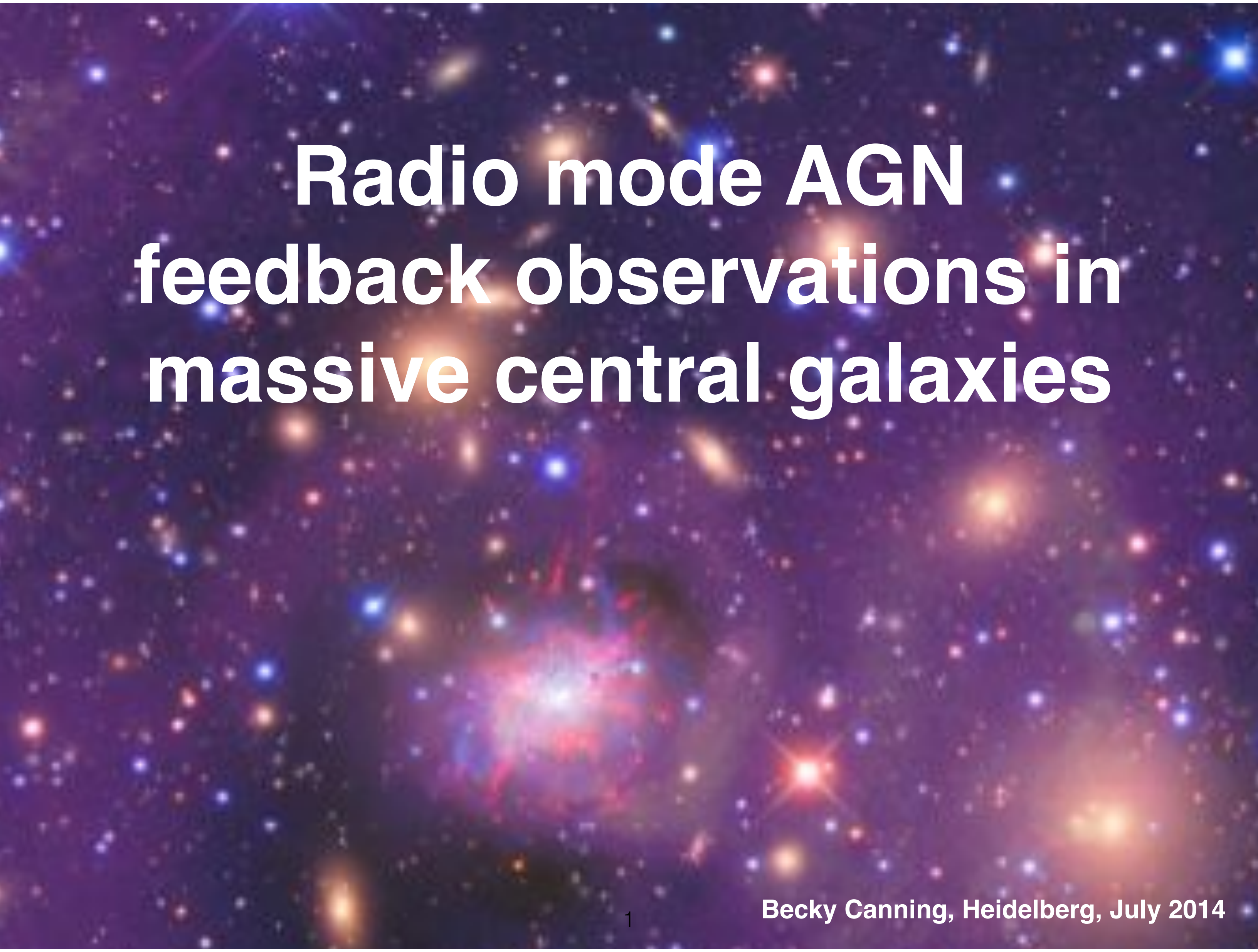
Radio mode AGN feedback observations in massive central galaxies



Becky Canning, Heidelberg, July 2014

Multiphase media in X-ray bright galaxies

Low redshift, X-ray bright, massive (central) galaxies

- Masses ~10^{11}-10^{12} solar masses
- Single SSP models suggest ages of ~ 10 billion years
- SFRs typically <0.1-1 solar mass per year (often upper limits from Galex - without correction for old stellar populations)
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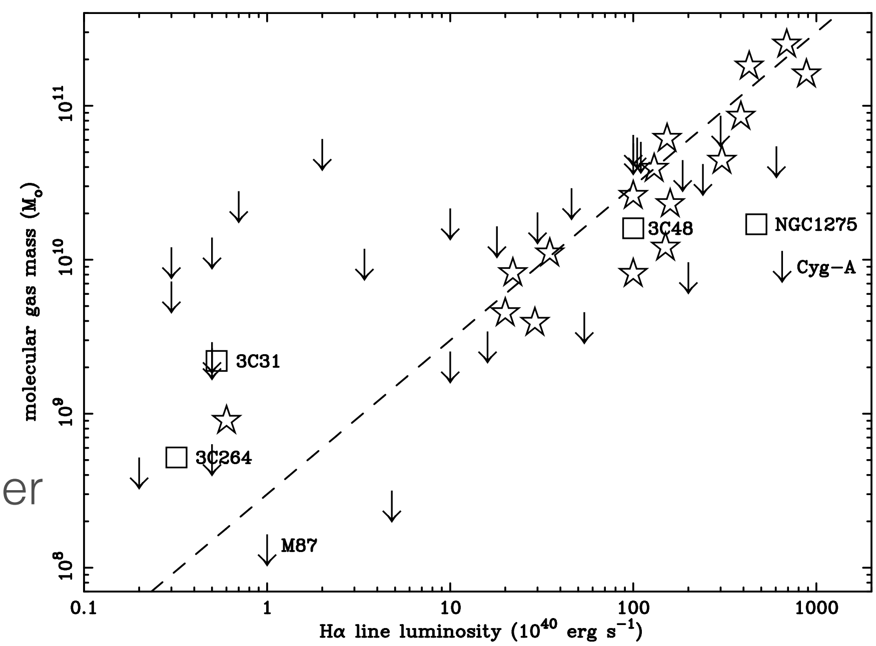

Edge et al. 2001

Multiphase media in X-ray bright galaxies

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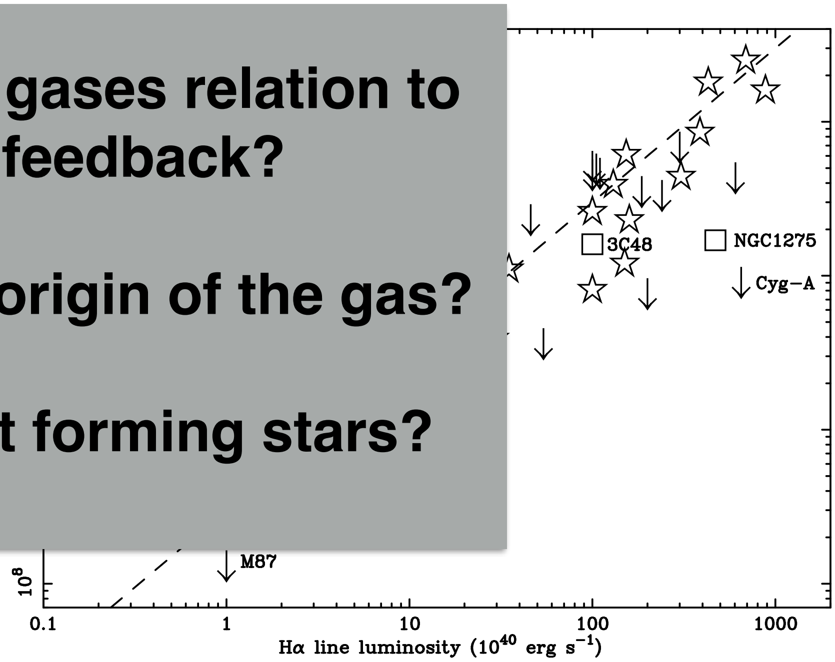
What is the gases relation to AGN feedback?

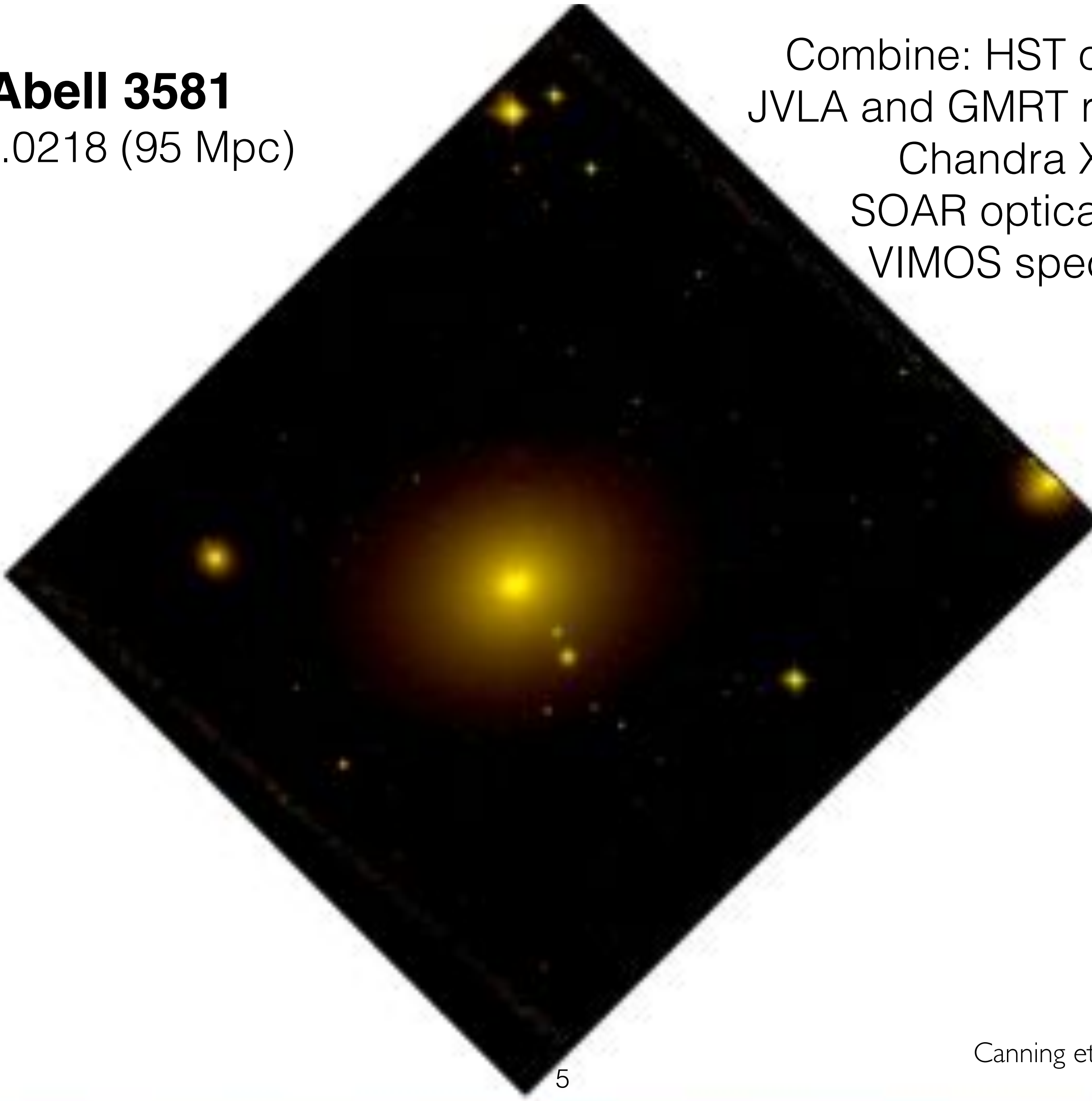
What is the origin of the gas?

Why isn't it forming stars?



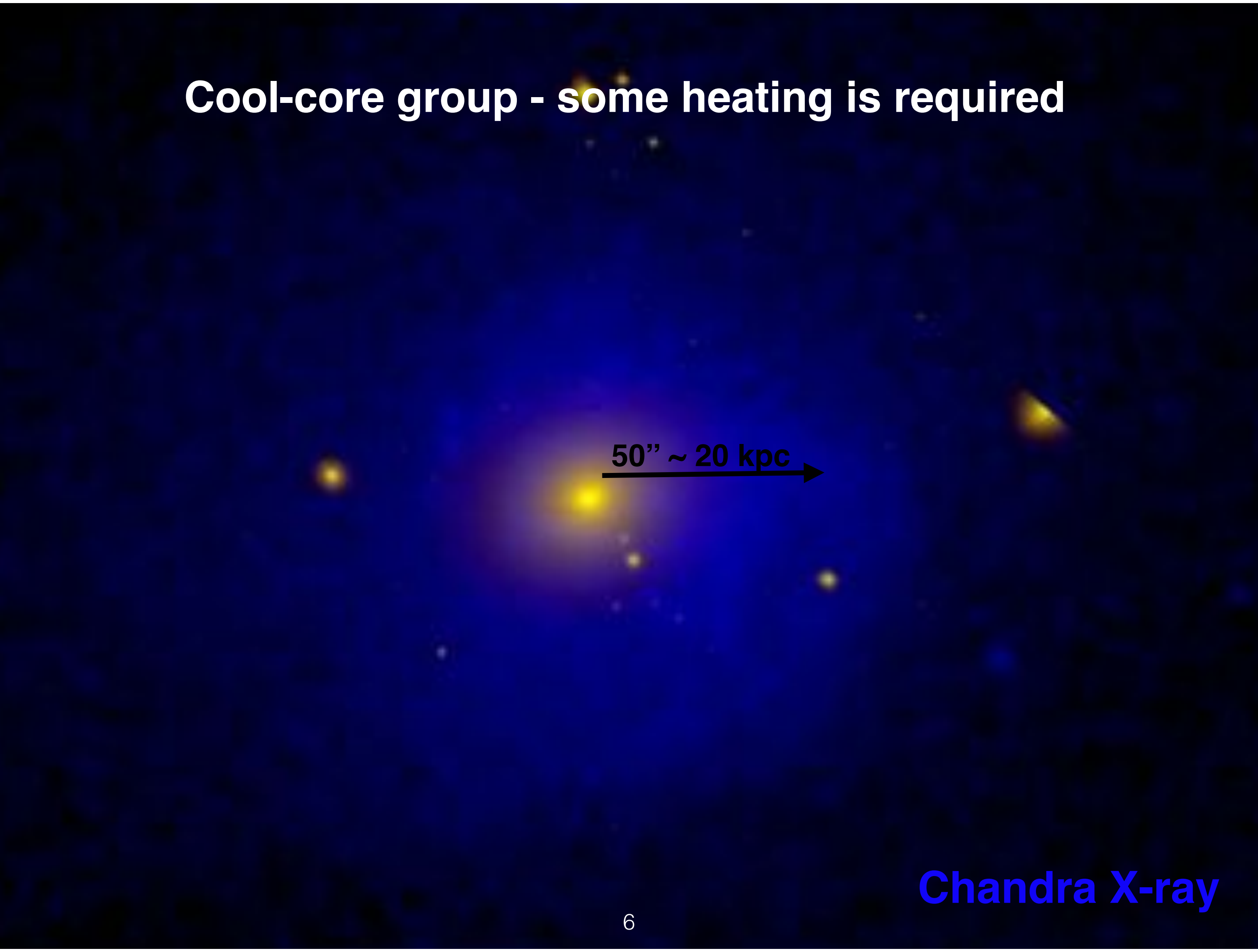
Edge et al. 2001

Abell 3581
z=0.0218 (95 Mpc)



Combine: HST optical/UV
JVLA and GMRT radio data
Chandra X-ray data
SOAR optical imaging
VIMOS spectroscopy

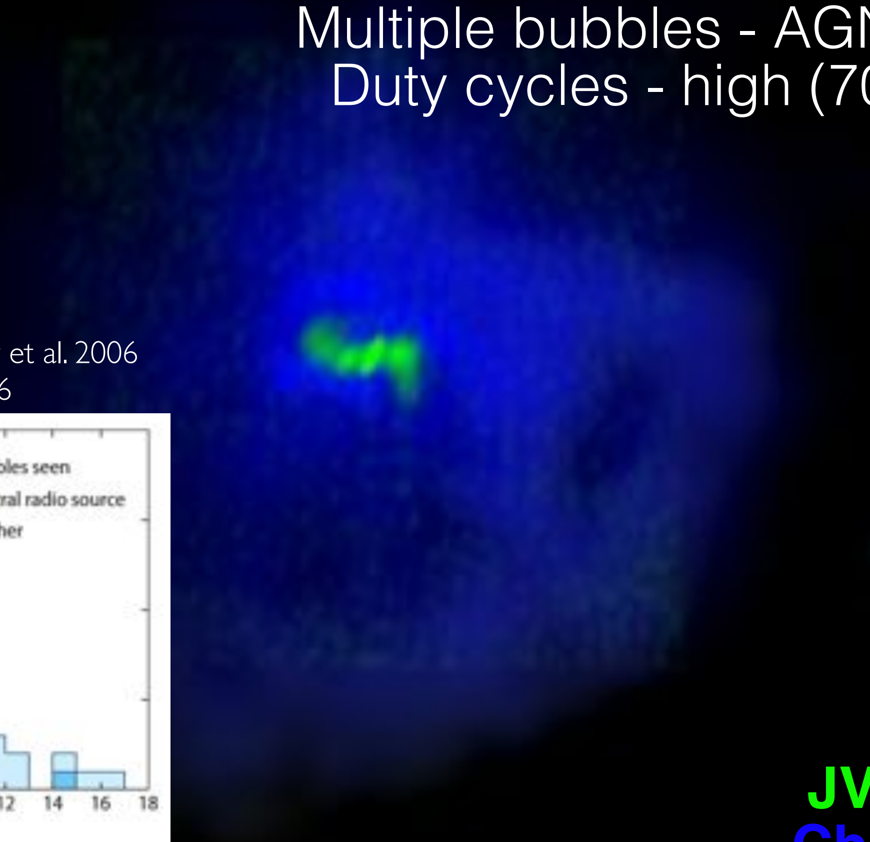
Canning et al. 2013


Cool-core group - some heating is required
50'' ~ 20 kpc
Chandra X-ray

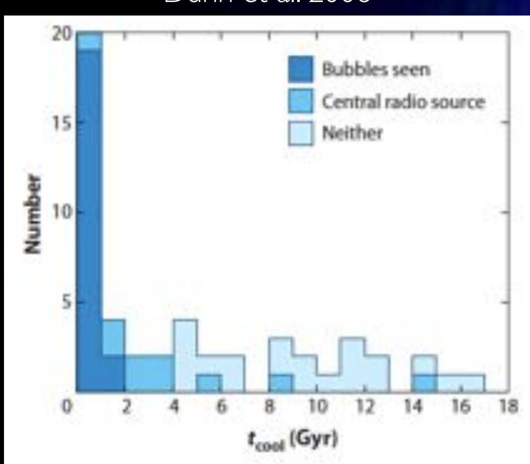
L_X in the core ~ P_{cav} in inner bubbles

2.1×10^{42} $ergs^{-1}$ ~ 2.2×10^{42} $ergs^{-1}$

Multiple bubbles - AGN timescales
Duty cycles - high (70% to 100%)

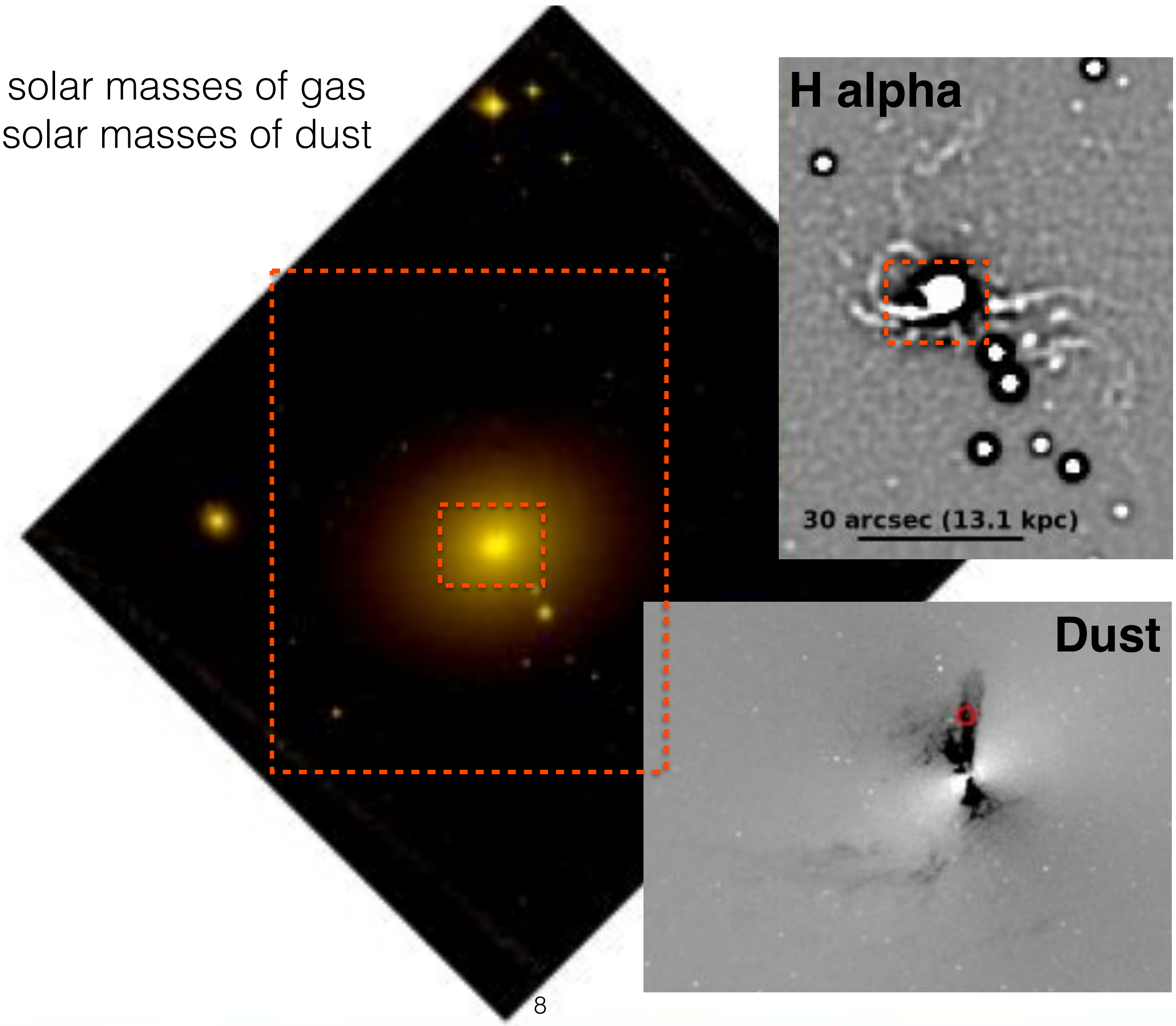


Birzan et al. 2004, Rafferty et al. 2006
Dunn et al. 2006



JVLA 1.4 GHz
Chandra X-ray

~10^8 solar masses of gas
~10^6 solar masses of dust

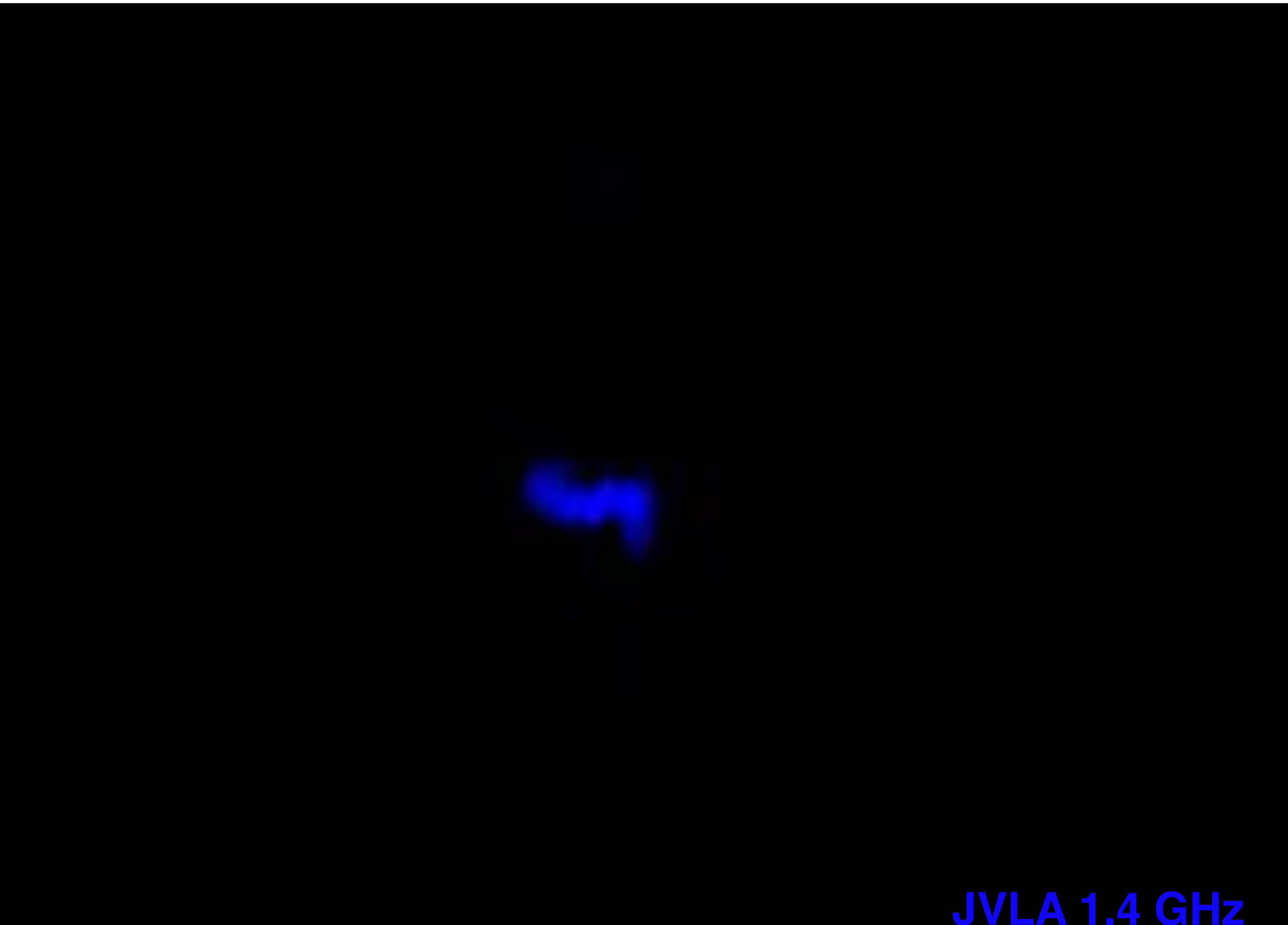


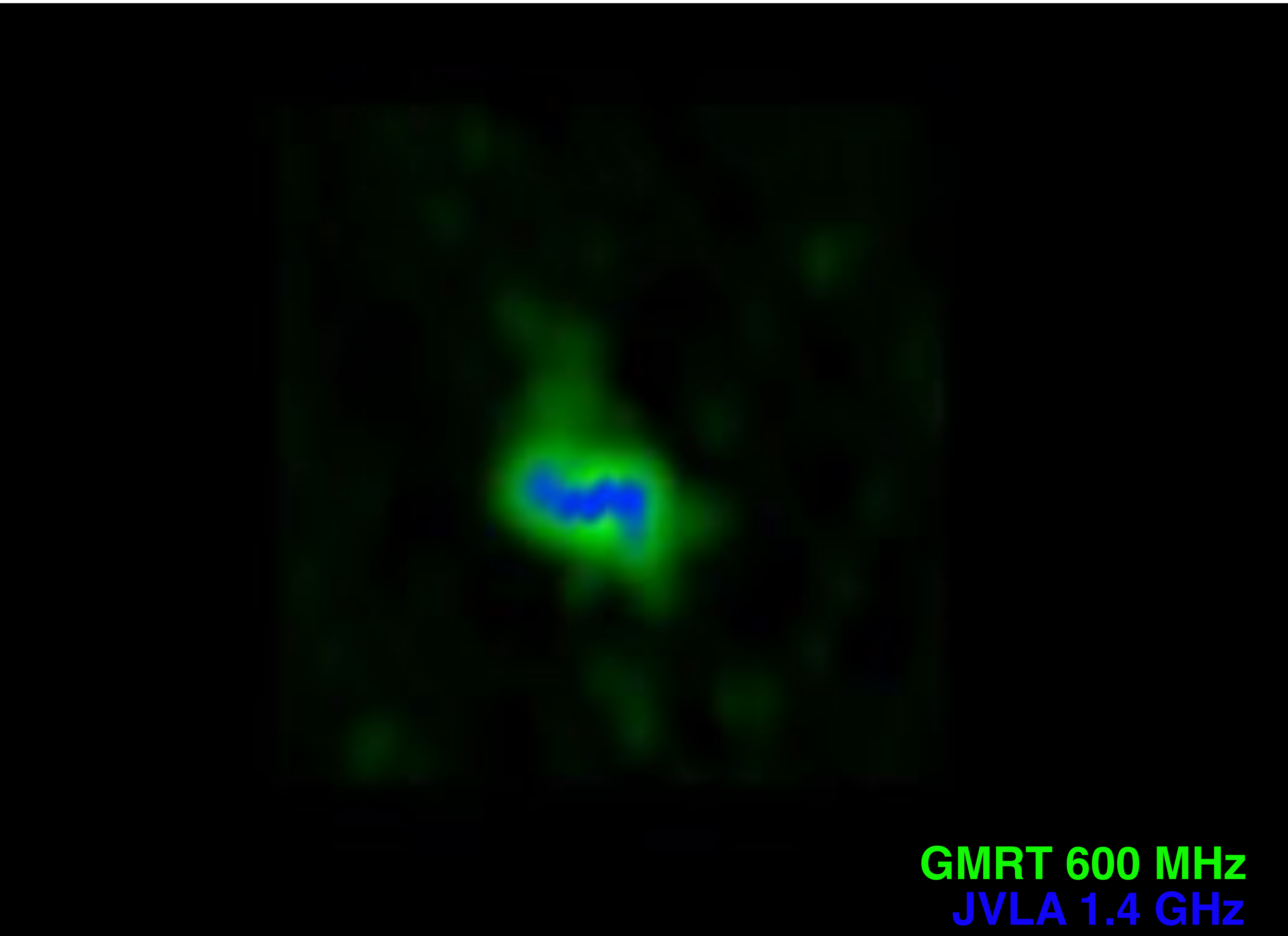
How can radio mode feedback affect galaxy evolution

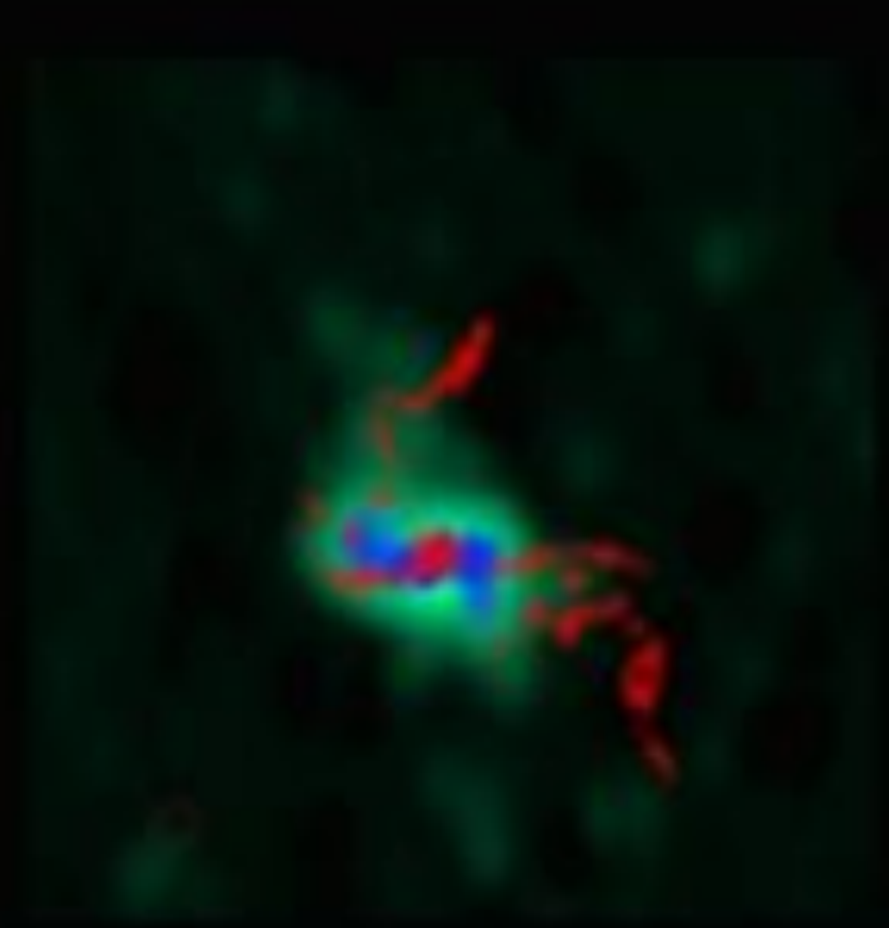
Quiescence: Keeping hot gas hot

But cool and cold gas are observed in massive X-ray bright galaxies.

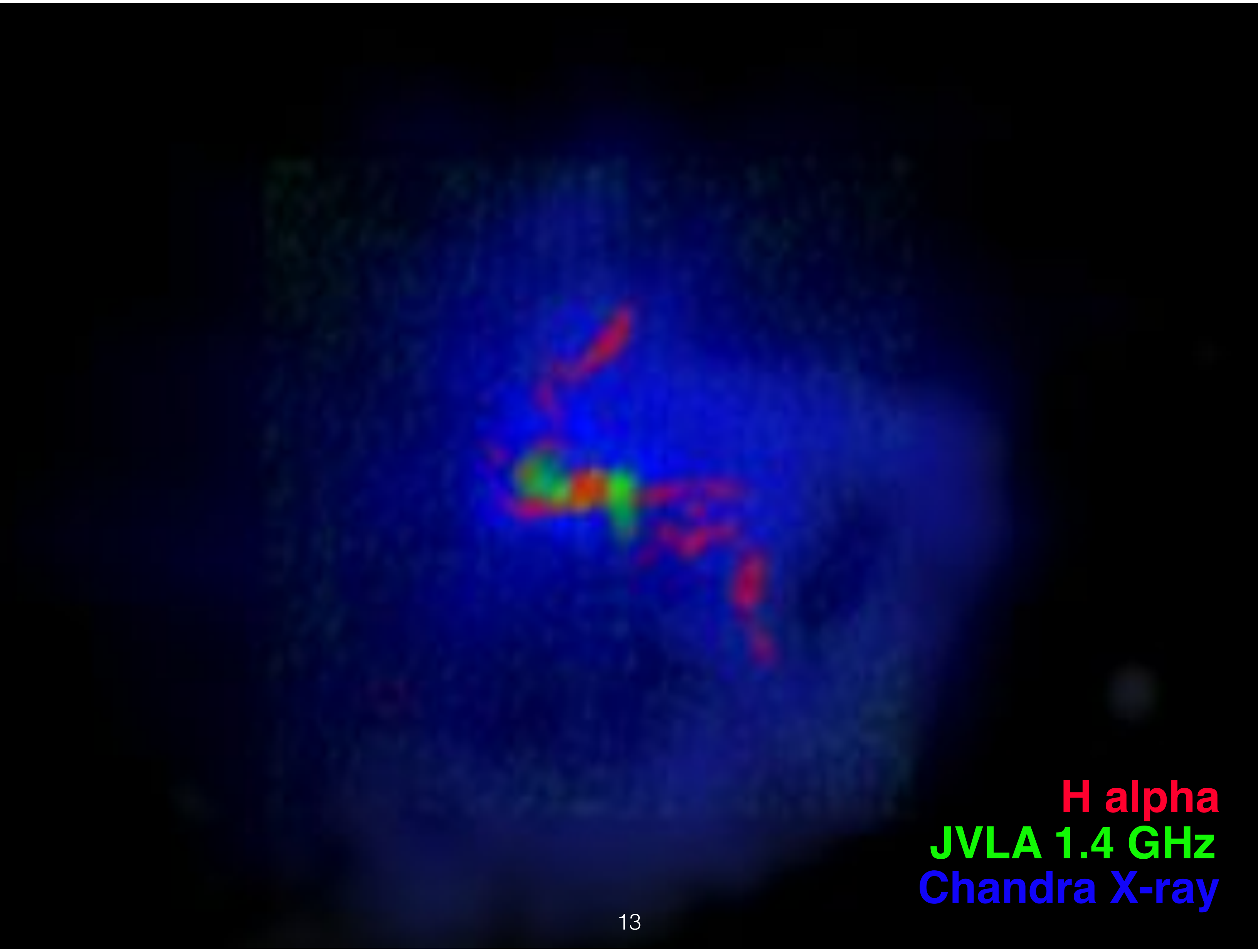
Argue here that this *gas originates from the hot gas* and is heated/redistributed in the galaxy by RM AGN feedback. So *RM feedback also important for 'quenching'* (preventing cool/cold gas from forming stars).


JVLA 1.4 GHz


GMRT 600 MHz
JVLA 1.4 GHz



H alpha
GMRT 600 MHz
JVLA 1.4 GHz


H alpha
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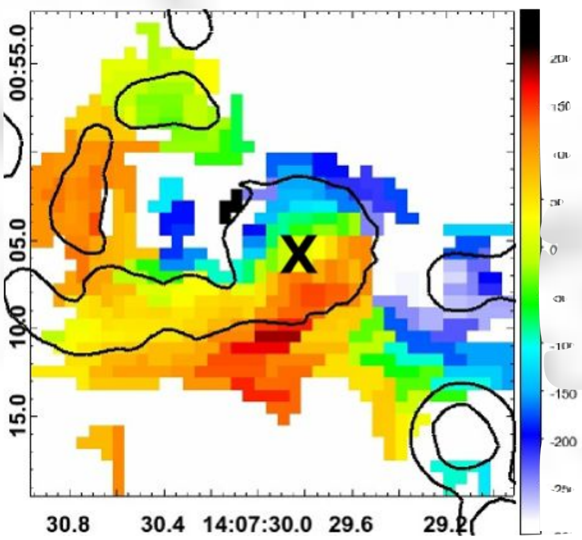
Chandra X-ray

Velocities in the cool gas

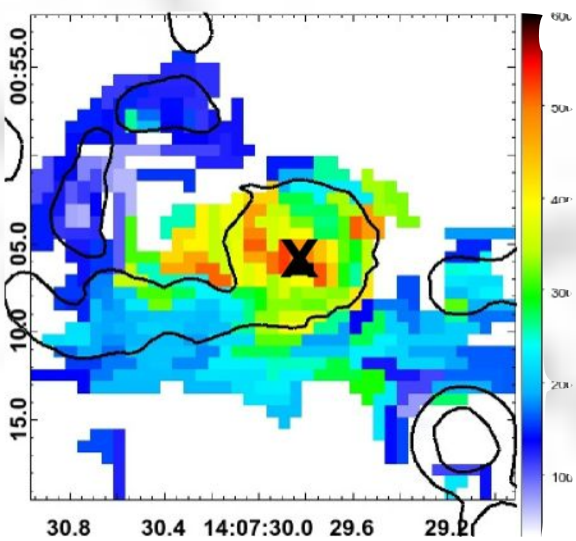


Cool gas encases inner bubbles

Smooth line-of-sight velocities

Canning et al. 2013

Velocities in the cool gas



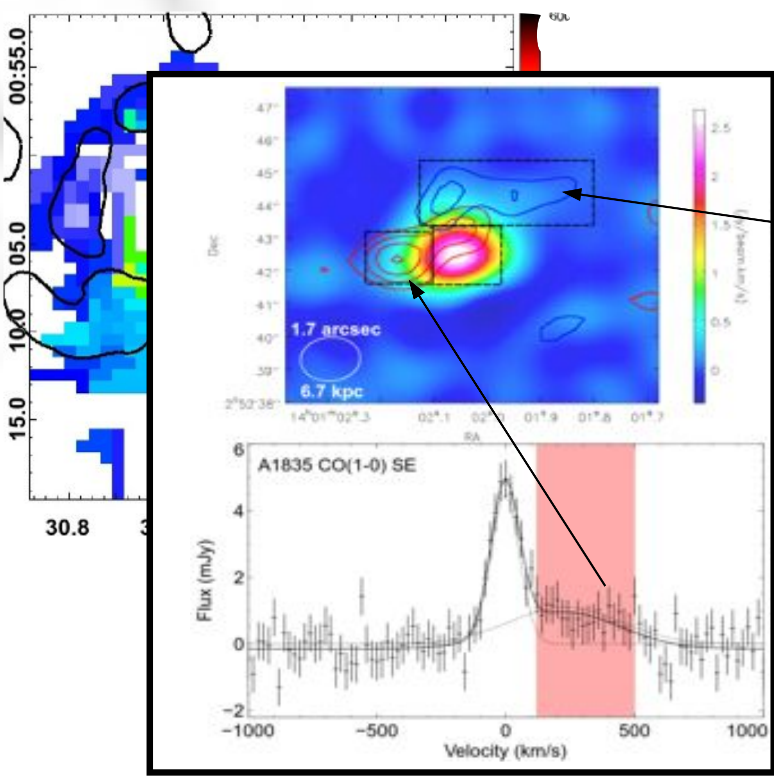
High velocities observed near base of bubble

AGN bubbles (and maybe jet) displacing and redistributing the cool and cold gas

No SF observed in filaments ~0.2 solar masses per year in core

Canning et al. 2013

Velocities in the cool gas



High velocities observed

masses per year

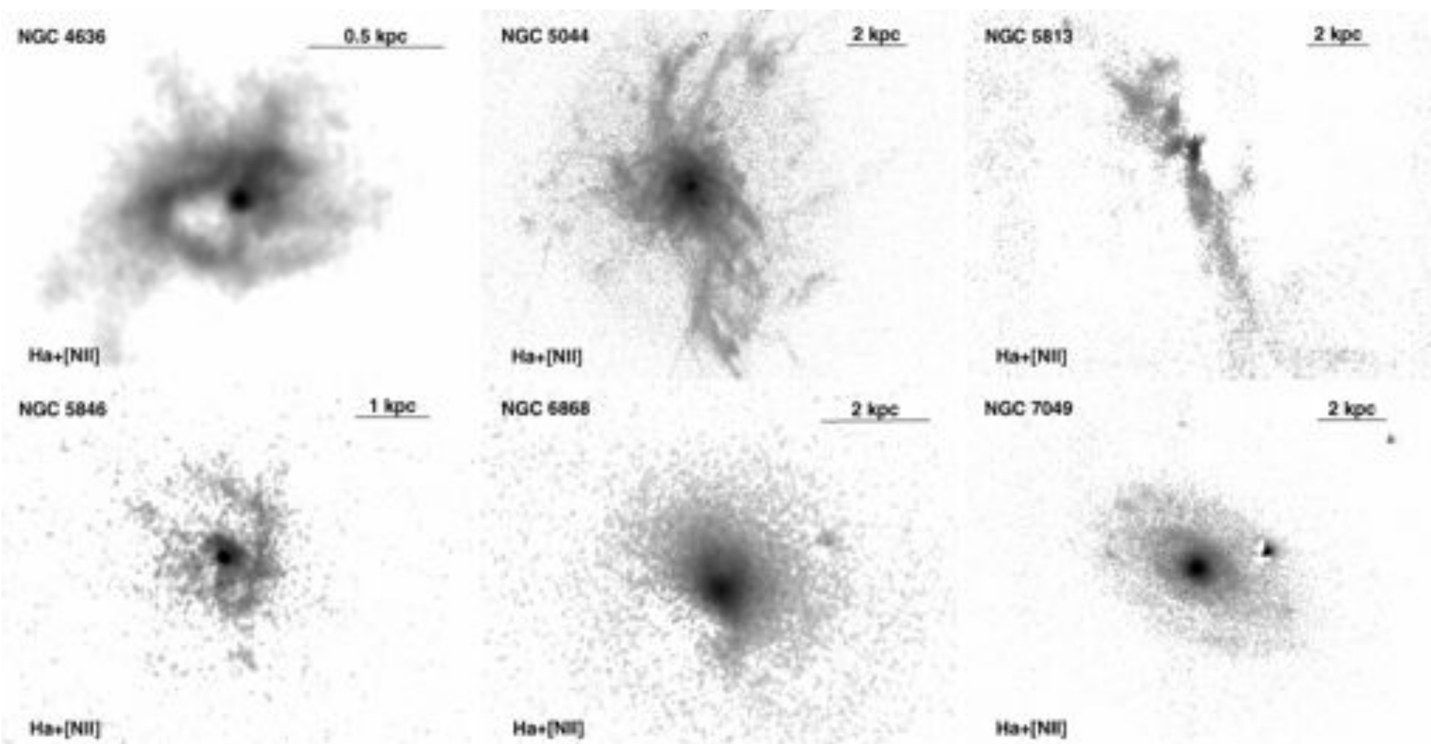
Early science ALMA results show outflow of ~600 km s-1 in very cold gas

McNamara et al. 2013, Russell et al. 2013

Canning et al. 2013

H alpha emission (6/8)

8 nearby brightest group galaxies with similar SFR, stellar masses and halo masses.



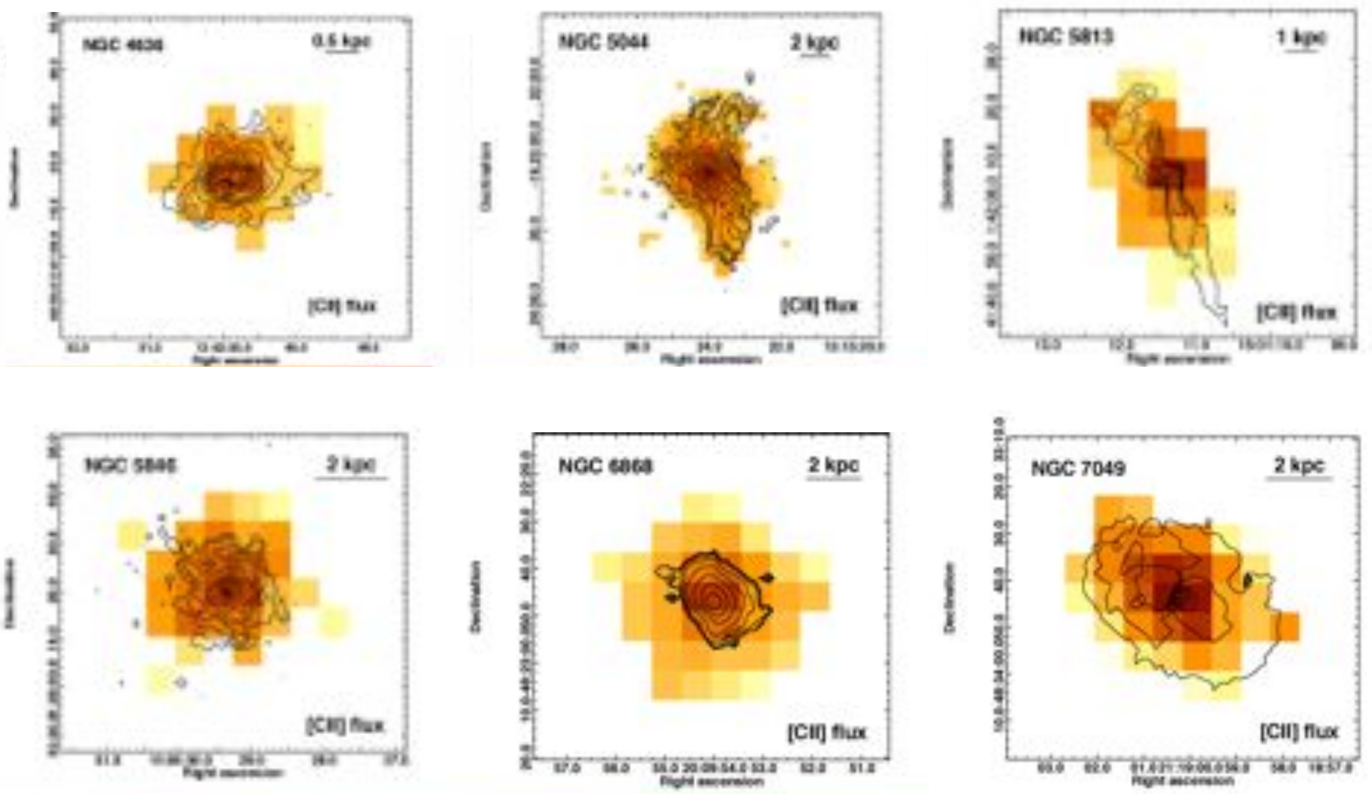
Werner et al. 2014

[C II] emission (6/8)

Cold gas morphologies and kinematics follow ionised gas

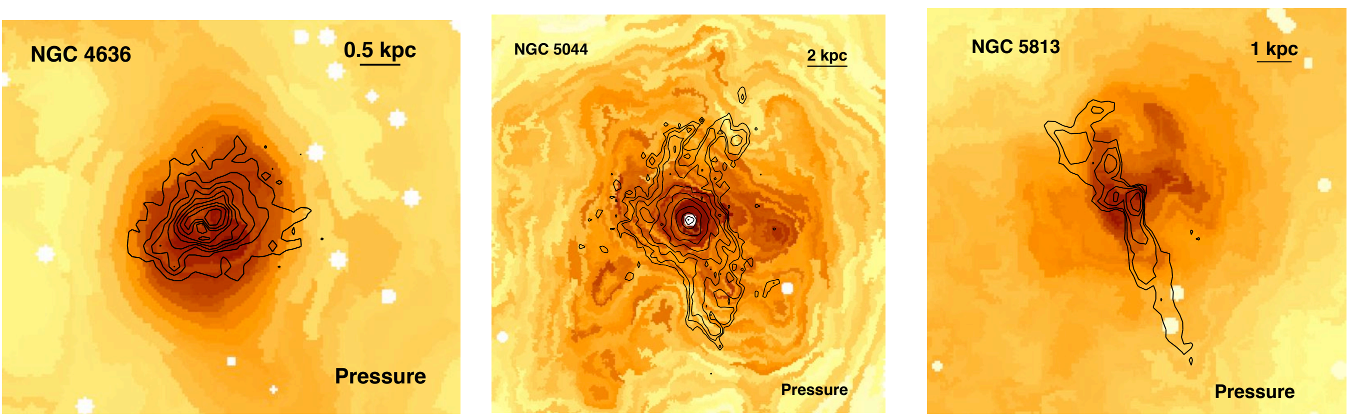
Cold phase embedded in the ionised phase

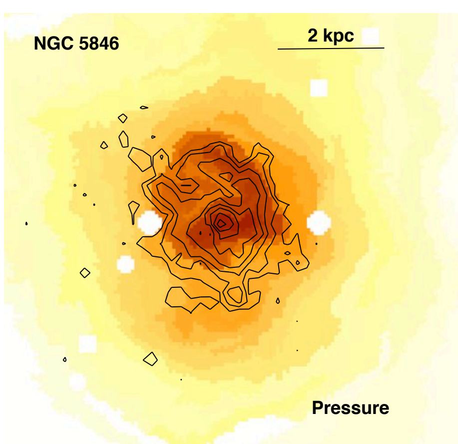
No H alpha = No extended cold gas

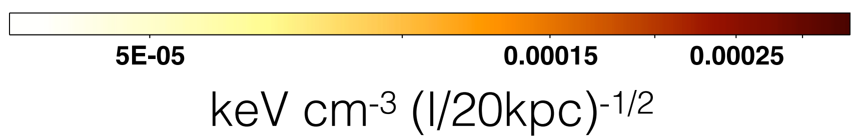


Werner et al. 2014

X-ray pressure





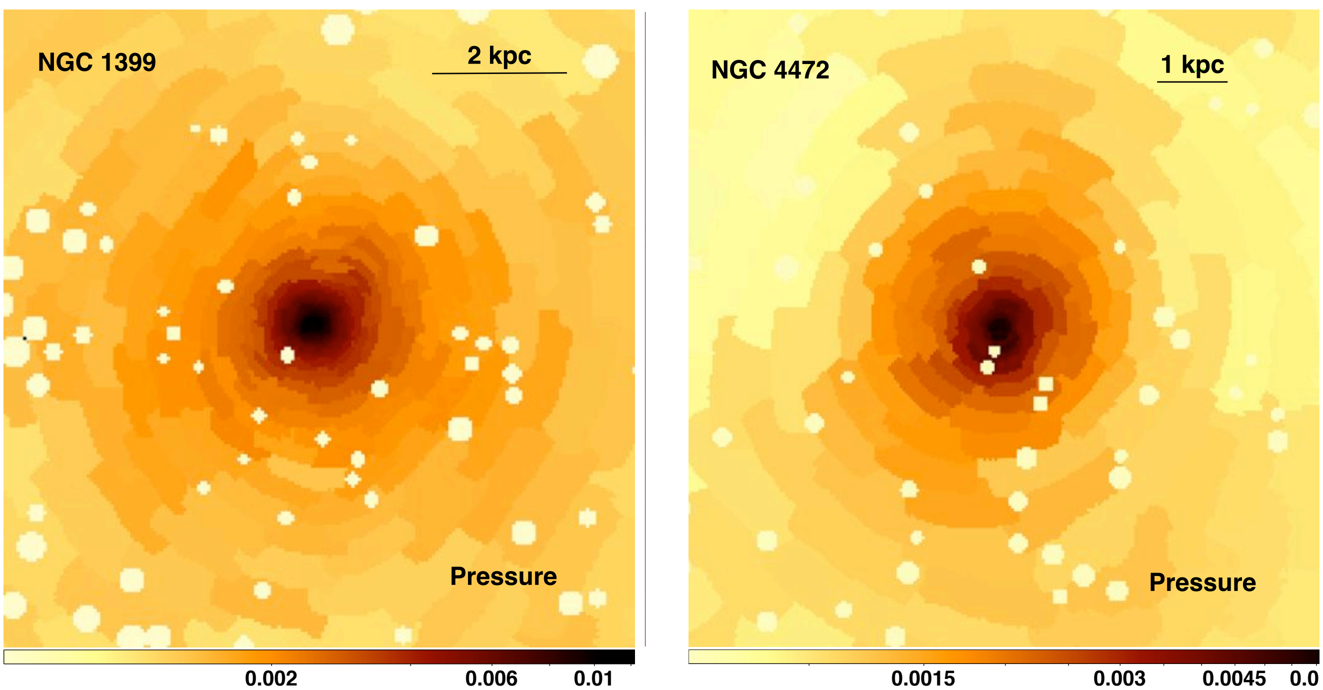


Cold gas rich

Werner et al. 2014

X-ray pressure

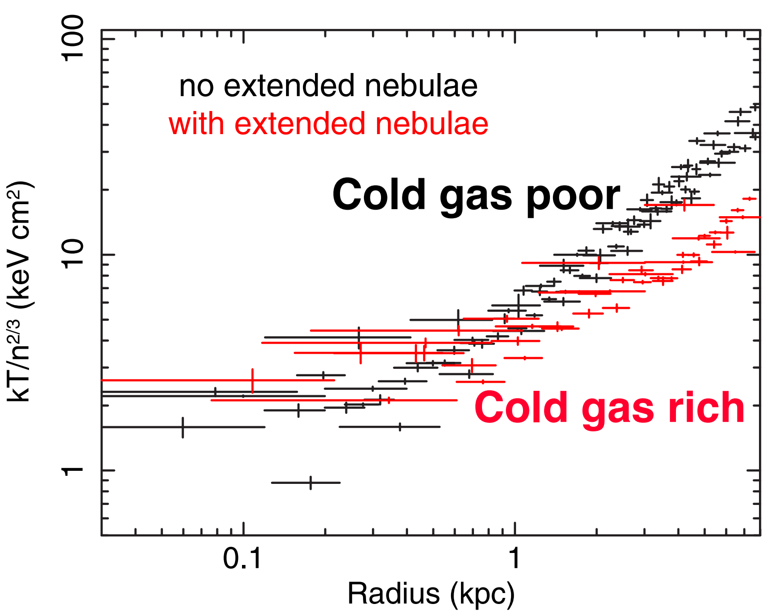
Cold gas poor



keV cm^{-3} (l/20kpc)$^{-1/2}$

Werner et al. 2014

Cold gas and hot gas

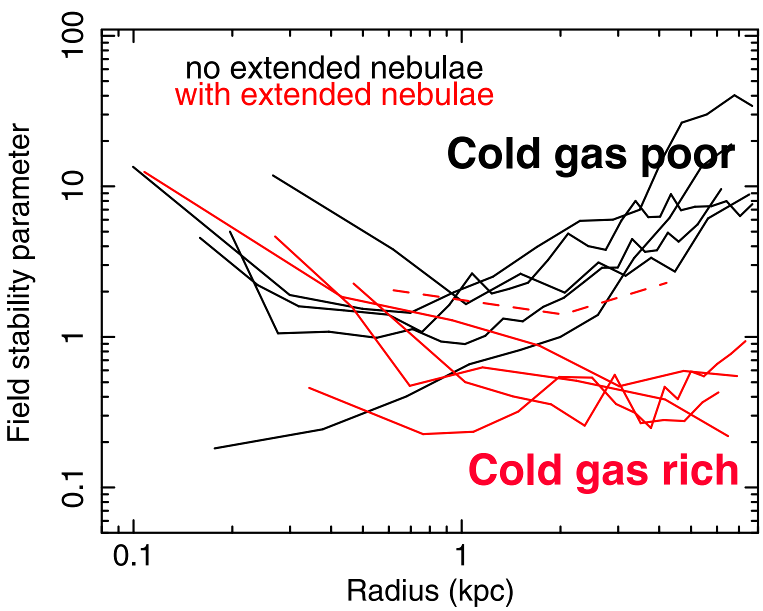


Including 3 additional relaxed GEs

Outside of the innermost core, the entropy of systems containing cold gas is lower

Werner et al. 2012, 2014

Cold gas and hot gas



The Field stability parameter, defined as

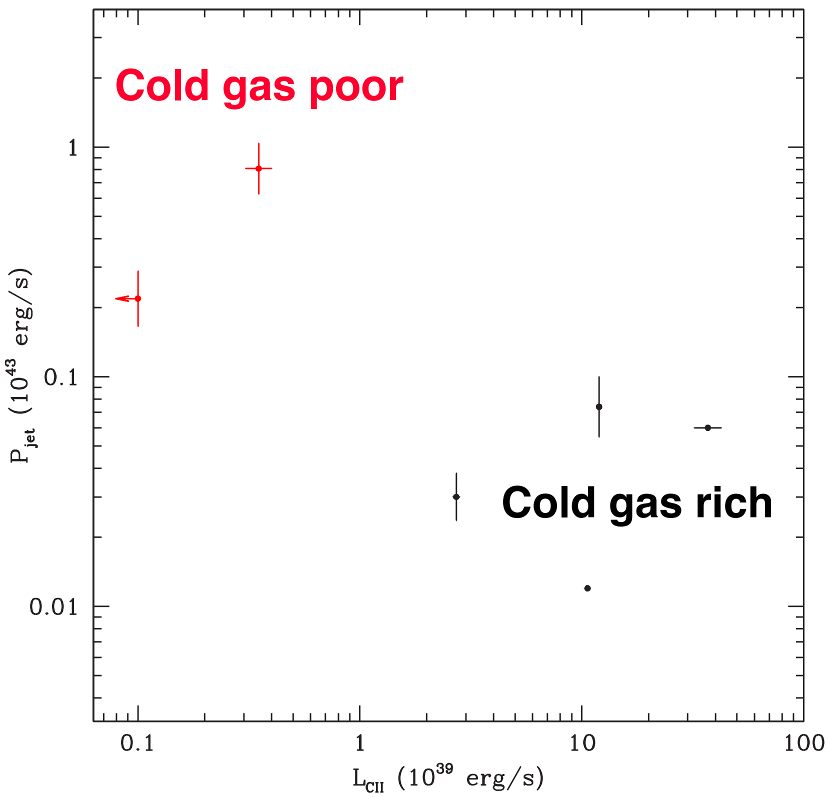
$$\Pi_{\mathrm{F}} = \frac{\kappa T}{n_{\mathrm{e}} n_{\mathrm{H}} \Lambda(T) r^2}$$

is the ratio of the conductive heating to the radiative cooling rate.

There is a dichotomy with the cold-gas-rich system remaining unstable out to relatively large radii.

Werner et al. 2014

Jet powers and cold gas

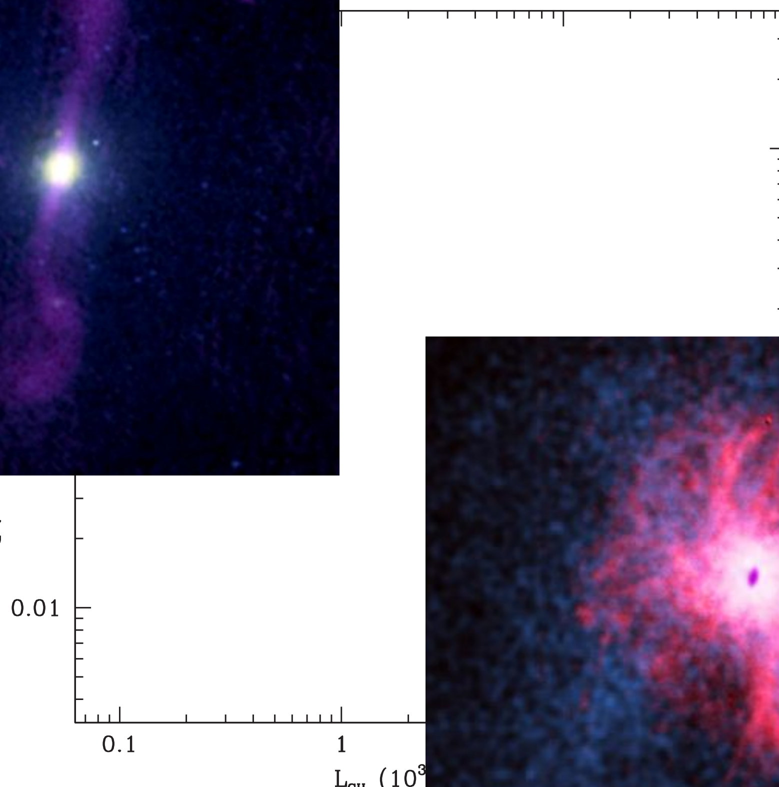


Power input (measured from X-ray cavities) to ICM from radio mode feedback does not increase with amount of cold gas

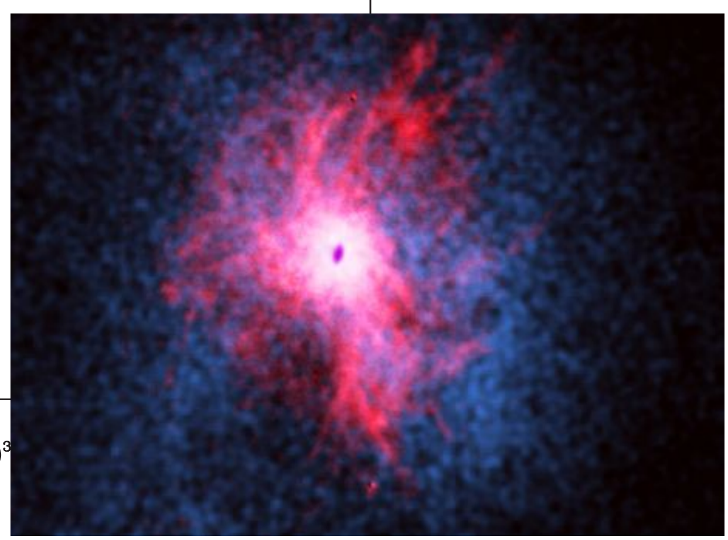
Werner et al. 2014

Jet powers and cold gas

Large jet power,
no cold gas,
relaxed X-ray

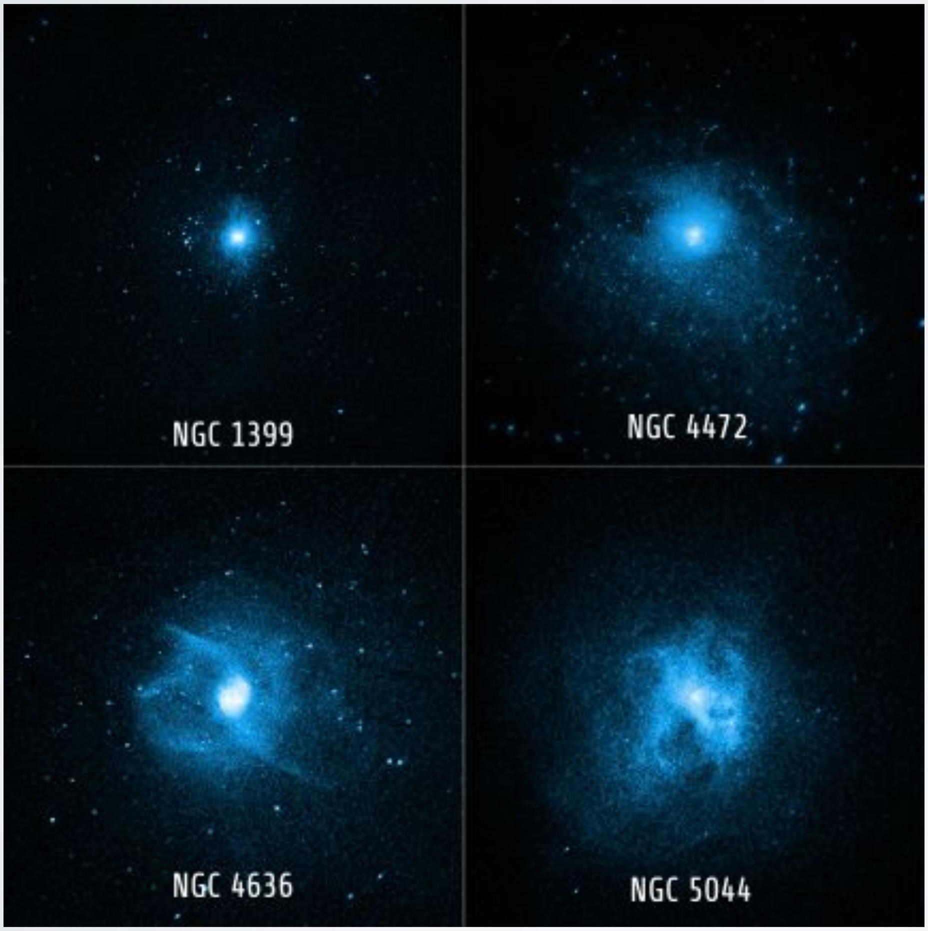


Small jet power,
many X-ray
cavities and
disturbed
morphology,
plenty of cold gas



Werner et al. 2014

A cycle or end state?



- High pressure X-ray gas powers persistent strong jets
- Cool and cold gas destroyed
- Jets propagate farther

- AGN outbursts less steady - clumpy cold gas?
- Interact with surrounding high density cool and cold gas

Summary:

Cool and cold gas can be plentiful in X-ray bright massive galaxies but not necessarily in all.

The gas likely originates from cooling of the hot ISM

We identify two states:
1. Relaxed, dynamically stable ETGs cooling from the hot phase is not detected
2. Disturbed massive X-ray bright galaxies are often cold gas rich

Radio mode feedback can couple to both hot and cold gas in massive galaxies in order to ‘quench’ the SF