INVESTIGATING THE GAP IN THE L/T TRANSITION

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Abstract

The overarching goal of this project is to learn more about how brown dwarf atmospheres evolve. We will accomplish this goal by investigating a) the validity of and b) the cause of the apparent gap in the brown dwarf L/T transition observed by Best et al. (2021). This gap is not predicted by current models, and has never been observed before Best's paper. This will allow for improved brown dwarf models, which are crucial to many aspects of brown dwarf research. Even though the most popular set of models to date, those created by Saumon and Marley (2008), have been used and cited in many papers, they are known to be imperfect. Due to incomplete opacity data, the models are unable to illustrate certain chemical properties of brown dwarf atmospheres such as the methane band around 1.6 microns in T-dwarfs (Yurchenko, 2014). Projects such as this one that dig in to specific features that are found in data and not currently reflected in the models are critically important if we are to ever have truly accurate brown dwarf models. Furthermore, improving the accuracy of our brown dwarf models will better equip us to model and understand atmospheres of exoplanets as we search for other habitable worlds through missions like TESS.

1 NICFPS PHOTOMETRY

NICFPS is the infrared instrument on the 3.5 meter telescope at Apache Point Observatory used to obtain photometric data for this project. In this section I detail the procedures we used while observing, the targets observed and conditions encountered each night, and the data reduction process.

1.1 NICFPS Observing Procedures

- ☐ Ensure that Fowler sampling is set to 8.
  - ☐ Observe using all 5 locations for the dither pattern.
  - ☐ Take darks.
    - ☐ 11 x 6-second darks.
    - ☐ 11 x 15-second darks.
  - ☐ Observe target
    - ☐ Slew to target.
    - ☐ Take 3 cycles with 15 second exposures in the J-filter. (Use the point source script)
    - ☐ Take 3 cycles with 15 second exposures in the H-filter. (Use the point source script)

- ☐ Take 3 cycles with 15 second exposures in the K-filter. (Use the point source script)

- ☐ Observe standard
  - ☐ Slew to standard.
  - ☐ Take 3 cycles with 6 second exposures in the J-filter. (Use the point source script)
  - ☐ Take 3 cycles with 6 second exposures in the H-filter. (Use the point source script)
  - ☐ Take 3 cycles with 6 second exposures in the K-filter. (Use the point source script)

1.2 December 16, 2021 B-half

This was our first attempt at NICFPS. We were able to obtain data for 3 objects and their standards. However, after NICFPS crashed towards the beginning of the night our Fowler Sampling was reset to 0. We did not catch this until the end of our observations. The data may be useless. Data files are listed in [1].

December 16th, 2021						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
J0807	APO	Dec 16, 2021	J	210-224	p259-c	163-177
RA = 08:07:00.23			H	180-194	RA = 09 03 20.60	133-147
dec = +41:30:26.8			K	195-209	dec = +34 21 03.9	148-162
J0819	APO	Dec 16, 2021	J	110-124	LHS2026	63-77
RA = 08:19:58.05			H	80-94	RA = 08 32 30.50	33-47
dec = -03:35:29.0			K	95-109	dec = -01 34 37.0	48-62
J0857	APO	Dec 16, 2021	J	258-264	p259-c	163-177
RA = 08:57:58.45			H	228-242	RA = 09 03 20.60	133-147
dec = +57:08:51.4			K	243-257	dec = +34 21 03.9	148-162

Figure 1. List of data files from Dec 16th.

1.3 December 25th, 2021 A-half

We were completely clouded out this night.

1.4 January 5th, 2022 A-half

Conner and I observed this night on our own. The weather was clear and the seeing was great. Data files are listed in [2].

January 5th, 2022						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
2MASS J0046+02	APO	Jan 5, 2022	H	81-98	SA92-342	144-158
RA = 00:46:15.51			K	99-113	RA = 00:55:09.93	159-173
Dec = +02:52:00			J	114-128	dec = 00:43:13.10	129-143
ULAS J0006+15	APO	Jan 5, 2022	K	174-188	SA92-342	159-173
RA = 00:06:13.00			H	189-203	RA = 00:55:09.93	144-158
dec = 15:40:21.0			J	204-218	dec = 00:43:13.10	129-143
WISEA J0043+22	APO	Jan 5, 2022	J	219-233	fs2	294-308
RA = 00:43:26.90			H	234-248	RA = 00:13:43.58	279-293
dec = +22:21:24.0			K	249-263	dec = 30:37:59.90	264-278
WISEA J0145-03	APO	Jan 5, 2022	J	309-323	S754-C	385-399
RA = 01:45:35.23			H	324-338	RA = 01:03:15.80	370-384
dec = -03:14:12.9			K	339-353	dec = -04:20:44.00	354-369
WISEPA J0206+26	APO	Jan 5, 2022	J	401-415	P530-D	476-490
RA = 02:06:25.26			H	416-430	RA = 02:33:32.10	461-475
dec = +26:40:23.6			K	431-445	dec = 06:25:38.00	446-460
WISEP J0607+24	APO	Jan 5, 2022	J	491-505	LHS 216	566-580
RA = 06:07:38.65			H	506-520	RA = 06:14:01.44	551-565
dec = +24:29:53.4			K	521-535	dec = 15:09:58.30	536-550
WISEPA J0656+42	APO	Jan 5, 2022	J	581-599	p161-D	654-664
RA = 06:56:09.60			H	600-614	RA = 7:00:52.02	645-652
dec = +42:05:31			K	615-629	dec = 48:29:24.00	630-644

Figure 2. List of data files from Jan 5th.

1.5 April 14th, 2022 A-half

Conner and I observed on our own again this night. It was another beautiful, clear night with great seeing. Data files are listed in [3].

April 14th, 2022						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
2mass0652	APO	Apr 14, 2022	J	85-99	P161	160-174
RA = 06:52:30.7			H	100-114	RA = 07 00 52.02	145-159
dec = +47:10:34			K	115-129	dec = 48 29 24.0	130-144
2mass0656	APO	Apr 14, 2022	J	175-189	P161	160-174
RA = 06:56:09.60			H	190-204	RA = 07 00 52.02	145-159
dec = +42:05:31.0			K	205-219	dec = 48 29 24.0	130-144
2mass0819	APO	Apr 14, 2022	J	220-234	LHS 2026	295-309
RA = 08:19:58.05			H	235-249	RA = 08 32 30.50	280-294
dec = -03:35:29.0			K	250-264	dec = -01 34 37.0	265-279
2mass0807	APO	Apr 14,2022	J	310-324	p259	355-369
RA = 08:07:00.23			H	325-339	RA = 09 03 20.60	370-384
dec = +41:30:26.8			K	340-354	dec = +34 21 03.9	385-399
2mass0852	APO	Apr 14, 2022	J	430-444	p259	355-369
RA = 08:52:34.90			H	415-429	RA = 09 03 20.60	370-384
dec = +47:20:35.0			K	400-414	dec = +34 21 03.9	385-399
2mass0857	APO	Apr 14, 2022	J	445-459	p259	505-519
RA = 08:57:58.45			H	460-474	RA = 09 03 20.60	490-504
dec = +57:08:51.4			K	475-489	dec = +34 21 03.9	520-534
2mass0908	APO	Apr 14, 2022	J	565-579	p259	505-519
RA = 09:08:38.0			H	550-579	RA = 09 03 20.60	490-504
dec = +50:32:08			K	535-549	dec = +34 21 03.9	520-534
sdss1007	APO	Apr 14, 2022	J	580-589	p259 ?	505-519
RA = 10:07:11.74			K	590 - 599	RA = 09 03 20.60	520-534
dec = +19:30:56.2					dec = +34 21 03.9	

Figure 3. List of data files from Apr 14th.

1.6 July 8th, 2022 A-half

I observed on my own from home this night. The weather was garbage. There was rain on the radar, so I took darks when my time was supposed to start and then we waited for the radar to clear before opening up the dome. We finally were able to open up around 11:50 pm, and my time ended at 1:00pm. I started with SDSS1520, but it was so deep in the clouds that I bailed after one cycle and switched to a different object located in a hole in the clouds. We observed the one object, its standard, and then one cycle of one filter of a second object that would work with the same standard before time was up. As I did not get enough data to make the partially-observed objects usable, I will not include them in my list of observed objects. Data files are listed in [4].

July 8th, 2022						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
2MASS1746	APO	July 8th, 2022	J	100-114	p138-c	115-129
RA = 17:46:11.99			H	70-84	RA = 17 13 44.6	130-144
dec = +50:34:03.6			K	85-99	dec = +54 33 21.0	145-149

Figure 4. List of data files from July 8th.

1.7 October 3rd, 2022 A-half

Conner and I observed together on campus. The weather was once again trash. Amanda was able to open the dome up at about 12:40, so by the time we focused we had about 25 minutes to take data. We only had time to observe WISE0031 and its standard. For the sake of time we only took data in two of the usual 5 dither locations, and only observed in filters J and K. Data files are listed in [5].

October 3rd, 2022						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
WISE0031	APO	October 3rd, 2022	J	56-61	p241-g	74-81
RA = 00:31:10.04					RA = 00 36 29.60	
dec = +57:49:36.3			K	62-67	dec = ++37 42 54.3	68-73

Figure 5. List of data files from October 3rd.

1.8 October 30, 2022 B-half

Dr. Mosenkov was kind enough to give us his half-night since we were clouded out on October 3rd. There were thin clouds and NICFPS broke down for an hour and a half, but overall this was the best observing night we had in a long time.

October 30th, 2022						
Object	Telescope	Date	Filter	Image Files	Standard Star	Image Files
WISE J0031	APO	October 30th, 2022	J	111-125	fs2-29	89-103
RA = 00:31:10.04			H	126-140	RA = 00 13 43.58	59-73
dec = +57:49:36.3			K	141-155	dec = +30 37 59.9	74-88
2MASS J0500	APO	October 30th, 2022	J	158-170	fs2-53	216-230
RA = 05:00:21.00			H	186-200	RA = 05 02 57.44	231-245
dec = +03:30:50.1			K	201-215	dec = -01 46 42.6	246-260
2MASS J0501	APO	October 30th, 2022	J	261-275	fs2-53	216-230
RA = 05:01:24.06			H	276-290	RA = 05 02 57.44	231-245
dec = -00:10:45.2			K	291-305	dec = -01 46 42.6	246-260
SDSS J0758	APO	October 30th, 2022	J	311-325	P309-U	356-370
RA = 07:58:40.33			H	326-340	RA = 07 30 34.50	470-484
dec = +32:47:23.4			K	341-355	dec = +29 51 12.0	485-499
SDSS J0809	APO	October 30th, 2022	J	380-394	P309-U	356-370
RA = 08:09:59.01			H	395-409	RA = 07 30 34.50	470-484
dec = +44:34:22.2			K	410-424	dec = +29 51 12.0	485-499
SDSS J0858	APO	October 30th, 2022	J	425-439	p259-c	500-505
RA = 08:58:34.42			H	440-454	RA = 09 03 20.60	512-526
dec = +32:56:27.7			K	455-469	dec = +34 21 03.9	506-511

Figure 6. List of data files from October 30th.

2 NICFPS Data Reduction

2.1 Organization of Data

I created a new spreadsheet in the Stephens Research google drive entitled "NICFPS Observed and Reduced." Said document can be reached via this link. The first page contains all of the objects observed to date, sorted by half-night. The image file numbers are listed next to each object, excluding known failed images. The standard star for each object is also listed to the side. Note that the observations from December 16th have been listed, although most of the data from that night will probably be useless as Fowler sampling was accidentally reset to 0.

The data files are in my personal folder on the data drive in the "APO" folder (data/Savanah_Turner/APO), sorted by date and separated into folders for each object.

2.2 Reduction Steps

Below are the steps followed for NICFPS data reduction.

1. Look through all of the images and ensure that the dithering worked/ images came down correctly.

2. Create super darks.

   - Create .txt file containing names of the dark files to be combined. The command is ls dark6*.fits > dark6.txt". Be sure to only combine darks of the same exposure time. Remember to include the extension [0] at the end of the name of each object in the text file. Use find and replace to add this.
   - Run imcombine @"name of txt file" "name of superdark".
   - Subtract superdark from each image, not overwriting the raw images. The most efficient way is to use ls to create 2 text files, one a list of all the objects (including the extension) and another that is a copy of the first without the extension and with "ds" for dark subtracted added to the beginning of each object name. Then call imarith @objectfile - superdark.fits @dsobjectfile.

3. Complete pair subtraction.

   - First use imcombine to combine each of the three images taken at the same position.
   - Run imarith 1 - 2 into 1.
   - Run imarith 2 - 3 into 2.
   - Run imarith 3 - 4 into 3.
   - Run imarith 4 - 5 into 4.
   - Run imarith 5 - 1 into 5.

4. Create super flat.

   - Use imcombine to merge all 15 dark-subtracted images of the same object and same filter.
   - Use imstat to find the midpoint of each superflat, and use imarith to divide the superflat by this value.

- Divide each pair-subtracted image by its corresponding superflat. This takes care of both dark and flat correction.

5. Perform aperture photometry.

   - Open DS9 in iraf using the command ! ds9 &. Then load images to the ds9 application by typing displ "imageName" "frame number." For example, load image H1.fits into frame 1 by typing displ H1.fits 1.
   - Use the imexamine command in iraf to launch the image examining tool. Once launching the tool, hover over the target in each image frame and click "a". This will give you the x,y coordinates for the center-ish of the target.
   - Use DS9 to find the x,y coordinates for each object in each filter. Put these in a coords.txt file labeled well for the object and filter.
   - Use DS9 to determine the best aperture size for each object. To do this, use the same imexamine tool as before but this time hover over the object and push "r" for FWHM information. The aperture should be somewhere around 1.4 times the FWHM. Use epar phot to change the aperture size accordingly.
   - Run phot on each image.
   - Use txdump to print out the computed instrumental magnitudes for each object.

6. Calculate apparent magnitudes.

   - Find apparent magnitudes for each standard on the Gemini/UKIRT page where I found the standards in the first place.
   - Use an excel sheet to find the difference between the instrumental and apparent magnitudes of each standard in each filter. Average the 5 differences (same object, same filter) together to get an approximate offset.
   - Subtract the offsets from each target object (matching filters). The result is the object apparent magnitude.
   - Inspect the 5 apparent magnitudes calculated per object per filter to ensure that they are all close. If there are drastic differences, inspect data or consider restarting. If all seems in order, average the 5 magnitudes to find a final answer.

Questions remaining that I need to ask for help/ research regarding photometry:

- How do I calculate errors?
- How do I transform from K to Ks?
- Standard mags are K and data is Ks. What do I do about that?
- Does APO have filter profiles for me?
- Did my apertures need to be a certain size?
- Visually check all apertures to be sure they look good.
- How to perform PSF fitting with DAOphot?
- Does Leggett have my standards in Ks? Or transformations for me?

2.2.1 Jan 5th 2M0046 Redux Notes

The finder chart and field of view (with the target marked) are given in [7].

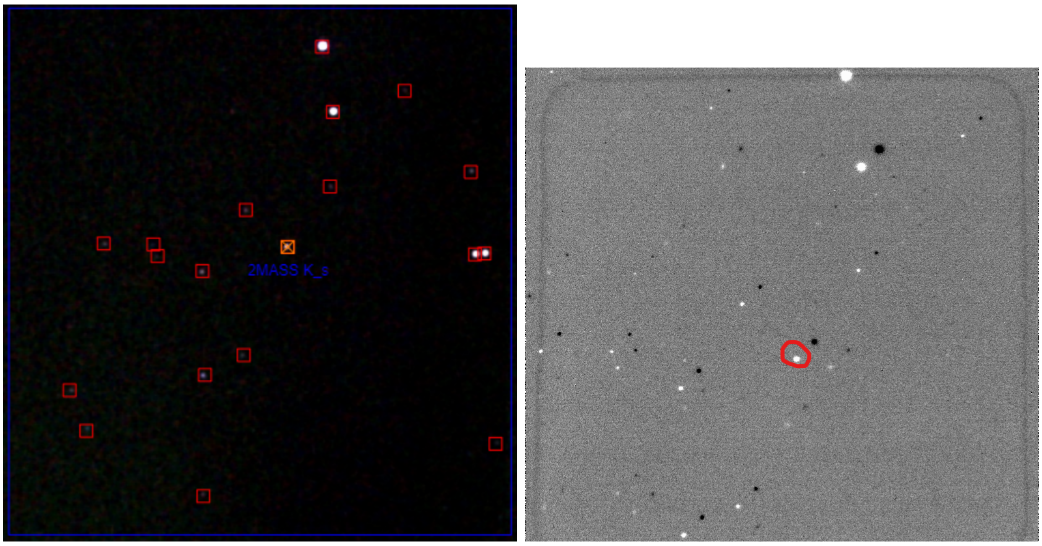

Figure 7. Left is the 2MASS finder chart from IRSA used to identify the object 2M0046. Right is one of the K images showing the field of view. The target is circled in red.

The plots I generated using imexamine to find the FWHM for each filter are given in [8], [9], and [10]. I determine the FWHM for J, H, and K to be 2.75 * 2 = 5.5, 2 * 2 = 4, and 2.1 * 2 = 4.2 respectively. Multiplying these numbers by 1.4 gives me apertures of 7.7, 5.6, and 5.88. I used radii of 10 and 10 for the sky background.

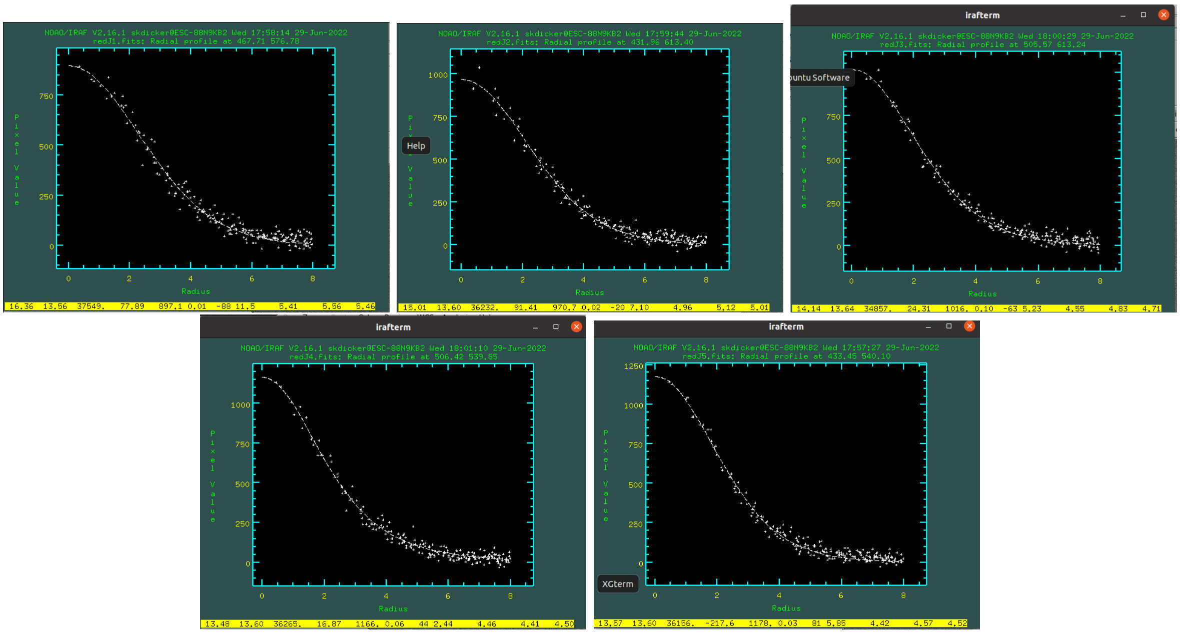

Figure 8. Flux vs radius plots for 2M0046 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

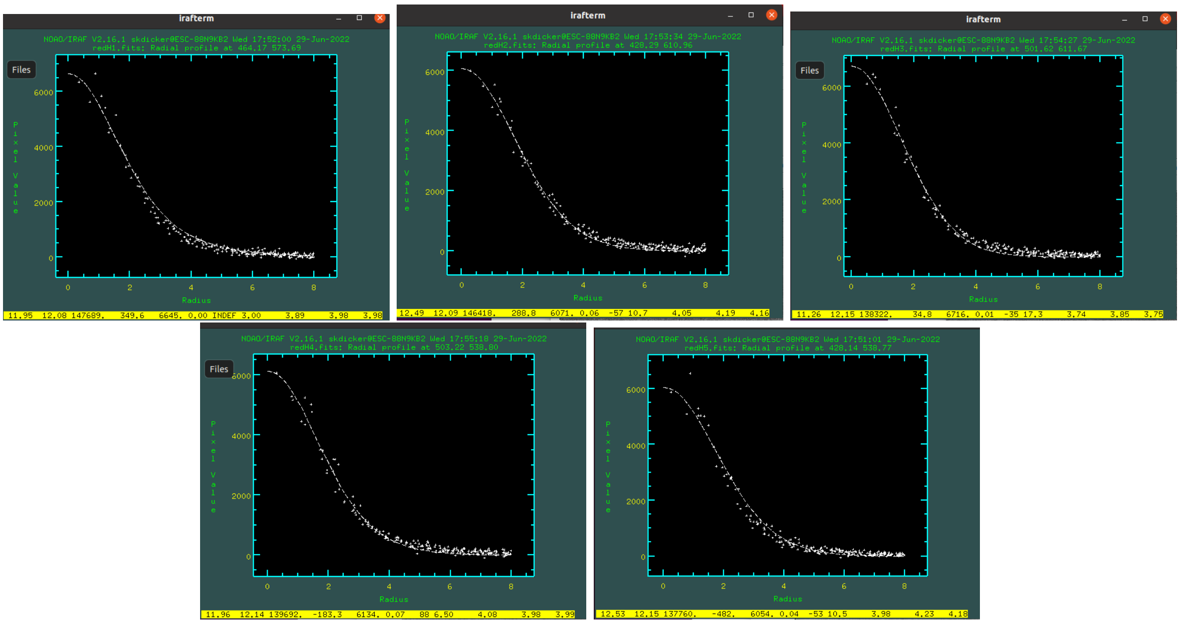

Figure 9. Flux vs radius plots for 2M0046 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

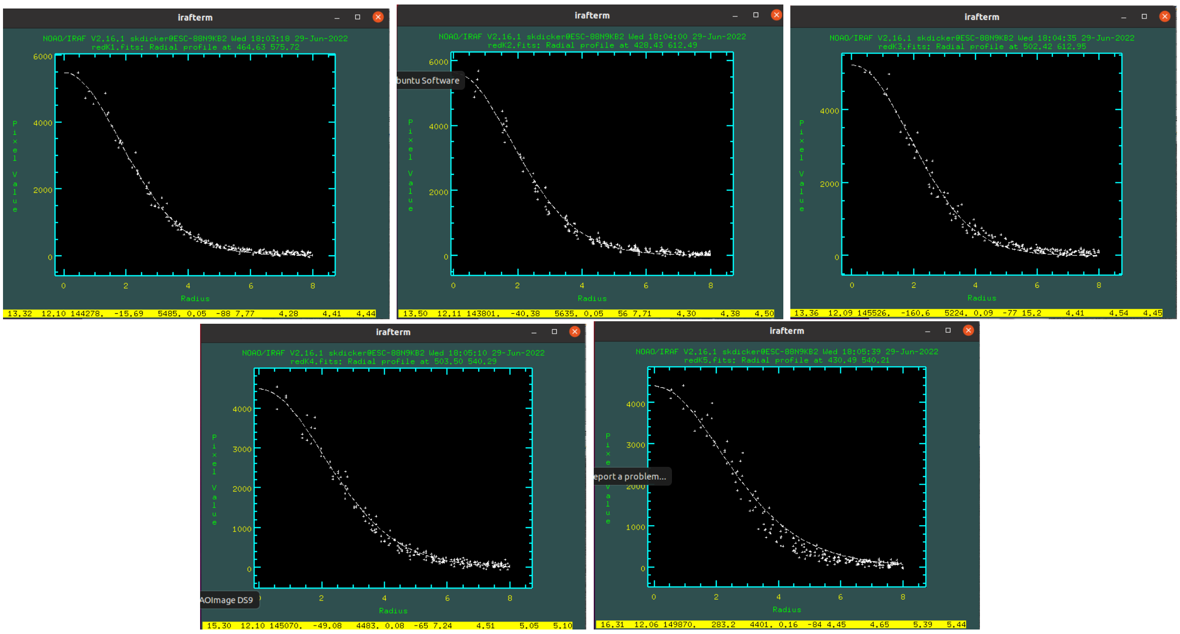

Figure 10. Flux vs radius plots for 2M0046 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.2 Jan 5th ULAS0006 Redux Notes

The finder chart and field of view (with the target marked) are given in [11]. This object was really faint and really hard to find in the field. It wasn't visible in the 2MASS images, so I had to search the WISE catalog instead. I am not sure how well this data is going to work out with how faint the object is.

The plots I generated using imexamine to find the FWHM for each filter are given in [12], [13], and [14]. I determine the FWHM for J, H, and K to all be about 2*2 = 4. Multiplying by 1.4 gives

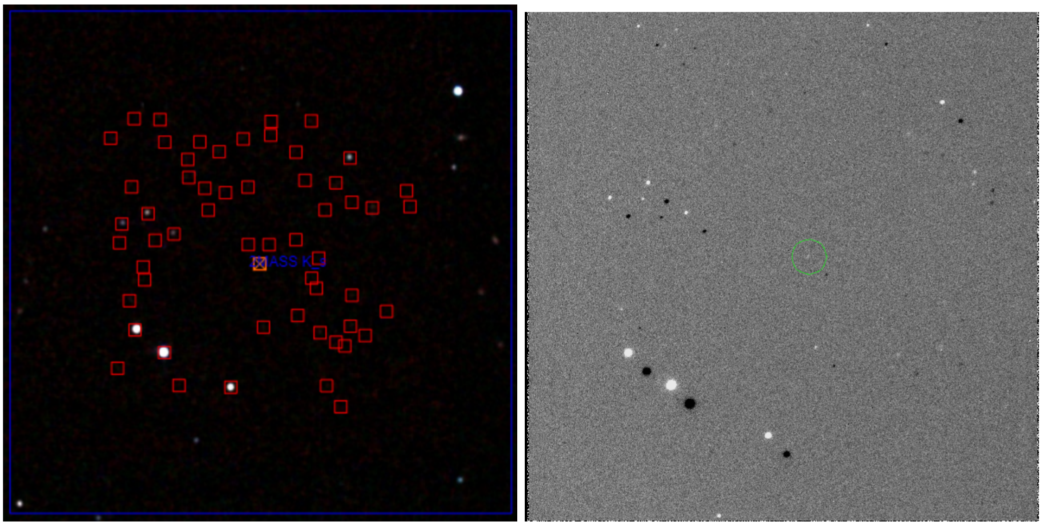

Figure 11. Left is the WISE finder chart from IRSA used to identify the object ULAS0006. Right is one of the H images showing the field of view. The target is circled in green.

me an aperture of about 5.6. I used this aperture for all 3 filters. I used radii of 10 and 10 for the sky background again here.

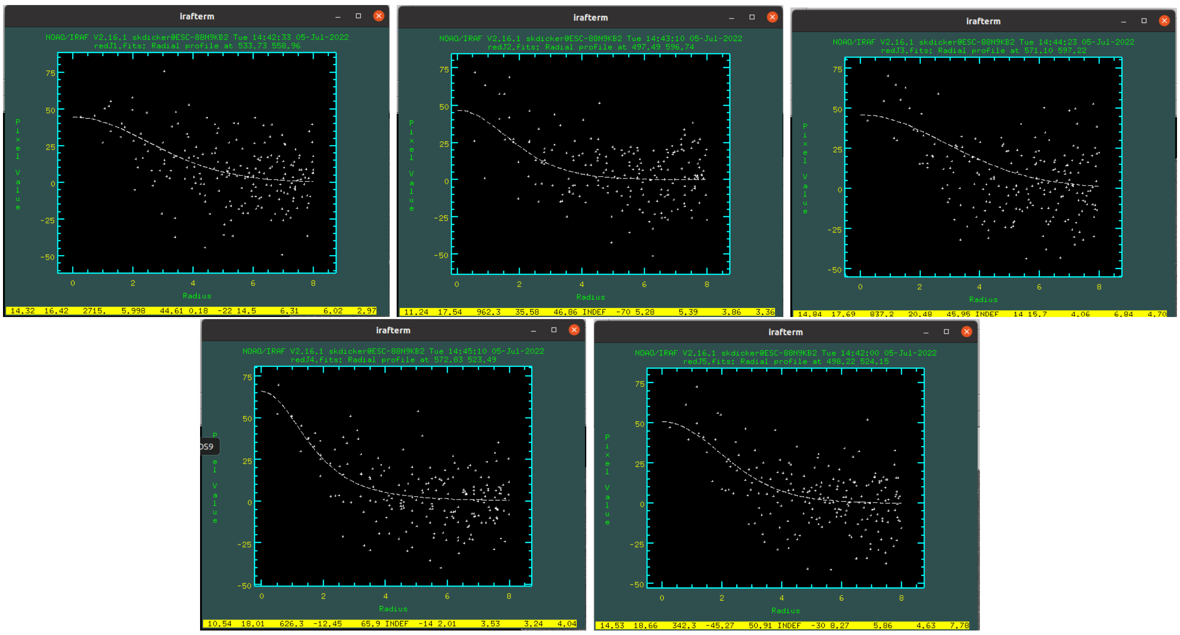

Figure 12. Flux vs radius plots for ULAS0006 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.3 Jan 5th WISE0043 Redux Notes

The data for this object looked pretty good. One thing to be aware of is that the field was crowded enough that the negative of another star overlaps our object in the position 1 - position 2 images. They are close but not physically overlapping in the position 3 - position 4 images. I probably will need to throw out the magnitudes from these pair subtracted images and just use the other 3 positions.

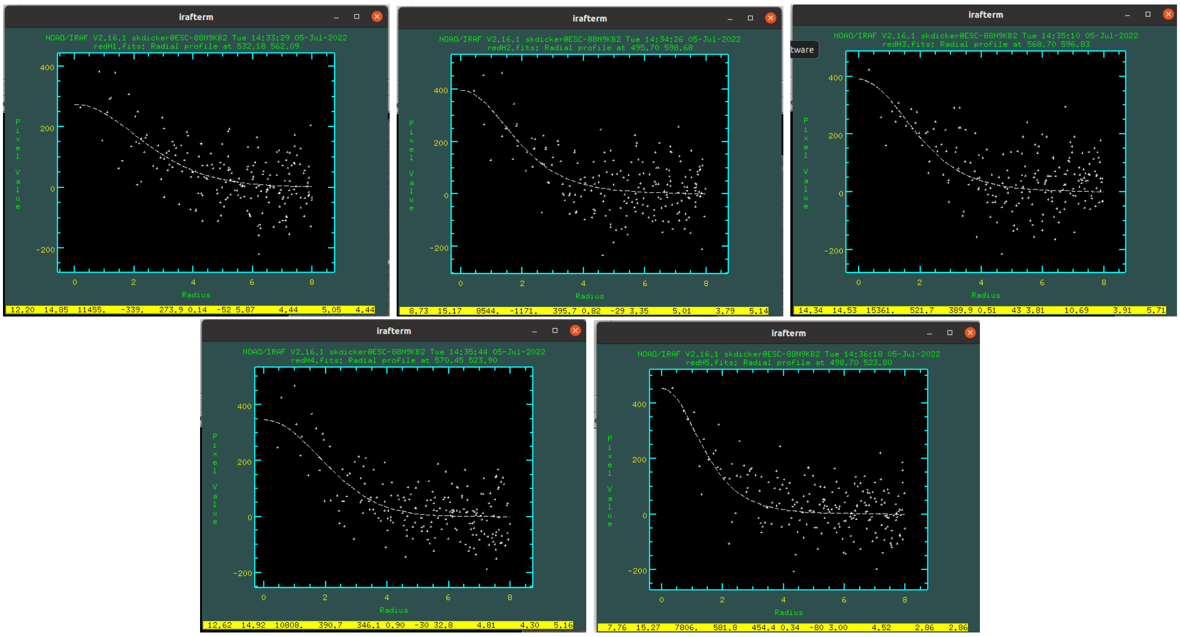

Figure 13. Flux vs radius plots for ULAS0006 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

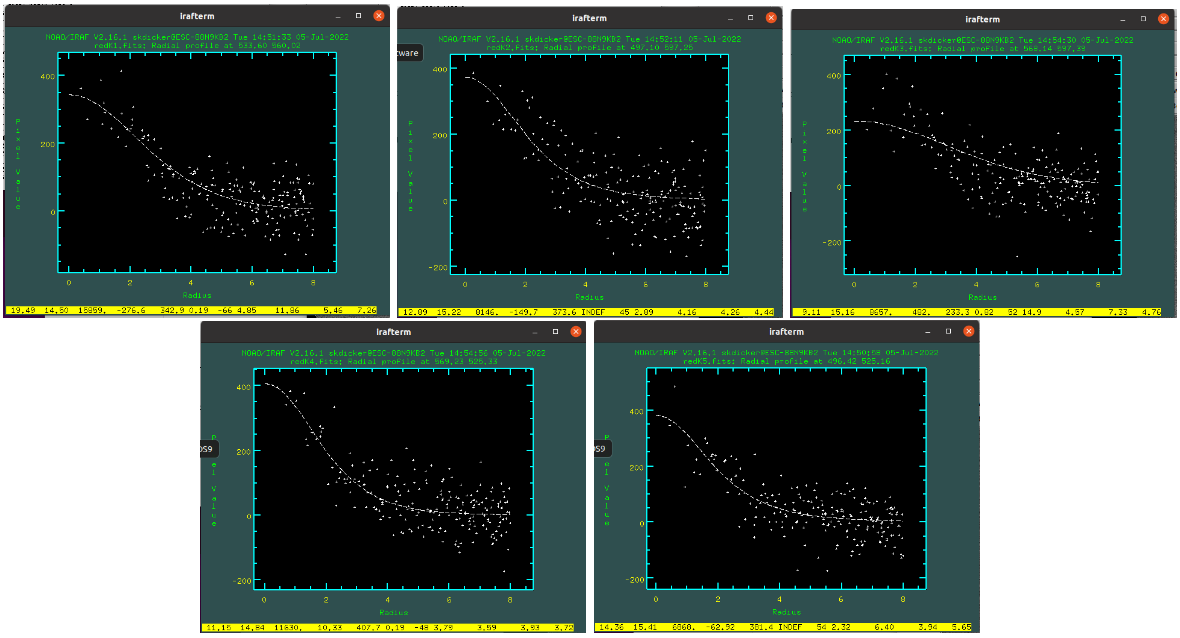

Figure 14. Flux vs radius plots for ULAS0006 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

The finder chart and field of view (with the target marked) are given in [15]. I used the WISE finder chart from IRSA.

The plots I generated using imexamine to find the FWHM for each filter are given in [16], [17], and [18]. I determine the FWHM for J, H, and K to all be 2*2 = 4, 2.5*2 = 5, and 3*2 = 6 respectively. Multiplying by 1.4 gives me apertures of 5.6, 7, and 8.4. For the sky background I used 10 and 10 for the annulus sizes.

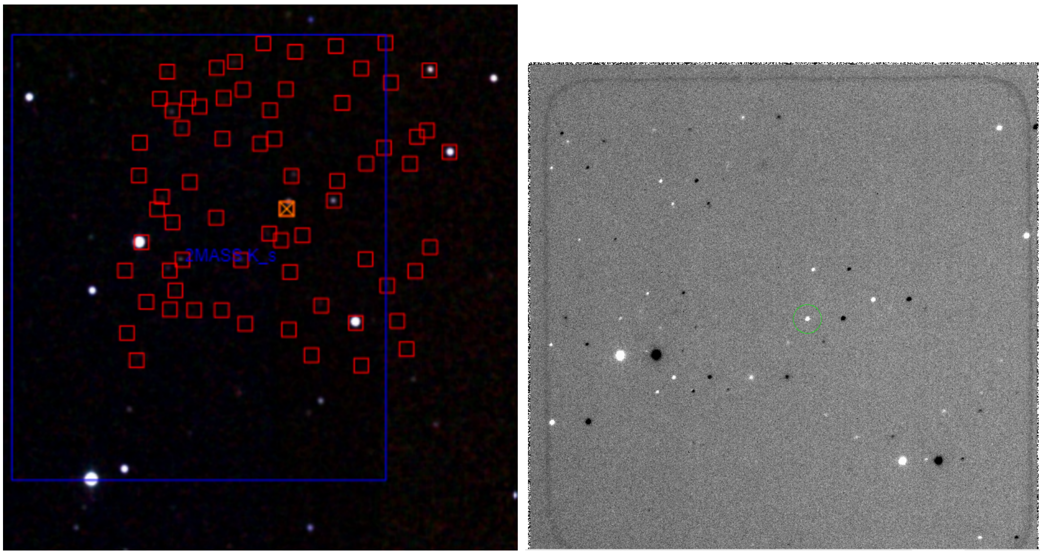

Figure 15. Left is the WISE finder chart from IRSA used to identify the object WISE0043. Right is one of the H images showing the field of view. The target is circled in green.

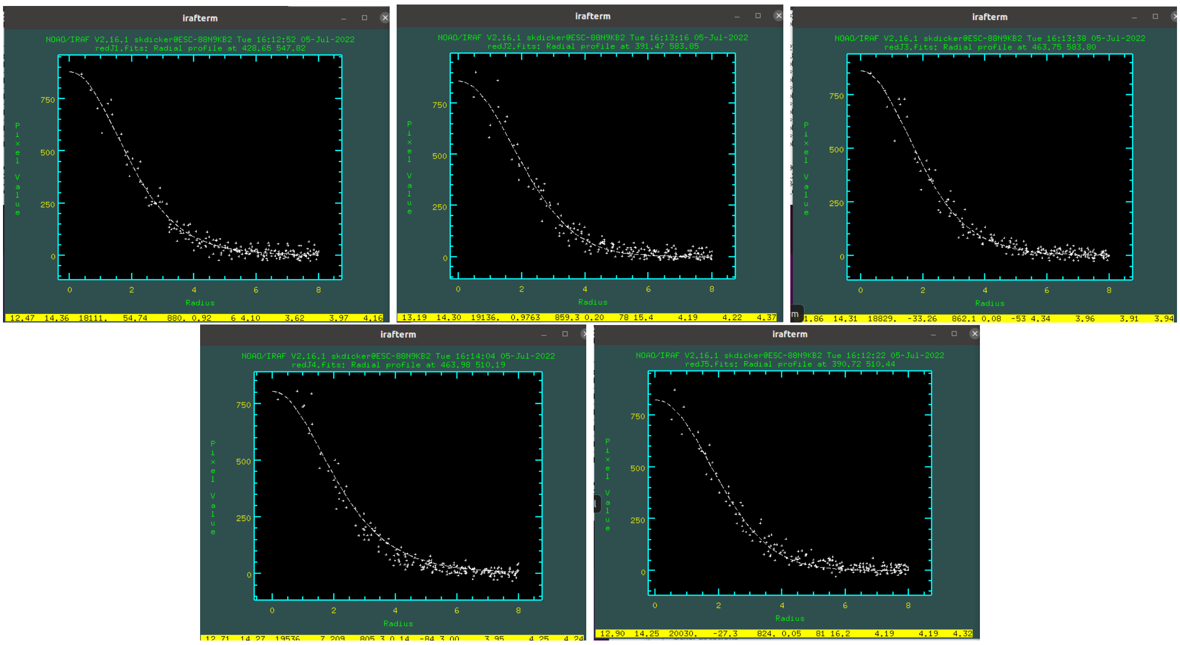

Figure 16. Flux vs radius plots for WISE0043 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.4 Jan 5th WISE0145 Redux Notes

The finder chart and field of view (with the target marked) are given in [19]. The finder chart for this object was full of faint stars and thus a little hard to work with, but I believe that I have identified the correct object.

The plots I generated using imexamine to find the FWHM for each filter are given in [20], [21], and [22]. I determine the FWHM for J, H, and K to all be about 1.7 * 2 = 3.4. Multiplying by 1.4 gives me apertures of 4.8. For the sky background I used 10 and 10 for the annulus sizes.

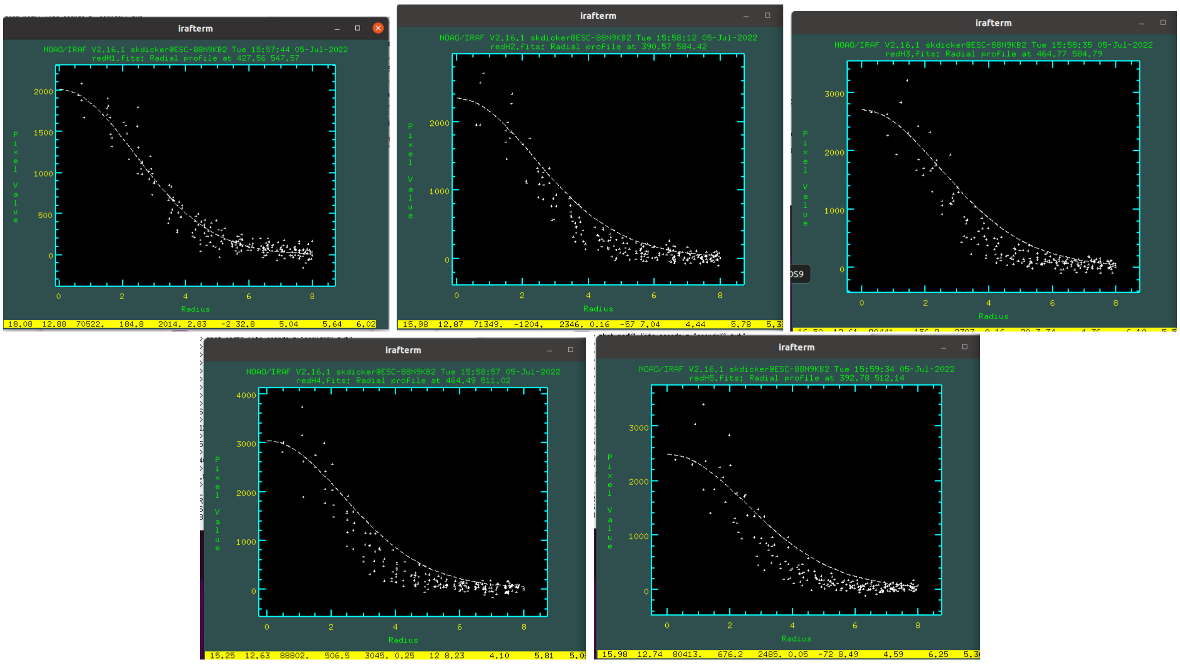

Figure 17. Flux vs radius plots for WISE0043 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

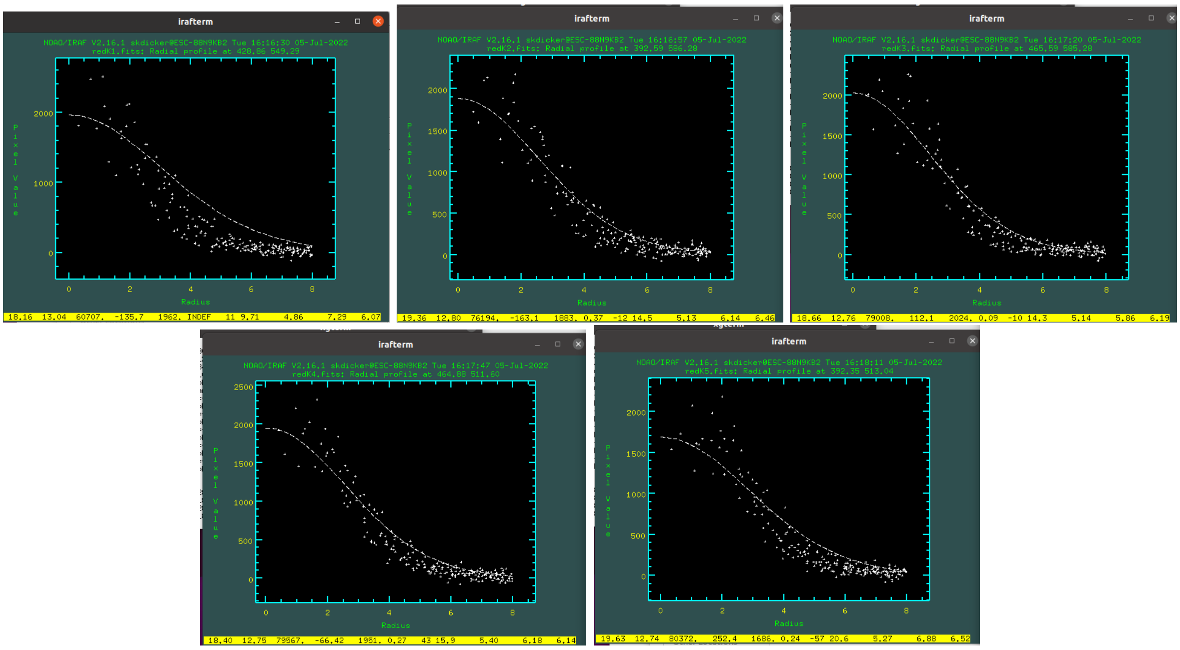

Figure 18. Flux vs radius plots for WISE0043 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.5 Jan 5th WISE0206 Redux Notes

The finder chart and field of view (with the target marked) are given in [23]. I ended up using the 2MASS finder chart because the WISE chart was so crowded.

The plots I generated using imexamine to find the FWHM for each filter are given in [24], [25], and [26]. I determine the FWHM for J, H, and K to all be about 1.9 * 2 = 3.8. Multiplying by 1.4

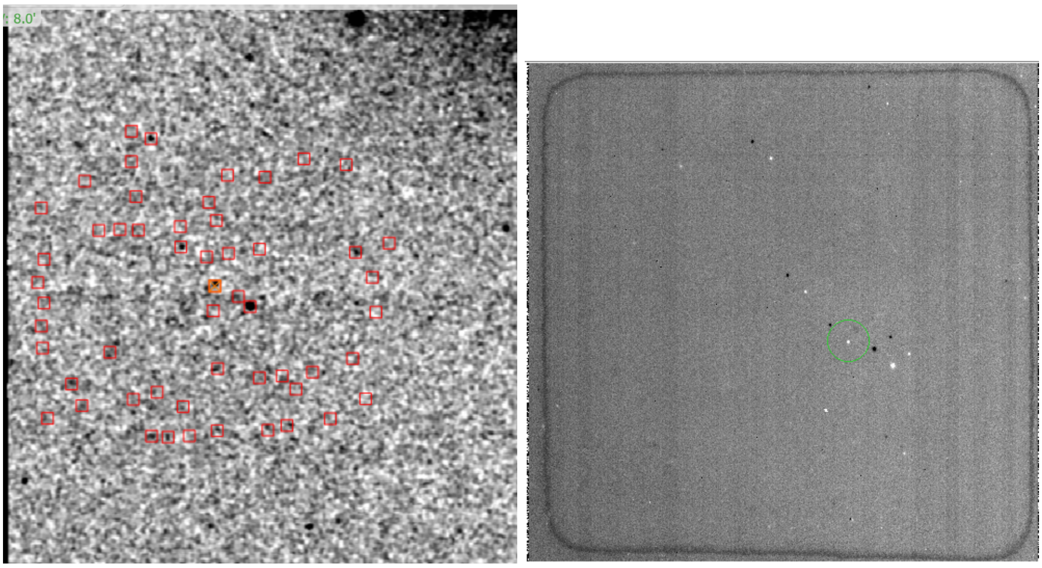

Figure 19. Left is the WISE finder chart from IRSA used to identify the object WISE0145. Right is one of the H images showing the field of view. The target is circled in green.

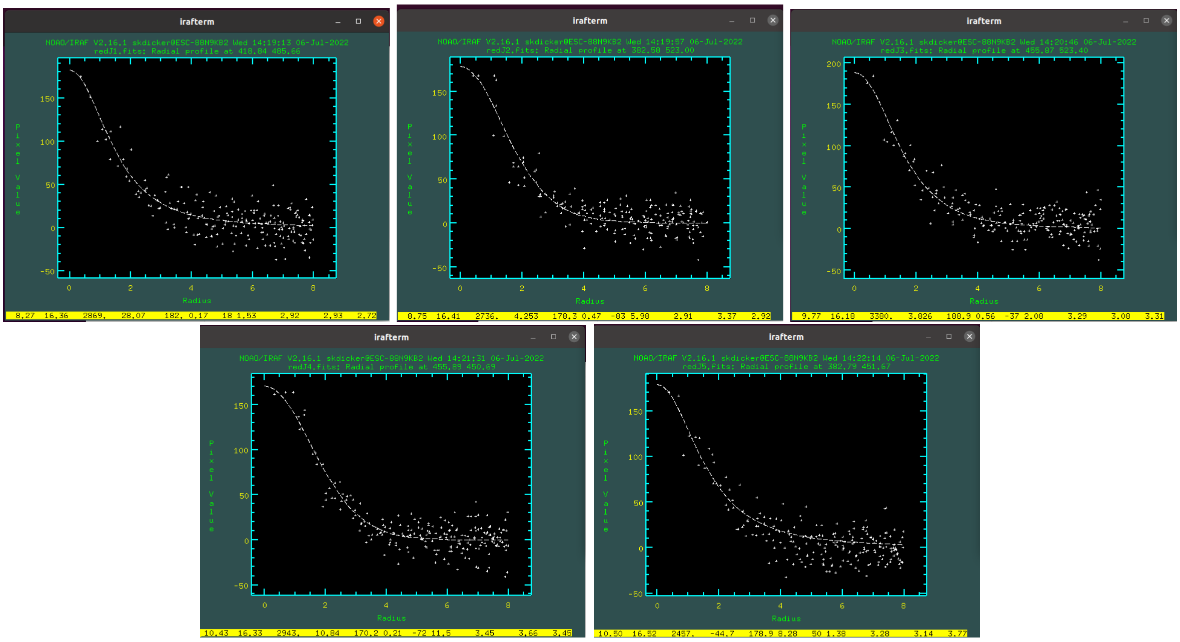

Figure 20. Flux vs radius plots for WISE0145 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

gives me apertures of 5.32. For the sky background I used 10 and 10 for the annulus sizes.

2.2.6 Jan 5th WISE0607 Redux Notes

The finder chart and field of view (with the target marked) are given in [27]. I tried both the 2MASS and the WISE charts and it was very unclear which star is the target. The marked object based on the WISE coordinates fell right in-between two objects that were otherwise not marked. The same was true about the marker for the 2mass image, but the 2mass coordinates labeled as a brown dwarf were closer to the brighter of the 2 objects so I am assuming that is the target. If the magnitudes come out

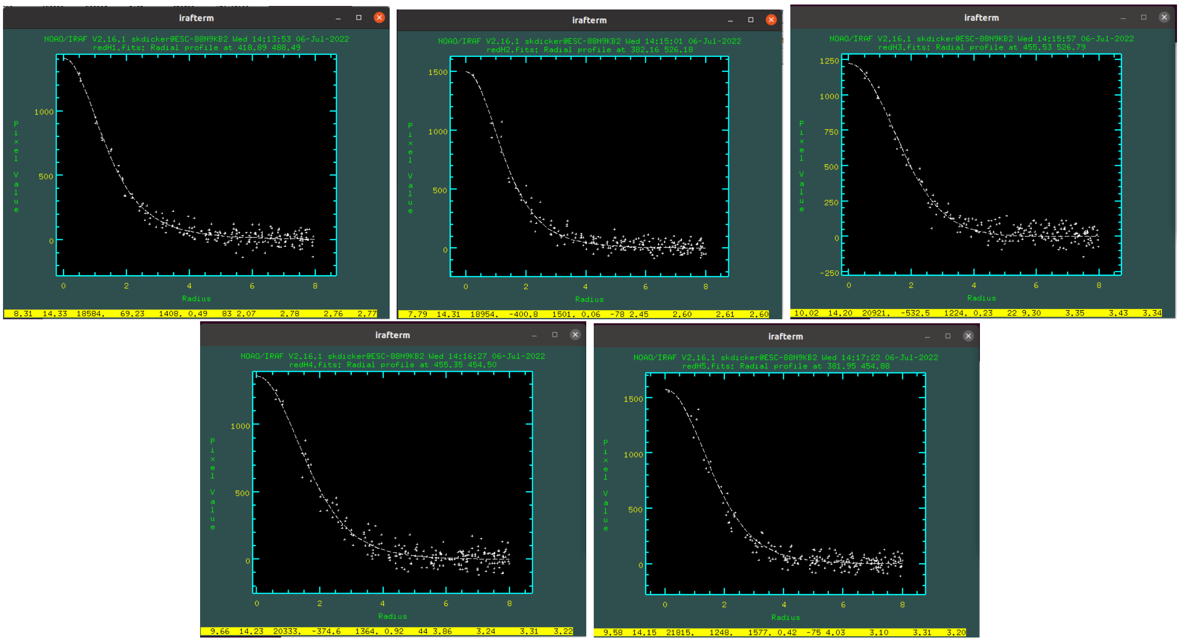

Figure 21. Flux vs radius plots for WISE0145 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

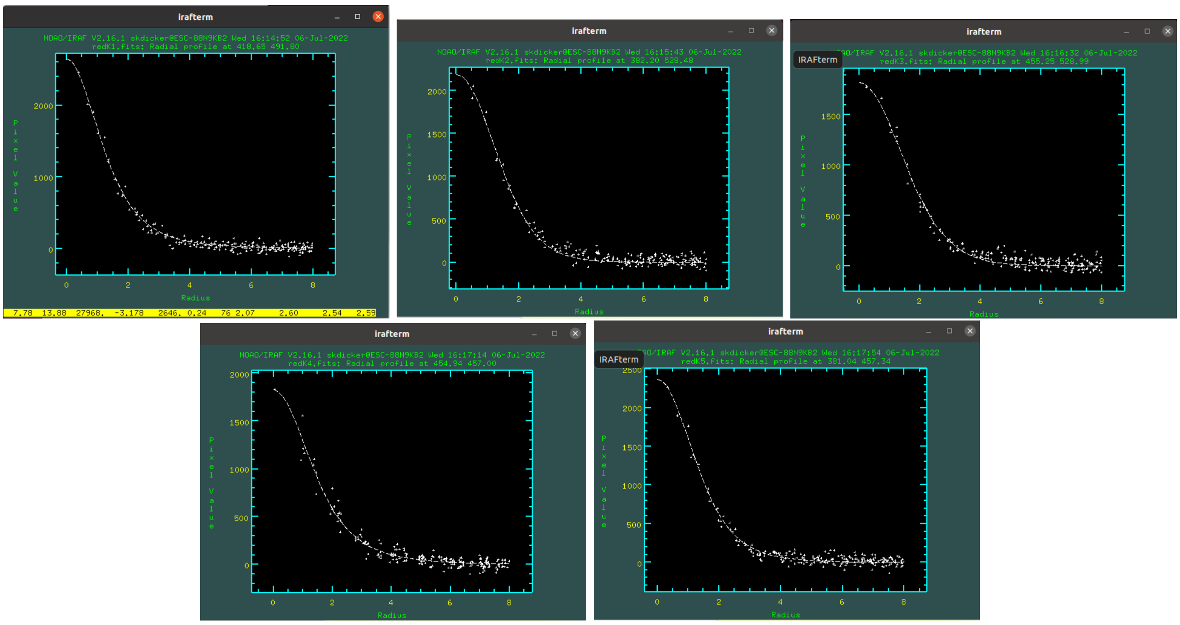

Figure 22. Flux vs radius plots for WISE0145 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

wonky I will try the second option.

I am a little disheartened by how crowded this field is. I need to talk to Dr. S about how to go about doing photometry in such a busy field where I cannot help but get other objects in my apertures. I will pause here and move on until I have a chance to do so.

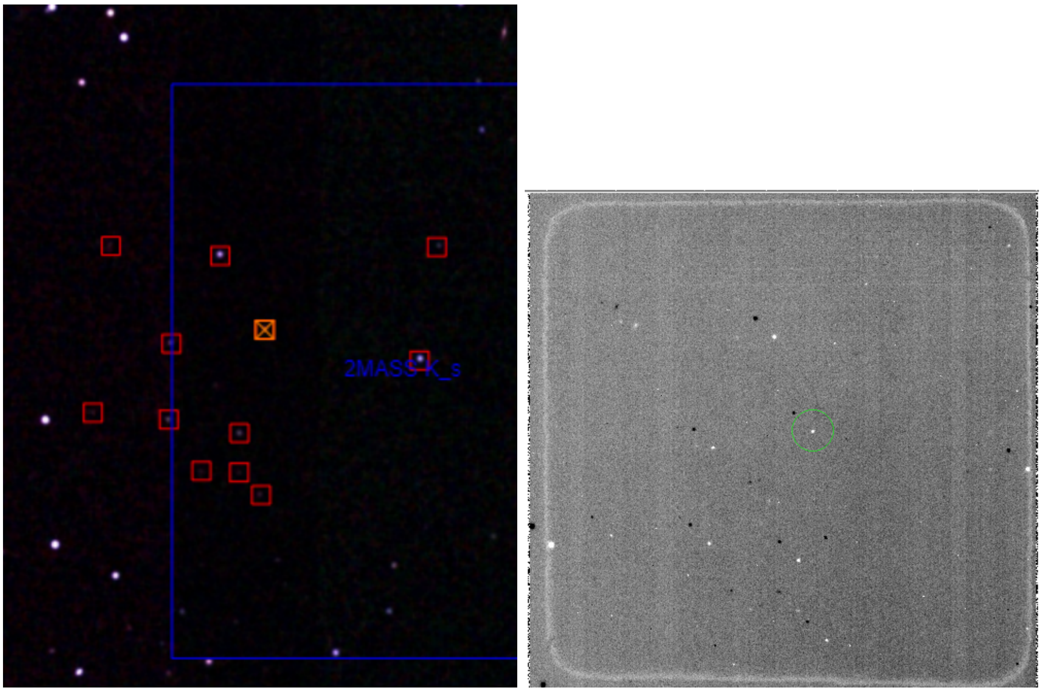

Figure 23. Left is the 2MASS finder chart from IRSA used to identify the object WISE0206. Right is one of the H images showing the field of view. The target is circled in green.

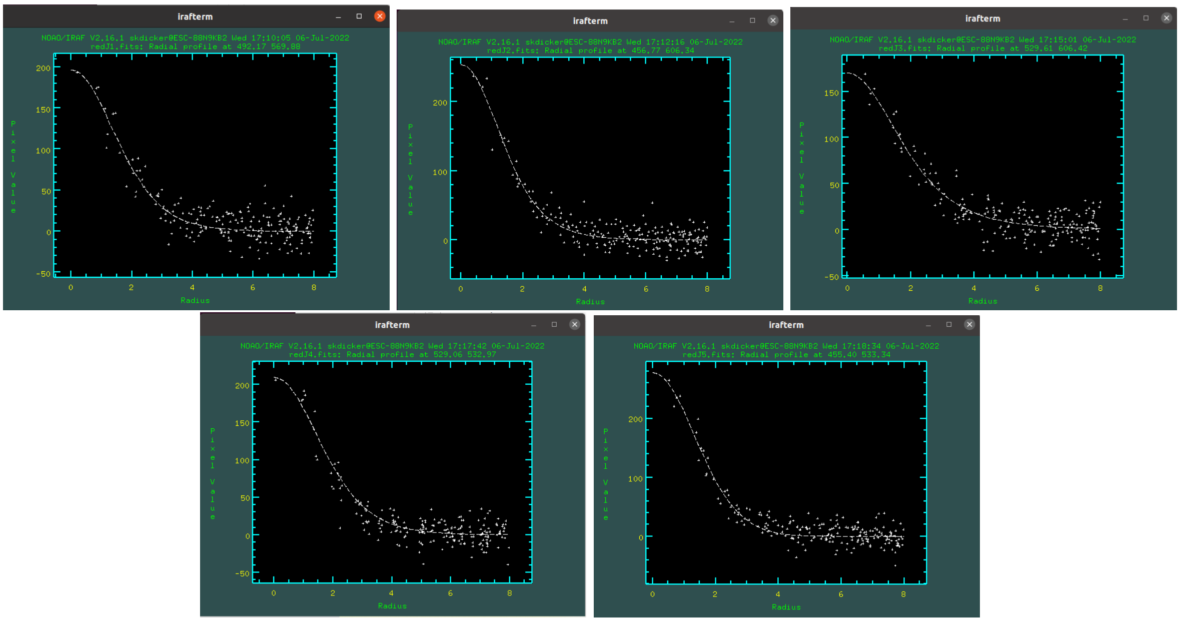

Figure 24. Flux vs radius plots for WISE0206 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.7 *Jan 5th WISE0656 Redux Notes*

This field is much less crowded than the last, although position 1 has a shadow on top of the object so I might need to watch this. The finder chart and field of view (with the target marked) are given in [28].

The plots I generated using imexamine to find the FWHM for each filter are given in [29], [30],

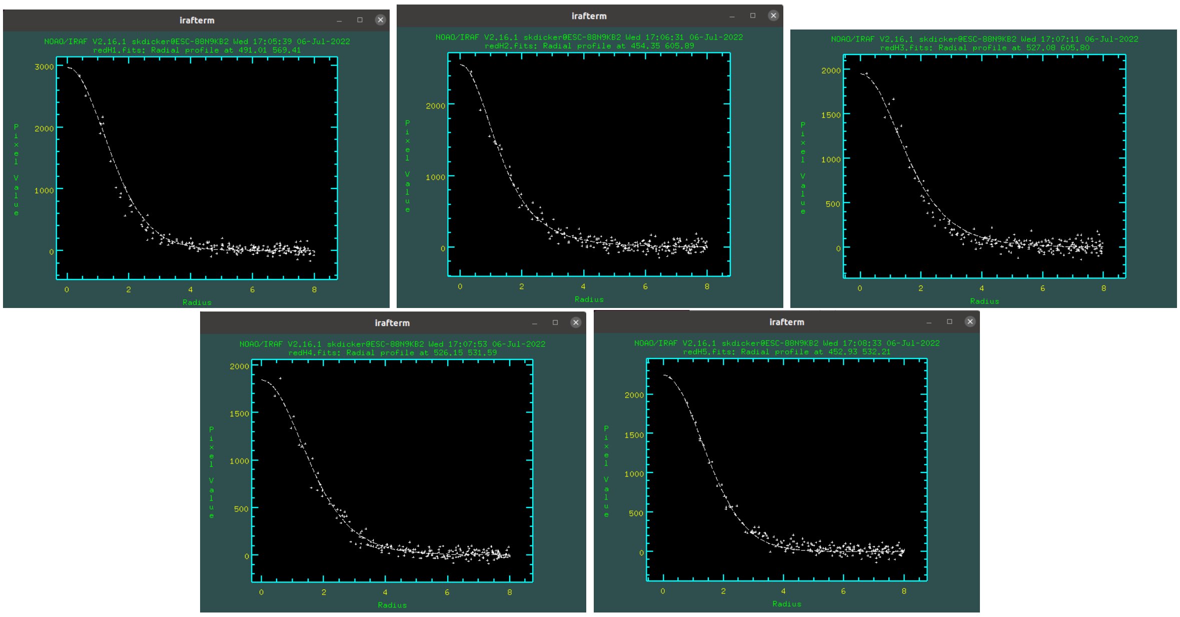

Figure 25. Flux vs radius plots for WISE0206 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

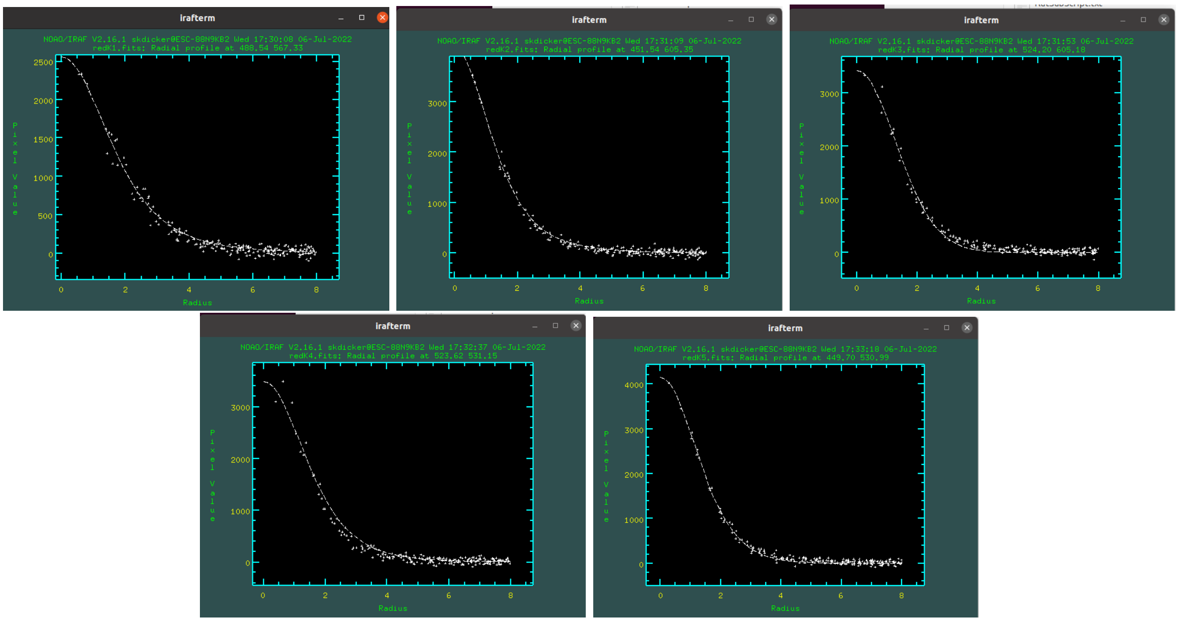

Figure 26. Flux vs radius plots for WISE0206 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

and [31]. I determine the FWHM to be 1.5*2 = 3, 1.5*2 = 3, and 2*2 = 4. Multiplying by 1.4 gives me apertures of 4.2, 4.2, and 5.6. For the sky background I used 10 and 10 for the annulus sizes.

2.2.8 Jan 5th fs2 Redux Notes

The finder chart and field of view (with the target marked) are given in [32].

The plots I generated using imexamine to find the FWHM for each filter are given in [33], [34], and [35]. I determine the FWHM for J, H, and K to be 2.5*2 = 5, 3.5*2 = 7, and 3*2 = 6 respectively.

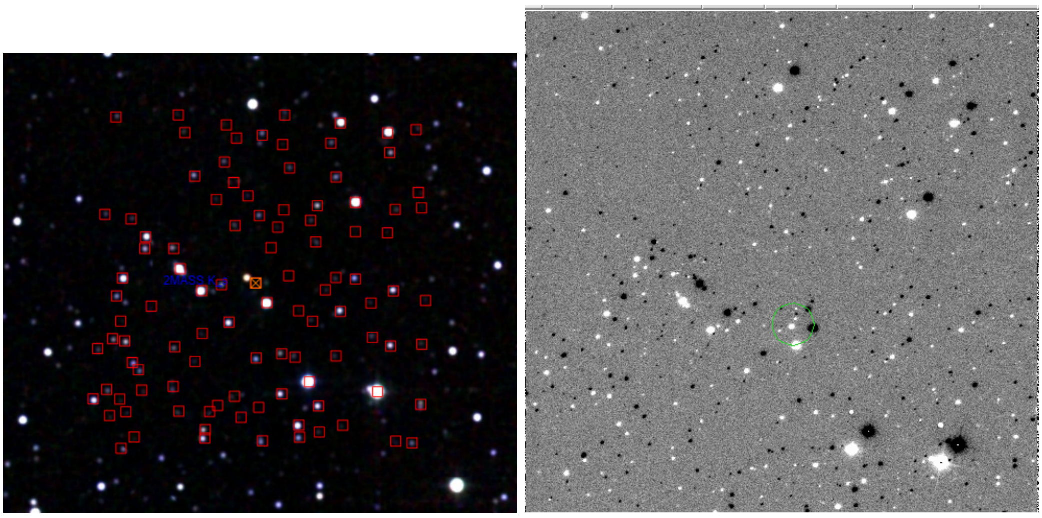

Figure 27. Left is the WISE finder chart from IRSA used to identify the object WISE0607. Right is one of the H images showing the field of view. The target is circled in green.

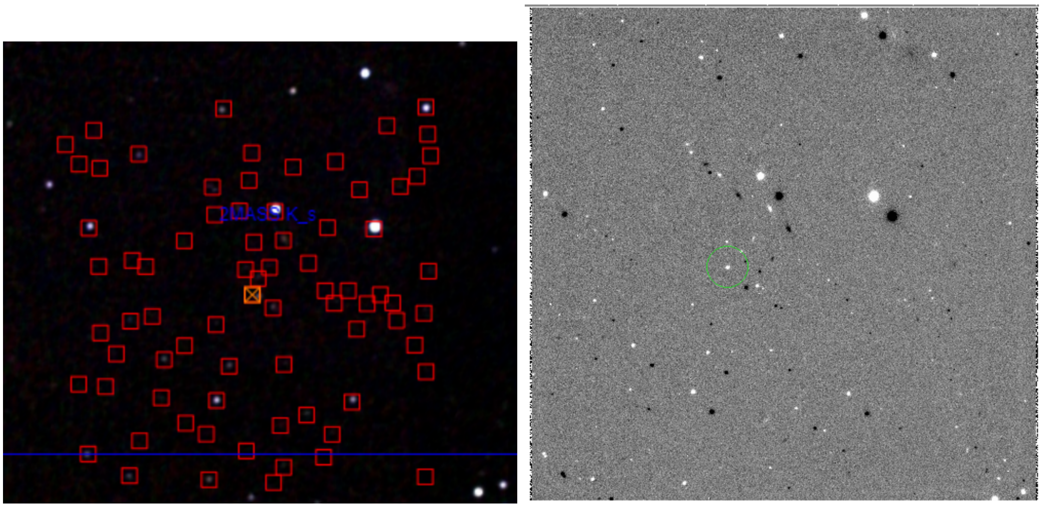

Figure 28. Left is the WISE finder chart from IRSA used to identify the object WISE0656. Right is one of the H images showing the field of view. The target is circled in green.

Multiplying by 1.4 gives me apertures of 7, 9.8, and 8.4. For the sky background I used 10 and 10 for the annulus sizes.

2.2.9 Jan5th LHS216

This field is pretty crowded, and finding the target is proving to be a bit of a pain. The 2MASS finders chart shows the target to be bright, but nothing that bright is in that area of the field in my images. I can find all the stars around it, but not the right standard. Same thing is going on with the WISE field. Talk to Dr. S. about this one.

2.2.10 Jan 5th P161

Due to time constraints, we were unable to get as many images for this standard as we usually do. After reduction we ended up with only 2 H-positions, 2 J-positions, and 5 K-positions. The finder

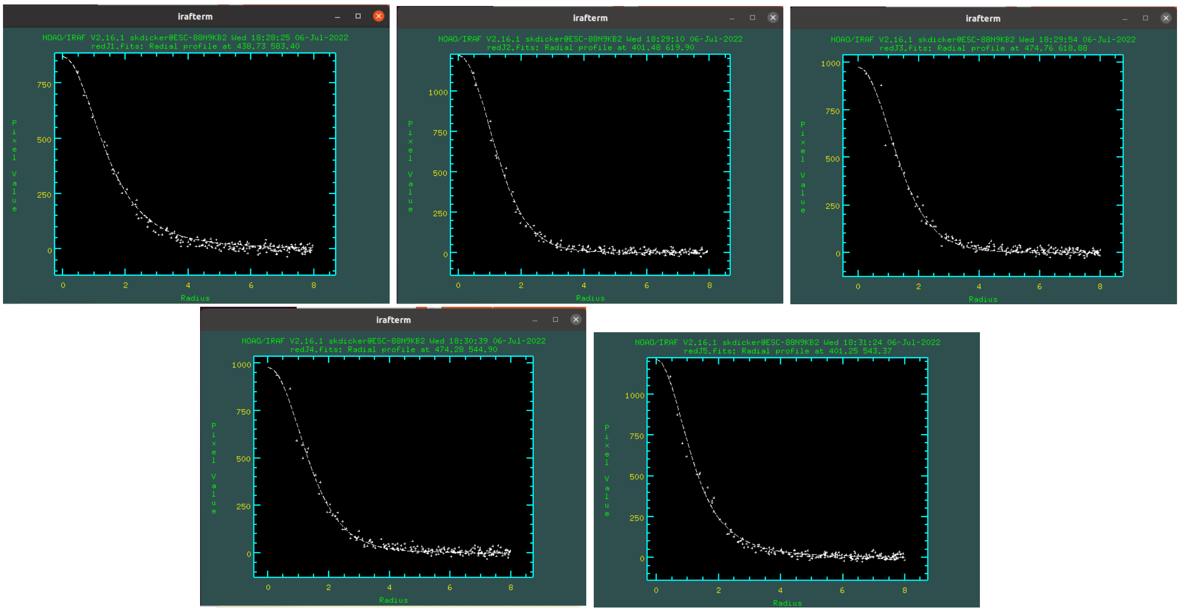

Figure 29. Flux vs radius plots for WISE0656 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

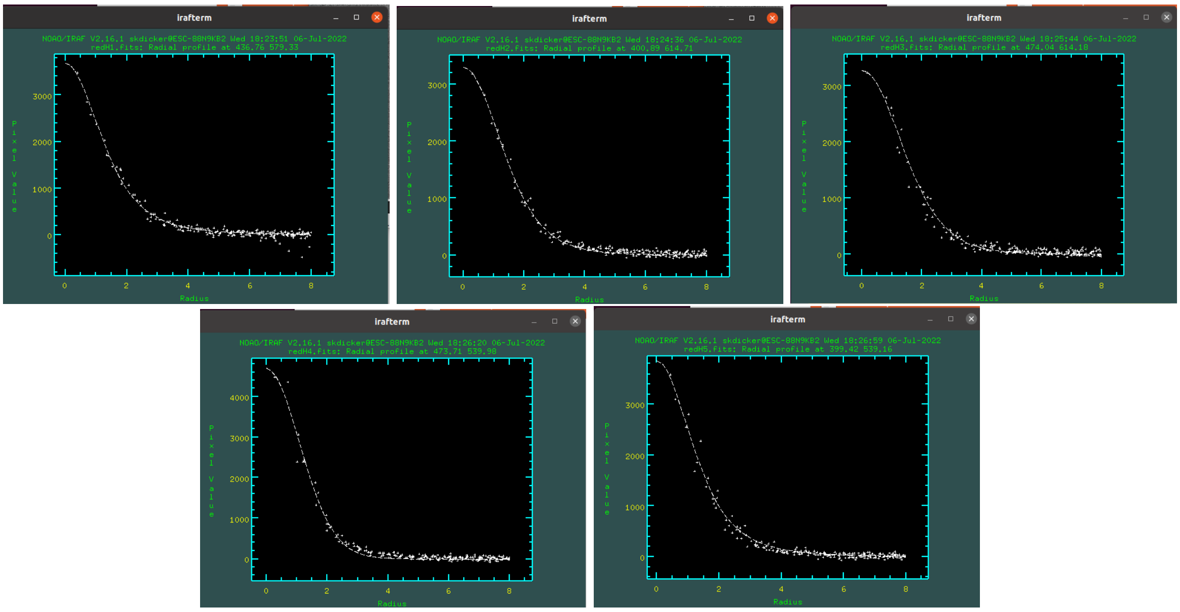

Figure 30. Flux vs radius plots for WISE0656 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

chart and field of view (with the target marked) are given in [36].

The plots I generated using imexamine to find the FWHM for each filter are given in [37], [38], and [39]. I determine the FWHM for J, H, and K to be 1.2 * 2 = 2.4, 2*2 = 4, and 2*2 = 4 respectively. Multiplying by 1.4 gives me apertures of 3.4, 5.6, and 5.6. For the sky background I used 10 and 10 for the annulus sizes.

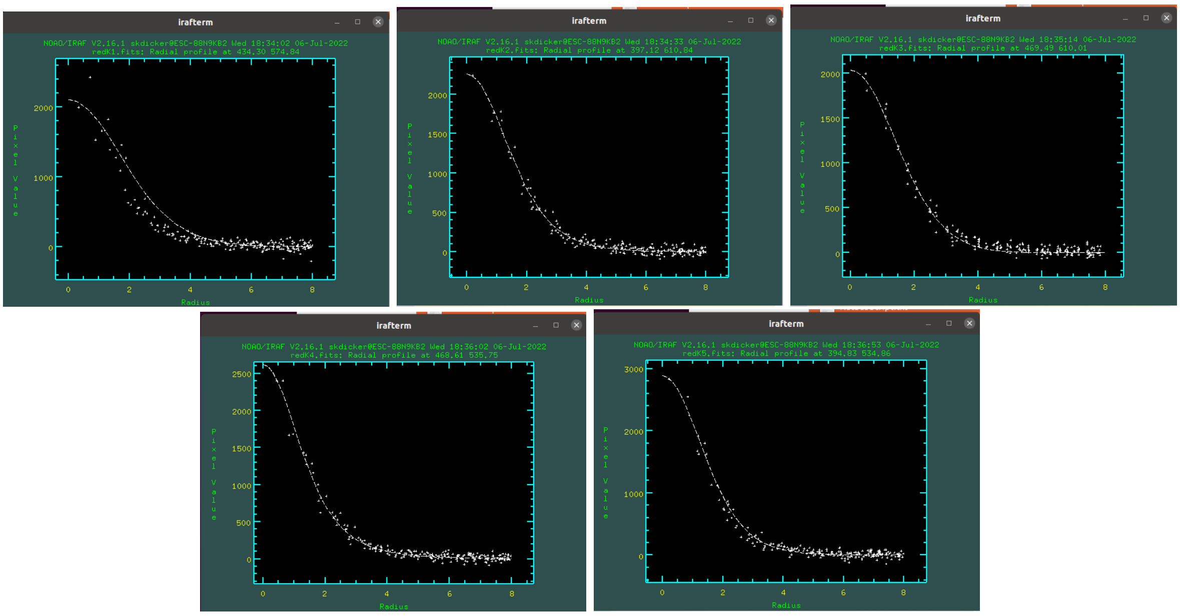

Figure 31. Flux vs radius plots for WISE0656 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

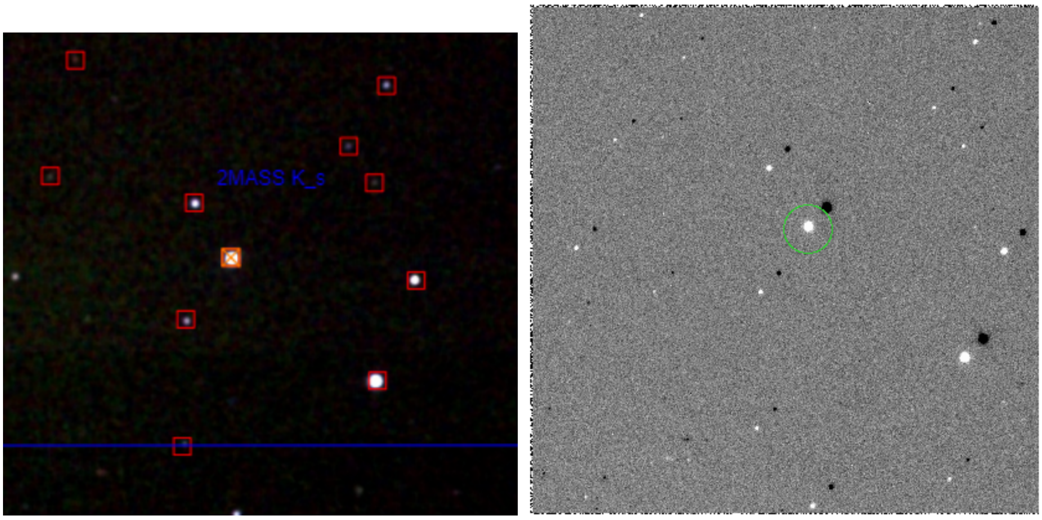

Figure 32. Left is the 2MASS finder chart from IRSA used to identify the object fs2. Right is one of the H images showing the field of view. The target is circled in green.

2.2.11 Jan 5th P530

The finder chart and field of view (with the target marked) are given in [40].

The plots I generated using imexamine to find the FWHM for each filter are given in [41], [42], and [43]. I determine the FWHM for J, H, and K to be about 2*2 = 4 for all. (I am not sure why the FWHM plot fits are so horrible for this object. I went off the data points not the fitted curves) Multiplying by 1.4 gives me apertures of 5.6. For the sky background I used 10 and 10 for the annulus sizes.

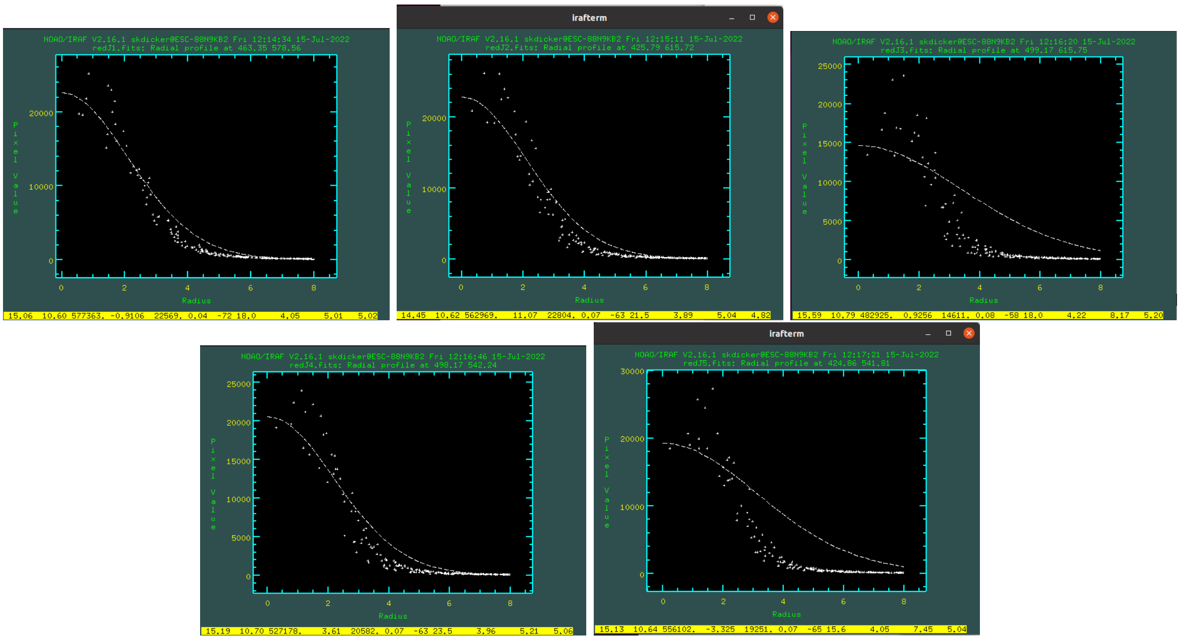

Figure 33. Flux vs radius plots for fs2 in the J-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

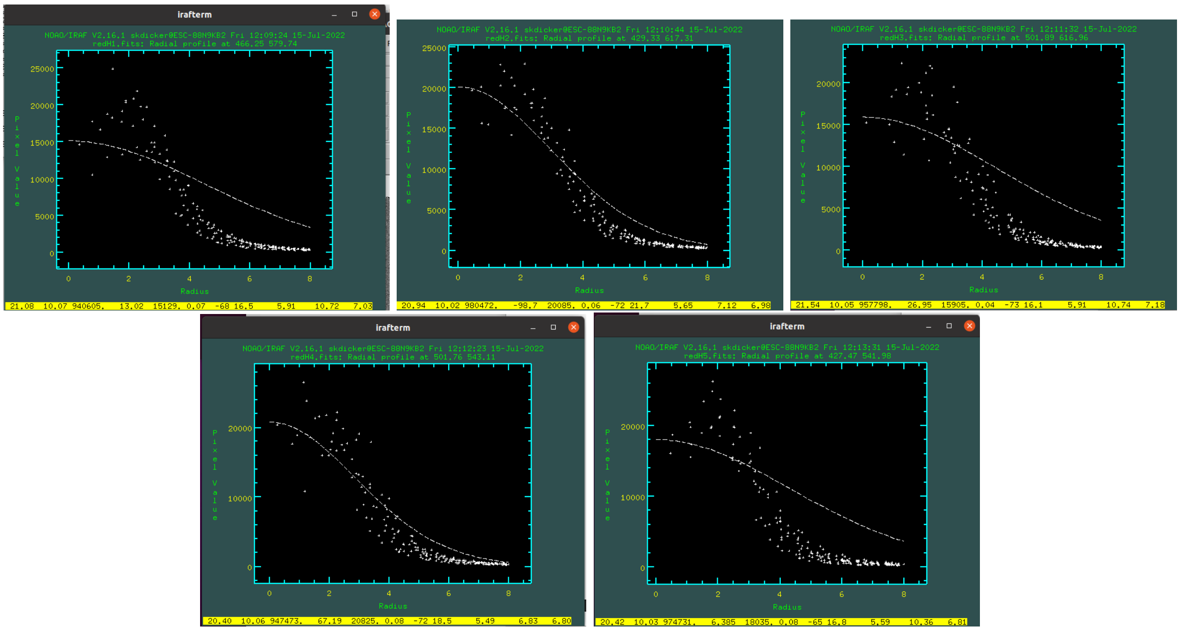

Figure 34. Flux vs radius plots for fs2 in the H-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.12 Jan 5th S754

The finder chart and field of view (with the target marked) are given in [44].

The plots I generated using imexamine to find the FWHM for each filter are given in [45], [46], and [47]. I determine the FWHM for J, H, and K to be about 2.5*2 = 5 for each. Multiplying by 1.4 gives me apertures of 7. For the sky background I used 10 and 10 for the annulus sizes.

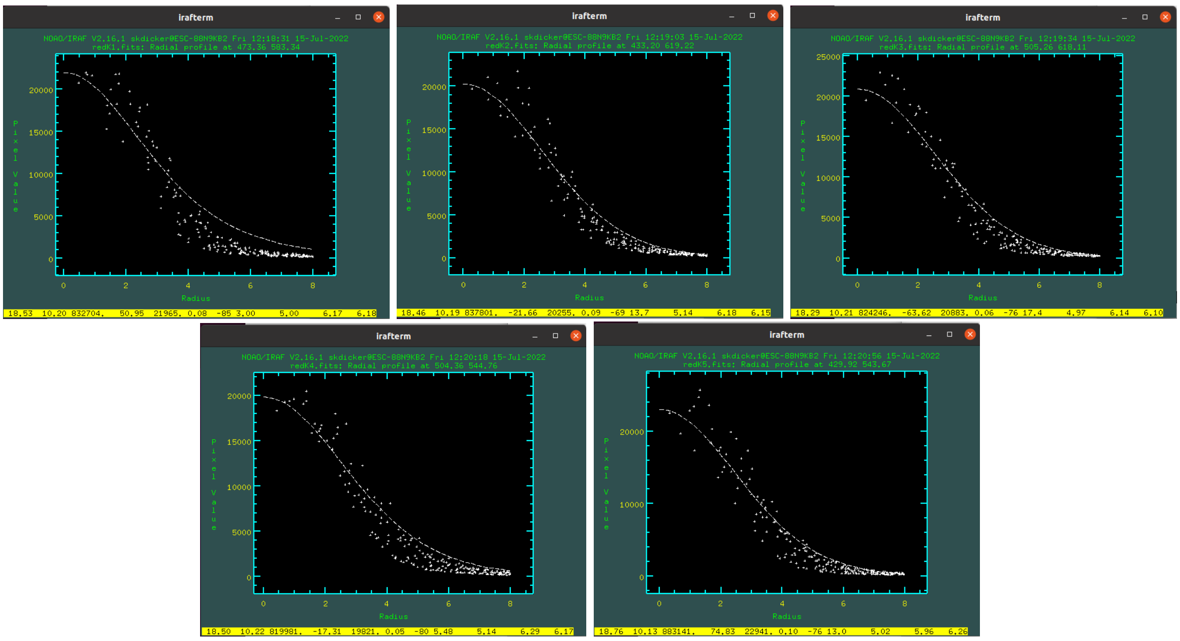

Figure 35. Flux vs radius plots for fs2 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

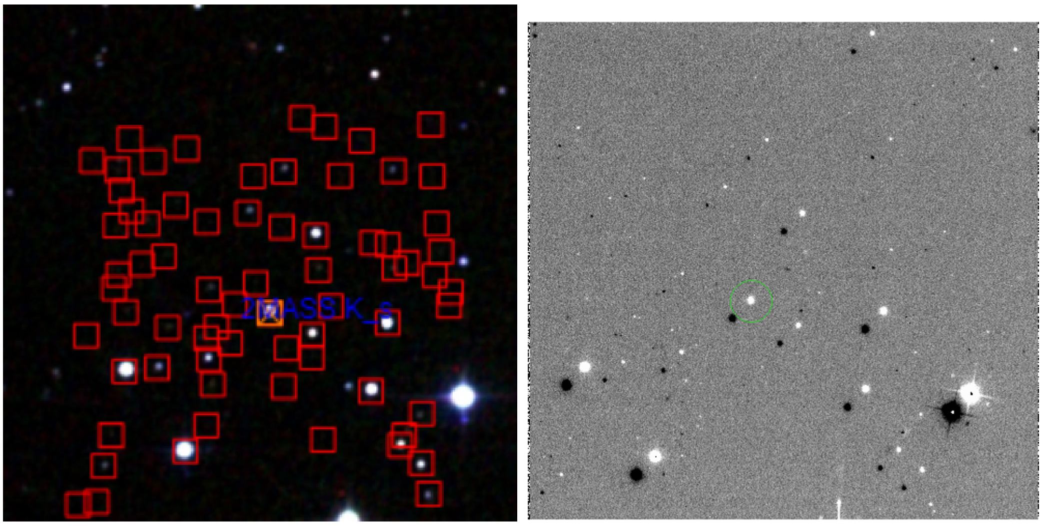

Figure 36. Left is the WISE finder chart from IRSA used to identify the object P161. Right is one of the H images showing the field of view. The target is circled in green.

2.2.13 Jan 5th SA92

The finder chart and field of view (with the target marked) are given in [48].

The plots I generated using imexamine to find the FWHM for each filter are given in [49], [50], and [51]. I determine the FWHM for J, H, and K to be about 2.5*2 = 5, 3*2 = 6, and 3*2 = 6. Multiplying by 1.4 gives me apertures of 7, 8.4, and 8.4. For the sky background I used 10 and 10 for the annulus sizes.

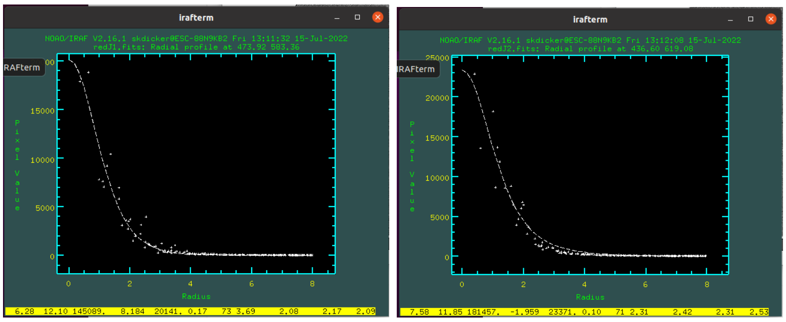

Figure 37. Flux vs radius plots for P161 in the J-filter (We only had enough images for 2 of the positions). Used to find FWHM for aperture photometry.

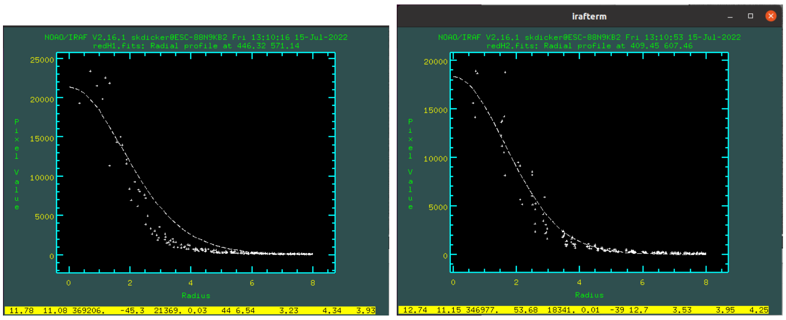

Figure 38. Flux vs radius plots for P161 in the H-filter (We only had enough images for 2 of the positions). Used to find FWHM for aperture photometry.

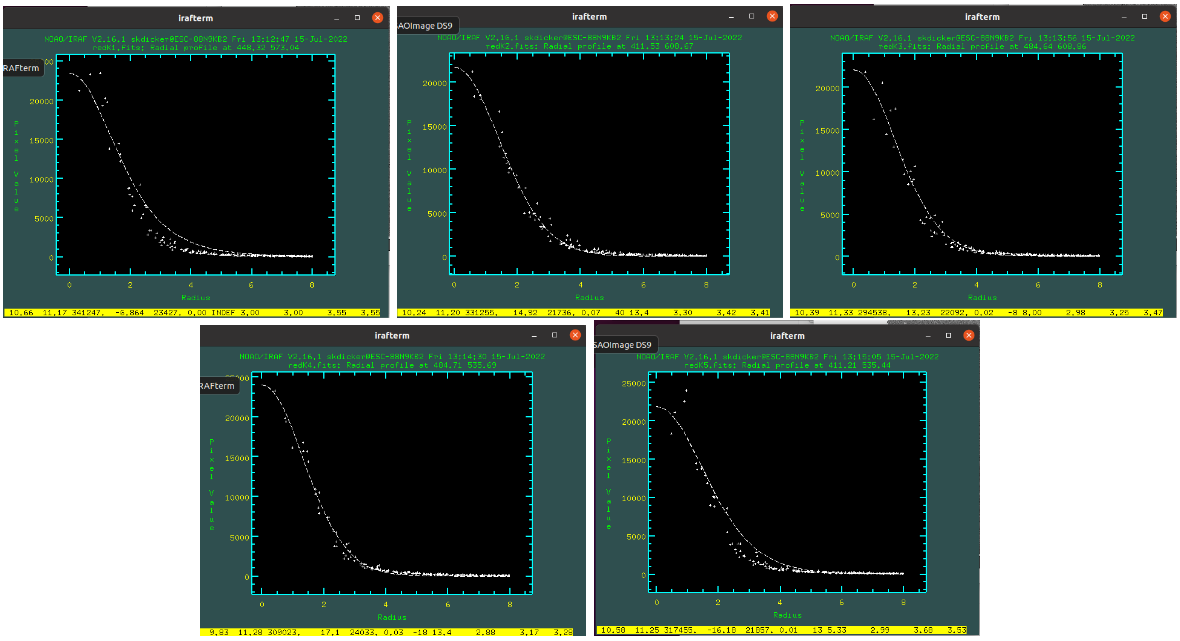

Figure 39. Flux vs radius plots for P161 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.14 April 14th 0652

The finder chart and field of view (with the target marked) are given in [52]. Note that the first two J-band images are junk. These were the first images we took for the night and it seems like the sky

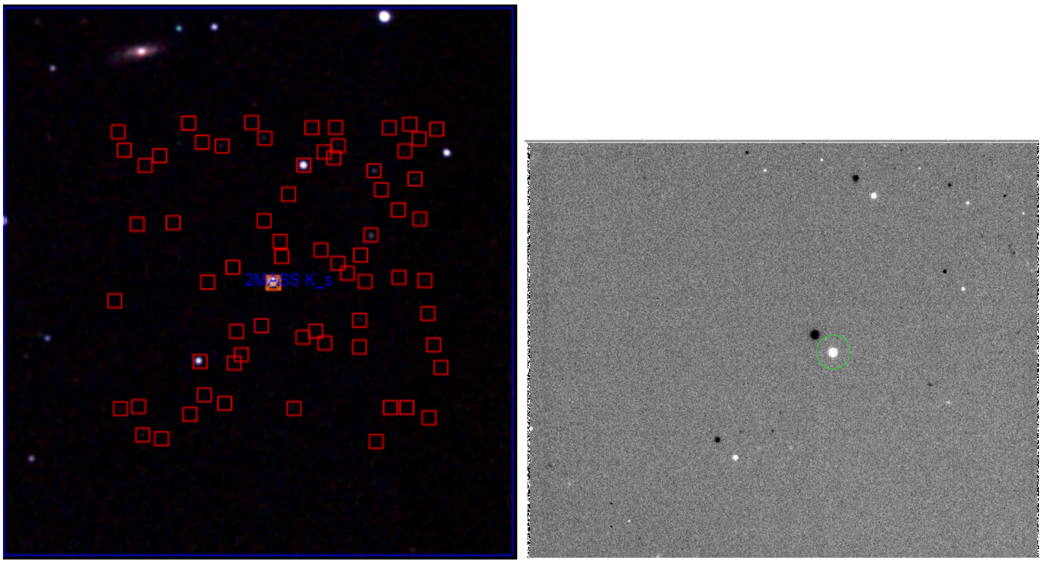

Figure 40. Left is the WISE finder chart from IRSA used to identify the object P530. Right is one of the H images showing the field of view. The target is circled in green.

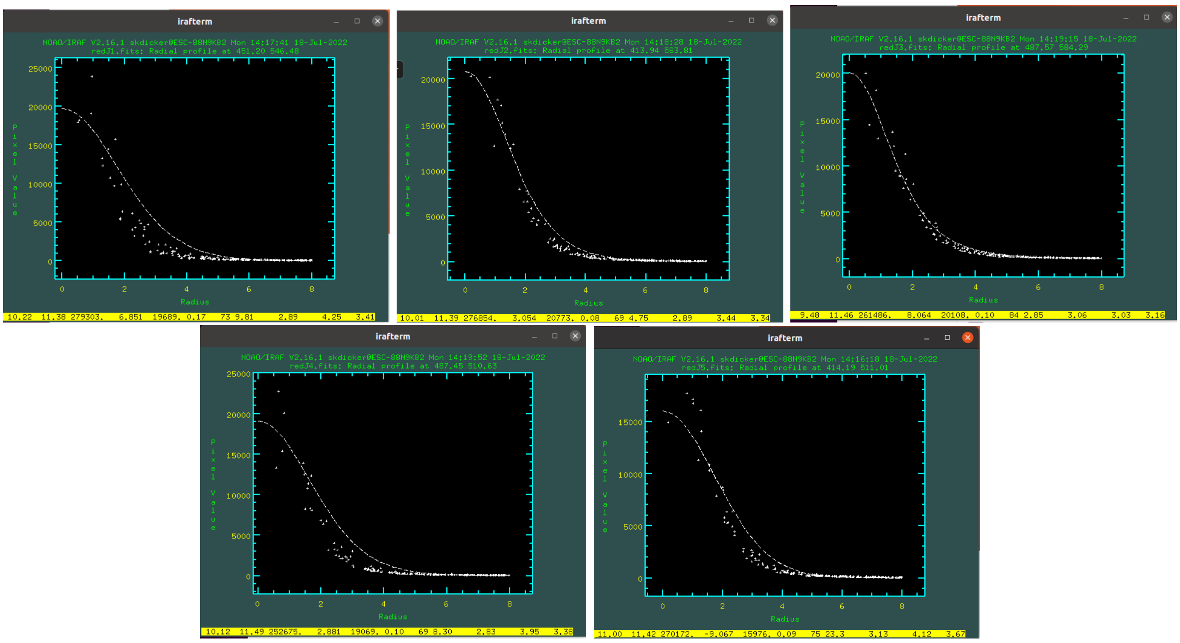

Figure 41. Flux vs radius plots for P530 in the J-filter. Used to find FWHM for aperture photometry.

was too bright. Images 3-5 get progressively better. Hopefully we can work with those. This object does also have a fairly close companion that I should watch as I am performing aperture photometry.

The plots I generated using imexamine to find the FWHM for each filter are given in [53], [54], and [55]. I determine the FWHM for J, H, and K to be about 1*2 = 2, 2*2 = 4, and 2.5*2 = 5. Multiplying by 1.4 gives me apertures of 2.8, 5.6, and 7. For the sky background I used 10 and 10 for the annulus sizes.

NOTE: I did not use the mags from J1 and J2 in my calculations as these images looked horrible and the magnitudes were outliers by a few mag.

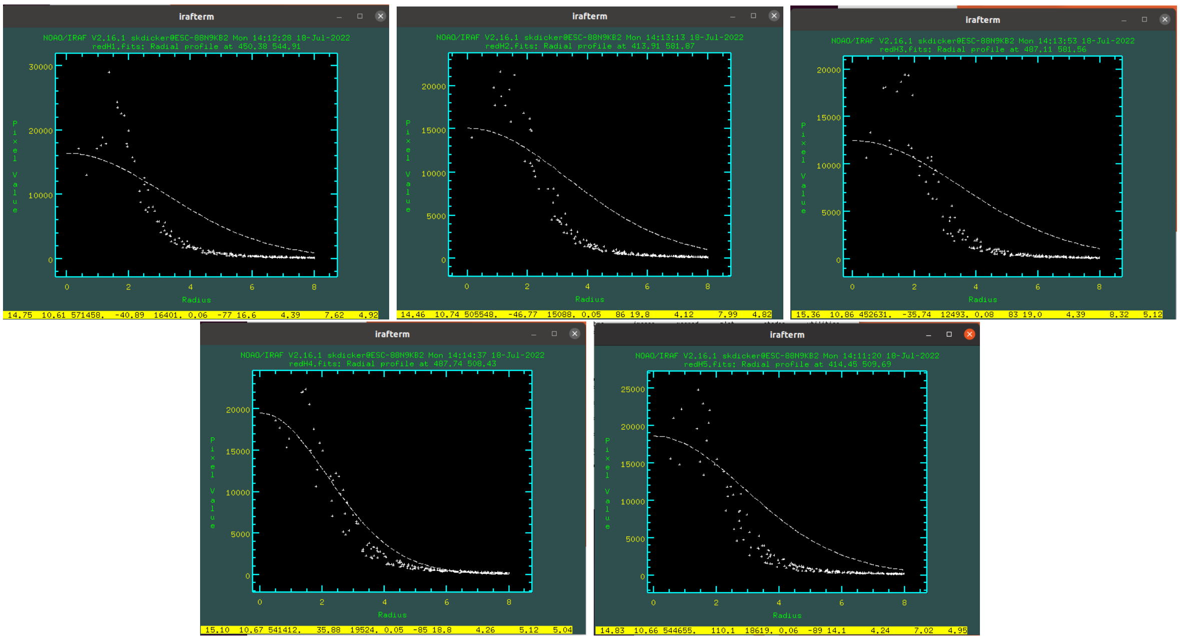

Figure 42. Flux vs radius plots for P530 in the H-filter. Used to find FWHM for aperture photometry.

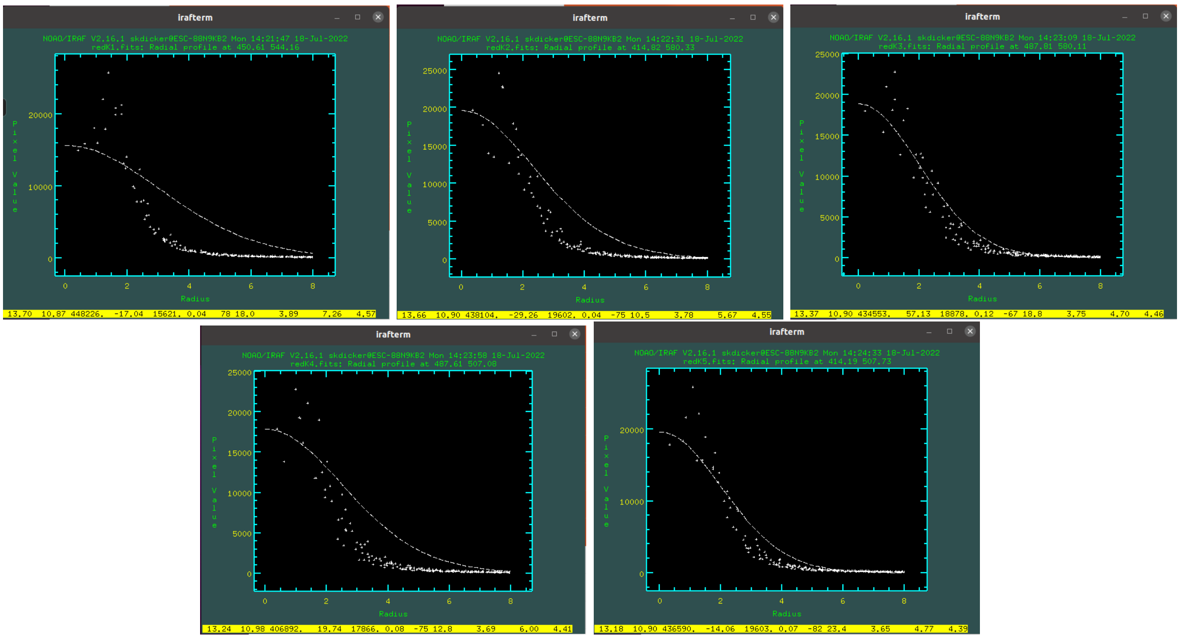

Figure 43. Flux vs radius plots for P530 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.15 April 14th 0656

Something went way wrong with this object. Only the K-frames are useful. I am hoping that I just did something horribly wrong during data reduction. I need to start over and try again and see if the J and H frames will turn out at all.

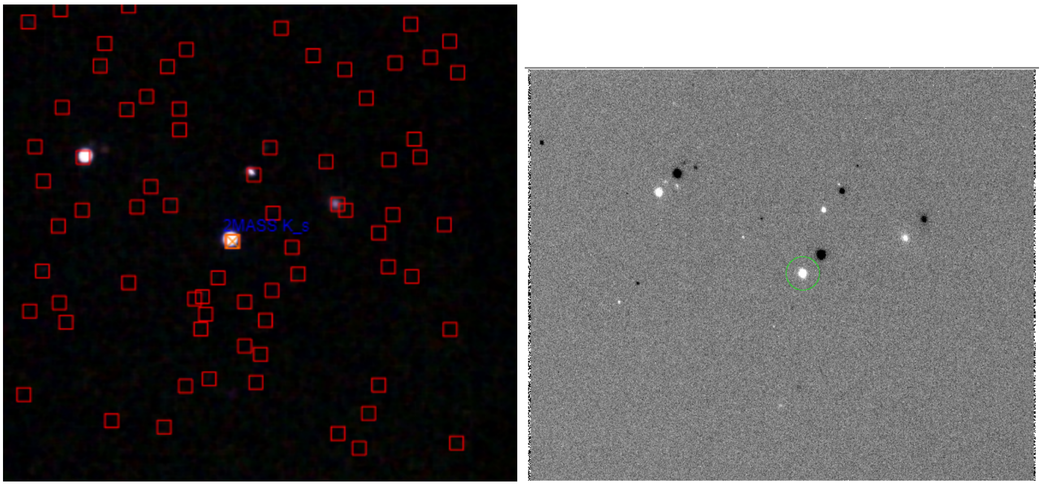

Figure 44. Left is the WISE finder chart from IRSA used to identify the object S754. Right is one of the H images showing the field of view. The target is circled in green.

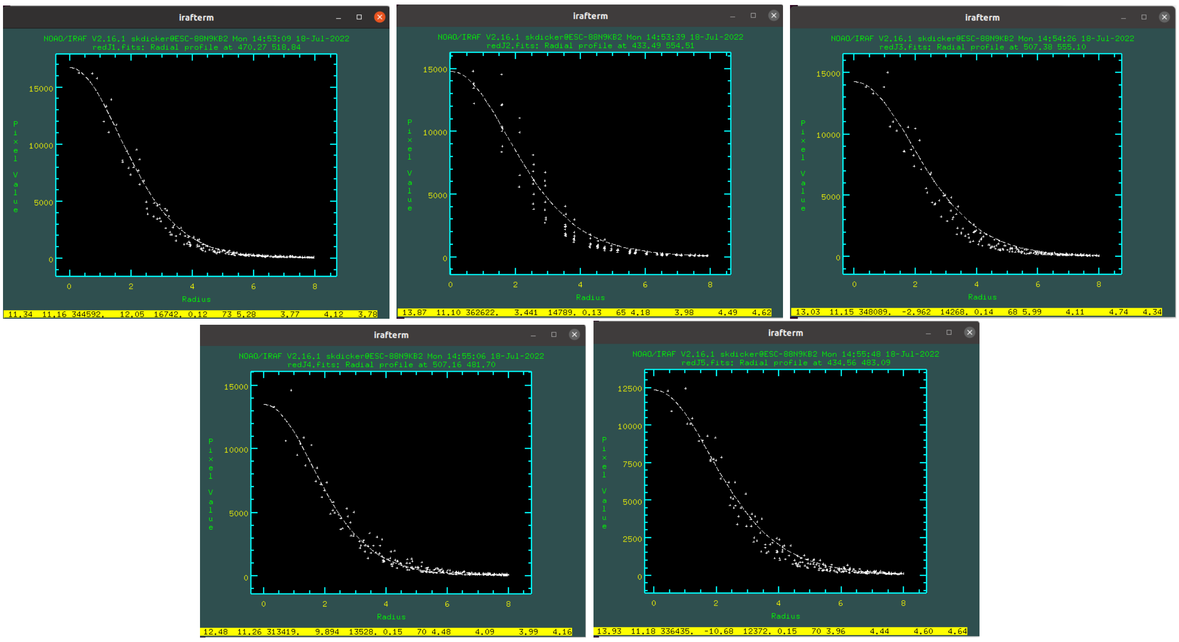

Figure 45. Flux vs radius plots for S754 in the J-filter. Used to find FWHM for aperture photometry.

2.2.16 April 14th 0807

The finder chart and field of view (with the target marked) are given in [56].

The plots I generated using imexamine to find the FWHM for each filter are given in [57], [58], and [59]. I determine the FWHM for J, H, and K to be about 1.7 * 2 = 3.4 for all. Multiplying by 1.4 gives me apertures of 4.76. For the sky background I used 10 and 10 for the annulus sizes.

For some reason, H3 is not converging to give me a magnitude. I tried a bunch of different apertures and none that made sense gave me anything other than ”INDEF”. I have checked the images and my coordinates and everything appears to be in order. The other images look good, so I will just toss this one.

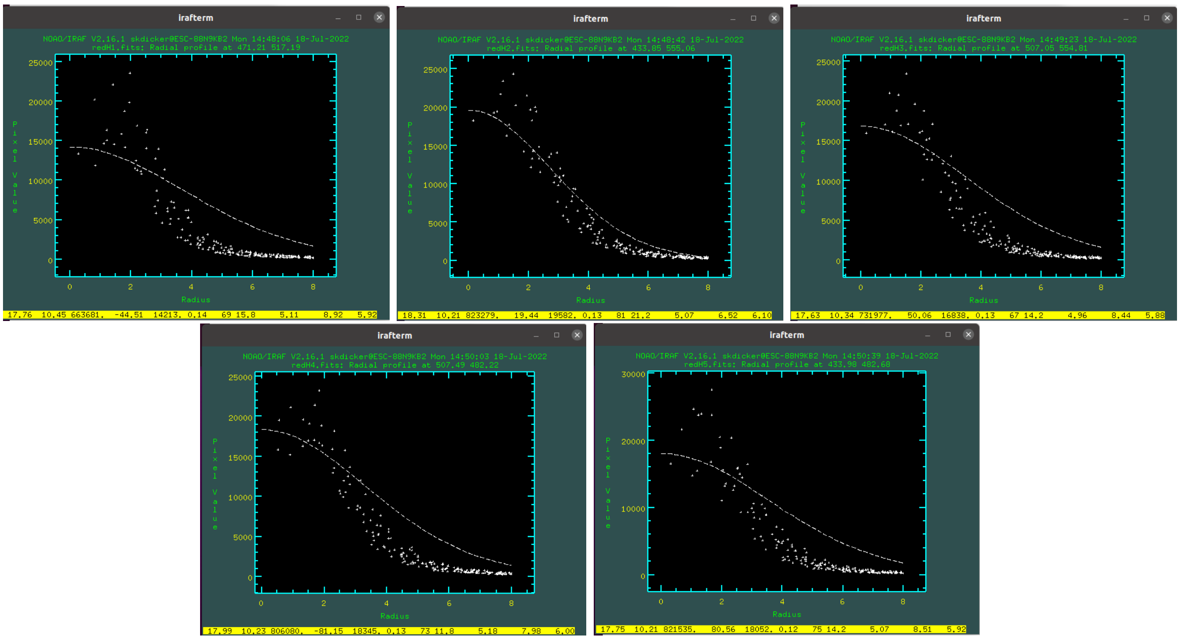

Figure 46. Flux vs radius plots for S754 in the H-filter. Used to find FWHM for aperture photometry.

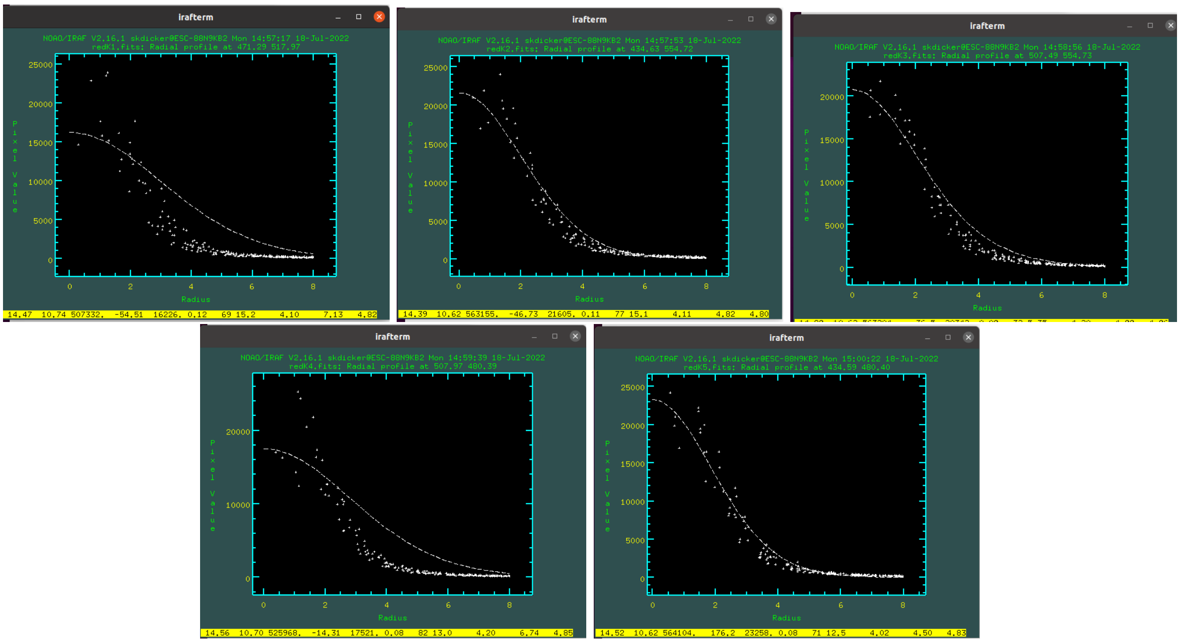

Figure 47. Flux vs radius plots for S754 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.17 April 14th 0819

The finder chart and field of view (with the target marked) are given in [60].

The plots I generated using imexamine to find the FWHM for each filter are given in [61], [62], and [63]. I determine the FWHM for J, H, and K to be about 1.7*2 = 3.4, 2*2 = 4, and 2*2 = 4. Multiplying by 1.4 gives me apertures of 4.76, 5.6, and 5.6. For the sky background I used 10 and 10 for the annulus sizes.

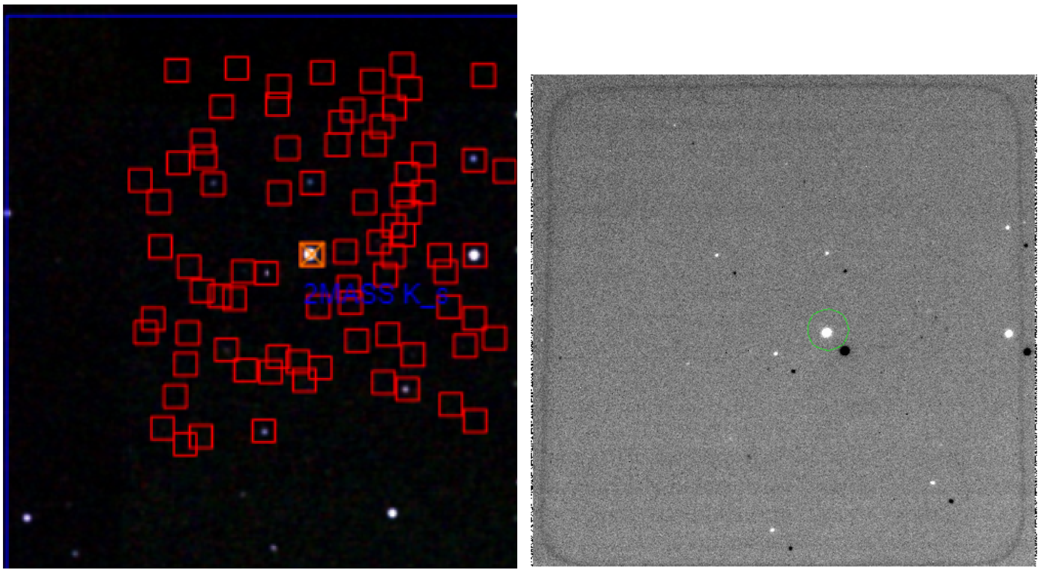

Figure 48. Left is the WISE finder chart from IRSA used to identify the object SA92. Right is one of the H images showing the field of view. The target is circled in green.

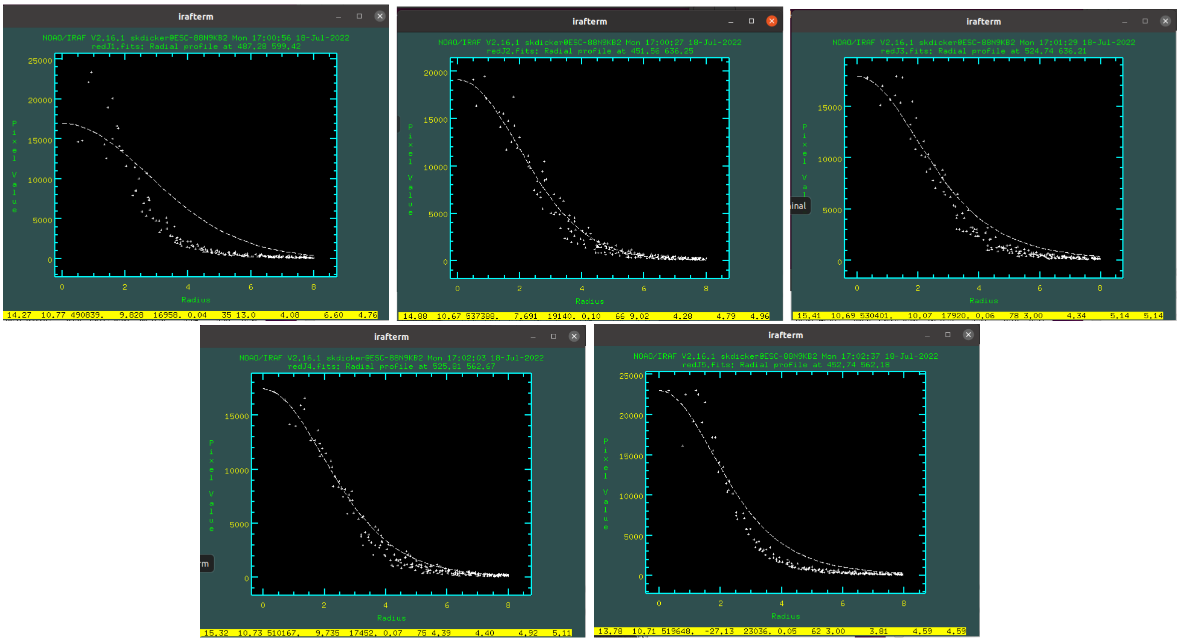

Figure 49. Flux vs radius plots for SA92 in the J-filter. Used to find FWHM for aperture photometry.

2.2.18 April 14th 0852

The finder chart and field of view (with the target marked) are given in [64].

The plots I generated using imexamine to find the FWHM for each filter are given in [65], [66], and [67]. I determine the FWHM for J, H, and K to be about 1.5*2 = 3. Multiplying by 1.4 gives me apertures of 4.2. For the sky background I used 10 and 10 for the annulus sizes.

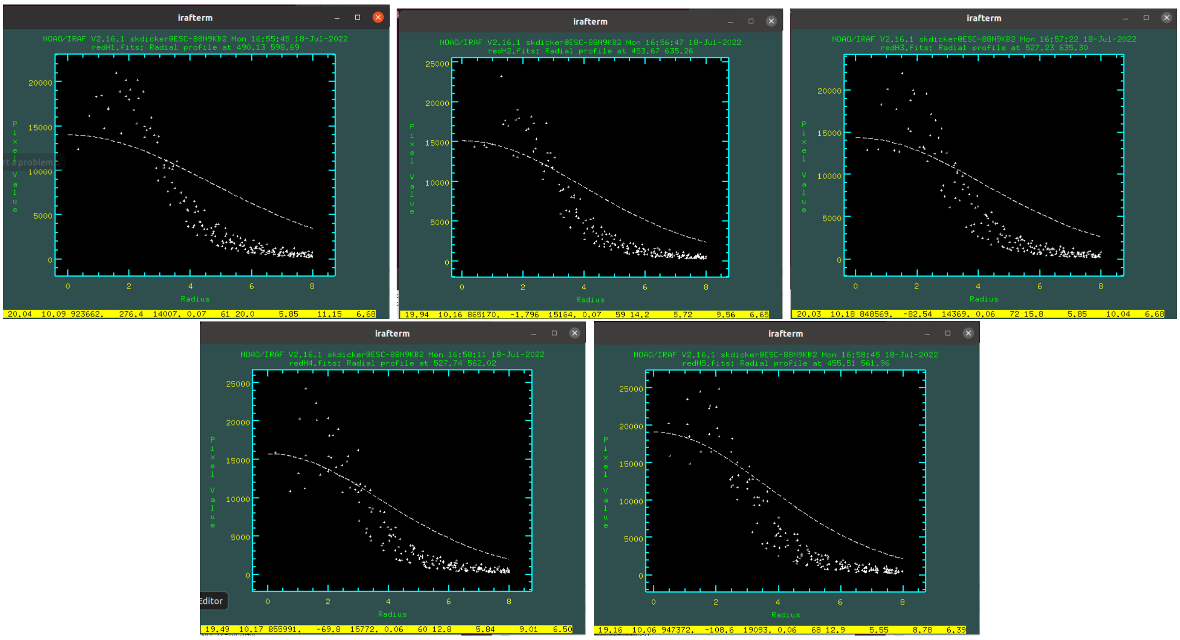

Figure 50. Flux vs radius plots for SA92 in the H-filter. Used to find FWHM for aperture photometry.

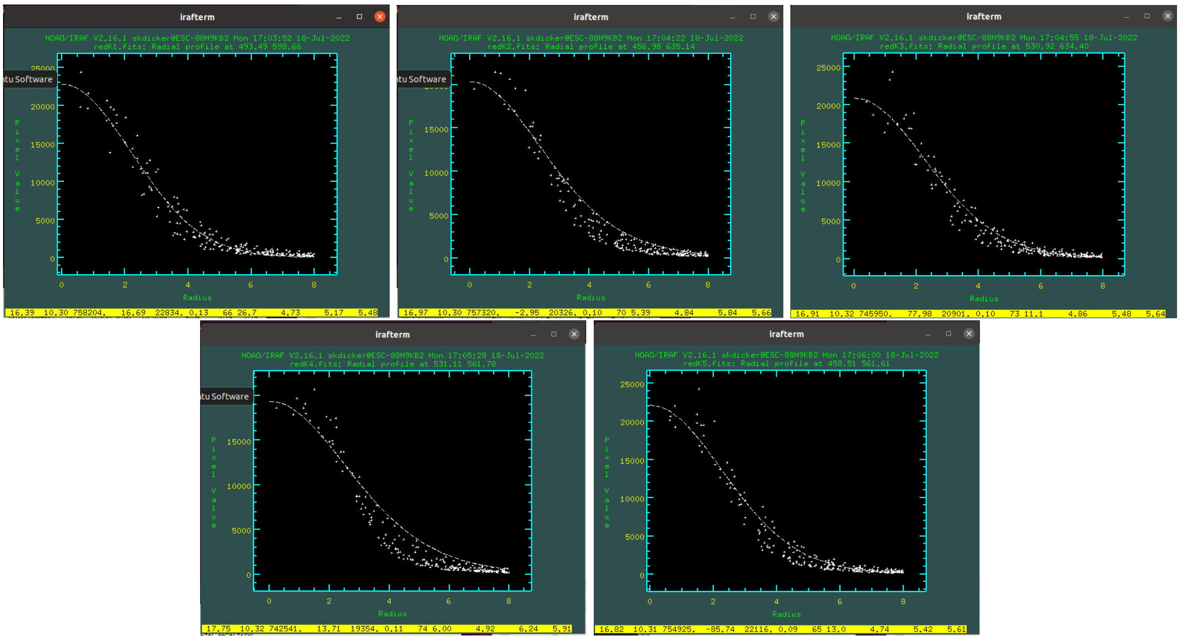

Figure 51. Flux vs radius plots for SA92 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.19 April 14th 0857

The finder chart and field of view (with the target marked) are given in [68]. This field was full of faint objects. I am only about 75 percent sure that I found the correct object in the field. There are other objects/shadows very close to the object so this could be a problem during reduction. Keep an eye on photometry results to see if I need to do something different.

The plots I generated using imexamine to find the FWHM for each filter are given in [69], [70], and [71]. I determine the FWHM for J, H, and K to be about 1.7*2 = 3.4. Multiplying by 1.4 gives

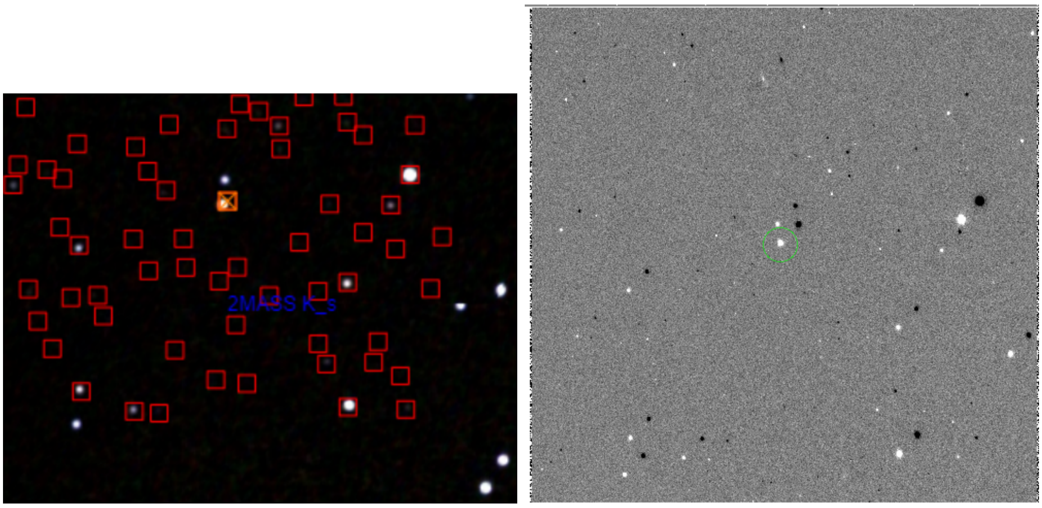

Figure 52. Left is the WISE finder chart from IRSA used to identify the object 0652. Right is one of the H images showing the field of view. The target is circled in green.

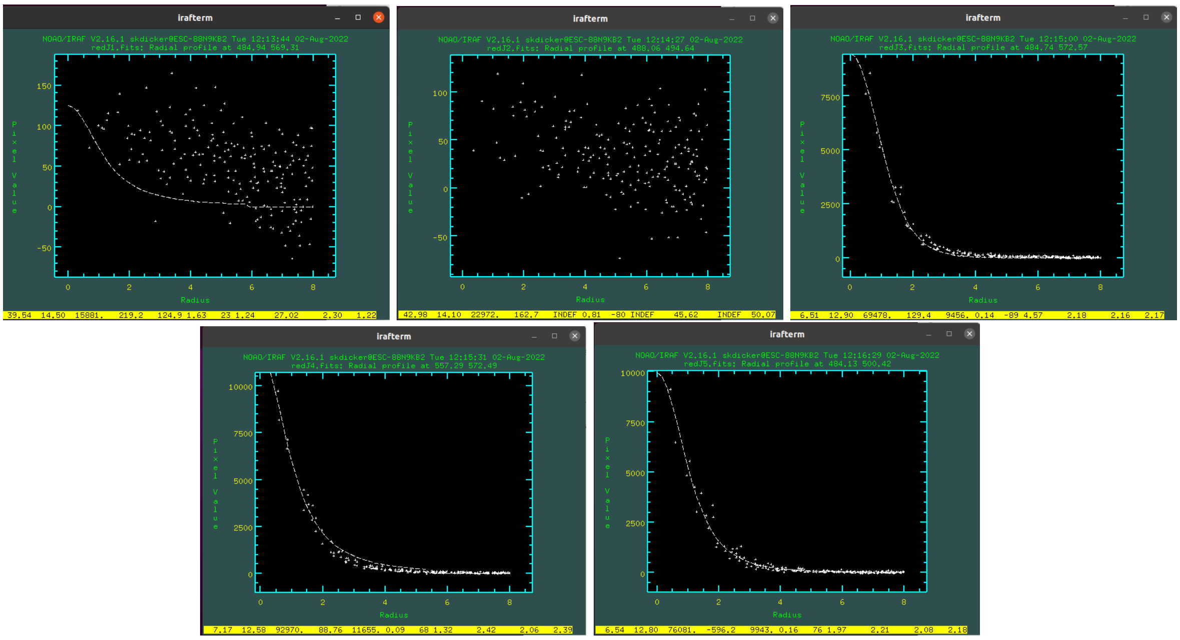

Figure 53. Flux vs radius plots for 0652 in the J-filter. The lack of flux in the first two images is most likely because we started taking data too soon and the objects were lost in the sky flux. Used to find FWHM for aperture photometry.

me apertures of 4.76. For the sky background I used 10 and 10 for the annulus sizes.

2.2.20 April 14th 0908

The finder chart and field of view (with the target marked) are given in [72]. This field was very empty and there was not much to go off of while looking for the target.

The plots I generated using imexamine to find the FWHM for each filter are given in [73], [74], and [75]. I determine the FWHM for J, H, and K to be about 2*2 = 4. Multiplying by 1.4 gives me apertures of 5.6. For the sky background I used 10 and 10 for the annulus sizes.

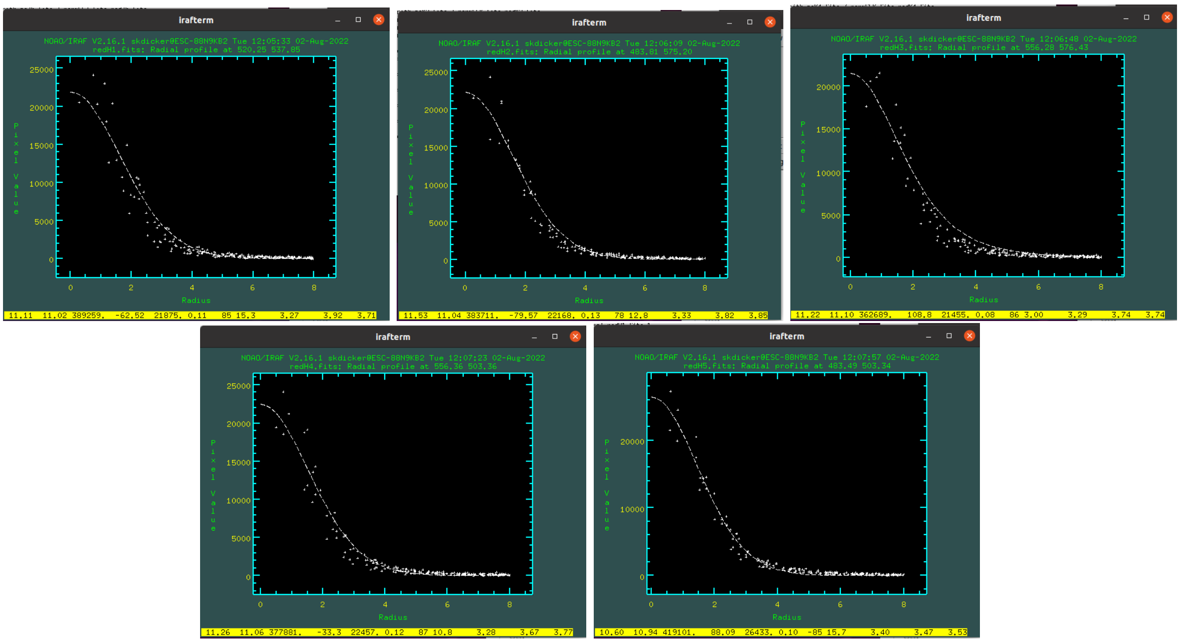

Figure 54. Flux vs radius plots for 0652 in the H-filter. Used to find FWHM for aperture photometry.

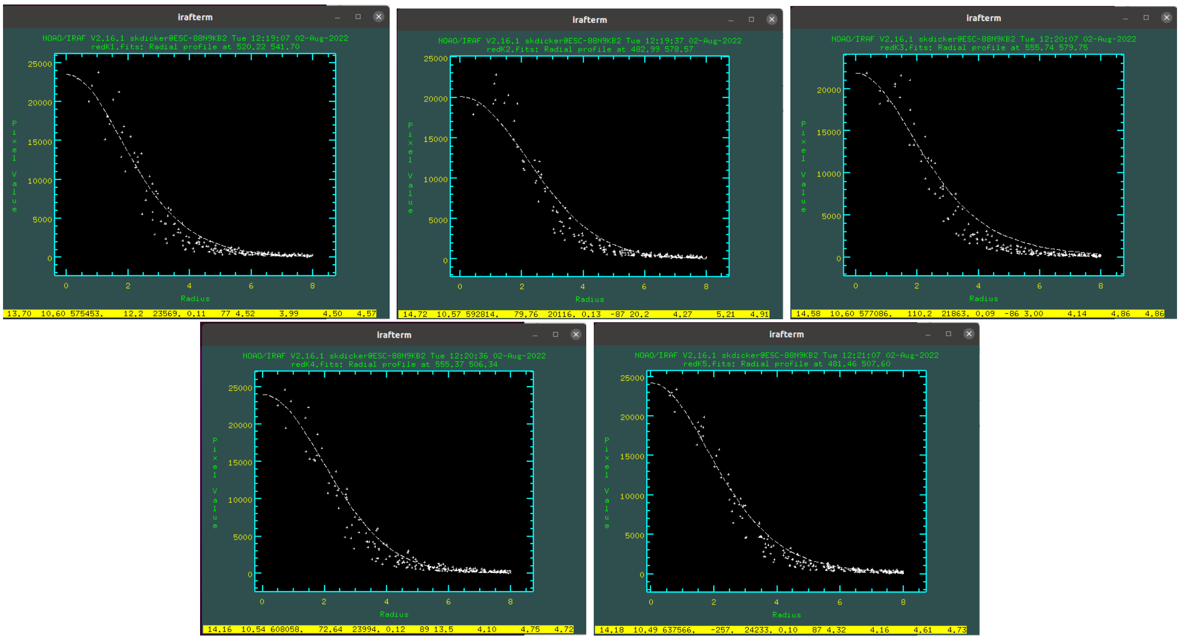

Figure 55. Flux vs radius plots for 0652 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.21 April 14th 1007

The finder chart and field of view (with the target marked) are given in [76]. We didn't have time to get H-filter frames, and we only got 3 each J- and K-frames. Unfortunately, the J1 image is horribly dim and the J2 image is pretty blurry. I can probably only use J2-3 and K1-3.

The plots I generated using imexamine to find the FWHM for each filter are given in [77] and [78]. I determine the FWHM for J and K to be about 2*2 = 4 and 1.5*2 = 3. Multiplying by 1.4 gives me apertures of 5.6 and 4.2. For the sky background I used 10 and 10 for the annulus sizes.

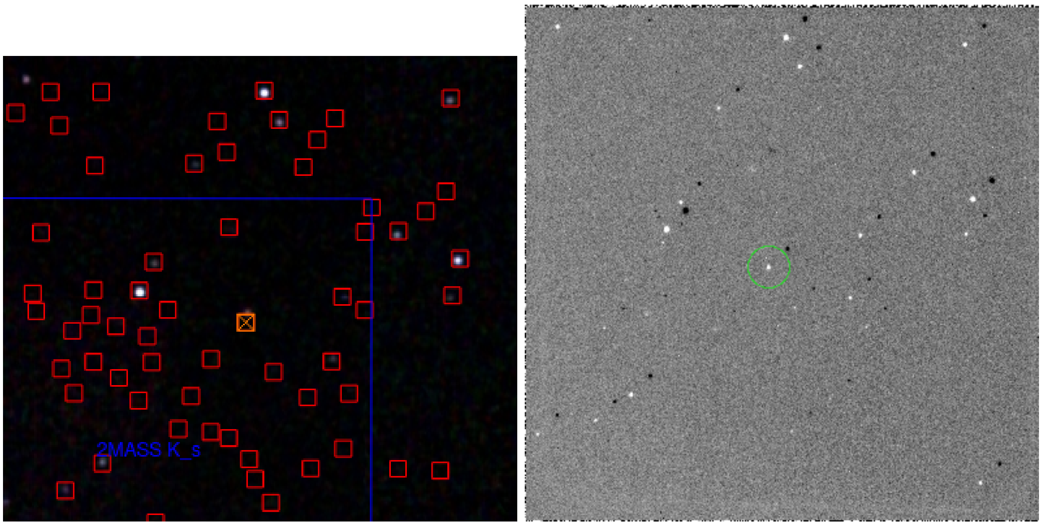

Figure 56. Left is the WISE finder chart from IRSA used to identify the object 0807. Right is one of the H images showing the field of view. The target is circled in green.

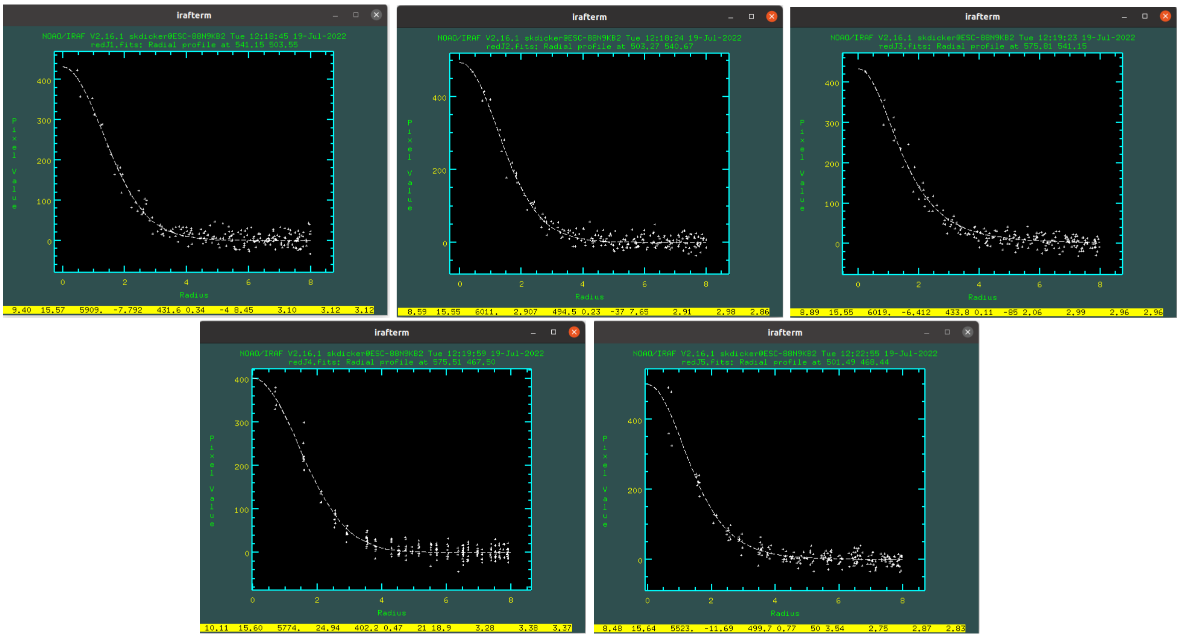

Figure 57. Flux vs radius plots for 0807 in the J-filter. Used to find FWHM for aperture photometry.

2.2.22 April 14th LHS2026

The finder chart and field of view (with the target marked) are given in [79].

The plots I generated using imexamine to find the FWHM for each filter are given in [80], [81], and [82]. I determine the FWHM for J, H, and K to be about 2*2 = 4. Multiplying by 1.4 gives me apertures of 5.6. For the sky background I used 10 and 10 for the annulus sizes.

The mags I got for all of my K images were extremely different from the mags I got for J and H. I checked my coordinate files and realized that my K coordinate files were all mixed up. Fixing that gave me magnitudes that made more sense.

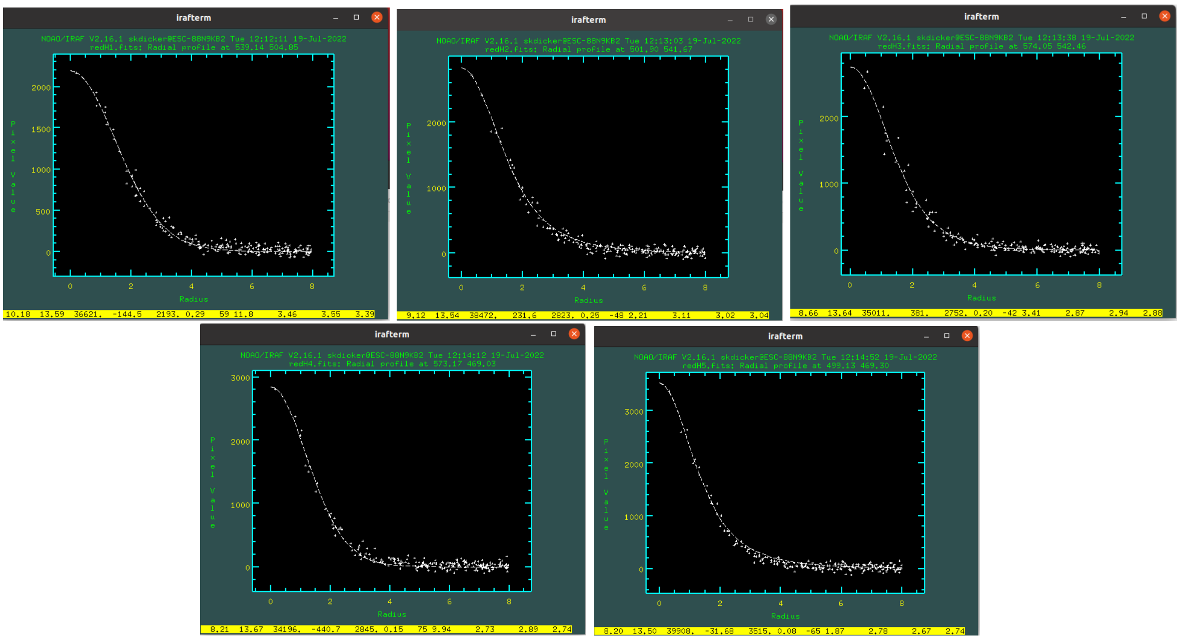

Figure 58. Flux vs radius plots for 0807 in the H-filter. Used to find FWHM for aperture photometry.

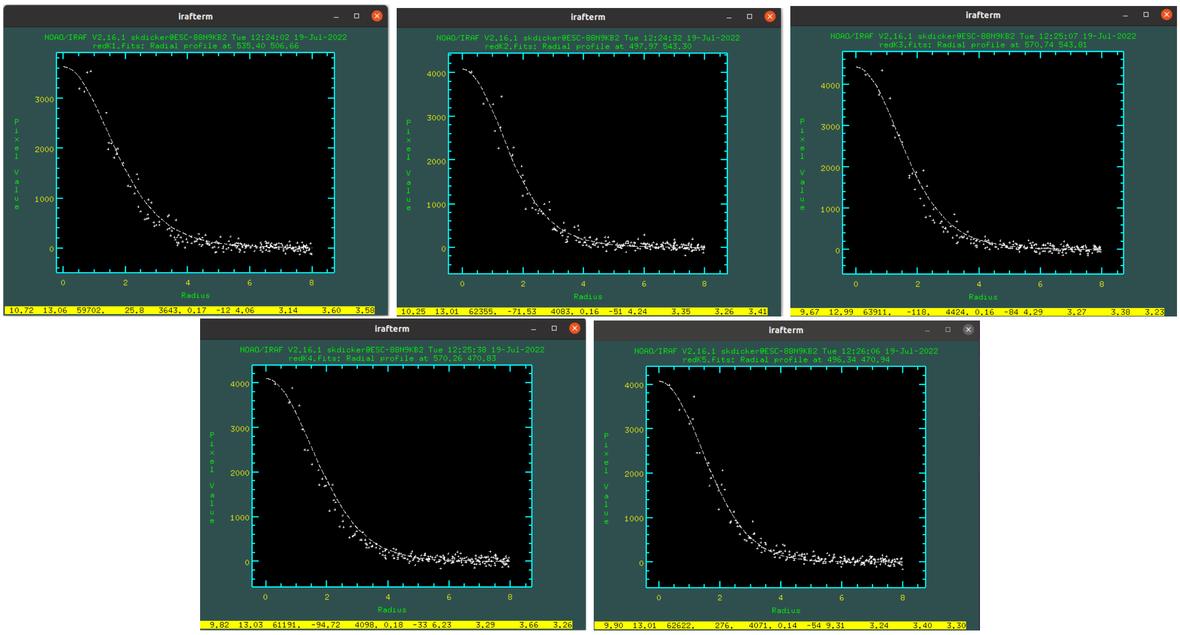

Figure 59. Flux vs radius plots for 0807 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.23 April 14th p259

The finder chart and field of view (with the target marked) are given in [83].

Note that I used this standard for enough objects that I needed to observe it twice in one night. The data files from the two different observations were all reduced separately due to the differing airmass.

The plots I generated using imexamine to find the FWHM for each filter are given in [84],[87], [85],[88], [86] and [89]. I determine the FWHM for J, H, and K to be about 2.5*2 = 5. It was a little hard to determine this as the radius plots failed to converge, so this might be worth checking.

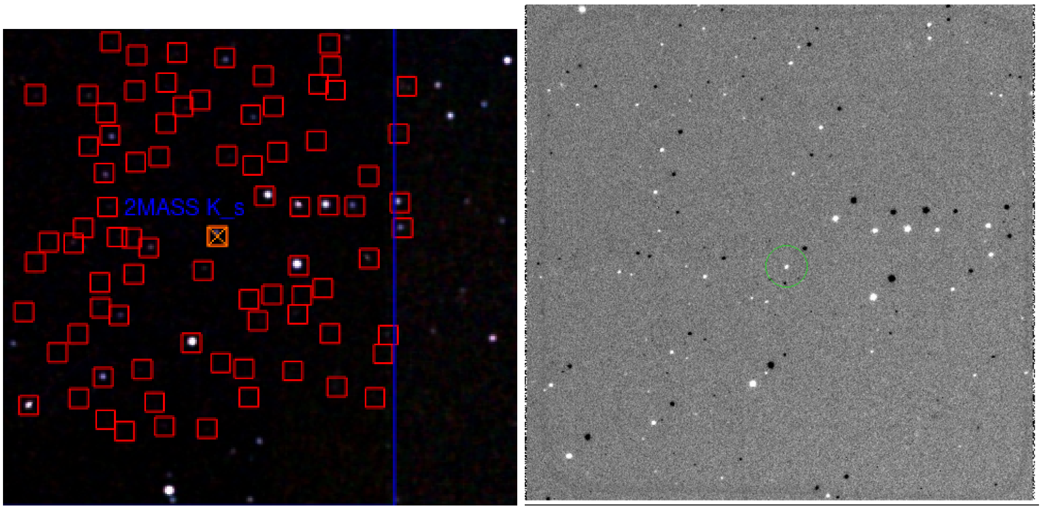

Figure 60. Left is the WISE finder chart from IRSA used to identify the object 0819. Right is one of the H images showing the field of view. The target is circled in green.

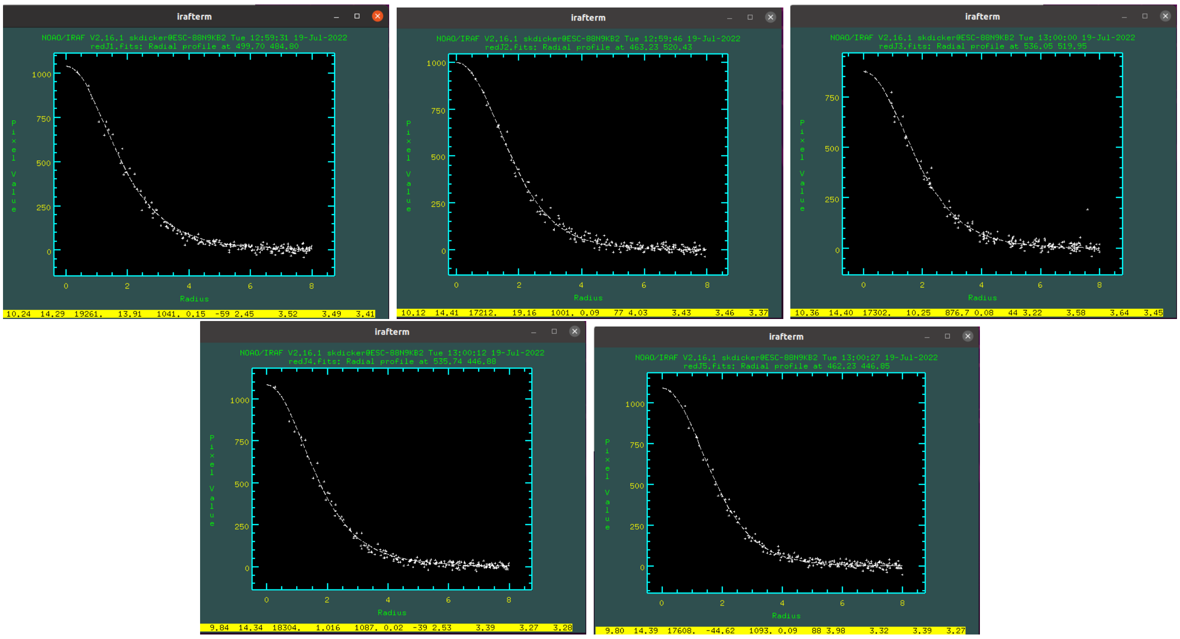

Figure 61. Flux vs radius plots for 0819 in the J-filter. Used to find FWHM for aperture photometry.

Multiplying by 1.4 gives me apertures of 7. For J2, H2, and K2 I find the FWHM to be 2*2 = 4. Again, this was hard to determine as H and K did not converge. Multiplying by 1.4 gives me apertures of 5.6. For the sky background I used 10 and 10 for the annulus sizes.

2.2.24 April 14th p161

The finder chart and field of view (with the target marked) are given in [90].

The plots I generated using imexamine to find the FWHM for each filter are given in [91], [92], and [93]. I determine the FWHM for J, H, and K to be about 1.5*2 = 3, 2*2 = 4, and 2*2 = 4. Multiplying by 1.4 gives me apertures of 4.3, 5.6, 5.6. For the sky background I used 10 and 10 for the annulus sizes.

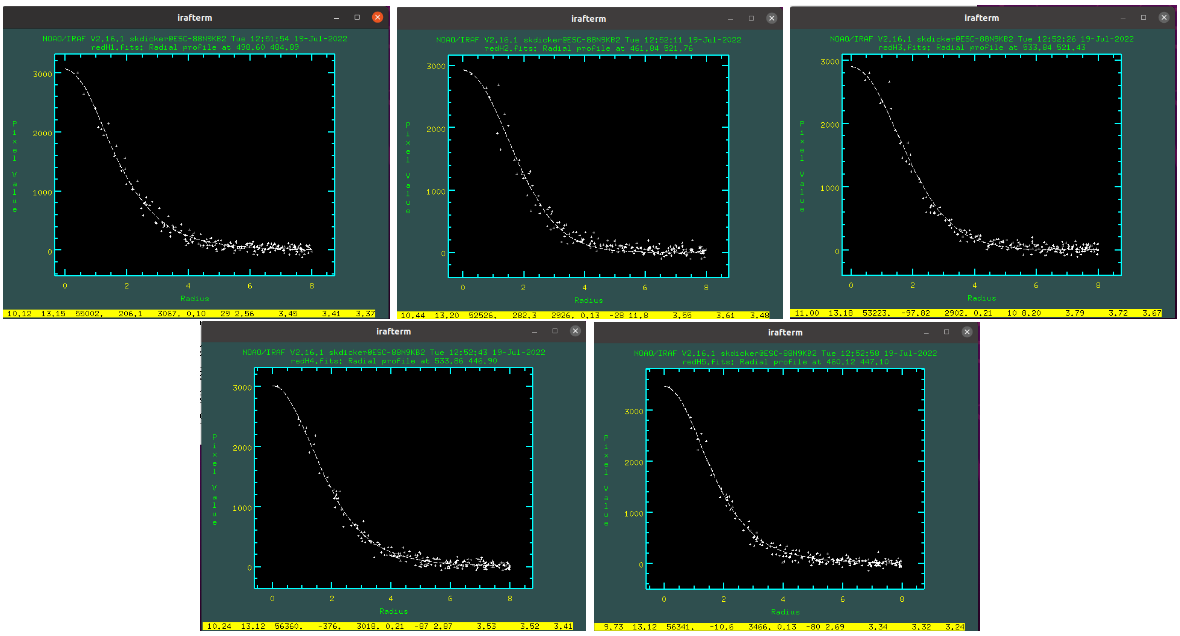

Figure 62. Flux vs radius plots for 0819 in the H-filter. Used to find FWHM for aperture photometry.

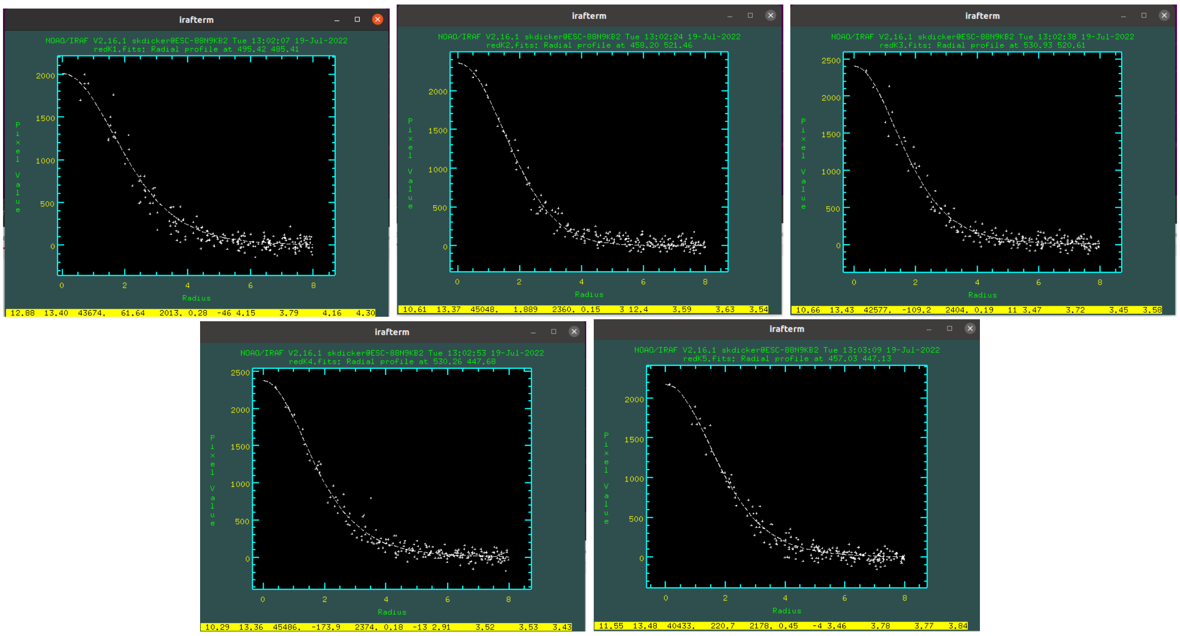

Figure 63. Flux vs radius plots for 0819 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

2.2.25 July 8th 1746

The finder chart and field of view (with the target marked) are given in [94].

The plots I generated using imexamine to find the FWHM for each filter are given in [95], [96], and [97]. I determine the FWHM for J, H, and K to be about 1.5*2 = 3, 1*2 = 2, and 2*2 = 4. Multiplying by 1.4 gives me apertures of 4.2, 2.8, and 5.6. For the sky background I used 10 and 10 for the annulus sizes.

I rejected image H1 from my calculations as the magnitude was almost 2 mags off from the others.

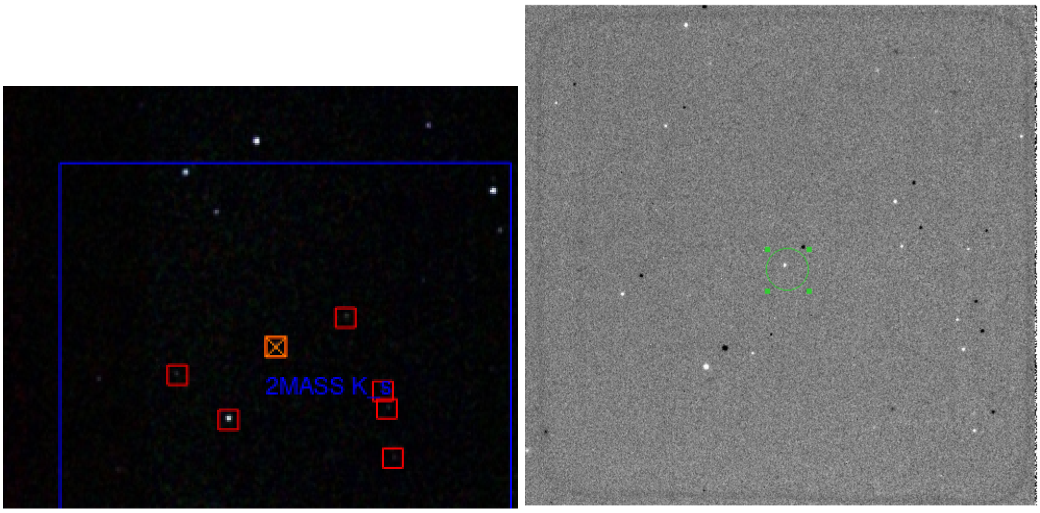

Figure 64. Left is the WISE finder chart from IRSA used to identify the object 0852. Right is one of the H images showing the field of view. The target is circled in green.

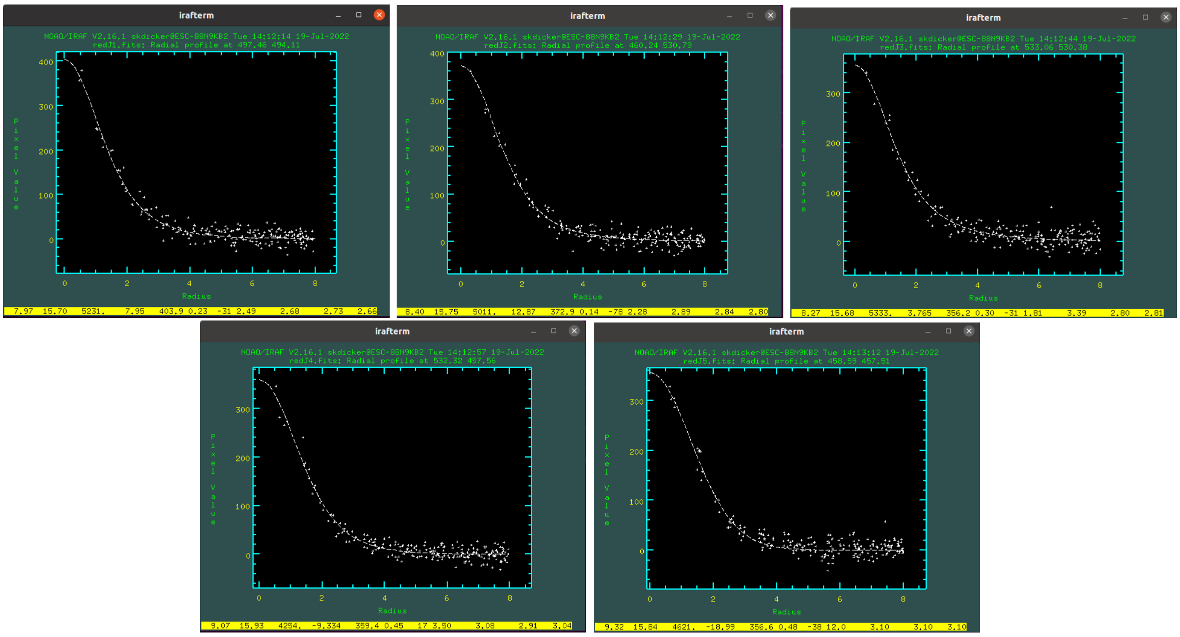

Figure 65. Flux vs radius plots for 0852 in the J-filter. Used to find FWHM for aperture photometry.

Justification: graph failed to converge and had really low counts.

2.2.26 July 8th p138

The finder chart and field of view (with the target marked) are given in [98].

The plots I generated using imexamine to find the FWHM for each filter are given in [99], [100], and [101]. I determine the FWHM for J, H, and K to be about 2.5*2=5, 3.5*2=7, and 4.5*2=9. Multiplying by 1.4 gives me apertures of 7, 9.8, and 12.6. For the sky background I used 15 and 10 for the annulus sizes.

The J5 image is majorly broken. I am not yet sure if I messed something up during reduction or if the image was wiped to begin with. Check on this later.

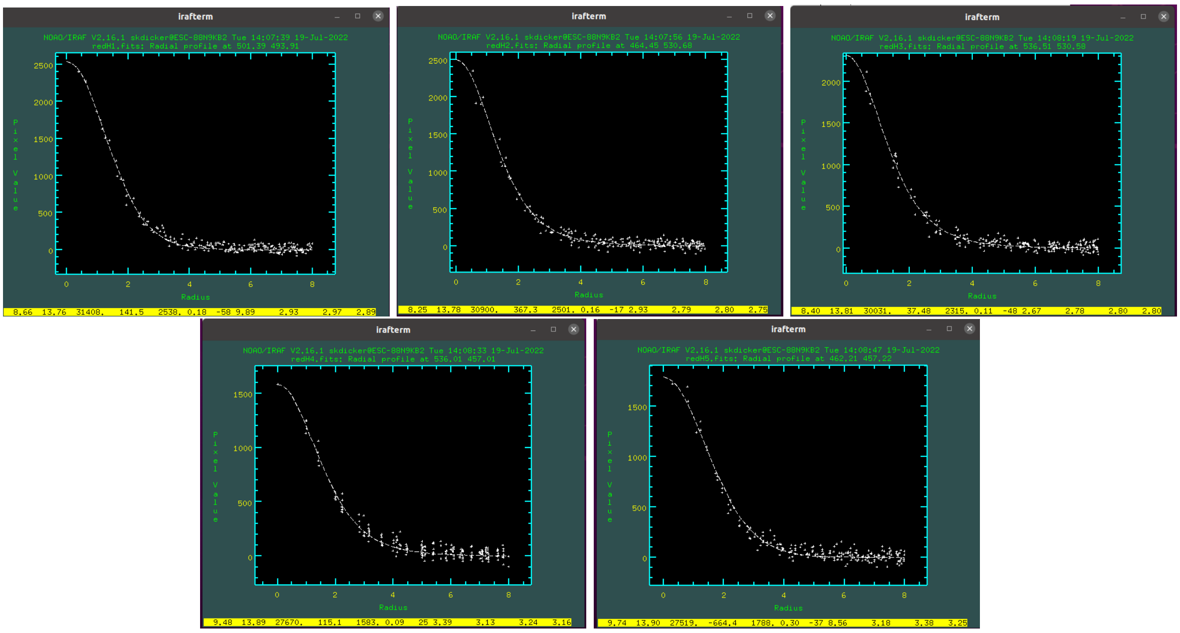

Figure 66. Flux vs radius plots for 0852 in the H-filter. Used to find FWHM for aperture photometry.

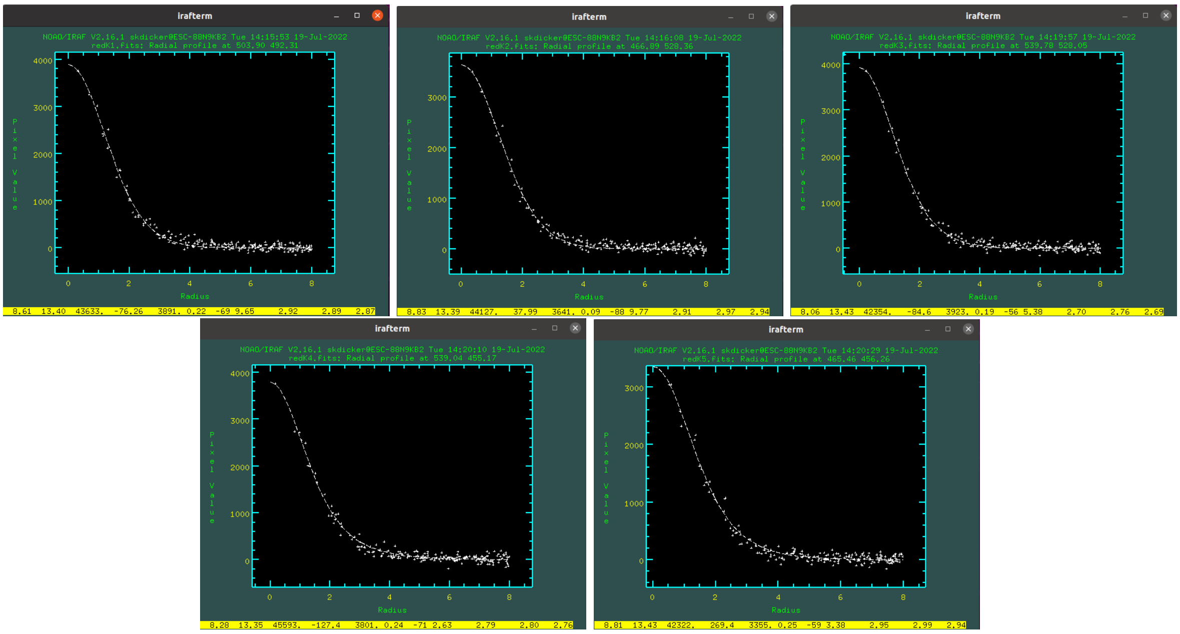

Figure 67. Flux vs radius plots for 0852 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

Is it a problem that my sky annuli are different for this standard than for the target? Research this.

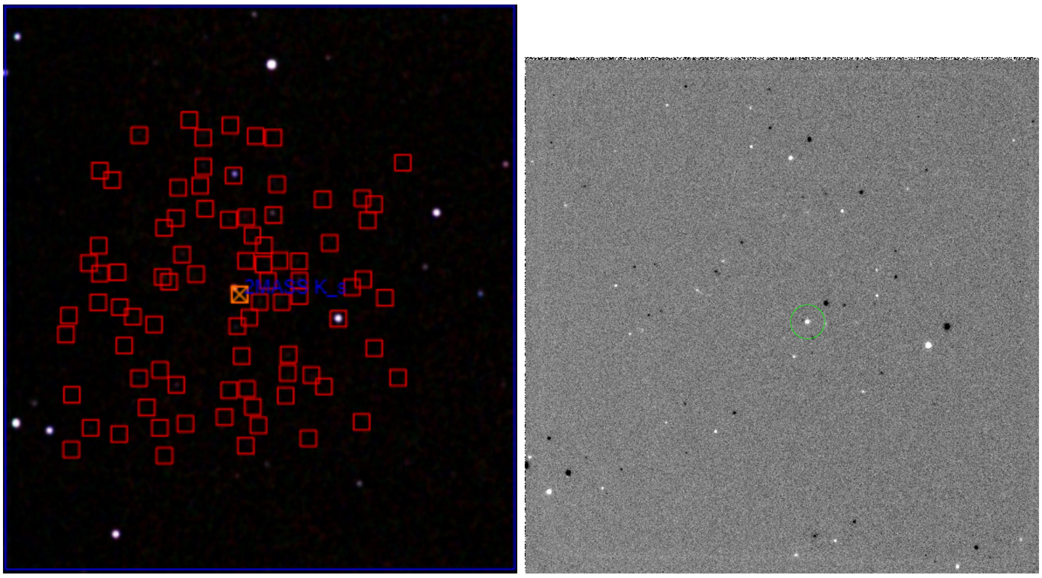

Figure 68. Left is the WISE finder chart from IRSA used to identify the object 0857. Right is one of the H images showing the field of view. The target is circled in green.

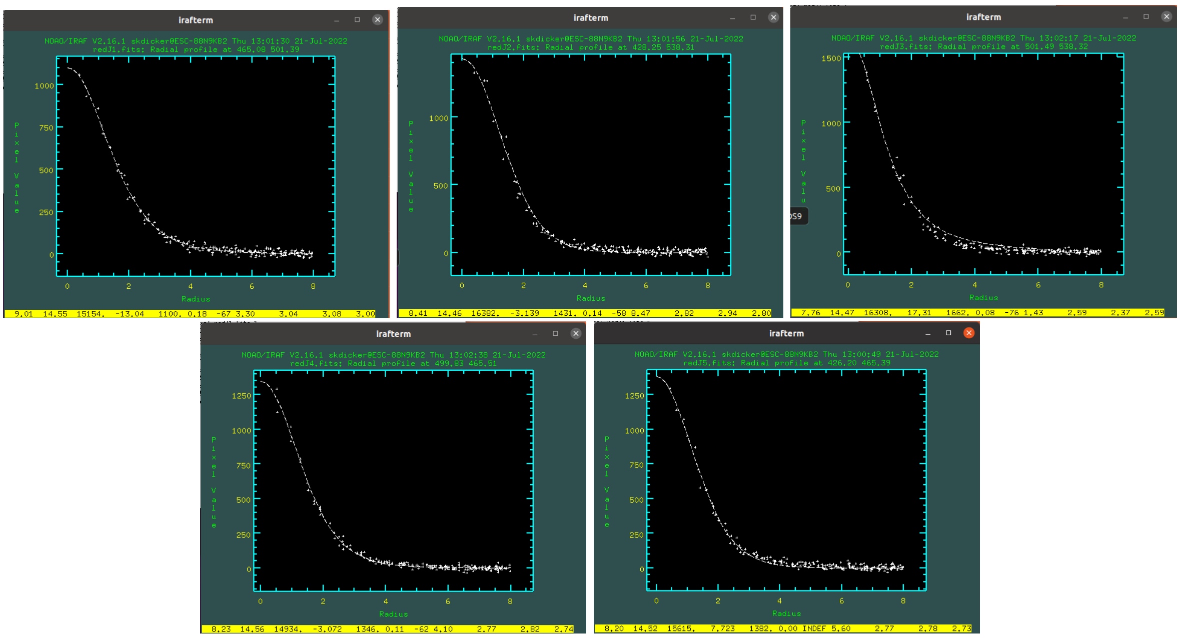

Figure 69. Flux vs radius plots for 0857 in the J-filter. Used to find FWHM for aperture photometry.

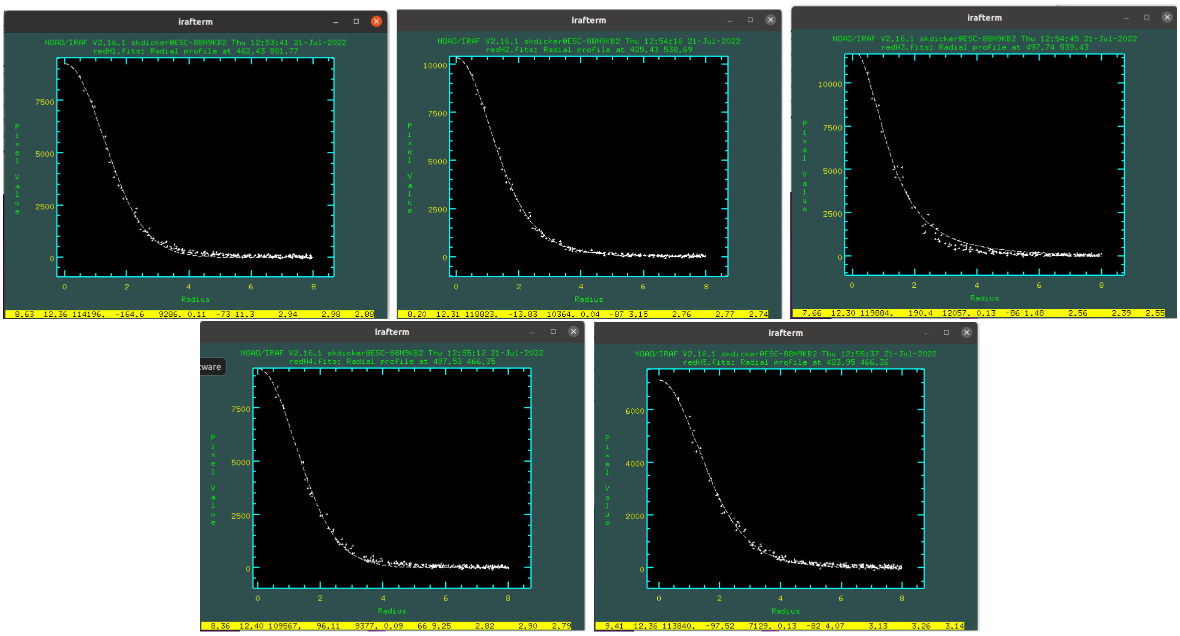

Figure 70. Flux vs radius plots for 0857 in the H-filter. Used to find FWHM for aperture photometry.

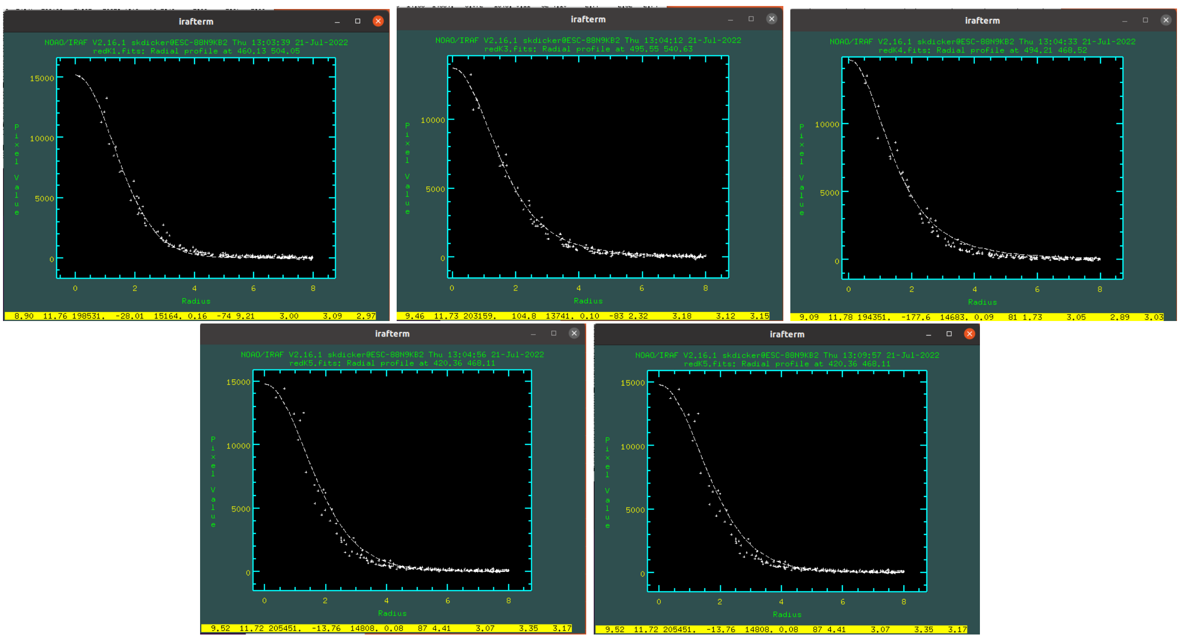

Figure 71. Flux vs radius plots for 0857 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

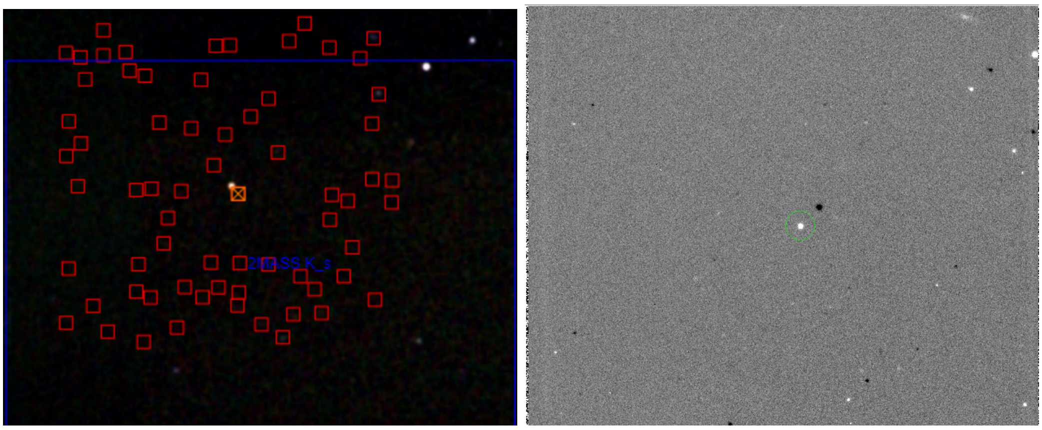

Figure 72. Left is the WISE finder chart from IRSA used to identify the object 0908. Right is one of the H images showing the field of view. The target is circled in green.

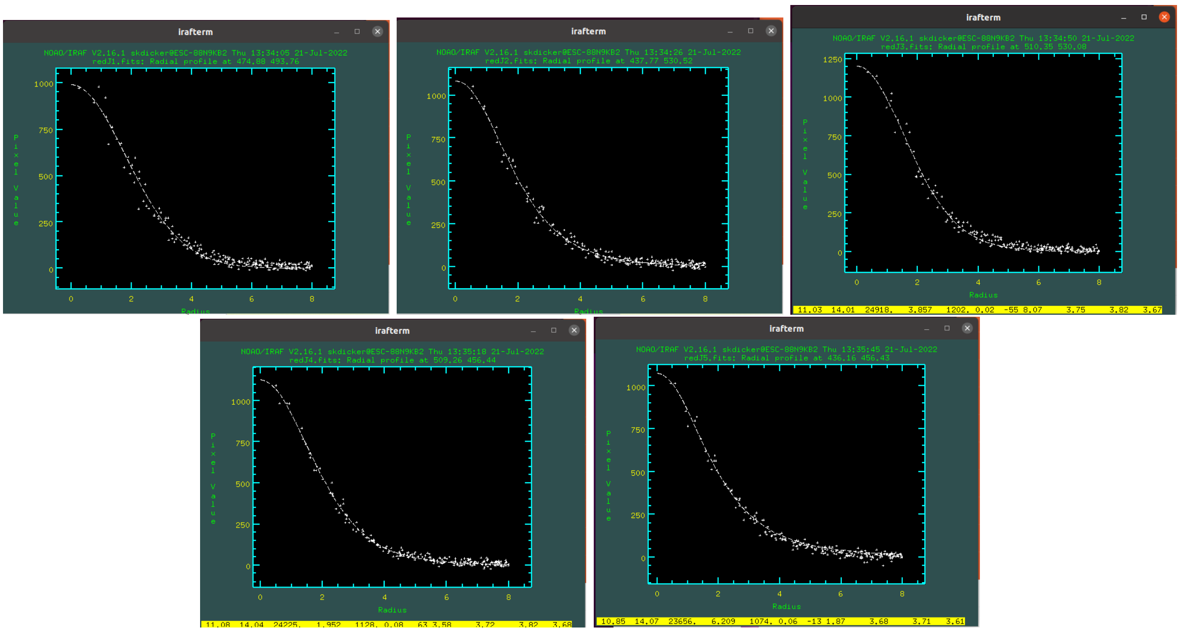

Figure 73. Flux vs radius plots for 0908 in the J-filter. Used to find FWHM for aperture photometry.

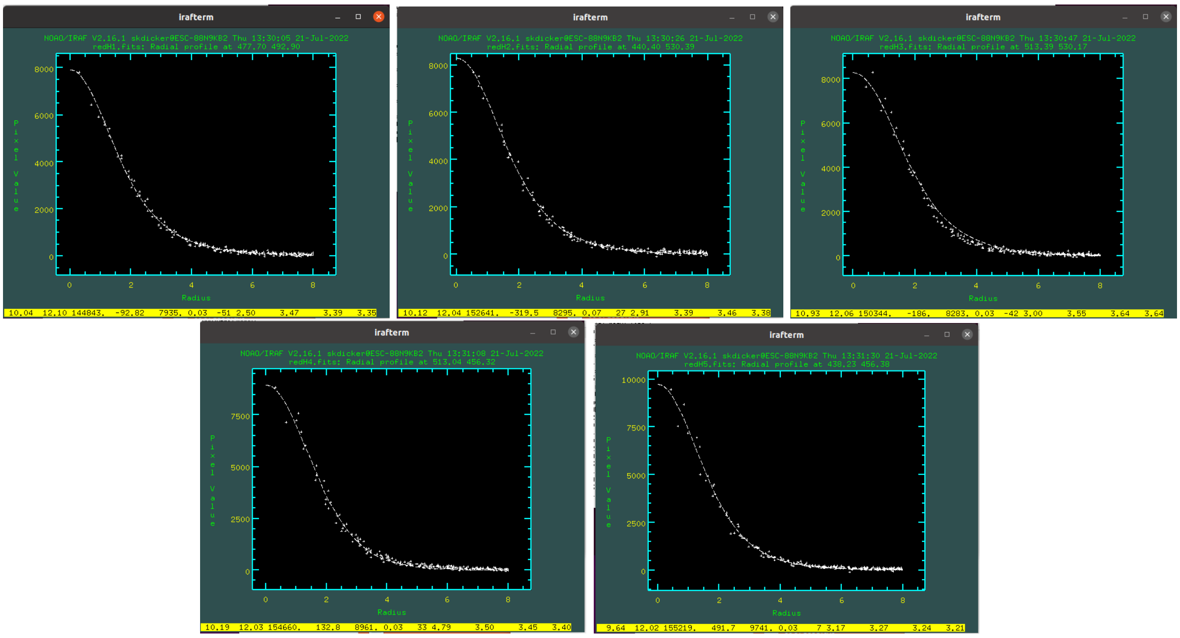

Figure 74. Flux vs radius plots for 0908 in the H-filter. Used to find FWHM for aperture photometry.

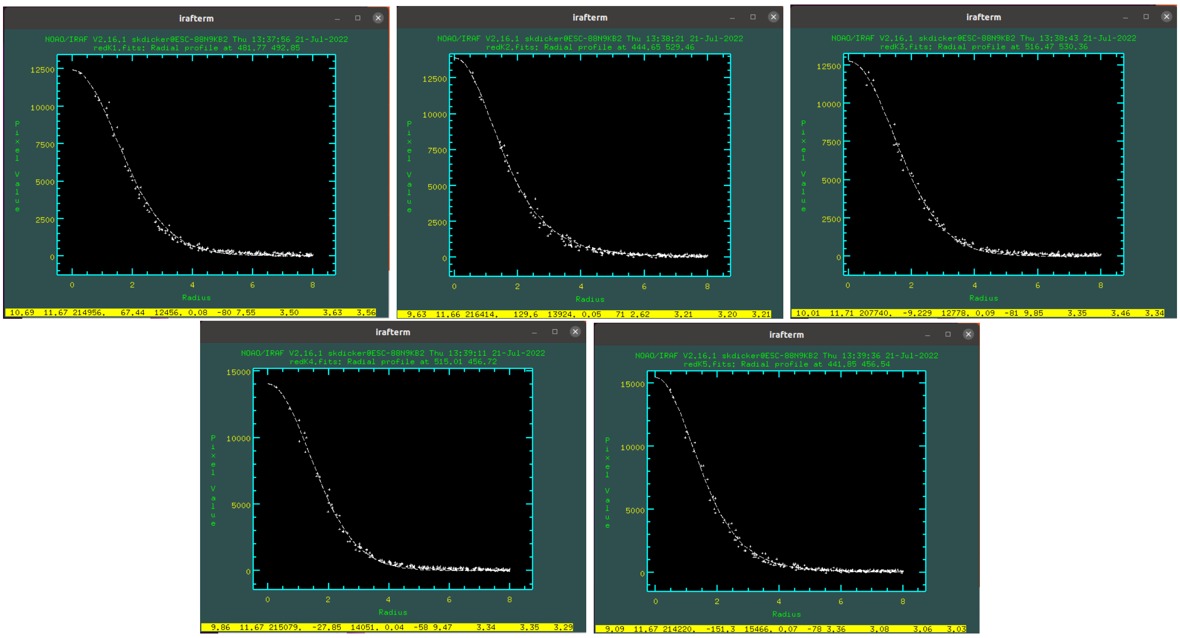

Figure 75. Flux vs radius plots for 0908 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

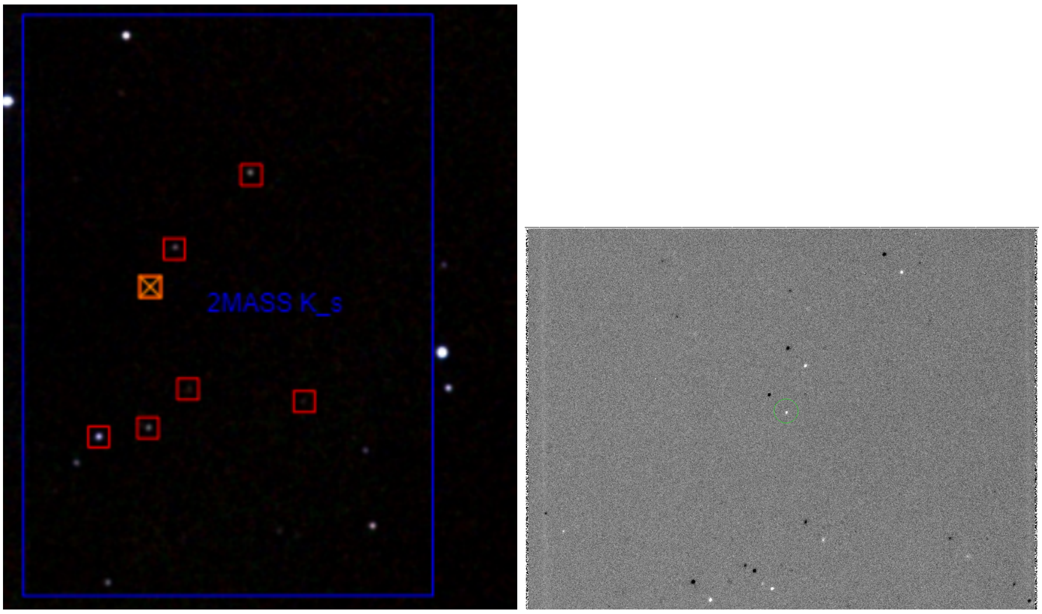

Figure 76. Left is the WISE finder chart from IRSA used to identify the object 1007. Right is one of the H images showing the field of view. The target is circled in green.

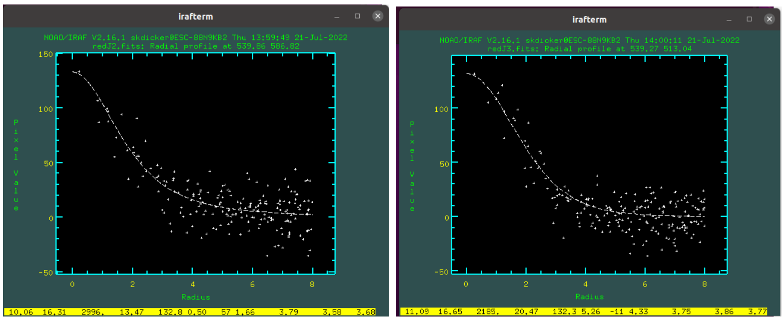

Figure 77. Flux vs radius plots for 1007 in the J-filter. Used to find FWHM for aperture photometry.

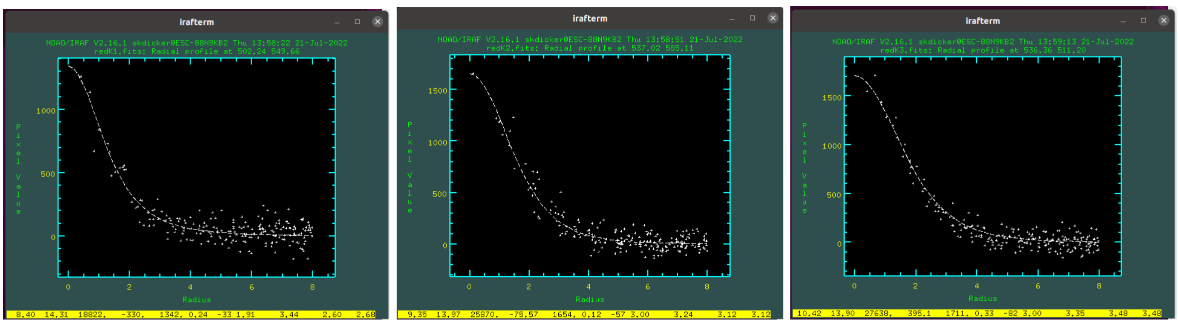

Figure 78. Flux vs radius plots for 1007 in the K-filter. Used to find FWHM for aperture photometry.

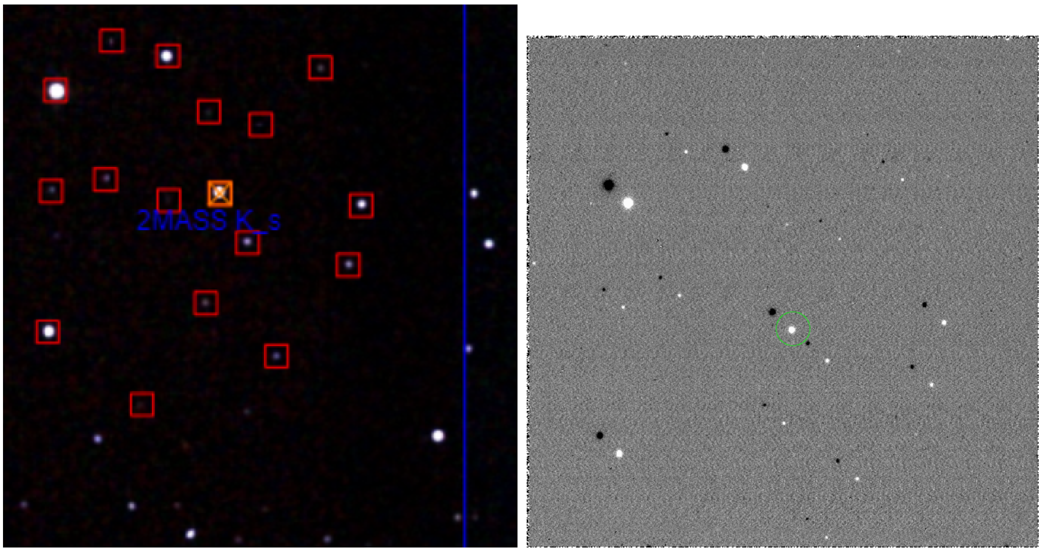

Figure 79. Left is the WISE finder chart from IRSA used to identify the object LHS2026. Right is one of the H images showing the field of view. The target is circled in green.

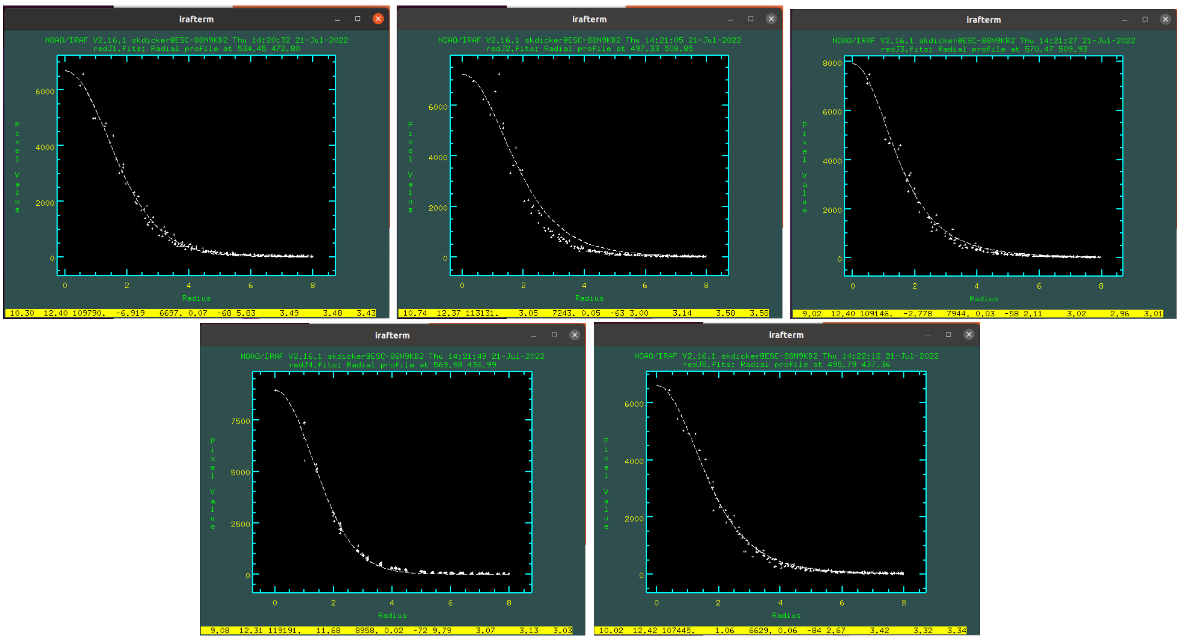

Figure 80. Flux vs radius plots for LHS2026 in the J-filter. Used to find FWHM for aperture photometry.

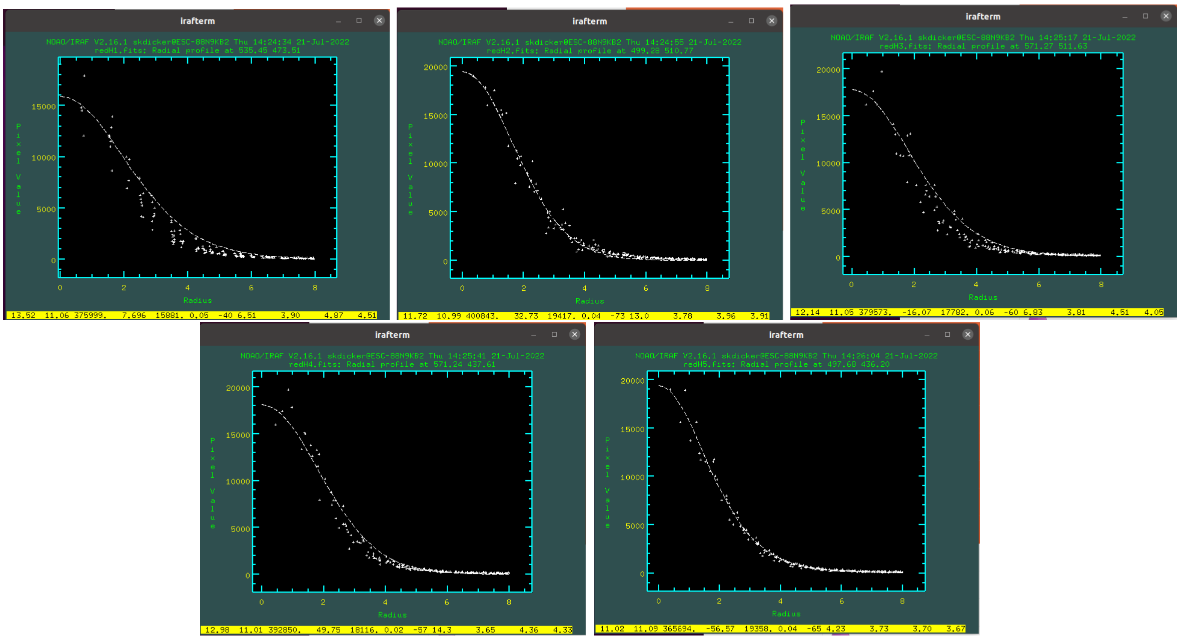

Figure 81. Flux vs radius plots for LHS2026 in the H-filter. Used to find FWHM for aperture photometry.

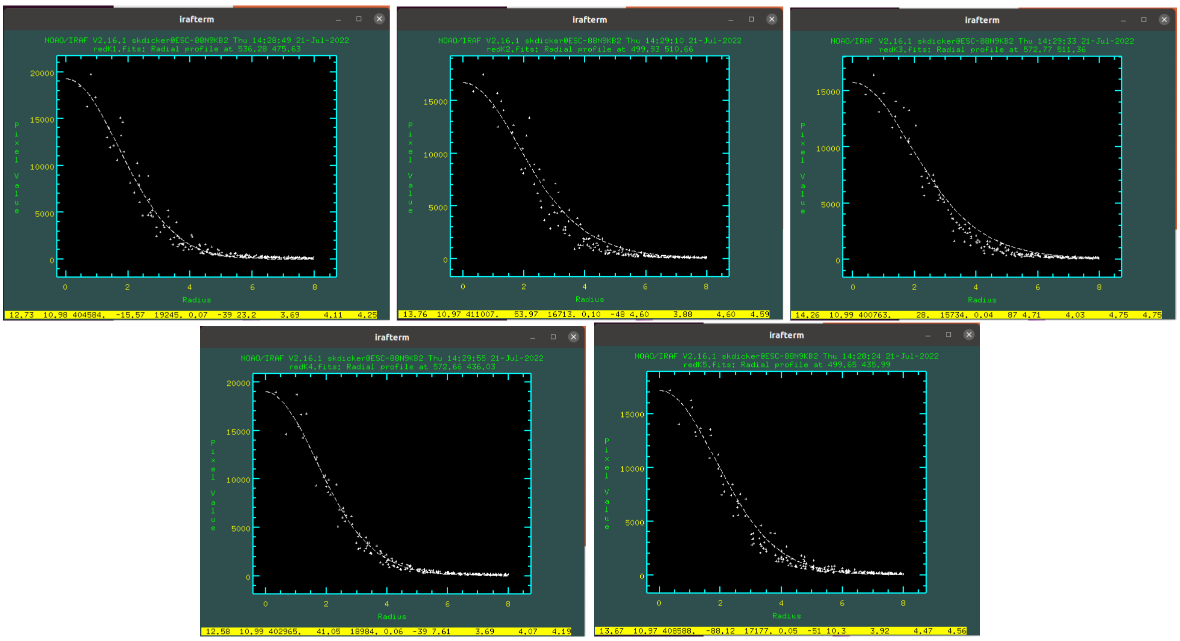

Figure 82. Flux vs radius plots for LHS2026 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

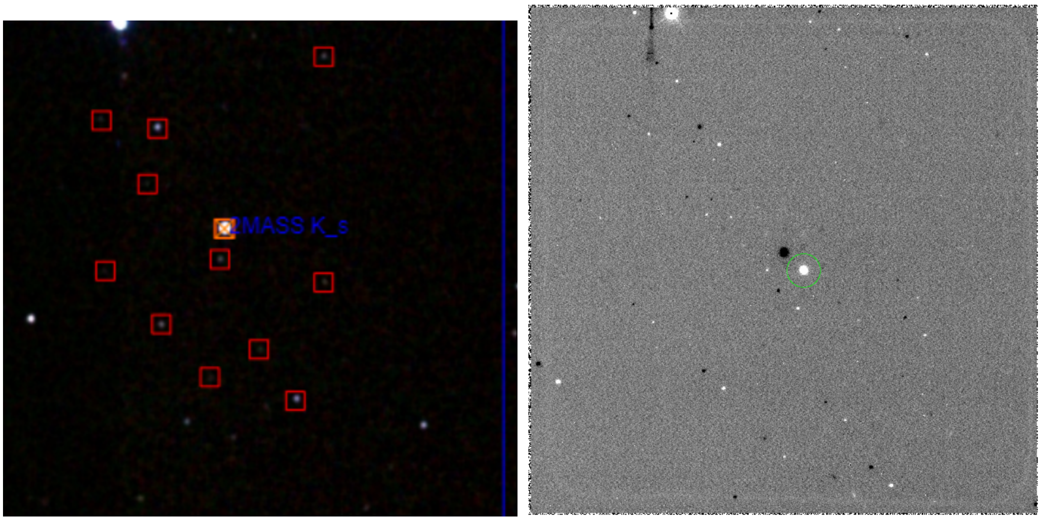

Figure 83. Left is the WISE finder chart from IRSA used to identify the object p259. Right is one of the H images showing the field of view. The target is circled in green.

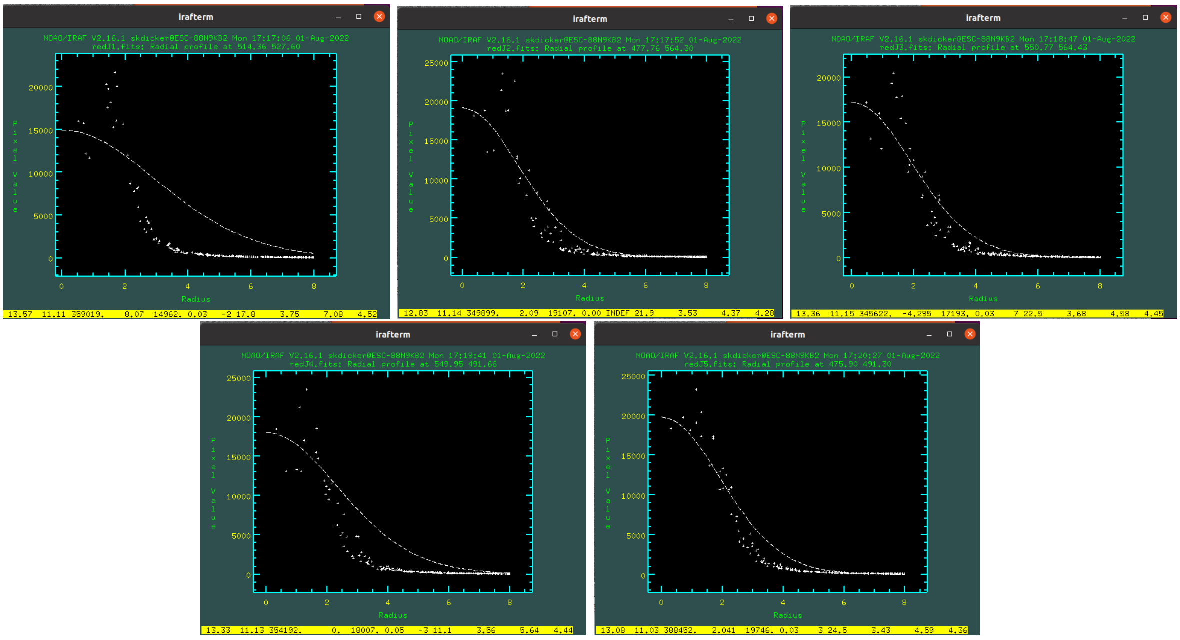

Figure 84. Flux vs radius plots for p259 in the J-filter. Used to find FWHM for aperture photometry.

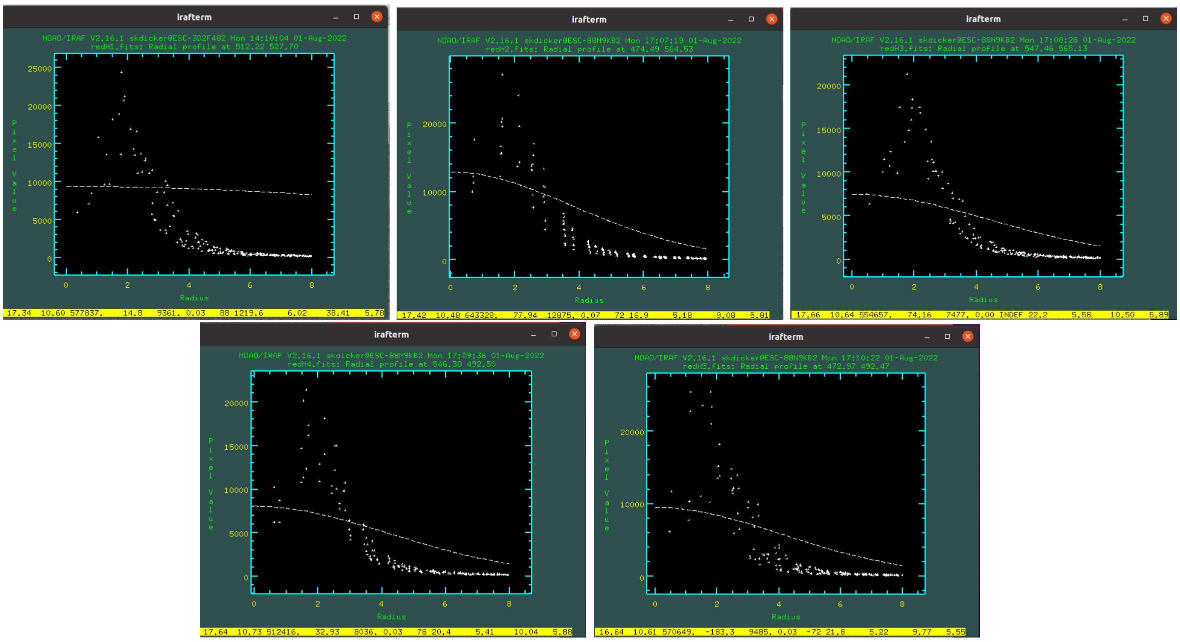

Figure 85. Flux vs radius plots for p259 in the H-filter. Used to find FWHM for aperture photometry.

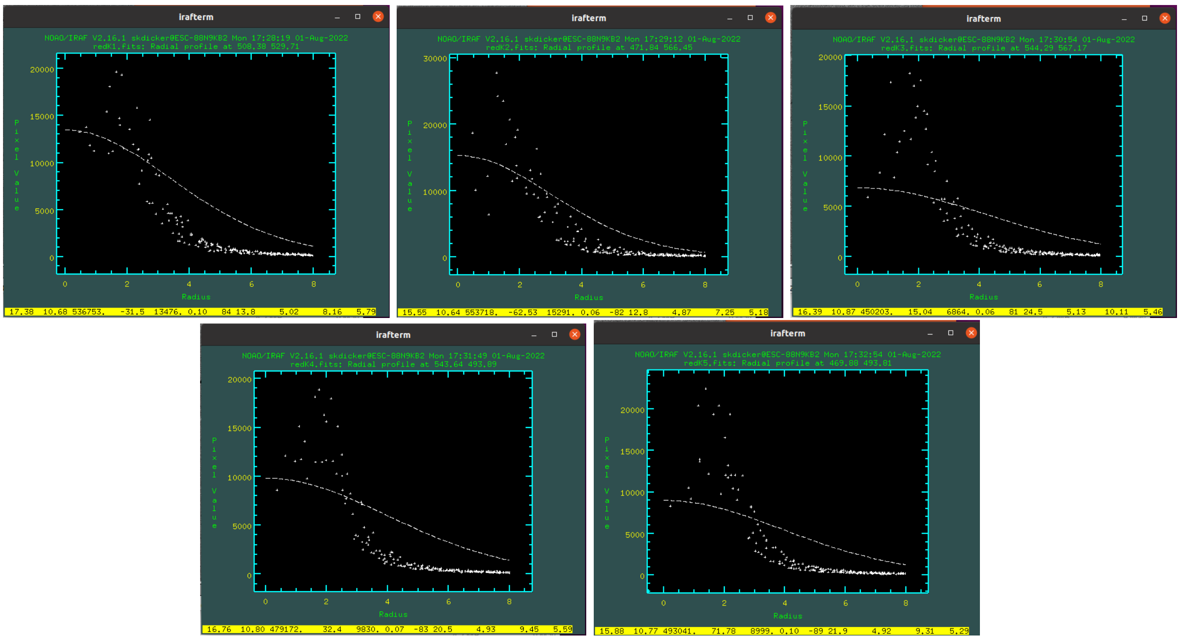

Figure 86. Flux vs radius plots for p259 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

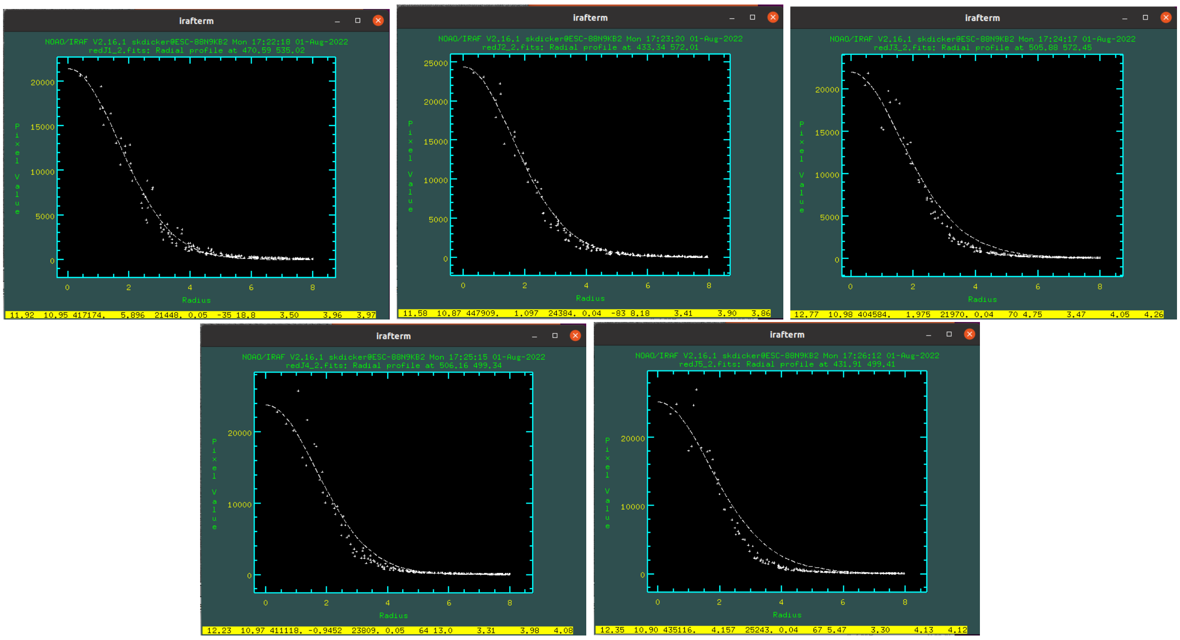

Figure 87. Flux vs radius plots for p259 in the J-filter (second observation). Used to find FWHM for aperture photometry.

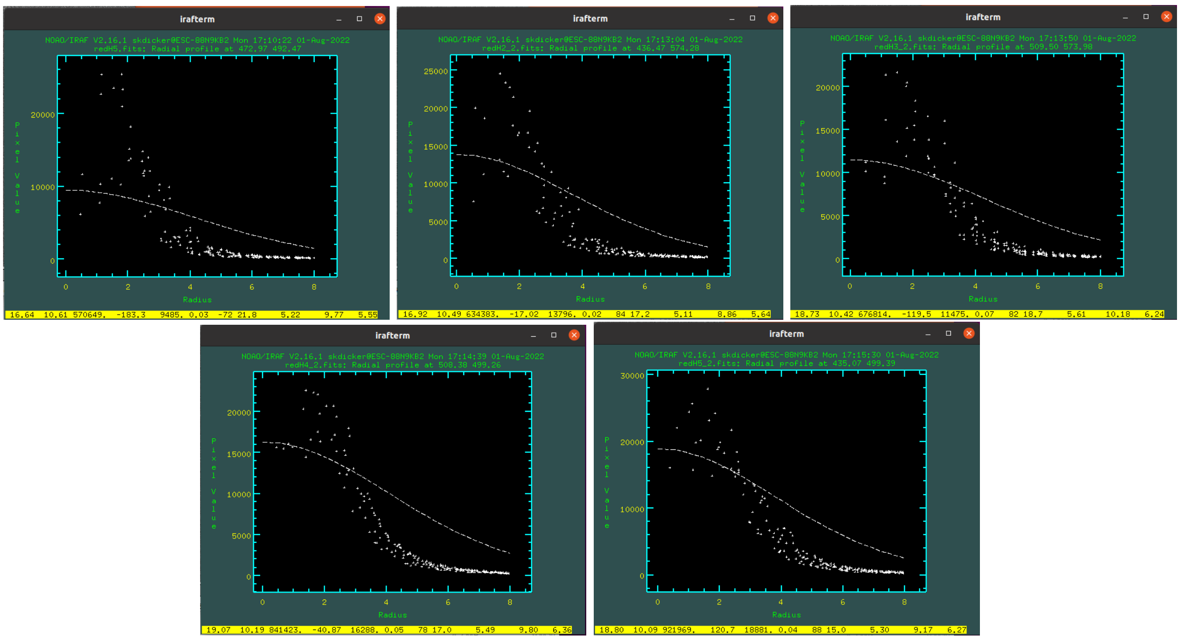

Figure 88. Flux vs radius plots for p259 in the H-filter (second observation). Used to find FWHM for aperture photometry.

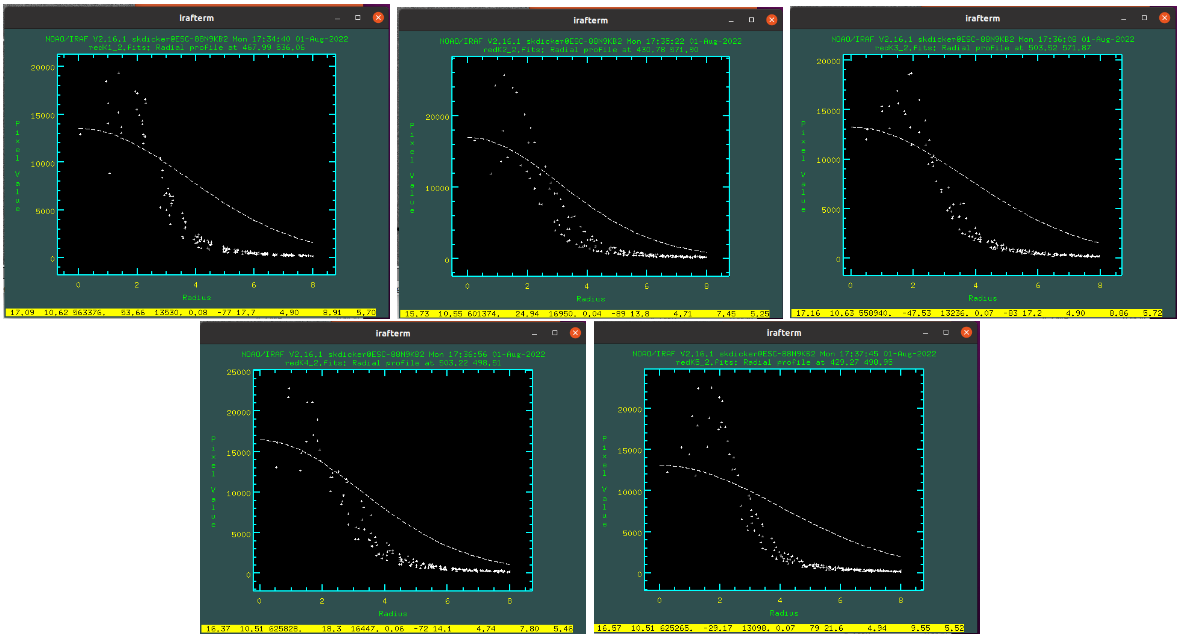

Figure 89. Flux vs radius plots for p259 in the K-filter (second observation). Used to find FWHM for aperture photometry.

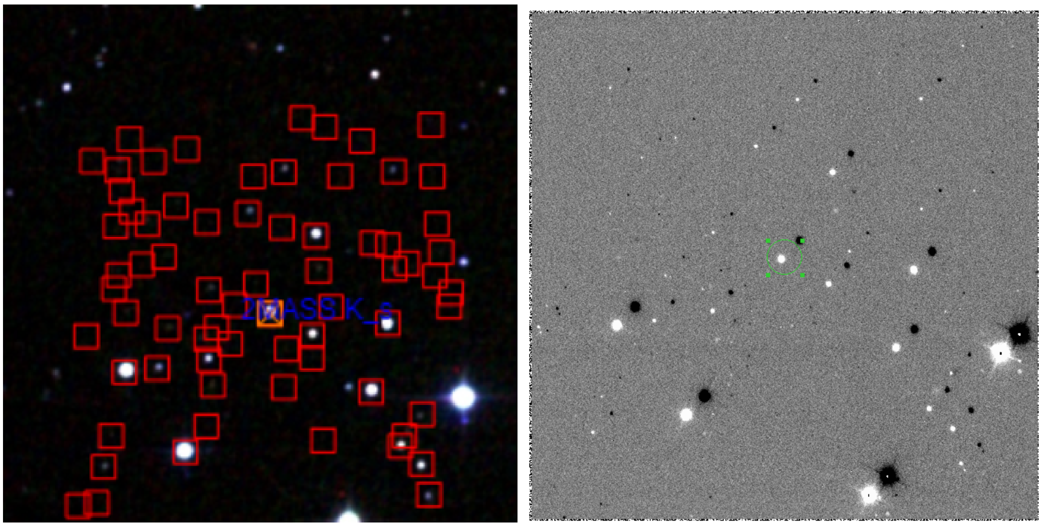

Figure 90. Left is the WISE finder chart from IRSA used to identify the object p161. Right is one of the H images showing the field of view. The target is circled in green.

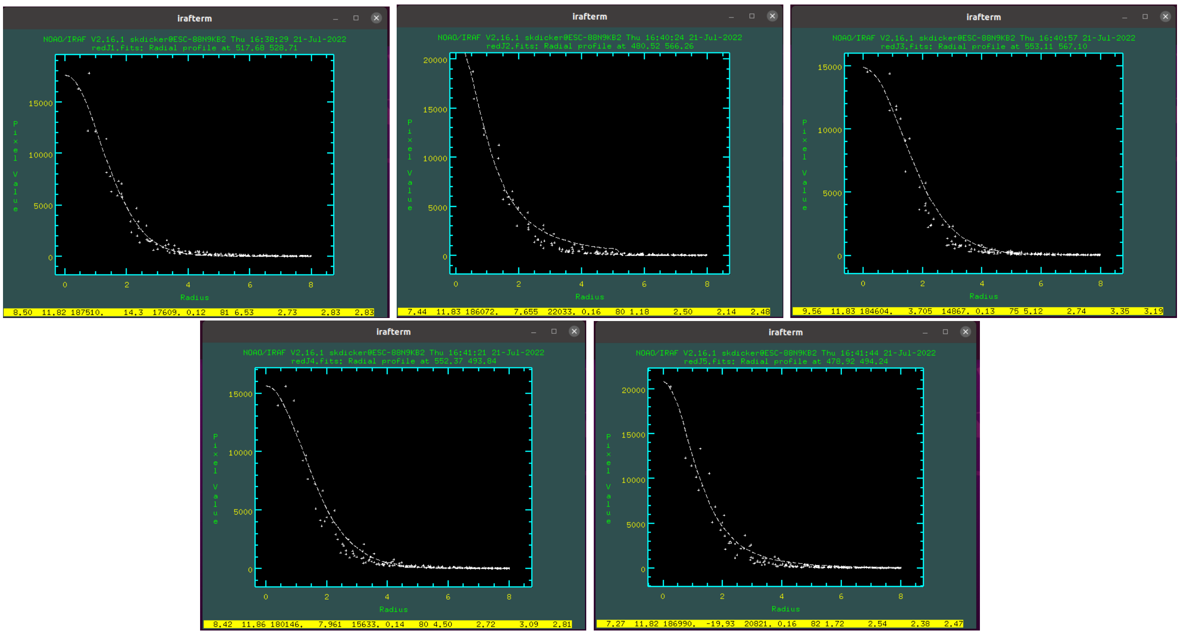

Figure 91. Flux vs radius plots for p161 in the J-filter. Used to find FWHM for aperture photometry.

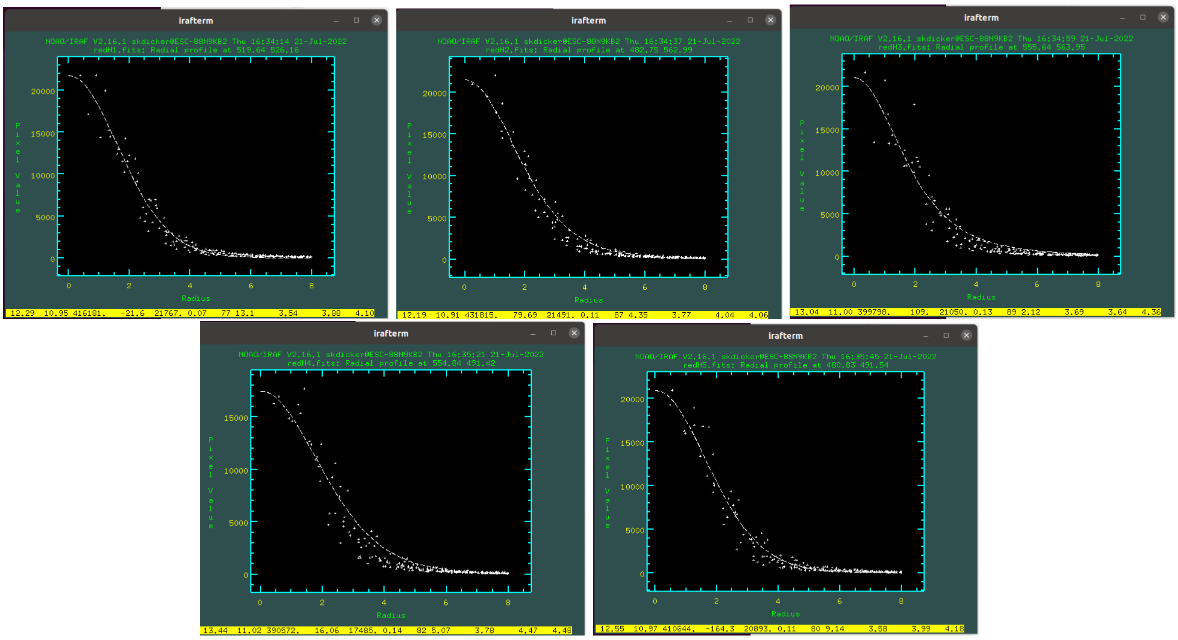

Figure 92. Flux vs radius plots for p161b in the H-filter. Used to find FWHM for aperture photometry.

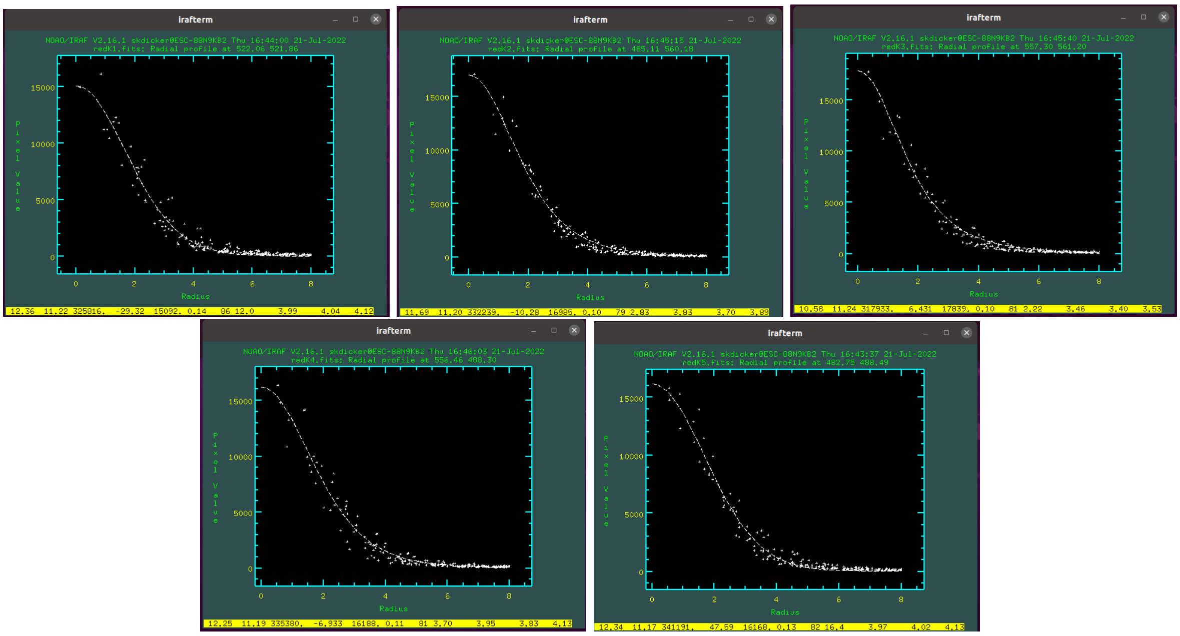

Figure 93. Flux vs radius plots for p161b in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

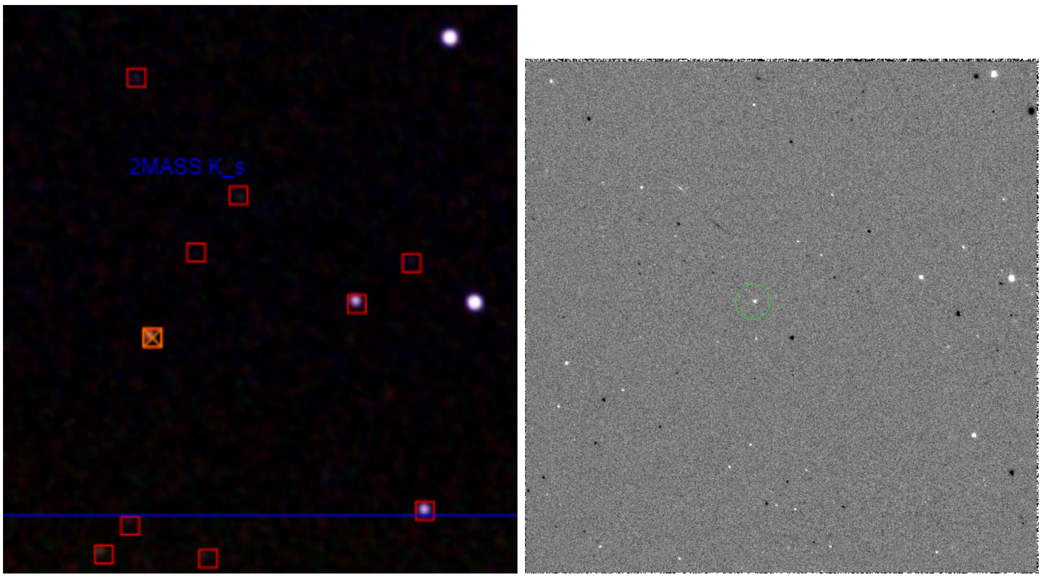

Figure 94. Left is the WISE finder chart from IRSA used to identify the object 1746. Right is one of the H images showing the field of view. The target is circled in green.

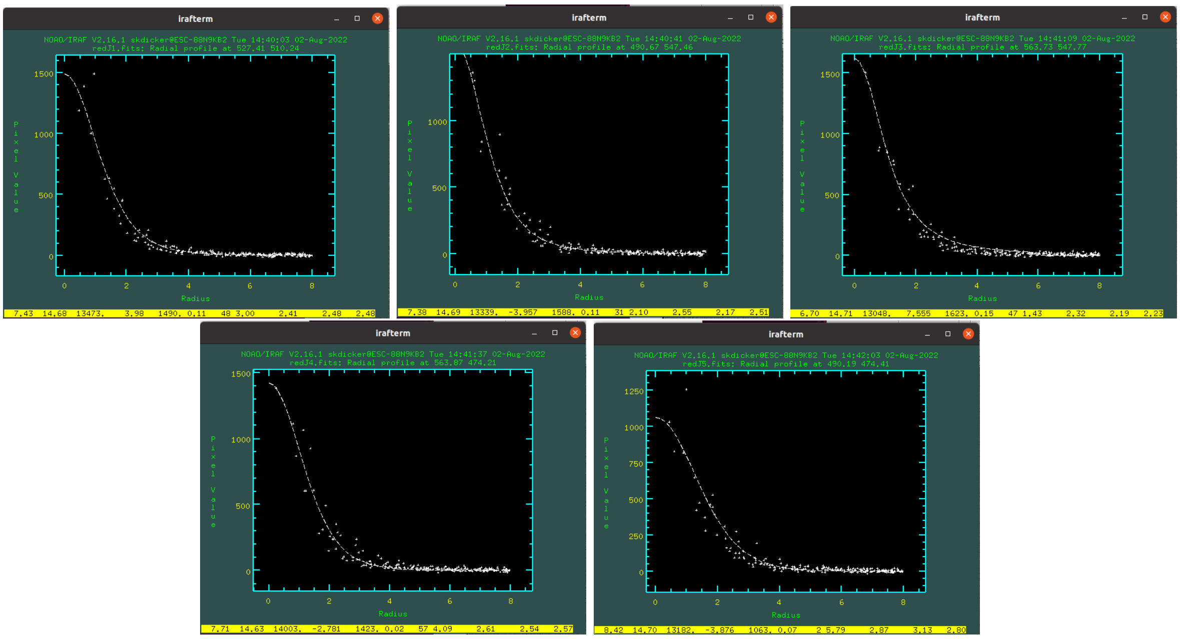

Figure 95. Flux vs radius plots for 1746 in the J-filter. Used to find FWHM for aperture photometry.

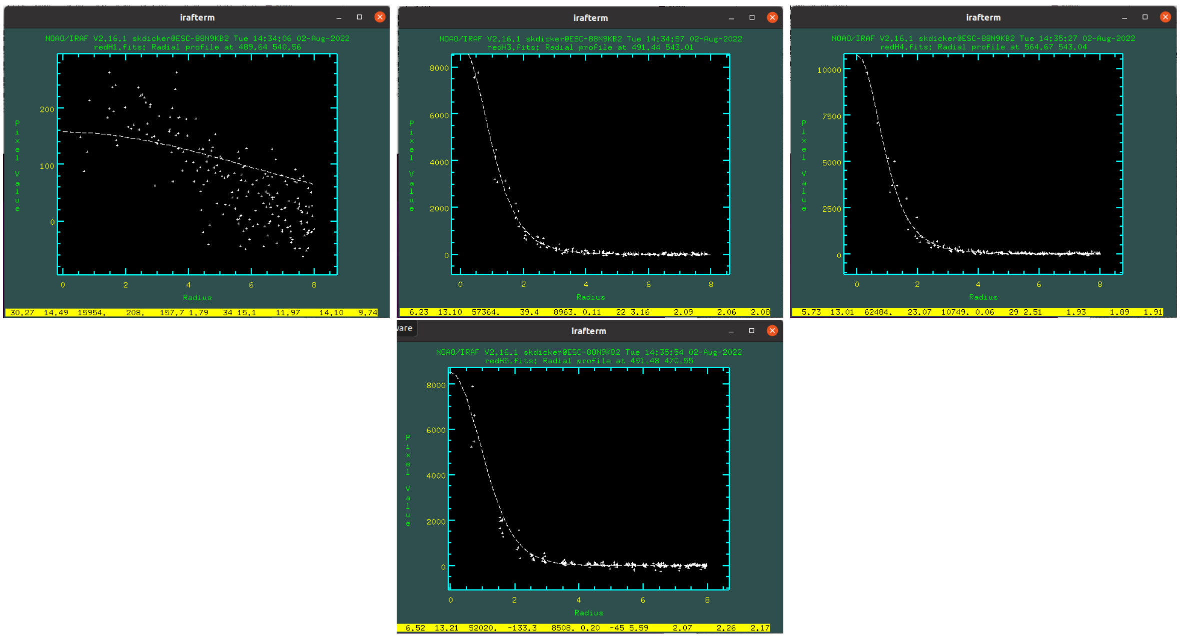

Figure 96. Flux vs radius plots for 1746 in the H-filter. Used to find FWHM for aperture photometry.

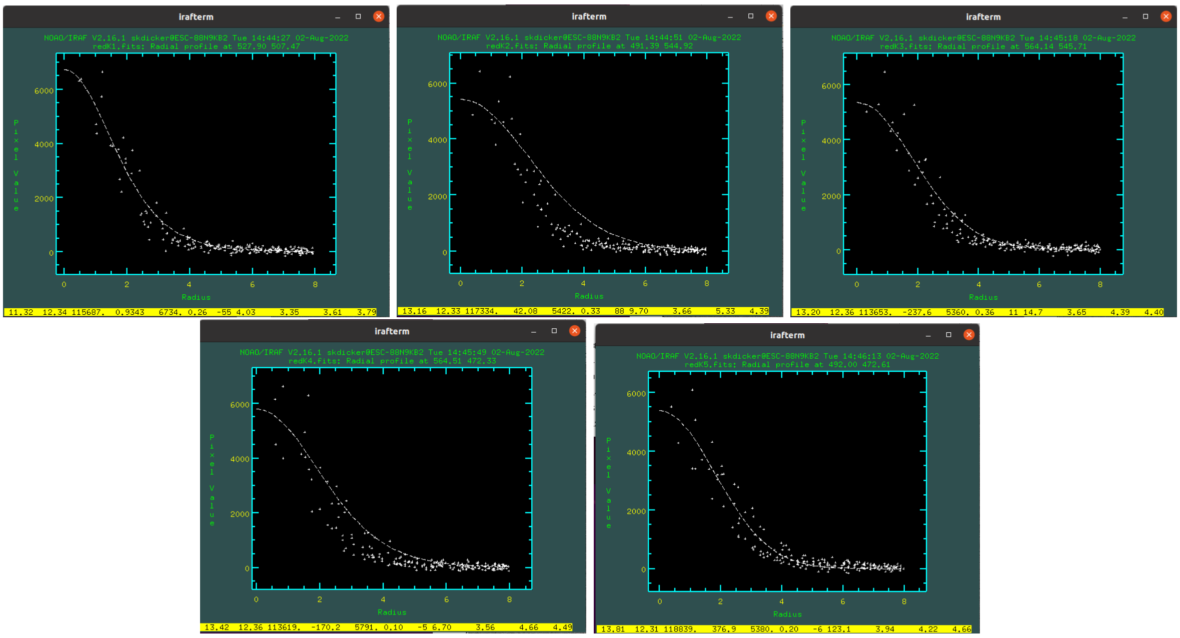

Figure 97. Flux vs radius plots for 1746 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

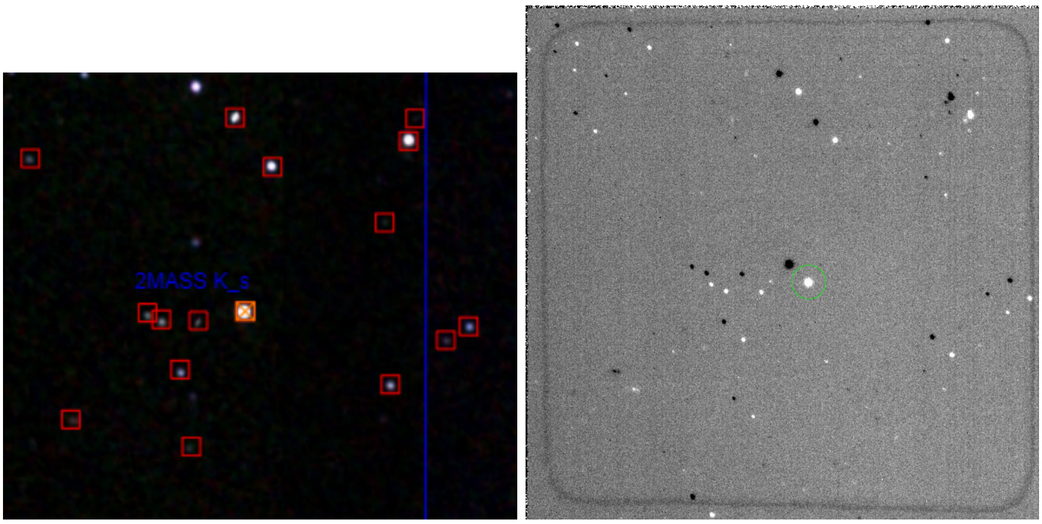

Figure 98. Left is the 2MASS finder chart from IRSA used to identify the object p138. Right is one of the H images showing the field of view. The target is circled in green.

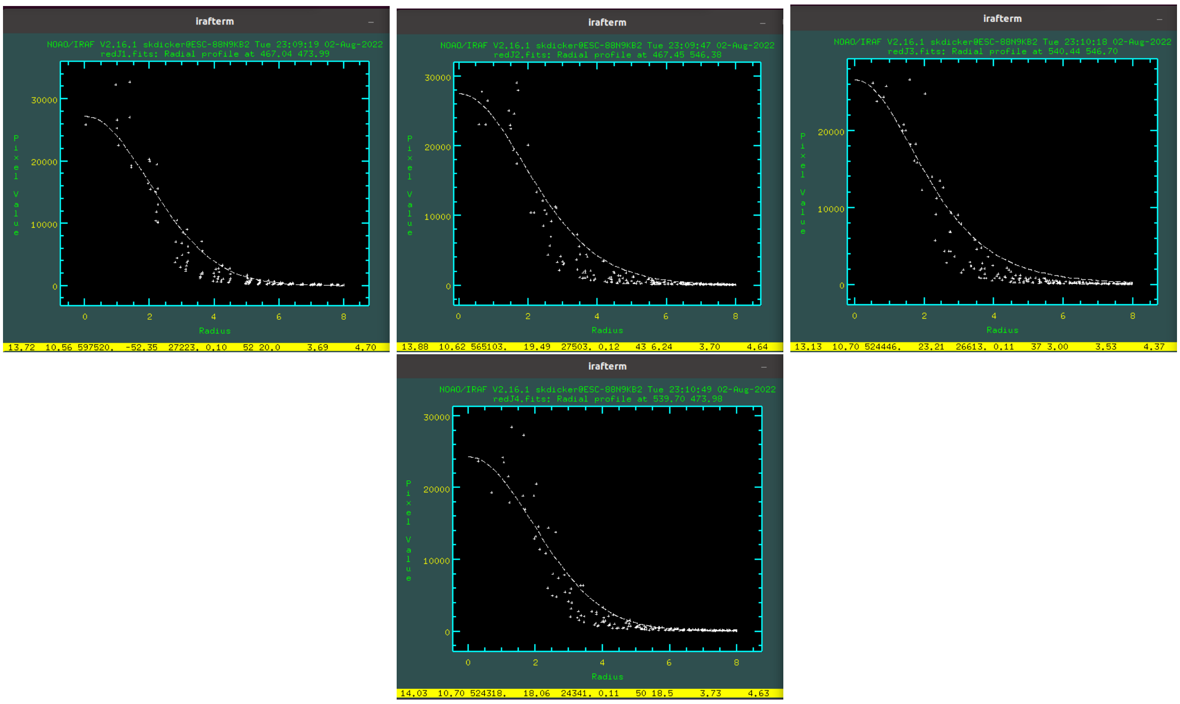

Figure 99. Flux vs radius plots for p138 in the J-filter. Used to find FWHM for aperture photometry.

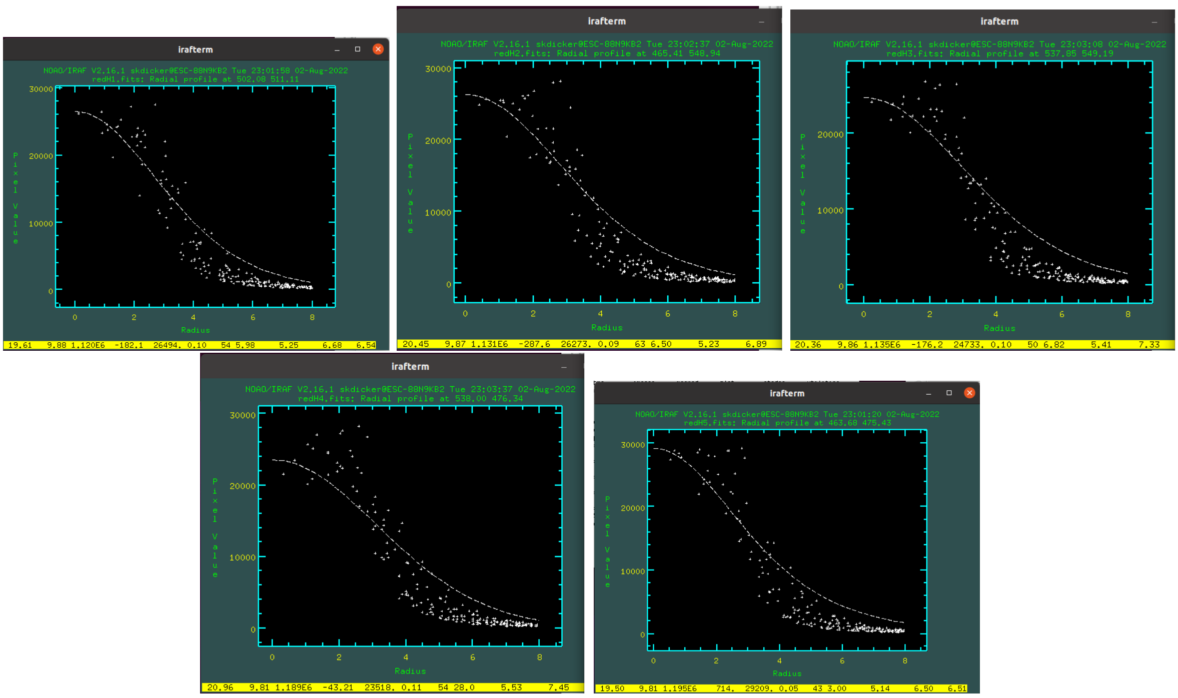

Figure 100. Flux vs radius plots for p138 in the H-filter. Used to find FWHM for aperture photometry.

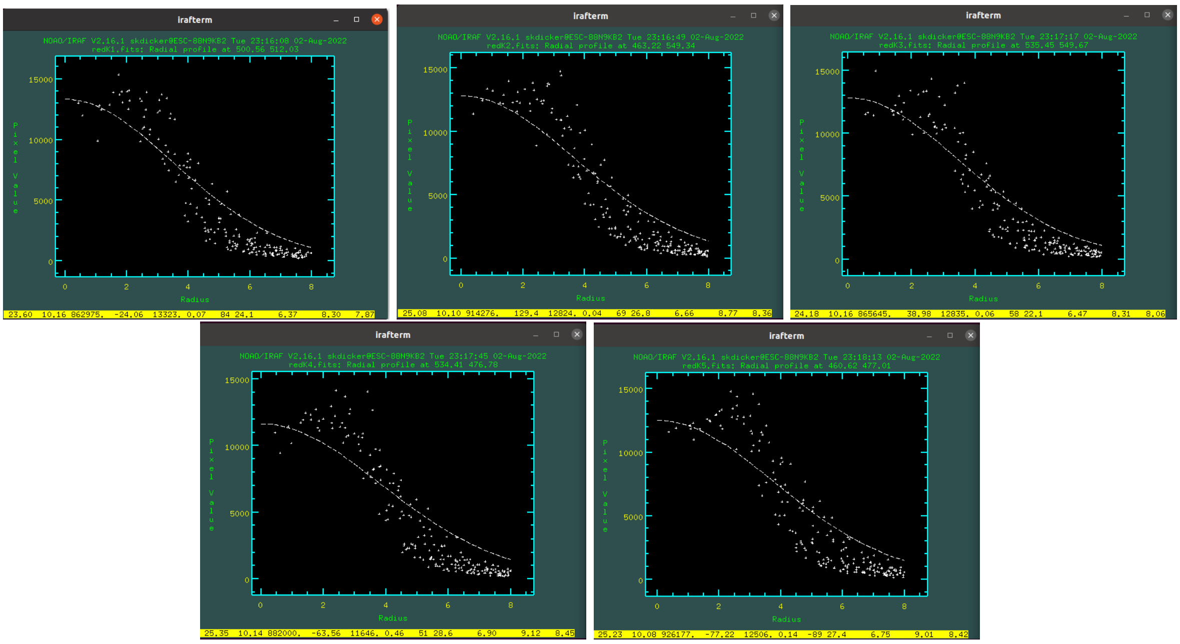

Figure 101. Flux vs radius plots for p138 in the K-filter (5 plots due to the 5 position dither pattern). Used to find FWHM for aperture photometry.

3 TSPEC SPECTROSCOPY

3.1 TSPEC Observing Procedures

- ☐ Take flats.
  - ☐ 10 x 60-sec exposures with bright quartz on.
  - ☐ 10 x 60-sec exposures with lamps off.
- ☐ Observe target
  - ☐ Slew to target.
  - ☐ Expose with Tspec slit viewer
  - ☐ Offset
  - ☐ Turn on background subtraction and expose again
  - ☐ Use a finder chart to identify the target
  - ☐ Use ”center select” to move the target to the slit
  - ☐ Turn guiding on
  - ☐ Start 1 exp, 8 cycles, 120 sec in the nod script GUI
  - ☐ Use the nudger tool to keep the target on the slit
- ☐ Observe standard
  - ☐ Same as for the target but should be 30s exposures

3.2 September 16, 2021 A-half

This was the first time I observed using Tspec with Dr. Stephens. Seeing was good and Conner says the data looks good as well. Observed objects are listed in [102].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
2MASS J17114559+4028578		9/16/2021	Good	J and J-K put it in the Best gap				
WISE J203042.79+074934.7	HD 195198	9/16/2021	Good	Just outside the Best gap	T1.5	14.05	13.48	13.36
2MASS J22362452+4751425B		9/16/2021	Good	Not sure--outside the color range	Late L pec	N/A	N/A	N/A

Figure 102. List of objects observed September 16th.

3.3 September 21st, 2021 B-half

Unfortunately, this night was pretty cloudy. After starting reduction Conner said that the data quality is poor. Observed objects are listed in [103].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
2MASS J21265916+7617440		9/21/2021	Poor	J and J-K put it in the Best gap	T0 pec	N/A	N/A	N/A
WISEA J035705.03+152923.4		9/21/2021	Poor	J and J-K put it in the Best gap	L1 pec	N/A	N/A	N/A
SDSSp J033035.13-002534.5		9/21/2021	Poor	Just outside the Best gap	L6.5	N/A	N/A	N/A
SDSSp J042348.57-041403.5		9/21/2021	Poor	J and J-K put it in the Best gap	T0	14.3	13.51	12.96

Figure 103. List of objects observed September 21st.

3.4 October 10th, 2021 A-half

We did this observing on site at APO with Candace’s help. The whole group that traveled to APO with us helped with the observations as well. We had a nice, clear night and the data looks good. Observed objects are listed in [104].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
WISE J165842.56+510335.0	HIP 70817	10/10/2021	Good	Just outside the Best gap		N/A	N/A	N/A
WISE J185101.83+593508.6	HIP 94140	10/10/2021	Good	Just outside the Best gap	L9 pec	14.85	14.03	13.45
SIMP J013656.57+093347.3	HIP 13917	10/10/2021	Good	J and J-K put it in the Best gap	T2	13.252	12.809	12.585

Figure 104. List of objects observed October 10th.

3.5 *October 22nd, 2021 B-half*

Another night of good data. Observed objects are listed in [105].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
SDSSp J053951.99-005902.0	HIP 24311	10/22/2021	Good	Just outside the Best gap	L5	13.85	13.04	12.4
SDSS J075840.33+324723.4	HIP 41789	10/22/2021	Good	J and J-K put it in the Best gap	T2.5	14.73	14.21	13.9
WISE J092055.40+453856.3	HIP 41798	10/22/2021	Good	Just outside the Best gap	L9	15.04	14.19	13.77

Figure 105. List of objects observed October 22nd.

3.6 *May 11th, 2022 A-half*

Just Conner and I tonight. Candace was the obspec and helped refresh us on how to run Tspec. The data looks good so far. Observed objects are listed in [106].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
2MASSI J0908380+503208	HIP 41798	5/11/2022	Good	J-K just outside the Best gap	L6	14.43	13.56	12.93
2MASS J11061197+2754225	HIP 41798	5/11/2022	Good	J and J-K put it in the Best gap	T2.5	14.96	14.2	13.84
SDSS J080531.84+481233.0AE	HIP 55627	5/11/2022	Poor	J and J-K put it in the Best gap	L9	14.61	14.01	13.51

Figure 106. List of objects observed May 10th.

3.7 *June 14th, 2022 B-half*

Conner and I observed from the lobby of our hotel in Pasadena, California during AAS 240. It was a dusty night with scattered clouds especially towards the end of the night, and some of our targets were quite faint. Air mass was high for the first object, but Conner says the data looks good at least for the first object. The last object might be an issue because of clouds. Observed objects are listed in [107].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
WISE J003110.04+574936.3	HIP 4182	6/14/2022	Good	Just outside the Best gap	L8	14.79	13.862	13.21
DENIS-P J153941.96-052042.4	HIP 77516	6/14/2022	Poor	J and J-K put it in the Best gap	L4.2	13.84	13.08	12.54
2MASS J17114559+4028578	HIP 85382	6/14/2022	Poor	J and J-K put it in the Best gap	L5	14.96	14.38	13.78

Figure 107. List of objects observed June 14th.

3.8 *July 11th, 2022 A-half*

We were totally clouded out for this night. Jack finally opened up the dome close to midnight when there at least was no rain on the radar, but all we were able to get were a few cycles of the standard before the clouds thickened up and we couldn't see anything. No useful data from this night.

3.9 *August 24th, 2022 A-half*

Conner observed alone this night. Observed objects are listed in [108].

Object	Standard	Date Obtained	Data Quality	Why it was observed	SpT	MKO J	MKO H	MKO K
2MASSW J1515008+484742	HIP 71172	8/24/2022	Better	Just outside the Best gap	L5.5	13.97	13.18	12.48
WISE J180952.53-044812.5AB	HIP 90967	8/24/2022	Better	J-K color and J mag	T0.5	15.15	14.44	13.98
2MASS J21265916+7617440	HD 219485	8/24/2022	Better	Back-up target	T0 pec	14.336	13.586	13.16

Figure 108. List of objects observed August 24th.

3.10 October 6th, 2022 A-half

Conner and I observed together on campus this night. We were totally clouded out.

3.11 December 5th, 2022 B-half

Conner observed alone this night. The humidity was at a full 100% so the dome was never opened.

3.12 December 12th, 2022 B-half

Conner observed alone again this night. He was clouded out yet again.

4 TSPEC Data Reduction

Conner has completed all TSPEC reduction to date. He is the resident TSPEC expert. I met with him one day in July 2022 for a lesson on spectral reduction. He has put together a very clear instructional document, so I will refrain from repeating anything here and instead refer to his document.

5 Objects Observed both Photometrically and Spectroscopically

Part of my project will require having objects that have been observed with both TSPEC and NICFPS. Items to date observed by both:

- 2MASSI J0908380+503208
- SDSS J075840.33+324723.4
- WISE J003110.04+574936.3

6 BINARY FIT CODE

I created a github repo called binary-fit that can be found using this link once made public. All files required to run binary-fit will be placed here.

6.1 Code Goals

With so many possible directions to go with the code, I made a list of my goals in priority order to help keep me from disappearing down rabbit holes. My goals for the code are as follows:

1. Go through the entire code and simplify
2. Fix the code to regrid models again each time
3. Fix the code to fit to unnormalized data
4. Switch from using GSL to something easier to download
5. Come up with a better method of parameter selection and include in README.txt
6. clean up the MAKEFILE, add a python equivalent
7. add method to fit to both real and model templates
8. print out results in more sensical, useful form
9. develop a GUI
10. add timer like Ben's code
11. properly cite all sources and authors

6.2 Goal 1: General Code Overhaul

I started by creating a new main.py function to replace the old WTII.py function. I am working through the code step-by-step and adding the necessary pieces back in to the main.py function. I am changing the coding style to be consistent instead of still being a conglomerate of others' code as I go. I am focusing on ease of use, mainly making all options available in the params file so there is no need to have different versions of the code or comment out pieces when I want a certain type of fit.

7 Using the Code to Look for Unresolved Binaries in Archival Data

8 Apples to Oranges

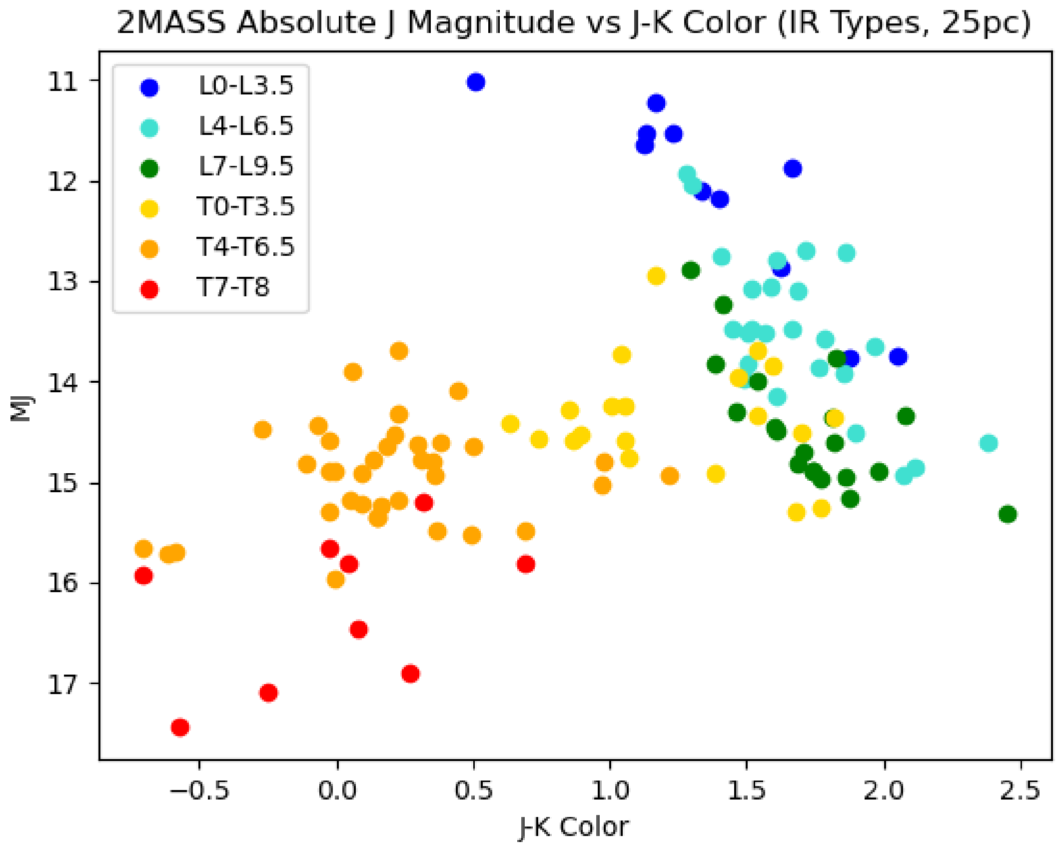

Figure 109. Caption

9 AAS Presentation 2023

Planning notes for the talk I will be giving at AAS 2023.

9.1 Possible Figures

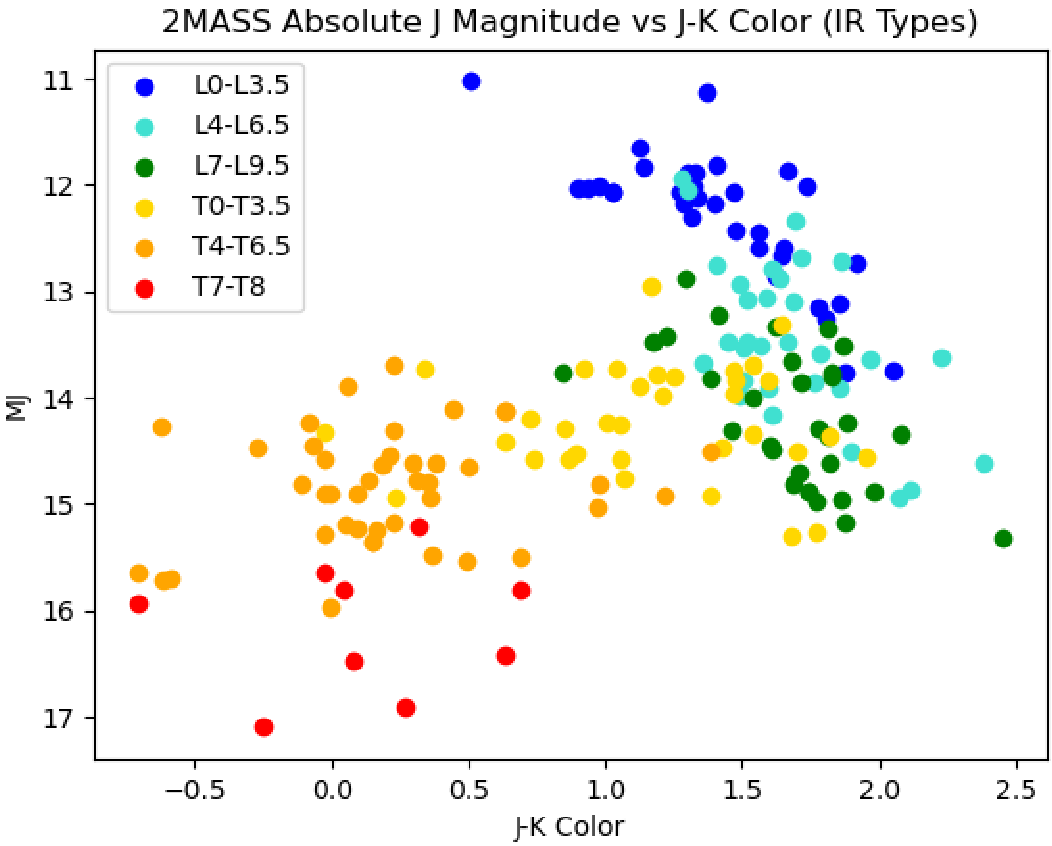

Figure 110. Caption

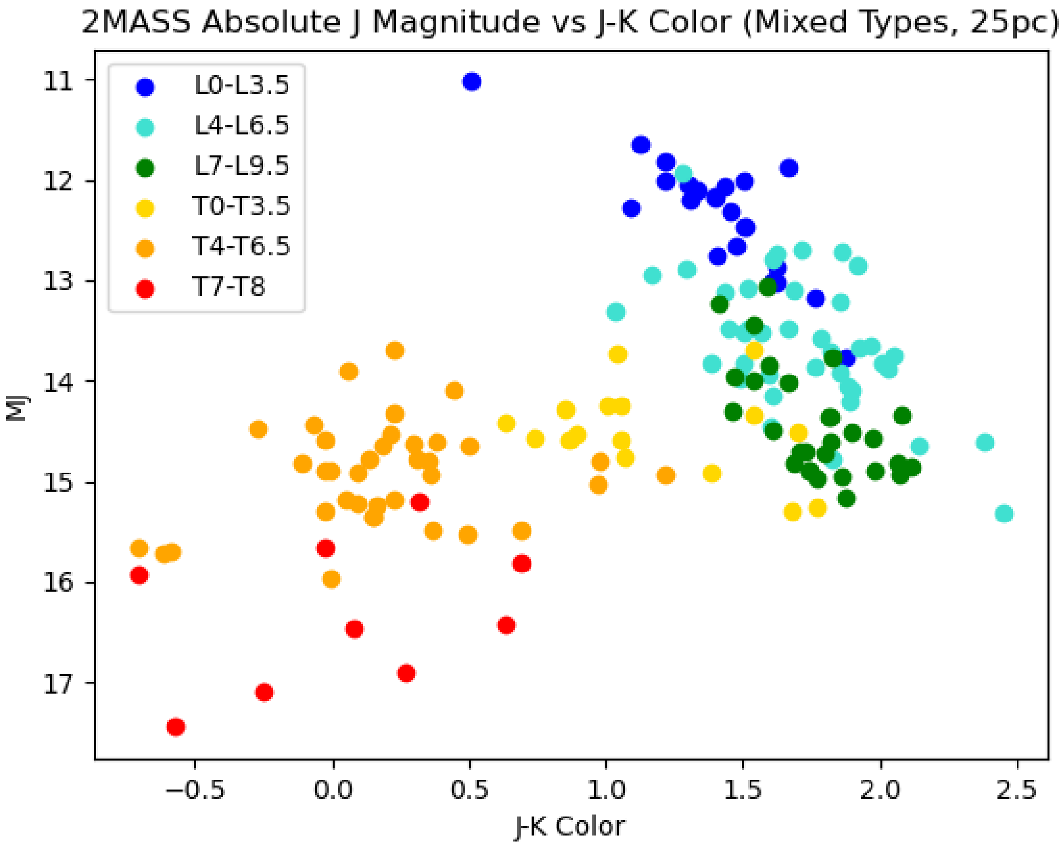

Figure 111. Caption

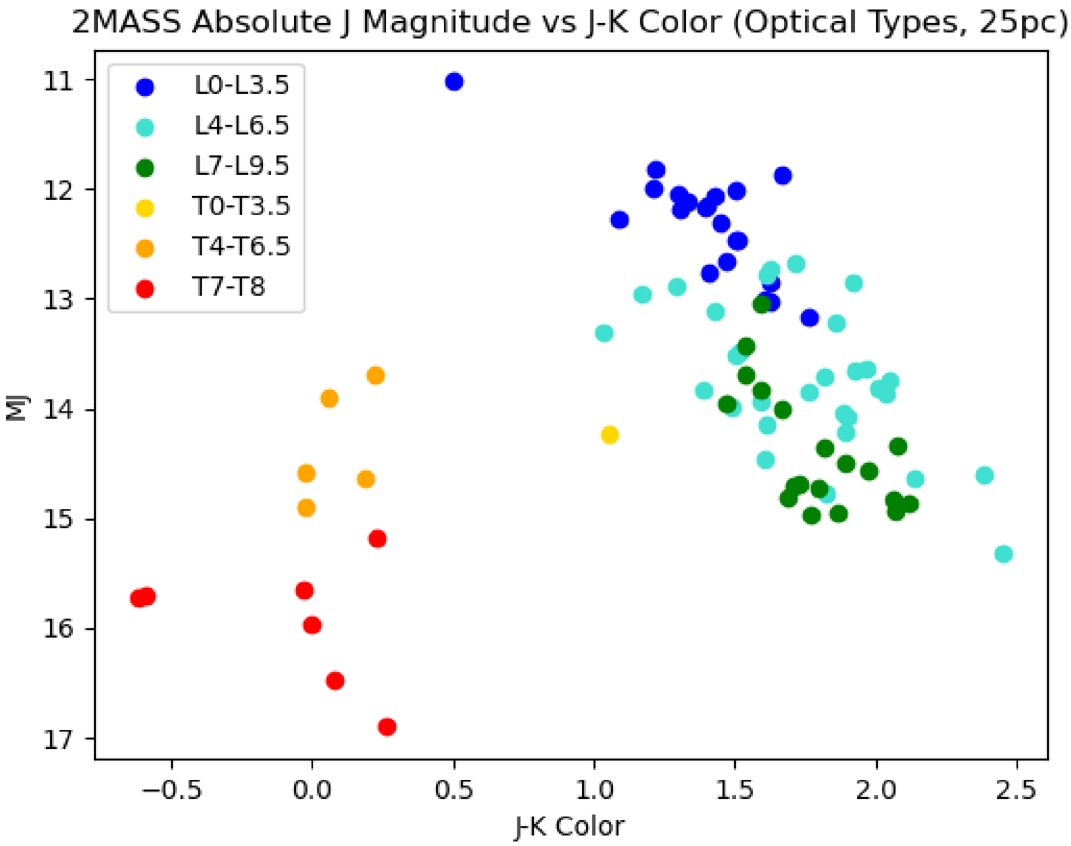

Figure 112. Caption

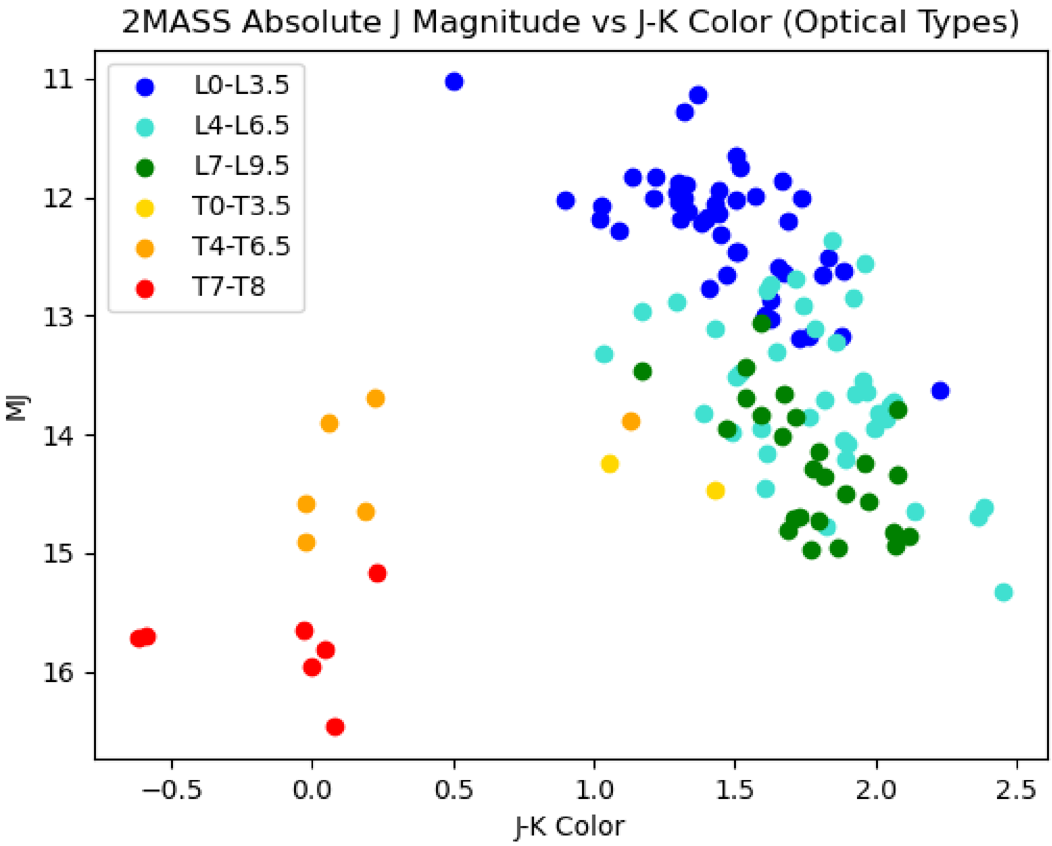

Figure 113. Caption

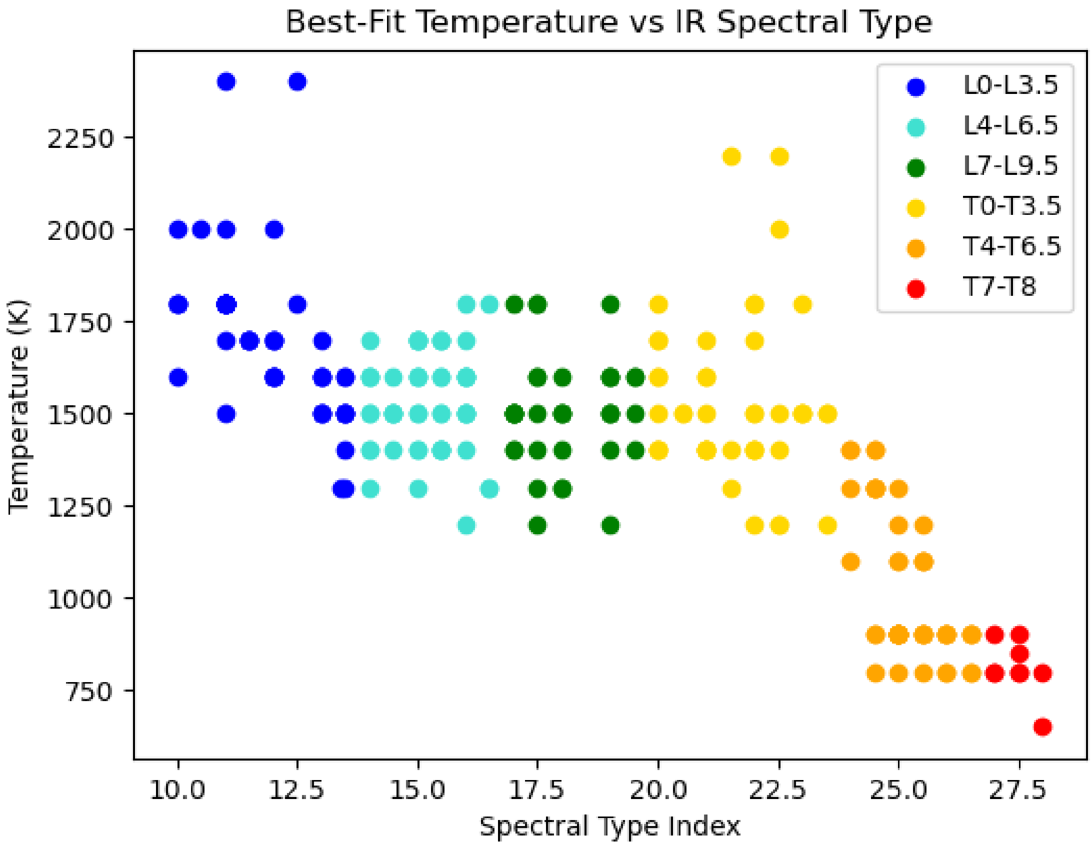

Figure 114. Caption

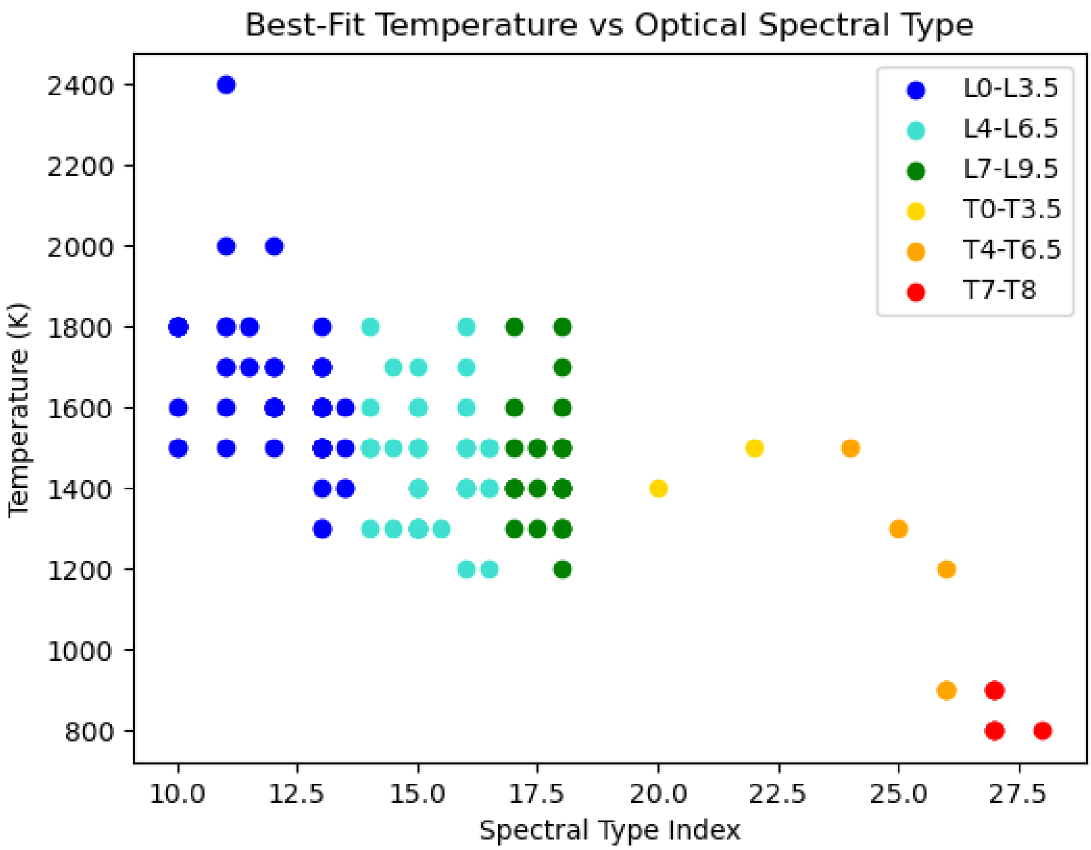

Figure 115. Caption

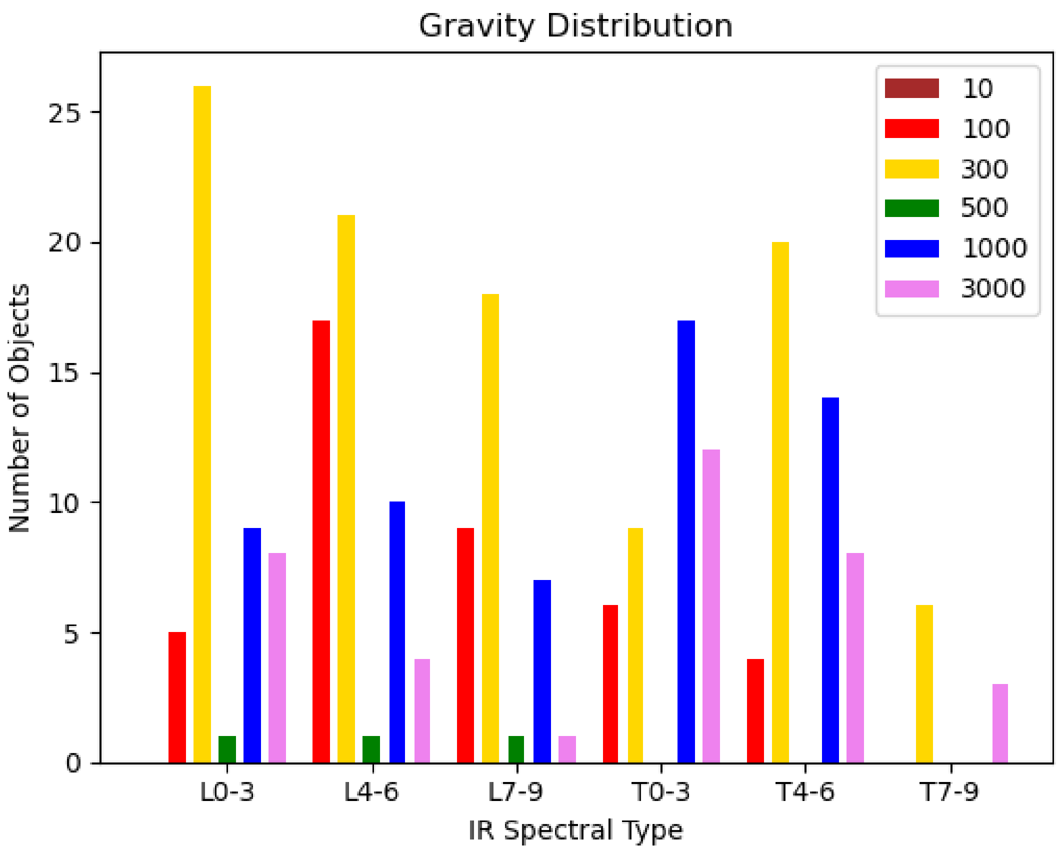

Figure 116. Caption

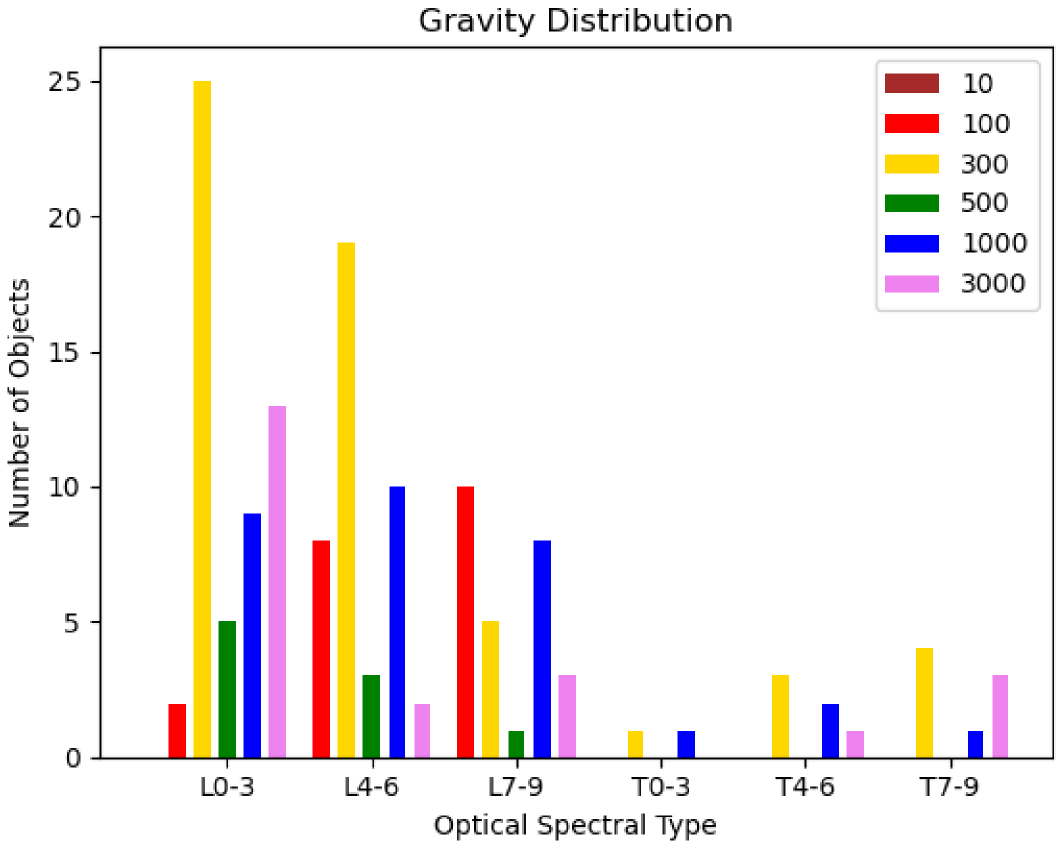

Figure 117. Caption

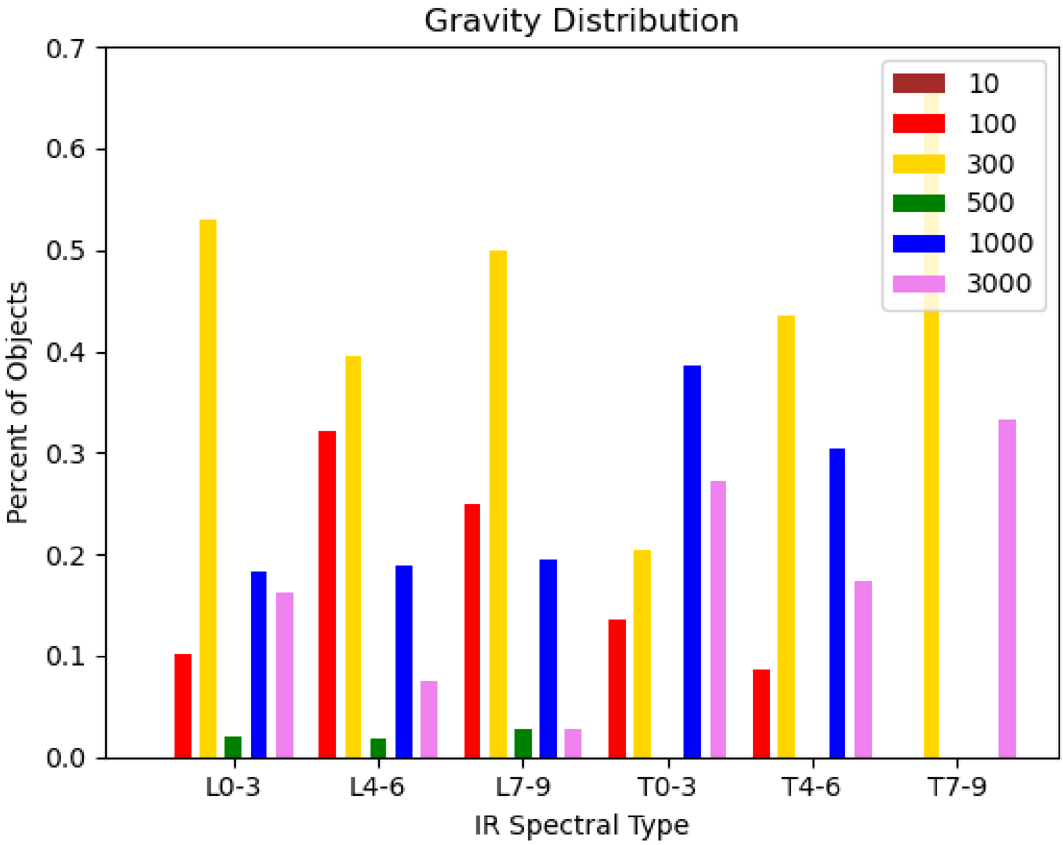

Figure 118. Caption

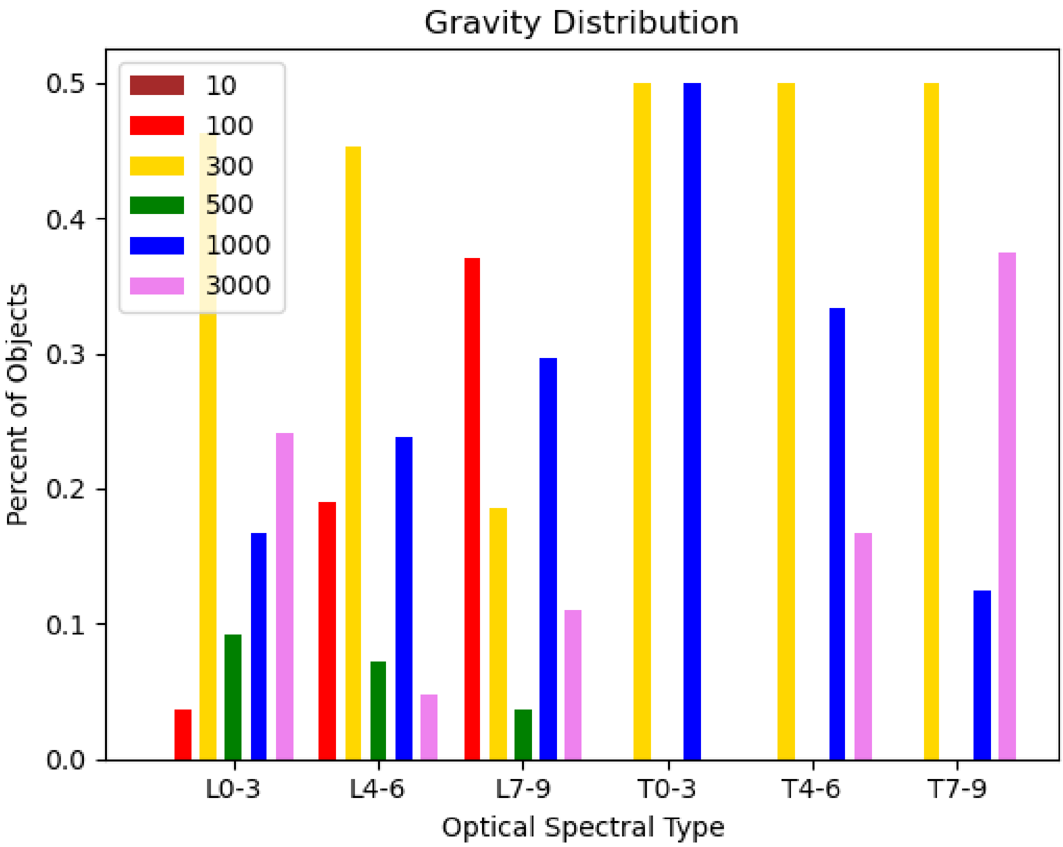

Figure 119. Caption

10 JWST PROPOSALS CYCLE 2

10.1 Proposal Idea 1: Calculate SEDs for L and early Ts

Mike Cushing's cycle 1 program obtained included 24 late T and yearly Y dwarfs

10.2 Proposal Idea 2:

11 Ongoing ToDo List

- ☐ Finish Binary Fitting for Apples to Oranges
- ☐ Fix code so it outputs ”raw” file
- ☐ Fix gravity plots for AAS to be log-based
- ☐ Reduce new NICFPS data
- ☐ Create color-magnitude plot with binaries marked
- ☐ Implement Dr. R’s stats suggestions
- ☐ Fix code outputs to read names
- ☐ Add cholla models after AAS
- ☐ Ask Mark to add me to the slack
- ☐ Fit binaries with each individual model set
- ☐ Look into renewing space grant
- ☐ Make APT account
- ☐ Select targets for JWST
- ☐ Update this document
- ☐ Add summary sheet printout

References