Sharpless CHARcuterie Playground (SCHARP): Looking for Young Stars in Interesting Places

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Abstract:

We propose to use archival data to search for and identify candidate young stellar objects (YSOs) in selected Sharpless Catalog regions. Stuart Sharpless identified and cataloged 313 H II regions in the entire sky north of declination -27° (Sharpless, 1959). Many of those HII regions are well known star forming regions, already studied extensively using multiwavelength data. Of these 313 regions, we identified about 60 Sharpless regions that have not yet been mined for YSOs using infrared (IR) and optical data but look like they might harbor YSOs. We noticed patterns in the target list: (a) targets where there was obvious IR nebulosity and likely YSOs; (b) targets with small, largely circular clumps of blue stars; (c) dispersed red stars. We plan to analyze 5 regions encompassing 8 Sharpless targets distributed over these groups to look for YSO candidates. We also have a "control" target that does not appear like any of those regions so that we can use it as a comparison but is still a Sharpless catalog object. To identify candidate YSOs, we will collect and combine the catalogs across wavelengths (bandmerge) archival infrared and optical survey data from multiple catalogs. We will construct color-color and color-magnitude diagrams to select YSO candidates, inspect images, and build spectral energy distributions (SEDs) for each candidate. We will compare the "yield" of YSOs across the different types of regions, and see which type is more likely to harbor YSO candidates.

1.0 Science Introduction and Context.

Wanting to understand how we got here is as old as humanity. In order to understand how we got here, how planets form, we need to understand how stars form. Because we can't put a star in a bottle and watch it go from start to finish, the only way we can learn about how stars form is to find lots of them in many places and study them en masse. So, we need to find young stars in interesting places, including those tucked out-of-the-way in galactic backwaters heretofore not analyzed. By studying star formation in varied environments, we can learn more about the processes that led to the formation of our own Solar System and potentially discover other planetary systems. The study of young stellar objects (YSOs) helps us to understand how stars form and evolve, and how they interact with their surroundings. (The term "YSOs" includes all kinds of young stars, from the earliest stages of star formation through stars that have recently started burning hydrogen on the main sequence.) Studying star formation allows us to learn more about the processes that govern the Universe and helps us build a more complete picture of how the cosmos has evolved. Star formation plays a key role in shaping galaxies and driving their evolution over time. Finally, the study of YSOs is crucial for understanding the conditions that are necessary for the formation of habitable planets and the development of life.

In our project, we are looking for young stars in a wide variety of places. In this section, we first explain the basics of how (low-mass) stars form, and then we explain how we picked our targets, and what is known about them.

1.1 How (Low-Mass) Stars Form.

Figure 1 (Greene, 2001) is a high-level overview of how low-mass stars form; objects in panels c-f. could be called YSOs. Stars begin their lives in a cloud of gas and dust (a nebula). Gravitational forces cause the nebula to start to condense, or shrink (Figure 1, panels a & b).

As the nebula shrinks, it begins to spin more rapidly. Conservation of angular momentum means that the dust and gas in the nebula doesn't fall straight into the center; it spirals onto a disk surrounding the central object, and from the disk, the matter falls onto the central object (Fig 1, panel c). The temperature at the center of the condensing nebula rises due to increasing pressure and friction between the particles. Figure 1 has this stage labeled as a "protostar"; beginning at this stage, and until the star starts to turn hydrogen (H) into helium (He), the object is also called a YSO. Since the protostar is still embedded in a thick cloud of gas and dust, it can't be detected in the optical images.

When the protostar enters the next stage, labeled in the figure as the T Tauri stage (Fig 1, panel d), it is still gaining mass and contracting slowly because material is still falling onto it. It begins to eject gas in two giant jets, sometimes called bipolar flows. These jets and stellar winds eventually sweep away the envelope of gas still surrounding the YSO. In the surrounding disk, protoplanets may begin to form.

Leftover material in the disk surrounding the star clumps together to form larger objects, which likely undergo many collisions until most of the material has been gravitationally swept up into planets, asteroids, and comets (Fig 1, panel e).

The YSO's life so far has been governed by the continuous inward pressure of gravity. The gravitational pressure keeps compressing the gas into a smaller and smaller volume, making it hotter and hotter in the core. As soon as the temperature in the core of the YSO becomes great enough, nuclear fusion begins. When this nuclear fusion begins, finally the star has a way to counter gravity. So much energy is released in this reaction that it enables the star to "push back" with an outward radiation pressure that balances the inward pull of gravity. The protostar is now a full-fledged star, fusing H into He in its core (Fig1, panel f).

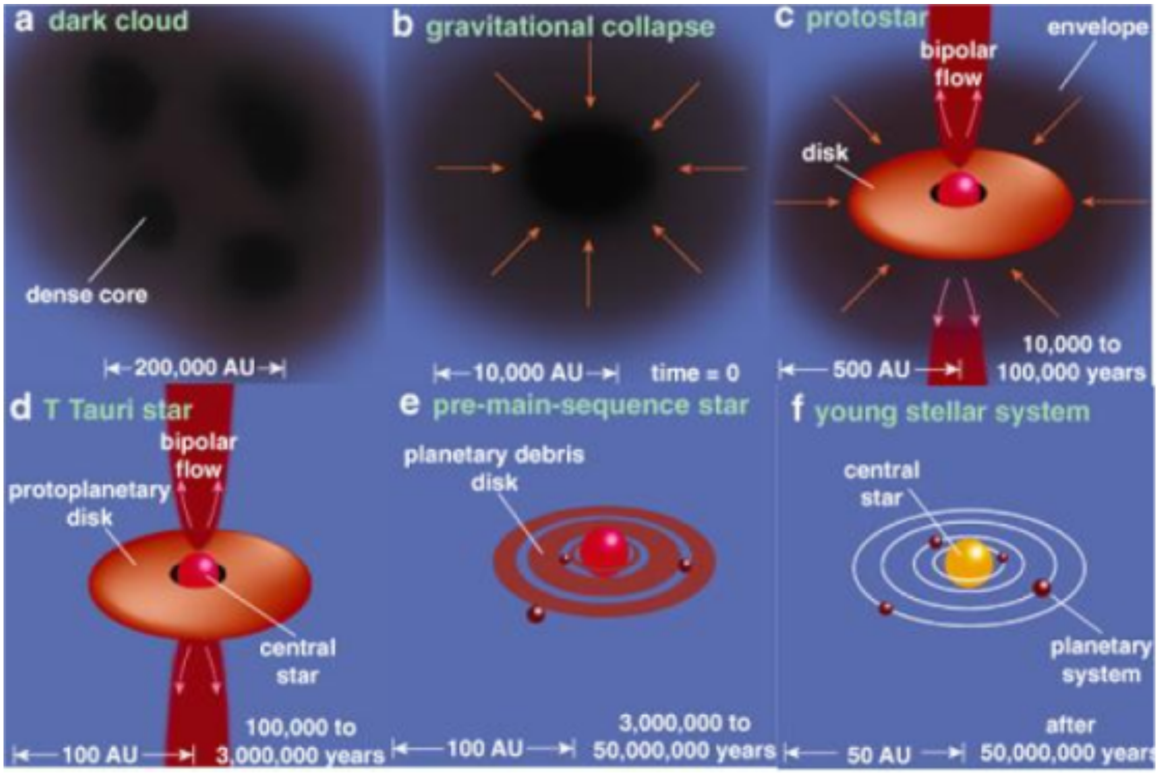


Figure 1: Stages of (low-mass) star formation. From Greene, American Scientist, Jul-Aug 2001.

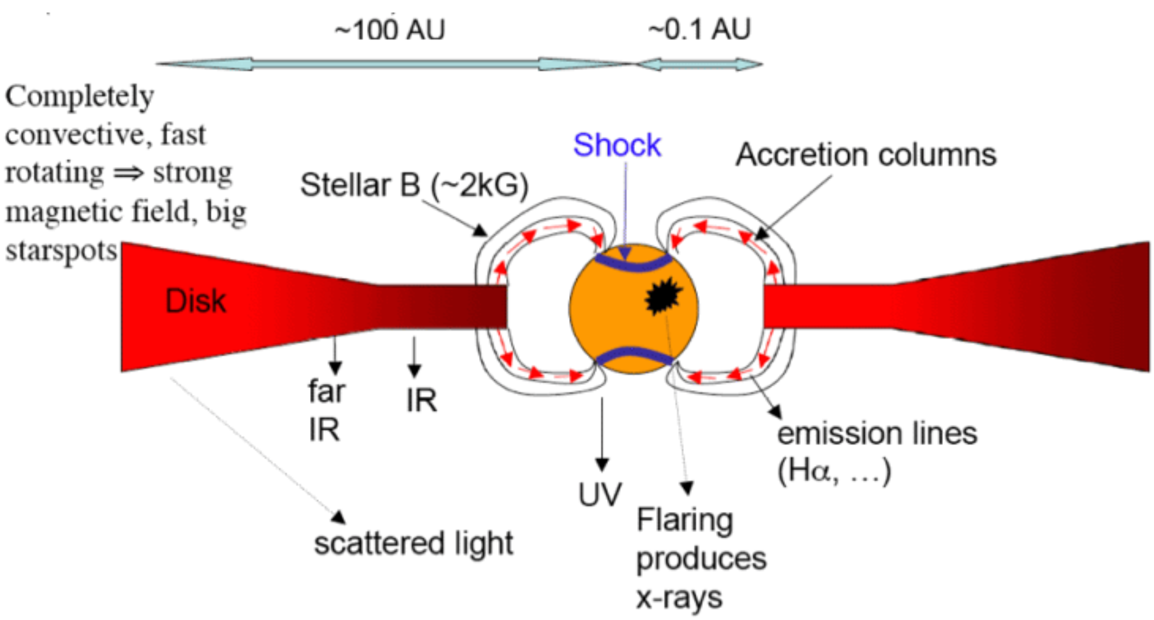


Figure 2: Anatomy of a young star. The annotation "Stellar B (~2 kG)" means "stellar magnetic field of about 2 kiloGauss". X-rays and H-alpha emission comes from stellar activity (flares), H-alpha and other emission lines come from accretion columns, UV excess comes from the accretion shock, IR excess comes from the circumstellar disk (Rebull, 2011, p. 2)

1.2 Finding YSOs.

YSOs are different from main sequence stars in many subtle and not-so-subtle ways, and many different methods can be used to identify YSOs from out of the set of foreground/background objects. Note that typically, several indicators of youth are necessary, including via spectroscopy, before it is accepted that a YSO candidate is a genuine YSO. Figure 2 shows the basic anatomy of a YSO, as shown in panels d and e in Figure 1. Figure 2 also shows how observations in different wavelengths can be used as markers for different processes occurring in YSOs.

X-rays. YSOs can be very active and have strong flares that are bright in X-rays. One example of using X-rays to look for YSOs is Alcala et al. (1996). However, in order to do this, obviously, one needs X-ray data, and sufficiently sensitive X-ray data is not always available.

Outflows. Very young YSOs can have bipolar flows (e.g., Fig 1, panels c and d). Ogura et al. (2002) and Walawender et al. (2006) are examples of investigators using outflows to identify young stars. However, YSOs do not spend much time in the "outflow phase", so it is difficult to "catch them in the act." In order to find outflows, stars of the right age, and data that includes emission lines found in outflows, are needed, which are not always available.

UV excess. When YSOs are actively accreting mass, the accretion process itself can produce an ultraviolet (UV) excess – that is, more UV light than is expected for a star that is not accreting – because the matter crashing down onto the star creates a shock front that creates a hotspot, which is bright in the UV. Rebull et al. (2000) is an example of a study using UV excess to look for YSOs. However, UV data can be difficult to collect, especially in regions where there is a lot of dust (like star-forming regions), because shorter-wavelength light scatters easily in dusty regions. For stars with a high enough accretion rate, the UV excess can spill over into the blue bands, which may produce a blue excess at longer wavelengths than the UV.

H-alpha emission. When YSOs are actively accreting mass, they are bright in emission lines, which arise from the accretion columns connecting the disk to the YSO. Ogura et al. (2002) is an example of finding YSOs from H-alpha emission. Stars that are young enough to still be rotating quickly can be very active and thus be bright in H-alpha from stellar activity, not accretion. Stars that are old but anomalously active can contaminate a sample of YSOs selected solely based on H-alpha, but those levels of H-alpha are generally far lower than that from accretion and can be judiciously eliminated with careful H-alpha limits (see, e.g., Slesnick et al., 2008); spectroscopy is particularly needed in these borderline cases.

Variability. YSOs are variable – indeed, variability was one of the original defining characteristics of young stars (Joy, 1945 and Herbig, 1952). One example of an investigation using variability to identify YSOs is Rebull et al. (2014). Stars that have convective outer zones (Fig. 1, mid-f and later) have starspots and therefore will be variable, but older stars are generally variable at much lower levels than young stars, even those without disks (see Fischer et al., 2022 and

Rebull et al., 2018). Stars that still have circumstellar disks often have stochastic variability (see, e.g., Cody et al., 2022, Fischer et al., 2022). Contaminants in a sample of YSOs selected based on large-amplitude variability could include red giants.

Infrared (IR) excess. YSOs can have dusty circumstellar disks. Those disks absorb radiation from the star, heat up, and re-emit in the IR, so the YSO therefore has an IR excess, e.g., more IR light than is expected from a star that does not have a disk. Many people have used IR excesses, particularly from Spitzer (e.g., Gutermuth et al., 2008, 2009) or WISE (e.g., Koenig & Leisawitz, 2014), to find YSO candidates. These techniques use cuts in multiple color-color and color-magnitude diagrams to select likely YSO candidates out of the general population. Contaminants for a YSO candidate sample selected in this way include primarily background asymptotic giant branch (AGB) stars and active galactic nuclei (AGN). Having optical data helps tremendously in weeding out these contaminants.

Location in the sky. YSOs are often found in regions of high extinction or are associated with nebulosity. When used in conjunction with other data, making an initial selection of YSO candidates based on position on the sky is a common approach (see, e.g., Kiss et al. 2006, Padgett et al. 2004, Rebull et al. 2007, among many others).

IR excesses (and UV excesses) make young stars easy to select out from color-color and color-magnitude diagrams; the size of IR excesses (and UV excesses) can easily be assessed from spectral energy distributions (SEDs). Figure 3 shows example SEDs for a disk-free star, a star with a dusty disk, and a star with a dusty ring. The IR excesses can be seen clearly in the SEDs.

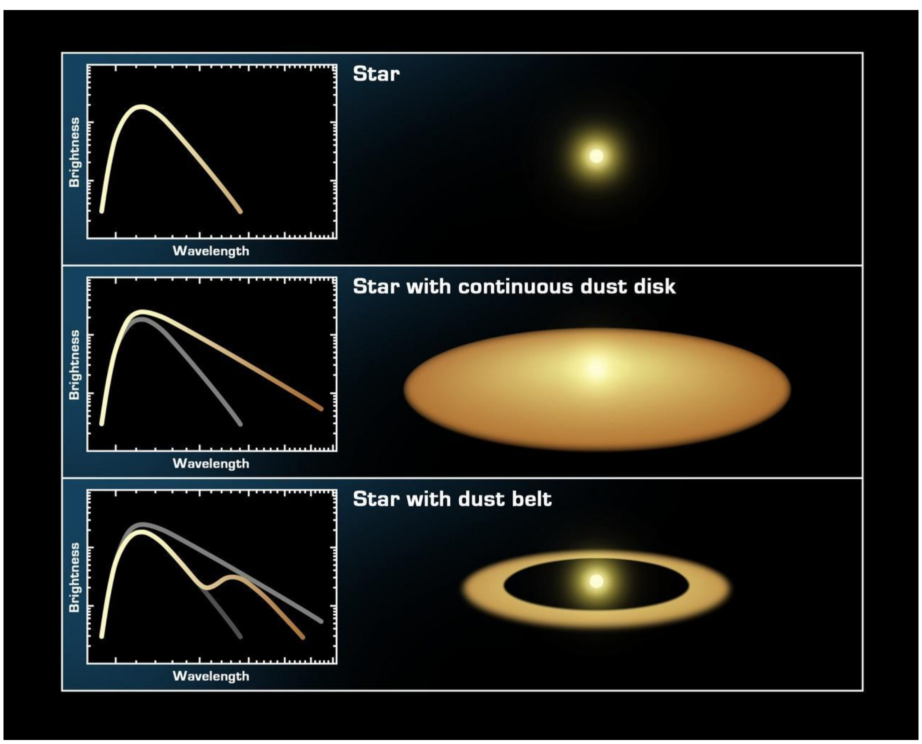


Figure 3: Graphic from Spitzer press release sig 05-026, showing a YSO(+disk) on the right and corresponding SED on the left. The dust-free star's SED in the top row is replicated as a grey SED in the center and bottom rows for comparison. The SEDs for the YSO+disk or ring both have more IR emission than the star without dust, e.g., an IR excess. (Image: NASA/JPL-Caltech/T. Pyle [SSC])

When one has a wealth of data, it becomes powerful to combine as many of these methods as possible, such as Kuhn et al. (2021), who used IR excess, location, and variability, or Getman et al. (2017), who combined IR excess, location, and X-ray detections. Optical data can help flesh out SEDs for objects selected based on IR excesses, and make it less likely that such objects are AGN, for example. It is also important to note that having many photometric bands, three-dimensional space motions from Gaia, high-resolution spectroscopic data, even multi-wavelength monitoring, can still result in confusing and contradictory information about any given star, and judgment calls still need to be made. Even for stars in the Taurus Molecular Cloud, only 140 parsecs away and studied for more than 100 years, there is room for debate (see discussion in Luhman 2023).

1.3 Sharpless's Catalog and Selecting Our Targets.

In the mid 1950s, Stewart Sharpless visually inspected the entire Palomar Observatory Sky Survey (POSS), which consists of photographic plates of the entire sky visible from Palomar, which is north of declination -27 degrees. He made a catalog of things that he thought were likely to be HII regions, e.g., star formation regions, or SFRs. (The notation "HII" means ionized hydrogen, or gas heated by hot stars – young stars). Sharpless published a first version of his catalog in 1953 and then a final version of it in 1959; because the second catalog is the final version, the notation for the catalog is Sh 2- xxx -- Sh = Sharpless, 2 = 2nd catalog, xxx = the catalog entry's number.

Sharpless identified 313 new and known HII regions, which is what he had set out to do. Many of the Sharpless objects are famous, even though they might not be known by their Sharpless name. Sh 2-49 is M16, the Eagle Nebula; Sh 2-275 is the Rosette Nebula. Sharpless kept track of how big his objects were, and some of the Sharpless objects are enormous – Sh 2-276 is Barnard's Loop, which is about 10 degrees across! Others are much, much smaller; Sh 2-4 is a 5 arcminute diameter source that turned out to be an IRAS source (IRAS 17149-3916). Some are known to be close and some are known to be distant. Not all of the Sharpless objects have turned out to be actual SFRs; some have ended up being galaxies (e.g., Sh 2-191=Maffei 1) or planetary nebulae (e.g., Sh 2-274=Medusa Nebula).

Because WISE has surveyed the entire sky in the mid-IR, at 3.5, 4.6, 12, and 22 microns, we can easily look at all the Sharpless sources and see whether they still look likely to harbor YSOs based on the IR images. HII regions, or SFRs, should be impressive in the IR, full of nebulosity and red stars.

We started with the entire Sharpless catalog, and compared the catalog against Simbad to see how many references each object had as a rough guide to how much work had been done in each location. Via this comparison to Simbad, we were able to drop the sources that were already known to be galaxies or planetary nebulae, or very famous SFRs.

We uploaded the remaining Sharpless catalog to the IRSA tool Finder Chart and looked at the images in WISE bands over a 20 to 48 arcminute region. All Sharpless had at the time were the optical photographic plates; he did not have access to wavelengths other than the optical for comparison. For many targets, once we looked in the IR, it was quite clear what he was identifying as the interesting source, but for others, it's much less clear in the IR (or even in the optical, also provided in Finder Chart) what he thought was interesting (what he thought was the HII region).

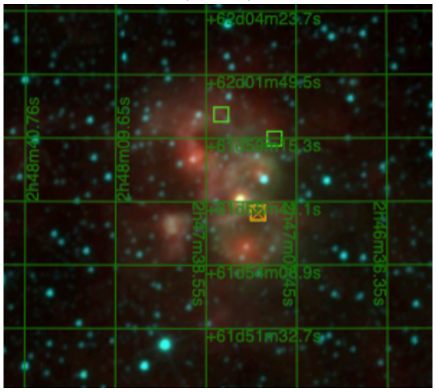
Based on the WISE color images created by Finder Chart (a visualization tool at IRSA that allows the cross comparison of images from different surveys of various wavelengths) and Spitzer images where available, we could identify things that were likely rich with YSOs, then iterated back and checked with Simbad, looking again to see if there was literature that had already looked for YSOs using Spitzer and/or WISE IR excesses in that region. We then were able to rule out, for example, Sh 2-11= NGC 6357 because Kuhn et al. (2021) already used IR to find YSOs there.

After this process, we had about 60 Sharpless objects that are not currently known to be galaxies or planetary nebulae. They are also not located where other investigators have already studied YSOs in detail using Spitzer and/or WISE data. Out of those ~60, we noticed some patterns in the WISE color images. Some fields are so close to the Galactic Center such that source confusion, especially with WISE (whose spatial resolution is ~6 arcsec), would make those targets very hard for us to work with to search for YSOs. Others seemed to be effectively blank fields, meaning we couldn't easily tell what Sharpless had in mind as the HII region. Of the remaining fields, there were (a) targets where there was obvious IR nebulosity and likely YSOs; (b) targets with small, largely circular clumps of blue stars; (c) dispersed apparently red stars. We then focused more intently on those in the three groups, and did more literature searching to be confident that no one else has yet looked for YSO candidates using IR excesses from WISE and/or Spitzer in these regions. We then ranked the regions by how likely we thought that it would be for us to find YSOs there. **We plan to analyze at least one from each of these three groups** (obvious IR nebulosity, blue clumps of stars, dispersed red stars) **to look for YSO candidates**.

While we were culling the list, one of us "rediscovered" one of the Sharpless regions we had earlier discarded as being unclear which target Sharpless had in mind as the HII region. Since this process is going to be a learning experience for us, we decided to add this nominally "unimpressive" region as a sort of "control" for comparison to the regions where we thought it more likely that we'd find YSOs.

1.4 Our Targets.

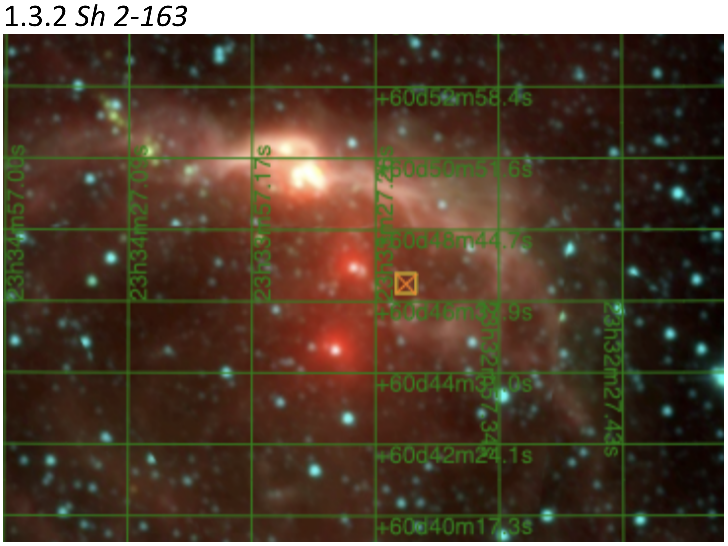
1.3.1 *Sh 2-192/193/194*



Sh 2-192/193/194 – These three Sharpless sources are close to each other on the sky, and based on the IR image, we suspect that they might all be related. We will treat the trio as one target, in the category of “obvious IR nebulosity and likely YSOs.”

These regions have been explored from a cursory level but not in the context of identifying a list of YSOs. Azimlu and Fich (2011) “studied the physical properties of molecular clouds associated with a sample of 10 H II regions.” They identified “dense and hot clumps' ' in their sample of Sh 2-192, 193, and 194. While acknowledging that these clumps could be candidates for the formation of massive stars, Azimlu and Fich did not compile a specific list of YSO candidates. Bica et al (2003) identified Sh 2-192 as an infrared cluster candidate (IRCC). IRCCs are “probably clusters, but are essentially unresolved, and require higher resolution and deeper images for a definitive diagnostic.” Similarly, Kronberger et al. (2006) identified a bright star within Sh 2-193 using 2MASS data, but did not identify it as a young star. We will follow this up and use Gaia, PanSTARRS, and Spitzer data to continue to explore their candidates, see if we can identify specific YSO candidates, and explore specifically the blue clumps of stars seen in the figure here.

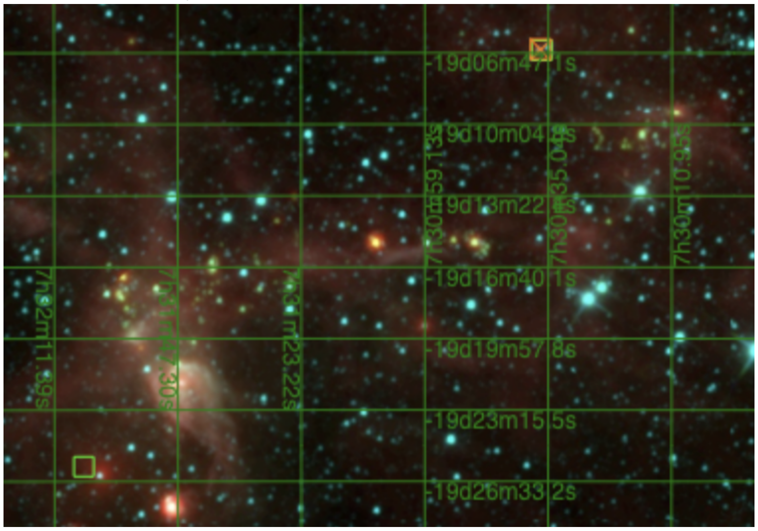
1.3.2 *Sh 2-163*



Sh 2-163 is another in the category of obvious IR nebulosity and likely YSOs.

Yu et al. (2014) investigated Sh 2-163 using multiwavelength observations, including 2MASS and MSX, two of the surveys we plan to use. They were, however, more interested in the longer wavelengths and the extended emission. They published a short list of YSO candidates based on the NIR; we will include their YSO candidates in our list of YSO candidates and use our data to see if we can identify more YSO candidates and bolster the case for or refute the YSO status of their YSO candidates.

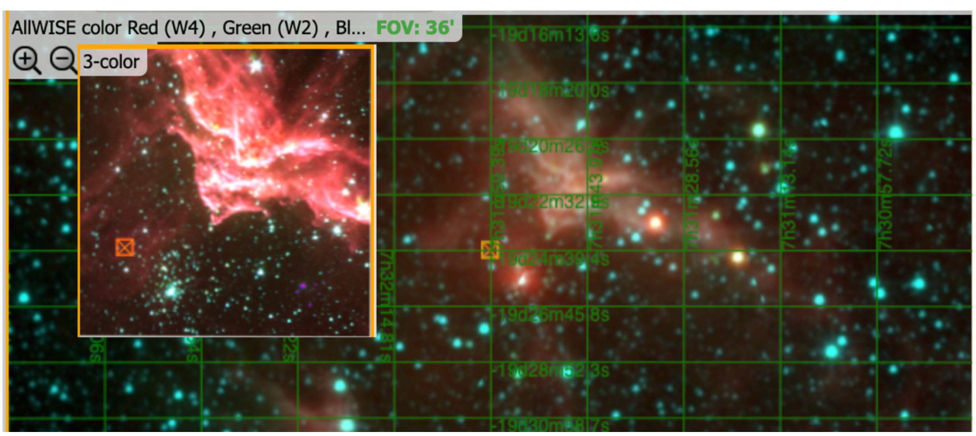
1.3.3 *Sh 2-306/309*



Sh 2-306/309 – These two objects are near each other in the sky, but (unlike Sh 2-193/194/195) based on the IR morphology, may or may not be related. This is in the category of "dispersed red stars."

Dutra et al. (2003) sought embedded star clusters in the Southern part of the Milky Way based on 2MASS JHK images and radio surveys. This region was identified as a cluster in that work, with an estimated distance of 4 kpc and age of 10 Myr. If this is correct, there should still be stars with IR excesses for us to find. (They did not report a list of YSOs or candidates.)

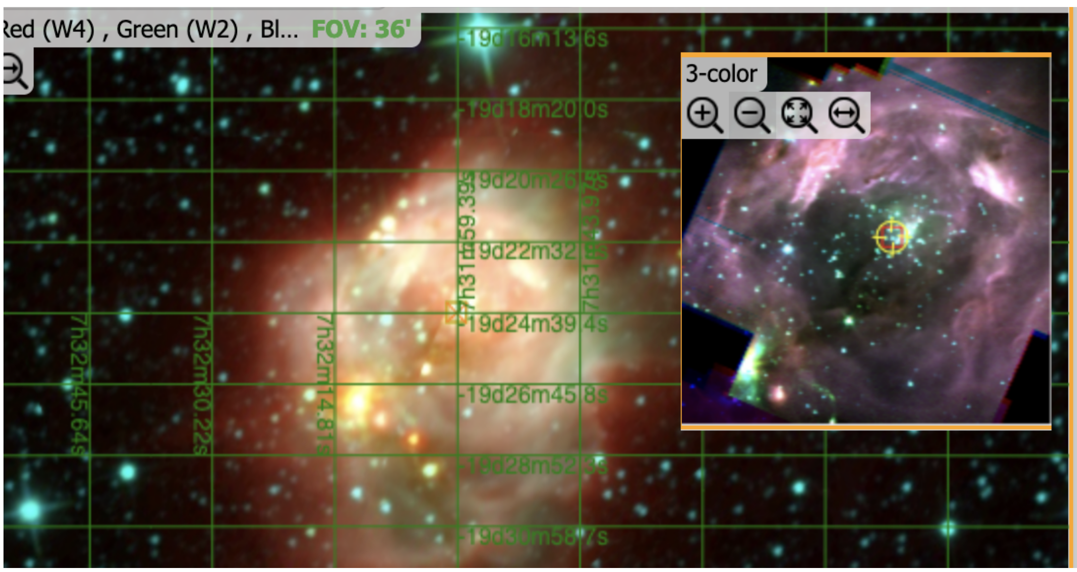
1.3.4 *Sh 2-135*



Sh 2-135 is one of the targets with a small, circular cluster of blue stars. You can only see the blue cluster, however, in the Spitzer data (inset). The WISE data (larger image) does not have high enough spatial resolution to see the cluster. This region was included in the big study by Winston et al. (2020) which combined GLIMPSE360, WISE, and 2MASS data to look for YSOs in the outer Galaxy. However, as shown in Rebull et al. (2023, submitted), not all of their candidate YSOs are necessarily point sources, something that becomes immediately apparent when we combine the IR catalogs with Gaia, PanSTARRS, and IPHAS, as we plan to do. We will include the ~170 YSO candidates from this region in our list of possible YSOs. Jayasinghe et al. (2019) report that this target was identified as part of the Milky Way Project but no other useful information (well, useful to us) was reported. Kim et al. (2018) reports that this target is an HII region, bright in H-alpha (they call it WK05). They have not published anything specific with the YSOs contained therein. Foster & Brunt (2015) identified this target as having a distance of 1.40+/-0.28 kpc and an ionizing star of type O9.5V. Anderson et al. (2015) found a spectrophotometric distance of 1.2+/-0.3 kpc and a much different kinematic distance of 3.1+/-1.3 kpc; they hypothesize that the discrepancy is due to non-circular motions in the Perseus arm, and they believe the closer distance is correct. Foster &

McWilliams (2006) report three distances: 1.93 kpc (kinematic), 1.53 kpc (stellar), 1.64 kpc (their new method), and the O9.5V star as BD +57 2513. 1.3 kpc is the distance to this object. The blue cluster is identified variously as DSH J2222.0+5843=Juchert 21 (Kronberger et al., 2006) or [FSR2007] 0367 (Buckner & Froebrich, 2013). Kronberger et al. (2006) identify it as a "candidate open cluster"; Buckner & Froebrich (2013) place it much further away than the rest of the objects at 9.7 kpc. We will investigate whether it is at ~10 kpc or ~2 kpc, which should be straightforward with Gaia. Several sources in this region are found in Fratta et al. (2021) which used Gaia+IPHAS to select H-alpha-bright sources. These are potential YSOs, which we will also include in our set of YSO candidates from the literature.

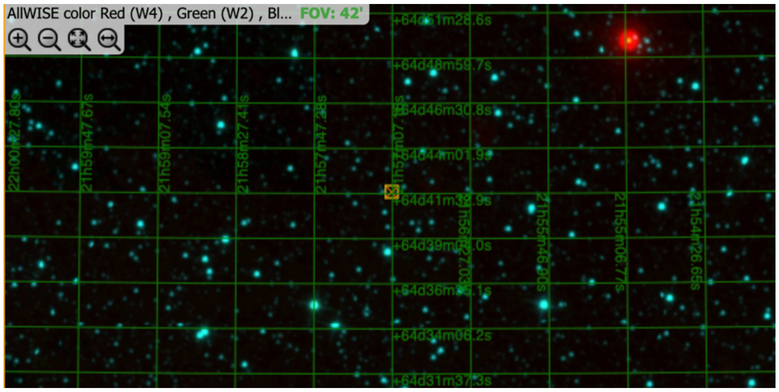
1.3.5 *Sh 2-187*



Sh 2-187 is another target with a circular clump of blue stars. For this one as well, you have to go to Spitzer (inset) rather than WISE (larger image) to see the blue cluster.

Kang et al. (2017) explored this region with WISE data, using IR excesses to find YSO candidates, but they did not publish a list of their candidates. We will investigate their color-color and color-magnitude technique, and use Gaia, PanSTARRS, and Spitzer data to continue to explore this region, see if we can identify more YSO candidates, and explore specifically the blue cluster of stars seen in the figure here. Richards et al. (2012) has a distance to this cluster of 1.44 ± 0.26 kpc, and also has plots with YSOs, but no table of YSOs, though it references a forthcoming paper that we have been unable to locate.

1.3.6 *Sh 2-137*



Sh 2-137 is the “control” field. In contrast to the other targets shown above, there seems to be no obvious IR structure present here. The red source in the upper right is an AGB star (IRAS 21537+6435).

Patel et al. (1998) identified this region as being on the edge of the Cepheus bubble. Fich et al. (1990) observed this region in H-alpha but did not call it out as anything unusual other than an HII region.

In addition to these 6 targets, we are holding a few additional targets “in reserve”, should we want to pursue further.

2.0 Analysis plan.

Our scientific goals here are to identify potential YSO candidates in each of our targets and see which one yields more YSO candidates. We will need to use all of the data we can find on these targets, and develop a YSO selection approach based on those in the literature. We will do this by constructing color-color and color-magnitude diagrams, constructing SEDs, and inspecting images to make sure that the targets we select are point sources at all available bands. This follows the same general approach used by other NITARP teams, e.g., Rebull et al. (2023) or Rebull et al. (2011).

Most of Sharpless’ targets are in or near the Galactic Plane, so there is quite a bit of serendipitous data to be found. There is often – but not always – Spitzer data from the GLIMPSE survey, so at least IRAC-1 and -2, but if we’re lucky, there will also be IRAC-3 and -4, and MIPS-24 data. WISE data covers the whole sky, so we will use that. There is often IPHAS optical (r, i, and H-alpha) and/or PanSTARRS optical (grizy) data for our targets, so we will use that when available. Gaia data is available over the whole sky, but may not go deep enough in the dusty regions to be very helpful for targets that are >2 kpc away. We will take advantage of it where we can. The optical data, where available, will be very helpful in weeding out background giants and galaxies from our YSO candidate lists. When we can, we will include Akari, Herschel, and MSX data.

Table 1 has a list of each of our targets from Section 1 with a list of all the data that we plan to use for each target.

Table 1: Sharpless Objects of Interest, Locations, and Available Survey Data

Sharpless Region Identifier	RA	DEC	Available Survey Data
Sh 2-194	41.83301	61.9378	GLIMPSE; DSS; 2-MASS; WISE; AKARI
Sh 2-193	41.8856	41.8856	GLIMPSE; DSS; 2-MASS; WISE; AKARI
Sh 2-192	41.809097	61.987957	GLIMPSE; DSS; 2-MASS; WISE; AKARI
Sh 2-163	353.3317	60.78567	DSS; 2-MASS; WISE; AKARI
Sh 2-309	113.02529	-19.429546	GLIMPSE; DSS; 2-MASS; WISE; AKARI
Sh 2-135	335.54852	58.73837	SEIP; DSS; 2-MASS; WISE; AKARI
Sh 2-187	20.782394	61.856647	SEIP; DSS; 2-MASS; WISE; AKARI
Sh 2-306	112.65302	-19.109518	GLIMPSE; DSS; 2-MASS; WISE; AKARI
Sh 2-137	329.30000	64.68333	SEIP; DSS; 2MASS; WISE; AKARI

We will not use X-rays, because there is no X-ray data to be had in most of these largely ignored-to-this-point regions. The YSOs we might find are likely to be too old to have outflows, but if we are so lucky as to find very young YSOs, any outflows will show up in Spitzer data (see e.g., Ray & Ferreira 2021). We won't have any UV data, but the shortest wavelength to which we have access is the PanSTARRS g band, and very large accretion rates may spill over and affect this band; we will look for any influence of accretion on this band, but we may not find it. We will have narrowband H-alpha imaging from IPHAS for many targets; we can look for stars that are bright in H-alpha using these data. Our plan at this time is *not* to extend our work into time series analysis to look for variability, just for reasons of time, but many of our targets are observed by ZTF, and possibly a later NITARP team could explore this. **The main method we will use to find YSO candidates is IR excess, based on WISE and Spitzer mid-IR data**, having selected an initial region based on location on the sky (near a Sharpless target and IR nebulosity or red sources, as described above). **By including all the optical and IR photometric data we can find, we will minimize the contamination from background giants and galaxies**. We will use Gaia data where possible to determine distances to the targets.

We will use the photometry published with these various surveys. If we need to do our own photometry on the Spitzer images, we will follow the best practices laid out in the IRAC Instrument Manual and use the Aperture Photometry Tool (APT) (Laher et al., 2012). We will use Microsoft Excel to create some SEDs, but will rely on Dr. Rebull's software to bandmerge the catalogs and create SEDs en masse. We will use Microsoft Excel and IRSA tools to create color-color and color-magnitude diagrams and select YSO candidates.

3.0 Educational/Outreach plan.

This will be a year-long original and authentic research project in astronomy for students and teachers. Students and teachers will learn basics of infrared astronomy, how to analyze data through telescopes and archived data, and basics of software usage. Our project will contribute to continuing research in our proposed studies. Our teachers plan to present at professional development workshops, conferences, and provide articles and presentations to the scientific community. There are several ways in which we plan to share our research in the hope of providing opportunities for others to become involved.

3.1 Debbie McKay

As an ambassador for AUI's ACEAP program (Astronomy in Chile Educator Ambassadors' Program), I will have the opportunity to share with many astronomy educators and professionals. Also, as a member of the West Virginia Science Teachers' Association, I have presented sessions at their annual conference and would like to share my experience with other teachers to show how they and their students can apply to be involved in NITARP research. As a science teacher for West Virginia University's HSTA program, an after-school program in which underrepresented high school students conduct scientific research for four consecutive years, I would like to share this experience. Finally, presentations to the community at our local environmental center which has weekly astronomy programs and viewings, would be an ideal place to share this knowledge.

3.2 Ace Schwarz

I plan to present my research to my followers on Instagram (44.3k) and share about my experience with NITARP in general. Many middle and high school teachers follow me, and I think it would be a natural recruitment opportunity. NITARP is often geared towards high school students and educators due to the complexity of the content. As a middle school teacher, I know that students can and are capable of understanding complex topics if it is explained in a way they can understand. Part of my educational outreach is to "translate" the following videos/articles from the NITARP resource list into middle school language:

- Movie on IR Light
- How Stars Form
- Color Images
- Magnitudes, Filters, and Colors

3.3 Rosina Garcia

Students will be involved in each aspect of the research process, from literature review to analysis and presentation. I will be taking three students to Pasadena in summer 2023 to gain hands-on experience and to collaborate with teammates. Additionally, I plan on taking the same students with me to the American Astronomical Society conference in New Orleans in January 2024. Currently, I have been having bi-weekly meetings with three students to discuss the research and next steps.

This experience expands science education beyond the required basic biology, chemistry, and physics to larger fields and creates space for "applied" science. With student involvement, I am able to expand the reach and influence of the Astronomy and Astrophysics Club and encourage future/other members to participate in research work.

I also plan on organizing a "space day" conference with the UC San Diego's Center for Research Educational Equity, Assessment, and Teaching Excellence in collaboration with the San Diego Science Project to share NITARP's work and resources for how to integrate astronomy into secondary science classes.

3.4 Olivia Kuper

- Presentation by my students and myself to the Board of Trustees monthly meeting Greene County Schools
- Presentation by my students and myself to the Bays Mountain Astronomy Club
- Student presentation to the North Greene High School Science Club

- Share this information with the EXES Astronomy group at the University of Texas
- Share this information on Teaching Astronomy, a Facebook group that I administer
- Present a talk at a National Science Teaching Association meeting
- Present a talk at the Phillips Exeter Academy Astronomy Conference
- Present a talk at the Society for Science's Research Teachers Conference

3.5 Damian Baraty

Currently, three capable young women who have been leading the Astronomy Club's efforts at Severn School have indicated their willingness to journey on the NITARP path and learn about conducting this research project. I am incorporating the tutorial videos into an EdPuzzle classroom to have these students learn the basics of our project and would hope to share this classroom resource with other interested parties.

I hope to present this project in one of my school's faculty meetings, showing our findings and taking teachers through the process of doing archival research. If the opportunity presents itself, it may be a possibility to share our progress with outside astronomy groups, such as our nearby community college, in hopes of creating more connections and ties between my school and the college.

Finally, like Olivia above, I plan to reach out through conferences such as the Phillips Exeter Academy Astronomy Conference and our state's Computer Science Teachers Association at a monthly meeting focused on teacher learning opportunities.

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