A SEARCH FOR VARIABLE RADIOSOURCES AT 1410 MHz

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RESUMEN. El presente trabajo informa sobre los primeros resultados obtenidos en la búsqueda de variabilidad, en 1410 MHz, de radiofuentes extragalácticas. Las observaciones abarcan algo más de un año y el programa contiene 80 fuentes. Se encontró variabilidad, que en un caso llega a sobrepasar el 100%, en un 4% de las fuentes observadas.

También comparamos nuestras mediciones con los valores publicados con anterioridad y esa comparación sugiere que el 60% de los objetos que hemos observado son, en realidad, variables.

ABSTRACT. The first results of a search for variability of extragalactic sources at 1410 MHz are reported. The observations cover more than a year of observations and the program contains 80 objects. Variability was found in 4% of the observed radiosources, the variation reaching over 100% in one case.

Our measurements are also compared with the values already published for our program radiosources and the comparison suggests that 60% of the objects are actually variable in flux density.

I. INTRODUCTION

The flux density measurements made by different investigators since 1965 have shown that almost all radiosources which are compact and have a flat spectrum ($|\alpha| \leq 0.5$), are variables. The variations are apparently not periodic and, in general, the amplitude of the variations increases with frequency. A possible interpretation of such variations is in terms of random explosions, the emission arising in a cloud of relativistic electrons which are partially opaque to their own radiation and move in an expanding magnetic field.

At low frequencies (λ < 20 cm) about 100 variable radiosources had been detected. At such frequencies the variations occur at larger intervals, the amplitude of the variations is smaller and there seems to exist no correlation with the variations at higher frequencies (Fanti *et al.* 1983).

With the purpose of contributing to the knowledge of flux variations, particularly in the southern sky, for which available data are very meager, we have started the systematic observations, in 1410 MHz, of some 80 radiosources with flux densities larger than 1 Jy, and spectral index $|\alpha| \leq 0.5$. We have included in the program all known BL Lacertae objects south of declination -10°.

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II. THE OBSERVATIONS

We have carried out the observations with the 30-m antenna of the Instituto Argentino de Radioastronomía. The central frequency was 1410 MHz and the bandwidth, 40 MHz. The receiver was operated on the Dicke system and was continuously calibrated with noise injection by a 6°6 K diode. The system temperature was 85°K.

At each observing session, each radiosource was observed three times in succession, and the scanning in right ascension was done with the speed of 2° per minute. The integration time for each observation was 8 seconds, approximately, and the minimum detectable temperature 13 mK.

In the present paper we will report on the observations that cover the interval June, 1982 - October, 1983.

Table 1 lists the sources which were used as standards, together with the adopted flux density for 1410 MHz, as given in Wills (1975) catalogue.

TABLE 1

The flux density in 1410 MHz of standard sources

NAME	S Jy
0043-42	8.14
0114-21	4.15
0408-65	15.75
0915-11	43.80
1938-15	7.17
1954-55	6.29
2211-17	9.39

III. THE REDUCTION OF THE OBSERVATIONS

The scale for the determination of the flux density was derived by plotting flux density of the standard sources against antenna temperature and by adjusting, by least squares, a straight line through the plot. The derived value was 8.41 Jy degree^{-1}.

The flux density for each radiosource was computed by taking the average of the results from the successive observations, subtracting a linear base and fitting the data to a Gaussian beam. Fig. 1 illustrates the Gaussian fitting in the cases of the four radiosources observed.

We estimate that the mean square error is yielded by the expression: $\pm \sqrt{(0.11)^2 + (3\%S)^2}$ Jy, where S is the flux density; the value 0.11 Jy is due to the receiver's noise and the term 3% S includes the error that arises from variations in the noise from the calibrating diode and the pointing error that amounts to 3', approximately. We did not detect variations in the antenna gain with either declination or hour angle.

To decide upon the variability of the radiosources we have followed the criterion used by several authors (i.e. Kesteven *et al.* 1976) who determine the quantity

$$x^2 = \sum_{1=1}^{n} (S_1 - \overline{S})^2 / \sigma_1^2 ,$$

where S is the weighted mean of the n average flux values and S_i and σ_i are the individual measures of the flux density and the standard deviation taht corresponds to a certain source. If w are dealing with random errors, x^2 has a distribution similar to that of χ^2 with n-1 degrees of freedom.

We consider that a source is variable if the probability of obtaining a value x^2 is smaller than 0.1%, and we consider that the source is not variable if such a probability is larger than 5%. If the probability is somewhere between 0.1% and 5%, then we decide that we are dealing with a possible variable. This kind of statistics does not detect slow long period variations since it does not consider any possible correlation of flux density with time.

The results obtained are presented in Table 2, where the different columns give, from first to seventh, the radiosource designations; Wills (1975) flux densities in 1410 MHz; flux densities in 1410 MHz from 1969 Parkes catalogue reduced to Wills (1975) scale; the averag flux density measured at the I.A.R. for those radiosources that did not vary during the interva

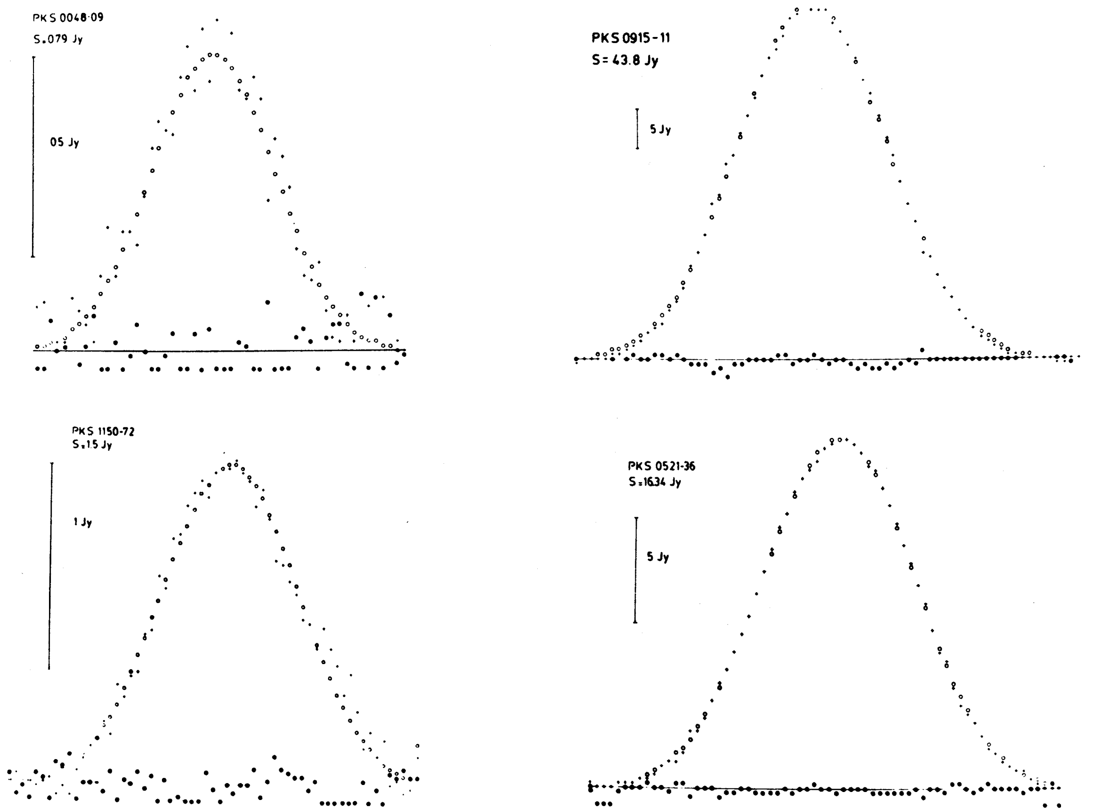

Fig. 1. Gaussian fits of radio sources: + represents observation, o represents the Gaussian beam and • the difference between the observations and the Gaussian beam.

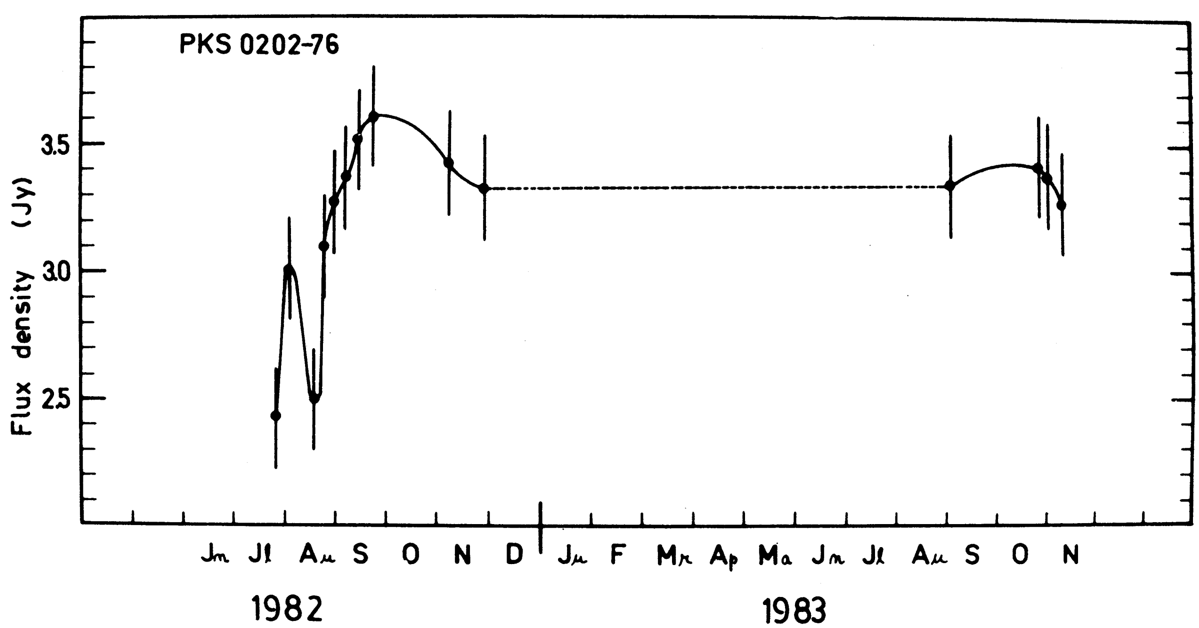

Fig. 2. The flux density as a function of time for the variable source PKS 0202-76.

TABLE 2

PARAMETERS OF OBSERVED RADIOSOURCES

NAME (PKS)	S(1410) (JY) B.J.Wills	S(1410) (JY) Parkes	S(1410) (JY) I.A.R.	VARIATION	PROPERTIES Variability in others frequencies	PROPERTIES Identification
0008-42	4.62±0.07	4.21	4.37±0.17	?		G
0023-26	8.87±0.11	6.96	8.66±0.28	?		
0036-62		1.07	1.26±0.11			G
0048-097		1.20	0.76±0.11	Yes	Yes	BL Lac
0202-17	1.71±0.11	1.31	1.17±0.11	Yes	PV	QSO
0202-76	2.51±0.09	2.06	See Table III		Yes	QSO
0405-12	3.03±0.31	2.94	3.15±0.14		Yes	QSO
0438-43	6.83±0.16	5.29	5.21±0.19	?	Yes	QSO
0454-46		2.06	2.44±0.13	Yes	Yes	QSO
0506-61		1.76	2.42±0.13	Yes	Yes	QSO
0517-56		0.88	1.26±0.11	Yes		G
0521-365	17.5±0.10		16.23±0.50	Yes	Yes	BL Lac
0537-441			3.86±0.16		Yes	BL Lac
0548-322			0.71±0.11		Yes	BL Lac
0607-15		2.51	1.09±0.11	Yes	Yes	QSO
0614-34	2.91±0.13	2.16	2.69±0.13	Yes	Yes	G
0616-48		1.27	1.93±0.12	Yes	Yes	G
0620-52		2.65	3.53±0.15	Yes	Yes	G
0637-75	5.33±0.16	5.29	5.72±0.20		Yes	QSO
0648-16		1.74	2.28±0.13	Yes		
0651-56		0.88	1.51±0.12	Yes		
0651-60		1.08	1.51±0.12	Yes	Yes	G
0706-15		1.42	0.98±0.11	Yes		
0719-55		1.57	1.51±0.12		Yes	G
0727-11		2.07	1.68±0.12	Yes	Yes	
0733-17		3.05	3.27±0.15			
0818-128			1.13±0.11		Yes	BL Lac
0834-20		3.70	3.19±0.14	Yes	Yes	QSO
0842-75		3.43	4.58±0.17	Yes		QSO
0847-57	1.21±0.11	0.98	0.67±0.11	Yes	Yes	G
0859-14	3.43±0.09	3.27	3.19±0.14	?	Yes	QSO
0920-39		1.86	2.35±0.13	Yes		QSO
1015-31		2.74	3.19±0.14	Yes		
1020-103			0.59±0.11			QSO
1030-34		1.08	1.34±0.12	Yes		
1034-293			1.81±0.12		Yes	BL Lac
1127-14	6.63±0.21	6.54	5.63±0.20	Yes	Yes	QSO
1144-379			2.23±0.13			QSO
1150-72		1.08	See Table III			
1151-34	6.33±0.14	5.00	6.39±0.22	?		QSO

TABLE 2 (continued)

NAME	S(1410) (JY)		S(1410) (JY)	VARIATION	PROPERTIES	
(PKS)	B.J.Wills	Parkes	I.A.R.		Variability in others frequencies	Identification
1213-17		1.63	1.43±0.11			
1221-66		1.47	2.48±0.13	Yes		
1240-20	1.69±0.11	1.37	1.60±0.12	?		G
1259-44		1.27	1.18±0.11			G
1301-192			0.84±0.11		Yes	BL Lac
1309-216			1.60±0.12		Yes	BL Lac
1355-41		3.50	4.76±0.18	Yes		QSO
1424-41		2.74	2.65±0.13			QSO
1445-16		1.43	1.09±0.11	Yes		QSO
1453-10		3.92	See Table	III		QSO
1504-167	3.24±0.14		2.44±0.13	Yes		QSO
1514-241	2.18±0.11		2.94±0.14	Yes	Yes	BL Lac
1539-09		1.31	0.92±0.11	Yes		
1622-29		1.67	2.60±0.13	Yes		
1622-31		1.27	1.43±0.11			QSO
1635-14		1.31	1.18±0.11			QSO
1637-77		5.19	6.31±0.22	Yes		G
1730-13	5.43±0.21	4.50	4.80±0.18	Yes	Yes	
1814-63	13.16±0.60	11.27	13.54±0.42	?		G
1819-67		1.66	2.19±0.13	Yes		
1904-80		1.18	1.35±0.12			
1934-63	16.12±0.15	12.74	14.80±0.46	?	PV	G
1951-50		1.18	2.52±0.13	Yes		QSO
2002-50		1.27	1.68±0.12	Yes		G
2052-47		2.35	1.85±0.12	Yes	Yes	G
2111-25		2.06	2.19±0.13			QSO
2128-12	1.85±0.09	1.85	1.09±0.11	Yes	PV	QSO
2141-75		1.47	1.43±0.12			QSO
2149-28		2.45	2.94±0.14	Yes		
2155-152			0.73±0.11		Yes	BL Lac
2155-304			0.59±0.11		Yes	BL Lac
2203-18	6.32±0.20	6.52	6.31±0.22		PV	QSO
2204-54	2.98±0.16	1.86	1.77±0.12	?	Yes	QSO
2207-43		0.88	1.01±0.11			G
2210-25		0.98	1.99±0.12	Yes		QSO
2227-399			0.78±0.11		Yes	QSO
2252-53		2.74	3.33±0.15	Yes		G
2319-55		1.66	1.73±0.12			QSO
2323-40		3.04	3.54±0.15	Yes		G
2345-16	1.88±0.16	1.31	0.42±0.11	Yes	Yes	QSO
2354-11	2.13±0.11	1.85	2.42±0.13	?	PV	QSO

of our observations; the differences between our measurements and those in columns 2 and 3, the variability in other frequencies from Verón-Cetty and Verón (1983), and the optical identifications, from Véron-Cetty and Véron (1983).

In Table 3 we list the measured flux density and the corresponding observing epoch for radiosources PKS 0202-76, PKS 1150-72 and PKS 1453-10 that have definitely undergone variations during the interval of our observations. These variations are graphically shown in Figs. 2, 3 and 4, while Figs. 5 and 6 show plots of our observations of the standard radiosources PKS 0915-11 and PKS 2211-17.

TABLE 3

THE FLUX DENSITY AS A FUNCTION OF TIME FOR VARIABLE SOURCES

PKS 0202-76		PKS 1150-72	
Date of Observation	1410 MHz Flux Density (JY)	Date of observation	1410 MHz Flux Density (JY)
		10-Jun-82	1.35±0.12
29-Jul-82	1.43±0.11	12-Jul-82	1.93±0.12
4-Aug-82	2.02±0.12	19-Aug-82	0.84±0.11
20-Aug-82	1.51±0.11	24-Aug-82	1.26±0.11
26-Aug-82	2.10±0.12	9-Sep-82	1.51±0.12
31-Aug-82	2.27±0.13	5-Nov-82	1.43±0.12
10-Sep-82	2.35±0.13	12-Nov-82	0.67±0.11
14_Sep-82	2.52±0.13	19-Nov-82	2.52±0.13
20-Sep-82	2.60±0.13	26-Nov-82	1.93±0.12
8-Nov-82	2.43±0.13	10-Dec-82	1.68±0.12
30-Nov-82	2.35±0.13	17-Dec-82	1.60±0.12
2-Sep-83	2.35±0.13	23-Dec-82	1.51±0.12
26-Oct-83	2.43±0.13	14-Jun-83	1.34±0.12
2-Nov-83	2.35±0.13	10-Feb-83	1.51±0.12
10-Nov-83	2.27±0.13	4-Mar-83	1.34±0.12

TABLE 3 (continued)

PKS 1453-10	
Date of observation	1410 MHz Flux Density (JY)
26-Jun-82	2.86±0.14
12-Jul-82	4.71±0.18
5-Aug-82	4.37±0.17
19-Aug-82	4.62±0.17
9-Sep-82	3.78±0.16
27-Sep-82	3.87±0.16
14-Jun-83	4.71±0.18
10-Feb-83	4.37±0.17
17-Feb-83	4.37±0.17
19-Jul-83	4.54±0.17

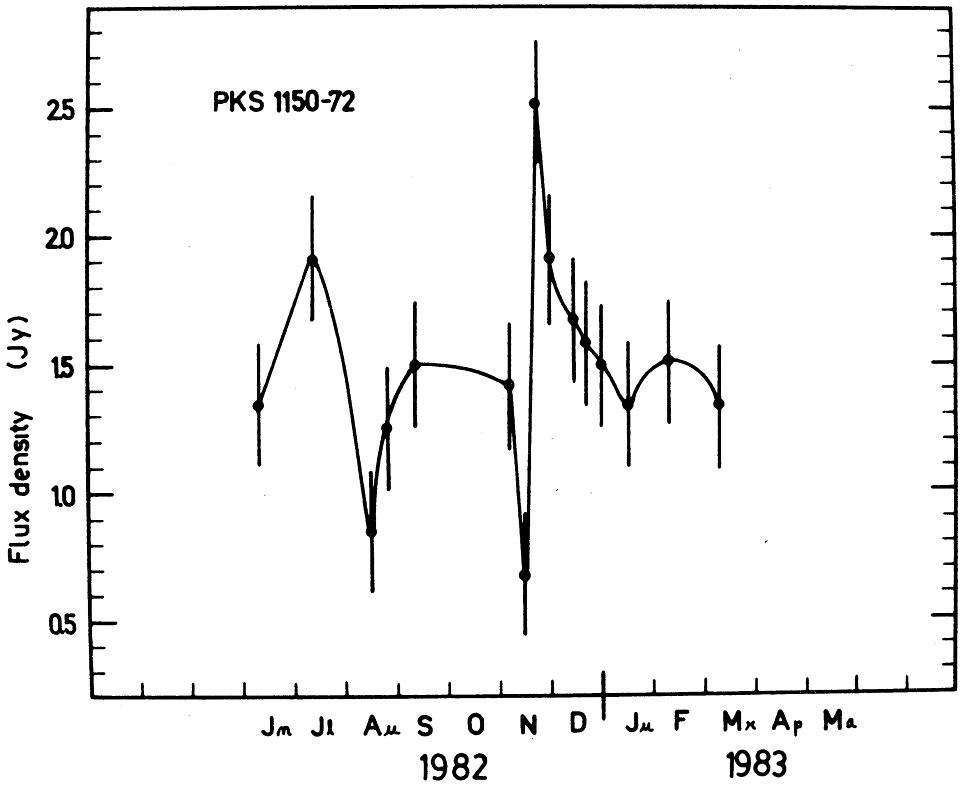

Fig. 3. The flux density as a function of time for the variable source PKS 1150-72.

IV. SUMMARY OF RESULTS

The results from our search can be summarized as follows, namely,

a) in the interval of approximately one year of observations, variations have been detected in only 4% of the observed sources;

b) among the 34 QSO's that were observed, only two of them, namely, PKS 0202-76 and PKS 1453-10, have undergone variations and such variations were up to 40%;

c) among the 19 optically unidentified radiosources, only one of them, PKS 1150-72, have displayed variations and they were larger than 100%;

d) among the 19 galaxies and 11 BL Lacertae objects observed, no variations were detected.

We should point out, however, that when we compare our measurements at 1410 MHz of the program objects, with the flux densities recorder in the 1969 Parkes catalogue and in Wills (1975) Catalogue we find flux density variations of up to 70% in 44 radiosources, that is in 60% of the total number of observed objects. In 10 cases, it has not been possible to ascertain whether or not there are variations.

Since the variations at low frequencies seem to be, in general, of long period and small amplitude, the conclusion is that observations should be carried out during a very long time interval to be able to decide whether or not a source is actually variable. Moreover, a large amount of observing time would be required to reach a good knowledge of the variability law at different frequencies and to attempt to explain the observations. Perhaps an attempt should be made to select a few appropiate sources and observe them intensively.

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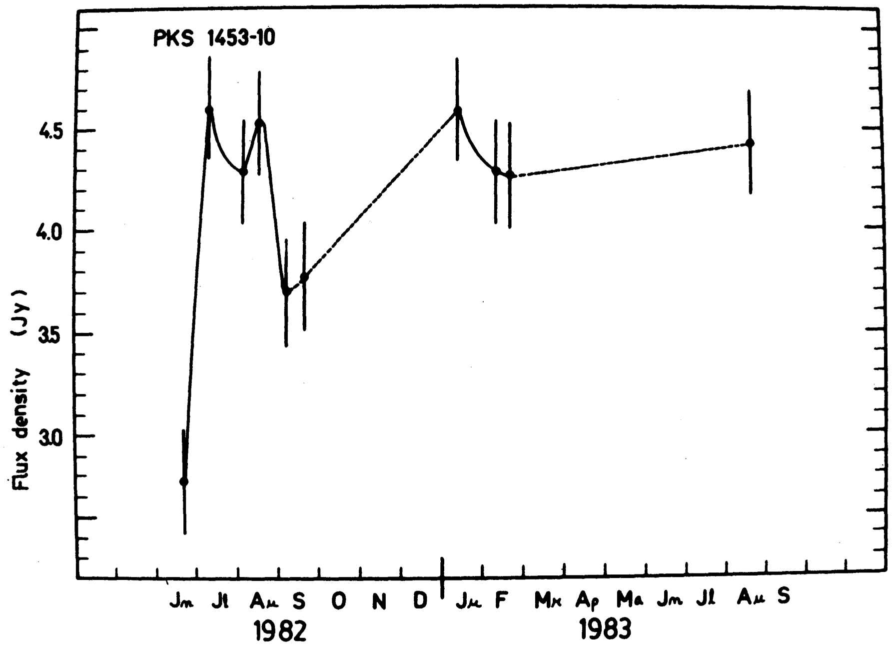

Fig. 4. The flux density as a function of time for the variable source PKS 1453-10.

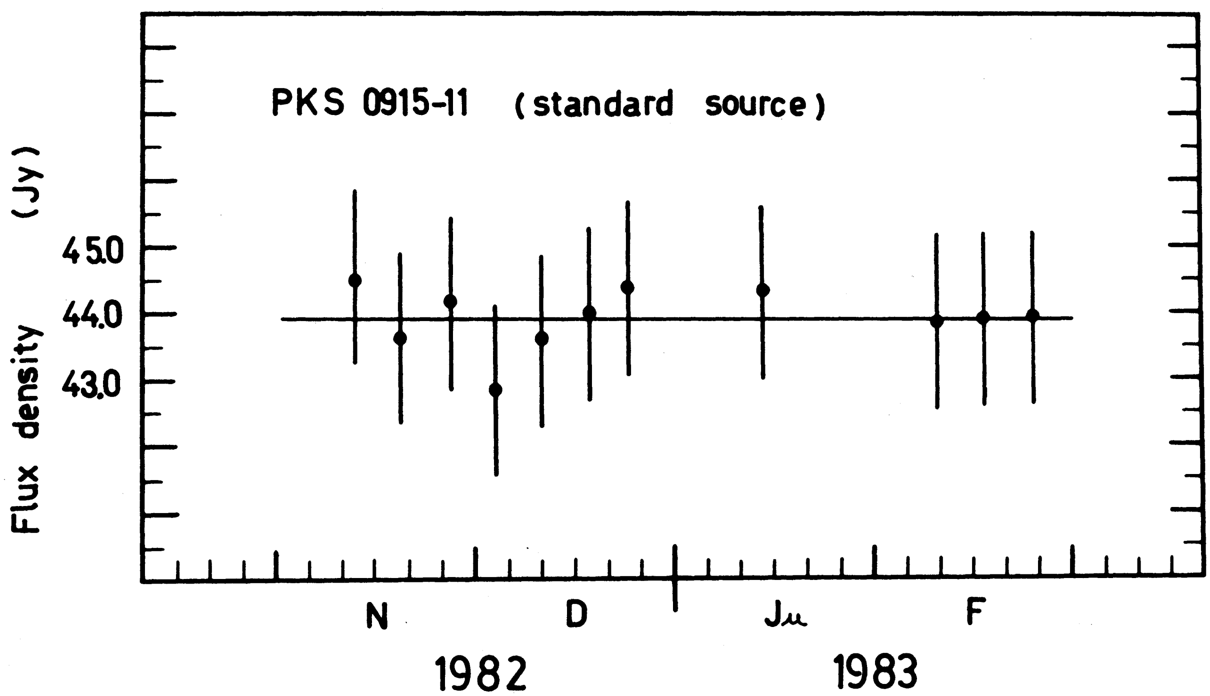

Fig. 5. The flux density as a function of time for the standard source PKS 0915-11.

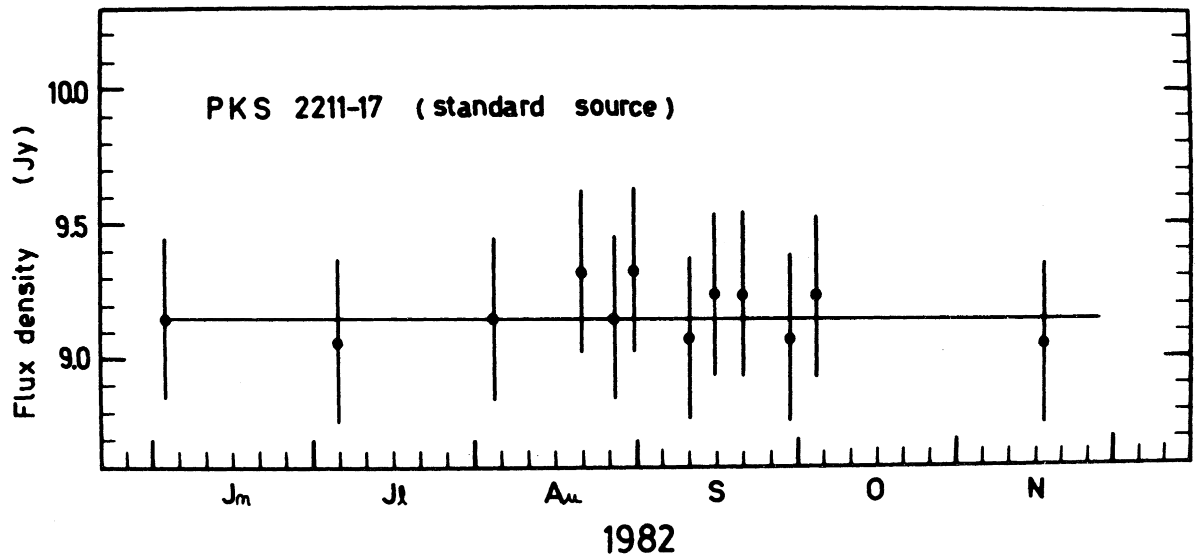

Fig. 6. The flux density as a function of time for the standard source PKS 2211-17.

REFERENCES

Fanti, C., Fanti, R., Ficarra, A., Gregorini, L., Mantovani, F., Padrielli, L. 1983, *Astr. Ap.* 118, 171.
Kers, J.A. 1969, *Australian J. Phys. Astrophys. Suppl.* 7, 1.
Kesteven, M.J.L., Bridle, A.H., Brandie, G.W. 1976, *A. J.* 81, 919.
Véron-Cetty, M.P., Véron, P. 1983, *Astr. Ap. Suppl.* 53, 219.
Wills, B.J. 1975, *Australian J. Phys. Astrophys. Suppl.* 38, 1.

F.R. Colomb, E.B. Giacani, N. Loiseau, C. Martín, Z. Quiniento, J. Sahade and J.C. Testori: Instituto Argentino de Radioastronomía, C.C. 5, 1894 Villa Elisa, Buenos Aires, Argentina.