AGN do not destroy star-forming molecular gas

Rosario et al. 2018, MNRAS, 473, 5658

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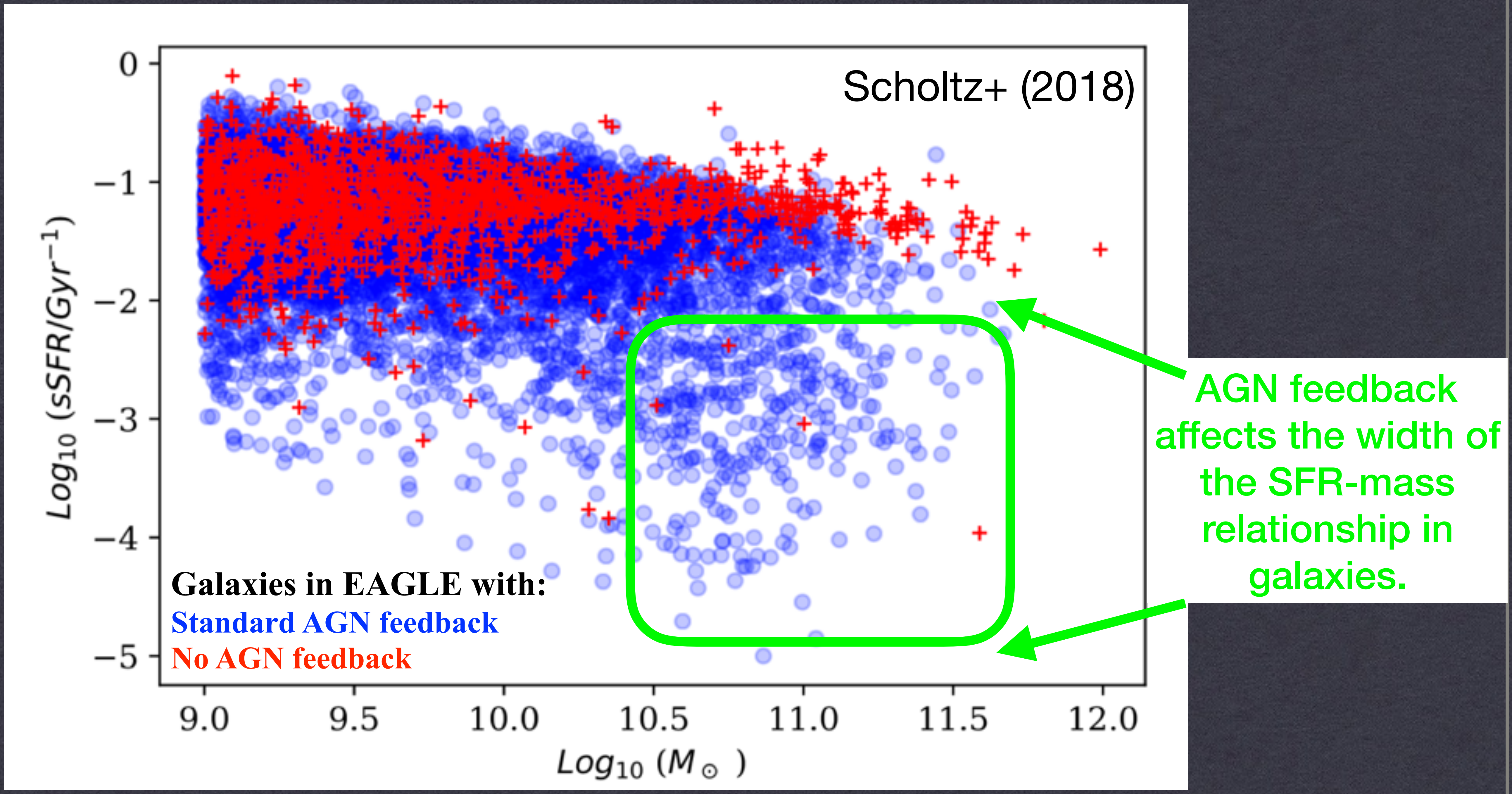
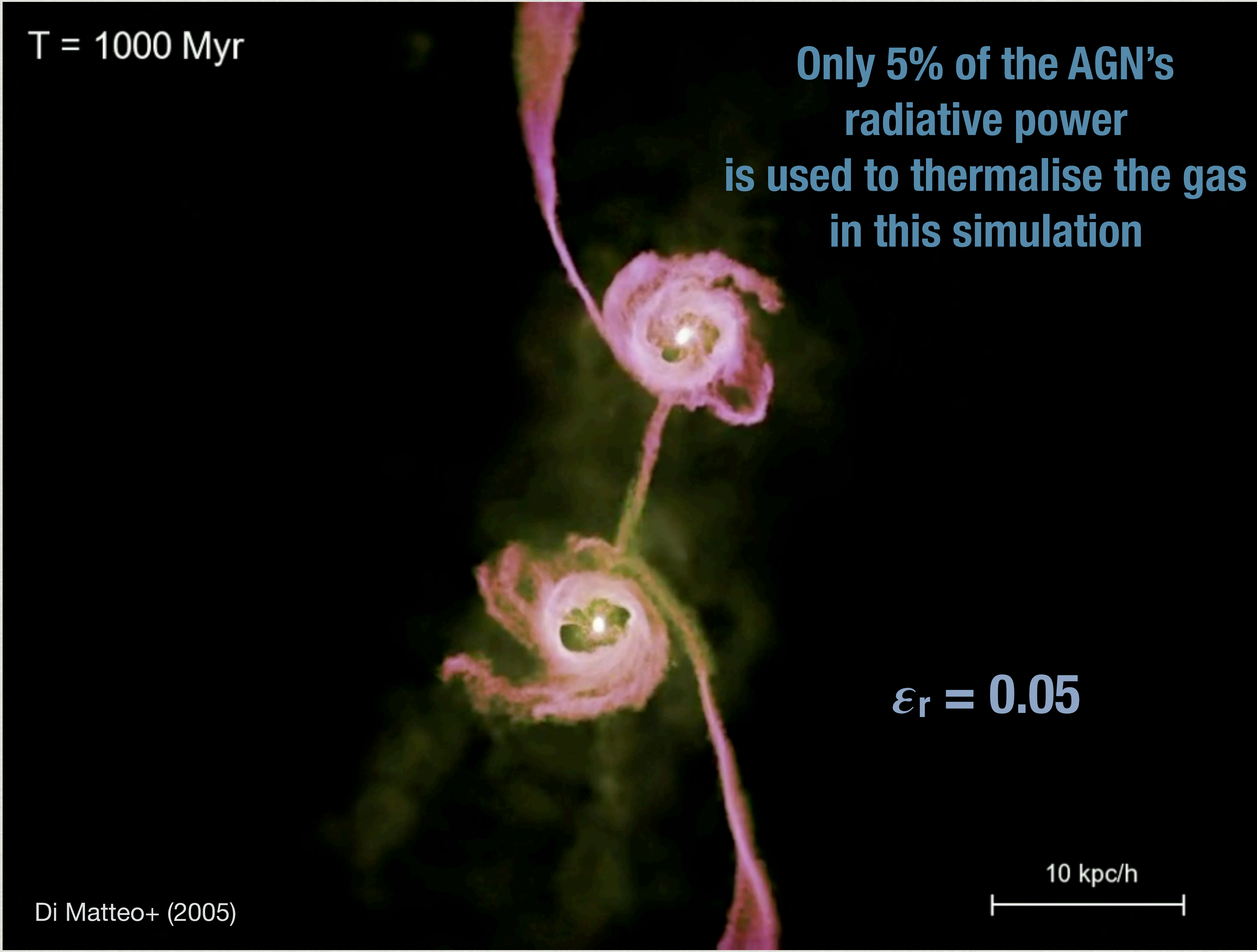
THE ROLE OF AGN IN GALAXY EVOLUTION

The EAGLE hydrodynamic simulation at z=0





Only 5% of the AGN's radiative power is used to thermalise the gas in this simulation

$\varepsilon_r = 0.05$

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

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

Consider an AGN with bolometric luminosity L_{bol} accreting steadily for a time t_{AGN}

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

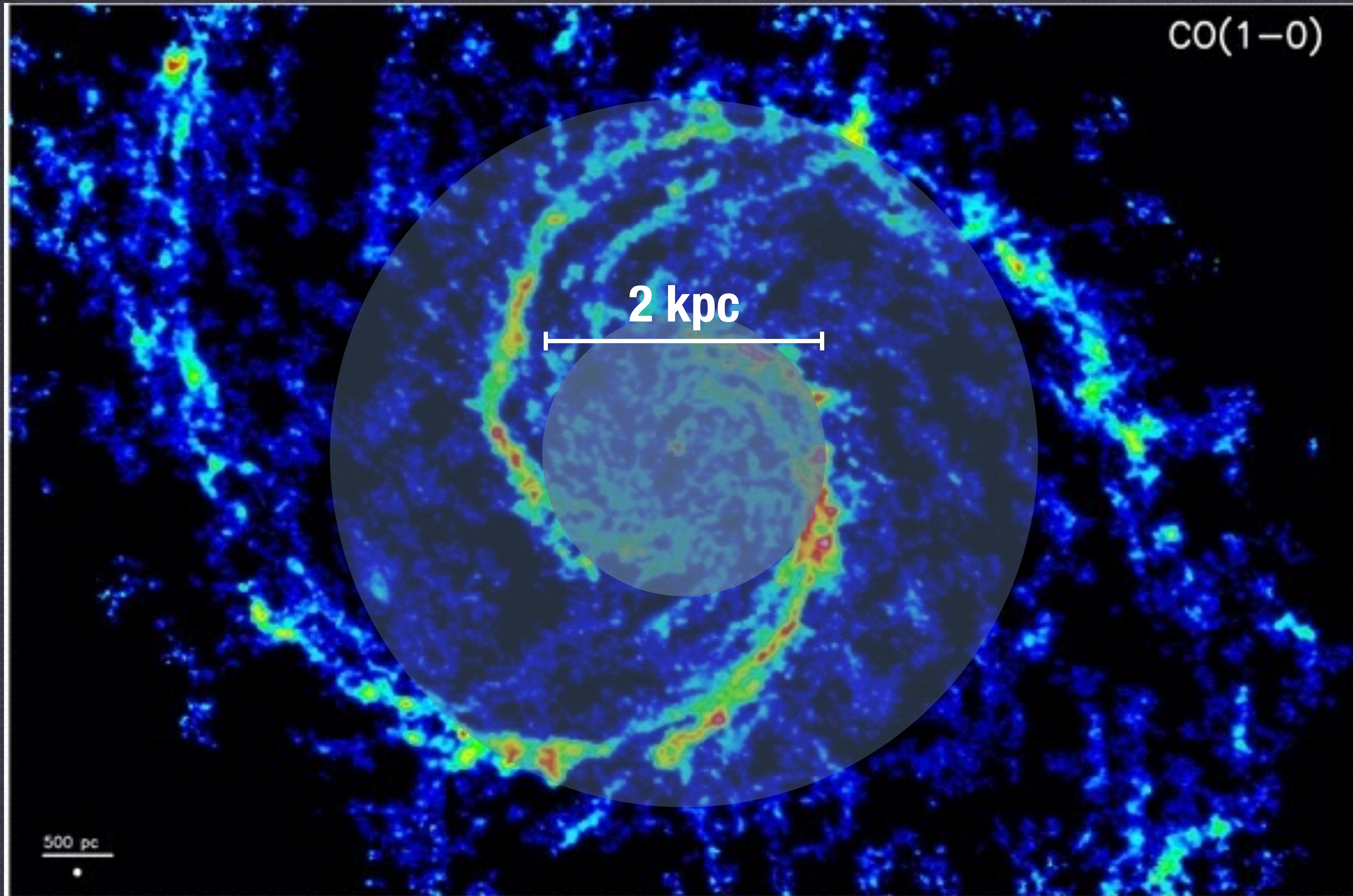
and

$t_{AGN} = 1$ Myr

then

$Dist = 1$ kpc


CO(1−0)


CO(1–0)
2 kpc
500 pc

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

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

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

geometrical factor $\eta = 1$ for a uniform disk

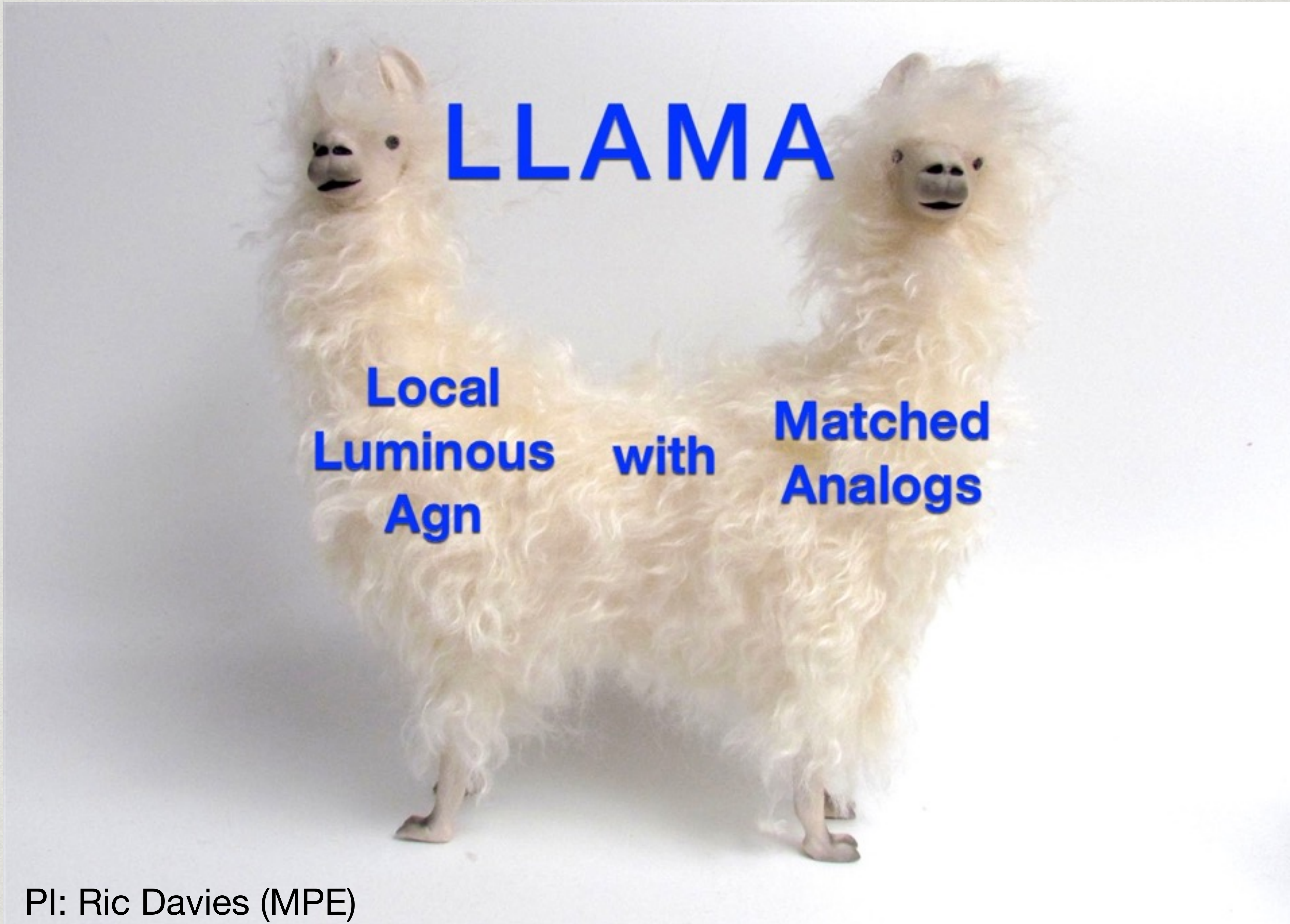
in a singular isothermal spherical potential

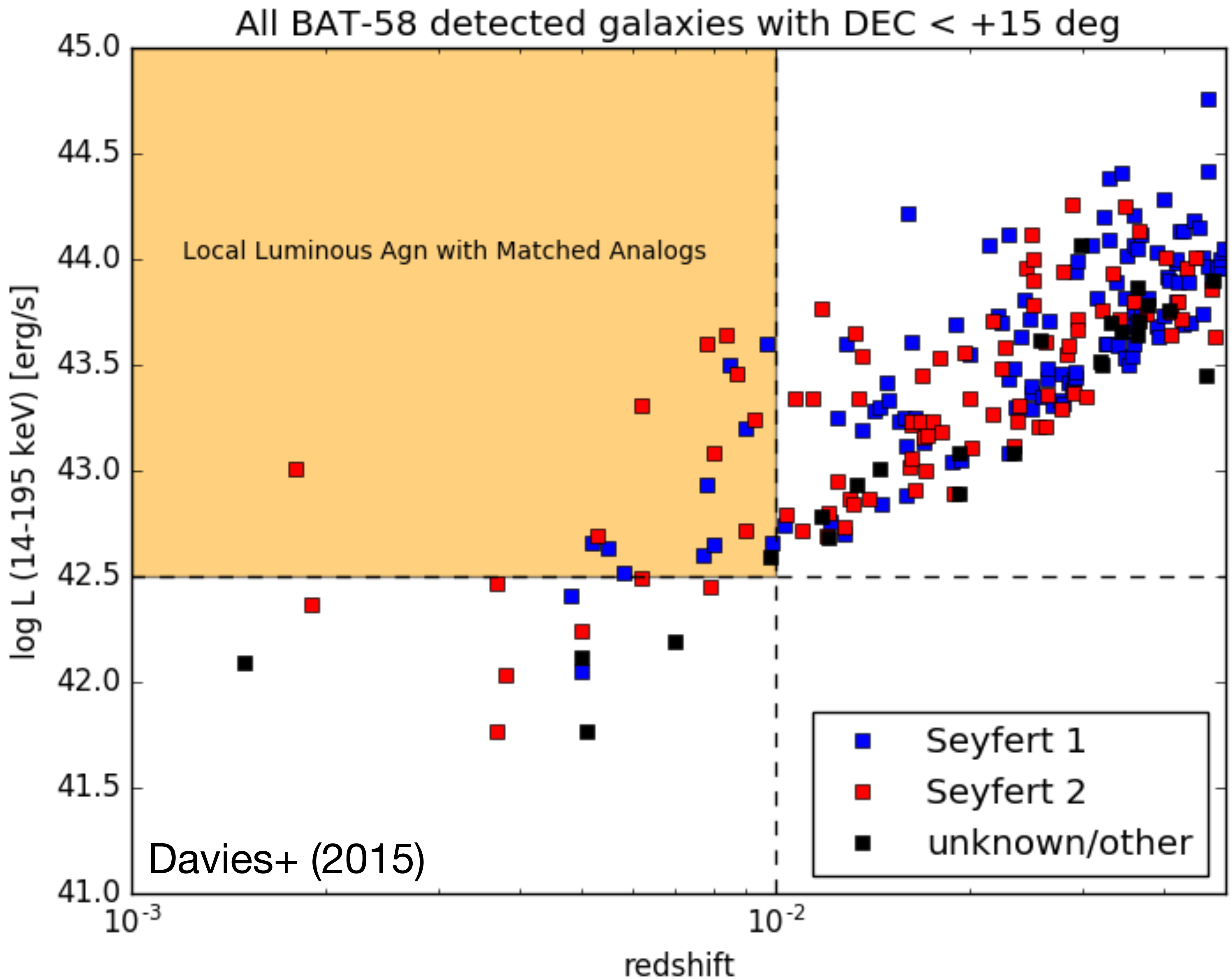
If the ratio

$E_{rad} / |E_{PE}| \sim 1$

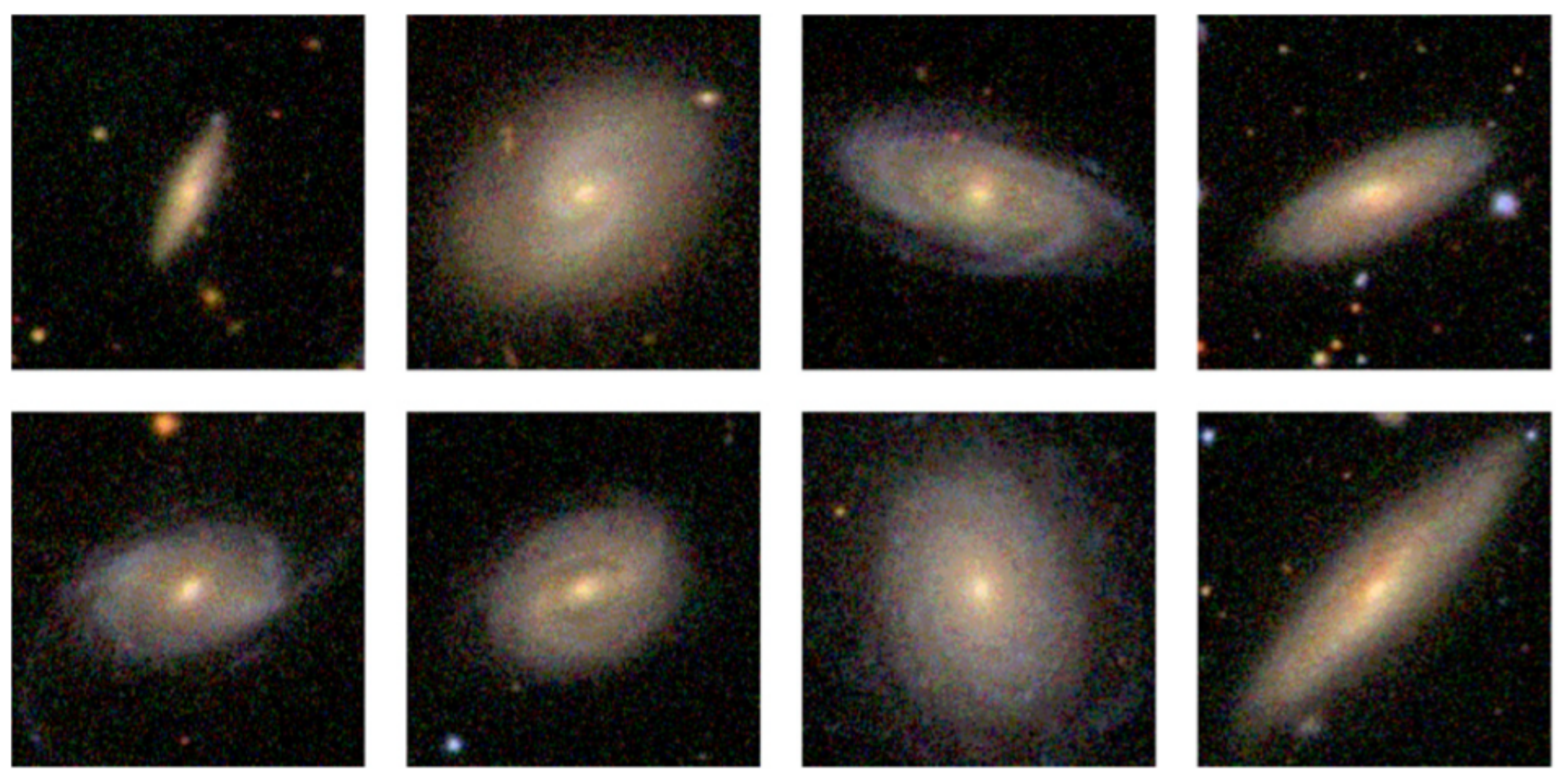
in a galaxy's central region,

the AGN can displace significant molecular gas.


LLAMA
Local
Luminous
Agn
with
Matched
Analogs
PI: Ric Davies (MPE)


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

Local AGN hosts are mostly massive disks with substantial bulges

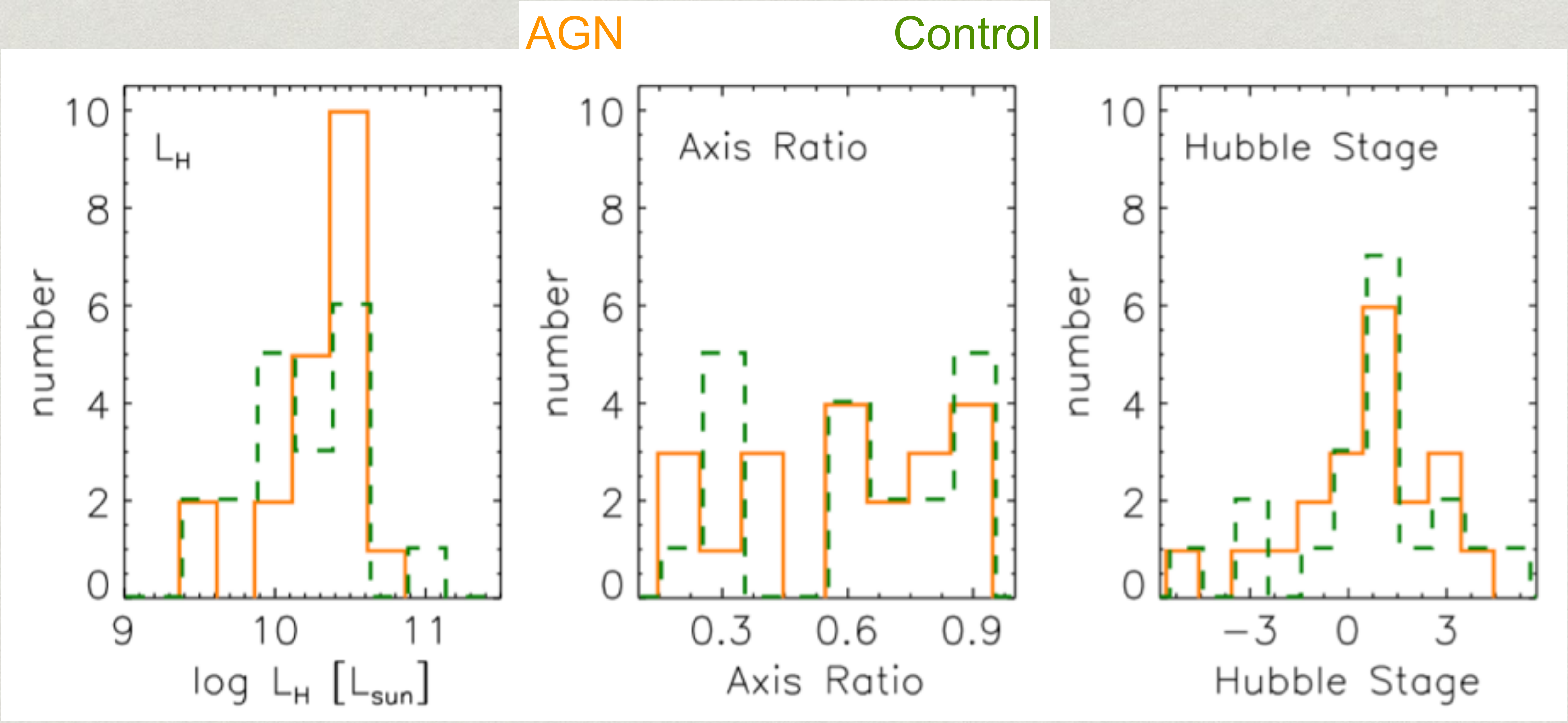


Schawinski+ (2010)

AGN are matched to a set of completely inactive galaxies

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

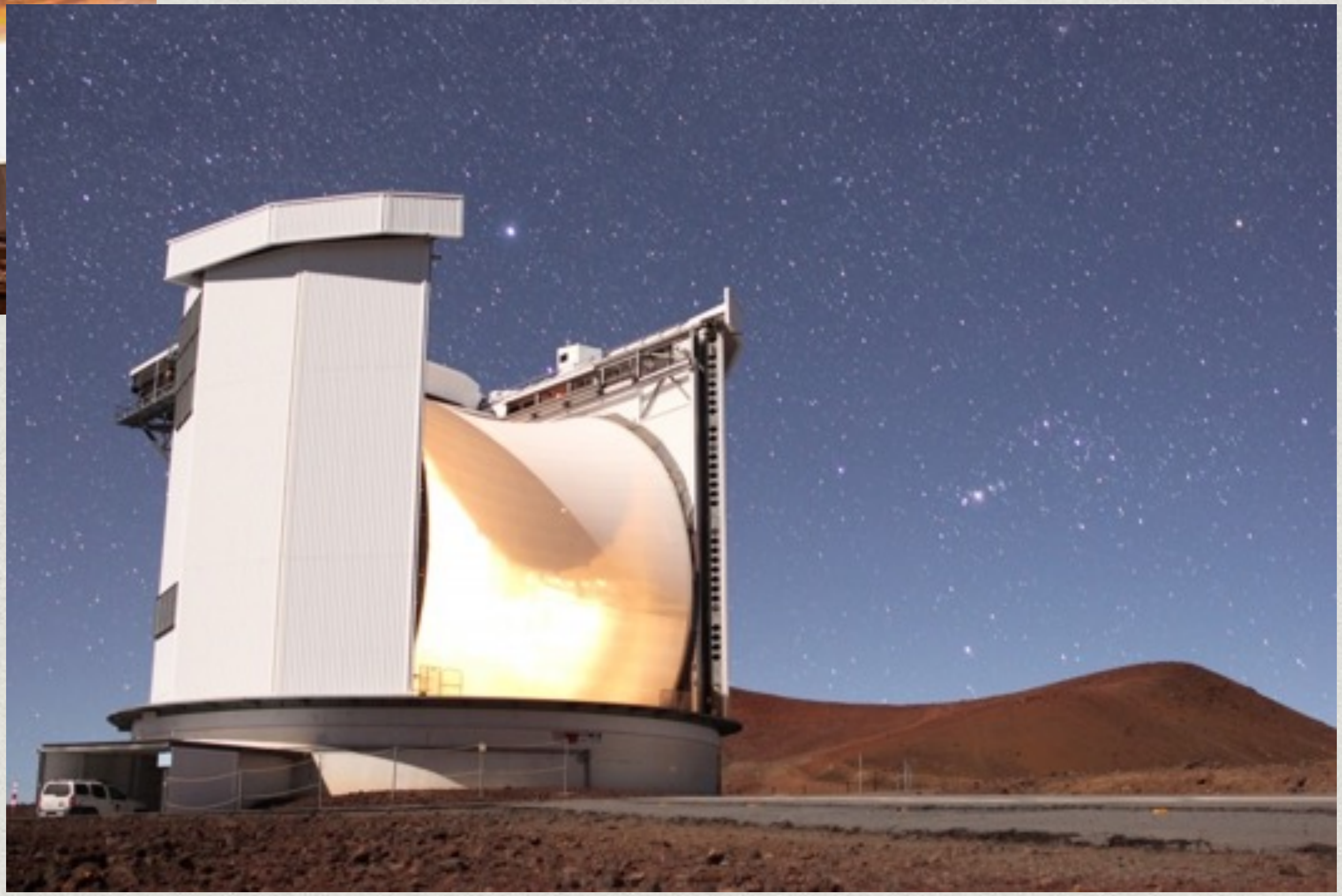
by NIR luminosity, galaxy morphology and inclination



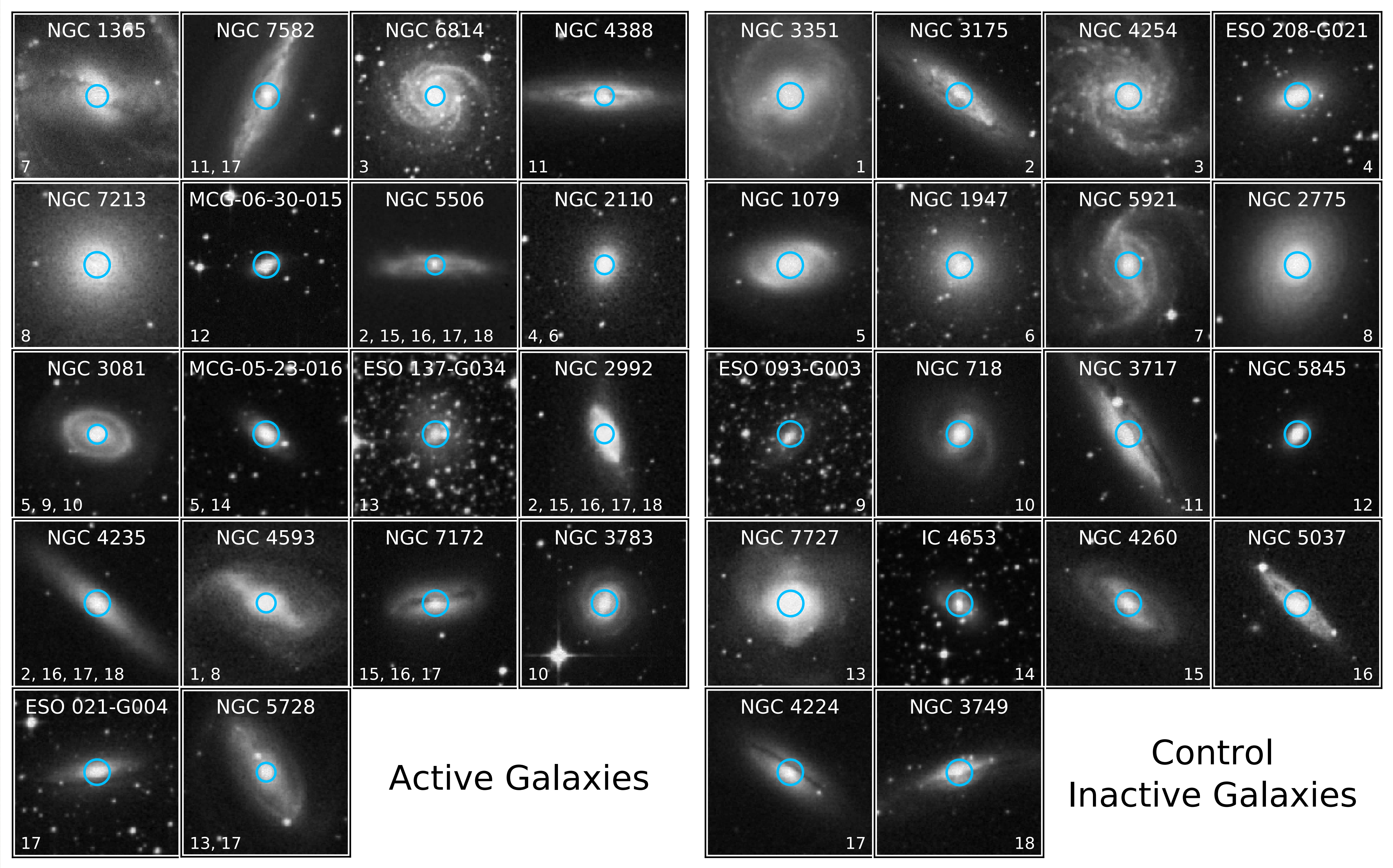
Davies+ (2015)

Millimetre telescopes for the South

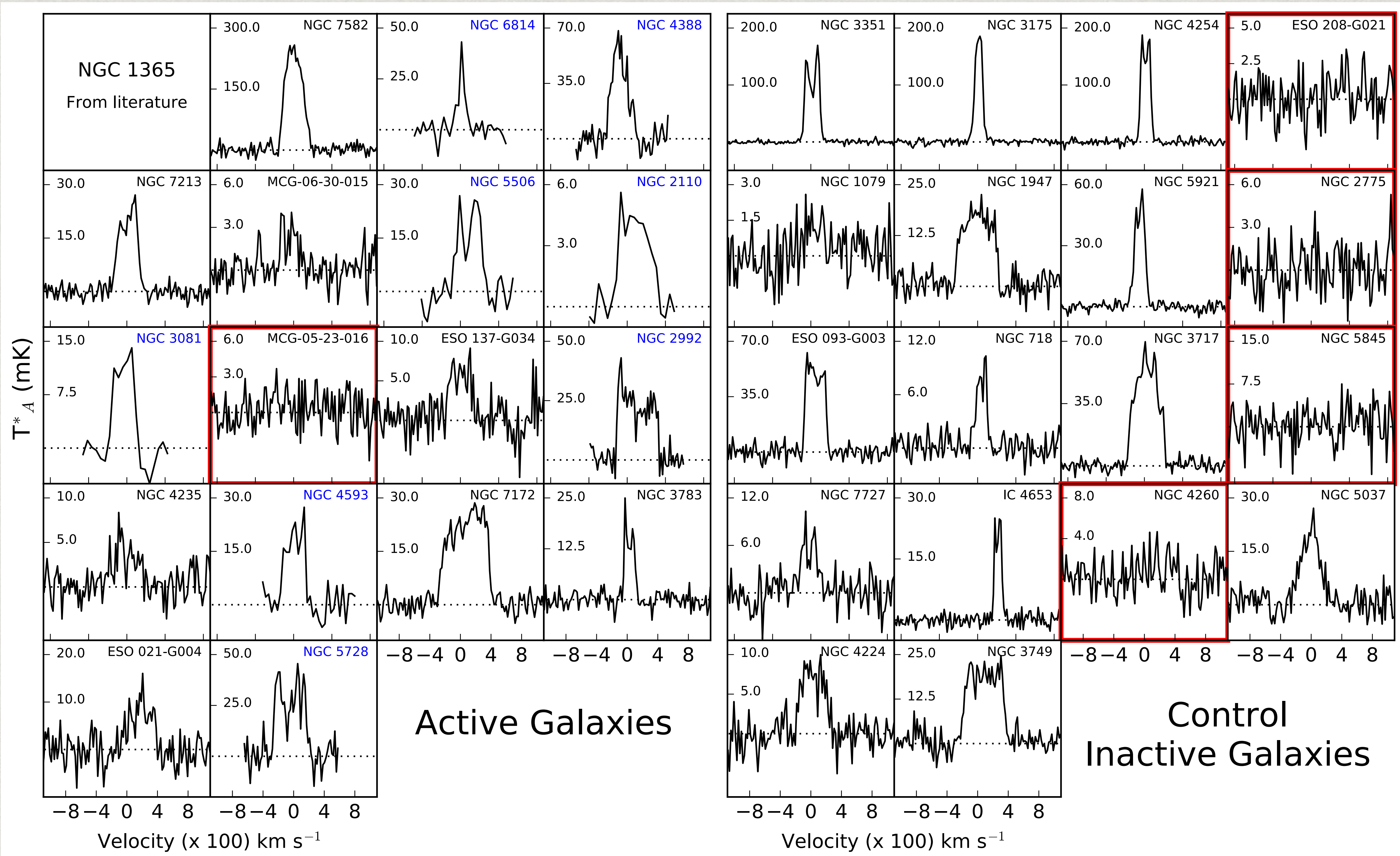
APEX 12m, Chajnantor, Chile



JCMT 15m, Mauna Kea, Hawaii



DSS R-band images, 3’ on a side



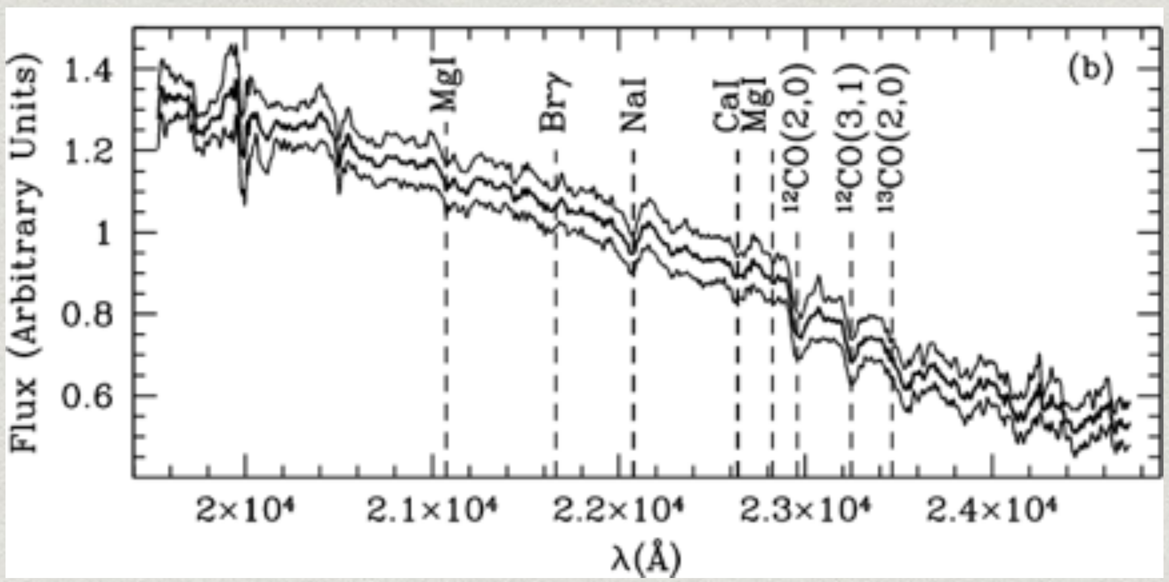
CO 2→1 spectra of 36 galaxies (18 active/18 inactive)

~90% detected with S/N > 3 detections

Central Stellar Masses

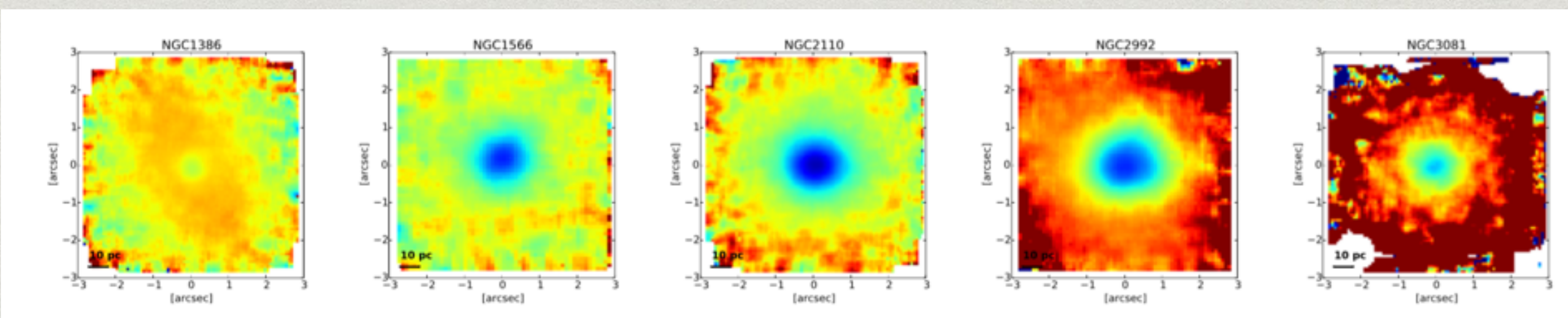
A) Step 1: Measure the stellar mass over the CO beam

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 → $M_\star$

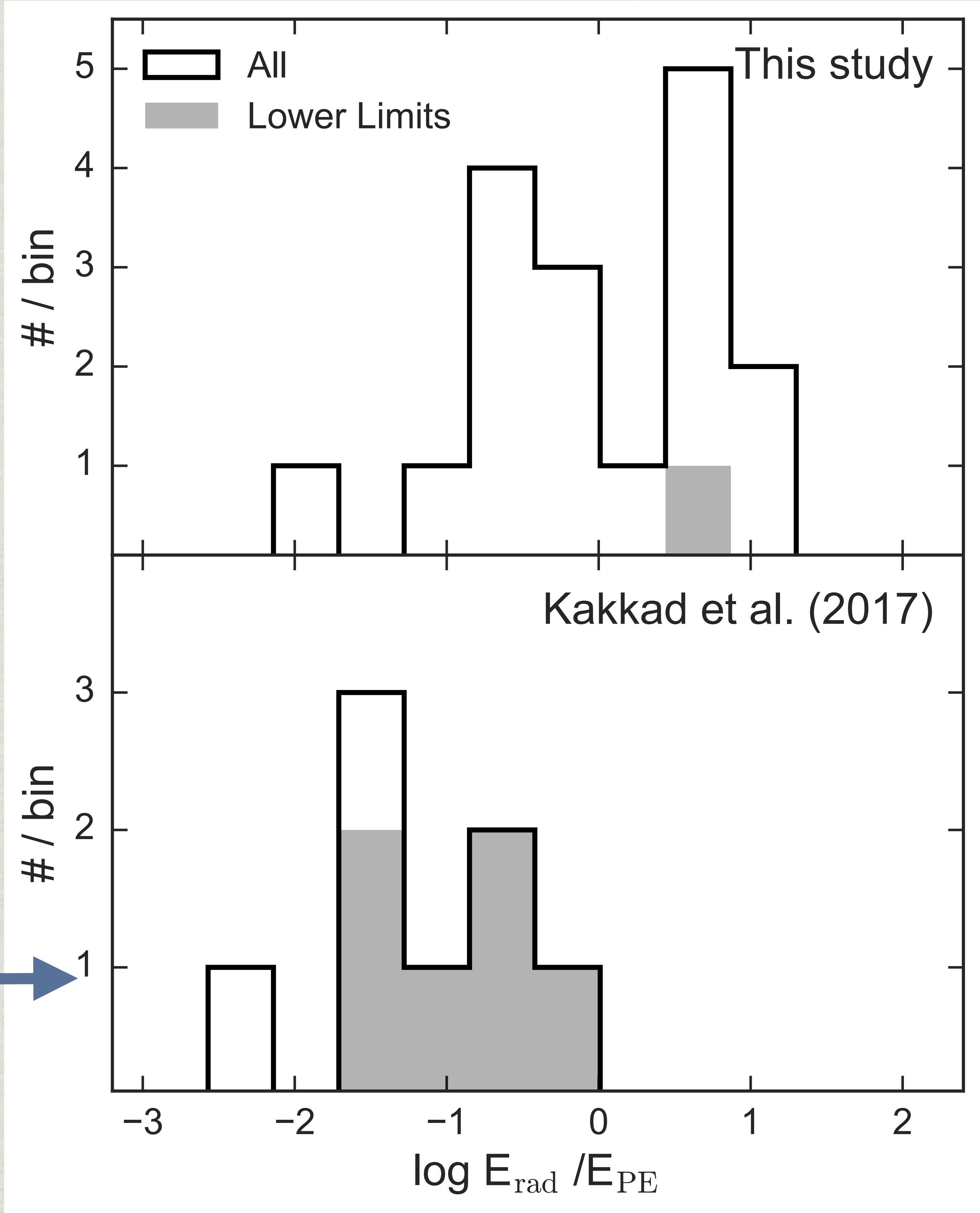
c) CO luminosity → M_{H2}

d) R_{beam} = CO beamsize

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

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

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



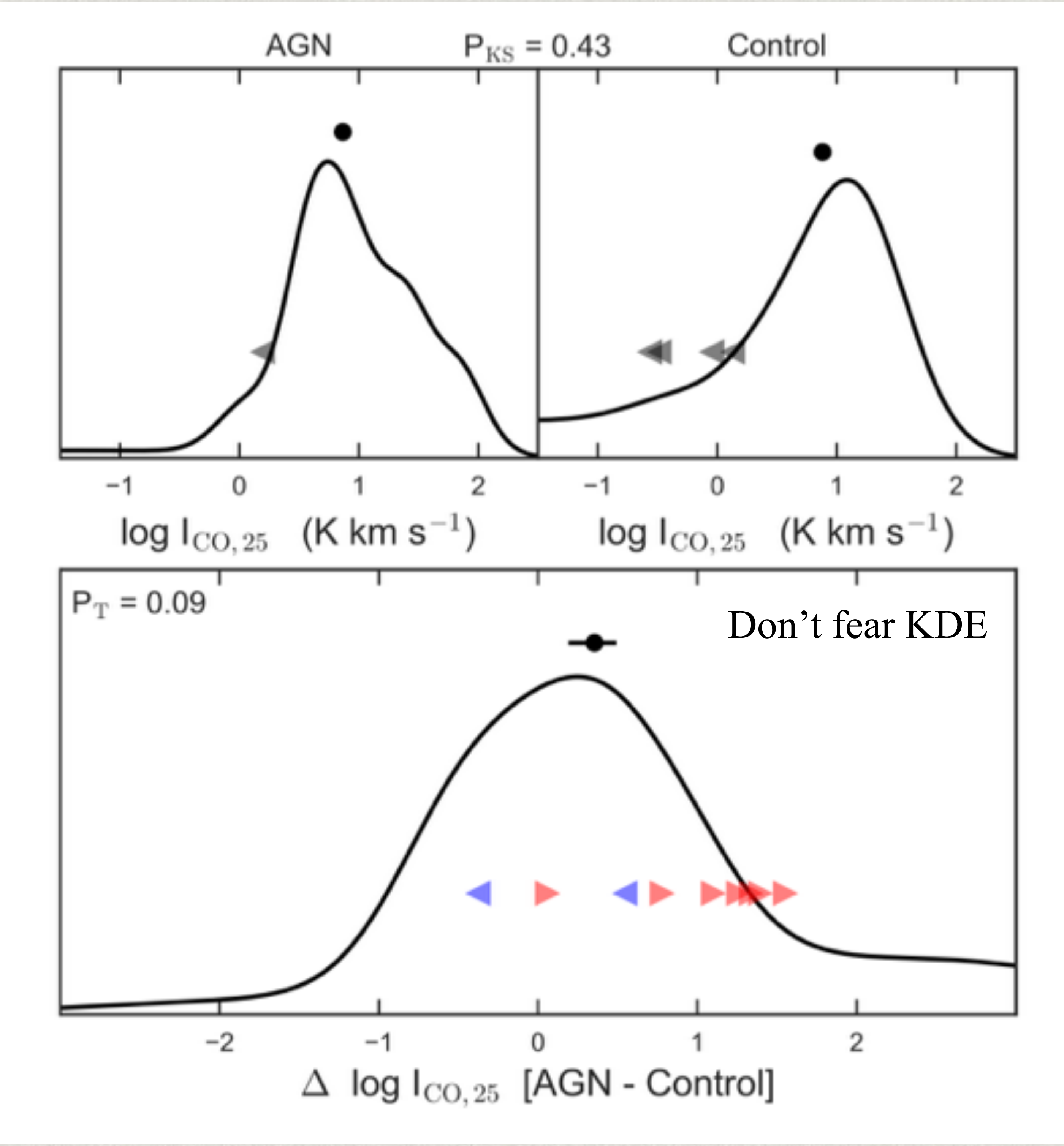
Among 50% of the LLAMA AGN, there is enough nuclear power to potentially destroy molecular gas on kpc scales.

The physics uncovered in nearby Seyferts is relevant to 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:

a) The molecular gas fraction (f_{gas}): If AGN destroy or drive away molecular gas, f_{gas} will drop.

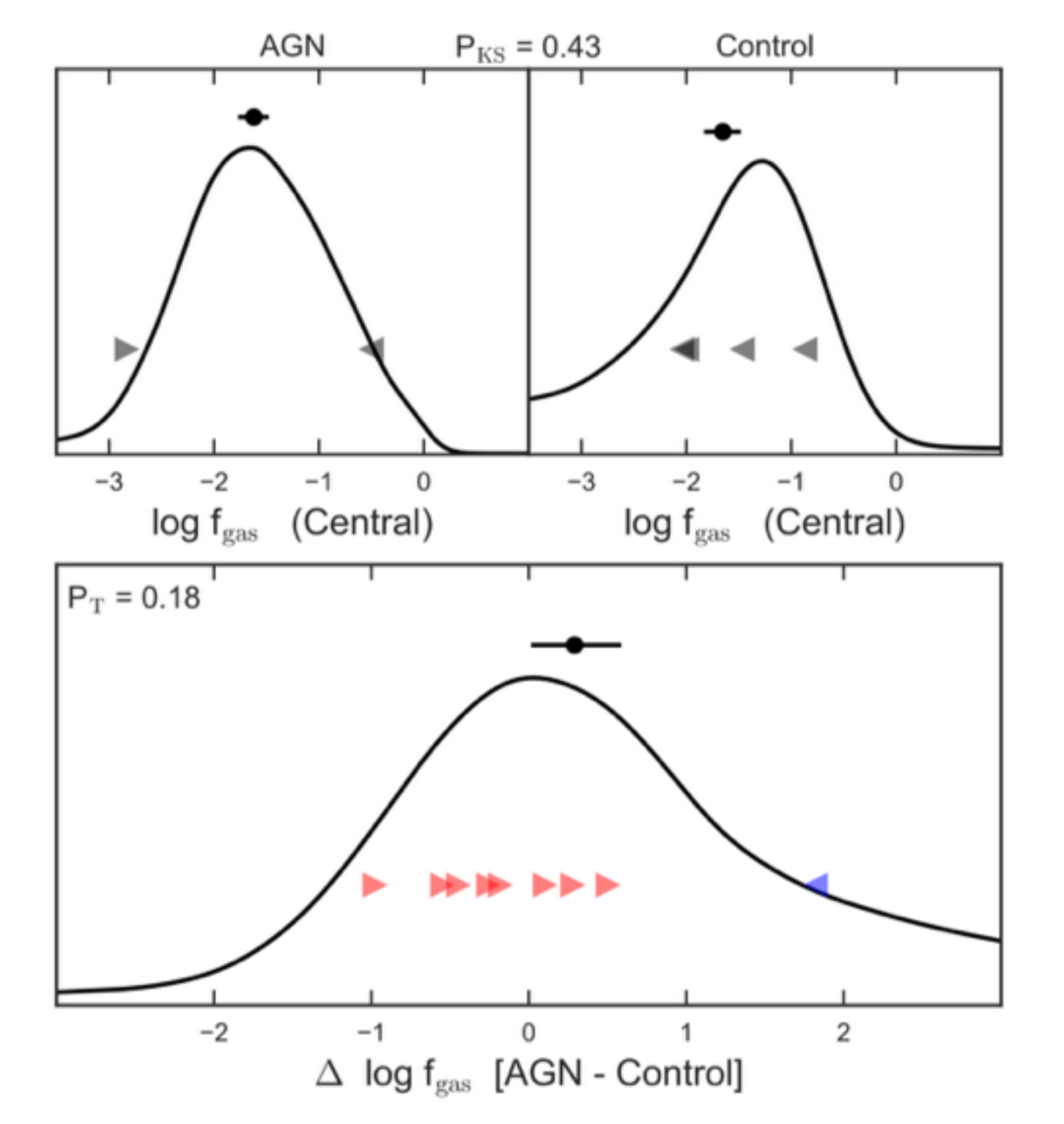
>> We also need the central stellar mass.

b) The star formation efficiency (SFR / M_{H2}): If AGN destabilise molecular clouds, the SFE will drop (negative feedback) or rise (positive feedback).

>> We also need the central star formation rate.

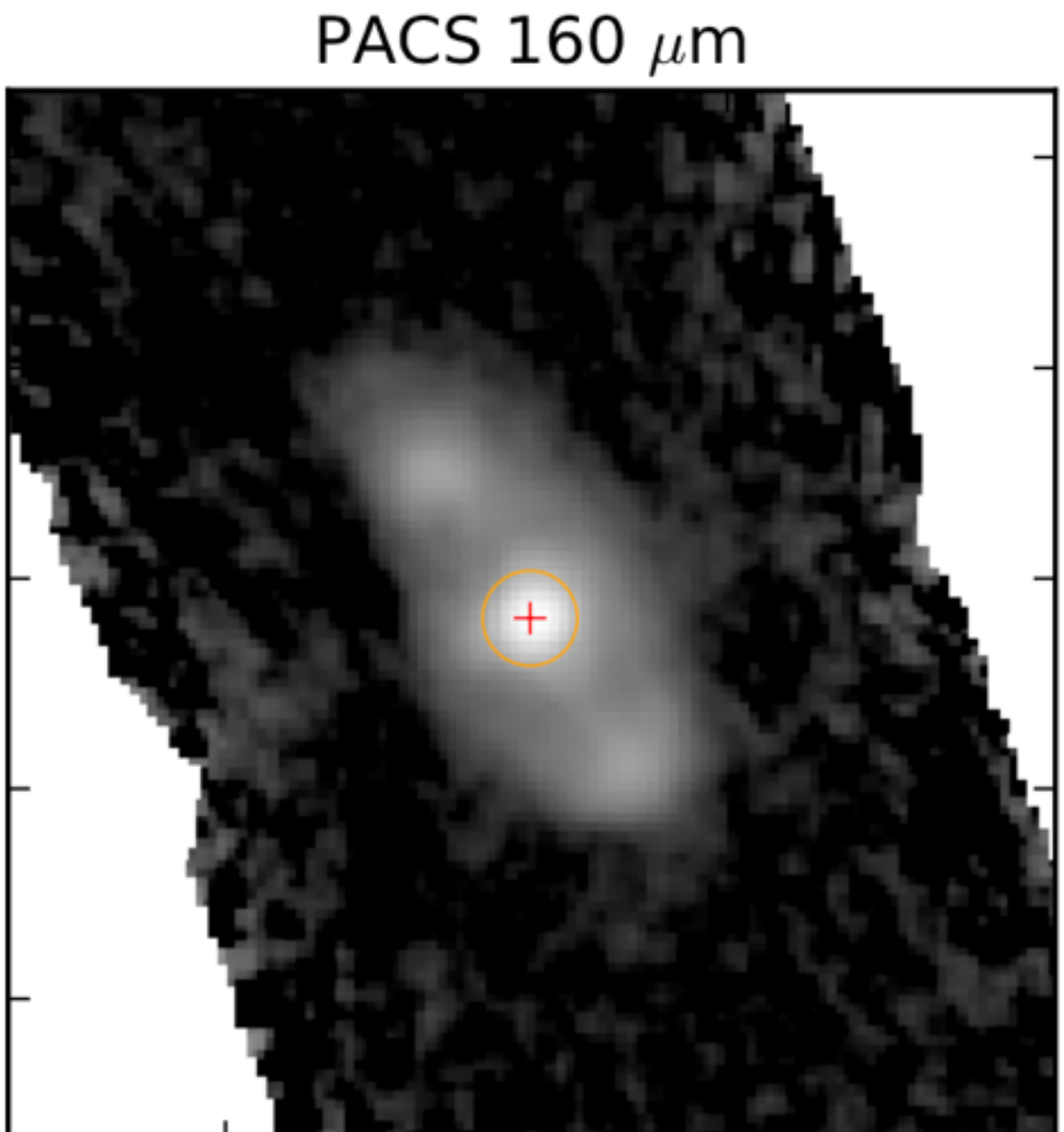
Molecular gas fractions

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

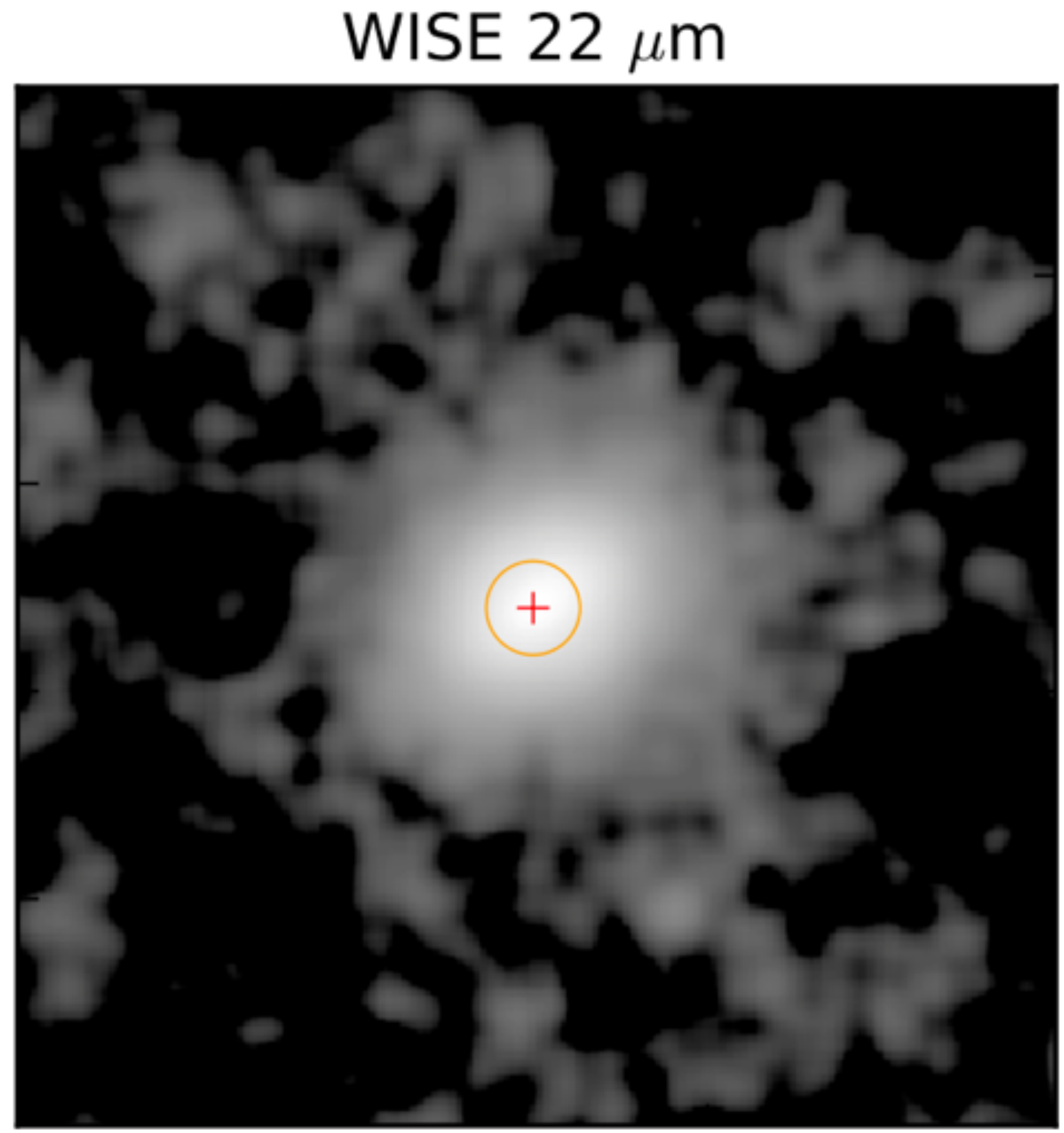


Central Star Formation Rates

NGC 5728



NGC 1947



FortesFit

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

Many Bayesian SED fitting codes are on the market, but…

- Most are not truly Bayesian - they can only handle flat priors.
- Models are only evaluated on a grid, complicated likelihoods.
- Most have limited freedom with models. Adding models is a development effort.
- Some priors are hard-wired, e.g., “energy balance”.

FortesFit

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

FortesFit addresses these issues with:

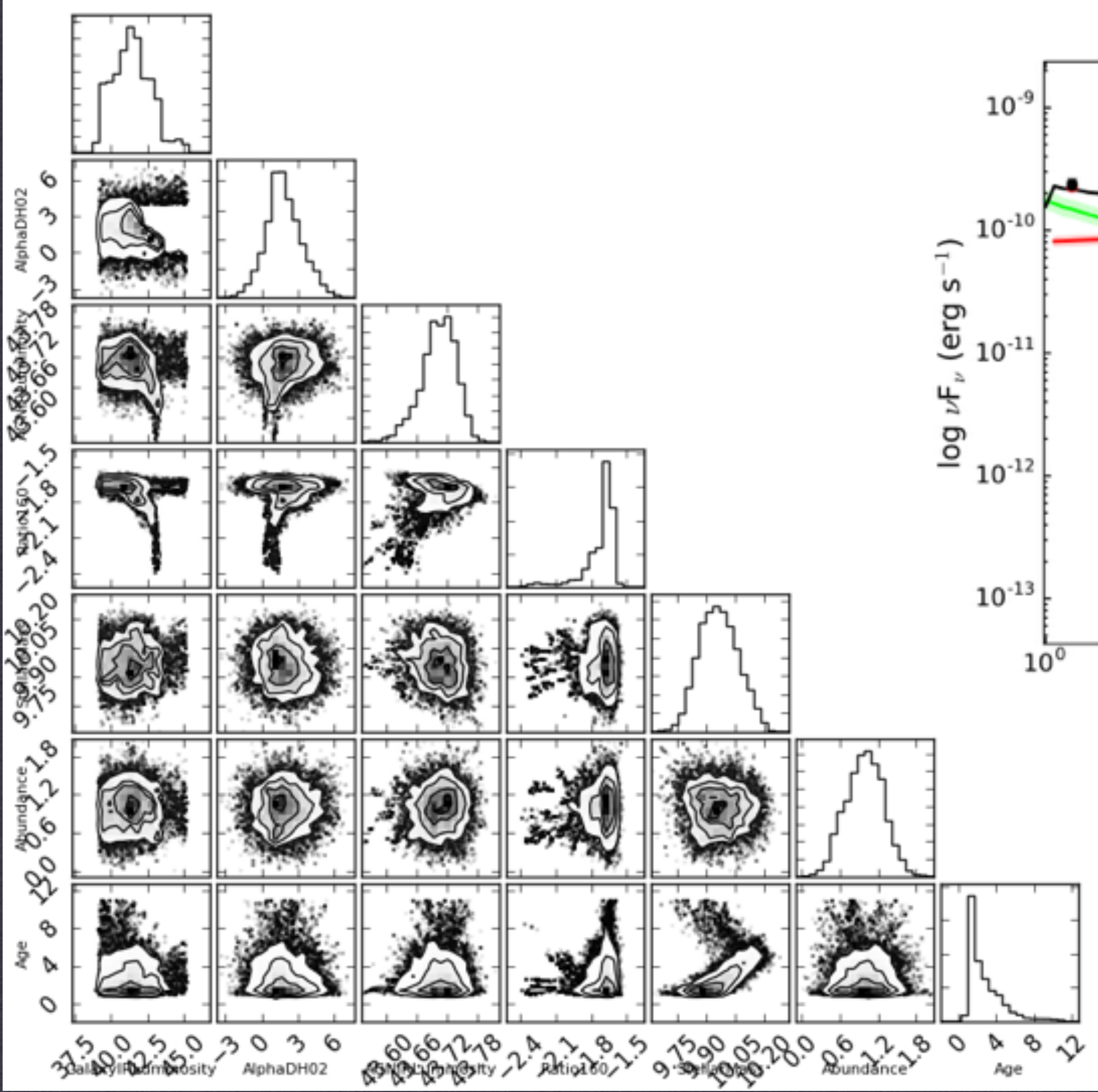
- ✓ A general approach to painlessly add any parameterised SED model, and combine them in the fit.
- ✓ A full treatment of continuous, informative priors, including SciPy stats distributions.
- ✓ Functionality for hyperpriors (“dependencies”).
- ✓ Out of the box MCMC and the capability to add other fitting engines with minor development.

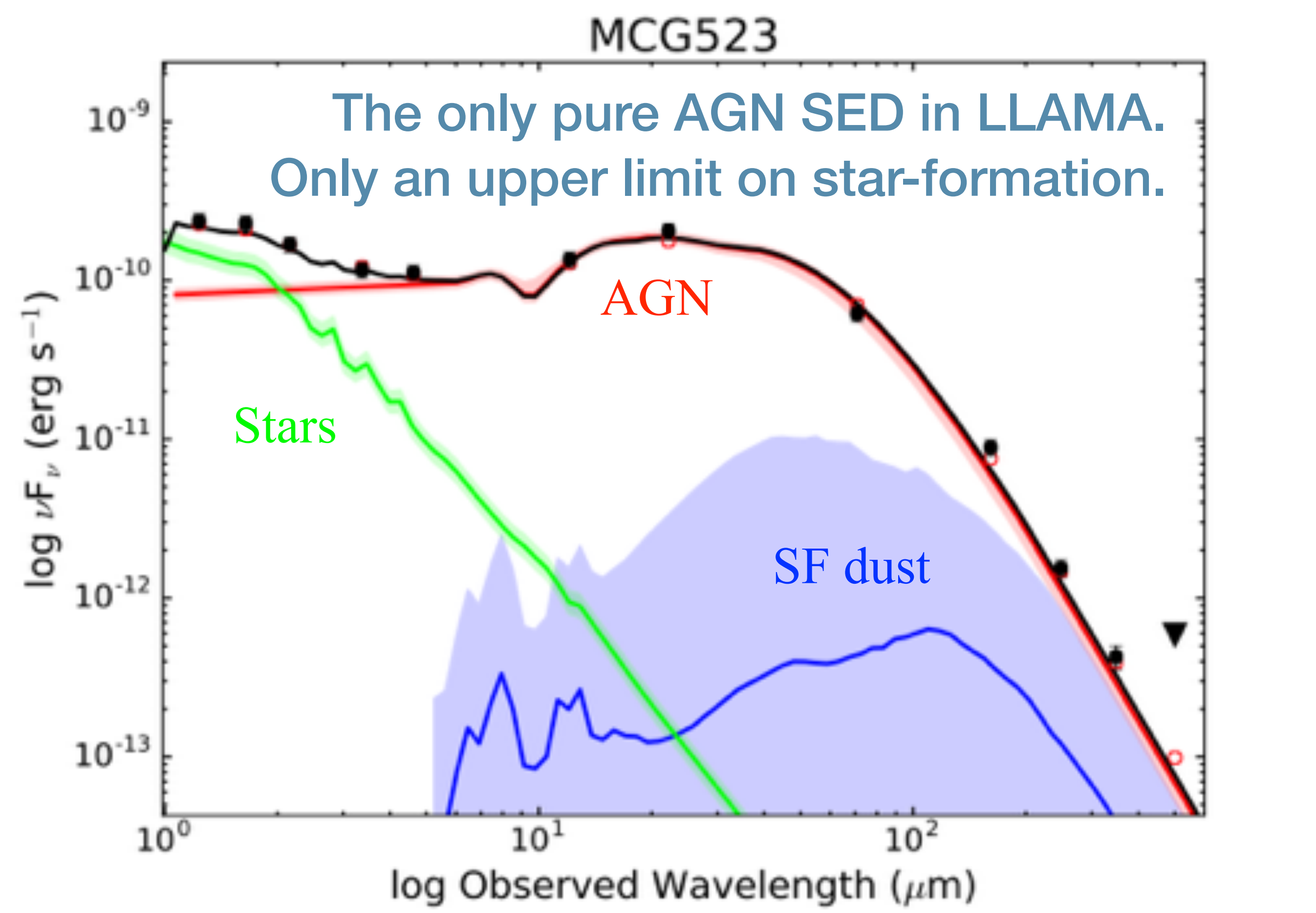
Code has been put into public domain, has been used in a published paper, and is in development for used with the KASHz and BASS programs.

Looking for co-developers, testers, users.

FortesFit

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

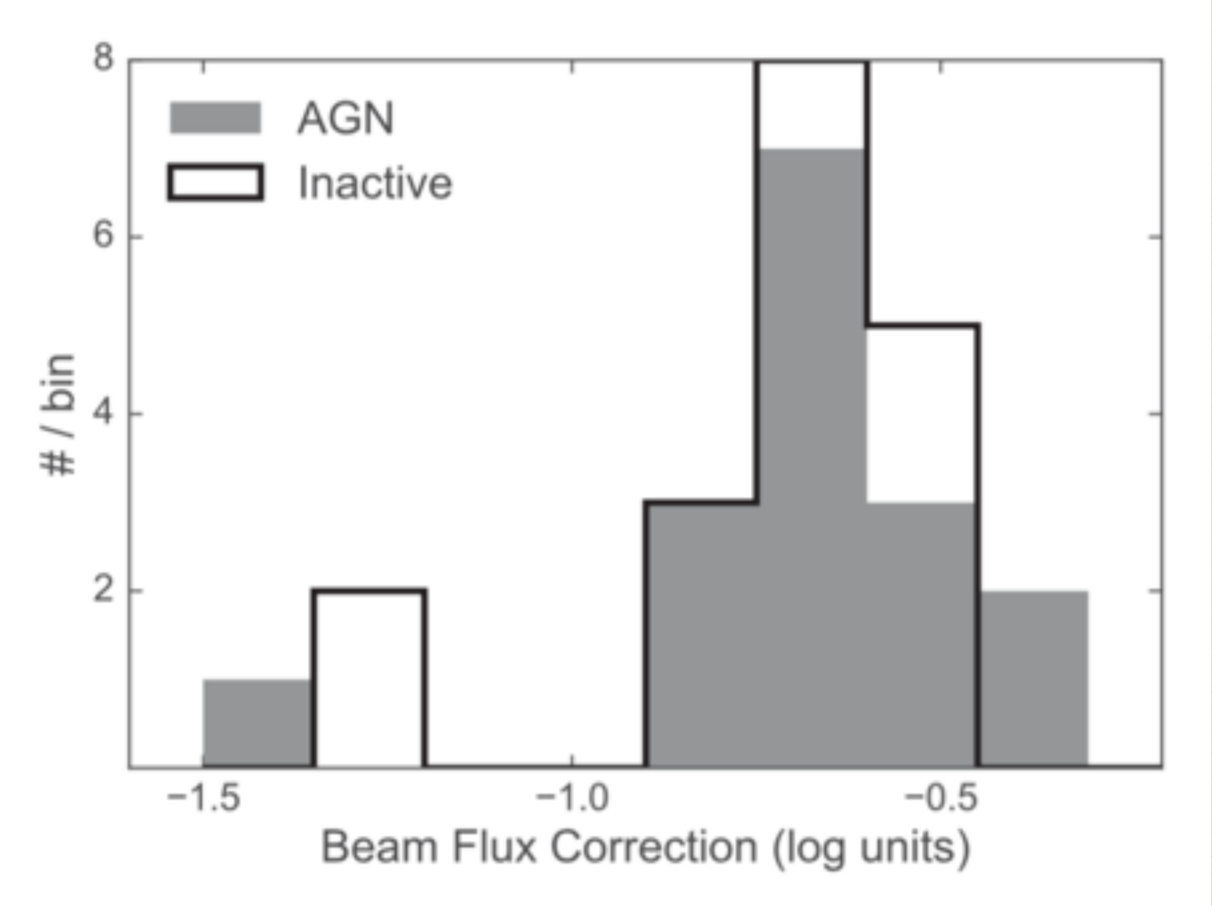




A three component fit: stellar SSP, multi-shape IR AGN model, dust from SF

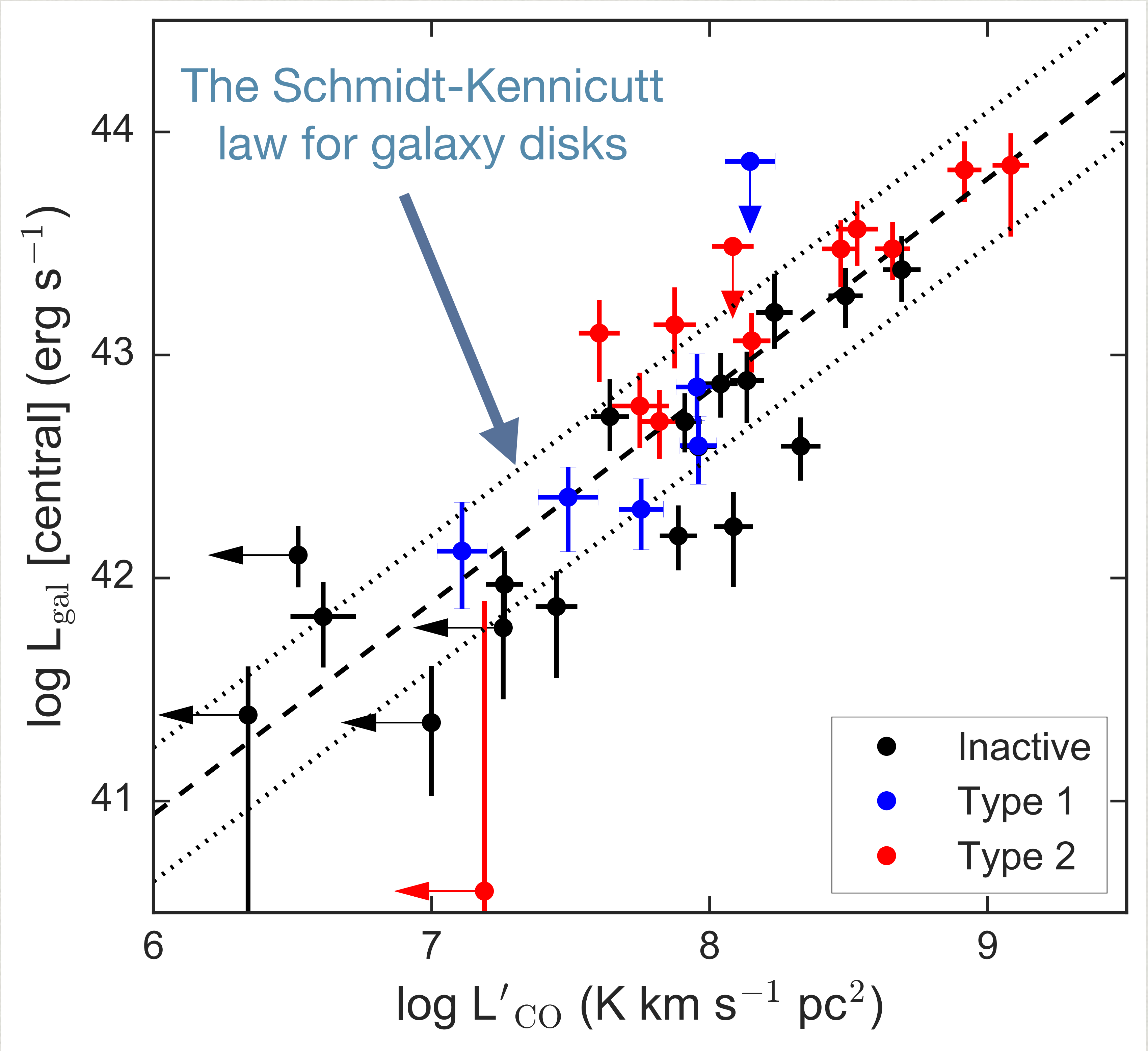
Central Star Formation Rates

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.

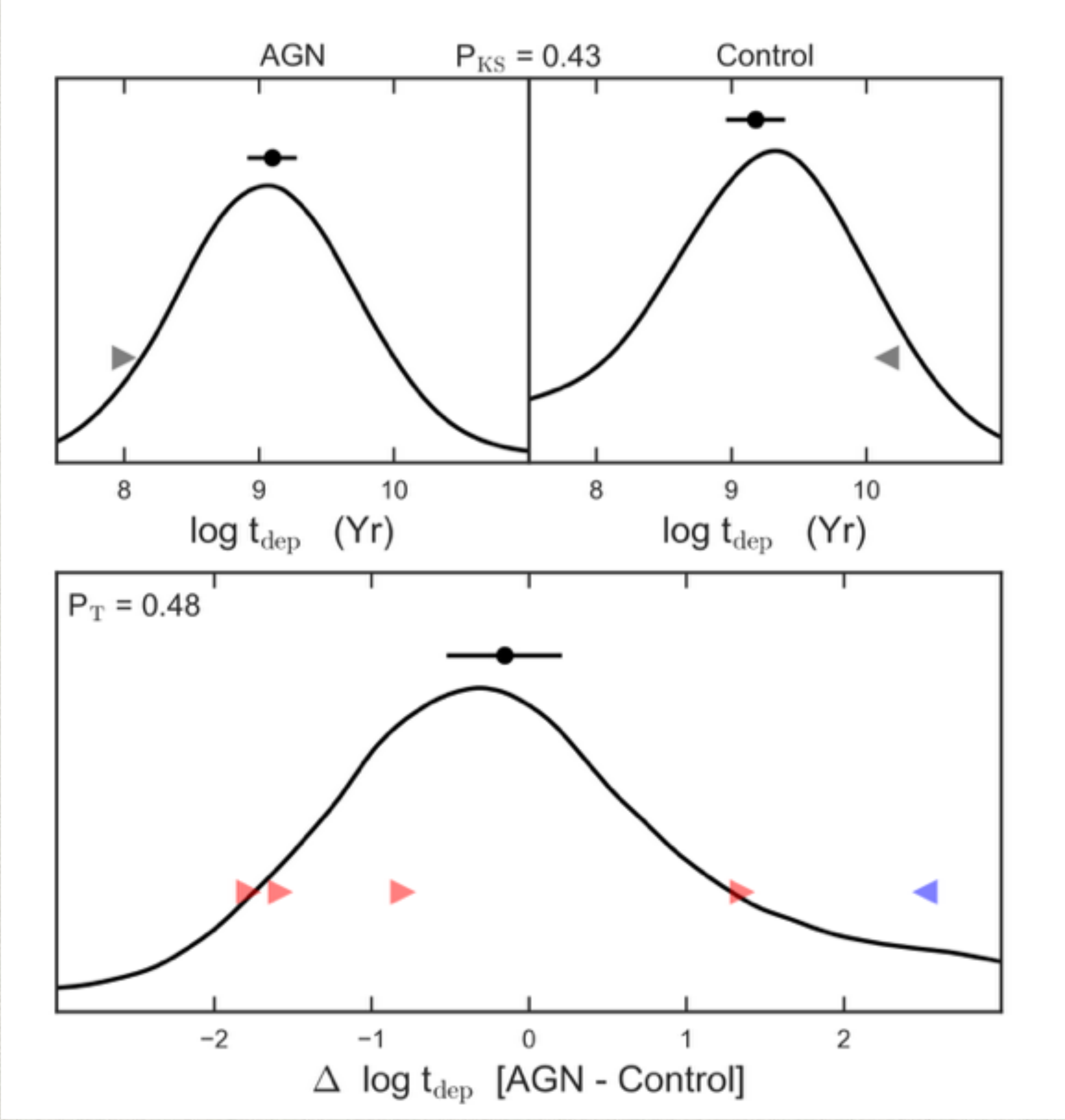
The star-formation efficiency of the central molecular gas



Molecular gas "depletion times"

The inverse of the star formation efficiency.

No statistical difference between AGN and control galaxies.



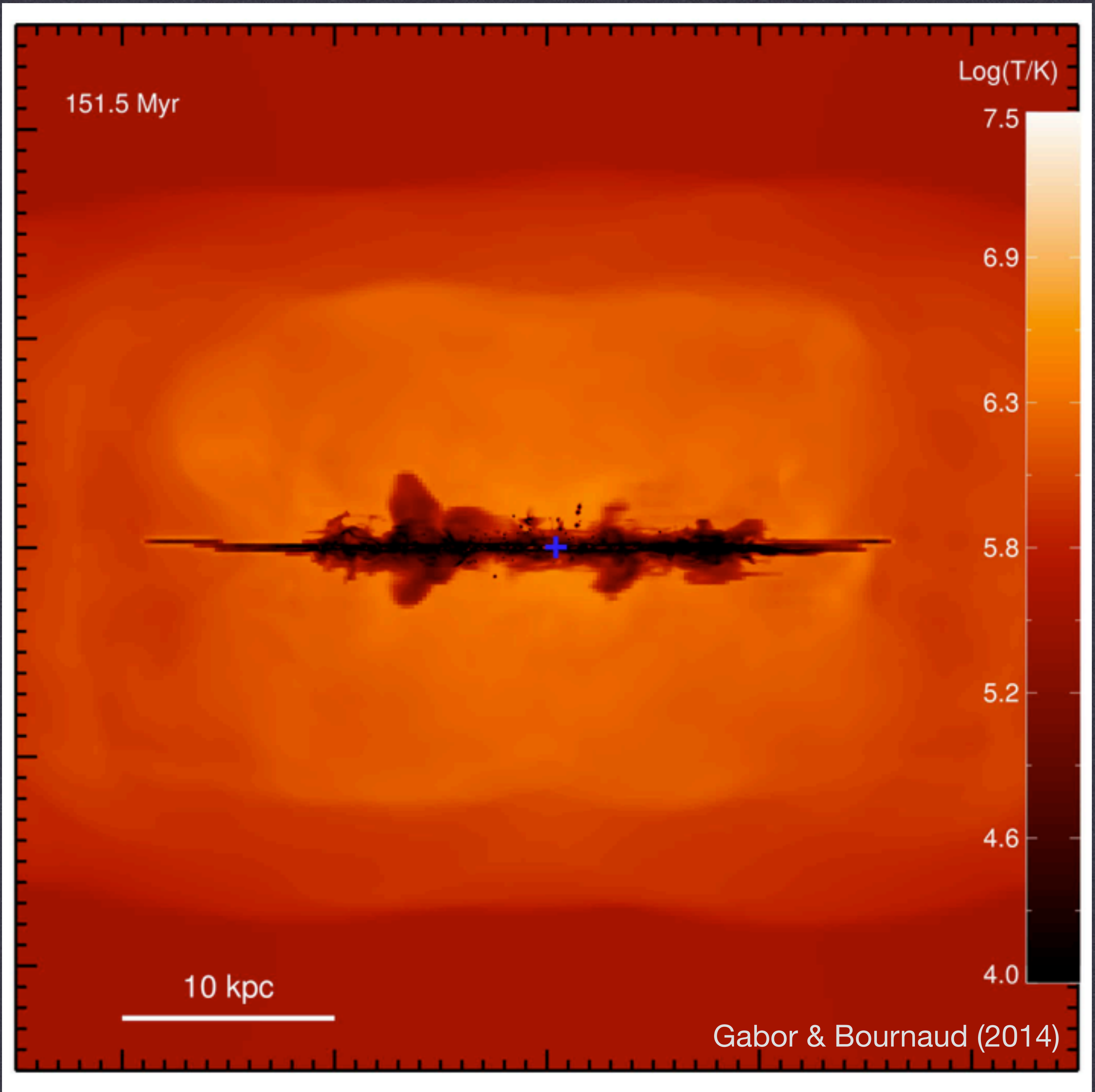
SUMMARY

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.

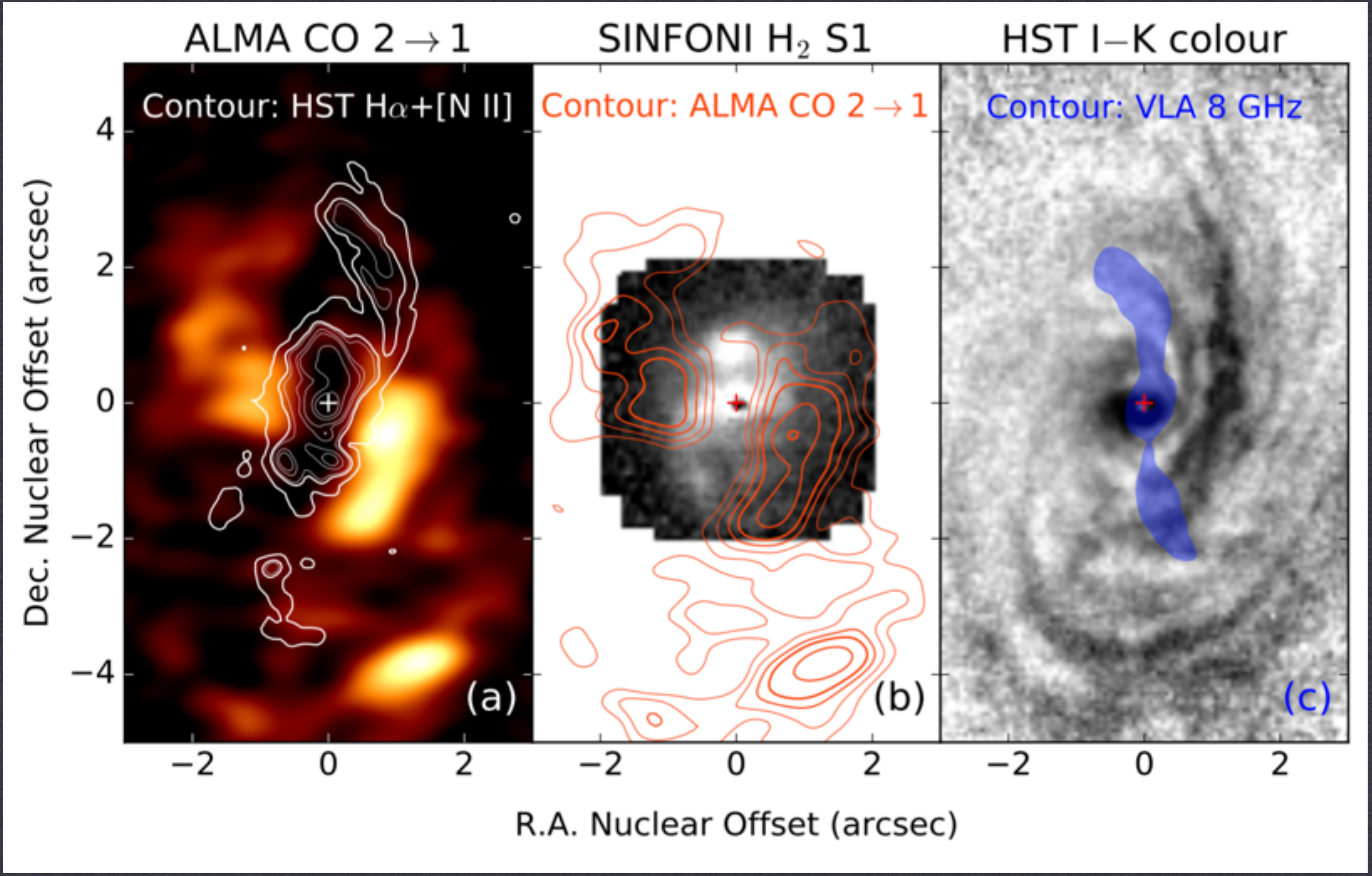
How do AGN quench galaxies?



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



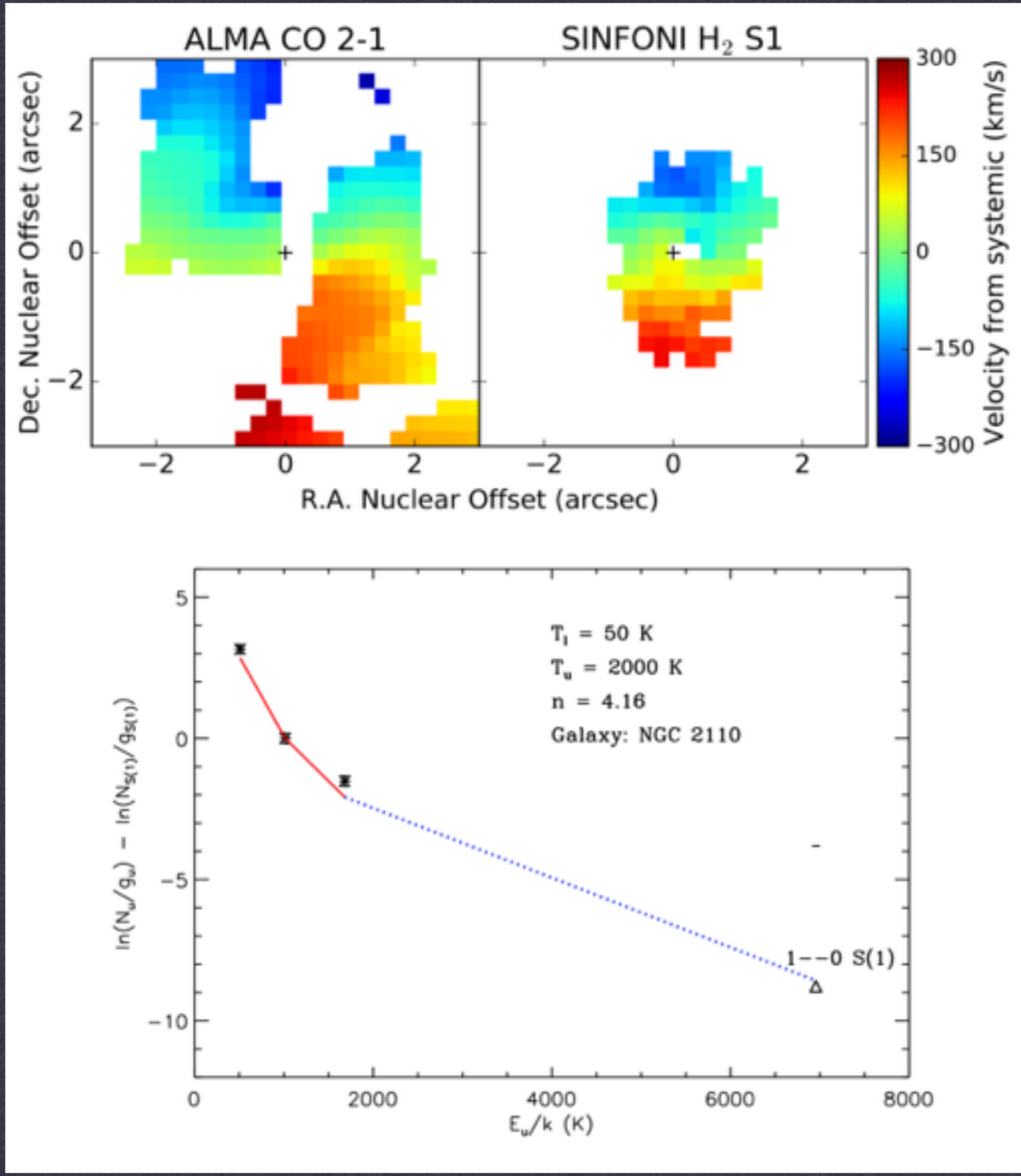
Rosario+ 2018, in prep.

NGC 2110: A CASE STUDY

Using MIR H2 lines, we find that the molecular gas surface density in the CO hole is similar to the CO-emitting gas outside.

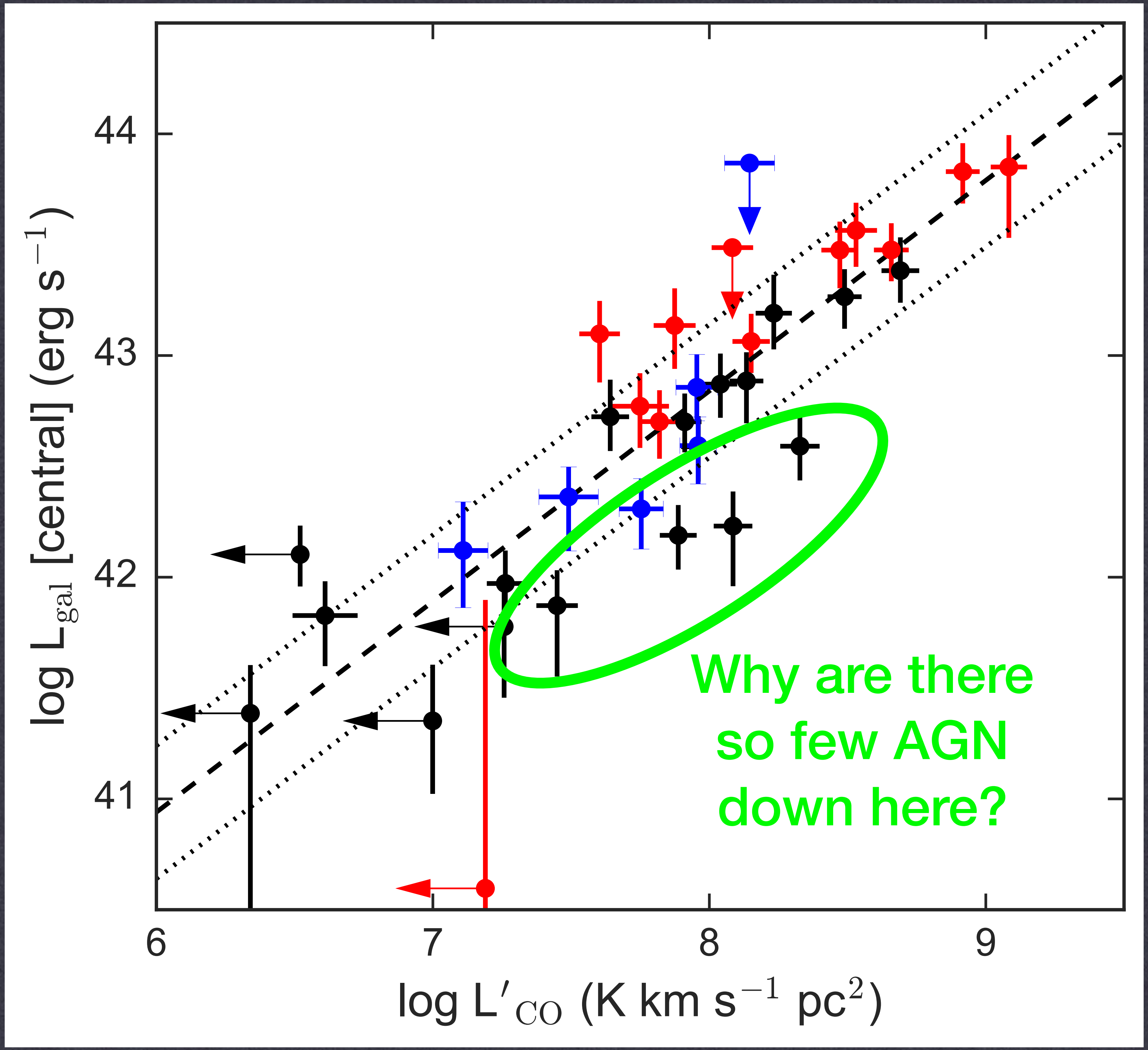
It shares the same rotation as the CO.

The AGN heats and excites the molecular gas, but it does not seem to accelerate or destroy it.



Rosario+ 2018, in prep.

SPECULATION: IS SELF-GRAVITATION A PRE-REQUISITE FOR AGN FUELLING?



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.