CIG grant (eEASy)
2013-2016

Feedback in action in a prototypical outflowing QSO at z~1.5

Marcella Brusa
DIFA-Dipartimento di Fisica e Astronomia / Università di Bologna &
INAF / Osservatorio Astronomico di Bologna

Molecular outflow and feedback in the obscured Quasar XID2028 revealed by ALMA

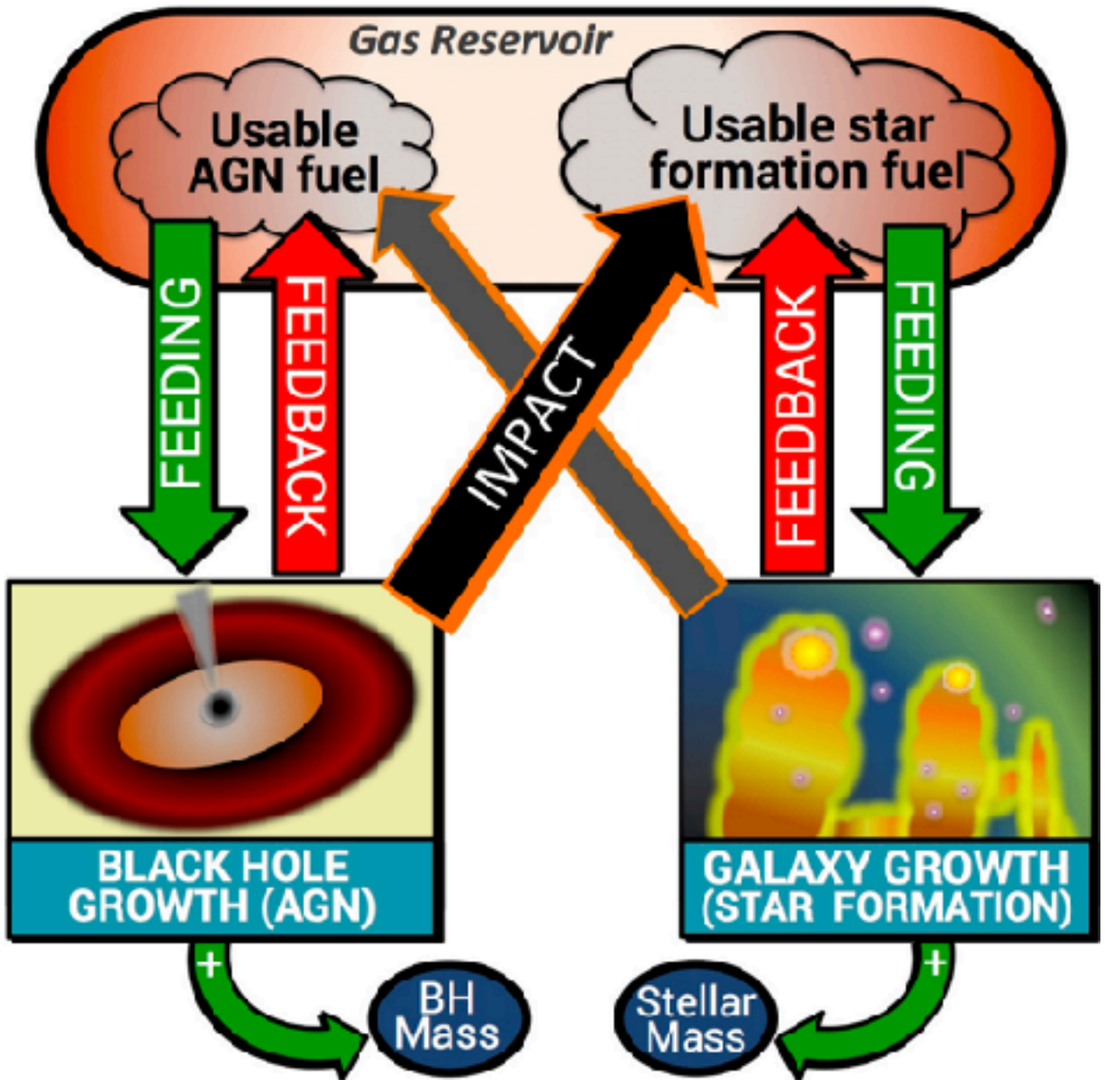
M. Brusa[1,2], G. Cresci[3], E. Daddi[4], R. Paladino[5], M. Perna[3], A. Bongiorno[6], E. Lusso[7], M. T. Sargent[8], V. Casasola[3], C. Feruglio[9], F. Fraternali[1], I. Georgiev[10], V. Mainieri[11], S. Carniani[12,13], A. Comastri[2], F. Duras[6], F. Fiore[6], F. Mannucci[3], A. Marconi[14], E. Piconcelli[6], G. Zamorani[2], R. Gilli[2], F. La Franca[15], G. Lanzuisi[1,2], D. Lutz[16], P. Santini[6], N. Z. Scoville[17], C. Vignali[1,2], F. Vito[18,19], S. Rabien[16], L. Busoni[3], and M. Bonaglia[3]

A&A resubmitted

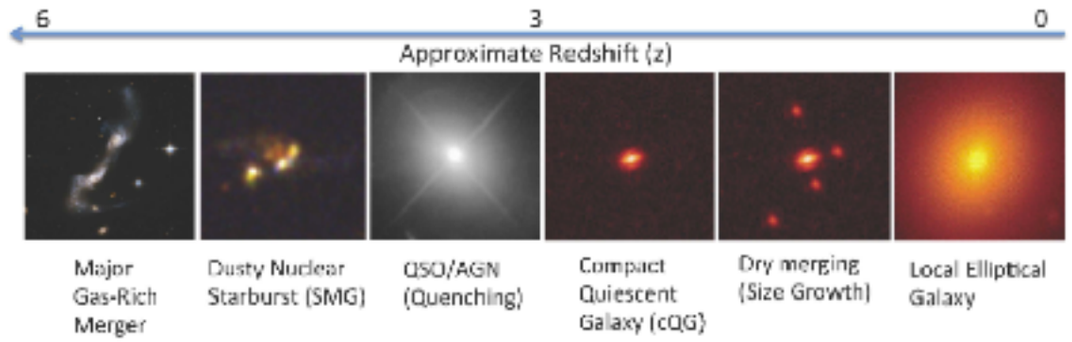
GEE 5 - Arcetri - November 15-17 2017

Feeding & Feedback in galaxies & AGN

Harrison 2017 review

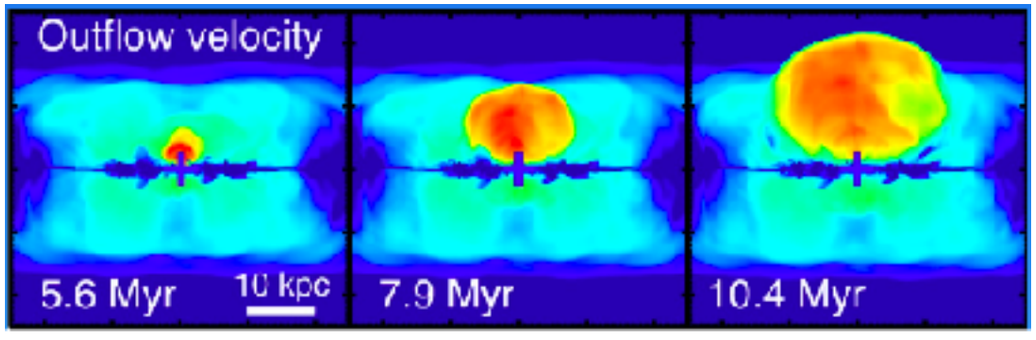


"AGN" is a phase



Toft+2014

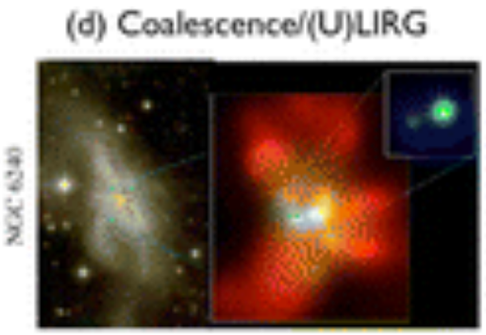
Outflows (in luminous systems)



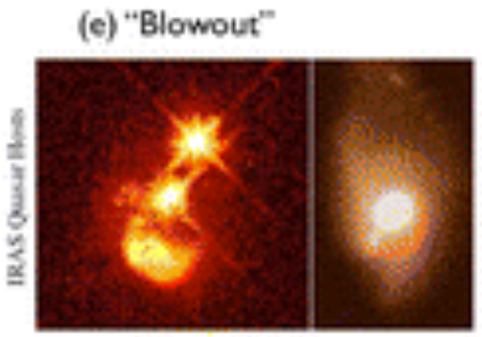
Gabor&Bournaud2014

Models predictions for the feedback phase

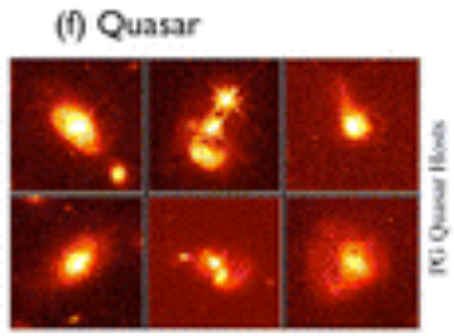
Hopkins+2008



Compton Thick
BH Growth
INFRARED



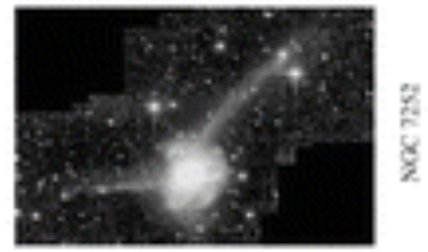
~Coeval SB-AGN
X-RAY



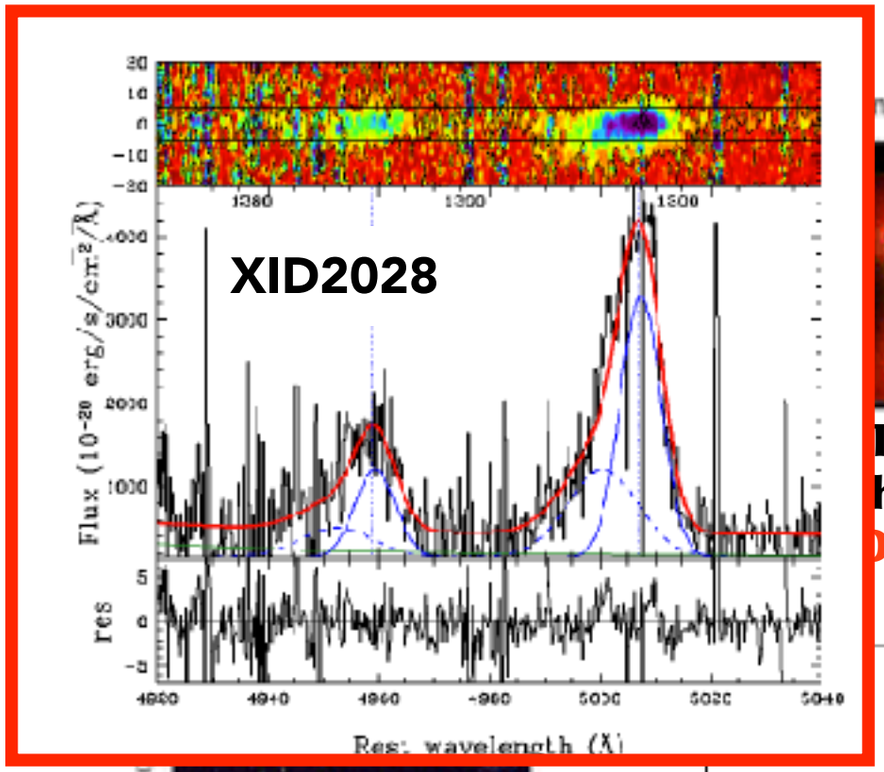
unobscured QSO
OPTICAL

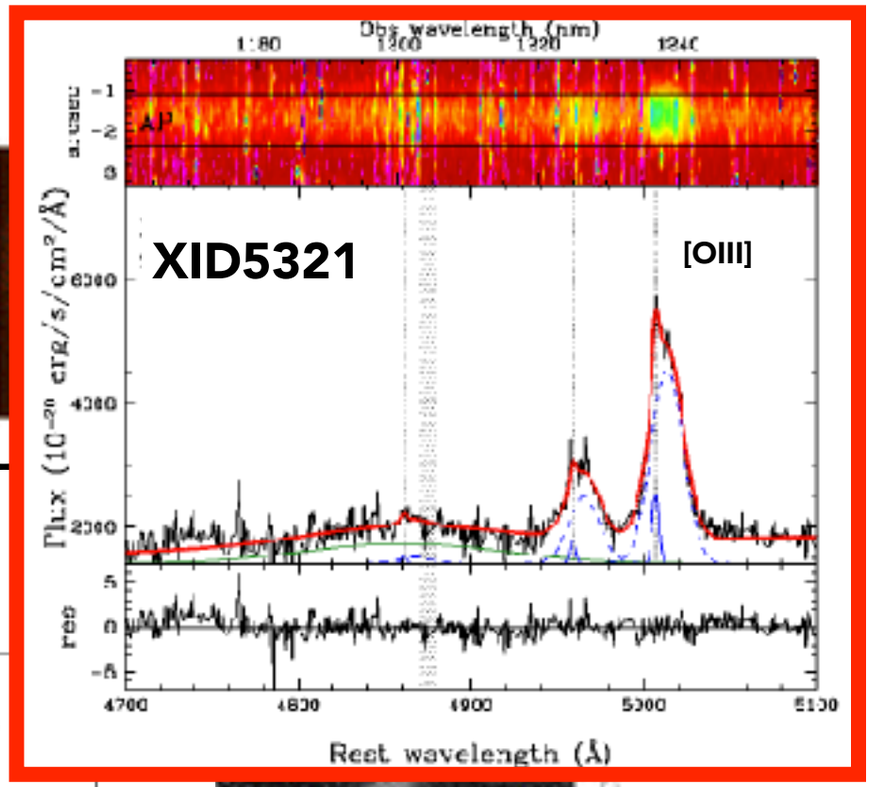
Major mergers model predictions:

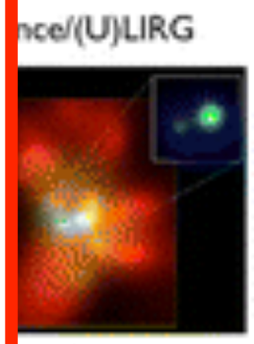
- 1) **BH growth and SF** almost "**simultaneous**"
- **2**) **blow-out** phase very short (**< 100 Myr)**
- **3) blow-out** phase **IR bright (dusty)**
- **4) blow-out** phase **X-ray obscured**
- **5) blow-out** phase **radiates at the 0.1-1 L/ LEdd**
- **6) Outflows (radiatively driven winds) should be present**



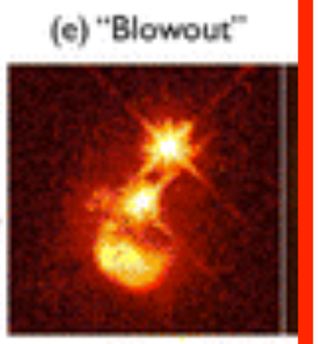
Models predictions for the feedback phase



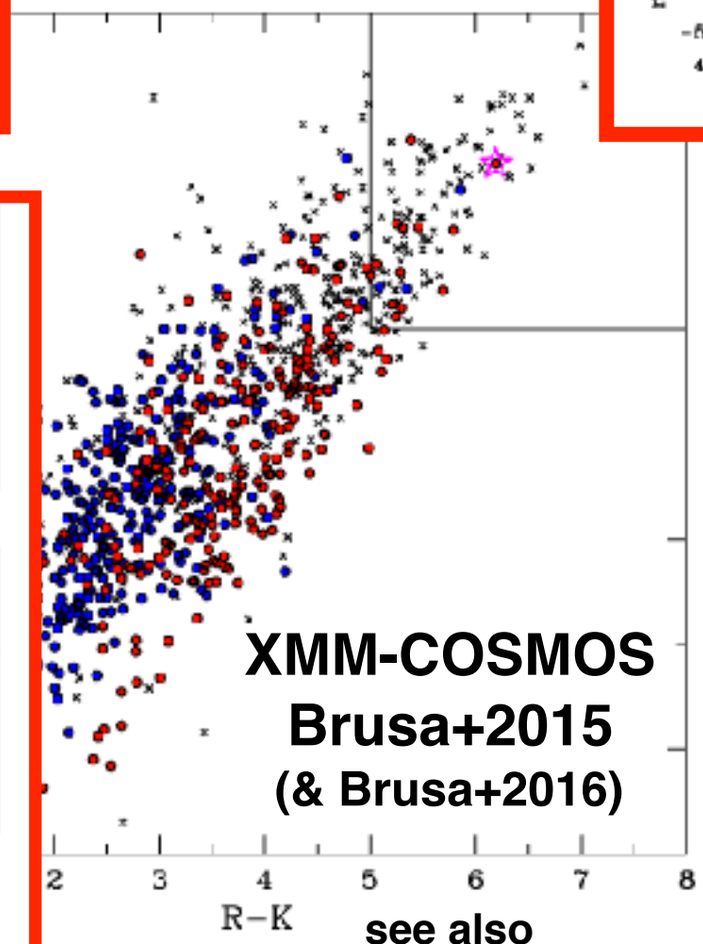




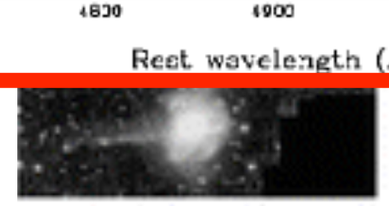
Thick
h



~Coeval SB-
X-RAY



XMM-COSMOS
Brusa+2015
(& Brusa+2016)



QSO luminosity fades rapidly
- tidal features visible only with very deep observations
remnant reddens rapidly (E+A/K+A)
"hot halo" from feedback
- sets up quasi-static cooling

(h) "Dead" Elliptical

- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

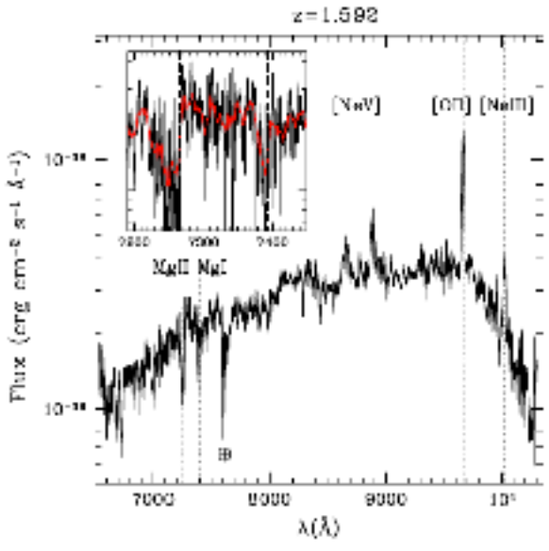
see also
Banerji+12, Perna+15, Kakkad+17, Zakamska+16 etc

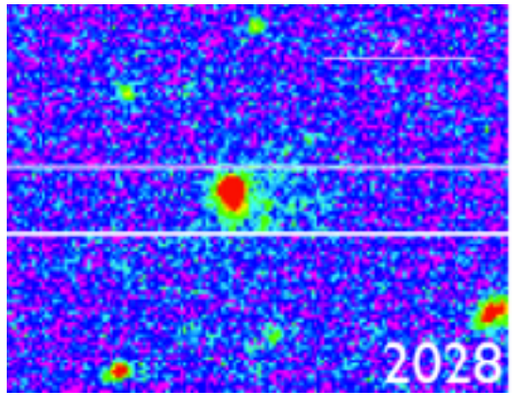
XID2028 (z=1.5930)
a QSO selected to be in the blow-out phase

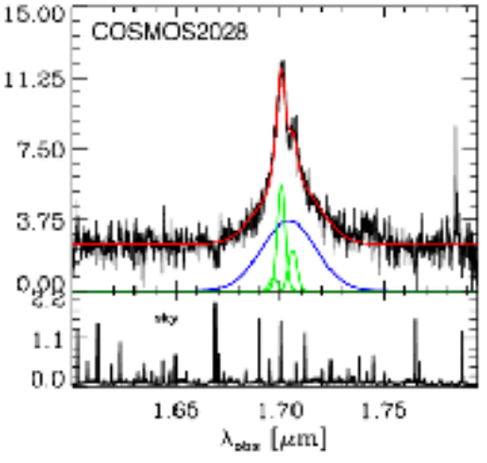
Discovery

(1 out of 1800 XMM-COSMOS sources) Brusa+2010

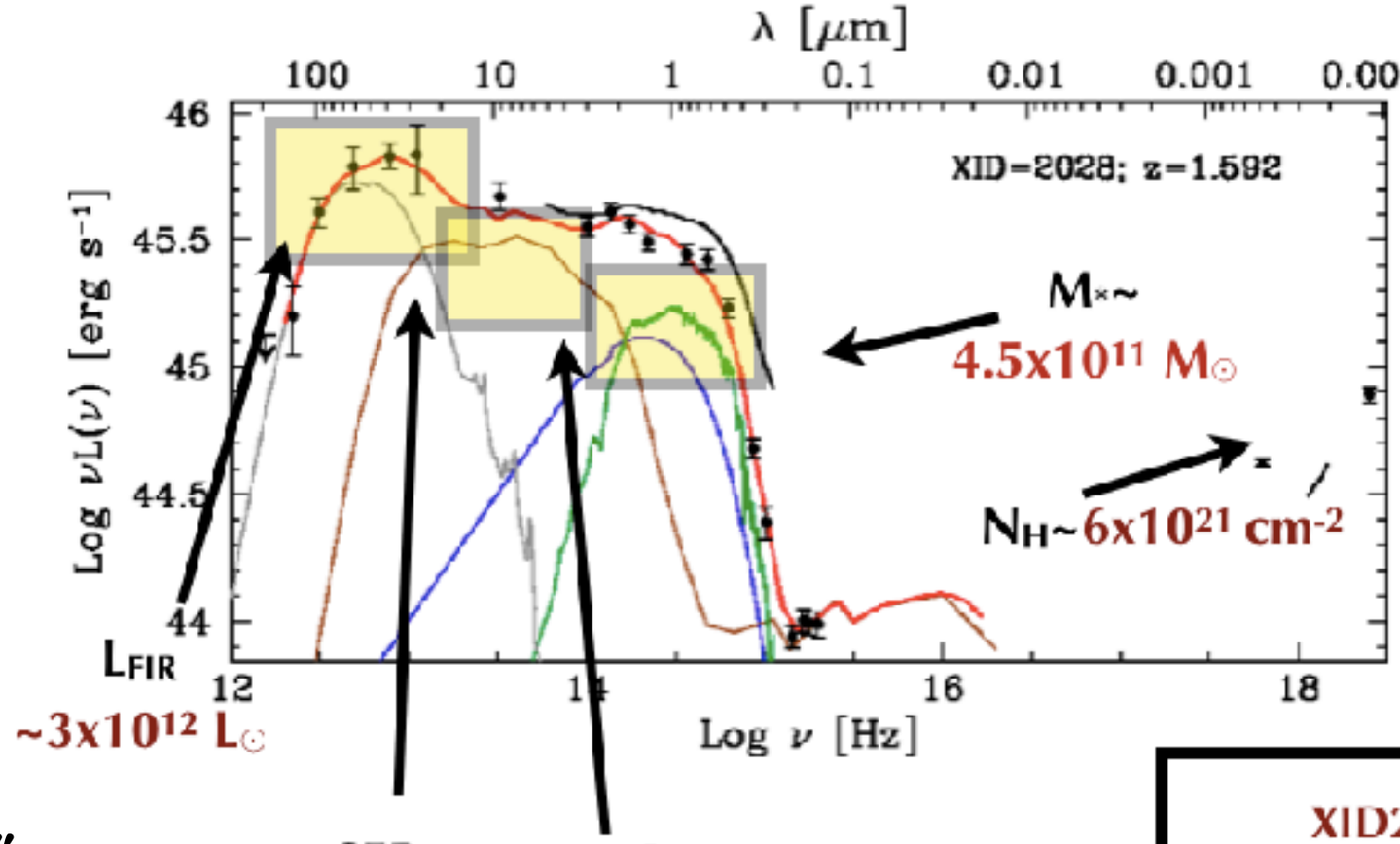
9. A PROTOTYPICAL OBSCURED QSO AT $z = 1.59$







figures from
Bongiorno+2014
Brusa+2015a
Perna+2015



M_{BH}~
$4.5x10^9$ $M_\odot$
(Bongiorno+2014)

λ_{Edd}~5%

M_*~
$4.5x10^{11}$ $M_\odot$

N_H~$6x10^{21}$ cm^{-2}

L_{FIR}
~$3x10^{12}$ $L_\odot$

SFR
~230-270 $M_\odot$/yr

L_{bol} ~$2x10^{46}$ erg/s

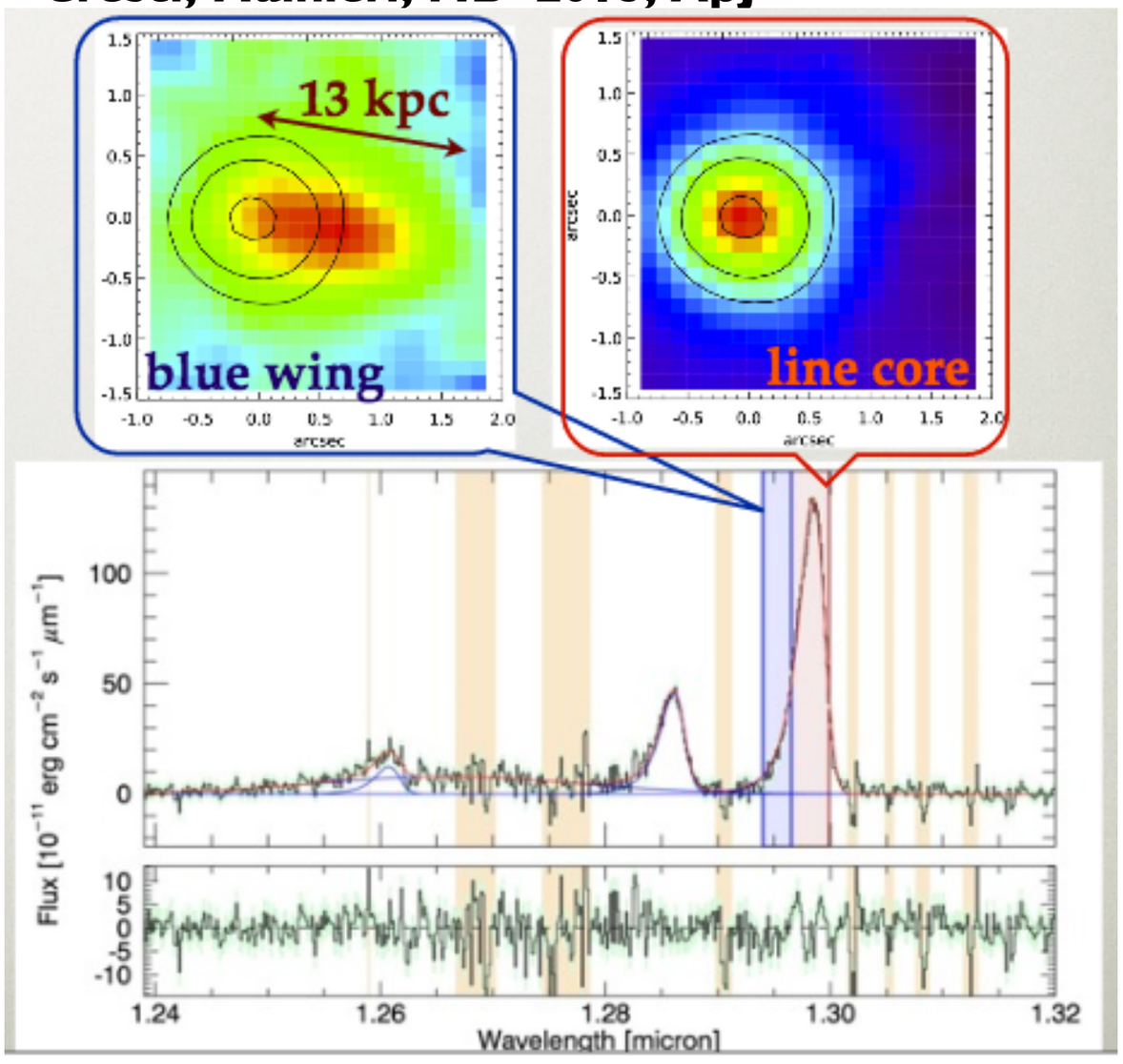
Radio "quiet"

$L_{1.4GHz} < 10^{24}$ W/Hz

XID2028 is a QSO/ULIRG hosted in a MS galaxy (SB in main sequence)

A spatially resolved ionised outflow

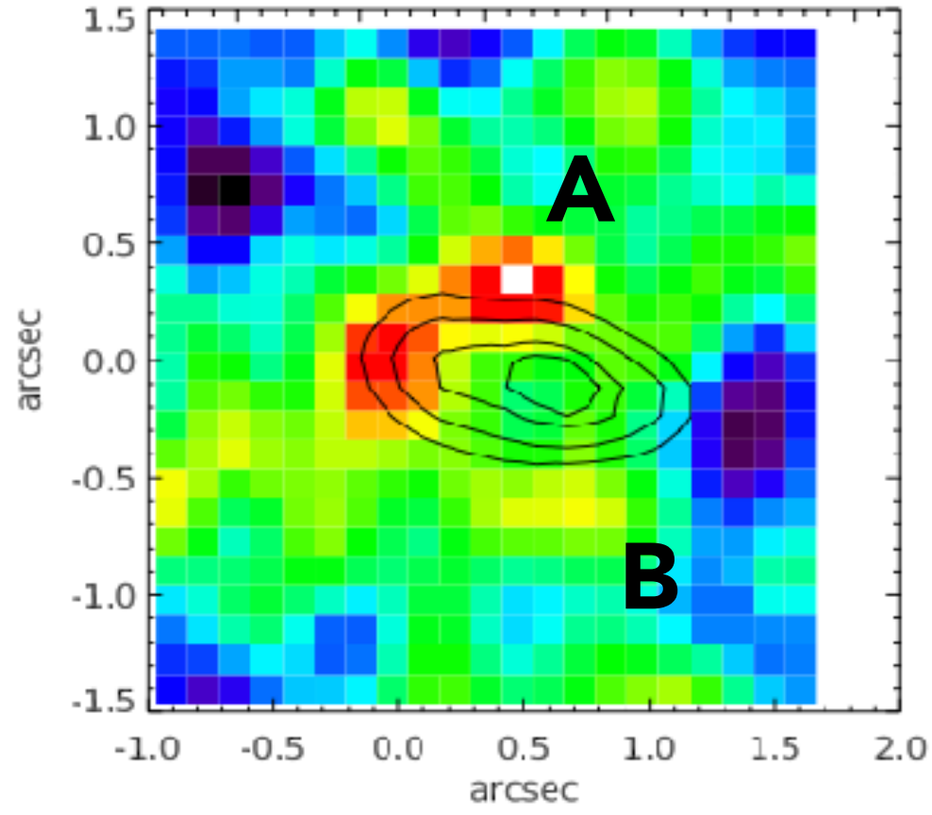
Cresci, Mainieri, MB+2015, ApJ



J-band SINFONI

v_{max}~1500 km/s
$\dot{M}_{ion}$~300 $M_\odot$/yr
$\dot{M}_{ion}$> SFR (~250 $M_\odot$/yr)
(following Cano-Diaz+2012)

Residual map of **narrow Hα component** (tracing star formation) from H+K SINFONI data



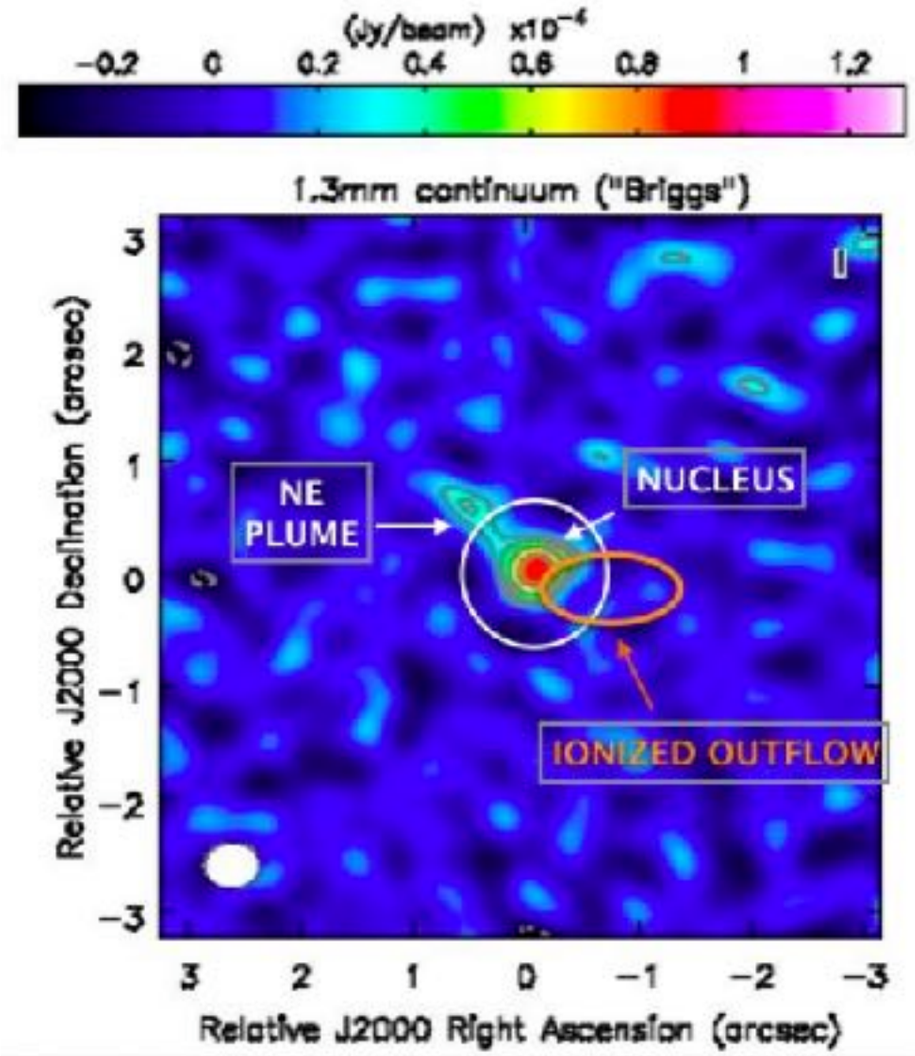
Outflow lies at the center of a cavity in SF regions

the outflow is removing gas from the host galaxy **(negative feedback)** and is triggering SF by outflow induced pressure at the edges **(positive feedback)**

PdBI (DDT) +
ALMA (Cycle 3) +
LUCI+ARGOS (commissioning)

1) A compact nucleus

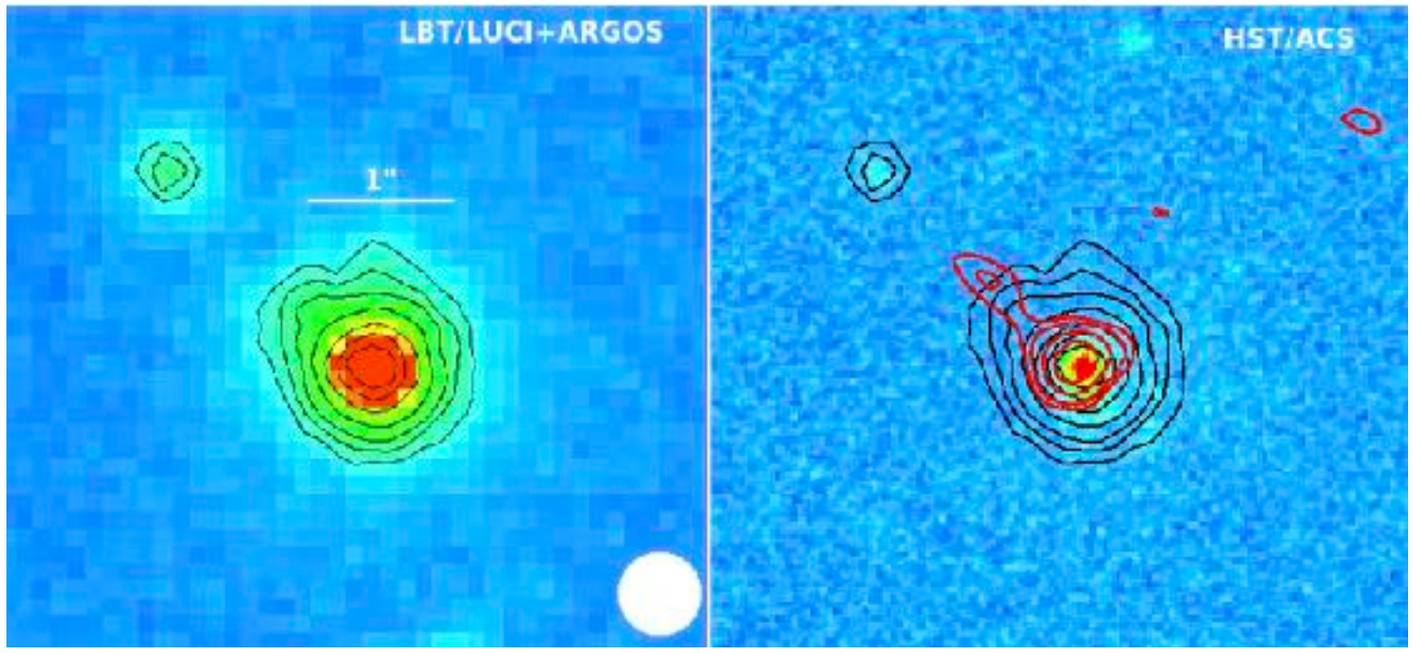
Brusa et al. 2017, A&A re-submitted



ALMA band 6 (6.5hr)
continuum image, 20σ detection

resolved in "nucleus" and "plume"

Dust emitting region: ~1.5 kpc radius



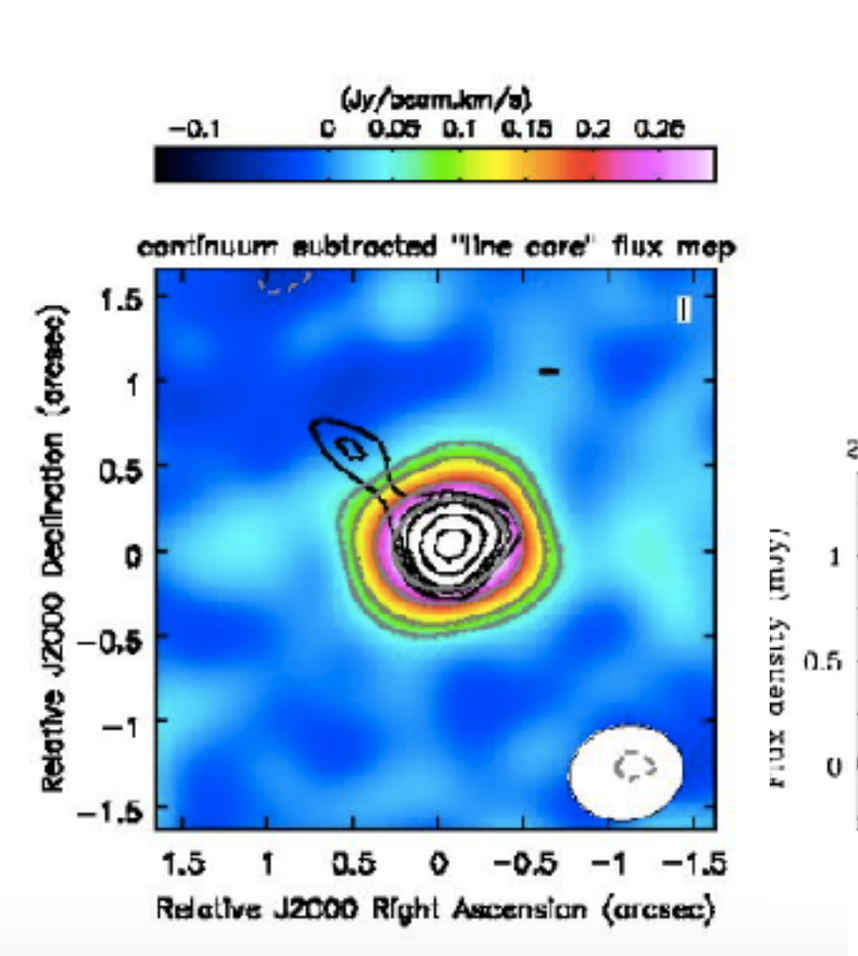
LBT LUCI+ARGOS AO K band imaging

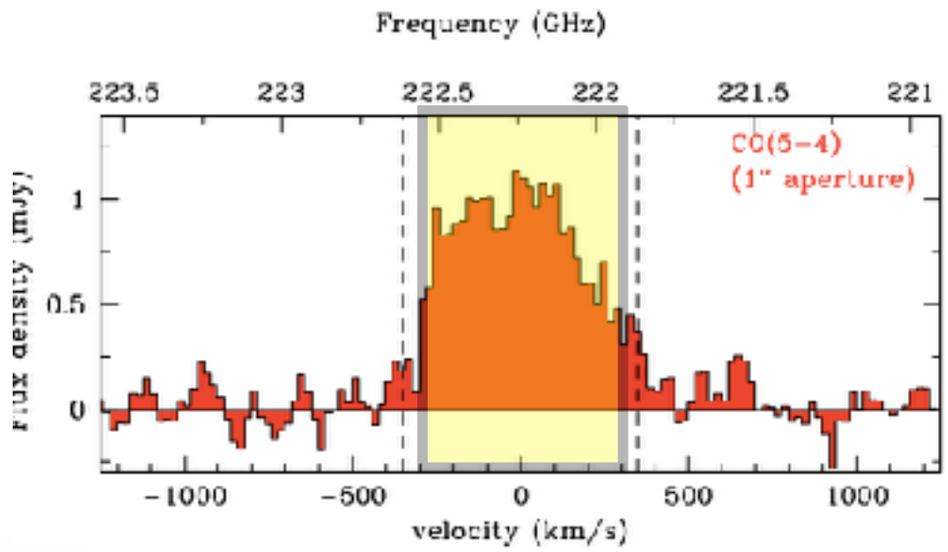
host galaxy *resolved* in LUCI, radius 5-10 kpc

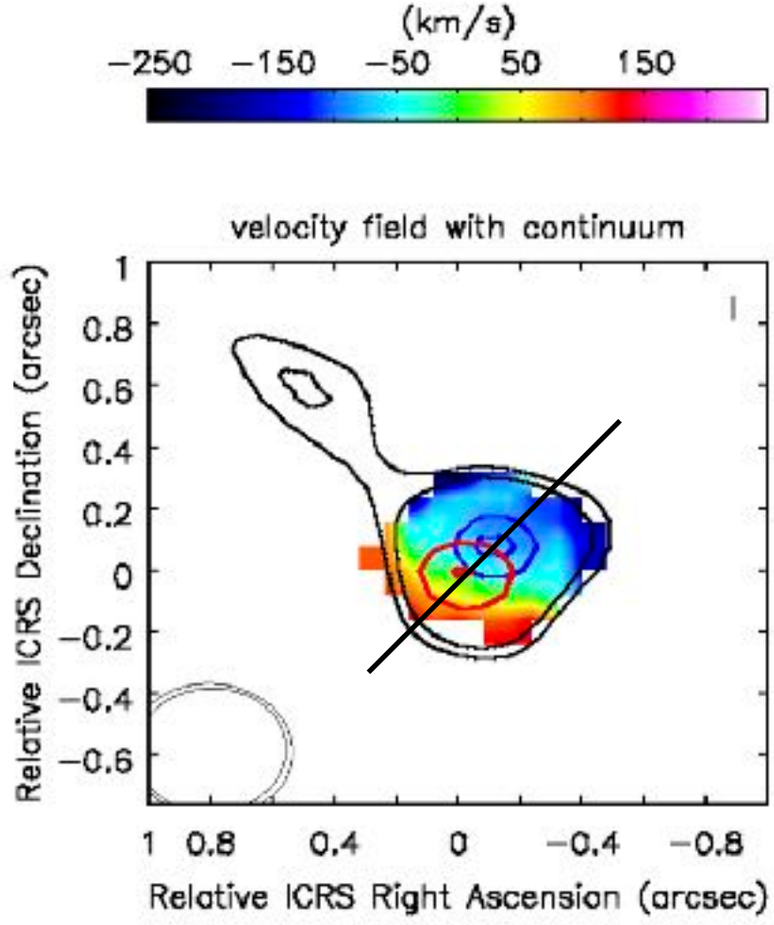
Elongation seen in K-band, corresponding ~ to the plume location (North-East), nothing on HST/ACS

Merging faint source? tidal tail?

2) A fast rotating disk







CO(5-4) reconstructed image

same (deconvolved) size
as dust continuum

same spatial origin

ALMA band 6 (6.5hr)
CO(5-4) spectrum, 30σ detection

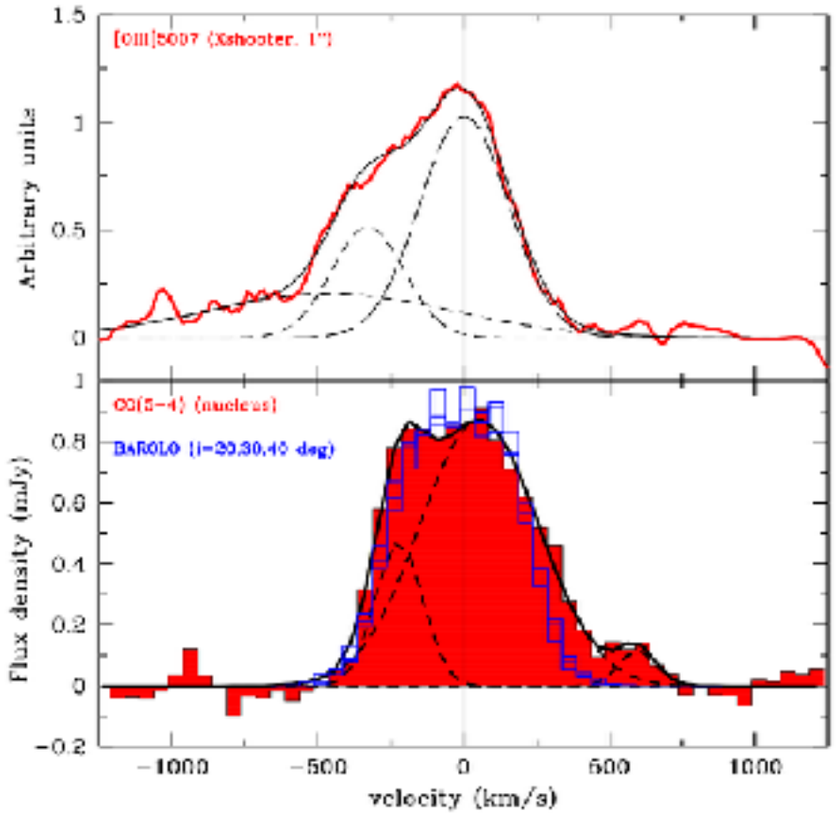
Velocity gradient along the source in the NW-SE direction

assuming rotating disc: v~400 km/s
(3DBarolo diTeodoro&Fraternali 2015)

(merging unlikely as gradient origin)

Brusa et al. 2017, A&A re-submitted

3) A spatially resolved molecular outflow

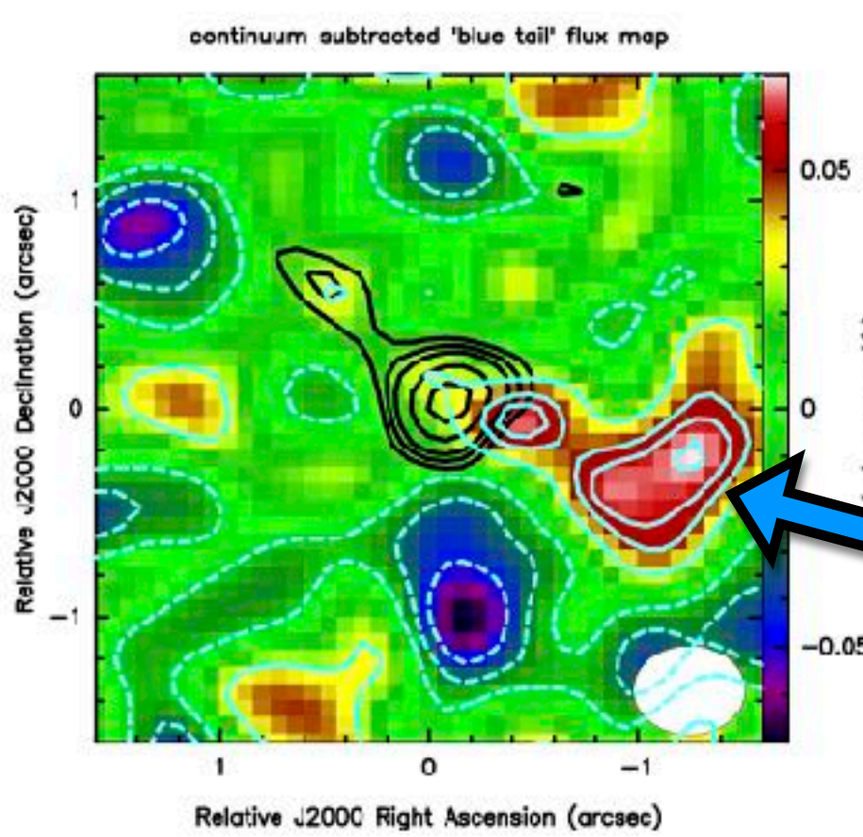


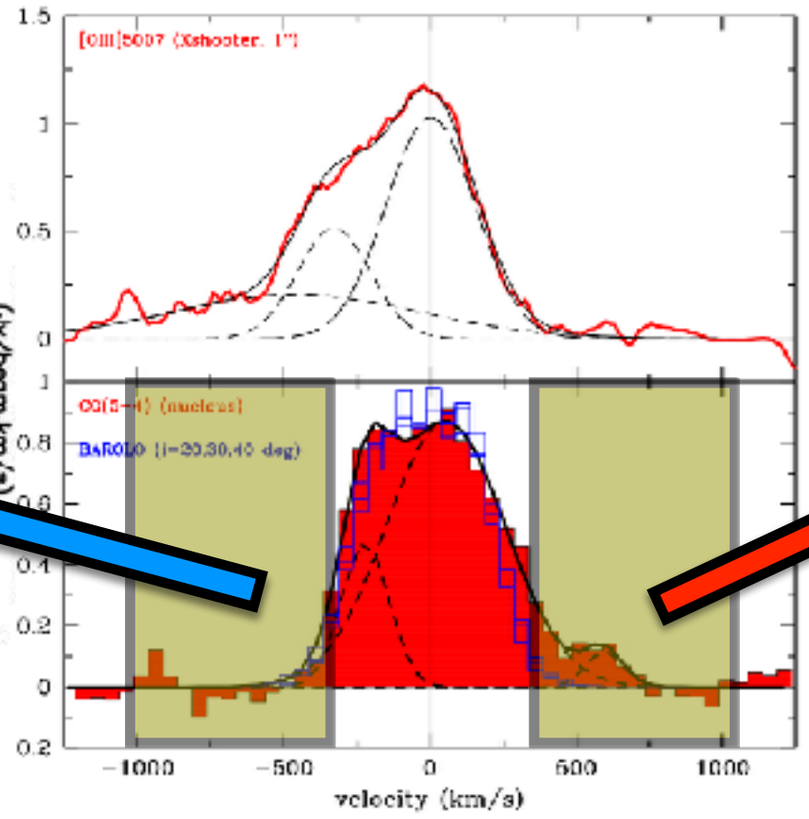
ALMA band 6 (6.5hr)
CO(5-4) spectrum, 30σ detection

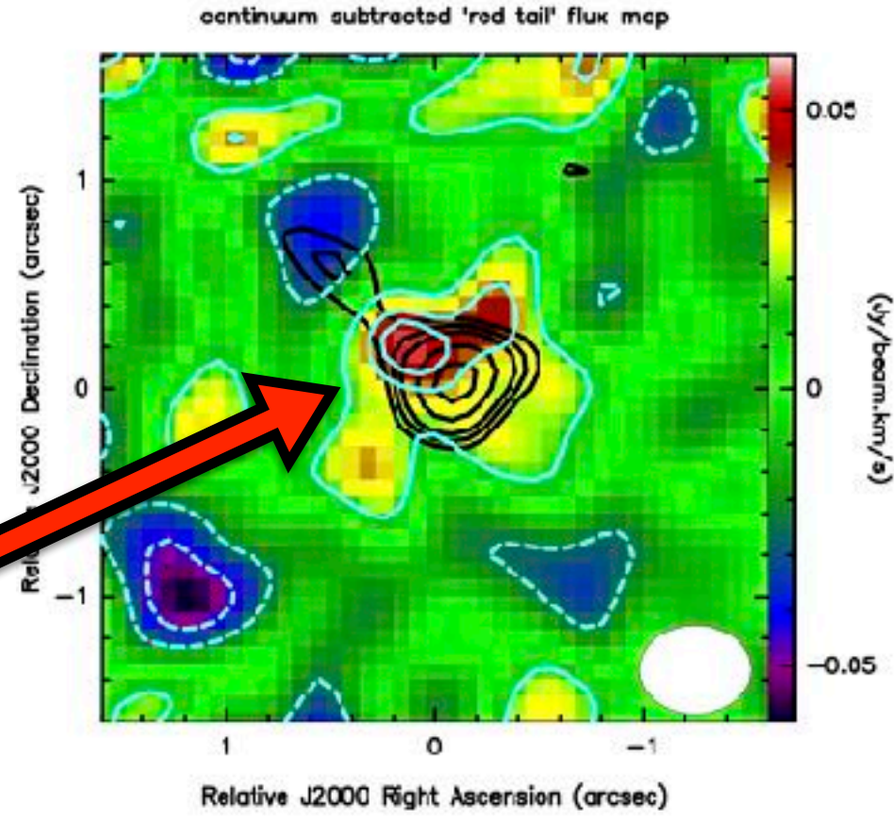
FWHM~500 km/s, but asymmetric line profile, reproduced with blue- and red-shifted components (as [OIII])

Brusa et al. 2017, A&A re-submitted

3) A spatially resolved molecular outflow



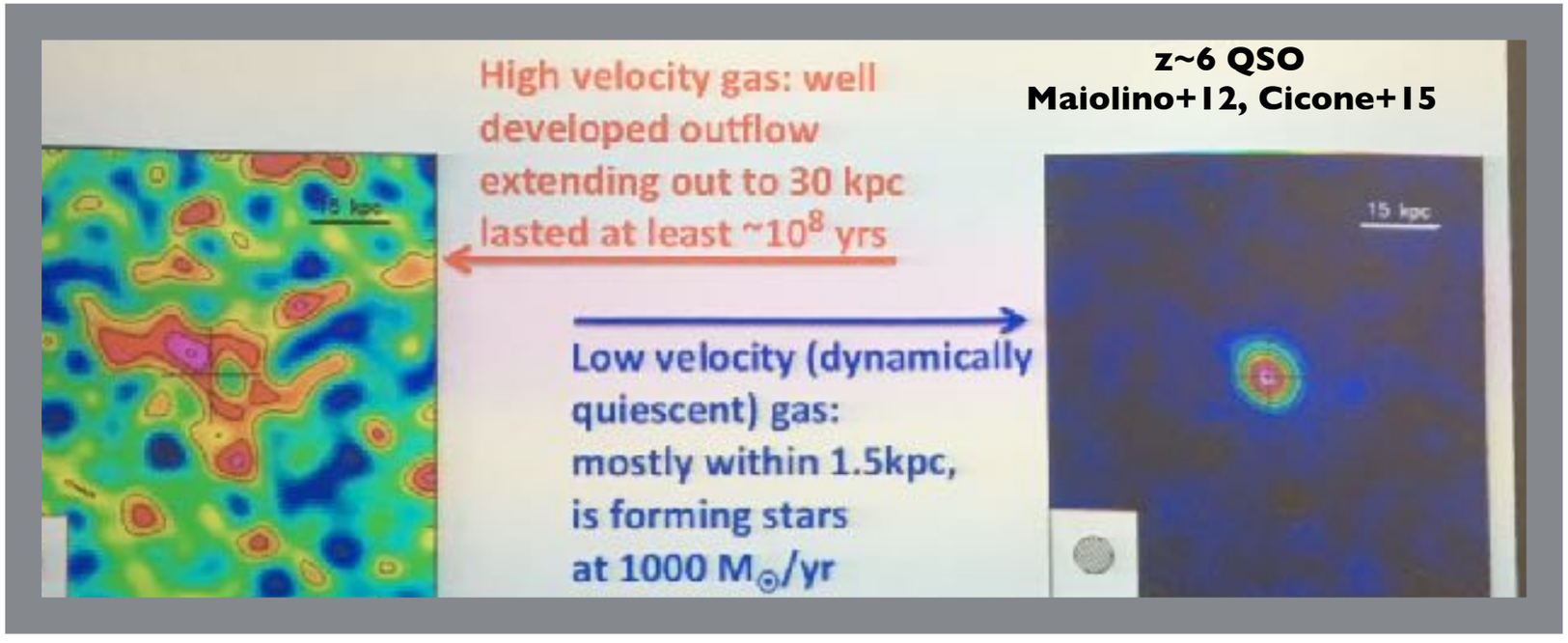




Imaging of the blue (< -350 km/s) and red (>350 km/s) channels

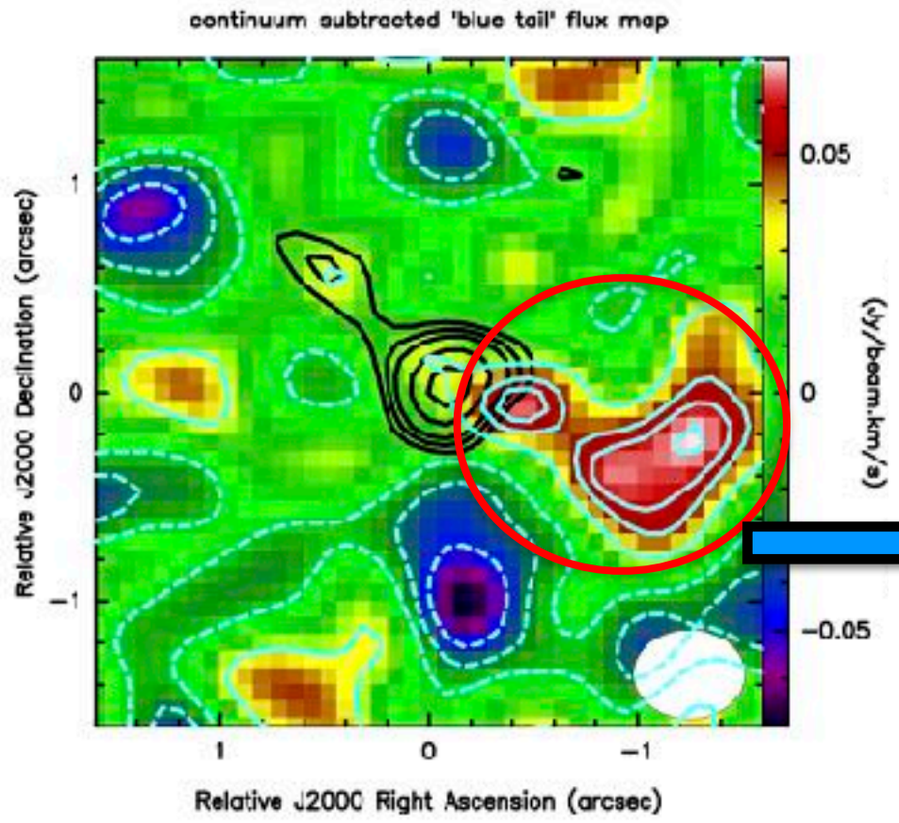
bi-directional outflow out to ~ 10 kpc and v~700 km/s

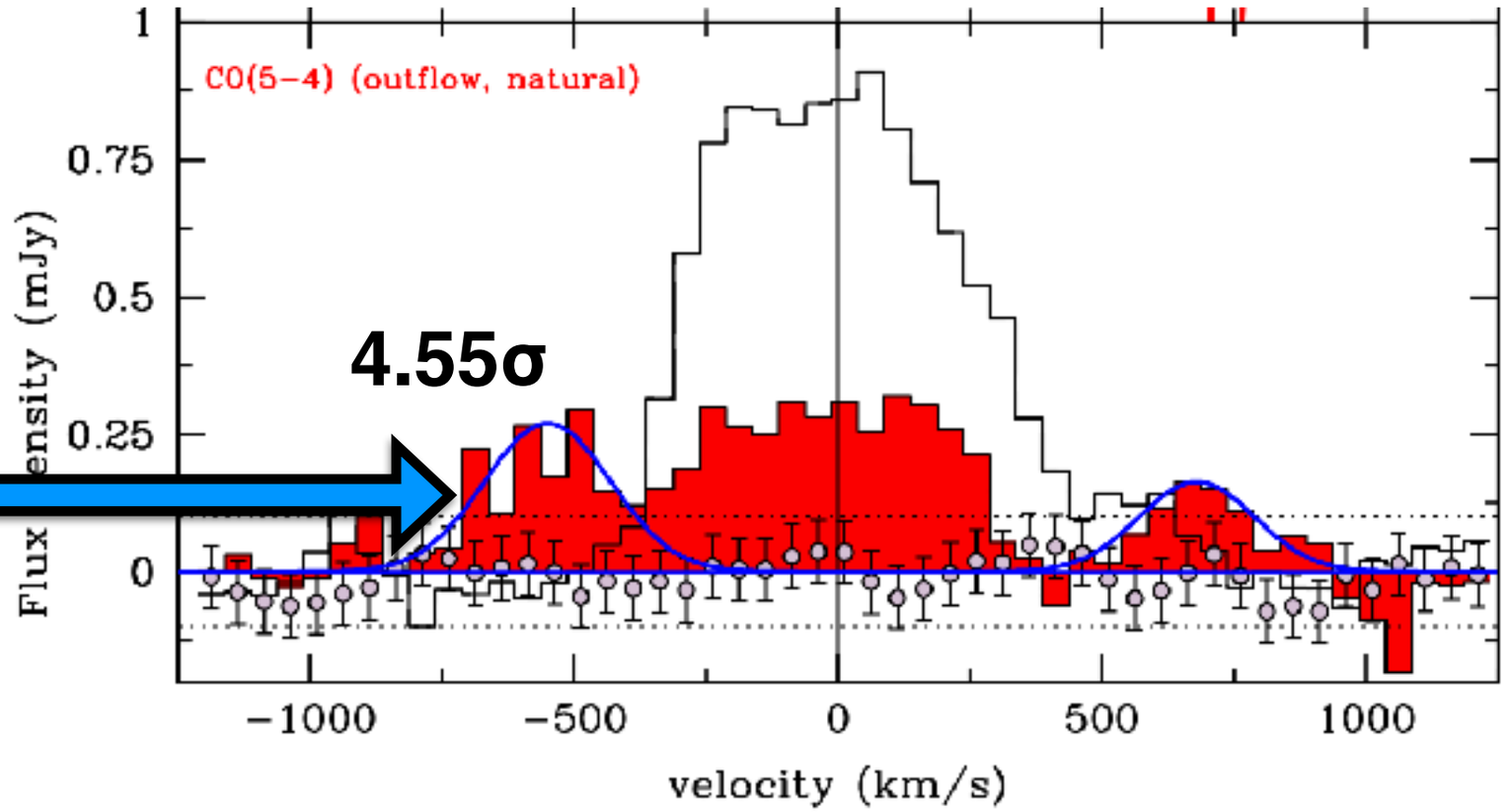
perpendicular to the rotation axis

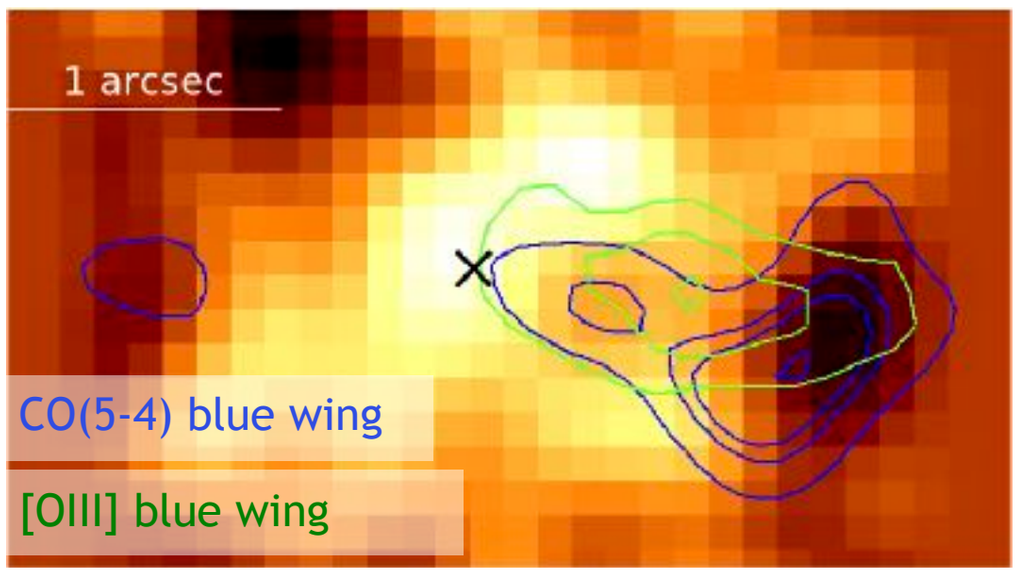


Brusa et al. 2017, A&A re-submitted

3) A spatially resolved molecular outflow







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 resolved CO outflow spatially coincident with the ionized outflow component

Brusa et al. 2017, A&A re-submitted

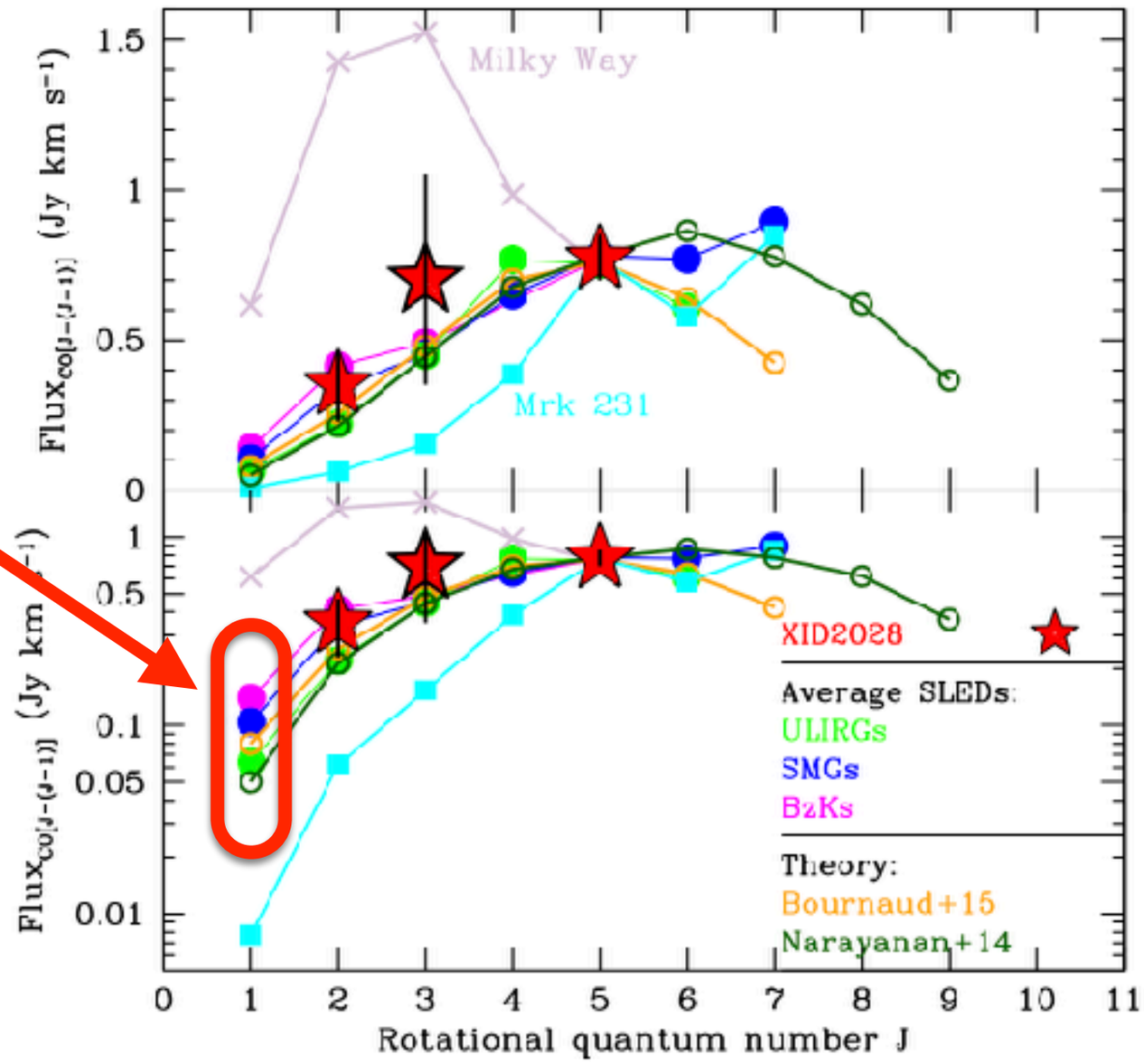
4) An (exceptionally) low gas fraction…

Brusa et al. 2017, A&A re-submitted

1.3mm cont + CO(5-4): ALMA Cycle 3
CO(3-2): PdBI
CO(2-1): ALMA Cycle 3 (PI: Daddi)
850micron cont: ALMA Cycle 3 (PI: Scoville)

CO excitation ladder consistent with
ULIRGs, SMGs and BzKs

—> inferred CO(1-0) within a factor 3



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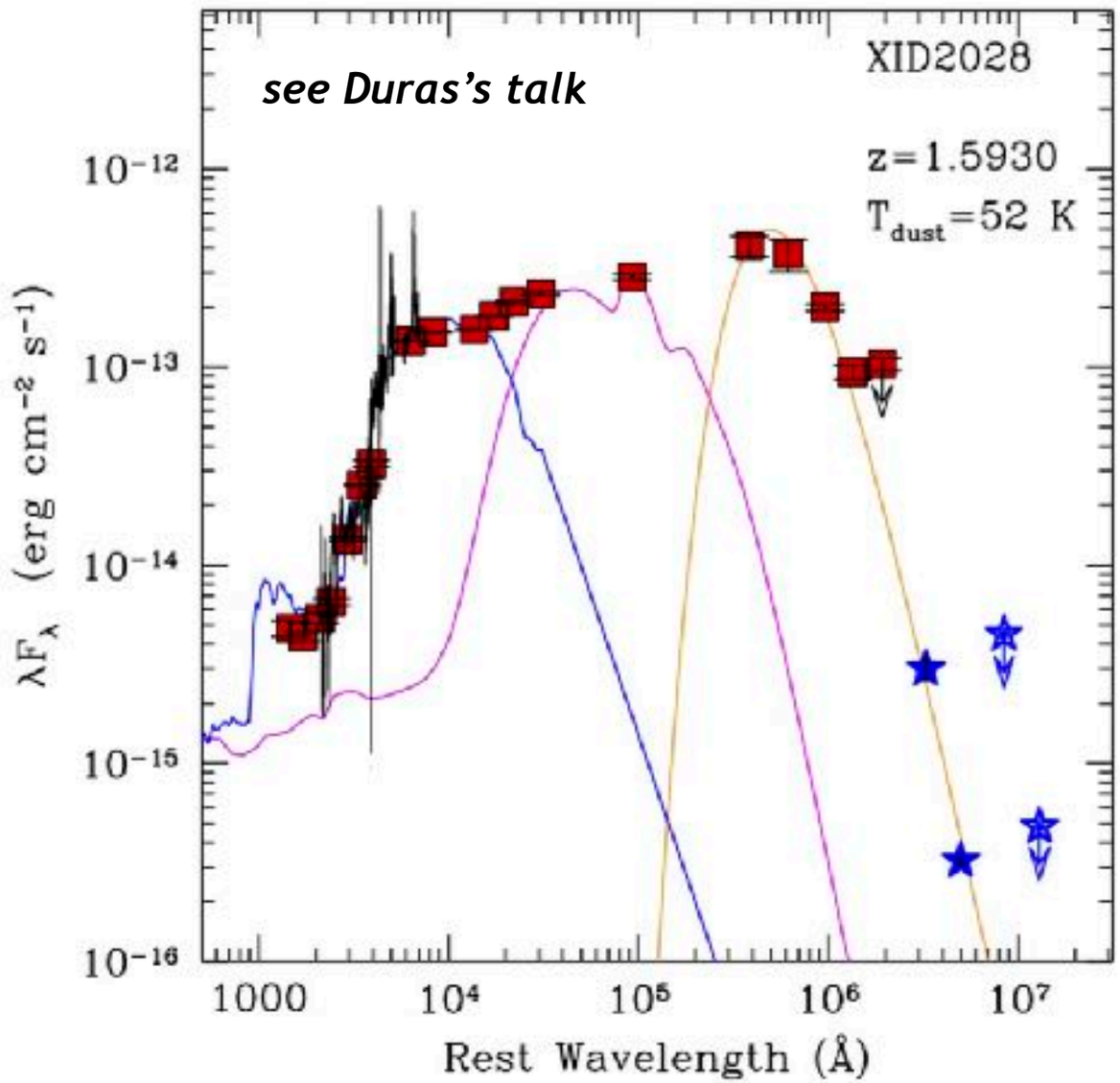


compact SF galaxy (Σ_{SFR} ~ 25 $M_\odot$/yr kpc^{-2})
(comparable with bright sub-mm galaxies)
Dust temperature from Greybody fit **~50 K**

—> SB like α_{co}=0.8

Total **M_{gas} = 1±0.5 x 10^{10} $M_\odot$**
(consistent with RJ continuum estimate)

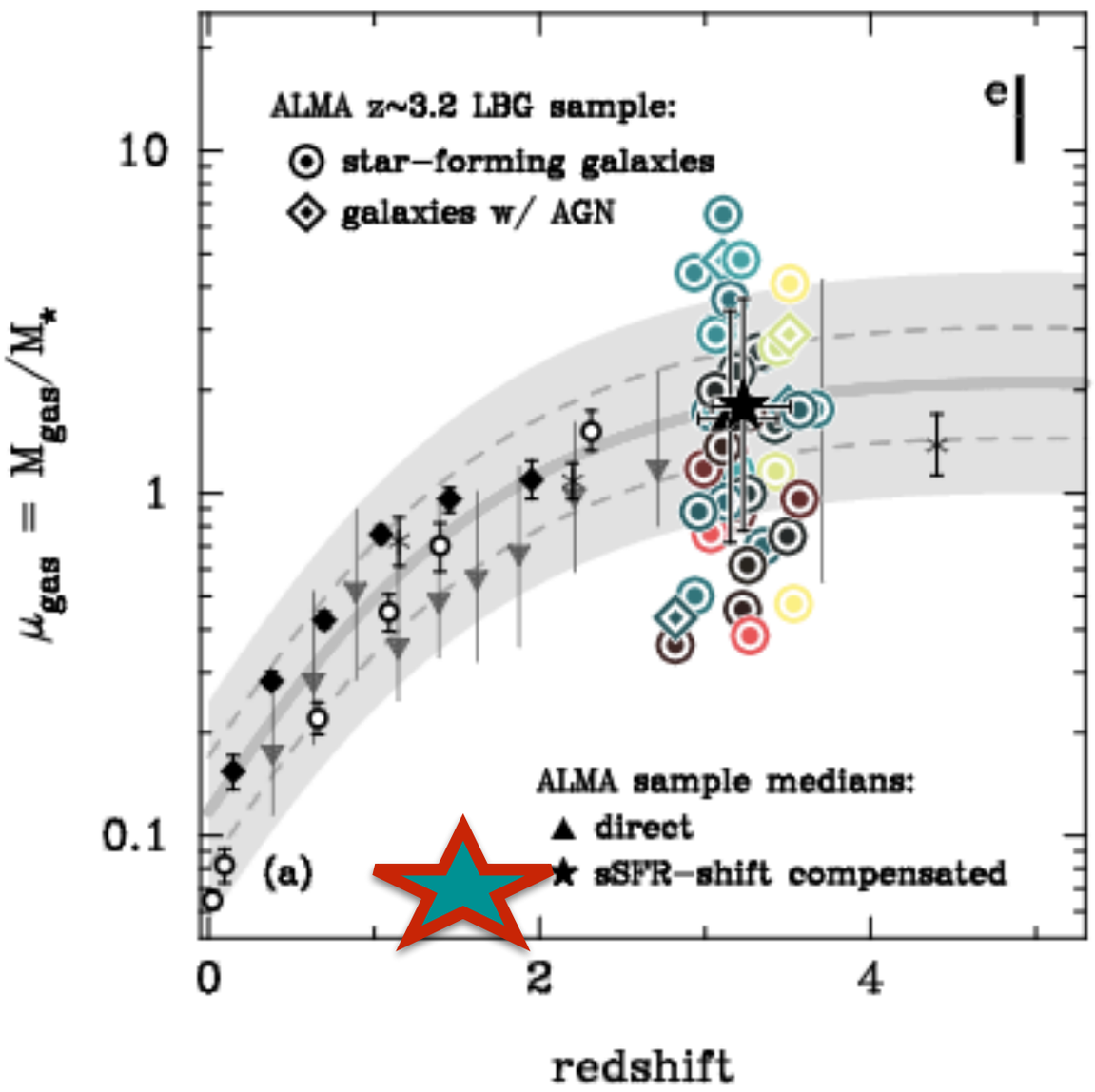
Gas fraction < 5%
despite SFR~270 $M_\odot$/yr!

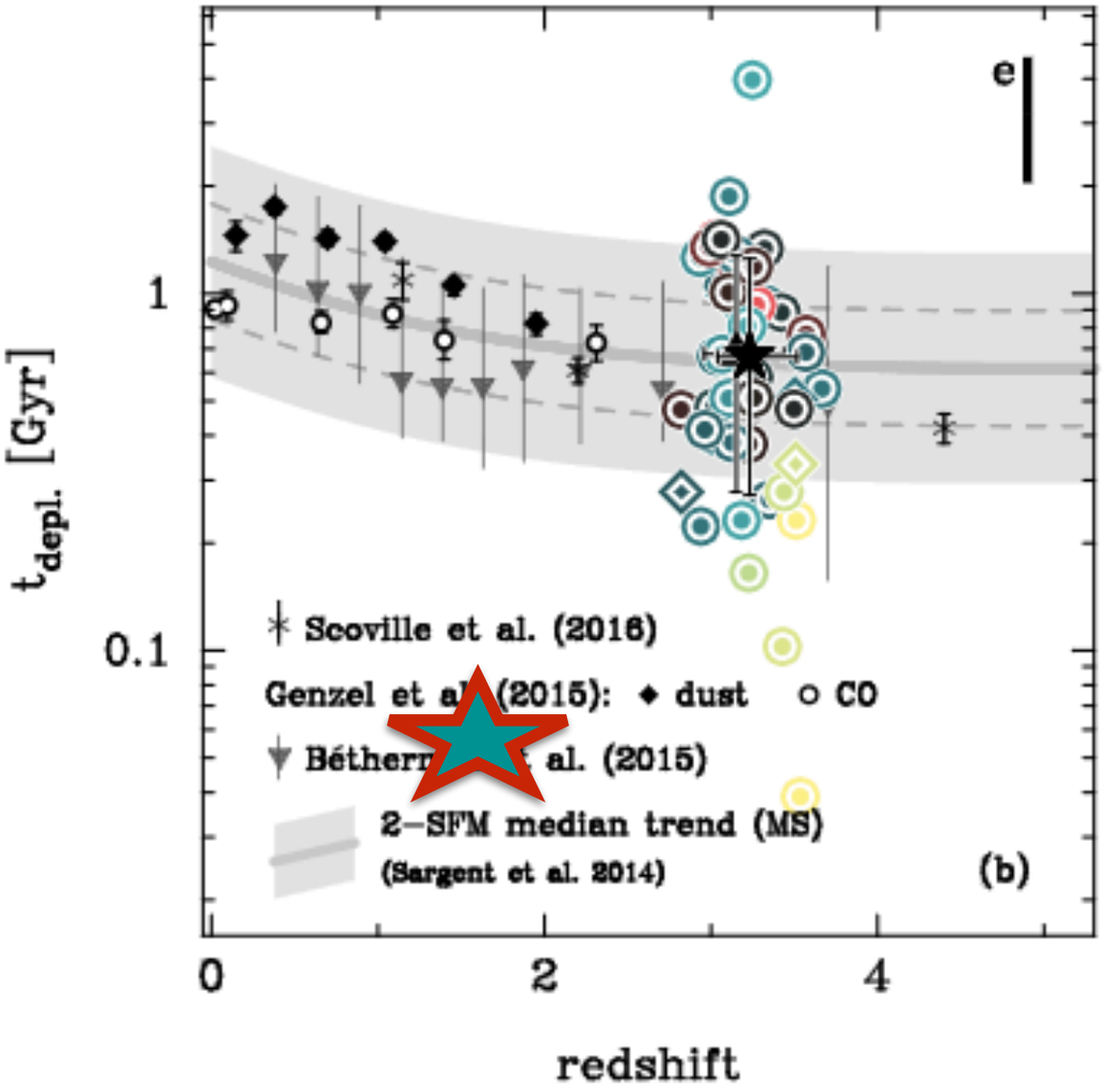
An (exceptionally) low gas fraction… and depletion timescale

Gas fraction < 5% (<10%)

t_{depl} ~40 Myr (< 100 Myr)

Schinnerer+2016

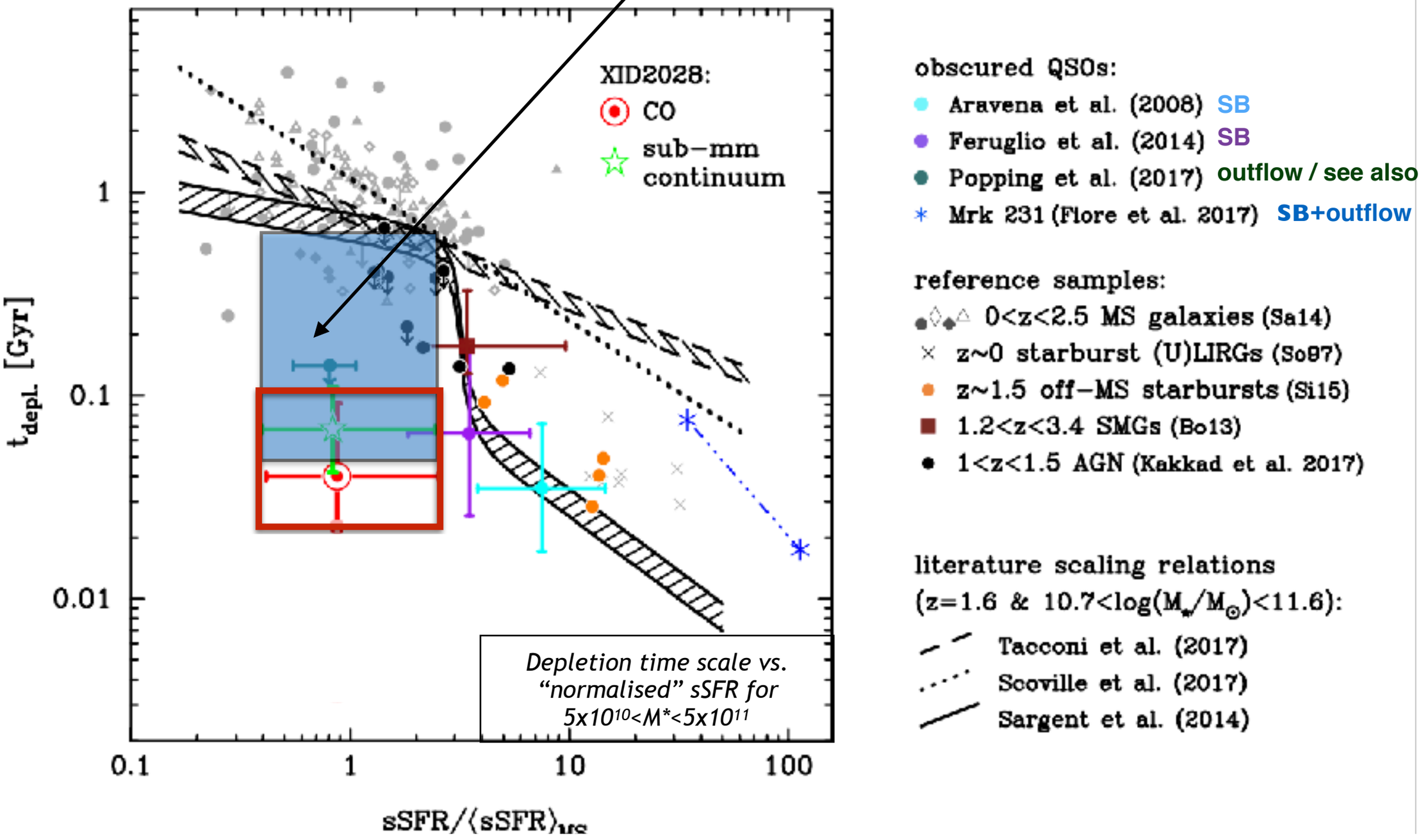




Evidence for removal of molecular gas in AGN systems with outflows

Brusa et al. 2017, A&A re-submitted

Brusa et al. 2015b, PdBI data



Depletion time scale below that of inactive galaxies of similar SFR/M* properties

Evidence for removal of molecular gas (or change into ionised phase?) and/or of higher SFE in converting into stars the residual gas

Summary

RESULTS on a prototypical luminous, obscured QSO (XID2028)

Fast and powerful ionised/neutral/molecular winds with negative and positive feedback effects

[O III], [O II], MgII, CO(5-4) asymmetric line profile, v>700-1500 km/s, up to ~10 kpc !
ionised component comparable or *larger* than molecular one
XID2028 (+XID5321, XID5395) in the NIRSpec GTO target list !

Compact and rotating SF molecular disc + high ΣSFR into an (already) massive galaxy

ALMA 1.3mm continuum and CO(5-4) sizes

Molecular gas has been removed (or destroyed?) in AGN systems (with outflows)

Very low molecular gas fraction and depletion timescale

Summary

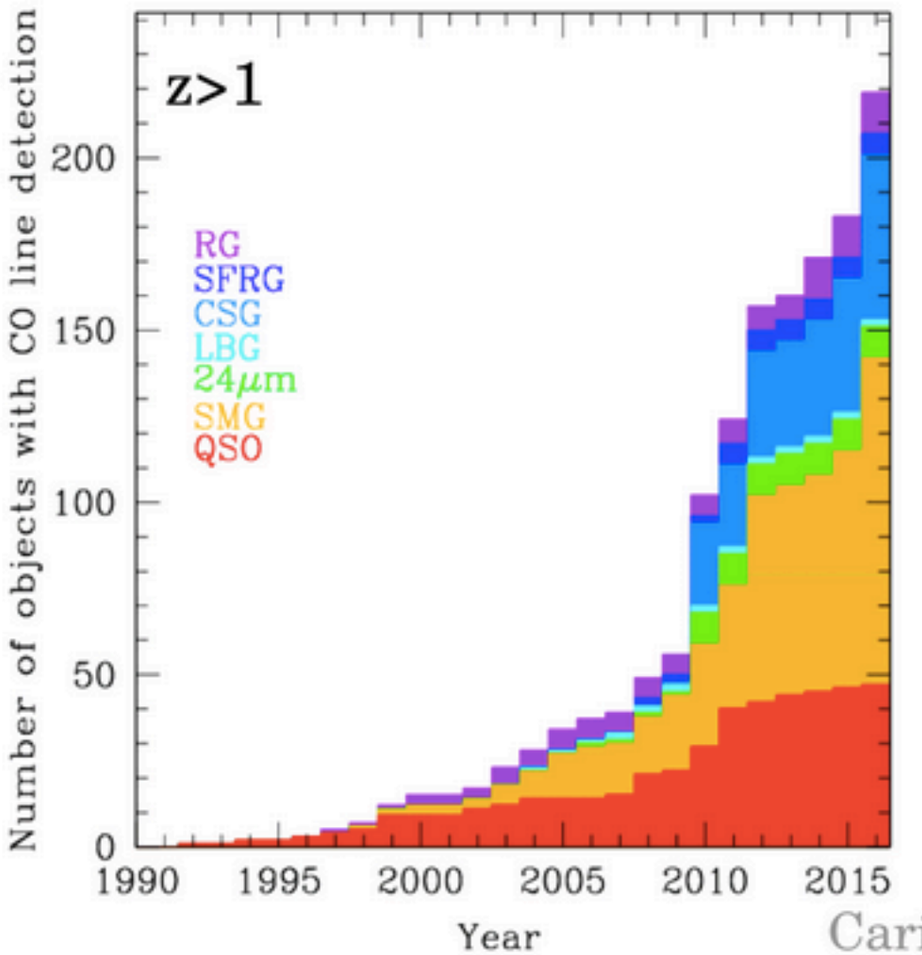
(1)AGN outflows do have effects on host galaxy properties

(2) Effects of outflows can be studied only through multiwavelength approach

Importance of ***survey*** + ***dedicated follow-up***

*** XMM-Newton + COSMOS + multiwavelength photometry**

*** X-shooter + SINFONI + DEIMOS + LUCI/ARGOS + PdBI + ALMA + …**



courtesy R. Decarli

(large) *obscured* AGN samples mapped in CO/dust at z=1-3 are still *MISSING*….

Need *more molecular gas observations* of AGN host galaxies at z~1-3, coupled with information on presence of winds and reliable measurements of stellar masses

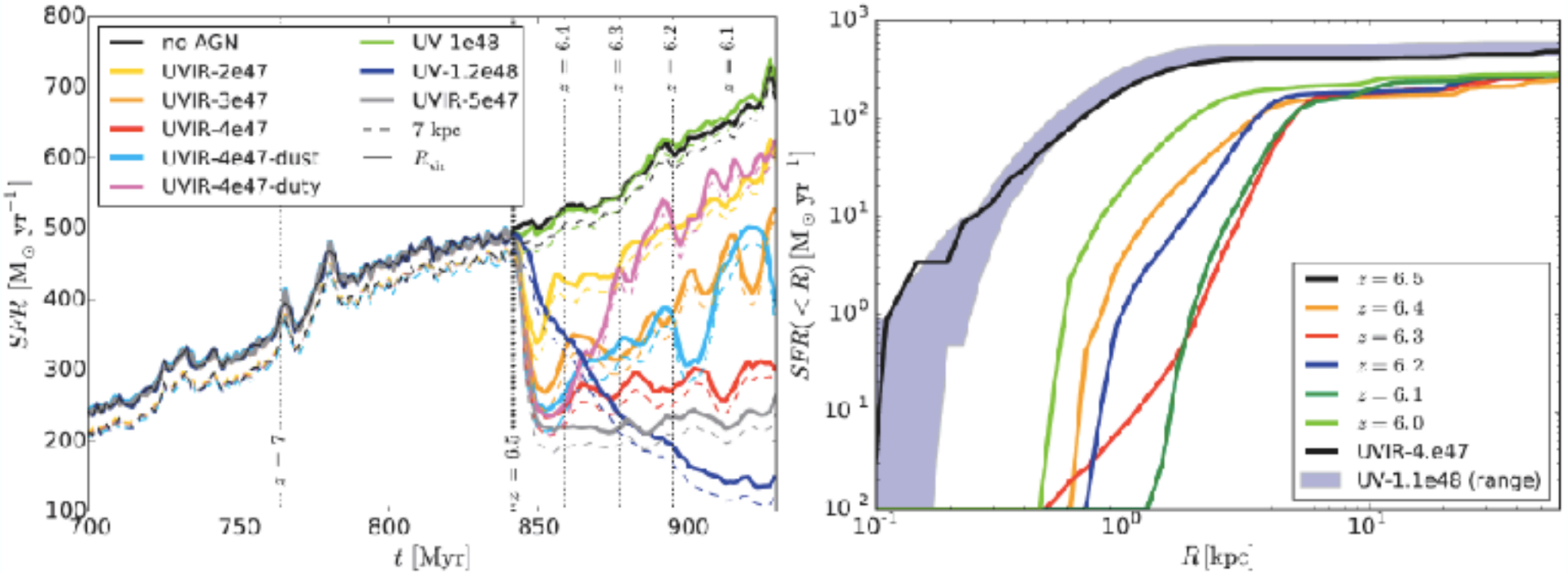
SUPER-ALMA survey (PI: Mainieri;~few tens sources)

Backup slides

Feeding & Feedback in galaxies & AGN

IR radiation pressure suppresses star formation efficiently

Costa+2017



Star formation drops by factors ~ 2 - 3 halo-wide due to IR radiation pressure.
Star formation completely quenched in the innermost ~ 1 kpc.

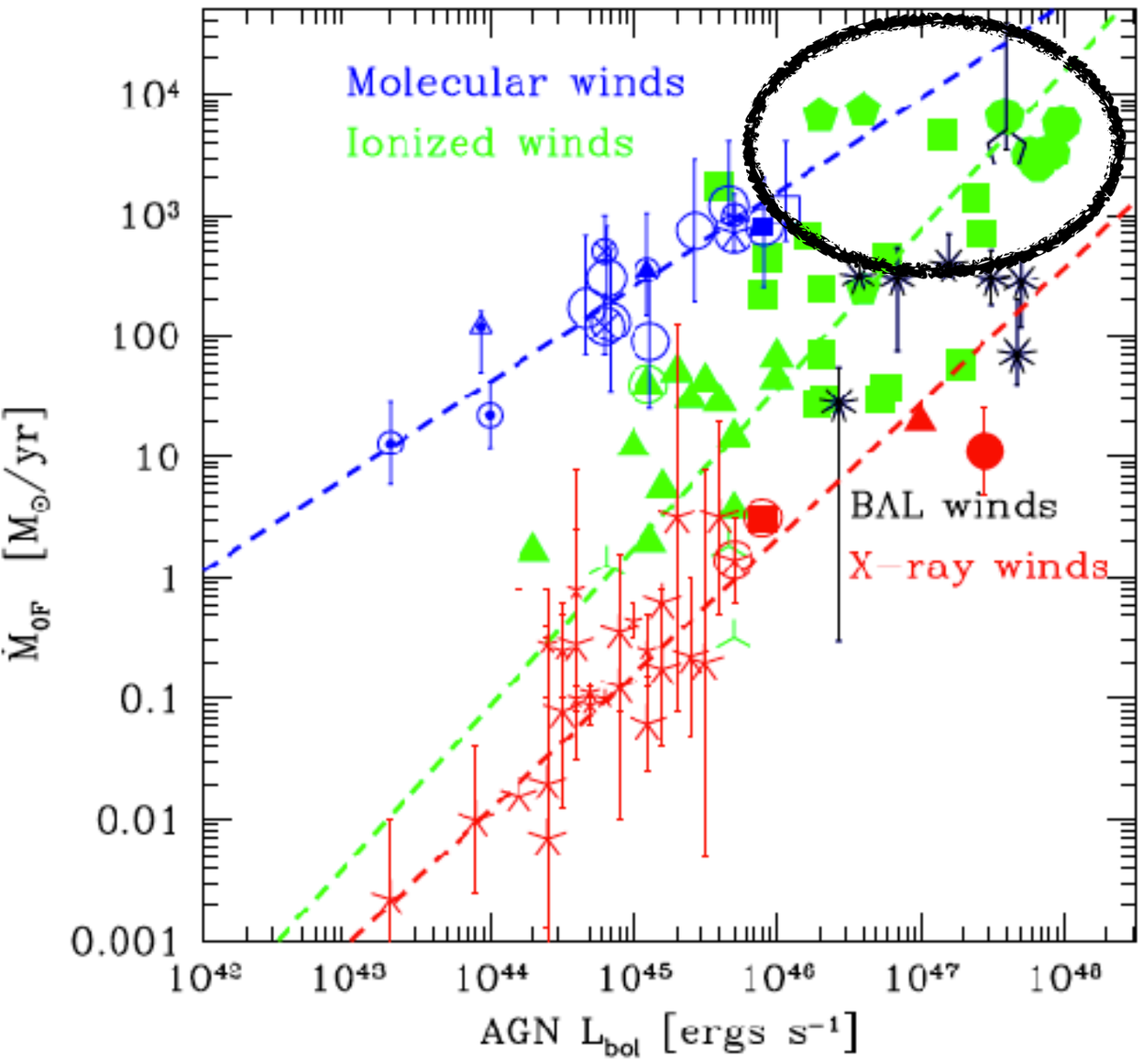
BUT need gas to be optically thick in IR.

Need **high** central gas densities, **high** dust masses, **high** gas covering fraction.

Multiphase winds

Fiore et al. 2017

compilation of ~90 AGN with outflows in different phases



at the highest AGN luminosity (Lbol>10^46) molecular and ionised winds have comparable mass outflow rates

XID2028:
mass outflow rate in the ionised gas component comparable or larger than molecular component

con:

- **only few sources with 2 gas phases**
- **statistical relation / biases samples!**

dust 1mm photometry
dust FIR SED
other CO
CO bursters: SMGs, (U)LIRGs
CO xCOLDGASS
CO PHIBSS 1/2

Whitaker 12
Whitaker 14

3D-HST: log(M*/M⊙)>9.9

3D-HST: log(M*/M⊙)>8.8

log(sSFR/sSFR(MS,z,M*)Speagle14)

log(1+z)

log(M*/Msun)