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ABSTRACT

An unusual transient pulse of $\geqslant$ 50 keV photons was detected on 1979 March 5 by the gamma-ray burst sensor network using nine space probes and satellites. Its characteristics are unlike those of the known variety of gamma-ray bursts and therefore suggest that it was formed either by a completely different origin species or in a very different manner. It is identified with the LMC supernova remnant N49 in the accompanying Letter (Evans et al., 1979a).

I. INTRODUCTION

A gamma ray transient has been detected with the recently formed interplanetary gamma-ray burst sensor network. Its unusual features, which are sufficiently anomalous to suggest that it is not a gamma burst of the type observed for several years (Klebesadel et al., 1973), are as follows. First, its maximum intensity is more than an order of magnitude greater than the most intense gamma-ray bursts previously seen. Second, its rise time is faster than can be resolved, <0.25 millisecond, which is about two orders of magni-

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tude shorter than for previously measured bursts or for previous measurement limits, although not necessarily shorter than for all earlier bursts. Third, the high-intensity portion is exceptionally brief; with a ≈ 120-millisecond width, it is shorter than over 95 percent of all earlier events detected, although similar in extent to two or three low-intensity events. Fourth, its initial pulse shape is regular, with a smooth shape having little modulation, unlike typical gamma ray bursts which are generally highly structured. This fast decay from high intensity is followed by a long, regularly pulsing decay at a much lower intensity. It is not known whether gamma ray bursts in general also have this property since, relative to their intensity, such a low level post-burst decay feature is below detectability. Fifth, its existence is a singular feature; it was not found solely because of the recent formation of the interplanetary network, but in fact is the only event of its kind in over ten years of essentially continuous operation of the Vela system, which could have detected other similar events had they occurred. Sixth, its spectrum is much softer than that of typical gamma ray bursts: a descriptive energy appears to be in the 50-keV region, as opposed to the typical exponential at 150 keV (Cline and Desai, 1975). Seventh, its source direction (Evans et al., 1979a) is entirely consistent with a known celestial object, completely unlike gamma ray bursts, which have not yet been found to have source directions consistent with candidate or identifiable objects (e.g., Cline et al., 1979b). Even if this event is in fact a variation on the gamma ray burst phenomenon, it remains a spectacularly unusual event, and the puzzle as to the origin mechanism of the typical kind of burst event remains unsolved.

II. INSTRUMENTATION

The 1979 March 5 event was observed with all the instruments recently launched to form the interplanetary gamma-ray burst network and with three of the four Vela satellites, now incorporated in that network, that originally provided the discovery of the gamma-ray burst phenomenon (Klebesadel et al., 1973). The interplanetary network consists of a Goddard Space Flight center experiment on Helios-2, launched in 1976, a Los Alamos Scientific Laboratory experiment on Pioneer-Venus Orbiter, launch in 1978, two GSFC experiments and one LASL experiment on the International Sun-Earth Explorer-3, launch in 1978, three experiments by the collaborative team of the Soviet Academy of Sciences and the Space Research Institute of Moscow, and the Centre d'Etude Spatiale des Rayonnements of Toulouse, on Venera-11 and Venera-12, launched in 1978, and on the Earth-Orbiter Prognoz-7, launched in 1978, and the four Vela satellites, launched in 1969. Helios-2 is in solar orbit since launch, Pioneer Venus Orbiter is in orbit around Venus since injection in December 1978, ISEE-3 is in an actively maintained, artificial orbit around the gravitational null or Langrangian point between the Earth and the Sun since October 1978, and Venera-11 and Venera-12 are in solar orbits after Venus gravitational deflections in December 1978. In each case the gamma-ray burst detector on board these space vehicles was designed with the purpose of high-accuracy gamma-ray burst source direction determination by means of interplanetary wavefront timing, i.e., long-baseline source triangulation. As is clear from the accompanying Letter, this technique is achieving its purpose of providing the most accurate source positions in gamma-ray astronomy, resulting in ~ 1-arc-minute source field definition.

The GSFC sensor on Helios-2 has been previously described (Cline et al., 1979a, 1979b), as has the LASL sensor on Pioneer Venus (Evans et al., 1979b). The GSFC and LASL detectors on ISEE-3 are generally similar to their predecessor instruments, although they use host experimentation for the sensors, provided by the Max Planck Institute cosmic ray experiment (Hovestadt et al., 1978) and the University of California solar flare experiment (Anderson et al., 1978), respectively. In addition, the GSFC experiment on ISEE-3 uses a second, Ge gamma-ray detector with a separate memory (Cline et al., 1978). The French-Soviet experiments on Venera-11 and -12 and on Prognoz-7 use gamma-ray burst instrumentation provided by the CESR in Toulouse (Chambon et al., 1979). It is adequate to describe all the interplanetary network detectors here as scintillation or solid state photon counters that are approximately omnidirectional in response (except for spacecraft shadowing), with energy sensitivity that maximizes in the ≈100 keV region, but with some energy response from ~ 30 keV to ~1200 keV. They each employ accurate timing, in the 1 millisecond to 4 millisecond range, and each use an on-board memory with capacity to completely describe the entire temporal profile of a gamma-ray burst transient before and after trigger time with 0.2-16ms differential timing accuracy. The detectors of the Vela system have been described earlier (Klebesadel et al., 1973) and are comparable in character, except that their temporal response geometrically broadens following trigger, and there is no pre-trigger memory. The sizes and consequent sensitivities of all the detectors in the interplanetary network are roughly similar, although the three Soviet-French units are somewhat larger and have sensitivities extending to somewhat lower photon energies. As a result, a general uniformity of response throughout the network makes possible the study of the properties of any burst wavefront at each of the network vertices with approximately similar accuracy.

III. RESULTS

The unique properties of the 1979 March 5 gamma-ray transient are illustrated in Figures 1, 2 and 3. The first and dominant feature is the initial spike, which is at least 10 times the instantaneous counting rate of any previously observed transient in its energy region of over 100 keV. The rise time is short compared with the temporal resolution capabilities of the instruments: a two order of magnitude increase in less than one millisecond implies a time constant of less than 0.2 msec. The decay is monotonic, represented roughly by two exponentials, with the shorter time-constant feature following the longer. The unusual features, however, are the brevity and the regularity of the main pulse shape, characteristics very dissimilar to typical gamma ray bursts with their irregular pattern and usual durations of seconds to tens of seconds. The other very striking features are exhibited in the presence of a relatively low-intensity, long duration decay phase, which contains both a smooth, monotonic average-intensity decay with a time constant of about 50 seconds superimposed with a regular pulsing character of 8 seconds period with compound features. Since the intensity of this decay pulse is roughly one percent that of the main pulse, which is itself about 100 times as intense as the average gamma ray burst, it is not experimentally verifiable whether gamma ray bursts in general also have this post-burst decay feature. The observable portions of known bursts, at least, do not contain either such regular pulsations or such a smooth, average intensity decay pattern.

The features of this transient, including the temporal characters, shapes and relative intensities, are entirely comparable in the results from the variously equipped eleven sensors used (three on ISEE-C, and one each on Pioneer Venus Orbiter, Helios-2, Prognoz-7, and on two Veneras and three Velas). Also, the spacecraft relative separations extend to over 600 light-seconds. We are therefore confident that there is no measurement distortion due to an environmental effect on any single observation, such as the Earth's influence. Three basically different electronic counting rate encoding schemes were used (counts per fixed unit of time, on 4 sensors, time to accumulate a fixed number of counts, on 4 sensors, and counts per variable unit of time, on 3 sensors). Accordingly, the results shown are samples chosen as appropriate to illustrate each feature of the transient. In several cases, for example, the count rate history exhibits an initial rise for about 20 milliseconds following the

<1 msec onset. It is a relatively small effect but indications are that its existence is detector independent. Also, the ≈120-msec flatter portion and the abrupt transition to a ≈ 35 msec time-constant decay is observed in all nine sensors with compatible results. The long-term continuation of the regular, 8-second periodic decay is observed best with only one of the sensors, (the GSFC/MPI/UM crystal on ISEE-3), although several of the initial cycles are seen with all units and were independently observed with other Venera sensors (Mazets et al., 1979). The ISEE-3 measurement cannot be severely spin modulated since the source direction (Evans et al., 1979a) is only 3.5 degrees from the spin axis.

IV. DISCUSSION

The unusual intensity of this event is illustrated in Figure 4, showing a plot of instantaneous maximum intensity vs. total intensity for all Helios-2 gamma-ray bursts observed since January 1976. Although this transient is very much more intense than the others at maximum, its total apparent intensity is similar to that of a typical gamma ray burst. To identify it as such, however, creates a conflict with the probable source identification as an object at the distance of the Large Magellanic Cloud (Evans et al., 1979a); that implies an intrinsic intensity several orders of magnitude greater than those of typical gamma-ray bursts, assuming a nearby source volume from their approximate isotropy. For example, there should have been observed a large number of even more intense events from the galactic disk region. It is known that three events detected during the last ten years' operation of the Vela system (R. Klebesadel, unpublished) have a similar ≈ 100 msec width, like the initial spike in this event; they are of much lower total intensity, with more typical maximum intensity. Their directions are not well defined and the existence of post-burst oscillations in these is also not known; it is therefore possible that, of the ≈ 90 known events compiled during 1969 to 1979, these three others may be entirely like the 1979 March 5 event. If so, and if the four narrow events were postulated as forming a separate transient event class, however, other problems arise, including an expected greater rate of lower-intensity narrow events that would be predicted from the existence of the 1979 March 5 event, assuming a -1.5 index size spectrum power law. However, the rate of March 5 event-sized transients could be much rarer than the observed fact of once in ten years, assuming a simple statistical fluctuation. Finally, the energy spectrum of this event is unlike the $\approx$ 150-keV model found to be typical for many gamma-ray bursts (Cline and Desai, 1975) and in fact for most bursts (Cline and Desai, to be published). The available spectral observations will need further analysis before accurate differential spectra can be obtained. However, it is clear that the spectrum of the initial spike is much better described as characteristic of $\leqslant$ 50 keV than of 150-keV, and/or can be fit to a steeper power law in energy. The spectrum of the long-decay portion is even softer. Thus, even if the source object of this event is postulated as belonging to the same class as gamma-ray burst sources, which seems unlikely, the emission process in this case must have been very different.

Acknowledgements

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FIGURE CAPTIONS

Figure 1. The time history of the 1979 March 5 transient as observed with the ISEE-3 space probe. Following the extremely high-intensity spike of very brief duration, there are regularly periodic pulses with monotonically decreasing intensity that occur every 8 seconds, mixed with interpulse features of varying structure and intensity.

Figure 2. The first 22 cycles of the March 5 event, plotted on an 8.00-second per period basis, with the event onset chosen as zero of time, folded with an increasing number of cycles per plot. The initially larger peak appears statistically consistent with a position at constant phase to within 1 second, yielding an average period of 8.00 $\pm$0.05 seconds. A varying, initially smaller interpulse appears to remain in phase with the intense onset spike.

Figure 3a. The onset of the high intensity portion of the 1979 March 5 transient. A time constant of less than 0.2 millisecond is inferred from the increase of two orders of magnitude from near background to essentially full intensity within a resolution time of 1 millisecond. In this instrument the time to accumulate 64 photons is recorded to 1 msec accuracy. The first several readings are in fact 1-msec and 2-msec accumulations. This $\leq$ 1 msec full rise in the onset shape is seen with each of 3 independently instrumented sensors on ISEE-3 and with the sensor on Pioneer Venus. Using Venera-11 and -12 it is seen with 2 msec and using Helios-2 with 4 msec resolution, each with a counts per linear-time-base-technique.

Figure 3b. Details of the high intensity portion of the 1979 March 5 transient, as observed with the Helios-2 sensor. A maximum slightly above the initial rise, reached about 20 msec after onset, is observed in the Pioneer Venus and Venera data, as from this instrument. The intensity decay following maximum is roughly monotonic, but appears to have an initial ≈100 msec interval obeying a ≈150 msec exponential time constant, followed by a steeper slope of ≈35 msec time constant. These features are observed with all of the various sensors employed.

Figure 3c. The low-intensity decay portion of the 1979 March 5 event, averaged in units of the 8-second period. The general feature is that of a ≈50-second time-constant exponential, although the adjustment to this shape does not take place immediately after the initial maximum.

Figure 4. Diagrams of total intensity vs. maximum intensity for the known gamma-ray bursts observed by Helios-2, indicating the unique position of the 1979 March 5 event. Since typical burst rise times and temporal structures vary widely, observations using two different linear time bases are illustrated. (The 32-msec histories on Helios-2 are obtained for only 64 seconds following trigger; thus, the maximum intensity values derived in those events with greater total duration must be considered lower limits.) The more extensive Vela burst observations (e.g., Klebesadel and Strong, 1976) cannot be used for this purpose since they are recorded with a geometrically lengthening time base and bursts do not always have maximum intensity near their onset. If a search is made for Vela transients assumed to be similar to the March 5 event, with maximum intensity following trigger, a comparison of onset intensity vs. total intensity gives a similar result.

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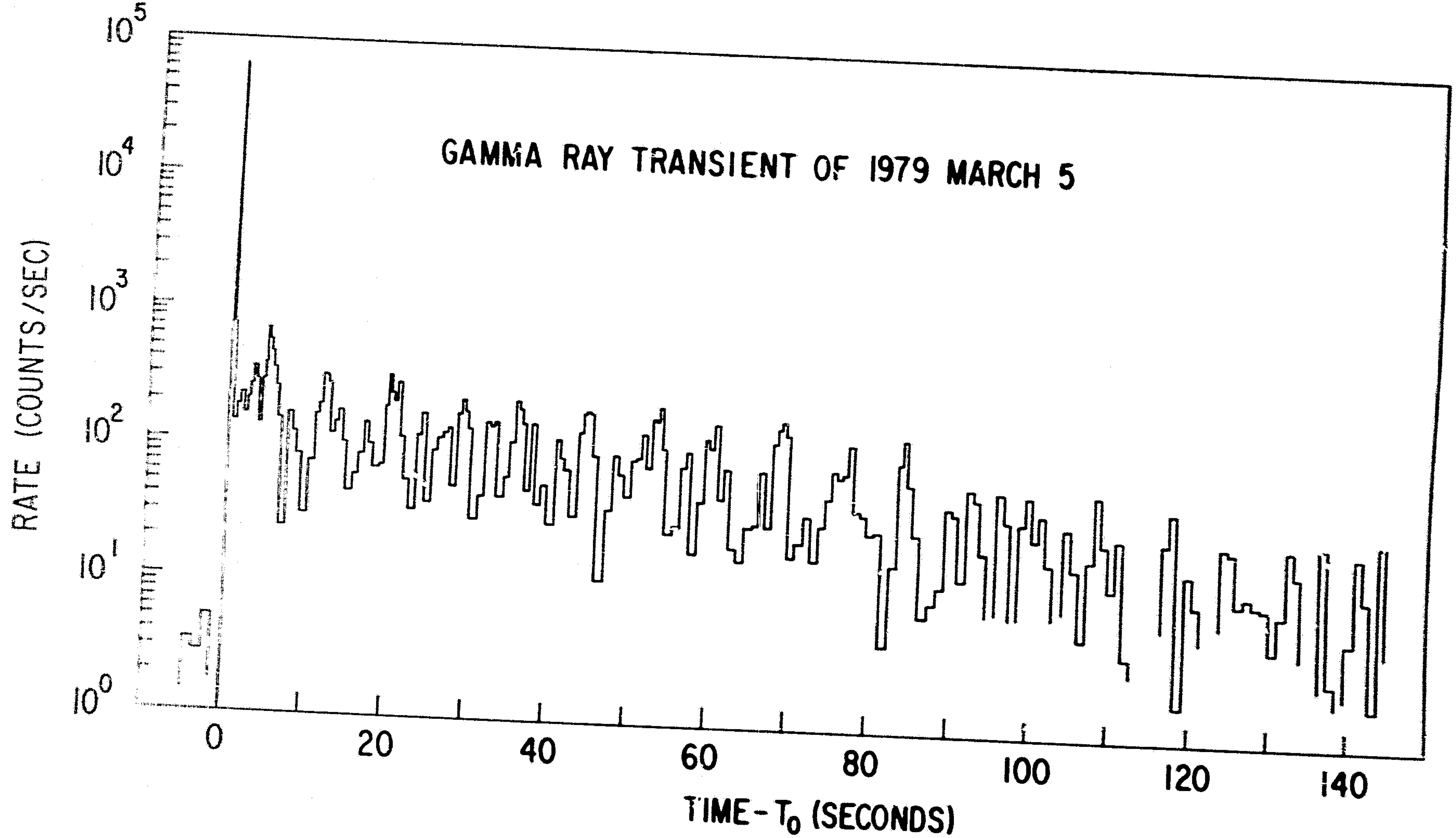
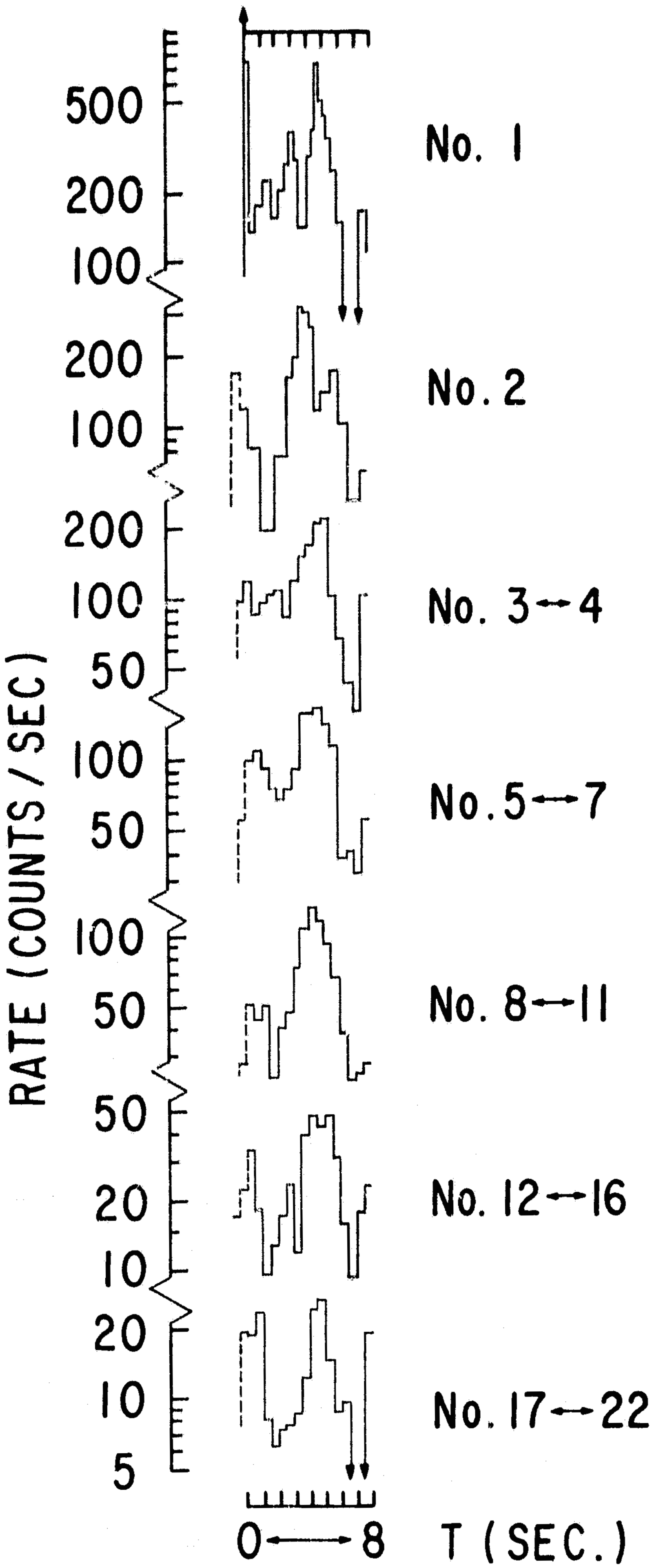

GAMMA RAY TRANSIENT OF 1979 MARCH 5
RATE (COUNTS/SEC)
10^5
10^4
10^3
10^2
10^1
10^0
0
20
40
60
80
100
120
140
TIME-T0 (SECONDS)

Fig. 1



RATE (COUNTS / SEC)
500
200
100
No. 1
200
100
No. 2
200
100
50
No. 3↔4
100
50
No. 5↔7
100
50
No. 8↔11
50
20
10
No. 12↔16
20
10
5
No. 17↔22
0↔8
T (SEC.)

Fig. 2

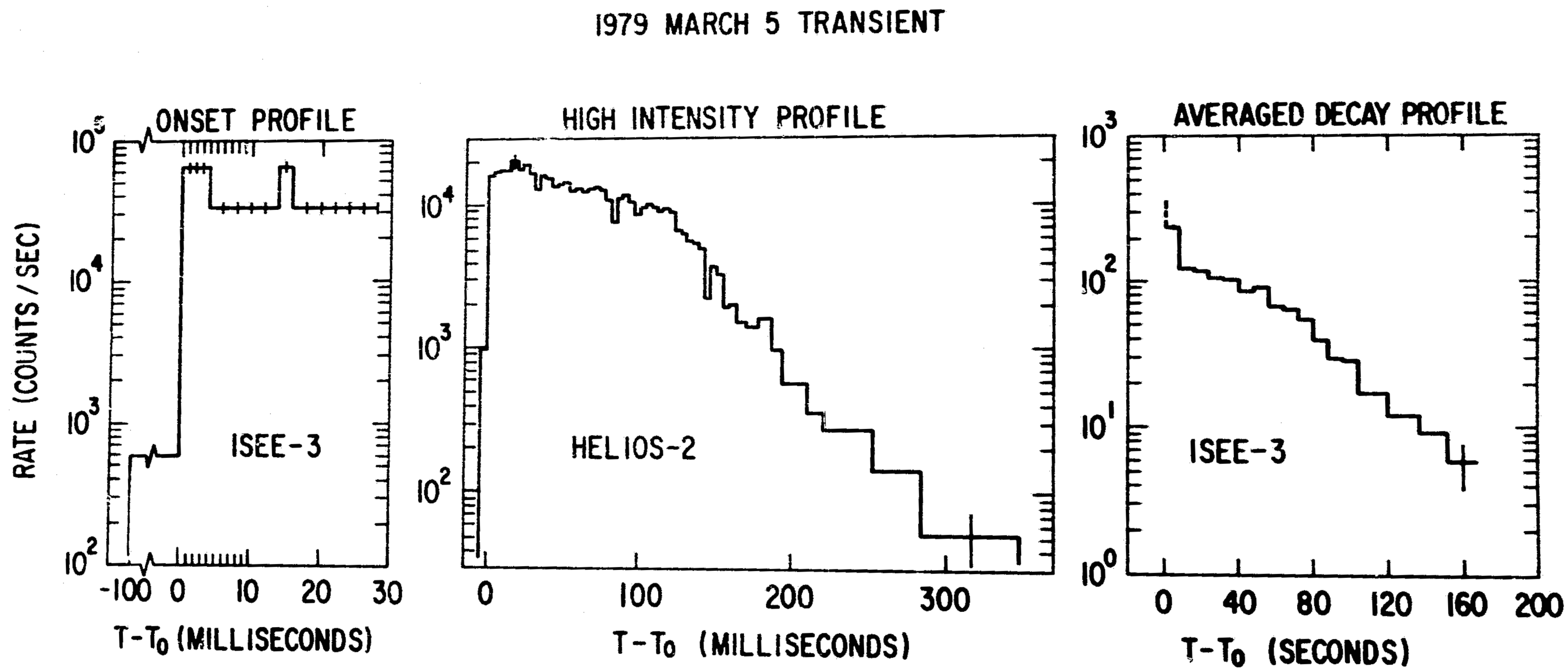
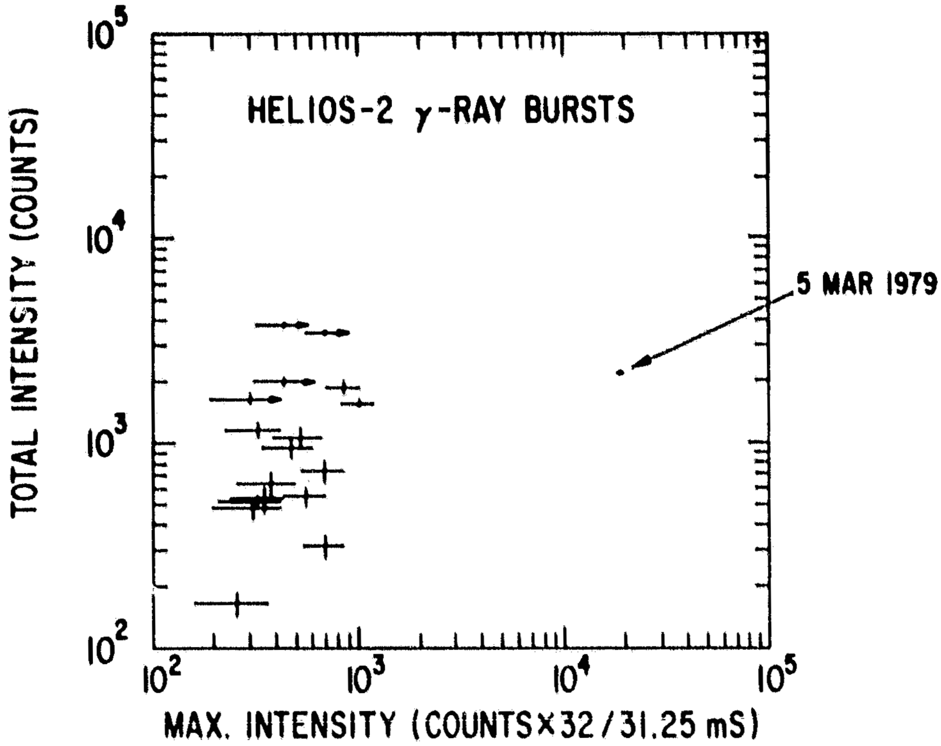

1979 MARCH 5 TRANSIENT
ONSET PROFILE
HIGH INTENSITY PROFILE
AVERAGED DECAY PROFILE
RATE (COUNTS / SEC)
ISEE-3
HELIOS-2
ISEE-3
-100
0
10
20
30
100
200
300
40
80
120
160
200
T-T0 (MILLISECONDS)
T-T0 (MILLISECONDS)
T-T0 (SECONDS)

Fig.3


HELIOS-2 γ-RAY BURSTS
5 MAR 1979
TOTAL INTENSITY (COUNTS)
MAX. INTENSITY (COUNTS×32/31.25 mS)

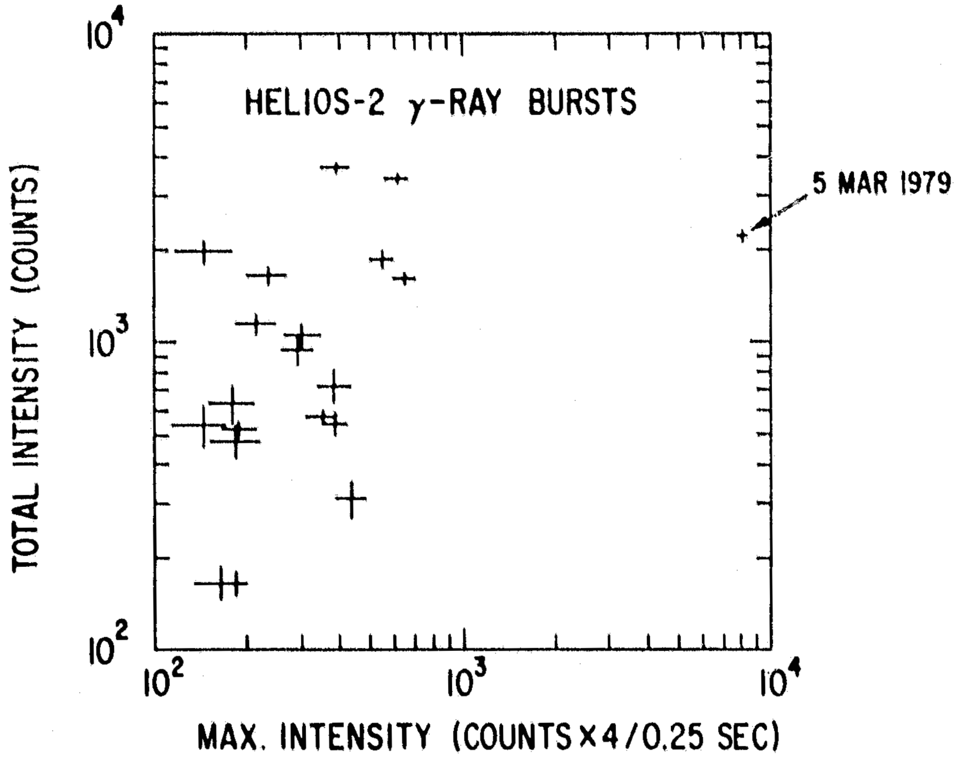

HELIOS-2 γ-RAY BURSTS
5 MAR 1979
TOTAL INTENSITY (COUNTS)
MAX. INTENSITY (COUNTS×4/0.25 SEC)

Fig. 4