CHAPTER IV

A MULTIFREQUENCY STUDY OF RADIO INTENSITY VARIATIONS FOR ACTIVE GALACTIC NUCLEI OF DIFFERENT OPTICAL CLASSES.

4.1 INTRODUCTION

In order to look for correlations of low frequency variability (LFV) with other intrinsic properties of active galactic nuclei; between 1985 and 1988 we monitored the 327-MHz flux densities of a sample of flat-spectrum extragalactic radio sources comprising BL-Lac objects, high-optical-polarization quasars (HPQs) and low-optical-polarization quasars (LPQs). Currently, the origin of high optical polarization in quasars is not well understood. Some models invoke isotropic nonthermal optical emission, which in the case of a LPQ is obscured, reprocessed, and depolarized by an optically thick cloud. Other models require an anisotropic polarized optical component, probably associated with a relativistic radio jet, superposed on isotropic unpolarized emission, and viewed at a small angle to the line-of-sight in the case of a HPQ. However, the observed wavelength dependence of optical polarization in LPQs can be well accounted for if the polarization is caused by dust scattering from a thick disc around the central continuum source (Moore and Stockman, 1984). BL-Lac objects are very similar to HPQs in their optical polarization properties (hence the common classification of both as 'Blazars') although they differ in the prominence of the emission lines in their spectra.

The radio properties of these objects seem to bear some relation to their optical characteristics. For example, it has been found that most blazars have flat radio spectra whereas the spectra of LPQs can be either steep or flat. Many blazars, but few LPQs, are found to be superluminal sources. Hence, BL Lacs, HPQs and LPQs seem to represent objects that are either intrisically, or geometrically, different or at different stages of evolution. Regarding their LFV properties, Moore and Stockman (1984) found high optical polarization to be associated with LFV, although they noted the inadequacy of their sample to determine whether the occurrence of LFV is greater among flat-spectrum sources in general. This led us to investigate whether LFV properties are different among BL Lacs, HPQs and LPQs in an unbiased sample of flat-spectrum radio sources. If any such effect were to be found it would definitely point to an intrinsic origin of LFV, although nondetection of such a correlation would not necessarily rule out the possibility of intrinsic effects.

We also decided to extend our study to include an examination of radio intensity variations for sources of different optical polarimetric/spectroscopic properties over a wide range of observing frequencies, since high-frequency variability over timescales of months is generally considered to be intrinsic. This has been achieved by supplementing our observations with the published results from other monitoring programmes spanning a frequency range from 0.318 to 90 GHz.

In this chapter we present our measurements of 327-MHz flux densities and the results of the above-mentioned comparative study.

4.2 OBSERVATIONS

The sample observed consists of 8 BL Lac objects, 17 high optical-polarization quasars (HPQ, with > 3% polarization) and 9 low optical-polarization quasars (LPQ), satisfying the following criteria:

i) flat radio spectrum at decimetric wavelengths ($\alpha \leq +0.5$; $S_\nu \propto \nu^{-\alpha}$)

ii) $|\delta| \leq 35°$

iii) $|b^{II}| > 10°$

iv) $S_{327} \geq 1$ Jy

(expected from interpolation/extrapolation of the spectrum)

v) evidence for a core-dominated structure at 327 MHz, based on published interplanetary-scintillation, or VLBI, observations at metre wavelengths.

In addition, 11 steep-spectrum double sources with angular sizes in the range 7 to 12 arcsec (Lawrence et al., 1986), and hence unresolved by OSRT, were monitored as control sources. The median flux density of these sources is 1.7 Jy, which is identical to the median flux density for the sources in the sample. Another group of 25 control sources was selected from the catalogue of OSRT flux-density calibrators. This latter group of 'strong' ($S_{327} > 6$ Jy) sources was used to calibrate the flux-density scale (Baars et al. 1977) of our observations. A few known low-frequency variable sources were included in the programme at a later stage, although these have not been used in making any statistical inferences. Also monitored were two compact double sources (CDs), since CDs are generally considered to be intrinsically non-variable at all radio frequencies (Readhead et al.,1987; Hodges and Mutel, 1987). The structure of a CD is dominated by a pair of hotspots with sizes $\lesssim$ 10 mas at decimetric wavelengths (Phillips and Mutel, 1982). The occurrence of a spectral peak around 1 GHz, with a sharp cut-off to longer wavelengths, suggests similar pre-scattering sizes for them at metre wavelengths. Thus, the radio components are compact enough to undergo strong refractive interstellar scintillations at low frequencies. Another high-latitude source, 0237-233, with an overall size of ~ 6 mas at 5 GHz (Carvalho, 1985), was also included in the list. This source has a spectral peak at ~ 1 GHz suggesting equally compact low-frequency structure (Kuhr et al., 1981a).

Using the method described in Chapter III, we measured the 327-MHz flux densities of these sources over a period of three years. The effective rms measurement error has been derived for individual sources from the monitoring of the calibration and control sources (10 weaker than 3 Jy at 327 MHz). Table IV-1 lists the flux densities and their associated errors at the various epochs of observation for all sources in our sample.

4.3 RESULTS

4.3.1 Intensity variations at low frequencies (LFV)

The Ooty Sample: We parametrize the degree of flux-density variations by the (corrected) variability index,

$$m_c = \left[(\sigma_s^2 - \varepsilon^2)^{1/2}/\overline{S}\right] . 100\%$$

where, $\overline{S}$ is the mean flux density over the period of observations, σ_s is the observed rms flux-density variation and ε is the rms measurement error derived from the monitoring of the control sample. Where $\sigma_s < \varepsilon$, m_c was set to zero. Values of m_c for our compact source sample are given in Table IV-2; the additional sources and the CDs are not included in this table. In view of the recent detection of a blazar component in the LPQ, 3C273, this source has also been excluded from this table. While the histogram of m_c for the control group (Fig. IV-1a) shows a tail extending

TABLE IV-1: 327-MHz FLUX DENSITIES AND ERRORS (in mJy) AT DIFFERENT EPOCHS

0048-097 * CODE : BL LAC

8-FEB-86	781.18	107.36
16-MAY-86	838.10	108.43
24-AUG-86	923.81	110.15
16-DEC-86	834.44	108.35
08-JAN-88	864.04	108.93

0122-003 * CODE : LPQ

8-FEB-86	815.00	107.98
16-MAY-86	1098.10	114.08
24-AUG-86	1122.92	114.68
16-DEC-86	1028.33	112.44
28-SEP-87	1173.24	115.94
10-JAN-88	895.83	109.57

0202+149 * CODE : ADDS

8-FEB-86	6247.92	328.01
24-AUG-86	5918.42	312.36
16-DEC-86	4472.22	244.95
09-JAN-88	4609.00	251.21

0235+164 * CODE : BL LAC

28-SEP-85	908.00	118.49
24-AUG-86	1180.28	129.72
18-DEC-86	883.86	117.59
08-JAN-88	1443.33	142.15

0237-233 * CODE : GPS

28-SEP-85	2347.06	192.33
8-FEB-86	3021.11	233.93
16-MAY-86	2747.50	216.77
24-AUG-86	2631.95	209.63
18-DEC-86	2785.97	219.16
3-APR-87	2977.50	231.17
8-JAN-88	3017.27	233.69

0336-019 * CODE : HPQ

14-MAY-85	1293.33	119.09
8-FEB-86	1343.12	120.46
24-AUG-86	981.14	111.38
18-DEC-86	1229.73	117.39
30-MAR-87	1755.51	133.06
28-SEP-87	1431.67	122.98
09-JAN-88	1143.61	115.19

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     0420-014 * CODE : HPQ
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   10-MAY-85        929.17   110.27
    8-FEB-86        918.01   110.03
   24-AUG-86        797.08   107.65
   17-DEC-86        942.78   110.55
   26-MAR-87        970.91   111.16
   28-SEP-87       1135.50   114.99
   11-JAN-88       1016.11   112.17
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     0422+005 * CODE : ADDS
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   12-MAY-85        737.66   106.58
    8-FEB-86        870.84   109.07
   24-AUG-86        810.84   107.91
   17-DEC-86        820.30   108.08
   24-MAR-87        746.39   106.74
   11-JAN-88        840.74   108.48
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     0430+052 * CODE : ADDS
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    8-FEB-86       4306.22   237.40
   23-AUG-86       3863.33   217.52
   17-DEC-86       3812.68   215.27
   24-MAR-87       3739.67   212.04
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     0458-020 * CODE : HPQ
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   14-MAY-85       2133.33   146.21
   27-SEP-85       2095.56   144.84
    8-FEB-86       2399.72   156.19
   16-MAY-86       2272.73   151.37
   23-AUG-86       2368.89   155.01
   17-DEC-86       2639.27   165.57
   24-MAR-87       2525.83   161.09
   29-SEP-87       2365.50   154.88

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     0605-085 * CODE : HPQ
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    9-FEB-86       3542.78   203.42
   16-MAY-86       2742.33   169.71
   22-AUG-86       2465.83   158.75
   19-DEC-86       3061.54   182.85
   24-MAR-87       2750.56   170.04
   29-SEP-87       2457.32   158.42
   09-JAN-88       2630.53   165.22

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     0607-157 * CODE : ADDS
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    9-FEB-86       1426.04   122.82
   16-MAY-86       1063.89   113.27
   22-AUG-86        556.67   103.80
   19-DEC-86        968.61   111.11
   24-MAR-87        743.06   106.68
   29-SEP-87        833.64   108.34
   09-JAN-88        924.00   110.16

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    0735+178 * CODE : BL LAC
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  15-MAY-85     1740.28    157.61
   9-FEB-86     2117.00    178.77
  16-MAY-86     2310.78    190.17
  22-AUG-86     1606.00    150.46
  17-DEC-86     1685.56    154.67
  02-OCT-87     2191.67    183.13
  10-JAN-88     1821.11    162.02
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      0736+017 * CODE : HPQ
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   9-FEB-86     1676.95    130.50
  16-MAY-86     1675.95    130.47
  22-AUG-86     1576.67    127.34
  19-DEC-86     1813.39    134.99
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      0738+313 * CODE : LPQ
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 26-SEP-85     1794.70    160.57
   9-FEB-86     1425.78    141.28
 16-MAY-86     1642.22    152.36
 22-AUG-86     1724.67    156.76
 19-DEC-86     1546.11    147.35
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    0851+202 * CODE : BL LAC
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  15-MAY-85      773.53    113.72
  10-FEB-86     1124.93    127.28
  12-MAY-86     1260.00    133.34
  20-DEC-86     1150.25    128.39
  28-MAR-87     1132.73    127.62
  29-SEP-87     1145.69    128.19
  08-JAN-88      980.56    121.29

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      0906+015 * CODE : HPQ
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  29-APR-85      775.83    107.26
  15-MAY-85      651.67    105.17
  10-FEB-86      793.82    107.59
  12-MAY-86      899.44    109.65
  20-DEC-86      902.92    109.72
  25-MAR-87     1110.89    114.39
  05-OCT-87      607.78    104.52
  08-JAN-88      786.67    107.46

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      1038+064 * CODE : LPQ
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 29-APR-85     1456.38    123.70
   9-MAY-85     1536.67    126.11
   9-FEB-86     1302.40    119.33
 12-MAY-86     1526.67    125.80
 19-DEC-86     1502.29    125.07
 20-MAR-87     1064.44    113.28
 11-JAN-88     1158.89    115.57

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      1055+018 * CODE : HPQ
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   9-MAY-85       4426.25    242.86
  10-FEB-86       4421.95    242.66
  12-MAY-86       4465.83    244.66
  19-DEC-86       4593.89    250.52
  20-MAR-87       4753.75    257.87
  11-JAN-88       4314.44    237.77
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      1117+146 * CODE : ADDS
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   7-FEB-86       3138.10    186.06
  16-MAY-86       2542.50    161.74
  18-DEC-86       2795.56    171.87
  20-MAR-87       2975.00    179.24
  28-JAN-88       3528.33    202.79
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      1156+295 * CODE : HPQ
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 25-APR-85        3258.00    249.02
  7-FEB-86        3988.89    296.59
 16-MAY-86        1725.83    156.83
 22-AUG-86        2958.33    229.96
 18-DEC-86        3637.92    273.59
 27-MAR-87        3472.23    262.82
 08-JAN-88        3567.50    269.00
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      1219+285 * CODE : BL LAC
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  25-APR-85       1322.14    136.26
   7-FEB-86       1522.22    146.13
  16-MAY-86       1771.15    159.28
  22-AUG-86       1435.23    141.75
  18-DEC-86       1663.33    153.48
  20-MAR-87       1448.33    142.40
  08-JAN-88       1003.33    122.20

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      1226+023 * CODE : LPQ
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  26-APR-85     63483.58   3175.75
   7-FEB-86     62893.33   3146.26
  17-MAY-86     60459.59   3024.63
  22-AUG-86     63716.78   3187.41
  18-DEC-86     58340.00   2918.71
  26-MAR-87     69250.00   3463.94
  08-JAN-88     62572.22   3130.21

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      1253-055 * CODE : HPQ
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  25-APR-85      11408.51    579.12
   7-FEB-86      14522.22    732.96
  17-MAY-86      15289.59    770.99
  22-AUG-86      15063.89    759.80
  20-MAR-87      16556.67    833.85
  08-JAN-88      13011.11    658.20

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      1502+106 * CODE : HPQ                  1504-166 * CODE : HPQ                  1510-089 * CODE : HPQ
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   11-MAY-85      705.82   106.04         12-FEB-86    1087.50   125.68         11-MAY-85    2747.50   169.92
   29-SEP-85      776.82   107.28         15-MAY-86    1006.39   122.32         24-SEP-85    2629.17   165.17
   12-FEB-86     1078.75   113.62         23-AUG-86    1226.11   131.78         12-FEB-86    2510.08   160.47
   15-MAY-86      762.23   107.02         25-DEC-86    1575.44   148.87         14-MAY-86    2083.08   144.39
   23-AUG-86      965.83   111.05         28-MAR-87    1403.89   140.21         23-AUG-86    2636.33   165.46
   25-DEC-86      922.44   110.12         29-SEP-87    1360.00   138.07         24-DEC-86    2360.83   154.71
   28-MAR-87      896.11   109.58         10-JAN-88    1731.88   157.15         24-MAR-87    2607.75   164.32
   29-SEP-87      989.00   111.56                                                29-SEP-87    2129.72   146.08
   10-JAN-88      886.67   109.39                                                10-JAN-88    2005.00   141.60

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      1514-241 * CODE : BL LAC               1518+047 * CODE : CD                   1524-136 * CODE : ADDS
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   28-APR-85     1571.16   148.65         26-APR-85    1833.06   135.65         12-FEB-86    5353.78   285.76
   24-SEP-85     1918.00   167.41         24-SEP-85    2543.33   161.78         18-MAY-86    6060.00   319.08
   12-FEB-86     2473.00   199.92         12-FEB-86    1782.90   133.97         23-AUG-86    5398.89   287.87
   18-MAY-86     2025.67   173.51         18-MAY-86    1937.92   139.24         23-DEC-86    5526.00   293.84
   23-AUG-86     2064.17   175.72         23-AUG-86    1793.33   134.31         26-SEP-87    6023.75   317.35
   24-DEC-86     1900.34   166.42         22-DEC-86    2060.97   143.59         10-JAN-88    5822.78   307.83
   20-MAR-87     1859.44   164.14         29-SEP-87    1902.02   138.00
   29-SEP-87     1521.07   146.07         10-JAN-88    1650.00   129.64
   10-JAN-88     1964.17   170.01

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      1538+149 * CODE : BL LAC
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   28-APR-85       2184.58    148.09
   28-SEP-85       2818.89    172.82
   12-FEB-86       2628.67    165.15
   23-AUG-86       2558.75    162.38
   24-DEC-86       2657.52    166.30
   27-MAR-87       2410.95    156.63
   29-SEP-87       2396.90    156.09
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      1546+027 * CODE : HPQ
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   28-APR-85        417.50    102.16
   12-FEB-86        367.50    101.67
   18-MAY-86        461.43    102.63
   22-AUG-86        644.44    105.06
   26-DEC-86        569.44    103.97
   26-MAR-87        487.78    102.93
   29-SEP-87        562.20    103.88
   10-JAN-88        703.64    106.01
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      1607+268 * CODE : CD
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   28-APR-85       2050.24    174.92
   12-FEB-86       1767.50    159.08
   18-MAY-86       2216.67    184.60
   23-AUG-86       2424.44    196.98
   26-MAR-87       2130.24    179.54
   29-SEP-87       2227.40    185.23
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      1611+343 * CODE : LPQ
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   12-FEB-86       2040.00    174.33
   18-MAY-86       2277.92    188.22
   23-AUG-86       4210.00    311.20
   26-MAR-87       2831.67    222.01
   29-SEP-87       3668.37    275.57
   11-JAN-88       4203.33    310.76

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      1730-130 * CODE : LPQ
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   11-MAY-85      6461.67      338.21
   14-FEB-86      4656.67      253.40
   22-AUG-86      5916.84      312.29
   26-MAR-87      6035.00      317.89
   29-SEP-87      5323.05      284.32

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      1741-038 * CODE : LPQ
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   22-AUG-86        816.33      108.01
   27-MAR-87        903.75      109.74
   29-SEP-87        830.28      108.27
   10-JAN-88        760.22      106.98

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     1748-253 * CODE : ADDS
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   27-MAR-87      815.56     115.15
   29-SEP-87      727.77     112.23
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      2050+364 * CODE : CD
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   3-MAY-85     2585.00     206.74
   7-FEB-86     2224.52     185.06
  14-MAY-86     2195.83     183.37
  22-AUG-86     2551.67     204.70
  17-DEC-86     2438.33     197.82
  27-MAR-87     2650.83     210.79
  09-JAN-88     2344.52     192.18
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      2128-123 * CODE : LPQ
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  23-AUG-86     1447.50     123.44
  17-DEC-86     1212.67     116.95
  27-MAR-87     1427.78     122.87
  28-SEP-87     1302.84     119.35
   9-JAN-88     1466.11     123.99
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     2145+067 * CODE : ADDS
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   26-SEP-85     3277.77    191.99
   23-AUG-86     3756.67    212.79
   18-DEC-86     3197.14    188.56
   27-MAR-87     2672.08    166.88
   28-SEP-87     3272.08    191.75
   09-JAN-88     3340.00    194.65

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      2155-152 * CODE : BL LAC
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  22-APR-85     1744.71     132.70
  25-SEP-85     2008.20     141.71
  13-MAY-86     1582.22     127.51
  23-AUG-86     2413.33     156.72
  28-SEP-87     2043.00     142.95
  09-JAN-88     2162.22     147.27

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      2201+315 * CODE : LPQ
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   26-APR-85     1145.60     128.18
    3-MAY-85     1252.08     132.97
   11-FEB-86     1818.22     161.86
   14-MAY-86     1028.33     123.21
   22-AUG-86     2420.00     196.71
   26-MAR-87     1202.27     130.70
   28-SEP-87     1466.33     143.30

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      2223-052 * CODE : HPQ
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   22-APR-85     11501.85     583.72
   27-MAY-85     13587.50     686.70
   25-SEP-85     11733.33     595.13
   14-MAY-86     11041.67     561.07
   22-AUG-86     12827.78     649.14
   17-DEC-86     11316.67     574.60
   26-MAR-87     12585.71     637.18
   29-SEP-87     12988.34     657.07
   11-JAN-88     13240.00     669.51

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      2230+114 * CODE : HPQ
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   26-APR-85     6392.40     334.90
    3-MAY-85     8510.00     437.09
    7-FEB-86     6635.00     346.49
   14-MAY-86     7347.50     380.74
   22-AUG-86     7361.11     381.40
   18-DEC-86     7809.17     403.06
   26-MAR-87     5482.00     291.77
   28-SEP-87     6618.04     345.68
   11-JAN-88     6011.11     316.75

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      2251+158 * CODE : HPQ
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   25-APR-85     12449.00     630.43
    3-MAY-85     12458.33     630.89
   29-SEP-85     11541.33     585.67
   11-FEB-86     11338.86     575.69
   14-MAY-86      8557.13     439.39
   17-DEC-86     11194.44     568.58
   26-MAR-87     11544.44     585.82
   28-SEP-87     11799.90     598.41
   09-JAN-88     12472.96     631.61

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      2345-167 * CODE : HPQ
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   27-APR-85     2809.30     220.62
   11-FEB-86     2534.52     203.66
   16-MAY-86     2217.92     184.67
   22-AUG-86     2774.58     218.45
   17-DEC-86     1850.56     163.65
   26-MAR-87     2036.67     174.14
   28-SEP-87     2146.60     180.50
   09-JAN-88     2136.67     179.92

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0023-263 * CODE : CAL

28-APR-85	16887.50	1186.35
25-SEP-85	18962.00	1331.10

0134+329 * CODE : CAL

24-AUG-86	45462.50	3183.95
16-DEC-86	57775.00	4045.49
24-SEP-87	48125.00	3370.23
02-OCT-87	46843.75	3280.59
10-JAN-88	46075.00	3226.80

0218-021 * CODE : CAL

7-FEB-86	13154.16	665.27
24-AUG-86	12677.09	641.69
18-DEC-86	12759.72	645.78
09-JAN-88	13626.70	688.63

0350-073 * CODE : CAL

12-MAY-85	10247.53	522.04
28-SEP-85	11446.78	581.01
8-FEB-86	10875.33	552.89
24-AUG-86	9742.72	497.29
18-DEC-86	10471.03	533.02
27-MAR-87	10260.00	522.66
28-SEP-87	10945.83	556.35
10-JAN-88	10312.50	525.23

0358+004 * CODE : CAL

8-FEB-86	6257.98	328.49
24-AUG-86	5962.71	314.46
18-DEC-86	6122.69	322.05
27-MAR-87	6018.00	317.08
28-SEP-87	5925.00	312.67
10-JAN-88	5898.13	311.40

0406-180 * CODE : CAL

26-MAR-87	5772.92	416.29
28-SEP-87	5306.19	384.66
11-JAN-88	5685.00	410.32

0518+165 * CODE : CAL

14-MAY-85	21900.00	1536.26
27-SEP-85	18550.00	1302.34
22-AUG-86	17450.00	1225.59
19-DEC-86	17859.38	1254.15
28-SEP-87	19494.30	1368.26
11-JAN-88	19300.00	1354.70

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     0732+332 * CODE : CAL
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   9-FEB-86     6708.03   480.09
  16-MAY-86     6951.82   496.80
  22-AUG-86     6167.22   443.14
  17-DEC-86     6567.50   470.48
  29-SEP-87     7249.59   517.23
  10-JAN-88     7168.75   511.68
```

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------------------------------------
      0741-063 * CODE : CAL
------------------------------------

  15-MAY-85    10745.46   546.50
  26-SEP-85     9879.15   503.98
   9-FEB-86    10181.67   518.81
  16-MAY-86    10418.75   530.45
  26-MAR-87     9379.17   479.50
  10-JAN-88    10195.00   519.47
```

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-----------------------------------
      0758+143 * CODE : CAL
-----------------------------------

  26-SEP-85     9137.50   467.69
   9-FEB-86    10040.16   511.87
  14-MAY-86    10280.72   523.67
  22-AUG-86     9515.38   486.16
  19-DEC-86     9698.41   495.12
  05-OCT-87    10422.22   530.62
  10-JAN-88     9325.00   476.85
```

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-----------------------------------
     0855+280 * CODE : CAL
-----------------------------------

  15-MAY-85     9180.00   650.33
  30-SEP-85     8858.33   628.09
  26-MAR-87     7987.50   568.00
  29-SEP-87     8134.00   578.09
  08-JAN-88     7160.00   511.08

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```

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------------------------------------
      1140+223 * CODE : CAL
------------------------------------

  25-APR-85    12140.00   855.66
  25-APR-85    11222.22   791.89
   7-FEB-86    12429.17   875.77
  14-MAY-86    11385.71   803.25
  18-DEC-86    11671.43   823.10
  20-MAR-87    11908.33   839.56
  08-JAN-88    11100.00   783.41

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-----------------------------------
      1239-044 * CODE : CAL
-----------------------------------

  25-APR-85    10868.30   552.54
   7-FEB-86    10687.50   543.65
  14-MAY-86    10566.07   537.68
  22-AUG-86    10441.67   531.57
  20-MAR-87    11890.00   602.85
  08-JAN-88    11664.29   591.73

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```

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-----------------------------------
      1328+307 * CODE : CAL
-----------------------------------

   7-FEB-86    30292.86  2122.86
  16-MAY-86    26999.37  1892.60
  22-AUG-86    25675.00  1800.03
  29-SEP-87    29901.79  2095.51
  08-JAN-88    26433.33  1853.03
```

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-----------------------------------
      1416+067 * CODE : CAL
-----------------------------------

  12-FEB-86    30061.11   1506.38
  16-MAY-86    27446.33   1375.96
  22-AUG-86    29431.25   1474.96
  25-DEC-86    29341.28   1470.47
  20-MAR-87    28268.75   1416.97
  29-SEP-87    30695.50   1538.03
  10-JAN-88    28130.00   1410.05
```

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-----------------------------------
      1436-167 * CODE : CAL
-----------------------------------

  28-APR-85     5325.00    385.93
  24-SEP-85     6455.00    462.78
  12-FEB-86     6137.01    441.08
  15-MAY-86     4474.38    328.78
  22-AUG-86     5743.18    414.27
  25-DEC-86     5670.31    409.32
  24-MAR-87     5756.83    415.20
  29-SEP-87     5246.00    380.59
  10-JAN-88     6116.43    439.67
```

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-----------------------------------
      1517+204 * CODE : CAL
-----------------------------------

  12-FEB-86     9390.00    664.86
  23-AUG-86     9295.00    658.29
  21-DEC-86     8759.77    621.28
  20-MAR-87     8013.50    569.79
  29-SEP-87     8826.60    625.90
  10-JAN-88     9050.00    641.34

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```

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-----------------------------------
      1547+309 * CODE : CAL
-----------------------------------

  12-FEB-86     5130.00    372.76
  18-MAY-86     5305.42    384.61
  22-AUG-86     5390.00    390.33
  26-DEC-86     5829.44    420.14
  26-MAR-87     5515.45    398.82
  29-SEP-87     5395.60    390.71
  10-JAN-88     5455.33    394.75

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      1643+022 * CODE : CAL
-----------------------------------

  14-FEB-86     6344.00    332.59
  23-AUG-86     6413.33    335.90
  26-MAR-87     6681.67    348.73
  30-SEP-87     6356.80    333.20

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```

1756+134 * CODE : CAL

14-FEB-86	6597.50	344.70
18-MAY-86	7209.50	374.09
22-AUG-86	6219.38	326.65
27-MAR-87	6741.25	351.58
29-SEP-87	6271.25	329.12
10-JAN-88	5491.67	292.23

1828+487 * CODE : CAL

14-FEB-86	37472.00	2624.95
18-MAY-86	41498.97	2906.65
22-AUG-86	41783.33	2926.54
17-DEC-86	41216.67	2886.90
26-MAR-87	34150.00	2392.59
10-JAN-88	28050.00	1966.04

2244+366 * CODE : CAL

11-FEB-86	5437.23	393.52
13-MAY-86	5263.00	381.74
23-AUG-86	5837.78	420.70
26-MAR-87	5078.89	369.32
28-SEP-87	5524.16	399.41
11-JAN-88	5478.89	396.35

2252+129 * CODE : CAL

7-FEB-86	9216.67	471.56
13-MAY-86	7918.12	408.34
23-AUG-86	8310.53	427.39
26-MAR-87	8155.00	419.83
29-SEP-87	8672.25	444.99
09-JAN-88	8162.50	420.20

2314+038 * CODE : CAL

29-APR-85	17740.11	892.62
3-MAY-85	19950.00	1002.50
29-SEP-85	18381.25	924.49
7-FEB-86	17822.22	896.70
16-MAY-86	15585.00	785.64
23-AUG-86	18785.71	944.59
27-SEP-87	18395.80	925.21
09-JAN-88	17191.67	865.38

2338+042 * CODE : CAL

14-FEB-86	5703.53	302.20
22-AUG-86	5777.50	305.69
28-SEP-87	5823.90	307.89
09-JAN-88	5876.88	310.39

```
-----------------------------------
    0300+107 * CODE : NONV
-----------------------------------

  3-APR-87        840.42   108.47
 27-SEP-87        584.50   104.18
 09-JAN-88        777.78   107.30

-----------------------------------
    0359+055 * CODE : NONV
-----------------------------------

 27-MAR-87       2343.33   154.04
 02-OCT-87       1783.33   133.98
 10-JAN-88       2007.78   141.70

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-----------------------------------
    0325+180 * CODE : NONV
-----------------------------------

 31-MAR-87       1514.00   145.71
 27-SEP-87       1459.81   142.98
 09-JAN-88       1586.67   149.45

-----------------------------------
    0432+034 * CODE : NONV
-----------------------------------

 26-MAR-87       2062.65   143.65
 28-SEP-87       2261.16   150.94

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    0357+035 * CODE : NONV
-----------------------------------

 27-MAR-87       1043.89   112.80
 28-SEP-87        995.67   111.71
 10-JAN-88        826.67   108.21

-----------------------------------
    0532+100 * CODE : NONV
-----------------------------------

 26-MAR-87       2688.89   167.56
 28-SEP-87       2696.87   167.88
 11-JAN-88       3050.00   182.36

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     0718+132 * CODE : NONV                        0840+184 * CODE : NONV                     0855+176 * CODE : NONV
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   26-MAR-87     1239.44   117.65           26-MAR-87     1527.22   146.39            26-MAR-87     1499.52   144.98
   29-SEP-87     1361.33   120.97           29-SEP-87     1771.66   159.31            26-SEP-87     1762.22   158.80
   10-JAN-88     1430.00   122.93           08-JAN-88     1590.40   149.65            03-OCT-87     1895.00   166.12

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     0909+165 * CODE : NONV                        0940+029 * CODE : NONV
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   26-MAR-87     4899.17   357.22           28-MAR-87     2988.33   179.79
   05-OCT-87     5170.00   375.46           05-OCT-87     2840.00   173.68
   08-JAN-88     4598.33   337.06           05-OCT-87     2945.00   178.00

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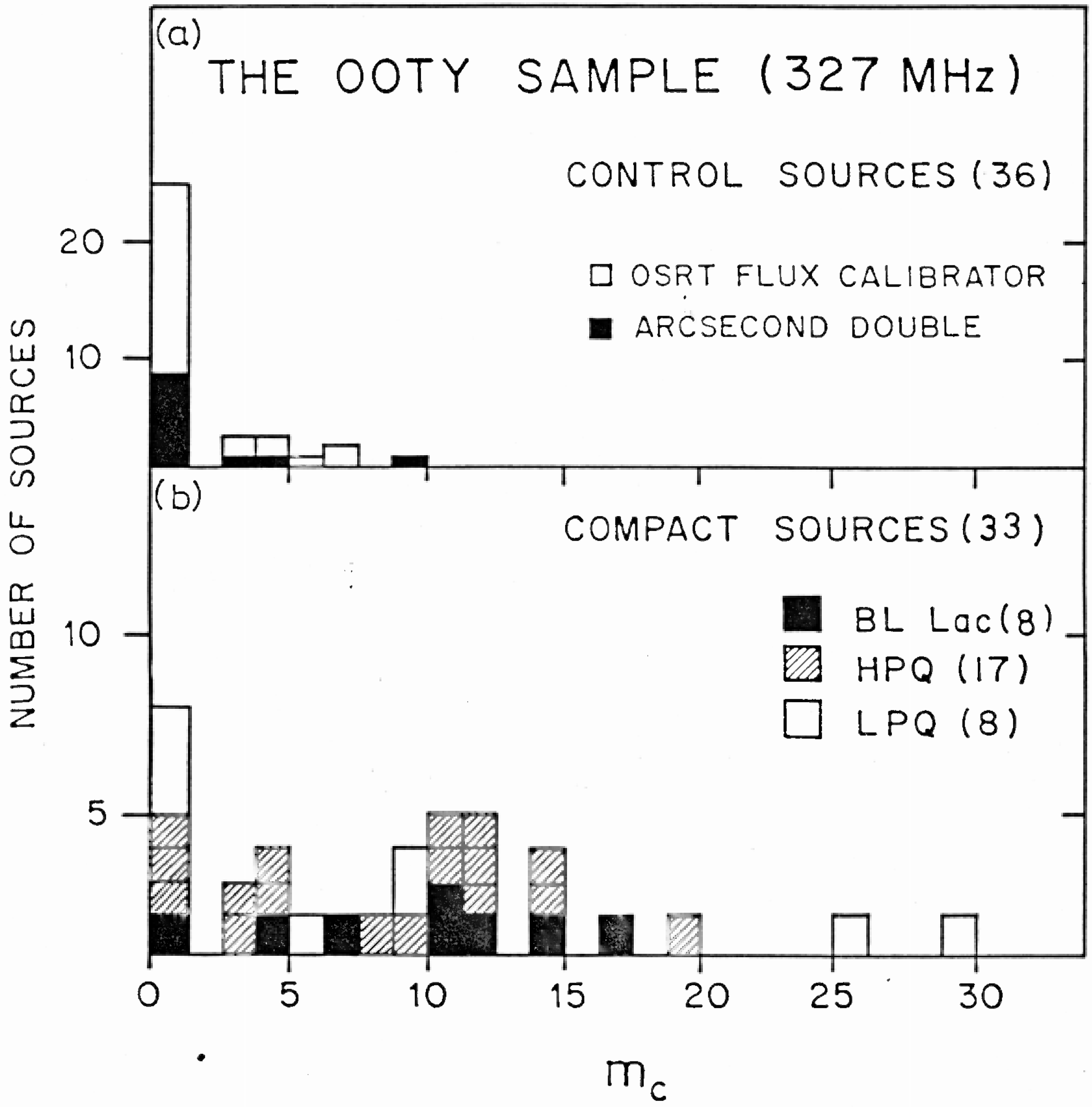

Fig. IV-1: a) The histogram of variability index at 327 MHz, (m_c), for 36 control sources.

b) As a for the sample of 33 compact radio sources consisting of BL Lacs and high and low-optical polarization quasars.

to variability indices of ~ 10% (part of this spread could be caused by the variability of compact hotspots due to propagation effects), the histogram for the compact source sample (Fig. IV-1b) extends to much greater values of m_c, and shows very similar median values (~ 10%) for each of the three optical types.

To illustrate this more clearly, in Fig. IV-2b we have plotted the fraction of sources in the Ooty sample with variability index less than a given m_c against m_c for the BL Lacs, HPQs and LPQs separately. From these normalised integral variability counts, it is evident that the degrees of LFV shown by objects of the three types are indistinguishable, in contrast to some earlier claims (e.g. Moore and Stockman, 1984). The difference in these conclusions is probably due to a higher fraction of steep-spectrum (i.e., extended) radio sources being included among the LPQs in the earlier samples. In fact, the maximum LFV in the Ooty sample is associated with the LPQs, 1611+343 and 2201+315 (Fig. IV-1b). The low optical polarization of 2201+315 ($P < 3\%$) has been confirmed by repeated observations during 1986-88, carried out by Drs.P.Smith, D.Wills and B.Wills (Prof.P.J.Wiita, Private Communication).

The variability indices (m_c) at 327 MHz for the three CDs are found to be 4%, 11% and 2%, placing them in the lower half of the variability range spanned by the LPQs, HPQs and BL Lacs at this frequency (Fig. IV-1b). However, this trend needs to be confirmed by monitoring a larger sample of CDs for LFV.

The Bologna and Arecibo samples: We have attempted to compare our results with other low-frequency monitoring programmes and have plotted normalised integral variability counts for sources selected from two other samples monitored at 318 and 408 MHz at Arecibo and Bologna, respectively (Table IV-3, Figs. IV-2a and c). Our basic criteria for selecting sources from these samples are listed in the footnote to Table IV-3. From the Bologna sample we included all quasars and BL-Lac objects in Table 2 of Fanti et al. (1981) whose radio spectra are flat or inverted (Kuhr et al., 1981a; Kuhr et al. 1981b), provided that the optical type could be established from published data (Moore and Stockman, 1981, 1984; Stockman, Moore and Angel, 1984; Ledden and O'Dell, 1985; Ve'ron-Cetty and Ve'ron, 1985; Impey and Tapia, 1988; Fugmann, Meisenheimer and Roser, 1988; Hewitt and Burbidge, 1989). Similarly, only the objects designated as flat/inverted-spectrum sources were selected from the Arecibo sample and classified optically. Other low-frequency samples could not be used as either the published information was not adequate for computing the variability index ($m = \sigma_S/\overline{S}$) or the optical type could not be established for a minimum of ten sources among the flat-spectrum subsets. Recently, Slee and Siegman (1988) have reported a survey of intensity variations at 80 and 160 MHz for a large sample of 412 radio sources. However, optical classification was possible for only 20 of their flat-spectrum sources, 14 of which they classified as non-variable, leading to unacceptably small numbers of variable sources in the different optical classes.

As with the Ooty sample (Fig. IV-2b), it is seen from Figs. IV-2a and c that the integral LFV profiles for the three optical types almost overlap, the possible exception being the BL Lacs in the Arecibo sample for which LFV may be somewhat higher, as discussed below.

4.3.2 Flux-density variations at high frequencies (HFV)

In order to perform a similar analysis for variability surveys above 1 GHz, optical classifications were established using the literature listed above for as many compact (flat-spectrum) sources as possible in six samples monitored for HFV between 2.7 and 90 GHz. Information on the

Table IV-2: The Ooty sample of compact extragalactic radio sources *

Source	Opt type	-Z-	S_{327} (Jy)	α_{327}^{1465}	m %^{c}	ℓ^{II} deg	b^{II} deg
0048-097	BL		0.85	-0.02	0.0	122.3	-72.4
0122-003	LPQ	1.070	1.02	-0.03	5.9	141.2	-61.8
0235+164	BL	0.851	1.10	-0.38	17.2	156.8	-39.1
0336-019	HPQ	0.852	1.31	-0.35	14.6	188.0	-42.5
0420-014	HPQ	0.915	0.96	-0.10	0.0	195.3	-33.1
0458-020	HPQ	2.286	2.35	0.05	3.2	201.5	-25.3
0605-085	HPQ		2.81	-0.03	11.1	215.8	-13.5
0735+178	BL		1.92	-0.09	10.1	201.9	18.1
0736+017	HPQ	0.191	1.69	-0.32	0.0	216.9	11.4
0738+313	LPQ	0.630	1.63	-0.14	0.0	188.6	23.6
0851+202	BL	0.306	1.08	-0.31	7.0	206.8	35.8
0906+015	HPQ	1.012	0.82	0.01	12.3	226.9	30.9
1038+064	LPQ	1.27	1.36	-0.06	9.5	241.1	52.7
1055+018	HPQ	0.888	4.50	0.27	0.0	251.5	52.8
1156+295	HPQ	0.729	3.23	0.37	19.6	199.4	78.4
1219+285	BL	0.103	1.45	-0.15	12.4	201.7	83.3
1253-055	HPQ	0.536	14.31	0.50	10.5	305.1	57.1
1502+106	HPQ	1.833	0.89	-0.35	3.2	11.4	54.6
1504-166	HPQ	0.876	1.34	-0.29	14.6	343.6	35.1
1510-089	HPQ	0.361	2.46	0.03	8.7	351.3	40.1
1514-241	BL	0.049	1.92	-0.11	10.6	340.7	27.6
1538+149	BL		2.51	0.35	3.8	24.3	48.8
1546+027	HPQ	0.412	0.53	-0.43	5.0	10.9	40.9
1611+343	LPQ	1.404	3.21	0.13	26.2	55.2	46.4
1730-130	LPQ	0.902	5.68	0.17	9.7	12.0	10.8
1741-038	LPQ	1.058	0.83	-0.41	0.0	21.6	13.2
2128-123	LPQ	0.501	1.37	0.02	0.0	40.5	-40.9
2155-152	BL		1.99	0.47	14.1	40.6	-48.0
2201+315	LPQ	0.298	1.48	-0.00	29.2	86.0	-18.8
2223-052	HPQ	1.404	12.31	0.50	5.0	59.0	-49.0
2230+114	HPQ	1.037	6.91	0.07	11.7	77.4	-38.6
2251+158	HPQ	0.859	11.48	0.15	8.5	86.1	-38.2
2345-167	HPQ	0.600	2.31	0.14	11.6	65.5	-71.9

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* Spectral index, α, is defined as $S_\nu \propto \nu^{-\alpha}$ and refers to the frequency range 327 to 1465 MHz. The flux densities at 327 MHz are averages of the Ooty measurements and those at 1465 MHz are adopted from the VLA measurements by Perley (1982).

Table IV-3: Parameters of the flux-density variability samples

Original Sample+ (size)	Telescope used for monitoring	Freq. (GHz)	Beam-width	Total span of observations (year)	Monitoring interval (Approx.)	Subset selected by us *
[1]ARECIBO (188)	Arecibo	0.318	16'	8	8 years (2 epochs only)	BL Lac: 11 HPQ : 16 LPQ : 12
[2]OOTY (33)	OSRT	0.327	40"X7'	3	3 months	BL Lac: 8 HPQ : 17 LPQ : 8
[3]BOLOGNA (114)	Bologna Cross	0.408	4'X100'	5	1 month	BL Lac: 5 HPQ : 12 LPQ : 14
[4]NRAO (365)	NRAO 91-m	2.7	4'.7	2	3 months	BL Lac: 18 HPQ : 22 LPQ : 18
[5]MICHIGAN (97)	Univ.of Michigan 26-m	8.0	5'	10,20	1 month	BL Lac: 31(27 HPQ : 16(11 LPQ : 15(12
[6]GBI 1 (82)	Green-Bank Interferometer	2.7 8.1	9" 3"	4	3 months	BL Lac: 9(9) HPQ : 19(12 LPQ : 20(17)
[7]GBI 2 (29)	Green-Bank Interferometer	2.7 8.1	9" 3"	6	1 day	BL Lac: 6(5) HPQ : 5(3) LPQ : 6(6)
[8]OVRO (176)	OVRO 40-m	20.0	1'.5	1	1 year (2 epochs only)	BL Lac: 25(22 HPQ : 23(18 LPQ : 24(16
[9]IRAM (294)	IRAM 30-m	90.0	30"	2	1 month	BL Lac: 27(24 HPQ : 23(19 LPQ : 12(10

+ Sample references

(1) Condon et al., 1979; Dennison et al., 1981
(2) Ghosh et al., 1989
(3) Fanti et al., 1981
(4) Kesteven, Bridle and Brandie, 1977
(5) Aller et al., 1985
(6) Altschuler and Wardle, 1976
(7) Fiedler et al., 1987
(8) Edelson, 1987
(9) Steppe et al., 1988

* Selection criteria: (i) The degree of optical polarization known from literature, except for BL Lacs; (ii) flat spectrum at decimetre/centimetre wavelengths, either known or inferred from compact radio size (< 0".5) or high radio-frequency flux variations. The source 3C273 has been excluded from all the samples in view of the recent detection of a blazar component in this LPQ (Courvoisier et al., 1988). The numbers inside the brackets refer to sources with spectral index flatter than 0.2 (see text).

time spans of observation and monitoring intervals for the various samples is summarised in Table IV-3, together with the beamwidths for the respective observations. Table IV-4 presents a comprehensive list of all the sources belonging to the three optical categories chosen from the various samples and their corresponding variability indices. For these subsets of sources from each sample, the computed integral variability counts are shown in Figs. IV-2d to k with different filled symbols for the three optical types. Smooth curves have been drawn through the sets of symbols to depict the trends. In contrast to the situation at low frequencies, these profiles consistently show different levels of HFV for different optical types. The variability index shows a systematic trend over the entire frequency range, being largest for BL-Lac objects and smallest for LPQs. Further, HPQs exhibit distinctly less variability than BL Lacs. However, the exact magnitude of the separation between the profiles for the three optical types depends on several factors, such as the sampling rate as compared to the inherent time-scales of the variability. Other factors are the angular resolution of the telescope used and the flux-density measurement error, the increase of which would lead to an overestimation of m. On the other hand, substantial time-averaging of flux densities would cause an underestimation of m. Thus a direct comparision of the observed dependence of variability on the optical classification among different samples is not very meaningful and only the trends within the individual samples can be considered. These show distinctly different behaviour at low and high frequencies.

In order to decide the statistical significance of these trends, we have employed the Kruskal-Wallis one-way analysis of variance by rank test (Siegal and Castellan, 1988) to all the samples considered here. We present the results of this test in Table IV-5. For each sample, we list

TABLE IV-4: MULTIFREQUENCY VARIABILITY PARAMETERS OF BL LACs, HPQs AND LPQs

	SOURCE	NAME	- Z -	VARIABILITY PARAMETERS in different monitoring programs at various frequencies (GHz)										
				Arecibo	Ooty	Bologna	GBI 1		GBI 2		NRAO	Michign	OVRO	I R A M
				0.318	0.327	0.408	2.7	8.1	2.7	8.1	2.7	8	20	90
B L L A C :														
1.	0003-066													1.5
2.	0048-097				0.00		11.0	20.0			7.2	22.2		36.0
3.	0119+115			13.7							<2.0			20.0
4.	0133+476	DA 55					28.0	26.0	7.9	0.4	12.8	15.2	24.0	15.0
5.	0215+015		1.649									22.2		
6.	0219+428	3C 66A										7.6		
7.	0235+164		0.851	32.6	17.15		32.0	46.0	37.5	45.0	21.6	30.0	64.0	41.0
8.	0256+075			64.5							4.8			
9.	0300+470						17.0	21.0				7.6		
10.	0306+102											10.6		
11.	0316+413	3C 84	0.017			0.33					12.8			
12.	0422+005			59.2		4.67					11.6	19.0		
13.	0422+124					0.00								
14.	0426-380													37.0
15.	0454-234												55.0	54.0
16.	0454+844													24.0
17.	0511-220												7.0	6.0
18.	0716+714												36.0	35.0
19.	0735+178			32.6	10.09	<2.33	10.6	24.3			2.8	8.0	49.0	11.0
20.	0743-066										<1.2		2.0	
21.	0754+100											24.0	45.0	
22.	0808+019										13.2	22.6	34.0	
23.	0814+425										5.2		13.0	15.0
24.	0818-128											14.0	5.0	
25.	0820+225			14.6							12.0			6.0

26.	0828+493										5.6		51.0	44.0
27.	0829+046										<2.8	18.6		
28.	0851+202	OJ 287	0.306	30.1	6.98		15.0	23.0	19.9	26.5	10.0	23.2	25.0	33.0
29.	1034-293											12.6	35.0	21.0
30.	1101+384	MK 421	0.031			<4.00						8.6		
31.	1147+245			8.1								8.0		
32.	1219+285		0.103		12.40		19.0	19.0				8.4	9.0	
33.	1308+326		0.996	0.7								11.0	88.0	60.0
34.	1400+162		0.244											
35.	1418+546												63.0	19.0
36.	1514-241	AP LIB	0.049		10.55		9.6	23.0				10.6	7.0	
37.	1538+149	4C 14.60		4.3	3.80							10.2	17.0	3.0
38.	1652+398	MK 501	0.034									5.4		19.0
39.	1727+502	IZW 187	0.055									16.0		
40.	1732+389													66.0
41.	1749+096	4C +09.57		0.7			16.0	34.0	25.1	43.6	7.6	19.2		22.0
42.	1749+701								15.9	19.9		15.6		22.0
43.	1803+784											10.0	25.0	17.0
44.	1807+698		0.051										31.0	14.0
45.	1823+568											6.4	2.0	
46.	2007+777											11.4	10.0	19.0
47.	2131-021		0.557								8.8	17.2	1.0	
48.	2155-152				14.08							17.6	22.0	
49.	2200+420	BL LAC	0.070			12.33	29.0	35.0	40.8	57.2	0.148	29.0	38.0	34.0

HPQ:

1.	0106+013		2.107	4.0			20.0	17.0			12.8	7.8		
2.	0229+132			11.2									20.0	
3.	0336-019	CTA 26	0.852	22.5	14.60		17.0	22.0	14.7	15.4	9.2	13.4	4.0	19.6
4.	0420-014		0.915	32.5	0.00		6.9	8.5	4.4	13.8	6.4	18.0	20.0	15.0
5.	0440-003	NRAO 190	0.844	3.5			8.6	13.0			6.8			
6.	0458-020		2.286		3.18		9.0	20.0			2.0		0.0	9.0
7.	0605-085				11.06	4.00	8.3	12.5			4.4	9.2	4.0	14.0
8.	0736+017		0.191	8.3	0.00	7.67	8.1	10.1			4.0	17.6	30.0	18.0
9.	0823-223													26.0

10.	0906+015		1.012	8.8	12.32						5.6		9.0	
11.	1055+018	4C 01.28	0.888	10.0	0.00	4.00	4.2	7.0			1.6	6.4	6.0	3.0
12.	1156+295	4C 29.45	0.729		19.60	4.00					3.6	10.2	43.0	11.0
13.	1244-255		0.633										62.0	43.0
14.	1253-055	3C 279	0.536		10.50	3.60					2.8	10.60	14.0	14.0
15.	1335-127		0.541									10.60		
16.	1502+106		1.833	8.8	3.21		6.0	13.0	10.7	24.1	2.8		17.0	11.0
17.	1504-166		0.876		14.60	7.67	3.0	6.0				3.80	10.0	
18.	1510-089		0.361		8.65	10.33	22.0	29.0			12.8	24.80	3.0	45.0
19.	1532+016			13.9							1.6			
20.	1546+027		0.412	27.4	4.97						3.2		33.0	17.0
21.	1548+056			21.7							3.2		4.0	
22.	1633+382	4C 38.41	1.814			<1.67	6.0	20.0						7.0
23.	1641+399	3C 345	0.594		3.67		6.0	6.0	13.8	19.6	8.8	18.60	3.0	9.0
24.	1921-293	OV 236	0.352				7.0	11.0				20.00		19.0
25.	2145+067		0.990	11.9							1.6		14.0	19.0
26.	2155-152						14.0	10.0						
27.	2223-052	3C 446	1.404		4.97	1.67	4.0	12.0			2.8	18.40	27.0	21.0
28.	2230+114	CTA 102	1.037	15.6	11.70	1.67	2.0	8.0			1.2	7.80	4.0	14.0
29.	2234+282		0.795	21.0							7.2		38.0	4.0
30.	2243-123		0.630											21.0
31.	2251+158	3C 454.3	0.859	14.0	8.50	8.67	3.0	15.0	17.7	30.4	3.2	21.20	30.0	12.0
32.	2345-167		0.600		11.60		6.0	10.0					33.0	26.0

LPQ:

1.	0007+106	III ZW2										36.2		
2.	0056-001	DA 032	0.717	9.0		<1.67					<1.2			
3.	0122-003		1.070	4.7	5.90						5.2			
4.	0202+319			23.0									16.0	
5.	0333+321	NRAO 140	1.253	31.4		6.33	5.0	7.0	7.9	9.4	2.0	10.0	6.0	
6.	0405-123		0.574			<1.67								
7.	0528+134												5.0	
8.	0642+449		3.402				6.4	6.6			4.0		4.0	15.0
9.	0727-115												20.0	
10.	0738+313		0.630	15.5	0.00	6.67	4.4	5.4			2.4	11.8		

11. 0834-201					4.00	9.3	9.6				20.8		
12. 0859-140		1.327			6.00	2.0	5.6				5.2	8.0	
13. 0923+392	4C 39.25	0.699			<1.67	2.0	5.0	1.3	3.3	<0.4	15.0	16.0	13.0
14. 0953+254		0.712	5.2			6.0	8.0			2.8			
15. 0954+556		0.901				1.3	3.0			0.8	4.4		
16. 0955+327												10.0	
17. 1038+064				9.47									
18. 1049+215			4.1										
19. 1127-145		1.187			4.00	4.0	8.0				16.0	6.0	
20. 1148-001		1.982	2.8		4.67	3.0	4.0			0.8	5.8	6.0	
21. 1252+119												1.0	
22. 1302-102		0.286										10.0	4.0
23. 1334-127						9.0	18.0					11.0	
24. 1354+195	4C 19.44	0.720				9.5	13.0			4.4		10.0	19.0
25. 1548+056	4C 05.64					7.0	4.0						11.0
26. 1555+001	DA 393	1.770				10.0	17.0	13.1	11.8	6.0			
27. 1611+343	DA 406	1.404	30.0	26.15	9.67	3.0	7.0	2.4	4.3	<0.8	4.2	20.0	
28. 1633+382		1.814									17.2		
29. 1656+053		0.879				4.0	10.0			<0.8	21.0		
30. 1730-130	NRAO 530			9.70	1.67	7.0	8.0				13.4	24.0	14.0
31. 1741-038				0.00		10.0	12.0	9.5	3.8	9.2		69.0	5.0
32. 1928+738												4.0	
33. 1954+513		1.230										14.0	4.0
34. 2128-123		0.501		0.00								17.0	15.0
35. 2134+004		1.936			<4.00	2.0	7.0	1.8	4.6		7.2	8.0	
36. 2136+141			3.6										
37. 2201+315		0.298	27.1	29.15						5.6	21.0		8.0
38. 2203-188												2.0	8.0
39. 2216-038		0.901				6.0	9.0			5.2		11.0	23.0
40. 2223+210		1.959			<1.67					1.6			
41. 2344+092	4C 09.44	0.677	6.4		<1.67					1.2		8.0	

the calculated value of the H-statistics used in the test, and the corresponding probability of the null hypothesis, p(Ho), that the three subsamples (i.e., HPQs, LPQs and BL Lacs) come from the same population. It is evident that this null hypothesis can be rejected for all the high-frequency samples, with the exception of the Michigan sample; with high level of significance. In contrast, the low frequency samples show fair chances that the corresponding sub-samples are drawn from the same population in regard to their variability properties.

4.4 DISCUSSION

Figs. IV-2a to c show that the integral variability counts between 318 and 408 MHz for BL Lacs, HPQs and LPQs virtually overlap and are statistically indistinguishable (Table IV-5). If the spectroscopic and polarimetric classification of compact extragalactic sources into the three types means that they are either geometrically different, or represent different evolutionary stages, these properties clearly do not strongly influence their LFV on the time scale of several months. This is in contrast to their HFV (Figs. IV- 2d - k). Therefore, such "short-term" LFV is likely to arise extrinsically, probably from propagation effects in the interstellar medium (Section 1). On the other hand, HFV over similar time-scales appears to be predominantly intrinsic, although rapid HFV over time-scales of hours to days (flickering) may well arise from refractive scintillations in the ISM (Heeschen et al., 1987; Quirrenbach et al., 1989).

In the Arecibo and Bologna samples (Figs. IV-2a and c) there is a slight tendency for the integral variability counts of the three optical types to separate out in the same way as at high frequencies. Although these trends are not statistically highly significant (Table IV-5), they

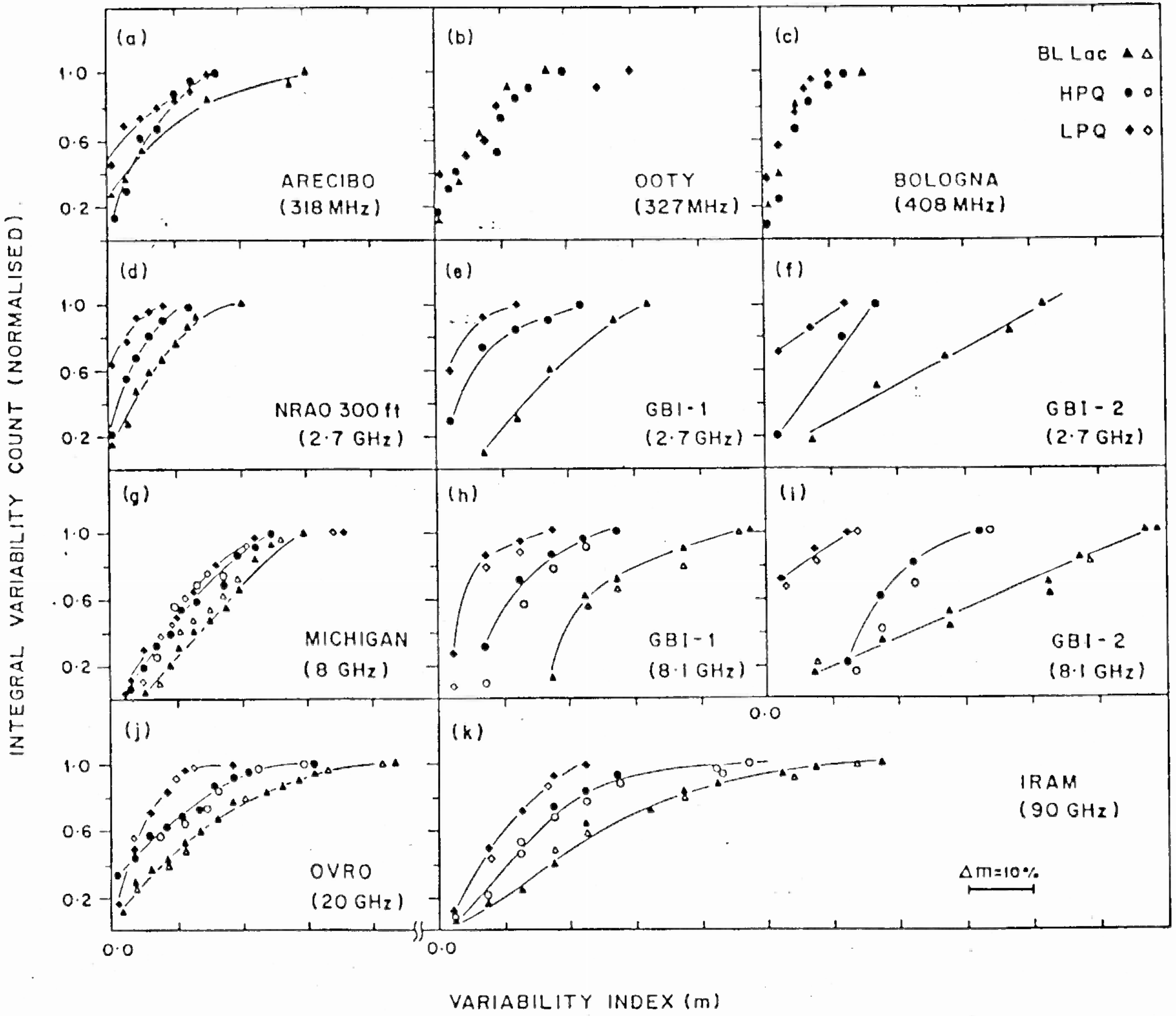

Fig. IV-2,a-k: Integral variability counts are plotted for samples of compact radio sources monitored at seven frequencies. The open symbols refer to the subsamples derived by excluding sources with spectral index(α) steeper than 0.2.

Table IV-5:Kruskal-Wallis test

Sample	Freq. (GHz)	The value of H-statistics	Probability $p(H_o)$
ARECIBO	0.318	4.078	0.12
OOTY	0.327	0.473	0.82
BOLOGNA	0.408	3.18	0.22
NRAO	2.7	21.65	<< 0.001
MICHIGAN	8.1	2.9	0.24
GBI 1	2.7	23.6	<< 0.001
	8.1	30.2	<< 0.001
GBI 2	2.7	11.0	0.004
	8.1	8.09	0.017
OVRO	20	8.66	0.013
IRAM	90	11.8	0.0027

could indicate that intrinsic variations contribute to long-term LFV ($\tau \gg 1$yr), since the total monitoring spans for those two samples were considerably longer (Table IV-3) than the 3-year monitoring programme at Ooty. The presence of long-term intrinsic LFV has also been suggested by Fanti et al. (1987) and Spangler et al. (1989). The latter authors have published values of m for long-term variability ($\tau > 1$-2 yr) for some sources of the Bologna sample. Of these sources, five could be classified as LPQs, six as HPQs and one as a BL-Lac object. This small sample also appears to conform to the above statistical trend for HPQs to show higher long-term LFV compared with LPQs.

However, the above observational result does not, per se, exclude the possibility of intrinsic effects also contributing to the "short-term" LFV. For instance, it has been suggested that the continuum emission from quasars is a mixture of a highly compact, anisotropic component showing rapid, strong photometric/polarimetric variability and a less variable, quasi-isotropic, weakly-polarized component (e.g., Malkan and Moore, 1986; Impey, 1987). It is conceivable that at low frequencies the latter component alone remains important in all three types of objects, causing the observed similarity between their integral LFV counts (Fig. IV-2a to c). However, if the radio emission has an incoherent synchrotron origin, this hypothesis implies anisotropic emission at metre wavelengths characterised by highly-relativistic bulk motion of the emitting plasma (Chapter II). The required values of Doppler factors in this case can often be very large ($\gamma \approx 50$-100; Singal and Gopal-Krishna, 1985).

The systematic difference found between the degrees of HFV for BL Lacs and HPQs (Figs. IV-2d to k) has important implications for the

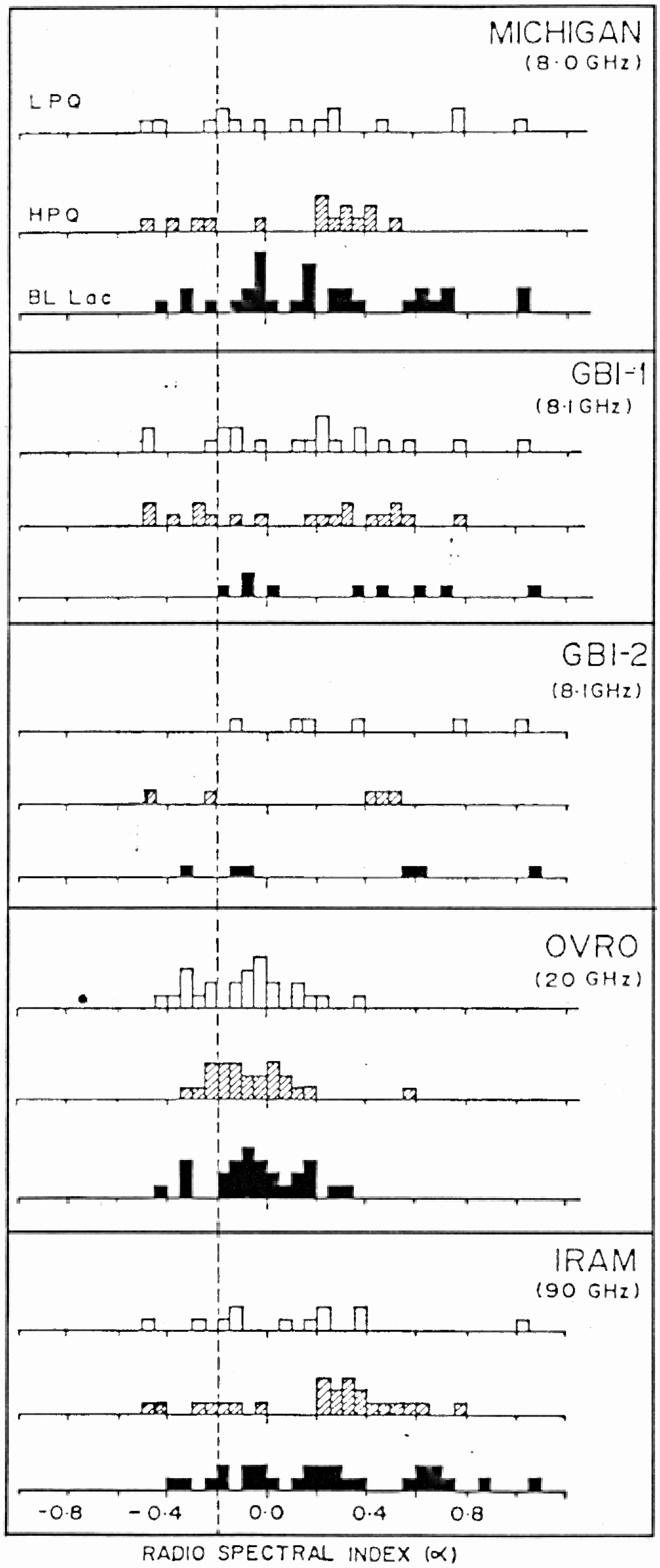

Fig. IV-3: Spectral index distributions for BL Lacs, HPQs and LPQs belonging to five samples of compact radio sources monitored at frequencies of 8 GHz and higher (Table 3; Fig.2g-k). The dotted line marks the spectral index 0.2.

schemes proposed for unifying these two groups of active galactic nuclei which are often included under the common classification of blazars. While both HPQs and BL Lacs are dominated by a nonthermal continuum and characterised by strong flat-spectrum radio emission, rapid photometric/polarimetric variability and a steep optical continuum, the BL-Lac classification applies to objects whose optical emission lines are weak or undetected (Angel and Stockman, 1980). Relativistic motions of nonthermally-emitting plasma at small angles to the line-of-sight have been invoked to explain the observations of superluminal motion, one-sided and bent radio jets, rapid variability and weak X-ray emission in these objects (Begelman, Blandford and Rees, 1984). The beamed optical continuum could swamp the emission lines in BL Lacs. However, unexpectedly, the Doppler factors inferred from VLBI sizes and X-ray luminosities seem to be larger for HPQs than for BL Lacs (Madau, Ghisellini and Persic, 1987).

The relativistic-beaming picture has also been employed to explore quantitatively the underlying connections between LPQs and blazars and thus estimate selection biases (e.g., Biermann et al., 1981; Impey and Tapia, 1988; Fugmann, 1988). It has been argued that flat-spectrum LPQs, HPQs and BL Lacs are not different types of objects but active and passive phases of the same type of objects. Thus, practically all strong ultra-flat spectrum radio sources ($\alpha < 0.2$) may be blazars if observed long enough (e.g., Fugmann, 1988). In this picture, the temporary transformation of a 'normal' quasar (LPQ) into a blazar begins with outbursts of relativistically-moving plasma from the nucleus, appearing as an intense, variable component of linearly-polarized synchrotron emission with a flat (self-absorbed) radio spectrum. The correlation of such activity with the flat radio spectrum and optical polarization is well established. We may enquire to what extent, if at all, these two observables are independent manifestations of the activity. To this end, we have recomputed the integral variability counts for the five samples monitored for HFV at 8 GHz and higher frequencies (Table IV-3), including only these sources with ultra-flat radio spectra ($\alpha < 0.2$). The spectral indices are defined in the range 1.4 to 5 GHz using data given either in the respective original papers, or in Kuhr et al., (1981a,b); Weiler and Johnston (1980); Perley (1982); Jones et al. (1981) and Gower and Hutchings (1984). The sources with $\alpha < 0.2$ have similar median values of spectral index and spectral-index distributions for the three optical groups in each sample (Fig. IV-3). From the integral variability counts, plotted for the ultra-flat spectrum sources with open symbols in Figs. IV-2g to k, it is found that the degrees of HFV for the three optical groups remain distinctly different, despite the similarity of their spectral-index distributions. We therefore conclude that optical polarization is strongly linked to HFV, independent of the flatness of their radio spectra.

Recently, another scheme has been proposed for unifying HPQs and BL Lacs. This invokes selective amplification of the nuclear optical continuum via gravitational micro-lensing by star-like objects along the line-of-sight (Ostriker and Vietri, 1985; Schneider and Weiss, 1987). To reconcile this proposition with the systematically different HFV found for HPQs and BL Lacs (Fig. IV-2) it would be necessary to demonstrate that the selective amplification process also encompases the physically-much-larger radio-emitting region but, at the same time, leaves the broad emission-line region essentially unaffected.