Finding Young Stars in IC 417

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1. Abstract

We propose to look for candidate young stellar objects (YSOs) in an interstellar nursery found in the constellation Auriga, the IC 417 nebula. IC 417 is towards the Galactic anti-center, in the Perseus arm, at a distance of ~2.3 kpc. Stars form from clouds of interstellar dust and gas. A signature of star formation is excess infrared (IR) emission associated with the stars, suggesting circumstellar dust around these young stars. Our investigation will look for infrared excesses using near- and mid-IR data from the Wide-field Infrared Survey Explorer (WISE) and the Two Micron All-Sky Survey (2MASS). We will build on past studies of this region by Jose et al. (2008) and Camargo et al. (2012), who identified several clusters they believe to be young (a few million years old), and associated with IC 417. We will use a series of color cuts in various 2MASS/WISE color-magnitude and color-color diagrams following Koenig & Leisawitz (2014) to identify YSO candidates; we will inspect these objects in the 2MASS and WISE images and inspect their spectral energy distributions (SEDs) assembled from archival data ranging from wavelengths of 0.7 to 22 μm. Through this analysis process, we will assemble a set of objects we believe to be YSO candidates. From this set of likely members, we can start the process of determining the distribution of masses within the cluster (the initial mass function, IMF) and total cluster mass for comparison to other clusters in our Galaxy and in other galaxies. Obtaining a complete IMF for this region is important for assessing if there is a difference between the IMF in the outer Galaxy and the inner Galaxy.

2.0 Science Introduction and Context

2.1 Science Background: Star Formation

Stars form in dense concentrations of gas and dust called a nebula. These nebulae act as incubators in which newborn stars form; see Figure 1. The dust and gas in one of these concentrations collapses inward due to gravity. The matter cannot fall radially into the central object because angular momentum must be conserved. Even if the cloud is rotating only a little bit, it still has angular momentum. So, the matter falls into a "pancake" disk, from which this dust and gas spirals into the central core. Some of the accreting matter gets ejected above and below the disk in outflows or jets. Eventually the envelope around the disk disappears and the accretion process slows down. The jets stop, the disk thins out, and the disk becomes a proto-planetary debris disk. Hydrogen eventually ignites (fusion of H into He begins) in the protostellar core and it becomes a new star.

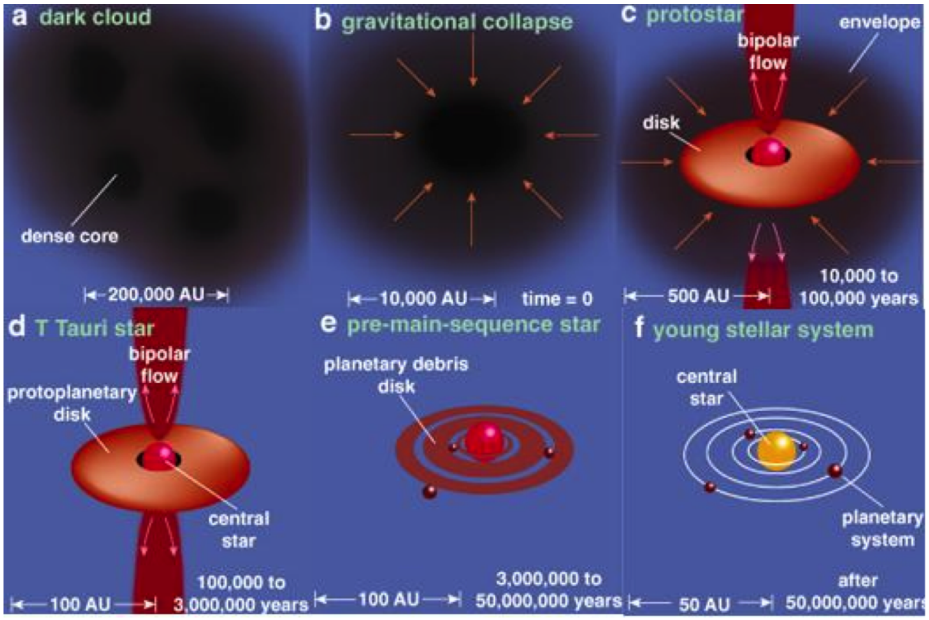

Figure 1: *The process of low-mass star formation. (Figure from Greene, American Scientist, Jul-Aug 2001.)*

During most of this process of star formation, the central object, or young stellar object (YSO), has a dusty disk or envelope around it. This dust absorbs radiation from the YSO and reprocesses (re-emits) it into the infrared (IR). Thus, we can identify YSOs by looking for stars with an IR excess, e.g., more IR emission expected than for a star that does not have a disk or envelope. Any given field of view that contains young stars also includes foreground/background stars (and extragalactic objects); we can use this property of IR excess to identify young stars in a field consisting of both young stars and other sources, such as stars that are too old to have an IR excess. As the star forms, progressively less and less dust surrounds it, and the amount of IR excess correspondingly decreases.

YSOs have historically been organized along an evolutionary sequence based on the shape of their spectral energy distributions (SEDs). An SED is a graph of the energy emitted by an object as a function of wavelength. As seen in Figure 2, the SED for the youngest YSOs starts off as a cold black body because all the energy it emits is reprocessed through its dusty envelope. As it sheds its cocoon, emission from the central object is more readily apparent, and the black body radiation from the heat of the central core becomes more dominant. The SEDs in Figure 2 show the IR excess – the IR excess is the difference between the solid lines and the dashed lines in each SED. Nomenclature is still actively evolving in this field, but some commonly used terms are indicated in Figure 2.

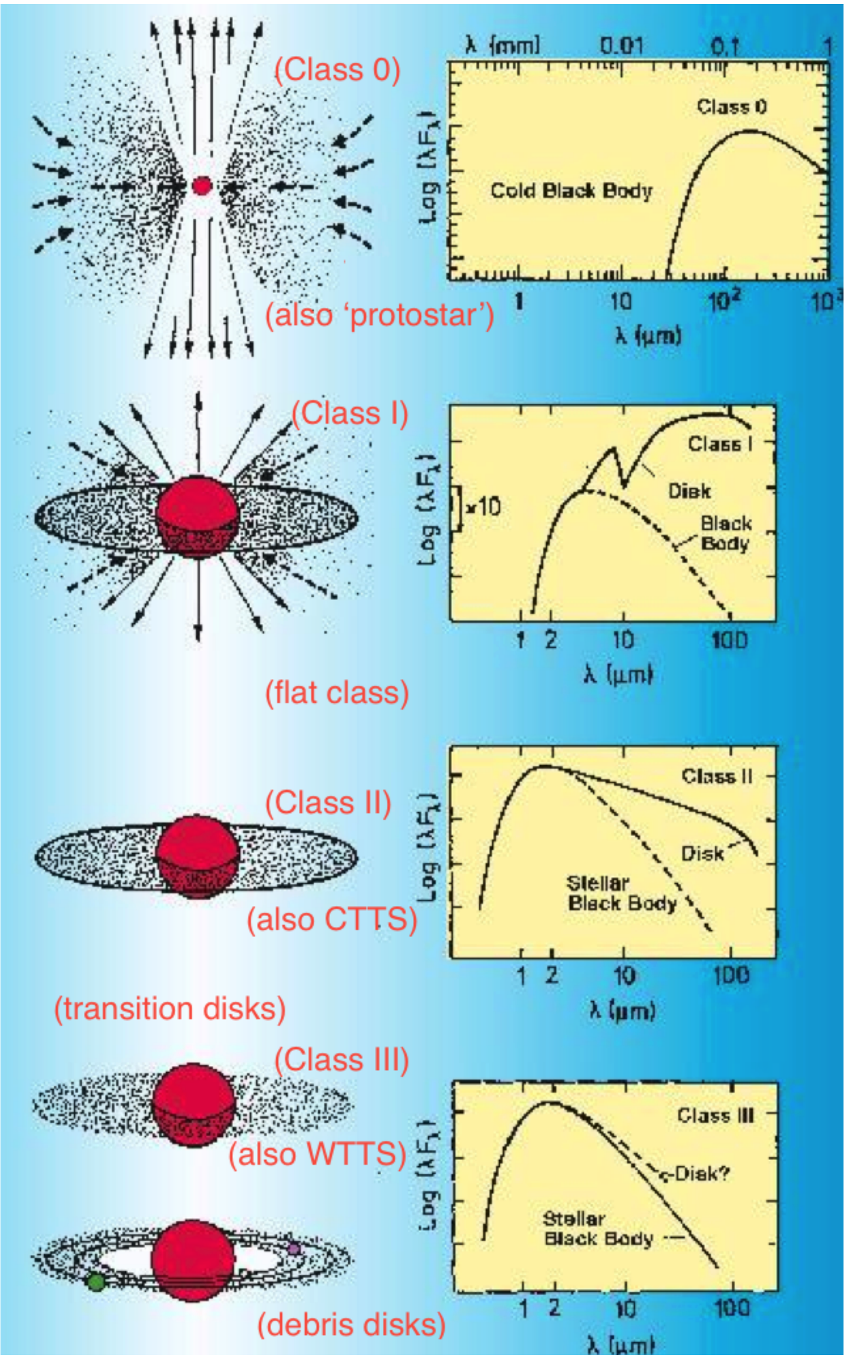

Figure 2: *Low-mass star formation with SEDs. (Figure adapted from Bachiller 1996 and Andre & Montmerle 1994.) The illustrations on the left are similar stages as were illustrated in Figure 1. The plots on the right are illustrative SEDs, showing the IR excess above the stellar blackbody. Nomenclature in this field can be complicated, so a variety of names of stages is provided in the figure. The SEDs are Class 0 (also called protostar), Class I, Flat, Class II (also called classical TTauri stars, or CTTS), and Class III (also called weak-lined TTauri stars, or WTTS). Sometimes 'transition disk' is used to refer to the state between having a substantial disk and having a tenuous disk. The last, most tenuous disk can also be called a debris disk.*

Because all of these YSO stages have IR excesses, astronomers can very effectively identify YSOs through their IR excesses with missions such as the Spitzer Space Telescope (Werner et al. 2004) or the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). Indeed, results from these two missions have recently greatly enhanced our understanding of how young stars form (see, e.g., Werner et al. 2006).

2.2 Science Background: Outer Galaxy

Many of the most well-known star forming regions are relatively close to us, and therefore bright and easy to study. Most of these regions are in the plane of our Galaxy, and (from our perspective) in the half of the Galaxy including the Galactic Center, simply because that is where the majority of the Galaxy appears to us to be – see Figure 3. We do not have a very complete understanding or inventory of the star clusters (how many there are, where they are, and their contents) in the other direction looking away from the Galactic center (Galactic anti-center).

Studying the outer Galaxy is useful for a variety of reasons. One reason is to further understanding of the initial mass function (IMF) of stars, which is the distribution of masses of stars as they form within a cluster. Is the IMF universal? Is it the same in the outer Galaxy as it is in the relatively crowded "downtown" of the Galactic Center and its immediate "suburbs"? The outer Galaxy is relatively less dense and may have lower metallicity (lesser amounts of elements other than H and He) than the rest of the Galaxy. Most stars are thought to form in clusters and it is important to know if the outer Galaxy is forming stars with different mass ranges than the rest of the Galaxy. Most stars are not high mass, but are more like our Sun and less massive. Insight into the distribution of lower masses is important because it represents a substantial fraction of the stars in the Galaxy. Similarly, another reason to study the Outer Galaxy is to further understanding of the *cluster* mass function in our Galaxy, and how it compares to those in other nearby galaxies. It is important to know if the Milky Way contains fewer, the same number, or more of the relatively isolated clusters in order to compare the evolution of our Galaxy with those of others.

We have chosen to study a region (likely containing several clusters) in the outer Galaxy in order to further the understanding of star formation and structure of the Milky Way. By studying just one young cluster (or even a few), we will not be able to resolve the larger issues of the universality of the IMF. We will invest time to get a clean, well-defined sample of stars thought to be young cluster members in one of these outer Galaxy clusters. This research can be combined with other work to shed light on the universality of the IMF and cluster sizes. If the IMF is substantially different in other places in our Galaxy or in other galaxies, it has a bearing on the total masses assumed for other clusters and galaxies.

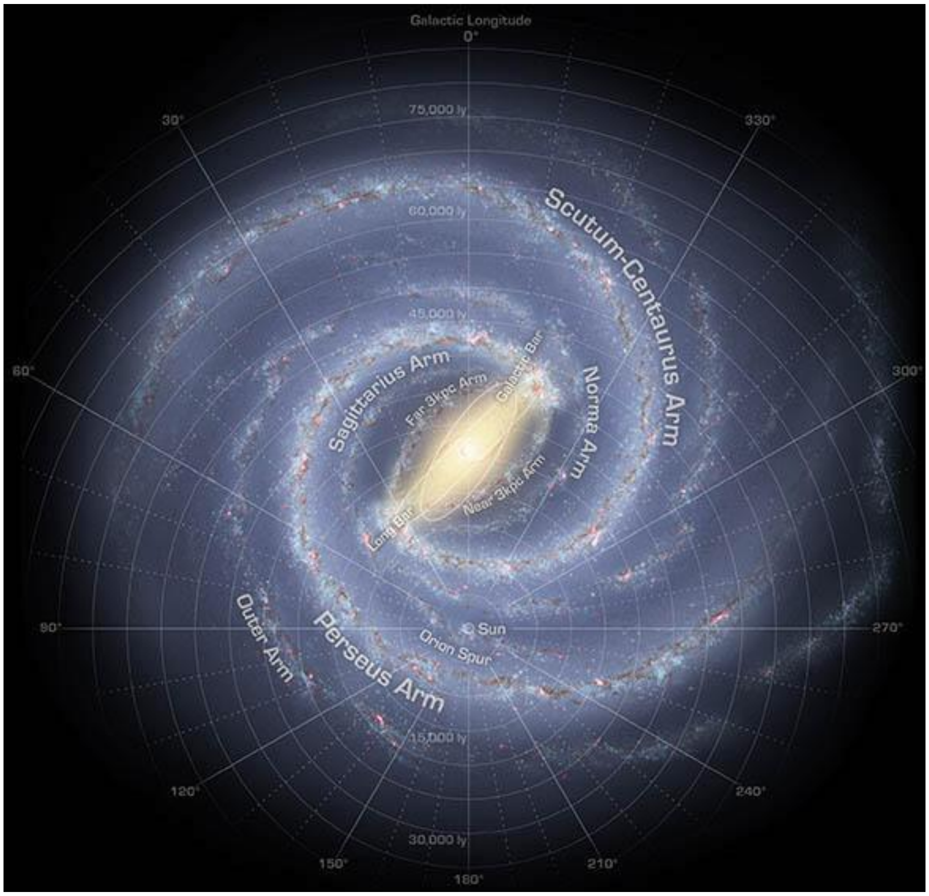

Figure 3: *Annotated view of our own Galaxy. (Image from NASA/JPL-Caltech/R. Hurt, SSC press release ssc2008-10b.) Most of the star formation regions that are well studied are between Galactic longitude 90 and 270 degrees, simply because that's where the rest of the Galaxy largely is (appears to us to be). Our inventory of star formation regions in the other direction is incomplete. The object we will study here, IC 417, is at 173 degrees longitude, so very close to the Galactic anti-center.*

2.3 Science Background: Our Target

Our goal in this study is to identify YSOs in IC 417. IC 417 is in the Auriga constellation. Jose et al. (2008) find IC 417 to be at a distance of 2.3 kpc, so it is not part of the Tau-Aur star forming region or the Auriga-California Molecular Cloud, but rather in the Perseus arm (Camargo et al. 2012), one of the outer arms of our Galaxy (see Fig. 3). IC 417 is located at J2000 RA 05:28:11, Dec 34:25:28 and at a Galactic longitude, latitude (l,b) of 173.38, -00.20 degrees. It is almost exactly opposite from the Galactic Center, and is therefore a part of the Galactic anti-center. IC 417 is a bright emission nebula that is believed to be related to several clusters, including one called Stock 8. Figures 4 and 5 show this region in the mid-IR; Figure 4 is a WISE large-scale view of the region (image is ~2 deg on a side). Jose et al. (2008) identified a "nebulous stream" to the East of IC 417 in the near-IR; the nebulous stream can clearly be seen on the left in Figure 4 or 5, the latter of which is the IRAC-2 (4.5 μm) image. In these mid-IR images, clustering can even be seen by eye, especially in Figure 5.

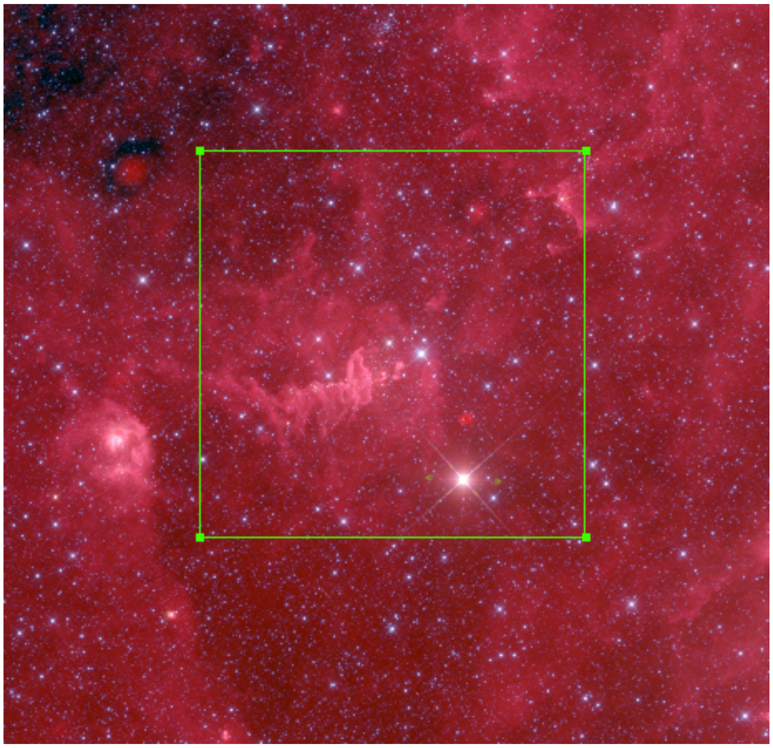

Figure 4: *WISE 3-color image (with r=[22],g=[4.6],b=[3.5]) of the neighborhood of IC 417; North is up. The green square delineates the region (~1 deg on a side) that we will study, and corresponds to the region shown in Figure 7 below. The bright red dot above the bright star in the lower left is scattered light (scattered within the WISE instruments) from the bright star, and is an example of the image artifacts that we may need to deal with.*

Figure 5: *GLIMPSE IRAC-2 (4.5 μm) image of the heart of IC 417; North is up, and the image is about 25' left-to-right. The "nebulous stream" is extending to the left (East), and the cluster Stock 8 is just to the right (West) of the nebulous 'wall' near the center of the image. Clustering is obvious enough that it can be identified by eye in these regions.*

Figure 6: *This optical picture of "The Spider and The Fly" by Steve Cannistra (StarryWonders) was retrieved from http://apod.nasa.gov/apod/ap061027.html. The "Spider" (right nebula) is IC 417. The nebulous stream can be seen towards the center of the photo stretching out to "The Fly" (NGC 1931).*

Two recent studies, Jose et al. (2008) and Camargo et al. (2012), have studied this region and identified several clusters they claim to be young and associated with IC 417. We now summarize these papers.

Jose et al. (2008) used optical (*UBVI*) photometry, near-IR photometry (*JHK$_s$* from the Two-Micron All-Sky Survey, 2MASS; Skrutskie et al. 2006), and Hα slitless spectroscopy to study the cluster Stock 8 to determine its "amount of interstellar extinction, distance, age, stellar contents and initial mass function (IMF)." They also identified the "nebulous stream" on the east side of IC 417 (see Fig. 4, 5, or 6) and found a cluster as well as YSOs in the stream. They found these sources are younger stars compared to those in the Stock 8 cluster. Jose et al. provided a full catalog of sources they detected in this region, not just the YSOs. The full catalog will be of a great help to us in our study of this region, because the optical data help define the short-wavelength side of the SED here, and will allow us to make optical color-magnitude diagrams. We note that they studied the IMF here statistically and did not spend much time identifying individual sources.

The aim of Camargo et al. (2012) was "to improve the census of the star clusters towards the Galactic anti-center." They used 2MASS *JHK$_s$* data to identify clusters from star count distributions. One area of focus was the IC 417 region where they identified several new clusters, as well as confirming other clusters from Jose et al. (2008) and other literature. Figure 7 is a reproduction of Figure 19 from Camargo et al., and calls out 11 clusters in this region. They determined all of these clusters to be a few million years old and at a distance of around 2.5 kpc (e.g., associated with IC 417). Given this, there should be many young stars in this region that still have substantial, detectable IR excesses.

Because of the specific scientific goals of Jose et al. (2008) and Camargo et al. (2012), neither one of these recent studies spent a lot of time working with individual sources, and neither one investigated the properties of the point sources at wavelengths longer than K band (2.2 μm).

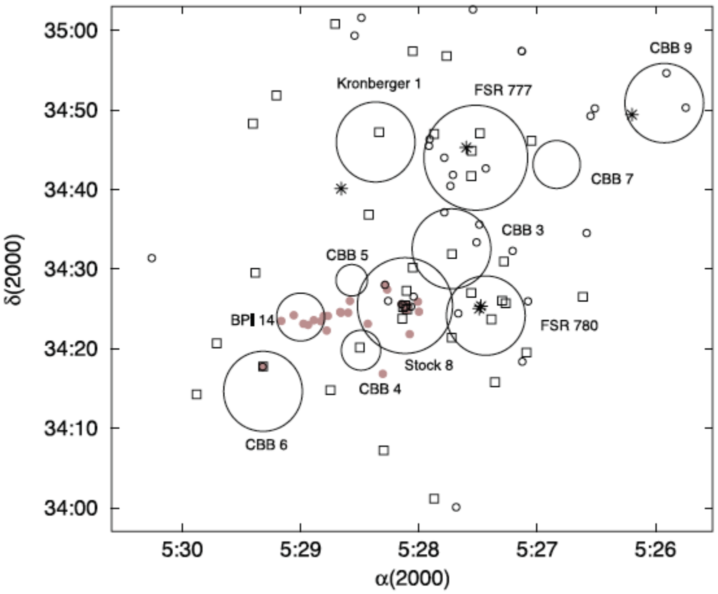

Figure 7: *Reproduction of Fig 19 from Camargo et al. (2012), covering the region in which we plan to look for YSO candidates. Large circles are the clusters identified (largely from the near-IR) in Camargo et al. and other literature. Large brown dots are YSO candidates from Jose et al. (2008). According to the Camargo et al. figure caption, open circles are Hα emitters, squares are B stars, and asterisks are undefined. We have obtained the OB and Hα star catalogs that they used, and will identify these objects in our database.*

Our plan is to look for YSOs in the region shown in Fig. 4, which is well-matched to the region shown in Fig. 7. This area is ~1 degree on a side and centered on 5:28:00 34:30:00 (J2000). Camargo et al. (2012) identified the clusters as shown in our Fig. 7, and they assert that these clusters are all a few million years old. As such, the *bona fide* cluster members should be YSOs and therefore many should be identifiable from IR excesses. (There are other ways of identifying young stars, but the IR excess approach has not yet been employed in this region.) Xavier Koenig and collaborators (most recently Koenig & Leisawitz 2014) have developed a series of color cuts in more than 10 2MASS/WISE color-magnitude and color-color diagrams to identify YSOs. We will use this approach here. By finding things in the IC 417 region that have colors similar to known YSOs, we can identify candidate YSOs from IR colors. While we can use IR excess to identify things that look young, we need to remember that until follow-up spectroscopy can be obtained, everything so identified is formally a YSO *candidate*, because other objects in the sky can have IR colors like YSOs. We will limit the contamination by including information from the literature and archival data at other bands; see section 3.6 below.

Prior work looking for YSOs in this region only used the near-IR. Only the largest YSO disks show up at *K* (see shapes of SEDs in Fig. 2—the larger disks found at younger ages contribute IR excess at 2 μm, but the weaker disks found at older ages do not contribute an IR excess at 2 μm). By using the mid-IR WISE data, we believe we will have an opportunity to contribute significantly to the identification of YSOs in this region. We will contribute the first detailed analysis of this region classifying YSO candidates past 2 μm. The only stars with known spectral types in this region are O and B stars, so we seek to work our way down in mass in this cluster and identify some candidate lower-mass members to 'flesh out' the IMF. We know that we will find contaminants in this region due to objects within our own galaxy (carbon stars, asymptotic giant branch stars), and to some extent background galaxies. Being in the Galactic Plane means that few background galaxies will be bright enough to seen through the Galaxy, and therefore our most likely contaminants will be Galactic sources. (See section 3.6 below on contaminants.)

There are a few other studies that included objects in this region, none of which did very much in terms of the individual objects in this region. We briefly list them here. Kronberger et al. (2006) identified one cluster, and Froebrich et al. (2007) identified a few clusters in this region. These clusters are identified in Fig. 7 – the cluster from Kronberger et al. is easy to identify; the Froebrich et al. clusters are the "FSR" clusters. Bica et al. (2003) used 2MASS data to look for clusters and found one candidate (their number 69) in this region, which is a rediscovery of Stock 8. Borissova et al. (2003) identify one cluster here (the "BPI" cluster in Fig. 7) but this paper as well does not do really any analysis on it. Ivanov et al. (2005) reports on deep NIR observations of this region, but does not include any photometry or even locations (even for their YSO candidates), so we cannot make much use of this work. Finally, two studies identify specific stars of interest in this region. Mayer & Macak (1971) and Malysheva (1990) report on photometry of OB stars in the region, which are young by definition. Vetesnik (1979) identified a carbon star in this region – carbon stars are often dust-producers, so their colors resemble that of YSOs. Knowing that this star is here will allow us to rule it out as a YSO candidate.

3.0 Analysis plan

3.1 Overview

Our approach will be to find sources that display colors indicative of YSOs with an IR excess, following the approach of Koenig and collaborators. The bulk of our time, however, will focus on a detailed analysis of these sources and assessing whether or not they are likely to be YSOs by looking directly at images, assembling SEDs that are as complete as possible based on the data available in the region, and making color-color and color magnitude plots of the sources.

Broadly, our approach includes the following tasks:

a) assemble a master multi-wavelength catalog from IRSA archives and the literature, spanning optical through 22 microns;
b) run Koenig's color selection on the WISE+2MASS data to identify YSO candidates in the master multi-wavelength catalog;
c) identify the stars already called out in the literature as YSO candidates in the master multi-wavelength catalog;
d) for each of the objects of interest (Koenig-selected plus literature-identified YSO candidates), examine the sources in images;
e) for each of the objects of interest, construct an SED and examine the SED;

f) based on a combination of image and SED assessment, decide which of the Koenig-selected YSO candidates are plausible YSO candidates;
g) for the literature-identified YSO candidates not selected by Koenig's approach, identify why Koenig did not select them, and assess whether or not they have an IR excess;
h) finally, arrive at at a list of high-confidence YSO candidates we can present at the 2016 AAS.

3.2 Photometric Data and the master catalog

The photometric data for our study will come from a variety of sources. Because this region is in the Galactic Plane, it is also included in several Galactic Plane surveys.

Infrared: Infrared data allow us to determine if sources have IR excesses – and allows us to identify YSO candidates in the first place. WISE has mapped the entire sky (including this region) in infrared and the data are available at 3.4, 4.5, 12, & 22 μm. 2MASS data are similarly available at JHK_s bands (1.2, 1.6, & 2.2 μm). Catalogs and images from GLIMPSE360 (Spitzer warm mission) are available for the region at 3.6 and 4.5 μm. GLIMPSE360 is a relatively shallow survey, but the spatial resolution is superior to that of WISE. Data from the UKIRT Infrared Deep Sky Survey (UKIDSS) is available over about half of the region. This will provide *J* and *K* photometry that is deeper than 2MASS over the southern half of our field.

Optical: Optical data will be particularly helpful in defining the short-wavelength (Wien) side of the SED, and in making optical color-magnitude diagrams of our YSO candidates. The optical data will therefore help us to weed out, e.g., extragalactic sources with flat SEDs, or background/foreground objects that will be too faint/bright in a color-magnitude diagram. We have already downloaded the *UBVI* photometry over a ~13'x~23' region that was reported by Jose et al. (2012); it includes Stock 8 and the Nebulous Stream. Data from the INT (Isaac Newton Telescope) Photometric H-Alpha Survey (IPHAS; Drew et al., 2005, Barentsen et al., 2014) is also available. This will provide deep optical photometry in *r*, *i*, and $H\alpha$ over the entire region (as opposed to just the subregion studied by Jose et al. 2008).

For all of these data sources, photometry is already available, so we will not need to do our own photometry. We will need to be cautious about merging across wavelengths, because the spatial resolution varies from <1" to 12" for the surveys we will use. This, in addition to the likelihood of instrumental artifacts, is the other important reason we will need to inspect images by hand for the sources we have identified as possible YSO candidates.

There will be uneven coverage across these surveys, e.g., not every object will have data in all available bands. However, as is the case for all astronomy research, we will do the best that we can with what we have.

3.3 YSO Selection and 'objects of interest'

As discussed above, Koenig's approach makes use of the 2MASS+WISE catalogs. (We have more data in this region than just 2MASS+WISE, but Koenig's approach uses only 2MASS+WISE, because it was derived for use in the general case where no optical data are available.) Koenig & Leisawitz (2014) describe the approach both in terms of the AllWISE catalog but also Koenig's own processing approach using his routine PhotVis. Xavier Koenig (priv. comm.) has already kindly run his approach on this region for us, and provided us a list of YSO candidates identified from either AllWISE or the PhotVis approach. Most of these are likely to be true YSO candidates, but a significant fraction is likely to be image artifacts, or affected enough by image artifacts that they are not trustworthy YSO candidates. This is one important reason why we have to examine each object in the images.

We have data here from Spitzer in IRAC's two shortest bands. While IRAC's shortest two bands are similar to WISE's shortest two bands, the bandpasses are not identical. Koenig's approach has been tuned to work specifically with the WISE bands, so we do not expect to be able to swap in the two shortest IRAC bands for the two shortest WISE bands and have the selection process still select YSOs as well as Koenig has shown. We will, however, make use of the IRAC data (as well as all the other data) in the analysis of the objects.

There are other objects likely to be YSOs that are identified in the literature. Jose et al. (2008) list some Halpha stars and some OB stars. Mayer & Macak (1971) identify additional OB stars in the vicinity. The IPHAS group has also identified stars bright in Halpha in our region.

The combination of the Koenig-selected objects (either method) plus the literature-identified YSO candidates constitutes our list of about 200 'objects of interest.' For each of the objects on this list, we will inspect the sources in as many images as we can access, and assemble SEDs using all of the bands in our master catalog.

Figure 8 graphically represents this process.

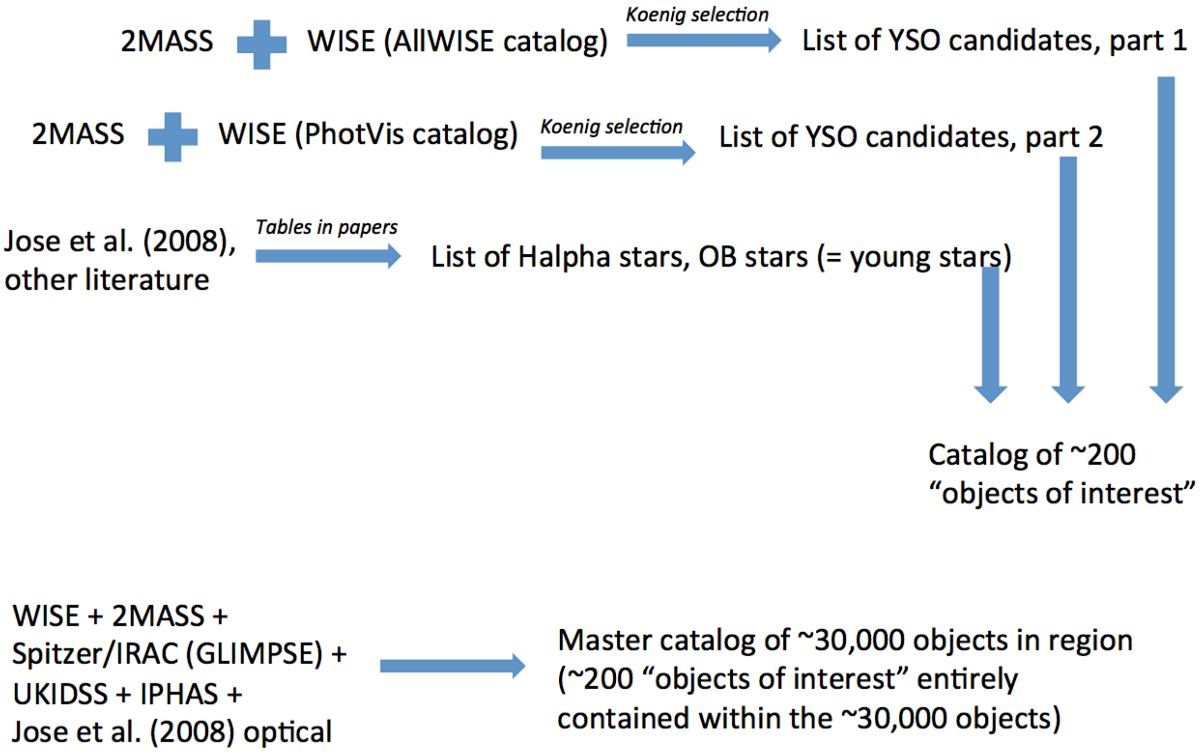

Figure 8: *Graphical representation of the assembly of the master catalog and the subset of "objects of interest."*

3.4 Software

After assembling as much photometric data as possible from this region, we will construct SEDs using Microsoft Excel for each of the YSO candidates identified by Koenig or the literature. We will use the IRSA tool FinderChart and DS9 to inspect images of these sources. We will create color-color and color-magnitude diagrams (using Excel), which will be helpful in identifying sources that likely do not belong to the cluster (either extragalactic sources, or foreground/background stars).

3.5 What we expect to find

To date, the point sources in this region have not been studied in wavelengths longer than K (2.2 μm), and ~40 young star candidates have been identified in the literature, with an additional ~20 from IPHAS alone. We will be adding photometric data from WISE, which includes photometry at out to 22 μm. Because of this additional data beyond 2 μm, we expect to find a number of new YSO candidates. Koenig's color selection run on both the AllWISE catalog and the PhotVis catalog has produced an additional ~130 unique objects not yet identified as YSO candidates. Not all of these objects will turn out to be legitimate YSO candidates, but we will **potentially triple the number of YSOs suspected in this**

region. We will also look explicitly at the properties of the objects previously identified in the literature as YSOs or OB stars to assess whether or not they have IR excesses as well. We expect that this work will result in a much more complete survey of this interesting star forming region.

3.6 Addressing contamination

Especially since we are working in the Galactic plane, contamination of our sample is unavoidable. There will be foreground and background objects in our sample that are not legitimate young star members of IC 417. Koenig's color cuts do their best to avoid these non-YSO objects. As discussed in his papers, he works to omit quasars and other background extragalactic objects, but they will still be in our sample. For example, giant stars (at the end of their lives) can produce dust in their outer atmospheres, resulting in a sphere or equatorial ring of dust. Such dusty giants (including carbon stars like the one identified in Vetesnik 1979 above) will be indistinguishable from young stars using our approach. Follow-up spectra will be needed to distinguish old dusty stars from young dusty stars.

We can attempt to limit the contamination by including information from the literature and archival data at other bands we have amassed. Here are three examples of limiting contamination:

(1) Koenig's cuts do not use optical magnitudes because they are not generally available, but we will make an optical color-magnitude diagram using the optical ancillary data. In such a CMD, background or foreground giants and background or foreground YSOs not belonging to IC417 will not be clumped with the rest of the cluster members above the main sequence at a location appropriate for young stars at the distance of IC417. (For a real-life example of this process, see, e.g., Guieu et al. 2010.)

(2) Optical imaging has been shown (Rebull et al. 2010) to be important in assessing whether or not a YSO candidate is a point source (and likely a star) or a background galaxy. Because WISE has relatively low spatial resolution, and because star formation has the same colors whether it is in our Galaxy or a nearby galaxy, a point source in WISE can be revealed to be a nearby star-forming galaxy when viewed in high-spatial-resolution optical images. We will check POSS and IPHAS images of our candidate YSOs. (However, note that all of the objects in IC417 are far enough away that they are well outside of the region of space where we can actually resolve the circumstellar disks.)

(3) WISE has relatively low spatial resolution compared to Spitzer. Because it is in the Galactic plane, even though it is in the direction opposite to the Galactic Center, there are portions of the sky near IC417 where the surface density of objects is quite high. If WISE combines the light from an early type star with a later-type star, the net SED (of, say, an O star combined with a G or K or later star) will resemble a star with a small IR excess. We will check the Spitzer images of the WISE-selected

sources so that we can identify such cases where Spitzer sees two objects too close together for WISE to resolve them.

Even though we will try to limit confusion, the results of our work will be identifying YSO candidates until follow-up spectroscopy can be obtained to confirm or refute their status as *bona fide* YSOs. Follow-up spectroscopy is also critical to inferring stellar masses, from which we can obtain an estimate of the IMF in this cluster.

4.0 Educational/Outreach plan

Our education plan will consist of two components. First, each educator will develop a plan of action at their individual school (see below). Second, we will attempt contact with both student and teacher alumni of NITARP and ask them to take a survey to determine the extent of impact of their NITARP experience.

A focus of inquiry with the teachers will be the effect of the NITARP experience on their educational practices. For the students, we will inquire as to how the experience affected their educational plans and whether or not it was a positive or negative experience. One other form of data gathering will be comments offered up by the past participants.

We anticipate a logistical challenge in contacting former students as many have graduated. We will contact former NITARP teacher participants to assist us in assembling a database of contact information for as many participants as possible.

Online anonymous surveys will be administered for both groups. A quantitative analysis of the data will be conducted and the results along with statements offered by participants will be displayed on an educational poster that will be presented at the 226th meeting of the AAS in Kissimmee, Florida in January of 2016.

Caroline Odden

- Coach students involved with the IC 417 project to present their methods and findings at the annual Phillips Academy Science Symposium (Spring 2016). A student led poster session is followed by a series of presentations from students on their research projects. The event is open to the entire school community.
- Continue to revise the Phillips Academy astronomy curriculum to reflect the NITARP experience. Specific topics in the introductory course, such as star formation, will be infused with concrete examples derived from this NITARP experience.
- Give presentations to local alumni, prospective parents and students, and other local groups such as elementary school groups in her role as the Director of the Phillips Academy Observatory.
- Host a daylong conference for local astronomy educators interested in enhancing astronomy research offerings at their school. The IC 417

project will be emphasized and educators will also have a chance to take part in an evening session in the Phillips Academy Observatory.

Rick Sanchez
- Work with student participants to present to local teachers their experiences with NITARP and discuss the effects of the program on their educational goals. Emphasis will be given on the experience of doing real scientific research.
- The NITARP team will present to the Johnson County School Board with the hopes of establishing future funding for similar opportunities for students.
- The NITARP students will be instrumental in helping to develop an astronomy curriculum for middle school students. Currently astronomy is taught in science classes as a separate topic and usually lasts between a couple of days to a week or so. There is an elective opportunity for astronomy at the 6th grade level. The goal will be to have elective classes at 7th and 8th grade as well as to develop more in-depth astronomy studies in the science classes.
- The team will be involved in hosting several local “Star Parties” for the community over the following year. They will present on their participation in NITARP as well as help organize other presentations by current middle school students.

Garrison Hall
- Facilitate and coach a Gable Middle School team with the basics of authentic astronomy research. This includes experiences with infrared telescope archival data and research.
- This Gable Middle School NITARP team will create a poster of their findings and will present to the faculty and the school board.
- The team will present their findings to the local science center (Roper Mountain Science Center) during one or more of their Second Saturday Events.
- The team will present at the Roper Mountain Science Center Planetarium during an evening when I am running the show.
- The team will present at a Roper Mountain Science Center Starry Night Friday session at the observatory. This includes the public and local astronomers.

5.0 References

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