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16. Summary/Notes - *A long series of daily observations (24 days) of the radio sources 3C273, Cen A, Sgr A and OV-236 was carried out at 22.2GHz. Known or suspected short-term variable 3C273, Cen A and Sgr A remained quiescent in the period, within 10 percent accuracy. Some short-term variability was suggested for OV-236 and it is discussed. During the observing period, the flux density of Cen A decreased consistently at a rate of (0.2 ± 0.02) Jy day^{-1} and the flux density of OV-236 increased in (0.1 ± 0.02) Jy day^{-1}. Cen A 22.2 GHz flux was the highest ever measured in the last seven years.*

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EVIDENCE FOR QUIESCENT PERIODS IN SHORT TERM VARIABLE RADIOSOURCES

Z.ABRAHAM, P.KAUFMANN and L.C.L.BOTTI

CRAAM/INPE: Instituto de Pesquisas Espaciais, CNPq, C.P. 515, 12200 São José dos Campos, S.Paulo, SP, Brasil.

ABSTRACT

A long series of daily observations (24 days) of the radio sources 3C273, Cen A, Sgr A and OV-236 was carried out at 22.2 GHz. Known or suspected short-term variable 3C273, Cen A and Sgr A remained quiescent in the period, within 10 percent accuracy. Some short-term variability was suggested for OV-236 and it is discussed. During the observing period, the flux density of Cen A decreased consistently at a rate of (0.2 ± 0.02) Jy day^{-1} and the flux density of OV-236 increased in (0.1 ± 0.02) Jy day^{-1}. Cen A 22.2 GHz flux was the highest ever measured in the last seven years.

I. INTRODUCTION

The study of short-term variability of quasars and galactic nuclei is important for the understanding of the physical conditions in these objects. In this paper we present the results of the study of the daily variation of four radio sources: Sgr A, Cen A, 3C273 and OV-236. These objects were selected because of their known long and sometimes short-term variability, strong radio fluxes at millimeter wavelengths and favorable positions for observations in the Southern Hemisphere. Although all the flux densities are of the same order (between 15 and 50 Jy) the sources cover the whole range of known radio, infrared and X-ray luminosities of extragalactic sources.

The center of our galaxy (Sgr A) is intrinsically the smallest and weakest of our studied objects. It has a non-thermal point source of diameter around 200 a.u.(Balick and Brown,1974;Kellermann *et al.* 1977; Lo *et al.* 1977). Surrounding this source there is a "halo", with a diameter that increases quadratically with wavelength, probably produced when the radiation from the core is scattered by electron-density irregularities in the interestellar plasma(Ozernoi and Shishov 1978,1979). The point source coincides in position with a strong infrared source, probably due to a dense star cluster of 10^6 $M_{\odot}pc^{-3}$(Becklin *et al.* 1978). The hard X-ray source at the Galactic center also coincides with the compact radio source (Dennis *et al.* 1980). A radio flare in Sgr A was observed in 1975 (Davis *et al.* 1976) following an X-ray flare in the same region (Eyles *et al.* 1975). However, the magnitude and duration of this radio flare are not known.

Centaurus A (NGC 5128) is the closest radio-galaxy. It has also a compact radio source at the center, which shows strong infrared and

X-ray variable emission. (Lawrence,Pye and Elvis 1977). Short-term variability at centimeter and millimeter wavelengths is now well established. Kellermann(1974) reported a variation of 50 percent in the flux density at 3.4 cm within an interval of one day. Kaufmann *et al.* (1977) reported an event occuring during November-December 1976 Beall *et al.* (1978) observed long and short-term variability in the flux density at several radio frequencies and also in X-rays. Kaufmann and Raffaelli (1979) found an 8-day quasi-periodicity in the flux density variations at 7 and 14 mm during a 43 days observing period. Kaufmann *et al.* (1980) observed a mm-wave and X-ray correlated flare during December, 1979.

3C273 was the first extragalactic radio source discovered to be variable (Dent 1965) at 3.75 cm. It was suggested by Pauliny-Toth and Kellermann(1966) that this source may exhibit fluctuations at cm-wavelengths on a time scale of a few days. Observations by Allen,Barrett and Crowther(1968) from February to May, 1966 indicated no short-term variability. However, daily and even intra-day variability was reported during the periods March-April, 1976 (Efanov *et al.* 1977) and April-June, 1977 (Efanov *et al.* 1980). VLBI observations showed a brightness distribution compatible with a strong central source and two almost colinear sources, one of them varying slowly (Legg *et al.* 1977). X-ray fluxes from this source were also reported to be variable in a time scale of months (Primini *et al.* 1979).

OV-236 (1921-29) is a quasar with red shift z = 0.352. It has been followed in radio frequencies of 7.9 GHz, 15.5 GHz, 31.4 GHz and 89.6 GHz by Dent and Balonek(1980) during the period 1972-1980 and in optical wavelengths by Gilmore (1980). A very good correlation between optical and radio variability was found. In particular, during our observing time this source was in a stage of optical and radio activity that had started in the middle of 1979.

II. OBSERVATIONS

The observations were made with the 14 m radome-enclosed Itapetinga radio-telescope* at the wavelength of 13.5 cm. The transmission of the radome at this wavelength is 0.77. The receiver is a K-band mixer with a 500 MHz passband that gave a system temperature of about 1000 K. The observing technique consisted of scans across the source, each one with a duration of 20 seconds and amplitude of one degree for all the sources except Sgr A for which the amplitude was 2 degrees. We made five ten minute daily observations of the sources. Each observation is the average of 30 scans, and is preceeded by the observation of a microwave absorber used as a calibrator. This method of calibration automatically eliminates the effect of atmospheric attenuation (Ulich and Haas, 1976). In Figure 1 we present, as an example, an observation of Virgo A (10 minute observation) consisting of 43 data samples separated by 1 arc min. A baseline was fitted to 15 points at each side of the source to subtract the contribution of the sky. The solid line represents a Gaussian fitted to the central 13 points. We also give the peak flux density, half power beamwidth and the standard error of each point, given by the rms fluctuation around the baseline. The error in the peak temperature of the Gaussian is 0.7 times this value (Strauss and Tateyama 1980).

This scanning technique, although reducing considerably the integration time on the source, was found to be better than the ON-ON or

*Operated by CRAAM/INPE, Instituto de Pesquisas Espaciais.

synchronous ON-OFF techniques because it allows a better determination of the changing contribution of the sky specially under rain and cloudy conditions, which is one of the principal sources of error in millimeter-wave flux determinations.

The scans were made at constant azimuth in all the sources except Cen A and Sgr A. These two sources have angular dimensions comparable and even larger than our beamwidth (4 arc min) and within the width of the azimuth scan there was little sky left to determine a good baseline. For that reason the scans were made in the direction perpendicular to the planes of Cen A and our Galaxy respectively.

In order to improve our receiver stability we used load-switching. The rectangular horn accepted radiation with horizontal E vector. The effects of possible linear polarization of the observed sources are expected to be smaller than the accuracy of our observations (limited by short-term changes in atmospheric attenuation and by the effect of ambient temperature on the antenna structure). In all cases, the observations were made at approximately the same paralactic angle, in order to eliminate the possibility of detecting variability due to polarization.

The transformation from antenna temperatureto flux density was made by assuming the average flux density of Virgo A during the observing period to be 21.5 Jy at 22.2 GHz.

III. RESULTS

The observations were made daily during the period July 8 to August 1. Besides the 4 program sources (3C273, Cen A, Sgr A and OV-236) we observed Jupiter, the HII region G298.2-0.3 and Virgo A, all of them considered non-variable. The results of the observations are presented in figure 2, where we give the percentual changes of the flux densities for the sources relative to their mean value during the observing period as a function of time. In the case of Jupiter, the flux density has been corrected for variation of its distance to the earth during the observing period.

The error bars represent only the standard deviation of the observations,as determined from the fluctuations around the baseline. Other uncertainties are known to be difficult to determine at mm-waves, such as short term fluctuations in atmospheric transmission affecting the calibration, and transmission characteristics under rain or overcast conditions. These uncertainties limit the precision of all millimeter-wave flux determinations and can be determined from the daily observations of non-variable sources.Allen, Barret and Crowther (1968) found 5 percent fluctuations in antenna temperatures at 8 and 15 GHz, with time scales of 0.25 hour during the summer months and larger daily fluctuations. Landau, Epstein and Ratber(1980)reported fluctuations of the same order at 90 GHz with the Kitt Peak 11-m radio telescope. In our data we obtained 10% peak - to-peak daily fluctuations both for the calibrators and for the program sources,including days with cloudy or rainy conditions (indicated by arrows in figure 2). This is a reasonably good range for a long series of daily mm-wave observations, during which we were searching for larger variations (i.e., larger than 20 percent).

OV-236 has shown considerably larger daily variations, compared to the other sources.They are likely to be real, although OV-236 observations were carried out just after sunset, when atmospheric drop in temperature and rise in humidity are known to add occasionally extra-turbulence effects on the measurements. However, Sgr A observed in the same period of the night has not shown such larger variations.

On the other hand, the kind of erratic atmospheric fluctuations mentioned above, recommend the use of comparison control sources. In this respect, questions might be rised on the short-term variability of 3C273 and other sources reported by Efanov *et al.* (1976, 1980), since the daily and even hourly behavior of the calibration sources were not presented.

We did not detect any periodic oscillation or flare in Cen A, but there was a continuous decrease in flux density. This is better seen in Table 1, where we present the mean flux density and the coefficients of a linear regresion for all the sources. The only sources that presented significant slope are Cen A (-0.2 ± 0.02 Jy/day) and OV-236 (0.1 ± 0.02 Jy/ day). The fact that the coefficients of linear regression for the calibrators are smaller than their statistical errors indicate the relative stability for our systems.

In figure 3 we present the flux density of Cen A in 22.2GHz from 1974 up to the present, obtained at Itapetinga. The source appears extremely variable, sometimes in a slow regime, as in the present observations, sometimes quasi-periodically as in July, 1978, sometimes in form of a burst (December, 1979). An overall minimum in 1976-1977 is consistent with the X-ray light-curve published by Lawrence, Pye and Elvis (1977) for the "slow" outburst component (scale of years).

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Z.ABRAHAM, P.KAUFMANN and L.C.L.BOTTI, CRAAM/INPE

Rua Itacolomi, 615, 01239, São Paulo, SP. Brasil.

FIGURE CAPTIONS

Fig. 1 - Sample of 10 minute observations of Virgo A. Each point is separate by 1 arc min. The solid line represents a Gaussian fitted to the data after subtracting the baseline.

Fig. 2 - Percentual representation of flux density at 22.2 GHz for the sources observed, relative to their mean value during the observing period as a function of time.

Fig. 3 - Flux density of Cen A at 22.2 GHz as a function of time. Points joint together by a dashed line correspond to periods of daily observations of the source.

Table 1. Mean flux density S and coefficient of linear regression C of the data from July 8 to August 1, 1980.

SOURCE	S(Jy)	C(Jy day^{-1})
Jupiter	36.6 ± 0.3	−0.013 ± 0.017
G 298.2−0.3	18.9 ± 0.2	−0.016 ± 0.020
3C 273	25.0 ± 0.2	−0.044 ± 0.016
Cen A	26.9 ± 0.3	−0.200 ± 0.017
Virgo A	21.5 ± 0.2	0.002 ± 0.017
Sgr A	51.8 ± 0.5	−0.049 ± 0.021
OV−236	15.8 ± 0.3	0.096 ± 0.017

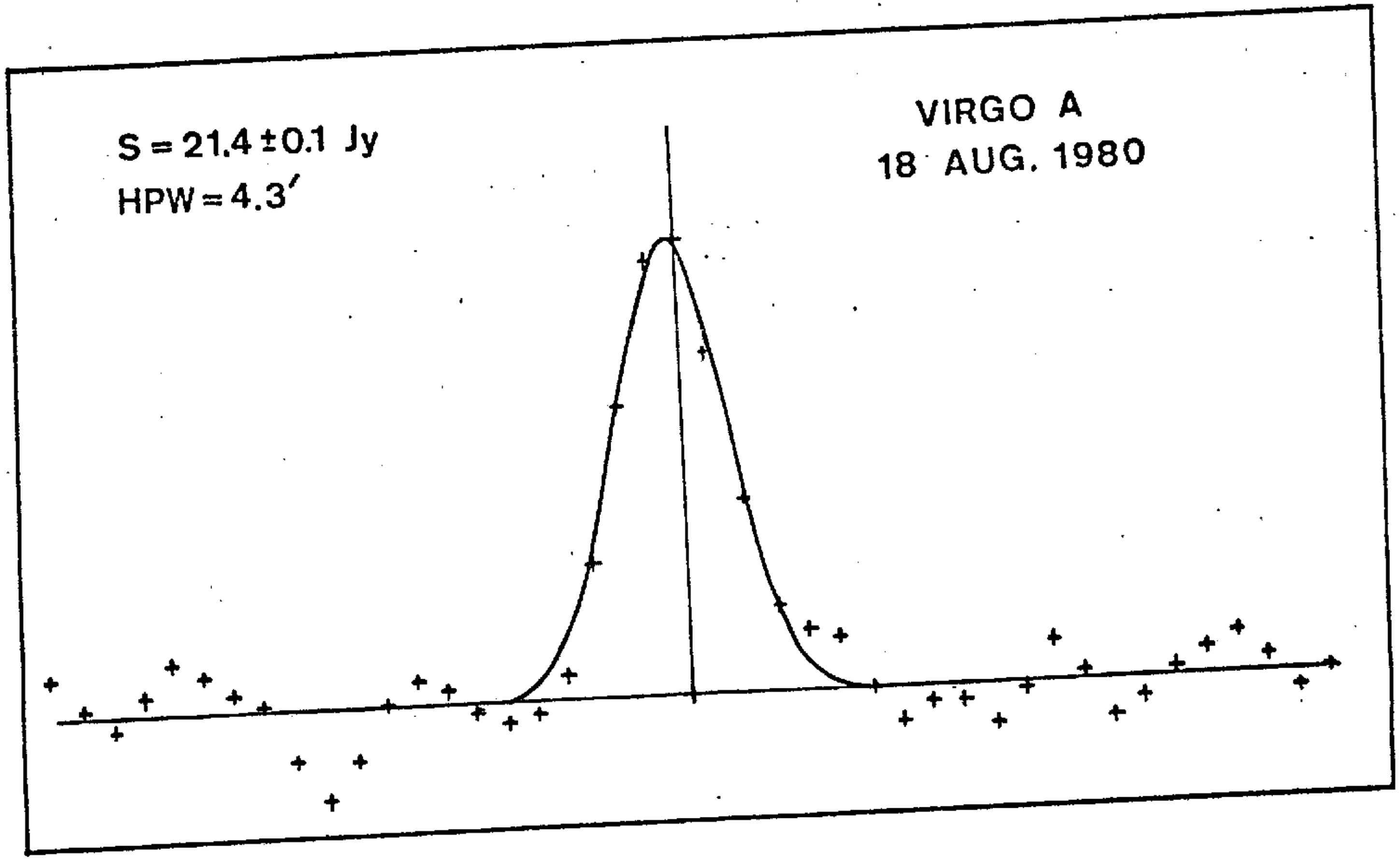


Fig 1

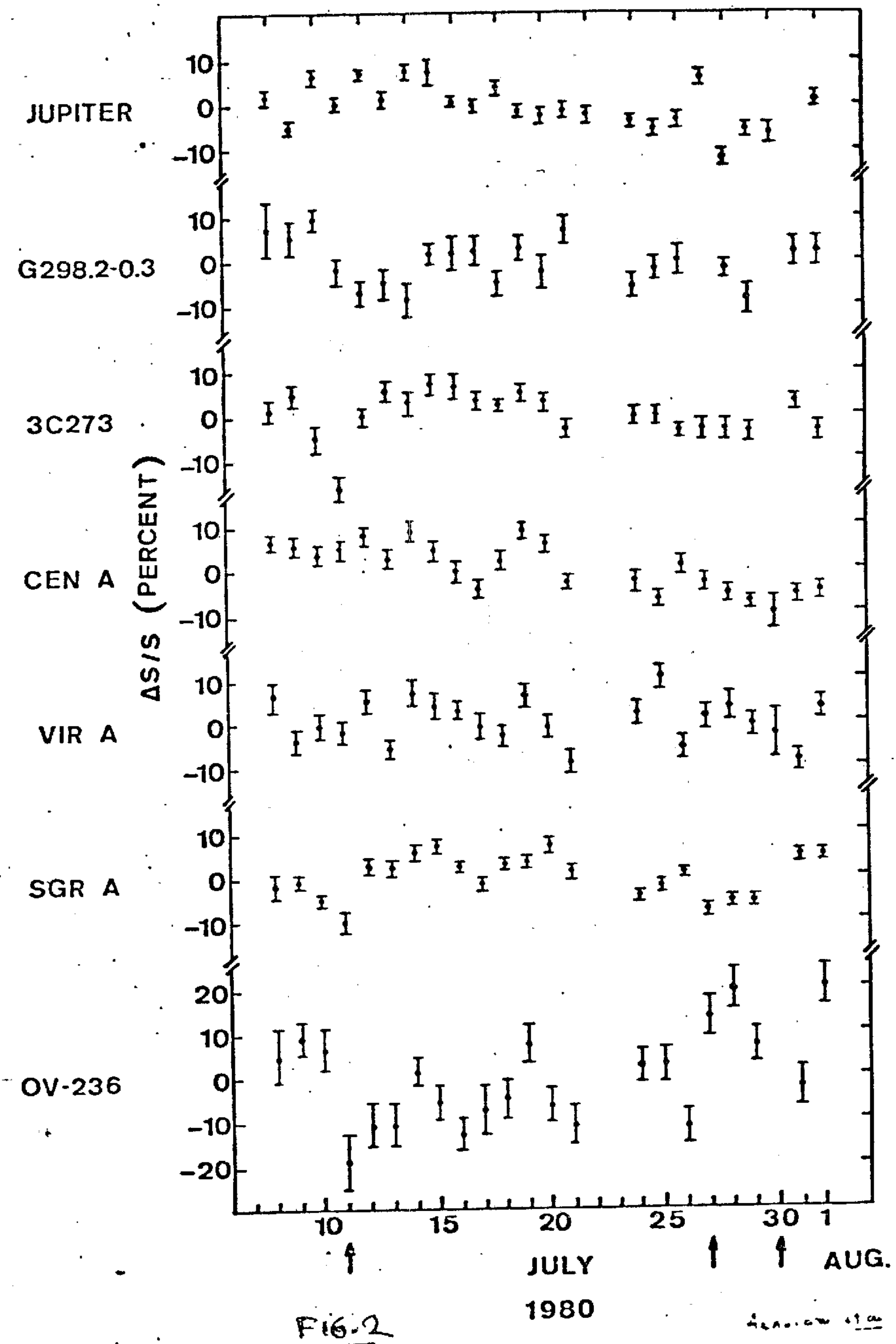
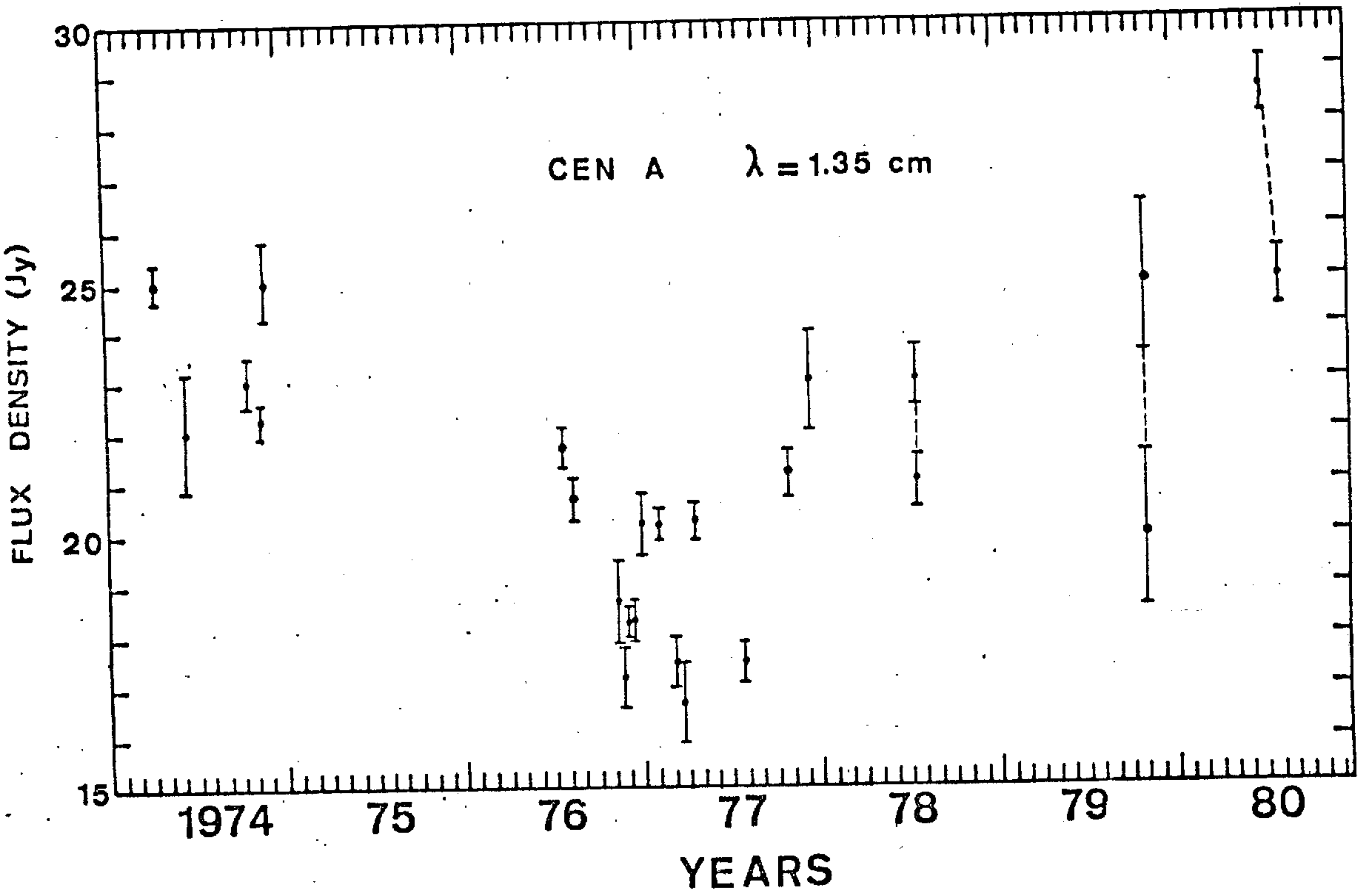

JUPITER
G298.2-0.3
3C273
CEN A
VIR A
SGR A
OV-236
ΔS/S (PERCENT)
10
0
-10
20
-20
10
15
20
25
30
1
JULY
AUG.
1980

FIG-2



CEN A λ = 1.35 cm
30
25
20
15
FLUX DENSITY (Jy)
1974
75
76
77
78
79
80
YEARS

Fig. 3