Astrophysics

Comet showers and γ-ray bursts

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BRIGHT bursts of γ-rays originating from a single point in the sky continue to puzzle astrophysicists. Typically the position of the sources is known to an accuracy of a few arcminutes at best, making any identification with known objects in the sky impossible. Also, almost all bursters have been observed only once. A few have flashed repeatedly, and on page 716 of this issue[1], Boer, Hameury and Lasota suggest that comets falling onto magnetic, white-dwarf stars could be the cause of these repeaters. Their theory has the unusual merit in this field of predicting testable effects.

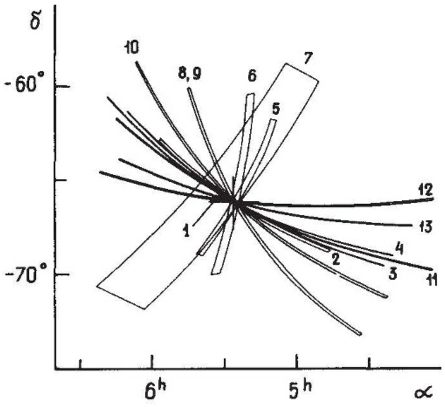
There are a few hundred cosmic γ-ray bursts known, and almost a hundred new bursts are discovered every year with many space probes. There is no such thing as a typical burst. The duration of various events ranges from less than 10 milliseconds to more than 1,000 seconds, the typical photon energies may be 30 keV for some, and 3 MeV for others, the limits of all these ranges being instrumental.

Only three γ-ray bursters are known to repeat: GB790305 (ref. 2), GB790324 (ref. 3) and GB790107 (refs 4,5). The first burst of GB790305 was the famous '5 March 1979' event, by far the most intense of all bursts ever detected, and unique in almost all observable properties. Therefore, even though it was followed by about 15 weaker and softer events over the next 2 years (see figure), it is most likely a different type of object from the other two.

GB790324 was detected on 24, 25 and 27 March 1979, and GB 790107 flashed for the first time on 1 January 1979 and was recorded almost 100 times over the next 5 years. The two differ in the number of repetitions, but otherwise they are remarkably similar: their spectra are unusually soft, and are characterized by a thermal energy of about 40 keV, they are all short, approximately 0.1 s in duration, both were seen close to the galactic plane and both were detected for the first time in the first quarter of 1979. No other soft γ-ray repeater has been discovered since. Some of these remarkable common features are essential, and some are not.

A few explanations for the repeaters have been proposed. For example, I have suggested[6,7] that the gravitational lensing by a cluster of galaxies of a single non-repeating γ-ray burst could lead to a series of micro-images that arrive at different times in the error box of the repeater. Kouveliotou *et al.*[8], considering the directions to the three repeaters, suggest that they could be population I (young, metal-rich) stars in our Galaxy and in the nearby Large Magellanic Cloud. Livio and Taam[9] have proposed that comets falling onto a neutron star would give the right kind of γ-ray spectrum and repeat frequency. Other models have included starquakes and local thermonuclear runaways on the surface of accreting neutron stars.

The model of Boer *et al.*[1] is similar to that of Livio and Taam[8]. The authors



Error boxes for the positions of 13 bursts from the source of the 5 March 1979 event, detected between 5 March 1979 and 31 December 1982 by detectors on pairs of Venera spacecraft. Pinpointing the source of γ-ray bursts is difficult because of their transient nature. These positions were determined by triangulation. Burst durations varied between 0.1 s and 3.5 s. (From ref. 2.)

propose that the repeaters are due to comets falling onto nearby magnetic white dwarfs. Livio and Taam noted that the spectra of the repeaters are very similar to those of X-ray binary pulsars, which are known to be magnetic neutron stars accreting matter from a binary partner. (The distinction between the 'soft' γ-rays of the bursters and the 'hard' X-rays of the binaries is largely artificial, both occupying a range in the electromagnetic spectrum around 40 keV.) If the accretion was intermittent, as would be the case if comets and not gas were the accreted matter, the source might be a soft γ-ray repeater.

But there is a problem: neutron stars are supernova remnants and any cloud of comets would probably be ejected during a supernova explosion. Boer *et al.*[1] noticed that the spectra of soft γ-ray repeaters are also very similar to those of accreting magnetic white dwarfs observed in binary systems known as polars (AM Her type stars). As the formation of white dwarfs is a gentle process, there is no reason not to have comets around them. Presumably, on its first passage close to a white dwarf, the nucleus of a comet would be broken up into several pieces, so that on subsequent orbits there would be a series of accretion events, giving rise to recurrent bursts.

The strength, duration, and interval between the bursts are difficult to estimate, and probably impossible to calculate with any precision. The spectrum may also be very difficult to calculate. Fortunately, a semi-empirical approach is possible, and fairly convincing. Observations of polars demonstrate that an accreting magnetic white dwarf produces a hard X-ray spectrum, and the accretion luminosity of polars is known to vary on a very short timescale, so burst-like events should be possible.

If the two soft repeaters are indeed white dwarfs, then they must be very nearby to account for the observed intensity. Boer *et al.* estimate that their distance should be no more than 15 parsecs — a thousand times closer than the Galactic Centre. The faintest (presumably the oldest) white dwarfs known have absolute visual magnitude $M_V \approx 16$ (ref. 10). At a distance of 15 parsecs the faintest white dwarf should have an apparent magnitude of $m_V \approx 17$. The error box for the position of GB790107 is a very elongated ellipse, with a total area of about 0.12 square degrees[4], and that of GB790324 is only slightly larger[3]. Therefore, it should be a fairly straightforward matter to look for nearby stars in these areas, identifiable by their high proper motion. The only problem is that the fields are very crowded, right in the Milky Way.

The new theory has a very clear prediction. If two magnetic white dwarfs are discovered in the two small error boxes then they will have to be associated with the two soft γ-ray repeaters, no matter how difficult it might be to work out theoretical details. The *a priori* probability of finding two magnetic white dwarfs in two randomly placed error boxes is only 10^{-9} (ref. 11). If no white dwarfs can be seen, then the theory is dead, no matter how well the details can be worked out. □

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