Circumstellar Environments of Luminous Infrared Stellar Objects in the Magellanic Clouds

Abigail Azari

JET PROPULSION LAB

Major: Physics and Astronomy

USRP Fall Session

Date: 05 DEC 11

Circumstellar Environments of Luminous Infrared Stellar Objects in the Magellanic Clouds

Abigail Azari[*] and Raghvendra Sahai[†]
Jet Propulsion Lab, California Institute of Technology, Pasadena, CA 91109

Young stars are formed out of the interstellar medium (ISM) which is replenished by mass loss rates from evolved stars. Circumstellar matter around young and evolved stellar objects usually emits energy in the infrared (IR) wavelength range as the matter is heated by the central star. Surveys of the Magellanic Clouds with the Spitzer Space Telescope in the 3.6–160 micron range have previously been completed. These surveys have led to catalogs of infrared sources: which include HII regions, young stars, super giants, asymptotic giant branch (AGB) stars, post-asymptotic giant branch (post-AGB) stars, and planetary nebulae. The utility of such surveys can be improved upon by using Hubble Space Telescope (HST) data. HST provides higher angular resolution than Spitzer and has allowed for more detailed investigation of these luminous IR objects. This project used previously obtained HST archival data to examine luminous IR objects at optical wavelengths. This allows for the reclassification of stellar objects previously thought as one type of object or in a particular stage of their stellar evolution. An overall objective of this project included looking for extended nebulosity around evolved stars to better understand the life cycle of such objects and classify these nebulae by shape.

Nomenclature

″	=	arcsecond
′	=	arcminute
M_{SUN}	=	Mass of Sun
μm	=	micrometer, 10^{-6} meters
kpc	=	kiloparsec, 10^{3} meters

I. Introduction

The Magellanic Clouds have been surveyed and catalogued in the infrared wavelengths by the Spitzer Space Telescope previously though the SAGE (Surveying the Agents of a Galaxy's Evolution) survey. SAGE's goals included the detection of diffuse interstellar medium (ISM), a census of newly formed stars and evolved stars with a mass-loss rate of $>10^{-8}$ solar masses per year[1]. This mass loss from evolved stars replenishes the interstellar medium where new stars are born. Such infrared surveys are very useful as telescopes in the visual wavelength ranges can be limited by dust and other objects. The Magellanic Clouds are used for such catalogues due to their location and viewing angle. The Large Magellanic Cloud in particular is used to do surveys of stellar population since its close, ~50 kpc, and has a viewing angle of 35 degrees[2]. The Small Magellanic Cloud is ~60 kpc away [3]. All the objects within the LMC or SMC are essentially the same distance from us due to the Cloud's large distance from Earth. This allows for direct luminosity and size measurements due to this known distance.

Luminous infrared sources are usually an effect of the presence of circumstellar matter around young and evolved stars. As such, researchers have used the SAGE survey's results to catalogue these luminous infrared sources into different types of objects which are assumed to have a central stellar body heating the surrounding area. These objects primarily include HII regions, young stars, super giants, AGB stars, post-AGB stars, planetary nebulae, and runaway stars. In the case of runaway stars, a stellar body is moving quickly through the interstellar medium and due to its wind the star displaces the material as it moves through. This produces a bow shock which emits infrared light. Also of particular interest to this project are post-AGB stars. The current time a star spends within this particular stage is still unknown, although it is thought to be around ~1000 years. Compared to the lifetime of our sun on the main sequence, 10 billion years, which is an average star, 1000 years is a very short time in a star's lifespan. As

[*] Undergraduate Student Intern, Physics and Astronomy, Smith College.
[†] Principal Research Scientist, Origins of Stars and Planets, 4800 Oak Grove Drive, M/S 183-900, Pasadena, CA 91109, NASA-JPL.

such, post-AGB stars are rare to find among other stars since the majority of a stars lifetime is not spent in the post-AGB phase. In order to answer more detailed questions about post-AGB objects, their evolution, dynamical processes and other interesting infrared phenomena a more improved system of identification using infrared surveys and data would be immensely helpful to complete further in depth studies of such objects.

Current surveys using Spitzer are hampered in visual identification and categorization by the resolution of the instrument itself. Spitzer looks at the sky with two primary instruments, IRAC and MIPS. IRAC looks at the sky with measurements at 3.6, 4.5, 5.8 and 8.0 µm, MIPS includes 24, 70 and 160 µm. The resolution of Spitzer for IRAC is ~0.87 – 1.94″ while MIPS is ~2.5 – 18 ″[4 & 5]. For a size comparison, a circumstellar envelope found in planetary nebulas and other objects is ~ 10^{18} cm in diameter. At the distance of the LMC, this size is equivalent to 1.3″. The Hubble Space Telescope observes from the ultraviolet to the near infrared wavelength ranges and within its substantial wavelength range its angular resolution is ~0.05″. HST is able to resolve certain circumstellar envelope features that Spitzer is challenged by. For example, if the SAGE survey, based on Spitzer data, classified multiple objects as one star, HST could potentially resolve this object into its individual components. Therefore by utilizing both HST and Spitzer images we can better classify and observe luminous infrared objects.

II Approach

NASA ADS[‡], an astronomical paper database, was used to search for papers that had classified luminous infrared objects within the Magellanic Cloud. The first list of catalogued objects and NASA ADS was searched for the papers linked to this original paper through citations. Once a particular paper was found with a list of categorized objects coordinates were obtained from the paper. Using these object coordinates the HST public database[§] was searched to see if HST had imaged any of the objects within a set search radius of 1.5′. Limiting the search radius to 1.5′ decreased the chance of the object not being in the imaged Hubble field of view although this still did occur in some of the images. Once all the HST image sets with IR objects within a radius of 1.5′ had been found they were downloaded and examined with SAOImage DS9 (ds9), an astronomical imaging and data visualization application. With ds9 the HST image set for each object was examined to see if there was any extended nebulosity or features in its circumstellar environment. The images chosen for this evaluation were those of different filters and longest exposure times. Objects that were deemed to have interesting features were then compared to their Spitzer images obtained from the IRSA Spitzer database[**]. The SIMBAD database[††] was also utilized to see if the IR object had any other identification.

III Results

A) Post-AGB Objects

A survey of the post-AGB population of the Large Magellanic Cloud was completed by cross correlating the SAGE catalogue with optical catalogues [6]. This was compiled by utilizing the two types of spectral energy distributions (SED) found in galactic post-AGB objects. The paper then categorizes each source as one of three possible options: shell, disk and disc or shell. Shell post-AGB stars, show a double-peaked SED where the longer wavelength peak is due to the expanding shell of mass lost in the AGB phase, the central star may or may not be obscured by its circumstellar matter but if not is detectable at shorter wavelengths. Disk post-AGB stars have SEDs that show an overall excess with an onset in the near IR. This shows that hot dust is still within the system and that instead of an expanding envelope of matter the circumstellar environment contains a disk instead. This type of post-AGB is most likely due to stellar dynamics from another star in proximity to the post-AGB object. The disc or shell category is due to an SED that is some mix of both shell and disc characteristics.

[‡] NASA ADS – The SAO/NASA Astrophysics Data System: http://adswww.harvard.edu/
[§] MAST HST at STScI – Astronomical Database: http://archive.stsci.edu/
[**] Infrared Science Archive – Spitzer: http://irsa.ipac.caltech.edu/Missions/spitzer.html
[††] SIMBAD Astronomical Database: http://simbak.cfa.harvard.edu/simbad/

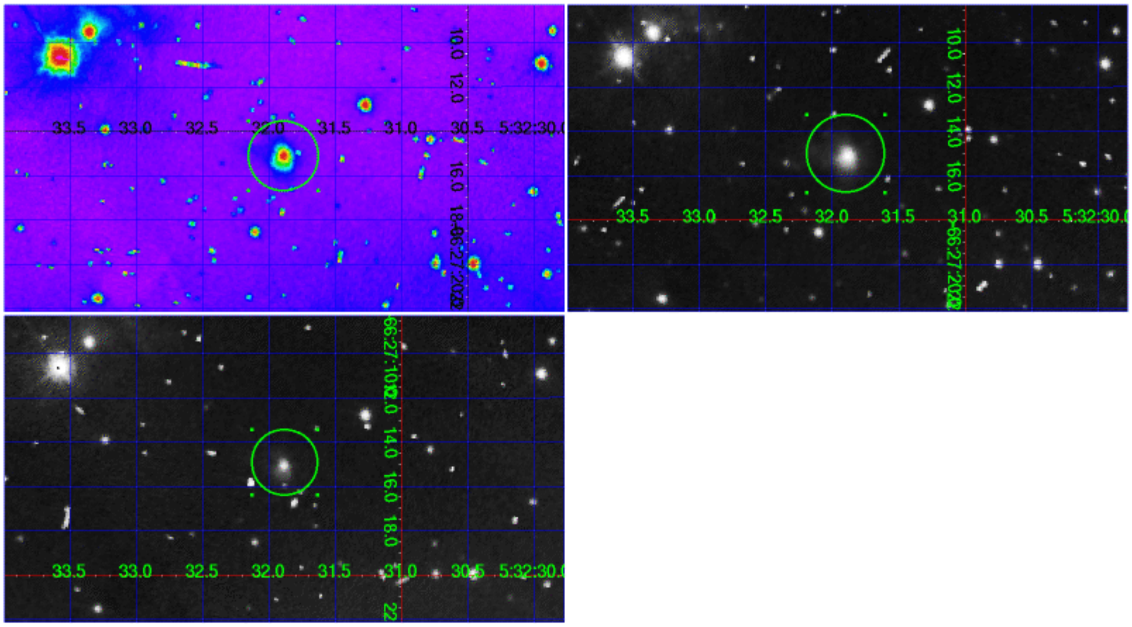

Figure 2. HST view of J053231.96-662515.4. *Images from left to right: F555W, F814W, F450W with WFPC on HST. Observe an extended circumstellar envelope suggesting not-symmetric stellar wind dynamics.*

A post-AGB object is a stellar object in the phase during the end of a low to intermediate mass (i.e. 1 - 8 M_{sun}) star's life cycle before a planetary nebula but after an asymptotic giant branch star. These objects are very important to the chemical composition and evolution of the interstellar medium (ISM) and therefore galactic evolution since the mass-loss process in these stars is the main donor for nucleo-synthetically enhanced material in the ISM. Much is unknown about the physics and chemical composition of the mass loss in AGB and post-AGB stars as well as the processes involved in shaping the circumstellar environment around these stars. Post-AGB stars are very rare since the star's lifetime in this phase is believed to be ~1000 years and often times the distance to galactic post-AGB objects is unknown and therefore their luminosity as well. By using post-AGB populations for study in other galaxies, like the LMC, this distance issue is a known value. Post-AGB stars are presumed to be especially bright in the infrared wavelengths due to the mass-loss remnants of the AGB phase.

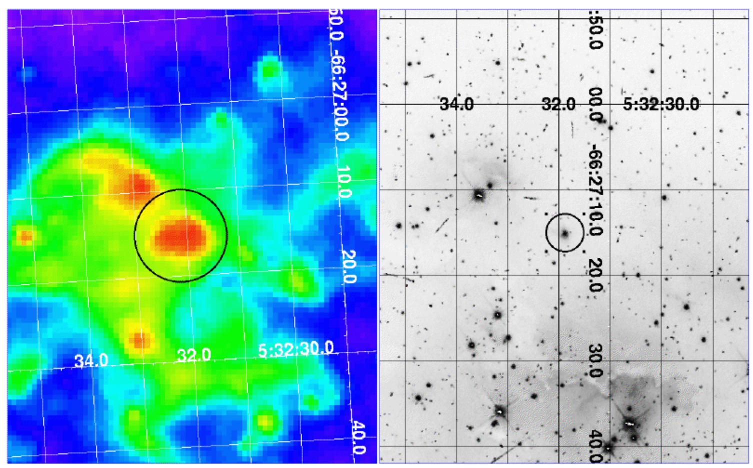

Figure 2. Spitzer and HST view of J053231.96-662515.4. *Image on left taken with Spitzer-IRAC at 3.6 μm while the image on the right is taken with HST-WFPC2 with F555W.*

The HST database was searched for ~1400 post-AGB candidate stars, HST imaged the coordinates of ~123 within a 1.5′ radius of its primary target and of these ~98 were found to be located on the image files. 5 were examined further with Spitzer due to circumstellar effects and other features observed in the HST images. See Table 1 for a list of post-AGB objects further examined with Spitzer and their properties.

B) Compact 8 µm Luminous Sources

Approximately 250 of the LMC's most luminous 8 µm sources were identified by Kastner et al by using an altered color classification scheme based on the 2MASS-MSX scheme by Buchanan et al. The researchers used 2MASS and MSX photometry to classify the objects [7]. This survey constituted of most of the mid IR-luminous objects in the LMC. In the survey there are carbon rich AGB stars (C-AGB), followed by red super giants (RSG), compact HII regions, and oxygen rich AGB (O-AGB) in decreasing population. One of the goals of the survey was to create a color classification scheme can be used to classify any sources in external galaxies where the objects are resolvable by 2MASS and Spitzer. Certain objects were unclassifiable and are referred to as unidentifiable (U). The HST images were examined for visual confirmation between different classifications of objects. For example HII regions should be in general much more nebulous than AGB stars. Around 270 objects were searched for in the HST archive. As an efficiency measure the HST images were then examined based on group so that a sample of each type of category could be evaluated. There were many HII regions which had HST data but due to time constraints not all of these images were looked

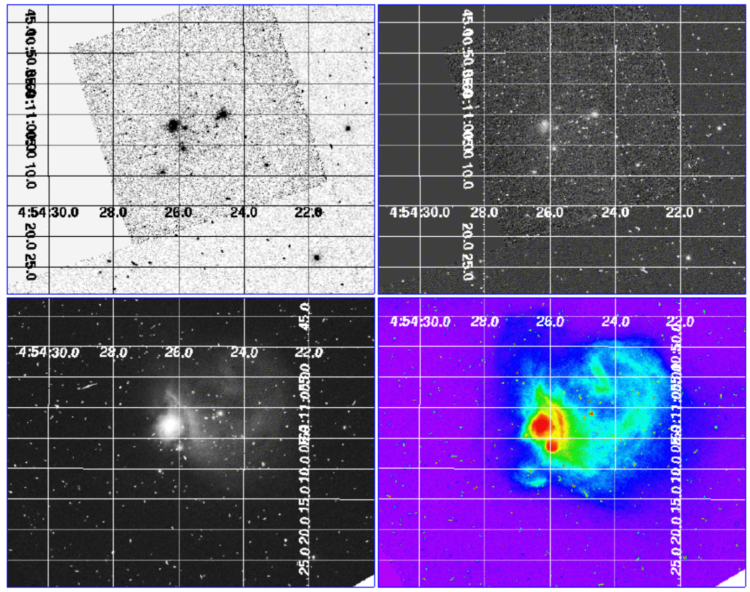

Figure 3. HST-WFPC2 view of J045426.173-691102.563. *From left to right, top row: F300W and F410M, bottom row: F502N and F656N*

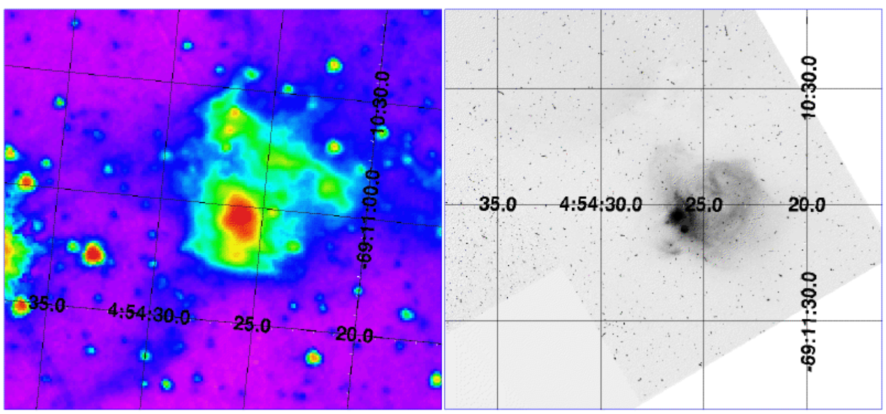

Figure 4. Spitzer and HST view of J045426.173-691102.563. *Image on the left is taken with MIPS 3.6 µm and the image on the right is taken with HST 656N.*

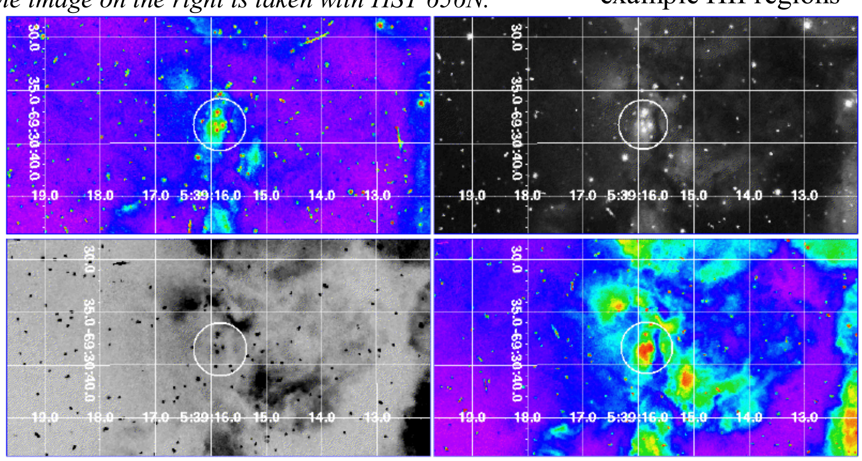

Figure 5. HST view of J053915.87-693038.45. *From left to right, top row: F673N and F606W, bottom row: F502N and F656N.*

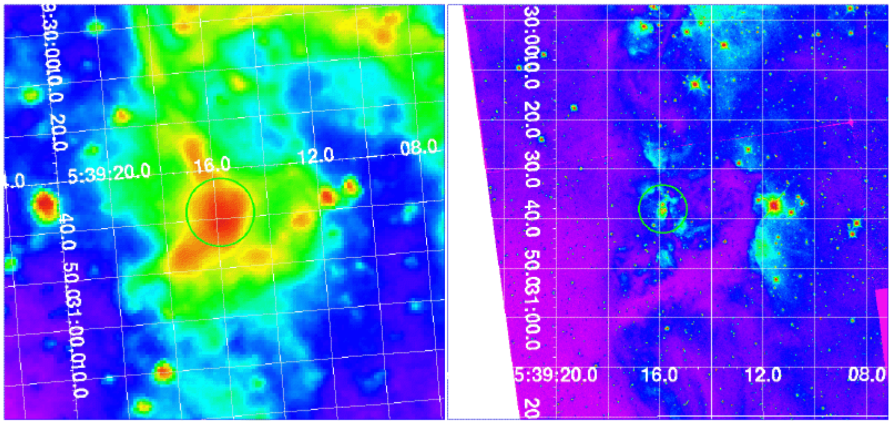

Figure 6. Spitzer and HST view of J053915.87-693038.45. *Image on left is taken with Spitzer 3.6 µm and the image on the right was taken with HST.*

at. Approximately 26 Kastner objects were found to have HST counterparts, while ~23 had coordinates in the image. Only 17 were looked at however due to time constraints and 7 were deemed to contain anomalous or interesting results pertaining to the categorization scheme and were examined further with Spitzer. See Table 2 for a list of compact 8 µm luminous sources further examined with Spitzer and their properties.

C) WR Binaries

Foellmi et al. searched for Wolf-Rayet binary stars by spectroscopic periodic radial velocity variations[8 & 9]. Within the SMC the search was limited to nitrogen rich WN Wolf Rayet (WR) Stars. The researchers also used time dependent photometric data from the OGLE and MACHO databases and x-ray data to narrow down their results. WR stars are very large massive bright hot stars with extended stellar sizes due to their atmosphere. They lose mass due to a strong wind at a high rate, about 10^{-5} of M_{SUN} per year, for comparison purposes our sun loses about 10^{-14} solar masses per year. These evolved stars lose so much mass due to their stellar wind that the central star is usually obscured. Through Hubble a WR star should appear to be a cloud of hot gas with possible extended structures from the displacement of material from the stellar wind. The HST database was searched for 11 WR binaries in the SMC and 61 WR binaries in the LMC, within the LMC 19 were within 1.5″ of a previous HST image and 5 within the SMC. Only 8 of those former 19 had coordinates on the image and all 5 were on the image within the SMC and 2 were examined further with Spitzer. See Table 3 for a list of WR binaries further examined with Spitzer and their properties.

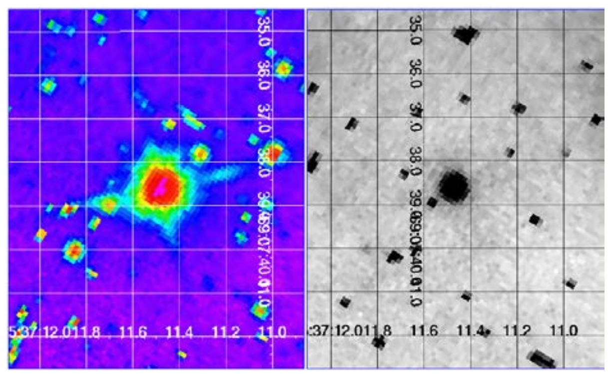

Figure 7. HST WFPC2 view of J053711.51-690737.4. *Image on left is taken with HST F814W and the image on the right was taken with HST F656N.*

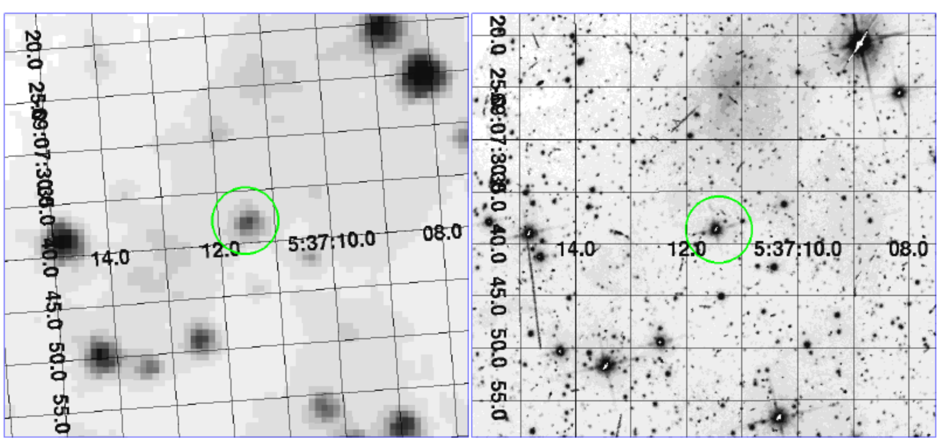

Figure 8. Spitzer vs HST view of J053711.51-690737.4. *Image on left is taken with Spitzer IRAC 3.6 µm and the image on the right was taken with HST .*

D) Extreme Carbon

Gruendl et al. found 13 potential extreme carbon stars within the LMC by examining the IRAC and MIPS observations with Spitzer[10]. Unfortunately, none of these extreme carbon stars were within 1.5 ″ of an HST image.

E) Variable Stars and Young Stellar Objects

Variable and young stellar objects were catalogued by Vijh et al. using the SAGE survey [11]. The researchers looked for thermal infrared variability from the two different epochs of the SAGE survey which were separated by three months. Most of the variable sources were classified as AGB stars while a smaller fraction of C-AGB and O-AGB stars were detected. Young stellar objects have been looked at previously with HST, which is discussed in Vidya et al [12]. As such the YSO objects from this paper were discarded and only the variable and unknown sources were used as much work on YSO's with HST images has previously been completed. The table was manipulated to obtain coordinates of only the variable sources by a python program. AGB stars are hard to visually discover due to their dust that usually surrounds them which gets thicker over time. Variable AGB stars are such that the stellar center experiences pulsation shocks. This in turn affects how the dust is blown away from the star in its last stages of life. Later in their life AGB stars are usually more dust enshrouded and as such using the IR surveys are a very good way to find post-AGB stars. Of the ~970 variable star coordinates searched for with the HST archive ~52 were found and ~36 had coordinates on the image while 6 were further examined with Spitzer. See Table 4 for a list of variable objects further examined with Spitzer and their properties.

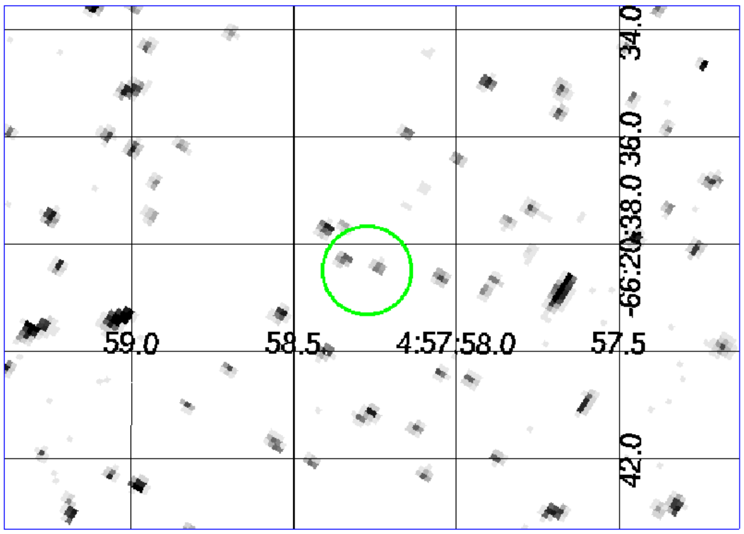

Figure 9. HST view of J045758.2-662038.4. *Image is taken with HST-WFPC2 F300W, observe there is not an object at the coordinates.*

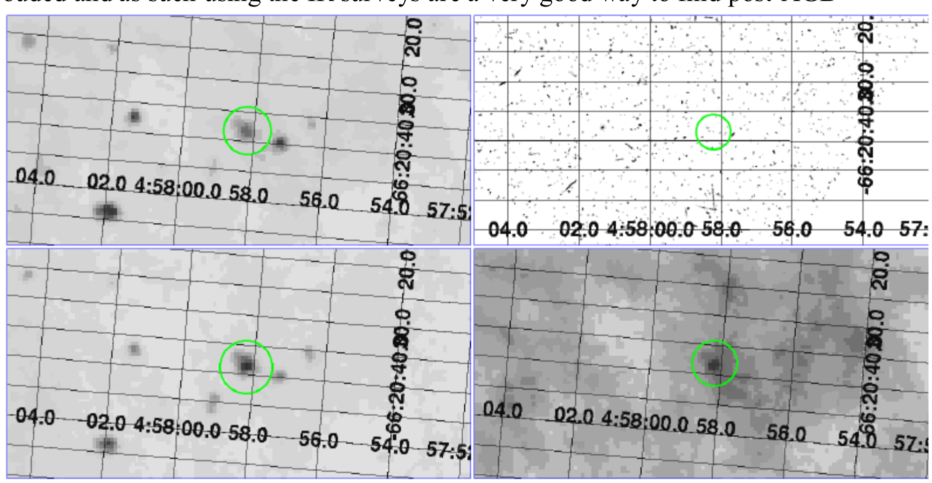

Figure 10. Spitzer vs HST view of J045758.2-662038.4. *Images from left to right, top row: IRAC 3.6μm, HST F300W, bottom row: IRAC 4.5μm and IRAC 5.8 μm.*

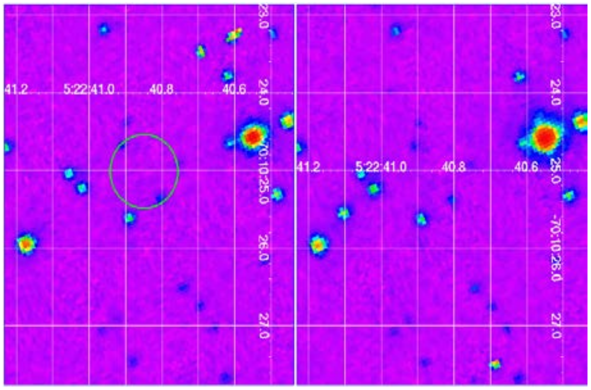

Figure 11. HST-ACS view of J052240.85-701024.96. *Images from left to right, F555W;Clear2L and Clear1L;F814W*

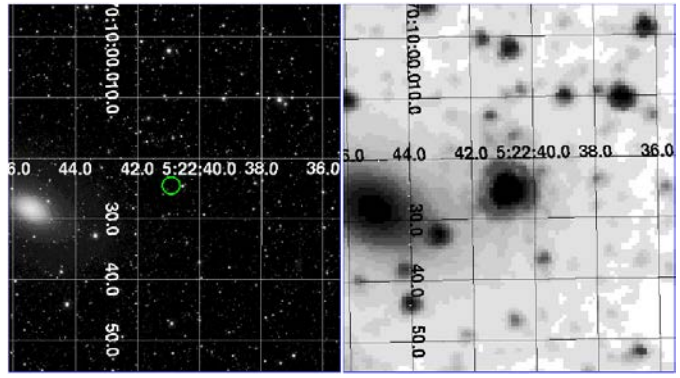

Figure 12. Spitzer vs HST view of J052240.85-701024.96. *Images from left to right, HST-ACS and IRAC 3.6μm.*

F) Compact sources

van Loon et al. looked at far-IR spectra from Spitzer of luminous compact objects in the LMC [13]. The objects were classified based on a spectral classification scheme. Many of the objects presented by are repeats with the Kastner and post-AGB list of objects so their HST files had already been observed. Repeats were accounted for by searching all coordinate lists against previous coordinate lists. In total however, there were 61 objects, 17 of which had HST data, and 2 objects in total were further looked into with Spitzer. See Table 5 for a list of compact source objects further examined with Spitzer and their properties.

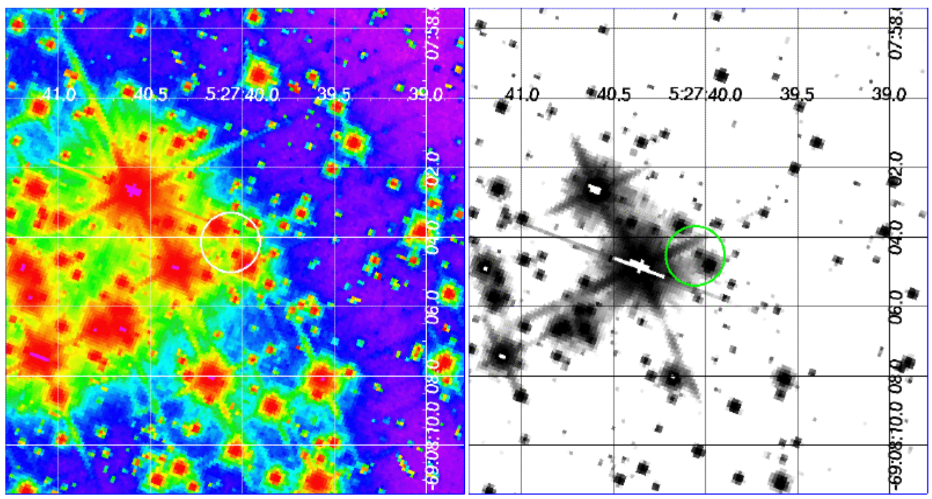

Figure 13. HST-WFPC2 view of J052740.06-690804.6. *Images from left to right: F555W and F814W.*

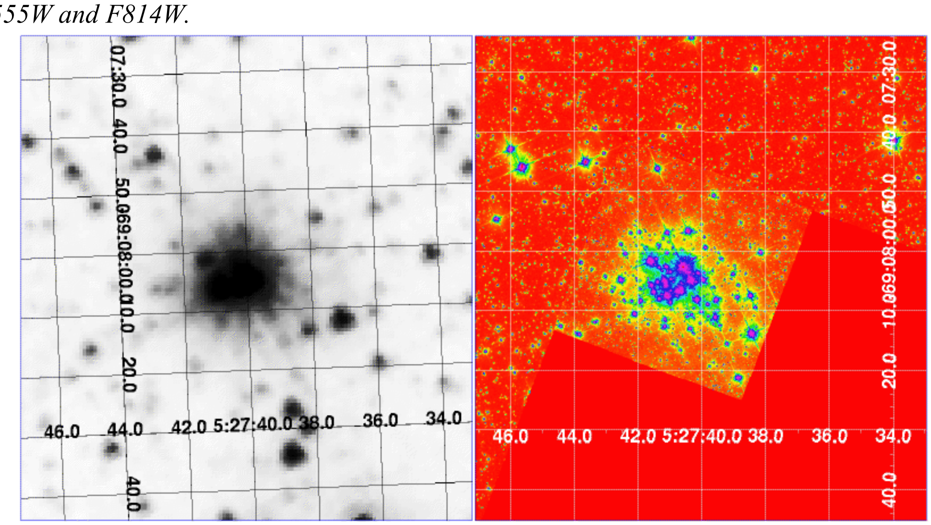

Figure 14. Spitzer and HST view of J052740.06-690804.6. *Images from left to right: Spitzer 3.6 μm and HST WFPC2.*

G) Runaways

Through a combination of three separate papers detailing studies on three body encounters, bow shocks and massive runaway stars the HST archive was searched for ~20 different runaway stars in the LMC and SMC [14 & 15 & 16]. 6 of these were found in the archive and 4 were further examined further with Spitzer. Some of the runaway stars were only listed by name and to find the coordinates in order to search the HST MAST archive the SIMBAD database was used to find alternative names and coordinates. Massive stars are thought to be ejected from their star forming clusters through gravitational interaction with other massive stars. These stars move very fast through the interstellar medium and create bow shocks as they displace the material around themselves. To produce a detectable bow shock the runaway star must be moving through the ISM with a supersonic velocity, which is > 10 km/s in the warm ionized medium. The medium itself also must be dense enough to display bow shocks in the infrared and Hα. See Table 6 for a list of runaway stellar objects further examined with Spitzer and their properties

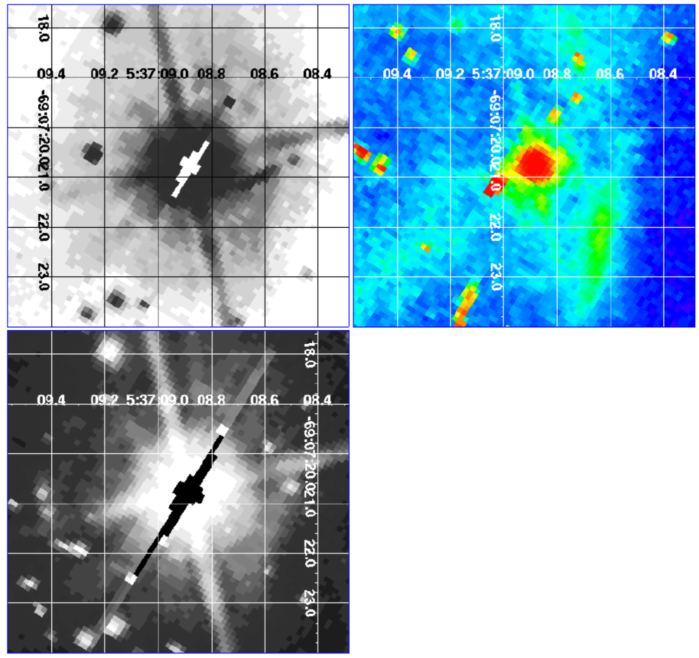

Figure 15. HST view of J053708.88-690720.36. *Images from left to right, top to bottom: WFPC2 F675W, F656N and F814W .*

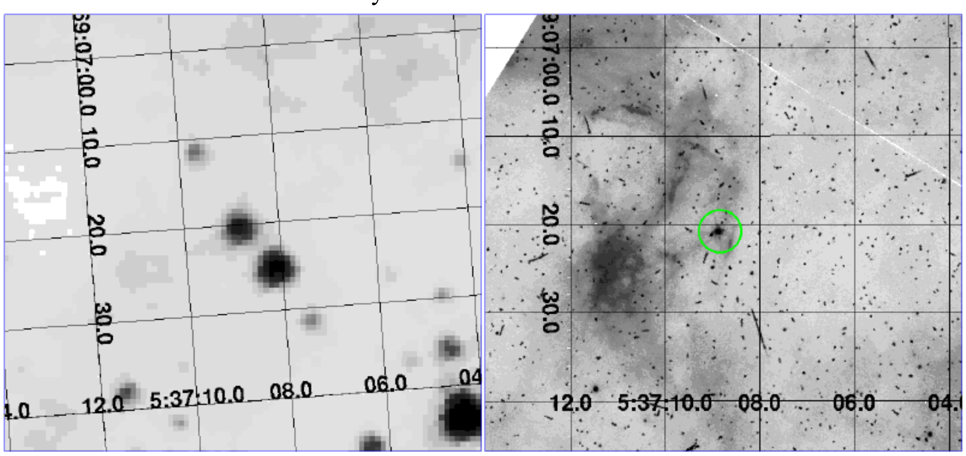

Figure 16. Spitzer and HST view of J053708.88-690720.36. *Images from left to right: Spitzer IRAC 3.6 µm and HST WFPC2.*

IV: Source Identification and Image Analysis

A) Highly dust obscured objects:

The selected images above are few of many images examined. J052240.85 701024.96 and J045758.2-662038.4 both demonstrate objects that are very luminous in the infrared which appear as very faint or not at all within the range of HST. J045758.2-662038.4 for example displays no object at the coordinates in the Hubble image but when examined with Spitzer-IRAC a very faint object appears, becoming more luminous in 5.8 μm and 4.5 μm than in the 3.6 μm bands. It is probable that the suspected variable star is highly obscured by dust that is luminous in the infrared. The Spitzer images for this object also shows structures in this area of space which are not seen in the 'blank' Hubble image. The HST image for J052240.85-701024.96 on the other hand does not show a region of empty space but rather several objects on either side of the coordinates. In Spitzer 3.6 band however the object at the coordinates is so large that it is undeterminable if any of the objects in HST on either side of the coordinates are the object in question or if there is so much dust that the object itself is obscured in the visual wavelengths.

B) Multiple sources:

Within stellar clusters it becomes especially hard to decipher which object is the luminous infrared one, if there is only one. It's possible that two or more objects contribute to the Spitzer object. In J052740.06-690804.6 and J053915.87-693038.45, both objects are within a cluster or high density stellar material region. It is difficult to determine which object the coordinates are referring to in the HST images. In the HST for J053915.87-693038.45 there appears to be four separate objects within a nebulous region at the coordinates but in the Spitzer wavelength range there only appears to be one object. The same effect occurs in J052740.06-690804.6 where the coordinates lie within a star cluster but this cluster appears to be a singular object within the Spitzer images.

C) Associated Circumstellar / Interstellar Structures:

Due to the resolution of HST, certain structures and details can be seen that are not resolvable in the Spitzer images. The Spitzer images for J053231.96-662515.4 from the post-AGB list show pockets of more luminous material surrounded by less luminous nebulosity. In the HST images this is resolved to an obvious stellar object with circumstellar features. There appears to be an extension of a shell around the star and the shell is further away from the star on one side then the other. This is possibly due to an irregular or non-symmetric solar wind. This is very interesting as post-AGB objects are rare to find and the physics governing the processes that occur within this life phase are not yet fully understood. J045426.173-691102.563 and J053708.88-690720.36 also show features in HST that are not readily observable within their Spitzer images. In the Spitzer images for J053708.88-690720.36, the object appears to be compact with no associated nebulosity. In HST however a potential bow shock structure is revealed although it could be a part of the greater nebula within the region. J045426.173-691102.563 in the HST images also shows potential bow shock structures clearly as well as an extended non-symmetric nebulosity which could be blowing away from the star unevenly. In the Spitzer images the nebulosity is shown but the details of the bow shock structure and the two objects in the center of the cloud appear to be one elongated object.

V: Summary

In total the HST archive was searched for ~2800 luminous infrared objects and ~250 objects were found to be within 1.5 ″ of an image set, ~170 of those objects were actually contained on the image and of that ~ 30 images were compared against their Spitzer images. The Hubble Space Telescope and other wavelength telescopes with greater resolution than Spitzer are very useful in confirming categorization techniques of luminous infrared objects. Future research is suggested to complete the comparison of the found HST images to their Spitzer counterparts for all ~170 objects as well as more in depth analysis of the HST images to try and verify their classifications.

Acknowledgments:

A. Azari would like to thank my mentor, Dr. Raghvendra Sahai for introducing me to the astrophysical research community and the Jet Propulsion Laboratory. I would also like to thank my fellow office mates, Fonda Day and Alex Gruson for supporting me during my time here. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France. This research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by undergraduate Student Research Program (USRP).

References:

1) Meixner et al. 2006, AJ, 132, 2268.

2) Shaw et al. 2007, PASP, 119, 9.

3) Gvaramadze et al. 2011, aap, 525, A17.

4) Fazio et al. 2004, ApJ Supp Ser 154, 10.

5) Rieke et al. 2004, ApJ Supp Ser 154, 25.

6) van Aarle, E., van Winckel, H., Lloyd Evans, T., et al. 2011, aap, 530, A90.

7) Kastner, J.H., Thorndike, S.L., Romanczyk, P.A., et al. 2008, aj, 136, 1221.

8) Foellmi, C., Moffat, A.F.J., & Guerrero, M.A. 2003, mnras, 338, 1025.

9) Foellmi, C., Moffat, A.F.J., & Guerrero, M.A. 2003, mnras, 338, 360.

10) Gruendl, R.A., Chu, Y.H., Seale, J.P., et al. 2008, apjl, 688, L9.

11) Vijh, U.P., Meixner, M., Babler, B., et al. 2009, aj, 137, 3139.

12) Vaidya, K., Chu, Y.H., Gruendl, R.A., Chen, C.H.R., & Looney, L.W. 2009, apj, 707, 1417.

13) van Loon J.T., Oliveira, J.M., Gordon, K.D., et al. 2010, aj, 139, 68.

14) Gvaramadze, V.V., Pflamm-Altenburg, J., & Kroupa, P. 2011, aap, 525, A17.

15) Gvaramadze, V.V., Pflamm-Altenburg, J., & Kroupa, P. 2010, aap, 519, A33.

16) Gvaramadze, V.V., & Gualandris, A. 2011, mnras, 410, 304.

Table 1: Post-AGB Objects

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J051920.83-695812.7	pAGB-s	None	None	WFPC2 F606W, F450W, F814W, F300W	diff spikes, features in CSE
J052429.44-693723.7	pAGB-s	None	None	WFPC2 F555W, F675W	diff spikes & halo
J052558.27-713637.7	pAGB-s	None	None	WFPC2 F606W, F300W	diff spikes & halo & nebulous
J053231.96-662715.4	pAGB-s	2MASS J05323195-6627154 / MASX J05323197-6627158	Y*O / G	WFPC2 F555W, F814W, F450W	compact & halo & nebulous
J053620.70-671807.6	pAGB-s	LHA 120-N 66	PN	STIS MIRVIS	nebulous- classified as PN

Table 2: Compact 8 µm Luminous Sources

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J045426.173-691102.563	HII	2MASSI J0454260-691102	*iA	WFPC2 F300W, F410M, F502N, F656N	Bow shock & nebulous
J045647.08-662431.2	HII	2MASS J04564707-6624312	*	WFPC2, F656N, F502N ACS F550M;CLEAR2L	Nebulous - not illuminated by central object
J045747.96-692016.210	U	2MASS J045747.95-662844.8	*	WFPC2, F606W, F450W, F814W, F300W	diff spikes & nebulous & interesting CSE
J051722.39-692016.210	U	HD 3523	mul	ACS CLEAR1L:F814W, F555W:CLEAR2L	Star cluster-object identification uncertain
J053020.67-665301.95	RSG	2MASS J05302067-6653018	*iC	ACS CLEAR1L:F814W F555W:CLEAR2L	No source at coords – incorrect coords with HST image – shifted RA
J053542.21-691152.7	WR?	Brey 58a	WR*	ACS F550M:CLEAR2L, WFPC2 F606W, F300W, STIS MIRVIS	Coords in dense stellar region not as dusty as HII regions – no central star obvious
J053915.87-693038.45	HII	2MASS J05391587-6930384	MoC	WFPC2 F673N, F606W, F502N, F656N	4 dense objs in center of nebulous region – appears to be one object in Spitzer

Table 3: WR Binaries

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J013104.29-732503.9,	WR-bin	2MASS J01310412-7325038	WR*	WFPC2 F336W, F439W , F555W	No Spitzer data found, bow shock? diff spikes
J053711.51-690737.4	WR-bin	4Brey 69	WR*	WFPC2 F814W, F656N	diff spike?/jets? Faint in 3.6 μm

Table 4: Variable Stars

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J051944.088-695938.4	X	MSX LMC 378	Mi*	ACS F775W:CLEAR2L	Compact, possible shell?
J051953.232-694117.52	O	SHV 0520170-694410	sr*	WFPC2, F555W, F814W	diff spikes or CSE? Possible shell?
J052102.832-693522.56	X	2MASS J05210284-6935229	Mi*	WFPC2 F547M	No source at cords
J052155.368-693204.92	C	2MASS J05215533-6932051	Mi*	ACS F606W:CLEAR2L	diff spikes
J052213.2-692713.32	C	2MASS J05221323-6927132	sr*	WFPC2 F555W, F380W, F439W, F675W , F814W, F953N	diff spikes, more luminous in higher filts
J052240.85-701024.96	X	MSX LMC 436	Mi*	ACS F555W:CLEAR2L, CLEAR1L:F814W	coords in between 2 objs in HST
J052249.296-694657	O	2MASS J05224928-6946573	Mi*	WFPC2 F814W, F555W	diff spikes – extended CSE - features at PA +145 (in F814W), +45 (both), & -45 (F555W)
J052441.28-693918.36	O	2MASS J05244124 -6939186,0.33	Mi*	WFPC2 F502N, F375N, F673N, F547M	obj not found at coords
J052458.31-6948120.37	O	SHV 0525238-695044	Mi*	WFPC2 F606W, F675W, F814W, F555W	diff spikes & feature at PA -135
J052501.176-694834.56	X	MSX LMC 493	Mi*	WFPC2 F606W, F675W, F814W, F555W	Compact object, obvious in Spitzer
J052716.56-704521.6C,	C	SHV 0527525- 704742,	sr*	ACS CLEAR1L:F814W, CLEAR1L:F435W, F555W:CLEAR2L	No Spitzer data – diff spikes, PSF?
J052752.632-685908.52	X	HD 269582	V*	ACS F555W:CLEAR2L,	No source at coords

				CLEAR1L:F814W	
J045758.2-662038.4	U	MSX LMC 1288	*	WFPC2 F300W	No source at coords, very faint in Spitzer Band 1 and 2
J050337.2-662036.96	U	MACHO 53.3850.978	V*	WFPC2 F555W, F814W	diff spikes & feature at PA -135?

Table 5: Compact Sources

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J052603.10-660517.2	N-51 YSO	MACHO 62.7484.180	*	WFPC2 F300W, F547M, F380W	No source at coords – in nebulous region
J052740.06-690804.6	RSG	2MASS J05274010-6908044	*	WFPC2 F555W, F814W	Star cluster –source identification unclear - Spitzer not resolvable

Table 6: Runaway Stars

Name	Type	SIMBAD Name	SIMBAD Type	HST Images	Comments
J045652.52-661956.1	Runaway Star	[ElS2006] n11 026 & 2MASS J04565252-6619560	*iC	WFPC2 F606W	diff spikes & extension of CSE SW of center
J045727.44-673902.9	Runaway Star	Brey 10a & Sk -6722,	WR*	STIS MIRVIS	Diff spikes – elongated shape
J053536.01-690706.1	Runaway Star	Sk -69206 & GSC 09162-00972	*	WFPC2 F450W, F814W, F300W, F656N	Diff spikes, Bow shock?
J053708.88-690720.36	Runaway Star	30Dor016 & 2MASS J05370888-6907203	IR	WFPC2 F675W, F656N, F814W	Diff spikes, Bow shock?

Nomenclature

*iC = star in cluster
WR* = Wolf-Rayet Star
* = Star
IR = Infrared Source
V* = Variable star
Sr* = Semi-regular Pulsating star
Mi* = Variable Star of the Mira Cet type
MoC = Molecular Cloud
*iA = star in association
PN = Planetary nebula

G = Galaxy
pAGB-s = post asymptotic giant branch star – shell structure
HII = Hydrogen II Region
U = Unidentified
X = extreme asymptotic giant branch
C = carbon asymptotic giant branch
O = oxygen asymptotic giant branch
YSO = young stellar object
RSG = red super giant
PA = Position angle
CSE = circumstellar environment
diff spikes= diffraction spikes
WR-bin = Wolf-Rayet Binary