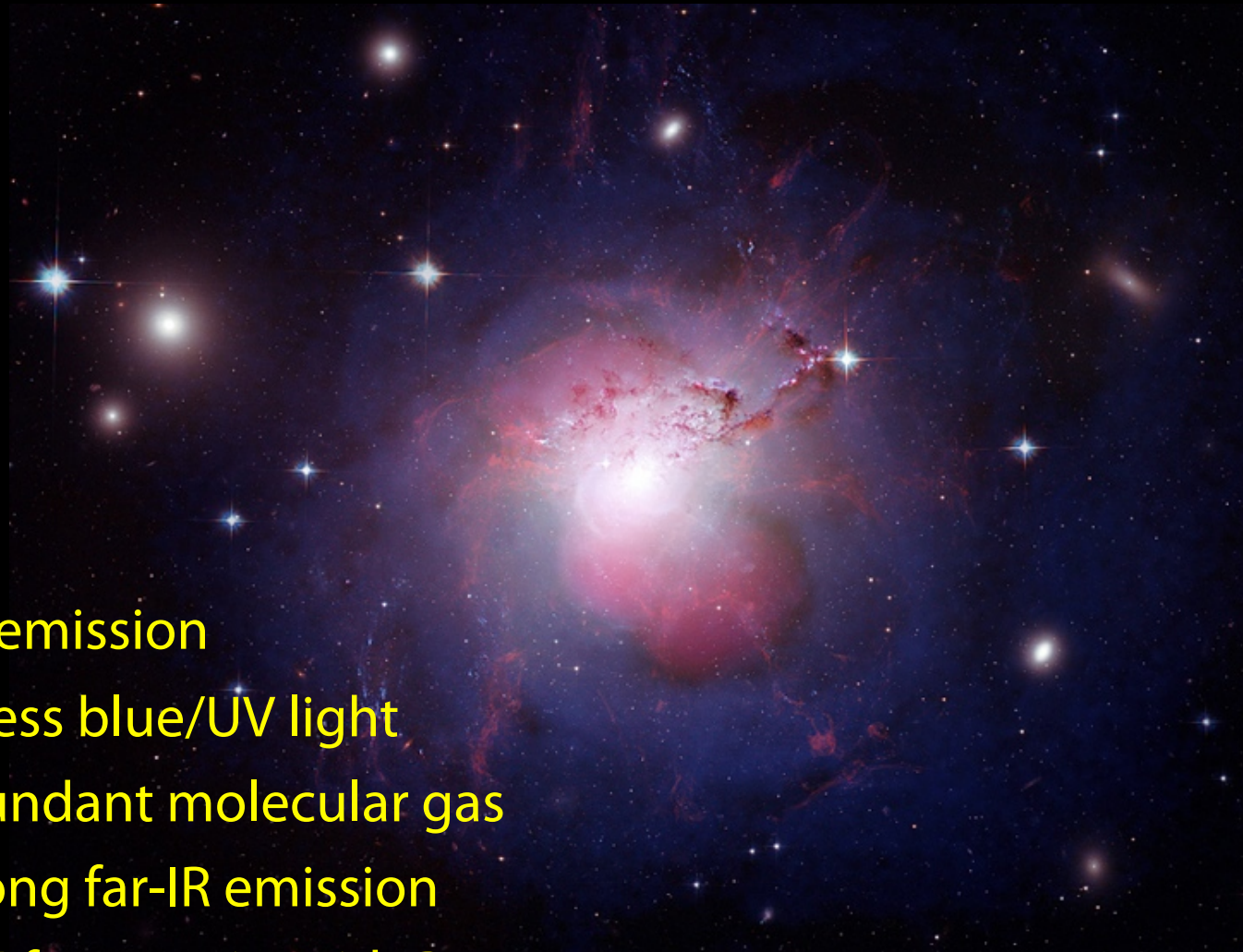


*Conduction and Multiphase
Structure in Cluster Cores*

Multiphase Gas in Cluster Cores

Star Formation in BCGs

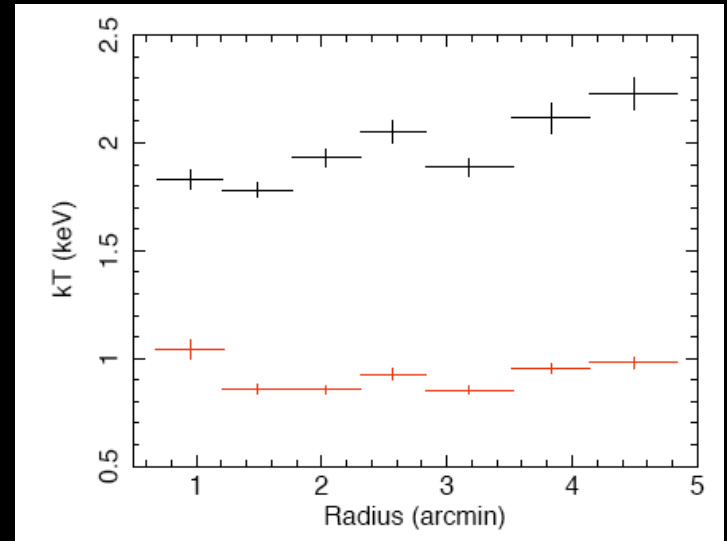
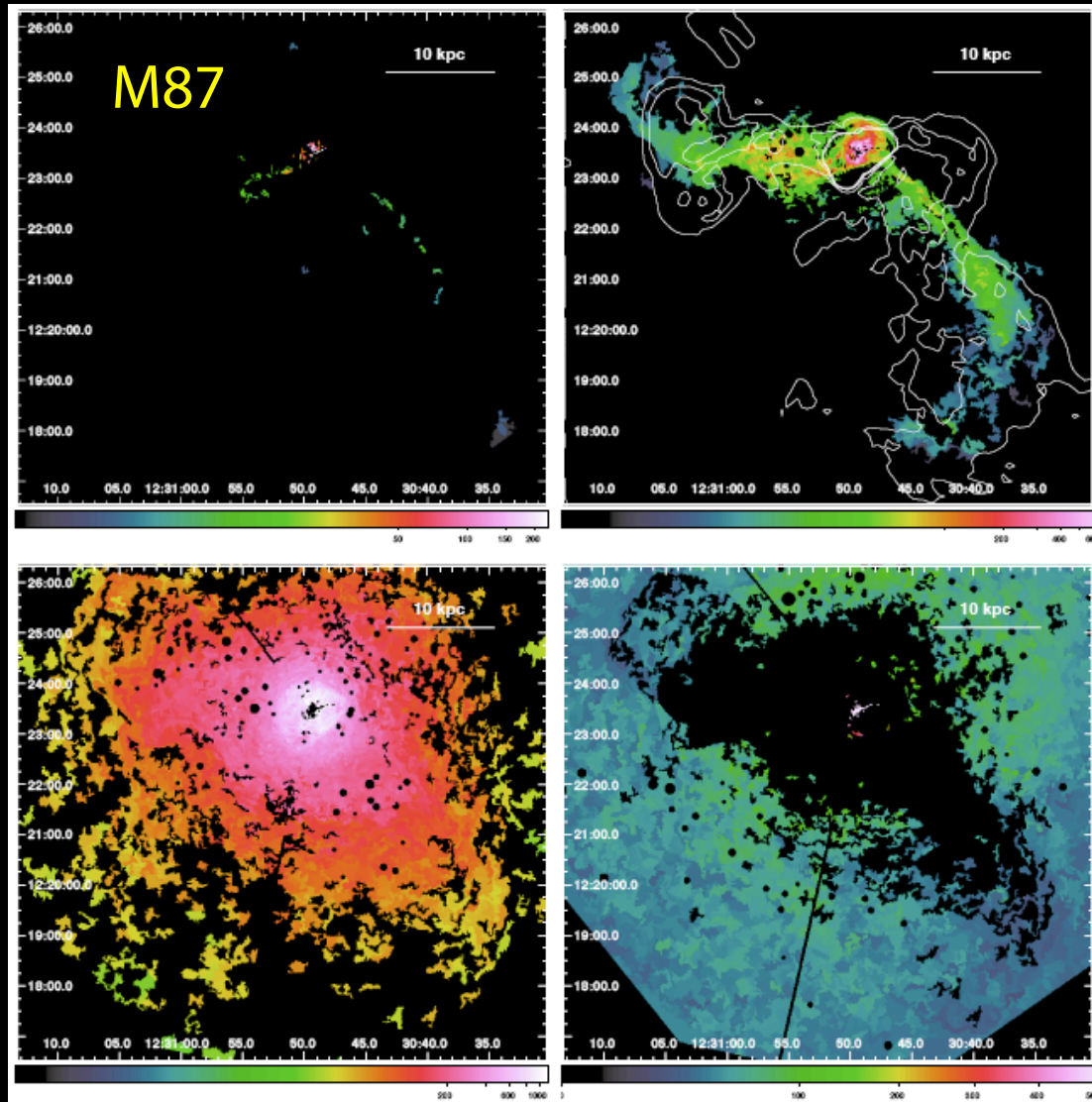


- $H\alpha$ emission
- Excess blue/UV light
- Abundant molecular gas
- Strong far-IR emission
- PAH features in mid-IR

NGC 1275: Perseus

Evidence for Conduction

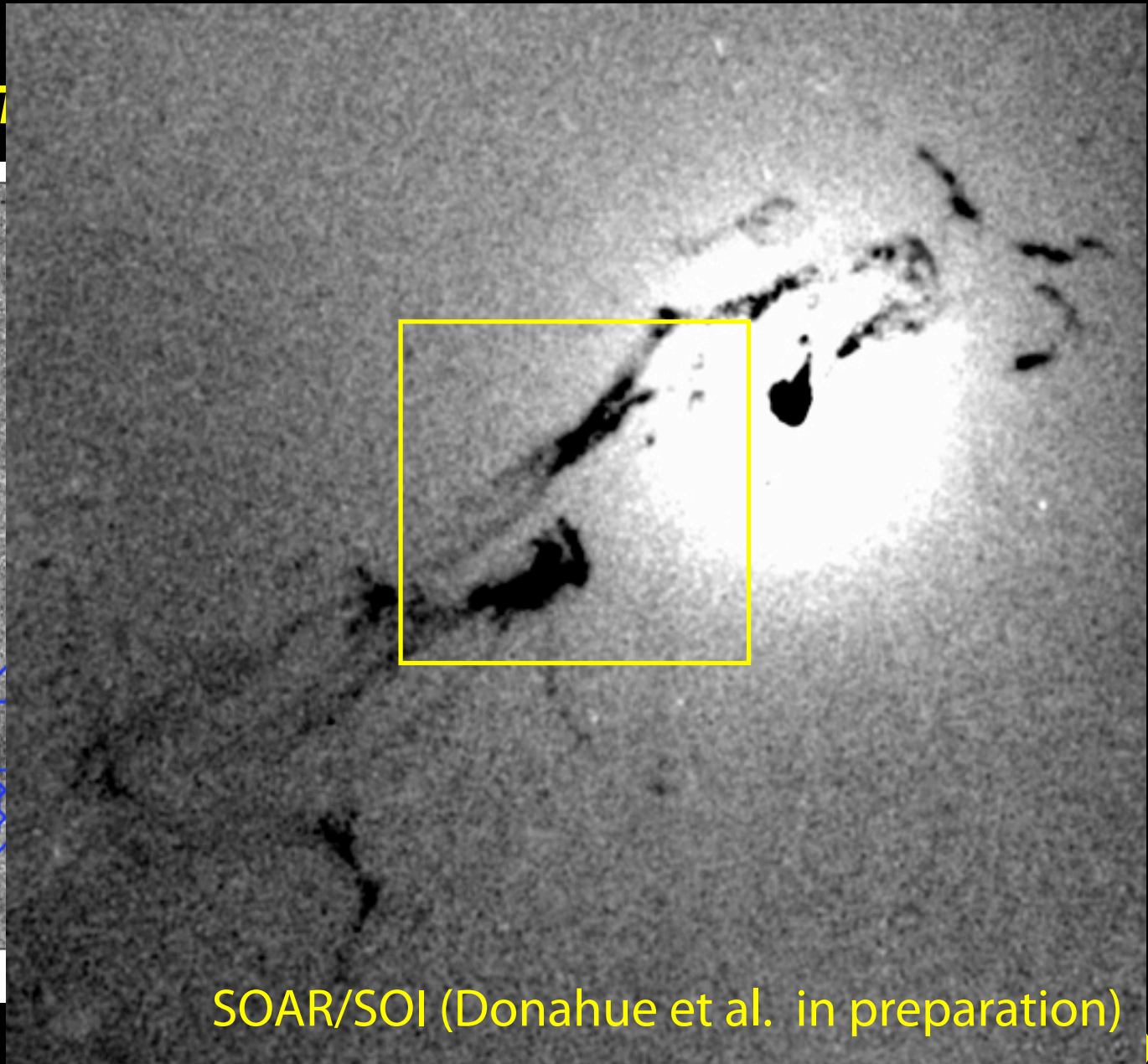
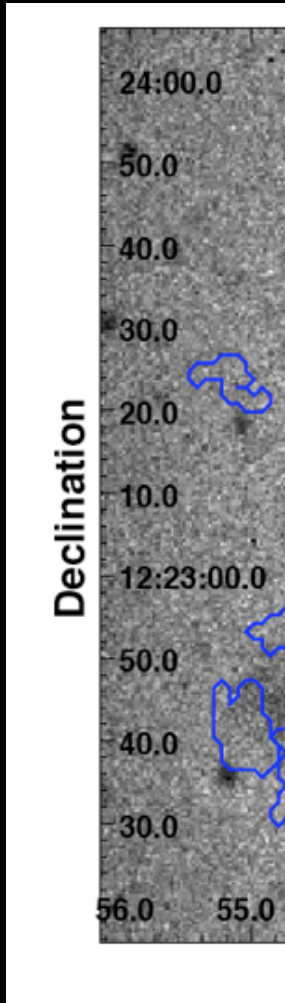
X-ray Filaments



Conduction along filaments
... see also Molendi (2002)

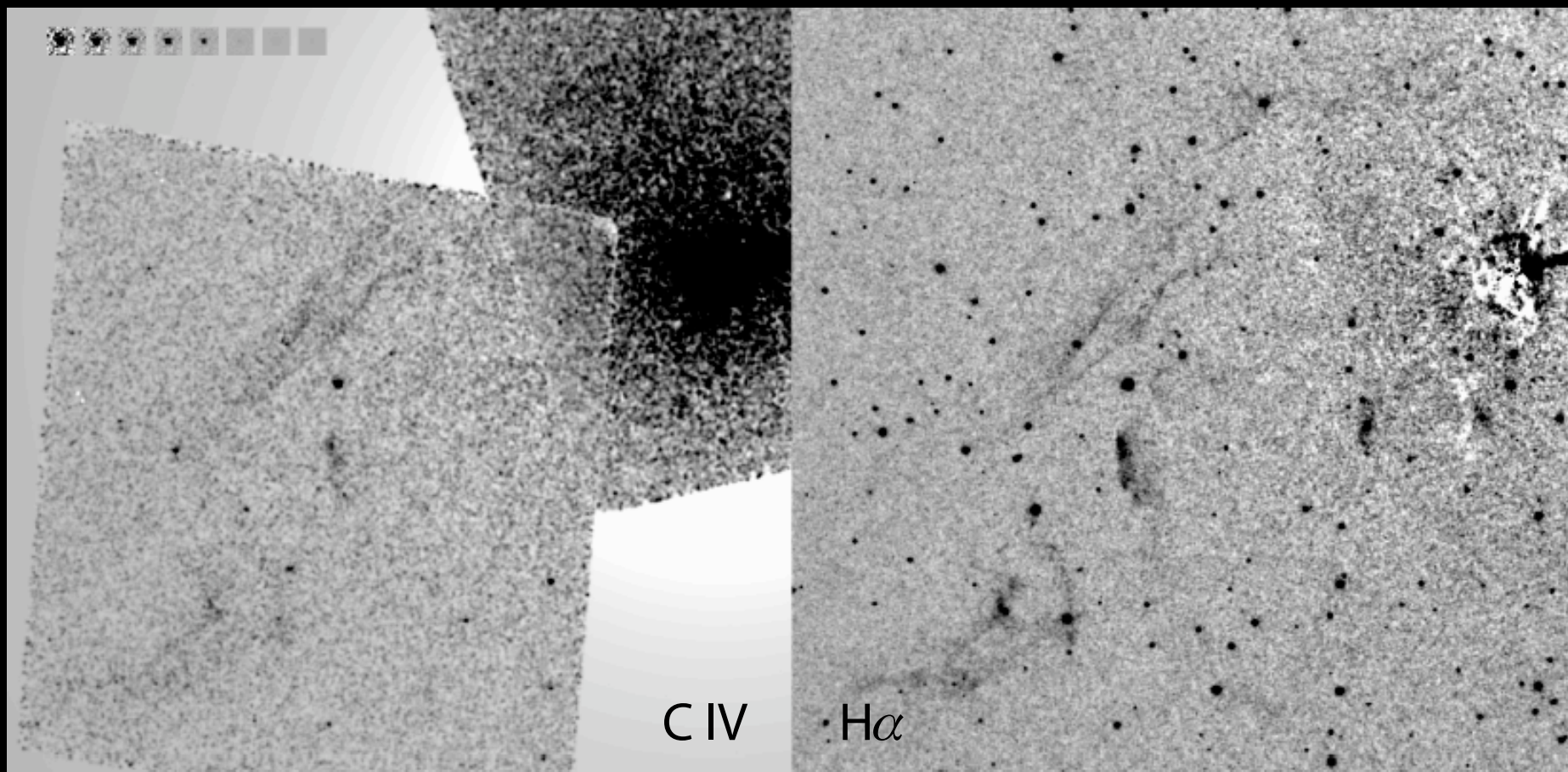
Werner et al. (2010)

H



SOAR/SOI (Donahue et al. in preparation)

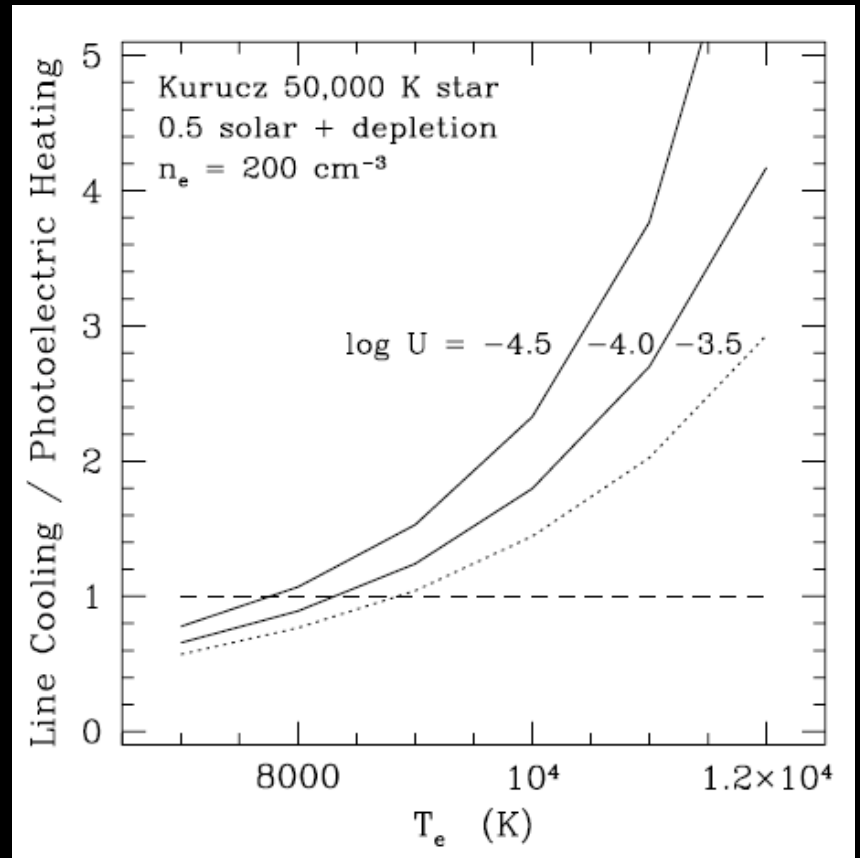
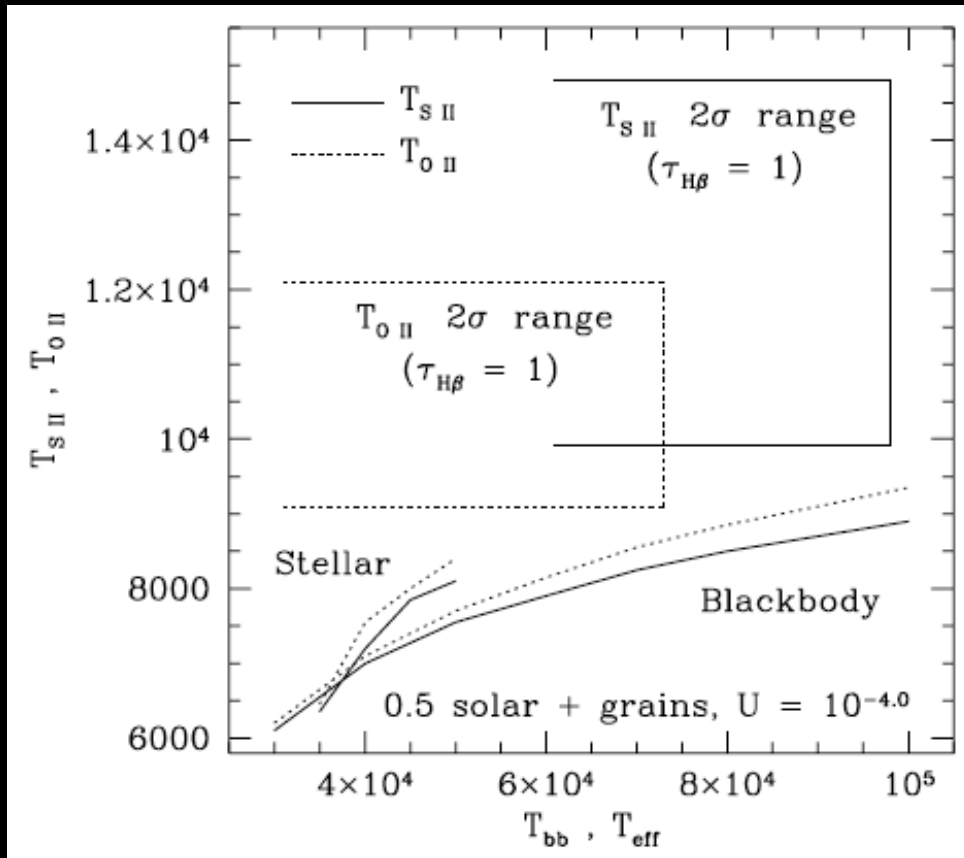
Warm Gas in Filaments



M87

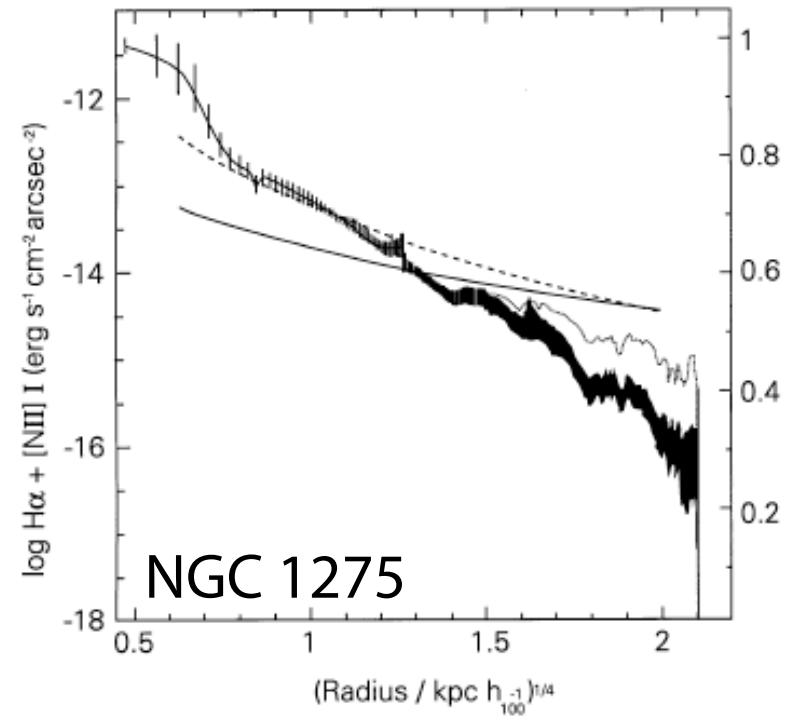
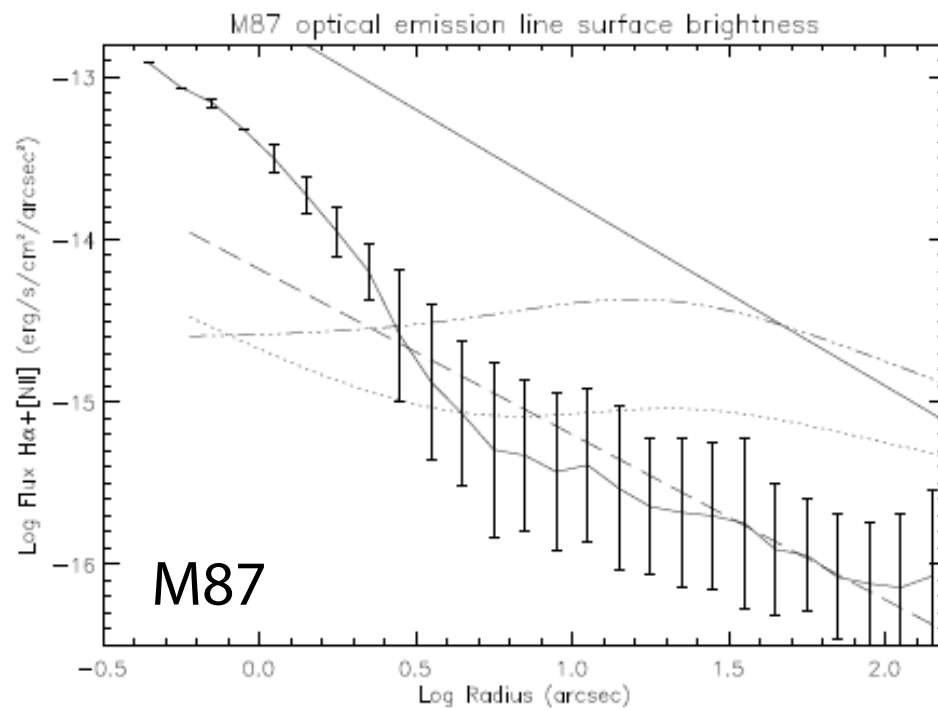
Sparks et al. (2009)

Heating of H α Filaments



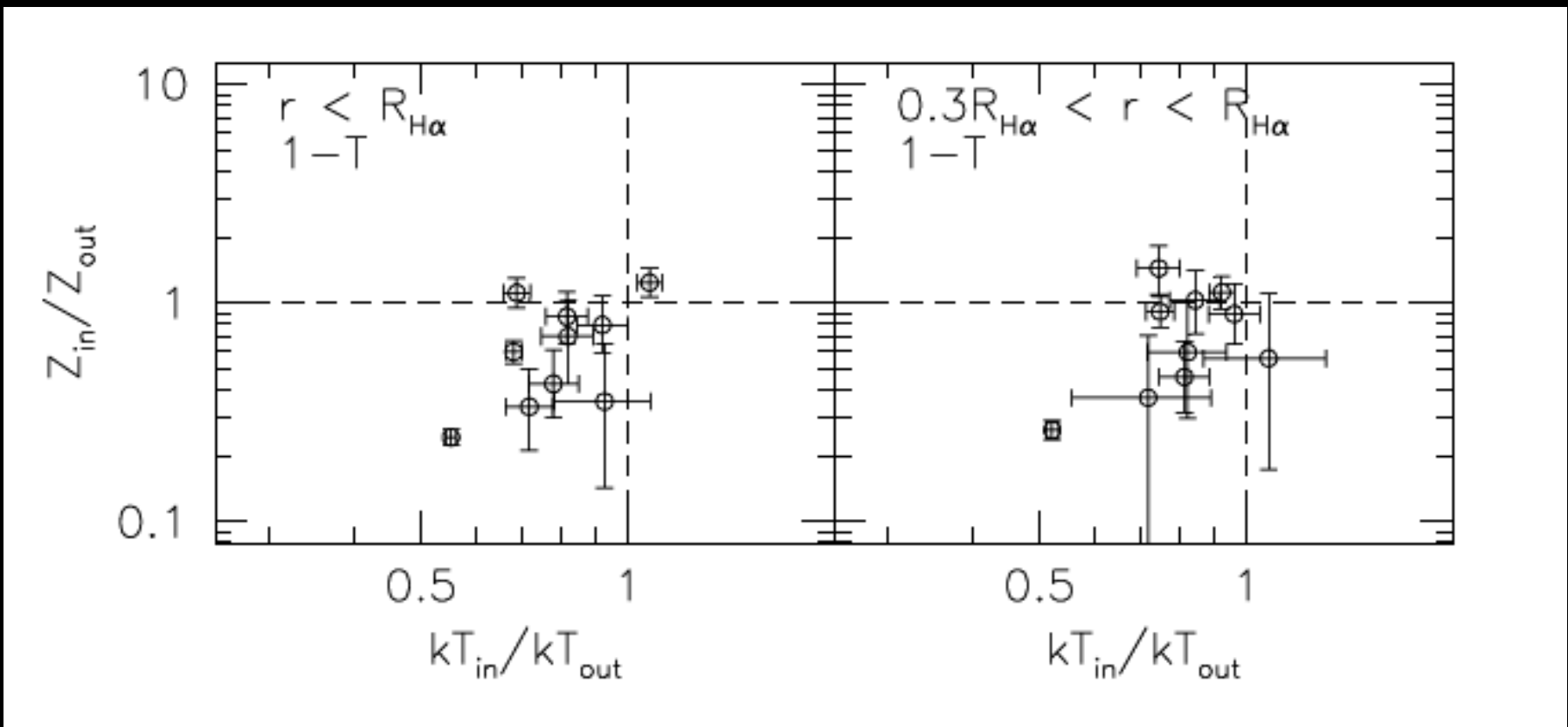
Voit & Donahue (1997)

Saturated Conduction?



Sparks et al. (2004)

Filaments Linked with Cooler X-ray Gas



McDonald & Veilleux (2010)

Double Tail: Magnetic Draping?

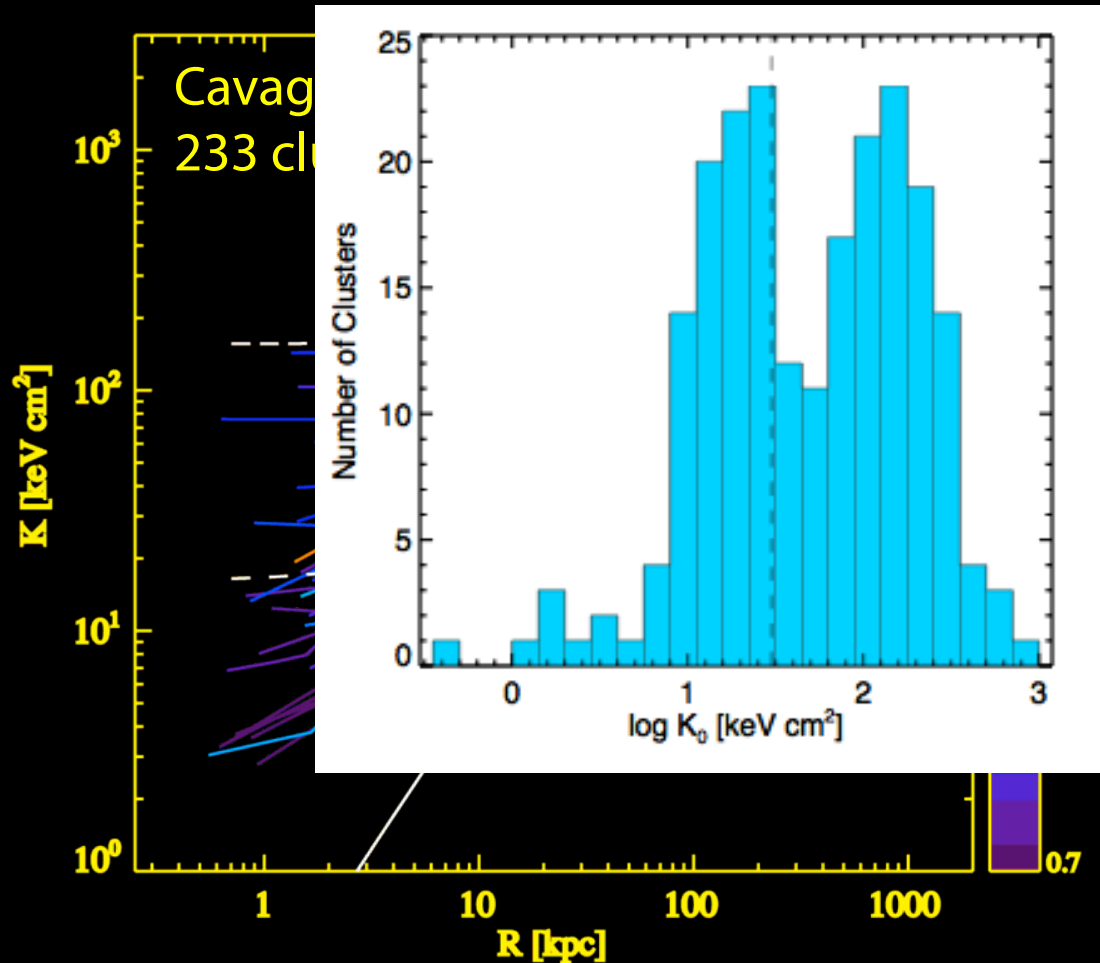


ESO137-001

Sun et al. (2010)

Conduction & Bimodality

Chandra Entropy Profiles



Pure cooling model is lower limit to observed profiles

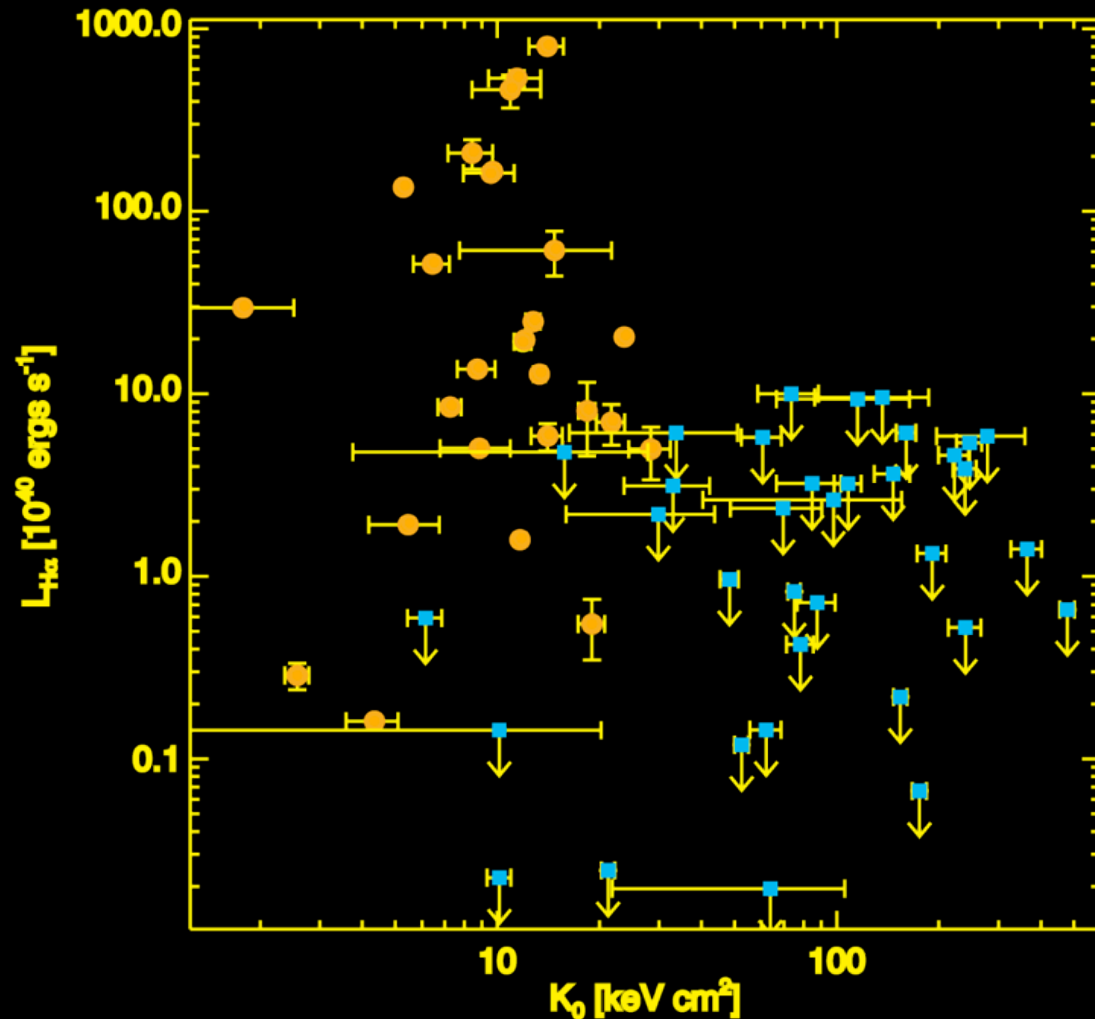
Most profiles are well fit with:

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

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

$$\alpha \sim 1.2$$

K_0 and H α Emission



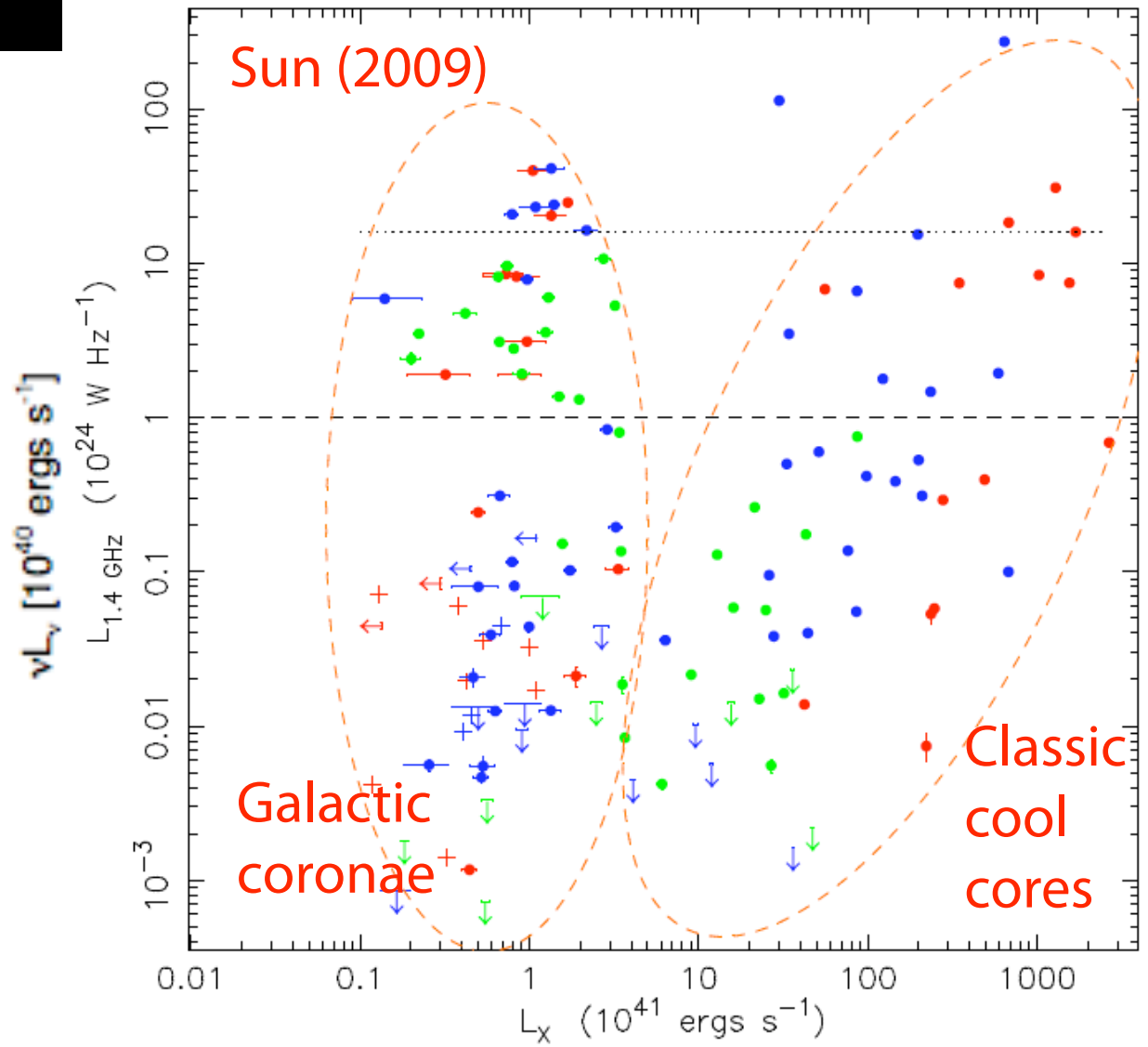
Central galaxy can have emission-line nebulosity only if

$$K_0 < 30 \text{ keV cm}^2$$

H α data from many diverse sources

Cavagnolo et al. (2008)

K_0 and Radio Power



central galaxy of a
 < 0.2 cluster can
 be a strong radio
 source only if

$$K_0 < 30 \text{ keV cm}^2$$

radio data from
 VSS+SUMMS
 within 20" of X-ray
 peak

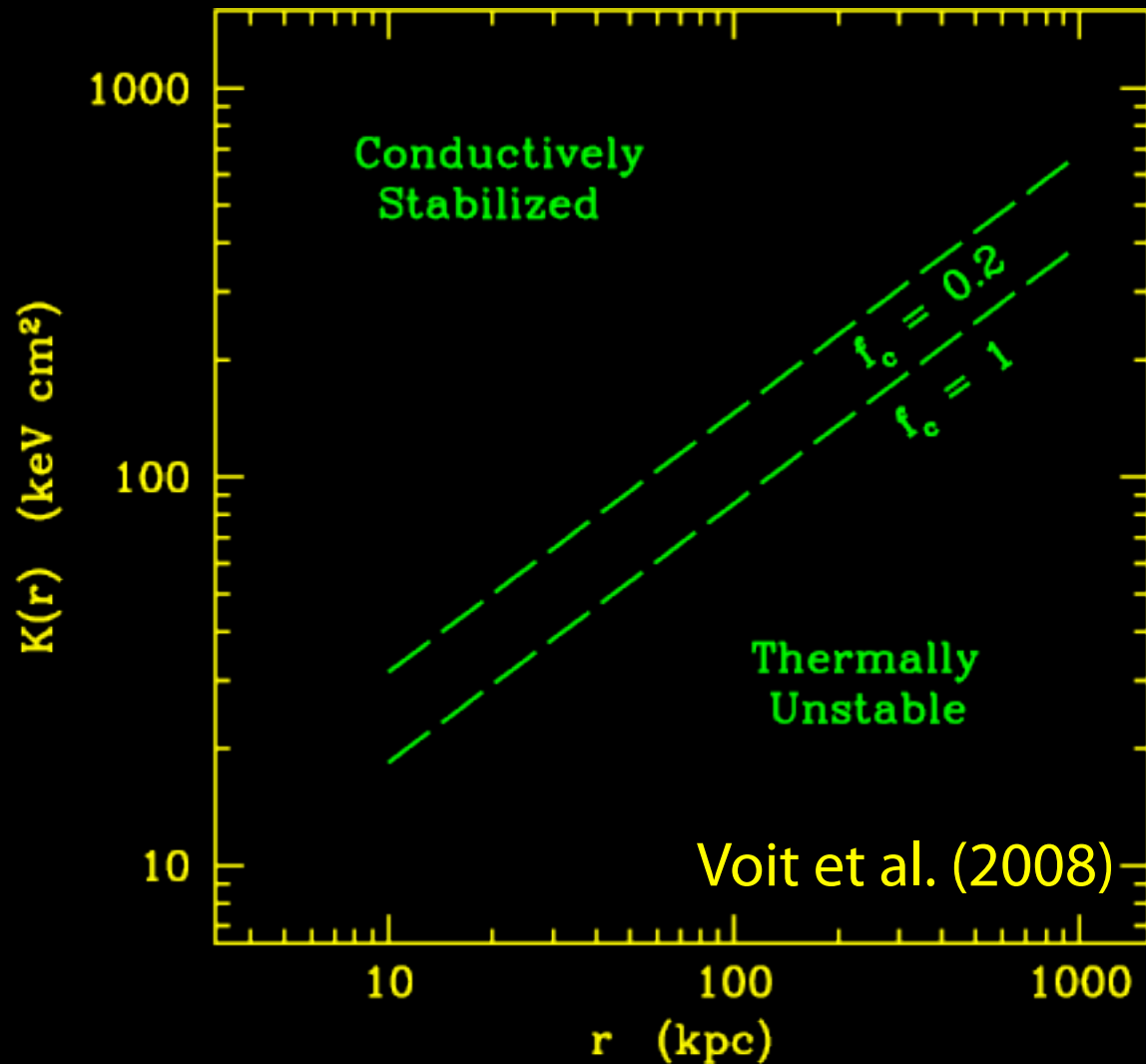
vagnolo et al. (2008)

Conduction vs. Cooling

$$\lambda_F = \sqrt{\frac{kT}{n_e^2 \Lambda}} \approx 4 \text{ kpc} (K / 10 \text{ keV cm}^2)^{3/2} f_c^{1/2}$$

- Field length λ_F depends uniquely on K for free-free cooling and Spitzer conductivity
- Conduction cannot erase inhomogeneity of core gas if λ_F is too small
- Tug of war between cooling and conduction may produce bifurcation in cluster properties (Donahue et al. 2006; see also Guo, Oh, & Ruszkowski 2008)

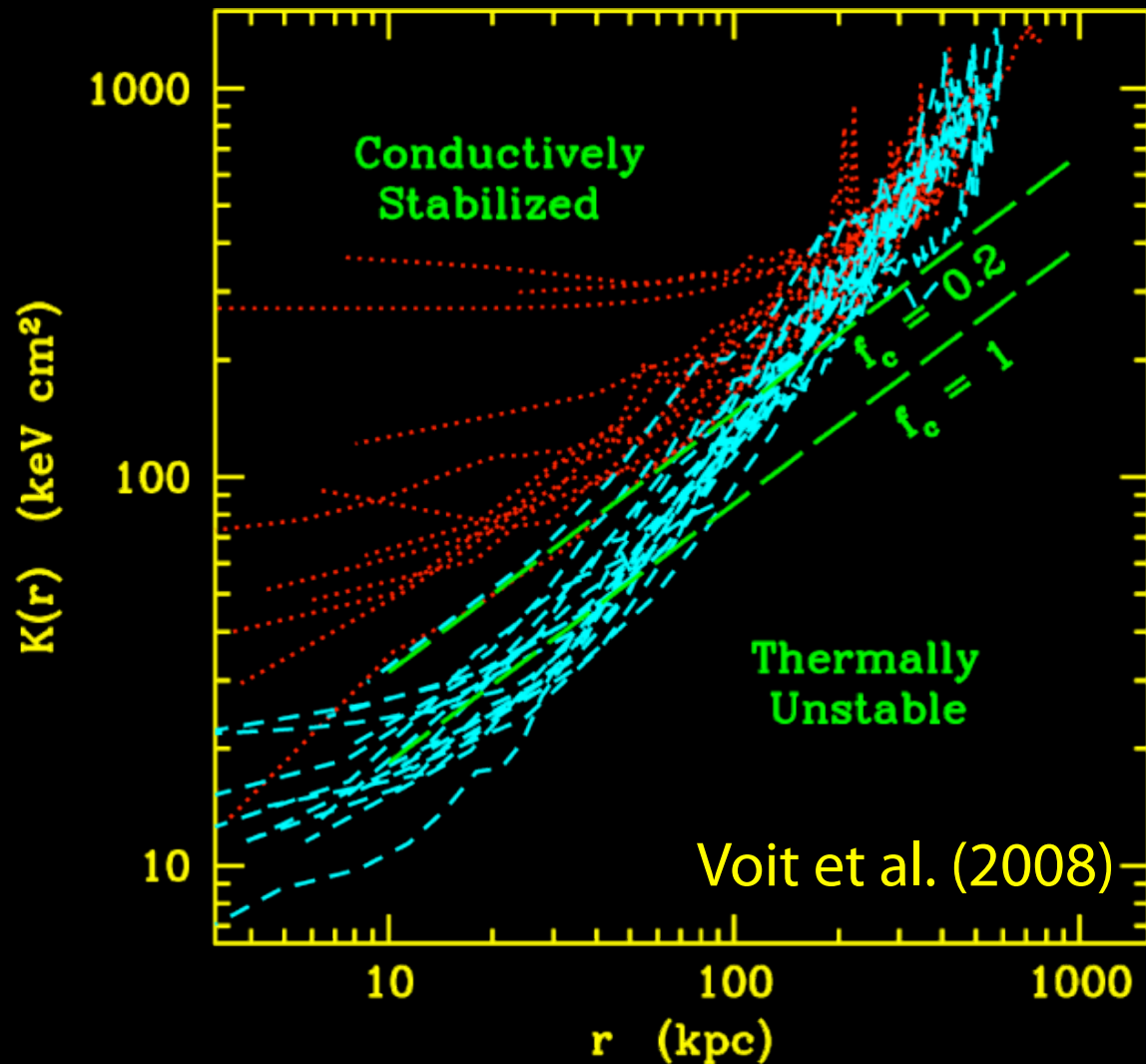
Conduction & Multiphase Structure



High-entropy gas can be stabilized by conduction

Low-entropy gas is thermally unstable

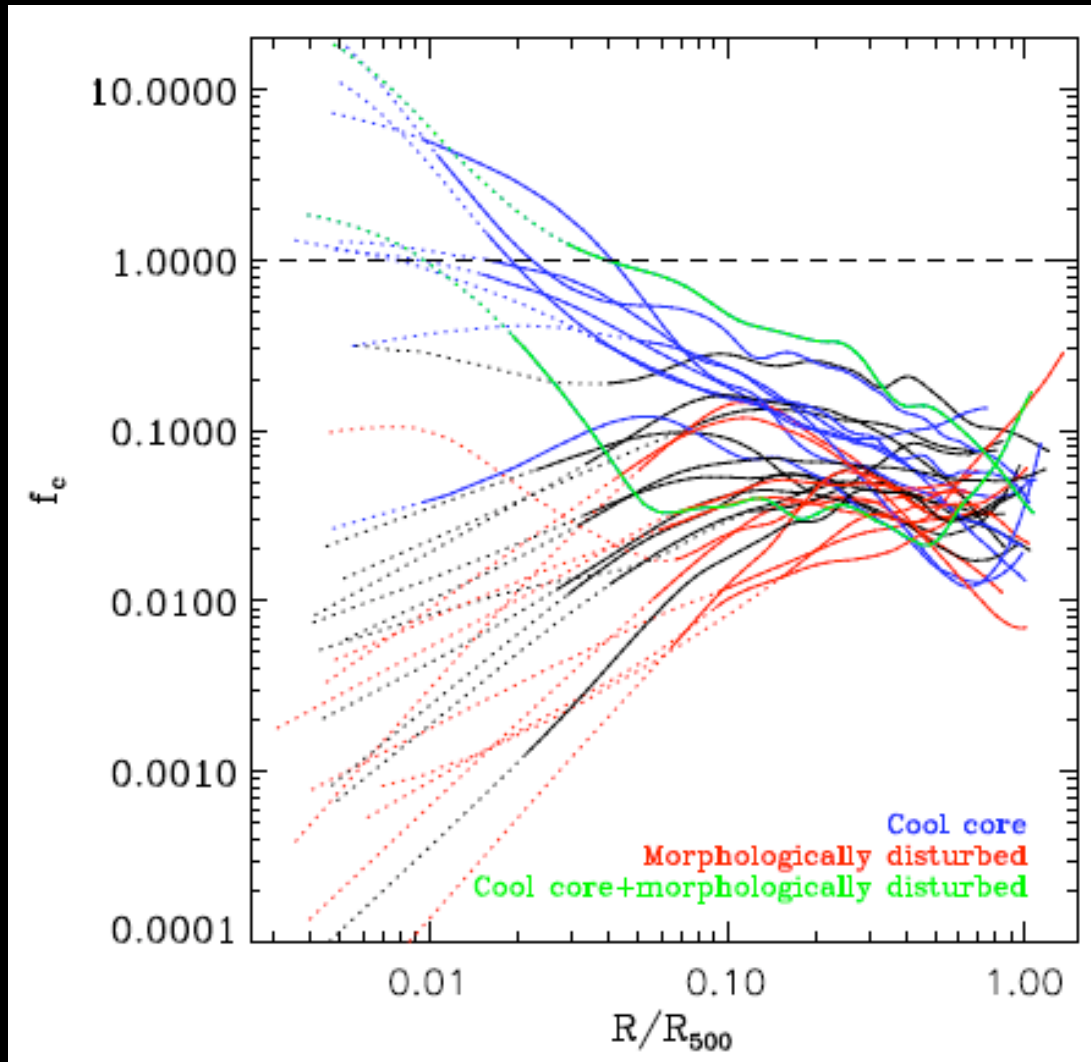
Conduction & Multiphase Structure



Red $K(r)$ profiles of BCGs without star formation or $H\alpha$ remain above $f_c \sim 0.2$ threshold

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

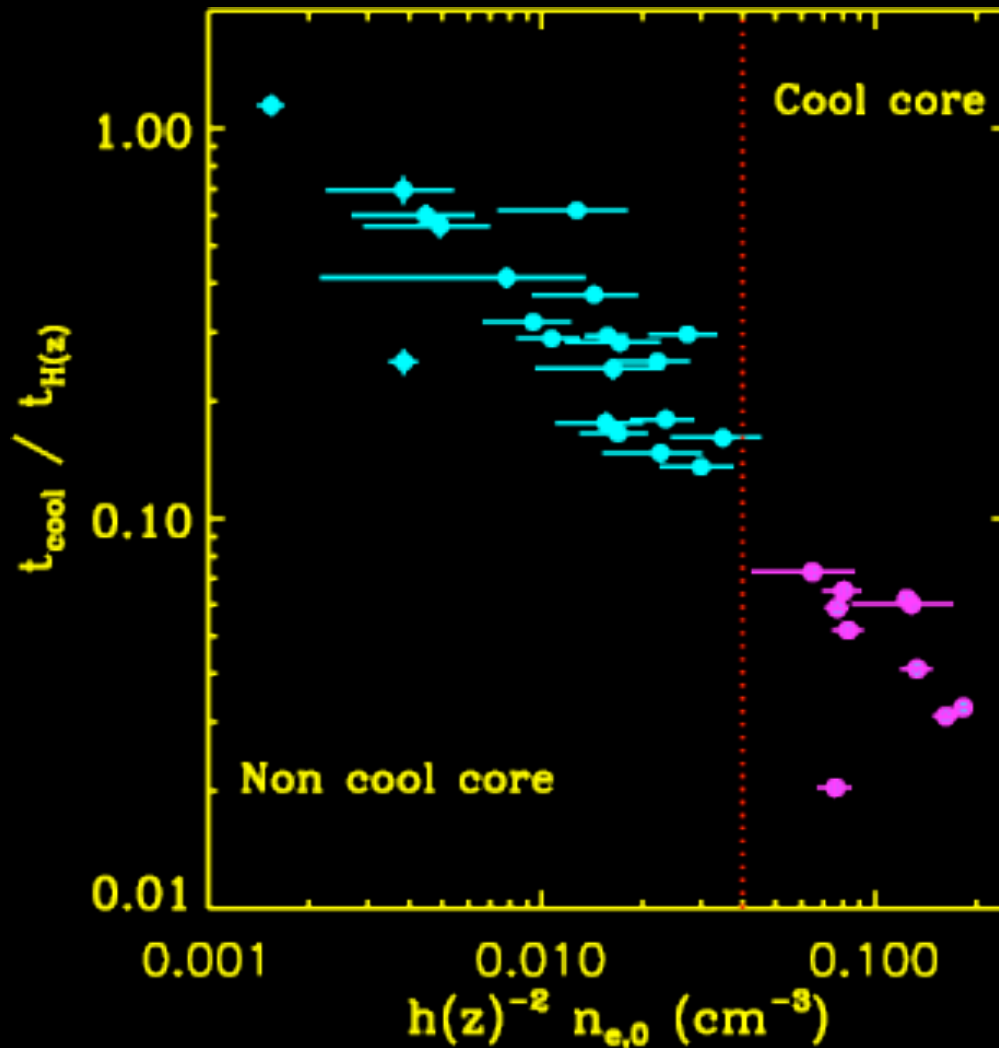
Conduction & Bimodality



More evidence for bimodality: effective f_c profiles of REXCESS clusters avoid $f_c \sim 0.2$ within core

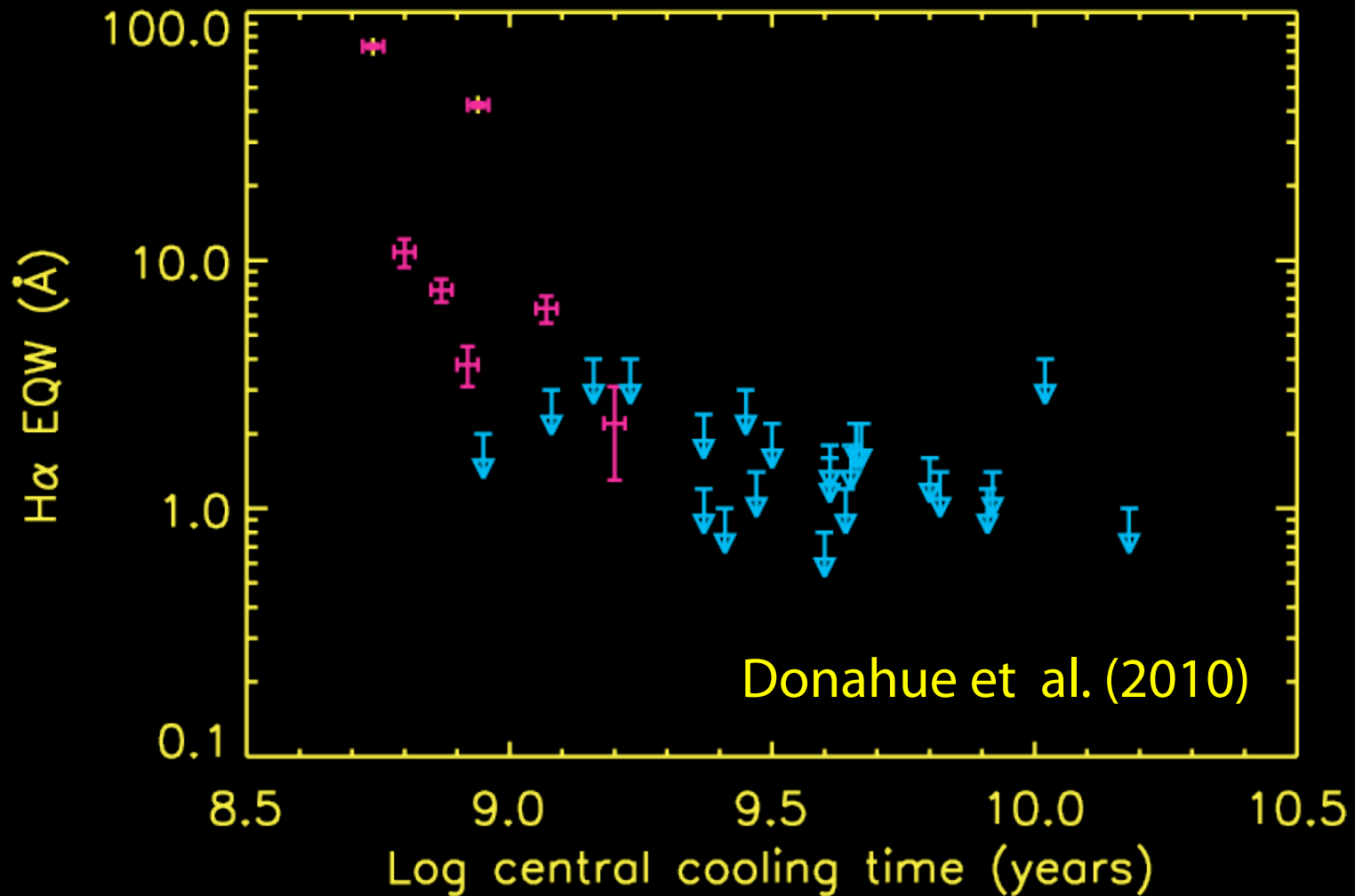
Pratt et al. (2010)

REXCESS Cooling Times

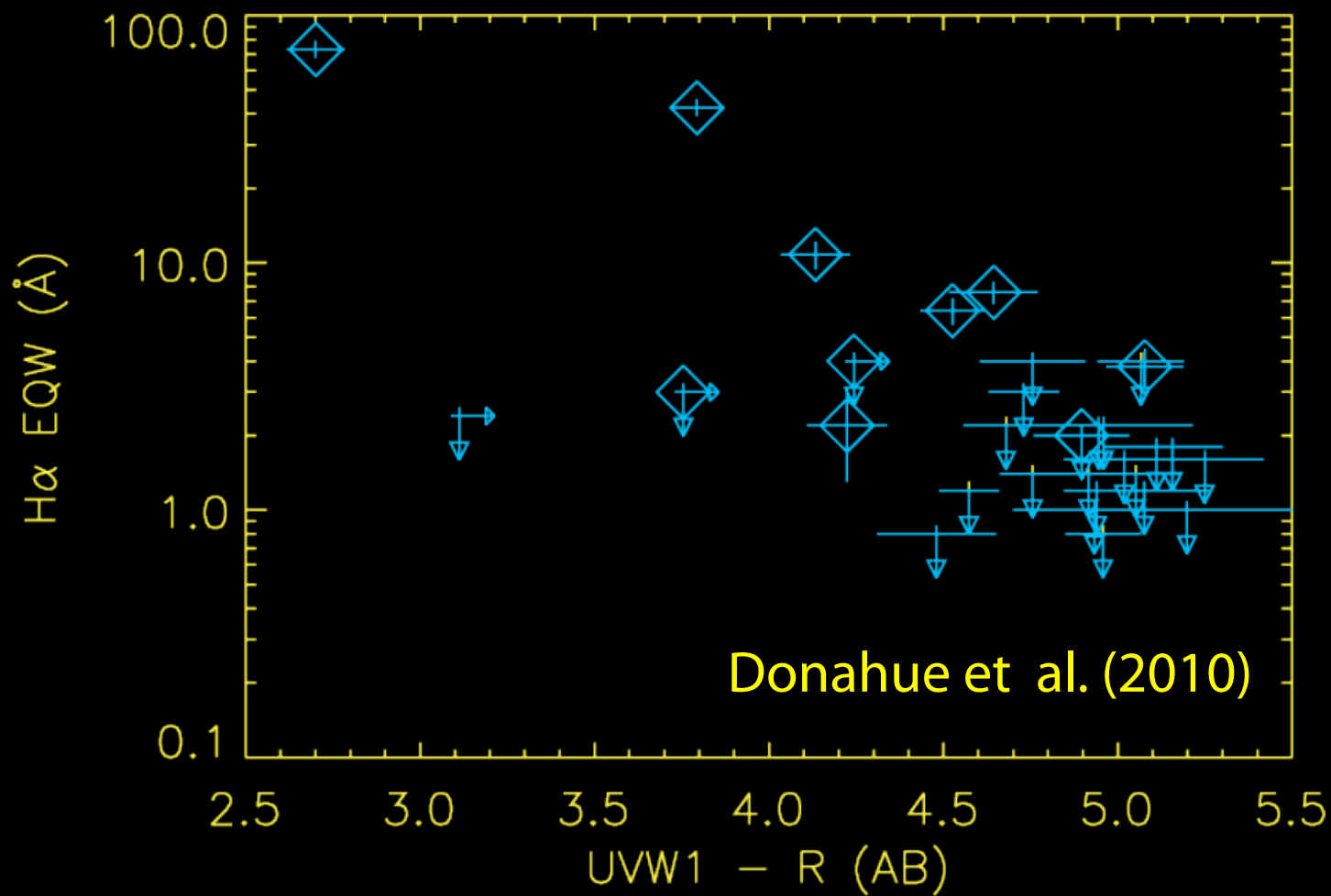


REXCESS cool-core classification based on t_{cool} at $0.003 R_{500}$

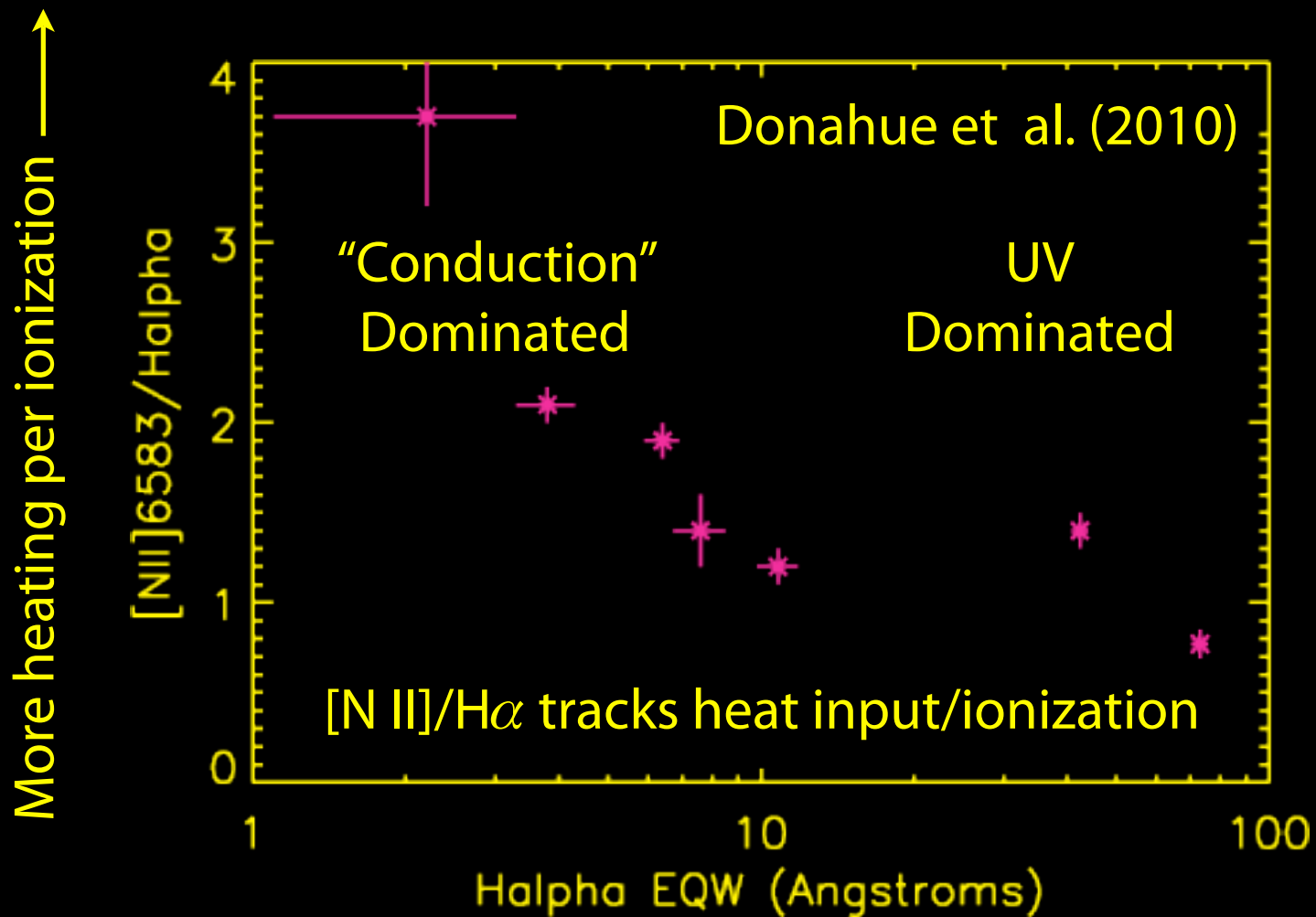
Cooling-Time Threshold for H α



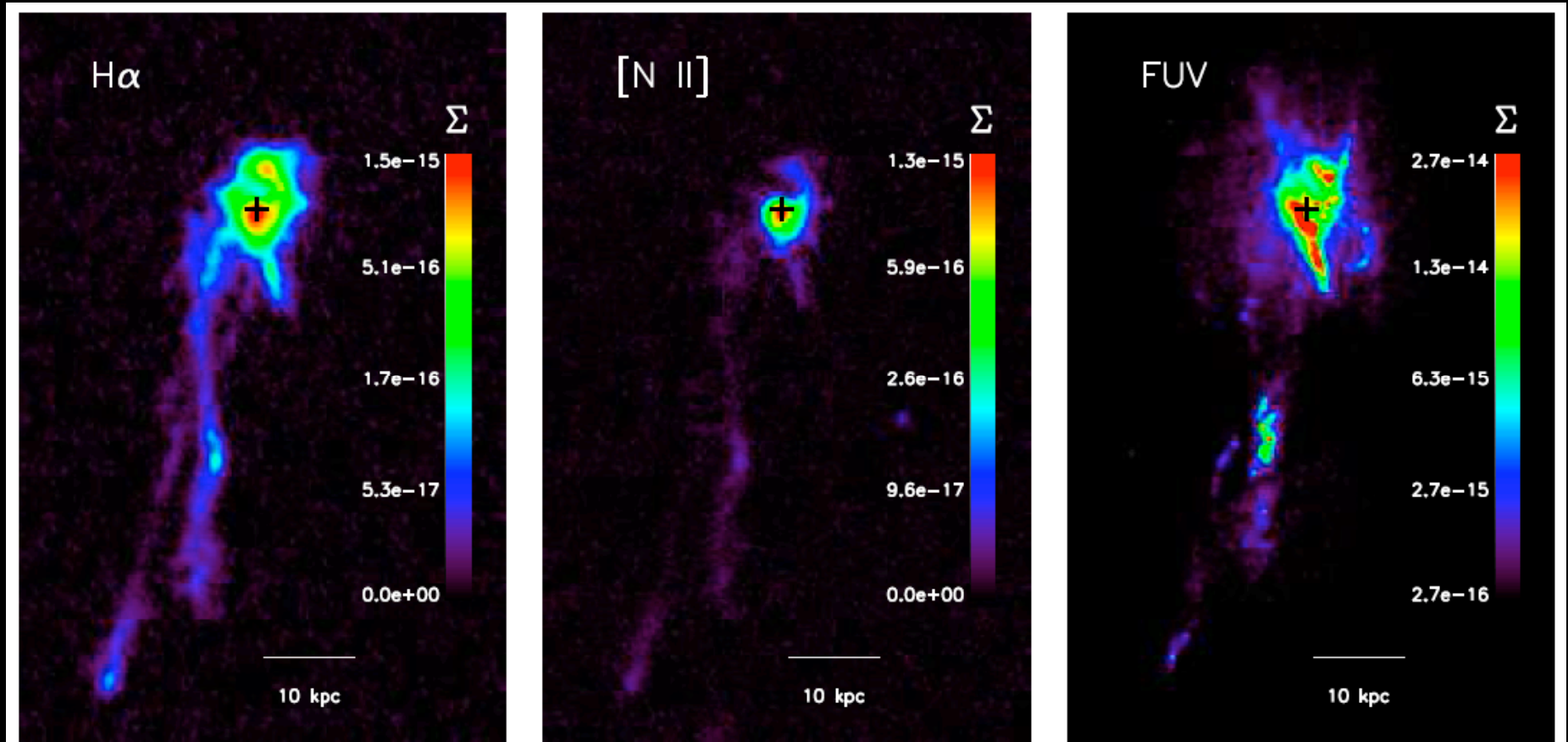
UV-H α Correlation



[N II]/H α and Filament Heating

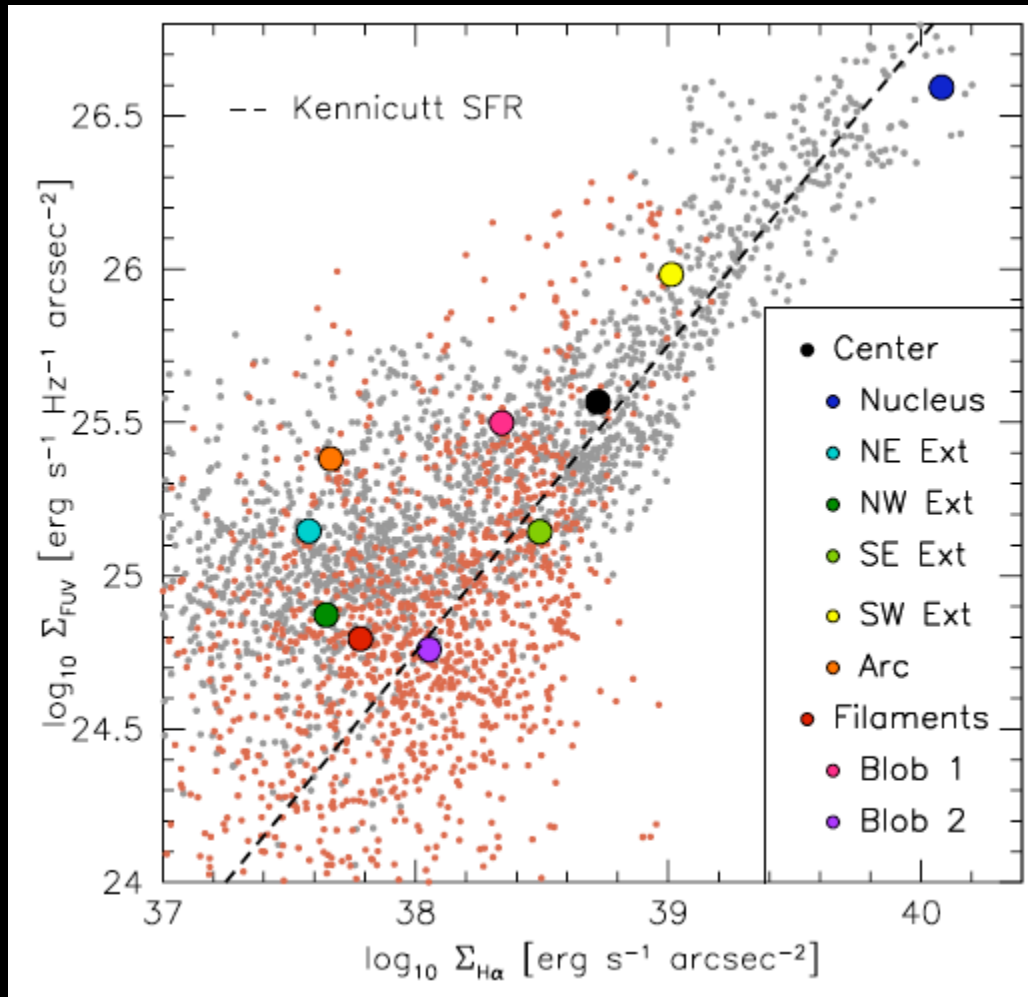


H α & UV in Abell 1795



McDonald & Veilleux (2009)

H α -UV Spatial Correlation



In Abell 1795,
correlation is
strong in bright
regions and poor
in dim regions

McDonald & Veilleux
(2010)

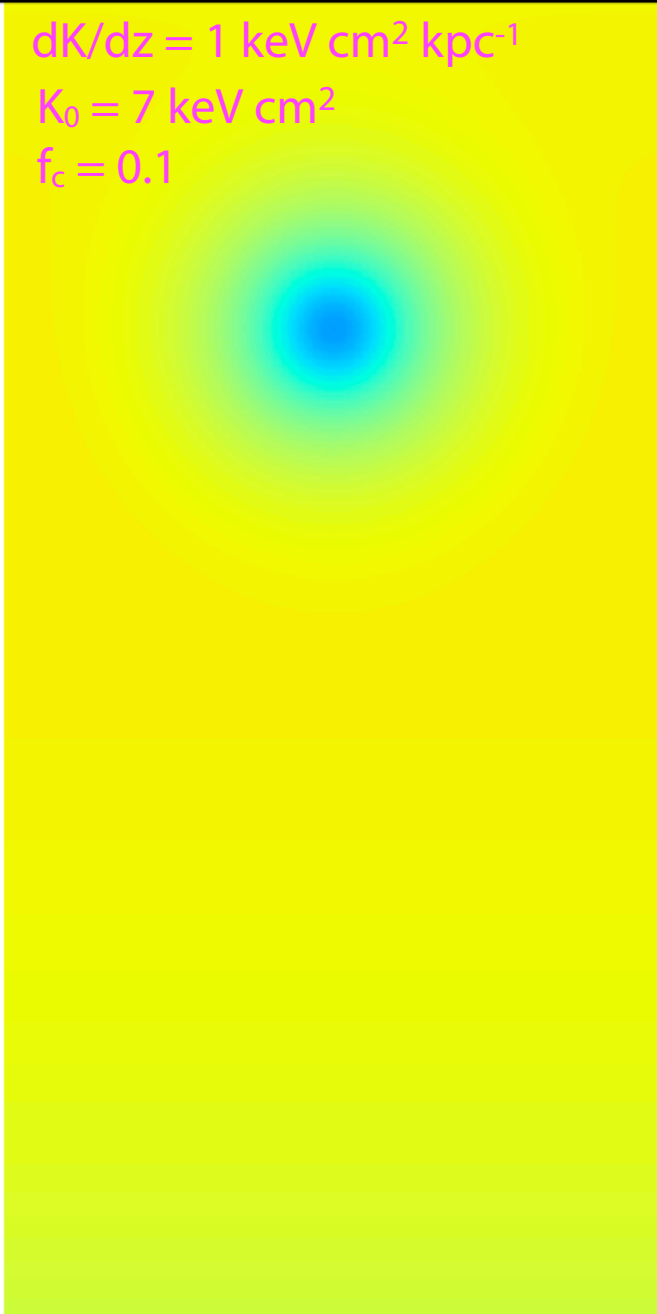
preliminary

*ENZO Simulations of Multiphase
ICM Structure*

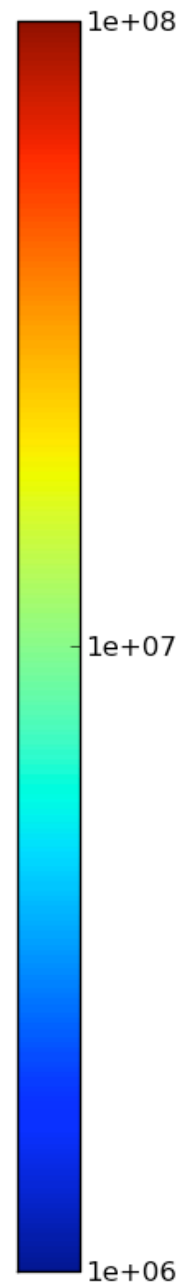
ENZO Modifications

- Isotropic conduction implemented by Brian O'Shea
- MHD version of ENZO now exists
- Implementation of anisotropic conduction on the way

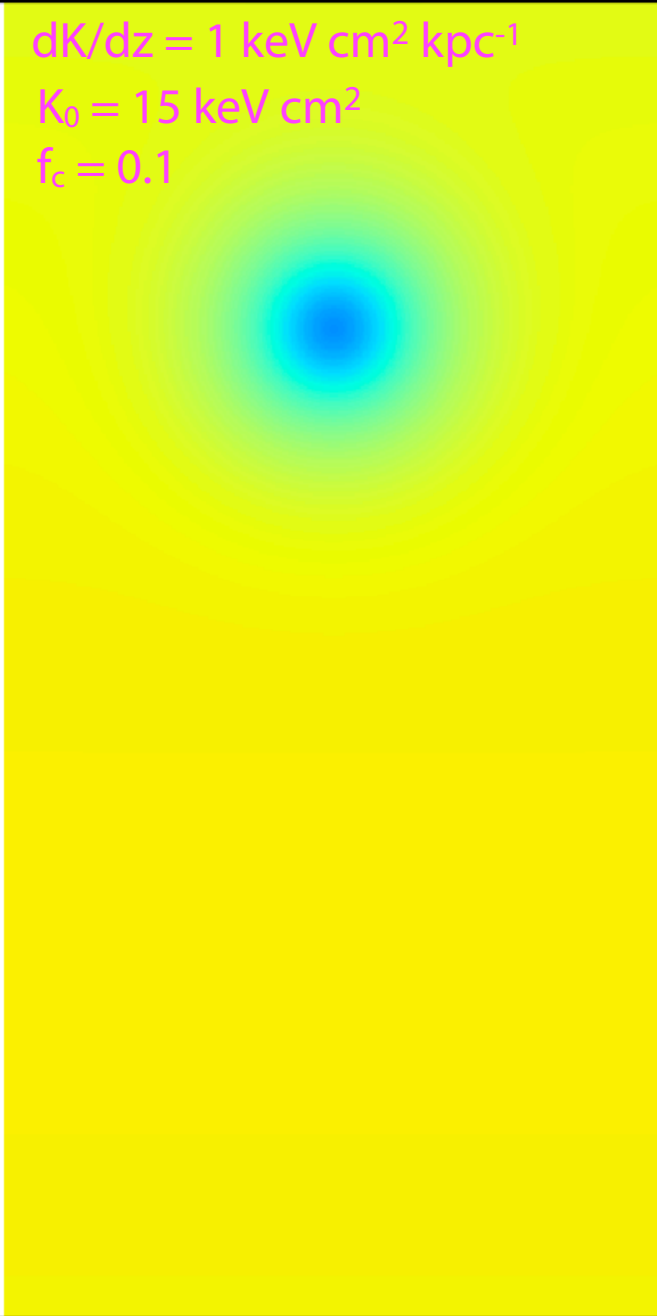
$dK/dz = 1 \text{ keV cm}^2 \text{ kpc}^{-1}$
 $K_0 = 7 \text{ keV cm}^2$
 $f_c = 0.1$



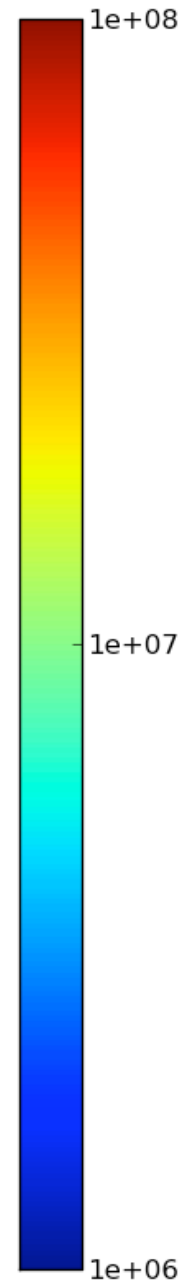
40 kpc



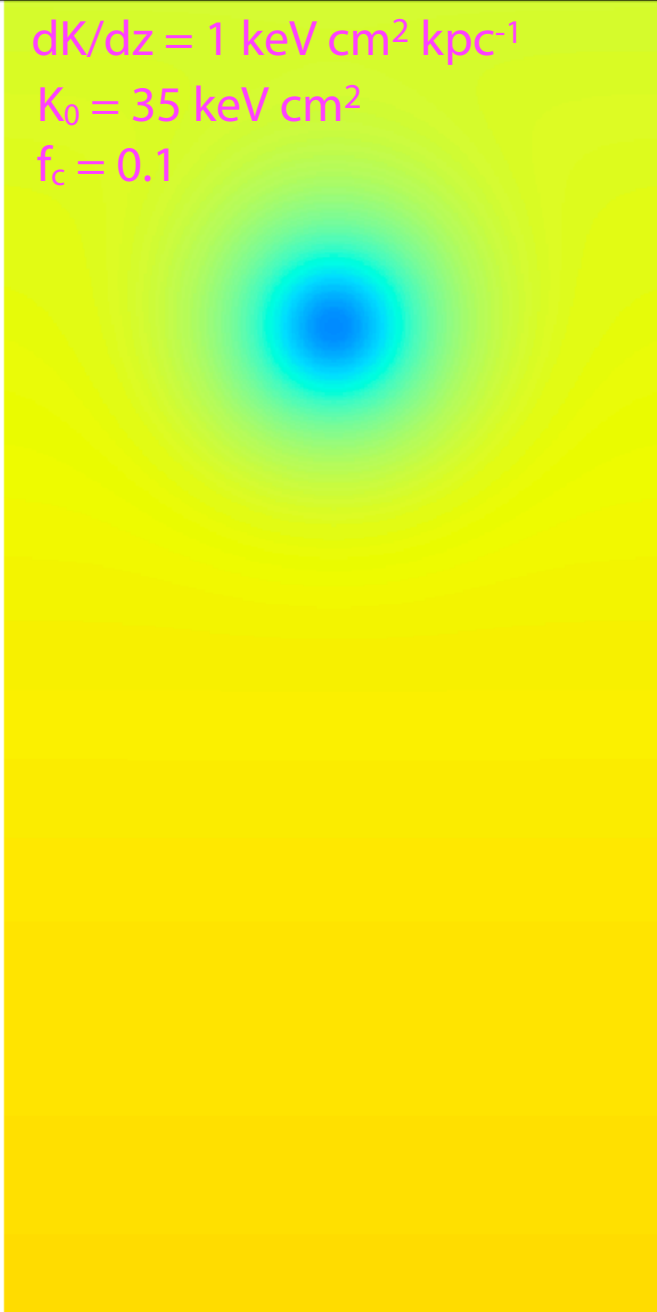
$dK/dz = 1 \text{ keV cm}^2 \text{ kpc}^{-1}$
 $K_0 = 15 \text{ keV cm}^2$
 $f_c = 0.1$



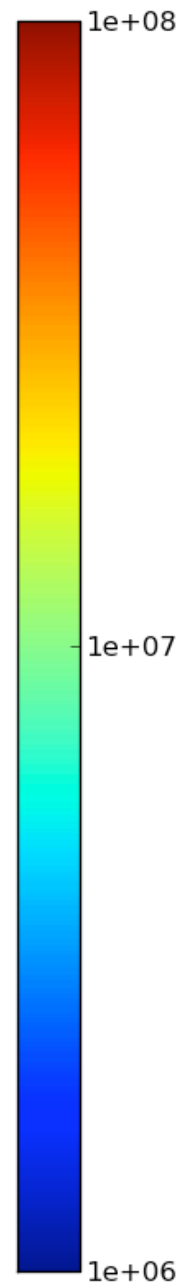
40 kpc



$dK/dz = 1 \text{ keV cm}^2 \text{ kpc}^{-1}$
 $K_0 = 35 \text{ keV cm}^2$
 $f_c = 0.1$



40 kpc



Summary

- AGN feedback and multiphase gas are directly linked to the state of the hot ICM
- Presence of multiphase gas may be governed by conduction, indicating $f_c \sim 0.2$
- Conduction qualitatively alters condensation of ICM if it is present