Star Finders: Assembling a Multi-Wavelength Catalog of Young Stellar Objects in Serpens Main

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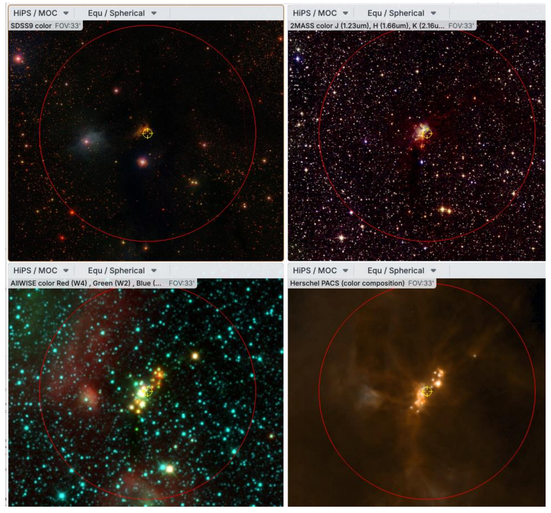
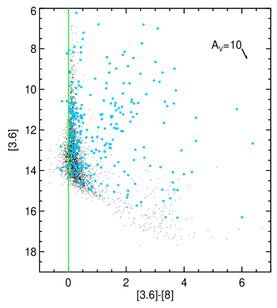
Background:

- Serpens Main is a well-studied, embedded star-forming region 1-2 million years old and 415 parsecs away
- Since 1974, there have been over 1,100 journal articles about YSOs and YSO candidates within Serpens (e.g. Strom et al., 1974)
  - Since 2008, 87 papers have published lists of candidate or confirmed YSOs
- It was a target for time series observations in Spitzer YSOVAR program (Rebull et al. 2014, AJ, 148, 92) and is proposed to be in the Roman Galactic Plane Survey (Galactic Plane Survey Definition Committee, 2025, arXiv, 2511.07494)
- We saw an opportunity: **It would be useful to create a unified catalog of YSOs and candidate YSOs based on all literature-identified YSOs and many of the large-scale archival photometric surveys**



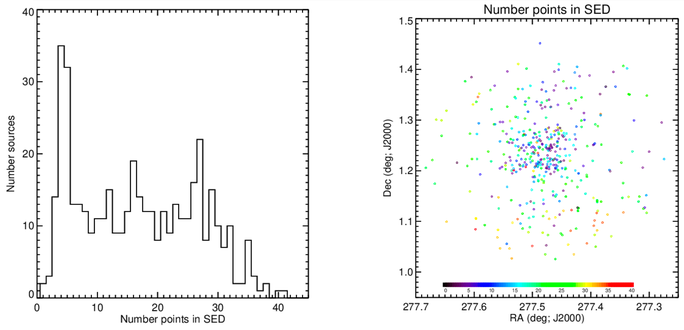
← Our region of study in four composite bands: SDSS (optical), 2MASS (NIR), WISE (MIR), and Herschel (FIR) HiPS images using IRSA Viewer. Red circle is our region of study (0.22° radius), yellow reticle is the center position, north is up. Moving to longer wavelengths makes it far easier to see through the dust to the YSOs embedded in the cloud.



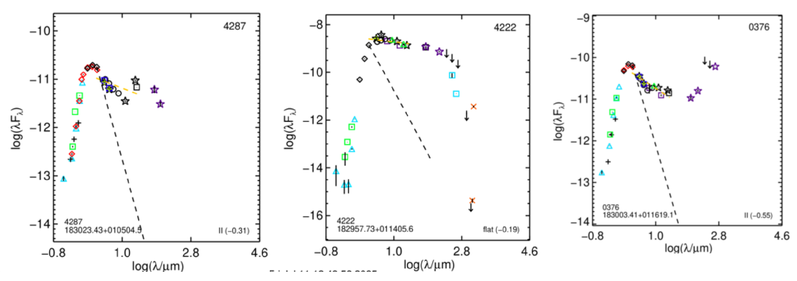
IRAC color-magnitude diagram for our region. Black points are → everything in our catalog from this region in general; blue points are those objects on our YSO shortlist. Green line is the expected photospheric color for most dust-free stars. Most of the objects on our YSO list have an 8 micron excess, sometimes a very large excess.

Methods:

- Our work focused on targets within 0.22° of 18h29m55.17s, +1d14m23.3s, J2000 because that's where YSOVAR has light curves
- We identified 87 journal articles with lists of YSOs or candidate YSOs in Serpens Main.
  - Our final catalog has wavelengths ranging from X-rays (wavelengths ~0.1 nm, or 0.0001 um) to radio (wavelengths 6.7 cm, or 67,000 um), so 8 orders of magnitude in wavelength. Not all of those catalogs (especially those from the literature) cover our whole region, and very few sources have data spanning all or even most of those wavelengths.
- We merged Gaia, PanSTARRS, SDSS, UKIDSS, 2MASS, Spitzer (c2d and SEIP), WISE (AllWISE, CatWISE, unWISE), Akari, Herschel (HHLI and HGBS).
  - This list also includes YSOVAR time series data (74 sources)
- After merging the catalogs by position, we had 439 literature YSOs or candidates in our list.
- Then we constructed spectral energy distributions (SEDs) from u-band to ~1 cm, although few sources have all these possible wavelengths.
- We then went through each of the sources in the list, examining each SED, using the IRSA tools, Finder Chart, and IRSA Viewer to inspect individual images, and assessed each source to see if the bandmerging across catalogs was correct, if the WISE-3 and -4 bands were real detections, etc.
  - In some cases, we corrected merges made solely by position.
  - In a few cases, we have not yet figured out the counterparts to what the original authors identified, and the original source may not be possible to recover.
- In some cases, YSO candidates were identified solely from IR properties
  - If we now have optical counterparts, we have more insight as to whether a target is legitimate YSO at distance of Serpens



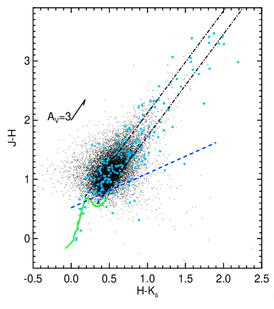
↑ For the current version of our YSO list, half the sources have at least 17 points in its SED. Most sources have nothing longer than 8 or 24 microns (IRAC-4 or MIPS-24), and very few of the sources have detections at X-rays.



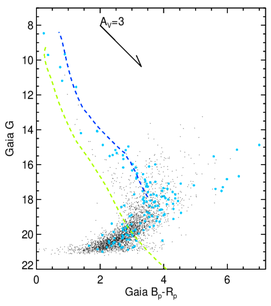
↑ Examples of very well-populated SEDs for selected sources. Different symbols correspond to different surveys of origin. Black dashed line corresponds to the location of a photosphere, assuming that K is on the photosphere. The yellow dashed line is a linear fit to all the detections between 2 and 25 microns, e.g., the fit that identifies the SED class of the YSO. That fit and the resultant SED class is printed in the lower right of each plot.

Results:

- Most of the YSOs cluster near the center of the field of view, as expected.
- Nearly all the sources on our YSO list (~95%) have an IRAC-1 measurement, consistent with a lot of the YSO searching work involving the infrared or even specifically Spitzer.
- Only ~35% of the sources on our YSO list have a Gaia counterpart, which is consistent with the high degree of reddening towards this cluster.
- Spectral types are available for only ~25% of the sources on our YSO list; future work should include spectra of these objects, which would also help with verification that they are YSOs and not background/foreground objects.
- About 60% of the YSO list also has a light curve in at least one IRAC band from YSOVAR. Future work includes exploration of the variability properties of these YSOs; 57% of those with light curves are variable as per the 'standard criteria' laid out in Rebull et al. (2014).
- More work is needed to continue to refine list of YSOs and YSO candidates



← NIR color-color diagram using JHKs (largely but not exclusively from 2MASS). Black points are everything in our catalog from this region in general; blue points are those objects on our YSO shortlist. Green line is the Zero-Age Main Sequence (ZAMS) from Pecaut & Mamajek (2013). Blue dashed line is the T Tauri locus from Meyer et al. (1997). Reddening vectors (here and in other similar figures) follow the reddening law from Indebetouw et al. (2008) and Mathis (1990); dot-dashed lines are extensions of the ZAMS such that objects between those two lines have colors consistent with reddened main sequence stars. A few objects on our YSO list are consistent with dust-free stars, but most of the objects on our YSO list are highly reddened, and some have IR excesses even at NIR bands.



← Observed Gaia color-magnitude diagram for our region. Black points are everything in our catalog from this region in general; blue points are those objects on our YSO shortlist. Dashed lines are are 6 and 9 Myr isochrones from PARSEC models (Bressan et al. 2012), shifted to Serpens distance. We knew from the JHK diagram that reddening significantly impacts these data, and that is immediately apparent from this plot. However, the brighter YSOs/candidates fall on the younger isochrone, as expected.