Monitoring Observations of Buried AGNs in the NEP Field with *SPICA*

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ABSTRACT

We propose *SPICA*/MCS monitoring observation at North Ecliptic Pole region to search MIR-variable faint obscured AGNs to study faint end early phase AGN properties. We have carried out deep near to mid infrared survey with *AKARI*/IRC (2–24 μm) and follow-up multi-wavelength observations (X-ray–radio), and found many AGN candidates. However there is possibility to miss identify obscured AGNs which can be just-activated early phase ones. *SPICA*/MCS monitoring survey will give us a great help to investigate these early phase AGNs. When we carry out 1 hour observation, once per half a month, then we can survey 12 MCS-field-of-views ($12 \times 5' \times 5'$), and ~50 type-1 AGN and ~50–200 type-2 AGN detection is expected. This survey can monitor long time scale (3–5 years) variability of these AGNs.

1. ACTIVE GALACTIC NUCLEI

Studies in the last two decades indicate that there exists a strong correlation between properties of the galactic bulge (e.g., mass, luminosity, and velocity dispersion) and the mass of its central Super Massive Black Hole (SMBH) (Magorrian et al. 1998). The correlation links the notion that SMBHs may play an intrinsic role in galaxy formation and evolution. Active Galactic Nucleus (AGN) emits vast amounts of energy from the center region of galaxies by releasing gravitational potential energy of materials accreting onto a SMBH into radiative energy, indicating that the SMBH is in a phase of rapid growth. Therefore, an understanding the AGN properties is one of the most essential aspects in the study of AGN–galaxy co-evolution.

1.1. AGN identification

As AGNs are broadband emitters, they can be identified via a variety of multi-wavelength techniques. X-ray emission in AGN is thought to form in a hot corona around the accretion disk. Electrons in the corona inverse-Compton scatter optical and UV accretion disk photons to higher (i.e., X-ray) energies. These X-ray can easily come though the obscuring medium, provided that the column density of the torus is not Compton-thick (i.e., $N_{\mathrm{H}} > 10^{24}\,\mathrm{cm}^{-2}$). In the optical, prominent emission lines are usually visible in spectra of AGNs, resulting from accretion disk photons ionizing the surrounding gas. AGN can be identified with emission lines with broad line width (type-1 AGN) or emission line ratios (i.e., [O III]5007Å/Hβ and [N II]6583Å/Hα) known as BPT diagrams (Baldwin et al. 1981). Obscuring medium enshrouding an AGN absorbs optical and UV accretion disk photons and re-radiates the emission in the infrared. AGNs can thus be identified based on their MIR spectral energy distribution (SED) of power-law shape, or ratios of flux densities, providing a useful tool for selection those sources where the optical and UV emission are affected by strong extinction. Thus, in order to identify AGNs, multi-band data sets are needed.

1.2. *AKARI* NEP-Deep field

Japanese infrared satellite *AKARI* carried out wide and deep surveys with all nine bands (2–24 μm) of IRC in the North Ecliptic Pole (NEP) survey program (Figure 1). In addition, we carried out many follow-up observations at the NEP field in multi-wavelength (Table 1). These multi-band data sets are very powerful for studying AGN properties. From *Chandra* data (*left panel* of Figure 2), we can identify ~420 X-ray sources as AGN candidates. Several dozen of optical spectra show broad emission lines, and a few hundred *AKARI* sources have MIR power-law SED (right panel of Figure 2).

These different selection methods have various biases. X-ray emission will be extinct in Compton-thick sources due to both photo-electric absorption of X-ray photons and Compton scattering of photons out of the line of sight. Since optical emission lines used to identify AGN are attenuated in dusty galaxies, causing some AGN be missed. AGN samples selected by IR methods can be contaminated by star-forming galaxies, while some faint AGNs which do not dominate their MIR SED can be missed.

2. MONITORING SURVEY AT NEP FIELD WITH *SPICA*

2.1. Variability survey for AGNs

At the beginning of AGN phase, just-triggered AGN activities should be weak and AGN could be varied by a large amount of gas and dust. Although these objects are thought to exist as faint end obscured AGNs, they are hardly identified as AGN with those methods above. For identification of faint end dust obscured AGNs, variability observation can be

Table 1. Multi-wavelength data at NEP-Deep area

Imaging Data			
Observatory	Band	Area	Sensitivity
Chandra	0.5–7 keV	~0.25 deg^2	analyzing
GALEX	FUV, NUV	0.6° ϕ	NUV ~26 mag
Subaru/S-Cam	*B, V, R, i', z'*	27′ × 34′	*B*=28 AB
CFHT/MegaCam	*u*,g',r',i',z'*	~1 deg^2	*z'* ~24.5 mag
CFHT/WIRCam	Y, J, K_s	0.58 deg^2	YJK_s~23 mag
Herschel/PACS	100, 160 μm	~0.50 deg^2	100 μm ~4.8 mJy
Herschel/SPIRE	250, 350, 500 μm	7.11 deg^2	250 μm ~9.0 mJy
WSRT	1.5 GHz/20 cm	1.70 deg^2	0.5 mJy

Spectroscopic Data			
Observatory	Band	Sources	Sensitivity
Keck/DEIMOS	optical	~420	R~24 AB
MMT/Hectoscpec	optical	~1800	R~23 AB
+ WIYN/HYDRA			
Subaru/FMOS	*J*-long	~100	analyzing

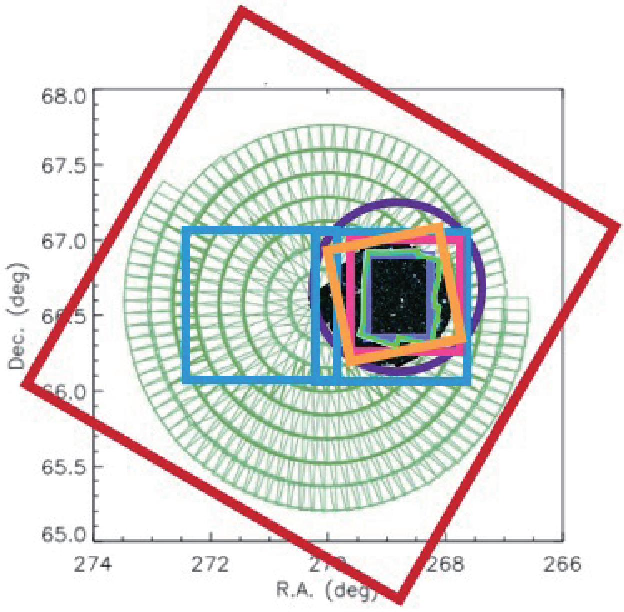
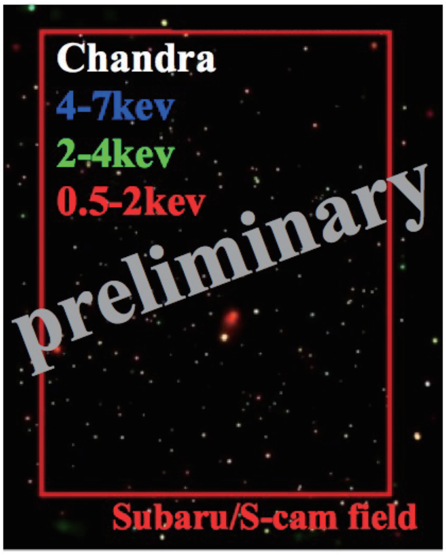


Figure 1. The coverage of multi-band surveys in the NEP field. Dark green circle and image regions represent *AKARI* NEP-Wide and Deep survey areas. The light green, dark purple, light purple, light blue, pink, orange, and dark red show the regions of *Chandra*, *GALEX*, Subaru/S-Cam, CFHT/MegaCam, CFHT/WIRCam, and *Herschel*/PACS, and *Herschel*/SPIRE observation areas, respectively.

powerful. In the past, many studies of AGN variability have carried in optical wavelength (e.g., Vanden Berk et al. 2004; Morokuma et al. 2008), and found that variability amplitude is higher for lower luminosity AGN — meaning that variability study could be a great method for identification of faint AGNs. In fact, ~50 % of variability sources are not identified by X-ray nor MIR, suggesting the possibility that the AGNs identified by variability are early phase AGNs. However, it is still possible that heavily obscured AGNs can be missed in optical observation.

Kozłowski et al. (2010) carried out the monitoring survey with *Spitzer* (<18 mag in 3.6 and 4.5 μm) and found that variability amplitude of AGN is still higher for lower luminosity in infrared wavelength — meaning the IR variability



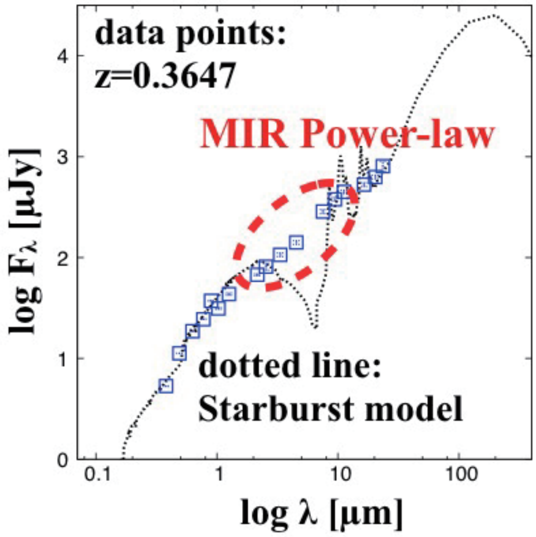


Figure 2. (*Left*) Three color X-ray image made with *Chandra* images (*blue*:4–7 keV, *green*:2–4 keV, *red*:0.5–2keV). ~420 sources are detected. (*Right*) Power-law shape MIR SED. Blue squares are observed data, and dotted line represents starburst SED model.

study is also powerful for faint AGNs. The monitoring survey carried out for ~ 2 years and objects brighter that 18 mag are detected. However, from optical variability surveys, there should exist sources fainter than 18 mag in infrared band.

2.2. **Survey Design**

We aim to investigate properties of faint end dusty AGNs, we propose monitoring survey at NEP field with *SPICA*/MCS. This survey utilizes the great sensitivity of *SPICA*/MCS and good location of NEP where is observable in and out of season from space. Moreover, since we already have multi-band data sets, we can scrutinize the properties of discovered faint end obscured AGN from every angle.

From the previous optical and infrared variability AGN studies, the scale of variability amplitude is more than 0.1 mag on timescales of 1–2 years. In order to detect the amplitude of 0.1 mag with S/N = 3, S/N ~ 30 detection on each epoch is needed. The sensitivity of MCS/WFC-S (5–25 μm) is 0.13–3.5 μJy (1 hour, 5σ). When we run 1 hour observation, sources with up to 0.78–21 μJy (24.16–20.59 mag) can be detected with $>30\sigma$. 20.5 mag at 25 μm consists with $i \sim 24.5$ mag with SED templates of Bruzual & Charlot (2003) and Dale & Helou (2002). According to Morokuma et al. (2008), surface density of type-1 AGN is ~500 type-1 AGN/deg^2 (i<24.5 mag). Since the field-of-view (FoV) of MCS is $5' \times 5'$, 4 type-1 AGN could be detected in the FoV with $>30\sigma$. The number of type-2 AGN would be 1 to 4 times larger than those of type-1 AGN, 4 to 16 type-2 AGN/FoV($5' \times '$) detection can be expected. If we carry out 1 hour observation, once per half a month, then we can survey 12 MCS FoV in a half year, and then ~50 type-1 AGN and ~50–200 type-2 AGN detection is expected. When we continue this monitoring observation for 3–5 years (*SPICA*'s life) as a half month is 1 cycle, we can monitor variability of these AGNs with long time scale.

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