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Soft X-ray properties of a complete sample of QSOs

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Abstract. In order to study systematically the soft X-ray emission of AGNs, we have analyzed *ROSAT* PSPC spectra of 22 QSOs. The QSOs form a complete sample with soft X-ray flux $\geq 1.4 \times 10^{-14}$ erg cm^{-2} s^{-1} in the energy band of 0.1–2.0 keV in a circular region of radius 15 arcmin in the sky. The highest redshift QSO in the sample has $z = 3.4$. The average photon index (Γ) of the QSOs is 2.39 with a dispersion of 0.57. There are only 3 QSOs with $\Gamma x \geq 3.0$. The average slope of the soft X-ray spectra of the QSOs flattens at higher redshifts. Only three out of 22 QSOs show the presence of a significant excess absorption over the Galactic value.

Key words : galaxies:active – galaxies:nuclei – X-rays:galaxies

1. The Sample

The QSOs were selected from the second deepest *ROSAT* PSPC survey of McHardy et al. (1998). The *ROSAT* survey consists of two observations with PSPC and one observation with HRI (see below). We have selected 22 QSOs detected above 4.5σ level in the PSPC observations of 1991. The soft X-ray selected sample of 22 QSOs is complete to a flux limit of $\sim 1.41 \times 10^{-14}$ erg cm^{-2} s^{-1} in the energy band of 0.1–2.0 keV.

2. Observations

The QSOs were observed twice on 1991 June 23 and 1993 June 19 with the *ROSAT* (Trümper 1983) Position Sensitive Proportional Counter (PSPC, 0.1 – 2.4 keV) and once with the High Resolution Imager (HRI, 0.1 – 2.4 keV) (Pfeffermann et al. 1987) on 1997 June 4. The two PSPC observations with exposure times 71803s and 37658s, respectively, together comprise the second deepest *ROSAT* PSPC survey in a region of sky of extremely low obscuration (Galactic $N_H = 7.9 \times 10^{19}$ cm^{-2}). The HRI observation was also a deep survey with exposure time 201513s.

3. Results and discussion

The X-ray sources, presented in this paper, were identified with QSOs, based on deep R-band and PSPC images and optical spectra by McHardy et al. (1998). The optical magnitudes in the

B-band has not been measured for any of the objects, therefore standard classification of the objects into Seyferts and QSOs was not possible based on their B-band luminosity. However, all the objects appear to be point-like in the R-band images and are located at high redshifts (> 0.26). Following McHardy et al. (1998), the objects will be referred as QSOs. All the QSOs show broad (full width at half maximum (FWHM) > 1000 km s^{-1}) permitted emission lines (Jones et al. 1997; McHardy et al. 1998). We have analyzed the HRI data for the first time and confirmed the identifications by overlaying contours of high resolution HRI images onto the R-band optical images. Analysis of the X-ray data has been carried out using HEASOFT package (for details, see Dewangan et al. 2001a). The total source counts, light curve, and the count spectrum for each QSO were obtained in the energy band of 0.1–2.0 keV from the unsmoothed PSPC images using a circle centered on the peak positions, and after subtracting the background estimated from 3-4 nearby circular regions. The radii of circles, used to extract the source counts, vary from 45-90 arcsec. A χ^2 analysis shown that background count rates obtained separately for each QSO are reasonably constant. It is also found that all QSOs, except MJM 10, do not show significant soft X-ray variability. See Dewangan et al. (2001b) for the soft X-ray variability of MJM 10.

The soft X-ray spectrum of each QSO was fitted with absorbed and redshifted power-law model. All the QSO spectra, except for MJM 7, MJM 10, and MJM 15 are well described by the above model with N_H fixed at the Galactic value. The QSOs, MJM 7, MJM 10, and MJM 15 show evidence for excess absorption. The inferred intrinsic N_H is ~ 9.7 x 10^{20} cm^{-2} for MJM 7, ~ 2.8 x 10^{20} cm^{-2} for MJM 10, and ~ 9.5 x 10^{20} cm^{-2} for MJN 15.

The shape of the soft X-ray continua is described by the power-law photon indices derived from the best-fit power-law models. The photon indices of the QSOs range from 1.4 to 3.7. The average photon index, $< \Gamma x >$, is 2.39 (with a dispersion of 0.57). The average photon index of the QSOs with $z > 1.6$ in our sample is 2.12 with a dispersion of 0.39 which appears to be flatter (at 1.25σ level) than that found for QSOs in the nearby universe ($< \Gamma x > = 2.62 \pm 0.09$ for QSOs with $z \leq 0.4$; Laor et al. 1997). This is consistent with the trend that the power-law slope flattens at higher redshift, seen in earlier studies (see Schartel al. 1996; Stewart et al. 1994). The flattening of the average photon index can be understood in terms of the redshift effect of mean intrinsic QSO spectrum consisting of two components – a soft X-ray excess and a power-law component. There are three QSOs, MJM 7, MJM 10, and MJM 15 which show steeper soft X-ray continua ($\Gamma x > 3.0$). MJM 10 is known to be a narrow-line QSO (see also Dewangan et al. 2001c, this issue). MJM 7 amd MJM 15 are also likely to be NLQSOs.

5. Conclusion

We have determined the shape of the soft X-ray continua of a complete sample of QSOs. The mean soft X-ray slope flattens at higher redshift. Only three QSOs, MJM 7, MJM 10, and MJM 15 show steeper soft X-ray spectra similar to that observed in NLS1 galaxies. Also the same three QSOs show excess absorption over the Galactic absorption.

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