Properties of Dust and Galaxies in Dusty Era at z=1-2 explored by Multi-wavelengths Survey toward the North Ecliptic Pole

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To understand the physical process of evolution of galaxies over the cosmic time, it is essential to directly probe the "Dusty Era" at $1 < z < 3$. This era is hidden to optical tracers, and represents the bulk of the star formation and black hole accretion. Although near to far-infrared wavelengths are quite rich in various mineral, organic and ice features of cosmic dust, spectroscopic diagnostic study of such obscured galaxies has not yet been done so much by the space infrared telescopes ever launched due to their limited sensitivity, and therefore the dust properties in "Dusty Era" need to be studied by observations of broad-band spectral energy distributions. We have undertaken multi-wavelength deep surveys toward the North Ecliptic Pole (NEP) (0.5 deg^2, NEP-Deep, and 5.4 deg^2, NEP-Wide). The survey provides us with a few ten-thousands of 15 μm or 18 μm selected sample of galaxies, which is the largest sample ever made at this wavelengths. Here we introduce recent major results on the properties of dust and obscured galaxies out to z = 2 revealed by the NEP survey.

A continuous filter coverage in the mid-infrared wavelength (7, 9, 11, 15, 18, and 24 μm) of AKARI is unique and vital to unveil the luminosity density evolution from both starbursts and dusty AGNs out to z = 2. For example, rest-frame 8 μm is covered by AKRI bands at 11, 15, 18 and 24 μm bands for galaxies at $0.15 < z < 0.49$, $0.75 < z < 1.34$, $1.34 < z < 1.7$ and $1.7 < z < 2.05$, respectively. Goto et al. (2015) estimated rest-frame 8 and 12 μm, and total infrared luminosity functions at $0.15 < z < 2$, which were found to be consistent with previous works, but with reduced uncertainties. In order to study the evolution of dust attenuation, Buat et al. (2015) built an 8 μm selected sample of galaxies (about 4000 sources) in the NEP-Deep field. The attenuation in our mid-IR selected sample is found ~2 mag higher than that found globally in the universe or in UV and Hα line selections in the same redshift range. This difference is well explained by an increase of dust attenuation with the stellar mass, in global agreement with other recent studies. We conclude that the galaxies selected in IR and dominating the star formation exhibit a higher attenuation than those measured on average in the universe because they are massive systems. Furthermore, Oi et al. (2017) selected 47 dust-obscured galaxies (DOGs; defined by $R - [24] \geq 7.5$ AB mag; Dey et al. 2008), most of which are either bump-DOGs or power-law DOGs, and found that the dust temperature of power-law DOGs are higher than that of bump-DOGs, probably due to the AGN activity.

Recently, we carried out deep imaging of the NEP-Wide field in 5 broad bands (g,r,i,z, and y) using Hyper Suprime-Camera (HSC) on Subaru telescope (Goto et al. 2017). Also the NEP is now selected as a JCMT/SCUBA-2 legacy survey field (PI: Hyung Mok Lee), and 850 μm deep survey is on-going. Finally, it is noteworthy that NEP is one of high visibility regions in the sky with future space observatories; JWST, e-ROSITA, Euclid, and SPICA. Namely SPICA, the unique next-generation infrared space telescope with unprecedented spectroscopic sensitivity, will unveil the composition and physical properties of cosmic dust in the "Dusty Era".