CONTINUUM MONITORING OF BRIGHT QUASARS

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ABSTRACT. Beginning in 1980, the fluxes of over 40 bright quasars, BL Lacs and Seyferts have been monitored at radio and optical wavelengths in a Finnish-Soviet collaboration. The chief aims of the program are to provide information about the variability characteristics of active nuclei over a wide range of timescales and to fill a gap in monitoring programs at millimeter wavelengths. The results are also used as a basis for various other investigations.

1. THE PROGRAM AND THE OBSERVATIONS

The monitoring program is a collaboration between Turku University Observatory (Finland), Helsinki University of Technology (Finland) and Crimean Astrophysical Observatory (USSR). Additional measurements have also been done at NRAO, West Virginia (USA) and at Sodankylä Geophysical Observatory (Finland).

The principal radio telescopes used are the 13.7-m telescope in Metsähovi, Finland (12, 22, 37, 77 and 90 GHz) and the 22-m telescope in Simiz, Crimea (22 and 37 GHz). Observations with the 32-m telescope in Sodankylä, Finland, have recently been initiated at 933 MHz. Polarimetry is possible with the 933 MHz and 90 GHz receivers. The flexible scheduling of observing time has allowed us to investigate extensively also shorter timescales (hours to weeks), which are not resolved in other comparable monitoring programs, and for which rather little systematic information exists, especially on frequencies above 15 GHz.

The radio sample consists of 42 bright (over 1 Jy) compact sources known to be variable. Over 1/3 of the known blazars are included. About 25 sources have been monitored monthly or more often, mainly at 22 and 37 GHz with some additional measurements at 12 and 77 GHz. Monitoring at 90 GHz has started recently with the new very sensitive receiver at Metsähovi (Räisänen, 1983). The radio data up to June 1985, over 3000 measurements, has been reduced (Urpo et al., in preparation). Several sources have also been monitored extensively with good time resolution for rapid variability. Earlier results are described in Salonen et al. (1983) and in Valtaoja et al. (1985).

G. Swarup and V. K. Kapahi (eds.), Quasars, 79–83.

The optical observations complement the radio monitoring. Results are described in Sillanpää et al. (1985, and in preparation).

2. DIFFERENT TYPES OF VARIABILITY

The observed variability behaviour at 22 and 37 GHz can be broadly divided into three distinct classes, which may have different underlying causes:

1) Slow quasilinear trends (timescale 10 years). This type is exemplified by NRAO 150, PKS 0735+17, 3C 273 and AO 1308+32, among others.

2) Outbursts (1 year). Prominent outbursts were seen in about 1/3 of the well-observed sources. Both the durations of the outbursts and their normalized lightcurves are very similar in the rest frames of the sources, independent of the source type; they seem to be well described by the canonical expanding source models with $T_b \sim 10^{12}$ K. There seems to be a tendency for the stronger outbursts to have more rapid rise times.

3) Flickering (0.1 year). Some sources show a rather chaotic behaviour on timescales of weeks or months, with apparently random flickering. This flickering may be superposed on other trends or outbursts. The amount of flickering may be quite different in sources of the same type. In BL Lac there is very little variation on monthly timescales (besides the outburst-related trends), while OJ 287 shows flickering down to at least daily timescales. This could indicate that the radiation from OJ 287 is beamed more directly towards us.

3. MAXIMUM AMPLITUDE OF VARIATIONS

Our coverage gives information about the variability characteristics of the sample over 4 orders of magnitude in time resolution (hours to 5 years). Of particular interest for theoretical models are the largest observed flux variations on different timescales. For each source in the sample, we have searched for the largest observed changes $\Delta S(max)$ within 0.1, 1, 10, 100 and 1800 days. (Note that this $\Delta S(max)$, which may represent a single event during five years of observing, will be much larger than the *average* variations on the timescale in question.) As Figure 1 shows, $\Delta S(max) \propto \Delta t^{0.3}$ both on the average for the sources in the sample as well as for the largest variations found in any QSO in the sample. A similar dependence for the rapidity of variations is also noticeable in the reported extreme flux changes (taken from Epstein et al. (1980) and Reich and Steffen (1982)). Since on shortest timescales the random statistical errors start to affect the data, possibly causing spurious large variations, the data for 3C 84 (several measurements) is also shown.

Since the brightness temperature $T_b \propto (\Delta S/\Delta t)^2$, our data indicates that $T_b \propto \Delta t^{-1.4}$, and the more rapid variations exceed the 10^{12} K limit in most of the sources.

We have made altogether about 130 flux measurements with $\Delta t < 6$ h, and over 400 measurements with $\Delta t < 30$ h to study short-timescale vari-

https://doi.org/10.1017/S0074180900152313 Published online by Cambridge University Press

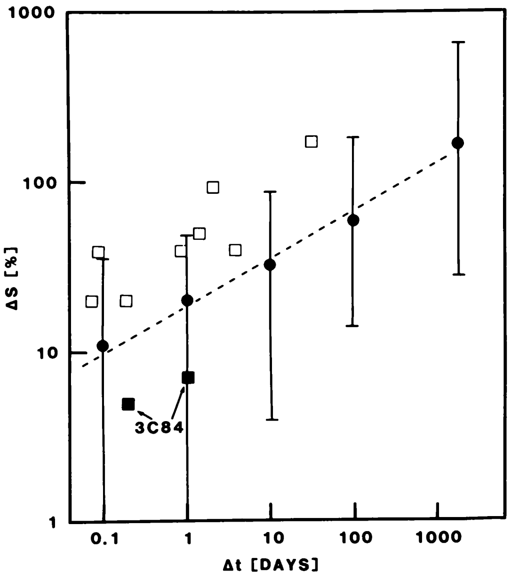

Figure 1. Largest observed variations on different timescales. In addition to the sample average, both the largest and the smallest variations found in any of the sample sources are shown. Open squares are extreme variations reported in the literature. The dashed line is the dependence $\Delta S(max) \propto \Delta t^{0.3}$.

ations. To see whether the sample sources on the average are variable from day to day we have plotted all the observed flux changes ΔS(1,2) in units of $\sigma(1,2) = \{\sigma(1)^2+\sigma(2)^2\}^{1/2}$. The observed spread in ΔS is consistent with no average daily variability larger than about $\sigma(1,2)/2 \simeq$ 4 % (a conservative upper limit).

Even if the sources are generally not variable on daily timescales, some individual large changes may still occur. It may be significant that many of the most dramatic flux changes reported in the literature are sudden drops from a constant level with subsequent recovery; after careful consideration we have removed several such occurrences from our data as being possibly due to some undetected errors resulting in abnormally low fluxes. The largest remaining variations in our data are a 36 % (3.3σ) drop in 2 hours in OJ 287 and a 49 % (3.1σ) drop in one day

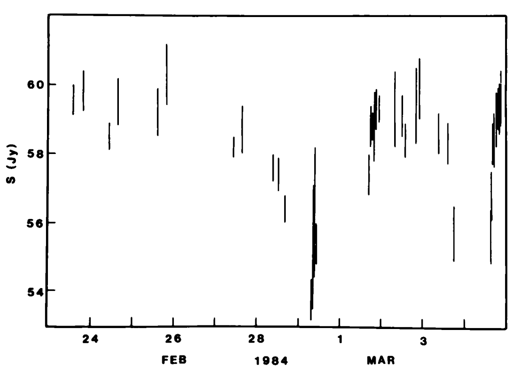

Figure 2. Rapid variability in 3C 84 at 12 GHz in Feb-Mar 1984.

https://doi.org/10.1017/S0074180900152313 Published online by Cambridge University Press

in 4C 38.41. As Figure 1 shows, most of the sources have had at least one episode of daily variability with $\Delta S > 10$ %, but many of these may simply be the tail end of the gaussian distribution of errors. The largest well-documented daily changes are comparable to those shown in Figure 2 for 3C 84.

4. FUTURE WORK

The radio monitoring will be continued mainly at 37 and 90 GHz. Of special interest is the relation between mm- and optical wavelengths. Attempts to link cm- and optical data have remained rather inconclusive; we hope to establish better correlations with simultaneous 90 GHz and optical flux and polarization measurements.

Simultaneous UBVRI photopolarimetry (Korhonen et al., 1984) of blazars has recently been added to the monitoring program to study rapid variability and the little known frequency dependent polarization. The most interesting observation so far concerns OJ 287, where our observations, combined with those of Sitko et al. (1985), show transient FDP occurring in connection with a sudden drop in optical flux, preceded by linear rotation of the position angle during the previous week and a sudden change in P.A. simultaneously with the drop.

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DISCUSSION

Petrosian : Have you seen any periodic variability ?

Valtaoja : Our best candidate is OJ 287 with a possible 15.7 min period. We cannot do absolute flux measurements on so short timescales but must instead use Fourier analyses to search for periodicities in long continuous observing runs, and try to identify all the extrinsic factors that could cause apparent periodicities. After that it becomes a question of statistical significance of peaks in Fourier spectra. We estimate that the probability for the 15.7 min period being spurious is less than one percent.

https://doi.org/10.1017/S0074180900152313 Published online by Cambridge University Press

"Most quasar optical light curves appear essentially the same whether displayed inverted or even with time-reversal."

\- Harlan Smith and Ronald Angione (p.88)