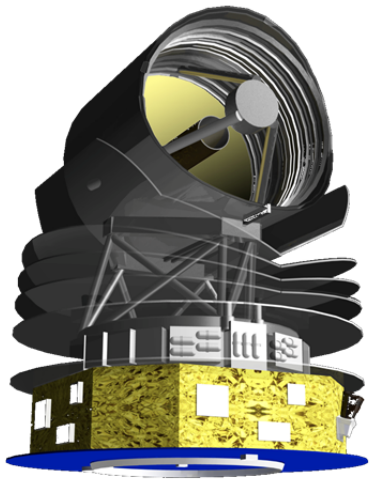
SPICA IR spectroscopy of distant ULIRGs ($L_{IR} > 10^{12}$ Lo)

Masa Imanishi（今西昌俊）

NAOJ Subaru/Optical and IR div.



2017 Nov 22 @ ISAS

SPICA PASP papers of distant ULIRGs ($L_{IR} > 10^{12}$ Lo)

- Spinoglio+17 arXiv:1710.02189

  AGN and starburst (IR spectroscopy)

- Gonzalez-Alfonso+17 arXiv:1710.02356

  SAFARI: Molecular outflow

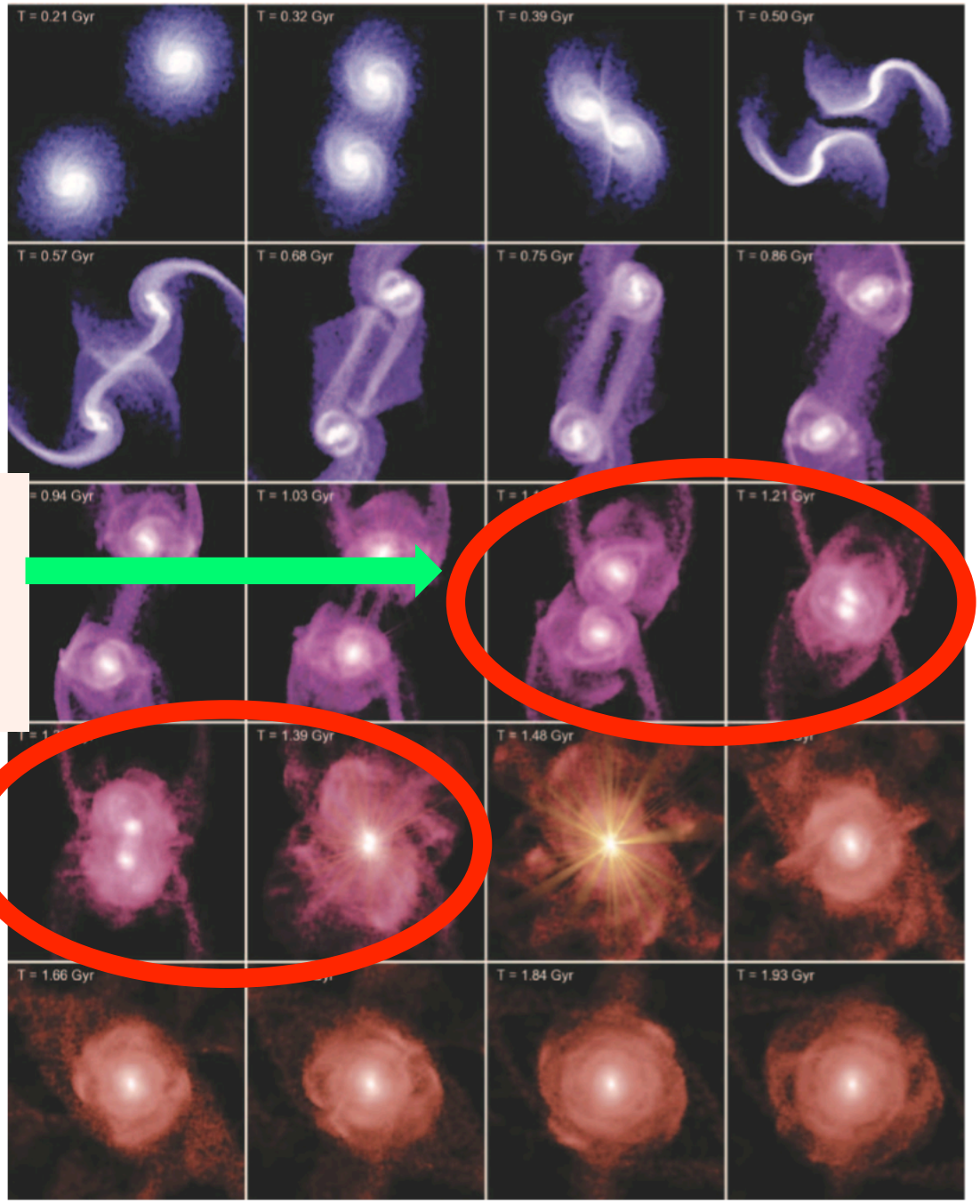
- Fernandez-Ontiveros+17 arXiv:1710.02150

  SMI+SAFARI: Chemical evolution

- Kaneda+17 arXiv:1710.07103

  SMI: PAH survey

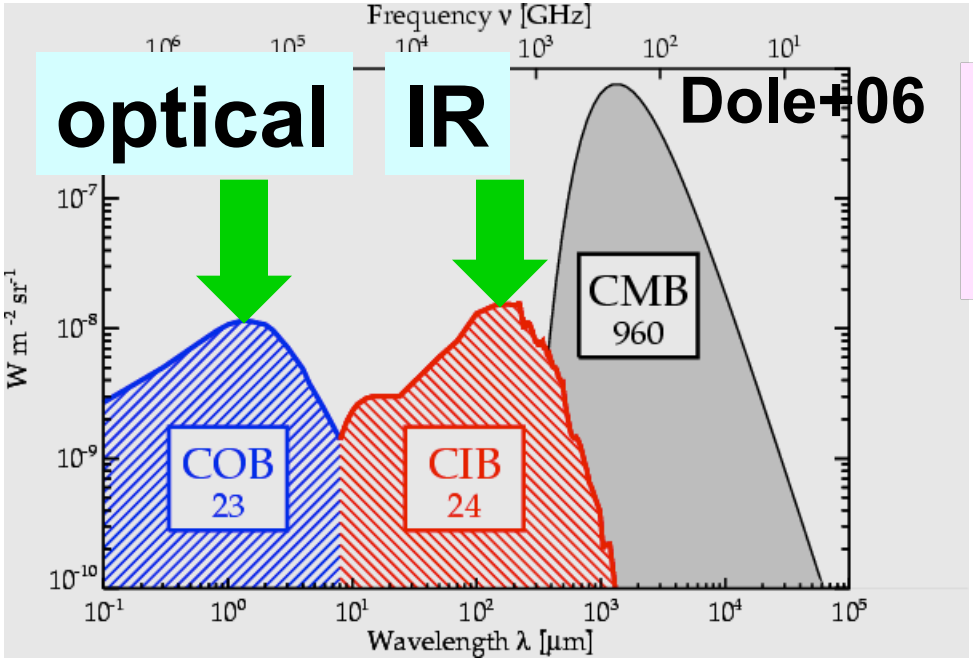
Gas rich galaxy mergers

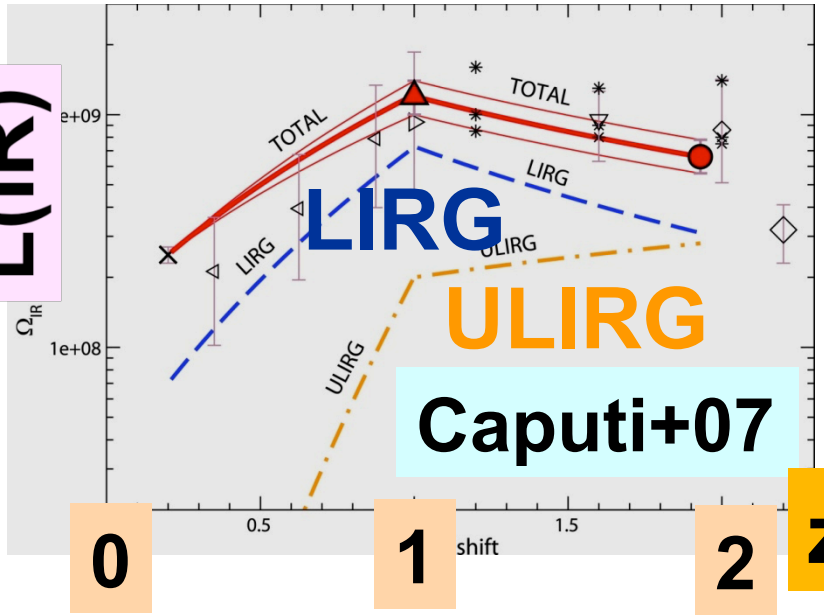


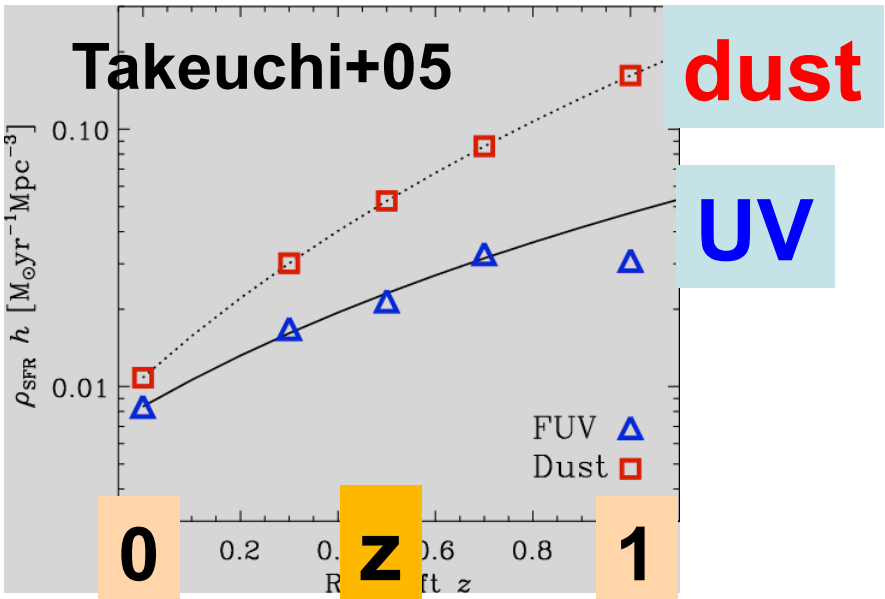
ULIRG ($L_{IR} > 10^{12}$ Lo): SMBH growth behind dust

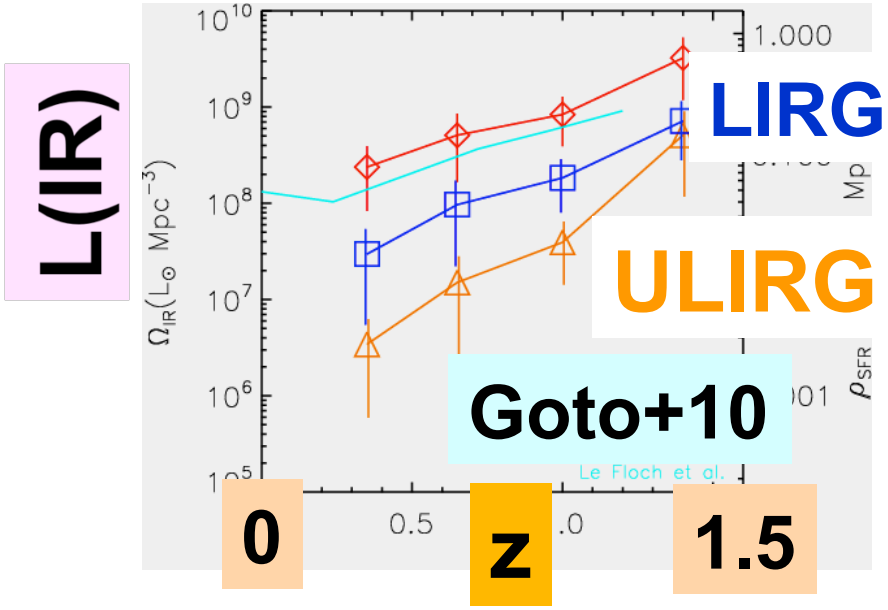
Hopkins+08
ApJS 175 356

More than half of cosmic activity is obscured

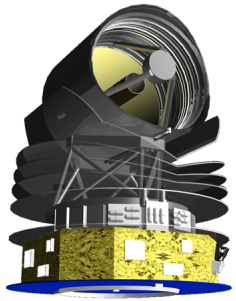








SPICA science



1. Buried AGNs in z~2 ULIRGs ?

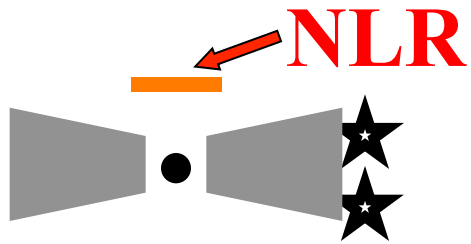
Low-R (R ~ 50-100) spec: SMI is better than SAFARI

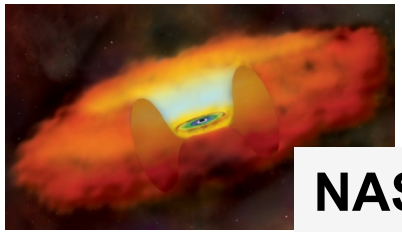
2. AGN feedback ?

P Cygni ➡ Molecular outflow

SPICA + ALMA

Obscured AGNs



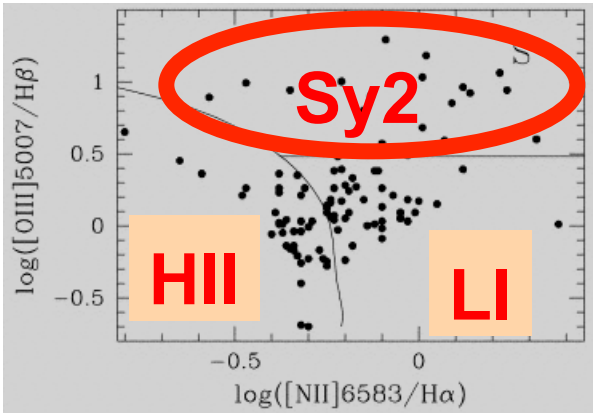


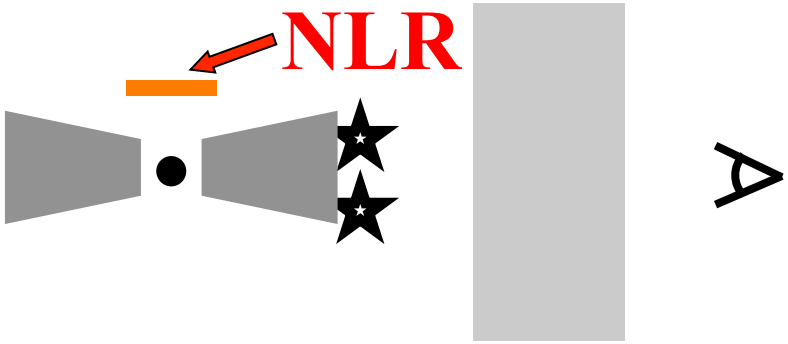
AGN surrounded by torus

Sy2

Optically identifiable

Veilleux+99

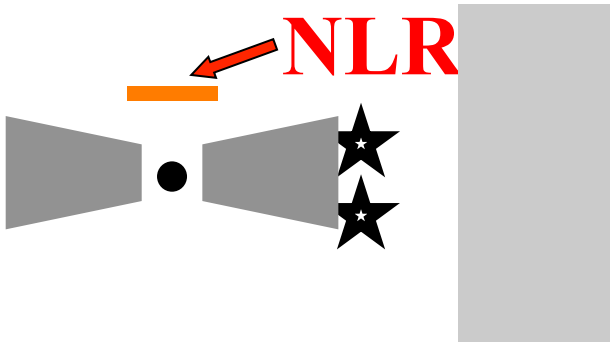




A

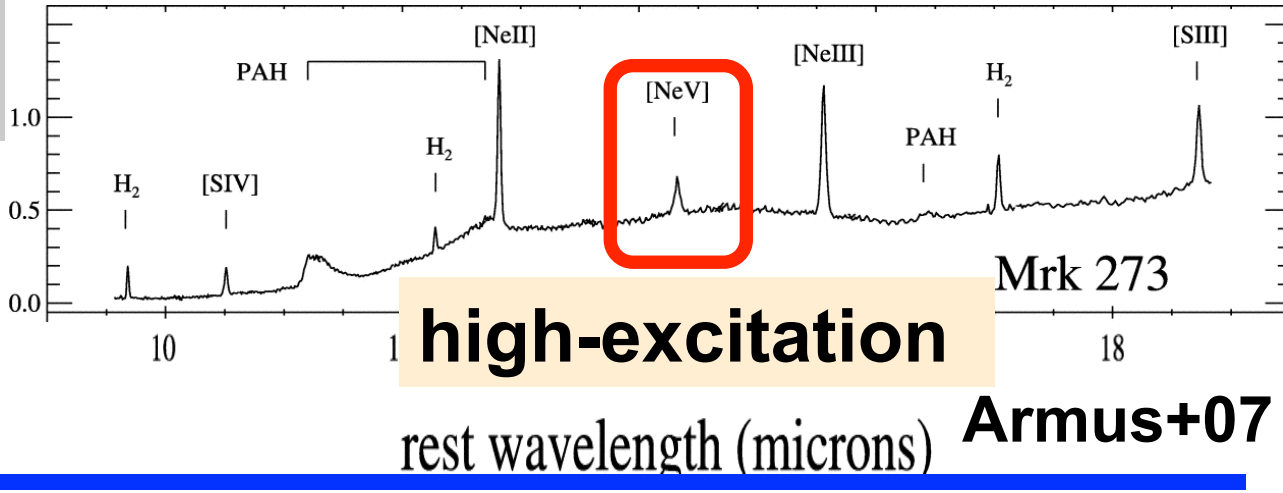
dust in host

AGN is not identifiable by optical spectroscopy



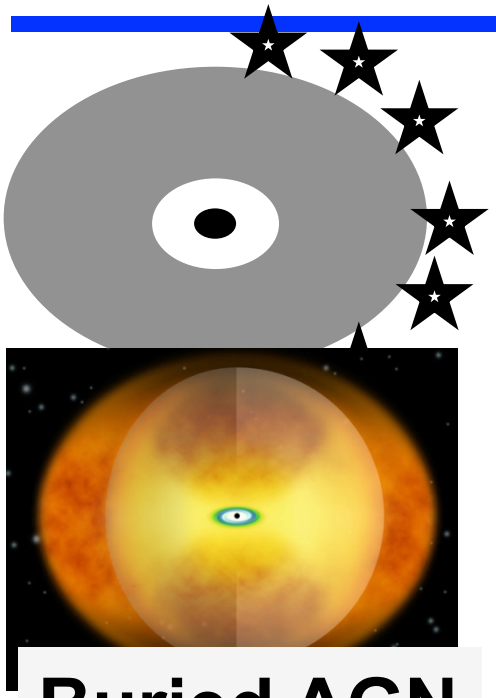
dust in host

AGN identifiable (MIR forbidden lines)



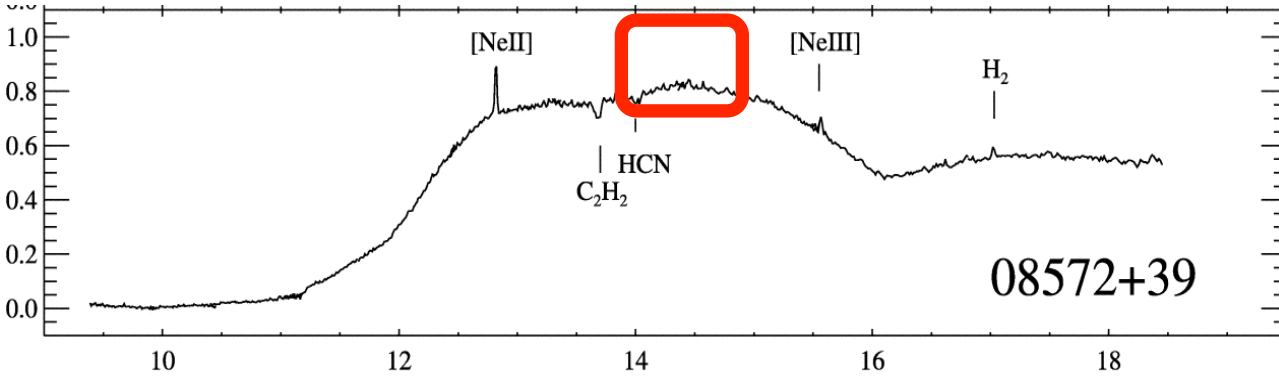
high-excitation

Armus+07



Buried AGN

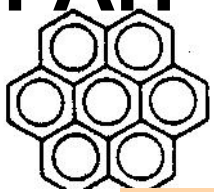
Buried AGN not identifiable via MIR forbidden emission lines



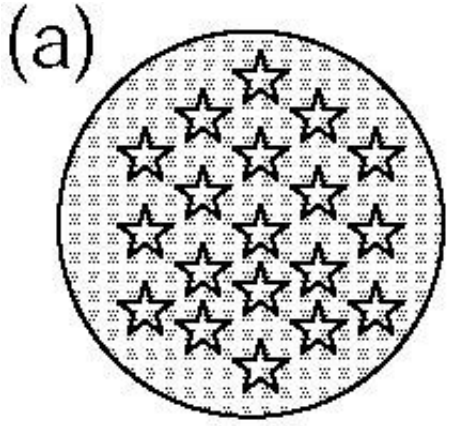
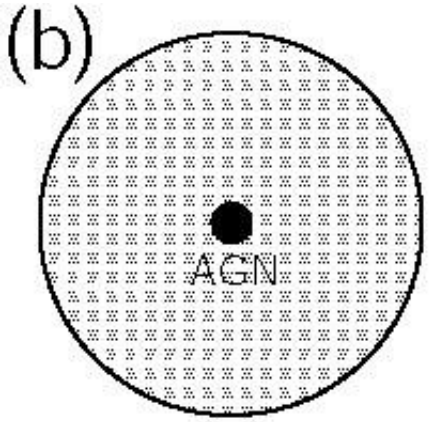
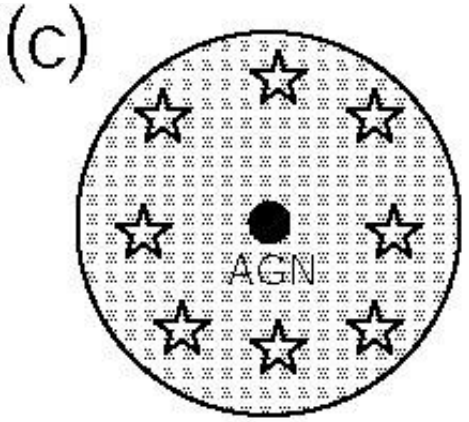
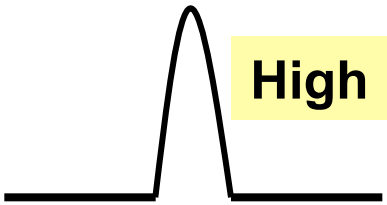
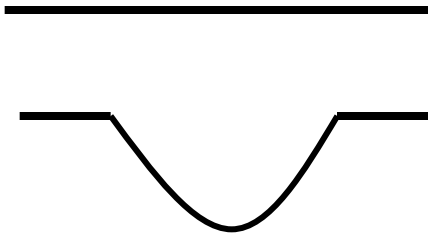
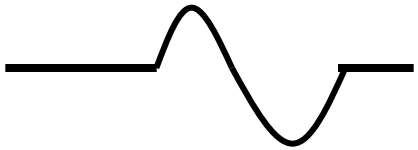
Armus+07

1. IR 3-25 um R=50-100 spectroscopy

PAH

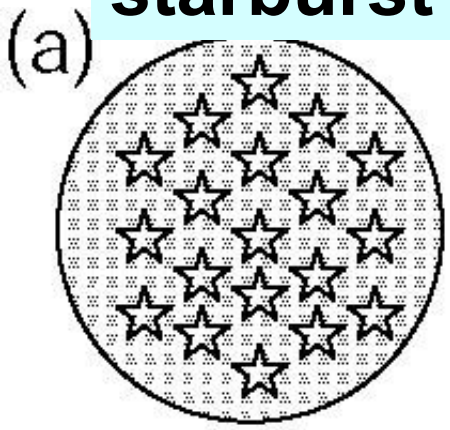


PAHs are excited in starburst PDRs but destroyed near an AGN

Starburst(SB)	Buried AGN	AGN+SB
		
PAH	featureless	
High EW(PAH)		Low EW(PAH)
		
3.3, 6.2, 7.7, 11.3 um	3.1, 3.4, 9.7, 18 um	

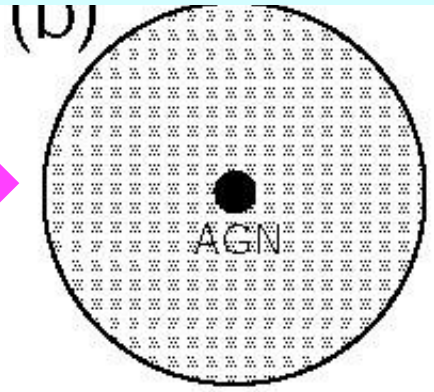
2. Dust absorption feature strength

starburst



(U)LIRG core
<500pc

Buried AGN



Mixed dust model

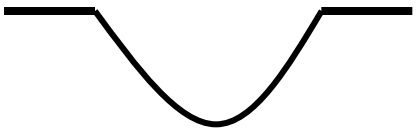
$$\frac{1-\exp(-\tau)}{\tau}$$

Dust absorption feature: weak

Foreground screen dust model

$\exp(-\tau)$

strong



Imanishi+06,07

3-4 um

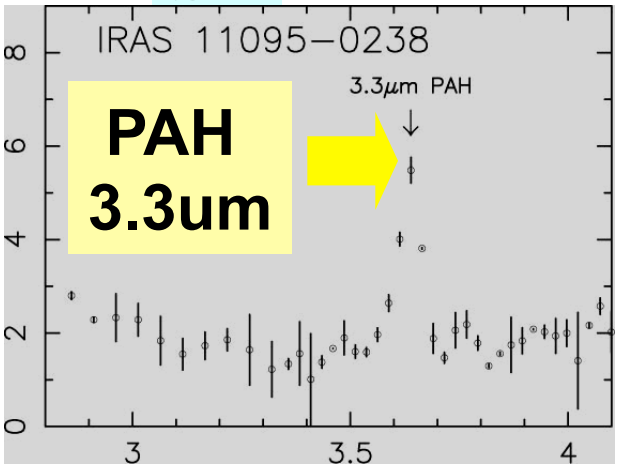
z<0.15 ULIRG

Subaru

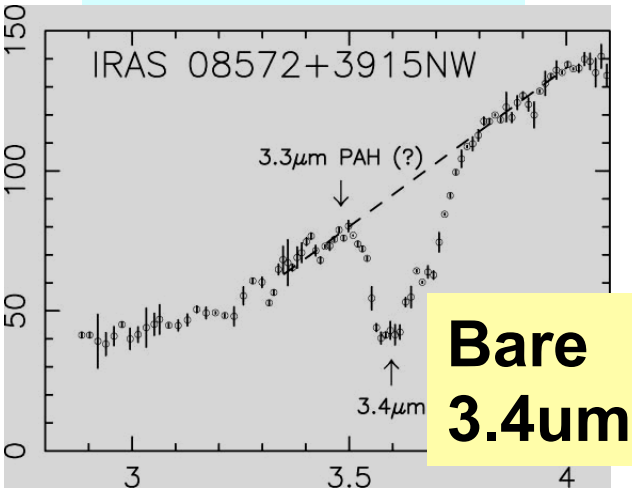
SB

Buried AGN

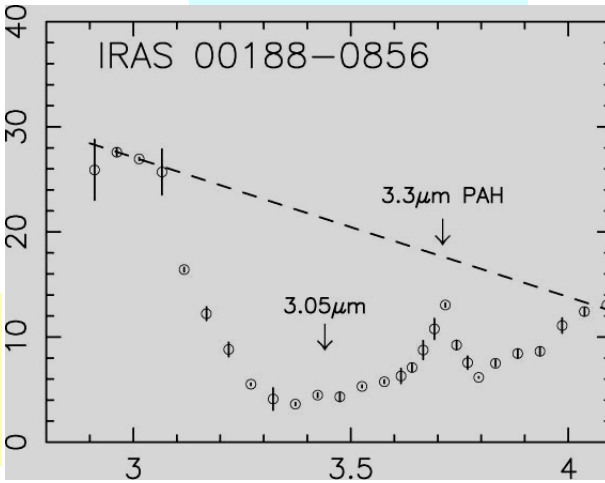
AGN+SB

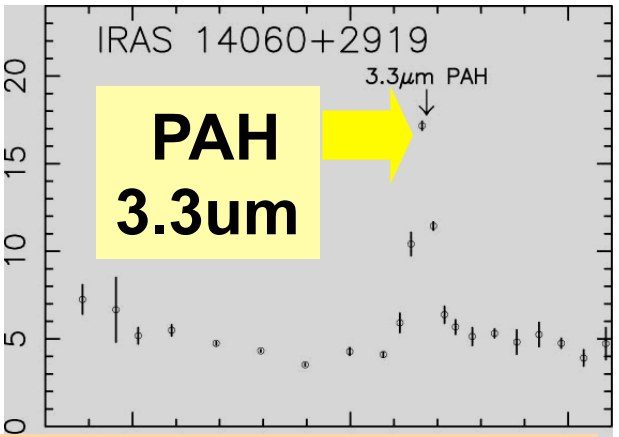


PAH 3.3um

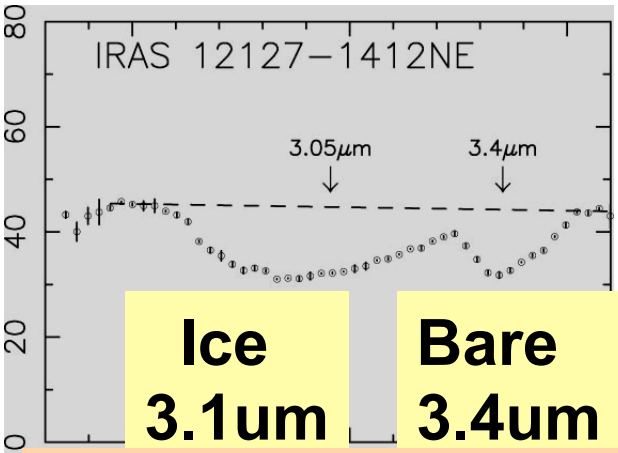


Bare 3.4um



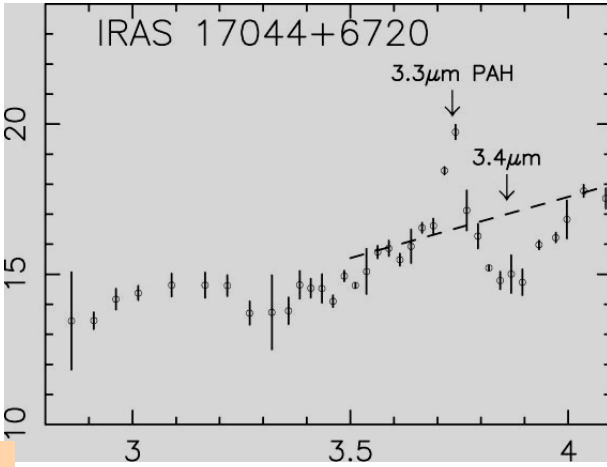


PAH 3.3um



Ice 3.1um

Bare 3.4um



PAH **strong** (SB):
Dust abs. **weak**

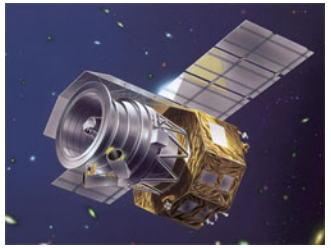
PAH **weak** (AGN):
Dust abs. **strong**

wavelength

Imanishi+06

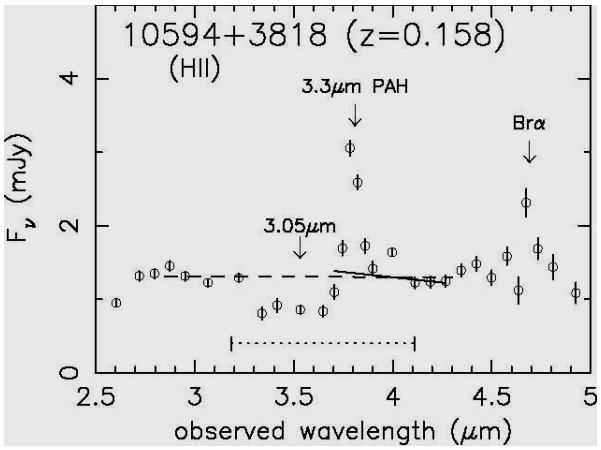
2.5-5 um

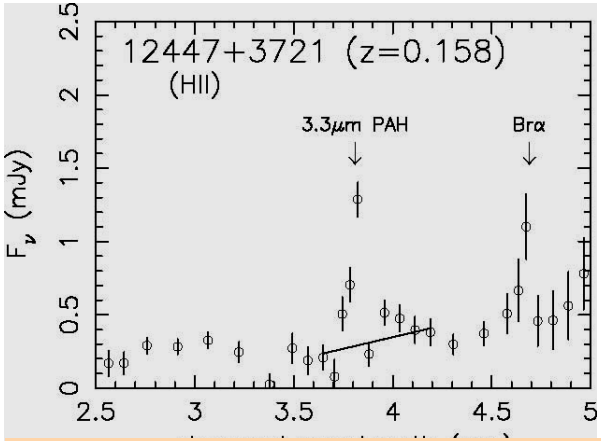
z>0.15 ULIRG



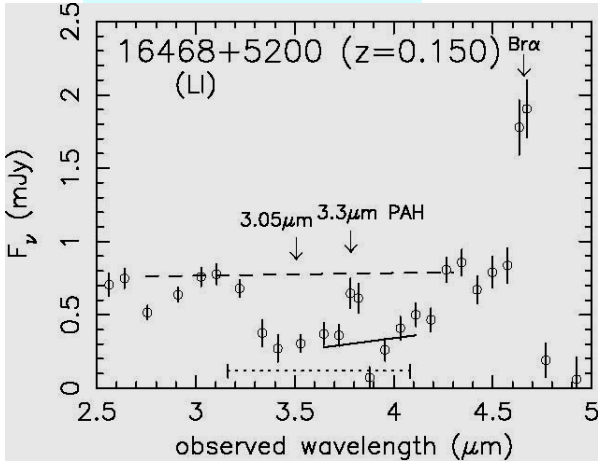
AKARI

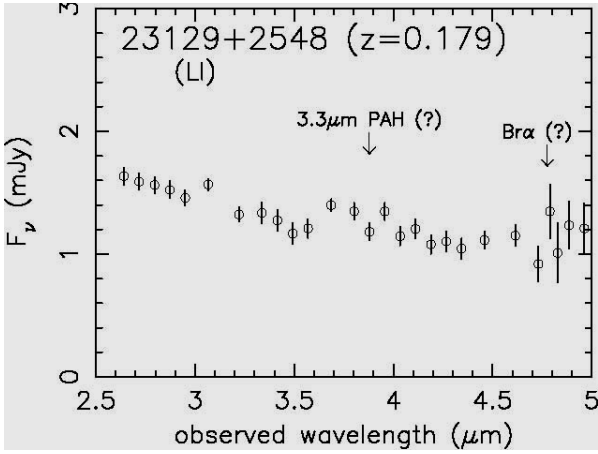
SB

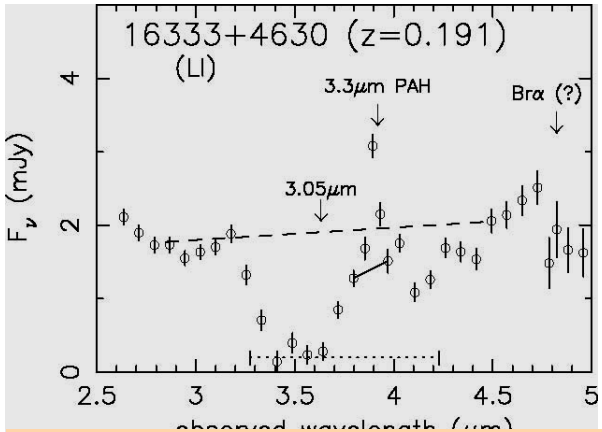


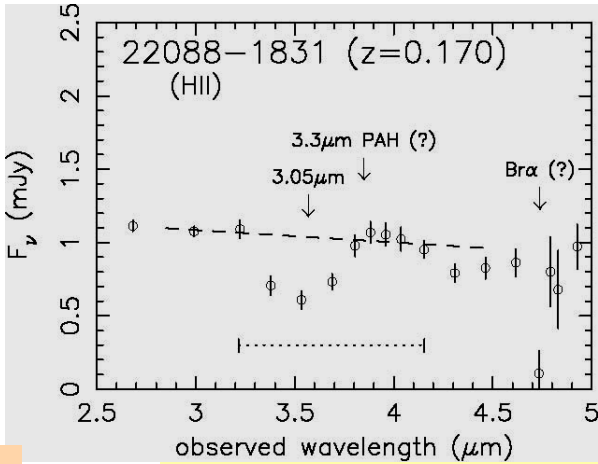


AGN+SB









PAH strong (SB):
Dust abs. weak

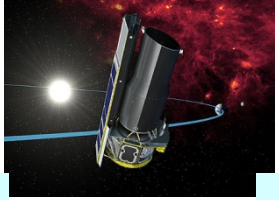
PAH weak (AGN):
Dust abs. strong

wavelength

Imanishi+08,+10a

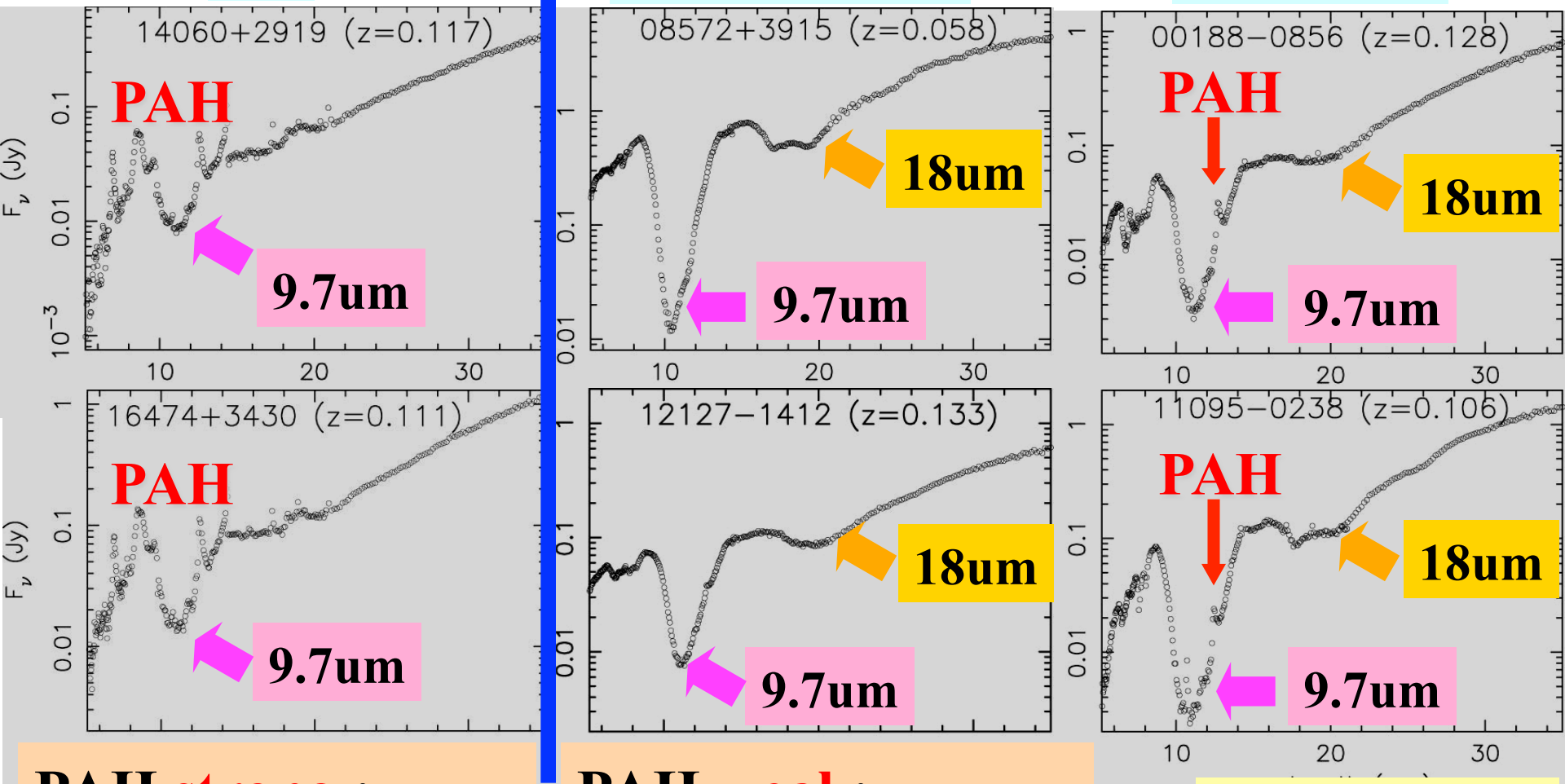
5-35 um

z<0.3 ULIRG



Spitzer

SB | **Buried AGN** | **AGN+SB**

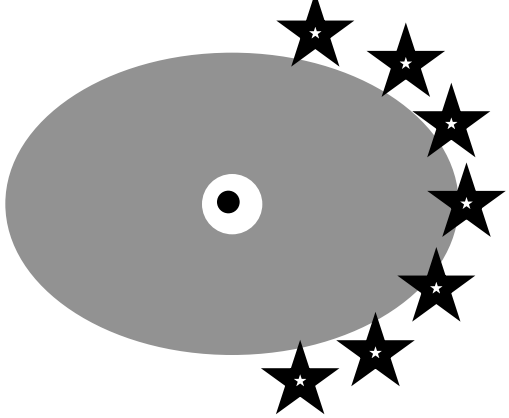


PAH strong :
Silicate Abs. weak

PAH weak:
Silicate Abs. strong

Imanishi+07,09,10b

Results



nearby($z<0.3$) >130 sources

Opical non-Seyfert (U)LIRGs

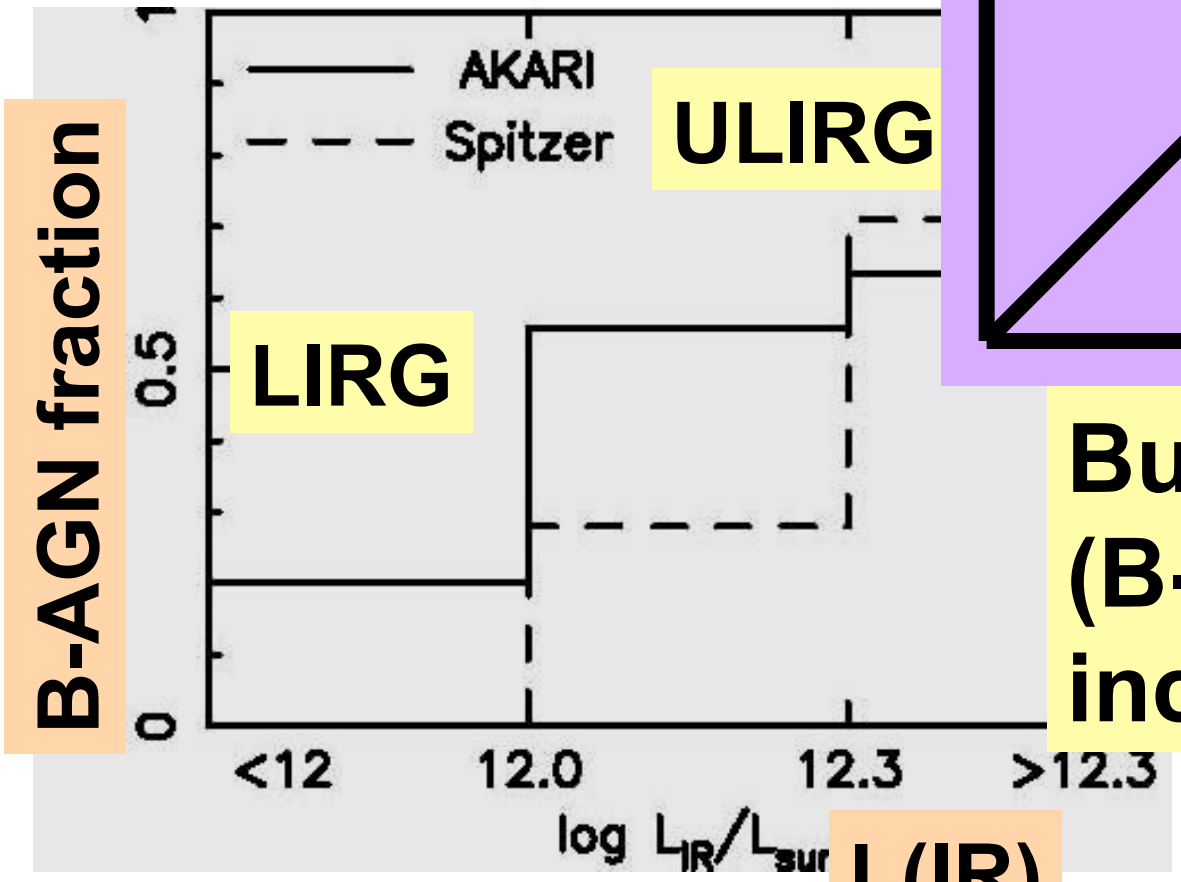
↳ Luminous buried AGNs > 50%

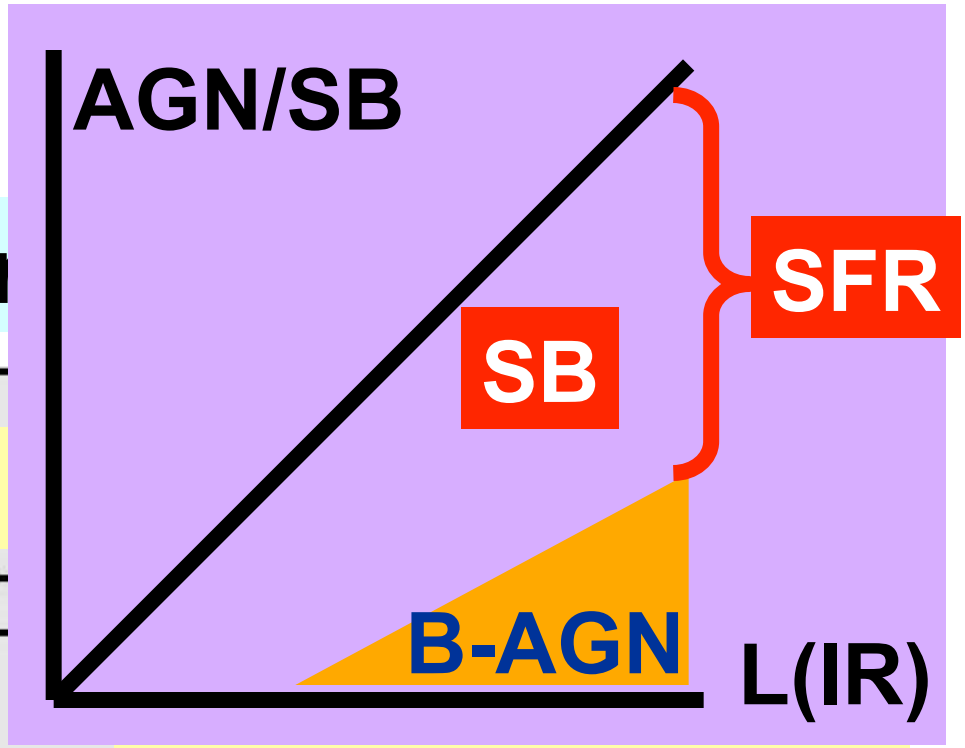
↓

Luminous buried AGNs are common in the local universe

AKARI **Spitzer**

z<0.3 **>130 sour**





Buried AGNs (B-AGN) increase with L_{IR}

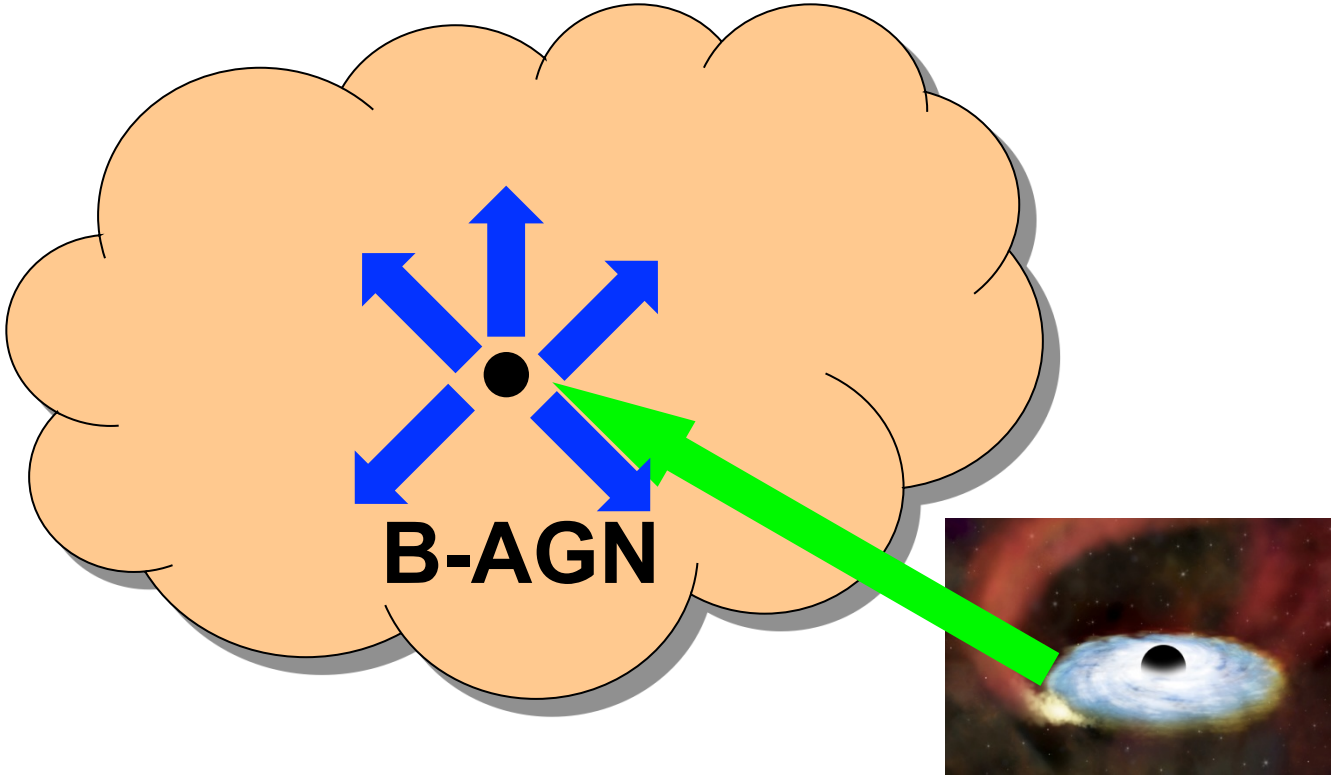
Optical non-Sy (U)LIRGs only

See also Veilleux+09 Nardini+10

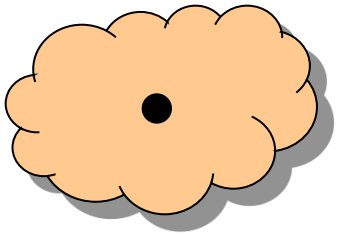
AGN feebback

Granato+04, Springel+05
Sijacki+07, Hopkins+10

massive galaxies



less massive



AGN weak

Armus+07

TABLE 7
SPECTRAL CLASSIFICATIONS

AGN contribution

MIR R~1000 << EW(PAH)

OBJECT (1)	OPTICAL/NIR CLASS (2)	[Ne v]/[Ne II] (%) (4)	[O IV]/[Ne II] (%) (5)	(6.2 μm EQW) (%) (6)
Mrk 231	S1[a]	<10	<10	98
Arp 220	L[c]	<2	<5	50
05189−2524	S2/S1[e]	60	33	94
Mrk 273	S2	17	33	70
08572+3915	L[c]	<10	<10	>95
15250+3609	SB	<5	<5	96
UGC 5101	L[i]	8	6	65
22491−1808	SB[a,i]	<5	<5	<1
12112+0305	L[c,k]	<1	<5	8
14348−1447	L[a,k]	<1	<5	55
Mrk 1014	S1[a]	62	50	90
Mrk 463e	S2/S1[e,m]	>99	>99	>99
NGC 6240	L	2	4	15

Armus+07

AGN contribution

MIR mid-R only confirms optically ID AGNs

MIR R~1000 << EW(PAH)

TABLE 7

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Mrk 1014	S1[a]	62	50	90
Mrk 463e	S2/S1[e,m]	>99	>99	>99
NGC 6240	L	2	4	15

Armus+07

Low-R detects optically unID AGNs

AGN contribution

MIR R~1000 << EW(PAH)

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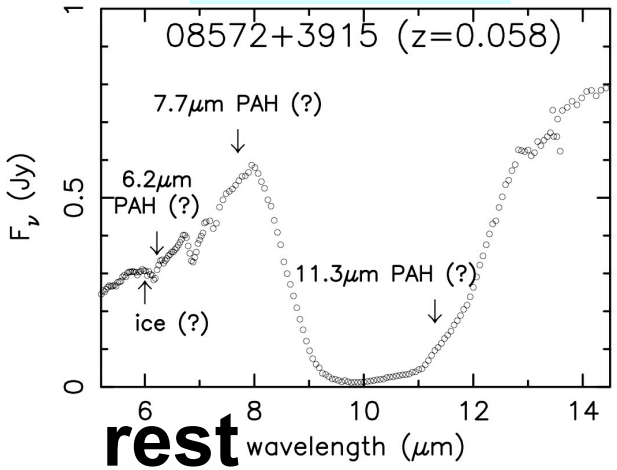
NGC 6240	L	2	4	15

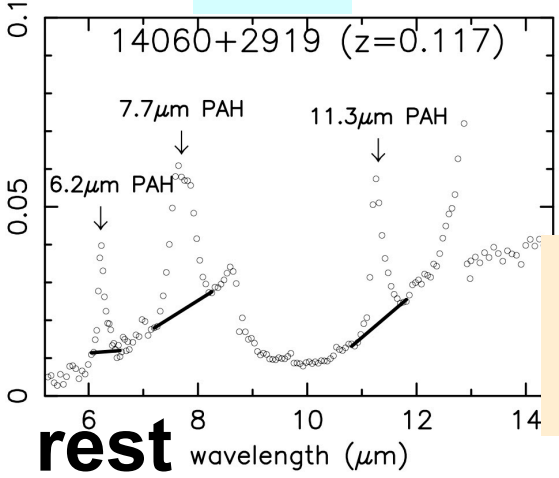
Kaneda+17

SMI 17-36 um spectroscopic survey

B-AGN



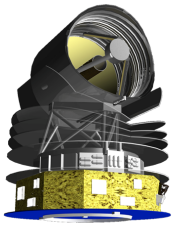
SB



Imanishi+07b

Rest=5.5-14 um (6-13um)

energy diagnostics at z~2



20-30um bright → **biased to AGN（hot dust）**

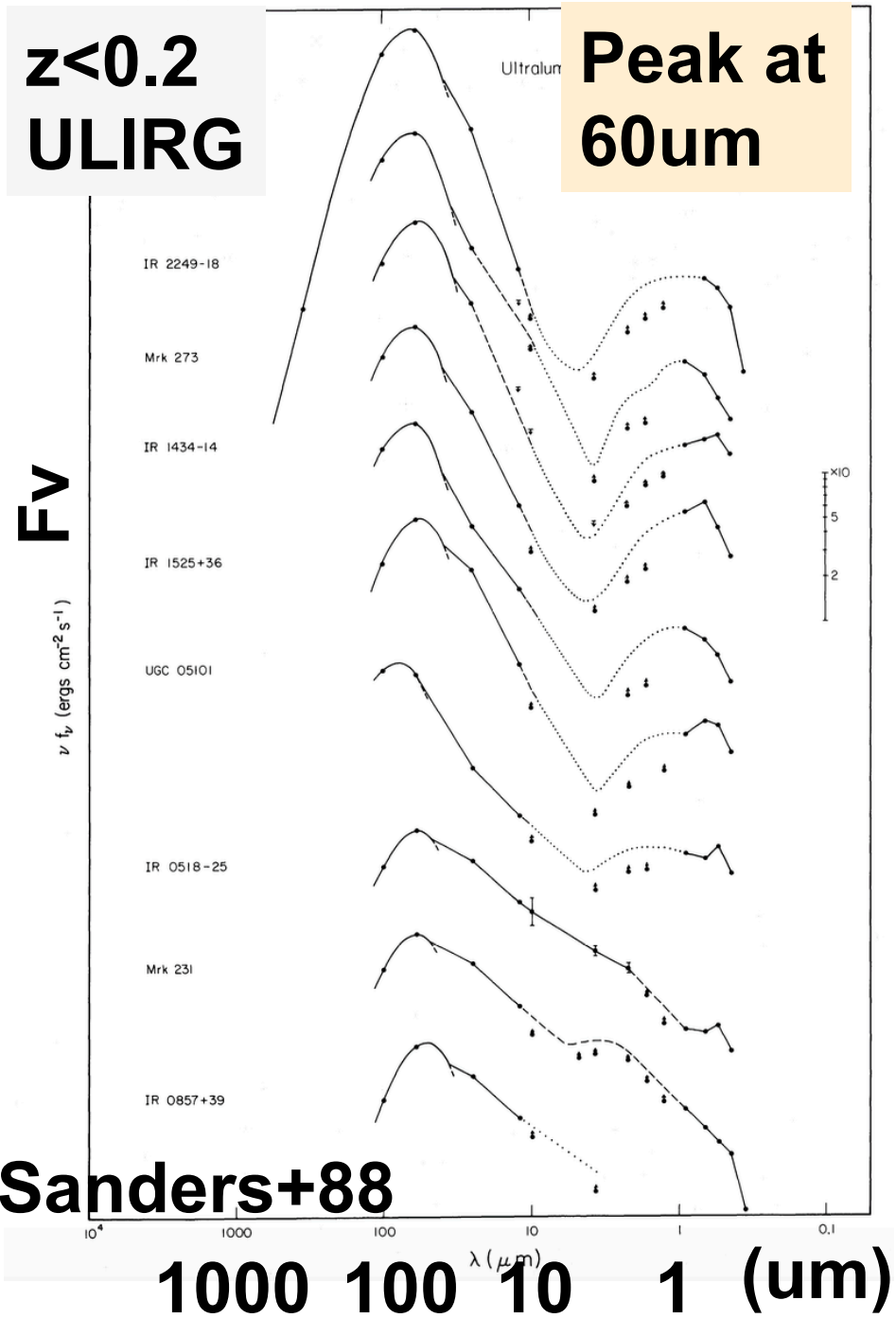
z~2 SB (7.7um PAH strong)

SMG → **long-λ selected（rest > 250um at z~2）**

Biased to SB

z<0.2 ULIRG

Peak at 60um

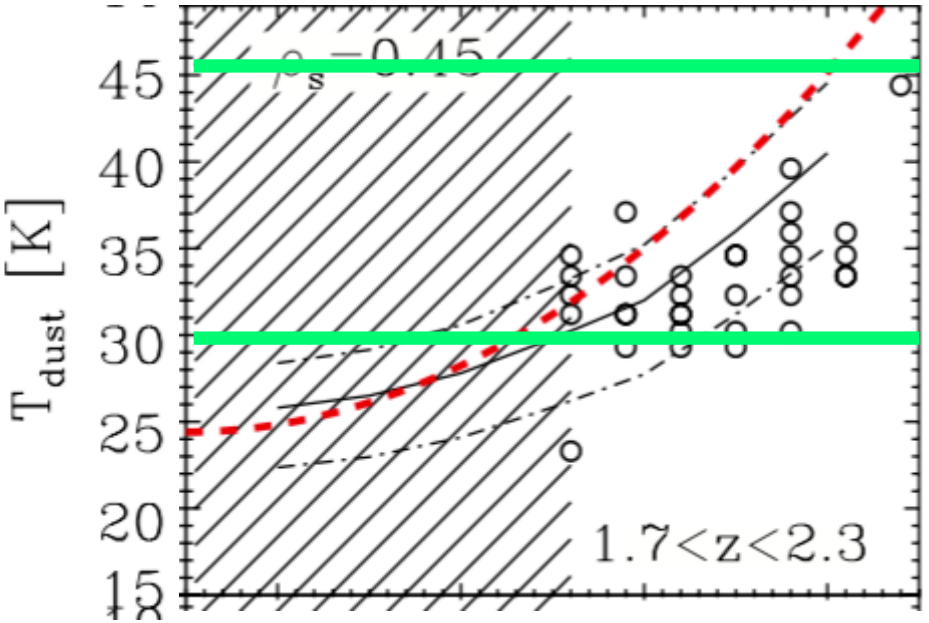


Fv

Sanders+88

1000 100 10 1 (um)

z=2 ULIRG
Tdust=30-50 K

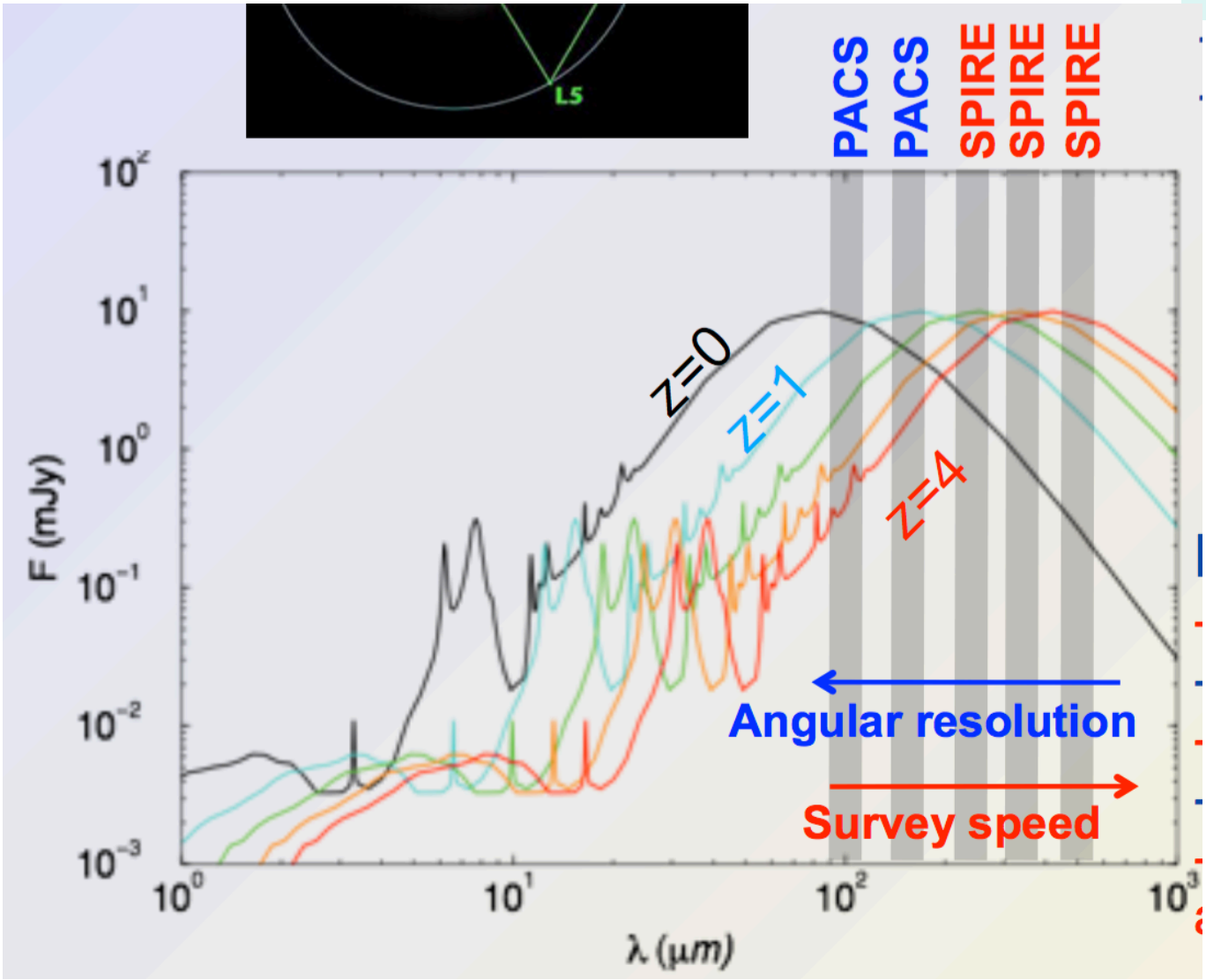


Magnelli+14

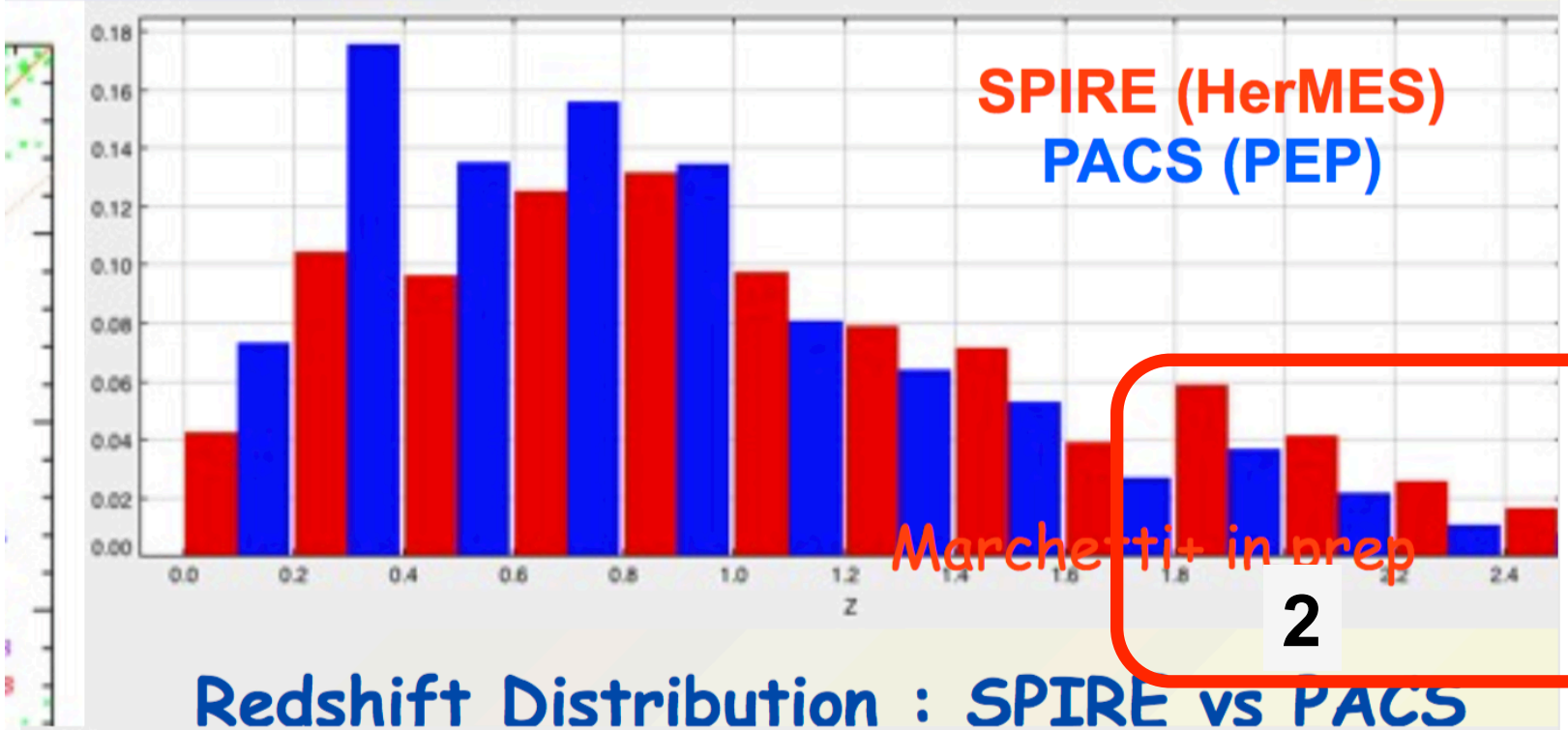
Peak at rest=60-100um

Herschel : PACS 100, 160 um
SPIRE 250, 350, 500um

Select z~2 ULIRG at rest=60-100um

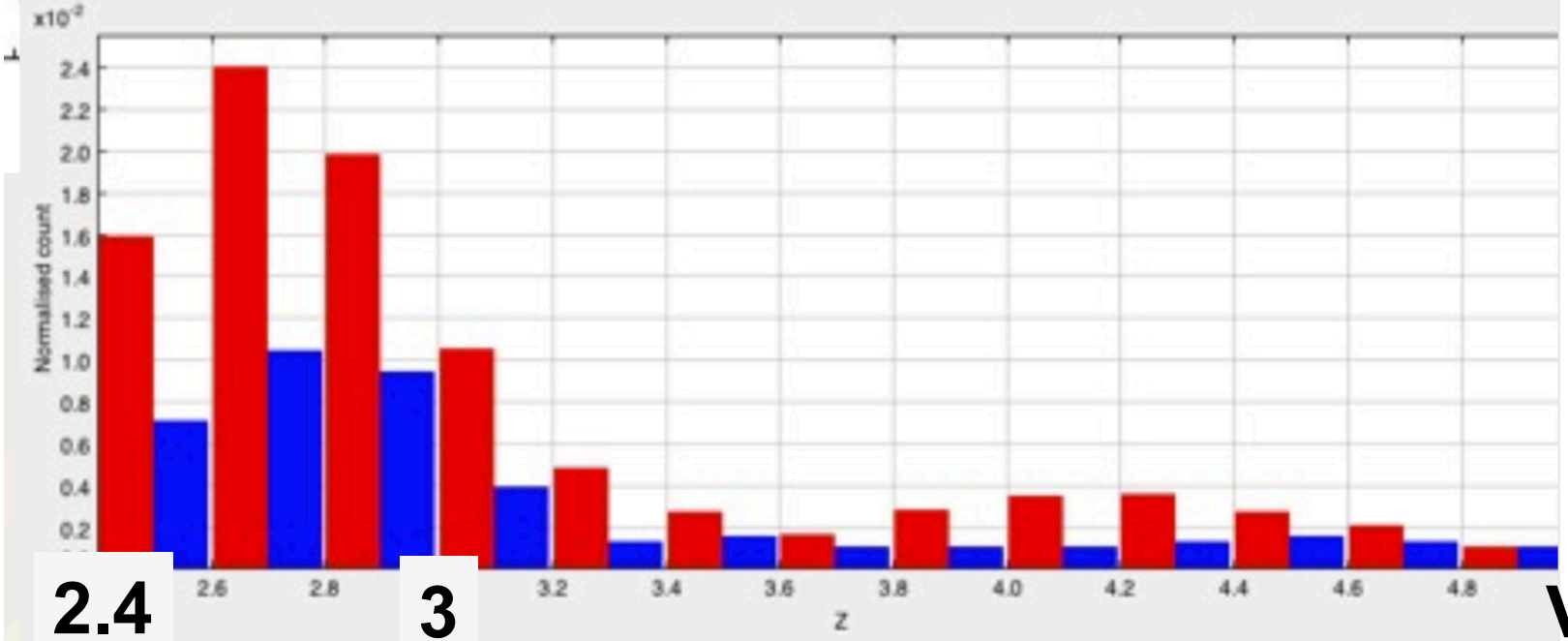


Vaccari+



2

Redshift Distribution : SPIRE vs PACS



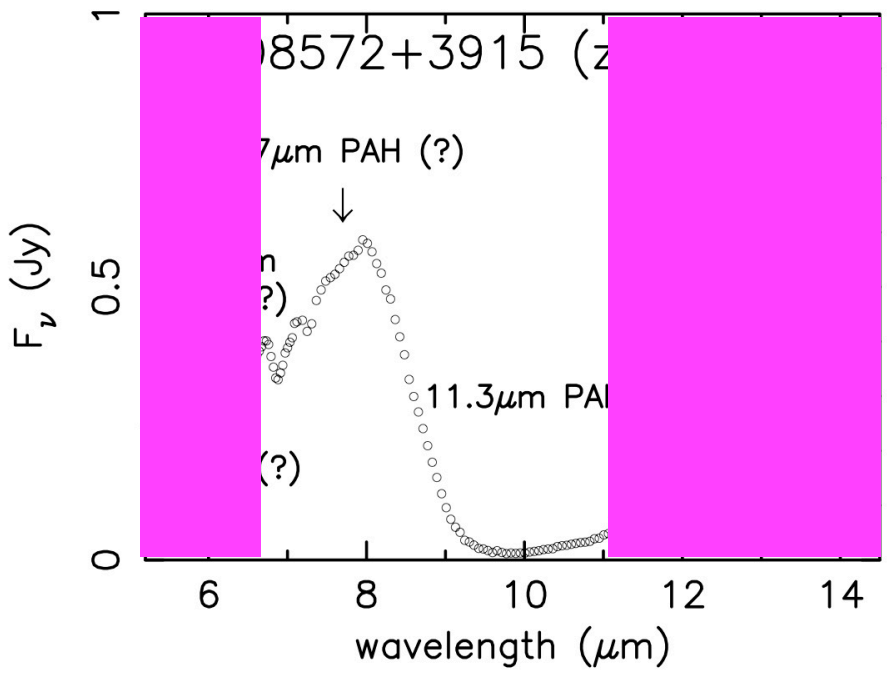
2.4

3

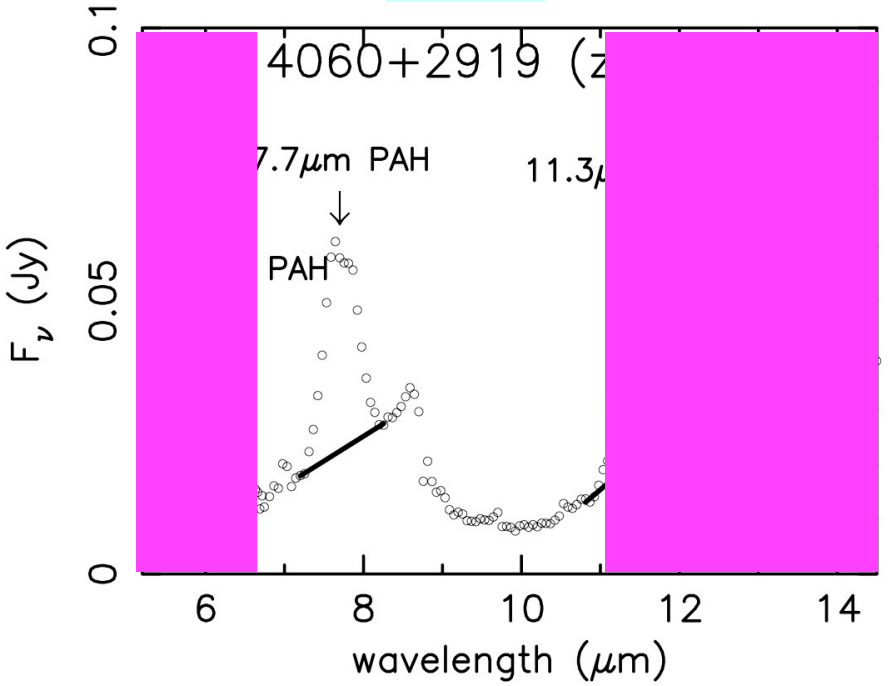
Vaccari+

rest = 5.5-14 um (6-13um) low-R spec

B-AGN



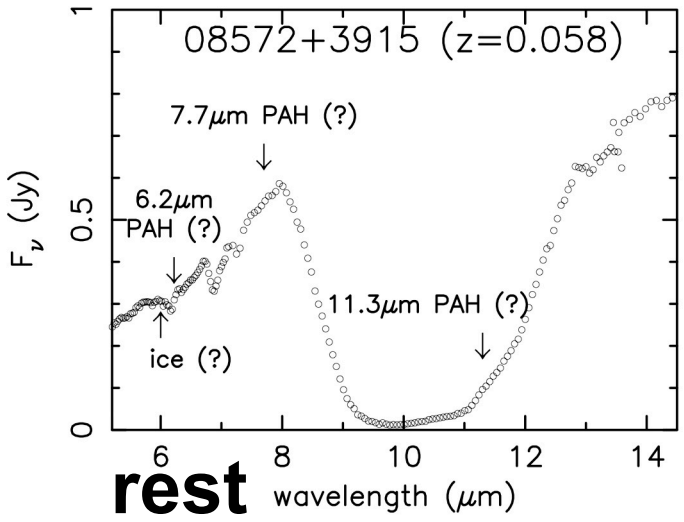
SB



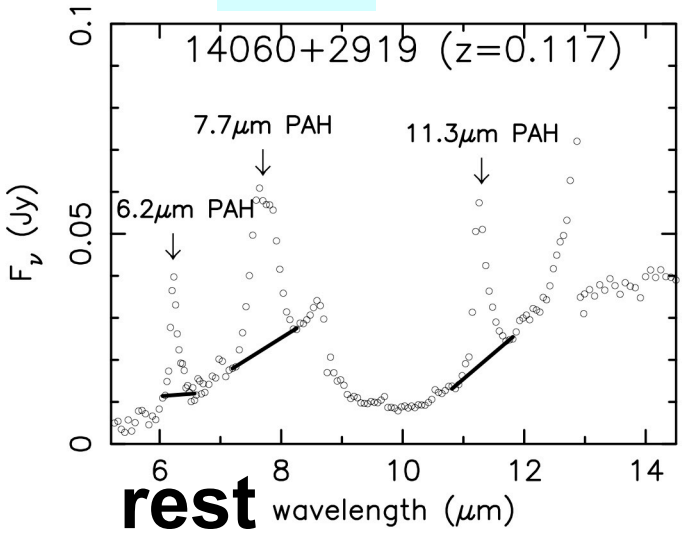
SB (strong 7.7um PAH) and B-AGN (strong 9.7um silicate abs) are not distinguished if λ-coverage is insufficient.

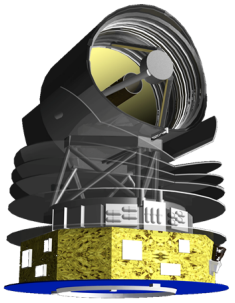
rest = 5.5-14 um (6-13um) low-R spec.

B-AGN



SB





SMI 17-36um

Imanishi+07b

SPICA

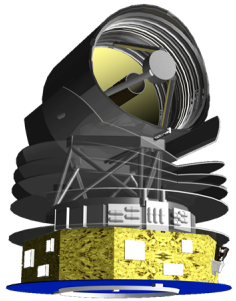
Cover 12-36um (by reducing R?)

JWST/MIRI

Low-R: 5-12 um

Mid-R: 5-28.8 um（three settings needed）

SPICA science



1. Buried AGNs in z~2 ULIRGs ?

Low-R spec.: SMI is better than SAFARI

2. AGN feedback ?

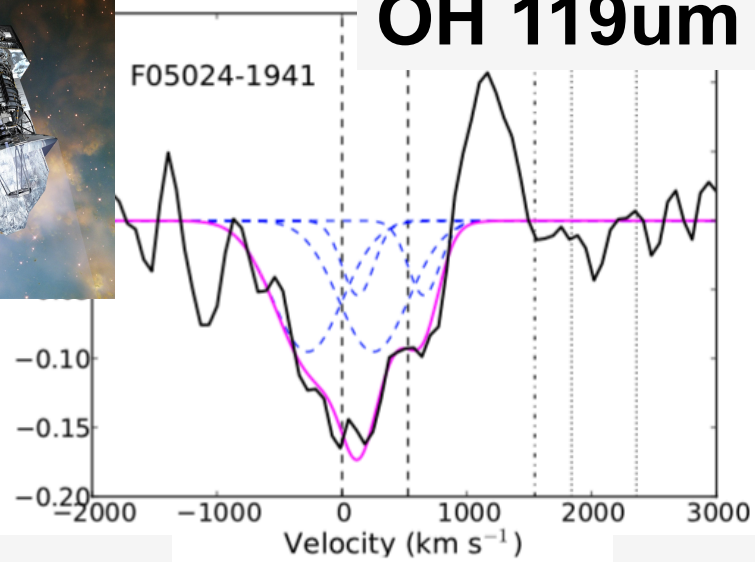
P Cygni ➡ Molecular outflow

SPICA + ALMA

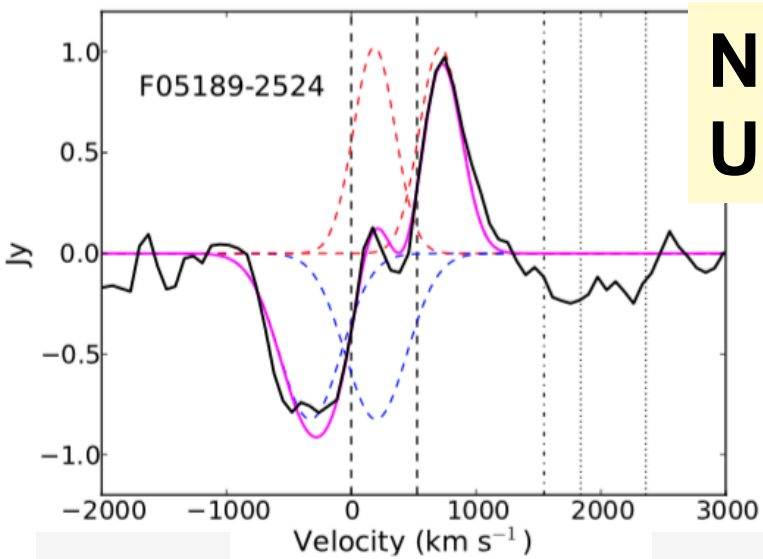
Herschel

OH 119um

P Cygni → outflow

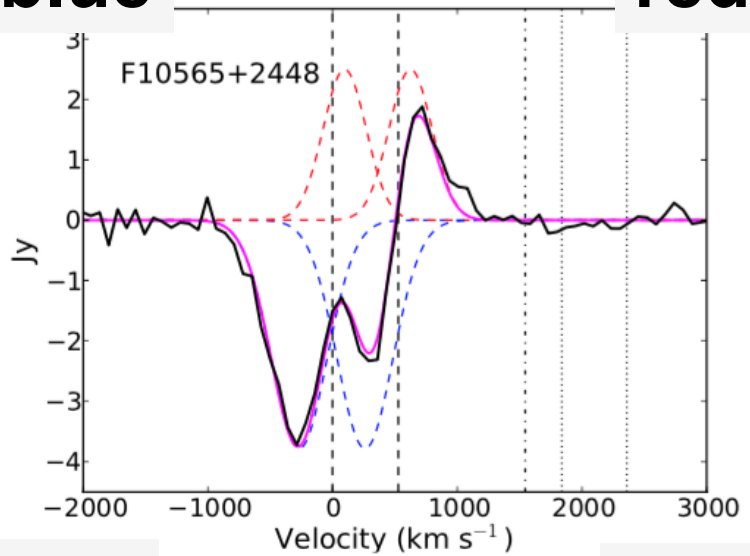


blue red

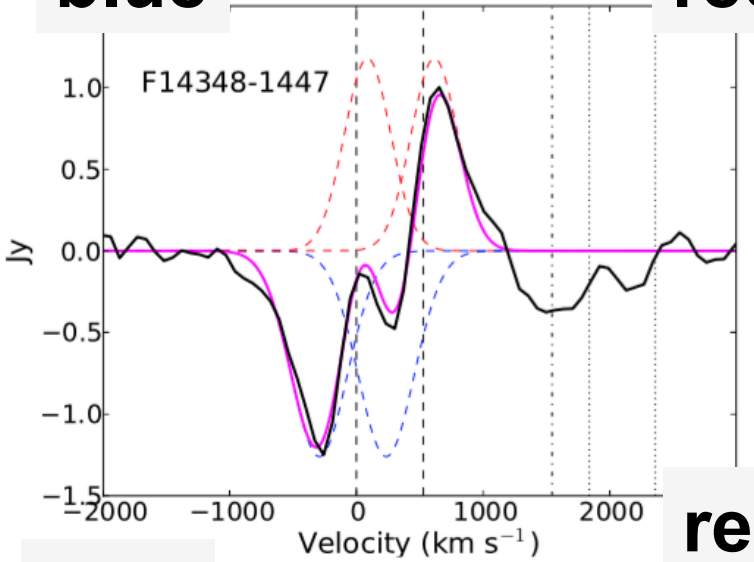


Nearby ULIRG

blue red



blue red



red

blue

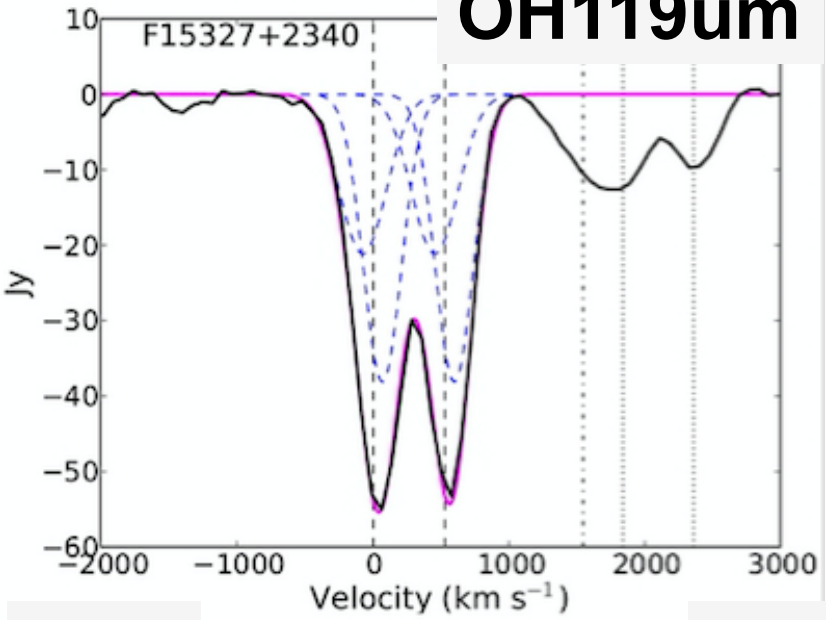
Veilleux+13

Arp 220（z=0.018 ULIRG）

Herschel

No P Cygni

OH119um

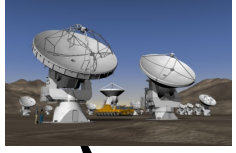


blue

red

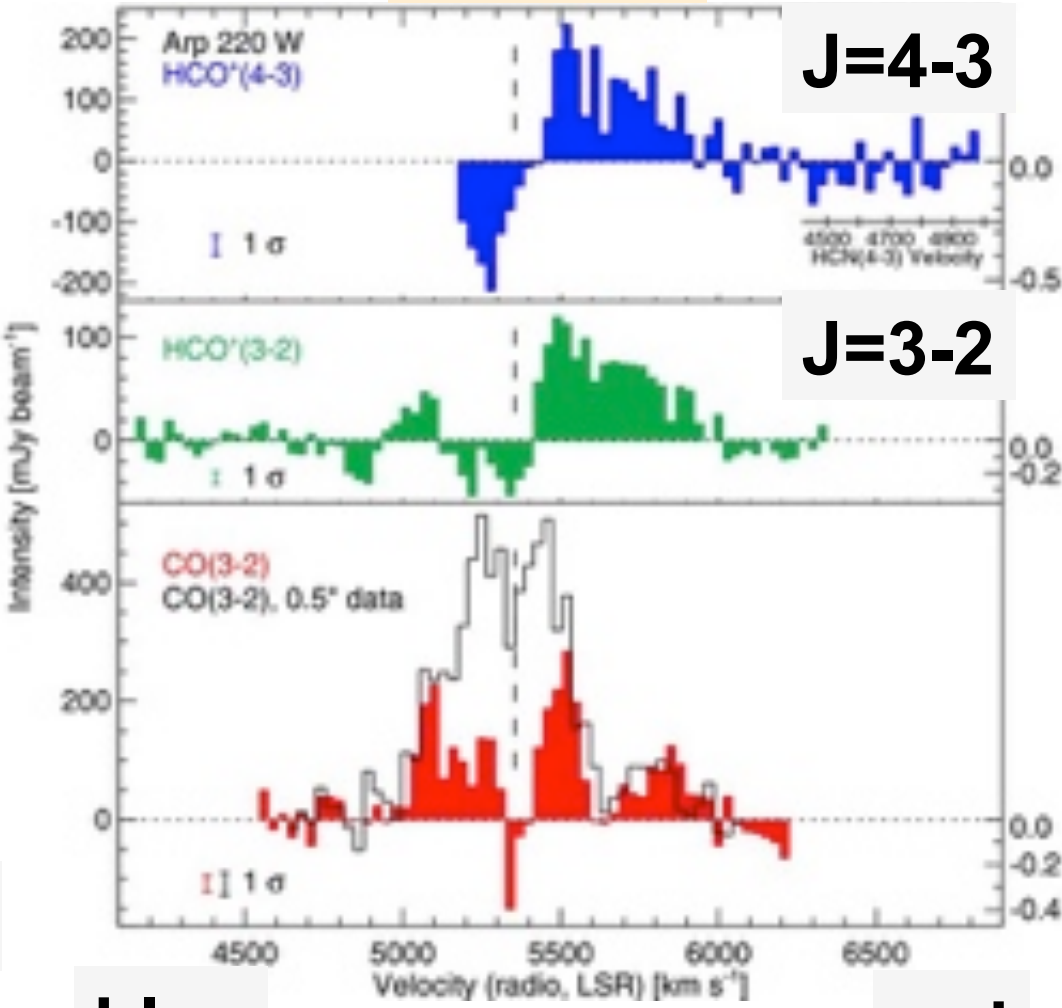
Veilleux+13

ALMA



HCO^+ (850um, 1100um)

P Cygni



blue

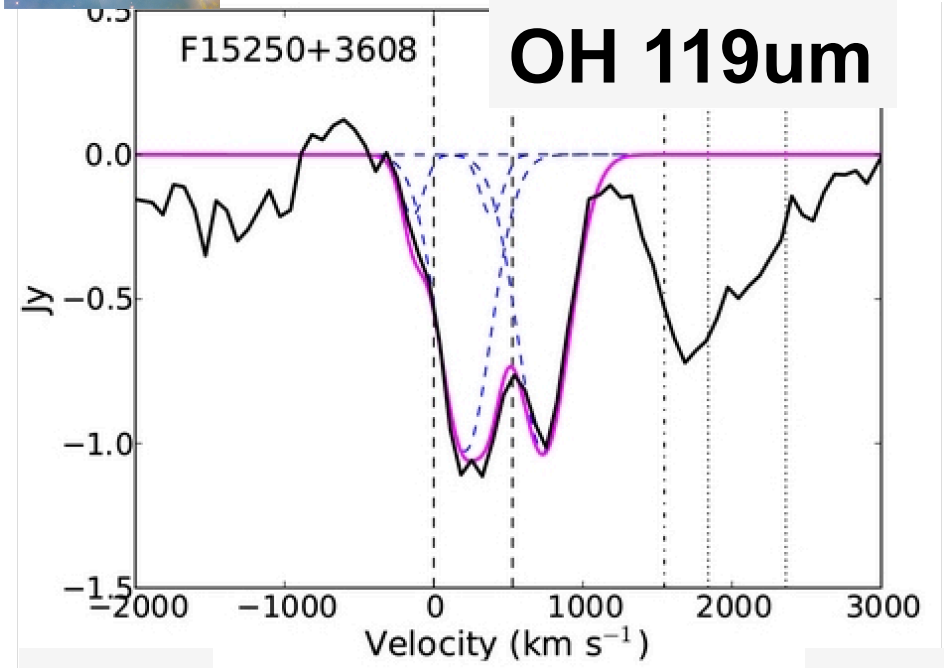
red

Sakamoto+09

IRAS 15250+3609（z=0.055 ULIRG）

Herschel

Inflow only

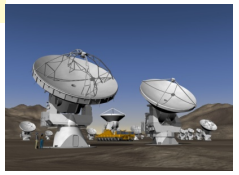


OH 119um

blue **red**

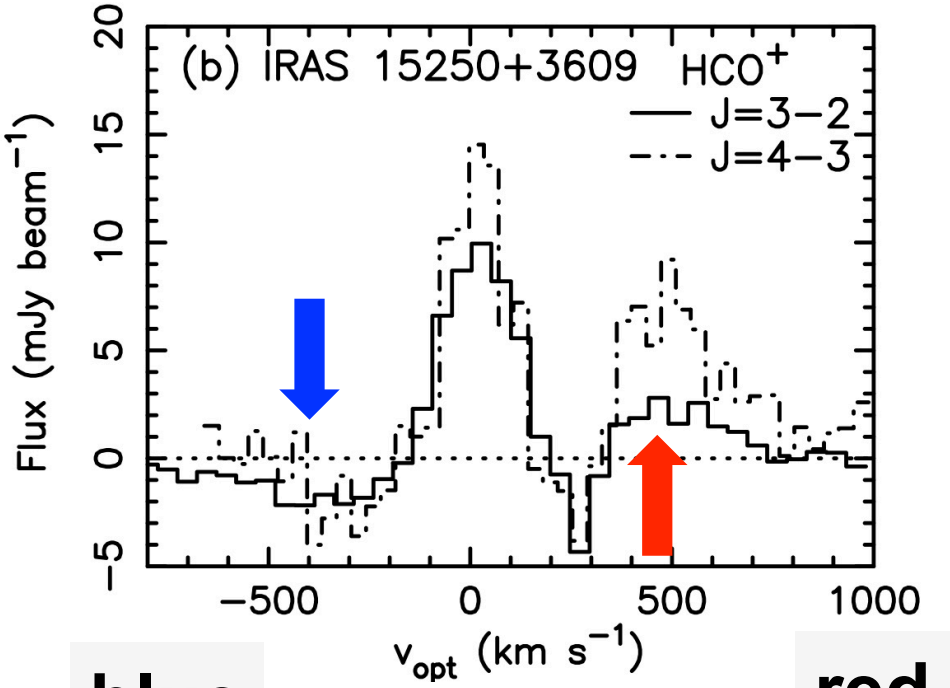
Veilleux+13

ALMA



HCO$^+$ (850um, 1100um)

P Cygni



blue **red**

Imanishi+17 in prep

Summary

1. SPICA SMI low-R spec. to study buried AGNs in z~2 ULIRGs most efficiently

λ-coverage:17-36um -> 12-36 um (?)

2. Molecular outflow -> AGN feedback

SPICA+ALMA

End