RESULTS FROM A MONITORING PROGRAM OF LOW FREQUENCY VARIABLE SOURCES

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INTRODUCTION

The flux variability of extragalactic radio sources at decimetric wavelengths (Low Frequency Variability LFV) is mostly associated with the nuclei of compact radio sources. But is a not yet well understood phenomenon. The main question still is: where does this phenomenon take place?

Two categories of models have been proposed to account for this phenomenon: a) the intrinsic models, among which a general consensus emerges for the interpretation of the flux variations in terms of synchrotron emission of relativistic electrons beamed in a direction close to the line of sight. In this case the LFV is directly related to the way the 'central engine' produces and transfers relativistic particles. Estimates of the relativistic Lorentz factor (γ) can be derived from the LFV. b) The extrinsic models, that attribute the LFV to propagation effects through the interstellar medium. In this case the LFV could be used for measuring the properties of the interstellar turbulence.

An analysis of multifrequency observations at 0.4, 2.3, 4.8, 8.0 and 14.4 GHz of 51 radiosources selected from the Bologna monitoring program (Fanti et al 1981) over a period longer than 5 years allowed us to identify three classes of sources showing LFV and to evaluate their occurrence in an unbiased sample of variable sources (Padrielli et al, 1986a).

SOURCES DISPLAYING CORRELATED BROAD BAND VARIABILITY

This class contains sources with broad frequency band activity, which appears to be correlated across the whole radio frequency band. The outbursts are either quasi-simultaneous or regularly drifting to lower frequencies, with somewhat reduced amplitude. A light-curve of a source belonging to this class is shown in Fig. 1.

In our sample there are 4 good cases of these objects: 3C 120, 0605-085, 1510-089, BL Lac and some probable ones. The occurrence of this class in our sample of LF Variables is from 10% to 20%.

For the two sources 0605-085 and 1510-089 we obtained two epoch VLBI observations at 18 cm with an array of 8 stations, corresponding to a

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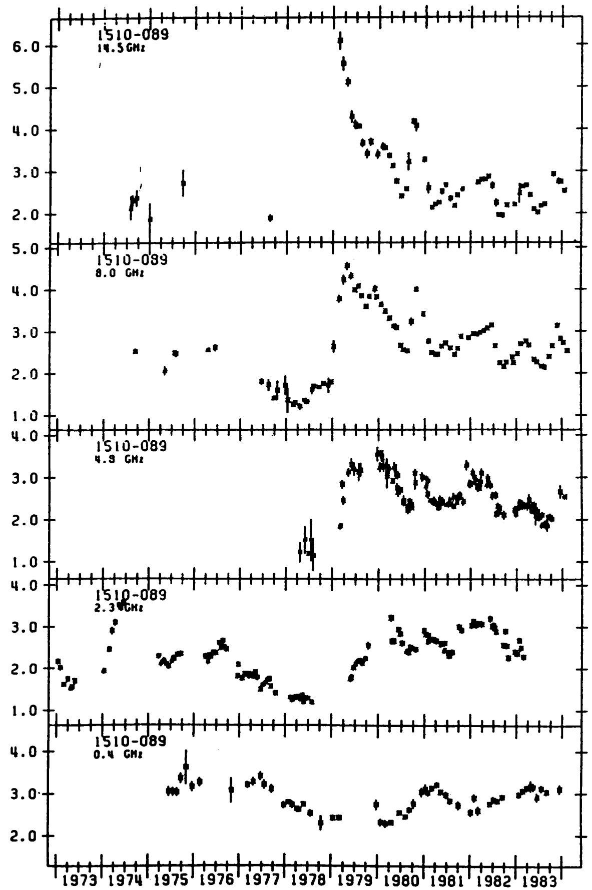

Fig. 1 – Light-curves of the source 1510-089 at different frequencies.

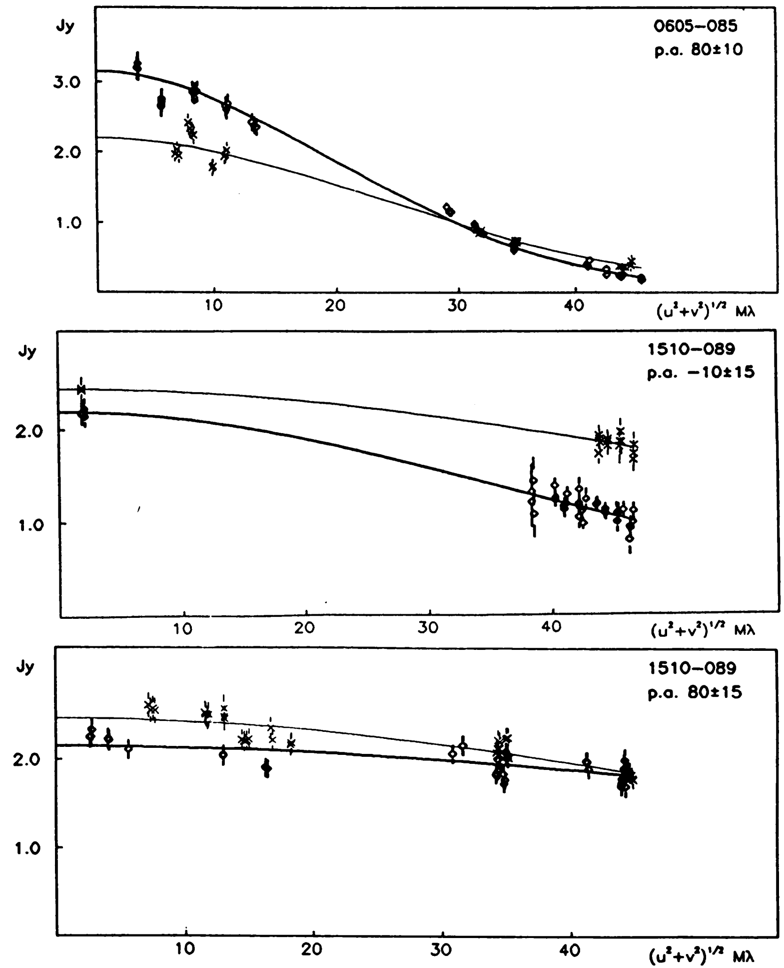

Fig. 2 – Fringe visibility amplitudes vs baseline length in specific directions on the u-v plane. **x** represents first epoch data (1980.1), ◊ second epoch data (1981.8)

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resolving power of 2-3 mas (Romney et al 1984, Padrielli et al. 1986b).

From the time scale of the LFV between the two epochs we can compute the angular diameter of the varying component, its brightness temperature and then the lower limit to the bulk Lorentz factor. For these sources our VLBI observations give evidence of statistically significant structural changes between the two epochs. A careful analysis of the fringe visibilities at the longest baselines (b>30 Mλ) shows that a possible interpretation of the differences is an increase of the angular size of the more compact component. The corresponding expansion rate is in agreement with the Lorentz factors derived from the LFV (with the simple assumption of an angle between the line of sight and the ejection direction of the order of $1/\gamma$). Fringe visibility amplitudes of the two epochs are shown in Fig. 2. 3C 120 and BL Lac are also well known superluminally expanding sources with rates that are in agreement with the γ derived by the LFV.

For the sources of this class, the whole observational scenario is in agreement with models requiring relativistic bulk motions. These models successfully explain an activity extending from the very high frequencies to meter wavelengths.

SOURCES WHOSE VARIABILITY IS CONFINED TO THE LOW FREQUENCY RANGE

This second class contains sources that are strong variables at low frequency (ν<1 GHz) and weak at high frequency. The occurence of this class of objects is 35% in our sample of LF Variables.

Fig. 3 shows the light-curve of DA 406, source well studied by several authors and prototype of the category (see for references Altschuler et al. 1984).

We have two epoch VLBI measurements at 18 cm only for two objects of this class. 0859-140 did not vary between the two epochs, but 1611+343 (DA 406) had a spectacular variation at 0.4 GHz. If we interpret this variation in terms of relativistic motions, we obtain a lower limit for the Lorentz factor of the order of 12 (H=100 Km s^{-1} Mpc^{-1}, q_o=1), which leads to an expected expansion of 0.7 mas (with an angle between the beam and the line of sight of $1/\gamma$). The fringe visibilities do not show evidence for a significant angular increase between the two epochs (Fig. 4).

In this case we do not find a direct evidence of relativistic motions associated with the LFV ant it could be due to a distinct phenomenon.

SOURCES WITH UNCORRELATED BROAD BAND VARIABILITY

This class contains sources which have both high and low frequency activity, that appear to be unrelated, with each other, and display a minimum of activity at the intermediate frequencies ($\nu\sim$1 GHz). The occurrence of this category of objects in our sample is from 20% to 30%. In Fig. 5 an example of light-curves of this kind of sources is shown.

We have 2 epoch VLBI information for several objects in this variability class, but, due to the lack of correlation of high and low frequency activity any discussion on the structural changes from 18 cm data can only done if we have spectral information, which will allow the determination of the components responsible for the LFV. This is the case of the source 3C 454.3 (Pauliny-Toth et al. 1981). After the first

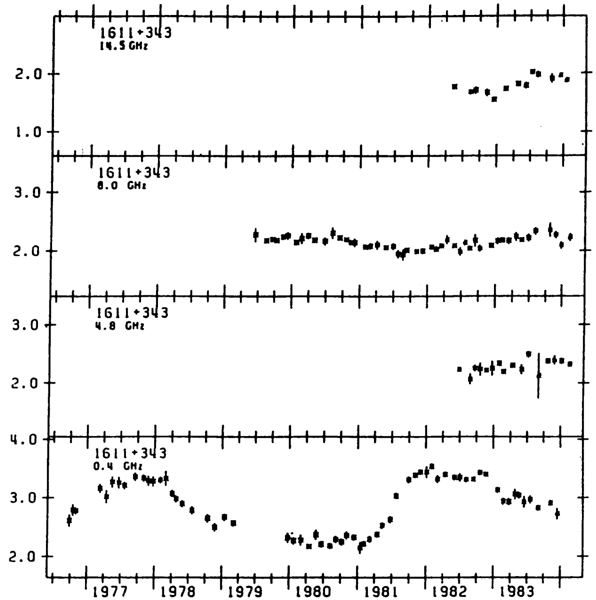

Fig. 3 - Light-curves of the source 1611+343

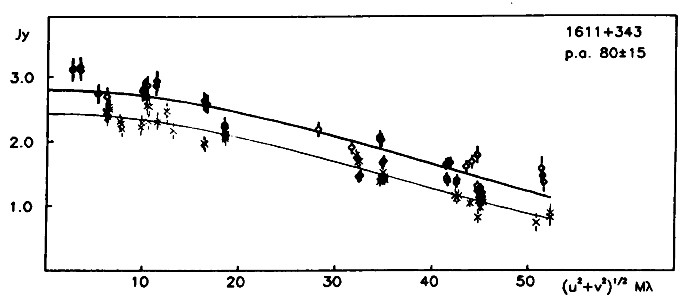

Fig. 4 - For explanation see Fig. 2

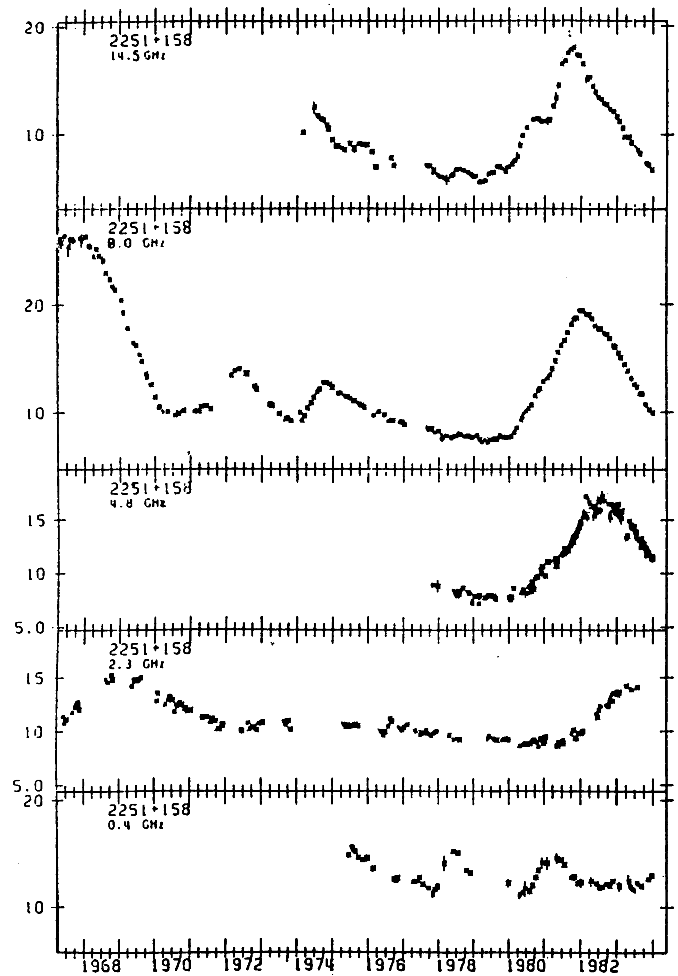

Fig. 5 - Light-curves of the source 2251+158 (3C 454.3) at different frequencies.

VLBI measurement, the source had a strong burst at 0.4 GHz and the corresponding brightness temperature leads to a γ limit ~11. The two VLBI maps are very similar to each other and the separation between the core and the jet (the region we expect to see at 0.4 GHz) is unchanged (Fig. 6). Other sources in this category do not show the angular expansion that is expected on the basis of 0.4 GHz time variability from relativistic models. The behaviour of the variability of this third class could probably be due to a superposition of the two different processes.

EXTRINSIC INTERPRETATION

We have focused our attention on the objects of the last two classes of LFV, comparing the observed variability amplitudes and time scales at 0.4 GHz with the expectations from effects of the refractive focusing of the large scale irregularities of the galactic medium as it has considered by Rickett et al. (1984).

We define m as the ratio between the flux density r.m.s. and the mean flux density and ΔT as the half power full width of the decorrelation functions of the 0.4 GHz light-curves that span over ~10 years. The theory predicts for the extragalactic sources a dependence of the variability and time scale on the galactic latidude (b) and the angular size of the source itself, for 'relatively extended sources'. Furthermore, the product of m and T should statistically depend only on the galactic latidude.

Fig. 7 gives the plot of $m*\Delta T$ versus sin b. We have divided the sources according to their galactic longitude (l) into two groups, one projected in the direction of the Galactic Centre and the other one in the opposite side. A correlation was not found, but nevertheless there is an interesting difference between the two samples. While the (variability * time scale) product is completely uncorrelated with the galactic latitude for sources in the anticentre direction, the same quantity shows a sort of a lower bound that depends on the galactic latitude for the sample projected in the direction of the galactic centre. In this direction, the source radiation passes through many irregularity patterns, and we expect to find a statistical behaviour in agreement with the theory at least in the lower limits of the scintillation. The slope of the straight line of the limits is about 1.2, in agreement with the expected slope of 1.6.

An independent test on the extrinsic interpretation is obtained by comparing of the B2 and B3 surveys on a time scale of about ten years (Colla et al. 1970, Colla et al. 1973, Ficarra et al. 1985). The surveys consist of 24 hours of observations in the declination range 31°-40°. The covered sky is all in the direction of the galactic anticentre and a comparison between the two sky regions cannot be done.

We have found 42 variables sources over about 2000 sources stronger than 0.4 Jy. Fig. 8 shows the distribution of the percentage of variable sources vs the galactic latitude. The probability of a uniform distribution of this plot is less than 1%.

What can be concluded? The data suggest a certain degree of agreement with the extrinsic explanation for the LFV when it is uncorrelated with the high frequency one. Clearly the problem is not resolved and a better description of the galactic medium should be necessary.

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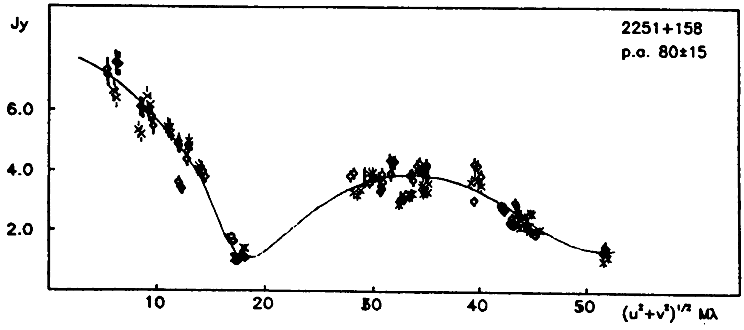

Fig. 6 - For explanation see Fig.2

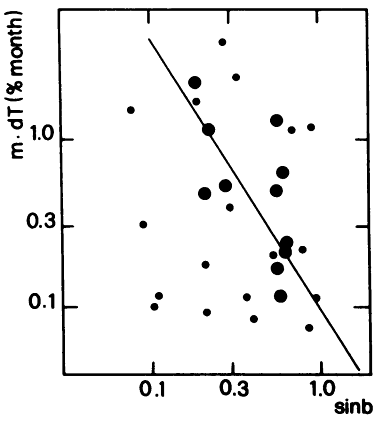

Fig. 7 - m·ΔT plotted vs sin b. ● represents sources with l<90° or l>270°. • represents sources with 90°<l<270°

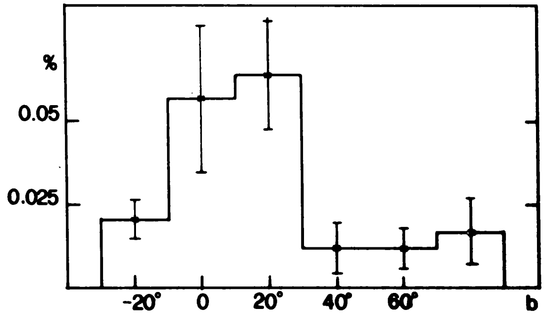

Fig. 8 - Distribution of the percentage of variable sources vs the galactic latitude.

DISCUSSION

Baldwin : To test the interstellar explanation of variability we have searched for sources which are compact and nonvariable at high frequencies and, from their spectra, are compact also at low frequencies. CTD93 is the best example of these and at 151 MHz it has varied by less than 5% over 18 months.

Burbidge : The important question is : are there some sources which definitely show low frequency variability which is intrinsic ?

Padrielli : There are ~ 20% of low frequency variable sources that show activity correlated across our entire frequency range from 0.4 to 14.5 GHz, with superluminal expanding motions associated to the L.F. variations. I think that this can be interpreted as evidence of intrinsic variability.

Cohen : For the few cases where relativistic motions explain both the low frequency variability and the VLBI changes, what values of Lorentz Factor (and Hubble Constant) do you find ?

Padrielli : The Lorentz factor ranges from 2 to 5 for $H = 100$ km/sec/Mpc and $q_o = 1$.

Mutel : The large scatter of galactic latitude - variability plot is probably due to known clumpy structure of interstellar turbulence, as deduced for example, from studies of angular broadening of compact sources in the galactic plane.

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"Relativistic beaming is such a strong amplifier that we may be "blinded" by a realtively insignificant part of the source coming towards us."

\- Roger Blandford (p.221)