A BCG WITH OFFSET COOLING: IS THE AGN FEEDBACK CYCLE BROKEN IN A2495?

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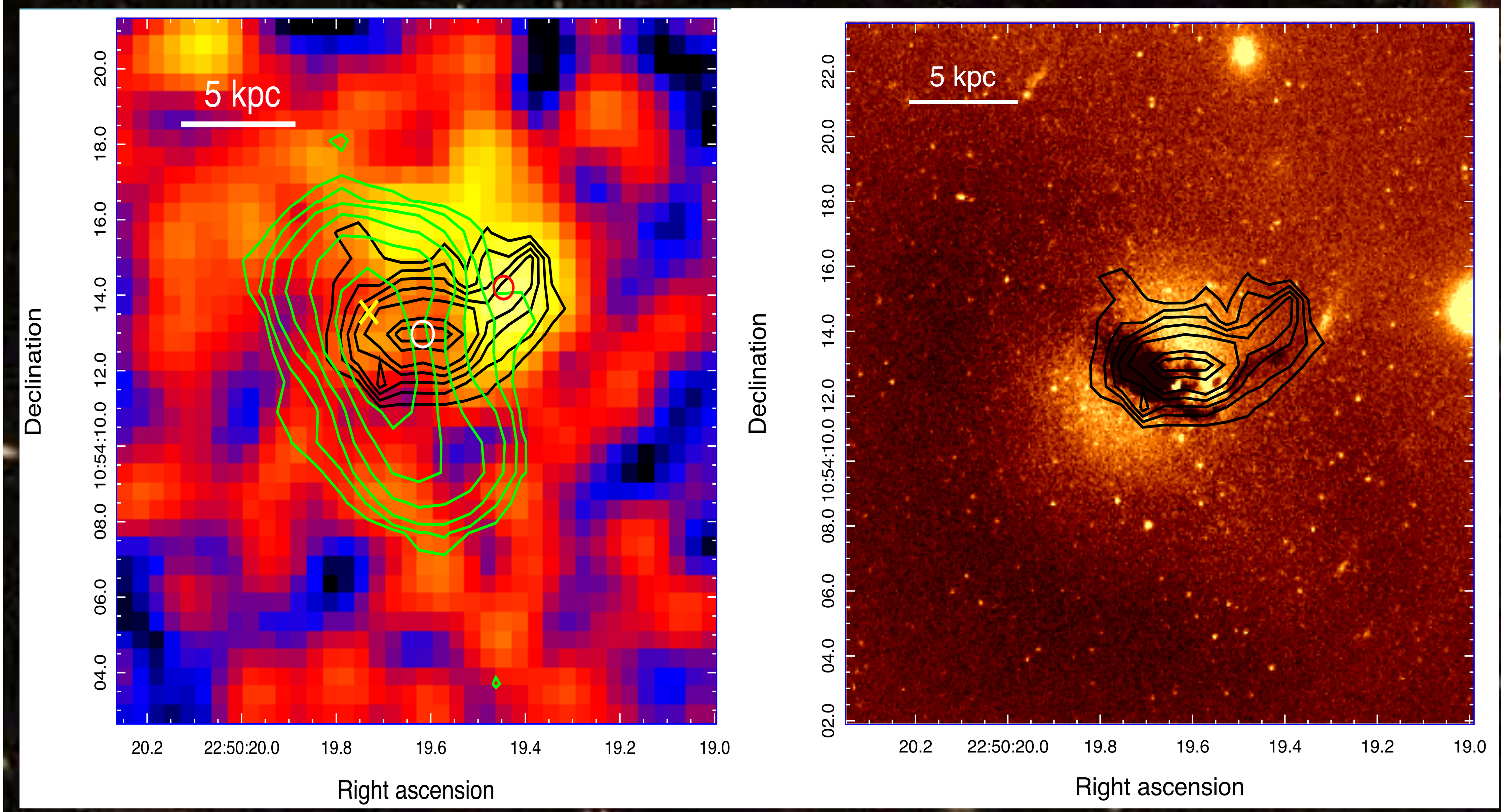


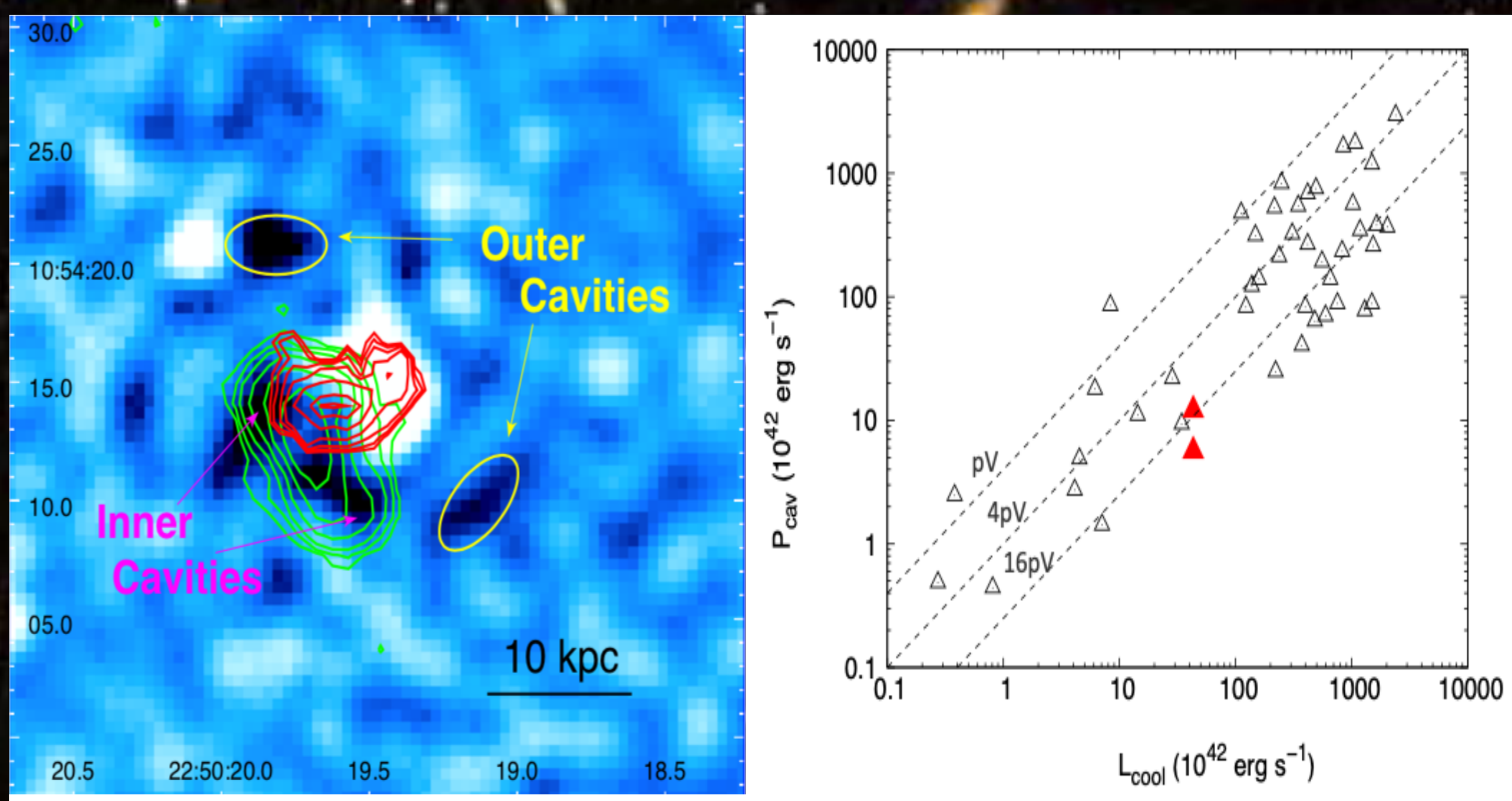
Figure 1: *Left Panel:* 1.4 GHz (green) and Hα (black) contours overlaid on the 0.5-2 keV *Chandra* image of A2495. The red and white circles represent the X-ray and Hα peaks, respetively, while the yellow cross is the position of the X-ray centroid, coincident with the BCG centre. *Right Panel:* Dust absorption filament, that encircles the inner region of the BCG and stretches towards the outskirts. Overlaid are the Hα contours.

Abstract

In dynamically-relaxed galaxy clusters, we expect the Brightest Cluster Galaxy (BCG) to be at the centre of the cluster potential well. In this scenario, the galaxy should be coincident with both the cluster cool core centre and the Hα line emission from warm (~10^4 K) ionized gas. However, in the case of interactions with other (sub)clusters, all these components are likely to shift, thus inducing spatial offsets between them.
We present a multi-wavelength analysis of the galaxy cluster Abell 2495, selected among the brightest in X-ray and Hα, performed with new *Chandra* and EVLA observations (P.I. Gitti) and archive Hα (VIMOS) and optical (HST) data. We find an offset of ~ 6 kpc between the cluster BCG and the peak of the X-ray emission, suggesting that the cooling process is not taking place on the central galaxy nucleus. We propose that gas motions ('sloshing') could be responsible for this separation.
Furthermore, we find two putative systems of cavities, whose age difference appears to be consistent with the free-fall time of the central cooling gas and with the offset timescale estimated with the Hα kinematic data, suggesting that the same sloshing motions could switch the AGN on and off, forming different generations of cavities. The cavities' power analysis shows that the AGN energy injection is able to sustain the feedback cycle, despite cooling being offset from the BCG nucleus.

Offsets as an indicator of the cluster dynamical evolution

In Fig. 1 (left panel) we show the radio and Hα contours overlaid onto the 0.5-2 keV band image . The X-ray centroid (yellow cross) and peak (red circle) exhibit an offset of ~ 6 kpc , likely produced by sloshing. This mechanism is usually tied to the formation of cold fronts (Markevitch & Vikhlinin 2007), discontinuities between the hot cluster atmosphere and a cooler region that are moving with respect to each other. In this scenario, the oscillation of the ICM has displaced the X- ray peak from the cluster's centre: the cooling process is not taking place on the BCG nucleus. On the other hand, the Hα structure stretches towards and surrounds the X-ray peak, connecting it to the BCG. This could suggest that the line emission is not produced by ionisation coming from stellar radiation or from the AGN, but it is likely connected to the cooling ICM (e.g., Crawford et al. 2005; Canning et al. 2012). We detect a ~7 kpc dust filament in absorption, that is morphologically associated with the lower ridge of the Hα emission (Fig.1, right panel). We also highlight the presence of a ~3.7 kpc offset between the Hα (white circle) and the X-ray peaks, that could originate from the different hydrodynamic conditions of the ICM. Another hypothesis is that thermal instabilities occurring in the inner regions of the cluster could have produced the 10^4 K gas in situ, following the chaotic cold accretion scenario (CCA) (e.g., Gaspari et al. 2012; Voit et al. 2015).



	Sound velocity			Buoyancy velocity		
	c_s [km s^{-1}]	Age [Myr]	P_{cav} [10^{42} erg s^{-1}]	v [km s^{-1}]	Age [Myr]	P_{cav} [10^{42} erg s^{-1}]
Inner	790^{+105}_{-83}	$6.0^{+0.8}_{-0.6}$	$18.3^{+7.5}_{-6.6}$	259 ± 58	18 ± 4	$6.0^{+2.3}_{-2.1}$
Outer	790^{+105}_{-83}	$14.4^{+1.7}_{-1.5}$	$10.4^{+3.7}_{-4.1}$	214 ± 42	53 ± 11	$2.8^{+0.9}_{-1.1}$

Fig. 2: *Left Panel:* the two putative cavity systems detected in A2495, with the first being coincident with the radio lobes and the second symmetrical with respect to the X-ray peak. Hα and radio contours are in red and green, respectively. *Right Panel:* Black triangles are the data from Bîrzan et al. (2017), while in red are the values for the two cavity systems in A2495. *Bottom Panel:* Cavity properties estimated both with the sound and the buoyancy velocity.

Cavity Analysis

We detect two putative pairs of ICM depressions (~30% surface brightness deficits, see Fig. 2, Left Panel). The first pair is coincident with the radio galaxy lobes, while the second is centered on, and falls on opposite sides of, the X-ray excess. The age difference of the two systems (see Table above) is consistent with the free-fall time of the cooling gas and with the offset dynamical timescale estimated from the line emitting gas. We propose that in A2495 the sloshing process likely plays a part in the feedback cycle: when the cooler region approaches the BCG, the AGN begins to accrete, producing the first generation of cavities. Subsequently, because of sloshing, the accreting material diminishes and the SMBH is switched off. The oscillation could, at a later time, make the process to repeat, producing different generations of cavities. In order to investigate whether the offset cooling mechanism is able to break the feeding-feedback cycle in this cluster, we compared the A2495 cavity power and cooling luminosity values with data from other systems (Bîrzan et al 2017), finding that the values for A2495 are in good agreement with the global scatter of the observed relation (see Fig. 2, right panel). Therefore, we can argue that offset cooling seems to not break the feedback cyle, despite the evidence that cooling is not currently depositing gas into the BCG core.

References

- Bîrzan, Rafferty, Brüggen, & Intema, 2017, MNRAS, 471, 1766
- Canning, Russell, Hatch, et al. 2012, MNRAS, 420, 2956
- Crawford, Sanders, & Fabian, 2005, MNRAS, 361, 17
- Gaspari, Ruszkowski, & Sharma, 2012, ApJ, 746, 94
- Markevitch & Vikhlinin, 2007, PhR, 443, 1
- Voit, Donahue, Bryan, & McDonald, 2015, Nature, 519, 203