3A 0535+262 IN OUTBURST

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ABSTRACT

The Be/X-ray binary 3A 0535+262 has the highest magnetic field determined by cyclotron line studies of all accreting X-ray pulsars, despite an open debate if the fundamental line was rather at 50 or above 100 keV as observed by different instruments in past outbursts. The source went into quiescence for more than ten years since its last outbursts in 1994. Observing during a 'normal' outburst August/September 2005 with *Integral* and *RXTE* we find a strong cyclotron line feature at ∼45 keV and have for the first time since 1975 determined the low energy pulse profile.

Key words: X-rays: binaries; stars: magnetic fields.

1. INTRODUCTION

The Be/X-ray binary and accreting pulsar 3A 0535+262 was first detected by Ariel V (Rosenberg et al., 1975) and has been studied intensively since. For an exhaustive review see Giovannelli & Graziati (1992). The X-ray intensity of 3A 0535+262 varies by almost three orders of magnitude with three basic intensity states: quiescence with flux levels below ∼10 mCrab, normal outbursts (10 mCrab – 1 Crab), and very large ("giant") outbursts.

Since the last giant outburst in 1994 and two subsequent weaker outbursts spaced at the orbital period (Finger et al., 1996), the source had gone into quiescence. It reappeared in a giant outburst in May/June 2005 (Tueller et al., 2005; Smith et al., 2005) but so close to the Sun that it could only be observed by a few instruments. Another outburst a the 'normal' level was detected by Finger M.H. (2005a,b) and led to our *Integral* and *RXTE* TOO observations. During the *Integral* observations the average flux in the 5–100 keV range was 300 mCrab

2. DATA REDUCTION

All *Integral* data have been reduced using the Offline Scientific Analysis software v. 5 (OSA5). To generate phase resolved spectra and lightcurves from ISGRI data, alternative software provided by the IASF Palermo (`http://www.pa.iasf.cnr.it/~ferrigno/INTEGRALsoftware.html`) has been used in addition to the OSA5 software. *RXTE* data have been reduced using HEASOFT v5.3.1.

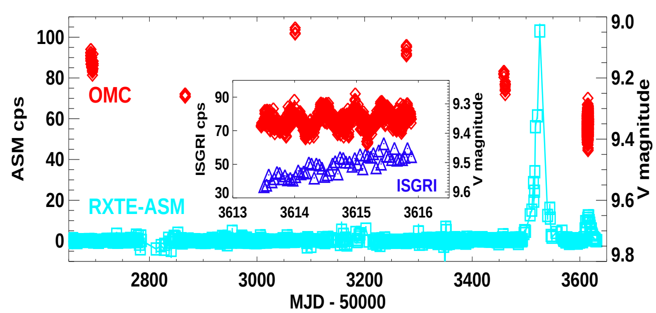

Figure 1. Long term lightcurves of the binary system 3A 0535+262/HD 245770 obtained with the RXTE ASM (left Y axis) and the Integral OMC (right Y axis). The inset shows the OMC and ISGRI lightcurves during the Integral TOO observations.

3. OPTICAL & ALL-SKY MONITOR DATA

3A 0535+262 has been monitored serendipitously by the Optical Monitoring Camera (OMC) onboard *Integral*, e.g., during Crab observations. The long term lightcurve shows a marked decline of the optical brightness in the time leading up to the outburst. During the outburst, small variability, typical for Be systems is observed.

4. PULSATIONS

A quick-look analysis of the *Integral* data without correcting for orbital motion finds a pulse period of 103.3765±0.0014 s for the reference time MJD 53613.46176 (2005-08-30, 11:04:56). For the generation of lightcurves and pulse profiles, the uncorrected motion was taken into account as a pulse drift of $-(8.5\pm0.8)\times10^{-8}$ s/s.

The broad-band pulse profile is shown in Fig. 2. This is the first determination of the low energy pulse profile since Bradt et al. (1976). Similar to other accreting pulsars, the source displays a complex pattern in the soft X-ray range and a simple two-peaked profile, with very different spectral shape of the pulses, at higher energies. The pulse profile is similar to that seen in previous outbursts but differs significantly in various details, hinting at a variable accretion geometry.

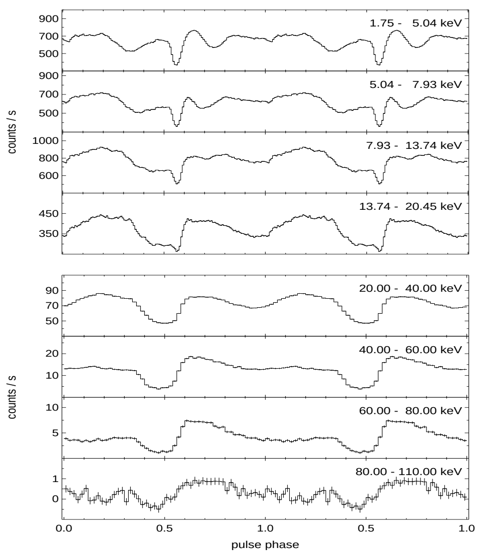

Figure 2. Broad-band pulse profile of 3A 0535+262 combining data from RXTE-PCA and Integral-ISGRI observations during this outburst.

5. SPECTROSCOPY

Pulse phase averaged spectra were generated from all *Integral* data of the TOO observation and from the available *RXTE* data. While the data are not strictly contemporaneous, the spectra agree well in all important characteristics. Fig. 3 shows results of preliminary fits to the near real time data using a model based on a power law continuum with a "Fermi-Dirac cutoff", modified by one or two lines with a gaussian optical depth profile (Kreykenbohm et al., 2004). The best fit values for important parameters are given in Table 1, the main parameters agree very well. The strong broad line feature at ∼45 keV proves that the pulsar's B field is $\sim4\times10^{12}$ G instead of almost 10^{13} G as often claimed in the literature. In contrast to previous outbursts, a feature above 100 keV is only weakly visible.

Table 1. Comparison of salient model parameters.

Parameter	*Integral*	*RossiXTE*
$Energy_1$ [keV]	45.4±0.4	45.6±0.4
$Depth_1$	0.45±0.01	0.62±0.03
$Width_1$ [keV]	10.3±0.5	12.7±0.8
$Energy_2$ [keV]	99±4	102±3
$Depth_2$	0.5±0.1	0.7±0.2
$Width_2$ [keV]	8±3	8±3
folding Energy	17.7±0.6	17.0±0.3

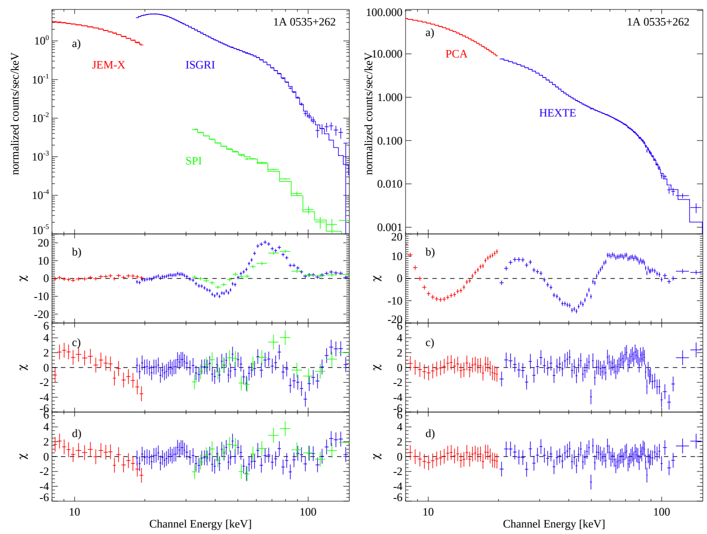

Figure 3. Preliminary fits to the near real time data for Integral (left) and RXTE (right). On both sides, panel a) shows the folded best fit model, panels b), c) and d) show fit residuals if the data is modeled with no cyclotron line, a single broad line at ∼45 keV or two line features at ∼45 and ∼100 keV, respectively.

REFERENCES

Bradt, H., Mayer, W., Buff, J., et al. 1976, ApJ, 204, L67

Finger, M. H., Wilson, R. B., & Harmon, B. A. 1996, ApJ, 459, 288

Finger M.H. 2005a, The Astronomer's Telegram, 595

Finger M.H. 2005b, The Astronomer's Telegram, 597

Giovannelli, F. & Graziati, L. S. 1992, Space Sci. Rev., 59, 1

Kreykenbohm, I., Wilms, J., Coburn, W., et al. 2004, A&A, 427, 975

Rosenberg, F. D., Eyles, C. J., Skinner, G. K., & Willmore, A. P. 1975, Nature, 256, 628

Smith, D. M., Hazelton, B., Coburn, W., et al. 2005, The Astronomer's Telegram, 557

Tueller, J., Ajello, M., Barthelmy, S., et al. 2005, The Astronomer's Telegram, 504