francesco.ubertosi2@unibo.it

ARE JETS OF FR0 RADIO GALAXIES ABLE TO EXCAVATE CAVITIES IN THE ICM? New insights from a Chandra observation of A795.

F. Ubertosi[1,2], M. Gitti[1,3], E. Torresi[2], F. Brighenti[1,4], P. Grandi[2]

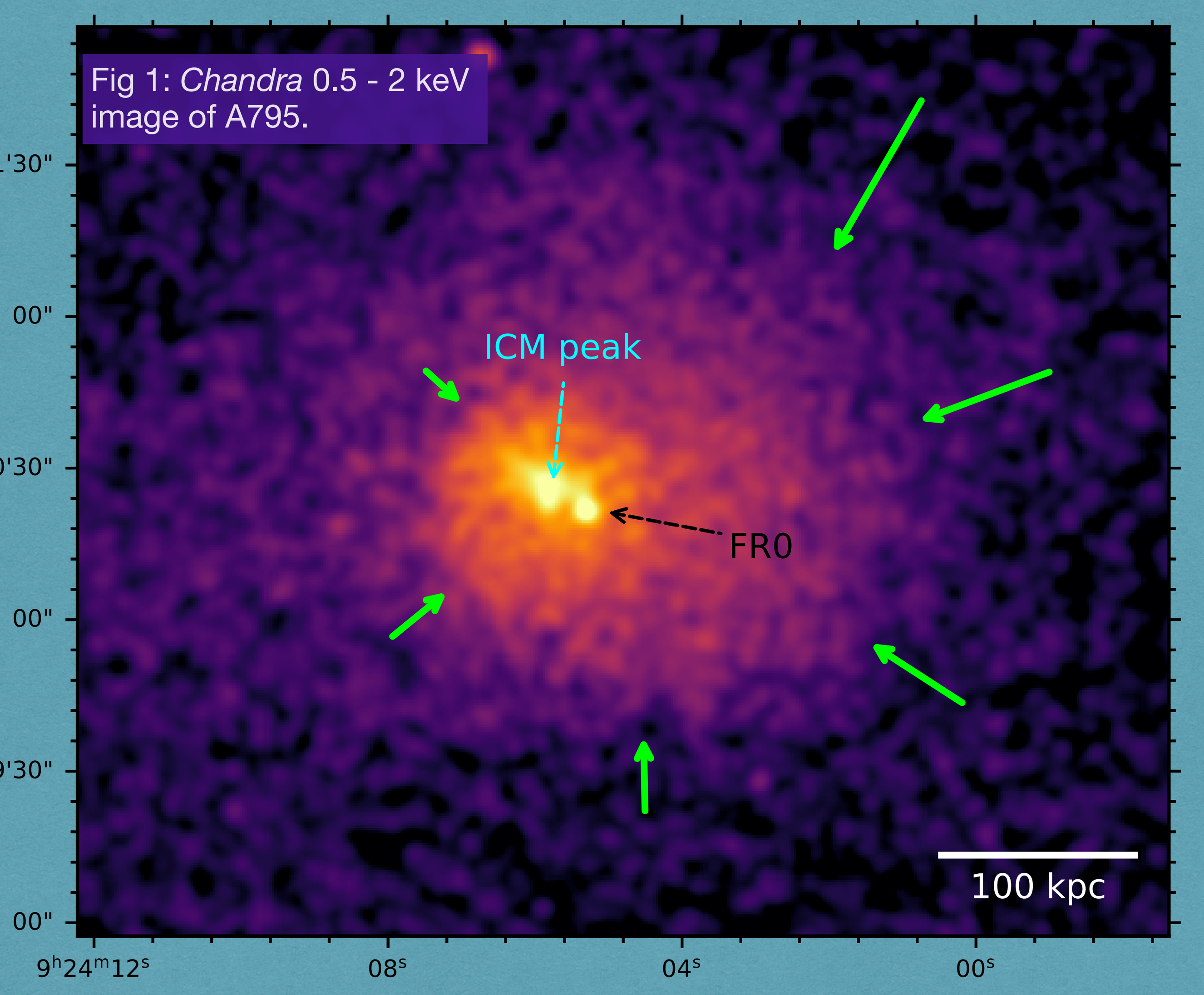
[1] DIFA, Università di Bologna, Italy [2] INAF - OAS, Bologna, Italy [3] INAF - IRA, Bologna, Italy [4] University of California, USA

INTRODUCTION

The recently discovered FR0 compact radio galaxies are five times more numerous than FRIs in the local Universe, but in contrast to well-studied extended AGNs their properties are largely unexplored. It has been suggested that their lack of extended radio emission derives either from an intrinsic jet weakness, or from an hostile environment limiting the growth of the radio galaxy (e.g., Baldi et al., 2015).

To investigate whether the intracluster medium could represent a source of frustration for FR0s living in galaxy clusters, we performed a detailed study of A795, a galaxy cluster hosting a FR0 in the BCG. Using archival *Chandra* data we found a dynamically disturbed environment with evidence for ICM sloshing. We argue that the environment cannot explain the compactness of the FR0, as similar conditions are also found around extended FRIs, thus the jet propagation is likely hampered by an intrinsic weakness. The unexpected discovery of a pair of X-ray cavities in the proximity of the FR0 could provide a different way to interpret the behavior of this new class of compact AGN.

ABELL 795 AS SEEN BY CHANDRA



The archival 30 ks *Chandra ACIS-S* observation of the galaxy cluster A795 (z~0.13) unveils an **offset of ~18 kpc** between the **central radio galaxy** and the **ICM peak**, and sharp edges in surface brightness surrounding the core.

The **BCG has been classified as a compact FR0** radio galaxy (Torresi et al., 2018). It is unresolved by FIRST (with a 5" resolution) at 1.4 GHz. MERLIN observations at 5 GHz have revealed a small core+jet morphology (0.7 kpc in total size, Kunert-Bajraszewska et al., 2010).

AN UNEXPECTED PAIR OF X-RAY CAVITIES

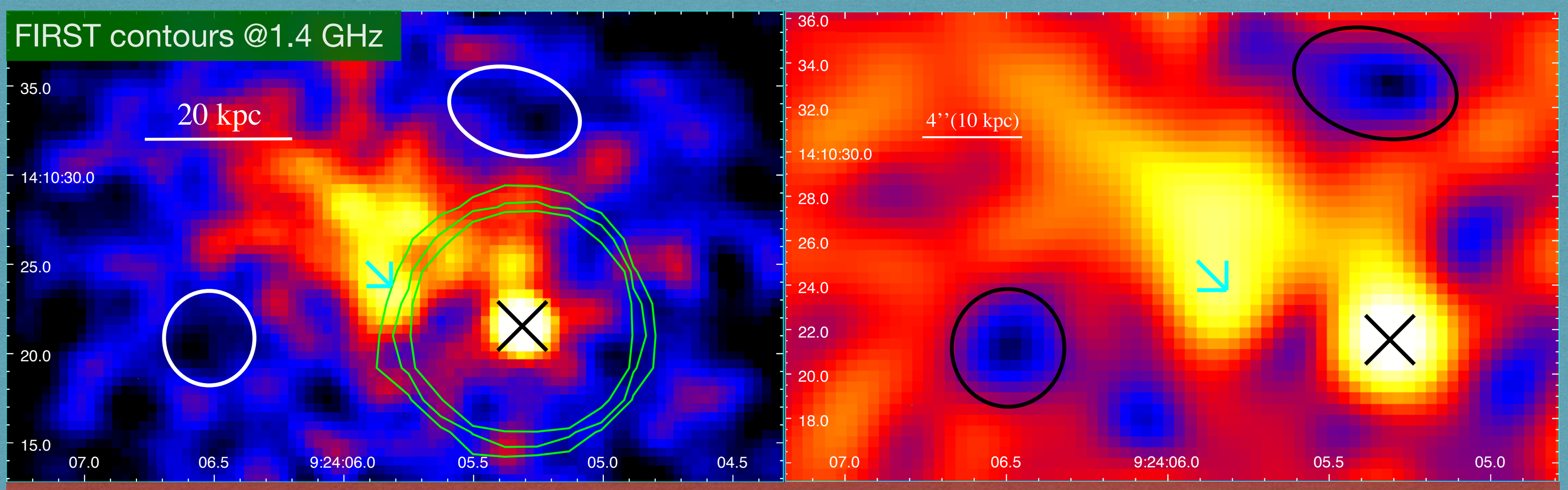


Fig. 4: Left: *Chandra* image of the core of A795. Green contours are from FIRST at 1.4 GHz. White ellipses mark the position of the putative X-ray cavities. Right: *Chandra* unsharp mask image of A795, obtained by subtracting a 5" smoothed image from a 1" smoothed one. The image highlights the X-ray cavities. In both panels, the black cross and the cyan arrow mark the position of the FR0 and the ICM peak, respectively.

	R_M kpc	R_m kpc	D kpc	pV 10^{58}erg	t_{age} Myr	P_{cav} 10^{43}erg s^{-1}
D1	6.4	6.2	40.6	2.0±0.5	42.4±2.0 83.2±12.5	1.0±0.6
D2	9.9	4.6	27.7	1.4±0.2	28.8±1.3 53.7±8.1	1.2±0.5

Tab 1: Properties of the X-ray cavities: major and minor axes, distance from the AGN, work done to create the cavities, estimated cavity ages and cavity power $P_{cav} = pV/t_{age}$

The inspection of the central regions of A795 has revealed the presence of two depressions in the ICM, with a significance of ~2σ. Considering their depth (30% less counts than their surroundings), slightly elliptical shape and symmetric position w.r.t. the ICM peak, we classified these features as **putative X-ray cavities**. The depressions are offset towards north-east of the FR0, which is also the direction of sloshing motions. The scenario we proposed is that these cavities might have been excavated nearby the FR0, so within a few kpc from the AGN. Later, the large scale oscillation could have dragged them away (see Fig. 4).

By computing the cavity power (see Tab. 1) and comparing it with the luminosity associated to the cooling of the ICM we found that **the cavity system of A795 nicely follows the distribution of other galaxy clusters with FRI-inflated X-ray cavities** (see Fig. 5).

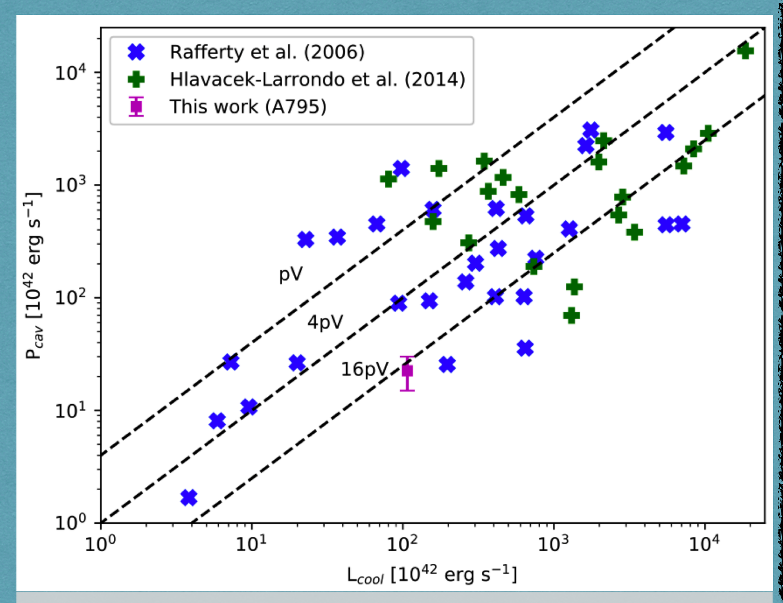


Fig. 5: The correlation between cavity power and cooling luminosity supports the AGN feedback scenario to explain reduced cooling in galaxy clusters.

If the cavities will be confirmed (with future deep *Chandra* exposures and sensitive radio observations), **the FR0 in A795 would be the first one for which evidences of AGN feedback have been found.**

THE TURBULENT INTRACLUSTER MEDIUM

A sloshing mechanism (oscillating motion of the cold ICM following a minor merger, see e.g., Markevitch & Vikhlinin 2007) could explain the observed offset and the presence of surface brightness edges.

By subtracting a $\beta-$model from the 0.5 -2 keV image we produced a residual image (see Fig. 2): **the ICM is clearly arranged in a spiral geometry** on a scale of ~200 kpc.

The spiral is particularly enhanced in two opposite arcs: with the spectral analysis we confirmed the **cold fronts** origin of the two edges: the inner side of each front is **colder and denser** than the outside.

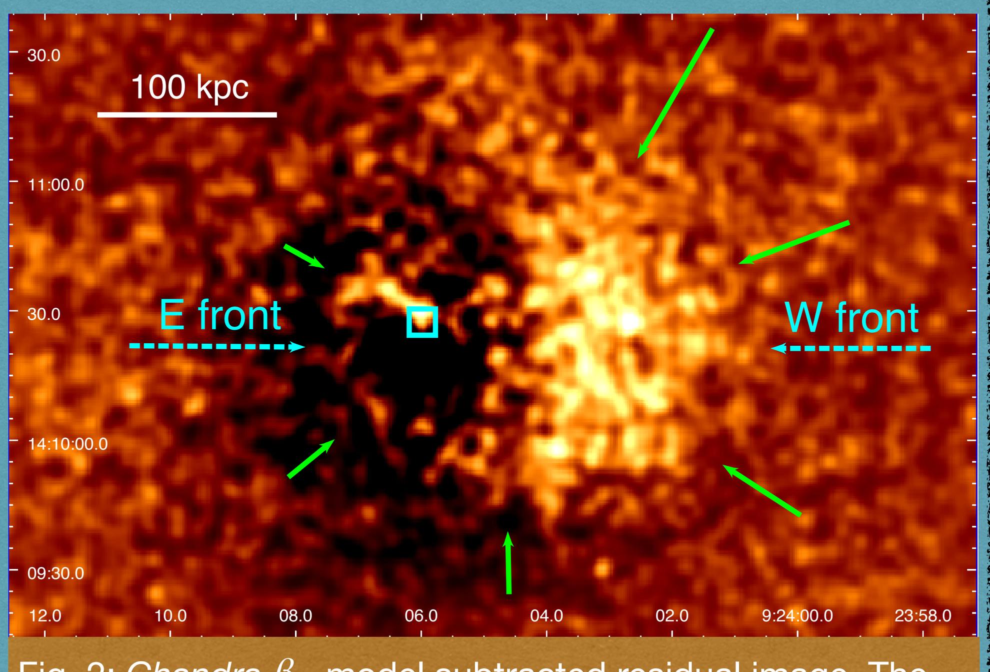


Fig. 2: *Chandra* $\beta-$model subtracted residual image. The east and west cold fronts are marked with cyan arrows.

Our analysis confirms that the cold phase of the ICM in A795 has been displaced from its original configuration.

We computed the sloshing timescale following the method of e.g., Su et al., 2017 finding that **the large scale perturbation has been set ~1 Gyr ago.**

Question: is the ICM hampering the FR0's jet propagation?

In order to establish a connection between the radio size of the FR0 in the BCG and the properties of the cluster environment, we verified whether the ICM conditions nearby the AGN were peculiar w.r.t. those commonly observed around FRI radio galaxies in clusters.

We found temperature gradients around the FR0, thus verifying that the large scale ICM oscillation is present even in the innermost regions (<20 kpc). We also measured the mean ICM density around the BCG, finding $n_e \sim 0.02\,\mathrm{cm}^{-3}$, which is typical of ICM density around extended FRIs.

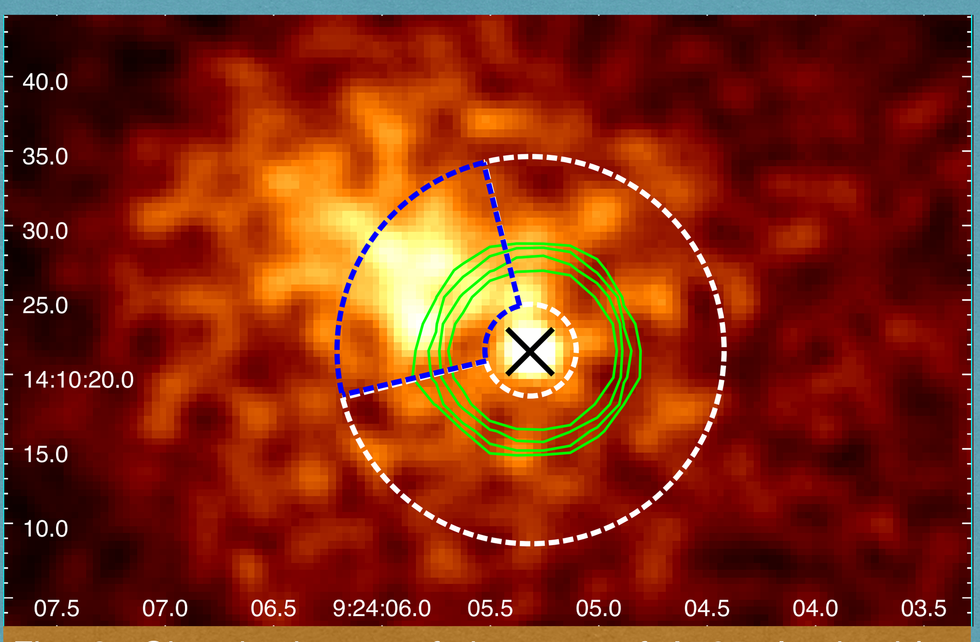


Fig. 3: *Chandra* image of the core of A795. In the blue sector the temperature of the ICM is colder than in the white one ($kT_{in} = 3.5 \pm 0.3$ keV, $kT_{out} = 4.3 \pm 0.3$ keV).

Our conclusion is that **while the environment is disturbed, these conditions are not peculiar**: sloshing has been observed around FRIs, whose jets have not been destroyed (e.g., Kolokythas et al., 2020).

Our results imply that the environment is not playing the major role in determining the radio compactness of the BCG, and that an intrinsic jet weakness is favored.

SUMMARY

- A795 is a dynamically disturbed cluster, showing ICM sloshing motions extended from large scales (~200 kpc) to the innermost regions (<20 kpc).
- The ICM properties around the FR0 do not differ from typical FRI-cluster environments: this suggests that the propagation of the FR0's jets is not hampered by the environment, but likely due to an intrinsic weakness.
- A pair of putative X-ray cavities, whose power is enough to reduce ICM cooling, was found nearby the FR0. These might have been created during a past outburst and later moved towards north-east following the ICM oscillation. If supported by new observations, the FR0 of A795 would have established a feedback loop cycle.

REFERENCES

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