classification of 65 Class I (11%), 52 Flat Class (8%), 225 Class II 37%), & 273 Class III (44%) objects.

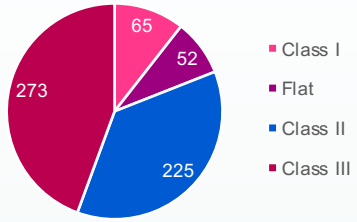

Figure 5. *YSO distribution by classification. Most of the YSOs are class II or class III.*

Future Work

- We have begun investigating distances from Gaia DR2 and will incorporate Gaia DR3.
- We have begun work with CMDs and CCDs but need to continue exploring the distribution of points in many different color spaces.
- There are Akari (9 and 18 μm), Herschel (70 μm), and MSX (8-20 μm) data in this region as well; we can explore the long wavelength counterparts to our YSO candidates.
- This region was observed by the Zwicky Transient Facility (ZTF) and we can explore the optical variability of our candidates.

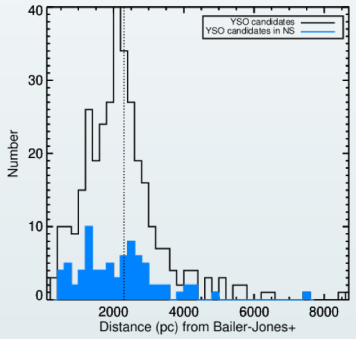

Figure 6. *Histogram of distances of our sample from Gaia DR2 (Bailer-Jones et al. 2018). Blue histogram indicates NS population. Most of our candidate YSOs are near the expected distance of 2.3 kpc (dotted line).*

Acknowledgements

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