A strong clustering of FIR-selected galaxies in the AKARI All-Sky Survey

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ABSTRACT

Various previous galaxy surveys have revealed that different types of galaxies show different spatial distributions. By comparing properties of their spatial distributions or clustering strengths, we can investigate the relationship between the environments where galaxies reside and the properties of galaxies. This provides us vital information on when, where, and how galaxies are formed. In our study, we focus on FIR-selected galaxies from AKARI All-Sky Survey data, which are considered to be dusty star-forming galaxies. We derive their three-dimensional power spectra to explore the statistical properties of their spatial distribution. Our final result is well approximated by a single power-law and similar to the one obtained from the previous study using IRAS PSCz data. Moreover, we also compare our result with the previous studies which use different samples of galaxies selected at other wavelengths, such as optical and UV. We find that our FIR-selected samples are more strongly clustered than the UV-selected galaxies, which are also actively star forming galaxies but tend to be younger than the dusty star forming galaxies. This result may be reflecting the spatial propagation of star forming activities from dense regions to less dense outer regions, or it may be due to some external environmental effects which induce dusty star formation in dense environments. Resolving the internal structures of the FIR-selected galaxies with AO imaging and/or IFU spectroscopy will tell us why they are strongly clustering and what their physical origins are.

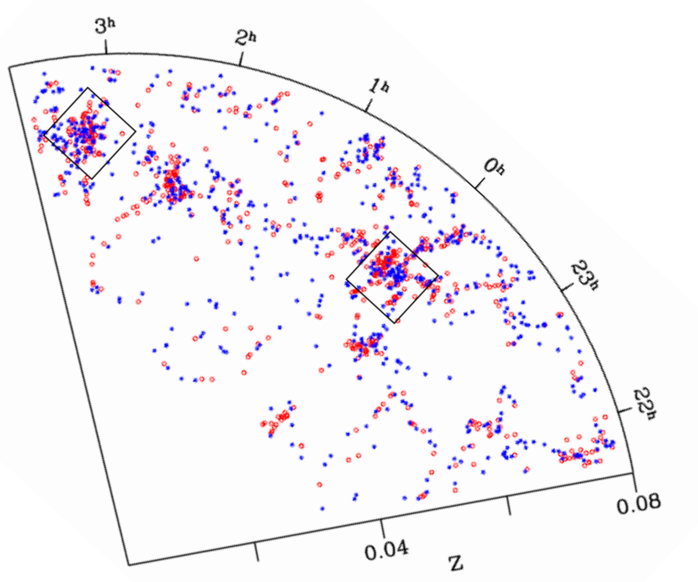
Introduction

◎ Spatial distribution of galaxies

➡ relate to various physical properties of galaxies

e.g., early-type galaxies or luminous galaxies show stronger clustering than late-type or less luminous galaxies (right figure).

This relationship is the key to understand the scenario of galaxy formation and evolution including their surrounding environments.



▲ Spatial distribution of galaxies observed by 2dFGRS : ● early-type, ● late-type (Norberg et al. 2002)

◎ Our motivation

Focus on the FIR-selected galaxies, which are considered as active star-forming galaxies obscured by dust, and investigate the statistical properties of their spatial distribution by estimating power spectrum.

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Compare power spectrum of FIR-selected galaxies with some galaxy samples detected at other wavelengths.

➡ How is the spatial distribution of dusty star-forming galaxies characterized compared with other galaxy populations??

Data & Sample selection

AKARI

- an infrared astronomical satellite launched by JAXA in 2006 (Murakami et al. 2006)
- two imaging instruments, the Far-Infrared Surveyor (FIS) and the InfraRed Camera (IRC)
- performed the second all-sky survey at infrared wavebands after IRAS
  : AKARI All-Sky Survey
- higher positional accuracy, higher sensitivity, and higher angular resolution

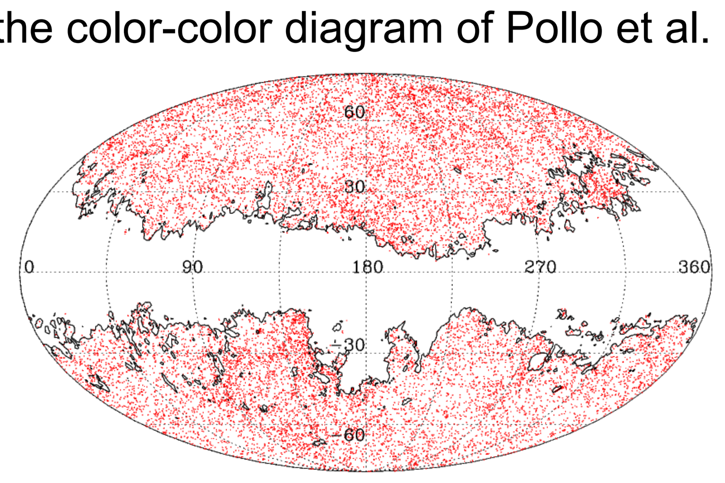
AKARI FIS Bright Source Catalog v.1.0

- Four wavebands centered at 65μm (*N60*), 90μm (*WIDE-S*), 140μm (*WIDE-L*), and 160 μm (*N160*)
- 427,071 point sources

Sample selection criteria

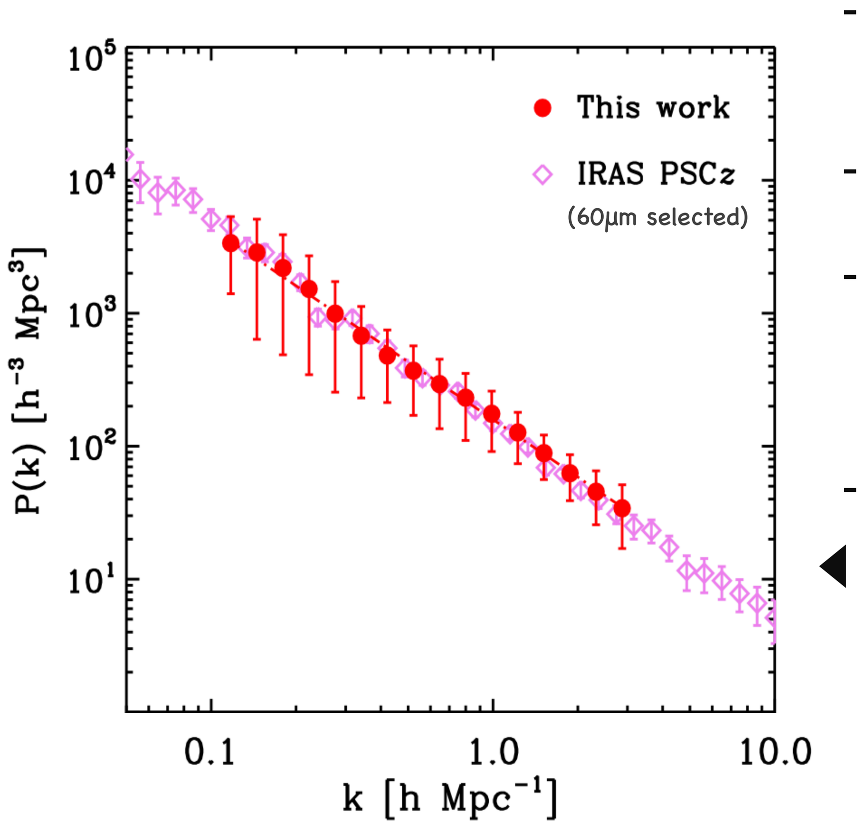
1. Scanned by AKARI at least 3 times and flux quality indicator : *FQUAL*=3 (high quality) at 90μm.
2. Reside in good sky region of IR, where 100μm emission measured from the Schlegel map is low ($I_{100} < 5$ [MJy sr^{-1}]).
3. Satisfy the criterion of star-galaxy separation by the color-color diagram of Pollo et al. (2010).

We obtained 18,077 galaxy candidates.



▶ Sky distribution of AKARI/FIS galaxies
The contour represents the threshold we adopted on the Schlegel map.

Power Spectrum of AKARI/FIS galaxies



◎ Method

- Divide sources into 4 regions along the Galactic longitude for northern and southern hemisphere respectively.
- Estimate two-dimensional power spectra $P_2(K)$ with the flat-sky approximation for each region.
- Convert two-dimensional power spectrum to three-dimensional power spectrum $P(k)$ by using Limber's equation (Baugh & Efstathiou 1994).
- Average power spectra of all 8 regions.

◀ Our final result

: well approximated by a single power-law

$$P(k) = 10^A k^n \quad \left\{ \begin{array}{l} n = -1.44 \pm 0.33 \\ A = \left(1.58^{+0.53}_{-0.40}\right) \times 10^2 \end{array} \right.$$

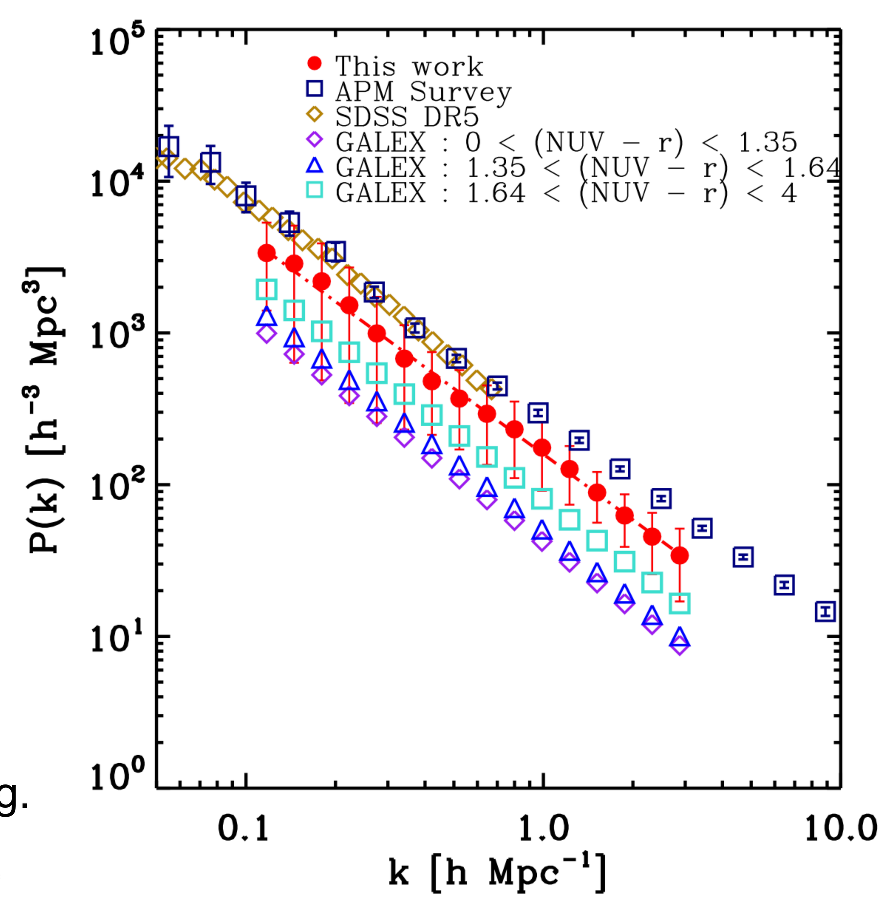
at k : 0.1 – 3 [hMpc^{-1}]

Consistent with the previous study using IRAS PSCz catalog (Hamilton & Tegmark 2002).

Comparison with other galaxy samples

◎ Optical-selected galaxies

- APM Galaxy Survey : Padilla & Baugh 2003
  galaxy sample brighter than $b_J = 20$
- SDSS DR5 : Percival et al. 2007
  main galaxy sample brighter than r=17.7
  + Luminous Red Galaxies (z < 0.5)



AKARI galaxies show lower clustering strength than APM and SDSS galaxies.

➡ FIR-selected galaxies distribute more uniformly than optical-selected galaxies.

Galaxies detected by optical survey
: include star-forming galaxies and non star-forming galaxies (early-type galaxies).

➡ early-type galaxies exist in more crowded regions, and thus they show strong clustering.

➡ this result reflects that FIR-selected galaxies are mainly star-forming galaxies.

◎ UV-selected galaxies

- GALEX : Heinis et al. 2009

➡ They derived three-dimensional correlation function *ξ(r)* for GALEX samples matched with SDSS galaxies at z < 0.3, and we estimated their power spectra by the fourier transformation. Samples were divided into three with their colors, NUV – r.

- 0 < (NUV – r) < 1.35
- 1.35 < (NUV – r) < 1.64
- 1.64 < (NUV – r) < 4

Blue ↑

GALEX sample with bluer color show lower clustering strength, and our AKARI galaxies show stronger clustering strength than any GALEX sample.

➡ FIR-selected galaxies have more biased spatial distribution than UV-selected galaxies.

★FIR- & UV- selected galaxies

Both of FIR and UV are good tracers of star-forming activity of galaxies.
UV and optical light from massive stars are more strongly obscured as star formation proceeds and dust amount increases.
Buat et al. (2007) found that galaxies in the local Universe with high bolometric luminosity (combination of IR and UV fluxes) are not contained in UV-selected samples. This means that galaxies with higher SFR are not detected at UV wavelengths because of the strong obscuration by dust.
From this, we suggest that our FIR-selected galaxies are more luminous and thus more actively star-forming than UV-selected galaxies on average.

➡ more actively star-forming galaxies show stronger clustering, i.e. they tend to distribute in denser regions.

Future prospects

What do our results mean??

★ star-forming activities spatially propagate from denser region to less dense outer region.
★ there are some environmental effects that induce dusty star formation in dense region.

Detailed observations of FIR-selected galaxies are required to consider these possibilities!!

➡ Resolving the internal structure of FIR-selected galaxies with AO imaging and/or IFU spectroscopy enables us to investigate the physical processes occurring in galaxies.

Performing high spatial resolution observations for FIR-selected galaxies in various environments and investigating the physical processes causing their properties lead to understanding which physical processes cause the strong clustering of dusty star-forming galaxies.

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