Thermodynamic structure of Cluster of Galaxies with Chandra X-ray Observation

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Abstract: Galaxies preferentially found in groups are called clusters. Galaxy clusters act as remarkable laboratories to know more about astrophysics, dark matter, baryons, plasma and high-energy physics. This poster presentation will present the thermodynamic structure of galaxy cluster Abell 2069 and Abell 1995. We have analyzed Chandra X-ray archival data of A2069 and A1995 to create thermodynamic maps. We have used Adaptive Circular Binning technique. A diffused extended source and an active merger event has been found in A2069. Our results show that the central region of A1995 is hotter than the peripheral regions of the cluster.

Introduction: Galaxy clusters are formed due to the collapse of the largest gravitationally bound over-densities in the initial density field. Clusters are dynamically evolving systems that have no well-defined boundary. Cluster mergers are the mechanism by which galaxy clusters are formed. The merger of galaxy cluster, structures such as cold front and shock wave have been found in many clusters of galaxies by using data from Chandra X-ray Observatory. The merging of galaxy clusters are the most energetic events in the present day Universe. We have created temperature, flux density, pseudo-entropy and pseudo-pressure maps of Abell 2069 and Abell 1995.

Galaxy Cluster
Credit: NASA

Methodology: A systematic calibration and analysis pipeline ClusterPyXT has been used along with Chandra Interactive Analysis of Observations *(CIAO*) and Chandra Calibration Database *(CALDB).*

Significant steps of the data analysis pipeline are as below :

1. Data download automatically and ObsId's are provided
2. It calibrates and cleans the data, removed point sources
3. Global response files are generated using specextract task, inbuild in CIAO
4. Region selection in the range 0.7-8.0 keV
5. The pipeline calculates the circular bin centered at every pixel using Adaptive Circular Binning Method to create a scale map
6. APEC thermal and PHABS (photoelectric absorption) models are used to fit the spectra and a temperature map is created corresponding to the best-fitted temperature of the APEC model.

Results

Abell 2069: There is two hot regions near the center, one at north-west from the center, another at south-east of the center of A2069. Pseudo-pressure, pseudo-entropy and flux density are higher in the core and at an extended region and decreases gradually moving outwards from the central region. Direct evidence for merging of clusters has been found from the morphology of the X-ray emission.

Exposure time: *55.42 ksec*
Total count: *234695*
Number of ObsId: 1.

Projected density, $n \propto S^{1/2}$
Pseudo-pressure, $P=nkT \propto TS^{1/2}$
Pseudo-entropy, $K=kT/n^{2/3} \propto T/S^{1/3}$
S- surface brightness, *T*- temperature.

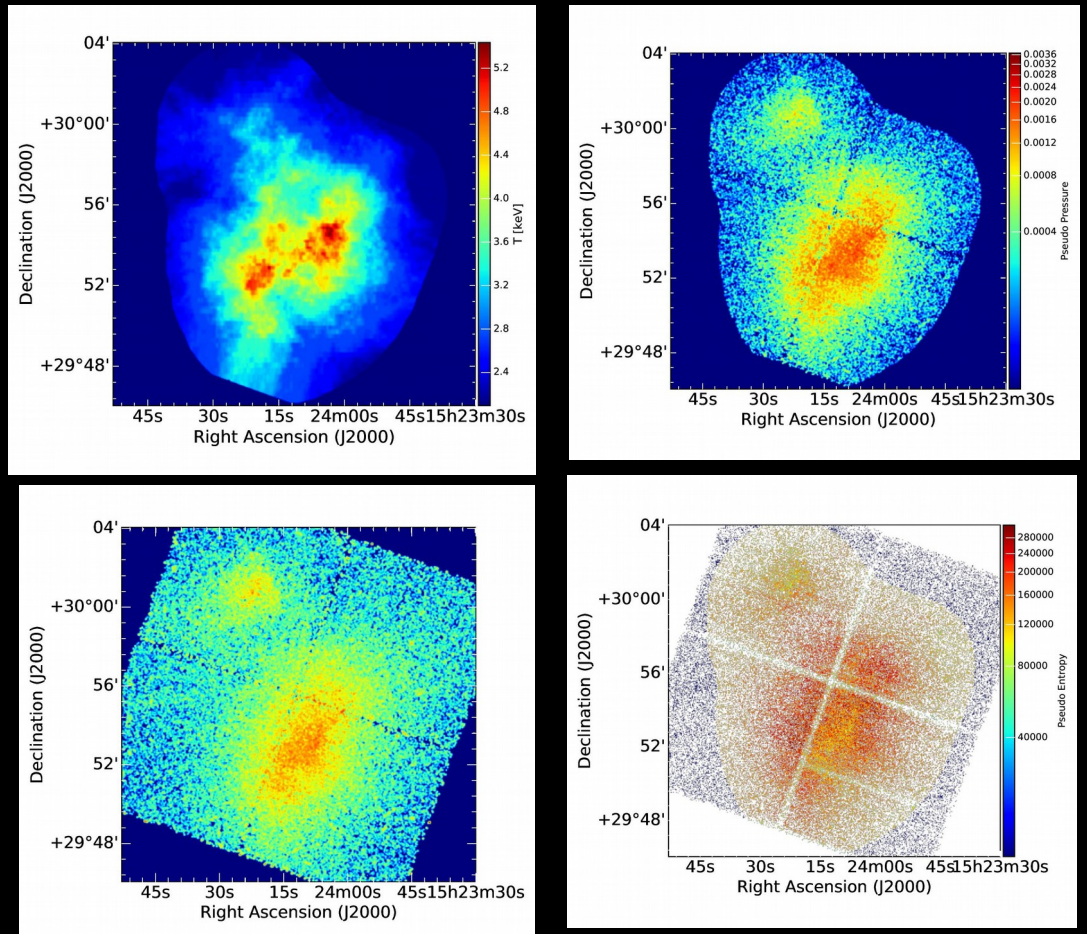

Figure 1: *Top Left*: Chandra X-Ray (*ACIS-I*) Temperature map of A2069. *Top Right:* Pseudo-Pressure map of A2069. *Bottom Left:Flux density map of A2069, Bottom Right:* *Pseudo-entropy* map of A2069. Color bar indicates the temperature.

Results

Abell 1995: The temperature map shows that the central region is the hottest part of the galaxy cluster Abell 1995. Pseudo-pressure and the flux density is also maximum in the core whereas pseudo-entropy is least in the core and gradually increases moving outside from the center of the galaxy cluster.

Exposure time: 55.62 ksec
Total count: 500932
Number of ObsId: 2

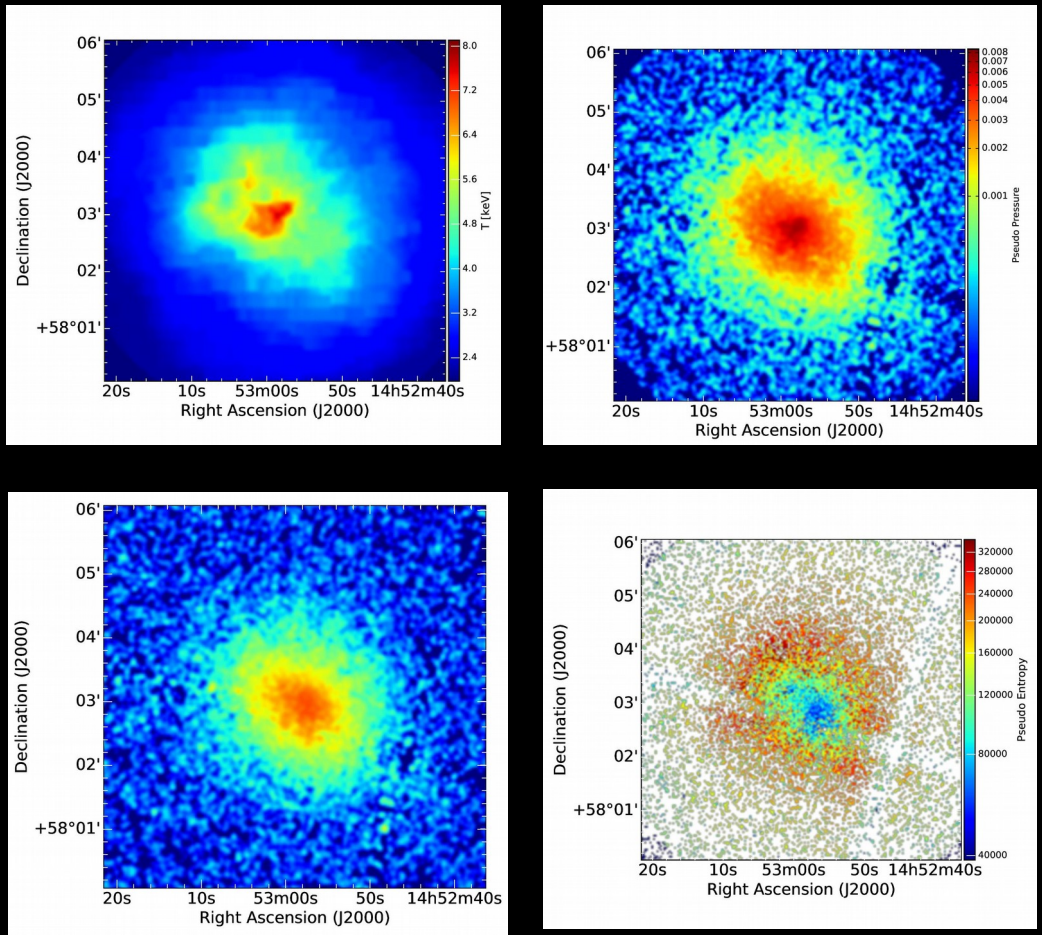

Figure 2: *Top Left:* Temperature map of A1995, *Top Right*: Pseudo-pressure map of A1995. *Bottom Left:* Flux density map of A1995, *Bottom Right:* Pseudo- entropy map of A1995. Color bar indicates the temperature.

Conclusions: Thermodynamic maps for two clusters have been created. Both of the clusters have different morphology.

The temperature map of A2069 shows that two subclusters are colliding. A2069 is a non-relaxed galaxy cluster. Based on the flux density, pseudo-pressure and pseudo-entropy map it is clear that there is an extended diffuse emission in Abell 2069.

From all the thermodynamic maps of Abell 1995, we can conclude that the core of the galaxy cluster is more ordered, and no merging event is going on. The temperature is highest at the core whereas entropy is greater in the core's outer region.

These two galaxy clusters are identical and independent. For better insight about the dynamics of the central region, we have to study it in detail.

References: 1) Datta et al. 2014, arXiv: 1408.5123v1
2) Santos et al. 2019, arXiv: 1910.07405v1
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5) Giovannini et al. 2009, ApJ, 507, 1257

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