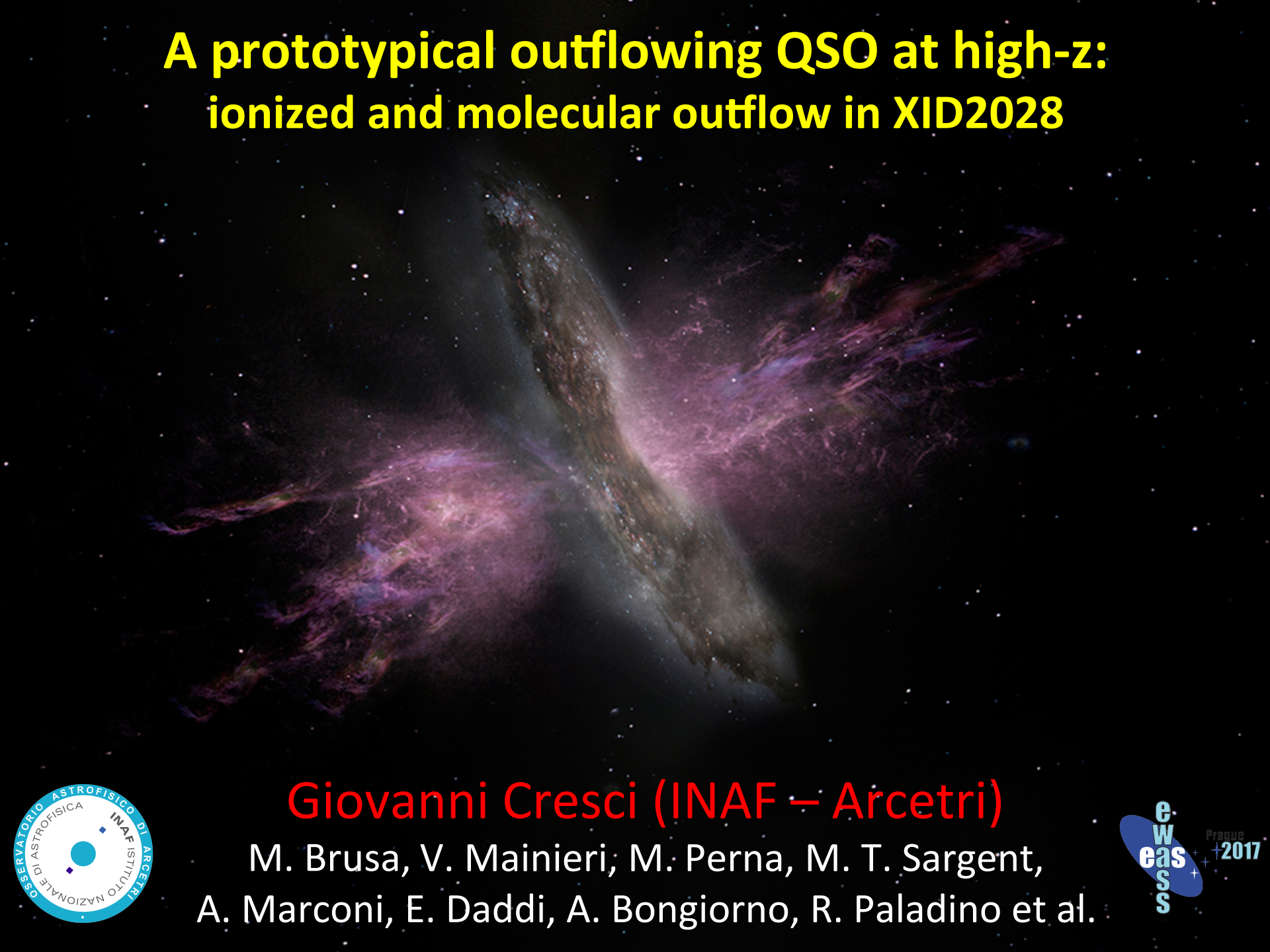
A prototypical outflowing QSO at high-z: ionized and molecular outflow in XID2028

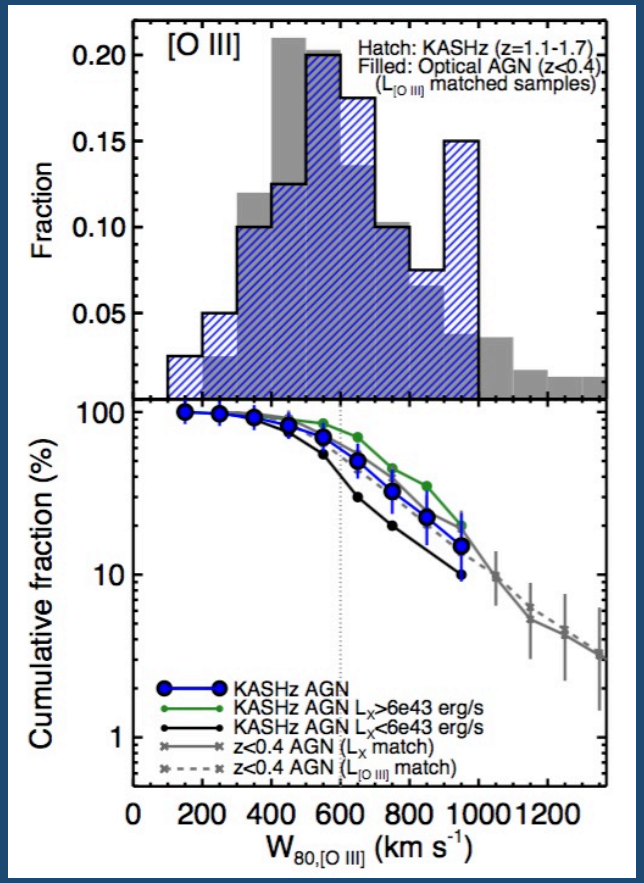


Giovanni Cresci (INAF – Arcetri)

M. Brusa, V. Mainieri, M. Perna, M. T. Sargent,

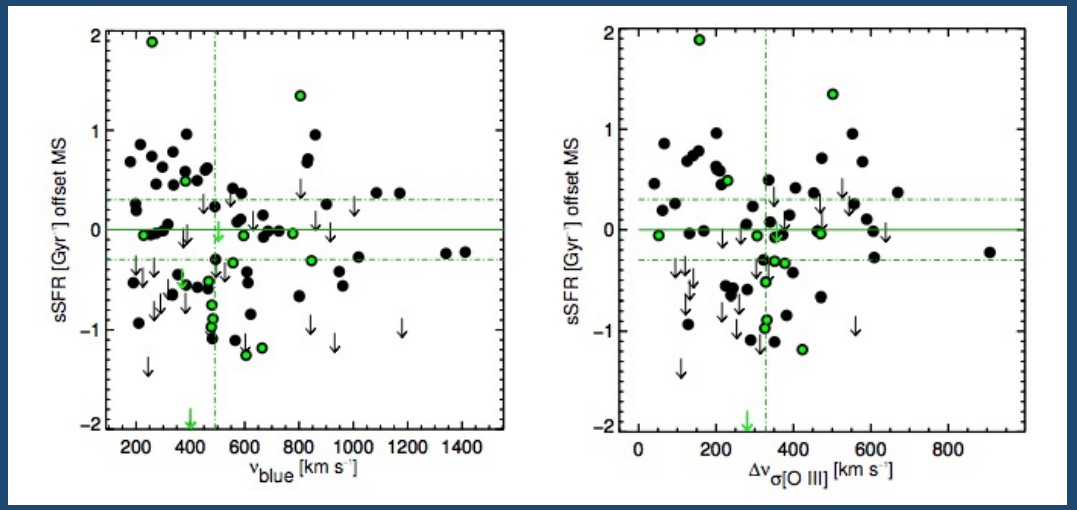
A. Marconi, E. Daddi, A. Bongiorno, R. Paladino et al.

Are Outflows ubiquitous?



Harrison et al. (2015) – KASHz

Do we have evidences of effects on the host?



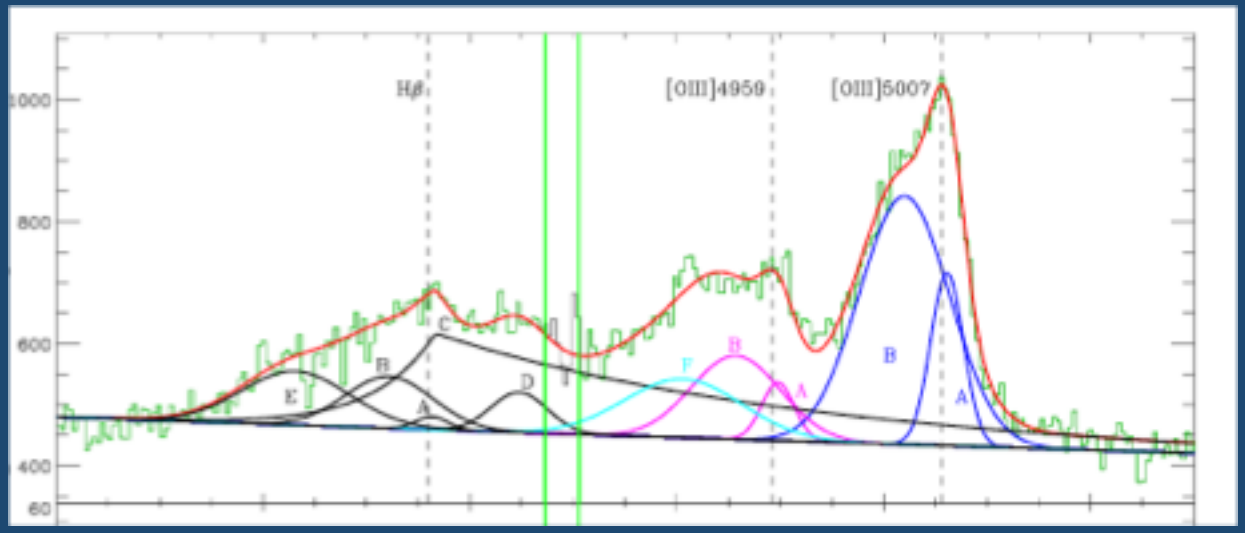
Balmaverde, GC et al. (2015): SDSS+Herschel selected QSOs

No trend between outflow velocity and SFR (BUT: different timescales…)

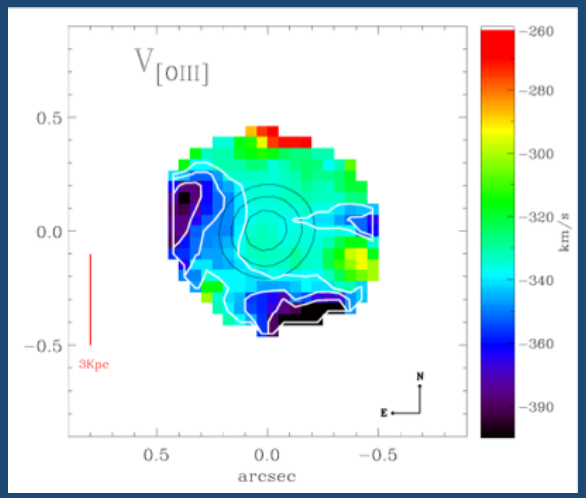
Many theoretical predictions, increasing evidences of widespread outflows, but still few observations of feedback effects on host galaxies…

Negative Feedback: a first observational evidence

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

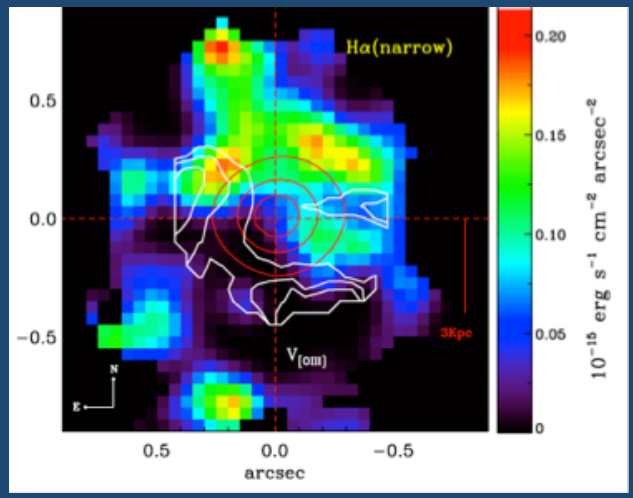


SINFONI H and K observations:
very asymmetric and broad [OIII]
FWHM ~1500 km/s



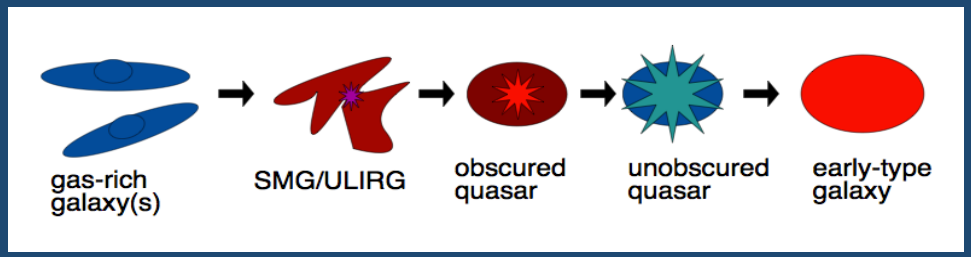
Asymmetric blueshift in the velocity map

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



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

Selecting outflowing AGNs

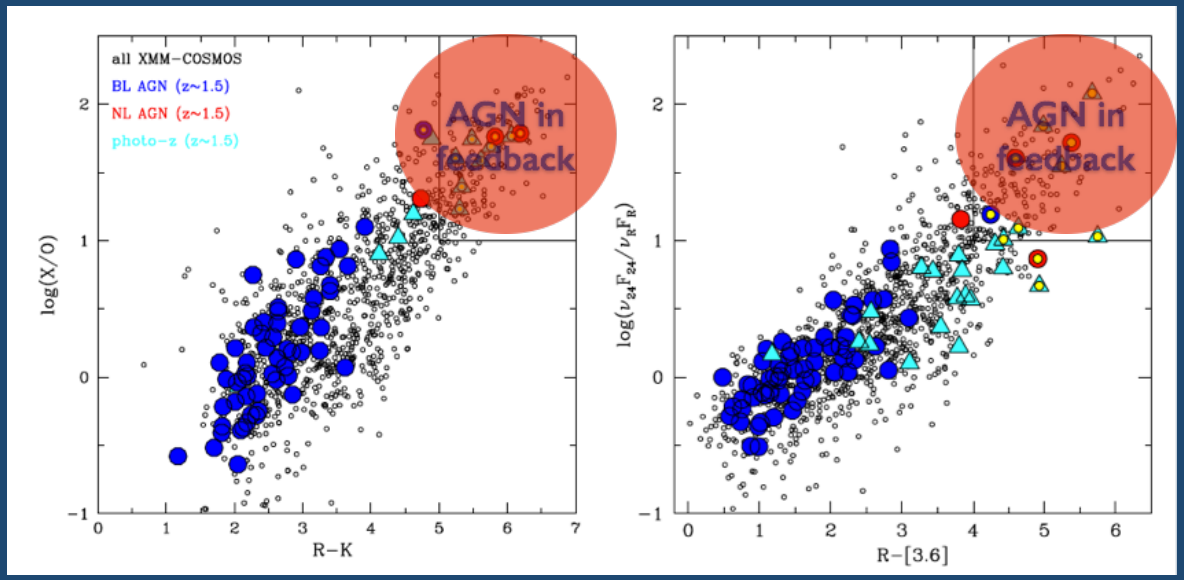


Models predict:

- 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

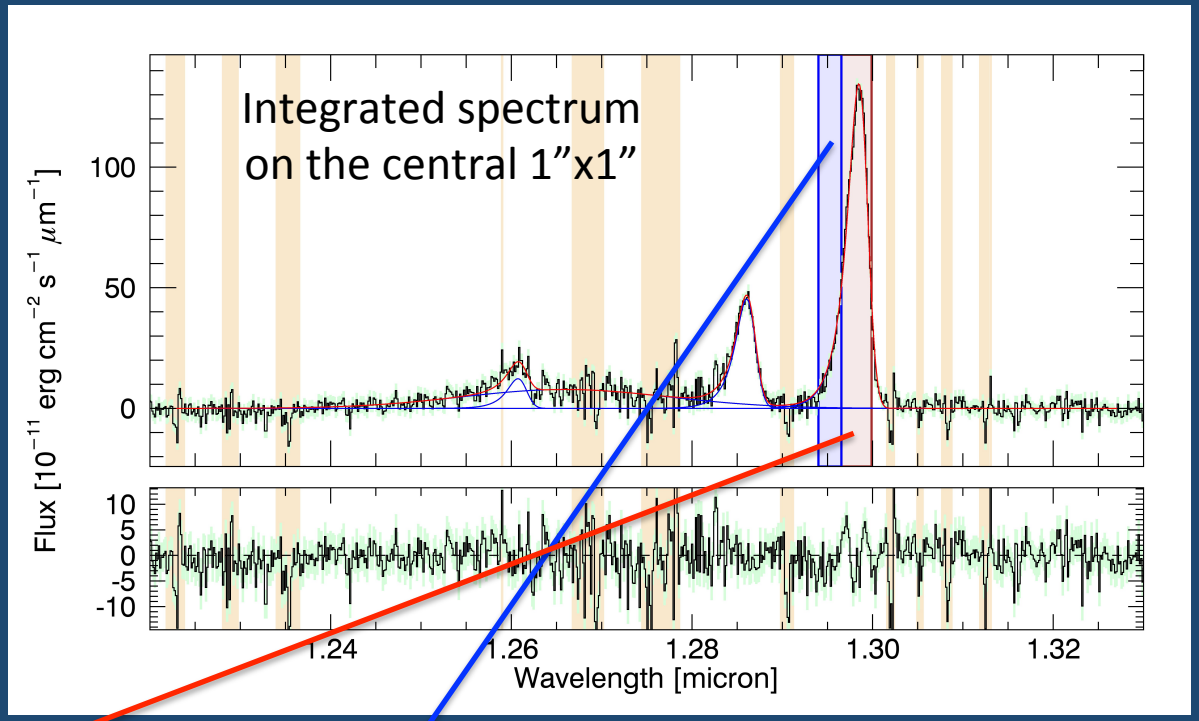
(Brusa, GC et al. 2015)

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

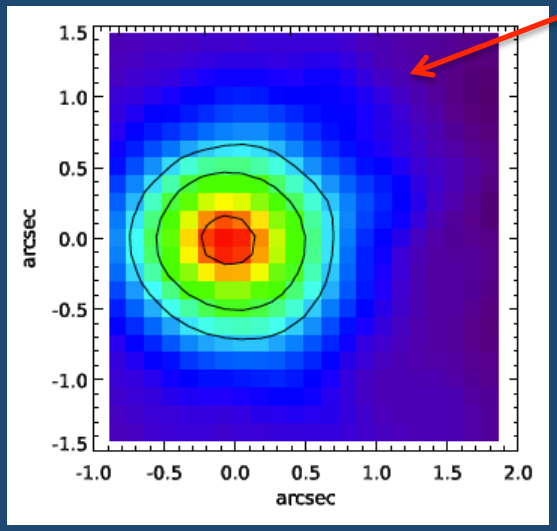
Brusa, Bongiorno, GC et al. (2015)

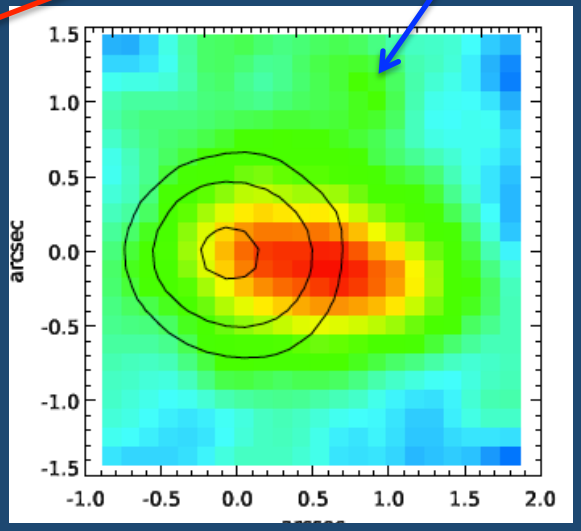
SINFONI IFU observations of high-z feedback: XID2028

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



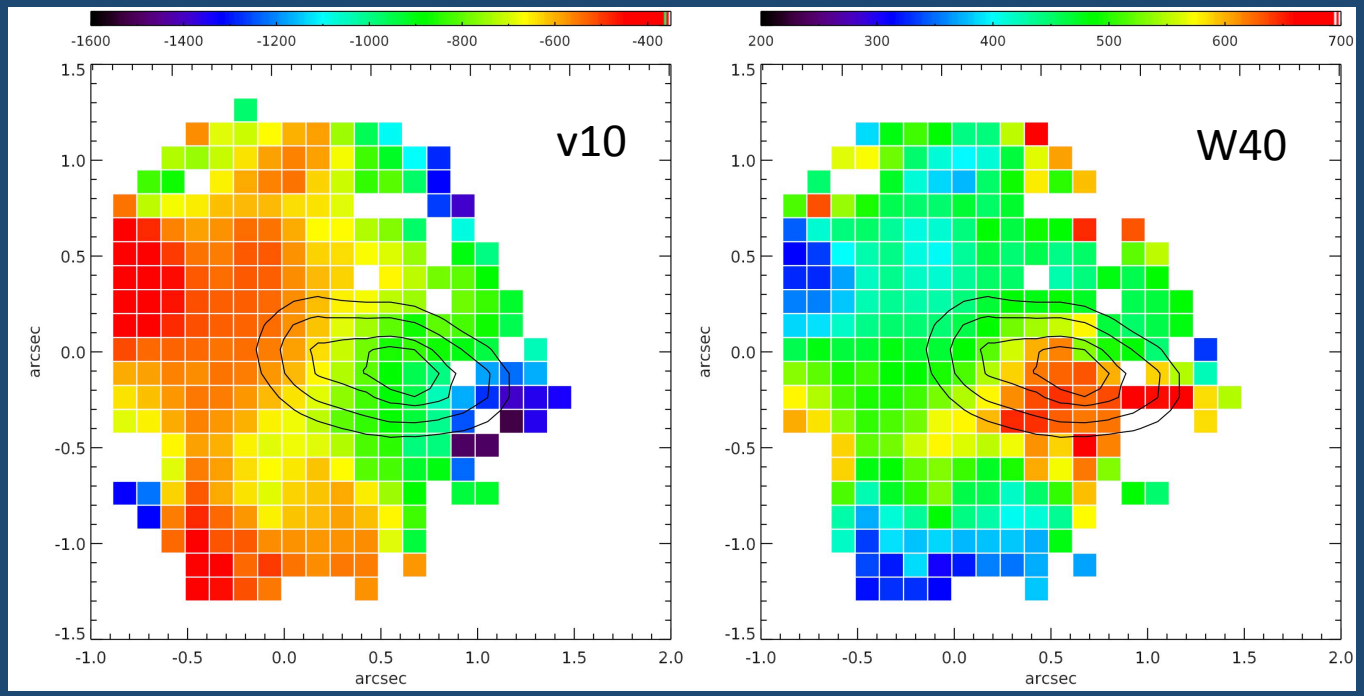
GC et al. (2015)





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

Outflow dynamics & energetics



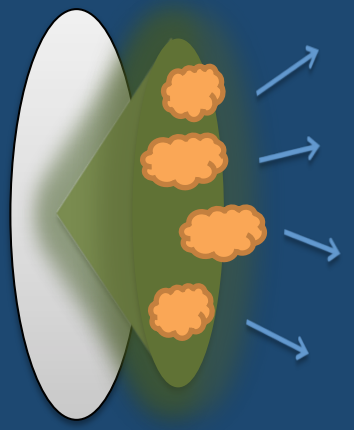
Outflow with v(out)~1500 km/s out to 13 kpc

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

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

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

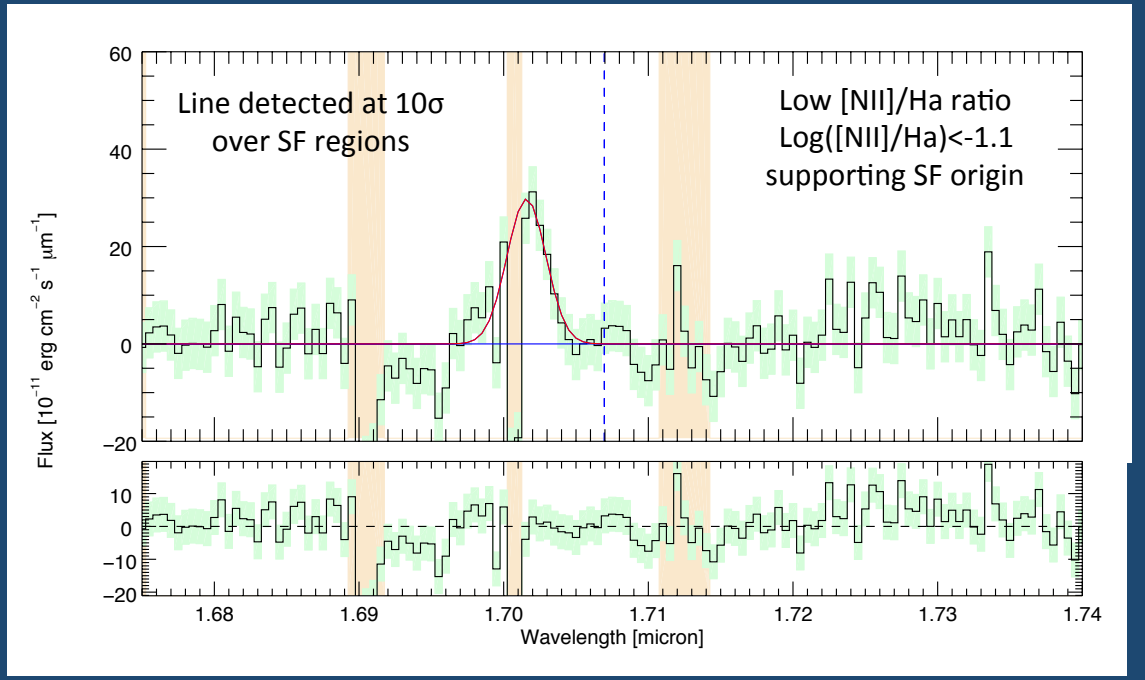
Outflow velocity and energetics suggest AGN driven outflow



Outflow effects on the host galaxy

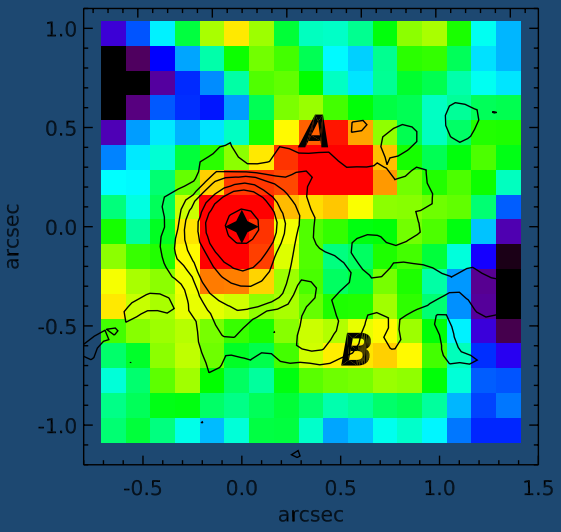
Archival H band (20’)
integrated spectrum
on the central 1”x1”

Residual spectrum integrated
on Regions A and B

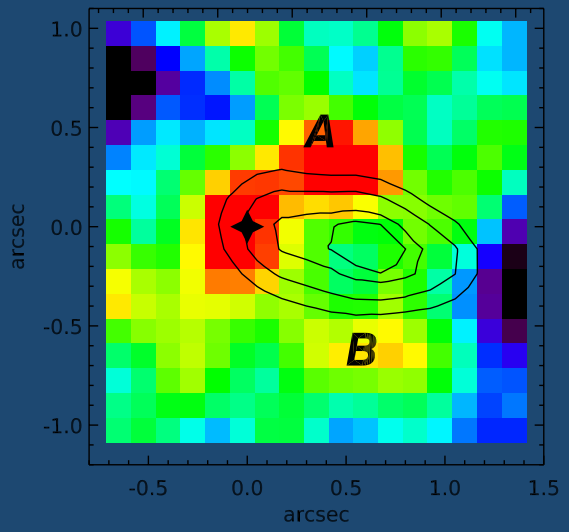


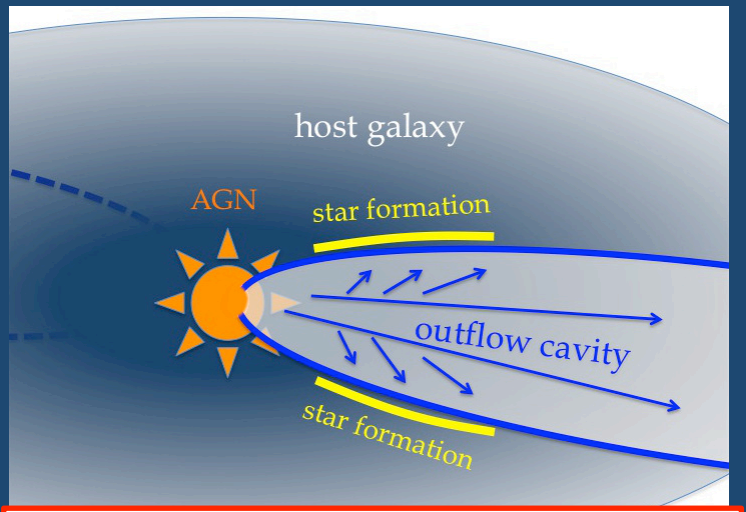
Narrow Ha map with contours of:

Rest frame U band (HST)



[OIII] blue wing flux





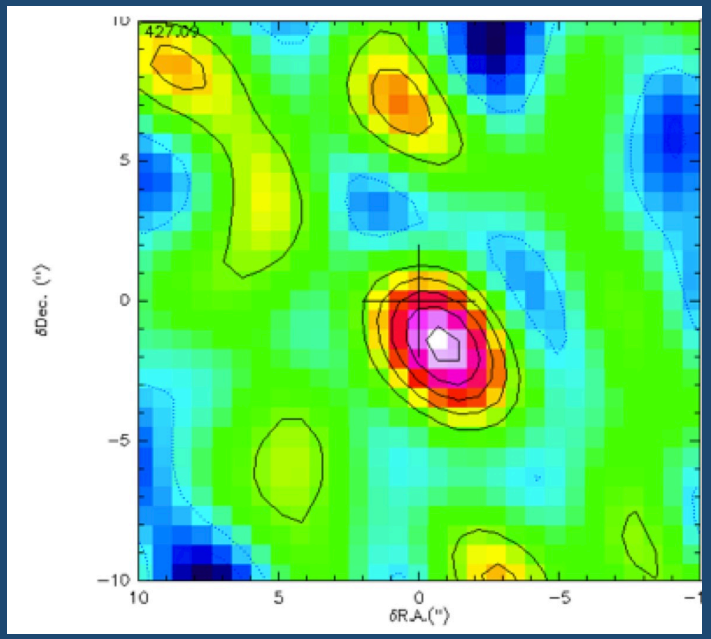
Both “Positive” and “Negative” feedback in action

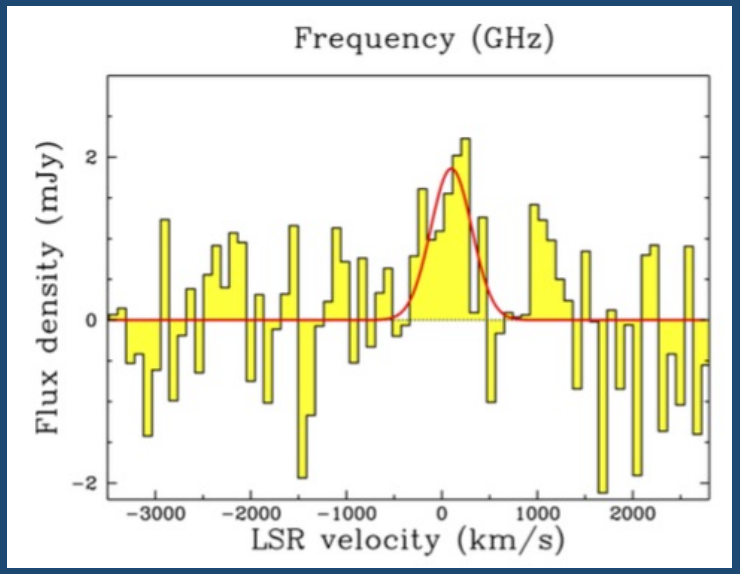
The molecular gas content of XID2028: PdBI follow-up

IRAM PdBI observations

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

Beam 4.5"x3.4" : no spatially resolved information





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

M_{gas} ~ 2-20 x 10^{10} $M_\odot$

(depending on α_{CO} and assumed sled)

Brusa, Feruglio, GC et al. 2015

ALMA deep follow-up of XID2028: continuum

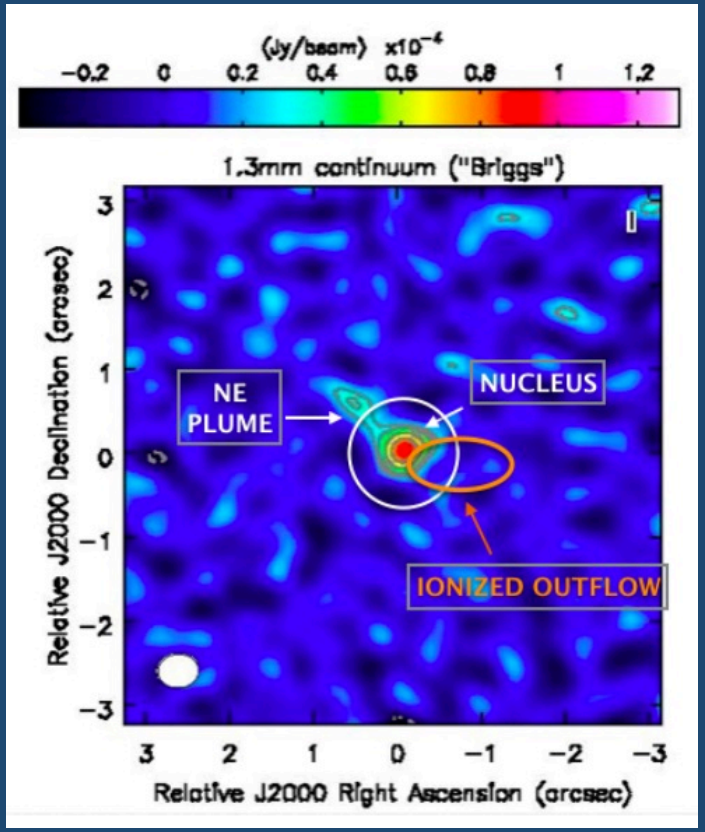
ALMA Observations in CO(5-4) + continuum taken in Cycle 3

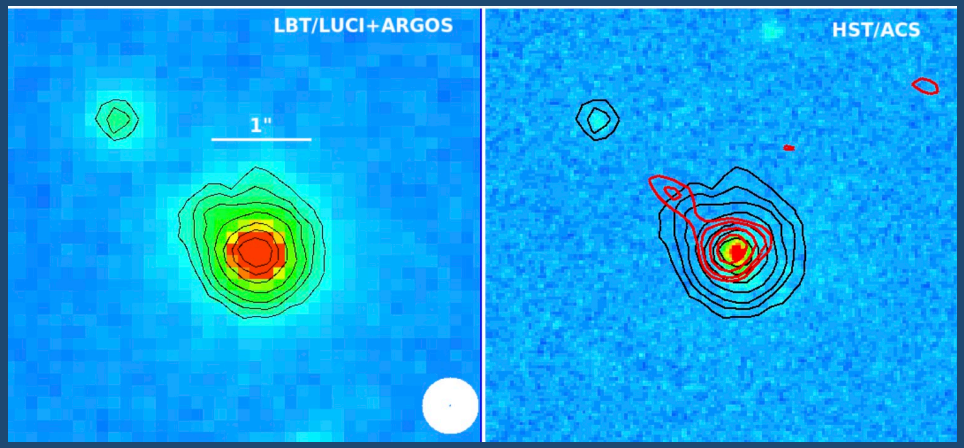
- 3.5 hours on source
- resolution 0.54”x0.45” (~ SINFONI)

The 1.3 mm dust continuum is detected at ~ 8 σ (210 μJy)

The core is slightly resolved, showing hint of a “banana” shape as narrow Hα

There is a fainter feature extending to the NE, corresponding to the elongation seen in LBT LUCI+ARGOS AO K band imaging





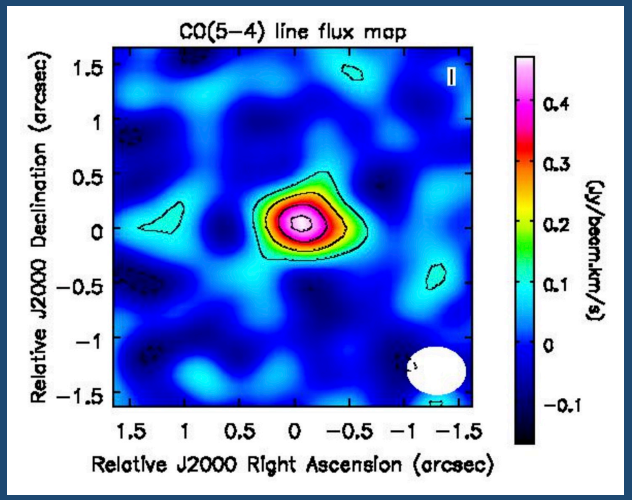
Brusa, GC et al. 2017, submitted

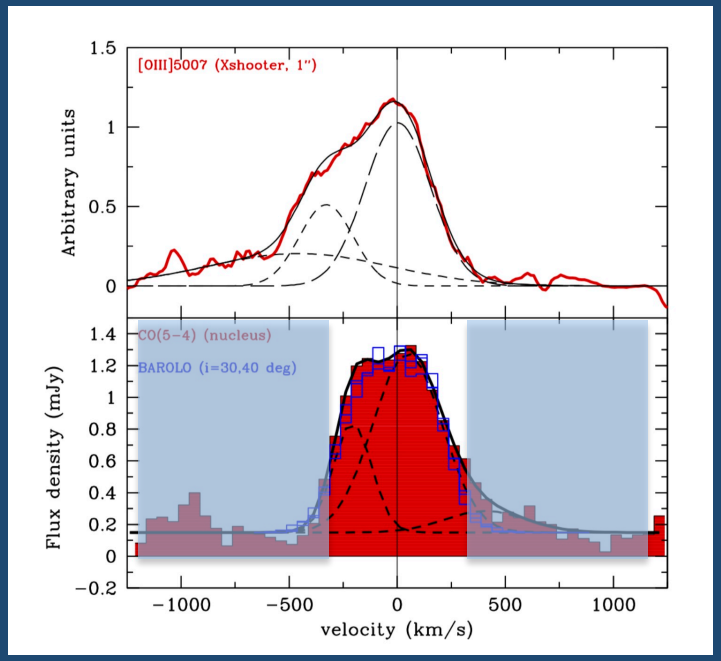
ALMA deep follow-up of XID2028: CO(5-4) line emission

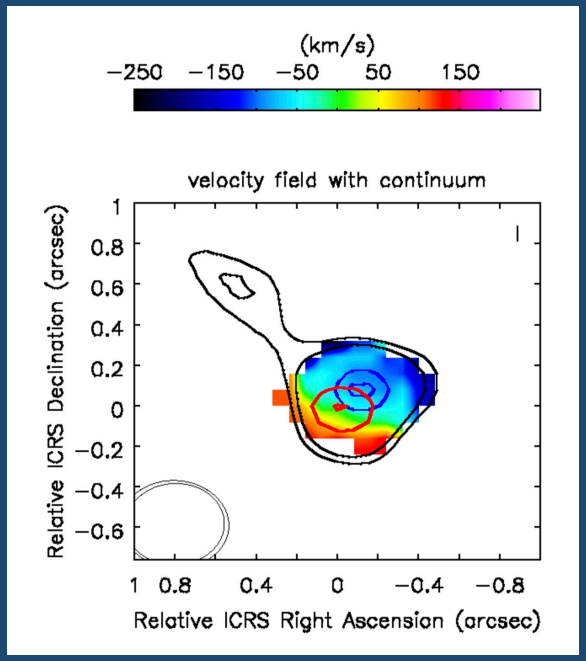
ALMA Observations in CO(5-4) + continuum taken in Cycle 3

CO(5-4) is detected at >10 σ, FWHM=0.33”
$\log(L'_{CO(5-4)}/\mathrm{K\ km\ s^{-1}\ pc^{-2}}) = 9.63$

Broad (FWHM~500 km/s) asymmetric line profile, better reproduced with an additional blueshifted component as [OIII]







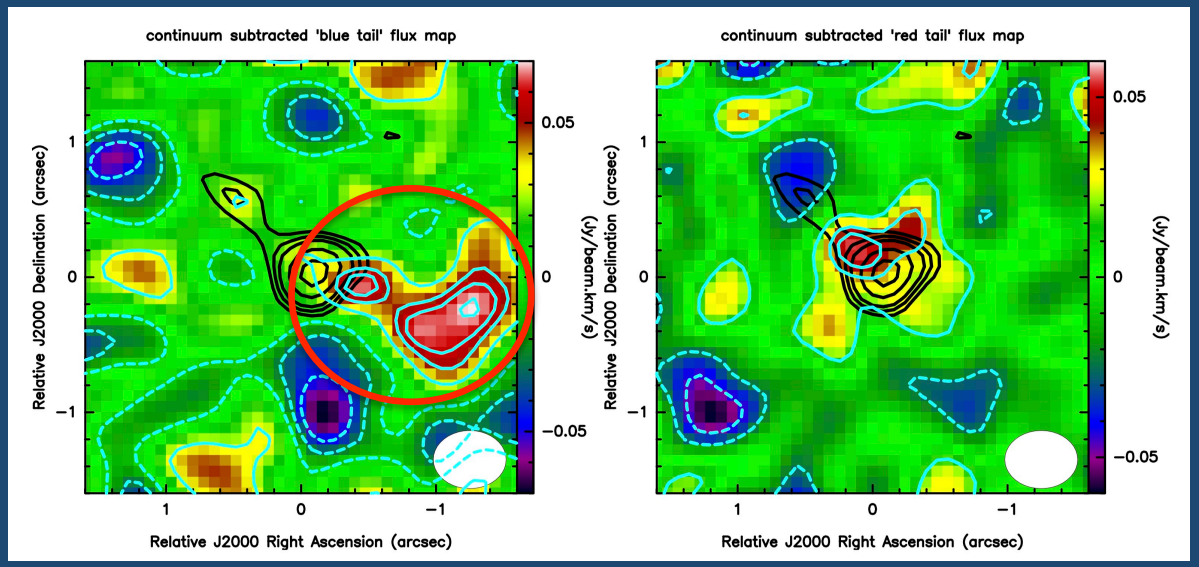
The central component shows a velocity gradient along the source in the NW-SE direction

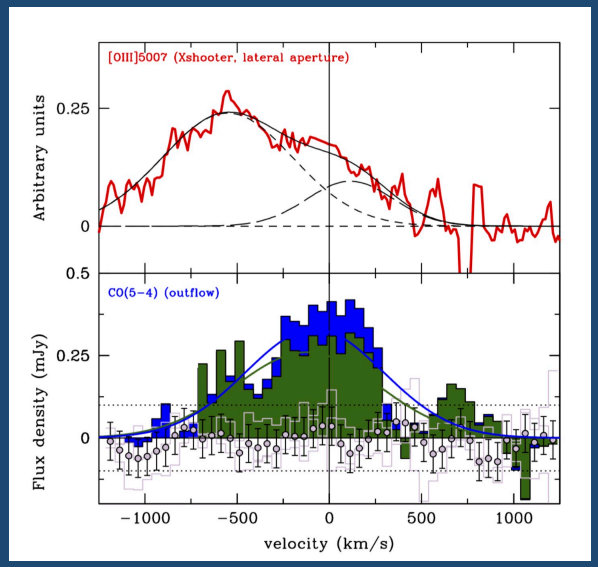
$M_{dyn} \approx 6 \times 10^{11}\ M_{\odot}$

Brusa, GC et al. 2017, submitted

Brusa, GC et al. 2017, submitted

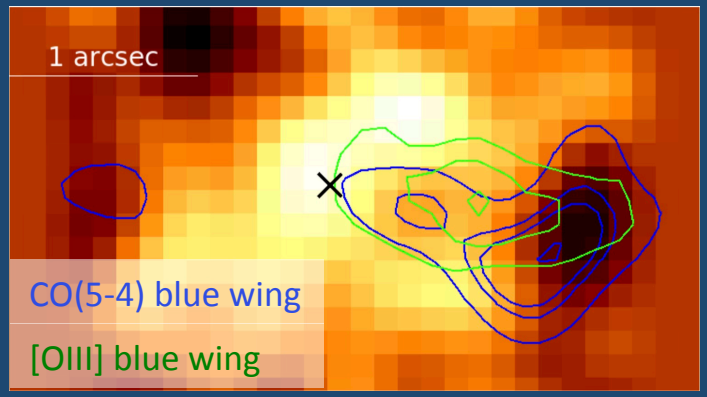
A spatially resolved CO(5-4) outflow





Imaging of the blue (< -350 km/s) and of the red tail (>350 km/s) reveal a bi-directional outflow out to ~ 10 kpc and v ~ 700 km/s

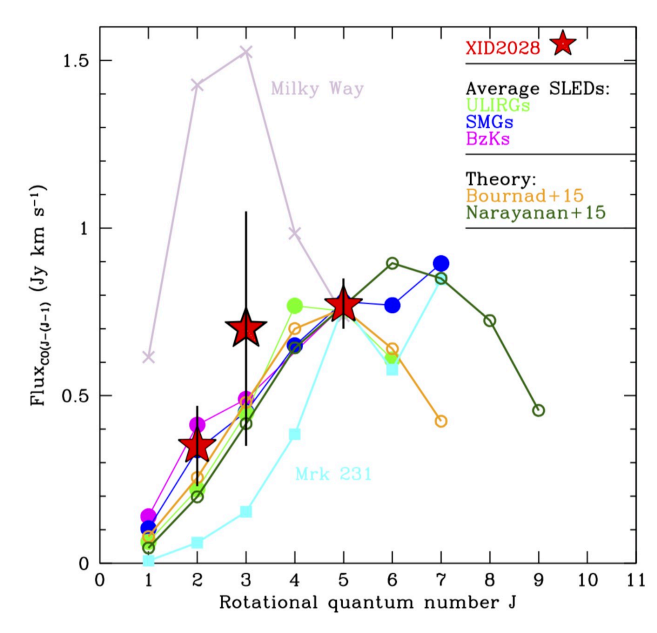
The blueshifted outflow is co-spatial with the ionized outflow from [OIII], in between the star forming regions traced by Hα, dust continuum and U band



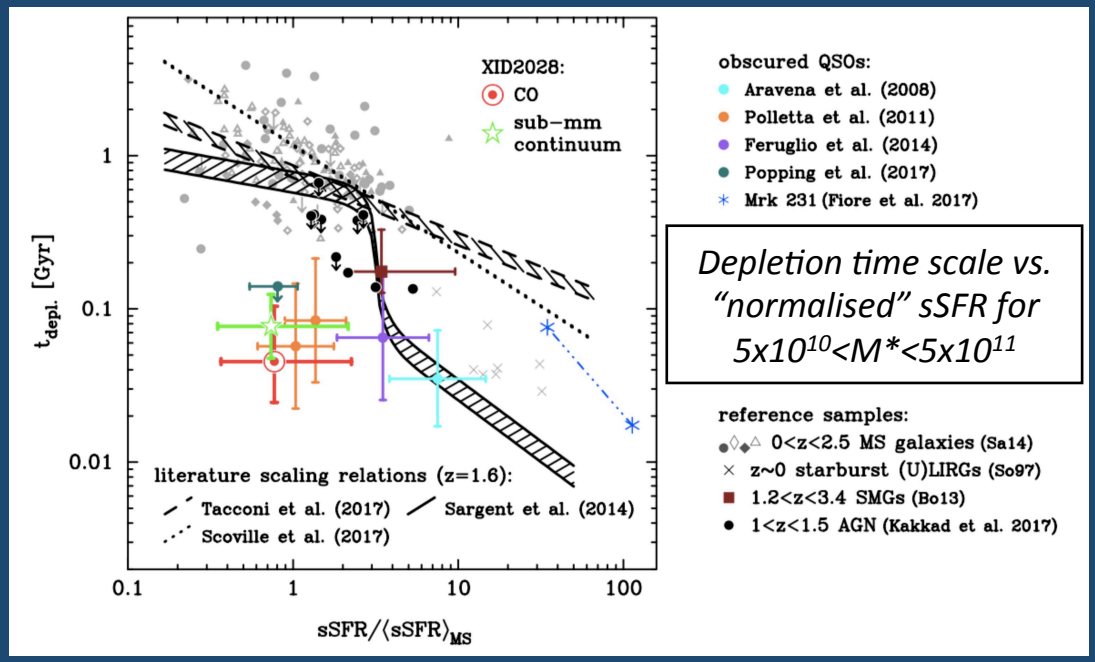
First direct detection of a spatially resolved CO outflow
Spatially coincident with the ionized outflow component

Brusa, GC et al. 2017, submitted

Molecular gas content of XID2028



We derive a total M_{gas} = 1±0.5 x 10^{10} $M_\odot$
consistent with estimate from RJ dust continuum
Gas fraction < 5% despite SFR~270 $M_\odot$/yr!



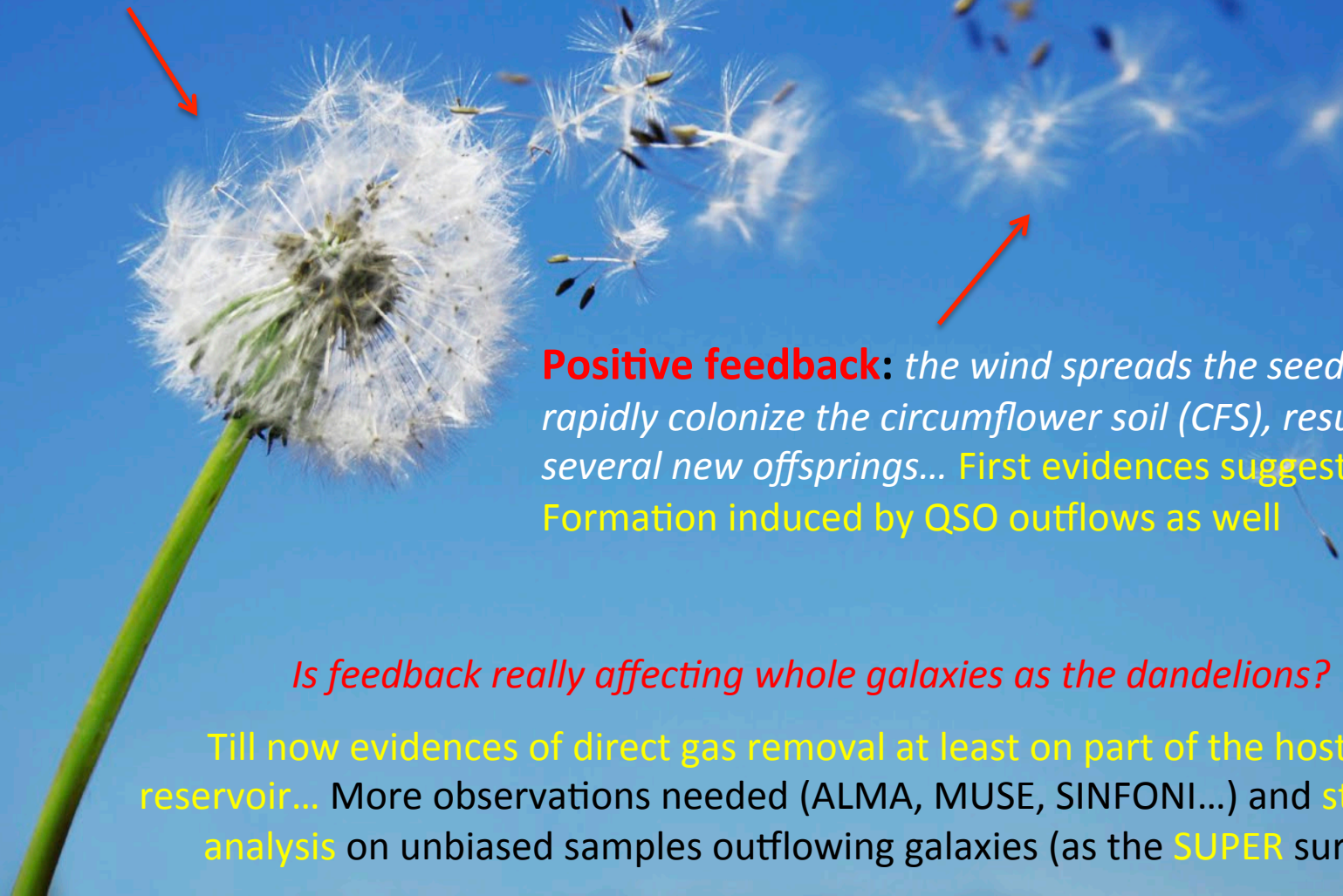
Derived CO excitation ladder consistent with high-z ULIRGs, SMGs and BzKs:
-> SB like α_{co}=0.8 assumed

This converts in a t_{depl}=45-80 Myr, more than an order of magnitude lower than the expected position on the plot for its sSFR

Evidences of QSO feedback
Removing gas from the star forming host galaxy!

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 first example of 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 whole galaxies as the dandelions?

Till now evidences of direct gas removal at least 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)

The SED and M_* of XID2028

From SED fitting:
$M_\star \sim 4.5 \times 10^{11}\ M_\odot$
SFR ~ 250 $M_\odot$/yr

LUCI AO imaging suggest a resolved host galaxy contribution to the K-band flux of at least ~20%
-> lower limit of $M_* > 2\times 10^{11}\ M_\odot$

We derive a $\Sigma_{SFR} \sim 40\ M_\odot/yr\ kpc^{-2}$, comparable with bright sub-mm galaxies