GB841215 the Fastest Gamma-Ray Burst?

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Published in:
Nature

DOI:
10.1038/318448a0

Citation for published version (APA):
Laros, J. G., Fenimore, E. E., Fikani, M. M., Klebesadel, R. W., van der Klis, M., & Gottwald, M. (1985). GB841215 the Fastest Gamma-Ray Burst? Nature, 318(6045), 448-449. DOI: 10.1038/318448a0

continuum emission. This continuity has been noticed already for several other properties (polarization, fluctuations of flux and polarization and their timescales)[22], with the BL Lacs always having the most extreme properties.

(3) The position of the optical continuum source should not be centred on the image of the associated galaxy, where observed. Two examples of this sort[1,23], where the distances are 6.5 and 12 arc s, respectively, are known already, whereas if the BL Lac object is in the galaxy, it should always be centrally located. One might also expect a few objects to have multiple images, or the radio source not to coincide with the optical galaxy[24].

(4) But if, contrary to our hypothesis, the strong hard spectrum source sits in the core of a nearby elliptical galaxy, one would often expect to see Balmer line emission from the galaxy, while in our model this should not happen, as there is no physical connection between the hard spectrum source and the galaxy.

We thank M. J. Rees, B. Paczynski and E. L. Turner for helpful discussions. This work was supported in part by NASA grant NAGW-765.

Received 3 July; accepted 13 September 1985.

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GB841215, the fastest γ-ray burst?

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In the 12 yr since the discovery of γ-ray bursts by Klebesadel *et al.*[1], several hundred of these enigmatic events have been observed and catalogued (see, for example, refs 2–5). Their time histories have exhibited a tremendous diversity: they can have durations of milliseconds or minutes; they may contain one or a dozen individual peaks; and they can be highly impulsive or slowly varying. Possibly the only truly unifying observational property of γ-ray bursts is that, with very few exceptions[6,7], the bulk of the energy output seems to be in the form of γ-rays. Here we report the detection on 15 December 1984 at 08.25 UT of an extraordinary outburst, qualitatively different in appearance from all previously observed γ-ray bursts. It is described most conveniently as a 'classical' multi-peaked, hard-spectrum burst that has been compressed in time by a factor of 10–100 while simultaneously having its intensity increased by a like factor (thus conserving fluence). Its peak intensity was much higher than any other known γ-ray burst except for GB790305b, which had an unusually soft spectrum and other unique features that set it apart from 'classical' γ-ray bursts[8]. However, a key point is that if the intensity of GB841215 had been 'normal', its narrow individual spikes would not have been statistically significant with current instrumentation, and the event would have had the appearance of a rather ordinary, short γ-ray burst.

GB841215 was observed by the Los Alamos γ-Burst Detector experiment on the Pioneer Venus Orbiter (PVO)[9], by the UCB/Los Alamos Solar X-ray/γ-Ray Burst experiment on the International Cometary Explorer (ICE, previously ISEE 3)[10], and by the medium-energy detectors[11] on the European Space Agency's X-ray observatory EXOSAT. Figure 1 shows the time history of GB841215 as obtained by the ICE and PVO experiments. Due to excessively high counting rates induced by this event, EXOSAT suffered a 'crash' of its onboard computer and lost all useful data except for an approximate event onset time. The time bins in Fig. 1 are of unequal length because both the ICE and PVO experiments store data in memories that automatically convert to a 'time-to-spill' mode whenever the rate exceeds $1{,}365\ \mathrm{s}^{-1}$, that is, the higher rates are derived from the time interval required to accumulate a specific number of counts (16 in Fig. 1*a* and 32 in Fig. 1*b*). The statistical properties of such a plot are quite different from those of the familiar Poisson distribution and tend to produce a spikier appearance because the fractional standard deviations do not decrease with increasing rate. The rate changes seen in Fig. 1*a*, *b* are significant if they exceed a factor of ~2 or ~1.4, respectively. Thus, during the ~0.3-s impulsive phase of the event, at least seven distinct peaks are evident in both parts of Fig. 1, with the sharpest of these having a full width of $\leqslant 0.005$ s in Fig. 1*a*. No other γ-ray burst has exhibited such rapid multi-peaked structure (hence the word 'fastest' in the title, even though GB790305b may have had a faster rise time). However, it would be unwarranted to conclude that such narrow multiple spikes are rare or unique, because the ability to detect rapid variations is a strong function of intensity—especially in systems with rate-dependent time resolution. If GB841215 had been a factor of 10 or more weaker, it would have had peak rates comparable with other intense bursts, but, its remarkable signature would not have been discernible. Instead, a rather uninspiring 0.3-s event with probable ~0.1-s structure would have been observed. (In fact, other short events observed by PVO have had marginally significant—but never convincing—indications of very fast structure.)

Because of the different energy thresholds of the two experiments (260-keV minimum for the ICE memory data versus 100 keV for PVO), the respective time histories are qualitatively different. In Fig. 1*a* (higher threshold), the peaks are sharper and the 'valleys' are broader and deeper, relative to *b*. Evident only in Fig. 1*b* is the beginning of a weak tail with a softer spectrum that is present for ~10 s. The tail does not show any clear modulations, but we have not yet thoroughly investigated this matter. The spectrum of GB841215 is generally very hard, with considerable emission above 1.5 MeV. The total >30-keV fluence of $4\times10^{-4}\ \mathrm{erg\ cm^{-2}}$ is large, but not exceptional. The peak intensity of $\sim2.5\times10^{-3}\ \mathrm{erg\ cm^{-2}\ s^{-1}}$ is exceptional, and has been exceeded only by GB790305b.

The location information for GB841215 is derived from only a three-satellite arrival-time analysis. Accordingly, there are two non-redundantly determined error boxes located approximately symmetrically with respect to the ecliptic plane. (We are still searching for additional data that could lead to a better localization for this event, but the probability of success is not high.) The $\geqslant 90\%$ confidence error boxes are centred at $(\alpha, \delta)_{1950} =$ (16 h 44 min 48.2 s, −6°42′59″) and (16 h 17 min 09.2 s, −42°24′10″), or $(L_2, B_2) = (11.2, 23.6)$ and (338.8, 5.3). They are best described as 2°-long segments of an annulus whose axis is located at $(\alpha, \delta)_{1950} =$ (21 h 13 min 19.4 s, −18°10′20″) and whose radius is 66°13′19″ ±4″. The ends of the two segments are located at (16 h 43 min 37.9 s, −7°40′57″), (16 h 45 min 56.3 s, −5°48′03″) and (16 h 17 min 29.6 s, −41°23′44″), (16 h 16 min 51.7 s, −43°21′33″). The total error box area is 33 arc min². Searches

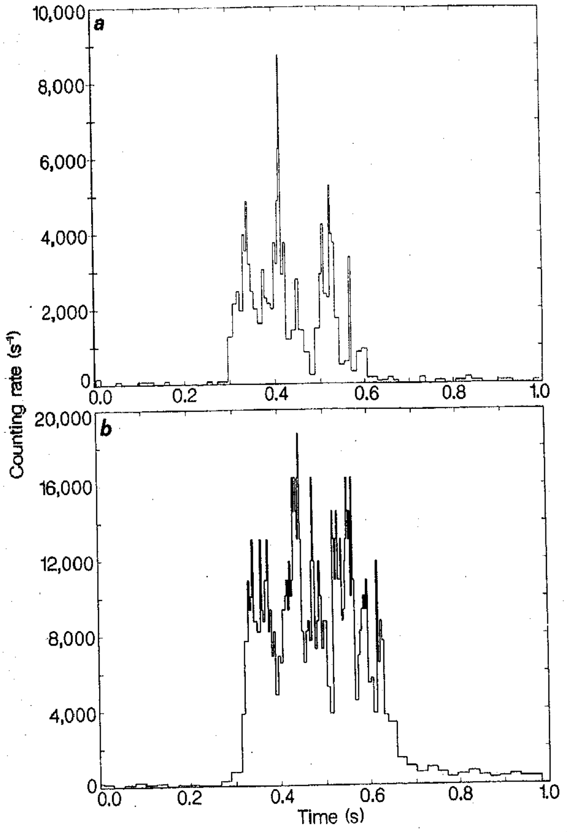

Fig. 1 *a*, ICE time history of GB841215. The energy range is 0.26–2.5 MeV, and the time resolution varies from 0.002 s to 0.012 s. *b*, PVO time history of GB841215. The energy range is 0.1–2.0 MeV, and the time resolution varies from 0.0017 s to 0.012 s.

through various catalogues of γ-ray bursts, pulsars, supernova remnants, flare stars, and high-energy emitters did not result in any source candidates.

We have observed a γ-ray burst with an apparently unique time history. The uniqueness stems from the event's intensity and the rapidity of its temporal structure. However, it is not clear whether the time history is really unique, or whether other events have had similar structure that went undetected due to lack of sufficient event intensity and/or experiment time resolution. If the latter is true, then we must ask if the true 'face' of a γ-ray burst has ever been seen. Are any of our observed γ-ray burst peaks really single peaks? Have any of our measurements (including this one) revealed the underlying fluctuation time scale of a γ-ray burst? Are measured γ-ray burst spectra distorted by pulse pile-up effects? (This could be the case if the photons are emitted preferentially in packets only moderately shorter than the peaks observed in GB841215.) A more detailed discussion of these and other points, as well as a detailed spectral and temporal analysis of this event, will be presented elsewhere.

We thank N. White for valuable help in expediting communications between the widely separated institutions that participated in this research. This work was supported by the US Department of Energy and by NASA under contracts A-98331A and NAS 5-25980.

Received 17 June; accepted 19 September 1985.

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Change of solar oscillation eigenfrequencies with the solar cycle

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Solar acoustic eigenfrequencies depend on the internal structure of the Sun, which may change during the 11-yr cycle of magnetic activity as a result of various effects associated with the solar dynamo. Observations of low-degree acoustic frequencies were made, using the ACRIM instrument on the Solar Maximum Mission (SMM) satellite, in 1980 (near solar maximum) and 1984 (near solar minimum). The analysis of these data, presented here, indicates that the frequencies of $l = 0$ and $l = 1$ acoustic modes in the 5-min band have decreased from 1980 to 1984, by ~0.42 μHz or 1.3 parts in 10^4. This finding may have important implications for our understanding of the mechanism of the solar activity cycle.

The ACRIM solar total irradiance data have been described in detail elsewhere[1]. For the analysis of 5-min oscillations we use a series of flux estimates obtained at the rate of 1/131.072 s, as defined by the periodic chopping of the solar input to the ACRIM sensor by mechanical shuttering. These data are interrupted by the passage of the SMM into the Earth's shadow about every 96 min and by other, apparently random, data gaps.

Data of sufficient quality for studying the 5-min acoustic (p-mode) frequencies were obtained during 1980 from 18 February to 1 December and in 1984 from 1 May (following the successful repair of SMM) to 31 December. Data obtained in 1985 have not yet been analysed.

Frequencies of low-degree p-modes were derived for both the 1980 and 1984 epochs, by means of discrete Fourier transforms of the data from each epoch. The smoothed periodogram of the 1984 data, for example, is shown in Fig. 1. Figure 2 shows the frequency difference (1980 minus 1984) for the nine strongest oscillation peaks in the ACRIM power spectrum. With one exception, the 1980 frequencies of these modes are higher than their 1984 frequencies. To quantify this trend, we assume that all true frequency differences are identical, and that the error distribution is the same for all measured modes. Then we calculate the mean frequency difference, and estimate its error from the standard deviation of the mean of the points:

$$\Delta\nu = 0.42 \pm 0.14 \ \mu\text{Hz} \qquad (1)$$

The 1980 and 1984 observing windows differ in their details. In particular, data from days 243–273 of 1984 were not available

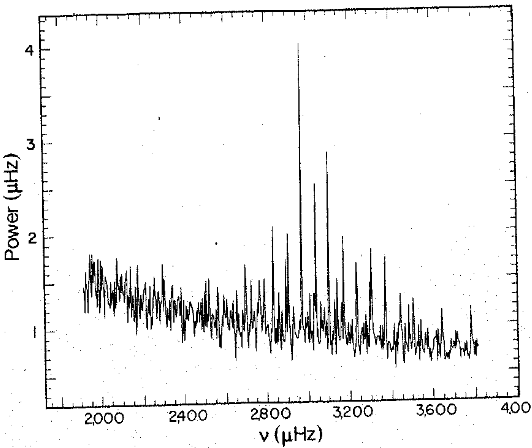

Fig. 1 Smoothed periodogram of 1984 ACRIM data in the 5-min band, showing solar oscillation modes of degree $l = 0$, 1 and 2, and radial order n in the range ~17–26. The unit of power is mean square fractional irradiance variation.