Journal of The Korean Astronomical Society
42: 81 ∼ 91, 2009 August

A CATALOG OF AGB STARS IN IRAS PSC

Kyung-Won Suh and Young-Joo Kwon
Dept. of Astronomy and Space Science, Chungbuk National University Cheongju 361-763, Korea
E-mail: kwsuh@chungbuk.ac.kr
(Received June 12, 2009 ; Accepted August 7, 2009)

ABSTRACT

We make a new catalog of AGB stars in our Galaxy from the sources listed in the Infrared Astronomical Satellite (*IRAS*) point source catalog (PSC) compiling the lists of previous works with verifying processes. We verify the class identification of AGB stars into oxygen-rich and carbon-rich stars using the information from recent investigations. For the large sample of AGB stars, we present infrared two-color diagrams from the observations at near infrared bands and *IRAS* PSC. On the two-color diagrams, we plot the tracks of theoretical radiative transfer model results with increasing dust shell optical depths. Comparing the observations with the theoretical tracks, we discuss the meaning of the infrared two-color diagrams.

Key words : stars: AGB and post-AGB - circumstellar matter - infrared: stars - dust, extinction - radiative transfer.

I. INTRODUCTION

Asymptotic Giant Branch (AGB) stars are generally classified to be oxygen-rich (M-type) or carbon-rich (C-type) based on chemistry of the photosphere and/or the outer envelope.

Evolutionary sequences of AGB stars are not well known yet. Chan & Kwok (1990) argued that a M-type star may become a carbon star when the star goes through C dredge-up processes and thus the abundance of C is larger than that of O. S stars are generally regarded as intermediate between M-type and carbon stars in their properties (e.g., Lloyd Evans & Little-Marenin 1999). Only the S stars with Tc (also called intrinsic S stars) are believed to be actually in the AGB phase following the evolution sequence M-S-C (Iben & Renzini 1983; Jorissen & Mayor 1988, 1992).

The chemistry of C and O for AGB stars has been a controversial topic in many areas of astronomy. It would be meaningful to have the detected numbers for different classes of AGB stars in our Galaxy.

In this paper, we make a new catalog of AGB stars in our Galaxy from the sources listed in *IRAS* PSC compiling the lists of previous works with verifying processes. Suh, Lee, & Kim (2001, hereafter Paper I) presented a list of 1429 O-rich AGB stars and 832 C-rich AGB stars. Since then, many more AGB stars have been identified and new methods are developed for detecting, verifying, and classifying AGB stars.

Corresponding Author: Kyung-Won Suh

II. SAMPLE

In this paper, we make a new catalog of AGB stars in our Galaxy from the sources listed in the *IRAS* PSC compiling the lists of previous works with verifying processes. The AGB stars in our catalog are divided into four groups; O-rich stars (M-type Miras and OH/IR stars), C-rich stars (C-type stars or carbon stars), S stars, and silicate carbon stars.

The *IRAS* Low Resolution Spectrograph (LRS; $\lambda =$ 8−22 μm) data are very useful to identify important features of O-rich and C-rich dust grains in AGB stars (e.g., Kwok, Volk, & Bidelman 1997). The data from Infrared Space Observatory (*ISO*) Short Wavelength Spectrometer (SWS; λ = 2.4−45.2 μm), *ISO* Long Wavelength Spectrometer (LWS; λ = 43−197 μm) are useful for identifying more detailed dust features (e.g., Suh 2002).

Near infrared (NIR) data are useful for identifying the molecular feature of AGB stars. The data from the Near Infrared Spectrometer (NIRS; 1.4−4.0 μm) boarded in Infrared Telescope in Space (*IRTS*) are useful to identify the features of molecules for the AGB stars with thin dust envelopes (Le Bertre et al. 2003; 2005).

AGB stars are strong sources of radio molecular maser emission. The radio OH and SiO maser surveys for *IRAS* color-selected objects have been very useful to identify AGB stars (e.g., Lewis, Eder, & Terzian 1990).

The Midcourse Space Experiment (*MSX*) project (Egan et al. 2003) provides useful photometric data at 8.28, 12.13, 14.65, 21.34 μm wavelength bands. The two micron all sky survey (2*MASS*) project (Skrutskie

Table 1.
O-rich AGB stars as identified and verified

References	Original	Excluded	Selected	Duplicate	Remaining	Paper I
Rowan-Robinson et al. (1986)	95	1	94		94	1
Epchtein et al.(1990)	31	10	21	0	21	21
Lewis et al. (1990)	86	1	85	1	84	86
Le Squeren et al. (1992)	112	3	109	8	101	83
Blommaert et al. (1993)	15	1	14	5	9	10
Chengalur et al. (1993)	131	1	130	13	117	152
David et al. (1993)	139	1	138	17	121	139
Kastner et al. (1993)	19	1	18	3	15	18
Loup et al. (1993)	184	10	174	81	93	113
Nyman et al. (1993)	44	4	40	12	28	41
Whitelock et al. (1994)	61	3	58	14	44	58
Xiong, Chen, & Gao (1994)	59	1	58	38	20	58
Lepine et al. (1995)	380	5	375	179	196	382
Guglielmo et al. (1997)	16	0	16	2	14	10
Lewis (1997)	231	0	231	183	48	229
Willacy & Millar (1997)	4	0	4	4	0	4
Guglielmo et al. (1998)	23	2	21	0	21	12
van Loon et al. (1998)	0	0	0	0	0	12
Sevenster et al. (2001)	286	12	274	79	195	-
Chen et al. (2001)	1024	38	986	581	405	-
Le Bertre et al. (2003)	563	20	543	46	497	-
Lewis et al. (2004)	134	0	134	122	12	-
Jimenez-Esteban et al. (2005)	371	4	367	340	27	-
Jimenez-Esteban et al. (2006)	94	0	94	63	31	-
total number	4102	118	3984	1791	2193	1429
IRAS two-color					1211	

et al. 2006) provides the PSC that contains fluxes at J, H, and K bands.

For each classified object, our catalog contains the *IRAS* PSC number, the *IRAS* four color fluxes from *IRAS* PSC (version 2.1), and known properties for related objects; the *IRAS* LRS class (Kwok et al. 1997), the radio maser emission, the information from more recent IR observations (*IRTS*, *ISO*, *MSX*, and 2*MASS*), and other special features.

(a) O-rich Stars

O-rich AGB stars typically show the conspicuous 10 μm and 18 μm features in emission or absorption. They suggest the presence of silicate dust grains in the outer envelopes around them (e.g., Suh 1999). Low mass-loss rate O-rich AGB (LMOA) stars with thin dust envelopes show the 10 μm and 18 μm emission features. And high mass-loss rate O-rich AGB (HMOA) stars with thick dust envelopes show the absorbing features at the same wavelengths.

In *IRAS* LRS, O-rich AGB stars are classified into class of E (10 μm in emission) and A (10 μm in absorption). Kwok et al. (1997) used *IRAS* LRS to identify the class E and the class A objects. Some of the class A or E objects are young stellar objects or planetary nebulae.

LMOA stars show many molecular lines at NIR bands. The most conspicuous lines are the water vapor absorption at 1.9 and 2.9 μm and CO absorption at 2.3 and 4.6 μm produced in the photosphere and expanded envelope of the central stars. These absorption lines of H_2O and CO make the K band magnitude larger for LMOA stars. Investigating the NIR molecular lines, Le Bertre et al. (2003) identified O-rich stars from the data obtained with the *IRTS*.

For OH maser detecting methods, we use the data obtained by the Arecibo survey (Lewis et al. 1990; Chengalur et al. 1993; Lewis 1997; Lewis, Kopon, & Terzian 2004; Jimenez-Esteban et al. 2005), the Nancay survey (Le Squeren et al. 1992; David, Le Squeren, Sivagnanam 1993), ATCL/VLA survey (Sevenster et al. 2001), and the GLMP survey (Jimenez-Esteban et al. 2006). Nyman, Hall, & Le Bertre (1993) detected SiO maser emission for a sample of OH/IR stars. The *IRAS* color-selected OH maser detecting is very effective and highly certain, but it is not a perfect way to identify O-rich AGB stars. The sample using this method may contain massive star forming regions or compact H II regions, and some C-rich AGB stars emit OH maser.

Table 1 lists the number of O-rich AGB stars as identified by various authors and verified in this paper. We confirm that 2193 objects are O-rich AGB stars. We have *IRAS* LRS data for 1400 objects. 815 stars are classified as *IRAS* LRS class E and 180 stars are classified as class A.

The 22 objects listed as O-rich stars in Rowan-Robinson et al. (1986), Epchtein, Le Bertre, & Lepine (1990), Lewis et al. (1990), Le Squeren et al. (1992), Blommaert, van der Veen, & Habing (1993), Chengalur et al. (1993), Kastner et al. (1993), Whitelock et al. (1994), and Guglielmo, Le Bertre, & Epchtein (1998) are carbon stars. These stars are listed in the General catalog of galactic carbon stars (GCGCS) by Stephenson (Alksnis et al. 2001) or classified as *IRAS* LRS class C (Kwok et al. 1997).

One object (*IRAS* 05358-0704) listed in David et al.

Table 2.
C-rich AGB stars as identified and verified

References	Original	Excluded/Added	Selected	Duplicate	Remaining	Optical	Paper I
Rowan-Robinson et al. (1986)	40	0/1	41	0	41	18	39
Chan & Kwok (1990)	145	0/0	145	22	123	31	145
Epchtein et al.(1990)	216	7/0	209	60	149	49	196
Egan & Leung (1991)	125	1/0	124	78	46	39	47
Volk, Kwok, & Langill (1992)	32	0/0	32	9	23	0	32
Chan (1993)	106	0/0	106	55	51	51	69
Groenewegen, de Jong, & Baas (1993)	25	0/0	25	14	11	2	25
Guglielmo et al. (1993)	106	5/0	101	0	101	9	175
Kastner et al. (1993)	18	0/0	18	9	9	0	15
Volk, Kwok, & Woodsworth (1993)	17	0/0	17	13	4	0	6
Groenewegen, de Jong, & Geballe (1994)	16	0/0	16	14	2	0	5
Lorenz-Martins & Lefevre (1994)	32	0/0	32	30	2	1	2
Whitelock et al. (1994)	3	0/0	3	3	0	0	3
Groenewegen (1995)	21	0/0	21	21	0	0	14
Groenewegen, van den Hoek, & de Jong (1995)	21	0/0	21	10	11	11	12
Guglielmo et al. (1997)	20	0/0	20	0	20	1	20
Kwok et al. (1997)	715	0/0	715	390	325	131	-
Guglielmo et al. (1998)	27	0/0	27	2	25	5	27
Groenwegen et al. (2002)	252	14/0	238	208	30	4	-
Le Bertre et al. (2005)	143	4/0	139	38	101	59	-
Guandalini et al. (2006)	269	14/0	255	234	21	6	-
Menzies, Feast, & Whitelock (2006)	177	2/0	175	146	29	25	-
Whitelock et al. (2006)	257	36/0	221	178	43	29	-
Chen & Shan (2008)	348	0/0	348	348	0	0	-
total number	3131	83/1	3049	1882	1167	471	832
IRAS two-color					772	317	

Table 3.
S stars and Silicate carbon stars

References	Original	Duplicate	Remaining	Note
Yang et al. (2006)	287	0	287	S stars
IRAS two-color			76	
Kwok & Chan(1993)	15	0	15	silicate C
Chen, Wang, & Wang (1999)	22	15	7	silicate C
Trams et al. (1999)	1	0	1	silicate C
Jiang et al. (2000)	1	0	1	silicate C
Molster et al. (2001)	1	0	1	silicate C
Chen & Wang (2001)	1	0	1	silicate C
Chen & Zhang (2006)	9	0	9	silicate C
Boboltz et al. (2007)	1	0	1	silicate C
total number	51	15	36	silicate C
IRAS two-color			26	

(1993) is an unusual nebula. The 4 objects in Nyman et al. (1993) are planetary nebulae (PNe). One object (IRC+40448; NML Cyg) in Xiong et al. (1994) is not listed in *IRAS* PSC. We excluded 10 stars from Loup et al. (1993); 4 PNe, 2 carbon stars, a H II region, a RV Tau type variable star, and 2 objects (IRC+40448 and IRC+40483) not listed in *IRAS* PSC.

The five objects excluded from Lepine, Ortiz, & Epchtein (1995) are 3 carbon stars, a silicate carbon star (*IRAS* 18006-3213), and a PN. We exclude 12 stars from Sevenster et al. (2001): 2 doubly counted stars (*IRAS* 18625-2113, *IRAS* 18438-0154), 6 H II regions, a supernova remnant (*IRAS* 18455-0200), a T Tauri star (*IRAS* 18286-1610), an open cluster (*IRAS* 18295-1216), and a PN (*IRAS* 18234-1444).

From Chen et al. (2001), we exclude 17 PNe, 9 carbon stars, 7 H II regions, and 2 WR stars as mentioned in the paper. We exclude 3 more objects: *IRAS* 19327+3024 is not a OH maser source, *IRAS* 16527-4001 appears twice, and *IRAS* 18006-3213 is a silicate carbon star. From Le Bertre et al. (2003), we exclude a carbon star, 16 objects without *IRAS* PSC numbers, and 3 doubly counted stars. Four stars are removed from Jimenez-Esteban et al. (2005): one (*IRAS* 18551+0323) is a carbon star, 2 objects are PNe, and one is a H II region.

(b) C-rich Stars

The main components of dust in the envelopes around carbon stars are believed to be featureless amorphous carbon (AMC) grains and SiC grains producing the 11.3 μm emission feature (e.g., Suh 2000). The carbon stars with SiC grains belong to *IRAS* LRS class C.

The carbon stars with thin dust envelopes show many molecular lines at NIR bands. The most conspicuous ones are the HCN and C_2H_2 absorption lines at 3.1 μm produced in the expanded atmosphere of the

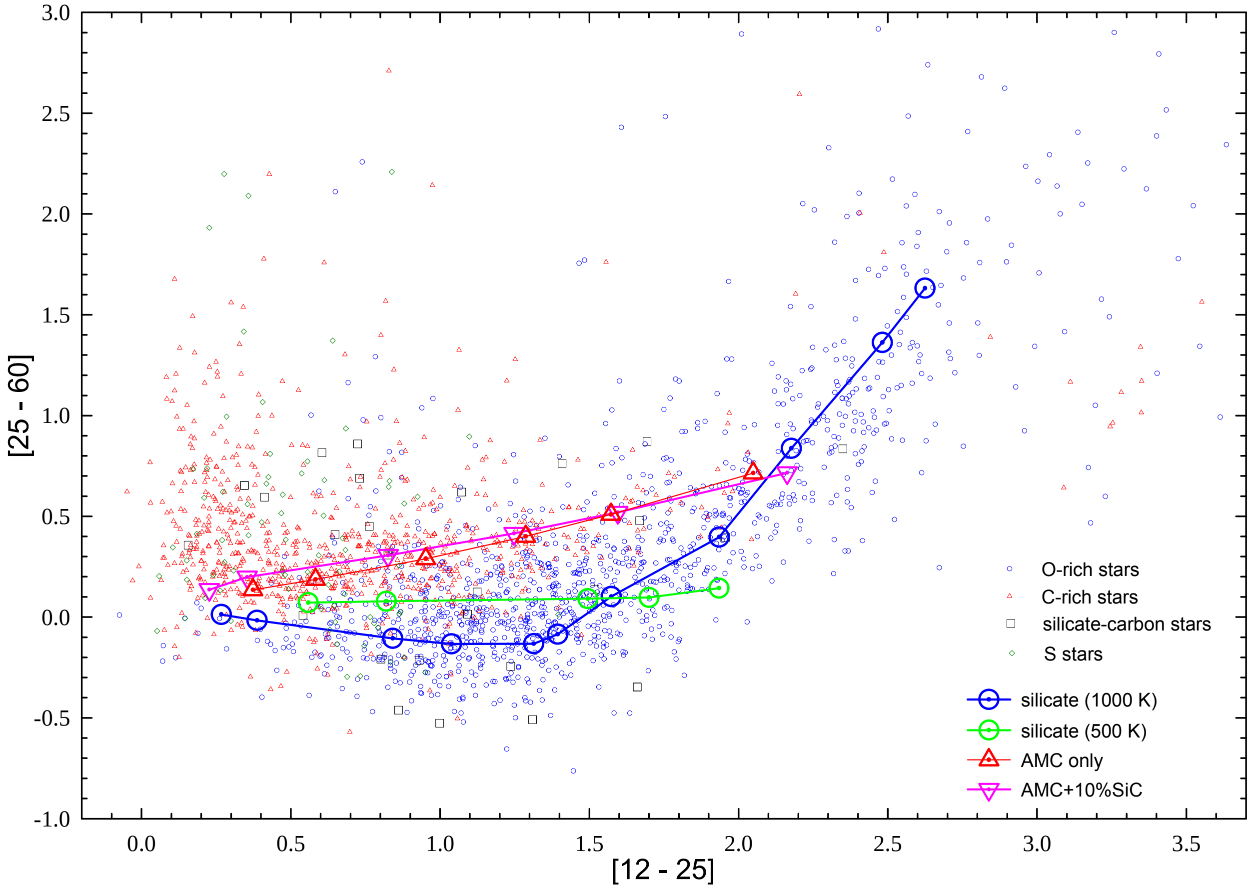

Fig. 1.— The *IRAS* two-color diagram.

central stars. Le Bertre et al. (2005) identified C-rich stars from the NIR data obtained with the *IRTS*.

Table 2 lists the number of C-rich AGB stars as identified by various authors and verified in this paper. We confirm that 1167 objects are C-rich AGB stars. We have *IRAS* LRS data for 931 objects and 716 stars are classified as *IRAS* LRS class C.

We may discriminate optical carbon stars from our C-rich stars catalog. Most optical carbon stars have large far infrared excesses (low [12-25] color and high [25-60] color; Egen & Leung 1991). We select those sources which are listed in the general catalog of galactic carbon stars (GCGCS) by Stephenson (Alksnis et al. 2001). We find 471 optical carbon stars.

We exclude 25 stars listed in Epchtein et al. (1990), Egan & Leung (1991), Guglielmo et al. (1993), and Groenwegen et al. (2002) because they are *IRAS* LRS class E or A. From Le Bertre et al. (2005), we exclude two objects without *IRAS* PSC numbers, an S star (*IRAS* 19505+5332), and a silicate carbon star (*IRAS* 07206-1032). Menzies et al. (2006) listed one object without *IRAS* PSC number and one silicate carbon star (*IRAS* 00519+5817). We exclude 14 stars from Guandalini et al. (2006); 3 stars without *IRAS* PSC numbers, 2 PNe, and 9 O-rich stars. From Whitelock et al. (2006), we exclude 18 objects classified to be peculiar and uncertain stars, 17 objects without *IRAS* PSC numbers, and an object blended with OH/IR star in *IRAS* photometry.

(c) S Stars

The General Catalogue of Galactic S Stars (GCGSS; Stephenson 1984) lists 1347 S stars, which may include a number of extrinsic S stars in binary systems. Extrinsic S stars are not AGB stars. Several methods have been used to separate extrinsic and intrinsic S stars (e.g., Yang et al. 2006). S stars tend to have low mass-loss rate, implying less efficient dust formation. However, Yang et al. (2007) finds that some S stars show silicate dust emission features.

For the sample of S stars in AGB phase, we use the list of objects which are classified to be intrinsic S stars

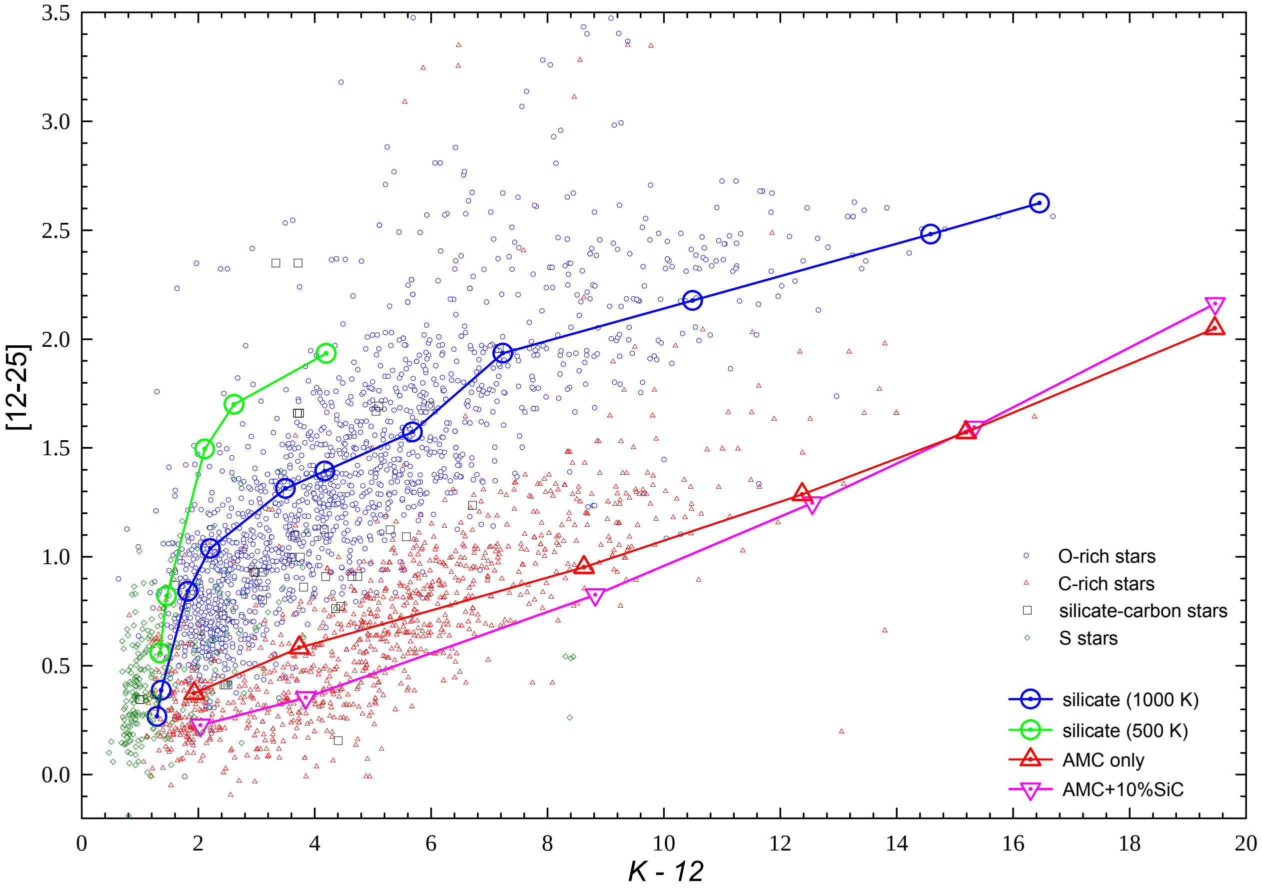

Fig. 2.— K-12 versus [12-25] diagram.

by Yang et al. (2006). We present the list of S stars in Table 3.

(d) Silicate Carbon Star

Silicate carbon stars are the carbon stars with silicate dust features. We have a compiled list of 36 silicate carbon stars (Table 3). Most of these stars belong to *IRAS* LRS class E. At least some of these silicate carbon stars may be in binary systems (e.g., *IRAS* 20350+5954; Yamamura et al. 2000, *IRAS* 03201+5459; Jiang, Szczerba & Deguchi 2000) which could have a past event of becoming a S star. We present the list of silicate carbon stars in Table 3.

(e) Doubly Classified Sources

We find that 11 stars are appeared in the O-rich and C-rich catalogs simultaneously (Table 4).

The object *IRAS* 07027-7934 is a PN (see Garcia-Hernandez et al. 2006). The object *IRAS* 19327+3024 is also a PN (Crowther, Morris, & Smith 2006). The object *IRAS* 16316-5026 is an S star (Van Eck et al. 2000). These three objects are removed from our list of AGB stars.

Using the data of NIRS PSC (Yamamura et al. 2003), we find that the three objects (*IRAS* 07233-1555, *IRAS* 16469-4753, and *IRAS* 17349-3022) show H_2O absorption at 1.9 μm. These objects are O-rich AGB stars.

The objects *IRAS* 16265-5100, *IRAS* 19296-2227, and *IRAS* 21444+5053 are not optical carbon stars and do not show the SiC feature at 11.3 μm. The location of the stars in the two-color diagram is on the O-rich region. For *IRAS* 19296-2227, OH and water maser emissions are detected by Engels (1996) and HCN lines are not detected. Because all these objects are in *IRAS* LRS class E (Kwok et al. 1997), they are classified to be O-rich AGB stars.

The object *IRAS* 18301-0656 is an O-rich AGB star. Kastner et al. (1993) detected OH maser emission from this star.

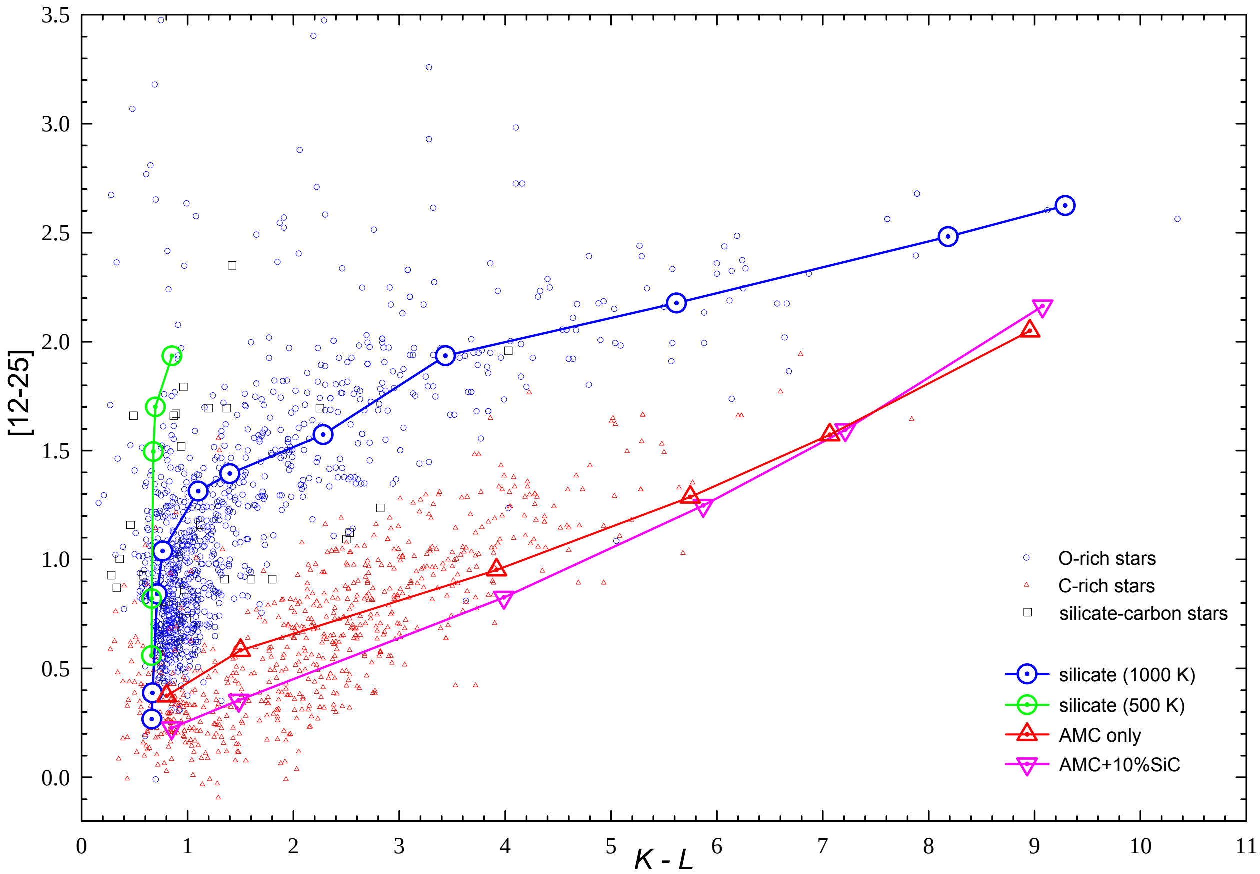

Fig. 3.— K-L versus [12-25] diagram.

(f) NIR Data

We have tried to collect all the available NIR data for the AGB stars listed in our catalog. Table 5 lists the number of collected NIR data at K and L bands. Some stars are observed more than one time.

The 2*MASS* used two highly-automated 1.3-m telescopes equipped with a three-channel camera capable of observing the sky simultaneously at J (1.25 microns), H (1.65 microns), and Ks (2.17 microns) bands. The PSC contains accurate positions and fluxes for about 300 million stars and other unresolved objects. We use NIR data of the 2*MASS* counterparts of *IRAS* PSC objects for 472 O-rich stars (Lewis et al. 2004; Jimenez-Esteban et al. 2005), 346 C-rich stars (Chen & Shan 2008), and 287 S stars (Yang et al. 2006).

III. INFRARED TWO-COLOR DIAGRAMS

Only a relatively small number of AGB stars have complete or nearly complete SEDs. A large number of stars have far infrared fluxes from the *IRAS* PSC and many sources have photometry from the near infrared to the 10 μm band. Although less useful than a full SED, the large number of observations with less extensive wavelength coverage can be used to form two-color diagrams that can be compared to theoretical model predictions.

The color index is defined by

$$M_{\lambda 1} - M_{\lambda 2} = 2.5 \log_{10} \frac{F_{\lambda 2}/ZMC_{\lambda 2}}{F_{\lambda 1}/ZMC_{\lambda 1}} \qquad (1)$$

where $ZMC_{\lambda i}$ means the zero magnitude calibration at given wavelength (λi). The magnitude scale of *IRAS* photometry is given in *IRAS* Explanatory Supplement (i.e., the zero magnitude fluxes at 12, 25, and 60 μm correspond to 28.3, 6.73 and 1.19 Jansky, respectively). For any two-color diagrams using *IRAS* PSC data, we plot only the objects with good quality (q=3) at any wavelength (see Table 1 through 3).

Figure 1 plots 1211 O-rich stars, 772 carbon stars, 76 S stars, and 26 silicate carbon stars in an *IRAS* two-color diagram using [60]−[25] versus [25]−[12]. The

Table 4.
Doubly classified stars.

IRAS number	LRS	O-rich	C-rich	note
07027-7934	H	LOE95;Chen01	G06	[WC]PN
07233-1555	-	LeBer.03	Gug93	O-rich
16265-5100	F	ELL90	GMS02	O-rich
16316-5026	E	ELL90	White06	S star
16469-4753	E	LeBer.03	GMS02;G06	O-rich
17349-3022	-	LeBer.03	Gug93	O-rich
18301-0656	U	ELL90;Kast.93	G06	O-rich
18401+2854	E	Loup93	G06	O-rich
19296+2227	I	Lewis97	GMS02;G06	O-rich
19327+3024	P	Chen01	G06	[WC]PN
21444+5053	E	Gug97	G06	O-rich

Chen01=Chen et al. (2001); G06=Guandalini et al. (2006); GMS02=Groenewegen et al. (2002); Gug93=Guglielmo et al. (1993); Gug97=Guglielmo et al. (1997); Kast.93=Kastner et al. (1993); LeBer.03=Le Bertre et al. (2003); Lewis97=Lewis (1997); LOE95=Lepine et al. (1995); Loup93=Loup et al. (1993); White06=Whitelock et al. (2006)

small triangles are the observational data and the lines with large symbols are the model calculations for a range in dust shell optical depth. We will discuss about the theoretical models in the next section. In this diagram, the stars in the upper-right region have thick dust shells with large optical depths. Carbon stars are distributed along a curve in the shape of a "C". A group of stars at the upper left part are optical carbon stars that show excessive flux at 60 μm which is due to the remnant of earlier phase when the star was an O-rich AGB star (e.g., Chan & Kwok 1990). A group of stars at the lower part, which extend to the right-hand side, are infrared carbon stars. The infrared carbon stars at the right part have thick dust shells with large optical depths.

Figure 2 shows the K-12 versus [12-25] plot. The observed colors generally fit the theoretical model lines. However, the K-12 colors of O-rich stars in the region of smaller optical depth are generally redder (larger number) than the theoretical model line. This is because the absorption lines of H_2O and CO make the K band magnitude larger for LMOA stars. For HMOA stars, the K band absorption is filled in by thick dust envelopes.

Figure 3 shows the K-L versus [12-25] diagram. The observed colors generally fit the theoretical model lines. Again, the effect of K band absorption occurs for the O-rich stars with thin dust envelopes.

It is well known that the position of an AGB star on a two-color diagram widely varies depending on the phase of pulsation (e.g., Suh 2004). If we are able use the colors observed and averaged for an entire pulsation period, the observed positions on the two-color diagrams will be more useful to be compared with the theoretical model lines.

IV. THEORETICAL MODELS

For this paper, we use the radiative transfer code DUSTY developed by Ivezić & Elitzur (1997) for a spherically symmetric dust shell. We have performed the model calculations in the wavelength range 0.01 to 36000 μm.

For all the models, we assume the dust density distribution is inversely proportional to the square of the distance ($\rho \propto r^{-2}$). The dust condensation temperature (T_c) is assumed to be 1000 K and 500 K. The outer radius of the dust shell is always taken to be 10^4 times inner radius (R_c).

For O-rich stars, we use the optical constants of warm and cool silicate grains derived by Suh (1999). The radii of spherical dust grains have been assumed to be 0.1 μm uniformly. We choose 10 μm as the fiducial wavelength that sets the scale of the optical depth (τ_{10}) and compute models for various optical depths (τ_{10} = 0.005, 0.01, 0.05, 0.1, 0.5, 1, 3, 7, 15, 30 and 40). For the central star, we assume that the luminosity is 10^4 $L_\odot$ and a stellar blackbody temperature is 2500 K for $\tau_{10} \leq 3$ and 2000 K for $\tau_{10} > 3$. Also, we use the warm silicate dust grains for LMOA stars (7 models with τ_{10} ≤ 3) and the cool ones for HMOA stars (4 models τ_{10} > 3).

Suh (2004) pointed out that a low dust condensation temperature is generally required for LMOA stars with thin dust envelopes. The models with a low dust condensation temperature (T_c = 500 K) for 5 models of LMOA stars with very thin dust envelopes (τ_{10} = 0.005, 0.01, 0.05, 0.1, and 0.5) are also shown for comparison. Because the models did not consider the contribution from molecules, the low temperature models look to be more deviated from the observations. If we consider the deep molecular absorption at K band, the low temperature model would fit the observations better for the LMOA stars.

For C-rich stars, we use the optical constants of amorphous carbon (AMC) grains derived by Suh (2000) and the optical constants of α SiC grains by Pégourié (1988). The radii of spherical dust grains have been assumed to be 0.1 μm uniformly. We choose 10 μm as the fiducial wavelength that sets the scale of the optical depth(τ_{10}) and perform the model calculations for various optical depths (τ_{10} = 0.01, 0.1, 1, 2, 3 and 5). For the central star, we assume that the luminosity is 10^4 $L_\odot$ and a stellar blackbody temperature is 2300 K

Table 5.
NIR observations of AGB stars.

	O-rich stars		C-rich stars		S stars		Silicate C	
reference	K	L	K	L	K	L	K	L
Epchtein et al.(1990)	21	21	209	209			3	3
Fouque et al. (1992)							4	4
Blommaert et al. (1993)	9	9						
Groenewegen et al. (1993)			25	25				
Guglielmo et al. (1993)			103	102				
Kastner et al. (1993)	18	17	15	14				
Nyman et al. (1993)	36	39						
Engels (1994)								10
Groenewegen et al. (1994)				14				
Whitelock et al. (1994)	58	58	3	3				
Xiong et al. (1994)	58	21						
Lepine et al. (1995)	375	348					1	1
Noguchi et al. 1995							8	8
Guglielmo et al. (1997)	16	16	20	20				
Kwok et al. (1997)								
Guglielmo et al. (1998)	21	21	27	27				
Trams et al. (1999)							3	3
Cutri et al. (2003)							15	
Le Bertre et al. (2003)	543	543						
Lewis et al. (2004)	134							
Le Bertre et al. (2005)			139	139			1	1
Jimenez-Esteban et al. (2005)	338							
Guandalini et al. (2006)			238	0				
Jimenez-Esteban et al. (2006)	59							
Whitelock et al. (2006)			220	218			2	2
Yang et al. (2006)					287			
Chen & Shan (2008)			346					
Izumiura et al. (2008)							3	3
total	1686(1366)	1090(992)	1343(886)	769(644)	287(287)		40(25)	35(19)
K-12 vs [12-25]	1568(1256)		1277(822)		236(236)		39(24)	
K-L vs [12-25]		990(898)		708(584)		0		35(19)

A number in a parenthesis means the number of stars

for $\tau_{10} \leq 0.1$ and 2000 K for $\tau_{10} > 0.1$. For model of carbon-rich stars, we use a simple mixture of AMC and SiC dust grains.

V. CONCLUSIONS

We have made a new catalog of AGB stars in our Galaxy from the sources listed in IRAS PSC compiling the lists of previous works with verifying processes. Using new information from recent investigations and observations, we have verified the class identification of AGB stars into the O-rich and C-rich stars. We present the catalog of 2193 O-rich stars, 1167 C-rich stars, 287 S stars, and 36 silicate carbon stars.

For the large sample of AGB stars, we present infrared two-color diagrams from the observations at NIR and *IRAS* PSC. On the two-color diagrams, we plot the tracks of theoretical radiative transfer model results with increasing dust shell optical depths for the O-rich and C-rich dust shells. We find that the basic theoretical model tracks roughly coincide with the densely populated observed points.

We expect that our new catalog would be helpful to identify and verify more AGB stars from new observations. The catalog data will be open to the public through the first author's world wide web site http://web.chungbuk.ac.kr/~kwsuh/.

ACKNOWLEDGEMENTS

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MEST) (No.R01-2008-000-20002-0). This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France.

REFERENCES

Alksnis, A., Balklavs, A., Dzervitis, U., Eglitis, I., Paupers, O., & Pundure, I., 2001, General Catalog of Galactic Carbon Stars by C. B. Stephenson. Third Edition, Baltic Astron., 10, 1

Blommaert, J. A. D. L., van der Veen, W. E. C. J., & Habing, H. J., 1993, Candidate OH/IR stars in the outer parts of our Galaxy, A&A, 267, 39

Boboltz, D. A., Ohnaka, K., Driebe, T., Murakawa, K., Wittkowski, M., Johnston, K. J., & Izumiura, H., 2007, Water Maser Emission Associated with the Silicate Carbon Star IRAS 07204-1032., AAS, 210, 8804

Chan, S. J., 1993, Evolution from visual to infrared carbon stars: Interrupted mass-loss model, PASP, 105, 1107

Chan, S. J. & Kwok, S., 1990, Evolution of infrared carbon stars, A&A, 237, 354

Chen, P. S. & Wang, X. H., 2001, IRAS 19111+2555(=S Lyr): A Possible Silicate Carbon Star, ChJAA, 1, 344

Chen, P. S. & Zhang, P., 2006, Newly Identified Silicate Carbon Stars from IRAS Low-Resolution Spectra, ChJAA, 6, 697

Chen, P. S. & Shan, H. G., 2008, Infrared study of infrared carbon stars based on 2MASS, IRAS and ISO SWS data, Ap&SS, 314, 291

Chen, P. S., Wang, X. H., & Wang, F., 1999, A further identification of silicate carbon stars, Acta Astron. Sinica, 40, 32

Chen, P. S., Szczerba, R., Kwok, S., & Volk, K., 2001, Properties of OH/IR stars with IRAS LRS spectra, A&A, 368, 1006

Chengalur, J. N., Lewis, B. M., Eder, J., & Terzian, Y., 1993, New OH/IR stars from color-selected IRAS sources. 3: A complete survey, ApJSS, 89, 189

Crowther, P. A., Morris, P. W., & Smith, J. D., 2006, An Ultraviolet to Mid-Infrared Study of the Physical and Wind Properties of HD 164270 (WC9) and Comparison to BD +30 3639 WC9, ApJ, 636, 1033

Cutri, R. M., et al., 2003, 2MASS All Sky Catalog of point sources, NASA/IPAC Infrared Science Archive

David P., Le Squeren A. M., & Sivagnanam P., 1993, An OH Satellite Line Maser Survey of Cool IRAS Sources and Circumstellar Envelope Evolution, A&A, 277, 453

Egan, M. P., & Leung, C. M., 1991, On the nature of the excess 100 micron flux associated with carbon stars, ApJ, 383, 314

Egan, M. P., Price, S. D., Kraemer, K. E., Mizuno, D. R., Carey, S. J., Wright, C. O., Engelke, C. W., Cohen, M., & Gugliotti, G. M., 2003, Air Force Research Laboratory Technical Report AFRL-VS-TR-2003-1589

Engels, D., 1994, More H_2O maser in J-type carbon stars, A&A, 285, 497

Engels, D., 1996, OH57.5+1.8: two OH masers corresponding to two IRAS sources 19295+2228 and 19296+2227, A&A, 315, 521

Epchtein, N., Le Bertre, T., & Lepine, J. R. D., 1990, Carbon star envelopes - Near-IR photometry, mass loss and evolutionary status of a sample of IRAS stars, A&A, 227, 82

Fouque, P., Le Bertre, T., Epchtein, N., Guglielmo, F., & Kerschbaum, F., 1992, Near-infrared photometry of a sample of IRAS point sources, A&AS, 93, 151

Garcia-Hernandez, D. A., Manchado, A., Garcia-Lario, P., Canete, A. Benitez, Acosta-Pulido, J. A., & Garcia, A. M., 2006, Revealing the Mid-Infrared Emission Structure of IRAS 16594-4656 and IRAS 07027-7934, ApJ, 640, 829

Groenewegen, M. A. T., 1995, Dust shells around infrared carbon stars, A&A, 293, 463

Groenewegen, M. A. T., van den Hoek, L. B., & de Jong, T., 1995, The evolution of galactic carbon stars, A&A, 293, 381

Groenewegen, M. A. T., de Jong, T., & Baas, F., 1993, Near Infrared and Submillimeter Photometry of Carbon Stars, A&AS, 101, 513

Groenewegen, M. A. T., de Jong, T., & Geballe, T. R., 1994, The 3 micrometer spectra of candidate carbon stars, A&A, 287, 163

Groenewegen, M. A. T., Sevenster, M., Spoon, H. W. W., & Perez, I., 2002, Millimetre observations of infrared carbon stars. I. The data, A&A, 390, 501

Guandalini, R., Busso, M., Ciprini, S., Silvestro, G., & Persi, P., 2006, Infrared photometry and evolution of mass-losing AGB stars. I. Carbon stars revisited, A&A, 445, 1069

Guglielmo, F., Epchtein, N., Le Bertre, T., Fouque, P., Hron, J., Kerschbaum, F., & Lepine, J. R. D., 1993, Identification of 106 new infrared carbon stars in the IRAS Point Source Catalog - Near-infrared photometry and their space distribution in the galaxy, A&AS, 99, 31

Guglielmo, F., Epchtein, N., Arditti, F., & Sevre, F., 1997, New infrared carbon stars in the IRAS point source catalog, A&AS, 122, 489

Guglielmo, F., Le Bertre, T., & Epchtein, N., 1998, Infrared carbon stars: new identifications and their space distribution in the Galaxy, A&A, 334, 609

Iben, I. & Renzini, A., 1983, Asymptotic giant branch evolution and beyond, ARA&A, 21, 271

Ivezić, A. & Elitzur, M., 1997, Self-similarity and scaling behaviour of infrared emission from radiatively heated dust - I. Theory, MNRAS, 287, 799

Izumiura, H., Noguchi, K., Aoki, W., Honda, S., Ando, H., Takada-Hidai, M., Kambe, E., Kawanomoto, S., Sadakane, K., Sato, B., Tajittsu, A., Tanaka, W., Okita, K., Watanabe, E., & Yoshida, M., 2008, Evidence for a Companion to BM Gem, a Silicate Carbon Star, ApJ, 682, 499

Jiang, B. W., Szczerba, R., & Deguchi, S., 2000, IRAS 03201+5459: a C-rich AGB star with silicate absorption, A&A, 362, 273

Jimenez-Esteban, F. M., Agudo-merida, L., Engels, D., & Garcia-Lario, P., 2005, An infrared study of galactic OH/IR stars. I. An optical/near-IR atlas of the Arecibo sample, A&A, 431, 779

Jimenez-Esteban, F. M., Garcia-Lario, P., Engels, D., & Perea Calderon, J. V., 2006, An infrared study of galactic OH/IR stars. II. The "GLMP sample" of red oxygen-rich AGB stars, A&A, 446, 773

Jorissen, A. & Mayor, M., 1988, Radial velocity monitoring of a sample of barium and S stars using CORAVEL - Towards an evolutionary link between barium and S stars?, A&A, 198, 187

Jorissen, A. & Mayor, M., 1992, Orbital elements of S stars - Revisiting the evolutionary status of S stars, A&A, 260, 115

Kastner, J. H., Forveille, T., Zuckerman, B., & Omont, A., 1993, Probing the AGB Tip - Luminous Carbon Stars in the Galactic Plane, A&A, 275, 163

Kwok, S. & Chan, S. J., 1993, Carbon stars with circumstellar silicate features, AJ, 106, 2140

Kwok, S., Volk, K., & Bidelman, W. P., 1997, Classification and Identification of IRAS Sources with Low-Resolution Spectra, ApJS, 112, 557

Le Bertre, T., Tanaka, M., Yamamura, I., & Murakami H., 2003, Galactic mass-losing AGB stars probed with the IRTS. II, A&A, 403, 943

Le Bertre, T., Tanaka, M., Yamamura, I., Murakami, H., & MacConnell, D. J., 2005, Carbon Stars in the Infrared Telescope in Space Survey, PASP, 117, 199

Le Squeren, A. M., Sivagnanam, P., Dennefeld, M., & David, P., 1992, A Complete Survey of OH / Infrared Objects from the IRAS LRS Sources Within a Domain of the Color Diagram, A&A, 254, 133

Lepine, J. R. D., Oritiz, R., & Epchtein, N. 1995, OH/IR stars: near-infrared photometry, and discussion of the Mira-OH/IR sequence, A&A, 299, 453

Lewis, B. M., 1997, Main-line OH Observations of the Arecibo Set of OH/IR Stars, ApJS, 109, 489

Lewis, B. M., Eder, J., & Terzian, Y., 1990, New OH/IR stars from color-selected IRAS sources. II - an unbiased 1612 MHz survey, ApJ, 362, 634

Lewis, B. M., Kopon, D. A., & Terzian, Y., 2004, 2MASS Counterparts for OH/IR Stars. I. The Arecibo Sample, AJ, 127, 501

Lloyd Evans, T. & Little-Marenin, I. R., 1999, Do S stars show strong silicate dust emission?, MNRAS, 304, 421

Lorenz-Martins, S. & Lefevre, J., 1994, SiC grains and evolution of carbon stars, A&A, 291, 831-841

Loup, C., Forveille, T., Omont, A., & Paul, J. F., 1993, CO and HCN observations of circumstellar envelopes. A catalogue - Mass loss rates and distributions, A&AS, 99, 291

Menzies, J. W., Feast, M. W., & Whitelock, P. A., 2006, Carbon-rich Mira variables: radial velocities and distances, MNRAS, 369,783

Molster, F. J., Yamamura, I., Waters, L. B. F. M., Nyman, L.-A., Kaufl, H.-U., de Jong, T., & Loup, C., 2001, IRAS 09425-6040: A carbon star surrounded by highly crystalline silicate dust, A&A, 366, 923

Noguchi, K., Qian, Z., Sun, J., & Wang., G., 1995, Probable candidates for silicate carbon stars in the northern Hemisphere, PASJ, 47, 41

Nyman, L.-A., Hall, P. J., & Le Bertre, T., 1993, Infrared and SiO maser observations of OH/IR stars, A&A, 280, 551

Pégourié, B., 1988, Optical properties of alpha silicon carbide, A&A, 194, 335

Rowan-Robinson, M., Lock, T. D., Walker, D. W., & Harris, S., 1986, Models for IRAS observations of circumstellar dust shells around late-type stars, MNRAS, 222, 273

Sevenster, M. N., van Langevelde, H. J., Moody, R. A., Chapman, J. M., Habing, H. J., & Killeen, N. E. B., 2001, The ATCA/VLA OH 1612 MHz survey. III. Observations of the Northern Galactic Plane, A&A, 366, 481

Skrutskie, M. F., et al., 2006, The Two Micron All Sky Survey (2MASS), AJ, 131, 1163S

Stephenson, C. B., 1984, A General Catalogue of Galactic S Stars (2nd ed; Cleveland: Case Western Reserve Univ.)

Suh, K.-W., 1999, Optical properties of the silicate dust grains in the envelopes around asymptotic giant branch stars, MNRAS, 304, 389

Suh, K.-W., 2000, Optical properties of the carbon dust grains in the envelopes around asymptotic giant branch stars, MNRAS, 315, 740

Suh, K.-W., 2002, Crystalline silicates in the envelopes and discs around oxygen-rich asymptotic giant branch stars, MNRAS, 332, 513

Suh, K.-W., 2004, Pulsation Phase-Dependent Dust Shell Models for Oxygen-rich Asymptotic Giant Branch Stars, ApJ, 615, 485

Suh, K.-W., Lee, J. W., & Kim, H. Y., 2001, The Evolution of AGB Stars on Infrared 2-Color Diagrams, JASS, 18, 15

Trams, N. R., Van Loon, J. Th., Zijlstra, A. A., Loup, C., Groenewegen, M. A. T., Waters, L. B. F. M., Whitelock, P. A., Blommaert, J. A. D. L., Siebenmorgen, R., & Heske, A., 1999, IRAS04496-6958: A luminous carbon star with silicate dust in the Large Magellanic Cloud, A&A, 344, L17

Van Eck, S., Jorissen, A., Udry, S., Mayor, M., Burki, G., Burnet, M., & Catchpole, R., 2000, The Henize sample of S stars. II. Data, A&AS, 145, 51

van Loon, J. Th., Zijlstra, A. A., Whitelock, P. A., Hekkert, P. L., Chapman, J. M., Lout, C., Groenewegen, M. A. T., Waters, L. B. F. M., & Trams, N. R., 1998, Obscured Asymptotic Giant Branch stars in the Magellanic Clouds. IV. Carbon stars and OH/IR stars, A&A, 329, 169

Volk, K., Kwok, S. & Langill, P., 1992, Candidates for extreme carbon stars, ApJ, 391, 285

Volk, K., Kwok, S. & Woodsworth, A. W., 1993, CO observations of candidates for carbon-rich asymptotic giant branch and post-asymptotic giant branch stars, ApJ, 402, 292

Whitelock, P. A., Menzies, J., Feast, M., Marang, F., Carter, B., Roberts, G., Catchploe, R., & Chapman, J., 1994, High Mass Agb-Stars in the South Galactic CAP, MNRAS, 267, 711

Whitelock, P. A., Feast, M. W., Marang, F., & Groenewegen, M. A. T., 2006, Near-infrared photometry of carbon stars, MNRAS, 369, 751

Willacy, K. & Millar, T. J., 1997, Chemistry in oxygen-rich circumstellar envelopes, A&A, 324, 237

Xiong, G. Z., Chen, P. S., & Gao, H., 1994, Infrared properties of OH/IR stars. I. Near infrared observation and some physical parameters of OH/IR stars, A&ASS, 108, 661

Yamamura, I., Dominik, C., de Jong, T., Waters, L. B. F. M., & Molster F. J., 2000, The origin of silicate carbon stars: ISO/SWS observation of V778 Cygni, A&A, 363, 629

Yamamura, I., et al., 2003, Exploiting the ISO Data Archive Infrared Astronomy in the Internet Age, ed. C. Gry et al. (ESASP 511;Noordwijk; ESA), 35

Yang, X. H., Chen, P., Wang, J., & He, J., 2006, Two Micron All Sky Survey, Infrared Astronomical Satellite, and Midcourse Space Experiment Color Properties of Intrinsic and Extrinsic S Stars, AJ, 132, 1468

Yang, X. H., Chen, P., Wang, J., & He, J., 2007, Analysis of ISO SWS01 spectra of S stars, A&A, 463, 663