RAPID X-RAY VARIABILITY IN ACTIVE GALACTIC NUCLEI

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SUMMARY

Recent EXOSAT observations of active galactic nuclei are presented. Unlike earlier X-ray satellites (all of which flew in low earth orbit), the deep orbit of EXOSAT allows long continuous observations of celestial X-ray sources, uninterrupted by earth occultation etc. We present the results of EXOSAT observations of several AGN which have been seen to vary rapidly (timescale 0.2-6 hours). We also consider the implications of rapid variability in AGN. For Seyfert galaxies and quasars, we find a highly significant correlation between the timescale of variability and their X-ray luminosity. They are not, howwever, bounded either by the (classical) Eddington limit nor by efficiency arguments. We sugest, rather, that the emitting plasma is dominated by electron-positron pairs.

Several AGN have been seen to vary on short timescales. The nearby spiral M81 was found to contain a powerful X-ray source (L_X - 3 x 10^{40} ergs/s) which showed repeated variations by a factor two in ten minutes or so. This is the lowest luminosity for any identified AGN.In three out of five EXOSAT observations (each lasting between five and ten hours), NGC 4593 was seen to vary by a factor two, always on a timescale of two hours or so. The more luminous Seyfert I NGC 7469 varied by a factor two in six hours during one observation (out of three). A six hour observation of the Seyfert I galaxy Fairall-9 in July 1985 revealed repeated rapid fluctuations ba a factor two in 15 minutes or so. The implied efficiency of conversion of matter to energy for this object (Fabian & Rees 1978) is $\eta \gtrsim 8\%$, as extreme as for the rapid variability found by Tennant et al. (1981) for the (much lower luminosity object) NGC 6814.

What can be learnt from observations of rapid X-ray variability in AGN? We have compiled from the literature an extensive sample of AGN whose reported X-ray variability is reliably established, time resolved and the fastest reported for that particular object. In Fig. 1 we plot the logarithm of the rest-frame 2-10 keV luminosity, log L_X, against the time for the source intensity to double, Δt. The BL Lac objects are considered separately from the Seyferts and

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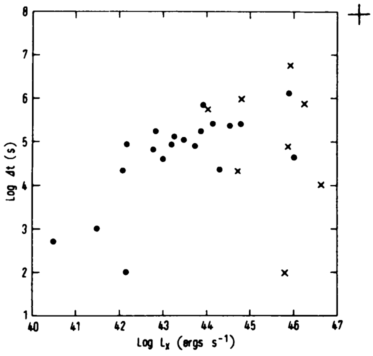

FIGURE 1.
The two-folding timescale of variability, log Δt, versus the mean 2-10 keV rest-frame luminosity, log L_X, for Seyferts and quasars (circles) and for BL Lac objects (crosses). A typical error bar is also shown.

quasars. For the Seyferts and quasars we find a significant trend, writing

$$\log L_X = A \log \Delta t + b \text{ ergs s}^{-1}$$

we find a highly significant correlation with a = 0.9±0.2, b = 39±1 and linear correlation coefficient r_c = 0.7. There is no such trend for the BL Lac objects, r_c = 0.2 Consider the Seyferts and quasars. If their hard X-ray spectra extend to 1 MeV (Bassini & Dean 1983) with spectral index of 0.7 (Rothschild et al. 1983), a bolometric correction of 1.0 to log L_X is indicated. Within the errors the correlation between L_X and t is linear. Thus the X-ray luminosity for this sample can be written

$$L_X/\Delta t = 10^{40} \text{ ergs s}^{-2}$$

and, since the source size $R \leq c\,\Delta t$, $L/R \gtrsim 10^{29.6}$ ergs s^{-1} cm^{-1}

What constrains the variability in Seyferts and quasars to this relationship? The implied efficiency of conversion of matter to energy is not large, $\eta \gtrsim 0.5\%$ nor is the Eddington limit a problem. Since $L/R < L_{Edd}/R_S$ where L_{Edd} is the classical Eddington limit and R_S the Schwarzschild radius, the observations indicate only $L <$ 0.001 L_{Edd}. One possibility is that the plasma is marginally pair dominated. 2-photon annihilation will lead to the formation of electron-positron pairs. Many workers have studied this phenomenon; a review with particular relevance to AGN is given by Svensson (1984). Copious pair production will occur if the compactness parameter $\ell = L\,\sigma_T/Rm_cc^3 > 4\pi$, where L is the γ-ray luminosity. Since the spectra of Seyferts and quasars are so hard, most of the luminosity is radiated as γ-rays. These observations indicate $\ell > 10$ and it is highly likely that copious pair production is occurring.

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DISCUSSION

Bregman : Could the few BL Lac sources that appears to radiate in the super Eddington regime have incorrect estimates for L_X because the redshift is unknown ?

Barr : This may be a problem for 1402+04 since the quoted redshift is a lower limit based on the lack of a host galaxy on deep CCD frames (see Maccagni et. al. - this symposium). However, the redshift of 0323+023 seems well established. In addition we have seen two new results presented at this symposium-PKS0548-322 (Agrawal et.al.) both of which have equally high implied efficiencies.

Filippenko : In response to the previous question (where did the redshift of H0323+022 come from ?) : The redshift of H0323+022 came from me - it is 0.1471 ± 0.0005

Barr : Good.

"Beaming is often a panacea for quasar problems, but the absence of corresponding optical and radio features has dissuaded us from suggesting ad hoc *X-ray beaming."*

\- Dan Harris (p.276)

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