銀河進化研究会 @NAOJ

June 5, 2014

Buried AGN activity in infrared galaxies studied by AKARI 2.5-5 um spectroscopy

submitted to ApJ

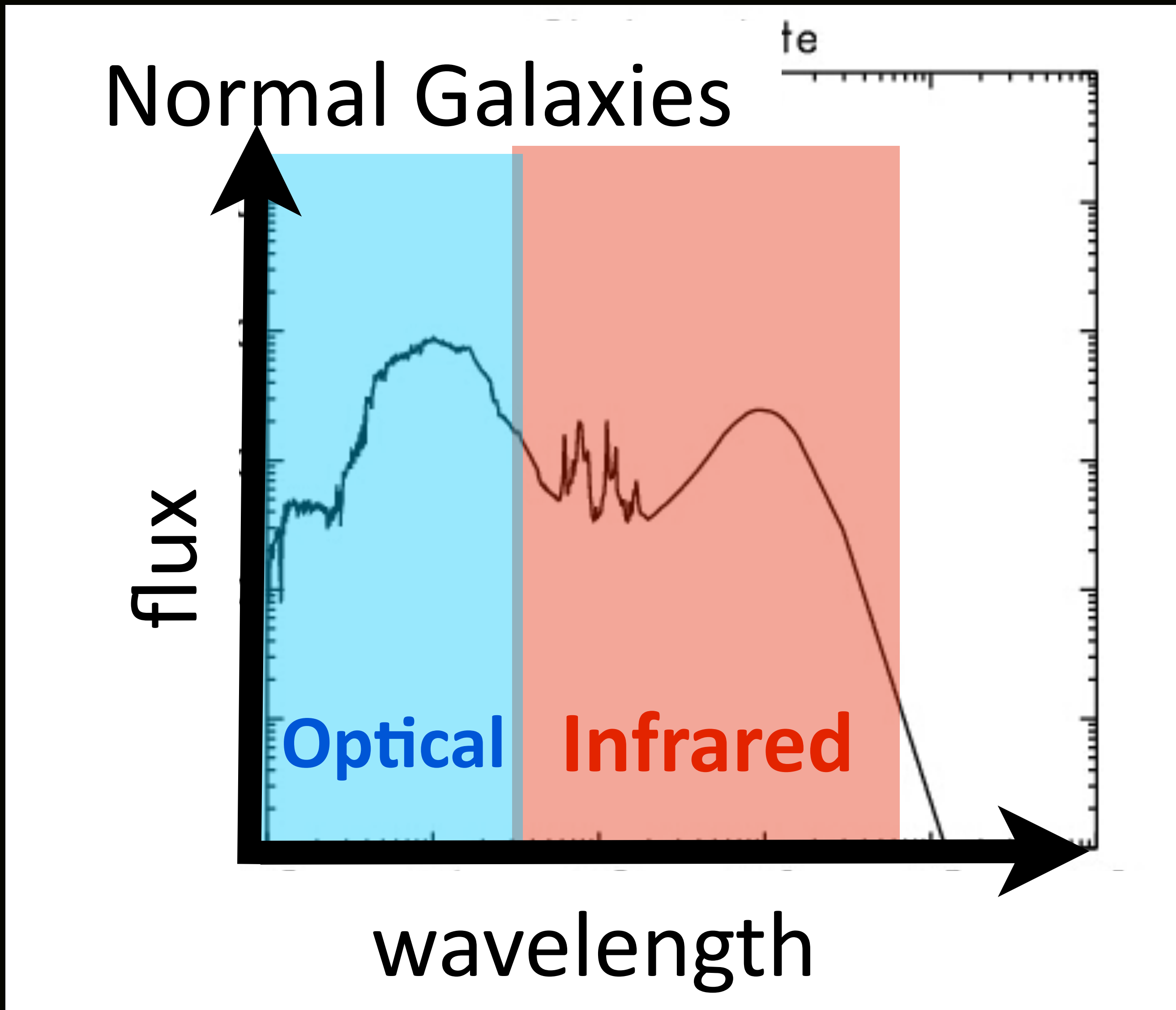
京都大学 KYOTO UNIVERSITY

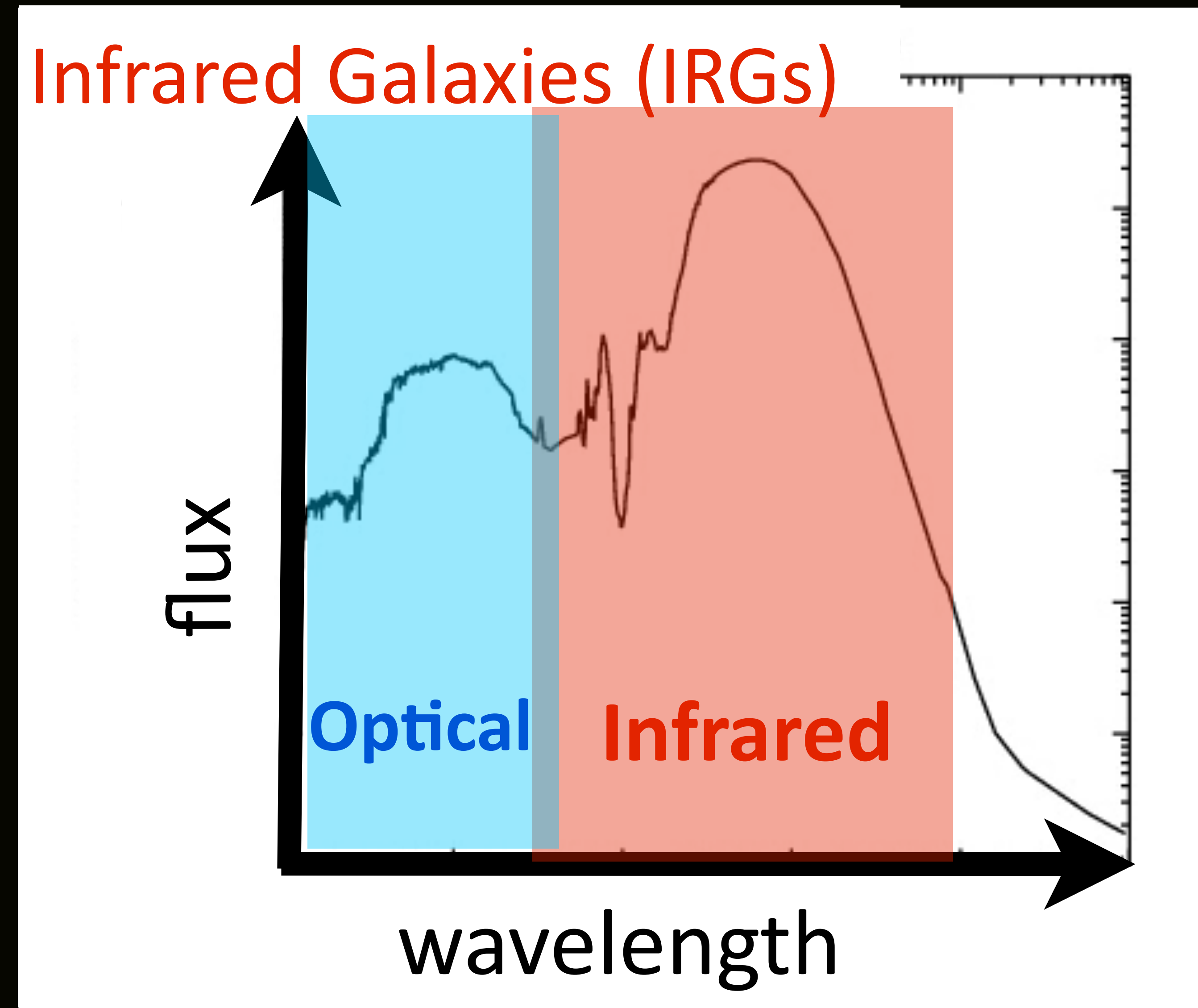
ICHIKAWA, Kohei
市川幸平
(Kyoto University)

Collaborators

Y. Ueda, M. Imanishi, T. Nakagawa, M. Shirahata, H. Kaneda, S. Oyabu

Motivation: Hidden Energy Source





Infrared Galaxies: very bright in IR than optical

✔ Hidden energy source should exist behind the dust

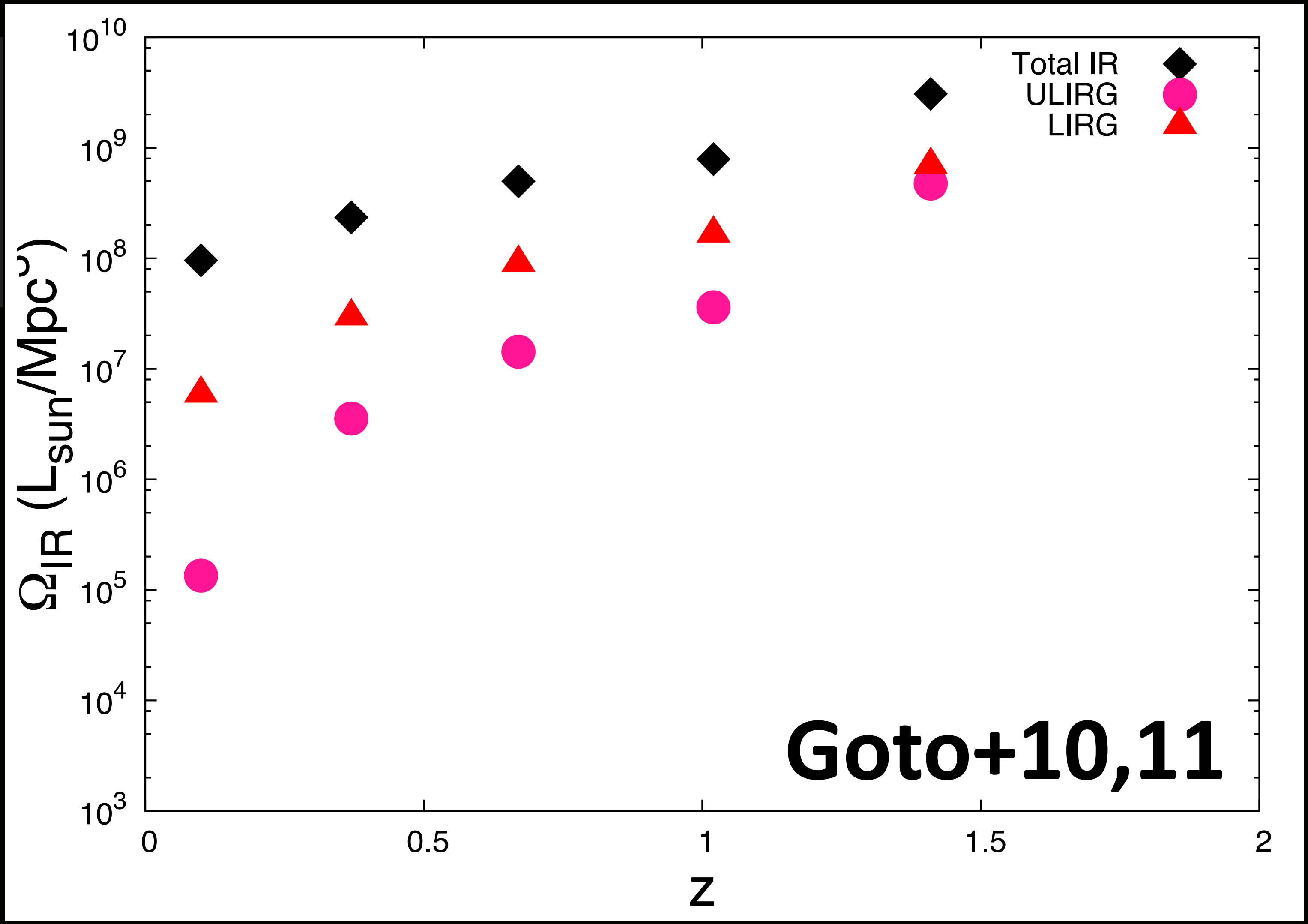
✔ Possible energy sources: Starburst (SB) and/or AGNs

→ **Disentangling two energy sources are crucial** to understand the starformation and AGN activity

Energy importance of infrared galaxies

LIRG: $L_{IR} > 10^{11}$ L_{sun}

ULIRG: $L_{IR} > 10^{12}$ L_{sun}



infrared galaxies become important energetically in high-z Universe, but still there are many observational difficulties

- ✔ **Making and testing a diagnostic model to disentangle two energy sources in the local Universe is crucial**
- ✔ **Then, applying the diagnostic in the future**

Sample: Infrared Galaxies

Our motivation: Finding very obscured, *"buried"* AGN

✔ **Infrared Galaxies w/o any AGN sign in the optical band in the local Universe are suitable.**

66 U/LIRGs are Selected from...

☑ Bright ULIRG catalog (ULIRGs w/ f_{60um} > 3 Jy; Klaas+01)

☑ IRAS BG LIRG catalog (LIRGs w/ f_{60um} > 5.4 Jy; Carico+88)

<- Far-IR flux limited (=good dust peak tracer)

12 IRGs ($L_{IR} < 10^{11} L_{sun}$) are selected from...

☑ IRAS 12 um catalog

<- To increase the number of IRGs

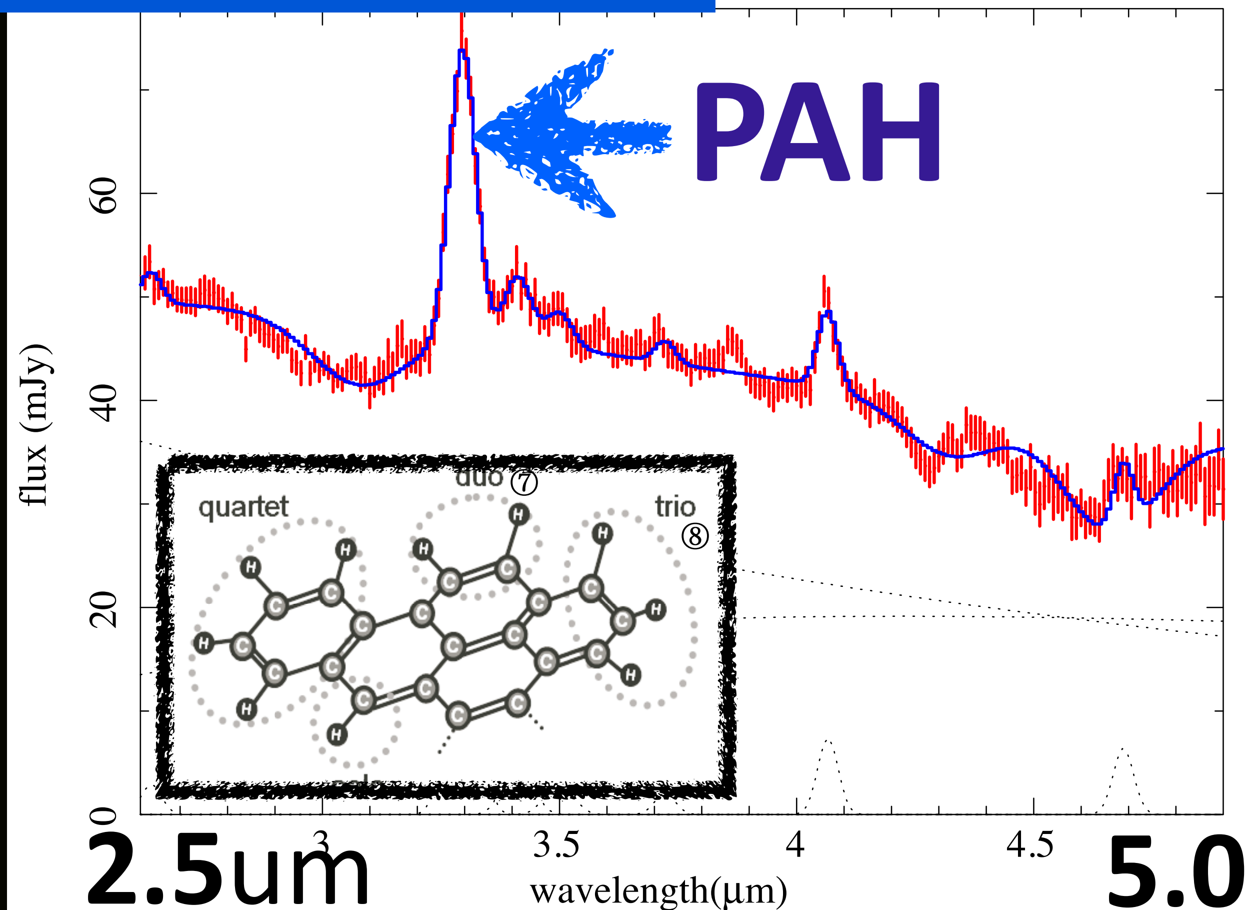
Observations: 2.5-5 um spectroscopy by AKARI

✔ It includes 3.3 um PAH emission line **(up to z~0.4)**

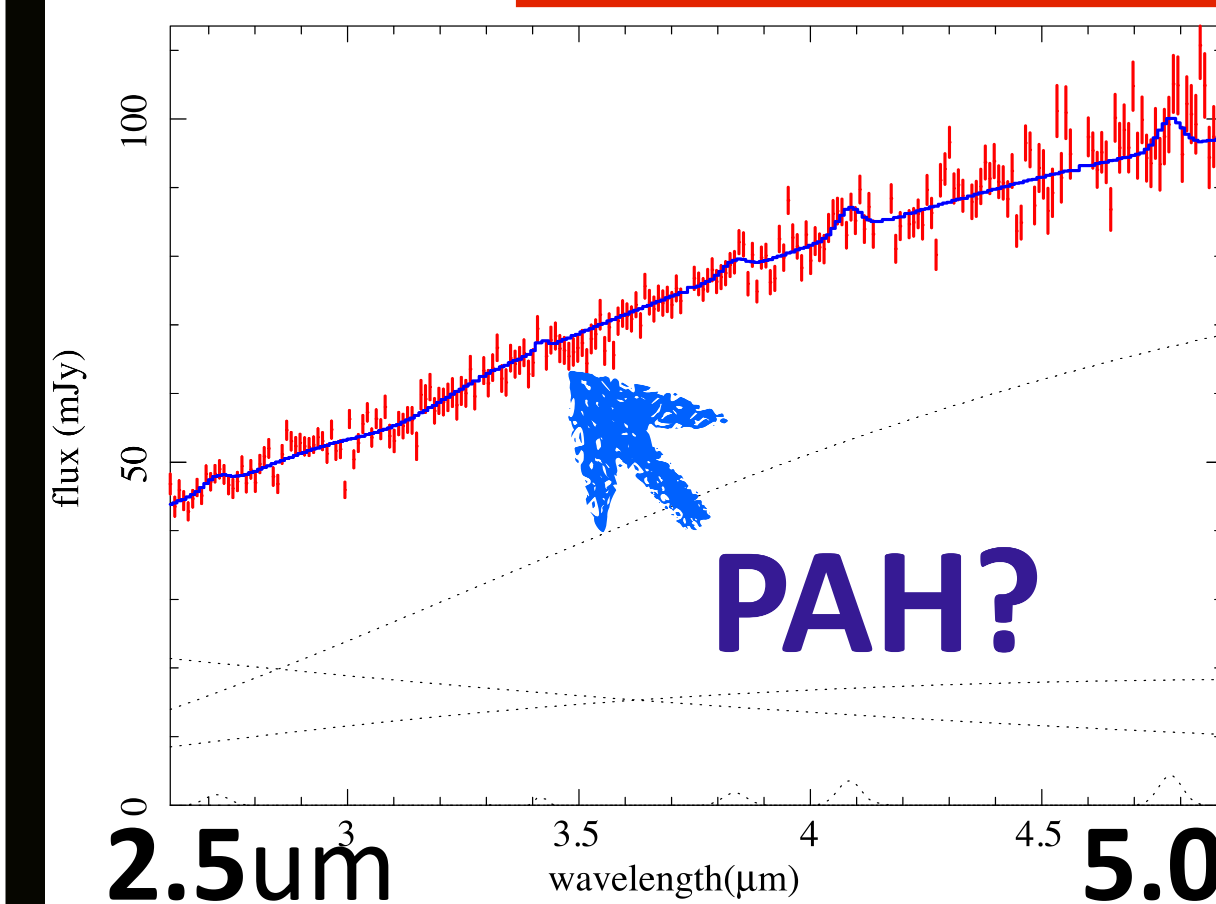
37 out of 78 sources are observed (Not complete)

Buried AGN diagnostics: PAH(多環芳香族炭化水素)

SB: EW>40nm



AGN: EW<40nm



PAH emission

✔ PAH is excited by UV radiation (from SB) = **strong** emission

✔ PAH is destroyed by X-ray (from AGN) + dusty continuum from AGN = **weak emission**

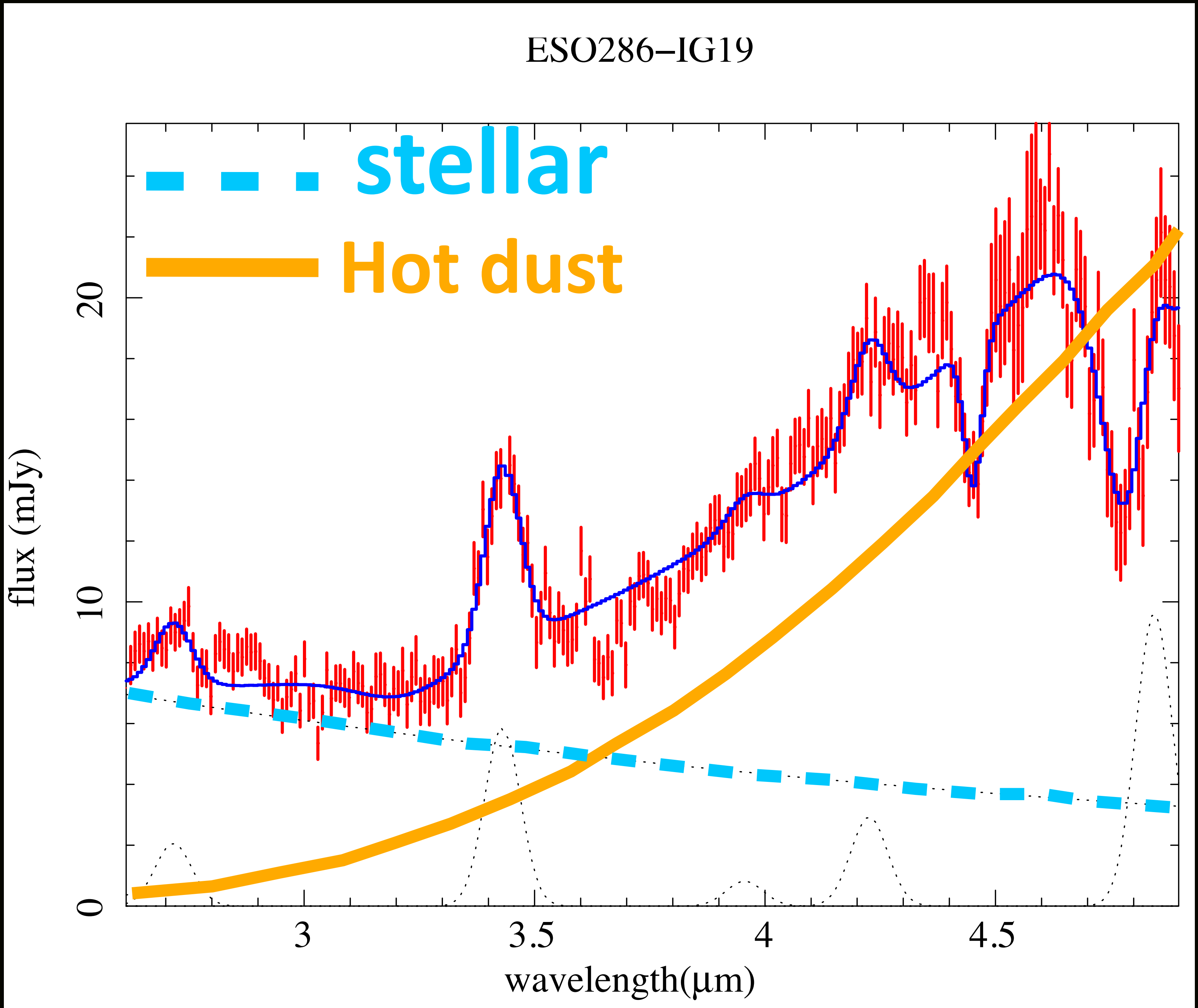
PAH Diagnostics (e.g., Imanishi+06, 10; mainly for ULIRGs)

✔ Weak PAH emission **(EW<40nm)**: a sign of **buried AGN**

Buried AGN diagnostics: continuum

Decomposing the continuum into two component

- ✔ stellar
- ✔ **MIR dust emission from AGN (e.g., Sani+08; Risaliti+10)**



Hot dust component

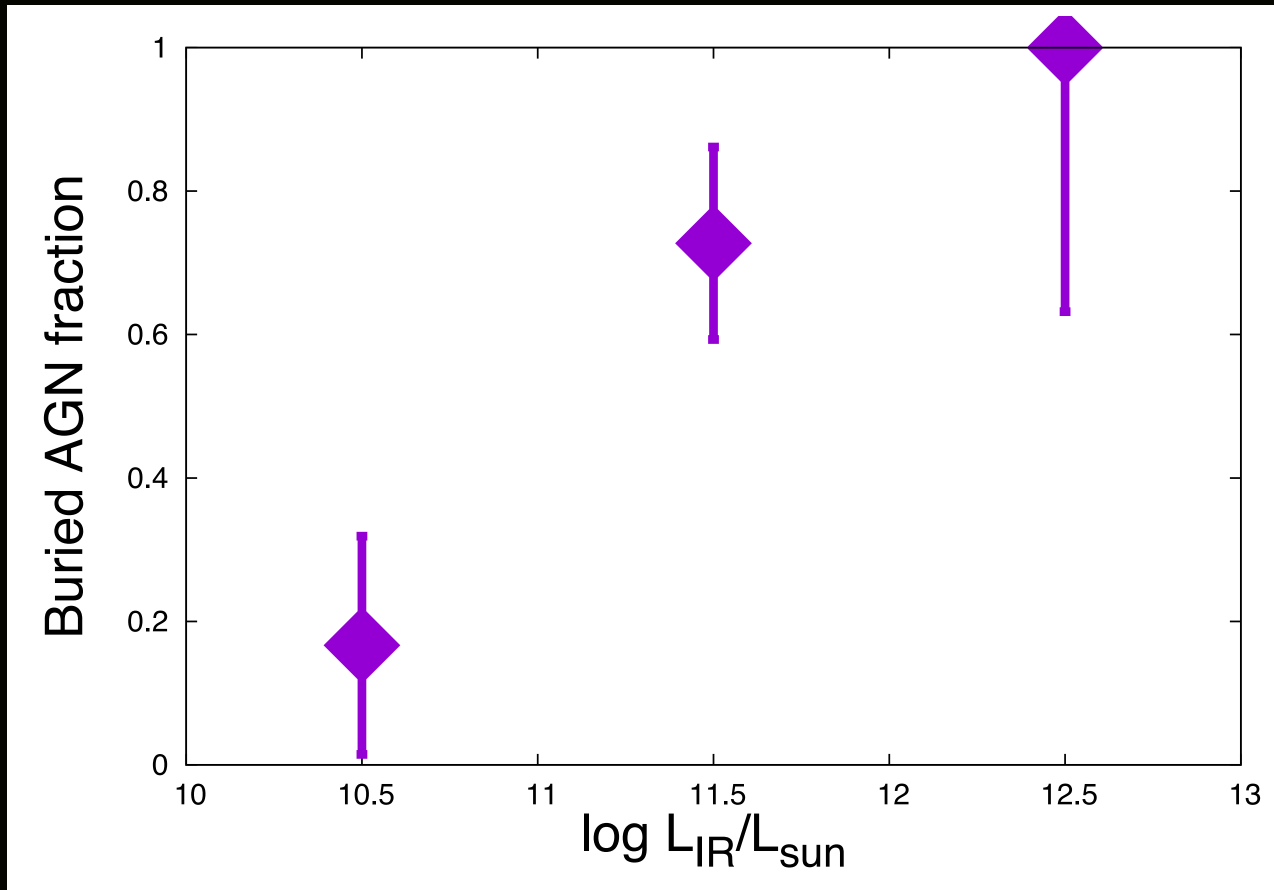
- ✔ starburst can heat only up to ~100K (e.g., Sanders+93)
- ✔ Hot dust (T>200K) continuum: a sign of **buried AGN**

Results: Buried AGN contribution

Buried AGN fraction

✔ increase with infrared Luminosity

✔ AGN activity is almost ubiquitous in U/LIRG range

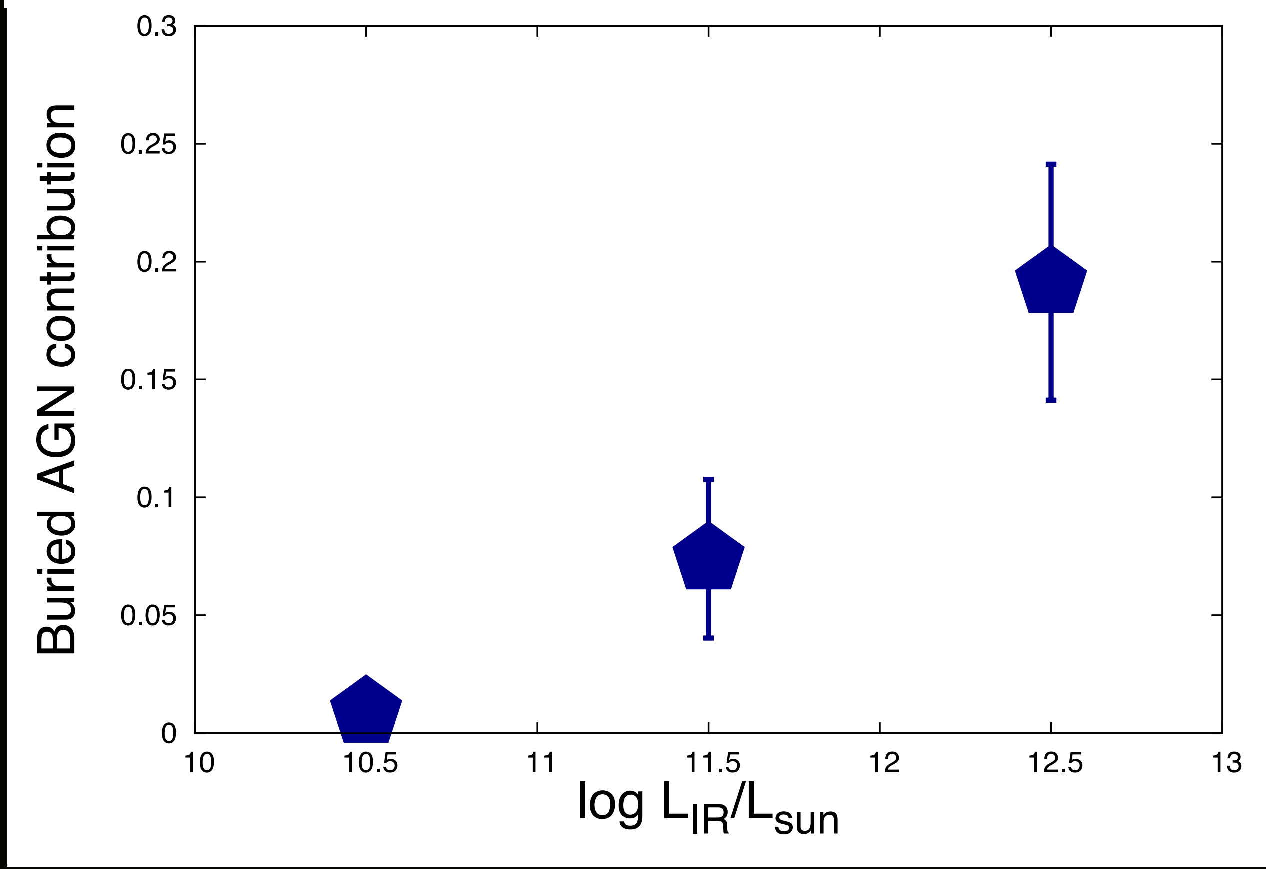


Buried AGN energy contribution

✔ increase with infrared Luminosity

✔ only up to ~10% at LIRG

✔ up to ~20% at ULIRG (very small!)



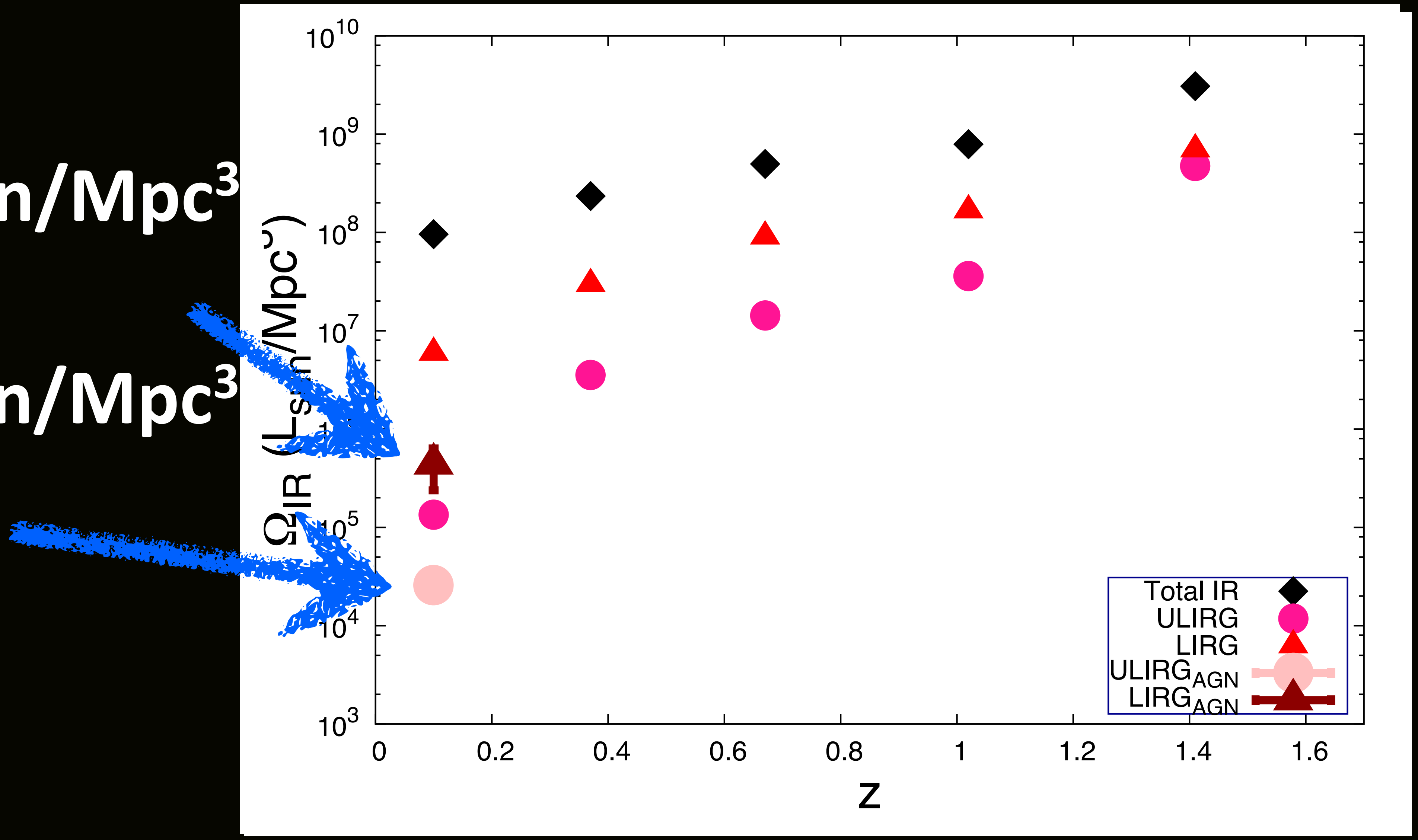
Bulk of infrared emission originates from SB, *NOT AGN!!*

IR energy density in the local Universe

We can calculate IR energy density of AGN

✔ 4.4×10^5 Lsun/Mpc^3 for LIRG

✔ 2.6×10^4 Lsun/Mpc^3 for ULIRG

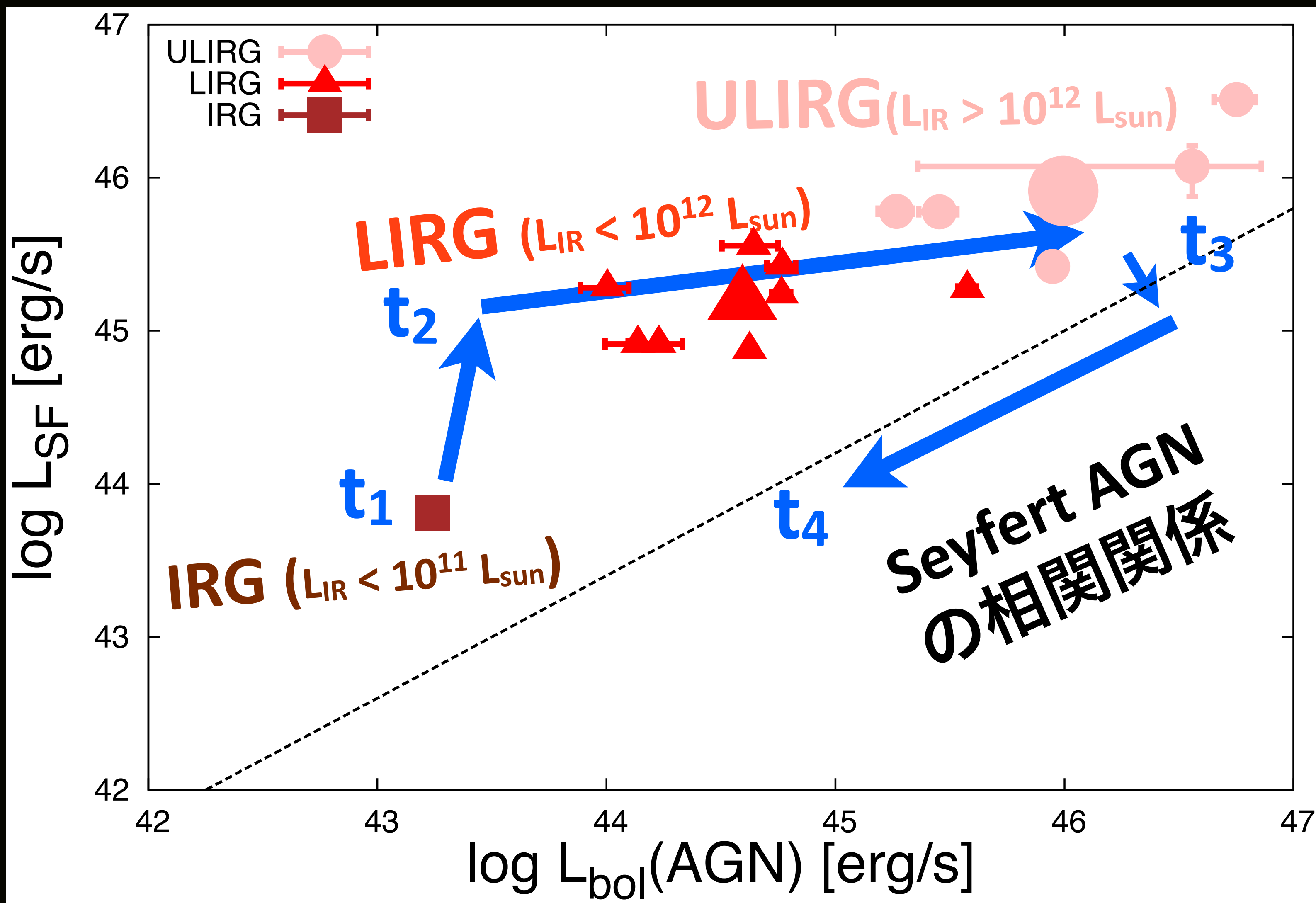


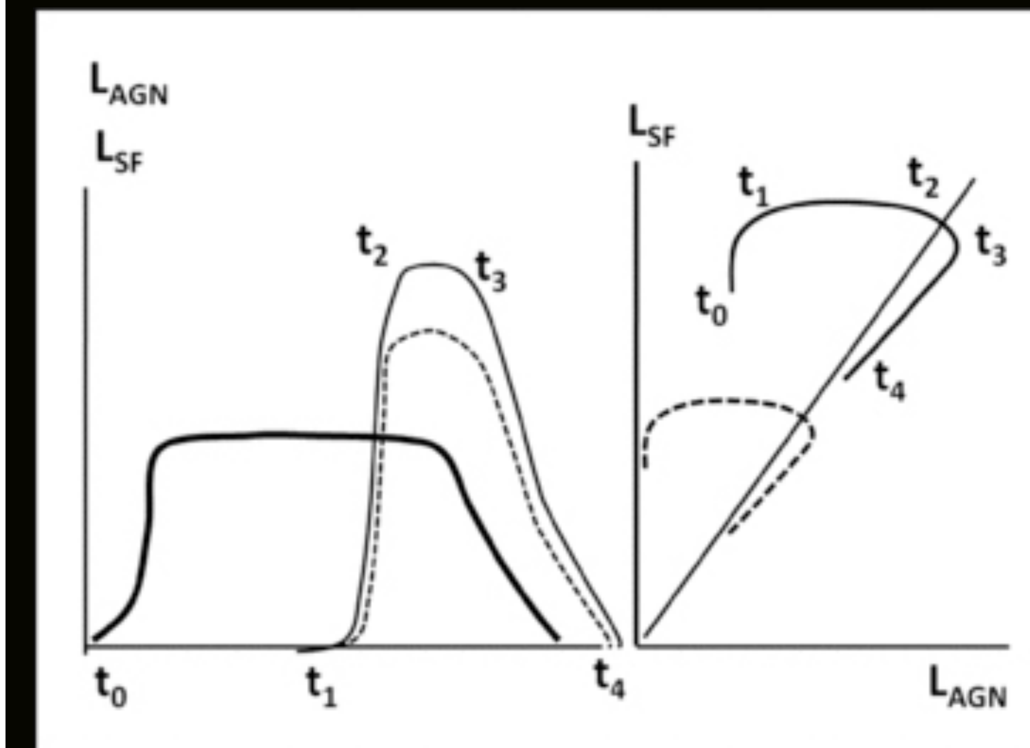
✔ How about the Ω_{IR} of AGN in the high-z Universe?

We need 500 uJy@z=1

This will be achieved by JWST/MIRI (~2020), and/or SPICA (after 2025)?

Evolutional track of AGN in IR galaxies





L_{SF} can be calculated with $L_{SF} = L_{IR} - L_{AGN}$

✔ Optically-selected AGN: following L_{SF} vs. L_{bol}(AGN) relations

✔ IR galaxies: are located **above** the relations

IR galaxies: from **T_2 to T_3** (where AGN activity is **increasing**)

✔ IR galaxies w/ buried AGN signs:

they could be **in early stage of AGN evolutional track**

Future plans

Within a year:

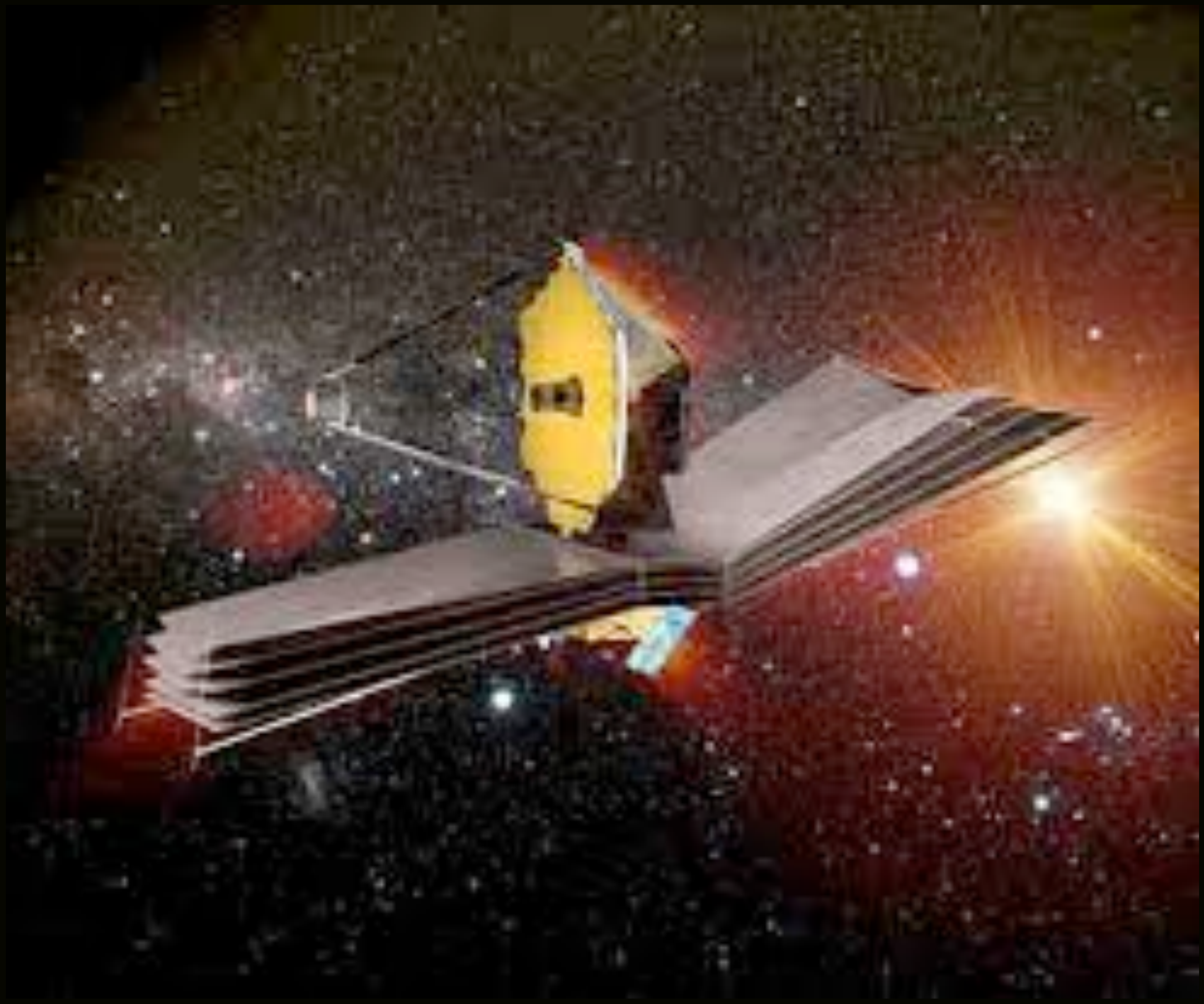
Current sample: NOT statistically complete

-> Imanishi+10 has a statistically unbiased & complete sample

Applying our method to the sample,

✔ **We can get statistically significant results**

Around 2020: the era of JWST



✔ Our method is **applicable to high-z IR galaxies** w/ JWST/MIRI (spec range: 5-28 um)

✔2.5-5 um is shifted to

-> 5.0-10 um (z=1)

-> 7.5-15 um (z=2)

✔ Which field is most suitable for applying?

Summary

Our motivation

Infrared Galaxies: very bright in IR than optical

✔ Hidden energy source should exist behind the dust

✔ Possible energy sources: Starburst (SB) or AGNs

-> Disentangling two energy sources!!

Results

✔ **Buried AGN is ubiquitous in infrared galaxies**

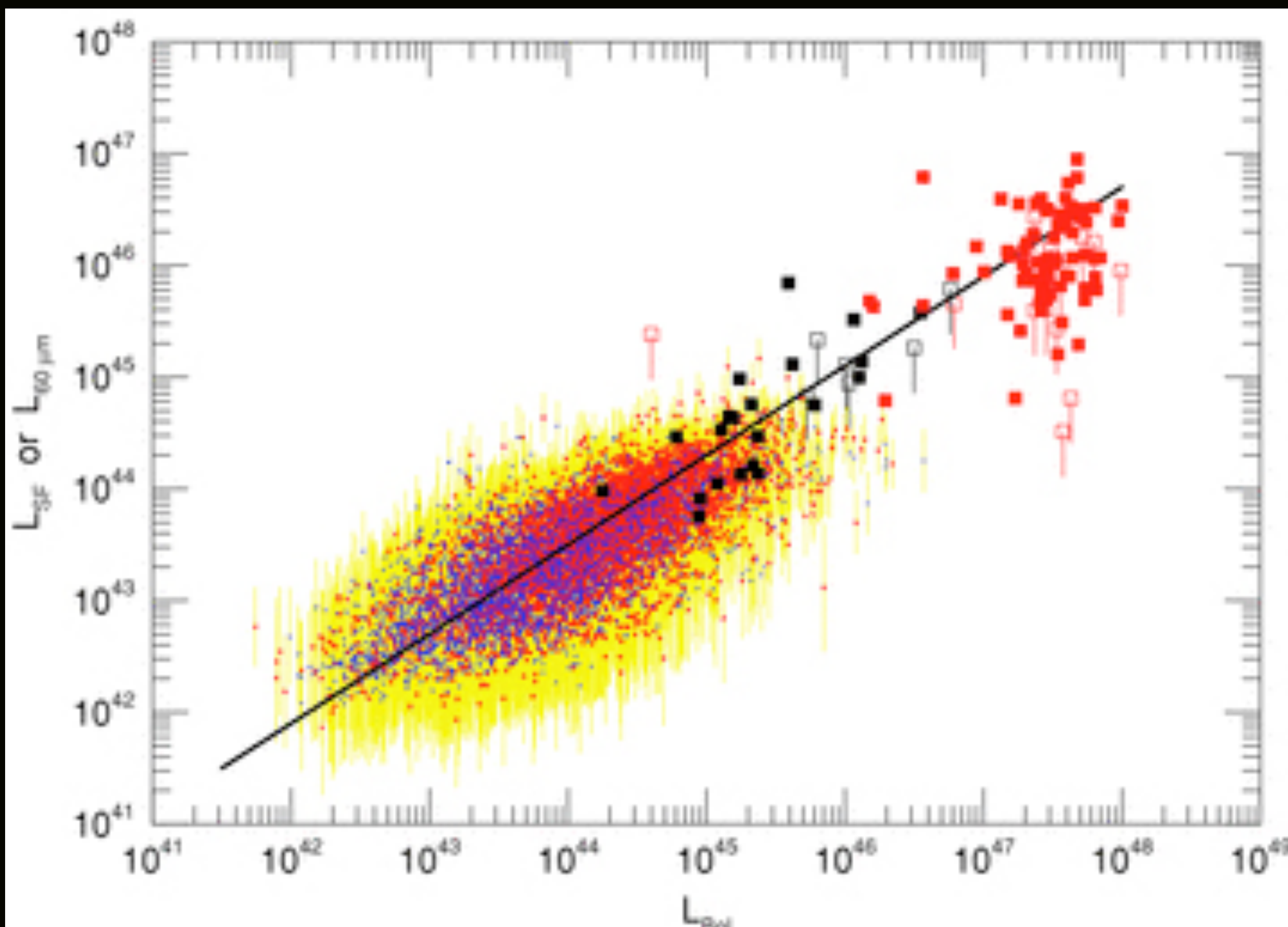
✔ **Buried AGN energy contribution is very small (only up to ~10%)**

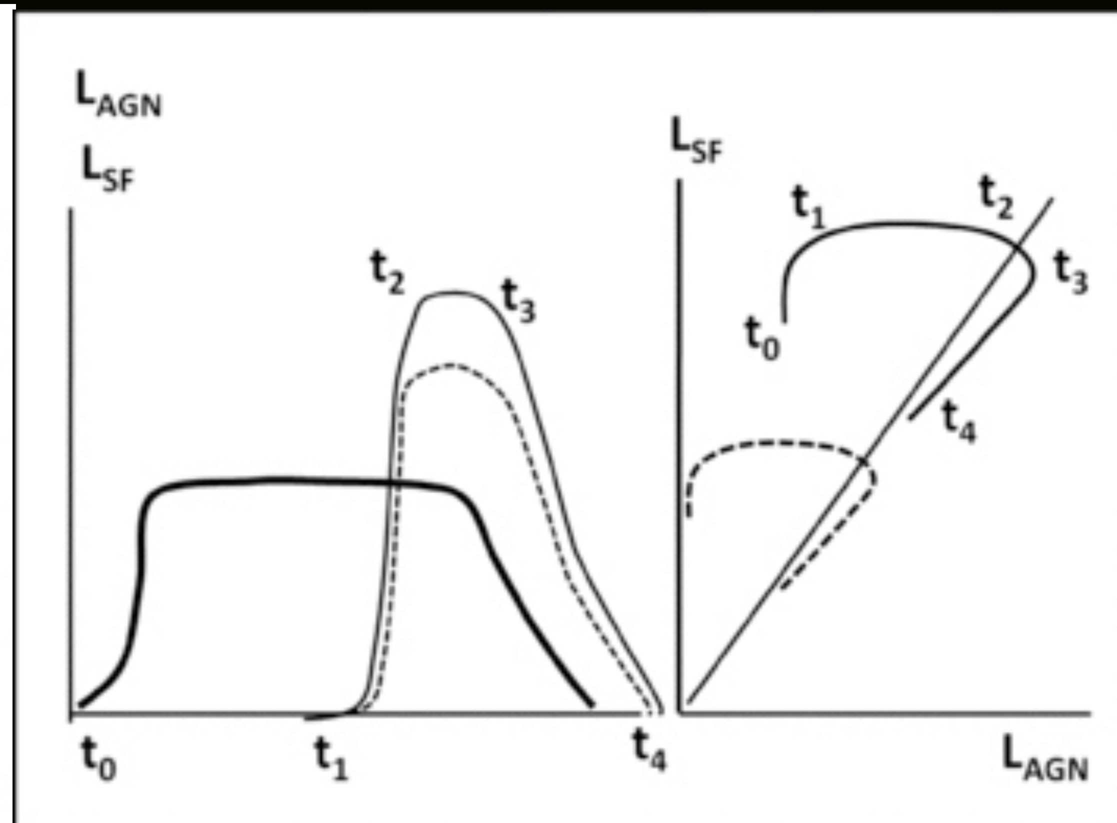
-> Bulk of infrared emission originates from SB, not AGN in the local Universe!!

✔ **IR galaxies could be the early stage of AGN evolutional track**

Thank you!!

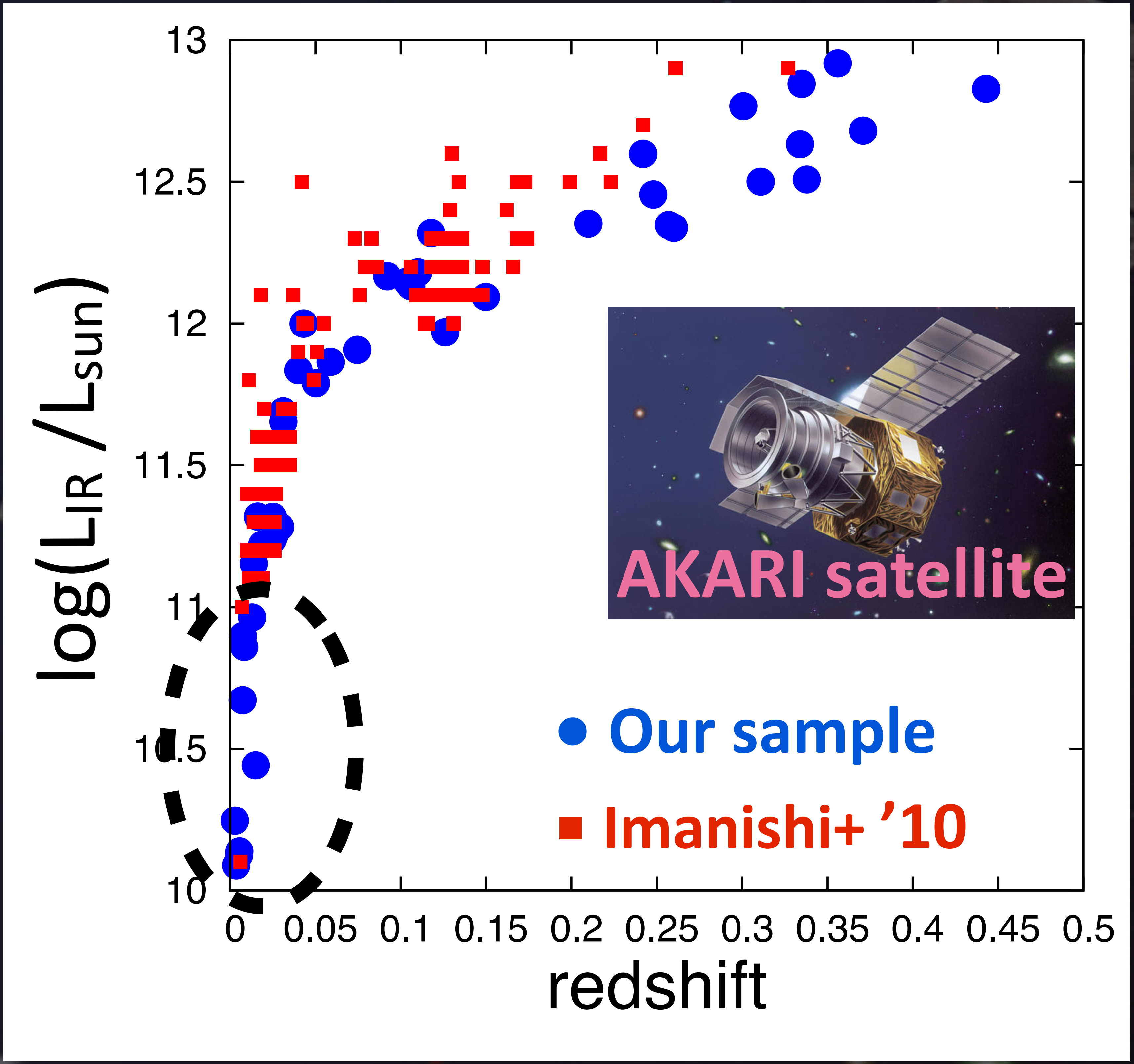
R~120 at 3.6um





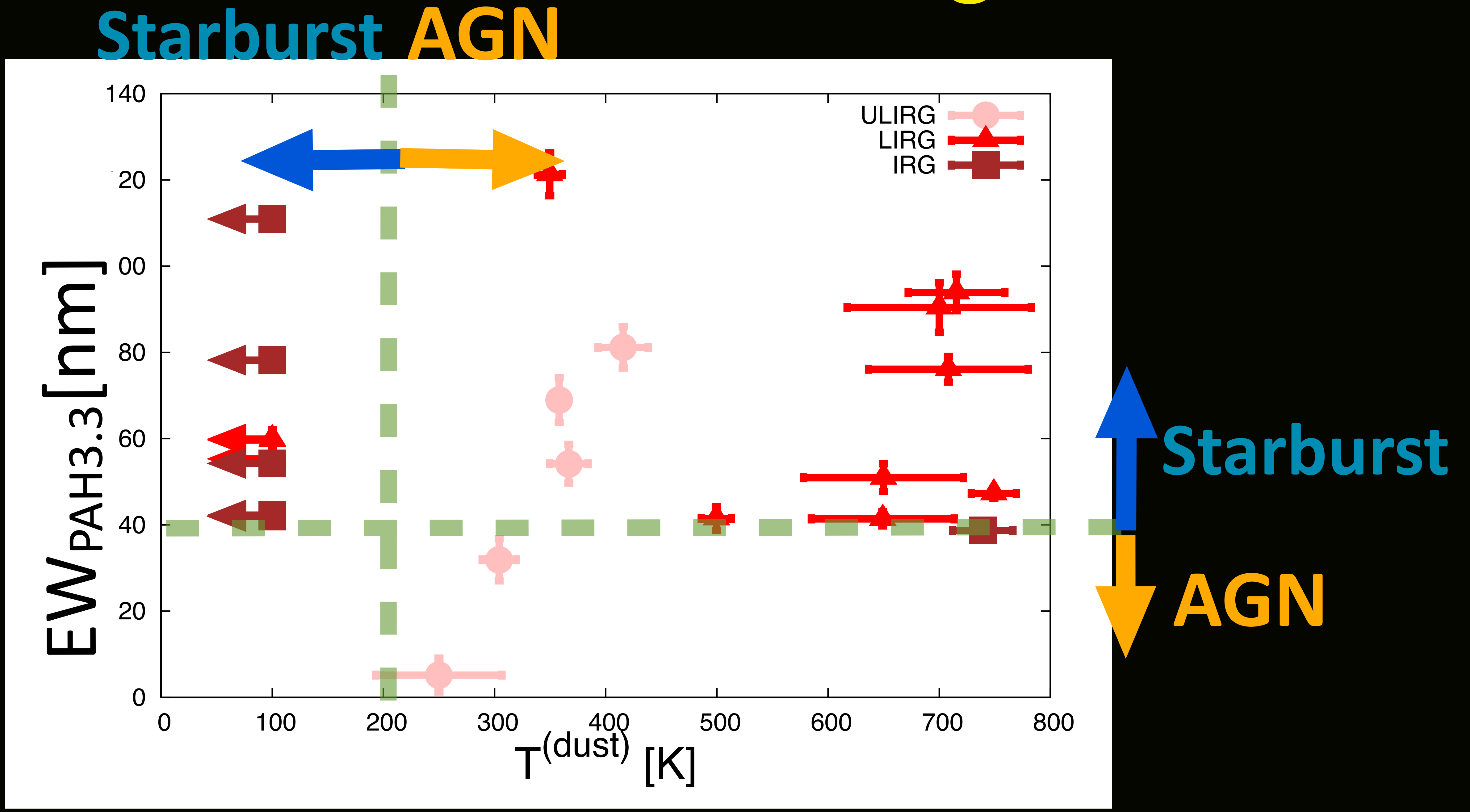
$L_{SF} \propto L_{AGN}^{0.8}$,

Sample: Infrared Galaxies



✔ **Our sample covers wide luminosity range ($10^{10}\ L_{sun} < L_{IR} < 10^{13}\ L_{sun}$)**

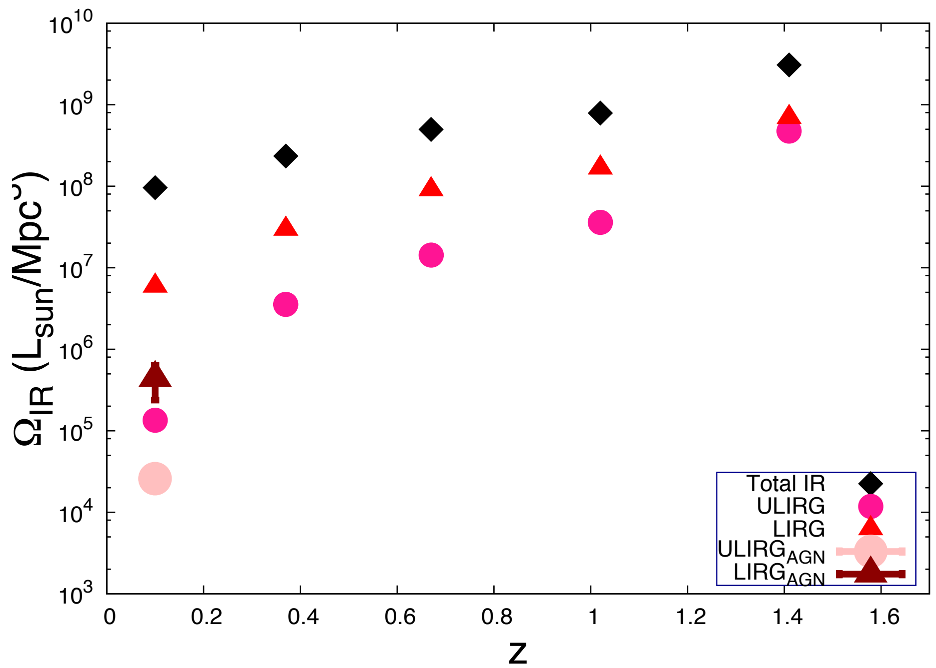
Results of 2 buried AGN diagnostics



All the sources with EW_{PAH33} <40nm have AGN hot dust component (T>200K)

PAH diagnostics can be highly affected by aperture

-> PAH diagnostics could miss many hidden AGNs

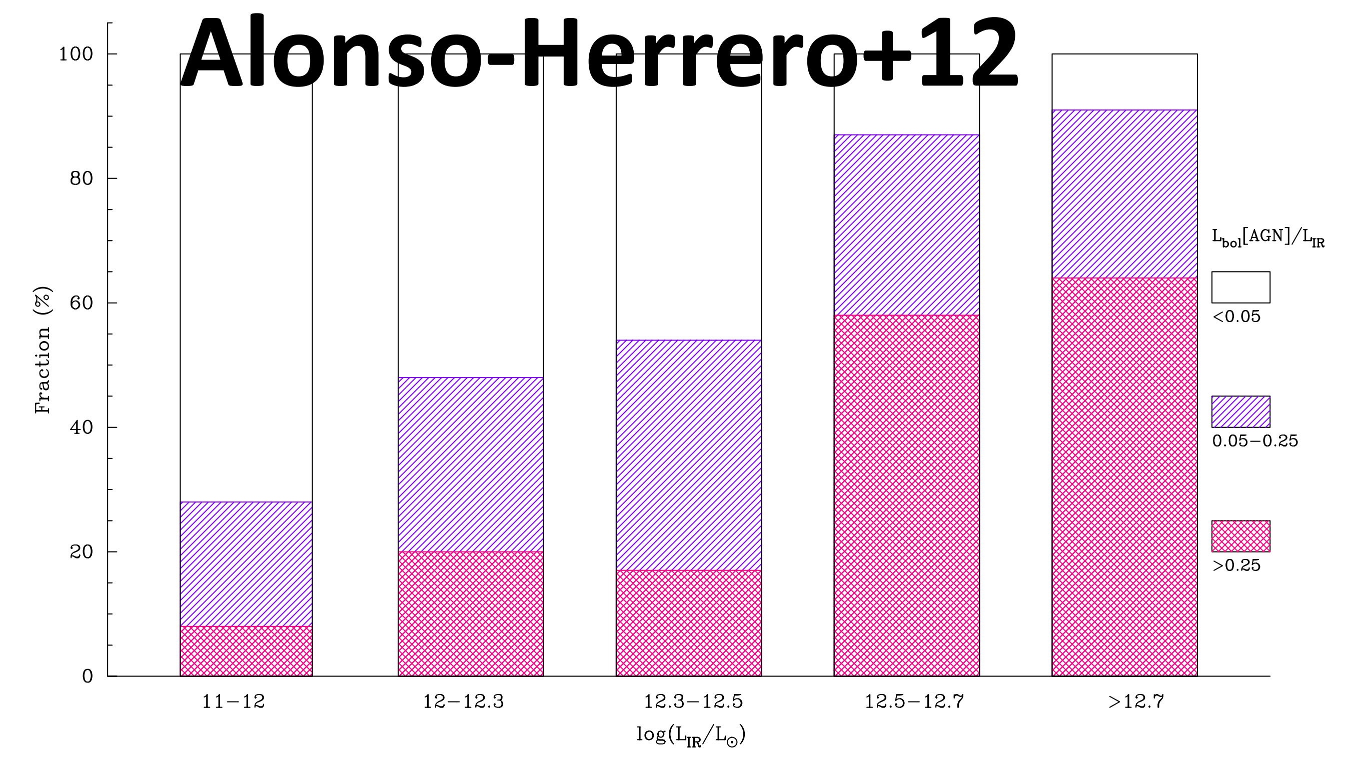


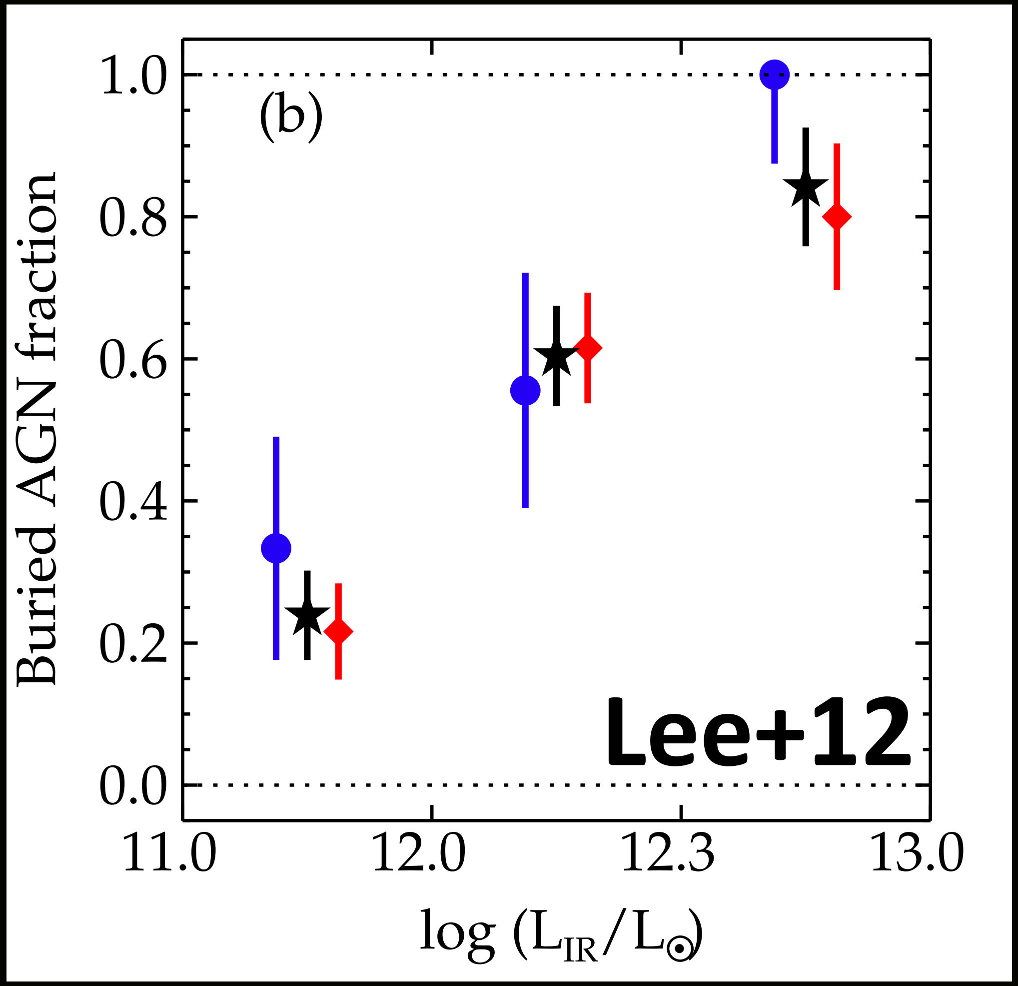
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
10^{5}
10^{4}
10^{3}
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
z
Ω_{IR} (L_{sun}/Mpc^3)
Total IR
ULIRG
LIRG
$ULIRG_{AGN}$
$LIRG_{AGN}$

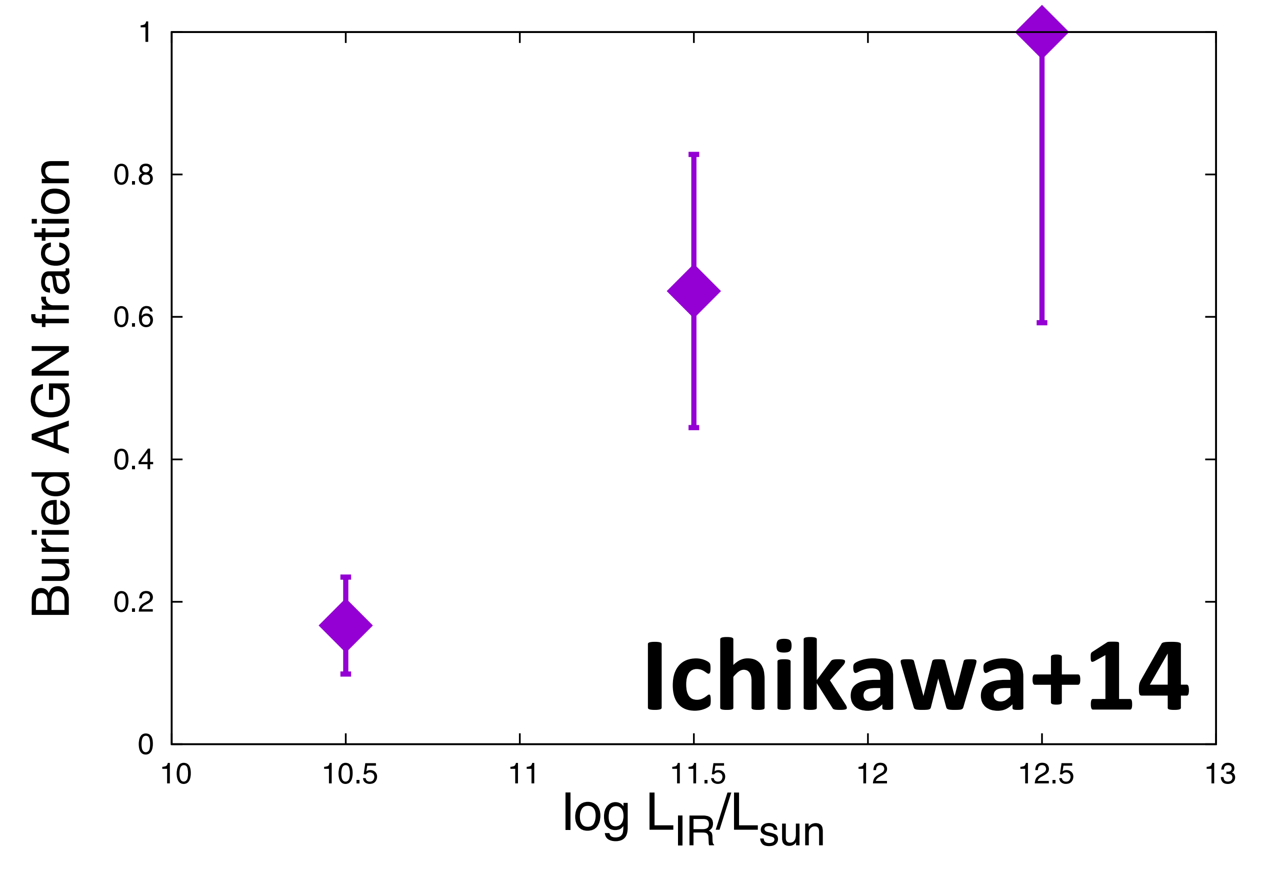
Results: Buried AGN contribution

Buried AGN fraction

✔ **increase with infrared Luminosity**



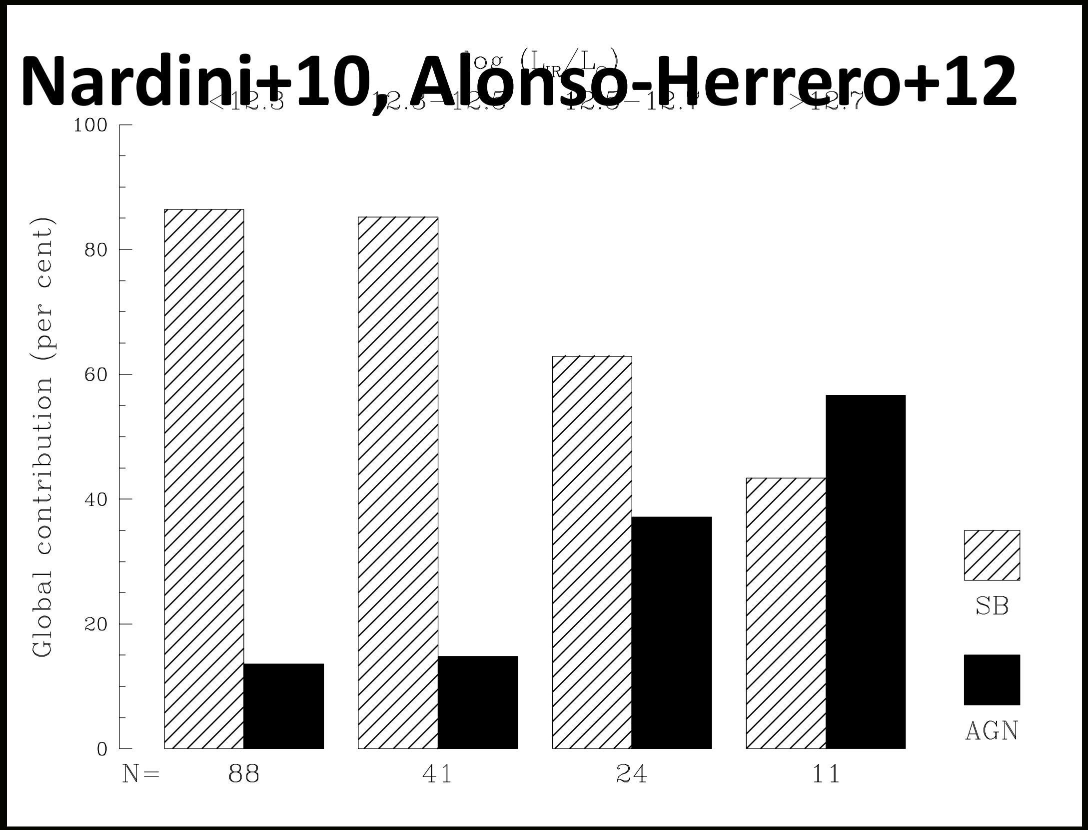


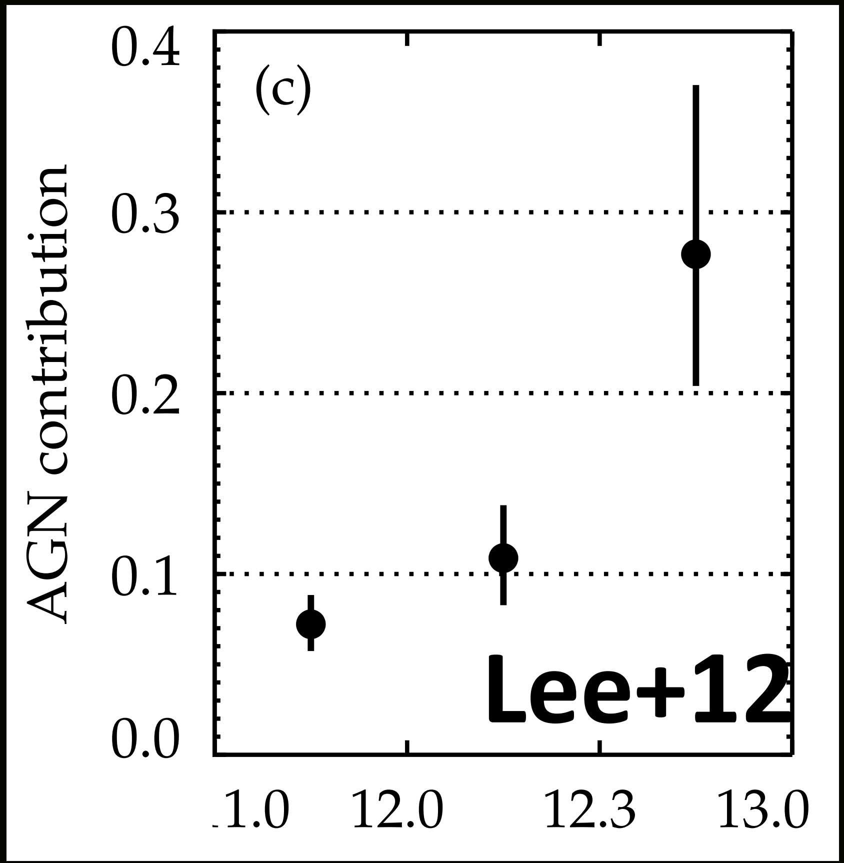


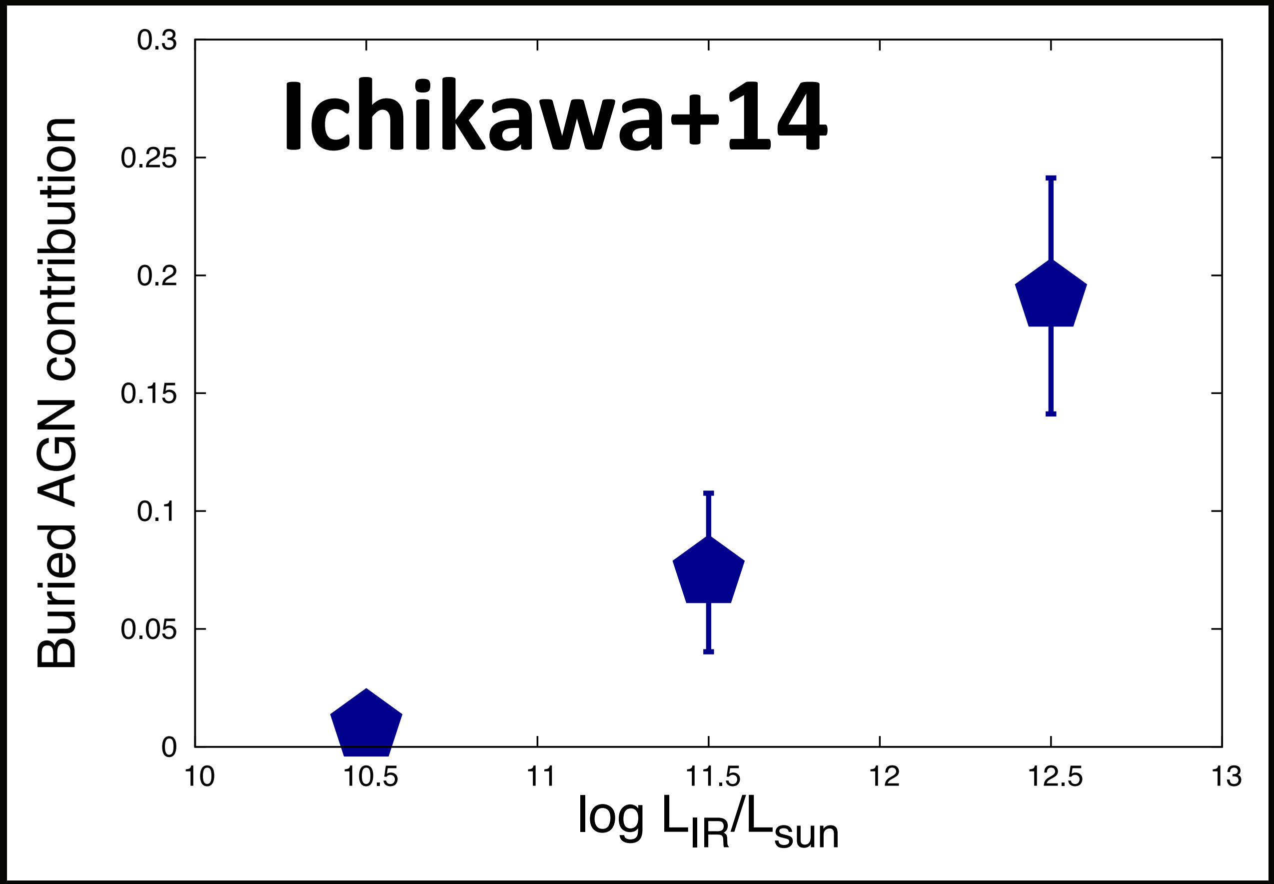
Results: Buried AGN contribution

Buried AGN energy contribution

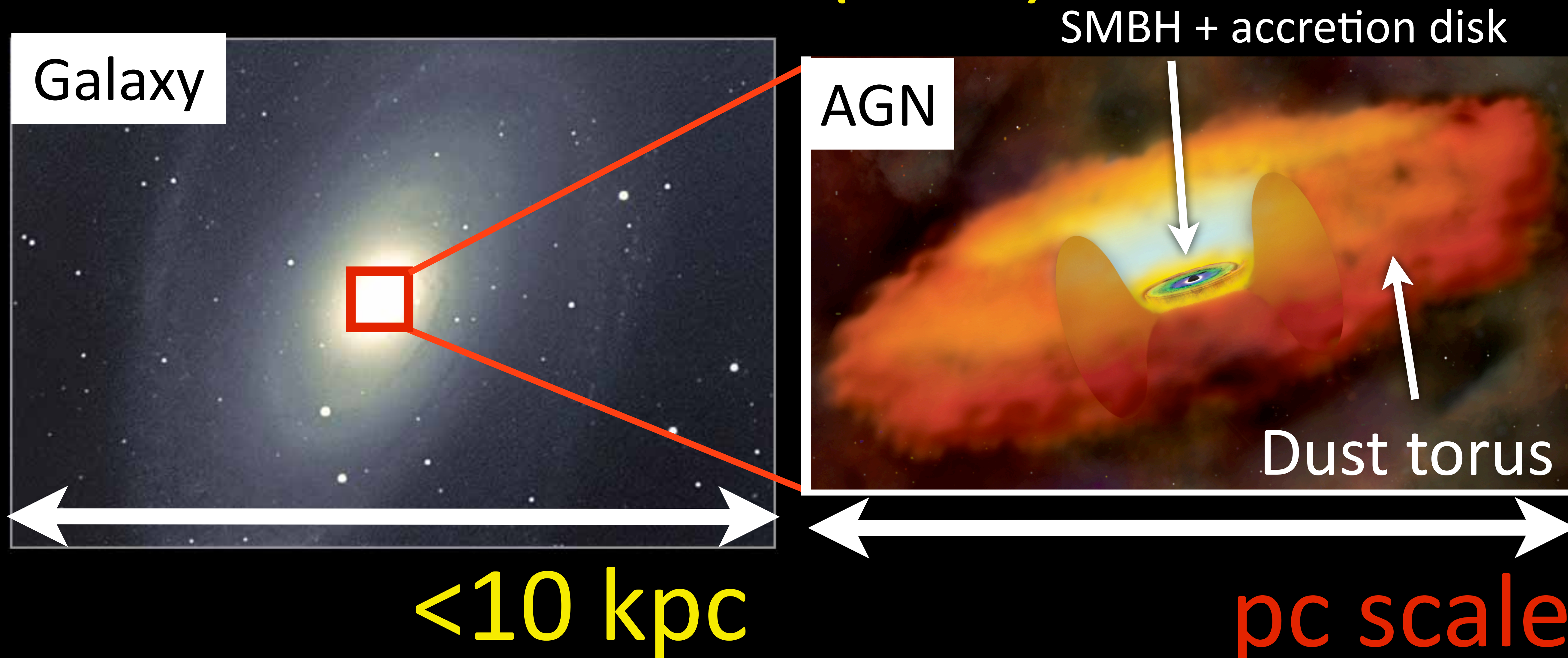
- ✔ increase with infrared Luminosity
- ✔ 10~30% @ULIRGs
- ✔ Our sample covers wider IR luminosity range







Active Galactic Nuclei (AGN)

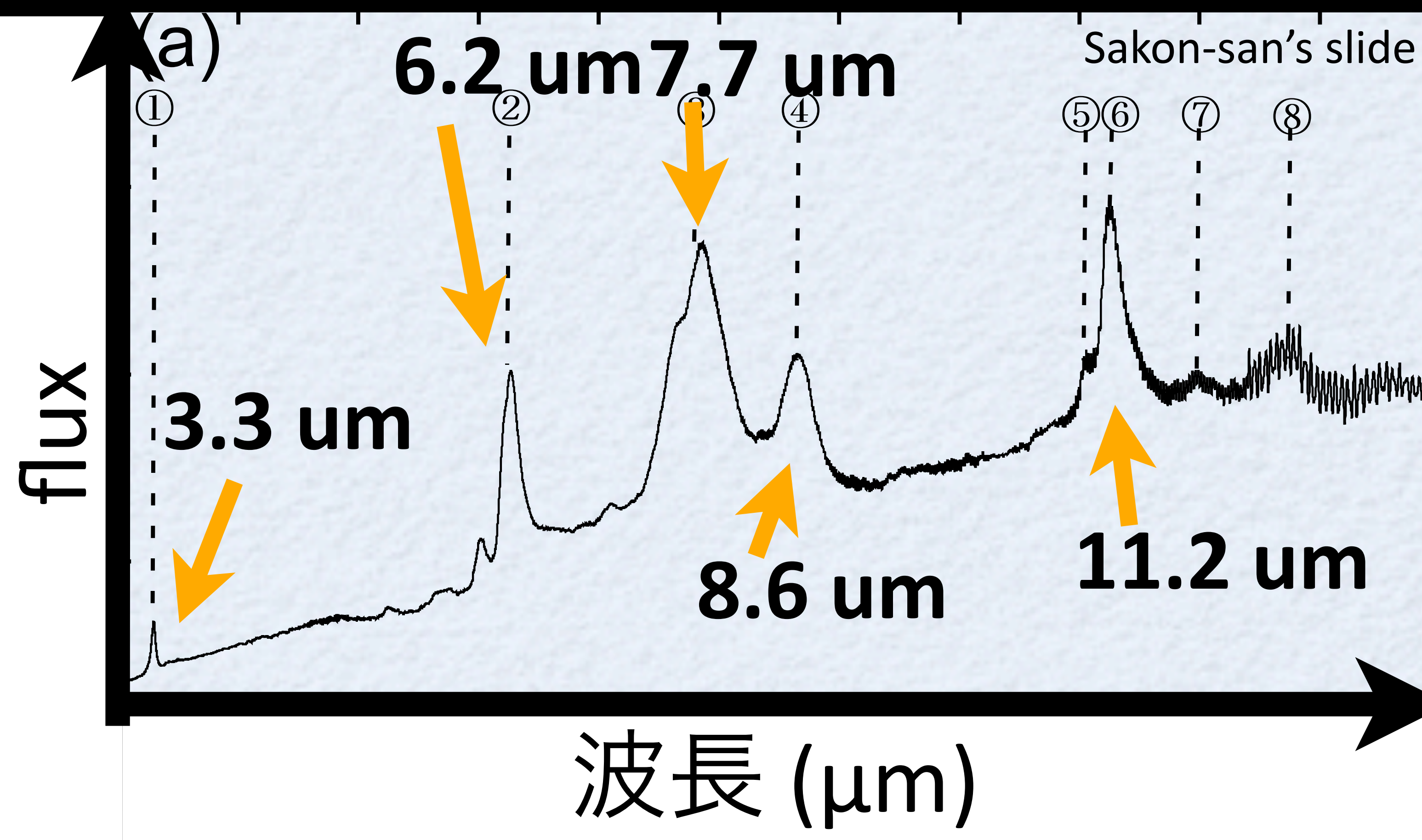


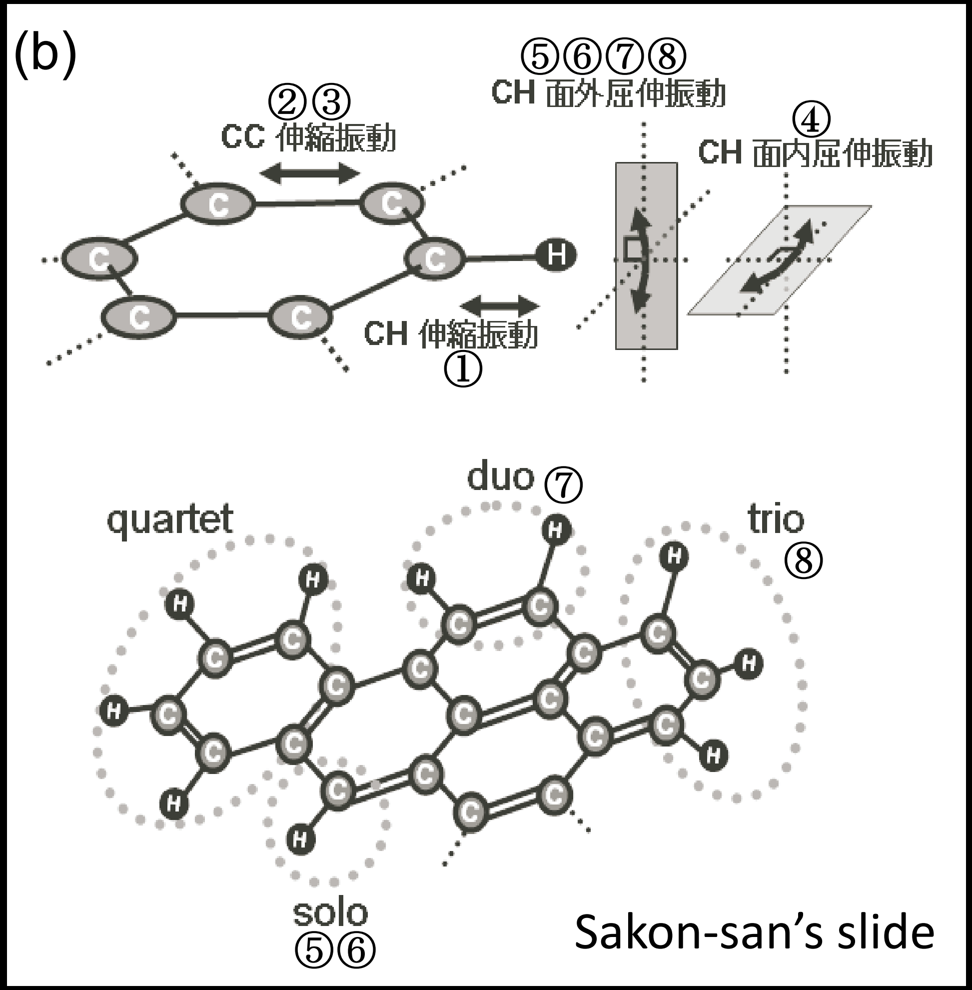
What we see at each energy band

Accretion disk：Optical to X-ray

Dust torus : mid/far Infrared

PAH(Polycyclic Aromatic Hydrocarbon)分子





PAH分子の性質

星生成(紫外線) → 励起され、赤外線で再放射

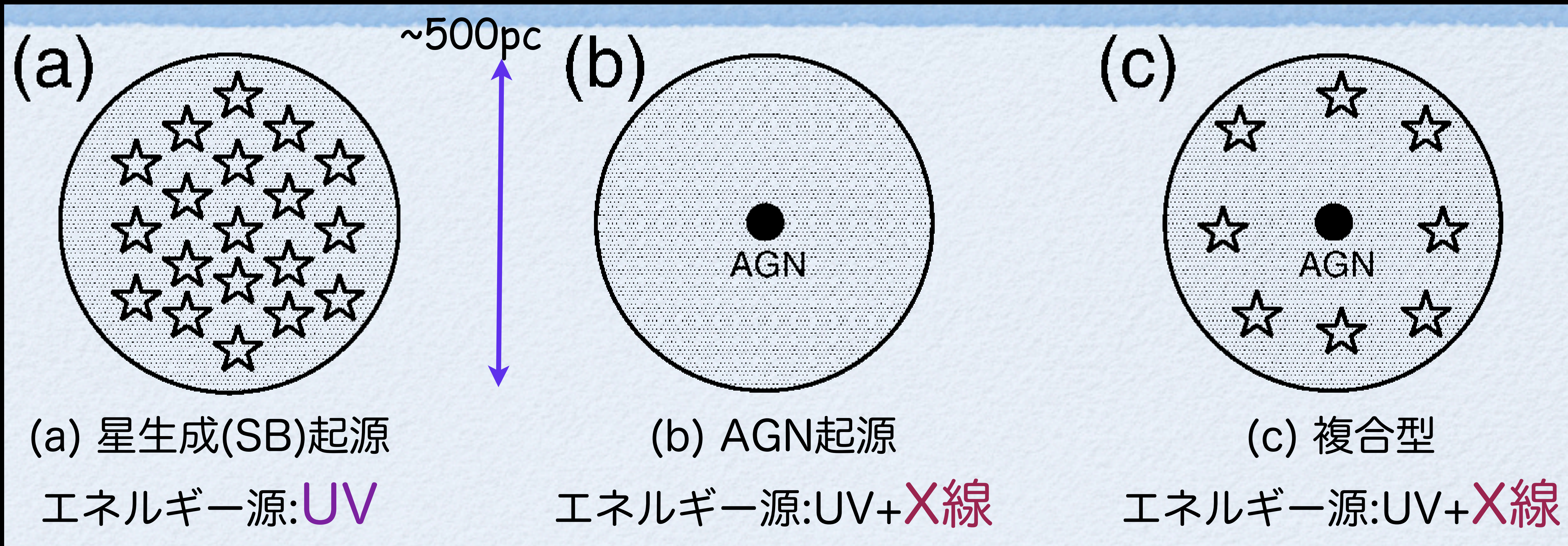
(輝線が見える)

AGN(X線) → 破壊される

(輝線が見えない)

PAH輝線の見え方

EW: 等価幅



EW(PAH)>40 nm

EW(PAH)<40 nm

(Moorwood 1986, Imanishi+ '08, '10)

サンプル

ULIRGに関しては、多数のサンプルがある (Imanishi+ ’06, ’10)
より低光度側のIRG, LIRGを中心としたサンプルからランダムに選択
IRG: 6天体, LIRG: 11天体, ULIRG: 6天体をAKARI IRCで観測

連続光
+輝線+吸収線で
フィッティング