Off-Axis Mergers and Cool Core Disruption

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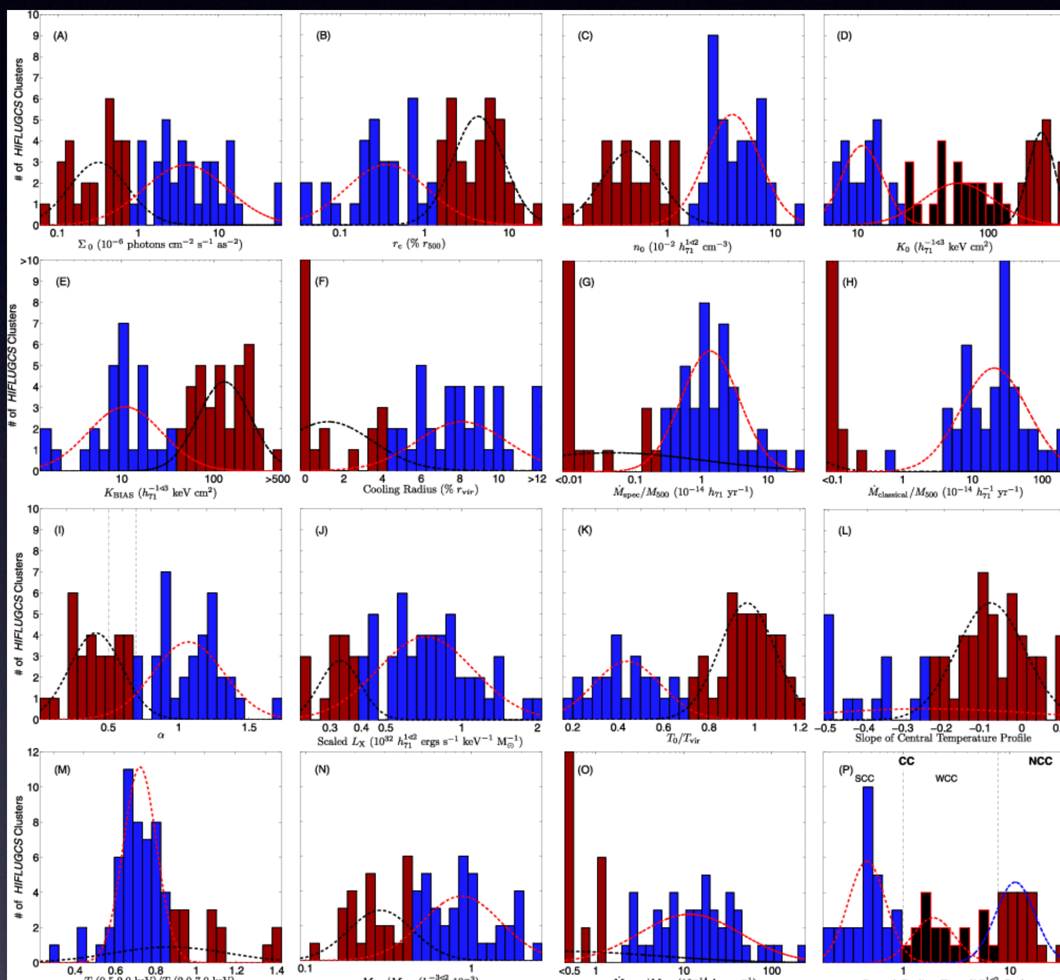
Cool Core / Non-Cool Core Population Distribution



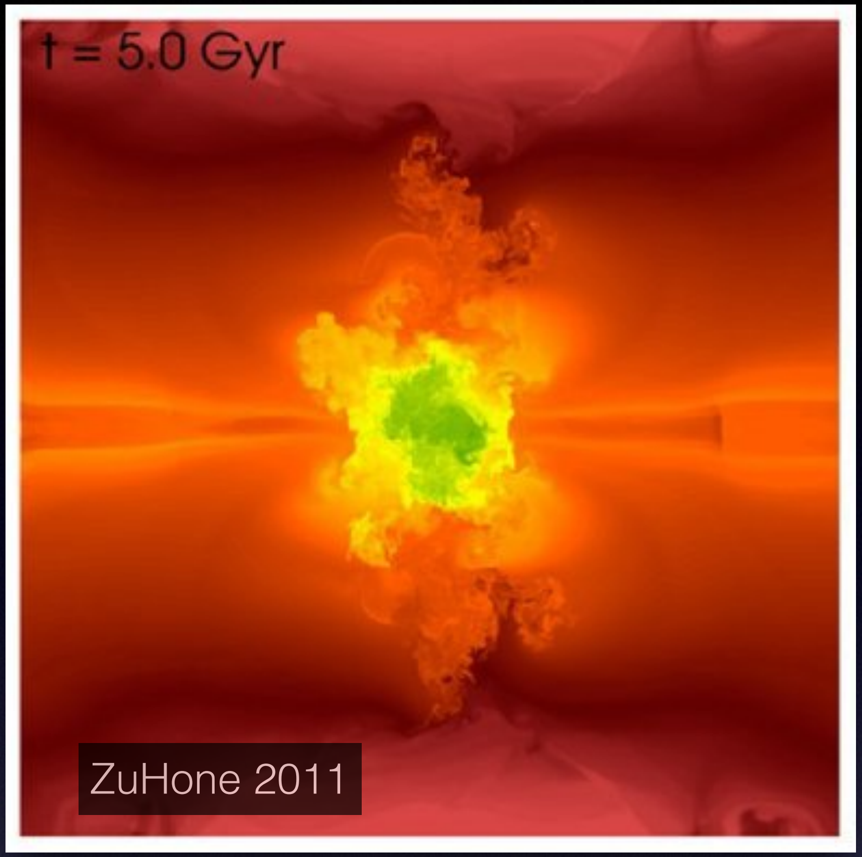
Hudson et al. (2010)

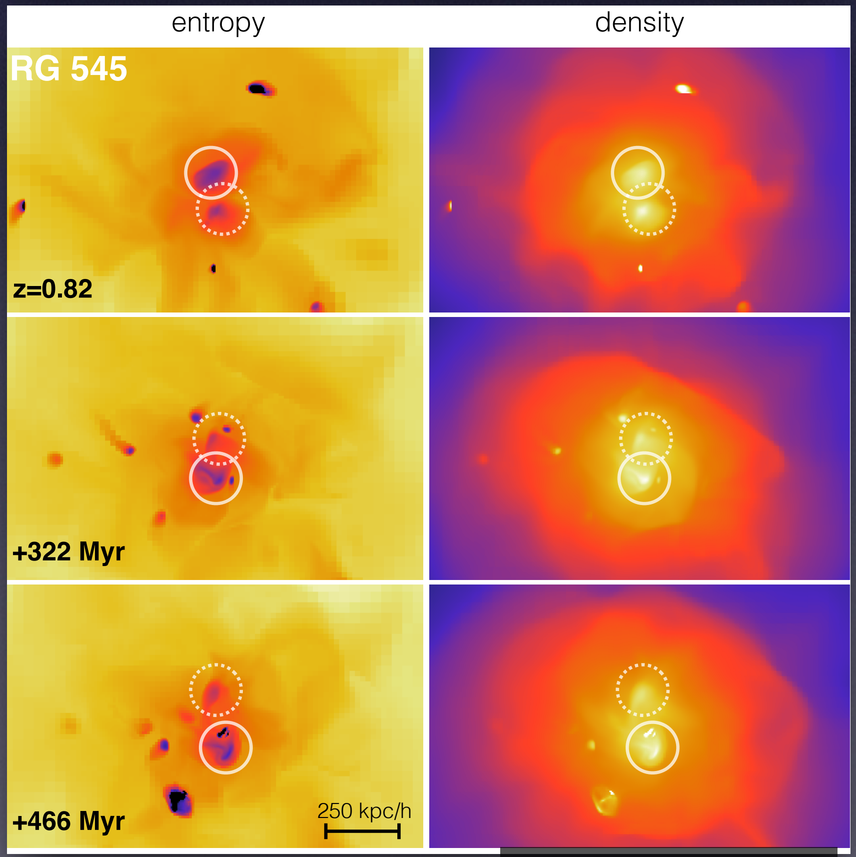
tcool

Hudson et al. (2010) examined the *HIFLUGCS (Reiprich & Boringer 2002)* against numerous CC diagnostics

Using tcool to segregate clusters:

44% Strong Cool Cores (tcool < 1 Gyr)
28% Weak Cool Cores (1 < tcool < 7.7 Gyr)
28% Non Cool Cores (tcool > 7.7 Gyr)





Hahn et al. 2017

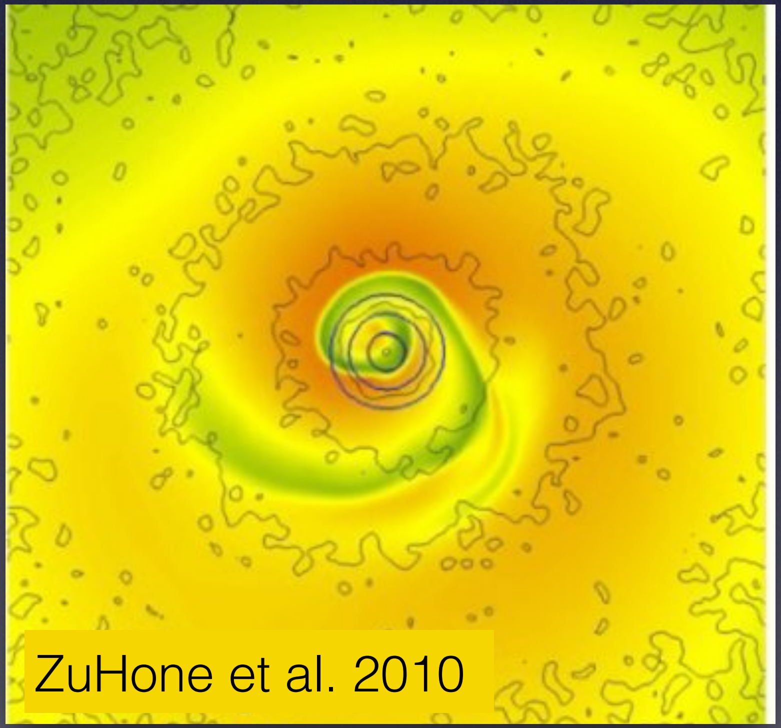
Cool Core Disruption via Cluster Mergers

numerous observations of disrupted cool cores in systems undergoing low angular momentum (head-on) major mergers

simulations of head-on CCs result in core entropies of ~ 300 keV cm^2 (e.g. ZuHone 2011)

While Ricker and Sarazin (2001), ZuHone (2011) showed off-axis mergers can significantly transform a cluster core, recent cosmological simulations of Hahn et al. (2017) suggest head-on mergers are required to produce long-lived NCCs

Sloshing of Cool Cores



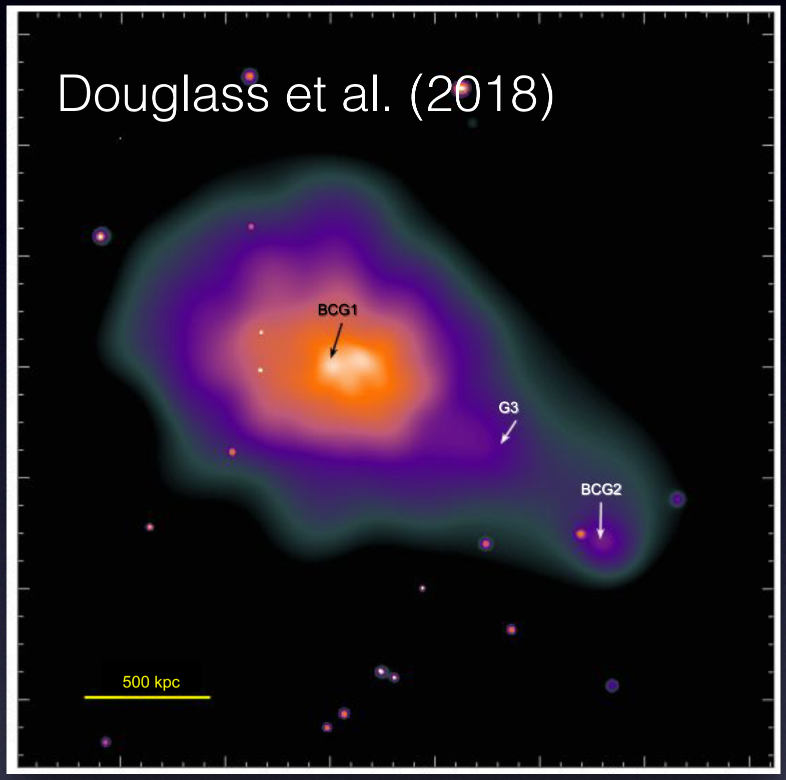
off-axis infall of sub cluster displaces ICM core from DM peak

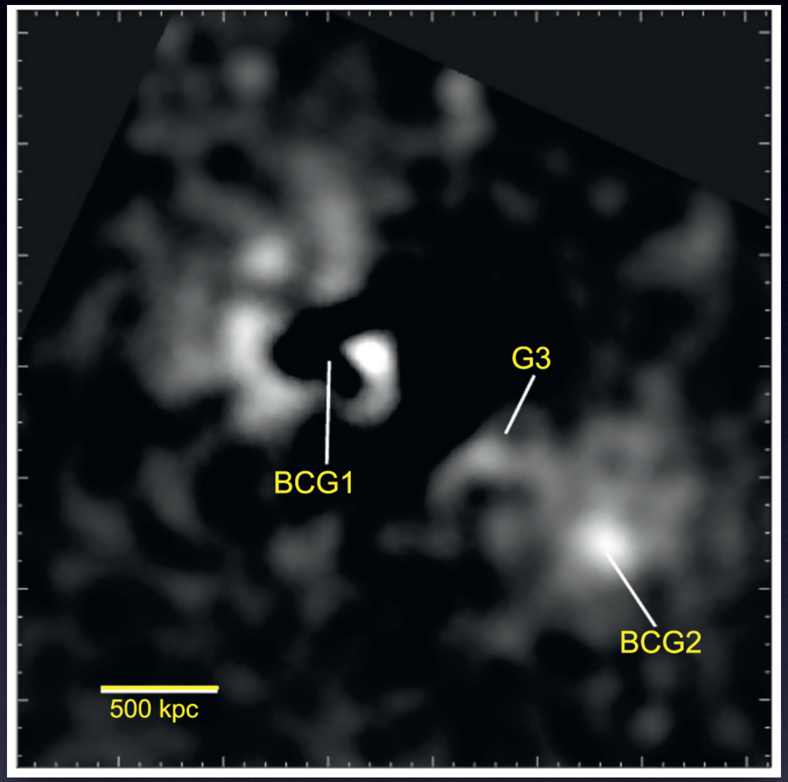
angular momentum introduced results in oscillatory motion of gas core about DM peak

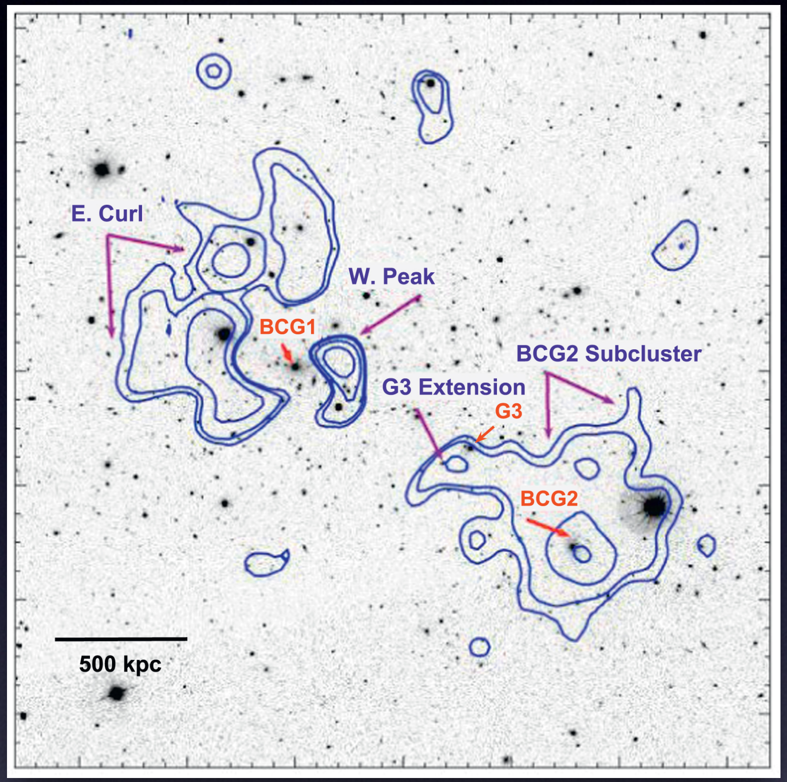
alternating cold fronts are launched by the oscillating cool core, resulting in the formation of spiral excess of cool, low entropy gas

typically associated with SCCs, generally not energetic enough to significantly off-set cooling (ZuHone 2010)

Abell 1763 (z = 0.231)







exp = 19.6 ksec (cycle 4)

kT = 8.0 keV.

Z_{IN} = 0.52 +/- 0.15

K_{30kpc} = 110 keV cm^2

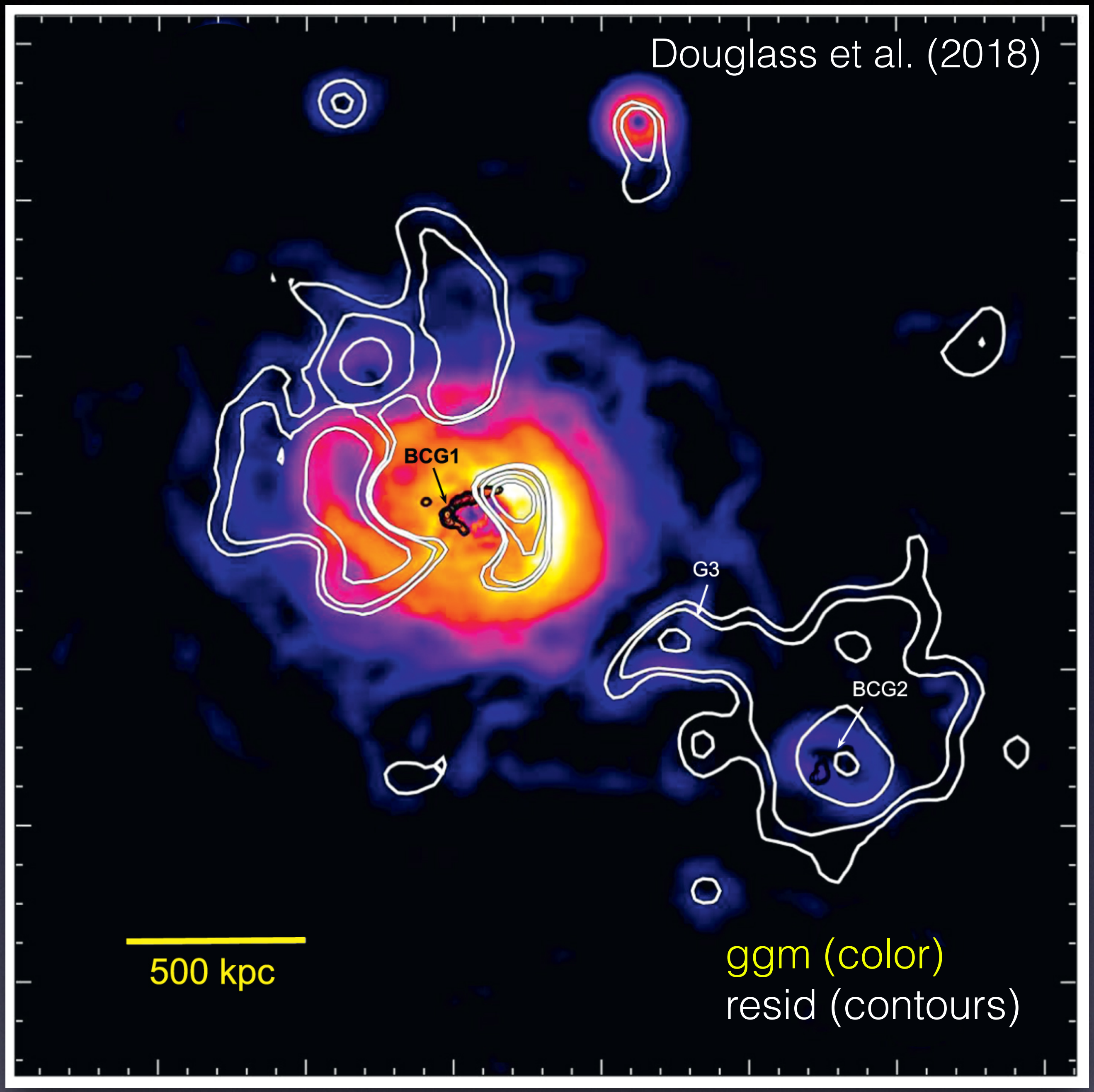
tcool = 6.8 Gyr

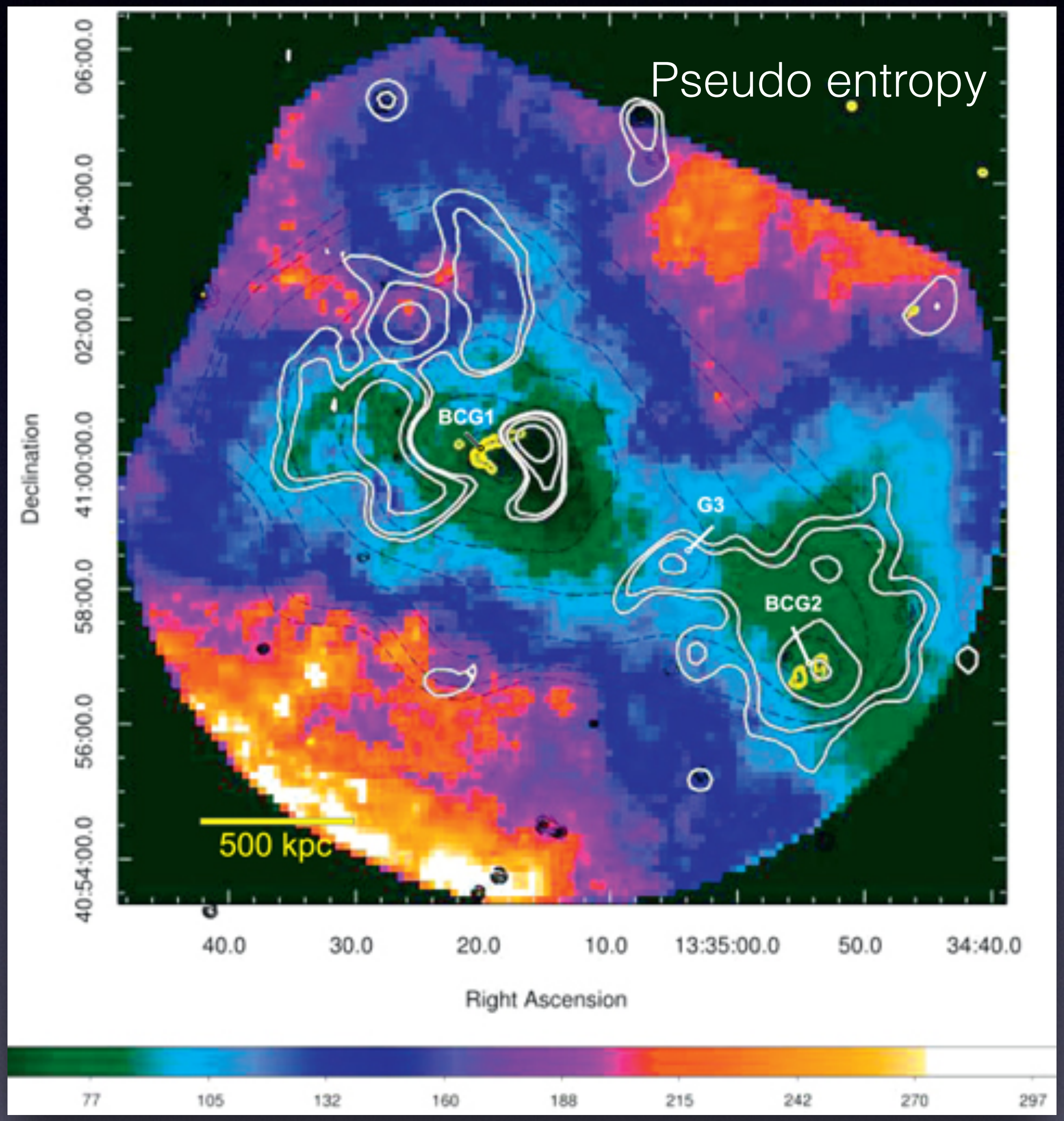
$M_{200} = 1.7 \times 10^{15} M_{sun}$ (Rines 2013)

somewhat similar to sloshing "warm core" seen in A2142

(Wang & Markevitch 2018, Rossetti 2013) K = 49 keV cm^2

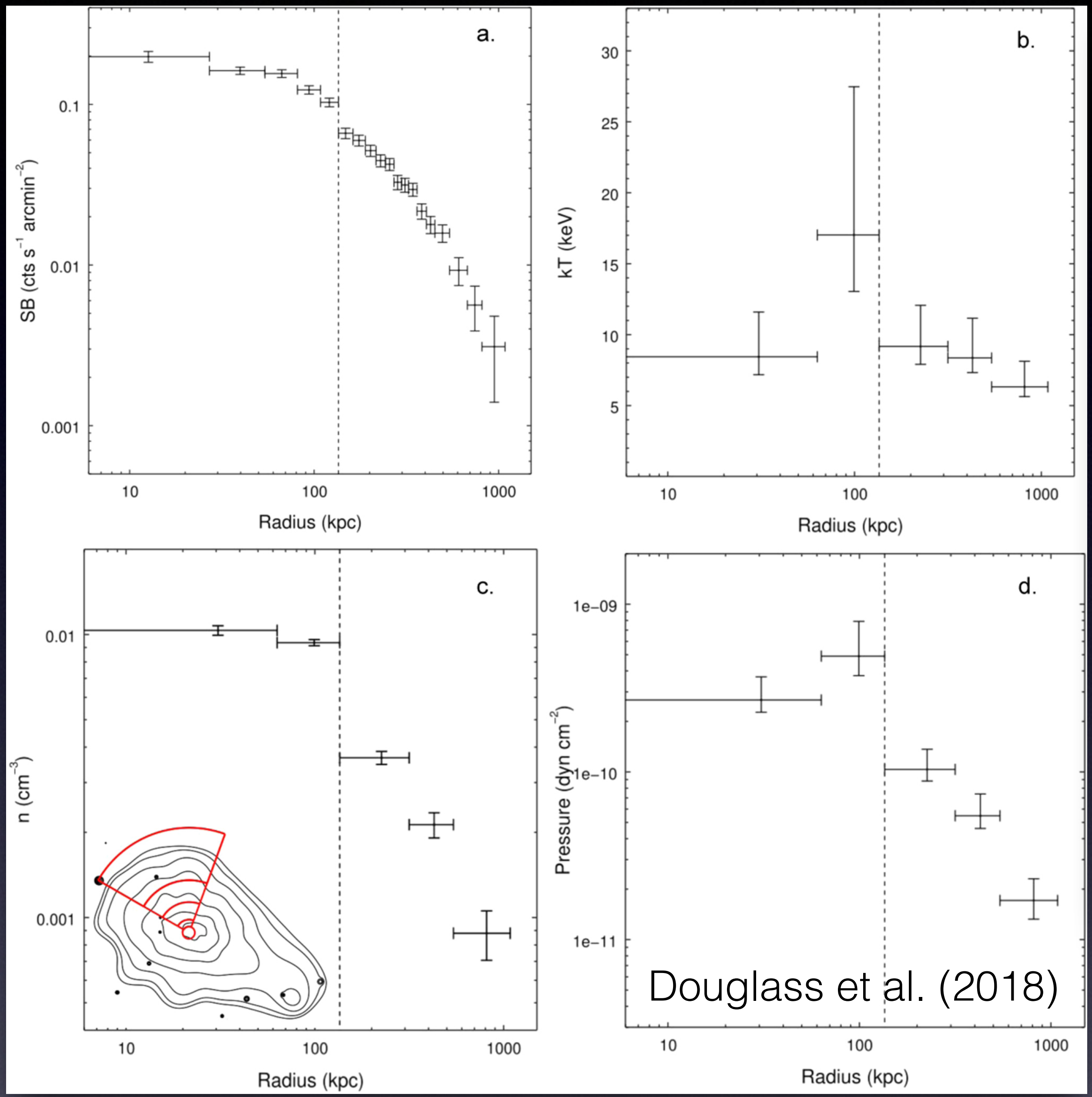
Abell 1763

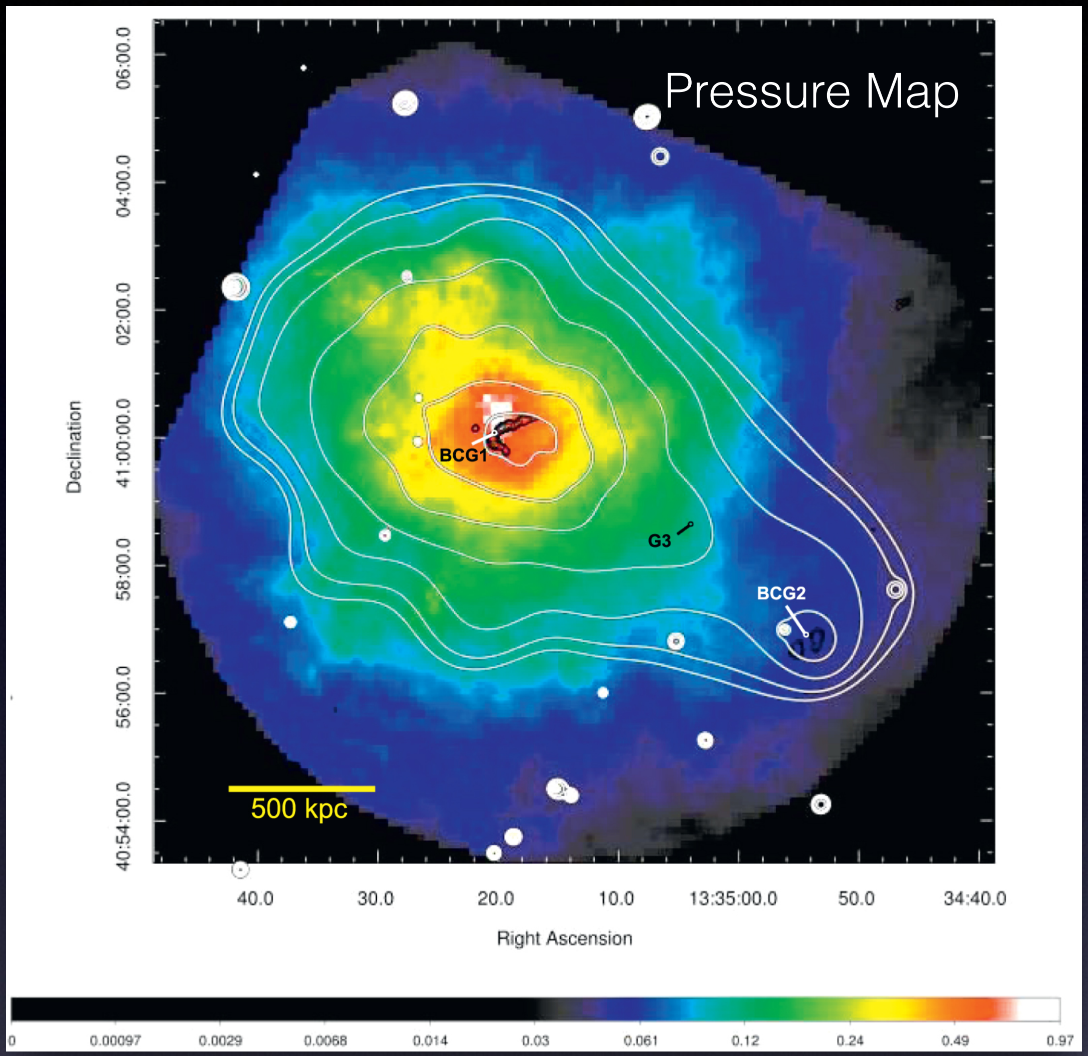




Excess spiral coincident with lower entropy gas, associated with steep surface brightness features revealed in Gaussian Gradient Magnitude (GGM) filtered image.

Abell 1763





Region of enhanced pressure to northeast of BCG1 at ~ 135 kpc

As seen in the off-axis merger simulations of ZuHone (2011), a shock is expected to develop during disruptive core sloshing as a cold front is launched into the high-velocity ICM counter flow induced by the infalling system.

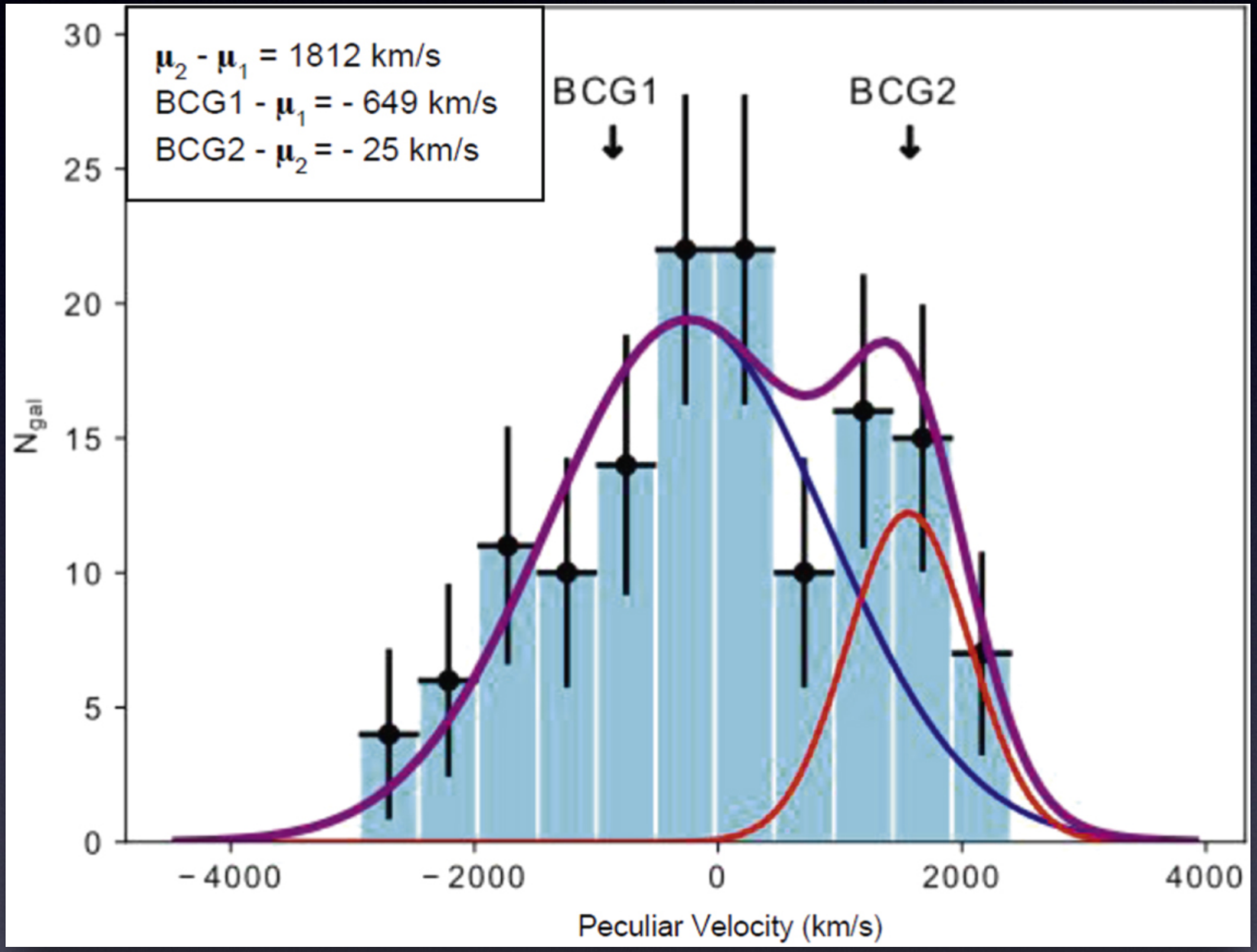
Abell 1763

dynamical analysis of cluster using a total of 137 galaxy redshifts

BCG2 in X-ray subcluster associated with secondary peak

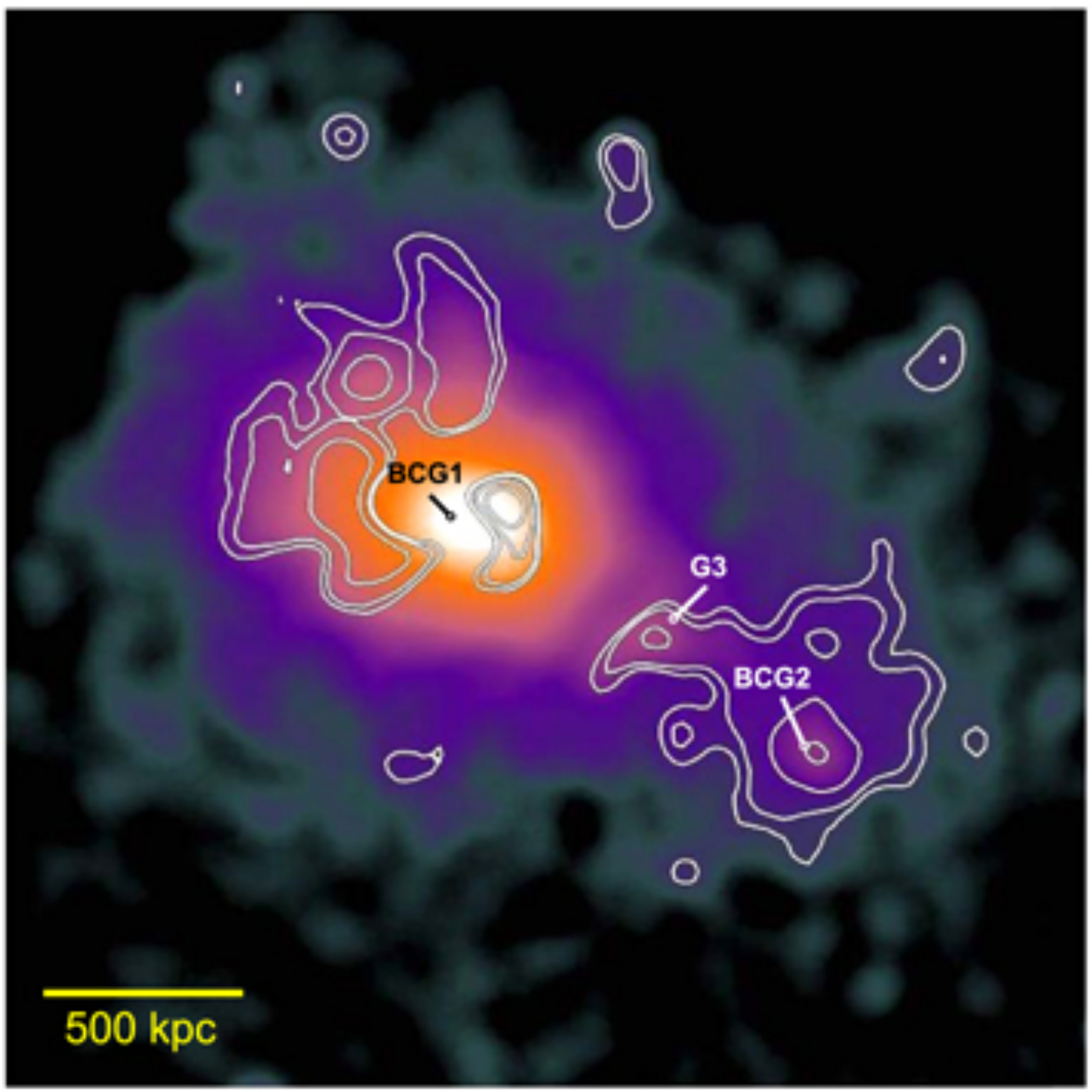
Large relative velocity between cluster / subcluster (1800 km/s)

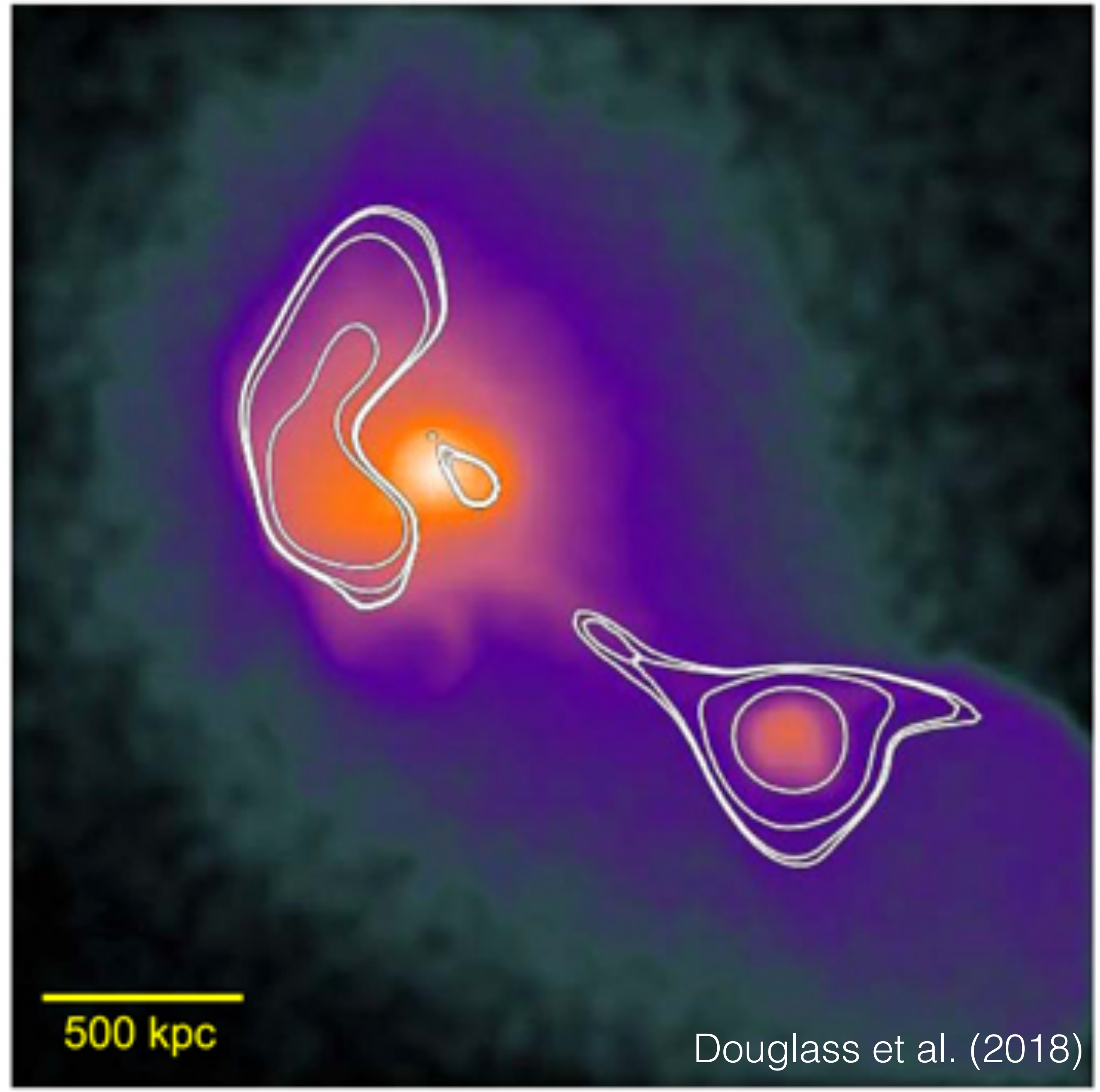
Large peculiar velocity of BCG1



Douglass et al. (2018)

Abell 1763





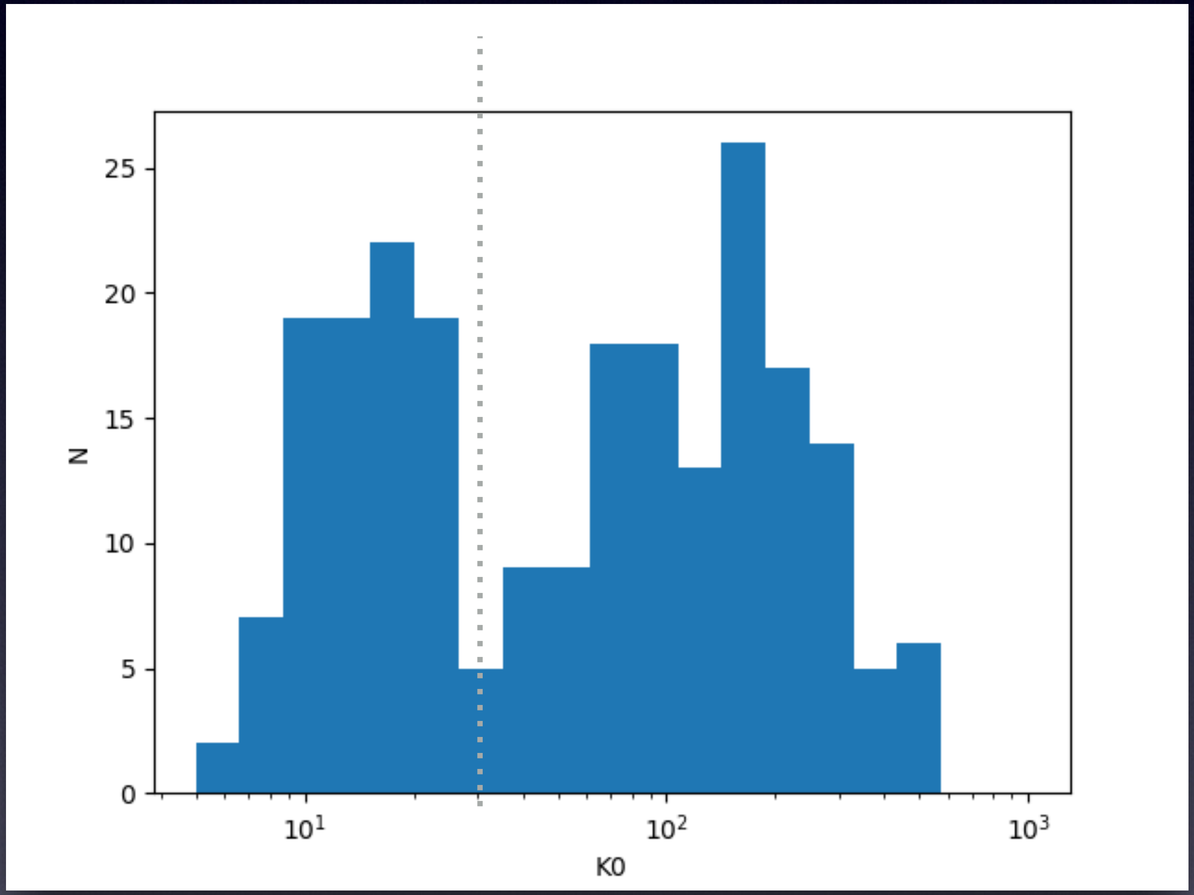
Abell 1763

3:1 Mass ratio, v_t = 1000 km/s
b=1 Mpc (ZuHone 2011)

Is this* happening elsewhere?

*cool core disruption via off-axis mergers

the *ACCEPT* Sample



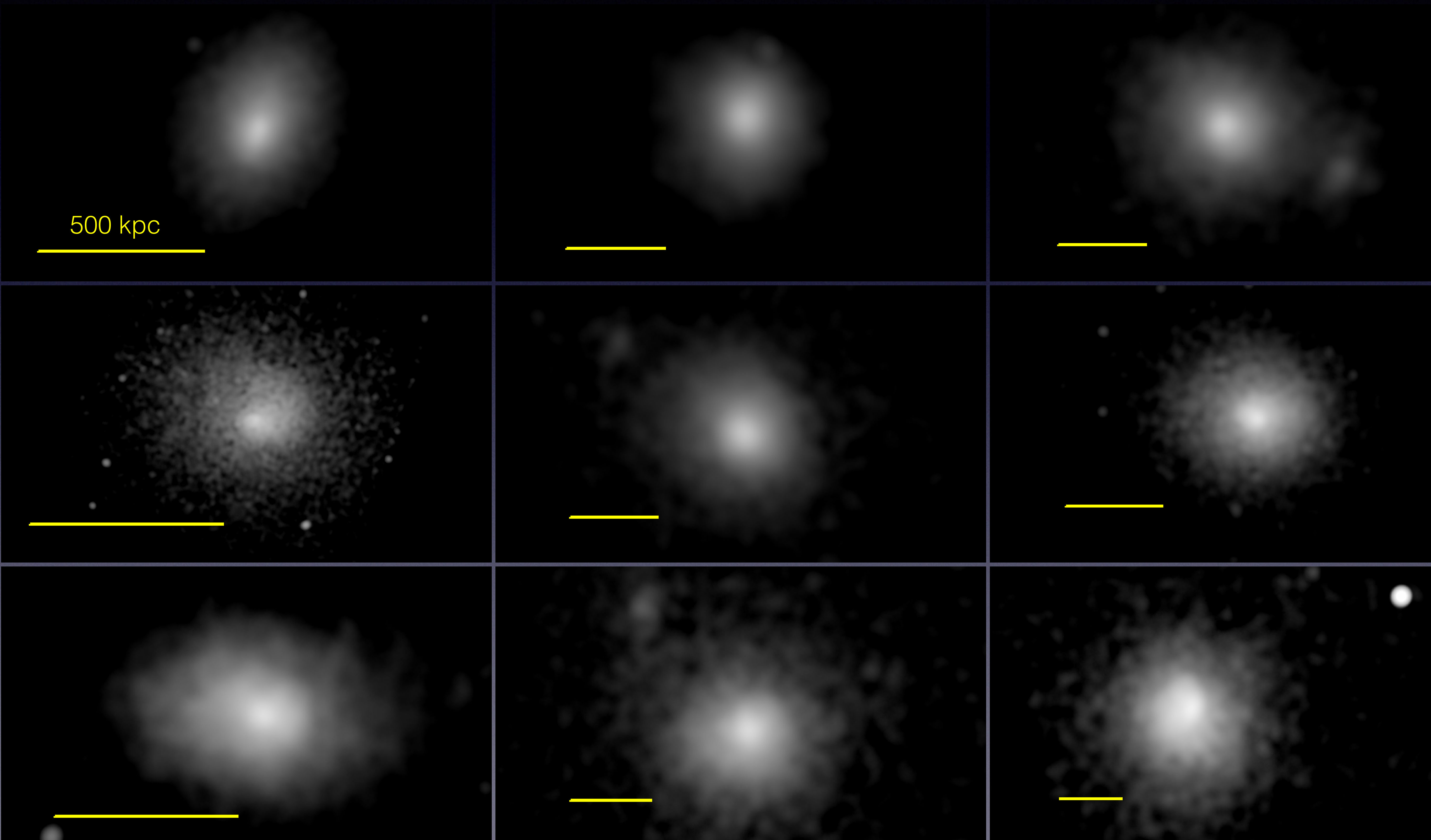
Cavagnolo et al. (2009) determined K0 for 239 clusters publicly available in the archive as of Feb 2009 (up to obsid: 9422)

Distinct Gap at K0 ~ 30-40 keV cm^2

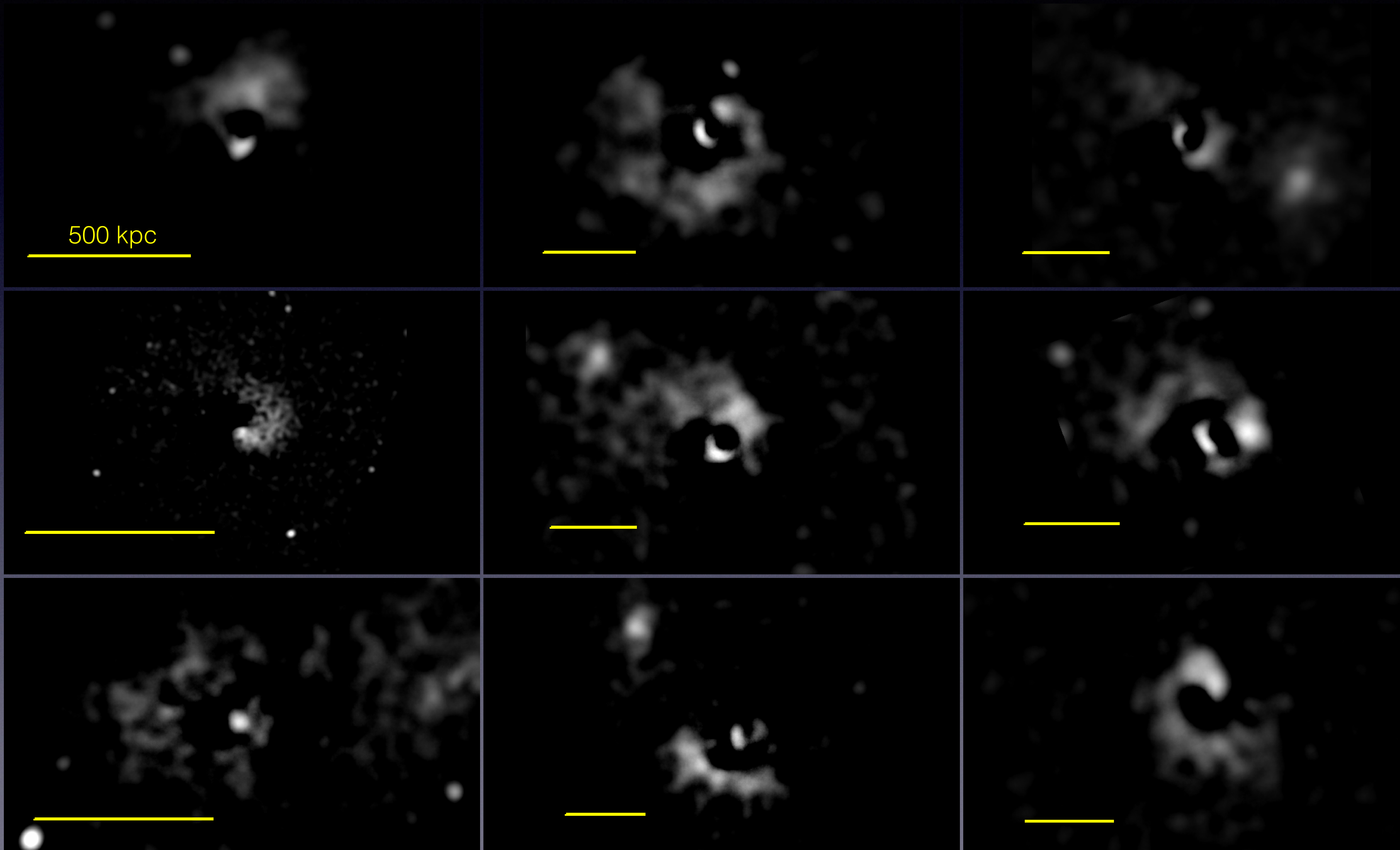
Two population peaks at:
K0 ~ 15 keV cm^2
K0 ~ 150 keV cm^2

K0 < 30 keV cm^2 107 clusters
K0 > 30 keV cm^2 132 clusters

some *ACCEPT* clusters with $K_0 > 30$ keV cm^2

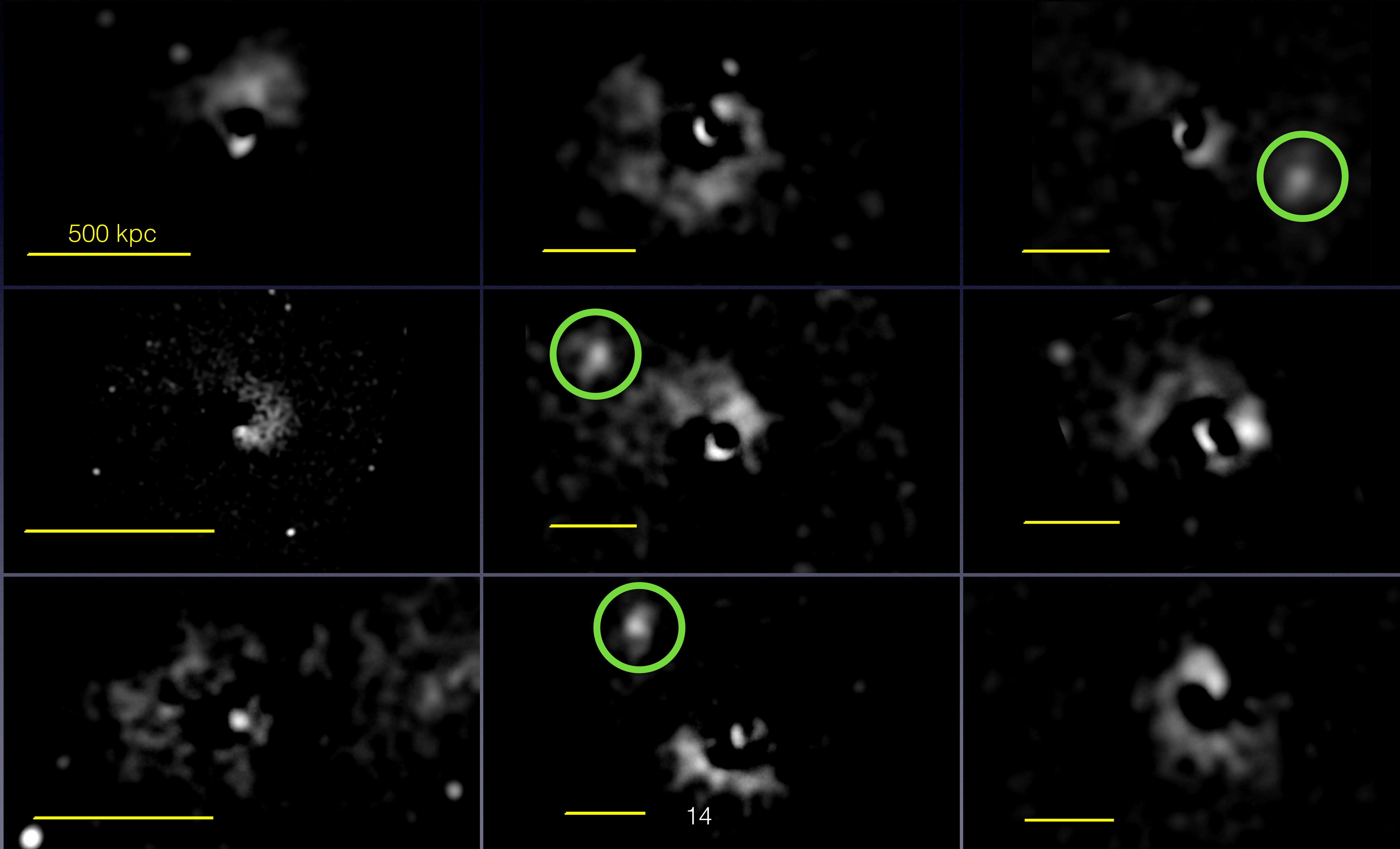


Beta-Model Subtraction Reveals Gas Sloshing Spirals

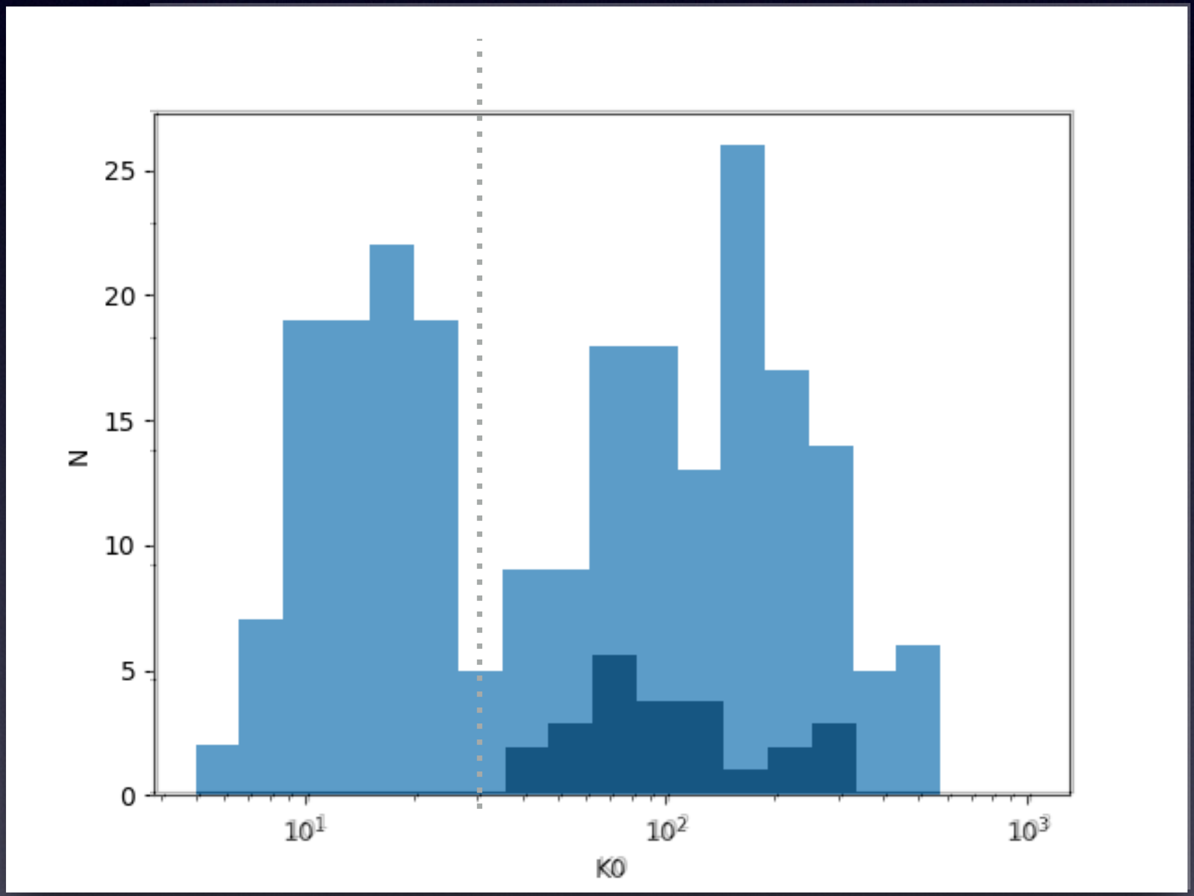


Beta-Model Subtraction Reveals Gas Sloshing Spirals

(gaseous perturbers)



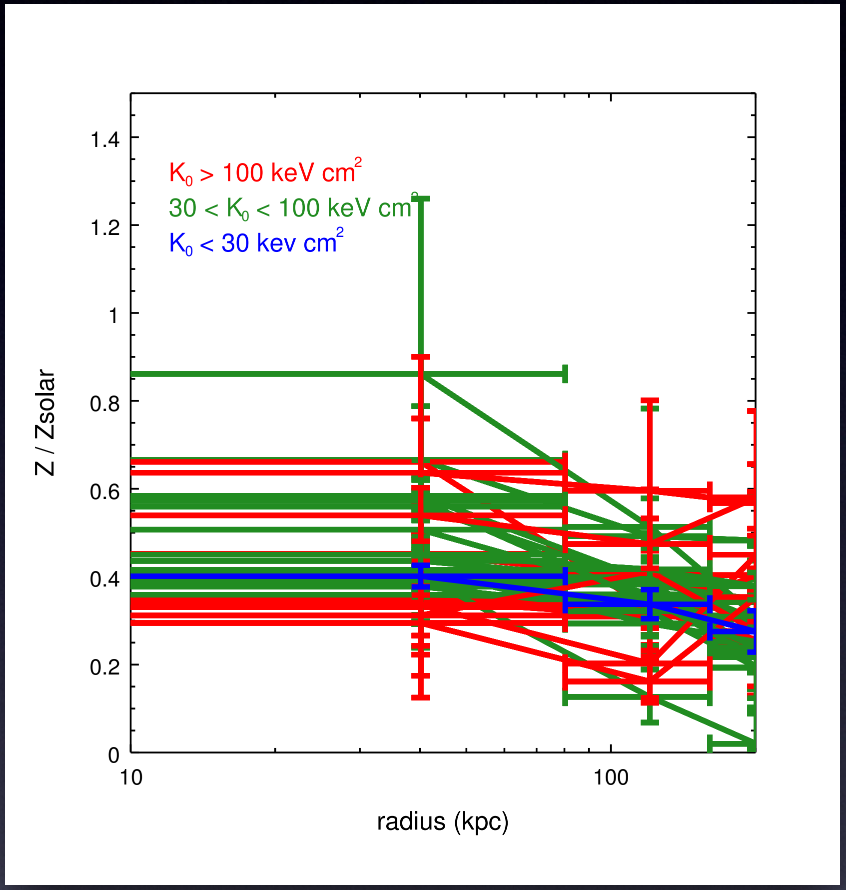
Examining the *ACCEPT* Sample

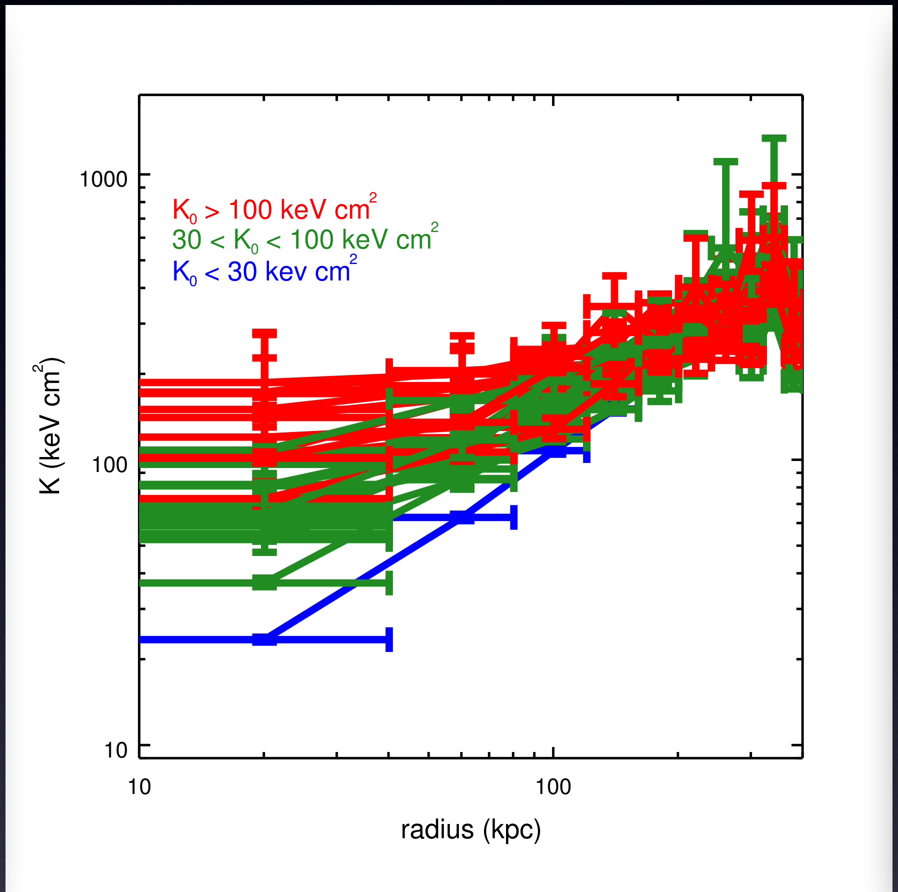


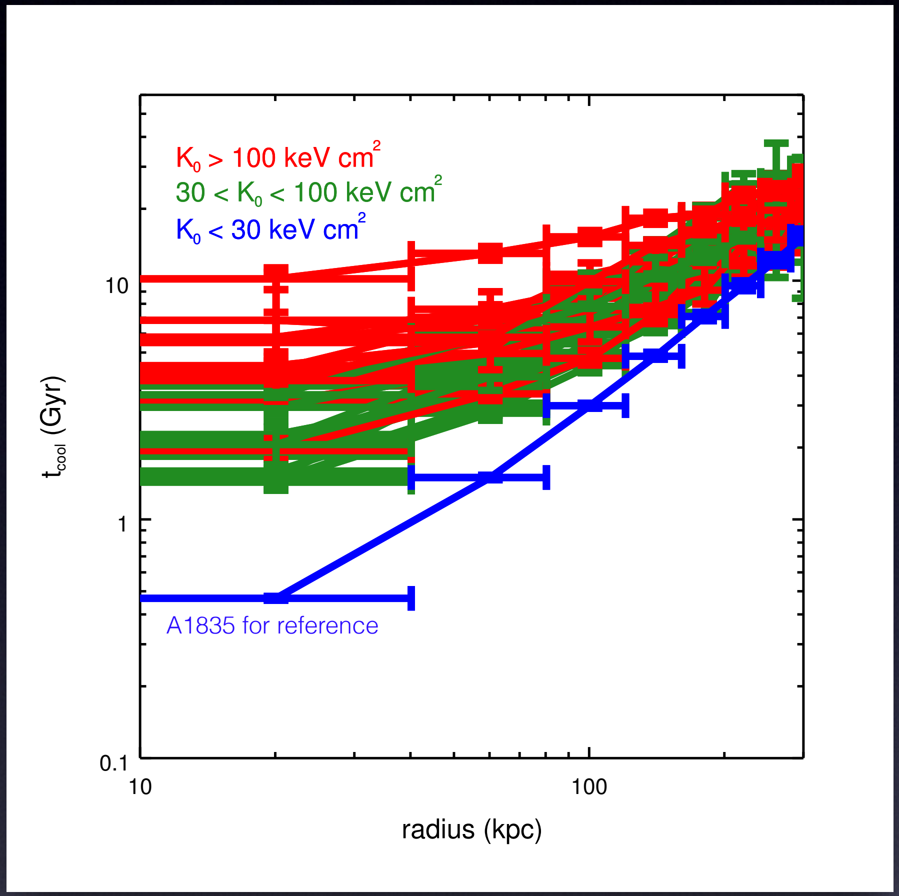
Performed substructure analysis (2D Beta model subtraction) of clusters with K0 > 30 keV cm^2 (132 clusters)

Identified 28 clusters with apparent spiral SB edges consistent with sloshing

Metallicity, Entropy, and Cooling Time



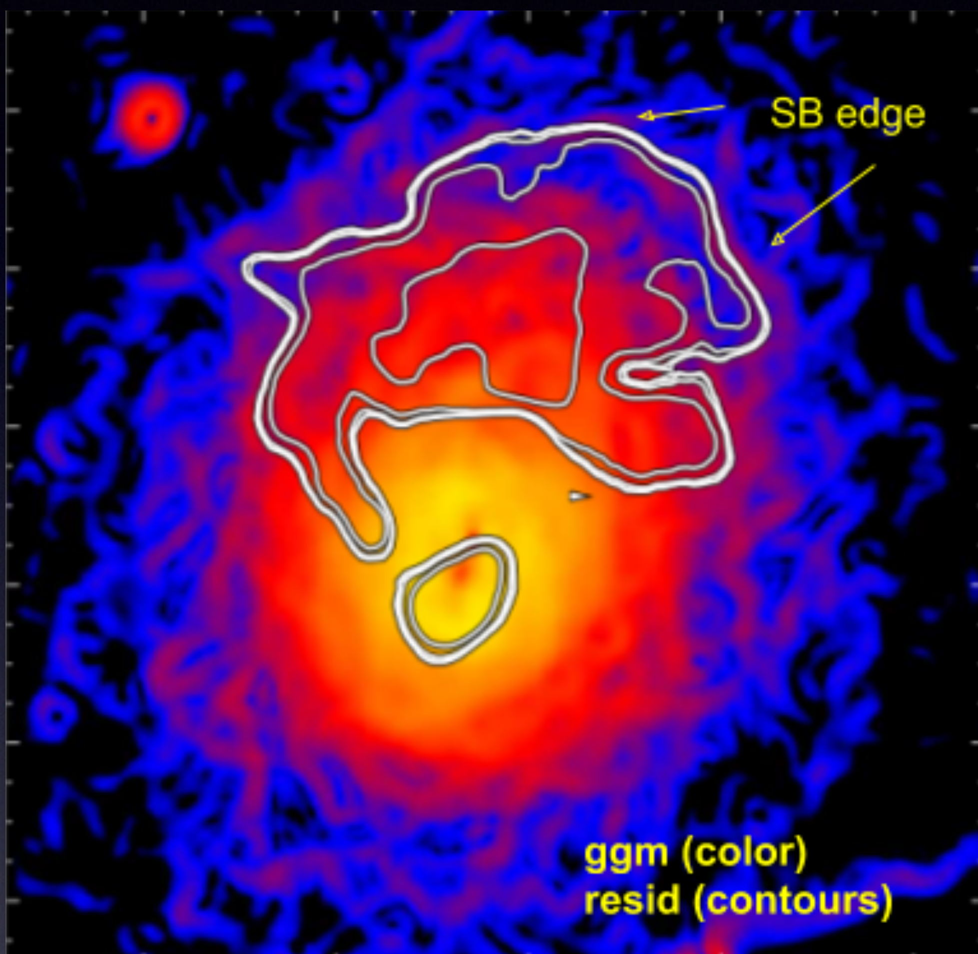




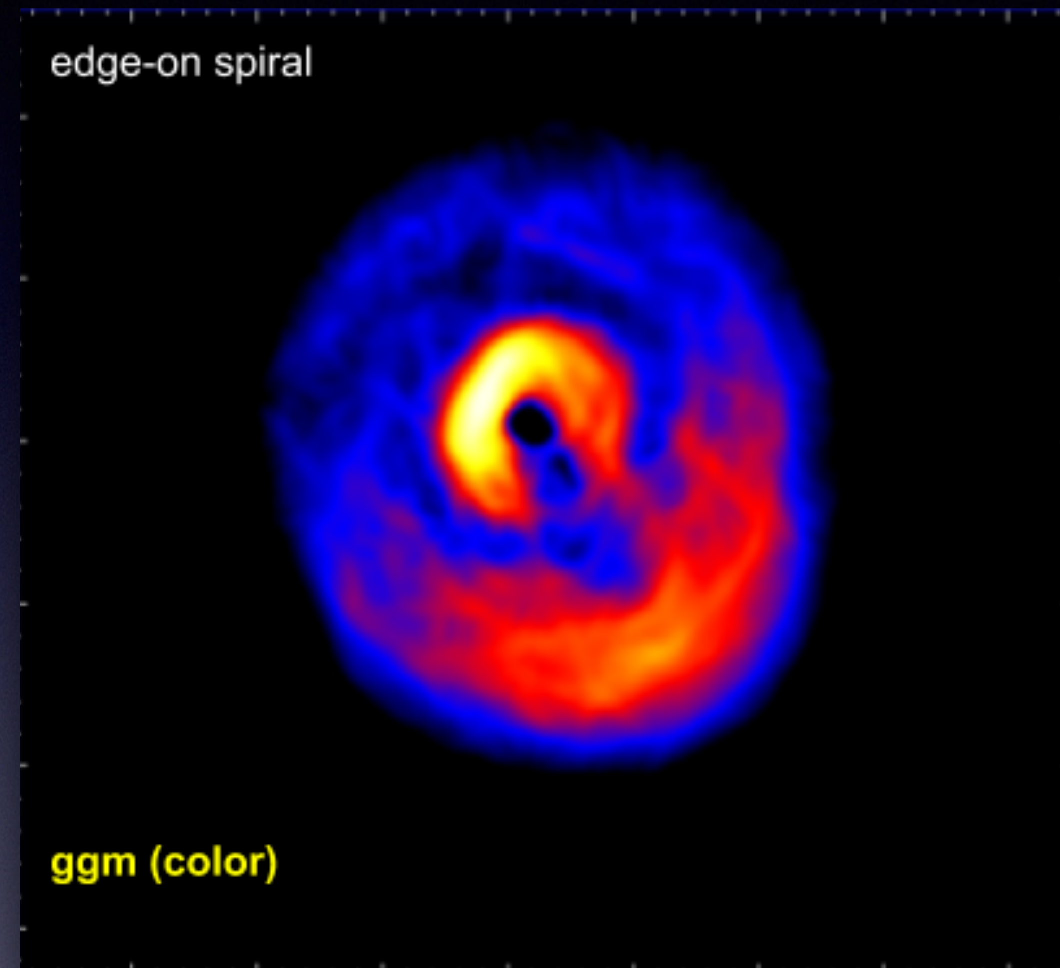
38 keV $cm^2 < K0 <$ 270 keV cm^2

1.5 Gyr $< t_{cool\ (40kpc)} <$ 11 Gyr

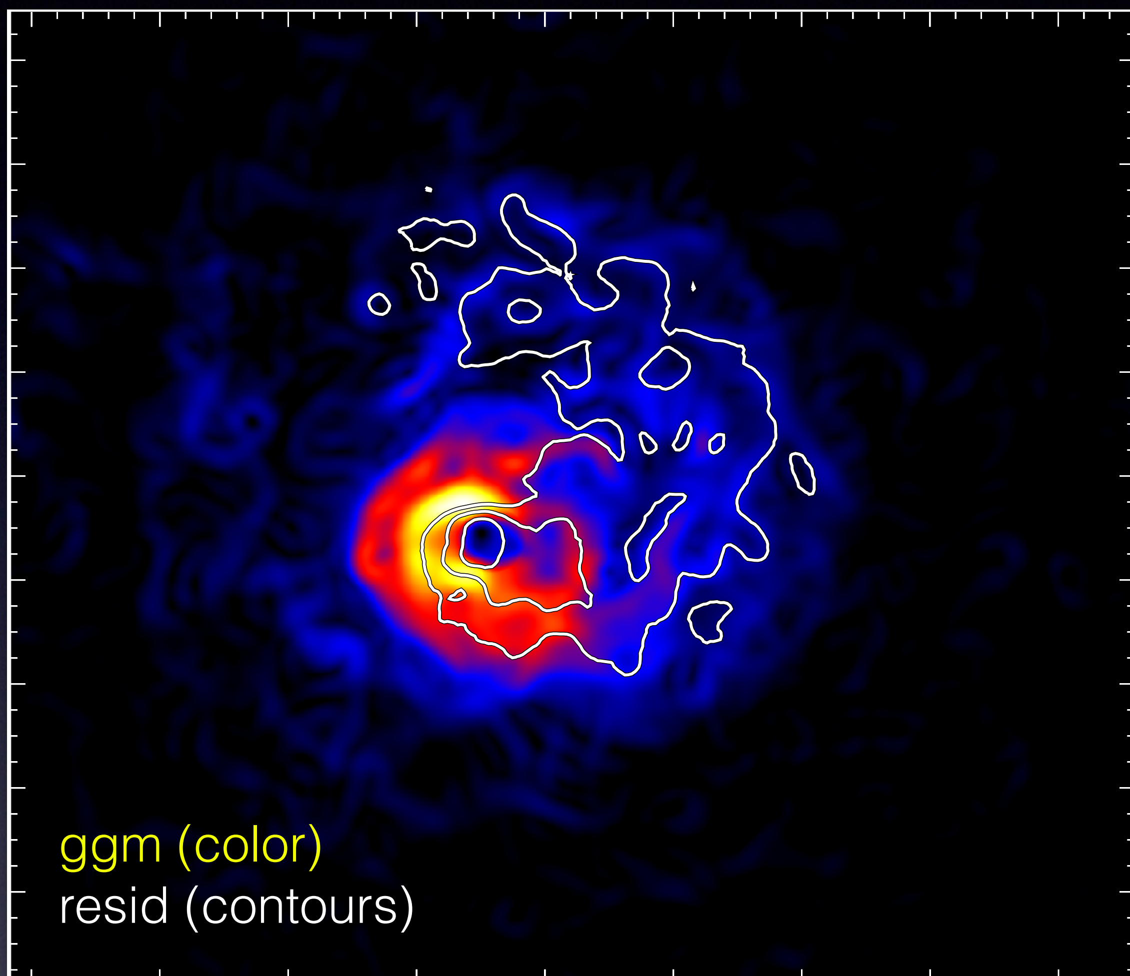
Break at $K_{(40kpc)}$ corresponding to
C_{SB} ~ 0.075 (Andrade-Santos 2008)



kT = 4.37 keV
Z_{40kpc} = 0.53 +/- 0.07
K_0 = 38 keV cm^2



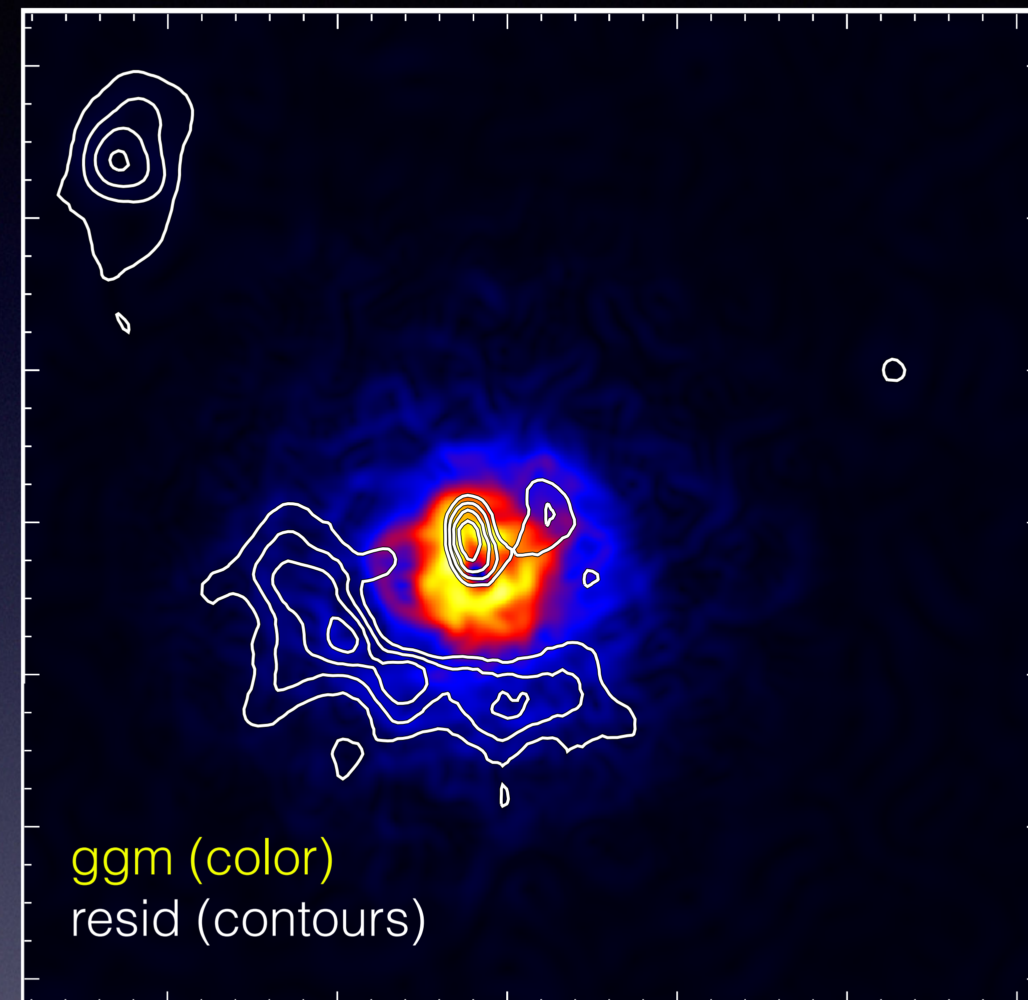
kT = 5.54 keV
Z_{40kpc} = 0.43 +/- 0.05
K_0 = 58 keV cm^2



$kT = 4.27$ keV

$Z_{40kpc} = 0.66 +/- 0.11$

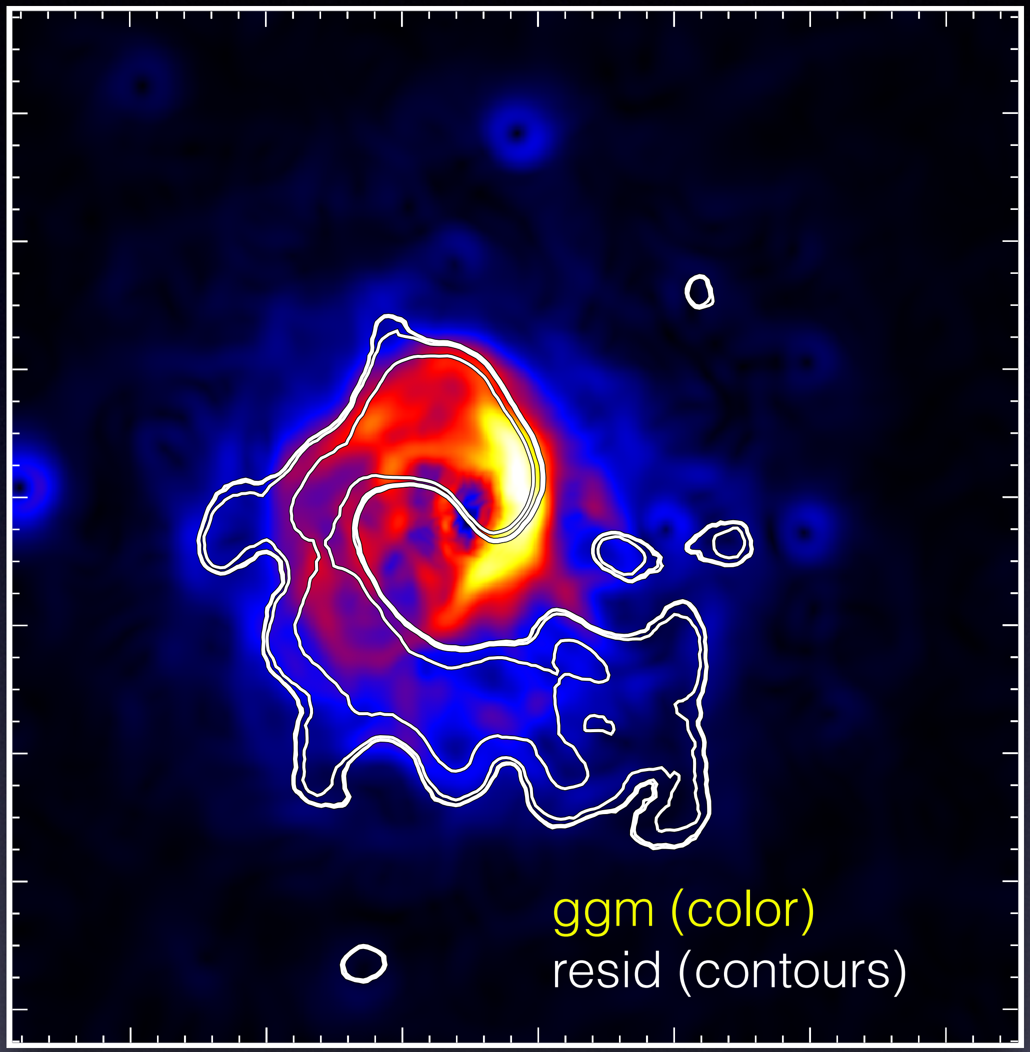
$K_0 = 65$ keV cm^2



$kT = 7.37$ keV

$Z_{40kpc} = 0.71 +/- 0.31$

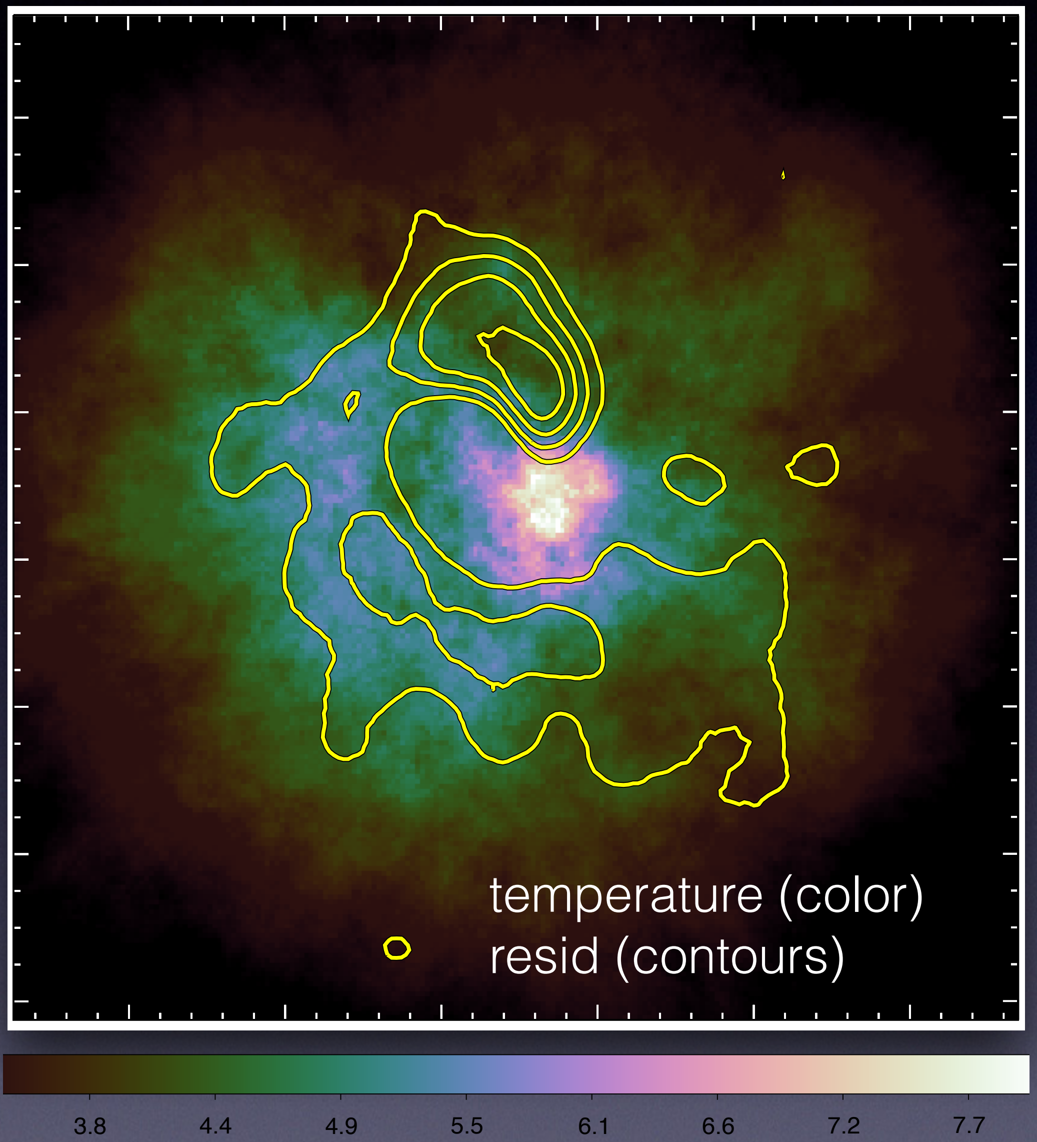
$K_0 = 212$ keV cm^2



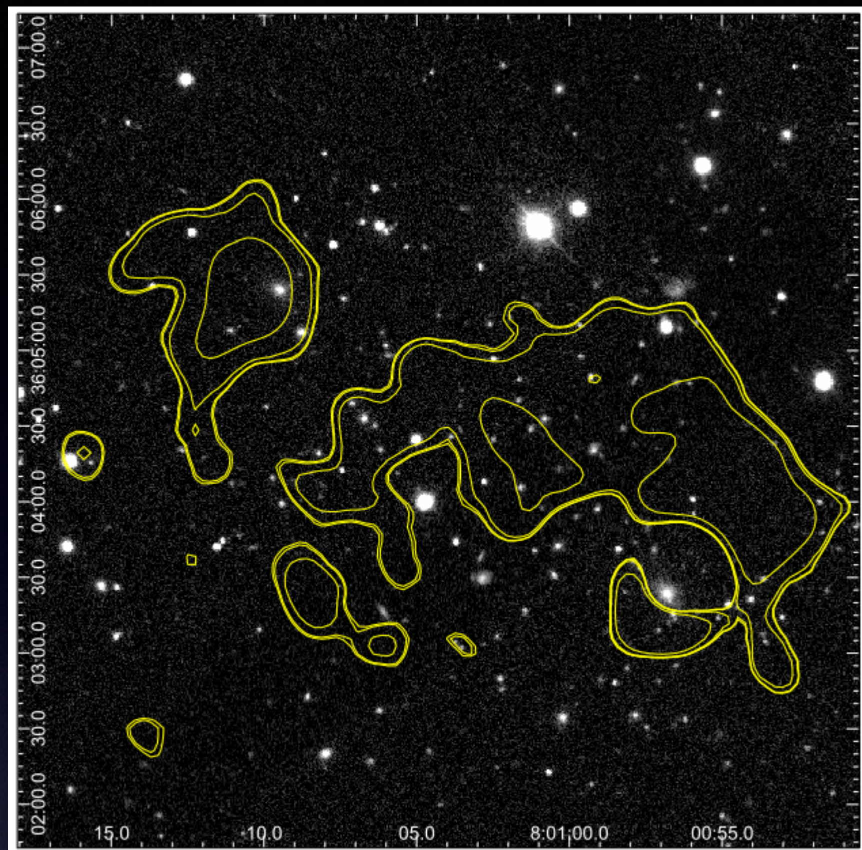
kT = 6.59 keV

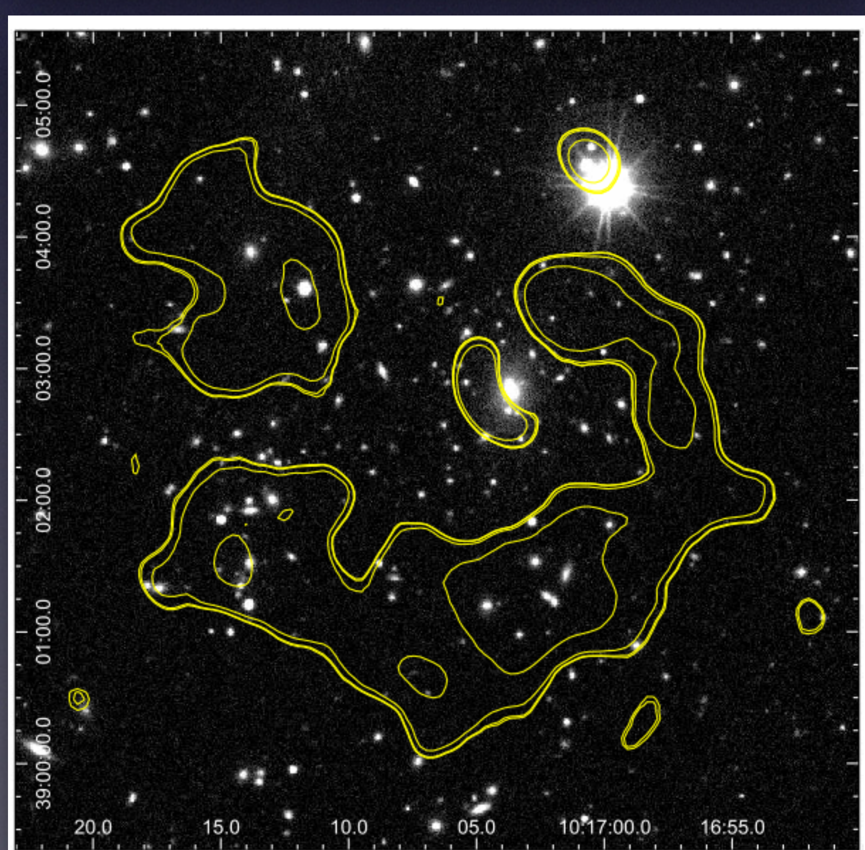
Z_{40kpc} = 0.35 +/- 0.06

K_0 = 268 keV cm^2



Temperature Map shows presence of high temperature region at apex of spiral (similar to A1763)





Conclusion

study has revealed a significant population of intermediate/high core entropy clusters which are currently undergoing off-axis cluster mergers

features within the gas consistent with pre-merger clusters hosting SCCs

results suggest off-axis mergers play a non-negligible role in populating the non-cool core cluster class