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The discovery of a shock in Abell 115 and its connection with the radio relic

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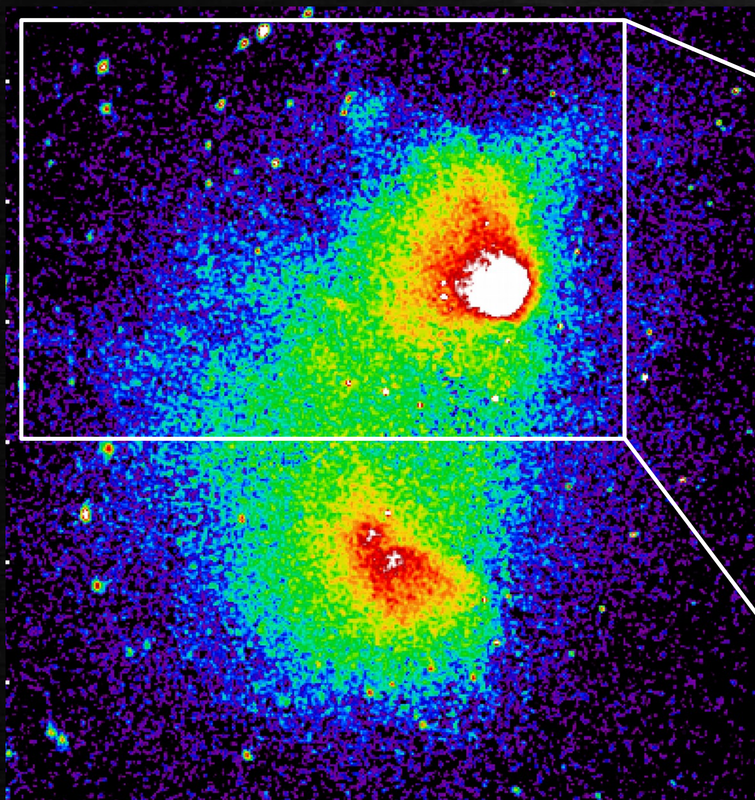
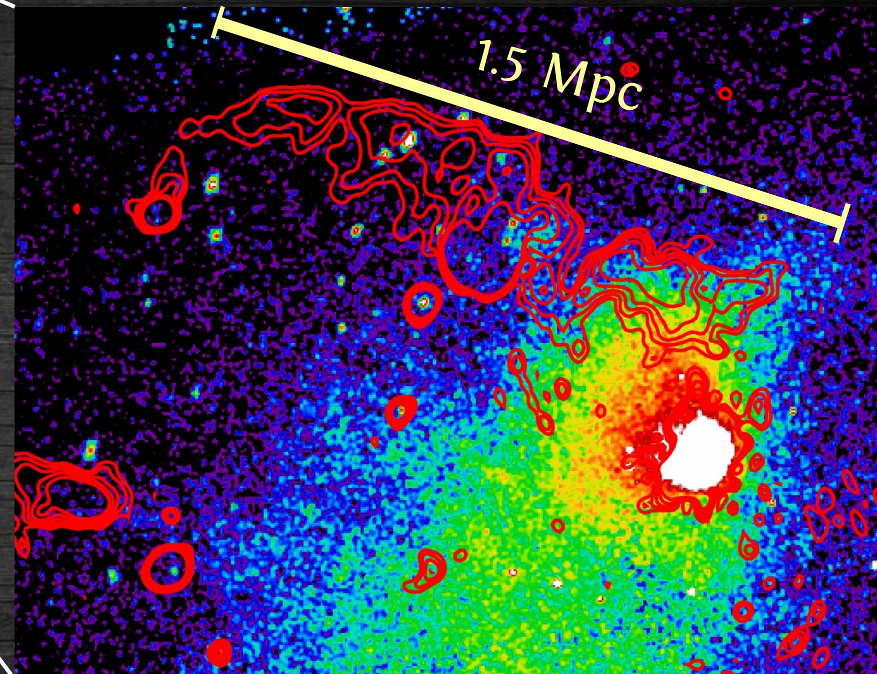
Abell 115

$z=0.192$
$L_{0.1\text{-}2.4\ keV} = 1.45 \times 10^{45}$ erg s^{-1}



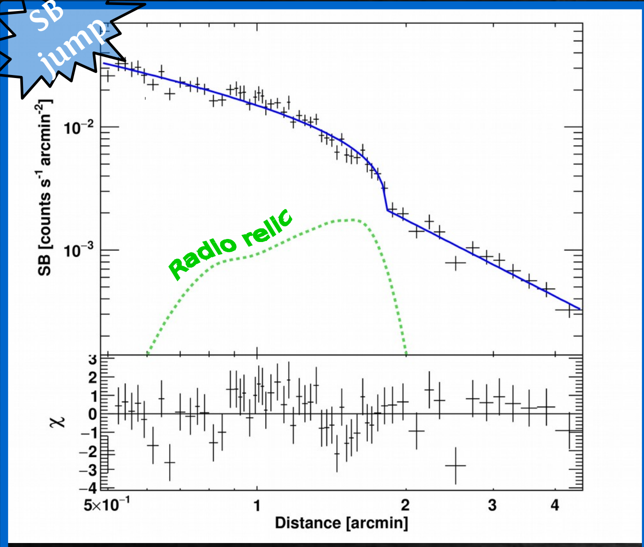


- **Dinamically disturbed**
- **Off-axis merger** (Gutierrez & Krawczynski 2005, Barrena et al. 2007)
- **Giant radio relic** (Govoni et al. 2001)

ⓘ *Chandra* 334 ks

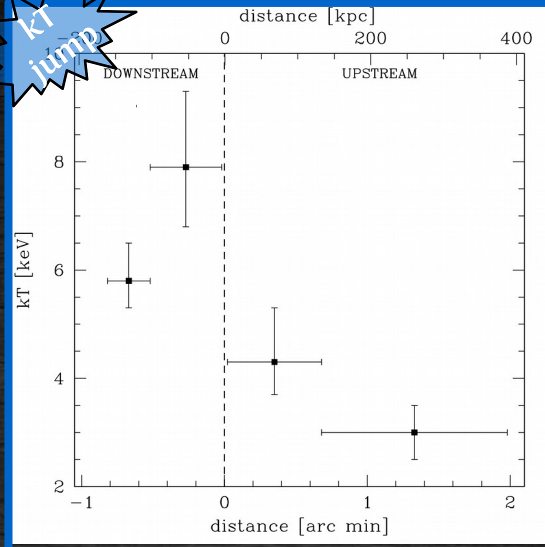
ⓘ VLA @ 1.4 GHz
Resolution 15” x 14”
r.m.s. 70 μJy/beam (1σ level)

The shock



$$\frac{\rho_d}{\rho_u} = \frac{4\mathcal{M}_{\rm SB}^2}{\mathcal{M}_{\rm SB}^2+3}$$

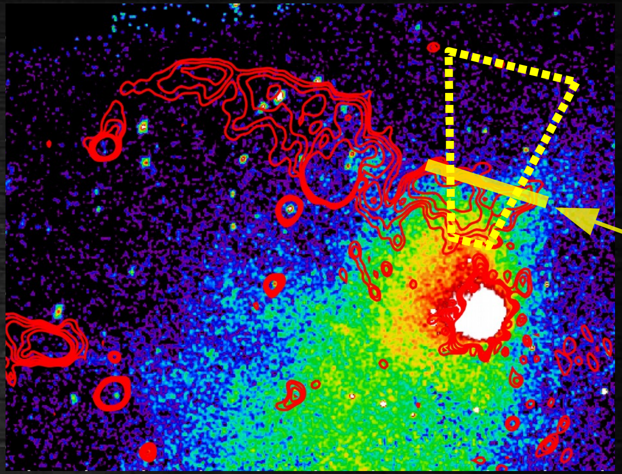
$$\mathcal{M}_{\rm SB} = 1.7 \pm 0.1$$



$$\frac{T_d}{T_u} = \frac{5\mathcal{M}_{\rm kT}^4 + 14\mathcal{M}_{\rm kT}^2 - 3}{16\mathcal{M}_{\rm kT}^2}$$

$$\mathcal{M}_{\rm kT} = 1.8^{+0.5}_{-0.4}$$

Excellent agreement between SB and kT jumps



From **D**iffusive **S**hock **A**cceleration:

$$\delta_{inj} = 2\frac{\mathcal{M}^2+1}{\mathcal{M}^2-1} = 4 - 3.8$$

$\alpha = \delta_{inj}/2$

NOT consistent with

$\alpha \sim 1.1$ (Govoni et al. 2001)

What about the relic origin?

The origin of the radio relic

Relic/shock connection

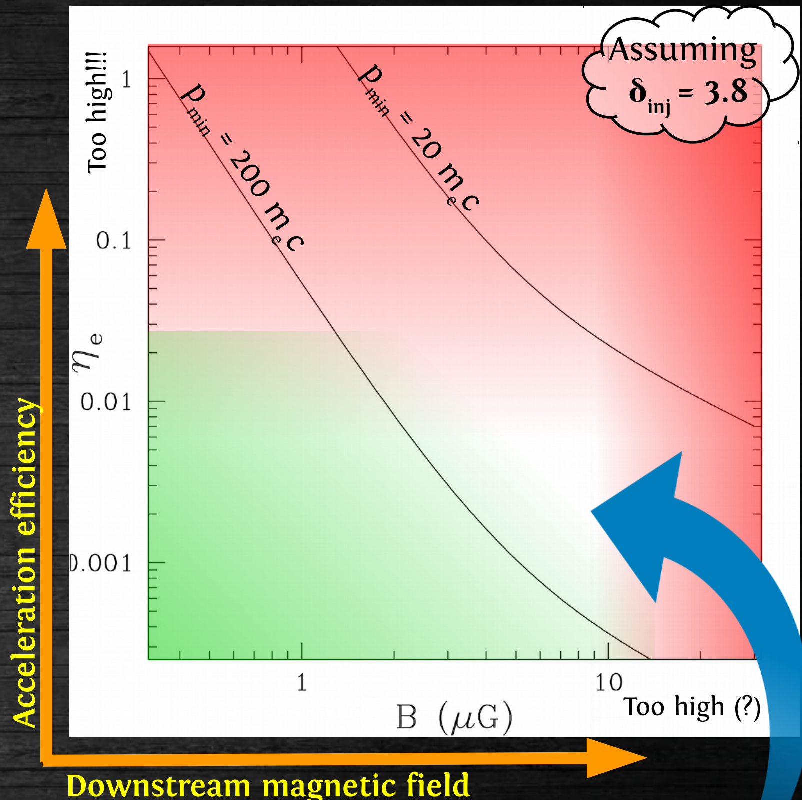
(e.g. Finoguenov et al. 2010, Akamatsu & Kawahara 2013, Bourdin et al. 2013, Shimwell et al. 2015)

DSA ruled out in many relics

(e.g. Macario et al. 2011, Ogrean et al. 2014, van Weeren et al. 2012, 2016)

Re-acceleration models invoked

(e.g. Bonafede et al. 2014, Shimwell et al. 2015)



For Abell 115:

- $$N_d(p) = (\delta_{inj} + 2) p^{-\delta_{inj}} \int_{p_{min}}^{p} x^{\delta_{inj}-1} N_u(x)\, dx$$
  downstream spectrum — upstream spectrum
  → e^- with $p_{min} \geq 100\ m_e c$ ok with η_e but not with α
- Re-acceleration of e^- with *flatter* spectrum (e.g. Kang & Ryu 2016)
  → Radio sources embedded in the relic could provide *seed* e^-

Main points

- *Clear* detection of a **M ~ 1.7-1.8** shock
- **Re-acceleration** models favored
- Relic position ok with *off-axis merger* (see Ricker & Sarazin 2001, Fig. 7)

A shock at the radio relic position in Abell 115

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ABSTRACT

We analysed a deep *Chandra* observation (334 ks) of the galaxy cluster Abell 115 and detected a shock cospatial with the radio relic. The X-ray surface brightness profile across the shock region presents a discontinuity, corresponding to a density compression factor $\mathcal{C} = 2.0 \pm 0.1$, leading to a Mach number $\mathcal{M} = 1.7 \pm 0.1$ ($\mathcal{M} = 1.4$–2 including systematics). Temperatures measured in the upstream and downstream regions are consistent with what expected for such a shock: $T_u = 4.3^{+1.0}_{-0.6}$ keV and $T_d = 7.9^{+1.4}_{-1.1}$ keV, respectively, implying a Mach number $\mathcal{M} = 1.8^{+0.5}_{-0.4}$. So far, only few other shocks discovered in galaxy clusters are consistently detected from both density and temperature jumps. The spatial coincidence between this discontinuity and the radio relic edge strongly supports the view that shocks play a crucial role in powering these synchrotron sources. We suggest that the relic is originated by shock re-acceleration of relativistic electrons rather than acceleration from the thermal pool. The position and curvature of the shock and the associated relic are consistent with an off-axis merger with unequal mass ratio where the shock is expected to bend around the core of the less massive cluster.

Botteon et al. 2016, MNRAS, 460, L84-88