Near Infrared Background Spectrum Obtained by AKARI

Tsumura et al. 2013, PASJ 65, 119: Zodiacal Light, Data Reduction
PASJ 65, 120: Diffuse Galactic Light
PASJ 65, 121: Extragalactic Background

Tsumura Kohji
Frontier Research Institute for Interdisciplinary Science,
Astronomical Institute, Graduate School of Science,
Tohoku University

with
Matsuura Shuji(Kwansei Gakuin)、Wada Takehiko(ISAS)
Matsumoto Toshio(ASIAA, ISAS)、Sakon Itsuki(UoT)
New NIR EBL observation is needed

- **COBE/DIRBE**
  - Launched in 1989
  - New result by Sano et al. (2015)

- **SFU/IRTS**
  - Launched in 1995
  - New result by Matsumoto (2015)

- **HST/WFPC2**
  - Launched in 1990
  - WFPC2 was installed in 1993

- **Pioneer 10/11**
  - Launched in 1972/1973

- **New observation**
  - **AKARI**

See his poster
AKARI InfraRed Camera

- InfraRed Camera (IRC) onboard AKARI (ASTRO-F)
  - Launched in 2006
- IRC has low/high-res. spectroscopy capability
  - low-res. spectroscopy ($\lambda \sim 1.8$-5.5 $\mu$m) for diffuse brightness at a slit with analysis

- It is difficult for Spitzer to observe absolute diffuse brightness because of the cold shutter problem.
- ISL can be negligible owing to its good spatial resolution and sensitivity ($K > 19$mag)

<table>
<thead>
<tr>
<th>Detector</th>
<th>NIR</th>
<th>MIR-S</th>
<th>MIR-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel number</td>
<td>512x412</td>
<td>256x256</td>
<td>256x256</td>
</tr>
<tr>
<td>FoV (arcmin)</td>
<td>9.5x10.0</td>
<td>9.1x10.0</td>
<td>10.3x10.2</td>
</tr>
<tr>
<td>Pixel scale (arcsec)</td>
<td>1.46</td>
<td>2.34</td>
<td>2.51x2.39</td>
</tr>
</tbody>
</table>
Data Reduction
Data selection

- Data obtained from AKARI Data Archive DARTS
  - Data obtained before LHe exhausted  (2006 Sep.~2007 May)
  - 349 data sets are selected
- Some “Bad” data were removed  (349→278)
  - Stray light and/or contaminations from nearby bright sources
  - Astronomical objects on the slit.
Dark Current variation

High charged particle density in South Atlantic Anomaly (SAA)

→

Dark Current was increased after SAA passage

Dark current decay timescale is \( \sim 10000 \text{ sec} \) (\( \geq \)orbital period)

Doi et al. 2015

Normal State

After SAA pass.

Doi et al. 2015

Time after SAA pass [sec]

Dark Current Level
New Method for Dark Frame Estimation

- 4500 frames taken before the LHe exhaustion (Phase-1/2)
- Good linear correlation between dark currents at the masked region and each pixel

\[ D_{ij} = A_{ij} \cdot C + B_{ij} \]

- \( C \): averaged dark current in the box
- \( D_{ij} \): dark current in a pixel at \((i, j)\) position
- Find \( A_{ij} \) and \( B_{ij} \) using 4500 dark frames
- Dark frame for science data can be estimated
Histogram

$A_{ij}$

$B_{ij}$
Point source masking

- Point sources brighter than 19 Vega mag @ 2µm was masked
  - ISL is negligible  ISL=0
- Hot pixels were also masked
- 1D spectrum was obtained by averaging of the masked images.
Distribution of the data

278 data points were used taken in the cold mission (before Exhaust of LH2) (2006/Nov ~ 2007/May)

Foreground separation by correlation analysis

\[ ZL \rightarrow \text{correlation to ZL model} \]
\[ DGL \rightarrow 100 \mu m \text{ dust correlation} \]

Spectral catalog public release
http://www.ir.isas.jaxa.jp/AKARI/Archive/Catalogues/IRC_diffuse_spec/

<table>
<thead>
<tr>
<th>Field</th>
<th>Data #</th>
</tr>
</thead>
<tbody>
<tr>
<td>① AKARI NEP field</td>
<td>80</td>
</tr>
<tr>
<td>② Spitzer dark field</td>
<td>38</td>
</tr>
<tr>
<td>③ Gal.Lat.&gt;5 deg(except ①&amp;②)</td>
<td>56</td>
</tr>
<tr>
<td>④ Gal. Plane (-5deg&lt; b&lt; 5 deg)</td>
<td>35</td>
</tr>
<tr>
<td>⑤ Gal.Lat.&lt; -5 deg</td>
<td>69</td>
</tr>
</tbody>
</table>
Examples of the spectra

Galactic plane

**DGL**

- 3.3um PAH
- 5.25um PAH

Br-α
Diffuse Galactic Light
Correlation of DGL to dust/gas

- Intensity of 3.3µm PAH in DGL was investigated to b<15 deg
  - Good correlations to dust (SFD 100um) and gas (HI)
  - Correlation to dust is much better than gas.
  - Previous works used the correlation to gas.
DGL separation

- DGL = radiation from dust in our Galaxy
- Galactic dust $\propto$ FIR(100um)

$\text{SKY}_{\lambda} = \text{ZL}_{\lambda} + \text{DGL}_{\lambda} + \text{EBL}_{\lambda}$

$\text{SKY}_{\lambda} - \text{ZL}_{\lambda} = \text{DGL}_{\lambda} + \text{EBL}_{\lambda}$

$= a_{\lambda} \times I_{100\mu m} + b_{\lambda}$

- First observational separation of DGL spectrum at NIR by correlation method to 100um map
- DGL spectrum was subtracted by scaling to SFD map

Tsumura et al. (2013b), PASJ 65, 120
DGL from optical to NIR

- Continuous DGL spectrum obtained with CIBER and AKARI

Arai et al. (2015) See his poster
Zodiacal Light
Two Components in ZL

- ZL has two components
  - Scattered sunlight (<3.5 µm)
  - Thermal Emission (>3.5 µm)

- Relative brightness of these depends on fields.
  ⇒ ZL model should be modeled separately

![Graphs showing intensity and ratio vs. wavelength in ZL](image)
Temperature of thermal component

- Previous observations showed $T_{\text{pole}} > T_{\text{plane}}$ at >5μm (main component)

  IRAS 12, 25, 60 μm (Hauser+84)
  Plane: 244±44 K
  Pole: 275±57 K

  ISO 5-16μm (Reach+03)
  Plane: 268.5±0.4 K (60deg)
  244.1±0.6 K (120deg)
  Pole: 274±1.1 K

- ZL at plane includes emission from farther dust with lower temperature

- IRTS found 300K component without ecl.lat dependent (Ootsubo+ 98,00)
AKARI confirmed the 300K component

- No Ecliptic latitude dependence at <5µm
- This high temperature component can be explained by sub-micron size dusts
  - Micro-craters on the samples from an asteroid by HAYABUSA

- Similar example can be found in a comet 17P/Holmes (2007)
  - 360±40K @3-4µm
    (Yang et al. 2009)
  - ~200K @12.4µm, 24.5µm
    (Watanabe et al. 2009)
- Mixture of large dust (200K) and submicron dust (>300K)
  (Ishiguro et al. 2010)
Zodiacal Light Modeling

- ZL spectrum was separated by ecliptic latitude dependence
  - DGL was subtracted before differencing
  - CIB was canceled out by differencing

- ZL absolute brightness is based on Kelsall model
  - Scattered sunlight: Kelsall 2.2 µm
  - Thermal emission: Kelsall 4.9 µm

\[
ZL_i(\lambda) = ZL_i^{\text{scat}}(\lambda) + ZL_i^{\text{thermal}}(\lambda),
\]
\[
ZL_i^{\text{scat}}(\lambda) = \text{DIRBE}_i^{2.2\mu m} \times ZL_i^{\text{scat}}(\lambda),
\]
\[
ZL_i^{\text{thermal}}(\lambda) = [\text{DIRBE}_i^{4.9\mu m} - ZL_i^{\text{scat}}(4.9\mu m)] \times ZL_i^{\text{thermal}}(\lambda).
\]
Extragalactic Background Light
ZL separation

- AKARI ZL spectrum was consistent with previous ZL observations.

- Correlation analysis

  SKY$_\lambda$ - DGL$_\lambda$ = ZL$_\lambda$ + EBL
  
  = $c_\lambda$*DIRBE + $b_\lambda$

  ZL scaling is based on DIRBE ZL model (Kelsall et al. 1998)

  $C_\lambda \sim 1(\pm 5\%)$, $b_\lambda$ is EBL

Tsumura et al. (2013a), PASJ 65, 119
EBL excess over ILG was confirmed by AKARI/IRC!

Tsumura et al. (2013c), PASJ 65, 121
Spatial structure

- No spatial structure was found.
- ZL and DGL were subtracted correctly.
Summary

- Low resolution spectroscopy of diffuse sky at 1.8-5.3 µm was obtained by AKARI
  - Much better point source removal than previous results by DIRBE and IRTS
- Component separation was successful by AKARI IRC low resolution spectroscopy
  - Diffuse spectra of 278 fields are open to public
    - [http://www.ir.isas.jaxa.jp/AKARI/Archive/Catalogues/IRC_diffuse_spec/](http://www.ir.isas.jaxa.jp/AKARI/Archive/Catalogues/IRC_diffuse_spec/)
  - EBL Excess emission after subtraction of ZL and DGL was confirmed.