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X-RAY EMISSION IN POWERFUL RADIO GALAXIES AND QUASARS

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ABSTRACT

ROSAT is the first mission to have detected X-ray emission in radio galaxies which are both powerful ($l_{178\ \mathrm{MHz}} > 10^{27}$ W Hz^{-1} sr^{-1}) and distant ($z > 0.4$), enabling tests of "unified schemes" through a comparison of the X-ray and radio properties of powerful quasars and radio galaxies. These radio galaxies are faint in X-rays, but, nevertheless, ROSAT is capable of resolving any associated X-ray-emitting gas of cluster dimension.

We present ROSAT PSPC observations of two such radio galaxies and suggest that there is a component of unresolved X-ray emission in powerful, high-redshift radio galaxies which may be related to the radio core; this will be tested by ROSAT observations of other powerful radio galaxies.

1. ROSAT PSPC Observations of two Radio Galaxies

We observed 3C 220.3 and 3C 280 with the ROSAT PSPC during the AO1 pointed phase of the mission (Table 1). 3C 220.3 was undetected. 3C 280 gives 71 ± 12 net counts ($0.2 - 1.9$ keV). For absorption only by gas in our Galaxy, the PSPC spectrum fits a power law with $0.5 < \alpha < 2.0$ and a 1 keV flux density of 1.7 ± 0.9 nJy. Some intrinsic absorption and a steeper power-law slope cannot be excluded, although there are sufficient counts in the low-energy channels to suggest that such absorption has a column density $\lesssim 4 \times 10^{21}$ atoms cm^{-2}. A Raymond-Smith thermal spectral model also agrees with the data; for Galactic absorption only, any temperature $\gtrsim 0.4$ keV is acceptable.

Table 1

Radio Galaxy	z	$\log N_H^a$	ROR [b]	Date	Exposure Time (s)
3C 220.3	0.685	20.515	700072	1991 Feb 27	8,791
3C 280	0.998	20.086	700073	1991 Jun 2-3	48,051

a. Galactic values from Stark et al. (1992).
b. ROSAT Observation Request number

2. X-ray Radial Profile of 3C 280

A point source alone gives a poor fit to the X-ray radial profile of 3C 280. A thermal β model (e.g., Sarazin 1986) gives a good fit, but the fit is improved still further if the source is modeled with a combination of a point source and β model (Fig. 1). The evidence for unresolved emission is suggestive, rather than compelling; moreover, the X-ray data do not distinguish between a thermal or a non-thermal origin for the possible unresolved component. However, the evidence for non-thermal X-rays from the nuclei of low-redshift radio galaxies (e.g., Fabbiano et al. 1984; Worrall & Birkinshaw 1994) and radio-loud quasars (e.g., Worrall et al. 1987) leads us to consider seriously the possibility that 3C 280 also emits non-thermal X-radiation from its radio core.

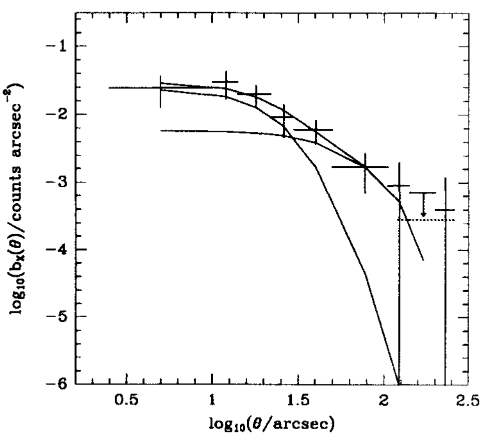

Figure 1: Background-subtracted PSPC radial profile for 3C 280. The best-fit model (upper curve), shown convolved with the PRF and background subtracted for comparison with the data, is a combination of an unresolved component (narrow curve) and a β model of core radius 65″ for $\beta = 2/3$ (broad curve). The dotted line shows the contribution of the model to the background annulus.

3. Radio Core-related X-rays in Quasars and Galaxies

In Figure 2 we compare the unresolved X-ray and core radio emissions for the two radio galaxies with those of radio-loud quasars which both have similar total (isotropic) power and were observed with the *Einstein* IPC (Wilkes et al. 1994). The luminosity-luminosity and flux-flux plots are similar because the sources lie in a relatively narrow band of redshift. The fraction, R, of 5 GHz flux density in the core component of the quasars has a bimodal distribution, in which core-dominated quasars with $R > 0.5$ (filled squares) can be clearly distinguished from lobe-dominated quasars (open squares). From Figure 2 we find:

(a.) A correlation between the core X-ray and radio emission in core-dominated quasars.

(b.) 3C 280 lies on an extrapolation of the correlation.

(c.) Lobe-dominated quasars have X-ray emission in excess of the correlation.

The inference from point (a), that the X-rays from core-dominated quasars are beamed, is supported by earlier work. Point (b) is most simply explained if the same core X-ray to radio relationship holds for radio galaxies as for core-

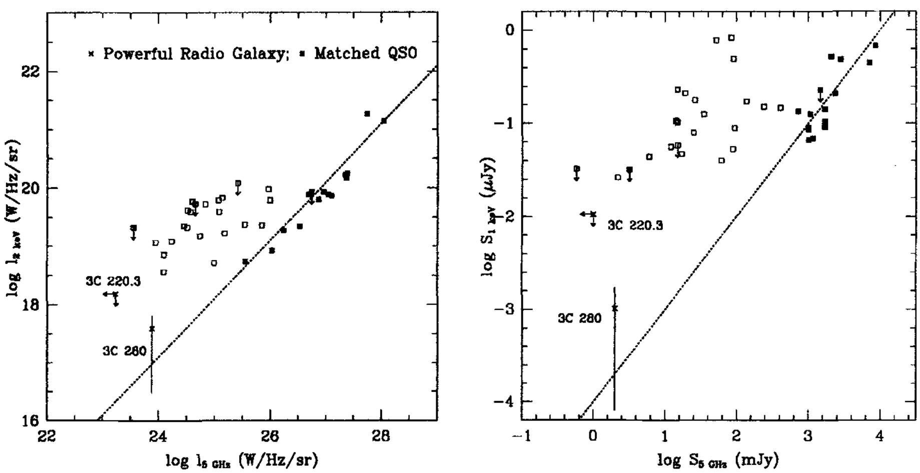

Figure 2: Core X-ray and radio flux densities for quasars (squares) matched in isotropic radio power with the radio galaxies 3C 220.3 and 3C 280. A line of slope unity (dotted) connects 3C 280 with the core-dominated quasars (filled squares), but not the lobe dominated quasars (open squares). Luminosity-luminosity (left) and flux-flux (right) plots are both presented to show that common-distance spreading has only a minor influence on the luminosity-luminosity plot and is not responsible for the correlation.

dominated quasars; this will be tested by ROSAT observations of other powerful radio galaxies. Point (c) suggests that lobe-dominated quasars contain an additional source of X-ray emission, possibly related to the nuclear X-ray emission in radio-quiet quasars. We infer that this compact X-ray component is obscured in radio galaxies, and dominated by beamed emission from the jet in core-dominated quasars. Further details of this work can be found in Worrall et al. (1994).

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