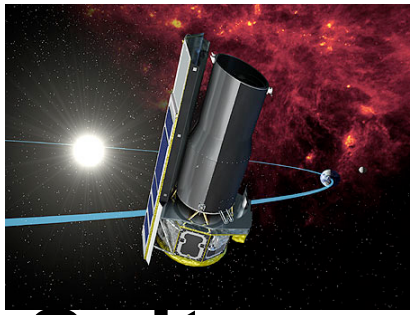
Luminous buried AGNs in the local universe ULIRGs

Masa Imanishi

NAOJ (National Astronomical Observatory of Japan)

Subaru



Spitzer

NMA

Ultraluminous Infrared Galaxies（ULIRGs）

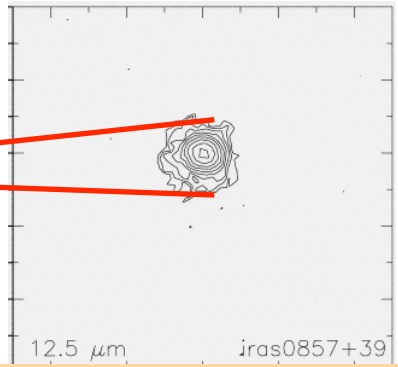
L(IR)>10^12Lsun

Powerful energy source is hidden behind dust

Ultraluminous Infrared Galaxies（ULIRGs）

L(IR)>10^12Lsun ➡ **Powerful energy source is hidden behind dust**

optical



IR(12um)

Soifer et al. 2000

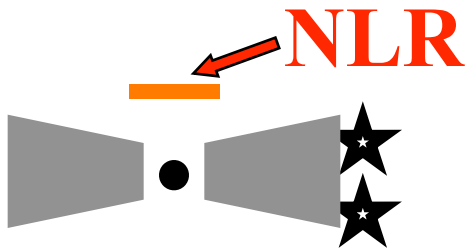
⬇

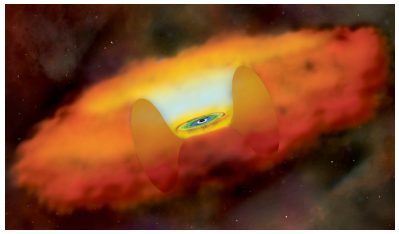
Compact cores (<500pc) are dominant

⬇

Very compact starburst or AGN ?

AGNs in ULIRGs are buried



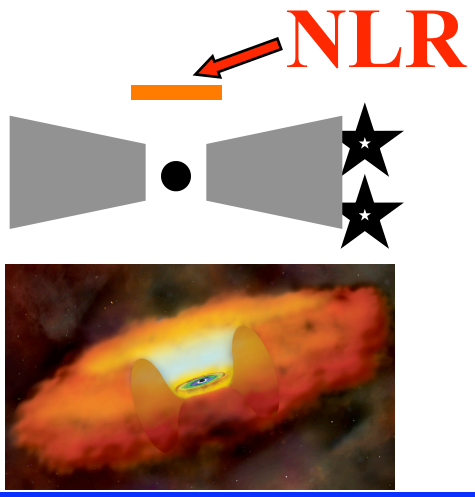


AGNs obscured by torus-shaped dust

Sy2

Detectable via optical spectroscopy

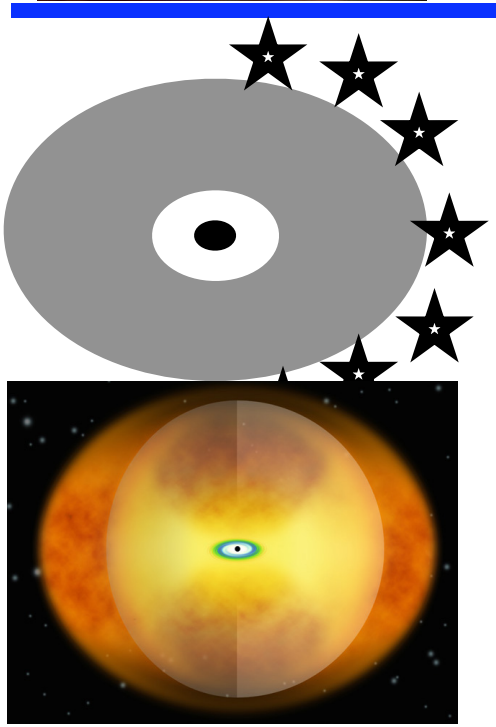
AGNs in ULIRGs are buried



AGNs obscured by torus-shaped dust

Sy2

Detectable via optical spectroscopy



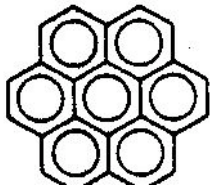
ULIRGs have a large amount of nuclear gas and dust

Buried AGNs are elusive

70% ULIRGs = non-Sy

1. Infrared spectral shape

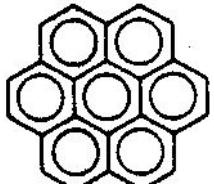
PAH



PAHs are excited in starburst PDRs but destroyed near an AGN

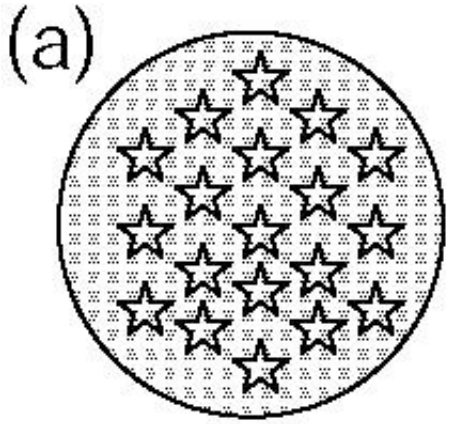
1. Infrared spectral shape

PAH

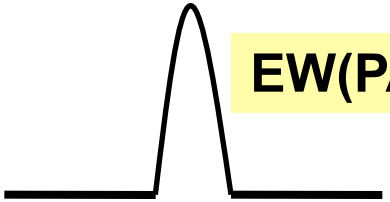


PAHs are excited in starburst PDRs but destroyed near an AGN

Starburst(SB)



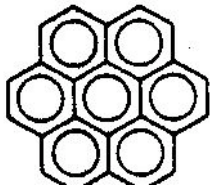
3.3um PAH



EW(PAH)~100nm

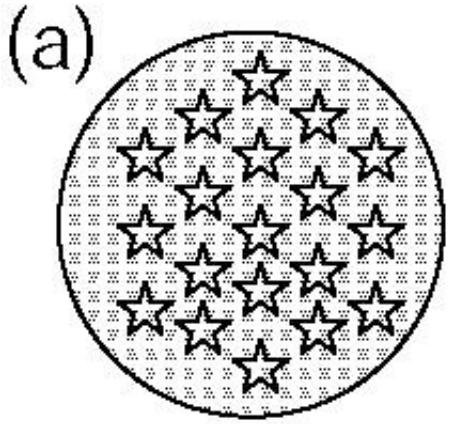
1. Infrared spectral shape

PAH



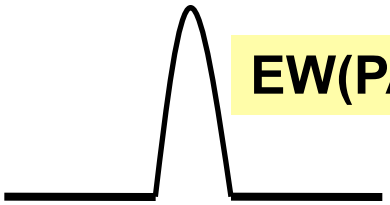
PAHs are excited in starburst PDRs but destroyed near an AGN

Starburst(SB)

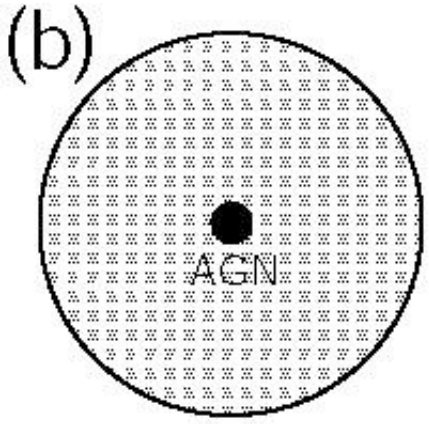


3.3um PAH

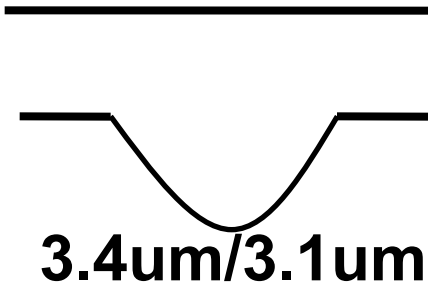
EW(PAH)~100nm



Buried AGN



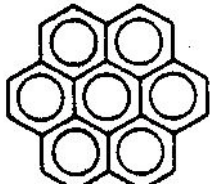
featureless



3.4um/3.1um

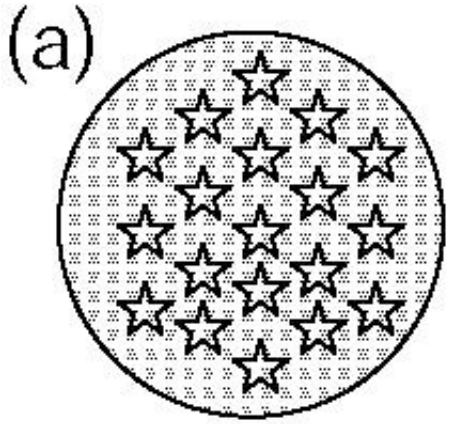
1. Infrared spectral shape

PAH



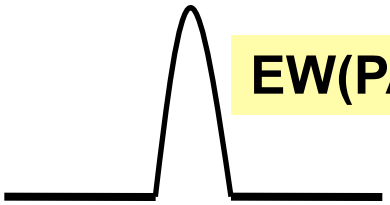
PAHs are excited in starburst PDRs but destroyed near an AGN

Starburst(SB)

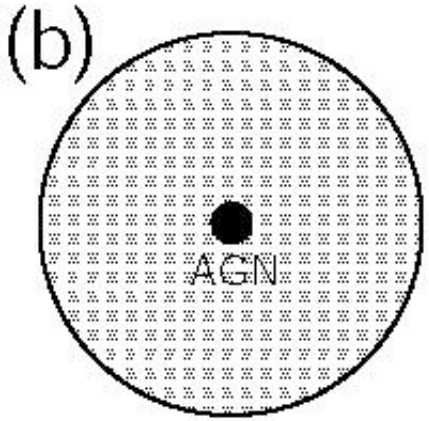


3.3um PAH

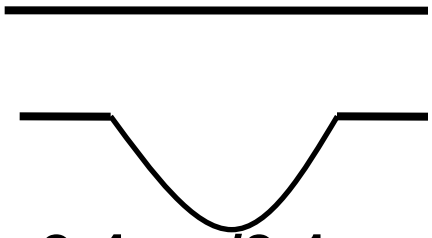
EW(PAH)~100nm



Buried AGN

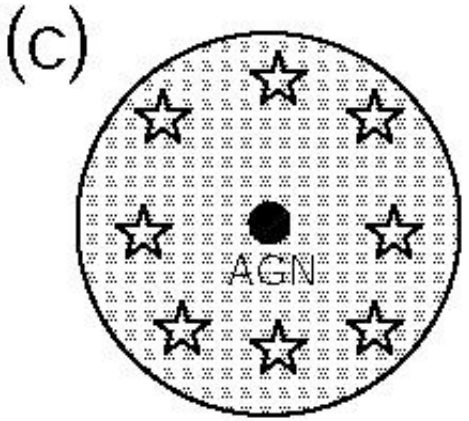


featureless

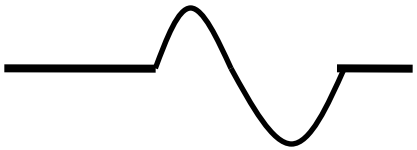


3.4um/3.1um

composite



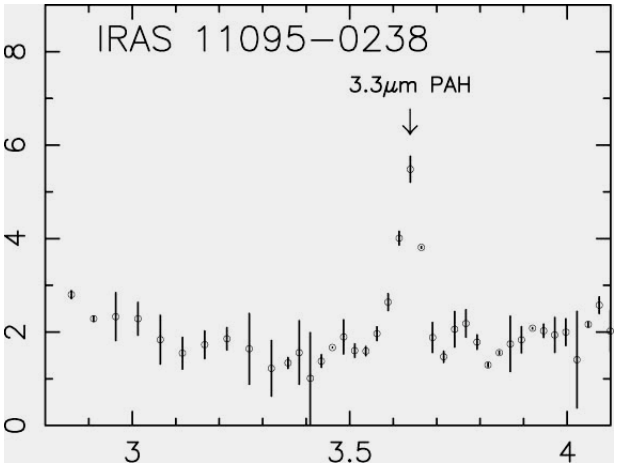
EW(PAH)<<100nm

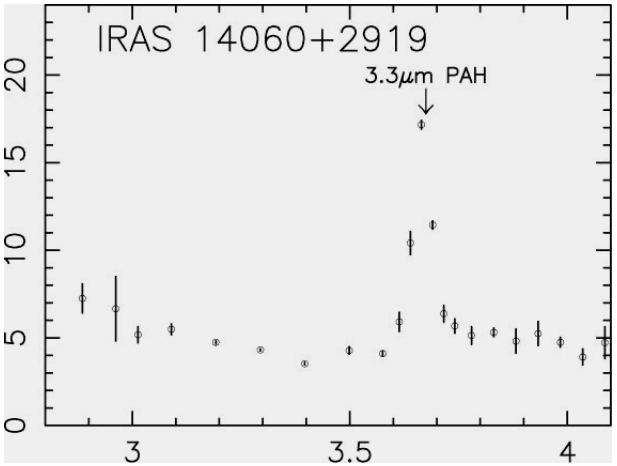


3-4 um

Subaru

Starburst(SB)





Strong PAH

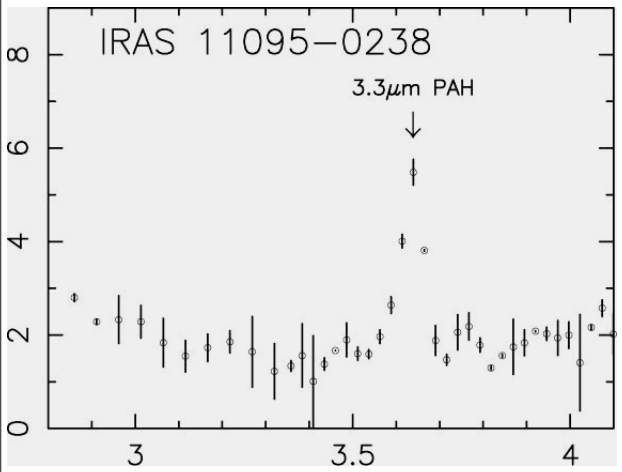
3-4 um

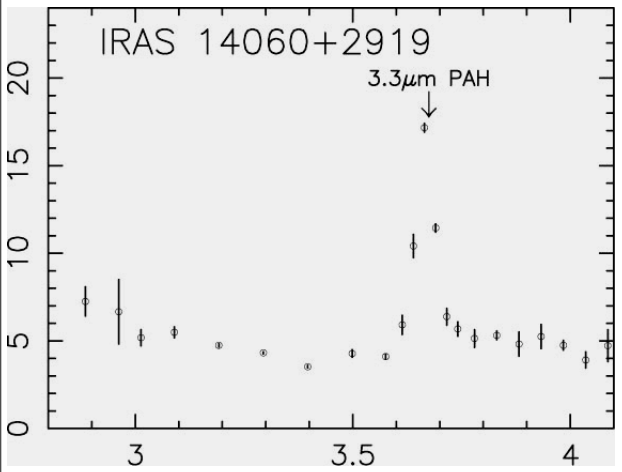
Subaru

Starburst(SB)

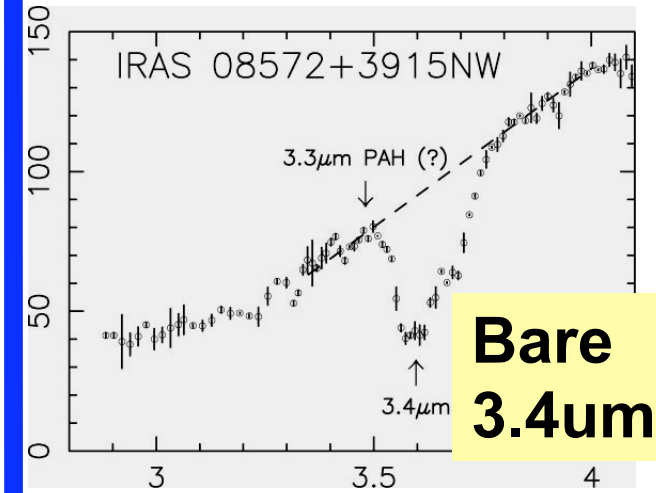
Buried AGN

AGN/SB composite

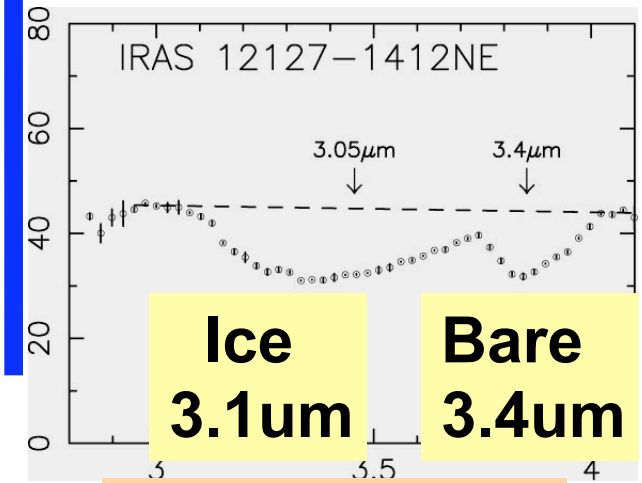




Strong PAH



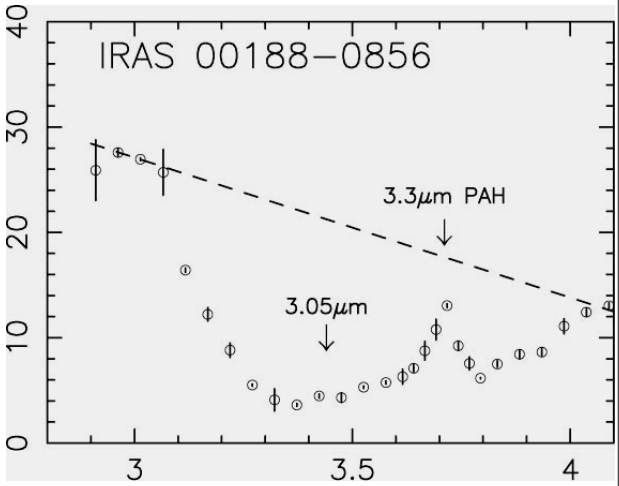
Bare 3.4um

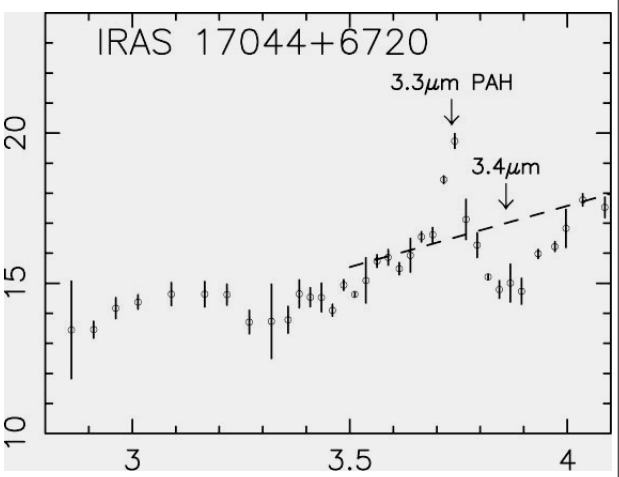


Ice 3.1um

Bare 3.4um

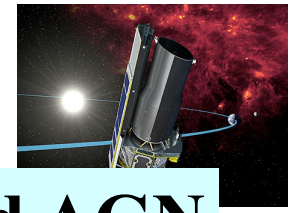
Abs. feature





Low EW(PAH)

5-35 um

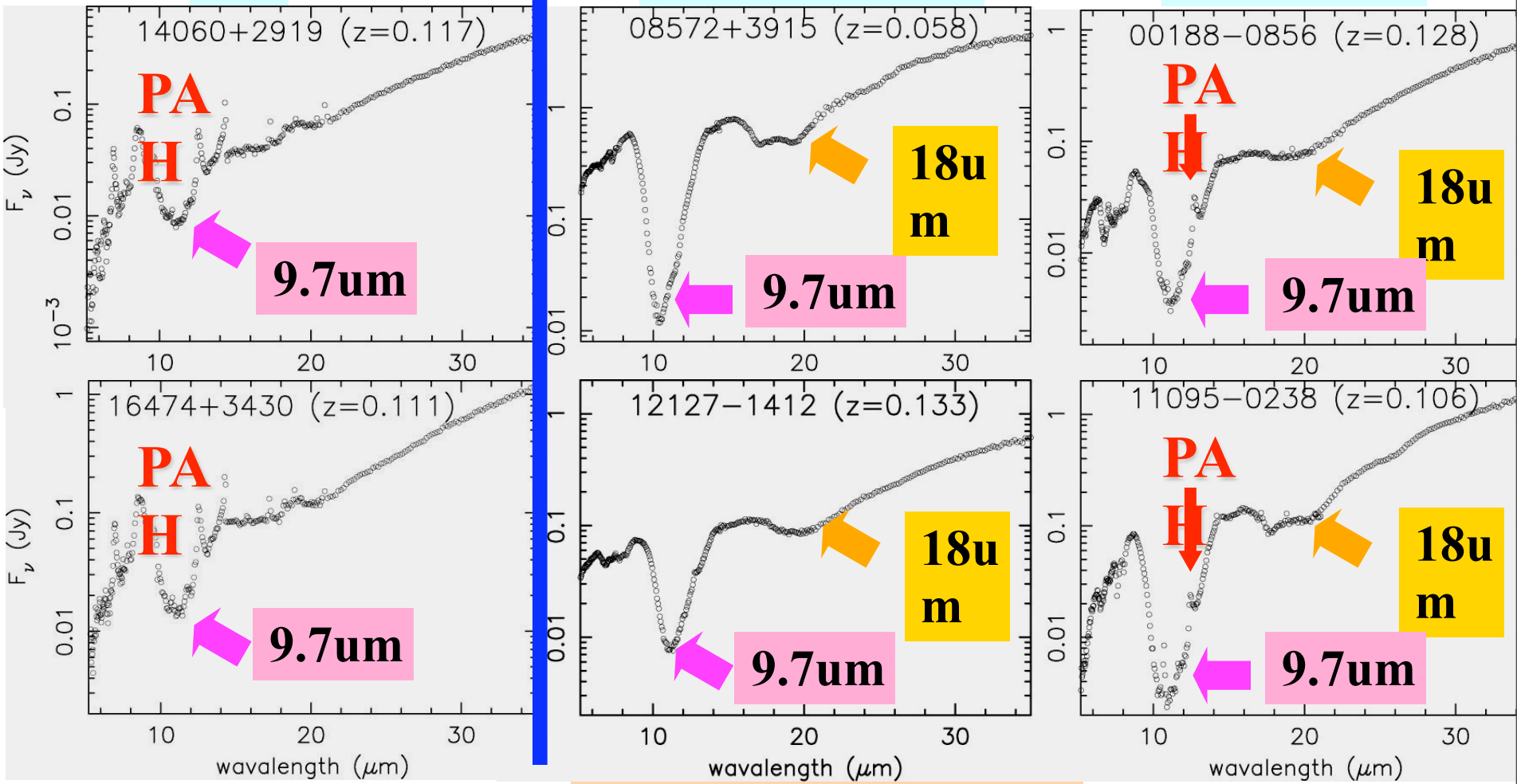


Spitzer GO1

SB

Buried AGN

AGN+SB



PAH strong

PAH weak
Silicate Abs. strong

2. Dust absorption feature strength

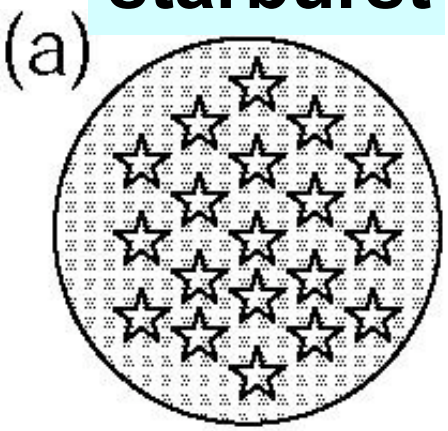
starburst

Buried AGN

ULIRG core <500pc

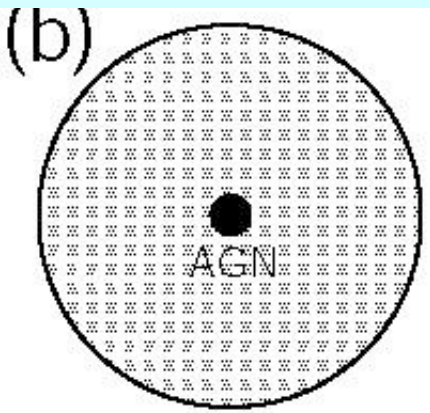
2. Dust absorption feature strength

starburst



ULIRG core
<500pc

Buried AGN



Mixed dust model

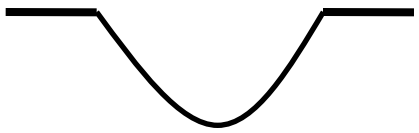
$$\frac{1-\exp(-\tau)}{\tau}$$

Dust absorption feature: weak

Foreground screen dust model

$\exp(-\tau)$

strong



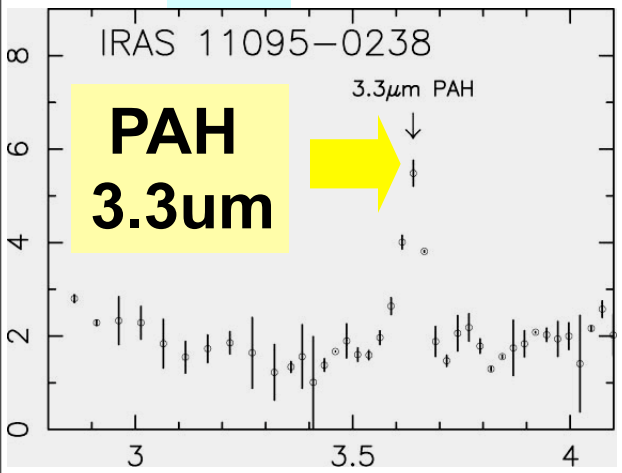
Tau(3.1) < 0.3 Tau(9.7) < 1.7

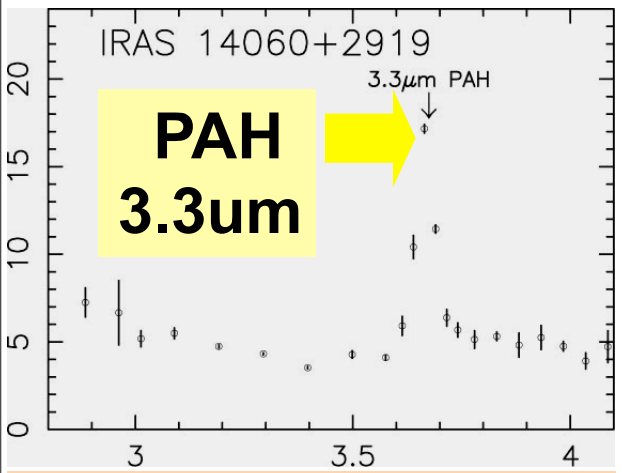
Tau(3.4) < 0.2 (Imanishi & Maloney 2003 ApJ 588 165

3-4 um

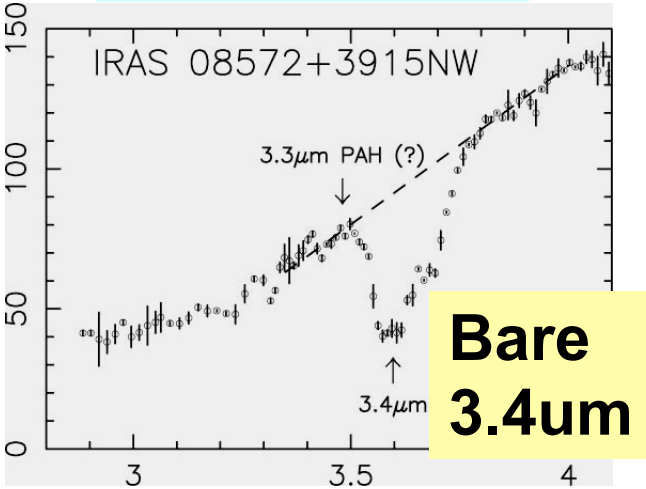
Subaru

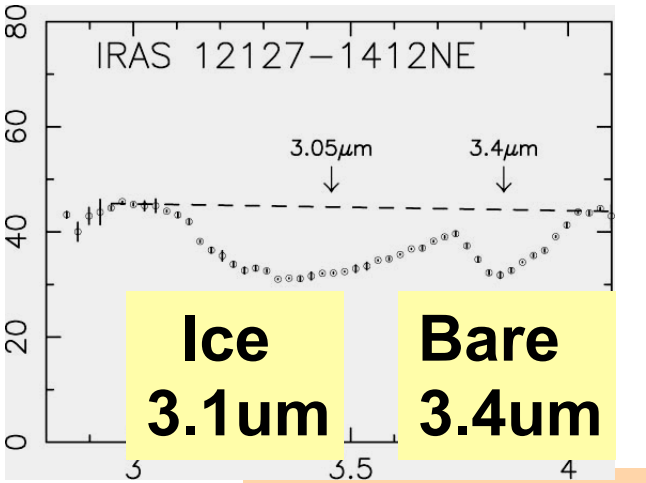
SB



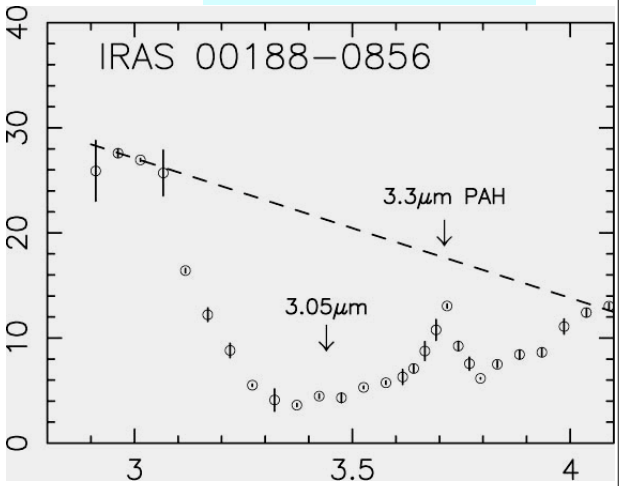


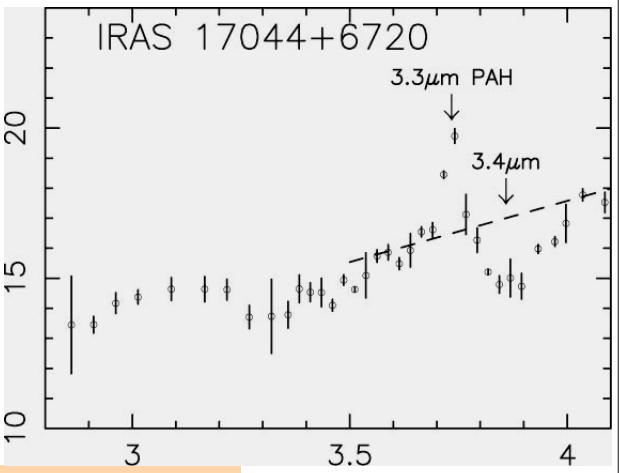
Buried AGN





AGN+SB

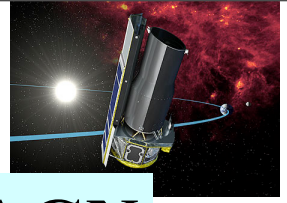




PAH strong (SB): Dust abs. weak

PAH weak (AGN): Dust abs. strong

5-35 um

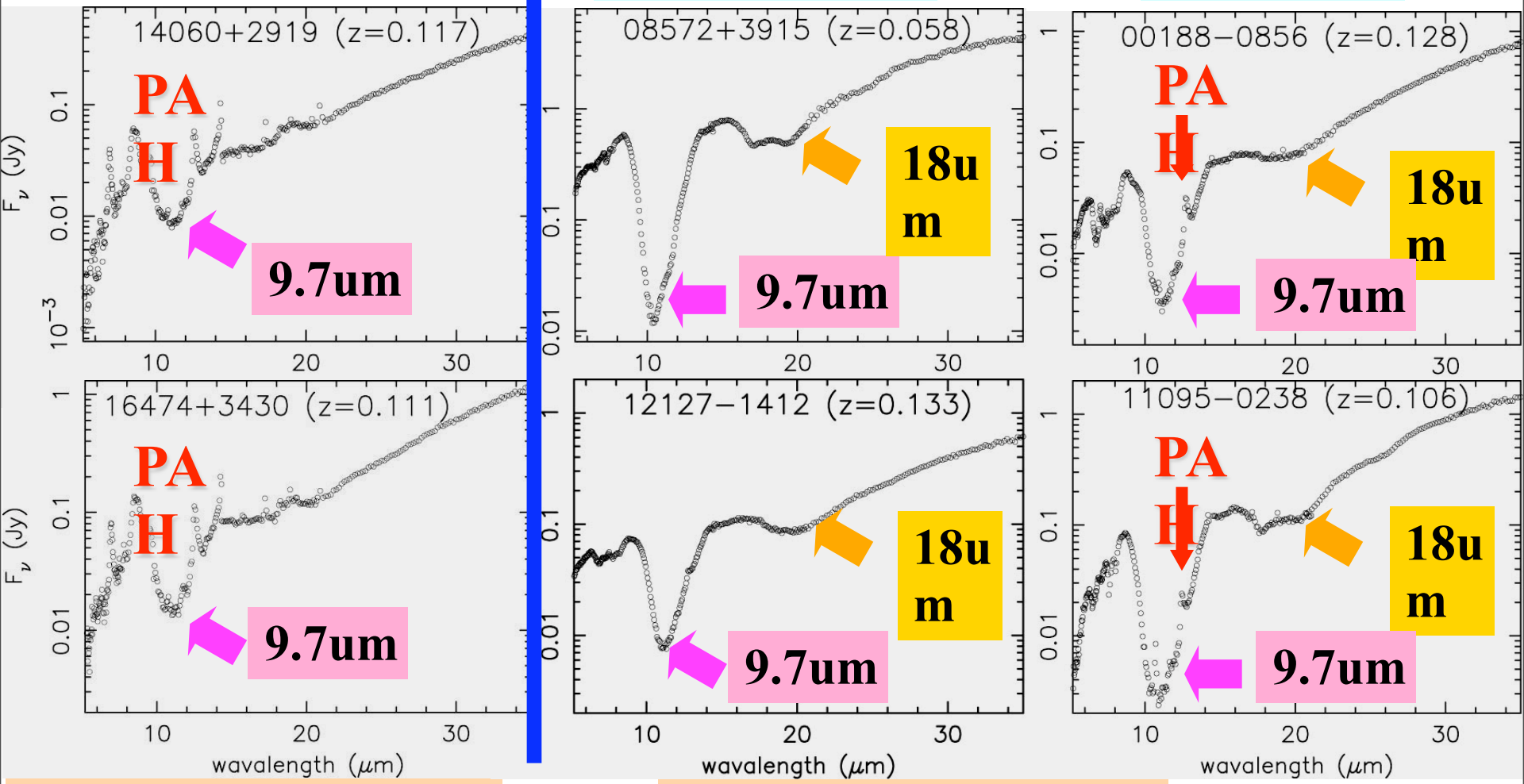


Spitzer GO1

SB

Buried AGN

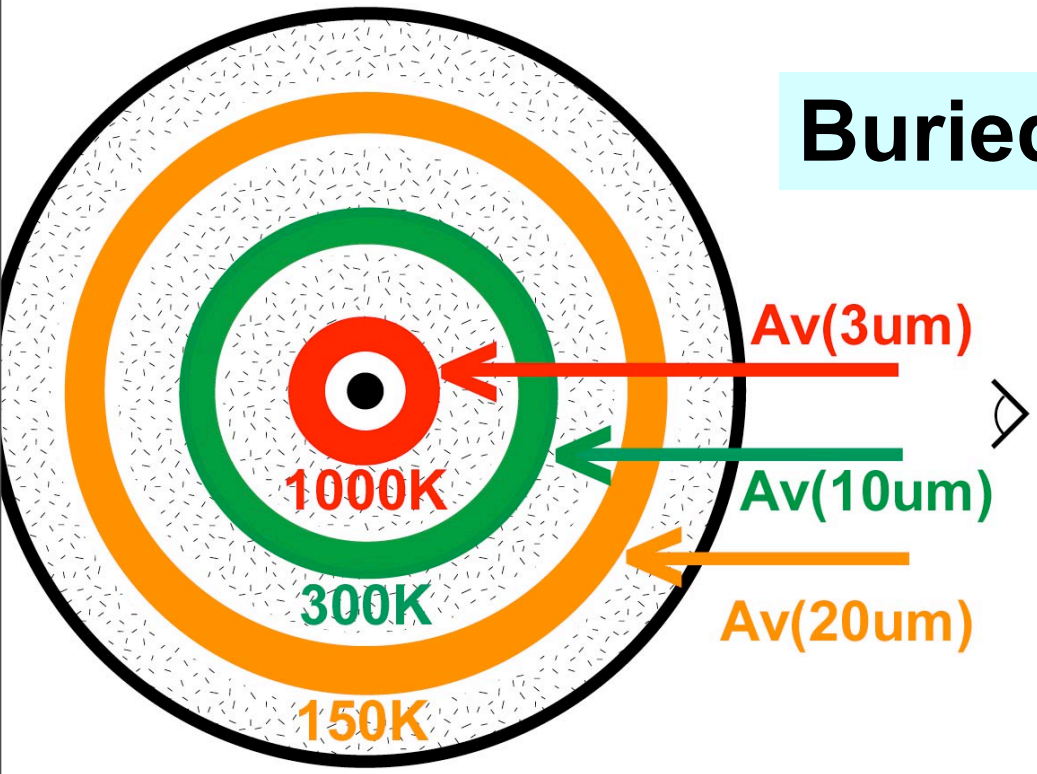
AGN+SB



PAH strong :
Silicate Abs. weak

PAH weak:
Silicate Abs. strong

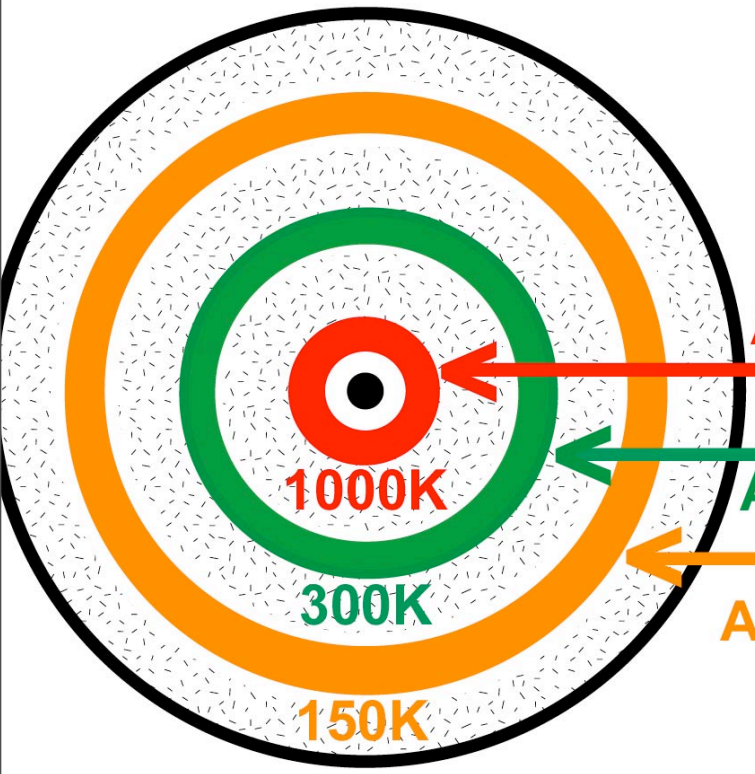
3. Dust temperature gradient



Buried AGN

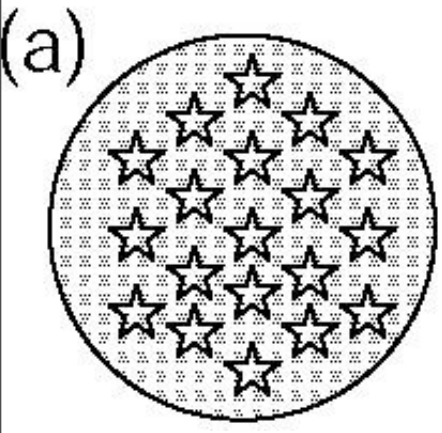
Av(3um) > Av(10um) > Av(20um)

3. Dust temperature gradient



Buried AGN

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

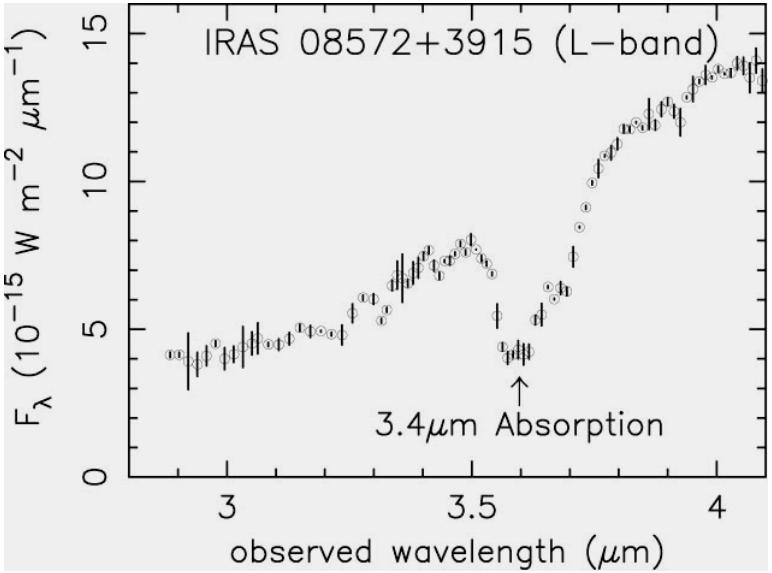


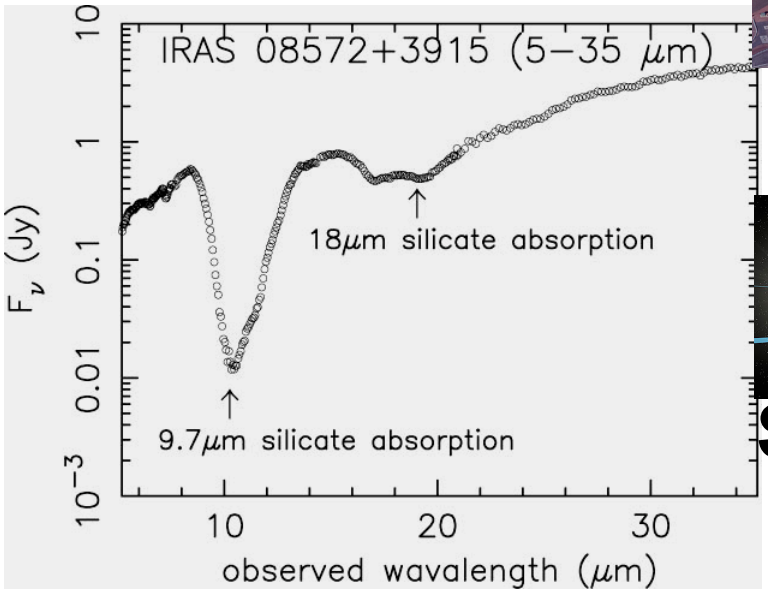
dust in edge-on host

Starburst

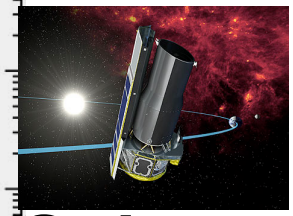
Av(3um) =< Av(10um) =< Av(20um)

How to detect T-gradient ?



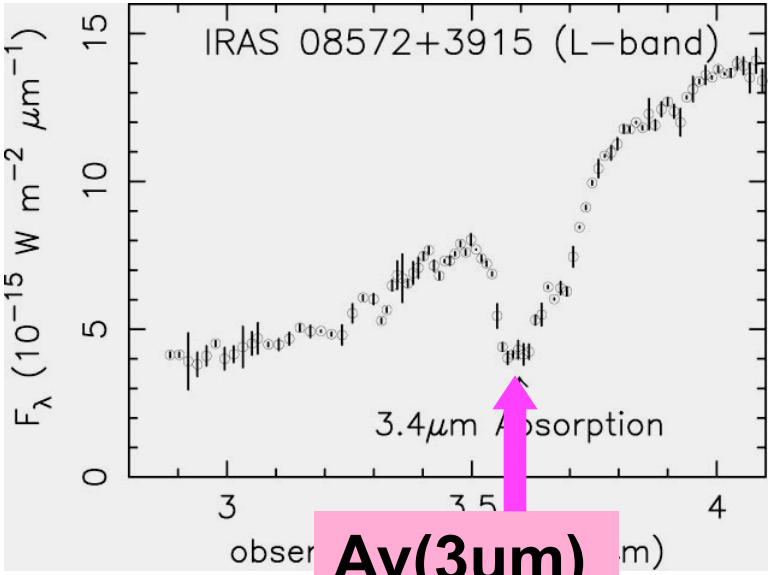


Subaru

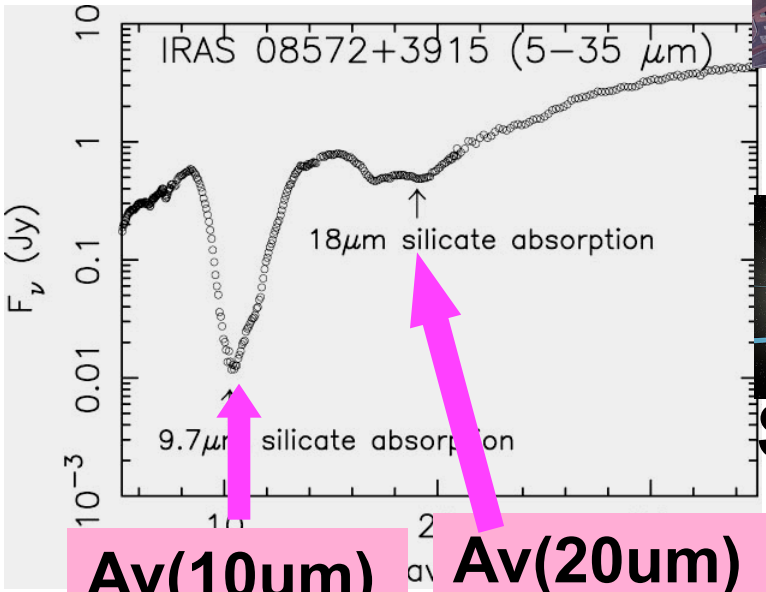


Spitzer

How to detect T-gradient ?



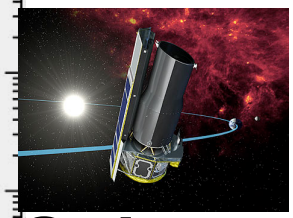
Av(3um)
~110mag



Av(10um)
~40mag

Av(20um)
~20mag

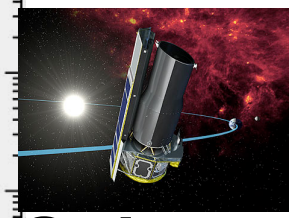
Subaru



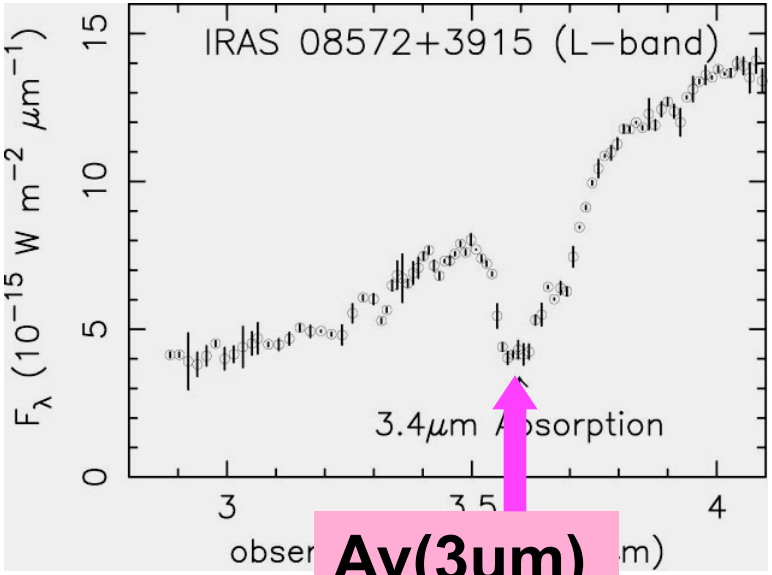
Spitzer

How to detect T-gradient ?

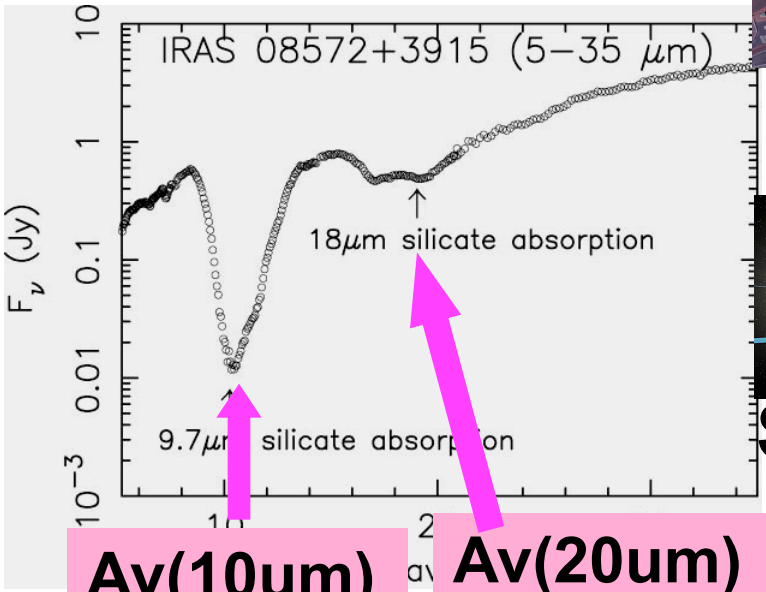
Subaru



Spitzer



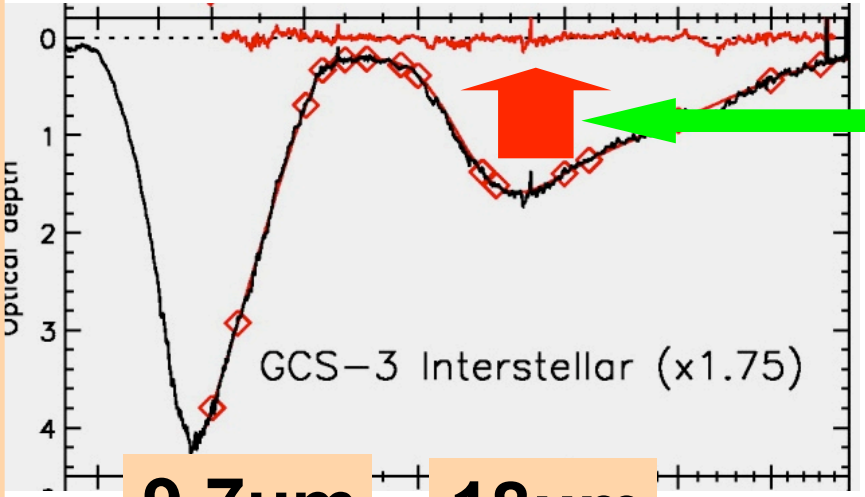
Av(3um)
~110mag



Av(10um)
~40mag

Av(20um)
~20mag

Optical depth



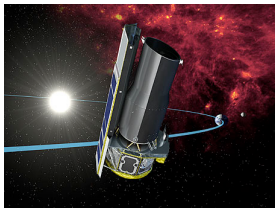
9.7um

18um

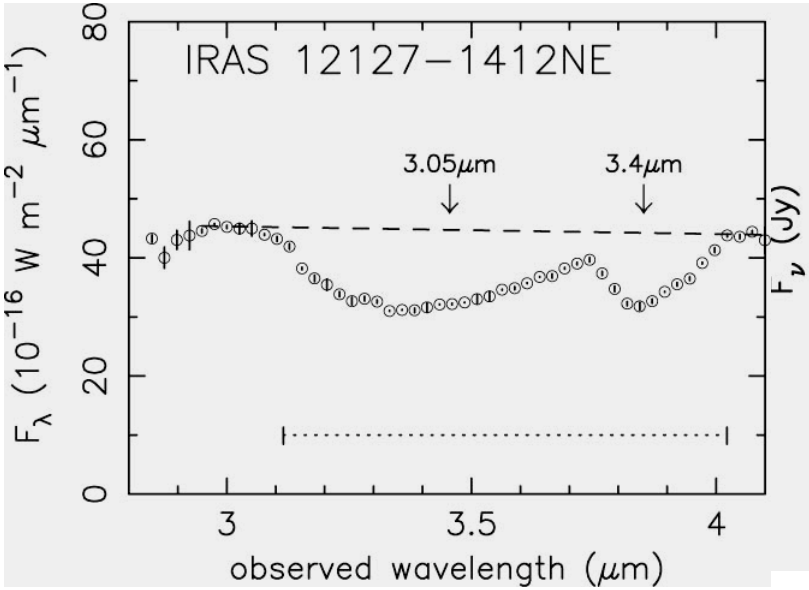
Dust temperature gradient

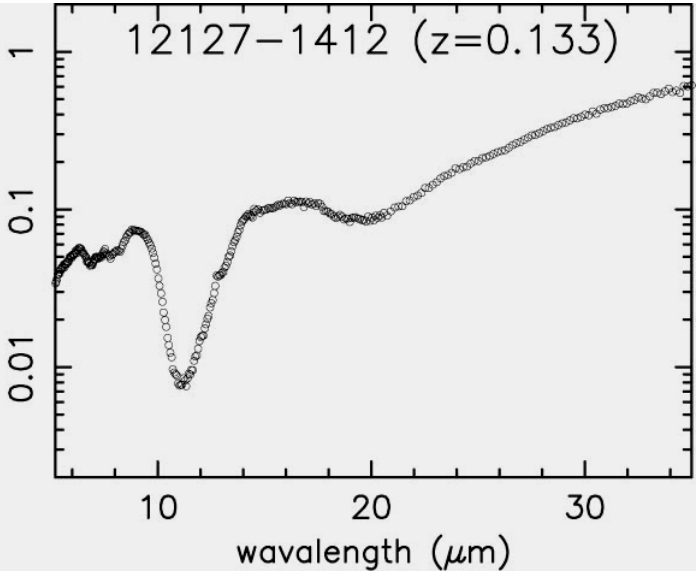
Strong T-gradient (II)

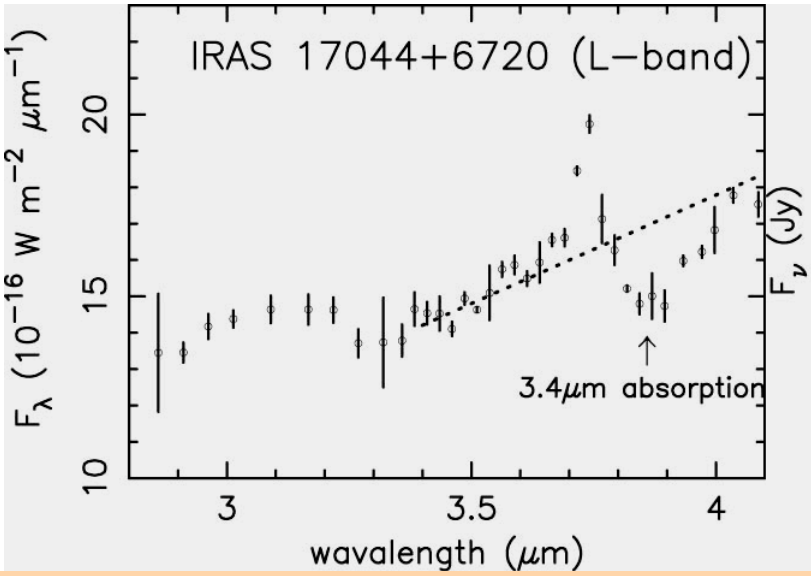
Subaru

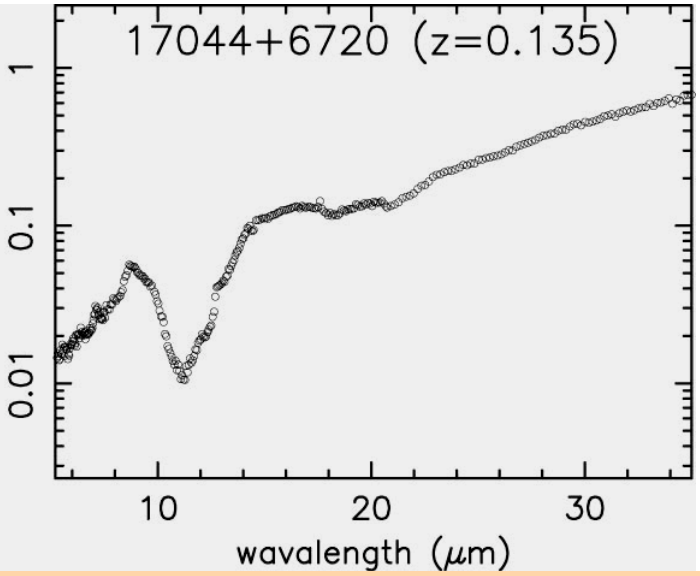


Spitzer





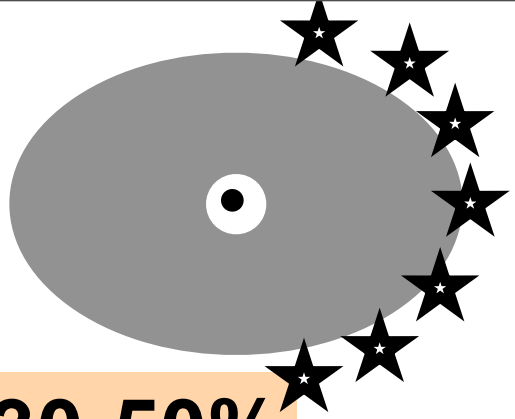




Strong abs ULIRGs -> often show T-gradient

Results

nearby($z<0.15$)

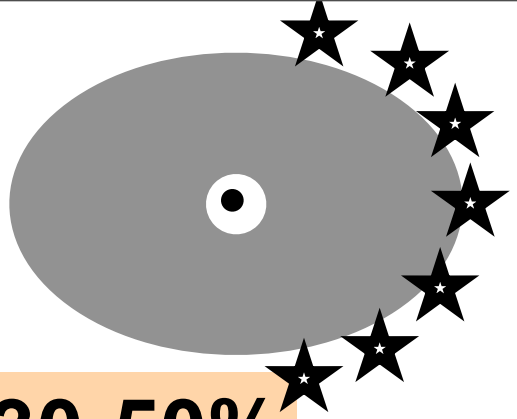


Opical non-Seyfert ULIRGs

→ Luminous buried AGNs = 30-50%

Results

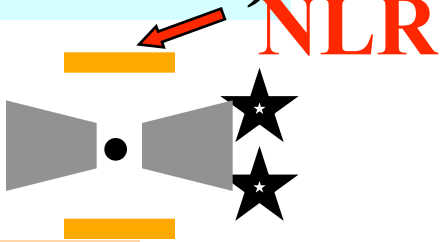
nearby(z<0.15)



Opical non-Seyfert ULIRGs

→ Luminous buried AGNs = 30-50%

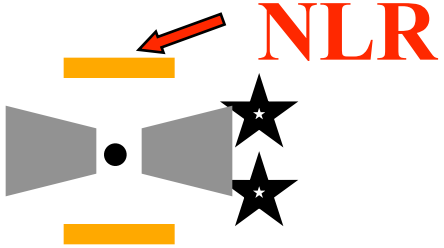
30% ULIRGs = optical Sy (AGN + torus)

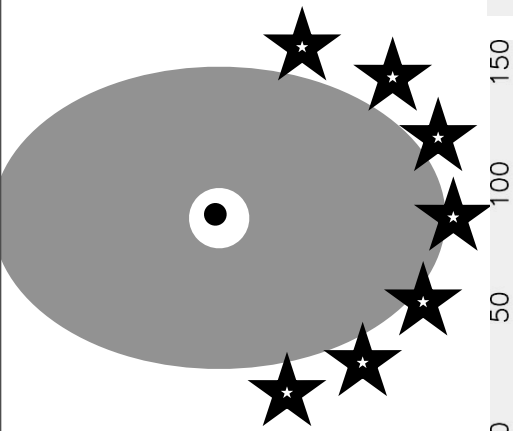


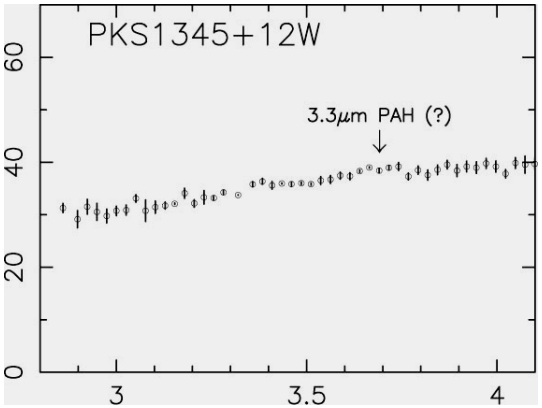
>50% ULIRGs = luminous AGN

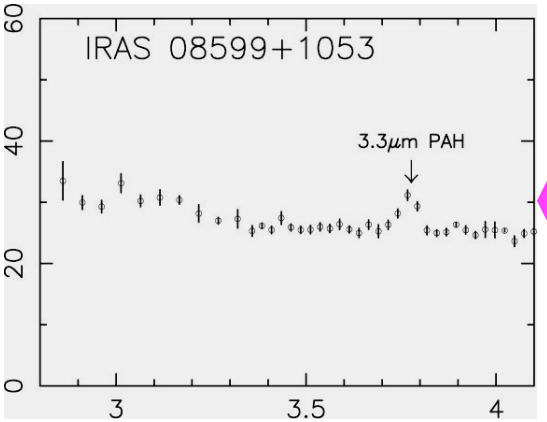
Buried AGNs fraction: LINER > HII

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

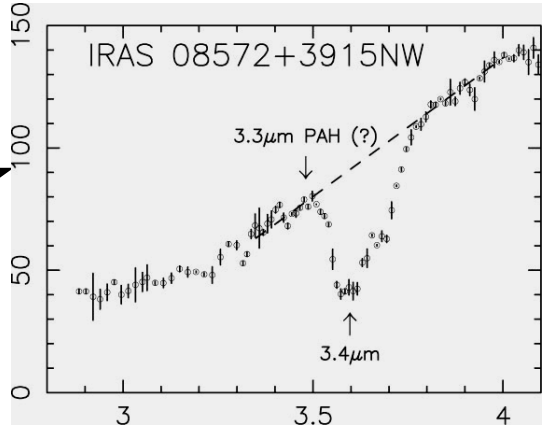


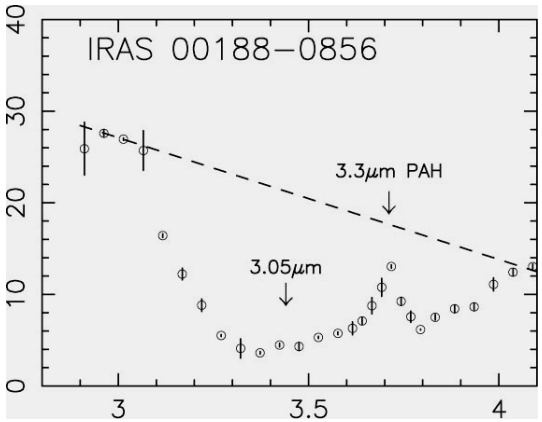






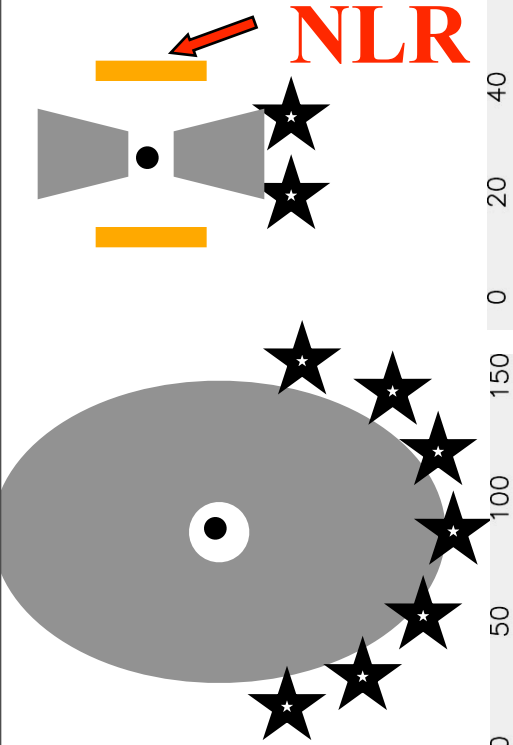
Sy2: Abs weak

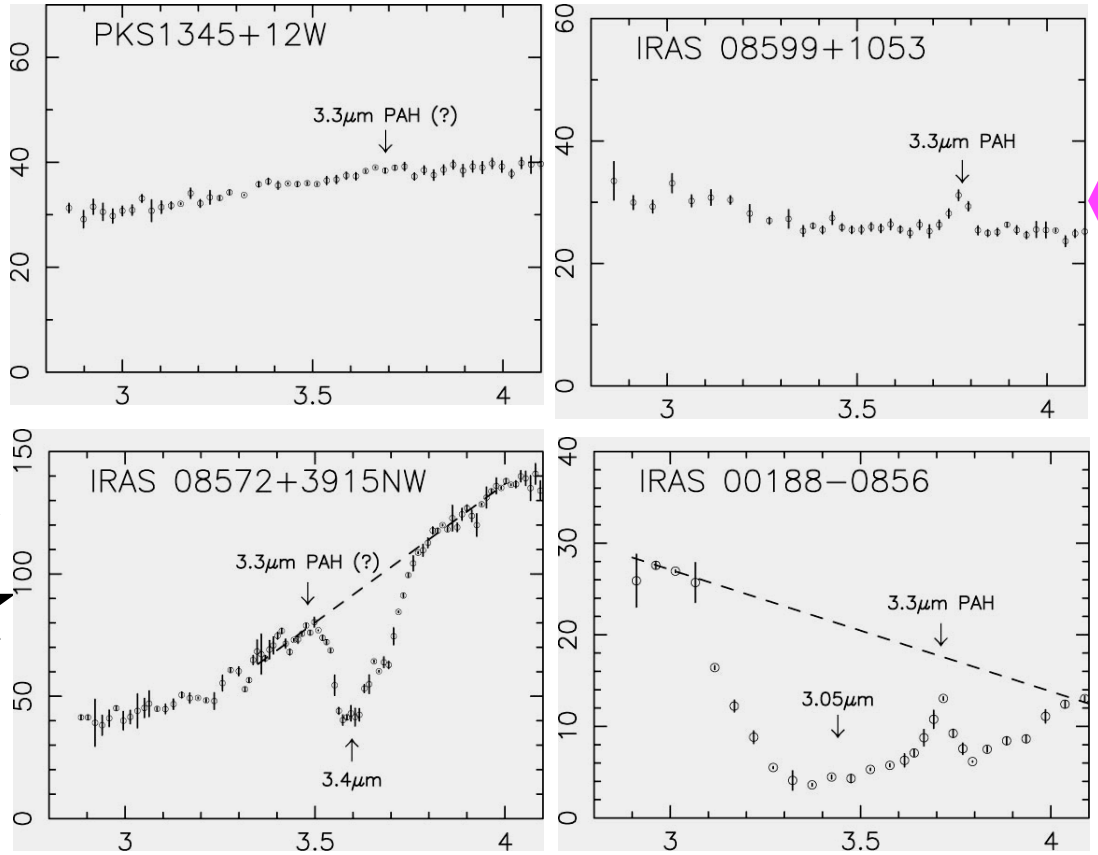




Non-Sy: strong

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



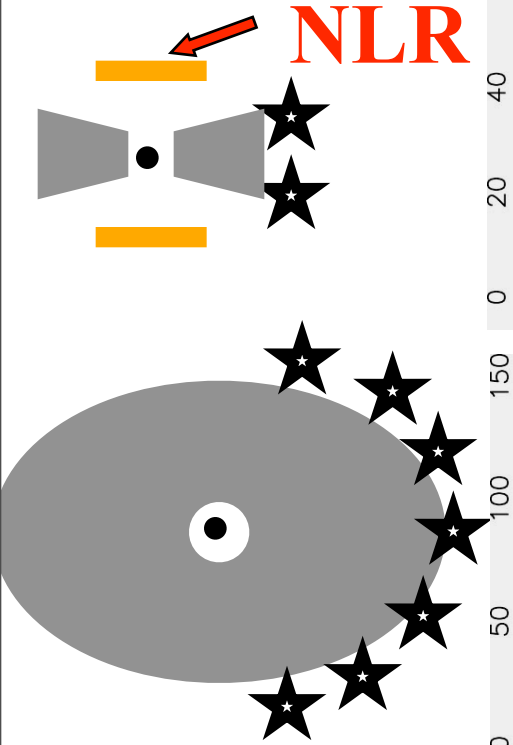


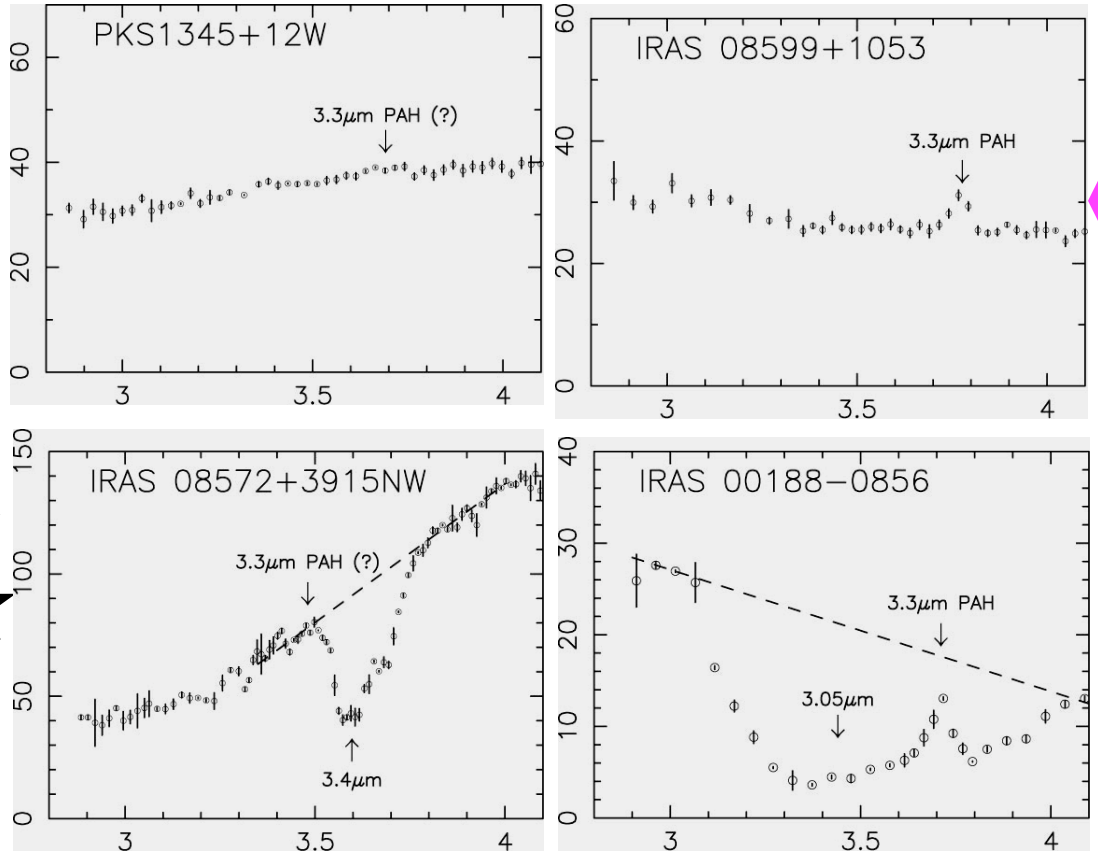
Sy2: Abs weak

Non-Sy: strong

Amount of nuclear dust: Non-Sy >> Sy2

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





Sy2: Abs weak

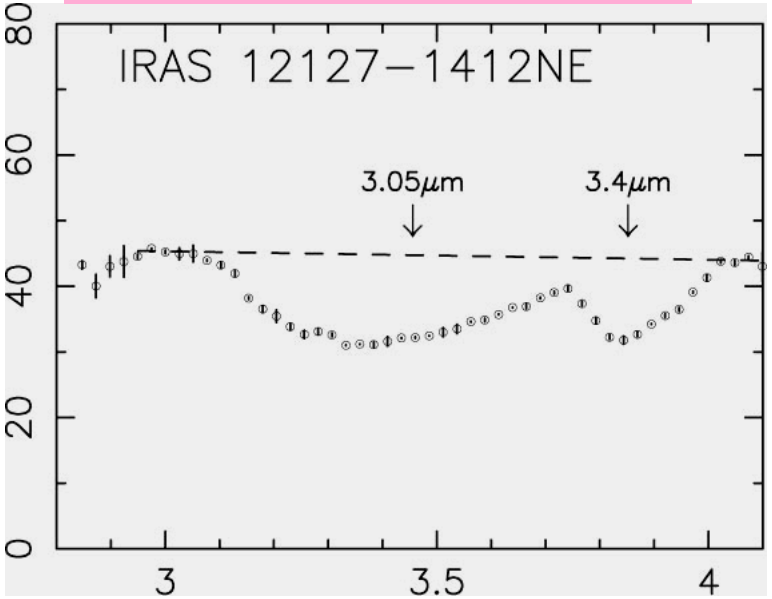
Non-Sy: strong

L(dereddened AGN) ~L(IR)

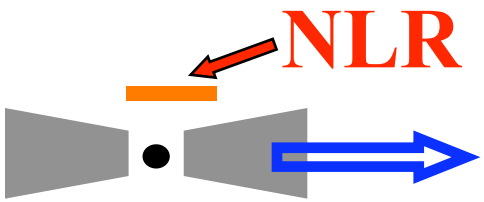
Amount of nuclear dust: Non-Sy >> Sy2

Buried AGNs: both warm/cool FIR colors

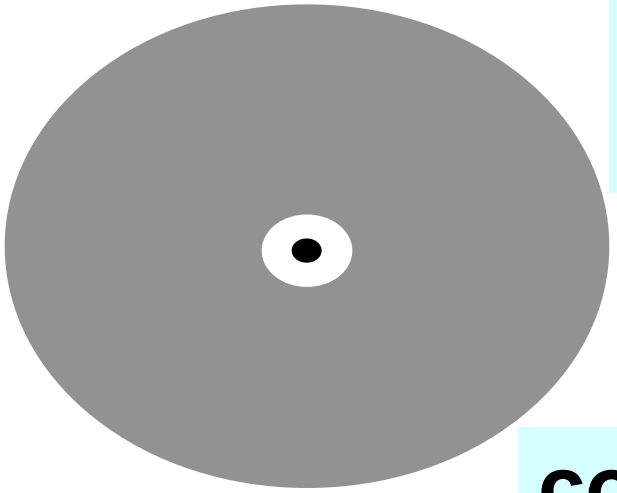
pure buried AGN



F25/F60=0.16 (cool)



warm

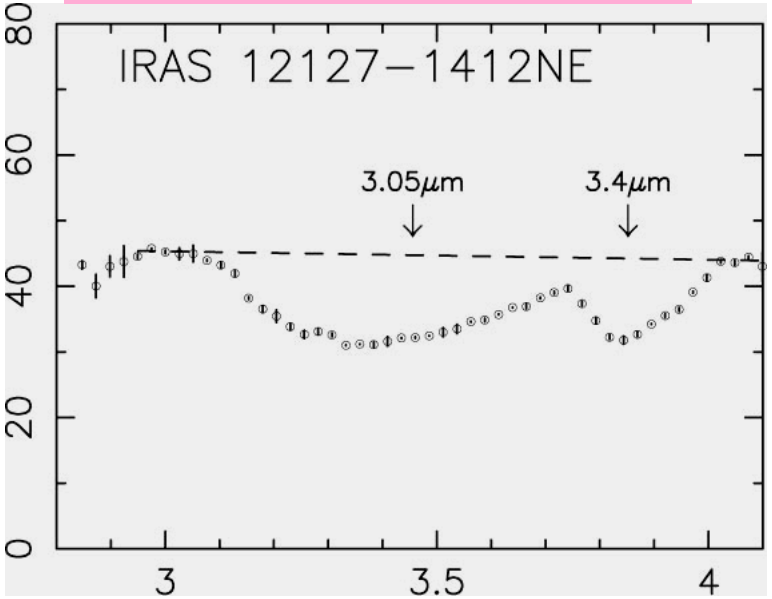


larger dust column

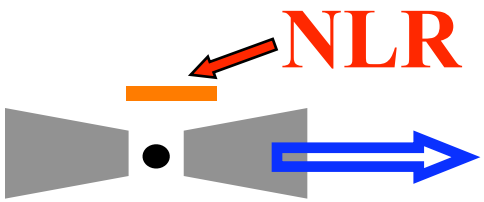
cool FIR color

Buried AGNs: both warm/cool FIR colors

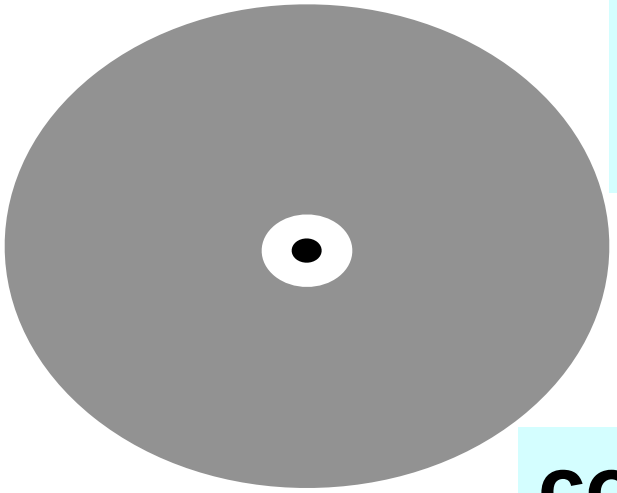
pure buried AGN



F25/F60=0.16 (cool)



warm

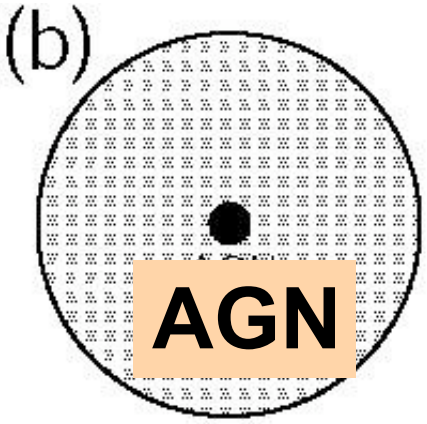


larger dust column

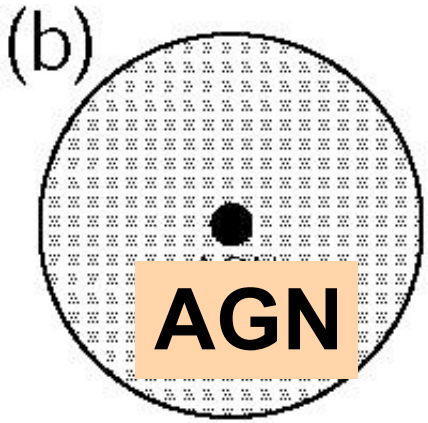
cool FIR color

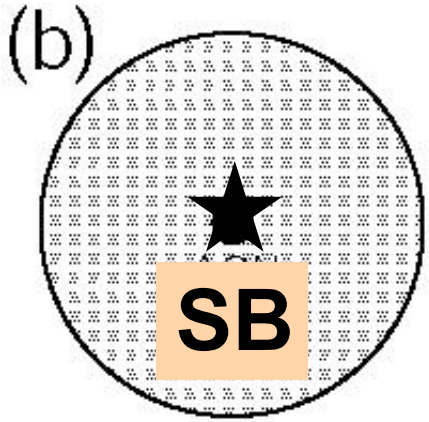
cool ≠ starburst

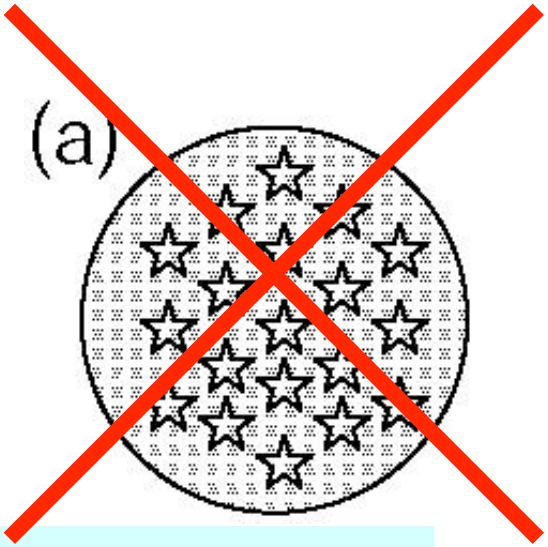
Remaining ambiguity



Remaining ambiguity







Exceptionally centrally-concentrated SB

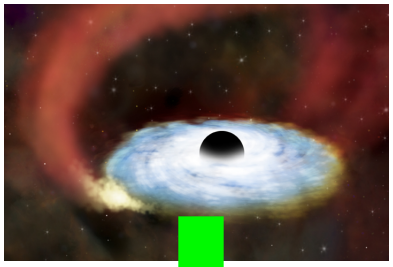
Very high surface brightness

>>10^13Lsun/kpc^2 (SB max)

Extreme SB?

Follow-up observations

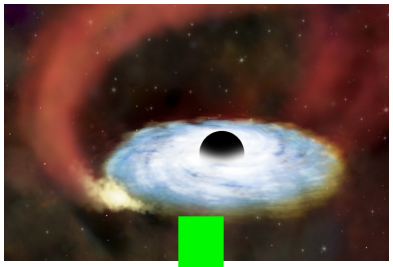
buried AGN or extreme SB ?



X-ray : AGN >> any SB

Follow-up observations

buried AGN or extreme SB ?

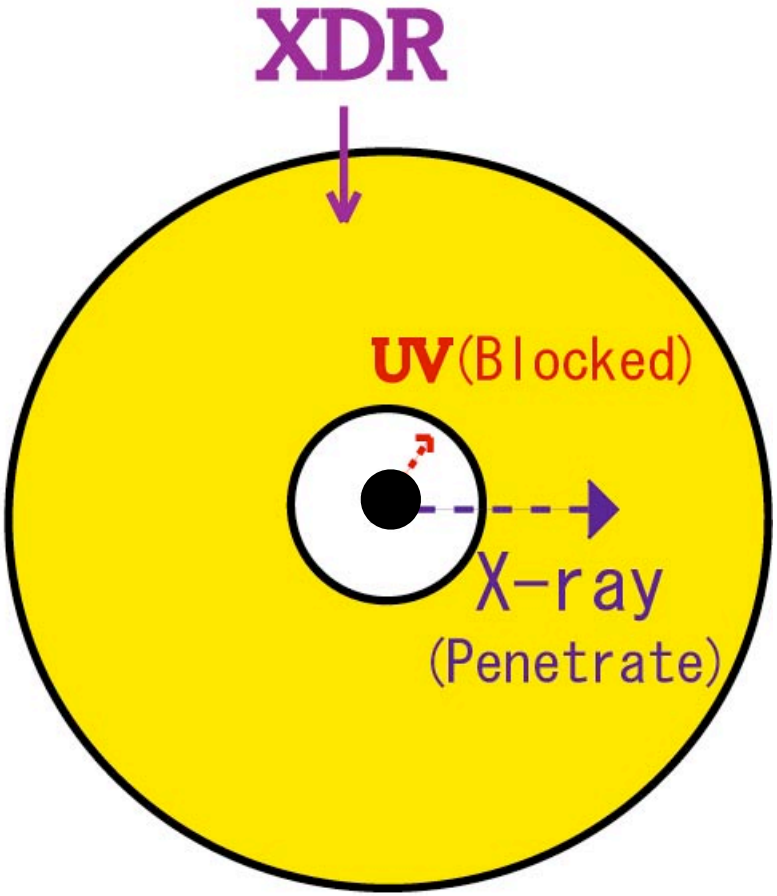


X-ray : AGN >> any SB

Compton thick (NH>10^24 cm-^2) buried AGN in ULIRGs

Future X-ray satellite sensitive at E > 10keV

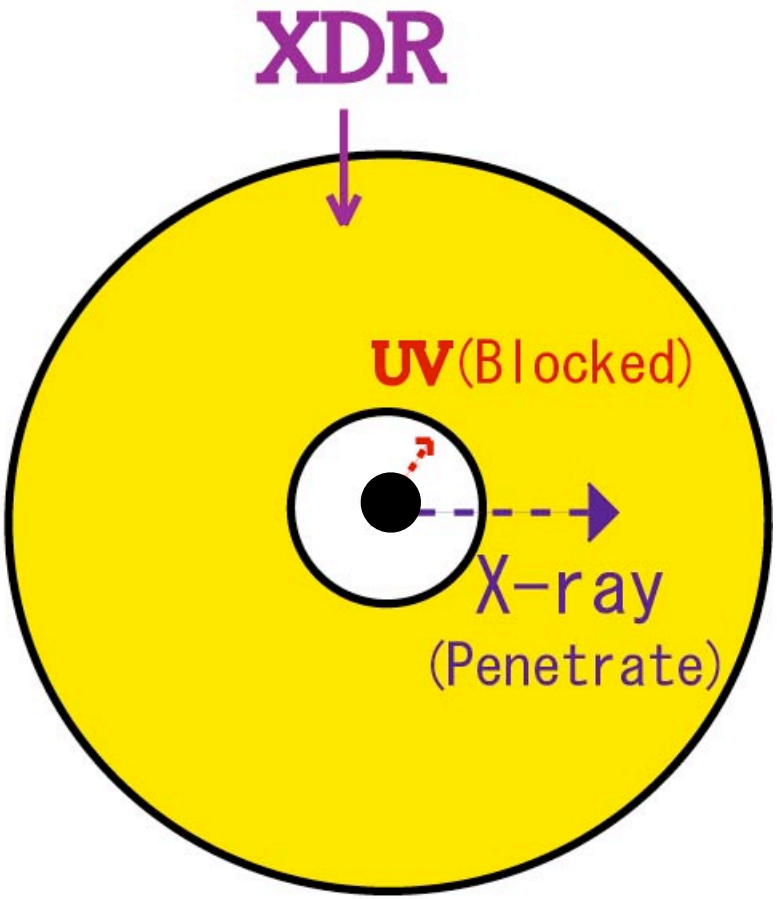
Chemical effects to the surrounding ISM



XDR around an X-ray emitting buried AGN

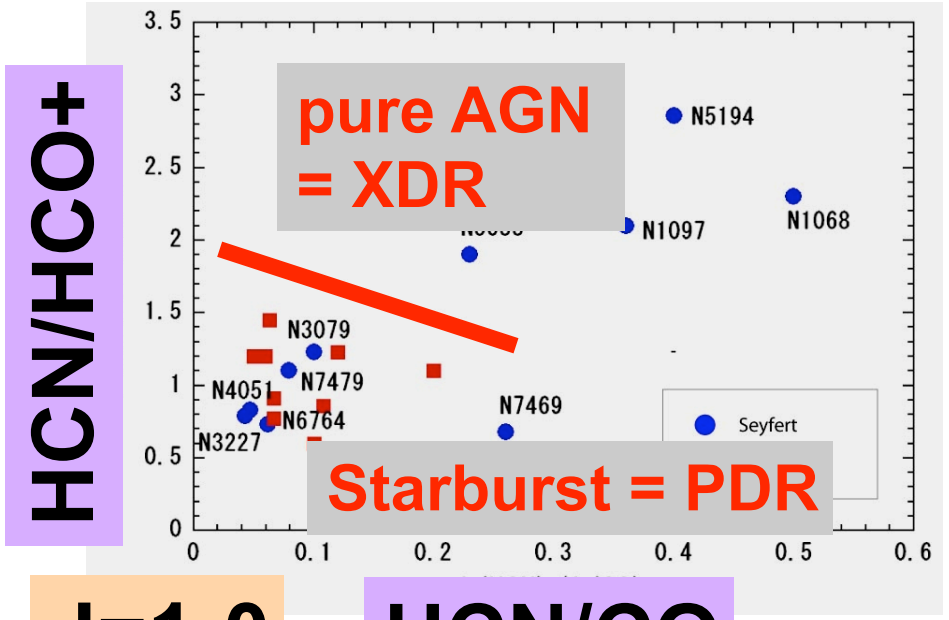
Maloney et al. 1996

Chemical effects to the surrounding ISM



Maloney et al. 1996

XDR around an X-ray emitting buried AGN



J=1-0 HCN/CO

(Kohno astro-ph/0508420)

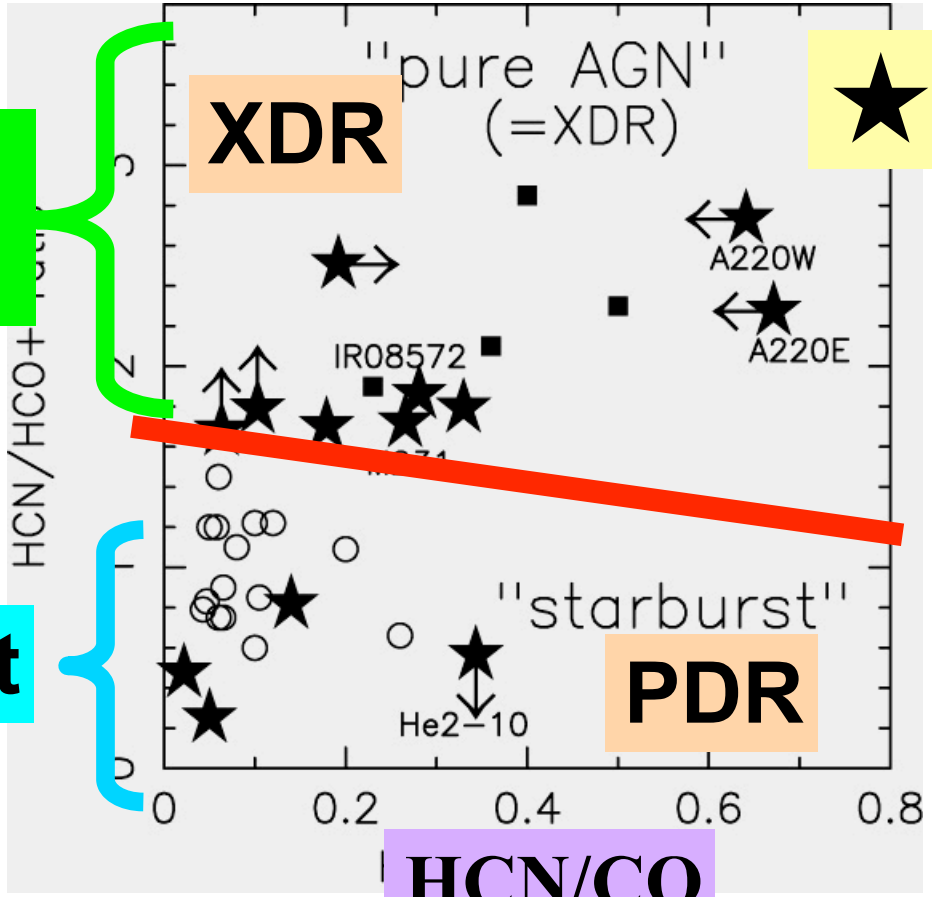
NMA
(RAINBOW)

HCN/HCO+

IR-buried
-AGNs

XDR

★:(U)LIRGs



IR-Starburst

HCN/CO

Imanishi et al. 2006 AJ 131 2888; 2007 in prep

Summary

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

   warm & cool

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

Summary

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

warm & cool

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
Imanishi et al. 2007 ApJS astro-ph/0702136

End