AGN & host galaxy scaling relations

Chiara Feruglio - OATs

AGN13
BEAUTY
and the
BEAST

Work done in collaboration with:
D'Odorico, Fiore, Cristiani @OATs
Pallottini, Gallerani, Ferrara, Carniani @SNS
Piconcelli, Bischetti @OAR
Malizia, Molina @ OAA
Marconi, Maiolino et al.

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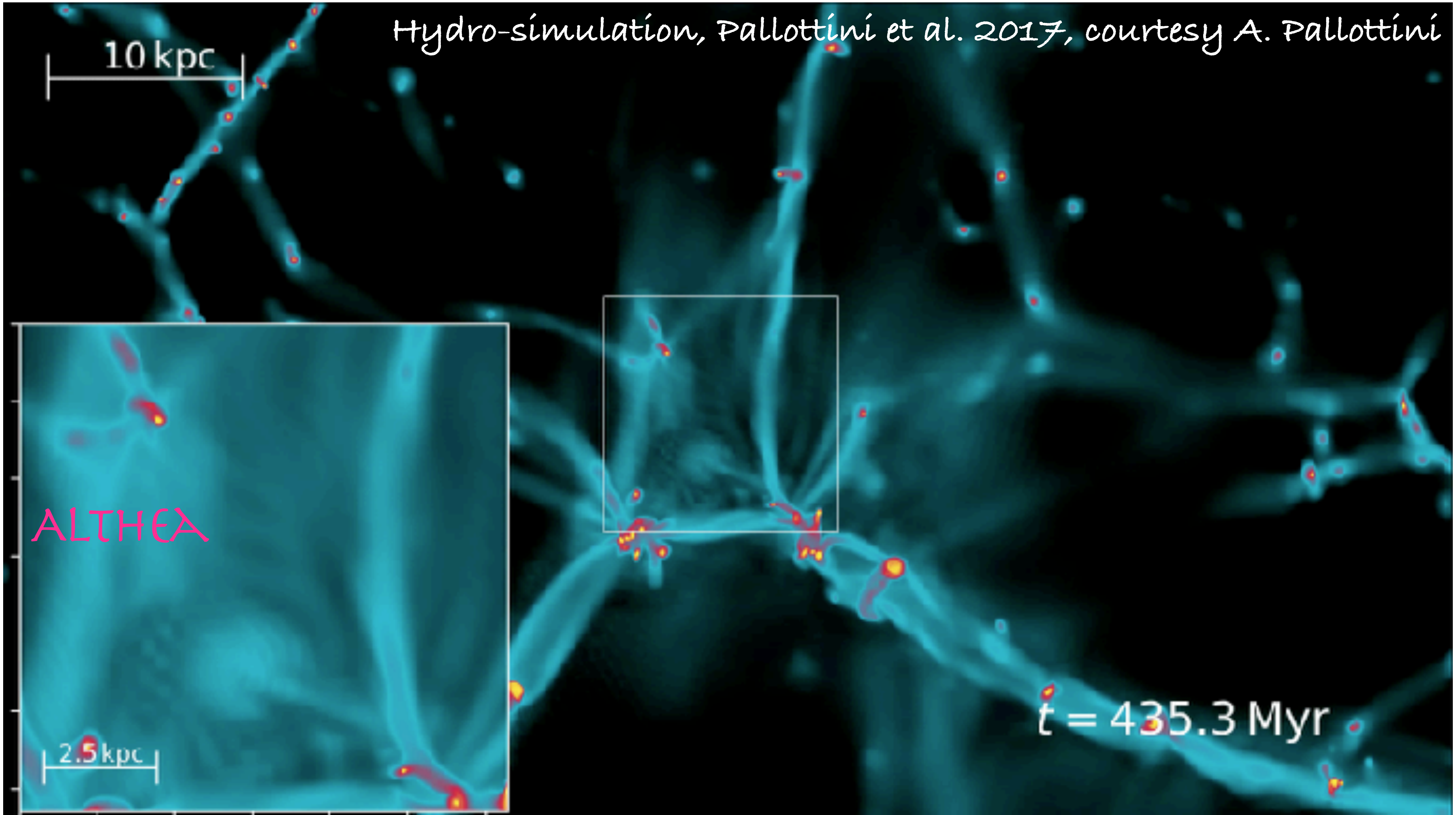
Main scenario of Galaxy and AGN early assembly

- low density filaments feed high density regions
- merging events (@ z~10)
- galaxies and SMBH form



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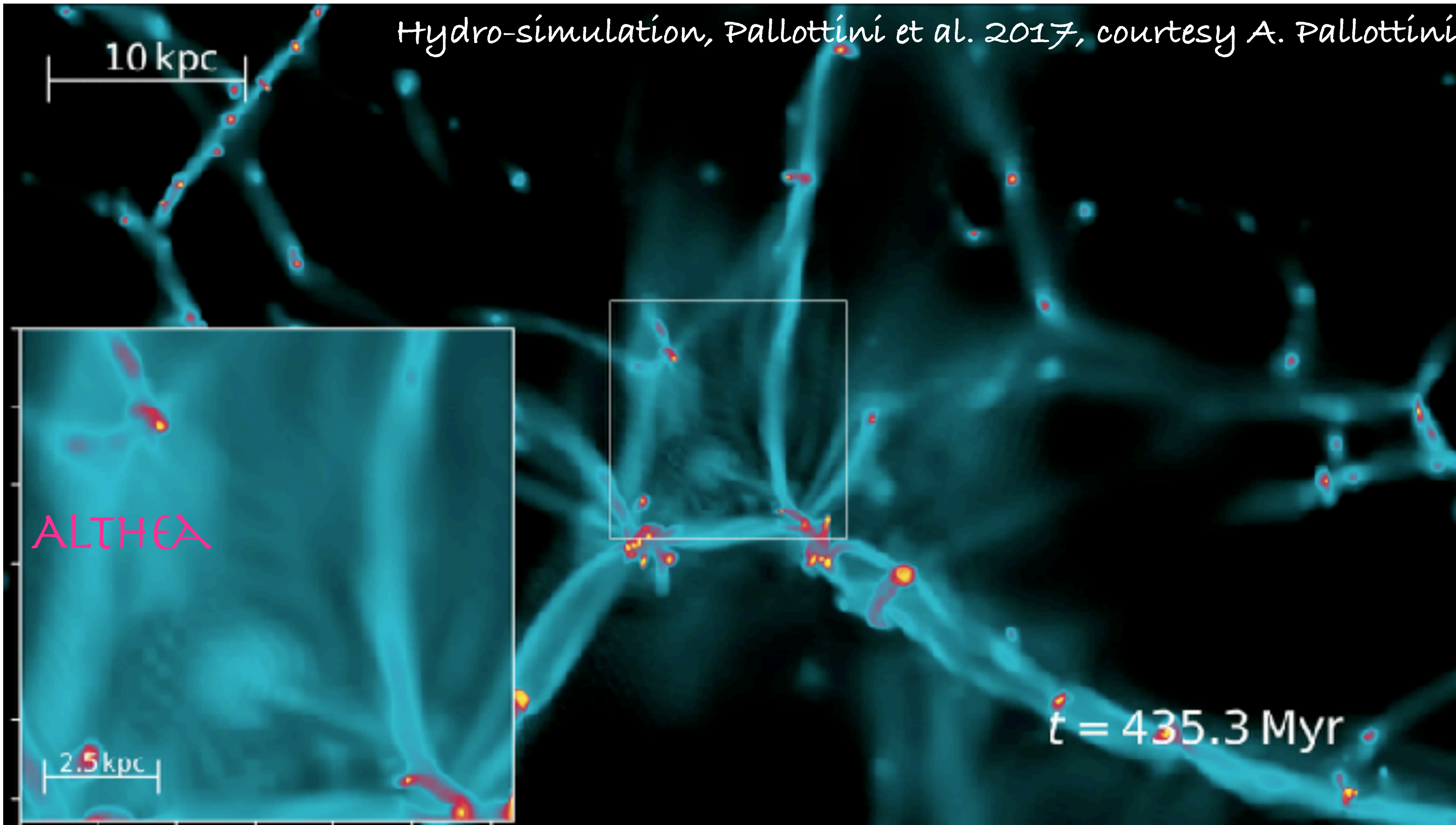
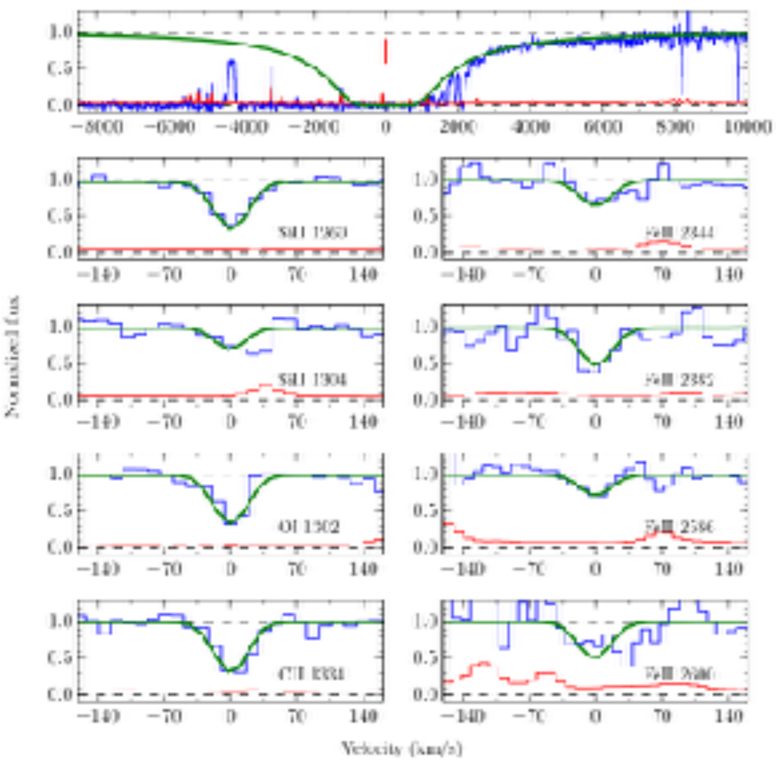


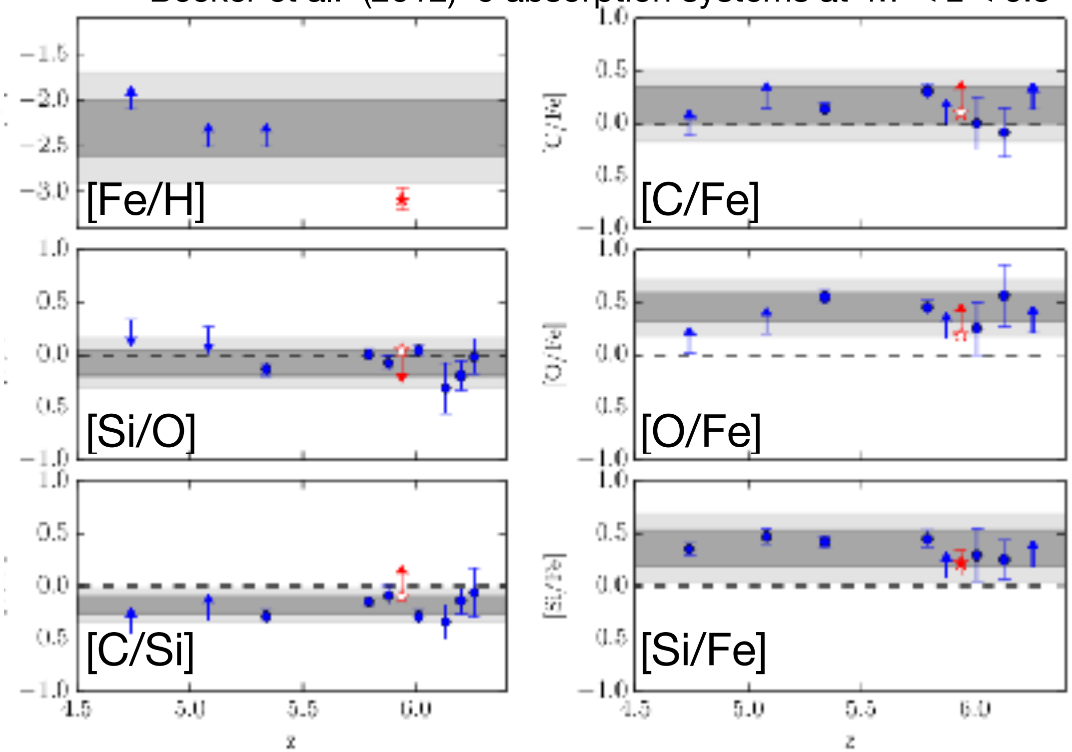
Witnessing galaxy assembly at the edge of the reionization epoch*

V. D'Odorico,[1,2] C. Feruglio,[1] A. Ferrara,[2] S. Gallerani,[2] A. Pallottini,[2,3] S. Carniani,[4,5] R. Maiolino,[4,5] S. Cristiani,[1] A. Marconi,[6,7] E. Piconcelli,[8] and F. Fiore[1]

2018 ApJL, 863, 29

A DLA at z=5.939 detected towards z=6.0025 QSO J2310+1855





in X-SHOOTER Archive data

Very metal poor, nearly pristine gas

[Fe/H] = -3.08 ± 0.12 [Si/H] = -2.86 ± 0.14

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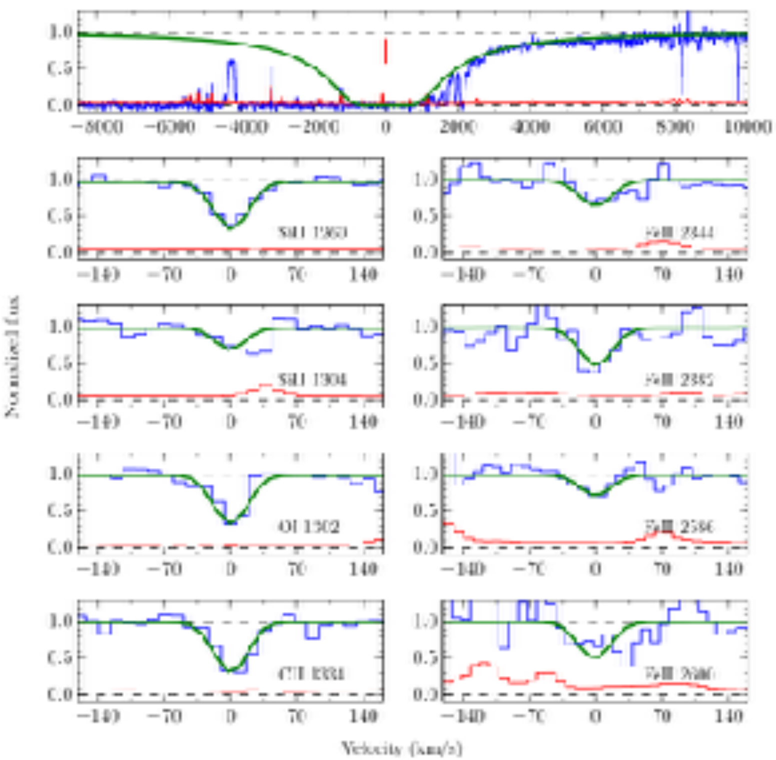
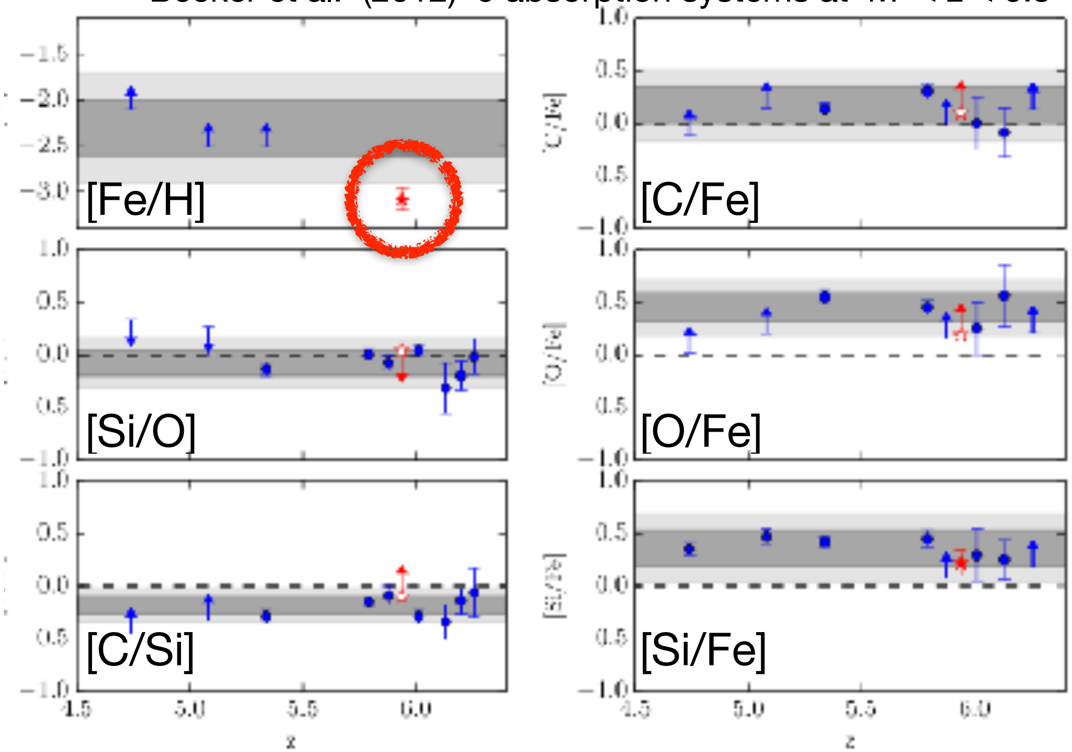


Becker et al. (2012) 9 absorption systems at 4.7 < z < 6.3



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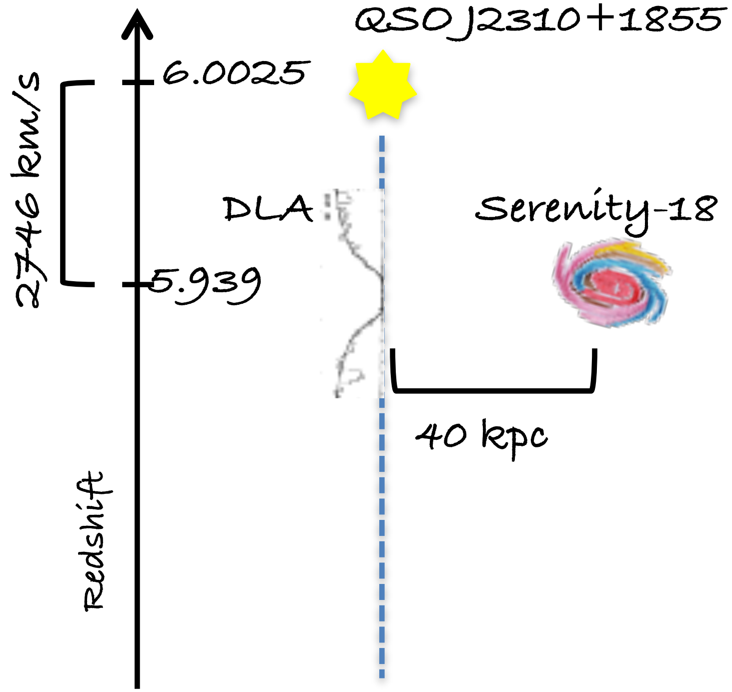
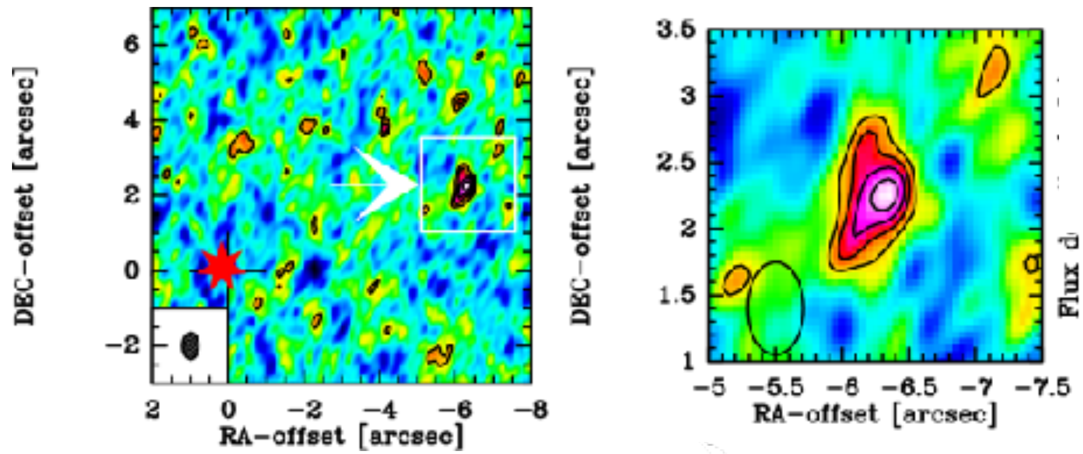
Serenity-18 : the Rosetta Stone of galaxy formation

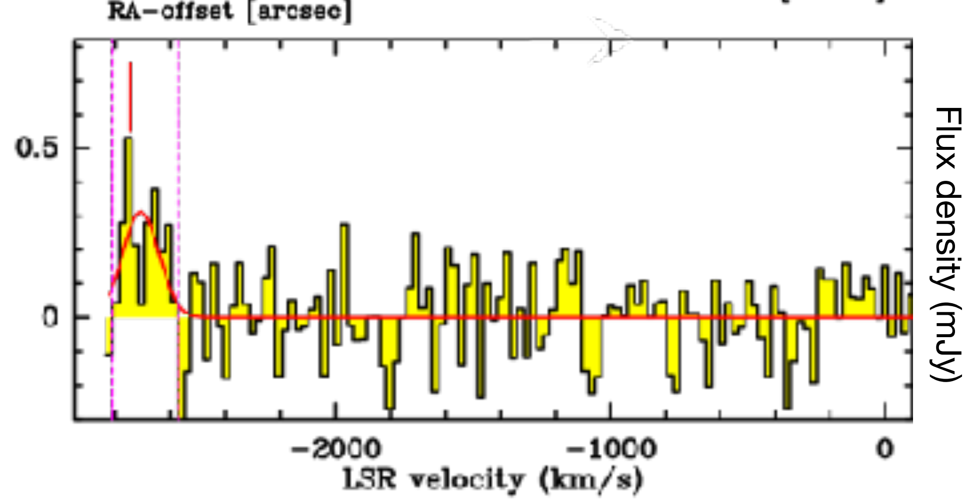
D'Odorico, CF + 2018 ApJL, 863, 29



Most sensitive ALMA observation of a QSO at cosmic dawn

Detection of CO(6-5)-emitting galaxy at z=5.939





ALMA J231038.44+185521.95	
RA (J2000)	23:10:38.44
DEC (J2000)	18:55:21.95
Redshift of CO(6-5) emission	5.93857
Impact parameter [arcsec]	6.7
$FWHM_{CO(6-5)}$ [km/s]	155 ± 30
$\int S_{CO(6-5)} dv$ [Jy km/s]	0.06 ± 0.012
$L'CO(6-5)$ [K km/s pc^{2}]	$(2 \pm 0.4) \times 10^9$
$M(H_2)$ [$M_\odot$]	$(5.4 \pm 0.5) \times 10^9$
$M_{dyn} \sin^2(i)$ [$M_\odot$]	$< 5.6 \times 10^9$
L_{FIR} [$L_\odot$]	$\approx 10^{12}$
SFR [$M_\odot$/yr]	≈ 115

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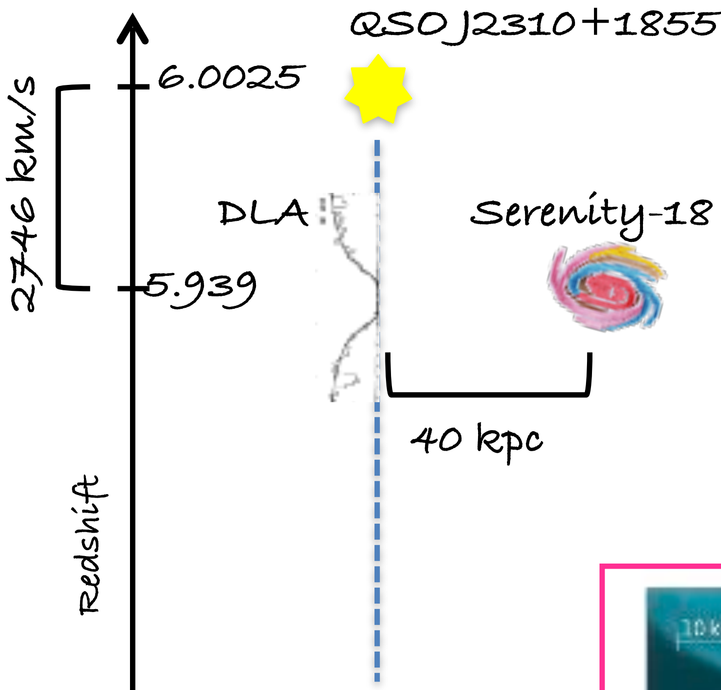

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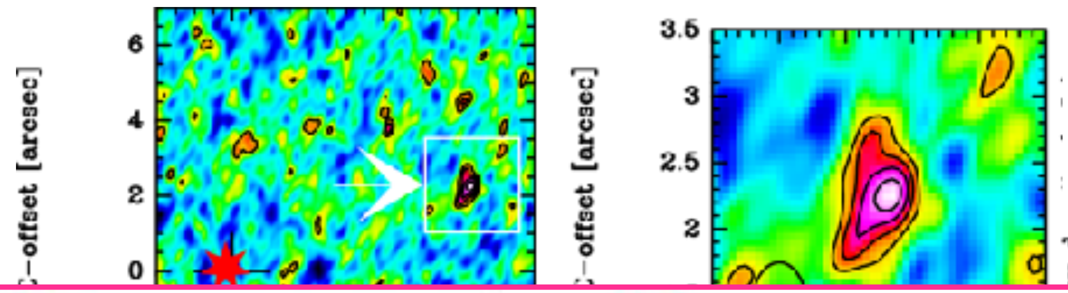

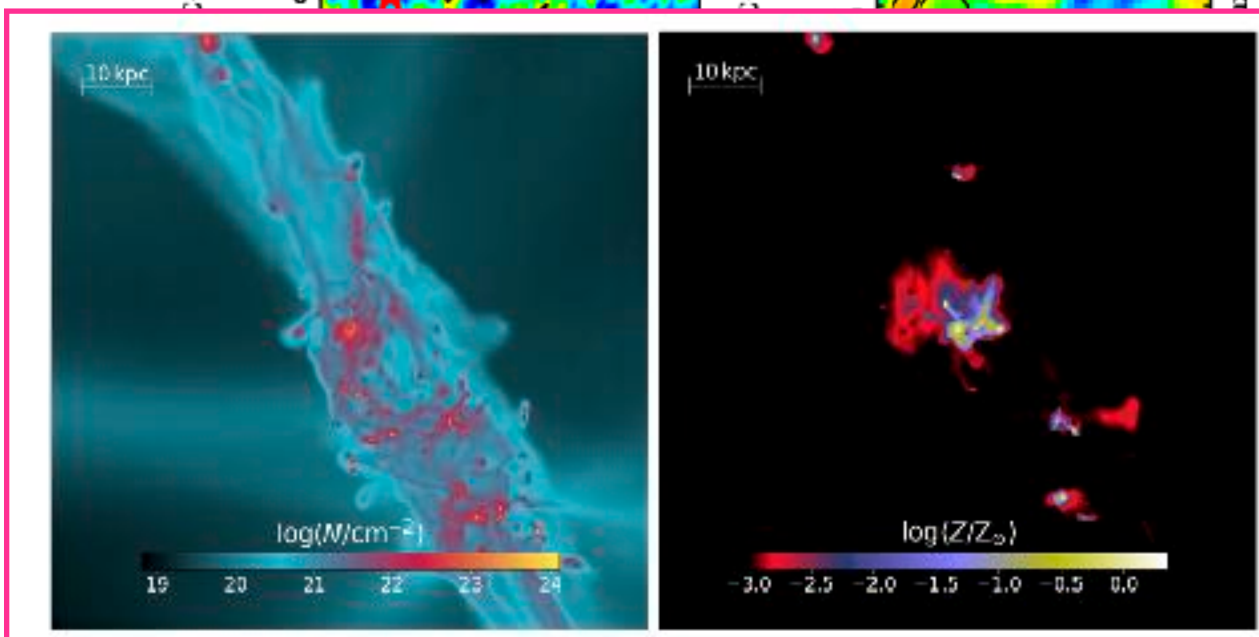

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AGN & host galaxy co-evolution

Main questions

- Relation SF-AGN feedback, quenching vs enhancement
- Agent(s) of AGN feedback (winds vs jets)
- Physical scales affected
- Net effect on host galaxy

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- Warm ionised gas
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Molecular emission lines CO, HCN, … also [CII] …

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Methods

Scaling relations between

$\dot{M}$, $\dot{M}$/SFR, $M(H_2)/M^*$, t_{depl}

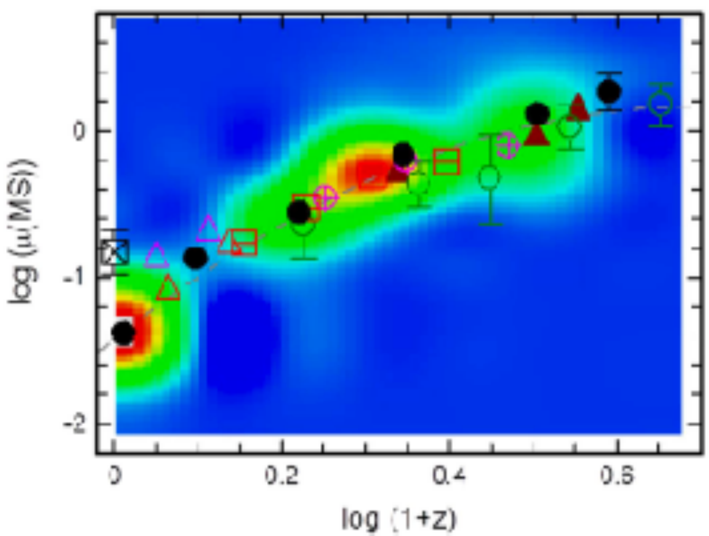
and M^*, L_{AGN}, M_{BH}, λ_{Edd}

- Need **unbiased AGN samples**

- ***IbisCO*** : low z AGN
- ***SUPER*** : z~2-3 AGN

SF galaxy scaling relations

Molecular gas fraction $F_{gas} = M(H_2)/M^*$ probes the richness of gas available for SF



Molecular Gas fraction

$M(H_2)/M^*$ strong function of z

Genzel+2015, Tacconi+2018

Star Forming galaxies

SF galaxy scaling relations

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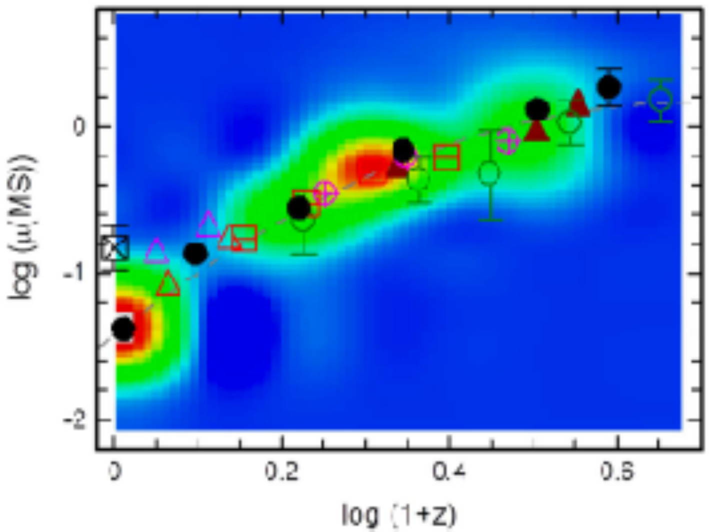


Molecular Gas fraction

$M(H_2)/M^*$ strong function of z

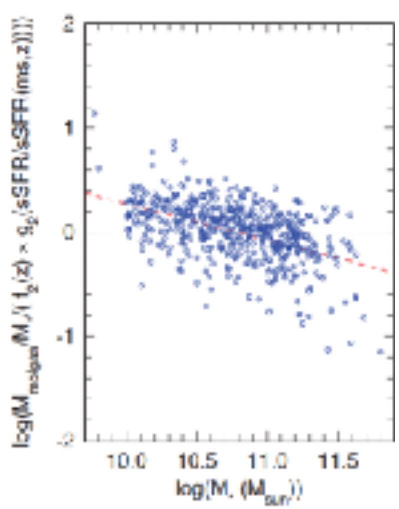
Genzel+2015, Tacconi+2018

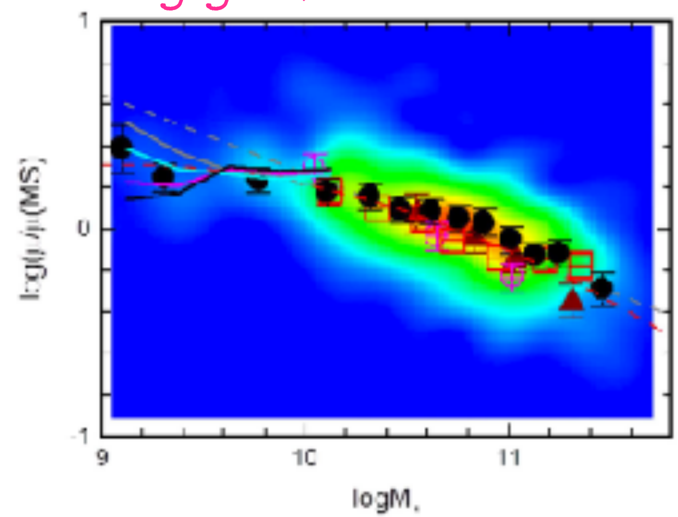
After correcting
offset from MS and z
MASS QUENCHING

$M(H_2)/M^*$ reduced at high M^*

AGN feedback at work?

Star Forming galaxies





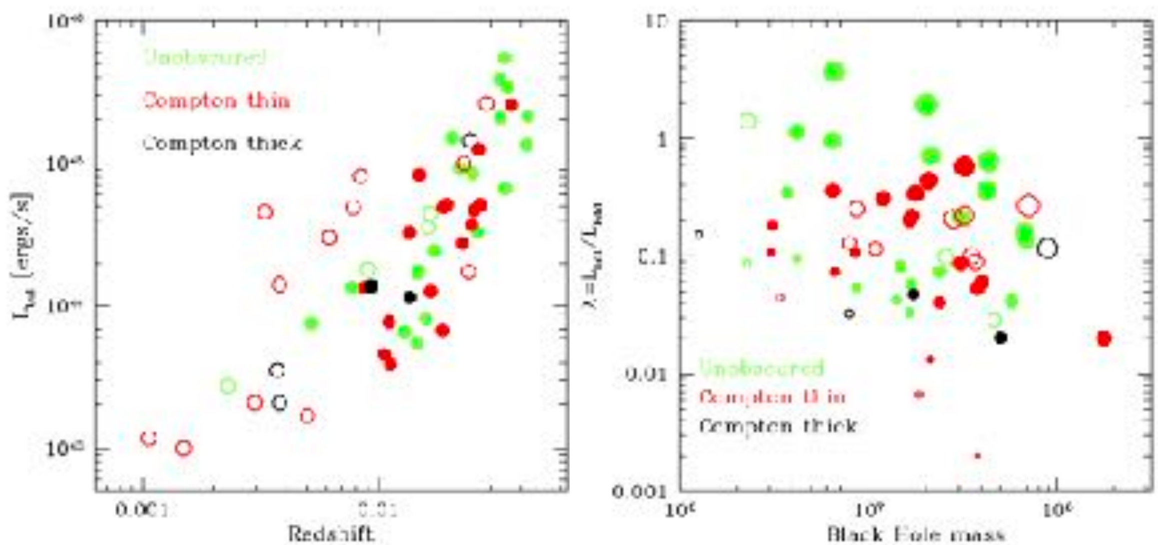
AGN host galaxy scaling relations
IbisCO survey design

Unbiased survey of H_2 reservoirs & outflows in AGN host galaxies

- 60 Hard X-ray 20-100 KeV AGN from the **IBIS Integral survey**
  unbiased against nuclear obscuration
- $L_X > 10^{43}$ erg/s
- $z < 0.05$
- Accurate BH masses
- M* , SFR

Several Seyferts from Maiolino+1997 and other works

Reaches fainter flux limits than BASS survey - Sample of NLSy1



Feruglio in prep.

IbisCO survey: Observations

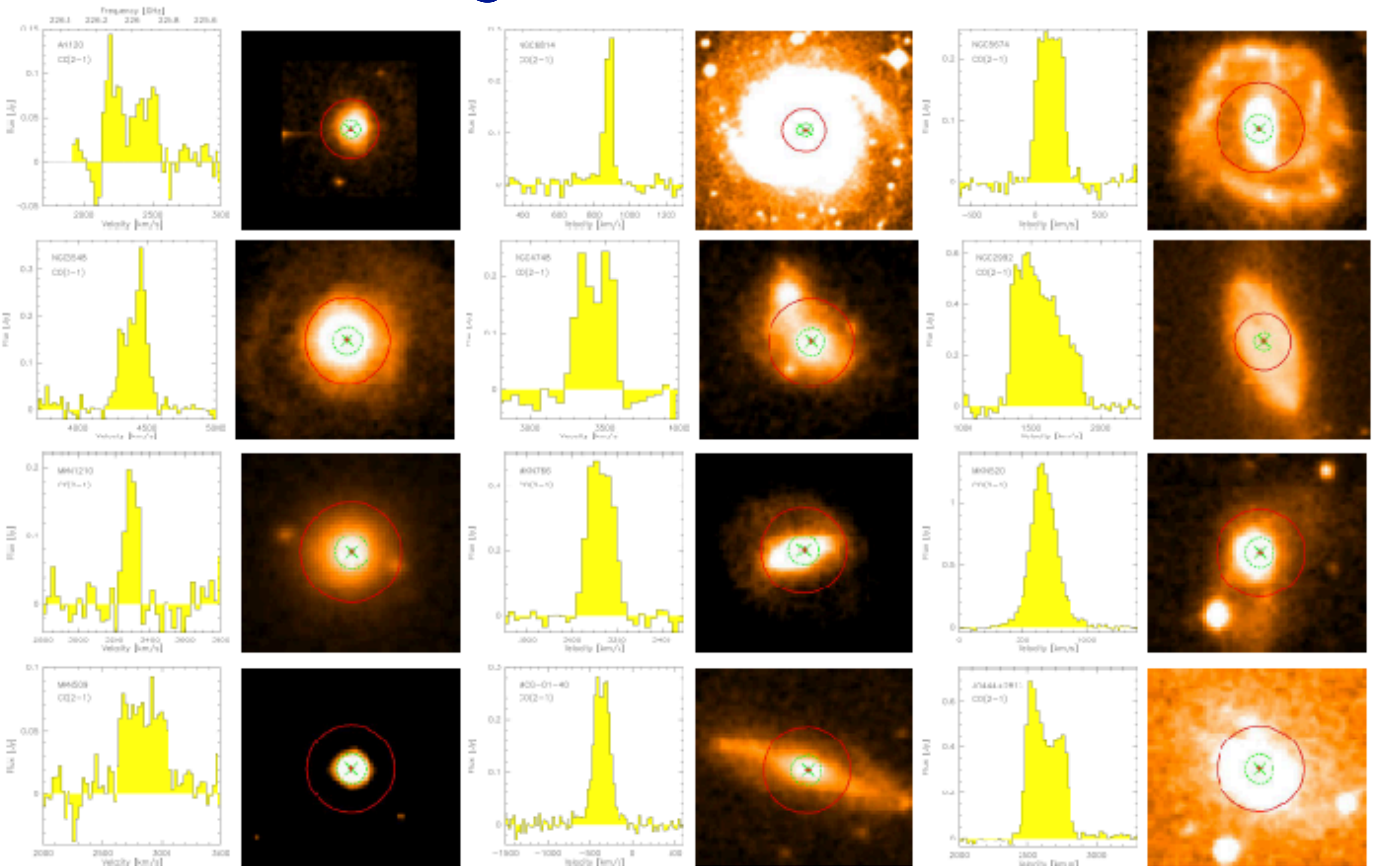
- **@IRAM 30m:** CO (1-0) & (2-1) - Gas reservoirs & outflows
  P.I. Feruglio - 70 hours survey completed 2017 - 80% detection rate

- **@ALMA band 6:** map CO with 50 pc resolution - P.I. Feruglio (cycle 5)

- **@INTEGRAL, NuSTAR, XMM:** X-ray spectra - P.I. Malizia
  —-> L_x, N_H, $\dot{M}_{ACC}$ + WA, UFO

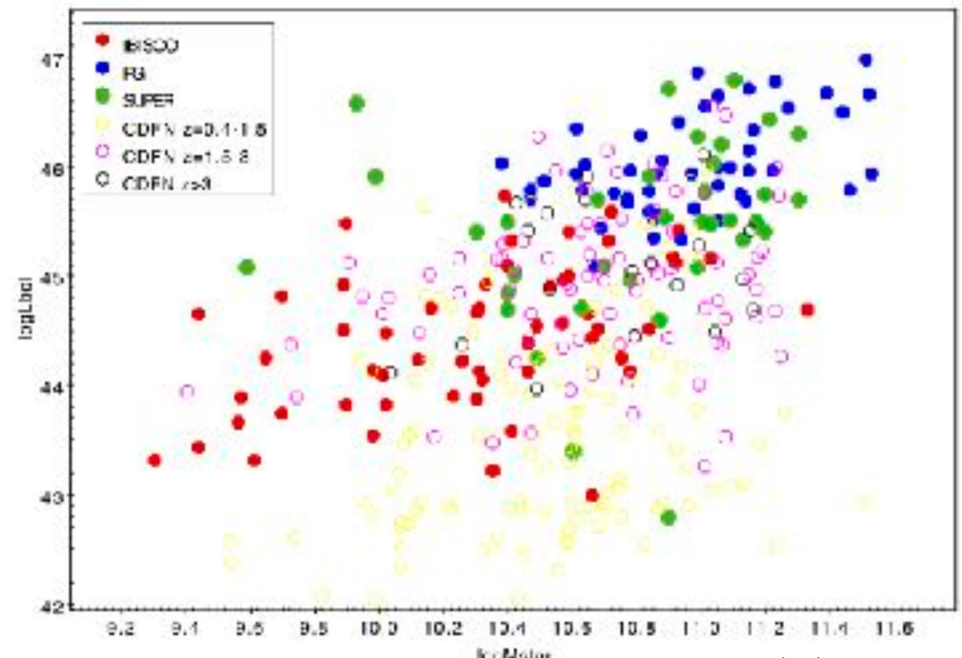
- + ancillary data from CALIFA, Manga: SFR, M^*, M_{BH}
  - Stellar Masses: Koss+2011, other literature, all corrected to match beam size
  - Beam 30m size (21”) probes different galaxy fractions at different z

IbisCO survey: Observations



IbisCO sample properties

IbisCO **43 < log L_{bol} < 45.5**
9< log M*< 11.4



Feruglio in prep.

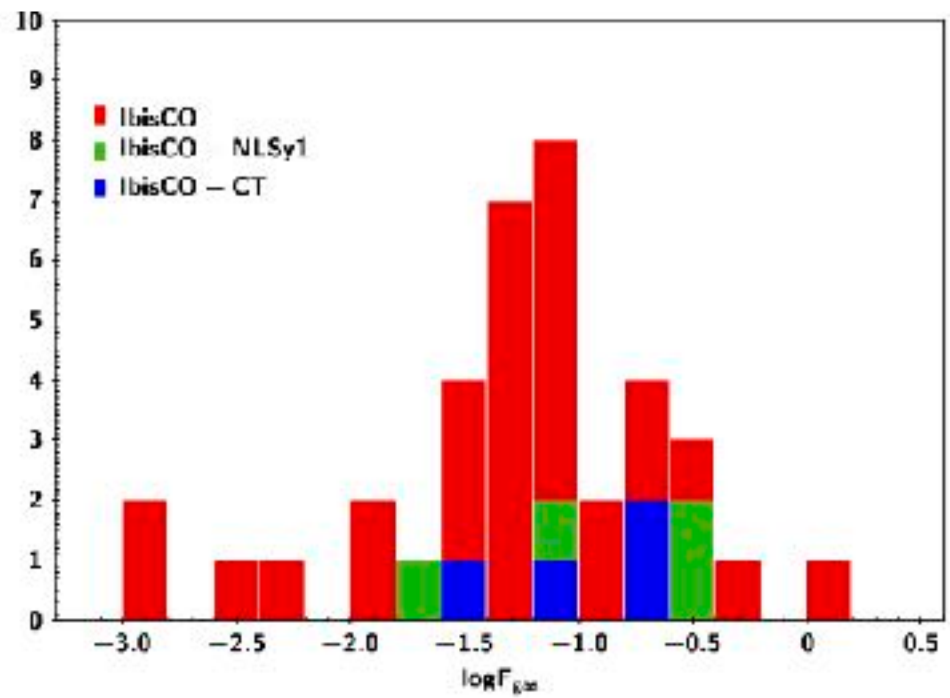
SUPER 44<logL_{bol}<47
9.5<log M*<11.4

PG QSO (Shangguan & Ho 2018)
45 <log L_{bol}<47
10<log M*< 11.6

IbisCO survey: gas fractions

Molecular gas fraction $F_{gas} = M(H_2)/M^*$ probes the richness of gas available for SF

- Molecular gas fraction of IbisCO host galaxies
- L(CO)-M(H2) Conversion factor $= 3.2\ M_\odot\ K^{-1}$ km/s pc^{-2} for all
- Metallicity dependence not yet included (can be refined)
- **Similar to COLDGASS Saintonge+2011/17**

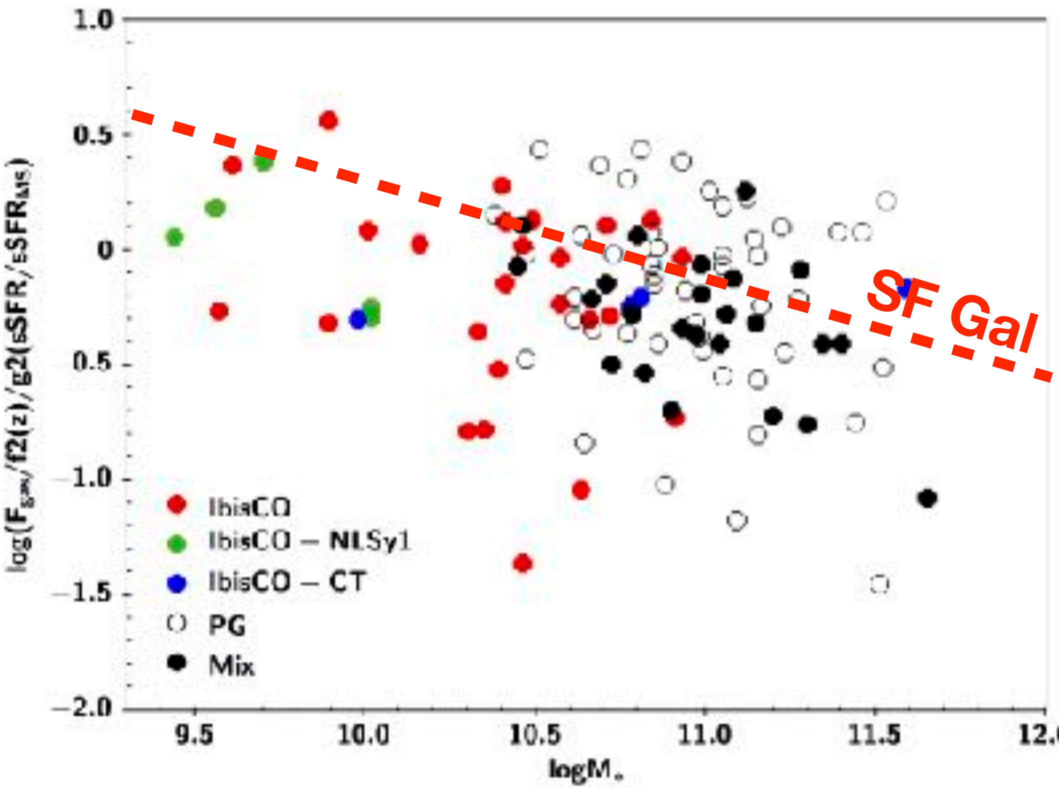


IRAM30m observations + Maiolino+1997 + others

Feruglio in prep.

IbisCO survey: F_{gas} vs M*

- **Do AGN have smaller F_{gas} than Main Sequence SF galaxies?**
  - **Normalized Gas Fraction consistent with SF galaxies**
  - Several have F_{gas} ~3-10 times smaller
  - Larger scatter at high M*
  - NLSY1 in lower M* hosts



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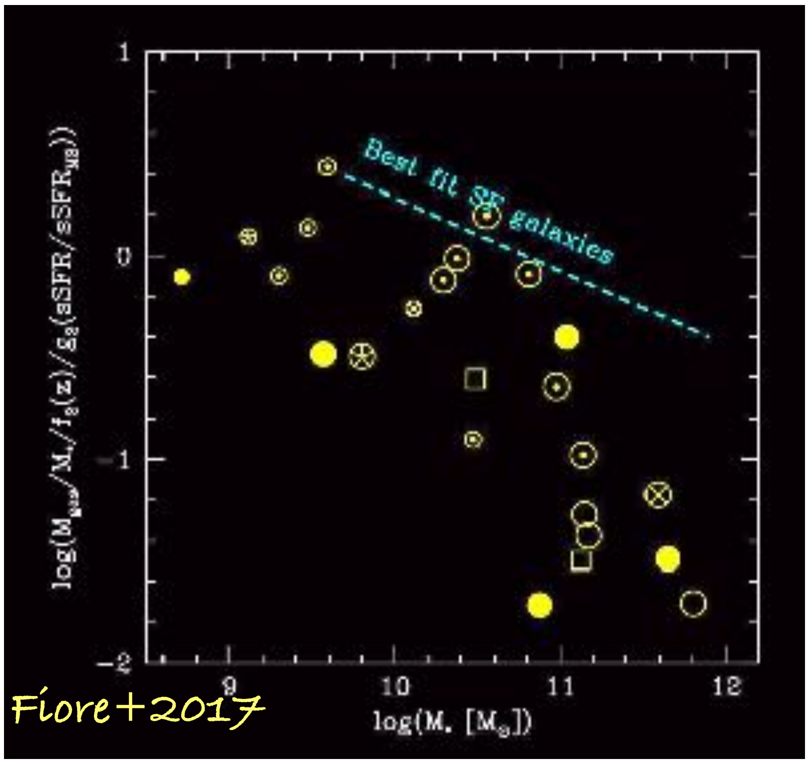
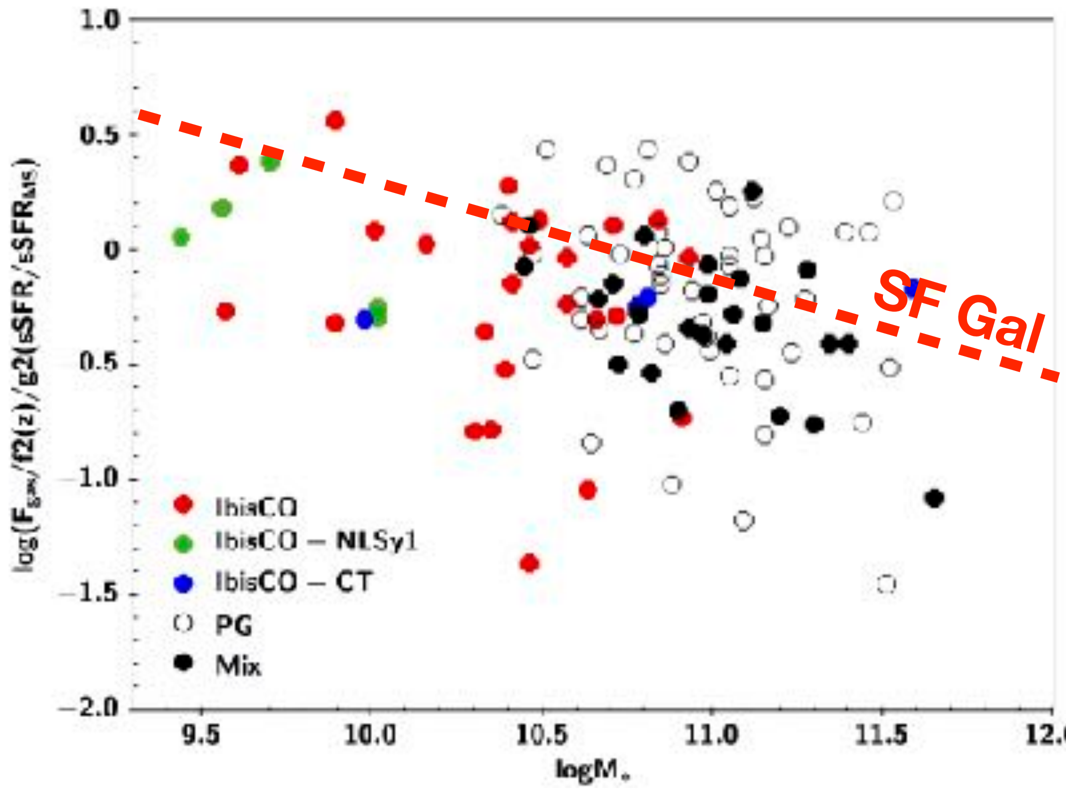




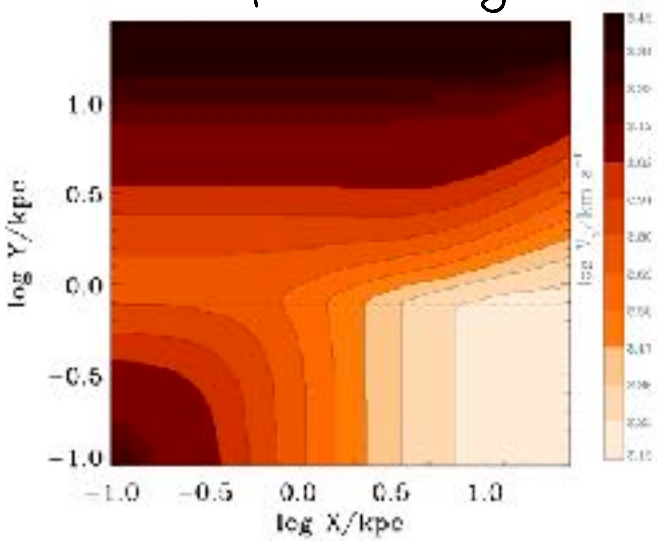
AGN with massive outflows do have smaller F_{gas}

Why?

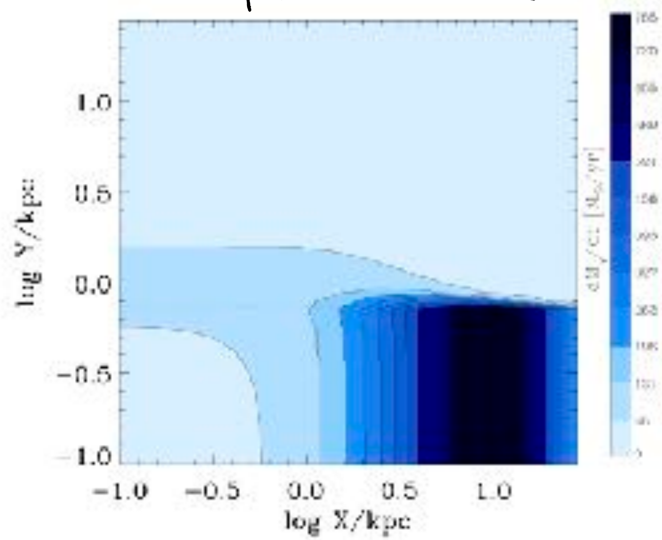
- FF17 biased sample
- FF17 F_{gas} - outflow regions matched
- single dish Fgas diluted by outer galaxy

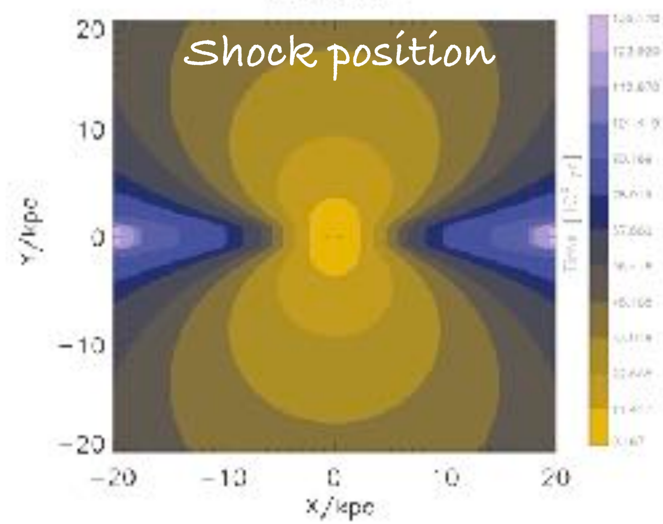
Menci+2018 blast model

Outflow velocity



Outflow mass rate

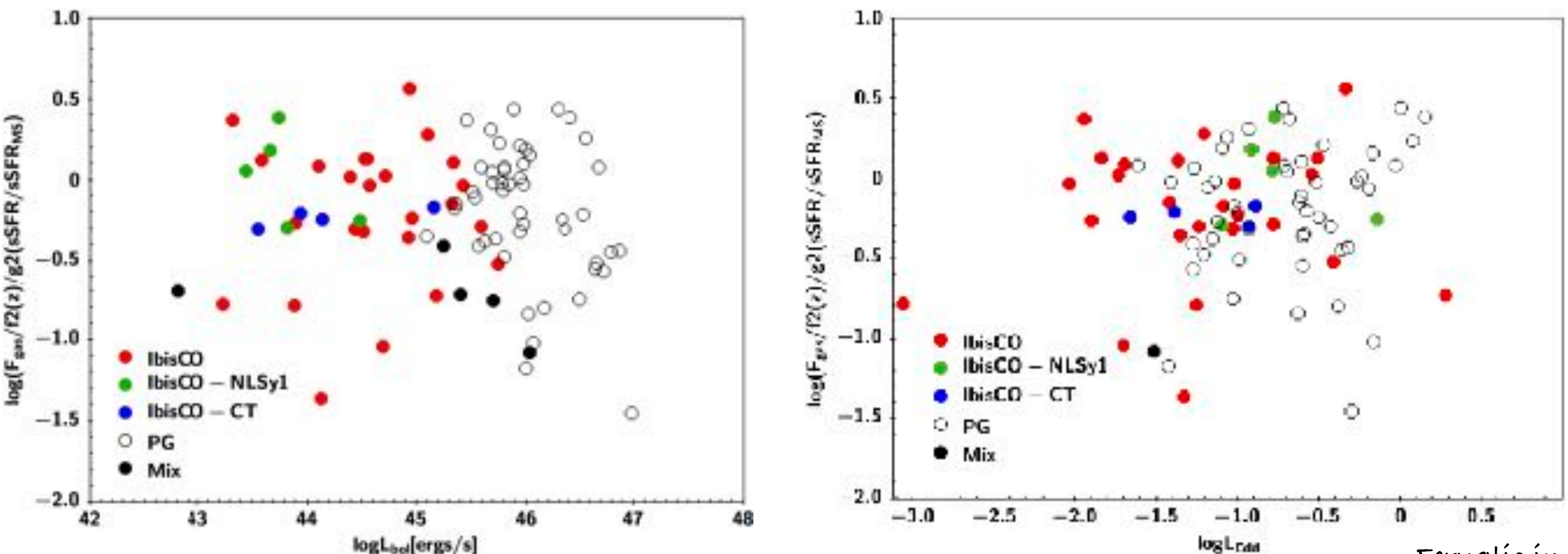




Biased sample:

Possible to measure strong outflows only if OF projected velocity is >~ disk velocity

IbisCO survey: F_{gas} vs Lbol - Lbol/LEdd



Feruglio in prep.

Normalized Gas Fraction : no trend with L_{bol} or L_{bol}/L_{Edd}

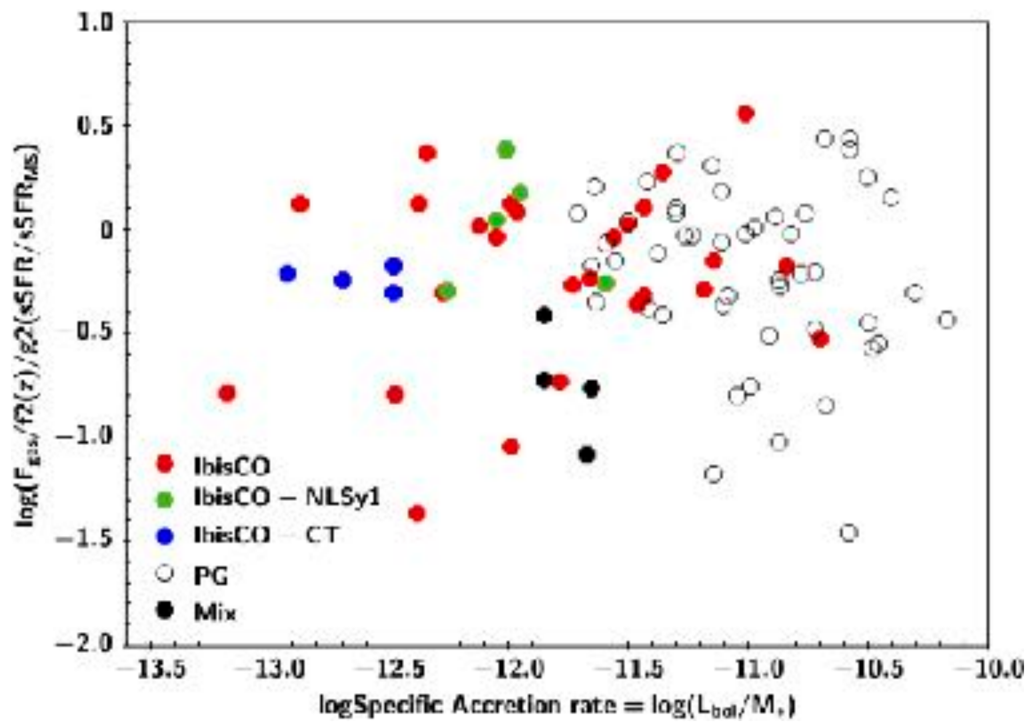
- NLSY1 gas fraction larger than CT AGN
- NLSY1 larger L_{bol}/L_{Edd} than CT AGN

Samples: PG QSO Shangguan & Ho 2018 - IR selected Kirkpatrick+14 - Brusa+18, Kakkad+17, Vayner+17, …

IbisCO survey: Fgas vs Lbol/M*

Normalized Gas Fraction vs AGN Specific Accretion Rate

- No trend
- Large scatter
- CT AGN on average lower specific accretion rates than NLSy1 and average IbisCO



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Conclusions

- AGN gas fractions similar to those of MS galaxies with similar masses (e.g. COLDGASS)
- Large scatter. Many outliers! both in IbisCO and other samples, with factor 3-10 smaller gas fraction
- For IbisCO the outliers are found when sampling the inner part of the galaxy
- No strong dependencies between gas fraction and AGN properties (L_{bol}, L_{bol}/L_{Edd}, specific accretion rate)