

# The ALMA view of the life cycle of galaxies

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# The life cycle of Galaxies

## Life cycle of Massive Galaxies



- ◆ Conversion of gas into stars
- ◆ Accretion onto Super Massive BH - AGN phases
- ◆ Energy injection in the ISM through winds, shocks, CR by AGN and SNe

# Outstanding questions

## Feeding

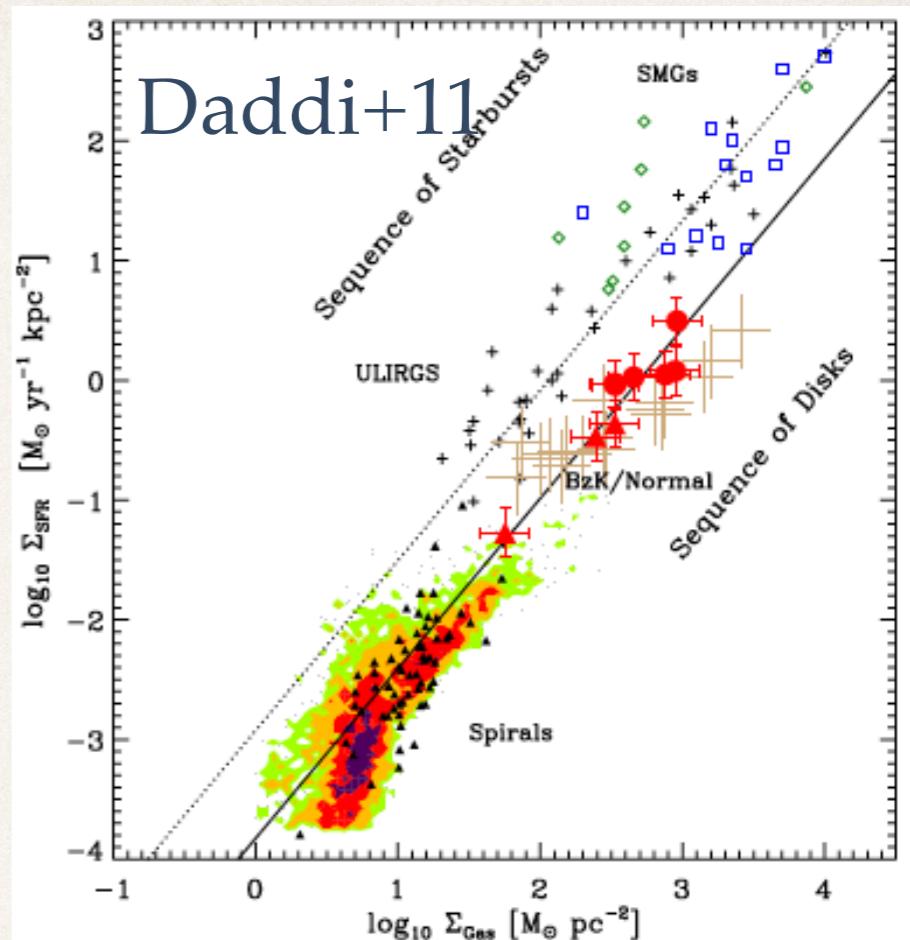
1. Conversion timescales of gas into stars
2. Fraction of gas into Star Formation vs accreted onto SMBH

## Feedback

1. If and how gas conversion into stars is affected by AGN winds

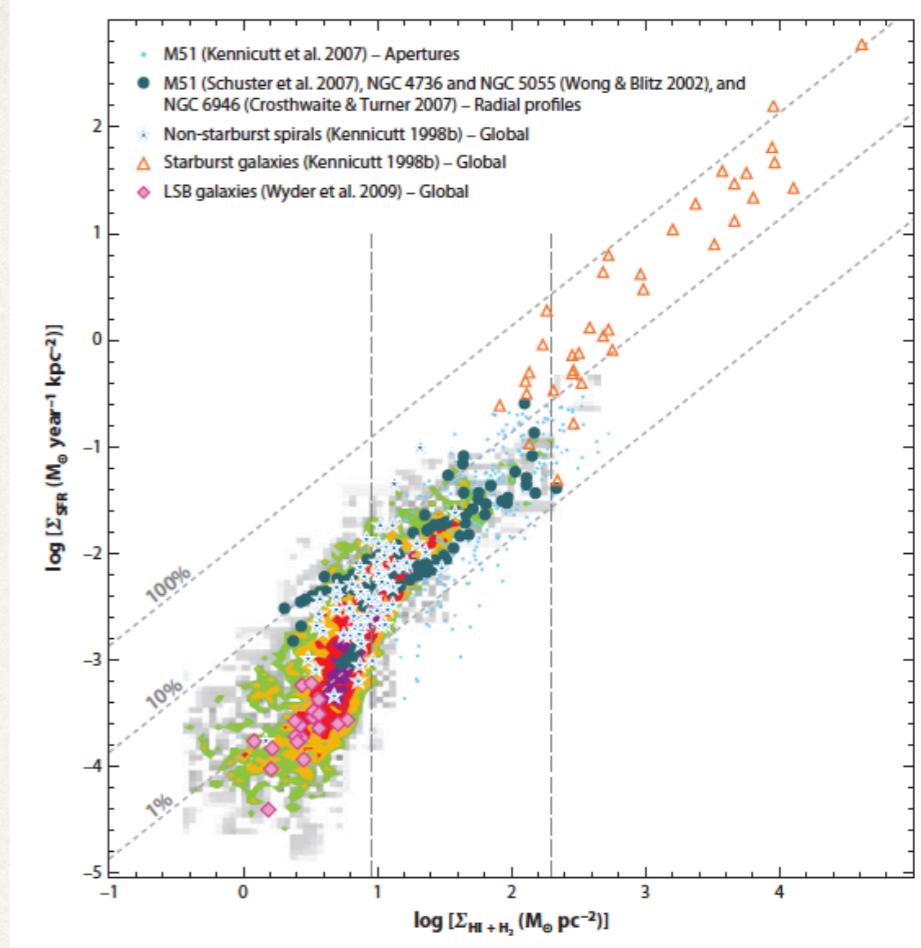
# Feeding - I

- Schmidt-Kennicutt (SK) : ULIRGs are off type (not in ULIRGs)
- 100 pc ~ typical distance bewteen GMC in MW



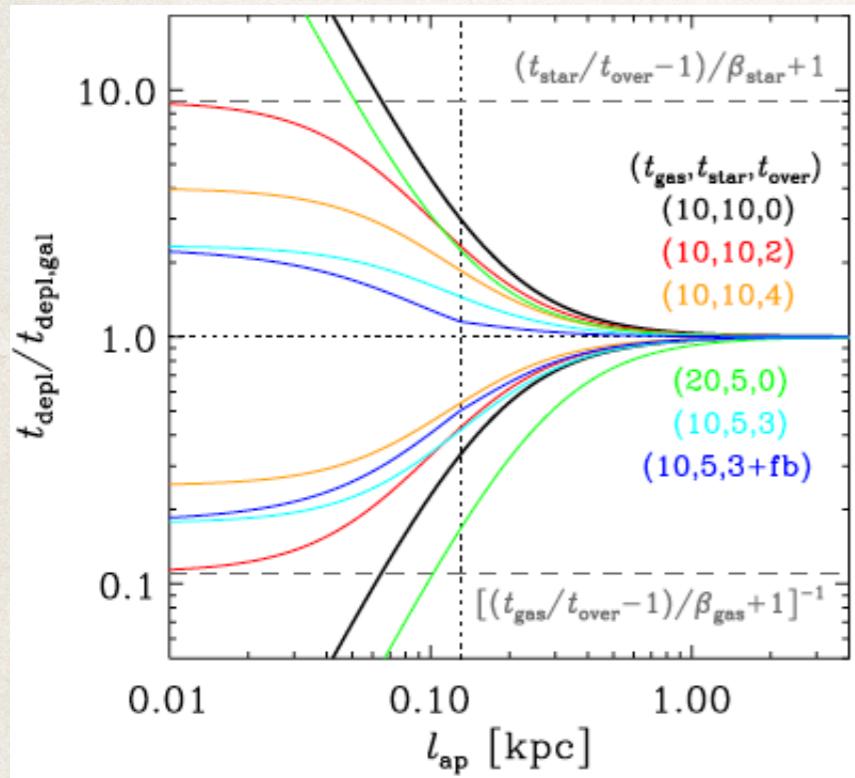
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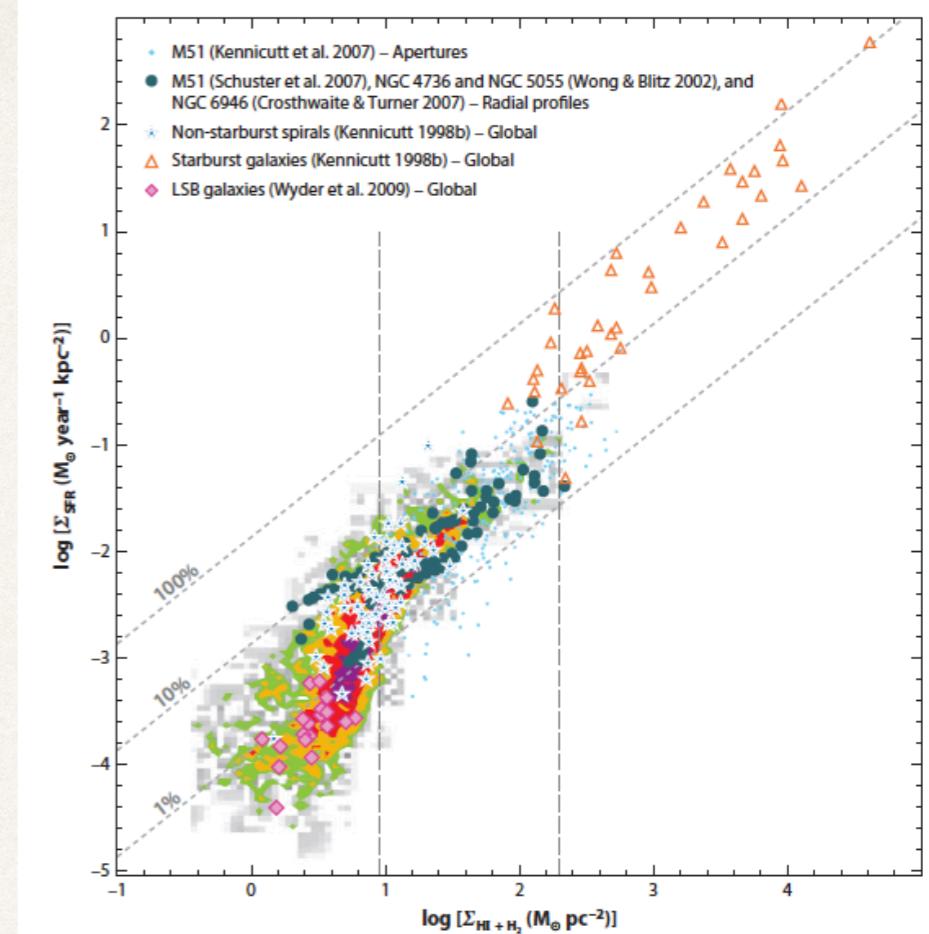


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$t_{\text{gas}}, t_{\text{star}}$



Kruijssen & Longmore 2014  
Different Timescales of Molecular Cloud lifetime,  
SF, stellar feedback  
With ~10-100 pc resolution, ALMA can measure

# Feeding - 2

What feeding mode in circum nuclear disks?

♦ Galaxy interactions Gas

$$\frac{\text{nuclear SB}}{\text{accreted onto SMBH}} = 4$$

Empirical  
Sander & Mirabel

♦ Disk instability

Gas

$$\frac{\text{nuclear SB}}{\text{accreted onto SMBH}} = 100$$

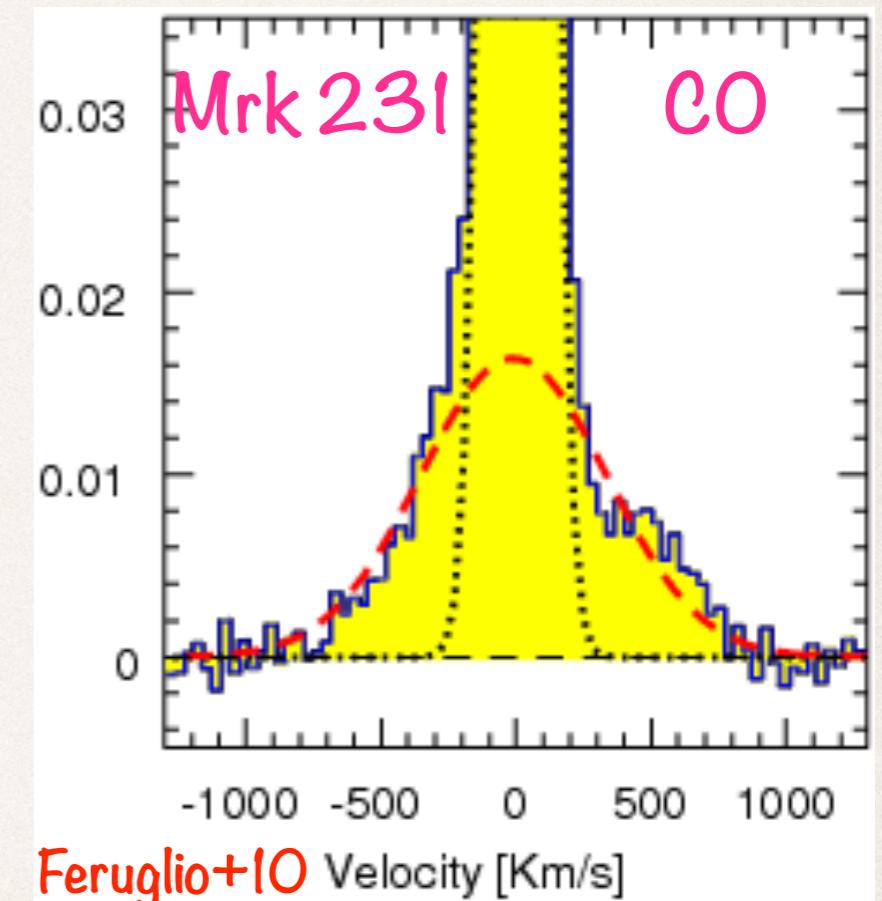
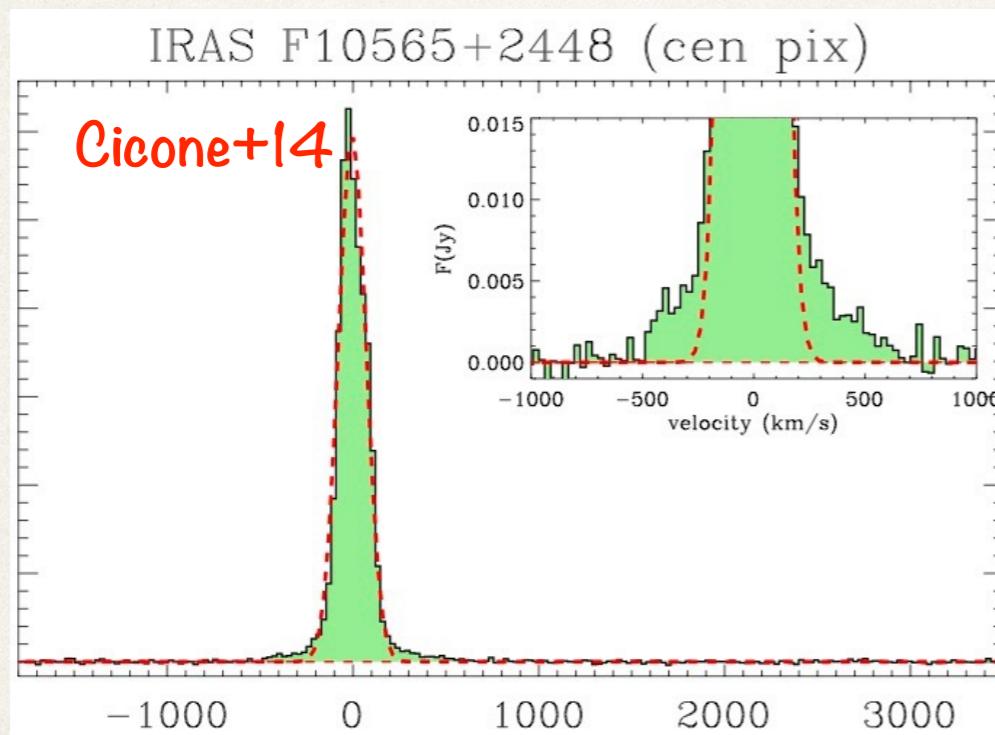
Model  
Menci+2014

# Feedback

## Do AGN winds affect gas conversion into stars?

### AGN-DRIVEN MASSIVE WINDS:

- Ubiquitous in luminous AGN hosts - kpc-wide
- Fast, mass loaded, Energetic ( few % of Lbol)

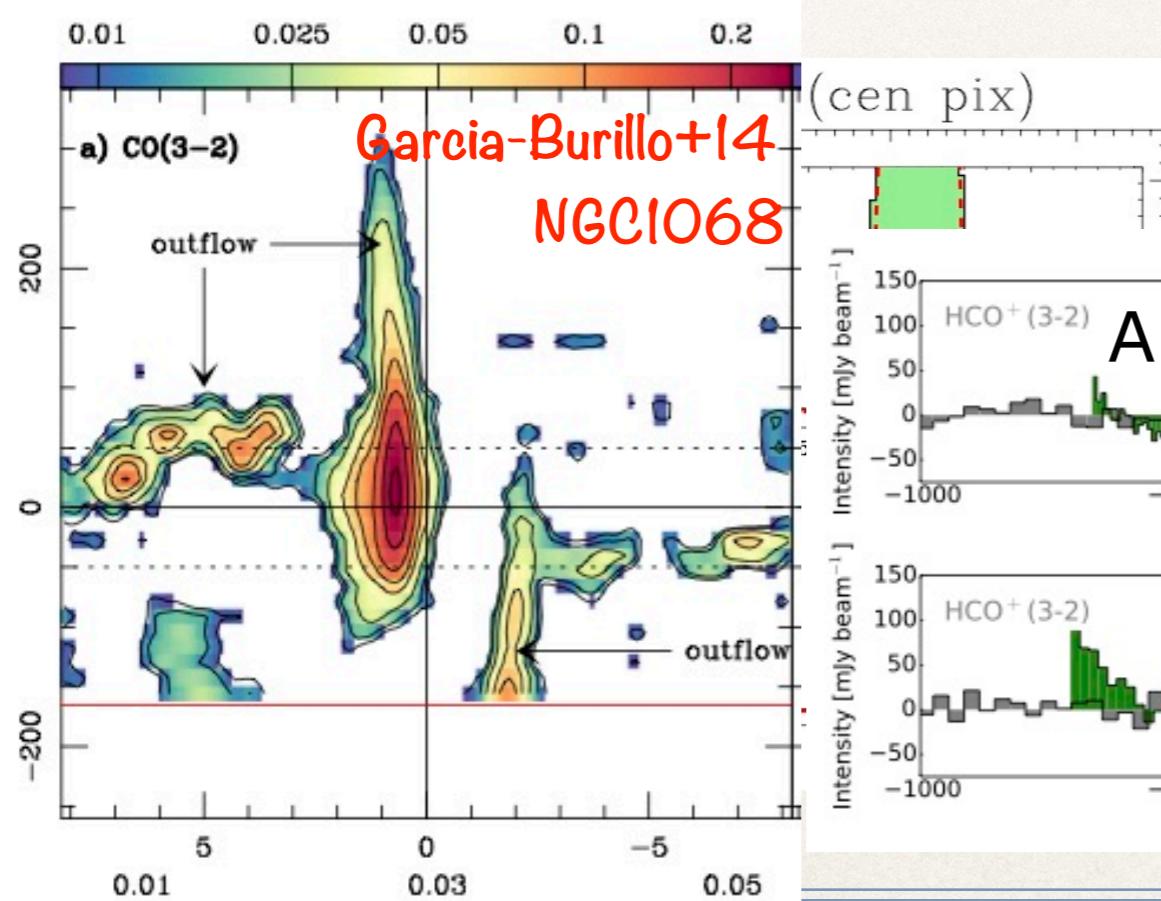


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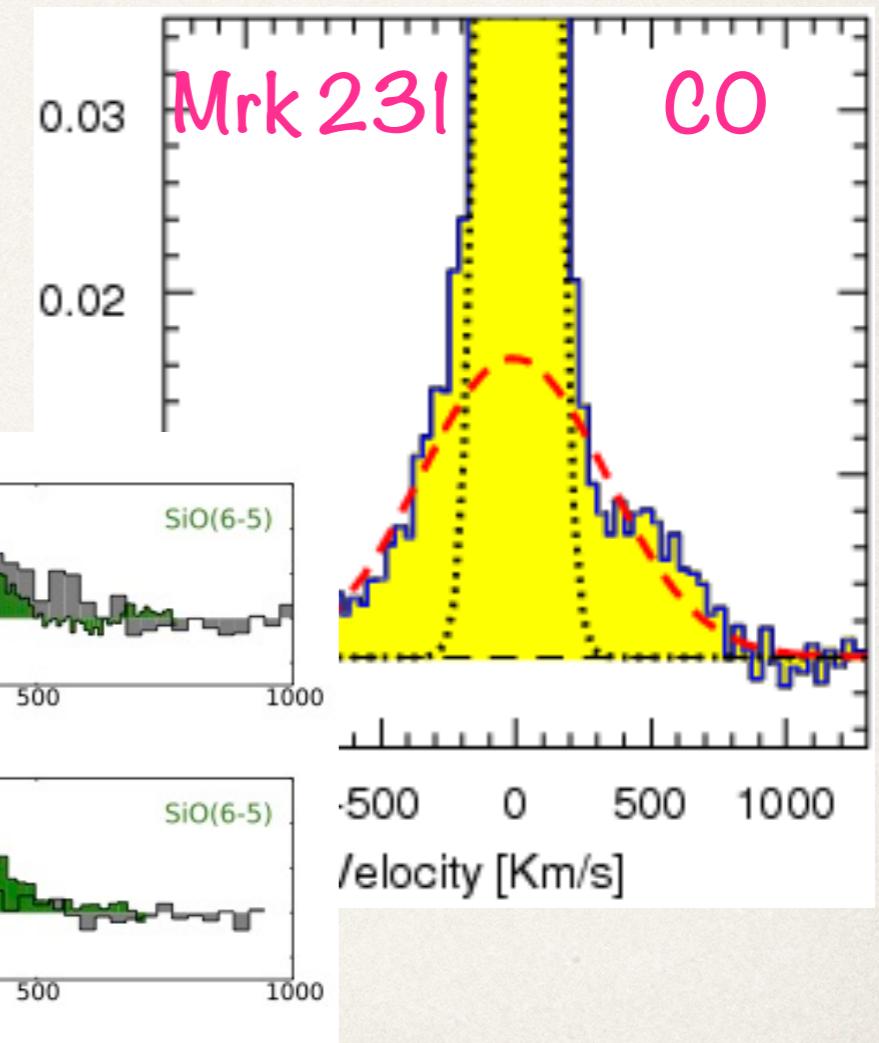
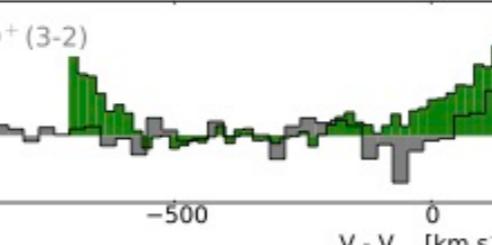
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Arp220 W

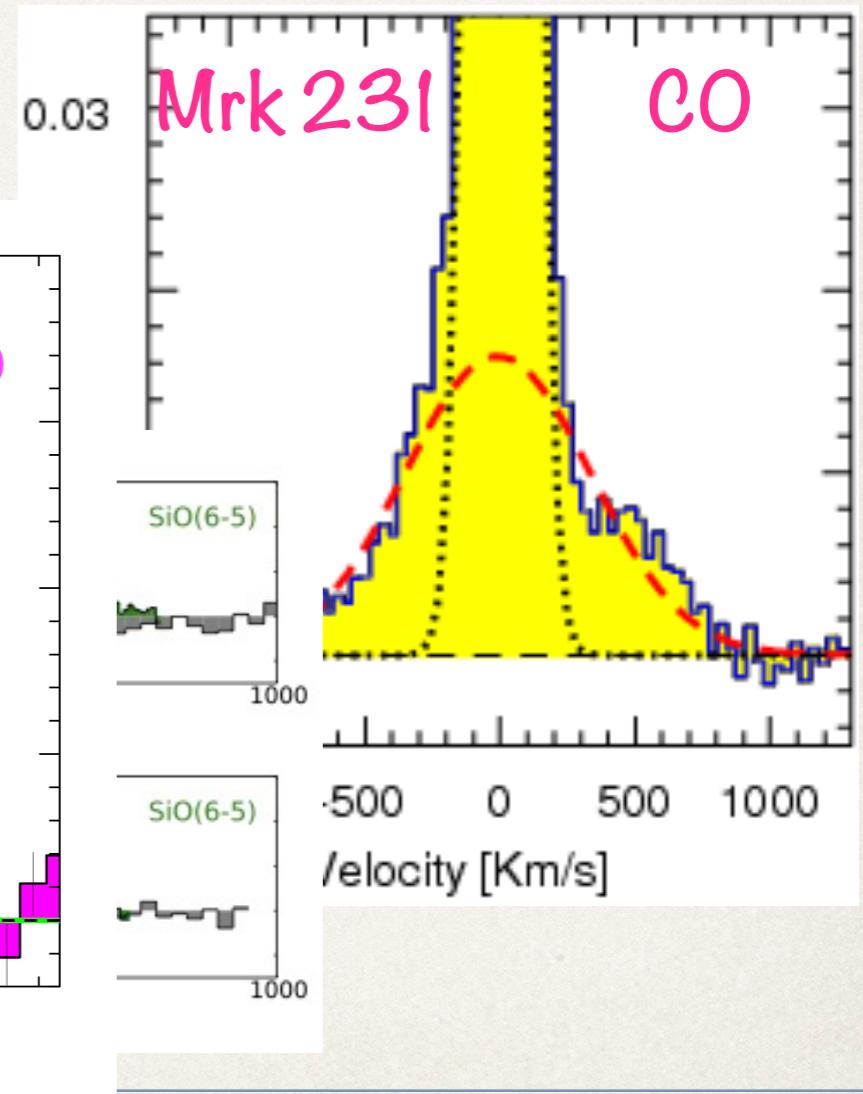
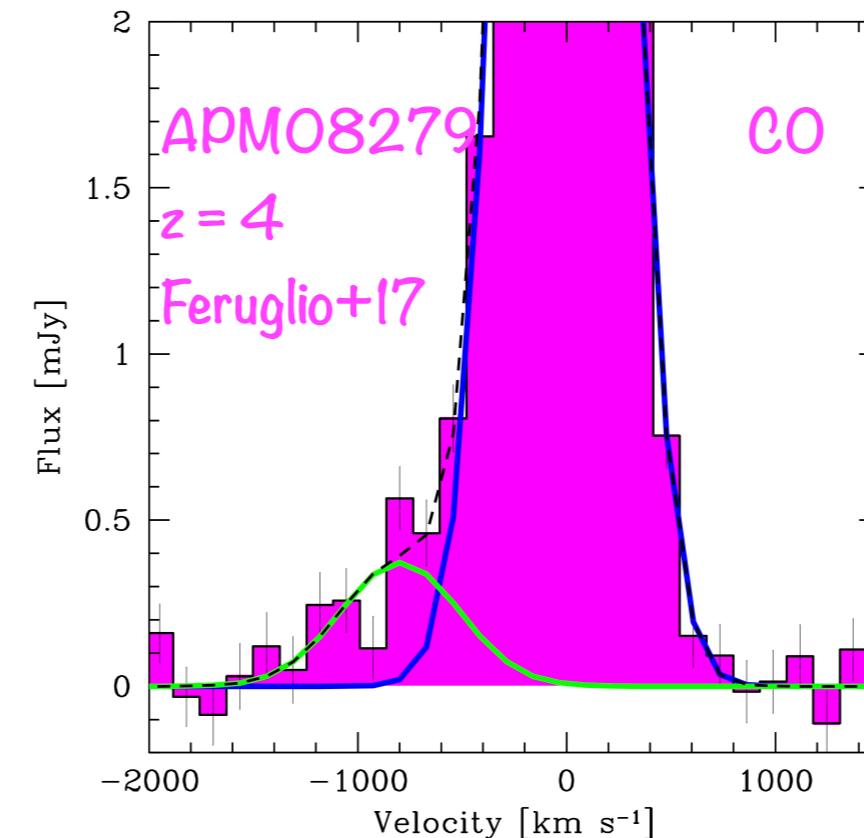
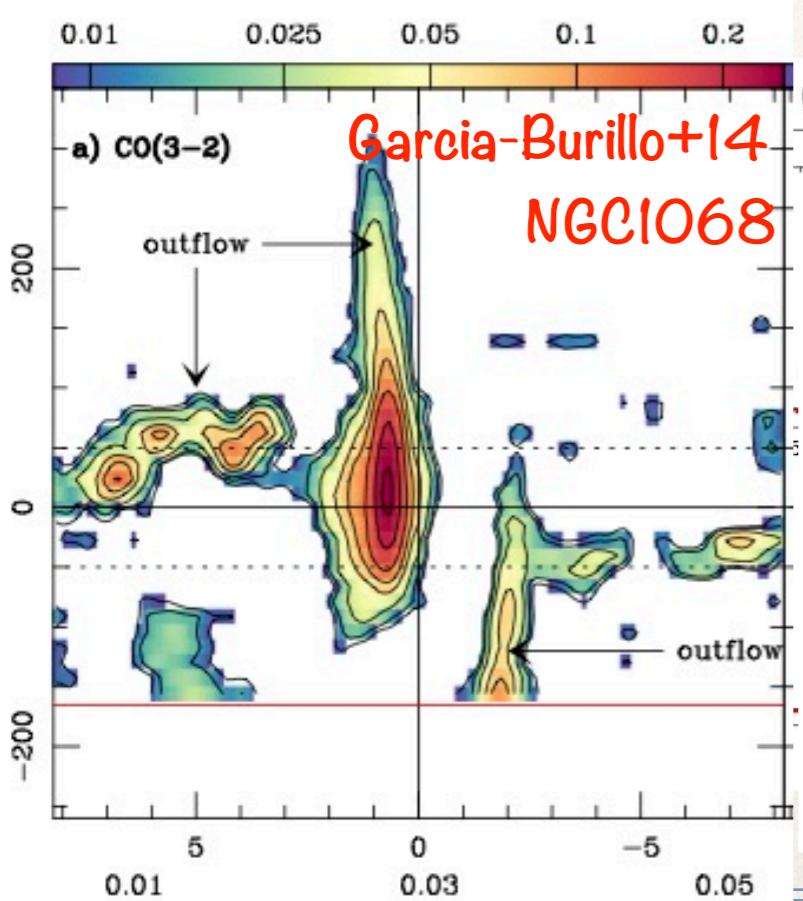


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# Probe AGN feedback- Strategy

Strategy is twofold:

## (I) High resolution studies of individual galaxies

- resolve/map AGN winds and their effect on SF

## (II) Scaling relations of statistical samples

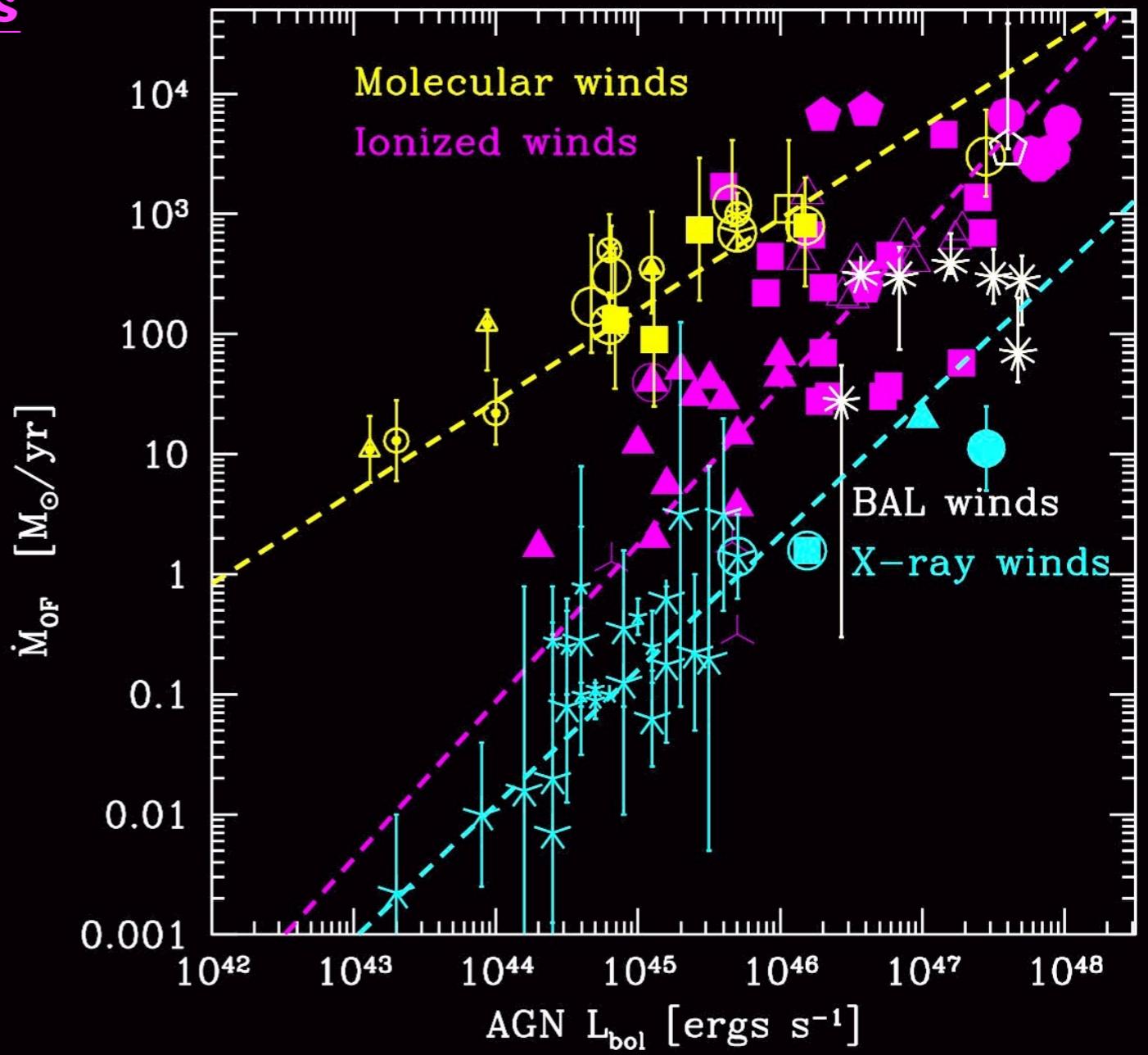
- up to now: biased samples
- SUPER survey @SINFONI/VLT                    $z=2-3$
- PHIBSS2 survey @NOEMA                        $z=0.5-2.5$
- IBISCO survey @IRAM 30, @ALMA band 6    $z < 0.05$

Requirements:

- unbiased samples
- high angular resolution

# AGN Wind scaling with $L_{\text{bol}}$

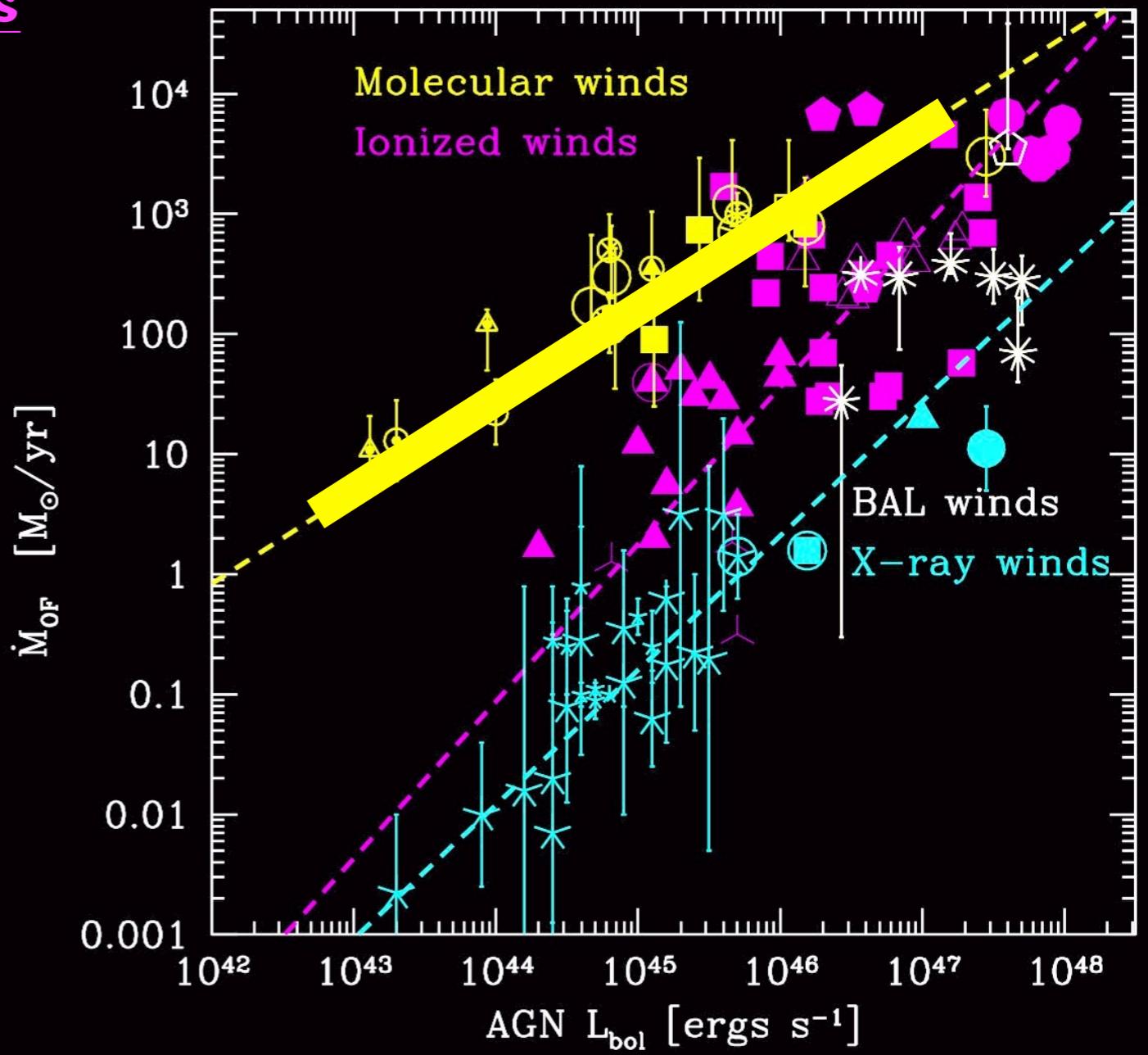
One application, on biased samples



# AGN Wind scaling with $L_{\text{bol}}$

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$$\text{Molecular } \dot{M}_{\text{OF}} \sim L_{\text{bol}}^{0.75}$$

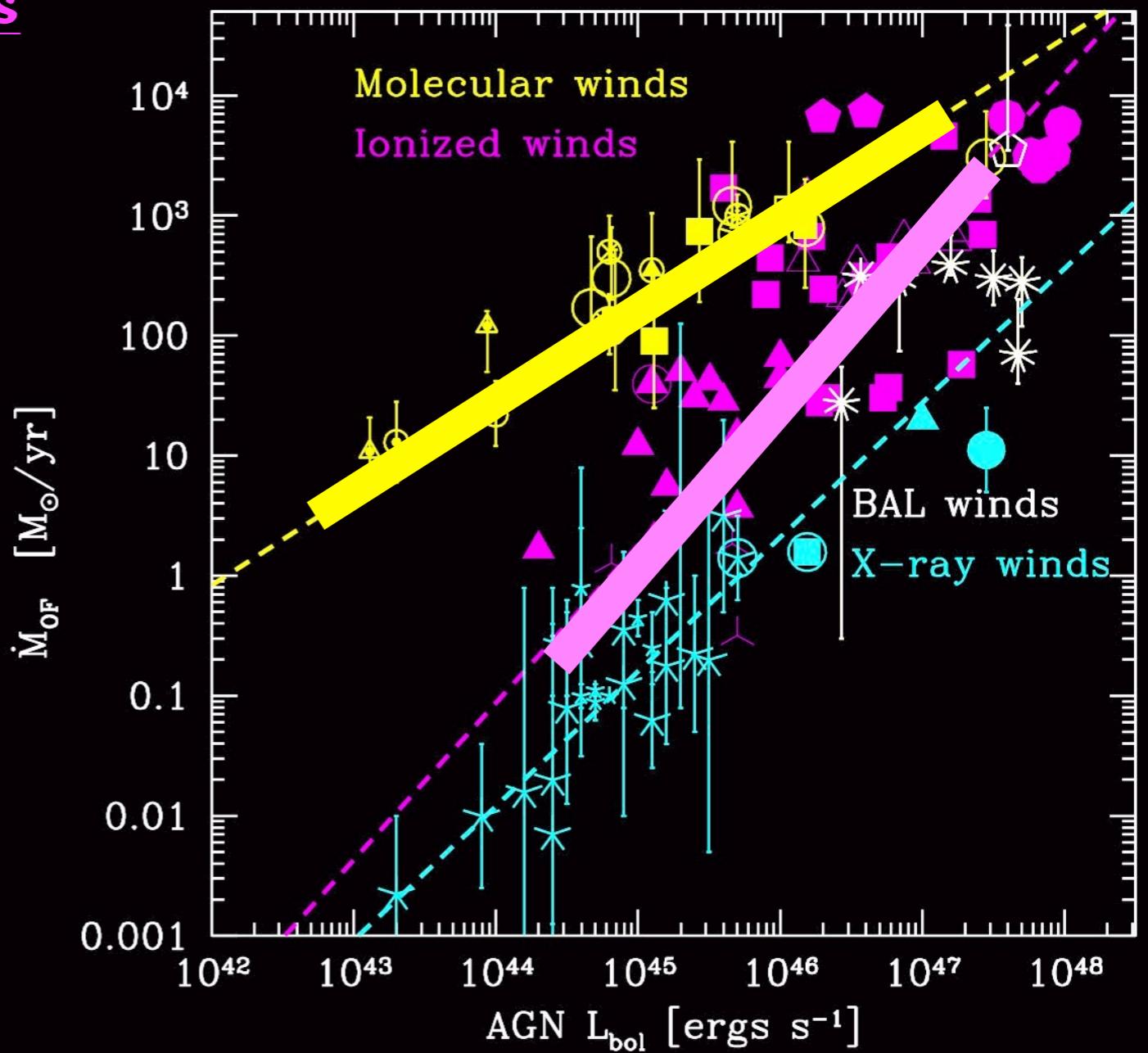


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$$\text{Molecular } \dot{M}_{\text{OF}} \sim L_{\text{bol}}^{0.75}$$

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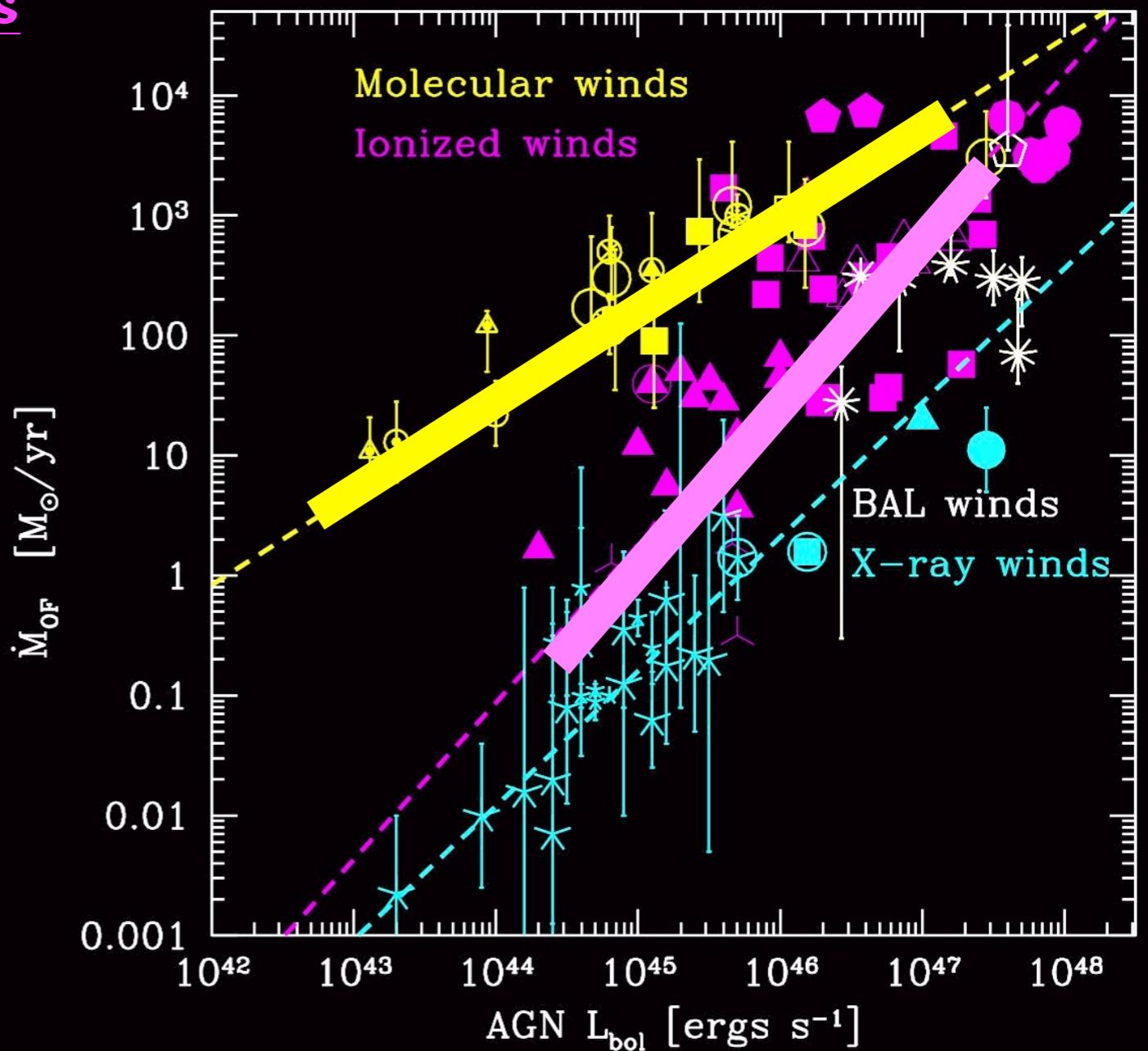
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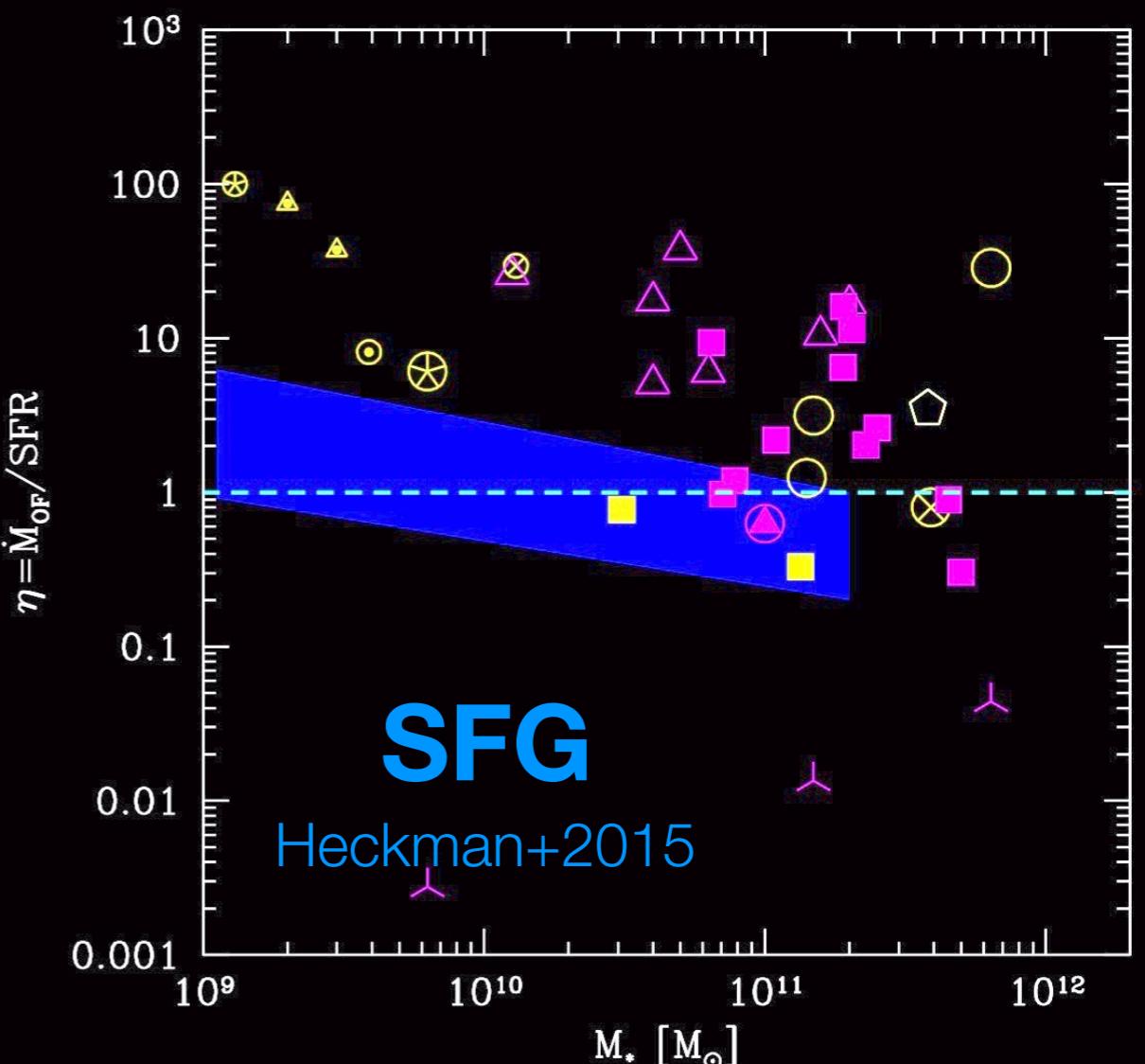
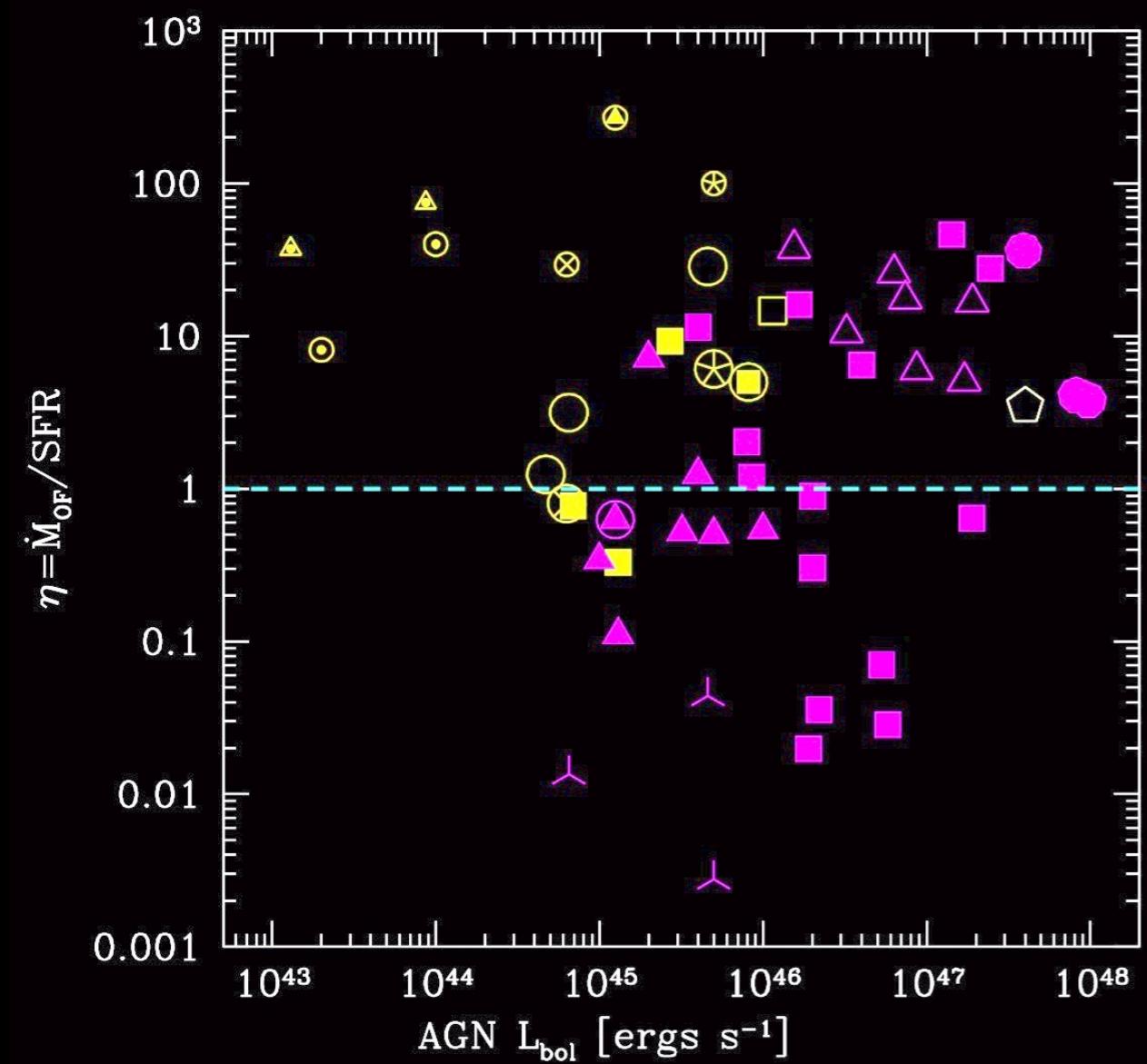
The mass ratio  
molecular/ionized wind  
reduces at high  $L_{\text{bol}}$



# AGN wind loading factor

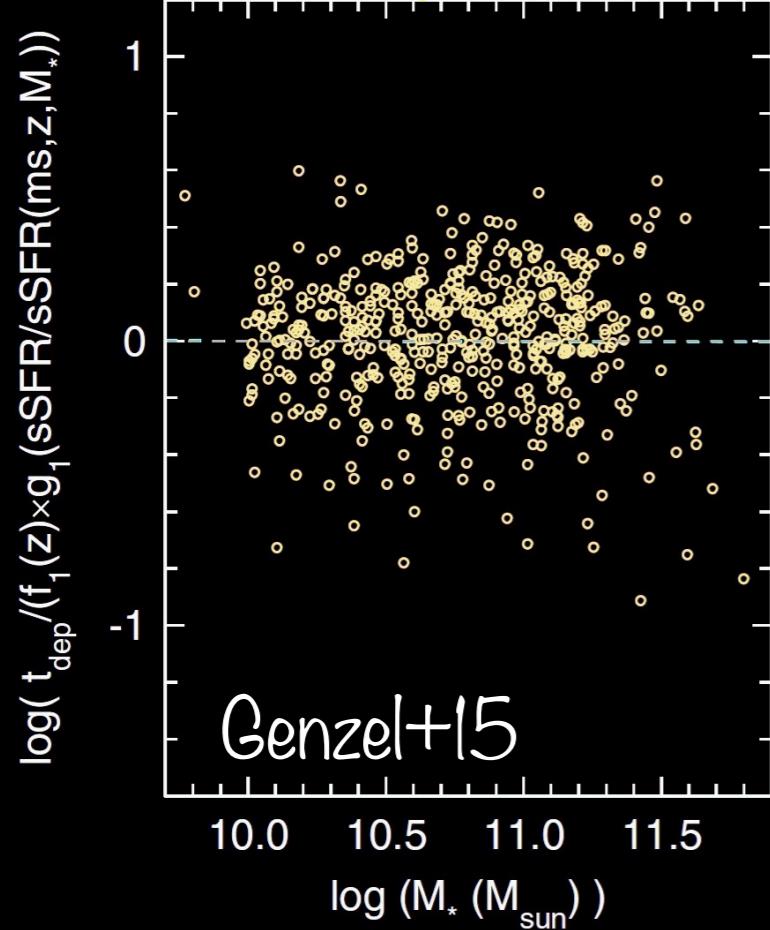
$$\eta = \dot{M}_{\text{OF}} / \text{SFR}$$

factor  $\sim 10$  larger than SFG winds

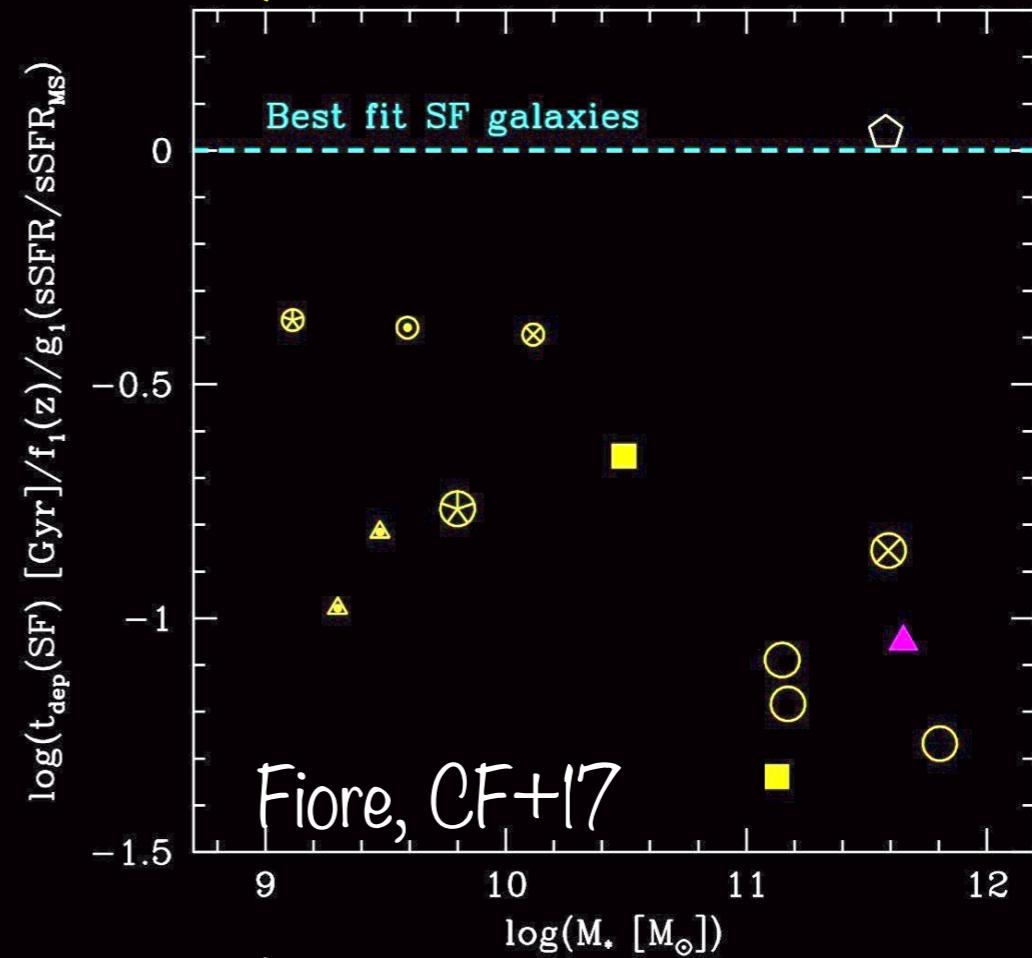


# Scaling relations: Depletion Timescale

SF galaxies



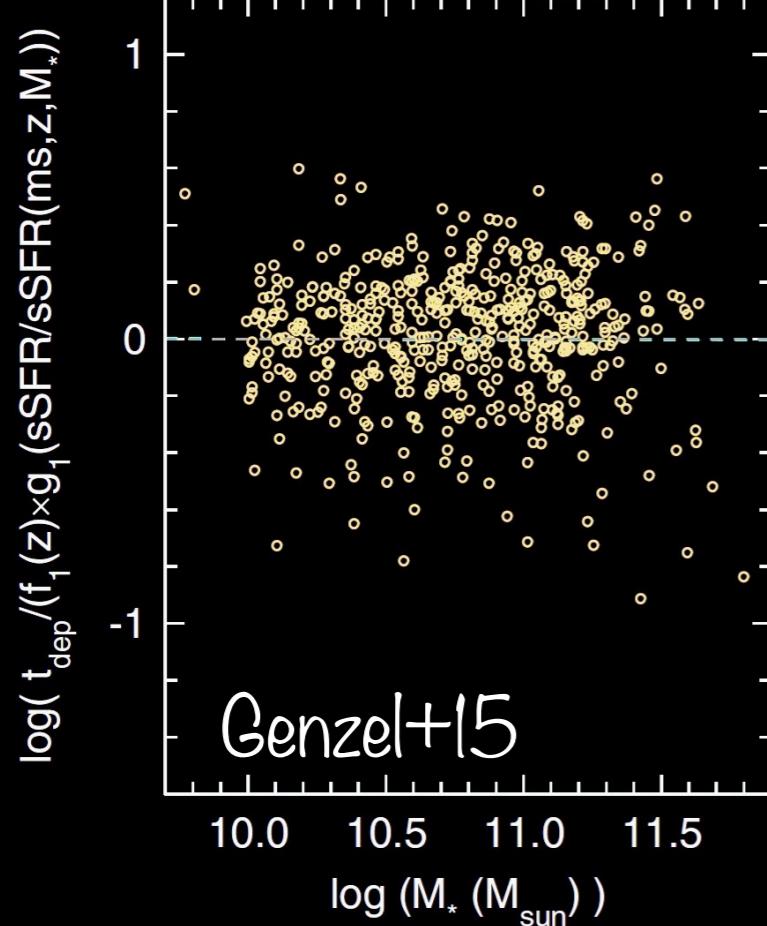
Galaxies with molecular outflows



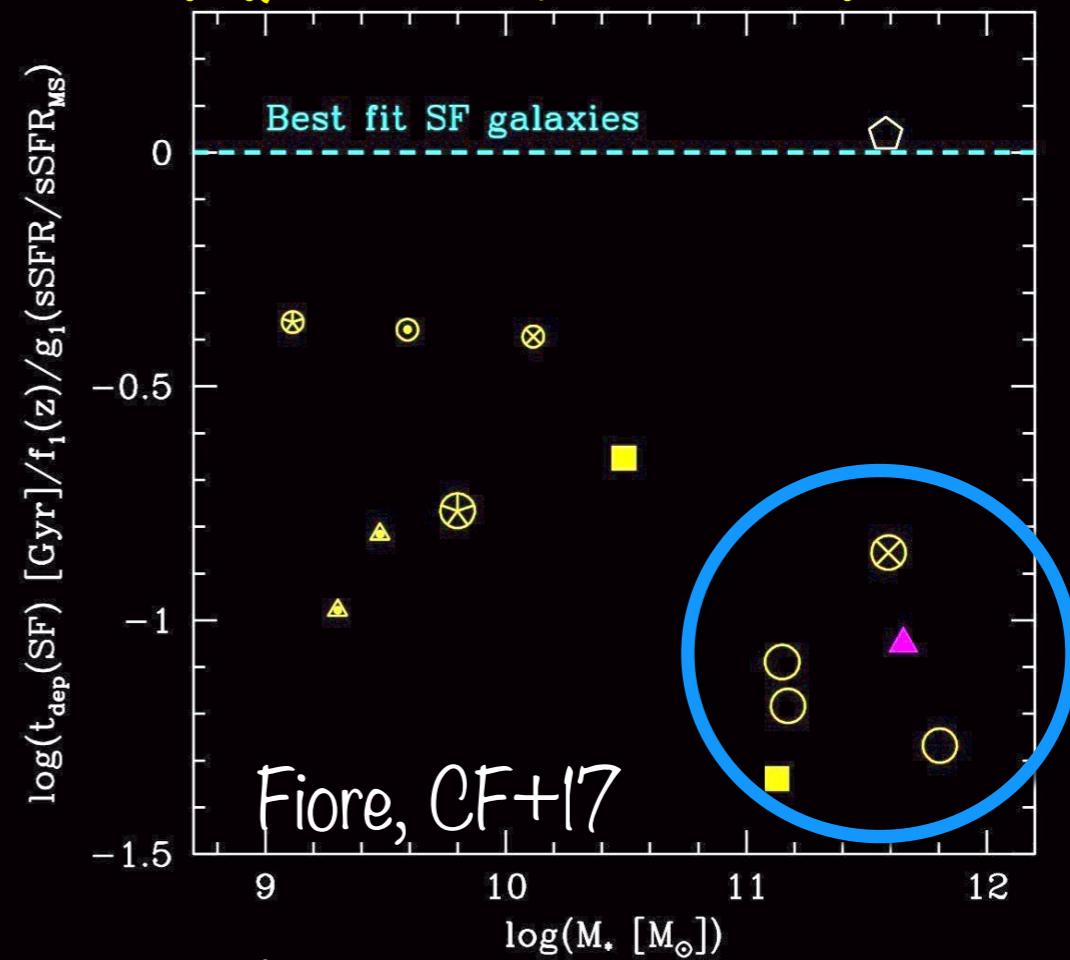
Gas depletion timescale ( $M_{\text{gas}}/\text{SFR}$ ) normalised for trends with  $z$  and offset from SF galaxy MS

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Gas depletion timescale ( $M_{\text{gas}}/\text{SFR}$ ) normalised for trends with  $z$  and offset from SF galaxy MS

$t_{\text{dep}} \sim 3\text{-}30 \text{ times shorter than average at high } M_*$

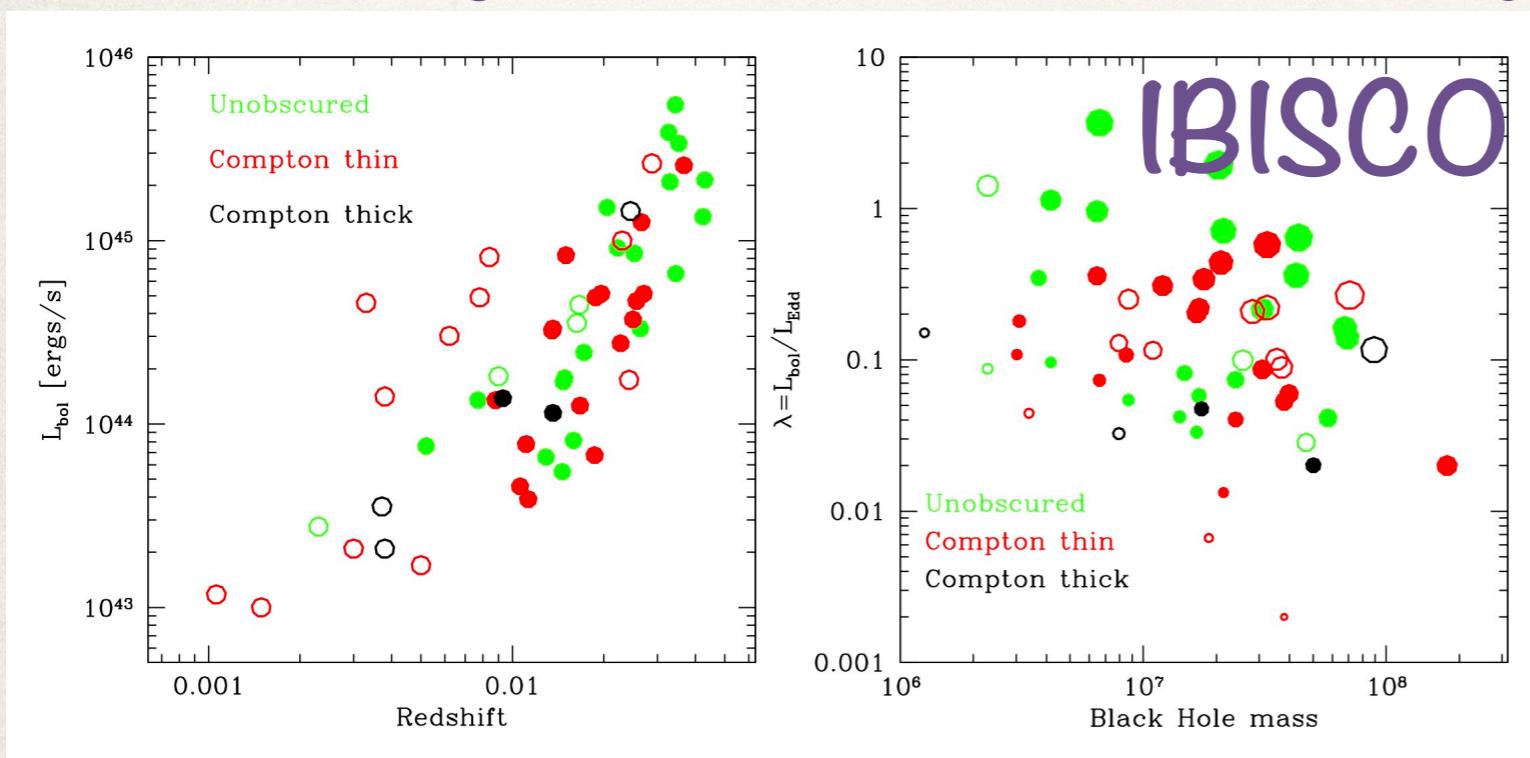
# The IBISCO project

- ♦ Multi-dimensional study of feeding and feedback in unbiased sample
- ♦ Scaling relations  $\dot{M}$ ,  $\dot{M}/SFR$ ,  $M(H_2)/M^*$ ,  $t_{\text{depl}}$  with  $L_{\text{AGN}}$ ,  $M_{\text{BH}}$ ,  $\lambda_{\text{Edd}}$
- ♦  $\dot{M}_{\text{acc}}$  scaling with  $M(H_2)$

## IBISCO sample:

- ♦ Hard X-ray selected AGN from IBIS Integral Survey - unbiased vs.

nuclear obscuration



- ♦  $L_x > 10^{43} \text{ erg/s}$
- ♦  $z < 0.05$
- ♦ Accurate BH masses

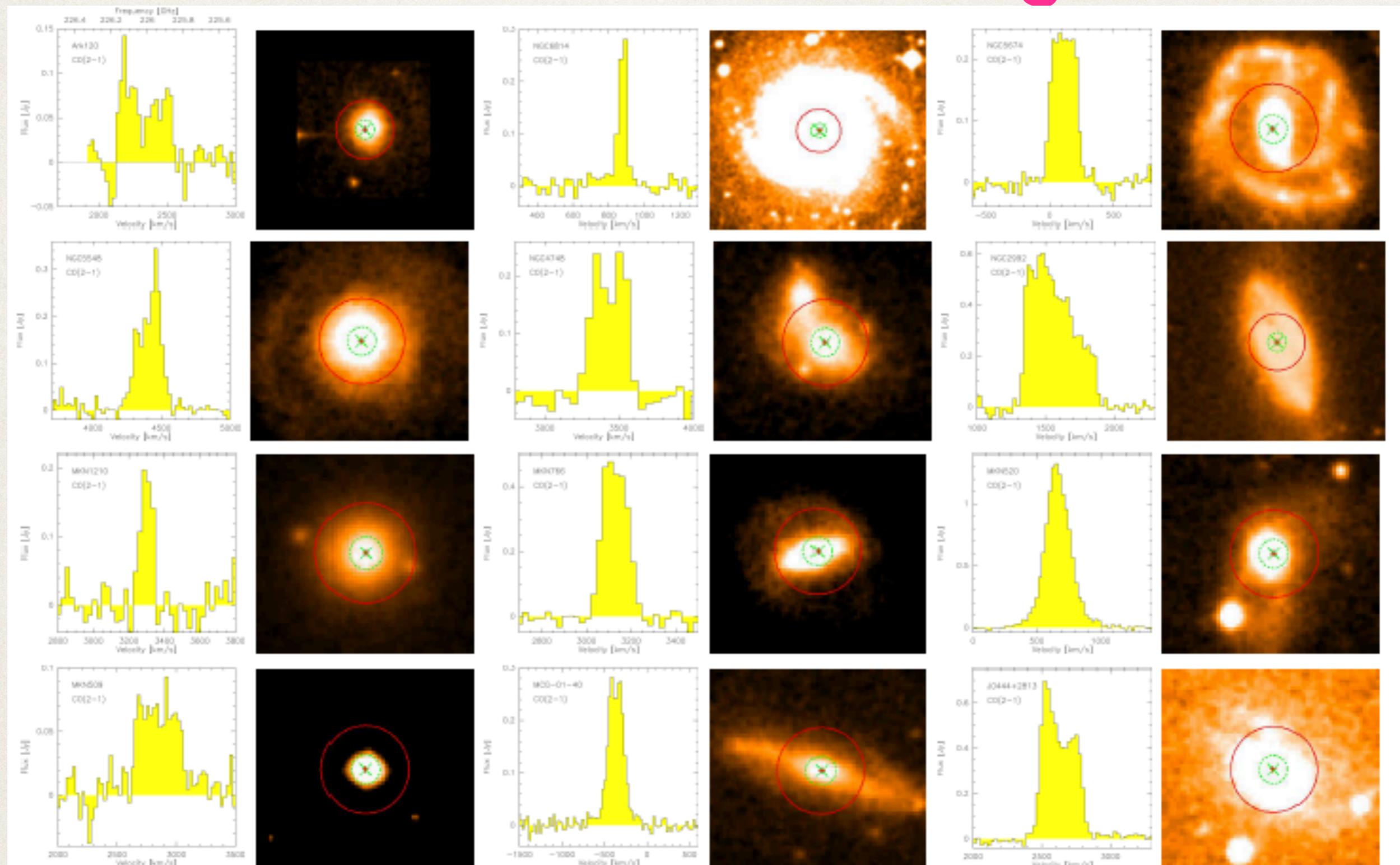
# The IBISCO survey

Establish a observationally motivated, dynamic view  
of the impact of AGN feedback on SF process

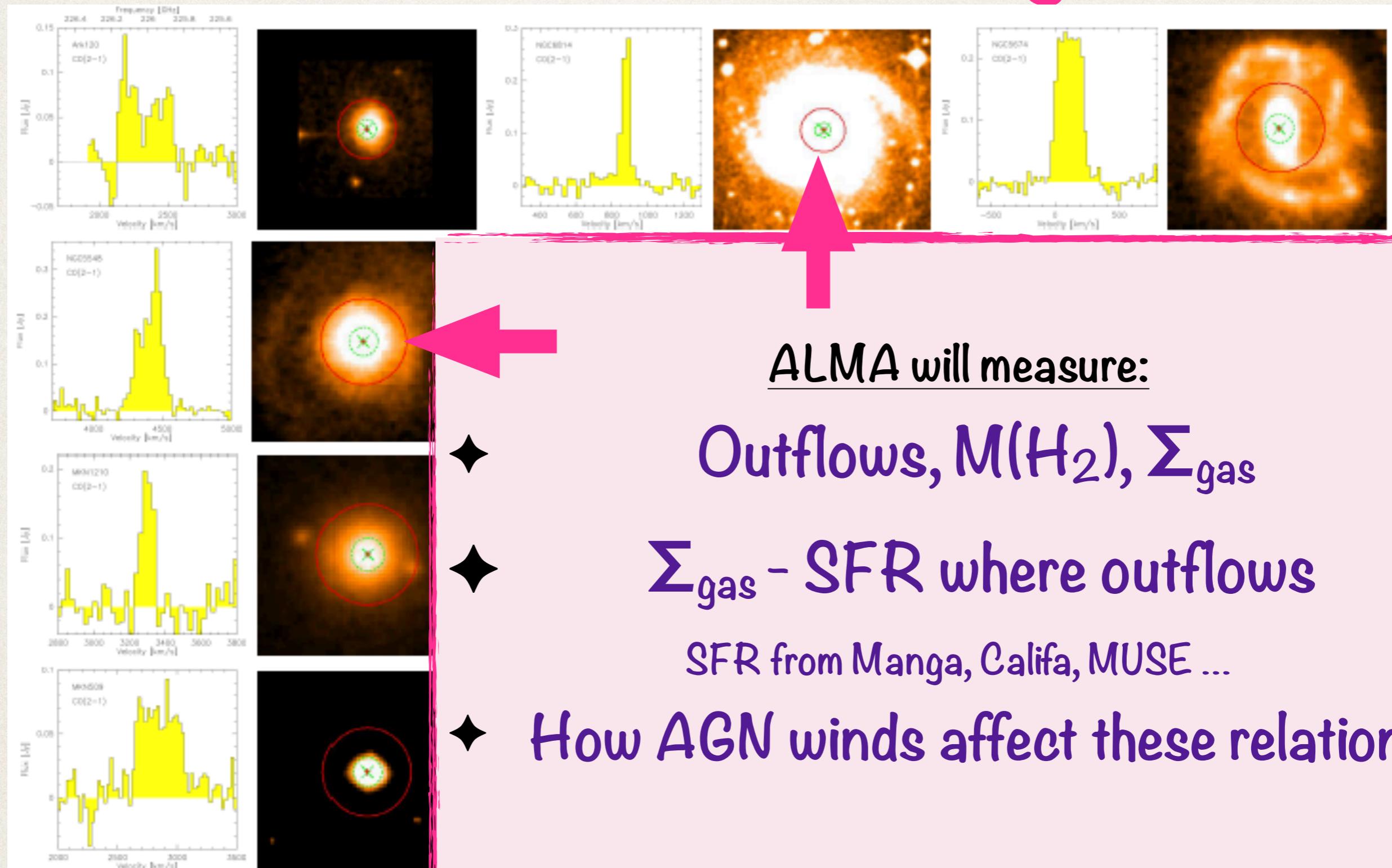
First Unbiased survey of H<sub>2</sub> reservoirs + outflows in 60 AGN hosts:

- @IRAM 30m (CO 1-0/2-1) - PI Feruglio  
70 hours survey completed 2017 - 70% detection rate
- ALMA band 6 : map CO with 50 pc resolution - PI Feruglio  
approved in cycle 5
- NuStar/XMM data Detailed X-ray spectral analysis - PI Malizia  
L<sub>x</sub>, NH, WA, UFOs

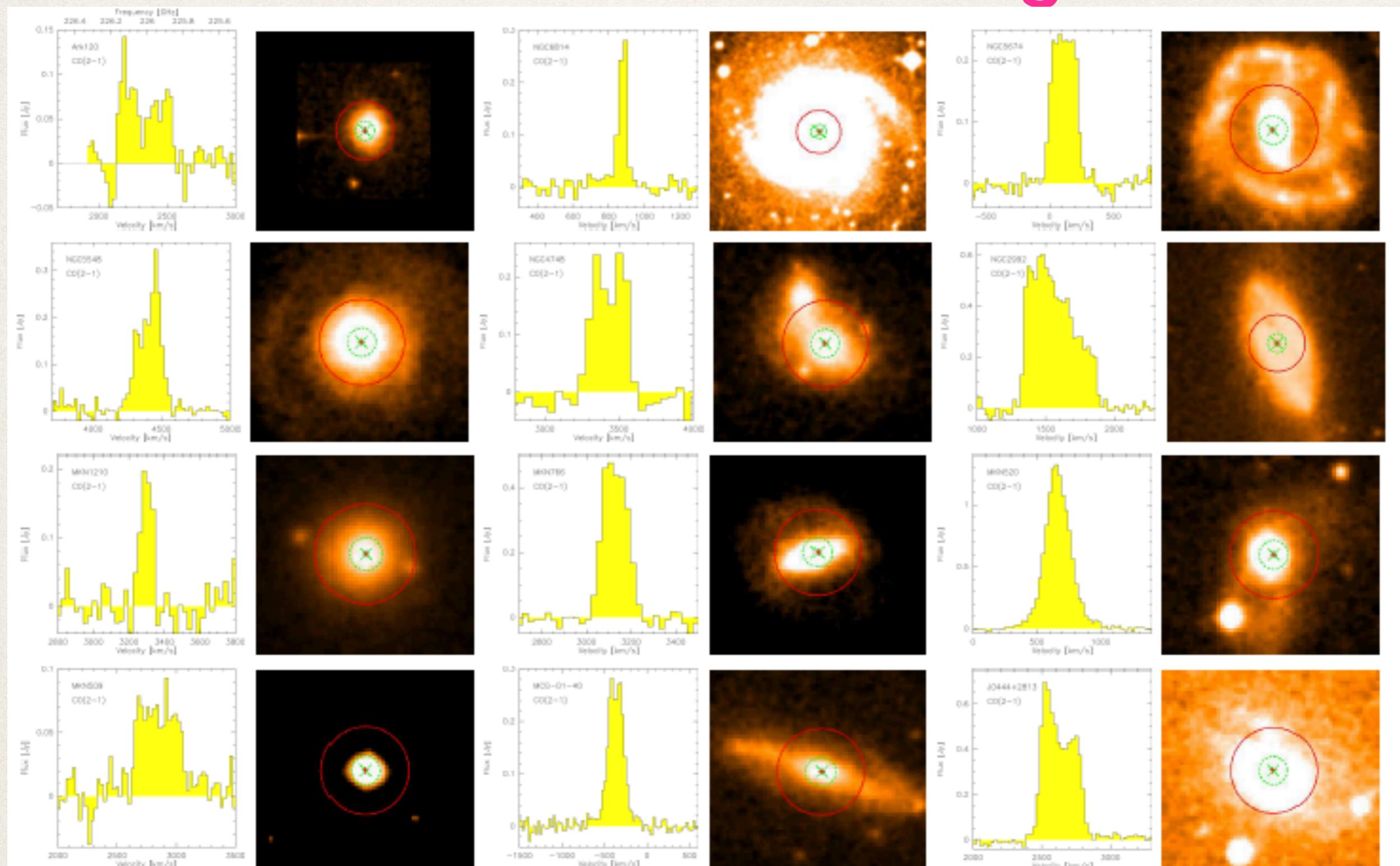
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# IBISCO - Feeding

Scaling of  $\dot{M}_{\text{Acc}}$ ,  $\dot{M}^*$  and  $M(H_2)$  for an unbiased sample

$\dot{M}^* \propto SFR$  (various indicators : H $\alpha$ , UV, Radio...)

$\dot{M}_{\text{Acc}} \propto L_{\text{bol}}, M_{\text{BH}}$        $L_{\text{bol}} = \epsilon \dot{M}_{\text{Acc}} c^2$        $\epsilon = 0.1$

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An example: NGC1068

$L_{\text{bol}} = 9 \times 10^{43}$  erg/s

$\dot{M}_{\text{Acc}} = 0.016 M_{\odot} / \text{yr}$

ongoing SFR in CND

$= 1.6 M_{\odot} / \text{yr}$        $= \dot{M}^*$

$\dot{M}^* / \dot{M}_{\text{Acc}} = 100$

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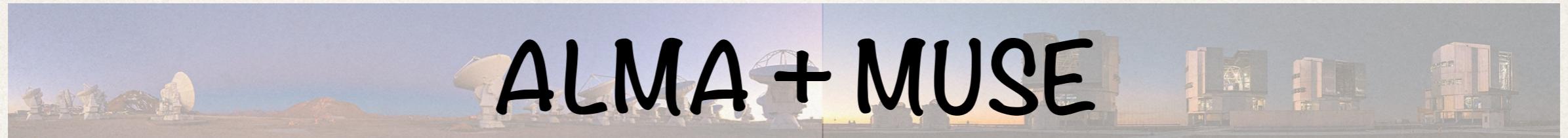
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Disk Instability

(Feruglio et al. in prep)

# IBISCO - FUTURE PROSPECTS

PAIR THE TWO ESO'S FLAGSHIP FACILITIES :



JOINT CHARACTERISATION OF COLD AND IONISED GAS with 50-100 pc resolution

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Molecular outflows

Ionised: H $\alpha$  Star Formation  
[OIII] ionised outflows

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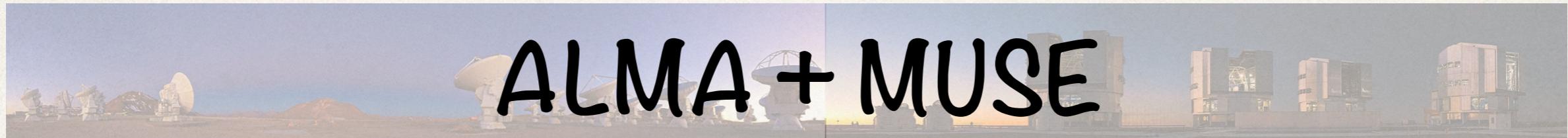
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- IMPACT OF AGN FEEDBACK

• CHEMICAL ENRICHMENT AND MIXING

ACROSS GALACTIC NUCLEI & LINKED TO THE LOCAL CONDITIONS

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FAR REACHING IMPLICATIONS ON THEORETICAL MODELS & SIMULATIONS  
BRIDGING FIELDS OF STAR FORMATION AND GALAXY/AGN EVOLUTION