The disturbed X-ray cluster Abell 3376 and its giant ring-like radio structures

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Abell 3376 is at a redshift 0.046

We discovered 2 Mpc diameter radio arcs with the VLA at 20 cm,
With no optical or X-ray counterparts (ROSAT or XMM)

The X-ray emission is elongated and asymmetric (ROSAT, XMM-Newton)

The zone of maximum X-ray emission is completely offcentered toards the northeast &nd coincides with a strong radio source

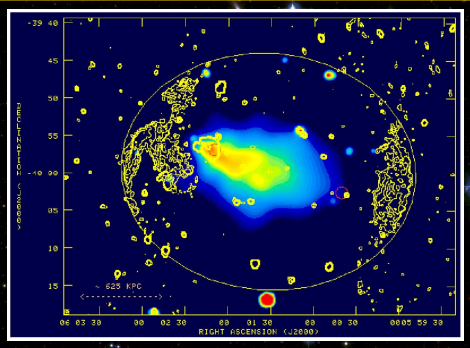

Fig. 1 VLA 20cm radio contours showing the 2 Mpc scale radio arcs around Abell 3376, superimposed on a smoothed ROSAT image

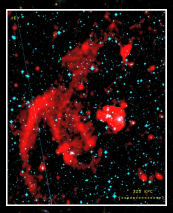

Fig. 2a. Zoom of the east large scale radio structure

Where do these radio arcs come from?

Distribution on an ellipse with major axis along direction of X-ray elongation

Radio synchrotron emission requires accelerated electrons

Two possibilities:
- Major cluster merger(s)
- Cosmological shock waves caused by energetic collisions, mergers and infall on the cluster

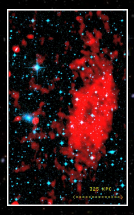

Fig. 2b. Zoom of the west large scale radio structure

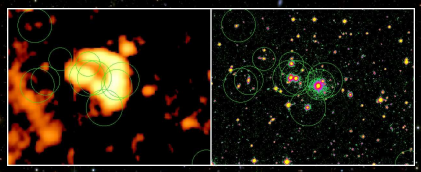

Fig. 3. Zoom of the smaller scale radio component (left) and corresponding optical image, with green circles showing galaxies at the cluster redshift

Fig. 4. Optical image. Circled galaxies have redshifts in the cluster and the squares show the two brightest galaxies.

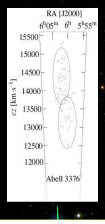

Fig. 5. Wedge diagram of galaxy velocities.

Optical evidence for one or several major mergers

Bright galaxies with cluster velocity are distributed along a very elongated structure (Fig. 4)

The merging appears to be occuring close to the plane of the sky (Fig. 5)

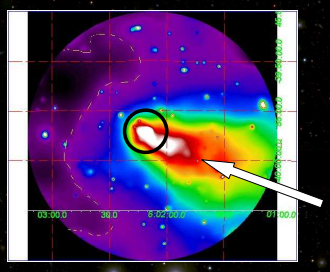

Fig. 6 Smoothed XMM-Newton image of Abell 3376.
The white arrow shows the merging direction.

XMM-Newton image of Abell 3376 shows strong asymmetry and suggests a major merger with a smaller cluster arriving from the southwest and crossing a larger one (Fig. 6, arrow)

Maximum of X-ray emission coincides with strong radio source (green circle). This region contains at least 5 AGN (Chandra).

No relation between east radio relic and X-ray emission

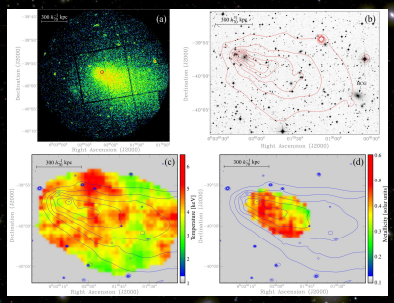

Fig. 7 Maps: top left: XMM raw image, top right: optical image and X-ray contours, bottom left: temperature map from XMM, bottom right: metallicty map from XMM

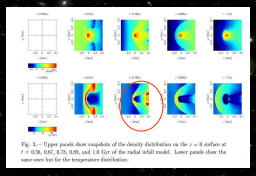

Fig. 8 Temperature map from numerical simulations by Takizawa (2005, ApJ 629, 791)

What do these maps tell us (see Fig. 7)?

Optical map: the brightest cluster galaxy is completely offset towards the SW

There is a group of bright galaxies coinciding with the region of maximum X-ray emission,
towards the north east

X-ray temperature map shows alternatively hotter and cooler gas.
The comparison with numerical simulations (Fig. 8) agree with the merger hypothesis

X-ray metallicity map shows inhomogeneous metal distribution

Conclusions

Abell 3376 is presently undergoing a major merger

The giant radio arcs are due to synchrotron emission from electrons which may be accelerated either by shock waves created by the merger, or may have been accelerated by cosmological shocks at the epoch of cluster formation.

For details, see
Bagchi, Durret, Lima Neto & Paul 2006, Science 314, 791