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Planetary Nebulae Detected in the AKARI Far-IR All-Sky Survey Maps

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Abstract. The *AKARI* Far-IR All-Sky Survey (AFASS) maps produced by the *AKARI* Infrared Astronomical Satellite enabled us to probe the far-IR sky for objects having surface brightnesses greater than a few to a couple of dozen MJy sr^{-1}. Recently, we have verified that, if AFASS-measured fluxes are properly corrected for using the aperture correction method based on the empirical point-spread-function templates derived directly from the AFASS maps, point-source photometry measured from the AFASS maps reproduces fluxes in the *AKARI* bright source catalogue (BSC). We have surveyed the far-IR sky in the AFASS for Galactic planetary nebulae (PNe) based on the University of Hong Kong/Australian Astronomical Observatory/Strasbourg Observatory Hα Planetary Nebula database (HASHPNDB), preliminarily yielding far-IR fluxes for roughly 1000 Galactic PNe including a few hundreds of PNe not listed in the *AKARI*/BSC.

Keywords. planetary nebulae: general, circumstellar matter, stars: mass loss, infrared: stars, surveys

1. AKARI and AFASS

The *AKARI* Infrared Astronomical Satellite (*AKARI*; Murakami *et al.* 2007) was launched on February 21, 2006 (UT), carrying out its 550-day cryogen mission until it exhausted liquid Helium on August 26, 2007 and continuing its post-cryogen mission in the near-IR until the satellite was finally switched off on November 24, 2011. *AKARI* was outfitted with a cryogenically-cooled telescope of a diameter of 68.5 cm and two instruments, the Far-Infrared Surveyor (FIS; Kawada *et al.* 2007) and the Infrared Camera (IRC; Onaka *et al.* 2007), covering a wavelength range of 2–180 μm.

For the AKARI Far-IR All-Sky Survey (AFASS), the natural 100-min sun-synchronous orbit was used to scan the entire sky at $3.6' \, s^{-1}$ at four far-IR bands (65, 90, 140, and 160 μm) during the survey period from April 2006 to August 2007, achieving 99 % sky coverage (Doi *et al.* 2015; Takita *et al.* 2015). The presently archived AFASS map data (the Public Release Ver. 1, AFASSv1 hereafter)† are absolutely calibrated against large-scale background emission detected by *COBE*/DIRBE (Matsuura *et al.* 2011). Ueta *et al.* (2018) have recently verified that point-source photometry directly measured from the AFASS maps would be consistent with fluxes in the *AKARI* bright source catalogue ver. 2 (BSCv2, hereafter; Yamamura *et al.* 2009), for which photometry was done directly from time-series detector signal readouts of the scan observations.

† Maintained by ISAS/JAXA at the Data ARchives and Transmission System (DARTS; http://www.darts.isas.ac.jp/astro/akari/).

Table 1. Preliminary detections of PNe from HASHPNDB in the AFASSv1 maps

	BSC					AFASS				
PN Type	**N60**	**WIDE-S**	**WIDE-L**	**N160**	**All**	**N60**	**WIDE-S**	**WIDE-L**	**N160**	**All**
True	407	768	195	54	30	636	891	368	277	107
Likely	32	70	22	8	4	58	76	31	36	7
Possible	76	122	56	28	18	93	78	57	43	12
All	515	960	273	90	52	787	1045	456	356	126

2. Galactic PNe Detected in the BSC and AFASS Maps

We have used both the BSCv2 and AFASSv1 to obtain far-IR fluxes of PNe based on the University of Hong Kong/Australian Astronomical Observatory/Strasbourg Observatory Hα Planetary Nebula database ((HASHPNDB; Parker *et al.* 2017). This work is motivated by recent suggestions that the colder dusty photo-dissociation regions (PDRs) are important in understanding the global energetics of objects such as PNe that are known as the hallmark of ionized/H^+ regions (e.g., Otsuka *et al.* 2017).

First, by crossmatching HASHPNDB and BSCv2 with a $30''$ search radius, we find 515, 960, 273, and 90 detections with FQUAL = 3 (i.e., detection validated) in the N60, WIDE-S, WIDE-L, and N160 bands at 65, 90, 140, and 160 μm, respectively. There are 52 PNe for which the flux is measured in all four bands.

Then, we search AFASSv1 at each of the HASHPNDB coordinates in each band to see if there is any source detection. One notable potential complication here is that PNe are not necessarily always point sources. Our method essentially starts with the peak of the target PN at the HASHPNDB coordinates and continues to enlarge the extent of the target PN defined by the thresholding surface brightness by lowering the thresholding surface brightness until the presence of another object is recognized. We preliminary measure far-IR fluxes of 787, 1045, 456, and 356 PNe in AFASSv1 in the N60, WIDE-S, WIDE-L, and N160 bands, respectively (272, 85, 183, and 266 more detections than BSCv2), for the total of 1321 PNe, as summarized in Table 1.

Presently, we are hashing out false positives included in these preliminary detections. We will present the results of analyses of legitimate far-IR PN detections in due course.

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