Expanding Gaseous Halos with AGN Feedback

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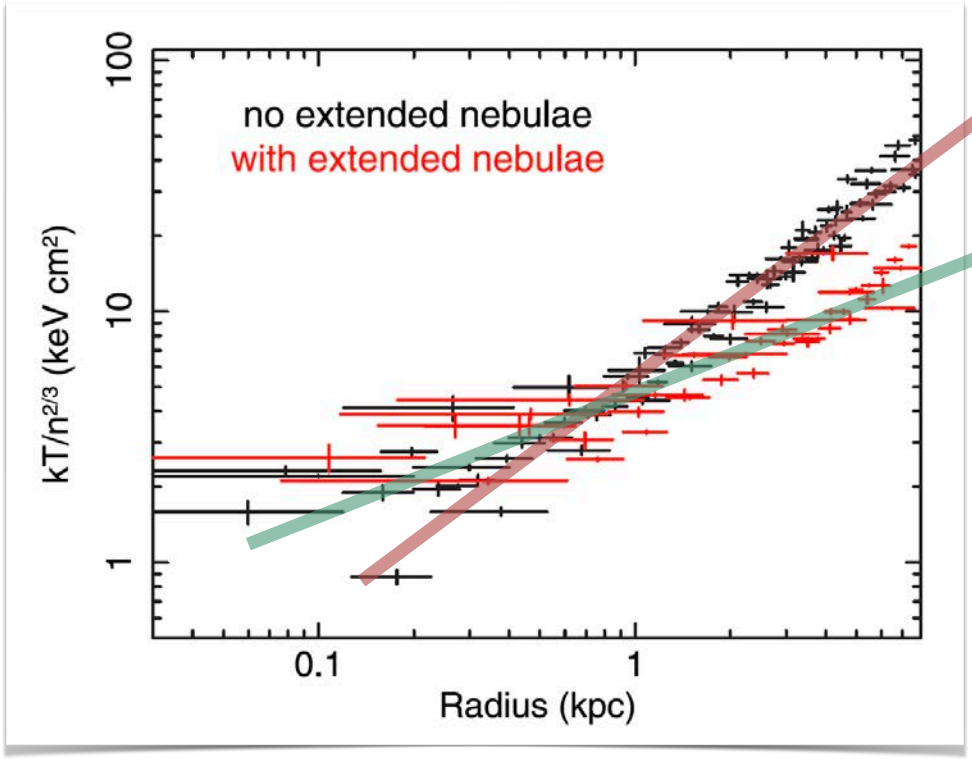
Please contribute a Pub

galacticatmospheres.pubpub.org

Copenhagen — 2014



Werner et al. (2014)

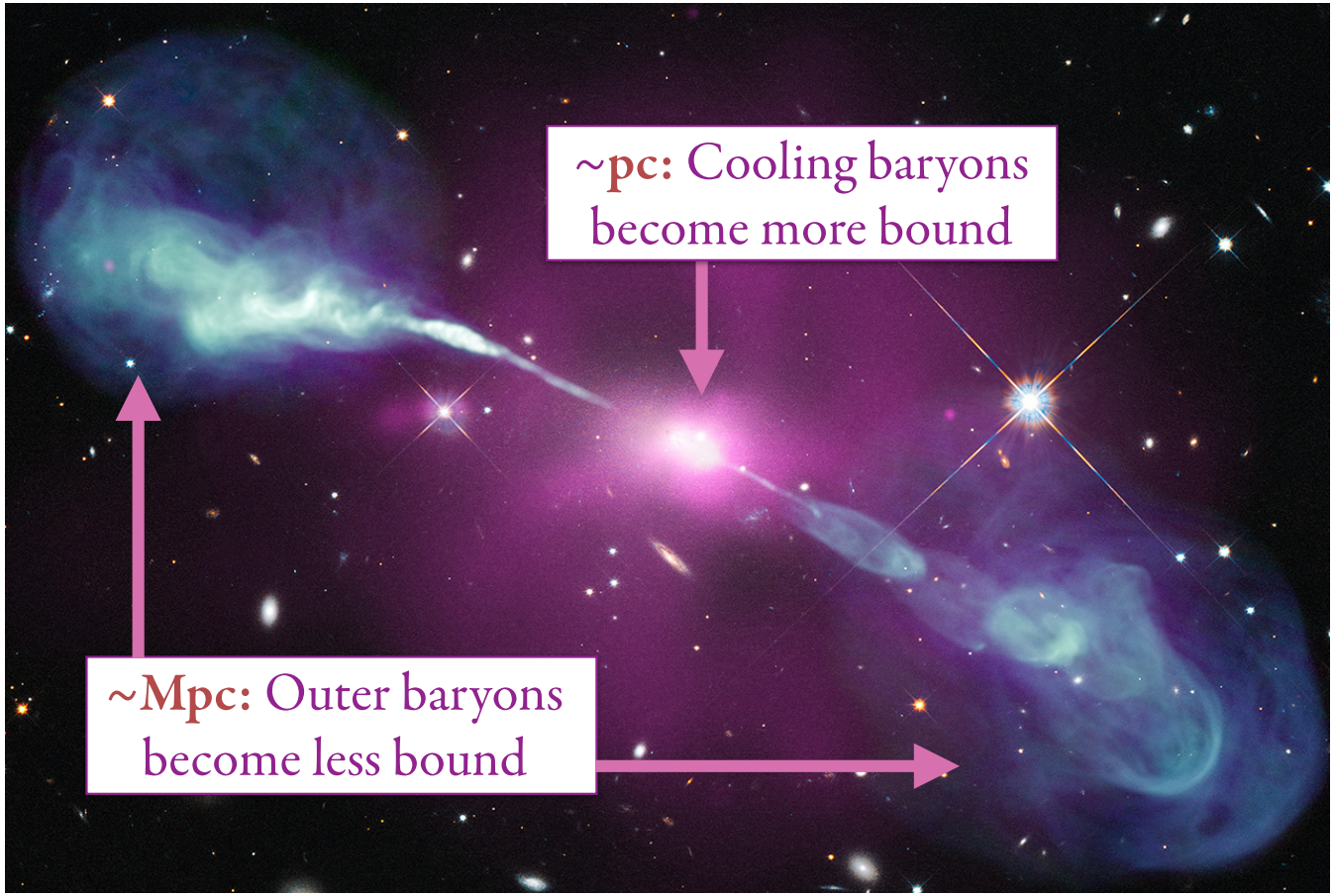
valve regulated

precipitation regulated

What closes feedback loops?

Donahue & Voit (2022)

Gravitational Binding Energy

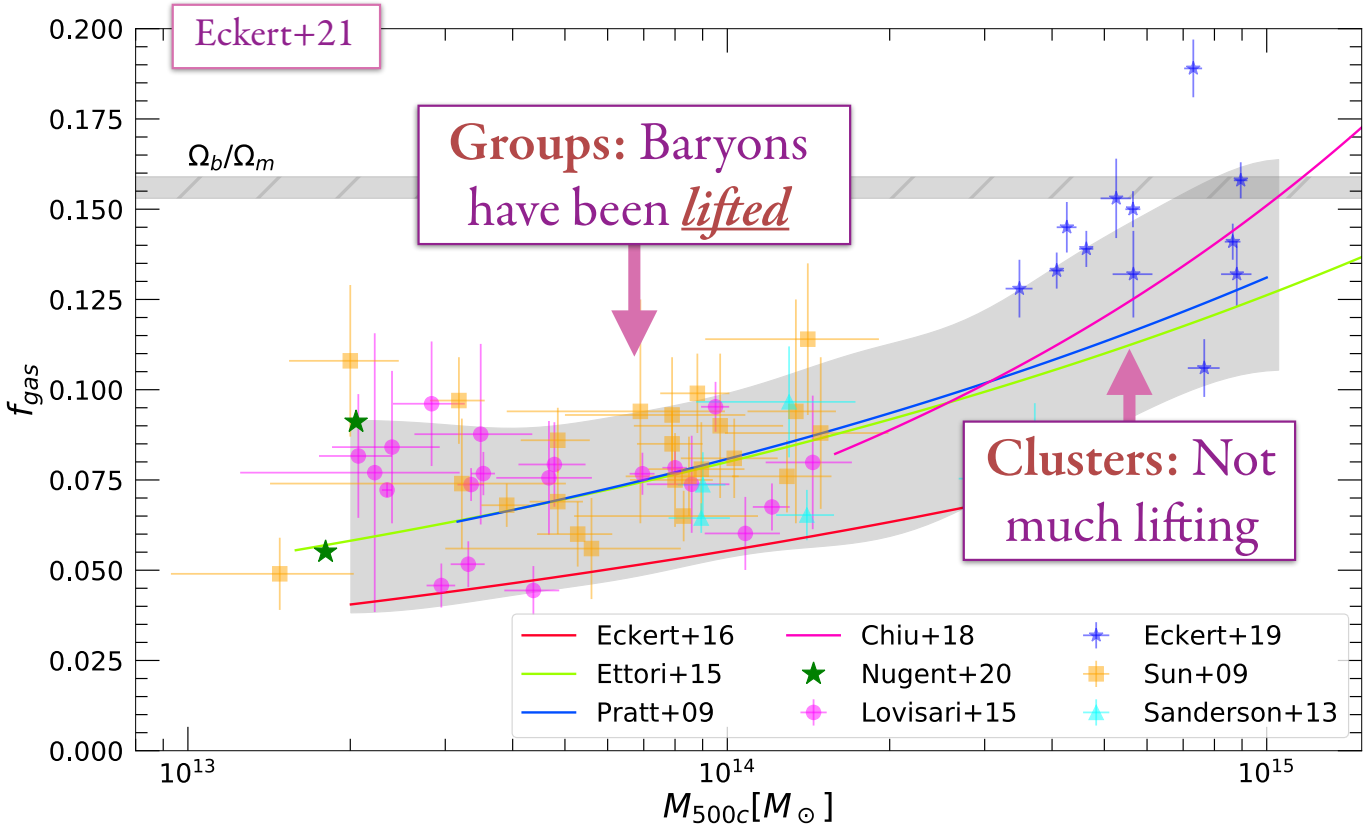


Primary task of AGN feedback:

Prevent Overcooling!

... but how is the BH aware of its environment?

Gravitational Binding Energy



CGM binding energy:

$$E_{\rm CGM} \sim kT\left(f_{\rm b}M_{\rm halo}/\mu m_p\right)$$

For groups:

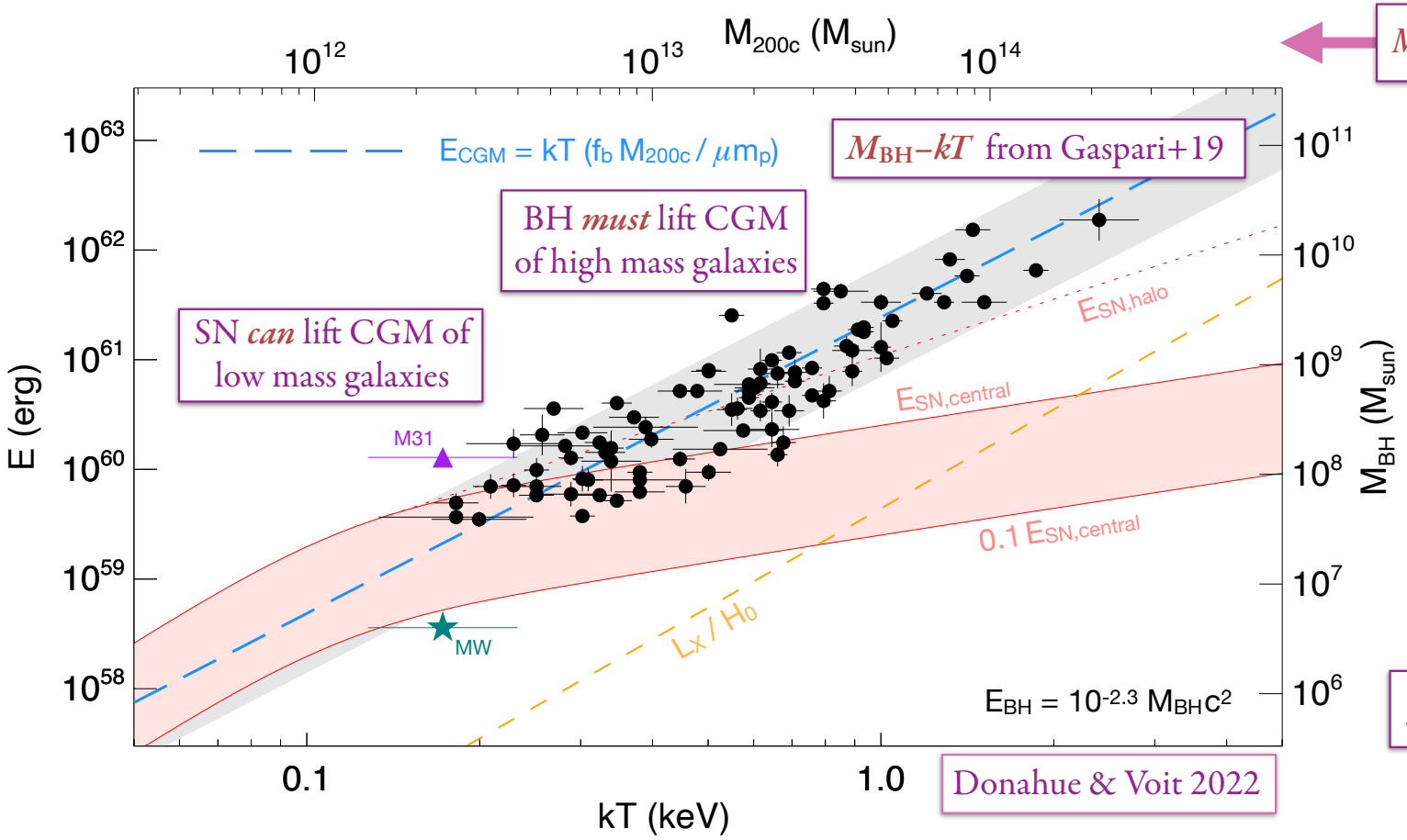
$$E_{\rm CGM} \sim 10^{60-61}\ {\rm erg}$$

$$E_{\rm CGM}H_0 \sim 10^{43-44}\ {\rm erg\ s^{-1}}$$

$$\langle \dot{E}_{\rm lifting}\rangle \gg L_{\rm cool}$$

Heating *exceeds* cooling

AGN Feedback & CGM Lifting



$M_{\rm halo} = 10^{13.7}\,(kT)^{1.7}_{\rm keV}\,M_\odot$

AGN feedback tunes itself to CGM properties

See also:

Booth & Schaye (2010)

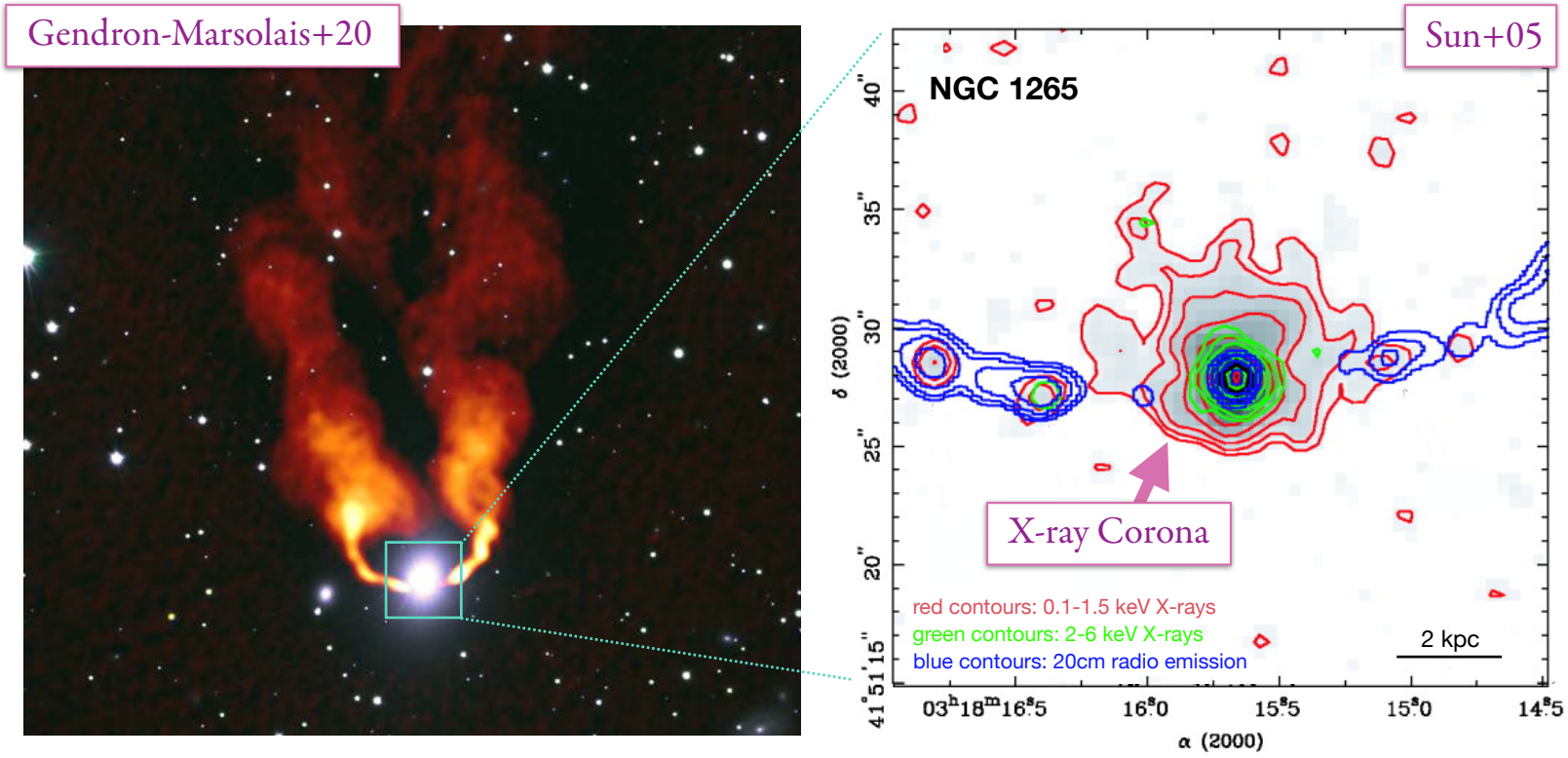
Truong talk

CGM lifting implies

$$\Delta E_{\rm CGM} \sim 10^{-2.3}\,M_{\rm BH}\,c^2$$

for $M_{\rm halo} \sim 10^{12.5}$ - $10^{14}\,M_{\rm Sun}$

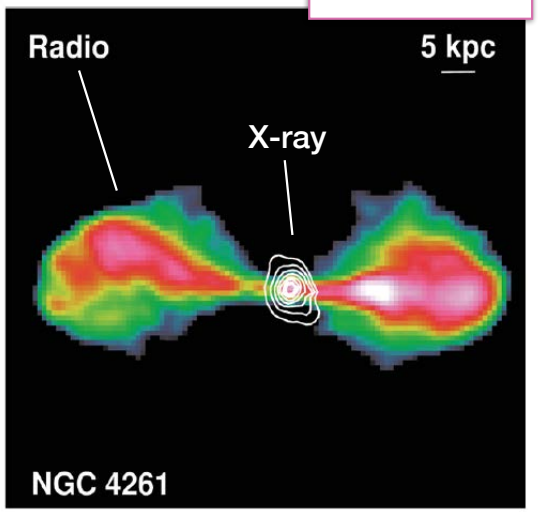
Puzzle: Strong Jets Bypass the Corona



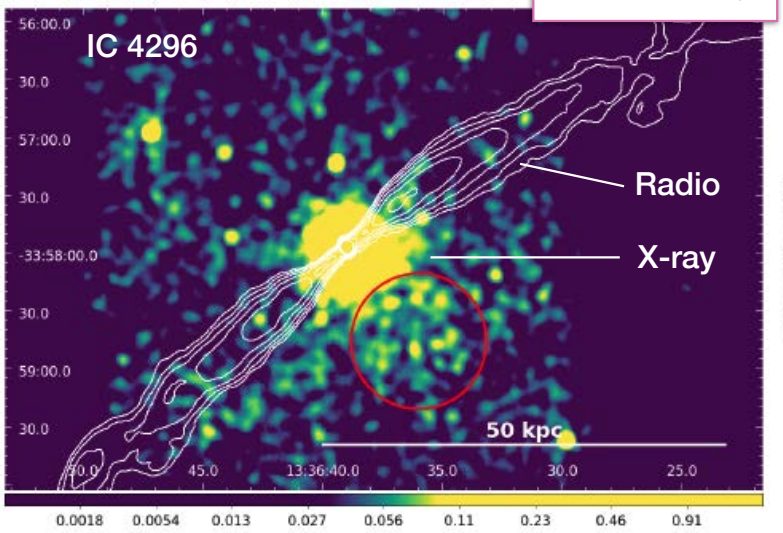
X-ray coronae manage to persist, while orders of magnitude more power passes through to the CGM

Puzzle: Strong Jets Bypass the Corona

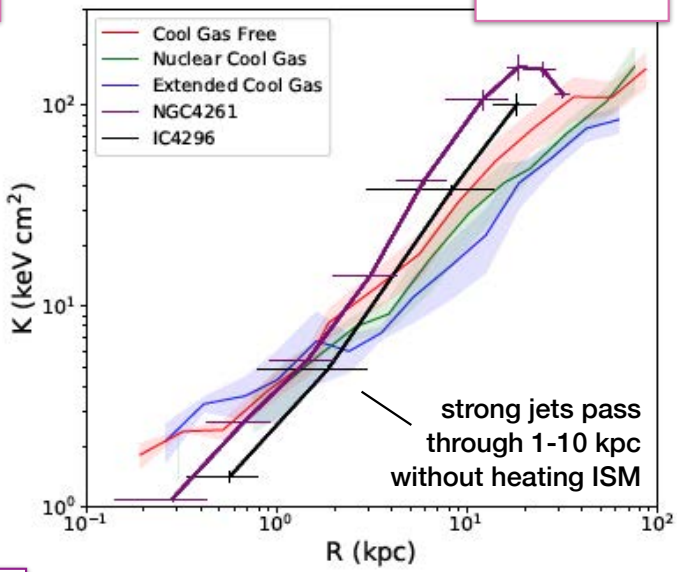
Werner+12



Grossova+19



Frisbie+22

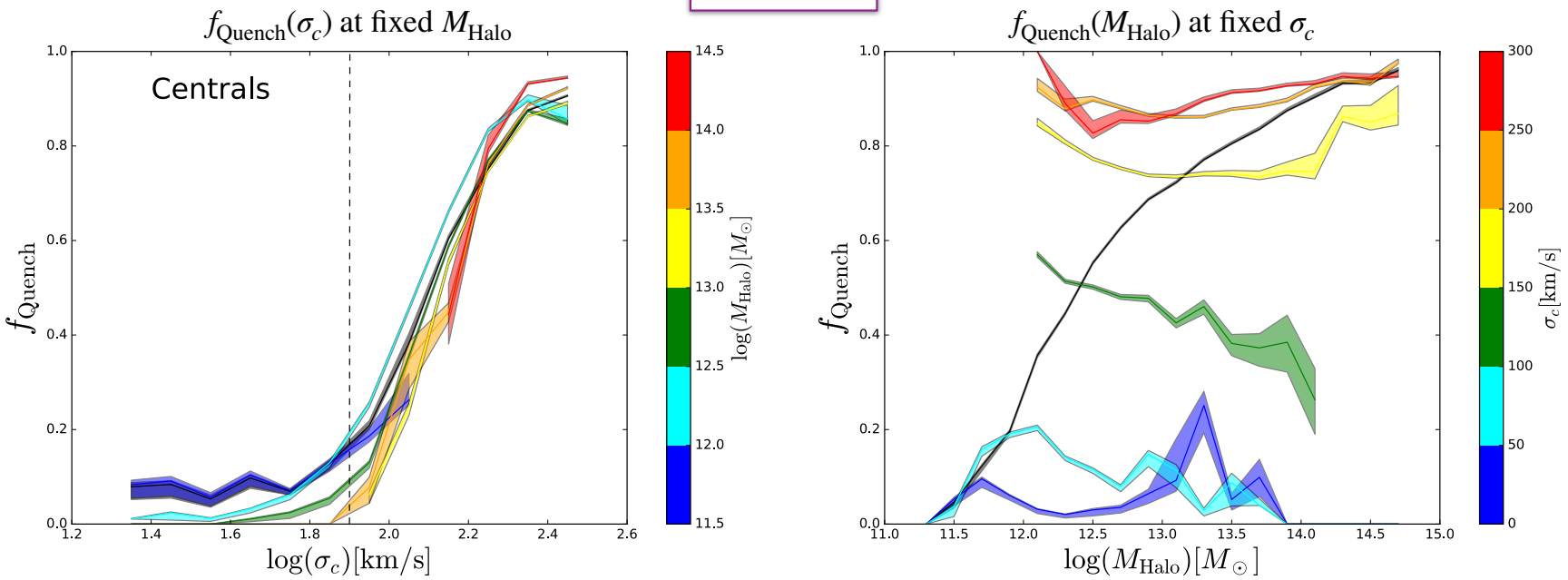


How do these systems self-regulate?

X-ray coronae manage to persist, while orders of magnitude more power passes through to the CGM

Puzzle: Quenching and Velocity Dispersion

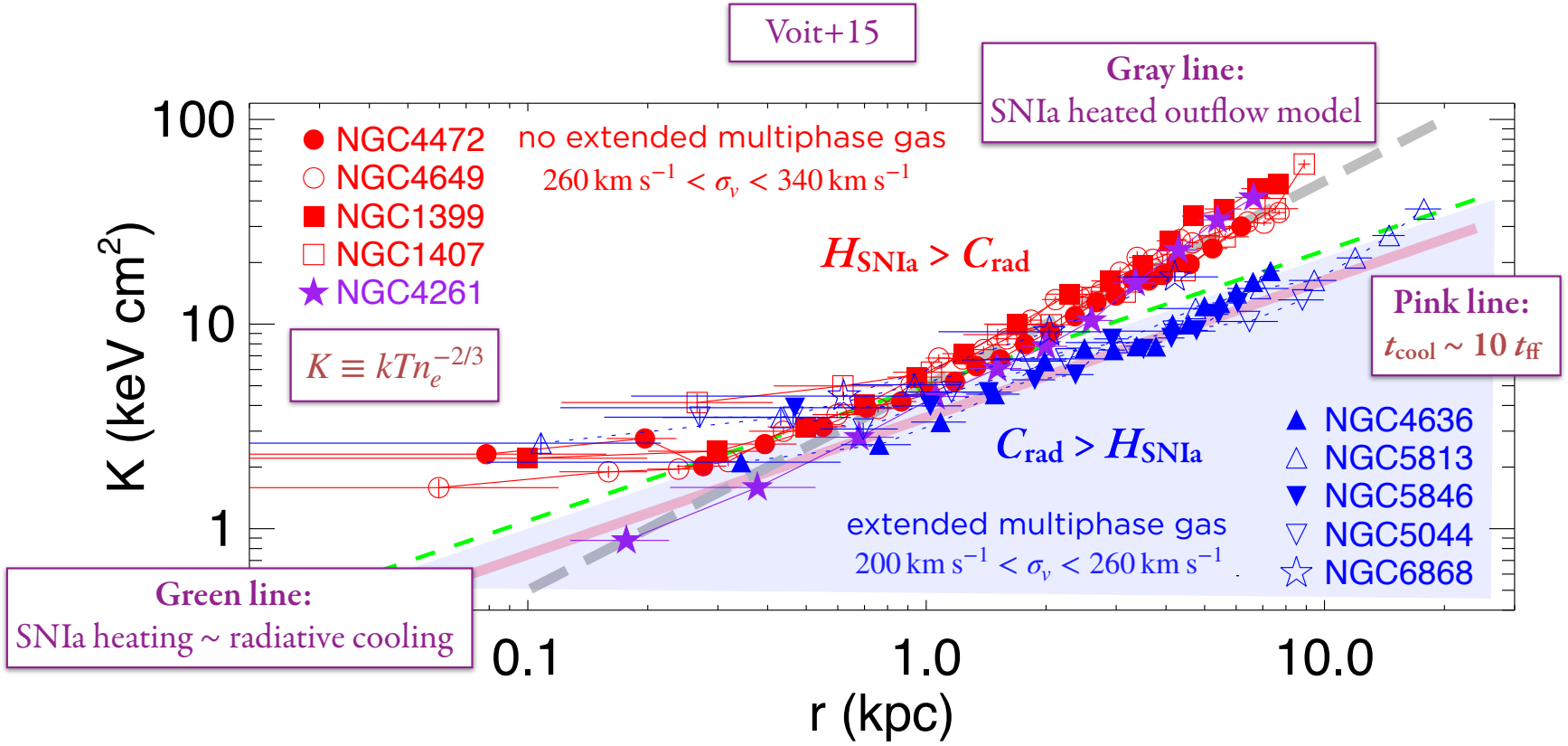
Bluck+16



Quenching of central galaxies depends more directly on stellar velocity dispersion than on anything else and is *independent of* $M_{\rm halo}$ at fixed σ_v!

Hypothesis: Galactic potential well determines ***efficacy*** of AGN feedback

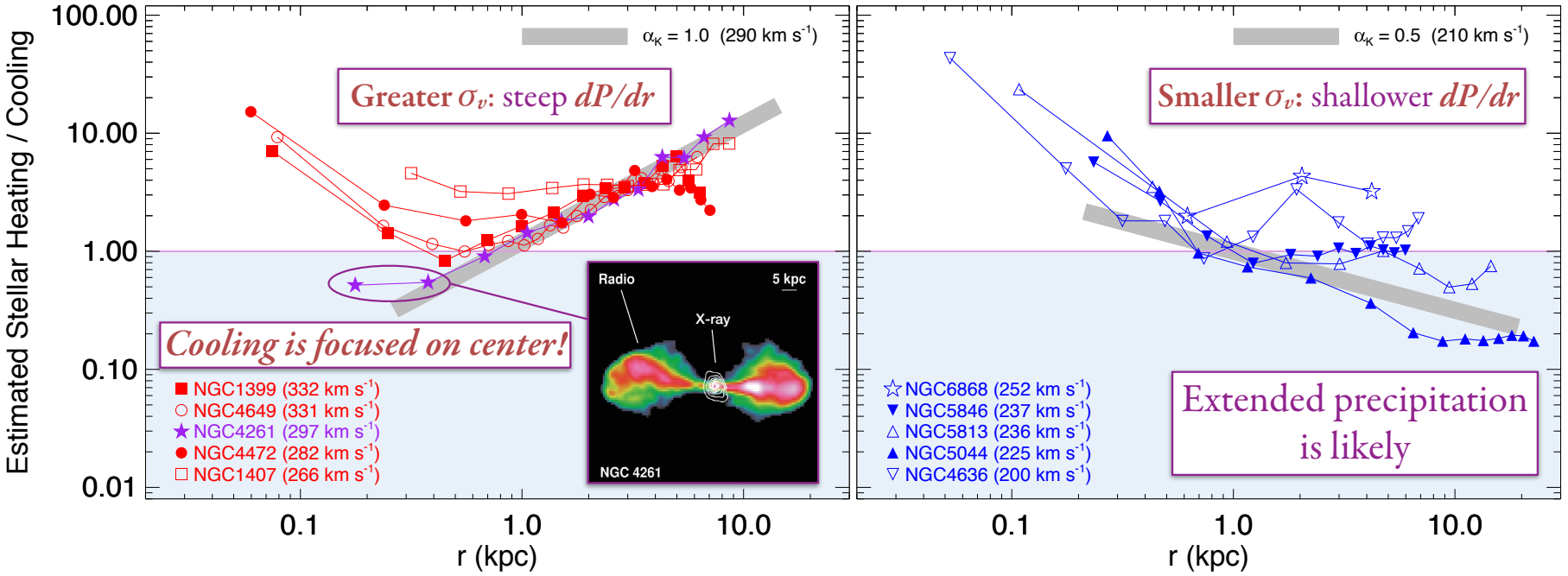
Radiative Cooling & SNIa Heating



X-ray profiles of massive ellipticals ***bifurcate*** around locus of heating/cooling equality

Radiative Cooling & SNIa Heating

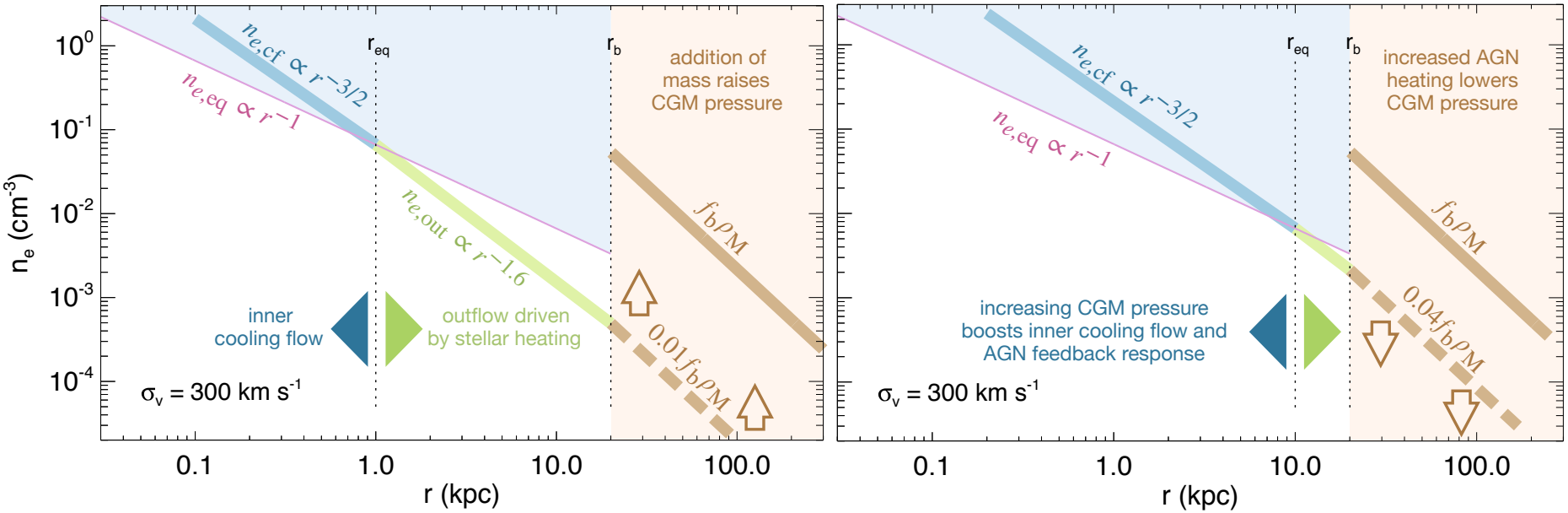
Voit+20



Fueling mode for AGN feedback depends on host galaxy properties!

The Feedback Valve Mechanism

Voit+20



If radial profiles of density/pressure/entropy have a steep enough slope, then ***P_{CGM} determines inner cooling-flow rate***, forming a closed feedback loop

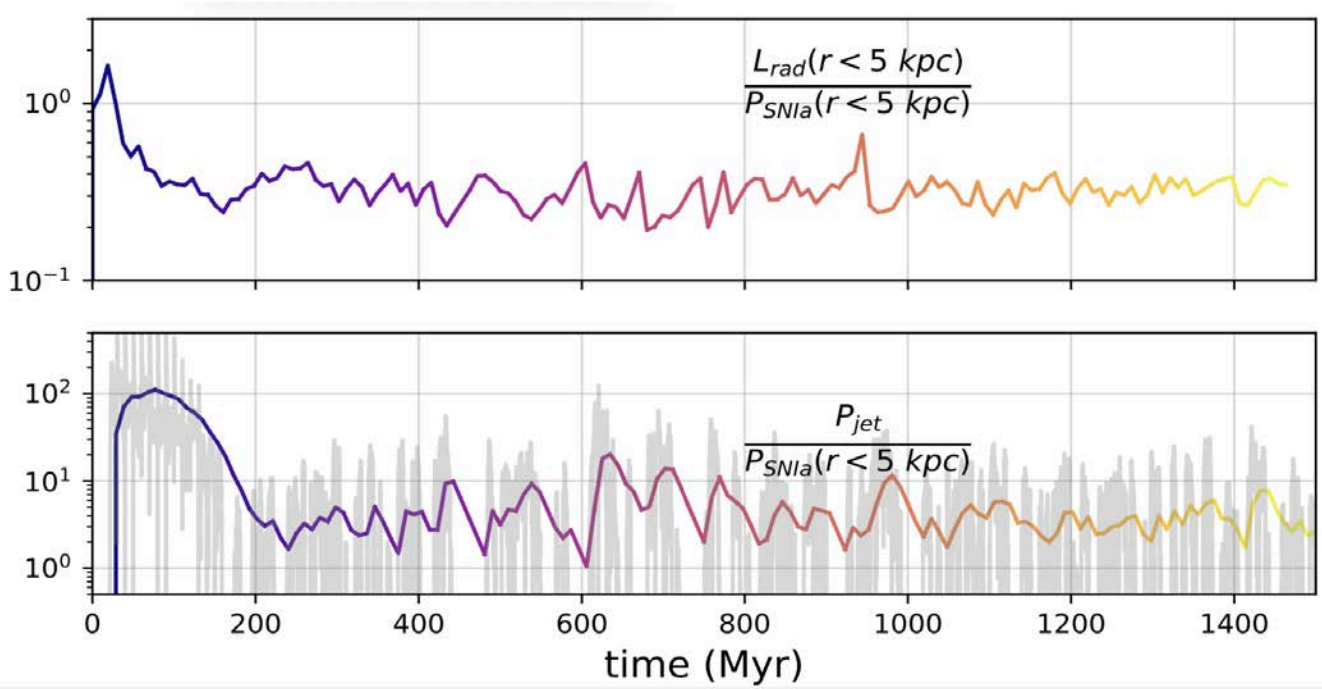
Simulations of the Mechanism

Prasad+20

Single-phase elliptical
(like NGC 4472)
$\sigma_v = 280$ km/s

Feedback rapidly pushes galaxy into a quasi-steady state with $H_{SNIa} > C_{rad}$ at ~1-5 kpc

Jet power exceeds SNIa power but propagates into CGM and lifts it



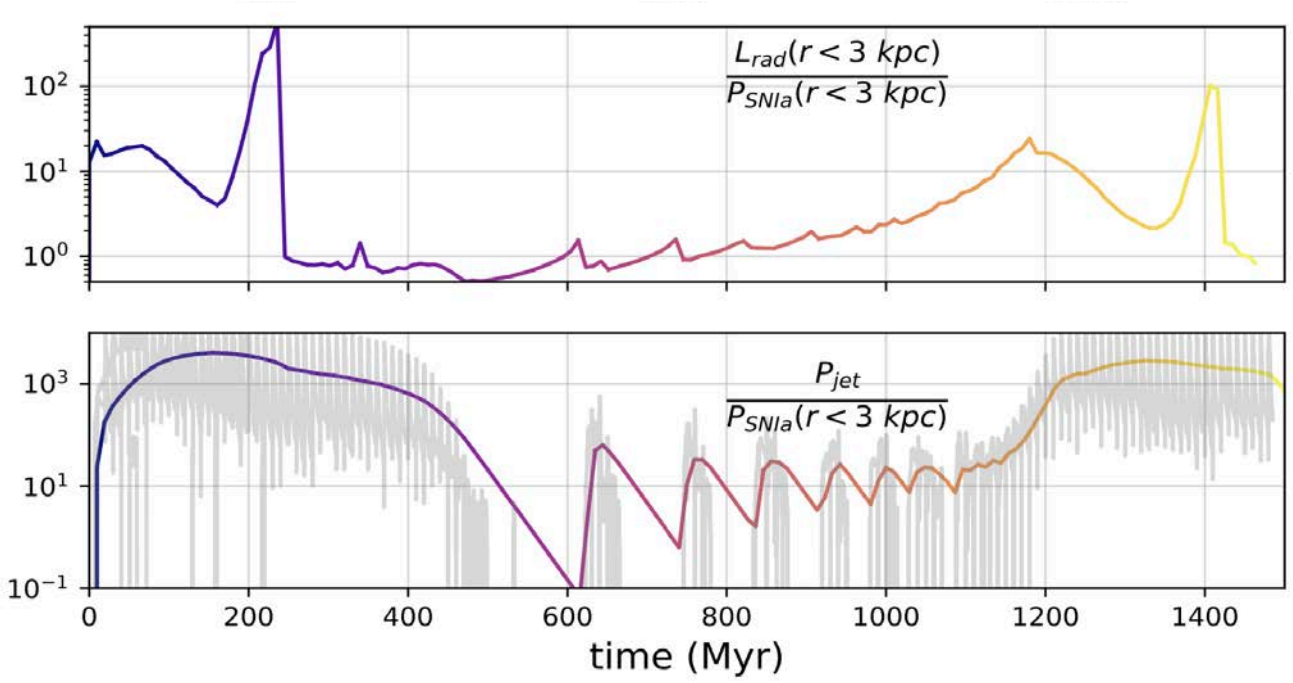
Simulations of the Mechanism

See Deovrat Prasad's talk!

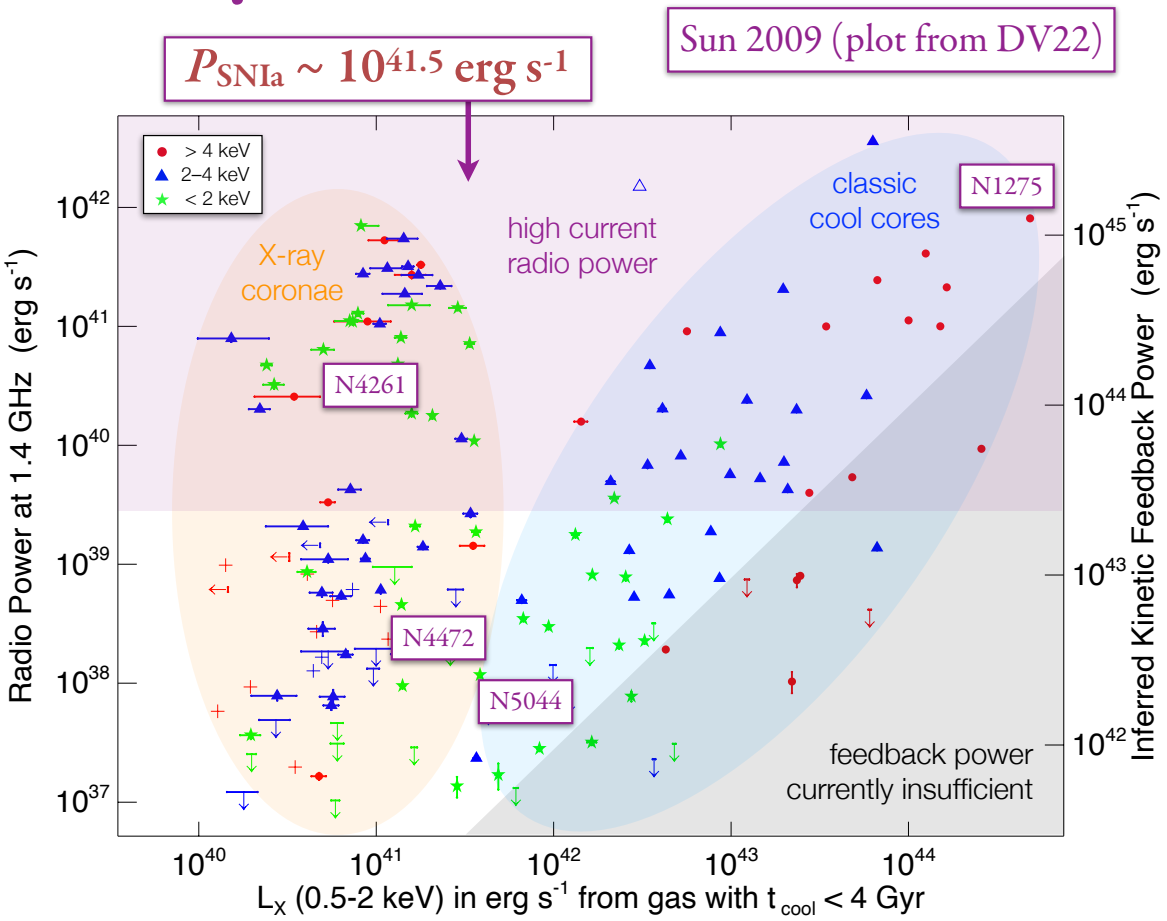
Multi-phase elliptical
(like NGC 5044)
$\sigma_v = 240$ km/s

Feedback causes galaxy to fluctuate in and out of states with $H_{SNIA} \sim C_{rad}$ at ~1-5 kpc

Episodes of high jet power subside when CGM lifting lowers pressure so that $H_{SNIA} \sim C_{rad}$ at small radii



X-ray Coronae versus Classic Cool Cores



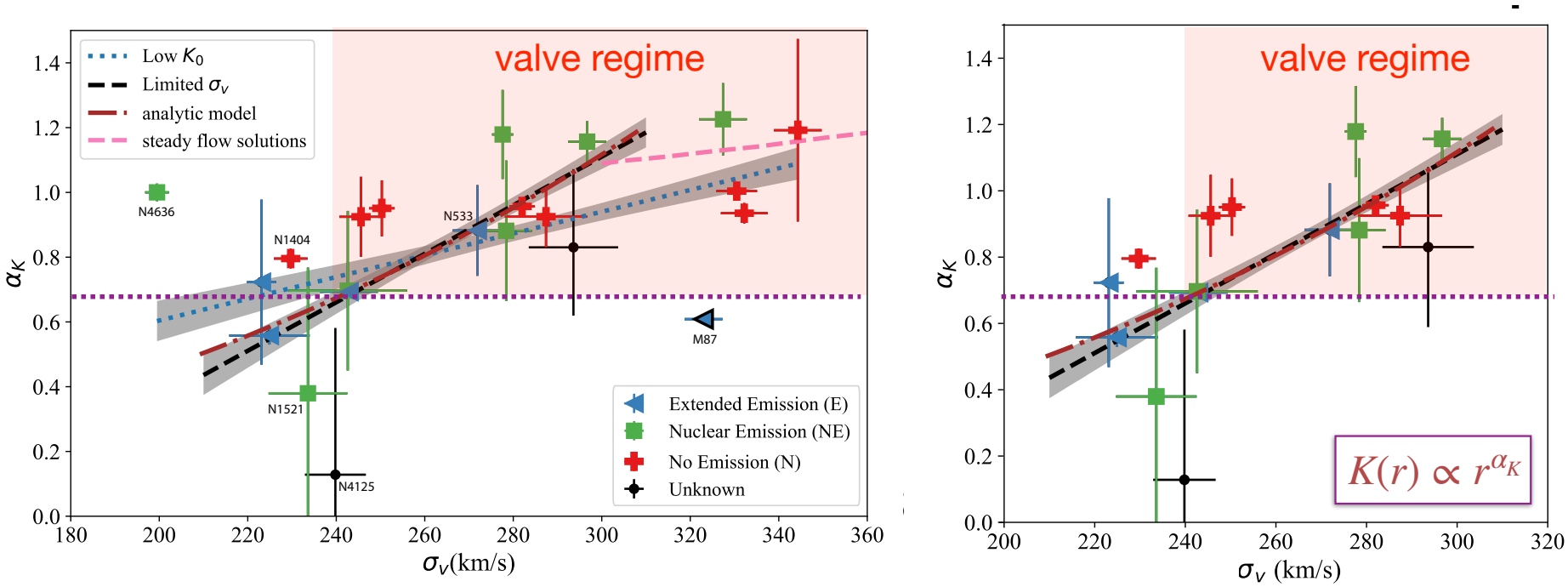
Radiative cooling exceeds SNIa heating everywhere in a high pressure halo

Valve mechanism suppressed in classic cool cores

.... but it might explain the dichotomy between X-ray coronae and classic cool cores

Testing the Predicted $\alpha_K - \sigma_v$ Correlation

Frisbie+22

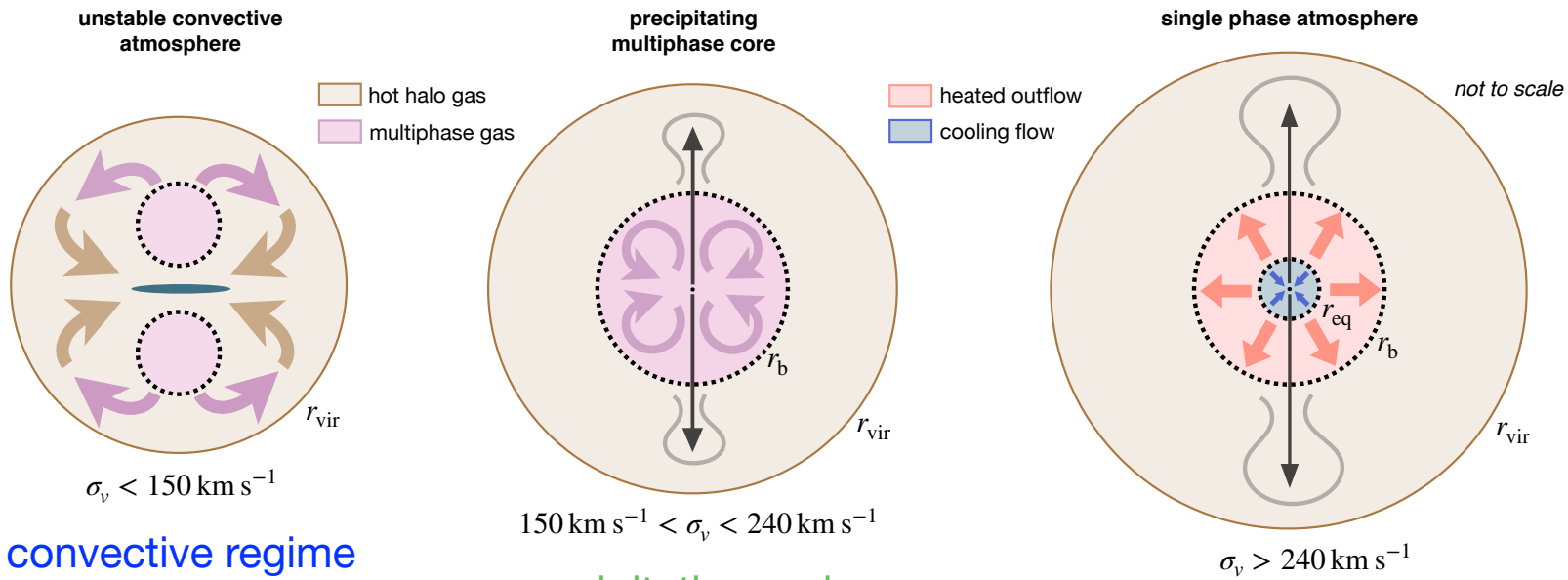


Analytical prediction for old stellar population: $\alpha_K \approx \frac{2}{3} + 1.7\left[\left(\frac{\sigma_v}{240\,\mathrm{km\,s^{-1}}}\right) - 1\right]$

Voit+20

CGM Structure & Regimes of Feedback

Voit+20



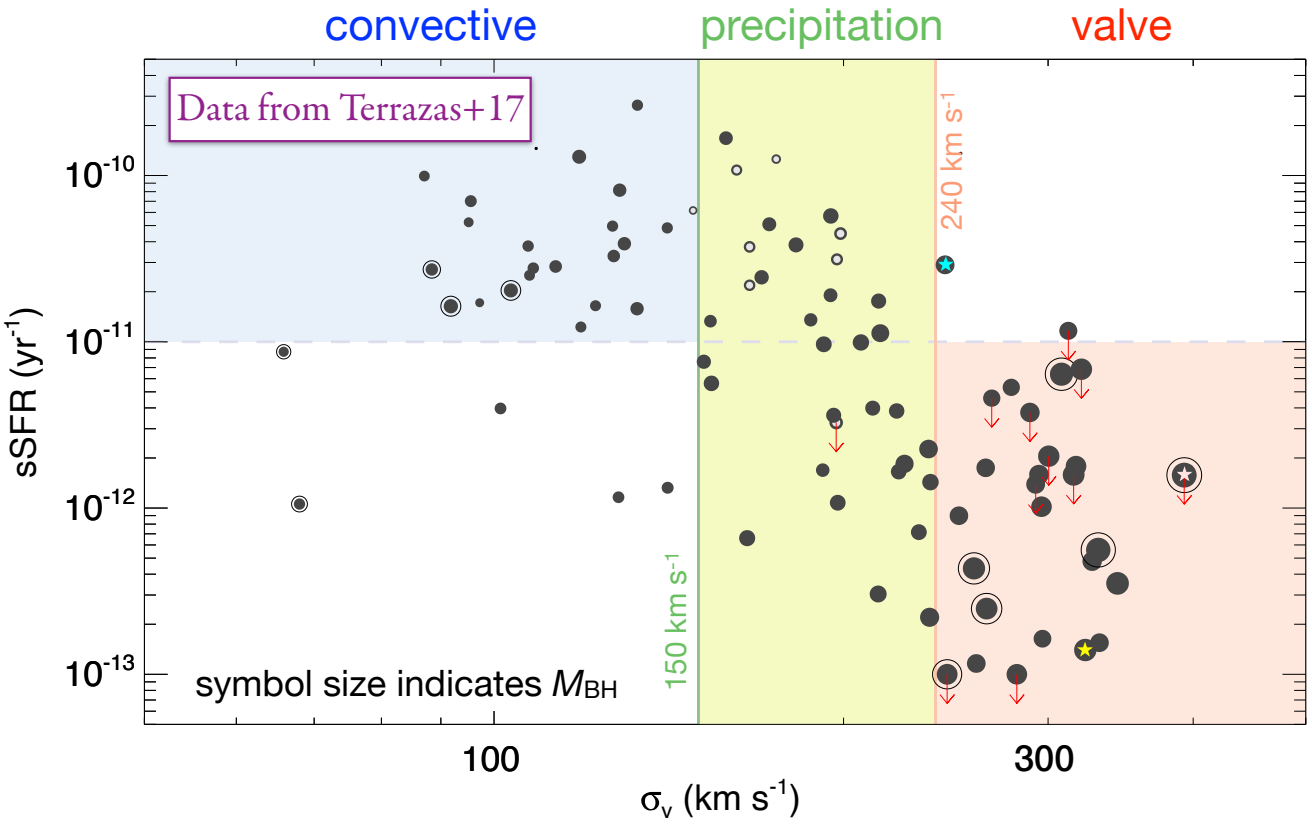
Feedback promotes multiphase medium

Multiphase medium regulates feedback

Multiphase cooling focused on center

Quenching & Regimes of Feedback

Donahue & Voit 2022



Specific star-formation rate (sSFR) is known to anticorrelate with M_{BH}

Anticorrelation is most pronounced in precipitation regime

No correlation is apparent in valve regime

Summary

- AGN feedback lifts the CGM on group scales
  - ➡ M_{BH} linked to ***CGM binding energy***

inner-outer connection

- Strong jets ***bypass the ISM***
- Quenching correlates best with σ_v

puzzles on ~kpc scales

- SNIa heating can ***close the feedback loop***
  - ➡ ***efficacy*** of AGN feedback depends on σ_v

galaxy properties determine inner/outer connection

Donahue & Voit (2022) Physics Reports, 973, 1-109 *it's only 109 pages!*