Mem. S.A.It. Vol. 75, 547

**Memorie** della

# The binary cluster system Abell 399/401

I. Sakelliou, T. J. Ponman

Physics & Astronomy, University of Birmingham, Birmingham B15 2TT

**Abstract.** A399 and A401 form a close pair of clusters. We have observed them with *XMM-Newton* in four pointings. Both central regions show significant departures from our idealised picture of relaxed rich clusters. We find enhanced X-ray flux and temperature in the intercluster region, and we argue that it is a compression region, as the two clusters are approaching each other for the first time. It seems likely that in the Abell 399/401 system, we are witnessing two merger remnants, just before they merge together to form a single rich cluster of galaxies.

**Key words.** X-rays : galaxies : clusters – intergalactic medium – galaxies : clusters : individual (Abell 399, Abell 401)

## 1. Introduction

A399 (z=0.0724) and A401 (z=0.0737) are both rich clusters, at temperatures of 7.2 keV and 8.5 keV respectively. They lie at a projected separation of ∼3 Mpc, forming a close pair.

Previous studies have reached contradictory conclusions about their past history. The *ASCA* satellite found evidence for some enhancement in the X-ray flux above what is expected from just the superposition of the two clusters, and a slight temperature increase in-between them, making Fujita et al. (1996) conclude that it is a pre-merging pair. The *ROSAT* HRI detector (Fabian et al. , 1997) revealed a linear structure that emanates from the centre of A399 and points towards A401. This feature led to the suggestion that the two clusters have already encountered each-other, and are now moving apart.

*Send offprint requests to*: I. Sakelliou

## 2. *XMM-Newton* observations

In order to disclose the dynamical state of the binary system, we observed it with *XMM-Newton* in four pointings. The exposure time of each observation was ∼10 ksec. In Fig. 1 we show an image mosaic. More information on the *XMM-Newton* analysis and results can be found in Sakelliou & Ponman (2003).

The temperature variations along a line that bisects the two clusters is presented in Fig. 2, where we compare the observed temperature profile with the theoretically derived 'universal profile' of Loken et al. (2002). Fig. 2 demonstrates that the temperature of the in-between space is slightly enhanced, but is not as high as would be if there was a strong shock.

## 3. Conclusions

The data confirm the lack of cooling flows in the cores of both clusters; the image analysis gives $\beta$ values that are lower than the expected canonical value of 0.65; in neither cluster is the

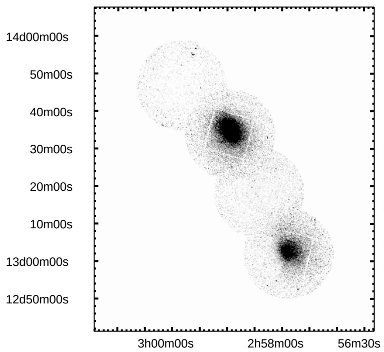


**Fig. 1.** A mosaic image in the (0.5-10) keV energy range. Background subtracted images from the two MOS instruments are superimposed. A401 is to the North.

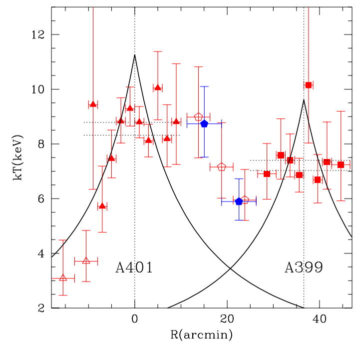


**Fig. 2.** Temperature variations along a line that bisects the two clusters. Solid lines plot the profiles predicted by the universal profile of Loken et al. (2002).

gas azimuthally symmetric around the central cD galaxy; a 2-dimensional analysis reveals a lop-sided excess (<200 kpc) around the central galaxies; there is temperature structure in the inner (200-400) kpc of both clusters, which argues for the presence of complex structures within the cluster cores, possibly due to shock waves; A399 shows a sharp edge to the East of its centre, which is associated with harder emission; the temperature profile to the North of A401 declines steeper than expected, and there is a lack of flux in the same area; both clusters appear to host central radio halos; the flux from the space between the two clusters is slightly enhanced, above what is expected from the superposition of the two clusters; this region appears also hotter.

The 'substructure' *XMM-Newton* finds in both core regions cannot be explained by tidal forces. On larger scales, 15 arcmin$\simeq$1.2 Mpc from their centres, tidal forces become gradually far more important, but we find that the cluster properties cannot again be solely due to their mutual interactions.

We also find that the properties of A399/401 cannot be reproduced by scenarios that either involve off-centre cluster collisions, or speculate that they have been through each other once. An offset collision provides the only single mechanism which might explain all the properties of the system, but that it doesn't seem consistent with the observed large separation and limited disturbance of the clusters at large radii from the cluster centres.

Our analysis finds evidence for increased flux and temperature in the region in-between the two. It appears that they have already stated interacting mildly, and that we are witnessing a compression region between them.

The most likely explanation for the properties we find in the core region of the clusters is that they are due to each ones past merger activity. It seems that each cluster is a merger remnant. A similar evolutionary scenario has been recently proposed by Belsole et al. (2003) to explain the unequal system Abell 1750. Hence we favour a model which combines some early interaction, with a minor merger history.

## References

Belsole, E., Pratt, G. W., Sauvageot, J-L., Bordin, H. 2003, astro-ph/0311556b

Fabian, A. C., Peres, C. B., White, D. A. 1997, MNRAS, 285, L35

Fujita, Y., Koyama, K., Tsuru, T., Matsumoto, H. 1996, PASJ, 48, 191

Loken, C., Norman, M. L., Nelson, E., Burns, J., Bryan, G. L., Motl, P. 2002, ApJ, 579, 571

Sakelliou, I. & Ponmani, T. J. 2003, MNRAS, submitted