# Blowin' in the wind:
## feedback from QSO outflows at high-z

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*Music by:* B. Dylan

The interplay between local and global processes in galaxies

Cozumel, 12/4/2016

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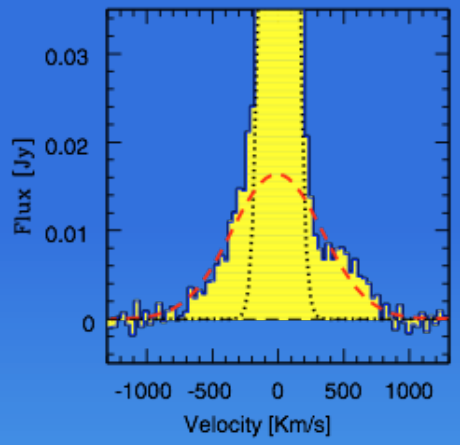
# *AGN Negative Feedback on host galaxies*

Galaxy-scale Outflows routinely observed as broad wings of forbidden lines in ionized gas and in molecular/neutral gas




Local galaxies:

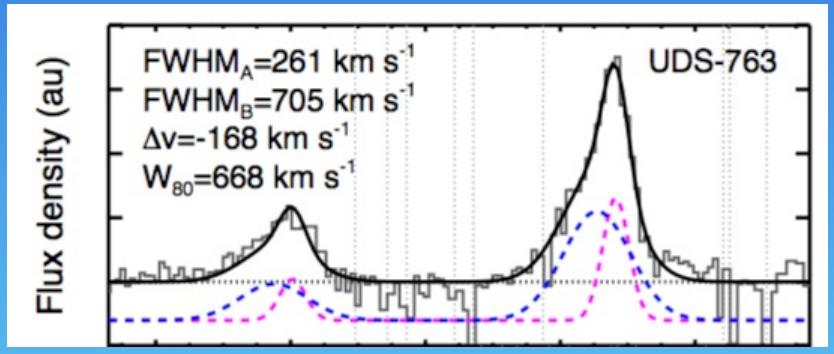
Feruglio et al. (2010): massive molecular outflow from CO(1-0) in Mrk231

*(see also Feruglio et al. 2013, Cicone et al. 2014, Sturm et al. 2011, Rupke & Veilleaux 2012, Davies et al. 2014, Feruglio et al. 2015, Tombesi et al. 2015, also Rodriguez-Zaurin et al. 2011, Zakamska & Green 2014, Liu et al. 2012,2013, Greene et al. 2009, 2012, etc)*

High-z galaxies:

Harrison et al. (2015): KMOS on z~1 AGNs

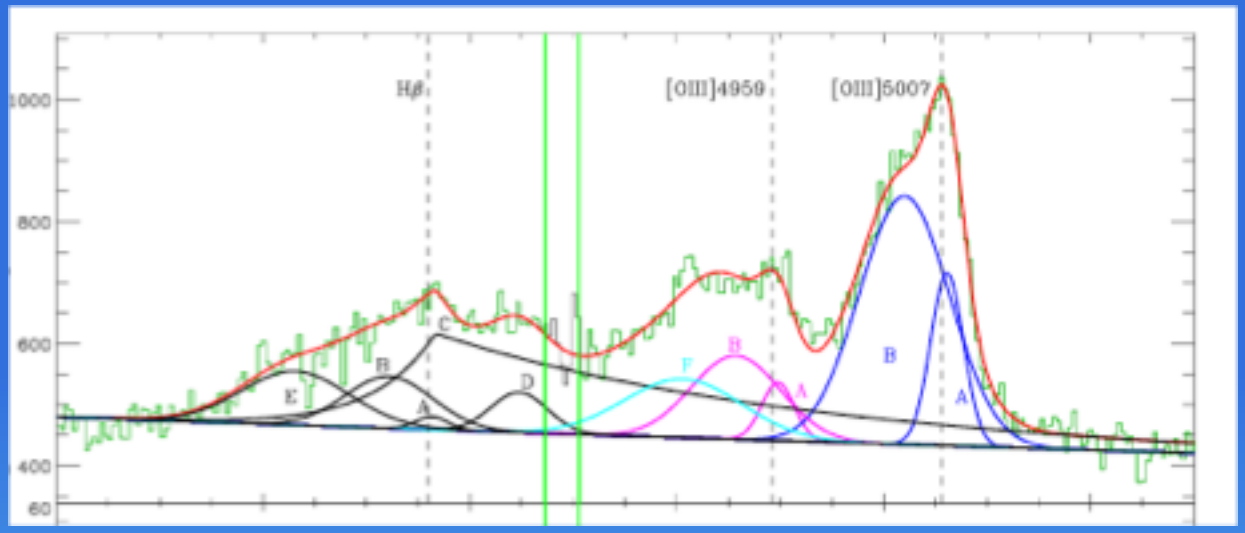
*(see also Nesvadba et al. 2009, 2011, Alexander et al. 2010, Allen et al. 2011, Forster-Schreiber et al. 2014, Genzel et al. 2014, Maiolino et al. 2012, Harrison et al. 2012, 2016, Zakamska et al. 2015 etc.)*



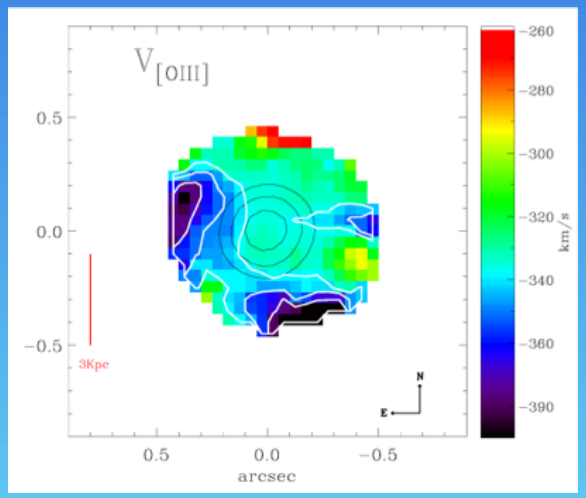

Many theoretical predictions, increasing evidences of widespread outflows, but still few observations of feedback effects on host galaxies…

# *Negative Feedback: observational evidences*

A first example of outflow effects on the SF in the host galaxy of a [OIII] luminous z=2.4 QSO

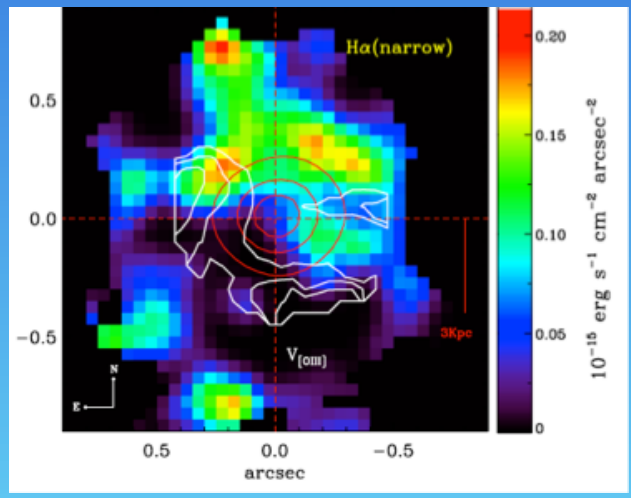



SINFONI H and K observations:
very asymmetric and broad [OIII]
FWHM ~1500 km/s



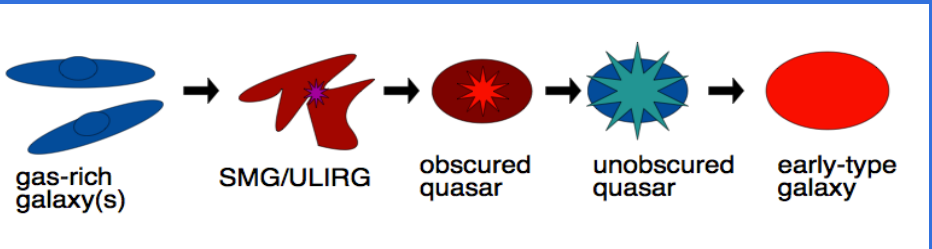

Asymmetric blueshift in the velocity map

No star formation traced by narrow Ha with fast outflow:
"negative" feedback




*Cano-Diaz, Maiolino, GC et al. (2012)*

# *Selecting outflowing AGNs*

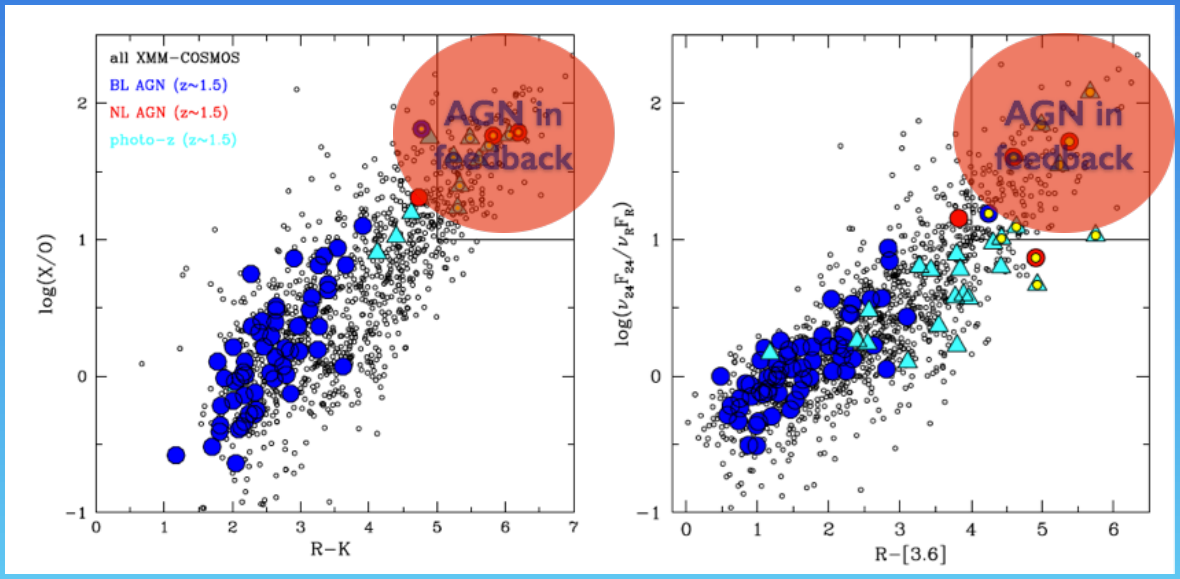



*Models predict:*

- short blow-out phase (<100 Myr)
- BH growth and SF "simultaneous"
- *blow-out/feedback phase obscured but IR bright?*

**Selecting X-bright but optically obscured QSOs to catch feedback at its peak:**

- Large area X-ray survey: XMM-COSMOS
- Selection based on X-ray to optical (luminous), MIR to optical (obscured) and NIR to optical (high-z) colors (Brusa et al. 2010)




10 brightest (Lx>44, K<19) targets at z~1.5 observed with VLT X-Shooter

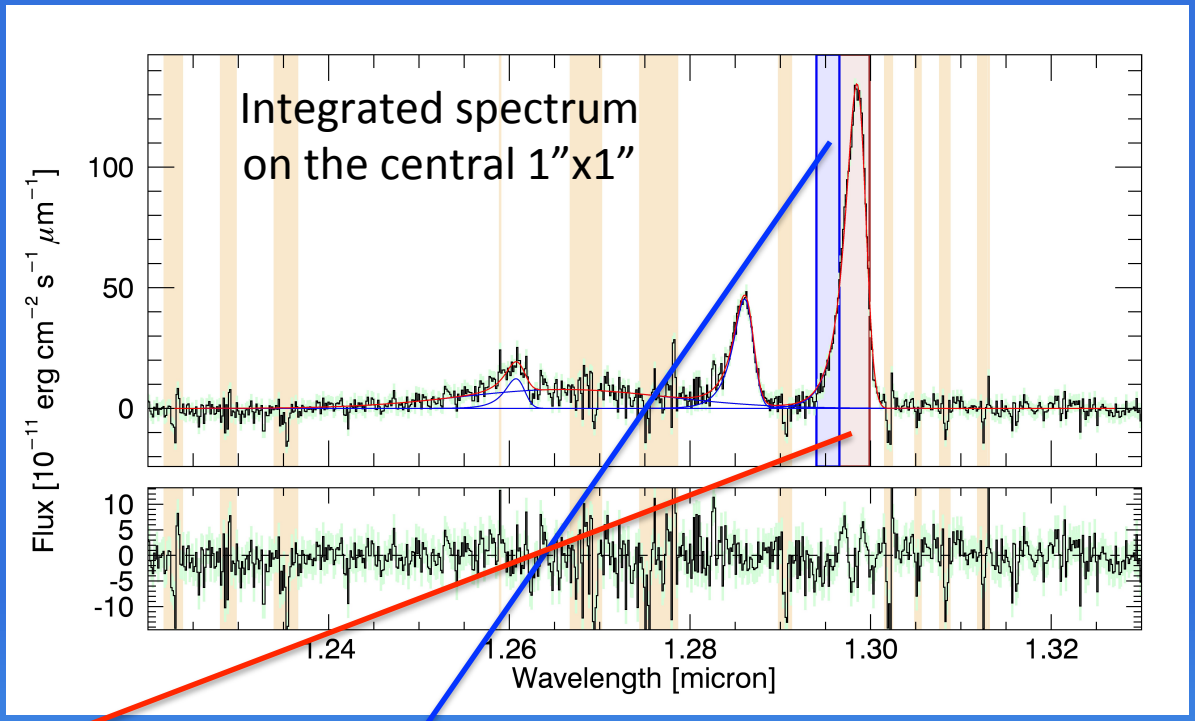
*(Brusa, GC et al. 2015)*

- Massive ($M_*>10^{11}$ $M_\odot$) but Main Sequence galaxies
- All Radio-quiet
- 75% showing outflows

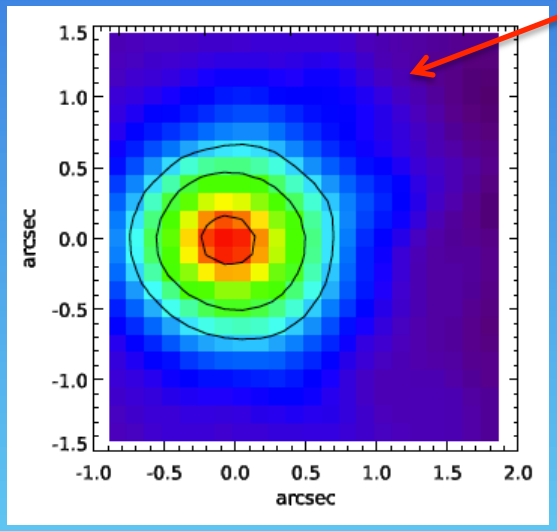
*Brusa, Bongiorno, GC et al. (2014)*

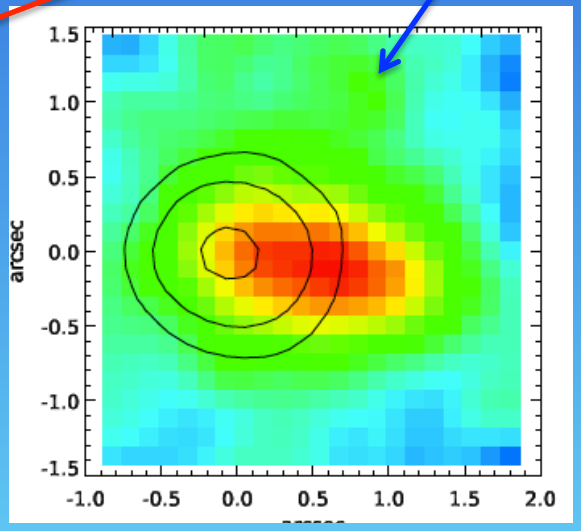
# *SINFONI observations of high-z feedback: XID2028*

J band, 6 hrs
*Scale 0.125”x0.125”*
*PSF=0.6”*



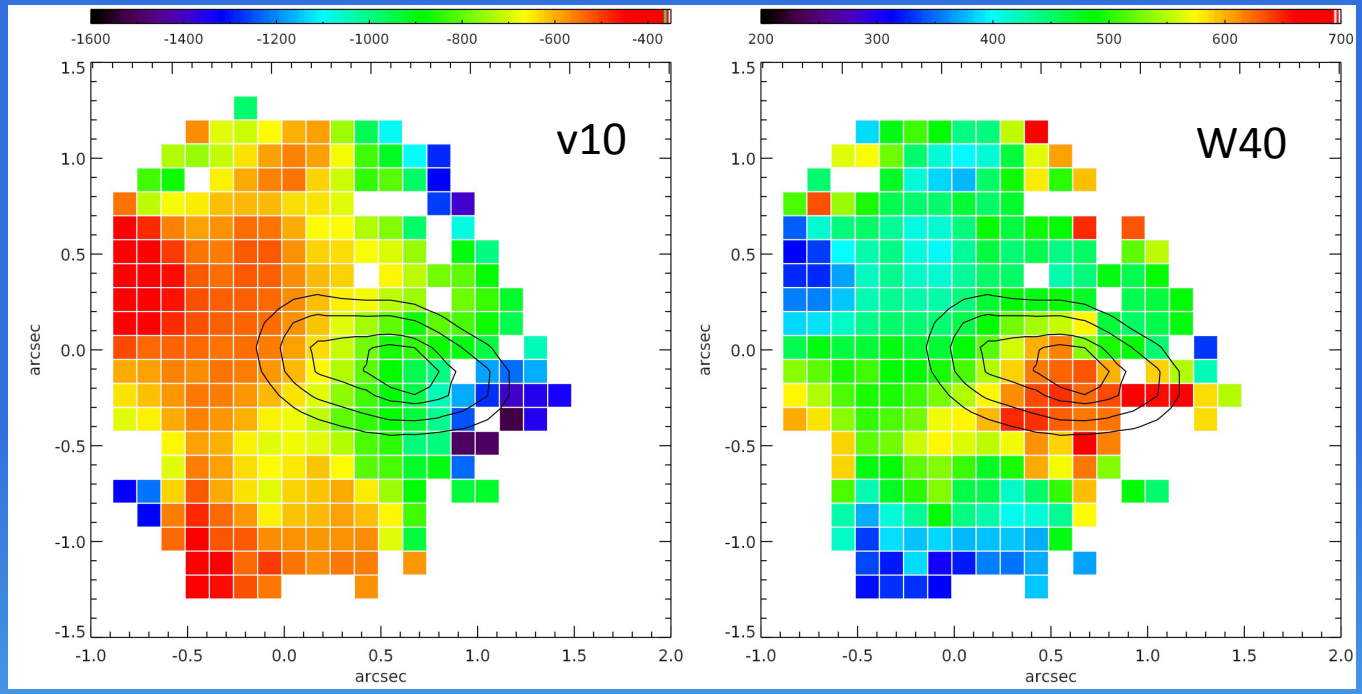

*GC, Mainieri, Brusa, Marconi et al. (2015)*




Integrated flux maps on the line core (left) and on the line wing (right)

# *Outflow dynamics & energetics*



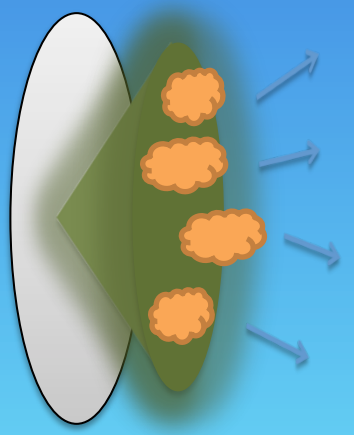

Outflow with v(out)~1500 km/s out to 13 kpc

Dispersion peaking at wing position
-> *no rotation*
high velocities and σ
-> *outflow not infall*

From Hβ luminosity we derive $\dot{M}_{(ion,out)}$>300 $M_\odot$/yr

This translate in a mass loading factor $\dot{M}_{(out)}$/SFR> 3
momentum flux $\dot{P}=\dot{M}_{(out)} \bullet v_{out} > 10\ L_{AGN}/c$

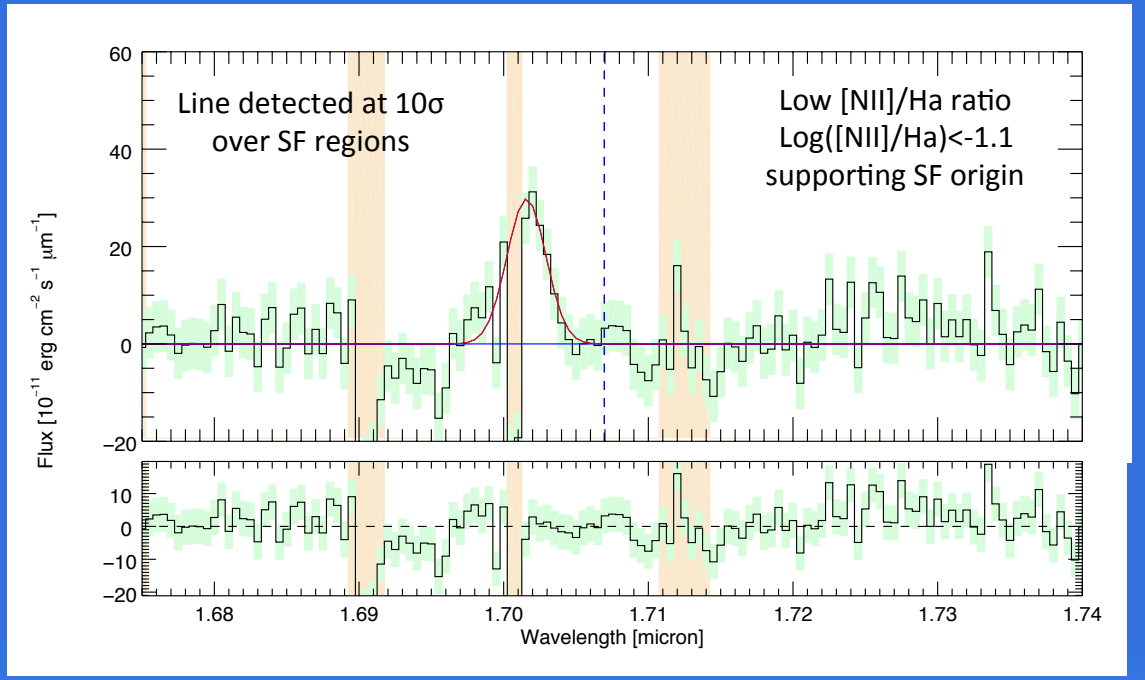
Outflow velocity and energetics suggest AGN driven outflow



# *Outflow effects on the host galaxy*

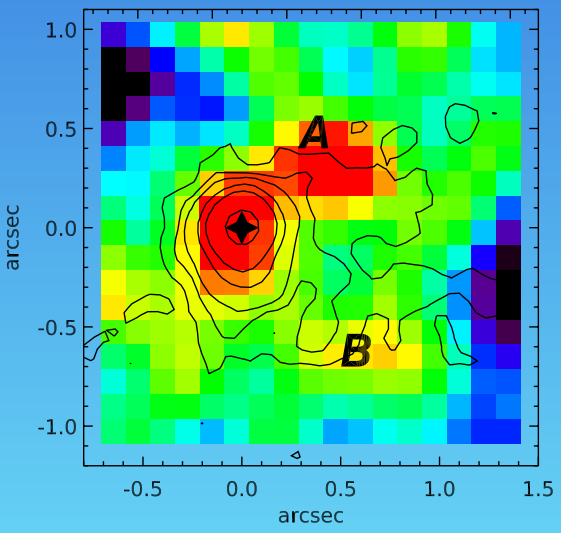
Archival H band (20')
integrated spectrum
on the central 1"x1"

Residual spectrum integrated
on Regions A and B

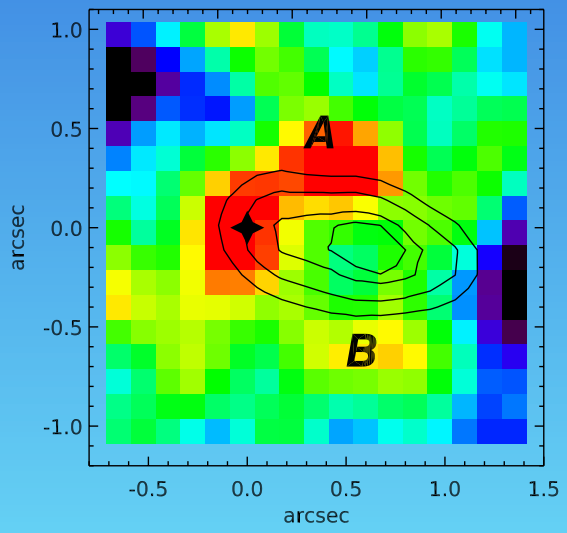


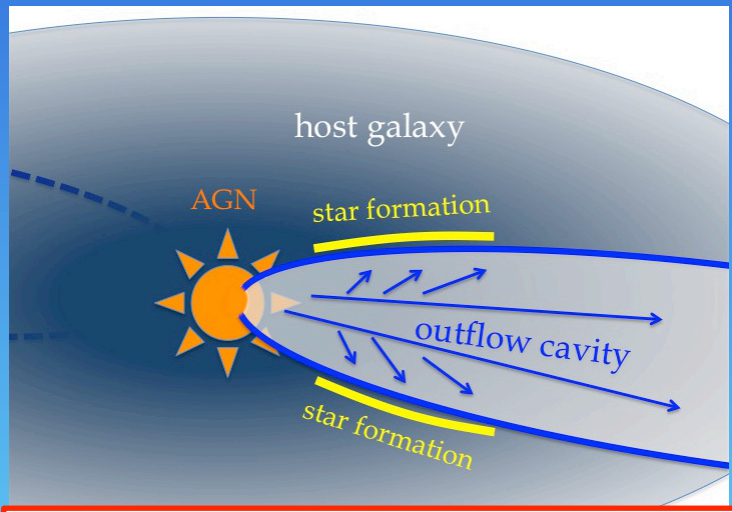

*Narrow Ha map with contours of:*

Rest frame U band (HST)




[OIII] blue wing flux



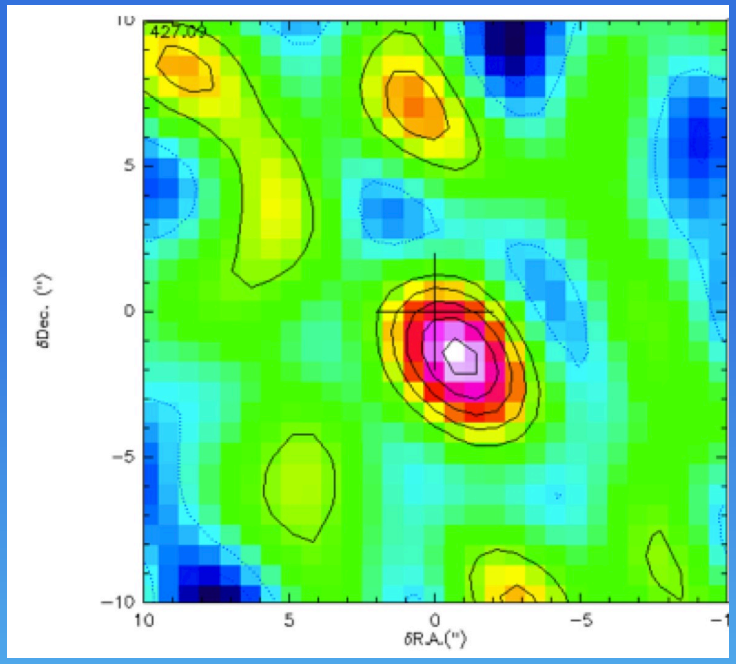




*Both "Positive" and "Negative" feedback in action*

# *Gas content of XID2028*

## IRAM PdBI observations

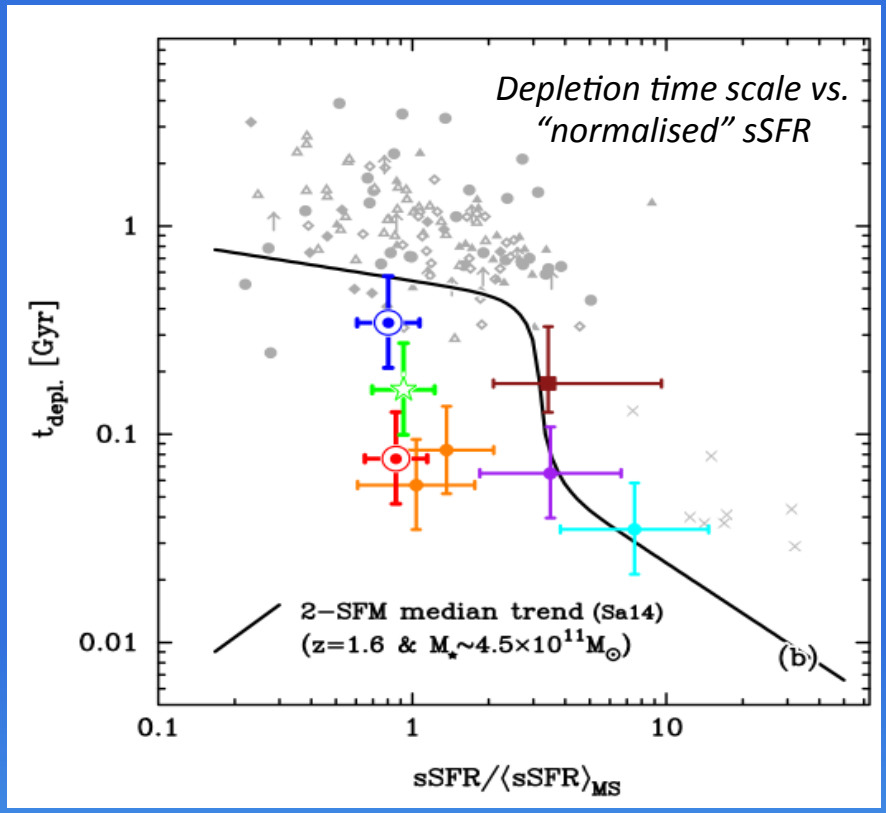
CO(3-2) observed @133.37 GHz;
5σ detection in 2.5 hrs




*Brusa, Feruglio, GC et al. 2015*

Log L'(CO) ~ 10.55 K km/s pc$^2$

$M_{gas}$ ~ 2-20 x $10^{10}$ $M_\odot$
(depending on $\alpha_{CO}$)

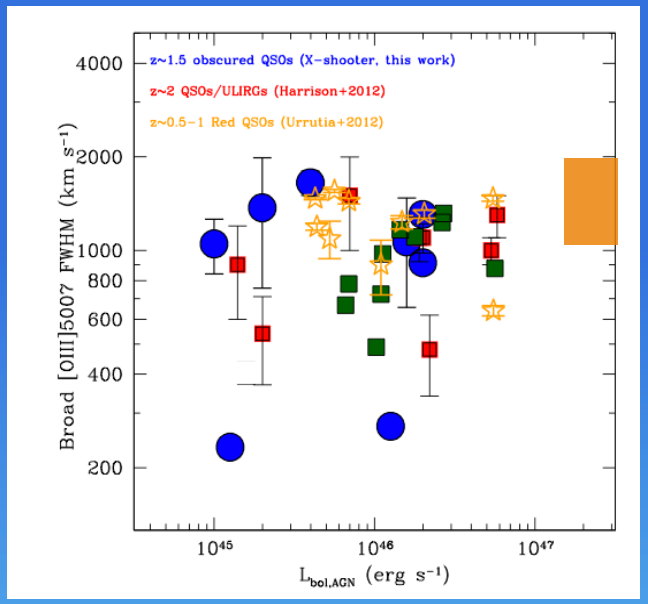



**XID2028** is among the objects with the **lowest gas fraction (<30%) for its sSFR** detected so far at high-z and a **clear outlier** in the **$t_{depl}$-sSFR plane,** a factor ~2 to 10 below the expected position on the plot

**QSO feedback**
**Removing gas from the host**

# *More outflows: High EW([OIII]) selection*

Additional sample of 6 QSOs at z~2.4 selected for high EW([OIII])>10Å observed with SINFONI:

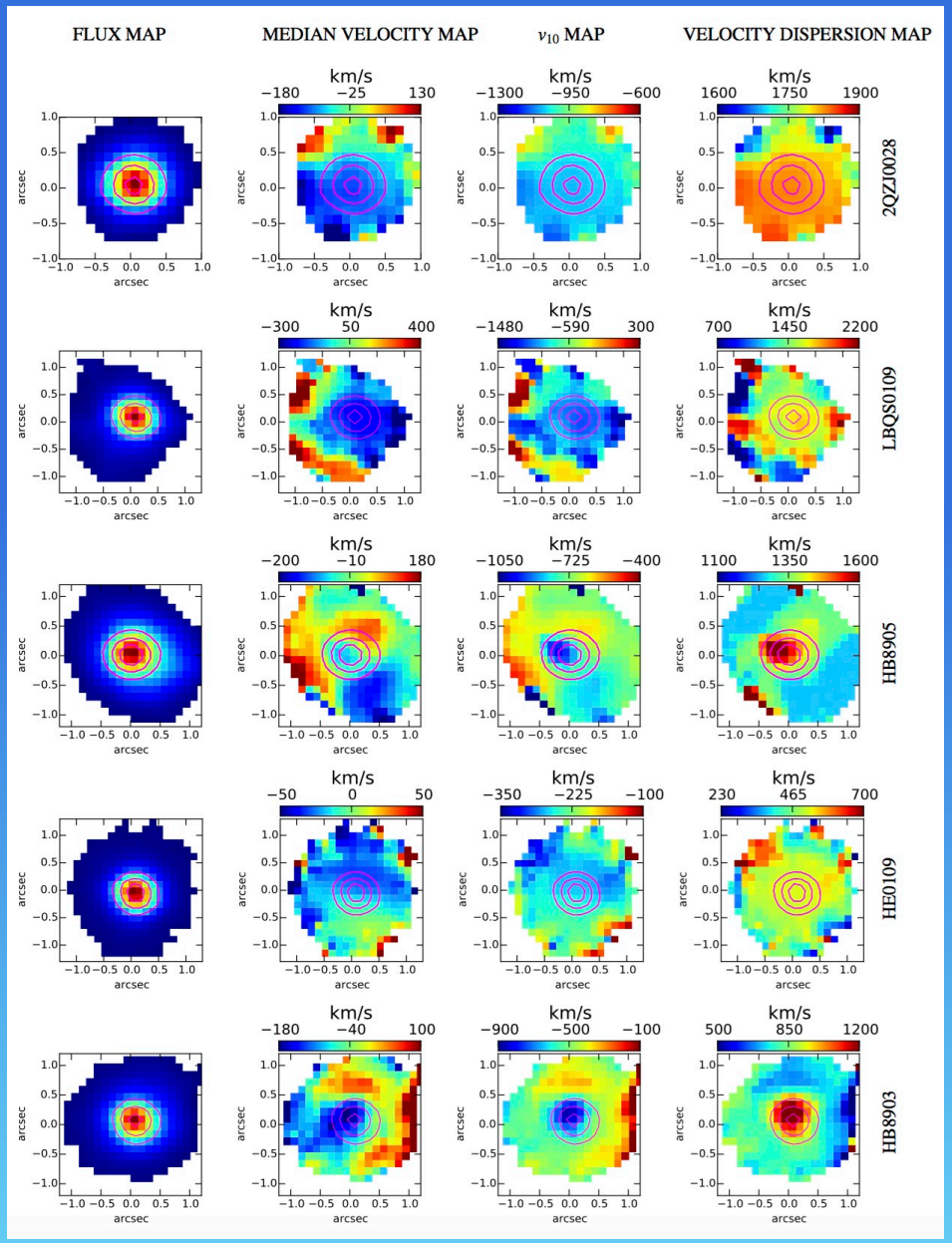



*Carniani, Marconi, GC et al. 2015*

Spatially resolved [OIII] kinematical maps for 5 objects:

Broad [OIII], FWHM ~ 1000-1500 km/s

Outflow velocities > 500 km/s



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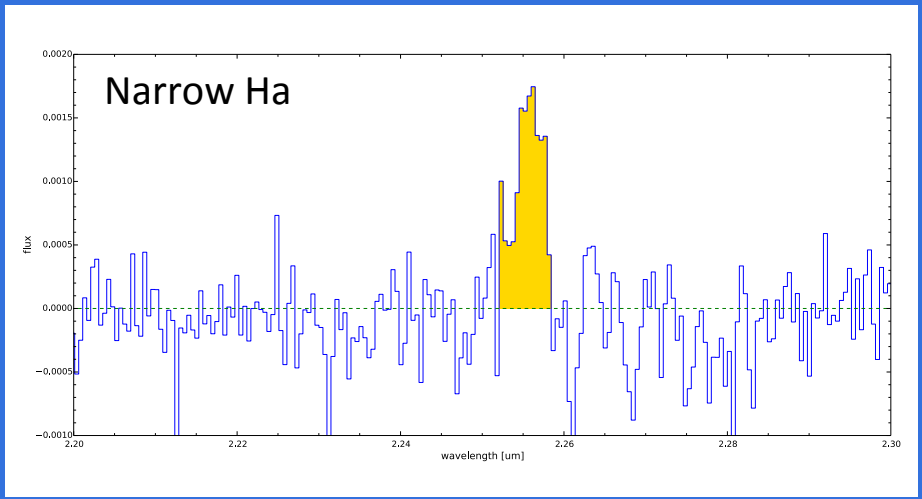
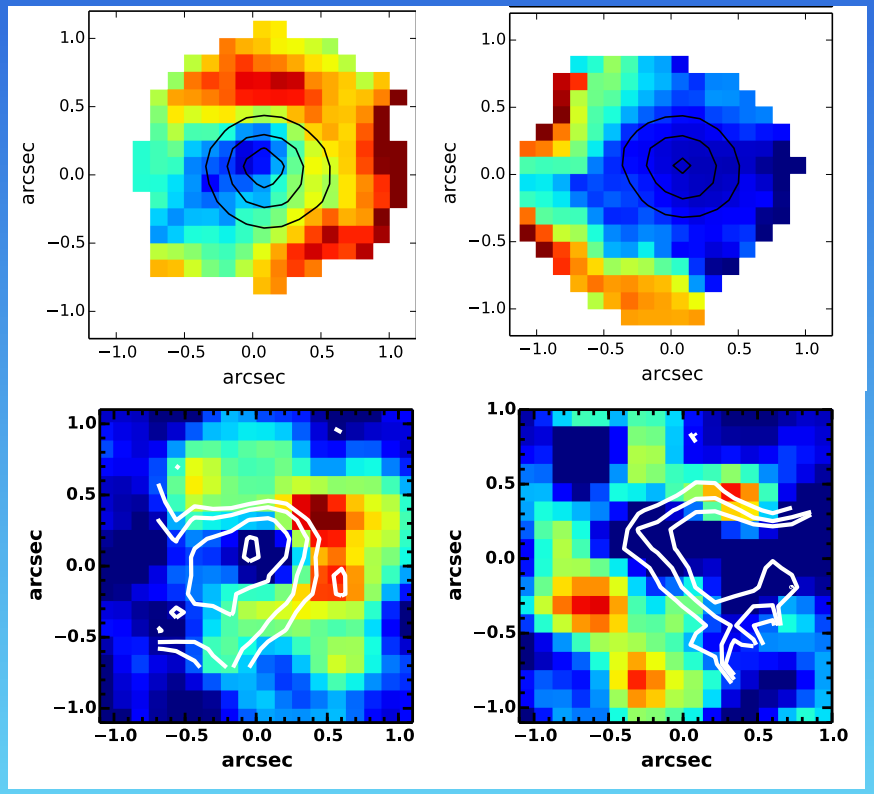



Subtracting broad components from Ha
Line profile shows narrow components
At the same z and FWHM of [OIII] ones

No [NII] emission → Star Formation!
100-150 $M_{sun}$/yr

Narrow Ha emission tracing star formation is
anti-correlated with fast outflows:

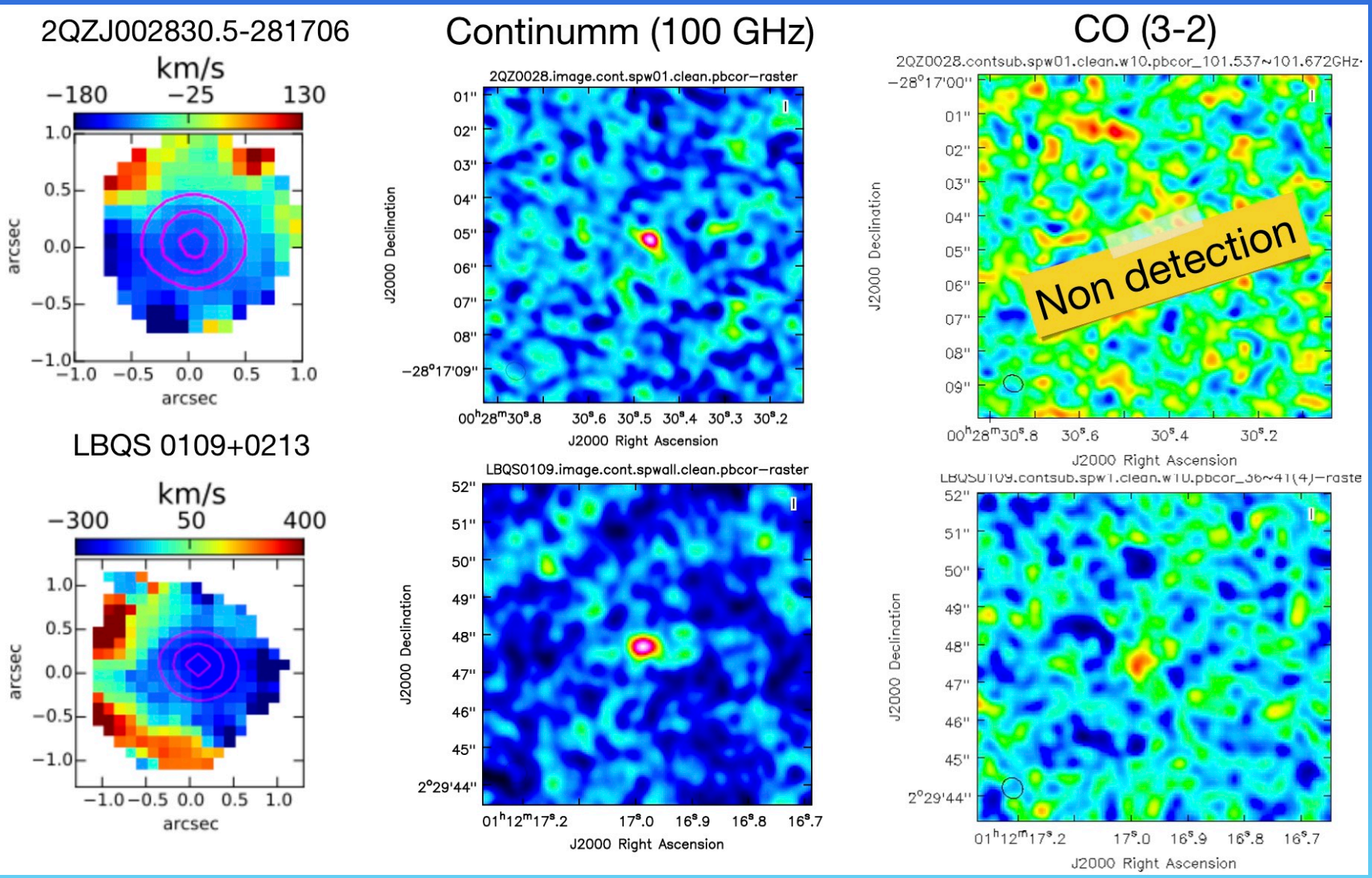
"negative" (+ "positive"?) feedback revealed




*Carniani, Marconi, GC et al. (2016)*

# *Preliminary results from ALMA Cycle 2*

Follow-up of the two targets with Ha mapping: Band 3 0.5” beam (~ SINFONI PSF)

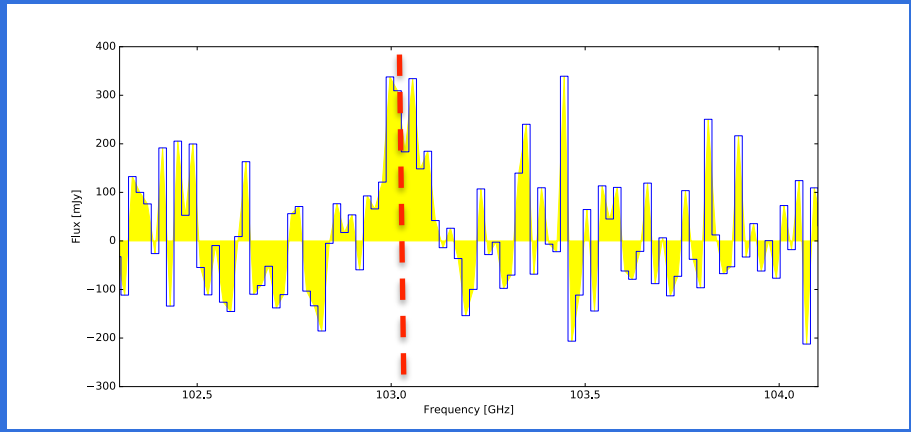


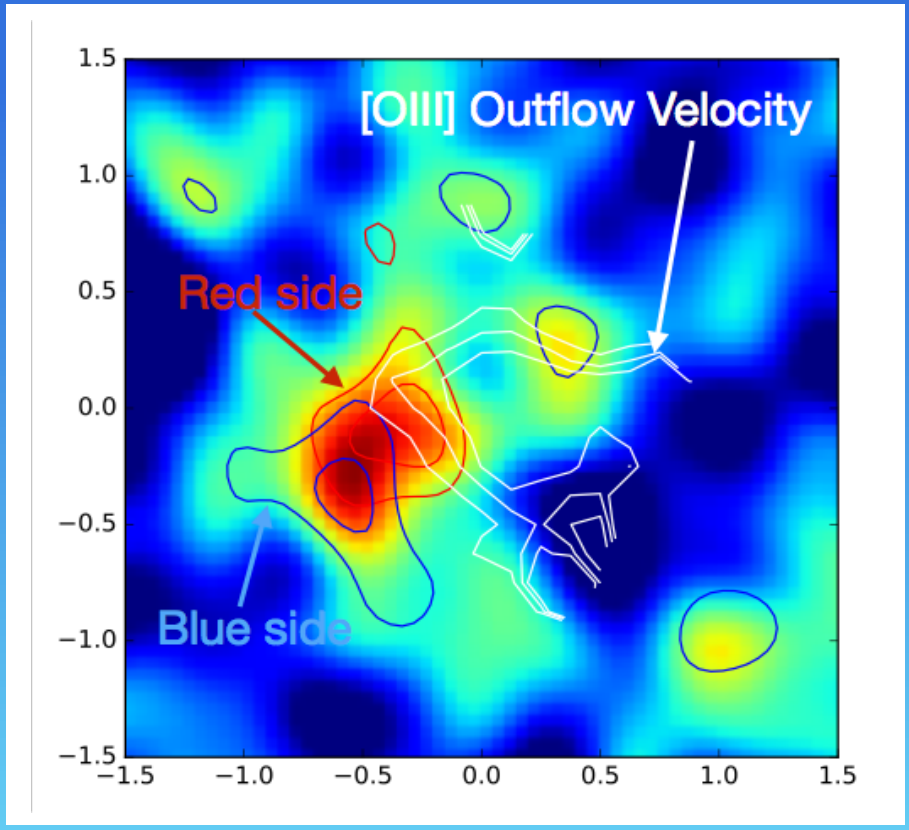
# *Preliminary results from ALMA Cycle 2*

Expected velocity from narrow H$\alpha$

FWHM ~ 300 km/s

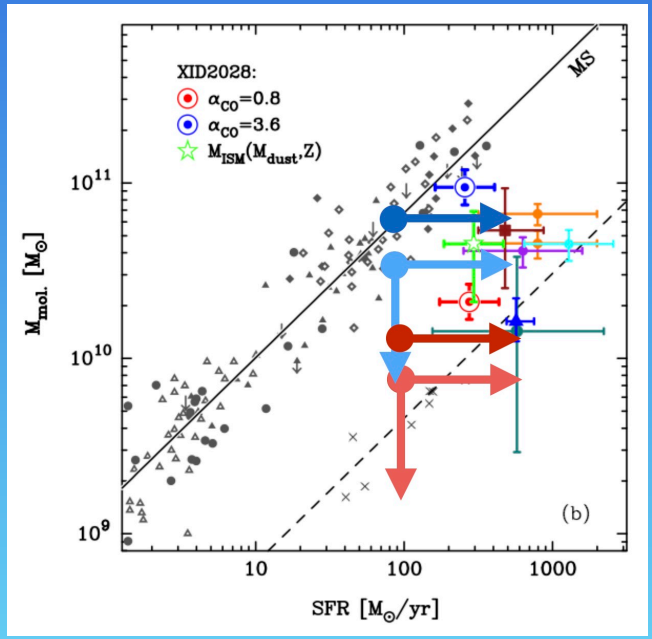
Horseshoe shape ~ anti-correlated with outflow



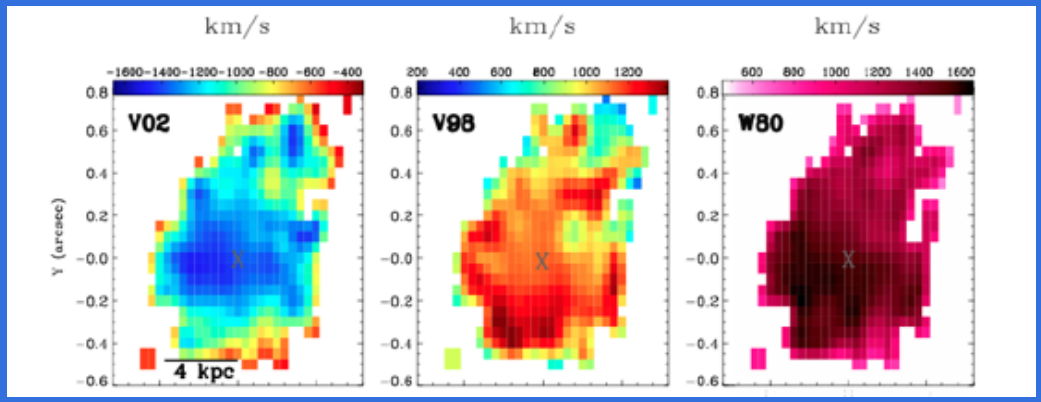

Estimated $H_2$ mass: ~1.2 $\times 10^{10}$ $M_\odot$:

QSO Feedback?

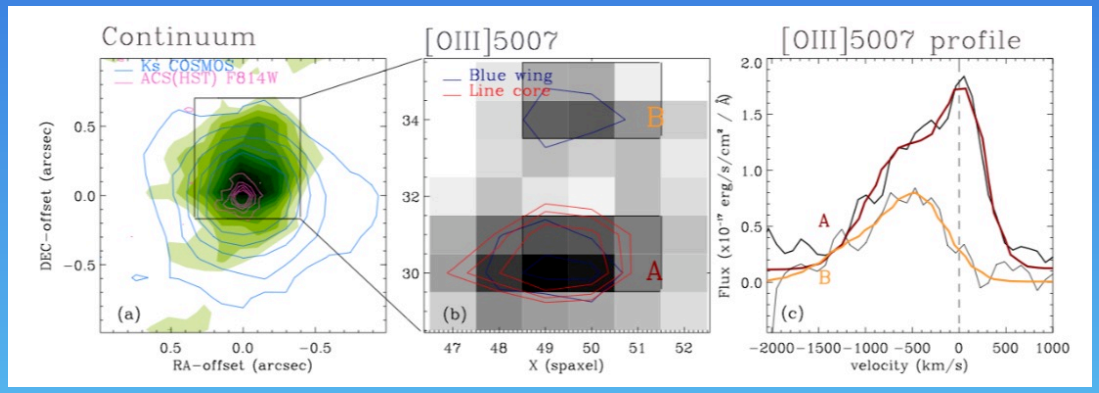


# *More outflows with different selections*

An extreme [OII] emitter at z ~1.47 observed with SINFONI + NGS AO (~0.2”): Both blue and red fast components (v>1000 km/s)




*Brusa, GC et al. 2016*




*Perna, Brusa, GC et al. 2015*

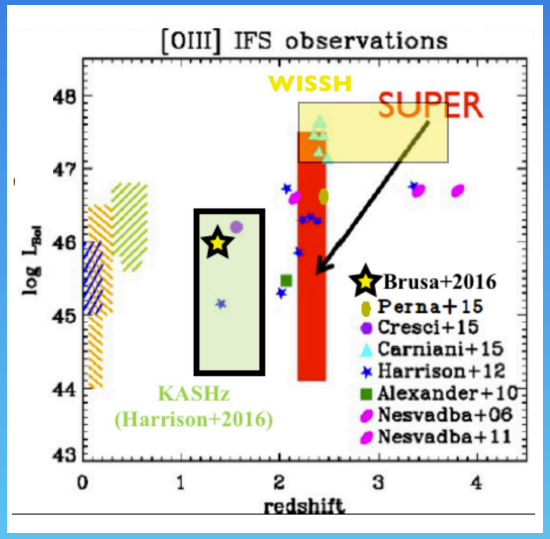
3 Obscured Compton-Thick QSOs at z ~1-2.5 observed with SINFONI: Fast (v~1500 km/s) extended (R~5 kpc) outflow in the highest S/N target

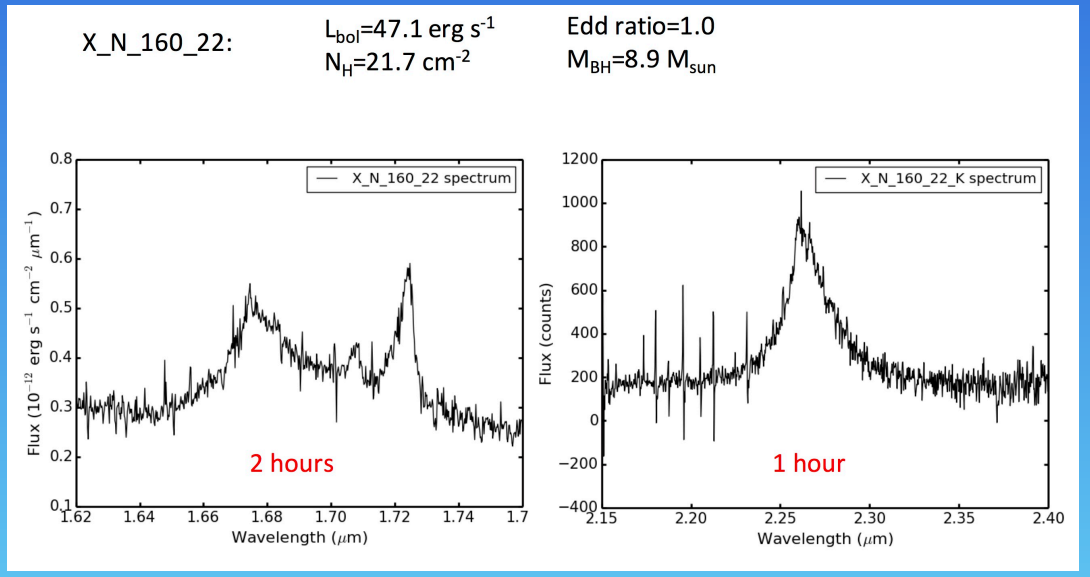
# *An unbiased search of outflowing AGNs: SUPER*

*a SINFONI Survey for Unveiling the Physics and Effects of Radiative feedback*

PI: V. Mainieri

- An ESO large program, 280 hrs in 2 years
- ~7 hrs/obj in 40 X-ray selected AGNs at z=2.3
- observing Large range in $L_{BOL}$, $L_{edd}$, Type 1 and Type 2, $N_H$
- LGS-AO, H+K bands: both outflows from [OIII] and SF from Hα
- Explore outflow power and demography as a function of AGN & host properties in unbiased sample

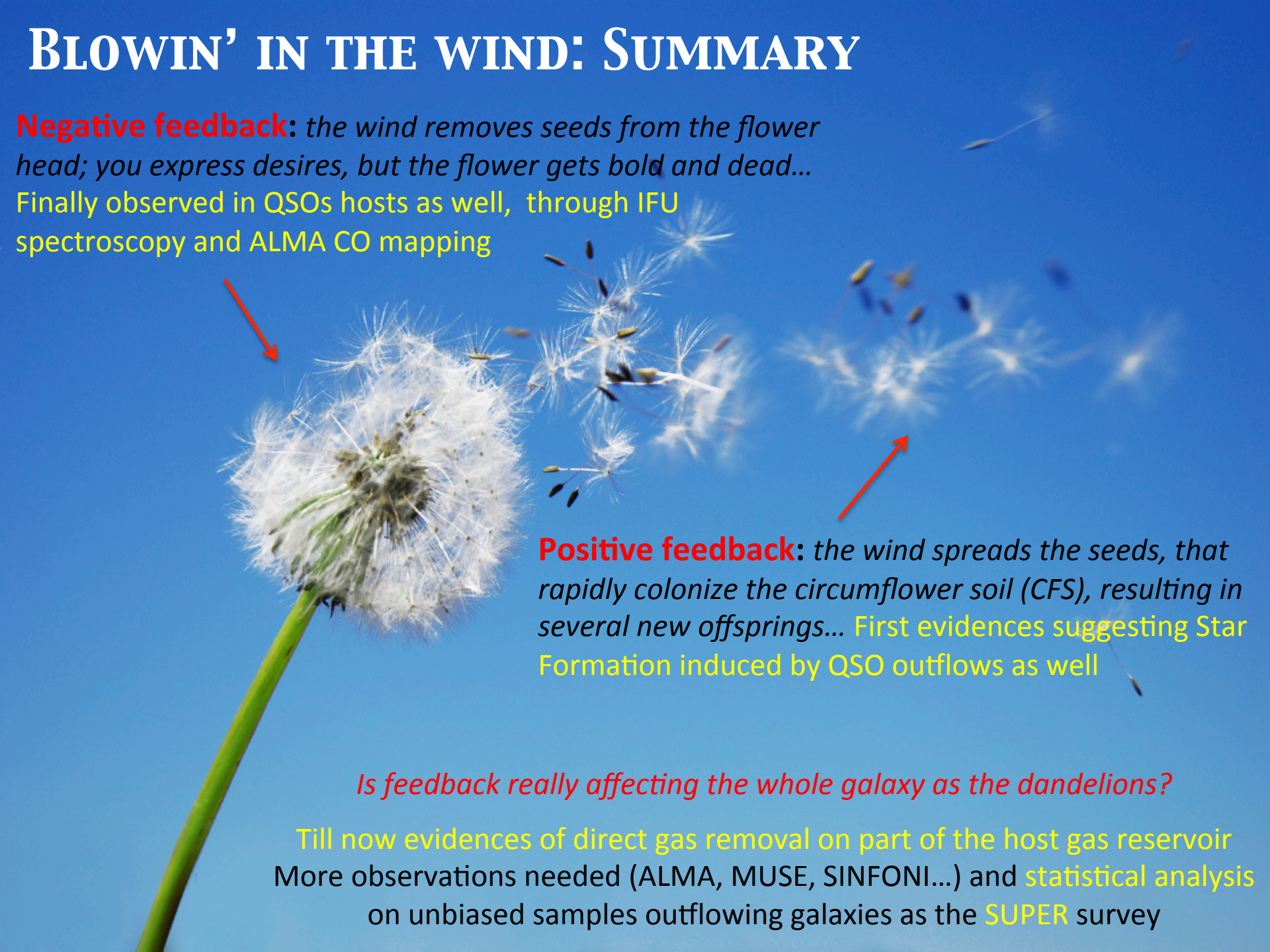



Observations ongoing! First data from P96

# Blowin' in the wind: Summary

**Negative feedback**: *the wind removes seeds from the flower head; you express desires, but the flower gets bold and dead…* Finally observed in QSOs hosts as well, through IFU spectroscopy and ALMA CO mapping



**Positive feedback**: *the wind spreads the seeds, that rapidly colonize the circumflower soil (CFS), resulting in several new offsprings…* First evidences suggesting Star Formation induced by QSO outflows as well

*Is feedback really affecting the whole galaxy as the dandelions?*

Till now evidences of direct gas removal on part of the host gas reservoir
More observations needed (ALMA, MUSE, SINFONI…) and statistical analysis on unbiased samples outflowing galaxies as the SUPER survey