Chandra Observations of the AS0295 cluster

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Motivation

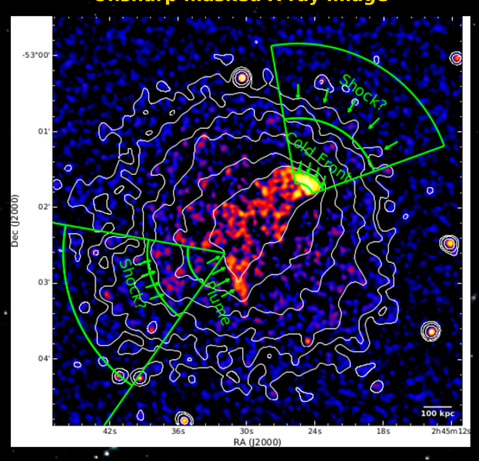
Major cluster mergers are highly energetic events capable of drastically changing the observed properties of clusters. When clusters collide, the intracluster medium suffers significant changes in its morphological and thermal properties. Typical merging signatures observable in X-rays are contact edges between regions of gas with different entropies (e.g. shocks and cold fronts). Mergers are also unique processes which can lead to a separation of gas from dark matter. Therefore, merging clusters represent sought-after targets for studies of the nature of dark matter and its interaction with the gaseous component, of cluster physics, as well as the understanding of the merging process itself.

AS0295 is a low redshift (z=0.3), massive cluster caught during the merging process. In this poster we present an X-ray study of the cluster using 205 ks Chandra observations. We investigate the spatial and spectral properties of the ICM with the aim of understanding the relationship between the observed properties and the dynamical state of the cluster.

What we learn from observations ...

Although our study is based on the information obtained from the X-ray analysis of the cluster, we used for our interpretation of results, multiwavelength studies of AS0295 available in the literature, such as strong lensing [1] and radio observations [3]. The middle image represents a composite of the AS0295 cluster with Hubble (optical image), Chandra (blue-red-yellow colormap), and strong lensing map from [1] (green color).

Unsharp masked X-ray image



We detect two significant surface brightness edges:

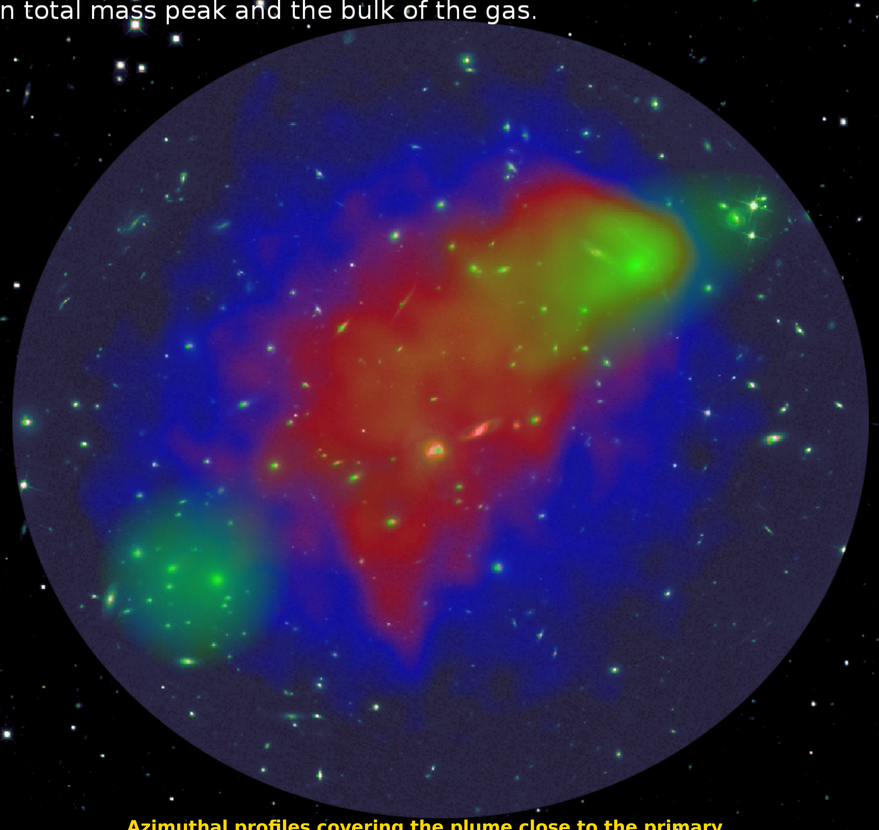
- the plume - a sharp surface brightness edge to the south of the primary's cluster core
- the cold front - the sharp drop in surface brightness in front of the secondary.

From the X-ray image:

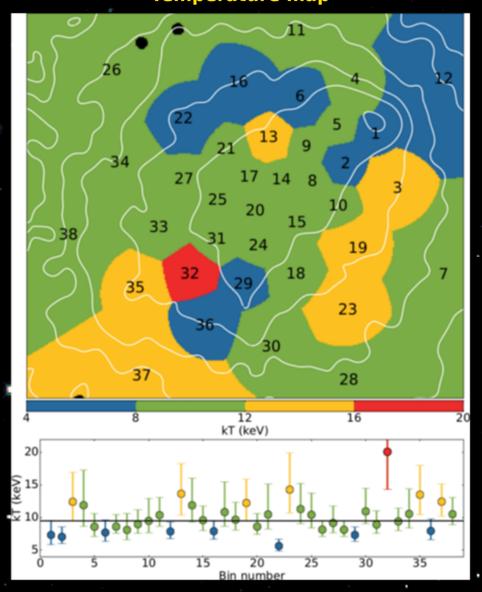
- AS0295 has a clearly disturbed morphology, which is typical for merging clusters.
- The binary nature of the merger is suggested by the X-ray peak visible in the NW (the secondary cluster) and the bulk of gas with a flat surface brightness distribution in the SE (the primary cluster).
- The SE-NW orientation of the merger axis is suggested by the elongated morphology in this direction and the "bunching up" of the contour lines in front of the secondary.

From the strong lensing map:

- The binary nature of the merger is confirmed by the presence of two peaks in the mass distribution.
- The total mass peak of the secondary coincides with the X-ray peak, while for the primary there is a clear offset between total mass peak and the bulk of the gas.

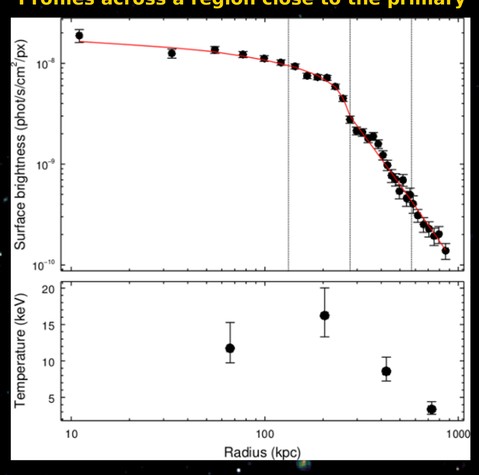


Temperature map



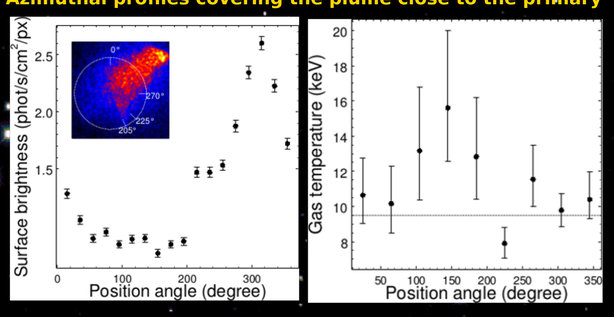
- The primary is a non-cool core cluster, with a gas temperature similar to the mean temperature of the cluster (9.5 keV).
- The secondary has cool gas ssociated with it.
- The highest gas temperature corresponds to a small region in the vecinity of the primary.

Profiles across a region close to the primary



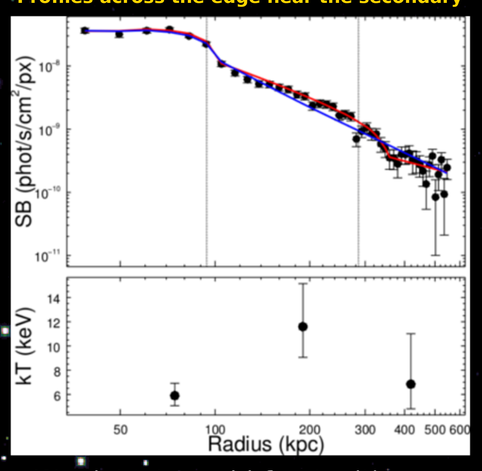
- A possible reverse shock, with a Mach number of 1.24±0.02, is found close to the primary cluster
- The amplitude of density jump is 1.35±0.003 and the temperature has a jump of $1.89^{+0.61}_{-0.45}$

Azimuthal profiles covering the plume close to the primary



- The plume detected to the south of the primary has a linear-like shape and extends over ~240 kpc.
- The gas forming the plume is significantly cooler compared to the adjacent regions.

Profiles across the edge near the secondary

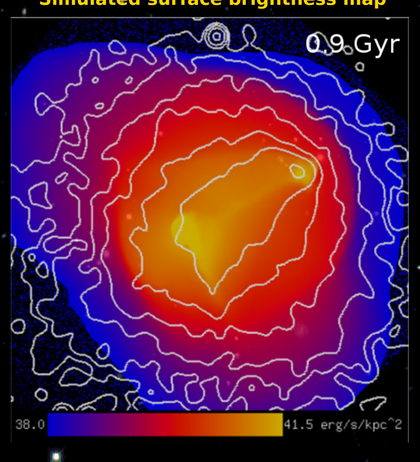


- We detect a cold front with a gas density jump of 2.19±0.29 and a temperature jump of 0.5±0.18 .
- There is weak evidence for the presence of a shock 246 kpc ahead from the cold front. The discovery of a radio relic at this position [3], brings additional evidence for the existence of a bow shock.

What we know from simulations ...

To learn more about the dynamical state of AS0295, we compare our observations with the results of hydrodynamical simulations of binary cluster mergers available in the literature. The figures below, which are adapted from simulated results [2], match the best our observations and show surface brightness (left) and temperature map (right) corresponding to a 3:1, off-axis, binary merger, caught at a time during the secondary's first travel between pericenter and apocenter. The two bottom panels show the surface brightness (left) and temperature (right) maps for the same merger, but at differnt stages in the merging process.

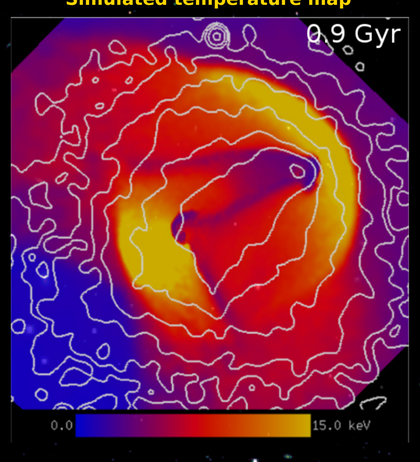
Simulated surface brightness map

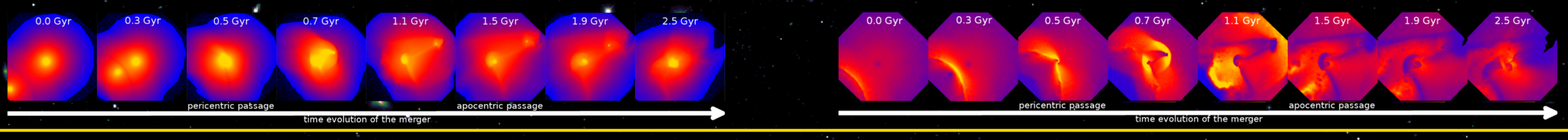


Simulations predict:

- an elongated distribution of the surface brightness along the direction of the merger (consistent with X-ray observations which show gas elongated in the SE-NW direction)
- the formation of a cold front in front of the secondary shortly before pericentric passage, which tipically survives until the second pericentric passage (consistent with the cold front detected in observations, although the morphology of the observed cold front is slightly different from the one seen in simulations).
- the formation of two outwardly propagating shocks, a bow shock and a reverse shock, shortly before the first pericentric passage (observationally we found some evidence for a reverse shock and very weak evidence for a bow shock)
- the formation of a plume of gas after the first pericentric passage of the secondary (consistent with the plume seen to the south of the primary)
- the formation of a sloshing cold front close to the primary core (not observed in the X-ray data)

Simulated temperature map





Conclusions

Comparison of the Chandra results with literature studies of binary galaxy cluster simulations, as well as optical and radio studies of AS0295 suggests that AS0295 cluster:

- is a low mass-ratio, off-axis, binary merging system, with the secondary close to the first apocentric passage
- shows signs of mergers in the ICM such as a cold front and a plume of cool gas
- shows weak signs for the presence of shocks: a reverse and possibly a bow shock
- shows a significant spatial offset between the peak of the gas and that of the dark matter in primary

AS0295 is a promisisng candidate for studies of the nature of dark matter and the merging process involving non-cool core clusters.

References

[1] Cibirka, N., Acebron, A., Zitrin, A., et al. 2018, ApJ, 863, 145
[2] Poole, G. B., Fardal, M. A., Babul, A., et al. 2006, MNRAS, 373, 881
[3] Zheng, Q., Johnston-Hollitt, M., Duchesne, S. W.,& Li, W. T. 2018, MNRAS, 479, 730

This poster is based on the work presented in:
Pascut, A., & Hughes, J.P., 2019, ApJ, 874, 71