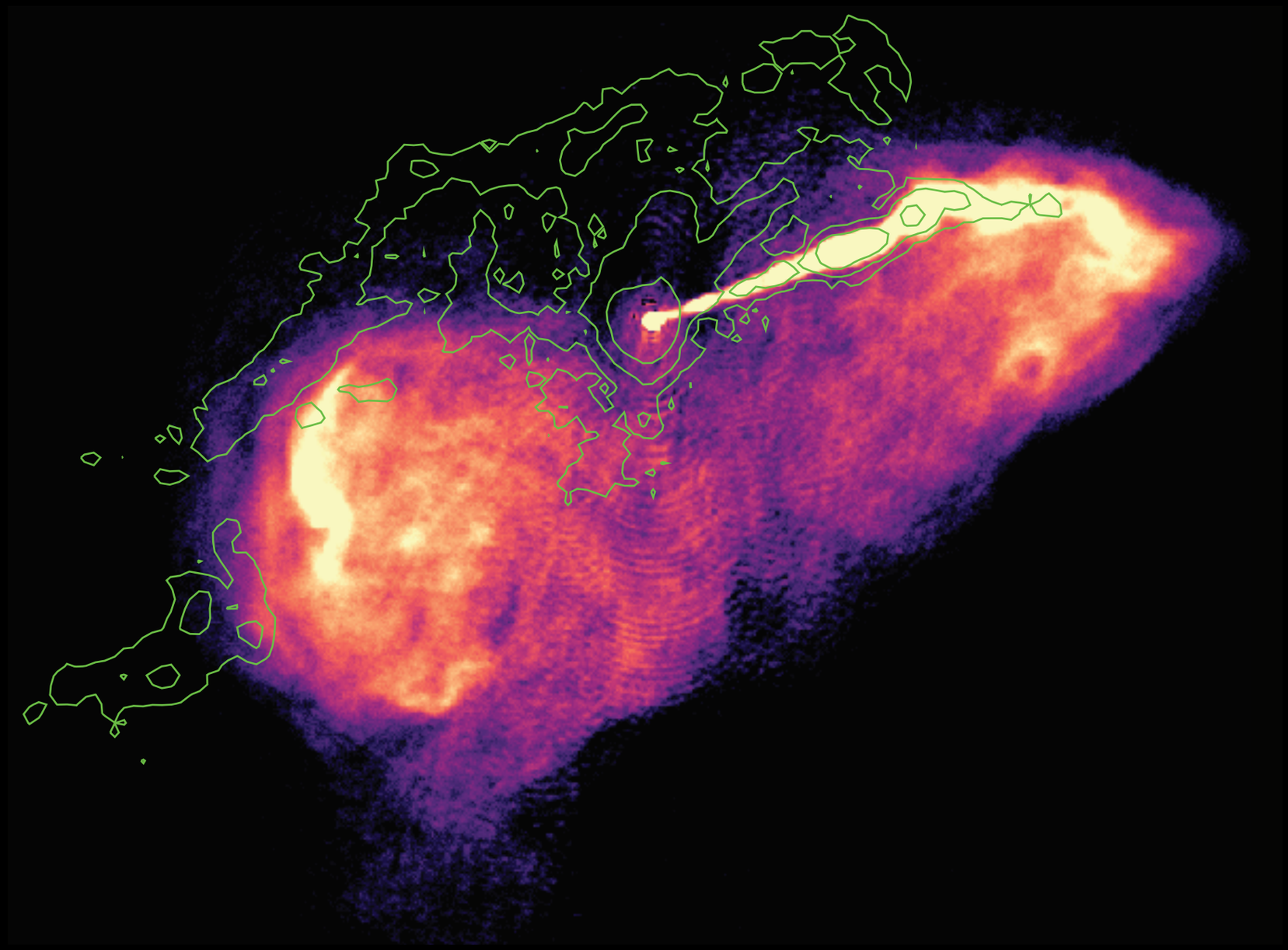
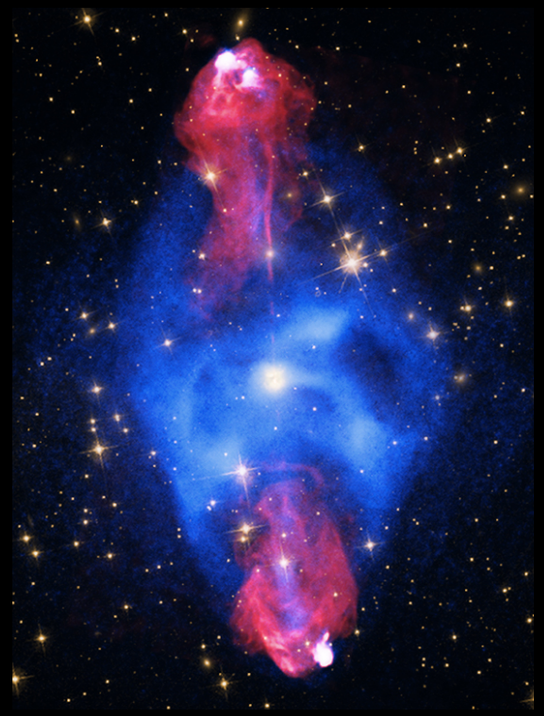
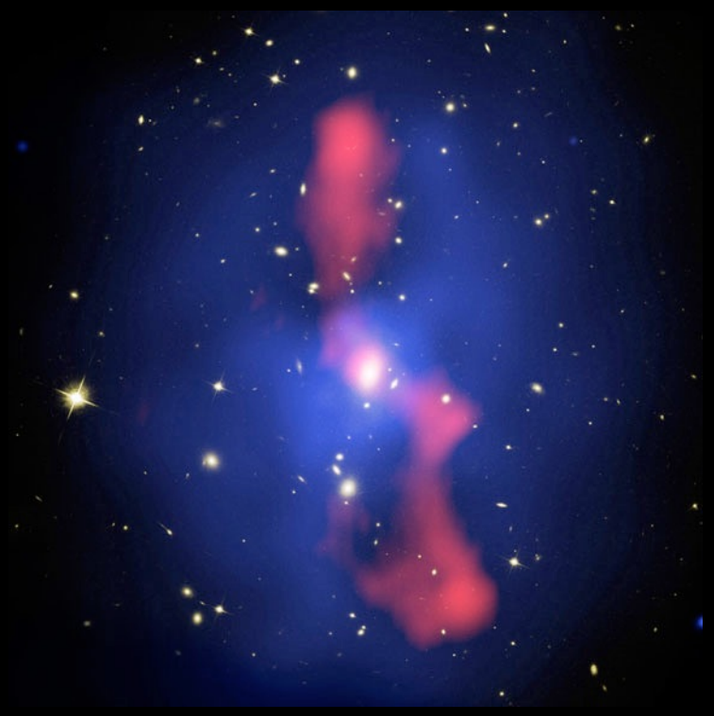
The discovery of molecular gas in the nearest cool core cluster of galaxies with ALMA



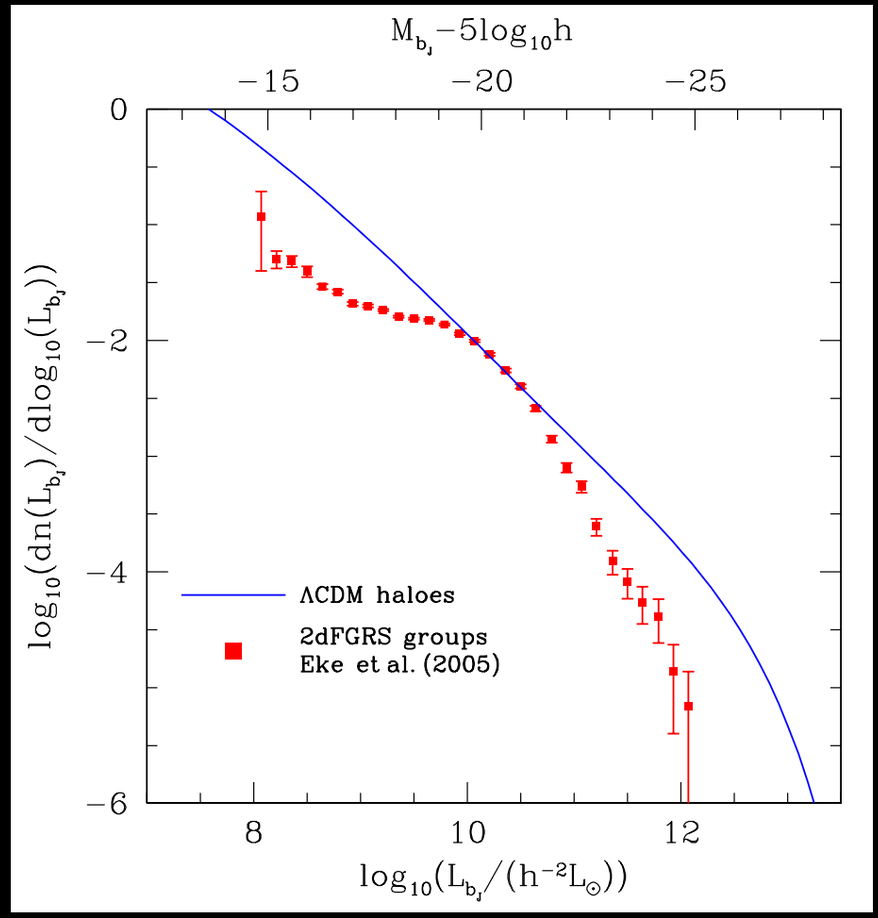
Aurora Simionescu (SRON)

CONTEXT





Globally, supermassive black holes provide the heating necessary to prevent the (excessive) formation of stars in the most massive galaxies

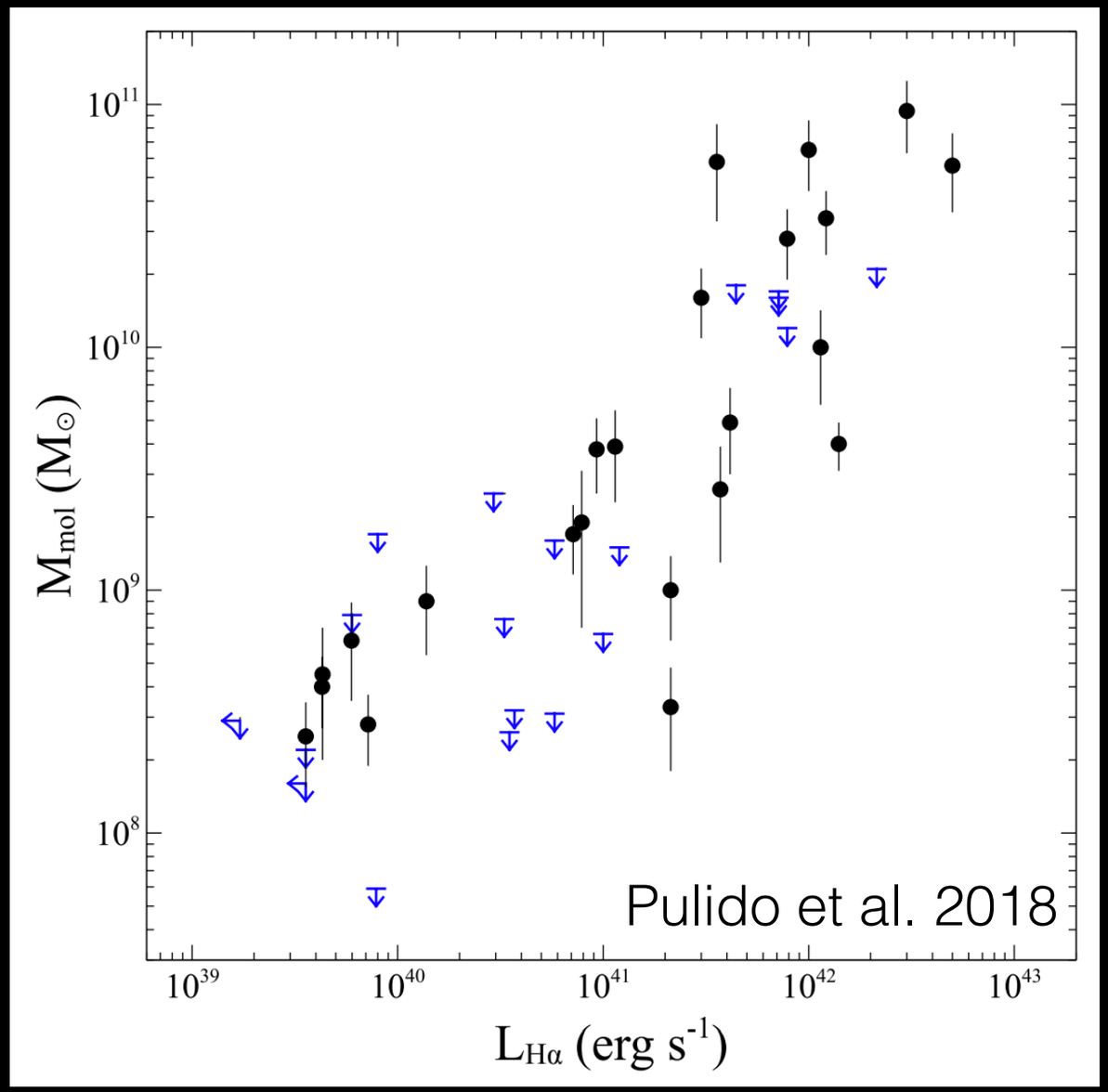


Phoenix Cluster
(Russell et al. 2017)

Thermal instabilities promote **localised** cooling

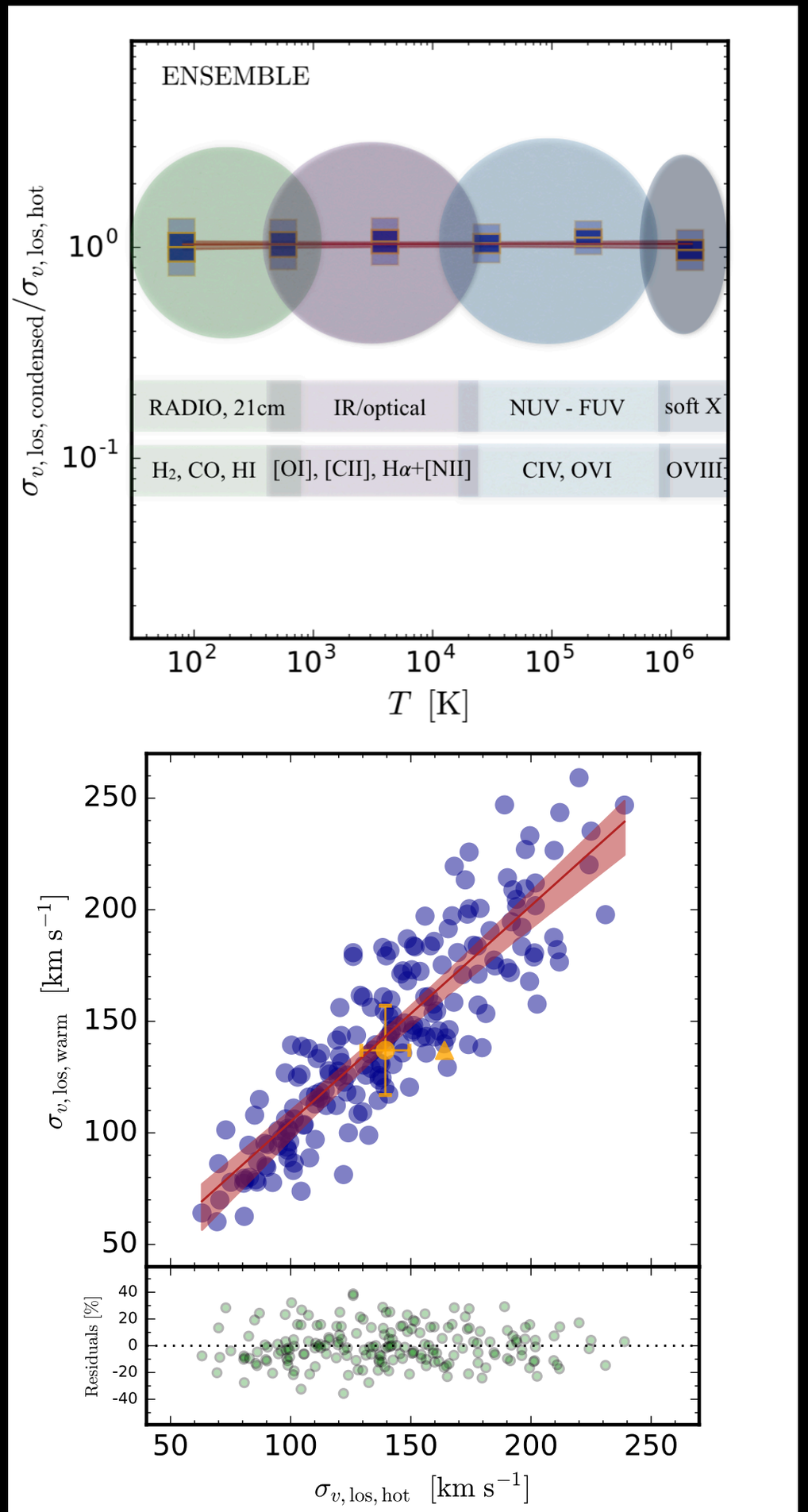
The cold gas is probably an important source of accretion onto the black hole, triggering further feedback events

Once thermal instabilities take place, cooling cascades through all phases down to molecular gas

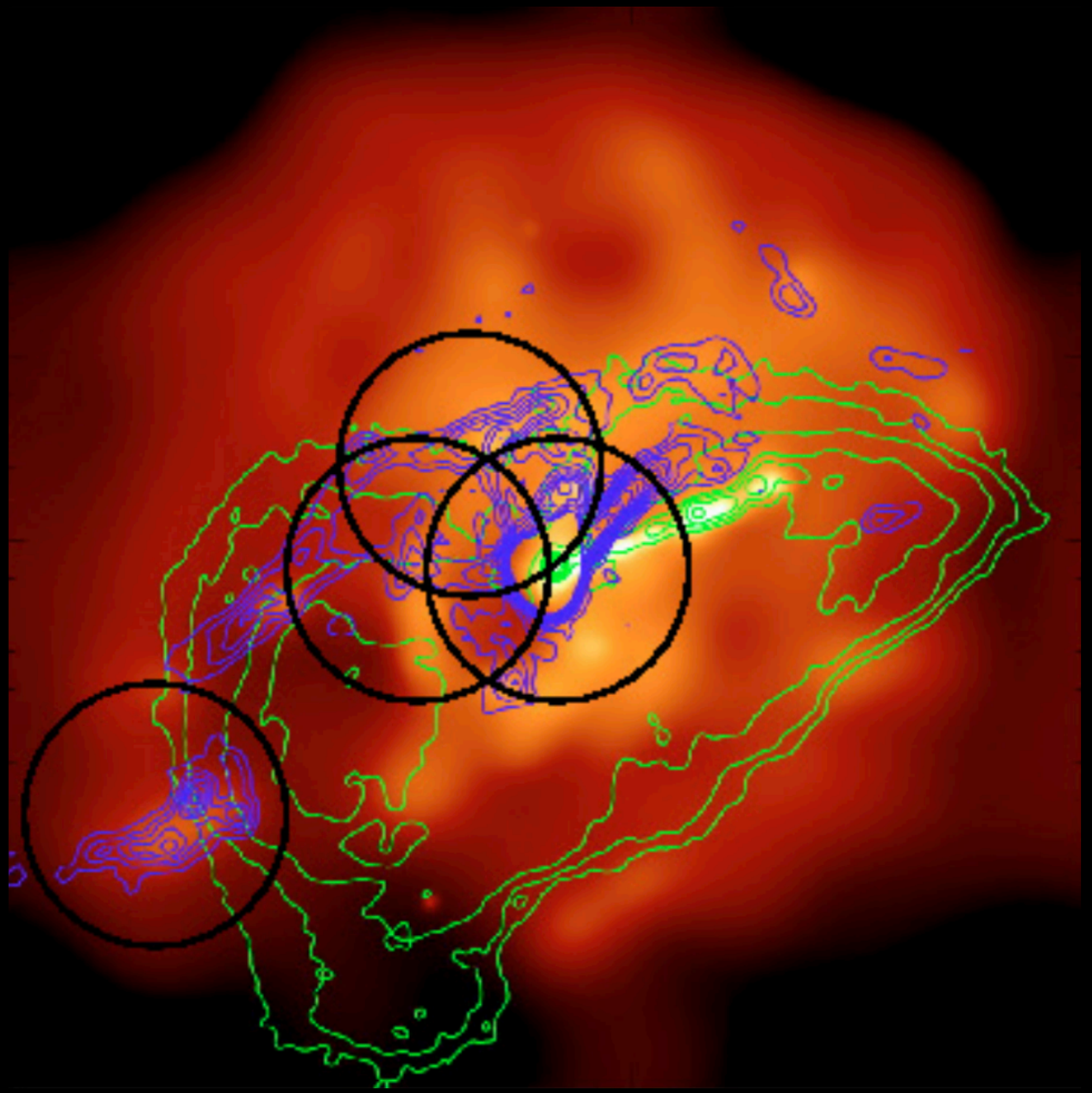


The ensemble velocity dispersion is expected to be tightly linked between all thermal phases

Gaspari et al. 2018

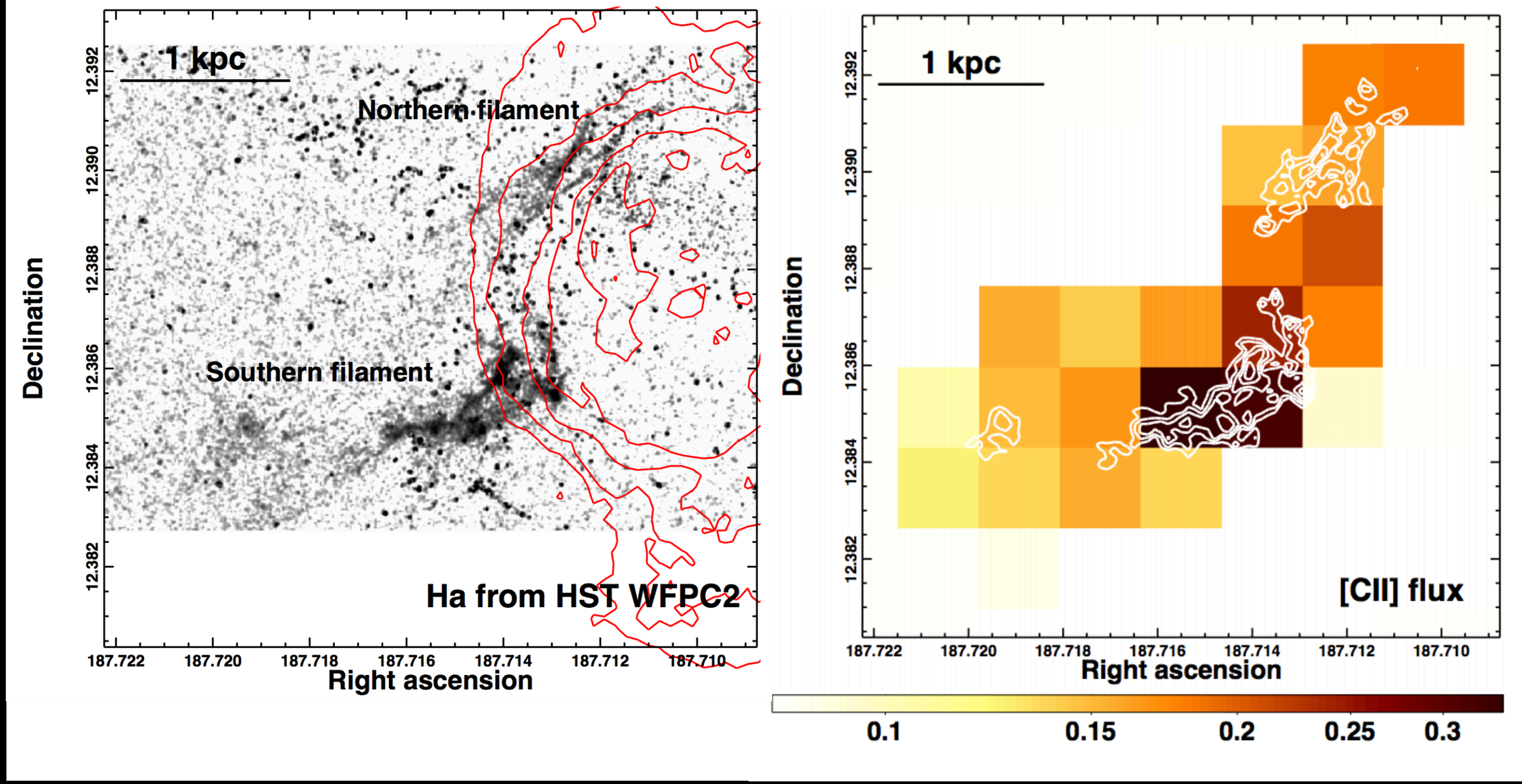


The Hunt for Molecular Gas in M87

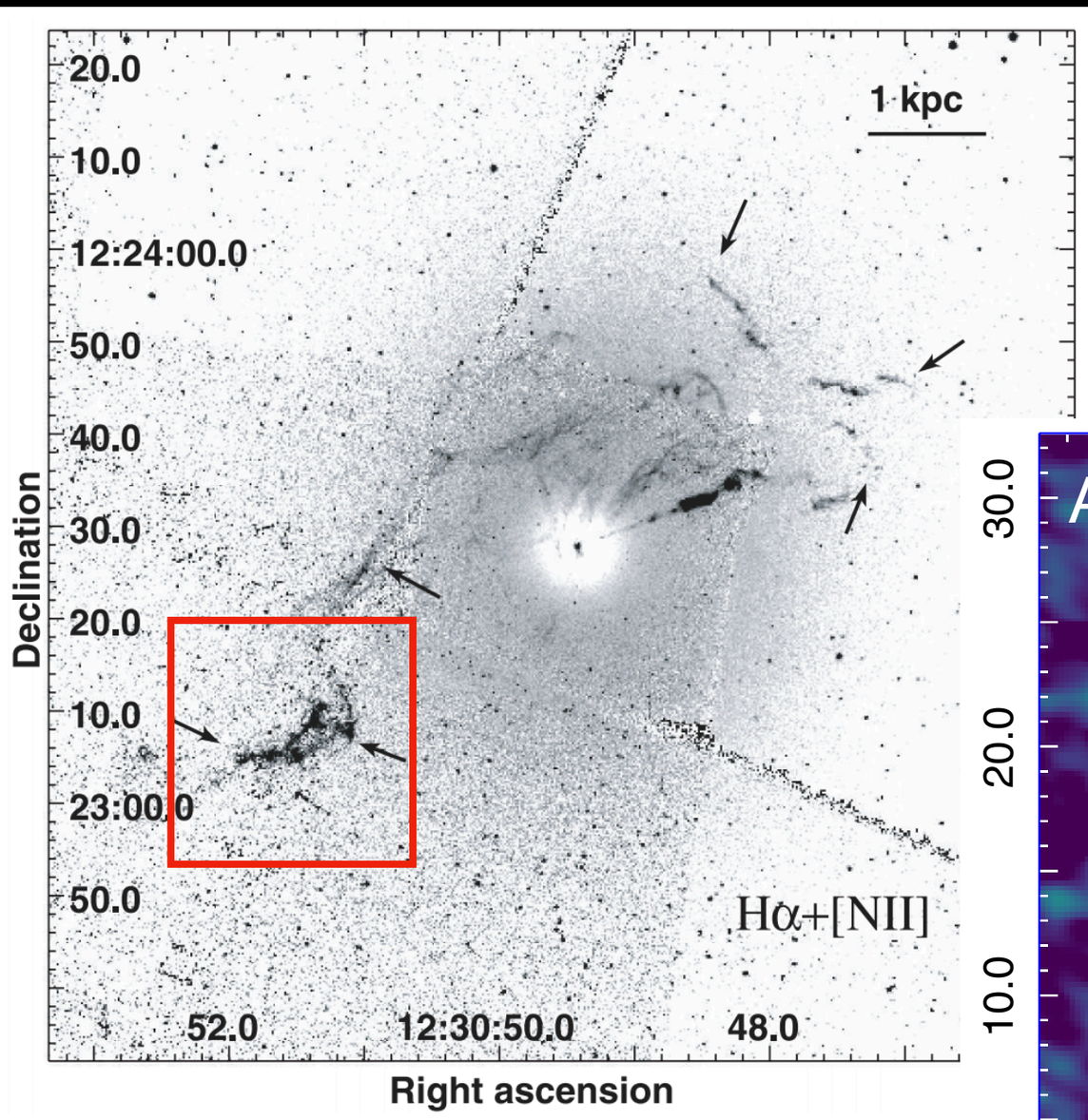


Salome & Combes 2008
no significant detection of molecular gas

Discovery of [CII] in M87 with Herschel/PACS

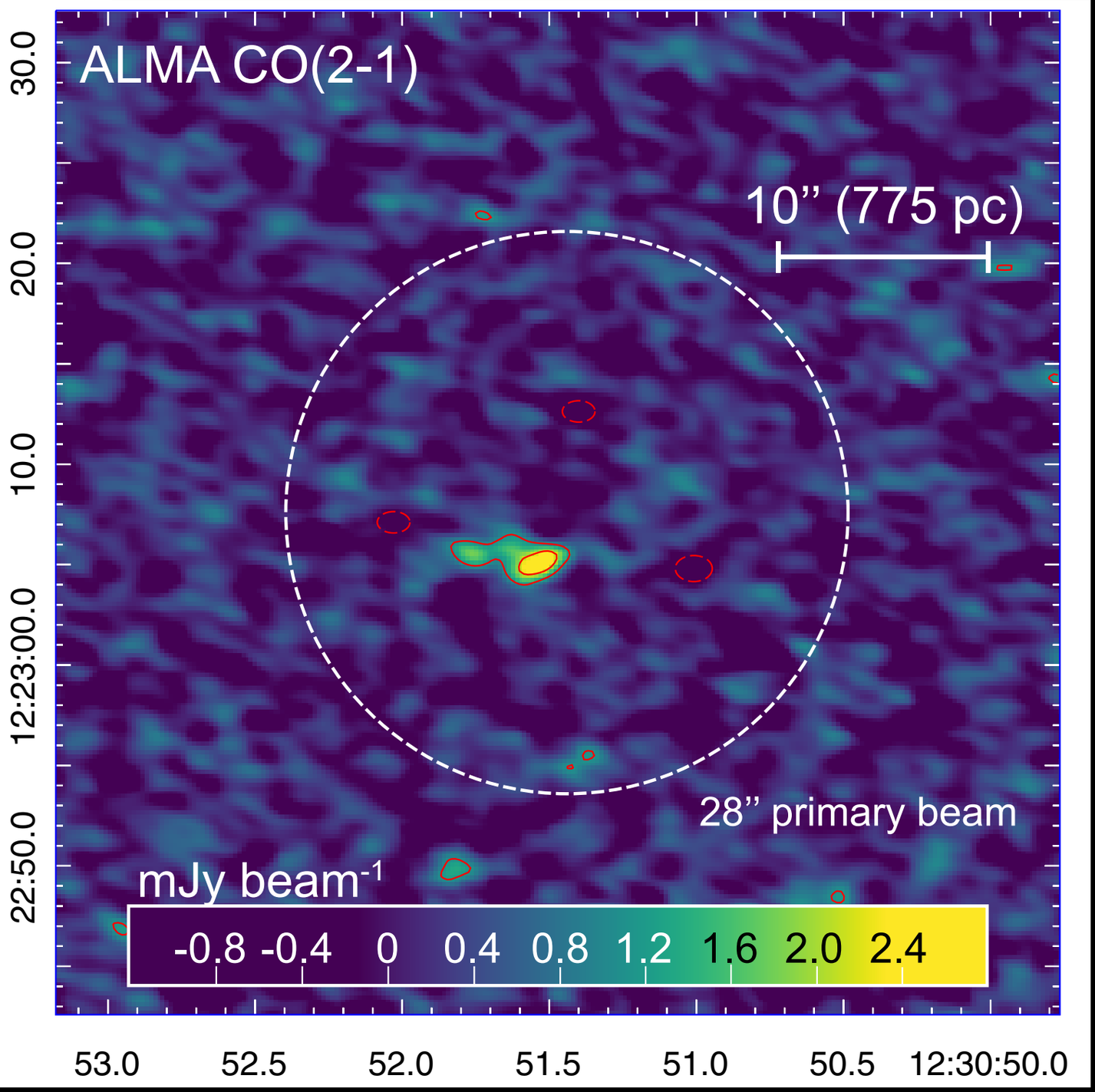


Werner et al. 2013

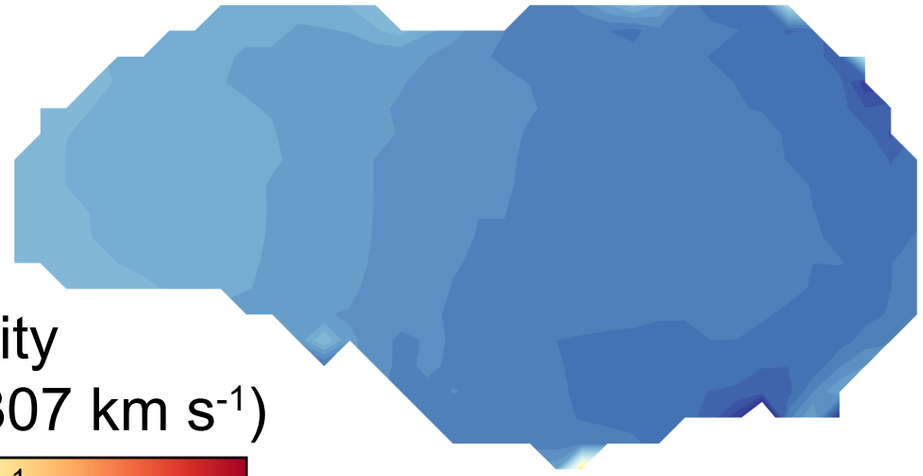


3h on source with ALMA
Simionescu et al. 2018

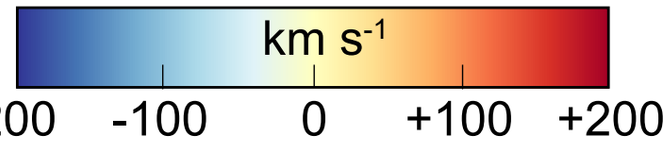
$$M_{H_2} = (4.7 \pm 0.4) \times 10^5 M_\odot$$

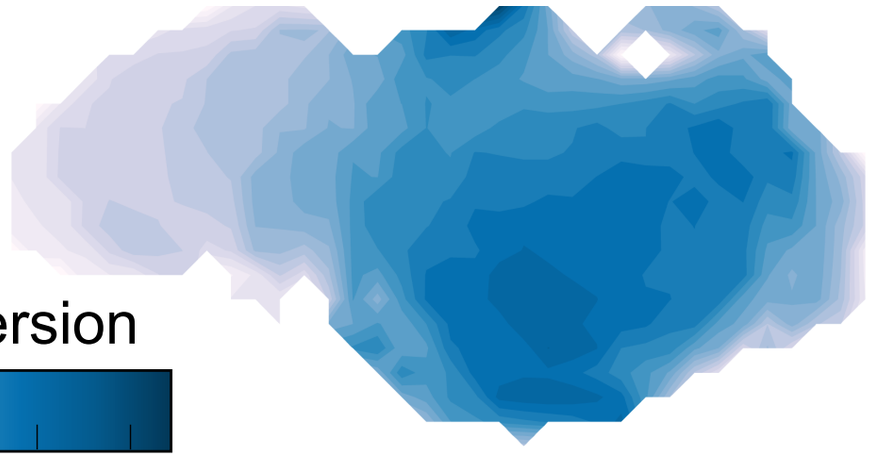


ALMA Moment Maps

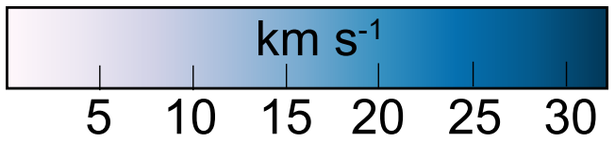


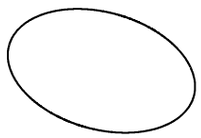
Velocity
(relative to 1307 km s^{-1})



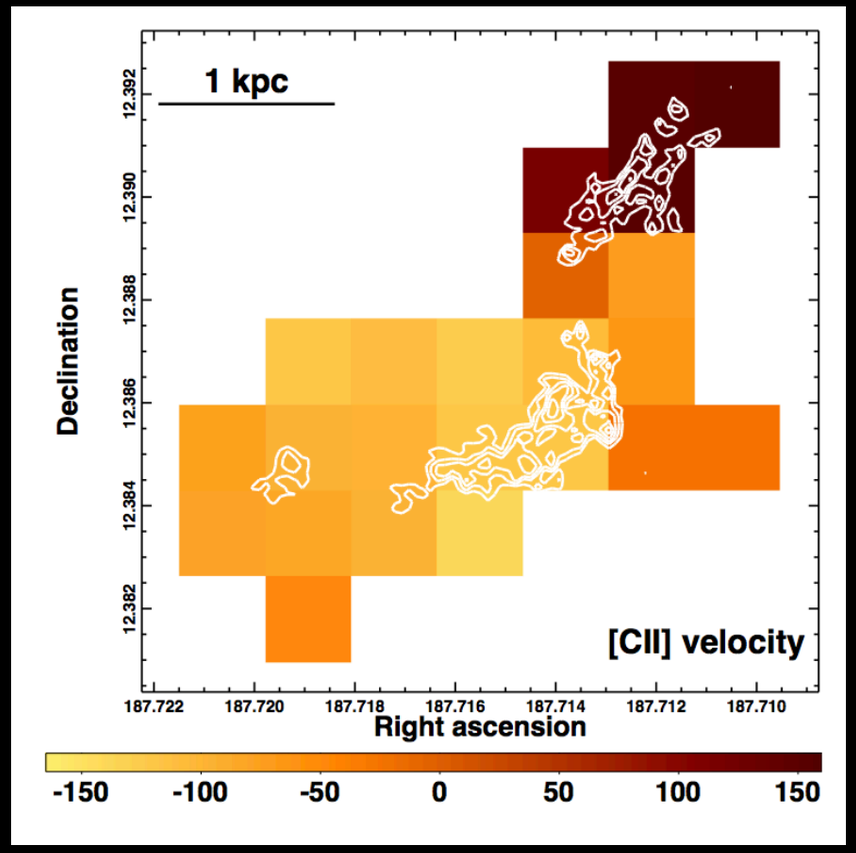


Velocity Dispersion

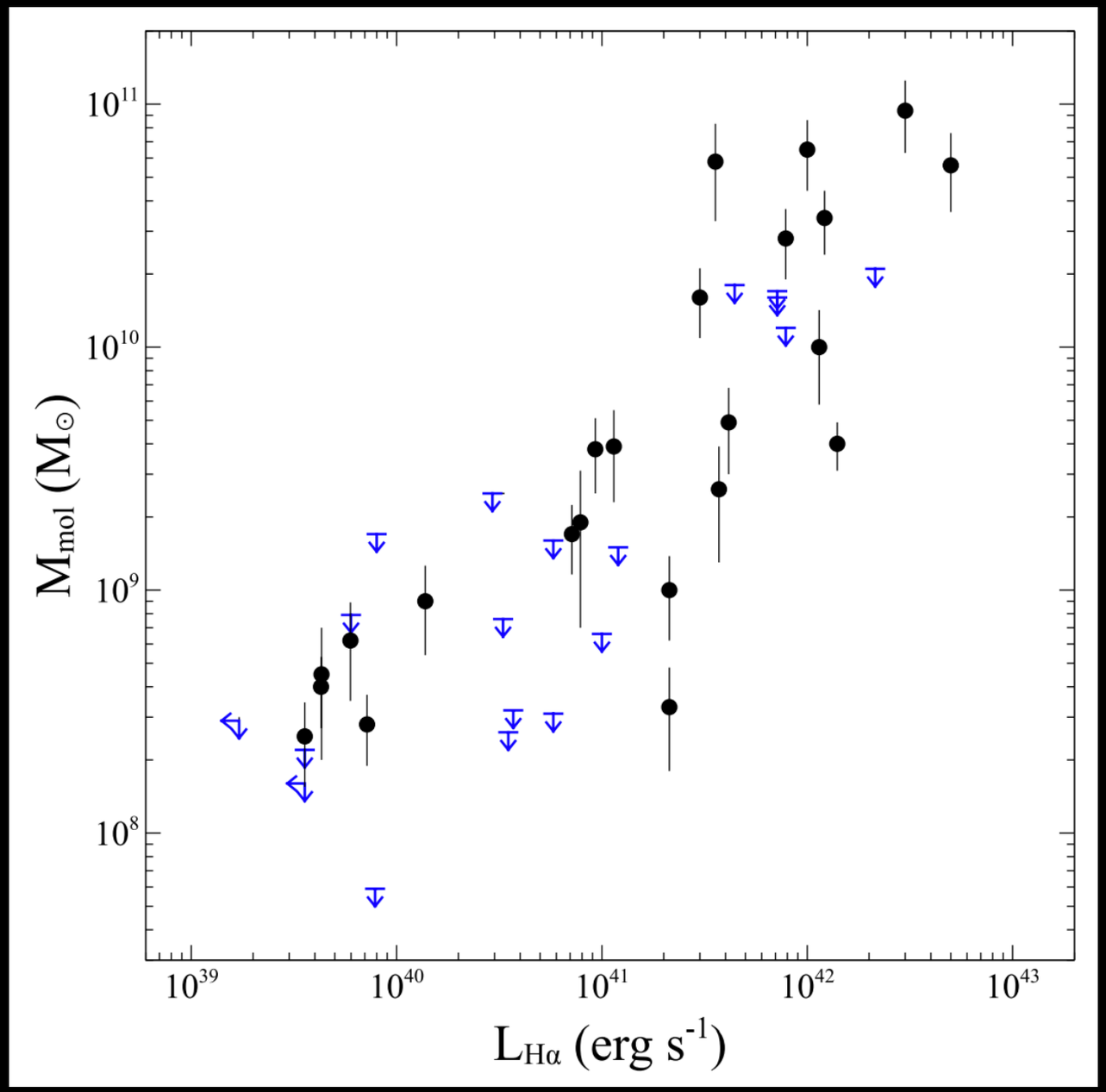




310 pc (4”)



Extremely narrow line; possibly not enough CO to fully trace the *ensemble* velocity dispersion of the X-ray gas.


10^{11}
10^{10}
10^{9}
10^{8}
M_{mol} ($M_\odot$)
10^{39}
10^{40}
10^{41}
10^{42}
10^{43}
$L_{H\alpha}$ (erg s^{-1})

★ M87

M87
Hα+[N II]

16” (1.2 kpc)

ALMA Pointing

ICM Pressure

Shock cocoon

6cm Radio

Hα+[N II] contours

ALMA CO(2-1) flux

Radio contours

Flux

mJy beam^{-1} x km s^{-1}

0 4 8

620 pc (8”)

FUV
Continuum

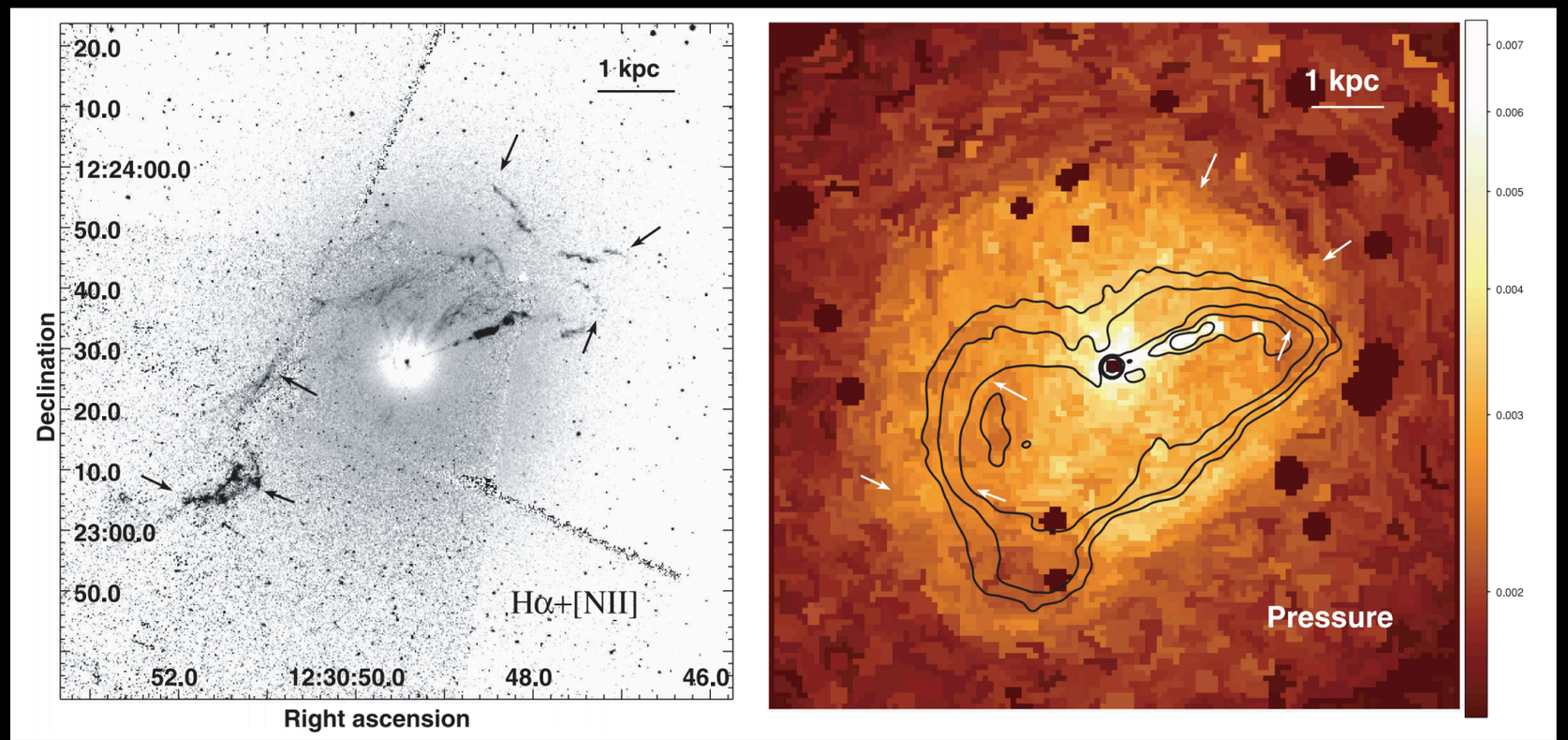
620 pc (8”)

[C II]

620 pc (8”)

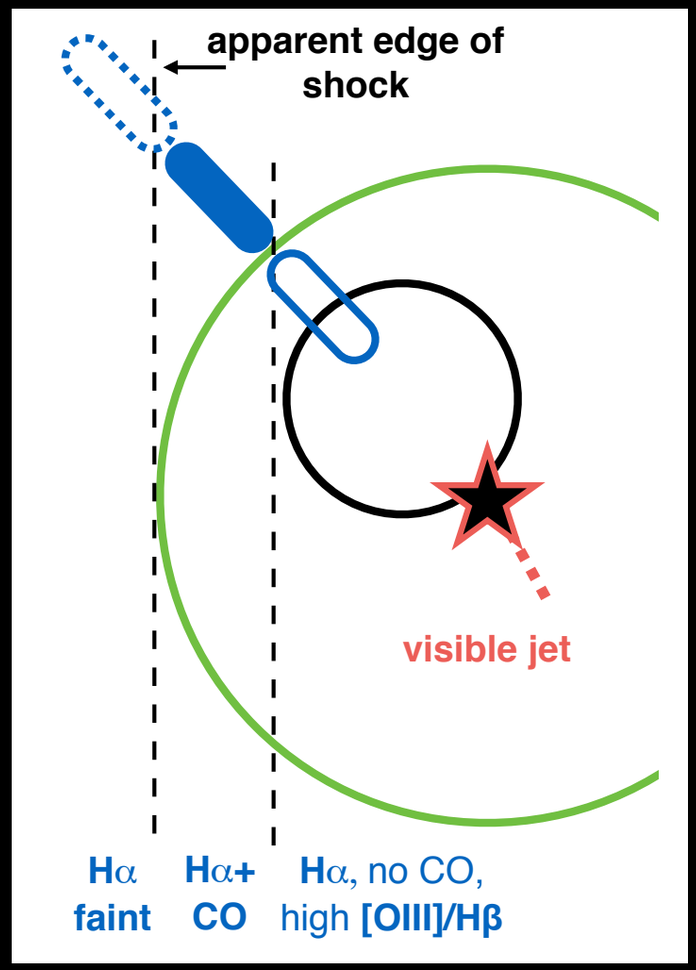
+ high [OIII]/Hb in the region without CO

- ★ CO(2-1) detected outside *but not inside* AGN radio lobe [in projection]
- ★ Ha to CO ratio changes by a factor >5 across radio lobe edge



Werner et al. 2010

Is this just projection?



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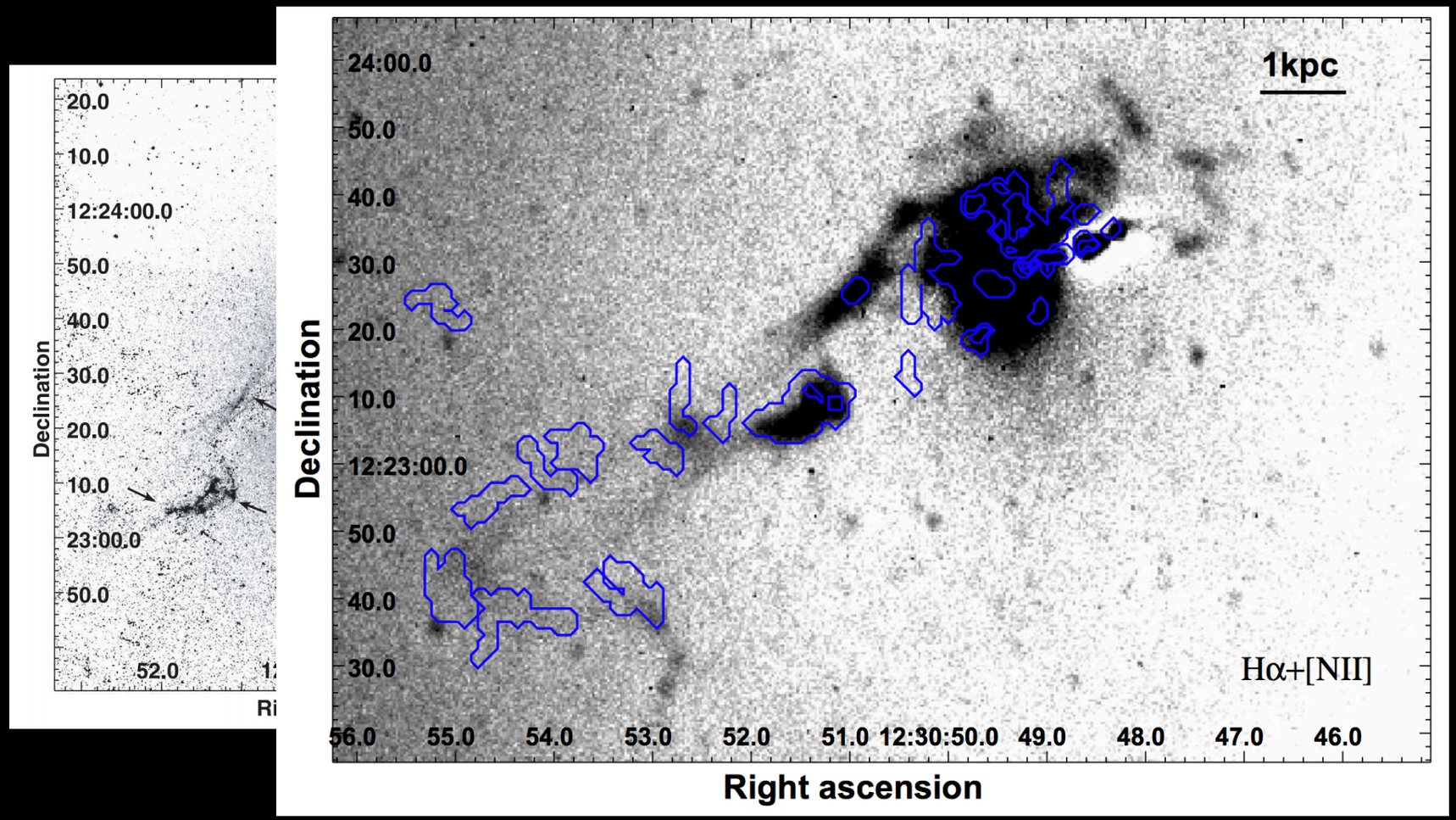
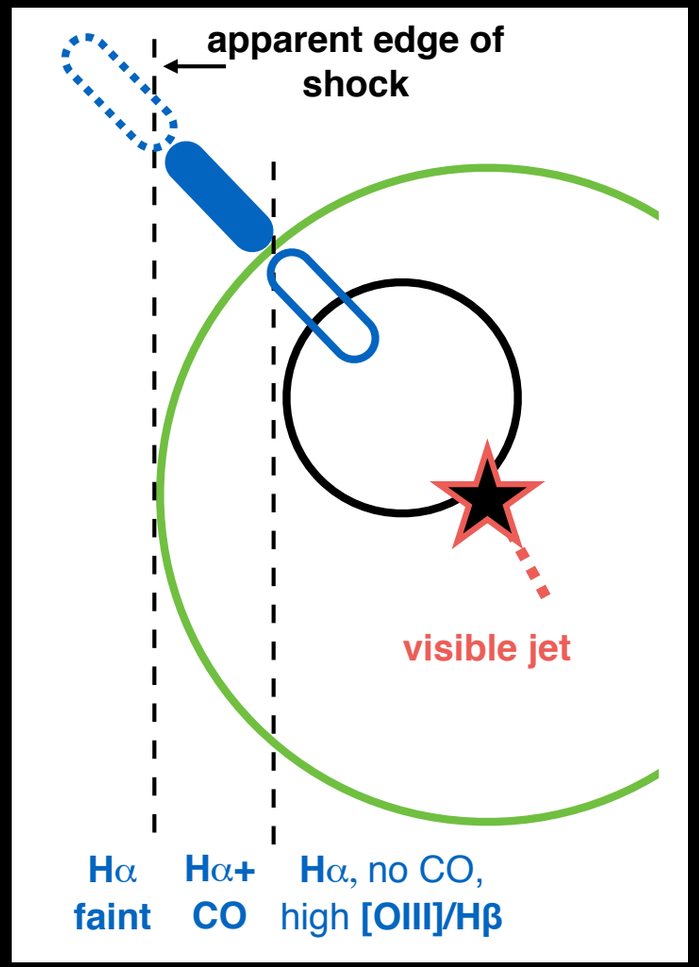
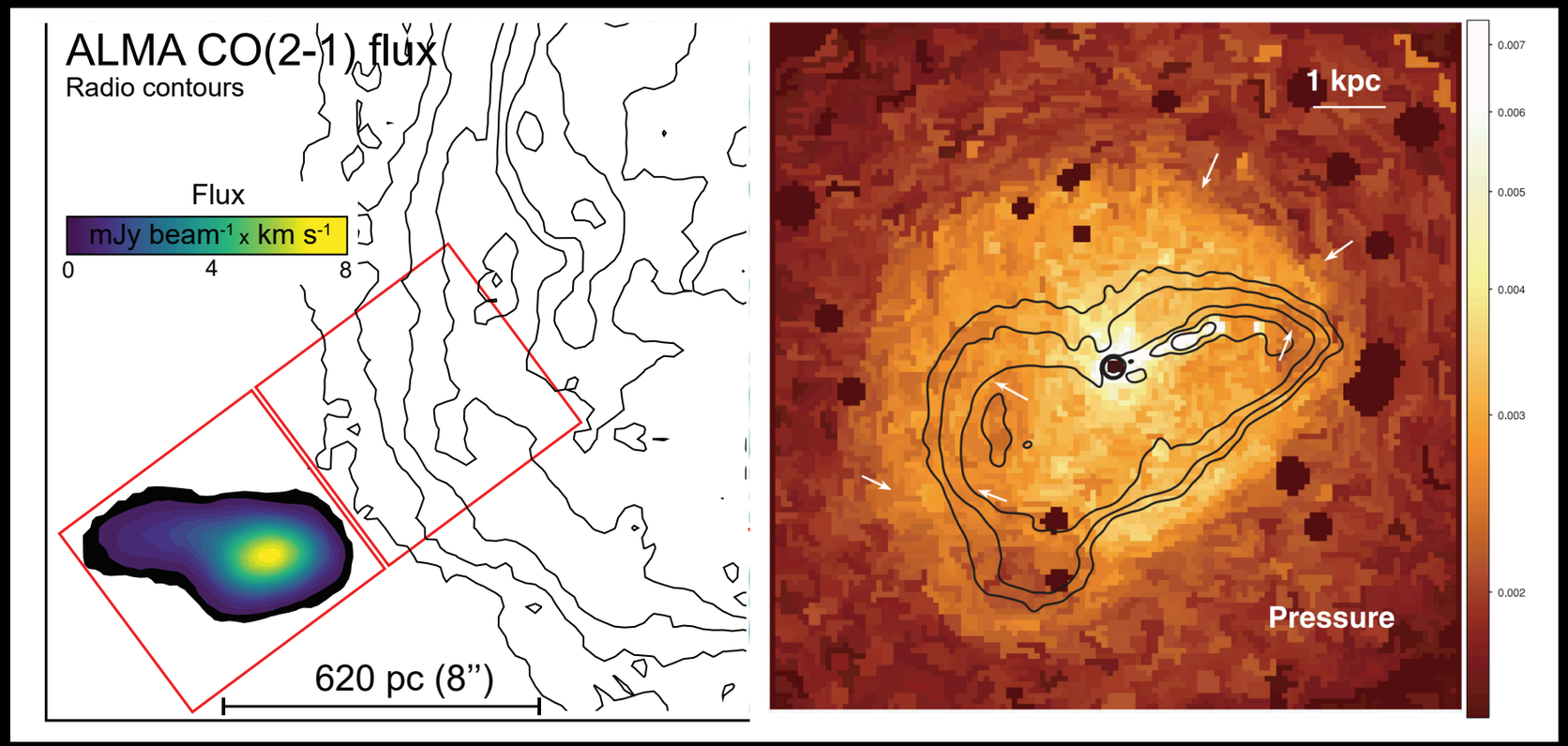


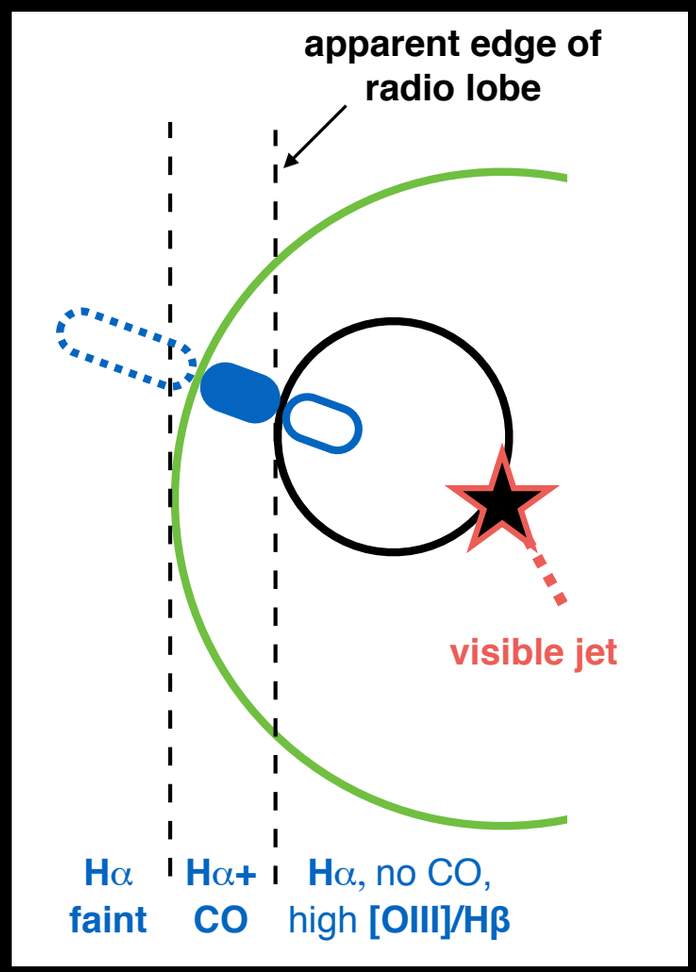


WHAT DESTROYS (DISRUPTS?) THE MOLECULAR GAS IN M87?

- ★ CO(2-1) detected outside *but not inside* AGN radio lobe ~~[in projection]~~
- ★ Ha to CO ratio changes by a factor >5 across radio lobe edge

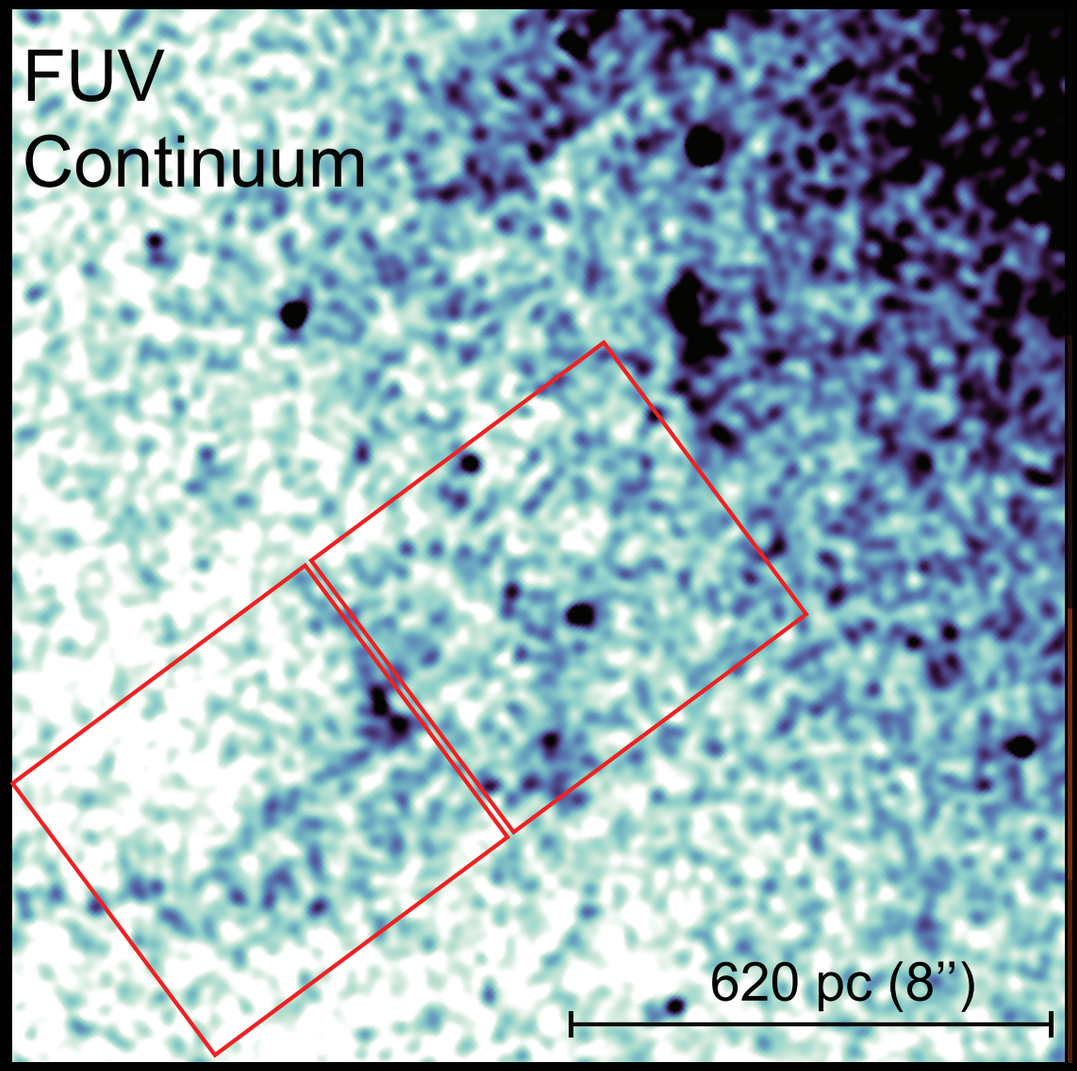
It's probably not projection!





What destroys (disrupts?) the molecular gas in M87?

- ~~Has the 'missing' molecular gas been converted into stars?~~



14 individual young stars should have been detected by HST in the Ha filament

What destroys (disrupts?) the molecular gas in M87?

- ~~Has the 'missing' molecular gas been converted into stars?~~
- ~~Does the shock promote the formation of molecular gas?~~

Too weak! Mach~1.2

What destroys (disrupts?) the molecular gas in M87?

- Is it just by chance?
- Does the relativistic plasma in the AGN radio lobe actively destroy the molecular gas (e.g. magnetic reconnection)?
- Does the X-ray shock destroy the gas, but with a "time delay"? (estimated time elapsed since shock passage: 1.1 Myr)
- Perhaps the molecular gas is not destroyed at all but heated/excited? (check other CO transitions?)

When is CO being destroyed rather than produced?

The mass of host halo? (M_{mol}/M_X smaller in galaxies than clusters, cf. Brian's talk)

Does it depend on the total mechanical power of the AGN?

The "phase" of the feedback cycle?