Suzaku observations of the peculiar cataclysmic variable FS Aurigae

Vitaly Neustroev [1] & Sergey Tsygankov [2,1]

[1] Astronomy Division, Department of Physics, University of Oulu, Finland

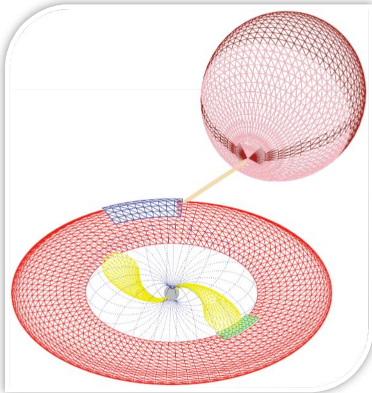
[2] Finnish Centre for Astronomy with ESO (FINCA), University of Turku, Finland

e-mail: vitaly@neustroev.net

INTRODUCTION AND OBSERVATIONS

FS Aurigae is a peculiar cataclysmic variable showing multiple periodic photometric and spectroscopic variabilities (Neustroev et al. 2013). The orbital period (OP) of 85.7 min which is only sometimes visible in the optical light curve, is determined from the radial velocity variations of emission lines. The light curve is usually dominated by modulations with a long photometric period (LPP) of 205.5 min (Neustroev 2002; Tovmassian et al. 2003) whose shape undergoes dramatic changes from almost perfectly sinusoidal to a double-hump shape. In addition, the system shows a second long spectroscopic period (LSP) of 147 min, appearing in the far wings of emission lines (Tovmassian et al. 2007). It is interesting that the LPP has never been detected spectroscopically, whereas the LSP is barely seen in the photometric data. However, there is a definite relation between all the three periods: $1/P_{\rm LSP} = 1/P_{\rm OP} - 1/P_{\rm LPP}$.

The puzzling behaviour of FS Aur is explained within the frame of the enhanced intermediate polar scenario with a rapidly rotating magnetic white dwarf precessing with the LSP (Tovmassian et al. 2003, 2007; Neustroev et al. 2013).



This hypothesis has received an observation confirmation after finding strong indications that the LSP signal detected in FS Aur's X-rays and optical photometry and spectroscopy is similar in nature to the spin modulation of the IPs (Neustroev et al. 2013). However, some of the conclusions made by Neustroev et al. (2013) on the base of X-ray observations, are not convincing owing to insufficient data.

Here we present the longest and most sensitive X-ray observations of FS Aur to date, performed with Suzaku on 2013 September 06–07, with a net exposure time of 17.3 h (62.2 ks) acquired over a 39 h time period. The X–ray Imaging Spectrometer (XIS) was operated in the normal mode, providing a time resolution of 8 s. Since we have detected no significant flux with the Hard X-ray detector (HXD), we use only the XIS data in this study. Three out of the four CCD chips were available in these observations: the front-illuminated XIS0 and XIS3 and the back-illuminated detector XIS1.

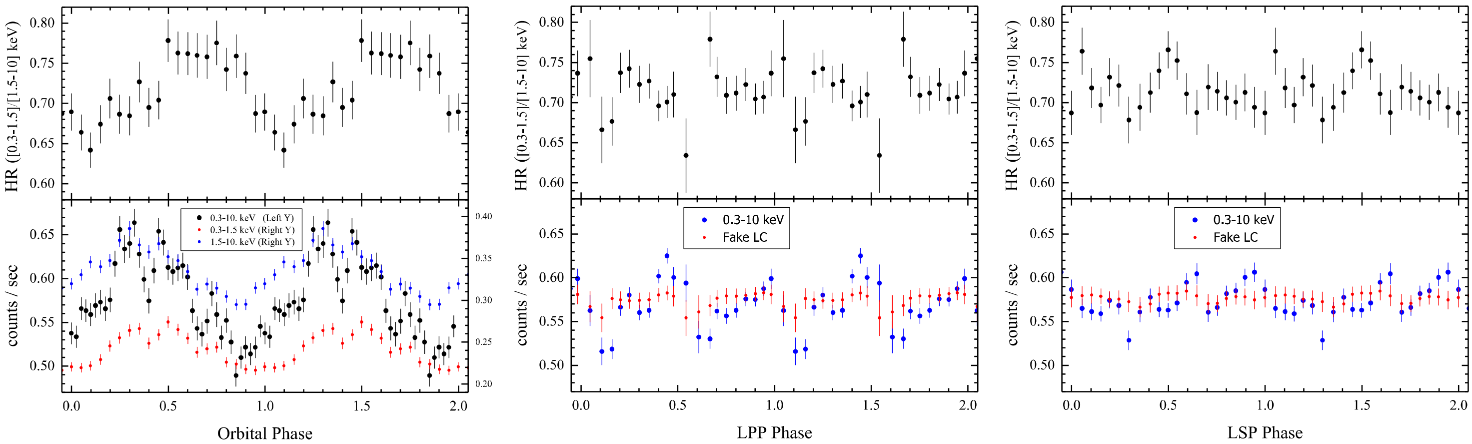
TEMPORAL ANALYSIS

We folded the X-ray light curve of FS Aur with the OP, LPP and LSP according to ephemeris from Neustroev et al. (2013). The OP modulation is clearly apparent and has a rather smooth, sine-like shape. There also is an apparent phase shift between modulations at softer and harder energy ranges that results in a significant variability in the hardness ratio.

The analysis of previous X-ray observations of FS Aur also revealed a strong modulation with the OP which shape varied significantly between different X-ray sets (Neustroev et al. 2013). The existence of modulations with two other periods in the previous observations is not so obvious. In the case of short observations multiple variabilities can strongly interfere with each other, making any conclusion on reality of modulations in folded light curves difficult. The longer observations with Suzaku allowed us to smear the concurrent modulations out and to make a confident conclusion on the reality of modulations with all the three periods.

The LPP modulation has a double-hump shape in an agreement with the previous observations. The variability with the LSP is less apparent in the folded light curve, but is clearly seen in the hardness ratio curve.

As a further check we created an artificial light curve of a sine wave with the OP and amplitude similar to the observed one, and with the same time-sampling and count-rate as our dataset. This fake light curve folded with the LPP and LSP, shows no variability with the corresponding period.

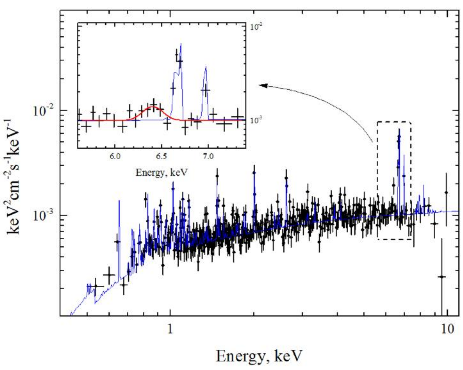


SPECTRAL ANALYSIS

For the spectral analysis we used a combined time-averaged spectrum from the front-illuminated XIS0 and XIS3 detectors. The spectrum is is best fitted by the sum of MEKAL plasma emission models with three different temperatures, modified by the interstellar absorption (PHABS in XSPEC). The fitted value of abundance is about 1 (using the Solar abundance table from Asplund et al., 2009). The best-fit spectral parameters are nH=1.2(3)×10^{21} cm^{-2}; kT=0.67(3), 3.6(2), 40(20) keV; Abund=1.1(1).

DETECTION OF THE 6.4 keV LINE

The high quality of the data allowed us to detect, for the first time from this source, an iron fluorescence line at 6.4 keV (see red line in fig. 2). The presence of this feature in the spectrum suggests that reflection from the white dwarf plays an important role (Hellier et al., 1998) and has to be taken into account in the future modelling.



CONCLUSION

- We confirm the existence of stable modulations with the orbital, long photometric and long spectroscopic periods in the X-ray light curve.
- The X-ray spectrum of FS Aur is typical of an intermediate polar type source.
- We report the detection of the fluorescent Fe Kα emission line at 6.4 keV.

REFERENCES:

Asplund M. et al., 2009, ARA&A, 47, 481
Hellier C. et al., 1998, MNRAS, 297, 526
Neustroev V.V., 2002, A&A, 382, 974
Neustroev V.V. et al., 2013, MNRAS, 432, 2596
Tovmassian G.H. et al., 2003, PASP, 115, 725
Tovmassian G.H. et al., 2007, ApJ, 655, 466