Smithsonian Astrophysical Observatory

Memorandum

To: AXSIO team mrg-2011-09-01
From: Mike Garcia, Randall Smith, Andrew Ptak, Simon Bandler
Date: Sept 27, 2011
Re: AXSIO rates for Bursting NS, definition of 'Crab'

Ref:

Introduction

Fluxes for bright sources are often given in Crab units, but the spectrum of these sources often differs substantially from the Crab Nebula. At high rates, the XMS response is sensitive to the actual makeup of the spectrum. The brightest sources AXSIO is likely to observe are neutron star "bursters" with the Galaxy, which typically have absorbing columns of $N_H \sim 1 \times 10^{22}$ cm^{-2} , corresponding to an optical depth $\tau>2$ .4 at 1 keV. Below we give the conversion rates for 'Crab' units in AXSIO, and the counting rates and spectral energy distribution for two bursters that are representative of the range of flux and spectra from bursters.

The rates calculated using XSPEC, using Response (RMF) file ixo_xms_none_20100524.rmf and Auxiliary Response (ARF) axsio_20110818.arf

We note the following definition of a 'Crab':
1 Crab = 75 RXTE / ASM counts/sec (2-10keV, 8 anodes, ASM web pages)
Crab spectrum (MVZ handbook)
$dN/dE = 10\ E^{-2.05} \exp(-\sigma N_H)$ photons/cm^2/s/keV
$N_H = 3 \times 10^{21}$ cm^{-2}
WEBPIMMS: 75 ASM c/s, with Crab spectrum:
Norm = 8.5, input energy range default
flux over 0.3-10.0 keV = 2.9e-8 ergs/cm2/s (observed)
flux over 0.3-10.0 keV = 4.8e-8 ergs/cm2/s (emitted)
flux over 2.0-10 keV = 2.0e-8 ergs/cm2/s
flux over 2.5-25.0 keV = 3.1e-8 ergs/cm2/s (observed)
(Note Galloway et al. 2008 footnote 10, 'Crab is 3.3e-8 erg/cm2/s 2.5-25keV'. Also, the true Crab spectrum is more complex; see Kaastra et al. (2009, A&A, 497, 291) for complete details.)

Source	Flux (ergs/cm^2/s)	N_H ($10^{22}cm^{-2}$)	'Crabs'	AXSIO Rate
Crab	3.1×10^{-8} (2-10keV)	0.3	1	45,000 c/s
4U1728-34	6.0×10^{-8} (2.5-25keV)	2.3	2	13,000 c/s
'Brightest'	12×10^{-8} (2.5-25keV)	2.3	4	26,000 c/s
EXO0748-676	2.1×10^{-8} (2.5-25keV)	0.4	0.66	6,300 c/s

The fluxes for the bursters above are at the peak of Type 1 X-ray bursts as observed with the XTE PCA, and are taken largely from Galloway et al. (2008 ApJS 179,360-422). We chose 4U1728-34 as representative because it has typical N_H for burster of 2.3 x 10^{22} (Galloway 2010), but is unusual in that it bursts regularly and often. It has a spin frequency = 363Hz. The average flux at the peak of the brightest (=radius expansion) bursts is 8.4 x 10^{-8} ergs/cm^2/s (bolometric, emitted, Galloway et al. 2008). The typical correction factor from observed 2.5-25keV flux to the (total) bolometric value, emitted, is 1.37 for 4U1728-34 and also averages 1.38 for all the bursters (Misanovic 2010, Galloway et al. 2008 Table 2). We therefore estimate the observed flux at the peak of the burst is 6 x 10^{-8} ergs/cm^2/s (2.5-25keV). This flux and spectrum will produce 13,200 c/s in the AXSIO XMS. Brightest bursts seen with RXTE in the compilation of Galloway et al. (2008) have peak fluxes no more than twice this, ie, from 4U1608-52 and SAX J1808.4-3658 (see Galloway et al. 2008 Table 9).

EXO0748-676 has one of the lowest cutoffs among the bursters, so is a good example of a source with substantial counts at low energies. N_H is estimated at 4 x 10^{21} cm^{-2} (Thomas et al. 1977, Wolff et al. 2005). This low absorption means the bolometric correction to the 2.5-25keV bandpass of RXTE is higher than average, at 1.93 (Galloway et al. 2008 Table 2). Peak bolometric fluxes in the strong bursts seen with RXTE are 4.1 x 10^{-8} ergs/cm^2/s, corresponding to 2.1 x 10^{-8} ergs/cm^2/s (2.5-25keV).

The figure below shows the predicted counts/keV for these three sources as would be seen in the AXSIO calorimeter, as well as the integrated counts over energy.

In order to determine the actual rates per pixel given a Gaussian PSF, we have numerically integrated a PSF with a linear Gaussian shape. While the actual PSF is very likely to have broad wings with a more compact core, this Gaussian approximation will give an upper limit and is sufficient for the task at hand. Numerical integration shows that 50% of the flux is contained within a radius = 1.2σ. The surface density falls by a factor of 2 from r=0 to r=1.2σ.

The inner AXSIO array as defined in memo rks-2011-02 is a 12x12 array (later revised to 24x24) of 1.5'' pixels. The flux from the Crab within the 10'' HPD beam amounts to 22,500 c/s spread over a 6.7 pixel diameter area, for an average rate of 640 c/s/pixel. Given the surface density profile above, we expect 850 c/s/pixel at the center of the beam and 425 c/s/pixel at the HPD point. Given the maximum rate capacity of the 75μ pixels of 300 c/s, we find a limit of ~1/3 Crab or ~15,000 c/s in the integrated beam.

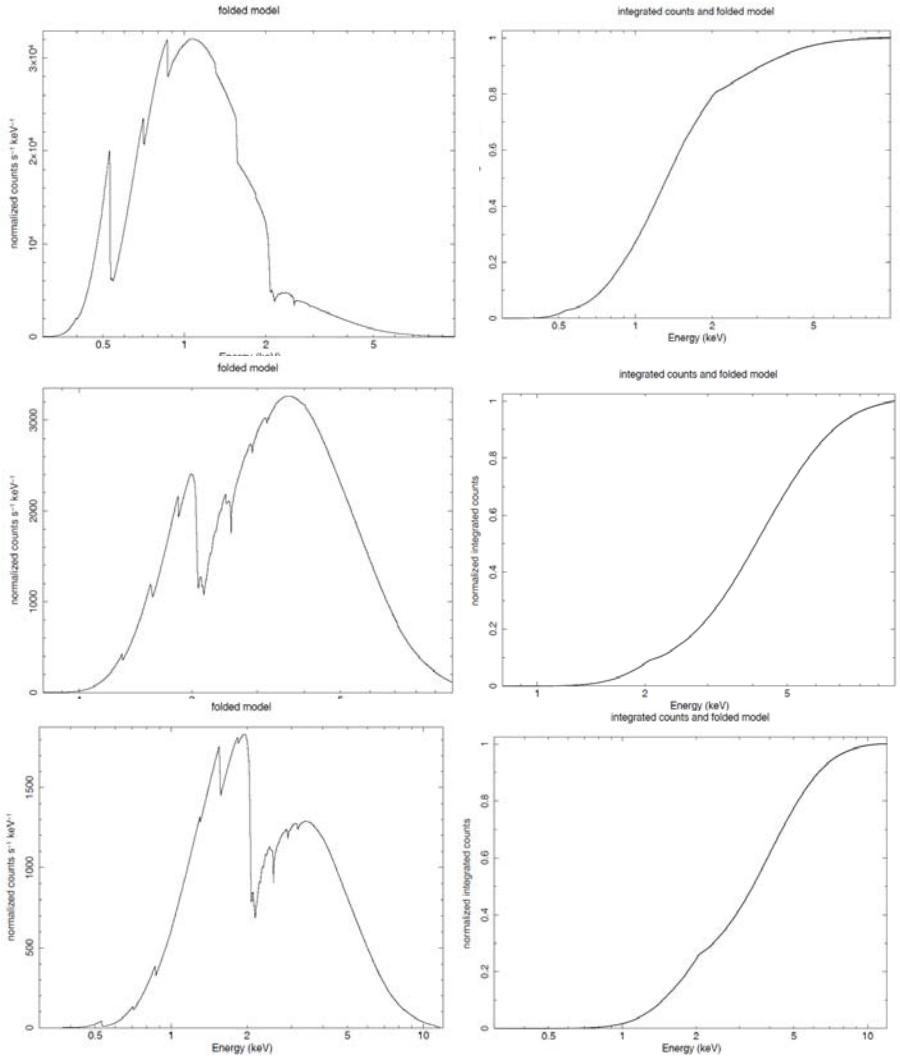

Figure: AXSIO counting rates for typical bright, bursting X-ray Binaries.