An AGN special:
Feedback across cosmic epochs

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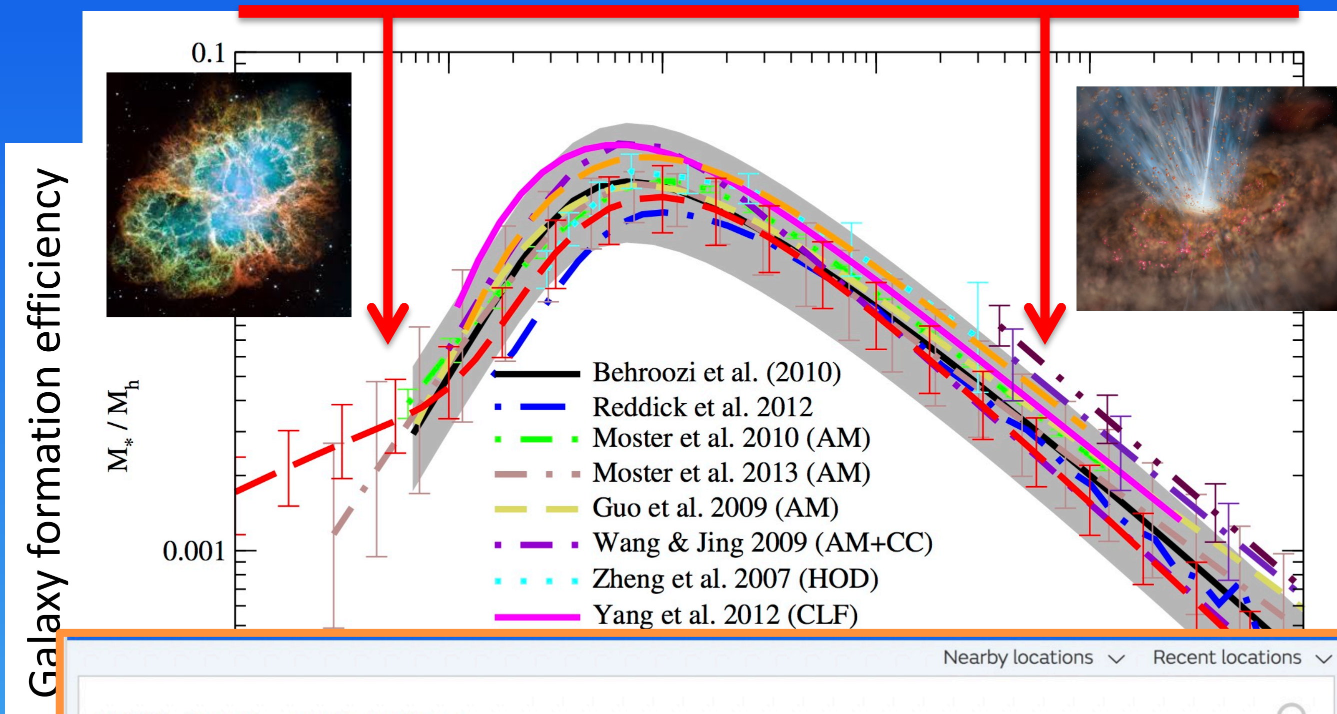
M. Mingozzi, G. Venturi and the MAGNUM team

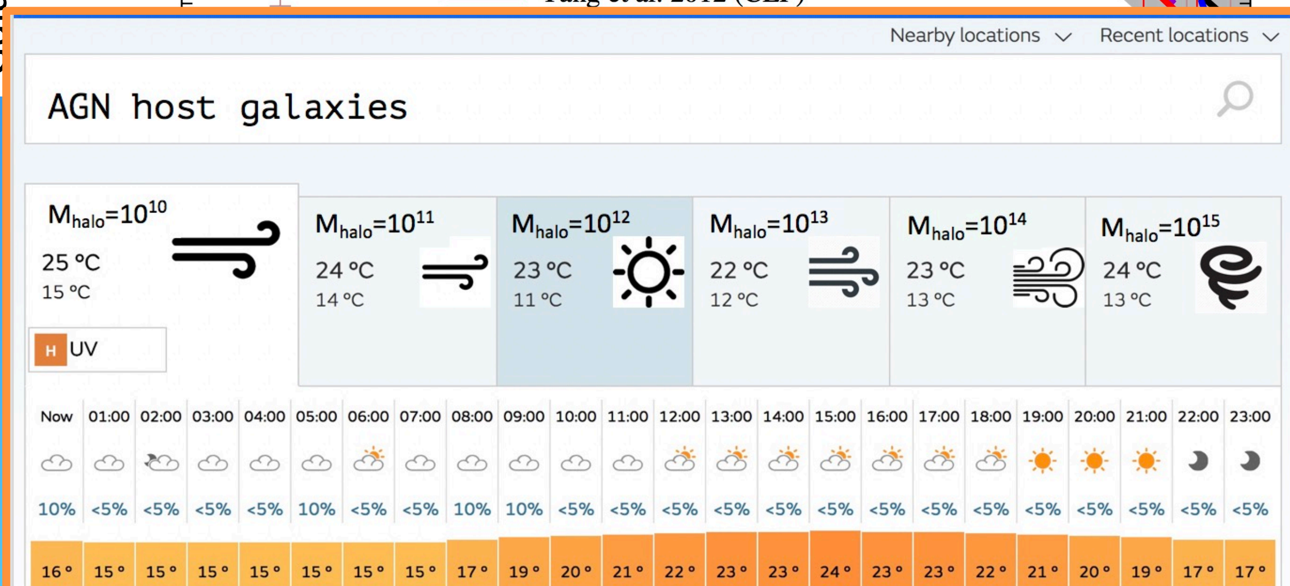
Durham, 2/8/18

Why most baryons are not condensed into stars?

Cosmic Baryon Fraction ($\Omega_b/\Omega_0 = 0.15$ from WMAP)



Stellar feedback can't explain missing massive galaxies (e.g. Hopkins+06, Croton+06, Murray+05, Menci+08, …)

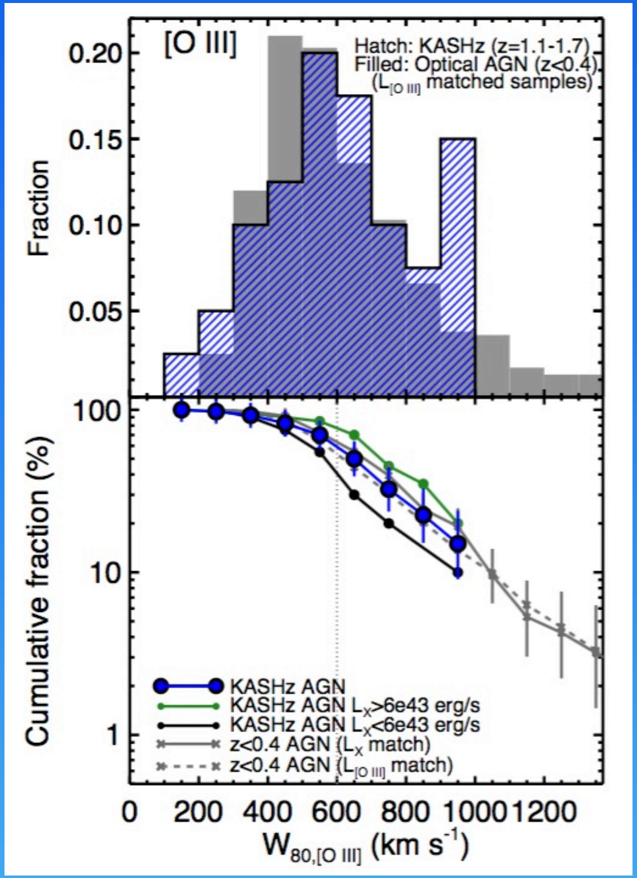


#AGNSPECIAL18

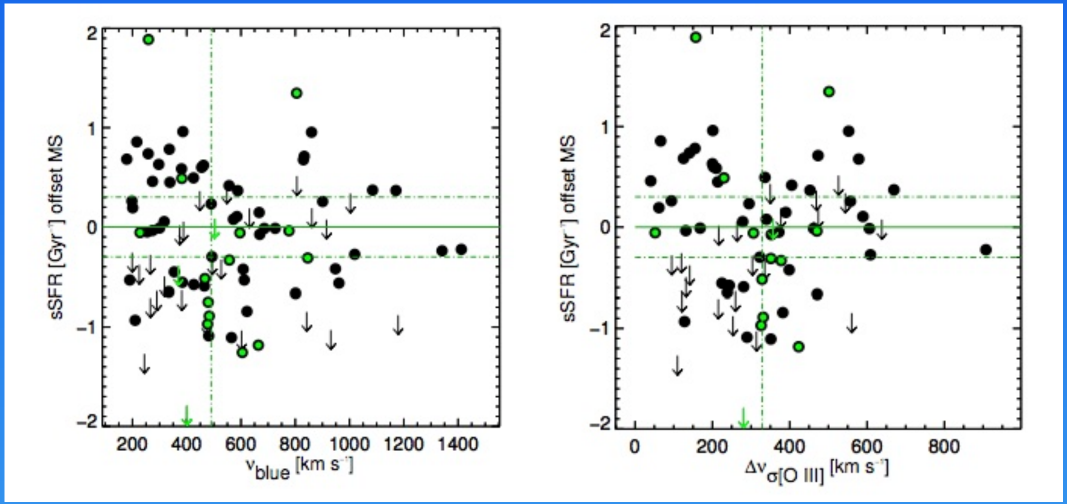
FEEDBACK FORECAST

Are Outflows ubiquitous?

Do we have evidences of effects on the host?



Harrison et al. (2015) – KASHz survey
82 x-ray selected AGNs with KMOS
(see also e.g. Perna+17, Forster-Schreiber+15,18)



Balmaverde et al. (2015): SDSS+Herschel selected QSOs
(see also e.g. Leung+17, Woo+17, and many others)

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

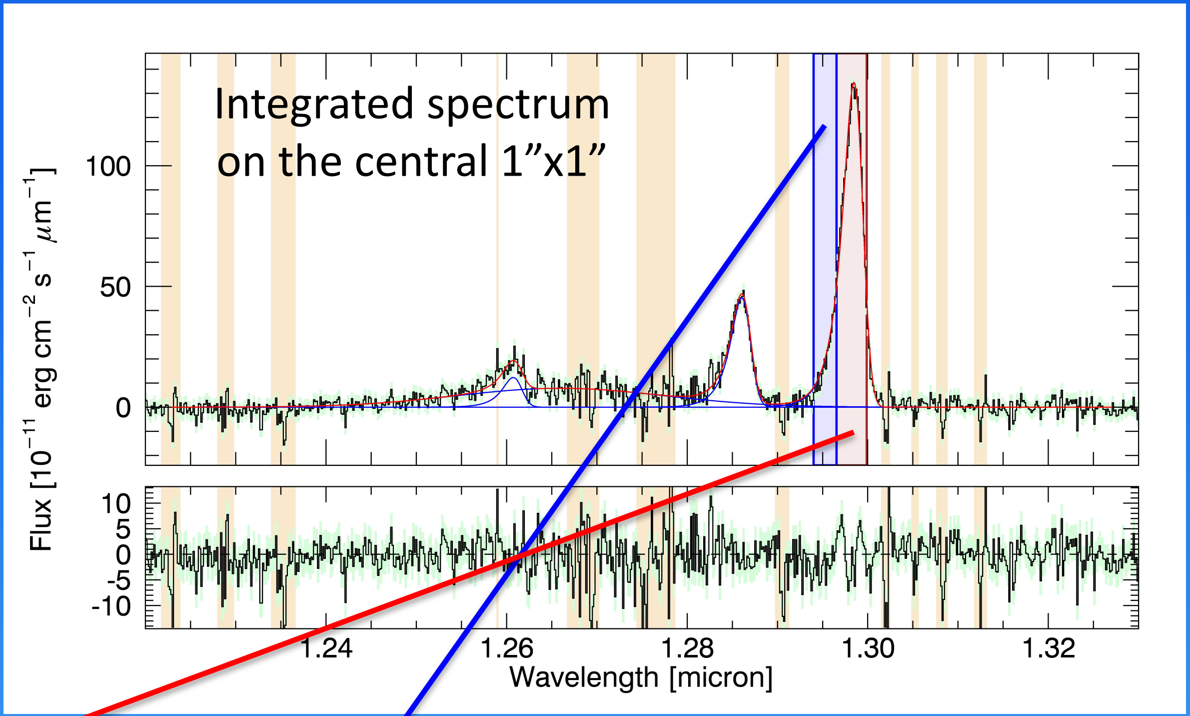
Many theoretical predictions, increasing evidences of widespread outflows,
but still few observations of feedback effects on host galaxies…

A feedback showcase: XID2028 at z=1.6

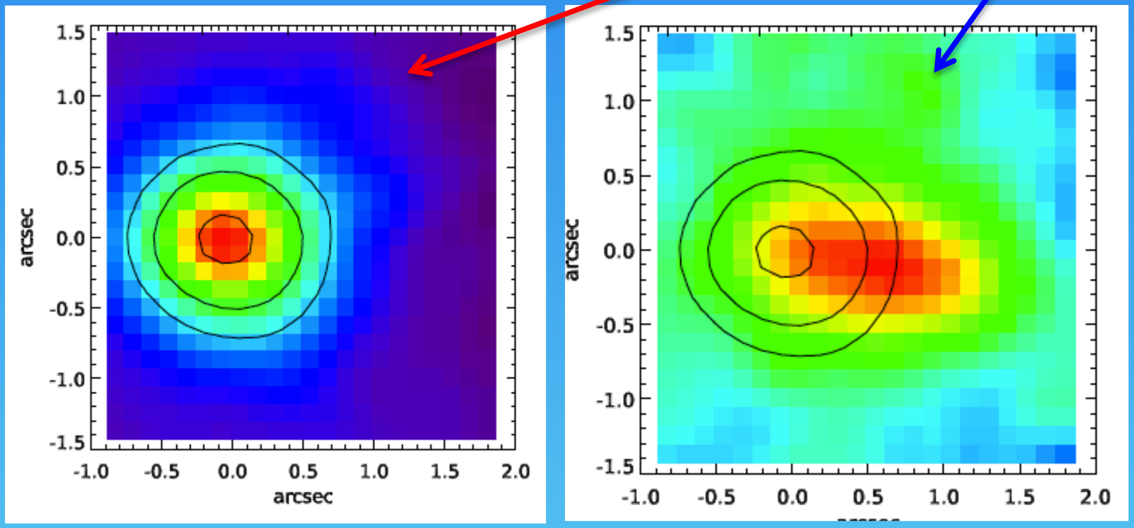
Selected to be X-ray bright and optically obscured (Brusa+10,15)

SINFONI IFU observations
J band 6 hrs

Scale 0.125”x0.125”
PSF=0.6”



GC et al. 2015



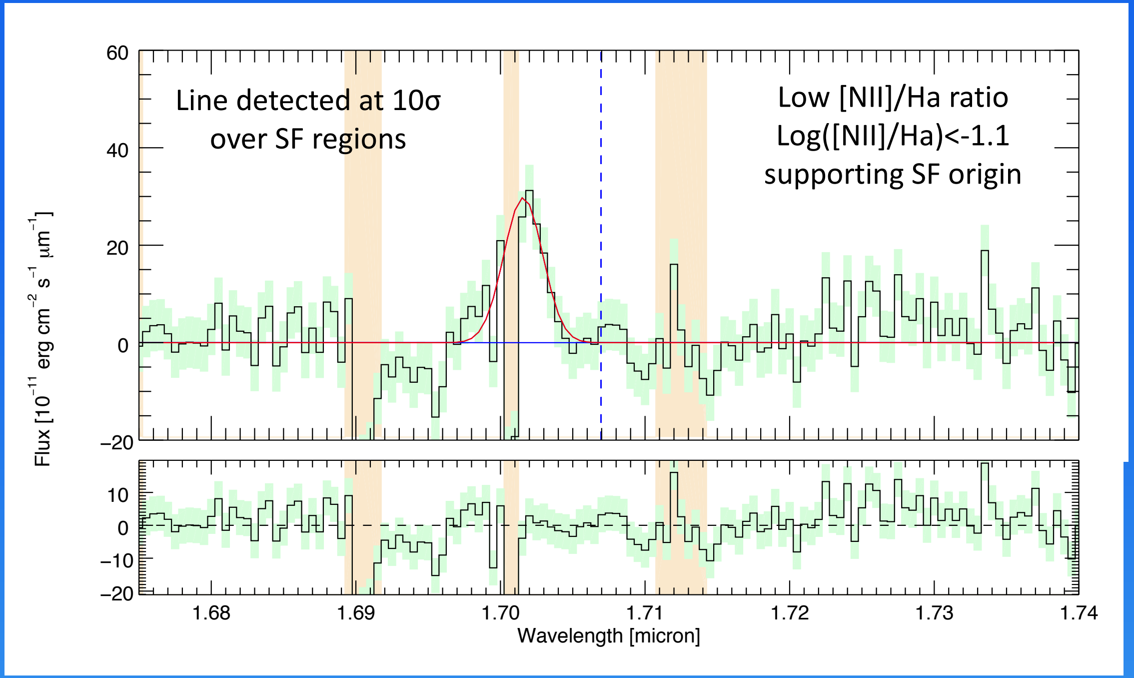
Integrated flux maps on the line core (left) and on the line wing (right)

Outflow with
v_{out}~ 1500 km/s
out to 13 kpc!
$\dot{M}$ > 300 $M_\odot$/yr

Outflow effects on the host galaxy

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

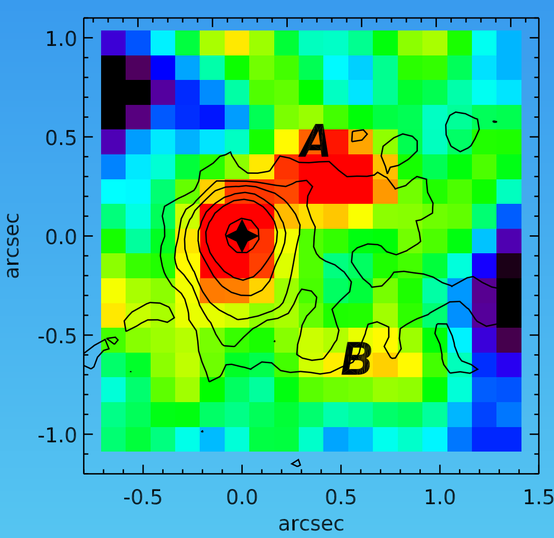
Residual spectrum integrated on Regions A and B



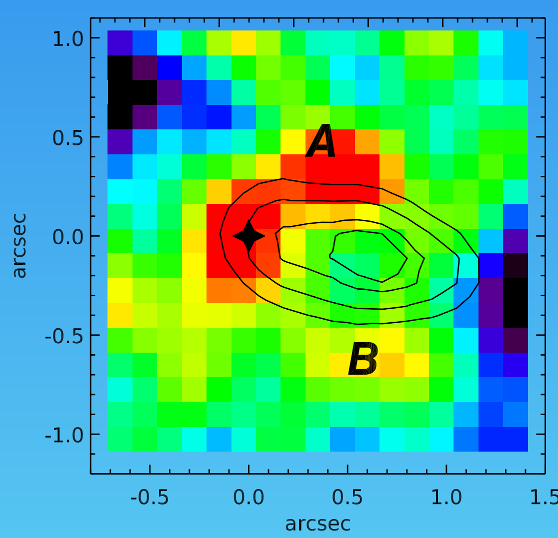
GC et al. 2015

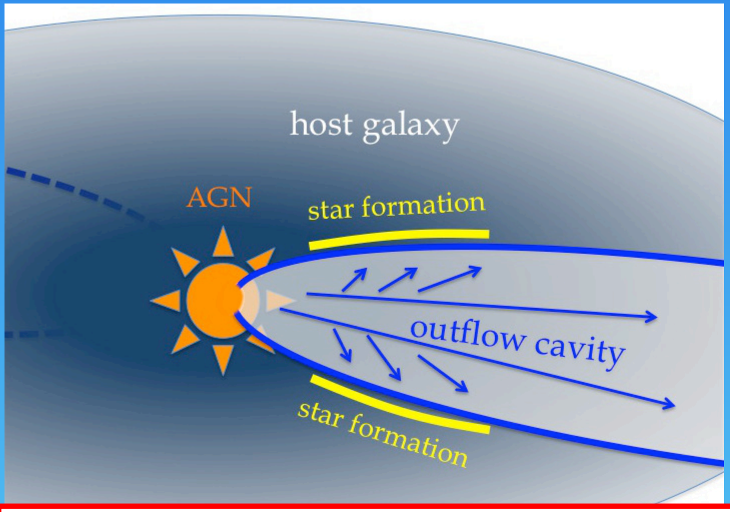
Narrow Ha map with contours of:

Rest frame U band (HST)



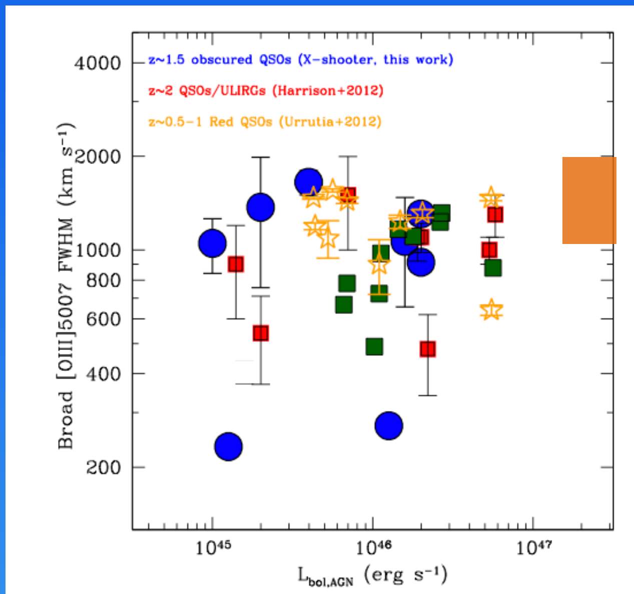
[OIII] blue wing flux





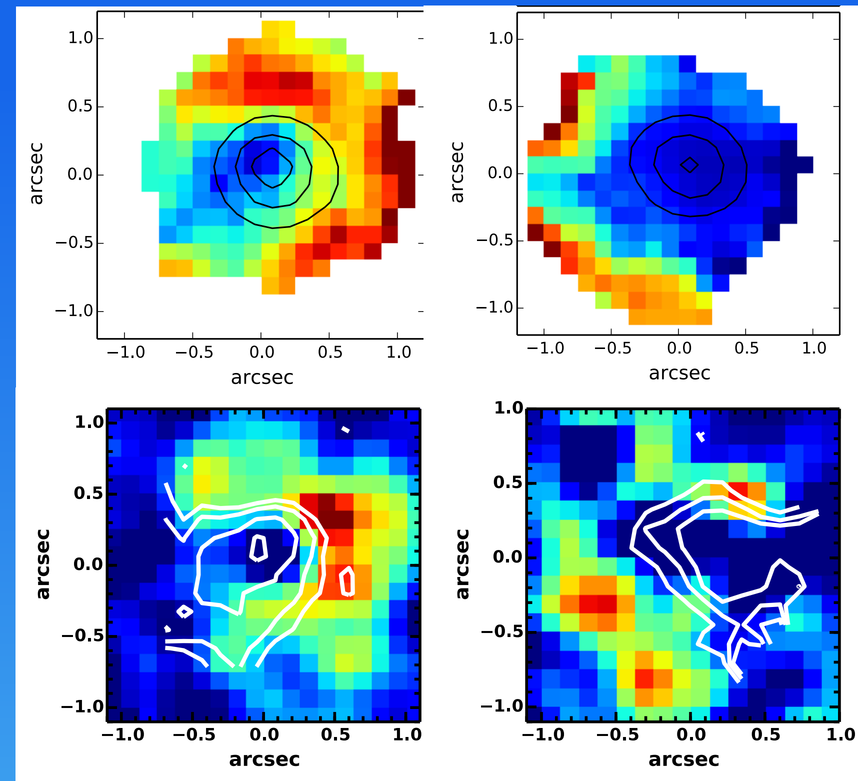
Both “Positive” and “Negative” feedback in action

More outflows and feedback: High EW([OIII]) selection



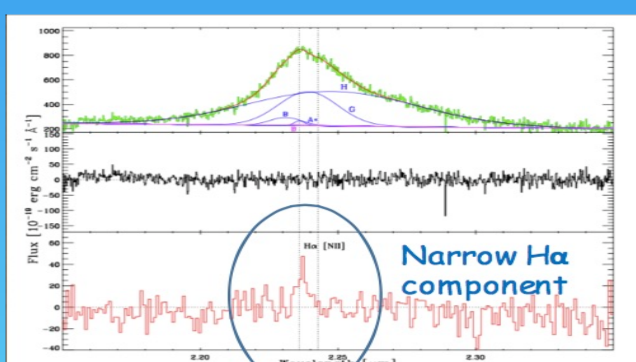
[OIII] velocity

Narrow Ha map



Carniani et al. (2015, 2016)

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



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

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

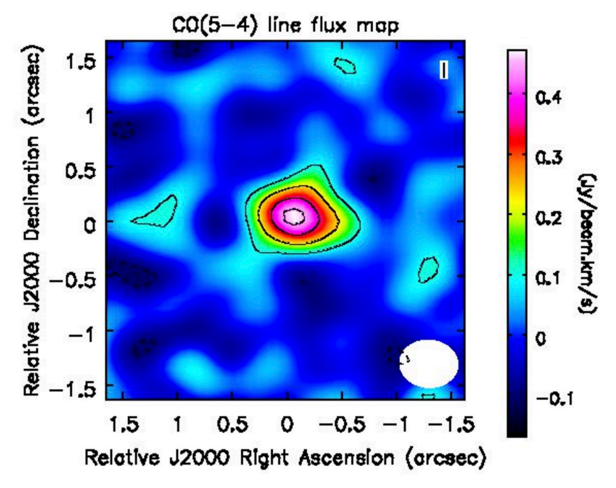
but still SFR>100 $M_\odot$/yr …

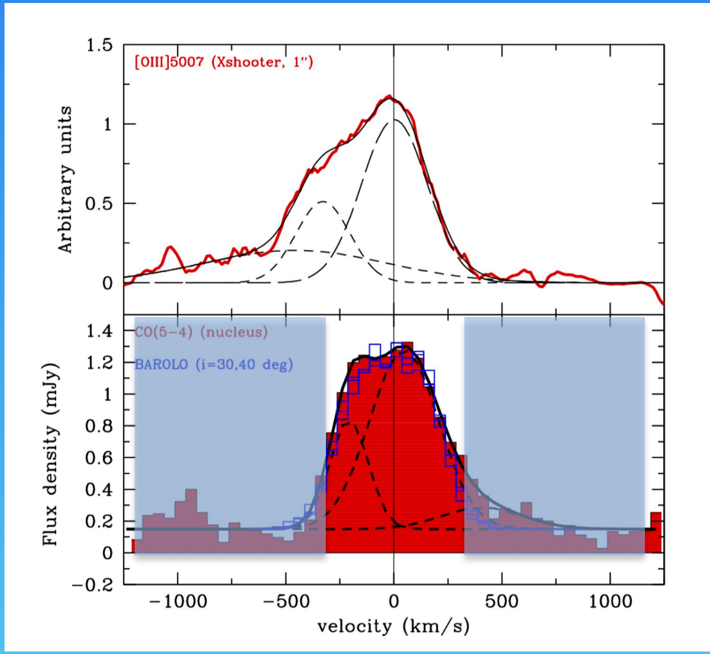
ALMA deep follow-up of XID2028: CO(5-4) line emission

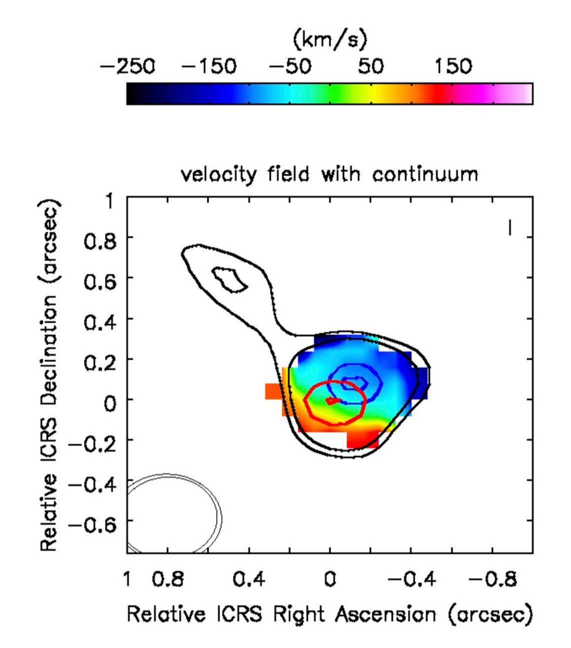
ALMA Observations in CO(5-4) + continuum taken in Cycle 3

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

Broad (FWHM~500 km/s) asymmetric line profile







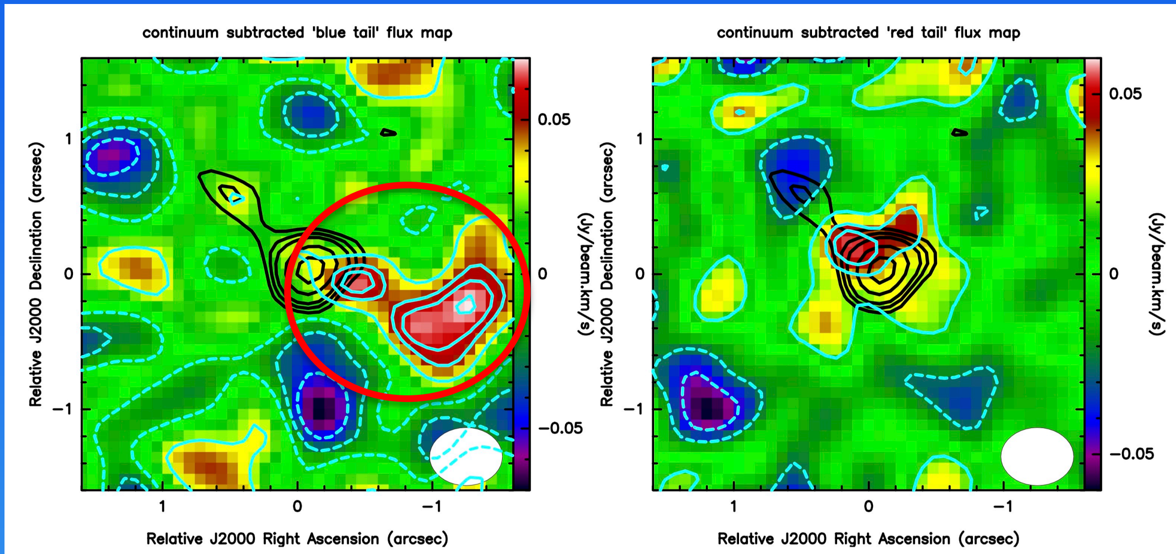
The central component shows a velocity gradient along the source in the NW-SE direction

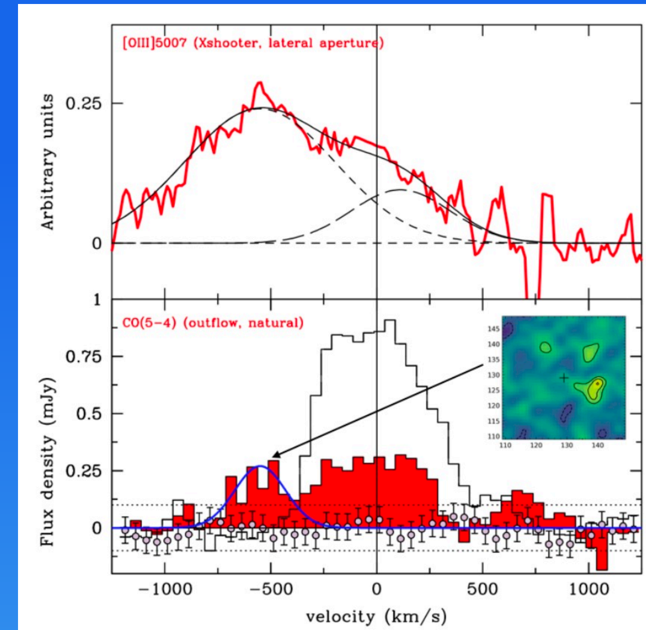
$M_{dyn} \approx 6 \times 10^{11}\ M_{\odot}$

Brusa, GC et al. 2018

Brusa, GC et al. 2018

A spatially resolved CO(5-4) outflow

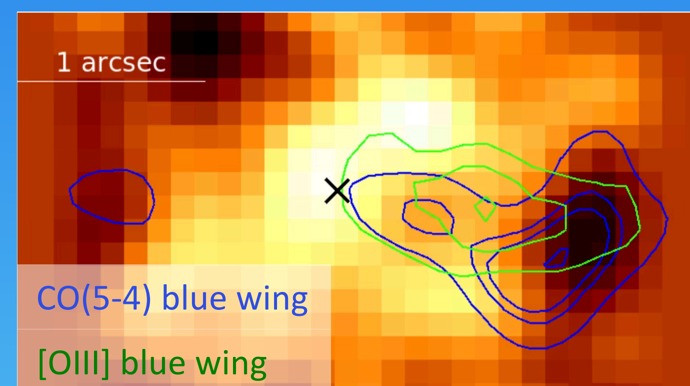




Imaging of the blue (< -350 km/s) and of the red tail (>350 km/s) reveal a bi-directional outflow out to ~ 10 kpc and v ~ 700 km/s

CO mass outflow rate ~ 150-750 $M_{\odot}$/yr

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



(see also Herrera-Camus+18)

First direct detection of a spatially resolved **CO outflow at high-z**

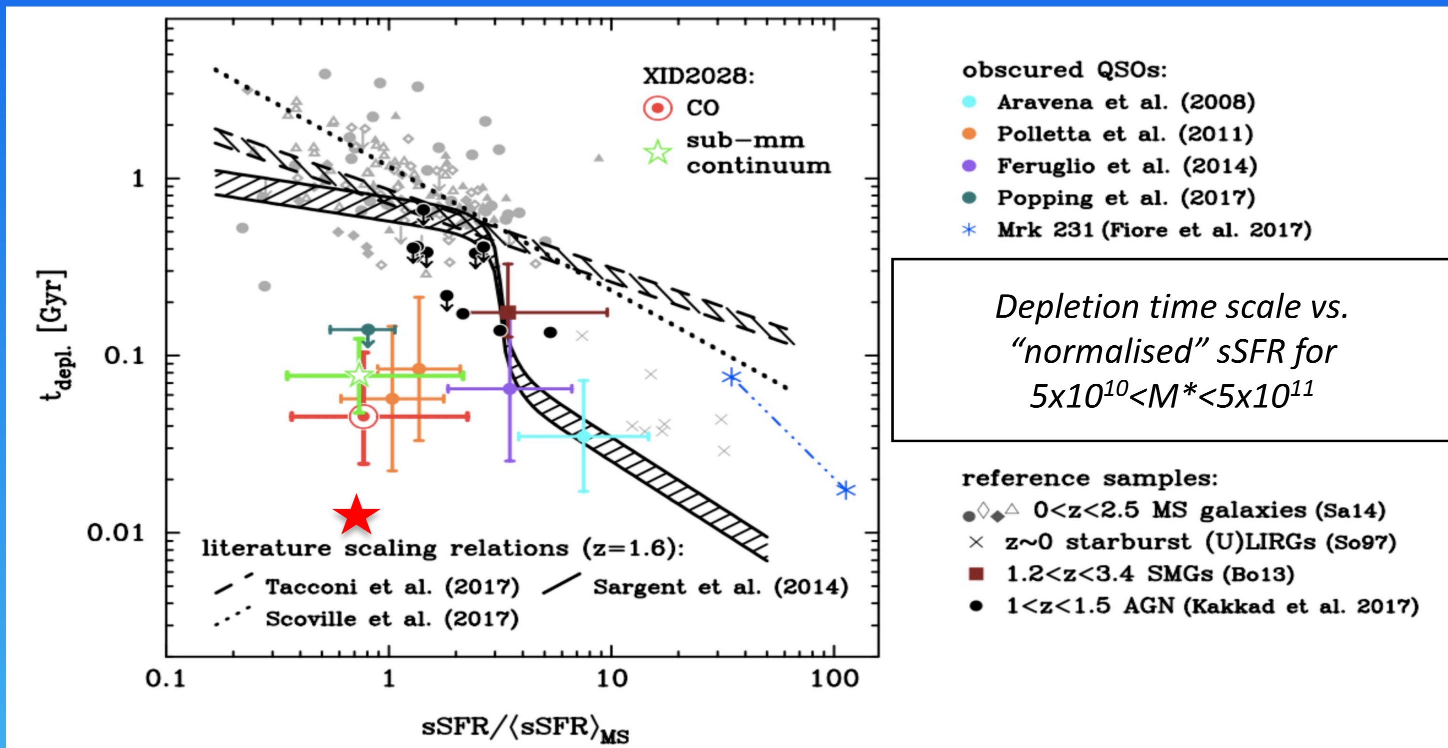
Spatially coincident with the ionized outflow component

Molecular gas content of XID2028

Brusa, GC et al. 2018

We derive a total $M_{gas} = 1\pm0.5 \times 10^{10}\ M_\odot$ consistent with estimate from RJ dust continuum

Gas fraction < 5% despite SFR~270 $M_\odot$/yr!

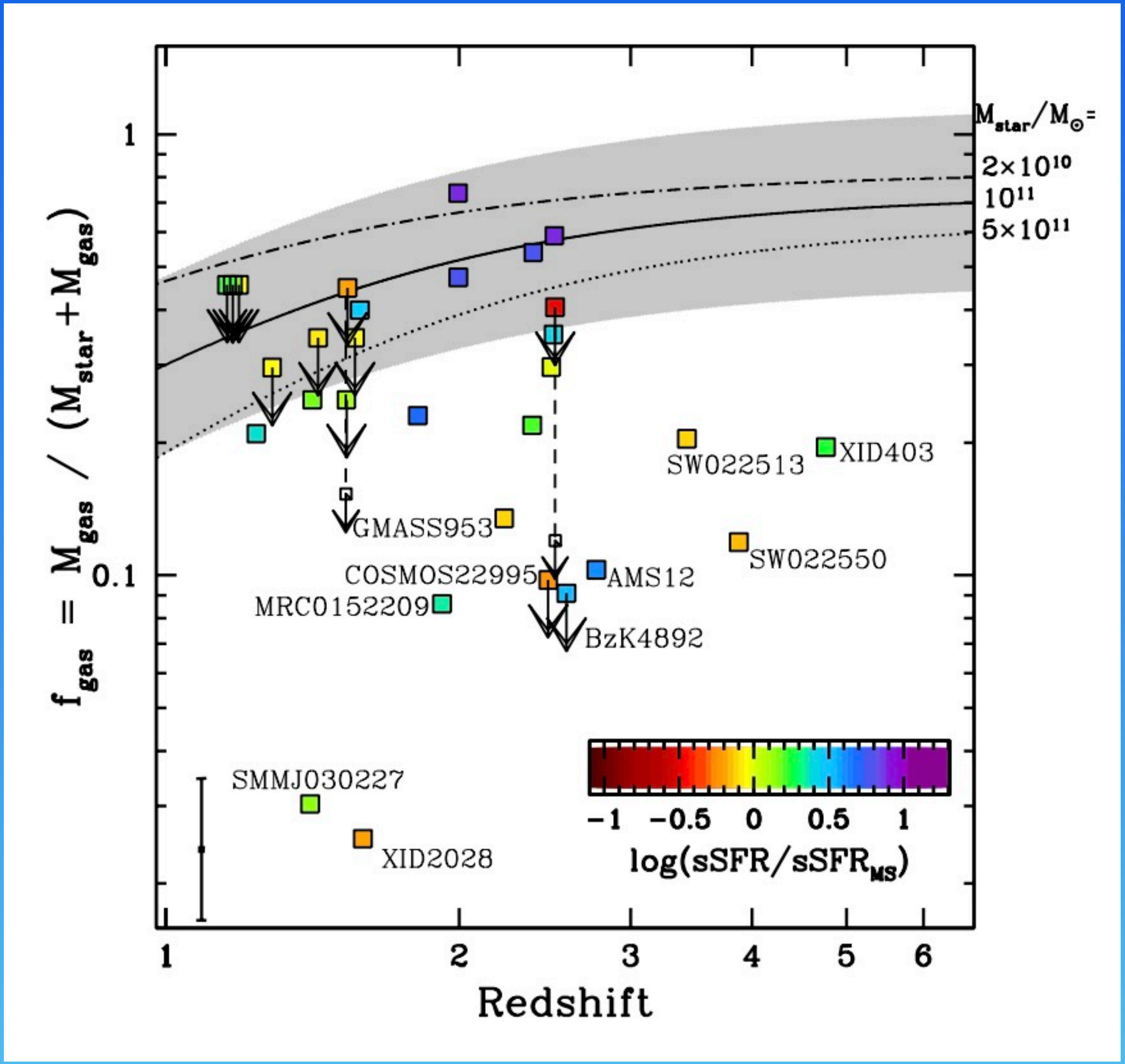


This converts in a t_{depl}=45-80 Myr (10-30 Myr including outflow), ~2 orders of magnitude lower than the expected position on the plot for its sSFR

Evidences of QSO feedback

Removing gas from the star forming host galaxy!

Gas masses in z>1 obscured QSO hosts



Compilation of all 24 z>1 obscured QSO hosts with M_* and CO observations

Indication that (some) QSO hosts have lower f_{gas} than normal galaxy (Sargent+14 model)

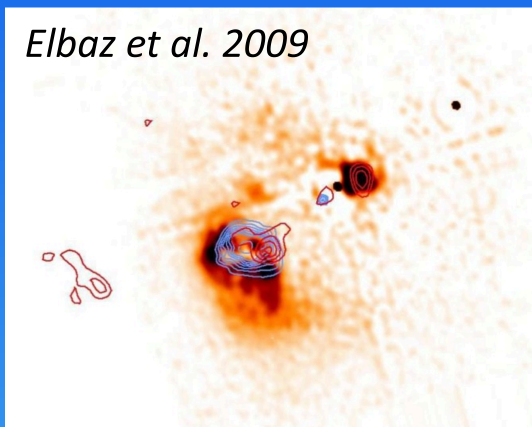
(see also M. Banerji's talk on Tuesday, D. Rosario's one later today and M. Talia's poster)

Perna, GC et al. 2018

Positive Feedback: A new mode of star formation?

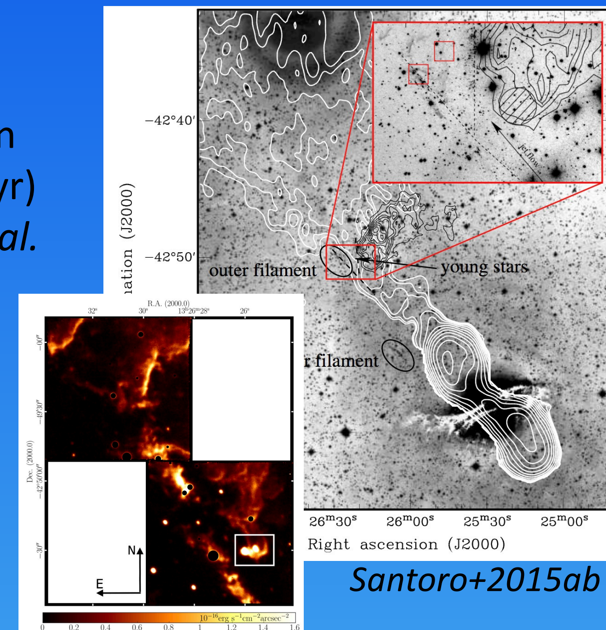
1) AGN-induced pressure on the gas-rich disk (e.g. *Silk et al. 2013*)

Very few direct observations so far:

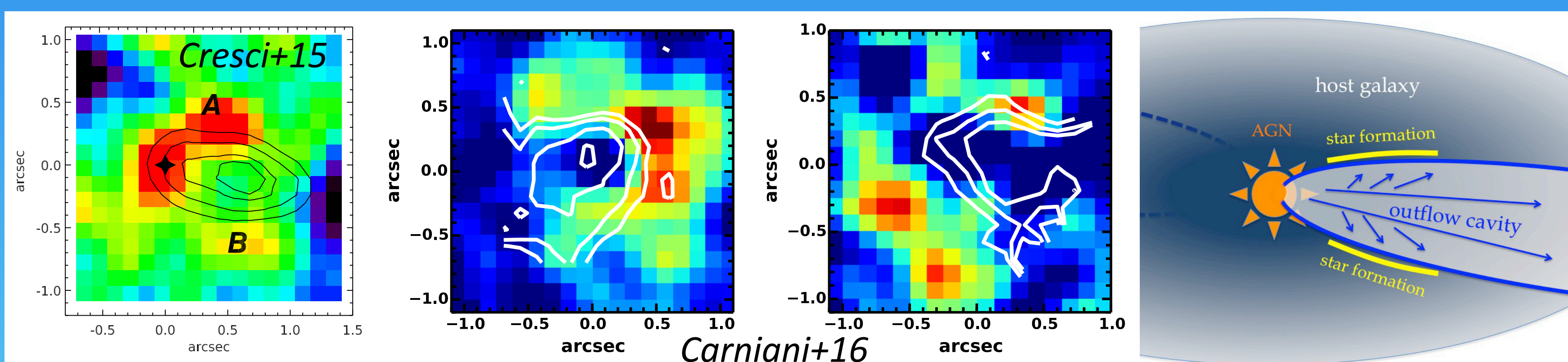


Radio jets inducing star formation on companion galaxies (SFR~1-200 $M_{\odot}$/yr) *(See also Kramer et al. 2004, Croft et al. 2006, Feain et al. 2007)*

Jet-ISM interaction triggering star formation *(see e.g. Crockett et al. 2012, Salome' et al. 2015, Santoro+2015ab,2016)*



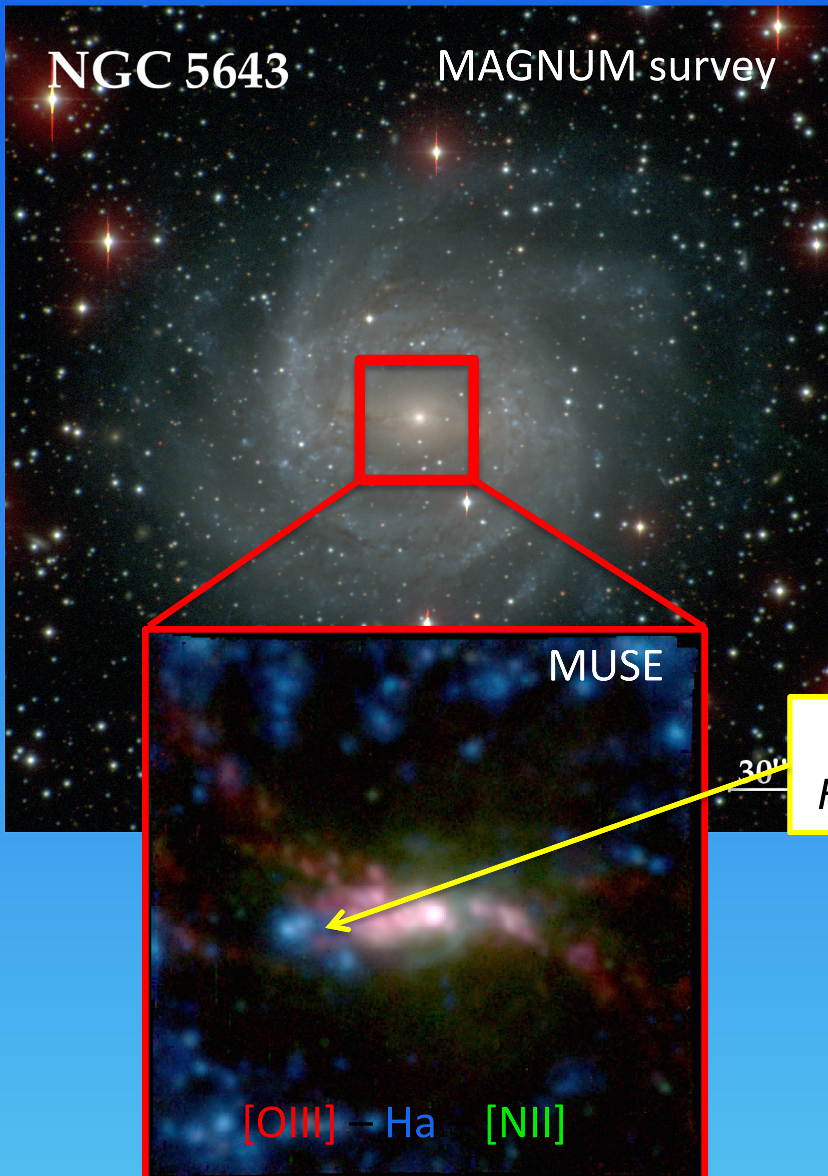
Santoro+2015ab



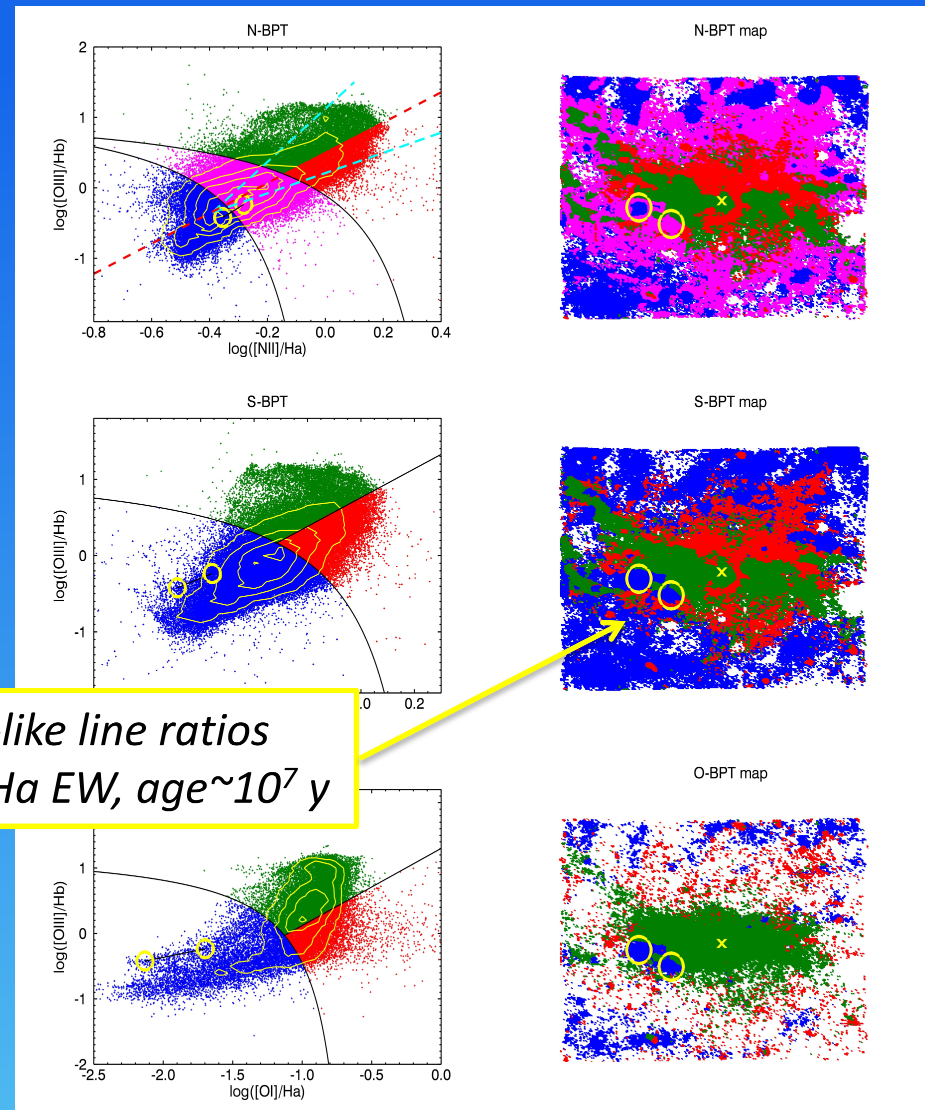
Powerful QSO outflows compressing gas in the disk (SFR~10-100 $M_{\odot}$/yr)

Positive Feedback: A new mode of star formation?

1) AGN-induced pressure on the gas-rich disk (e.g. *Silk et al. 2013*)



SF-like line ratios
High Ha EW, age~10^7 y



GC et al. 2015b

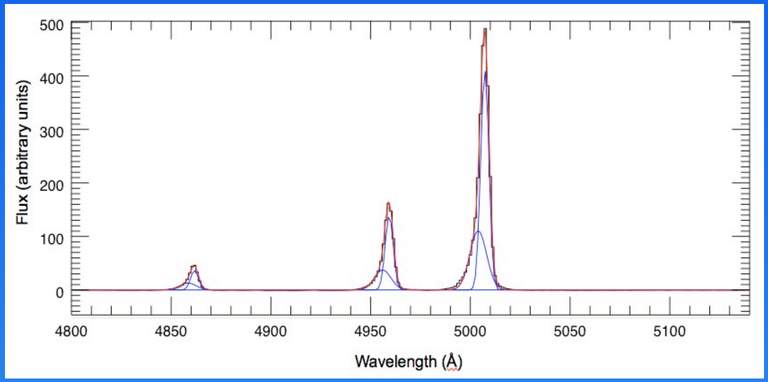
Seyfert 2, D=17.3 Mpc

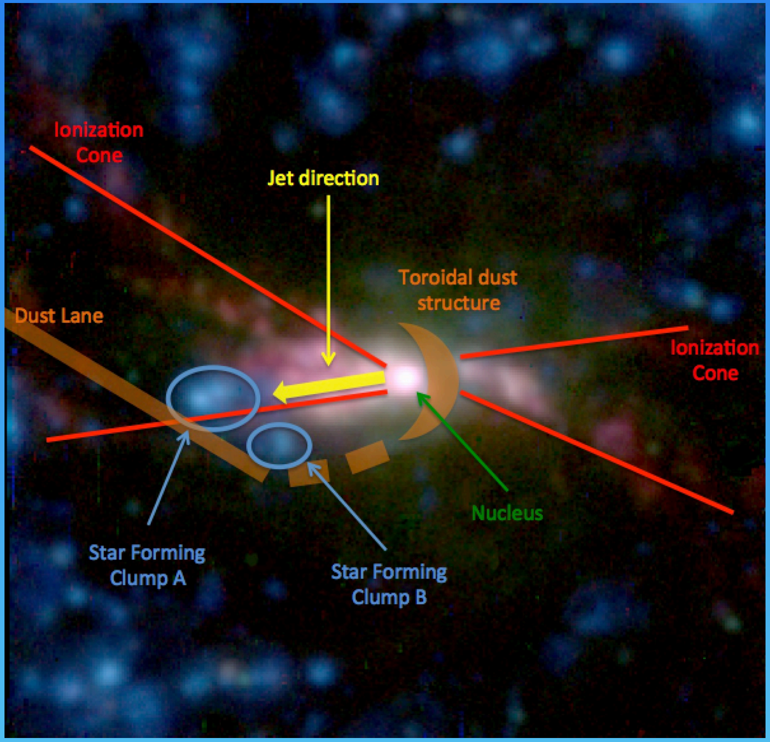
L_x=1 10^{40} erg/s; L_{bol}~7 10^{42} erg/s

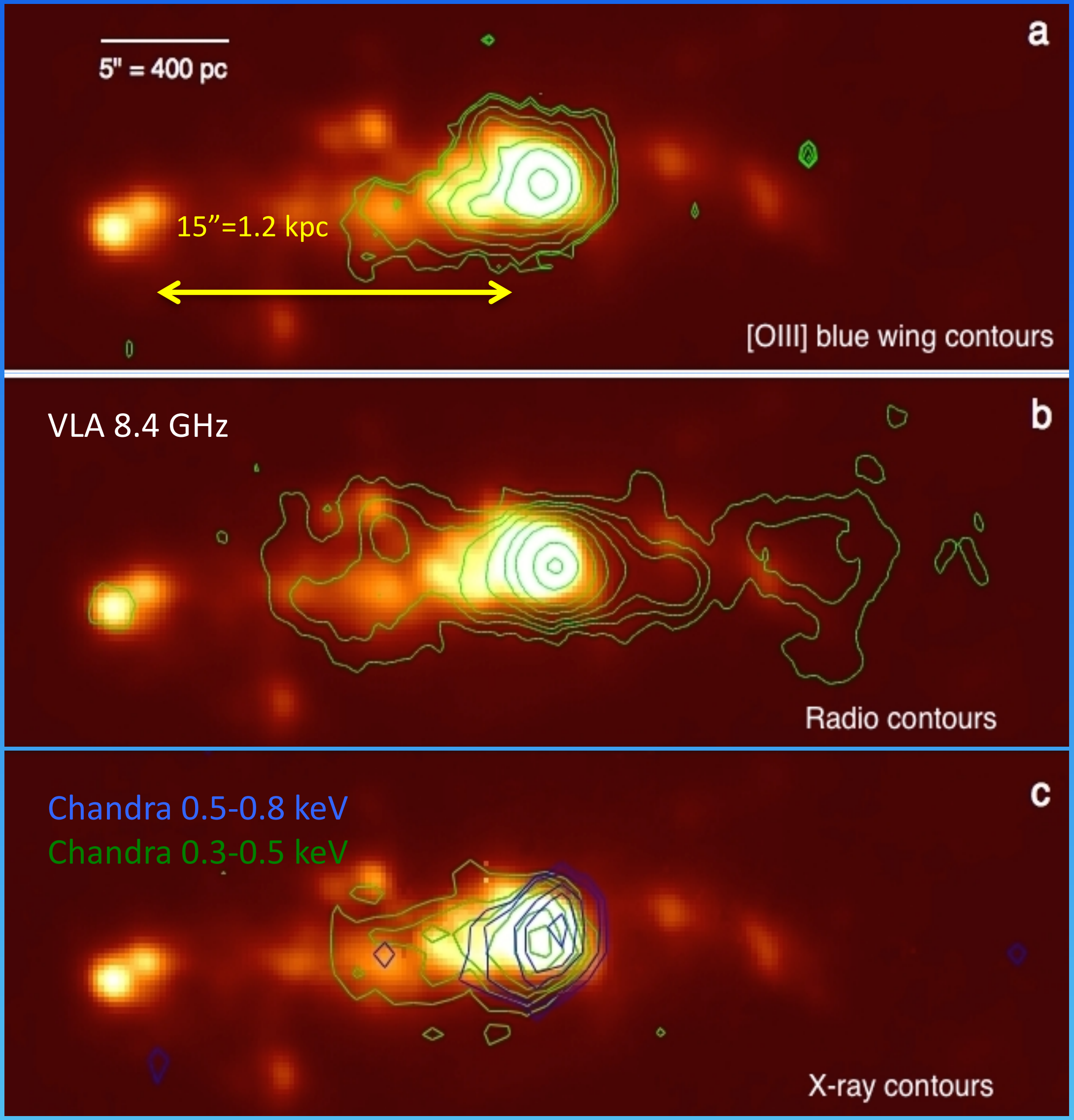
(see also Alonso-Herrero+18)

Positive Feedback: A new mode of star formation?

1) AGN-induced pressure on the gas-rich disk (e.g. *Silk et al. 2013*)





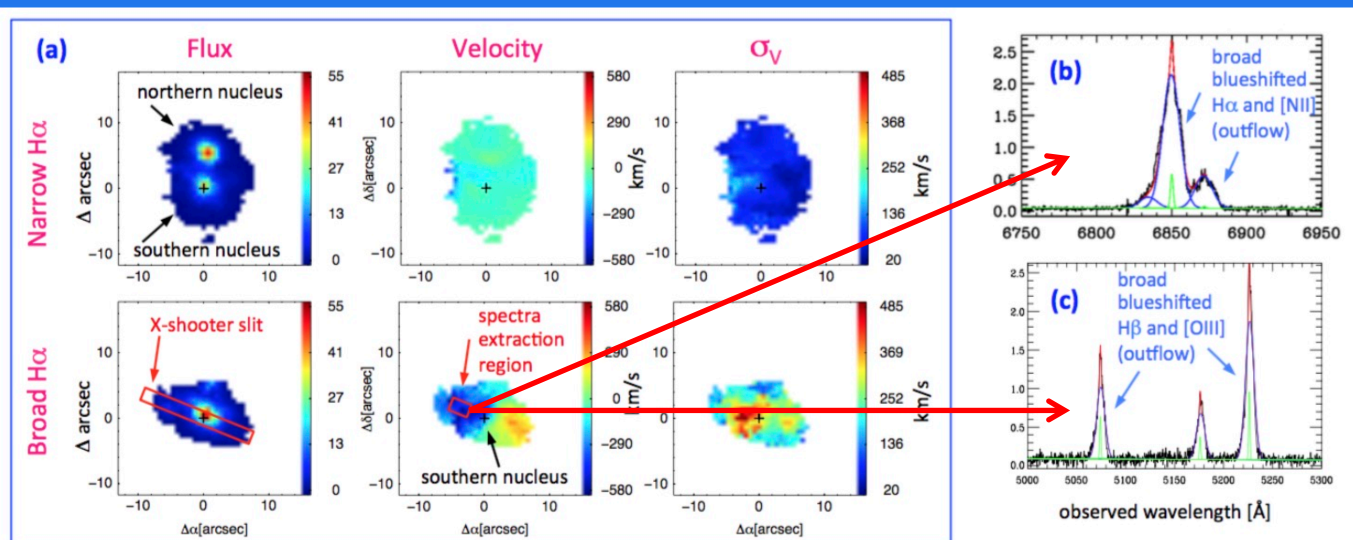


GC et al. 2015b

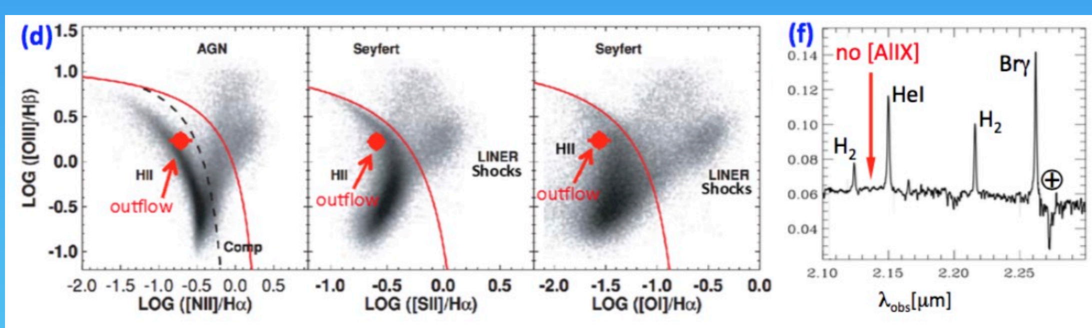
Positive Feedback: A new mode of star formation?

2) feedback-triggered star formation directly in the outflow (e.g. Ishibashi & Fabian 2013, 2014, Zubovas & King 2013,2014)

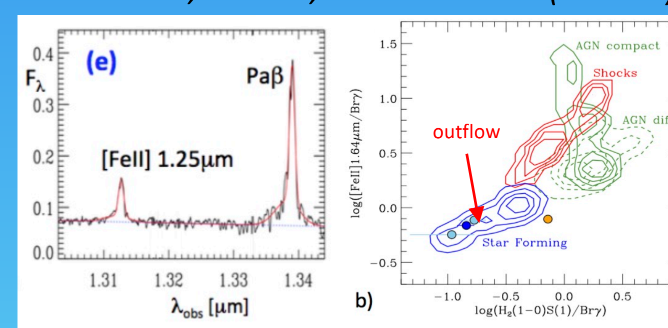
X-Shooter+MUSE observations of IRAS2318-59, a merging system at z=0.05 hosting both AGN and starburst activity



Maiolino, Russell, GC et al. 2017 (Nature)



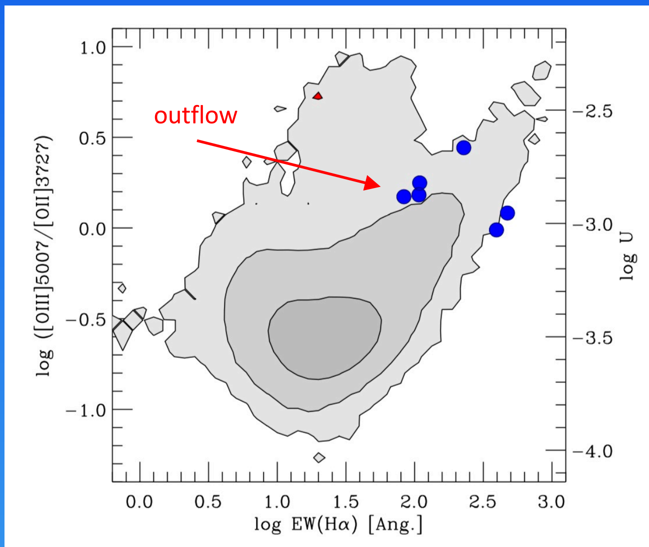
Ionization neither dominated by the AGN



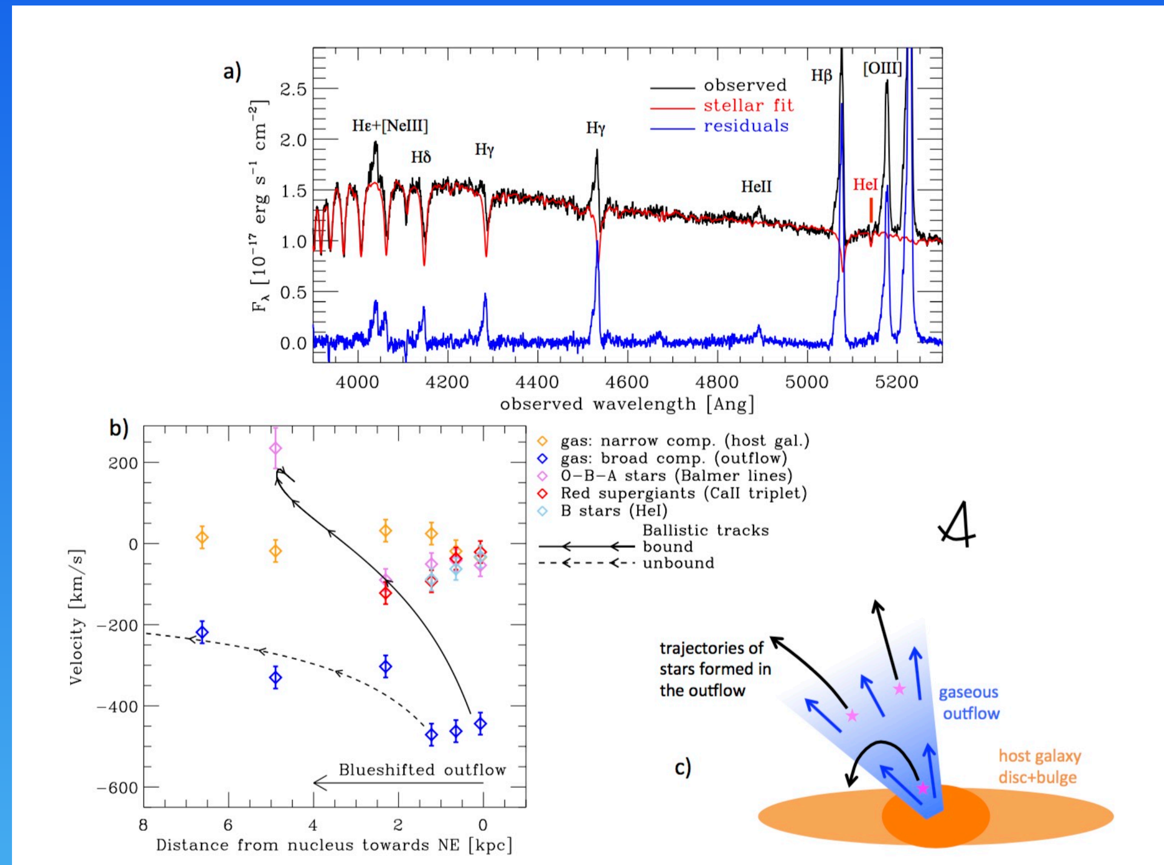
nor by shocks

Positive Feedback: A new mode of star formation?

2) feedback-triggered star formation directly in the outflow (e.g. Ishibashi & Fabian 2013, 2014, Zubovas & King 2013,2014)

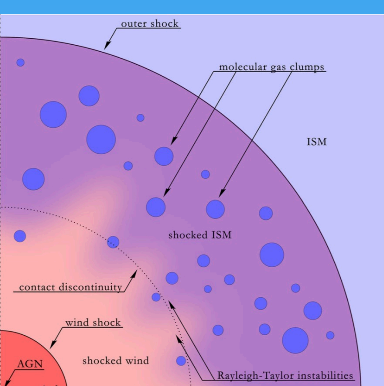


Ionization parameter comparable (or higher) to local SDSS galaxies → in situ star formation!



All stellar features in the outflow region (1-3 kpc distance), show a blueshift (v~100 km/s) relative to the galactic disc

Velocity difference with gas explained by simple dynamical model



Zubovas & King (2014)

Maiolino, Russell, GC et al. 2017 (Nature)

SUMMARY

Negative feedback:

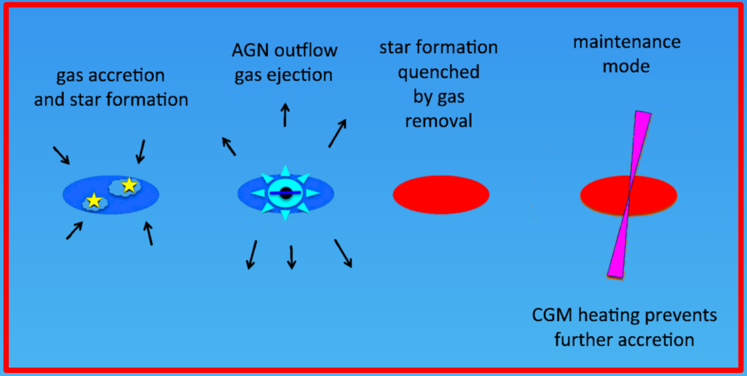
Finally directly observed in high-z QSOs hosts, through IFU spectroscopy and ALMA CO mapping

Positive feedback:

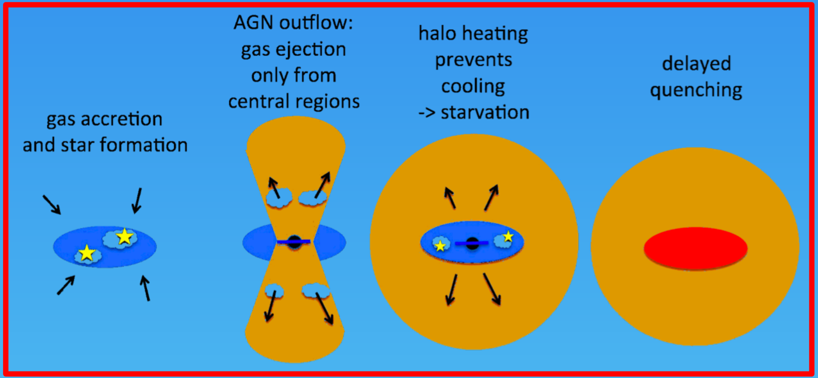
First evidences are now suggesting Star Formation induced and produced in QSO/AGN outflows as well

Open issues:

- which is the role of positive feedback?
- not yet clear if negative feedback is really affecting the whole galaxy gas reservoir and if the gas is escaping the halo → is feedback mostly ejective or delayed (or both)?



eject or prevent



(models: Muratov+15, Bower+16, Woo+17, Davè+16, Angles-Alcazar+17 etc…)

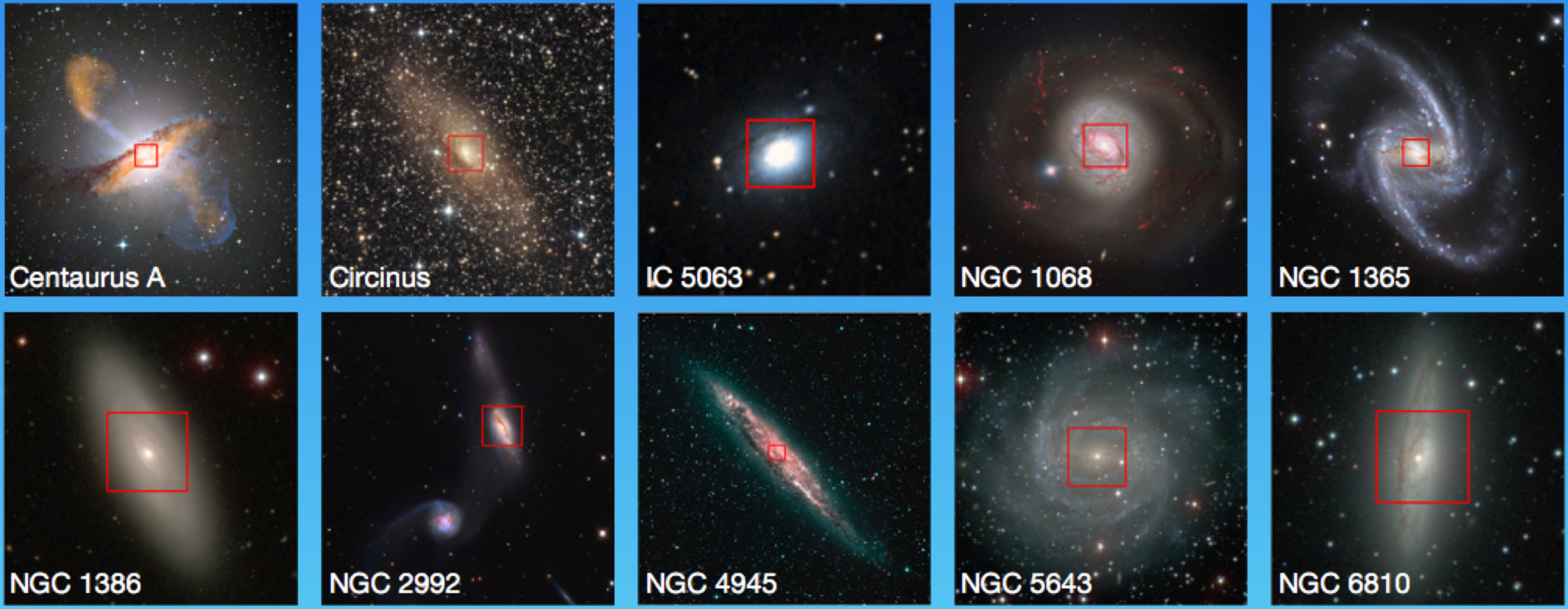
Next steps:

- Larger unbiased samples of AGN with IFU observations (e.g. SUPER survey)
- Detailed studies of outflow properties and its interaction in local galaxies (e.g. MAGNUM)

MAGNUM: *Measuring Active Galactic Nuclei Under MUSE Microscope*

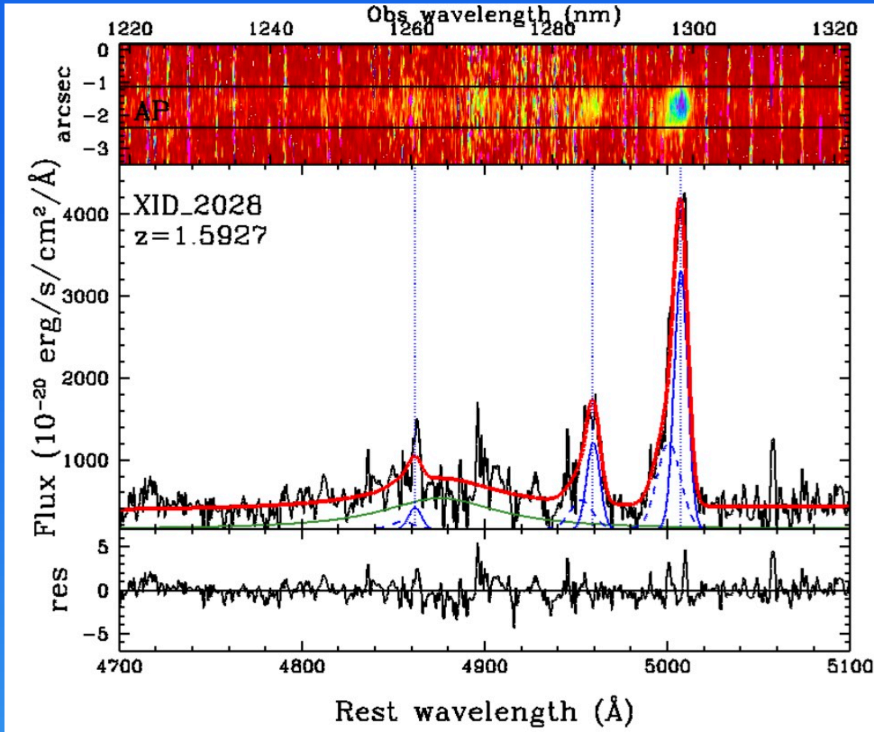
- Targeting Nearby AGNs (D < 50 Mpc) observable from ESO
- Seeing limited (~1"):
  15 pc (@4Mpc)
  115 pc (@30Mpc)
- so far 10 objects observed (900,000 spectra!!)
- Multi-wavelength data available: *Chandra, XMM-Newton, Galex, HST, Spitzer, Herschel, ALMA, Radio…*

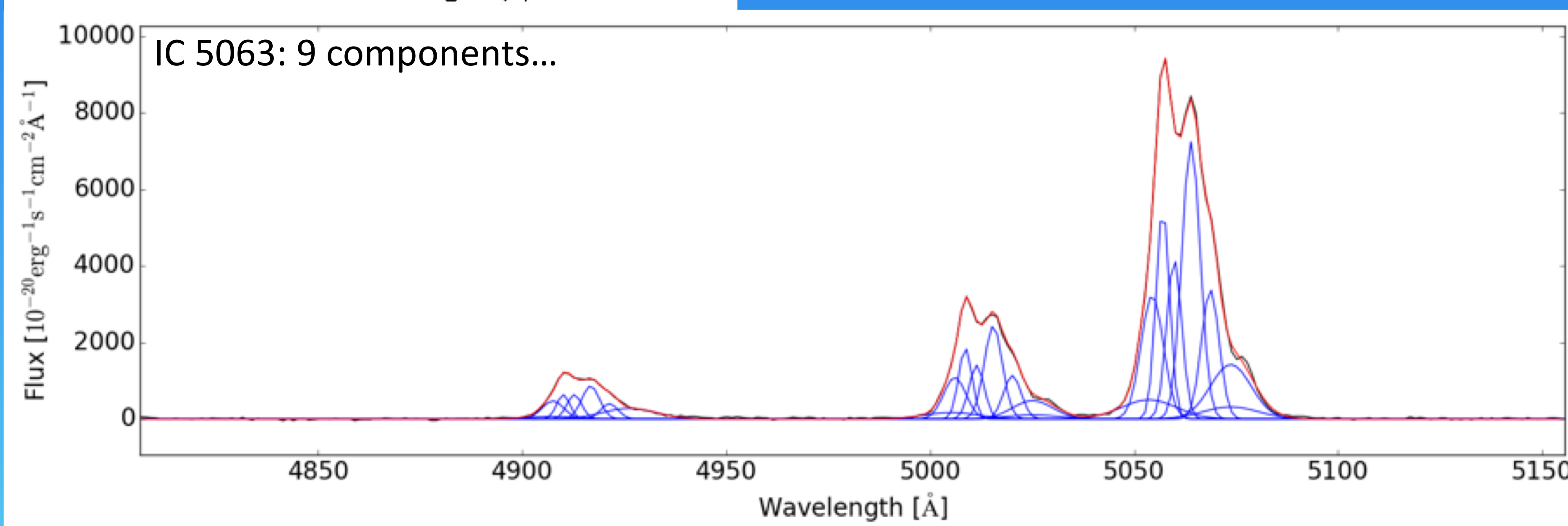
PI: A. Marconi (Univ. Firenze)



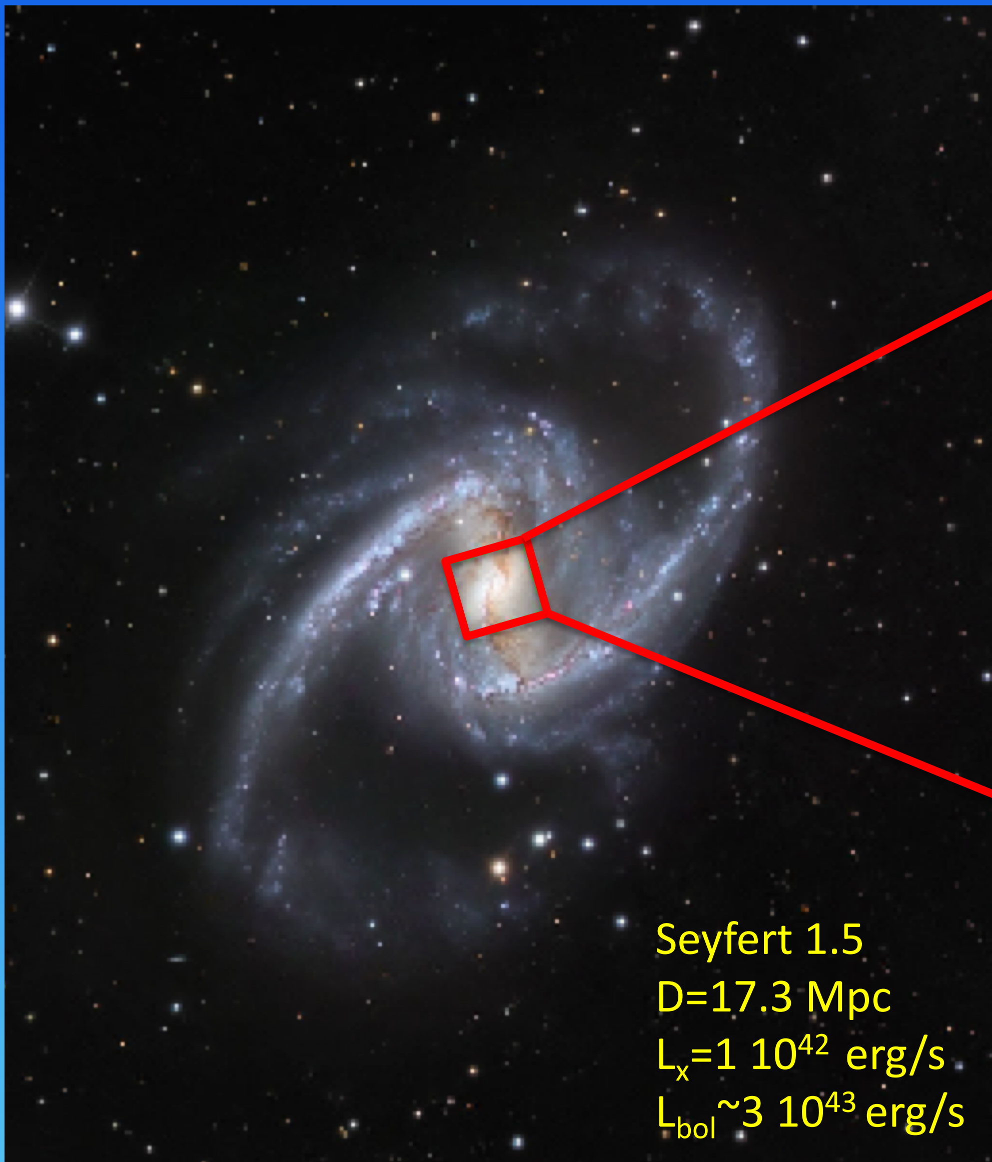
A great idea ??

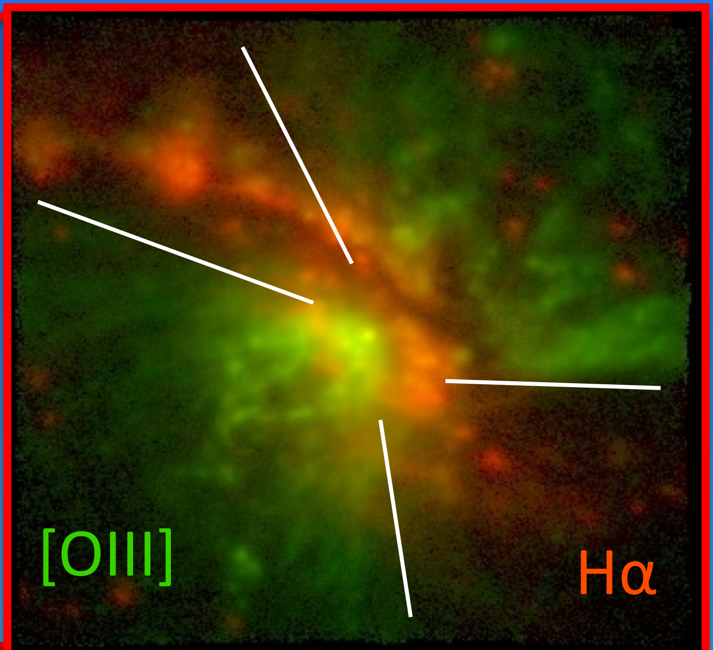
"From the frying pan into the fire"…



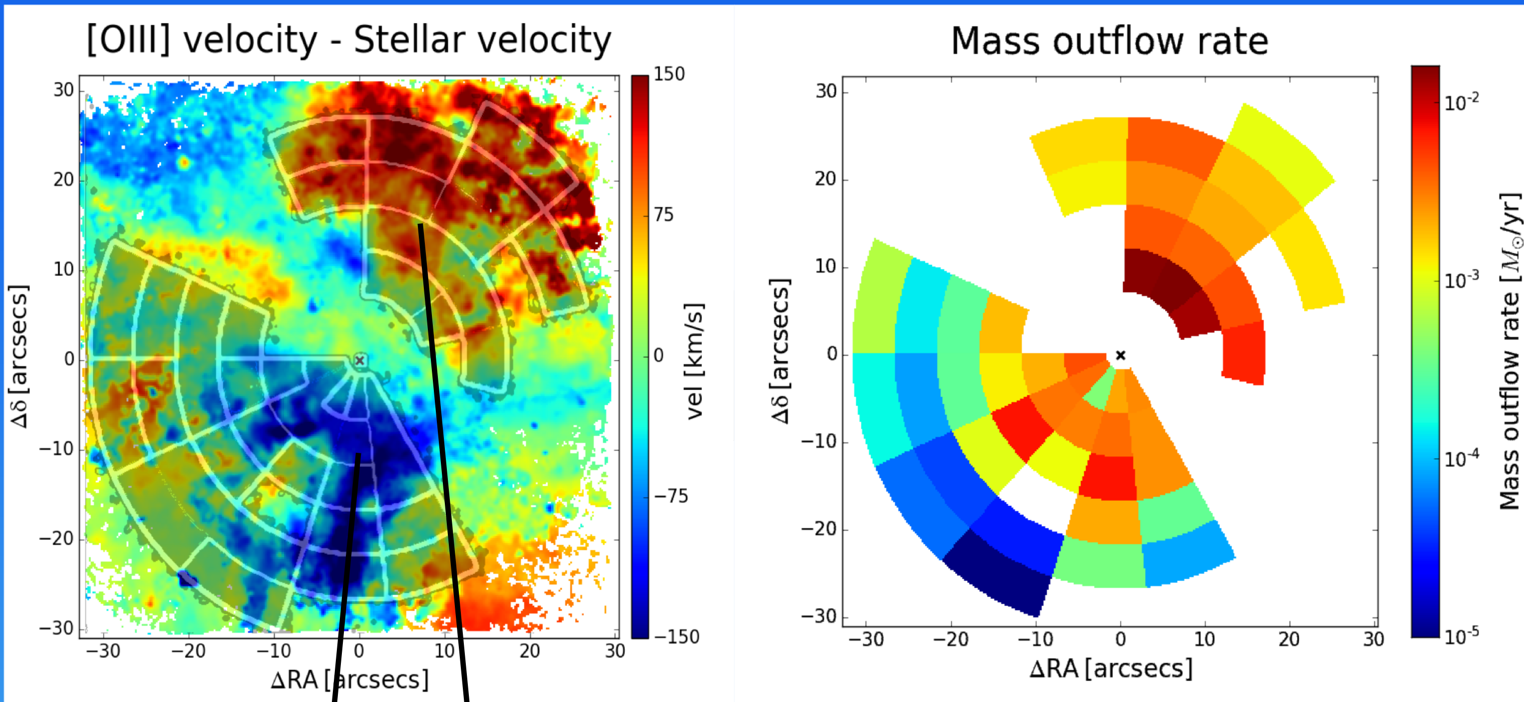


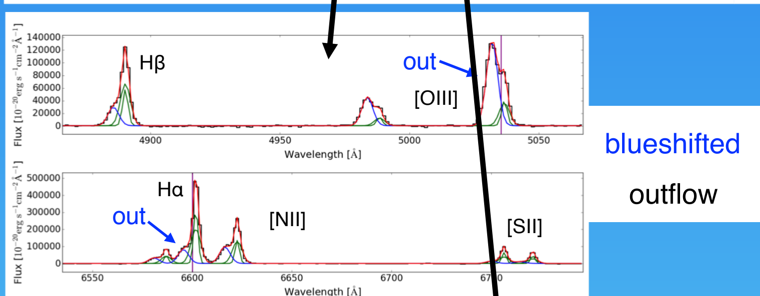
NGC 1365: an AGN in the Great Barred Galaxy

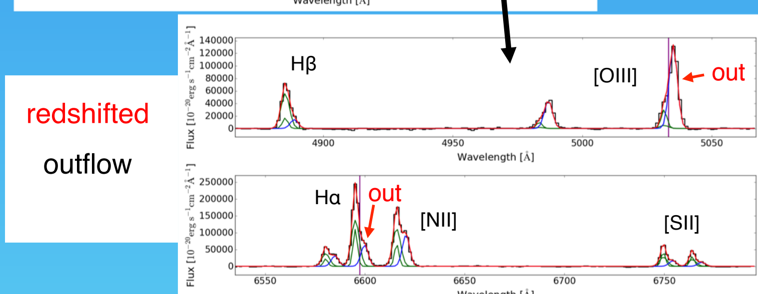




NGC 1365: mapping the mass outflow rate



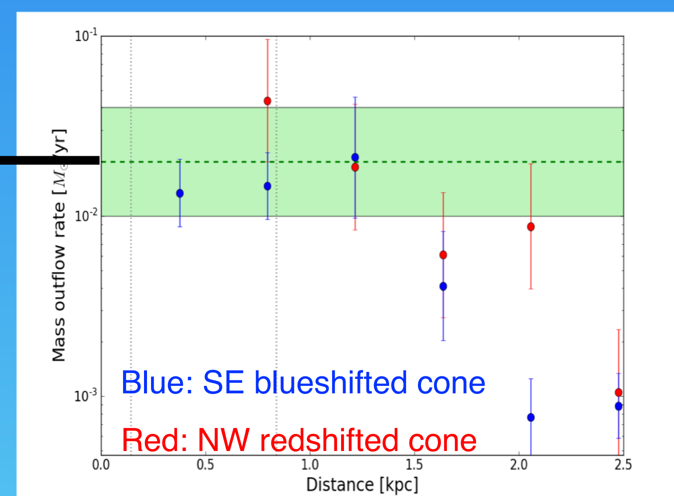




Mass outflow rate of nuclear X-ray wind

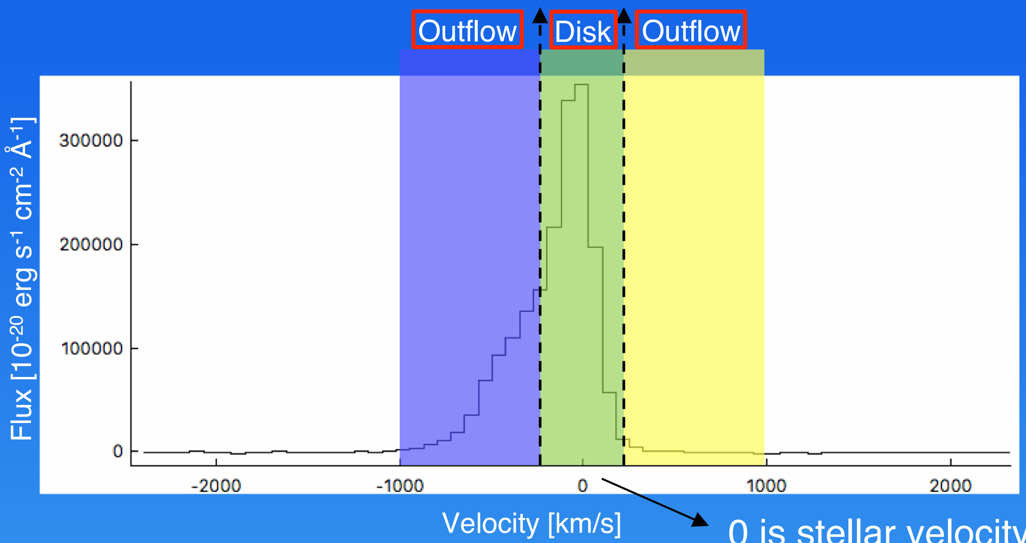
($v \sim 3000$ km/s) from Fe XXV and Fe XXVI absorption lines

$\dot{M} \sim 0.04\ M_\odot/\mathrm{yr}$



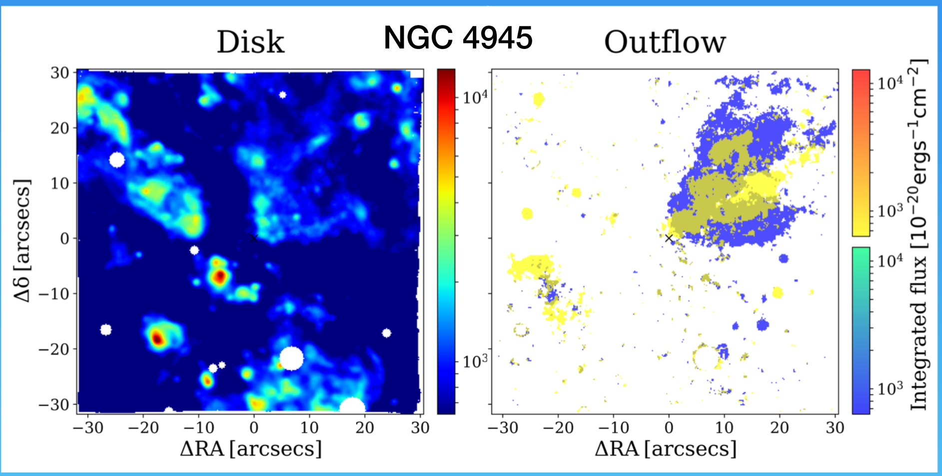
Venturi, GC et al. 2018 sub. (see also Crenshaw+14)

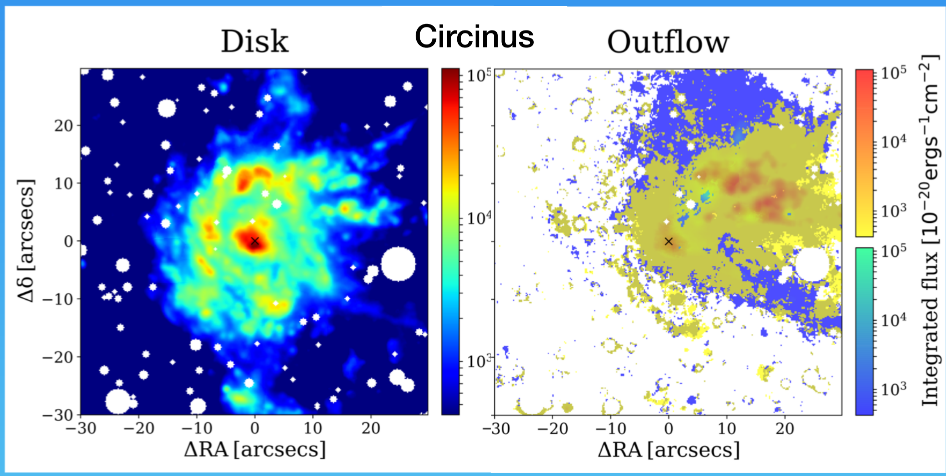
Velocity resolved BPT diagrams with MAGNUM



0 is stellar velocity measured in each spaxel

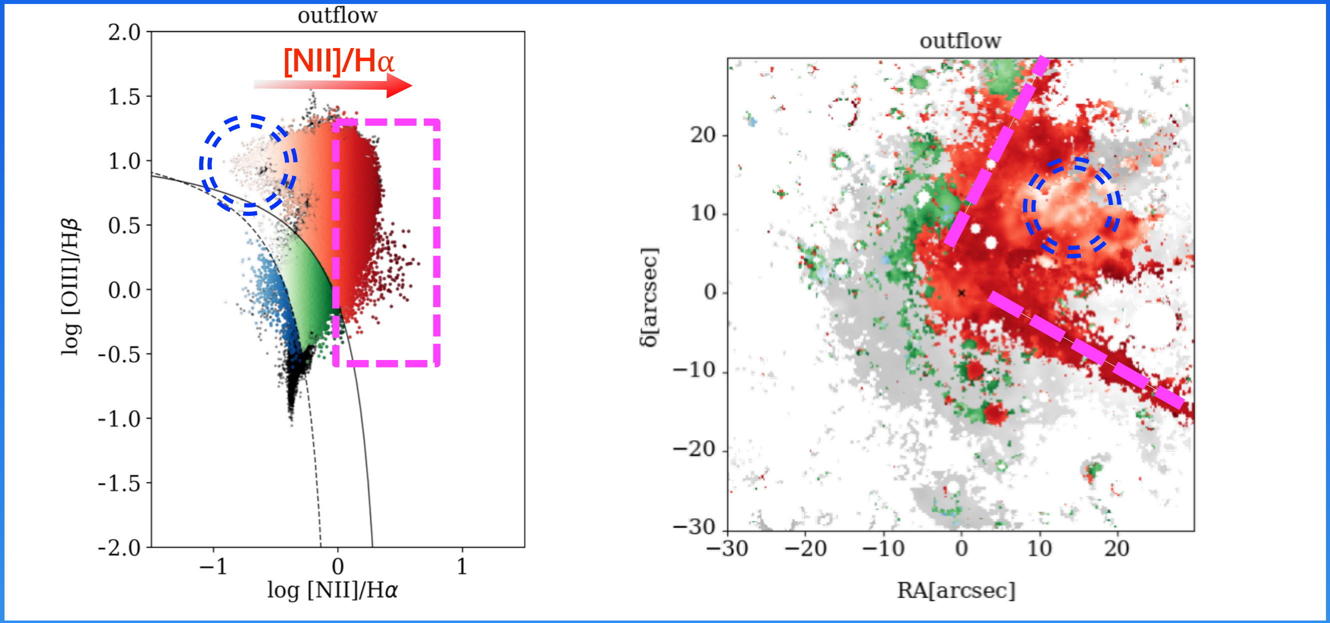
Emission line profiles divided in **velocity bins** to **separate outflows from disk**



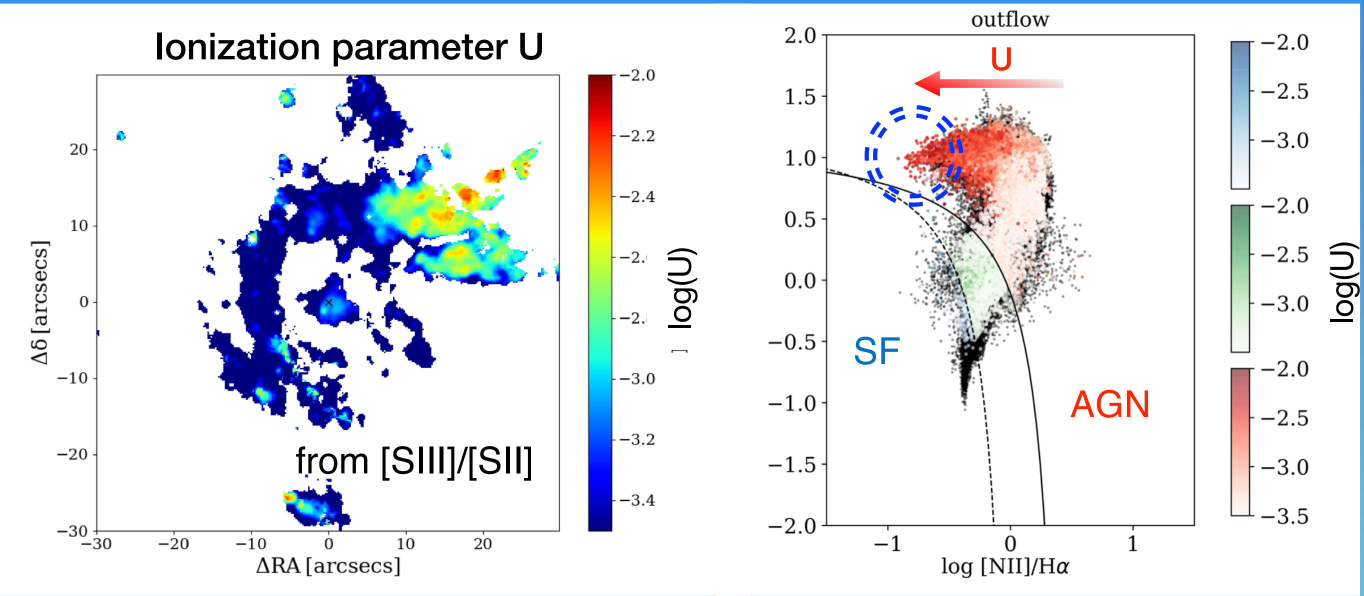


Mingozzi, GC et al. in prep

Velocity resolved BPT diagrams (Circinus)



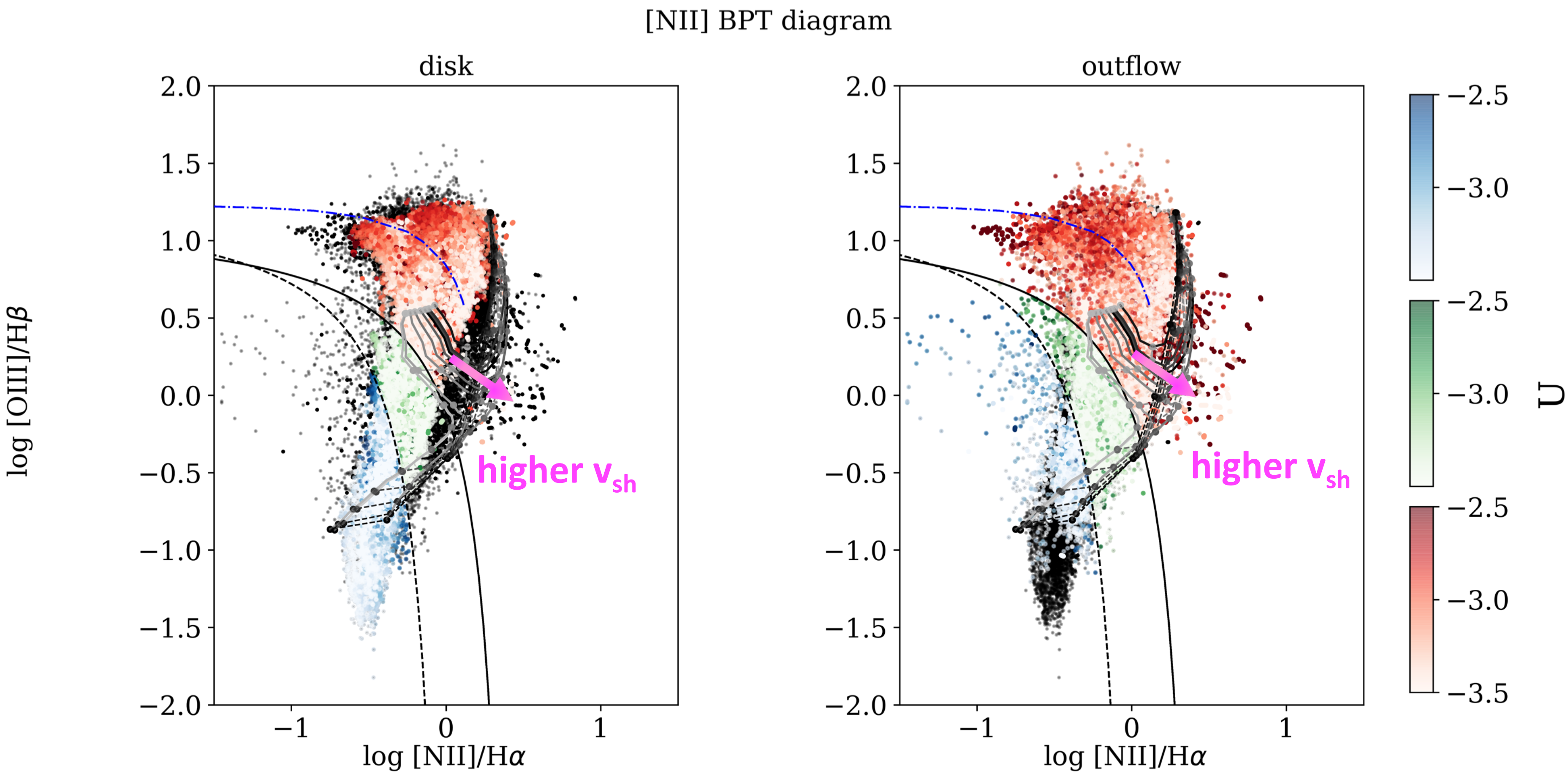
The highest **[N II]/Hα** ratios correspond to the **edges of the outflow and highest velocity dispersions:** Shock excitation?



The **lowest [N II]/Hα** ratios correspond to the **highest ionization parameters U in the center of the outflow:** Matter bounded Clouds?

Mingozzi et al. in prep

Velocity resolved BPT diagrams (global)



- **Binette et al. 1996 photoionization models with matter bounded clouds**
- **Allen et al. 2008 shock models (Mappings III) – n = 100 cm^{-3}**

Mingozzi , GC et al. in prep