SPECTROSCOPIC STUDY OF THE ULX-PULSAR NGC 7793 P13

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We will re-analyze the archived data of NGC 7793 P13 obtained with the ESO-VLT telescope in 2009-2011. The spectra contain a bright HeII λ4686 emission line, the nature of the variability of which indicates that it is formed in a supercritical accretion disk. We are constructing a radial velocity curve of this line, an analysis of which, together with data from the literature, allowed us to obtain the following system parameters: the semi-amplitude of the radial velocity of the accretor is $48 \pm 10 kms^{-1}$, the donor mass function is 0.738 $M_{\odot}$, and the orbit inclination is $20.3 \pm 1°$.

Keywords: ULX-pulsar – X-ray binaries – Radial velocity – Accretion – NGC 7793 P13

1. INTRODUCTION

The optical component of NGC 7793 P13 is a supergiant of spectral class B9Ia [5] with mass 18-23 $M_{\odot}$. [6] determined optical and ultraviolet photometric period equal to $\sim$ 64 days, which is also involved in the radial velocity of HeII. Fürst et al. (2018) performed a timing analysis of multiple observations XMM-Newton and NuSTAR of the ultra-luminous pulsar NGC 7793 P13, covered by the entire period of its variables of 65 days. Using the measured periods of pulsations to determine the ephemeris orbit, the authors were confirmed by the duration of the orbital period $P_{orb} = 63.9^{(+0.5)}_{(-0.6)}$ days and an eccentricity $e \leq 0.15$ was found.

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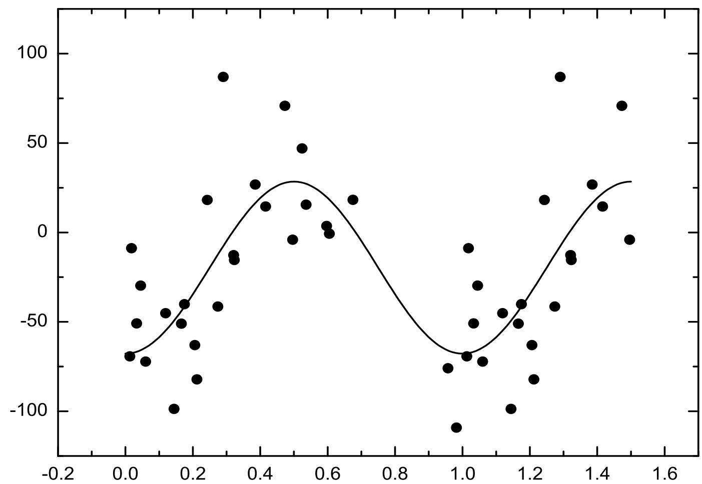

Fig. 1. Radial velocity curves of the HeII emission line

2. OBSERVATIONS

This work presents archival optical spectra of NGC 7793 P13 obtained on ESO-VLT (FORS2 spectrograph, 1200B Grism, $\lambda\lambda$ 3730-5190 ÅÅ, resolution 1800 per 4000 Å for 1" slit) in 2009-2011. The spectra were processed in a universal package astronomical data reduction and analysis software IRAF. The radial velocities of HeII λ4686 and H_β were measured by cross-correlation method. A total of 41 spectra were processed; spectra with a low signal-to-noise ratio were excluded from the analysis. The radial velocity values are not absolute, it is obtained accurate to the constant responsible for the instrumental correction, which was measured from the H_β lines of the emission nebula, because atmospheric telluric lines are absent. The accuracy of measuring radial velocities is better than 10 km s^{-1}.

3. RESULTS

The resulting radial velocity curve is shown in Fig. 1. The following orbital parameters were obtained: the semi-amplitude of the radial velocity curve is 48 $\pm$ 10 km s^{-1}, mass function is 0.738 $M_\odot$, period is 63.9 $\pm$ 1 d. Previously [6] received a relativistic object mass of more than 3.45 $M_\odot$. However, pulsed X-ray signals were detected in this object [1], which suggests that the object is a real

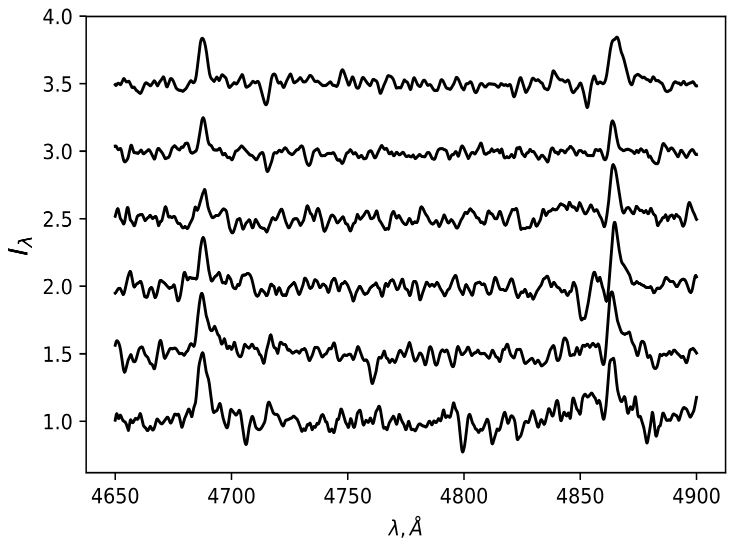

Fig. 2. Spectral variability of the HeII and λ4686 and H_β emission lines in 2011. The time interval between obtaining spectra is 2-3 days

pulsar. Then, if we assume that the line HeII indicate the velocity field of the neutron star, then taking the canonical value of the mass of the neutron star equal to 1.4 and the mass of the optical star 18-23 $M_\odot$, we obtain the inclination angle of the system $20.3 \pm 1°$. The found inclination is close to obtained from the X-ray light curves by Fürst et al. (2018), equal around 30°.

[3] examined all the ULXs (a little less than 10) for which spectral data were obtained by 2015. They showed that sources demonstrate fast (over an interval of several days) changes in the parameters of emission lines, which can most naturally be explained by the phenomena in the winds of supercritical disks in these objects. The spectral variability of the lines from night to night in NGC 7793 P13 have the same behavior (Fig.2). This fact can serve as an another confirmation that the line HeII is formed in the super-Eddington accretion disk around the neutron star. Equivalent widths and FWHM are given in table 1. Mean EW HeII $\lambda 4686 = 1.7 \pm 0.1$, mean EW $H_\beta = 2.7 \pm 0.2$.

The spectrum of NGC 7793 P13 indicating a B9Ia supergiant companion, which itself can not produce the HeII emission line. It is known that NGC 7793 P13 is a supercritical disk with a neutron star [2]. Therefore, the HeII line observed in NGC 7793 P13 must be formed in the second companion, namely, in a photoionized wind from the accretion disc [3].

Table 1. EW and FWHM of the HeII λ4686 and H_β emission lines

HJD	EW of HeII λ4686 Å	FWHM of HeII λ4686 Å	EW H_β	FWHM H_β
2455174.54630101	1.2	4.3	3.4	3.4
2455397.77179284	1.4	6.1	2.4	10.5
2455497.53612086	1.0	6.6	3.5	5.1
2455504.60394795	1.3	4.7	3.0	4.8
2455508.58838370	2.0	4.9	3.0	6.8
2455529.66018682	1.1	4.0	2.3	4.8
2455533.57651187	1.5	5.8	2.0	3.5
2455538.59743700	1.9	4.8	3.9	5.5
2455556.58197444	1.3	6.4	5.2	6.0
2455560.54188057	0.8	3.0	3.6	6.1
2455766.72186000	2.9	5.5	3.1	4.3
2455769.75889995	2.3	4.9	2.8	4.5
2455771.83248619	1.4	3.6	2.3	3.8
2455775.83682458	0.9	3.4	1.6	3.9
2455777.77416309	0.9	3.1	0.7	2.9
2455782.89898229	1.4	4.1	2.2	6.6
2455784.72214442	1.7	4.4	2.8	3.1
2455789.84889746	2.2	3.3	-	-
2455822.73375230	1.9	3.3	-	-
2455825.76307340	2.4	4.5	-	-
2455828.68433989	1.9	3.9	-	-
2455832.65638535	3.3	5.5	2.4	9.7
2455835.64745885	2.3	5.4	1.6	2.7
2455837.52440651	1.6	5.1	1.4	2.9

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