Mid-Infrared Spectroscopic Properties of Infrared Ultra-Luminous QSOs (IR QSOs)

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Cao et al. 2007, in preparation

IR QSOs

-- **Infrared Ultra-Luminous QSOs :**

ULIRGs ($L_{IR}>10^{12}L_{\odot}$) + **Type 1 AGN (optical)** → **IR QSOs** (Zheng et al. [2002]; Hao, C.N. et al. [2005])

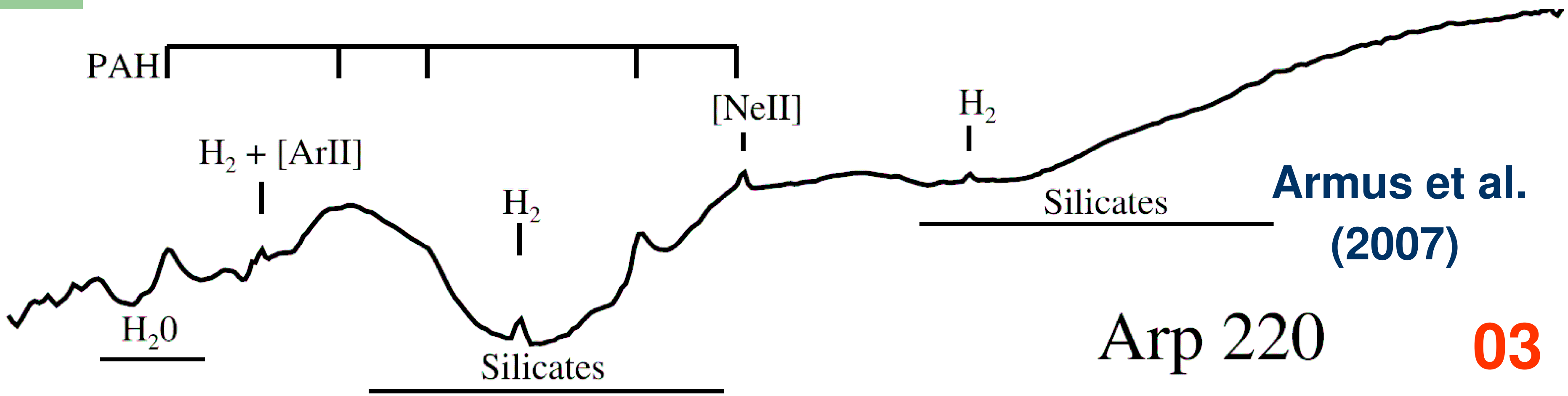
-- **Transitional Objects from ULIRGs to optically selected QSOs** (Canalizo & Stockton [2000, 2001]; Hao, C.N. et al. [2005])

-- **Crucial to understanding the probable evolutionary link between ULIRGs and QSOs** (Sanders et al. [1988] etc.)

Background

-- **IRS 5-40 μm** **Probe →**

* **6.2, 7.7, 8.6, 11.3, 12.7 μm PAHs (SFR?!)**
* **mid-IR fine-structure lines (SFR/AGN)**
* **9.7, 18 μm broad Silicate features (dust)**
* **warm-to-hot dust continuum emission (AGN?!)**



Armus et al. (2007)

Sample

* **IR QSOs: Hao05 + F14026** (HyLIRG+BALQ)

→ **available: 19 (15 have both low & high –res obs.)**

* **ULIRGs (non-S1):**

from *IRAS* 1-Jy sample and *Spitzer* GTO #105

+ High-res mid-IR data from Farrah et al. (2007)

* **PG QSOs: mainly from Spitzer GTO & GO #14, 3187 & 20142, with enough S/N, z<0.27**

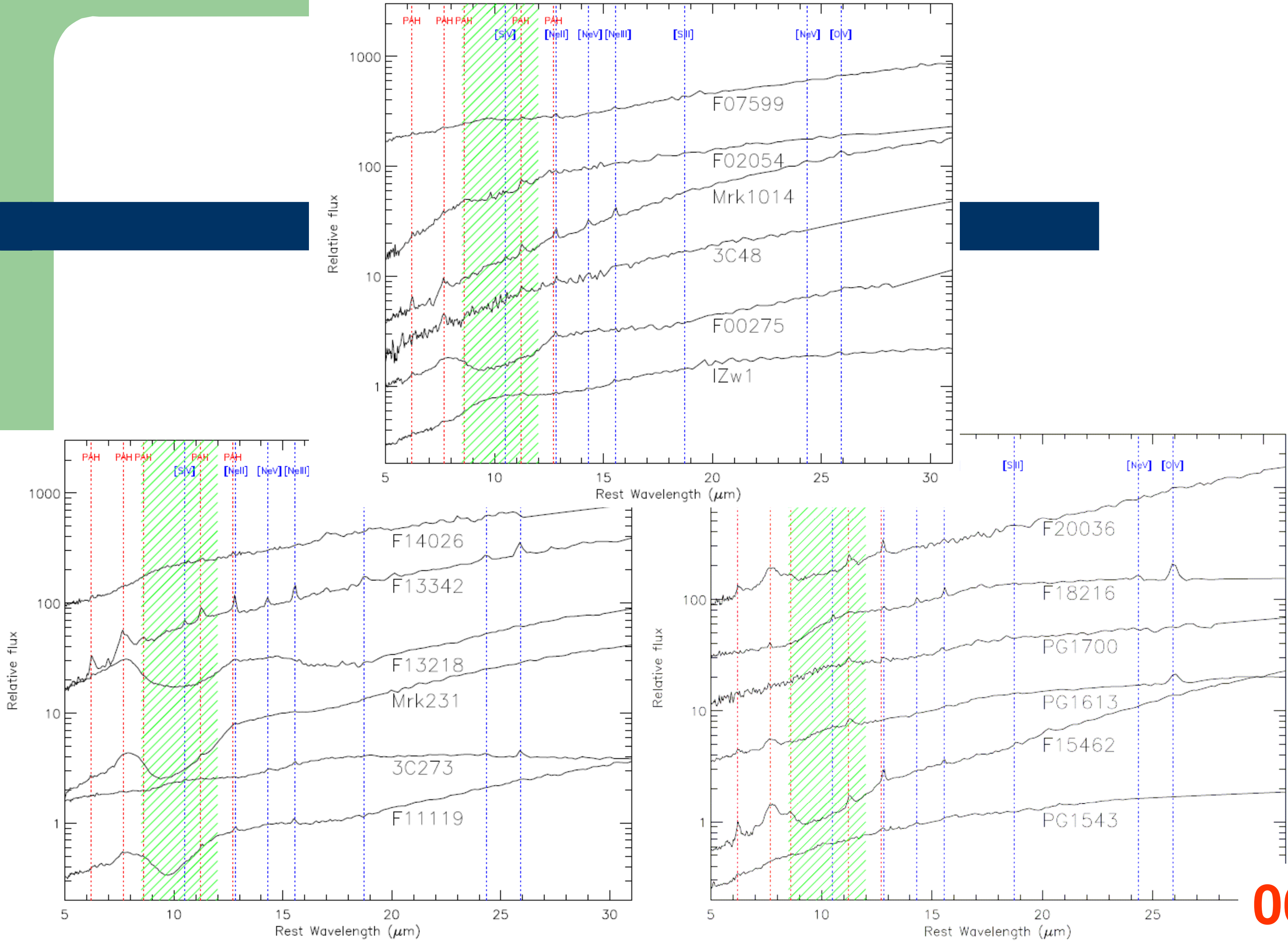
+ PG QSOs from QUEST.I (Schweitzer et al. [2006])

Data Reduction

- **Spectral Extraction: SMART** software (by IRS team of Cornell Univ.)
- **Scaling** the spectra**:** use 12 & 25μm flux densities from ***IRAS*** or ***ISO***
- Measuring **PAH** & **fine-structure lines** (following Desai et al. [2007]; Farrah et al. [2007]; Schweitzer et al. [2006])
- Fitting the **continua** & measuring **silicate strengths** (following Spoon et al. [2007])

Results

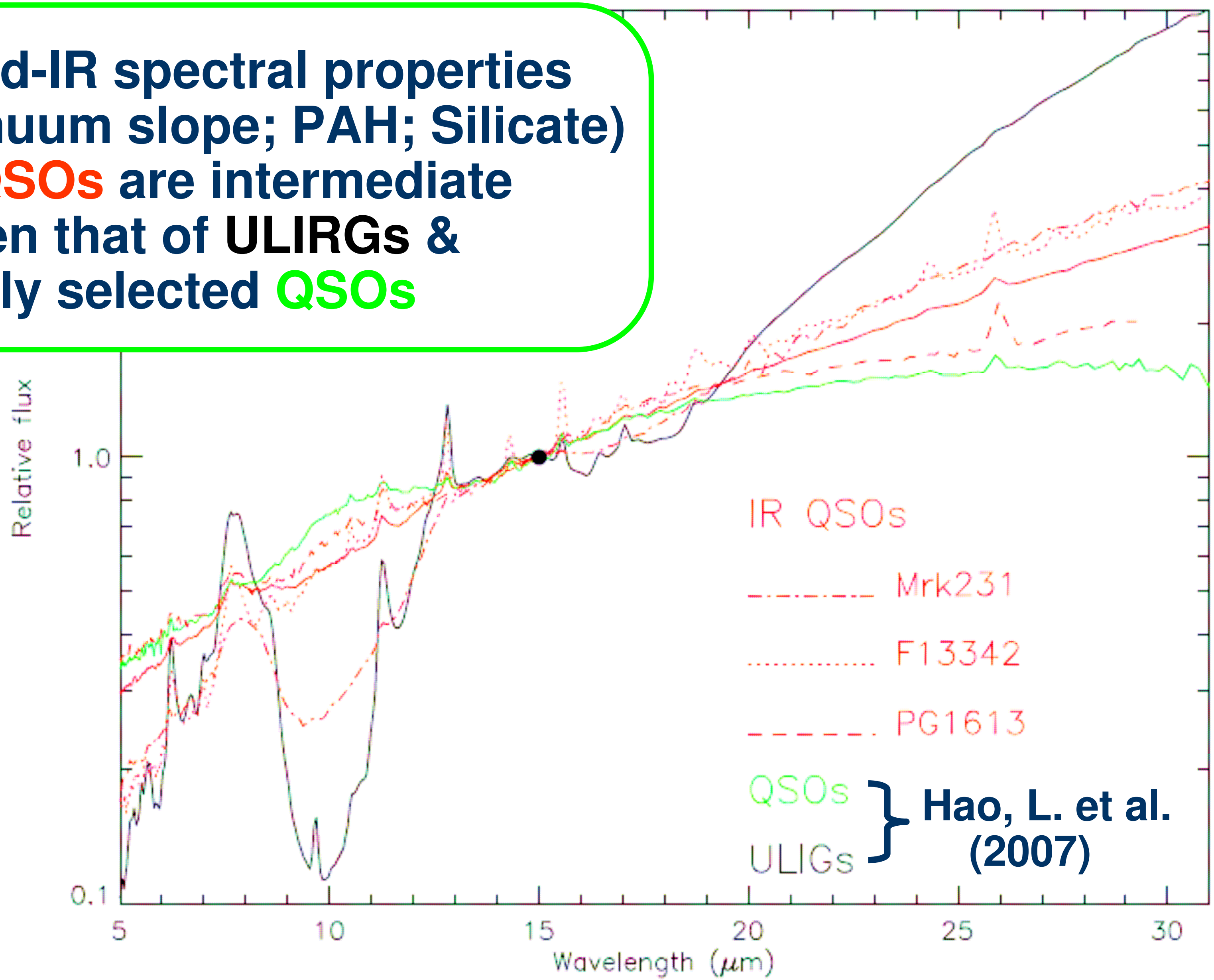
Low-Res Spectra of IR QSOs



Results

Average Spectra

The mid-IR spectral properties (continuum slope; PAH; Silicate) of IR QSOs are intermediate between that of ULIRGs & optically selected QSOs



Results

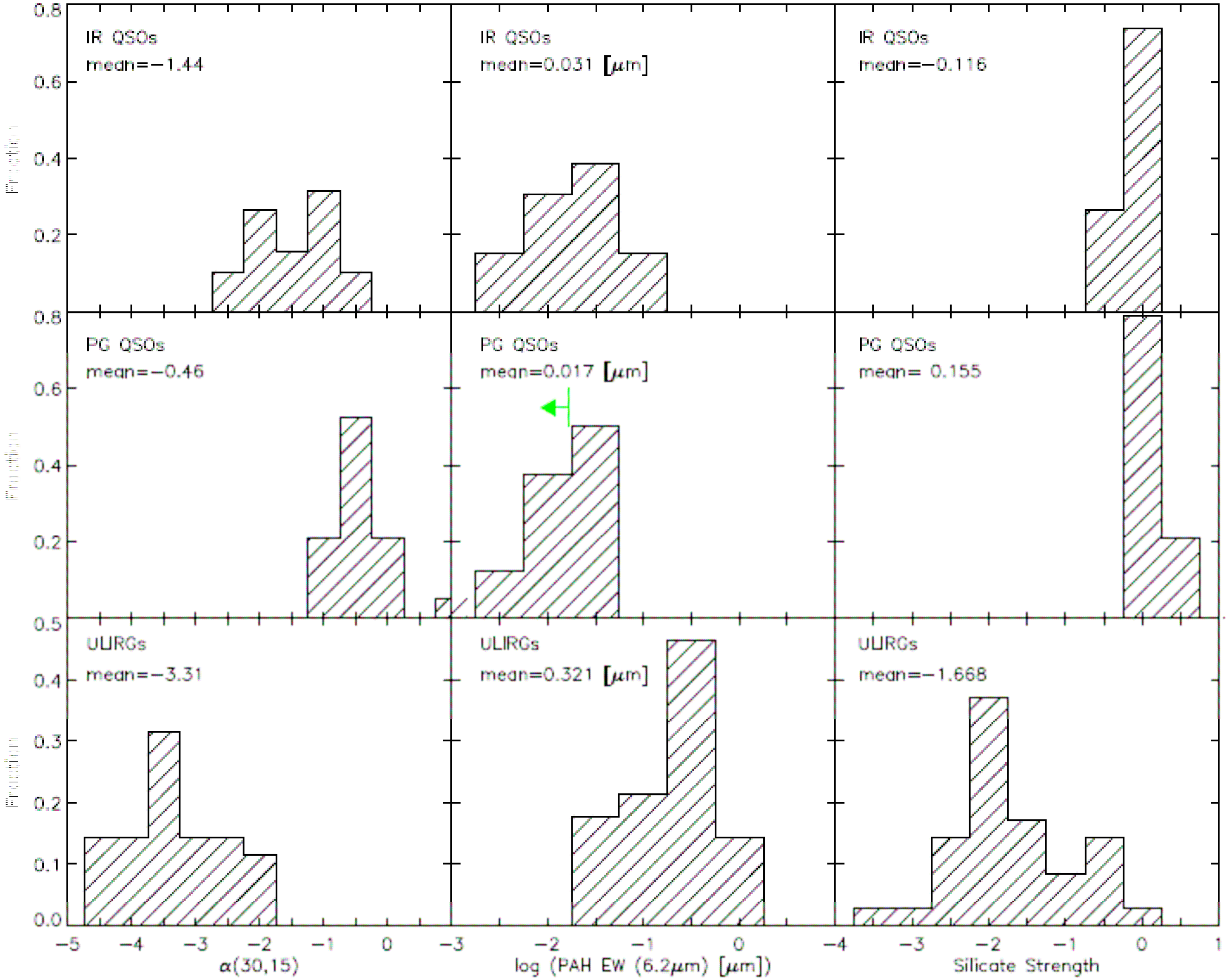
Histograms

IR QSOs

PG QSOs

ULIRGs

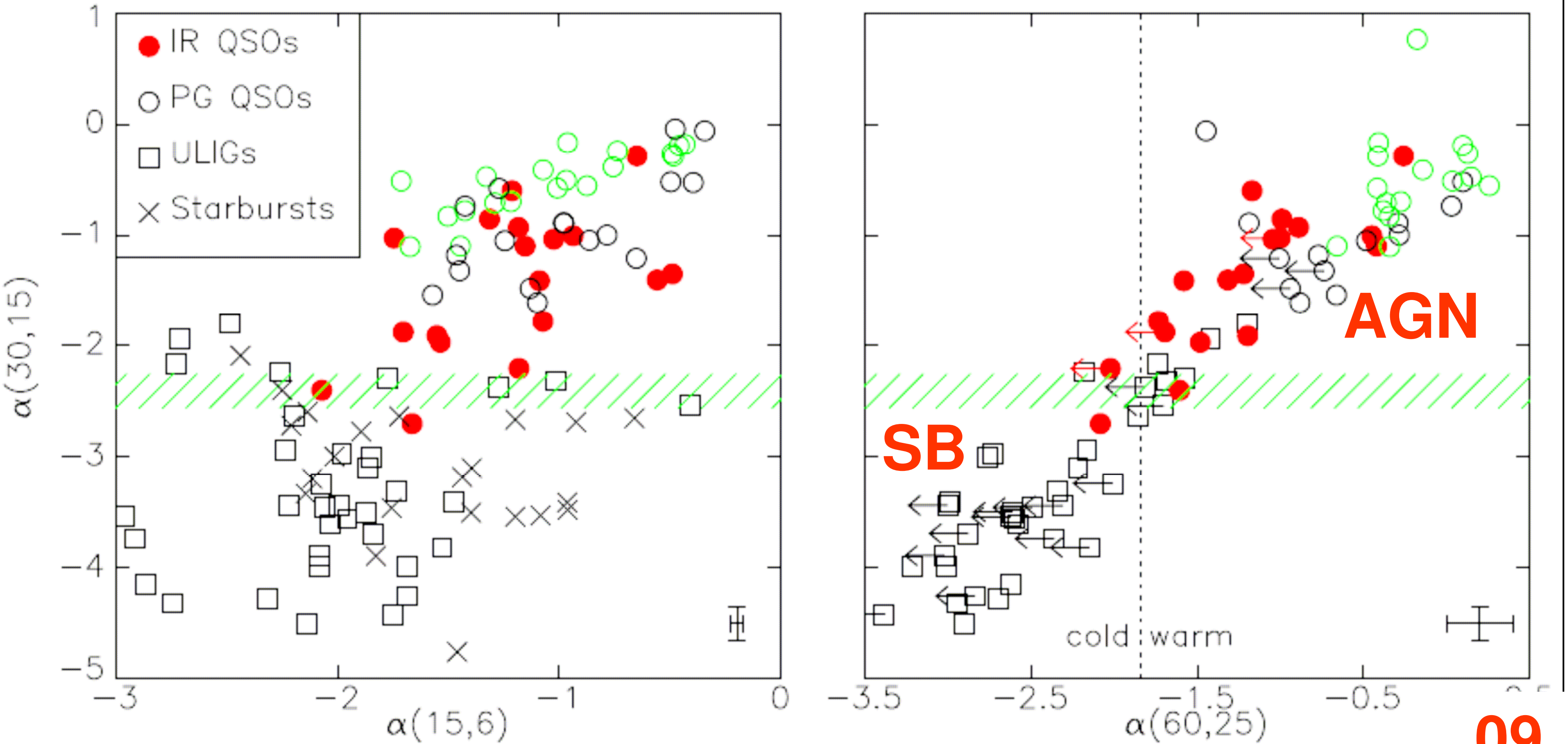
α(30,15) | EW(PAH) | S_{sil}



Mid-IR Diagnostics of SB and AGN activities (i)

Mid- and Far-IR color-color diagrams

α(15,6) vs. α(30,15)   α(60,25) vs. α(30,15)



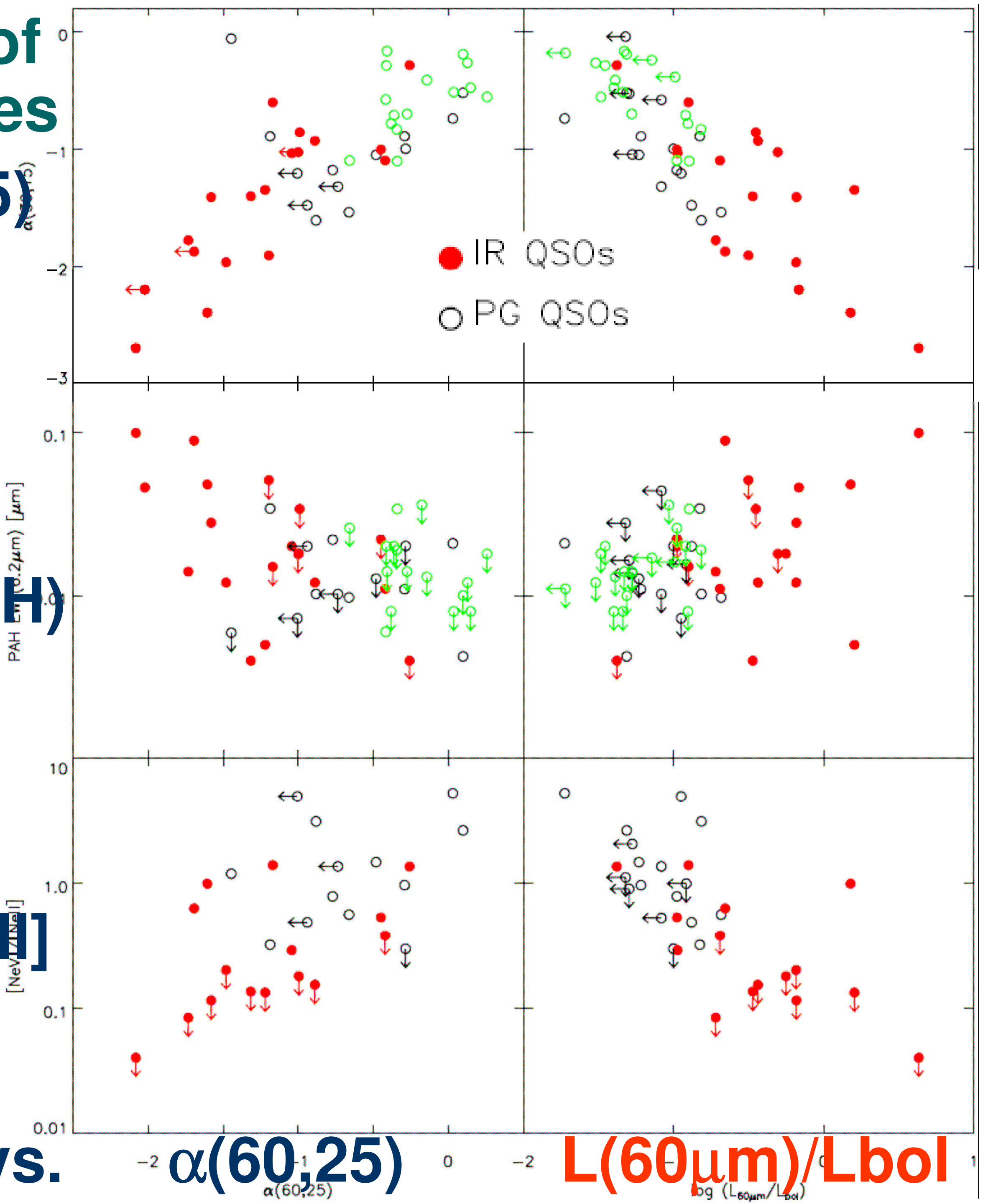
Mid-IR Diagnostics of SB and AGN activities (ii)

α(30,15)

EW (6.2μm PAH)

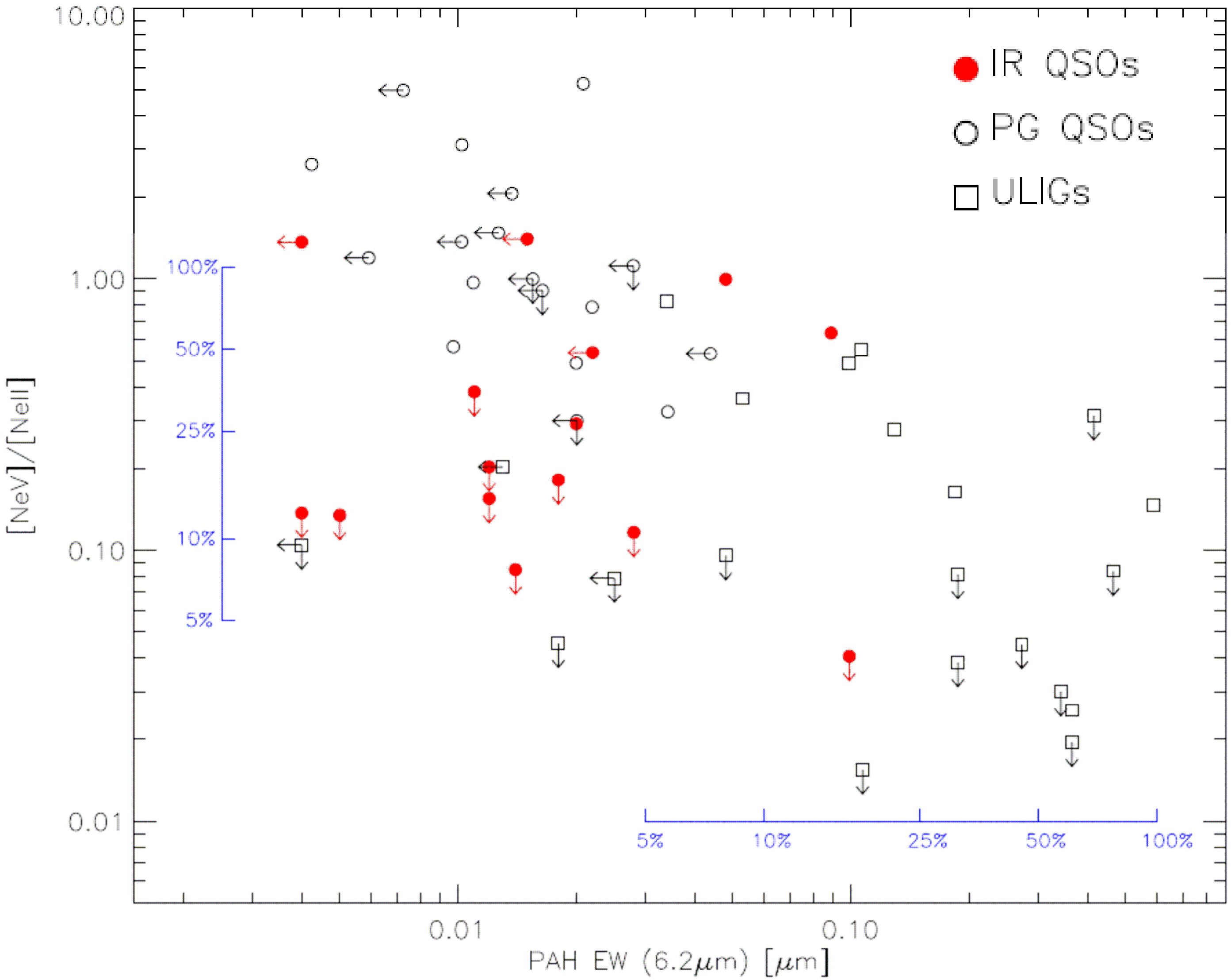
[NeV]/[NeII]

vs. α(60,25) L(60μm)/Lbol



Mid-IR Diagnostics of SB and AGN activities (iii)

Genzel Diagram -- EW(PAH) vs. [NeV]/[NeII]



Results

SFRs in QSOs & ULIRGs

-- Far-IR (60μm) : Hao, C.N. et al. (2005, 2007)

$$SFR = 3.26 M_\odot yr^{-1} \frac{L_{60\mu m}}{10^{10} L_\odot}$$

$$log(L_{60\mu m}(AGN)/L_\odot) = 0.794 log(\lambda L_\lambda(5100\AA)/L_\odot) + 2.016$$

-- PAH emission (6.2μm): Brandl et al. (2006)

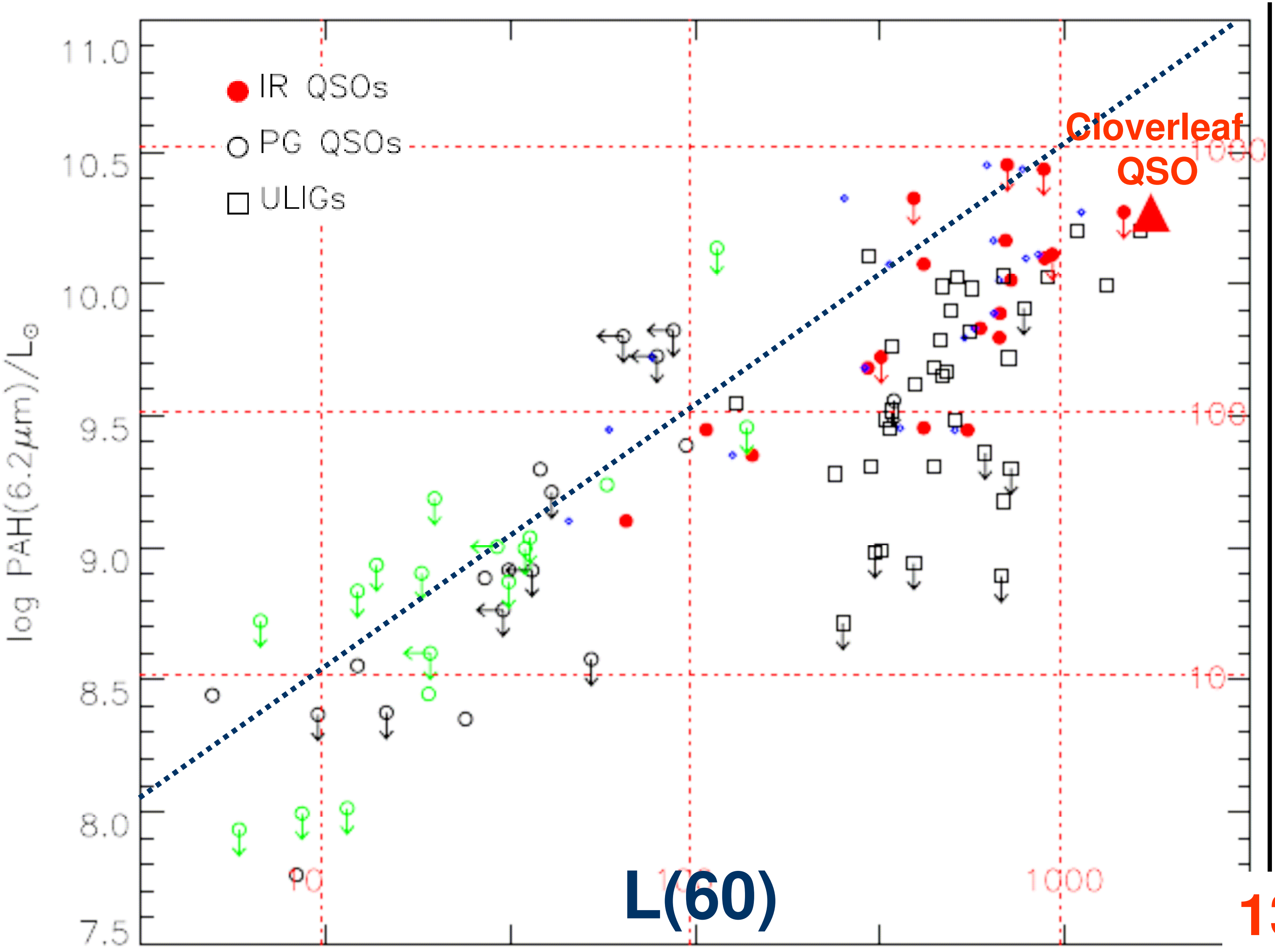
$$log(L_{IR}^{PAH}) = 1.13 \times log(F_{6.2\mu m PAH} D^2)$$

-- [NeII] emission line: Ho & Keto (2006)

$$\log L_{NeII} = (1.01 \pm 0.054) \log L_{IR} - (3.44 \pm 0.56)$$

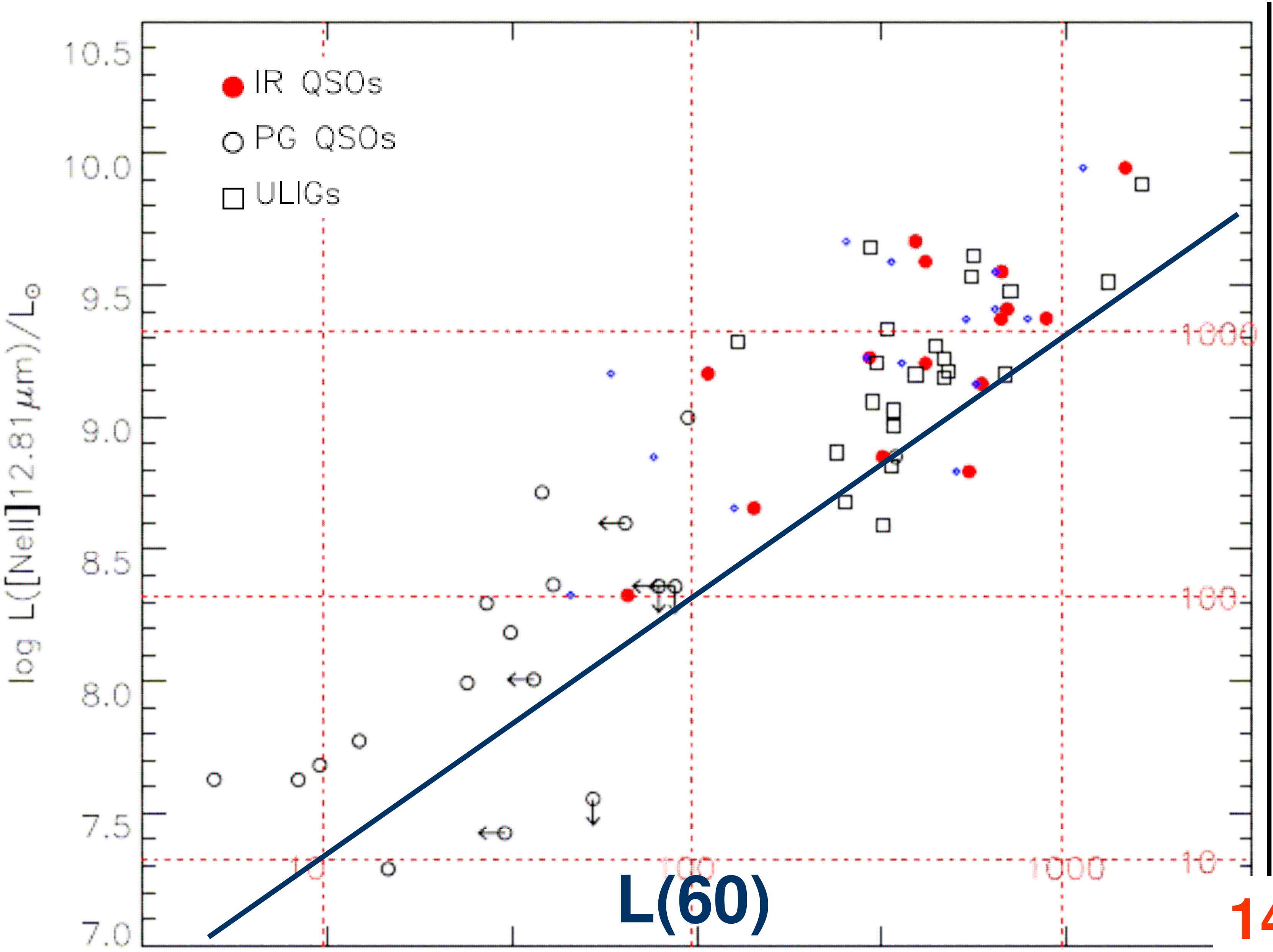
SFRs in QSOs

Comparison (i): L(60) vs. L(PAH)



SFRs in QSOs

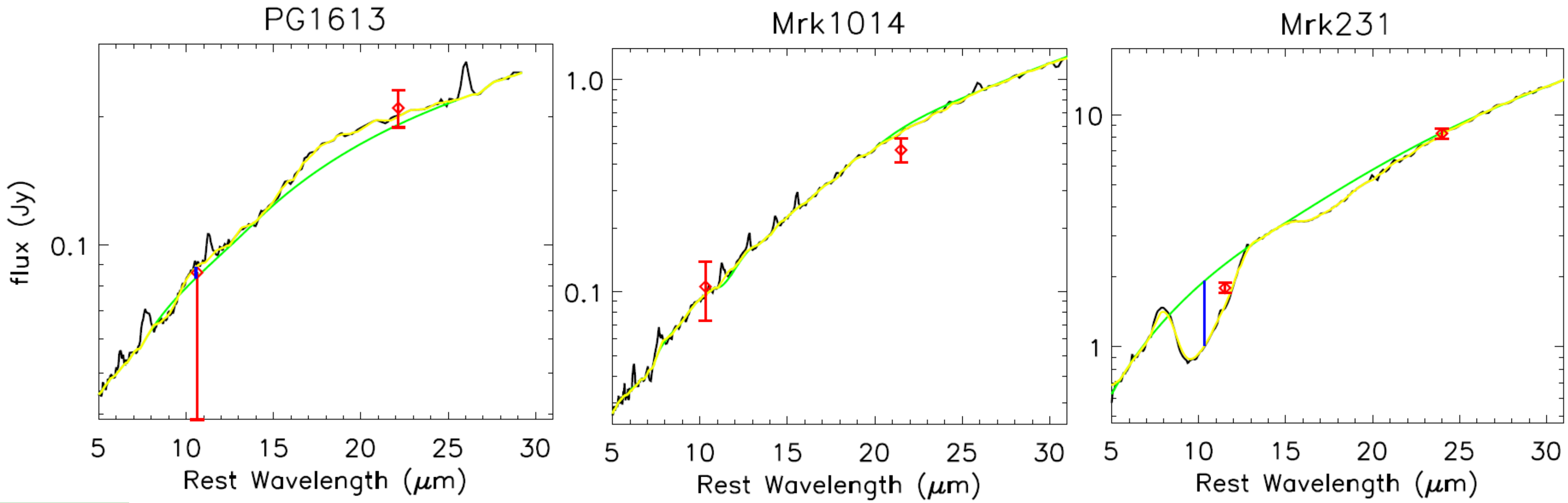
Comparison (ii): L(60) vs. L([NeII])



Discussion

Classification of IR QSOs

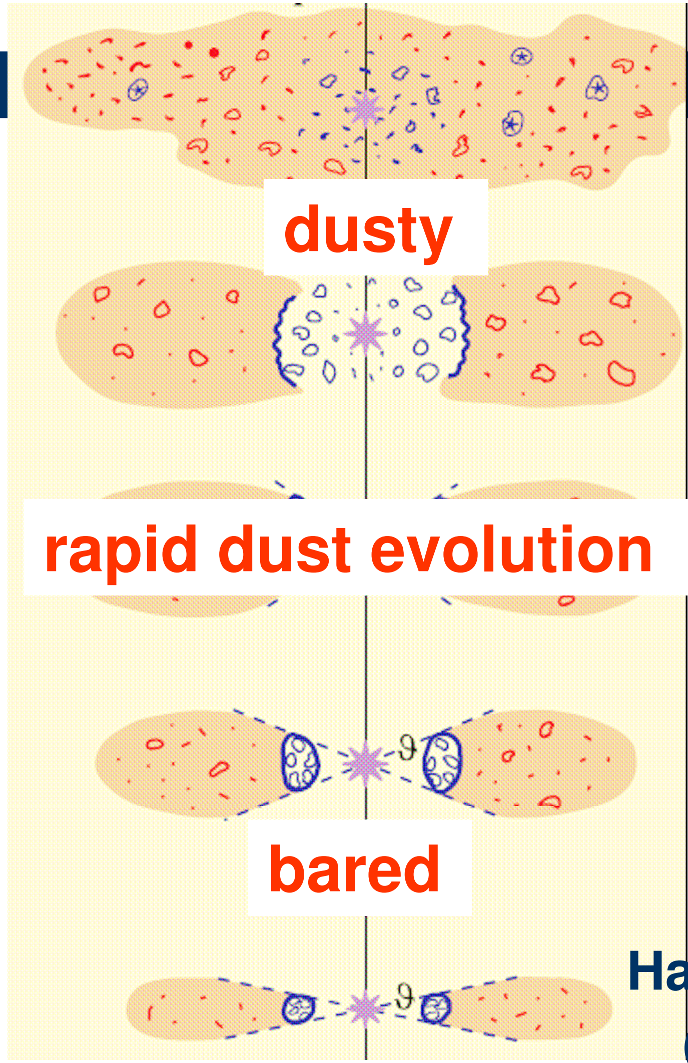
(pre)-Classical QSO	SB + QSO	ULIRG + QSO



	(pre)-Classical QSO	SB + QSO	ULIRG + QSO
<α(30,15)>	–0.83	–2.29	–1.72
<EW(PAH)>	< 0.017	0.071	0.018
<Ssil>	0.08	–0.14	–0.53

Discussion

Evolution of dust in IR QSOs



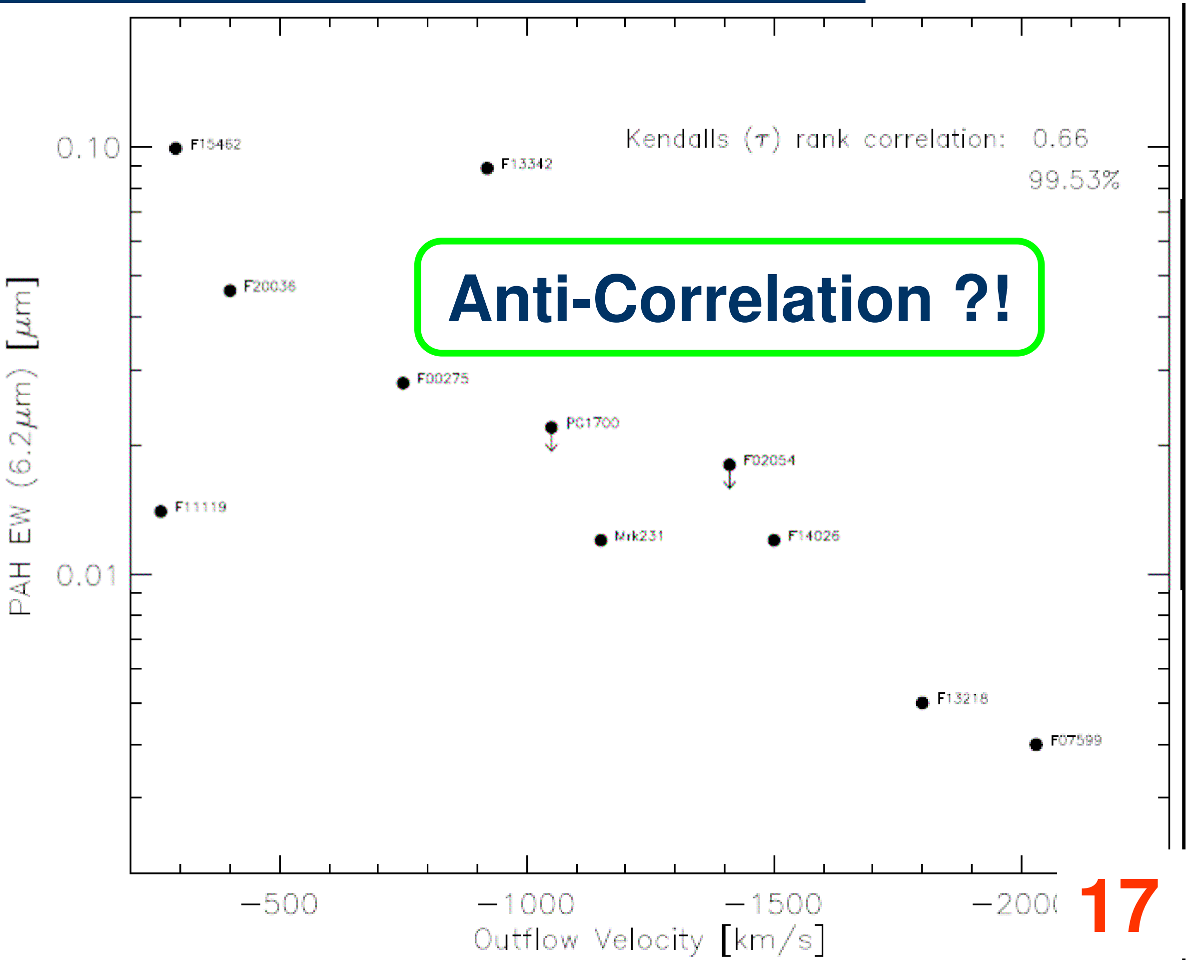
	<Ssil>
ULIRGs	–1.67
↓	
IR QSOs	–0.12
↓	
PG QSOs	+0.16

Haas et al. (2003)

Discussion

Star Formation suppressed caused by AGN feedback ?!

- **Outflowing Velocity : the offset broad Hβ emission** (Zheng et al. [2002])
- **SFR/Mdot: EW (6.2μm PAH)**



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