P. Kretschmar[1], K. Pottschmidt[2], C. Ferrigno[3], I. Kreykenbohm[4,5], A. Domingo[6] J. Wilms[7], R. Rothschild[2], W. Coburn[8], E. Kendziorra[5], R. Staubert[5], G. Schönherr[5], A. Santangelo[5], A. Segreto[4]

[1] ESA – European Space Astronomy Center, 28080 Madrid, Spain
[2] Center for Astrophysics and Space Science, UCSD, La Jolla, CA, USA
[3] Istituto di Astrofisica Spaziale (IASF-INAF), Palermo, Italy
[4] Institut für Astronomie und Astrophysik – Astronomie, Univ. of Tübingen, 72076 Tübingen, Germany
[5] INTEGRAL Science Data Center, 1290 Versoix, Switzerland
[6] Laboratori de Astrofísica Espacial y Física Fundamental, LAEFF-INTA, 28080 Madrid, Spain
[7] Department of Physics, University of Warwick, CV47AL Warwick, United Kingdom
[8] Space Sciences Laboratory, University of California, CA 94720-7450 Berkeley, USA

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 outburst. The source went into quiescence for more than ten years since its last giant outburst in 1994, leaving this issue and others unresolved. A new giant outburst in May/June 2005 took place as the source stood close to the Sun and thus could not be observed by astronomical space observatories. Another, weaker outburst took place end of August 2005 and has been observed by us with Integral and RXTE. We present early results from these observations, focussing on cyclotron line studies.

1 Introduction

The Be binary X-ray 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. Simplified, the source shows three intensity states: quiescence with flux levels below ∼10 mCrab, normal outbursts (10 mCrab – 1 Crab), and very large ("giant") outbursts, when 3A 0535+262 becomes one of the brightest high energy X-ray source in the sky with fluxes of several Crab in the hard X-ray range. Normal outbursts have been observed to correlate with the orbital period of 110.3±0.3 d (Finger et al. 1996) while giant outbursts can be out of phase relative to the normal ones (Motch et al. 1991).

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 *RossiXTE* TOO observations being triggered. 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 version 5 (OSA5) distributed by the *Integral* Science Data Centre. 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. *RossiXTE* data have been reduced using HEASOFT v5.3.1.

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. At the beginning of the *Integral* observations the Intgeral Burst Alert System triggered on the previously not blacklisted source which led the OMC to take Trigger Mode images at the start of the *Integral* observations.

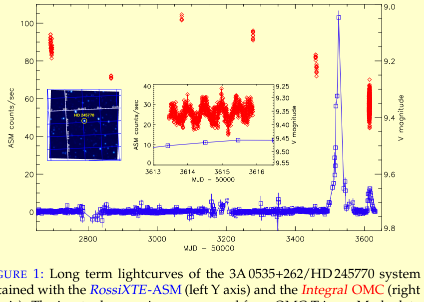

FIGURE 1: Long term lightcurves of the 3A 0535+262/HD 245770 system obtained with the *RossiXTE*-ASM (left Y axis) and the *Integral* OMC (right Y axis). The insets show an image summed from OMC Trigger Mode data and the lightcurves during the *Integral* TOO observations.

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 (30. Aug 2005, 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±0.8) × 10^{-8} s/s.

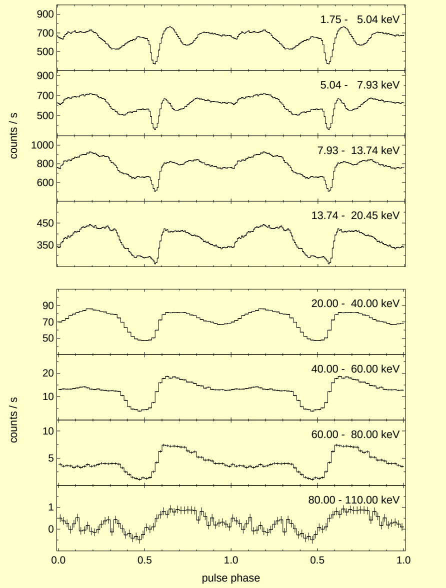

FIGURE 2: Broadband pulse profile of 3A 0535+262 combining data from *RossiXTE*-PCA and *Integral*-ISGRI observations during this outburst. This is the first determination of the low energy pulse profile since Bradt et al. (1976). Similar to other accreting pulsars, the source displays an evolution from a simple two-peaked profile at higher energies to a complex pattern in the soft X-ray range.

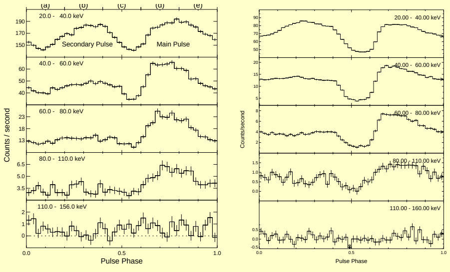

FIGURE 3: Comparison of pulse profiles from two different outbursts of 3A 0535+262. Left: pulse profile obtained from *Mir-HEXE* observations of the giant outburst in 1989 (Fig 1. of Kendziorra et al. 1994). Right: ISGRI pulse profile in the same energy bands from the current normal outburst. While basically very similar, the visible differences in the pulse shapes indicate a somewhat different accretion geometry; possibly a smaller hotspot with more pronounced shadowing due to the accretion column in the normal outburst on the right.

5 Spectroscopy

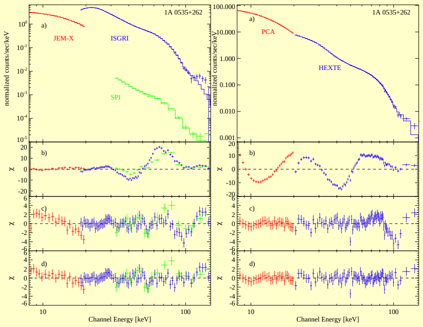

FIGURE 4: Preliminary fits to the near real time data for *Integral* (left) and *RossiXTE* (right) with a model based on a power law continuum with a "Fermi-Dirac cutoff". On both sides, panel a) shows the folded best fit model with two broad line features, panels b), c) and d) show fit residuals if 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.

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±3.0
folding Energy	17.7±0.6	17.0±0.3

TABLE 1: Comparison of preliminary fit results for salient model parameters. Pulse phase averaged spectra were fitted with an FDCUT continuum (fixed cutoff energy at 20 keV) modified by two lines with a gaussian optical depth profile (Kreykenbohm et al. 2004). For *Integral* all data from the TOO observation was used, for *RXTE* a subset as observations were not finished, the data are not strictly contemporaneous. Still, the agreement between the main parameters is very good.

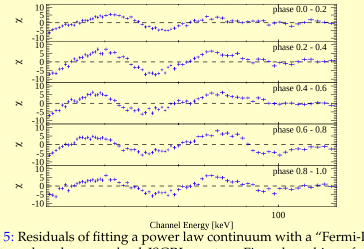

FIGURE 5: Residuals of fitting a power law continuum with a "Fermi-Dirac cutoff" to pulse phase resolved ISGRI spectra. Five phase bins of equal width were selected, with phases corresponding to the pulse profile shown in Fig. 2. The variation of the lines with pulse phase is evident, with the strongest indication for a harmonic line in the rising flank of the "main" pulse, consistent with the results of Kendziorra et al. (1994). A detailed analysis is still ongoing.

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`Peter.Kretschmar@esa.int`