Environmental Effects on AGN Activities from an Extinction-Free Mid-Infrared Census

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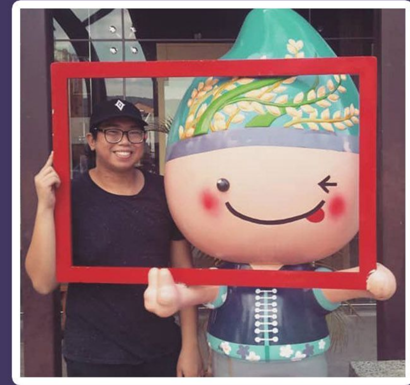


What is an AGN?

Active galactic nuclei (AGNs) are manifestations of the accretion (collection of materials) of supermassive black holes (SMBHs) that weigh up from milion to billion times the Sun's mass and are believed to reside in the center of most galaxies.

Credits: NASA JPL

The gravitational energy released by the accreted materials produces radiation of great luminosity.

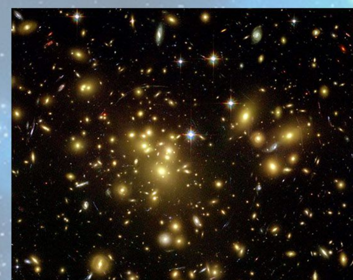
Why study AGNs?

Previous observations revealed that SMBH formation is correlated with galaxy formation as if they affect each other. However, the physical scale betwen the SMBH and galaxy is very different, that no one expects this correlation. This is one of the biggest mysteries in astronomy.

Role of galaxy environment in Black Hole-Galaxy Coevolution

The last key to uncovering the mystery of SMBHs is the role of galaxy environment. Galaxy environment refers to the immediate vicinity of galaxies, whether they live in:

Galaxy cluster or denser environment



Credits: UniverseToday

vs.

Isolated field or less dense environment

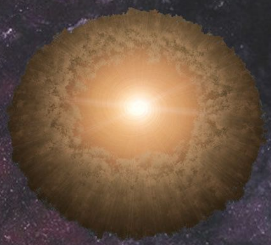
Credits: Frosty Drew Obsvervatory

Galaxy environment affects certain galaxy properties, but its effect on AGN activities is still unclear.

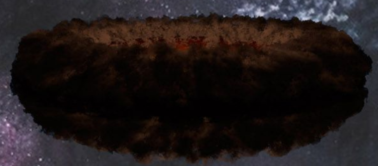
The last key in this research field: Unveiling the effect of galaxy environment on AGN activity

Credits: NASA WISE

Credits: JAXA



Non-obscured AGN

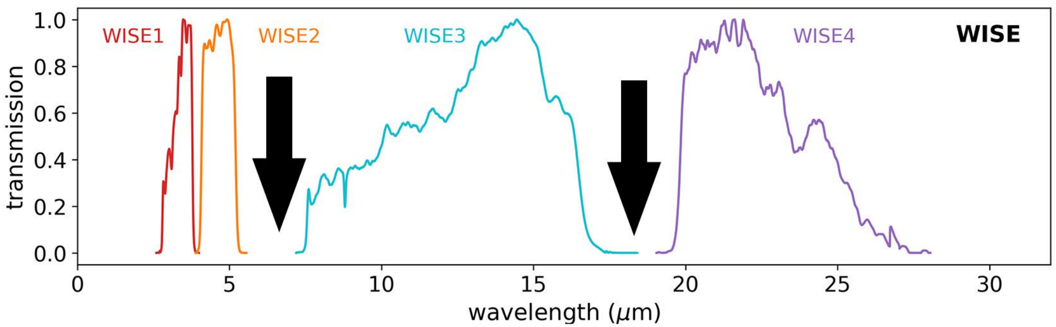


Obscured AGN

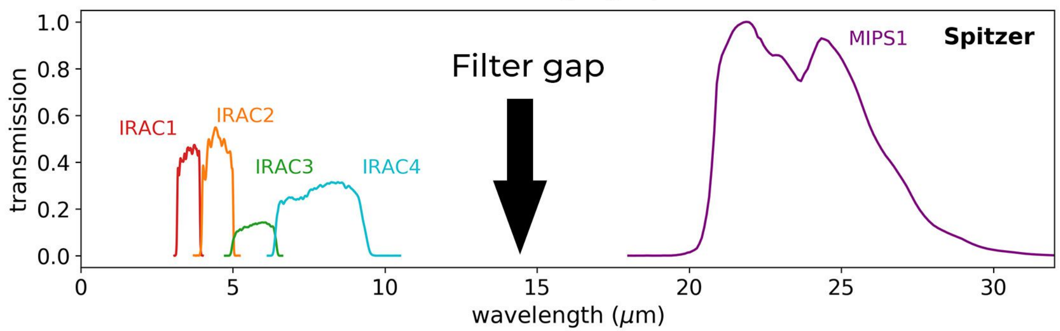
Some AGNs that are obscured by dust are missed by commonly used surveys in certain wavelength regions. Radio telescopes can only cover 10% of radio-luminous AGNs, while X-ray telescopes have limited sensitivity and are also expensive. Since dust emits radiation in the mid-infrared (MIR) region, it makes sense to use mid-infrared surveys to observe these dust-obscured AGNs.

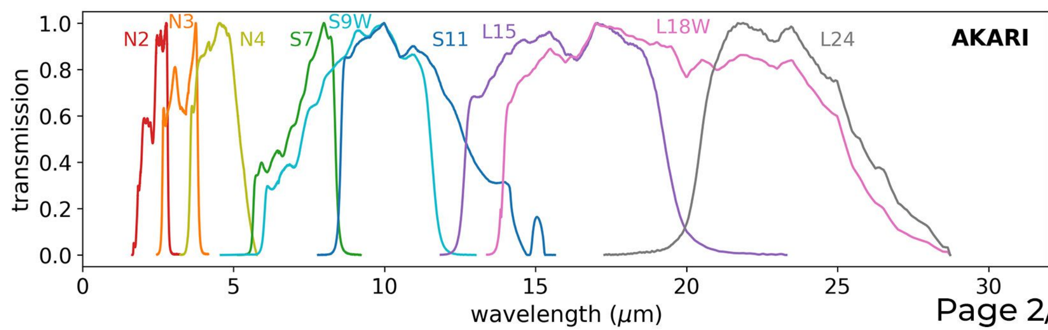
AKARI Infrared Telescope

We want to cover dust-obscured AGNs that can be observed in the mid-infrared region using the AKARI Infrared Telescope.



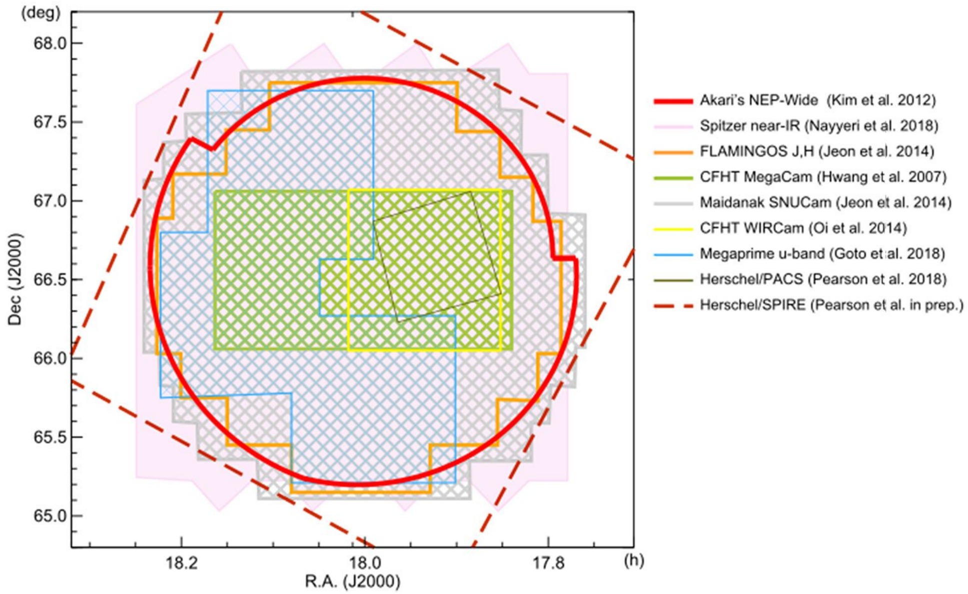
Other MIR telescopes like WISE and Spitzer have gaps in their filter responses (transmission vs. wavelength), which may be disadvantageous if the spectral features of AGNs/galaxies lie on these gaps. But with AKARI's 9-band continuous filter coverage, we can overcome this problem.





Where do we select MIR AGNs/galaxies?

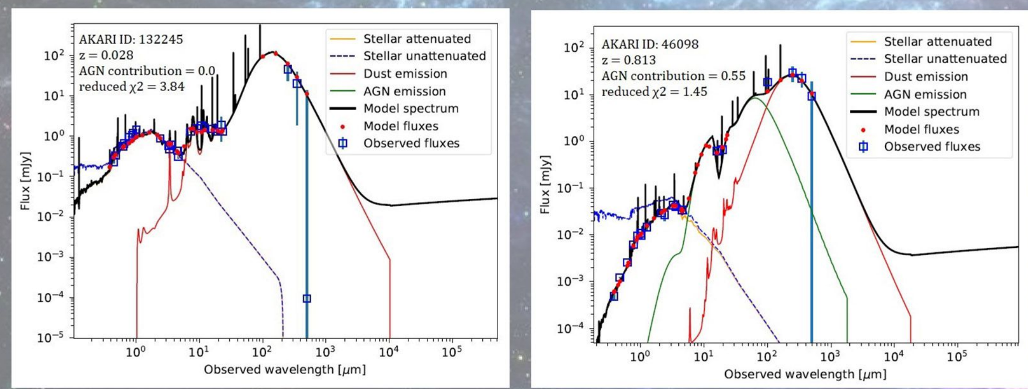
MIR galaxies are selected in the AKARI North Ecliptic Pole (NEP) Wide Field which is observed by many other telescopes (e.g. HSC, WISE, CFHT, etc.) providing multiwavelength observations for our sources (Kim et al. submitted).



AKARI NEP Wide Field and region coverages of other telescopes, derived from Kim et al. (submitted)

How do we constrain galaxy properties?

A spectral energy distribution (SED) is a plot of energy as a function of wavelength. The galaxy SED dramatically changes especialy at MIR wavelength, when the galaxy hosts an AGN due to its luminous radiation. Using the SED fitting code, CIGALE*, we produce the best SED fit from the multiwavelength data we have for our sources.



Sample SED fitting result using CIGALE for a galaxy (left) and AGN (right), derived from Santos et al. (in prep). Take note of the different emissions provided by the source in different colored lines.

*https://cigale.lam.fr/

How do we measure galaxy environment?

Galaxy number density is calculated using optically selected galaxies by the HSC telescope in the AKARI NEP Wide Field. It is inversely proportional to the square of the target galaxy's distance to the 10th nearest neighbor galaxy. Density values are then normalised by the median density of the redshift range where the density is calculated (if a galaxy has higher redshift, that means it lives in a more distant or earlier Universe).

Different types of IR Galaxies, and some AGN-related terminologies

Galaxies are classified based on total IR luminosity (L_{IR}) in units of luminosity of the Sun (L_{sun}).

Infrared Galaxies (IRGs): $\log(L_{IR}/L_{sun}) \leq 11$

Luminous IRGs (LIRGs): $11 < \log(L_{IR}/L_{sun}) \leq 12$

Ultraluminous IRGs (ULIRGs): $\log(L_{IR}/L_{sun}) > 12$

Galaxies in each luminosity type are divided into **redshift (z)** bins from 0 to 1.2.

AGN number fraction

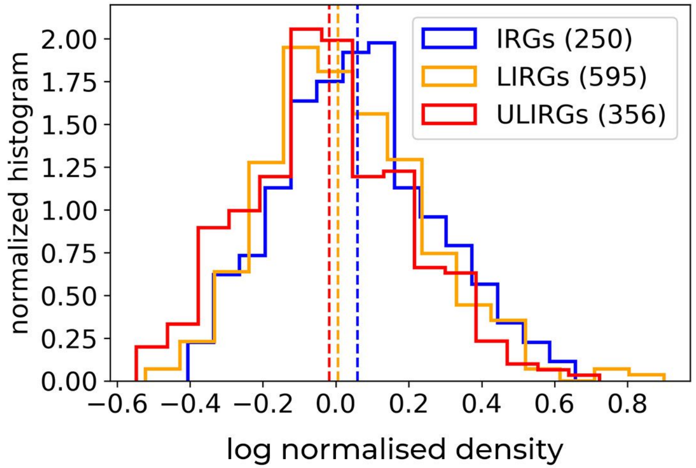
$$= \frac{\text{\# of AGNs in density bin}}{\text{total \# of galaxies in density bin}}$$

AGN contribution fraction

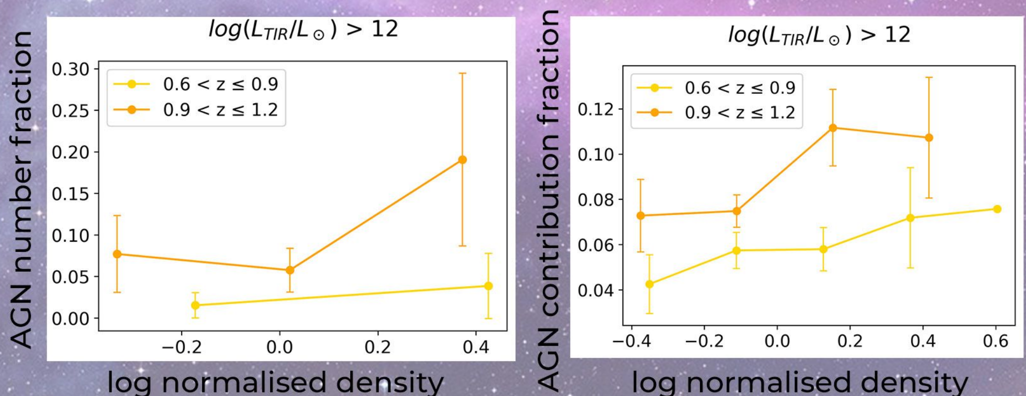
$$= \frac{\text{AGN luminosity}}{\text{total IR luminosity}}$$

More luminous galaxies live in less dense environments

Less dense environments provide better frequency for dynamical merging, supporting the fact that **very luminous IRGs (e.g. ULIRGs) are merger systems** (Goto, 2005)



ULIRG AGNs live and are more powerful in denser environments



Only for ULIRGs we find trend in their AGN activities: **there are more ULIRG AGNs in denser environments and they are more powerful there.**

Conclusion and Future Works

As we covered previously-missed dust-obscured populations, we found that only ULIRG AGNs are the ones affected by environmental effects. The exact reason as to why we see a trend only in ULIRG AGN activities is yet unclear. Looking into other environment definitions such as **cluster-field classification** (whether a galaxy is belongs to a cluster or not) and **clustercentric distance** (distance of galaxy to the nearest galaxy cluster center) will definitely help us pinpoint this reason in the near future.

Watch my summary talk about this research here:

Visit my personal website here: