An Unusual X-ray Burst from the Globular Cluster M28

E. V. Gotthelf
Laboratory for High Energy Astrophysics
NASA/GSFC, Greenbelt, MD 20771

S. R. Kulkarni
Division of Physics, Mathematics and Astronomy, 105-24
California Institute of Technology, Pasadena, CA 91125, USA

ABSTRACT

We report the discovery of an unusual X-ray burst from the direction of the Globular Cluster M28 using data acquired with the ASCA Observatory. The burst was recorded by all four ASCA telescopes and displays a fast ($\lesssim 70$ ms) rise followed by an exponential decay ($\tau = 7.5$ s) and a steady afterglow which lasts between 800 – 3250 s. The image of the burst is consistent with an ASCA point source and is centered on quiescent X-ray emission from the core of M28. The burst temporal profile is similar to Type I bursts emitted by accreting neutron stars of low mass X-ray binaries (LMXB). We argue that the burst arises from an LMXB that is located in the core of M28.

The burst is unique in two ways: it is intrinsically sub-luminous, $\sim 0.02L_E$ and more importantly, originates from a source whose quiescent luminosity is fainter than that of the known cluster bursters by three orders of magnitude. We suggest that this burst is from a highly magnetized neutron star accreting at a low rate. These accreting systems may account for the mysterious low luminosity X-ray sources in globular clusters.

Subject headings: stars: individual (M28,PSR B1821–24) — stars: neutron — X-rays: stars — X-rays: bursts

1. INTRODUCTION

The low mass X-ray binaries (LMXB) are the brightest X-ray sources in the sky. About 124 are known of which $\sim 40$ show Type I bursts (Lewin, van Paradijs, & Taam 1993). These bursts are characterized by a sharp rise time and a spectrum which becomes softer as the burst evolves.
The bursts have been interpreted as cooling of a thin layer of material on the surface of neutron stars that is heated by unstable nuclear fusion within this layer (Woosley & Taam 1976; Maraschi & Cavaliere 1977). The peak luminosity appears to have a small dispersion, less than a factor of 10 with a maximum value equal to the Eddington luminosity, \( L_E \sim 10^{38} \text{ erg s}^{-1} \). A disproportionate number of LMXBs are found in the Galactic globular clusters and all these have exhibited a Type I burst (Dotani et al. 1990).

A day long observation of the globular cluster M28 was conducted with the ASCA X-ray Observatory (Tanaka et al. 1994) on March 29, 1995 UT. The original motivation was to search for X-ray pulsations from the known 3-ms radio pulsar PSR B1821−24 (Lyne et al. 1987). These pulsations were subsequently detected (Saito et al. 1997). Recently, during the course of verification of a timing package, we analyzed this data. In the process we discovered an unusual X-ray flash, the analysis of which is reported in this Letter.

2. OBSERVATIONS

The ASCA satellite consists of four co-aligned telescopes, each of which is a conical foil mirror coupled to one of two types of focal plane sensors, the two Solid State Imaging Spectrometers (SIS–0 & SIS–1) or the two Gas Imaging Spectrometers (GIS–2 & GIS–3). The SIS detectors are sensitive to photons in the 0.4 − 10.0 keV energy band with a nominal spectral resolution of 2% at 6 keV, scaling as \( \sim E^{-1/2} \). The angular resolution of the SIS is \( \sim 1' \), limited by the mirror optics. The SIS data were acquired in the “4-CCD” mode, using 16 s integrations, with the 22' × 22' SIS field-of-view centered on the core of the M28 cluster.

The GIS detectors have a relatively modest spectral resolution of 8% at 6 keV, in comparison to the SIS, with a larger effective area at higher energies. The temporal resolution is also higher, 61 \( \mu \)s or 0.5 ms, depending on the mode that was selected. The images formed by the GIS suffers from an energy dependent blur which results in an effective angular resolution of 3'. The GIS data were edited using the standard “REV1” processing criteria to exclude periods of high background contamination. The SIS data were time filtered using the GIS good time intervals to directly compare the light curves from both instruments. The final effective exposure time is \( \sim 37 \text{ ks} \) per detector.

3. RESULTS

The ASCA image of the M28 region obtained using the entire data set contains a single unresolved source, AX J18245−2451. This source is located at the light centroid of the globular cluster M28 and has been studied in detail by Saito et al. (1997). We constructed light curves using photons from a 12' diameter aperture centered on AX J18245−2451 and found a flash, lasting tens of seconds, followed by an afterglow. The profile of the burst is essentially identical in
all instruments (Figure 1). The background light curves from each detector show no appreciable rise in the overall count-rate during the flash or the afterglow. The summed background light-curve is shown in Fig. 1 and contains photons from a concentric annulus of radius 12′ − 20′ (GIS) and > 12′ (SIS).

The background particle flux rate during the burst interval, as measured by the GIS radiation belt monitor, shows no unusual activity during this period. A careful study of the GIS scaler (discriminator) rates, which record the number of detections in each GIS before any detailed processing is done, also show no abnormal behavior. The scaler rates during the burst are at no time high enough to warrant dead-time correction. As expected, the burst count-rates measured by each detector are not the same. This is because the four mirrors are not quite co-aligned, and a source will fall at different off-axis angles for each mirror and thus suffer a varying amount of mirror vignetting (geometric shadowing). A second reason is that the relative detector efficiency is a strong function of position. The combined effect of the two is typically ∼ 30%. Indeed, we find that the relative burst fluence measured from each detector is consistent with that expected for a cosmic (i.e. a distant) source imaged through the telescopes; the relative count-rates for the burst are identical to those measured for the quiescent emission, within counting statistics and spectral differences.

Figure 2 shows the combined SIS (SIS–0 + SIS–1) images and spectra of AX J18245−2451 obtained during the time intervals defined in Table I: pre-burst, flash, afterglow, and post-burst. The images are centered on AX J18245−2451 and display the 22′ × 22′ field-of-view of the SIS. The burst and afterglow photons form an image which, within the photon counting errors, is a point source with the same pixel centroid as AX J18245−2451; the 95% confidence radius of the burst localization is 40″ (see Gotthelf 1996 for details on measurement accuracy with the SIS).

The facts presented so far – (1) the detection of the burst in all four detectors, (2) the absence of any abnormal behavior in the background rate, (3) the consistency of the image of the burst in each detector, including the variation in fluence expected from telescope vignetting – lead us to conclude that the burst is cosmic in origin. This conclusion motivated us to carry out a detailed analysis of the burst.

For each of the four sub-time intervals specified in Table 1 we created a spectrum from photons extracted from a 12′ diameter circular region centered on the image peak. These spectra are displayed in Fig. 2. To compare spectra from different time intervals we have normalized them by duration and plotted them auto-scaled to the peak value. The burst rate is almost 2 orders of magnitude higher than the quiescent rate. Even without any sophisticated analysis we note that the spectrum of the burst is distinctly different from that of the quiescent emission. The results discussed here are identically reproduced by the GIS data.

As with the SIS data, GIS photons within a 12′ diameter circular region centered on AX J18245−2451 were extracted. The burst profile derived from the combined GIS data is shown in Fig. 3. The rise of the burst is unresolved. A photon-by-photon arrival time analysis of the
high time resolution GIS data yields a turn-on time of < 70 ms. The burst decay signal is well represented by an exponential model, \( I(t) = I_p e^{-t/\tau} + I_a S(t) + I_q \), where \( S(t) \) is the step function, \( S(t) = 0, t < 0 \) and \( S(t) = 1, t > 0 \) and the subscripts \( p, a, \) \& \( q \) refer to the peak, afterglow and quiescent (pre-burst) counting rates. Fitting the data to this functional form we obtain \( I_p = 28.0 \) cps, \( I_a = 0.20 \) cps, \( I_q = 0.08 \) cps and \( \tau = 7.5 \) s; this model is displayed in Fig. 3 (solid line). The start time of the first significant burst emission measured by the two instruments is consistent with counting statistics (~ inverse of the count rate). The estimated uncertainty in the onset of the burst is about 40 ms. The afterglow increases the quiescent (pre-burst) count rate ~ 2.5 times and lasts between 800 s to 3250 s; the gap in the data is due to Earth block.

Comparison of the burst profile in the hard (> 2.0 keV) and soft-band (< 2.0 keV; see Figure 3) shows some indication of spectral evolution from the initial soft impulse. Specifically, the spectrum is seen to soften (i.e. more photons at lower energies relative to higher energies) as the burst evolves.

Spectral fits to the mean burst spectrum obtained from the two GISs are presented in Table 2. The background is a negligible contribution during this interval. We fit several standard models to the data, all of which produced reasonable fits. This is not surprising given the small number of counts. It is noteworthy that all three models require a best-fit \( N_H \) value larger than that obtained by Saito et al. (1997) from analysis of the 3-ms pulsar data. Saito et al.’s \( N_H \) value of \( 2.8 \times 10^{21} \) cm\(^{-2}\) is consistent with other measures of the interstellar absorption expected to the cluster M28. Thus we conclude that there is an additional absorption internal to the bursting source.

4. DISCUSSION

The duration of the flash is so short that we can safely exclude stellar flares (Greiner, Duerbeck & Gershberg 1994) from an active star such as UV Ceti or a T Tauri (young) stars. Our flash was not coincident in time with any known gamma ray burst, making it unlikely to be an X-ray precursor. This flash bears some similarity to the flashes reported from analysis of the database of the X-ray satellite EINSTEIN (Gotthelf, Hamilton & Helfand 1996). But the sky distribution of the EINSTEIN flashes does not suggest a globular cluster origin. We note that both the temporal and spectral properties of our flash are similar to those of Type I bursts. Furthermore, the flash is coincident with the core of a globular cluster and clusters are known to be relatively abundant in LMXBs. To our knowledge all LMXB’s in clusters have exhibited a Type I burst (Dotani et al. 1990). Thus we adopt the simplest hypothesis, viz., that this is a Type I burst originating in the globular cluster M28.

Using the mean spectrum for the flash (Table 2) we obtain a peak flux of \( 1.4 \times 10^{-9} \) erg cm\(^{-2}\) s\(^{-1}\) which translates to an (assumed) isotropic luminosity of \( L_B \sim 4.3 \times 10^{36} \) erg s\(^{-1}\); the distance to M28 is assumed to be 5.1 kpc (Rees & Cudworth 1991). The total energy in the burst is \( E_B \sim 3.1 \times 10^{37} \) ergs. Almost all Type I bursts reported in the literature have peak luminosities
Let $f L_E$ with $f$ ranging from more than 0.1 to 1 where $L_E \sim 2 \times 10^{38}$ erg s$^{-1}$ is the Eddington luminosity for a neutron star. Our burst appears to have $f \sim 0.02$. This may appear to be in conflict with our conclusion that the burst under discussion is a Type I burst. However, below, we argue that this is not a fatal objection.

Type I bursts are understood to be thermo-nuclear instabilities of the accreted matter on neutron stars. Once a critical column density, $C_{\text{cr}}$, is reached nuclear fusion produces far more heat than can be radiated away. This results in the layer getting heated till expansion sets in. The resulting cooling accounts for the softening of the spectrum as the burst progresses. At any given point on the surface of the neutron star, the critical column density is a function of the composition (including metallicity) of the accreted gas, the core temperature of the neutron star and the local accretion rate (Taan & Picklum 1978; Joss & Li 1980; Fujimoto, Hanawa & Miyaji 1981). $C_{\text{cr}}$ (Fujimoto, Hanawa & Miyaji 1981; Bildsten & Brown 1997) varies from $2 \times 10^{8}$ gm cm$^{-2}$ to $2 \times 10^{7}$ gm cm$^{-2}$ as the core temperature varies from $10^{7.5}$ K to $10^{9}$K.

Strong magnetic fields force the accretion to polar cap regions, thereby changing the local accretion rate. This fact explains why accreting X-ray pulsars (which are highly magnetized neutron stars) are not seen to burst and likewise why bursters do not pulse. For a given source, $C_{\text{cr}}$ is not expected to be highly time dependent. For values of $C_{\text{cr}}$ applicable to most bursters, the observed range in $f$ translates to an inference that the bursts are from a substantial portion, 10% to 100%, of the surface of the neutron star. This inference fits in well with our ideas that LMXBs are magnetically weak neutron stars and thus there is little impediment to prevent the spread of accreted material.

There is an alternative explanation for sub-luminous Type I bursts. Garcia & Grindlay (1987) noted that a Type I burst from 4U2129+47 had an even lower $f$ value, $\sim 0.002$. They persuasively argue that 4U2129+47 is a LMXB whose thick accretion disk obscures the neutron star from our sight. From our vantage point we only see a fraction of the quiescent and the burst emission that is scattered by the electrons in the corona. This accounts for the small value of $f$. This model also explains two other peculiarities of the 4U2129+47 burst, a longer rise time (6 s instead of the usual <1 s) and the higher effective temperature, $\sim 3$ keV instead of $\lesssim 2$ keV. Scattering allows multi-path propagation which then accounts for the longer rise time. Inverse Compton scattering of photons by the hot electrons in the corona also boosts the energy of the incident photon.

However, the flash reported here has a soft spectrum and a short rise time and appears to be no different from a typical Type I burst. Thus we conclude that our flash is a Type I burst but intrinsically sub-luminous. If so, we are forced to the conclusion that material from only a small area of the neutron star, between 0.1% to 1%, was involved in this burst, depending on the value of $C_{\text{cr}}$ we adopt. For a low luminosity source, $C_{\text{cr}}$ is higher and thus we prefer the smaller value for the area. The accreted material is probably confined by a strong magnetic field. With such a small area for the burst we should expect to see very deep modulation due to rotation. The lack of a significant modulation in the burst profile indicates that we are either looking down at the
magnetic pole or that the neutron star’s rotation period is much greater than 10 s.

In the Type I burster model, the burster must have a certain quiescent X-ray luminosity. The quiescent emission is generated from accretion of matter into the deep potential well of the neutron star. This gas subsequently undergoes nuclear fusion. Therefore, one expects the ratio of the quiescent luminosity to the mean burst luminosity to be the ratio of the potential energy of one gram of matter to the nuclear energy liberated from the same gram or about 25 (H-burning) or 100 (He-burning). Thus the mean time between bursts, $T$, is expected to satisfy the following relation: $T \gtrsim \alpha E_B / L_Q$. Here $E_B$ is the integrated energy of the burst and $L_Q$ is the luminosity due to accretion i.e. the luminosity of the source in quiescence.

From observation of the M28 region with the ROSAT High Resolution Imager (HRI) only two X-ray sources are found in the entire HRI field-of-view, the 3-ms radio pulsar RX J18245−2452P and RX J18245−2452E (Danner et al. 1997). These are separated by 10″ in the HRI images. However, at the resolution of the ASCA mirrors these two sources blend together and thus our ASCA source AX J18245−2451 is the sum of the two ROSAT sources. Danner et al. (1997) speculate that RX J18245−2452E is either a collection of low luminosity point sources or a synchrotron nebula. An upper limit to the quiescent flux of the burster is thus a fraction of the luminosity of RX J18245−2452E, say $L_Q \lesssim 10^{33}$ erg s$^{-1}$. Given that the energy of our burst is $E_B \sim 3.1 \times 10^{37}$ erg we find $T \sim 0.1(\alpha/100)$ yr. This estimate of $T$ is consistent with our lack of detections of any other burst from M28 in archival X-ray data from the ROSAT or EINSTEIN missions.

5. SUMMARY

We have discovered a Type I burst which is unique in two ways: (1) it is sub-Eddington by a factor of 100 and more importantly (2) the quiescent luminosity of the source is three orders of magnitude smaller than that of all previously known bursters. We propose that these two observations can be explained by a model of a highly magnetized neutron star accreting at a low rate. The low accretion rate results in an Alfvén radius that is large and thus an equilibrium spin period that is concomitantly long (Bidlsten & Brown 1997). This provides a natural explanation for the observed lack of any modulation in the burst profile despite the fact that the burst supposedly arises from a very small region.

Radio pulsars in globular clusters have a range of magnetic field strengths; see review by Kulkarni & Anderson (1996). These authors have argued that this observation can be explained by assuming that all cluster neutron stars are born with a distribution of magnetic field strengths similar to those in the disk (i.e. a typical dipole field strength of $10^{12}$ G). Depending on the accretion history a range of field strengths are then obtained. However, do note that Lyne, Manchester and D’Amico (1996) disagree with this conclusion. Leaving aside this dissenting view we note that in the picture of Kulkarni & Anderson highly magnetized neutron star accreting
matter at a low rate are expected to be quite common. Thus a natural explanation can be found in this framework for the type of LMXB we have hypothesized as the source of the burst discussed in this paper.

A natural consequence of this suggestion is that similar flashes should also be seen towards other clusters. Why have not such anomalous bursts been noticed before? We argue that previous non-imaging missions missed these bursts because of their limited dynamic range in sensitivity. Imaging telescopes have the sensitivity to detect such bursts. Unfortunately, the frequency of such flashes is low, a dozen per year per rich cluster. Discovery of another such burst from M28 would require two months of dedicated observations by the ASCA satellite! Thus it will not be easy to verify this prediction. We eagerly look forward to the deployment of large field-of-view imaging monitors such as that proposed by Priedhorsky et al. (1996).

Finally, we note that this class of bursts offers new insights into the physics of thermonuclear instabilities. For example, the fact that the quiescent luminosity is low enabled us to clearly recognize the afterglow. This phenomenon in itself is of interest to models of Type I bursts. The afterglow could arise from extended burning (Fushiki et al. 1992) or slow propagation of the burning front (Bildsten 1995) or simply the emission from a transiently heated surface. The first two reasons have been advocated for conventional Type I bursts but the latter is a new twist. It is important to note that the surface of the neutron stars in these systems is expected to be cooler than those of the brighter bursters, both because of a very small burst rate as well as a small quiescent luminosity. As remarked earlier, the value of the surface temperature (core temperature) is an important parameter in the theory of Type I bursts. This opens the possibility that such bursts offer tests of the model over a range of previously unexplored parameter space.

REFERENCES

Bildsten, L. 1995, ApJ, 438, 852
Bildsten, L. & Brown, E. F. 1997, ApJ, 477, 897
Danner, R. M., Kulkarni, S. R., Saito, Y. & Kawai, N. 1997, Nature, in press.
Dotani, T., Inoue, H., Murakami, T., Nagase, F., Tanaka, Y., Tsuru, T., Makishima, K., Ohashi, T. & Corbet, R. H. D. 1990, Nature, 347, 534
Fujimoto, M. Y., Hanawa, T. & Miyaji, S. 1981, ApJ 247, 267
Fushiki, I., Taam, R. E., Woosley, S. E. & Lamb, D. Q. 1992, ApJ, 390, 634
Garcia, M. R. & Grindlay, J. E. 1987, ApJ, 313, L59
Gotthelf, E. V., Hamilton, T. T. & Helfand, D. J. 1996, ApJ 466, 779
Gotthelf, E. V., in ASCANEWS, #4, HEASARC (Greenbelt: NASA/GSFC) (1996)

Greiner, J., Duerbeck, H. W. & Gershberg, R. E. (eds) 1994, Flares and Flashes, Springer-Verlag, 1-456

Hameury, J. M., Bonazzola, S., Heyvaerts, J. & Lasota, J. P. 1983, AA 128, 369

Joss, P. C. & Li, F. K. 1980, ApJ 238, 287

Kulkarni, S. R. & Anderson, S. B. 1996, IAU Symposium, 174, 181

Lewin, W. G., van Paradijs, J. & Taam, R. E. 1993, Space Sci. Reviews, 62, 223-389

Lyne, A. G., Brinklow, A., Middleditch, J. M., Kulkarni, S. R., Backer, D. C. & Clifton, T. R. 1987, Nature 328, 399

Lyne, A. G., Manchester, R. N. & D’Amico, N. 1996, ApJ, 460, L41

Maraschi, L. & Cavaliere, A. 1977, in Highlights in Astronomy, E. A. Müller (Ed.), (Reidel, Dordrecht), Vol. 4, 127

Priedhorsky, W. C., Peele, A. G. & Nugent, K. A. 1996, MNRAS, 279, 733

Rees, R. F. & Cudworth, K. M. 1991, AJ, 102, 152

Saito, Y., Kawai, N., Kamae, T., Shibata, S., Dotani, T. & Kulkarni, S. R. 1997, ApJ 477, L37

Taam, R. E. & Picklum, R. E. 1978, ApJ 224, 210

Tanaka, Y., Inoue, H. & Holt, S. S. 1994, PASJ, 46, L37

Woosley, S. E. & Taam, R. E. 1976, Nature, 263, 101

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Table 1
M28 Observation Log and Burst Time Intervals

| Interval     | Start Time    | Exposure\(^a\) | Counts\(^b\) | Rates \(^c\) |
|--------------|---------------|----------------|--------------|--------------|
|              | (UT)          | net(total) (sec) |              |             |
| Observation  | 28/03/95 17:23:36 | 74,220(207,328)   | 6,654         | 0.09         |
| Pre-burst    | 28/03/95 17:23:36 | 62,581(181,664)   | 5137          | 0.08         |
| Burst        | 29/03/95 18:37:33 | 90(90)           | 212           | 2.21         |
| Afterglow    | 29/03/95 18:38:18 | 1,440(1,528)      | 400           | 0.28         |
| Post-burst   | 29/03/95 18:51:02 | 10,109(24,036)    | 905           | 0.09         |

\(^a\) Screened (i.e. Good Time Interval, GTI) and total exposure time from both GIS sensors.

\(^b\) Total photons falling within a 6 arcmin radius aperture centered on the X-ray source (both GIS sensors).

\(^c\) Peak rate is 28 counts per sec.
Table 2
M28 Burst GIS Spectral Fits$^a$

| Model   | Continuum | $N_H^I$ $^b$ | Fluence$^c$ | $\chi^2_\nu (\nu)$ |
|---------|-----------|--------------|-------------|---------------------|
| Power Law | $3.7^{+1.2}_{-0.9}$ | $2.2^{+1.2}_{-1.0}$ | $1.1 \times 10^{-8}$ | 0.9 (12) |
| Blackbody | $0.6^{+0.1}_{-0.1}$ | $0.35^{+0.0}_{-0.0}$ | $7.7 \times 10^{-9}$ | 1.3 (12) |
| R–S | $1.6^{+1.0}_{-0.5}$ | $1.3^{+2.6}_{-0.9}$ | $1.1 \times 10^{-8}$ | 1.1 (12) |

$^a$ GIS-2 & GIS-3 photons collected using a 6 arcmin aperture centered on the source with no background subtraction (assumed negligible). Spectral fits are in the 1.0 – 10.0 keV range. Errors are 90% confidence region for a single interesting parameter.

$^b$ Intrinsic absorption, after allowing for an interstellar absorption of $2.9 \times 10^{21}$ cm$^2$ (from Saito et al. 1997)

$^c$ The unabsorbed fluence at the front of the telescope, integrated during the 45 sec burst interval.
Fig. 1.— The burst from M28 was observed by all four telescopes aboard the ASCA Observatory. The burst profile is essentially identical in all instruments with a bright peak and a distinct afterglow signature. These light curves are binned in 16 s steps. The amplitude of the burst (as defined by the height of the peak bin) is determined by the large, undersampled, binning and is somewhat arbitrary. No appreciable rise in the background rate accompanied the burst; the burst is coincident with the quiescent flux from the core of M28. The data gap between the interval 3.2 and 5.6 ksec is due to SAA passage.
Fig. 2.— The combined SIS (SIS–0 + SIS–1) images and spectra of AX J18245–2451 obtained during the time intervals defined in Table I: pre-burst (top left), flash (top right), afterglow (bottom right), and post-burst (bottom left). The images are centered on the (same) measured centroid of AX J18245–2451 and display the entire 22′ × 22′ field-of-view of the SIS. The burst and afterglow images are consistent with a celestial point source (of equivalent counts) focused on the detectors. The 12′ diameter circle denotes the extraction region for the spectra plotted here, which are gain corrected and shown rebinned in units of ∼ 125 eV per bin. The dashed vertical line indicates the energy channel equivalent of 1 keV. The dashed horizontal line denotes a fiducial count rate of 0.01 cps per bin; the burst rate is almost 2 orders of magnitude higher than the quiescent rate. These results are perfectly reproduced by the GIS data (not shown).
Fig. 3.— The combined GIS–2 and GIS–3 light curve binned in 1 sec steps and centered on the prominent burst interval (histogram). The burst risetime is unresolved and is limited by counting statistics to < 70 msec. The decay signal is well represented by an exponential model (solid line) with a e-fold time of $\tau = 7.5$ s. (Insert) The spectrally resolved light curves. The dash curves includes only photons with channel equivalent energy above 2 keV, whereas the solid histogram is for the remaining, soft photons. There is some indication of spectral evolution (see text).