V 1223 Sgr: long term variability and periodic modulation of X-ray emission

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Abstract

The intermediate polar V1223 Sgr is the most significantly detected cataclysmic variable by *INTEGRAL/IBIS*. Our analysis of all available observational data from *INTEGRAL* showed that the fluxes of V1223 Sgr are long-term variable, mainly in (15 - 25) and (25 - 40) keV bands. Moreover this hard X-ray / soft gamma ray variability is correlated with the changes in optical spectral band. Using our method of phase resolved mosaics we showed that the flux of V1223 Sgr in (15 - 25) keV band has sinusoidal variations with orbital period (3.37 h).

Introduction

Cataclysmic variables (CVs) are a special group of eruptive variable stars showing strong activity related to mass transfer in the whole spectrum up to gamma rays (Warner 1995). CVs are close binary systems consisting of a white dwarf (WD) accreting matter from a late-type star (typically a red dwarf).

In intermediate polars (IPs), significant magnetic field (10^6 – 10^7 G) of the WD can disrupt the accretion disc at some distance from the WD surface. The matter is then free-falling along the magnetic field lines onto the WD and forms a strong shock above its surface (Aizu 1973). The temperature in the post-shock region can be very high (~10–100 keV) and the plasma there is cooled mainly via optically thin bremsstrahlung radiation in the X-ray band (King & Lasota 1979).

Short-term X-ray modulations have been observed at the orbital period, spin period of the WD or a beat between the two. No significant modulation has been found so far in the (20-30) keV light curves (Barlow et al. 2006). The majority of the CVs seems to have persistent soft gamma ray fluxes.

The intermediate polar V 1223 Sgr is the most significantly detected CV in the current IBIS survey maps, with a significance of 38σ in the (20–40) keV final mosaic (Barlow et al. 2006). This system has also been detected by *RXTE* between 1996 and 2000 and the broad-band spectrum (3–100 keV) provides an estimate of the post-shock temperature of kT = 29 ± 2 keV (Revnivtsev et al. 2004).

V 1223 Sgr is bright X-ray source (4U 1849–31) with possible X-ray flare activity. Unusual high energy burst (a flare lasting for ~3.5 hrs with a peak flux ~3 times that of the average) was observed by *INTEGRAL/IBIS* at MJD = 52743 (Barlow et al. 2006). This outburst can be a result of a temporary increase in accretion rate onto the WD.

A short-term burst (the single optical outburst lasted between 6 and 24 hrs and resulted in an increase in flux by a factor of 3) has also been detected from this system in the optical by van Amerongen & van Paradijs (1989). Another two fast flares (~15 min and ~2.5 hr) were detected from V1223 Sgr on MJD=53110 and MJD = 53116 by *INTEGRAL/OMC* (Šimon et al. 2005). These outbursts are probably a result of disk instabilities or an increase in mass transfer from the secondary but there is no correlation between optical and X-rays burst activity.

Moreover the episodes of deep low state (decrease by several magnitudes) of 1223 Sgr in optical band were also detected (Garnavich and Szkody 1988).

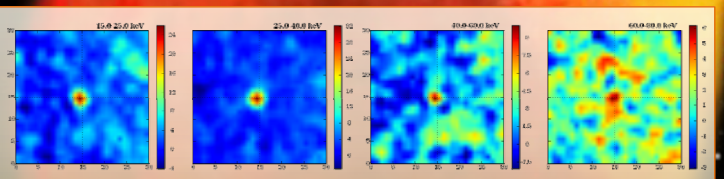

Figure 1: *INTEGRAL/IBIS* significance maps of the area around V1223 Sgr in (15 - 25) keV, (25 - 40) keV, (40 - 60) keV and (60 - 80) keV energy bands. Total observation time is 1.4 Msec.

Observations and analysis

We used all available observational data from *INTEGRAL/JEM-X* and *INTEGRAL/IBIS* detectors to study possible variability of V 1223 Sgr in X-ray and gamma ray spectral bands. This observational material represents 132 (*INTEGRAL/JEM-X*) and 1375 (*INTEGRAL/IBIS*) individual pointings obtained during almost three years (MJD 52710.38 - 53809.25). Observational data used in our analysis were processed by INTEGRAL's latest Offline Standard Analysis Package OSA7.

In addition, we used all available observational data from *INTEGRAL/OMC* to look for short–term periodic modulations as well as long-term variability of V1223 Sgr in optical spectral band.

The overall mosaics of all available data from *INTEGRAL/IBIS* (total exposure time 1405.5 ksec) showed that V 1223 Sgr is detectable up to the (60 - 80) keV band (see Figure 1). During monitored period the mean fluxes of this object were (103.00 ± 3.95)×10^{-12} erg cm^{-2} s^{-1}, (46.40 ± 1.42)×10^{-12} erg cm^{-2} s^{-1}, (15.10 ± 1.48)×10^{-12} erg cm^{-2} s^{-1} and (12.30 ± 1.97)×10^{-12} erg cm^{-2} s^{-1} in (15 - 25) keV, (25 - 40) keV, (40 - 60) keV and (60 – 80) keV band, respectively. The inspection of the data showed that observations were obtained during 7 separate season. As the next step we splitted the data according these seasons to investigate long-term X-ray/gamma ray variability. The obtained fluxes are listed in Table 1 and corresponding light curves are displayed on Figure 2. It is clear that the fluxes especially in (15 - 25) keV and (25 - 40) keV bands are long-term variable with significant drop around MJD ~ 53 650.

Table 1. *INTEGRAL/IBIS* fluxes of V1223 Sgr in corresponding energy bands . We used 3σ upper limits.

MJD	Exposure time	Flux (15 - 25)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (25 - 40)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (40 - 60)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (60 - 80)keV [10^{-12} erg cm^{-2}s^{-1}]
52 710.38 - 52 752.01	109.2	161.00 ± 14.50	57.90 ± 4.88	< 14.76	< 18.78
52 917.17 - 52 926.84	151.1	112.00 ± 11.30	51.10 ± 4.19	21.30 ± 4.24	< 16.83
53 082.07 - 53 119.10	228.1	127.00 ± 8.92	50.00 ± 3.28	23.10 ± 3.48	16.60 ± 4.54
53 267.41 - 53 305.97	134.5	126.00 ± 12.50	55.40 ± 4.46	25.40 ± 4.75	27.70 ± 6.23
53 440.61 - 53 479.81	90.9	155.00 ± 15.20	61.30 ± 5.53	24.10 ± 5.85	< 23.34
53 602.80 - 53 672.88	409.6	< 21.48	31.80 ± 2.65	< 8.67	< 11.61
53 781.06 - 53 809.24	282.1	132.00 ± 9.96	48.50 ± 3.50	13.90 ± 3.56	< 14.34

Table 2. *INTEGRAL/JEM-X* fluxes of V1223 Sgr in corresponding energy bands . We used 3σ upper limits.

MJD	Exposure time	Flux (3 - 6)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (6 - 10)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (10 - 15)keV [10^{-12} erg cm^{-2}s^{-1}]	Flux (15 - 25)keV [10^{-12} erg cm^{-2}s^{-1}]
52 729.19 - 52 748.22	8.4	4.86 ± 0.99	4.78 ± 1.03	4.06 ± 1.27	< 9.84
52 917.95 - 52 922.93	8.9	2.81 ± 0.94	3.77 ± 0.99	3.00 ± 1.22	< 9.84
53 109.19 - 53 119.10	23.3	2.39 ± 0.61	4.09 ± 0.59	3.12 ± 0.75	7.02 ± 2.00
53 290.73 - 53 292.94	10.8	3.72 ± 0.95	3.92 ± 0.93	3.36 ± 1.18	8.00 ± 3.07
53 440.66 - 53 442.35	7.2	3.90 ± 1.21	4.55 ± 1.16	3.07 ± 1.46	< 11.07
53 630.59 - 53 672.74	11.5	2.51 ± 1.02	3.99 ± 1.00	< 3.57	< 9.84
53 799.35 - 53 807.17	10.6	< 3.21	2.73 ± 1.01	< 3.57	< 9.84

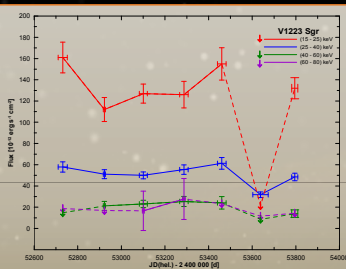

Figure 2. *INTEGRAL/IBIS* light curves of V 1223 Sgr in corresponding energy bands.

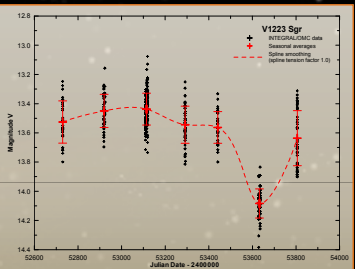

Figure 3. *INTEGRAL/OMC* light curve of V 1223 Sgr in optical spectral band.

The optical light curve of V1223 Sgr based on *INTEGRAL/OMC* data is showed in Figure 3. We can see, that optical brightness of this source is long-term variable. Moreover this variations are correlated with the changes in (15 – 25) keV, (25 – 40) keV and (40 – 60) keV spectral bands with correlation coefficient 0. 81, 0. 82 and 0.89, respectively. Our detailed period analysis of *INTEGRAL/OMC* data did not yield any significant period, only partial detection of the orbital period P_{orb} = 3.37 hrs (Jablonski and Steiner, 1987). This result is probably connected with complex intrinsic variability (flickering) of V 1223 Sgr and inappropriate time distribution of the data.

We prepared overall mosaics using all available data from *INTEGRAL/JEM- X too*. Total exposure time was 80.6 ksec. The medial fluxes of V 1223 Sgr during monitored period were (2.75 ± 0.35)×10^{-12} erg cm^{-2}s^{-1}, (3.65 ± 0.34)×10^{-12} erg cm^{-2} s^{-1}, (2.62 ± 0.43)×10^{-12} erg cm^{-2} s^{-1} and (4.87 ± 1.14)×10^{-12} erg cm^{-2} s^{-1} in (3 - 6) keV, (6 – 10) keV, (10-15) keV and (15 – 25) keV band, respectively. Like in the case of *INTEGRAL/IBIS* data were splitted to 7 seasons to investigate long-term X-ray variability of V 1223 Sgr. The fluxes in the corresponding energy bands are listed in Table 2. As we can see in Figure 4 the *INTEGRAL/JEM-X* fluxes of V 1223 Sgr are persistent within their errors.

Futher we tried to investigate the possible short-term variability of V 1223 Sgr in *INTEGRAL/IBIS* data. Typically, X-ray modulations have been observed at the orbital period, spin period of WD or a beat between the two in IPs. However, the IPs are close binary systems with orbital periods in order of hours and these objects are not detectable on this time scales by *INTEGRAL*/IBIS.. We prepared unique method of folding particular phase interval on the base of proper time intervals from individual science windows. Our method is applying Good Time Intervals (GTIs) according to (orbital or other) phase bin and creating phase resolved mosaics (supposing sufficient exposure) of a periodic source. Phase diagram of the fluxes V1223 Sgr in (15-25) keV band folded with orbital period and constructed using the data from time interval MJD (52 917.17 - 52 926.84) is showed in Figure 5.

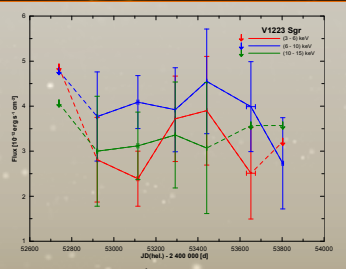

Figure 4. *INTEGRAL/JEM-X* light curves of V 1223 Sgr in corresponding energy bands.

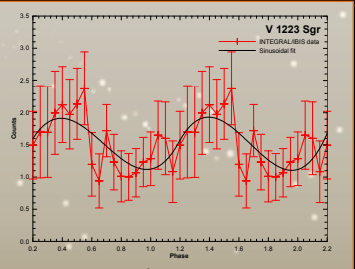

Figure 5. *INTEGRAL/IBIS* phase diagram of V 1223 Sgr in (15-25) keV band folded with orbital period (3.37hrs).

Conclusion

We analysed all available observational data from *INTEGRAL* for intermediate polar V 1223 Sgr. Our analysis of data from *INTEGRAL/IBIS* showed that the fluxes of this object are long-term variable, mainly in (15-25) and (25-40) keV bands. Moreover these hard X-ray / soft gamma ray variability is correlated with the changes in optical spectral band.

Our analysis revealed deep flux drop around MJD ~ 53 650 observed in both X-ray and optical bands. If the high energy emission is assumed to originate from the hot, shocked plasma in the accretion column, this drop is probably related with the decrease of the accretion rate in the system.

The fluxes from *INTEGRAL/JEM-X* were persistent within their errors in monitored time period.

Using our method of phase resolved mosaic we showed that the flux of V1223 Sgr in (15-25) keV band is variable with orbital period. Despite of relatively large errors we can see sinusoidal variations which are possible connected with the change of visibility of impact regions on the WD surface during orbital cycle.

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