Dear referee,

Thank you very much for your comments and suggestions. We accounted for them as much as possible, and the paper quality is now significantly improved. Changes in the text have been highlighted in bold face. We also provide below a response to each of the points that have been raised in the report.

Best regards.

Rémi Adam, Oliver Hahn and Florian Ruppin, on behalf of the NIKA and the Rhapsody-G collaborations.

Referee Report

A report on the A&A submitted manuscript:

"Sub-structure and merger detection in resolved NIKA Sunyaev-Zel'dovich images of distant clusters"

by R. Adam et al. (article reference AA/2017/31950)

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The submitted work by R. Adam et al. describes a systematic and thorough analysis of galaxy cluster substructures from resolved Sunyaev-Zel'dovich (SZ) effect images, as obtained through their NIKA bolometer camera at 150 GHz. These data and their analyses present a natural step forward for the cluster SZ science where individual objects are not necessarily considered as "spherical blobs". This progress is similar to what have been done with X-ray images from Chandra and XMM-Newton. Hence this is a timely work and I would recommend its publication in the A&A, but after addressing a few concerns that I have listed below.

The authors apply well-established tools borrowed from X-ray analysis of clusters to search for morphological features in their images. The validity of their methods are demonstrated through applying on highly simplified toy models as well as snapshots from recent hydro simulations. However, I think that the process of reconstructing their actual SZ maps in presence of noise is not sufficiently well discussed, and how that might generate "spurious" substructures. Moreover, their discussion on substructures found in the actual cluster sample is uneven, where some are considered real and others as noise artefacts in a somewhat ad-hoc manner. I think that the paper can be improved in its scientific content with simultaneous analysis of available X-ray data of some of the clusters in their sample.

Major concerns:
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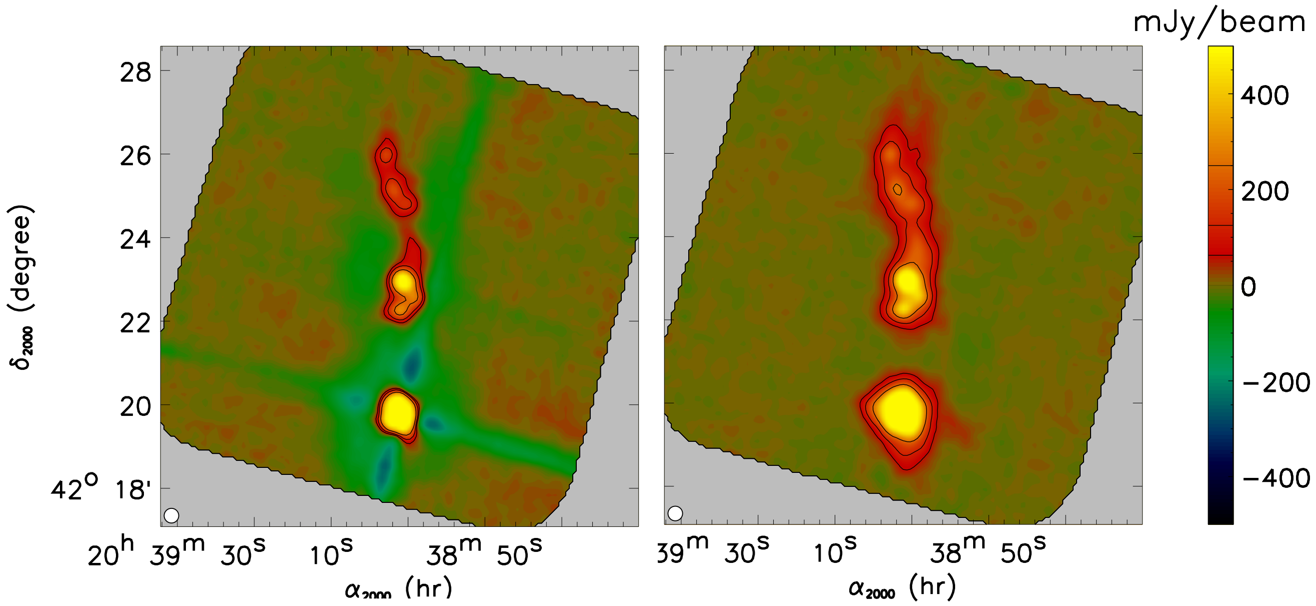
(1) A critically important step of ground-based SZ imaging with bolometer arrays is the removal of correlated atmospheric noise, which typically limits the extent of recoverable signal to roughly the field of view of the array. This high-pass spatial filtering is represented by the NIKA Transfer Function, which was described in Adam et al. (2015) and is referred to from here. But I find no details of the actual deconvolution process in either the original papers or here, for example, what kind of deconvolution algorithm is used and whether a smooth approximation of the transfer function is used. The Adam et al. (2015) used a cluster model that has very little signal beyond the field of view of the instrument, so how the filtering will change with a wider/asymmetric object? The spatial filtering usually produces a "positive ring" around bright clusters -- how well is that compensated in presence of noise (typical S/N here is less than 10), and whether is can cause a residual ! "ring like" gradient in the GGM filtered images seen here in almost all the clusters?

It is true that the transfer function due to the processing is a major concern when using the data quantitatively. In fact, since the paper by Adam et al. (2015), we have also improved our estimates of the transfer function. The latter is generally computed by injecting not only cluster signal under a specific, generally circular model, but also by using white noise that contain signal at all scales (more details are provided in appendix B).

Concerning the positive ring around bright SZ signal, they are significantly reduced by applying iterative masking of the source. This is illustrated below in the case of the bright source DR21OH (see also Catalano et al. (2014), where this map is published). The left panel provides the first iteration, i.e. without considering the source, and leads indeed to bouncing (typically up to 20% of the signal peak). Here the scale is saturated and the source scanning was done along two perpendicular directions that can be seen in the map. After iterating (3 times here), the source is well reconstructed and no more bouncing are visible. This is fully detailed in the thesis by Adam (2015), which is now given in the reference for further reading. As shown in the appendix, the ring like structure observed in most cluster cannot be associated with bouncing artifacts. It is rather due to the fact that at first order, all clusters are described by a spherical gNFW model, in which a ring like structure is expected, as shown in the toy models.



I urge the authors to give more details on the image reconstruction through deconvolution in presence of noise, and whether any filtering artefact like ring-like signals can be present in the noisy data. This can be done with the RHAPSODY-G images but after making sure the cluster sizes and map S/N are representative of the actual data. Then a S/N cut can be applied to GGM and DoG filtered images to establish the validity of the actual substructures.

This has been done and is now included in the appendix. In addition, we provide IDL scripts to use the transfer function in the data release of the NIKA sample.

Along this line there are some minor issues that should be addressed:
(i) What is the justification of using the numbers 15-150 arcsec for the spatial dynamic range of NIKA images?

These number provide the range of scales that is accessible with NIKA, i.e. where the signal dominates, if the maps are deep enough. 15 arcsec corresponds to the smallest scales that we can recover (typically the beam size), and 150 arcsec corresponds to slightly beyond the field-of-view, where we can still recover the signal (the transfer function of the processing). A clarification has been added in the text.

(ii) The RHAPSODY-G clusters are of lower mass than the actual cluster sample, hence they are smaller and the impact of transfer-function filtering is less severe. This should be matched better with the actual sample with appropriate rescaling.

This is now done by including another more nearby and very massive cluster, see in particular the appendix B that we now include. We do not want to apply rescaling to all RHAPSODY-G clusters because it might be tricky in terms of angular size if one wants to use the simulation also for interpretation.

(iii) Similarly, the representative S/N is chosen based on the deepest observation of the MACSJ0717 cluster. I think a more representative noise level should be used and then a S/N cut should be applied to the filtered images to pick out the prominent substructures.

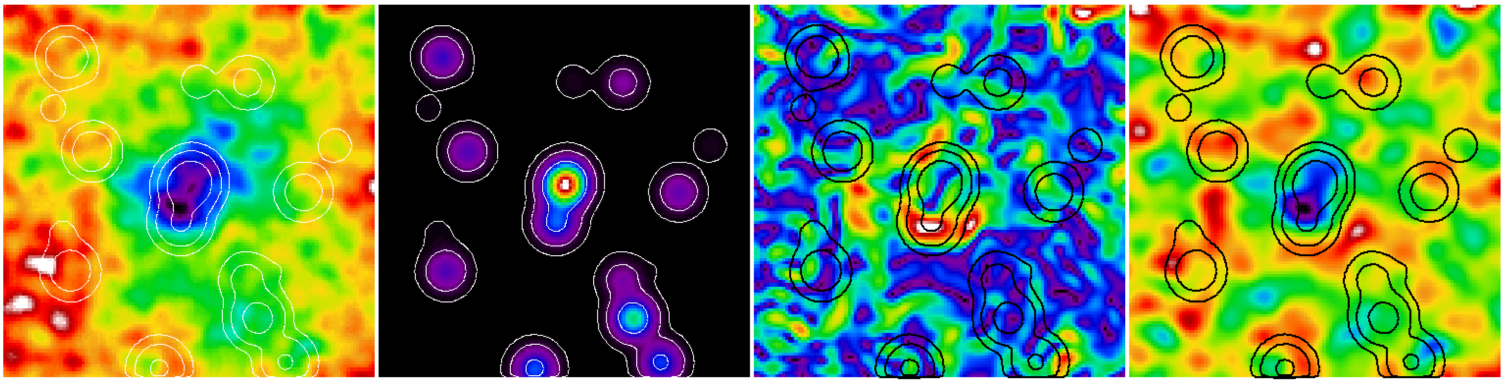
In fact when considering the highest S/N cluster, we also test the case of lower S/N since the signal reduces towards the outskirts. The noise is then estimated as discussed in section 5, and we have S/N maps, which are shown as contours in the images. Nevertheless, we have also included now a test case with peak S/N of 4 to test the behavior of the filter at the cluster peak in the low S/N regime (appendix B).

(2) I find the physical significance ascribed to the various substructures found in the actual cluster sample somewhat arbitrary. Some are ascribed to filtering artefact (RXJ1347) or point sources (MACSJ1423) while others are considered real features like shocks. A good way to categorize these features would be to class them according to their significance (for example in the GGM filtered maps) and then look for auxiliary data which can support these findings.

We have tried to clarify this point. The significance of the features we observe is well known from the signal to noise that we compute (as discussed in details in Section 5) and they are provided in the text. Then, a major systematic is the contamination by point sources (see the conclusion of section 5), and we cannot be absolutely sure that what we see is related to the ICM physics if we know that a point source might coincide with an observed feature.
For instance, the GGM peak is barely reaching 4 sigma in the case of MACSJ1424, and the peak coincides with two subtracted point sources, one of them being rather bright (see figure below, from left to right: surface brightness, point source model, GGM, DoG).

RXJ1347 has another issue because the corresponding data are not homogeneous with the rest of the sample, as discussed in section 6.1. In particular, we have concerns about the scanning strategy (see Adam et al. 2014). This is why we prefer to keep the discussion qualitative for this cluster, since we are not sure we can control all systematics. Nevertheless, what we observe seems to be consistent with results from other teams.

Further discussion has been added regarding this point.



There are deep X-ray data available for all of these clusters, and simple brightness jumps can be checked in the X-ray images in line with the findings of SZ gradient. I don't think this will be significantly out of scope for this paper, rather, it could help to validate their imaging analysis. Especially for the clusters MACSJ0717 and CLJ1226 I urge the authors to look into the Chandra images to see if any corresponding brightness jump can be seen. The same technique of GGM filtering can also be applied to the X-ray brightness to establish possible correspondence. In case no shock-like feature is found in the X-ray brightness, a discussion would highlight the importance of projection in determining shocks from the X-ray brightness.

I leave it to the authors how much they want to investigate into the X-ray analysis, but some attempt should be made to find corresponding gradient features in the brightness images (or refer to earlier published works).

This point has been addressed in the paper. We focused mainly on surface brightness comparison in the case of MACSJ0717 and CLJ1227 (Chandra data available and deep NIKA data). Applying GGM or DoG filter onto X-ray maps would required dealing with many effects that are well beyond the scope of this paper (i.e. reproducing section 5 for the X-ray maps).

Other remarks:
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(3) The scale of the SZ brightness profiles in Fig.3 (2nd row) should be inverted, in line with the images and the filtered profiles.

Accounted for

(4) The DoG filter is also commonly called "unsharp masking", especially in the X-ray community. This should be mentioned.

Accounted for

(5) References. For GGM filter I don't think the Sanders et al. (2016) is the appropriate one, please check the other 2016 paper (MNRAS 457) by Sanders, or earlier simulation based work by Roediger et al. (2013). For the cluster RXCJ1347, a very important reference of Kitayama et al. (2004) is missed. For discussion on merger rates (p.15) I don't think Cassano et al. (2016) is a correct reference, the paper by Fakhouri et al. (2010) can be cited instead.

Accounted for

(6) For the cluster RXCJ1347 and referring to the work by Kitayama et al. (2004), a discussion should be included whether the DoG filtered pressure hot spot coincides with what this earlier work found from Nobeyama data.

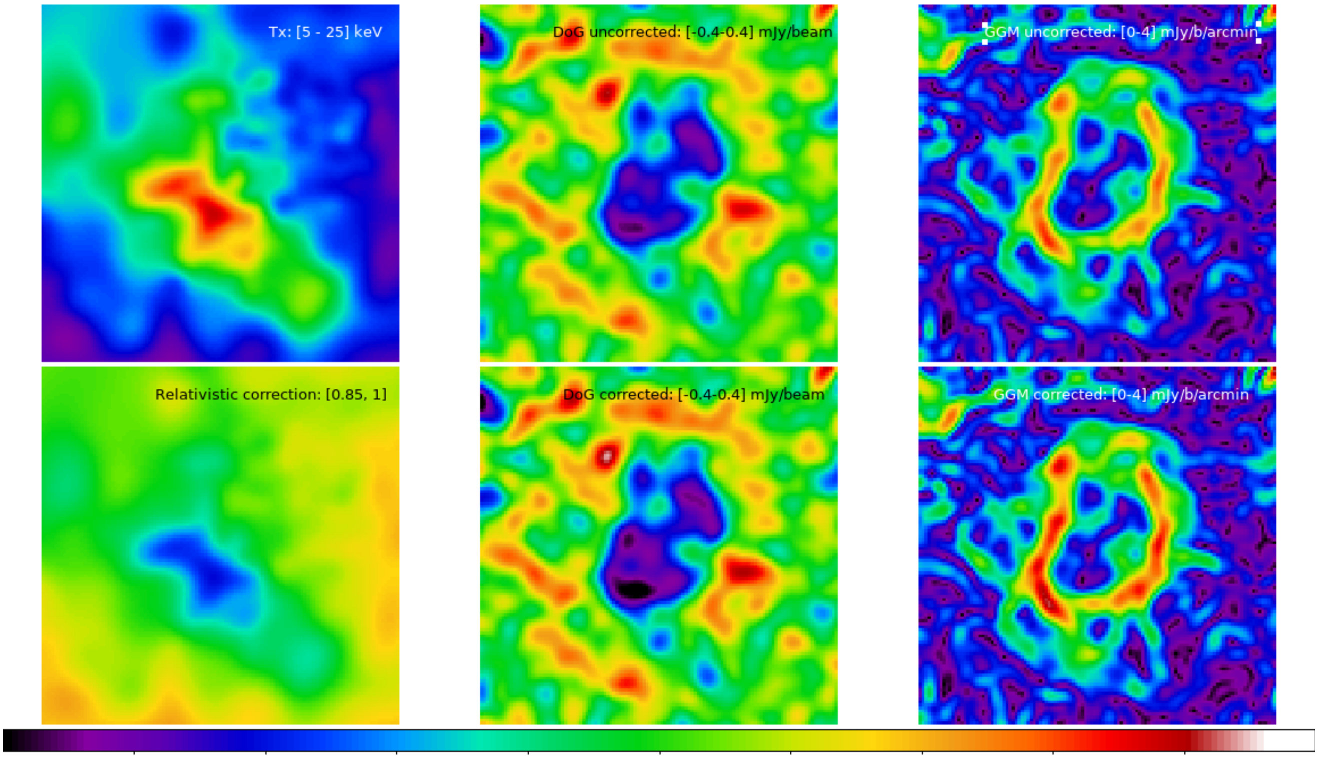
Accounted for

(7) Inclusion of a kSZ component makes the second SZ peak in MACSJ0717 DoG filtered map disappear, which is shown in the Appendix. This is important and can be a general issue with most merging systems, and should be mentioned clearly up front. Also, as shock heated gas can reach temperatures above 20 keV, it should be mentioned whether the relativistic corrections can affect the 150 GHz signal to more than 10% within specific regions.

Indeed, it is true that in some extreme cases such as MACSJ0717, kSZ signal can alter significantly the surface brightness map, as well as the filtered ones. Unfortunately, we do not have of an accurate kSZ correction due to uncertainties in its spatial modeling. While MACSJ0717 is certainly an extreme case, kSZ contamination potentially affects all SZ maps to some extent.

Concerning the relativistic corrections (rSZ), its impact was already investigated in detail for other works. It leads to up to 13% change in the surface brightness at this frequency, in the case of the hottest and most disturbed cluster MACSJ0717 (only up to ~8% peak to peak change over the cluster extension, as the gas is pretty hot all over our map). Since the rSZ correction acts, at first order, as an overall multiplicative factor of the surface brightness map, the impact on the filters is also a multiplicative factor, but spatial variation of the temperature leads to relative changes of ~8% in the surface brightness. However, the changes in the structures we observe are negligible compared to the noise, even in such an extreme case as MACSJ0717 (highest S/N and hottest cluster). Below we show the temperature map from XMM (see Adam et al. 2017), the rSZ correction map, and the difference between the filtered map when accounting or not for this correction (the scales are matched as indicated in the Figure).

A paragraph has been added concerning kSZ and rSZ (Sec 6.3)



(8) In Table 1 the title "Projected time" is confusing, is it the on-source time or integration time?

Accounted for. It is indeed the on-source time (after flagging bad data).

(9) I don't understand why determination of Mach number, along with gas temperatures, would lead to the measurement of "projected" gas velocities (as written in the last paragraph of Sec.7) if we assume the Mach determination is correct.

Accounted for. This sentence was indeed misleading. The second part has been removed.