Luminous buried AGNs in the local universe ULIRGs

origin of galaxy down-sizing ?

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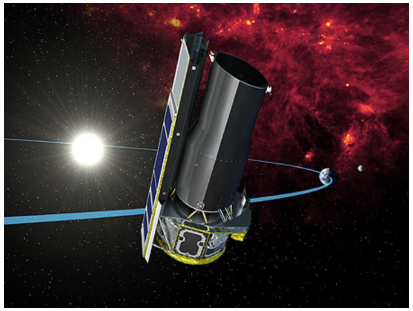
Subaru

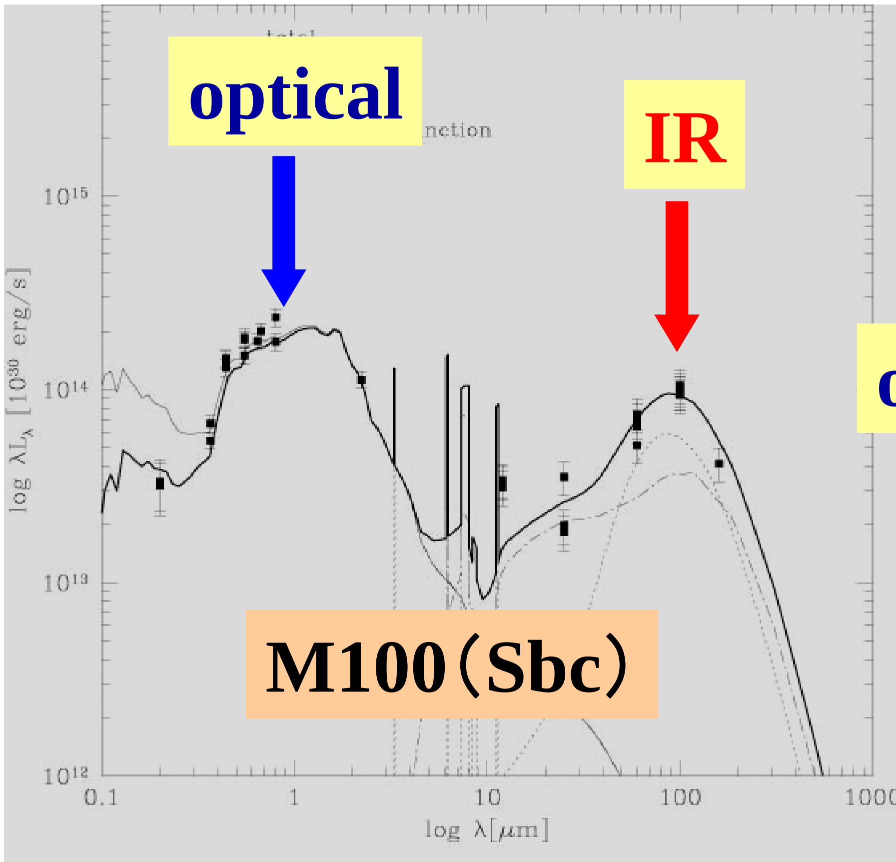


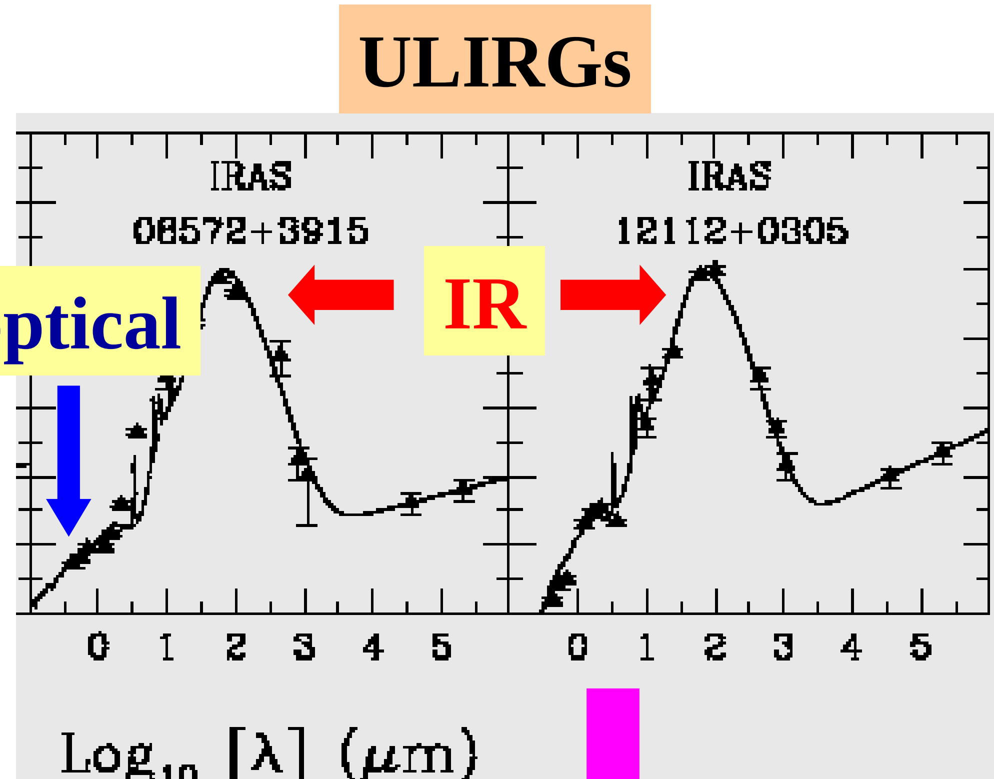
Spitzer

AKARI

Ultraluminous infrared galaxies (ULIRGs)

L(IR) > 10^12 Lsun (Normal spiral ~ 10^10 Lsun)

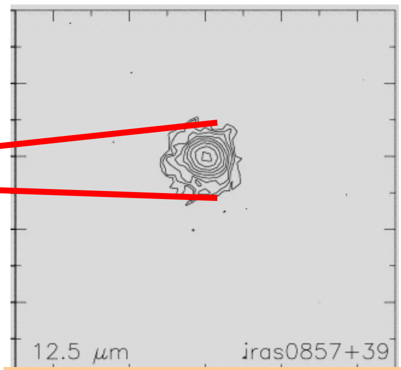




Luminous energy source is hidden behind dust

ULIRGs

optical



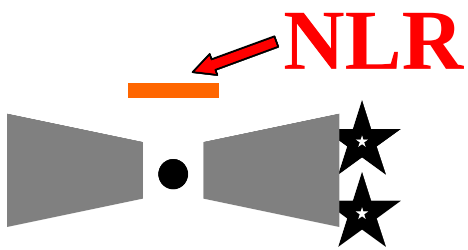
IR(12um)

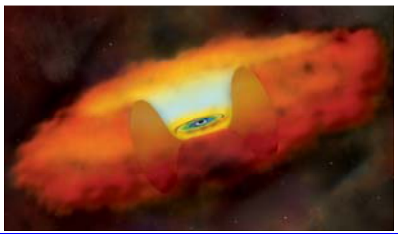
Soifer et al. 2000

Compact cores (<500pc) are energetically dominant

Very compact starburst or AGN ?

AGNs in ULIRGs are buried

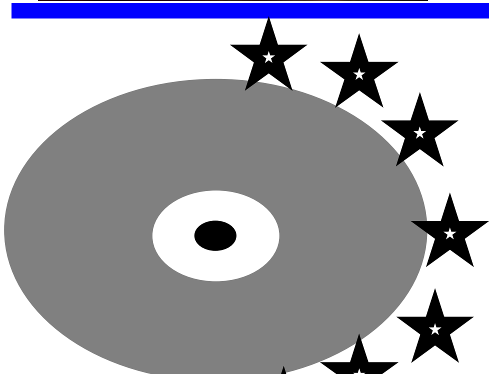


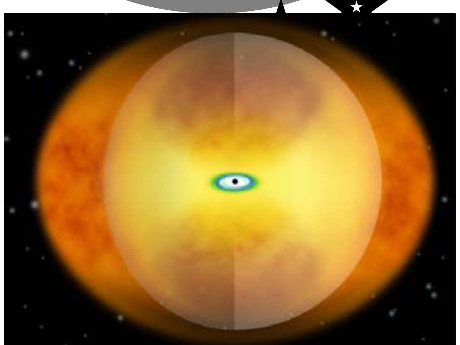


AGNs obscured by torus-shaped dust

Sy2

Detectable via optical spectroscopy





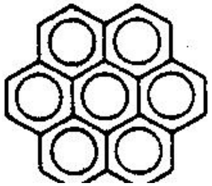
ULIRGs have a large amount of nuclear gas and dust

Buried AGNs are elusive

70% ULIRGs = non-Sy

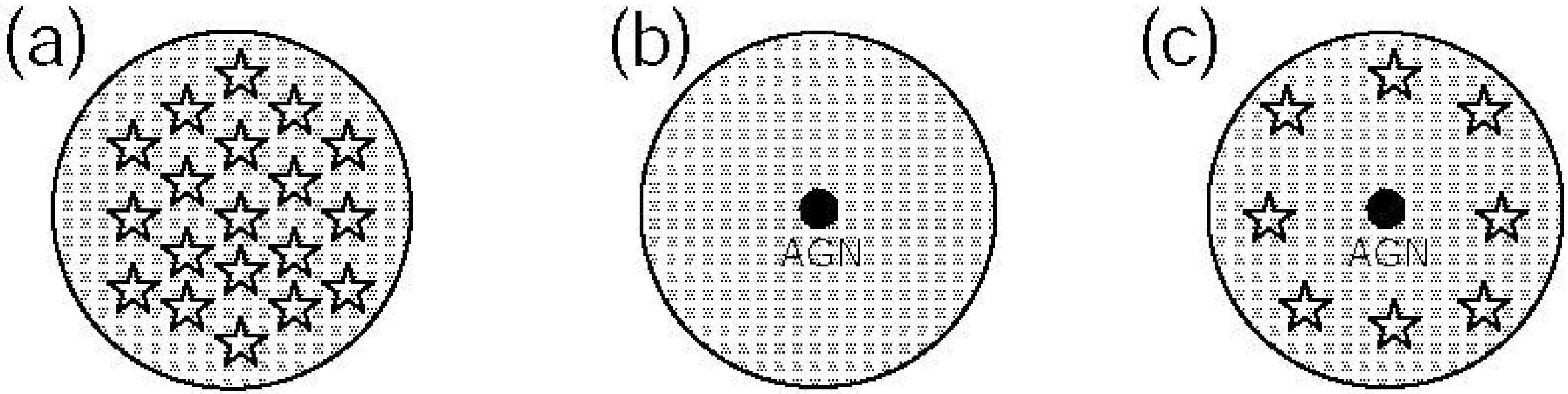
1. Infrared spectral shape

PAH

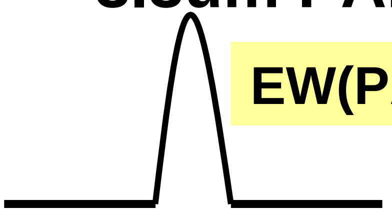


PAHs are excited in starburst PDRs but destroyed near an AGN

Starburst(SB)	Buried AGN	composite

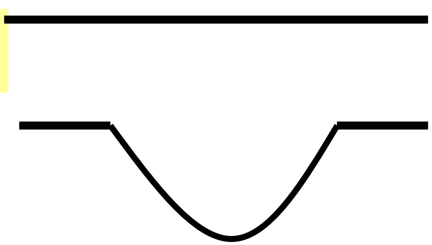


3.3um PAH



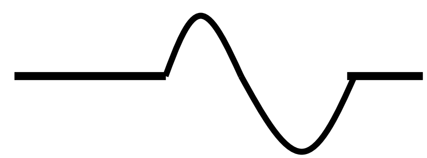
EW(PAH)~100nm

featureless



3.4um/3.1um

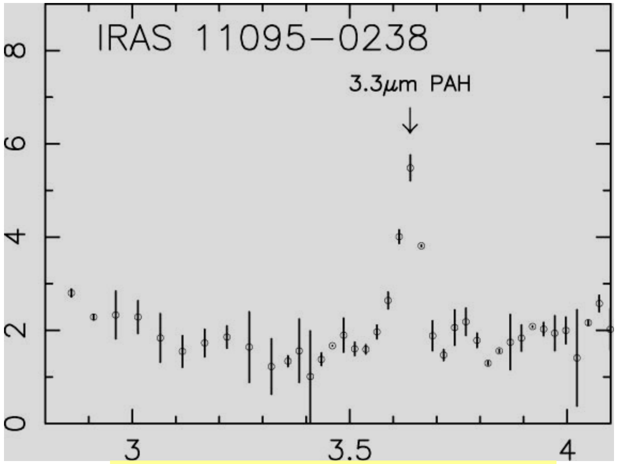
EW(PAH)<<100nm



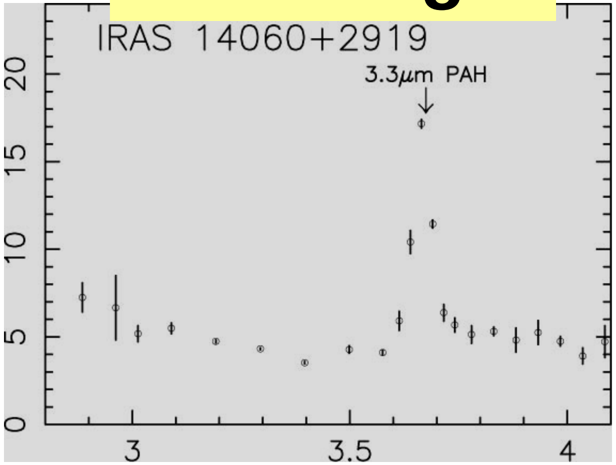
3-4 um

Subaru

Starburst(SB)

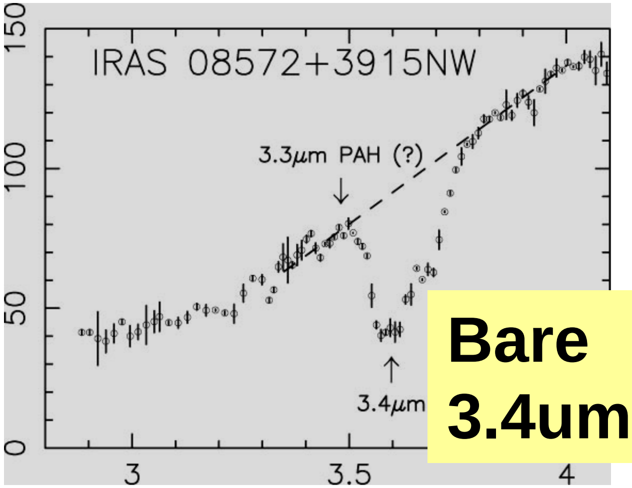


wavelength

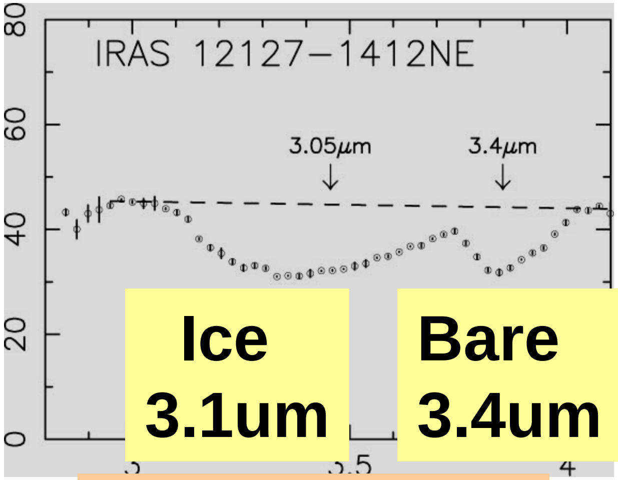


Strong PAH

Buried AGN



Bare
3.4um

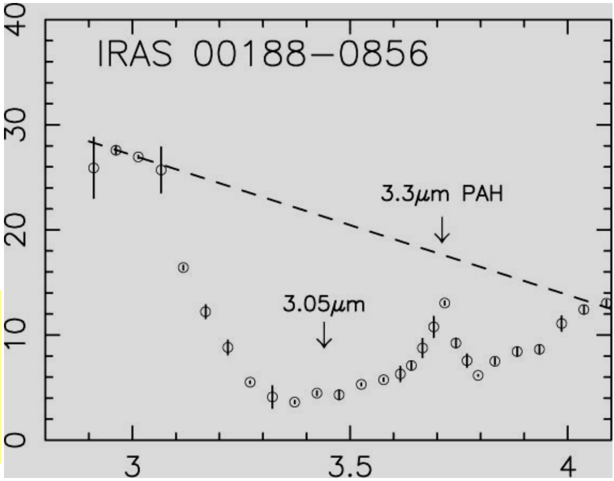


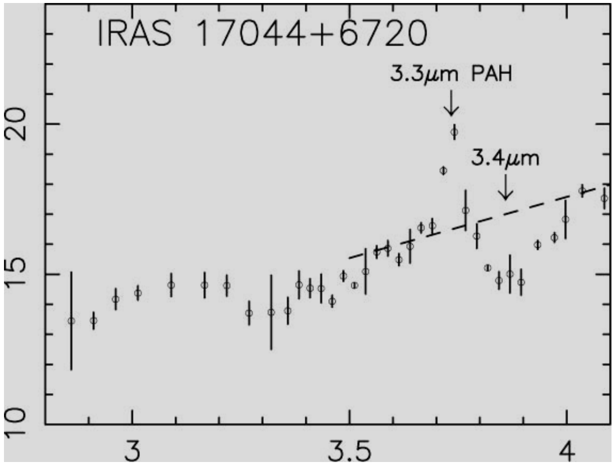
Ice
3.1um

Bare
3.4um

Abs. feature

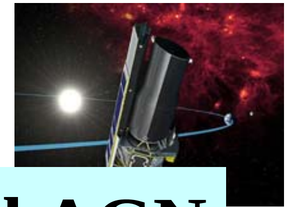
AGN/SB composite





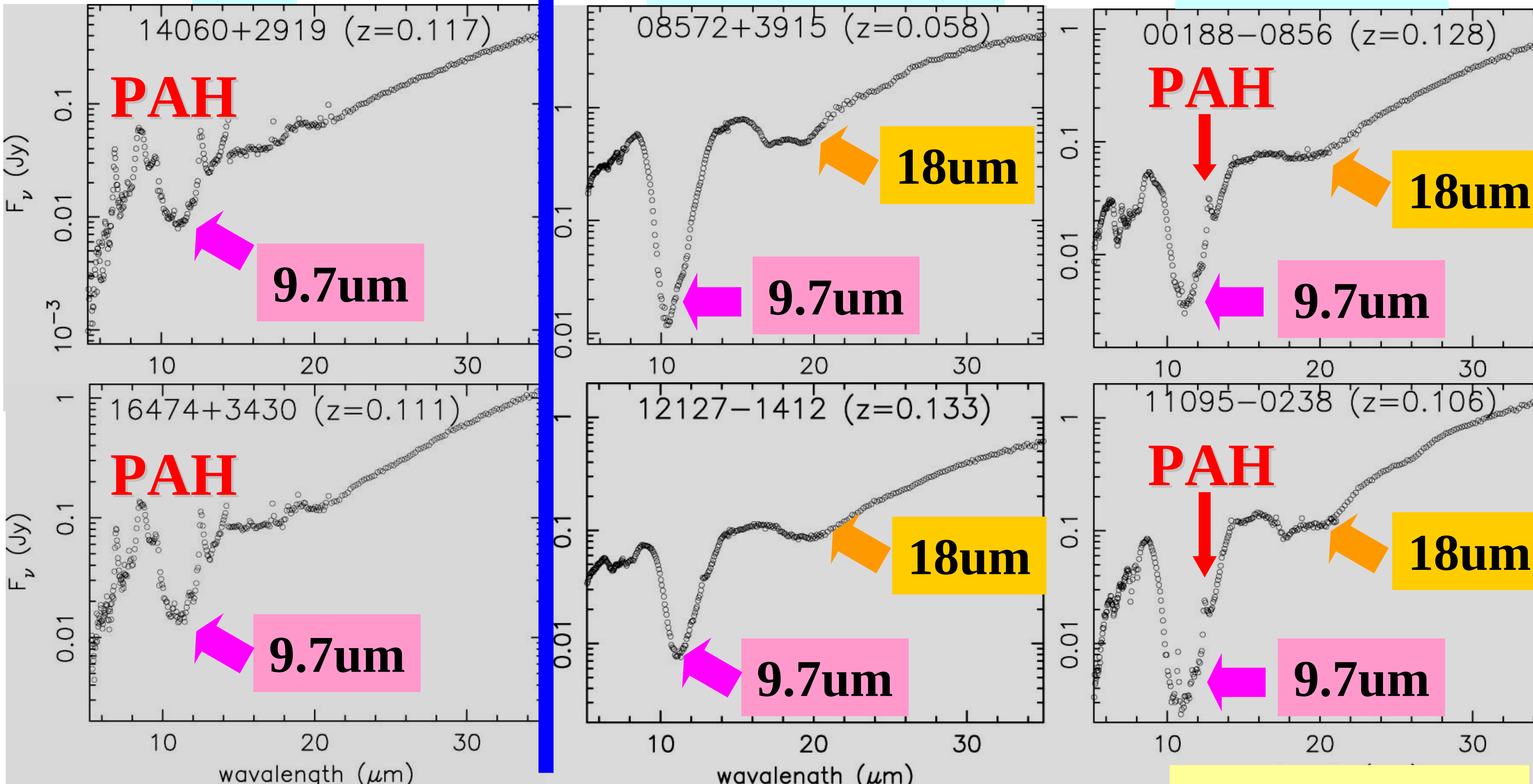
Low EW(PAH)

5-35 um



Spitzer GO1

SB | Buried AGN | AGN+SB



wavelength

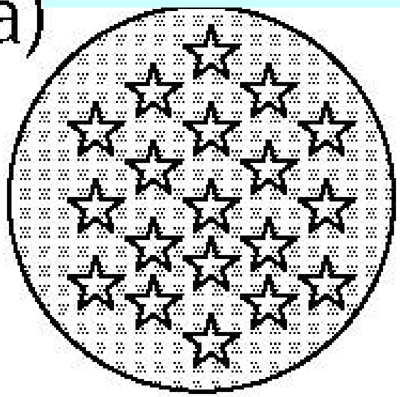
PAH **strong**

PAH **weak**
Silicate Abs. **strong**

2. Dust absorption feature strength

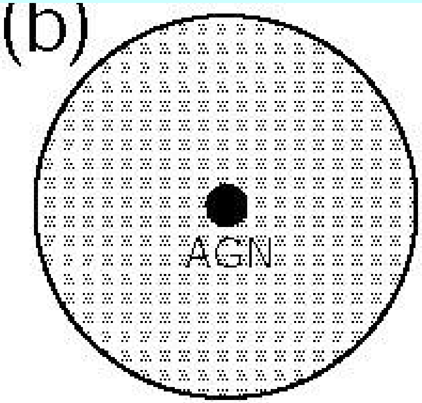
starburst

(a)



Buried AGN

(b)

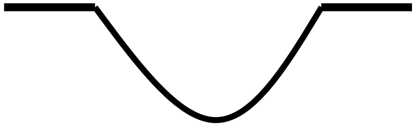


ULIRG core <500pc

Mixed dust model

$$\frac{1-\exp(-\mathrm{Tau})}{\mathrm{Tau}}$$

Dust absorption feature: weak



Foreground screen dust model

$$\exp(-\mathrm{Tau})$$

strong

Tau(3.1) < 0.3   Tau(9.7) < 1.7

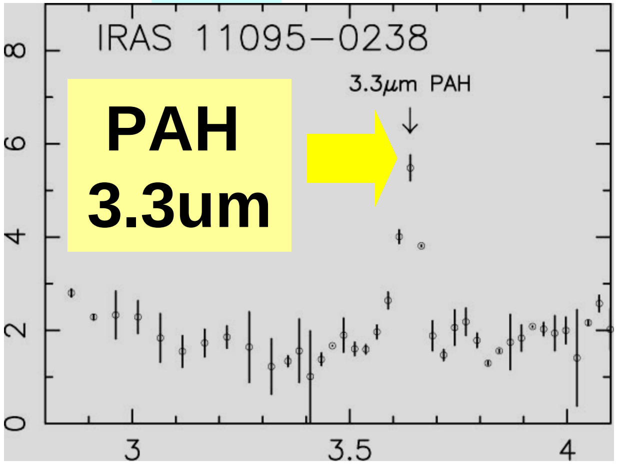
Tau(3.4) < 0.2 (Imanishi & Maloney 2003 ApJ 588 165

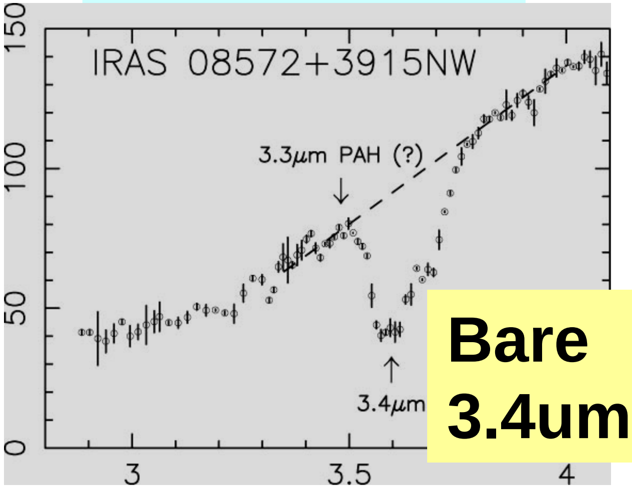
3-4 um

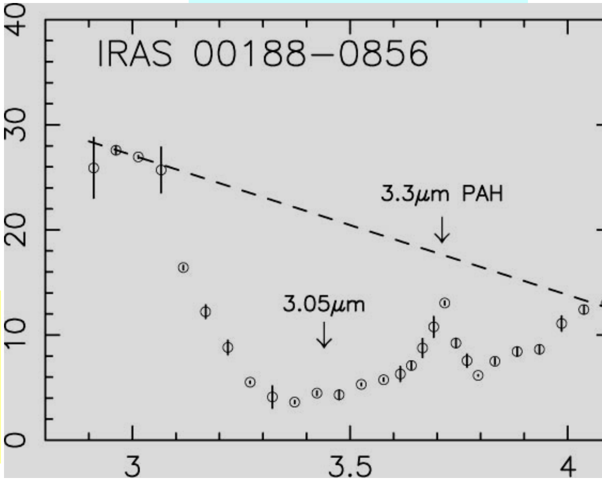
SB

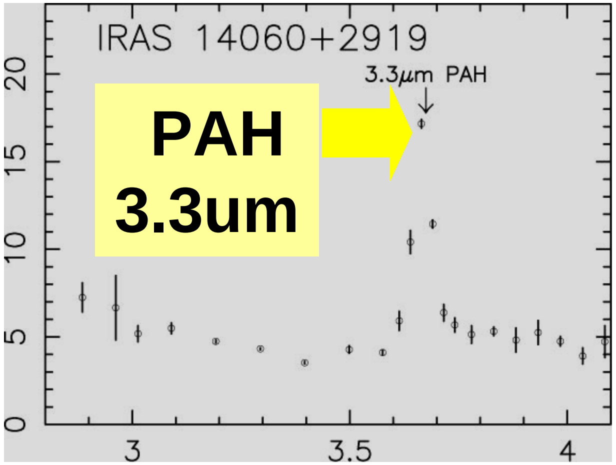
Buried AGN

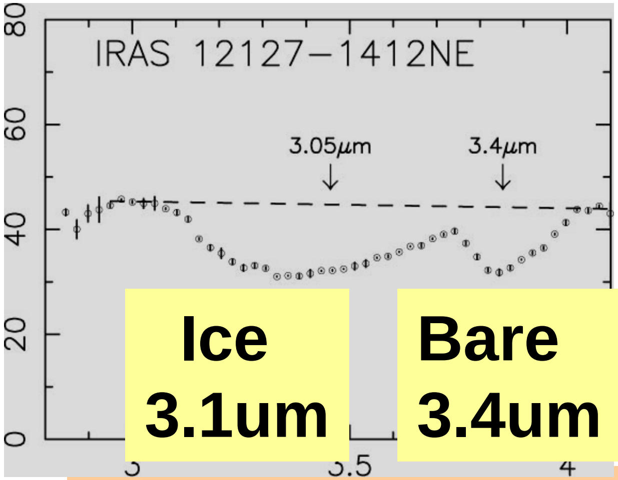
AGN+SB

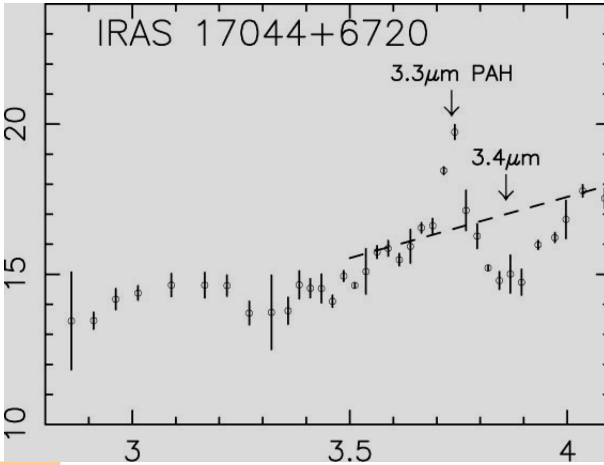










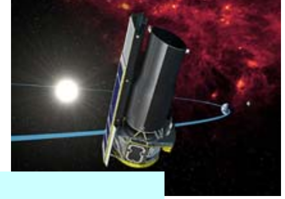


PAH strong (SB): Dust abs. weak

PAH weak (AGN): Dust abs. strong

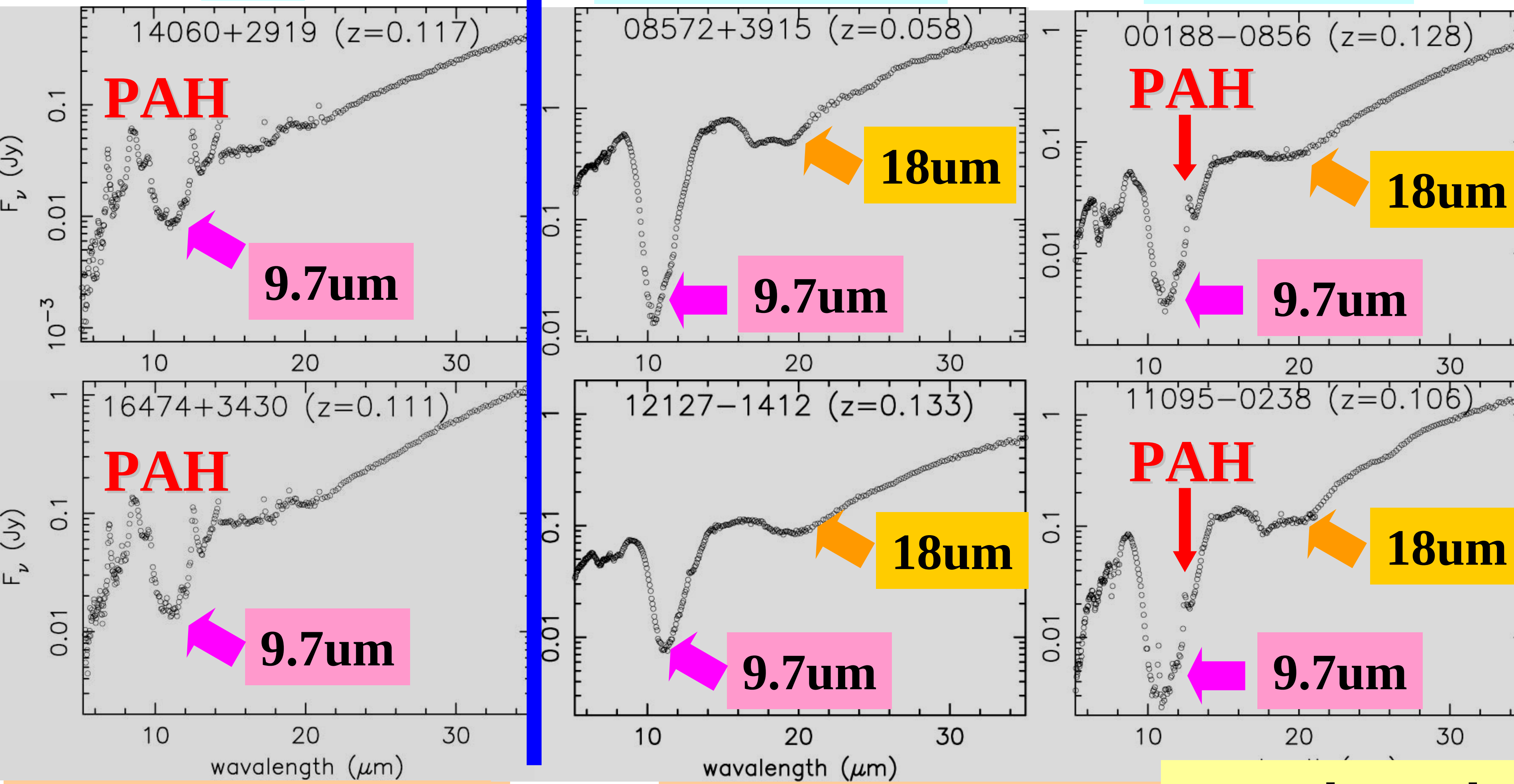
wavelength

5-35 um



Spitzer GO1

SB | Buried AGN | AGN+SB

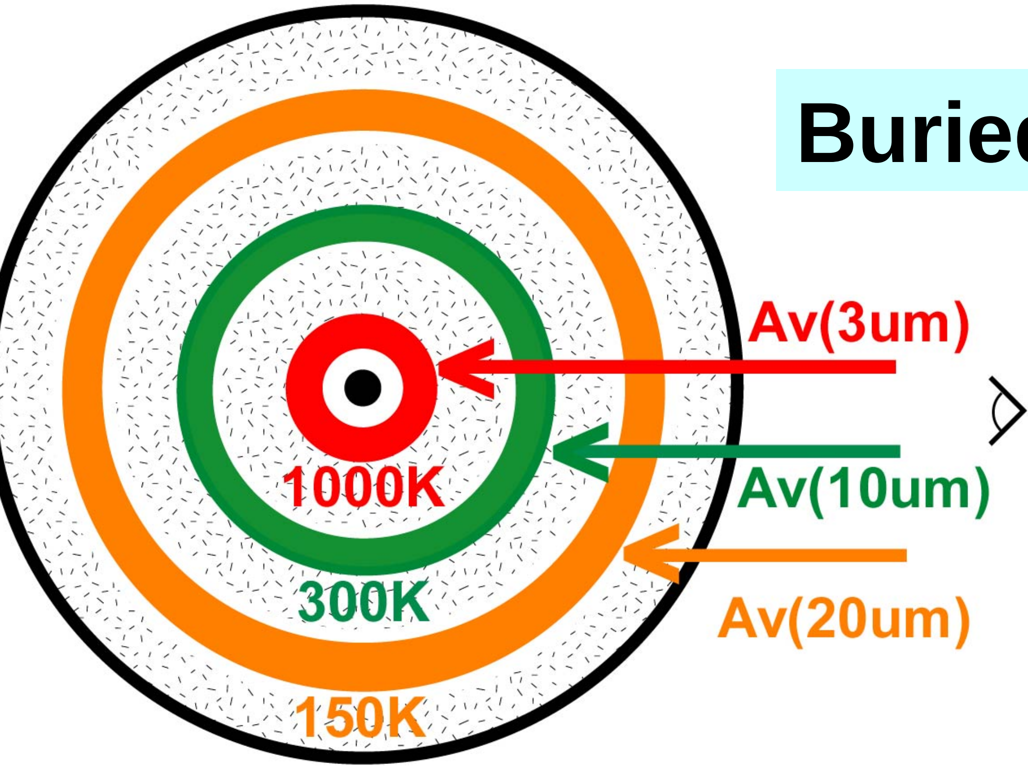


PAH **strong** :
Silicate Abs. **weak**

PAH **weak**:
Silicate Abs. **strong**

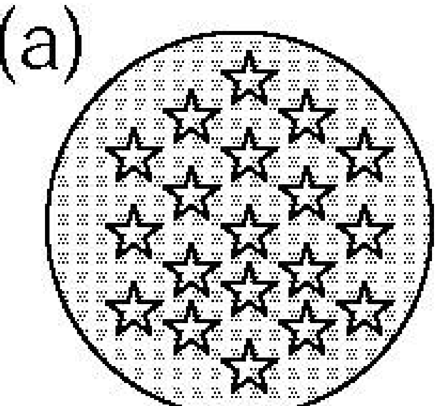
wavelength

3. Dust temperature gradient

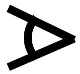


Buried AGN

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



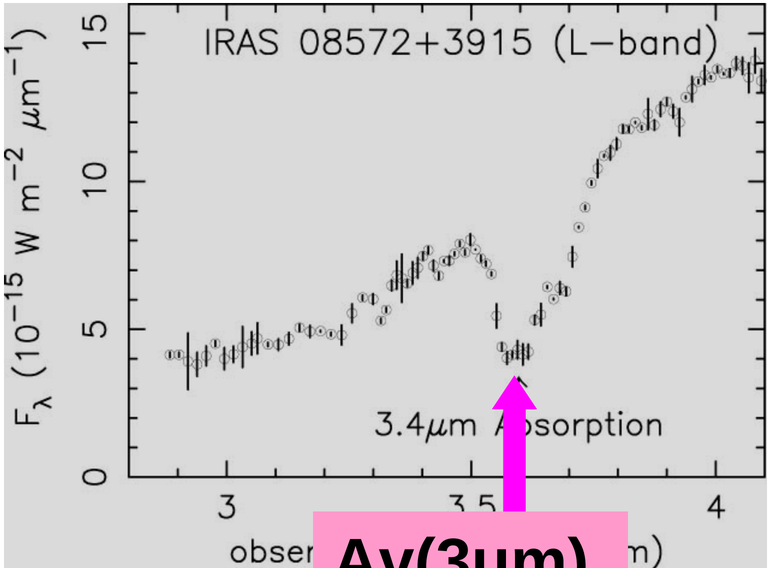
dust in edge-on host



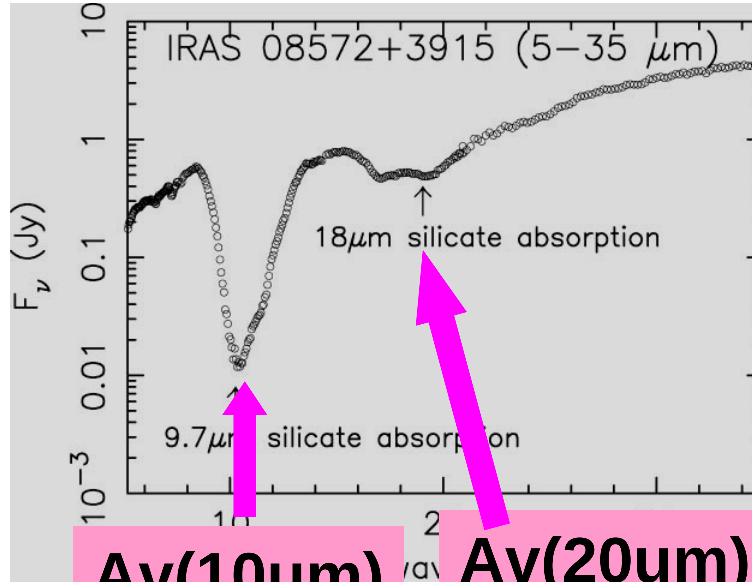
Starburst

Av(3um) =< Av(10um) =< Av(20um)

How to detect T-gradient ?



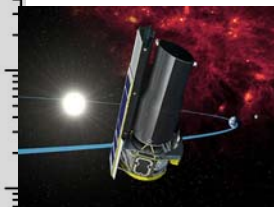
Av(3um)
~110mag



Av(10um)
~40mag

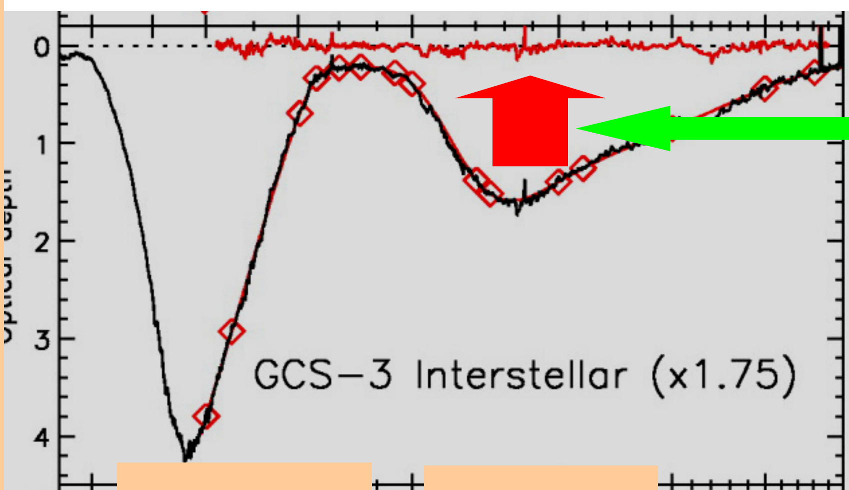
Av(20um)
~20mag

Subaru



Spitzer

Optical depth

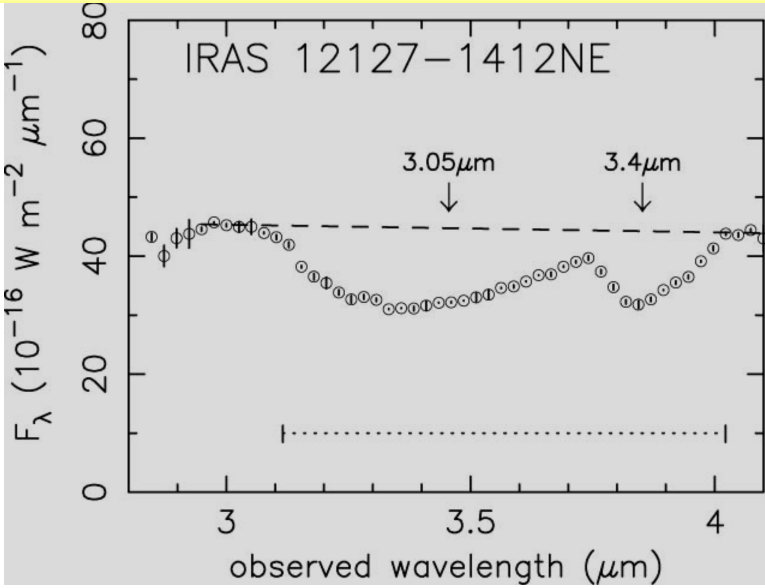


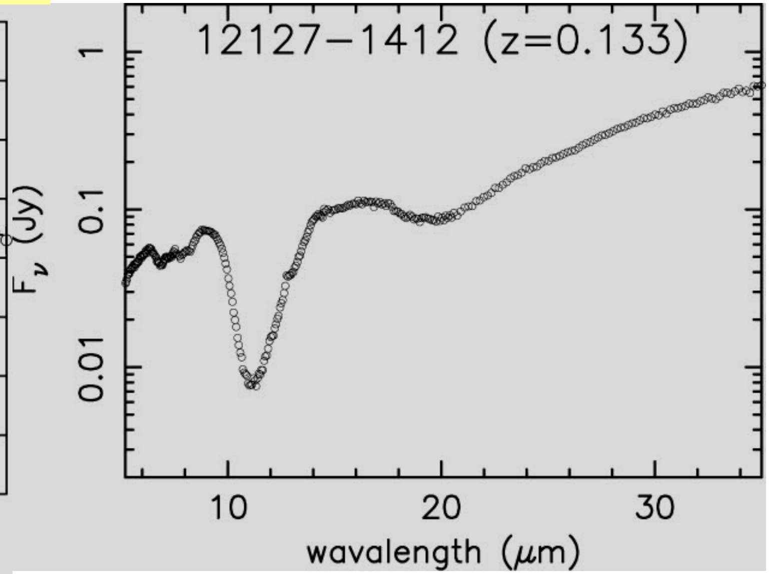
9.7um

18um

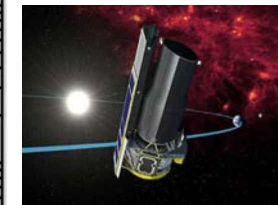
Dust temperature gradient

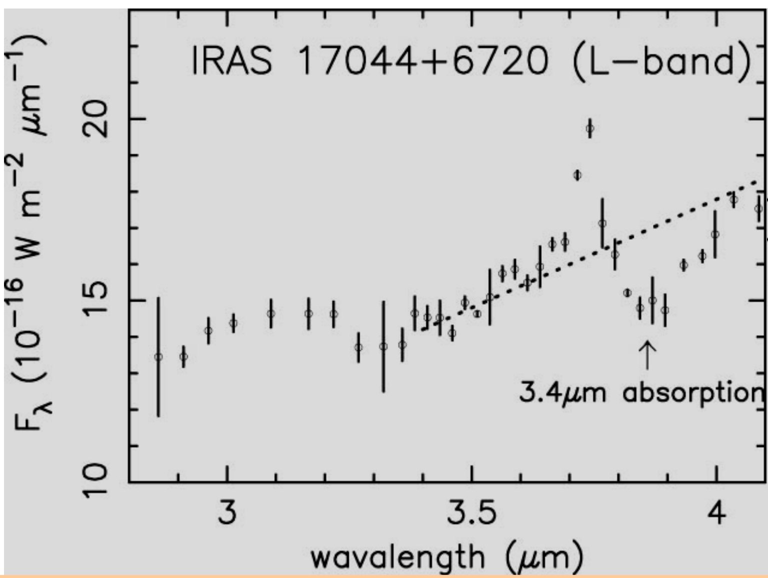
Strong T-gradient (II)

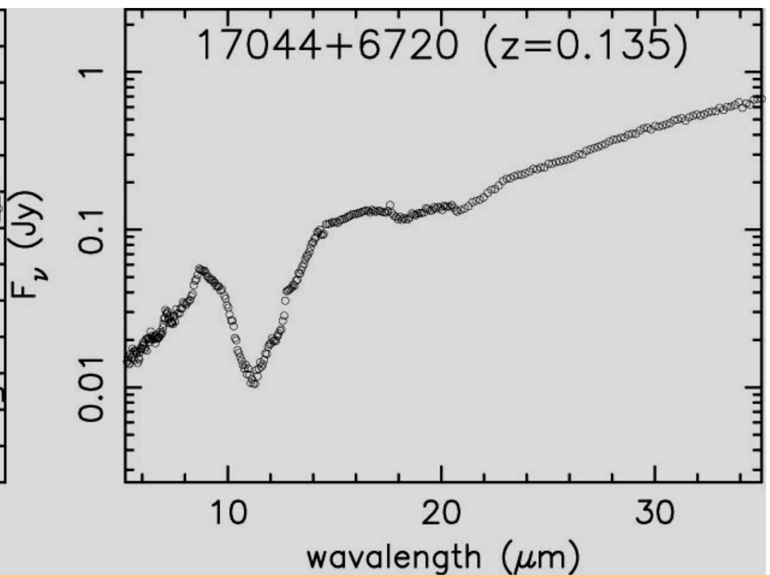





Subaru


Spitzer

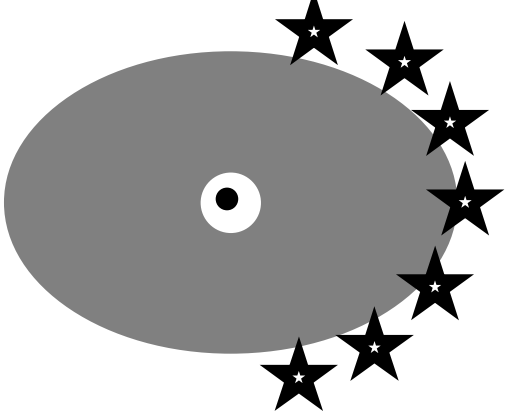




Strong abs ULIRGs -> often show T-gradient

Results

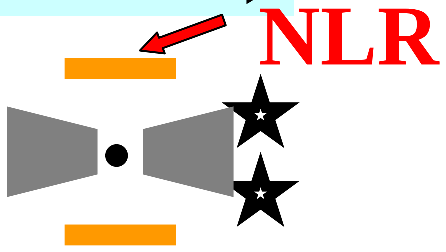
nearby(z<0.15)



Opical non-Seyfert ULIRGs

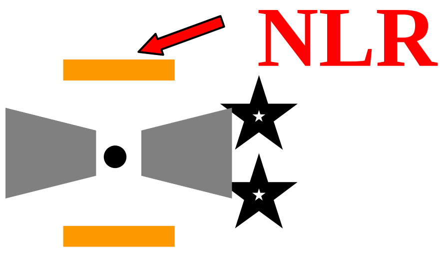
Luminous buried AGNs = 30-50%

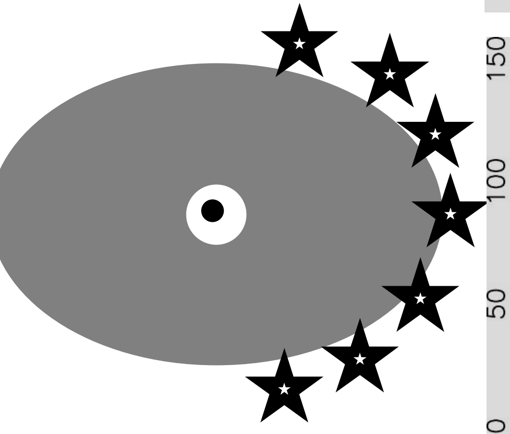
30% ULIRGs = optical Sy (AGN + torus)

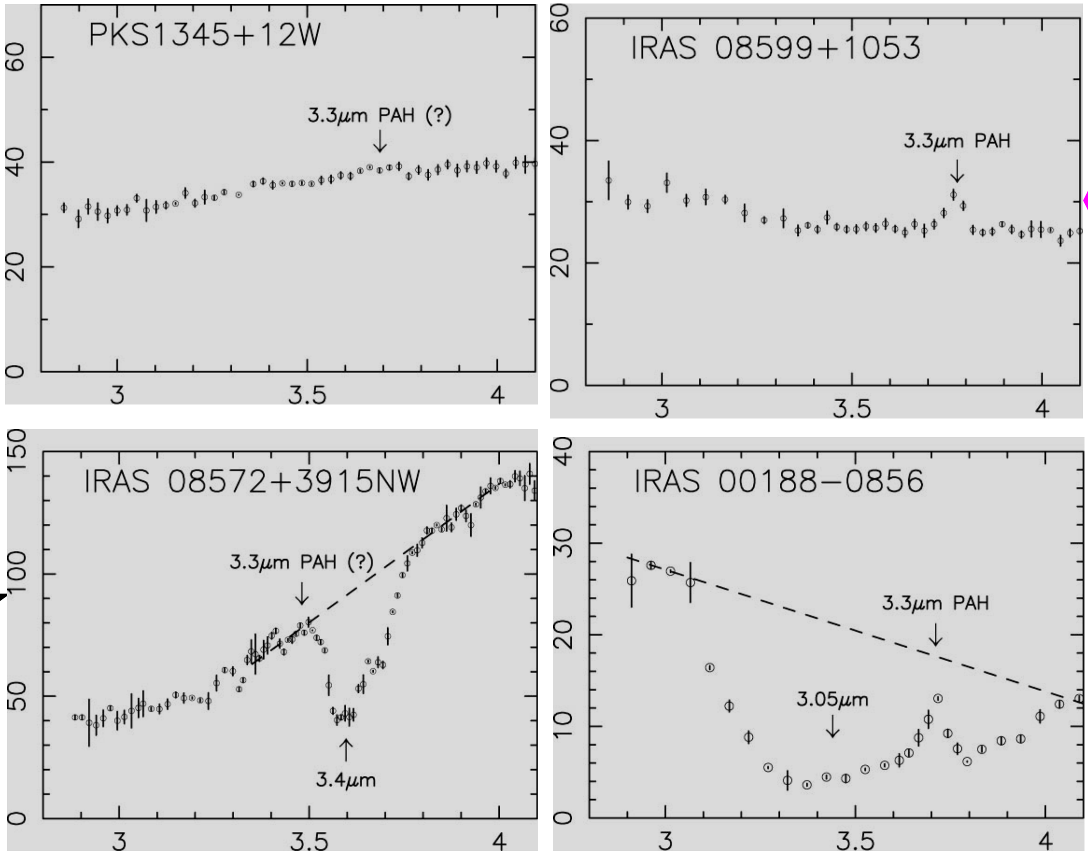


>50% ULIRGs = luminous AGN

Our line-of-sight obscuration: Non-Sy >> Sy2







Sy2: Abs weak

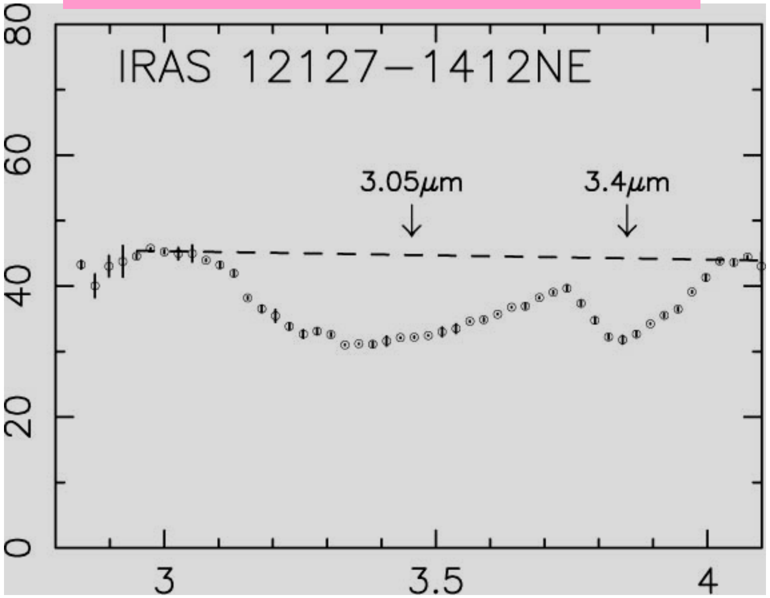
Non-Sy: strong

L(intrinsic AGN) ~L(IR)

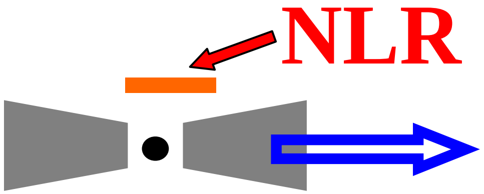
Amount of nuclear dust: Non-Sy >> Sy2

Buried AGNs: both warm/cool FIR colors

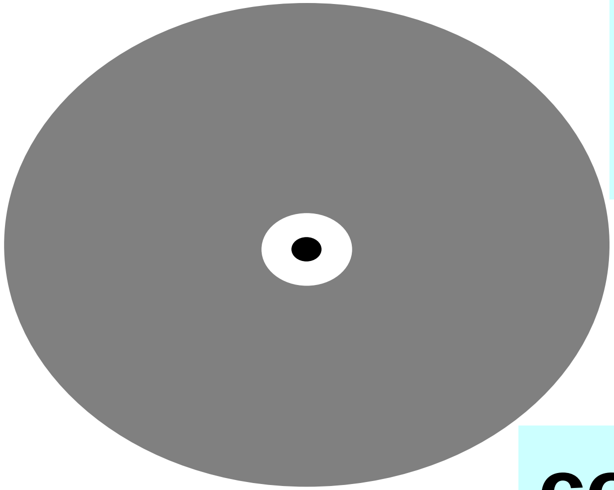
pure buried AGN



F25/F60=0.16(cool)



warm



larger dust column

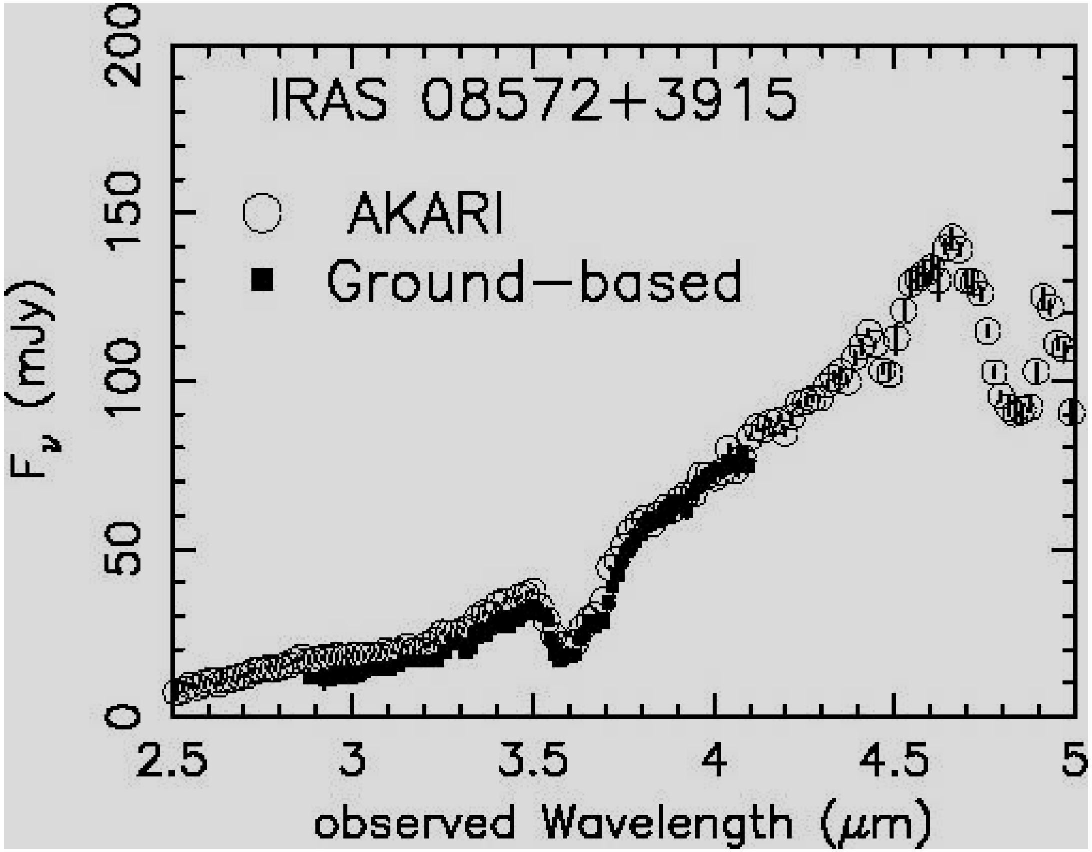
cool FIR color

cool ≠ starburst

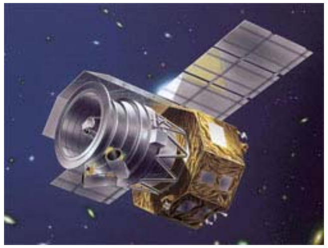
AKARI

2.5-5 um spectroscopy → **z > 0.15 ULIRG**

Unaffected by Earth's atmosphere

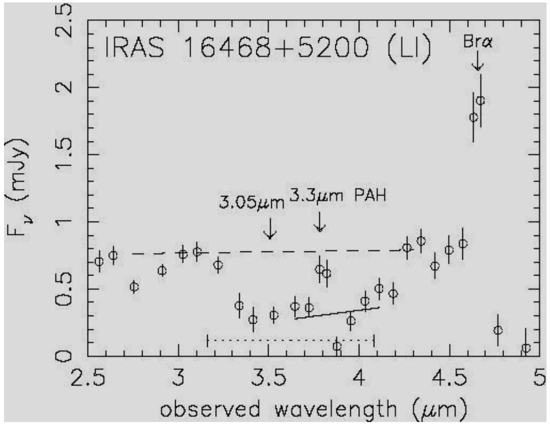


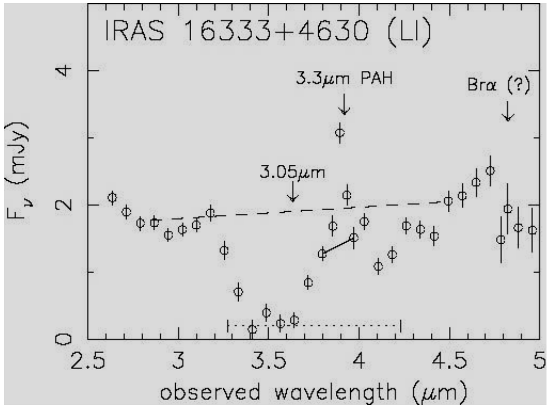
AKARI

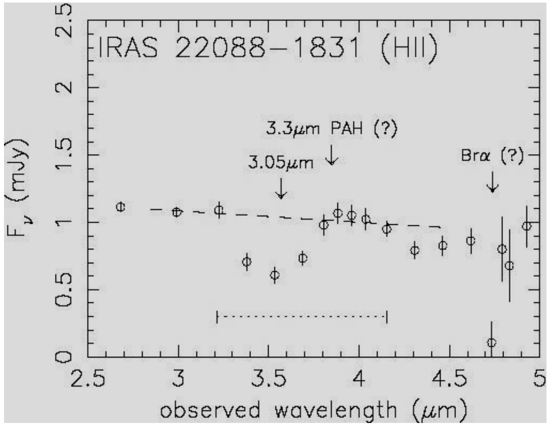


z>0.15 → **Higher L_{IR} ULIRGs**

Buried AGNs increase with L_{IR}







AGN-feedback for galaxy down-sizing ?

Summary

1. Buried AGNs : <u>30-50% non-Sy ULIRGs</u>

warm & cool

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

→ Optical Sy (non-)detectability depends on the amount of <u>nuclear dust</u>

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