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X-Ray Emission from Centaurus A

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ABSTRACT: The X-ray strength of Cen A (NGC 5128) was monitored for 10 years by Vela 5B, beginning in 1979. The 1973-1975 period of exceptional activity and strength was especially well covered, and was characterized by numerous rapid changes in intensity, in agreement with other data, indicating that the nucleus of Cen A is small but massive.

The Vela 5A and 5B spacecraft were launched in May 1969, and were among the first to be capable of X-ray astronomy. Vela 5B continued to monitor the X-ray sky for 10 years, until June 1979, and produced an unequalled long-term record of the X-ray sky. The spacecraft were put into orbits with a radius of 118000 km, so that they circled the earth in 112 hours, spinning every 64 seconds with the spin axis pointing at the earth. The Vela X-ray detectors were pairs of NaI(Tl) crystals coupled to photomultipliers, with 6.1° collimation. They were pointed perpendicular to the spin axis, and thus scanned the entire X-ray sky, in the 3-12 keV range, every 56 hours.

A number of transient X-ray sources were detected by Vela, beginning with Cen X-4 in 1969 (Conner, Evans, and Belian 1969). Several interesting transients appeared in 1973. One of these was the nearest active galaxy, Cen A, which suddenly brightened in April 1973, after a long period of quiescence. This sudden rise was observed by OSO-7 (Winkler and White 1975). Cen A (NGC 5128) remained in a bright and active phase for more than 3 years, during which it was observed more or less continuously by Vela 5B.

Fig. 1: X-ray sky map (galactic coordinates) for 1973.0-1976.0, from Vela 5B data (3-12 keV). The average counting rates above background are indicated by the intensity of the symbols.

Figure 1 shows the X-ray sky as seen by Vela, averaged over the years 1973 through 1975. The average counting rate for each $2^\circ \times 2^\circ$ area of the sky is indicated by the intensity of the symbols. The counting threshold is set at 0.6 c/sec, so that a few of the weaker sources such as Cas A and SMC show up. The data on Cen A were particularly good during this period, as one pole of the spacecraft orbit was about 10° away in 1973, and only 4° away in late 1975. Since the poles of the orbit were scanned every 64 seconds, the areas near the poles were especially well observed. The other pole in 1973 was, fortunately, within 11° of the bright transient V0332+53 (Terrell and Priedhorsky 1984), also seen in Fig. 1. This source was not seen again until November 1983, when it reappeared in dimmer form (Tanaka et al. 1983).

During most of 1973 and 1974 Vela 5B was the only operational X-ray spacecraft with all-sky monitoring ability. Thus the Vela data on Cen A during its most active phase are much more complete than anything else available. No other data are available for 1973-1974 after the Copernicus observation of June 1973 (Davison et al. 1975). Later observations were made in 1975 and 1976 by ANS (Grindlay et al. 1975), Ariel V (Lawrence, Pye, and Elvis 1977), Copernicus (Stark et al. 1976), OSO-8 (Mushotzky et al. 1978), and SAS-3 (Delvaille, Epstein, and Schnopper 1978).

Fig. 2: X-ray time history of Cen A, 3-month averages (1969.5--1979.5).

Fig. 3: X-ray intensity of Cen A, 10-day averages (1972.5--1976.5).

The 10-year history of Cen A as observed by Vela 5B is shown in Fig. 2. These intensities have been determined by a least-squares fitting method applied to the series of sky maps which have been produced from the data of Vela 5B. Sky maps have been evaluated for each 10-day period from May 1969 to June 1976 (and for 3-month intervals until June 1979). The data have been averaged into 3-month intervals in Fig. 2, to reduce statistical errors. It is clear that Cen A was in a bright and active phase for about 3 years, during which it was 5 or 10 times brighter than previously, and that in 1976 it returned to its low state. It then remained inactive for several years, as was observed by HEAO-1 in 1978 (Baity et al. 1981). The data during the most active phase were exceptionally good because of the fortunate location of Vela 5B, as is indicated by the smaller standard deviations of the points. In 1979 Cen A became bright again, as was also observed by Einstein (Feigelson et al. 1981), but here the Vela record ends.

Figure 3 shows the more detailed time history of Cen A during its most active phase, as observed by Vela 5B. The average counting rate observed for the galaxy is shown for every 10-day period from the middle of 1972 to the middle of 1976. The sudden increase in intensity around 9 April 1973 (Winkler and White 1975) is quite evident in Fig. 3. In June 1973 the intensity fell fairly suddenly to a lower value, and such fluctuations continued into 1976. Peak fluxes were reached several times in 1974, and quite noticeably in January 1975 and June 1975. The counting rate reached maxima of more than 4 c/sec, with each count corresponding to $\sim 4.5 \times 10^{-10}$ ergs, or about 10^{42} ergs emitted by Cen A in the 3-12 keV range. Thus the nucleus of Cen A emitted more than 10^{43} ergs/sec during its active phase, including higher-energy X-rays (Winkler and White 1975). These data differ slightly from an earlier report (Terrell 1982), because of improvements in the least-squares fitting procedures (Priedhorsky, Terrell, and Holt 1983). The data agree very well with other available data, allowing for differing observation dates of a rapidly varying source.

It is clear that on a number of occasions the X-ray flux from Cen A changed by a considerable factor in a matter of days. This indicates that the source, undoubtedly the nucleus of the galaxy, behaved like a single source of small size and great mass. There were a number of times when the intensity reached a peak lasting 50 or 60 days, as may be seen in Fig. 3. The power spectrum of these fluctuations is suggestive of shot noise (Terrell and Olsen 1970, Terrell 1972) due to pulses with such an effective length, which could only reasonably come from a source smaller than 100 light-days in radius. An even smaller size is indicated by the most rapid changes reported here, as well as elsewhere (Winkler and White 1975; Delvaille, Epstein, and Schnopper 1978; Mushotzky et al. 1978).

A lower limit to the mass of the source is indicated by the intensity, which corresponds to the Eddington limit for $\sim 10^5 M_{\odot}$. If the mass of the nucleus were less than this, the X-ray intensity would be sufficient to eject the outer parts of the galactic nucleus at relativistic speeds. A considerably larger mass than this would have been necessary for ejection of the matter which comprises the strong radio sources far out from this galaxy. This work was supported by the U. S. Department of Energy.

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