XMM-NEWTON OBSERVATIONS OF PSR B1259–63 NEAR THE 2004 PERIASTRON PASSAGE.

M. Chernyakova[1,2], A. Lutovinov[3], J. Rodriguez [4], and S. Johnston[5]

[1]*INTEGRAL* Science Data Center, 16 Ch. d'Ecogia, CH-1290 Versoix, Switzerland
[2]Observatoire de Gèneve, 51 chemin des Maillettes, 1290 Sauverny, Switzerland
[3]Space Research Institute, 81/32 Profsoyuznaya, 117997 Moscow, Russia
[4] CEA Saclay, DSM/DAPNIA/Service d'Astrophysique (CNRS UMR 7158 AIM), 91191 Gif-Sur-Yvette Cedex,France
[5] Australia Telescope National Facility, CSIRO, P.O. Box 76, Epping, NSW 1710, Australia.

ABSTRACT

PSR B1259–63 is in a highly eccentric 3.4 year orbit with a Be star and crosses the Be star disc twice per orbit, just prior to and just after periastron. We present here the results of new *XMM-Newton* observations of the PSR B1259–63 system during the beginning of 2004, as the pulsar approaches the disc of the Be star. We combine these results with earlier X-ray data from *Beppo*SAX, *XMM-Newton* and *ASCA*. The X-ray light curve looks similar to the radio light curve with a rapid increase in the flux around the time of the disc crossing. This supports a model in which the X-ray emission from the system is due to inverse Compton scattering of the pulsar wind relativistic particles with $\gamma \sim 10 - 100$ on the Be star soft photons.

Key words: pulsars : individual: PSR B1259–63 – X-rays: binaries – X-rays: individual: PSR B1259–63 .

1. INTRODUCTION

PSR B1259–63 is a ∼48 ms radio pulsar in a highly eccentric (e∼0.87), 3.4 year orbit with a Be star SS 2883. Be stars are well-known to be sources of strong highly anisotropic matter outflow. Both a dilute polar wind and a denser equatorial disc have been invoked to reconcile models for infra-red, ultra-violet and optical observations. Timing analysis of the PSR B1259–63 system show that the disc of Be star is highly tilted with respect to the orbital plane and that the line of intersection of the disc plane and the orbital plane is at almost 90° to the orbital major axis. Thus the pulsar crosses the disc twice per orbit.

The properties of the radio emission from this system are very different before and after the periastron passage. Radio observations show that when the pulsar is far from periastron the observed radio emission is comprised entirely of pulsed emission from the pulsar itself. Due to the misalignment of the Be star disc with the orbital plane, pulsed radio emission disappears entirely as the pulsar enters the disc and is hidden behind it (relative to the observer). Shortly before the disc crossing **unpulsed** radio emission appears and within several days rises to a peak value several times higher than the intensity of the pulsed emission far from the periastron. Afterwards the unpulsed flux slightly decreases, as the pulsar passes through periastron before reaching a second peak just after the pulsar crosses the disc for the second time. This unpulsed radio emission is still detected until at least 100 days after the periastron passage (Johnston et al. 2005 and references there in).

Since its discovery system PSR B1259-63 was observed several times with different X-ray instruments. The most recent published observations of the system in X-rays were carried out with the *ASCA* satellite in 1994 and 1995 (Hirayama et al. 1999, and references therein). These observations showed that X-ray emission is approximately twice as high at the time of the disc crossing than at periastron.

2. OBSERVATIONS AND DATA ANALYSIS

Thus X-ray and radio data have similar two-peak structure around the periastron. However X-ray data are much more sparse than radio ones, and it was not clear whether similar to radio data X-ray emission rapidly grows around the moment of the first disk crossing, or its behavior is much smoother. To answer this question we have organized a set of *XMM-Newton* observations of the system, as the pulsar approaches the disk.

A simple power law with a photoelectrical absorption describes the data well, with no evidence for line features. The results are given in Figure 1 in comparison with the results obtained by *ASCA*.

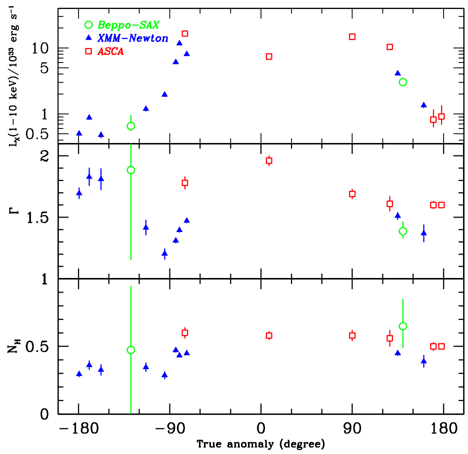

Figure 1. Summary of XMM-Newton BeppoSAX and ASCA observations of the PSR B1259-63. The figure shows the time variation of the X-ray luminosity, spectral slope and column density as a function of orbital phase.

3. DISCUSSION

In all models explaining the unpulsed emission from PSR B1259–63 the collision of the relativistic pulsar wind with the (non-relativistic) wind of the Be star plays a crucial role. Due to the interaction of the winds a system of two shock waves arises between the stars. In the beginning both the relativistic and non-relativistic winds are radial but after passing the shocks particles turn and start to flow along the contact surface, losing their energy in form of synchrotron and inverse Compton (with the seed photons being the Be star soft photons) emission. The big difference in the velocities of the winds at different sides of the contact surface can lead to the growth of instability and two winds could be macroscopically mixed between the shocks. In this case the massive non-relativistic wind will slow down the drift velocity of the relativistic particles. The frequency of the emission depends on the Lorentz factor of the relativistic electrons. Up to now there is no unified self-consistent theory of the pulsar magnetosphere allowing us to predict the value of the Lorentz factor γ of the particles in the relativistic pulsar wind. The range of the predicted values is quite wide, from $\gamma \sim 10^7$ (e.g. Muslimov & Harding 2004), to $\gamma \sim 100$ (e.g. Kirk et al. 2002), and as low as $\gamma \sim 10$ (Malov 2003).

Models with assumptions of low and high Lorentz factors have been applied to the PSR B1259–63 system. Tavani & Arons (1997) assumed a high Lorentz factor of $\gamma = 10^6$. Under this assumption, synchrotron emission of the relativistic electrons leads to the X-ray emission. While as shown in Figure 2 this model was in a good agreement with *ASCA* observations (marked with squares), new *XMM-Newton* data (marked with triangles) show a much more rapid growth than it was predicted. In the model with moderate Lorentz factor, γ= 10 – 100,

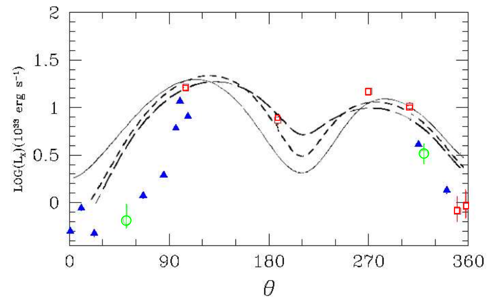

Figure 2. Comparison of the X-ray data with the prediction of the Tavani&Arons model

discussed by Chernyakova & Illarionov (1999, 2000), the observed X-ray emission is due to inverse Compton scattering of the pulsar wind relativistic particles on the Be star soft photons. The observed radio emission within this model is due to the synchrotron emission of the electrons of the pulsar wind. In this case the intensity of the observed unpulsed X-ray and radio emission strongly depends on the outflow velocity of the relativistic particles after the shock wave. The lower the drift velocity, the higher is the X-ray and radio luminosity. The interaction with the pulsar leads to the partial destruction of the Be star disc (Ivanov et al. 1998). The matter starts to be ejected from the disc shortly before and lasts for a while after the pulsar passage through it, perturbing the outflow beyond the shock. This leads to a mix of relativistic and non-relativistic winds, and hence to an increase of the unpulsed radio and X-ray emission. *XMM-Newton* data presented here supports this model, showing an increase of the absorption column relative to the apastron value during the period the unpulsed radio emission is detected.

Thus in the model of Chernyakova & Illarionov the X-ray and radio emission is generating by the same population of particles, and the lightcurves should be similar. Unfortunately in the 2004 observations, there are no simultaneous X-ray and radio observations for the quantitative comparison, but the observed rapid increase of the X-ray flux strongly supports the model.

REFERENCES

Chernyakova M., Illarionov A.,1999 MNRAS, 304,359

Chernyakova M., Illarionov A., 2000 ApSS, 274, 177

Hirayama M. et al., 1999 ApJ 521, 718

Ivanov P. et al., 1998 ApJ, 507, 131

Johnston S. et al., 1992 ApJ, 387, L37

Kirk, J. G. et al., 2002 A&A, 388, L29

Malov I., 2003 AstL, 29, 502

Muslimov A., Harding A., 2004 ApJ, 617, 471

Tavani M., Arons J., 1997 ApJ, 477, 439