X-RAY VARIABILITY IN ACTIVE GALAXY NUCLEI AND QUASARS IN LESS THAN ONE DAY

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Active galaxy-X-ray sources are well known to be variable on timescales of days to years (Ricketts, et al. 1977, Mushotzky, et al. 1979, Lawrence 1979). Here we present some new data from the Einstein Observatory which shows that these sources also vary in less than one day, on timescales of hours. Large luminosity changes in such short times promise to allow the investigation of the physics of such sources in several new ways. We shall give some examples of how this can be begun. This is only a preliminary report of this work. A full account will be given elsewhere.

The Einstein Observatory (Giacconi, et al. 1979) is capable of exploring this regime of variability because its imaging capability gives it two unique advantages. Firstly, the background rate in one beam area is negligible so that intensity determinations are limited only by Poisson counting statistics. Secondly, the background counts in the remainder of the field can be integrated to give a *simultaneous* monitor with the *same instrument* of cosmic ray and background X-ray events. Thus, any peculiarities in detector behaviour, telemetry or software can be traced and separated from real source variations. This is a significant advantage and gives us a great deal more confidence in our results. Many sources do not show variability. For example, in our data, Cen A is constant to ∿2% over 1 day.

Figure 1 shows the light curve of NGC 6814, a nearby, low luminosity, Seyfert 1 galaxy, binned in 10,000 sec bins. There is clearly a large scatter of points about the mean and a χ^2 test gives a probability of less than 10^{-3} that the source is constant. Note the low and very constant background count rate. The error bars on the background have been made very small by using a large part of the approximately one square degree field of the IPC (Imaging Proportional Counter). The event around 50 ksec into the observation stands out clearly and can be seen at other binnings. NGC 6814 clearly varies by factors > 2 on timescales < 20,000 sec (∿ 1/4 day).

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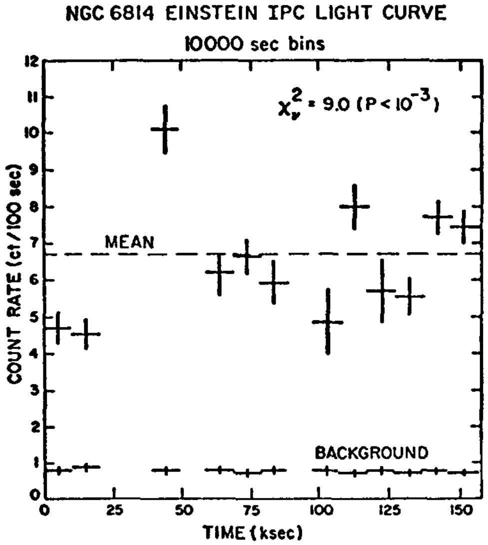

Figure 1

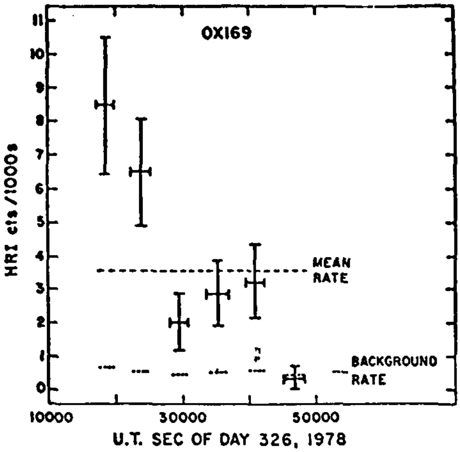

Figure 2

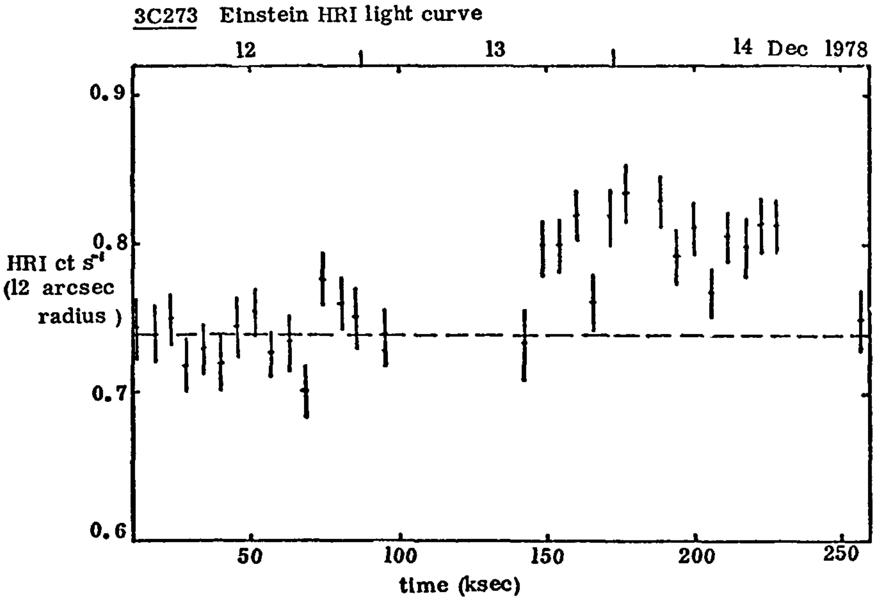

Figure 3

We know from NGC 4151 that the low energy spectral cutoff seen in some Seyfert galaxies can be variable (Barr, et al. 1977). Observations of changing low-energy absorption would be valuable to make estimates of the size, density and geometry of the clouds believed to exist in the broad line emitting region. We can use the spectral data provided by the IPC to look for such changes in NGC 6814. However, no correlation of total count rate with spectral 'hardness' is present. It seems that this event is due to a change in the underlying continuum source.

Many of the long observations we have performed have used the HRI (High Resolution Imager), the second of the two imaging instruments on the Einstein Observatory. This has lower quantum efficiency than the IPC and gives no spectral information. It gives instead ∿ arcsec spatial resolution in contrast to the ∿ arcmin resolution of the IPC and so is used to examine structure and obtain accurate positions. Thus, its exposures are typically longer.

The next two examples are both from such HRI observations. In both cases we shall return to the object for an IPC observation specifically designed for variability studies. The light curve of the quasar OX 169 (Figure 2, Tananbaum, et al. 1979) shows a rapid intensity decrease over $\lesssim$ 20,000 sec. Fast decays can be used to investigate the radiation mechanism. For instance, if we assume that thermal bremsstrahlung is operating, then the cooling timescale is

$$t \simeq \frac{2 \times 10^{11}\ T^{1/2}}{n_e} \text{ sec.}$$

where T is the temperature and n_e is the electron density (cm^{-3}) (e.g. Fabian and Rees 1979). So for a typical active galaxy temperature (Mushotzky, et al. 1979) $\gtrsim 10^9$K, we find $n_e \sim 10^{11}\ cm^{-3}$. In this case, comptonisation would become the dominant loss mechanism leading to inconsistency. Thus, it seems that thermal bremsstrahlung cannot be the cause of the decay seen in OX 169.

3C 273 has been seen to increase its flux by ∿ 10% over ∿ 50,000 sec (Figure 3) between the first and second halves of the observation. Since 3C 273 is a high luminosity quasar ($L_X \sim 2 \times 10^{46}$ erg s^{-1}, 0.5 - 5 keV) even a small percentage increase in its output such as this corresponds to a large change in luminosity. Fabian and Rees (1979) have pointed out that, *in the absence of relativistic expansion effects*, one can derive a minimum efficiency, η , for energy release from the matter involved in the emission by using the electron scattering optical depth of the emitting matter itself.
They find

$$\eta \gtrsim \frac{5\ \Delta\ L_{43}}{\Delta\ t}$$

$\Delta\ L_{43}$ is the change in luminosity, in units of 10^{43} erg s^{-1}, in a time Δ t secs.

Applying this to 3C 273 we have $\eta \gtrsim 0.02$. If we assume the whole X to γ-ray spectrum of 3C 273 (Primini, et al. 1979) was involved in this outburst, then $\eta \geq 0.1$.

Until recently, arguments based on X-ray variability of active galaxies have been restricted to making size estimates from the simple light travel time argument. Clearly, the Einstein Observatory data allow us to enter regimes in which more detailed physical models can be explored.

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