Survey of dusty AGNs based on the mid-infrared all-sky survey catalog

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Introduction: Motivations

- Heavily obscured AGNs in the local Universe
- Many AGNs are obscured
- Local dusty AGNs are needed to explain Hard X-ray background

The nature of this population, even in the local universe, is only poorly understood, because of the strong selection bias against finding them at optical wavelengths.

*Imanishi et al. 2008*

*Treister et al. 2009*
Mid-infrared search for AGNs

- Using MIR bands,
  - we can detect thermal emission from dusty torus of AGNs
  - whether they are buried or not.

- IRAS 12micron follow-up (Rush et al. 1993)
  - IRAS $\sim 300$ mJy at 12$\mu$m

- ISOCAM parallel mode survey (Haas et al. 2003, Leipski et al. 2005)
  - was deeper than AKARI all-sky survey, but a survey area was only 10 square degrees.

- Spitzer made AGN search using deep surveys (e.g. Lacy et al. 2004; Alonso-Herrero et al. 2006; Polettea et al. 2006)
AKARI MIR All-Sky Survey catalog

※ Zodiacal light was removed with a simple way in this map.
The star atlas was made by Nagoya City Museum using Stellar Navigator (Astro. Arts Co.).

Table 1 Performance summary

<table>
<thead>
<tr>
<th>Channel</th>
<th>S9W</th>
<th>L18W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave coverage</td>
<td>6—12um</td>
<td>14—26um</td>
</tr>
<tr>
<td>Detection limit ($5\sigma$)</td>
<td>50 mJy</td>
<td>90 mJy</td>
</tr>
<tr>
<td>Saturation (80% linearity)</td>
<td>$&lt; 300$ Jy</td>
<td></td>
</tr>
<tr>
<td>Spatial resolution</td>
<td>$&lt; 9.4''$</td>
<td></td>
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</tbody>
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Ishihara et al. 2010
Target Selection

- AKARI mid-infrared all-sky survey catalog
  - $|b| < 30$, LMC, and SMC regions are excluded.
  - Identified with 2MASS

- Criteria of MIR excess
  $$\frac{F(9\mu m \text{ or } 18\mu m)}{F(Ks)} > 2$$

- ~1500 candidates
  - Famous objects are also included.

Observed sources
There is a problem.....

- We suffer from the contamination of PAH strong galaxies like M82.
Mission Program: MSAGN (Mid-infrared Search for AGNs)

- PI: S. Oyabu
- in AKARI Phase3 (Post Helium mission)
- IRC near-infrared spectroscopy of the mid-infrared sources

- To distinguish AGNs and others using the near-infrared spectra, and

- to detect PAH emission features at 3.3μm to reveal star-formation activity not only in star-forming galaxies but also in AGNs.
Result

- In MSAGN, 92 spectra are taken.
  - 44 AGNs (8 AGNs have PAH emission in 3.3 μm)
  - 36 star-forming galaxy
  - 12 red stars

- We also performed optical spectroscopy from the ground.
  - Lick 3m, KPNO 2m, SAAO 2m
The 9μm fluxes of our sample are below 300 mJy. Most of them are located at z<0.2. The redshift distribution of AGNs slightly shifts to higher redshift.
PAH emission features at 3.3μm in star-forming galaxies

(Yamada et al. #2-18)
Combination with other wavelength

- Subaru follow-up observation of an AKARI quasar
  - (Aoki, Oyabu et al. 2011)

- SDSS+α vs. AKARI MIR All Sky Sources
  - Toba et al. (Tomorrow)

- SWIFT/BAT vs. AKARI All Sky Sources
  - Ichikawa et al. (Today)
  - Matsuta et al. (Poster #1-10)

- XMM-Newton vs. AKARI All Sky Sources
  - Hirata et al. (They are not here.)
Discussion:

Hot dust in a star-forming galaxy

- LEDA 84274

Optical spectrum indicates it is a star-forming galaxy.

Steep continuum suggest AGN.

Z = 0.0377

(Oyabu et al. 2011)
In order to explain the NIR spectra, 600K blackbody is necessary.

(Oyabu et al. 2011)
The other example

- IRAS 01250+2832

Detail observations of CO absorptions are reported by Shirahata et al. #2-12.
SED of IRAS 01250+2832

For this galaxy, 500K black body is necessary.

Subaru near-infrared imaging with AO
The situation that OB stars produce more than $10^{11}$ Lsun in 1 cubic parsec are difficult, because crossing and relaxation times are short (10000yr and 1Myr, respectively). If the situation is 1000 ~ 10000 massive and obscured star forming regions with 500k dust, we can explain our 500k dust detection. This is reliable?????
We have performed X-ray observations with Suzaku at 0.4-10 keV.

Suzaku did not detect both of them.

- Expectations: $5 \times 10^{-12} - 2 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ with $N_H < 10^{24}$ cm$^{-2}$.
- Suzaku limits: $1 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$

Gandhi et al. 2009
The host galaxies

- **LEDA 84274**
  - $D_n(4000)=1.1$
  - Galaxy mass: $6\times10^9$ M$_\odot$

- **IRAS 01250+2832**
  - $D_n(4000)=1.6$
  - Galaxy mass: $4\times10^9$ M$_\odot$

- The AGNs from our mid-infrared search harbor in less massive galaxies than optically-selected AGNs do.
- If dusty AGNs are in the growing stage, the relation between a dusty and a less massive host galaxy might be important.

Kauffmann et al. 03
One more Dusty AGN

• MSAGN 1920074

6dF Spectrum
z=0.019

2.5 um 5.0 um

vLv(L_sun)

$\text{Ha}$

450K dust
AGNs and the host galaxies

- **LEDA 84274**
  - D$_n$(4000) = 1.1
  - Galaxy mass: 6x10$^9$ M$_{\odot}$

- **IRAS 01250+2832**
  - D$_n$(4000) = 1.6
  - Galaxy mass: 4x10$^9$ M$_{\odot}$

- **MSAGN 1920074**
  - Galaxy mass: 3x10$^{10}$ M$_{\odot}$

We can still say they are in less massive population, but ....
Summary

- We are performing dusty AGN search with AKARI MIR All-Sky Survey and AKARI NIR spectroscopy.
- We took 92 near-infrared spectra with AKARI IRC in Phase 3.
- We detected hot dust in 3 galaxies which do not show any evidence of AGNs in other wavelengths.
  - The suitable explanation is the existence of AGNs.
- These dusty AGNs might live in less massive galaxies than optically selected AGNs do.
  - We only have 3 samples. We need to investigate more.