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Physics department

IKI
(Space Research Institute
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Close-up view of an ongoing merger between the NGC 4839 group and the Coma cluster

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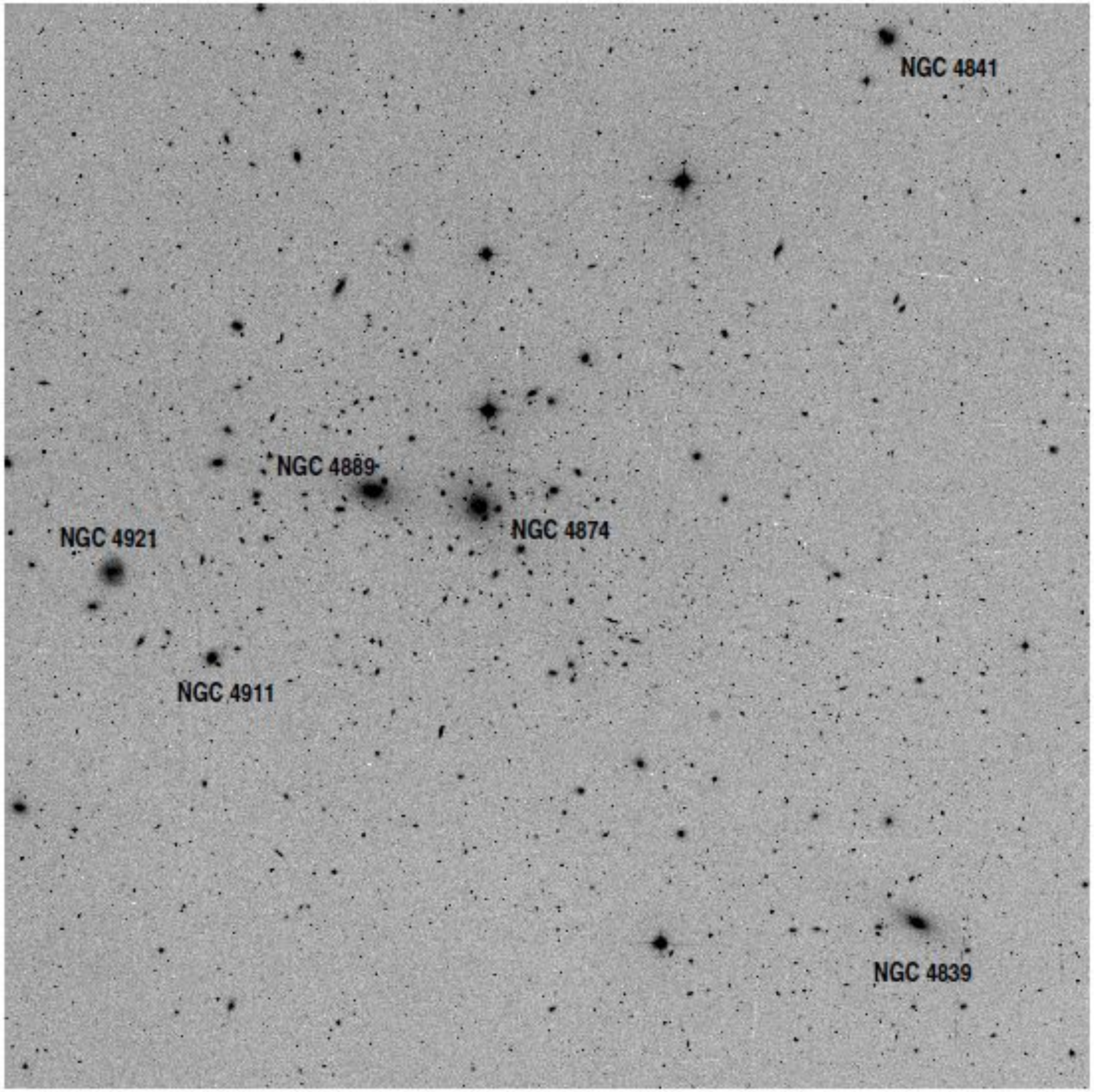
Coma (Abell 1656)



Rich cluster

redshift z = 0.0231

distance D ~ 100 Mpc

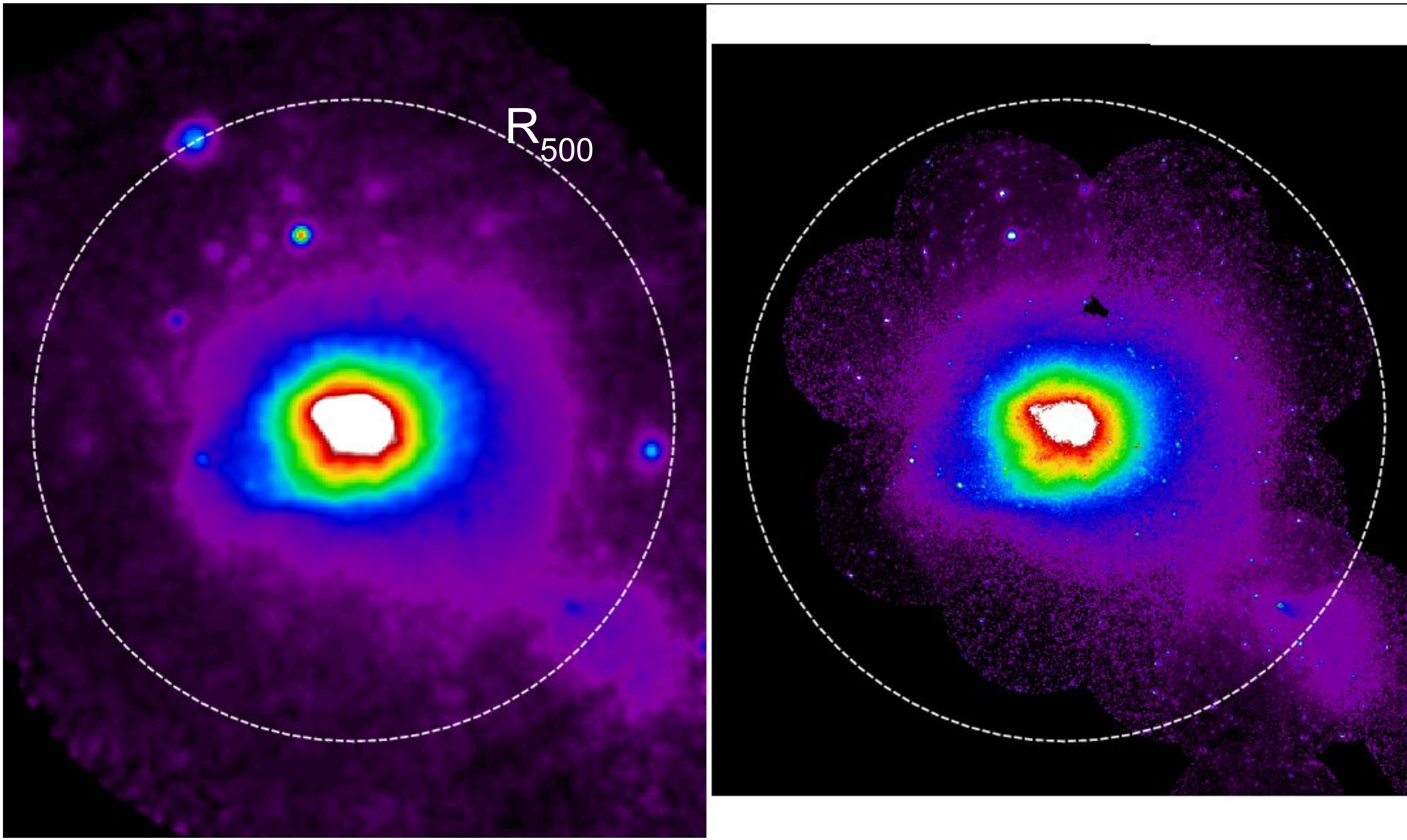
k<T> = 8 keV

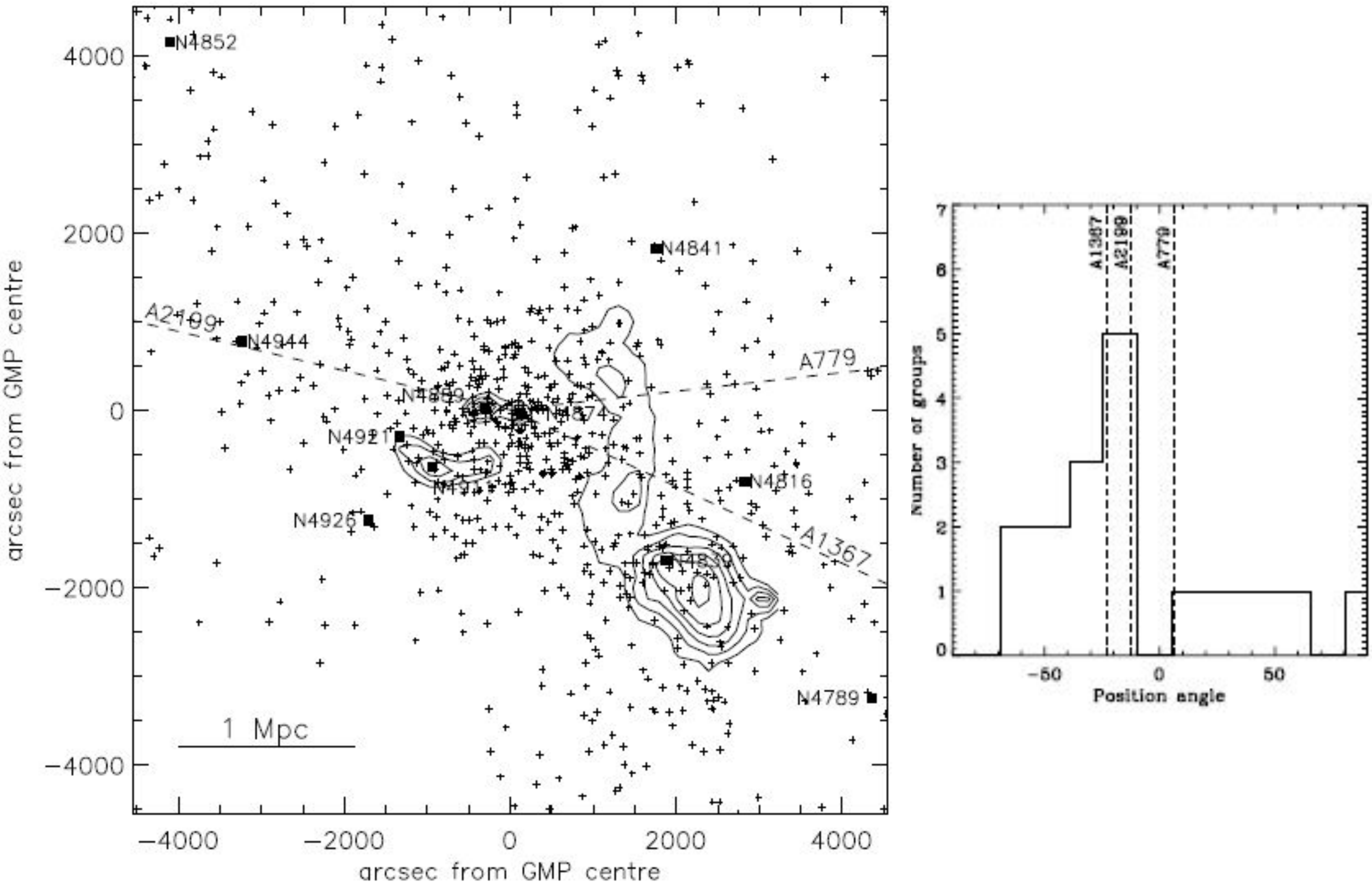
Velocity dispersion ~ 1000 km/s

mass M ~ 10^{15} $M_{\odot}$

virial radius Rvir ~ 2.7 Mpc

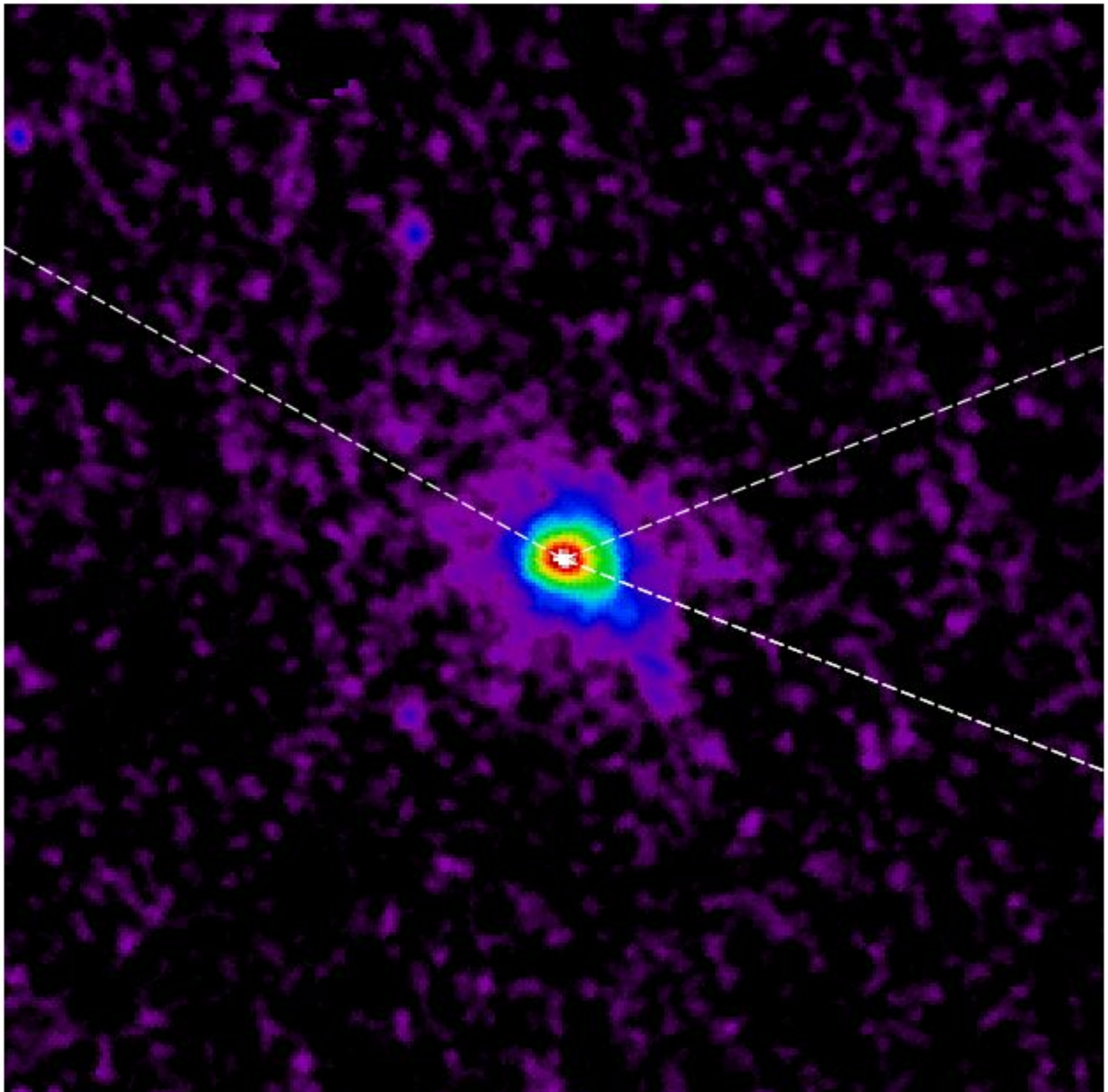
ROSAT (left image) and XMM-Newton (right image) 0.5-2.5 keV





Adami et al. 2005, X-ray contours from Neumann et. al 2001

y - map (Planck Collaboration et al. 2013)



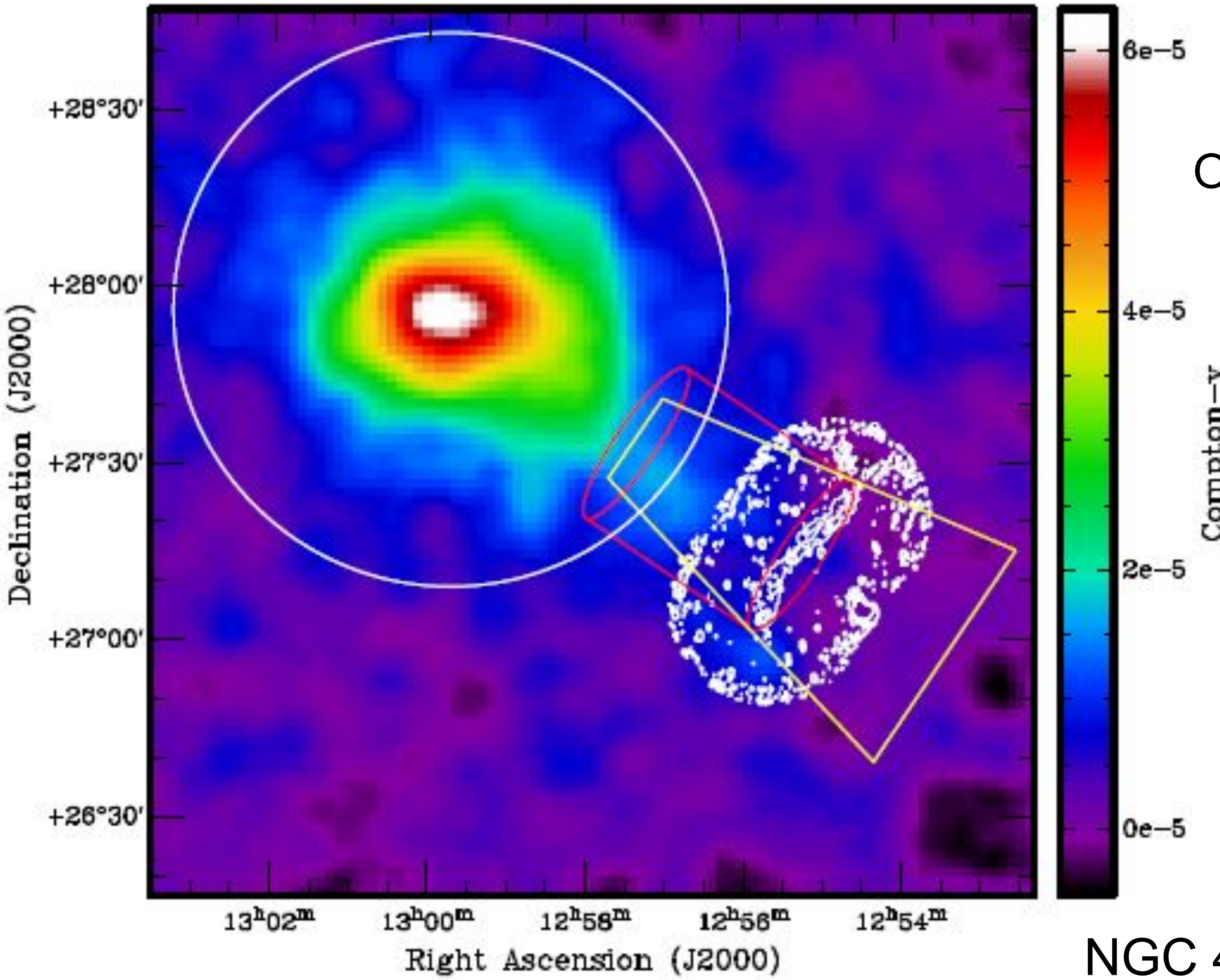
$y \propto \int P_e(r)dl$

Abell 2199

Abell 779

to Abell 1367

y - map + radio relic



Erler et al. 2015

Akamatsu et al. 2013, Ogrean & Bruggen 2013:

Shock across the radio relic

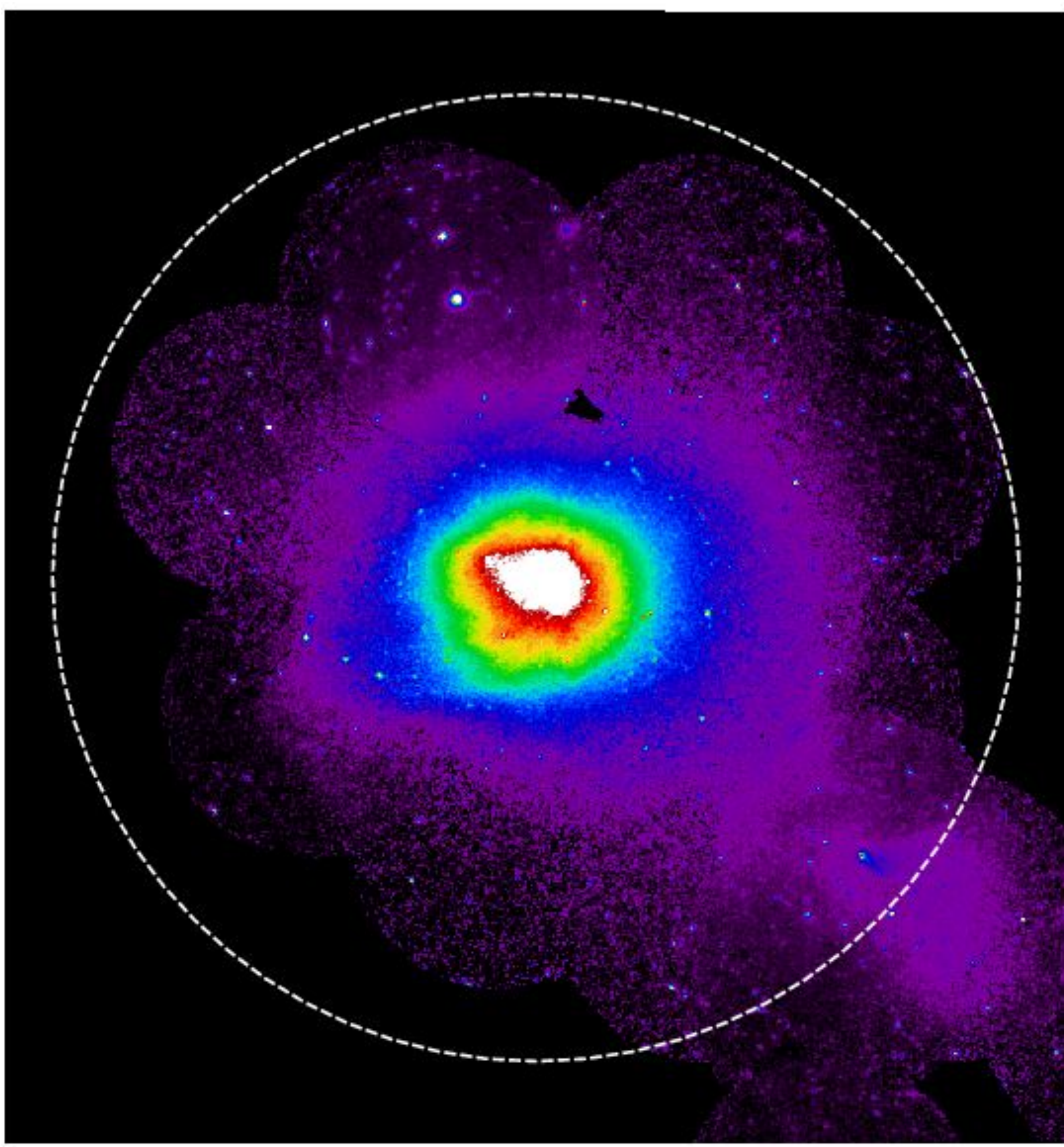
↓

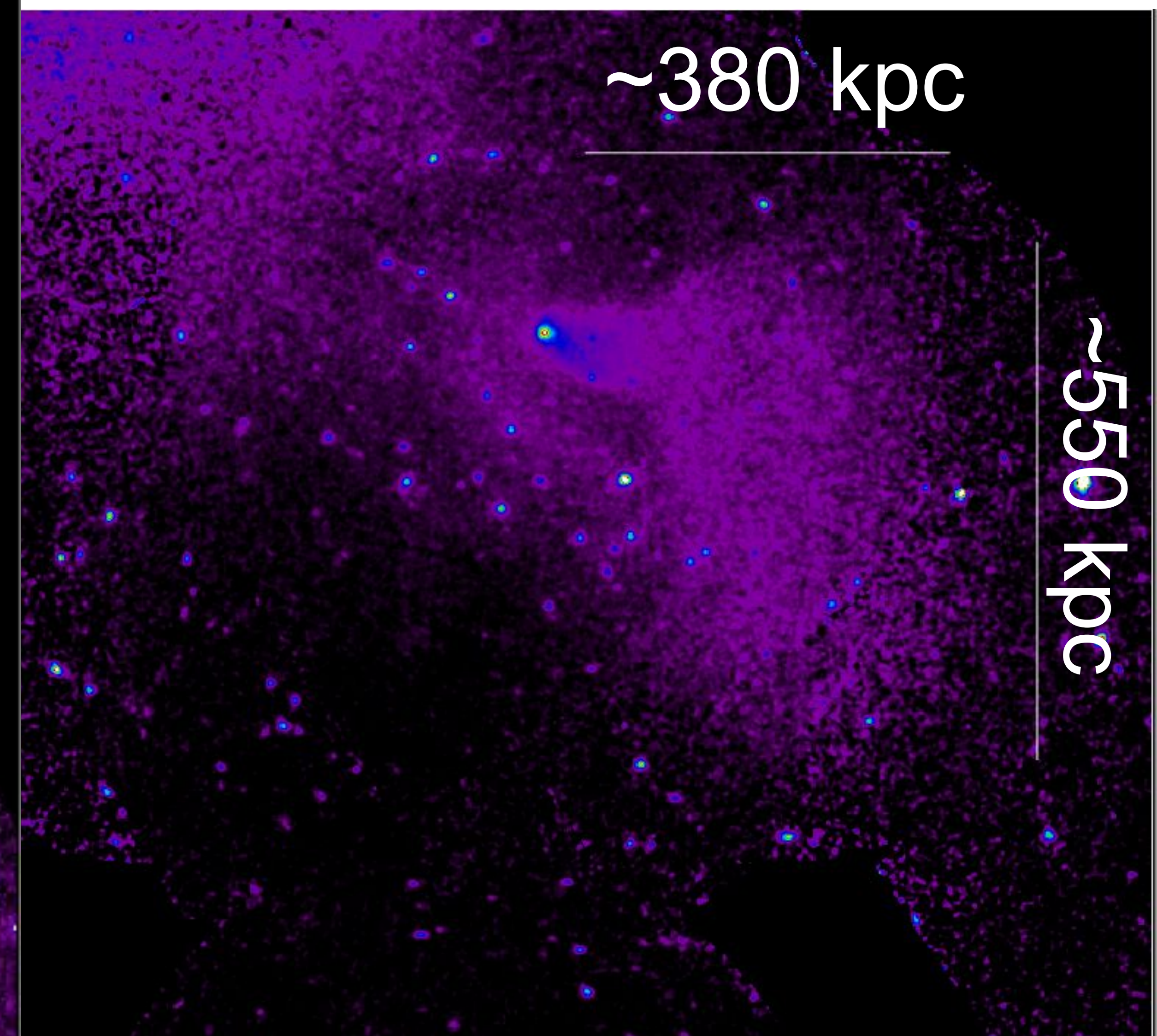
This shock may be generated by the merger between the Coma cluster and the NGC 4839 group

↓

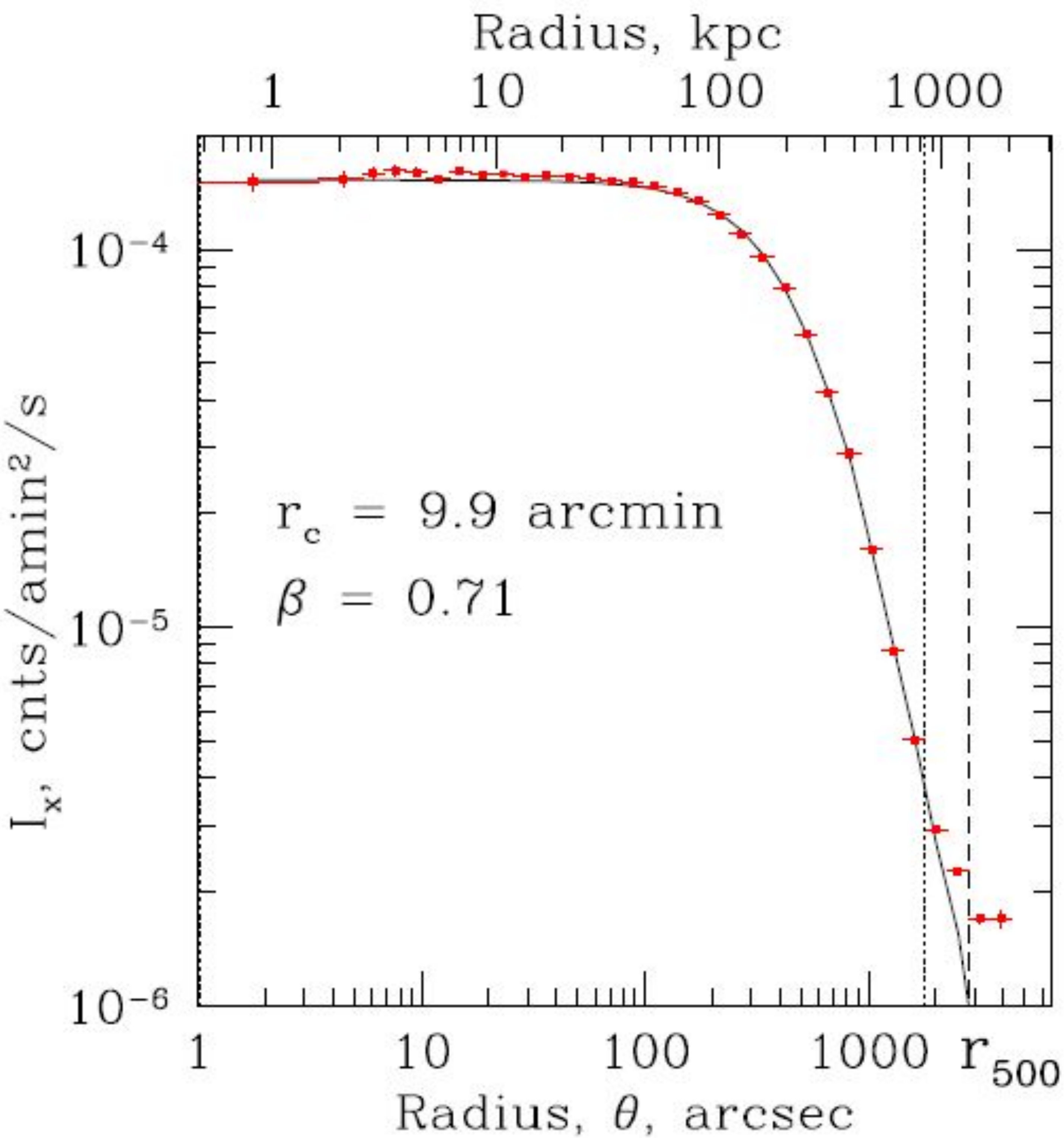
NGC 4839 group is falling into Coma along a NE-SW-oriented cosmic filament

XMM - mosaic



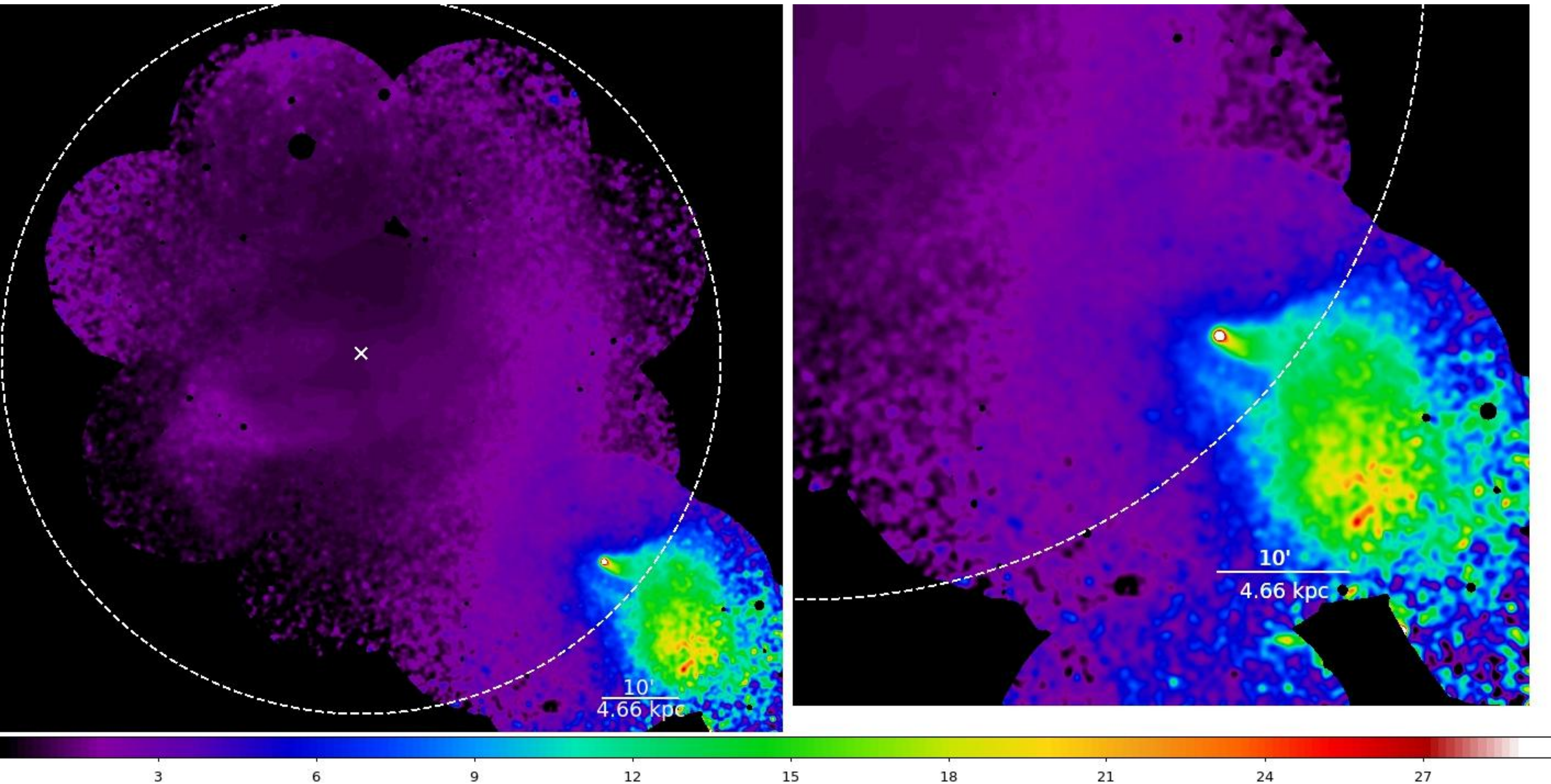


X-ray surface brightness profile. β-model.

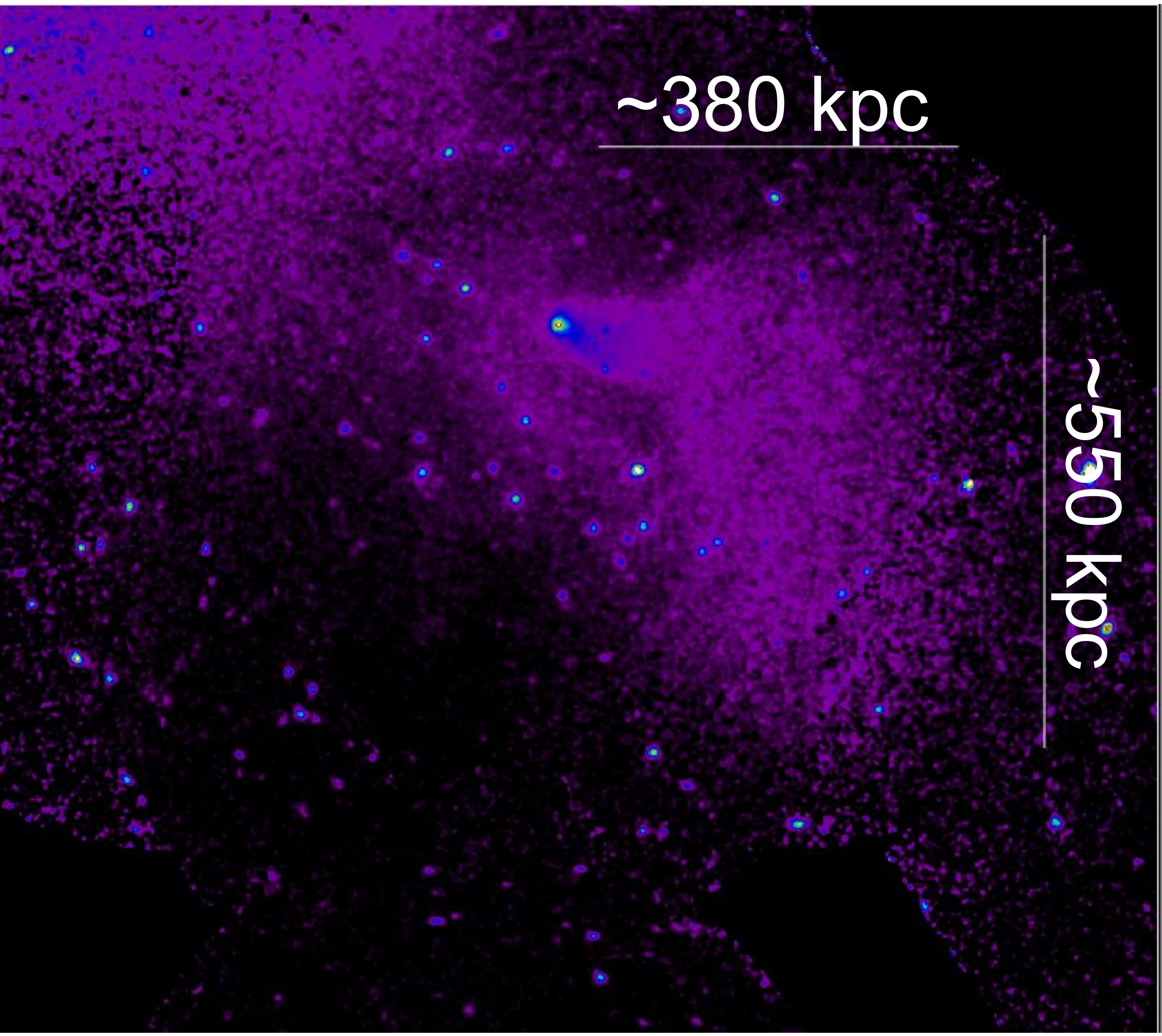


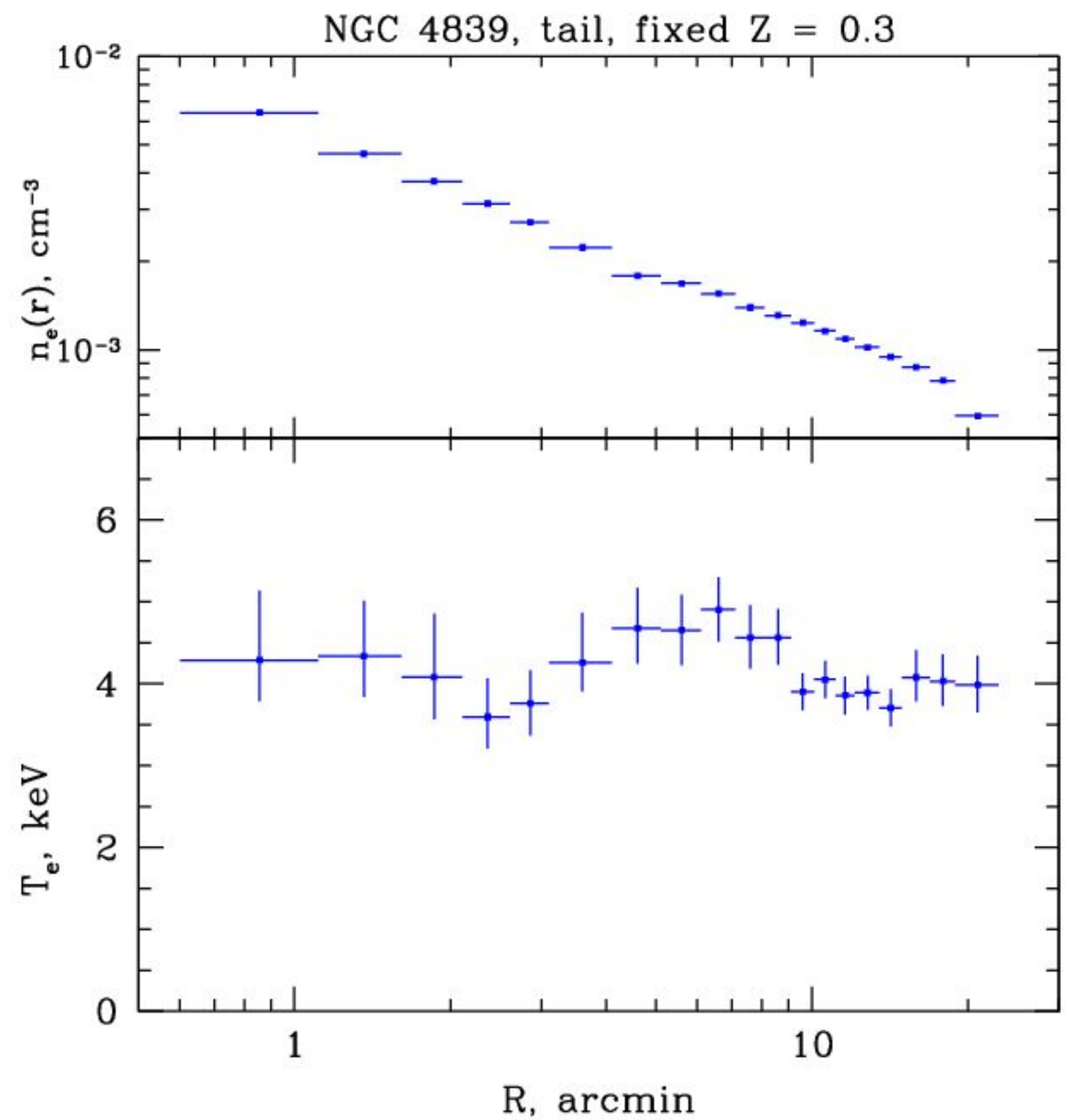
$$I(R) = I_o \left(1 - \frac{R^2}{r_c^2}\right)^{1/2-3\beta}$$

Surface brightness divided by the best-fit β-model

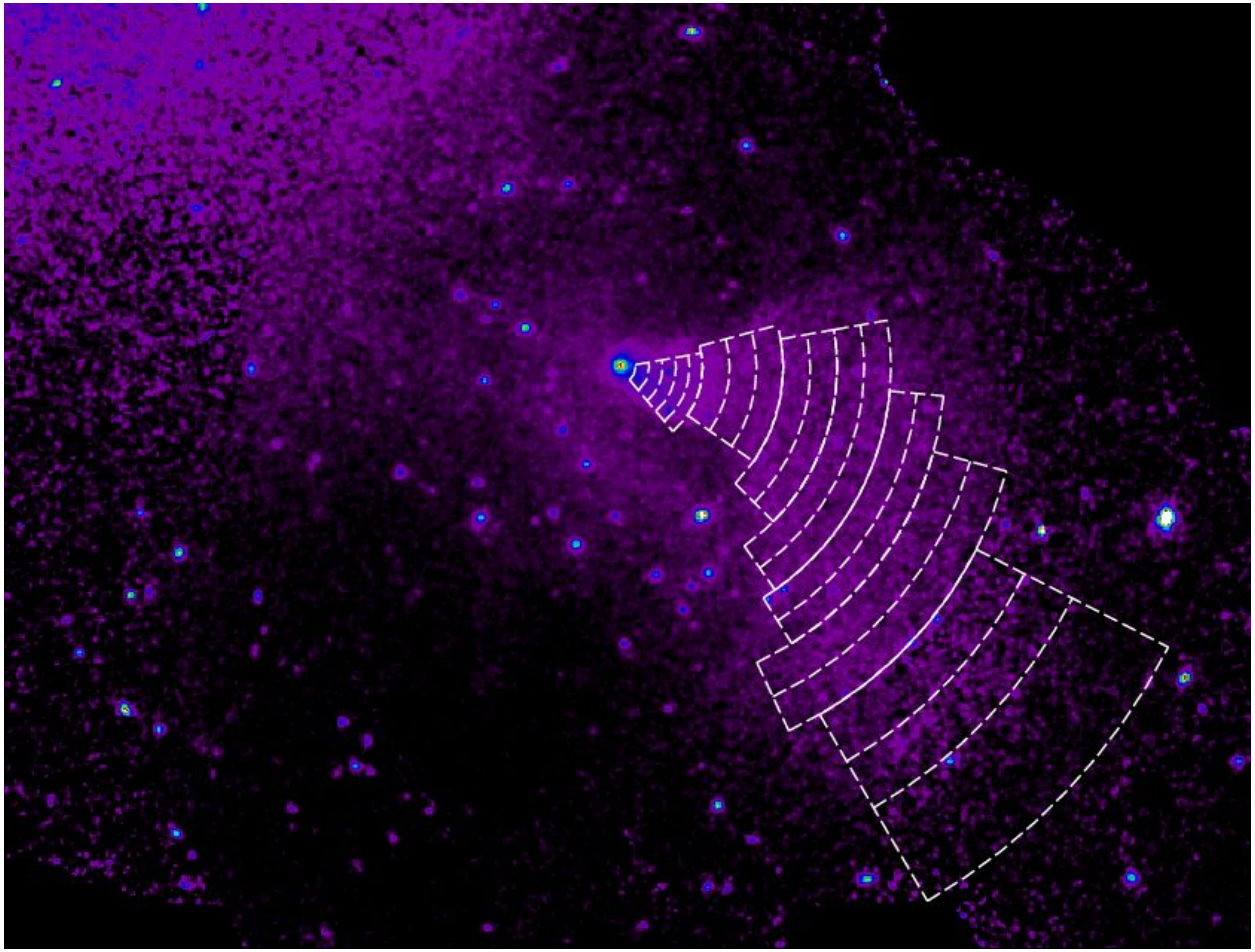


NGC 4839 tail





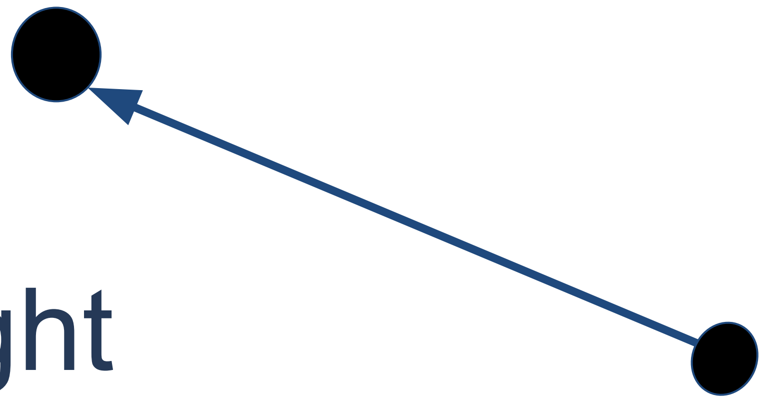
NGC 4839 tail



Gas mass of the tail $M \approx 1.1 \times 10^{12}\ M_\odot$, what agrees well with an estimate based on *Suzaku* data $M \approx (9.6 \pm 0.3) \times 10^{11}\ M_\odot$ (Sasaki et al. 2016)

Merging scenario: radial infall

$kT = 5\ keV \Rightarrow$ speed of sound $c_s = 1140\ km/s$.

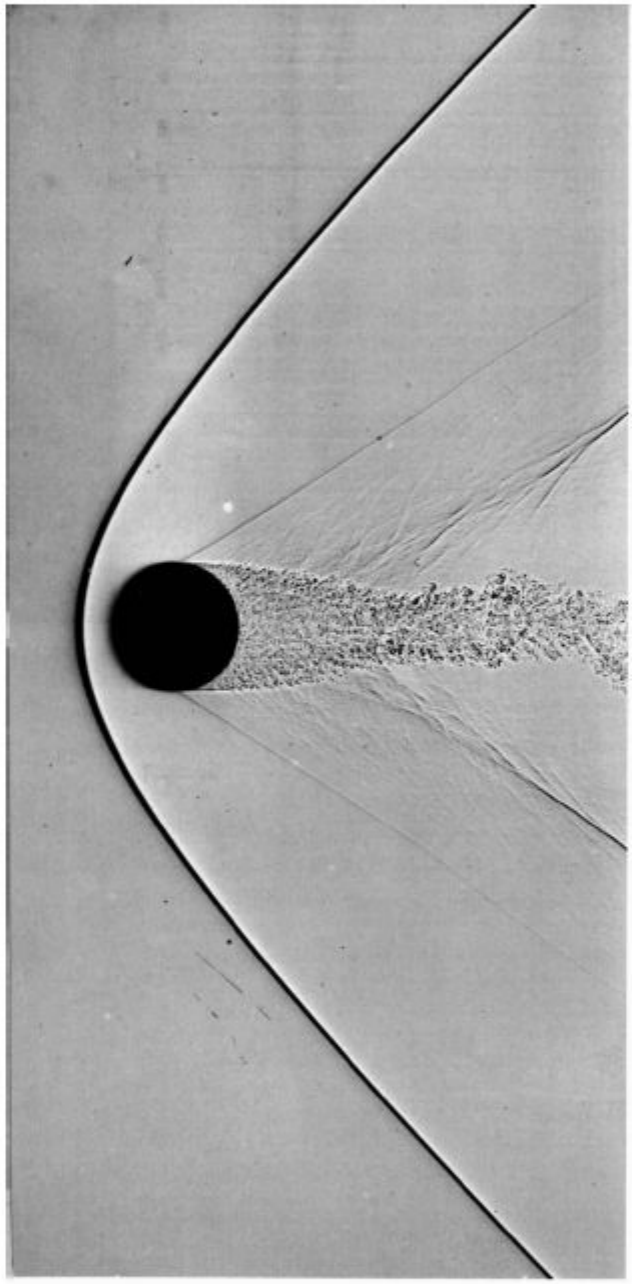


Colless & Dunn 1996:

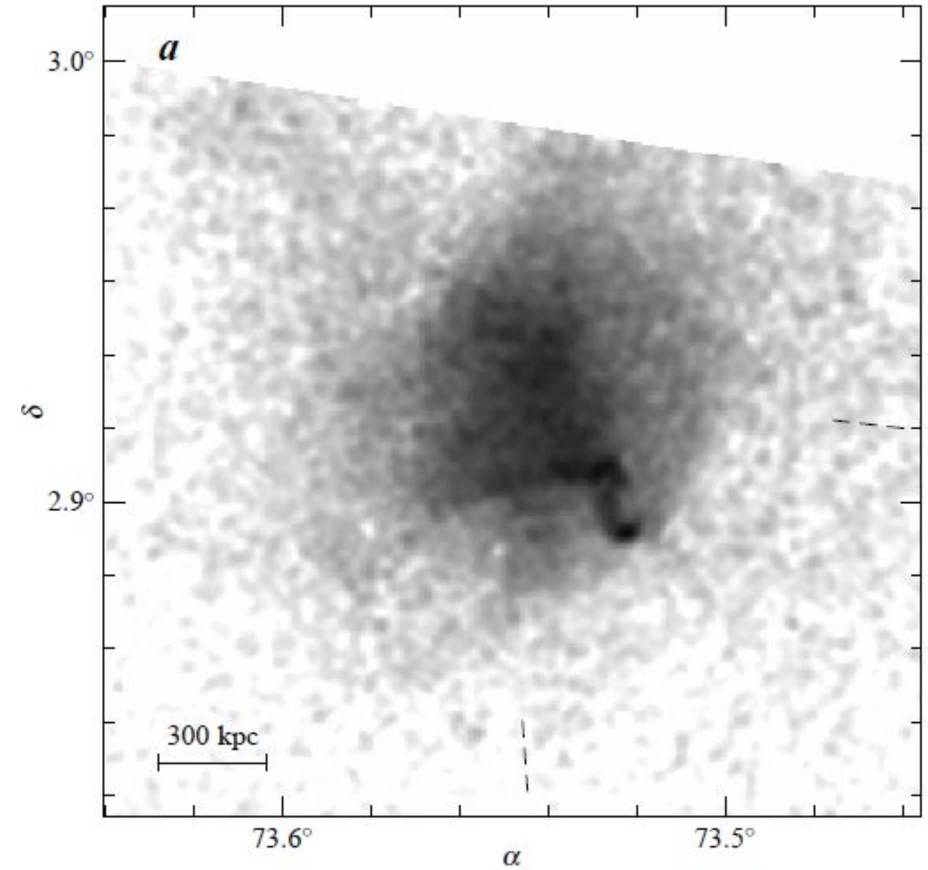
$|V_{total}| = 1700\ km/s$, 74^o to line of sight

Expectation: Mach number $\boldsymbol{M > 1}$

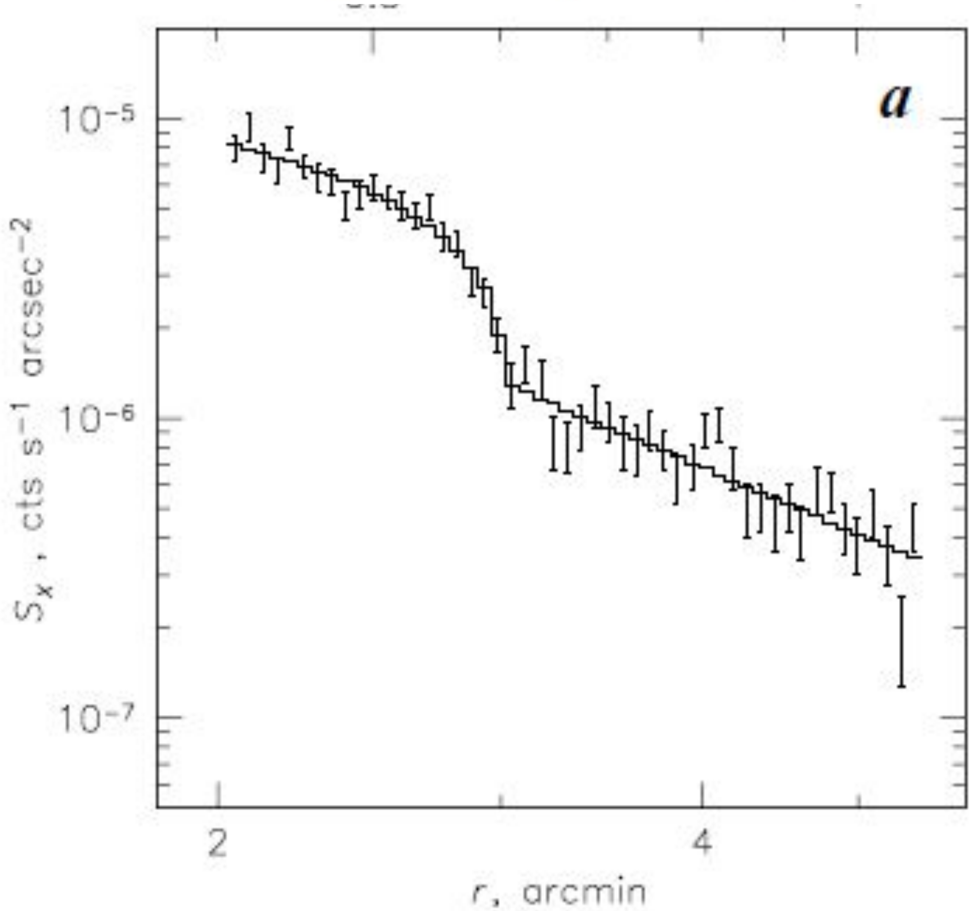
How does a shock wave look like?

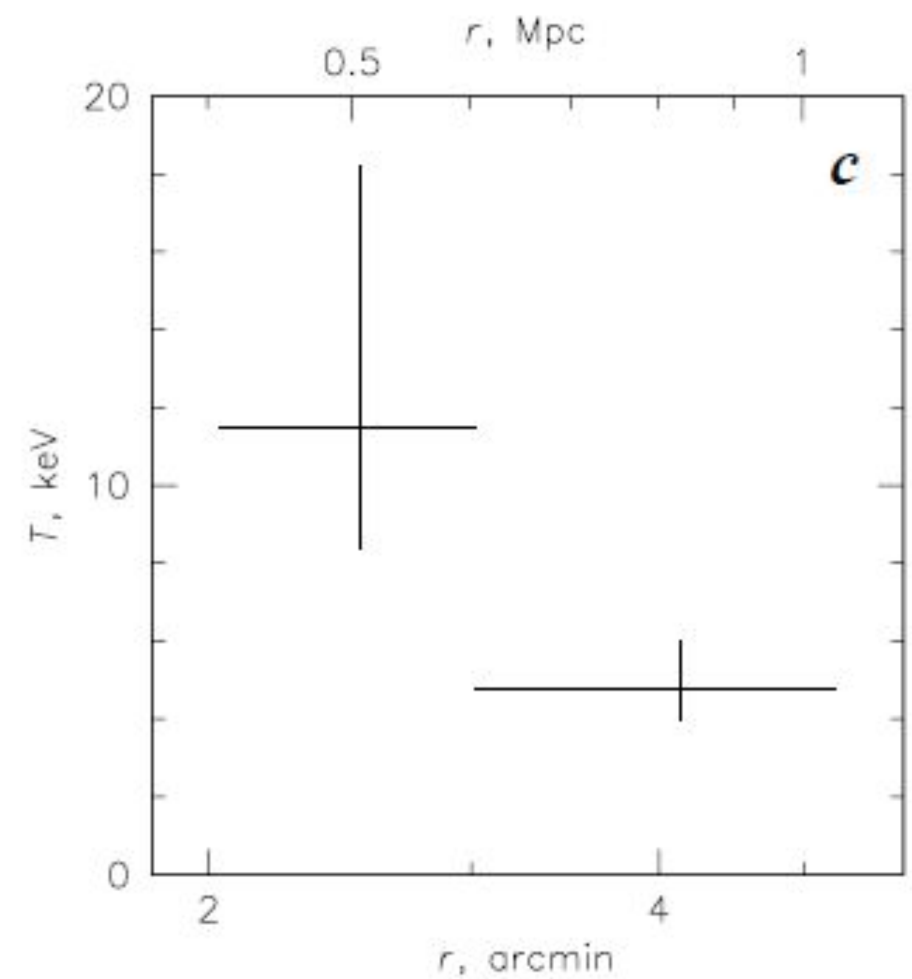


M = 1.53
Van Dyke,
An Album of
Fluid Motion

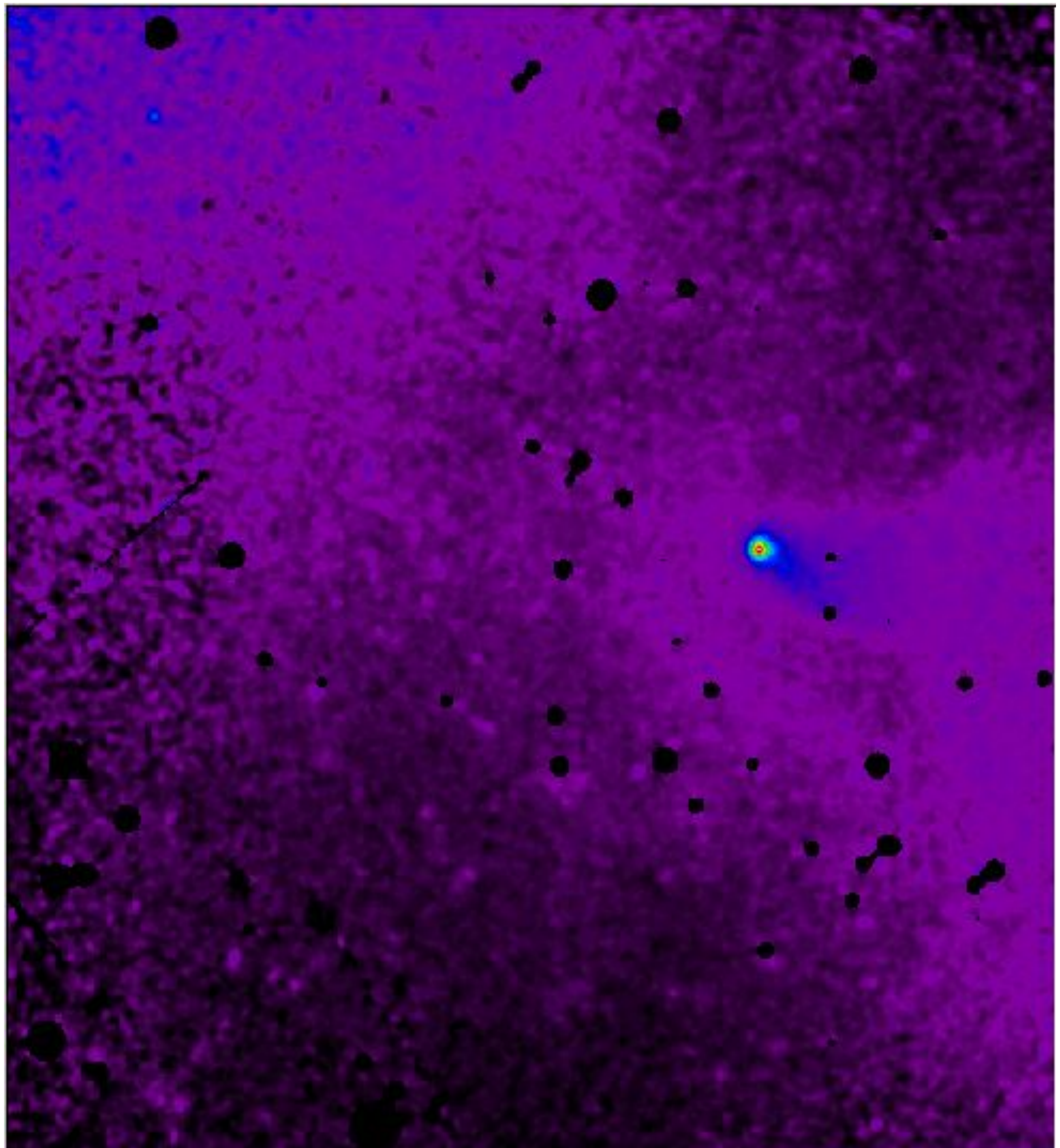


A520 cluster,
M ≈ 2,
Markevitch et al. 2005

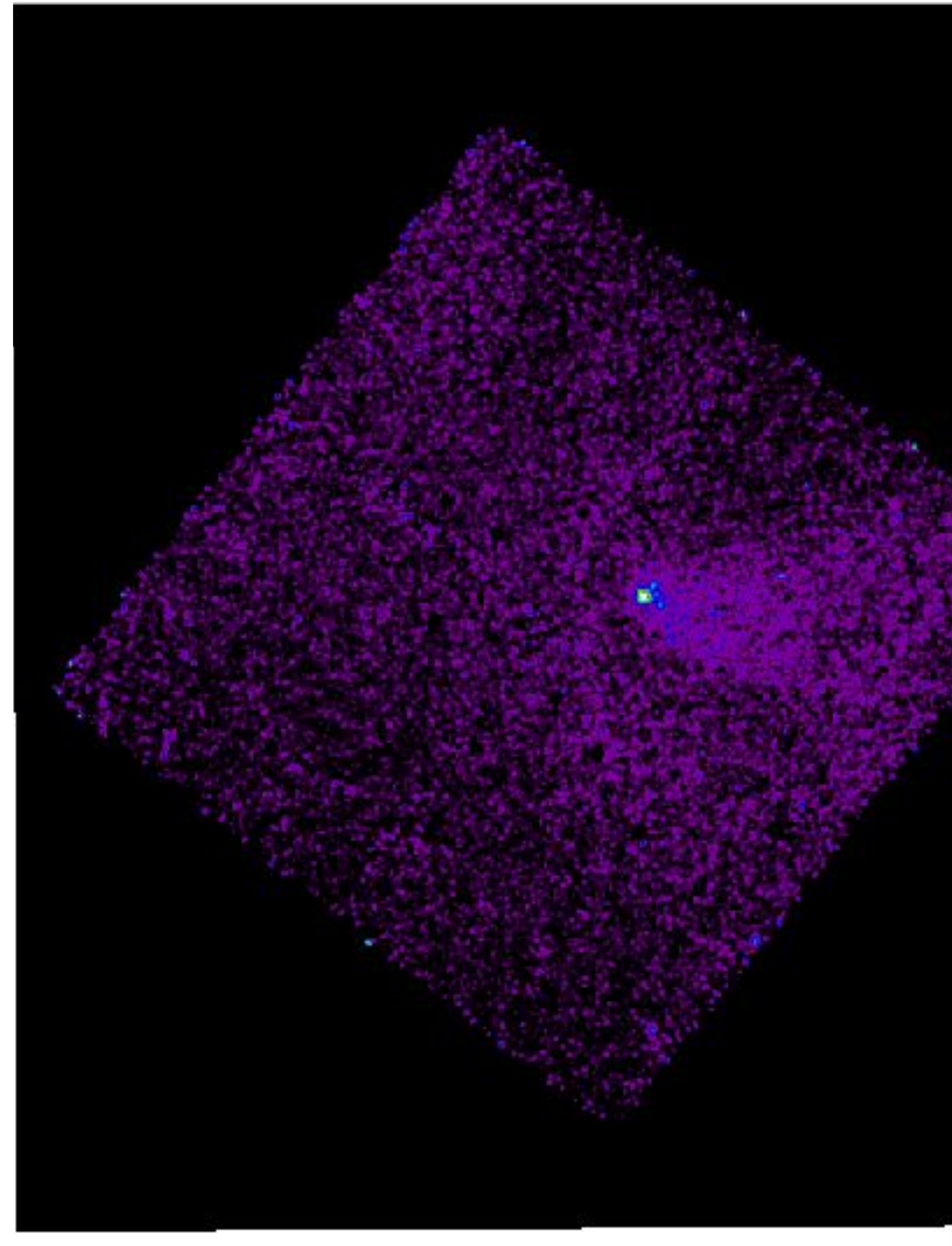




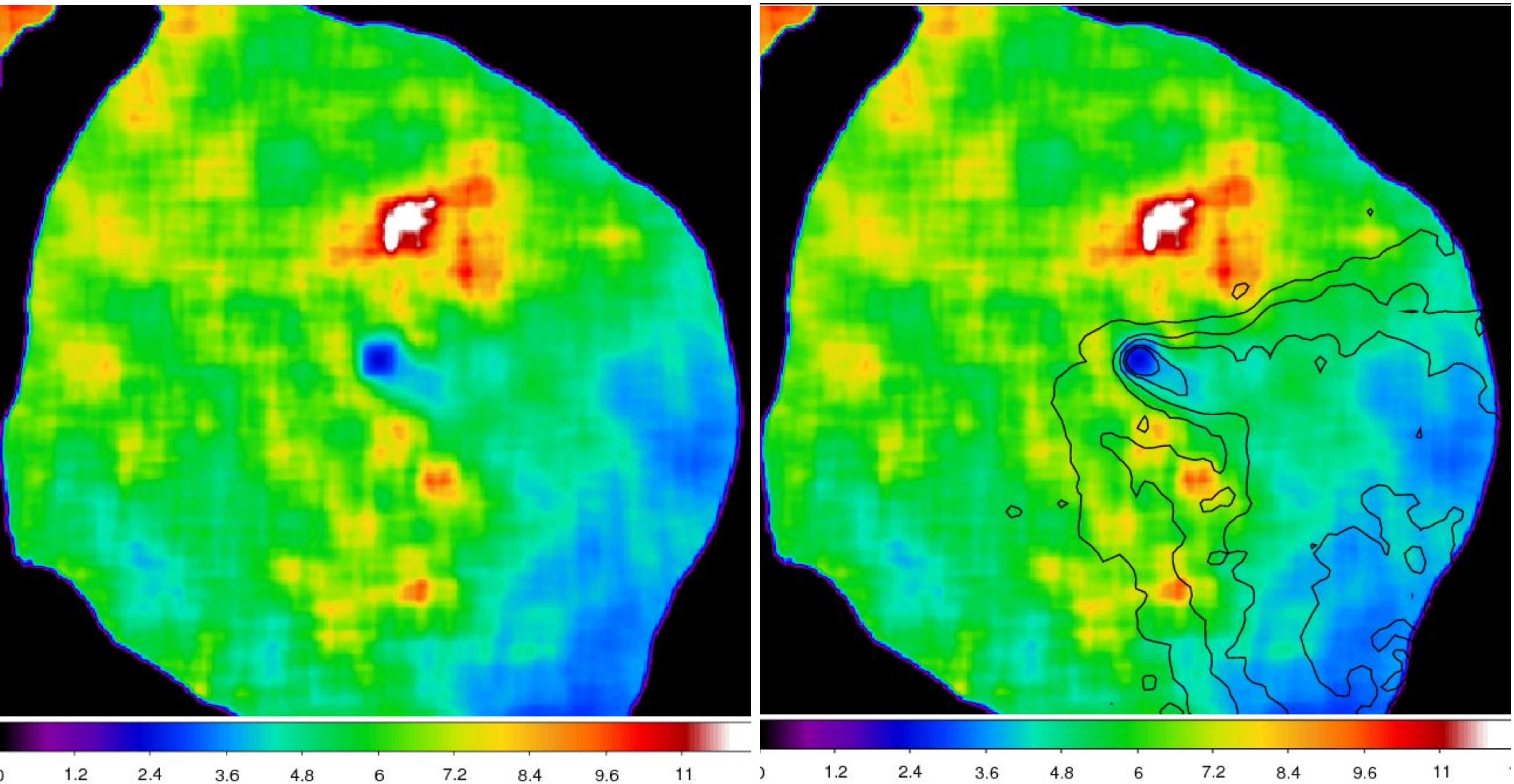
XMM



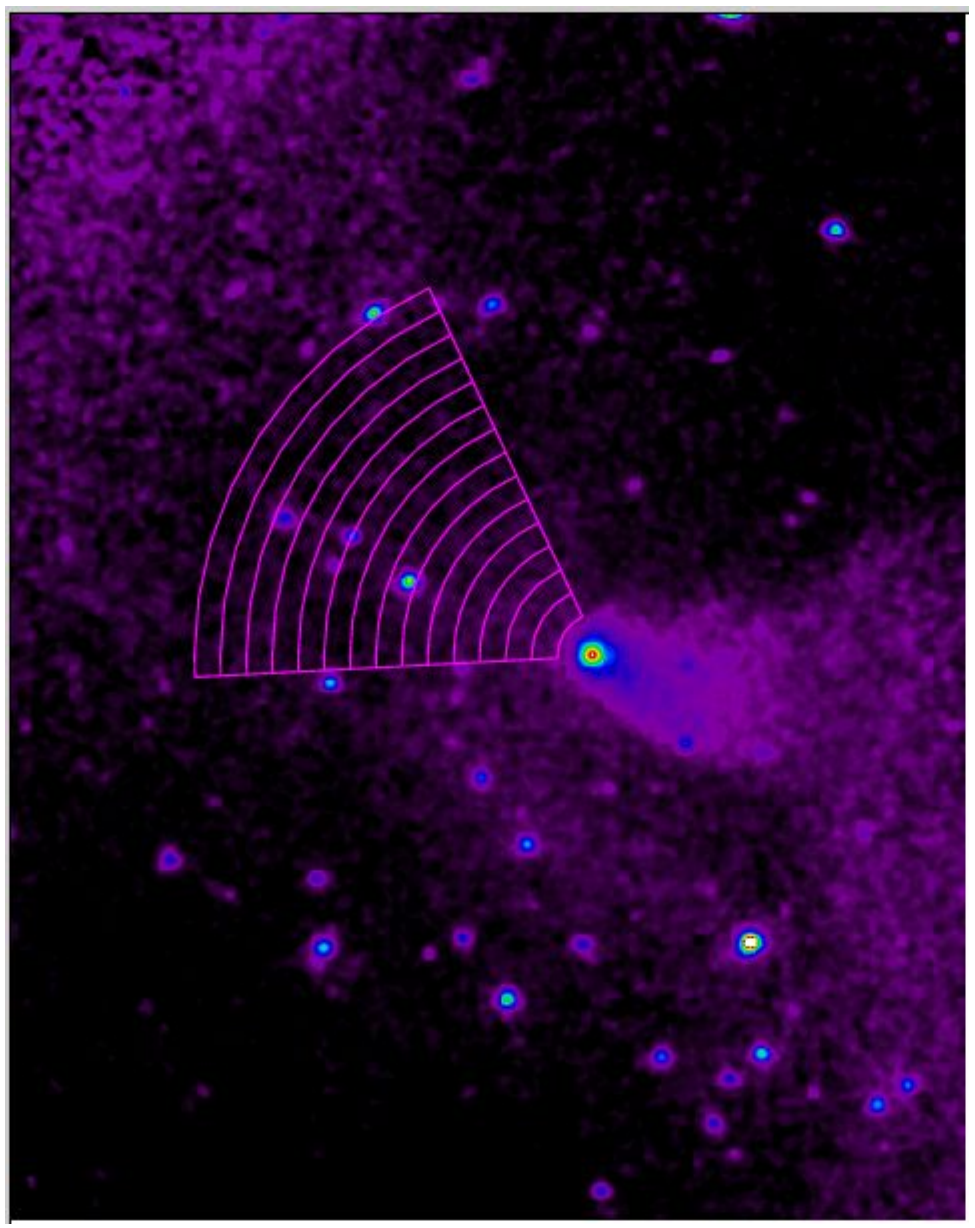
Chandra

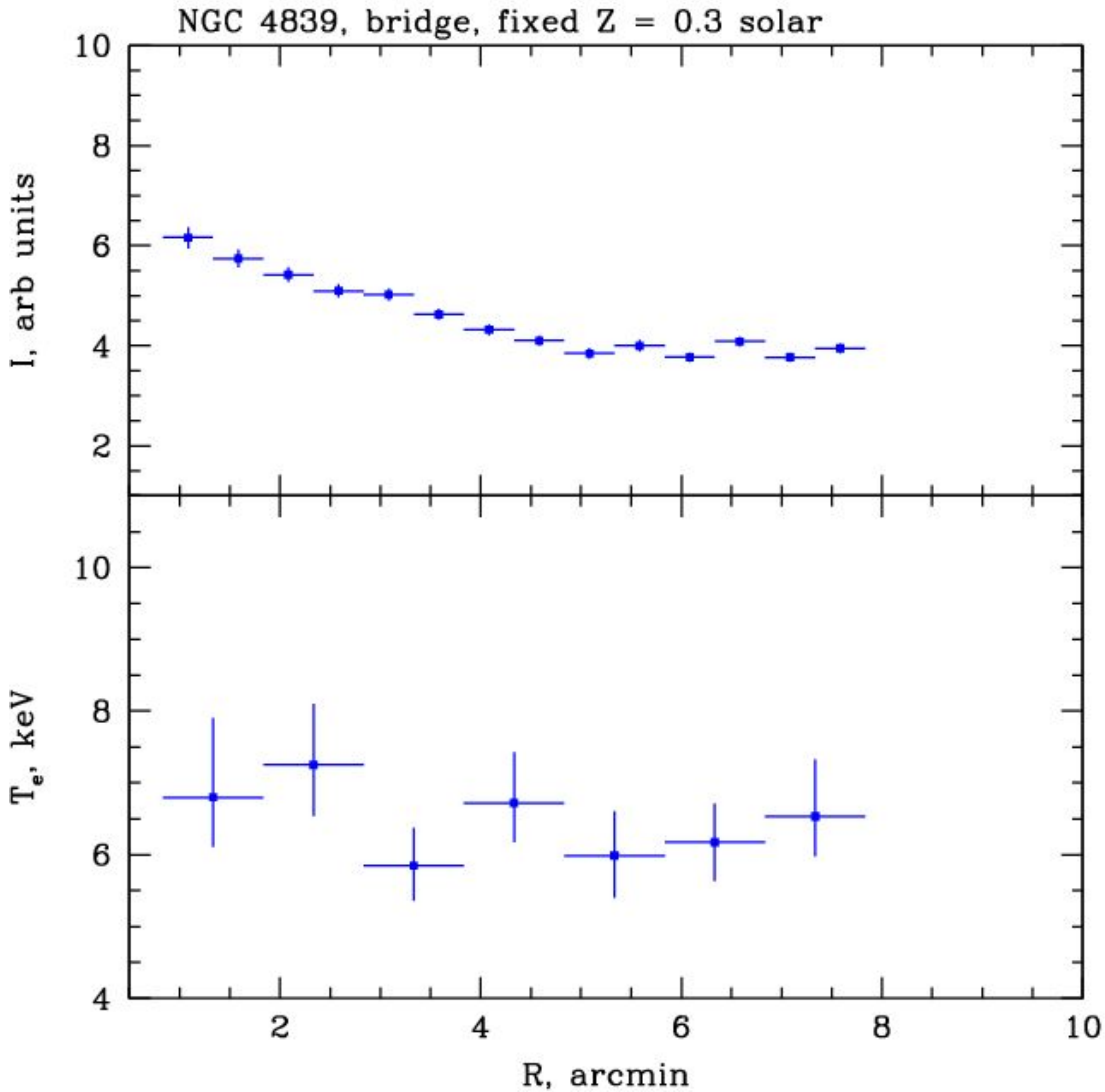


+ Comparison with the temperature map



X-ray surface brightness and temperature profiles





No evidence for a bow shock. Why?

- the line of sight passes through the Mach cone:

$$\mathrm{ArcSin}[c_s / V_{total}] > \mathrm{ArcCos}[V_r / V_{total}]$$

$$\Rightarrow M \leq 1.06$$

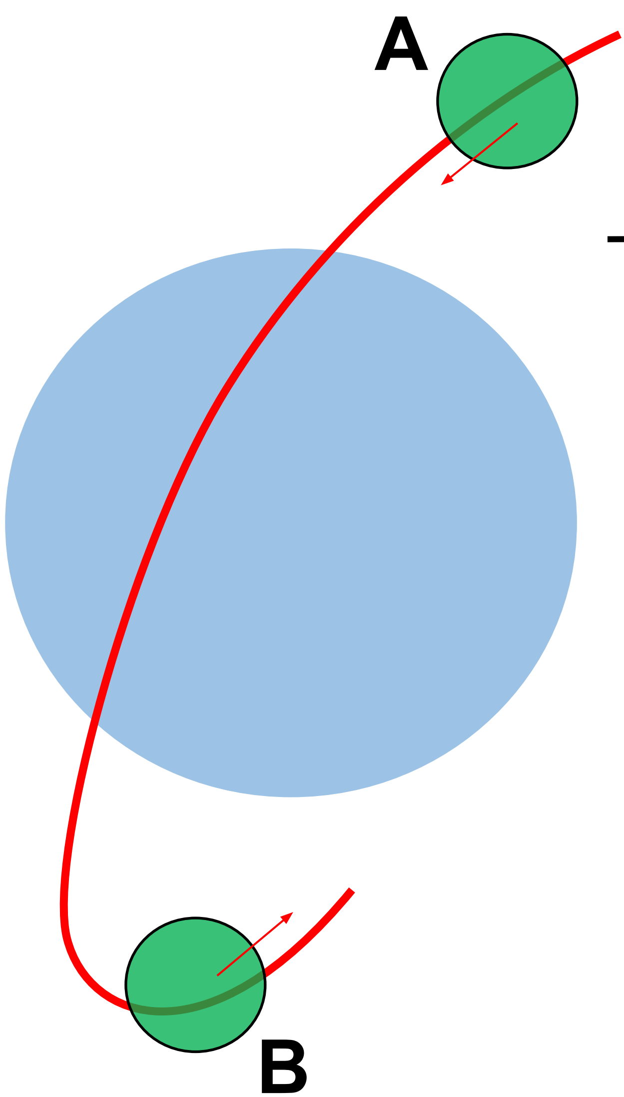
- subsonic velocity of the NGC 4839 group

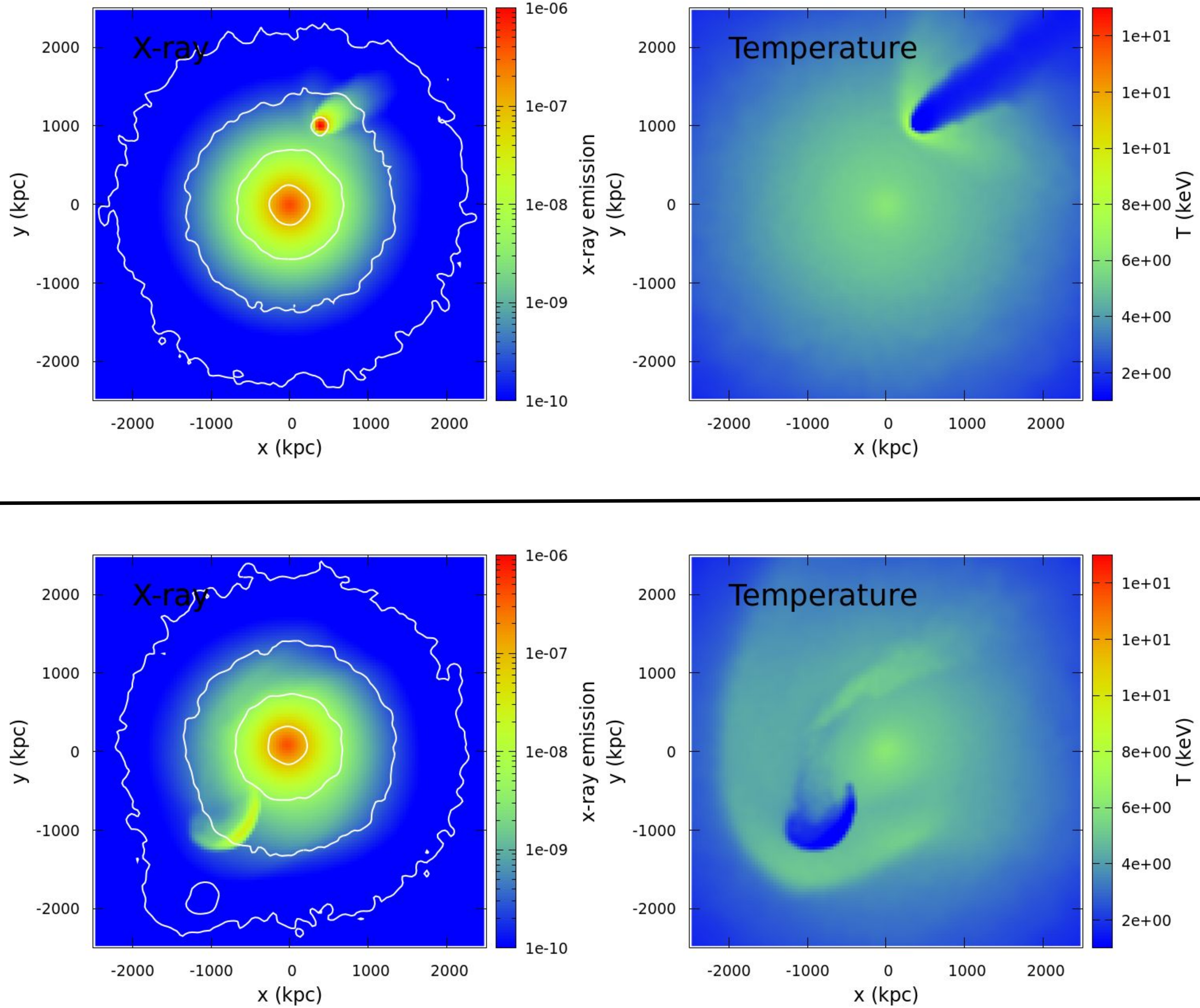
- weak shock → not enough data to detect it

Plausible scenario

$M_1 = 1.2 \times 10^{15}\ M_\odot$

$M_2 = \mathbf{0.2 \times 10^{14}}\ M_\odot$



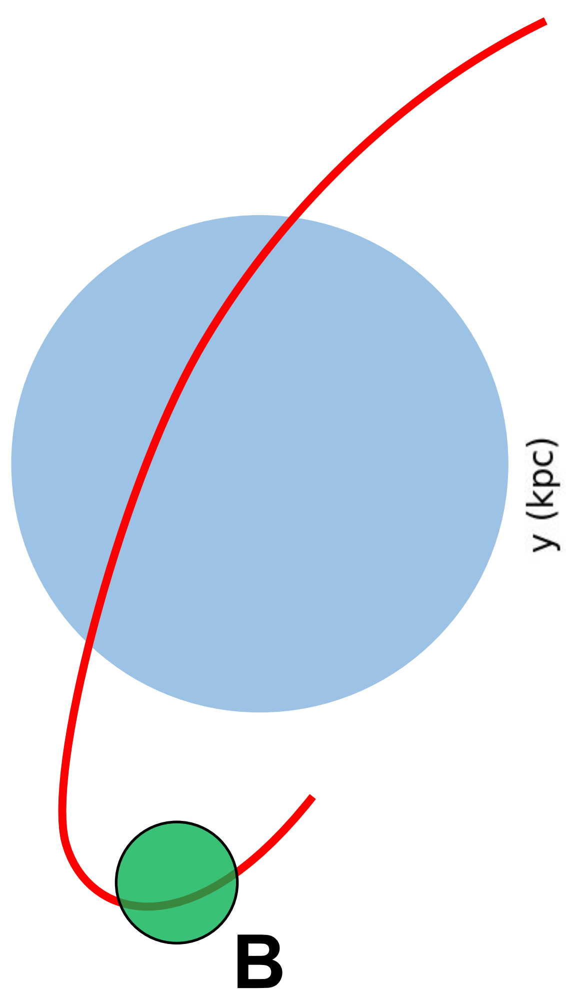


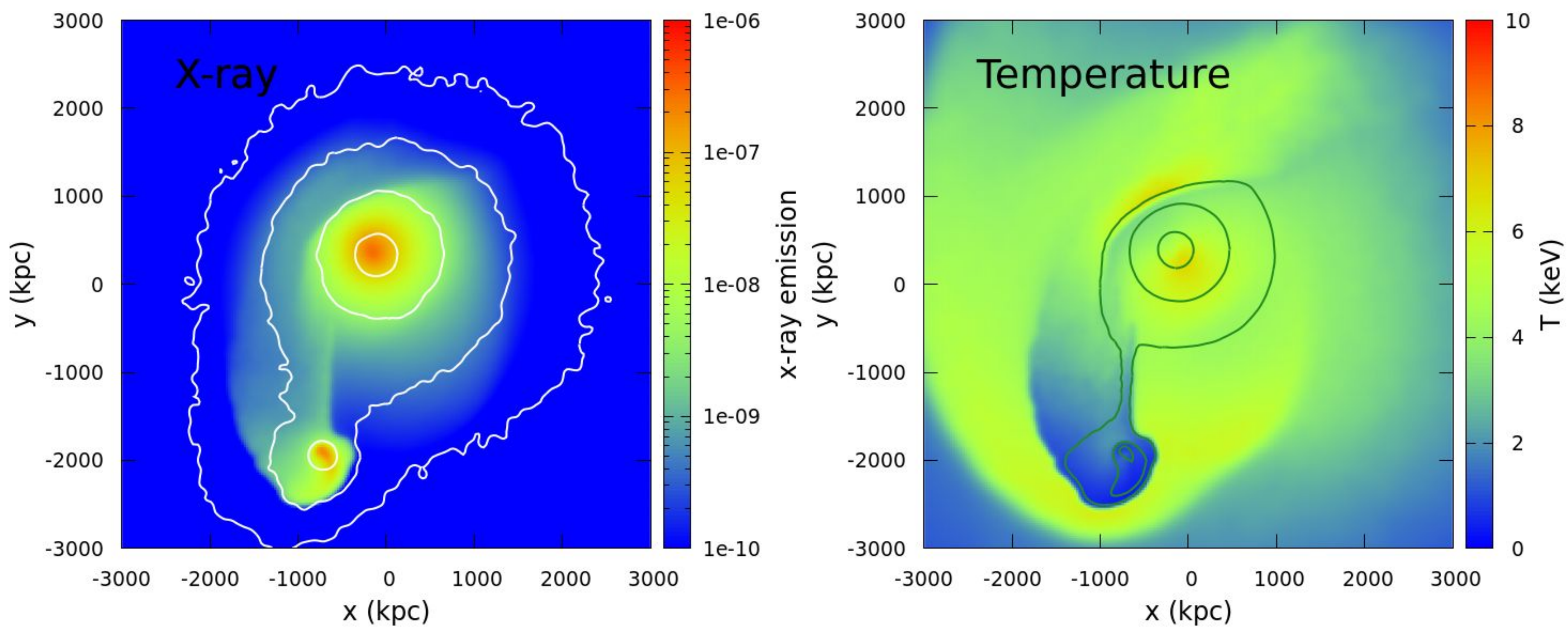
Plausible scenario - **qualitative** agreement with observations

$M_1 = 1.2 \times 10^{15}\ M_\odot$

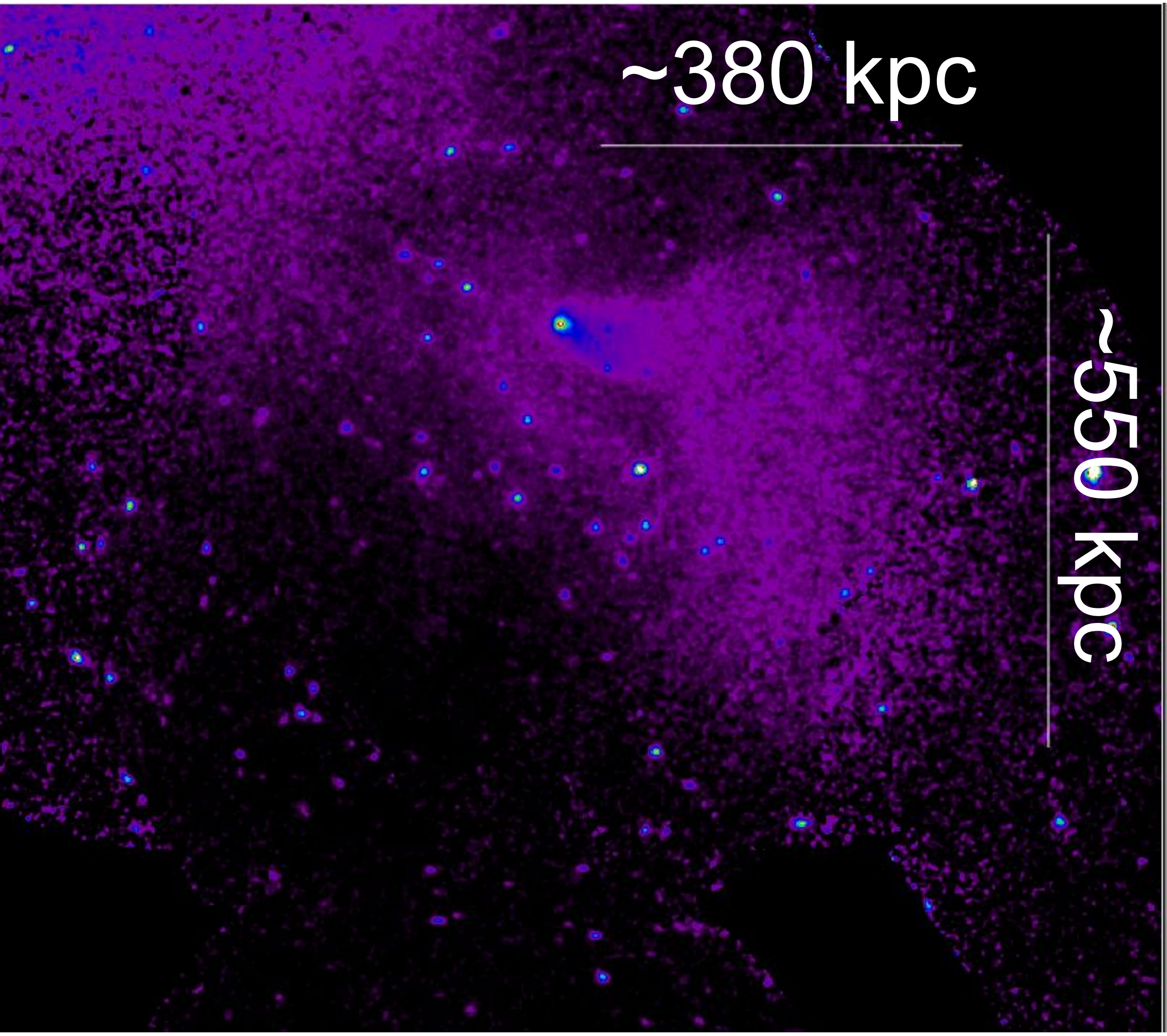
$M_2 = \mathbf{1.2 \times 10^{14}}\ M_\odot$

It is possible that the subcluster is still moving outwards.





Conclusions

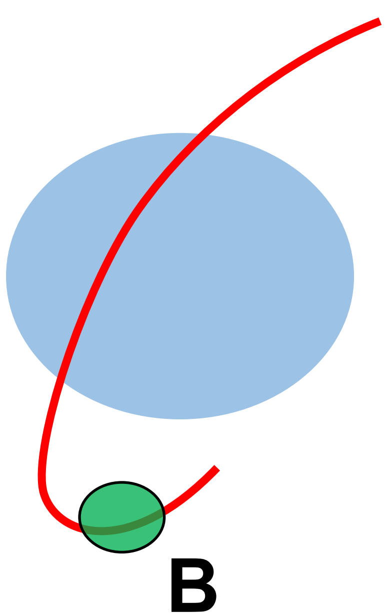


- Gas mass in the tail
  $M \approx 1.1 \times 10^{12}\ M_{\odot}$

- No shock

⇩

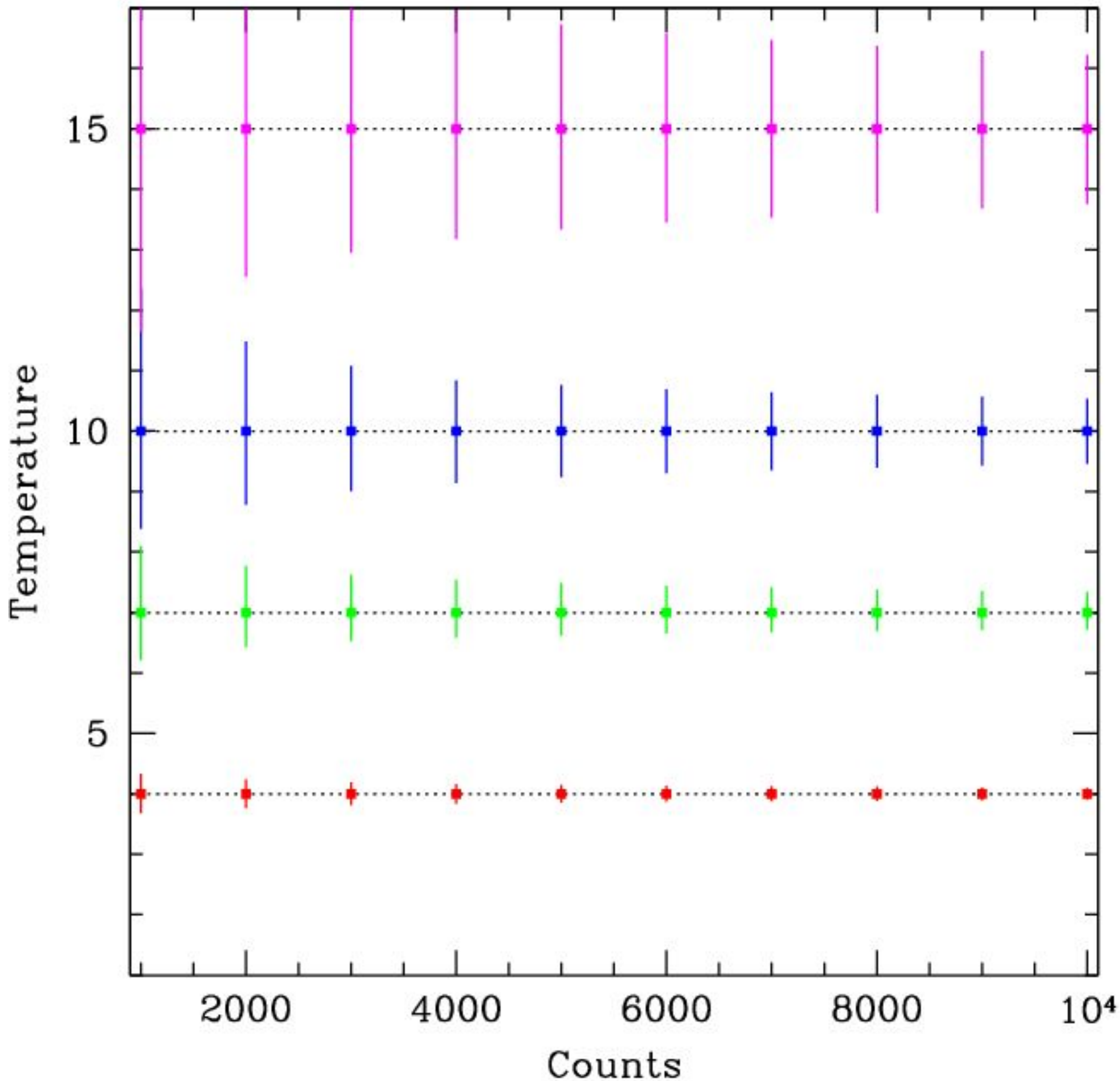
Radial infall scenario is disfavoured

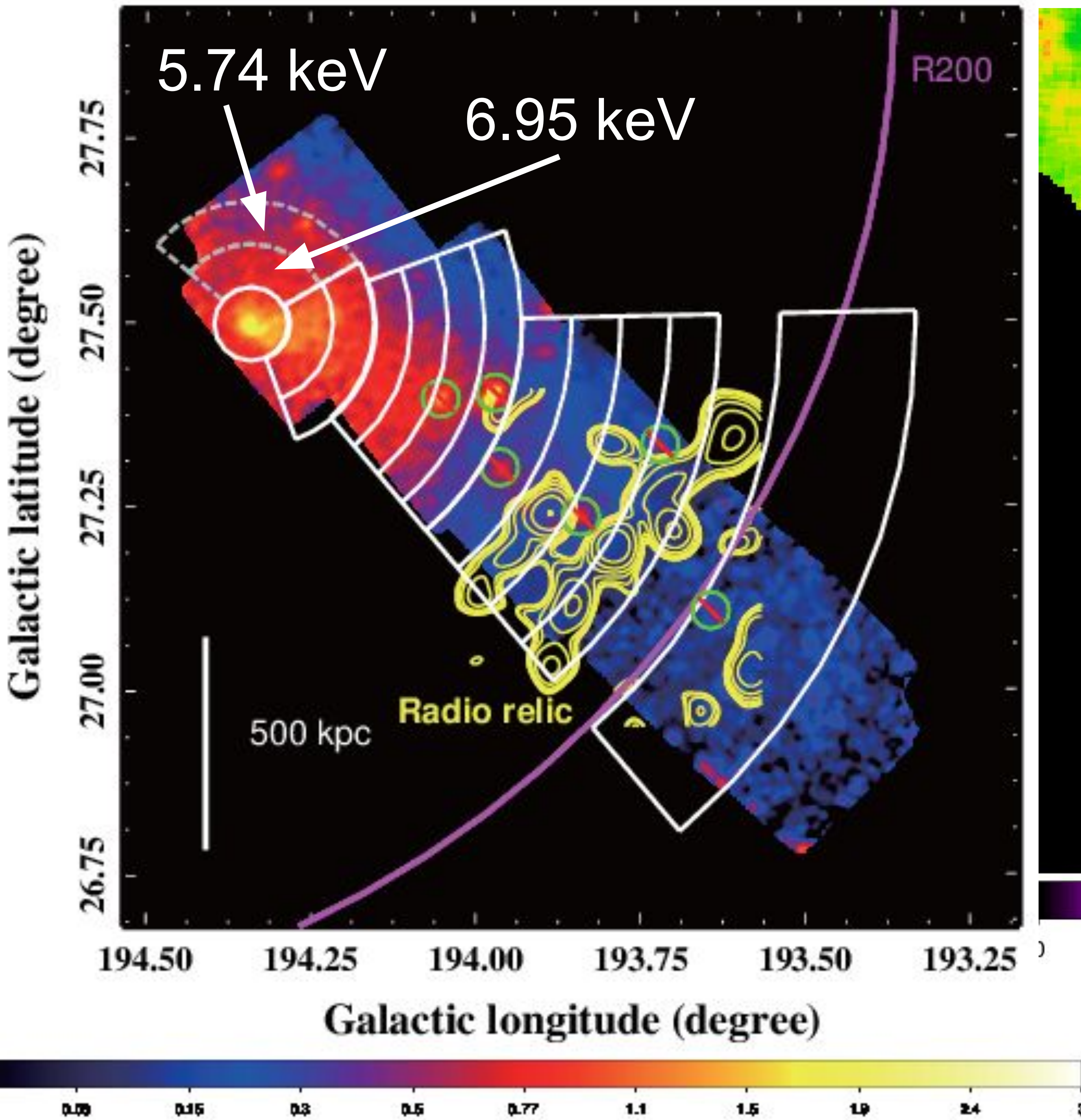


The NGC 4839 group might arrive near the apocenter. The observed X-ray structure is formed by rotation of the gas core

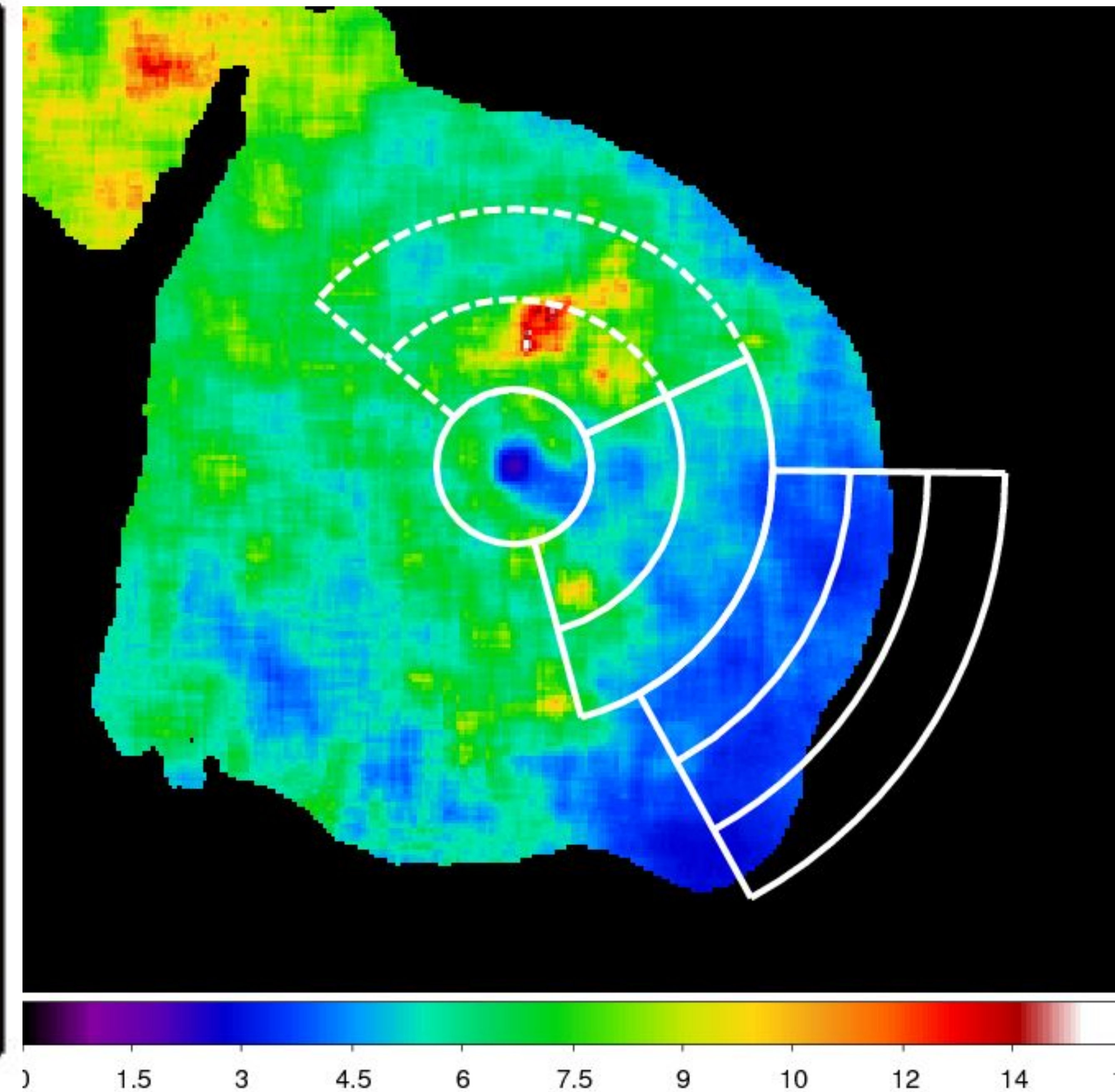
Thank you for your attention!

Expected uncertainty on the temperature measurements for different plasma temperature and photon counts





Suzaku mosaic image in 0.5 - 8 keV band from Akamatsu + 2013

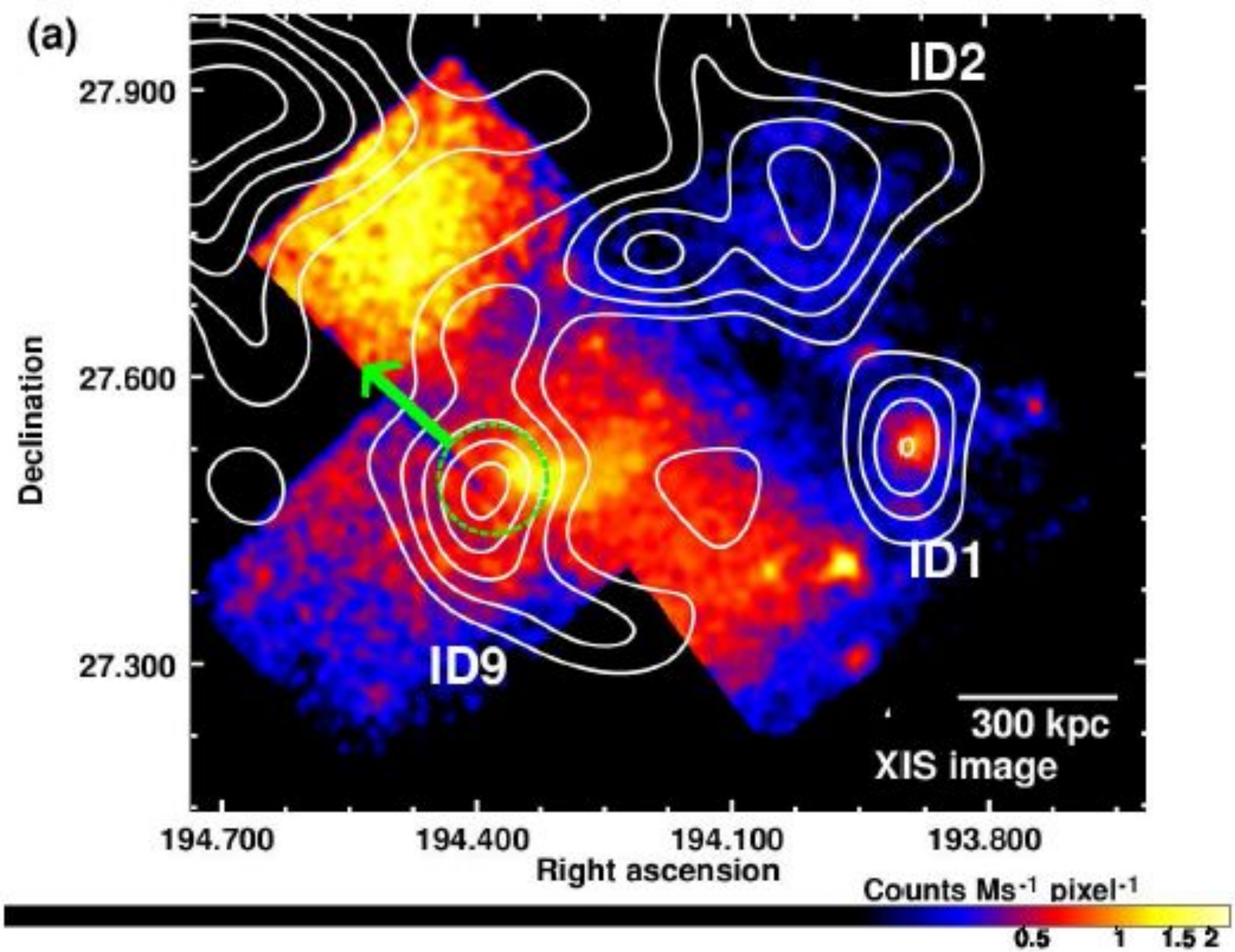


T-map (based on XMM data)

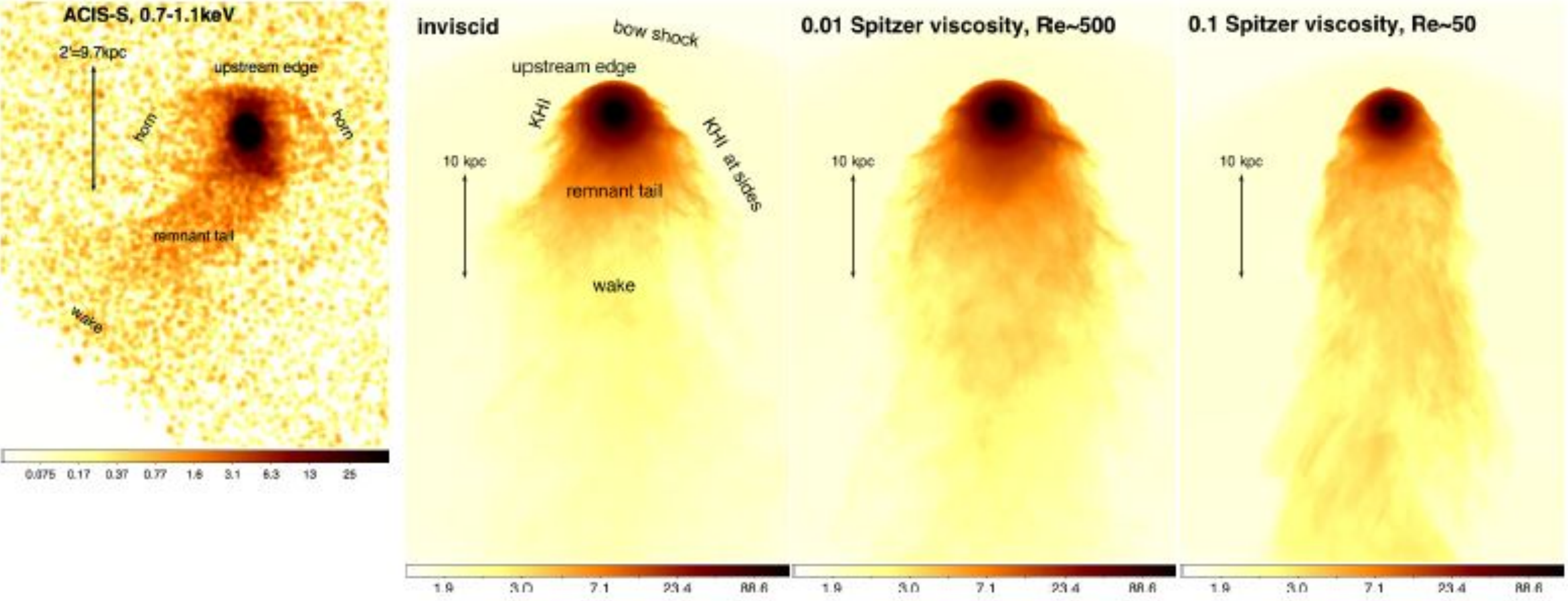
+

regions from the left figure

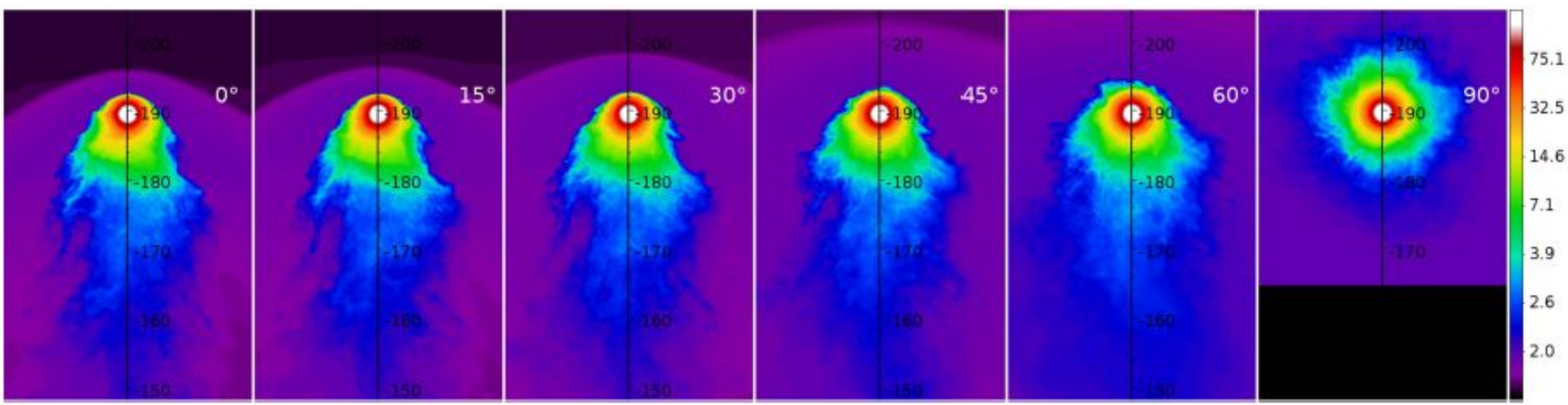
Suzaku image (Sasaki et al. 2016)



0.5-5 keV



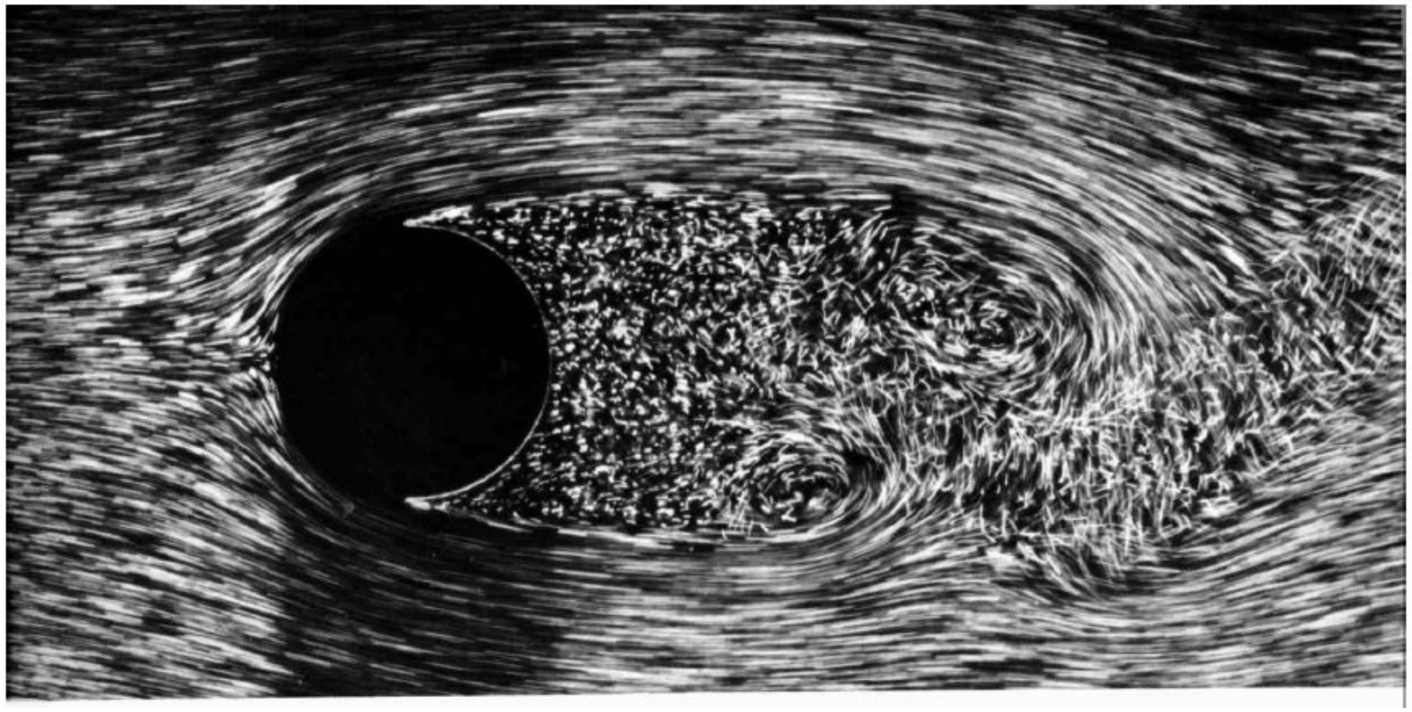
M89 in the Virgo cluster: Chandra data + hydrodynamic simulations by Roediger et al. 2015, Kraft et al. 2016



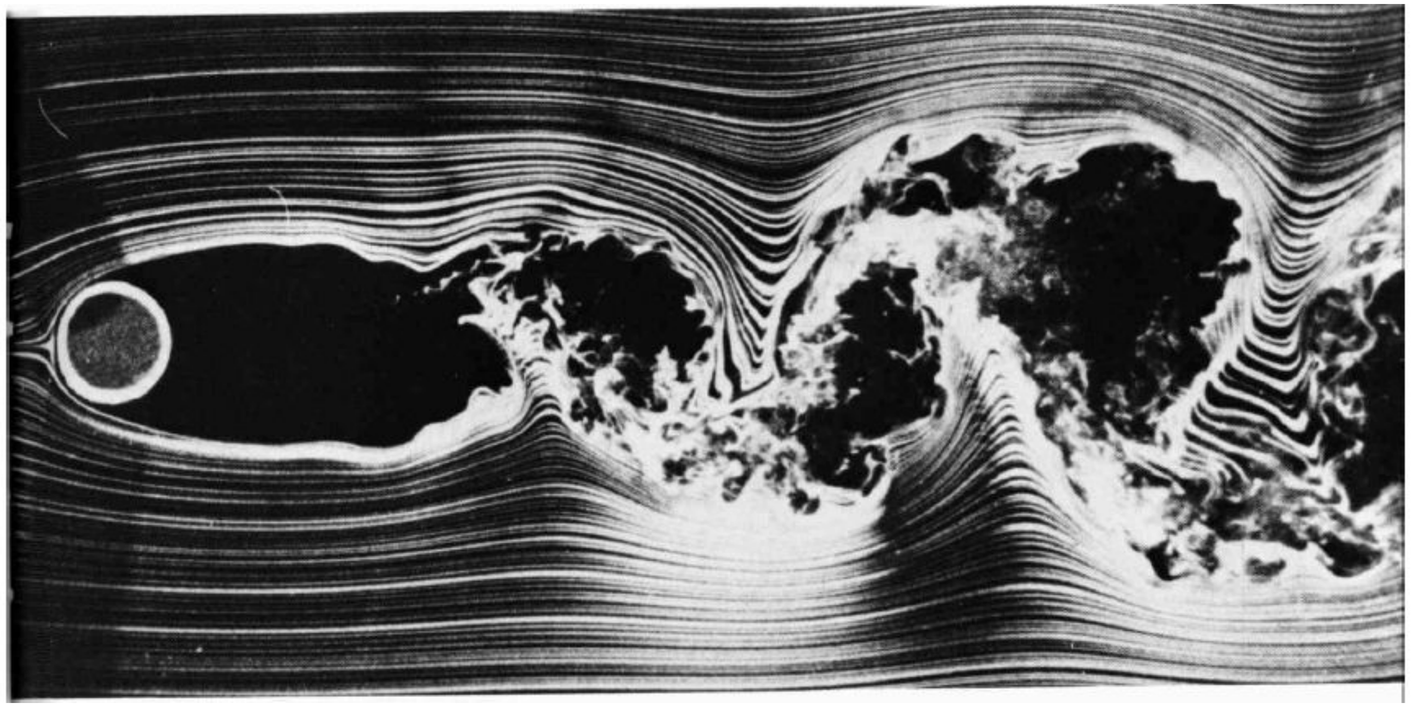
Total mass of the NGC 4839 group

From M-T relation
"Tail": $M_{gas} \sim 10^{12}\ M_\odot \rightarrow M_{total} \sim 10^{13}\ M_\odot$.
Gas temperature of the groupT ~ 4 keV $\rightarrow M_{total} \sim (2 - 3) \cdot 10^{14}\ M_\odot$

Assumptions:
incompressible fluid, solid body, constant velocity



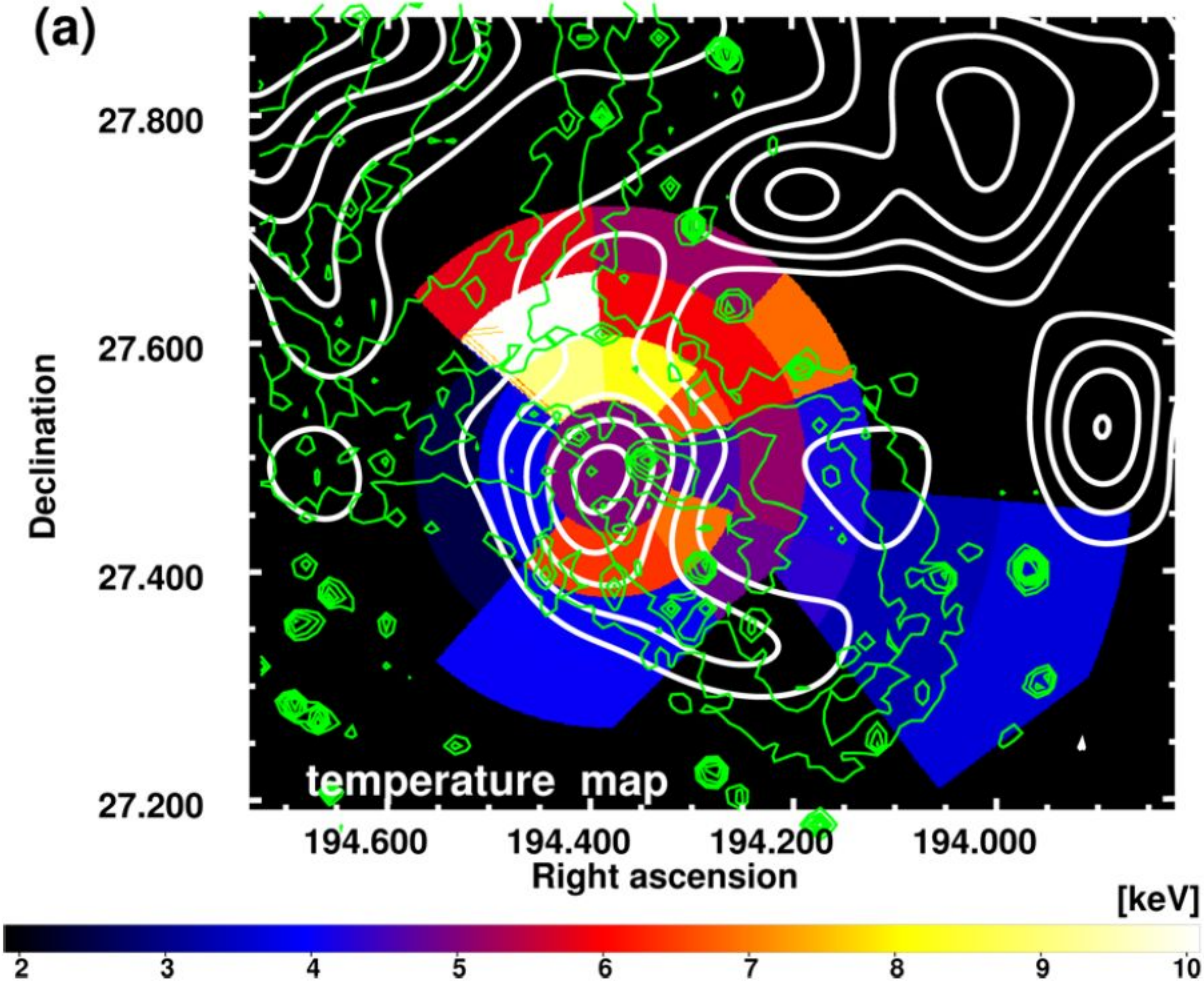
Re = 2000



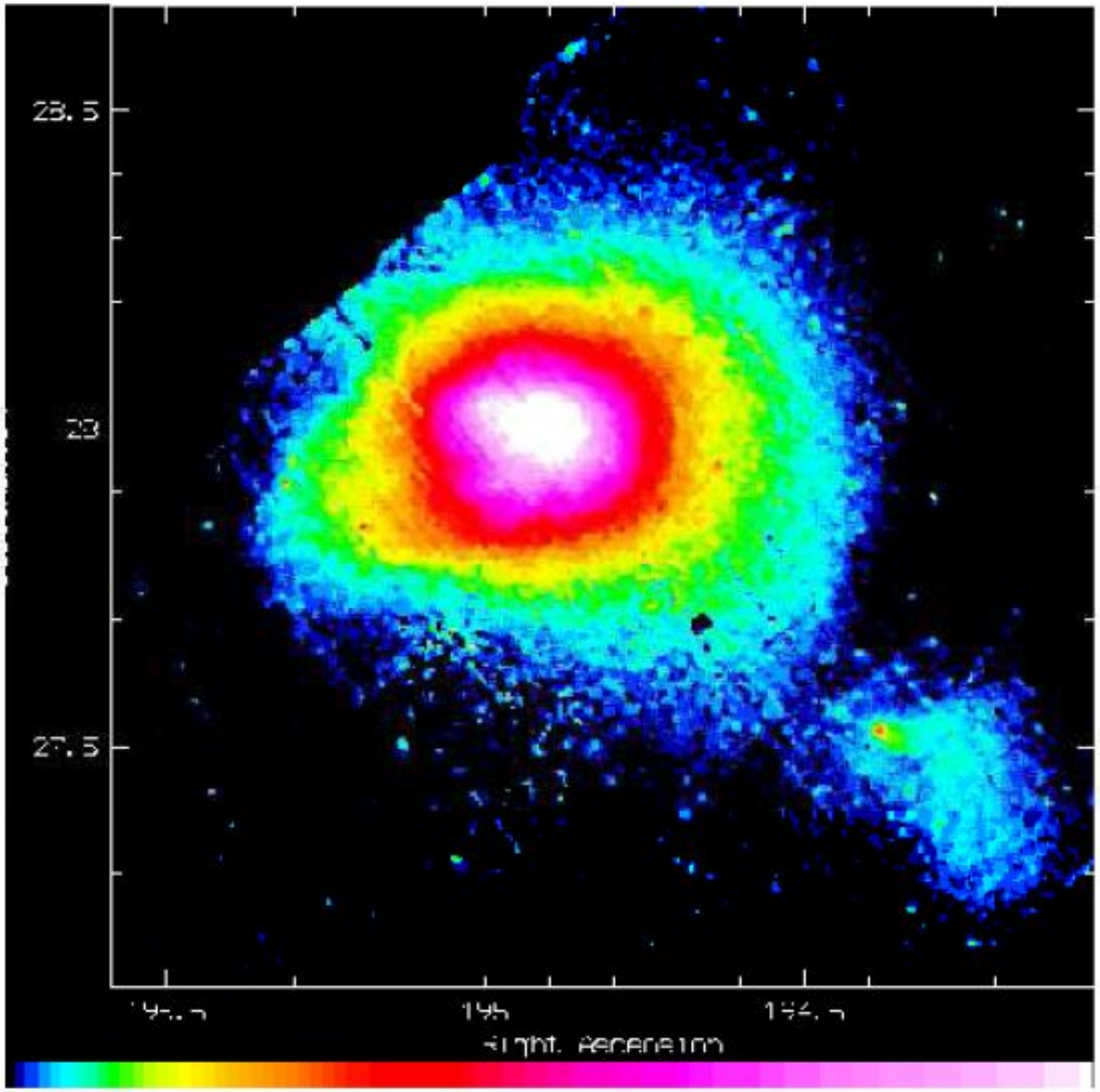
Re = 10000

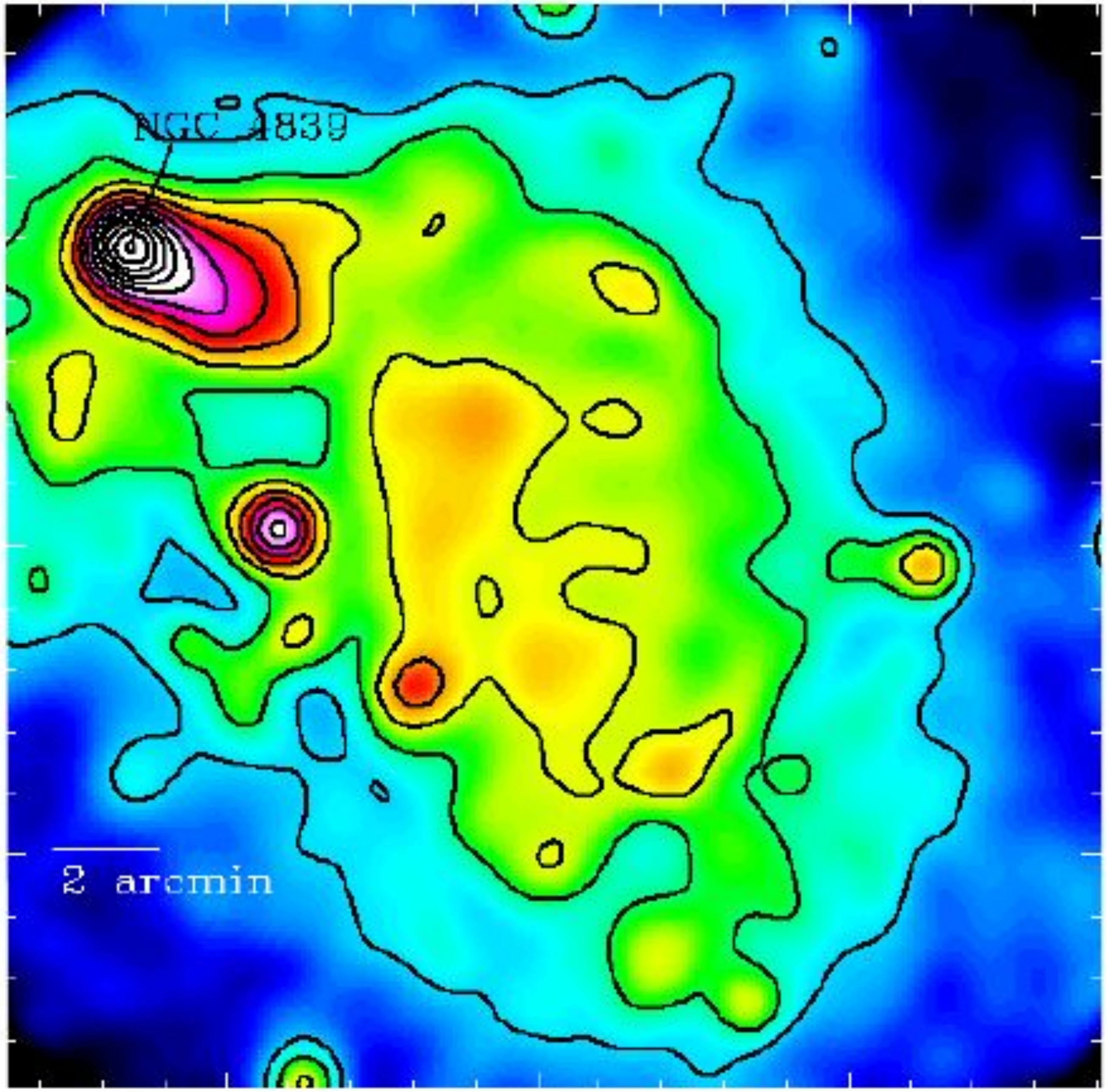
Van Dyke, An Album of Fluid Motion

Temperature map from Suzaku data (Sasaki et al. 2016)



Neumann et al. 2001, 2003 (based XMM-Newton data)





0.5 - 2 keV

The length of the stripped tail can provide an independent diagnostic of the plasma viscosity. Through hydrodynamic simulations, Roediger et al. (2015a) predict that a stripped tail in a plasma of high viscosity should be as cold as the remnant core and extend out to 30 kpc behind the Galaxy, while in the case of an inviscid plasma, the stripped tail is mixed efficiently with the ICM. In practice, however, the remnant core of a galaxy can temporarily shield a stripped tail. In other words, a long extended tail can be expected in newly infalling galaxies even in a fully turbulent plasma. Fortunately, NGC 1404 has entered the Fornax Cluster long ago and the shielding effect is by now greatly reduced (see Paper 1). Thus, it is appropriate to use the tail length of NGC 1404 to diagnose the viscosity of the plasma. For an inclination angle of 33°, the actual tail length is 10 kpc, remarkably short compared with typical stripped tails of early-type galaxies (M86—Randall et al. 2008; NGC 1400—Su et al. 2014). This result favors a low viscosity plasma.