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Letter to the Editor

Discovery of X-ray pulsations from IGR J16320–4751 = AX J1631.9–4752

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Abstract. We report a discovery of strong modulations of the X-ray flux detected from IGR J16320−4751 = AX J1631.9−4752 with a period of $P \sim 1300$ s. We reanalyzed the data of an XMM-Newton ToO performed soon after the discovery of the source by INTEGRAL and found the modulation at a period of $P = 1309 \pm 40$ s with a high significance. Modulations of the source flux with two possible periods of ∼1300 and ∼1500 s were identified in the ASCA archival data. It is very likely that the modulation can be interpreted as X-ray pulsations, favouring a pulsar as the compact object in IGR/AX J16320−4752. Thus for the moment this source became the fourth source from a new class of highly absorbed binary systems for which the pulsations are observed.

Key words. individual: IGR J16320−4751 = AX J1631.9−4752 – binaries: general – X-rays: binaries

1. Introduction

For the moment about a dozen new hard X-ray sources were discovered (or rediscovered) with the INTEGRAL observatory in the direction to the Norma Galactic spiral arm. Most of them as believed are members of high mass X-ray binaries with early type primary stars. From three of such objects (IGR J16358−4726, AX J163904−4642, IGR J16465−4507) X-ray pulsations were detected (Patel et al. 2004; Walter 2004; Lutovinov et al. 2004).

The transient hard X-ray source IGR J16320−4751 was discovered on Feb. 1, 2003 with the INTEGRAL observatory during ToO observations of 4U1630-47 (Tomsick et al. 2003). The source demonstrated a significant high energy variability on a time scale of several thousand of seconds (Tomsick et al. 2003; Foschini et al. 2004). Its position was coincident with the one reported by Sugizaki et al. (2001) for AX J1631.9−4752, which was observed previously by ASCA (therefore below we will call this source as IGR/AX J16320−4752). The follow-up observation of IGR/AX J16320−4752 with XMM-Newton on March 4, 2003 confirmed a complex behaviour of the source lightcurve and demonstrated flare-like events with durations of ∼1 ks without significant variations in the hardness (Rodriguez et al. 2003). The total exposure of this observation was about ∼25 ks, but due to soft proton flares only ∼4.9 ks of the data were used for the analysis. Rodriguez et al. (2003) searched for the pulsations in the power spectrum of the source, but due to the short good time interval selected could not obtain strong constraints.

In this letter we reanalyze the XMM-Newton data of March 2003 and the archival data of ASCA observations of Sep. 1997 with a special attention to long period variations and show that the source demonstrates clear pulsations with a period about ∼1.3 ks. The source was also observed simultaneously with INTEGRAL and XMM-Newton observatories in August 2004. Detailed spectral and temporal analysis of these two data sets will be presented in a forthcoming paper. We note, however, that a preliminary quick look analysis of those data confirmed the presence of pulsations in IGR/AX 16320−4751 (L. Foschini, private comm.). These pulsations on the ∼1.3 ks time scale could not have detected before by the INTEGRAL observatory due to the source faintness and the large time bin size (∼15−20 ks) chosen for the lightcurve building (Foschini et al. 2004).

2. Data reduction

IGR/AX J16320−4752 was observed with the XMM-Newton observatory on March 4, 2003. In our analysis we used data of the EPIC-PN camera, which operated in the Large Window science mode, thus offering a time resolution of 48 ms. The data were processed with the Science Analysis System (SAS) v6.0.0. As was mentioned above during the previous scientific spectral and timing analysis

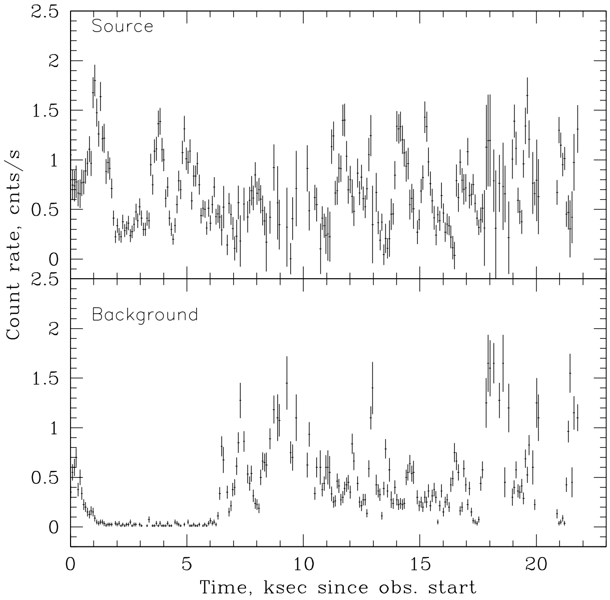

Fig. 1. Lightcurve of the source (*upper panel*) and the background (*lower panel*) during March 4, 2003 observation of IGR/AX J16320−4752 with XMM-Newton.

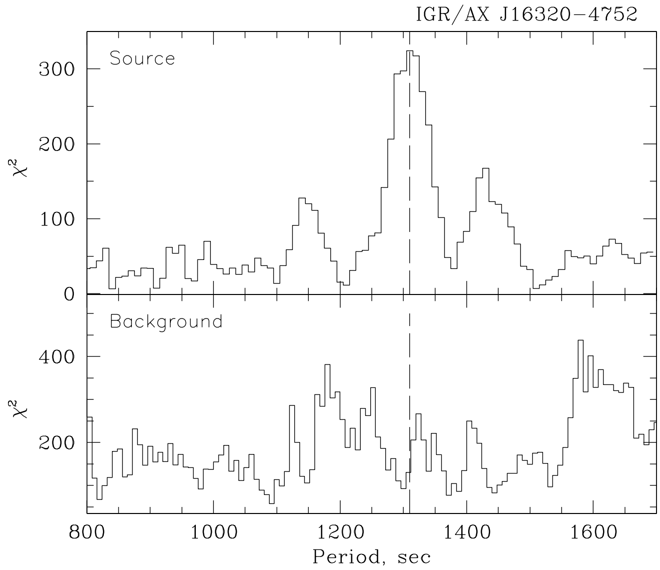

Fig. 2. χ^2 distribution obtained while folding the source and the background lightcurves during March 4, 2003 observation of IGR/AX J16320−4752 with XMM-Newton. It is seen that the background lightcurves does not demonstrate a coherent signal with the period of ~1300 s.

(Rodriguez et al. 2003) the significant part of data was excluded from the analysis due to proton flares. Such a filtering reduces the length of useful observing time to ~5 ks and therefore makes searches for long periodic variations almost impossible. Since the proton flares originate from the interaction of the soft protons in the Earth's magnetosphere with the telescope, their timing behavior is supposed to have no periodic structure. Therefore, for our purpose of a periodic signal search, this step could be omitted and we applied practically no filtering to the data. We used only the simplest criteria, i.e. selected events with pattern 0–4 (singles and doubles) and flag #XMMEA_EP. A barycentric correction was applied to all selected counts. The lightcurve was extracted from the 40″ circle around the source with its total duration being ~22 ks.

The region around the source was observed several times by ASCA, but here we will analyze only data with the largest exposure time (~13.7 ks) obtained on Sep. 4, 1997. Another observation of the source with ASCA (Sep. 3, 1994) when it was significantly detected has only ~3 ks exposure time and is not suitable for our study. In order to increase the statistics we analyzed joint data of GIS2 and GIS3 telescopes. The source was out of the field of view of both SIS detectors. We analyzed data with the help of standard tasks of LHEASOFT/FTOOLS 5.2 package in accordance with ASCA Guest Observer Facility recommendations.

3. Results

The lightcurves of the source (background subtracted) and the background obtained with XMM-Newton on March 4, 2003 in the energy band 1–10 keV are presented in Fig. 1. It is seen that the background is quite strong during most of the observation. However, in spite of this the background subtracted lightcurve gives an impression about possible periodic variations of the source flux. Search for pulsations with the epoch folding technique in these two lightcurves gives the results presented in Fig. 2. Very significant peak at $P \sim 1300$ s is clearly seen for the source lightcurve, while the background curve does not show any peak at this period. Therefore we can be sure that the periodic variability can not be caused by the background variations. The statistical significance of pulsations in the lightcurve of IGR/AX J16320−4752 can be estimated either with the help of standard formulas (e.g. Leahy et al. 1983) or directly from the data after the construction of the statistical distribution of obtained χ^2 values for trial periods apart from the pulse period. The statistical significance of the detection of pulsations with the XMM-Newton data exceeds 10σ, and can be considered as unambiguous.

The lightcurve of the source observed by ASCA during its Sep. 4, 1997 observation is presented in Fig. 3 (upper panel). The dependence of χ^2 value on the value of trial periods used for the epoch folding of this lightcurve is presented in Fig. 3 (lower panel). As it is seen from the figure there are two clear candidates for the coherent variations of the X-ray flux, around 1300 s and around 1500 s. Two possible periods can appear as a result of gaps in the ASCA data, due to the short ~90 min orbital period, and a significant "red" noise in the source variability (we can clearly see the long term decline of the source flux during first few ks). However, performed Monte-Carlo simulations of the lightcurve with gaps and red noise of different forms have not allowed us to solidly distinguish the real period from the possible "alias" period. Therefore it seems reasonable to consider below two possible values of the source period in 1997.

The best fit period of the pulsations of IGR/AX J16320−4752 according to the XMM-Newton

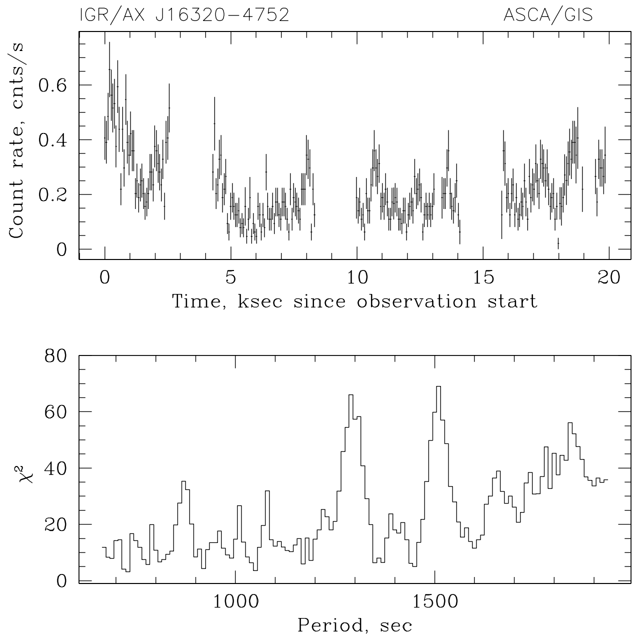

Fig. 3. Lightcurve of IGR/AX J16320−4752 obtained by ASCA/GIS (*upper panel*) and χ^2 distribution obtained while folding this lightcurve for various trial periods (*lower panel*).

data (March 2003) is $P = 1309 \pm 40$ s. The χ^2-dependence for the ASCA data demonstrates several peaks with two most prominent at $P = 1292 \pm 40$ s and $P = 1510 \pm 50$ s.

The lightcurve of IGR/AX J16320−4752 obtained with XMM-Newton folded with the period of 1309 s is presented in Fig. 4. Phases on this plots are arbitrary. The pulse fraction (which is defined as $P = (I_{\rm max} - I_{\rm min})/(I_{\rm max} + I_{\rm min})$, where $I_{\rm max}$ and $I_{\rm min}$ are intensities at the maximum and minimum of the pulse profile) are 26 ± 3%. We do not present here the ASCA folded lightcurve because it is not clear what was the pulsation period of the source at that time.

The time difference between observations of the source with ASCA and XMM-Newton is relatively large, approximately 7 years, that leaves the possibility for discussion of pulse period variations of IGR/AX J16320−4752. Accreting X-ray pulsars change their periods as a result of a spin-up induced by the angular momentum gain, transported to the neutron star by the accreting matter or a spin-down, caused by the angular momentum loss e.g. due to the "propeller" effect. Typical values of the accretion induced spin-up rate are approximately in the range of 10^{-13}–10^{-11} Hz s^{-1} depending on the accretion rate in the binary system (see e.g. Bildsten et al. 1997). If we assume that the real period of the pulsar in the system IGR/AX J16320−4752 during the ASCA observation (year 1997) was ∼1500 s than we should conclude that the source have demonstrated the average spin-up rate at the level of $\sim 5 \times 10^{-13}$ Hz s^{-1} during next seven years. This value corresponds to a source luminosity of $L \sim 2 \times 10^{36}$ erg s^{-1} in the simple model of a magnetized (a magnetic moment $\mu \sim 10^{30}$ G cm^3) neutron star (Ghosh & Lamb 1979). Alternatively we can estimate the source luminosity from its spectrum. The absorption corrected flux of the source in the

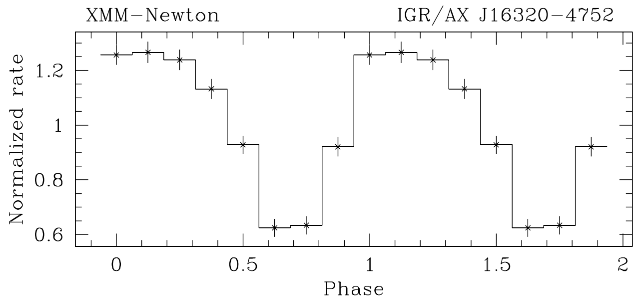

Fig. 4. Pulse profile of IGR/AX J16320−4752 obtained in the 1–10 keV energy band by folding of the XMM-Newton lightcurve with the period of 1309 s.

broad energy band (∼1−100 keV) during ASCA observations assuming the same spectral shape at high energy as it was seen by INTEGRAL (Foschini et al. 2004; Lutovinov et al. 2004) is approximately $\sim 5 \times 10^{-10}$ erg s^{-1} cm^{-2}, which corresponds to the source luminosity at the distance of 8 kpc (assuming the source is close to the Norma spiral arm tangent) $L \sim 4 \times 10^{36}$ erg s^{-1}, that is in an agreement with the above estimations.

Naturally, we can not exclude that the real pulse period of the source during ASCA observation was close to 1300 s. In this case periods of a high accretion rate (spin-up) in the system should alternate with periods of a spin down, similar to what is observed in other X-ray pulsars (e.g. Lutovinov et al. 1994; Bildsten et al. 1997).

4. Summary

We report the discovery of X-ray pulsations from IGR/AX J16320−4752 with help of XMM-Newton and ASCA data. The study of the XMM-Newton observation performed in 2003 allow us to unambiguously identify the true period of pulsations $P = 1309 \pm 40$ s. This confirmed a proposition of (Rodriguez et al. 2003) about the neutron star as a compact object in this high-mass X-ray binary system. The result obtained from the analysis of the ASCA data has not very high statistical significance and have two almost equally significant pulse period candidates, ∼1300 s and ∼1500 s. If the latter value is the real period of IGR/AX J16320−4752 during the ASCA observations in 1997, then we can conclude that the source should have a relatively persistent emission during last seven years providing the average spin-up rate $\dot{\nu} \sim 5 \times 10^{-13}$ Hz s^{-1}. We cannot exclude the source to be truly persistent, but the sensitivity of current all sky monitors is not enough to detect it in a such crowded region, like a Norma arm. If the former value is the real pulse period in 1997, then the source should alternate between high and low accretion rate regimes.

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