BRC Bigger Picture and Goals

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The big goal [edit]

We have Spitzer data for two tiny patches of sky likely to harbor young stars. One of the signatures of young stars is that they have "more infrared than you'd expect" (e.g., they are redder than you expect) because of their circumstellar disk. We will use this property, as seen in the Spitzer data, to identify new CANDIDATE young stars. The word "candidate" is important, because there is likely to be contamination in our sample from things that have colors that make them look like young stars, but they are actually not young stars. Most likely, the contaminants will be active galactic nuclei (AGN) in the distant background. The word "new" is also important -- there have been previous searches for young stars in these regions, so we need to make sure that we

Making color-color and color-magnitude plots

[edit]

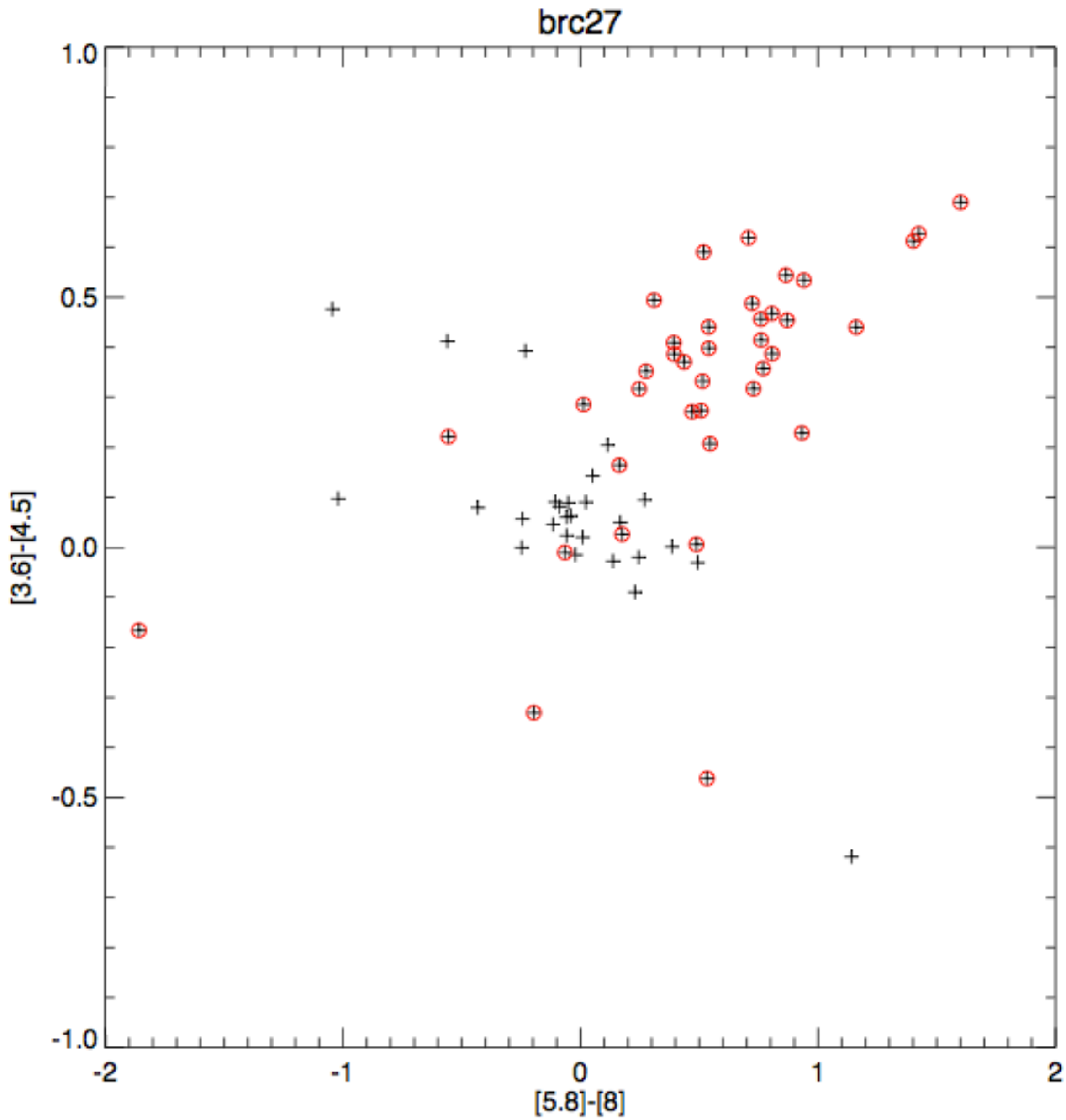
Big picture goal: Understand what plots to make. Understand the basic idea of using them to pick out certain objects.

More specific shorter term goals: Make some plots. Understand the basic approach of Gutermuth et al. (see Gutermuth et al. 2009, Appendix A)

Relevant links: Color-Magnitude and Color-Color plots and Finding cluster members and Color-color plot ideas and Gutermuth color selection

Questions for you:

1. Pick a diagnostic color-color or color-magnitude plot to make. Does my photometry seem ok?
2. Pick at least one color-color or color-magnitude plot to make. Figure out a way to ignore the -9 (no data) flags. Where are the plain stars? Where are the IR excess objects?
3. Where are the famous objects in the plot? Where are the new YSO candidates I used the Gutermuth method to find?
4. Make a new column in your Excel spreadsheet with some colors. Is there a way you can get Excel to tell you automatically which objects have an IR excess? Can you implement the Gutermuth selection? (You may not be able to do so.)
5. Make the plots that go into the Gutermuth selection, including the relevant lines on the plot.
6. Of the objects I have that fit the Gutermuth criteria, are any of them false or otherwise bad sources? How can you tell?
7. Bonus but very important question: How do you know that some of these sources aren't galaxies? Can you find something that is obviously a galaxy on the images? Can you think of a way using public data that already exist to check on the "galaxy-ness" of some of these objects?



brc27
1.0
0.5
0.0
-0.5
-1.0
[3.6]-[4.5]
-2
-1
0
1
2
[5.8]-[8]

Making color-color and color-magnitude plots [edit]

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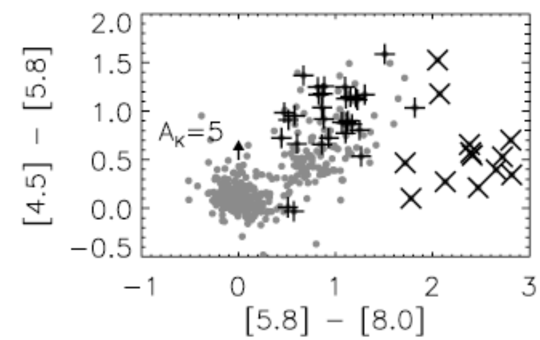
Gutermuth method, broken down

- **Drop** things that meet all of these 3 criteria

$$[4.5] - [5.8] < \frac{1.05}{1.2}([5.8] - [8.0] - 1),$$

$$[4.5] - [5.8] < 1.05,$$

$$[5.8] - [8.0] > 1.$$



Things that meet these criteria are galaxies with PAH emission.

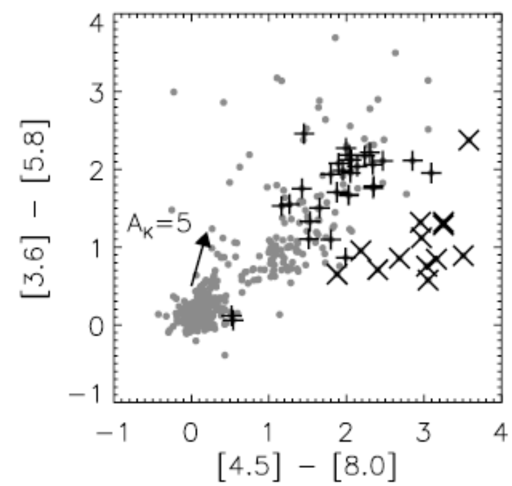
Gutermuth method, broken down

- **Drop** things that meet all of these 3 criteria

$$[3.6] - [5.8] < \frac{1.5}{2}([4.5] - [8.0] - 1),$$

$$[3.6] - [5.8] < 1.5,$$

$$[4.5] - [8.0] > 1.$$



Things that meet these criteria are also galaxies with PAH emission.

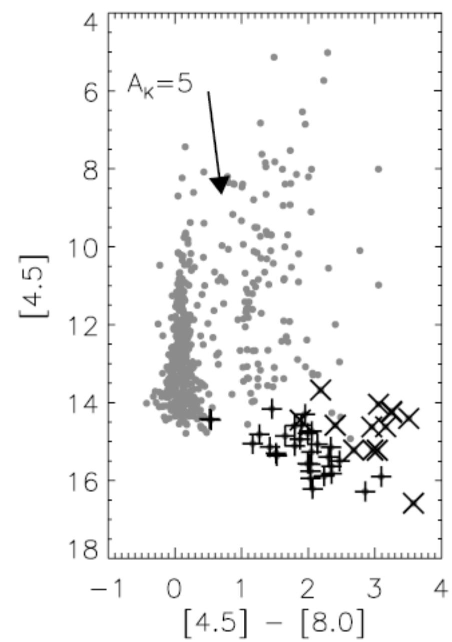
Gutermuth method, broken down

- **Drop** things that meet all of these criteria

$$[4.5] - [8.0] > 0.5,$$

$$[4.5] > 13.5 + ([4.5] - [8.0] - 2.3)/0.4,$$

$$[4.5] > 13.5.$$



- AND these as well:

$$[4.5] > 14 + ([4.5] - [8.0] - 0.5),$$

$$[4.5] > 14.5 - ([4.5] - [8.0] - 1.2)/0.3$$

$$[4.5] > 14.5.$$

Things that meet these criteria are AGN.

Gutermuth method, broken down

- **Drop** things that meet all of these 3 criteria

$$[3.6] - [4.5] > \frac{1.2}{0.55}([[4.5] - [5.8]] - 0.3) + 0.8,$$

$$[4.5] - [5.8] \leq 0.85,$$

$$[3.6] - [4.5] > 1.05.$$

Things that meet these criteria are likely unresolved blobs of dust (e.g. things that LOOK like points sources but really aren't), whose colors are dominated by shock emission.

Gutermuth method, broken down

- **Keep** things that meet all of these 3 criteria and don’t fail the earlier tests.

$$[4.5] - [8.0] > 0.5,$$

$$[3.6] - [5.8] > 0.35,$$

$$[3.6] - [5.8] \leq \frac{0.14}{0.04}([[4.5] - [8.0]] - 0.5) + 0.5.$$

Things that meet these criteria are likely Class II young stars.

Gutermuth method, broken down

- **Keep** things that meet all of these 3 criteria and don't fail the earlier tests.

Sources are likely protostars if they have an extremely red discriminant color ($[4.5] - [5.8] > 1$). In addition, any sources with a moderately red discriminant color ($0.7 < [4.5] - [5.8] \leq 1.0$) that also have $[3.6] - [4.5] > 0.7$ are likely protostars (see Fig. 7), although in rare cases a highly reddened Class II source could have these colors as well.

Things that meet these criteria are likely Class 0 or I young stars.

Gutermuth method, broken down

- You can keep going. (I didn't.)
- Rest of his method provided here for completeness.
- Go later for summary.

First we measure the line of sight extinction to each source as represented by the E_{J-H}/E_{H-K} color excess ratio, using baseline colors based on the classical T Tauri star (CTTS) locus of Meyer et al. (1997) and standard dwarf-star colors (Bessell & Brett 1988). To accomplish the latter task, we force $[J-H]_0 \geq 0.6$, a simplifying approximation for the intrinsic colors of low-mass dwarfs. These are the equations used to derive the adopted intrinsic colors from the photometry we have measured:

$$[J-H]_0 = 0.58[H-K]_0 + 0.52,$$

$$[H-K]_0 = [H-K]_{\text{meas}} - \left([J-H]_{\text{meas}} - [J-H]_0\right)\frac{E_{H-K}}{E_{J-H}},$$

$$[H-K]_0 = \frac{[J-H]_{\text{meas}} - [E_{J-H}/E_{H-K}][H-K]_{\text{meas}} - 0.52}{0.58 - [E_{J-H}/E_{H-K}]}.$$

Gutermuth method, broken down

Once we have measured the component of the $H - K$ color excess that is caused by reddening, we compute the dereddened $K - [3.6]$ and $[3.6] - [4.5]$ colors using the color excess ratios presented in Flaherty et al. (2007), specifically $E_{J-H}/E_{H-K} = 1.73$, $E_{H-K}/E_{K-[3.6]} = 1.49$, and $E_{H-K}/E_{K-[4.5]} = 1.17$:

$$[K - [3.6]]_0 = [K - [3.6]]_{\mathrm{meas}} - ([H - K]_{\mathrm{meas}} - [H - K]_0) \frac{E_{K-[3.6]}}{E_{H-K}},$$

$$[[3.6] - [4.5]]_0 = [[3.6] - [4.5]]_{\mathrm{meas}} - ([H - K]_{\mathrm{meas}} - [H - K]_0) \frac{E_{[3.6]-[4.5]}}{E_{H-K}},$$

$$\frac{E_{[3.6]-[4.5]}}{E_{H-K}} = \left(\left[\frac{E_{H-K}}{E_{K-[4.5]}} \right]^{-1} - \left[\frac{E_{H-K}}{E_{K-[3.6]}} \right]^{-1} \right)^{-1}.$$

Gutermuth method, broken down

- Having done the prior two steps, add things meeting all of these criteria to the YSO list.

$$\sigma_1 = \sigma[[3.6] - [4.5]]_{\mathrm{meas}},$$

$$\sigma_2 = \sigma[[K] - [3.6]]_{\mathrm{meas}};$$

$$[[3.6] - [4.5]]_0 - \sigma_1 > 0.101,$$

$$[K - [3.6]]_0 - \sigma_2 > 0,$$

$$[K - [3.6]]_0 - \sigma_2 > -2.85714([[3.6] - [4.5]]_0 - \sigma_1 - 0.101) + 0.5.$$

All sources classified as Class II with this method must have $[3.6]_0 < 14.5$,

Things that meet these criteria are likely Class II young stars.

Gutermuth method, broken down

- Add objects that meet all criteria on prior slide, plus these criteria, to the YSO list.

$$[K - [3.6]]_0 - \sigma_2 > -2.85714\big([[3.6] - [4.5]]_0 - \sigma_1 - 0.401\big) + 1.7.$$

All sources classified as protostars must have $[3.6]_0 < 15$.

Things that meet these criteria are likely Class 0/I young stars (protostars in his nomenclature).

Gutermuth method, broken down

We resume here…

- Add objects that meet all criteria on prior slide, plus these criteria, to the YSO list.

We reinclude flagged sources as likely protostars if they have both bright MIPS 24 μm photometry ($[24] < 7$, as before) and convincingly red IRAC/MIPS colors ($[3.6] - [5.8] > 0.5$ and $[4.5] - [24] > 4.5$ and $[8.0] - [24] > 4$).

Things that meet these criteria are likely Class 0/I young stars (protostars in his nomenclature).

Gutermuth method, broken down

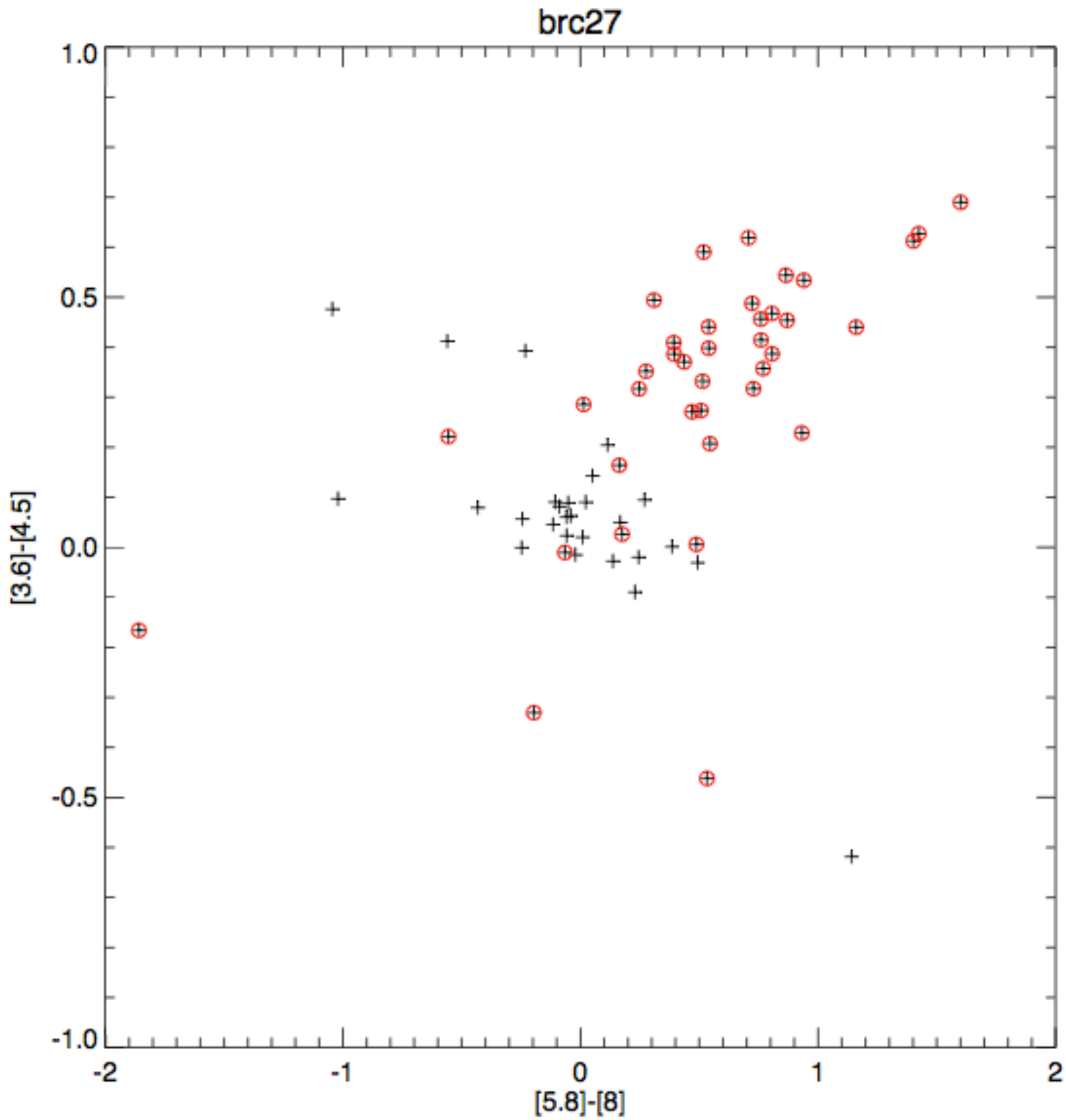
- Check everything on the YSO list.

Finally, all previously identified protostars that have 24 μm detections are checked to ensure that their SEDs do indeed continue to rise from IRAC to MIPS wavelengths. All protostars that have MIPS detections must have $[5.8] - [24] > 4$ if they possess 5.8 μm photometry, otherwise they must have $[4.5] - [24] > 4$.

Protostars in his nomenclature == Class 0 or I.

What we are doing

- We did the Gutermuth method (as far as we can).
- This provides an IRAC-based selection.
- We cannot deredden (we don't have enough information), so we can't do his JHK steps.
- We have an initial, automatic cut that produces a short list of objects and now we need to further examine properties of each and every one of those objects. (e.g. We need to look at things that are MIPS-only; do they also just fall out of the IRAC selection? Are there artifacts in the list? Duplicates? Previously studied objects? Are there previously studied objects NOT recovered?)


brc27
1.0
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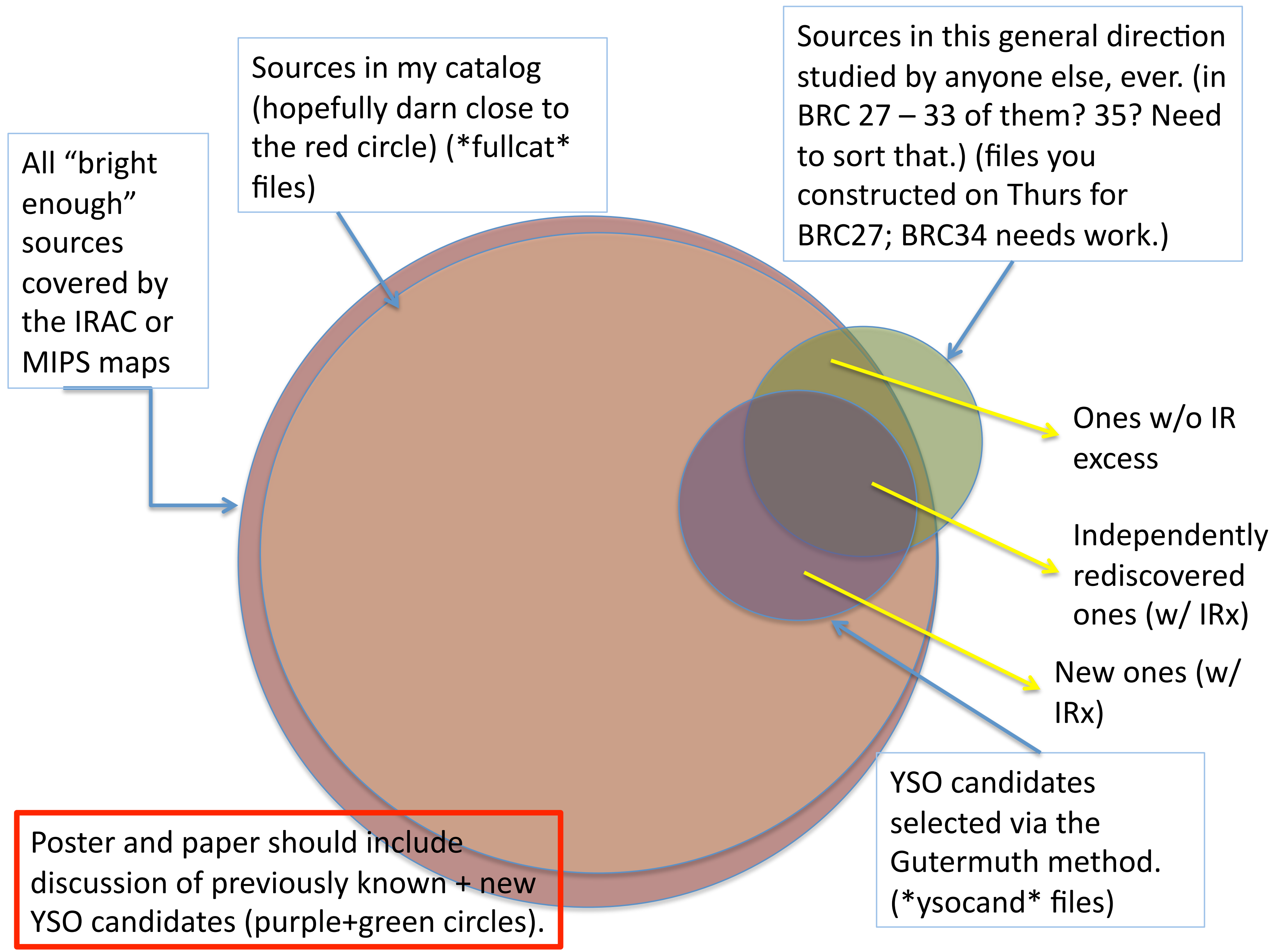
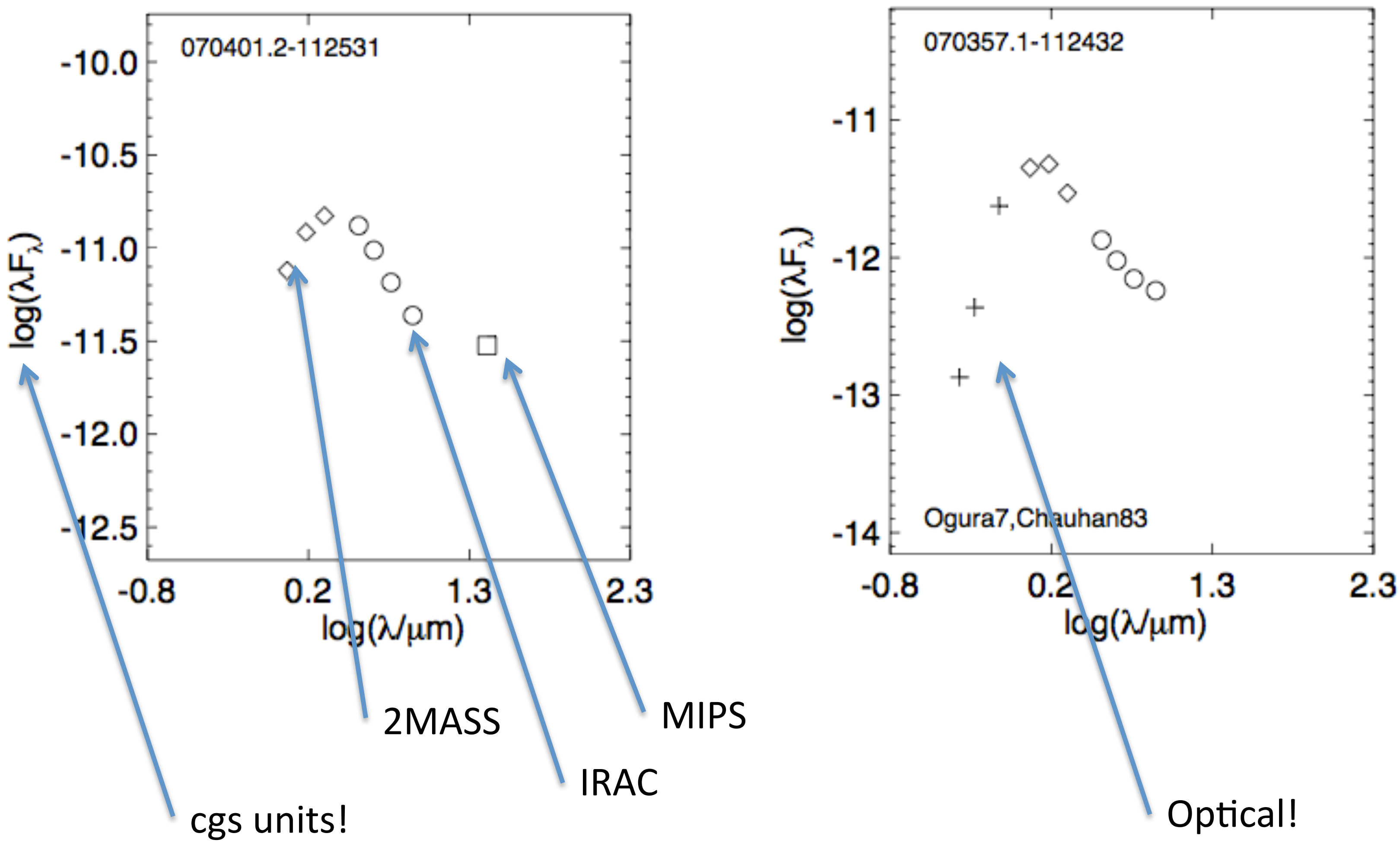
[3.6]-[4.5]
-2
-1
0
1
2
[5.8]-[8]


Sources in my catalog (hopefully darn close to the red circle) (*fullcat* files)
Sources in this general direction studied by anyone else, ever. (in BRC 27 – 33 of them? 35? Need to sort that.) (files you constructed on Thurs for BRC27; BRC34 needs work.)
All “bright enough” sources covered by the IRAC or MIPS maps
Ones w/o IR excess
Independently rediscovered ones (w/ IRx)
New ones (w/ IRx)
YSO candidates selected via the Gutermuth method. (*ysocand* files)
Poster and paper should include discussion of previously known + new YSO candidates (purple+green circles).

For the YSO cand+prev known ones

- Ultimately need SEDs for both kinds. Now, work on YSO candidates. *WHY?* Do the SEDs look 'reasonable'? Any photometry look bad (and need redoing)? (Especially for prev known ones, need to note which are missing any bands, and go back and fill them in.)
- Ultimately need to include data beyond Spitzer, including UBVRIc for known ones, WISE+Akari+anything else for any place you found additional data. Now, work on JHK (2MASS)+Spitzer. *WHY?* Need to add as much data as we can; does this change whether or not we think they are YSOs?
- Ultimately, need to look at images for each one (both kinds). Now, work on YSO candidates. *WHY?* Are the sources matched up right? Do any look like galaxies? Are any corrupted photometry/artifacts? What about the dupes? (really dupes?)
- (swapping order in wiki because you are going so fast you can do this now.)



070401.2-112531
-10.0
-10.5
-11.0
-11.5
-12.0
-12.5
-0.8
0.2
1.3
2.3
log(λF$_\lambda$)
log(λ/μm)
2MASS
IRAC
MIPS
cgs units!
070357.1-112432
-11
-12
-13
-14
Ogura7,Chauhan83
Optical!

Making SEDs

[edit]

WARNING: lots of math and programming spreadsheets here too.. you WILL do this more than once to get the units right!

Big picture goal: Understand what an SED is and why it matters.

More specific shorter term goals: Make at least one SED yourself. Examine the SEDs for all of our candidate objects. Use them to reassess our photometry if necessary, and to drop the bad objects off the YSO candidate list.

Relevant links: Units and SED plots and Studying Young Stars and for that matter the detailed object-by-object discussion in the appendix of the cg4 paper. See also Central wavelen[illegible] and zero points

Pick some o[illegible] up, maybe some of the previously-identified ones from above would be a good place to start, or the ones you flagged above as having an IR excess. Start w[illegible] one. It will take time to get the units right, but once you do it right the first time, all the rest come along for free (if you're working in a spreadsheet). [illegible] ome time looking at the SEDs. Look at their similarities and differences. Identify the bad ones, and discuss with the others why/whether to drop them off the lis[illegible] candidates. See also stuff above about data at other wavelengths, and include literature/archival data from other sources where appropriate and possible.

Questions for you:

1. What do the IR excesses look like in your plots? Do they look like you expected? Like objects in CG4 or elsewhere?
2. Make some SEDs of things you know are *not* young stars. What do they look like?
3. Which objects look like they have 1 or 2 bad photometry points? Go back and check the photometry for them.
4. Which objects look like clear YSO SEDs? Which objects do not?
5. Any photometry look bad? Go back and check it!
6. Any objects within the maps but undetected? Go back and get limits and add those too!