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Infrared studies of post-AGB stars and PNe

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Abstract. We present infrared two color diagrams (2CDs) for a large sample of AGB stars, post-AGB stars, and planetary nebulae (PNe) to study their spectral evolution in infrared bands. We discuss possible evolutionary tracks from AGB stars to PNe on the 2CDs. We use catalogs from the available literature for the sample of AGB stars, post-AGB stars, and PNe in our Galaxy.

Keywords. stars: AGB and post-AGB, planetary nebulae: general, infrared: stars

1. Introduction

The intermediate phase between the end of the asymptotic giant branch (AGB) phase and the planetary nebula (PN) phase is called the post-AGB or pre-PN phase. During the post-AGB phase, the dust shell formed in the AGB phase detaches from the central star and becomes optically thin after a few hundred years (e.g., Hrivnak *et al.* 1989; van Hoof *et al.* 1997; Suh 2015).

The *Infrared Astronomical Satellite* (*IRAS*) Point Source Catalog (PSC) (version 2.1) provides useful photometric data in four bands (12, 25, 60, and 100 μm). In characterizing the circumstellar environments of AGB and post-AGB stars, the two-color diagram (2CD) in the *IRAS* PSC has been useful (e.g., Suh & Kwon 2011; Suh 2015). The Midcourse Space Experiment (*MSX*; Egan *et al.* 2003) surveyed the Galactic plane in four bands (8.28, 12.13, 14.65, and 21.34 μm). *AKARI* (Murakami *et al.* 2007) provides PSC data in two bands (9 and 18 μm) from an all-sky survey.

The data from Wide-field Infrared Survey Explorer (WISE), which completed an entire sky survey in the 3.4, 4.6, 11.6 and 22.6 μm bands (hereafter named W1, W2, W3, and W4, respectively) with better angular resolutions and higher sensitivities (Wright *et al.* 2010), would be useful especially for dim objects.

In this work, we present infrared two-color diagrams (2CDs) for AGB stars, post-AGB stars, and PNe using the MSX and WISE data. We cross-identify the *IRAS*, *AKARI*, *MSX*, and WISE counterparts for each object in the sample. We discuss possible evolutionary tracks on the 2CDs.

Table 1. Sample of AGB stars, post-AGB stars, and PNe

Class	Reference	Number	*IRAS* PSC	*AKRAI* PSC	*MSX* PSC	WISE
O-AGB	Kwon & Suh (2012)	3373	3373	3241	2248	3371
C-AGB	Suh & Kwon (2011)	1168	1168	1157	758	1168
post-AGB	Szczerba *et al.* (2007)	326	236	254	117	325
Pre-PNe	Kohoutek (2001)	334	326	253	177	253
PNe	Kohoutek (2001)	1510	927	808	414	808
PNe (MASH1)	Parker *et al.* (2006)	903	161	135	103	900
PNe (MASH2)	Miszalski *et al.* (2008)	335	89	99	35	334

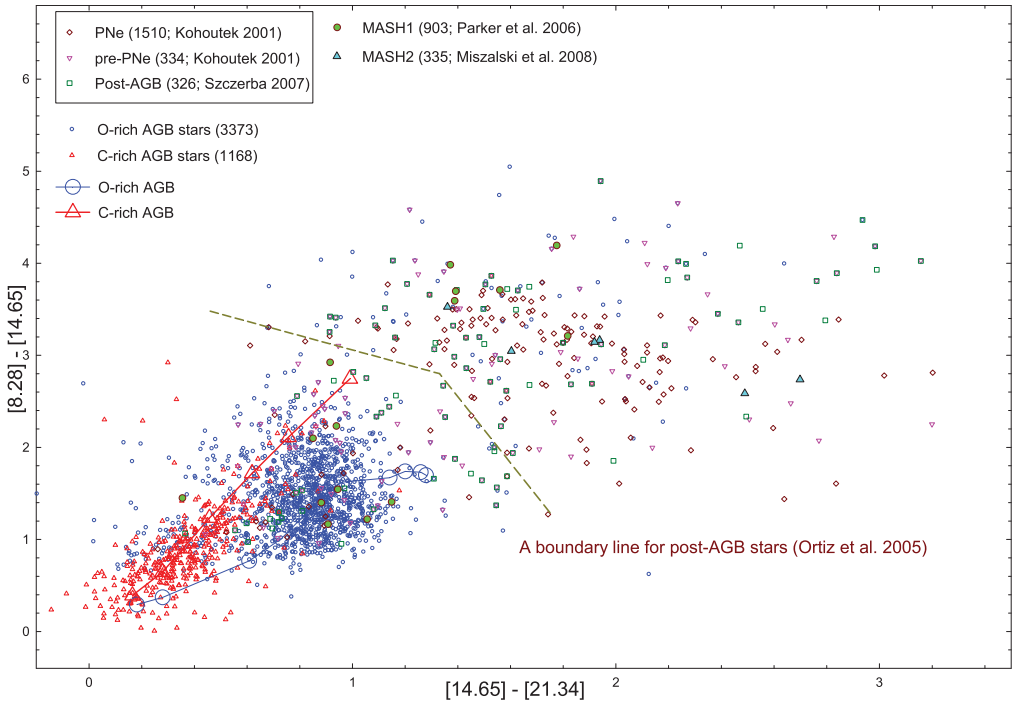

Figure 1. The MSX 2CD for AGB stars, post-AGB stars, and PNe.

2. Sample stars

We use catalogs from the available literature for the sample of 4541 AGB stars (3373 O-AGB; 1168 C-AGB), 660 post-AGB stars (326 post-AGB; 334 pre-PN), and 2748 PNe. For each object in the catalog, we cross-identify the *IRAS* PSC, *AKARI* PSC, *MSX* PSC, and WISE counterparts.

In Table 1, we list the reference, total number of objects, and numbers of the cross-identified *IRAS* PSC, *AKARI* PSC, *MSX* PSC, and WISE counterparts. Because *IRAS* has very low angular resolution, the WISE counterpart obtained from the position data from *AKARI* would be much more reliable. In this work, we improve the identification method presented by Suh (2015) using the more reliable scheme presented by Abrahamyana *et al.* (2015).

2.1. *AGB stars*

Suh & Kwon (2011) present a catalog of AGB stars consisting of 3003 O-rich, 1168 C-rich objects in our Galaxy. Kwon & Suh (2012) present a revised sample of 3373 O-rich AGB stars.

Using the *IRAS* PSC name, we cross-identify the *AKARI* and *WISE* counterparts of objects in the catalog of Abrahamyana *et al.* (2015). For *MSX*, we find the closest counterpart within 30″ of the best position from Abrahamyana *et al.* (2015). Note that the numbers of cross-identified sources are slightly larger than those presented in Suh (2015).

2.2. *Post-AGB stars*

In this work, we use the list of 326 objects from the catalog of post-AGB stars by Szczerba *et al.* (2007) and 334 pre-PNe from the catalogue of Galactic Planetary Nebulae (Updated Version 2000; Kohoutek 2001).

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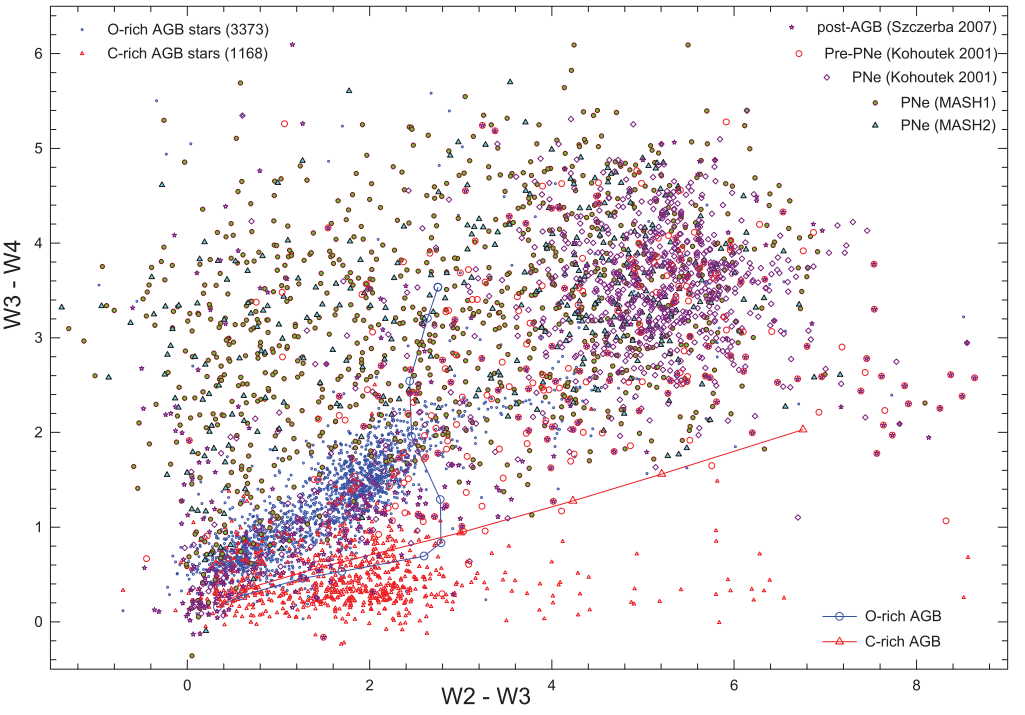

Figure 2. The WISE 2CD for AGB stars, post-AGB stars, and PNe.

For post-AGB stars, we cross-identify the $IRAS$, $AKARI$, MSX, and $WISE$ counterparts by finding the nearest source within 30″ using the position information in Szczerba *et al.* (2007) for each object. For pre-PNe, we use the $IRAS$ PSC counterparts listed in Kohoutek (2001). We cross-identify the $AKARI$ and MSX counterparts by finding the nearest source within 30″ using the position information in Kohoutek (2001). For the WISE counterpart, we find the closest source within 15″ of the position of the cross-identified $AKARI$ PSC source.

2.3. *Planetary Nebulae*

For this paper, we use the catalogue of Galactic Planetary Nebulae (Updated Version 2000; Kohoutek 2001). This catalogue contains 1510 objects classified as Galactic PNe up to the end of 1999. For PNe listed in Kohoutek (2001), we use $IRAS$ PSC counterparts listed in the reference. We cross-identify the $AKARI$ and MSX counterparts by finding the nearest source within 30″ using the position information in Kohoutek (2001) and Kerber *et al.* (2003). For the WISE counterpart, we find the closest source within 15″ of the position of the cross-identified $AKARI$ PSC source.

We also use the Macquarie/AAO/Strasbourg Hα (MASH) catalogues (Parker *et al.* 2006; Miszalski *et al.* 2008). MASH PNe are typically more evolved, obscured, and of lower surface brightness than those found in most previous surveys. For MASH PNe, we cross-identify the $IRAS$, $AKARI$, MSX, and $WISE$ counterparts by finding the nearest source within 30″ of the position given in Parker *et al.* (2006) and Miszalski *et al.* (2008).

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3. Infrared Two-Color Diagrams and implications

Figures 1 and 2 show infrared 2CDs for the sample stars. We plot only those objects with good quality measurements at wavelengths. Suh (2015) presents various infrared 2CDs for AGB stars, post-AGB stars, and PNe and investigates theoretical evolutionary model tracks for AGB and post-AGB stars. The theoretical model tracks for AGB stars from Suh (2015) are plotted on the 2CDs.

Figure 1 shows the MSX 2CD using [8.28]−[14.65] versus [14.65]−[21.34]. Suh (2015) presents theoretical model tracks for the 2CD. MASH1 objects are scattered over wide regions but MASH2 objects are confined to the post-AGB region as suggested by Ortiz *et al.* (2005).

Figure 2 shows the $WISE$ 2CD using W2−W3 versus W3−W4. Note that a major portion of the observed bright sources are severely saturated in the WISE photometry. So the theoretical model tracks for AGB stars show severe deviations from the observed points. Though MASH objects are scattered over wide regions in the 2CD, they are more densely populated in the upper-right region just like other PNe. Theoretically, the $WISE$ two-color diagram would be very useful to investigate the evolutionary tracks from AGB to PNe because the $WISE$ covers new wavelength bands (3.4, 4.6, 11.6 and 22.6 μm) which may contain some important dust features.

References

Abrahamyana, H. V., Mickaelian, A. M., & Knyazyanb, A. V. 2015, *Astronomy and computing*, 10, 99.

Egan, M. P., Price, S. D., Kraemer, K. E., *et al.* 2003, Air Force Research Laboratory Technical Report AFRL-VS-TR-2003-1589

Hrivnak, B. J., Kwok, S., & Volk, K. M. 1989, *ApJ*, 346, 265

Kerber, F., Mignani, R., Guglielmetti, F., & Wicenec, A. 2003, *A&A*, 408, 1029

Kohoutek, L. 2001, Catalogue of Galactic Planetary Nebulae (Updated Version 2000). Abhandlungen Hamburger Sternwarte, XII C

Kwon, Y.-J. & Suh, K.-W. 2012, *Journal of the Korean Astronomical Society*, 45, 139

Miszalski, B., Parker, Q. A., Acker,A., Birkby, J. L., Frew, D. J., & Kovacevic, A. 2008, *MNRAS*, 525, 534

Murakami, H., Baba, H., Barthel, P., *et al.* 2007, *PASJ*, 59, S369

Ortiz, R., Lorenz-Martins, S., Maciel, W. J., & Rangel, E. M. 2005, *A&A*, 431, 565

Parker, Q. A., Acker, A., & Frew, D. J., *et al.* 2006, *MNRAS*, 373, 79

Suh, K.-W. & Kwon, Y.-J. 2011, *MNRAS*, 417, 3047

Suh, K.-W. 2015, *ApJ*, 808, 165

Szczerba, R., Siódmiak, N., Stasińska, G., & Borkowski, J. 2007, *A&A*, 469, 799

van Hoof, P. A. M., Oudmaijer, R. D., & Waters, L. B. F. M. 1997, *MNRAS*, 289, 371

Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., *et al.* 2010, *AJ*, 140, 1868

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