Luminous buried AGNs in the local universe ULIRGs

origin of galaxy down-sizing?

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Ultraluminous infrared galaxies (ULIRGs)

L(IR) > 10^{12} L_{sun} (Normal spiral ~ 10^{10} L_{sun})

Luminous energy source is hidden behind dust
ULIRGs

Compact cores (<500pc) are energetically dominant

Soifer et al. 2000

Very compact starburst or AGN?
AGNs in ULIRGs are buried

AGNs obscured by torus-shaped dust
Detectable via optical spectroscopy

ULIRGs have a large amount of nuclear gas and dust

Buried AGNs are elusive

70% ULIRGs = non-Sy
1. Infrared spectral shape

PAHs are excited in starburst PDRs but destroyed near an AGN.

- **Starburst (SB)**
  - $3.3\mu m$ PAH
  - $\text{EW(PAH)} \approx 100\text{nm}$

- **Buried AGN**
  - Featureless
  - $3.4\mu m/3.1\mu m$
  - $\text{EW(PAH)} << 100\text{nm}$

- **Composite**
3-4 um

Starburst (SB)

Buried AGN

AGN/SB composite

IRAS 11095−0238
3.3\(\mu\)m PAH

IRAS 08572+3915NW
3.3\(\mu\)m PAH (?)

IRAS 00188−0856
3.3\(\mu\)m PAH

IRAS 14060+2919
3.3\(\mu\)m PAH

IRAS 12127−1412NE
3.05\(\mu\)m, 3.4\(\mu\)m

IRAS 17044+6720
3.3\(\mu\)m PAH

wavelength

Strong PAH

Abs. feature

Bare 3.4\(\mu\)m

Ice

3.1\(\mu\)m

Bare 3.4\(\mu\)m

Low EW(PAH)
2. Dust absorption feature strength

(a) starburst

Mixed dust model

\[ \frac{1 - \exp(-\tau)}{\tau} \]

Dust absorption feature: weak

\[ \tau(3.1) < 0.3 \quad \tau(9.7) < 1.7 \]
\[ \tau(3.4) < 0.2 \] (Imanishi & Maloney 2003 ApJ 588 165

(b) Buried AGN

ULIRG core <500pc

Foreground screen dust model

\[ \exp(-\tau) \]

strong
3-4 um

**SB**

PAH 3.3um

**Buried AGN**

PAH weak (AGN): Dust abs. strong

**AGN+SB**

PAH strong (SB): Dust abs. weak

**Bare 3.4um**

Ice 3.1um

**Bare 3.4um**

wavelength

Subaru wavelength

IRAS 11095–0238

IRAS 08572+3915NW

IRAS 00188–0856

IRAS 14060+2919

IRAS 12127–1412NE

IRAS 17044+6720
5-35 um

Spitzer GO1

SB

Buried AGN

AGN+SB

PAH strong:
Silicate Abs. weak

PAH weak:
Silicate Abs. strong

wavelength
3. Dust temperature gradient

Buried AGN

Av(3um) > Av(10um) > Av(20um)

Starburst

dust in edge-on host

Av(3um) =< Av(10um) =< Av(20um)
How to detect T-gradient?

- **Av(3μm)** ~110 mag
- **Av(10μm)** ~40 mag
- **Av(20μm)** ~20 mag

**Optical depth**
- 9.7μm
- 18μm

**Dust temperature gradient**
Strong T-gradient (II)

Strong abs ULIRGs -> often show T-gradient
Opical non-Seyfert ULIRGs

Results

Luminous buried AGNs = 30-50%

nearby (z<0.15)

30% ULIRGs = optical Sy (AGN + torus)

>50% ULIRGs = luminous AGN
Our line-of-sight obscuration: Non-Sy >> Sy2

Amount of nuclear dust: Non-Sy >> Sy2

\[ L(\text{intrinsic AGN}) \sim L(\text{IR}) \]
Buried AGNs: both warm/cool FIR colors

pure buried AGN

IRAS 12127−1412NE

F25/F60 = 0.16 (cool)

larger dust column

cool FIR color

cool ≠ starburst
AKARI

2.5-5 um spectroscopy

Unaffected by Earth’s atmosphere

z > 0.15 ULIRG
AKARI

$z > 0.15 \rightarrow$ Higher $L_{\text{IR}}$ ULIRGs

Buried AGNs increase with $L_{\text{IR}}$

AGN-feedback for galaxy down-sizing?
Summary

1. Buried AGNs: 30-50% non-Sy ULIRGs

2. Nuclear dust amount:
   non-Sy ULIRGs > Sy2 ULIRGs

Optical Sy (non-)detectability depends on the amount of nuclear dust

Imanishi et al. 2006 ApJ 637 114 (Subaru)
Imanishi et al. 2007 ApJS 171 72 (Spitzer)
Imanishi et al. 2008 PASJ submitted (AKARI)