Observations of accreting pulsars with Konus-Wind

A. A. Kaurov[1, 3, *], V. D. Pal'shin[2, 1, +]
[1] St. Petersburg State Polytechnical University, St. Petersburg, 195251, Russian Federation
[2] Ioffe Physical-Technical Institute of the Russian Academy of Sciences, St. Petersburg, 194021, Russian Federation
[3] Central Astronomical Observatory at Pulkovo, St. Petersburg, 196140, Russian Federation
* akaurov@gmail.com + val@mail.ioffe.ru

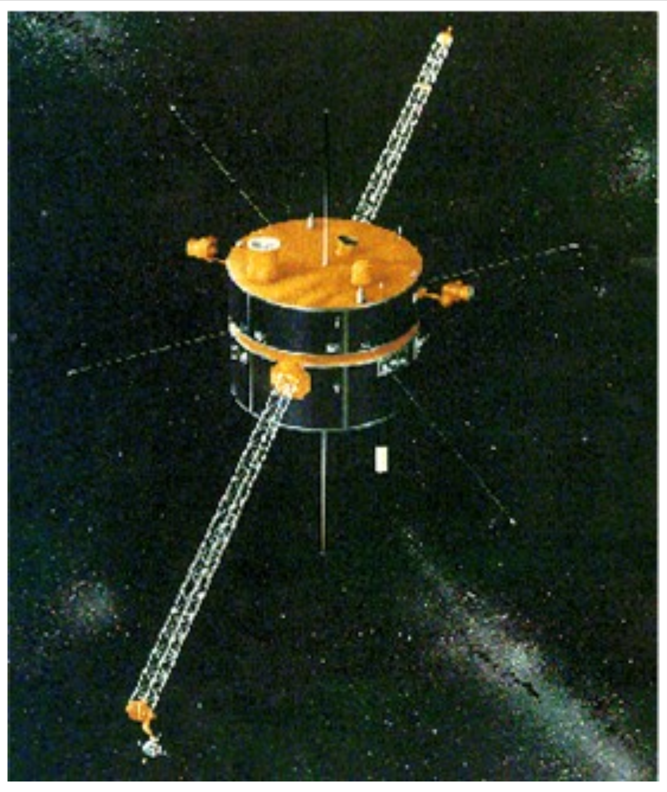

Fig. 1 The Wind spacecraft.

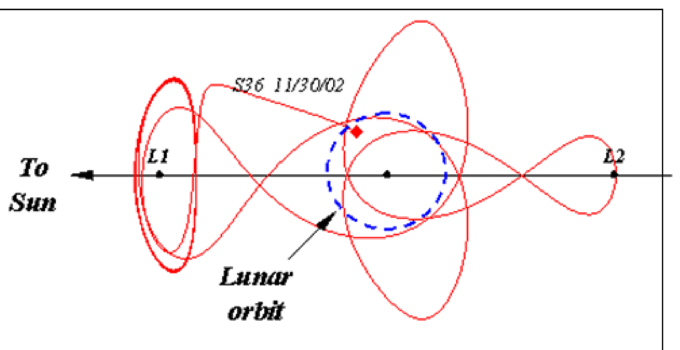

Fig. 2 The projection of the Wind orbit on the Ecliptic plane.

Introduction

Accreting X-ray pulsars are rotating and strongly magnetized neutron stars that accrete matter from a stellar companion. There are more than a hundred known accreting pulsars in our Galaxy and the Magellanic Clouds, with spin periods ranging from milliseconds through thousands of seconds. The Konus gamma-ray burst experiment on board the GGS Wind spacecraft has been successfully operating since 1994, November. Two omnidirectional detectors allow Konus-Wind to operate as a full-time, all-sky monitor for transients in hard X-ray/soft gamma-ray band. In addition, it has provided unprecedented continuous monitoring of pulsed sources above ~20 keV in the course of the mission. Here we demonstrate the possibility of studying of accretion-powered pulsars using the Konus-Wind background data. As an example of such a study we present the results of long-term monitoring of the transient Be/X-ray binary pulsar system A0535+26.

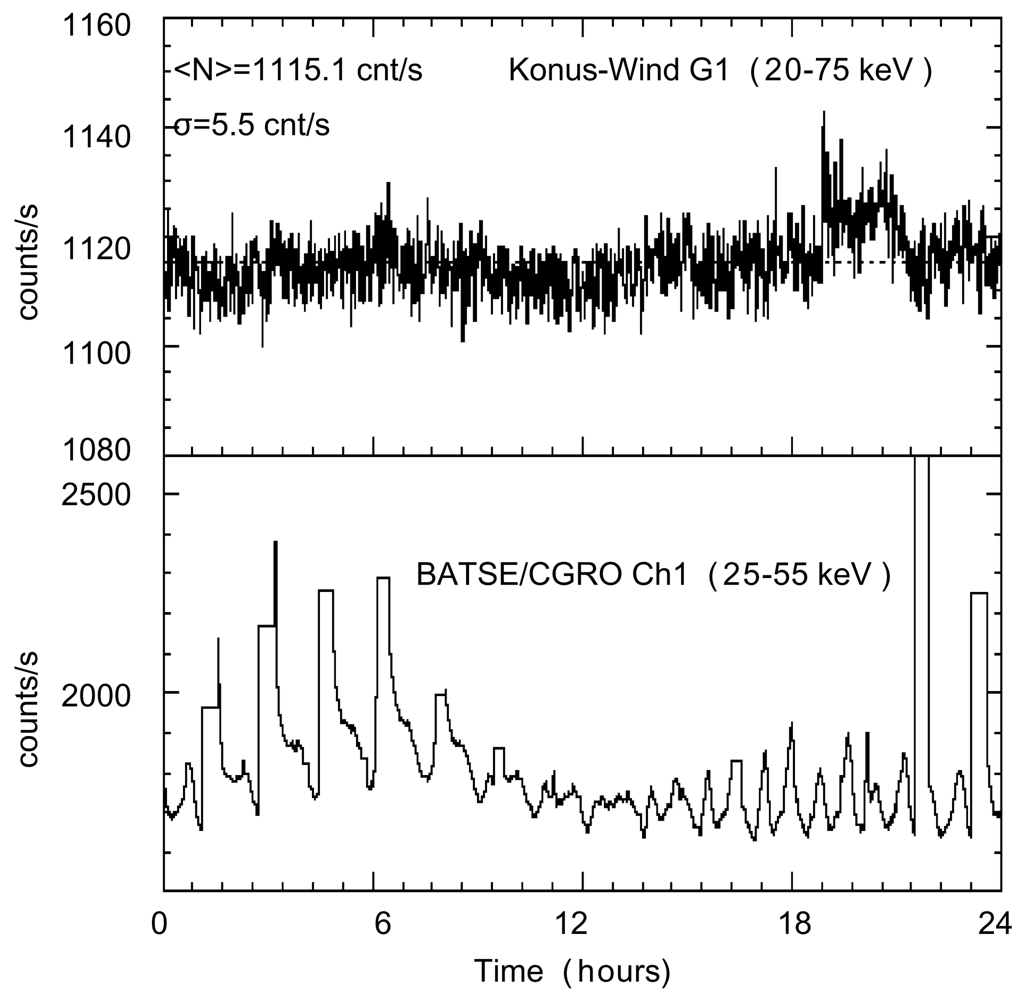

Fig. 3 Comparison of the **Konus-Wind** and **BATSE/CGRO** background light curves (1 min binning; averaged over two **KW** detectors and eight **LAT** detectors, respectively) for one day (January 10, 1998).

Instrumentation

The Konus-Wind is a gamma-ray spectrometer designed to study temporal and spectral characteristics of gamma-ray bursts, solar flares, SGR bursts, and other transient phenomena in a wide energy range from ~10 keV to ~10 MeV. It consists of two identical omnidirectional scintillation detectors (S1 and S2) mounted on the opposite faces of the rotationally stabilized Wind spacecraft (see **Fig. 1**). One of the detectors points toward the south ecliptic pole, thereby observing the south ecliptic hemisphere (S1); the other observes the north ecliptic hemisphere (S2). Each detector comprises a NaI(Tl) crystal 13 cm in diameter and 7.5 cm in height, and has an effective area of ~80–160cm^2, depending on the photon energy and incident angle. In interplanetary space far outside the Earth's magnetosphere (see **Fig. 2**), the Konus-Wind has the advantages over Earth-orbiting GRB monitors of continuous coverage, uninterrupted by Earth occultation, and a steady background, undistorted by passages through the Earth's trapped radiation (see **Fig. 3**). In the waiting mode the instrument measures the count rates from both detectors in four energy ranges with nominal bounds 10-50 (G1), 50-200 (G2), 200-750 (G3) keV, and >10 MeV (Z) with accumulation time of 2.944 seconds. Further details can be found in Aptekar et al. (1995).

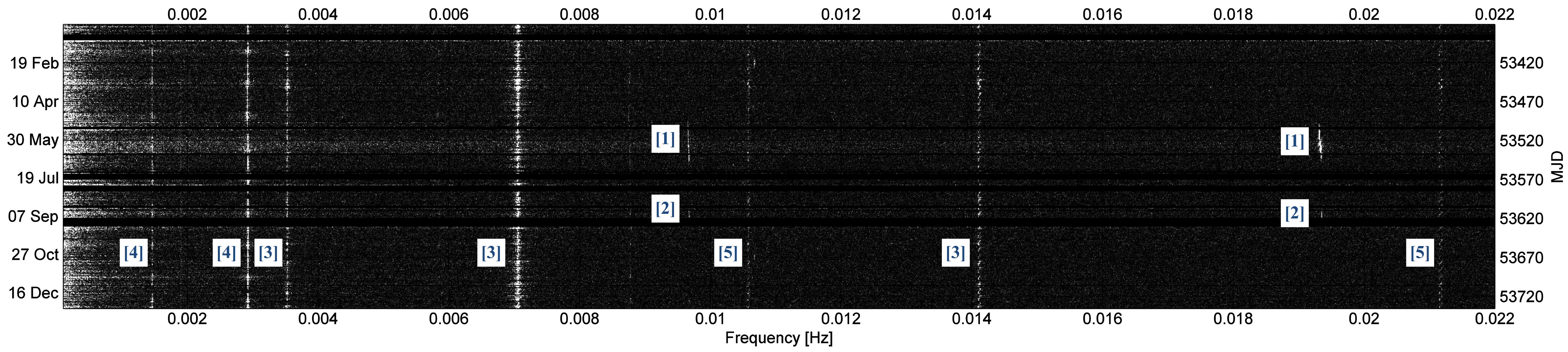

Fig. 4 Year long (1 Jan—31 Dec 2005) spectrogram. Color represents the presence of the signal with the corresponding frequency in the **G1** (25-75 keV) energy range.

[1] **A0535+262**
Type II outburst
($\nu \approx$ 9.7 mHz; P ≈ 103 s)
[2] **A0535+262**
Type I outburst
($\nu \approx$ 9.7 mHz; P ≈ 103 s)
[3] **Vela X-1**
($\nu \approx$ 3.5 mHz; P ≈ 283 s)
[4] **GX 301-2**
($\nu \approx$ 1.5 mHz; P ≈ 681 s)
[5] **GRO J1008-57**
($\nu \approx$ 10.6 mHz; P ≈ 94 s)
(in this figure a few first harmonics are visible)

Observations and Analysis

The signal from most accreting pulsars is 10^2-10^3 times smaller than the background count rates, so that we used a Fourier analysis to detect them. Prior to scientific analysis, the KW data undergo some processing: intervals of high solar activity, gamma-ray bursts and other fast transient phenomena, as long as spikes and data gaps are removed; a general background trend (which is close to linear in our case) is subtracted. Accreting pulsars are typically detected in the softest KW energy rage **G1** (~20-75 kev). **Fig. 4** shows the spectrogram for 2005 of the preprocessed KW light curves from the S1 detector in the **G1** range at 1 day time intervals. Several harmonics are clearly seen for bright pulsars (the second harmonic usually dominates since the pulsars show double-peaked pulse shape).

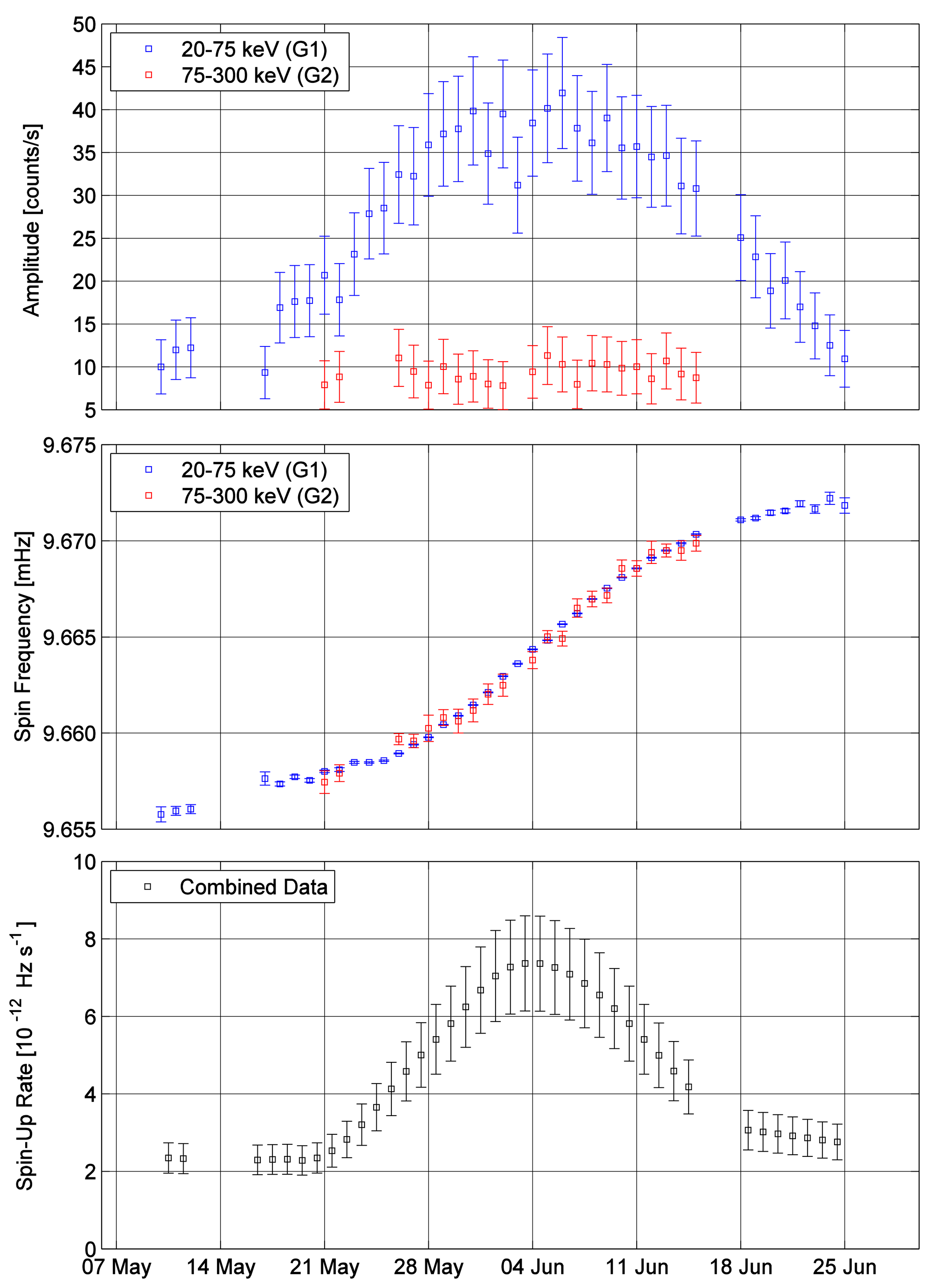

Fig. 5 Top panel: pulsed flux in the G1 and G2 ranges. Middle panel: estimated spin frequency during the outburst. Bottom panel: spin-up rate.

A0535+262

A0535+262 is a high-mass X-ray binary system. It consists of a neutron star spinning with a period of ≈ 103 s in an eccentric orbit (e = 0.47) with an O9.7-B0 IIIe star. At a distance of about 2 kpc, **A0535+262** is among the closest binary systems. The orbital period is ≈ 110 days. As other Be/X-ray binaries, **A0535+262** shows two types of X-ray outbursts: normal (or Type I) and giant (or Type II) (Stella et al. 1986). Type I outbursts are associated with the time of periastron passage as the neutron star passes closest to the Be donor. The X-ray luminosity is typically 10^{36}–10^{37} erg s^{-1} and they last for several days. Type II outbursts can occur at any phase of the orbit, they have X-ray luminosities close to the Eddington limit and they can last for several weeks. **A0535+262** was discovered by Ariel V during a giant outburst (Type II) in 1975. Since then, six giant outbursts have been detected: in October 1980, in June 1983, in March/April 1989, in February/March 1994, in May/June 2005, and in December 2009.

A0535+262 Giant Outburst (Type II)

May/June 2005

During the 2005 giant outburst the source was too close to the Sun to be observed by most instruments. The only reported observations were the Swift-BAT detection of the outburst onset on May 16 and >3 Crab flux estimated on May 31 (Tueller et al. 2005), and the RHESSI observations started on June 3 (with the best data obtained between June 11 and 24) with the maximum flux of about 4.5 Crab measured on June 12 (Smith et al. 2005). The Konus-Wind is the only instrument observed the outburst in its entirety. Since **A0535+262** is close to the ecliptic plane, its emission is detected by both Konus-Wind detectors (S1 and S2). To analyze the outburst we summed the light curves of both detectors. A pulse timing analysis was performed using DFT. The high signal-to-noise ratio allowed one to detect up to six Foirier harmonics in the power spectra of the **G1** (25-75 keV) and **G2** (75-300 keV) light curves. We used Z^2_6 to estimate amplitude and frequency at 1 day intervals. The resulting amplitudes, frequencies, and spin-up rates (extracted from the fitted spline model) are shown in **Fig. 5**. The gaps on 13-16 May and 16-17 June are due to the high solar activity. The inferred spin-up rate at the peak of the outburst was approximately 8×10^{-12} Hz s^{-1}, that is comparable with the maximum spin-up rate of 12×10^{-12} Hz s^{-1} measured during the giant outburst in February/March 1994 (Finger et al. 1996). As can be seen in the top panel, the amplitude in the soft energy range **G1** shows smooth rise and decay in course of the outburst, whereas the amplitude in the **G2** is nearly constant, implying a softening of the spectra with increasing luminosity. The similar softening was observed during the 1994 giant outburst (Finger et al. 1996). The pulse profile reconstructed using a six harmonic Fourier expansion is presented in **Fig. 6**. Here it is normalized to its peak value. Two snapshots for June 3 and 26 show how dramatically pulse shape changes during the outburst.

Summary

Thanks to its orbit in interplanetary space and two omnidirectional detectors, Konus-Wind effectively serves as an excellent full-time, all-sky monitor of accreting pulsars with periods of ≥ 6 s in hard X-rays. The only interruption of the continuous observation is solar activity. During 17 years of the mission the Konus-Wind has provided unprecedented data set for pulsed sources. Some data are unique, like the observation of the May/June 2005 giant outburst of **A0535+262** presented in this poster.

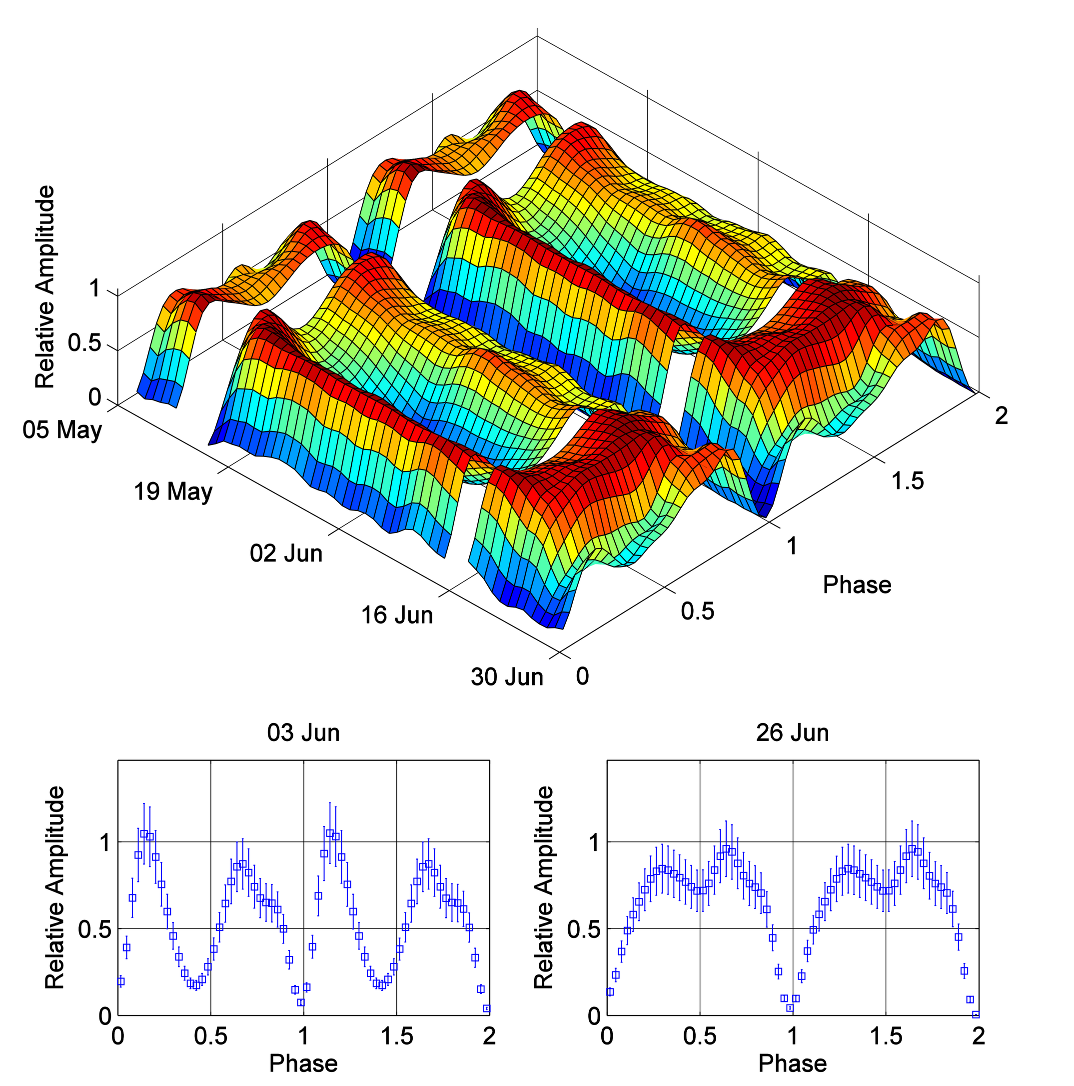

Fig. 6 Normalized pulse profile for the **G1 (25-75 keV)** energy range.

References

1. Aptekar, R. L. et al., 1995, SSRv, 71, 1-4, 265-272
2. Stella, L. et al., 1986, ApJ, 308, 669-679
3. Finger M. et al., 1996, ApJ, 459, 288
4. Tueller J. et al., 2005, ATel, 504, 1
5. Smith D. M. et al., 2005, ATel, 557, 1