Why Galaxies Care About AGB Stars: A Continuing Challenge through Cosmic Time
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Mass Loss History of Evolved Stars (MLHES) Excavated by AKARI

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Abstract. We performed a far-IR imaging survey of the circumstellar dust shells of 144 evolved stars as a mission program of the AKARI infrared astronomical satellite. Our objectives were to characterize the far-IR surface brightness distributions of the cold dust component in the circumstellar dust shells. We found that (1) far-IR emission was detected from all but one object, (2) roughly 60–70 % of the target sources showed some extension, (3) 29 sources were newly resolved in the far-IR in the vicinity of the target sources, (4) the results of photometry measurements were reasonable with respect to the entries in the AKARI/FIS Bright Source Catalogue, and (5) an IR two-color diagram would place the target sources in a roughly linear distribution that may correlate with the age of the circumstellar dust shell.

Keywords. stars: AGB and post-AGB, planetary nebulae: general, circumstellar matter, stars: mass loss, infrared: stars, surveys

1. The AKARI MLHES Mission Program

The *AKARI* Infrared Astronomical Satellite (*AKARI*; Murakami *et al.* 2007) was launched on February 21, 2006 (UT) to carry out its primary mission to map out the entire sky in the far-IR until the cryogen was exhausted on August 26, 2007. During all-sky survey scan observations that lasted for 1.5 years, some telescope time was allocated to perform pointed observations as *AKARI* mission programs. We carried out an imaging survey of the circumstellar dust shells (CDS) of evolved stars, at various stages of evolution from the tip of the first-ascent giant branch to planetary nebula phase, dubbed the "Mass Loss History of Evolved Stars" (MLHES), as one of such mission programs, using the Far-Infrared Surveyor (FIS; Kawada *et al.* 2007) and Infrared Camera (IRC; Onaka *et al.* 2007).

With MLHES, we aimed at observationally establishing the AGB mass loss history and understanding the mechanism(s) of mass loss and CDS formation by spatially resolving the CDS structures. Some of the MLHES data were already presented in the context of the interaction between the interstellar medium (ISM) and CDS (Ueta *et al.* 2008, 2010). In the context of MLHES, Izumiura *et al.* (2011) analyzed the detached CDS of the AGB star U Hya to conclude that (1) the temporal enhancement of mass loss due to thermal pulse and the subsequent two-wind interactions, or (2) the reverse/termination shock of the stellar wind bounced back from the wind-ISM interface. However, the marginal image quality at the preliminary stage of data reduction did not allow us to unequivocally conclude one of the two possibilities.

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2. Surface Brightness Recalibration of AKARI/FIS Slow-Scan Maps

Far-IR Ge:Ga detectors such as FIS is known to exhibit reduced sensitivity to bright point sources that is attributed to the delay in response to the incoming flux (e.g., Kaneda *et al.* 2012). Such slow transient responses in scan observations of bright objects would typically manifest themselves as underestimated surface brightnesses, resulting in reduced fluxes. Hence, while FIS data were absolutely calibrated against large-scale diffuse background emission based on the *COBE*/DIRBE data (Matsuura *et al.* 2011), the surface brightness of slow-scan maps would have to be recalibrated if target sources were more compact than diffuse background cirrus clouds (i.e., just like CDSs). We have recently established a general method to recalibrate AKARI/FIS slow-scan maps with the inverse power-law FIS response function based on the scale invariance characteristic of the FIS maps (i.e., the PSF shape remains the same irrespective of the source flux; Ueta *et al.* 2017). With this correction, surface brightnesses of the MLHES maps that were underestimated depending on the actual signal strength of the emission distribution have now been properly corrected for.

3. Present Status

The recalibrated MLHES data set will be presented soon by Ueta *et al.* (2008) with bare photometry completed. With *AKARI*'s better spatial resolution in comparison with its predecessors (*IRAS* and *ISO*), 29 new nearby sources are resolved in the vicinity of the MLHES targets, several of which have not been identified previously. The photometry measurements are reasonable with respect to the corresponding entries in the AKARI/FIS Bright Source Catalogue (Yamamura *et al.* 2009), with a reasonable amount of discrepancies because of the fact that many MLHES sources are genuinely extended. An *AKARI*-WISE two-color diagram, showing the MLHES sources in a roughly linear distribution that may correlate with the age of the circumstellar dust shell, could potentially be used to identify which targets were more extended than others. The detailed analyses of structures of the MLHES CDSs are presently being conducted by removing the PSF effects using a scaled super-PSF map constructed from images of reference point sources. The results of the structural analysis of the evolved star circumstellar shell for the entire MLHES sample will be presented elsewhere (Torres *et al. in preparation*).

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