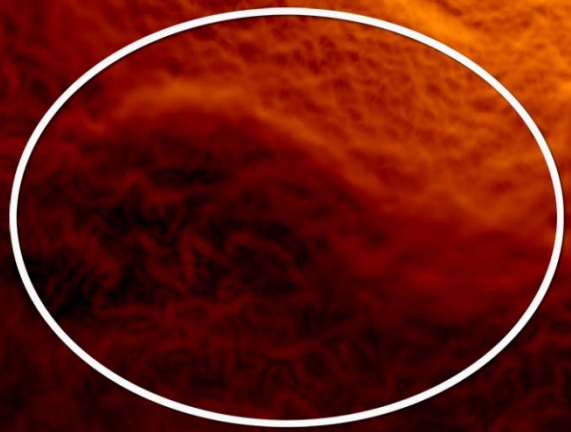
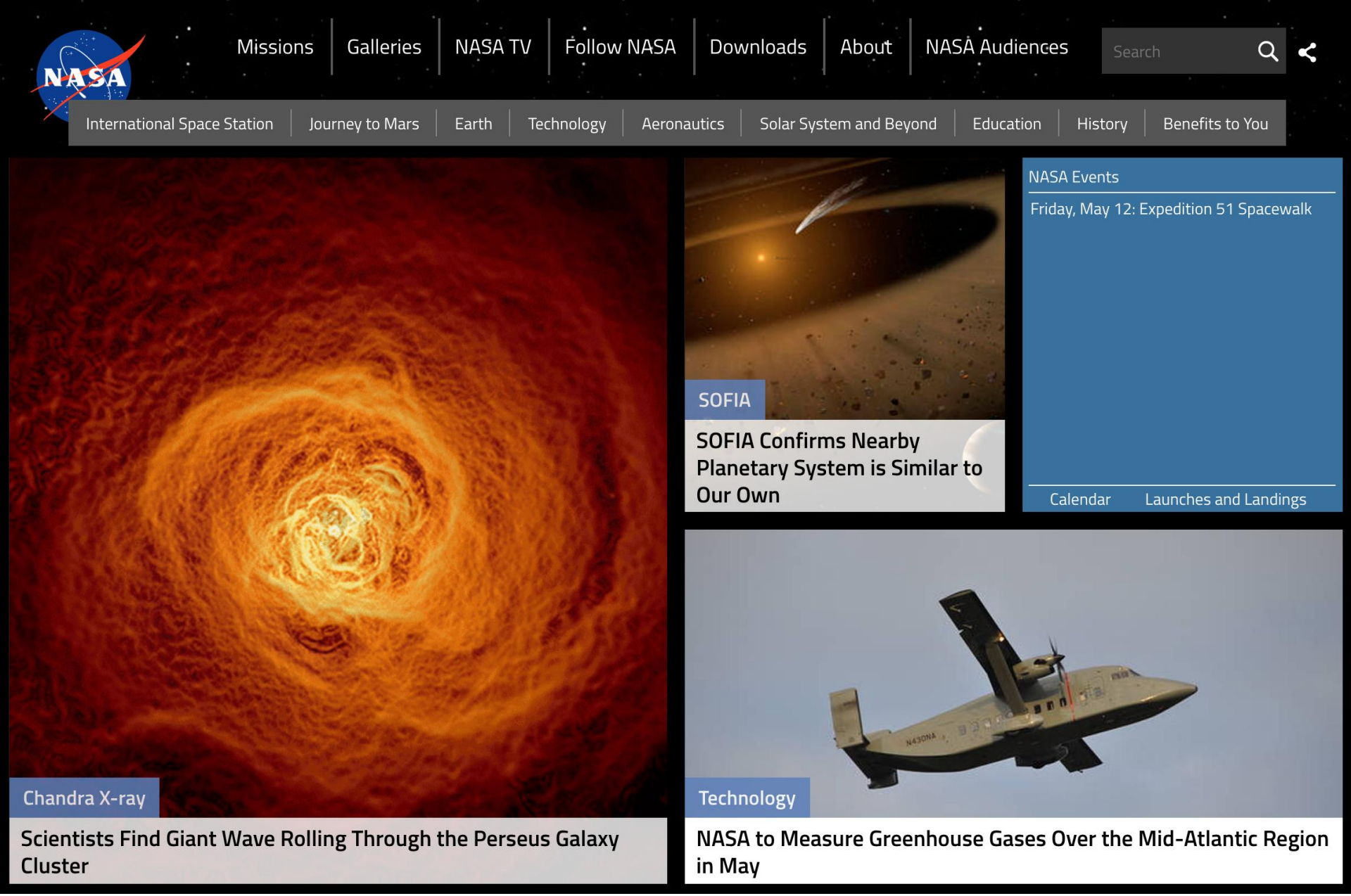
Is there a giant Kelvin-Helmholtz instability in the sloshing cold front of the Perseus cluster?



250,000 light-years

Stephen Walker (NASA/GSFC)

J. Hlavacek-Larrondo
M. Gendron-Marsolais
A. C. Fabian
H. Intema
J. S. Sanders
J. T. Bamford

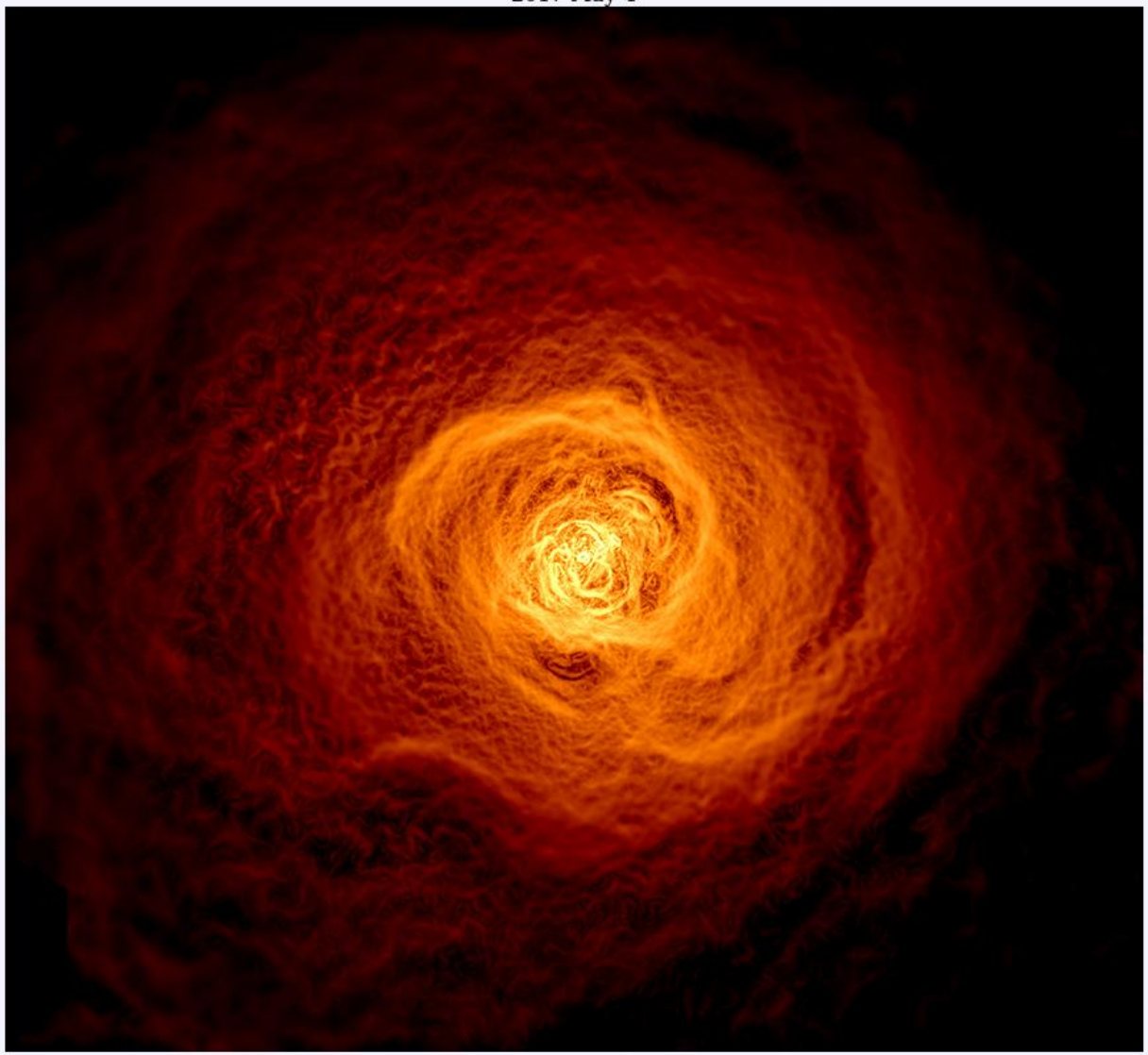


Walker et al. 2017, MNRAS 468, 2506, arXiv:1705.00011

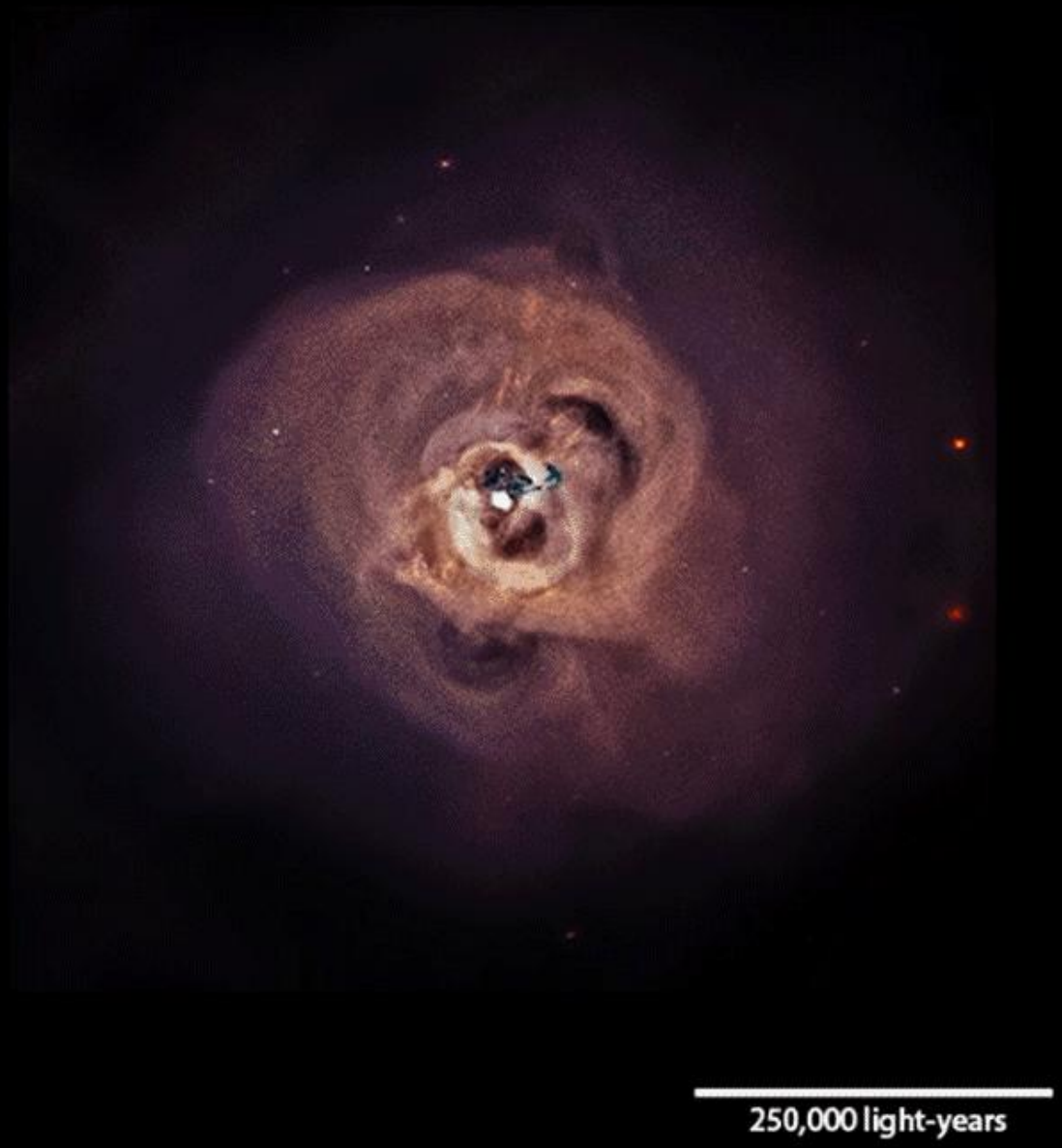
Astronomy Picture of the Day

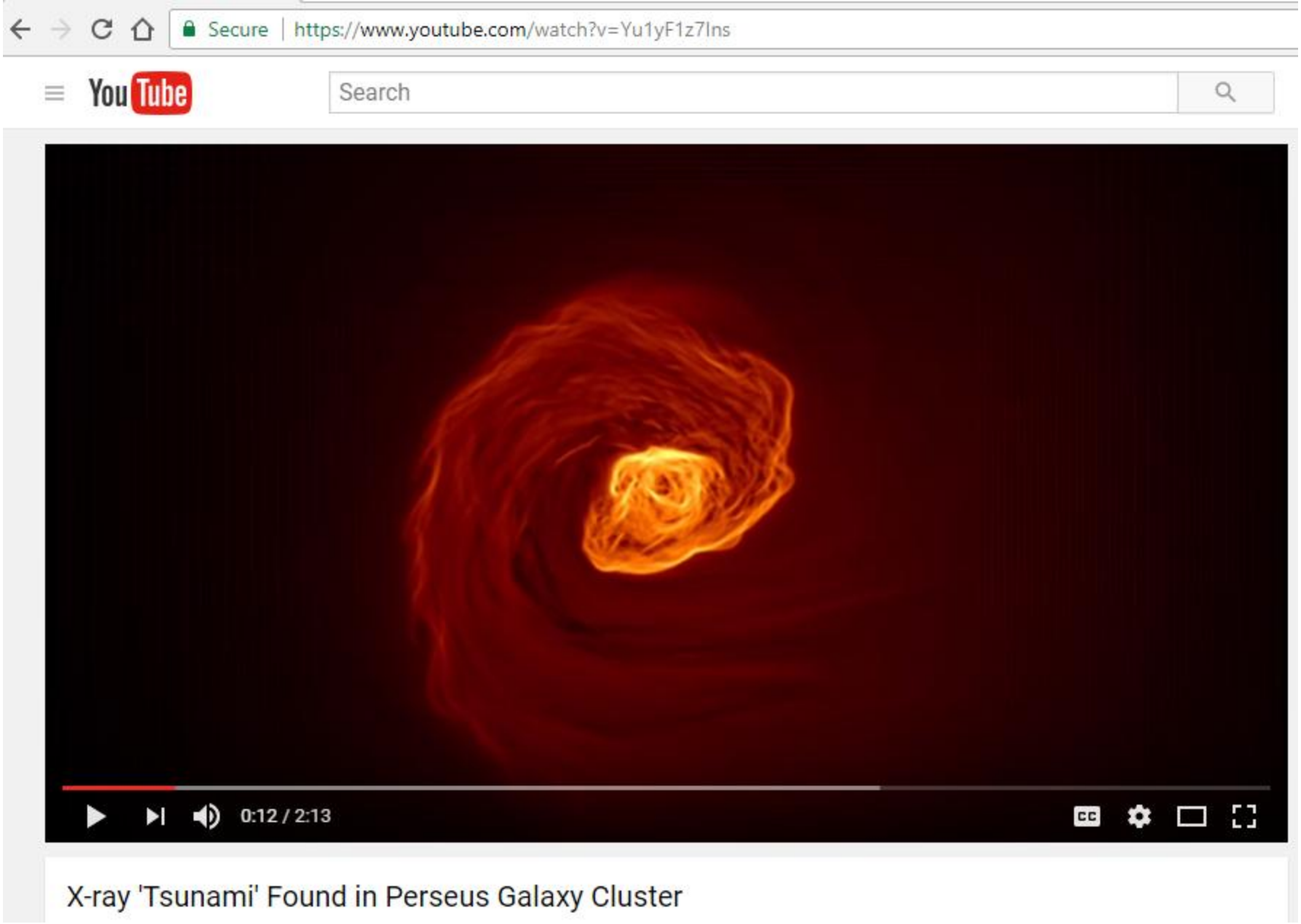
iscover the cosmos! Each day a different image or photograph of our fascinating universe is featured, along with a brief explanation written by a professional astronomer.

2017 May 4

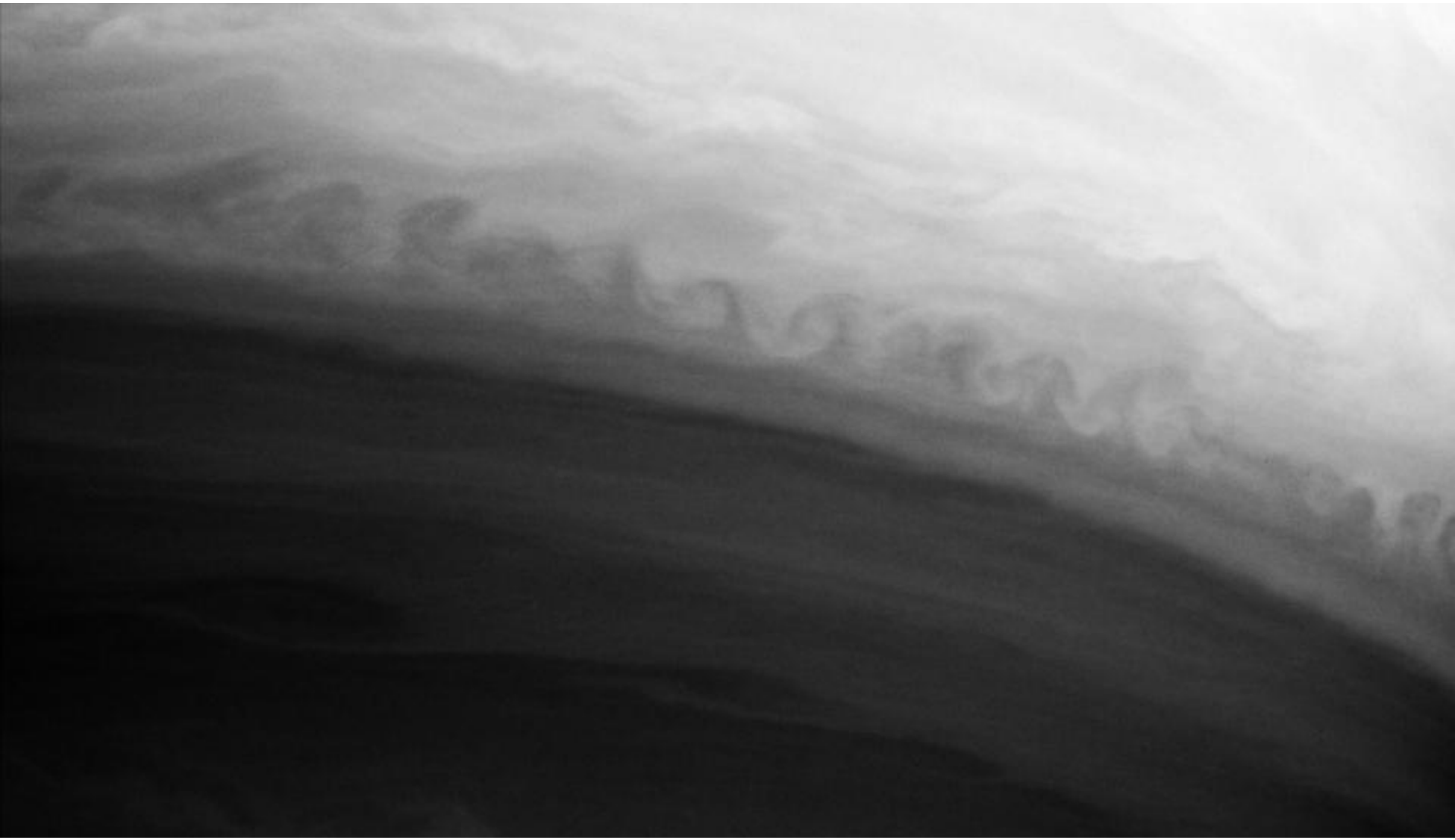


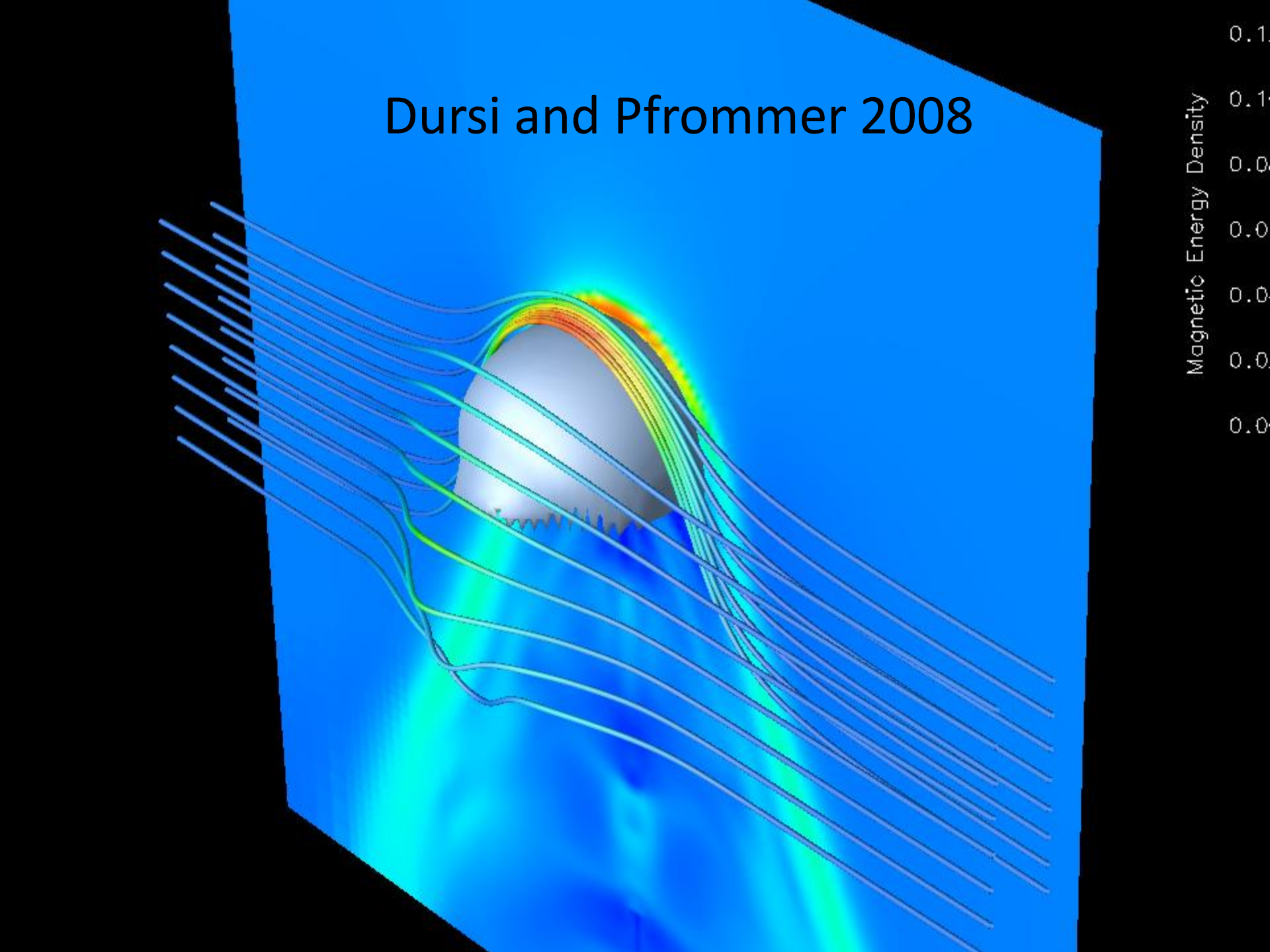
The Perseus Cluster Waves
Image Credit: NASA, CXC, GSFC, Stephen Walker, et al.

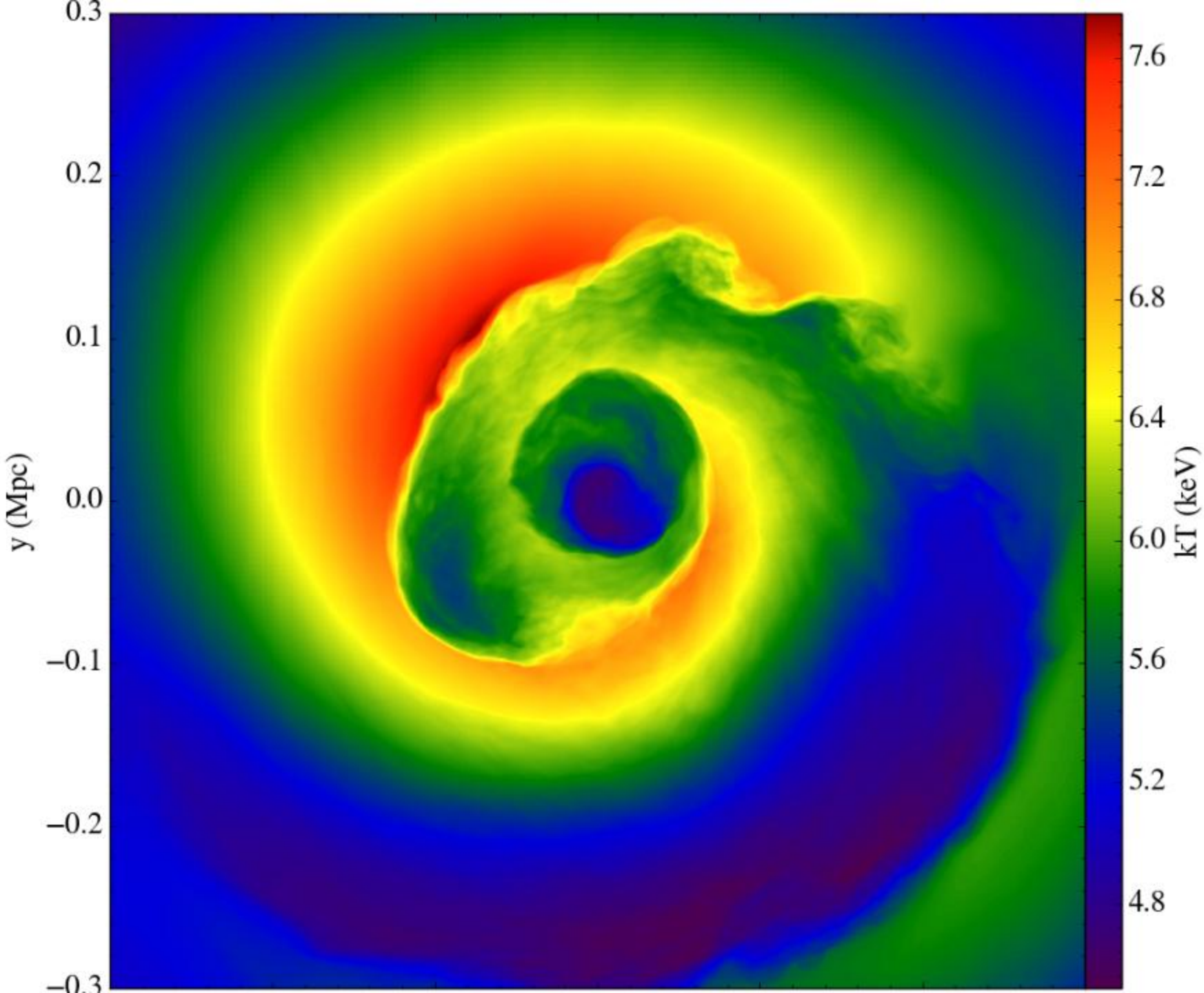

250,000 light-years

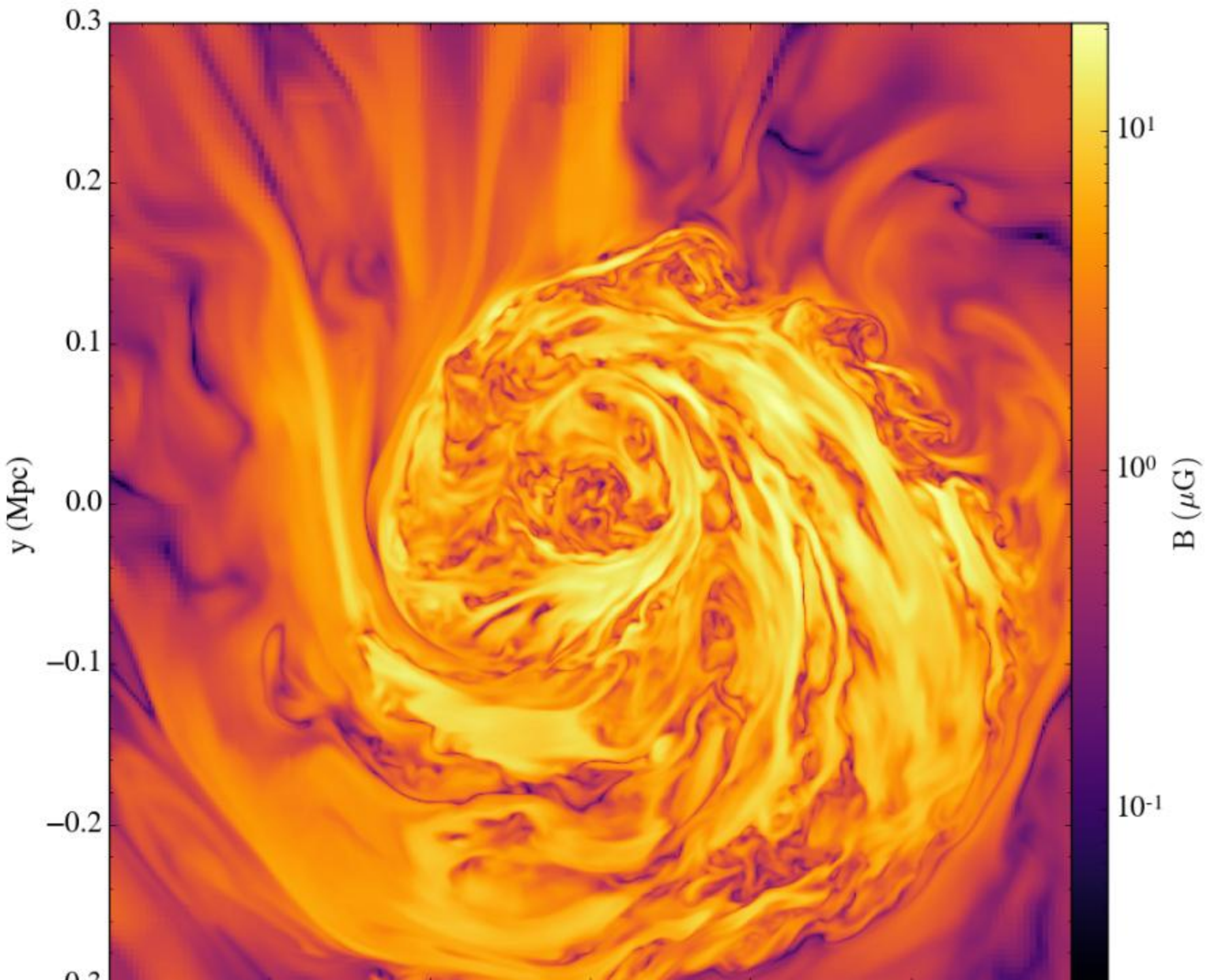


Video at: https://www.youtube.com/watch?v=Yu1yF1z7Ins




Dursi and Pfrommer 2008
Magnetic Energy Density

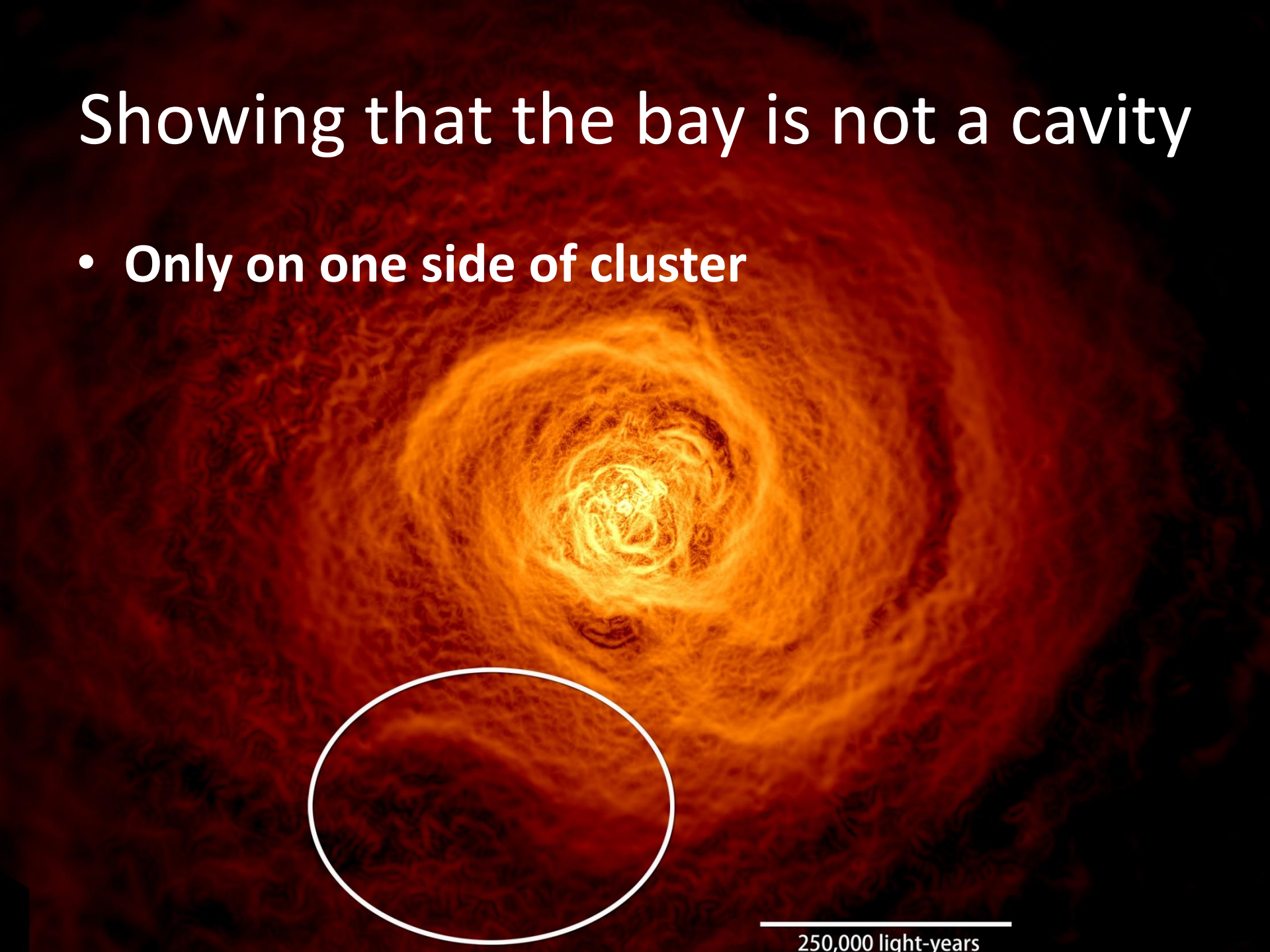

0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
y (Mpc)
7.6
7.2
6.8
6.4
6.0
5.6
5.2
4.8
kT (keV)


0.3
0.2
0.1
0.0
−0.1
−0.2
y (Mpc)
10^{1}
10^{0}
10^{-1}
B (μG)

Showing that the bay is not a cavity

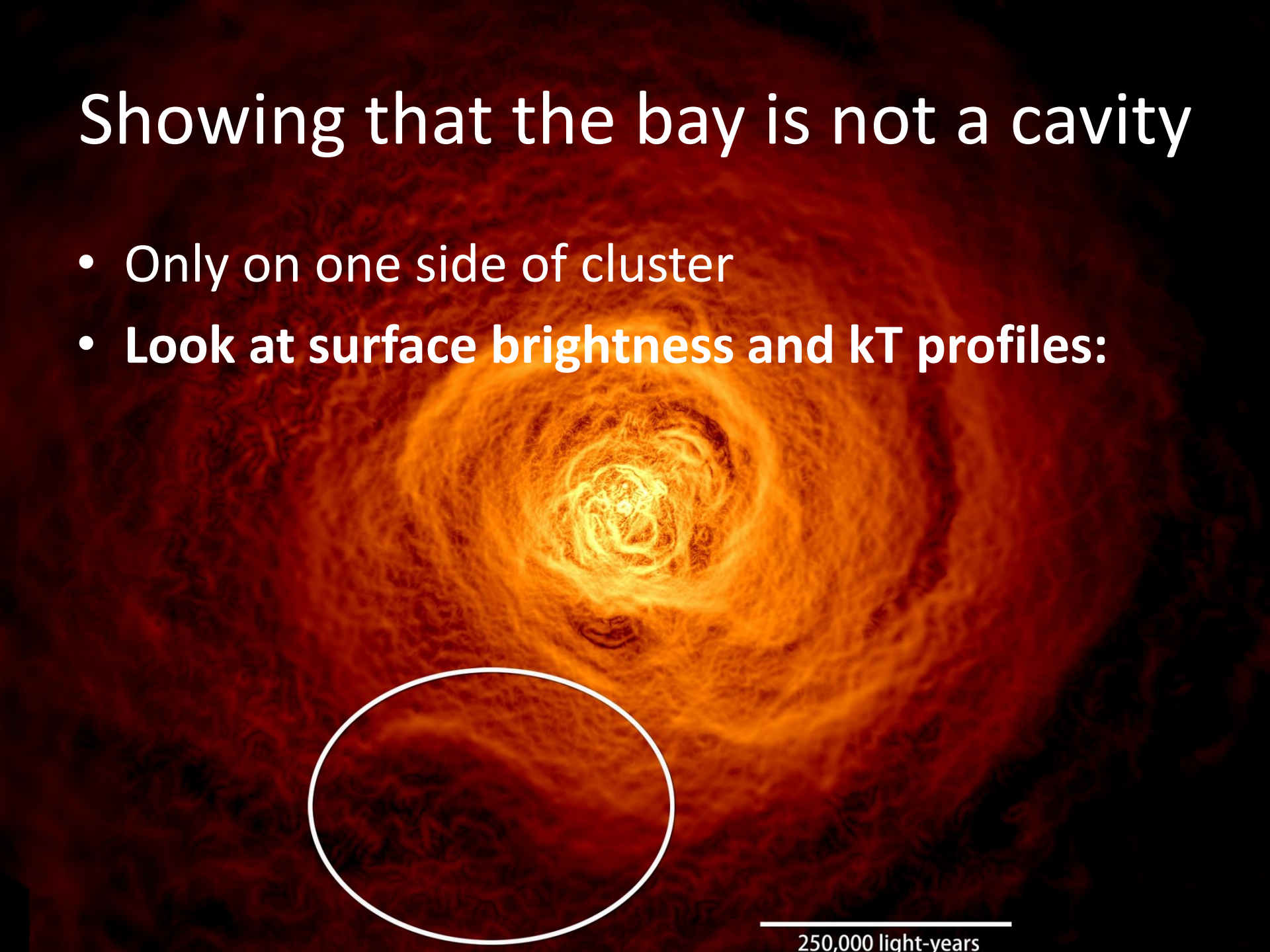
Showing that the bay is not a cavity

- **Only on one side of cluster**

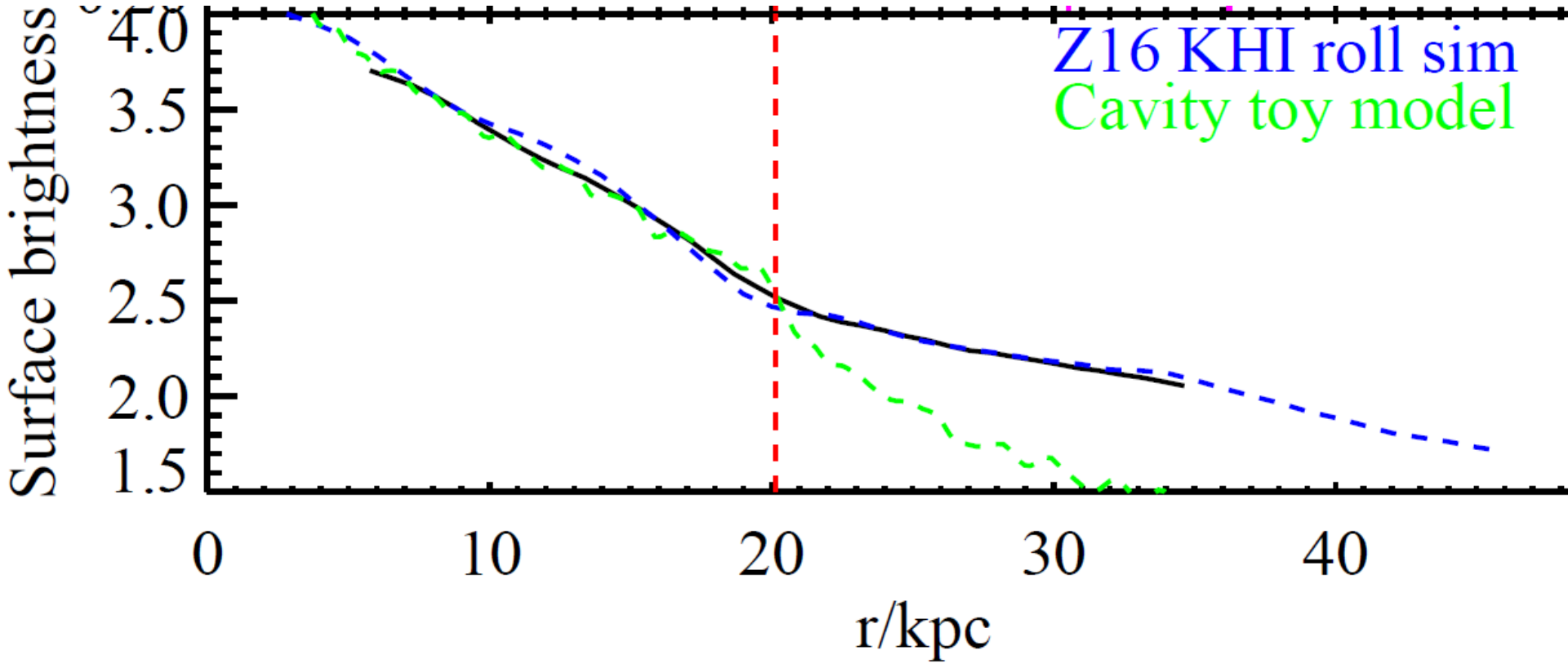


Showing that the bay is not a cavity

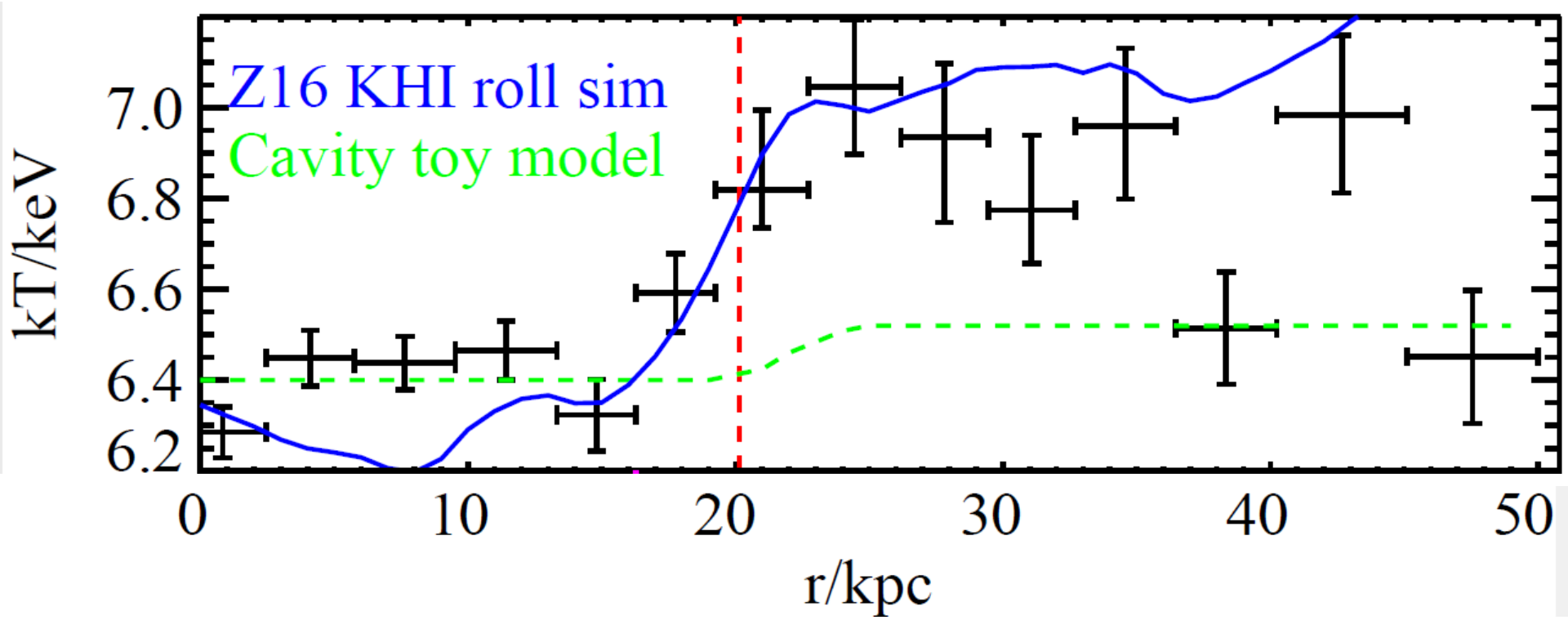
- Only on one side of cluster
- **Look at surface brightness and kT profiles:**



Surface brightness

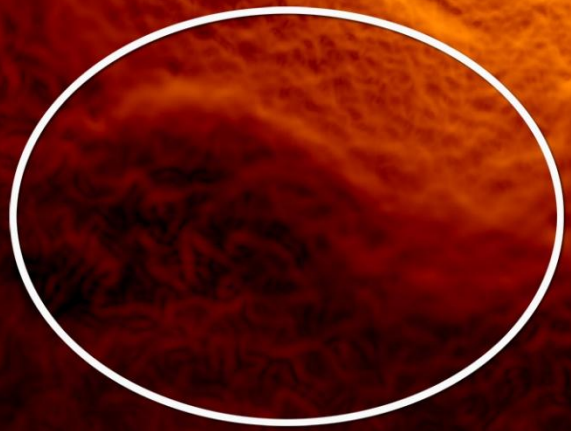


kT profiles


Z16 KHI roll sim
Cavity toy model
kT/keV
7.0
6.8
6.6
6.4
6.2
0
10
20
30
40
50
r/kpc

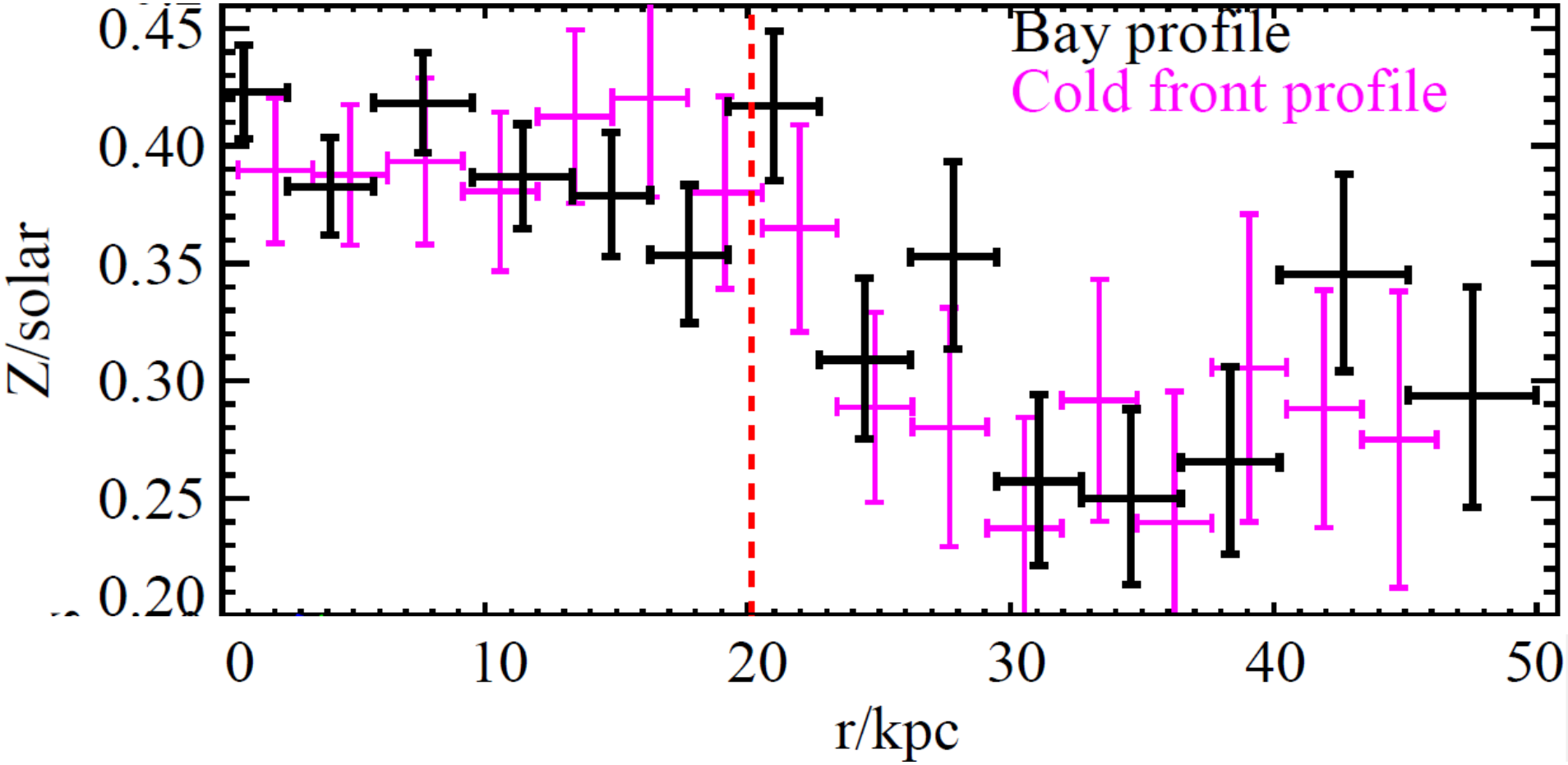
Showing that the bay is not a cavity

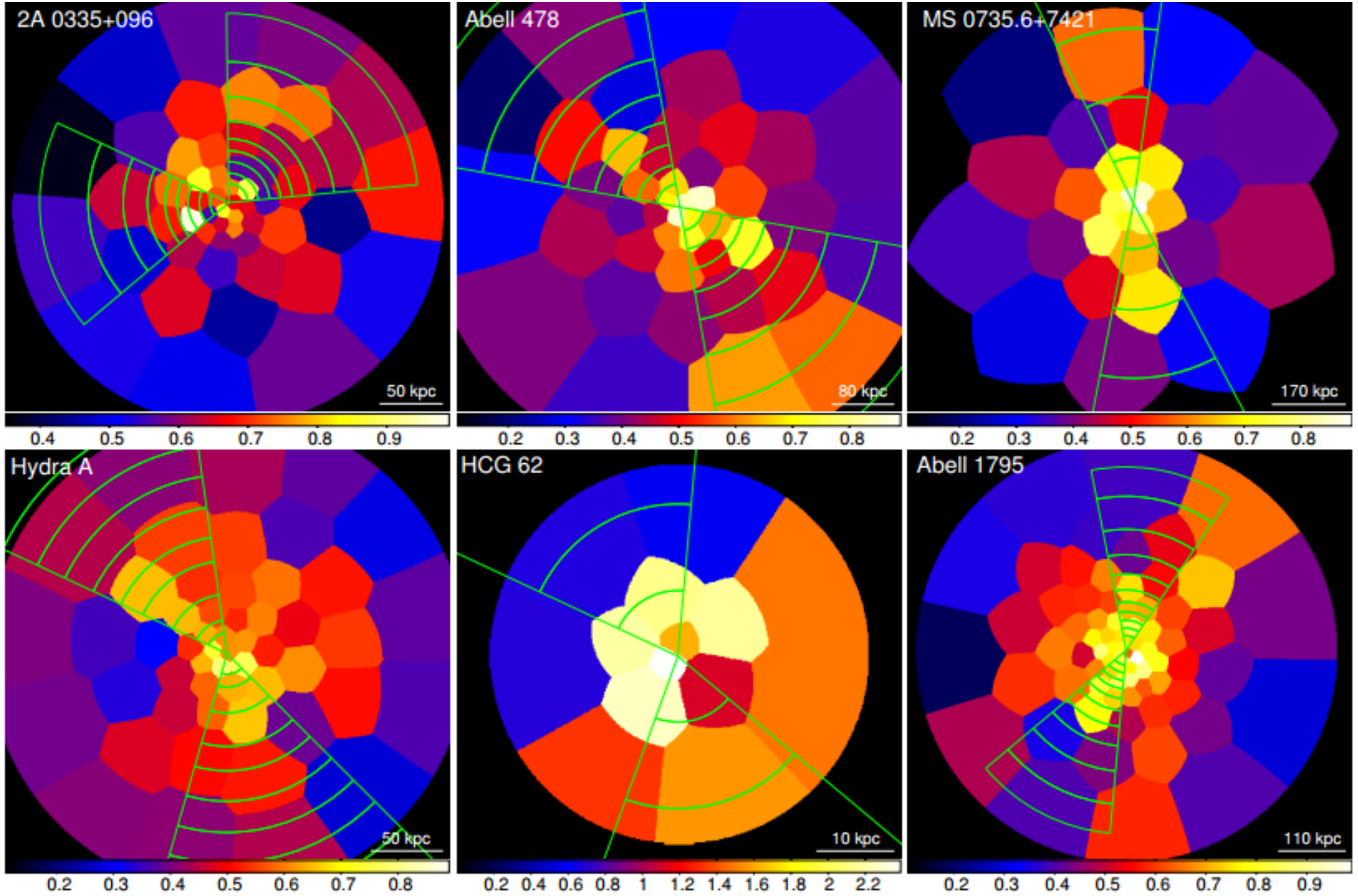
- Only on one side of cluster
- Look at surface brightness and kT profiles
- **Look at metallicity profiles:**



250,000 light-years

Metallicity profiles

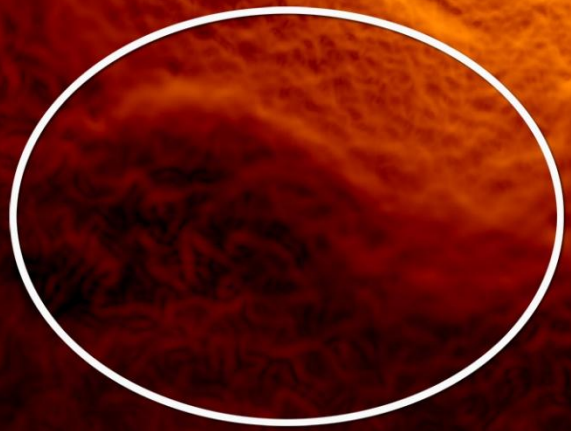




Kirkpatrick et al. 2015

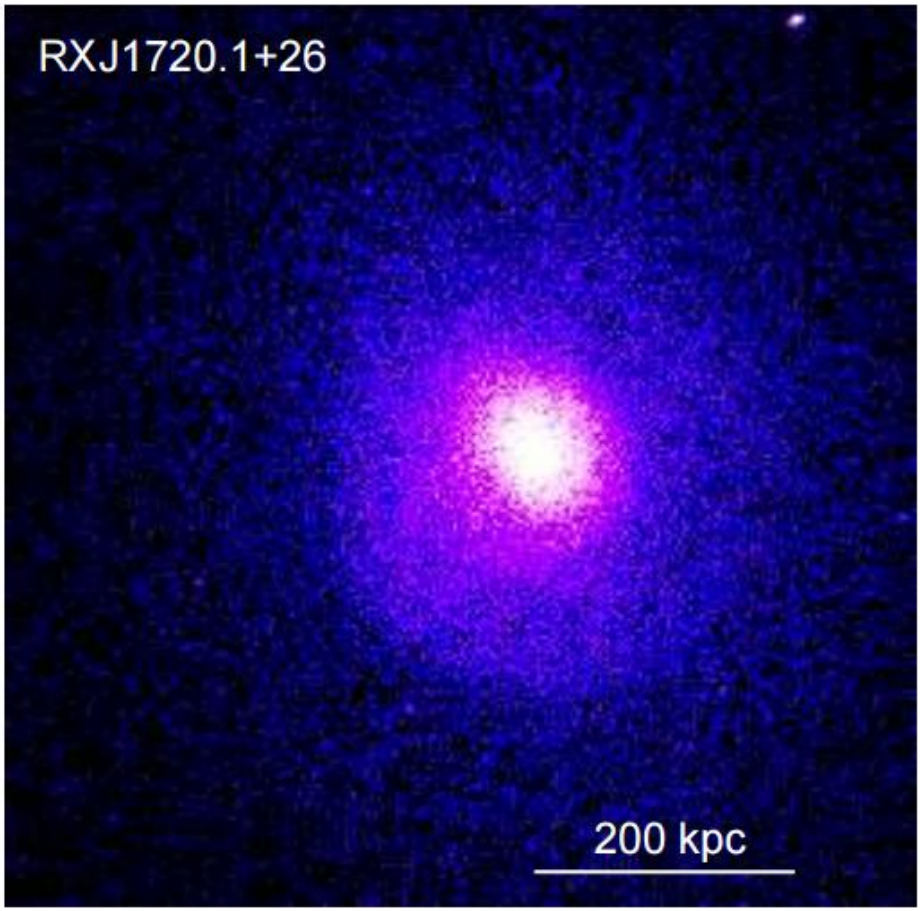
Showing that the bay is not a cavity

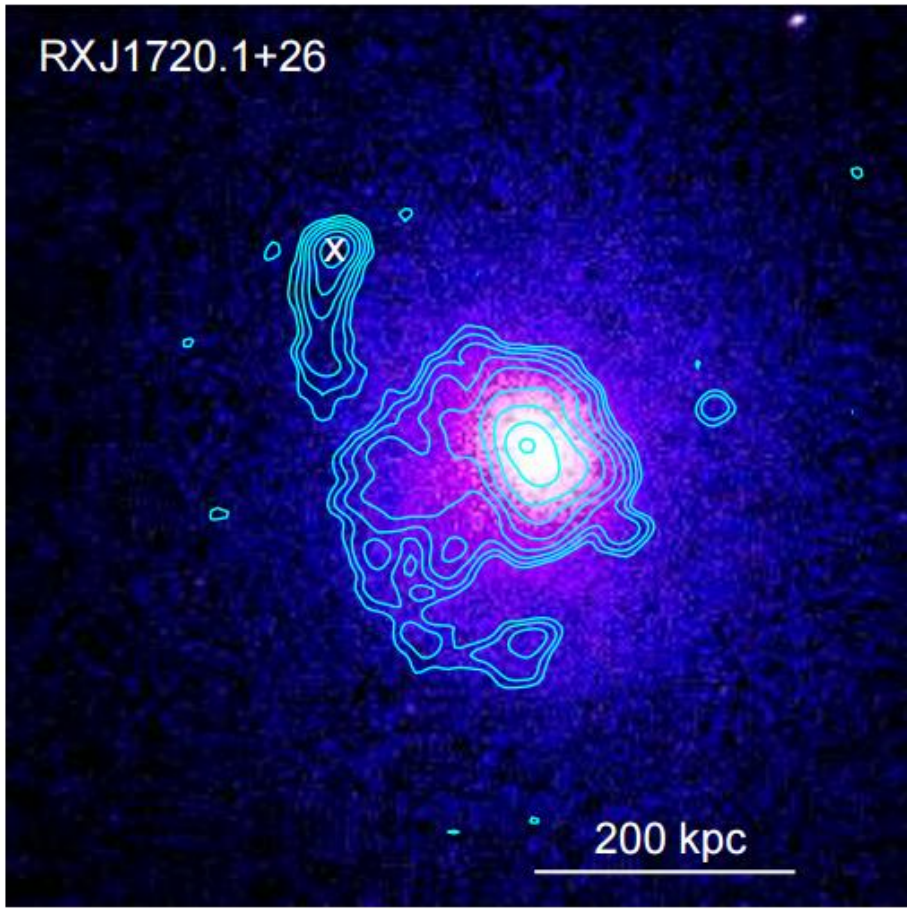
- Only on one side of cluster
- Look at surface brightness and kT profiles
- Look at metallicity profiles
- **Look at radio data**



250,000 light-years

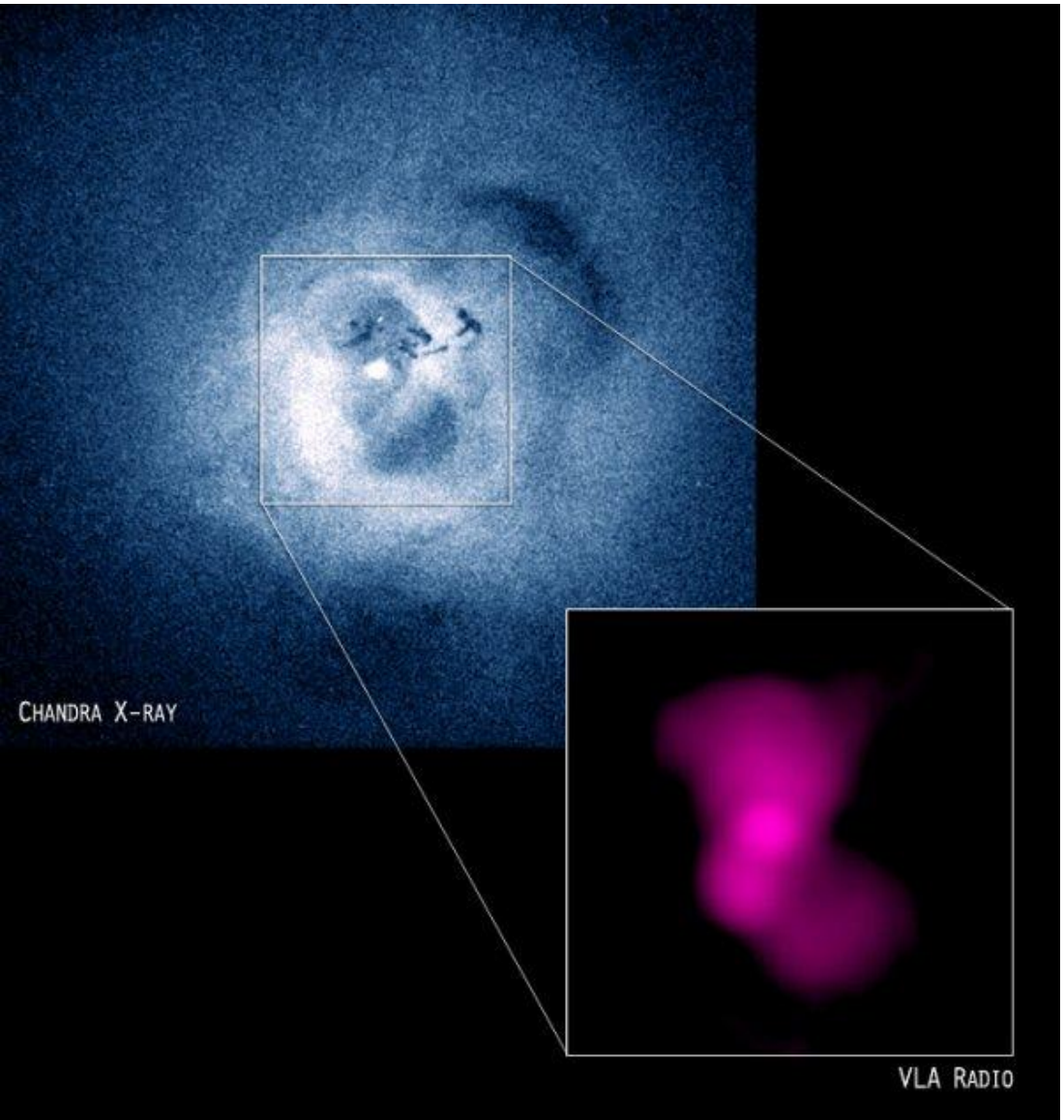
Radio constrained behind cold front

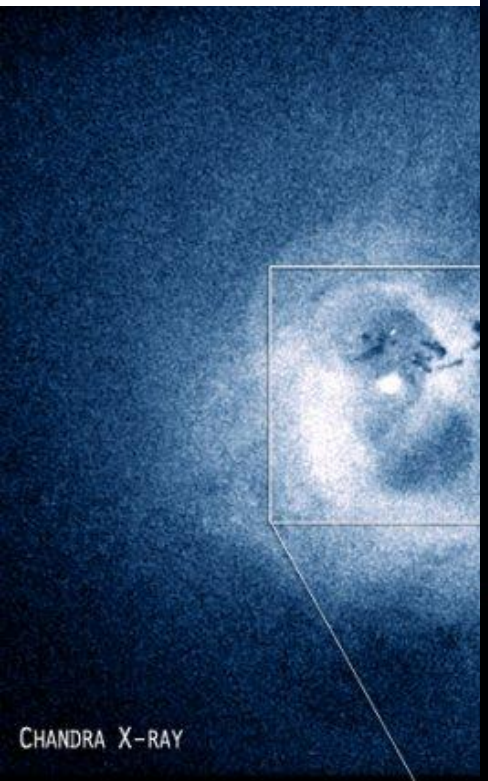


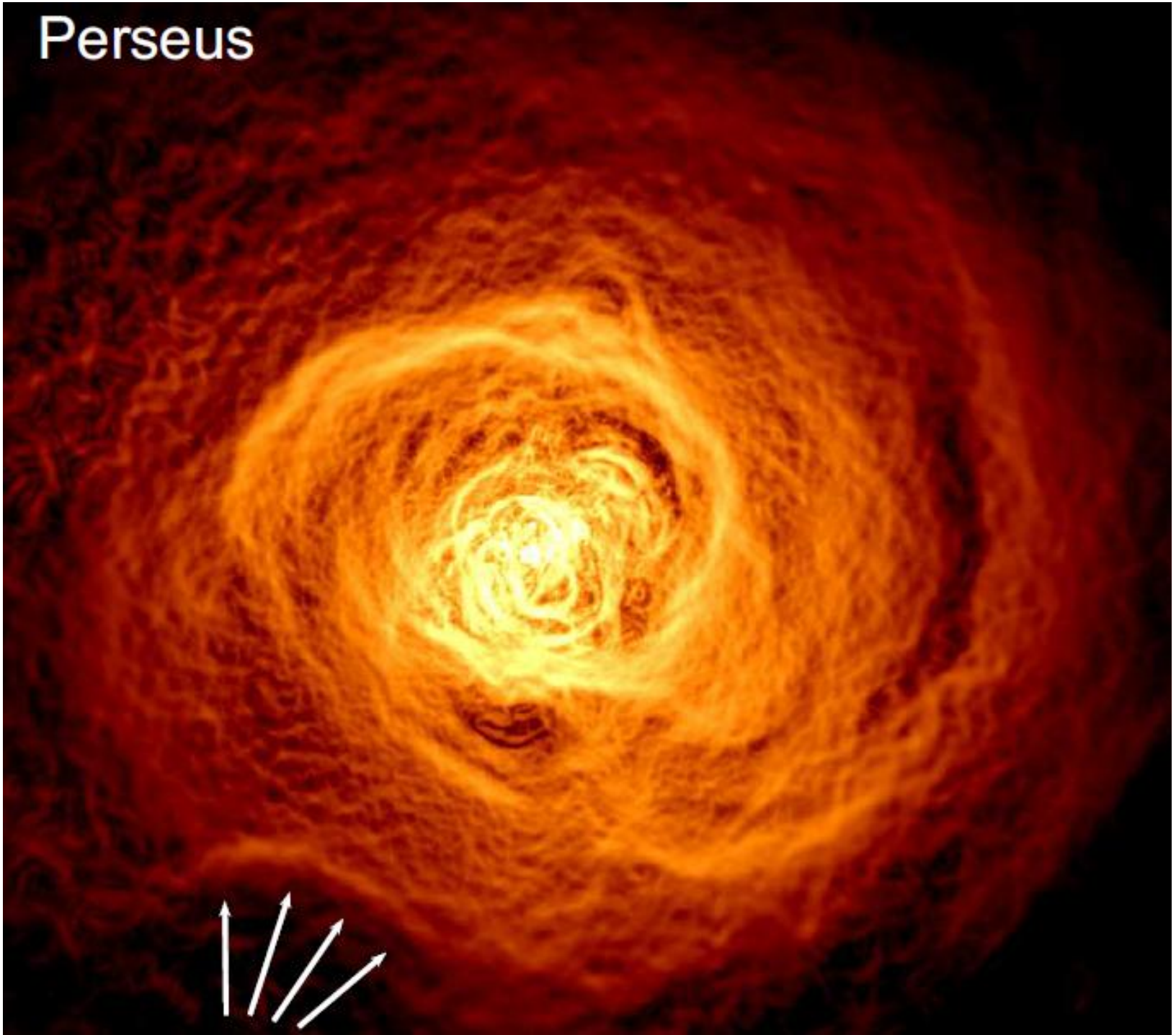


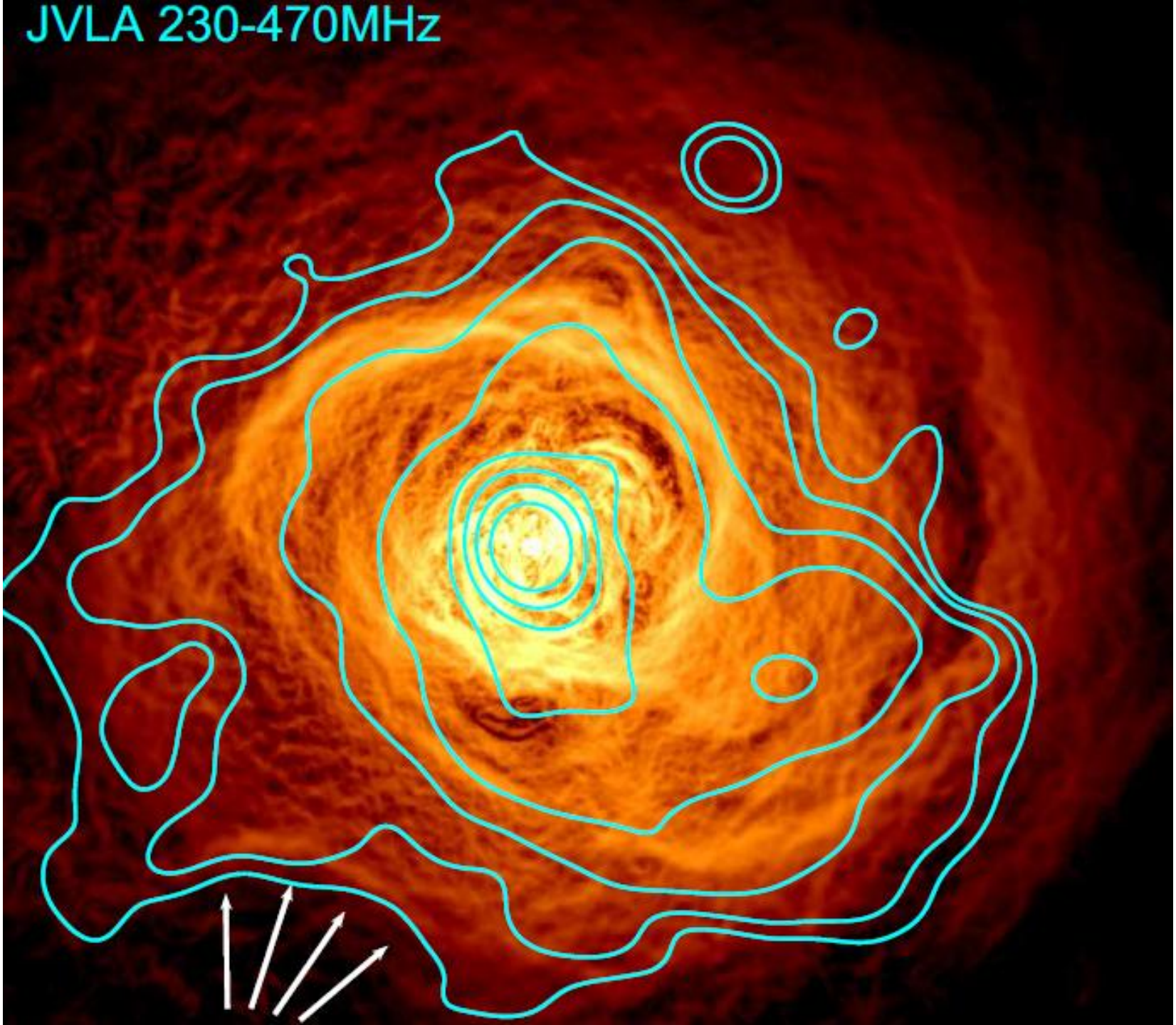
ZuHone et al. 2013

Radio fills bubbles

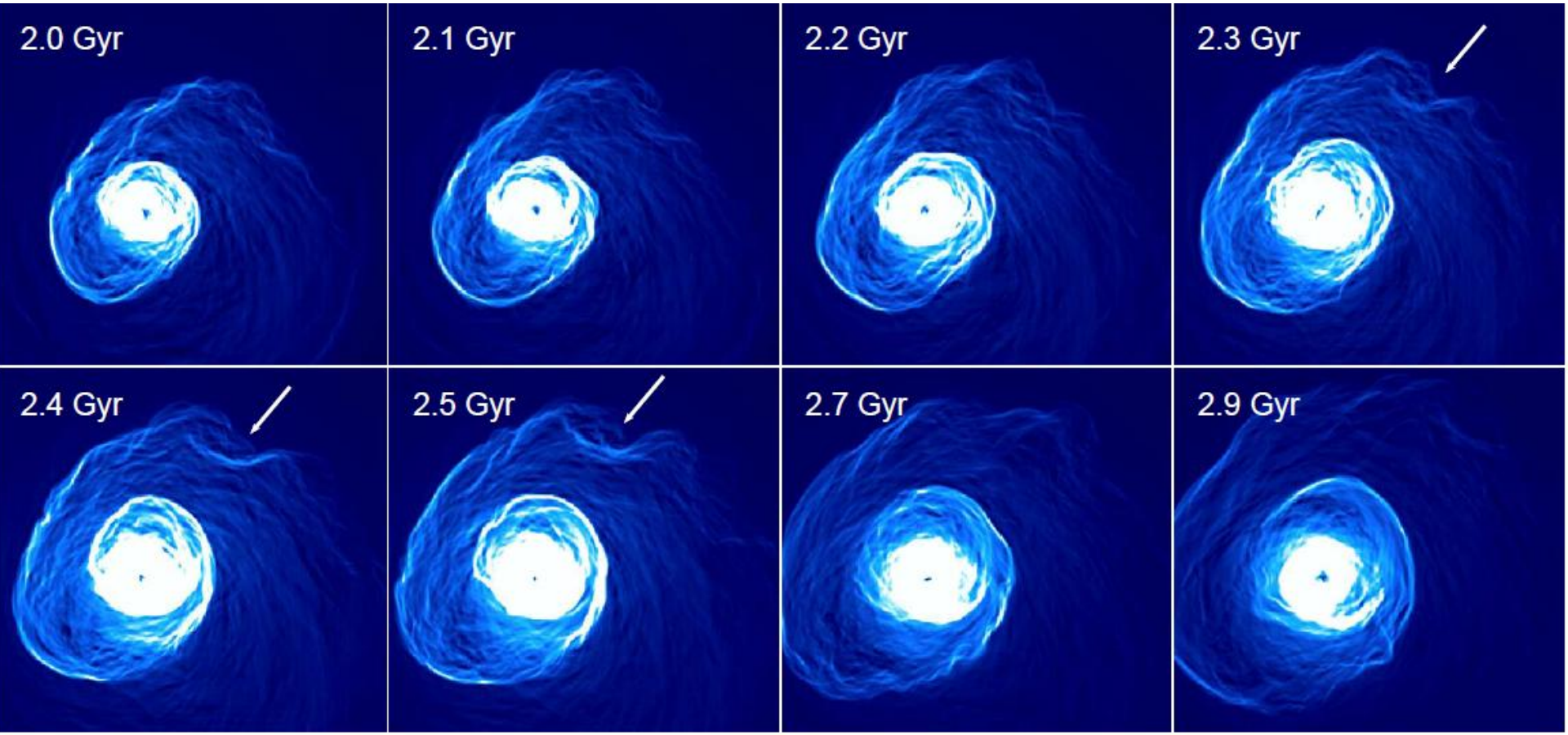



CHANDRA X-RAY

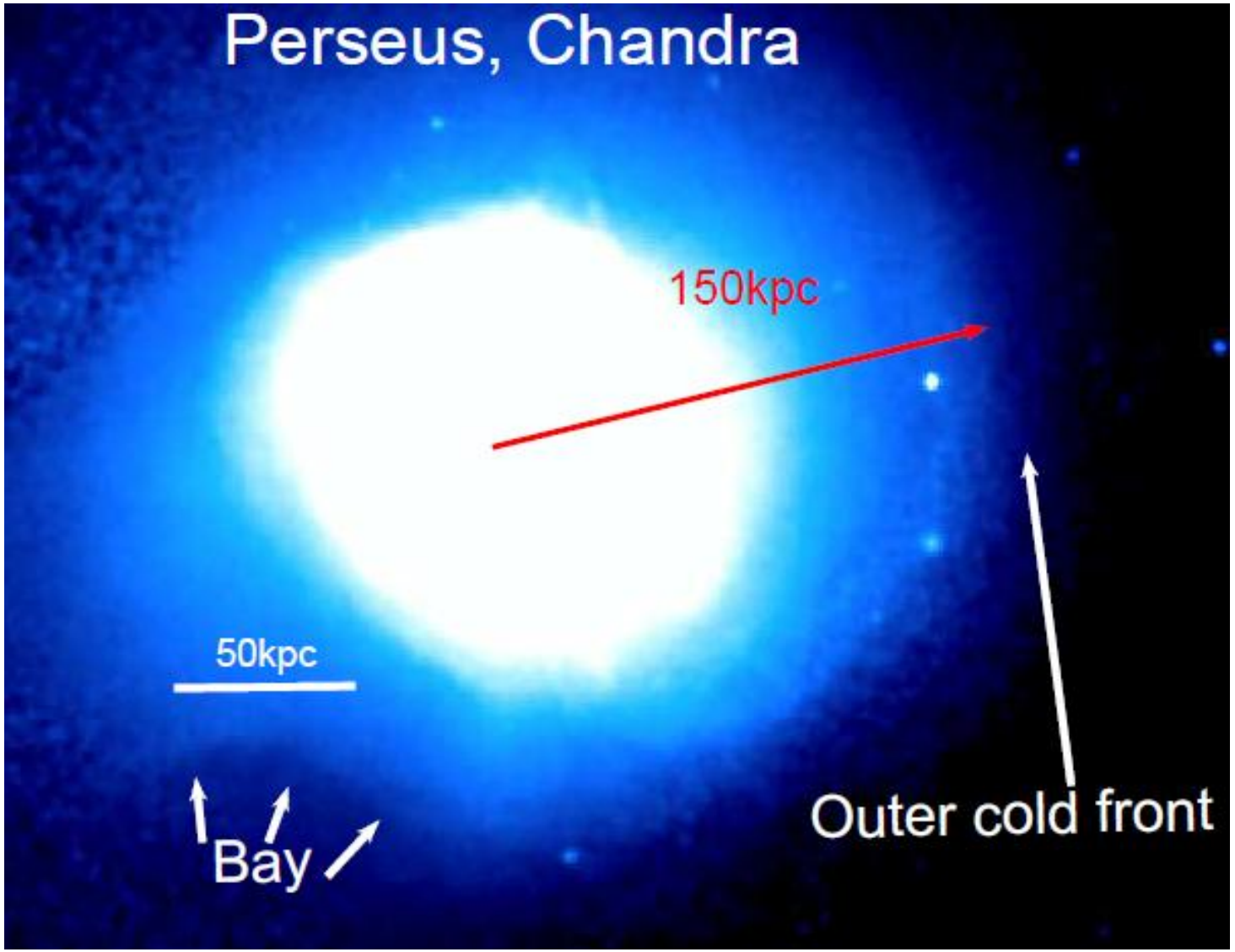

Perseus

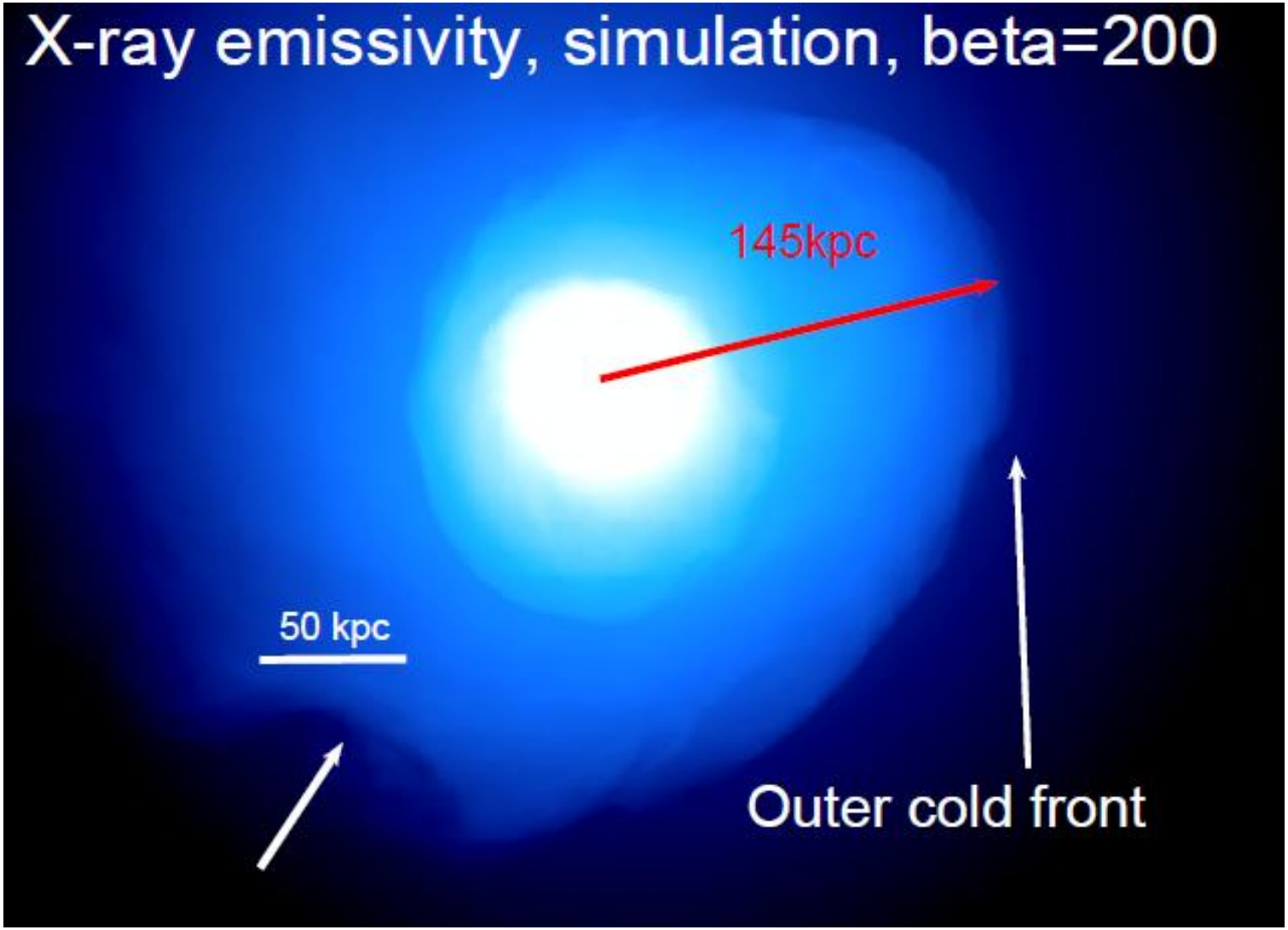

JVLA 230-470MHz

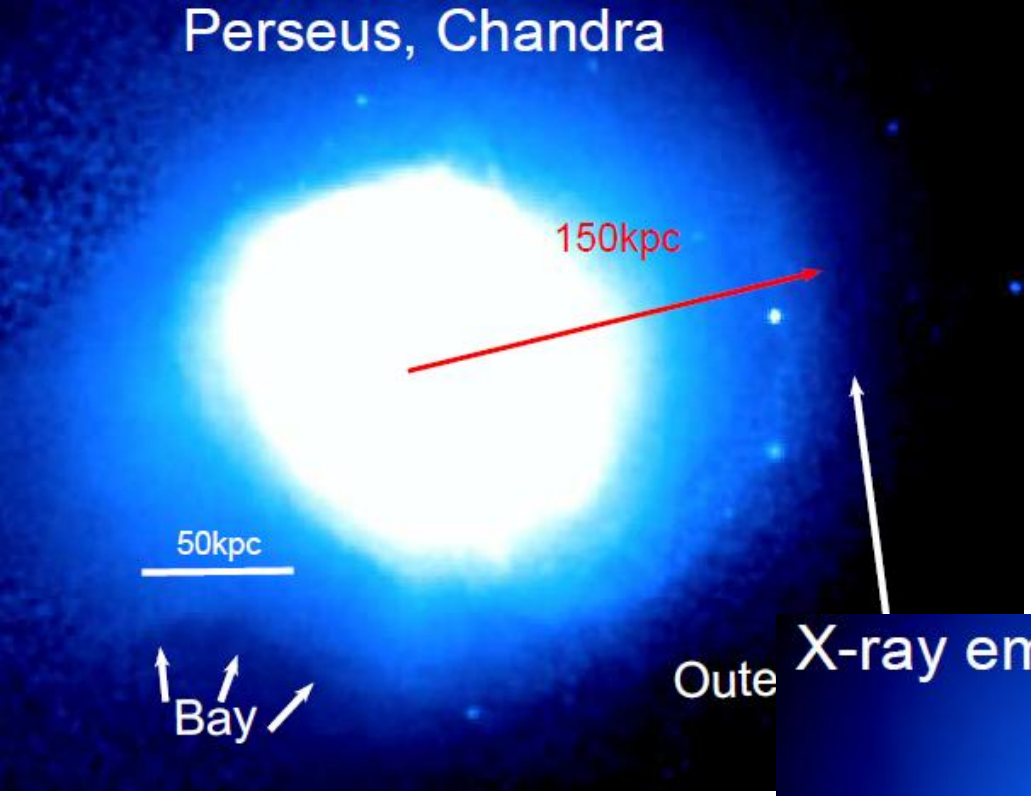
Comparing to simulations

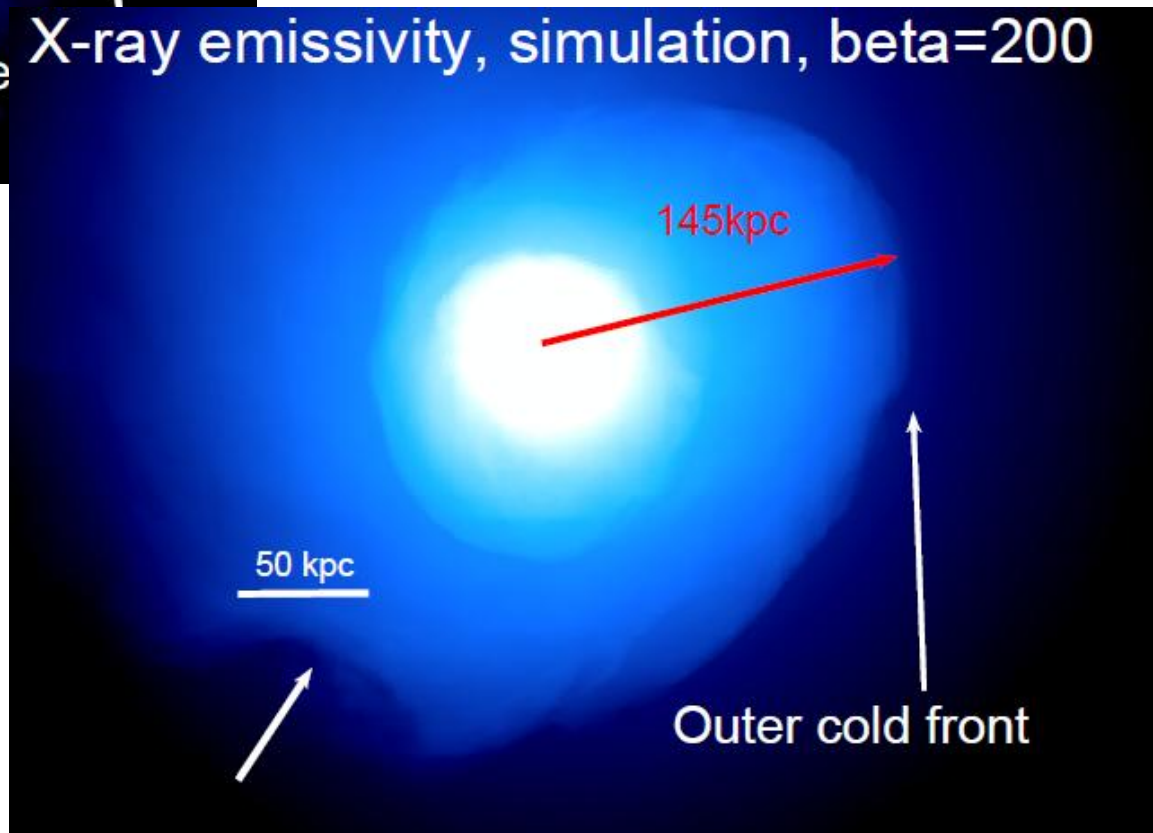


beta=p_{th}/p_B =200

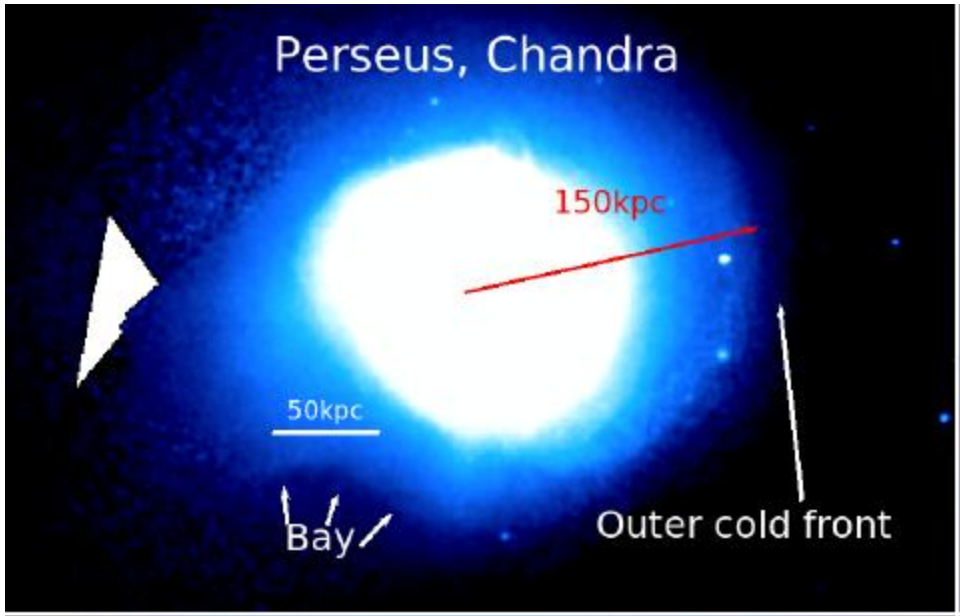

Perseus, Chandra
150kpc
50kpc
Bay
Outer cold front

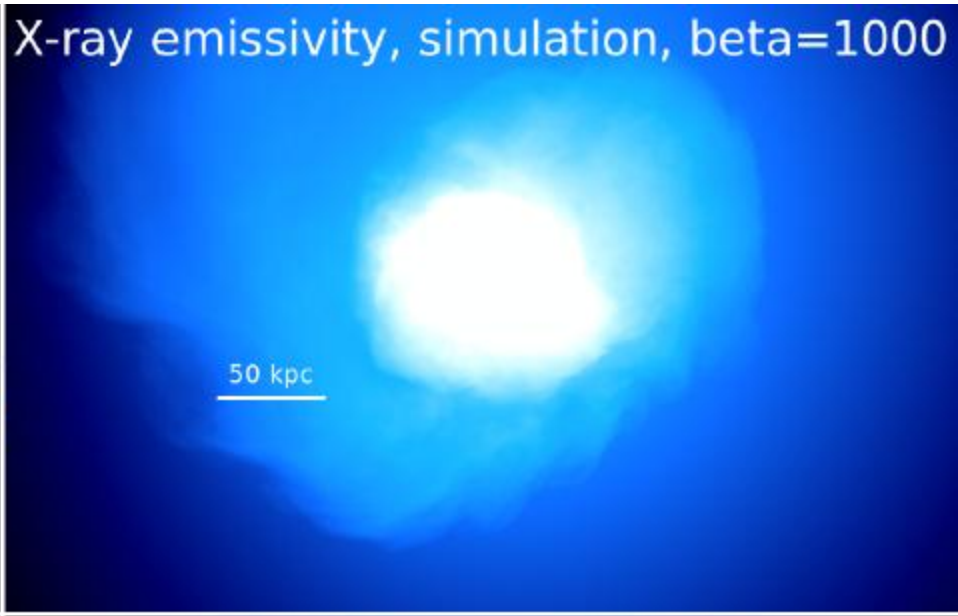

X-ray emissivity, simulation, beta=200
145kpc
50 kpc
Outer cold front

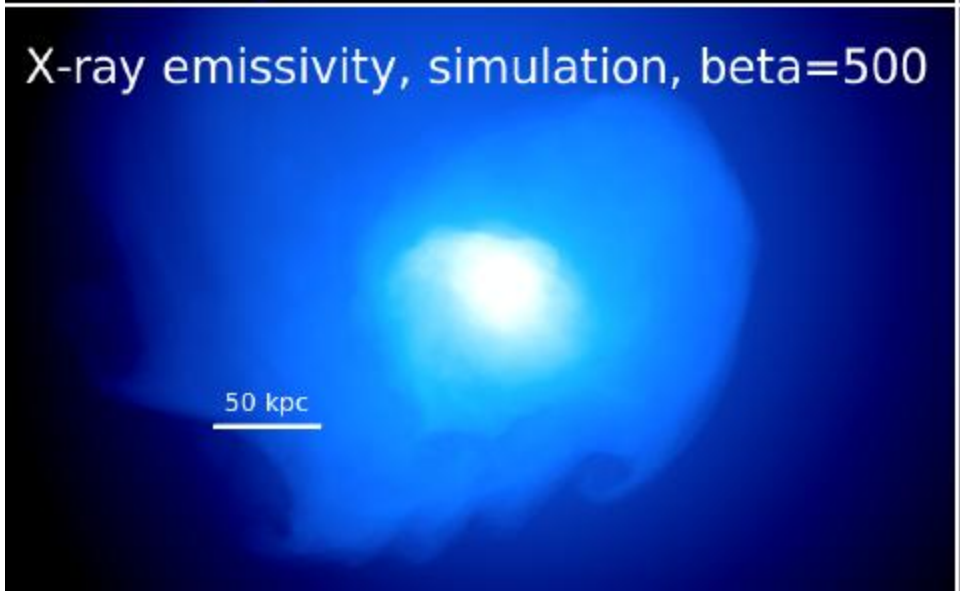

Perseus, Chandra
150kpc
50kpc
Bay
Oute

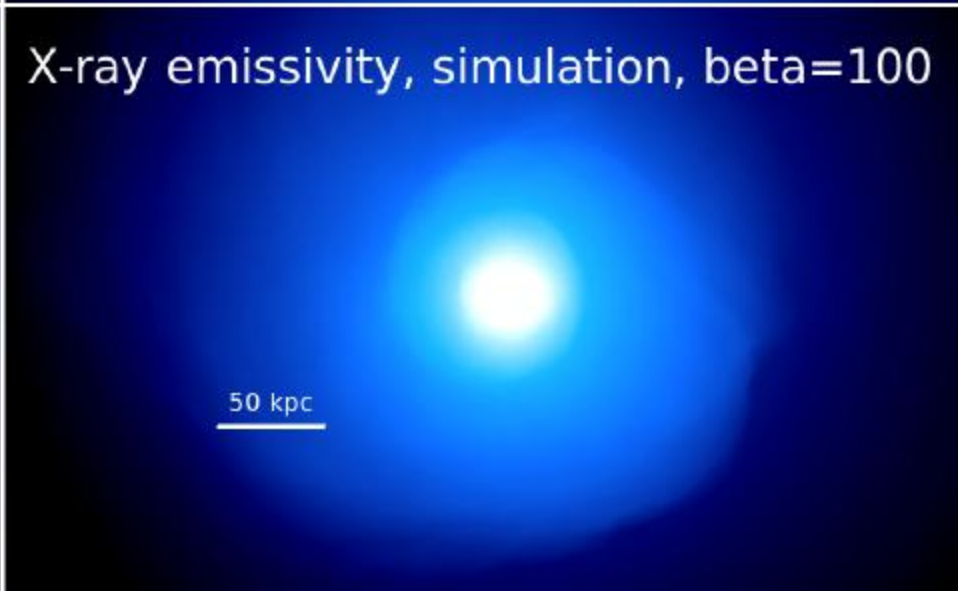

X-ray emissivity, simulation, beta=200
145kpc
50 kpc
Outer cold front

Different B field strengths don’t work

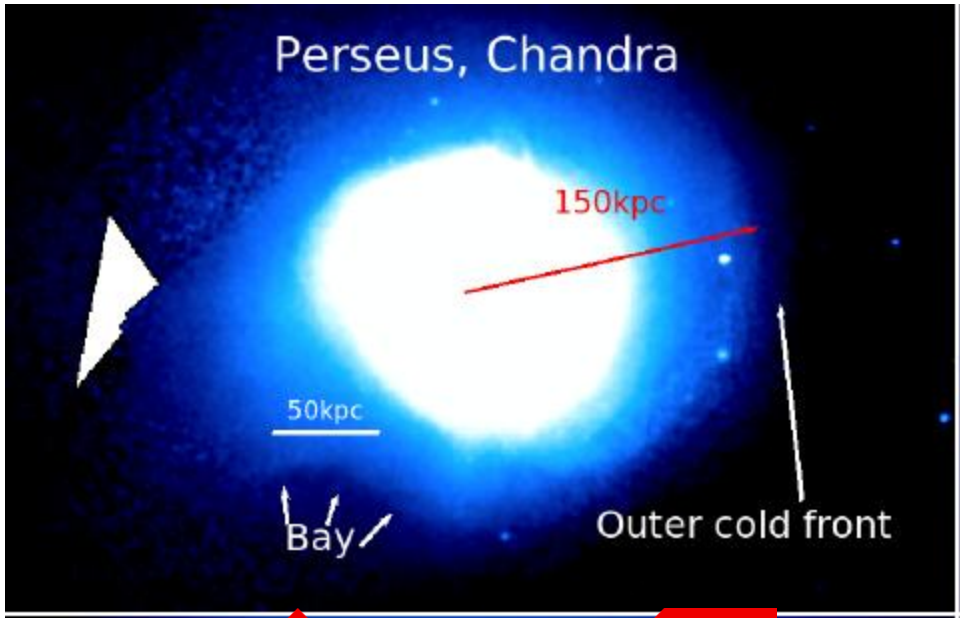


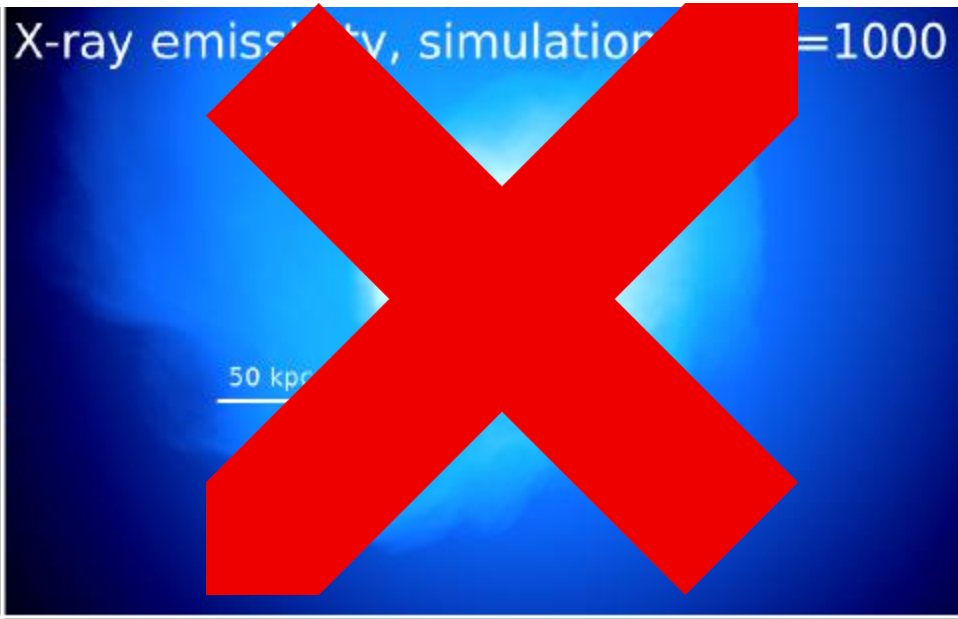


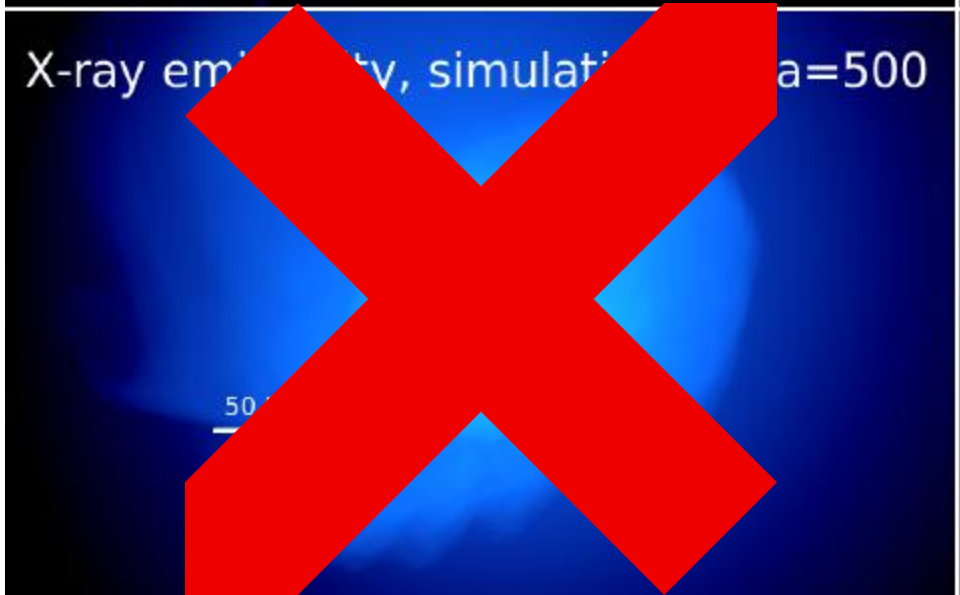


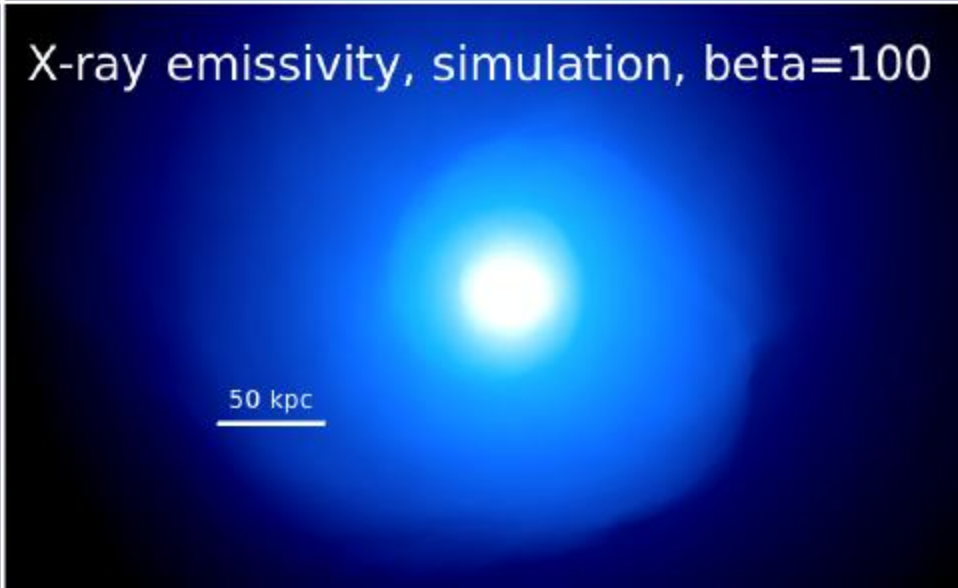


Different B field strengths don’t work

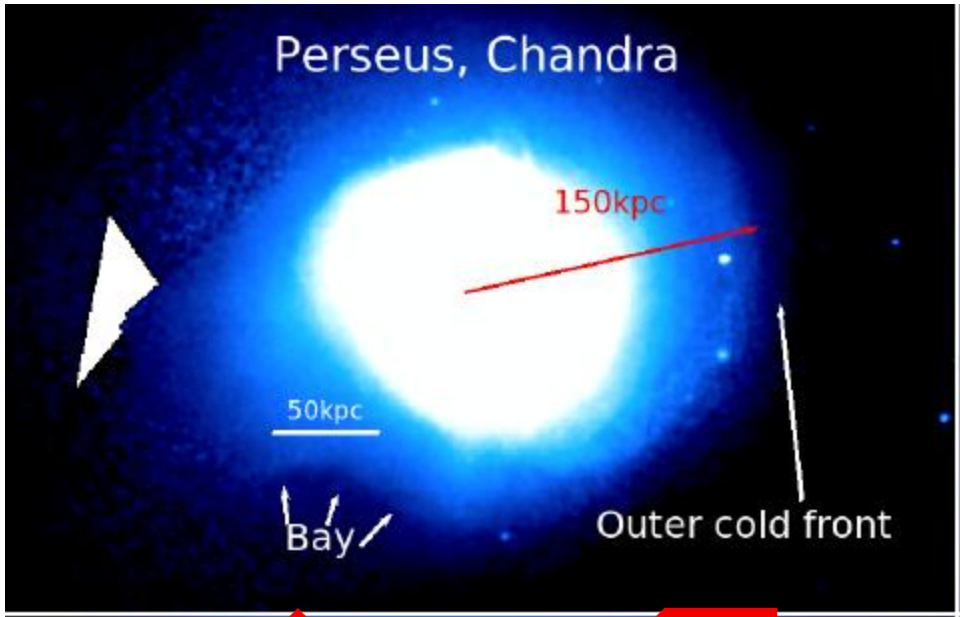


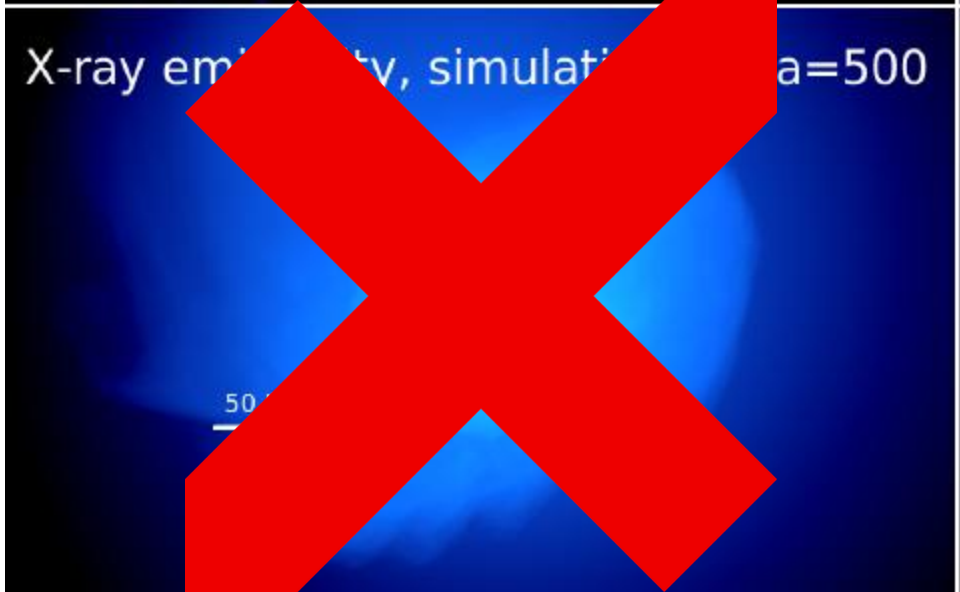


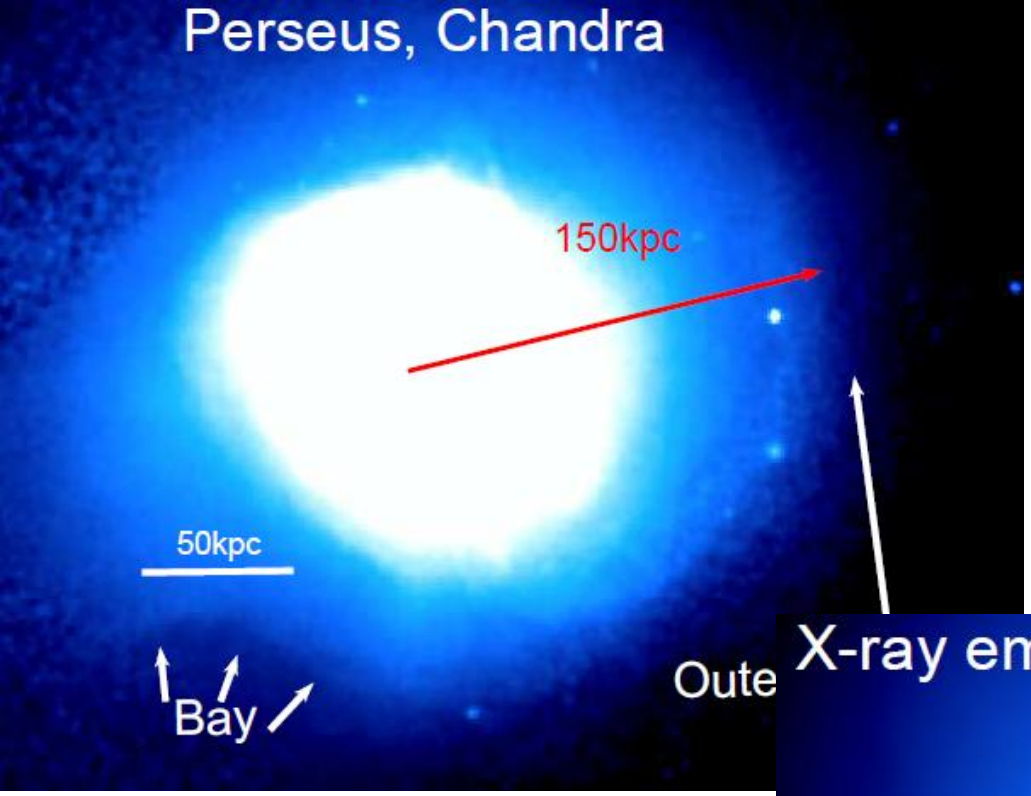


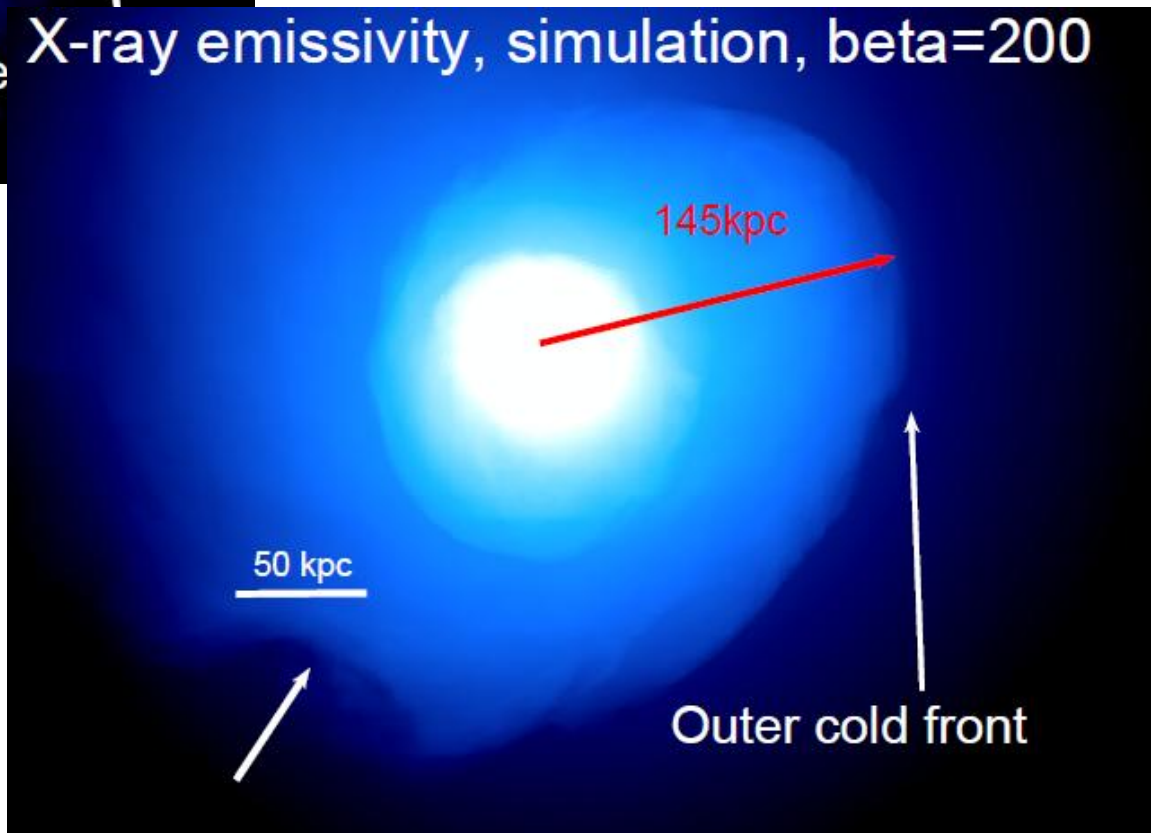


Different B field strengths don’t work

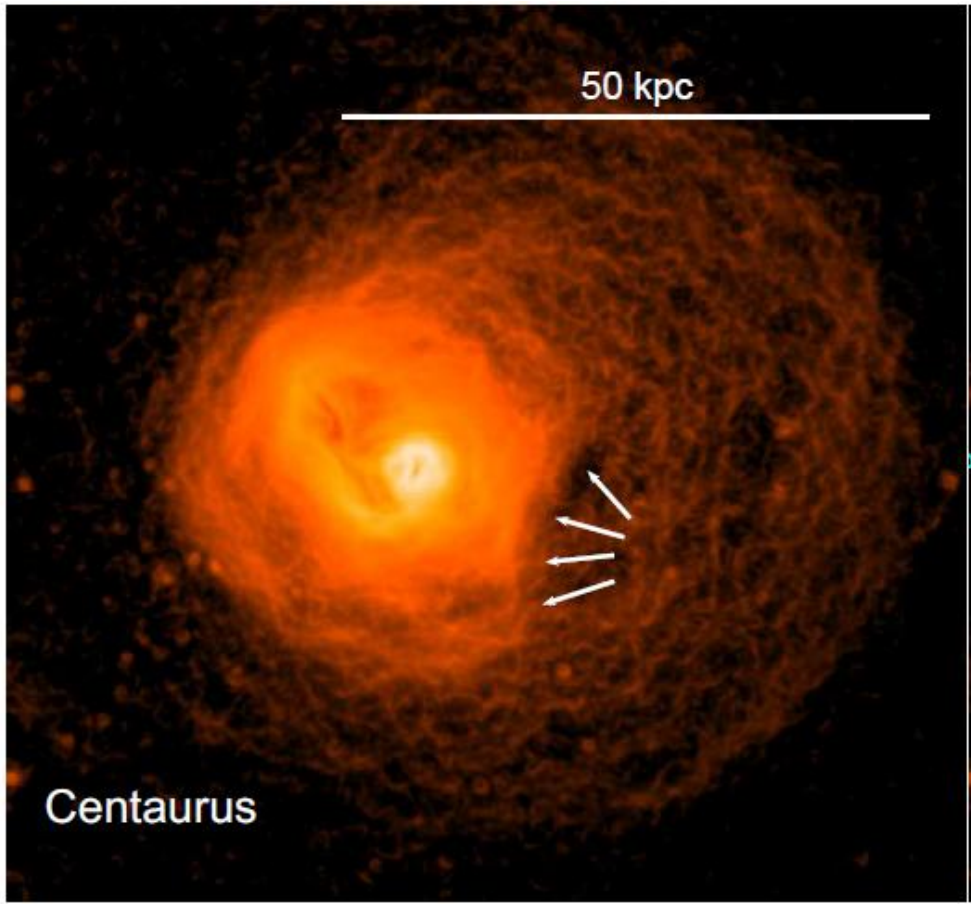


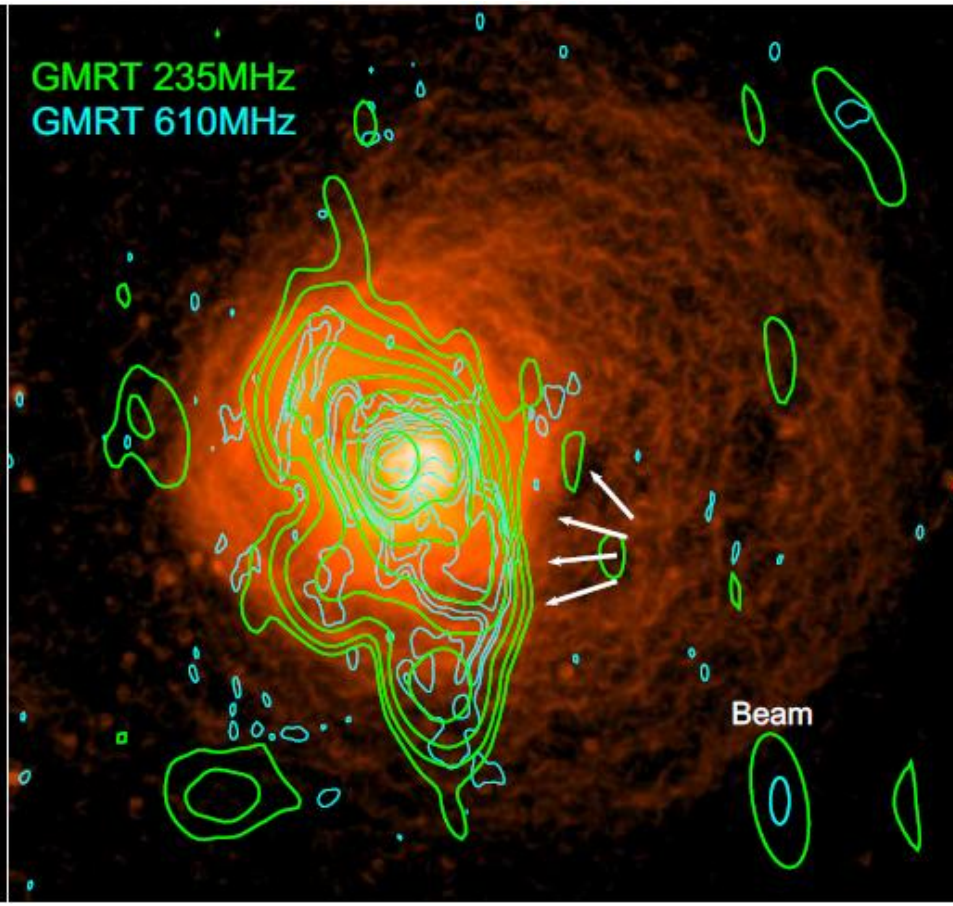



Perseus, Chandra
150kpc
50kpc
Bay
Oute

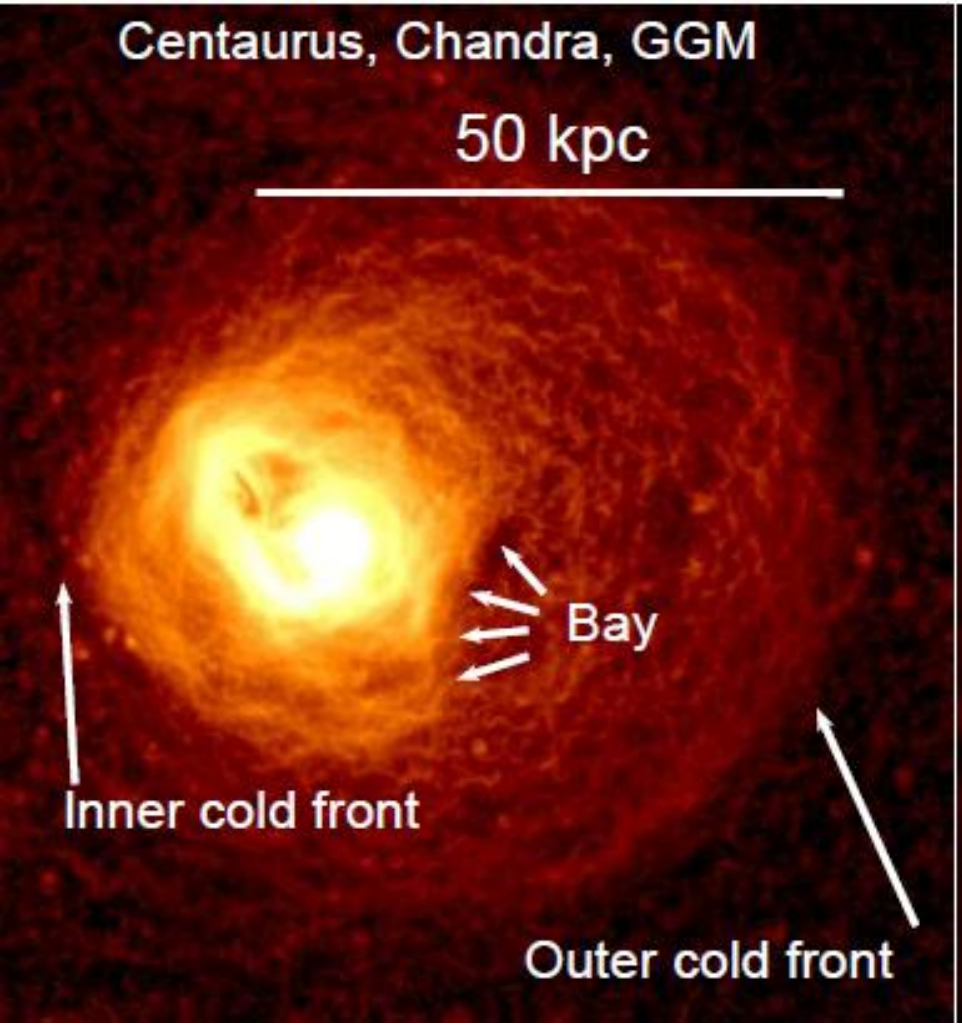

X-ray emissivity, simulation, beta=200
145kpc
50 kpc
Outer cold front

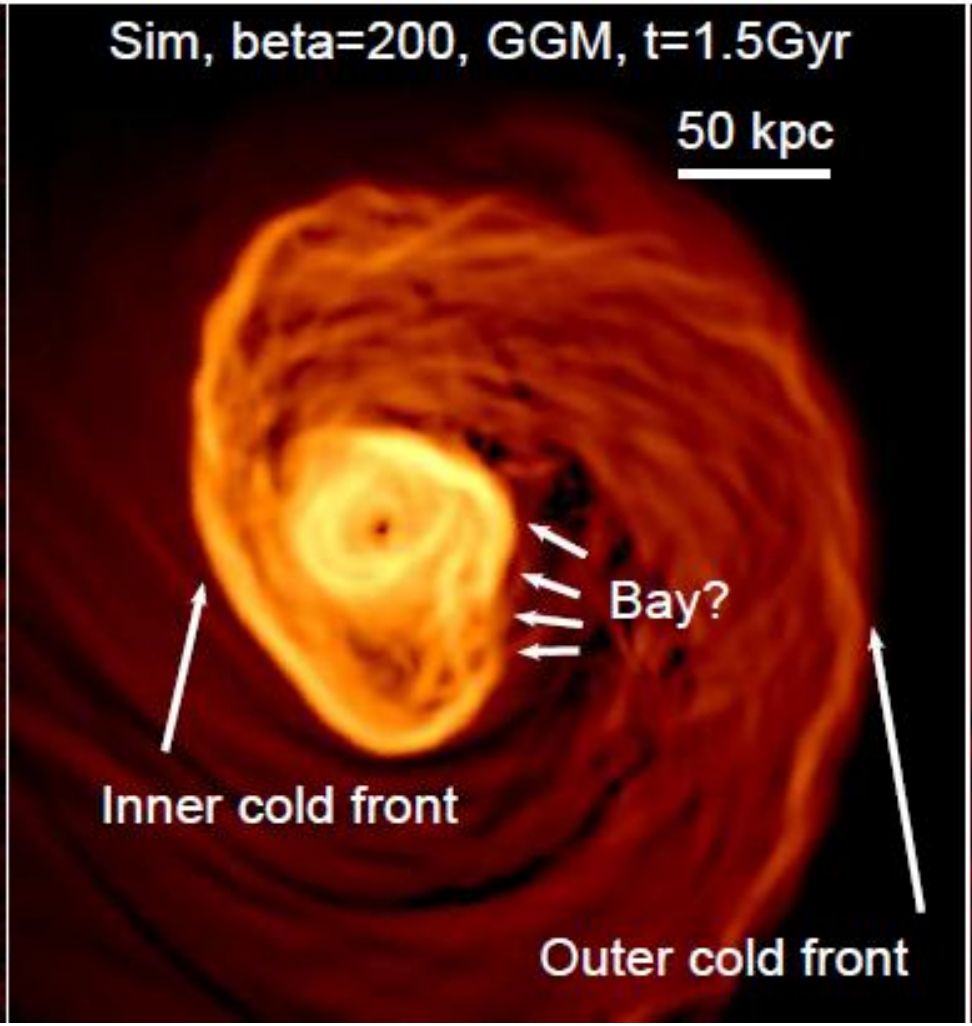
Centaurus



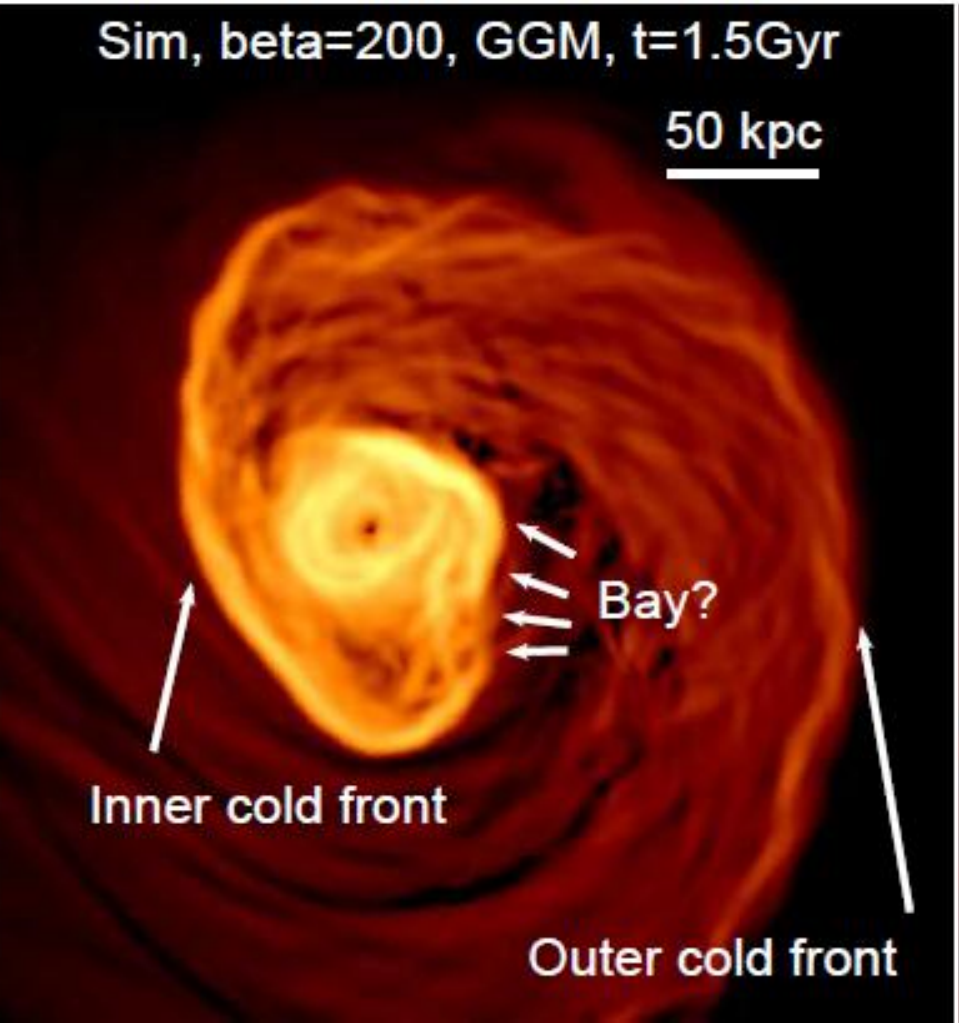


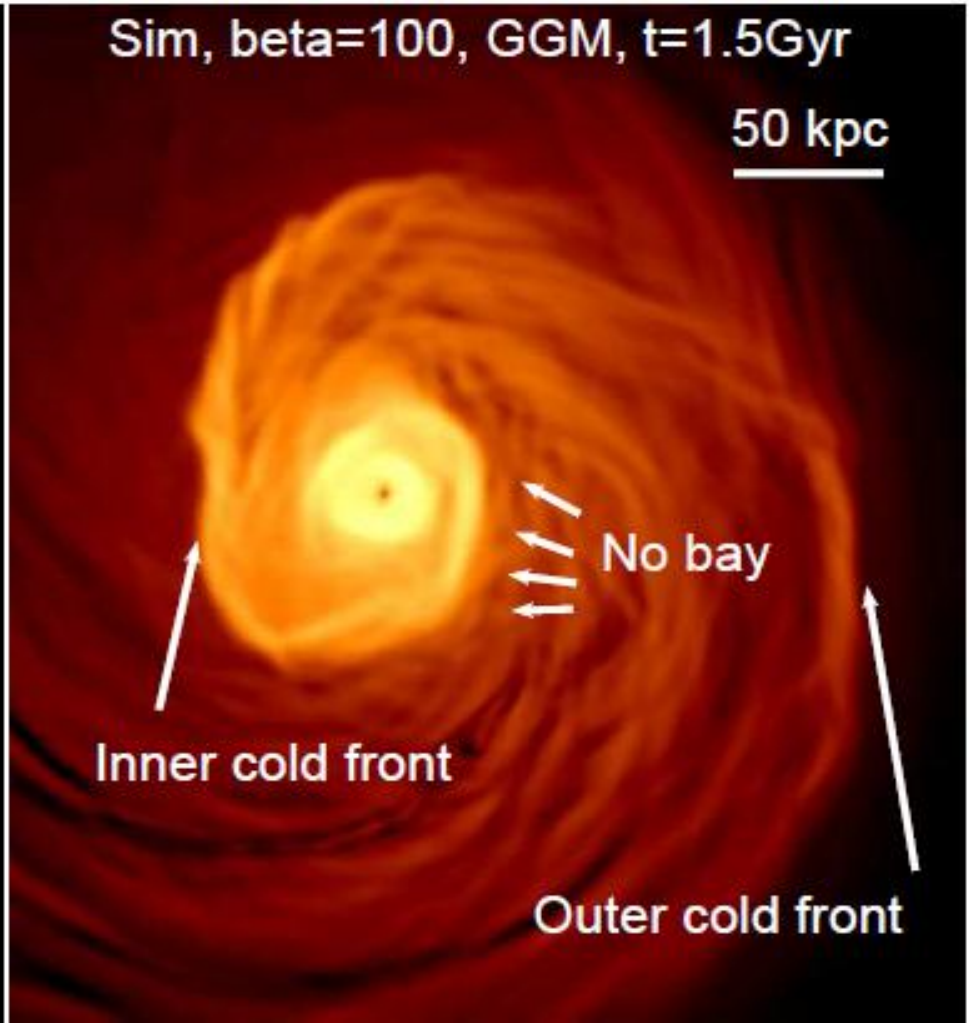
Centaurus


Centaurus, Chandra, GGM
50 kpc
Bay
Inner cold front
Outer cold front

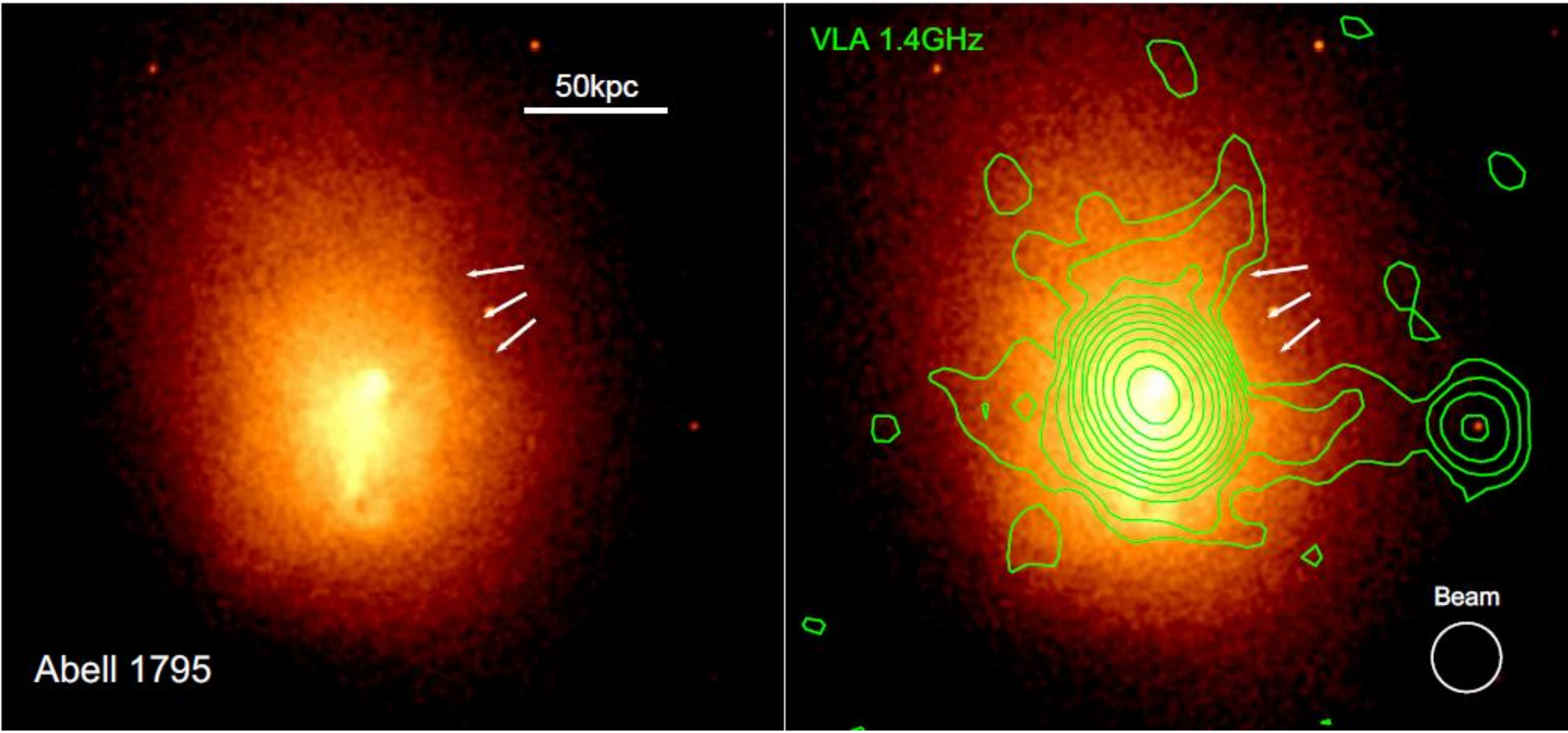

Sim, beta=200, GGM, t=1.5Gyr
50 kpc
Bay?
Inner cold front
Outer cold front

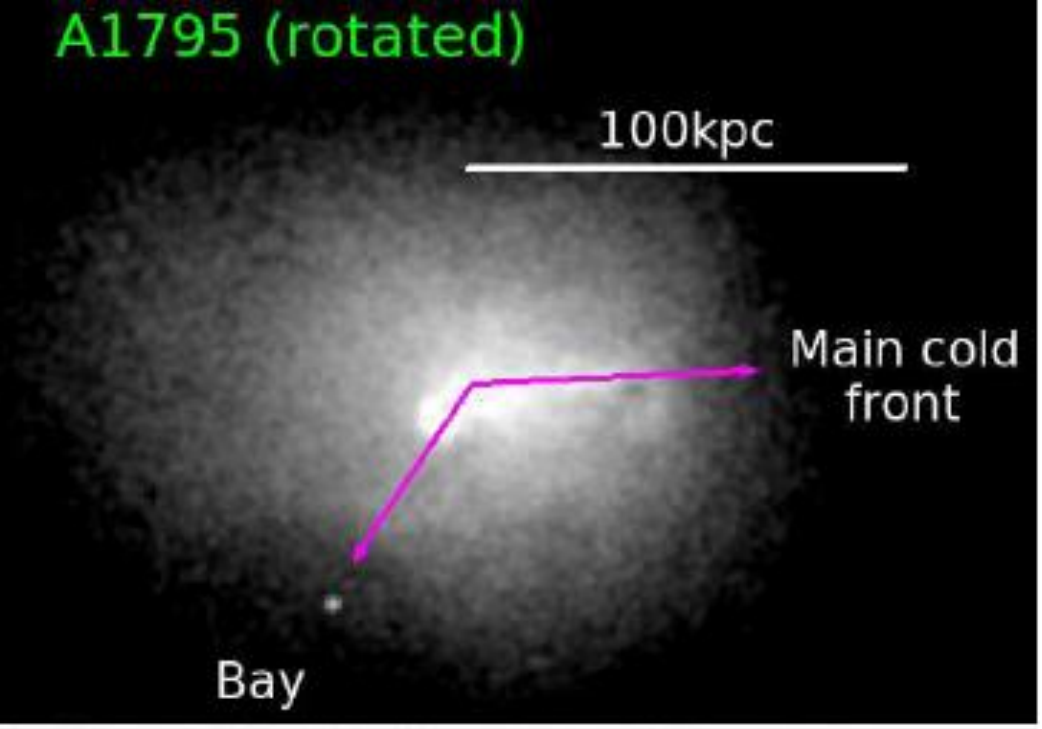
Centaurus

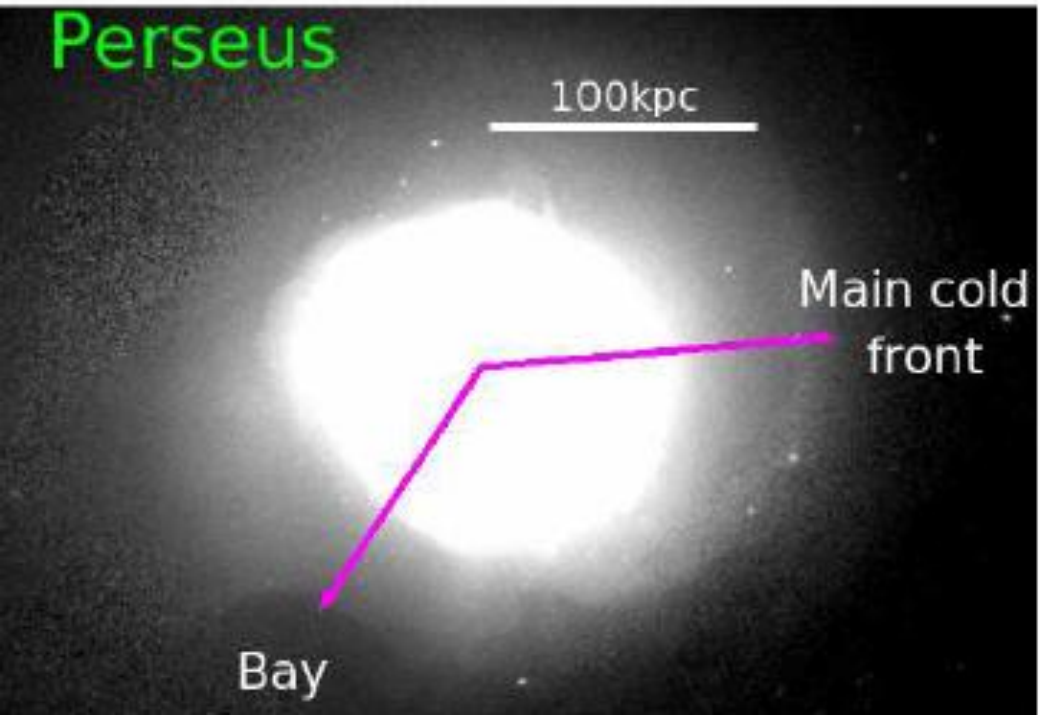

Sim, beta=200, GGM, t=1.5Gyr
50 kpc
Bay?
Inner cold front
Outer cold front


Sim, beta=100, GGM, t=1.5Gyr
50 kpc
No bay
Inner cold front
Outer cold front

Abell 1795




A1795 (rotated)
100kpc
Main cold front
Bay


Perseus
100kpc
Main cold front
Bay

Abell 1795

Conclusions

- Bay in Perseus is consistent with being an ‘inverted’ cold front
- Radio, X-ray surface brightness, temperature and metal distribution most consistent with this
- Consistent with simulations of gas sloshing
- If true, can provide constraints on ICM physics, B field

Conclusions

- Different scenarios for cluster microphysics lead to significant differences in large, (~50kpc) size structures.
- Similar features seen in Centaurus and Abell 1795
- All consistent with the same average magnetic/thermal pressure ratio (beta=200)
- Higher magnetic fields strongly disfavoured.


Grazie!