Mid-infrared imaging of dust in galaxies
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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2011

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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A.1 Is there a photometric edge effect in AKARI scans?

— G. van der Wolk —

Report of data quality testing performed at ISAS, Tokyo Japan (June, 2008)

AKARI is a Japanese satellite with a 68.5 cm cooled telescope which surveyed the sky in six wavelength bands from mid- to far-infrared for more than a year. The survey is ideal for studying star formation, evolved stellar populations and accretion activity in the SAURON sample and dust content of the radio galaxy sample studied in this thesis. We investigate if the automatic photometry extractor SUSEXtractor operates correctly when sources are located near the edge of 90 $\mu$m AKARI scans. We analyze 34 bright sources that are observed in 700 scans in total. We find an edge avoidance width of 3 pixels (24 arcsec) and we discuss other sources of off-scale photometry.

A.1.1 Introduction

AKARI is a Japanese satellite with a 68.5 cm cryogenically cooled telescope and two focal-plane instruments, the Far-infrared Surveyor (FIS; Kawada et al. 2007) and the Infrared Camera (IRC; Onaka et al. 2007), which surveyed the sky in six wavelength bands from mid- to far-infrared (9 to 180 $\mu$m) for more than a year (Murakami et al. 2007). AKARI operates from a low-Earth (700 km) Sun-synchronous polar orbit as to avoid light from the Earth and Sun. Due to this orbit and the large field of view of the instruments (10 arcmin) every sky position is observed at least twice. The primary goal of AKARI is to provide second-generation infrared catalogues obtained with a better spatial resolution and wider spectral coverage than was possible with the first infrared all-sky surveyor the Infrared Astronomy Satellite (IRAS; Soifer et al. 1987). The detection limits in the two AKARI mid-infrared bands are much better than those of IRAS, while the sensitivity in the far-infrared is comparable to that of IRAS. The survey is ideally suited for studying star formation, evolved stellar populations and accretion activity in the SAURON sample and dust content of the radio galaxy sample studied in this thesis.
To identify and accurately quantify the objects in the AKARI all-sky survey the source extraction method SUSSEXtractor (SXT; Savage & Oliver 2007) was developed. This method is based on Bayesian model selection and uses the Bayesian information criterion. It can measure the flux, position, local background and point-spread function of objects in a fast way. It is investigated if with SXT adequate photometry can be obtained when a source is close to the edge of a WIDE-S (90 \( \mu \)m) scan. If not, what should be the avoidance width? How does off-scale photometry relate to the ratio of the individual scan to the co-added logarithmic evidence values \( L_i/L_c \)? How do the off-scale sources relate to the chi-squared values (\( \chi^2 \)) and the number of effective fits (\( N_{\text{eff}} \)) to the data?

A.1.2 Data and methods

This analysis is based on the dataset of 34 bright Northern and Southern IRAS High Visibility (IRASHV) sources, distributed among the SXT testing team. The WIDE-S part of the data consists of 701 individual scans and 34 co-added images, each centred at the source position (Fig. A.1). The version of SXT of June 3 was used, at basic settings and with a LogEvidence threshold value of 15. The GreenBox version was of March 2008. Source extraction was performed successfully in 78\% of the individual scans (Table A.1).

One-third of the extracted sources from the individual scans show off-scale photometric results, as defined by ratios of individual to co-added fluxes \( F_i/F_c < 0.8 \) and \( F_i/F_c > 1.2 \). To investigate if these are sources close to the edge of the scan, a routine was written to determine the distance of the source to the edge. It retrieves the central pixel y-value from the header of the image file and at this position it makes a column profile along the x-axis. Then in this profile, the locations of both the edges, first of three consecutive zero-values on the left and right side of the central pixel, are searched for. This gives the distance \( d \) of the peak of the source to the edge, in cross-scan direction, which is perpendicular to the ecliptic. Image distortions, due to the coordinate changes, are taken into account. If \( d = 1 \) pixel the source is located at the edge, while if \( d = 35 \) pixels the source is located in the centre of the scan. Note that 1 pixel corresponds to 8 arcsec on the sky.

A.1.3 Results

1. This study of the 701 WIDE-S bright IRAS High Visibility scans and 34 co-added images, shows that with a LogEvidenceThreshold of 15 the current version of SXT, at basic settings, successfully performs source extraction in 78 \% (476/610) of the cases. The undetected sources are for 55 \% located less than 10 pixels from the edge (Table A.1 and Fig. A.2).

2. Furthermore, off-scale photometry, as traced by the individual to co-added flux ratio \( F_i/F_c < 0.8 \) and \( > 1.2 \), is in only 34 \% of the cases related to a source positioned close to the edge (\( d < 10 \) pixels) of the scan (Table A.1 and Fig. A.3). See NGC 1511 (Fig. A.4) for an example, where five scans close plus five far
Table A.1: Percentages of important parameters of the sources extracted from the individual WIDE-S scans.

<table>
<thead>
<tr>
<th>Description</th>
<th>%</th>
<th>Number/total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source is outside scan</td>
<td>13</td>
<td>91/701</td>
</tr>
<tr>
<td>Source is detected</td>
<td>78</td>
<td>476/610</td>
</tr>
<tr>
<td>Source is undetected</td>
<td>22</td>
<td>134/610</td>
</tr>
<tr>
<td>Source is detected and near edge (d &lt; 10 pixels away)</td>
<td>19</td>
<td>91/476</td>
</tr>
<tr>
<td>Source is undetected and near edge (d &lt; 10 pixels away)</td>
<td>55</td>
<td>73/134</td>
</tr>
<tr>
<td>Source has off-scale photometry</td>
<td>27</td>
<td>163/476</td>
</tr>
<tr>
<td>Off-scale photometry and near edge (d &lt; 10 pixels away)</td>
<td>34</td>
<td>55/163</td>
</tr>
<tr>
<td>Flux ratio of individual to co-added $F_i/F_c &lt; 0.8$</td>
<td>23</td>
<td>37/163</td>
</tr>
<tr>
<td>Flux ratio of individual to co-added $F_i/F_c &lt; 0.8$ and near edge</td>
<td>46</td>
<td>17/37</td>
</tr>
<tr>
<td>Flux ratio of individual to co-added $F_i/F_c &gt; 1.2$</td>
<td>77</td>
<td>126/163</td>
</tr>
<tr>
<td>Flux ratio of individual to co-added $F_i/F_c &gt; 1.2$ and near edge</td>
<td>30</td>
<td>38/126</td>
</tr>
<tr>
<td>Source has low LogEvidence ratio ($L_i/L_c &lt; 0.06$)</td>
<td>42</td>
<td>199/476</td>
</tr>
<tr>
<td>Off-scale photometry and low LogEvidence ratio</td>
<td>29</td>
<td>57/199</td>
</tr>
<tr>
<td>Source has high chi-square value ($\chi^2 &gt; 1.5$)</td>
<td>5</td>
<td>26/476</td>
</tr>
<tr>
<td>Source has low number of effective data fits ($N_{eff} &lt; 150$)</td>
<td>3</td>
<td>15/476</td>
</tr>
</tbody>
</table>

from the edge show off-scale photometry. Low off-scale flux ratios ($F_i/F_c < 0.8$) are in 46 % of the cases located close to the edge.

3. A small percentage (29 %) of the sources with low ratios of the individual to co-added LogEvidence, $L_i/L_c < 0.06$ show off-scale photometry.

4. Low flux level sources, $F_c < 2$ Jy, show an offset above the unity relation valid for bright sources $F_i/F_c$ (Fig. A.5). The same effect was found in the stellar calibration sample (StarSV) by Fukuda and Yamamura (June 4, 2008). An explanation could be that the noise levels of the individual scan images play a larger role in the flux determination for fainter sources than for brighter sources. Alternatively, it could be that the co-adding process does not work optimally for faint sources. The first explanation is considered more likely, because the individual scan images of low flux sources show larger scatter in flux than bright sources do.

5. If all detections that are positioned close to the edge of the scan ($d < 10$ pixels) are removed from the sample, this results in similar distributions of flux ratio, LogEvidence ratio and chi-squared as the parent distribution (second row in Fig. A.6 and A.7). It does change the distribution of the number of effective data fits: values of $N_{eff} < 150$ disappear from the distribution. These trends confirm result 2, suggesting that there is a small photometric edge effect.

6. Also, removing off-scale photometric detections from the sample results in similar distributions of flux ratio, LogEvidence ratio, chi-squared, and number of effective data fits as the parent distribution (third row in Fig. A.6 and A.7).

7. Finally, removing detections with $L_i/L_c < 0.06$ from the sample, results in an almost symmetric flux ratio distribution around unity, and removes ~ 40 % of the source detections near the edge of the scan, all high ($> 1.5$) chi-squared
values and all detections with low (\(<150\)) number of effective data fits (fourth row in Fig. A.6 and A.7).

8. All in all, this suggests that sources near the edge (\(<3\) pixels), with high chi-squared (\(>1.5\)) and low number of effective data fits (\(<150\)) having low LogEvidence ratios (\(<0.06\)) should be removed from the source extraction process.

A.1.4 Discussion

The edge, rampcurve noise, trailing emission and environment should be considered in explaining off-scale photometric sources. Low flux ratio sources are often found where the peak of the source is just beyond the edge. Sources with high flux ratios are mostly associated with low-level rampcurve noise stripes across the scan. Could it be that this noise enhances the flux of the source? Also off-scale sources look more smeared and are sometimes associated with trailing emission. Furthermore, it might be that bright neighbouring sources that are not in the scan produce high flux ratios in sources close to the edge.

Next step should be to investigate whether there is a difference between sources close to the left and to the right edge. Is the trailing emission always seen at the same position? If so at which position? The sources that are undetected with SXT should be checked by eye. What is their luminosity?

Acknowledgements

A special thanks to Issei Yamamura and Takao Nakagawa for helpful discussions.
Figure A.1: Zoomed in to the centres of all of the 701 WIDE-S IRASHV individual scans and 34 co-added sources. Of all the individual scans, where the source is inside, the current version of SXT successfully performs source extraction in 78% (476/610) of the cases.
Figure A.2: In 32% (225/701) of the scans no source is extracted at the central pixel. This plot shows that for 13% (91/701) of the cases the sources are outside the scan. The undetected sources, with positions that are inside the scan, are predominantly (55%) located less than 10 pixels from the edge.

Figure A.3: Off-scale photometry, as traced by flux ratios lower than $<0.8$ and higher than $>1.2$, is not necessarily related to a source positioned at the edge of the scan.
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Figure A.4: Off-scale photometry is not necessarily related to a source positioned at the edge of the scan or with a low ratio of individual to co-added LogEvidence, \( L_i / L_c \). Left panels: The distance of the source to the edge of the scan (in pixels) versus the ratio of the individual scan extracted and co-added flux, \( F_i / F_c \). A ratio of unity is indicated with a horizontal, solid line, while the median flux ratio is indicated with a dotted line. Filled diamonds indicate values with LogEvidence > 30, while triangles have values of 15 < LogEvidence \( \leq 30 \). Right panels: The ratio of the individual to co-added LogEvidence, \( L_i / L_c \), versus the flux ratio, \( F_i / F_c \). The vertical, solid line divides LogEvidence < 30 sources from sources with higher evidence values. The dash-dotted line represents a ratio of \( L_i / L_c = 0.06 \), which might be an indicator of off-scale photometry, as discussed in Section 3. Again the horizontal, solid line indicates a flux ratio of unity, while the median flux ratio is indicated with a dashed line. The numbers on the top indicate the extracted co-added flux (\( F_c \)) and the co-added LogEvidence (\( L_c \)).
Figure A.5: Low flux level sources, $F_c < 2 \text{ Jy}$, have larger ratios of individual over co-added flux, $F_i/F_c$. Top: The flux from the co-added map versus the median of the flux ratio for each of the 34 IRASHV sources. Bottom: Mean flux ratios.
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Figure A.6: Density distributions of the distance of the source to the edge, flux ratio $F_i/F_c$ and LogEvidence ratio $L_i/L_c$ (top row). They are used to investigate what happens if source detections are removed, that (i) are close to the edge (< 10 pixels) (second row), (ii) have a flux ratio < 0.8 and > 1.2 (third row), (iii) have a low LogEvidence ratio, $L_i/L_c < 0.06$ (fourth row).
Figure A.7: Density distributions of the chi-squared values and number of effective data fits (top row). They are used to investigate what happens if source detections are removed, that (i) are close to the edge (< 10 pixels) (second row), (ii) have a flux ratio < 0.8 and > 1.2 (third row), (iii) have a low LogEvidence ratio, $L_i/L_c < 0.06$ (fourth row).