Blowin' in the wind:

"Negative" and "positive" QSO feedback at high-z

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Music by: B. Dylan

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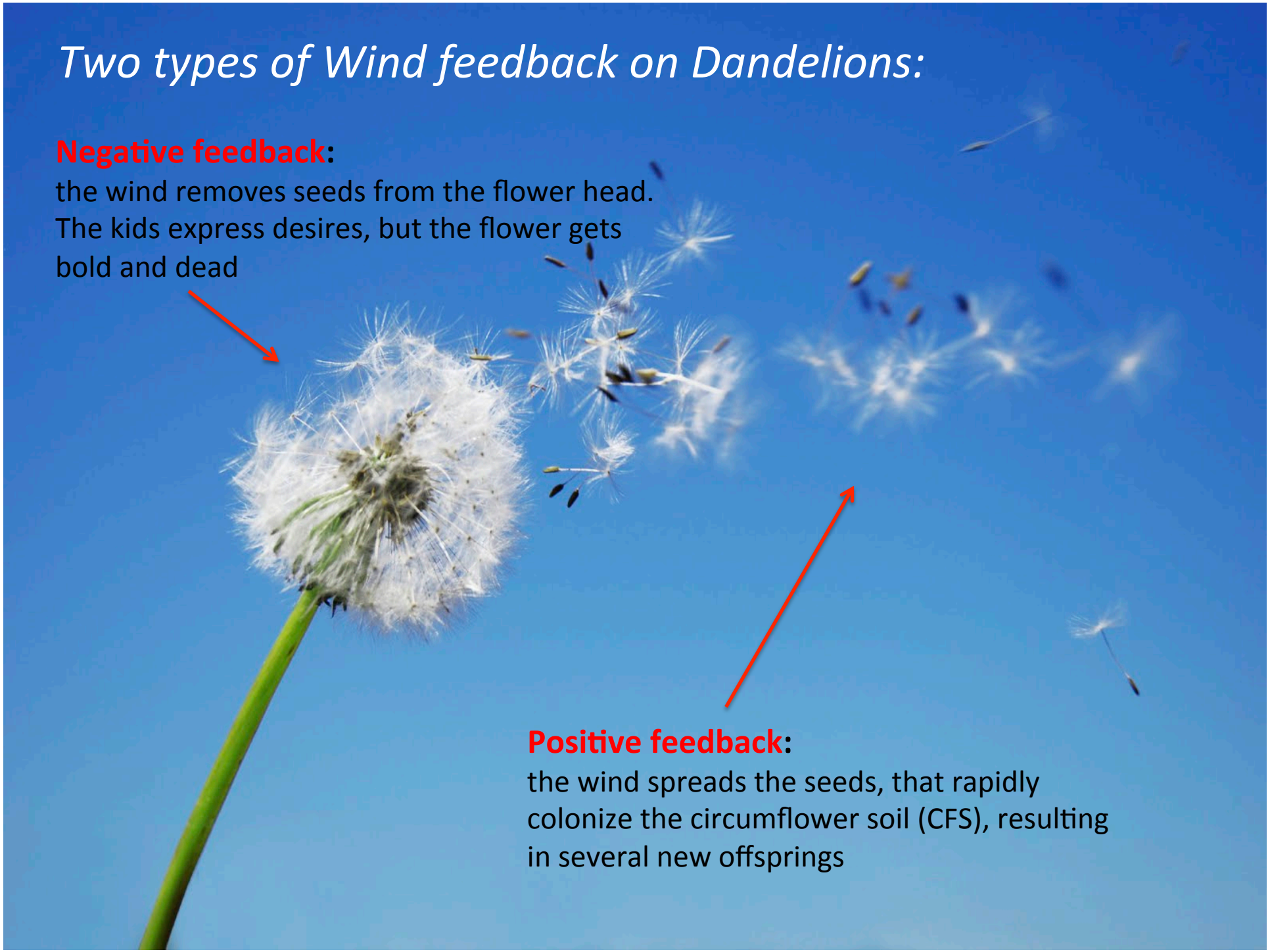
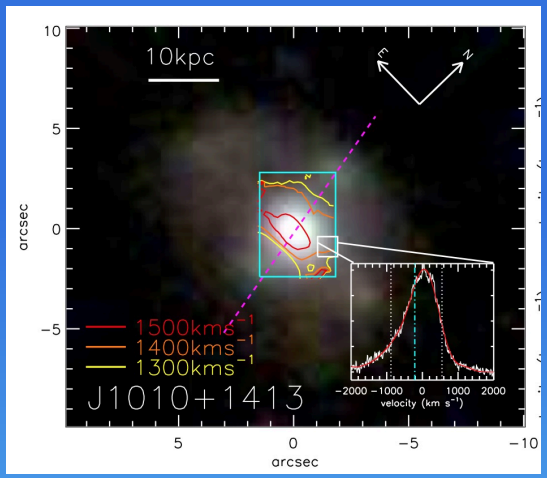

Two types of Wind feedback on Dandelions:
Negative feedback:
the wind removes seeds from the flower head.
The kids express desires, but the flower gets
bold and dead
Positive feedback:
the wind spreads the seeds, that rapidly
colonize the circumflower soil (CFS), resulting
in several new offsprings

But what about AGNs? 1 - Negative Feedback

Negative feedback invoked by most models to quench Star Formation in galaxies and reconcile simulations with observed galaxy populations (e.g. Granato+04, Di Matteo+05, Menci+06, Fabian+12 etc…)

Outflows observed as broad wings of forbidden lines in ionized gas…



Local/low-z galaxies:

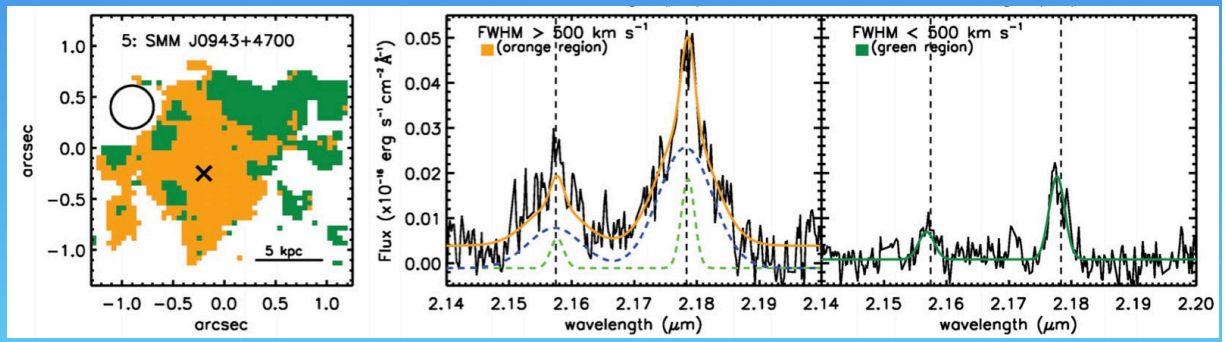
Harrison et al. (2014): GMOS observations of SDSS QSOs

(see also Rodriguez-Zaurin et al. 2011, Zakamska & Green 2014, Villar-Martin et al. 2011, Liu et al. 2012,2013, Greene et al. 2009, 2012, etc)

High-z galaxies:

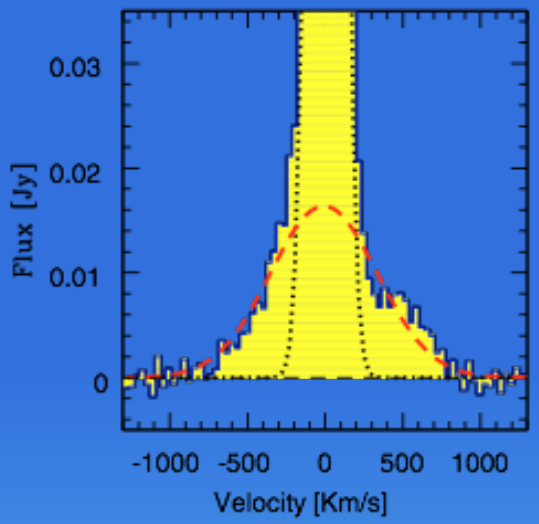
Harrison et al. (2012): NIFS/ SINFONI observations of SMGs

(see also Nesvadba et al. 2009, 2011, Alexander et al. 2010, Allen et al. 2011, Forster-Schreiber et al. 2014, Genzel et al. 2014 etc.)



But what about AGNs? 1 - Negative Feedback

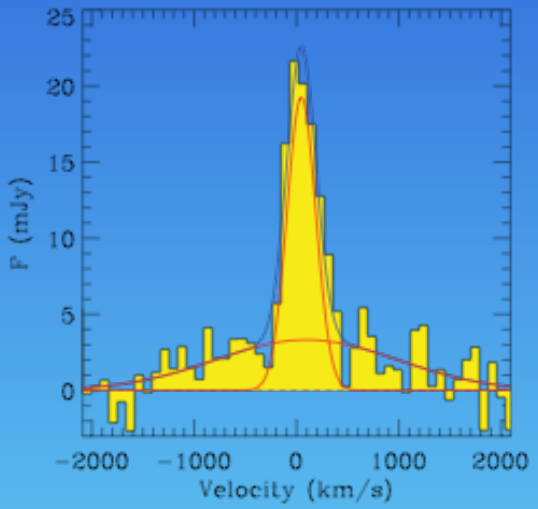
.. and in molecular/neutral gas



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, etc)



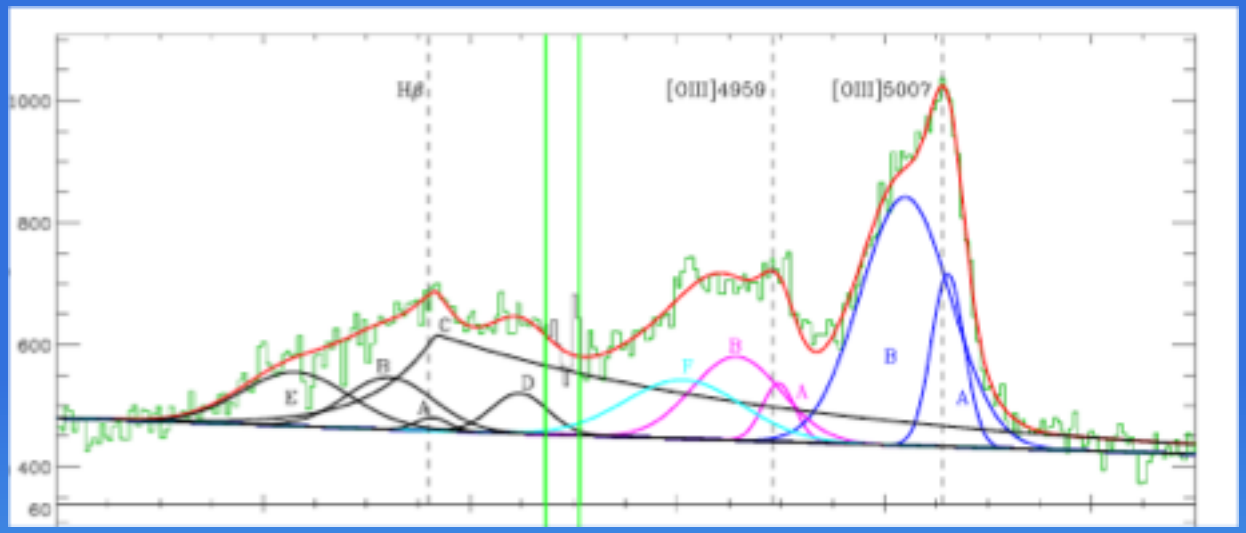
High-z galaxies:

Maiolino et al. (2012): molecular outflow from [CII]158µm in a z~6.4 QSO

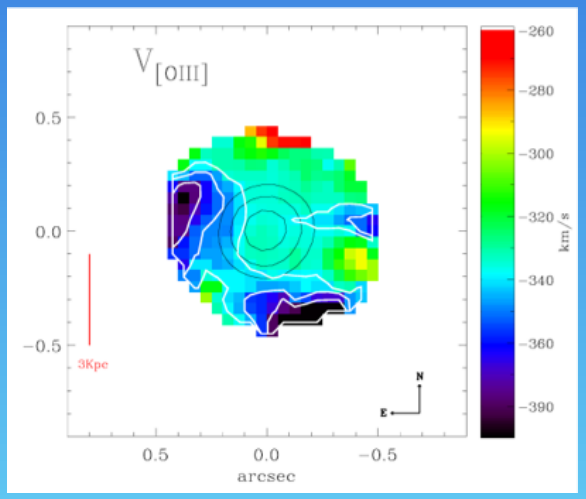
Many theoretical predictions, increasing evidences of widespread outflows, but still few observations of feedback effects on host galaxies…

But what about AGNs? 1 - Negative Feedback

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

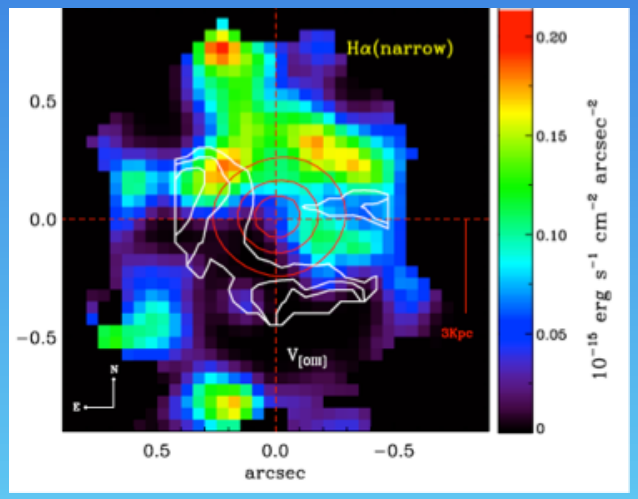


SINFONI H and K observations:
very asymmetric and broad [OIII]
FWHM ~1500 km/s



Asymmetric blueshift in the velocity map

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

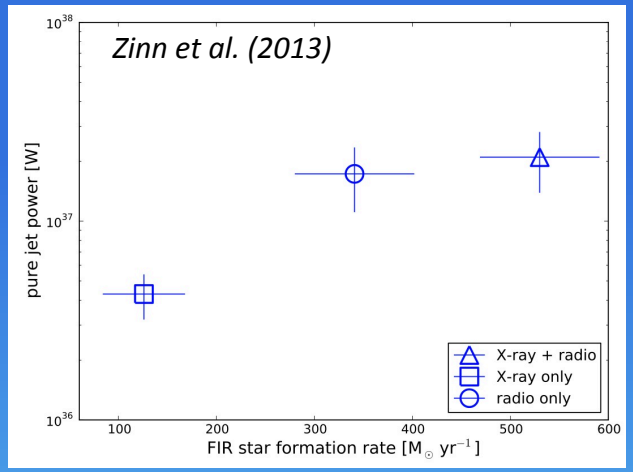


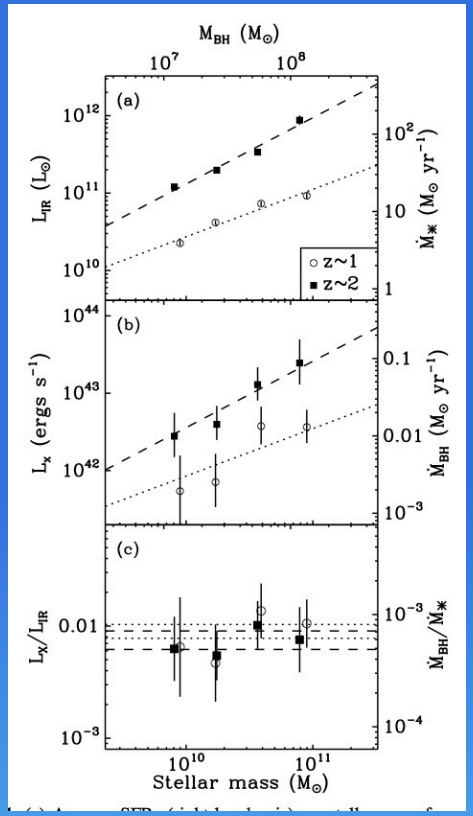
Cano-Diaz, Maiolino, GC et al. (2012) – see also S. Carniani's talk afterwards

But what about AGNs? 2 – Positive Feedback

Positive feedback is becoming increasingly popular in recent years, to explain the correlation between AGN luminosity/jet power and nuclear SFR, BH accretion rate and SFR and the M(BH)-σ relation

"Positive" Feedback is expected to be dominant at high redshift: would naturally accounts for sSFR evolution, and the higher SF efficiency in sub-mm and ULIRG galaxies





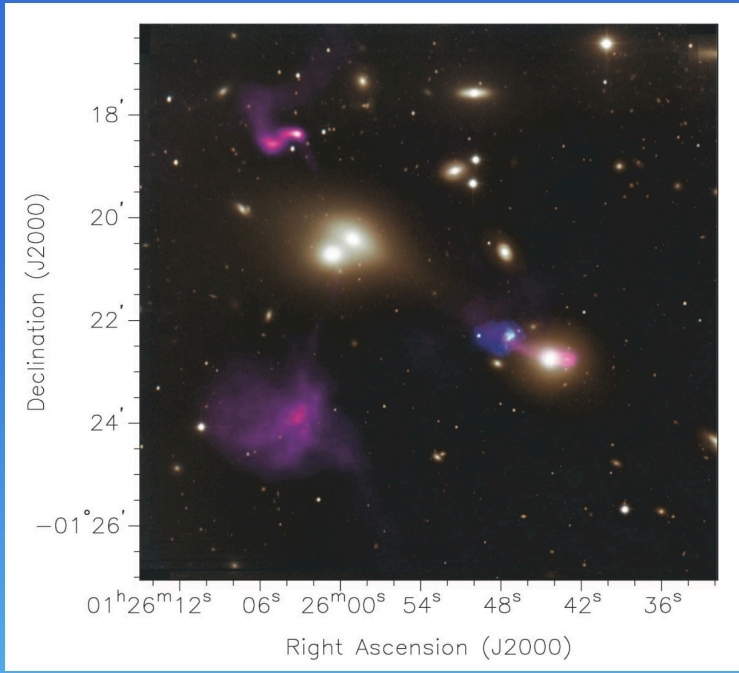
Mullaney et al. (2012)
(see also Azadi et al. 2014)

It is coming in two flavours:

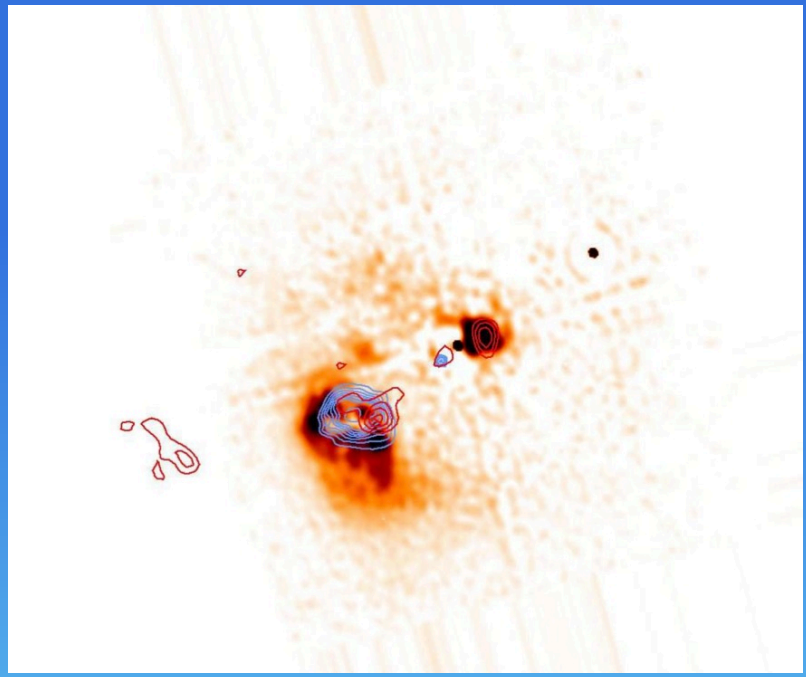
1. AGN-induced pressure on the gas-rich disk (e.g. *Silk et al. 2013*)
2. feedback-triggered star formation directly in the outflow (e.g. *Ishibashi & Fabian 2013, 2014, Zubovas & King 2013,2014*)

But what about AGNs? 2 – Positive Feedback

However, very few direct observations so far,
mostly radio jets inducing star formation on companion galaxies…



Croft et al. 2006



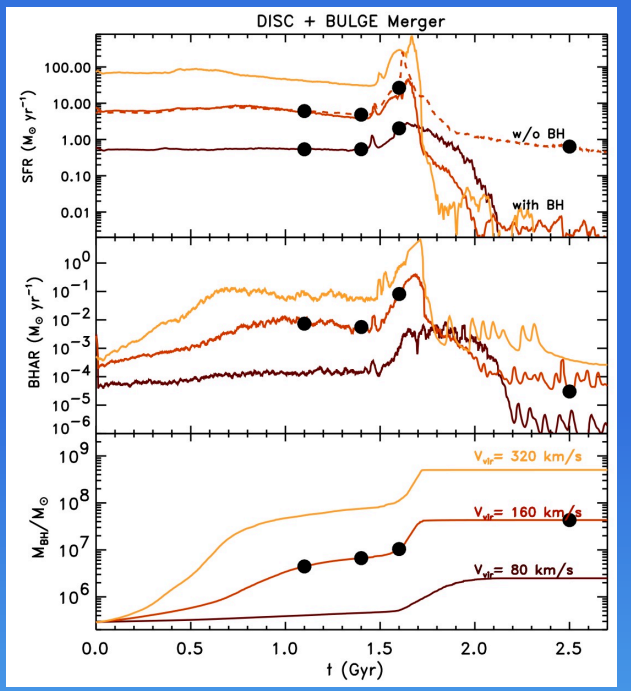
Elbaz et al. 2009

(See also Kramer et al. 2004, Feain et al. 2007, Crockett et al. 2012)

Why is it so difficult to get the smoking gun?

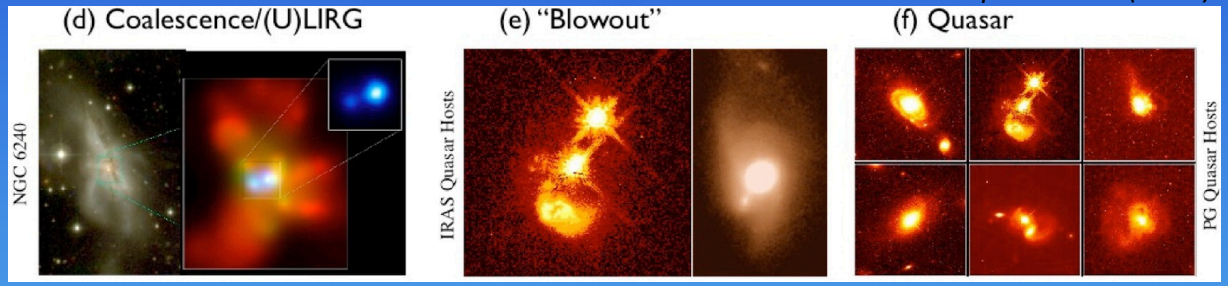
Models predict that:

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



Di Matteo et al. (2005)

Hopkins et al. (2008)



Compton Thick BH growth

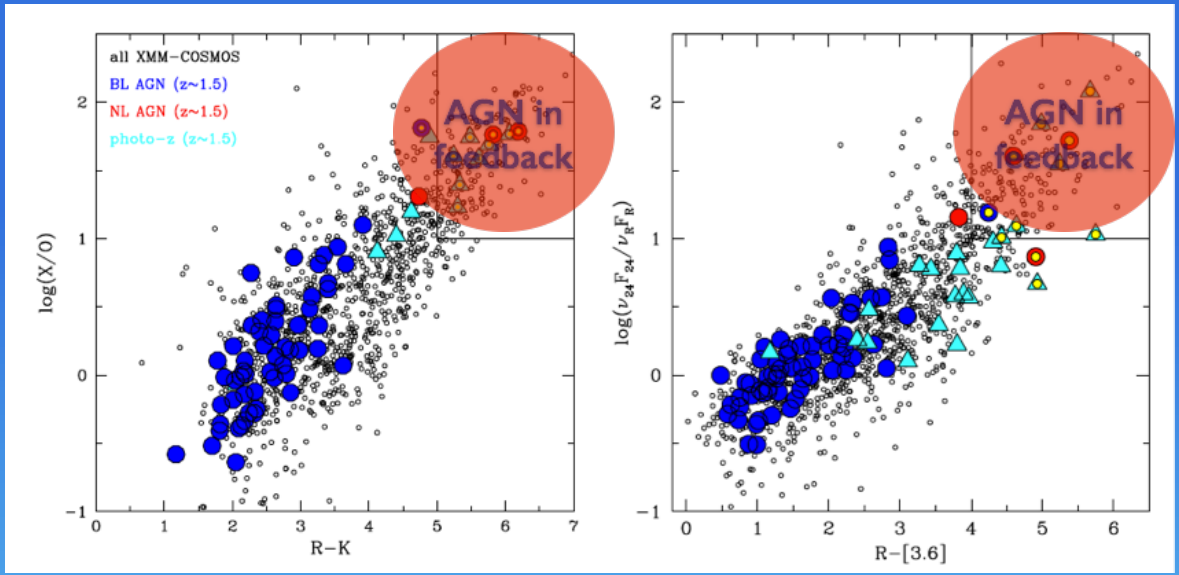
Reddened QSO Dust and Gas removed

Unobscured QSO

We have to select X-ray luminous, obscured and "dusty" QSO to pick up objects at the maximum of their feedback phase…

Selecting the Dandelions:

- 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)



Brusa, Bongiorno, GC et al. (2014)

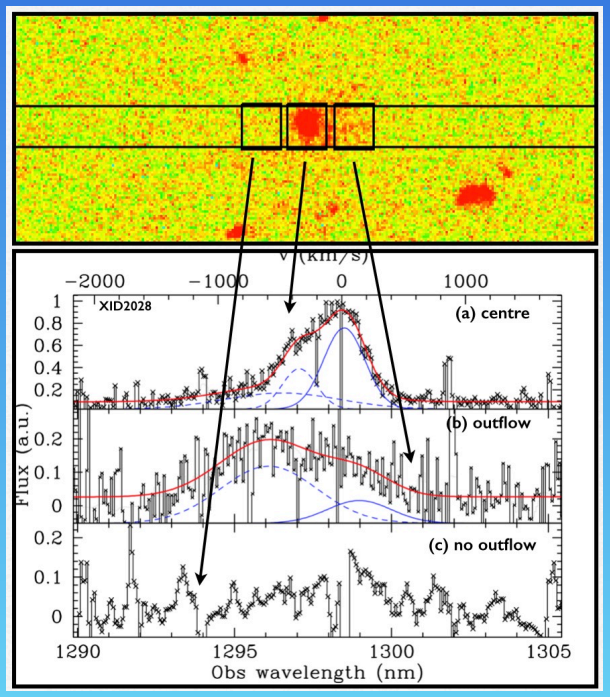
10 brightest (Lx>44, K<19) targets at z~1.5 observed with VLT X-Shooter

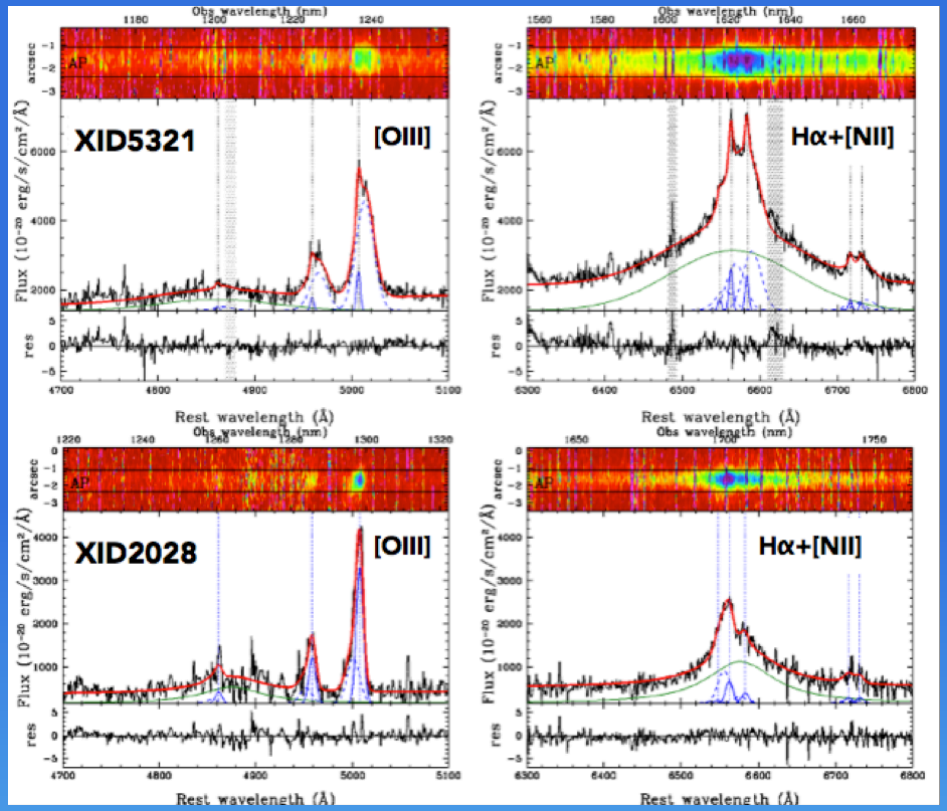
- Massive ($M_*>10^{11}\ M_\odot$) but Main Sequence galaxies
- All Radio-quiet (differently from Harrison+2012, Nesvabda+2008)

X-Shooter view of "blowing-out" QSOs (see M. Perna's talk!):

Multi-component fit: narrow+BLR+outflow

- Broad Hα (FWHM>2000 km/s) detected in 6/8
- SMBHs with $M_{BH}=10^{8}$-$10^{10}\,M_{\odot}$ -> massive! (*Bongiorno et al. 2014*)
- Broad asymmetric component (FWHM=900-1600 km/s) in forbidden lines ([OIII], [NII],[SII]) detected in 6/8 ascribed to outflows





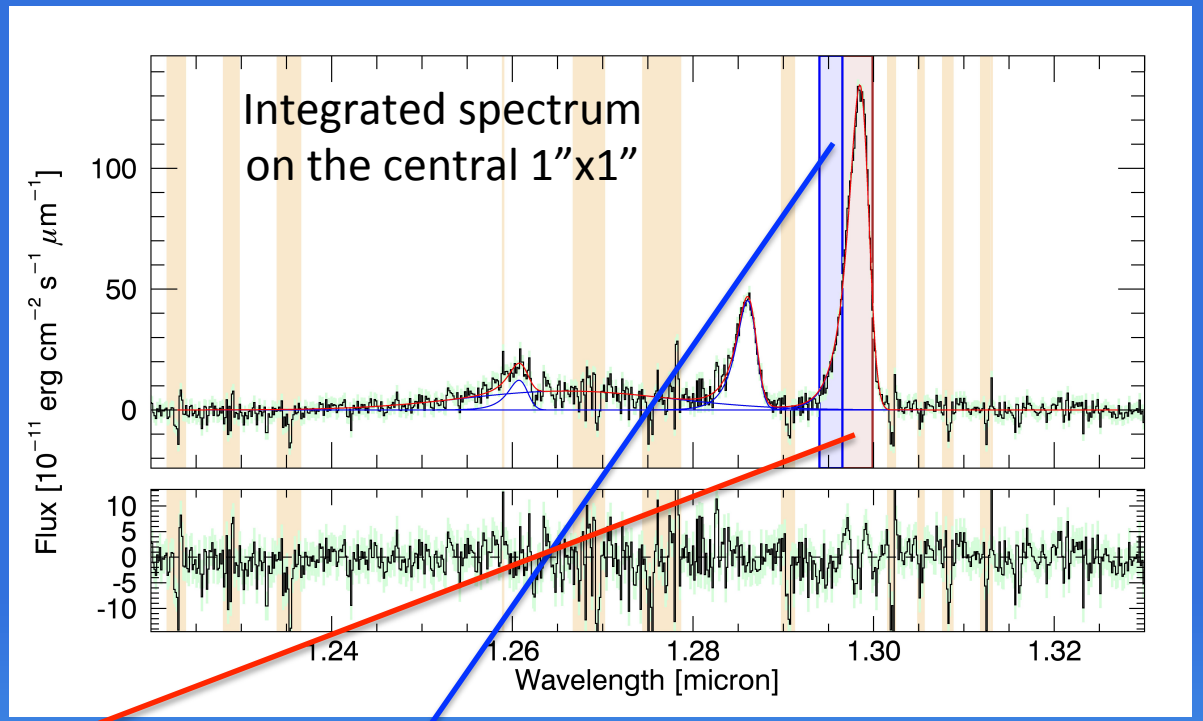
Brusa, Bongiorno, GC et al. (2014)

In XID2028 outflow extending beyond 10 kpc scale!

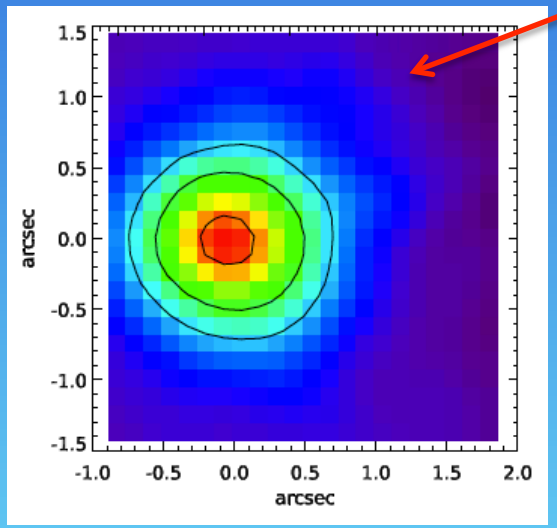
Perna, Brusa, GC et al. (2014)

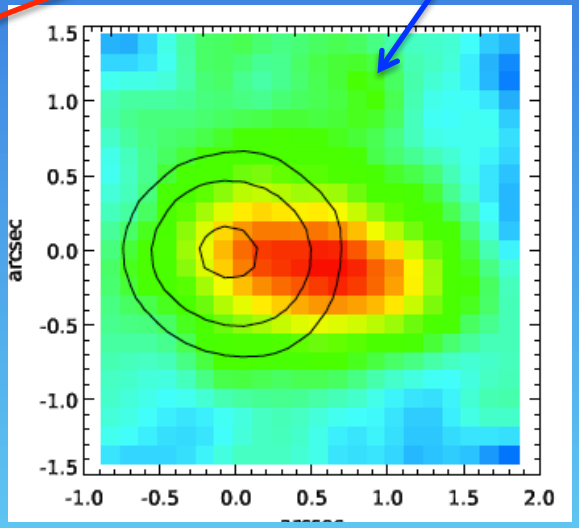
SINFONI observations of XID2028

J band (PI Mainieri) 6 hrs
Scale 0.125”x0.125”
PSF=0.6”



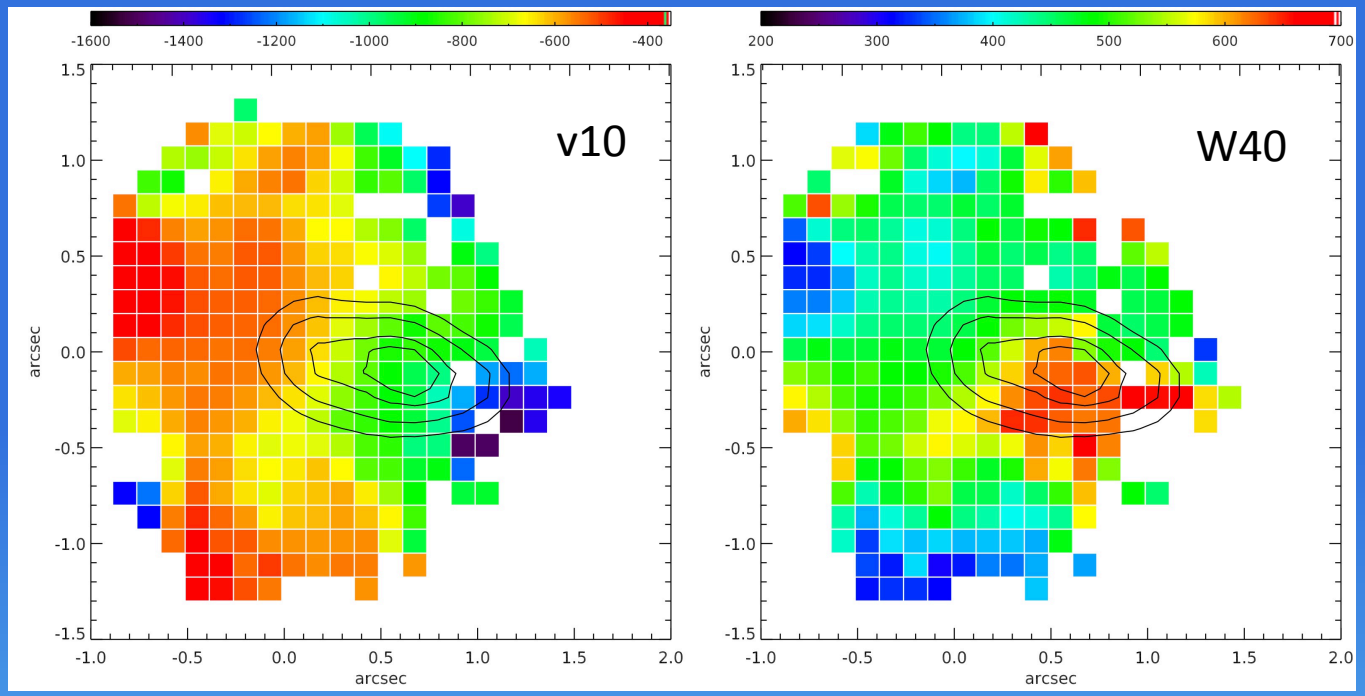
GC, Mainieri, Brusa, Marconi et al. (2014)





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*

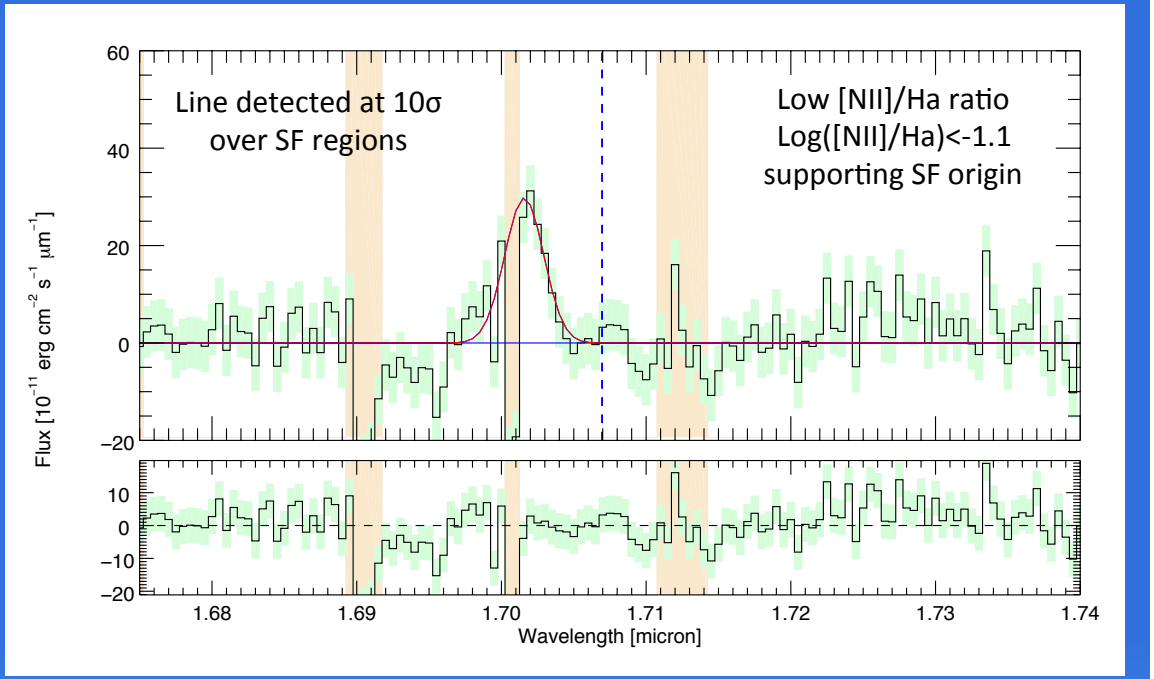
From Hβ luminosity we derive $\dot{M}_{(ion,out)}$>300 $M_\odot$/yr ($\dot{M}_{(tot)}$>1000 $M_\odot$/yr ?)

This translate in a mass loading factor $\dot{M}_{(out)}$/SFR> 3:
Outflow velocity and energetics not sustainable by Star Formation only!

Outflow effects on the host galaxy

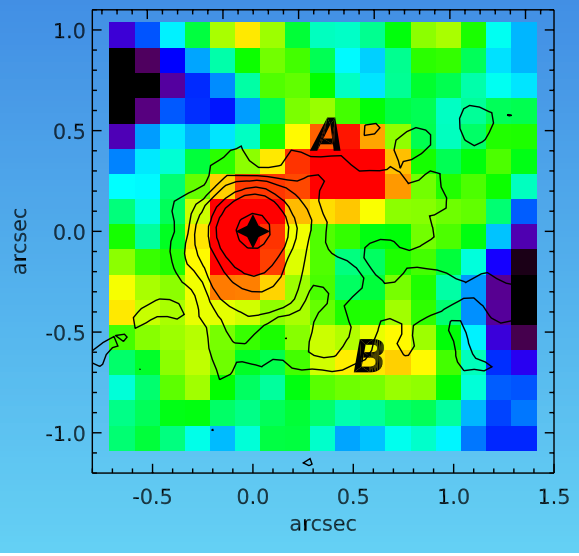
Archival H band (20')
integrated spectrum
on the central 1"x1"

Residual spectrum integrated
on Regions A and B

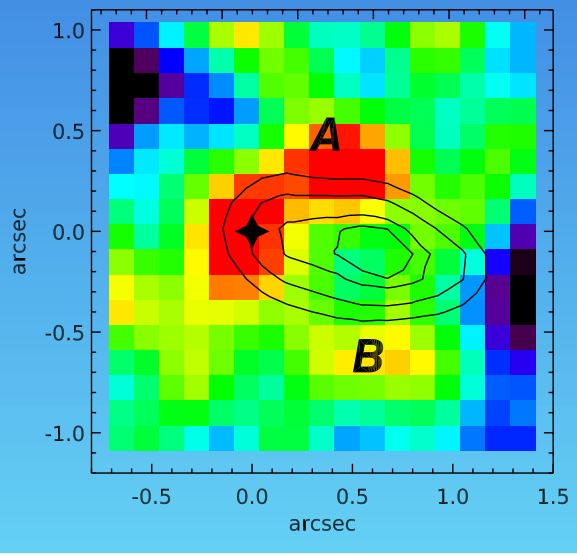


Narrow Ha map with contours of:

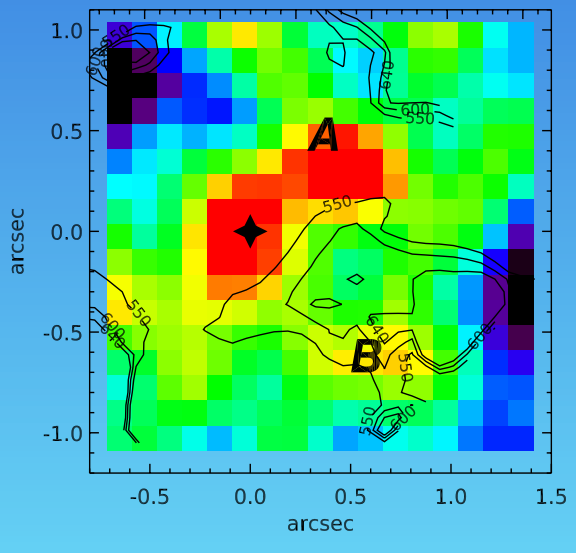
Rest frame U band (HST)

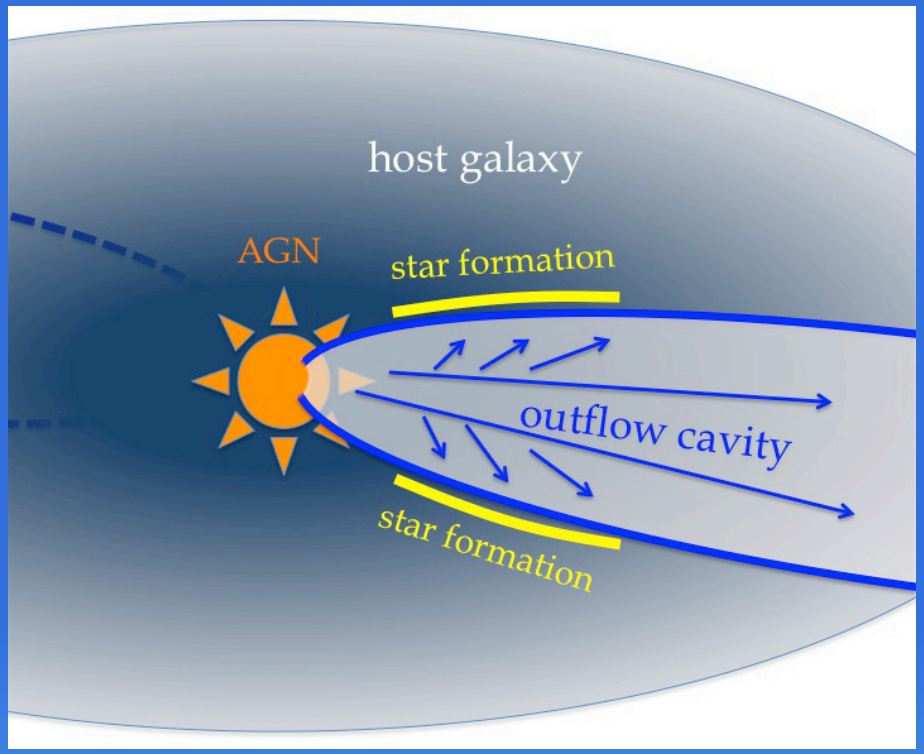


[OIII] blue wing flux

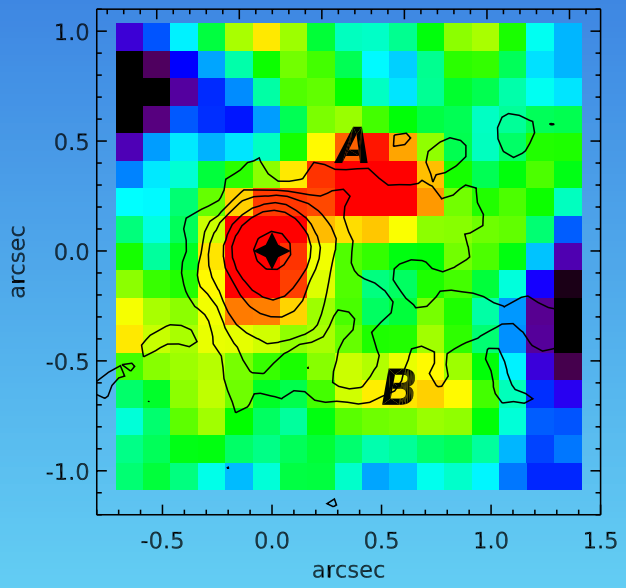


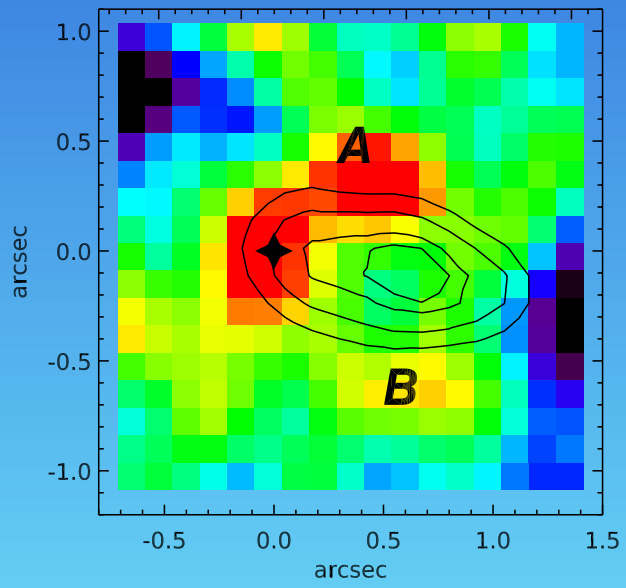
Outflow velocity width

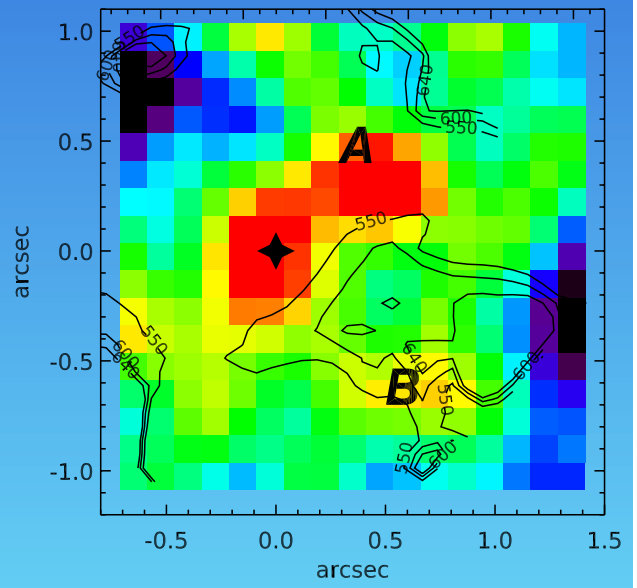




Both "Positive" and "Negative" feedback in action in the same galaxy







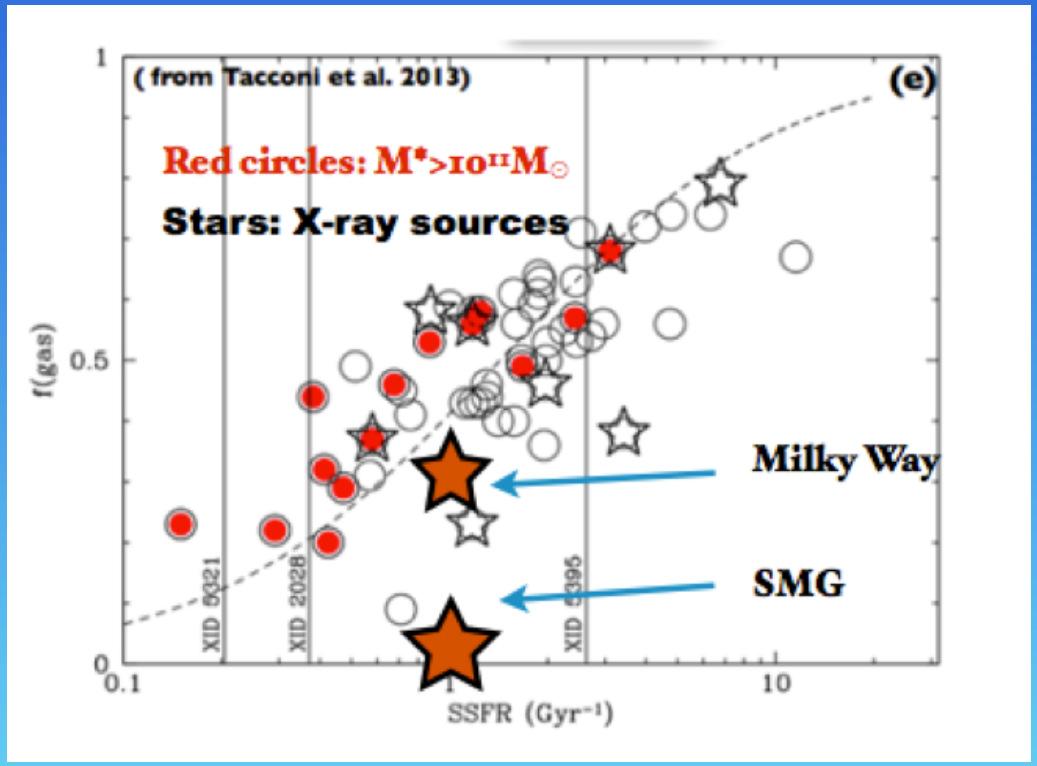
Gas content of XID2028

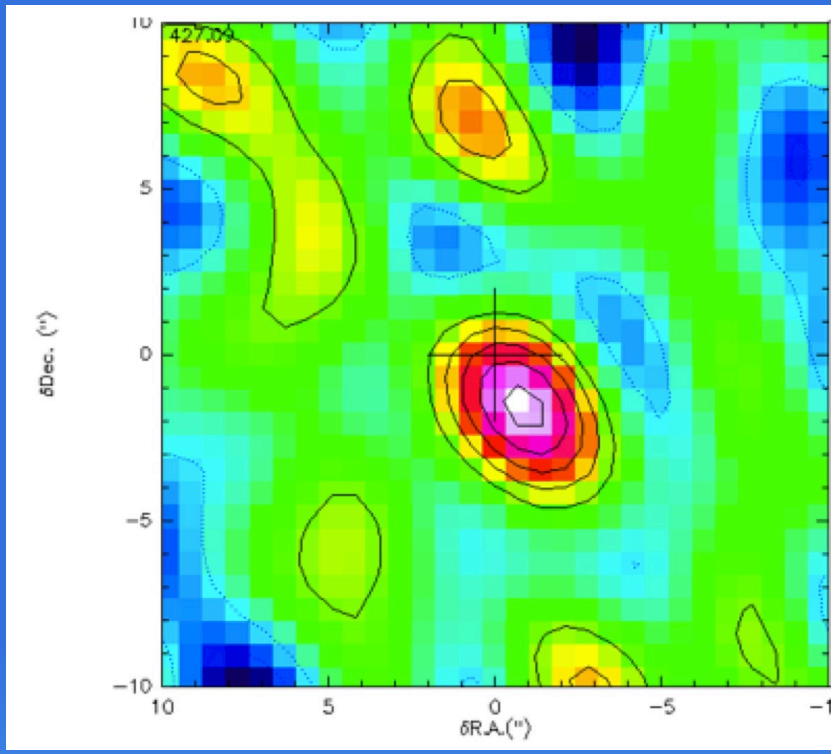
IRAM PdBI observations

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

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

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





Brusa, Feruglio, GC et al. in prep.

Gas fraction <30%

lower than normal "massive" galaxies and X-ray AGN

QSO feedback
Removing gas from the host?

Blowin' in the wind Summary

- QSO feedback effects on host galaxies at the peak epoch of galaxy and black hole assembly, where we expect to have the maximum influence of feedback on galaxy evolution, revealed by IFU IR observations of luminous QSOs

- Efficient criterion to select obscured, X-ray bright AGNs at the maximum of their feedback phase (Brusa et al. 2010): large scale outflows found in XMM-COSMOS QSOs using such criterion (Brusa et al. 2014, Perna et al. 2014) and X-Shooter@VLT

- SINFONI observations of **XID2028** reveal QSO effects on the host galaxy:
  - ✓ powerful, extended outflow detected in the [OIII] lines
  - ✓ outflow velocity and mass loading factor not sustainable by star formation only
  - ✓ first example of both "positive" and "negative" feedback in action in the same object

- IRAM observations have measured substantial molecular gas depletion in XID2028

- MUSE science verification data of the Seyfert galaxy NGC5643 show a possible additional example of positive feedback in a local AGN

- Approved SINFONI follow-up of two more X-Shooter targets with extended outflow evidences, and MUSE observations of a large sample local AGNs