Chandra X-ray Parameters for the Cluster Associated with the FRII Radio Galaxy 3C196.1

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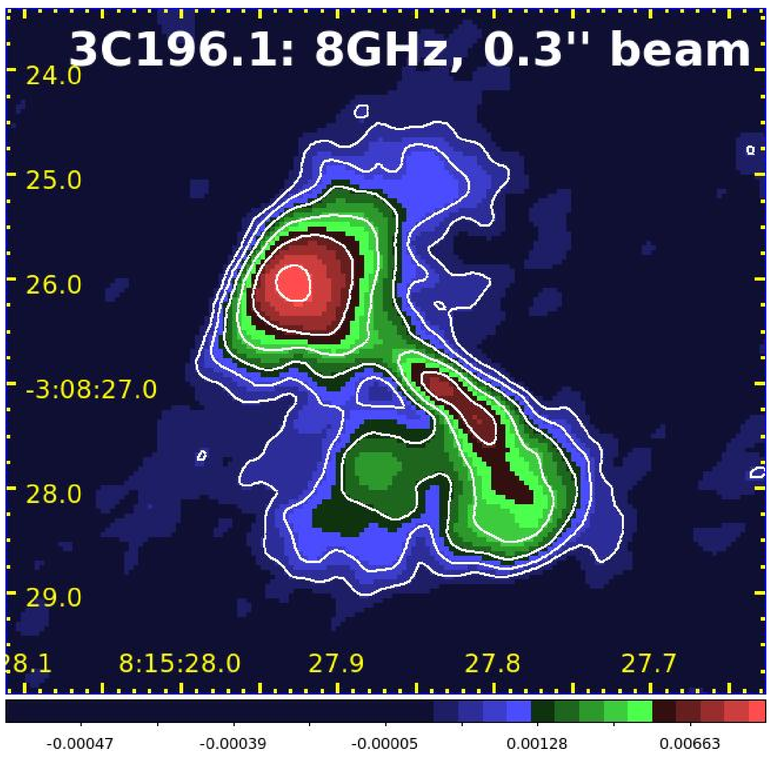
1 The Radio Source



3C196.1 at 8 GHz. Contours increase by factors of two; the lowest contour is 3/8 mJy/beam. Notice the brightness gradient along the NE edge of the lobe.

With a redshift of 0.198, the luminosity distance is 936 Mpc and the angular scale is 3.16 kpc per arcsec.

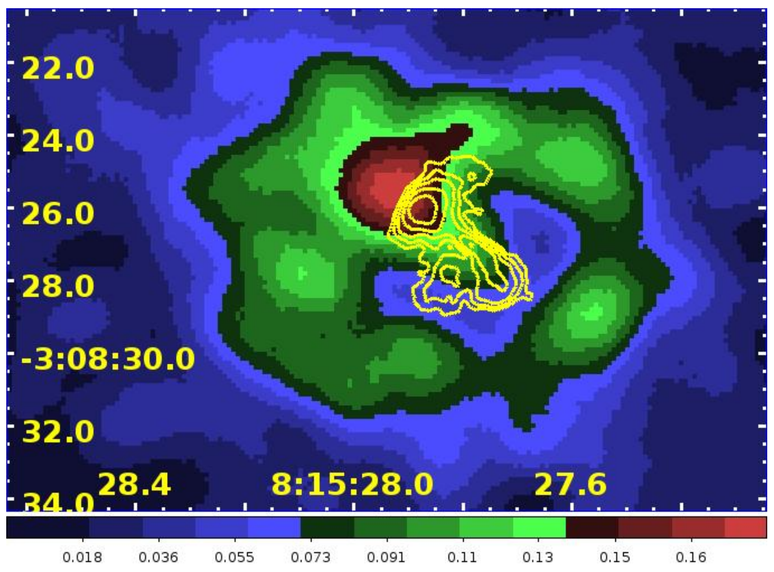
The radio source 3C196.1 has been classified as an FRII and is associated with the dominant galaxy of the cluster. The radio power and optical magnitude of 3C196.1 place it well above the dividing line between FRI and FRII of Owen and Ledlow. However, its morphology is strikingly different from the prototype FRII, Cygnus A, which also resides in a cluster. Unlike Cyg A with a total size of 120 kpc (from hotspot to hotspot), the extent of 3C196.1 is only 12 kpc. Thus it probably is wholly within the cD galaxy, although we cannot be sure of this since the irregular morphology precludes even a reasonable guess at projection effects. The physical size of 3C196.1 could be much larger than its projected size. The best description of this source with the available 0.3" resolution is a 'HYMORS', a so called 'HYbrid MOphology Radio Source'. In the case of 3C196.1, the NE side appears to be a classical FRII lobe whereas the SW side is more jet like.

On the basis of 5 and 8 GHz maps, the spectral index of the bright NE lobe is 0.8, whereas for the weak feature S of the jet, it is 1.5.

Rough estimates for physical parameters can be obtained from the usual synchrotron expressions assuming an equipartition magnetic field. For the NE lobe, we find:

- B $\approx$ 70μG
- $P_{NT}(min) \approx$ 4.6 10^{-10} *dyne cm*$^{-2}$
- log total non-thermal energy $\approx$ 56.6 ergs

2 The X-ray cluster gas

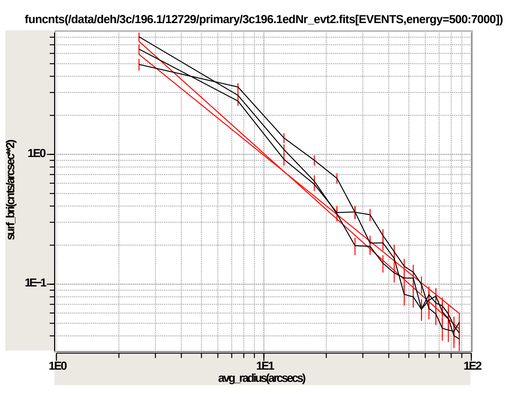


A heavily smoothed X-ray image with radio contours. This is the bright central region. In the figures, there appears to be a 'ghost cavity' wrapping around the SW jet/lobe. The steep (radio) spectrum 'S lobe' impinges on part of this cavity.

This source was recently observed by Chandra as part of the "Chandra 3C Snapshot Survey" (Massaro et al. ApJ 714, 589, 2010). Its cluster nature is obvious and it had already been catalogued in the ROSAT bright source catalog and by Kocevski et al. (2007 ApJ 662, 224) in their search for clusters in the zone of avoidance. Since the galactic latitude is 17deg, the optical attributes of the cluster are not known.

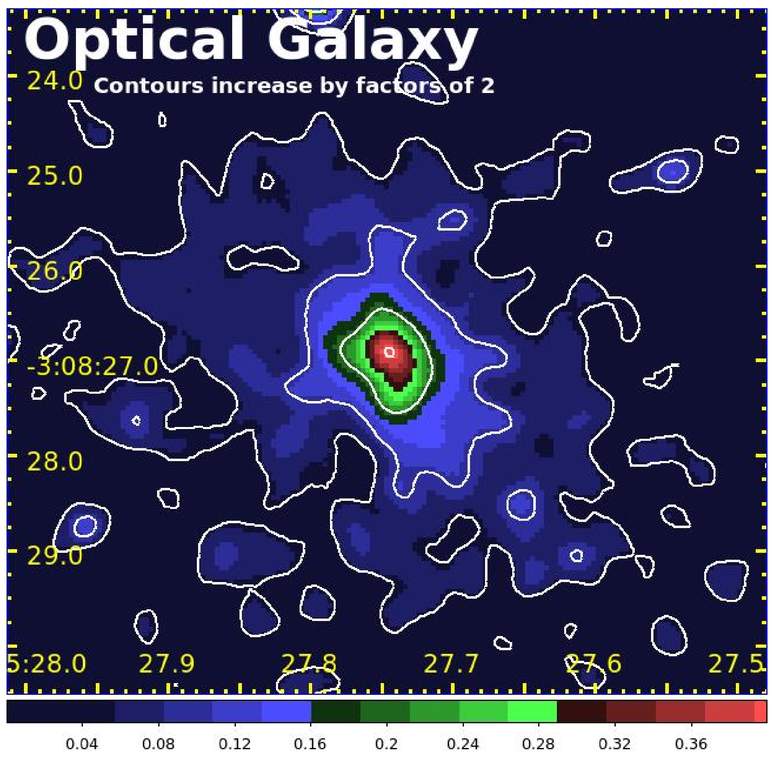
With an exposure of 8ks, there are 3700 net counts detected in a circle of radius 90″. The global temperature estimate for the entire cluster is 4.2 $\pm$ 0.2 keV. Restricting the spectral analysis to smaller circles, the temperature drops: 3.4 $\pm$ 0.2 for r=20″; 3.0 $\pm$ 0.3 for r=7″, and 1.0 keV for r=1.5″, the last value centered on the brightest part of the inner structure.

A very preliminary fit to a modified King model results in β=0.75 and a core radius of 7″ (22 kpc). The central density is of order 0.09 cm^{-3}, and for 1 keV this corresponds to a pressure of 3$\times$ 10^{-10} *dyne cm*$^{-2}$. The luminosity in the band 0.5 to 7 keV is 3$\times$ 10^{44} *erg s*$^{-1}$.



Radial profile for 3 90deg pie sections of the X-ray surface brightness. The bin width is 5″ and the energy band is 0.5-7 keV.

3 The optical galaxy



An HST image of 3C196.1 (Sparks, PI). The image has been slightly smoothed. The contours increase by factors of two. Taken in the visable (6500 angstroms).

The host galaxy is classified as a cD, although its position does not coincide with the ostensible center of the cluster gas. With a distance modulus of 39.9 and a magnitude of 18.5 to 17, the absolute magnitude is -21.4 to -23. The image shown is from the HST and does not display the full extent which is somewhat larger than the size of the radio source.

4 Heating the IGM

There are two bits of evidence for interaction between the radio bright NE lobe and the IGM/ISM. The first is the flattening of the NE lobe along its border with the highest surface brightness X-ray feature. The strong gradient in radio brightness indicates that the lobe is not free to expand easily along its natural path away from the radio nucleus. Furthermore, the equality of the non-thermal pressure characterizing the NE lobe with that of the central pressure of the cluster points to an interaction; i.e. the radio lobe is actually up against the highest density gas, and not displaced along the line of sight.

The energy required to inflate the lobe can be estimated to be of order a few times P$\times$V. With log V=67 cm^3 (r=0.5″), this works out to 10^{58} ergs, and for a typical age of 10^{14} s, the average power is 10^{44} *erg s*$^{-1}$, comparable to L_x.

Acknowledgments

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