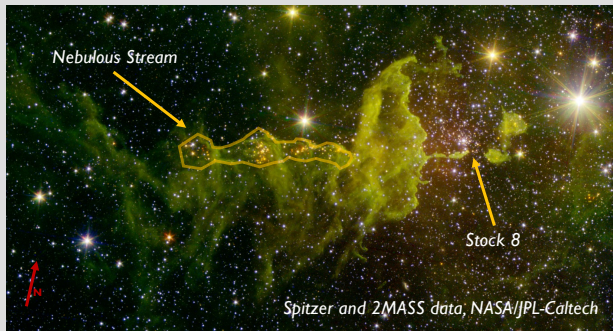




<http://nitarp.ipac.caltech.edu/>

Young Stellar Object Candidates in IC 417

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Spitzer and 2MASS data, NASA/JPL-Caltech

IC417 is:

- In the Galactic Plane, in the Northern hemisphere, so is observed in several different surveys (2MASS, Spitzer, WISE, UKIDSS, Gaia, IPHAS, PanSTARRS, MSX, AKARI, Herschel, plus ZTF, ASAS-SN, NEOWISE monitoring).
- Part of the Auriga complex, may very well be part of Aur OB2; on the southern edge of one of the bubbles making up this complex.
- Likely to be ~2 kpc away, near side of Perseus arm.
- Composed of several literature clusters identified based on 2MASS star counts, with ages all over the place (1-10 Myr); includes Stock 8, which is relatively famous; includes literature-identified OB stars, H α stars, IR excess stars, and variables.

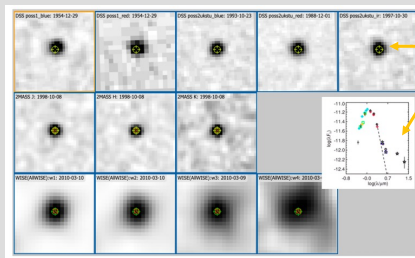
If the stars are really <10 Myr, we should be able to identify YSO candidates from IR excesses (& more!) here. The “Nebulous Stream” (NS) is identified in the literature (using NIR) and gorgeous in the MIR, containing 4 clumps of numerous obviously red stars, likely YSOs.

Approach:

- For list of YSO candidates (literature YSOs, new YSOs from WISE IR excess, new YSOs from NS):
- Check images using IRSA tools. Artifacts? Saturated? Extended? Confused? Or point source?
- Check SEDs. Well-matched across catalogs? Looks like SED of YSO? Or galaxy? Or nebular knot? We have a LOT of data defining most of these SEDs (~90% have 5 or more points, ~2/3rds have >20 points) so, we can make some solid guesses as to YSO status!
- Check color-color and color-mag diagrams. In the right place to be YSO at distance of IC417?
- If there is a Gaia distance, is it at the distance of IC417?
- At each step, put YSO candidate in “bins” reflecting confidence in YSO status. In the end had 5 coarse bins, plus sub-bins.

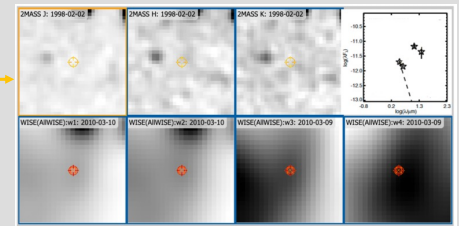
Summary: We placed the 710 surviving YSOs and candidate YSOs in ranked bins. The lowest-ranked bins include stars that are confused, or likely carbon stars. There are 503 in the higher-ranked bins; half are SED Class III, and ~40% are SED Class II. Our results agree with the literature in that we find that the NS and Stock 8 are at about the same distance from Earth (as are the rest of the YSOs in IC 417), and that the NS is the youngest region, with Stock 8 being a little older. We do not find any evidence for an age spread within the NS, consistent with the idea that the star formation trigger came from the north. We do not find that the other literature-identified clusters here are as young as either the NS or Stock 8; at best, they are older than Stock 8, and they may not all be legitimate clusters.

(See Rebull+, 2023, AJ, 166, 87 for all the details!)



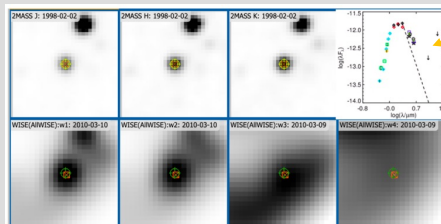
This is a good one:

- Nice, circular images.
- Great SED that looks like a YSO.
- Clear IR excess; perhaps small H α excess.
- No reddening in J-H/H-K diagram.
- Appropriate place in optical CMDs.
- Gaia DR3: 2062 pc.



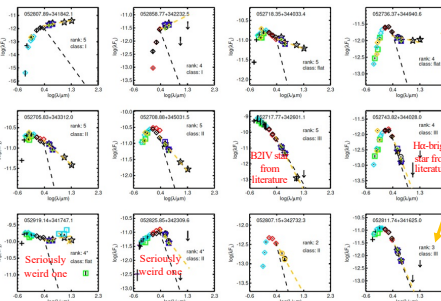
This is a bad one:

- Not a clear source in any band; awful SED!
- (Given how many bands we have, if it's a real source, it should have at least 1 other counterpart!)
- Nebular knot!
- This got tossed altogether.



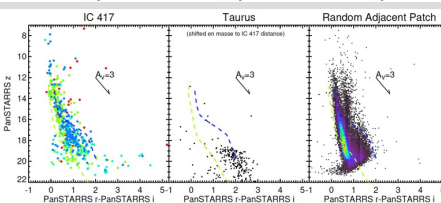
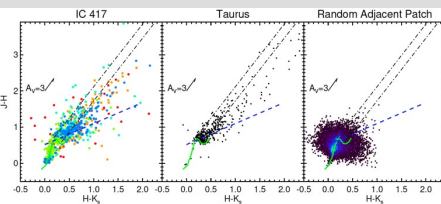
This is an example where we didn't trust the W3W4:

- Nice, circular images J through W2.
- Nice SED; ~7 σ IR excess at 4.5 μ m.
- W3 as measured could be consistent with SED, but images not encouraging.
- W4 not physical, and images not great \rightarrow Change W3W4 “detections” to limits.
- Appears in appropriate place in optical CMDs; reddened in J-H/H-K diagram.
- Lower limit of Gaia DR3 distance overlaps with distance: 4156 pc (2268-6216 pc 1 σ).



Example SEDs:

- Shows range of SED types, including range of: points in SEDs; literature early types/ H α stars; and “seriously weird ones” (stars for which everything is ok, including completely correct Gaia distances, but net SED shape is, clearly, odd).
- (Dashed black line is expected photosphere assuming K is on photosphere; dashed yellow line is fit to all points between 2 and 25 microns, e.g., Class I/flat/II/III.)



Final Assessments

- 5 – blue – Highest quality YSOs
- 4 – cyan
- 3 – green – Mid-quality YSOs
- 2 – orange
- 1 – red – Lowest quality YSOs

Color-mag and color-color diagrams of IC417, compared to Taurus (known YSOs) and a random patch of sky near IC417 (no YSOs but same data as IC417):

- All of the mid-to-high quality YSOs look more like Taurus than the random patch of sky. Many of the lowest quality YSOs are in ...suspicious places.
- (Symbol colors in IC417 panel corresponds to YSO quality; colors in “random patch of sky” plots correspond to point density. Solid green is ZAMS; dashed line in NIR plot is T Tauri locus; dashed lines in optical CMDs are models at 6 and 9 Myr.)
- Similar kinds of plots can be made for subsets of the region (the literature clusters), NS (and subclusters), and Stock 8. NS likely youngest, and Stock 8 slightly older. No compelling evidence for remaining literature clusters being obviously young, or maybe even obviously real.

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