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X-RAY TRANSIENTS AS SEEN BY VELA, 1969-1979

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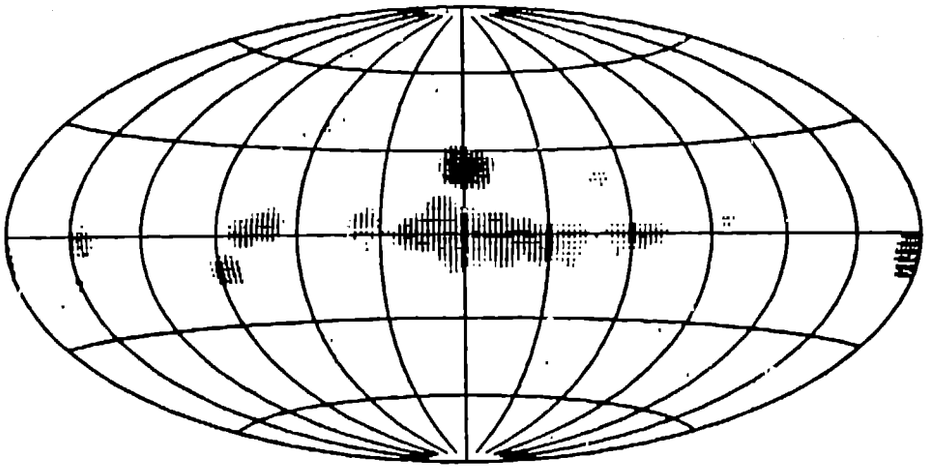
Vela spacecraft 5A and 5B were launched into orbit in May 1969, to monitor for nuclear tests in space. These spacecraft were among the first to be capable of X-ray astronomy. One of these, Vela 5B, monitored the entire X-ray sky for the unprecedented period of 10 years, from May 1969 to June 1979. Over the last several years the data produced have been re-analyzed to produce a series of skymaps. These have now been made into a movie, in color, showing the changes in the X-ray sky over the period 1969-1976.

The Vela spacecraft were put into orbit at 118000 km radius. Among the many detectors aboard were collimated NaI detectors sensitive to 3-12 keV X-rays. These scanned the sky over a 6.1° (FWHM) square field of view at 90° to the earth-spacecraft axis, so that the entire X-ray sky was observed in 56 hours, half of the orbital period. Any given source, when in view, was scanned every 64 sec (the rotation period) in two energy channels, with one-second count accumulations.

During the 10-year lifetime of the X-ray counters, the Vela spacecraft produced data on many new types of sources, including X-ray transients, X-ray bursts, and even gamma-ray bursts. Cen X-4, an exceedingly bright X-ray transient, was observed by Vela in the summer of 1969, shortly after launch (Conner, Evans, and Belian 1969). It did not return to the X-ray sky until May 1979. This source, with a very bright, hard precursor on 7 July 1969 (Belian, Conner, and Evans 1972), also produced the first of many X-ray bursts detected by Vela. A number of other high-latitude X-ray bursts have been detected, with no evidence of repeated bursts (Belian, Conner, and Evans 1976).

The Vela gamma-ray detectors revealed the new phenomenon of gamma-ray bursts (Klebesadel, Strong, and Olson 1973). It has recently been found that at least two gamma-ray bursts were also detected by the X-ray counters (Terrell et al. 1982b). One of these events (GB720514 = GBS1128+77) was in a known direction (Wheaton et al. 1973). The other (GB740723 = GBS0228-75) was found, by means of the collimated X-ray detectors, to lie in the direction of the Small Magellanic Cloud. The time histories of these two bursts as seen in X-rays (with brief observations every 64 sec) are similar in that both showed evidence of recurrences during the succeeding 1000 seconds.

The data produced by Vela 5B over the 7-year period May 1969-June 1976, during which real-time tracking was reasonably complete, have been put into the form of a series of 10-day skymaps. A 10-day interval is long enough to include four scans of the entire sky, so that gaps in coverage are usually filled in. This data base is well suited for determining the time histories of many sources, and in particular for Fourier analysis. The Vela X-ray detectors were relatively small (27 cm^2 effective area) but were sensitive enough to yield good data on Cen A (NGC 5128) during the period 1973-1975 (Terrell 1982). During this period Cen A was unusually bright and active (Beall et al. 1978). The new data show that it often changed dramatically in intensity in less than 10 days.



VELA 5B 3-12 KEV 73/01/07 - 74/01/02
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Fig. 1: X-ray skymap (3-12 keV, galactic coordinates) for 1973, from Vela 5B data. The average counting rate is indicated for each $2^{\circ}x2^{\circ}$ area by the darkness of the symbol (and by color in the movie), in half-magnitude steps. A previously unknown transient, V0332+53, is apparent near the left edge.

This series of 10-day skymaps has been recently made into a movie, showing the history of the X-ray sky over a 7-year period, during which many transient sources appeared and other sources fluctuated continually (Terrell et al. 1982a). This period includes times when no other spacecraft was able to monitor the sky. Sources as weak as Her X-1, Perseus, and SMC X-1 are often quite obvious in these skymaps, as are transient outbursts not previously known, such as 4U1145-61 in April 1973, Aql X-1 in May 1974, and 4U0115+63 in August 1974. An example of these skymaps is shown in Figure 1, in this case for the entire year 1973.

One source of considerable interest in this data is Cyg X-1, the well-known black-hole candidate. This X-ray source exhibits chaotic fluctuations, on a time scale of seconds, which have the characteristics of non-periodic shot noise (Terrell 1972). On longer time scales it is modulated by the 5.6-day orbital period (Holt et al. 1979) of the binary system including the supergiant star HDE226868, and has high and low states at irregular intervals over the years. The intensity of Cyg X-1 over 10 years is shown in Fig. 2, as given by Vela 5B. These data agree well with Ariel 5 All-Sky Monitor data in the period after October 1974 (Holt et al. 1979). In this graph the data have been grouped into 30-day intervals for clarity, and have not been corrected for a small contribution from Cyg X-3, 9° away. Each count/sec corresponds to $\sim 3.8 \times 10^{-10}$ erg/cm^{2}sec in the 3-12 keV range. In addition to the high and low states which are quite evident, a periodicity of $\sim$ 290 days is plainly present (Priedhorsky and Terrell 1982). Fourier analysis of the data, with separation of the Cyg X-3 data, leaves no doubt of the reality of the periodicity (Priedhorsky, Terrell, and Holt 1982). The origin of this 290-day periodicity is of considerable interest, whether it is due to precession of the supergiant companion or of the accretion disk, or to some other cause.

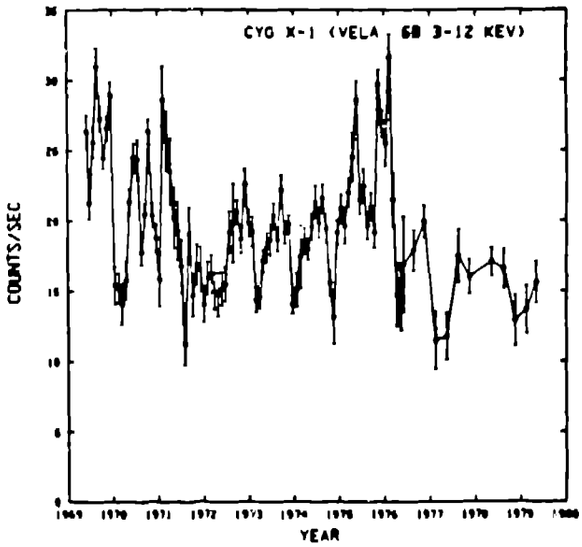

Fig. 2: Cyg X-1 intensity, 1969-1979.

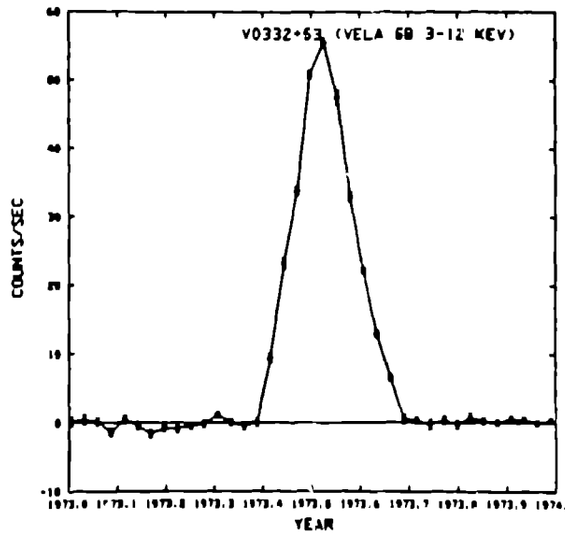

Fig. 3: V0332+53 intensity, 1973.

An otherwise unknown transient X-ray source was observed by Vela in Camelopardus during June-August 1973 (Terrell et al. 1982a). It is readily apparent in the skymap for 1973 (Fig. 1), at galactic coordinates 146.18°, -1.95°. (equatorial coordinates $\alpha = 53.22°$, $\delta = 53.13°$, epoch 1950.0; the position is known to within an uncertainty of ~0.2°) This hard X-ray transient (V0332+53) was brighter than the Crab in July 1973. It has not been seen since, and was not observed by other spacecraft, to our knowledge. Its time history, seen in Fig. 3, is different from that of other bright transients such as Cen X-4 and A0620-00, in its gradual rise to peak brightness. There are clear indications of rapid fluctuations in this source, but analysis so far has given no clear periodicity.

Much other evidence of outbursts, fluctuations, and periodicity is present in the Vela skymap data base, and highly visible in the movie made from them. It is clear that even the relatively small Vela detector, scanning the X-ray sky for many years, has yielded data of great value to X-ray astronomy.

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