The molecular gas content in obscured AGN at z > 1

Michele Perna
INAF - OA di Arcetri

MP, Sargent + 18, arXiv:1807.03378

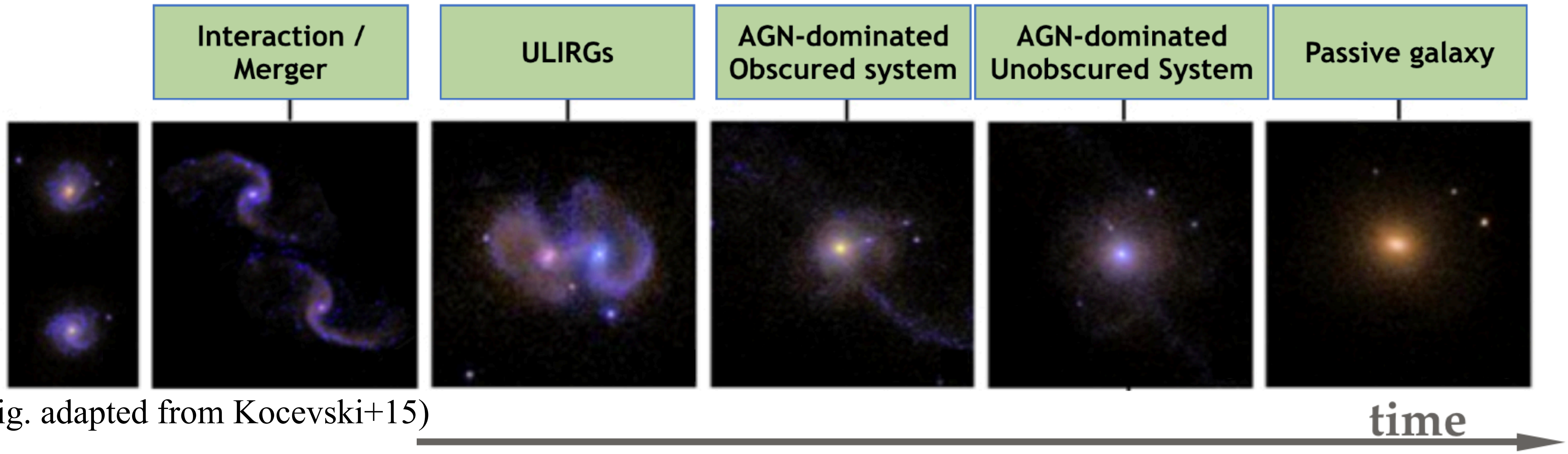
AGN13
BEAUTY
and the
BEAST

on behalf of:
M. T. Sargent, M. Brusa, G. Cresci, E. Daddi, C. Feruglio, G. Lanzuisi, E. Lusso, A. Comastri, R.T. Coogan, Q. D'Amato, R. Gilli, E. Piconcelli, C. Vignali

OSSERVATORIO ASTROFISICO DI ARCETRI
ISTITUTO NAZIONALE DI ASTROFISICA
INAF

MARIE CURIE ACTIONS
CIG grant (eEASy)

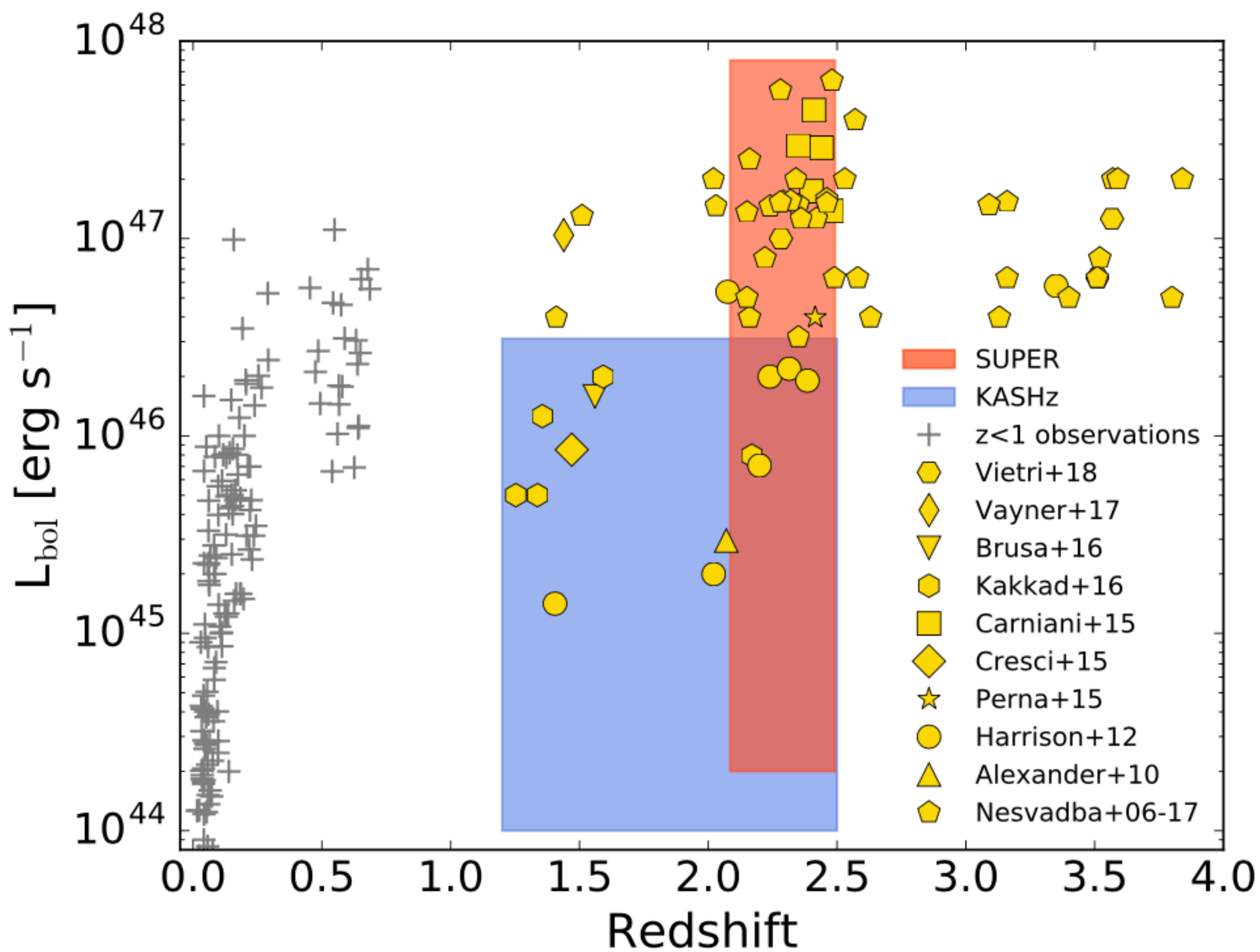
The SMBH- galaxy coevolution
The importance of outflows in galaxy evolution



(fig. adapted from Kocevski+15)

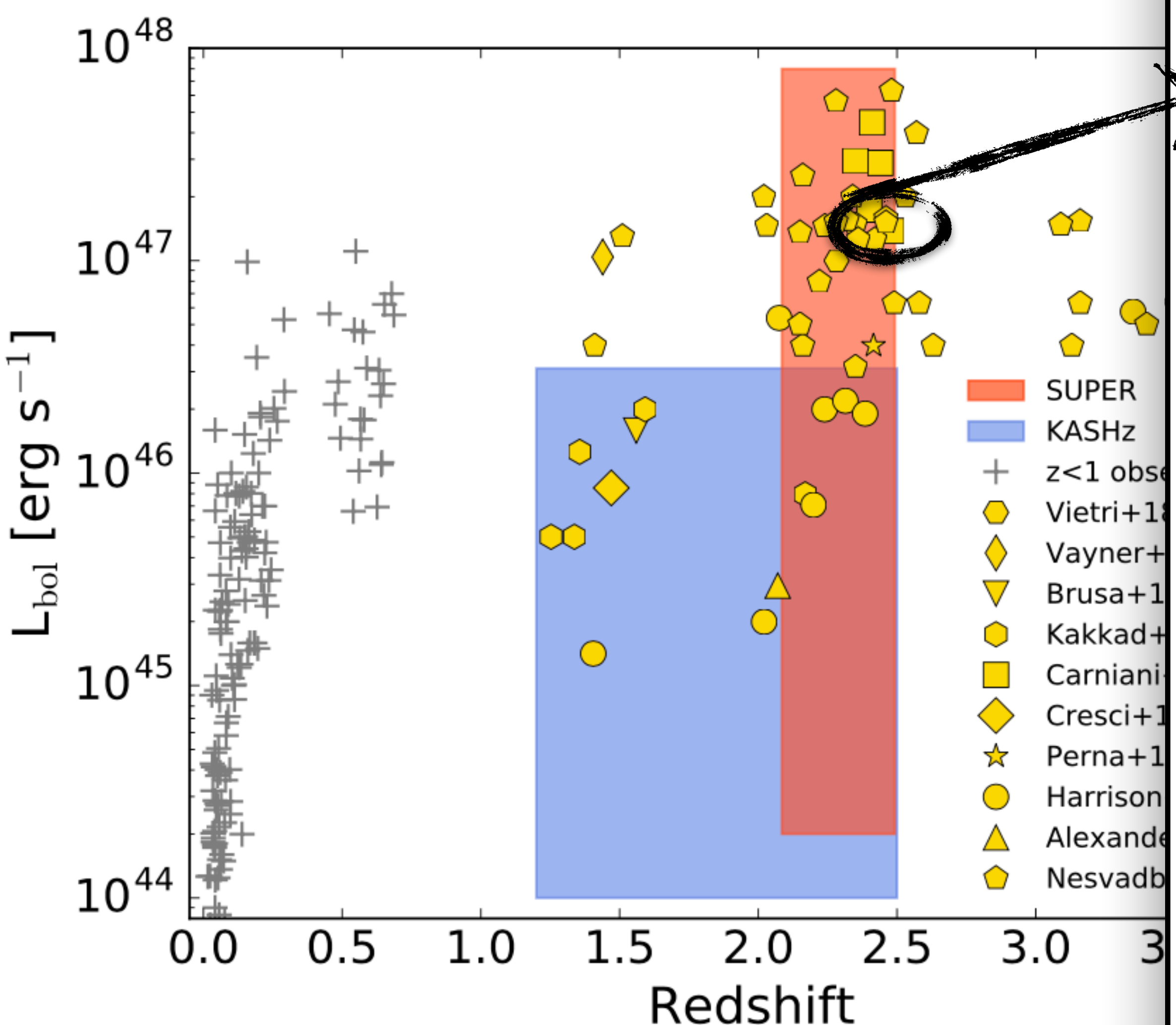
We are still far from being able to include in detail the physics of outflows to galaxy models and to understand their effects on galaxy evolution

The importance of outflows in galaxy evolution



AGN-driven outflows with optical / NIR IFS observations
(fig. from Circosta+18)

The importance of outflows in galaxy evolution



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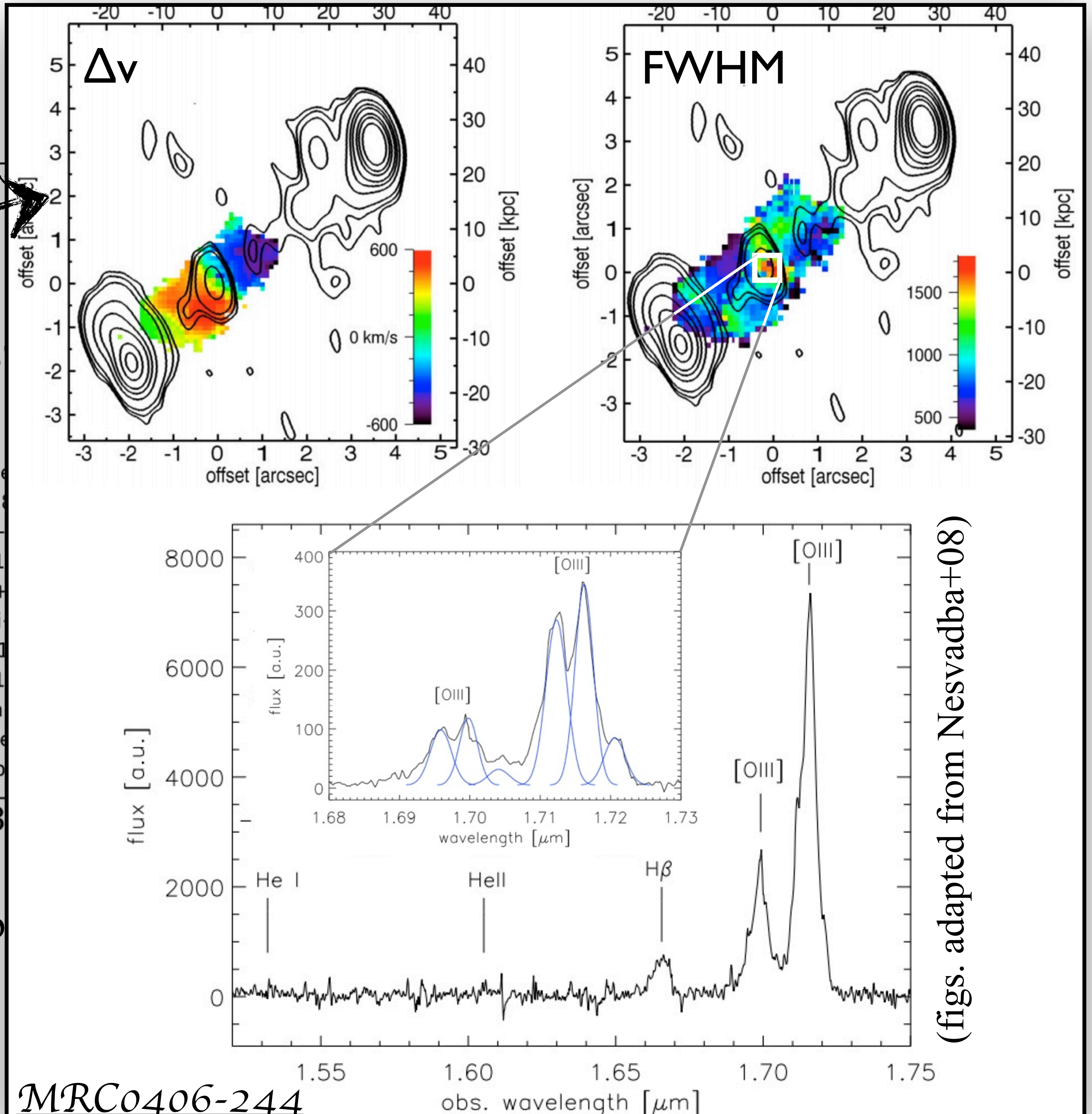
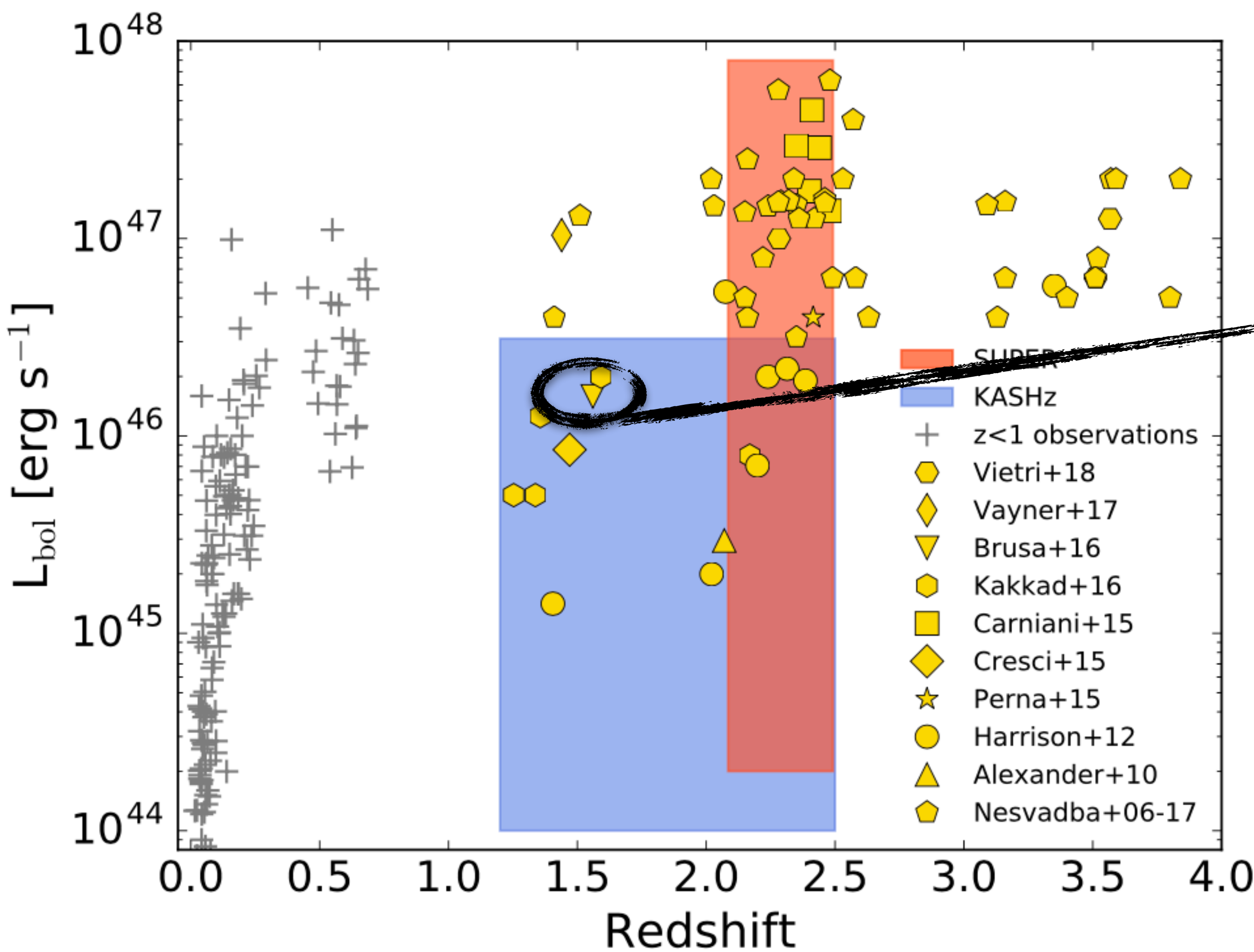


The importance of outflows in galaxy evolution



AGN-driven outflows with optical / NIR IFS observations
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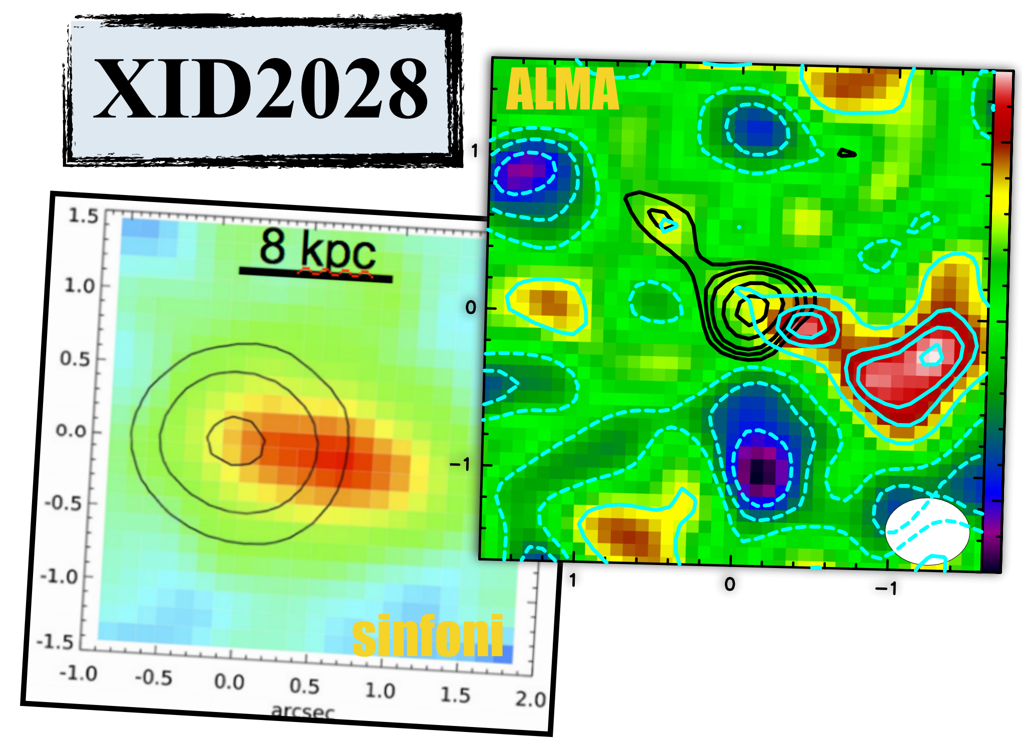
Multi-phase characterisation
for a few high-z AGN (Brusa+18, Vayner+17)



Total mass outflow rate: ~500-800 Msun/yr

$\dot{M}_{ion}$ ~300 Msun/yr (Cresci+15)
$\dot{M}_{neu}$ ~80 Msun/yr (MP+15)
$\dot{M}_{mol}$ ~50-350 Msun/yr (Brusa+18)

Methods and Definitions

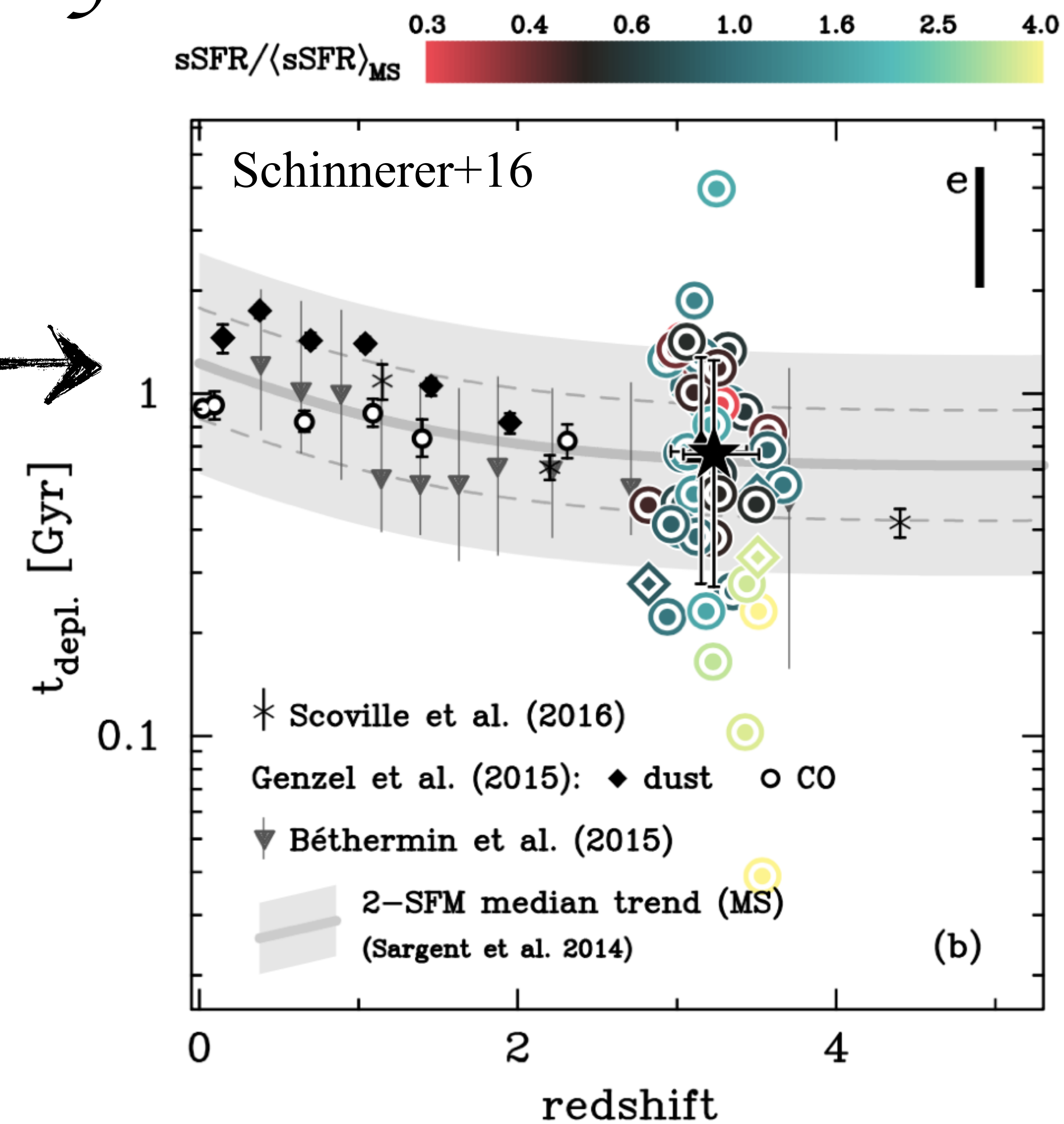
cold gas mass $M_{gas} = \alpha_{CO}\, L'_{CO}$

Depletion time $t_{depl.} = M_{gas} / SFR$

Star Formation Efficiency $SFE = SFR / M_{gas}$

$= L_{IR} / L'_{CO}$

(in $L_{\odot}/(K\ km\ s^{-1}\ pc^{2})$))



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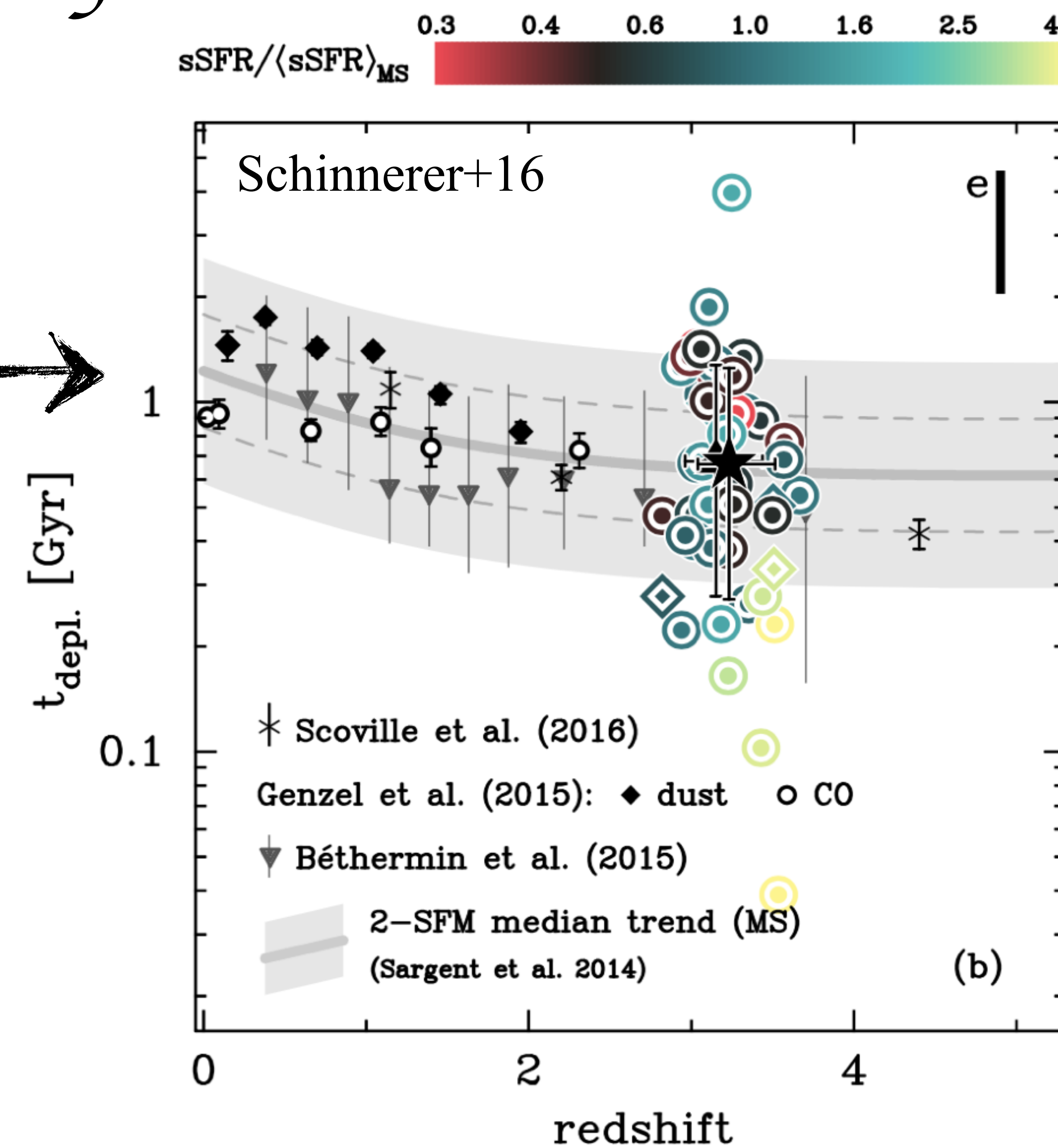

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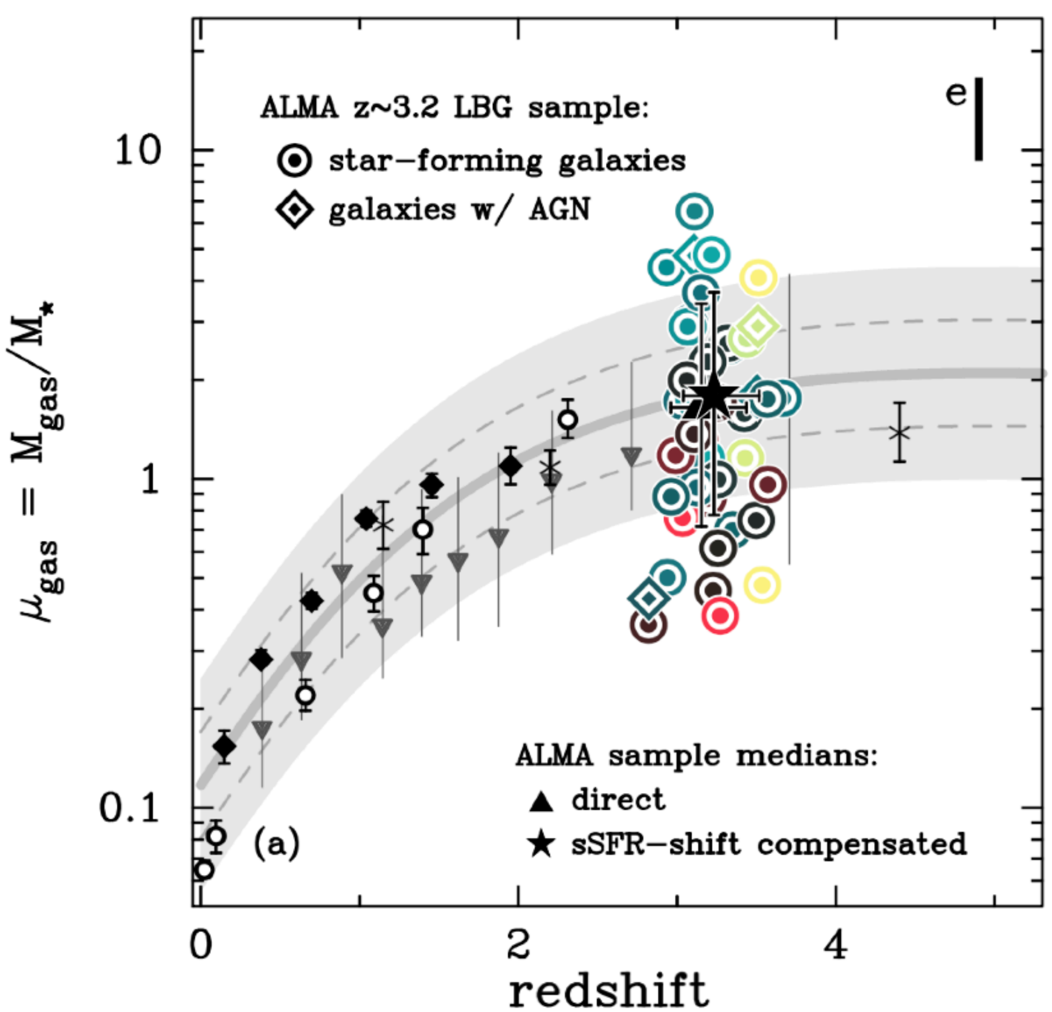
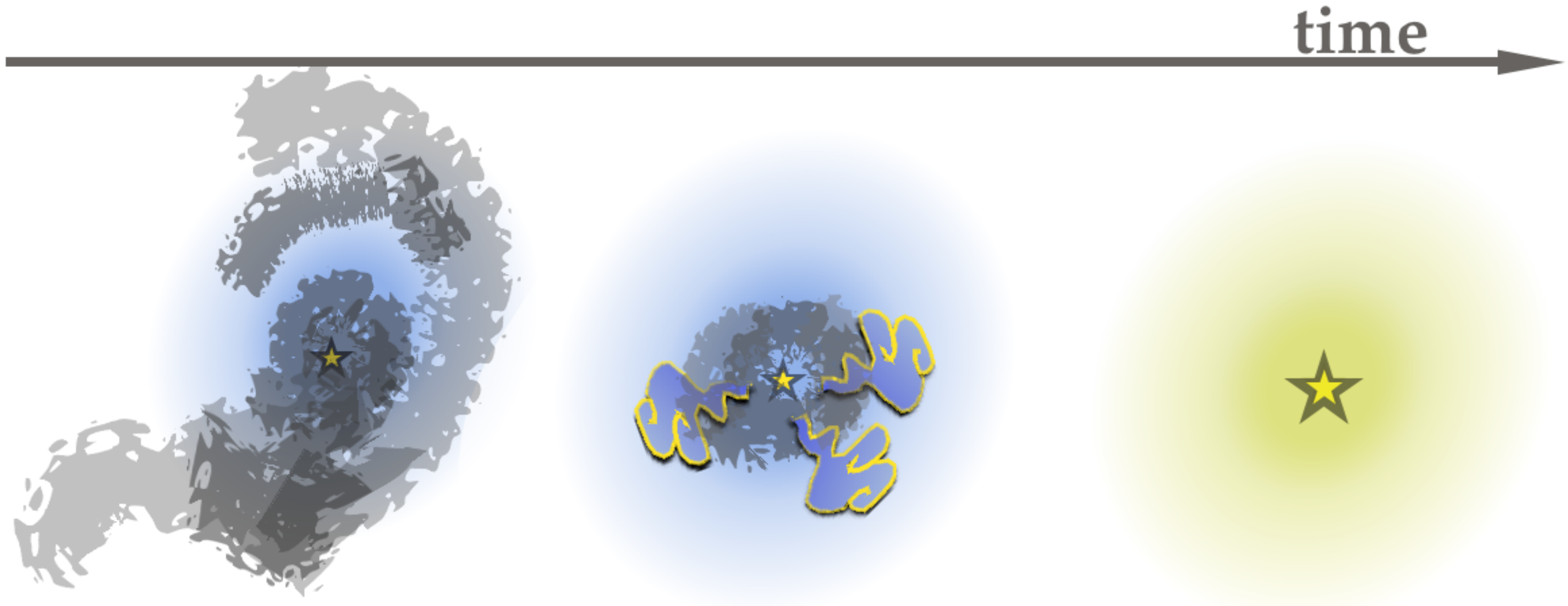


← gas fraction $f_{gas} = M_{gas} / (M_{star} + M_{gas})$

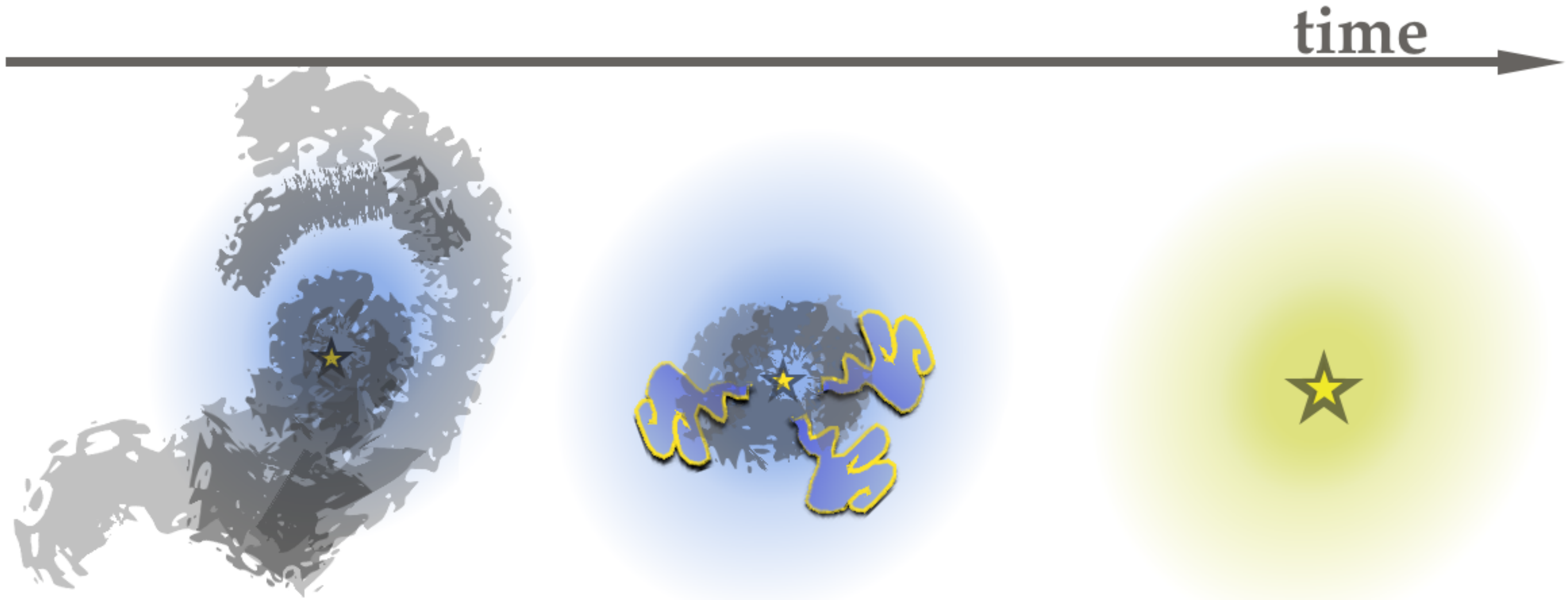
normalised gas fraction $\mu_{gas} = f_{gas} / f_{gas}|_{MS}$

A simple experiment



	SMG hosting CT/Highly Obscured QSO (?) **Massive gas reservoirs & enhanced SFR**	**Modestly-to-Mildly Obscured QSO** **Depleted gas reservoirs & ongoing stellar activity**	**Unobscured QSO** **Strongly depleted gas reservoirs & enduring stellar activity**	
SFE (L_{IR} / L'_{CO})	~ 40 - 200 / ?? **Sargent+14, Schinnerer+16, Tacconi+18**		~ 400 - 2000 **Feruglio+14, Carilli & Walter 13**	$L_\odot/(\mathrm{K\ km\ s^{-1}\ pc^2})$
μ_{gas} (f_{gas} / $f_{gas}\|_{MS}$)	~ 1 / ?? **Sargent+14, Genzel+15, Tacconi+18**		(???) **no M_{star}**	

A simple experiment



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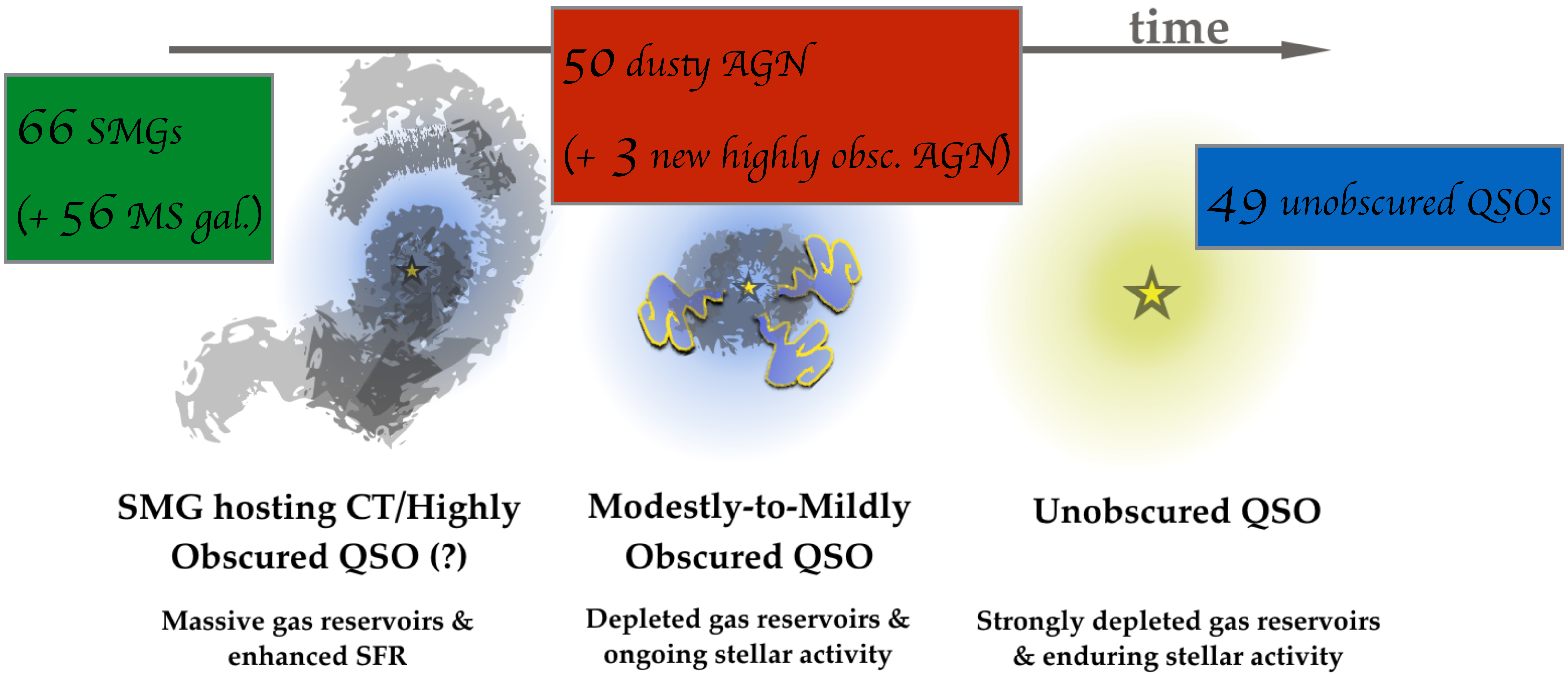
$L_\odot/(\mathrm{K\ km\ s^{-1}\ pc^2})$

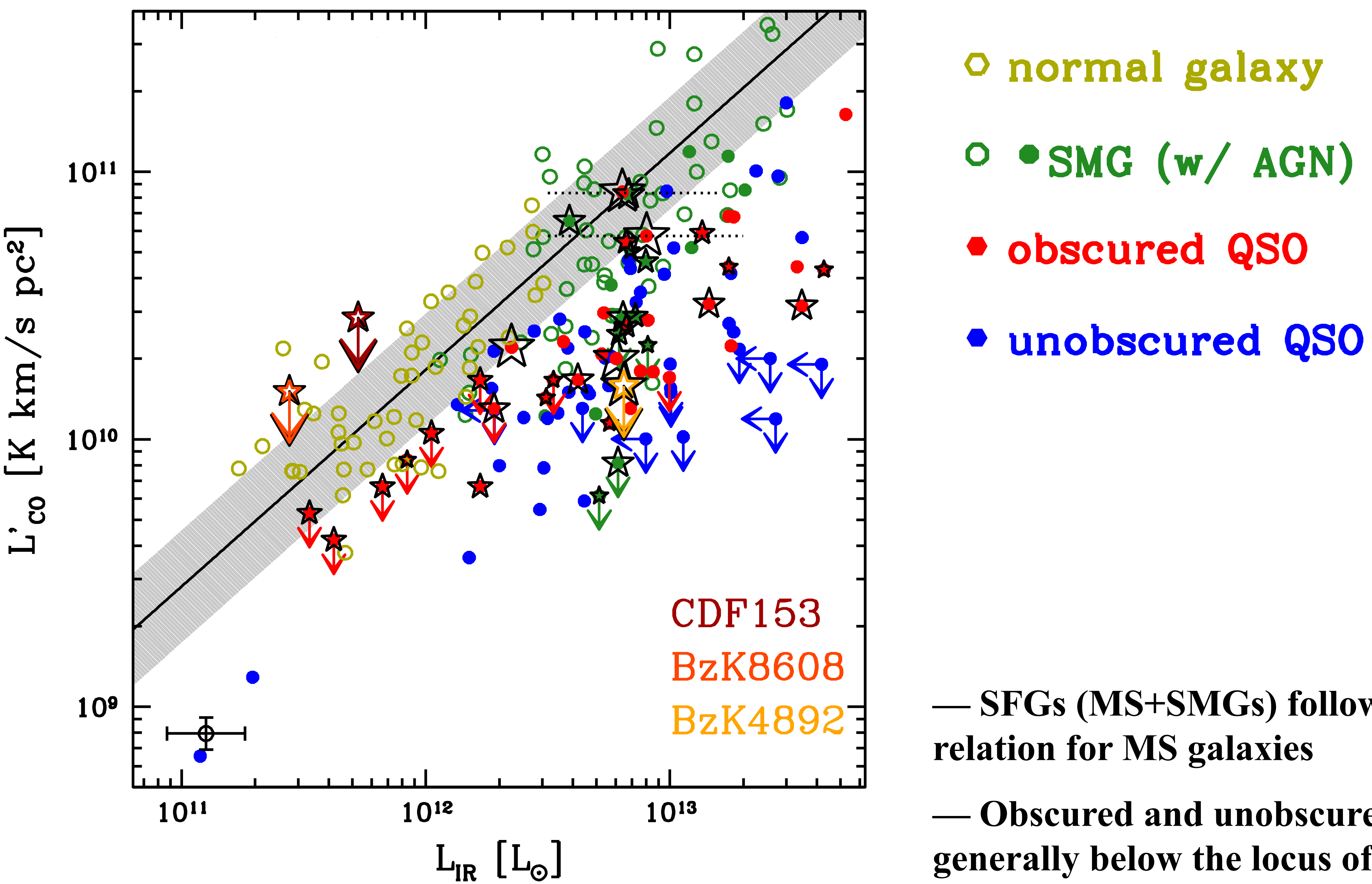
A simple experiment …

Compilation of CO observations for high-z AGN, normal MS and SMGs with L_{IR}, L'_{CO}, M_{star}, L_X, N_H (updated from Carilli & Walter 13)



<u>**Perna, Sargent, Brusa et al. 18**</u>

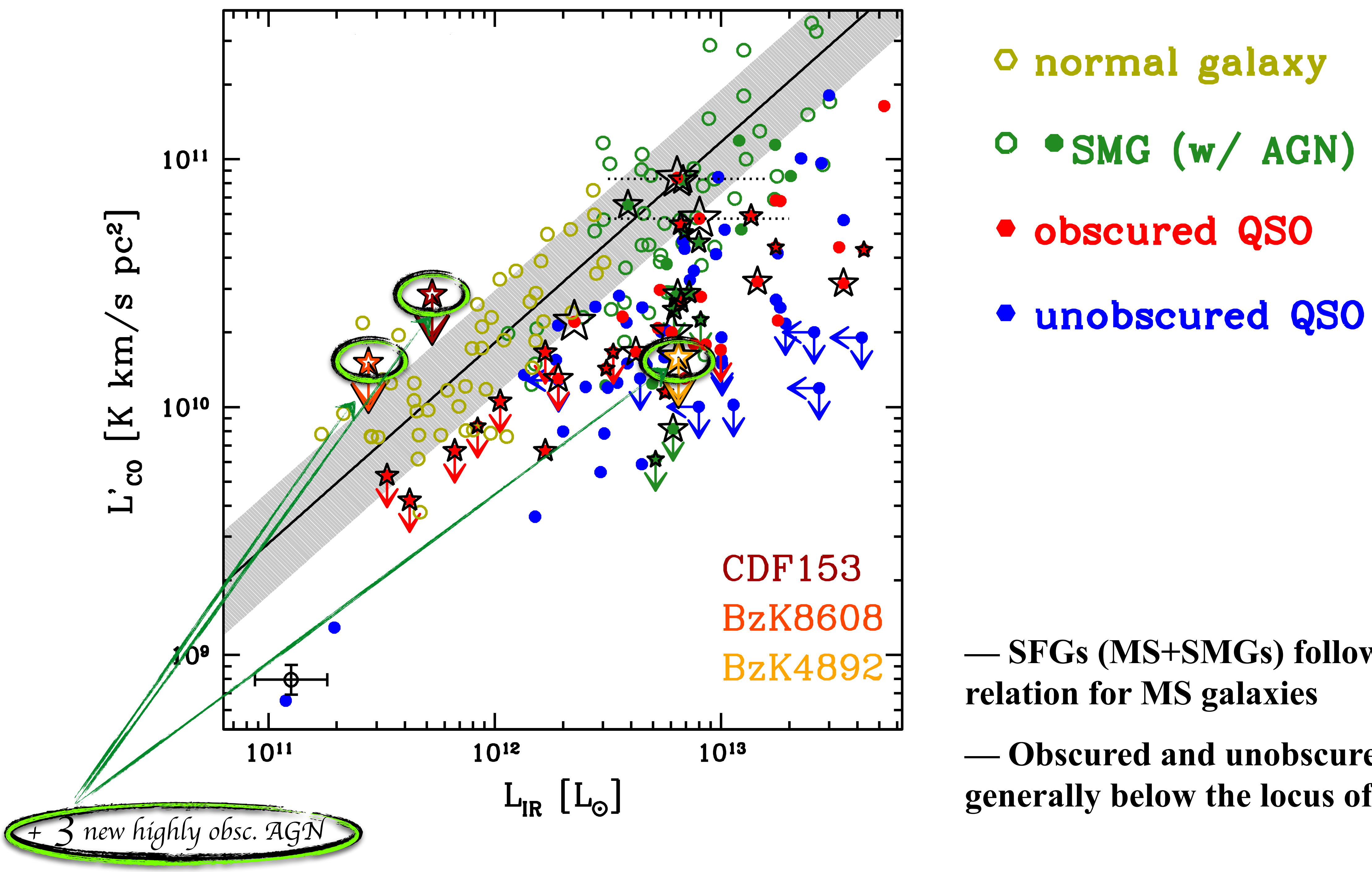
SFE and AGN obscuration



— SFGs (MS+SMGs) follow the Sargent+14 relation for MS galaxies

— Obscured and unobscured AGN are generally below the locus of MS

SFE and AGN obscuration



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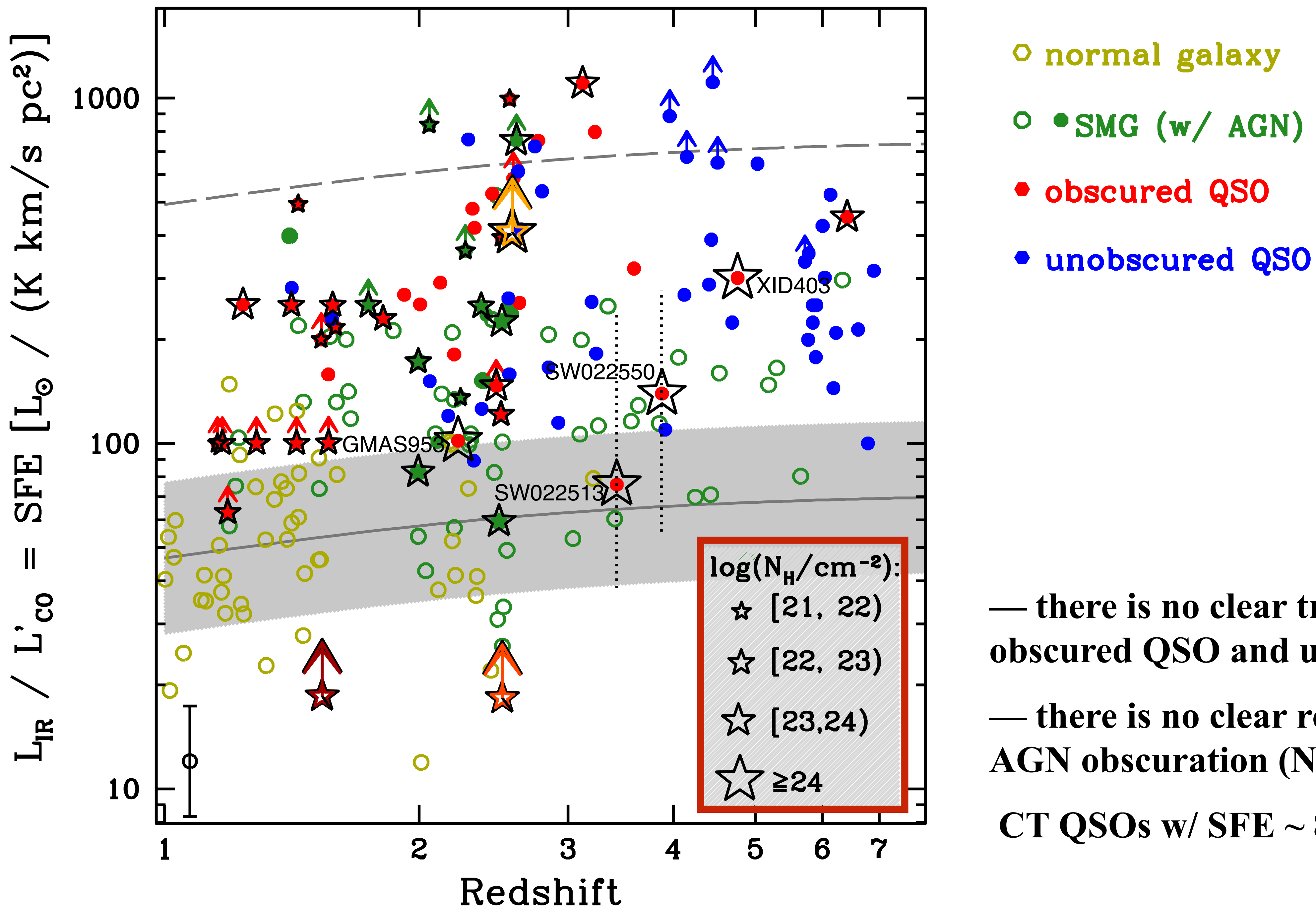


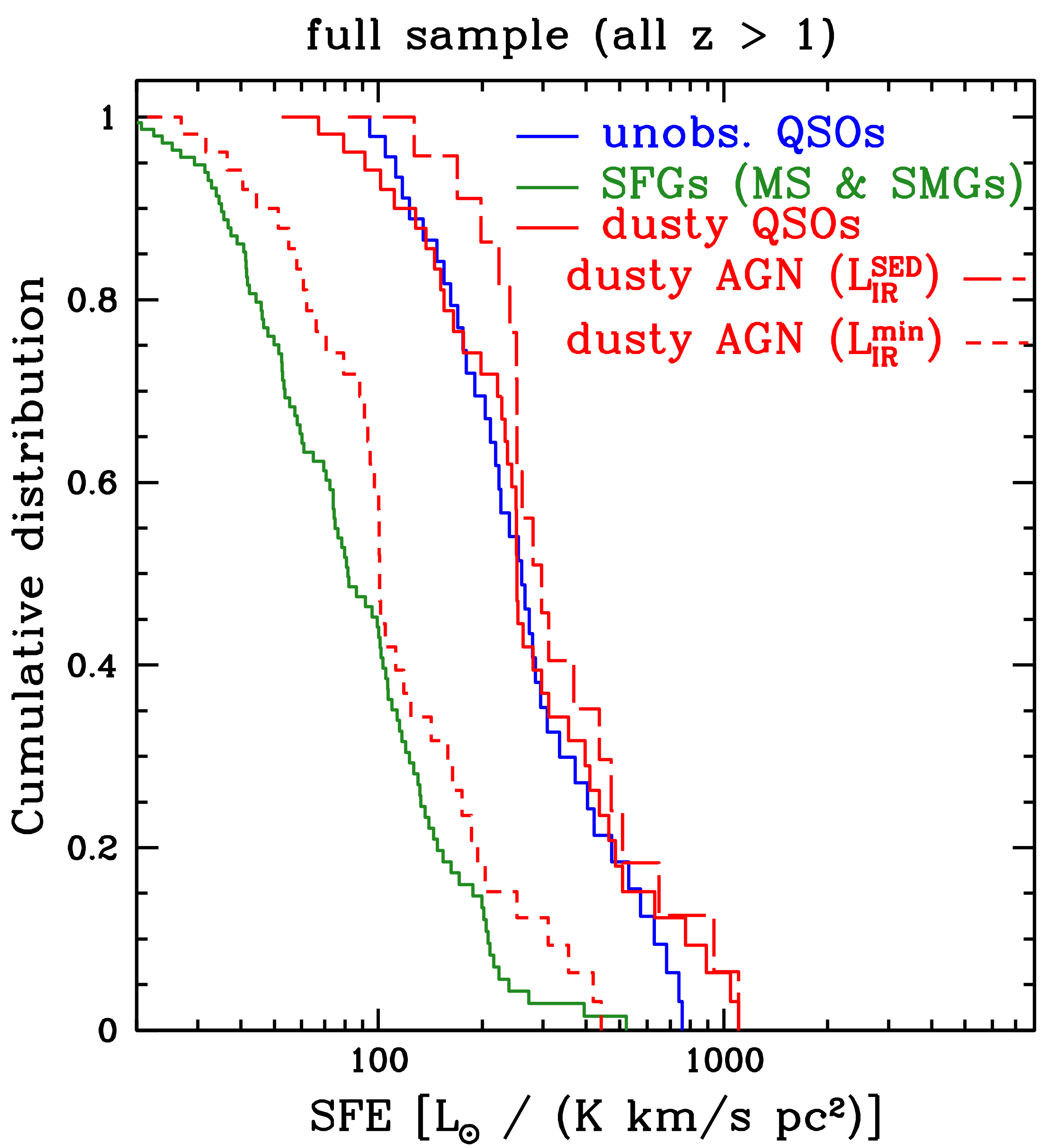
— there is no clear transition btw SMGs, obscured QSO and unobscured QSOs

— there is no clear relation between the AGN obscuration (N_H) and the SFE:

CT QSOs w/ SFE ~ 80 up to >400

<u>*5 Compton Thick (CT) AGN*</u> (1 new CO(1-0) + 4 literature)

SFE and AGN obscuration



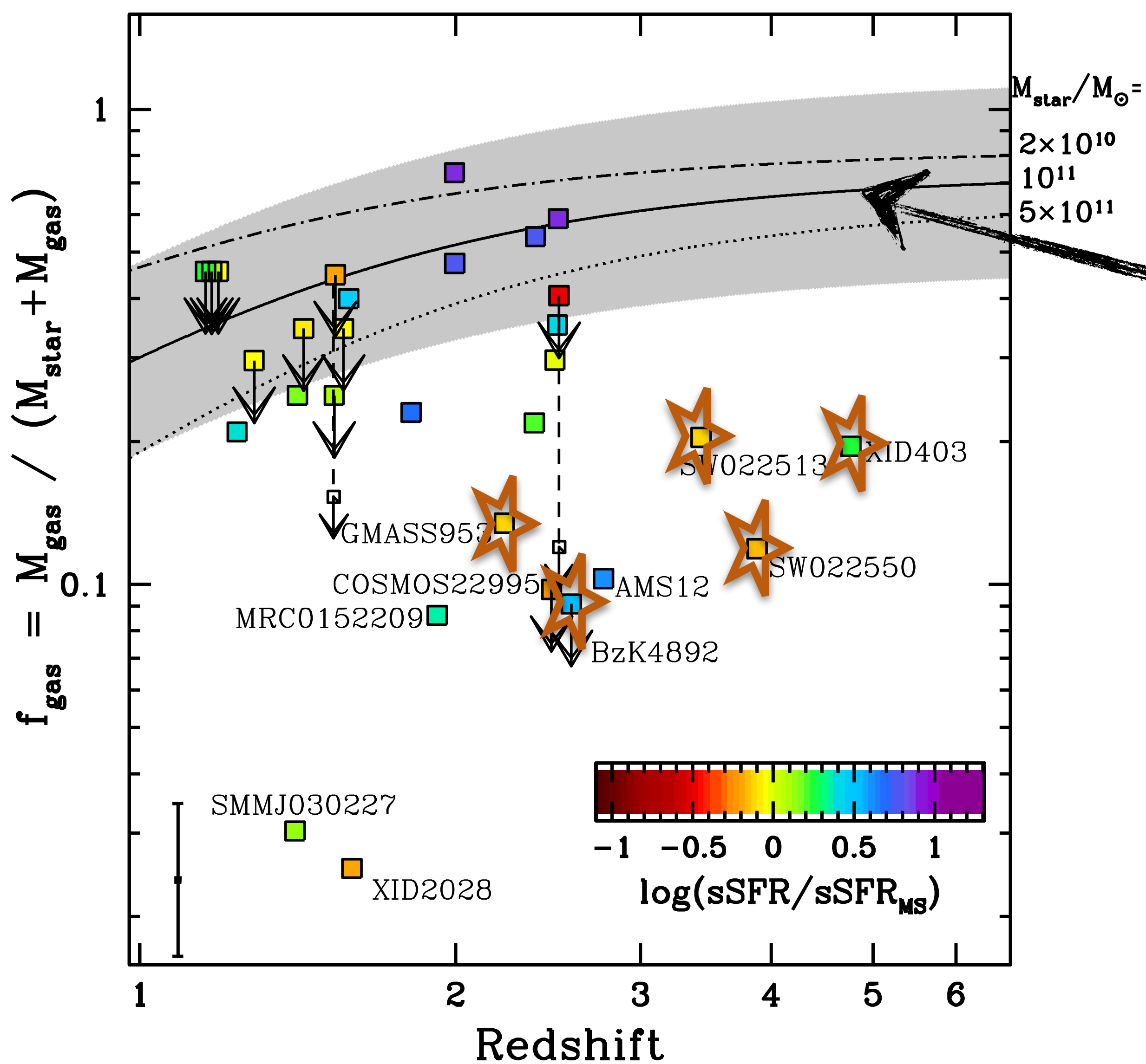
— there is a separation in SFE btw SFGs and QSOs (obscured & unobscured)

This separation cannot be explained by biases in SFE derivations and redshift distributions

— unobscured and obscured QSOs have similar high SFEs.

low gas fractions in dusty AGN

Gas fraction estimates for dusty AGN with known Mstar (mostly from SED; see Table C.2 in MP+18)



expected gas fraction for MS galaxies for given Mstar (Sargent+14; see also e.g. Dessauges-Zavadski+17,Tacconi+18)

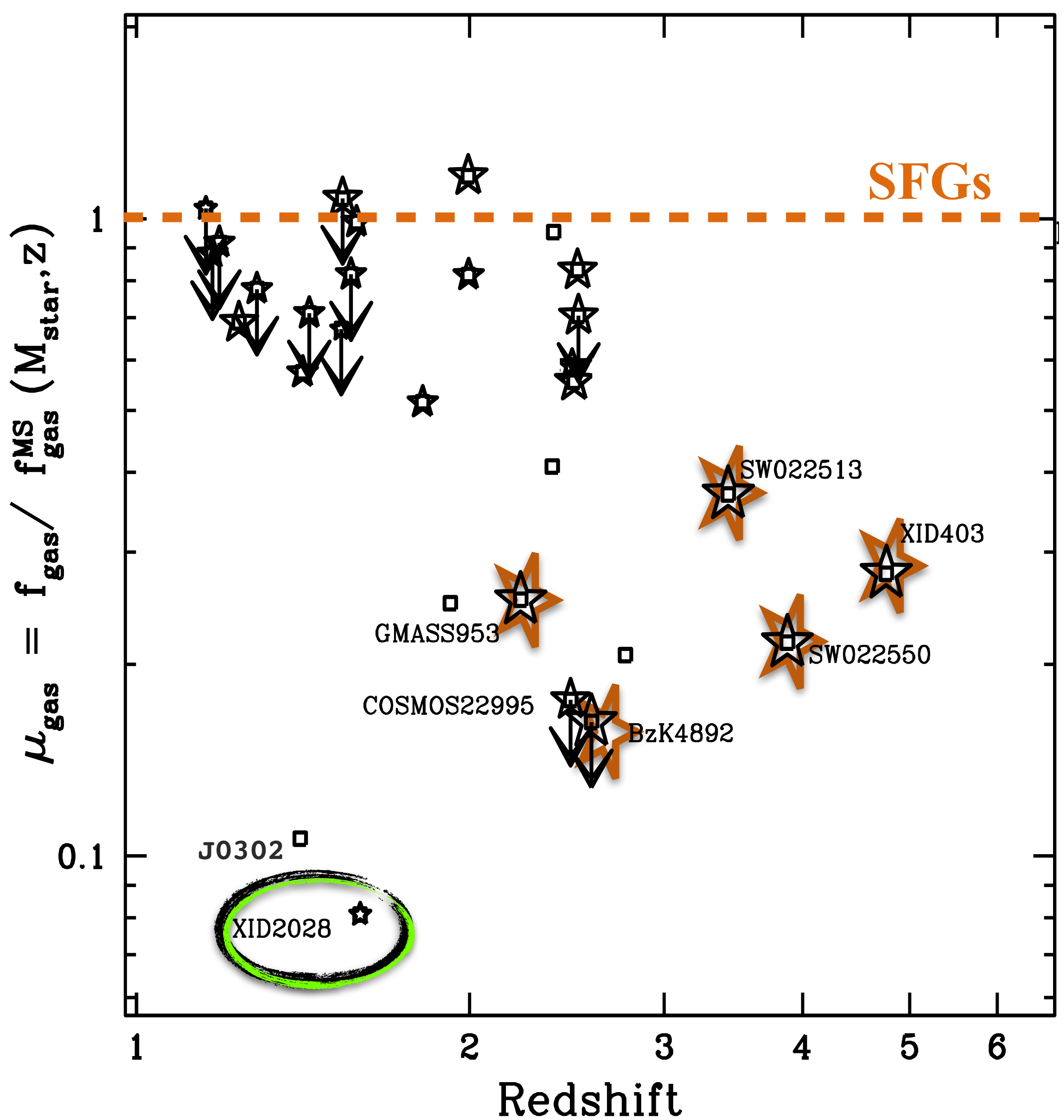
(SMGs should have similar or higher fgas; Sargent+14, Tacconi+18)

— obscured AGN are preferentially located below the relation expected for MS galaxies.

— CT AGN (star symbols) have f_{gas} < 0.2

low gas fractions in dusty AGN

Gas fraction estimates for dusty AGN with known Mstar (mostly from SED; see Table C.2 in MP+18)



— obscured AGN are preferentially located below the relation expected for MS galaxies.

— CT QSOs and merging systems are associated w/ very low μ_{gas}

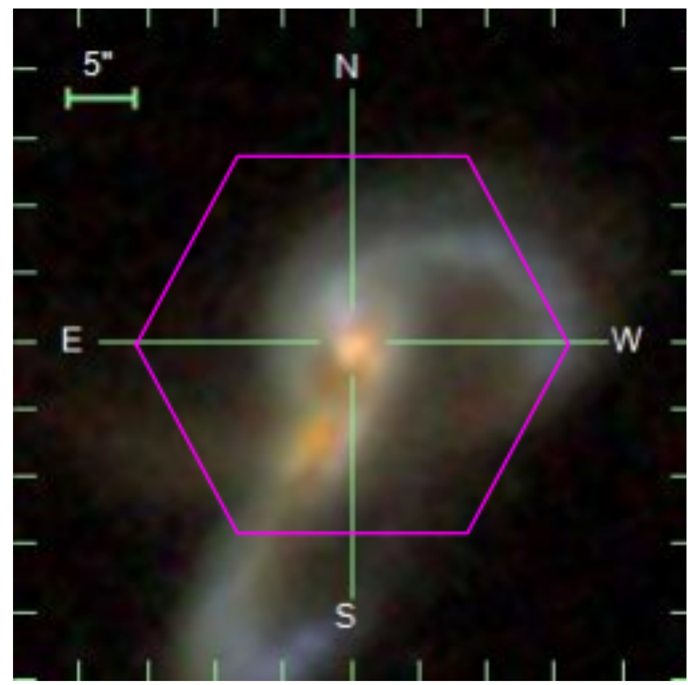
outflows?

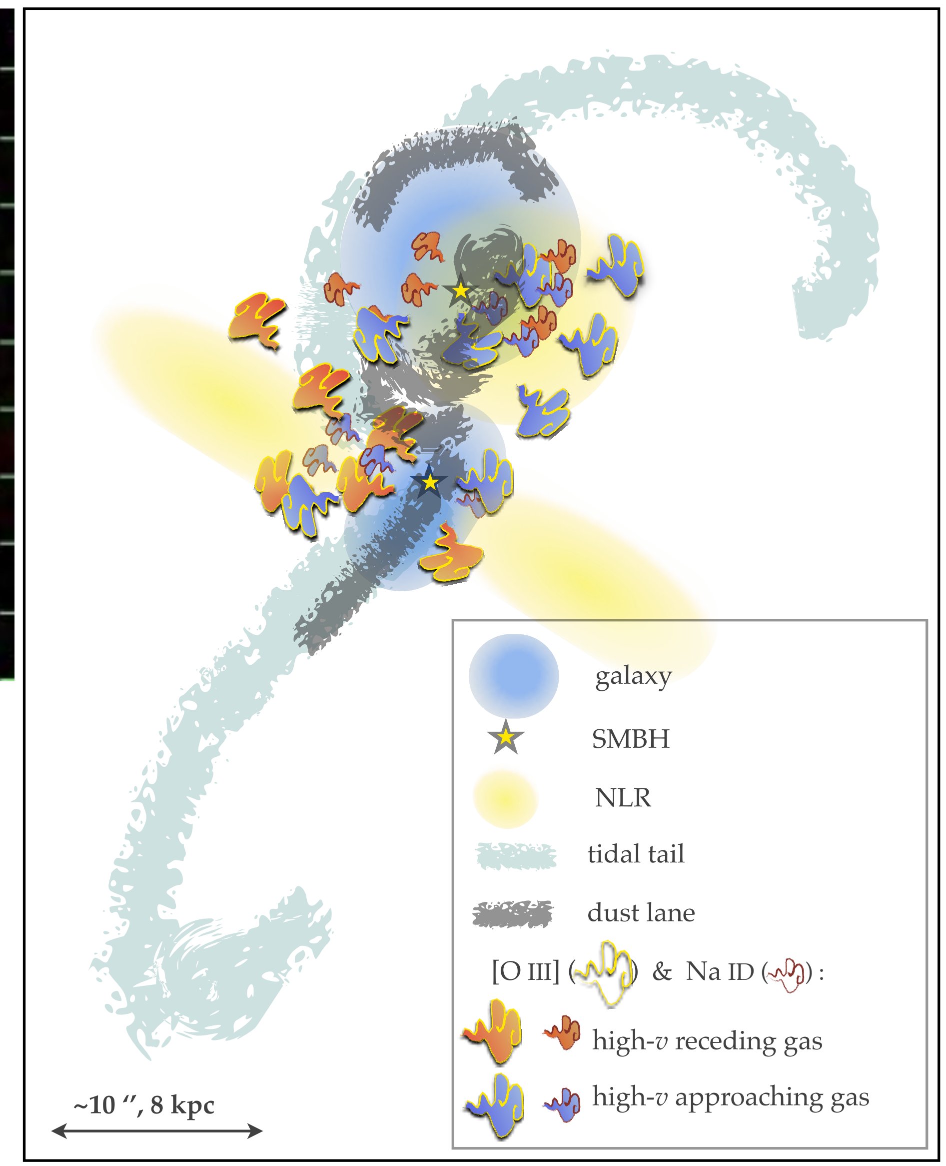
Evidence of outflow in SW targets (Polletta+08), GMASS953 (Talia+18), XID2028 (Brusa+18); J0302 is a merging system with complex kinematics (see refs. in MP+18)

Feedback effects in the early phases of the SB-QSO sequence

<u>*Mkn 848*</u>

Merging system at z ~ 0.04





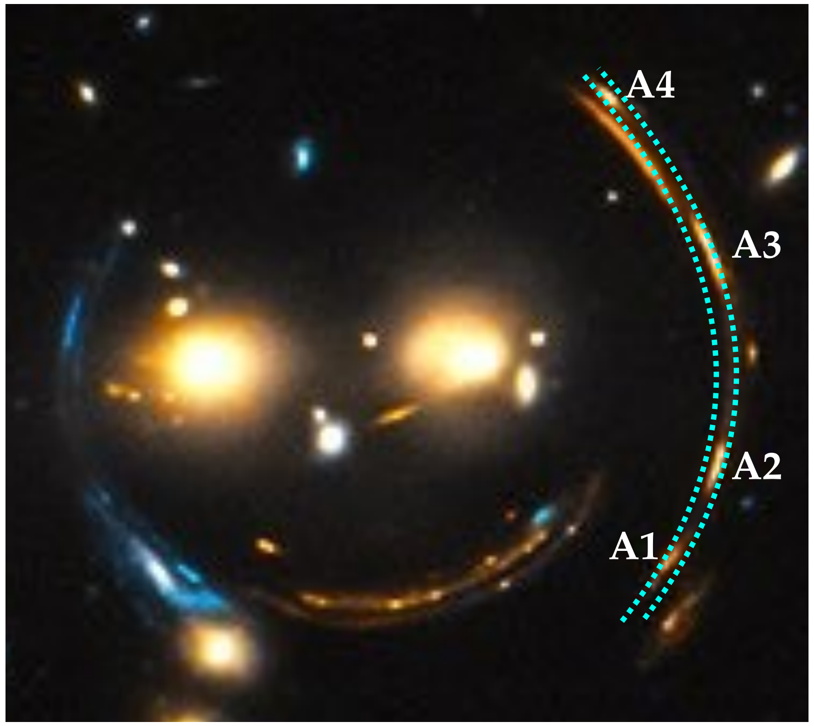
MaNGA data-cube analysis revealed multi-phase (atomic + ionised) outflows driven by AGN activity in both galaxies (MP, Cresci +18, subm. to A&A).

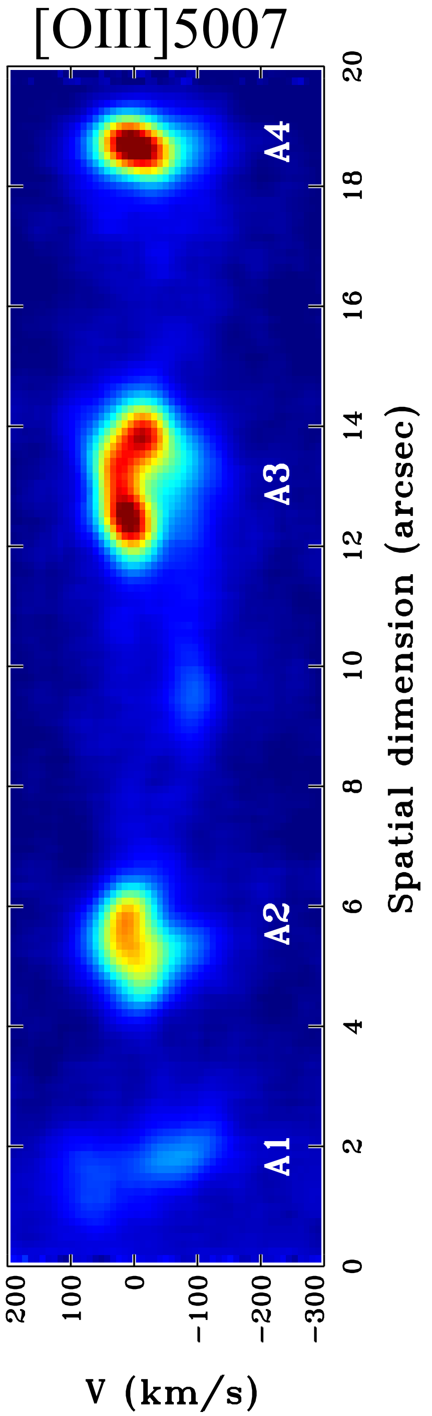
See also e.g. Feruglio+13,15, Rupke & Veilleux 13,15, Saito+17

Feedback effects in the early phases of the SB-QSO sequence

Cheshire Cat

lensed system at z ~ 2.2





LBT/ARGOS observations with *curved-slits* reveal the presence of ionised outflows in a lensed merging system at z ~ 2 (MP, Curti +18).

See also e.g. Vayner+17, Banerji+17, Harrison+12

Conclusions

— dusty AGN are associated with SFEs very similar to those of unobscured QSOs, and higher than those of SMGs

— the high SFE in dusty AGN is reasonably due to depleted cold gas reservoirs (low gas fractions) rather than significant SFR variations

Possible interpretation:

The high SFE and low gas fractions of dusty AGN could be due to multi-phase outflows.

— SFE and molecular dust reservoirs of CT AGN are significantly different from those of SFGs

— CT AGN may behave more similarly to unobscured QSOs than to SMGs.

Possible interpretations:

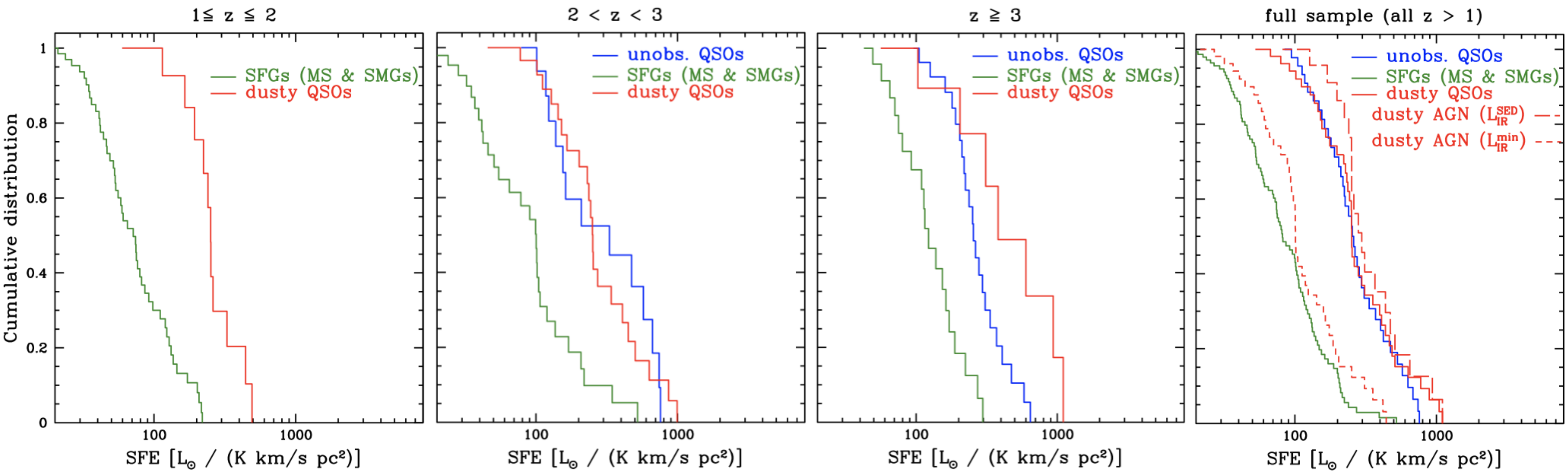
1) Powerful outflows can strongly deplete the cold gas reservoirs already from the early phases of the SB-QSO sequence.

2) Similar SFE in obscured and unobscured AGN could not imply a temporal sequence for the two samples

	SMGs	CT & dusty AGN	unobscured AGN
SFE	~ 40 - 200	~ 200 - 1000	~ 400 - 1000
μ_{gas}	~ 1	~ 0.8 - 0.08	(???)

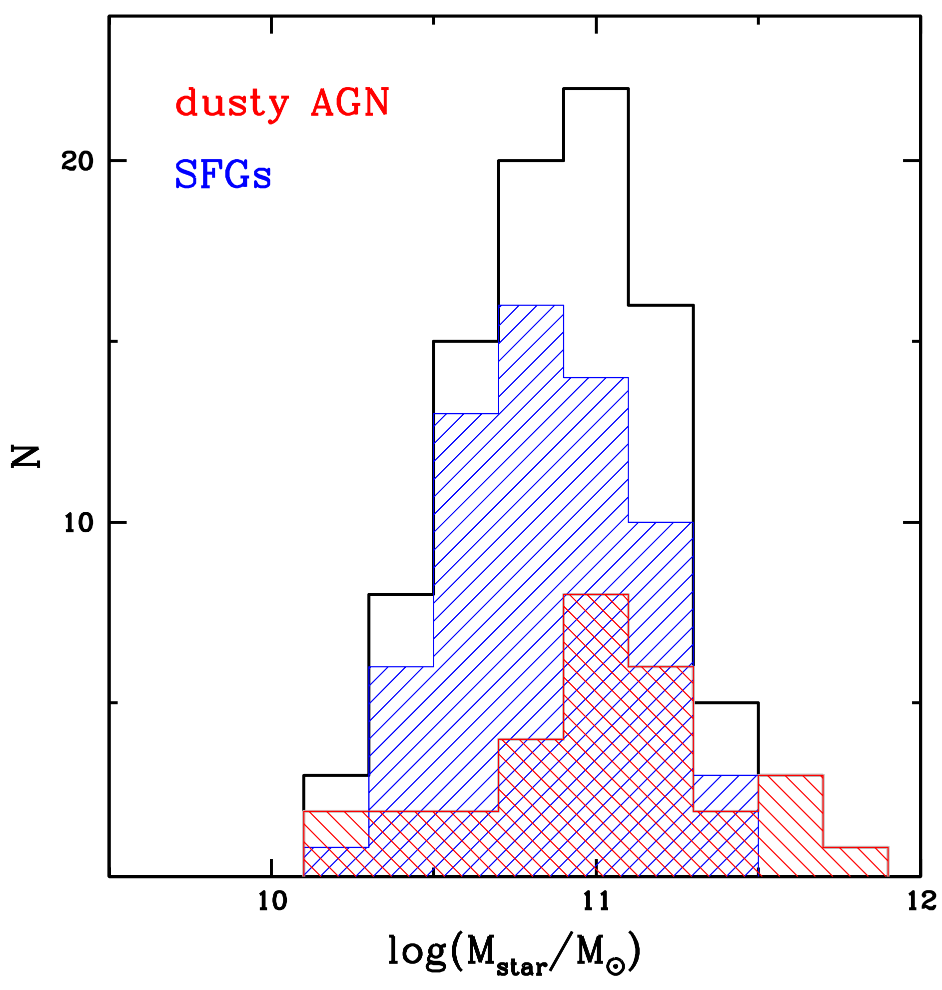
back-up slides

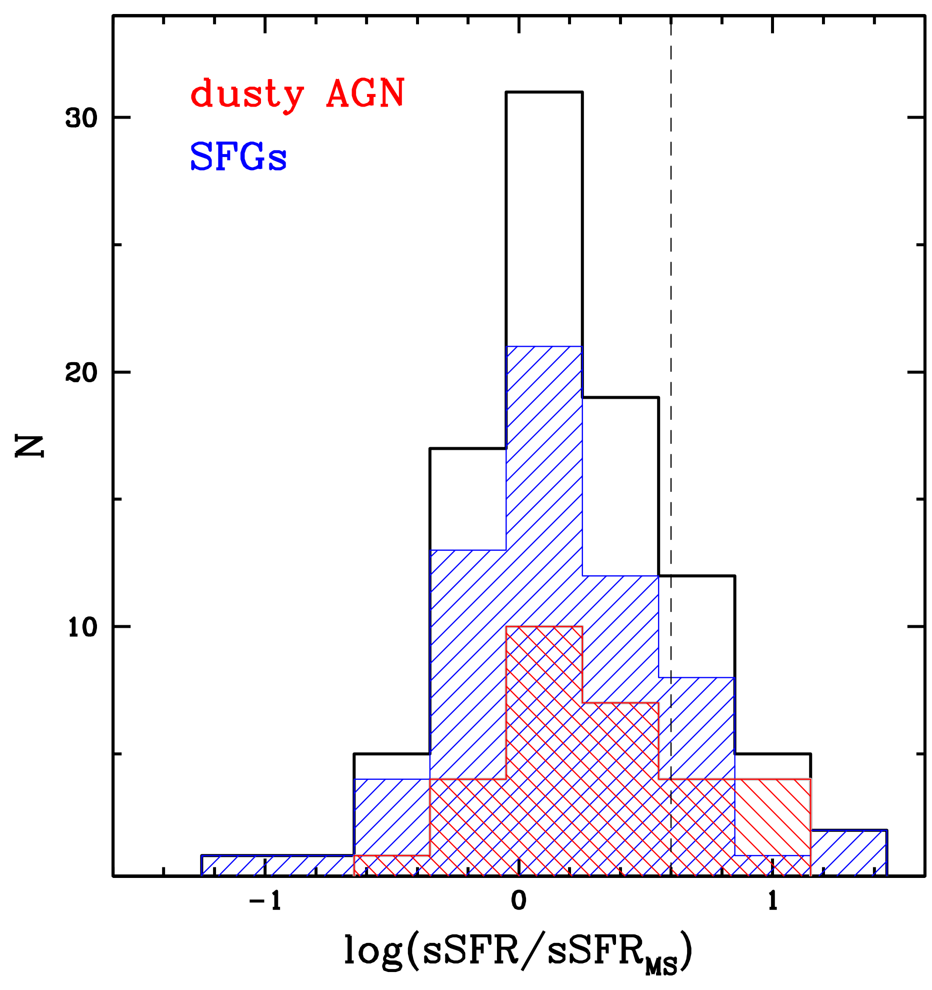
SFE cumulative distributions



back-up slides

SFGs & dusty AGN properties



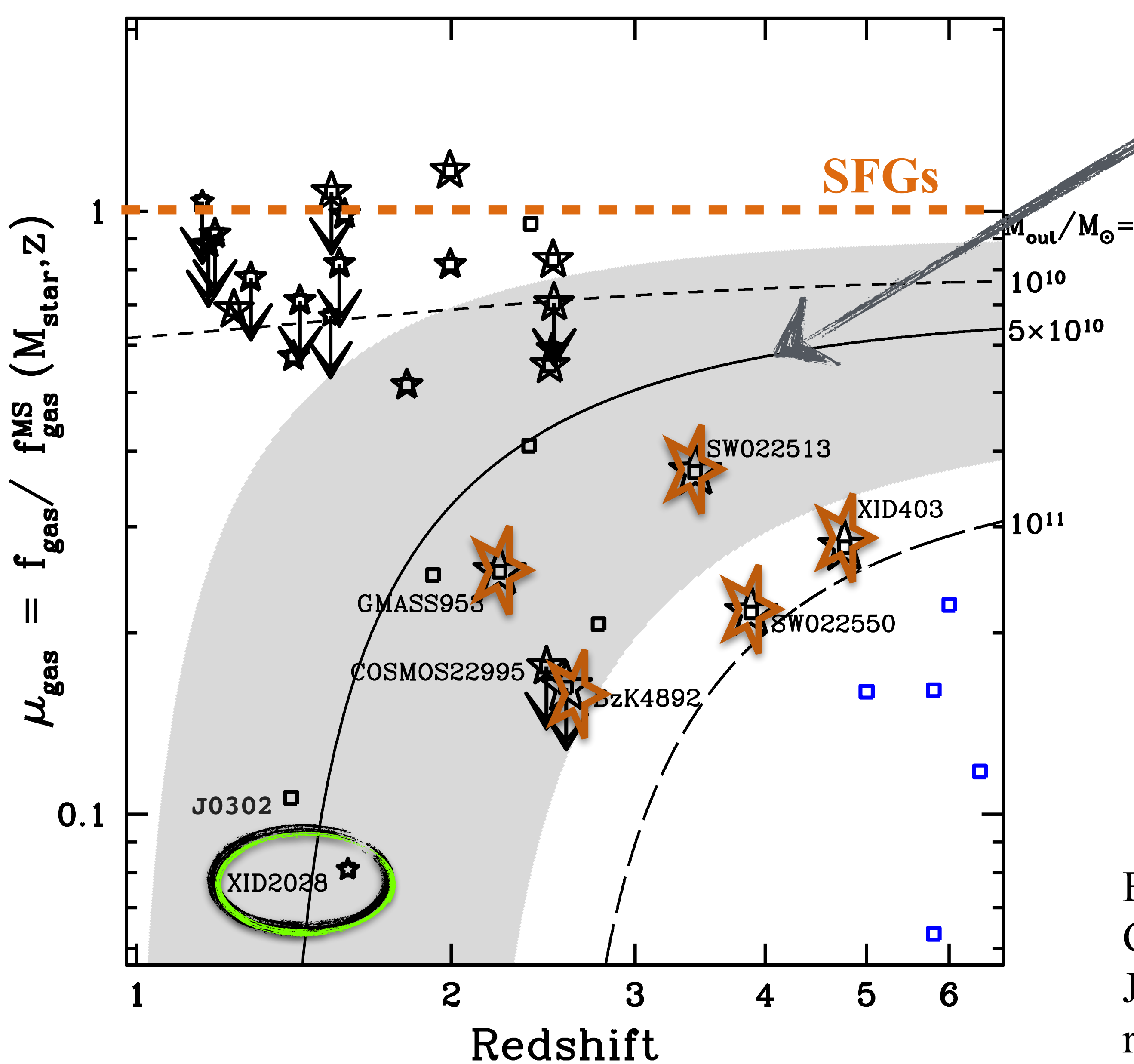


target	RA & DEC (J2000)	z	J_{up}	$r_{Jup,1}$	L'_{CO} (10^{10} K km/s pc^2)	M_{gas} (10^{10} $M_{\odot}$)	log(M_{star}) ($M_{\odot}$)	log(L_{IR}) ($L_{\odot}$)	ref	N_H (10^{22} cm^{-2})	log(L_X) erg/s	ref.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ULASJ0123	01:23:12 +15:25:22	2.629	3	0.8	6.8 ± 0.3	5.4 ± 0.2°		13.24 ± 0.07	Ba17			
W0149+2350	01:49:46 +23:50:14	3.228	4	0.87	2.24 ± 0.52	1.8 ± 0.4°		13.25 ± 0.05	F18	–	< 45.66	Vi17
MRC0152-209	01:54:55 −20:40:26	1.921	1	1.0	6.78 ± 0.82	5.44 ± 0.66°	11.76	13.26	E14			
W0220+0137	02:20:52 +01:37:11	3.122	4	0.87	3.15 ± 0.66	2.52 ± 0.53°		13.54 ± 0.07	F18	28.2 ± 0.9	44.49 ± 0.28	Vi17

back-up slides

low gas fractions in dusty AGN

Gas fraction estimates for dusty AGN w/ known Mstar (mostly from SED; see Table C.2 in MP+18)



expected μ_{gas} for a dusty AGN in the blow-out phase with

$\dot{M}_{out} = 5\times10^{10}$ M_{sun}/yr and

Δt_{out} = 10 Myr

(see e.g. Costa+18, Barai+18, Perna+15a, Fiore+17)

— obscured AGN are preferentially located below the relation expected for MS galaxies.

— CT QSOs and merging systems are associated w/ very low μ_{gas}

Evidence of outflow in SW targets (Polletta+08), GMASS953 (Talia+18), XID2028 (Brusa+18); J0302 is a merging system with complex kinematics (see refs. in MP+18)