Triggering of AGN Feedback

The Plan

1. The Threshold for Activity

2. Multiphase Gas & Feedback

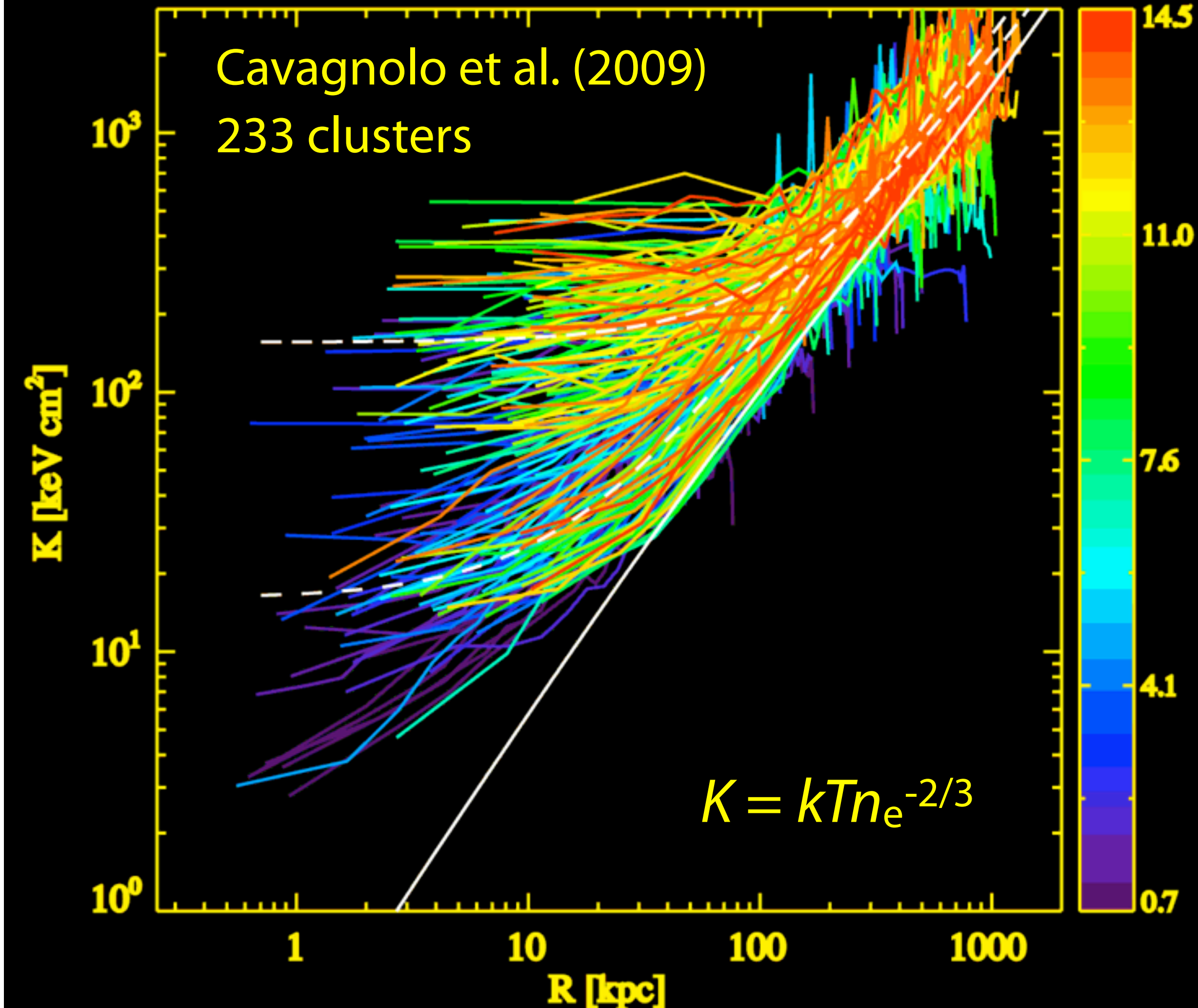
1

The Threshold for Activity

1 *Message*

- AGN feedback, star formation, & multiphase gas all appear in cluster cores at the same threshold in central entropy & cooling time.
- AGN feedback & star formation probably share a common trigger.

Chandra Entropy Profiles



Most profiles are well fit with:

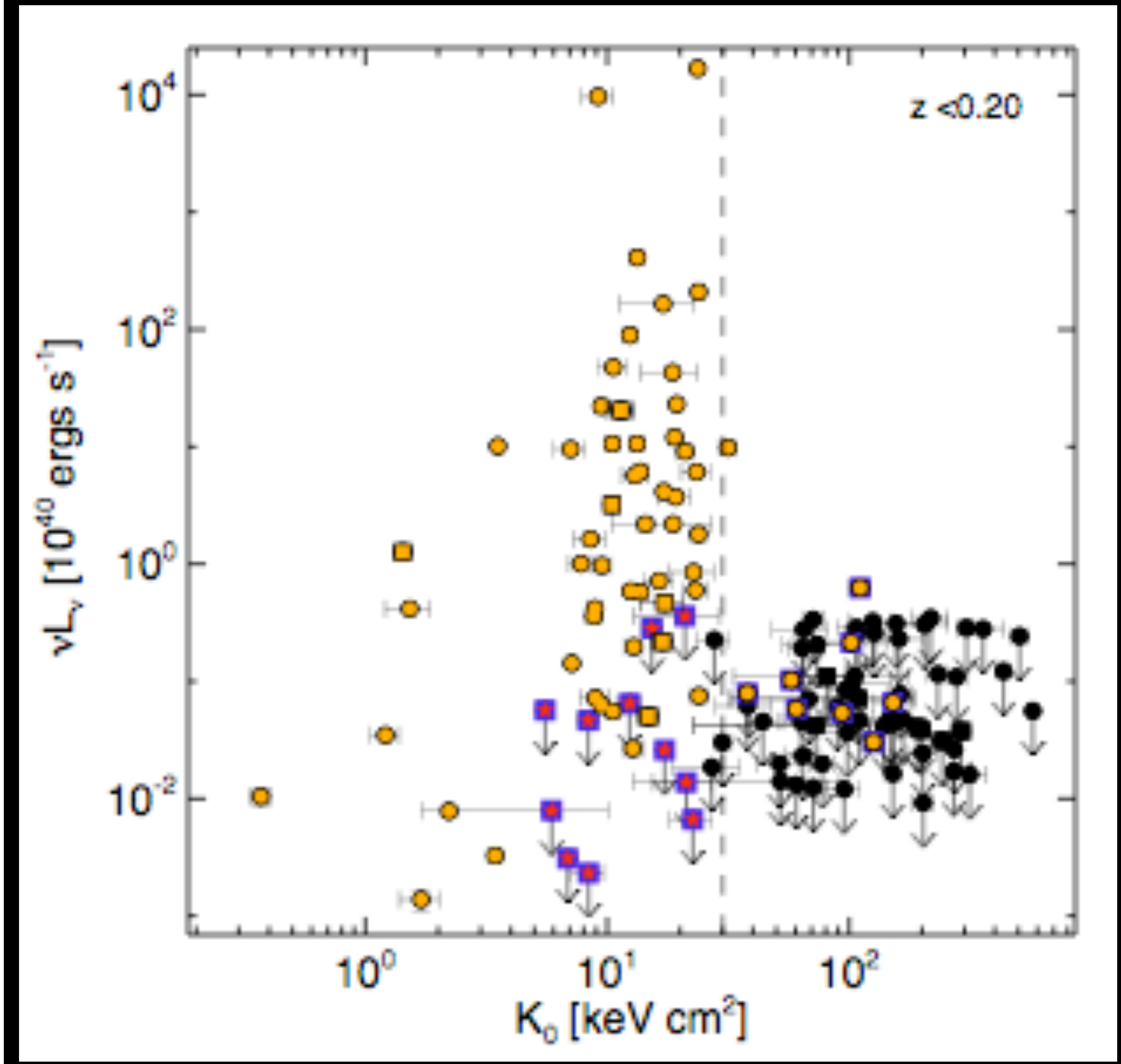
$$K(r) = K_0 + K_{100}\left(\frac{r}{100\ \mathrm{kpc}}\right)^{\alpha}$$

$K_{100} \sim 150$ keV cm^2

$\alpha \sim 1.2$

Pure cooling model is lower limit to observed profiles

K_0 and Radio Power



Central galaxy of a $z < 0.2$ cluster can be a strong radio source only if

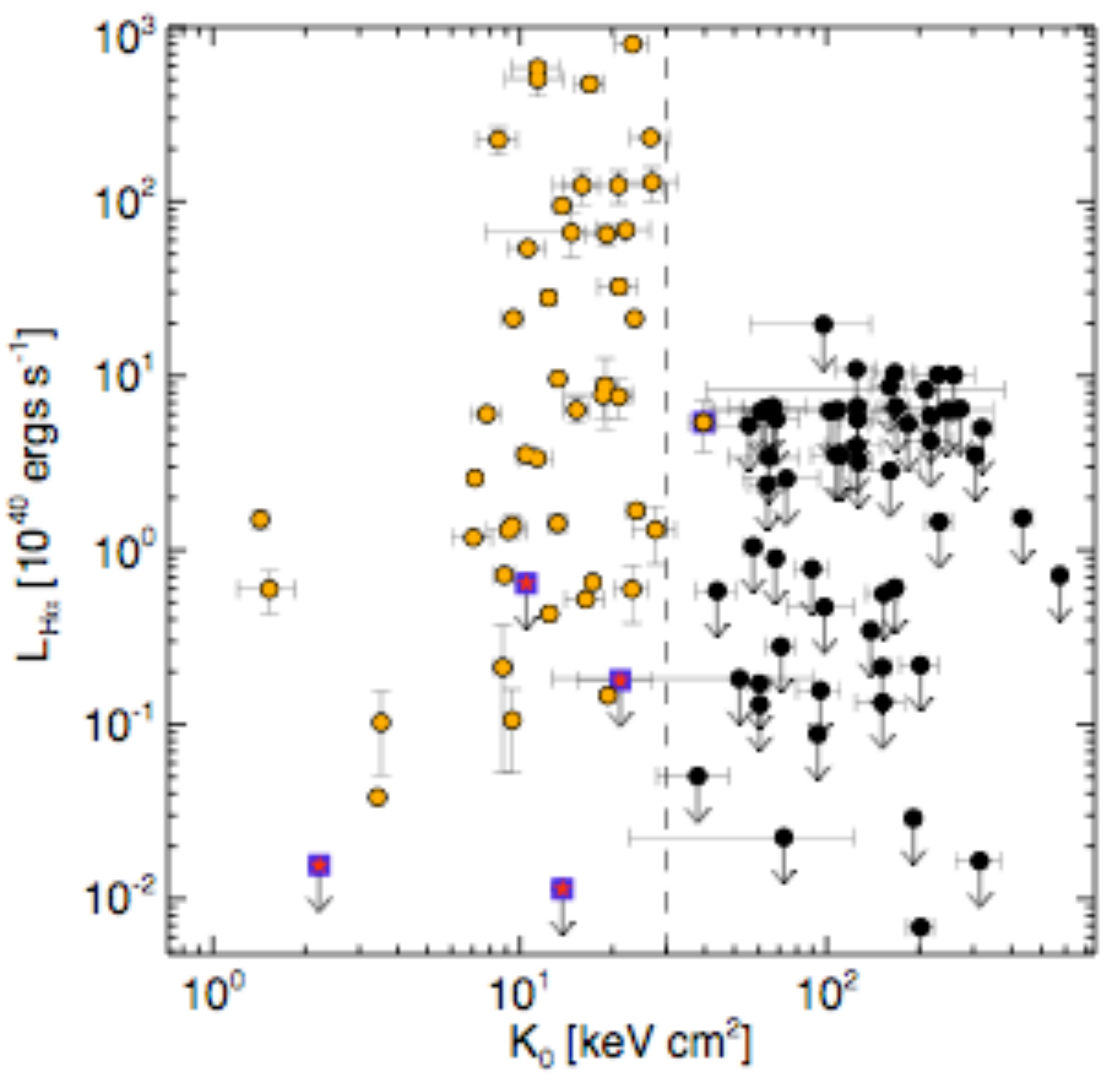
$K_0 < 30$ keV cm^2

Radio data from NVSS +SUMMS within 20″ of X-ray peak

Cavagnolo et al. (2008)

See also Dunn & Fabian

K_0 and Hα Emission

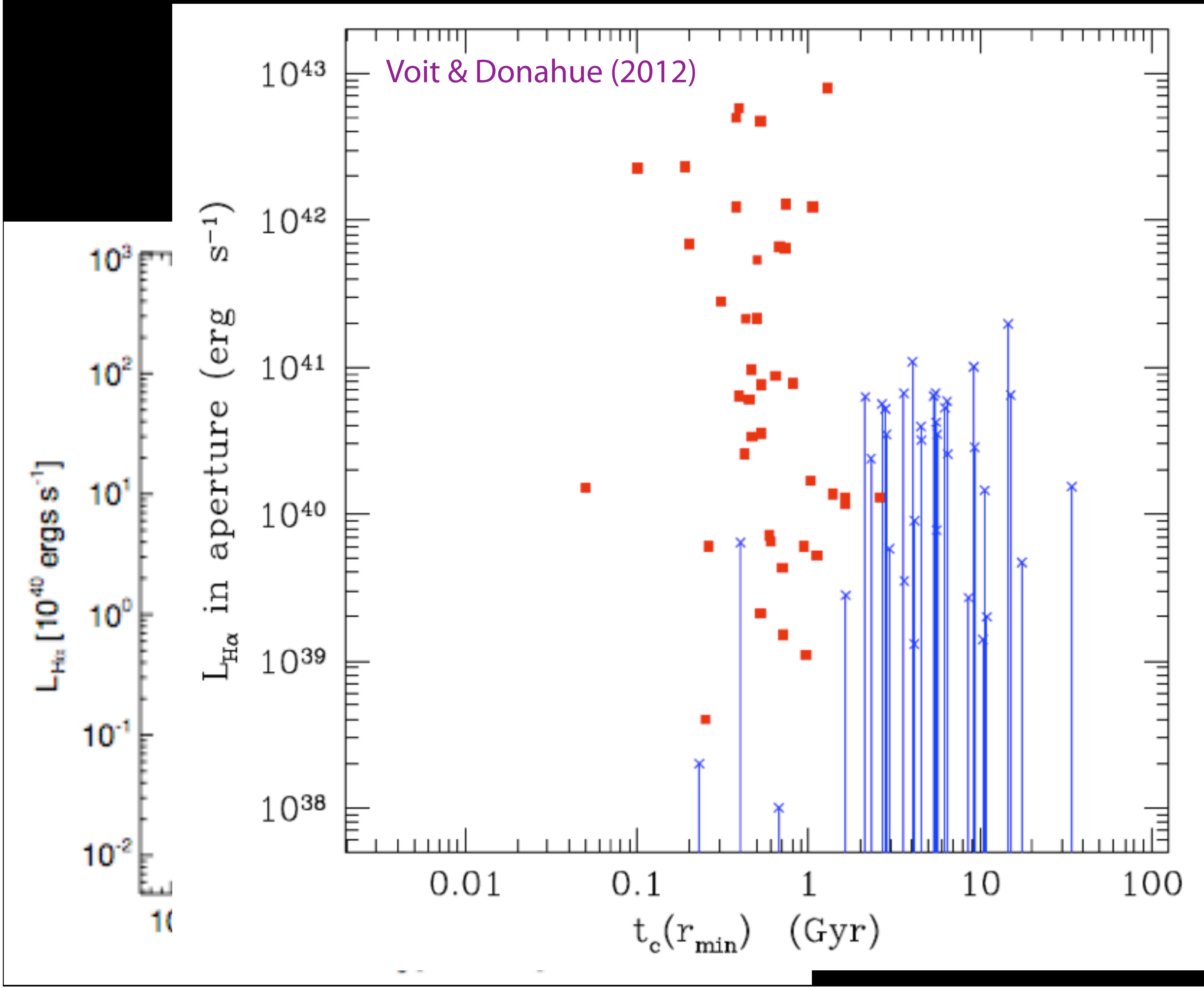


Central galaxy can have emission-line nebulosity only if

$K_0 < 30$ keV cm^2

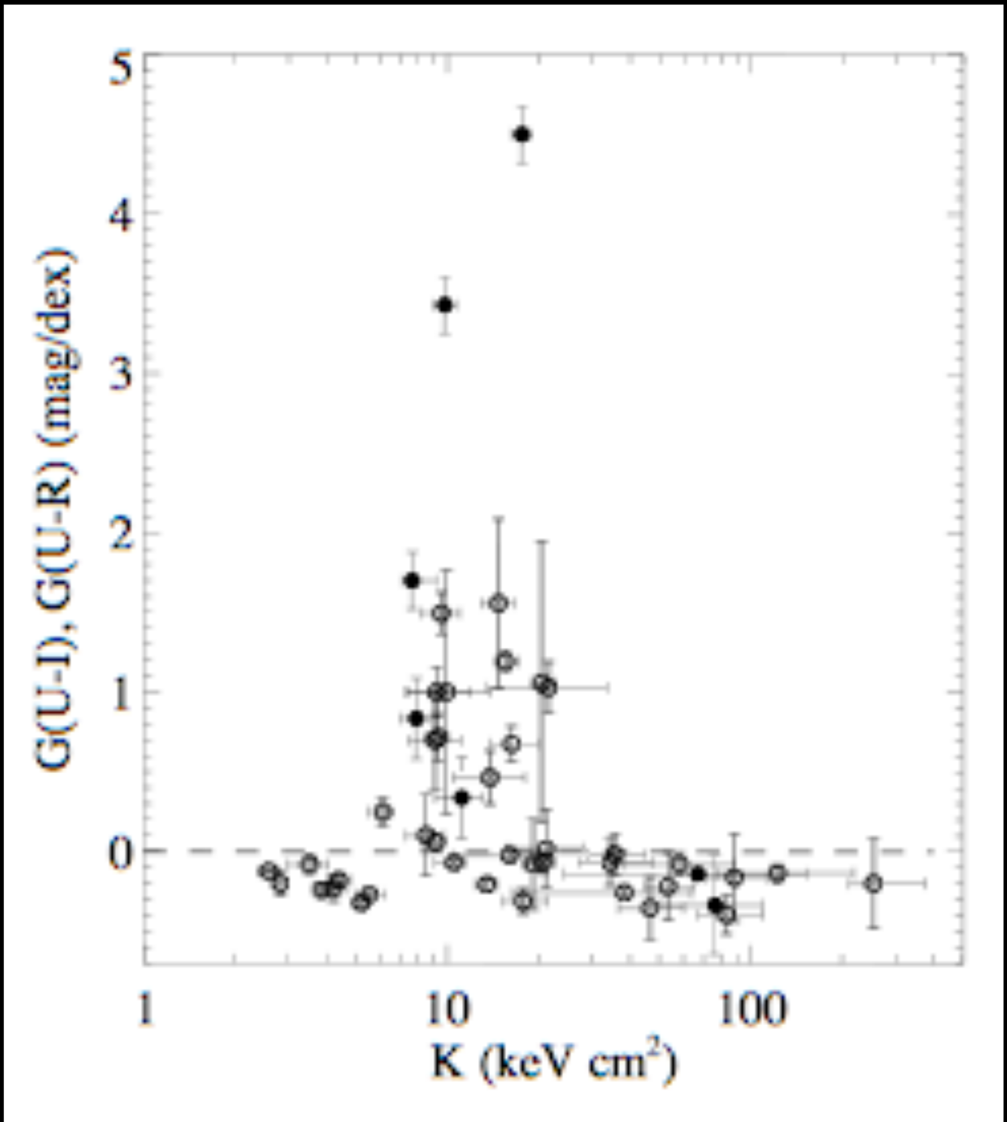
Hα data from many diverse sources

Cavagnolo et al. (2008)


Voit & Donahue (2012)
$L_{H\alpha}$ in aperture (erg s^{-1})
10^{43}
10^{42}
10^{41}
10^{40}
10^{39}
10^{38}
0.01
0.1
1
10
100
$t_c(r_{min})$ (Gyr)
$L_{H\alpha}$ [10^{40} ergs s^{-1}]
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}

ave

K_0 *and Star Formation*

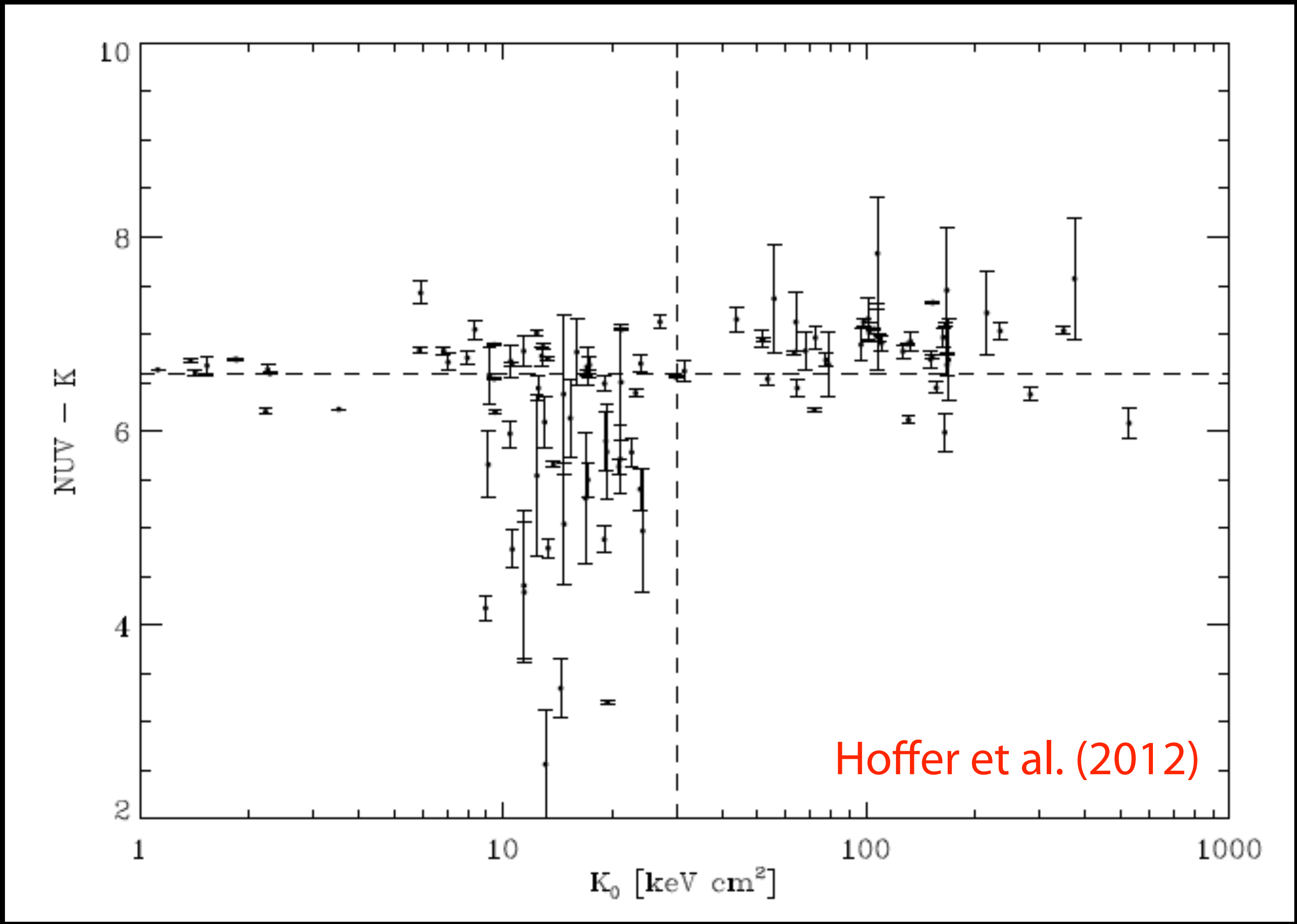


Central galaxy has blue core indicative of star formation only if

$K_0 < 30$ keV cm^2

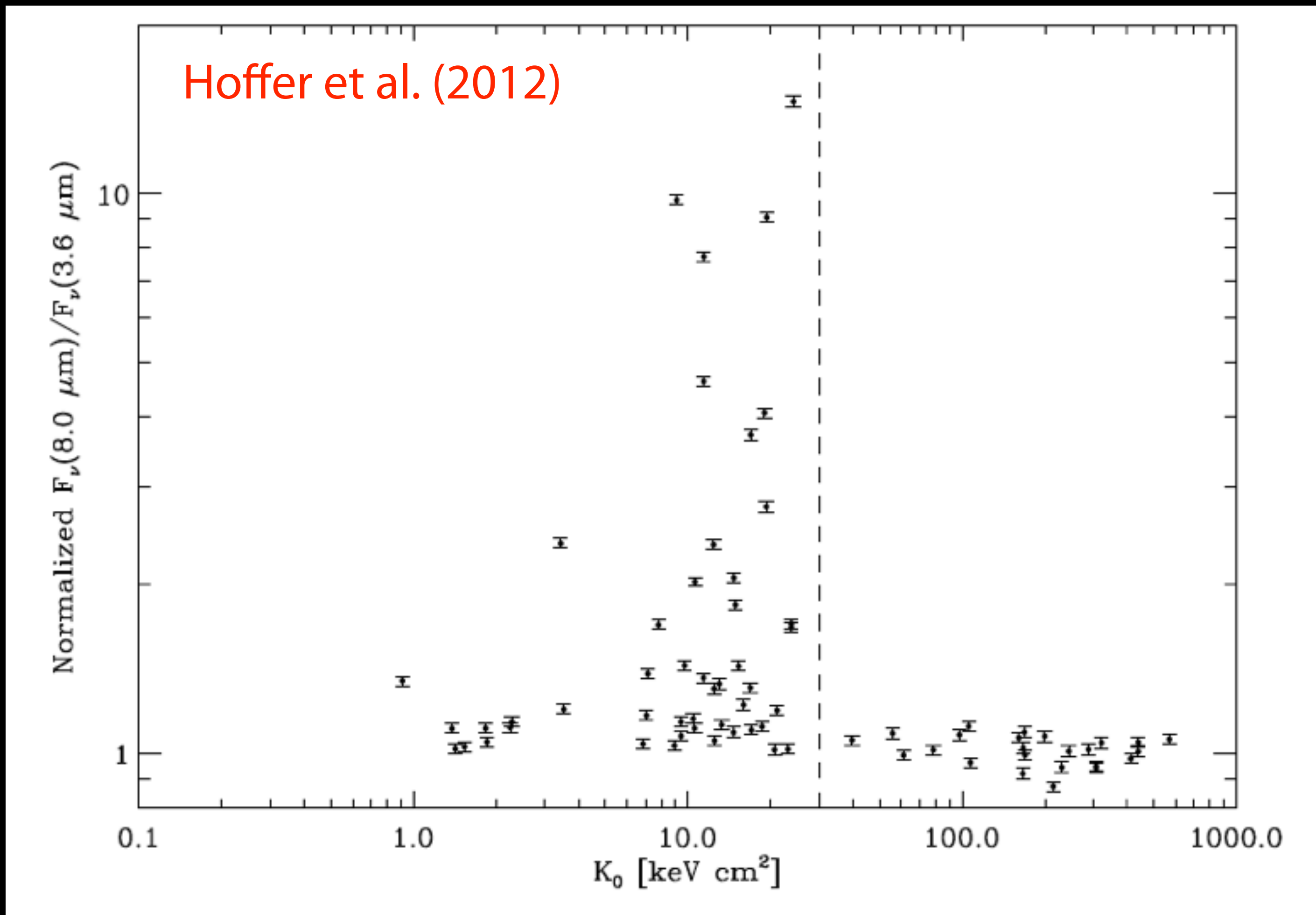
Rafferty et al. (2008)

K_0 and Star Formation



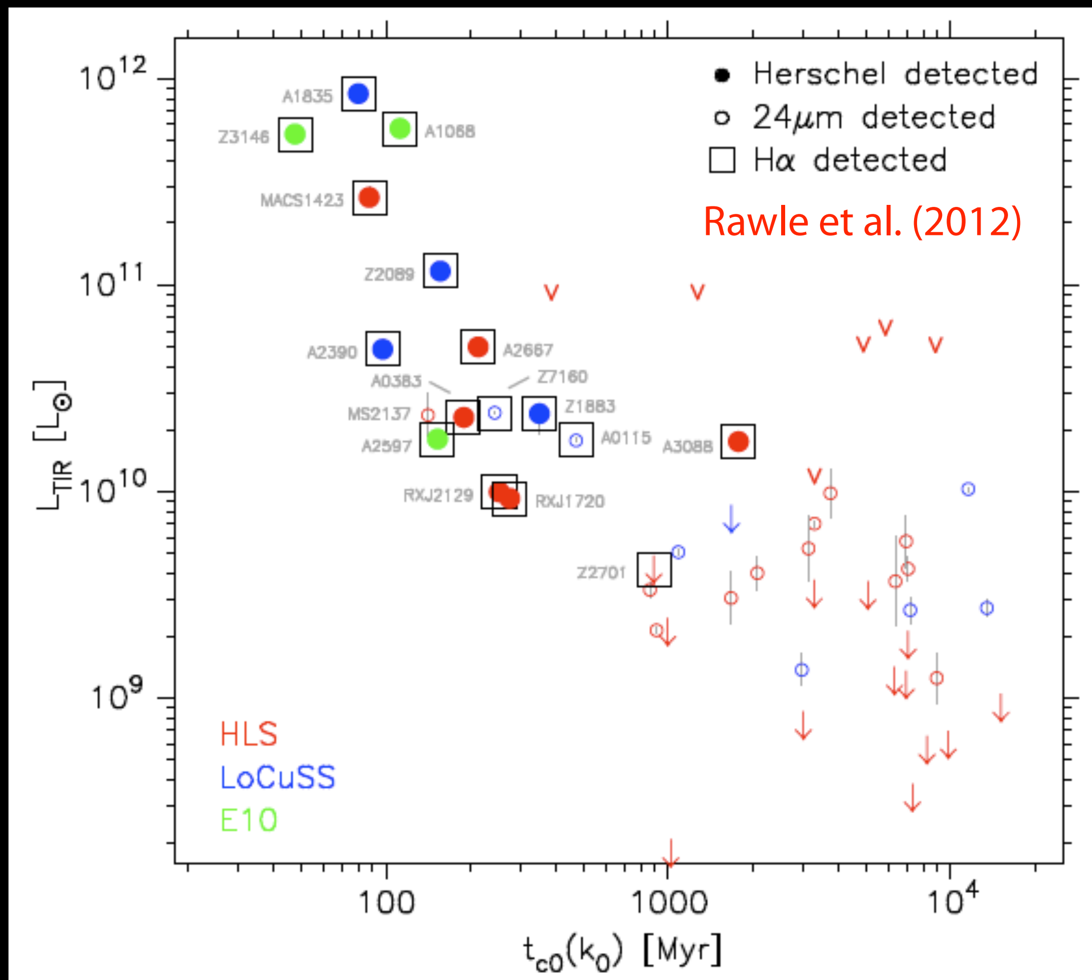
Central galaxy has excess UV emission only if $K_0 < 30$ keV cm^2

K_0 and Star Formation



Central galaxy has strong dust emission only if $K_0 < 30$ keV cm^2

K_0 and Star Formation



Central galaxy has strong dust emission only if $K_0 < 30$ keV cm^2

2

Multiphase Gas & Feedback

2 *Message*

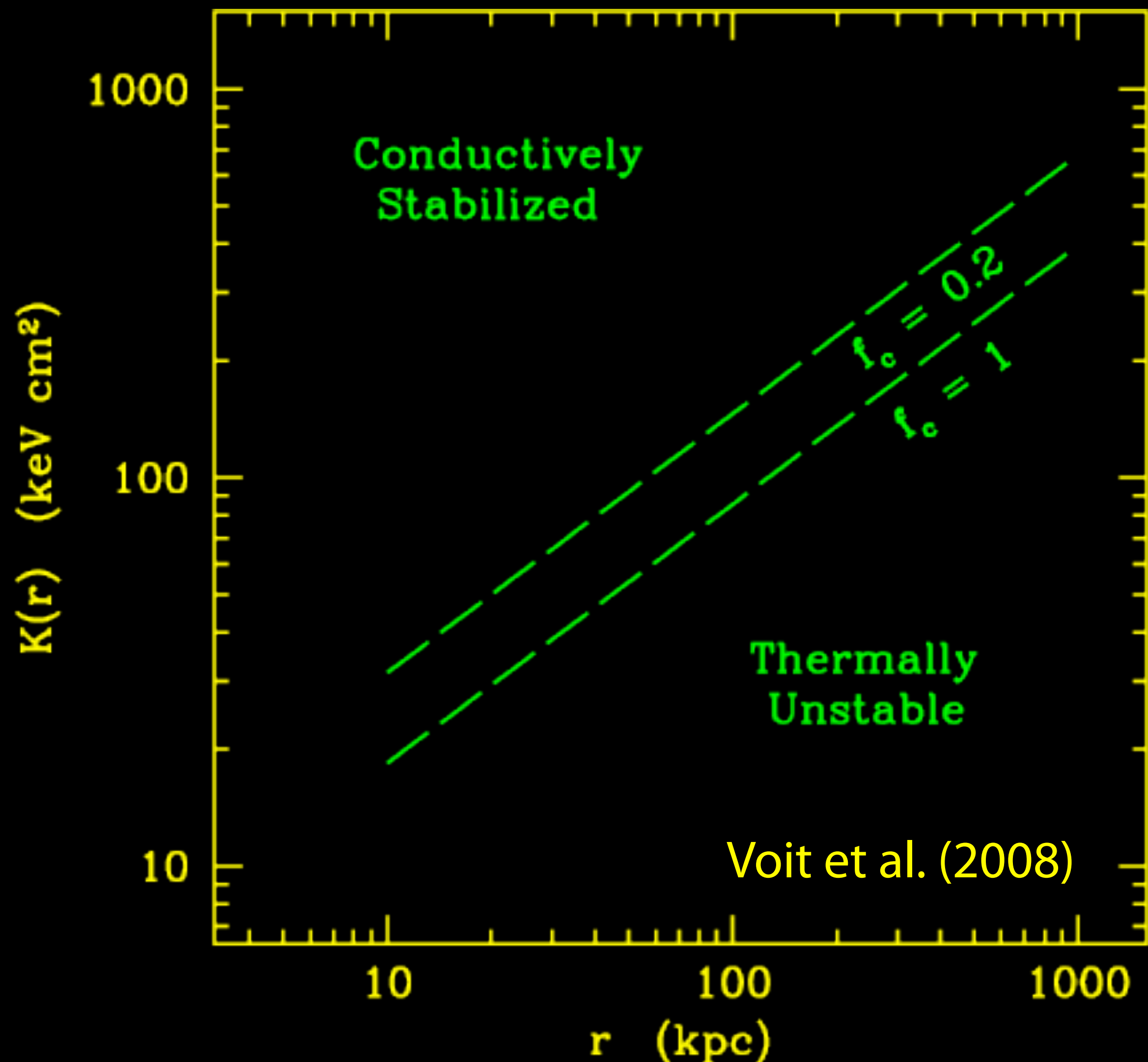
- Cold accretion fuels strong feedback.
- Conduction prohibits cold gas in high-entropy cores.
- Short cooling times promote accumulation of cold gas.
- Dust implicates stellar mass loss as a source of cold gas.

Hypothesis 1

Thermal conduction determines whether a multiphase medium can develop at the centers of galaxy clusters.

(Voit+ 2008)

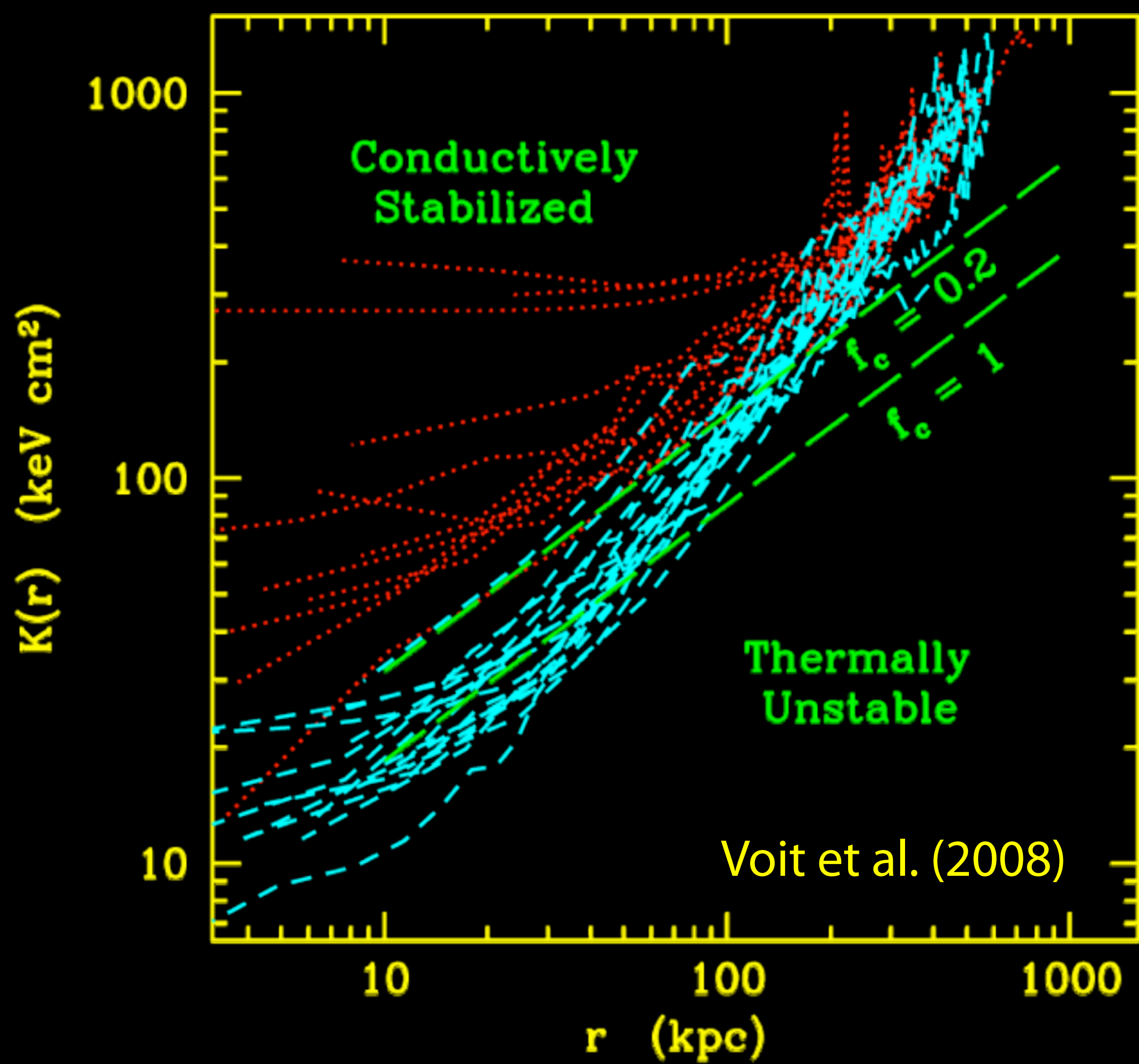
Conduction & Multiphase Structure



High-entropy gas can be stabilized by conduction

Low-entropy gas is potentially thermally unstable

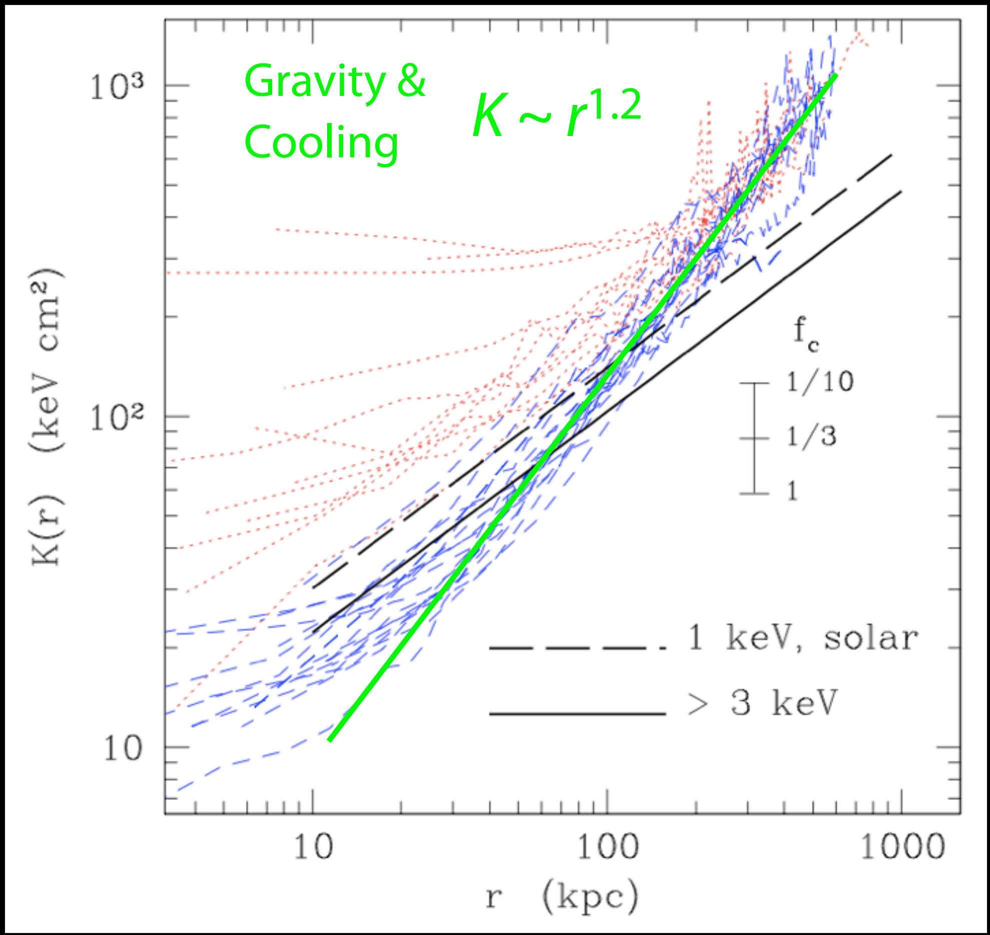
Conduction & Multiphase Structure



Red $K(r)$ profiles of BCGs without star formation or Hα remain above f_c ~ 0.2 threshold

Blue $K(r)$ profiles of Rafferty et al. (2008) clusters with star forming BCGs go below f_c ~ 0.2 threshold

Conduction & the Trigger



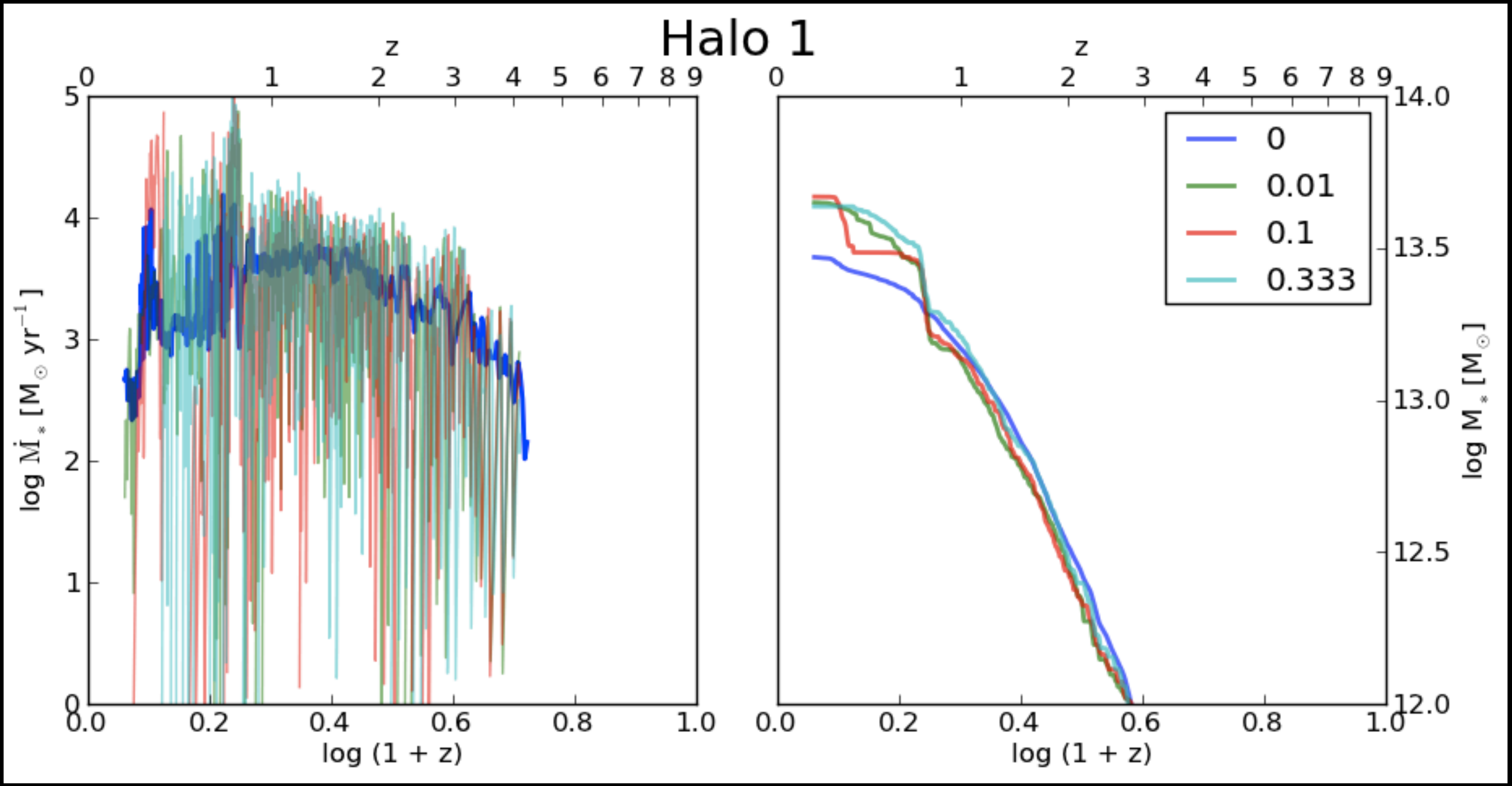
Voit 2011

Could the failure of conduction to prevent cooling be the switch that turns on AGN feedback?

See also:

Ruszkowski & Begelman 2002
Voigt & Fabian 2004
Guo+ 2008

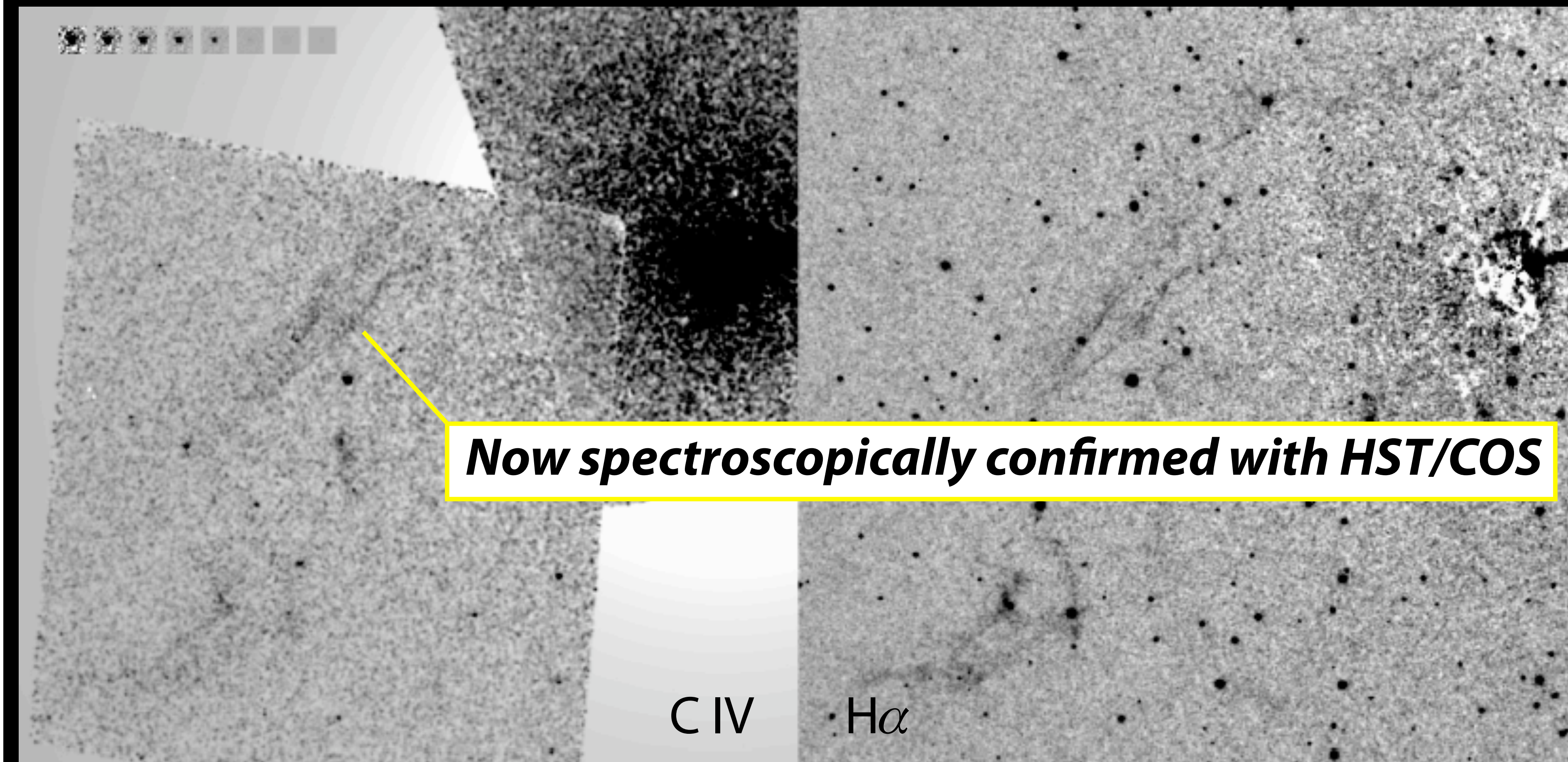
Simulations of Conductive Clusters



Without AGN feedback, even a small amount of conduction makes a cluster's star-formation history much more volatile.

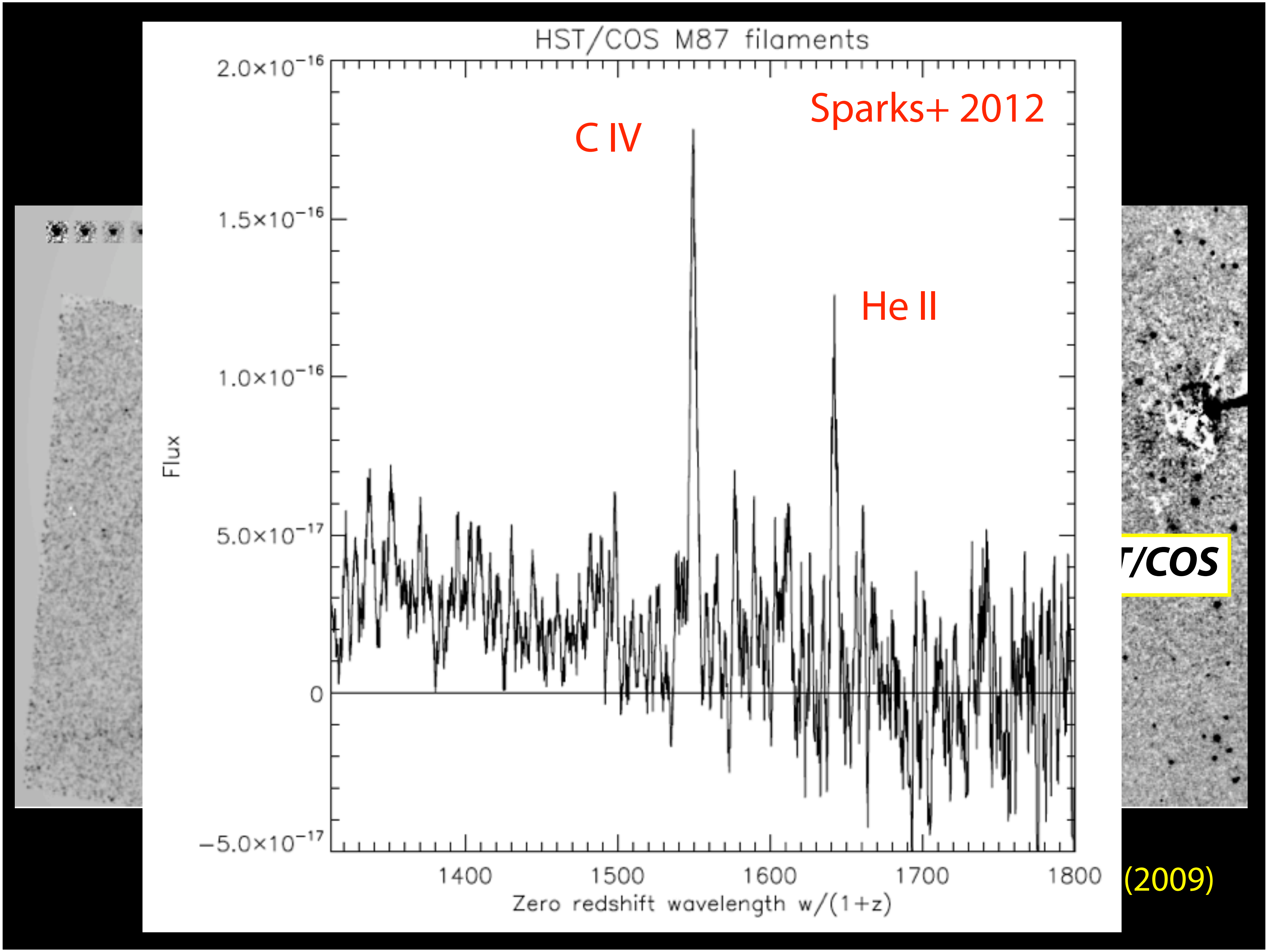
Smith+ , in prep

Warm Gas in Filaments



M87

Sparks et al. (2009)

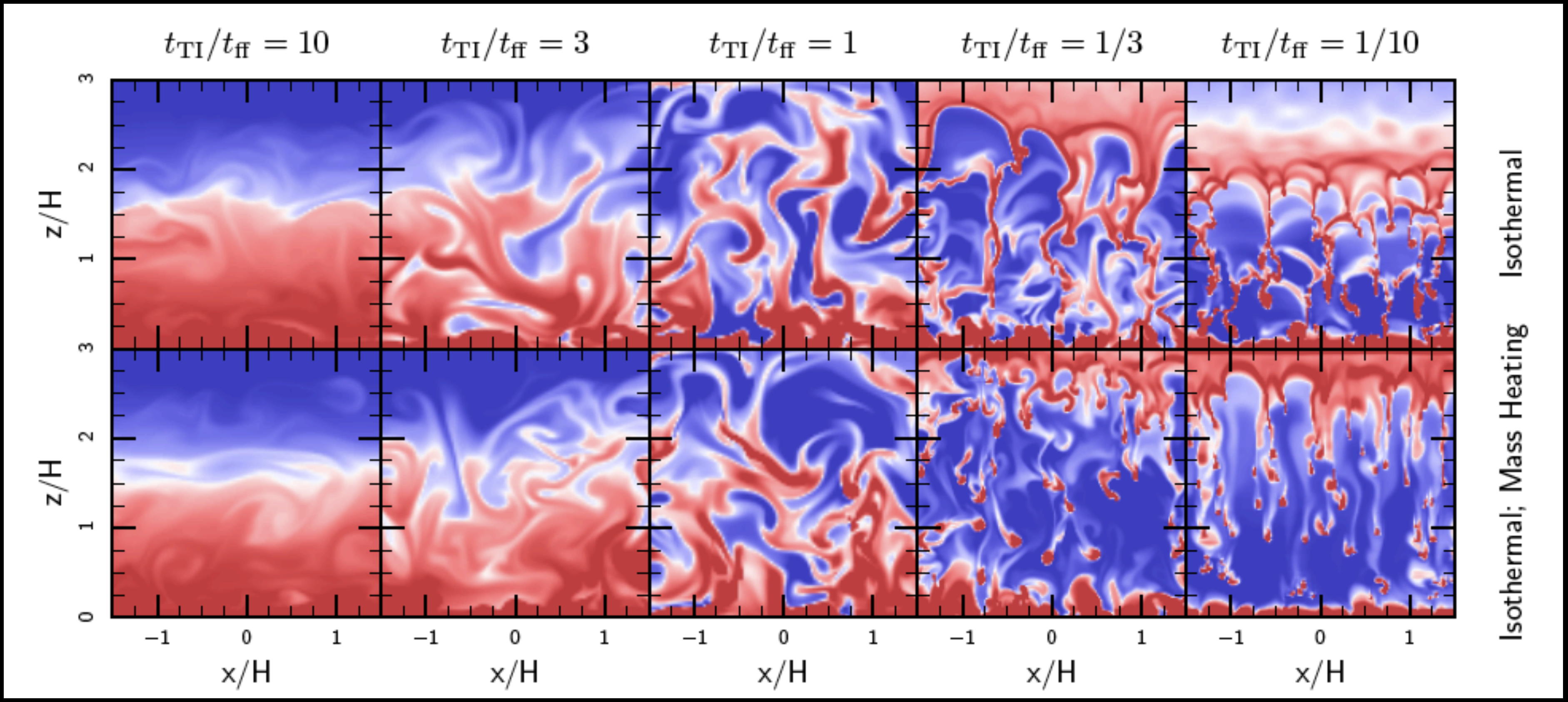

HST/COS M87 filaments
Sparks+ 2012
C IV
He II
2.0×10^-16
1.5×10^-16
1.0×10^-16
5.0×10^-17
0
−5.0×10^-17
Flux
1400
1500
1600
1700
1800
Zero redshift wavelength w/(1+z)
T/COS
(2009)

Hypothesis 2

Condensation of hot gas produces a multiphase intracluster medium when the ratio of cooling time to free-fall time becomes small enough.

(McCourt+ 2011; Sharma+ 2011; see also Soker 2008)

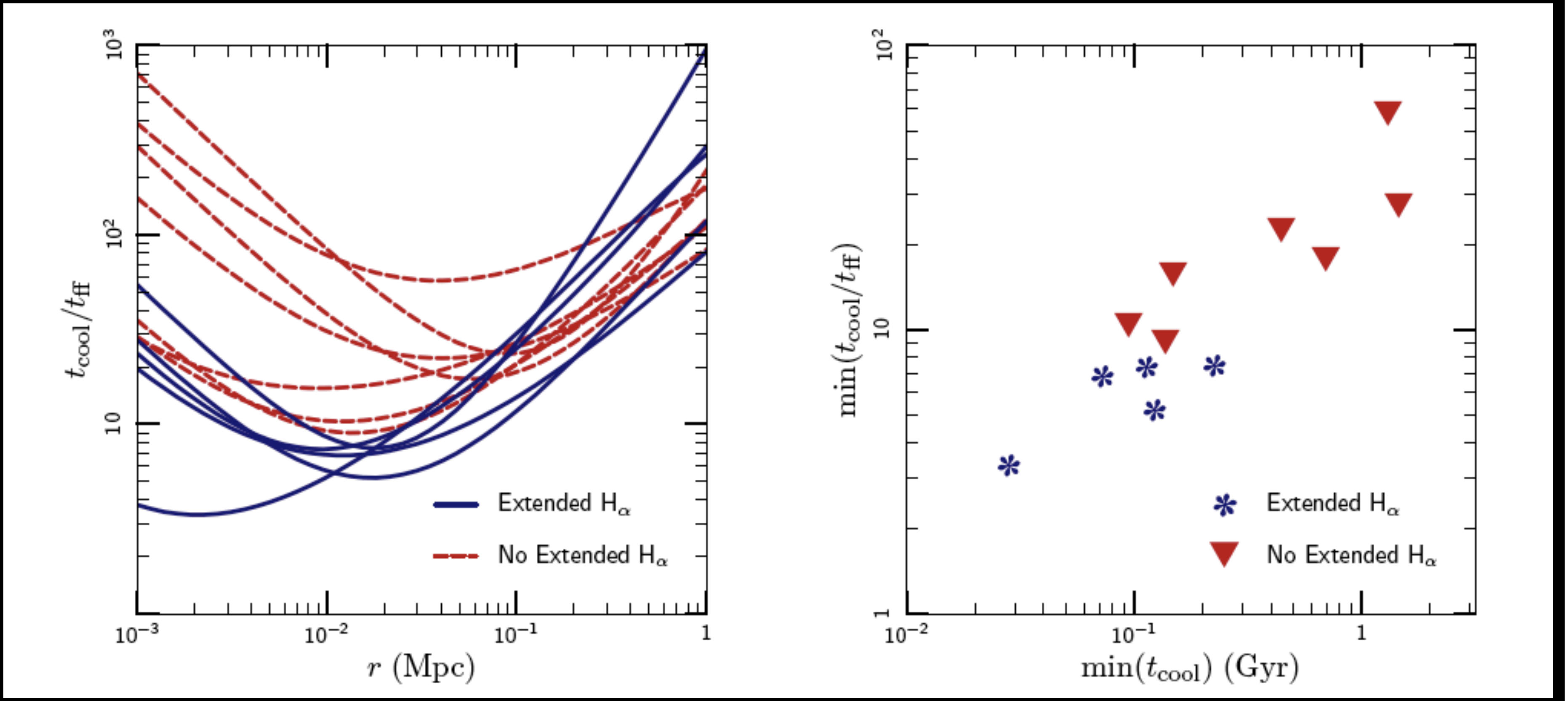
Instability & Multiphase Structure



McCourt et al. (2011), Sharma et al. (2011)

Thermal feedback can promote thermal instability if t_{cool}/t_{ff} is sufficiently small.

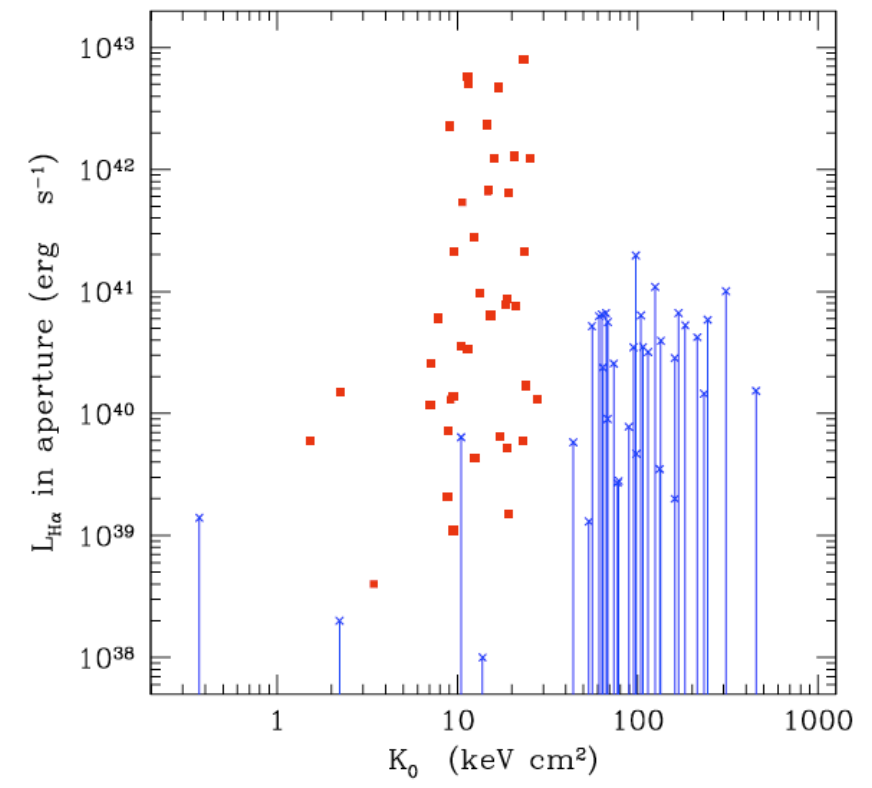
Instability & Multiphase Structure

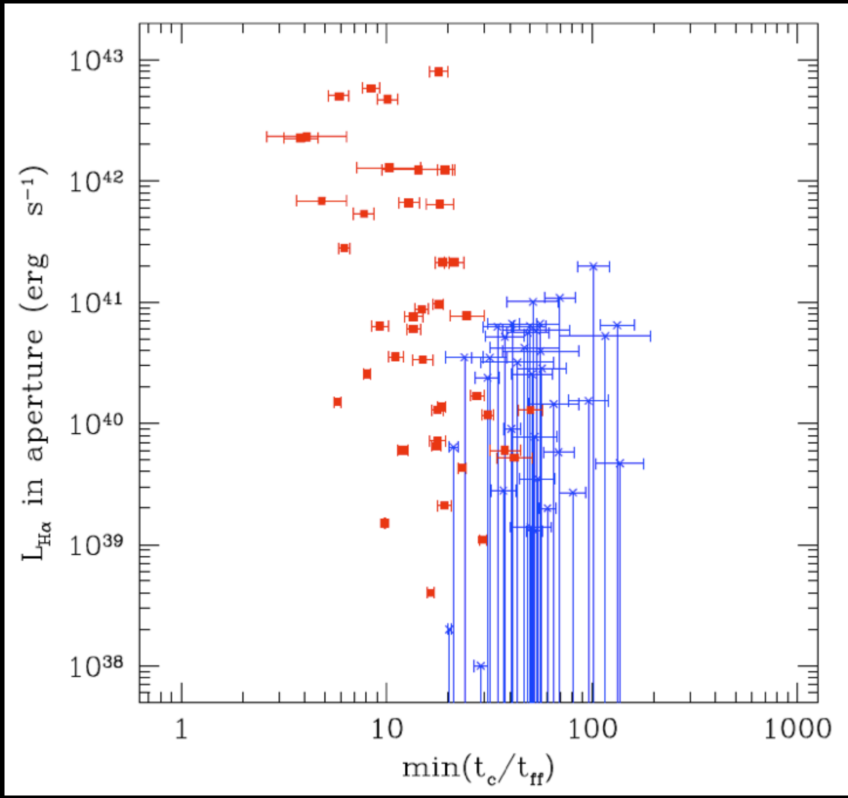


McCourt et al. (2011), Sharma et al. (2011)

Threshold for thermal instability claimed to be $t_{cool}/t_{ff} \sim 10$.

Crossing the Multiphase Threshold

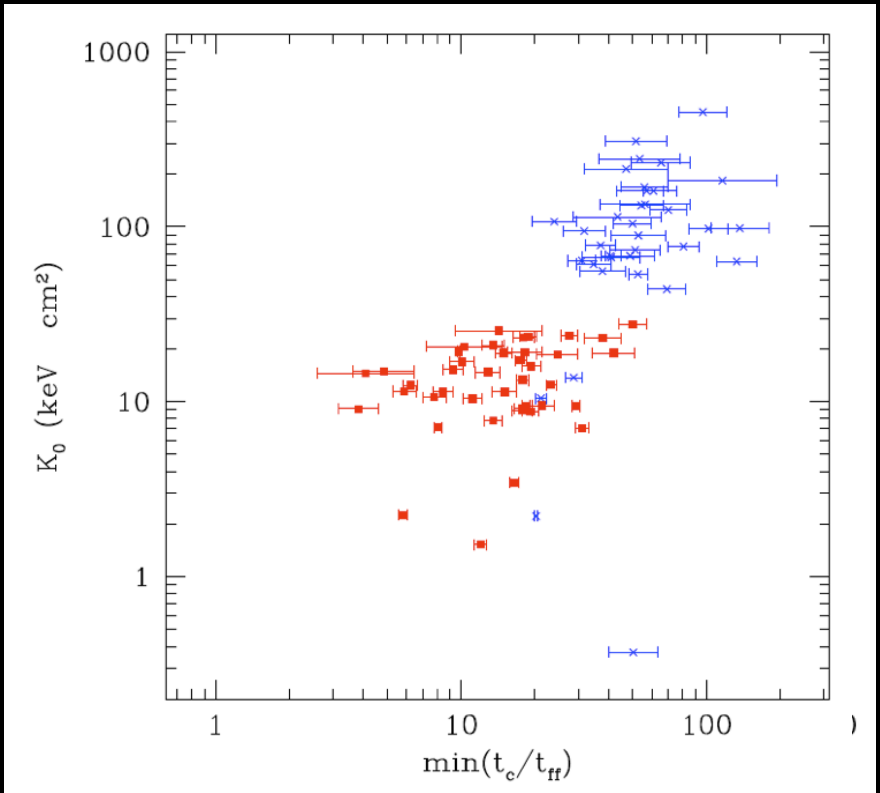


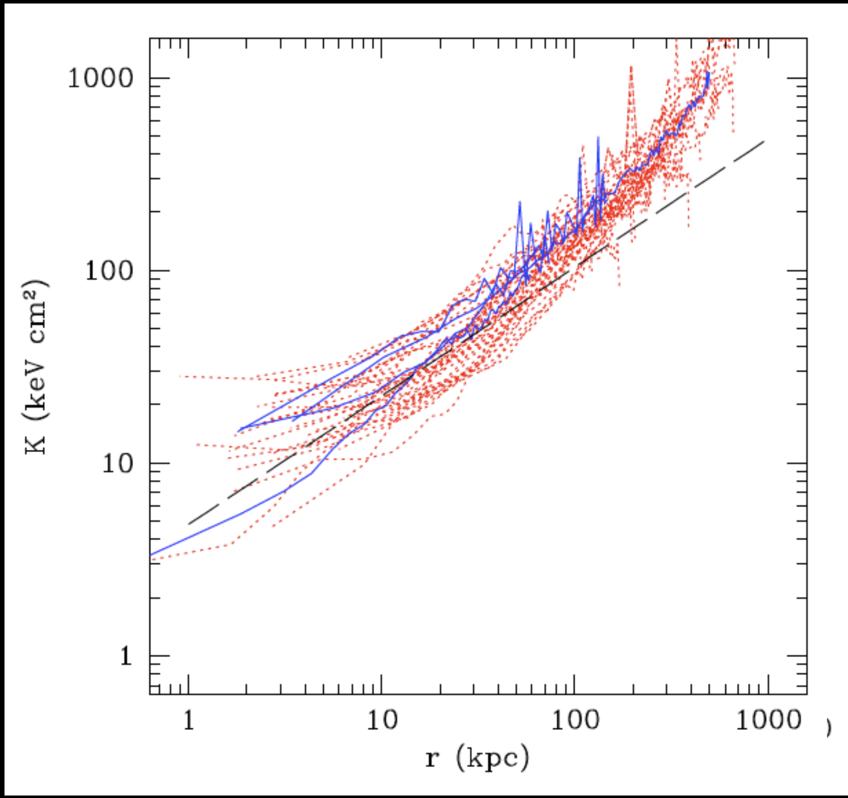


Voit & Donahue (2012)

Threshold determined by K_0; Condensation rate depends on t_{cool}/t_{ff}

Crossing the Multiphase Threshold



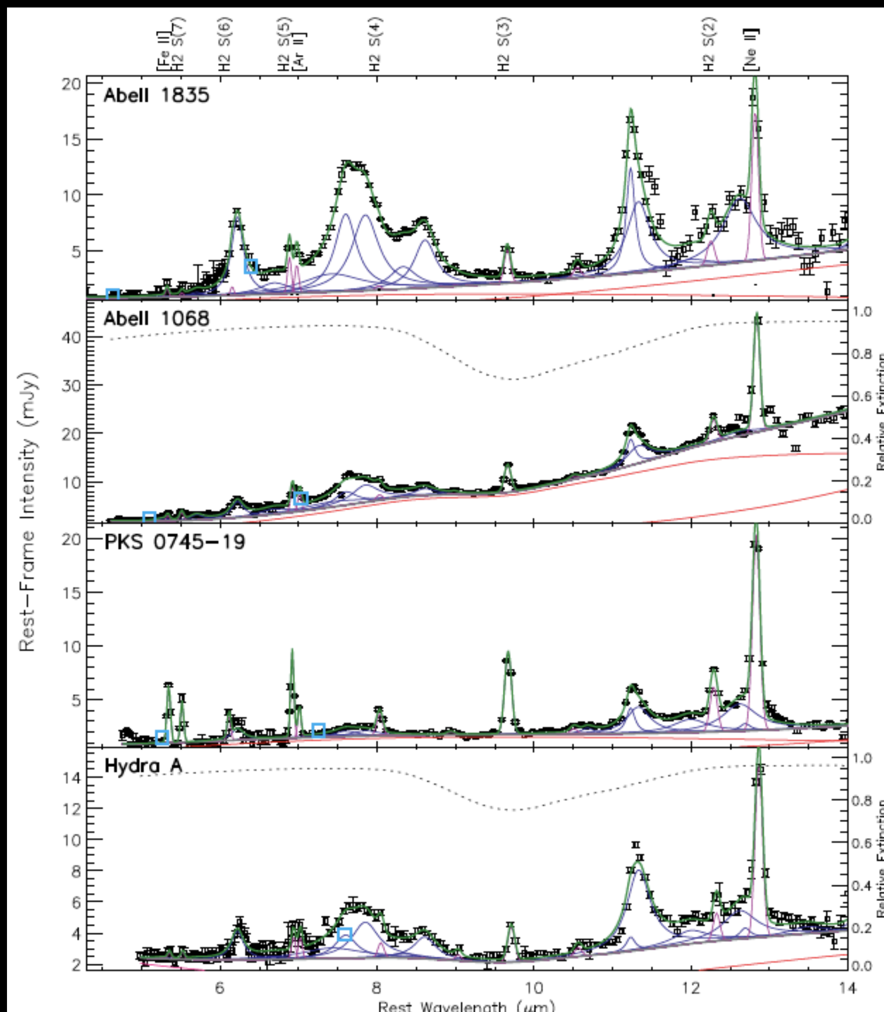


Voit & Donahue (2012)

Threshold determined by K_0; Condensation rate depends on t_{cool}/t_{ff}

But what about the dust?

Spitzer Spectroscopy of BCGs



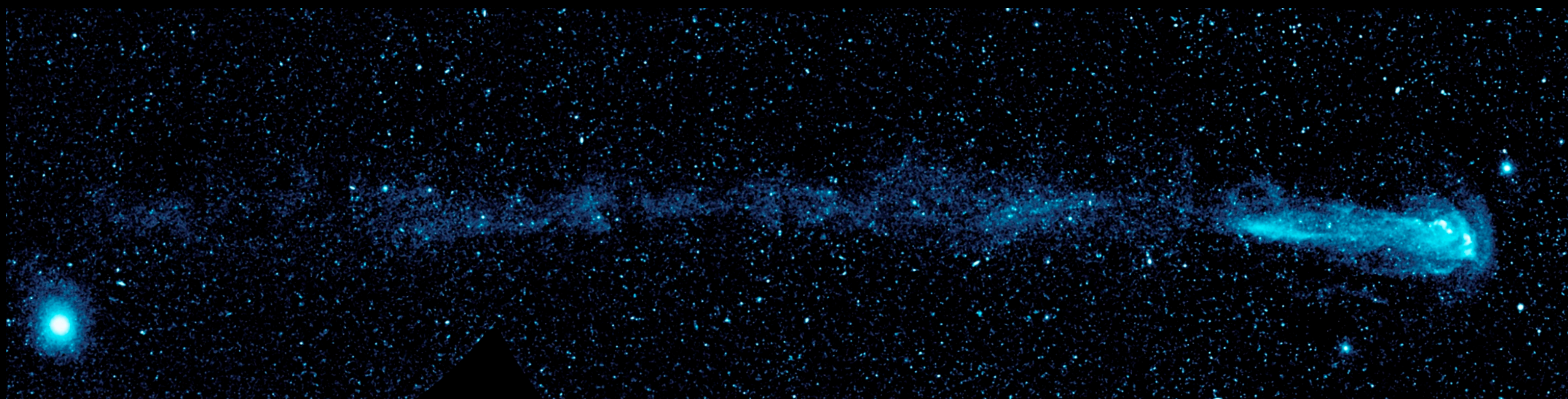
Donahue et al. 2011

Dust emission from star-forming BCGs, including PAHs (!), resembles that of normal star-forming galaxies.

Can stripped cold clouds survive the ICM?

Could stellar mass loss be the main source of cold gas?

Mira GALEX Image

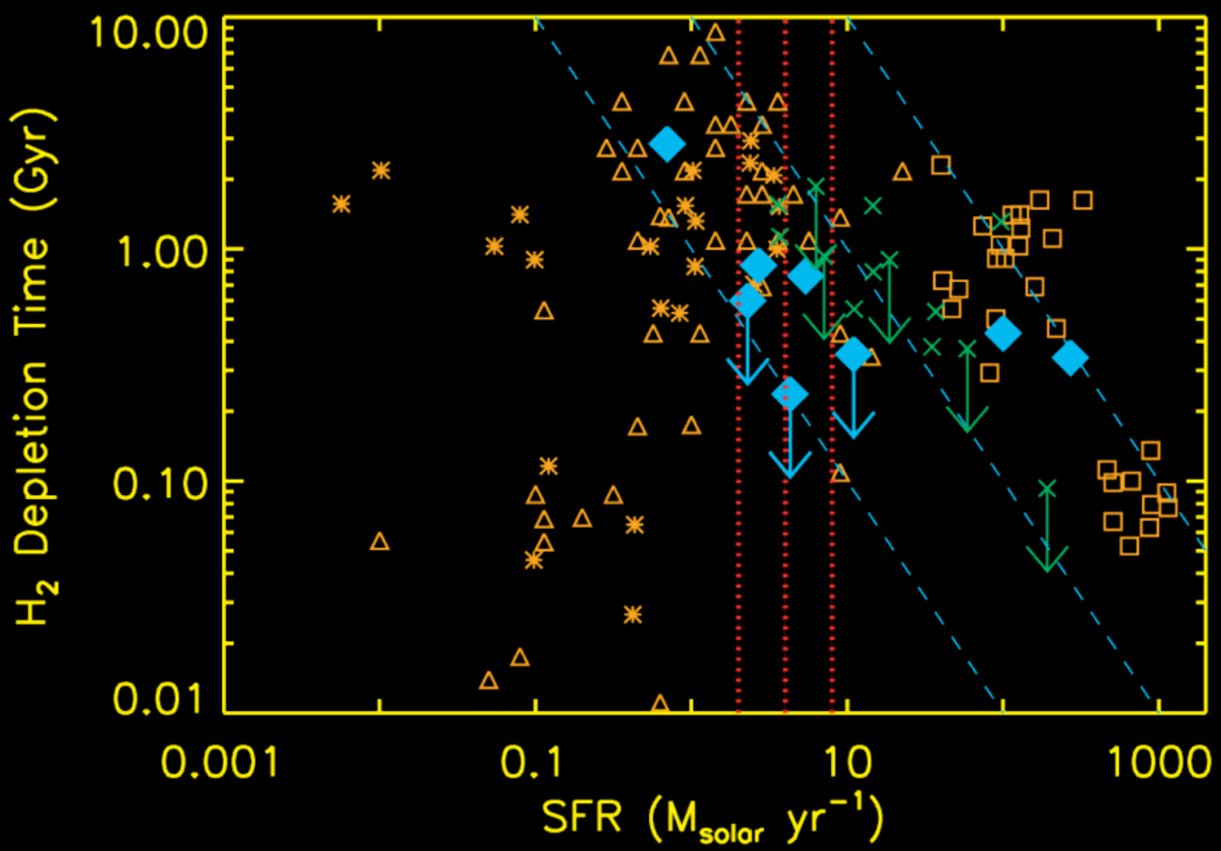


Martin et al. 2007

Nearby mass-losing star Mira has an extended tail apparently made of molecular hydrogen.

Can gas lost by a central galaxy's stars remain cold for many Myr?

Stellar Mass Loss from BCGs



In most BCGs the star-formation rate does not exceed the stellar mass-loss rate — could it be an important source?

Voit & Donahue (2011)