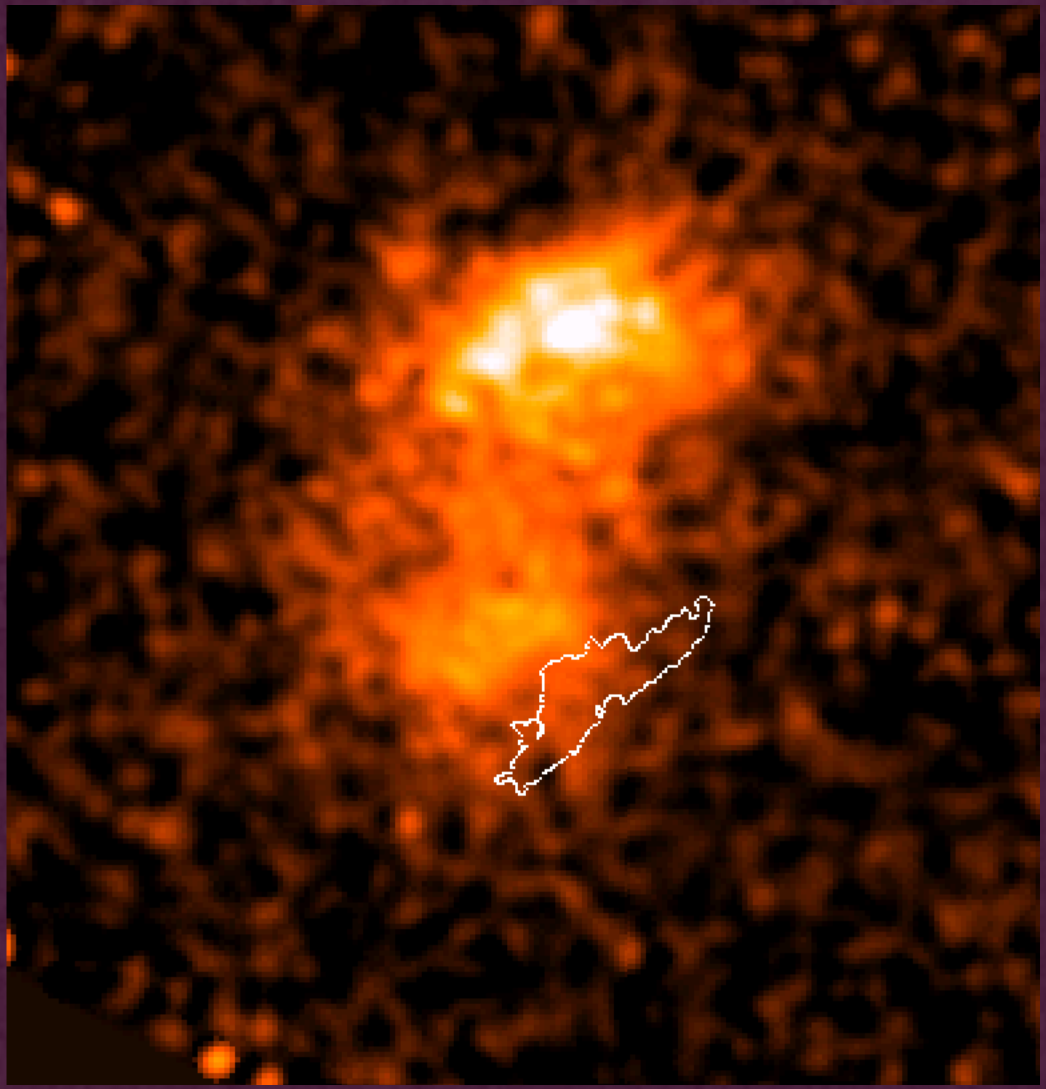
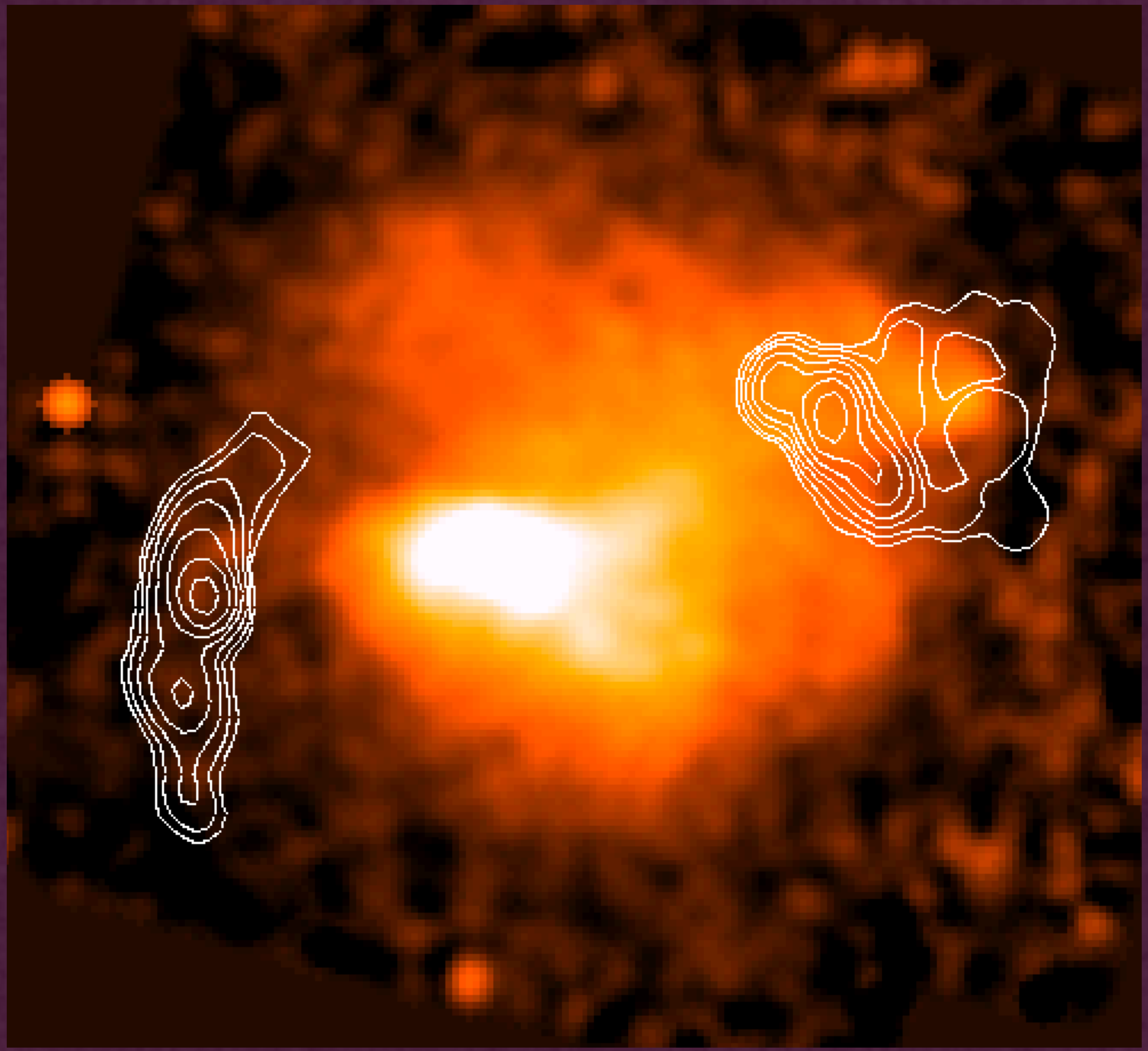
Searching for X-ray shock fronts at radio relic edges in PLCKESZ G200.9-28.2, Abell 2345 with Chandra

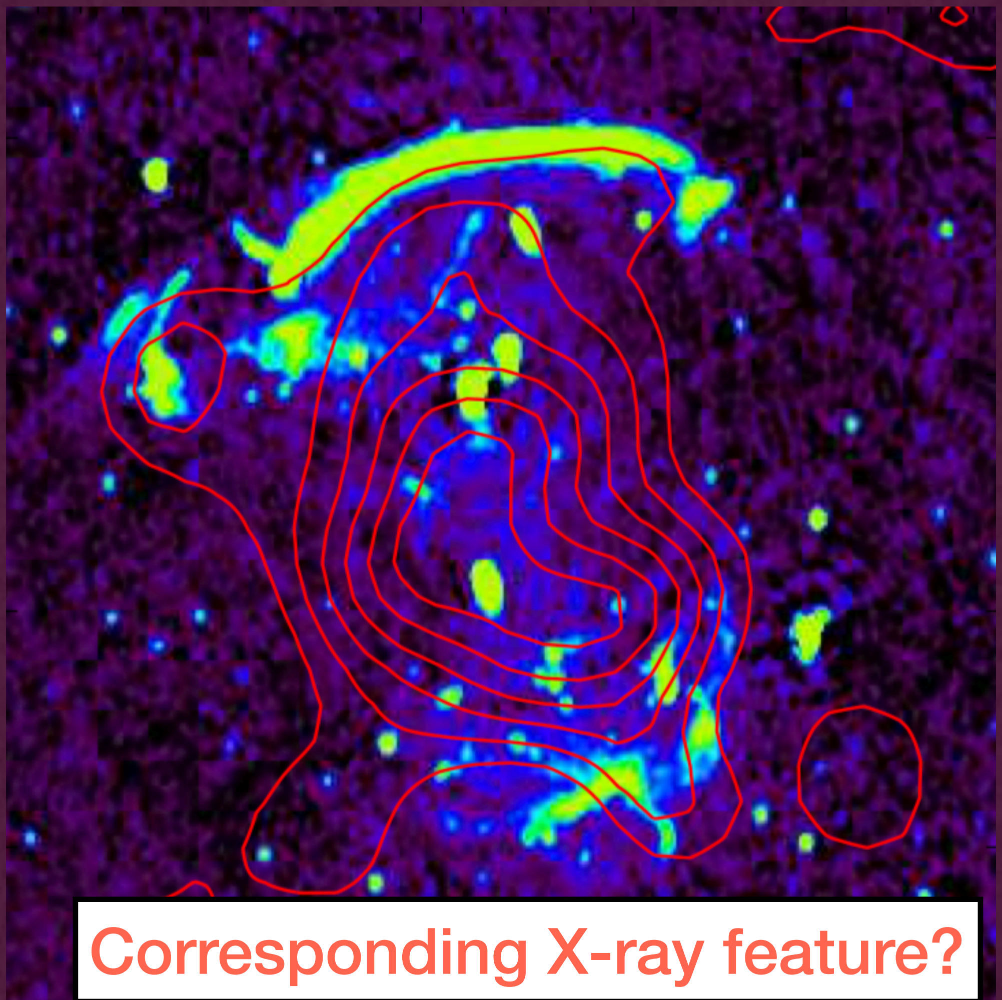


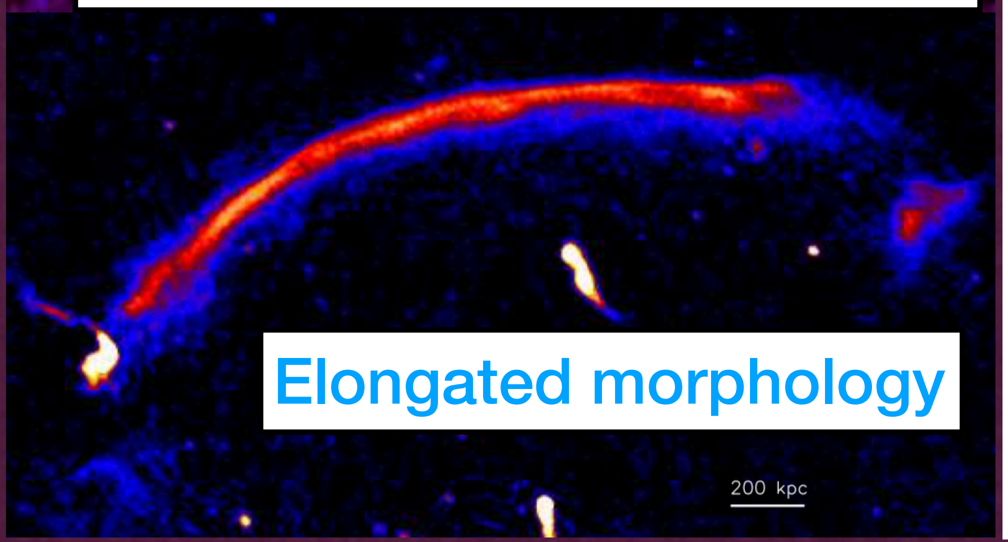


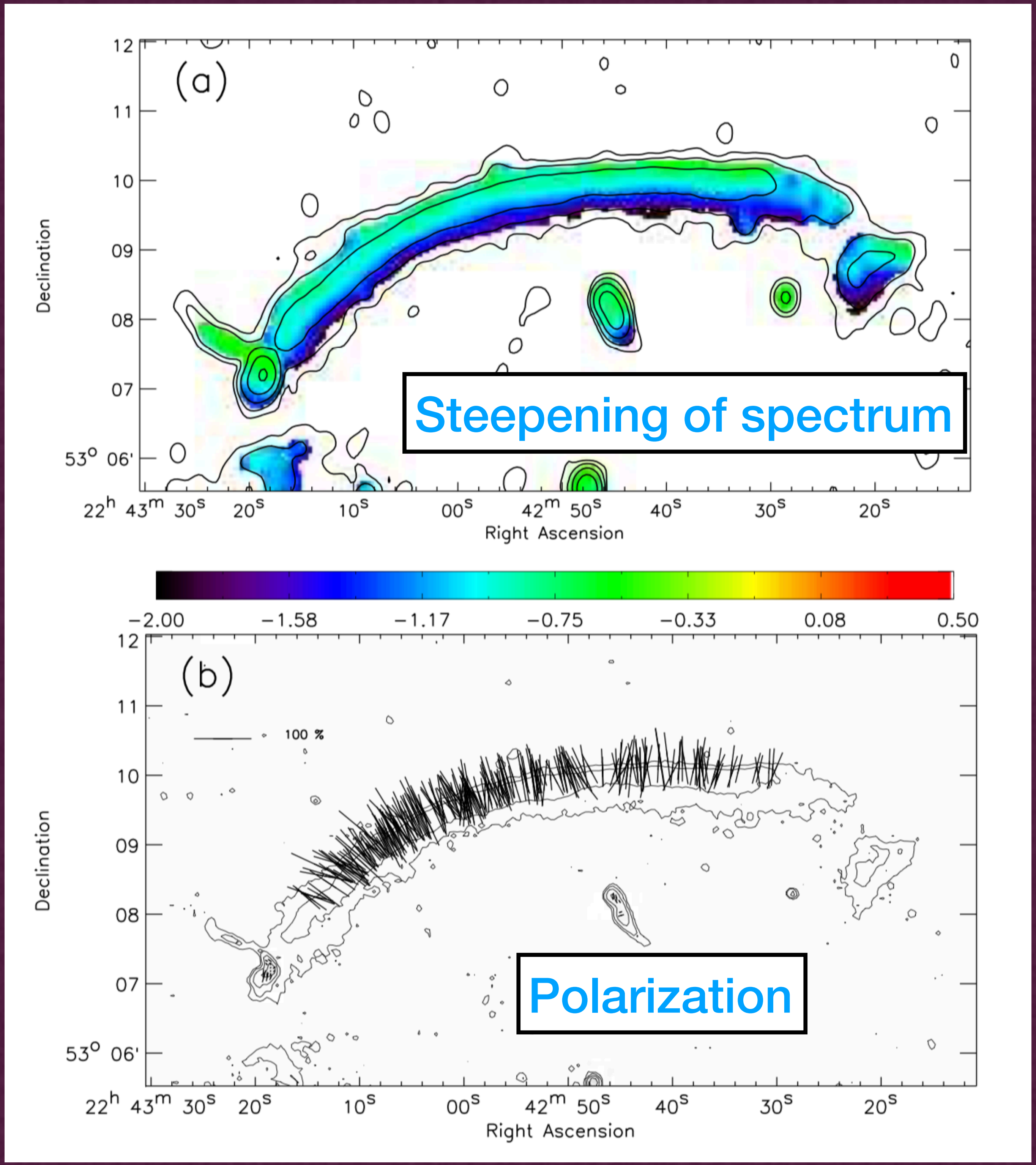
Qian Wang (University of Utah)

With Daniel Wik, Sarina Etheridge

Radio relics



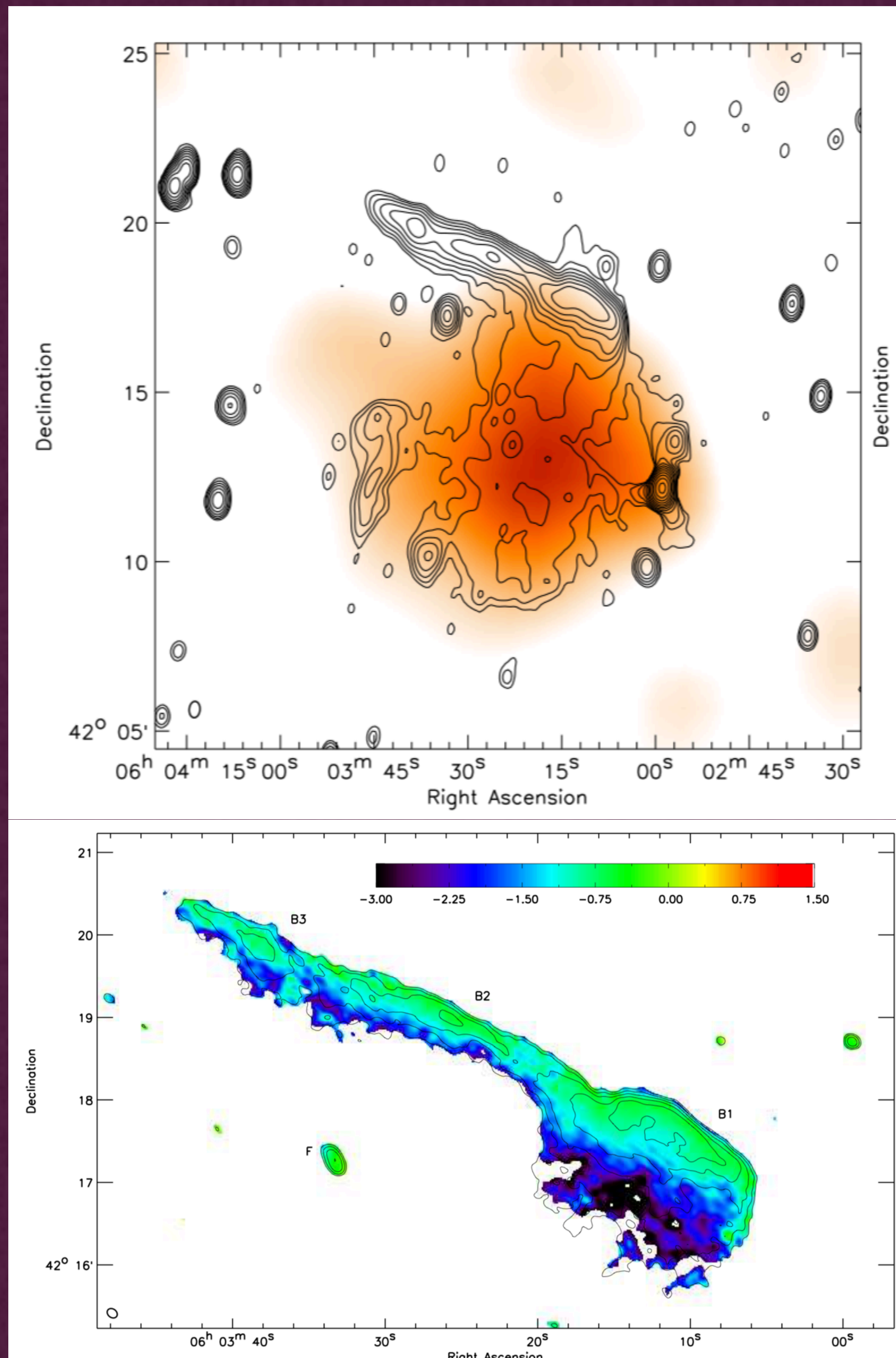




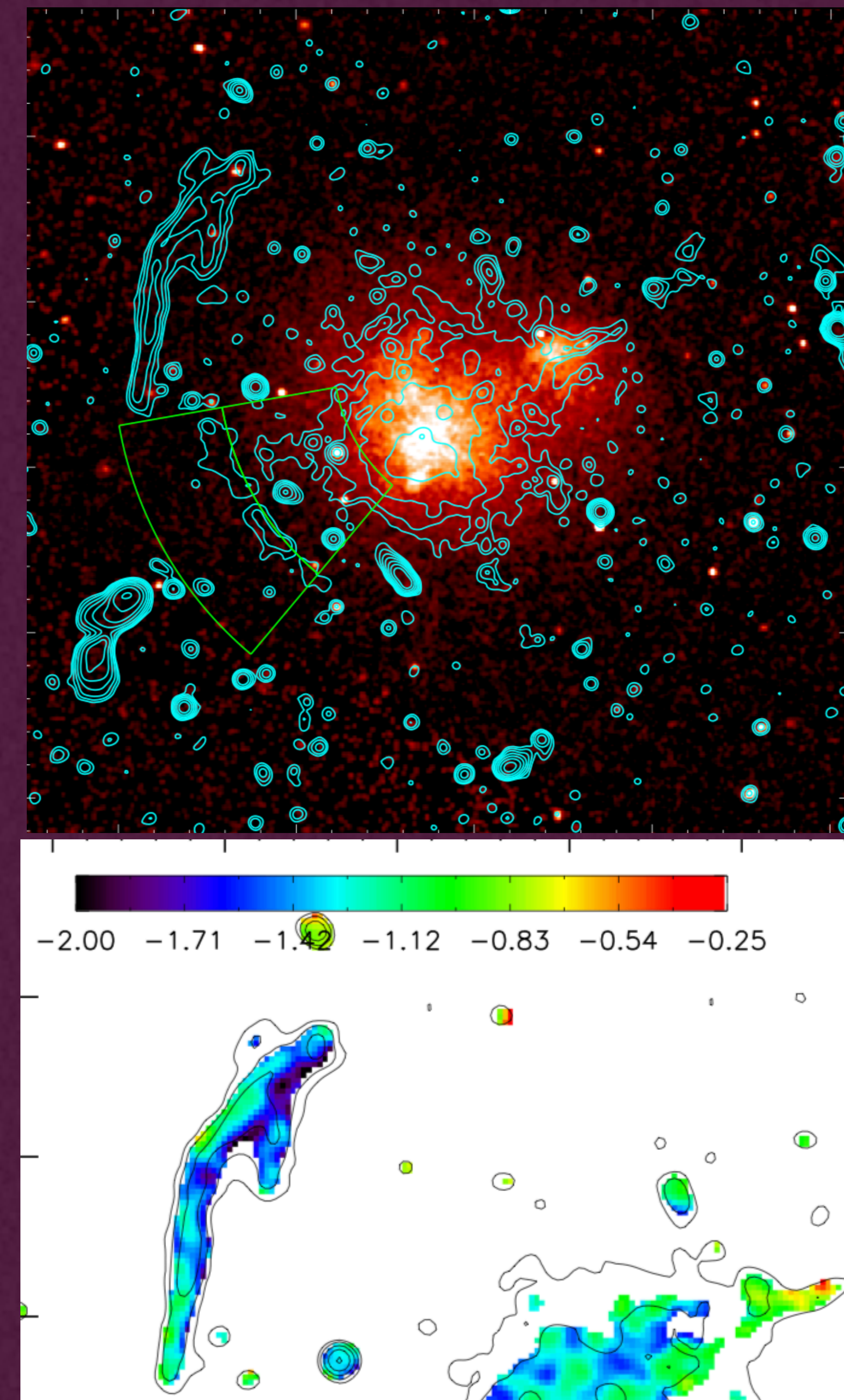
“Sausage” relic

van Weeren+ 2010

Radio relics

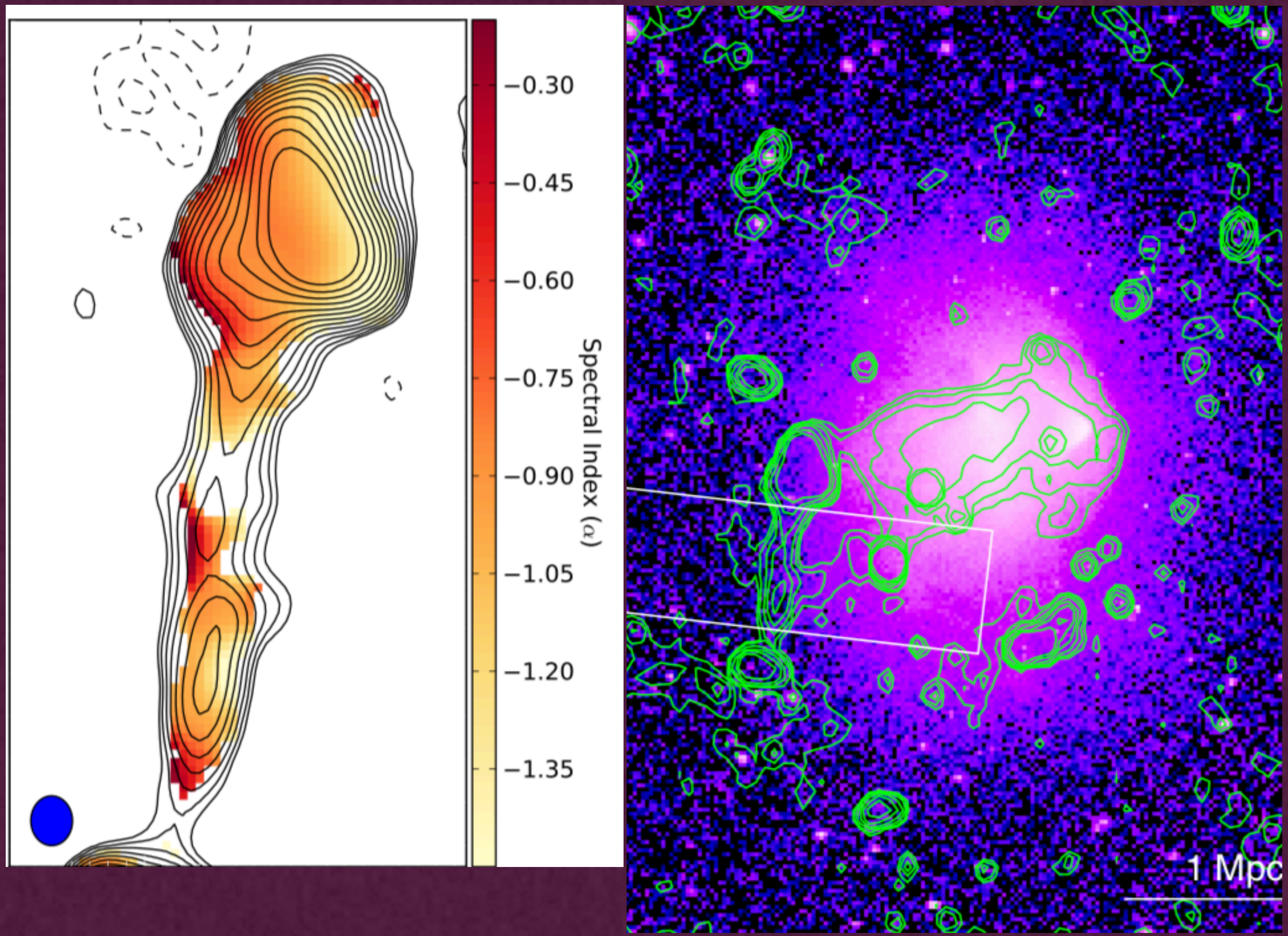


“Toothbrush” relic
van Weeren+ 2010



Abell 2744
Pearce+ 2017

Radio relics



“Bullet” cluster
Shimwell+ 2015

… and more.

Things in common:

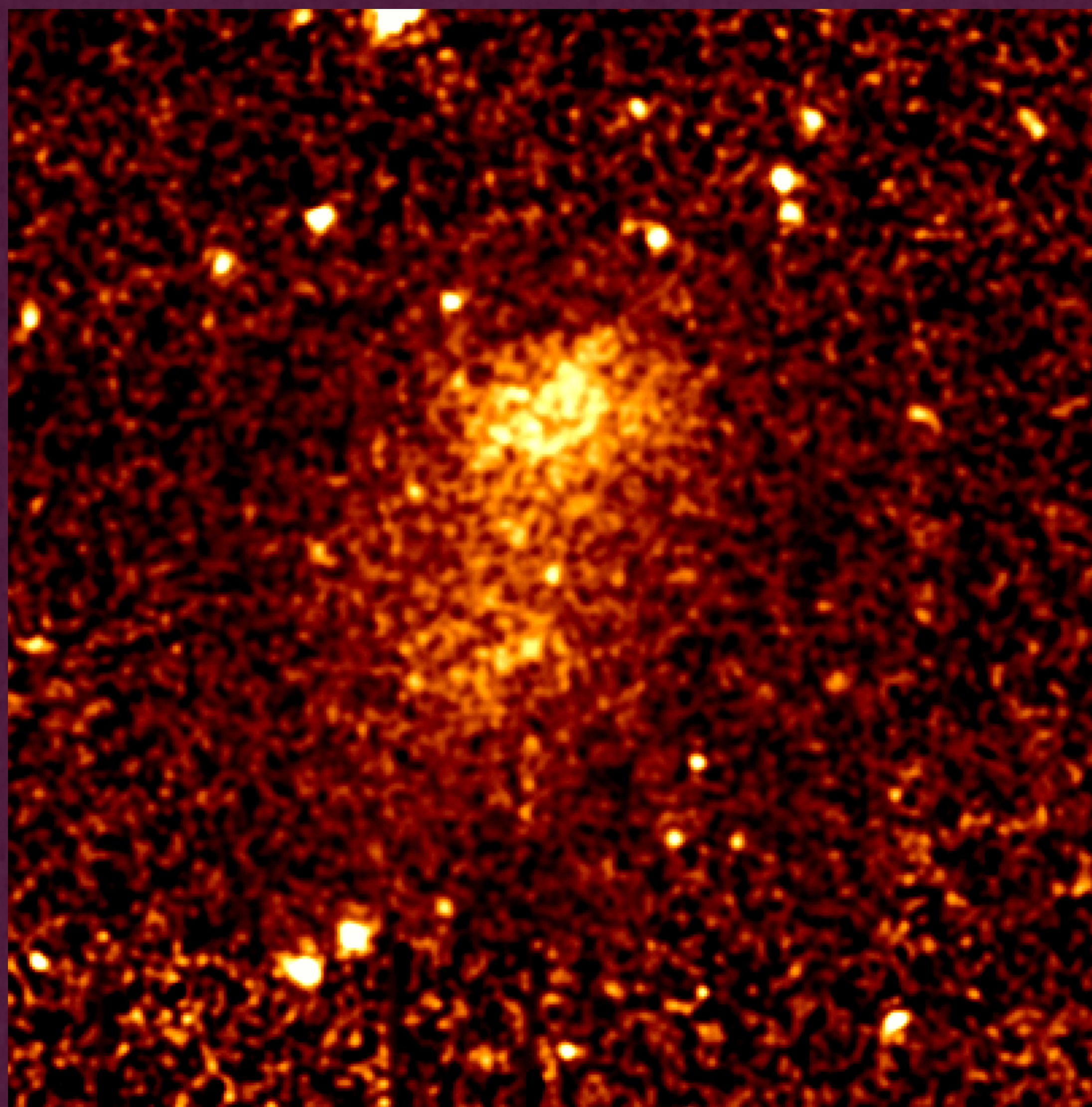
- Elongated morphology
- Large linear size
- Highly polarized
- Spectral index steepens

Radio relics

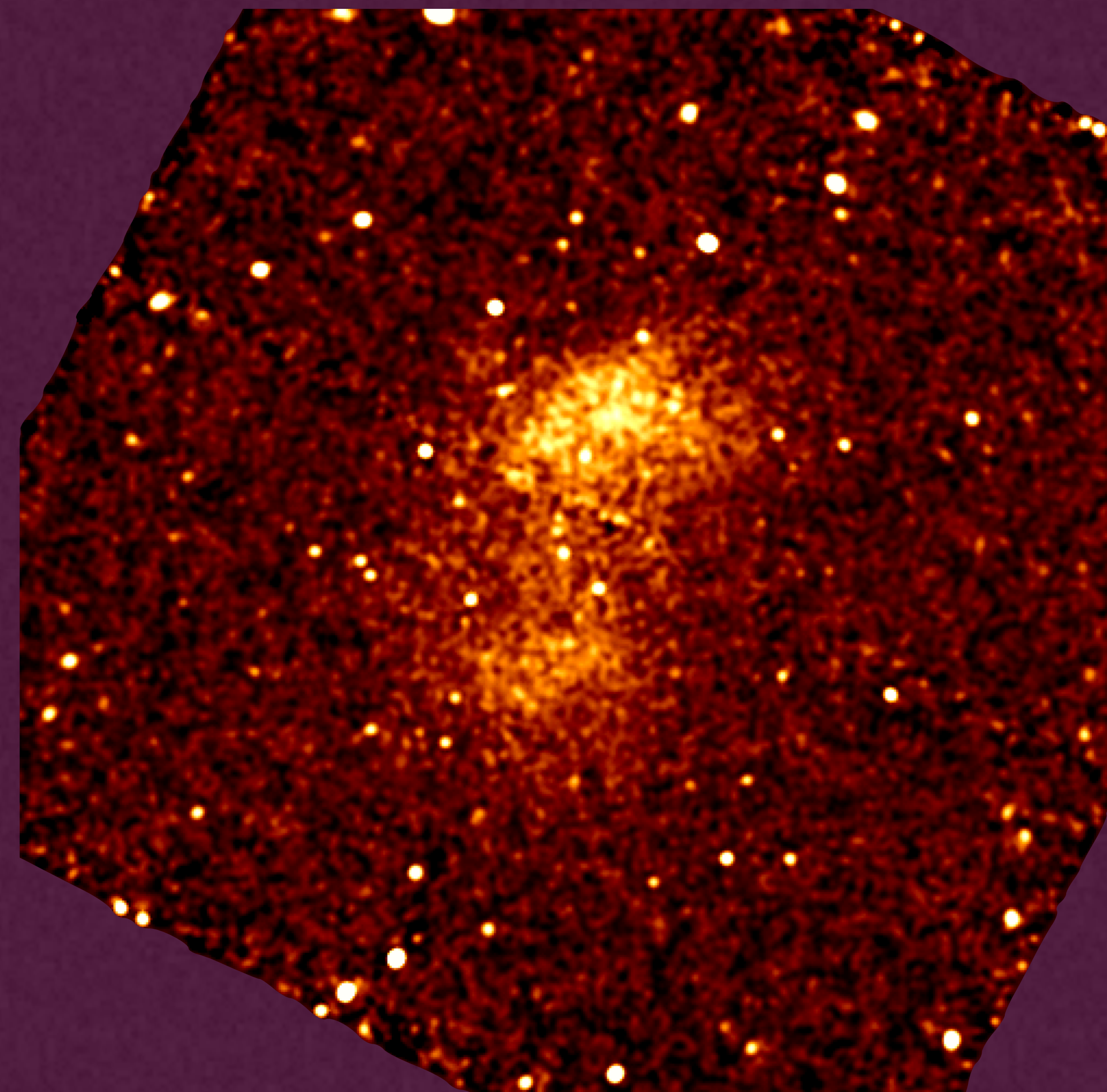
What happens at shocks?

- Adiabatic compression increases synchrotron brightness:
  - $I \sim n B^2 \sim n^2$ (radio spectrum unchanged)
- Diffusive shock acceleration (DSA) of electrons:
  - From thermal pool?
    - Low acceleration efficiency; needs strong shock (compare with supernovae remnant $M \sim 10^3$)
    - Radio spectral index $$\alpha = \frac{M^2 + 1}{M^2 - 1}$$ Stronger shock, flatter spectrum
  - From pre-existing fossil population?
    - Seed electrons required (aka fossil electrons)
    - Different radio spectra

PLCKESZ G200.9-28.2



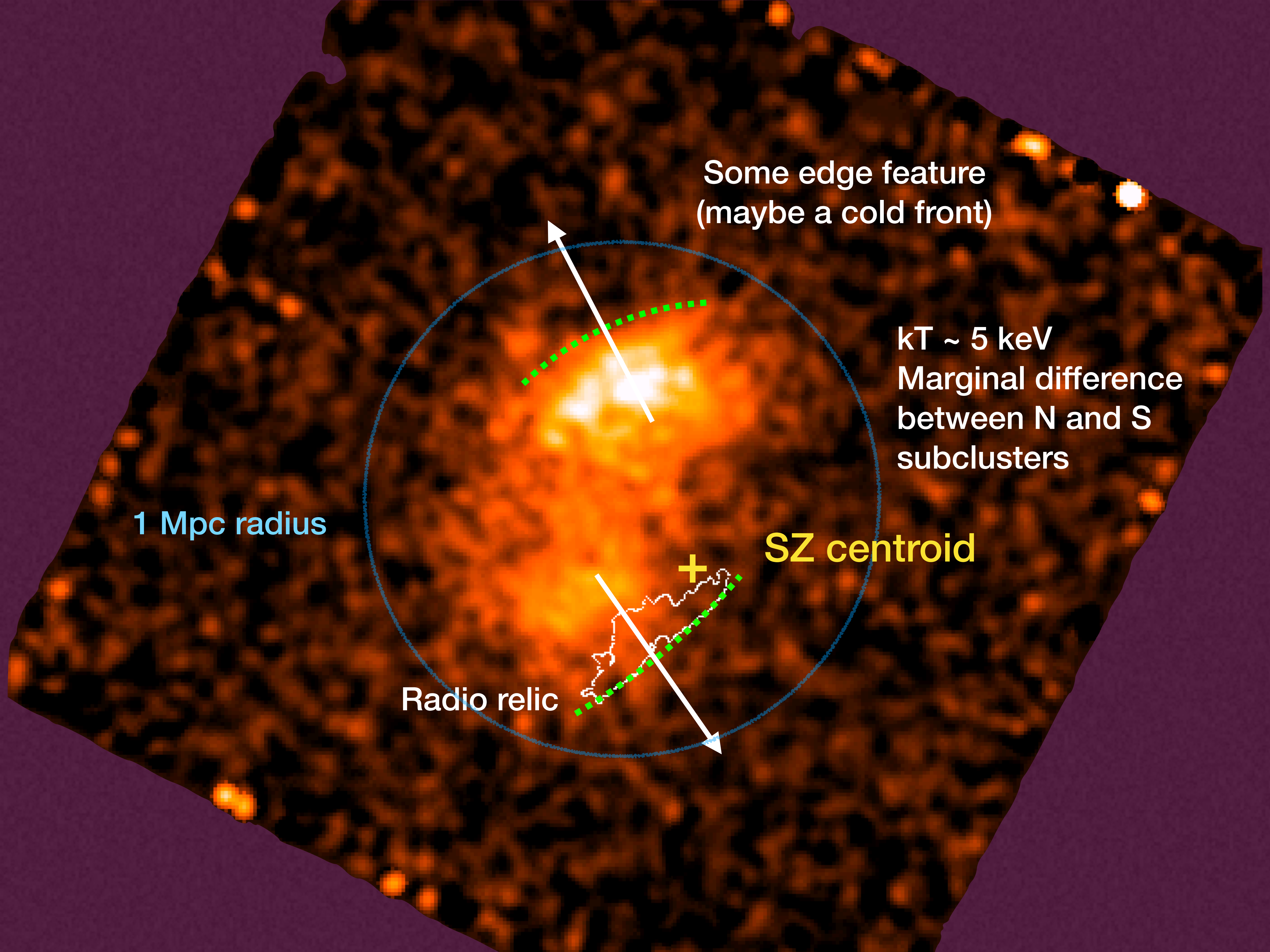
XMM



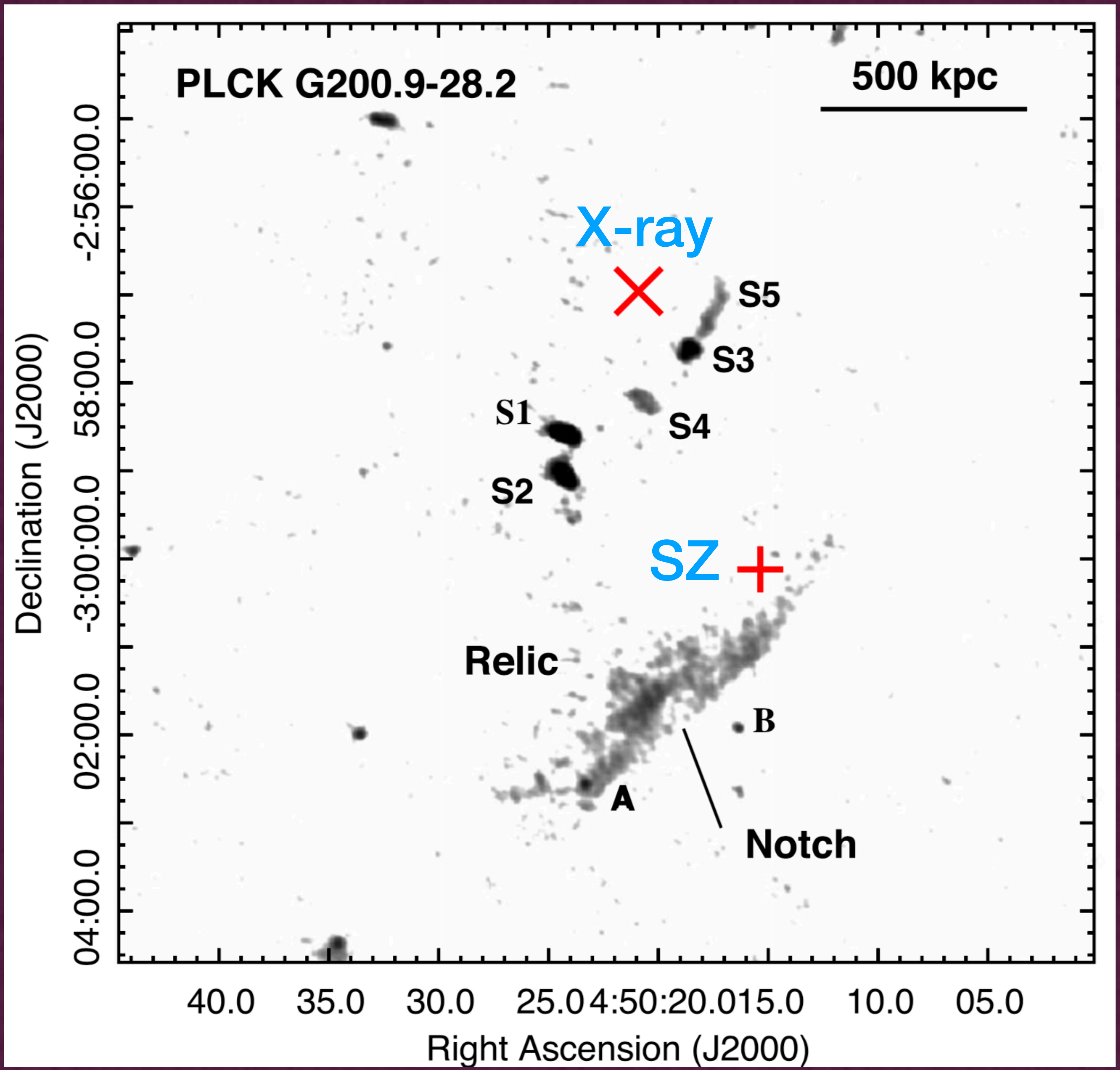
Chandra

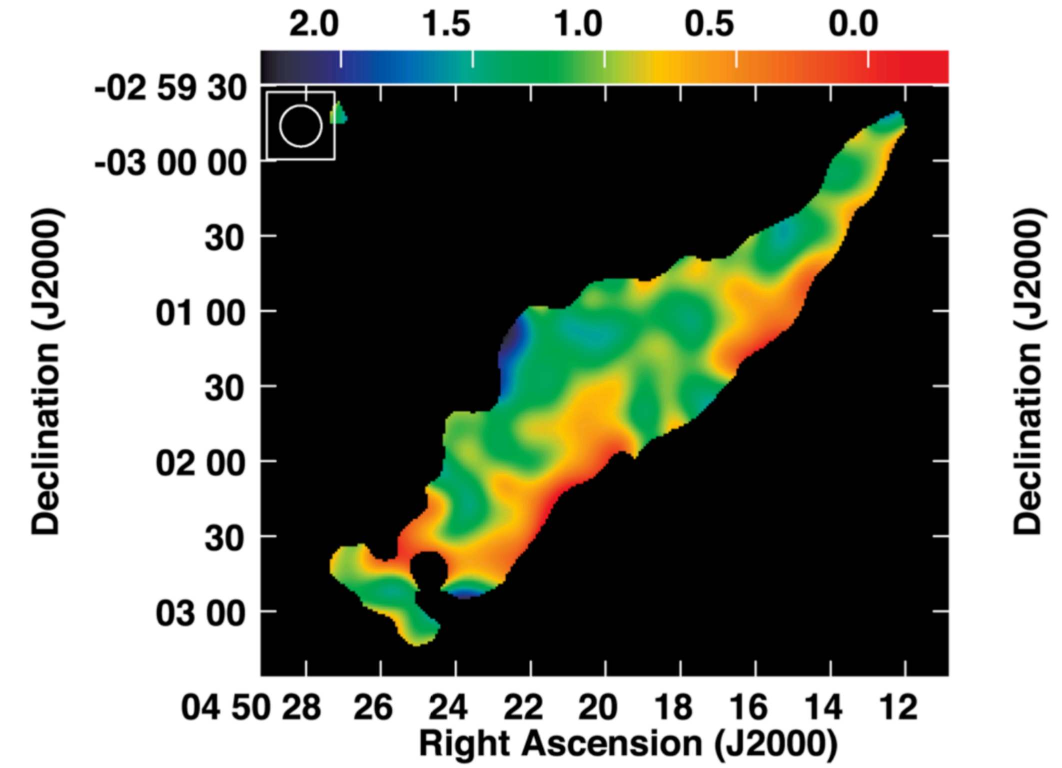
z = 0.22

Discovered by SZ, confirmed with XMM
(Planck Collaboration I, 2012)


Some edge feature
(maybe a cold front)
kT ~ 5 keV
Marginal difference
between N and S
subclusters
1 Mpc radius
SZ centroid
Radio relic

PLCKESZ G200.9-28.2's radio relic





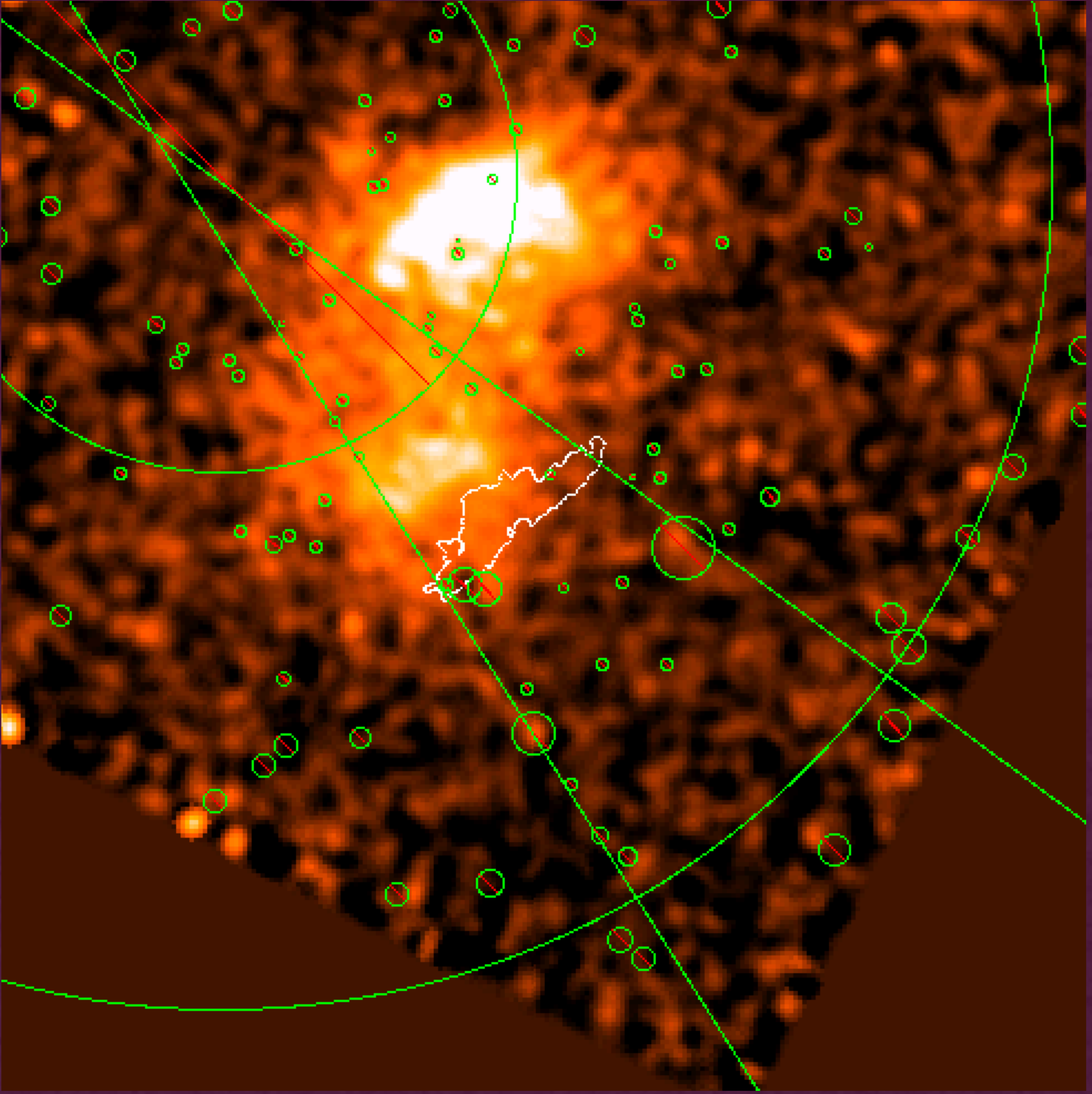
(a) Spectral index map

Figure 5. (a) The spectral index map of the radio relic between 235 and 610 MHz.

↑Possible substructure in relic

Kale+ 2017

Shape, and spectral index steepening, consistent with shock seen edge-on.
Very offset SZ centroid also suggests presence of shock heated gas.



Model:

density just behind edge

$$n = n_0 \left(\frac{r}{r_{edge}} \right)^{\alpha_1}, r \leq r_{edge}$$

$$n = \left(\frac{n_0}{x} \right) \left(\frac{r}{r_{edge}} \right)^{\alpha_2}, r > r_{edge}$$

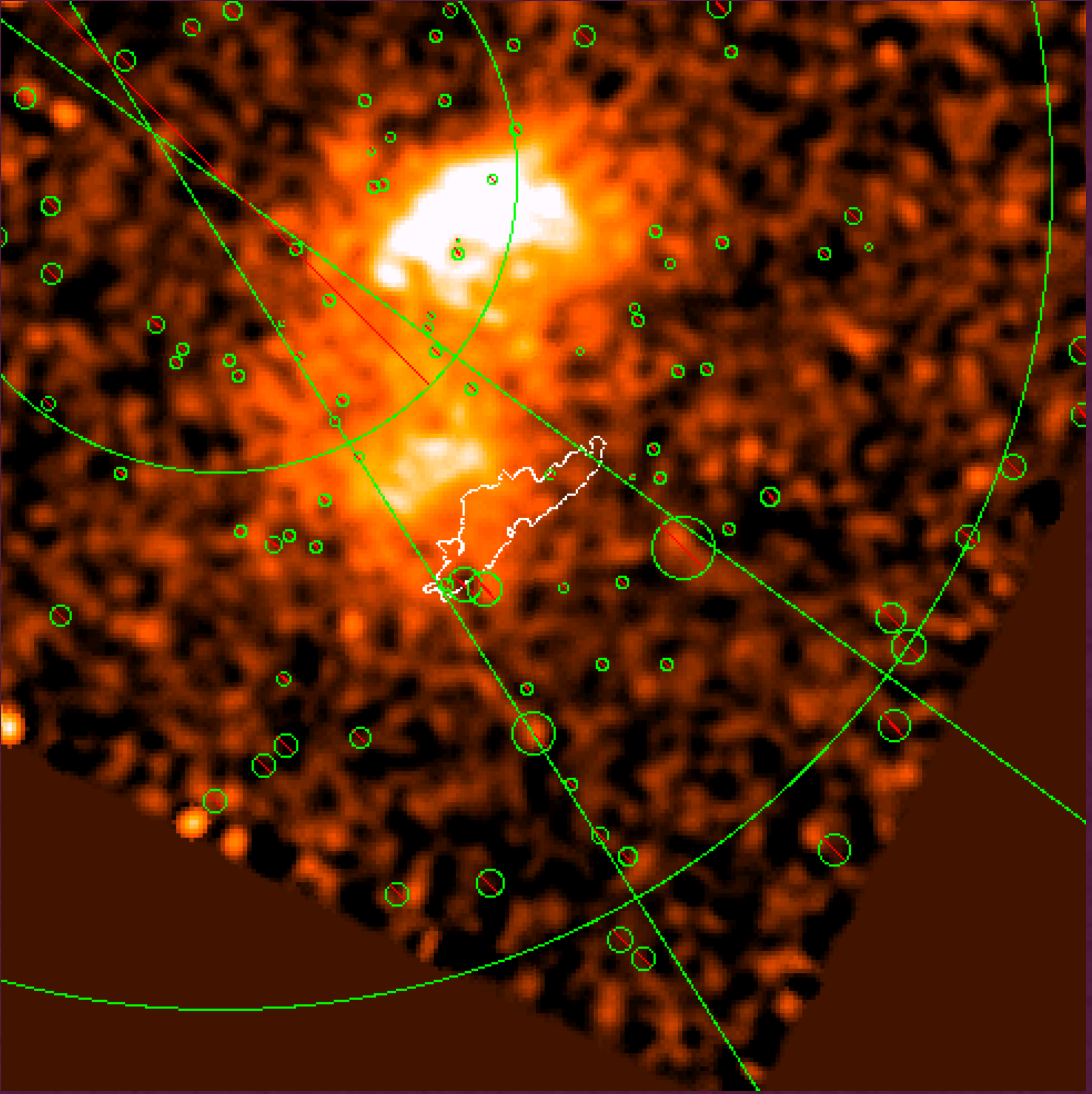
density jump   position

- Use Rankine-Hugoniot jump conditions at the shock to calculate Mach number

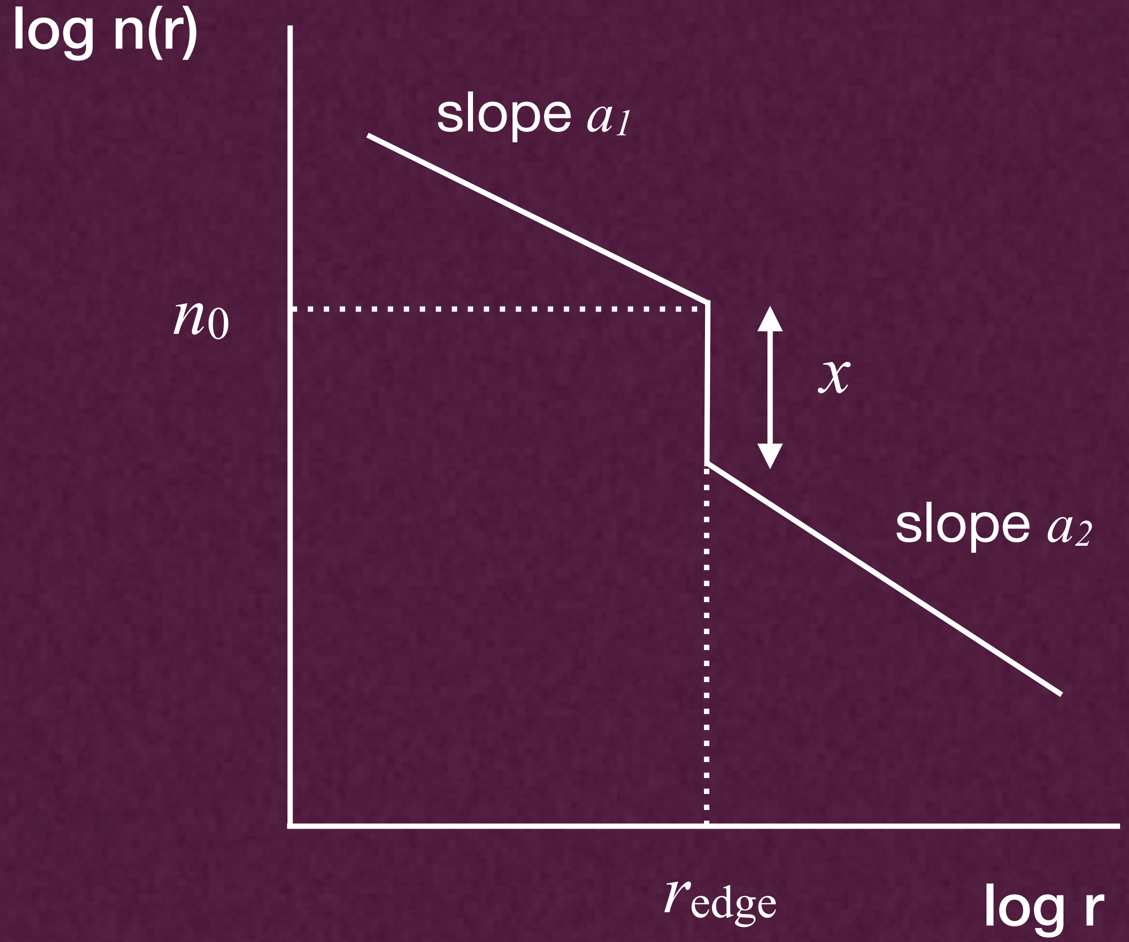
$$\frac{\rho_2}{\rho_1} = \frac{u_1}{u_2} = \frac{(\gamma+1)M_1^2}{(\gamma-1)M_1^2+2}$$

$$S_X = A \int_{los} [n(r)]^2 dV + S_{bg}$$

ACIS background
3% error (90% confidence)



Model:



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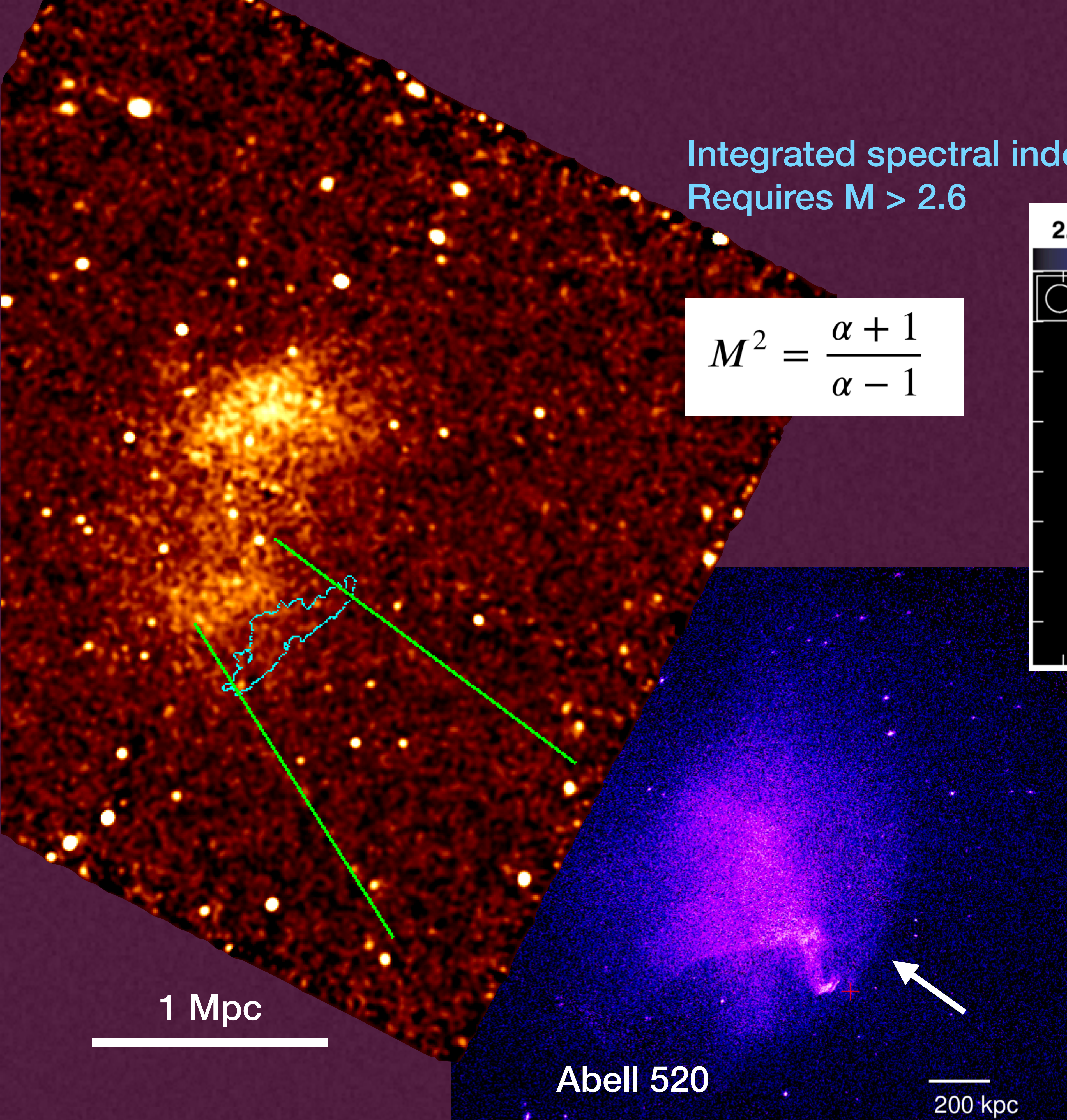
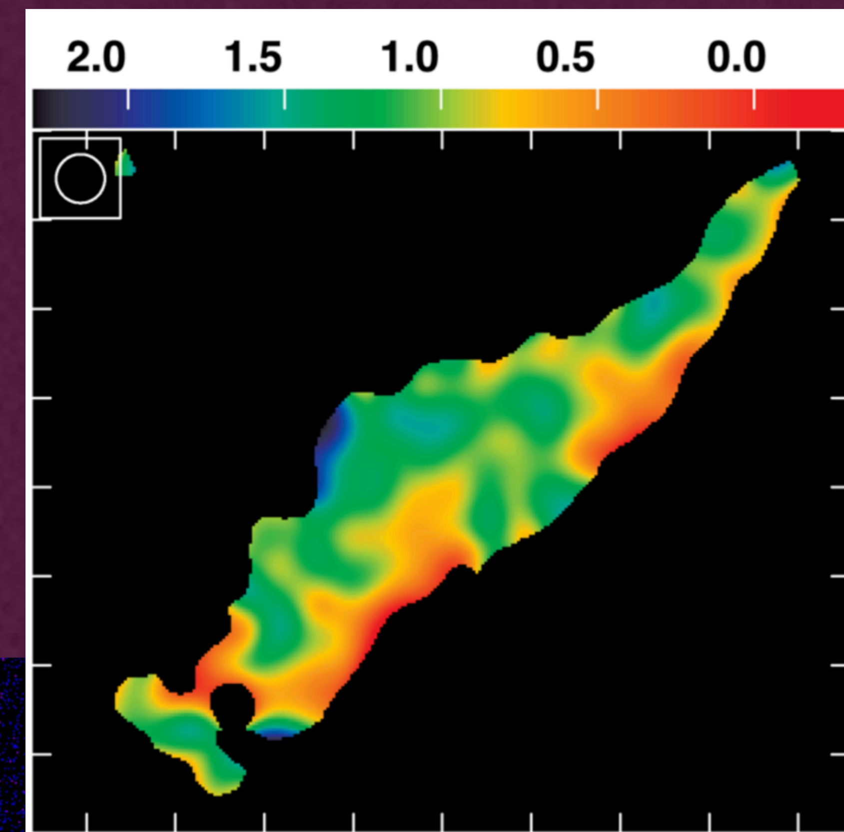


Integrated spectral index 1.21 ± 0.15

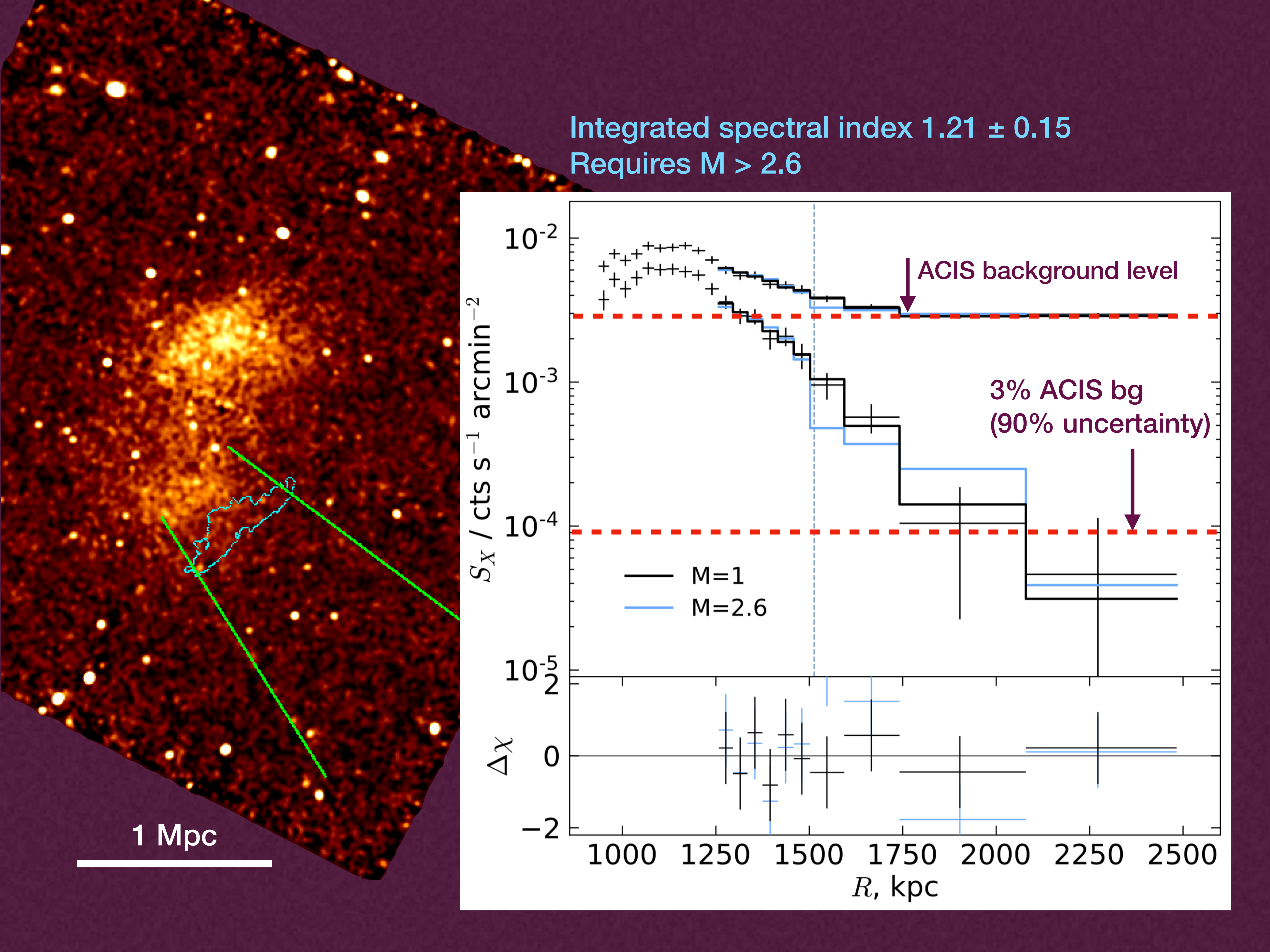
Requires M > 2.6

$$M^2 = \frac{\alpha + 1}{\alpha - 1}$$

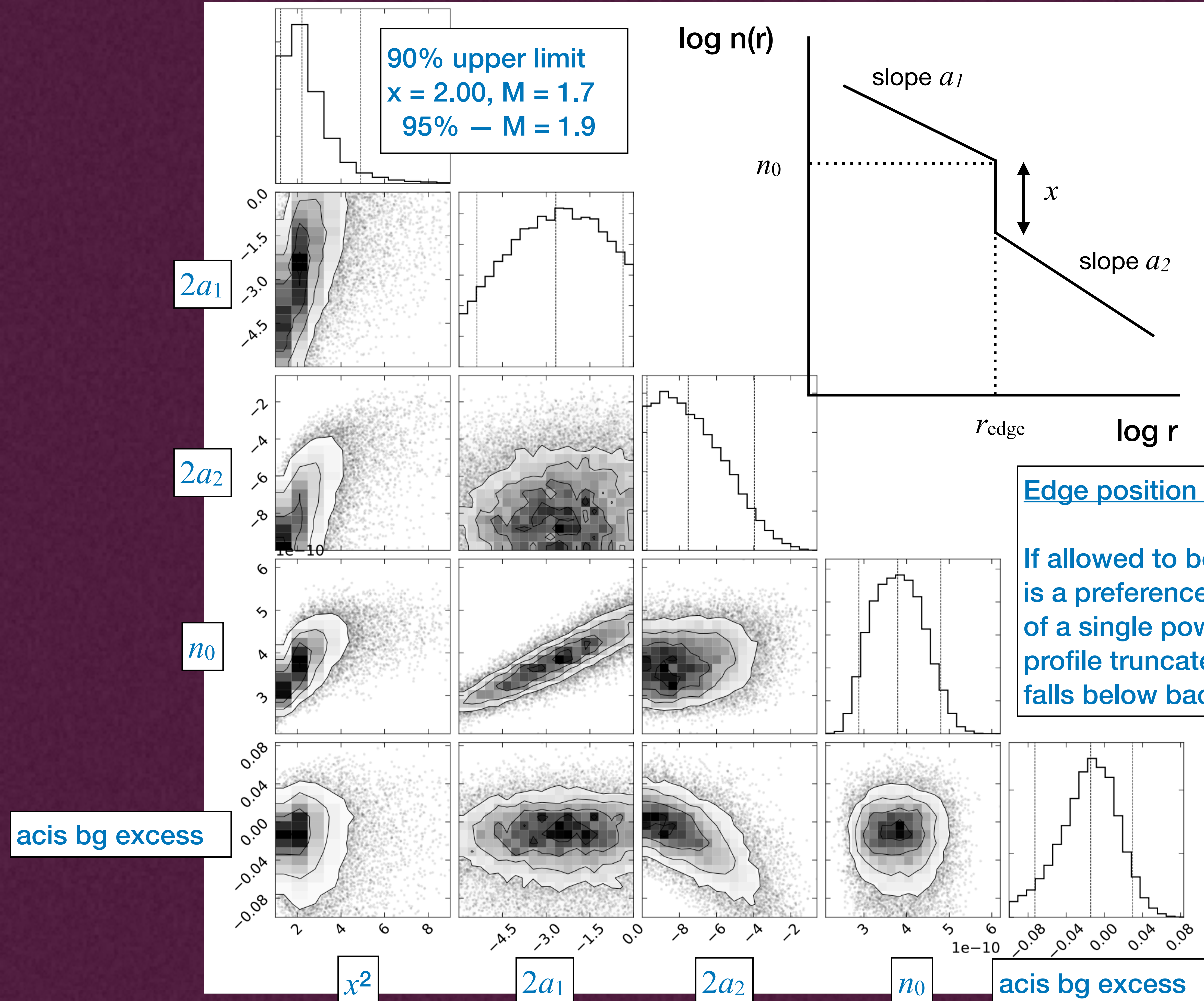


Kale+ 2017

This is what M = 2.4 looks like



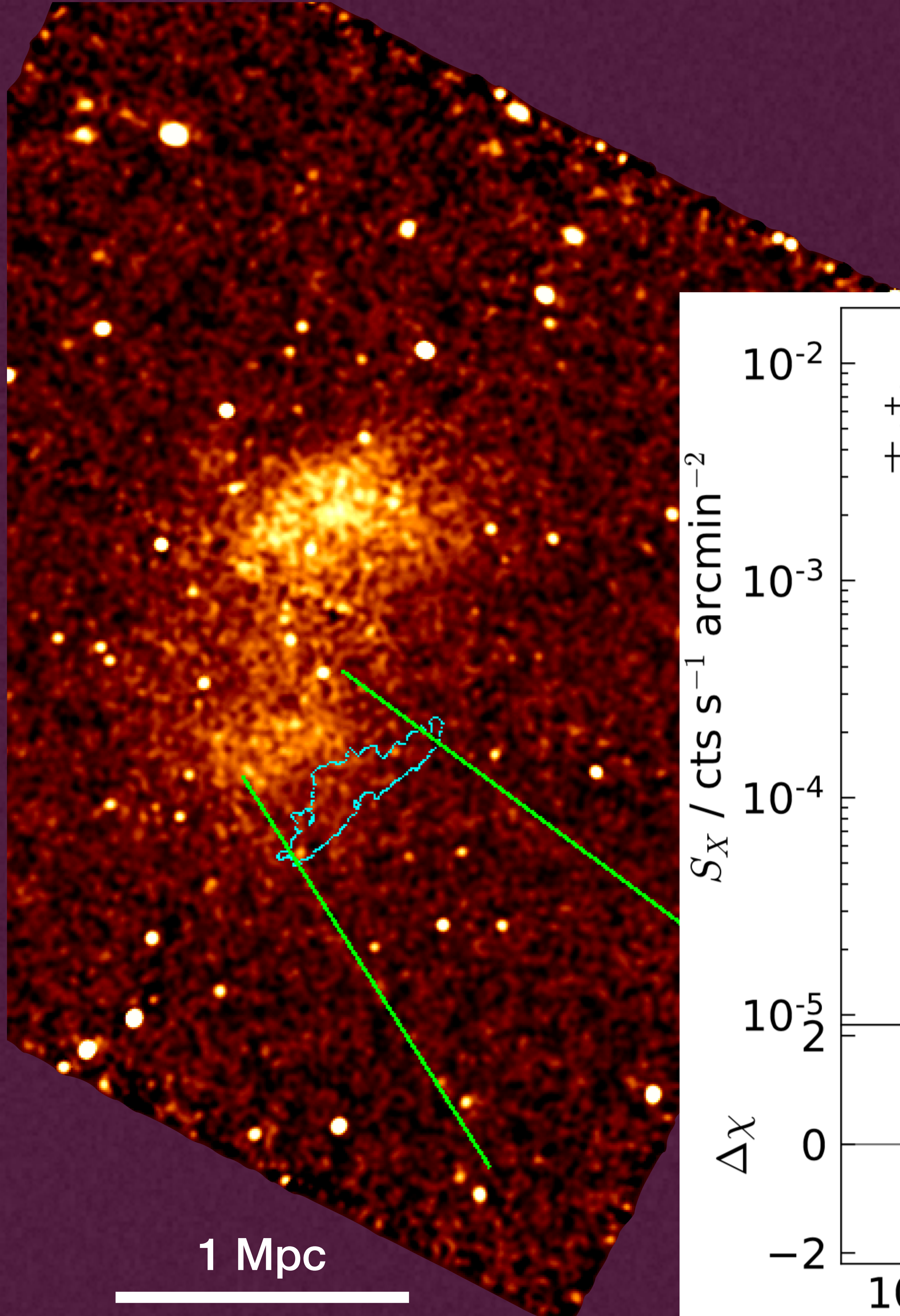
Integrated spectral index 1.21 ± 0.15
Requires M > 2.6
ACIS background level
3% ACIS bg
(90% uncertainty)
M=1
M=2.6
S_X / cts s^{-1} arcmin^{-2}
$\Delta\chi$
R, kpc
1 Mpc

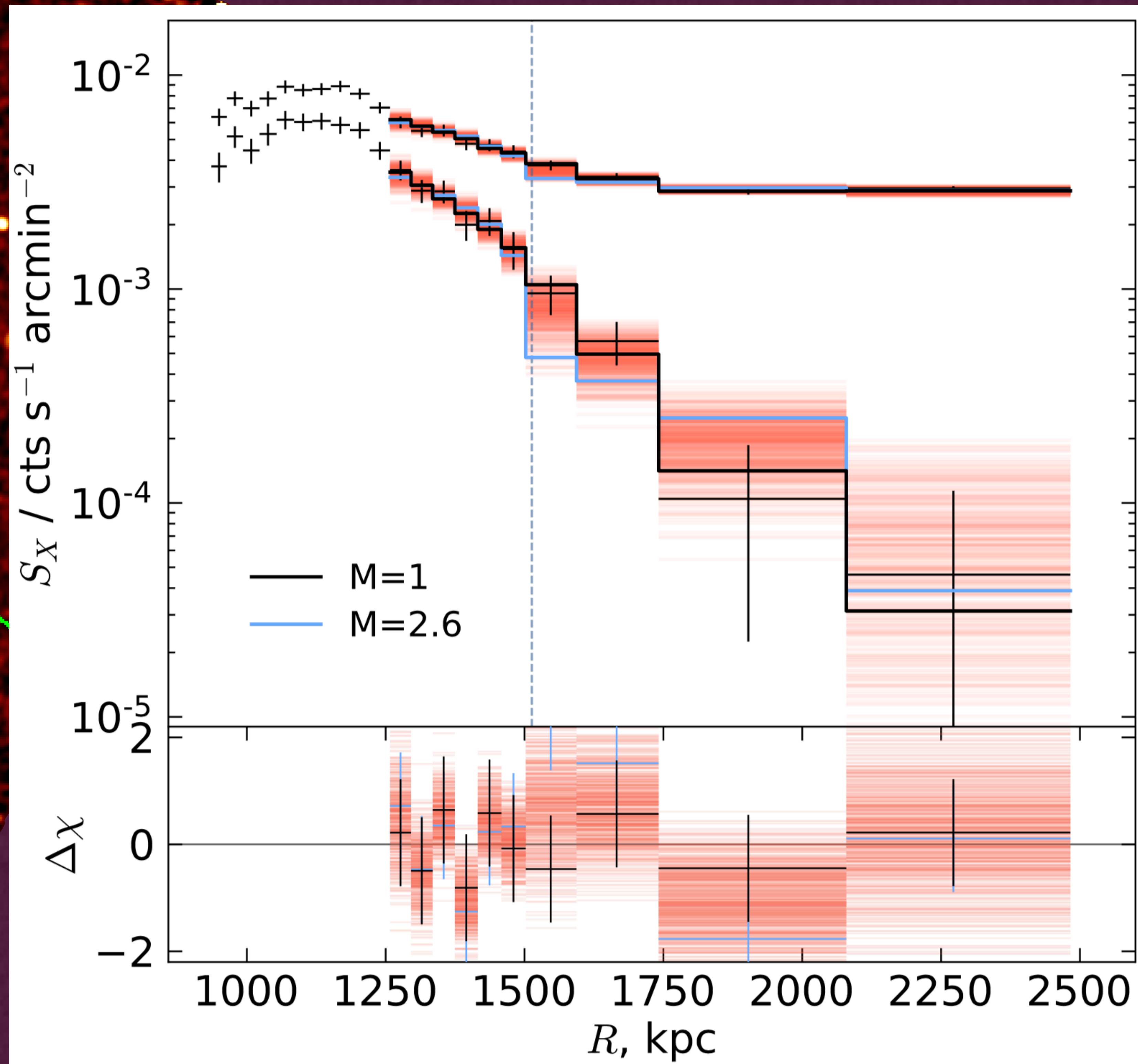


<u>Edge position is fixed</u>

If allowed to be free, there is a preference for a model of a single power law profile truncated where SB falls below background.

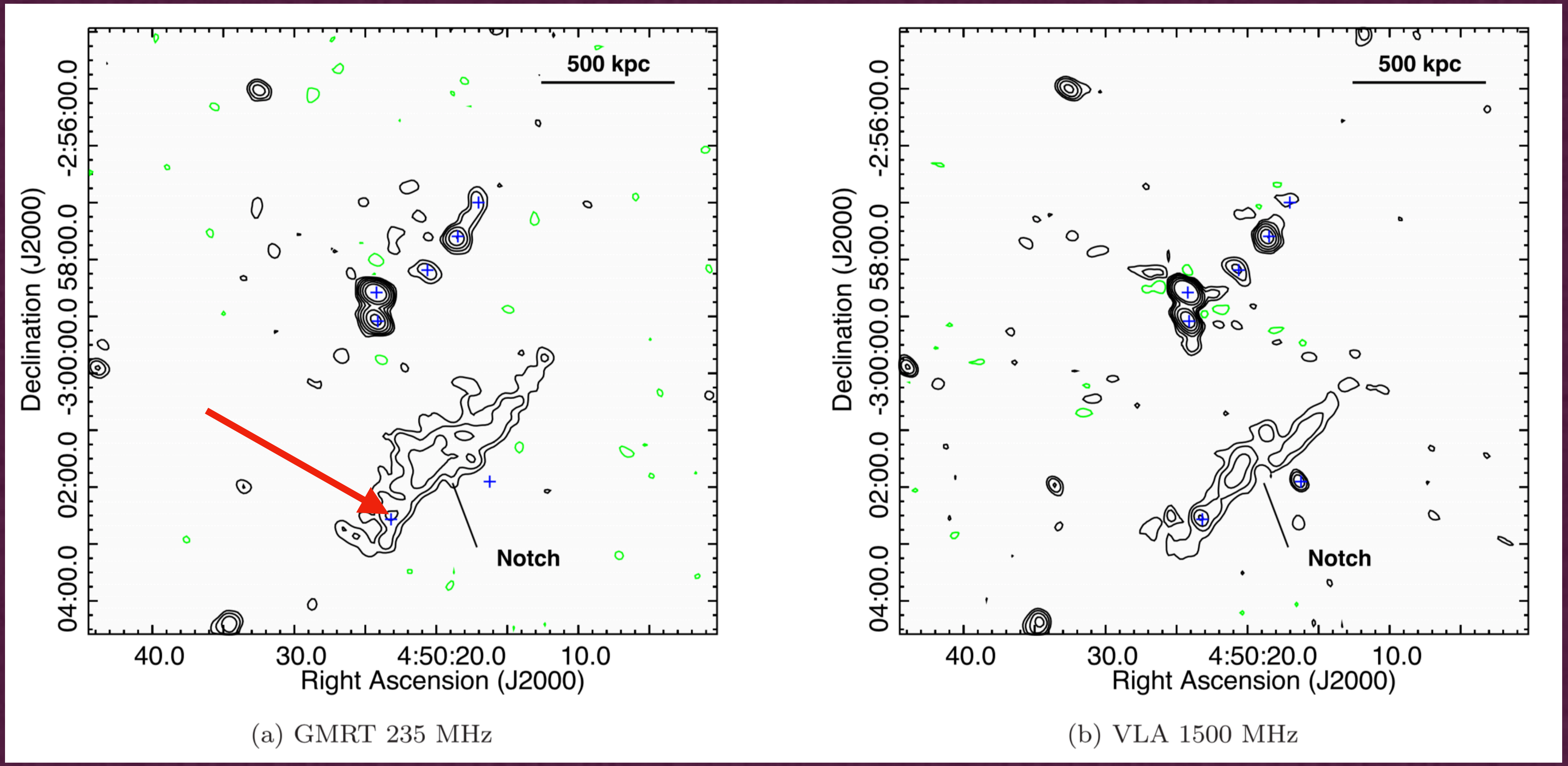
Samples from MCMC





PLCKESZ G200.9-28.2's radio relic

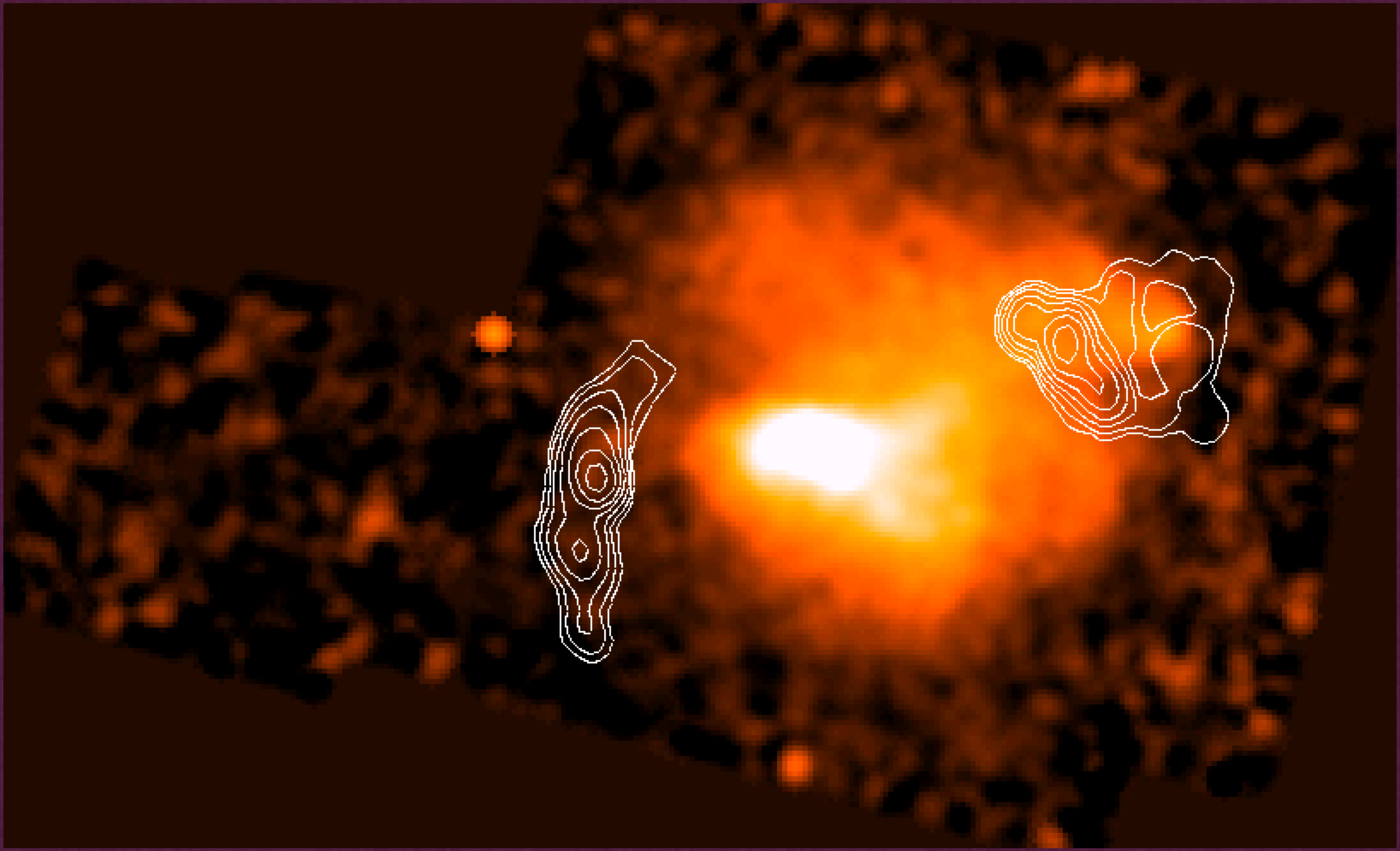
- Radio spectral index requires M > 2.6 shock for DSA from thermal
- X-ray surface brightness rule this out, suggesting a weak shock
- Re-acceleration of fossil electrons can do this



Radio galaxy — a source of fossil electrons for the re-acceleration scenario, potentially the origin of the relic electrons here

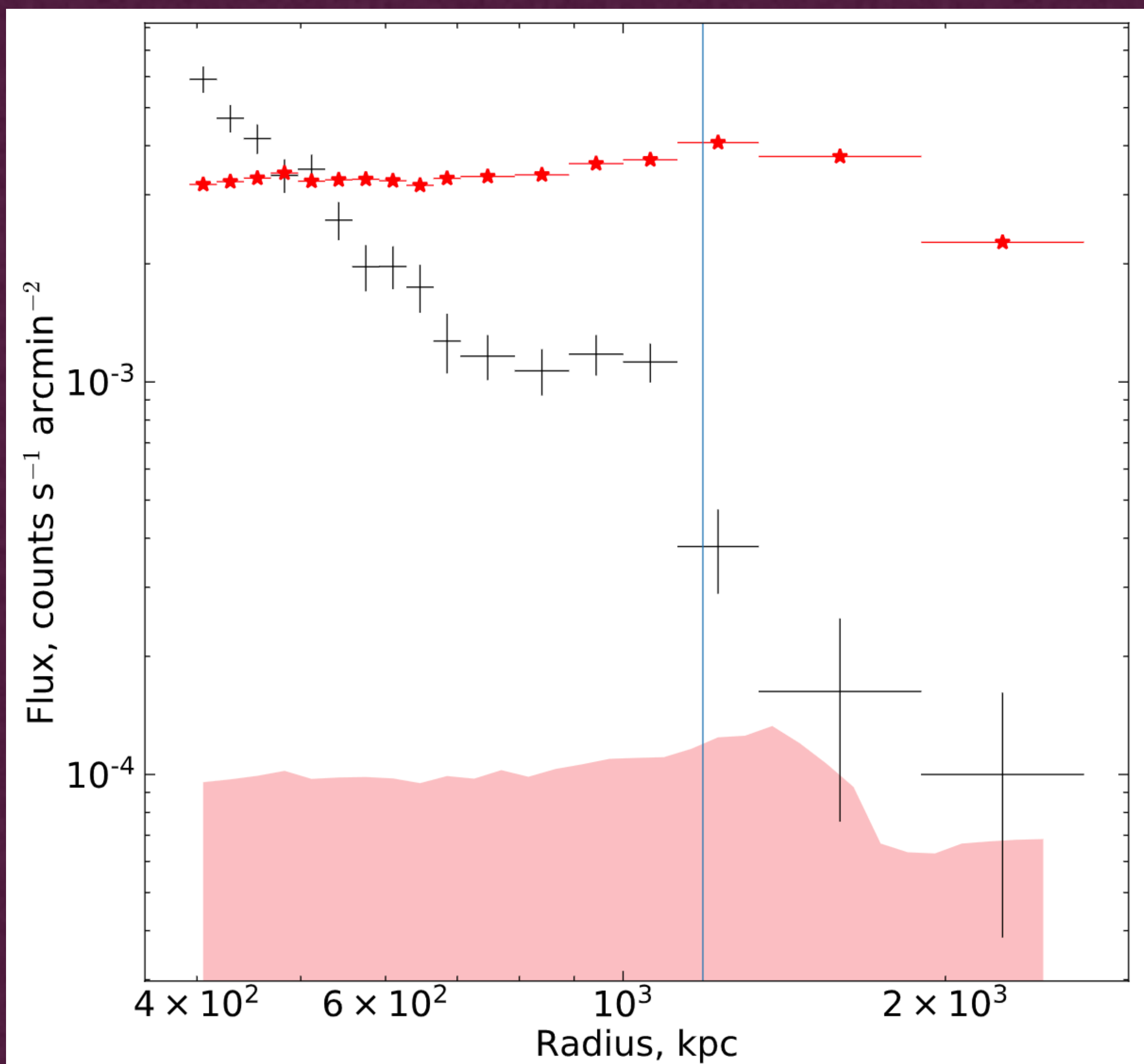
Kale+ 2017

Abell 2345



Pending one last observation

Abell 2345



** Preview **