CORRELATED X-RAY AND MILLIMETRE VARIABILITY OF THE BLAZAR 3C273

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Abstract. We present the results of X-ray and millimetre monitoring of the blazar 3C273 at 1–2 day intervals over the period 12 December 1992 to 24 January 1993. No large flares are seen in this period but variations in both wavebands of $\sim 30\%$ on few day timescales are apparent. The ROSAT PSPC X-ray spectrum consists of 2 power-law components with the harder component dominating above 0.5 keV. There is very little correlation between the variability of the soft and hard components. The soft component does not correlate with the millimetre variations, but the hard component correlates reasonably well and leads the millimetre variations by about 10 days. These results show that the hard X-ray component cannot be a simple extrapolation of the millimetre/IR synchrotron component but may be explained as a self-Compton component in a shocked jet.

Key words: Blazars, X-rays, millimetre observations

1. Introduction

It is now generally accepted that most of the emission from blazars such as 3C273 arises in a relativistic jet oriented relatively close to our line of sight, but there are many possible models for such jets. Observations of correlated X-ray and millimetre variability can, in principle, provide one of the best diagnostics for distinguishing between alternative models however previous studies have produced no firm conclusions because of poor temporal coverage (eg Courvoisier *et al.* 1990). Rapid variations (days - weeks) do occur in the millimetre and infrared bands (eg Robson *et al.* 1993) and in jet models (eg Marscher and Gear 1985) X-ray/millimetre lags of this order are expected and so we monitored 3C273 on 1–2 day intervals in the X-ray and millimetre bands for over a month to search for any such lags.

2. The X-ray Observations

3C273 was observed 14 times by ROSAT with the PSPC detector and once with the HRI detector in the period 12 December 1992 - 10 January 1993. The observations were of duration $\sim$ 2ksec and the average PSPC count rate was $\sim 10\ s^{-1}$. For each PSPC observation it was possible to measure the spectrum in the region 0.1-2.4 keV. It proved impossible to fit the spectra adequately with a simple two component model such as a power-law plus absorbing column. The best fits are provided by a model consisting of two power-laws plus an absorbing column. When

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the absorbing column is allowed to float free it reaches a value below the galactic column and so it was fixed at the galactic value. The energy index of one of the power-laws was fixed at -0.5, the value found by EXOSAT and GINGA in the 2–10 keV band. The energy index of the second power-law was then derived to be ~ -1.7. This second, softer, component dominates below ~ 0.5 keV.

We derived lightcurves in various energy bands, 0.1-0.5 keV (soft), 0.5-2.4 keV (hard), 1.5-2.4 keV (very hard) and 0.1-2.4 keV (total - figure 1). No huge flares are seen but all lightcurves show variations of amplitude $\sim 20\%$ on ~daily timescales. These observations show, contrary to some previous suggestions, that 3C273 does show short timescale X-ray variability; it is just that the timescales of variability are somewhat longer than in the lower luminosity Seyfert galaxies.

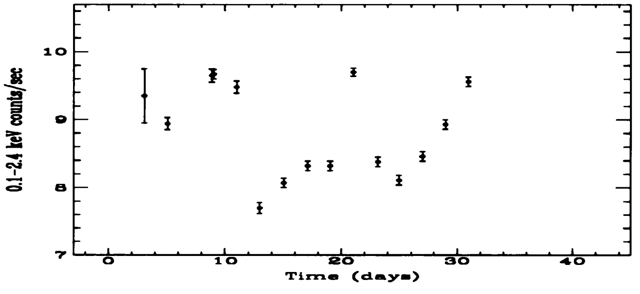

Fig. 1. 0.1-2.4 keV X-ray lightcurve. Day 0 = 0 hrs UT on 10 December 1992

The existence of two components in the PSPC band is already known (Staubert 1992) but here we are able to study their relative variability (figure 2). There is no obvious correlation; the two spectral components vary essentially independently.

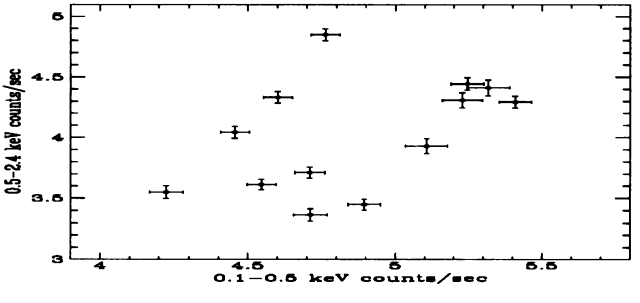

Fig. 2. Soft (0.1-0.5 keV) versus hard (0.5-2.4 keV) count rate.

3. The Millimetre Observations

Observations of 3C273 at 2, 1.1, 0.8 and 0.45mm were scheduled with the JCMT on Mauna Kea almost every night during the period 12 December 1992 - 24 January 1993. Unfortunately much of the programme was lost because of very poor weather conditions. Fortunately observations at 230 GHz were made during part of the lost period at IRAM and a small number of observations were made at 230 GHz by the NRAO 12m telescope on Kitt Peak. The millimetre spectrum of 3C273 was optically thin at this time and so, using the average spectral index (~ -0.7) we have extrapolated our 230 GHz fluxes to 273 GHz (1.1mm – figure 3). Variability of comparable amplitude to the X-ray variability, and on similar timescales, is apparent in the 1.1mm lightcurve. We also obtained some 104 GHz observations from SEST. Extrapolation to 1.1mm gives fluxes consistent with the other 1.1mm observations but, as the spectral extrapolation is quite substantial we do not, at least for the present, include these in our 1.1mm lightcurve.

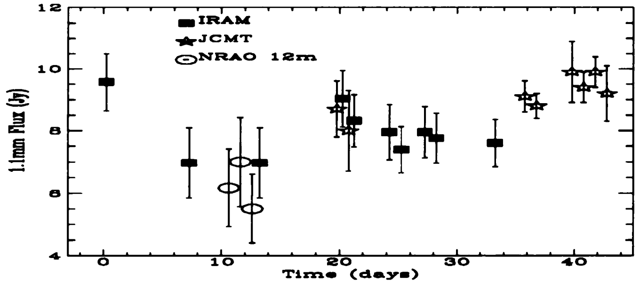

Fig. 3. 1.1mm lightcurve of 3C273. Day 0 = 0hrs UT on 10 December 1992

4. Cross-correlation of the X-ray and millimetre lightcurves

We separately cross–correlated the 1.1mm lightcurve with the various X-ray lightcurves. We used the discrete cross-correlation method of Edelson and Krolik (1988). There is a weak correlation with the 0.1-2.4 keV lightcurve with the X-rays possibly leading the millimetre variations by $\sim$ 10 days. There is no correlation with the 0.1-0.5 keV X-rays. The best correlation is with the hardest (1.5-2.4 keV) X-rays (figure 4). The correlation is significant at about 3σ.

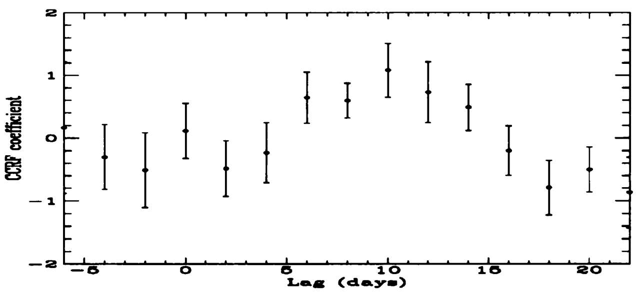

Fig. 4. Cross correlation of 1.5–2.4 keV X-ray and 1.1mm lightcurves.

5. Discussion

We have seen that the ROSAT pspc spectrum of 3C273 is described well by two power-law components, both of which vary rapidly and with large amplitude. The soft component fits broadly onto an extrapolation of the general millimetre/ infrared/optical continuum, which is generally assumed to be synchrotron emission, but does not correlate strongly with it. More work is required to determine the origin of the soft X-ray component.

The hard X-rays do correlate reasonably well with the synchtrotron component, but are not in phase. They are certainly not an extrapolation of the millimetre synchrotron component but may be produced by inverse compton emission associated with the synchrotron component. As there is a lag between the X-ray and millimetre bands the emission region cannot be optically thin and homogeneous and so a possible explanation is provided by inhomogeneous jet models (eg Marscher and Gear 1985). This model was derived to explain a flare of factor a few in the radio emission from 3C273 by means of a strong shock, but may well be applicable to the smaller amplitude variations here where disturbances propogating down the beam may encounter smaller scale weather. In such models we expect X-ray synchrotron self-compton emission to precede the synchrotron emission by ~weeks and so our observations are consistent with this model. A possible problem is that the millimetre spectral index (-0.7) is slightly steeper than the hard X-ray spectral index (-0.5). In simple SSC models these indices should should be the same. It is not yet clear whether this discrepancy is a result of measurement error, or whether a real physical effect remains to be explained.

Models not involving shocks (eg Maraschi *et al.* 1992; Melia and Konigl 1989) have greater difficulty explaining both the X-ray/millimetre lag and the hard X-ray spectral index but cannot be absolutely ruled out at this stage.

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