EXTENDED INVERSE COMPTON EMISSION FROM DISTANT POWERFUL RADIO GALAXIES

M. C. Erlund[1], A. C. Fabian[1], K. M. Blundell[2], A. Celotti[3], and C. Crawford[1]

[1]Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge, CB3 0HA, UK
[2]Department of Astrophysics, University of Oxford, Oxford, OX1 3RH, UK
[3]SISSA/ISAS, via Beirut 4, 34014 Trieste, Italy

ABSTRACT

Chandra observations of 3C 432, 3C 191 and B2 0902+34 are presented as part of an ongoing search for inverse-Compton scattering of the cosmic microwave background (CMB) from high redshift radio sources (Schwartz, 2000). The energy density of the CMB increases with redshift, z, as $(1+z)^4$, so the relatively high redshift of these powerful radio galaxies makes them good candidates for detecting extended inverse-Compton scattering along the radio jet axis: we do indeed detect radio-aligned X-ray emission.

Key words: inverse-Compton; powerful radio galaxies; high redshift.

1. INTRODUCTION

Inverse-Compton scattering of the cosmic microwave background (hereafter CMB) in high-redshift radio sources should be detectable, since the energy density of the CMB increases steeply with redshift, z, counterbalancing surface brightness dimming (Schwartz, 2000). Most high-redshift radio galaxies should therefore have extended X-ray emission produced by inverse-Compton scattering of the CMB, thus tracing an older relativistic electron population (with Lorentz factor $\gamma \sim 10^3$) compared with those producing the radio synchrotron emission ($\gamma \sim 10^5 - 10^6$). Several such sources have been detected (Schwartz, 2000, Belsole et al., 2004, Overzier et al., 2005, Scharf et al., 2003, Sambruna et al., 2004, and Blundell et al., 2005).

Here, *Chandra* observations of three high-redshift radio galaxies (3C 432, 3C 191 and B2 0902+34) are analysed with the aim of detecting and characterising their extended X-ray emission.

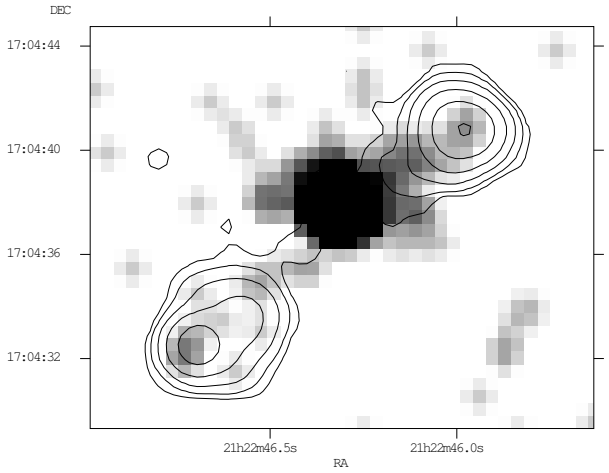

Figure 1. Image of 3C 432, Gaussian-smoothed by 0.49", with 1.54 GHz *radio contours overlaid (0.001, 0.003, 0.012, 0.042, 0.144, 0.5* Jy/beam*).*

2. 3C 432

A 19.77 ks-long observation of 3C 432 ($z = 1.785$, RA 21h22m46.2s Dec +17d04m38s) was taken by *Chandra* on 2005 January 7 in VFAINT (very faint) mode. Fig. 1 clearly shows extended X-ray emission lying along the radio jet, not only in the lobes but also in the bridge. Spectra were extracted from the nucleus; the total extended X-ray emission (i.e. that within a $8'' \times 18''$ region aligned along the radio axis); the emission within the 1.54 GHz radio contours, excluding the central source, and the background. The nucleus has a photon index of $\Gamma = 1.84^{+0.09}_{-0.11}$ and intrinsic absorption $N_H = 2.1^{+0.36}_{-0.21} \times 10^{21}\,\mathrm{cm}^{-2}$ assuming a Galactic absorption of $7.4 \times 10^{20}\,\mathrm{cm}^{-2}$. The total extended emission has $\Gamma = 1.57^{+0.27}_{-0.36}$, and the extended emission within the 1.54 GHz contours has $\Gamma = 1.52^{+0.27}_{-0.48}$. These values were calculated using C-statistics, however χ^2-statistics gives consistent values.

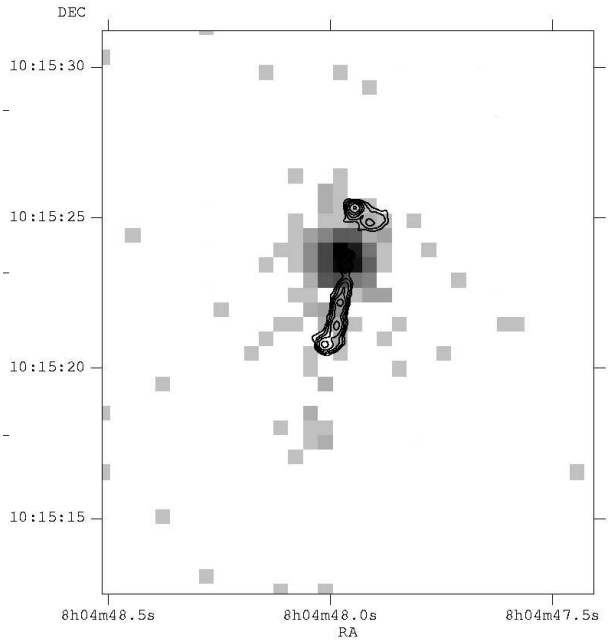

Figure 2. X-ray image of 3C 191 with 8.46 GHz *radio contours overlaid (0.0005, 0.0012, 0.0029, 0.0069, 0.0167, 0.04* Jy/beam*).*

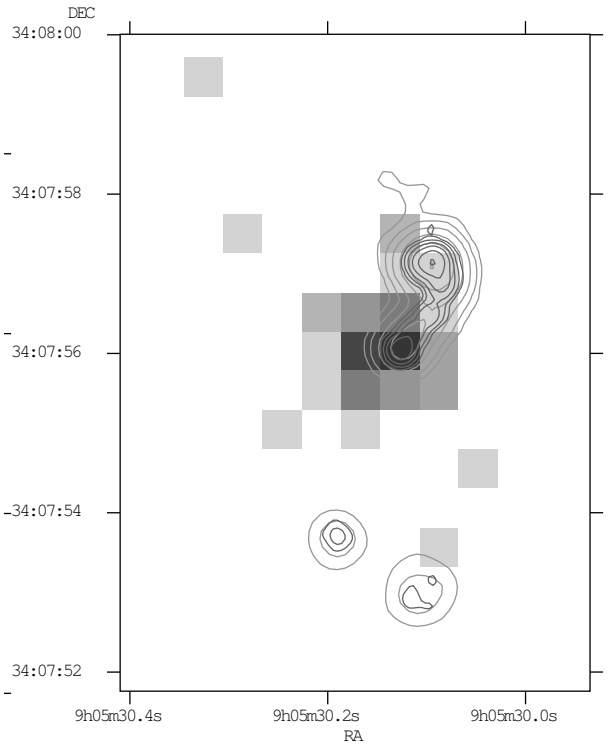

Figure 3. X-ray image of B2 0902+34, overlaid with 8.09 GHz *radio contours (0.00015, 0.00042, 0.0012, 0.0033, 0.0093, 0.26* Jy/beam*) in dark grey and 4.54* GHz *radio contours (0.0003, 0.00088, 0.0026, 0.0076, 0.022, 0.065* Jy/beam*) in light grey.*

3. 3C 191

Two observations of 3C 191 have been analysed ($z = 1.965$, RA 08h04m47.9s Dec +10d15m23s): the first is 8.32 ks-long (Sambruna et al., 2004), taken with *Chandra* in FAINT mode on 2001 March 7 and the second is 19.77 ks-long, taken on 2004 December 12 in VFAINT mode. Fig. 2 is the sum of the two observations and shows extended X-ray emission aligned along the radio jet which appears to extend beyond the radio emission to the south. The nucleus has an intrinsic absorbed power law with $N_H = 0.46^{+0.29}_{-0.35} \times 10^{22}\,\mathrm{cm}^{-2}$ and $\Gamma = 1.79^{+0.12}_{-0.12}$. The total extended emission ($6.5'' \times 10.5''$ region excluding the central source) has $\Gamma = 1.66^{+0.32}_{-0.29}$, and the emission within the contours of the lowest 8.46 GHz radio contour, shown in Fig. 2, has $\Gamma = 1.95^{+0.44}_{-0.20}$ (using C-statistics).

4. B2 0902+34

The *Chandra* image of B2 0902+34 ($z = 3.382$) is centred on the active nucleus. There are indications that the X-ray emission is slightly extended along the radio jet to the north (Fabian et al., 2002).

REFERENCES

Schwartz, D. A. 2002, ApJ, 569, 23

Fabian, A. C., Crawford, C. S., & Iwasawa, K. 2002, MNRAS, 331, 57

Blundell, K. M., Fabian, A. C., Crawford, C. S., et al., 2005, MNRAS, submitted

Sambruna, R. M., Gambill, J. K., Maraschi, L., et al., 2005, ApJ, 608, 698

Belsole, E., Worrall, D. M., Hardcastle, M. J., et al., 2004, MNRAS, 352, 924

Overzier, R. A., Harris, D. E., Carilli, C. L., et al., 2005, A&A, 433, 87

Scharf, C., Smail, I., Ivison, R., et al., 2003, ApJ, 596, 105