A New Catalog of Asymptotic Giant Branch Stars in Our Galaxy

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Abstract

We present a new catalog of 11,209 O-rich asymptotic giant branch (AGB) stars and 7172 C-rich AGB stars in our Galaxy, identifying more AGB stars in the bulge component and considering more visual carbon stars. For each object, we cross-identify the Infrared Astronomical Satellite (IRAS), AKARI, Midcourse Space Experiment, Wide-field Infrared Survey Explorer (WISE), Two-Micron All-Sky Survey, and American Association of Variable Star Observers counterparts. We present the new catalog in two parts: one is based on the IRAS PSC for brighter or more isolated objects; the other one is based on the ALLWISE source catalog for less bright objects or objects in crowded regions. We present various infrared two-color diagrams (2CDs) for the sample stars. We find that the theoretical dust shell models can roughly explain the observations of AGB stars on the various IR 2CDs. We investigate IR properties of SiO and OH maser emission sources in the catalog. For Mira variables in the sample stars, we find that the IR colors get redder for longer pulsation periods. We also study infrared variability of the sample stars using the WISE photometric data in the last 12 yr: the ALLWISE multiepoch data and the Near-Earth Object WISE Reactivation 2021 data release. We generate light curves using the WISE data at W1 and W2 bands and compute the Lomb–Scargle periodograms for all of the sample stars. From the WISE light curves, we have found useful variation parameters for 3710 objects in the catalog, for which periods were either known or unknown in previous works.

Unified Astronomy Thesaurus concepts: Asymptotic giant branch stars (2100); Circumstellar dust (236); Long period variable stars (935); Milky Way Galaxy (1054); Infrared astronomy (786); Radiative transfer (1335)

Supporting material: machine-readable tables

1. Introduction

Asymptotic giant branch (AGB) stars are believed to be low-to-intermediate-mass stars (0.5–10 \( M_\odot \)) in the last evolutionary phase evolving into post-AGB stars and planetary nebulae (Siess 2006; Höfner et al. 2018). Almost all AGB stars are long-period variables (LPVs) with large amplitude pulsations. As the early-phase AGB stars evolve into the thermally pulsing AGB (TP-AGB) phase, they produce dust grains more effectively and show higher mass-loss rates (e.g., Jiménez-Esteban & Engels 2015).

Based on the chemistry of the photospheres and/or the circumstellar dust envelope, AGB stars are classified as O-rich AGB (OAGB) or C-rich AGB (CAGB). The spectral energy distributions (SEDs) of OAGB stars show 10 and 18 \( \mu \)m features due to amorphous silicate dust. Low mass-loss-rate OAGB (LMOA) stars with thin dust envelopes show emission features and high mass-loss-rate OAGB (HMOA) stars with thick dust envelopes show absorption features at the same wavelengths (e.g., Suh 1999). To reproduce detailed SEDs of LMOA stars, amorphous alumina (\( Al_2O_3 \); Suh 2016) and Fe–Mg oxides (Posch et al. 2002), dust grains are also necessary. For CAGB stars, SiC and MgS grains as well as featureless amorphous carbon (AMC) dust can produce the SEDs (e.g., Suh 2000; Hony et al. 2002).

CAGB stars are generally believed to be the evolutionary successors of OAGB stars. When M-type OAGB stars of intermediate mass range (1.55 \( M_\odot \) ≤ \( M \) ≤ 4 \( M_\odot \); for solar metallicity; Groenewegen et al. 1995) go through carbon dredge-up processes and so the C/O ratio is larger than one, O-rich dust formation ceases and the stars become visual carbon stars in the AGB phase. The visual carbon stars evolve into infrared carbon stars with thick C-rich dust envelopes and high mass-loss rates (e.g., Suh 2000). It is generally thought that S stars (more specifically, intrinsic S stars) are in the intermediate phase between OAGB and CAGB stars (e.g., Suh & Kwon 2011). Though this M-S-C evolutionary sequence could not be right for all AGB stars (e.g., Chan & Kwok 1990), there is much evidence that supports this idea (e.g., Suh 2020).

The Infrared Astronomical Satellite (IRAS), Infrared Space Observatory (ISO), Midcourse Space Experiment (MSX), AKARI, Two-Micron All-Sky Survey (2MASS), and Wide-field Infrared Survey Explorer (WISE) have provided various IR observational data, which have been useful to identify and study new AGB stars. Using various IR two-color diagrams (2CDs), we can study properties of the central stars and dust envelopes for a large sample of AGB stars (e.g., Sevenster 2002; Suh & Kwon 2011). Thanks to the optical gravitational lensing experiment (OGLE) projects (Soszyński et al. 2013a), a larger number of LPVs in the Galactic bulge have been identified and studied.

In 2009, WISE (Wright et al. 2010) started mapping the sky. The ALLWISE multiepoch photometry table obtained in 2009–2010 provided photometric data at four bands (3.4, 4.6, 12, and 22 \( \mu \)m; W1, W2, W3, and W4). And the Near-Earth Object WISE Reactivation (NEOWISE-R) mission (Mainzer et al. 2014) has been providing photometric data at W1 and W2 bands for last seven years (14 epochs; 2021 data release), two in every year between 2019 and 2020. The ALLWISE multiepoch photometry table and the NEOWISE-R data may allow characterization of the periodic variations of IR emission from AGB stars at the W1 and W2 bands in last 12 years.

In this paper, we present a new catalog of AGB stars in our Galaxy, identifying more AGB stars in the bulge component and considering more visual carbon stars. Section 2 presents...
the new catalog in two parts: one is based on the IRAS PSC and the other is based on the ALLWISE source catalog. For each object, we cross-identify the IRAS, AKARI, MSX, WISE, and the other is based on the ALLWISE source catalog. For the new catalog in two parts: one is based on the IRAS PSC. For example, the IRAS PSC contains 3828 objects, while the ALLWISE source catalog contains 894 objects. Two S stars are included in the new catalog. For example, IRAS 18027-1316 is a typical visual carbon star. The number of the original IRAS PSC sources is 589 objects in OI-SH and one object in OI-JB. Sources with positive IRAS PSC counterparts. AAVSO Miras with IRAS LRS type E or subgroupes. In CI-SH. The number of OAGB stars is 539. In Table 1, IRAS 19354-0450 is a typical visual carbon star. A catalog of AGB stars for 3003 OAGB, 1168 CAGB, 329 S-type, and 35 silicate carbon stars in our Galaxy was presented by Suh & Kwon (2011) based on the IRAS PSC. Kwon & Suh (2012) presented a revised list of 3373 OAGB stars considering new SiO maser sources. Kwon & Suh (2014) presented the revised catalog of 3828 OAGB stars. Suh & Hong (2017) presented the revised catalog of 3828 OAGB stars. In this work, we present a new catalog of 11209 OAGB stars and 7172 CAGB stars in our Galaxy, identifying more AGB stars in the bulge component and considering more visual carbon stars (see Tables 1 and 2).

### Table 1

Sample of AGB Stars Based on the IRAS PSC (AGB-IRAS)

| Class         | Subgroup | Reference            | Number | Selected | Duplicate | Added–Excluded | Remaining* |
|---------------|----------|----------------------|--------|----------|-----------|----------------|------------|
| OAGB-IRAS     | OI-SH    | Suh & Hong (2017)    | 3828   | 3828     | 0         | 3⁸–5⁸         | 3826       |
| OAGB-IRAS     | OI-UR    | Urago et al. (2020)  | 42⁴    | 37⁷      | 0         | 0             | 37         |
| OAGB-IRAS     | OI-JB    | Jiménez-Esteban & Engels (2015) | 37 | 37      | 32⁶        | 0             | 5          |
| OAGB-IRAS     | OI-JB    | Blommaert et al. (2018) | 8 | 8      | 7⁷          | 0             | 1          |
| OAGB-IRAS     | OI-ME    | Messineo et al. (2018) | 571 | 166⁸    | 17⁷         | 22⁸           | 127        |
| OAGB-IRAS     | OI-ST    | Stroh et al. (2019)  | 1427   | 735⁸     | 59⁷+3³     | 0             | 673        |
| OAGB-IRAS     | OI-OI    | Soszynski et al. (2013a) | 6039⁹ | 1116⁷    | 59⁷         | 0             | 1057       |
| OAGB-IRAS     | OI-WU    | Wu et al. (2017)     | 44     | 44       | 25⁷         | 0             | 19         |
| OAGB-IRAS     | OI-AM    | This work (IRAS PSC) | 894   | 894      | 731⁸        | 0             | 163        |
| OAGB-IRAS     | OI-AM    | This work (IRAS PSC) | ...   | ...      | ...         | ...           | 5908       |

### Notes.

* Number in parentheses denotes number of Miras in AAVSO (version 2021 April 19; Watson et al. 2021).
* Three objects in CI-SH are SiO maser sources (OAGB stars) without clear CAGB evidence.
* YSOs or RSGs (see Tables 3).
* The number of the original IRAS PSC sources (108) minus duplicate OI-SH sources (66).
* Color-selected O-AGB or C-AGB stars (see Section 2.3).
* In OI-SH.
* In OI-SH.
* SiO maser sources with positive IRAS PSC counterparts.
* RSGs.
* 58 objects in OI-SH and one object in OI-JB.
* IRAS 17105-3746 is in CI-SH (IRAS LRS type C; SiO maser source), IRAS 17001-3651 is an S star (SI), IRAS 15575-5238 is a silicate carbon star (SCI).
* Color-selected OAGB or CAGB stars from the OGLE3 sample of Miras in the Galactic bulge (see Section 2.5). One exception is IRAS 18100-2808, which is an OAGB star (IRAS LRS type E) with the CAGB color.
* Sources with positive IRAS PSC counterparts.
* AAVSO Miras with IRAS LRS type E (see Section 2.3).
* 694 in OI-SH, 7 in OI-OI, 6 in OI-ST, 1 in OI-WU, 19 in SI, and 4 in SCI.
* IRAS 18027-1316 is a visual carbon star.
* IRAS 06176-1036 is a planetary nebula (Red Rectangle).
* In CI-SH.
* OAGB stars (in OI-SH).
* Two S stars (SI) and 18 silicate carbon stars (SCI).
* Duplicate objects.
* IRAS 19354+5005 is an intrinsic S star.

The catalog data. Finally, Section 10 summarizes results of the paper.

### 2. Sample Stars

A catalog of AGB stars for 3003 OAGB, 1168 CAGB, 329 S-type, and 35 silicate carbon stars in our Galaxy was presented by Suh & Kwon (2011) based on the IRAS PSC. Kwon & Suh (2012) presented a revised list of 3373 OAGB stars considering new SiO maser sources. Kwon & Suh (2014) presented a revised sample of 29 silicate carbon stars. Suh & Hong (2017) presented the revised catalog of 3828 OAGB and 1168 CAGB stars (version 2017; http://web.chungbuk.ac.kr/kwsuh/agb.htm).

In this work, we present a new catalog of 11209 OAGB stars and 7172 CAGB stars in our Galaxy, identifying more AGB stars in the bulge component and considering more visual carbon stars (see Tables 1 and 2).
Because IRAS has a large beam size and limited sensitivity, it is not possible to find appropriate counterparts for a major portion of newly identified AGB stars, most of which are less bright or smaller objects in crowded regions. Therefore, we present the new revised catalog in two parts: one is based on the IRAS PSC for brighter or more isolated objects; the other is based on the ALLWISE source catalog for less bright objects or objects in crowded regions, for which the IRAS could not observe properly. Table 3 lists five objects excluded from the list of OAGB Stars (OI-SH) in Suh & Hong (2017).

Table 1 lists the class name, subgroup name, original reference, and numbers of selected objects for AGB-IRAS objects. Table 2 lists the class name, subgroup name, original reference, and numbers of selected objects for AGB-WISE objects. While IRAS PSC data are available only for the 5908 OAGB-IRAS and 3596 CAGB-IRAS objects, the ALLWISE data are available for most of the AGB-IRAS objects as well as 5301 OAGB-WISE and 3576 CAGB-WISE objects.

Table 1 lists the objects whose original references are based on the IRAS PSC (subgroup names: SH, UR, JB, WU, and AM), all of which are compiled into the AGB-IRAS catalog (see Sections 2.3 and 2.4).

Tables 1 also lists a major portion of the objects whose original references are not based on the IRAS PSC (subgroup names: ME, ST, OG, and GC), which can be either AGB-IRAS or AGB-WISE objects depending on the existence of the positive IRAS PSC counterpart (see Section 2.2). The objects that can be positively identified with the IRAS PSC sources are compiled into the AGB-IRAS catalog (Table 1). All the other objects with ALLWISE counterparts, which cannot be positively identified with the IRAS PSC sources, are compiled into the AGB-WISE catalog (Table 2).

The sample of 18,381 Galactic AGB stars is composed of 8407 Mira variables (see Tables 1 and 2) according to the American Association of Variable Star Observers (AAVSO) international variable star index (VSX; version 2021 April 19; Watson et al., 2021). We have also considered the General Catalogue of Variable Stars (GCVS version 5.1; Samus et al., 2017). In this work, we use the AAVSO which includes all of the LPVs in the GCVS list as well as new lists from other observations.

### 2.1. Infrared Photometric Data for the Sample Stars

IRAS (Beichman et al., 1988) conducted an all-sky survey and the point source catalog (PSC) provided photometric data at four bands (12, 25, 60, and 100 μm). MSX (Egan et al., 2003) surveyed the Galactic plane with higher sensitivity and spatial resolution at four MIR bands (8.28, 12.13, 14.65, and 21.34 μm) for 441,879 sources. AKARI (Murakami et al., 2007) provided PSC data at two bands (9 and 18 μm) and bright-source catalog (BSC) data at four bands (65, 90, 140, and 160 μm). 2MASS (Cutri et al., 2003) provided fluxes at J (1.24 μm), H (1.66 μm), and K (2.16 μm) bands. The field-of-view (FOV) pixel sizes of the IRAS, MSX, AKARI PSC, AKARI BSC, and 2MASS images are 0.75 × (4′5–4′6), 18′3, 10″, 30″, and 2″, respectively.

WISE (Wright et al., 2010) surveyed the entire sky. The ALLWISE source catalog provided photometric data at 3.4 μm (W1), 4.6 μm (W2), 12 μm (W3), and 22 μm (W4) bands. The FOV pixel sizes are 2″75, 2″75, 2″75, and 5″5, and the 5σ photometric sensitivities are 0.068, 0.098, 0.86, and 5.4 mJy for the four WISE bands.

Though IRAS and AKARI data have been very useful for studying AGB stars in our Galaxy (e.g., Suh & Kwon, 2011), the number of cross-identified objects for the new sample stars was very limited because of the relatively large beam sizes and weak sensitivities. On the other hand, the WISE data would be more useful for studying dim objects or objects in crowded regions.

In this paper, we use only good-quality observational data at all wavelength bands for the IRAS, 2MASS, WISE, AKARI, and MSX photometric data. (q = 3 for IRAS and AKARI; q = A for 2MASS; q = A or B for WISE; q = 3 or 4 for MSX).

Table 4 lists the IR bands used in this work. For each band, the reference wavelength (λref) and zero-magnitude flux (ZMF) value are also shown. The color index is defined by

\[ M_{\lambda 1} - M_{\lambda 2} = -2.5 \log_{10} \frac{F_{\lambda 1}/ZMF_{\lambda 1}}{F_{\lambda 2}/ZMF_{\lambda 2}} \]  

(1)
where ZMF$_{\lambda_i}$ is the ZMF at given wavelength ($\lambda_i$) (see Table 4). We may obtain the color indices from given fluxes from observations (e.g., IRAS, AKARI, and MSX photometric data are in Jy unit) or from theoretical model SEDs using the reference (or effective or isophotal) wavelength and ZMF specified in the telescope system manual.

### 2.2. Cross-matches

For all IRAS PSC sources, we have found the AKARI, 2MASS, ALLWISE, MSX, and AAVSO counterparts by using the following method. We cross-identify the AKARI PSC or BSC counterpart by finding the nearest source within 60′ using the position given in the IRAS PSC (version 2.1). Then, we cross-identify the 2MASS, WISE, and MSX counterparts using the position of the available AKARI PSC or BSC counterpart. Only when there is no AKARI counterpart, have we used the position of the IRAS PSC.

For the objects whose original references are not based on the IRAS PSC (subgroup names: ME, ST, OG, and GC), we have found positive IRAS PSC counterparts using the following method. We find the nearest IRAS PSC, AKARI PSC, ALLWISE, 2MASS, MSX, and AAVSO counterparts within 5′–60′ (depending on the beam size of the telescope) using the position information in the original reference.

Because there could be multiple ALLWISE sources for one IRAS PSC source (with a larger beam size), we need to compare the ALLWISE counterpart obtained from the IRAS PSC position (see the previous paragraph) with the counterpart obtained from the position in the original references. If the ALLWISE (or AKARI or MSX) counterparts obtained from the two positions (from the IRAS PSC and the original reference) are the same, the IRAS PSC source would be a more reliable counterpart. These objects with positive IRAS PSC counterparts are compiled into the AGB-IRAS catalog (OAGB stars in Suh & Hong (2017) and CAGB stars in Suh & Hong (2017)). All other objects with ALLWISE counterparts, which cannot be positively identified with IRAS PSC sources, are compiled into the AGB-WISE catalog (OAGB-WISE and CAGB-WISE catalogs).

Tables 5 and 6 list the cross-matched counterparts for all AGB-IRAS and AGB-WISE sample stars.

### 2.3. Catalogs Based on IRAS PSC

Based on the catalog of AGB stars presented by Suh & Hong (2017) (3828 OAGB and 1168 CAGB stars), we have revised it using new available literature. We have excluded five objects from the OAGB list (OI-SH): four young stellar objects (YSOs) or red supergiants (RSGs) and a red hypergiant (RHG) (see Tables 3). We have moved from CI-SH to OI-SH three objects which are SiO maser sources without clear CAGB evidences (see Tables 1).
The IRAS Low Resolution Spectrograph (LRS; $\lambda = 8-22\mu m$) data have been very useful to identify important dust features of AGB stars. Kwok et al. (1997) used the IRAS LRS data for 11,224 IRAS PSC source to identify new OAGB and CAGB stars. In the IRAS LRS, OAGB stars with silicate dust envelopes are classified into type E (10 $\mu m$ in emission) or A (10 $\mu m$ in absorption). CAGB stars with SiC grains are classified into type C (11.3 $\mu m$ in emission). There are 715 objects that are classified into group C: 713 objects are in the list of CI-SH (see Table 1), one object (IRAS 13136-4426) is an S star (in SI), and the other one (IRAS 22306+5918) is a composite object.

Figure 2 shows a WISE-2MASS 2CD using W3[12]–W4[22] versus K[2.2]–W3[12] for the sample of AGB stars from Suh & Hong (2017; 3828 OAGB stars in OI-SH and 1168 CAGB stars in CI-SH), which can be used to find a rough guide line that distinguishes between OAGB and CAGB stars. The brown line roughly distinguishes between OAGB and CAGB stars. For OAGB models (silicate $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.05, 0.1, 0.3, 0.7, 1, 3, 7, 15, 30, 40$ from left to right. For CAGB models (AMC $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.1, 0.5, 1, 2, 3, 5$ from left to right. For each subgroup, the number of objects is shown. The number in parentheses denotes the number of the plotted objects on the 2CD with good-quality observed colors.

Figure 2. A WISE-2MASS 2CD for color-selected AGB-IRAS (OI-UR, CI-UR, OI-OG, and CI-OG) and AGB-WISE (OW-OG and CW-OG) stars (see Tables 1 and 2) compared with theoretical models (see Section 3). The brown line roughly distinguishes between OAGB and CAGB stars. For OAGB models (silicate $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.05, 0.1, 0.3, 0.7, 1, 3, 7, 15, 30, 40$ from left to right. For CAGB models (AMC $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.1, 0.5, 1, 2, 3, 5$ from left to right. For each subgroup, the number of objects is shown. The number in parentheses denotes the number of the plotted objects on the 2CD with good-quality observed colors.
2.4. New OAGB Stars

Jiménez-Esteban & Engels (2015) and Blommaert et al. (2018) studied extremely reddened AGB stars in the Galactic bulge and presented lists of OAGB stars. These OAGB stars are compiled into the catalog based on IRAS PSC (OI-JB in OAGB-IRAS; see Table 1).

SiO maser sources are generally believed to be associated with OAGB stars (mostly Mira variables) with a thin silicate dust envelope (e.g., Deguchi et al. 2012; Stroh et al. 2019). But, two CAGB stars (IRAS LRS type C objects in CI-SH) are SiO maser sources: IRAS 01022+6542 (Deguchi et al. 2012) and IRAS 17105-3746 (Stroh et al. 2019).

Messineo et al. (2018) performed the SiO maser survey of late-type stars in the inner Galaxy. Stroh et al. (2019) performed the Bulge Asymmetries and Dynamical Evolution (BAADE) SiO Maser Survey at 86 GHz with the Atacama Large Millimeter/submillimeter Array (ALMA) and presented a list of 1427 sources with useful information. The OAGB stars (SiO maser sources) from Messineo et al. (2018) and Stroh et al. (2019) are compiled into two separate catalogs based on the IRAS PSC (OI-ME and OI-ST in OAGB-IRAS) and the ALLWISE source catalog (OW-ME and OW-ST in OAGB-WISE; see Section 2.2).

Wu et al. (2017) performed SiO maser survey toward off-plane OAGB stars around the orbital plane of the Sagittarius stellar stream and detected SiO maser emission from 44 targets, which are IRAS PSC sources.

We have compiled these OAGB objects into the new OAGB catalog (OI-JB, OI-ME, OI-ME, OI-ST, OW-ST, and OW-WU; see Tables 1 and 2).

2.5. LPVs in the Galactic Bulge

The OGLE projects detected many LPVs in the bulge of our Galaxy. The 15th part of the OGLE-III Catalog of Variable Stars (OIII-CVS) contains 232,406 LPVs detected in the OGLE-II and OGLE-III fields toward the Galactic bulge. The sample consists of 6528 Miras, 33,235 semiregular variables (SRVs) and 192,643 OGLE small-amplitude red giants (OSARGs) (Soszyński et al. 2013a). A giant star is believed to evolve from an OSARG to an SRV and finally to a Mira, limiting the number of its excited modes and increasing its pulsating periods and amplitudes (Soszyński et al. 2013b). Though most SRVs and a majority of OSARGs could also be in the AGB phase, most Mira variables are surely in the AGB phase and they are usually oscillating in...
the fundamental mode and occupy a single sequence in the period–luminosity diagram (Soszyński et al. 2013b). In this work, we consider the 6528 OGLE3 Miras in the Galactic bulge for the new catalog of AGB stars.

Using the guide line on the WISE-2MASS 2CD (see Figure 2), we may roughly distinguish between OAGB and CAGB stars for the sample of the 6528 OGLE3 Miras in the Galactic bulge (Soszyński et al. 2013a). Figure 3 shows the 2CD for the sample of 6528 OGLE3 Miras in the Galactic bulge (Soszyński et al. 2013a), but 321 objects without good-quality observed colors (W3[12]–W4[22] and K[2.2]–W3 [12]) are not plotted and they are not compiled into the new catalog. The brown line roughly distinguishes between OAGB and CAGB stars. We find that 6038 and 169 objects can be classified into OAGB and CAGB, respectively. One exception is IRAS 18100-2808, which is an OAGB star (IRAS LRS type E) with CAGB color. Therefore, 6039 and 168 objects can be compiled into the OAGB and CAGB catalogs, respectively.

These OAGB and CAGB stars with the positive IRAS PSC counterparts (see Section 2.2) are compiled into the AGB-IRAS catalog (OI-OAGB and CI-CAGB; see Table 1) and others into the AGB-WISE catalog (OW-OAGB and CW-CAGB; see Table 2).

Figure 2 shows the WISE-2MASS 2CD for the color-selected sample stars from Soszyński et al. (2013a) in AGB-IRAS (OI-OAGB, and CI-CAGB) and AGB-WISE (OW-OAGB and CW-CAGB) catalogs. The 2CD also shows the color-selected AGB-IRAS objects (OI-UR and CI-UR) from Urago et al. (2020) (see Section 2.3).

2.6. Visual Carbon Stars

Alksnis et al. (2001) presented general catalog of galactic carbon stars (3rd edition) which consist of 6891 entries, most of which are believed to be visual carbon stars in the AGB phase. Most CAGB stars in previous catalog (CI-SH; Suh & Hong 2017) are infrared carbon stars with relatively thick C-rich dust envelopes.

Objects in Alksnis et al. (2001) are compiled into two separate catalogs based on the IRAS PSC and the ALLWISE source catalog (CI-GC or CW-GC in Tables 1 and 2; see Section 2.2).

Compared with other subgroups, the basic properties (e.g., detailed IR SEDs or pulsations) of the objects from Alksnis et al. (2001; in CI-GC or CW-GC) are less known, so it is possible that a greater portion of the objects from CI-GC or CW-GC could not be in the AGB phase. Some objects could be in the post-AGB phase or other stages of stellar evolution.

3. Theoretical Dust Shell Models

We use the radiative transfer code DUSTY (Ivezić & Elitzur 1997) for a spherically symmetric dust shell around a central star, which is a blackbody. We use the models of Suh (2020) adapted for the new IR bands. In this paper, we briefly describe the theoretical models. See Section 4 in Suh (2020) for details about the models and their limitations.

For all models, we use a continuous power law \( \phi \propto r^{-2} \) dust density distribution and assume that the dust formation temperature \( T_c \) is 1000 K. For LMOA stars, we also use \( T_c = 500 \) K. The inner radius of the dust shell is set by the \( T_c \) and the outer radius of the dust shell is taken to be \( 10^4 \) times the inner radius. We use 10 \( \mu \)m as the fiducial wavelength of the dust optical depth \( \tau_{10} \). The radii of spherical dust grains are assumed to be 0.1 \( \mu \)m uniformly.

For OAGB stars, we use optical constants of warm (SILW) and cold (SILC) silicate dust from Suh (1999). We also use amorphous alumina (Suh 2016) and Mg0.9Fe0.1O (Henning et al. 1995) dust for OAGB stars. For CAGB stars, we use the optical constants of AMC and SiC dust grains from Suh (2000) and Pégoraü (1988), respectively. We also use Mg0.9Fe0.1S (Begemann et al. 1994) for CAGB stars. Table 7 summarizes the model parameters.

Figure 4 shows model SEDs for AGB stars \( (T_c = 1000 \) K) for major dust optical depths. For OAGB models, silicate dust features at 10 and 18 \( \mu \)m are shown for various dust optical depths \( \tau_{10} \). For CAGB models, SiC dust features at 11.3 \( \mu \)m and Mg0.9Fe0.1S dust features at 28 \( \mu \)m are shown for different dust optical depths. The reference wavelengths for major IR bands are also indicated. We may obtain the theoretical model color indices from the model SEDs using the ZMF values at given reference wavelength (see Table 4 and Section 2.1).

4. Infrared Two-color Diagrams—Comparison between Theory and Observations

Although photometric fluxes are less useful than a full SED, the large number of observations at various wavelength bands can be used to form a 2CD, which can be compared with theoretical models. IR 2CDs are useful to statistically distinguish various properties of AGB stars and post-AGB
stars (e.g., Suh & Kwon 2011; Suh 2015). Table 4 lists the IR bands used for the IR 2CDs presented in this work. In this work, we use only good-quality observational data at all wavelength bands (see Section 2.1) for plotting IR 2CDs.

Figures 5–8 show various IR 2CDs using different combinations of observed IR colors. We compare the observations with the theoretical dust shell models (see Section 3) for AGB stars. We find that the theoretical dust shell model can roughly reproduce the observations of AGB stars on the IR 2CDs using the dust opacity functions of amorphous silicate and amorphous carbon with a mixture of other dust species.

To consider the Galactic extinction processes suggested by Gordon et al. (2009; for the wavelength range from visual to NIR bands) and Chiar & Tielens (2006; from NIR to MIR bands), we plot reddening vectors for IR 2CD using NIR data (see Figures 5–8).

Generally, the stars that have thick dust shells with large dust optical depths are located in the upper-right regions on the IR 2CDs. On all of the IR 2CDs, we also plot the sequences of theoretical dust shell models at increasing dust optical depth for AGB stars (see Section 3).

Because the 10 μm silicate feature changes from emission to absorption when the dust optical depth becomes larger, there is a change in the slope of the theoretical model line for OAGB stars.

We will discuss the meanings of these 2CDs in the following subsections by comparing the observations with theoretical models.

### 4.1. IRAS and 2MASS 2CDs

The upper panel of Figure 5 plots AGB stars in an IRAS 2CD using IR[25]−IR[60] versus IR[12]−IR[25]. We find that the basic theoretical model tracks can roughly explain the observed points. This 2CD has been widely used since van der Veen & Habing (1988; note that the authors did not make zero-magnitude calibrations for their 2CD) divided this 2CD into eight regions of different classes of heavenly bodies. Sevener (2002) used this 2CD to explain the properties of observed points of AGB stars and post-AGB stars. Using theoretical dust shell models for AGB stars and post-AGB stars, Suh (2015) presented possible evolutionary tracks from AGB stars to post-AGB stars and to planetary nebulae on this 2CD.

On the IRAS 2CD using IR[25]−IR[60] versus IR[12]−IR[25], CAGB stars are distributed along a curve in the shape of a “C.” A group of stars in the upper-left region consists of visual carbon stars (mostly objects in OI-GC; see Table 1) that show excessive flux at 60 μm due to the remnant of an earlier phase when the stars were OAGB stars (e.g., Chan & Kwok 1990). A group of stars in the lower region, which extends to the right side, consists of infrared carbon stars. The infrared carbon stars on the right side have thick dust envelopes with large dust optical depths.

The lower panel plots an 2MASS-IRAS 2CD using IR[12]−IR[60] versus K[2.2]−IR[12]. The separation between OAGB and CAGB stars is clearer on this 2CD. If we consider Galactic extinction (see the reddening vector on the 2CD), there would be more observed points of OAGB and CAGB stars that would fit the theoretical models well.

### 4.2. WISE and 2MASS 2CDs

Figure 6 shows 2CDs using WISE and 2MASS colors. The upper panel of Figure 6 shows WISE 2CDs using W3[12]−W4[22] versus W1[3.4]−W2[4.6]. The lower panel of Figure 6 shows WISE-2MASS 2CD using W3[12]−W4[22] versus K[2.2]−W3[12].

Generally, the theoretical dust shell models for OAGB and CAGB stars can reproduce the observed points fairly well on these IR 2CDs, but for the W1[3.4]−W2[4.6] color, the theoretical models with small dust optical depths do not reproduce the observations well. On these 2CDs, the theoretical dust shell models for CAGB stars with AMC, SiC, and Mg_{0.9}Fe_{0.1}S dust grains can reproduce a wider range of observed W3[12]−W4[22] colors.

There is a group of CAGB-WISE objects (visual carbon stars in CI-GC and CW-GC) that show different aspects from infrared carbon stars. The objects are in the upper-left regions of the 2CDs that show bluer W1[3.4]−W2[4.6] or K[2.2]−W3[12] colors but redder W3[12]−W4[22] colors, which would be due to detached O-rich dust shells (that are remnants of an earlier phase when the stars were OAGB stars).

### 4.3. AKARI, MSX, and 2MASS 2CDs

Figure 7 shows an AKARI-2MASS 2CD using AK[9]−AK[18] versus K[2.2]−AK[9]. On this 2CD, the theoretical dust shell models for OAGB stars with thin detached dust shells (T_c = 500 K) with warm silicate, amorphous alumina, and Fe_{0.9}Mg_{0.1}O dust are more useful to explain the observed points. We find that the theoretical dust shell models for CAGB stars can reproduce only a narrow range of AK[9]−AK[18] colors.

Figure 8 shows MSX-2MASS 2CDs for all IRAS-AGB and WISE-AGB objects. Though good-quality MSX data are available only for a portion of the sample stars, these 2CDs clearly divide between OAGB and CAGB. Compared with
Figure 5. IRAS-2MASS 2CDs for all IRAS-AGB stars (see Table 1) in our Galaxy compared with theoretical models (see Section 3). For OAGB models (silicate $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.05, 0.1, 0.5, 1, 3, 7, 15, 30$, and 40 from left to right. For CAGB models (AMC $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.1, 0.5, 1, 2, 3, and 5$ from left to right. For each class, the number of objects is shown. The number in parentheses denotes the number of the plotted objects on the 2CD with good-quality observed colors.
Figure 6. WISE-2MASS 2CDs for all IRAS-AGB and WISE-AGB stars (see Tables 1 and 2) in our Galaxy compared with theoretical models (see Section 3). For OAGB models (silicate $T_c = 1000$ K): $\tau_10 = 0.001, 0.01, 0.05, 0.1, 0.5, 1, 3, 7, 15, 30, \text{and} 40$ from left to right. For CAGB models (AMC $T_c = 1000$ K): $\tau_10 = 0.001, 0.01, 0.1, 0.5, 1, 2, 3, \text{and} 5$ from left to right. For each class, the number of objects is shown. The number in parentheses denotes the number of the plotted objects on the 2CD with good-quality observed colors.
other colors, the opacity used for the theoretical models do not reproduce the MSX colors using MA[8.3], MD[14.7], and ME[21.3] bands well. Again, the theoretical dust shell models for CAGB stars can reproduce only a narrow range of MA[8.3]−ME[21.3] and MA[8.3]−MD[14.7] colors.

The upper panel of Figure 8 shows a 2CD using K[2.2]−MA[8.3] versus MA[8.3]−ME[21.3]. Lewis et al. (2020) used this 2CD to discuss the line that separates CAGB and OAGB stars. We also find that the separation between OAGB and CAGB is relatively clear on this 2CD. If we consider Galactic extinction, there would be more observed points of OAGB stars that would fit the OAGB model with thin detached dust shells. The lower panel of Figure 8 shows a 2CD using MA[8.3]−MD[14.7] versus K[2.2]−MA[8.3].

5. Number Distributions of IR Colors

We may compare the number distribution of observed IR colors for different classes (or subgroups) of AGB stars to find differences in the IR properties. We may also compare the number distributions with theoretical model colors.

5.1. OAGB and CAGB Stars

Figure 9 shows number density distributions of observed IR magnitudes at W2[4.6] and W3[12] bands and colors for AGB stars in the AGB-IRAS and AGB-WISE catalogs. We choose two IR colors: W1[3.4]−W2[4.6] and K[2.2]−W3[12] (see Figure 6).

Generally, AGB-IRAS objects are brighter at MIR bands and show redder IR colors than AGB-WISE objects. We also find that AGB-WISE objects are more concentrated toward the bluer colors and the number decreases with the redder colors, whereas numbers for AGB-IRAS objects are more dispersed into redder colors. In general, AGB-IRAS objects look to be more evolved (or more massive) stars with thicker dust envelopes than AGB-WISE objects.

5.2. OH and SiO Maser Sources among OAGB Stars

A major portion of OAGB stars are SiO, H2O, OH maser sources (e.g., Kwon & Suh 2012). We use the lists of SiO maser sources compiled by Kwon & Suh (2012) and new SiO maser...
Figure 8. MSX-2MASS 2CDs for all IRAS-AGB and WISE-AGB stars (see Tables 1 and 2) in our Galaxy compared with theoretical models (see Section 3). For OAGB models (silicate $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.05, 0.1, 0.5, 1, 3, 7, 15, 30, \text{ and } 40$ from left to right. For CAGB models (AMC $T_c = 1000$ K): $\tau_{10} = 0.001, 0.01, 0.1, 0.5, 1, 2, 3, \text{ and } 5$ from left to right. For each class, the number of objects is shown. The number in parentheses denotes the number of the plotted objects on the 2CD with good-quality observed colors.
sources detected from the Galactic bulge (Messineo et al. 2018; Wu et al. 2017; Stroh et al. 2019; see Section 2.5). We have also compiled SiO maser sources detected by the Korean VLBI Network single-dish telescopes (Kim et al. 2010, 2013; Cho & Kim 2012; Yoon et al. 2014; Cho et al. 2017). There are 2527 and 388 SiO maser sources in OAGB-IRAS and OAGB-WISE catalogs, respectively (see Tables 1 and 2). In the OAGB-WISE catalog, all 388 SiO maser sources are in OW-ME and OW-ST.

OH/IR stars are generally considered to be more massive OAGB stars with thicker dust envelopes and higher mass-loss rates (Engels et al. 1983; Blommaert et al. 2018). Chen et al. (2001) presented a list of 1065 OH/IR stars in our Galaxy. The list has been corrected and updated (Suh & Kwon 2011; Kwon & Suh 2012). We also use the catalog of OH/IR stars presented by Engels & Bunzel (2015). There are 2079 OH/IR stars in OAGB-IRAS (1988 in OI-SH, 17 in OI-UR, 3 in OI-JB, 1 in OI-ME, 20 in OI-ST, 18 in OI-OG, 1 in OI-WU, and 31 in OI-AM; see Table 1), but there is only one known OH/IR star (OH 17.434-0.077) in OAGB-WISE (OW-ME) yet.

Figure 10 shows number distributions of IR colors \( K[2.2] - IR[12] \) and \( IR[12] - IR[25] \). Most OH maser sources are in the range of large dust optical depths (or mass-loss rates). However, most SiO maser sources are in the range of moderate dust optical depths (or mass-loss rates) for both colors.

We mark the theoretical model colors on Figures 10 and 11. For OAGB stars, the dust shell (silicate; \( T_c = 1000 \text{ K} \)) model...
colors for typical LMOA stars ($\tau_{10} = 0.1$ and 1) and HMOA stars ($\tau_{10} = 7$) are indicated (see Section 3).

Figure 11 shows number distributions of IR colors ($K[2.2] - W3[12]$ and $W2[4.6] - W3[12]$) for SiO maser sources and undetected (or unobserved) sources among all of the OAGB-IRAS and OAGB-WISE sample stars. Again, most SiO maser sources in OAGB-IRAS are in the range of moderate dust optical depths (or mass-loss rates) for both colors. Because the OAGB-WISE class lacks objects with thick dust envelopes (or redder IR colors), SiO maser sources look to be in the range of relatively large dust optical depths for the IR colors. Note that SiO maser observations have not been performed yet for a major portion of OAGB-WISE objects, which are OGLE3 Miras in the Galactic bulge (OW-OG; see Table 2).
5.3. Visual Carbon Stars

Unlike other subgroups of CAGB stars (in CI-SH, CI-UR, CI-OG, and CW-OG; see Tables 1–2), most objects in CI-GC and CW-GC (from Alksnis et al. 2001) are believed to be visual carbon stars in the AGB phase.

To find the differences of the IR colors of visual carbon stars from the colors of other groups that contain a mixture of infrared carbon stars and visual carbon stars, we compare the histograms in Figure 12.

We mark the theoretical model colors on Figure 12. For CAGB stars, the dust shell (AMC; $T_c = 1000$ K) model colors for the thin dust shell ($\tau_{10} = 0.1$) and thick dust shell ($\tau_{10} = 1$) model colors are indicated (see Section 3).

The left panels of Figure 12 show number density distributions of observed IR colors (IR[12]–IR[25], IR[25]–IR[60], K[2.2]–AK[9], and K[2.2]–MA[8.3]) for CAGB-IRAS objects. Compared with others, visual carbon stars (in CI-GC) show bluer IR[12]–IR[25], K[2.2]–AK[9], and K[2.2]–MA[8.3] colors and but redder IR[25]–IR[60] colors. This is because visual carbon stars show excessive flux at 60 μm due to the remnant of an earlier phase when they were OAGB stars (see Section 4.1).

The right panels of Figure 12 show number density distributions of observed IR colors (K[2.2]–W3[12] and W3[12]–W4[22]) for CAGB-IRAS and CAGB-WISE objects. For K[2.2]–W3[12], non CI-GC objects are in the wide ranges of
large dust optical depths, whereas CI-GC objects are in narrow ranges. For CAGB-WISE objects, the difference gets smaller because most of the non-CW-GC objects (in CW-OG) are likely to CAGB stars with thin dust shells.

For W3[12]−W4[22], the number density distributions for CAGB-IRAS objects are similar to those for IR[12]−IR[25]. For CAGB-WISE objects, some CW-GC objects show redder colors. This would be because visual carbon stars with detached dust shell ($T_c < 500$ K; remnant of an earlier phase when the stars were OAGB stars) may show redder W3[12]−W4[22] (see Section 4.2). Note that the theoretical model colors on Figure 12 are for hot dust shell ($T_c = 1000$ K), which are not applicable to detached dust shell models.

6. Spacial Distribution of AGB Stars

Figure 13 shows spacial distributions of AGB stars (AGB-IRAS and AGB-WISE) in Galactic coordinates. Figure 14 shows number distribution of the Galactic longitude and latitude for OAGB and CAGB stars in AGB-IRAS and AGB-WISE catalogs. In the bulge component, there are more OAGB stars than CAGB stars. The lack of OAGB-WISE objects at the Galactic center in the lower-left panel looks to be due to a selection effect of the sample stars.

The histograms for different Galactic latitudes are similar for both OAGB and CAGB stars. All AGB stars are concentrated toward the Galactic disk.

We find that OAGB stars are more concentrated toward the Galactic center and the number decreases with the Galactic longitude, while CAGB stars are distributed more uniformly from the center to large Galactic longitudes. Ishihara et al. (2011) also found that OAGB stars are concentrated toward the Galactic center and that the density decreases with Galacto-centric distance, whereas CAGB stars show a relatively uniform distribution within about 8 kpc of the Sun.

7. Period–Color Relations for Known Mira Variables

It is generally believed that more evolved (or more massive) AGB stars would show longer pulsation periods, larger pulsation amplitudes, higher mass-loss rates, thicker dust envelopes, and redder IR colors (e.g., De Beck et al. 2010; Suh & Kwon 2013). Studying IR properties of all types of LPVs in the Magellanic clouds, Suh (2020) showed that only...
Mira variables, among all types of LPVs, show a clear period–color relation (PCR): Miras with longer pulsation periods generally show redder IR colors. This is because Mira variables are usually oscillating in the fundamental mode and occupy a single sequence in the period–luminosity diagram (Soszyński et al. 2013b; see Section 2.5).

Because most of the known pulsation periods in AAVSO were obtained in optical observations and the longest wavelength band used by OGLE3 observations was the I band (0.8 μm), most Mira variables whose pulsation periods are listed in AAVSO are early-phase AGB stars with thin dust envelopes.

The left panels of Figure 15 show IR[12]−IR[25] and K[2.2]−IR[25] colors versus pulsation periods for Miras in the AGB-IRAS catalog (see Table 1). For both IR colors, CAGB stars show larger coefficients of determination ($R^2$), which mean higher strength of the relationship. We find that Mira variables show fairly strong PCRs.

Jiménez-Esteban et al. (2021) investigated variability properties of the Arecibo sample of OH/IR stars and presented periods for 348 Arecibo sources obtained from observations at NIR bands. All of those sources are in OI-SH except for one object, IRAS 18551+0323, which is a CAGB star (in CI-SH with IRAS LRS type C; this object could be a composite object).

The pulsation periods measured at NIR or radio bands for more evolved or massive AGB stars with thick dust envelopes are available only for a small number of AGB stars. We have compiled pulsation periods of 522 OAGB stars (495 OH/IR stars; 214 AAVSO Miras) measured at NIR, MIR, or radio bands presented by Chen et al. (2001), Kwon & Suh (2010b), Urago et al. (2020), and Jiménez-Esteban et al. (2021).

The right panels show PCRs for Miras in AGB-IRAS and AGB-WISE, respectively.

Though there are large scatters, we find that the PCRs for Miras in the sample stars show a noticeable trend: Miras with longer pulsation periods generally show redder IR colors.

8. Finding IR Variations of AGB Stars from WISE Data

Various observational data obtained in the last 50 yr are available for studying the variability of AGB stars. There are large amounts of photometric data at visual and NIR bands but the data in the MIR bands are available only for a limited number of objects. For AGB stars with thick dust envelopes, the variability can be more properly investigated from the observations at NIR bands (e.g., Engels et al. 1983; Kwon & Suh 2010b).

To study variability of AGB stars at W1[3.4] and W2[4.6] bands during the last 12 yr, we use the ALLWISE multiepoch photometry table obtained in 2009–2010 and the NEOWISE-R data (2021 data release) which give us the photometry data for 14 epochs, two in every year between 2014 and 2020.

We try to find Mira-like variations from the WISE light curves of the sample stars using a simple sinusoidal light-curve...
Figure 16. Period–color relations for AGB-IRAS and AGB-WISE objects known as Miras (AAVSO). For each class, the number of objects is shown. The number in parentheses denotes the number of the plotted objects with good-quality observed data. See Section 7.
A model with periods longer than 50 days (the shortest period of OGLE3 bulge Miras is 78.31 days). In this work, we use the Lomb–Scargle periodogram which is a commonly used statistical algorithm for detecting and characterizing periodic signals in unevenly spaced observations (e.g., Zechmeister & Kürster 2009; VanderPlas 2018). The Lomb–Scargle periodograms are computed using the implementations in AstroPy.¹ We use the AstroPy computing option of autopower using the “chi2” method, which utilizes the fact that the Lomb–Scargle periodogram at each frequency is equivalent to the least-squares fit of a sinusoid to the data. The advantage of the “chi2” method is that it allows extensions of the periodogram to multiple Fourier terms.

For each object in the sample, we have generated the light curves using WISE data and produced Lomb–Scargle periodograms. But the WISE data for a major part of the sample of AGB stars (mostly bright stars) are either saturated or show scatters too large to provide meaningful variation parameters. Therefore, we need to choose the objects with good-quality variation parameters for which the deviations of the observed points from the derived sinusoidal model light curves are smaller. To find objects with good-quality variation parameters

¹ https://docs.astropy.org/en/stable/timeseries/lombscargle.html#
**OH 26.5+0.6 (IRAS 18348-0526)**

\[ P=1557.79 \pm 8.65; \quad A=1.16 \pm 0.05; \quad R^2=0.751 \]

Figure 18. The combined light curve and Lomb–Scargle periodogram for an OH/IR star OH 26.5+0.6 (in OI-SH) using the \([3.4–3.6]\) band data acquired in 1974–2003 and the WISE W1\([3.4]\) band data acquired over the last 12 yr. In the Lomb–Scargle periodogram, the dashed brown horizontal line indicates the periodogram level corresponding to a maximum peak false alarm probability of 1%. Refer to Kwon & Suh (2010a) for details of the \(L\)-band data. See Section 8.1.

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**Figure 19.** Light curves and Lomb–Scargle periodograms for an OAGB-IRAS (OI-OG) object IRAS 18007-3012 (OGLE-BLG-LPV-196468) using the OGLE3 (\(I\) band) and WISE (W2 band) data. Soszyński et al. (2013a) obtained a period of 188.38 days. See Section 8.1.
at W1[3.4] and W2[4.6] bands (G-W1 and G-W2 objects), we choose objects with more than 100 observed points and the coefficients of determination ($R^2$) to fit the sinusoidal model to the observations is larger than 0.6, for which the Lomb–Scargle power is also stronger. Table 8 summarizes the results for the sample stars.

Figure 20. WISE light curves and Lomb–Scargle periodograms for six OAGB-IRAS objects known as Miras with periods. In the Lomb–Scargle periodogram, the red X and black cross marks indicate the primary and selected peaks, respectively, and the red dashed brown horizontal line indicates the periodogram level corresponding to a maximum peak false alarm probability of 1%. The upper two panels show OI-UR objects whose periods from Urago et al. (2020) are 268 and 394 days, respectively. The middle two panels show OI-SH and OI-OG objects (see Table 1). For the two objects (OI-OG objects) in lower panels, the second peak of the Lomb–Scargle power is selected for the period (GM-W2B objects). See Section 8.1.
Figure 17 compares the number density distributions of mean magnitudes for all objects whose WISE light curves are available (P-W1 and P-W2 objects) and those for the objects with good-quality parameters (G-W1 and G-W2). Generally, the objects with good-quality variation parameters are less bright.

Using the WISE data, we have obtained good-quality variation parameters for 3710 objects (G-W1 or G-W2; 885...
OAGB-IRAS, 141 CAGB-IRAS, 2468 OAGB-WISE, and 216 CAGB-WISE objects) in the catalog (see Table 8).

There are 2810 objects known as Miras with periods from AAVSO (GM-W1 or GM-W2; 284 OAGB-IRAS, 13 CAGB-IRAS, 2429 OAGB-WISE, and 84 CAGB-WISE objects). For about half of the objects (GM-W1A or GM-W2A objects), the obtained primary periods from the WISE data are similar to the period in AAVSO. For another half

Figure 22. WISE light curves and Lomb–Scargle periodograms for three CAGB-IRAS objects (objects in upper panels: CI-SH; IRAS 08546+1732: CI-GC) and three CAGB-WISE objects (CW-2323: CW-GC; objects in lower panels: CW-OG) known as Miras with periods. For CAGB-WISE, the object name is denoted by the CAGB-WISE identifier (CW-N; see Table 12). In the Lomb–Scargle periodogram, the red X and black cross marks indicate the primary and selected peaks, respectively and the red dashed brown horizontal line indicates the periodogram level corresponding to a maximum peak false alarm probability of 1%. Note that the second peak of the Lomb–Scargle power is selected for the periods of the three objects. See Section 8.1.
Figure 23. Properties of variation for OAGB-IRAS objects known as Miras with periods. The left panels show comparisons of the periods from AAVSO and the periods obtained from the WISE light curves. The green vertical (and horizontal) lines indicate the multiples of the interval of WISE observations (6 months). The right panels shows the period–amplitude and period–color relations. See Section 8.2.
Figure 24. Properties of variation for OAGB-WISE objects known as Miras with periods. The left panels show comparisons of the periods from AAVSO and the periods obtained from the WISE light curves. The green vertical (and horizontal) lines indicate the multiples of the interval of WISE observations (6 months). The right panels show the period–amplitude and period–color relations. See Section 8.2.
Figure 25. Properties of variation for CAGB-WISE objects known as Miras with periods. The left panels show comparisons of the periods from AAVSO and the periods obtained from the WISE light curves. The green vertical (and horizontal) lines indicate multiples of the interval of WISE observations (6 months). The right panels shows the period–amplitude and period–color relations. See Section 8.2.
Figure 26. The period–amplitude relation for all Miras in the Galactic bulge obtained from OGLE3 I (0.8 μm) band observations (Soszyński et al. 2013a).

(GM-W1B or GM-W2B objects), the obtained primary periods from WISE data are different from the periods in AAVSO (see Section 8.2).

And there are 656 objects with unknown periods (GN-W1 or GN-W2; 441 OAGB-IRAS, 97 CAGB-IRAS, 37 OAGB-WISE, and 81 CAGB-WISE objects) and 244 objects known as non-Mira variables with periods from AAVSO (GN-W1 or GN-W2; 160 OAGB-IRAS, 31 CAGB-IRAS, 2 OAGB-WISE, and 51 CAGB-WISE objects).

8.1. WISE Light Curves for Known Mira Variables

Kwon & Suh (2010a, 2010b) analyzed L- and M-band photometric data for 12 OH/IR stars acquired between the 1970s and 2004 and found their periods and amplitudes. Because $L[3.4–3.6]$ and $M[4.8–4.9]$ band wavelengths are near WISE W1[3.4] and W2[4.6] band wavelengths, we have analyzed the combined light curves. But the WISE data for most of these bright AGB stars are either saturated or show too-large scatters. We could plot a meaningful combined light curve for only one source (OH 26.5+0.6).

Figure 18 shows the light curve for the OH/IR star OH 26.5+0.6 (in OI-SH) using the data at the $L[3.4–3.6]$ band acquired in 1974–2003 and the WISE W1[3.4] band data acquired in the last 12 yr.

Figure 19 shows the OGLE3 and WISE light curves for IRAS 18007-3012 (in OI-G). The light curves at I (0.8 μm) and W2[4.6] bands show similar characteristics, though the amplitude at the W2[4.6] band is smaller. Unlike the OGLE3 light curve, there are multiple peaks with similar power values in the Lomb–Scargle periodogram obtained from the WISE light curve because the WISE data were taken in a regular interval (every six months).

We have obtained pulsation periods from the WISE light curves for 2810 objects known as Miras with periods from AAVSO (GM-W1 or GM-W2; 284 OAGB-IRAS, 13 CAGB-IRAS, 2429 OAGB-WISE, and 84 CAGB-WISE objects; see Table 8).

Figure 20 shows the light curves for six OAGB-IRAS objects known as Miras. The periods obtained from WISE data are similar to the ones in AAVSO, but there are multiple peaks with similar Lomb–Scargle power values. For the two objects in lower panels (GM-W2B objects), though the period from the primary peak of the Lomb–Scargle power is different from the AAVSO period, the period from the second peak is very similar to the AAVSO period and produce a similar fit to the observations.

Figure 21 shows the light curves for six OAGB-WISE objects known as Miras. The obtained primary period from WISE data is similar to the ones in AAVSO for three objects (GM-W2A objects). For the other three objects (GM-W2B objects), the period from the second peak of Lomb–Scargle power is similar to the AAVSO period.

Figure 22 shows the light curves for three CAGB-IRAS objects (objects in upper panels: CI-SH: IRAS 08546+1732: CI-GC) and three CAGB-WISE objects (CW-2323: CW-GC; objects in lower panels: CW-OG) known as Miras with periods. For three objects (GM-W2B objects), the period from the second peak of Lomb–Scargle power is similar to the AAVSO period.

For most Mira variables whose primary periods obtained from the WISE light curves are different from AAVSO periods (GM-W1B or GM-W2B objects), we can find a new (second or up to fourth) peak in the Lomb–Scargle power for which the new period is similar to the AAVSO period and produces a similar fit (a little worse fit with a smaller $R^2$ value) to the observations.

Because there are multiple peaks with similar Lomb–Scargle power values, it is not easy to obtain a precise period using only the WISE data (see Figures 20–22). The uncertainties in period and amplitude specified in Figures 18 and 19 are calculated by measuring the smooth imprecision in the selected peak of the Lomb–Scargle power. However, when there are multiple peaks with similar Lomb–Scargle power values, uncertainties expressed in this way cannot be meaningful because the uncertainties of periods can be more affected by the false peaks (VanderPlas 2018).

8.2. Comparison between AAVSO Periods and New Periods from WISE Data for Known Miras

If we compare the WISE periods with the AAVSO periods for the objects known as Miras with known periods from AAVSO (GM-W1 or GM-W2 objects; see Table 8), we may check the reliability of the WISE periods. For AGB-WISE objects, most of AAVSO periods are from OGLE3 I (0.8 μm) band observations (Soszyński et al. 2013a).

Figures 23–25 show the relations between AAVSO periods and the periods obtained from the WISE light curves for OAGB-IRAS, OAGB-WISE, and CAGB-WISE objects (known as Miras, with known periods from AAVSO), respectively. The figures also show the histograms of the periods obtained from the WISE light curves, period–amplitude relations, and period–color relations. For CAGB-IRAS objects, the numbers of sample stars (GM-W1 or GM-W2; see Table 8) are too small to make proper plots.

The upper-left panels of Figures 23–25 compare the periods from AAVSO (most of them are from OGLE3 I band observations) and the periods obtained from the WISE light curves for OAGB-IRAS, OAGB-WISE, and CAGB-WISE objects, respectively. For about half of the objects (GM-W1A or GM-W2A), the obtained primary periods from the WISE data are similar to the periods in AAVSO. For another half (GM-W1B or GM-W2B), the obtained primary periods from WISE data are different from the periods in AAVSO. The deviations look to occur more severely when the AAVSO or WISE periods are similar to the interval of the WISE observations (6 months).
These deviations could be due to the characteristic of the Lomb–Scargle periodogram with similar multiple peaks, which could be due to the regularity of the WISE observations (6 months). VanderPlas (2018) compared the true period and peak Lomb–Scargle period for 1000 simulated periodic light curves and found that the Lomb–Scargle peak does not always coincide with the true period because it is more similar to EP.

**Figure 27.** WISE light curves and Lomb–Scargle periodograms for OAGB-IRAS objects with unknown periods (IRAS 16254-4858 in OI-ST, IRAS 17128-3528 in OI-JB, and others in OI-SH). In the Lomb–Scargle periodogram, the red X and black cross marks indicate the primary and selected peaks, respectively, and the red dashed brown horizontal line indicates the periodogram level corresponding to a maximum peak false alarm probability of 1%. See Section 8.3. For four objects, P(EP) (the expected period from the IR color K[2.2]–W3[12]; see Section 8.4) is also shown. For two objects, the second peak of the Lomb–Scargle power is selected for the period because it is more similar to EP.
period, and there is noticeable structure among these failures, which is similar to the ones in upper-left panels of Figures 23–25. The noticeable structure is clearer for OAGB-WISE objects because the sample number is much larger than other classes. But for most GM-W1B or GM-W2B (see Table 8) objects, we can find a new (second or up to fourth) peak in the Lomb–Scargle power values, for which the new period is similar to the AAVSO period. This would be because the AAVSO periods

\[ P(EP) = \text{expected period from the IR color } K_{2.2} - W_{3.12}; \text{see Section 8.4} \]
Figure 29. For OAGB-IRAS objects with unknown periods or those objects known as non-Mira variables with periods, the upper-left panel compares the expected periods (EPs) obtained from the IR color (K[2.2] − W3[12]) with the periods obtained from the WISE light curves. The upper-right panels show the period–amplitude relation. The green vertical lines indicate multiples of the interval of WISE observations (6 months). The lower panels show the relations between the WISE periods and IR colors (K[2.2] − W3[12] and IR[12] − IR[25]). See Section 8.4.
Figure 30. For CAGB-IRAS objects with unknown periods or those objects known as non-Mira variables with periods, the upper-left panel compares the expected periods (EPs) obtained from the IR color ($K_{2.2} - W_{3.12}$) with the periods obtained from the WISE light curves. The upper-right panel show the period–amplitude relation. The green vertical lines indicate the multiples of the interval of WISE observations (6 months). The lower panels show the relations between the WISE periods and IR colors ($K_{2.2} - W_{3.12}$ and $IR_{12} - IR_{25}$). See Section 8.4.
can be regarded as true periods and the multiple peaks in the Lomb–Scargle power values are very similar (see Figures 20–22). When we select a new peak that is similar to the AAVSO period for the GM-W1B or GM-W2B objects, the periods obtained from the WISE light curves are very similar to the AAVSO periods for most objects.

The lower-left panels of Figures 23–25 show the histograms of the periods obtained from the WISE light curves. GM-W1A
or GM-W2A objects show a roughly single peak whereas GM-W1B or GM-W2B objects show multiple peaks. When we select new peaks for GM-W1B or GM-W2B objects, the histogram shows a roughly single peak just like GM-W1A or GM-W2A objects. Again, this effect is clearer for OAGB-WISE objects because the sample number is much larger than other classes.

Figure 32. WISE light curves and Lomb–Scargle periodograms for six CAGB (in CI-SH) objects with unknown periods. In the Lomb–Scargle periodogram, the red X and black cross marks indicate the primary and selected peaks, respectively and the red dashed brown horizontal line indicates the periodogram level corresponding to a maximum peak false alarm probability of 1%. P(EP) is the expected period from the IR color K[2.2]−W3[12] (see Section 8.4). For three objects, the second peak of the Lomb–Scargle power is selected for the period because it is more similar to EP. Note that the primary peaks at W1 and W2 bands are different for IRAS 19315+1807 (see the lower two panels).
The periods from the WISE data and AAVSO observations have a weak point due to the regularity of observation (6 months), the new periods obtained from the WISE W1[3.4] and W2[4.6] light curves are very similar to the periods in AAVSO. They also show very similar period-amplitude relations though the amplitudes from OGLE3 are generally larger.

Though the reliability of the periods obtained from WISE observations has a weak point due to the regularity of observation (6 months), the new periods obtained from the WISE W1[3.4] and W2[4.6] light curves, whether they are from primary peaks of Lomb–Scargle power or not, could be more reliable than AAVSO periods for some objects depending on the quality of the model fit.

8.3. Candidate Objects for New Mira Variables

We have obtained new pulsation periods from the WISE light curves for 656 objects with unknown periods and 244 objects known as non-Mira variables with periods from AAVSO (GN-W1 or GN-W2 objects; see Table 8). The 656 objects with unknown periods consist of 441 OAGB-IRAS, 97 CAGB-IRAS, 37 OAGB-WISE, and 81 CAGB-WISE objects. The 244 objects known as non-Mira variables with periods from AAVSO consist of 160 OAGB-IRAS, 31 CAGB-IRAS, 20 OAGB-WISE, and 51 CAGB-WISE objects. These objects can be candidates for new Mira variables.

Though it is not easy to obtain precise periods from the WISE light curves because the periodograms show multiple peaks with similar Lomb–Scargle power values, the derived variation parameters would be useful if there are enough observed points that fit the model well (stronger Lomb–Scargle power values or larger coefficients of determination for the model fit).

Figure 27 shows the WISE light curves and periodograms for the six OAGB-IRAS objects (OH/IR stars except for IRAS 16254-48580) with unknown periods, which can be candidate objects for new Miras. IRAS 16254-48580 was suspected to be a SRV with unknown period (see Walsh et al. 1998), the object is likely to be a typical OH/IR star because it shows a Mira-like regular pulsation period (251 or 671 days). Though IRAS 17436-2807 (in OI-ST) was suspected to be a HII region (Walsh et al. 1998), the object is likely to be a typical OH/IR star because it shows a Mira-like regular pulsation period (613 days) obtained from the WISE light curves.

Figure 28 shows the WISE light curves and periodograms for the four CAGB-IRAS (CI-SH) and two CAGB-WISE (CW-GC) objects with unknown periods, which can be candidate objects for new Miras. Note that IRAS 08276-5125 (CI-SH) was suspected to be a SRV with unknown period in AAVSO.

We have found new periods from the WISE light curves at W2[4.6] for 104 CW-GC objects (GN-W2; see Table 8) from which 33 objects were known to be SRVs with periods in AAVSO.

Table 5

Cross-identified IR Sources and AAVSO Objects for AGB-IRAS Sample Stars

| Subgroup | IRAS | AKARI | ALLWISE | MSX | AAVSO |
|----------|------|-------|---------|-----|-------|
| CI-SH    | 3826 | 3673  | 3820    | 2394| 2538  |
| CI-UR    | 37   | 35    | 37      | 28  | 18    |
| CI-JB    | 6    | 6     | 6       | 6   | 5     |
| CI-ME    | 127  | 120   | 127     | 127 | 26    |
| CI-ST    | 673  | 651   | 673     | 673 | 255   |
| CI-OG    | 1057 | 1011  | 1057    | 949 | 1057  |
| CI-GC    | 9    | 9     | 9       | 9   | 9     |
| CI-SH    | 1165 | 1149  | 1164    | 753 | 890   |
| CI-JR    | 5    | 5     | 5       | 4   | 1     |
| CI-ME    | 2417 | 2393  | 2413    | 1848| 2117  |
| CI-OG    | 3596 | 3555  | 3591    | 2612| 3017  |

Note.

See Table 1. The numbers of the cross-identified 2MASS sources are the same as the numbers of IRAS PSC sources.

Table 6

Cross-identified IR Sources and AAVSO Objects for AGB-WISE Sample Stars

| Subgroup | ALLWISE | 2MASS | AKARI | MSX | AAVSO |
|----------|---------|-------|-------|-----|-------|
| OW-ME    | 157     | 157   | 120   | 157 | 15    |
| OW-ST    | 231     | 231   | 190   | 231 | 29    |
| OW-OG    | 4913    | 4913  | 3159  | 4171| 4913  |
| OW-all   | 5301    | 5301  | 3469  | 4559| 4957  |
| CW-GC    | 3417    | 3187  | 1987  | 1627| 1388  |
| CW-OG    | 159     | 159   | 70    | 121 | 159   |
| CW-all   | 3576    | 3346  | 2057  | 1748| 1547  |

Note.

See Table 2.

Table 7

Dust Shell Model Parameters

| Model | Dust | $T_{\text{eff}}$ (K) | $T_{\text{e}}$ (K) | $T_{\text{g}}$ (K) |
|-------|------|----------------------|-------------------|------------------|
| LMOA  | O-rich\textsuperscript{a} | 0.001, 0.01, 0.05, 0.1 | 500 | 3000 |
| LMOA  | SILW | 0.001, 0.01, 0.05, 0.1 | 1000 | 3000 |
| LMOA  | SILW | 0.5, 1, 3 | 1000 | 2500 |
| CAGB  | C-rich\textsuperscript{a} | 0.001, 0.01, 0.1, 0.5 | 1000 | 2500 |
| CAGB  | C-rich\textsuperscript{a} | 1, 2, 3, 5 | 1000 | 2000 |
| HMOS  | SILC | 7, 15, 30, 40 | 1000 | 2000 |

Notes.

\textsuperscript{a} The blackbody temperature of the central star.

\textsuperscript{b} SILW, SILW + alumina (from Suh 2016), and SILW + Fe$_{0.7}$Mg$_{0.4}$O (from Henning et al. 1995).

\textsuperscript{c} AMC, AMC + SiC, and AMC + Mg$_{0.5}$Fe$_{0.9}$S (from Begemann et al. 1994).

On the whole, the periods from the WISE data and AAVSO show good correlations for all of the sample stars known as Miras (see upper-left panels of Figures 23–25). Upper-right panels of Figures 23–25 show the period–amplitude relations. Both the relations for the objects using primary peaks (GM-W1A or GM-W2A) and for the objects using new peaks (GM-W1B or GM-W2B) look similar to the one for Miras in OGLE3 bulge (see Figure 26), which show larger amplitudes. But for some objects, the amplitudes show large deviation from the general trend, especially when obtained periods are similar to the multiples of the interval of WISE observations (6 months). Compared with OAGB-WISE objects, OAGB-IRAS objects show generally larger periods and amplitudes.

Lower-right panels of Figures 23–25 show the PCRs for OAGB-IRAS, OAGB-WISE, and CAGB-WISE objects using the K[2.2]–W3[12] color. The objects show the similar PCRs to those for known Mira variables using AAVSO periods (see Figure 16).

For most objects that are known as Miras with periods in the catalog, we find that the new periods from the WISE W1[3.4] and W2[4.6] light curves are very similar to the periods in AAVSO. They also show very similar period–amplitude relations though the amplitudes from OGLE3 are generally larger.

The 656 objects known as non-Mira variables with periods from AAVSO (GN-W1 or GN-W2 objects; see Table 8). The 656 objects with unknown periods consist of 441 OAGB-IRAS, 97 CAGB-IRAS, 37 OAGB-WISE, and 81 CAGB-WISE objects. The 244 objects known as non-Mira variables with periods from AAVSO consist of 160 OAGB-IRAS, 31 CAGB-IRAS, 20 OAGB-WISE, and 51 CAGB-WISE objects. These objects can be candidates for new Mira variables.
8.4. Properties of the Candidate Objects for New Miras

As we discussed in Section 8.2, the obtained primary period from the WISE light curve are different from the true period (AAVSO period) for about half of the known Mira variables. Likewise, when we use only primary periods, the candidate objects for new Miras do not show the period–amplitude or period–color relations typical for Miras variables (see the upper-left panels of Figure 29–30).

Generally, Mira variables with longer pulsation periods show redder IR colors (see Figure 15–16 and 23–25). Though the PCRs show large scatter, we may roughly estimate the expected periods from the IR colors for the new Mira candidates. We use the relation between IR color ($K_{2.2} - W3$) and the period of Miras to estimate the expected period (EP).

We tried to use the PCR from the upper-right panel of Figure 15 for OAGB stars with known periods from radio or IR observations to obtain EP from $K_{2.2} - W3$. However, the PCR from the fit line produced too large EPs. After some trials with different slopes and intercepts, we find new PCRs (the blue and red lines in the panel) that produce a better relation between EPs and WISE periods for OAGB-IRAS objects (see the upper-left panel of Figure 29) and CAGB-IRAS objects (see the upper-left panel of Figure 30). Some discrepancies were not avoidable because EP cannot be regarded as the true period for all objects.

We use the following PCRs: $K_{2.2} - W3 = 6.87 \cdot \log_{10}(\text{EP}) - 9.95$ (for OAGB-IRAS) and $K_{2.2} - W3 = 9.54 \cdot \log_{10}(\text{EP}) - 17.9$ (for CAGB-IRAS); see the upper-right panel of Figure 15. For a major portion of the best quality periodograms of OAGB-IRAS and CAGB-IRAS objects (see Figures 31 and 32 for examples), the WISE periods are similar to EPs when we use these PCRs.

From the GW1-N and GW2-N objects in AGB-IRAS (Table 8), we select objects with good-quality $K_{2.2} - W3$ colors (OAGB-IRAS: 362 from 422 GW1-N objects and 380 from 439 GW2-N objects; CAGB-IRAS: 92 from 110 GW1-N objects and 50 from 63 GW2-N objects).

Figures 29 and 30 show the relations between EPs and the WISE periods, period–amplitude relations, and PCRs for OAGB-IRAS and CAGB-IRAS objects (with unknown periods or known as non-Mira variables with periods from AAVSO; GN-W1 and GN-W2 objects in Table 8), respectively.

The upper-left panels in Figure 29 and 30 compare EPs obtained from the IR colors ($K_{2.2} - W3$) and the periods obtained from the WISE light curves. There are objects whose primary WISE period is similar to EP (GN-W1A or GN-W2A) or objects whose new secondary (or up to fourth) period is similar to EP (GN-W1B or GN-W2B). For the GW1-NB or
### Table 9
OAGB-IRAS Objects (16 Columns; 5908 Rows)*

| OI-N  | Subgroup | IRAS PSC | AKARI PSC | AKARI BSC | RA.° | Decl.° | BP° | ALLWISE | SP° | LRS° | A-Name° | A-Type° | A-Period° |
|-------|----------|----------|-----------|-----------|-------|--------|-----|---------|------|------|---------|---------|-----------|
| 1     | OI-SH    | 00007    | +5524     | 0003214   | 0.83958 | 55.68099 | akari-p | J000321.45 | M7e  | E    | Y Cas   | M        | 417       |
| 2     | OI-SH    | 00017    | +3949     | 0004200   | 1.08372 | 40.10991 | akari-p | J000420.08 | M5.5e | F    | SV And  | M        | 313       |
| 3     | OI-SH    | 00042    | +4248     | 0006526   | 1.71972 | 43.08394 | akari-p | J000652.77 | M10  | E    | KU And  | M        | 720       |
| 4     | OI-SH    | 00050-   | +3924     | 0007362-  | 1.90107 | −25.49451 | akari-p | J000736.26 | M6e  | E    | SY Sc   | M        | 411       |
| 5     | OI-SH    | 00060-   | +5232     | 0008373-  | 2.15578 | −39.21801 | akari-p | J000837.35 | M5.5e | F    | V Sc   | M        | 296.1     |
| 6     | OI-SH    | 00075    | +5435     | 0010092   | 2.5386  | 54.87602 | akari-p | J001009.14 | M6e  | F    | TT Sc   | M        | 396       |
| 7     | OI-SH    | 00127    | +5437     | 0015248   | 3.85362 | 54.90609 | akari-p | J001524.85 | M6-e | F    | S Sc   | M        | 367       |
| 8     | OI-SH    | 00128-   | +5421     | 0015218-  | 3.84295 | −32.04537 | akari-p | J001522.28 | M6-e | F    | S Sc   | M        | 367       |
| 9     | OI-SH    | 00138    | +6544     | 0016365   | 4.15224 | 66.01937 | akari-p | J001636.49 | NSV  | 15060 |         | M        | 330       |
| 10    | OI-SH    | 00170    | +6542     | 0019516   | 4.9637  | 65.99148 | akari-p | J001951.28 | (OH) | E    |        | M        |          |
| 11    | OI-SH    | 00176    | +6931     | 0020255   | 5.10634 | 69.79903 | akari-p | J002025.52 | F    | NSVS | J0020257 | M        | 425       |
| 12    | OI-SH    | 00193-   | +694756   | 0021474-  | 5.44763 | −40.28772 | akari-p | J002147.41 | M9   | E    | BE Phe | M        |          |
| 13    | OI-SH    | 00205    | +5530     | 0023314   | 5.80928 | 55.79243 | akari-p | J002341.29 | M7.5e | F    | T Cas   | M        | 440       |
| 14    | OI-SH    | 00207-   | +554732   | 0023077-  | 5.78216 | −61.67143 | akari-p | J002307.67 | S    | Tuc  | M        | 242.4    |
| 15    | OI-SH    | 00222    | +6251     | 0025101   | 6.29223 | 70.14756 | akari-p | J002510.03 | M6   | F    | NQ Cep  | M        | 454       |
| 16    | OI-SH    | 00245-   | +680851   | 0027064-  | 6.77682 | −6.60471 | akari-p | J002706.42 | M7   | E    | UY Cet  | M        | 440       |
| 17    | OI-SH    | 00309-   | +79042    | 0032404-  | 8.16842 | −79.67251 | akari-p | J003240.38 | W    | Hyi  | M        | 280      |
| 18    | OI-SH    | 00336    | +6744     | 0036365   | 9.1524  | 68.02211 | akari-p | J003636.61 | V0861 | Cas  | M        | 210      |
| 19    | OI-SH    | 00340    | +630800   | 0036594   | 9.24777 | 63.13344 | akari-p | J003659.43 | M6   | E    | TY Sc   | M        | 645       |
| 20    | OI-SH    | 00347    | +8004     | 0038228   | 9.59516 | 80.35698 | akari-p | J003822.82 | M5e  | F    | Y Cep   | M        | 332.57    |
| 21    | OI-SH    | 00381-   | +802125   | 0039391-  | 9.91314 | −80.03467 | akari-p | J003938.99 | E    | X Hiy  | M        | 304      |
| 22    | OI-SH    | 00420    | +7533     | 0045280   | 11.36989 | 75.83947 | akari-p | J004528.05 | E    | NSVS | J0045283 | M        | 599       |
| 23    | OI-SH    | 00428    | +755022   | 0045264   | 11.36989 | 75.83947 | akari-p | J004528.05 | E    | NSVS | J0045283 | M        | 599       |
| 24    | OI-SH    | 00445    | +6854     | 0047189   | 11.82894 | 32.68564 | akari-p | J004718.91 | S6/2   | e    | RW And  | M        | 430       |
| Object Number | Target Name | RA (J2000) | Decl (J2000) | Source Position | J2000 | LRS Type | Name from AAVSO | Period (Days) |
|---------------|-------------|------------|--------------|----------------|--------|----------|-----------------|--------------|
| 25            | OI-SH       | 00453      | +5317        | +533400        | 12.04174 | M8       | V0414 Cas      | 195          |
| 26            | OI-SH       | 00459      | +4614        | +463047        | 12.27877 | M8       | V0865 Cas      | 180          |
| 27            | OI-SH       | 00479      | +4708        | +472502        | 13.17824 | M8       | RV Cas         | 331.68       |
| 28            | OI-SH       | 00498      | +6445        | +650156        | 13.35421 | M8/9     | NSV 15193     | 507          |
| 30            | OI-SH       | 00534      | +6031        | +604710        | 14.11806 | M8       | V0867 Cas      | 412          |
| 5899          | OI-AM       | 20499      | +4657        | +470909        | 312.90288 | E        | ZTF J205136.64 | 457.359067   |
| 5900          | OI-AM       | 21112      | +3150        | +320326        | 326.5831  | E        | V0472 Cyg      | 297          |
| 5901          | OI-AM       | 21444      | +4752        | +480648        | 329.00362 | M7       | LP Cyg         | 419          |
| 5902          | OI-AM       | 21543      | +5605        | +561927        | 329.00362 | M9       | V0720 Cep      | 305          |
| 5903          | OI-AM       | 22000      | +5643        | +565810        | 330.44911 | M7       | YY Cep         | 526.08       |
| 5904          | OI-AM       | 22049      | +4813        | +482755        | 331.71531 | M7       | AP Lac         | 524          |
| 5905          | OI-AM       | 22124      | +7315        | +732958        | 333.34096 | M7       | NSVS J2213225  | 429          |
| 5906          | OI-AM       | 22450      | +5829        | +584513        | 341.7659  | M7-8     | Mis V1170      | 730          |
| 5907          | OI-AM       | 23548      | +6539        | +652304        | 359.5966  | M5e      | R Tuc          | 286.06       |
| 5908          | OI-AM       | 23561      | +6037        | +605342        | 359.65948 | E        | EU Cas         | 447          |

Notes:
- Only 14 columns are shown in this example table. In the data file, there are two more columns: OH and SiO maser detection (see Section 5.2).
- The OAGB-IRAS identifier (see Table 1).
- The best position (R.A. and decl. J2000).
- The source of the best position (AKARI PSC, AKARI BSC, or IRAS PSC; see Section 2.2).
- The spectral type from Kwok et al. (1997).
- The IRAS LRS type from Kwok et al. (1997).
- The object name from AAVSO.
- The variable type from AAVSO.
- The period from AAVSO.

(This table is available in its entirety in machine-readable form.)
| CI-N° | Subgroup | IRAS PSC | AKARI PSC | AKARI BSC | R.A. | Decl. | BP | ALLWISE | SP | LRS | A-Name | A-Type | A-Period |
|-------|----------|----------|-----------|-----------|------|------|----|---------|----|-----|--------|--------|---------|
| 1     | CI-SH    | 00020    | 000364    | 000131    | 1.15175 | 43.55133 | akari-p | J000436.41 | C6.4 | S    | SU And | LC     |          |
| 2     | CI-SH    | 000367   | 0006142   | 0006131   | 1.59594 | 70.06723 | akari-p | J000614.21 | C   | C    | OR Cep | M      | 355.32  |
| 3     | CI-SH    | 00050    | 00073432  | 0007409   | 1.93001 | 74.23647 | akari-p | J00743.08 | C   | NSVS J0007434 | L   | 476    |
| 4     | CI-SH    | 00084-1851 | 00104359-183422 | 2.74137 | -18.57287 | akari-p | J010579.93-183422.7 | C4.5J | C | VX And | SRA    | 375     |
| 5     | CI-SH    | 00172    | 0019540   | 0019539   | 4.97506 | 44.70953 | akari-p | J001954.00 | C   | C    |                  |        |          |
| 6     | CI-SH    | 00210    | 0023508   | 0023507   | 5.96206 | 62.6364 | akari-p | J002350.87 | (CO) | U    |                  |        |          |
| 7     | CI-SH    | 00247    | 0027411   | 0027405   | 6.92134 | 69.64762 | akari-p | J002741.04 | (SiC) | C | V0668 Cas | M      | 650     |
| 8     | CI-SH    | 00248    | 0027316   | 0027315   | 6.88205 | 35.58736 | akari-p | J002731.69 | C5.4 | C | AQ And | SRA    | 169     |
| 9     | CI-SH    | 00422    | 0045070   | 0045069   | 11.27958 | 53.44656 | akari-p | J004507.07 | (SiC) | C | V0720 Cas | M      | 431     |
| 10    | CI-SH    | 00523    | 005340    | 005329    | 13.89167 | 68.48174 | akari-p | J005335.93 | C6.4 | C |                  |        | 377     |
| 11    | CI-SH    | 00535    | 0056330   | 0056329   | 14.13752 | 59.66235 | akari-p | J005633.03 | C   | C    | V0721 Cas | M      |          |
| 12    | CI-SH    | 00596    | 0102436   | 0102448   | 15.68168 | 61.8618 | akari-p | J010243.58 | C4.3 | S | HO Cas | LB     |          |
| 13    | CI-SH    | 01022    | 0105272   | 0101335   | 16.36364 | 65.98334 | akari-p | J010527.41 | M7   | C | V0888 Cas | M      | 341     |
| 14    | CI-SH    | 01080    | 011035    | 011035    | 17.76461 | 53.77274 | akari-p | J011034.46 | C4.3e | C | HV Cas | M      | 527     |
| 15    | CI-SH    | 01135    | 0113444   | 0113450   | 18.4352 | 62.96007 | akari-p | J011344.54 | C6.3e | C | NSV 438 | M      | 280     |
| 16    | CI-SH    | 01133    | 0116050   | 0116047   | 19.02099 | 25.75919 | akari-p | J011605.03 | C7.2 | F | Z Psc | SRB    | 155.8   |
| 17    | CI-SH    | 01142    | 0117335   | 0117337   | 19.38993 | 63.36806 | akari-p | J011733.56 | (SiC) | C |                  |        |          |
| 18    | CI-SH    | 01144    | 0117515   | 0117507   | 19.4674 | 67.23136 | akari-p | J011751.34 | (HCN) | U | V0829 Cas | M      | 1060    |
| 19    | CI-SH    | 01156    | 0118539   | 0118534   | 19.7246 | 68.82949 | akari-p | J011853.84 | C   | C | NSVS J0118537 | L   | 279     |
| 20    | CI-SH    | 01215    | 0124580   | 0124583   | 21.24174 | 64.77053 | akari-p | J012458.25 | C   | C | NSVS 1695145 | M      | 258     |
| 21    | CI-SH    | 01246-3248 | 0126580-323235 | 21.74177 | -32.54324 | akari-p | J012658.05-323236.0 | C6.4 | C | R ScI | SRB    | 370     |
| 22    | CI-SH    | 01324    | 0135288   | 0135287   | 23.87005 | 49.37836 | akari-p | J013528.78 | (SiC) | C | Dauban V257 | VAR   |          |
| 23    | CI-SH    | 01327    | 0136165   | 0136159   | 24.06899 | 65.3109 | akari-p | J013616.59 | C   | C | MGAB-V1402 | M      |          |
| 24    | CI-SH    | 01348    | 0138056   | 0138056   | 24.52342 | 55.97078 | akari-p | J013805.62 | PT Cas | M |                  |        | 300     |
| CI-N | Subgroup | IRAS PSC | AKARI PSC | AKARI BSC | R.A. | Decl. | BP | ALLWISE | SP | LRS | A-Name | A-Type | A-Period |
|------|----------|----------|-----------|-----------|------|-------|----|----------|----|------|--------|--------|----------|
| 25   | CI-SH    | 01411    | 0145087   | 0145087   | 26.28656 | 71.32098 | akari-p | J014508.73 | C   | F    | NSVS    | J0145096 | L        | 730    |
|      |          | +7104    | +711915   |           |       |       |    |          |    |      |         |        |          |        |
| 26   | CI-SH    | 01443    | 0147555   | 0147555   | 26.98151 | 64.54869 | akari-p | J014755.72 | C   | C    | NSVS    | J0147560 | L        | 476    |
|      |          | +6417    | +643255   | +643256   |       |       |    |          |    |      |         |        |          |        |
| 27   | CI-SH    | 01531    | 0156381   | 0156381   | 29.15886 | 59.25942 | akari-p | J015638.14 | C5,4e| C    | X Cas   | M        | 415      |        |
|      |          | +5900    | +591533   | +591528   |       |       |    |          |    |      |         |        |          |        |
| 28   | CI-SH    | 01551    | 0158294   | 0158294   | 29.62284 | 55.21626 | akari-p | J015829.47 | Ce  | F    | V0437   | M        | 470      |        |
|      |          | +5458    | +551258   | +551303   |       |       |    |          |    |      |         |        |          |        |
| 29   | CI-SH    | 01580    | 015803    | 015803    | 30.36713 | 58.30403 | akari-p | J020128.16 | Ce  | C    | V0666   | M        | 432.1    |        |
|      |          | +5803    | +581814   |           |       |       |    |          |    |      |         |        |          |        |
| 30   | CI-SH    | 02152    | 0218061   | 0218062   | 34.52542 | 28.61286 | akari-p | J021806.05 | (CO) | C    | YY Tri  | M        | 624      |        |
|      |          | +2822    | +283646   | +283645   |       |       |    |          |    |      |         |        |          |        |
| 3587 | CI-GC    | 23573    | 2359542   | 2359542   | 359.97602 | 56.97963 | akari-p | J235954.25 |     |      | V0533   | Cas      | SRA      | 305    |
|      |          | +2358    | +236046   |           |       |       |    |          |    |      |         |        |          |        |
| 3588 | CI-OG    | 17398-2146 | 1742510-214729 | 1742510-214729 | 265.71265 | −21.79161 | akari-p | J174250.99-214728 |     |      | OGLE-BLG-LPV-020858 | M | 469.6 |
|      |          | 17468-320 | 1750084-32118 |           |       |       |    |          |    |      |         |        |          |        |
| 3589 | CI-OG    | 17490-3414 | 1752190-341509 |           |       |       |    |          |    |      |         |        |          |        |
| 3590 | CI-OG    | 17514-3354 | 1758219-2814 | 268.682037 | −33.91691 | iras | J175443.43-335507.5 | (PN) | I    | OGLE-BLG-LPV-114752 | M | 448   |
| 3591 | CI-OG    | 17552-2814 | 1758219-2814 | 269.59127 | −28.28434 | akari-p | J175821.90-281452.7 | ZAND+M | 416.2 |
| 3592 | CI-OG    | 17570-3056 | 1800175-3056 | 270.07295 | −30.93992 | akari-p | J180017.57-305624.1 | OGLE-BLG-LPV-149402 | M | 449.7 |
| 3593 | CI-OG    | 18031-3229 | 1806270-3229 | 271.61265 | −32.48727 | akari-p | J180627.05-322913.8 | OGLE-BLG-LPV-169921 | M | 516.9 |
| 3594 | CI-OG    | 18039-3411 | 1807152-3411 | 271.81348 | −34.19048 | akari-p | J180715.23-341125.1 | OGLE-BLG-LPV-209822 | M | 378.8 |
| 3595 | CI-OG    | 18204-2133 | 1823282-2133 | 275.86784 | −21.52491 | akari-p | J182328.27-213130.6 | OGLE-BLG-LPV-212597 | M | 513.8 |
| 3596 | CI-OG    | 18204-2133 | 1823282-2133 | 275.86784 | −21.52491 | akari-p | J182328.27-213130.6 | OGLE-BLG-LPV-231922 | M | 513.8 |

**Notes.**

- a The CAGB-IRAS identifier (see Table 1).
- b The best position (R.A. and decl. J2000).
- c The source of the best position (AKARI PSC, AKARI BSC, or IRAS PSC; see Section 2.2).
- d The spectral type from Kwok et al. (1997).
- e The IRAS LRS type from Kwok et al. (1997).
- f The object name from AAVSO.
- g The variable type from AAVSO.
- h The period from AAVSO.

(This table is available in its entirety in machine-readable form.)

Sub
| OW-N° | Subgroup | Recno/Star | ALLWISE          | W-R.A. | W-Dec. | 2MASS   | AKARI PSC | MSX    | A-Name | A-Type | A-Period |
|------|---------|-----------|------------------|--------|--------|---------|-----------|--------|--------|--------|-----------|
| 1    | OW-ME  | 1         | J173140.97-320355.7 | 262.9207368 | -32.0654792 | 1731409-3203559 | 1731409-320355 | +0.8670 |        |        |           |
| 2    | OW-ME  | 3         | J173707.28-312131.2 | 264.2803606 | -31.3586915 | 1737072-3121312 | 1737072-312131 | +0.2780 |        |        |           |
| 3    | OW-ME  | 4         | J173729.36-311716.8 | 264.3723546 | -31.2880029 | 1737293-3117166 | 1737292-311717 | +0.2497 |        |        |           |
| 4    | OW-ME  | 6         | J173813.13-293941.4 | 264.5547352 | -29.6615113 | 1738124-2939385 | 1738125-293938 | +0.9902 |        |        |           |
| 5    | OW-ME  | 7         | J173817.04-294231.9 | 264.5710302 | -29.7088827 | 1738170-2942324 | 1738170-294231 | +0.9505 |        |        |           |
| 6    | OW-ME  | 9         | J173832.49-312042.5 | 264.6359444 | -31.3451427 | 1738325-3120427 | 1738324-312043 | +0.0294 |        |        |           |
| 7    | OW-ME  | 12        | J174057.23-294531.4 | 265.238484 | -29.7587303 | 1740572-2945314 | 1740571-294532 | +0.4335 |        |        |           |
| 8    | OW-ME  | 16        | J174136.83-292930.9 | 265.4034951 | -29.4919261 | 1741368-2929309 | 1741368-292930 | +0.4525 |        |        |           |
| 9    | OW-ME  | 17        | J174137.39-293205.7 | 265.4058107 | -29.5349427 | 1741374-2932057 | 1741374-293205 | +0.4283 |        |        |           |
| 10   | OW-ME  | 18        | J174204.33-295846.1 | 265.5180671 | -29.9794094 | 1742043-2958463 | 1742042-295846 | +0.1100 |        |        |           |
| 11   | OW-ME  | 19        | J174206.85-281832.4 | 265.5285433 | -28.3090071 | 1742068-2818323 | 1742068-281831 | +0.9838 |        |        |           |
| 12   | OW-ME  | 20        | J174223.29-293935.3 | 265.5970442 | -29.6598205 | 1742232-2939355 | 1742232-293936 | +0.2210 |        |        |           |
| 13   | OW-ME  | 21        | J174232.89-294126.9 | 265.6370525 | -29.6905646 | 1742329-2941251 | 1742325-294112 | +0.1783 |        |        |           |
| 14   | OW-ME  | 22        | J174232.47-294110.6 | 265.6352975 | -29.6862809 | 1742324-2941107 | 1742325-294112 | +0.1783 |        |        |           |
| 15   | OW-ME  | 24        | J174309.81-292403.1 | 265.7900368 | -29.4008852 | 1743098-2924033 | 1743097-292403 | +0.2140 |        |        |           |
| 16   | OW-ME  | 25        | J174323.47-285350.1 | 265.8477983 | -28.8972522 | 1743234-2853503 | 1743234-285349 | +0.4361 |        |        |           |
| 17   | OW-ME  | 26        | J174325.25-294528.6 | 265.8552409 | -29.7579569 | 1743252-2945285 | 1743251-294529 | G359.0484-00.0212 |        |        |        |           |
| 18   | OW-ME  | 27        | J174332.70-291539.2 | 265.8662747 | -29.2608935 | 1743327-2915393 | 1743326-291539 | G359.4858 |        |        |        |           |
| 19   | OW-ME  | 28        | J174333.12-295133.1 | 265.8880322 | -29.8592045 | 1743332-2951331 | 1743330-295134 | G358.9772-00.0984 |        |        |        |           |
| 20   | OW-ME  | 29        | J174334.83-294029.2 | 265.8951536 | -29.6747897 | 1743347-2940304 | 1743346-294031 | G359.1369-00.067 |        |        |        |           |
| 21   | OW-ME  | 30        | J174335.12-292447.3 | 265.896337 | -29.4131541 | 1743351-2924472 | 1743351-292447 | +0.1297 |        |        |           |
| 22   | OW-ME  | 32        | J174341.73-290118.9 | 265.9239097 | -29.0219439 | 1743417-2901190 | 1743417-290118 | G359.7068 |        |        |        |           |
| 23   | OW-ME  | 33        | J174349.53-290319.9 | 265.9564094 | -29.0555301 | 1743495-2903194 | 1743495-290319 | +0.3140 |        |        |           |
| 24   | OW-ME  | 34        | J174349.98-290121.4 | 265.9582628 | -29.0226238 | 1743497-2901213 | 1743497-290121 | +0.2721 |        |        |           |
| OW-N  | Subgroup | Recno/Star | ALLWISE | W-R.A. | W-Decl. | 2MASS | AKARI PSC | MSX | A-Name | A-Type | A-Period |
|-------|----------|------------|---------|--------|---------|-------|-----------|-----|--------|--------|----------|
| 25    | OW-ME    | 35 J174351.10-290028.8 | 265.9629185 | −29.0080118 | 17435106-2900292 | G359.7368 | +0.2924 |
| 26    | OW-ME    | 36 J174354.00-284128.5 | 265.975037 | −28.6912772 | 17435399-284128 | G000.0118 | +0.4492 |
| 27    | OW-ME    | 37 J174355.30-285649.9 | 265.9804646 | −29.0080118 | 17435531-285649 | G359.7064 | +0.3112 |
| 28    | OW-ME    | 38 J174357.27-293146.6 | 265.988648 | −29.5296325 | 17435729-293146 | G359.3035-00.0007 | |
| 29    | OW-ME    | 39 J174358.02-293052.2 | 265.99179 | −29.5145069 | 17435804-293052 | G359.3182 | +0.0059 |
| 30    | OW-ME    | 40 J174359.29-291951.5 | 265.997061 | −29.3309929 | 17435926-291951 | G359.4766 | +0.0982 |
| 5292  | OW-OG    | 232164 J182407.05-212750.1 | 276.0294118 | −21.4639172 | 18240706-212750 | G010.7840-03.9197 | OGLE-BLG-LPV-232164 | M | 305.1 |
| 5293  | OW-OG    | 232216 J182415.74-214049.6 | 276.0656208 | −21.6804648 | 18241570-214049 | G010.6070-04.0495 | OGLE-BLG-LPV-232216 | M | 325.8 |
| 5294  | OW-OG    | 232256 J182421.96-212222.4 | 276.0915081 | −21.372902 | 18242197-212222 | G010.8916-03.9294 | OGLE-BLG-LPV-232256 | M | 306.8 |
| 5295  | OW-OG    | 232307 J182431.29-220041.6 | 276.1304043 | −22.0115722 | 18243129-220041 | G010.3404-04.2554 | OGLE-BLG-LPV-232307 | M | 339.4 |
| 5296  | OW-OG    | 232329 J182438.95-252439.4 | 276.2456492 | −25.4109592 | 18245895-252439 | G010.2926-03.9197 | OGLE-BLG-LPV-232329 | M | 229.2 |
| 5297  | OW-OG    | 232339 J182508.99-253350.7 | 276.2874842 | −25.5641061 | 18250899-253350 | G010.7840-03.9197 | OGLE-BLG-LPV-232339 | M | 197.57 |
| 5298  | OW-OG    | 232340 J182510.62-255542.0 | 276.2924638 | −25.9283545 | 18251062-255542 | G010.7840-03.9197 | OGLE-BLG-LPV-232340 | M | 263.2 |
| 5299  | OW-OG    | 232350 J182547.17-251527.2 | 276.4465735 | −25.2575831 | 18254717-251527 | G010.7840-03.9197 | OGLE-BLG-LPV-232350 | M | 298.8 |
| 5300  | OW-OG    | 232364 J182640.02-251436.3 | 276.666693 | −25.2434178 | 18264001-251436 | G010.7840-03.9197 | OGLE-BLG-LPV-232364 | M | 199.55 |
| 5301  | OW-OG    | 232397 J183121.84-242406.1 | 277.8410132 | −24.4017158 | 18312183-242406 | G010.7840-03.9197 | OGLE-BLG-LPV-232397 | M | 303.8 |

**Notes.**

a The OAGB-WISE identifier (see Table 2).

b The ALLWISE source position (R.A. and decl. J2000). See Section 9.

(This table is available in its entirety in machine-readable form.)
| CW-N° | Subgroup | Recno/Star | ALLWISE | W-R.A. | W-Decl. | 2MASS | AKARI PSC | MSX | A-Name | A-Type | A-Period |
|-------|----------|------------|---------|--------|---------|-------|-----------|------|--------|--------|----------|
| 1     | CW-GC    | J000010.87 | 0.0453247 | 64.4318379 | 0001089 | +642554.6 | 00005295 | G117.668 | ZTF J00126.9 | SR | 253.5952999 |
| 2     | CW-GC    | J000012.89 | 0.2207225 | 56.9687165 | 0001089 | +658070.3 | 00005295 |       |       |        |          |
| 3     | CW-GC    | J000019.91 | 0.3742141 | 64.9188449 | 0001298 | +658070.8 | 00005295 |       |       |        |          |
| 4     | CW-GC    | J000023.10 | 0.5129277 | 62.983188  | 0001298 | +625859.4 | 00005295 |       |       |        |          |
| 5     | CW-GC    | J000027.99 | 0.5333304 | 62.983188  | 0001298 | +625859.4 | 00005295 |       |       |        |          |
| 6     | CW-GC    | J000032.06 | 0.5961116 | 56.0422064 | 0001298 | +560231.9 | 00005295 |       |       |        |          |
| 7     | CW-GC    | J000036.86 | 0.7536194 | 30.6398393 | 0001298 | +471232.4 | 00005295 |       |       |        |          |
| 8     | CW-GC    | J000041.96 | 0.8419097 | 8.7978933  | 0001298 | +471232.4 | 00005295 |       |       |        |          |
| 9     | CW-GC    | J000044.48 | 1.3541477 | 1.167398   | 0001298 | +110030.3 | 00005295 |       |       |        |          |
| 10    | CW-GC    | J000054.44 | 1.4353489 | 65.515888  | 0001298 | +650357.1 | 00005295 |       |       |        |          |
| 11    | CW-GC    | J000054.56 | 1.4380045 | 59.4966744 | 0001298 | +592948.0 | 00005295 |       |       |        |          |
| 12    | CW-GC    | J000057.12 | 2.299015  | 65.0239937 | 0001298 | +590128.3 | 00005295 |       |       |        |          |
| 13    | CW-GC    | J000060.46 | 2.7894529 | 64.4904191 | 0001298 | +62925.5  | 00005295 |       |       |        |          |
| 14    | CW-GC    | J000063.45 | 2.897721  | 63.3085687 | 0001298 | +631830.8 | 00005295 |       |       |        |          |
| 15    | CW-GC    | J000066.70 | 3.0195937 | 61.5471352 | 0001298 | +63249.6  | 00005295 |       |       |        |          |
| 16    | CW-GC    | J000070.30 | 3.292478  | 59.6097837 | 0001298 | +593635.2 | 00005295 |       |       |        |          |
| 17    | CW-GC    | J000074.63 | 3.3193147 | 63.0334166 | 0001298 | +630200.3 | 00005295 |       |       |        |          |
| 18    | CW-GC    | J000078.37 | 3.3423166 | 0.30.6792219 | 0001298 | +630200.3 | 00005295 |       |       |        |          |
| 19    | CW-GC    | J000082.40 | 3.4433605 | 68.2917322 | 0001298 | +681730.2 | 00005295 |       |       |        |          |
| 20    | CW-GC    | J000086.91 | 3.629571  | 60.9252917 | 0001298 | +605531.0 | 00005295 |       |       |        |          |
| 21    | CW-GC    | J000091.44 | 3.6857147 | 57.8035551 | 0001298 | +574812.7 | 00005295 |       |       |        |          |
| 22    | CW-GC    | J000106.26 | 3.7567599 | 60.1390482 | 0001298 | +600821.8 | 00005295 |       |       |        |          |
| 23    | CW-GC    | J000110.66 | 3.9736087 | 60.8912972 | 0001298 | +605328.6 | 00005295 |       |       |        |          |

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Table 12
CAGB-WISE Objects (12 Columns; 3576 Rows)
Table 12 (Continued)

| CW-N | Subgroup | Recno/Star | ALLWISE | W-R.A. | W-Decl. | 2MASS | AKARI PSC | MSX | A-Name | A-Type | A-Period |
|------|----------|------------|---------|--------|---------|-------|-----------|------|--------|--------|----------|
| 25   | CW-GC    | 50         | J001718.41 | 4.3267474 | 10.8675438 | 00171842 | +105203.1 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 26   | CW-GC    | 52         | J001751.22 | 4.4634252 | 63.0683664 | 00175122 | +630406.1 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 27   | CW-GC    | 53         | J001814.60 | 4.5608417 | 59.762053  | 00181456 | +594601.9 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 28   | CW-GC    | 57         | J002006.57 | 5.027391  | 61.9887875 | 00200656 | +615919.6 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 29   | CW-GC    | 58         | J002021.60 | 5.0900124 | 1.201865  | 00202160 | +011206.7 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 30   | CW-GC    | 60         | J002135.74 | 5.3947506 | 59.246851  | 00213583 | +591448.6 |       |        |        |          |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3567 | CW-OG    | 224006     | J181108.13-261611.8 | 272.7839129 | −26.2699694 | 18110815-2616119 |       | G005.1362-03.5662 | OGLE-BLG-LPV-224006 | M | 222.7 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3568 | CW-OG    | 224160     | J181113.68-251656.4 | 272.8070377 | −25.28234  | 18111369-2516563 |       | G006.0256-03.1142 | OGLE-BLG-LPV-224160 | M | 111.86 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3569 | CW-OG    | 226511     | J181316.97-253135.1 | 273.3207119 | −25.5264335 | 18131697-2531351 |       | 1813169-253136 | G006.0216-03.6336 | OGLE-BLG-LPV-226511 | RCB: |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3570 | CW-OG    | 226979     | J181346.26-253415.6 | 273.4427696 | −25.5710236 | 18134625-2534156 |       | 1813463-253416 | OGLE-BLG-LPV-226979 | M | 231.9 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3571 | CW-OG    | 227901     | J181447.50-282438.8 | 273.6979355 | −28.4107823 | 18144749-282438 |       | 1814474-282438 | OGLE-BLG-LPV-227901 | M | 359.7 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3572 | CW-OG    | 228903     | J181602.35-240937.0 | 274.0098284 | −24.1603045 | 18160237-240937 |       | 1816023-240936 | OGLE-BLG-LPV-228903 | M | 293.6 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3573 | CW-OG    | 230266     | J181744.12-252836.3 | 274.433864 | −25.4767681 | 18174413-2528361 |       | 1817441-252837 | OGLE-BLG-LPV-230266 | M | 501.2 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3574 | CW-OG    | 230608     | J181944.05-222311.2 | 274.9335824 | −22.3864556 | 18194444-2223039 |       | 1819443-222304 | OGLE-BLG-LPV-230608 | M | 366.9 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3575 | CW-OG    | 231818     | J182313.69-252653.8 | 275.8070795 | −25.4482779 | 18231371-2526540 |       | 1823137-252654 | OGLE-BLG-LPV-231818 | M | 355.8 |
|      |          |            |         |        |         |       |           |      |        |        |          |
| 3576 | CW-OG    | 231979     | J182335.93-262852.2 | 275.8997362 | −26.4811782 | 18233594-2628521 |       | 1823359-262852 | OGLE-BLG-LPV-231979 | M | 263.1 |

Notes.

a The CAGB-WISE identifier (see Table 2).
b The ALLWISE source position (R.A. and decl. J2000). See Section 9.
(This table is available in its entirety in machine-readable form.)
Table 13
OAGB-IRAS Objects with Variation Parameters Obtained from WISE Light Curves$^a$ (24 Columns; 885 Rows)

| OI-N | A-Type | A-Period | EP | G-W1(P) | G-W1(A) | G-W1(R$^2$) | GM-W1(P) | GM-W1(A) | GM-W1(R$^2$) | GN-W1(P) | GN-W1(A) | GN-W1(R$^2$) | G-W2(P) | G-W2(A) | G-W2(R$^2$) |
|------|--------|----------|----|---------|---------|------------|---------|---------|------------|---------|---------|------------|---------|---------|------------|
| 181  | L      | 880.56   | 532.78 | 0.816  | 0.731   | 532.78     | 0.816   | 0.731   | 532.78     | 0.816   | 0.731   | 532.78     | 0.816   | 0.731   |
| 183  | 80.56  | 70.48    | 59.55 | 0.829  | 0.677   | 88.53      | 0.837   | 0.615   | 125.44     | 0.839   | 0.700   |
| 264  | 316.24 | 1576.20  | 207.57 | 1.315  | 0.764   | 1464.18    | 1.302   | 0.779   | 130.5      | 1.023   | 0.643   |
| 295  | 338.01 | 132.85   | 543.11 | 1.213  | 0.808   | 136.26     | 1.199   | 0.771   | 550.95     | 1.318   | 0.627   |
| 323  | L      | 58.82    | 865.06 | 1.214  | 0.687   | 199.64     | 1.193   | 0.628   | 467.42     | 1.404   | 0.660   |
| 323  | VAR    | 428.80   | 467.42 | 1.123  | 0.766   | 467.42     | 1.123   | 0.766   | 467.42     | 1.404   | 0.660   |
| 555  | M      | 341.11   | 185.25 | 0.073  | 0.624   | 185.25     | 0.073   | 0.624   | 185.25     | 0.073   | 0.624   |
| 566  | 554.24 | 781.39   | 781.39 | 1.213  | 0.775   | 781.39     | 1.213   | 0.775   | 781.39     | 1.213   | 0.775   |
| 666  | 452.11 | 570.87   | 570.87 | 0.896  | 0.620   | 570.87     | 0.896   | 0.620   | 570.87     | 0.896   | 0.620   |
| 704  | VAR    | 664.36   | 1420.69| 1.050  | 0.632   | 208.97     | 1.084   | 0.622   | 208.97     | 1.084   | 0.622   |
| 709  | 359.41 | 234.67   | 234.67 | 1.257  | 0.726   | 234.67     | 1.257   | 0.726   | 234.67     | 1.257   | 0.726   |
| 713  | 952.69 | 835.88   | 835.88 | 1.361  | 0.736   | 835.88     | 1.361   | 0.736   | 962.30     | 0.946   | 0.800   |
| 737  | 125.16 | 282.57   | 419.00 | 878.19 | 1.498  | 229.32     | 1.414   | 0.565   | 229.32     | 1.414   | 0.565   |
| 802  | 683.28 | 1151.96  | 1151.96| 0.883  | 0.745   | 683.28     | 0.883   | 0.745   | 683.28     | 0.883   | 0.745   |
| 803  | 282.57 | 362.9    | 362.9  | 0.529  | 0.754   | 362.9      | 0.529   | 0.754   | 362.9      | 0.529   | 0.754   |
| 819  | 821.49 | 821.49   | 821.49 | 1.427  | 0.692   | 821.49     | 1.427   | 0.692   | 821.49     | 1.427   | 0.692   |
| 821  | VAR    | 263.99   | 1793.77 | 2290.05| 1.148  | 2290.05    | 1.148   | 0.845   | 2290.05    | 1.148   | 0.845   |
| 827  | VAR    | 455.15   | 716.64 | 0.935  | 0.611   | 243.98     | 0.788   | 0.615   | 243.98     | 0.788   | 0.615   |
| 835  | 436.78 | 546.37   | 546.37 | 1.035  | 0.694   | 546.37     | 1.035   | 0.694   | 546.37     | 1.035   | 0.694   |
| 5699 | M      | 301.3    | 398.82 | 8247036| 79.49   | 99.91      | 124.54   | 0.842   | 0.641      | 124.54   | 0.842   | 0.641      |

Notes.
$^a$ Only 16 columns are shown in this example table. In the data file, there are eight more columns: GM-W2(P), GM-W2(A), GM-W2(R$^2$), GN-W2(P), GN-W2(A), GN-W2(R$^2$), Subgroup, and IRAS PSC.
$^b$ The OAGB-IRAS identifier (see Tables 1 and 9). See Section 9.
(This table is available in its entirety in machine-readable form.)
Table 14
CAGB-IRAS Objects with Variation Parameters Obtained from WISE Light Curves\(^a\) (24 Columns; 141 Rows)

| CI-N\(^b\) | A-Type | A-Period | EP | G-W1(P) | G-W1(A) | G-W1(R\(^2\)) | GM-W1(P) | GM-W1(A) | GM-W1(R\(^2\)) | GN-W1(P) | GN-W1(A) | GN-W1(R\(^2\)) | G-W2(P) | G-W2(A) | G-W2(R\(^2\)) |
|---------|--------|----------|----|---------|---------|--------------|----------|----------|--------------|----------|----------|--------------|--------|--------|--------------|
| 6       | M      | 1060     |    | 1062.66 | 1.315   | 0.935        |          |          |              |          |          |              |        |        |              |
| 34      | M      |          |    | 798.05  | 1.243   | 0.796        |          |          |              |          |          |              |        |        |              |
| 35      |        |          |    | 1224.47 | 882.29  | 1.137        | 0.780    |          |              |          |          |              |        |        |              |
| 58      |        |          |    | 713.21  | 791.47  | 1.028        | 0.606    |          |              |          |          |              |        |        |              |
| 90      | EW     | 0.5546584|    | 626.50  | 147.96  | 0.753        | 0.702    |          |              |          |          |              |        |        |              |
| 91      |        |          |    | 362.81  | 628.79  | 0.749        | 0.716    |          |              |          |          |              |        |        |              |
| 106     | M      |          |    | 137.15  | 51.55   | 0.760        | 0.698    |          |              |          |          |              |        |        |              |
| 111     |        |          |    | 339.67  | 620.59  | 0.828        | 0.764    |          |              |          |          |              |        |        |              |
| 120     | SR     | 89.133574|    | 563.64  | 815.10  | 1.004        | 0.663    |          |              |          |          |              |        |        |              |
| 192     |        |          |    | 2199.82 | 898.91  | 0.855        | 0.696    |          |              |          |          |              |        |        |              |
| 210     |        |          |    | 978.01  | 839.98  | 1.115        | 0.872    |          |              |          |          |              |        |        |              |
| 230     |        |          |    | 706.87  | 485.67  | 1.007        | 0.833    |          |              |          |          |              |        |        |              |
| 233     | M      | 455.343749|   | 419.91  | 419.91  | 0.907        | 0.670    | 419.91   | 0.907       | 0.670    |          |              |        |        |              |
| 246     |        |          |    | 397.66  | 529.24  | 0.886        | 0.670    |          |              |          |          |              |        |        |              |
| 251     |        |          |    | 837.44  | 837.44  | 1.135        | 0.895    |          |              |          |          |              |        |        |              |
| 277     | SR     | 339.902532|  | 232.80  | 428.51  | 0.703        | 0.704    |          |              |          |          |              |        |        |              |
| 280     | ELL    | 1.083    |    | 696.54  | 855.04  | 1.049        | 0.818    |          |              |          |          |              |        |        |              |
|         | ROT    |          |    |         |         |             |          |          |              |          |          |              |        |        |              |
| 283     |        |          |    | 257.89  | 392.57  | 0.458        | 0.605    |          |              |          |          |              |        |        |              |
| 292     | M      | 443.003349|   | 179.95  | 209.46  | 0.659        | 0.620    | 255.25   | 0.600       | 0.220    |          |              |        |        |              |
| 313     |        |          |    | 595.25  | 641.20  | 0.976        | 0.883    |          |              |          |          |              |        |        |              |
| 317     |        |          |    | 290.27  | 528.43  | 0.820        | 0.694    |          |              |          |          |              |        |        |              |
| 338     |        |          |    | 325.23  | 519.87  | 0.644        | 0.740    |          |              |          |          |              |        |        |              |
| 348     | VAR    |          |    | 379.01  | 597.37  | 0.908        | 0.704    |          |              |          |          |              |        |        |              |
| 373     |        |          |    | 352.36  | 634.81  | 0.654        | 0.684    |          |              |          |          |              |        |        |              |
| 380     | EW     | 0.3634808|   | 765.67  | 689.44  | 1.288        | 0.867    |          |              |          |          |              |        |        |              |
| 396     |        |          |    | 135.96  | 87.41   | 1.707        | 0.641    |          |              |          |          |              |        |        |              |
| 406     |        |          |    | 292.60  | 577.60  | 0.668        | 0.605    |          |              |          |          |              |        |        |              |
| 407     |        |          |    | 380.11  | 104.06  | 1.378        | 0.644    |          |              |          |          |              |        |        |              |
| 2984    | SR     | 490      |    | 147.59  | 60.80   | 0.703        | 0.625    |          |              |          |          |              |        |        |              |
| 3052    | SRB    | 175.4    |    |         |         |             |          |          |              |          |          |              |        |        |              |
| 3089    | SR     | 858      |    | 128.80  | 175.93  | 0.641        | 0.650    |          |              |          |          |              |        |        |              |
| 3110    | SR     | 214.4446898| | 110.82  | 176.23  | 0.705        | 0.630    |          |              |          |          |              |        |        |              |
| 3157    |        |          |    | 129.65  |         |             |          |          |              |          |          |              |        |        |              |
| 3203    | SR     | 342      |    | 145.61  | 368.30  | 1.138        | 0.617    |          |              |          |          |              |        |        |              |
| 3267    | SR     | 130.58   |    | 86.95   | 185.12  | 0.943        | 0.659    |          |              |          |          |              |        |        |              |
| 3324    | SR     | 173.7469153| | 83.53  | 180.17  | 1.599        | 0.677    |          |              |          |          |              |        |        |              |
| 3410    | RCB    | 37.5     |    | 226.32  | 194.33  | 0.859        | 0.778    |          |              |          |          |              |        |        |              |
| 3590    | M      | 555.8    |    |         |         |             |          |          |              |          |          |              |        |        |              |

Notes.
\(^a\) Only 16 columns are shown in this example table. In the data file, there are eight more columns: GM-W2(P), GM-W2(A), GM-W2(R\(^2\)), GN-W2(P), GN-W2(A), GN-W2(R\(^2\)), Subgroup, and IRAS PSC.
\(^b\) The CAGB-IRAS identifier (see Tables 1 and 10). See Section 9.

(This table is available in its entirety in machine-readable form.)
| OW-N | Subgroup | A-Type | A-Period | G-W1(P) | G-W1(A) | G-W1(R) | GM-W1(P) | GM-W1(A) | GM-W1(R) | G-W2(P) | G-W2(A) | G-W2(R) | GM-W2(P) | GM-W2(A) | GM-W2(R) |
|------|----------|--------|----------|---------|---------|---------|----------|----------|----------|---------|---------|---------|----------|----------|----------|
| 21   | OW-ME    | O      | 597.79   | 0.605   | 0.707   |         |          |          |          |         |         |         |          |          |          |
| 30   | OW-ME    | M      | 455.23   | 0.672   | 0.683   |         |          |          |          |         |         |         |          |          |          |
| 43   | OW-ME    | M      | 325.59   | 0.500   | 0.741   |         |          |          |          |         |         |         |          |          |          |
| 48   | OW-ME    | M      | 541.79   | 1.082   | 0.740   |         |          |          |          |         |         |         |          |          |          |
| 82   | OW-ME    | M      | 21 OW-ME | 597.79   | 0.605   | 0.707   |          |          |          |         |         |         |          |          |          |
| 86   | OW-ME    | M      | 30 OW-ME | 455.23   | 0.672   | 0.683   |          |          |          |         |         |         |          |          |          |
| 95   | OW-ME    | M      | 43 OW-ME | 325.59   | 0.500   | 0.741   |          |          |          |         |         |         |          |          |          |
| 142  | OW-ME    | M      | 48 OW-ME | 541.79   | 1.082   | 0.740   |          |          |          |         |         |         |          |          |          |

**Note.**
- The OAGB-WISE identifier (see Tables 2 and 11). See Section 9.
- (This table is available in its entirety in machine-readable form.)
| CW-N | Subgroup | A-Type | A-Period | GM-W1(P) | GM-W1(A) | GM-W1(R²) | G-W1(P) | G-W1(A) | G-W1(R²) | GM-W2(P) | GM-W2(A) | GM-W2(R²) |
|------|----------|--------|----------|----------|----------|-----------|----------|----------|----------|----------|----------|-----------|
| 7    | CW-GC    | L      | 259      | 62.76    | 0.158    | 0.680     |          |          |          | 245.74   | 0.345    | 0.941     |
| 9    | CW-GC    | M:     | 259      | 245.74   | 0.611    | 0.933     |          |          |          | 151.26   | 0.117    | 0.657     |
| 65   | CW-GC    | SR     | 335      | 333.84   | 0.465    | 0.828     |          |          |          | 117.96   | 0.269    | 0.832     |
| 69   | CW-GC    | M      | 365      | 121.72   | 0.588    | 0.878     | 365.25   | 0.890    | 0.873    | 122.03   | 0.436    | 0.932     |
| 94   | CW-GC    | A      | 250      | 502.38   | 0.102    | 0.673     |          |          |          | 259.83   | 0.335    | 0.618     |
| 176  | CW-GC    | G      | 250      | 293.99   | 0.172    | 0.785     |          |          |          | 283.23   | 0.175    | 0.712     |
| 197  | CW-GC    | L:     | 234      | 149.61   | 0.068    | 0.710     |          |          |          | 427.38   | 0.119    | 0.672     |
| 252  | CW-GC    | M      | 234      | 178.72   | 0.460    | 0.615     |          |          |          | 356.78   | 0.275    | 0.640     |
| 261  | CW-GC    | L:     | 234      | 178.72   | 0.234    | 0.678     |          |          |          | 356.78   | 0.275    | 0.640     |
| 326  | CW-GC    | SR     | 356.4753836 | 371 | SR     | 356.4753836 | 371 | SR     | 356.4753836 | 371 | SR     | 356.4753836 | 371 | SR     | 356.4753836 |
| 392  | CW-GC    | SR     | 276      | 372.89   | 0.658    | 0.778     | 372.89   | 0.658    | 0.778    | 380.26   | 0.406    | 0.681     |
| 326  | CW-GC    | SR     | 276      | 401.80   | 0.359    | 0.696     |          |          |          | 334.13   | 0.205    | 0.856     |
| 598  | CW-GC    | VAR    | 271.08671 | 421   | VAR    | 271.08671 | 421   | VAR    | 271.08671 | 421   | VAR    | 271.08671 |
| 608  | CW-GC    | VAR    | 186.36   | 0.103    | 0.760     |          |          |          | 186.91   | 0.163    | 0.698     |
| 633  | CW-GC    | VAR    | 64.47    | 0.282    | 0.613     |          |          |          | 112.81   | 0.246    | 0.696     |
| 696  | CW-GC    | L      | 292      | 95.34    | 0.275    | 0.640     |          |          |          | 302.40   | 0.326    | 0.806     |
| 786  | CW-GC    | VAR    | 356.58   | 0.133    | 0.672     |          |          |          | 176.11   | 0.276    | 0.741     |
| 802  | CW-GC    | VAR    | 566.58   | 0.133    | 0.672     |          |          |          | 176.11   | 0.276    | 0.741     |
| 3557 | CW-OG    | M      | 242.5    | 131.41   | 0.313    | 0.848     | 301.91   | 0.319    | 0.844    | 101.42   | 0.160    | 0.664     |
| 3558 | CW-OG    | M      | 308      | 113.41   | 0.313    | 0.848     | 301.91   | 0.319    | 0.844    | 229.92   | 0.204    | 0.611     |
| 3560 | CW-OG    | M      | 229.3    | 101.42   | 0.214    | 0.662     | 229.92   | 0.204    | 0.611    | 146.70   | 0.113    | 0.664     |
| 3564 | CW-OG    | M      | 145.71   | 146.70   | 0.113    | 0.664     | 146.70   | 0.113    | 0.664    | 113.21   | 0.252    | 0.772     |
| 3568 | CW-OG    | M      | 111.86   | 113.21   | 0.252    | 0.772     | 113.21   | 0.252    | 0.772    | 250.00   | 0.222    | 0.775     |
| 3570 | CW-OG    | M      | 231.9    | 229.64   | 0.360    | 0.891     | 229.64   | 0.360    | 0.891    | 611.18   | 0.198    | 0.788     |
| 3571 | CW-OG    | M      | 359.7    | 73.28    | 0.429    | 0.906     | 363.40   | 1.396    | 0.902    | 356.71   | 0.975    | 0.929     |
| 3573 | CW-OG    | M      | 501.2    | 300.46   | 0.510    | 0.908     | 460.72   | 0.498    | 0.872    | 362.71   | 0.975    | 0.929     |
| 3576 | CW-OG    | M      | 263.1    | 257.16   | 0.315    | 0.849     | 257.16   | 0.315    | 0.849    | 459.61   | 0.480    | 0.897     |

Note.

The CAGB-WISE identifier (see Tables 2 and 12). See Section 9.

(This table is available in its entirety in machine-readable form.)
GW2-NB objects, the new WISE periods and EPs show a better correlation when we select the new (secondary or up to fourth) peak of the Lomb–Scargle power that is similar to EP. But the new correlation is still not as good as the one that uses the AAVSO period for the target period (see Figures 23–25) and shows larger deviations. There would be two possible reasons for larger deviations: the target period (EP from K[2.2] − W3[12]) cannot be the true period for all objects and some objects could not be actual Mira variables. Though this rough correlation is not as strong as the one between AAVSO and WISE periods, this comparison would be useful to find general characteristics of Mira variables for the candidate objects.

The upper-right panels in Figures 29 and 30 show the period–amplitude relations. And the lower panels in Figures 29 and 30 show PCRs using K[2.2] − IR[12] and IR[12] − IR[25] colors.

When we select the new peak, which is similar to EP, for the GN-W1B or GN-W2B objects, the candidate objects for new Miras show roughly similar period–amplitude relations and PCRs (see Figures 29 and 30) to those for known Mira variables (see Figures 15–16 and 23–25).

Figures 27 and 28 show WISE light curves and periodograms for AGB objects with unknown periods. For related objects with good-quality K[2.2] − W3[12] colors, EP is also shown. We find that the periods obtained from WISE light curves show some deviations from EPs for these objects.

Figure 31 shows WISE light curves and periodograms for six OAGB-IRAS objects (in OF-SH) with unknown periods, which can be candidate objects for new Miras. For these objects, we find that the periods obtained from WISE light curves are similar to EPs obtained from K[2.2] − W3[12]. Note that IRAS 17358-2711 can be identified as OGLE-BLG-ECL-054370 (angular distance: 33") with an E-type variable (period: 1.08 days) from AAVSO, but they could be different objects.

Figure 32 shows WISE light curves and periodograms for six CAGB-IRAS objects (in CI-SH) with unknown periods, which can be candidate objects for new Miras. Again, we find that the periods obtained from WISE light curves are similar to EPs obtained from K[2.2] − W3[12] for these objects.

9. The Catalog Data

For OAGB-IRAS objects (see Table 1), Table 9 lists the OAGB-IRAS identifier (OI-N), subgroup name, IRAS PSC number, counterparts of AKARI PSC and BSC, best position (right ascension and declination J2000: R.A. and decl.), source of the best position (AKARI PSC, AKARI BSC, or IRAS PSC; see Section 2.2; BP), ALLWISE counterpart, spectral type (SP), and IRAS LRS type (LRS) from Kwok et al. (1997): variable type (A-Type) and period (A-Period) from AAVSO; and information about SiO and OH maser emission (see Section 5.2). For CAGB-IRAS objects (see Table 1), Table 10 lists the CAGB-IRAS identifier (CI-N) and the same information except for the information about SiO and OH maser emission.

For OAGB-WISE objects (see Table 2), Table 11 lists the OAGB-WISE identifier (OW-N); subgroup name; source number from the original reference (recno/star); ALLWISE source name; ALLWISE source position (W-R.A., W-decl.); counterparts of 2MASS, AKARI PSC, MSX; and variable type (A-Type) and period (A-Period) from AAVSO. For CAGB-WISE objects (see Table 2), Table 12 lists the CAGB-WISE identifier (CW-N) and the same information.

For 3710 objects in the catalog (G-W1 or G-W2; see Table 8), the variation parameters obtained from WISE light curves at W1 and W2 bands are listed in Tables 13–16. For each obtained period (P), the amplitude (A) and coefficients of determination (R²) to fit the sinusoidal model to the observations are also listed.

For OAGB-IRAS objects with variation parameters obtained from WISE light curves, Table 13 lists the OAGB-IRAS identifier (OI-N), variable type (A-Type) and period (A-Period) from AAVSO, expected period from the IR color K[2.2] − W3[12] (EP; see Section 8.4), G-W1(P), G-W1(A), G-W1(R²), GM-W1(P), GM-W1(A), GM-W1(R²), GN-W1(P), GN-W1(A), GN-W1(R²), G-W2(P), G-W2(A), G-W2(R²), GM-W2(P), GM-W2(A), GM-W2(R²), GN-W2(P), GN-W2(A), GN-W2(R²), subgroup name, and IRAS PSC number. For CAGB-IRAS objects with variation parameters obtained from WISE light curves, Table 14 lists the CAGB-IRAS identifier (CI-N) and the same information.

For OAGB-WISE objects with variation parameters obtained from WISE light curves, Table 15 lists the OAGB-WISE identifier (OW-N), variable type (A-Type) and period (A-Period) from AAVSO, G-W1(P), G-W1(A), G-W1(R²), GM-W1(P), GM-W1(A), GM-W1(R²), G-W2(P), G-W2(A), G-W2(R²), GM-W2(P), GM-W2(A), and GM-W2(R²). For CAGB-WISE objects with variation parameters obtained from WISE light curves, Table 16 lists the CAGB-WISE identifier (CW-N) and the same information.

Note that G-W1(P) or G-W2(P) listed in Tables 13–16 are primary periods. However, GM-W1(P) and GN-W1(P) (or GM-W2(P) and GN-W2(P)) are selected periods, which can be different from the primary periods (see Sections 8.2 and 8.4).

10. Summary

We have presented a new catalog of 11,209 AGB stars and 7172 CAGB stars in our Galaxy identifying more AGB stars in the bulge component and considering more visual carbon stars. For each object, we have cross-identified the IRAS, AKARI, MSX, WISE, 2MASS, and AAVSO counterparts.

We have presented the new catalog in two parts: one (AGB-IRAS) is based on the IRAS PSC for brighter or more isolated objects, the other one (AGB-WISE) is based on the ALLWISE source catalog for less bright objects or small objects in crowded regions.

We have performed radiative transfer model calculations for AGB stars using various parameters of central stars and spherically symmetric dust shells.

We have presented various IR 2CDs for the sample stars. We have compared the various sequences of theoretical dust shell models at increasing dust optical depth with the observations of AGB stars on the IR 2CDs. We find that the theoretical dust shell models can roughly explain the observations of AGB stars on the various IR 2CDs.

We have compared number distributions of observed IR magnitudes and colors for AGB stars in the AGB-IRAS and AGB-WISE catalogs. Most AGB-IRAS objects are brighter at MIR bands and they show redder IR colors than AGB-WISE objects. In general, AGB-IRAS objects look to be more evolved (or massive) stars with thicker dust envelopes than AGB-WISE objects.

We have investigated the IR properties of SiO and OH maser emission sources in the OAGB-IRAS and OAGB-WISE catalogs. Almost all known OH maser sources are in the OAGB-IRAS catalog. We have found that most OH maser
sources are in the range of large dust optical depths (or mass-loss rates). On the other hand, most SiO maser sources in the OAGB-IRAS catalog are in the range of moderate dust optical depths (or mass-loss rates) for various IR colors. For a major portion of the OAGB stars in the OAGB-WISE catalog, OH or SiO maser observations have not been performed yet.

We have compared the IR properties of visual carbon stars from those of infrared carbon stars. Generally, visual carbon stars show bluer colors than infrared carbon stars because the dust shell optical depths for visual carbon stars are smaller. But some visual carbon stars show redder colors at MIR bands using longer wavelengths, which would be due to detached circumstellar dust shells that are remnants of an earlier phase when the stars were OAGB stars.

We have investigated number distribution of the Galactic longitude and latitude for AGB stars in the AGB-IRAS and AGB-WISE catalogs. We have found that OAGB stars are more concentrated toward the Galactic center and the number decreases with the Galactic longitude, while CAGB stars are distributed more uniformly from the center to large Galactic longitudes. The histograms for different Galactic latitudes are similar for both OAGB and CAGB stars. All AGB stars are concentrated toward the Galactic disk.

For known Mira variables in the sample stars, we have investigated the period–color relations and found that objects with longer pulsation periods generally show redder colors.

We have investigated infrared variability of the sample stars using the WISE photometric data in the last 12 yr: the ALLWISE multi-epoch data that were acquired between 2009 and 2010 and the NEOWISE-R 2021 data release that were acquired from 2013 until the end of 2020.

We have tried to find Mira-like variations from the WISE light curves of the sample stars using a simple sinusoidal light-curve model. Using the WISE data at W1 and W2 bands, we have generated the light curves and computed the Lomb–Scargle periodograms for all of the sample stars and found good-quality variation parameters for 3710 objects in the catalog, for which periods were either known or unknown in previous works.

We have obtained pulsation periods from the WISE light curves for 2810 objects, which are known to be Miras with periods from AAVSO. For about a half of the objects, the obtained primary periods from the WISE data are very similar to AAVSO periods. For another half of objects whose primary periods from WISE data are different from AAVSO periods, we can find a new (second or up to fourth) peak in the Lomb–Scargle power values, for which the new period is similar to the AAVSO period. This would be because the AAVSO periods can be regarded as true periods and the multiple peaks in the Lomb–Scargle power values are similar, which would be due to the regularity of the WISE observations (6 months). On the whole, the periods from the WISE data and AAVSO showed very good correlations for all of the sample stars known as Miras.

We have obtained pulsation periods from the WISE light curves for 656 objects with unknown periods and 244 objects known as non-Mira variables with periods from AAVSO. We have found that a major portion of these objects could be candidate objects for new Mira variables because they show similar period–amplitude and period–color relations to those of known Mira variables.

If we perform new photometric observations at L or M band at different pulsation phases of AGB stars, the WISE data would be more useful to find precise periods.

The catalog data are presented in Section 9 (and Tables 9–16). The data will also be accessible through the author’s webpage at http://web.chungbuk.ac.kr/~kwsuh/agb.htm.

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Software: For a major part of the computations and figures in this paper, we have used Python codes. We have used the Numpy (van der Walt et al. 2011), Pandas (McKinney 2010), AstroPy (Astropy Collaboration et al. 2013), and Matplotlib (Hunter 2007) packages.

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