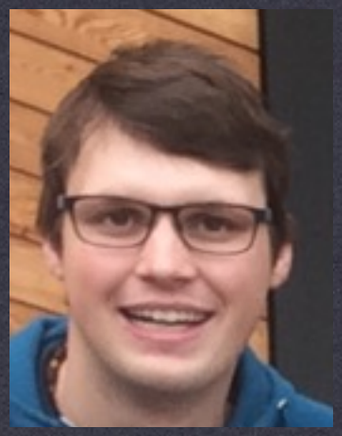
AGN do not destroy star-forming molecular gas

Rosario et al. 2018, MNRAS, 473, 5658

What is the clearest observational evidence that AGN suppress the stellar growth of galaxies?

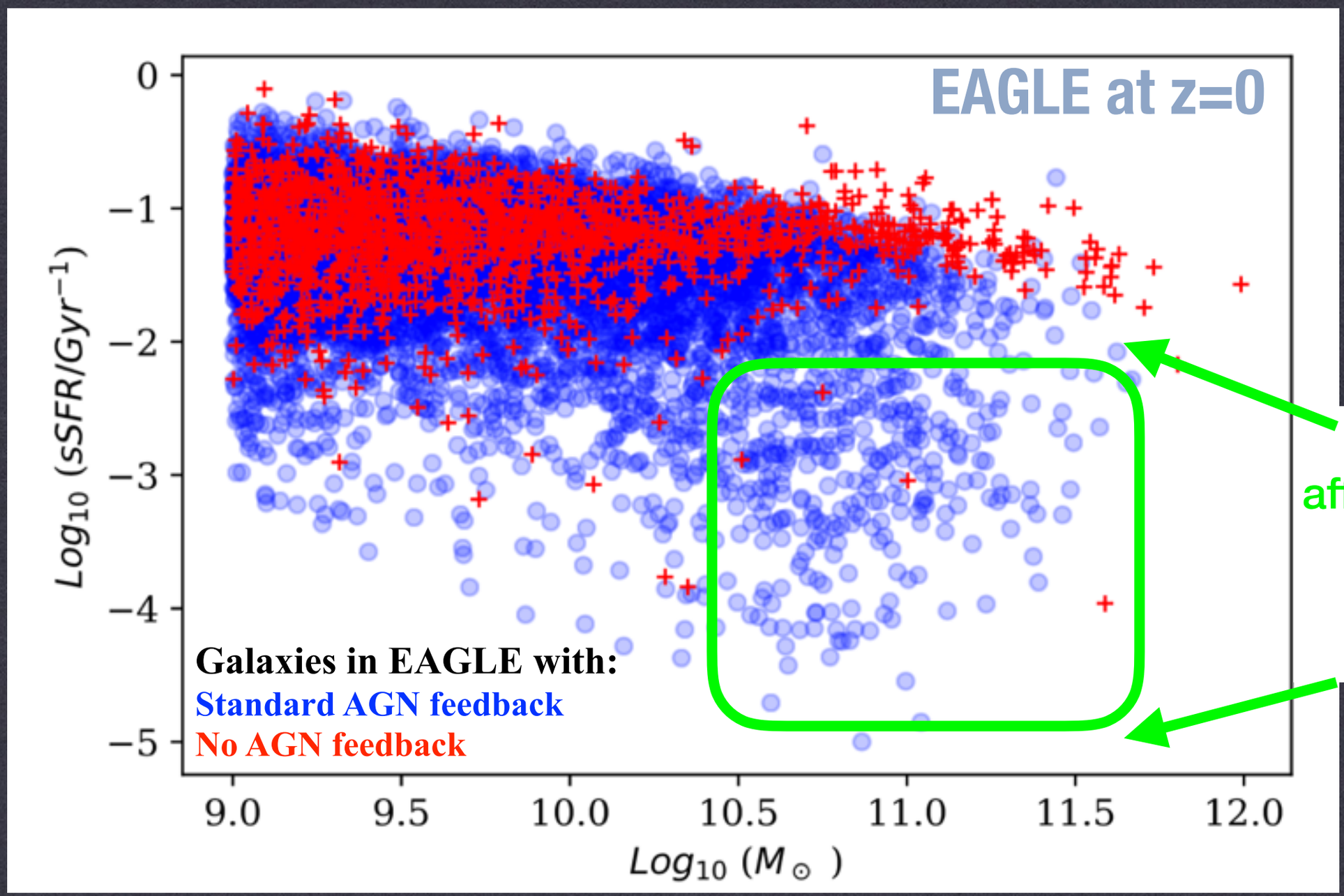


Jan Scholtz (PhD student)

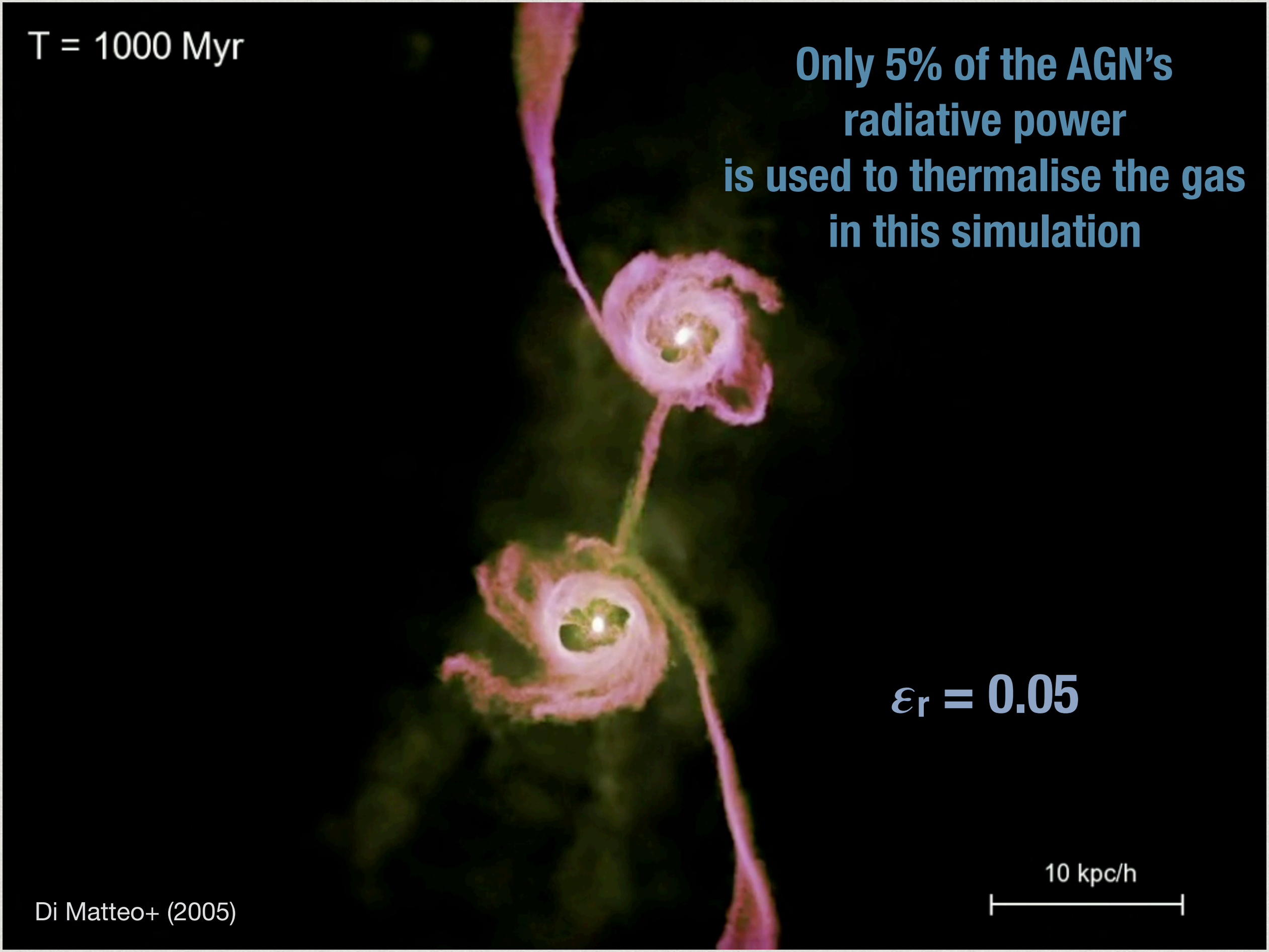
Scholtz+ (2018)

Thomas Jackson (MSc student)

Jackson+ (in prep.)



AGN feedback affects the width of the SFR-mass relationship in galaxies.


T = 1000 Myr
Only 5% of the AGN's
radiative power
is used to thermalise the gas
in this simulation
$\varepsilon_r = 0.05$
10 kpc/h
Di Matteo+ (2005)

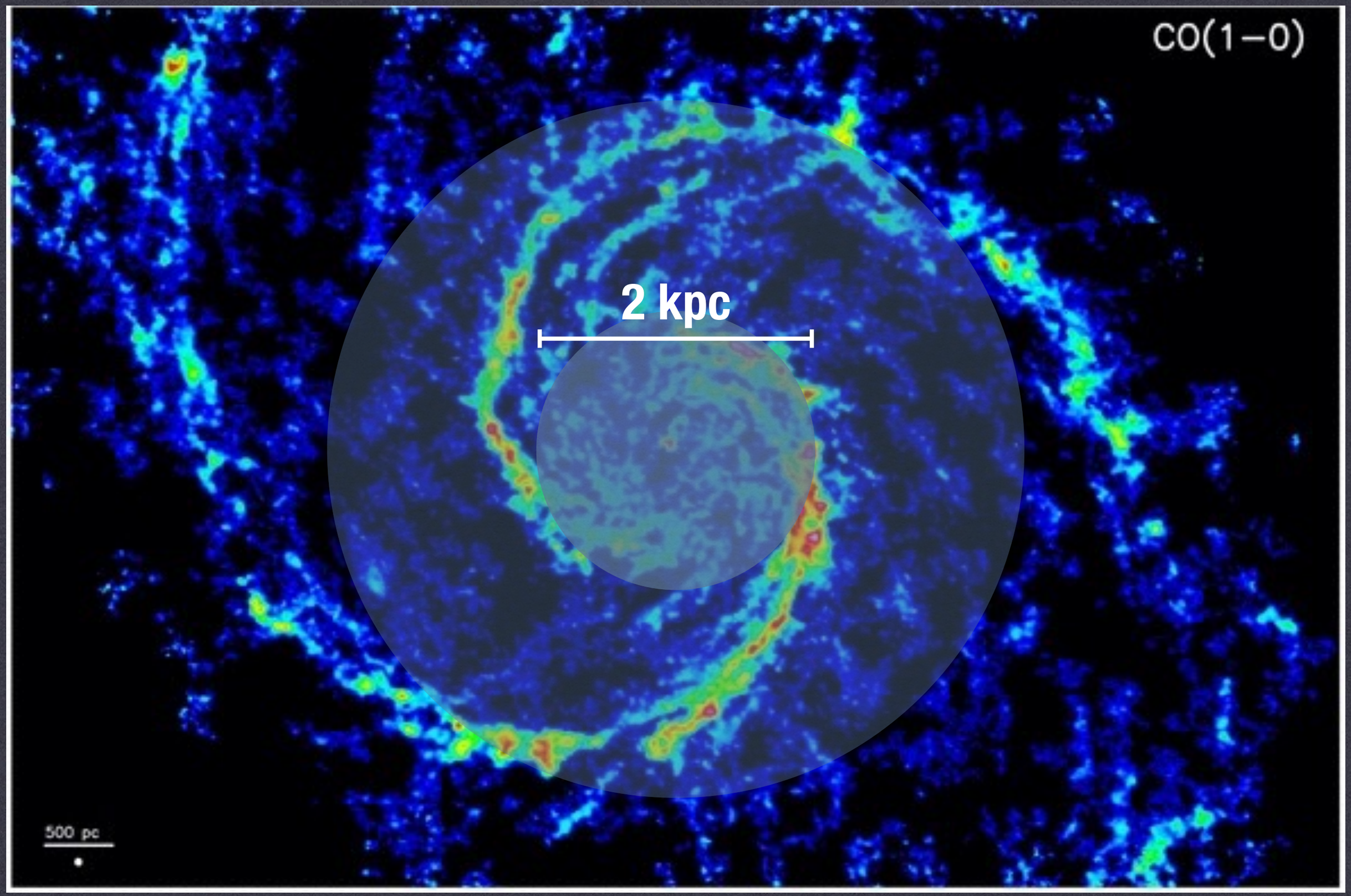
Radiative energy absorbed in the galaxy over the AGN's lifetime

$$E_{\rm rad} \approx \epsilon_r L_{bol} t_{\rm AGN}$$

A wind with terminal speed V_w travels from the nucleus to Dist = $V_w \times t_{AGN}$ over the AGN's lifetime

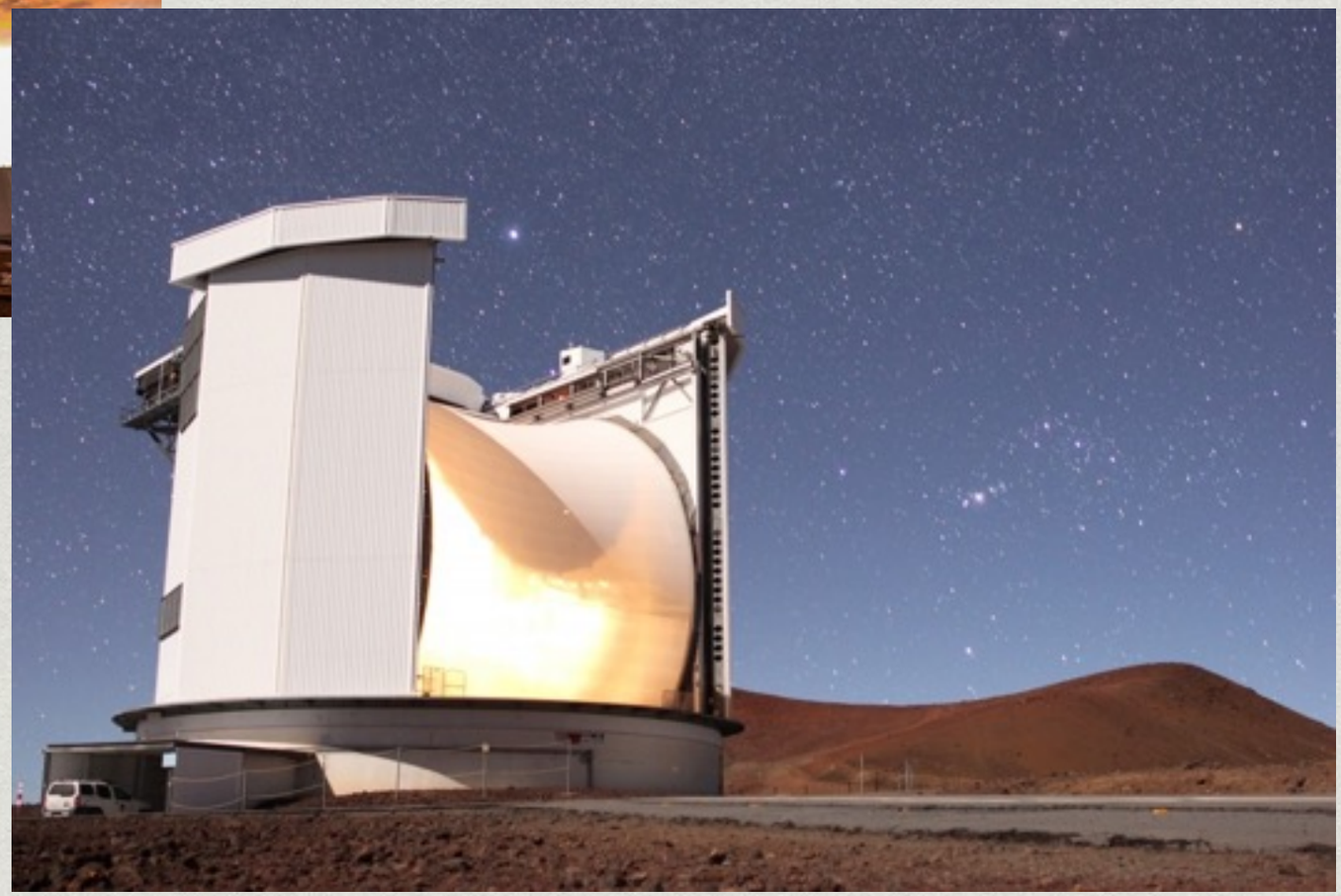
If: V_w = 1000 km/s and t_{AGN} = 1 Myr then Dist = 1 kpc

CO(1–0)


CO(1–0)
2 kpc
500 pc

Millimetre telescopes for the South

APEX 12m, Chajnantor, Chile



JCMT 15m, Mauna Kea, Hawaii

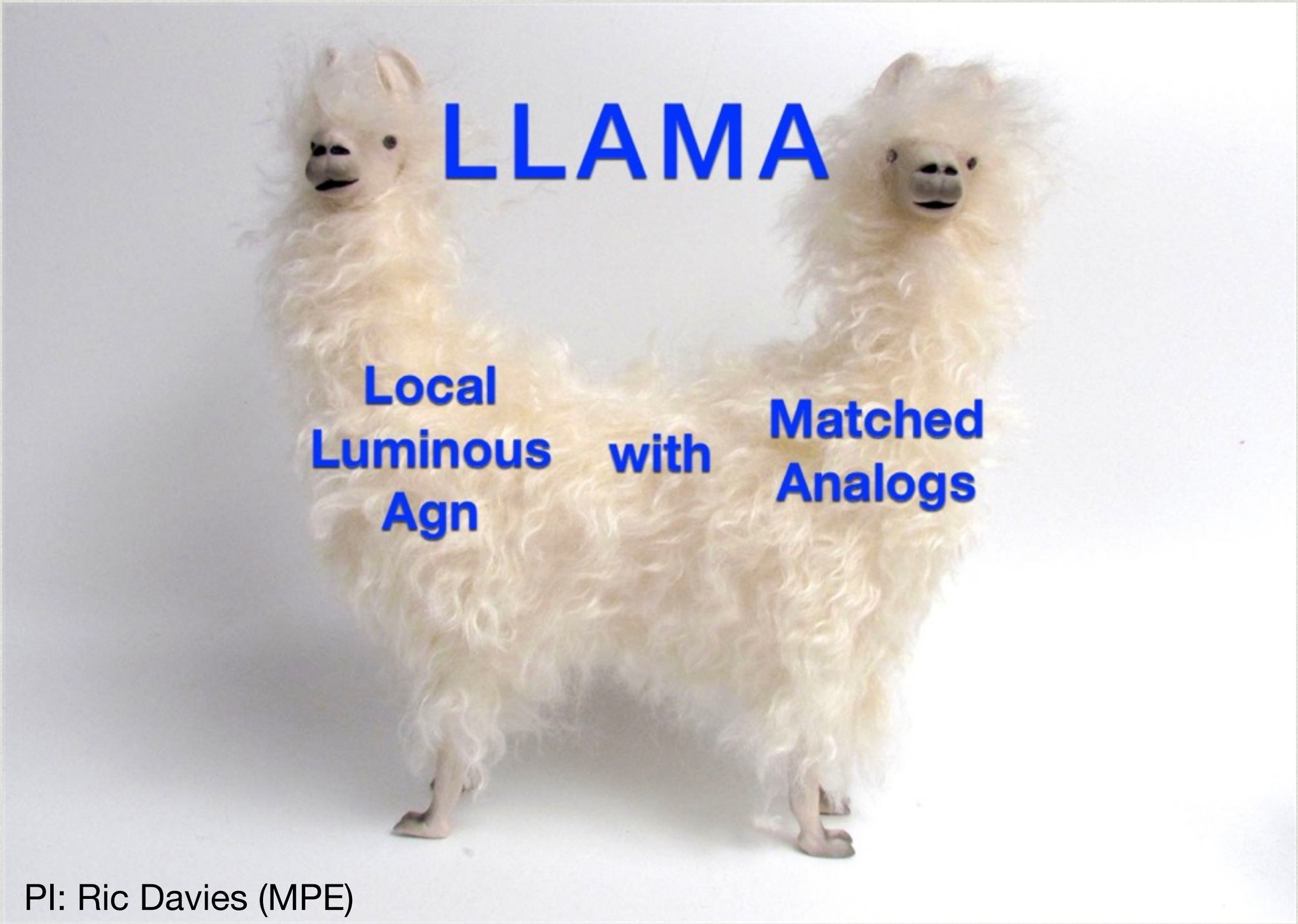
Gravitational potential energy of molecular gas in a galactic centre (insignificant dark matter, low HI fraction)

$$E_{\mathrm{PE}} \approx -\frac{G M_{\star} M_{H2}}{\eta\, R_{\mathrm{beam}}} (1 + f_{\mathrm{gas}})$$

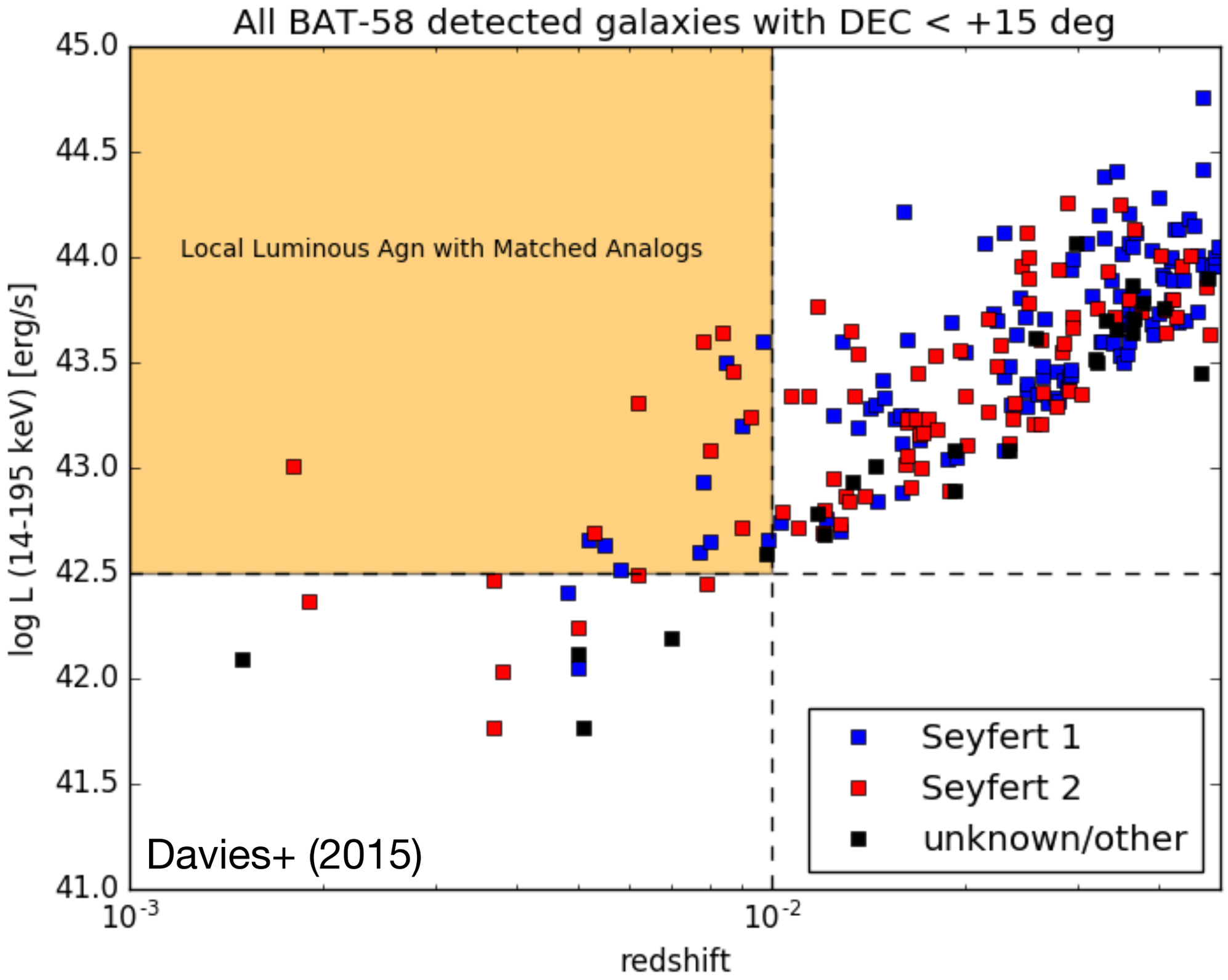
Gas fraction $f_{gas} = M_{H2} / M_{\star}$

geometrical factor $\eta = 1$ for a uniform disk
in a singular isothermal spherical potential

If the ratio
$E_{rad} / |E_{PE}| \sim 1$
in a galaxy's central region,
the AGN can displace significant molecular gas.



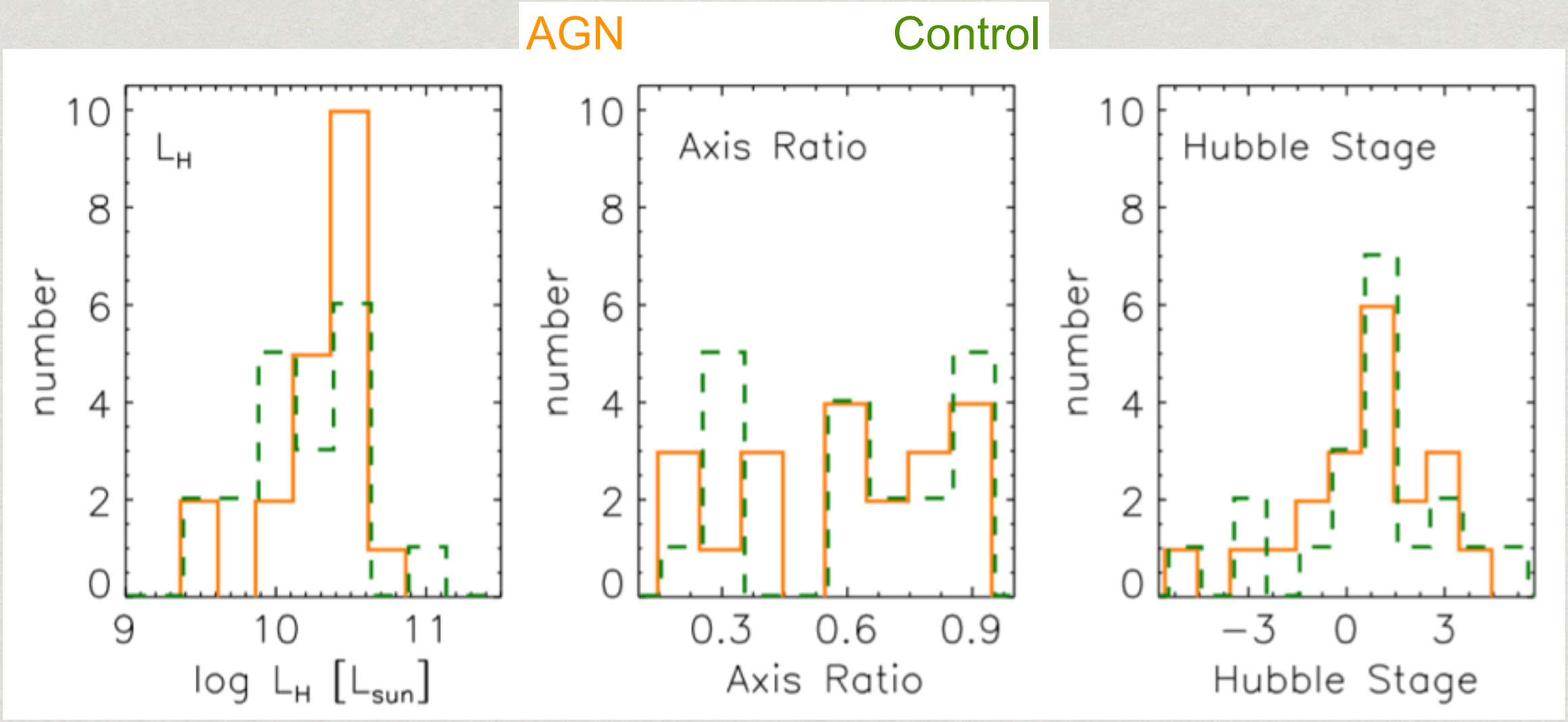
PI: Ric Davies (MPE)


All BAT-58 detected galaxies with DEC < +15 deg
Local Luminous Agn with Matched Analogs
Davies+ (2015)
Seyfert 1
Seyfert 2
unknown/other
log L (14-195 keV) [erg/s]
redshift
45.0
44.5
44.0
43.5
43.0
42.5
42.0
41.5
41.0
10^-3
10^-2

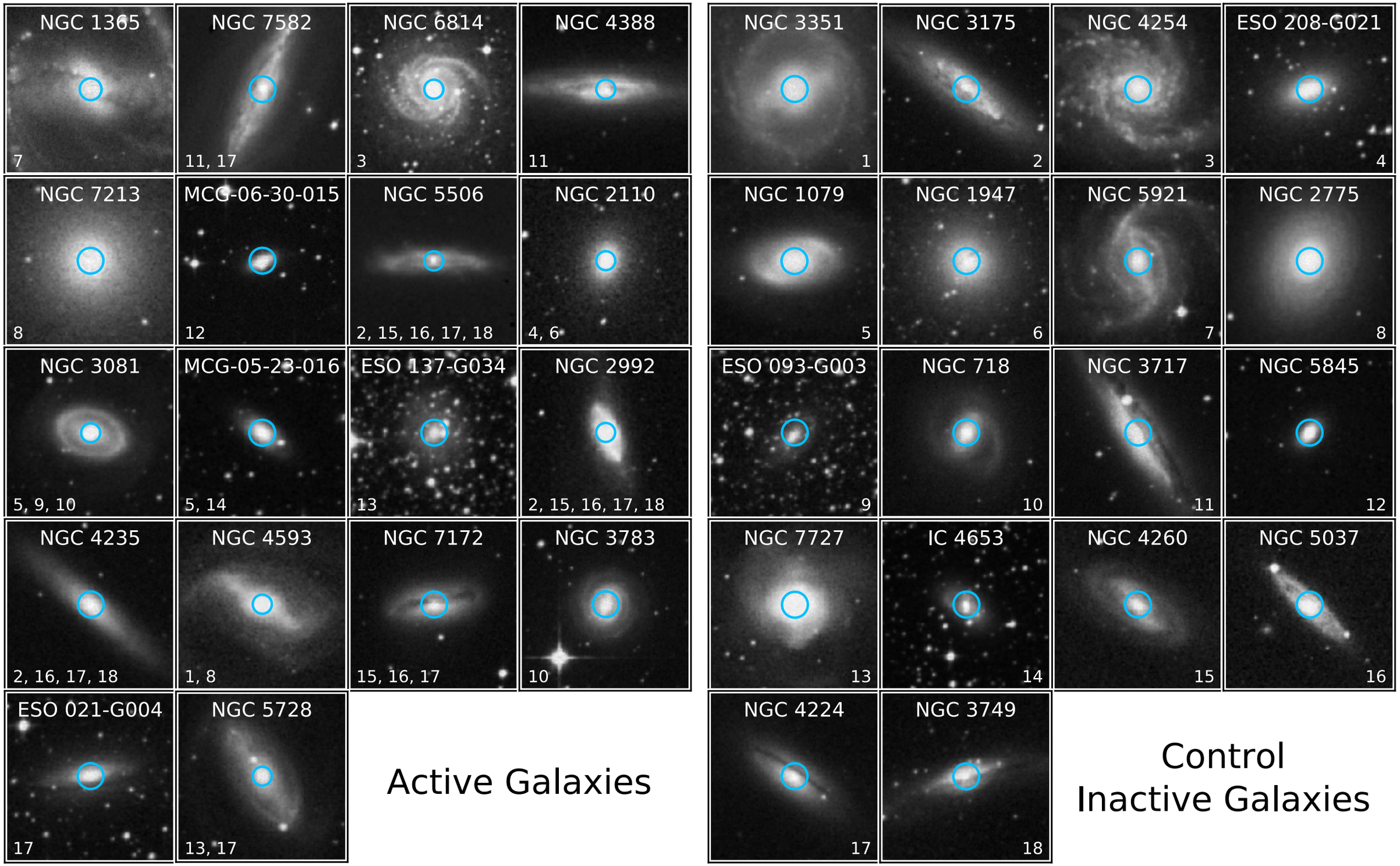
AGN are matched to a set of completely inactive galaxies

(No: X-rays, AGN lines, MIR excess, Gamma Rays)

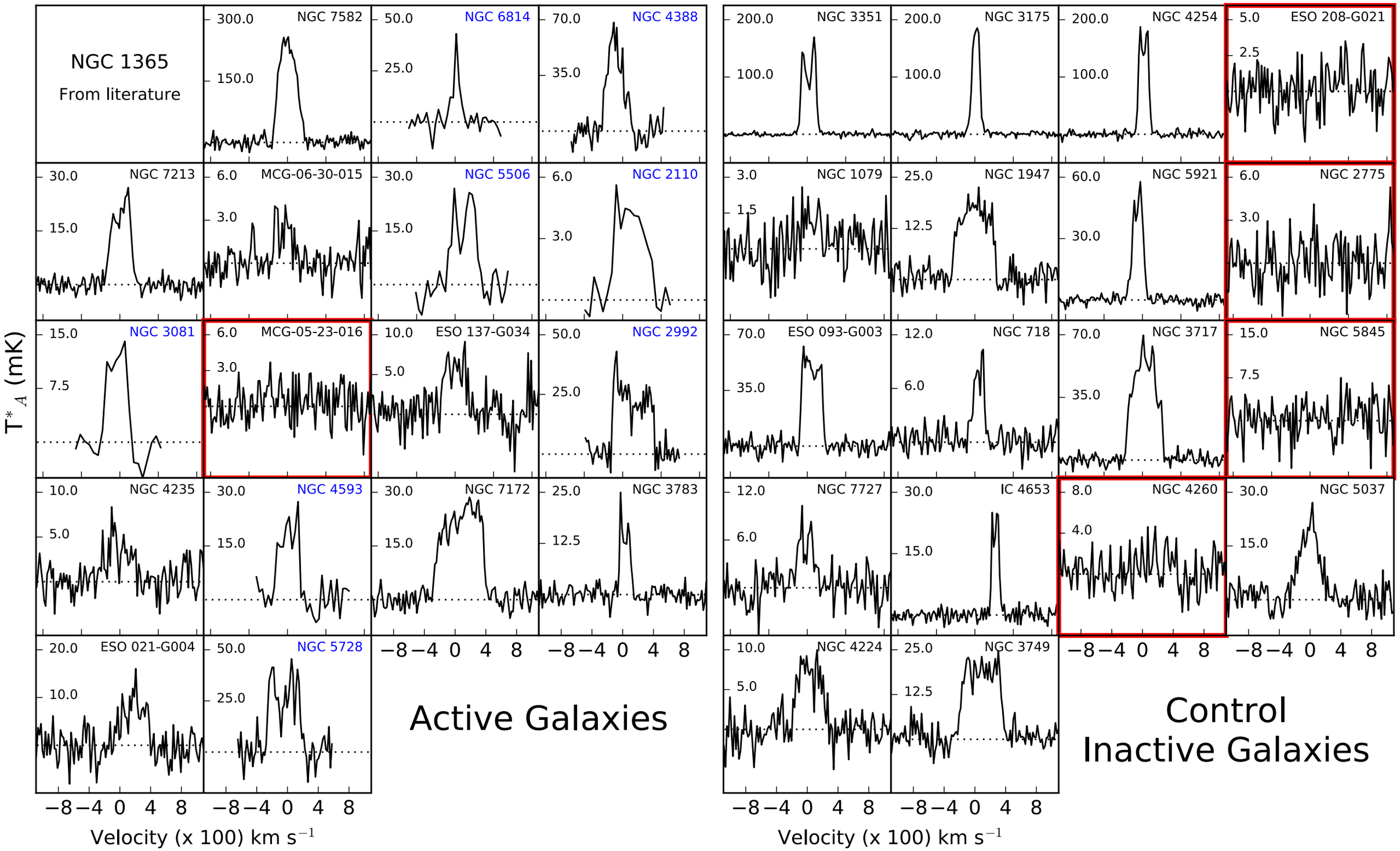
by NIR luminosity, galaxy morphology and inclination



Davies+ (2015)



DSS R-band images, 3’ on a side



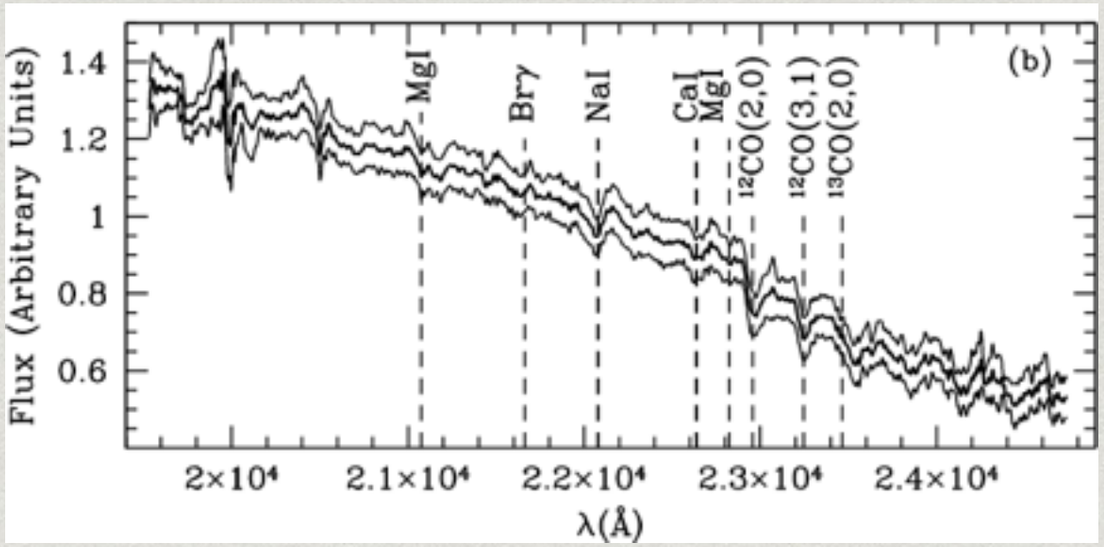
CO 2→1 spectra of 36 galaxies (18 active/18 inactive)

~90% detected with S/N > 3 detections

Central Stellar Masses

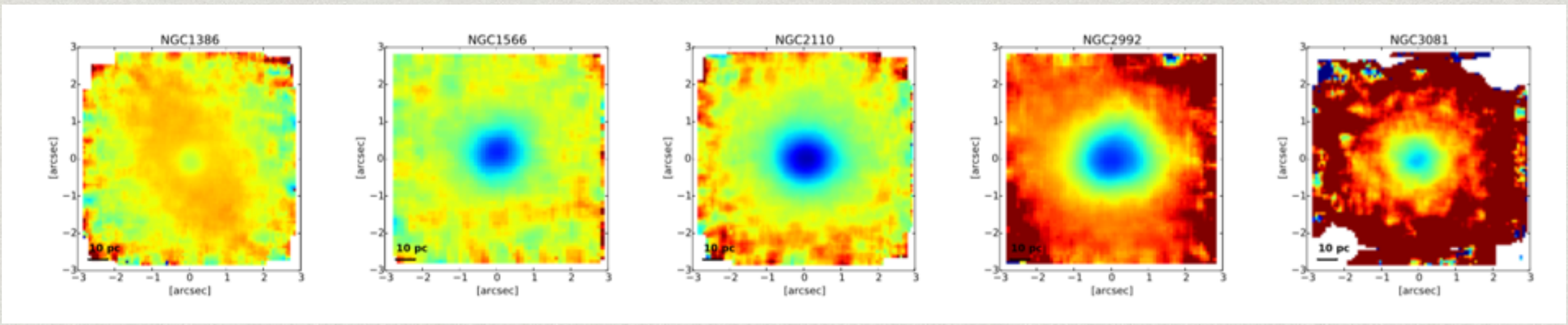
The stellar mass over the CO beam

This is not trivial for AGN. But IFU data exists for all our galaxies, so we use the dilution of the CO bandhead



Examples of LLAMA AGN with central CO bandhead dilution due to nuclear emission

Burtscher+ (2015)



a) $L_X \rightarrow L_{bol}$

b) NIR flux $\rightarrow M_\star$

c) CO luminosity $\rightarrow M_{H2}$

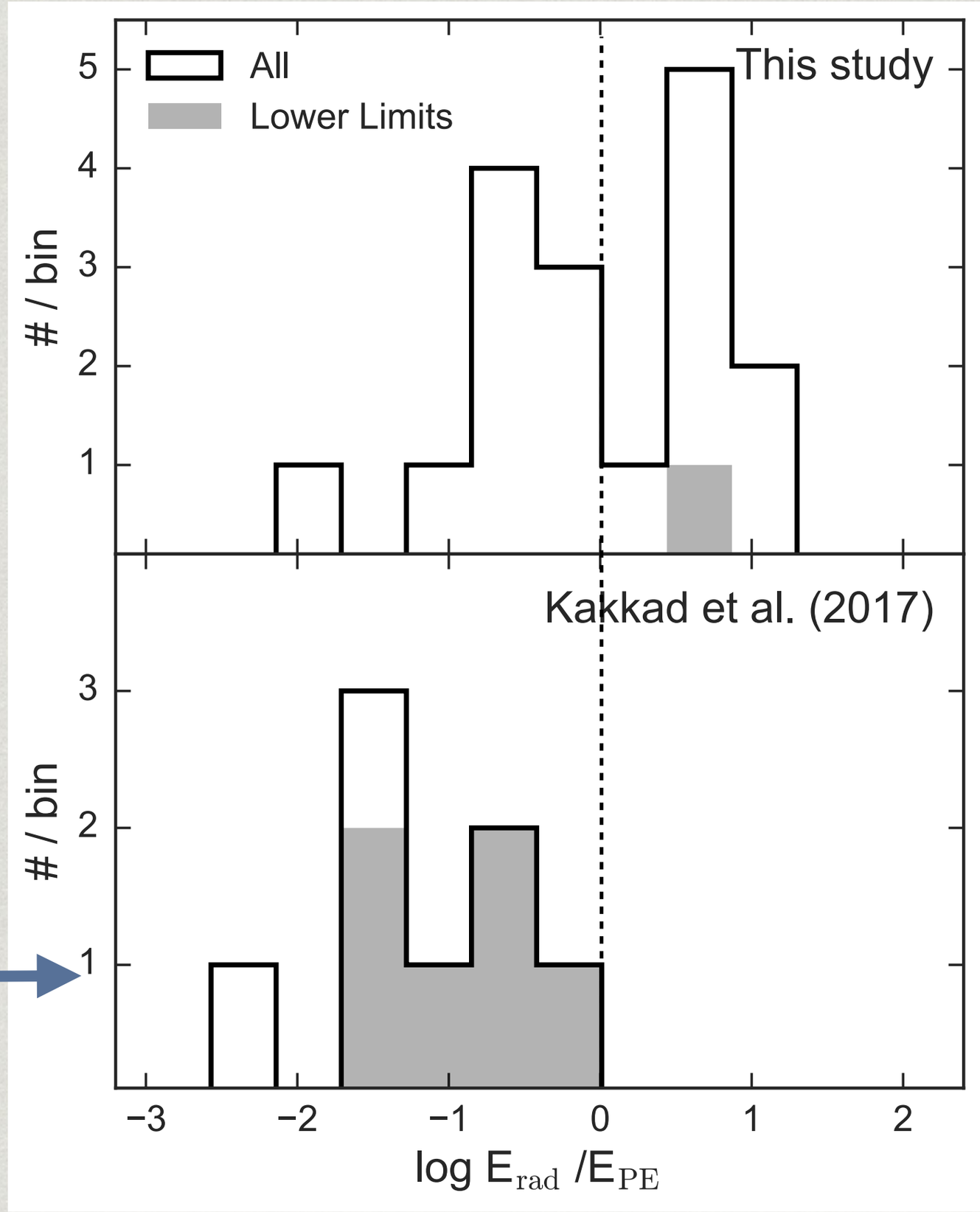
d) R_{beam} = CO beamsize

e) $\epsilon_r = 5\%$

$$E_{\rm rad} \approx \epsilon_r \, L_{bol} \, t_{\rm AGN}$$

$$E_{\rm PE} \approx -\frac{G M_\star M_{H2}}{\eta \, R_{\rm beam}} \, (1 + f_{\rm gas})$$

Similar analysis for AGN at z~1.5 with ALMA CO observations



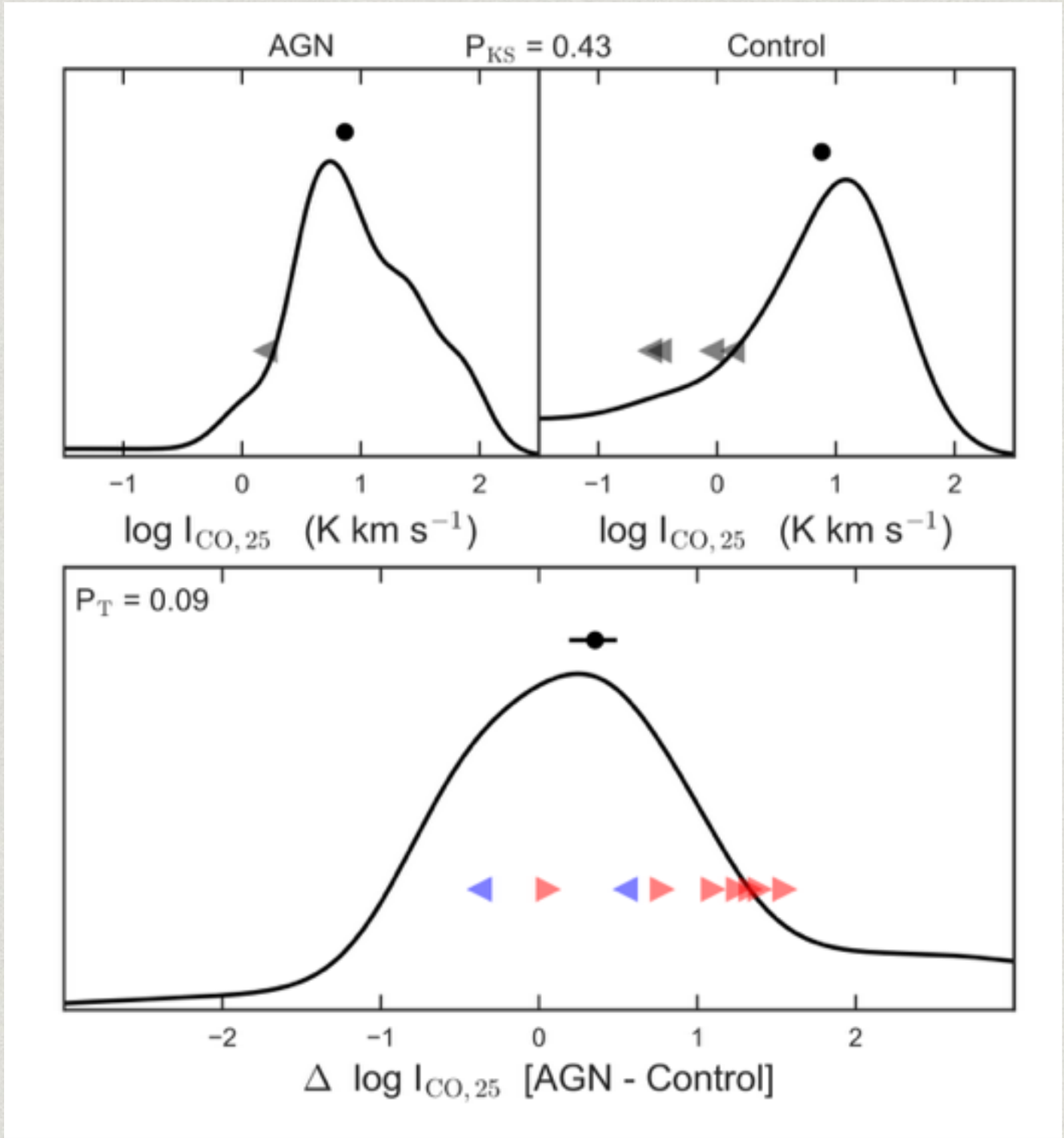
Among half of the LLAMA AGN, there is enough nuclear power to potentially destroy molecular gas on kpc scales.

The physics uncovered in nearby Seyferts is relevant for AGN feedback on molecular gas at high redshift.

CO intensity ∝ molecular gas mass

Individual distributions for both types of galaxy

Distributions of the difference with all control pairs considered together



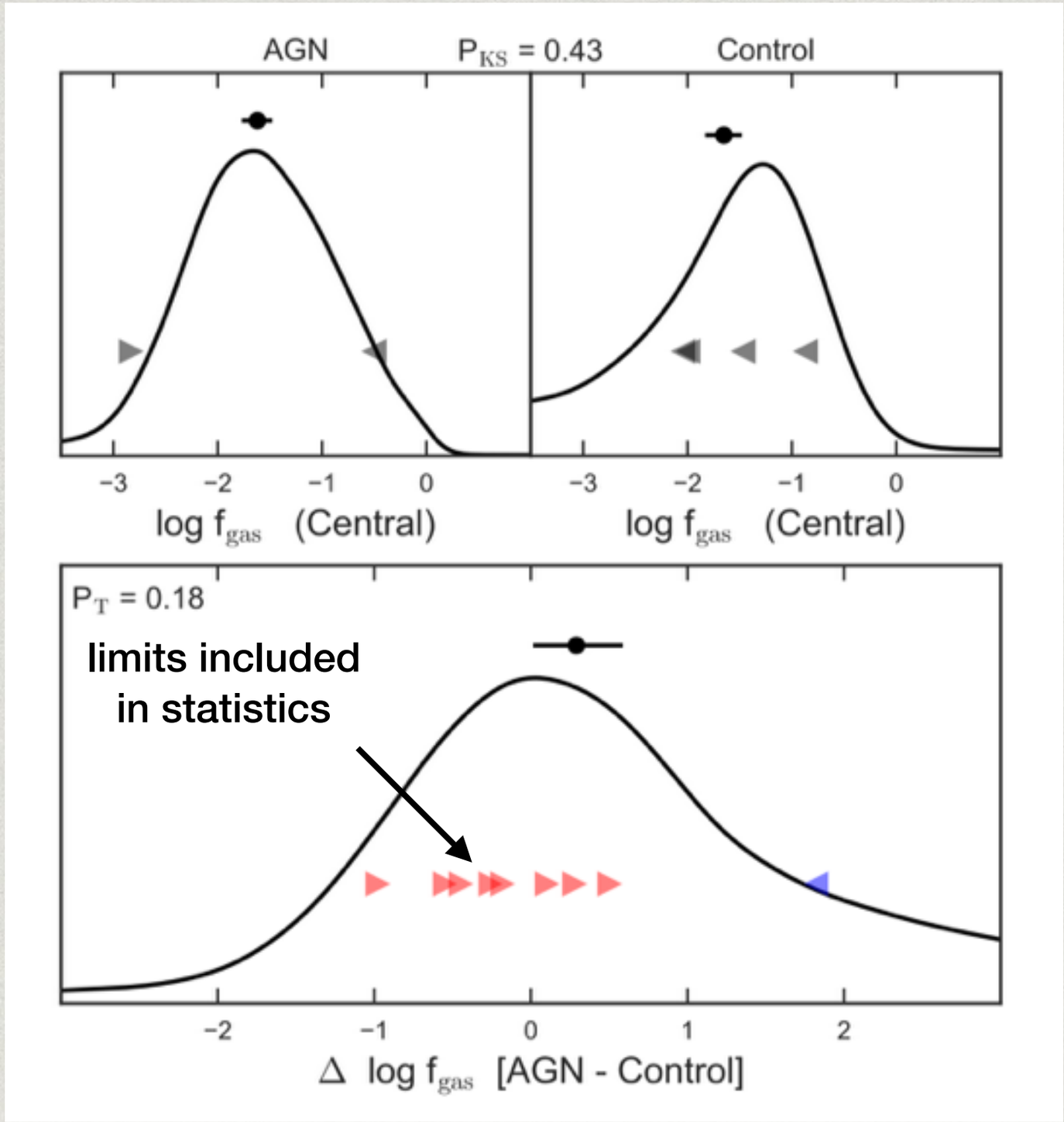
If we can measure
the molecular gas mass in the central kiloparsecs,
we can examine:

The molecular gas fraction (f_{gas})

If AGN destroy or drive away molecular gas,
f_{gas} will drop.

Molecular gas fractions

We adopt
$\alpha_{CO} = 1.5$
lower than the Milky Way, but consistent with the centres of nearby galaxies
(Sandstrom+ 2013)



If we can measure
the molecular gas mass in the central kiloparsecs,
we can examine:

The star formation efficiency (SFR / M_{H2})

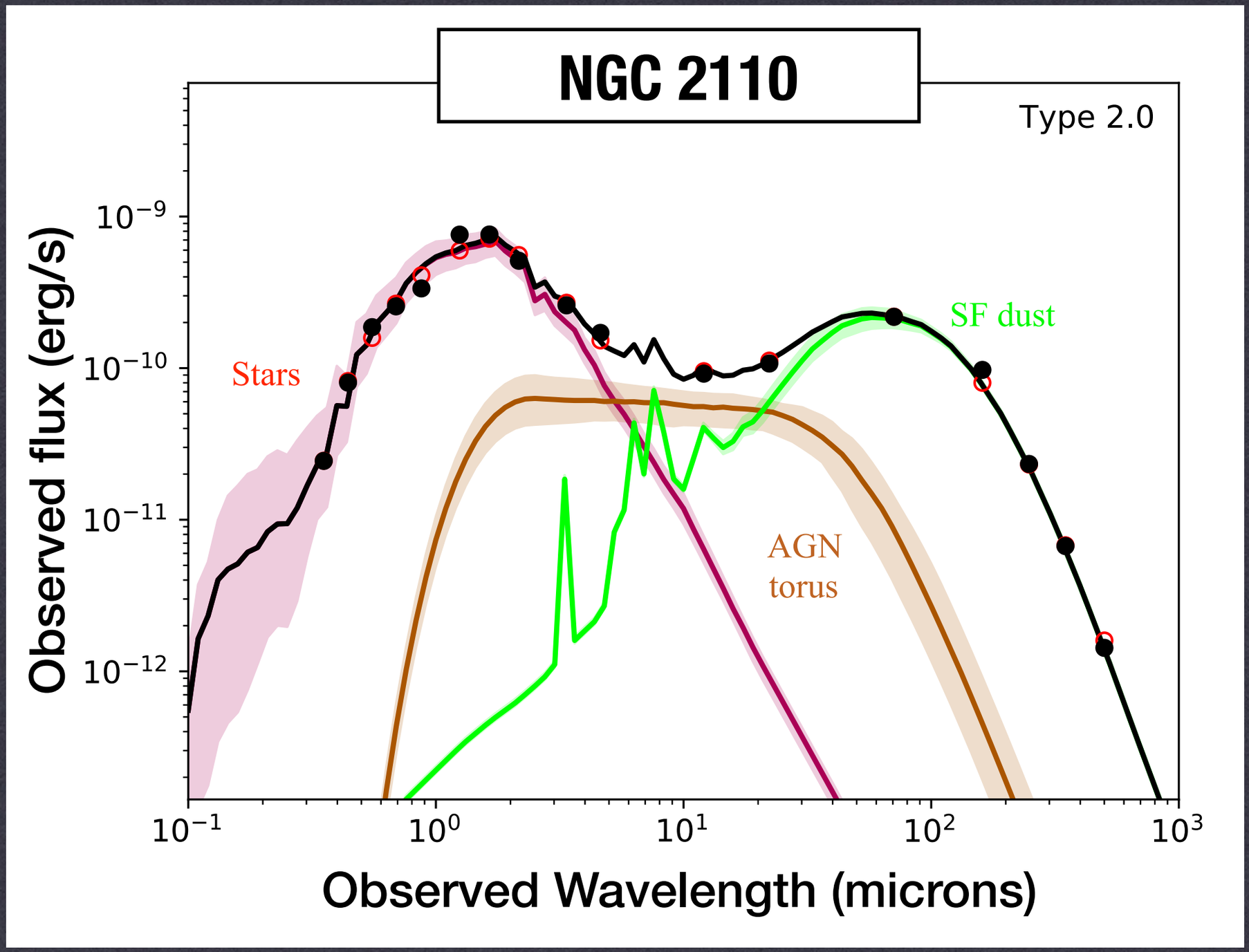
If AGN destabilise molecular clouds, this efficiency will drop (negative feedback) or rise (positive feedback).

But we need the SFR over the CO beam.

FortesFit

github.com/vikalibrate/FortesFit

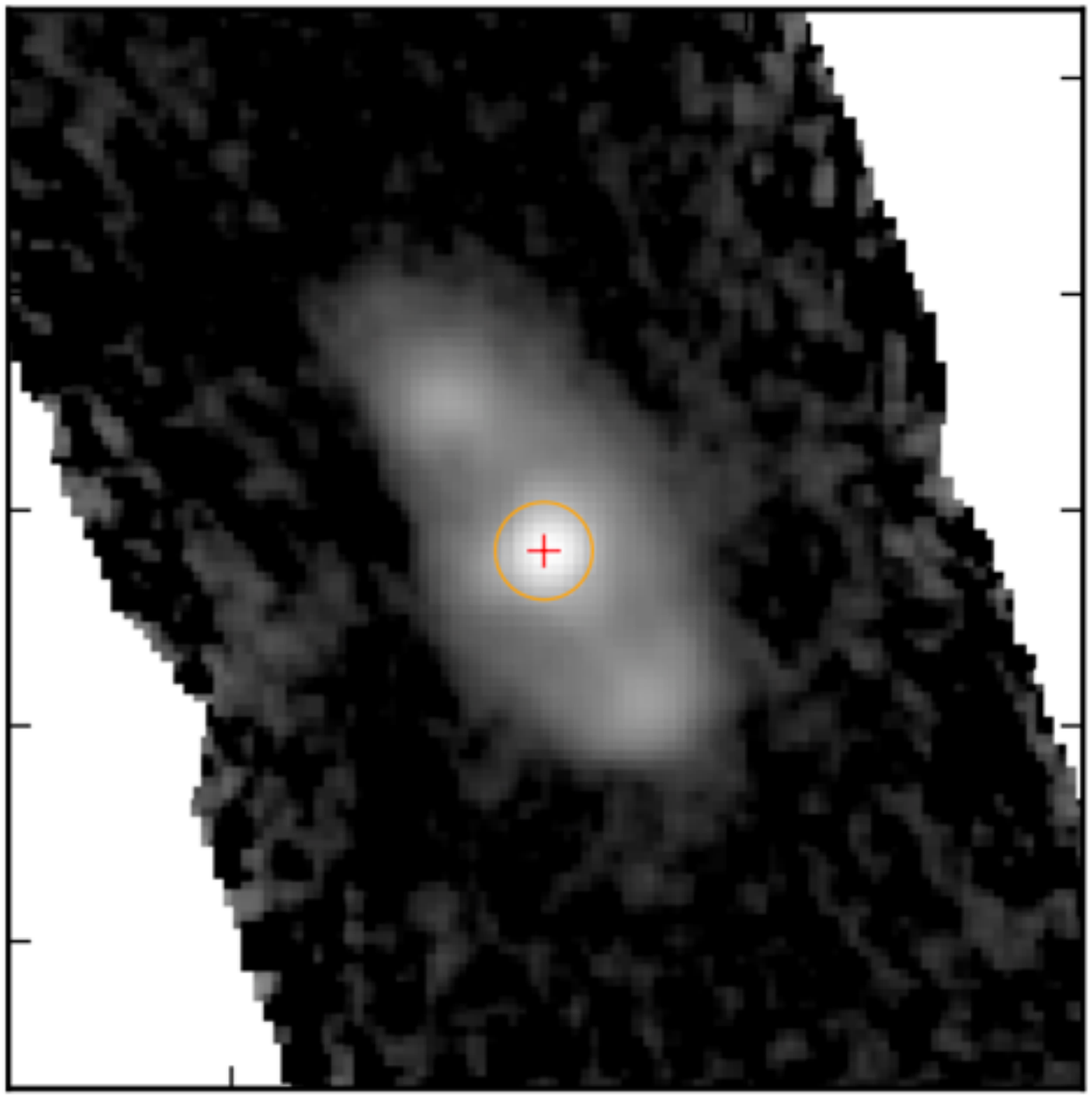
Rosario+ (in prep.)



Central Star Formation Rates

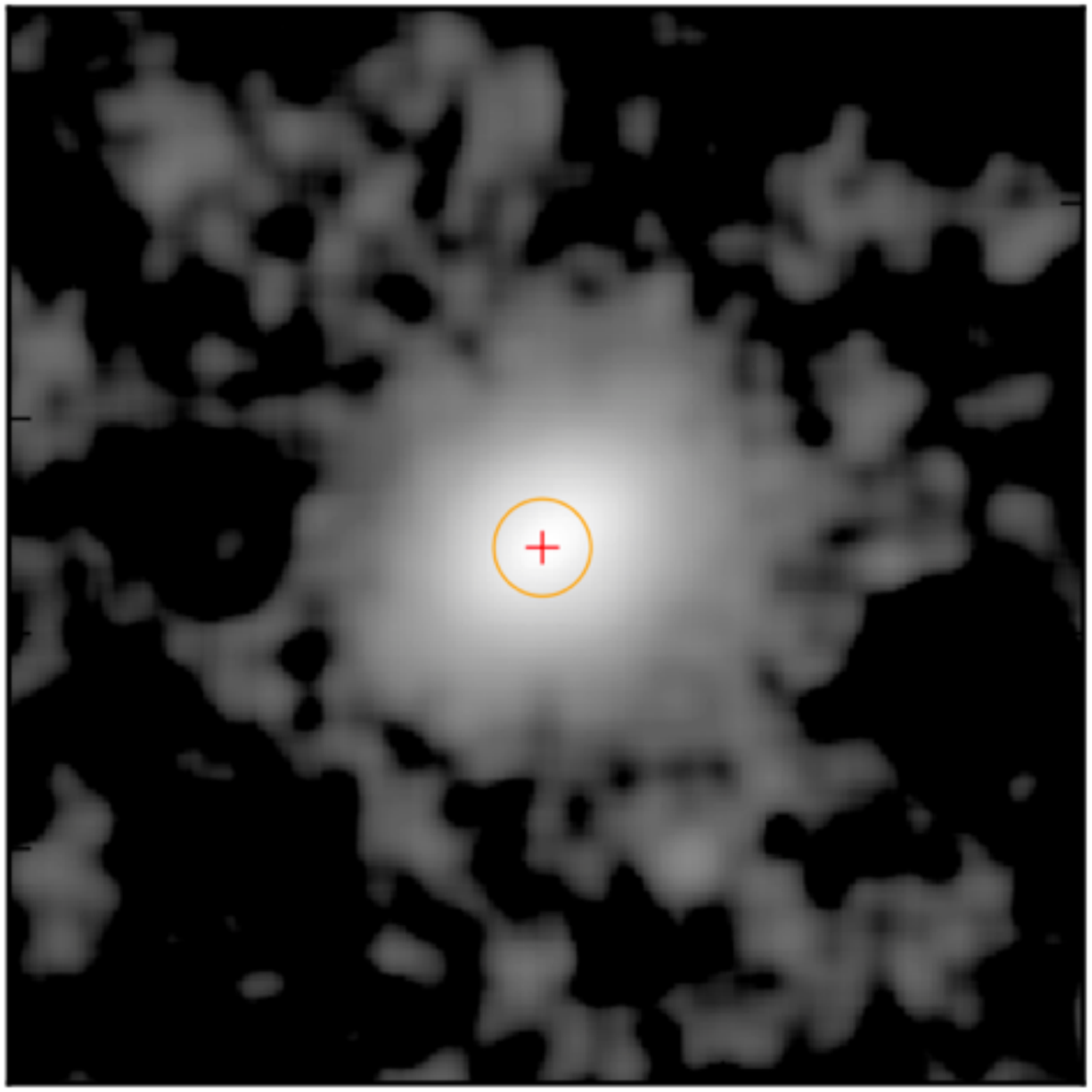
NGC 5728

PACS 160 μm



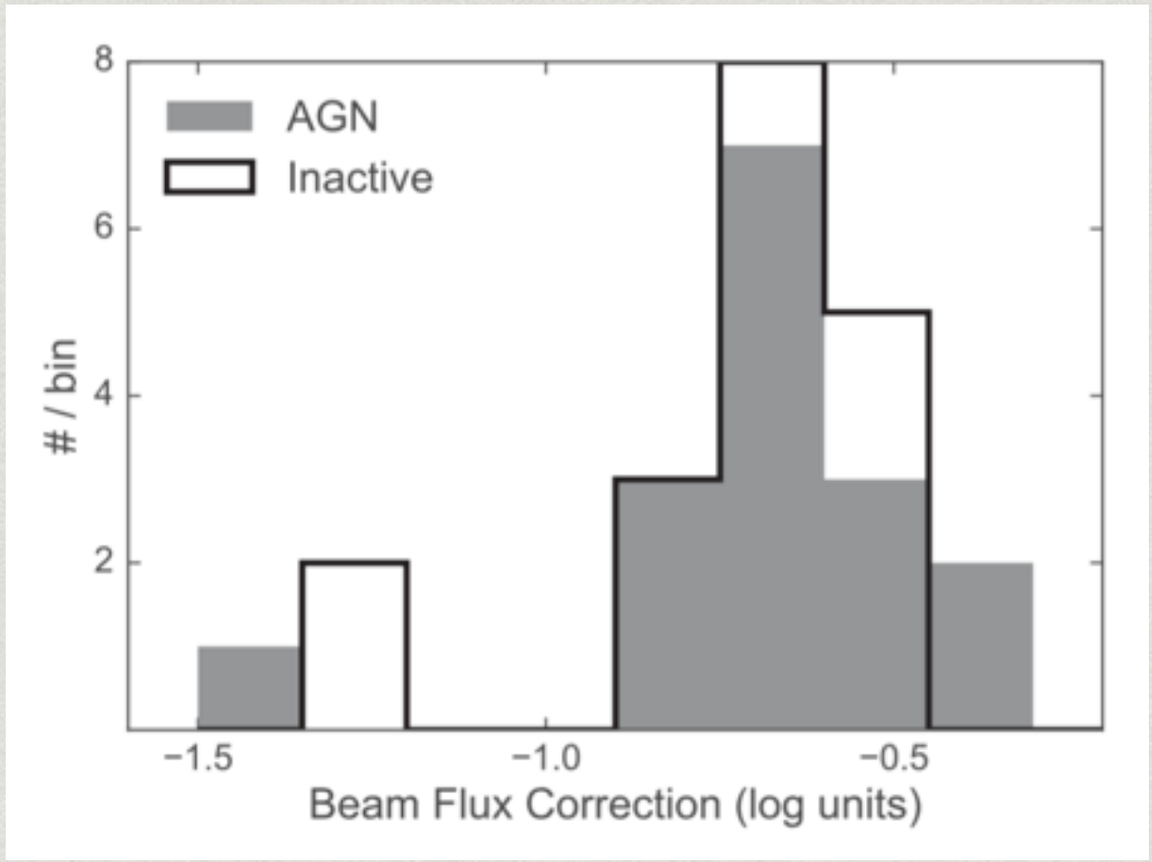
NGC 1947

WISE 22 μm



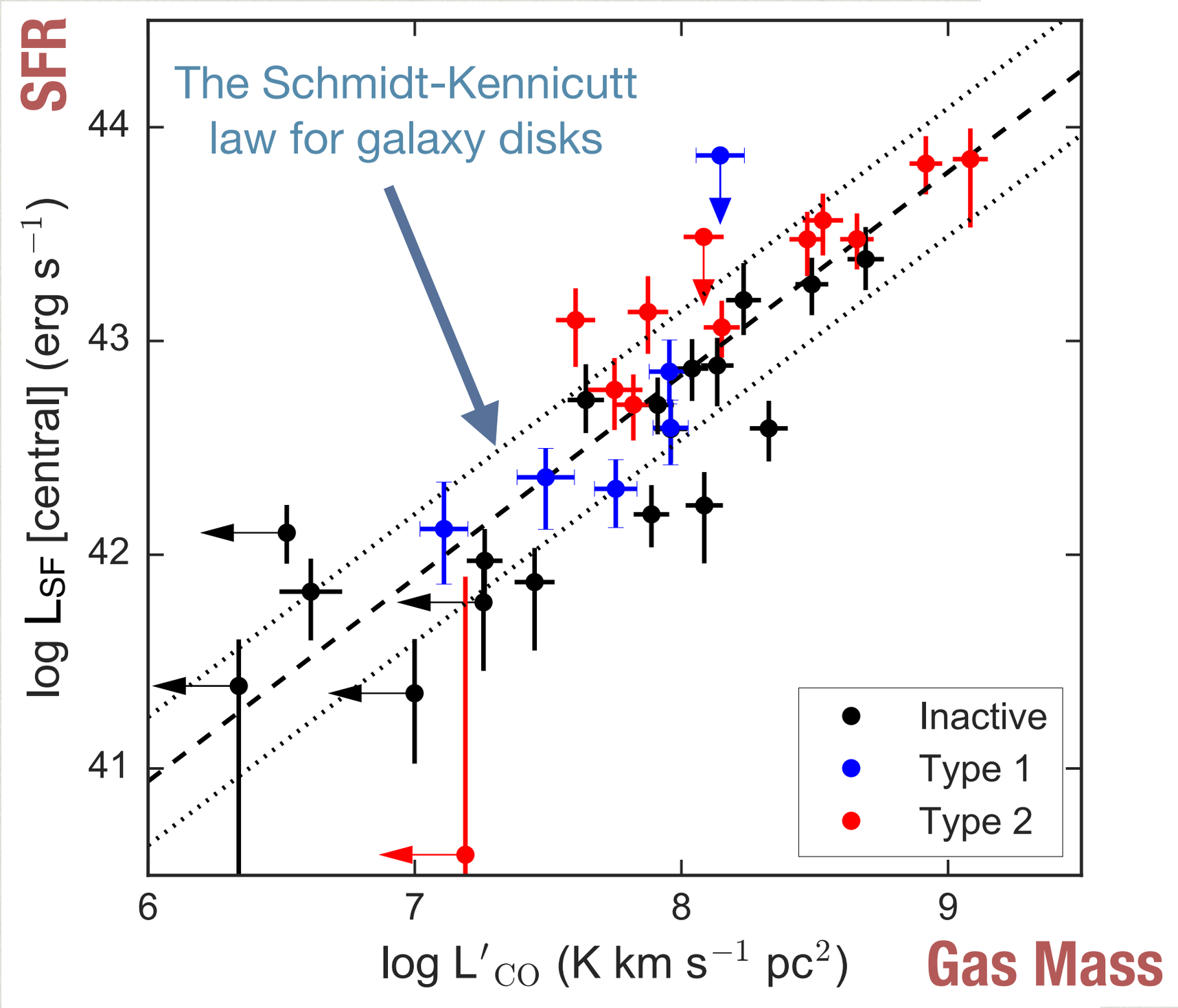
Central Star Formation Rates

FIR-based SFRs scaled to match the CO telescope beam.



A robust treatment of all uncertainties, including systematics of SFR calibrations, CO conversion factors, AGN contamination.

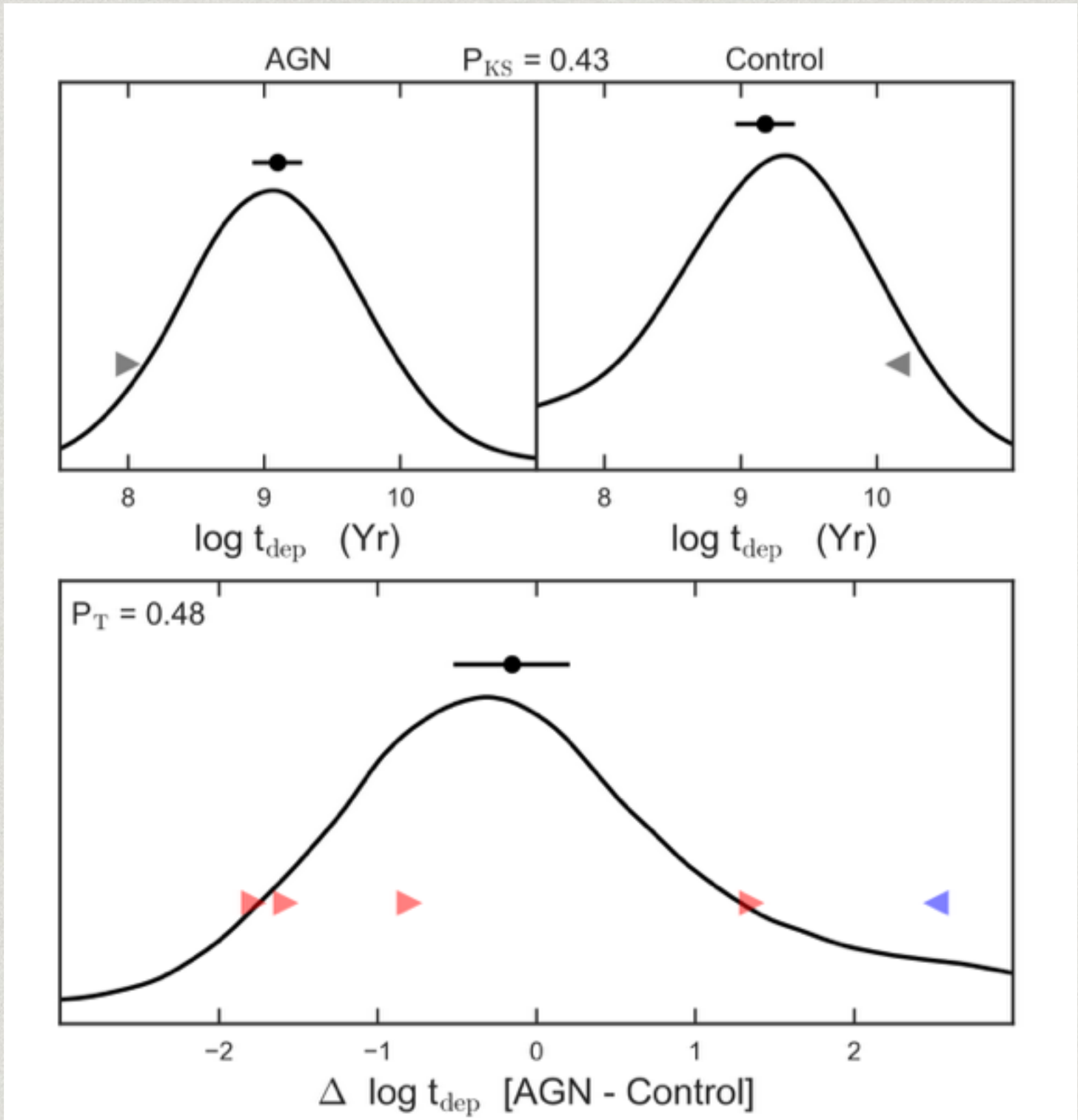
The star-formation efficiency of the central molecular gas



Molecular gas “depletion times”

The inverse of the star formation efficiency.

No statistical difference between AGN and control galaxies.



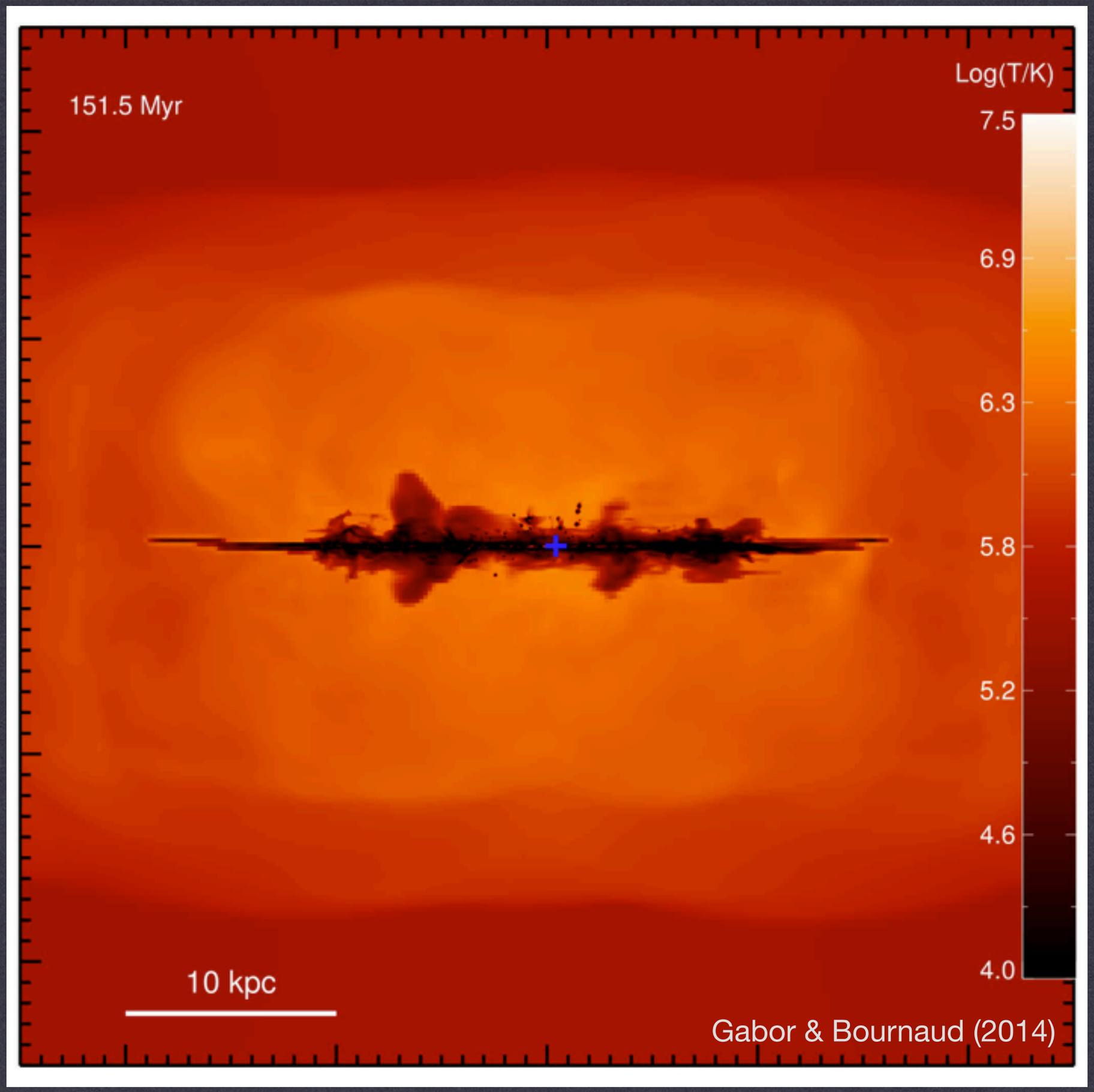
SUMMARY

The central molecular gas fractions and central star-formation efficiencies of local bright Seyferts are statistically indistinguishable from similar inactive galaxies.

But these Seyferts are energetic enough to destroy a substantial part of this molecular gas.

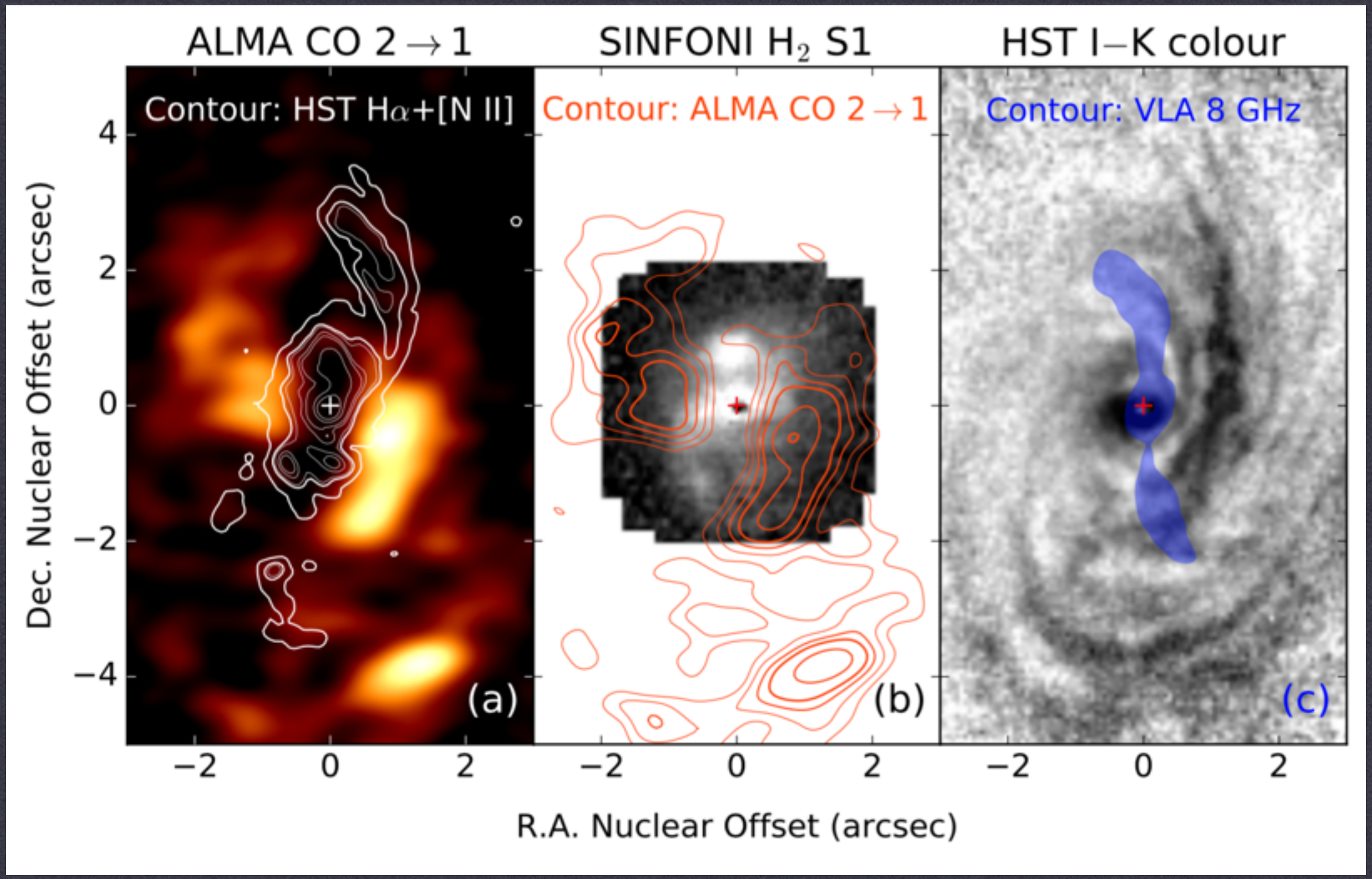
We conclude: the coupling of an AGN's luminosity to the star-forming material in its vicinity is not as strong as models demand.

How do AGN quench star-formation?


151.5 Myr
Log(T/K)
7.5
6.9
6.3
5.8
5.2
4.6
4.0
10 kpc
Gabor & Bournaud (2014)

NGC 2110: A CASE STUDY

Cold molecular gas Hot molecular gas Dusty gas



Rosario+ 2018 (submitted)

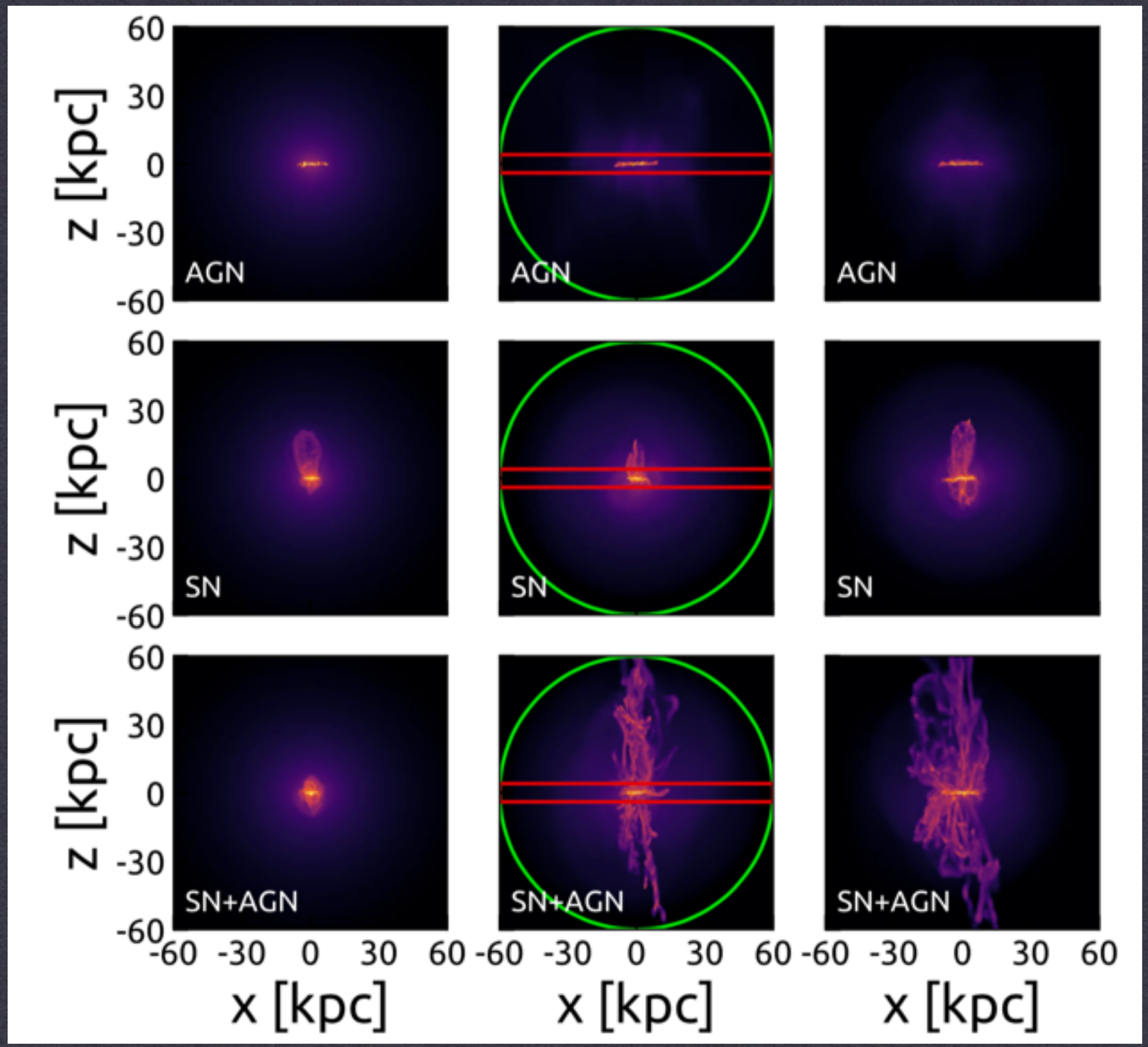
CONCLUSIONS / THOUGHTS

AGN do not summarily destroy dense, star-forming gas. Most of their feedback energy is probably carried away by a hot and ionised phase, with low coupling to molecular gas.

AGN can heat molecular gas, temporarily changing its properties, but the gas remains intact.

This is still enough to cut-off long term accretion of cold gas into galaxies. The role of AGN feedback in galaxy evolution is mostly to restrict supply.

Does star-formation promote AGN feedback?



Biernacki & Teyssier (2018)

FortesFit

github.com/vikalibrate/FortesFit; Rosario+ (in prep.)

FortesFit addresses these issues with:

✓ A general approach to painlessly add any parameterised SED model, and combine them in the fit.

✓ A full treatment of continuous, informative priors, including SciPy stats distributions.

✓ Functionality for hyperpriors (“dependencies”).

✓ Out of the box MCMC and the capability to add other fitting engines with minor development.

Code has been put into public domain, has been used in a published paper, and is in development for used with the KASHz and BASS programs.

Looking for co-developers, testers, users.