

AGN and galaxies



Vincenzo Mainieri

Based on conversations with Andrea Merloni and Paolo Padovani

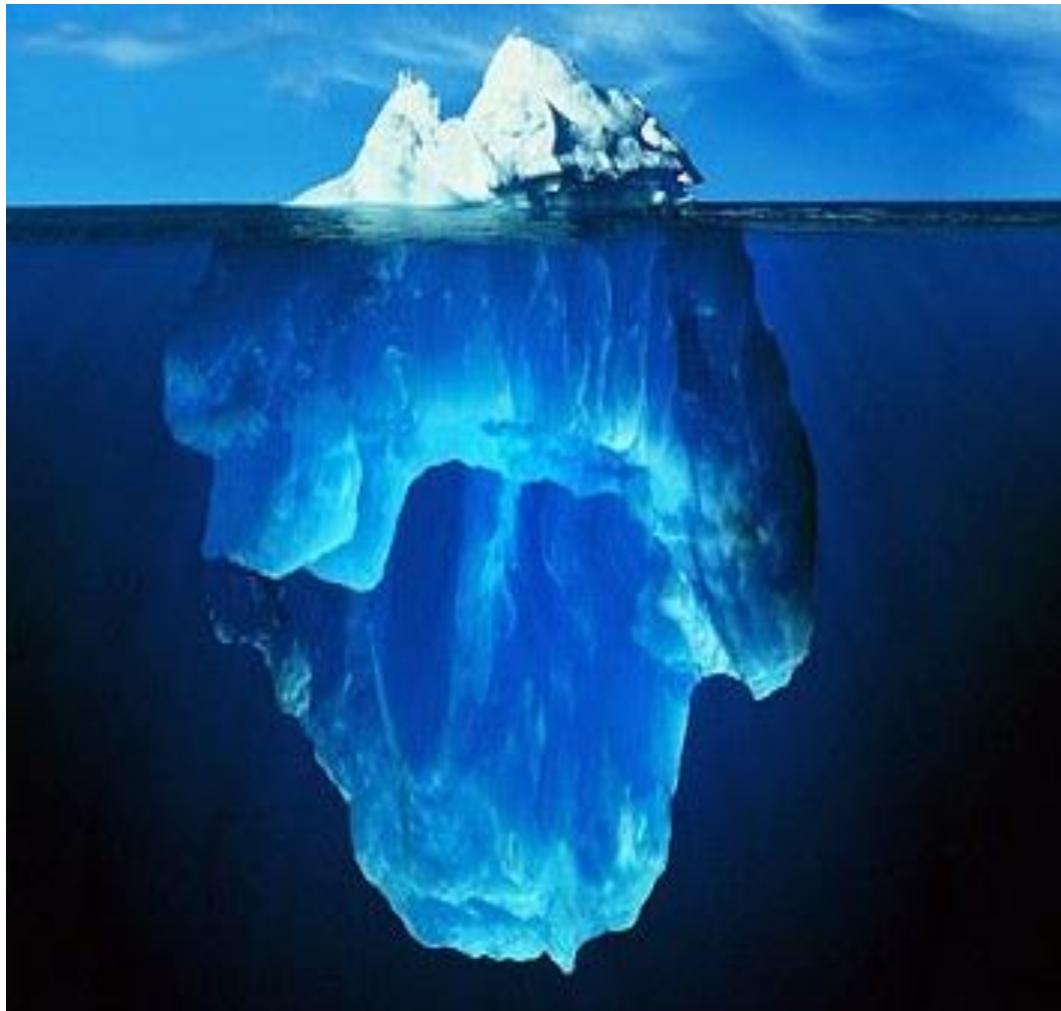
AGN feedback: challenges in the 2020s



Vincenzo Mainieri

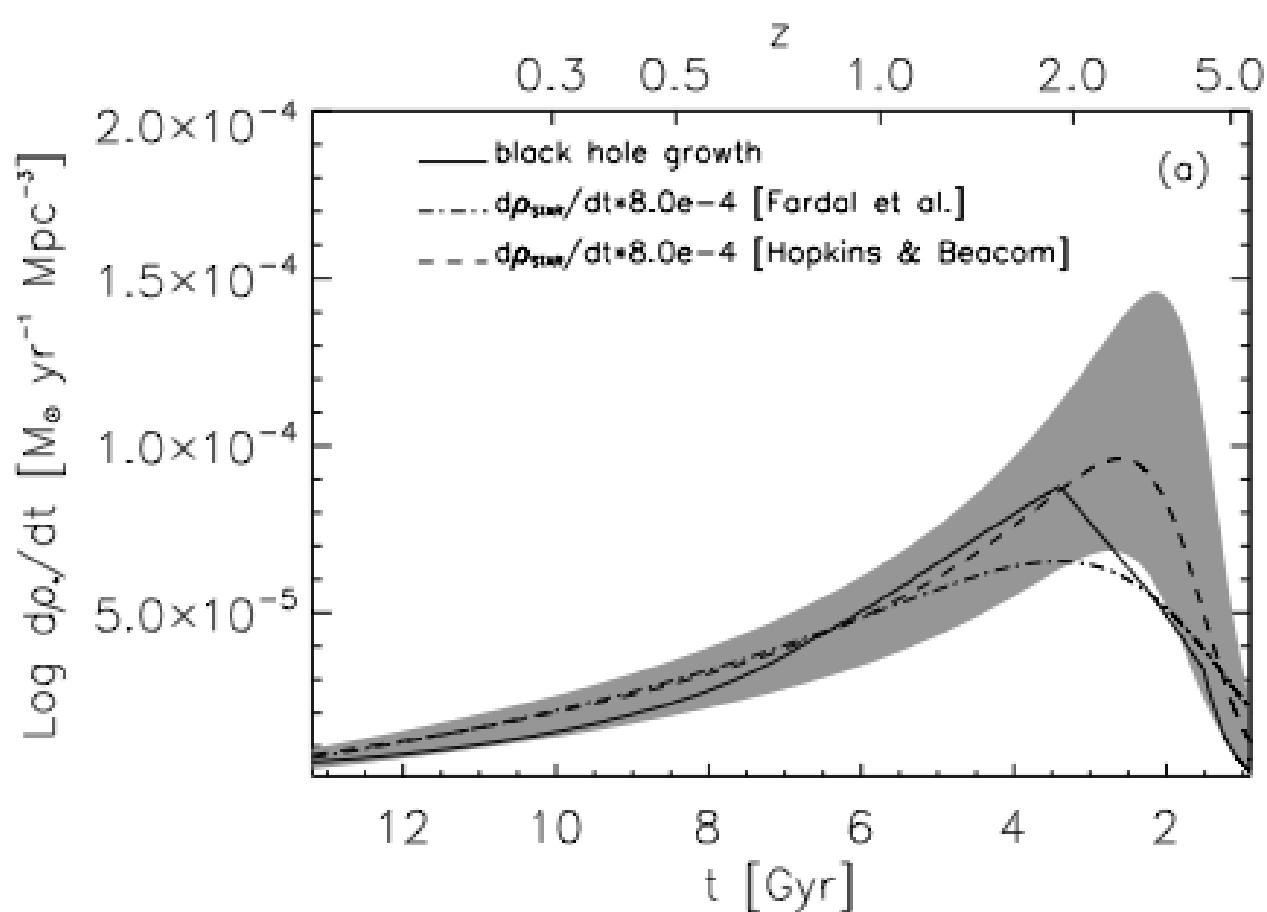
Based on conversations with Andrea Merloni and Paolo Padovani

AGN activity is not a rare event

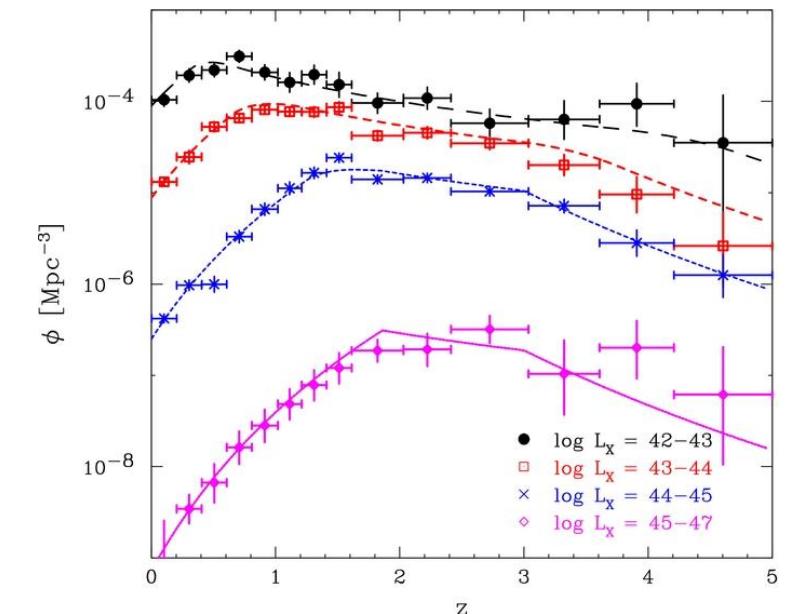


NGC4395 (Filippenko & Ho 2003)

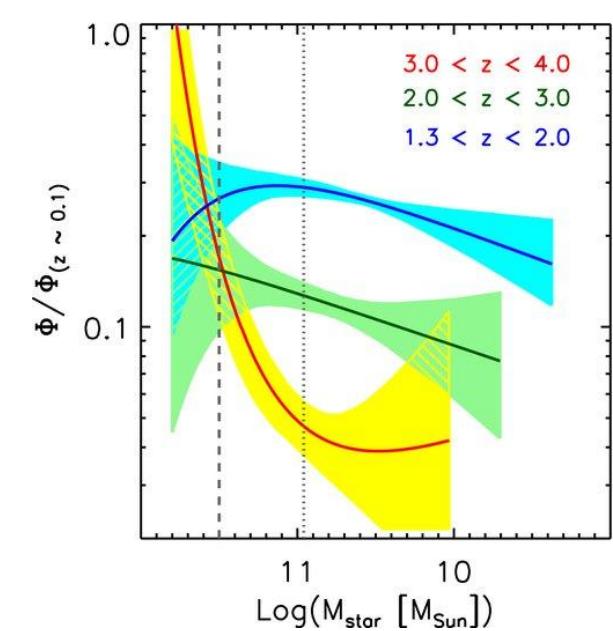
Similar mass build-up history



Shankar+09

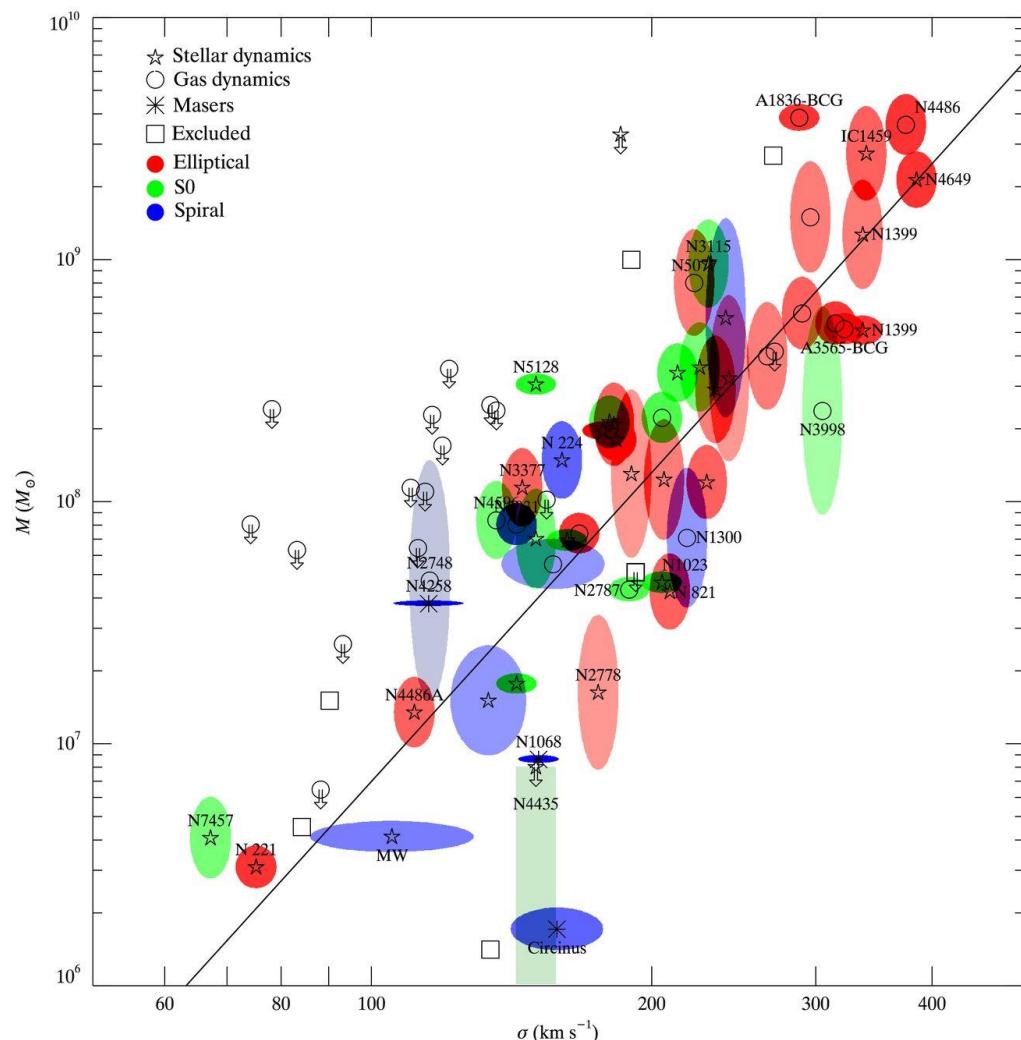


Ueda+14



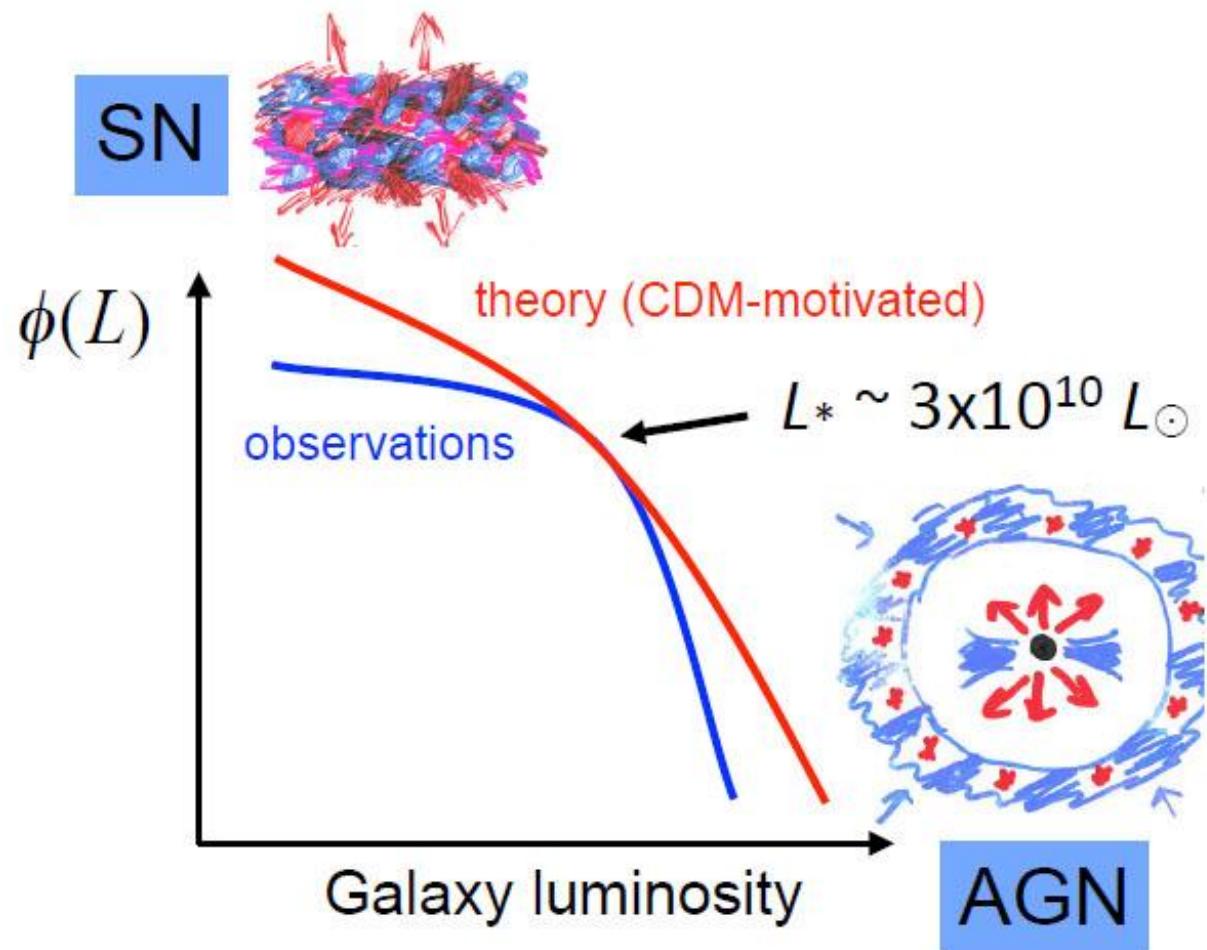
Marchesini+09

M- σ



Gültekin+09

AGN feedback:

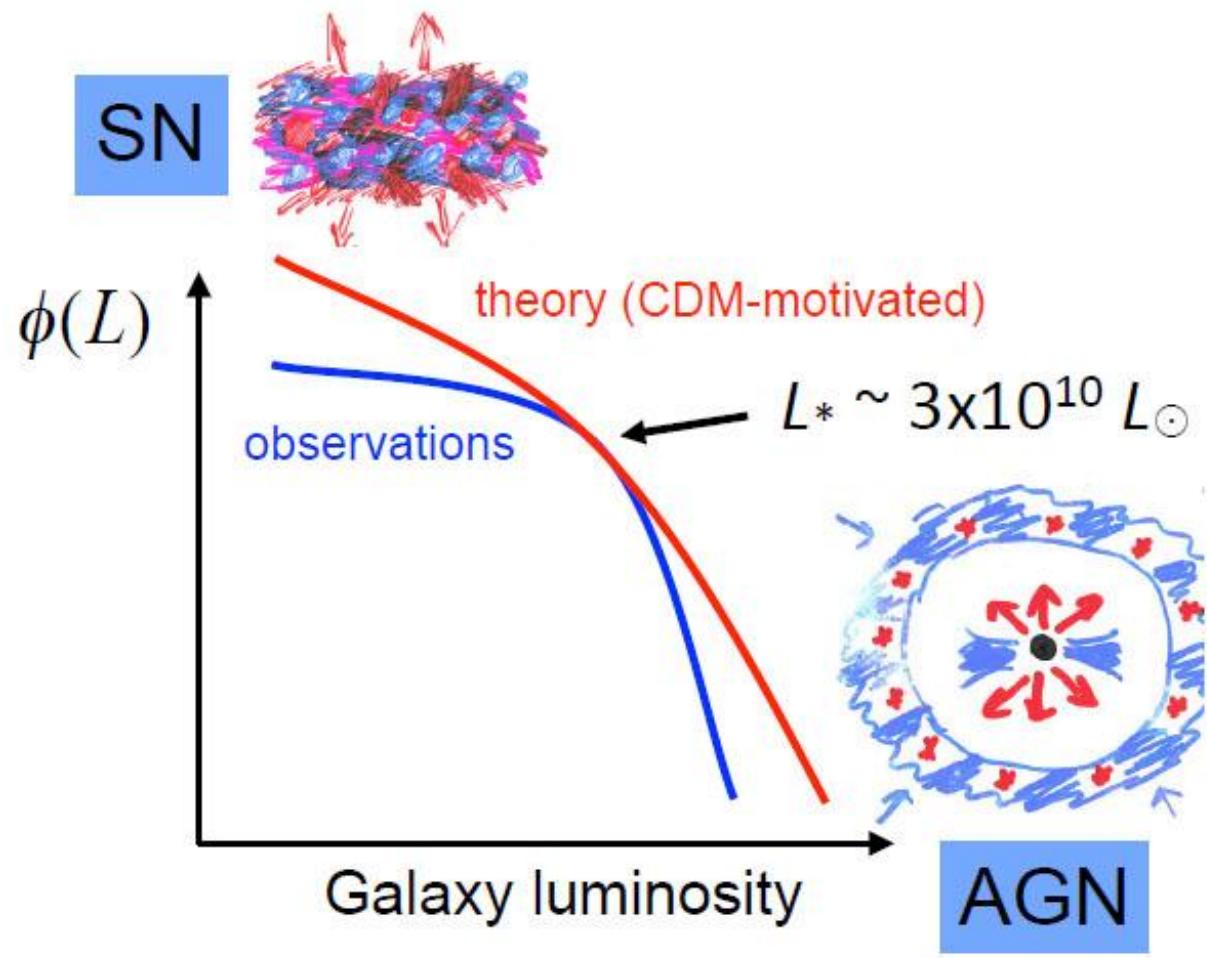


Silk+12

"It has been realized over the past decade that the black hole at the center of a galaxy bulge is no mere ornament but may play a major role in determining the final stellar mass of the bulge. The process by which this occurs is known as AGN (active galactic nuclei) feedback"

Fabian+12

AGN feedback:

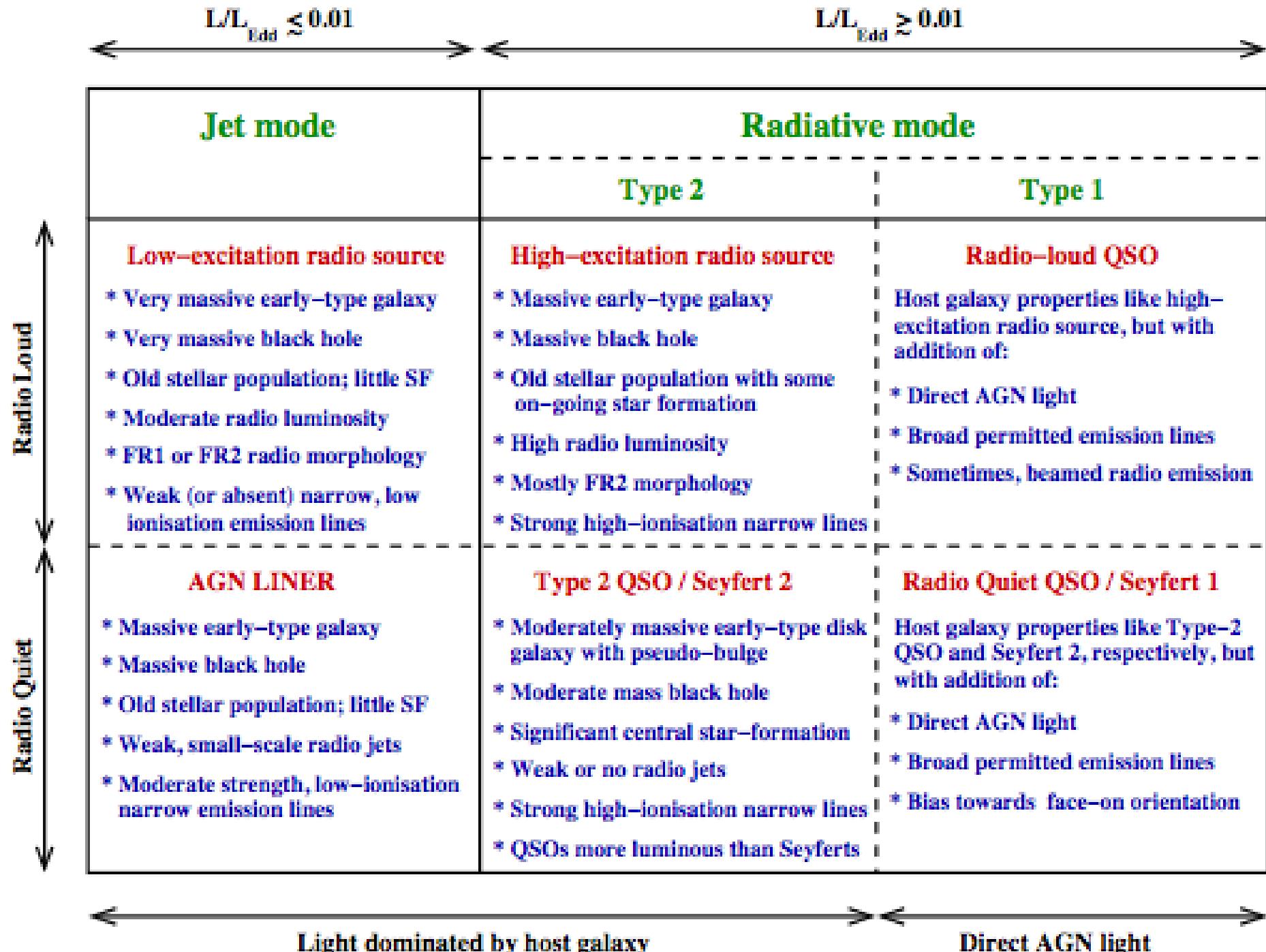


Silk+12

*"It has been realized over the past decade that the black hole at the center of a galaxy bulge is no mere ornament but **may play a major role** in determining the final stellar mass of the bulge. The process by which this occurs is known as AGN (active galactic nuclei) feedback"*

Fabian+12

AGN feedback: radio and quasar mode



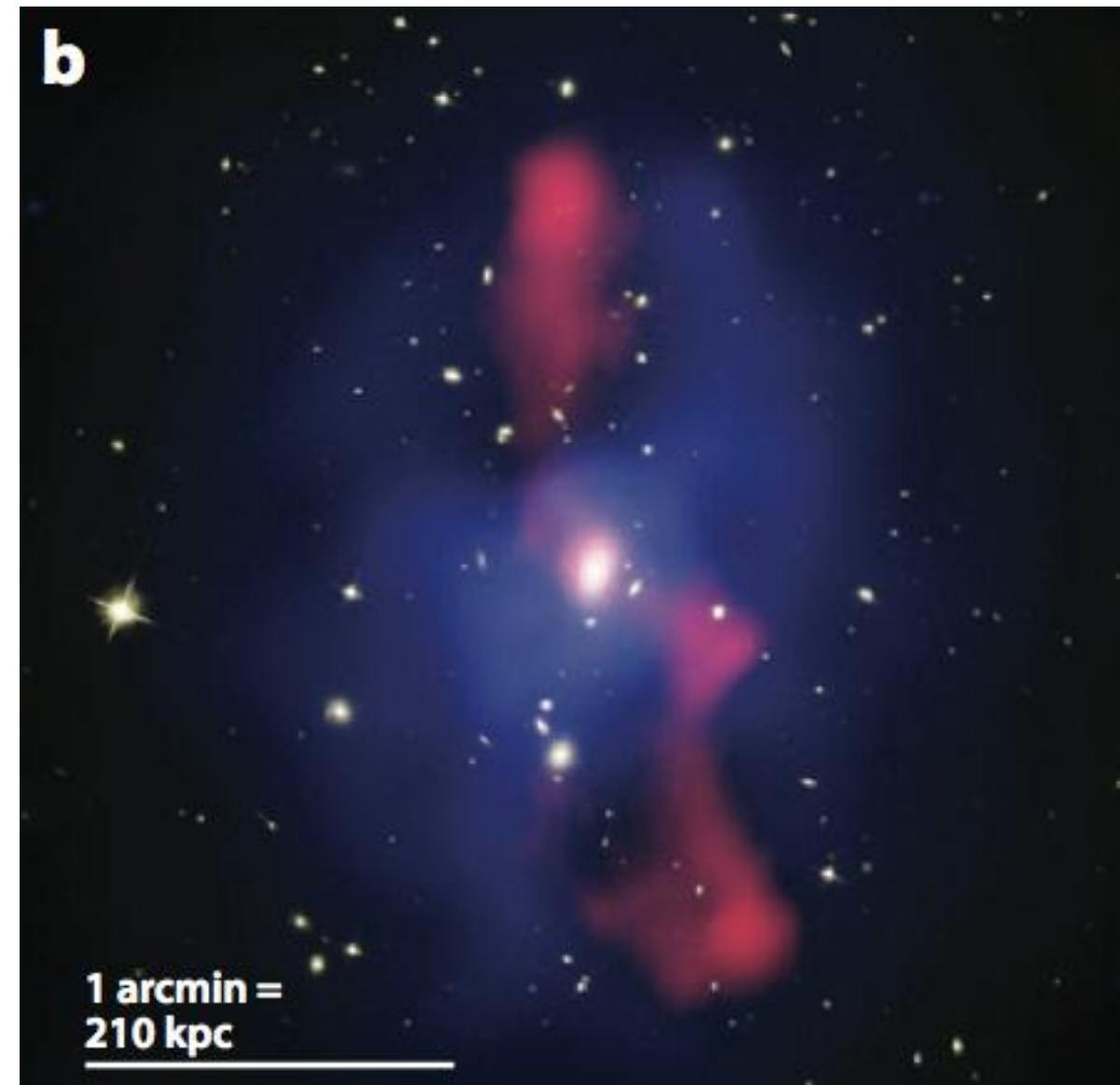
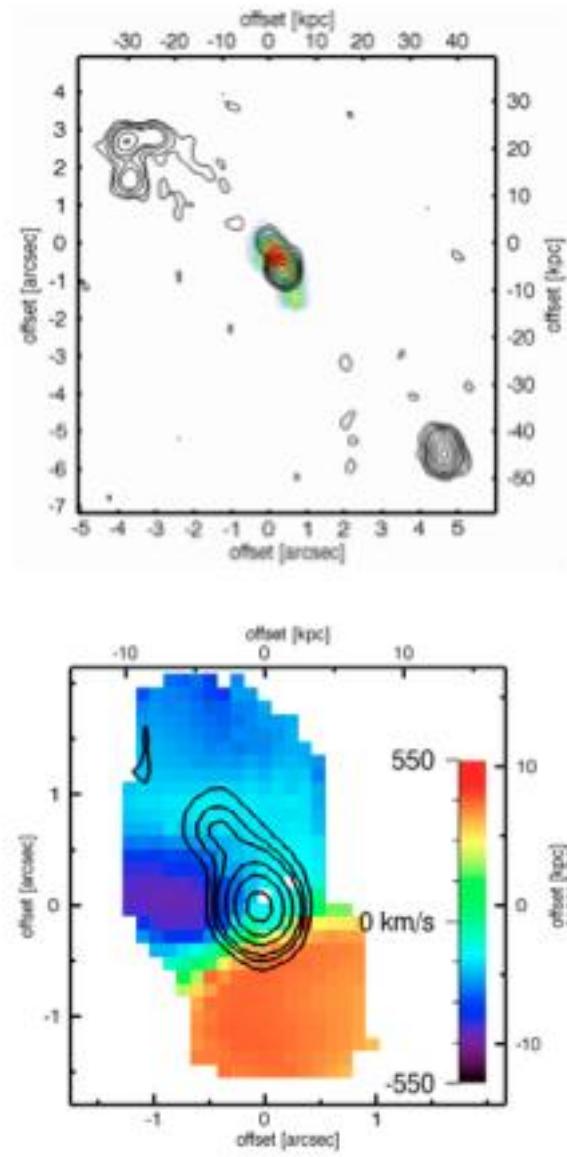
Heckman & Best 14

What have we learned?

AGN outflows are common

AGN feedback: radio mode

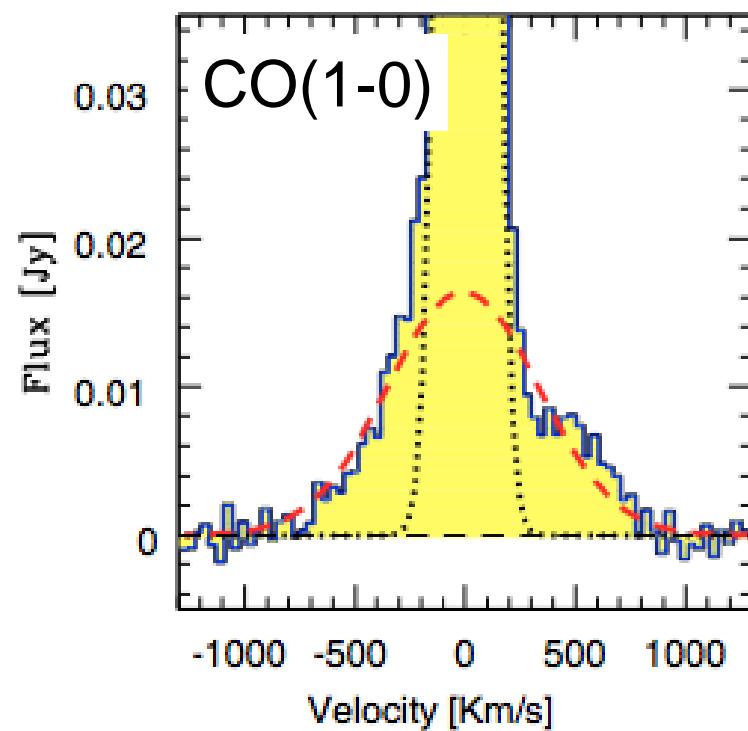
Nesvadba+08



McNamara+09

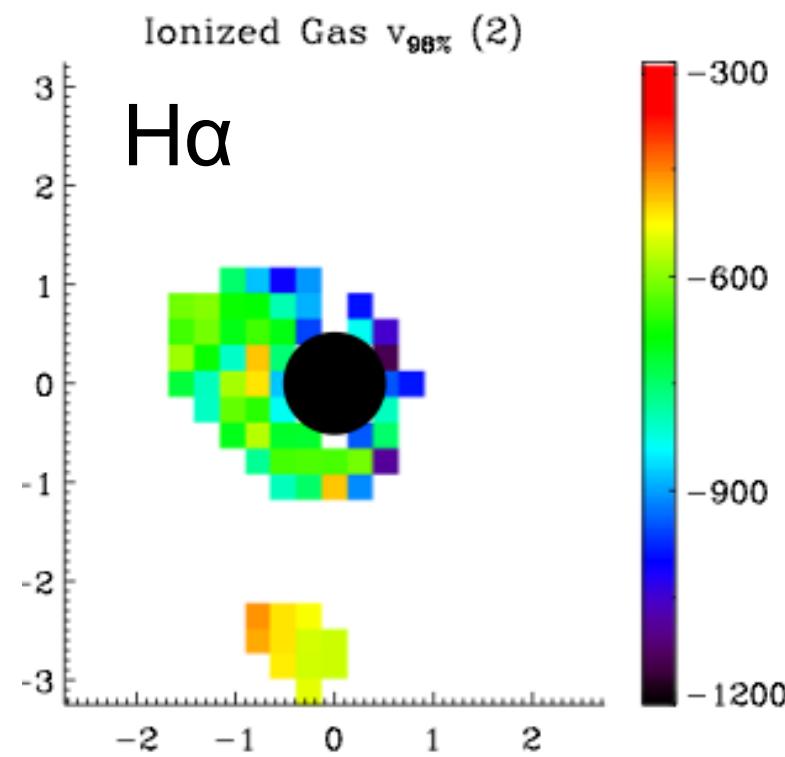
AGN feedback: local Universe

Molecular gas



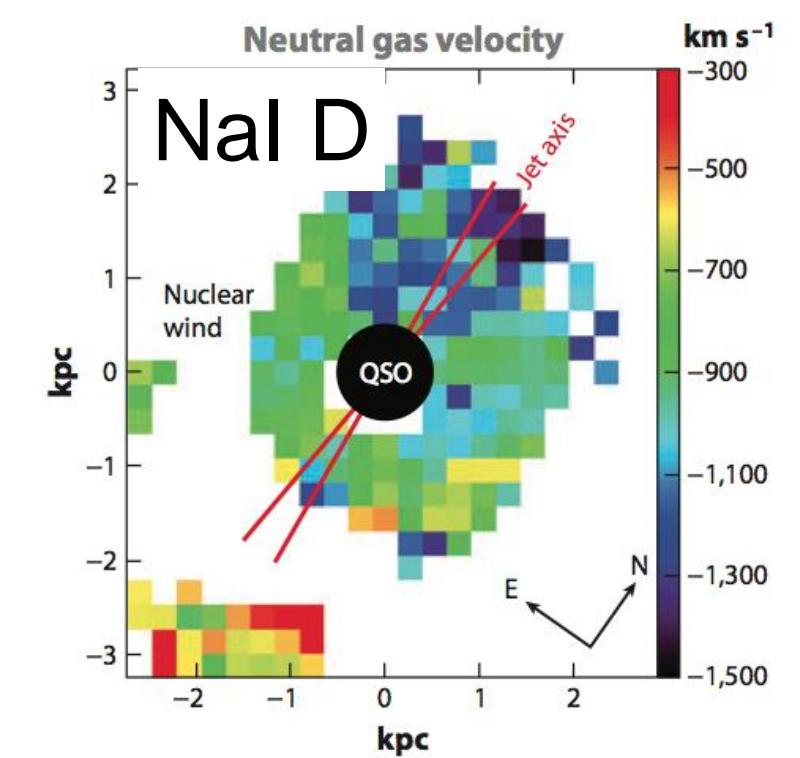
Mrk231 (Feruglio+10)

Ionized gas



Mrk231(Rupke & Veilleux 11)

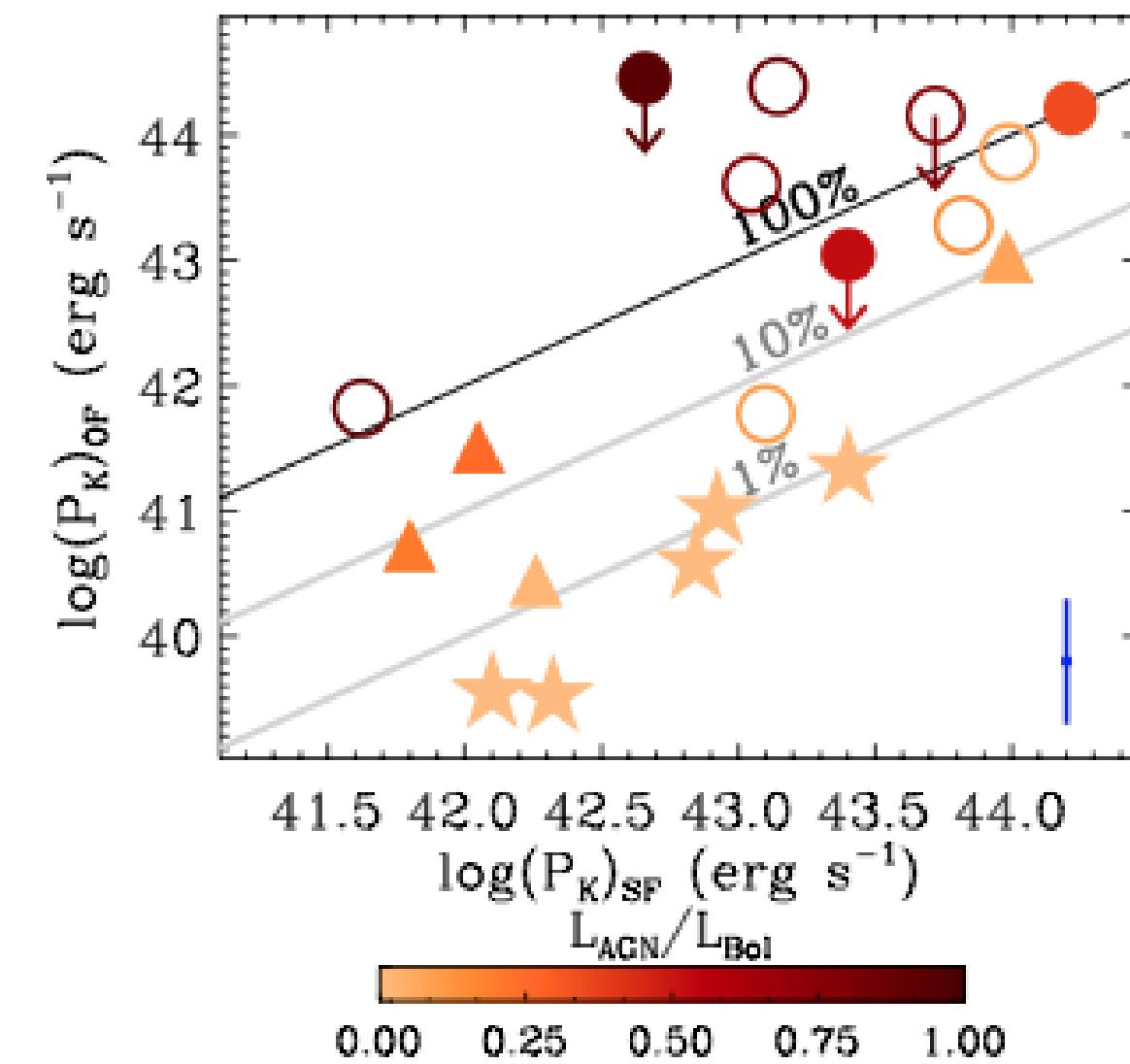
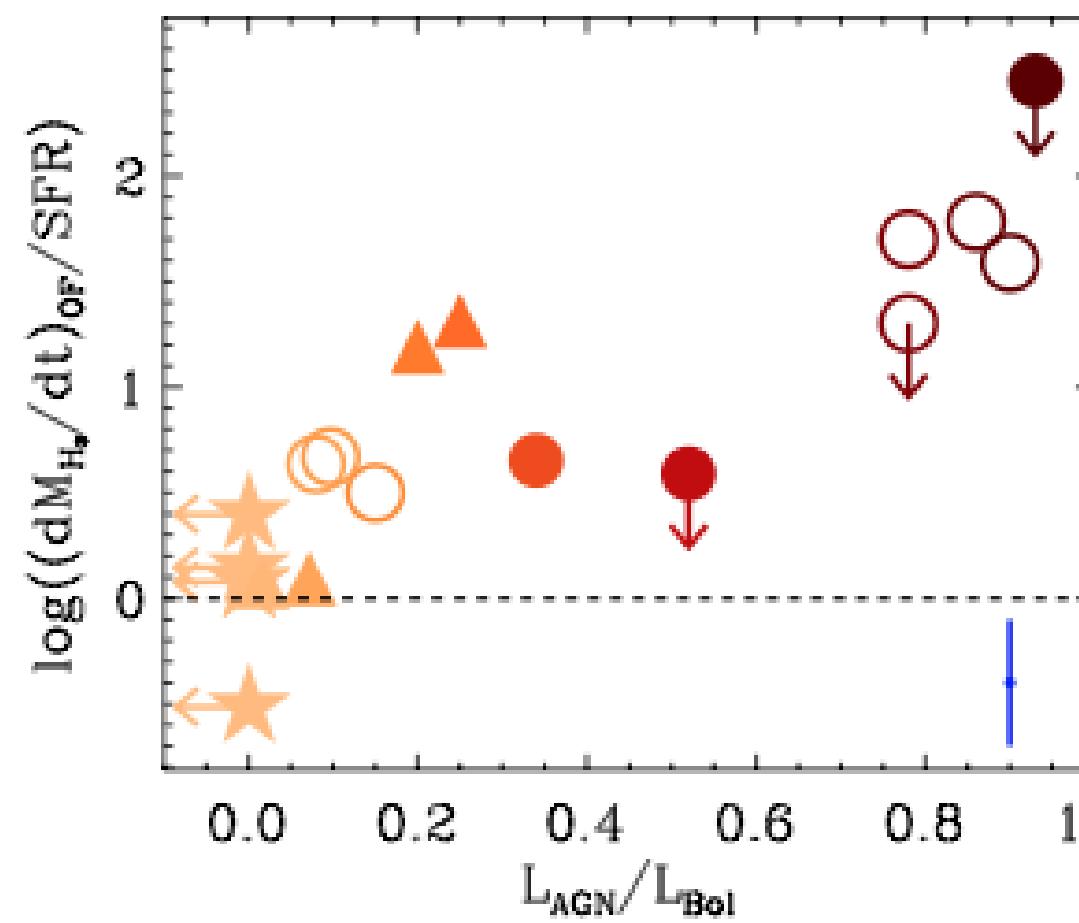
Neutral gas



Massive multi-phase outflows extended on kpc scales.

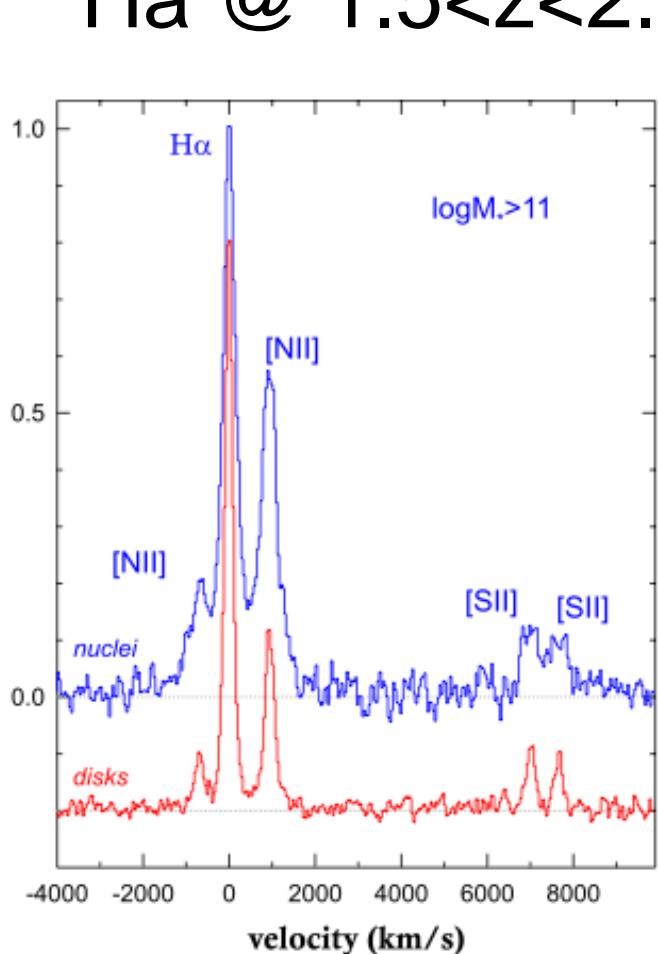
AGN-driven outflows

Cicone+14

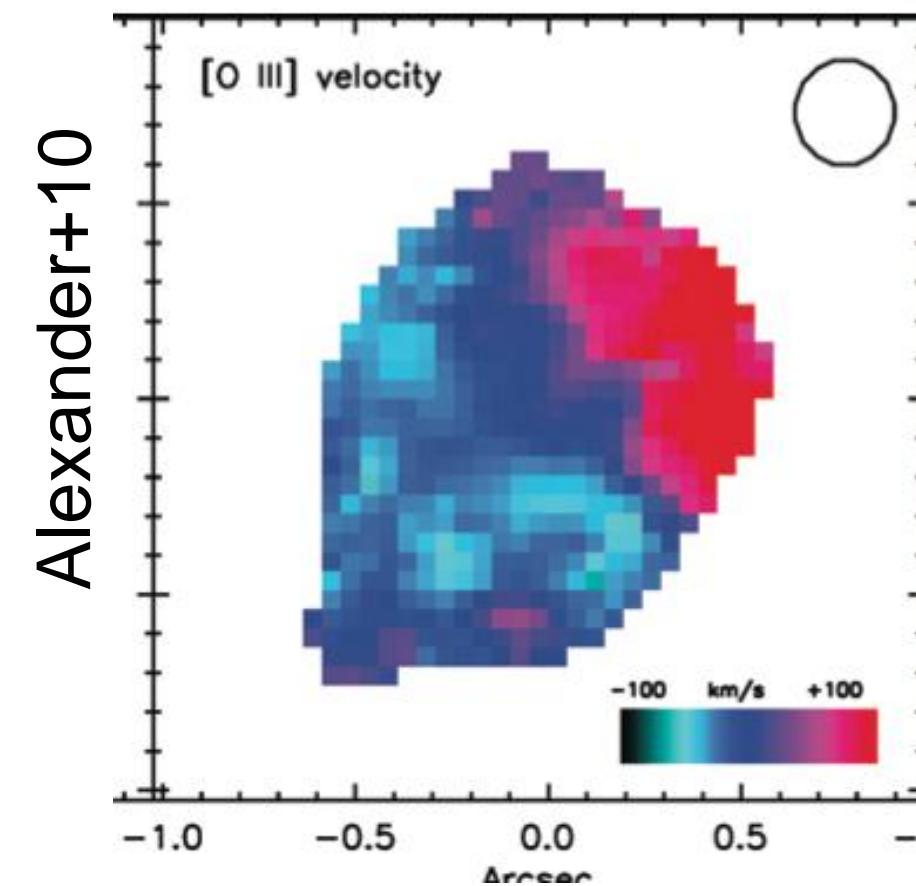


AGN feedback: high-z

Förster Schreiber+14

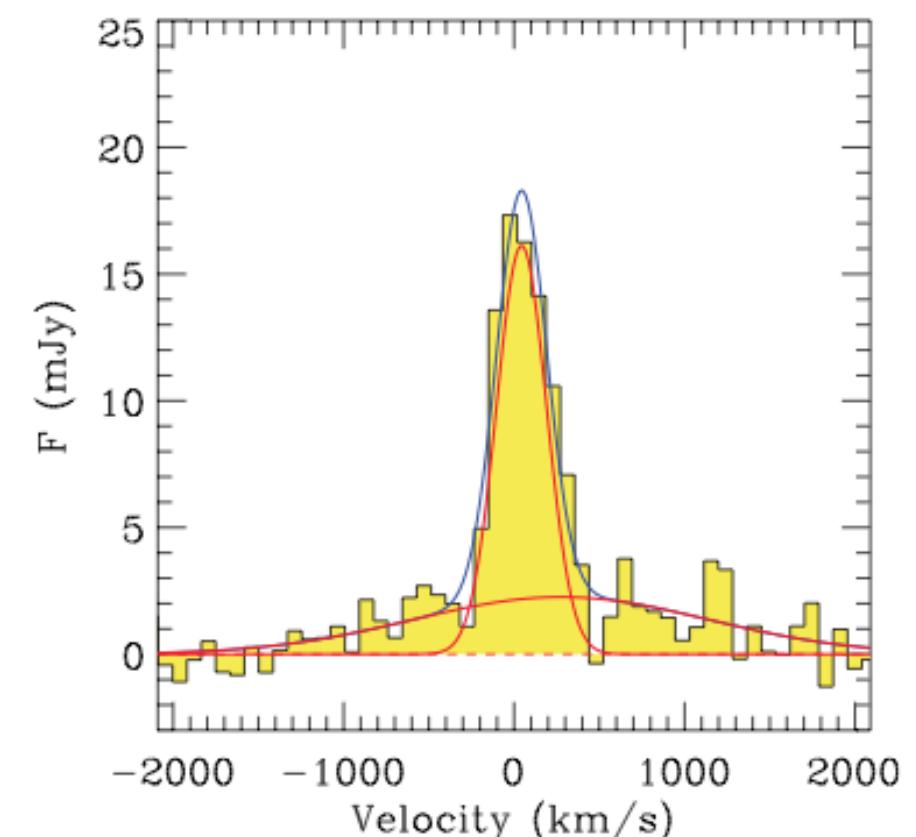


[OIII] @ $z \sim 2$



$v \sim 300$ km/s
size ~ 8 kpc

[CII] @ $z = 6.4$

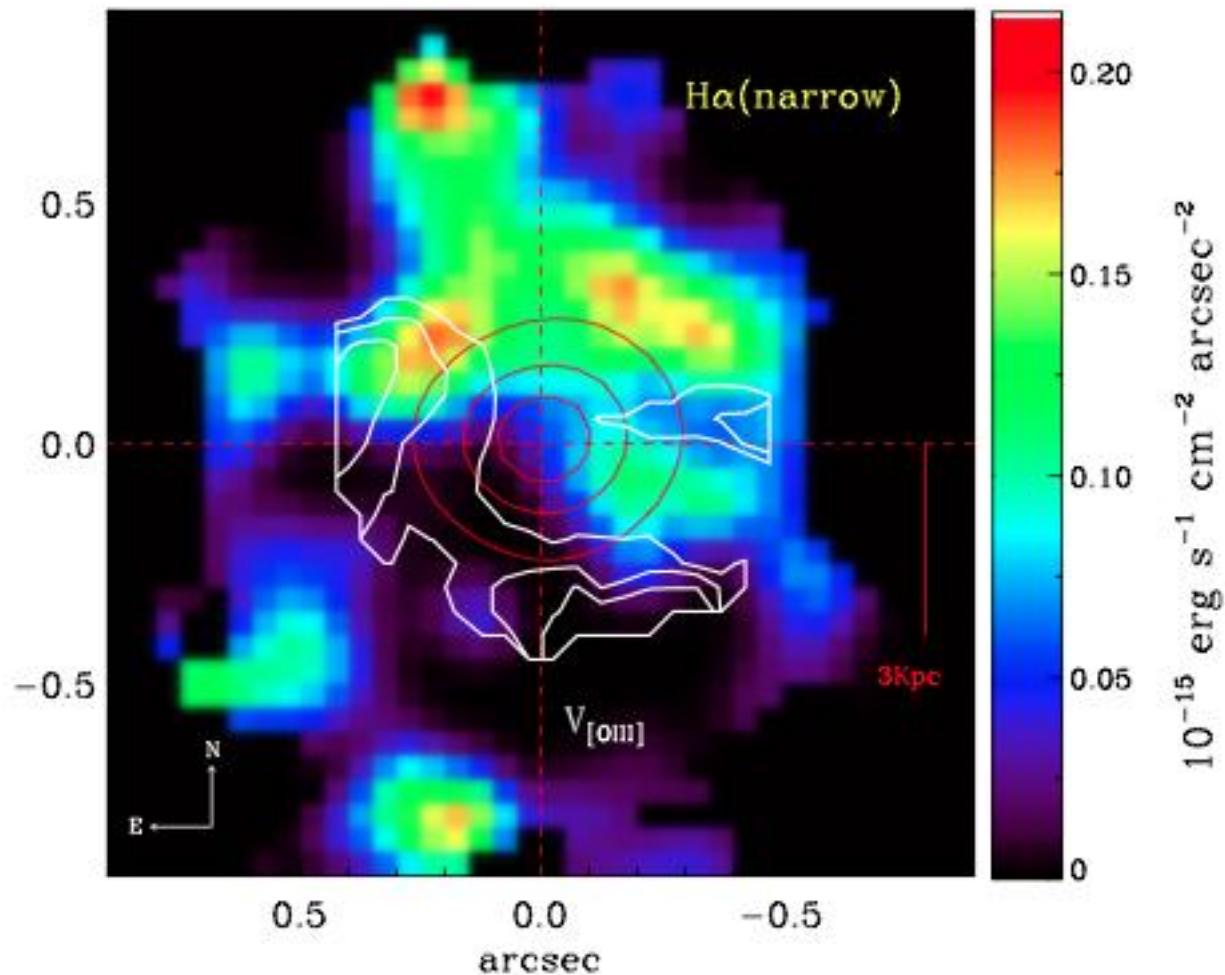


$v \sim 1300$ km/s
size ~ 16 kpc
 $M_{\text{outflow}} > 3500 M_{\odot}/\text{yr}$

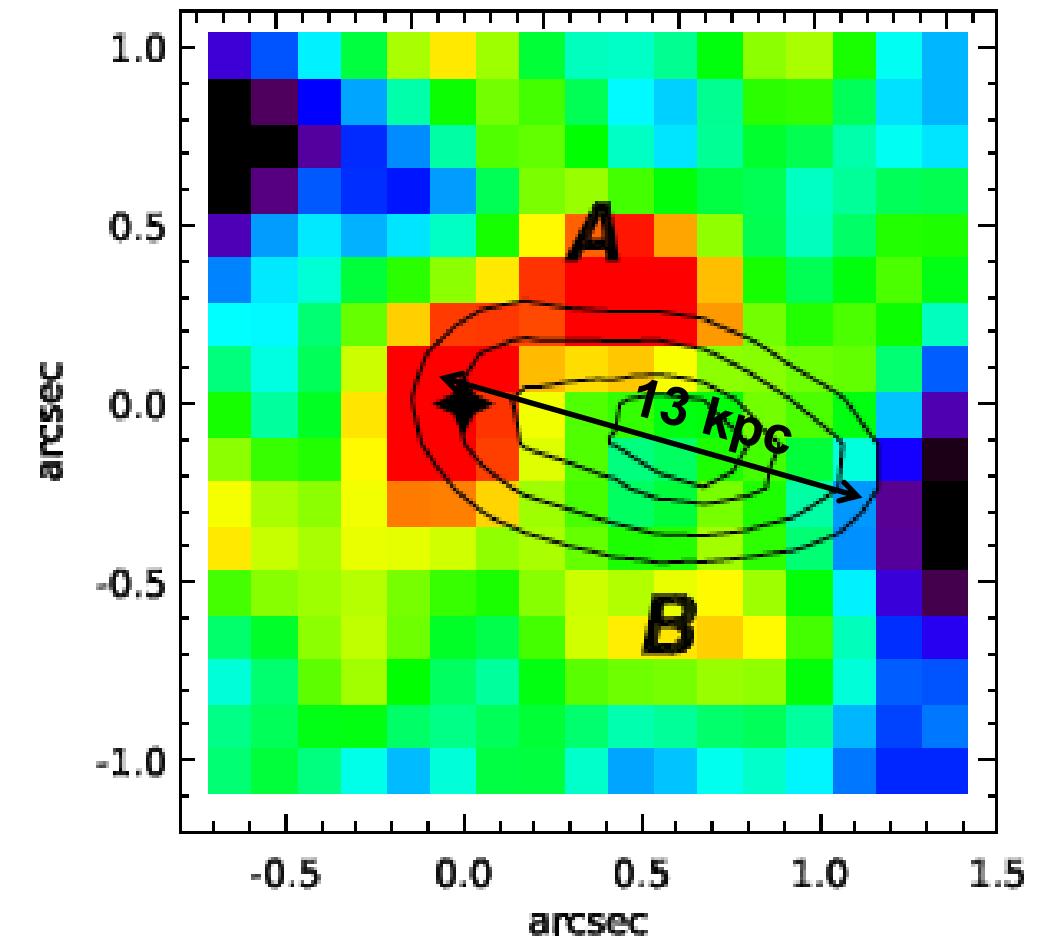
Maiolino+12

Is AGN affecting the host galaxy?

Cano-Diaz+12

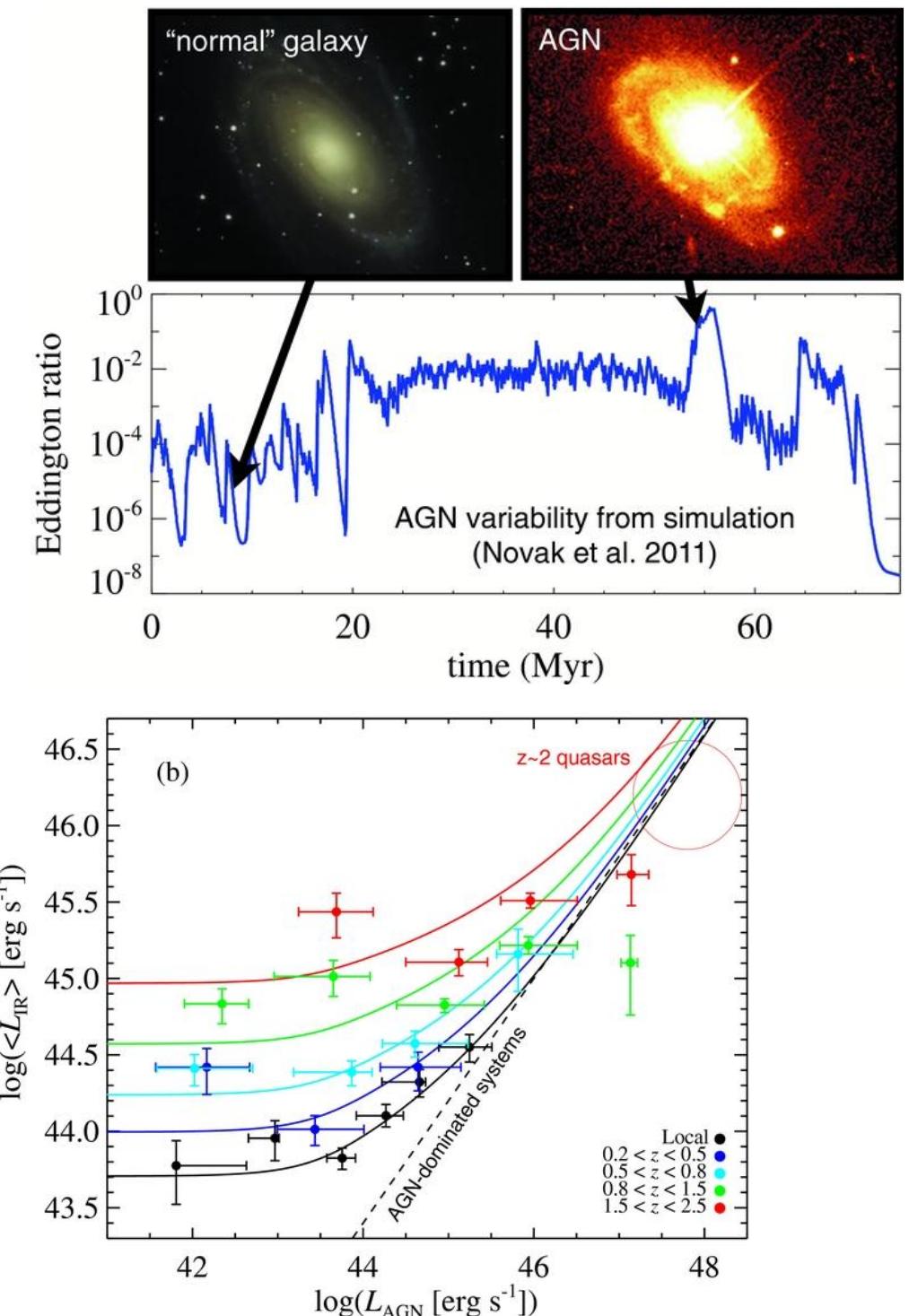
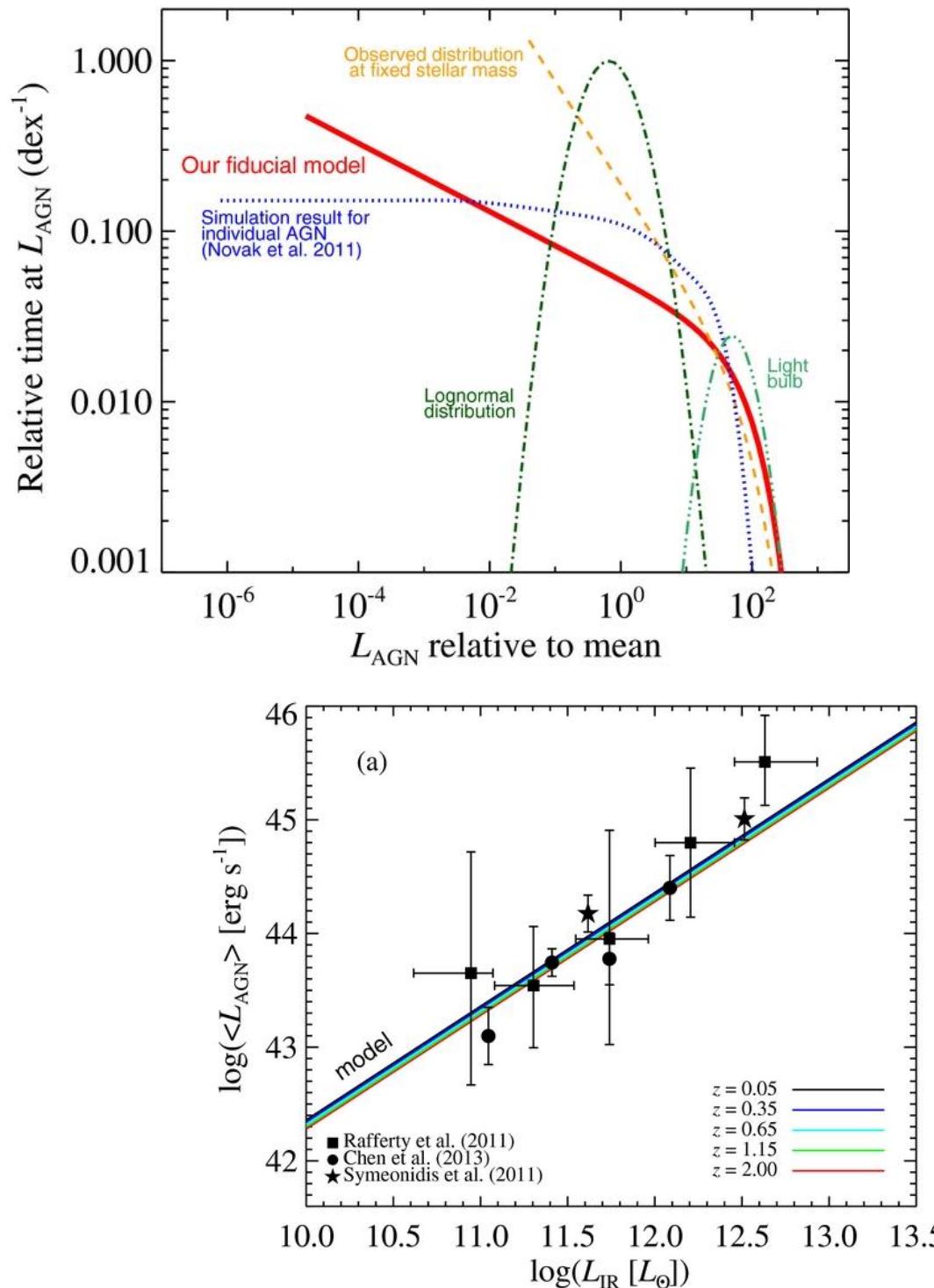


Cresci+14

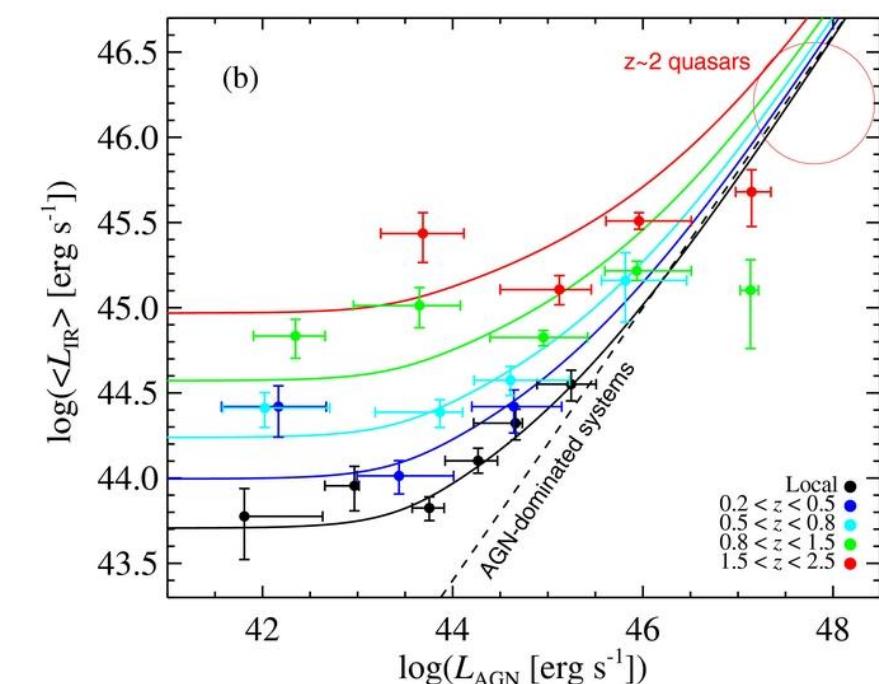
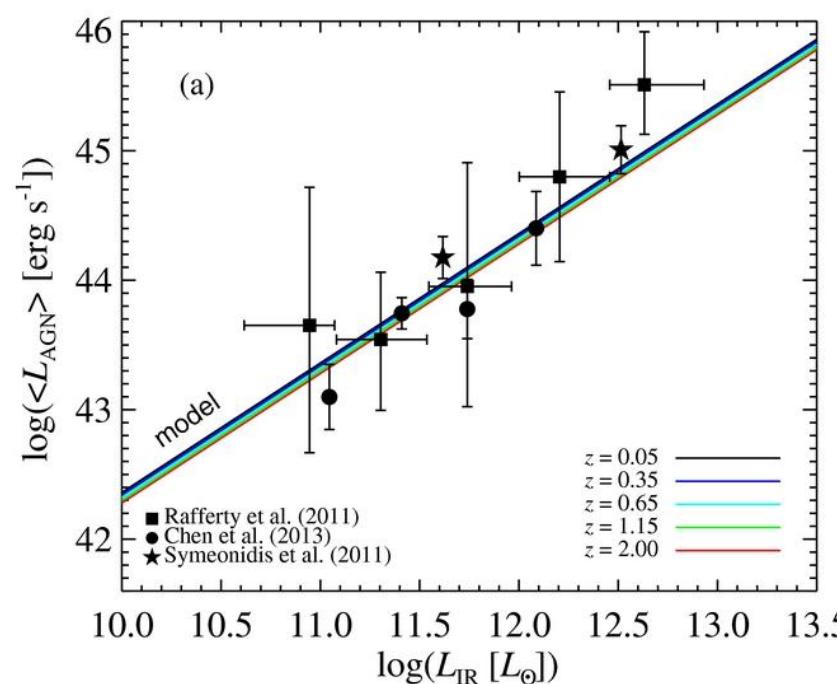


Star-formation (narrow H α) is heavily suppressed in the region where the strongest outflow is traced by [OIII] $\lambda 5007$

Timescales



Hickox+14

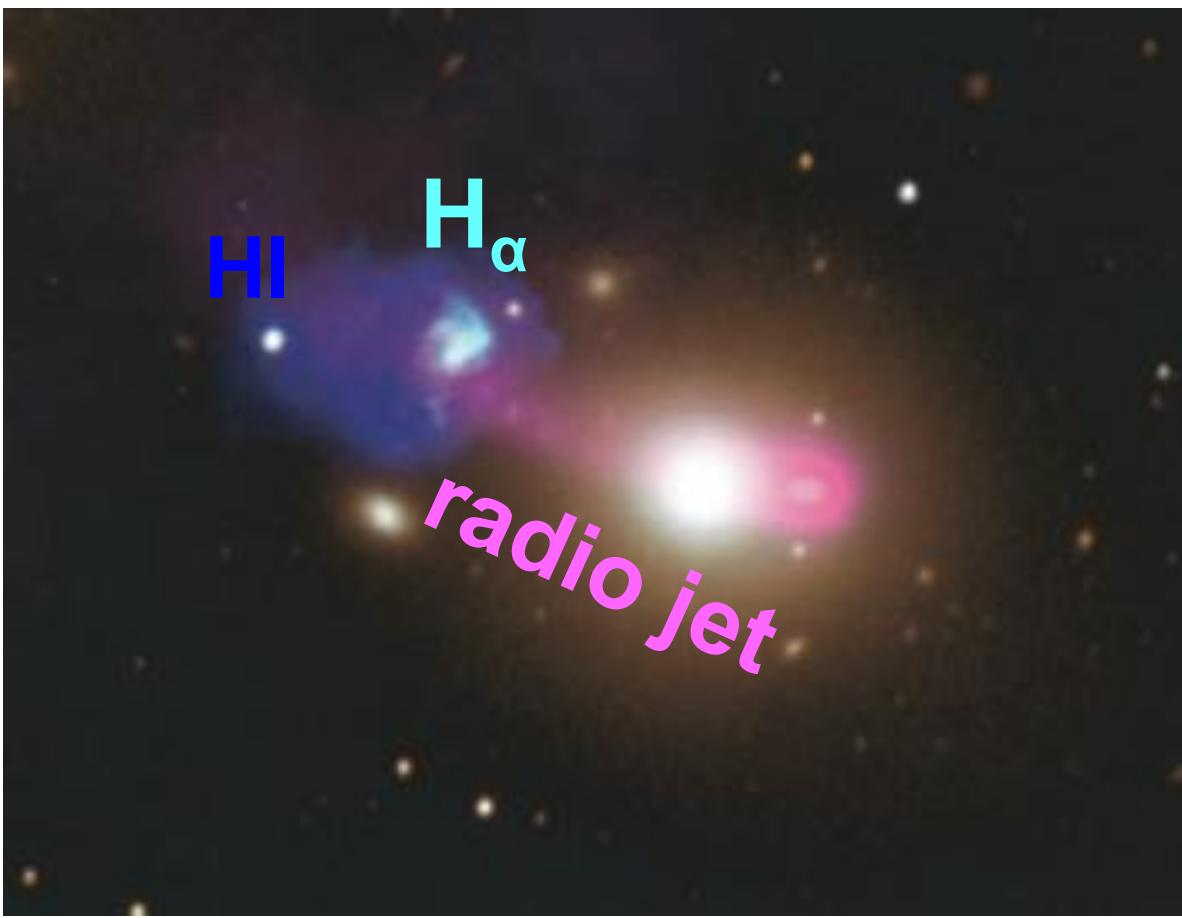


AGN feedback: positive

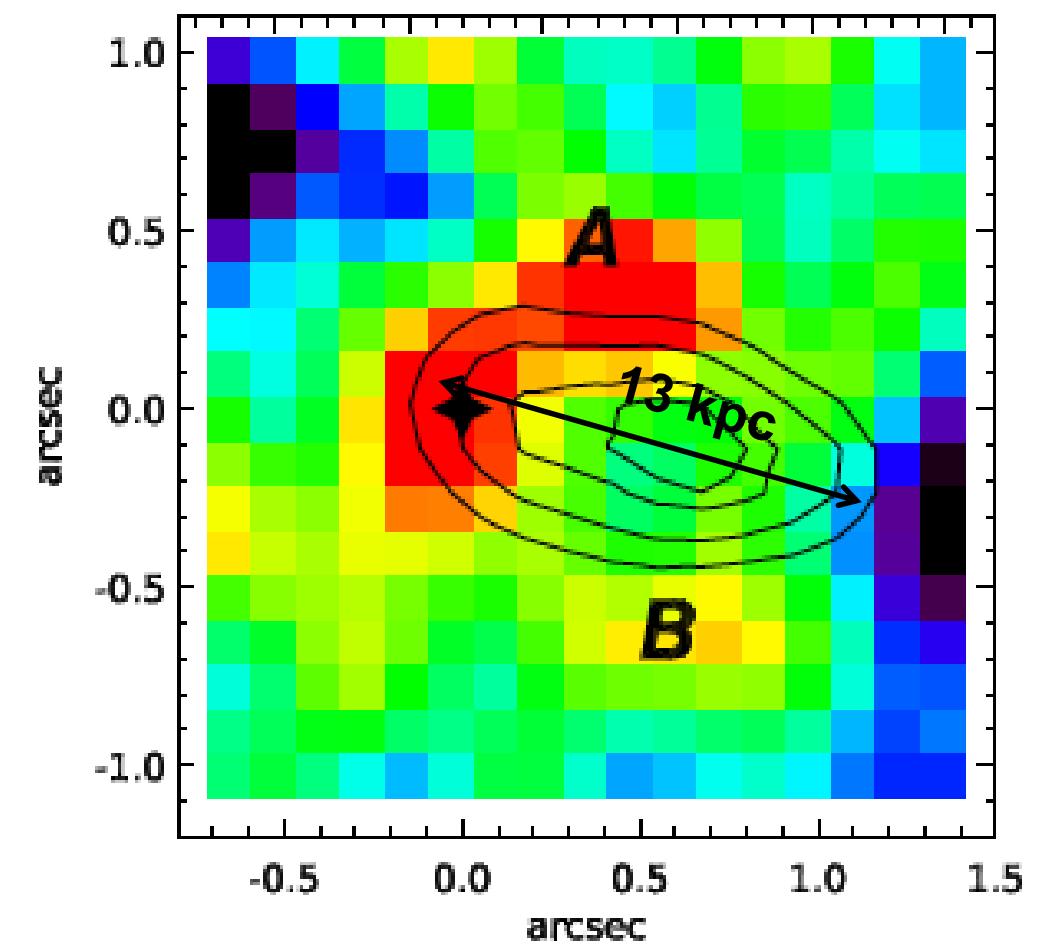
Theory: AGN-induced pressure on gas rich disk or triggered sf in the outflow
 (e.g. Silk+13; Ishibashi & Fabian 13; Zubovas & King 13, 14)

Observations

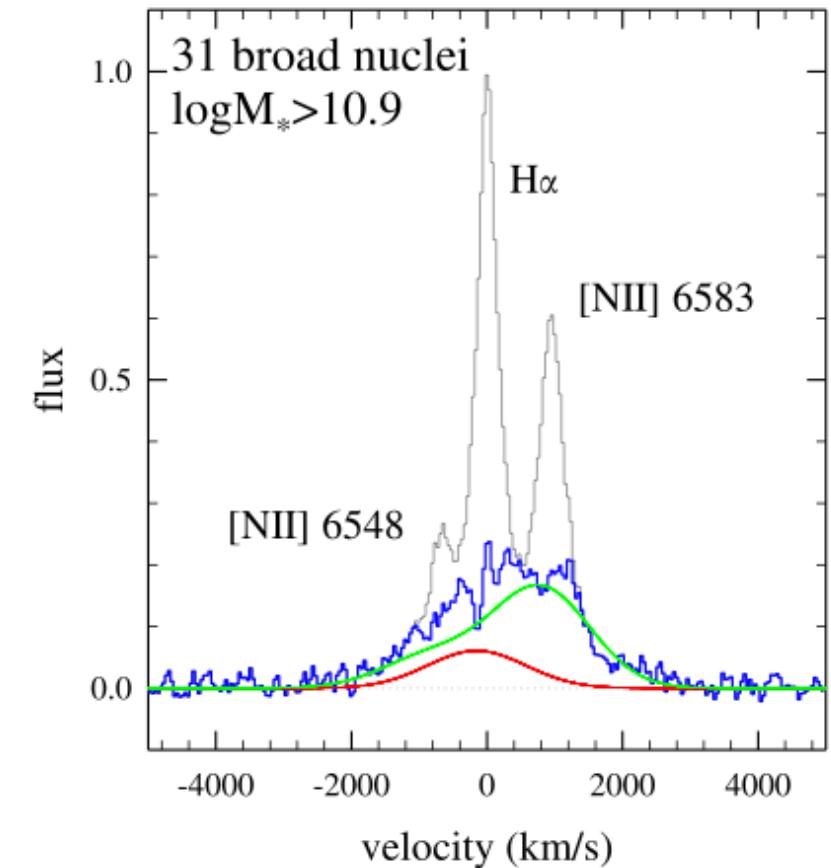
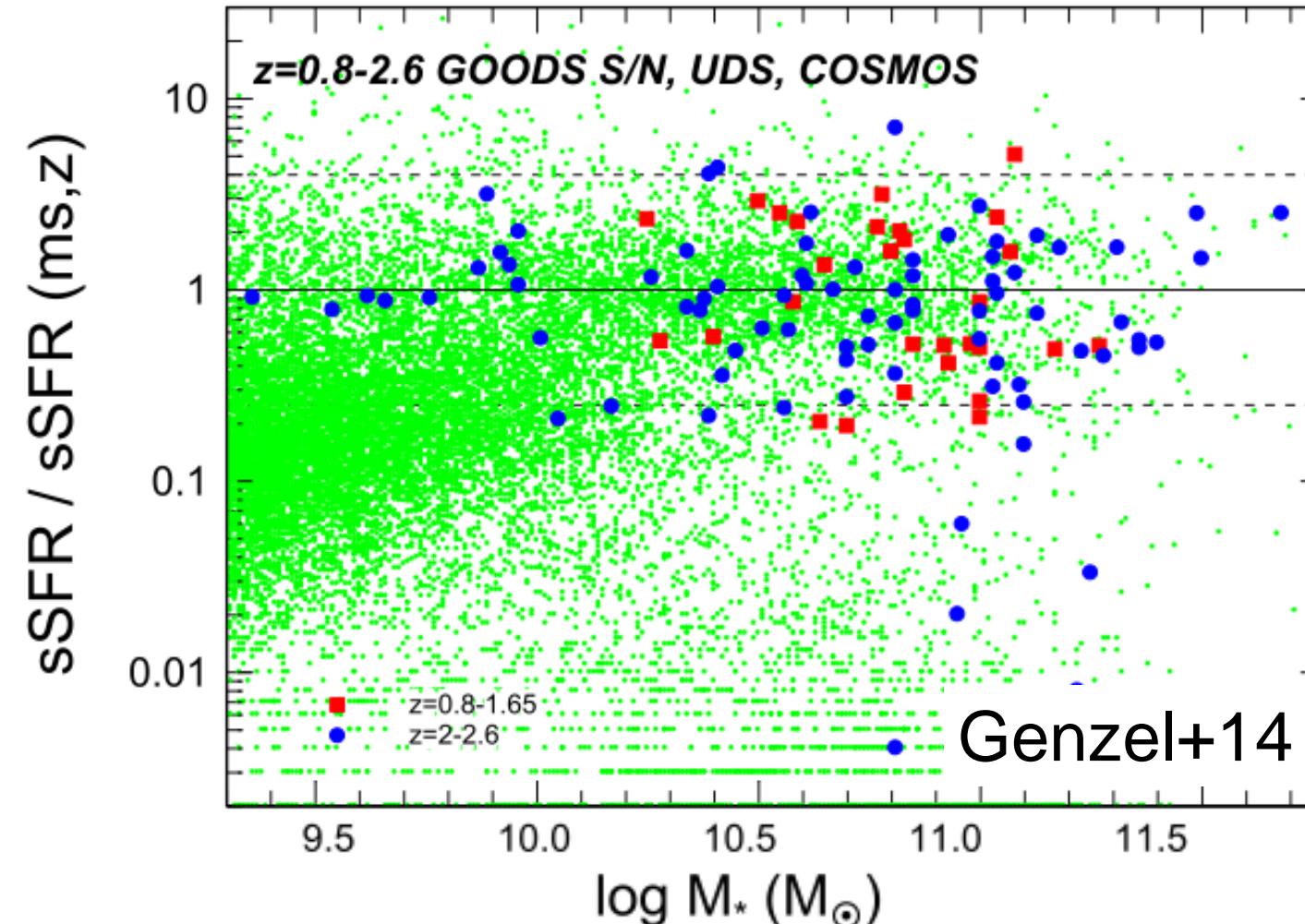
Croft+06



Cresci+14



Where we stand and (near) future



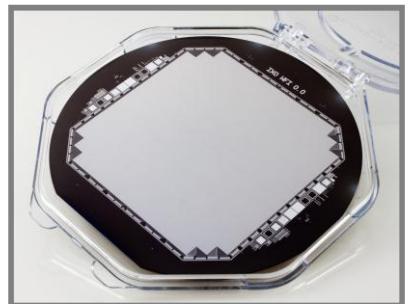
- Tracing feedback at different cosmic epochs
- Characterize the physic of the feedback process

How representative is my sample of the overall AGN population?

BH demography

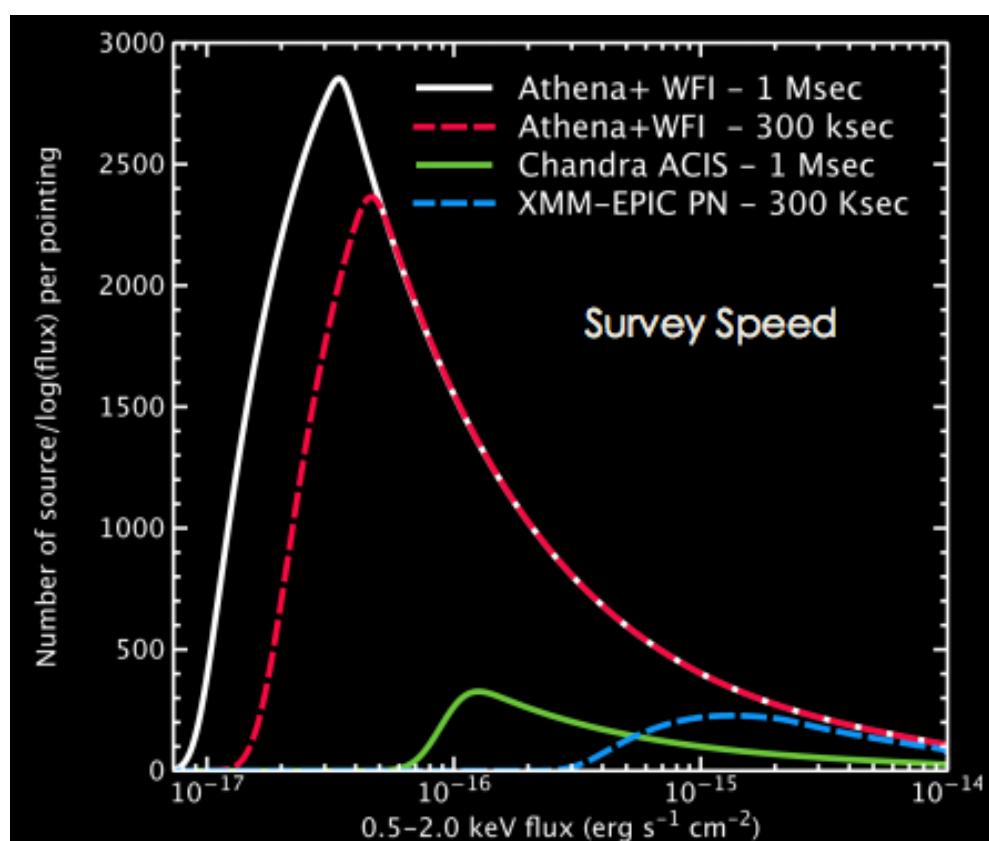
X-ray: Athena+

Wide Field Imager (WFI)

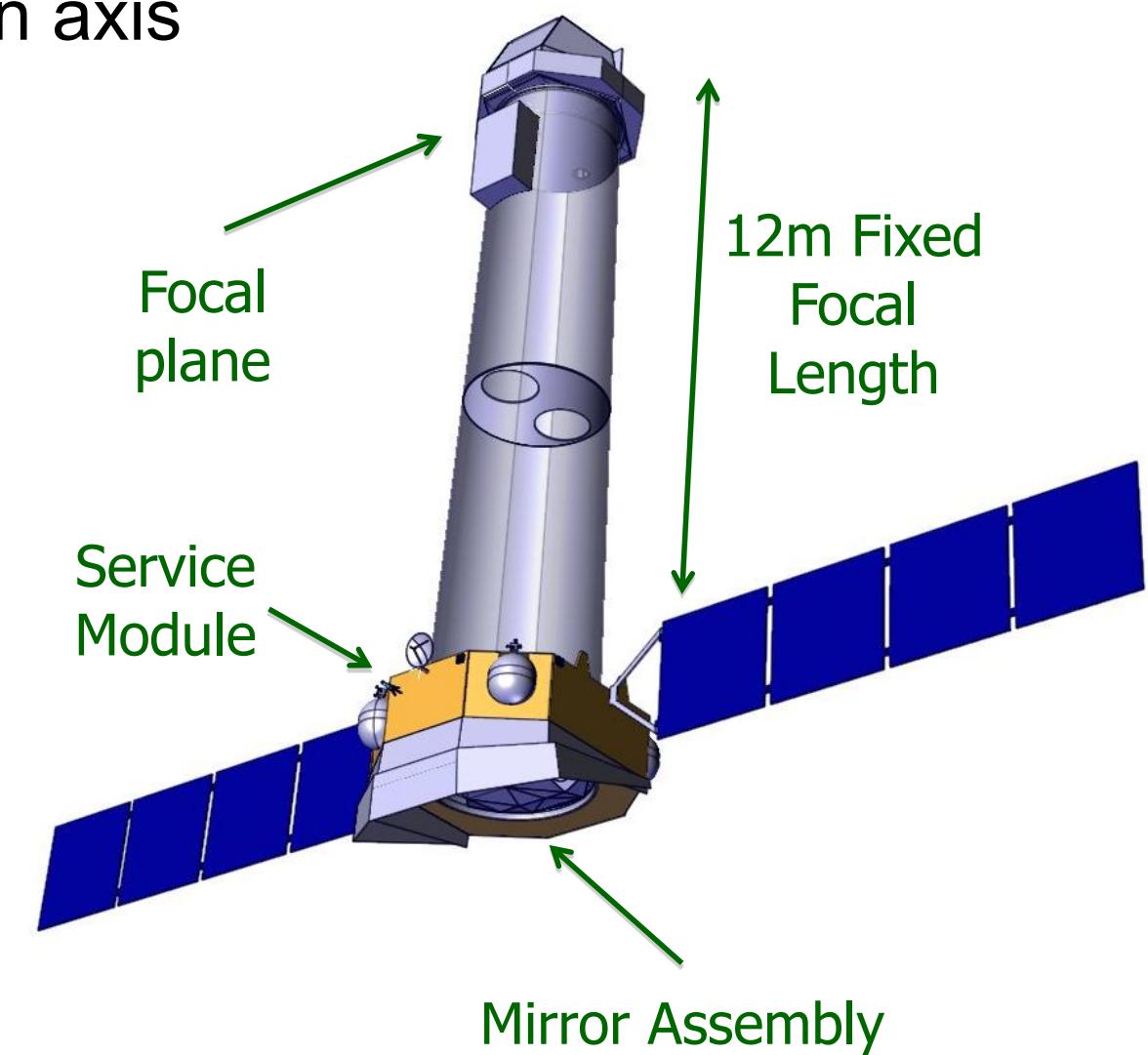


Angular resolution: 5" (goal 3") on axis
 Energy range: 0.3-12 keV
 Field of view: 40' (goal 50')

Barrett+13

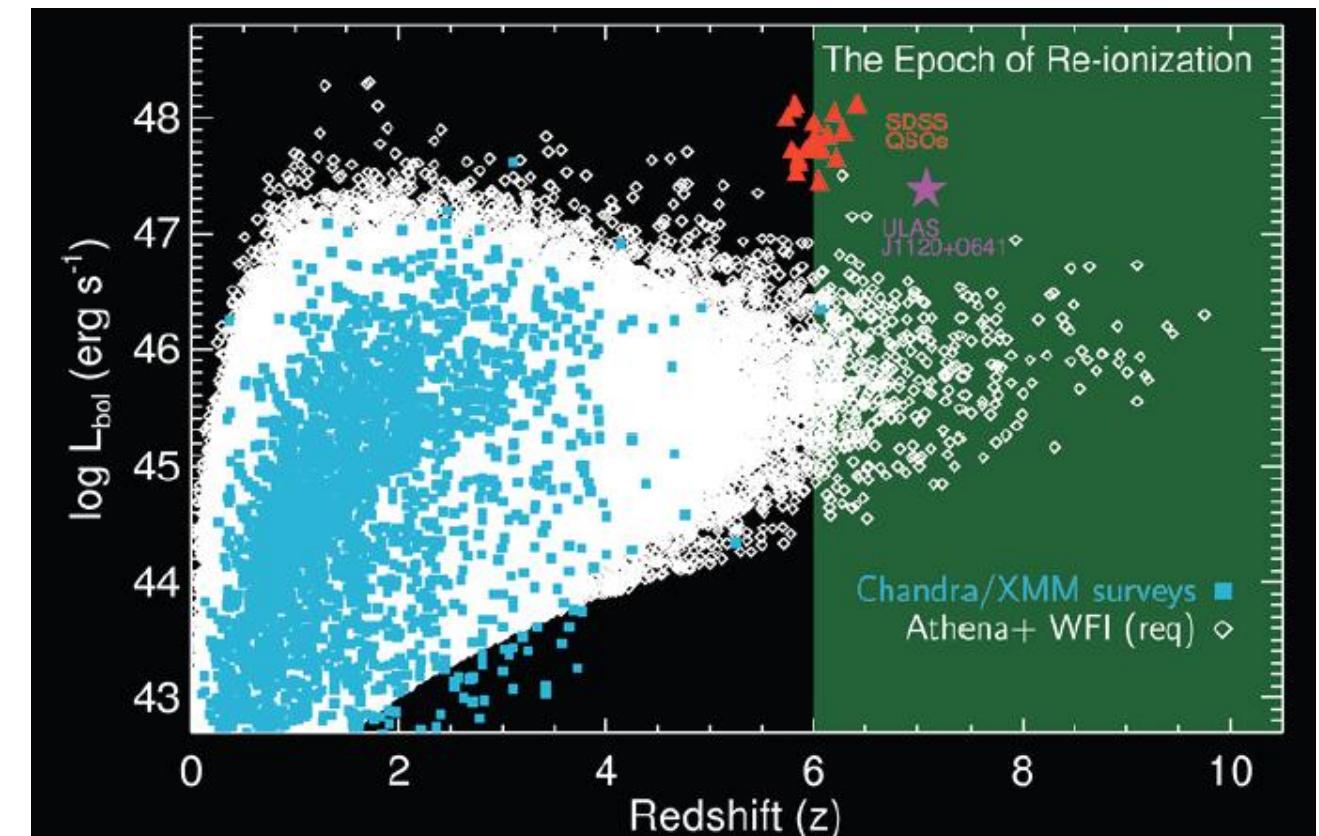
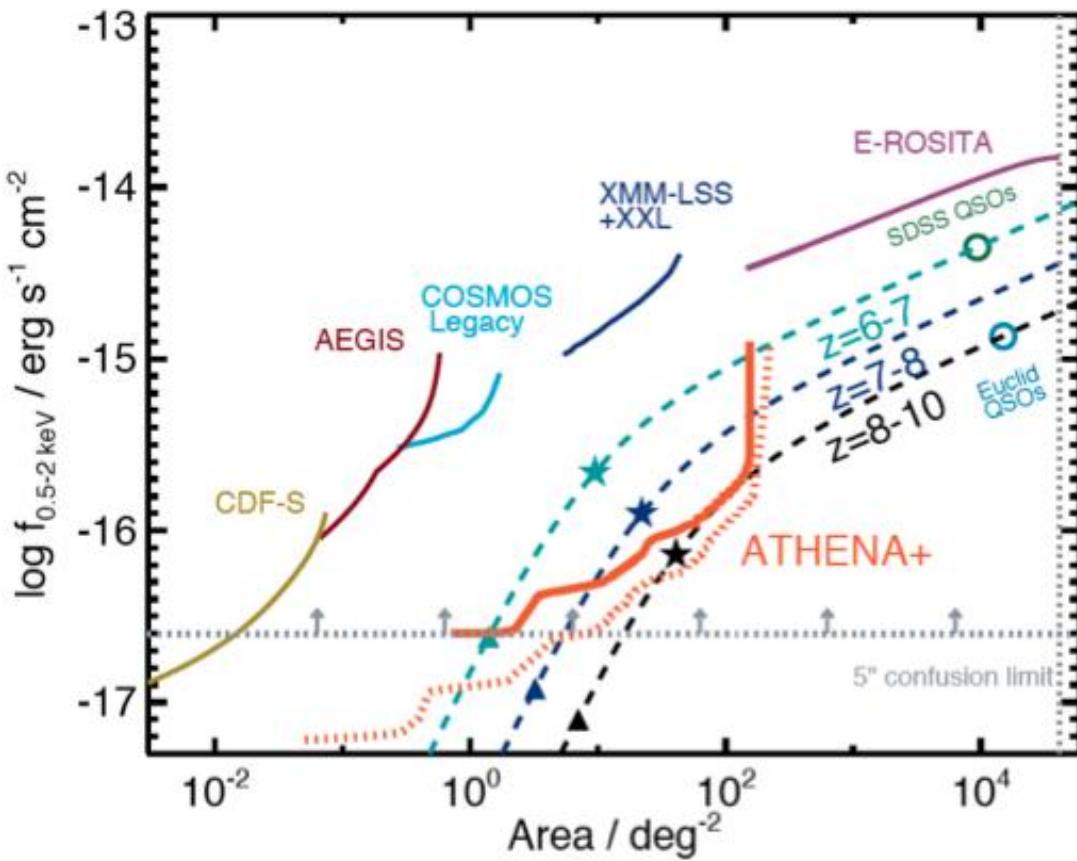


Launch date: 2028



X-ray: Athena+

Aird+13

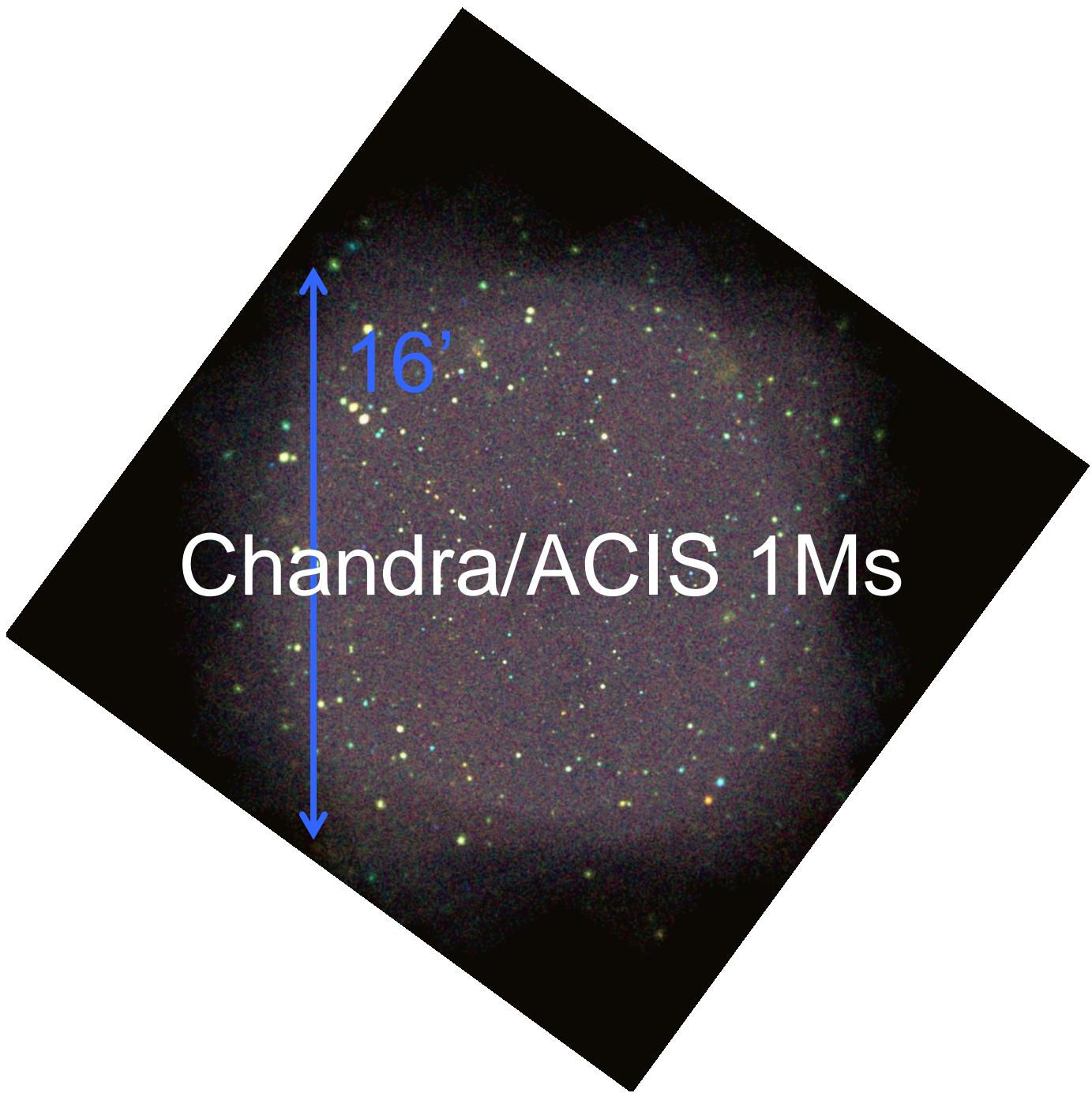
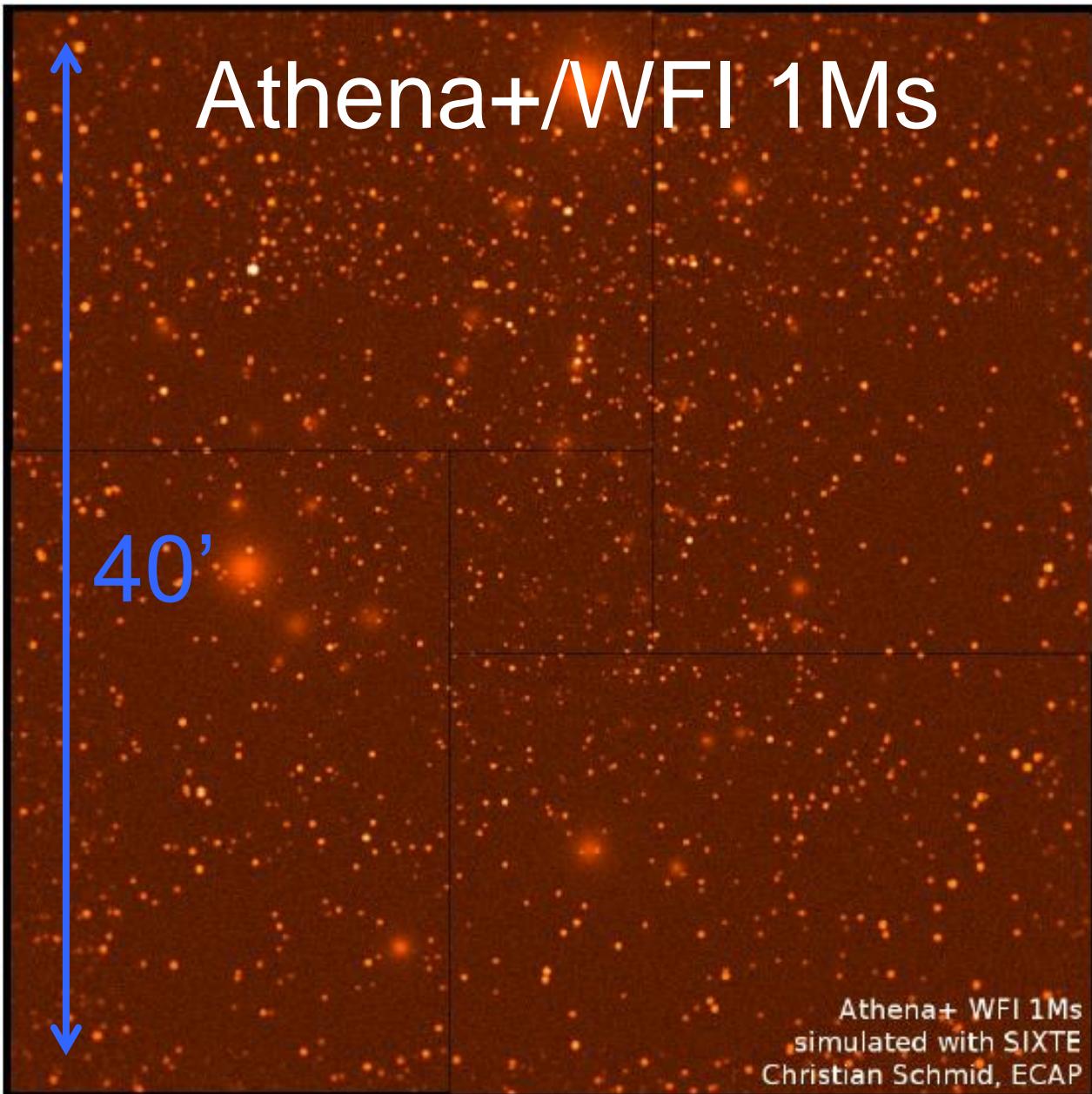


Barret+13

Athena+ will allow us to trace the BH growth at the re-ionization epoch BUT
we will get also for “free” large samples of Seyfert like AGNs at $2 < z < 6$

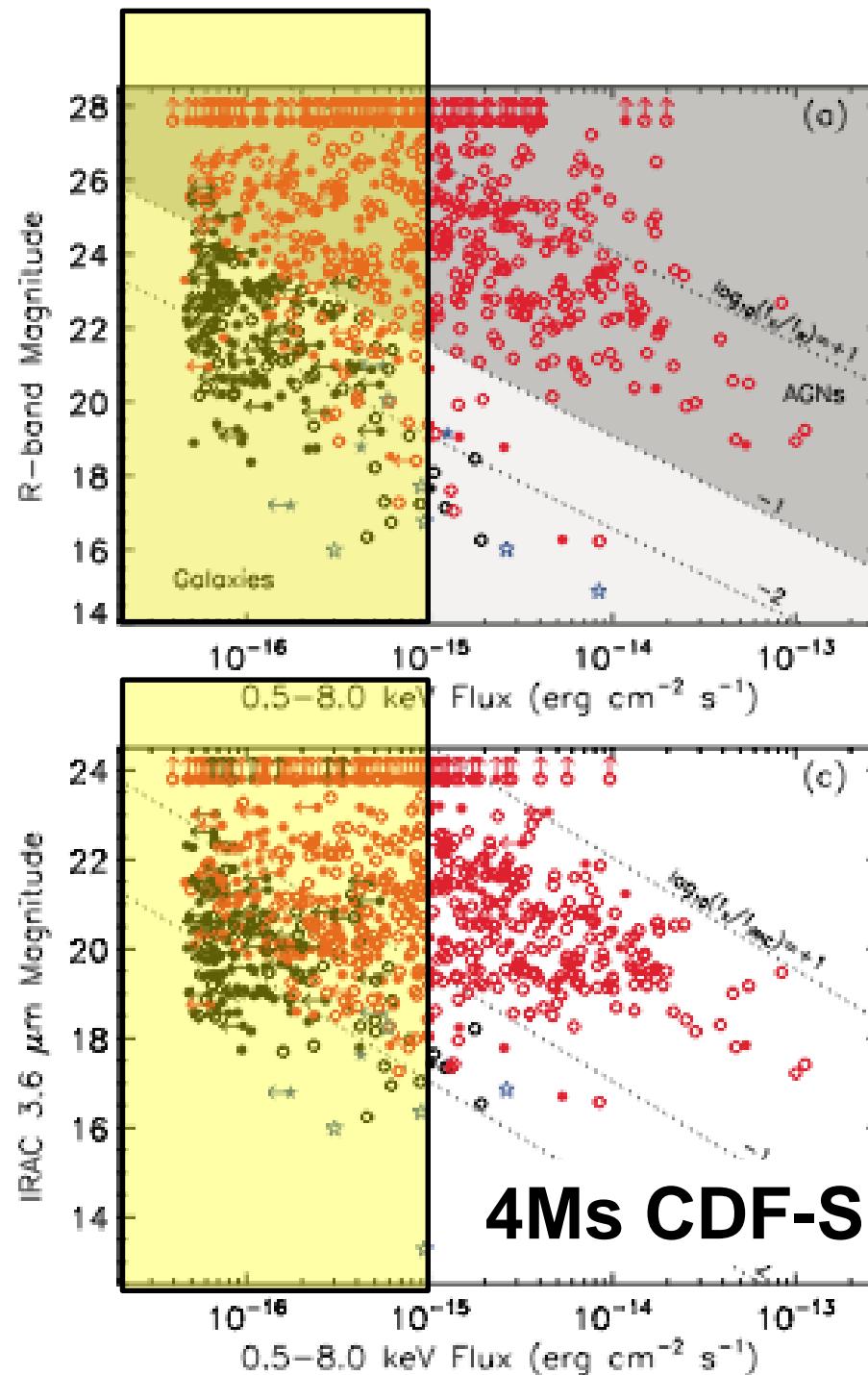
X-ray: Athena+ 1Ms field

CDF-S



X-ray: Athena+ → follow-up

Xue+11



Source density
 $N(S > 10^{-16.5} \text{ cgs}, z > 1) \sim 10,000 \text{ deg}^{-2}$

- NIR: $z > 1$
- FoV $\sim 500 \text{ armin}^2$
- Multiplexing: > 500 (~ 1300 targets)
- $R > 5,000$ (HR for BH masses)

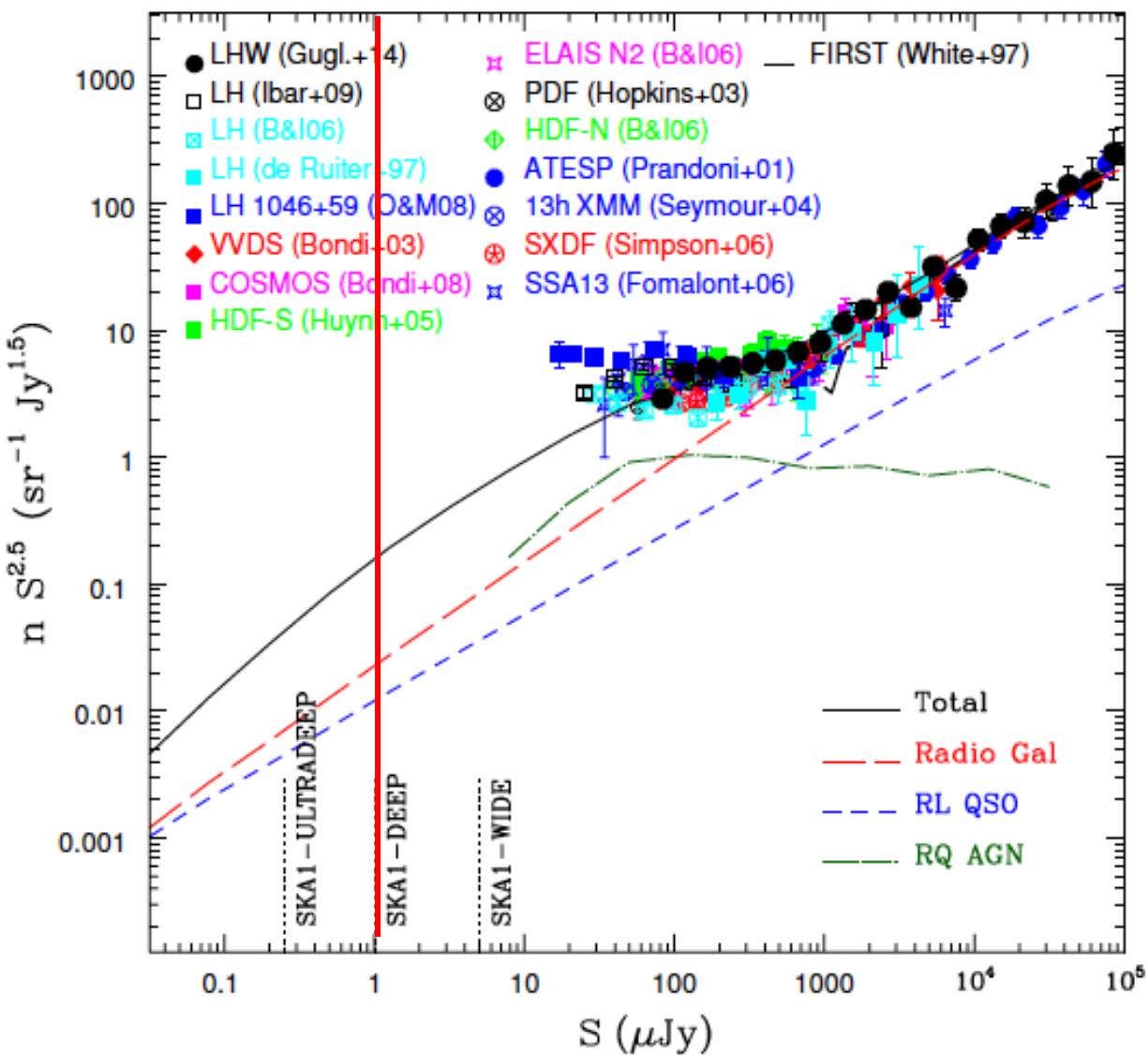
R<26: VLT (e.g. MOONS)
R>26: NIR MOS @ E-ELT

Radio: SKA deep radio surveys

2018 2019 2020 2021 2022

Why radio?

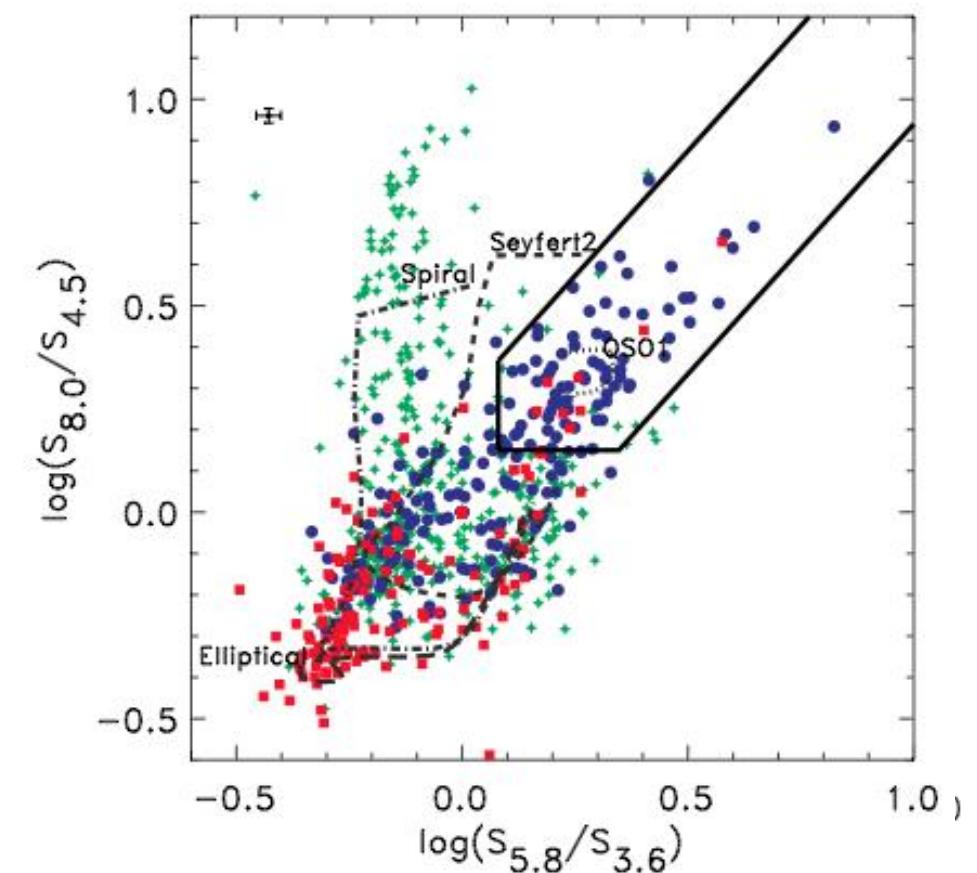
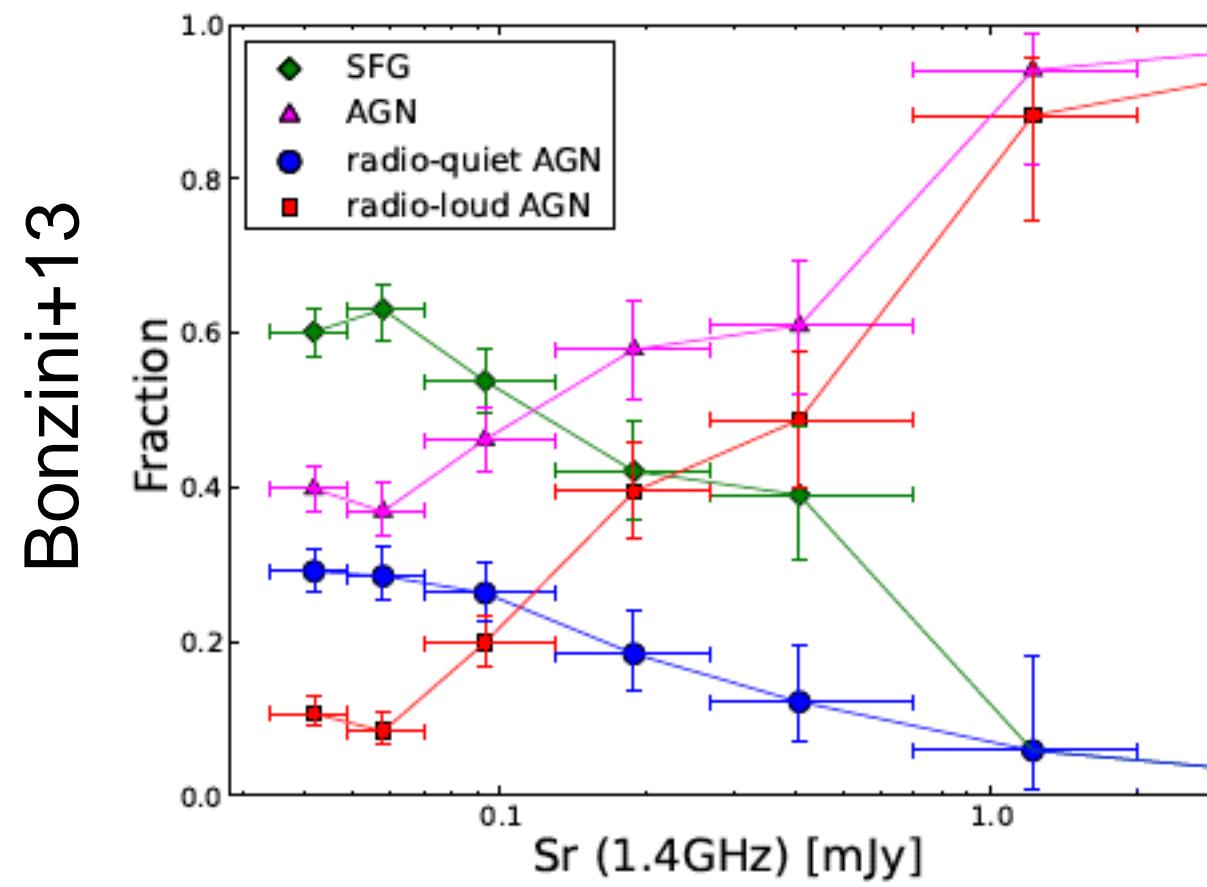
- ✓ Complete census of RL and RQ AGN
- ✓ Unaffected by obscuration
- ✓ Sub-arcsec resolution



Smolcic+15

Separate RQ AGN and SFG

The μ Jy sky will be dominated by SFG, and RQ AGN.

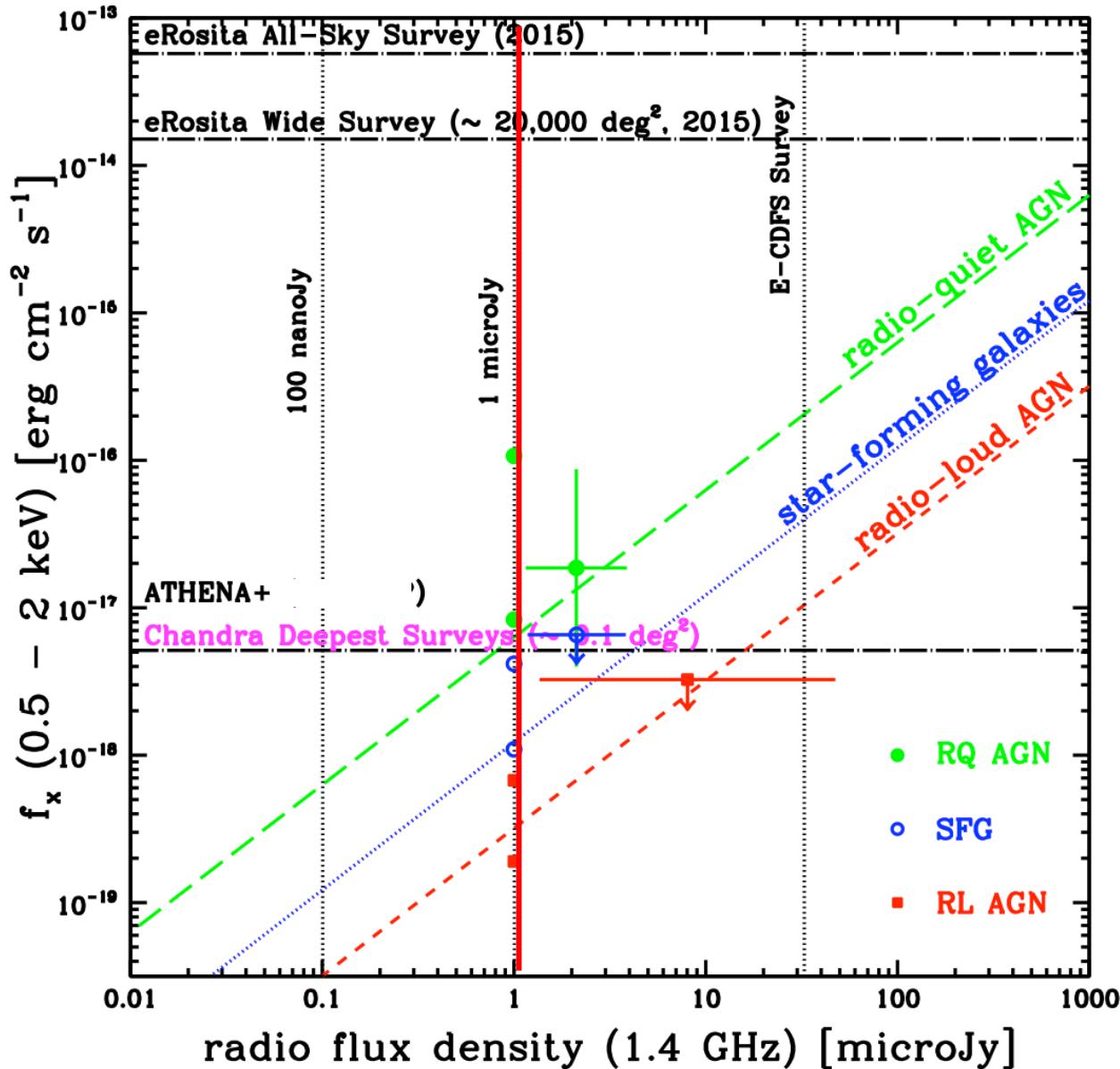


The radio emission in RQ AGN is probably due to SF activity (e.g. Padovani+13; Bonzini+15) → need multi-wl ancillary data (X-ray, optical, IR).

Separate RQ AGN and SFG

2018 2019 2020 2021 2022

X-ray counterparts

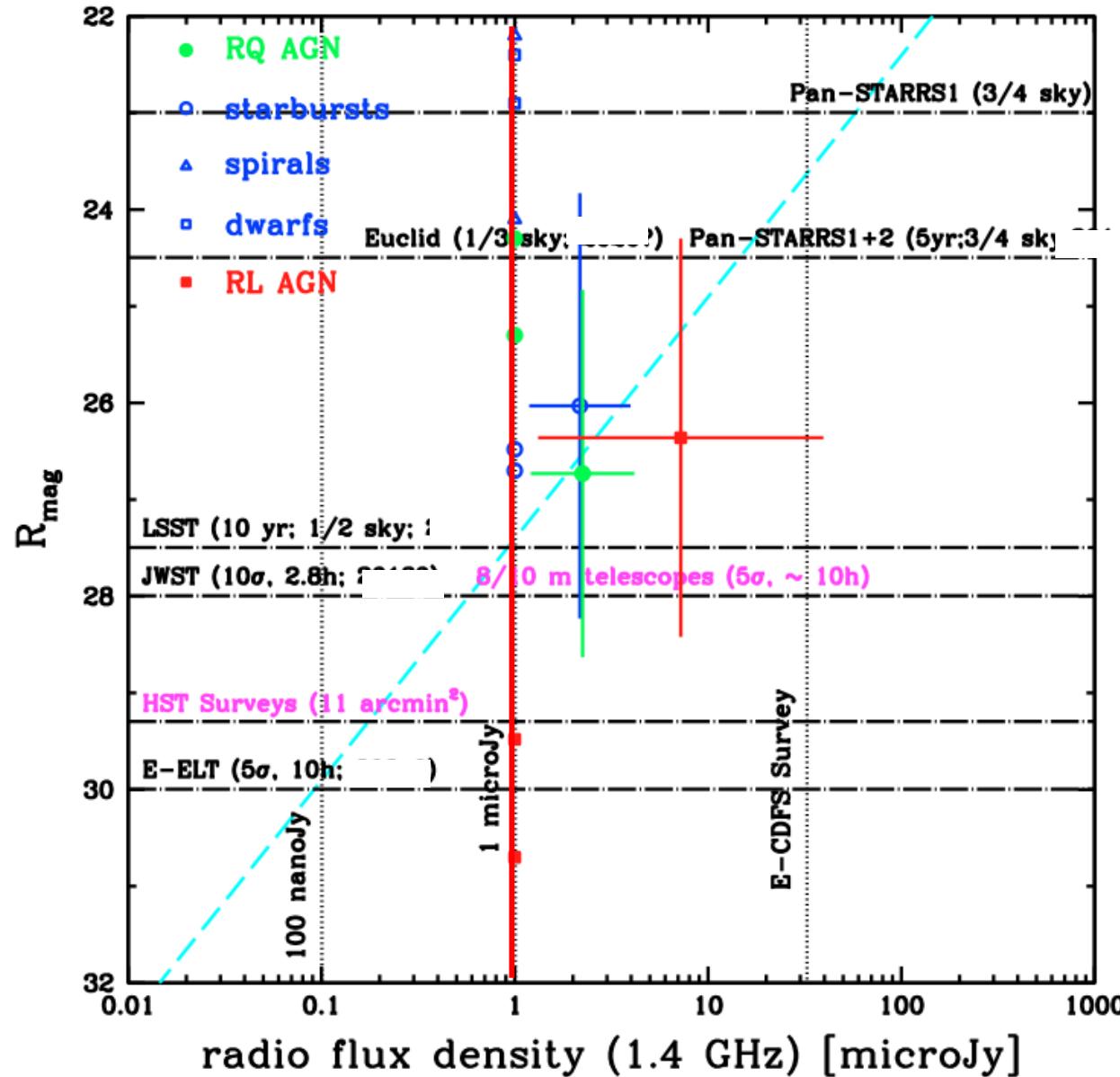


Updated from Padovani+11

Separate RQ AGN and SFG

2018 2019 2020 2021 2022

Optical counterparts

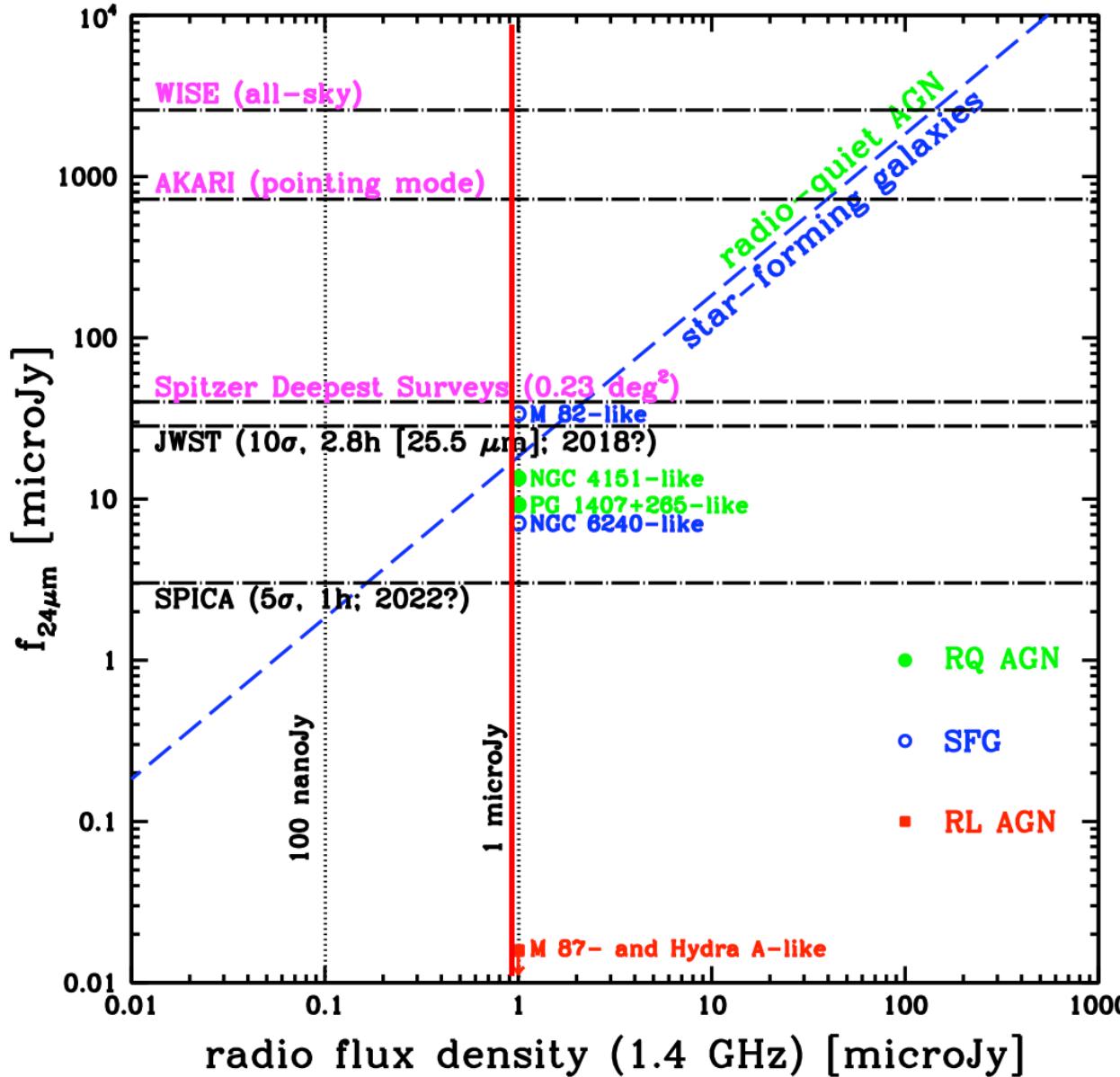


Updated from Padovani+11

Separate RQ AGN and SFG

2018 2019 2020 2021 2022

IR counterparts

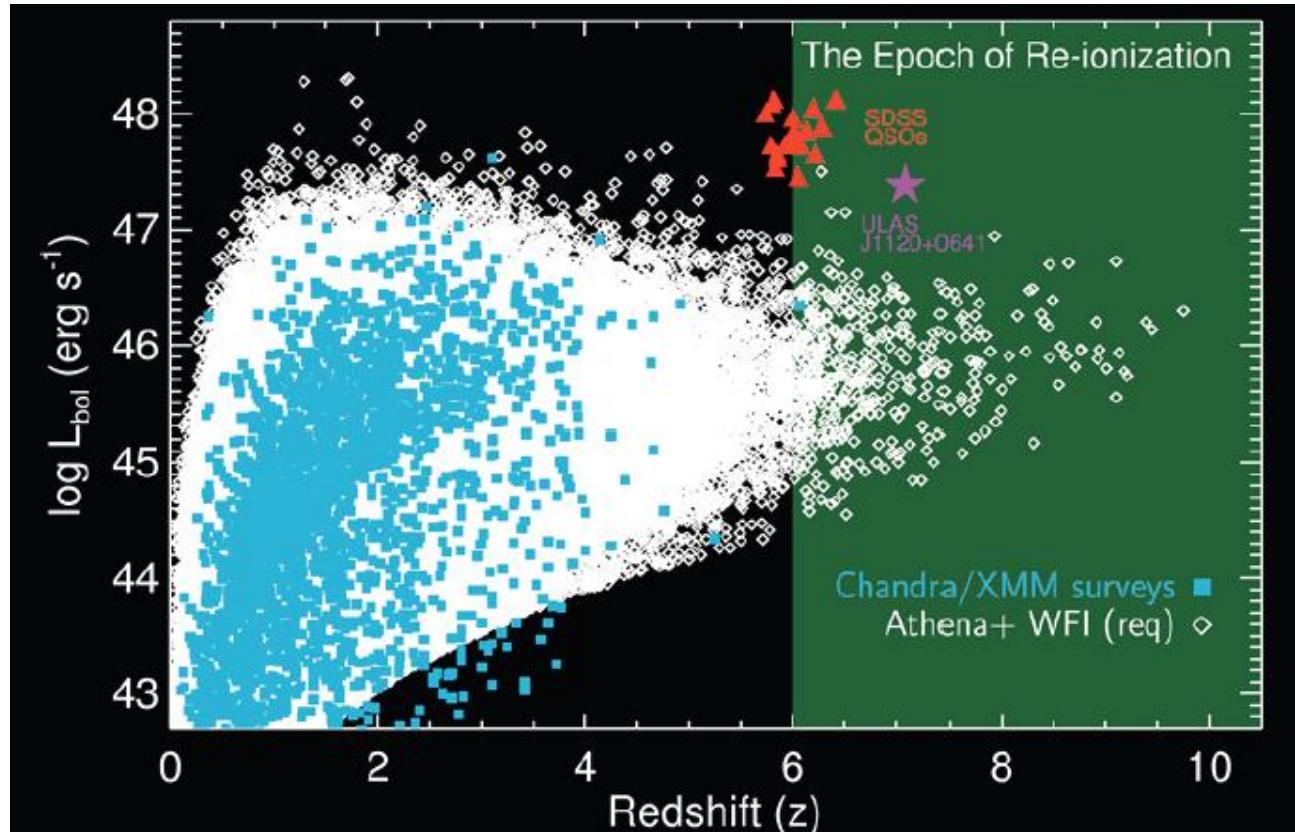


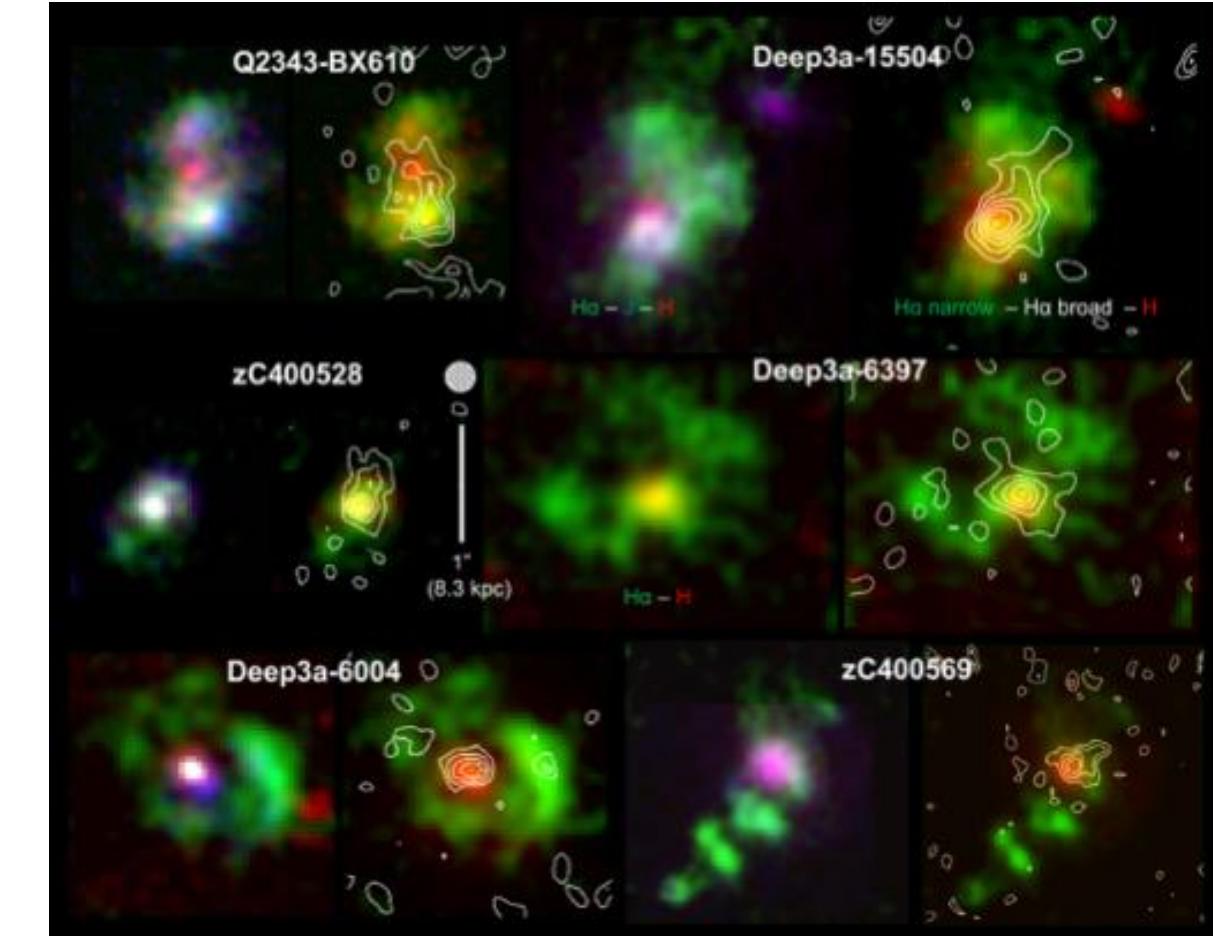
- $S > 1 \mu\text{Jy}$ good match with LSST and JWST and ELTs (but limited region of the sky)
- $S < 1 \mu\text{Jy}$ “radio only” information (HI redshifts, size, morphology, spectral index)

Updated from Padovani+11

Tracing AGN feedback at different epochs

Barret+13



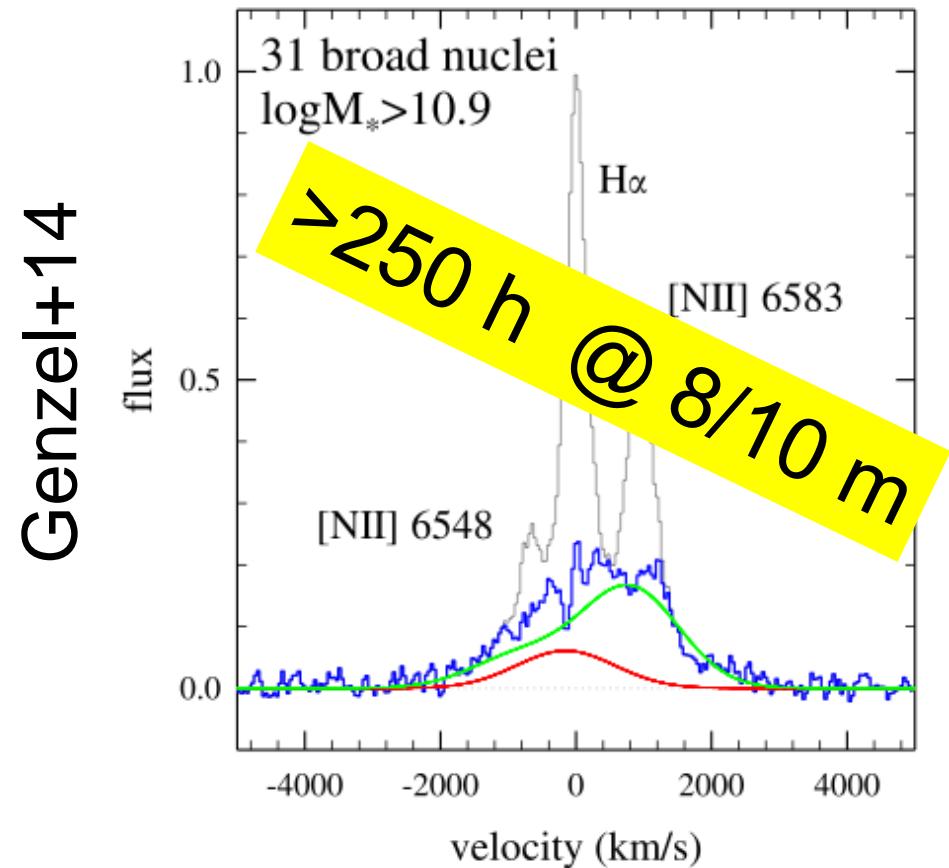


Tracing AGN feedback at different epochs

Tracing the ionized component at $z > 1$:
NIR IFU (e.g. $[\text{OIII}]\lambda 5007$)
mass-outflow rate & kinetic energy

0.2'' resolution
(1'' @ $z \sim 2 = 8.3\text{kpc}$)
AO assisted

Tracing AGN feedback at different epochs



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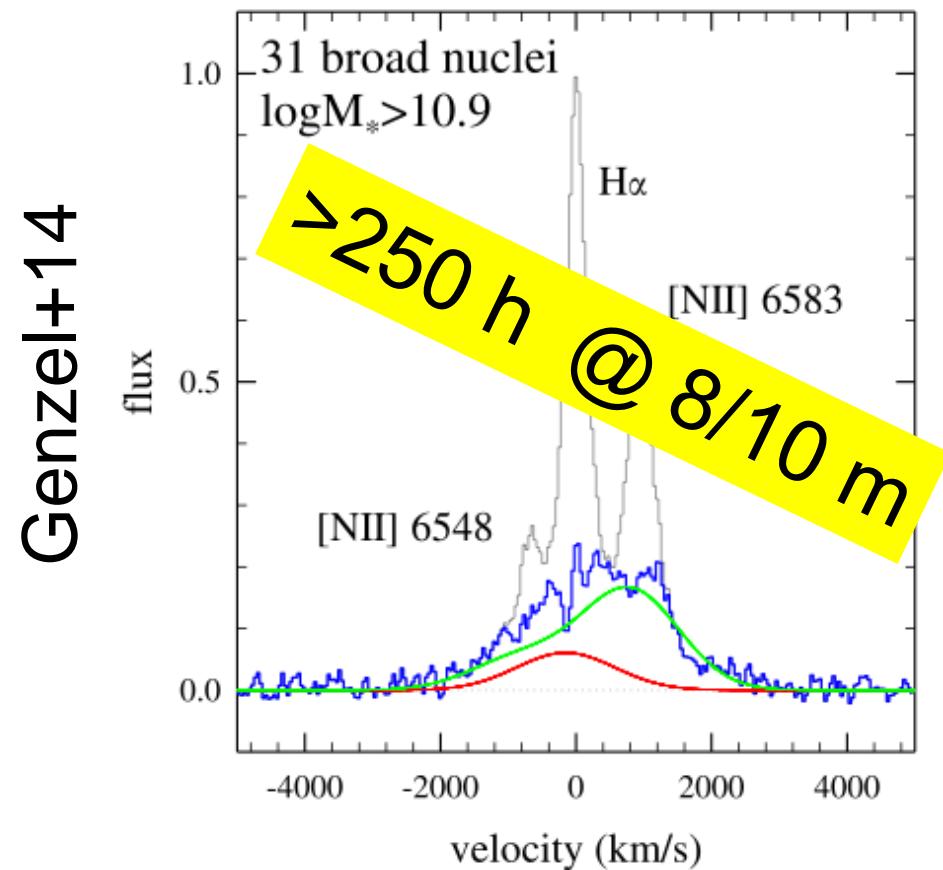
NIR IFU MOS + LTAO @ VLT

Source density and survey speed:

$N(S > 10^{-16} \text{ cgs}, z > 1) \sim 400 \text{ deg}^{-2}$ (20 objects in a KMOS like patrol field)

$N(S > 10^{-16.5} \text{ cgs}, z > 1) \sim 10,000 \text{ deg}^{-2}$ (480 objects in a KMOS like patrol field)

Tracing AGN feedback at different epochs



Tracing the ionized component at $z > 2$:
NIR IFU (e.g. $[OIII]\lambda 5007$)
 mass-outflow rate & kinetic energy

0.1" resolution
 (1" @ $z \sim 2 = 8.3 \text{ kpc}$)
AO assisted

NIR IFU + LTAO @ E-ELT

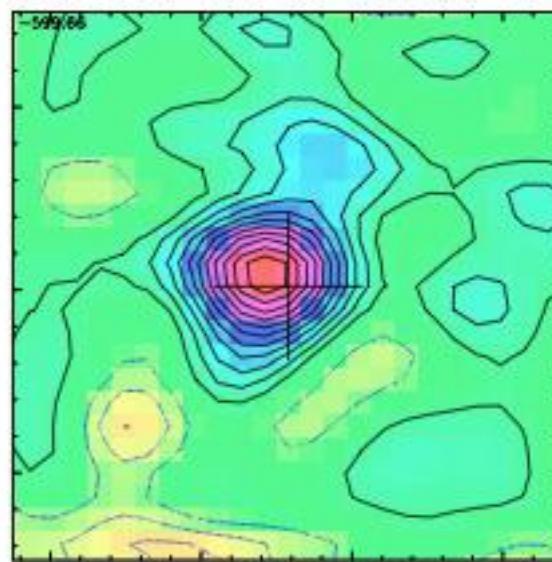
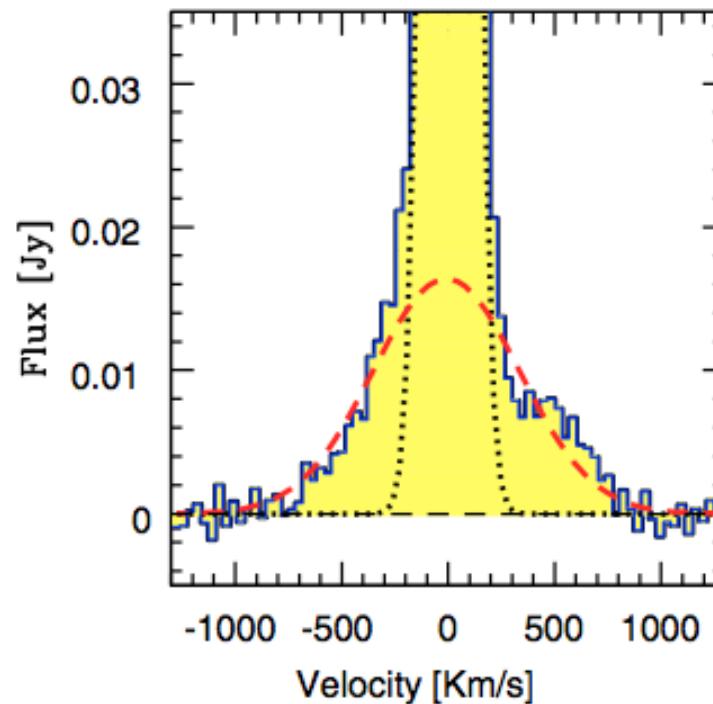
HARMONI spaxel: 20 x 20 mas
 fov: 3.0"x4.3"
 λ : 0.47-2.5 μm

MOS

Tracing AGN feedback at different epochs

Feruglio+10

CO(1-0)- PdBI

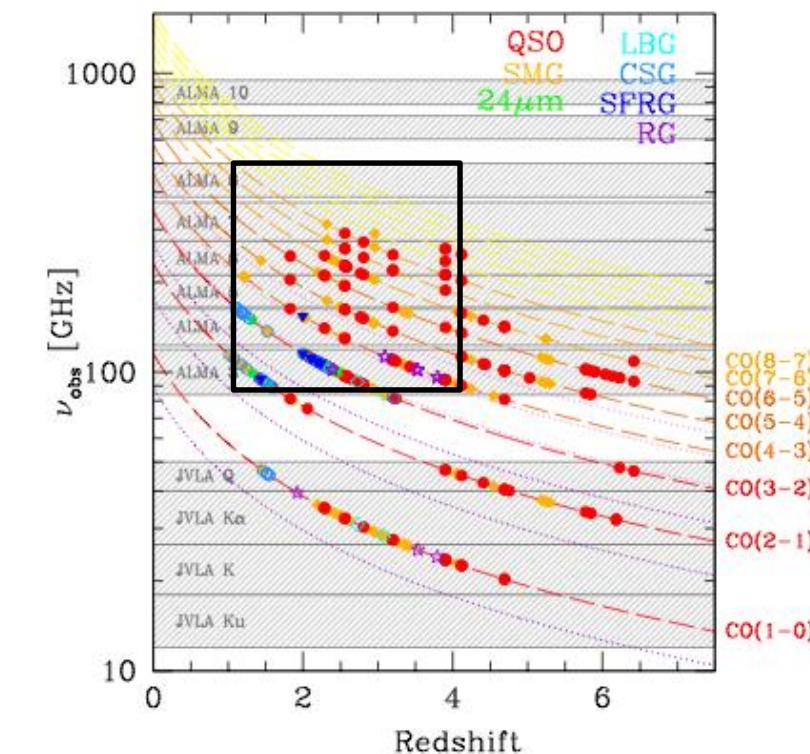


0.2" resolution
(1" @ $z \sim 2 = 8.3$ kpc)

Tracing the molecular component at

$z > 1$:

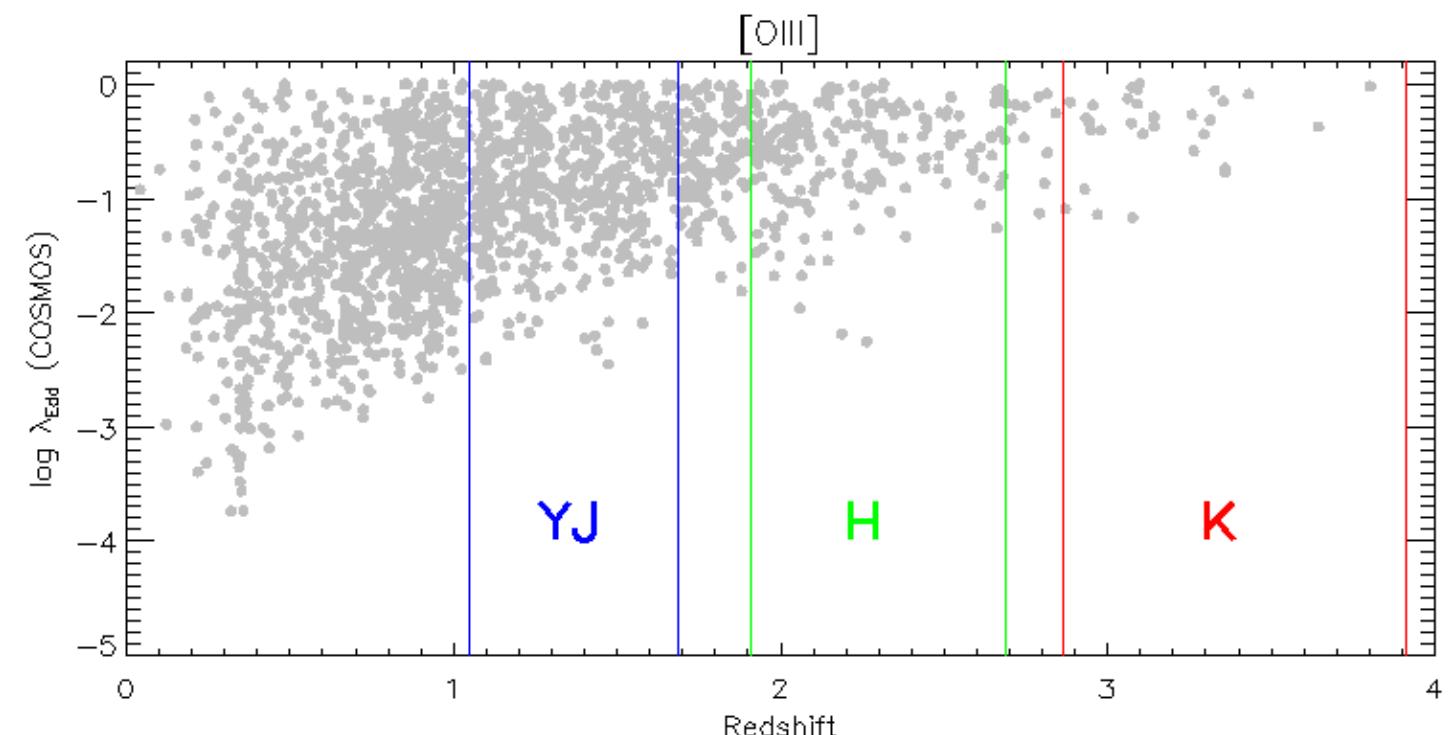
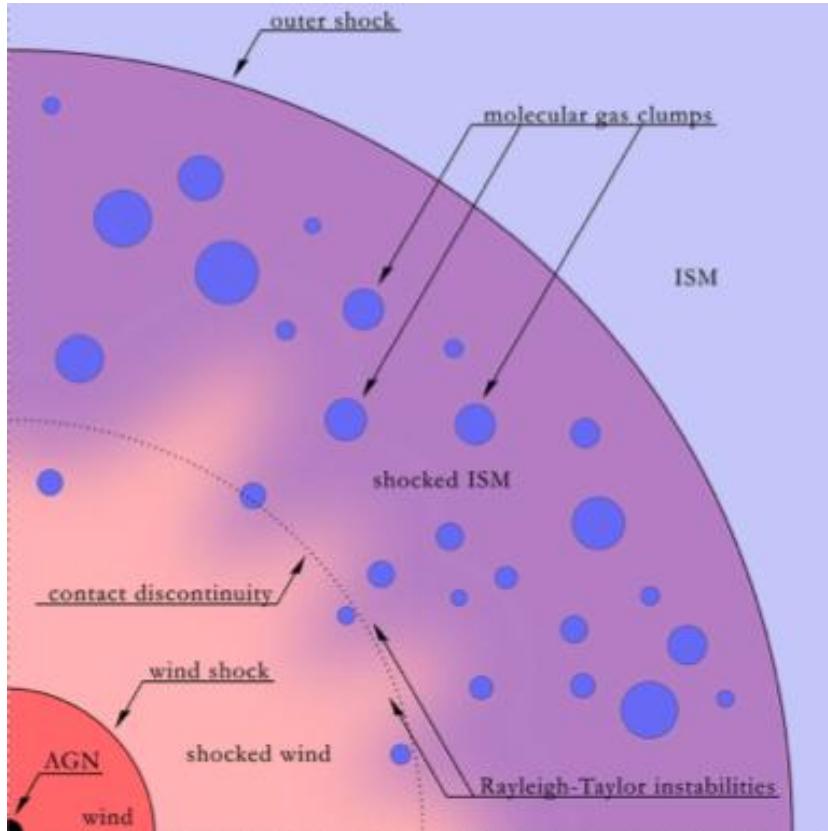
ALMA
CO J 2-1, 3-2, ...



Carilli & Walter 13

Physics of the AGN feedback

Zubovas & King 14



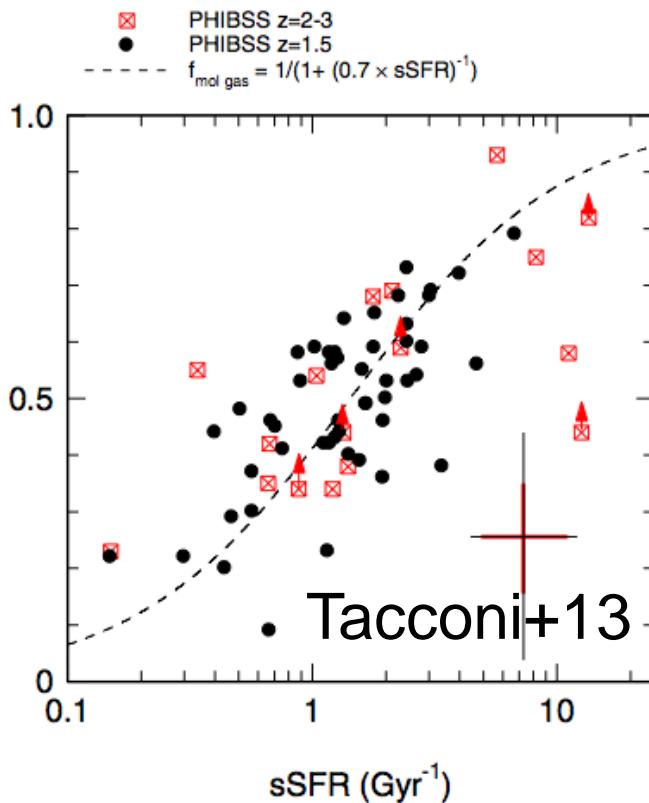
$\lambda_{\text{Edd}} \alpha M_{\text{BH}} / L_{\text{bol}}$: mid-high resolution NIR spectroscopy & UV-NIR photometry

Trace the multi-phase gas outflows as $f(\lambda_{\text{Edd}})$. **NIR IFU MOS + LTAO @ VLT**

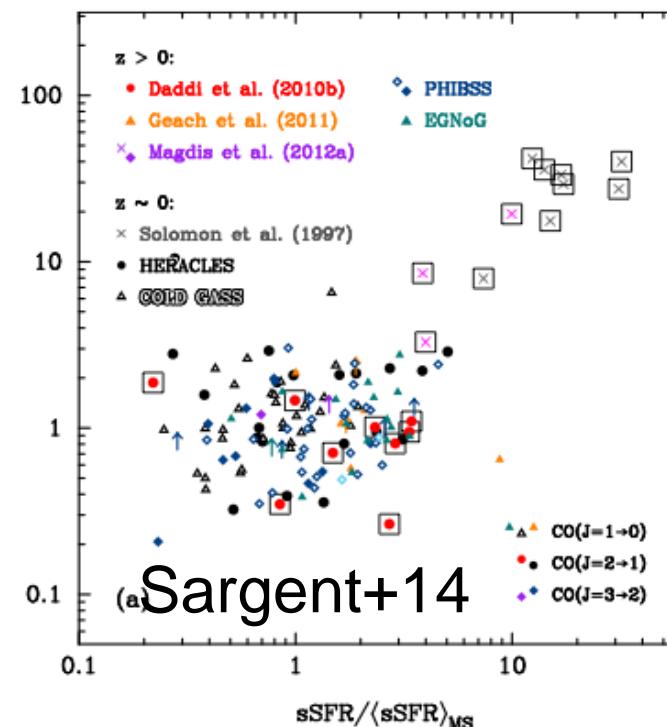
ALMA (CO, HCN)

AGN feedback impact on the host: statistical studies

M_{gas}/M_{tot}



SFE/M_{gas}



Does the AGN triggered outflows affect the cold gas reservoir and modify the SFE of its host?

“Normal” galaxies at $z > 1$: PdBI and now ALMA

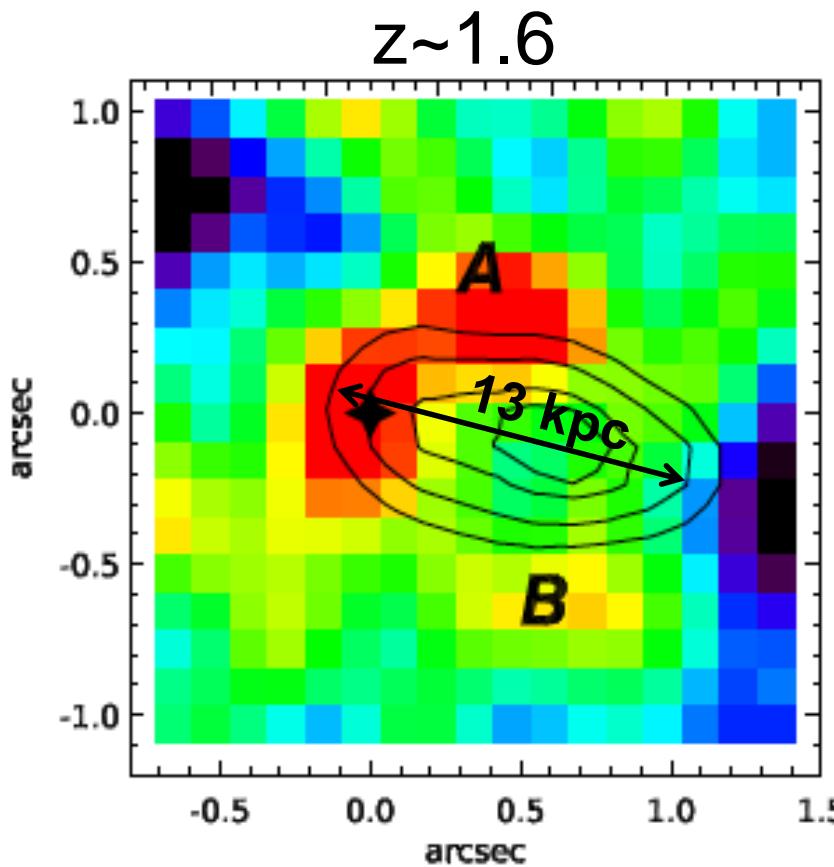
SFE, f_{gas} for statistical samples of AGN hosts (sampling the MS) in comparison to “normal” galaxies (e.g sSFR, z , M_{\star})

ALMA (CO and continuum)

(e.g. Scoville+14 ; Genzel+14)

AGN feedback impact on the host: detailed studies

Cresci+14



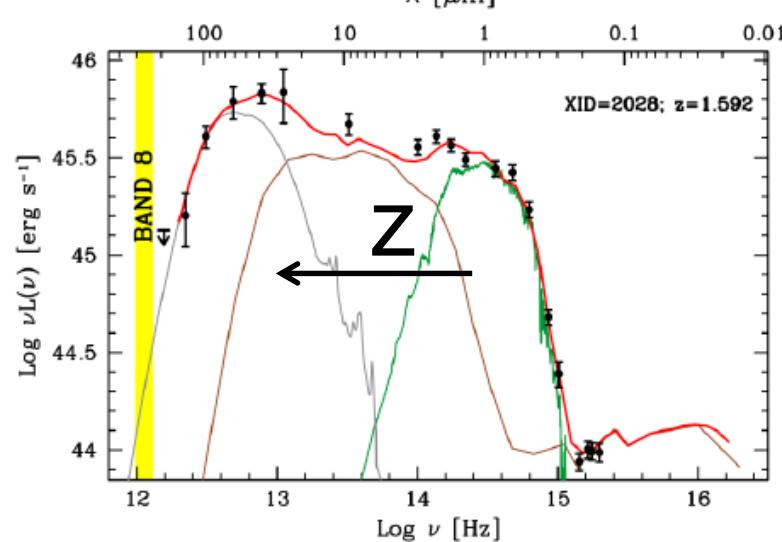
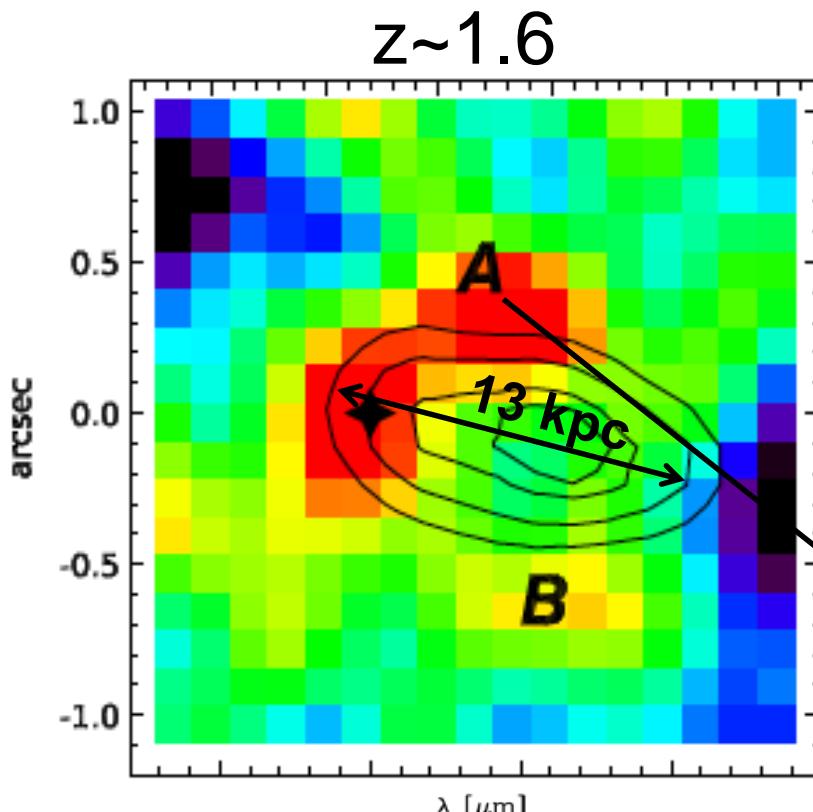
Which impact has AGN-driven outflows
on on-going star formation in the host?

Once we have detected the presence of an outflow we need to trace the star-formation in the host at (sub)-kpc scales:

NIR IFU + AO
(e.g narrow H_{α} but reddening)
6h SINFONI (J-band, 0.7") \rightarrow 20h-30h for
 H_{β}

AGN feedback impact on the host: detailed studies

Cresci+14



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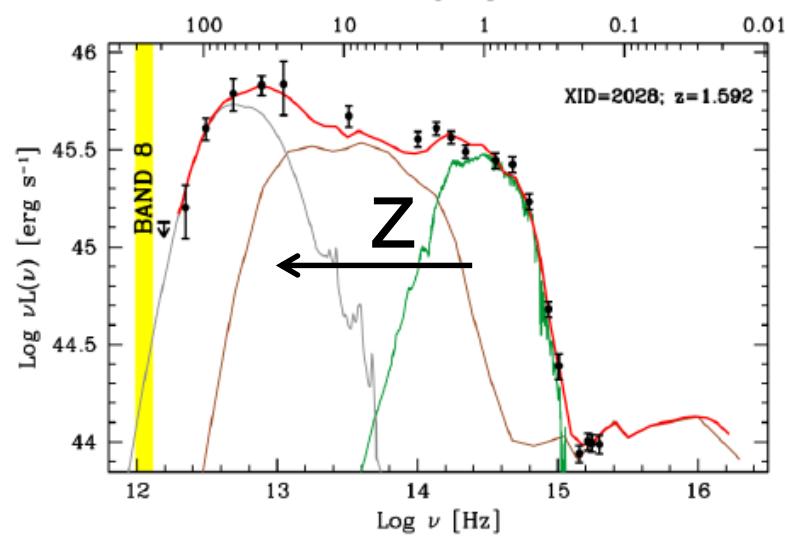
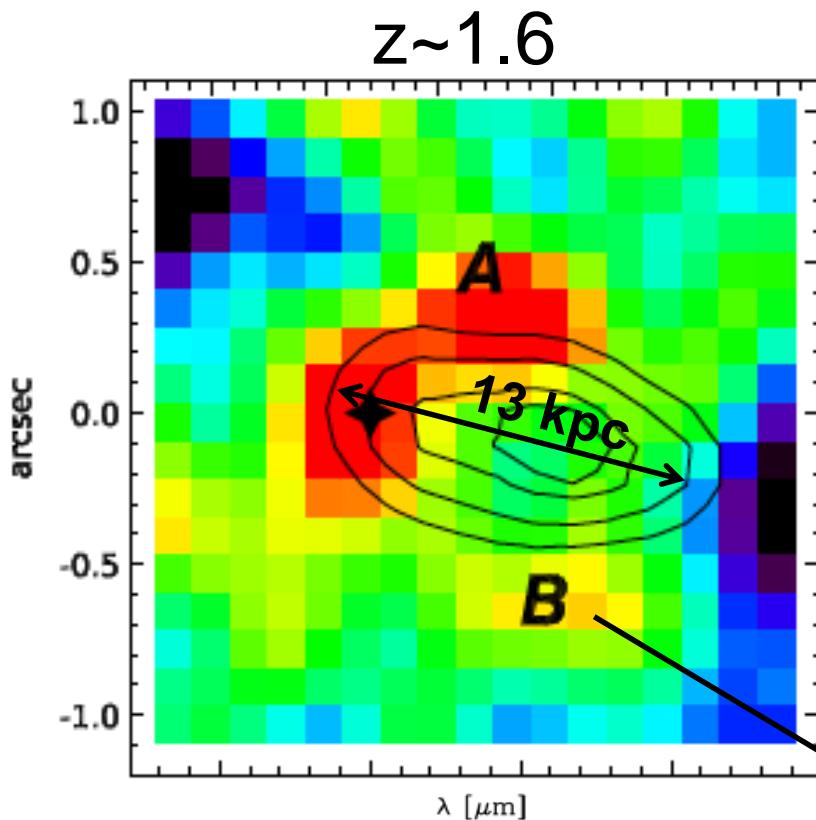
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H_β

ALMA
1h, S/N~5

AGN feedback impact on the host: detailed studies

Cresci+14



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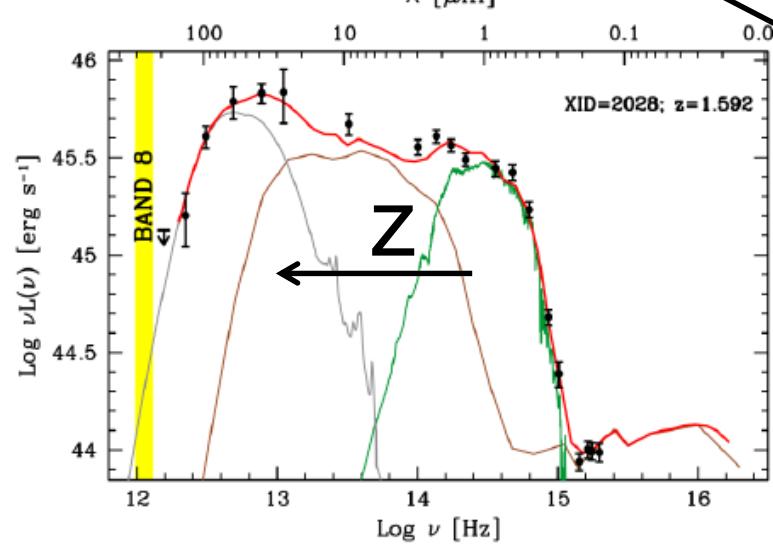
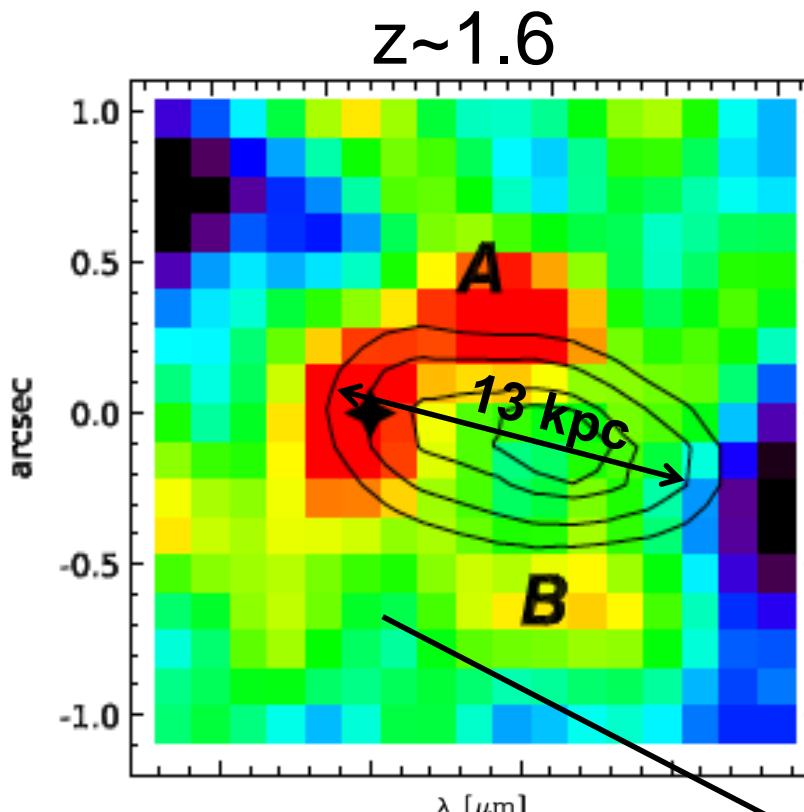
6h SINFONI (J-band, 0.7'') \rightarrow 20h-30h for

H_β

ALMA
3h, S/N~5

AGN feedback impact on the host: detailed studies

Cresci+14



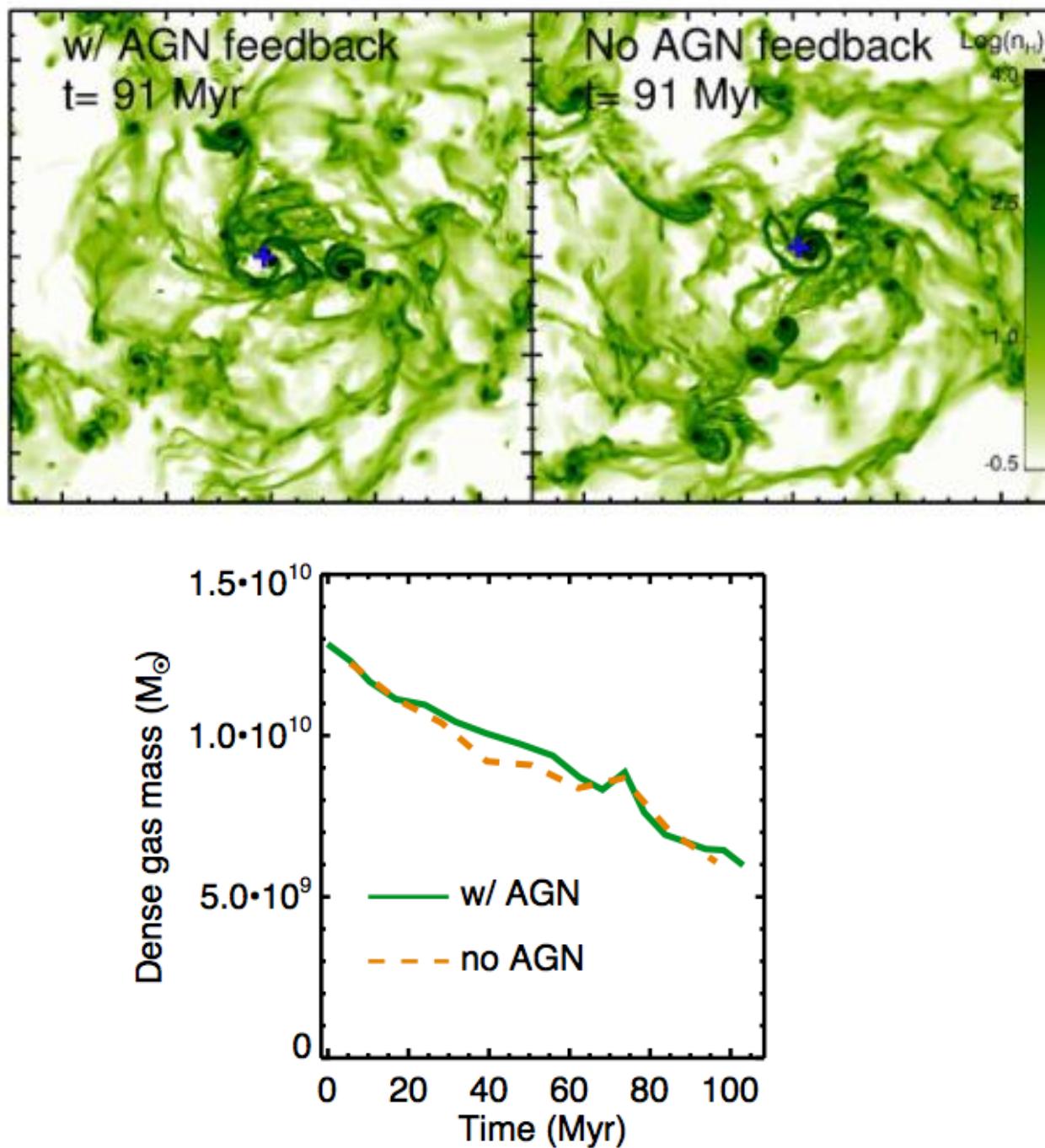
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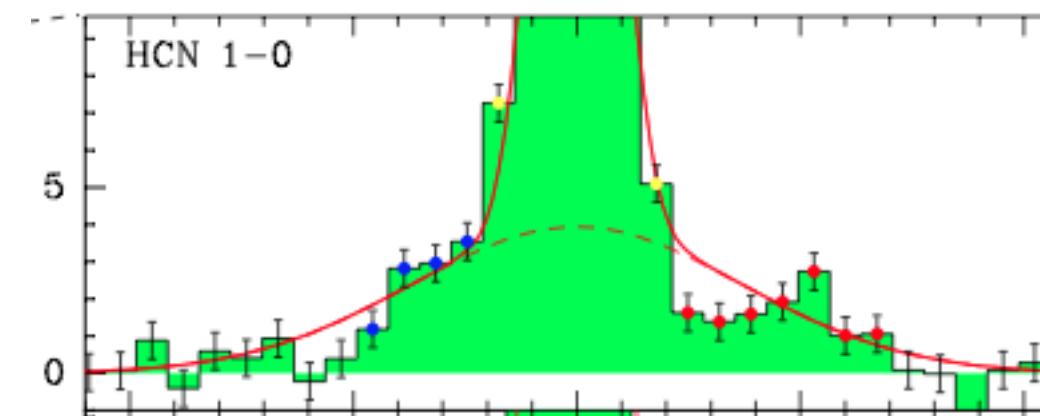
NIR IFU + AO
(e.g narrow H_{α} but reddening)
6h SINFONI (J-band, 0.7'') → 20h-30h for H_{β}
ALMA
10h, S/N~5

AGN feedback impact on the host: detailed studies

Gabor & Bournaud 14



Which impact has the AGN-driven outflow on dense molecular gas clouds?



Aalto+12

ALMA
(e.g. HCN J=3->2 in band3 @ z~2)

Is the AGN outflow mostly made of hot gas of low density?

Challenges and wish list

- Select representative AGN samples

Athena+
SKA
LSST



NIR MOS @ VLT
NIR MOS @ E-ELT

large LPs

- Trace AGN feedback at $z > 1$

MOS NIR IFU + LTAO @ VLT
(MOS) NIR IFU + LTAO @ E-
ELT



ALMA (CO, HCN)

- AGN feedback impact on the host galaxy and feedback physics

MOS NIR IFU + LTAO @ VLT
(MOS) NIR IFU + LTAO @ E-
ELT



ALMA
(continuum, CO, HCN)