NEAR INFRARED BACKGROUND RADIATION

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OUTLINE

• Introduction

• Fluctuation measurements with AKARI
  • Monitor field
  • NEP-deep field

• Origin
BACKGROUND RADIATION OVER WIDE SPECTRAL RANGES

Hauser & Dwek 2001, ARAA
COSMIC INFRARED BACKGROUND RADIATION (CIRB)

- Residual light in long exposure IR image after removal of contribution from all known sources
  - Stars
  - Galaxies
  - Diffuse Galactic light
  - Zodiacal light
- Issues
  - Accuracy of measurement
  - Origin

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RELEVANT STUDIES

• COBE
  • Hauser et al. (1998): excess emission in near to far IR
  • Cambresy et al. (2001), Levenson et al. (2007): Existence of CIRB in NIR

• IRTS
  • Matsumoto et al. (2005): spectrum from 1.6-4 micron

• Spitzer
  • Kashlinsky et al. (2005, 2007, 2012): significant fluctuations at 100-300 arcsec scale

• Other Telescopes
  • AKARI: Monitor Field (Matsumoto et al. 2011), NEP-Deep (Seo et al. 2015)
  • CIBER: NEP area (Zemcov et al. 2014)
CONTROVERSY

• Uncertainties in foreground Zodiacal Light

• TeV γ-ray Blazar spectrum favors no excess above the contributions from faint galaxies (Ahronian et al. 2005, Mazin & Raue 2007)

• Energetics: claimed background light means too much generation of Pop. III stars (Madau & Silk 2005)

• Large angular scale fluctuations
FLUCTUATION ANALYSIS OF SPITZER DATA

Kashlinsky et.al 2007
NEW MEASUREMENT WITH AKARI

- Cold shutter $\Rightarrow$ accurate determination of dark current
- Deep and Wide Surveys
- Wavelength coverage to shorter wavelength
- Other ancillary data available: optical, ground based high resolution near-IR, mid-IR
FIELDS

- Observed areas
- Monitor field (Matsumoto et al. 2011)
  - circular field with 10 arcmin radius, used for the performance of the instruments
- NEP-Deep (Seo et al. 2015)
  - Blank field survey area of ~0.6 sq. deg.
※ The number in the scale bar is ADU scale.
REMOVING FOREGROUND SOURCES

1. 2σ Clipping: Removing pixels above or below the average by 2σ. Repeat this process 10 times.
2. Subtraction of outer part of point source using carefully modeled PSF
3. Subtraction of outer part of extended sources identified by CFHT optical catalogue. Their Flamingo images (higher spatial resolution at K band) are convolved with AKARI PSF and subtracted.
4. In order to make contribution of identified sources negligible, we masked a layer of one pixel around masked region.
5. For sources that are not masked in step 1 but for which step 2 or 3 were applied, we masked 8 neighboring pixels around the center of these objects.
Final images

- 2.4 μm, 39.8%
- 3.2 μm, 39.3%
- 4.1 μm, 36.8%
AKARI MONITOR FIELD RESULTS

Upper: sky
Lower: Dark

Straight: shot noise due to unresolved galaxies

Excess powers at > 100 arcsec

Matsumoto, Seo, Lee, et al. (2011)
PIXEL CORRELATION BETWEEN DIFFERENT BANDS

Correlation coefficient ~ 0.8

Correlation coefficient ~ 0.5
SPECTRUM OF FLUCTUATING COMPONENT

- Average value of power at $100'' < \theta < 300''$
- Rayleigh Jeans like blue spectrum ($\propto \lambda^{-3}$)
LARGER ANGULAR SCALE STUDY: NEP-DEEP FIELD

Large portion (~60%) of NEP-Deep survey area was affected by earthshine. We excluded such area.

2.4 μm 3.2 μm
• MUXbleed caused sudden changes in background: we corrected it by fitting the average background to the linear function.
FLUCTUATION SPECTRA

- Noise power was obtained by computing the fluctuation power for the difference images of two subsets of stacked images.

- True fluctuation was obtained by quadratically subtracting the powers of mosaic and the subset.

- Excess fluctuation power over all angular scales.

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The computed power can be affected by:

- **Masking**: too much masking could cause artificial fluctuations (mode coupling)
- **Map making procedure**: adjustment of background level of adjacent images (map-making transfer)
- **Finite beam size**: smear out fluctuations in small angular scale (beam transfer)

\[
\tilde{P}_2(q) = M(q)T(q)B(q)P_2(q)
\]
ESTIMATED FLUCTUATION SPECTRA

- Excess fluctuation power over shot noise up to \( \sim 1000 \) arcsec.
- Smooth continuation from Monitor Field Results
LARGE SCALE FLUCTUATION FROM SPITZER

Shot Noise
Known galaxies fainter than detection limits

Red: Total
Blue: High-z ΛCDM

Kashlinsky et al. 2012
DIFFUSE GALACTIC LIGHT (DGL)?

- DGL: Scattered stellar light
- FIR Emission: Thermal emission

⇒ DGL and FIR emission should be well correlated

No correlation between NIR and FIR!

AKARI 90 µm image at Monitor field (Matsuura et al. 2010)

NEP-Deep field

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CLUSTERING OF FAINT GALAXIES AT Z=2~3?

- Spectrum of red dwarf galaxies is red at near infrared (Chary et al. 2008)
- Expected fluctuation of galaxies fainter than Ks(Vega)>21 mag: 0.03 nW m^{-2}sr^{-1} at 600"
- AKARI observation at 2.4 μm: nW m^{-2} sr^{-1}
- Estimated fluctuation power is lower than observed

Chary et al. 2008
POP III STARS?

- Difficulty in explaining the TeV $\gamma$-ray spectra
  - $\gamma$-ray photons experience inverse compton scattering with IR background radiation
  - However, intrinsic spectra of TeV $\gamma$-ray galaxies are not known.
- Too much metal production (Madau & Silk 2005)
  \[
  \Omega_* \approx 0.045\Omega_B \left( \frac{F_J}{2.5\text{nW/m}^2/\text{sr}^{-1}} \right)
  \]
  - Absolute level uncertain
  - Collapse into black hole?

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INTRA HALO LIGHT (IHL)

- Diffuse light in intracluster has been found (IHL or ICL)
- The fraction and origin of IHL are not well known: accretion or in-situ
- IHL becomes an interesting component in understanding the formation and evolution of galaxies
IHL AS SOURCE OF IR BACKGROUND

- Larger fluctuation means strong clustering
- Clusters are known to show strong clustering than galaxies
- Angular scale distance varies slowly from z>1
- Larger fluctuation is expected from objects in broad range of redshifts

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INTRA-HALO LIGHT (IHL) AND OBSERVED FLUCTUATIONS

Zemcov et al. (2014), CIBER

- IHL may be able to account for most of the fluctuation at 10-100 arcmin.
WHAT ELSE DO WE NEED?

• Current measurement extends to ~1 degree

• Recent analysis of IRTS data by Matsumoto et al. (private comm.) shows excess power up to ~40 degree (tentative)
  • Such a large scale structure due to the same component?
  • Very local?

• MIRIS will fill the gap of 1-10 degree fluctuations
MIRIS CONCEPT

- Optics
  8cm aperture, F2
  Refractive optics
- Picnic array:
  51.6” pixel scale,
  3.67° x 3.67°
- Telescope is passively cooled by radiation to ~180K
COSMIC NEAR-INFRARED BACKGROUND: MIRIS OBSERVATION

- I & H bands
- NEP (North Ecliptic Pole): $>10^\circ \times 10^\circ$ (FOV = 3.67$^\circ \times 3.67^\circ$)
SUMMARY

- Unambiguous detection of Cosmic Infrared Background (CIRB) from various surveys
  - Spitzer: GOODS, UDS, EGS
  - AKARI’s Monitor field and NE-Deep field
  - CIBER: NEP
- Excess powers 100-1000 arc second
- Nearly Rayleigh-Jeans SED with possible peak around ~ 1.8 μm
- Difficult to explain with zodiacal light, diffuse galactic light or low-z faint galaxies
- Possible explanations
  - Pop III stars, and epoch of reionization? Maybe difficult
  - IHL appears to be a viable candidate, but more elaborate studies are necessary
- Future
  - Measurements at larger angular scale (~up to 10 degrees) and spectrum will help to understand the origin