XMM-Newton Observations of the Toothbrush and Sausage Clusters of Galaxies

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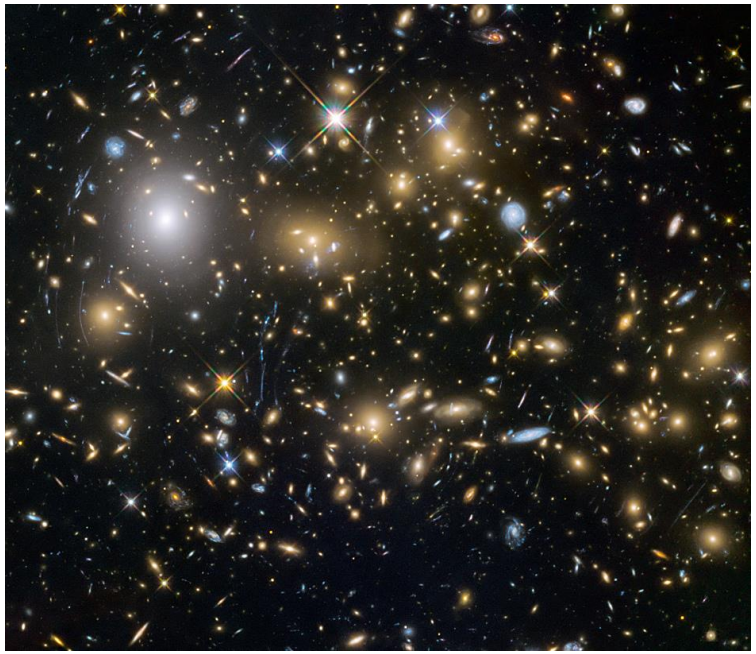
Galaxy Clusters

- **Largest** gravitationally bound objects in the universe.

- Contains **100-1000** galaxies.



Between the Galaxies

Intracluster Medium (ICM)

- Hot plasma that radiates X-ray between the galaxies.
- Has been enriched with metals produced by supernovae over the last billion years

The «Toothbrush» and «Sausage» Cluster

We present new results from XMM-Newton archival observations of the merging clusters 1RXSJ0603.3+4213 and CIZA J2242.8+5301.

Why are they interesting?

- The Toothbrush and Sausage clusters, show a large radio relic associated with **a merger shock** North of their respective core.

- How a merger shock affect the metal abundances and the temperature can be invsetigated.

Why is **this** investigation interesting?

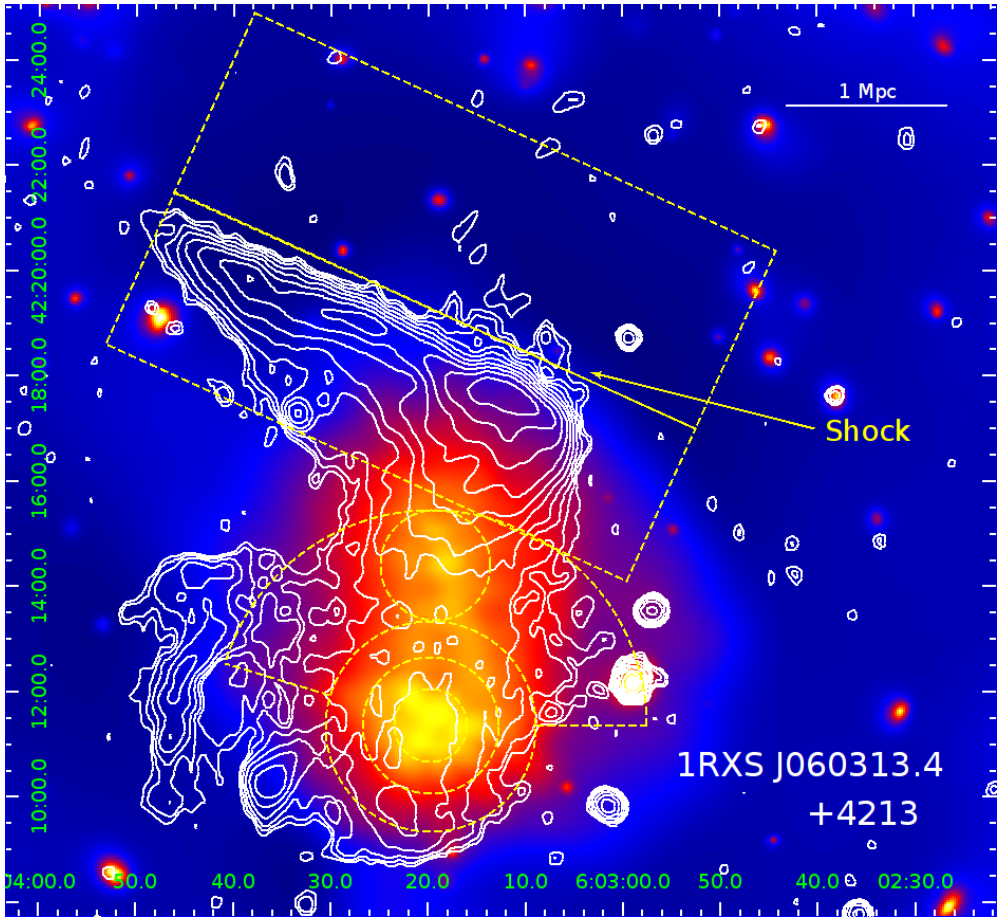
- For both the Toothbrush and the Sausage, the investigation of the **regions close to the shock** by XMM-Newton data is presented for the **first time**.

- We show the metal abundance and the temperature profile of the clusters.

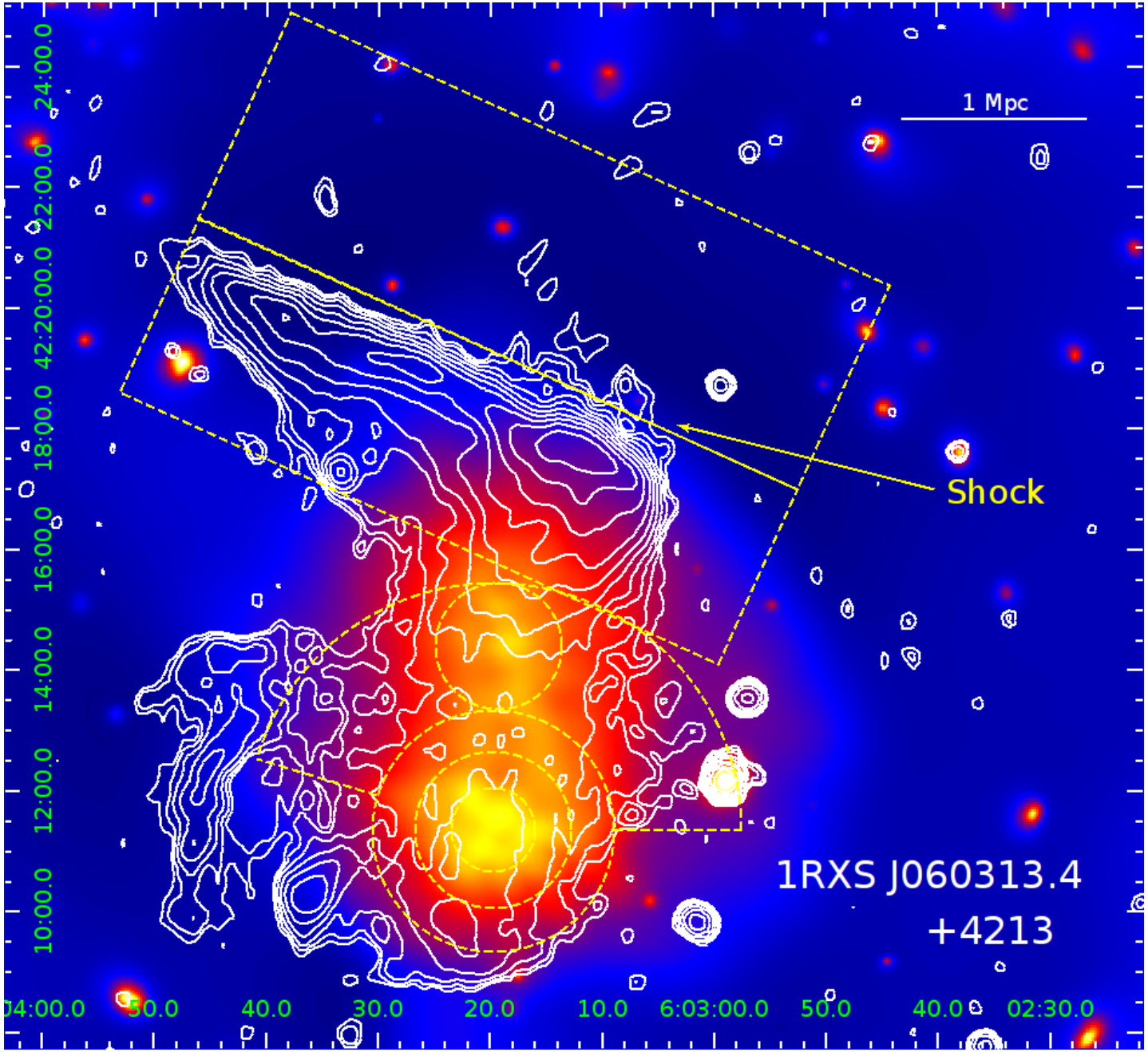
The Toothbrush

- We use the XMM-Newton data from the observation on 3 October 2011.

- The results are derived from spatially resolved X-ray spectra from the EPIC instrument on board XMM-Newton.



EPIC image of the Toothbrush cluster. The radio contours (white) are adapted from van Weeren, R. J., Brunetti, G., Brüggen, M., et al. The energy range is 0.2-2 keV. The yellow dashed lines show the regions we investigated for spectroscopy.


1 Mpc
Shock
1RXS J060313.4
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24:00.0
22:00.0
42:20:00.0
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50.0
40.0
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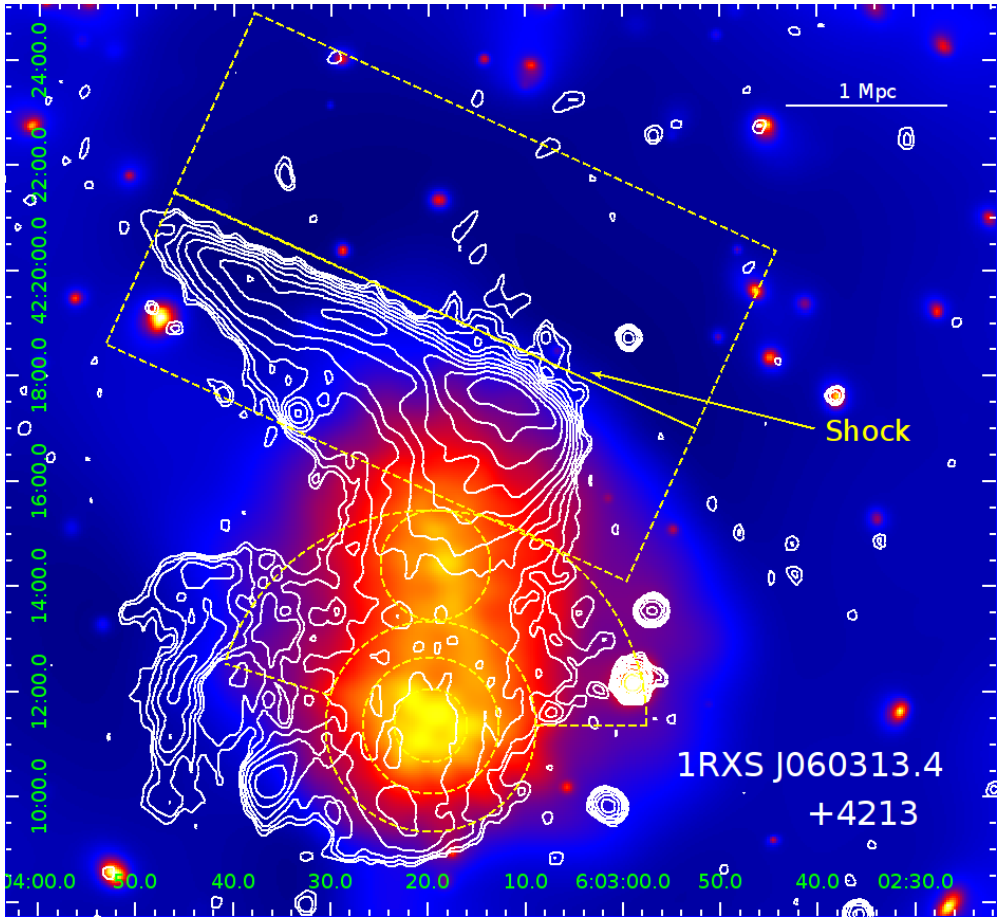
The spectra of the Toothbrush

The EPIC MOS 1, MOS 2 and pn data reduction is performed using the XMM Science Analysis System (SAS), the point sources have been detected and discarded. The spectral analysis is conducted with SPEX.



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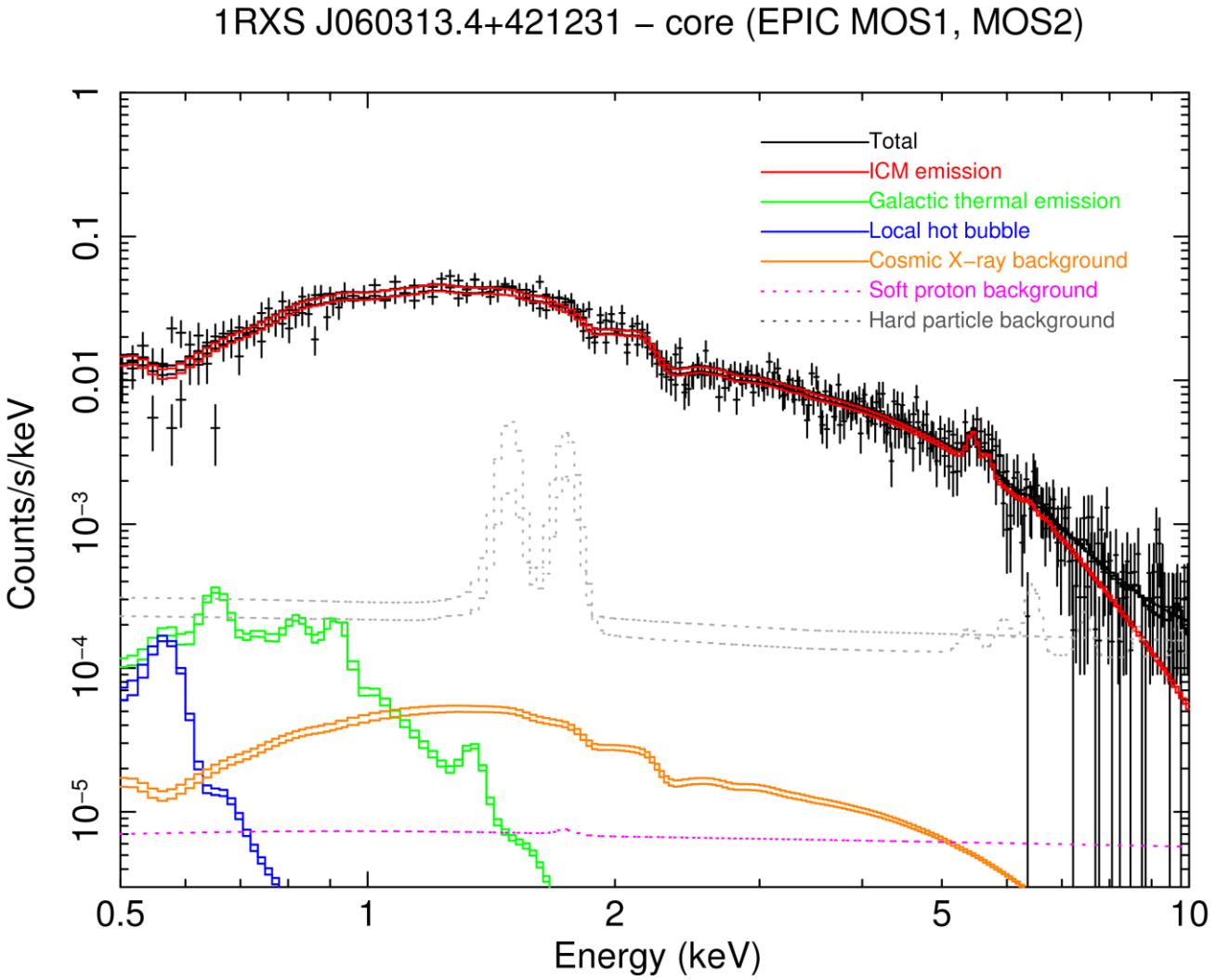
EPIC Spectra of the Toothbrush



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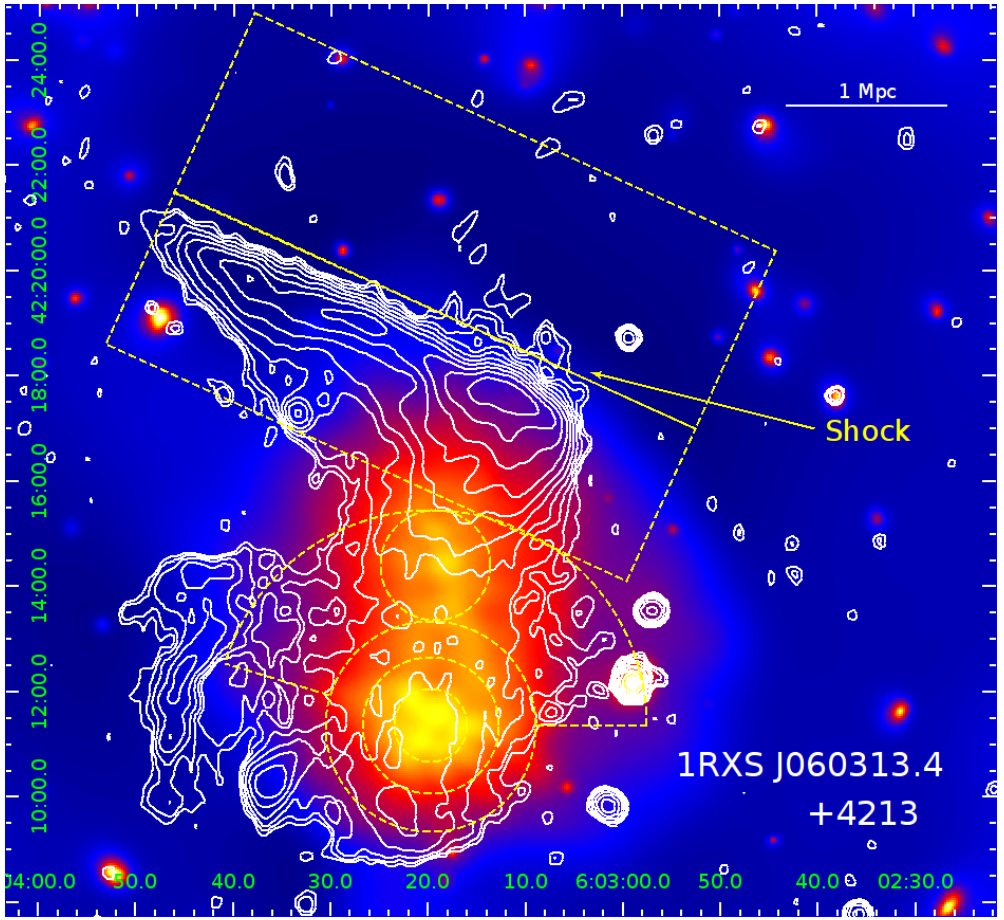

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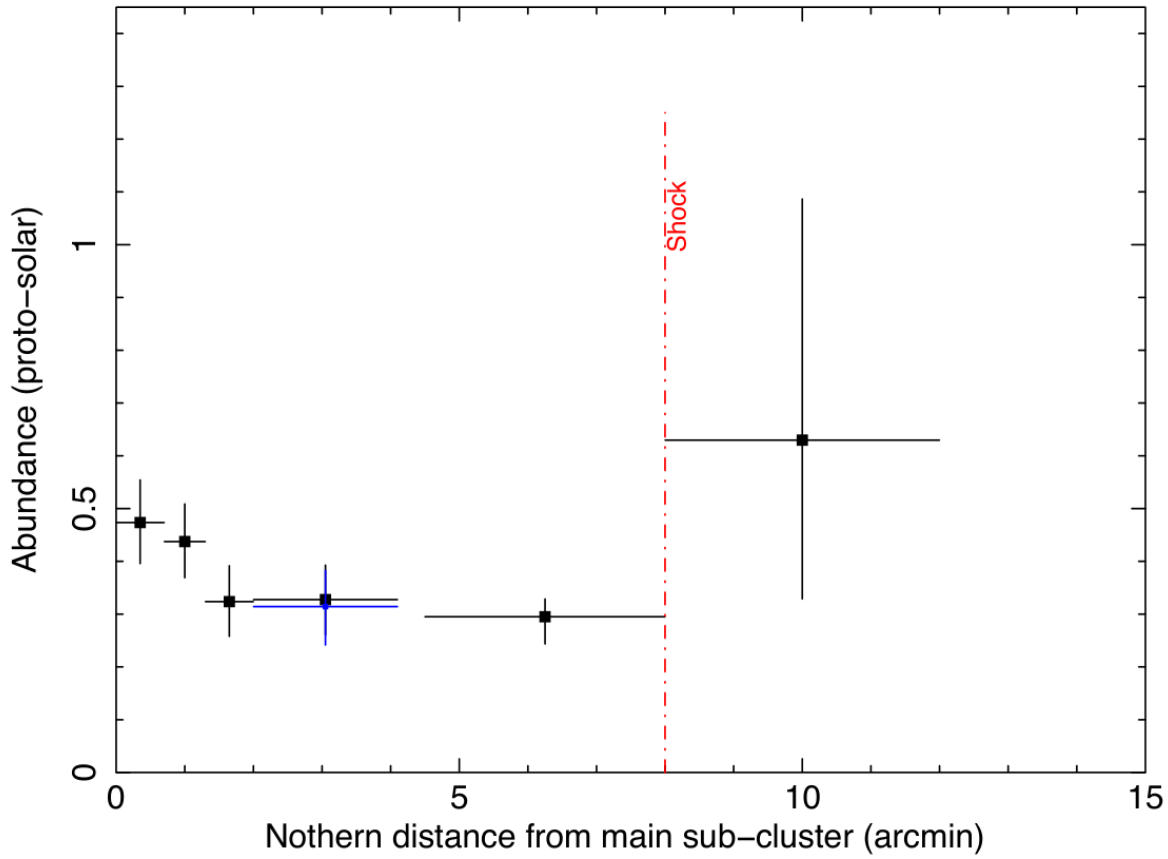
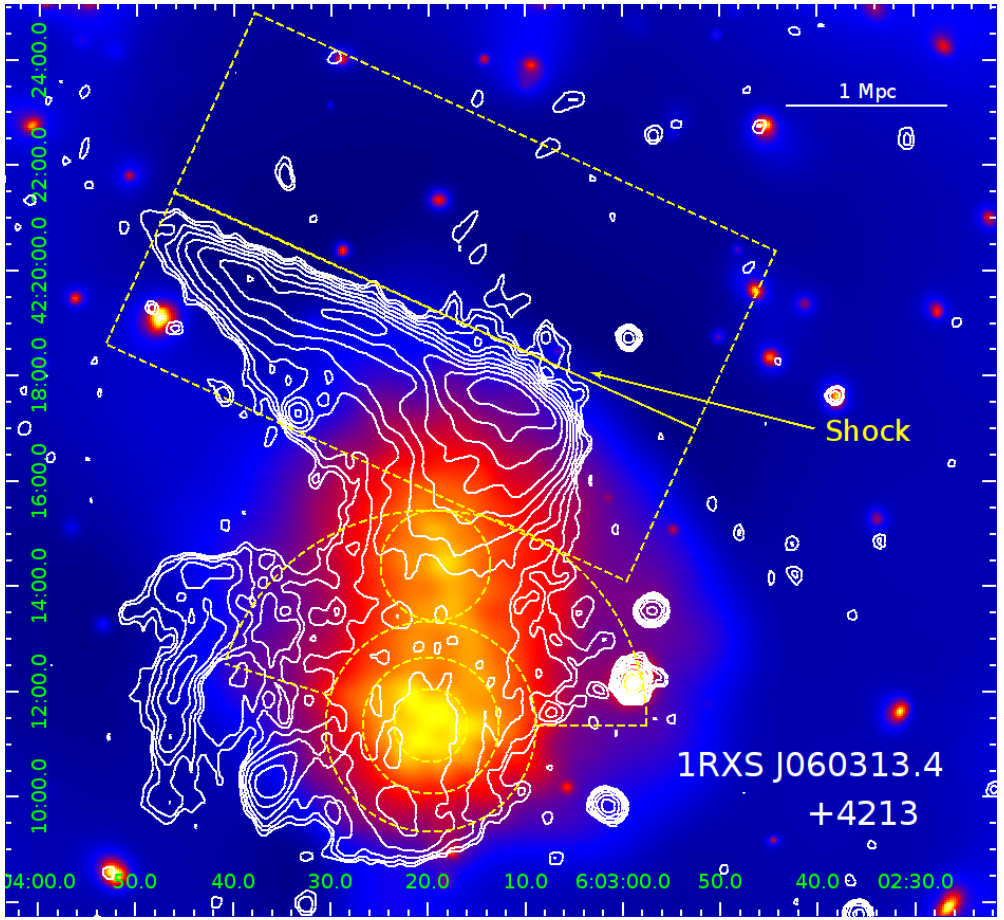
The Fe Abundance Profile of the Toothbrush





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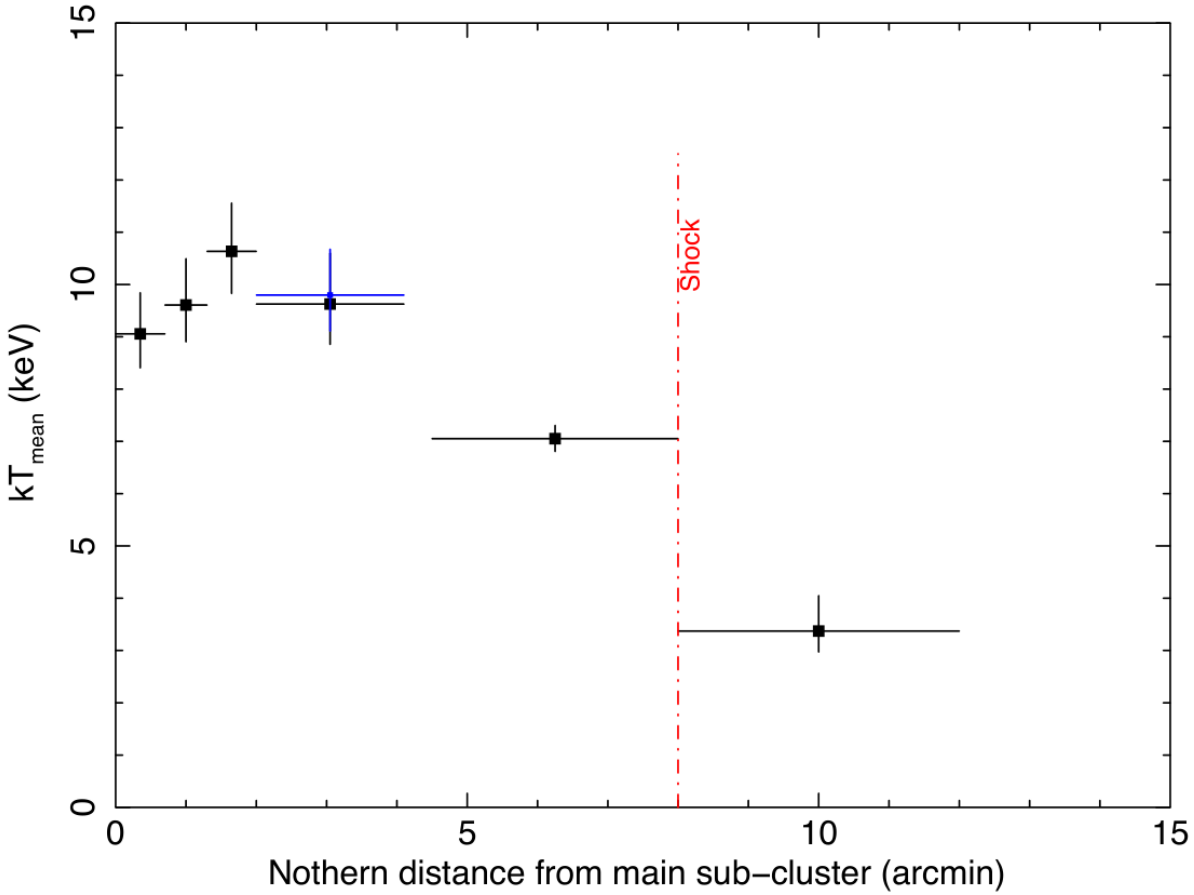
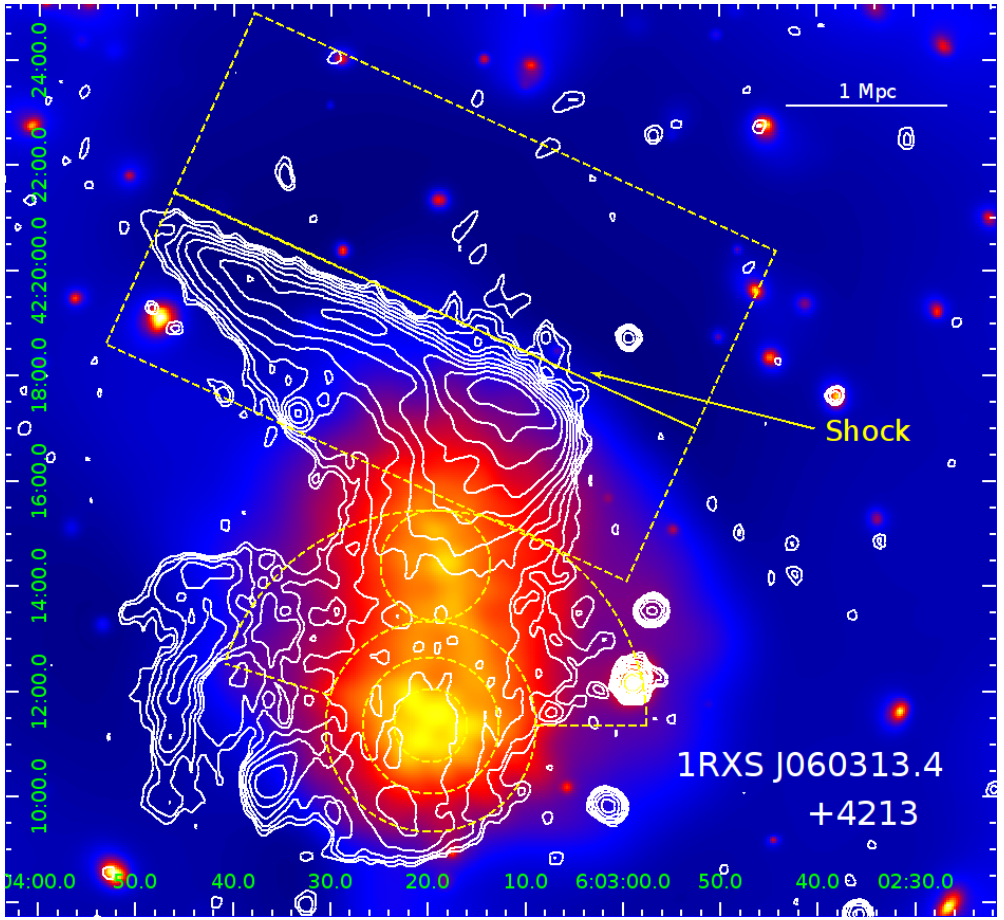
The Temperature Profile of the Toothbrush





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Conclusion of the Toothbrush

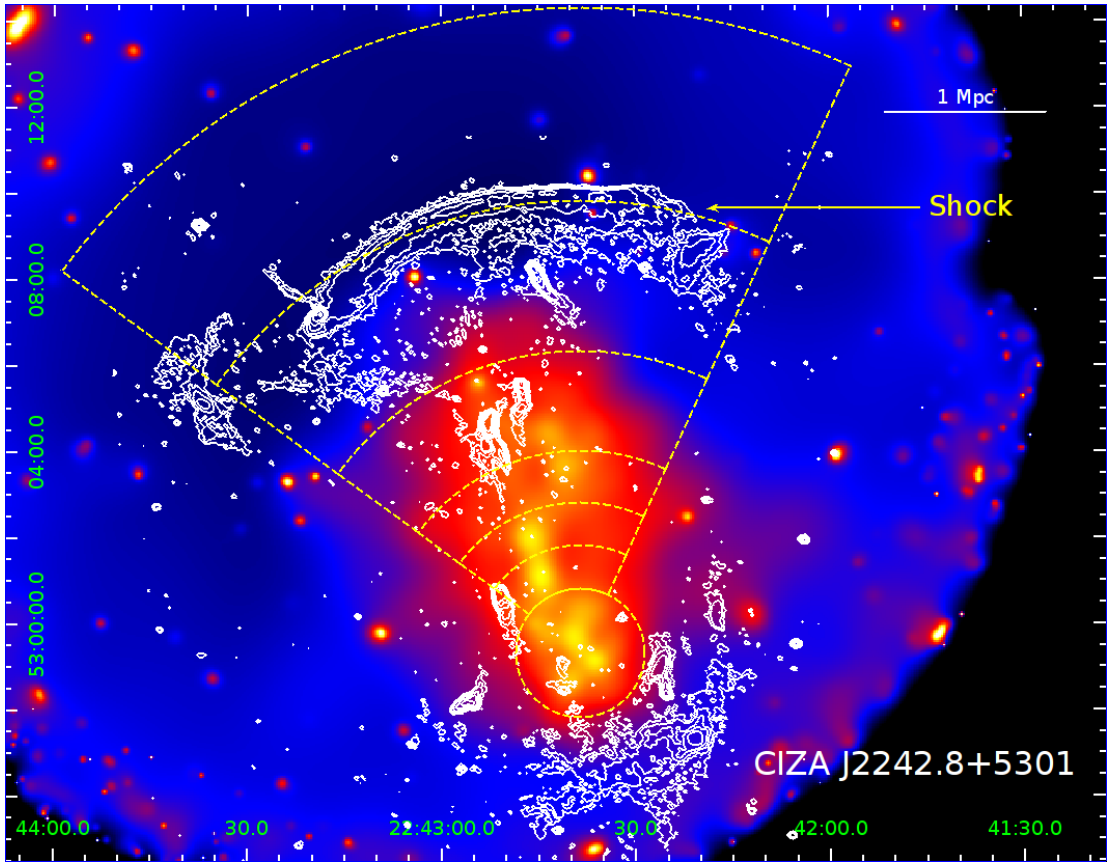
In the Toothbrush, we observe an abundance enhancement towards the core of the main subcluster. This Fe enhancement is accompanied by a slight temperature drop. These findings may point that before the merging, the main subcluster was **cool-core** and it has survived after the merging.

Outside the
core (>2 arcmin), the Fe distribution is uniform (~0.3 proto-solar) and the temperature decreases gradually. Based on the temperature profile, it is difficult to confirm the presence of a shock at the position of the radio relic.

The Sausage

- We use the XMM-Newton data from the observation on 3 October 2011.

- The results are derived from spatially resolved X-ray spectra from the EPIC instrument on board XMM-Newton.



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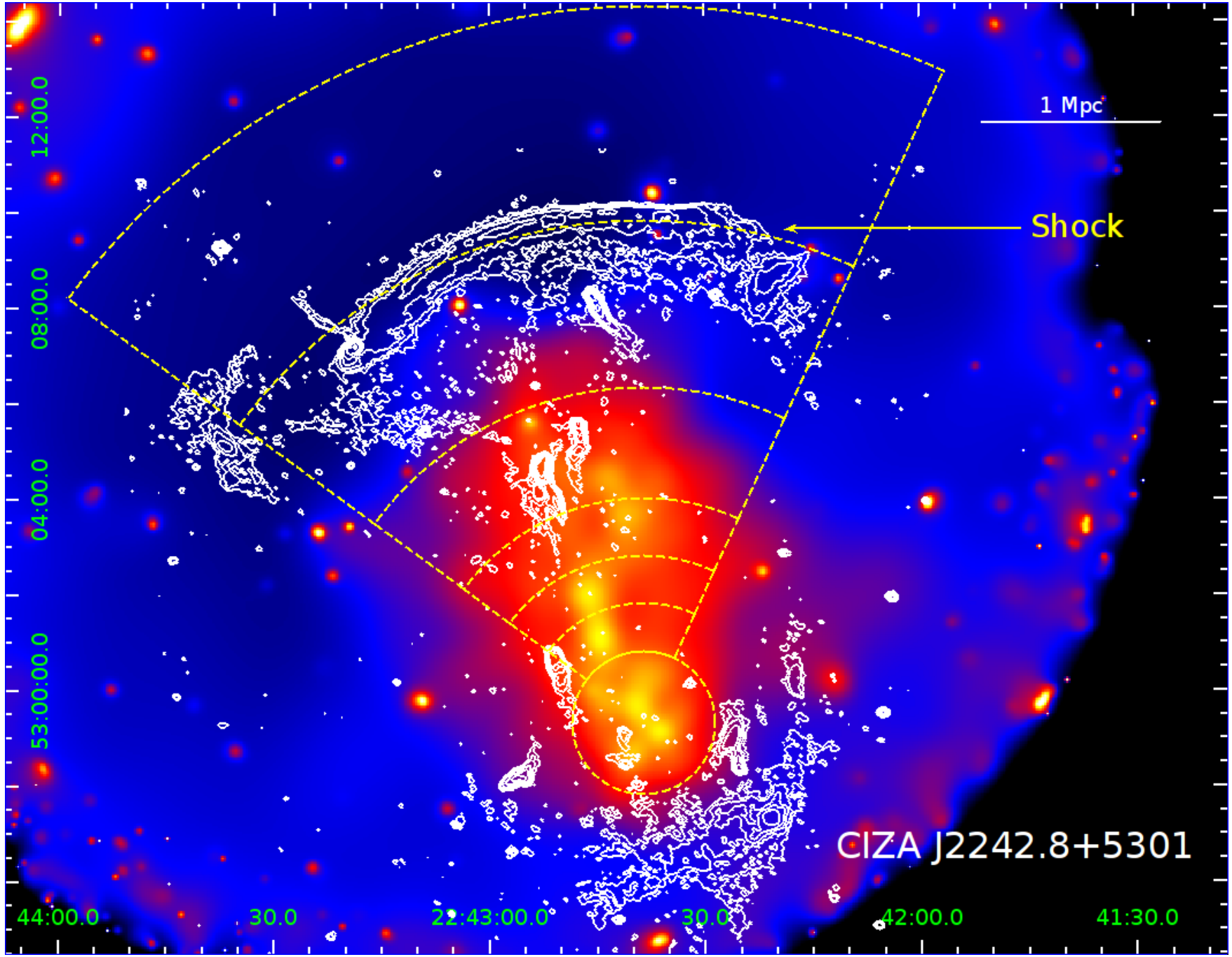
1 Mpc
Shock
CIZA J2242.8+5301
12:00.0
08:00.0
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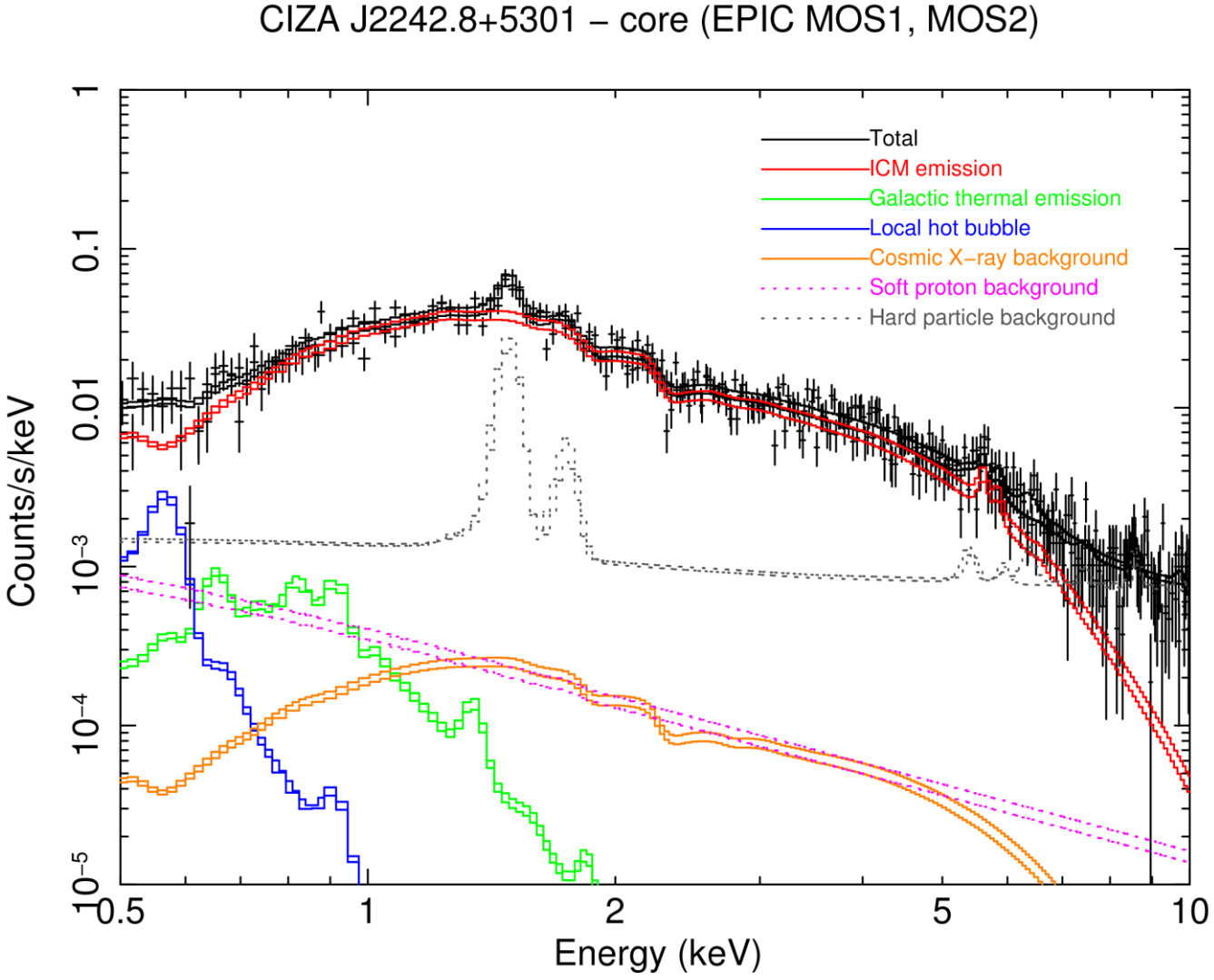
EPIC Spectra of the Sausage



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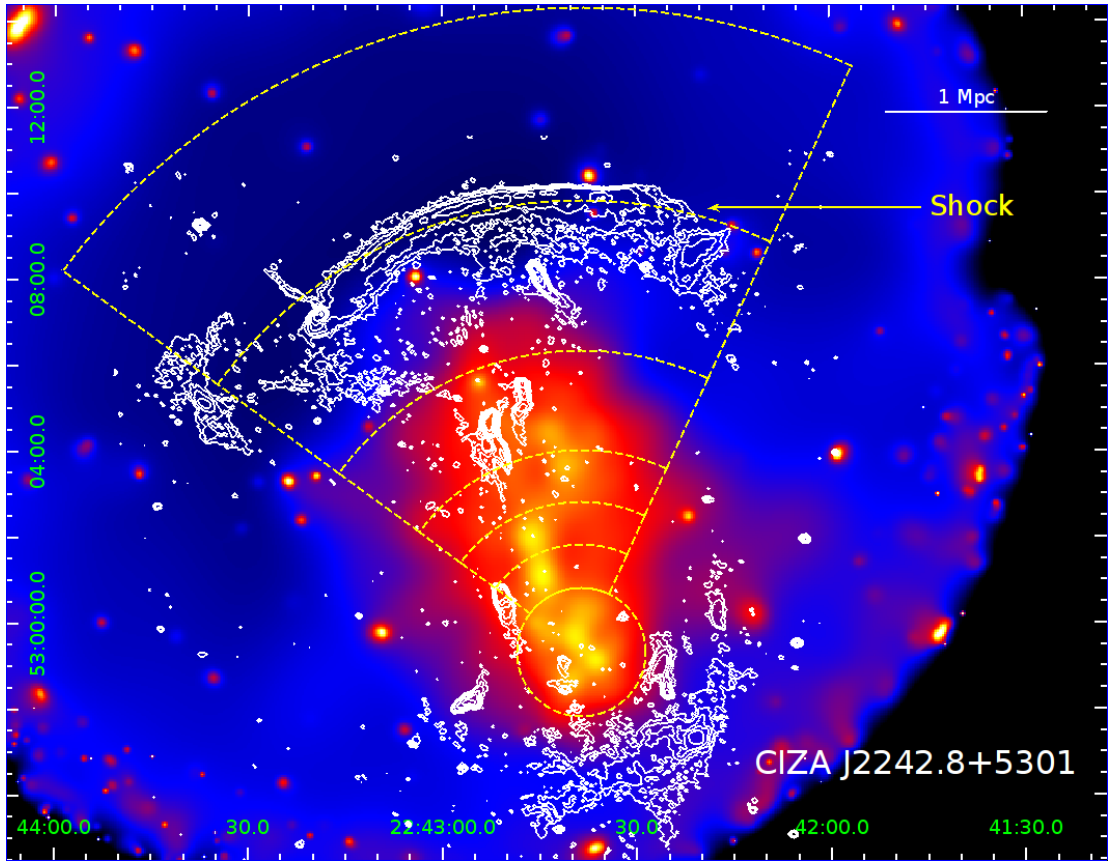

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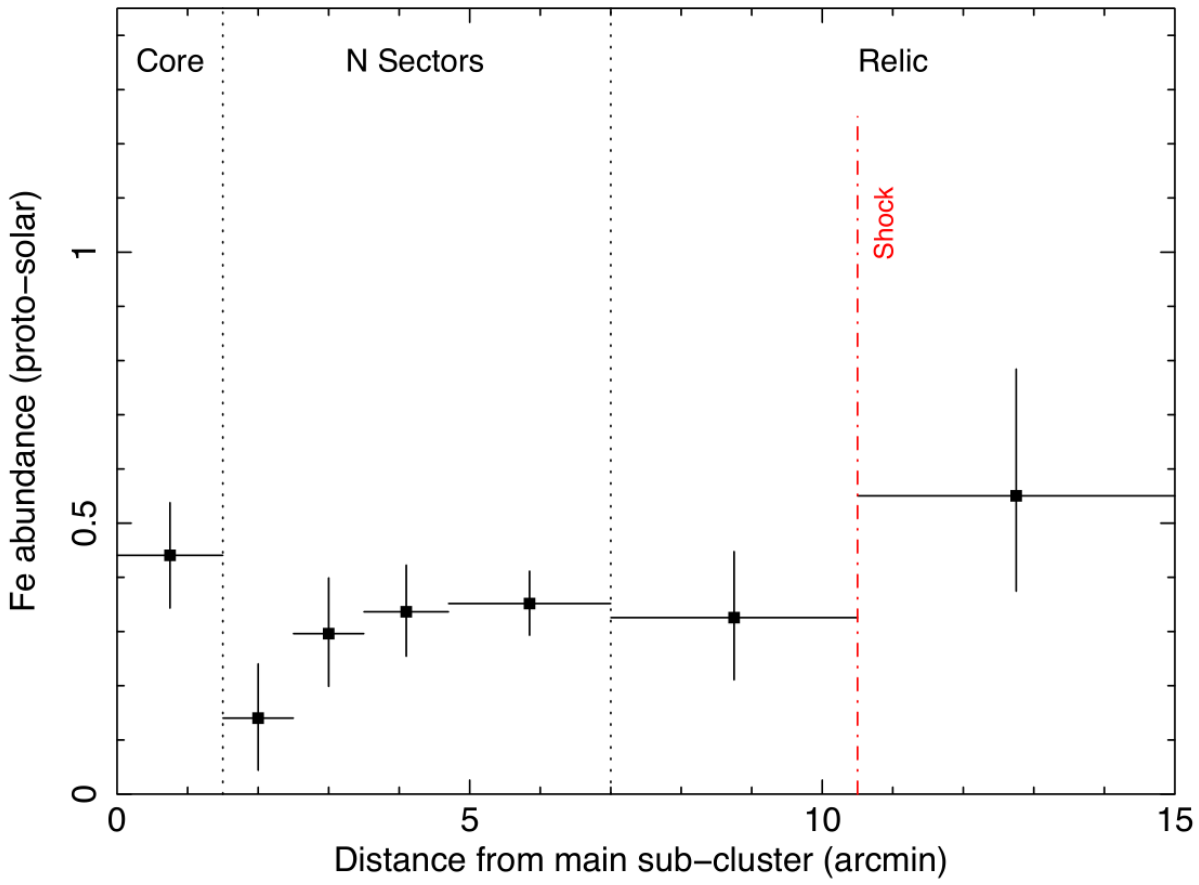
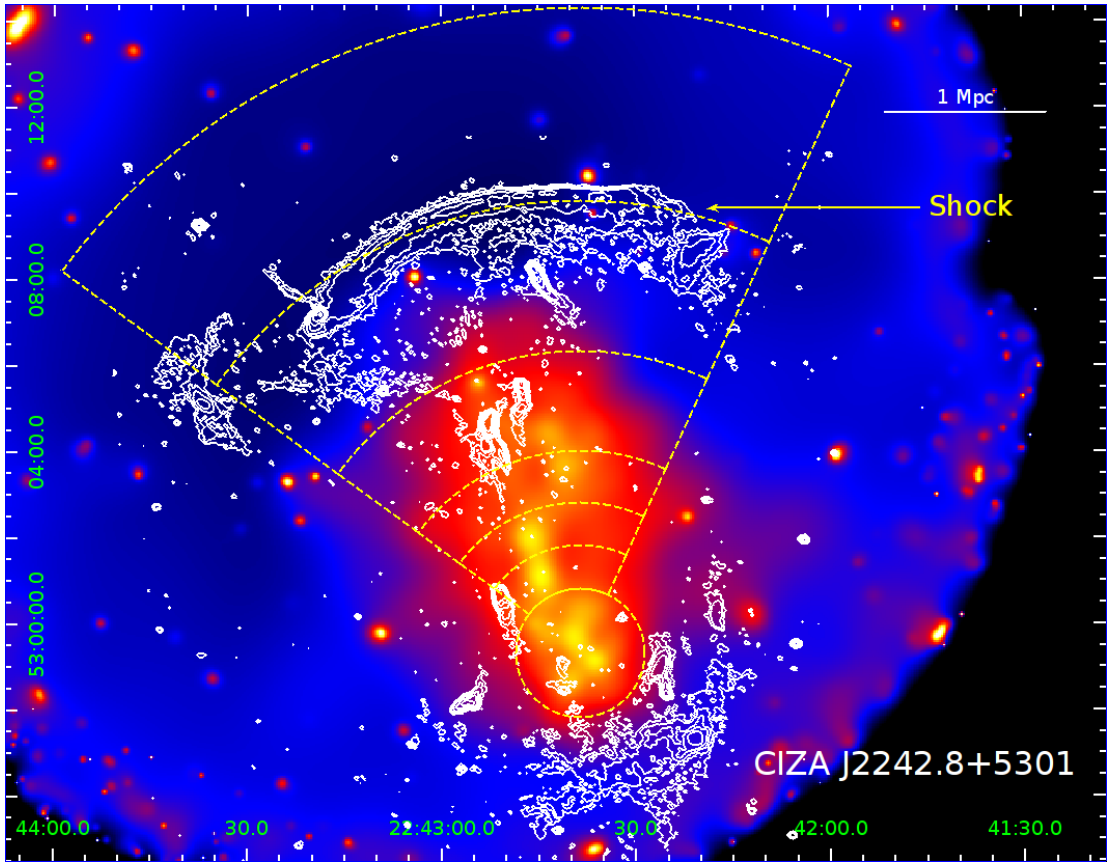
The Fe Abundance Profile of the Sausage





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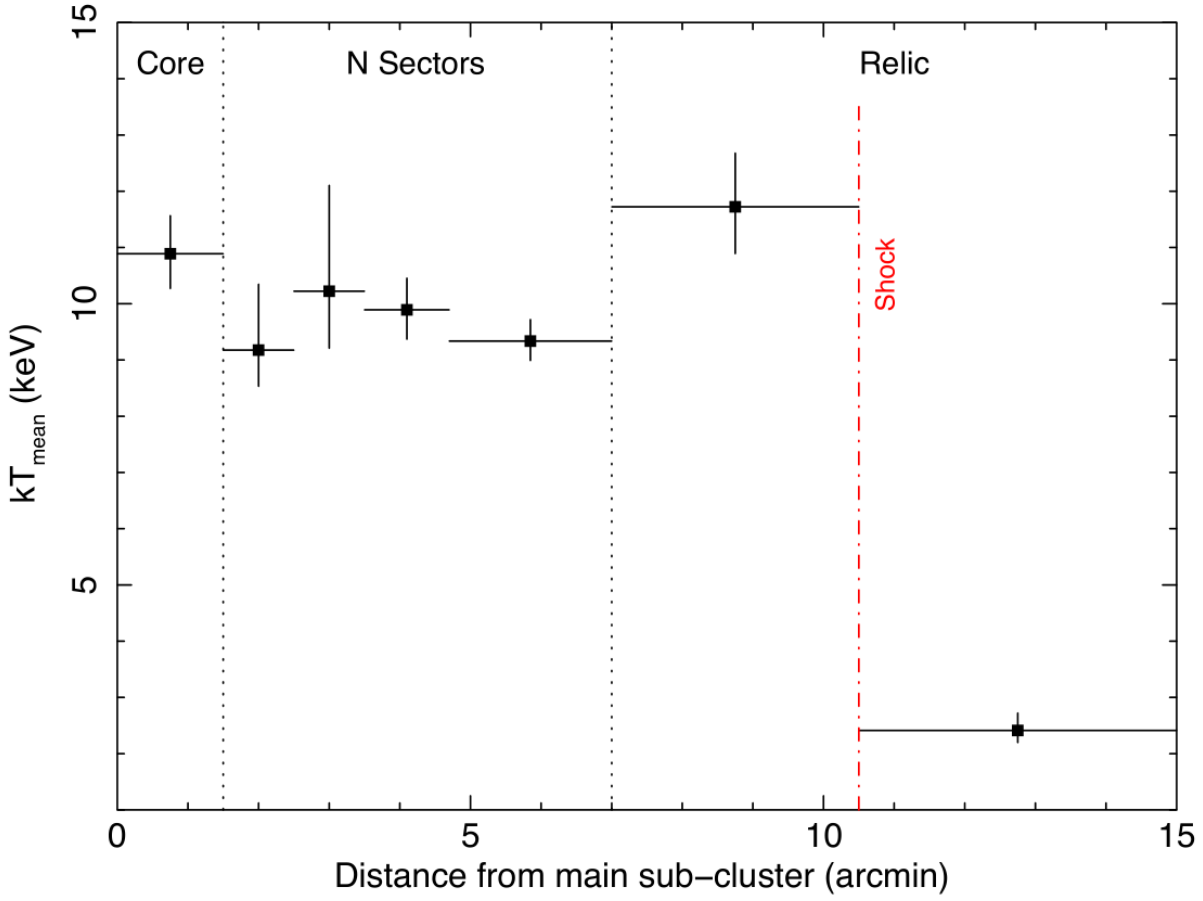
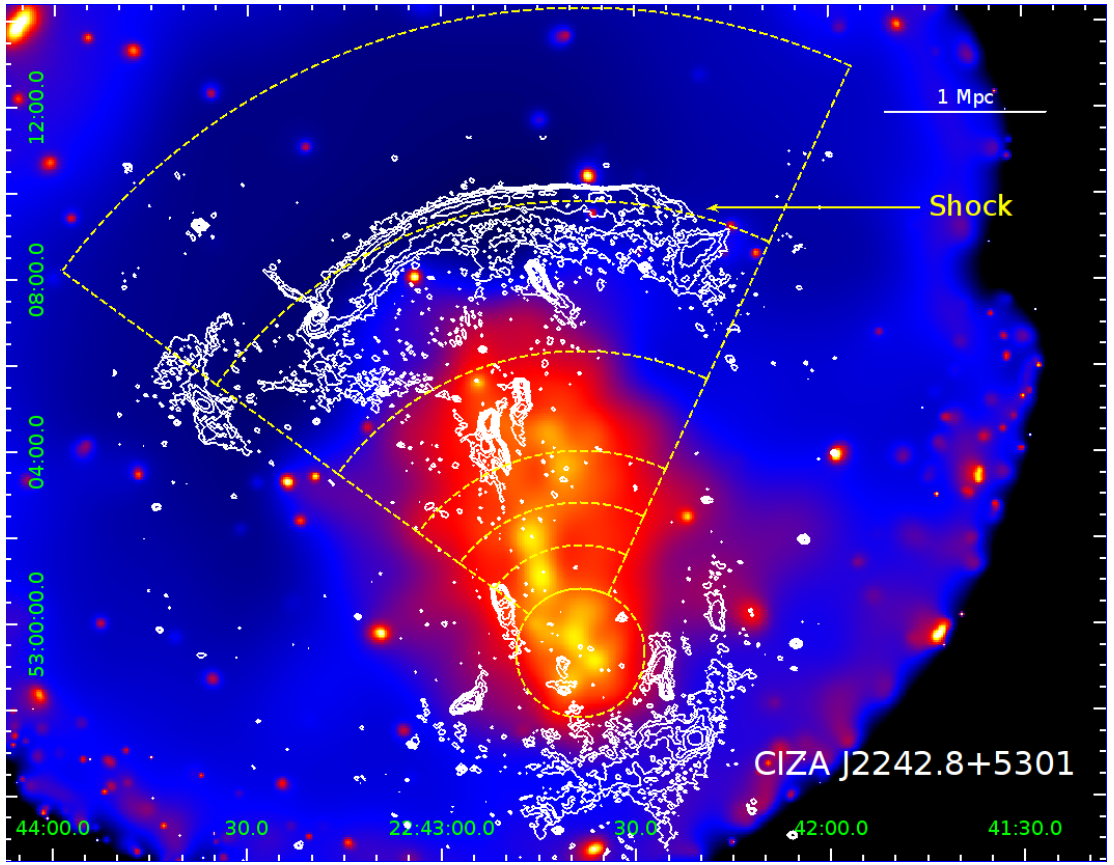
The Temperature Profile of the Sausage





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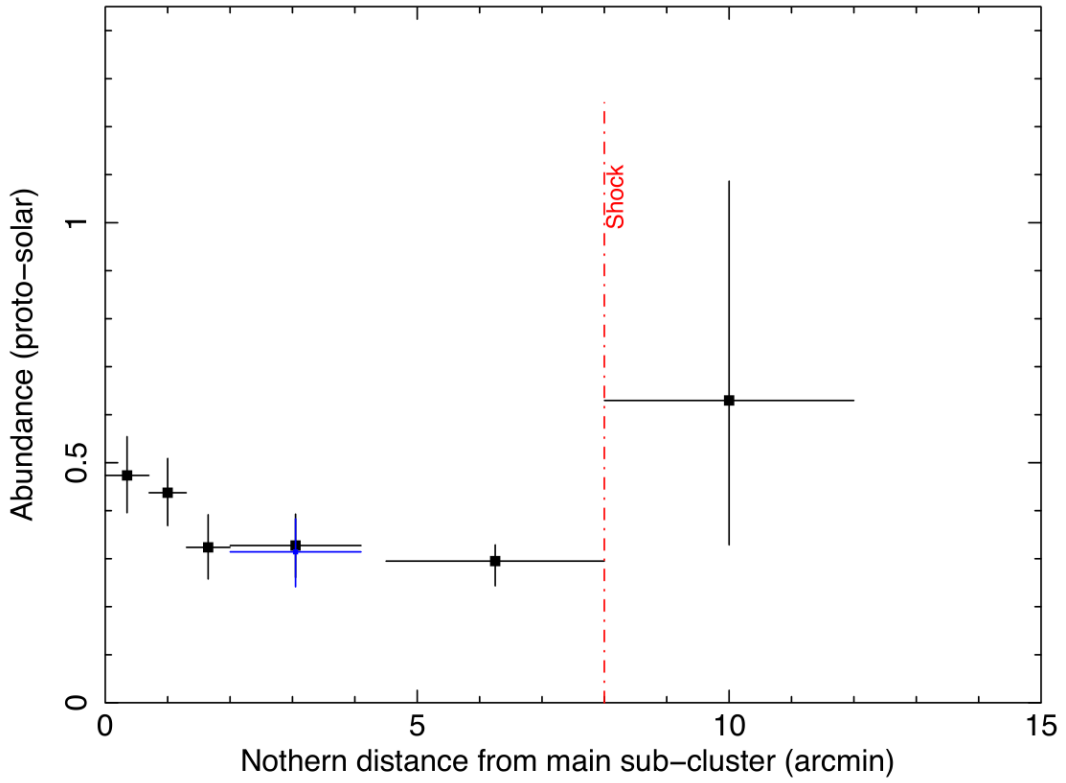
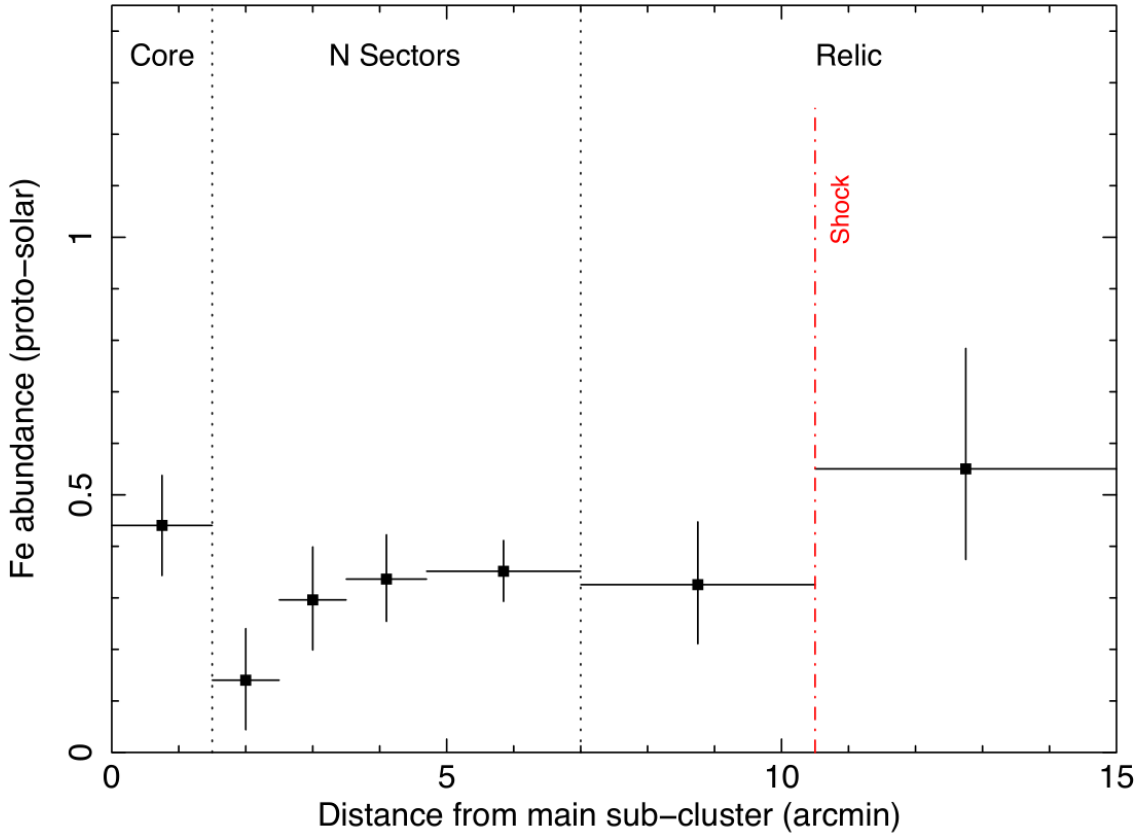
Conclusion of the Sausage

The temperature distribution of the Sausage cluster shows a flat behavior until it decreases dramatically beyond the shock. The pre-shock temperature is about 3-4 keV, which is in agreement with the findings from Suzaku.

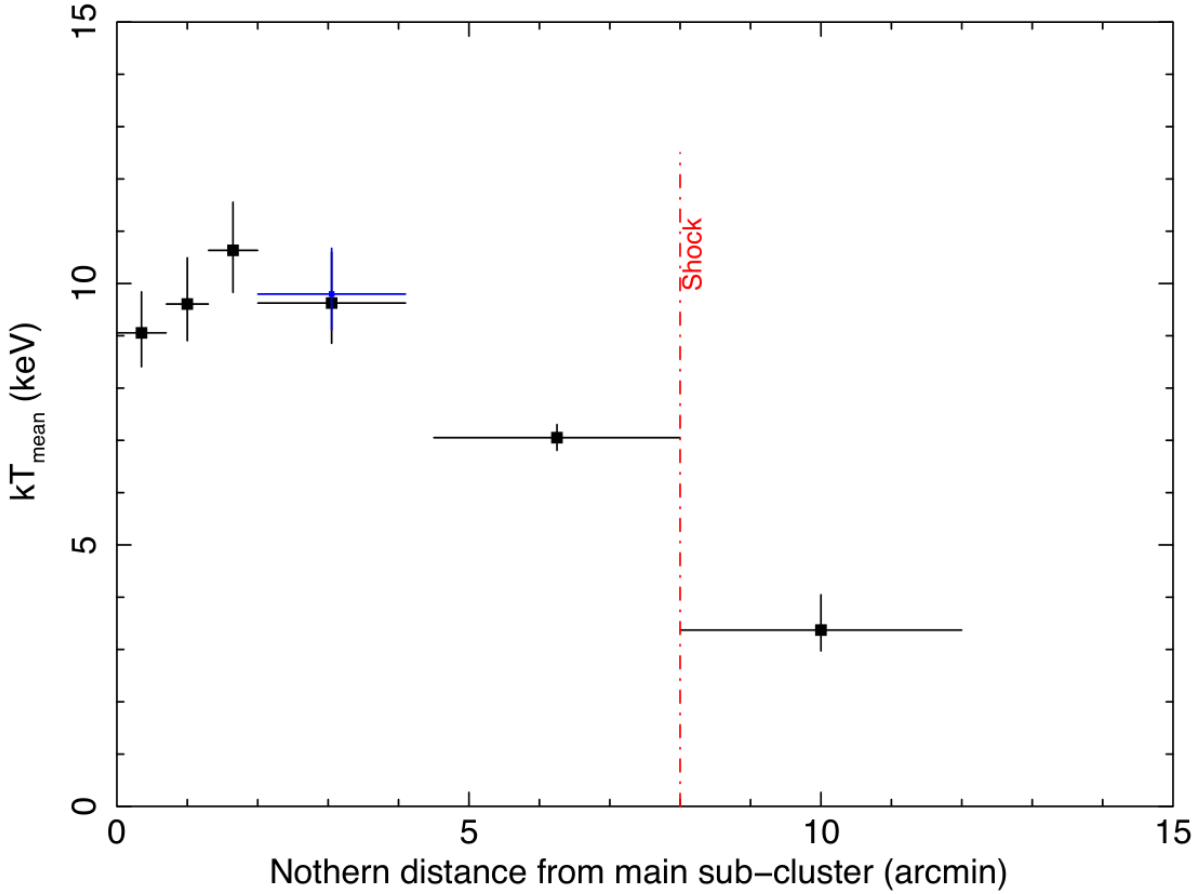
We observe a plateau with an uniform value of ~0.3, which is very similar to what is found in the outskirts of relaxed, non-merging clusters (Werner et al. 2013). Unlike the Toothbrush cluster, the violent merger in the Sausage cluster was very efficient in mixing the metals across the entire ICM.

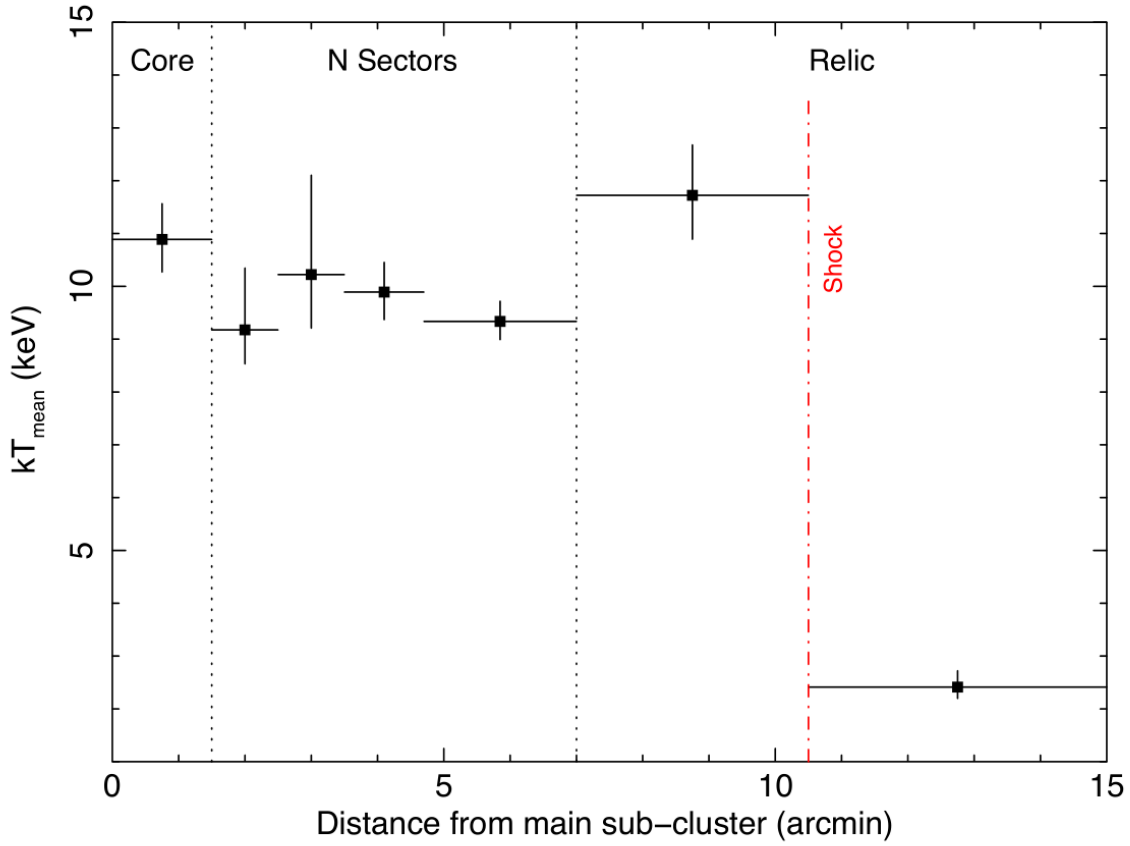
Summary of the Fe Abundances



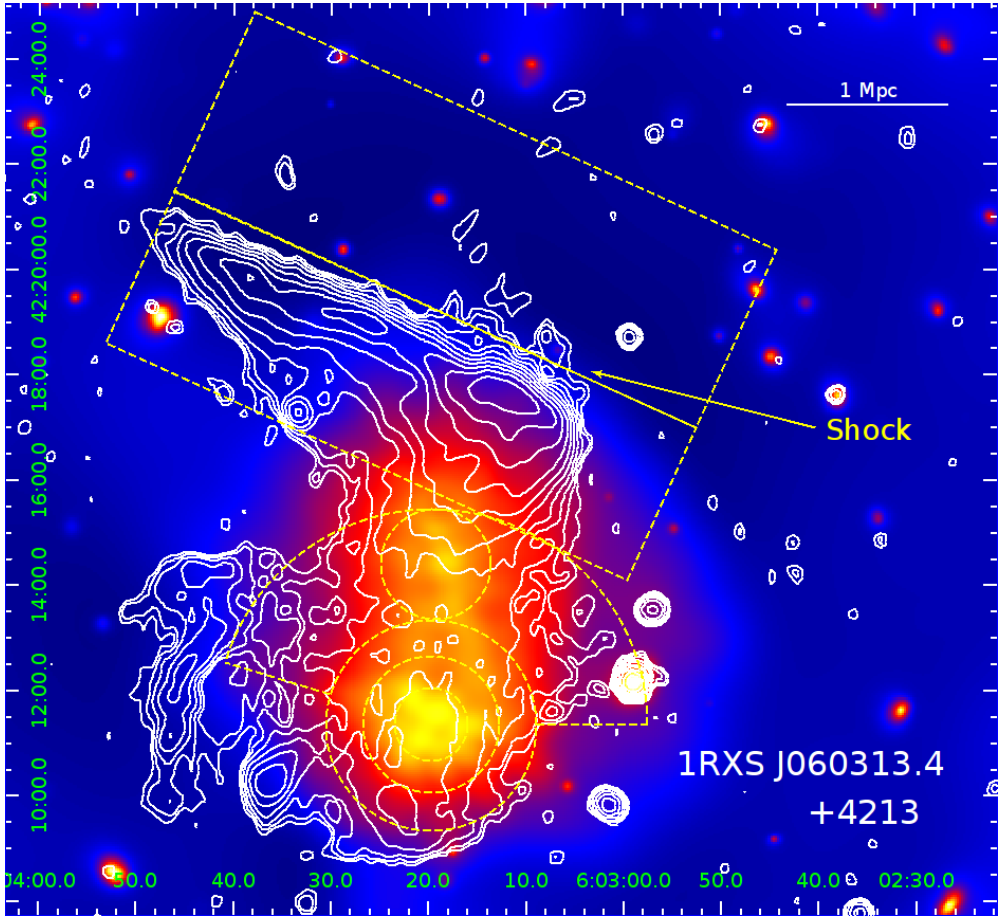


Summary of the Temperature Profile





Thanks!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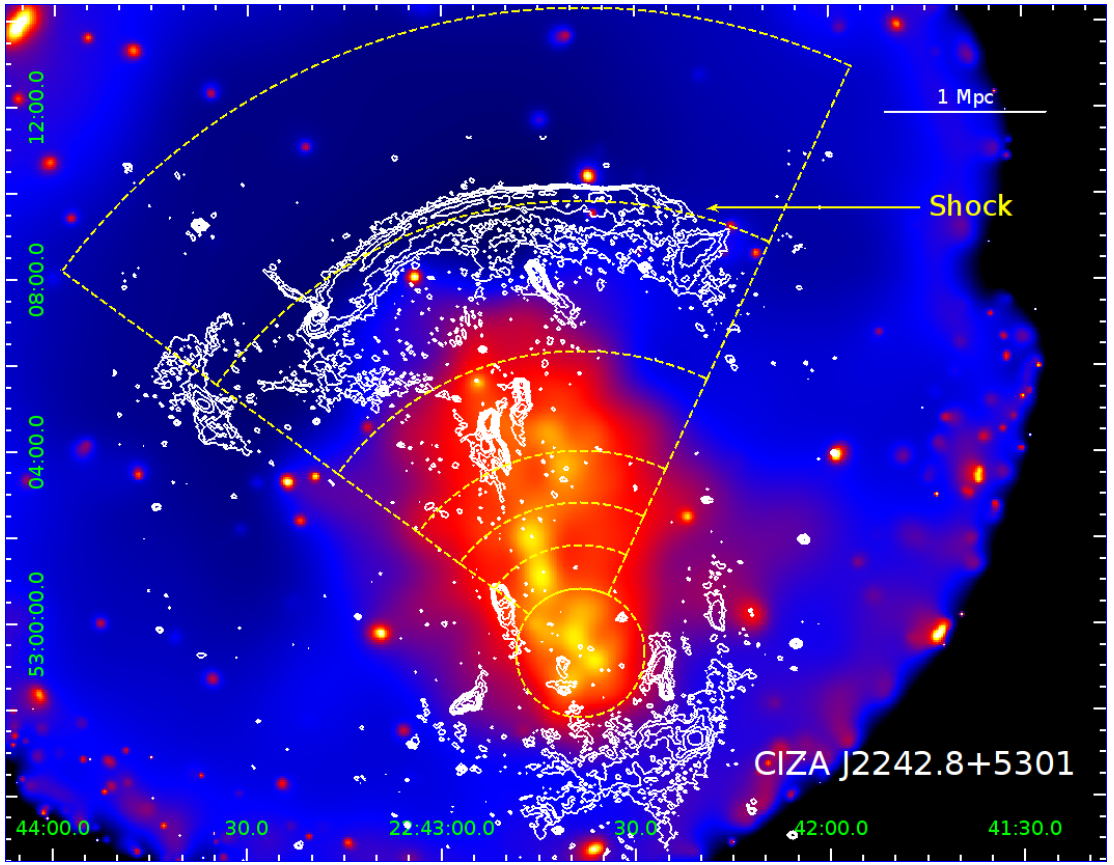
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