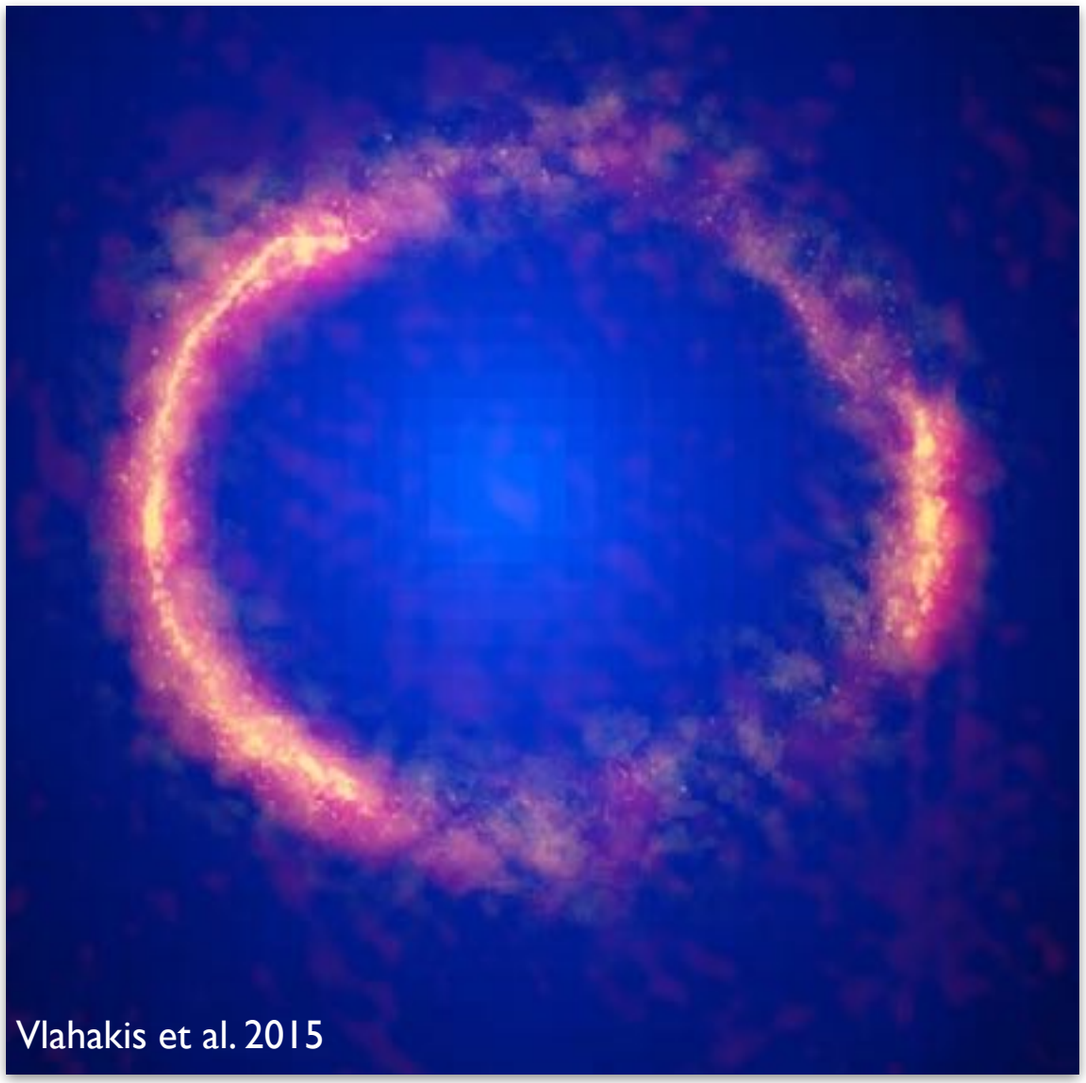
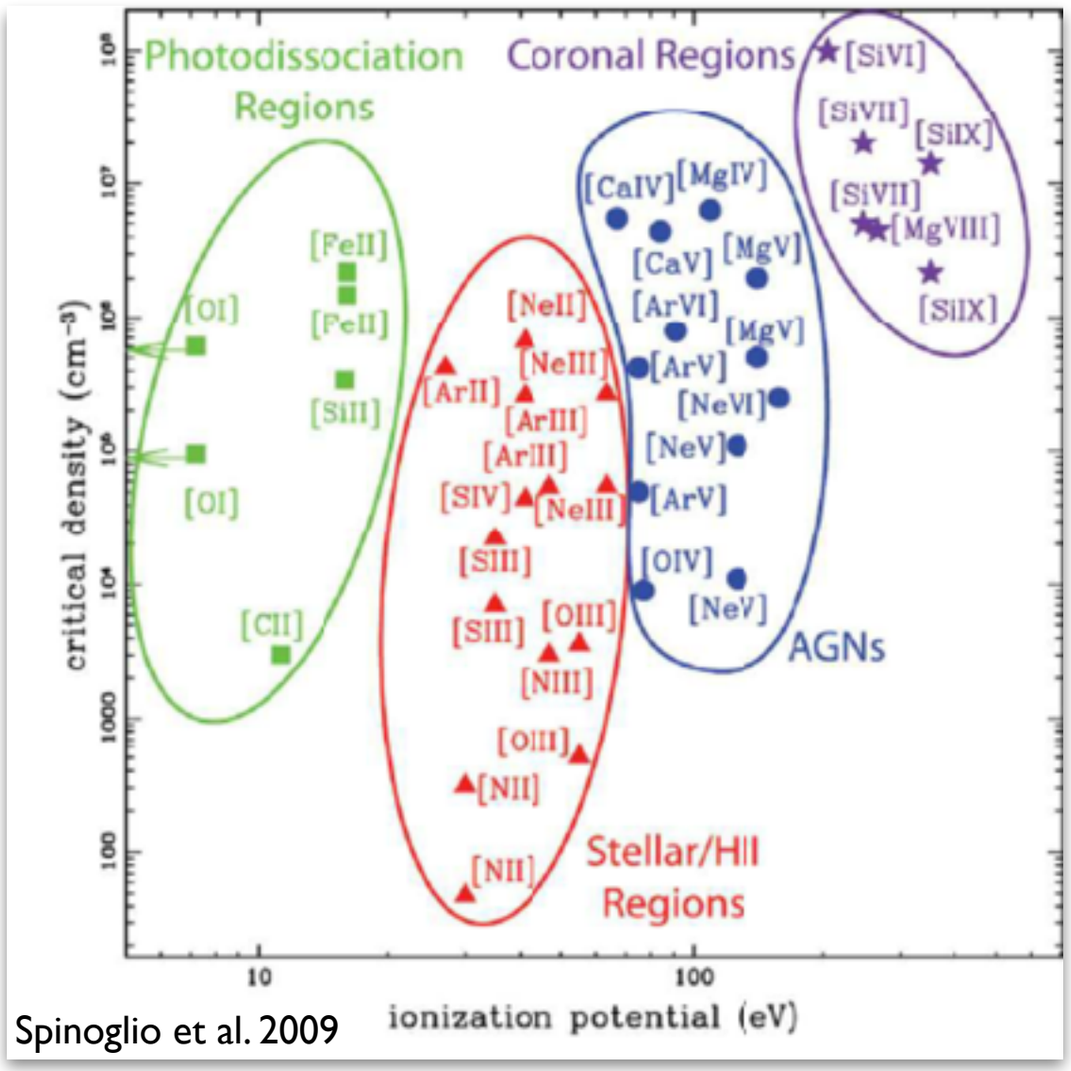
Lancaster University

SPICA and lensed galaxies: lessons from *Herschel*

Julie Wardlow

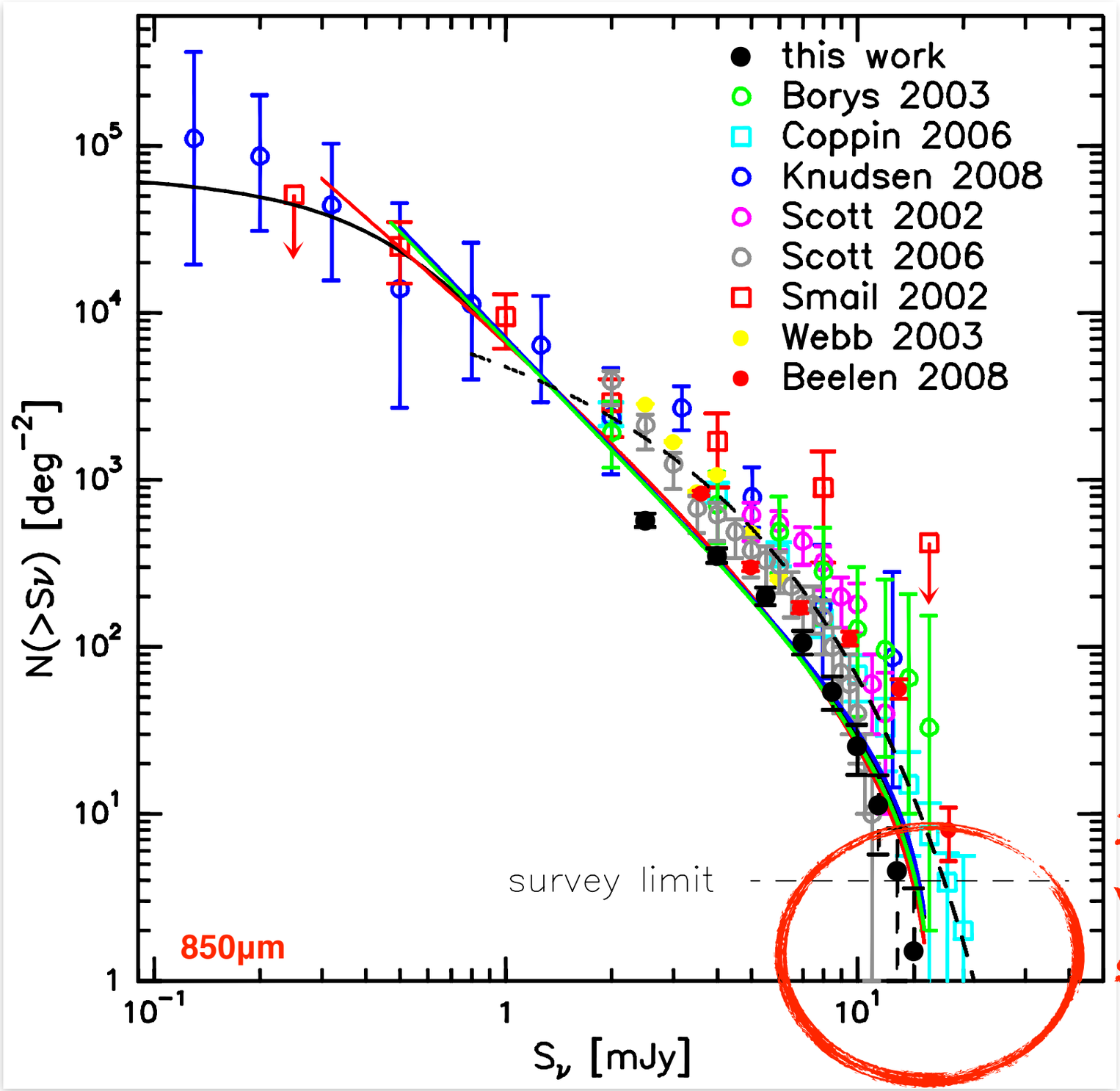


Vlahakis et al. 2015



Spinoglio et al. 2009

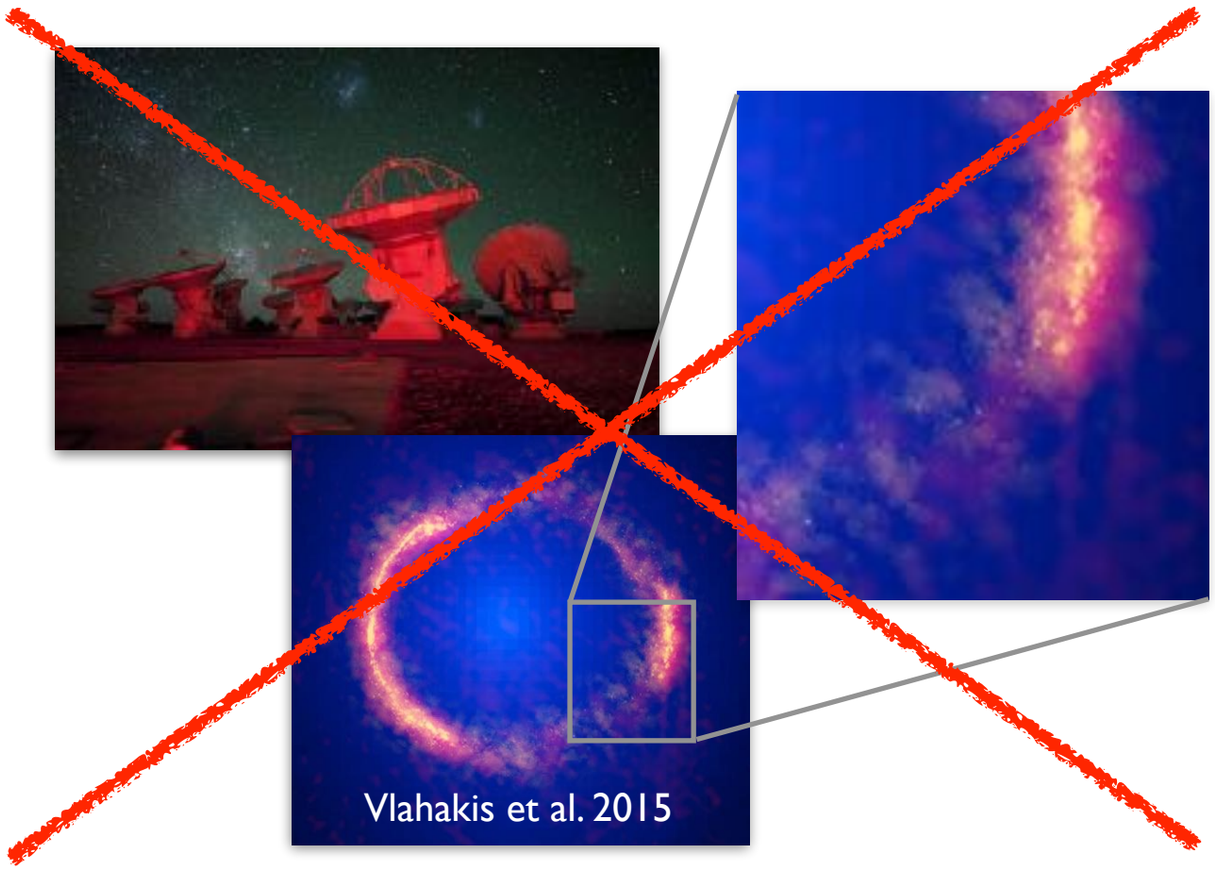
Far-IR number counts are steep at the bright end: very luminous SMGs are rare ⇒ simple lens selection

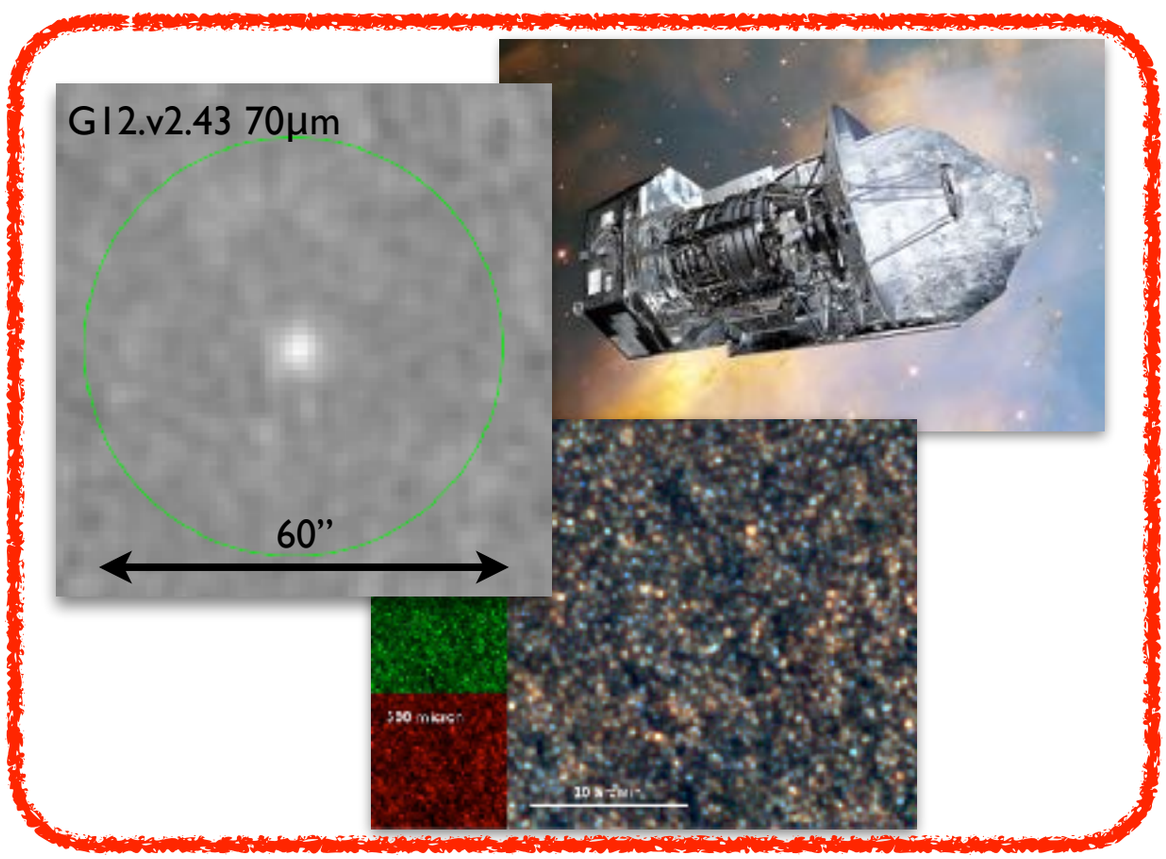


Weiss et al. 2009

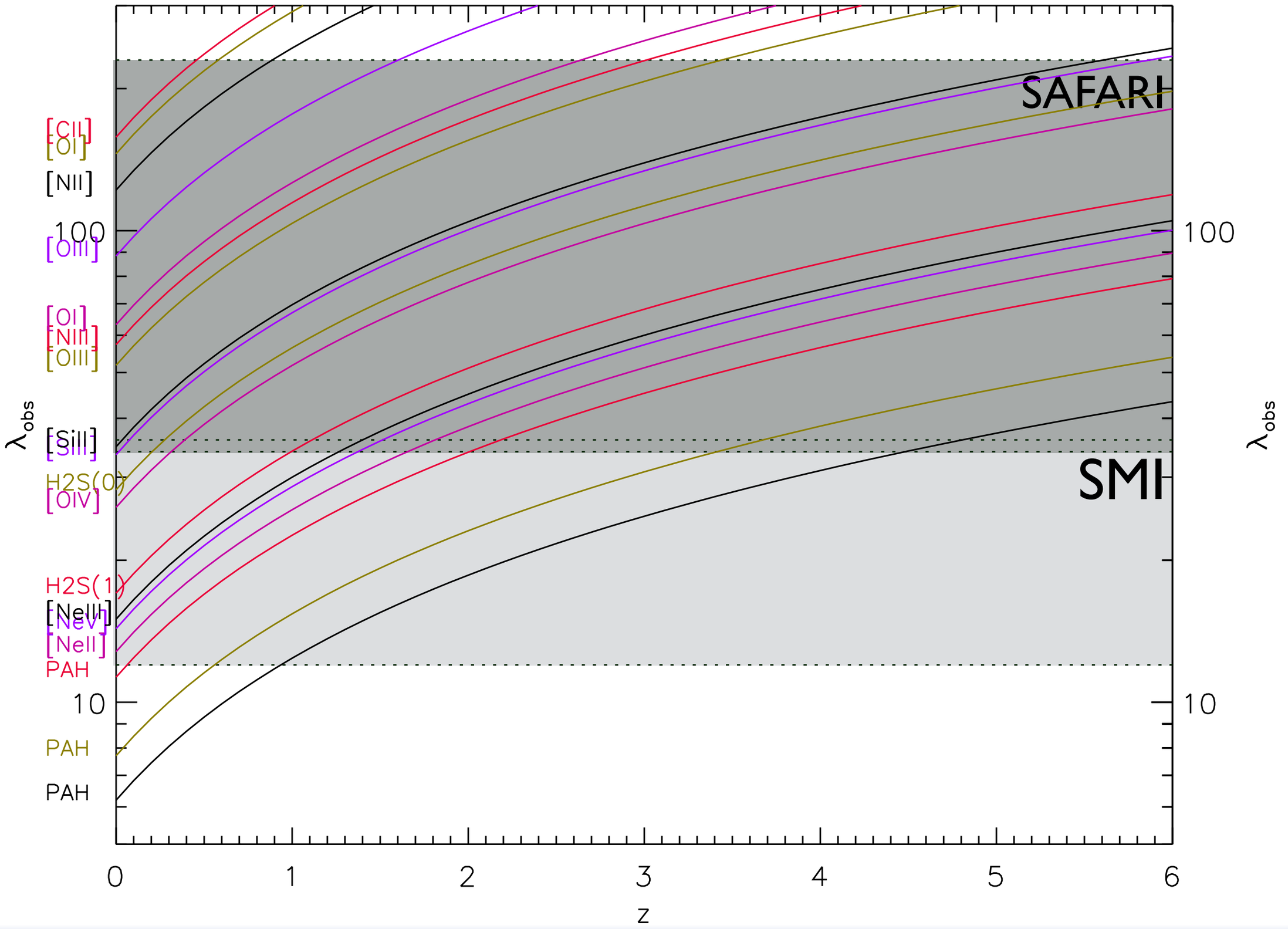
See also Blain et al. 1996

Remember that with SPICA lenses will be unresolved (similarly to *Herschel*)





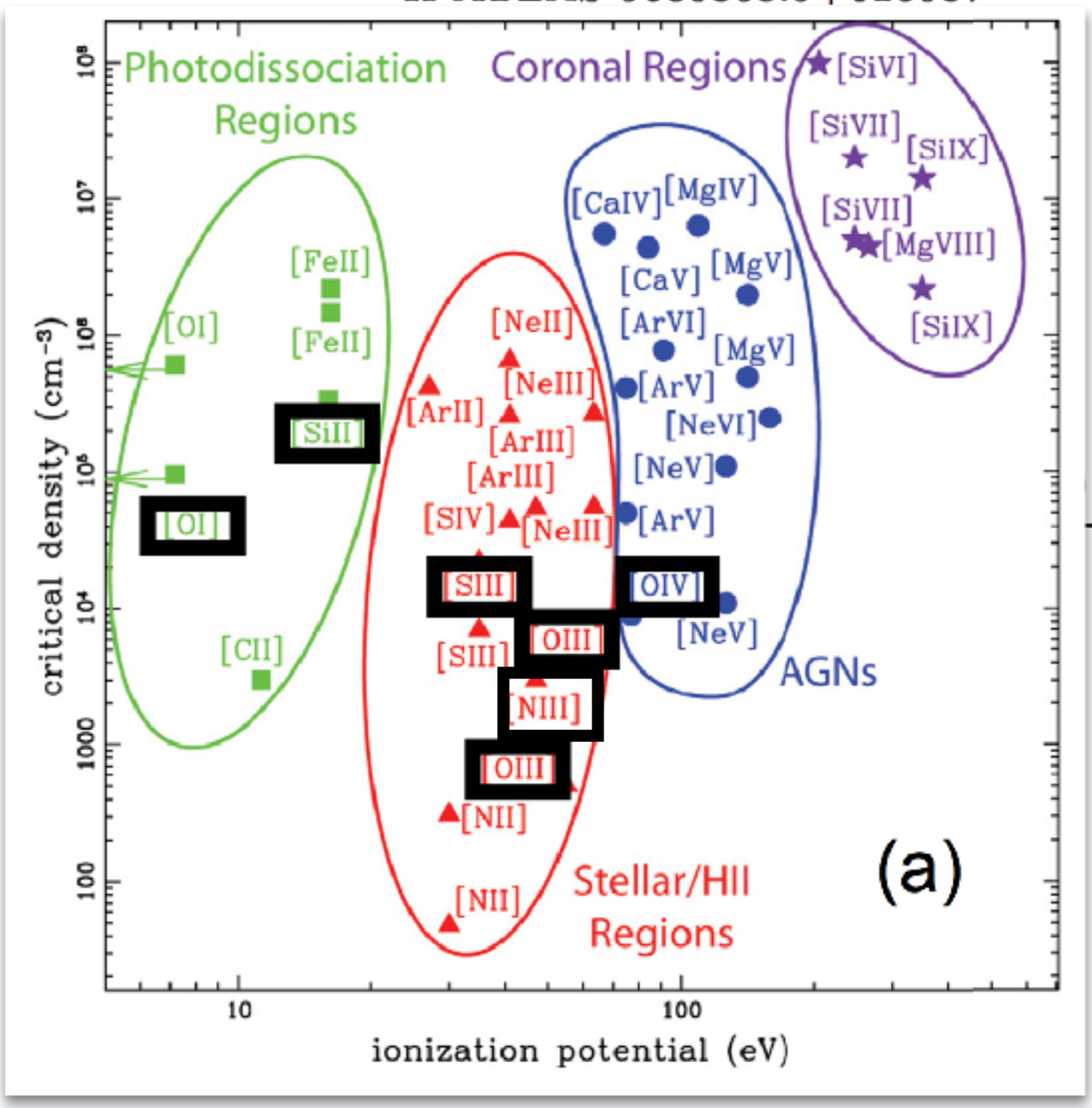
A variety of lines are accessible to SMI and SAFARI



Herschel PACS OT2 survey of 13 lenses to probe ISM conditions: targets

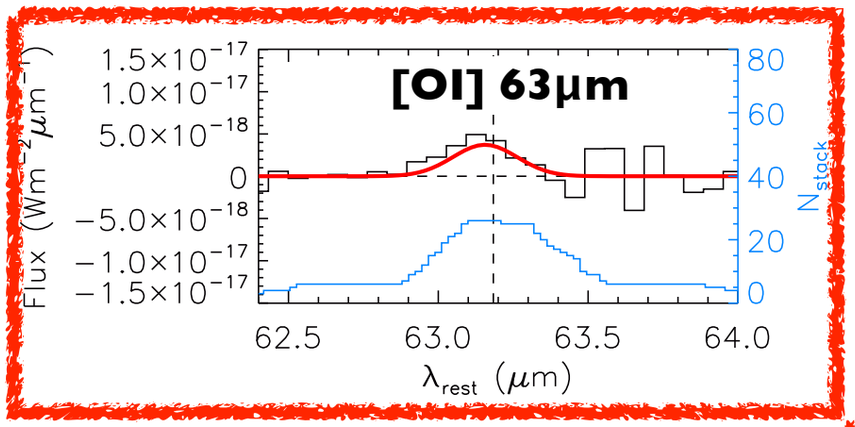
Target	Short Name	z_{source}	z_{lens}	Magnification
H-ATLAS J142935.3−002836	G15v2.19	1.027	0.218	9.7 ± 0.7^{a}
II-ATLAS J085358.9+015537	G09v1.40	2.091	...	15.3 ± 3.5
	G12v2.257	2.191	...	13.0 ± 7.0
	NGP.NA.144	2.202	...	4.4 ± 0.8
	NGP.NA.56	2.302	0.672	11.7 ± 0.9
	HXMM01	2.307	0.654	1.5 ± 0.3
	G09v1.124	2.410	0.348	2.8 ± 0.2
	G15v2.235	2.479	...	1.8 ± 0.3
	G09v1.326	2.581	...	1
	NGP.NB.78	3.111	0.428	13.0 ± 1.5
	G12v2.43	3.128	...	2.8 ± 0.4
	G12v2.30	3.259	1.225	9.5 ± 0.6
	HBootes01	3.274	0.590	4.5 ± 0.4

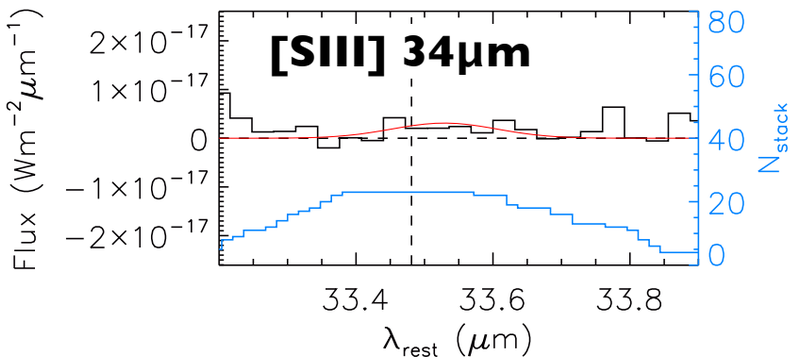
Wardlow et al. 2017

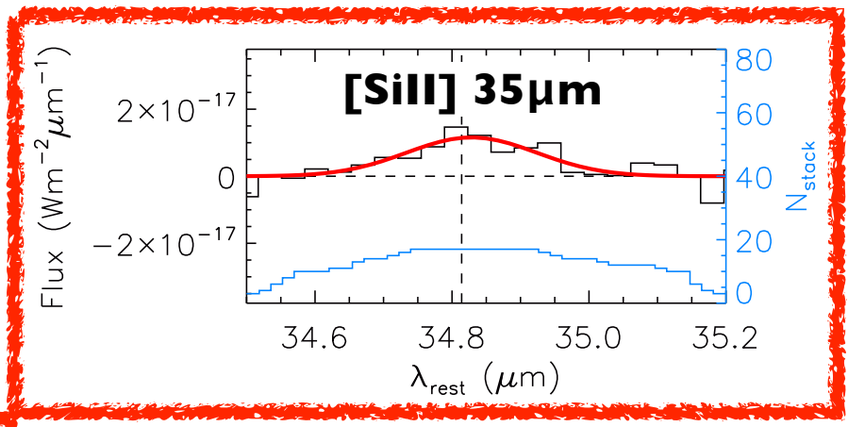


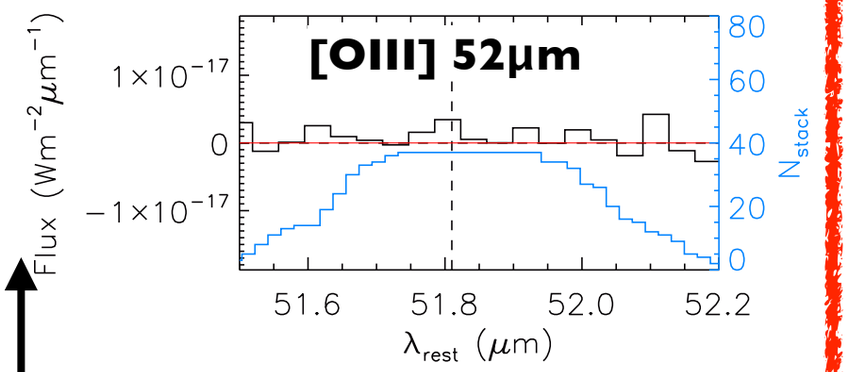
Spinoglio et al. 2009

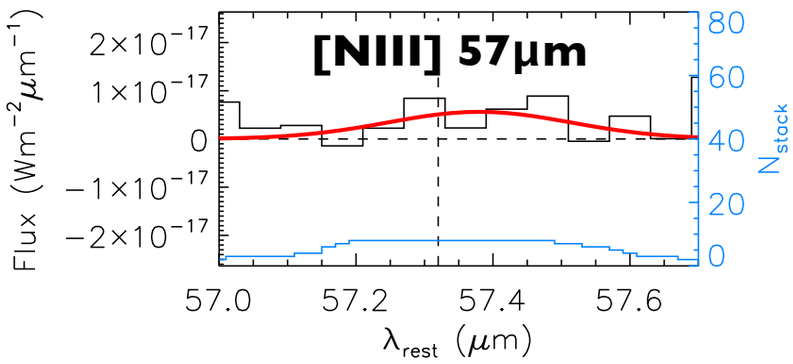
Most sources are undetected, so use stacking (45 SMGs) including 32 in the archive, to get deeper

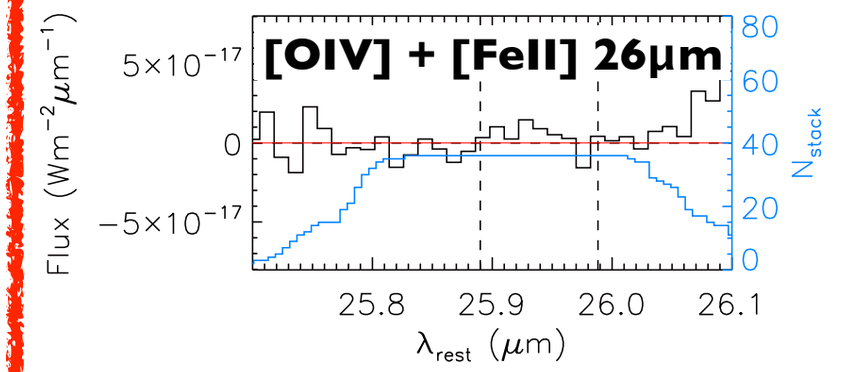


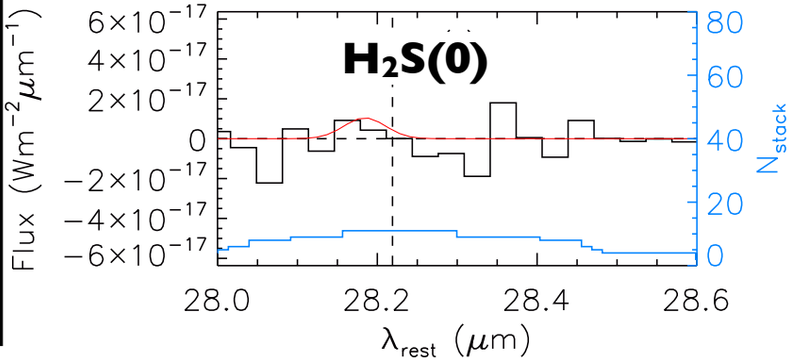


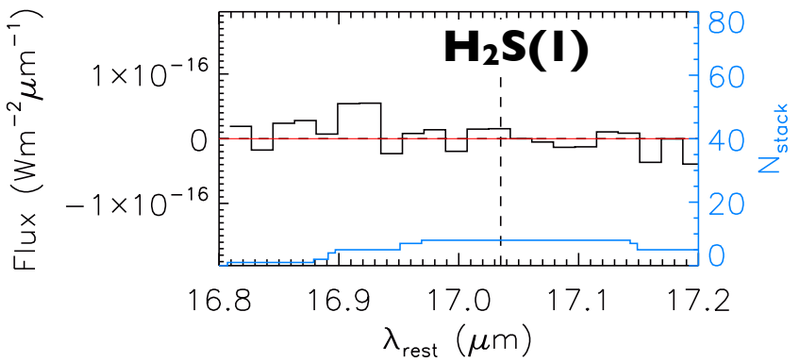












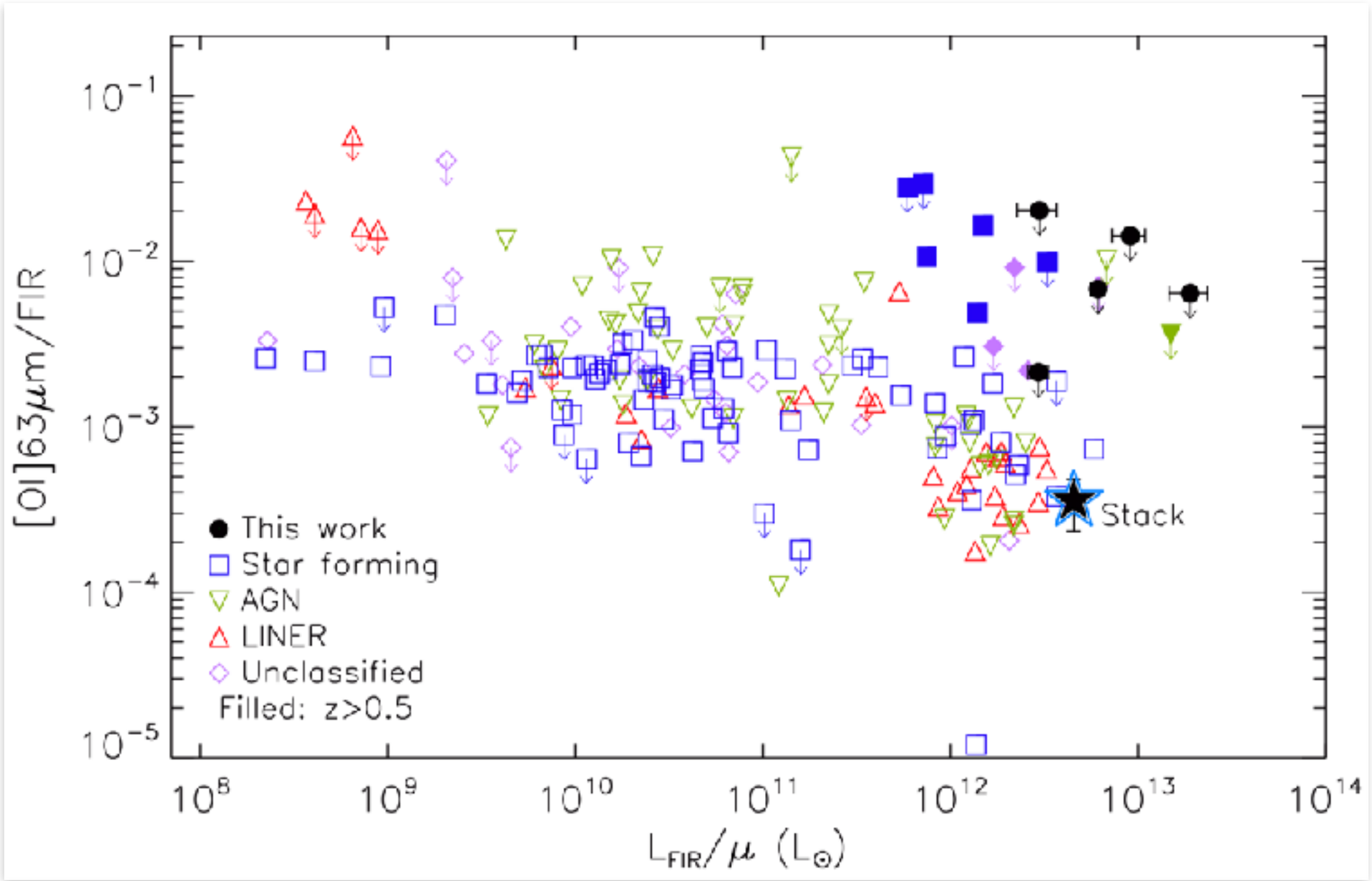
Wardlow et al. 2017

We reached typical (stack!) depths of ~few x10^{-18} W/m^2. Need to go deeper = SPICA!

Name	[O I]63 μm Line flux (10^{-18} Wm^{-2})	[O I]63 μm Line λ_{obs}[a] (μm)	[O I]63 μm Continuum[b] (mJy)	[S III]33 μm Line flux (10^{-18} Wm^{-2})	[S III]33 μm Line λ_{obs}[a] (μm)	[S III]33 μm Continuum[b] (mJy)
G15v2.19	<35.3	128.07	1044 ± 157	...	...	...
G09v1.40	<81.0	195.29	<549	...	...	...
G12v2.257	...	...	...	<10.5	106.84	<39
NGP.NA.144	<44.4	202.30	<312	<20.6	107.21	<76
NGP.NA.56	<34.0	208.62	<245	<24.5	110.55	<94
HXMM01	<12.7	208.94	<92	<13.7	110.72	<52
G09v1.124	...	...	...	<15.8	114.17	<62
G15v2.235	...	...	...	<12.8	116.48	<51
G09v1.326	...	...	...	<13.4	119.96	<55
NGP.NB.78	...	...	...	<19.1	137.64	128 ± 91
G12v2.43	...	...	...	<17.3	138.21	103 ± 82
G12v2.30	...	...	...	<32.4	142.60	<160
HBootes01	...	...	...	<11.2	143.10	<55
Mean Stack[c]	**1.0 ± 0.3**	**63.16**	...	**<0.9**	...	...

Wardlow et al. 2017

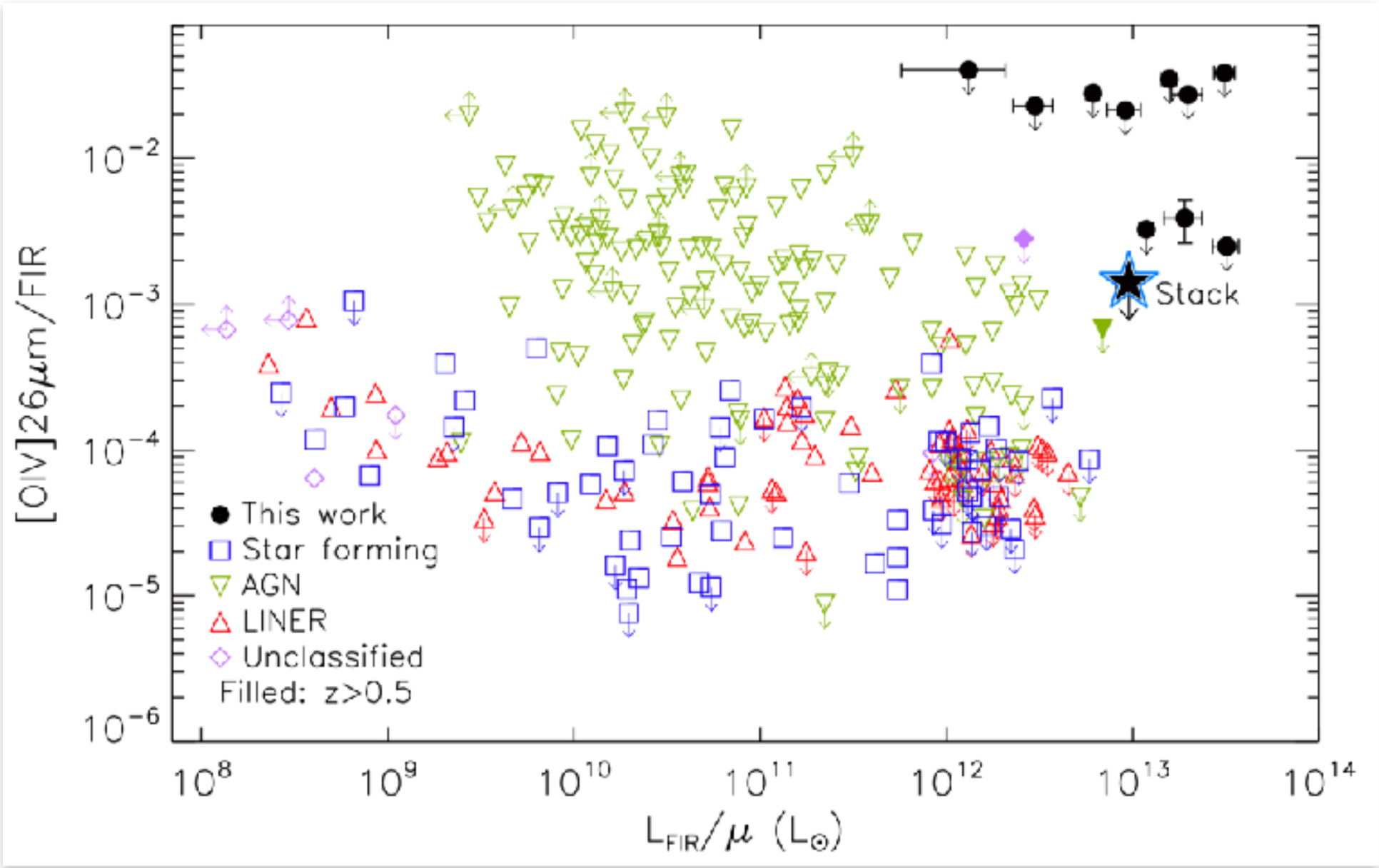
[OI]-63μm: on average suppressed similarly to low-z ULIRGs, but variety in different sources



Thanks to Javier Graciá-Carpio and SHINING for sharing their compilation of local data.

Wardlow et al. 2017

[OIV]-26μm: no evidence of AGN in the stack, but not deep enough to definitively rule out some contribution



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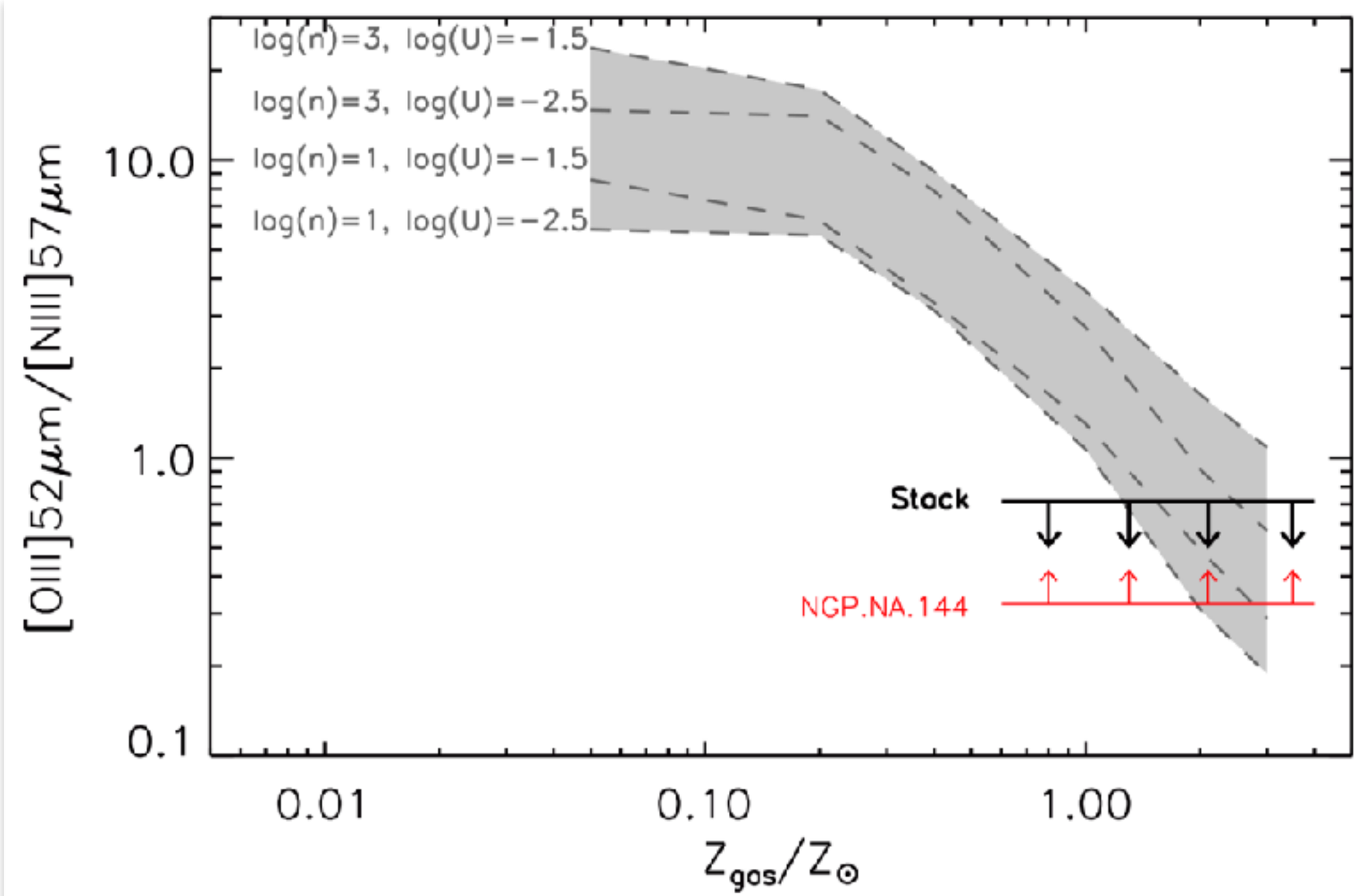
SMGs have high gas phase metallicity: $Z \gtrsim Z_\odot$

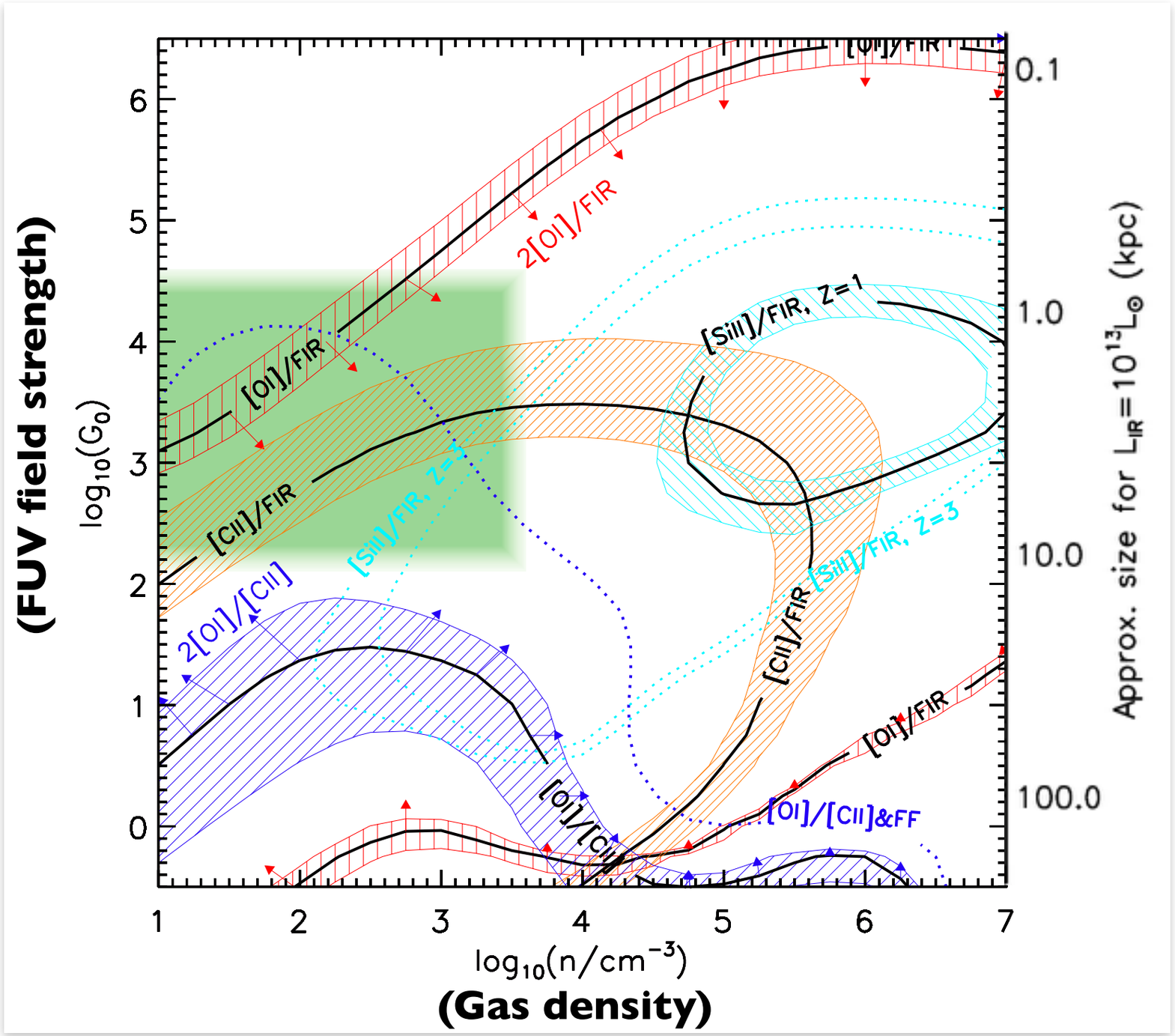


Wardlow et al. 2017
See also Pereira-Santaella et al. 2017 &
Rigopoulou et al. 2018

We use the [OI], [SiII] & (published) [CII] to constrain PDR (gas) parameters via modelling

Additional considerations

- [OI] self absorption
- Metallicity & AGN contribution
- HII region contribution
- Filling factors: M82 values from Kaufman et al. (1999) to estimate strength
- Optical thickness
- Differential lensing: use Serjeant (2012) to estimate effects.
- Source sizes



Using PDR Toolbox (Kaufman et al. 1999, 2006 models).
[CII] from Gullberg et al. 2015

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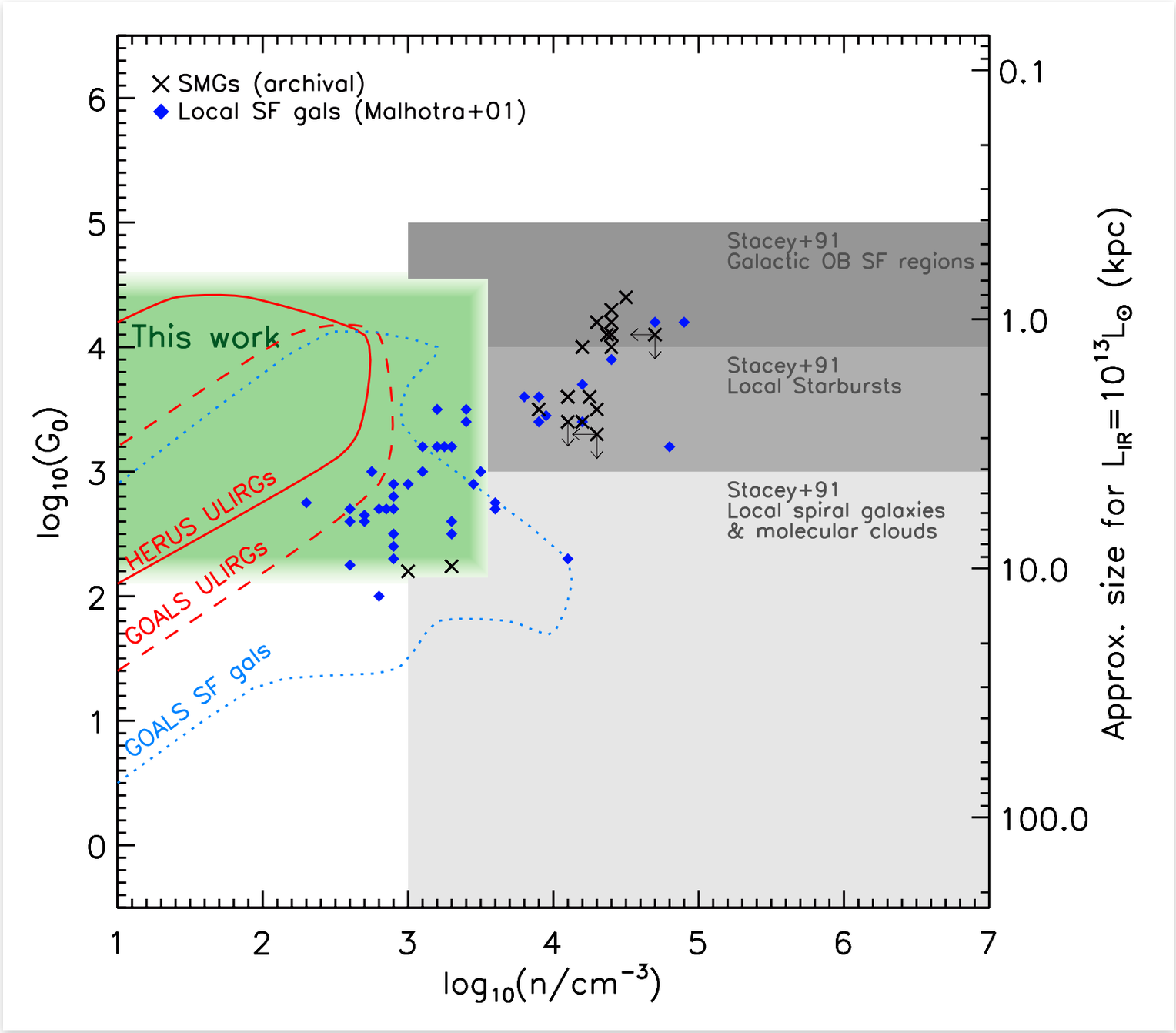
SMG PDR modelling of FS lines in tension with [CII] & CO: different regions? lensing effects? PACS misleading?



Using PDR Toolbox (Kaufman et al. 1999, 2006 models)

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Summary

- PACS observations of we fine structure & H_2 lines in some of the most apparently luminous z~2 galaxies (lensed SMGs) → **mostly non-detections, to ~10^{-17} W/m^2**.

- Stacking of up to 45 SMGs reached ≥3σ detections in [OI]63, [SiII]34 and [NIII]57μm, and non-detections in 6 other lines, down to **σ~10^{-18} W/m^2.**

- **We need to go substantially deeper than σ~10^{-18} W/m^2 to reliably detect even highly magnified SMGs → SPICA!**

- There is a tension between PDR modelling results from [CII]/CO lines and FS lines for SMGs. Only SPICA can provide the data to understand & reconcile this.