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PHOTOMETRIC BEHAVIOUR OF V1343 AQUILAE (SS 433) IN 2011

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The X-ray orbital satellite *INTEGRAL* observed SS 433 in October 2011. In order to synchronize these observations with the optical light curve, I have observed the star during 34 nights at the Crimean Astrophysical Observatory (Simeiz site), Ukraine, with the 1-m telescope. Two CCD detectors: VersArray 512UV (Peltier cooling, –50°C) and VersArray 1340×1300 (liquid nitrogen cooling, –110°C) were used. The same filter set for both detectors provided the instrumental systems close to the standard Johnson $UBVRI$. The observations at JD=2 455 856 (last point in Fig. 1) were made at Stará Lesná Observatory of the Astronomical Institute of the Slovak Academy of Sciences (VersArray 512UV camera and a 60-cm Zeiss reflector). All the observations were corrected for atmospheric extinction by the method described in Moshkalev and Khaliullin (1985) and reduced to the standard Johnson $UBVRI$ system. These data are available in electronic table. The mean errors of the individual observations in U, B, V, R, I are 0.07, 0.03, 0.02, 0.015 and 0.018 magnitude, respectively.

During three nights with the most stable atmospheric transparency, I obtained magnitudes of stars in the frame with respect of the secondary photometric standard GSC 479.740 = 111.2009 from the Moffett and Barnes (1979) list. The results are presented in Table 1.

Table 1. Photoelectric magnitudes of neighboring stars

Star	V	$U-B$	$B-V$	$V-R$	$R-I$
1	11.422(5)	1.112(25)	1.483(9)	1.347(6)	1.056(9)
2	13.396(6)	0.443(20)	1.037(9)	0.912(7)	0.748(10)
3	13.005(6)	0.237(23)	0.770(9)	0.709(7)	0.543(9)
4	12.769(7)	0.243(19)	0.799(10)	0.730(8)	0.575(6)
5	15.488(24)	0.575(83)	0.995(27)	0.958(25)	0.655(28)
26	12.886(5)	−0.031(10)	0.750(9)	0.732(6)	0.548(16)

The numbers of the stars are those from Leibowitz and Mendelson (1982; hereafter, LM). My standardization in the V band coincides with LM better than to $0\overset{m}{.}02$ for all stars in common except No. 1 and No 2. Star No. 1 was supposed to be variable with an amplitude of $0^{\mathrm{m}}\!.1$ by Kemp et al. (1986). It also shows irregular variations of brightness in present observations, with the full amplitude of $0^{\mathrm{m}}\!.04$ in V. Its spectral type derived from the photometry is M2V if we assume $A_V = 0$, see Fig. 2. The star's high proper motion, $\mu = 0.123''$/year in the Tycho-2 catalogue, indicates the proximity of the star and agrees with such a possibility. Thus, it could be a BY Dra variable. Star No. 2 has a red companion at $6''$ distance that could influence measurements on nights with bad seeing. Therefore, star No. 4 was used as the main comparison star and star No. 3, as the check one. Their magnitudes match LM data well, and these stars did not show any significant variability in the present observations.

I have used all available V-band observations of SS 433 collected by Goranskij (2011) and the ephemeris from the same publication to obtain the mean curve of the star phased with the precession period: HJD Max $= 2449998.0 + 162.278 \cdot E$.

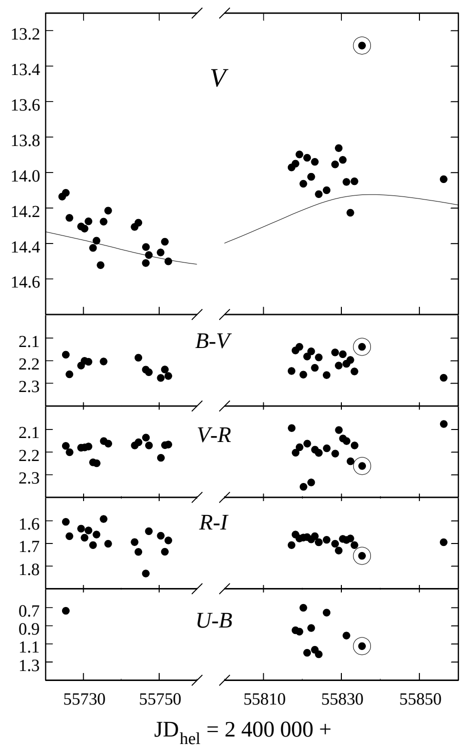

Figure 1. Nightly mean magnitudes of SS 433. The points corresponding to the flare are encircled. The solid curves in the upper panel denote the mean precession curve.

The comparison of this mean curve with the present data reveals that the object was in the active state during the autumn observations, see Fig. 1. A flare observed on JD 2455835 supports such an idea. It is interesting to note that the colours of the object did not change significantly during the flare (Fig. 1). Figure 2 displays the position of SS 433 in the two-colour $U-B, B-V$ diagram. Assuming that almost all the visible light comes from the thick disk (Leibowitz 1984, Antokhina and Cherepashchuk 1987, Hirai and Fukue 2001), one can find from this diagram that the spectrum of the object is B3 and $E(B-V) = 2.37 \pm 0.06$, so the lower limit of the temperature of the disk should be $T \approx 19000$ K. The interstellar extinction for SS 433 is $A_V = 7.35 \pm 0.18$, somewhat lower than the commonly accepted value from Perez and Blundell (2010): $A_V = 7.8$.

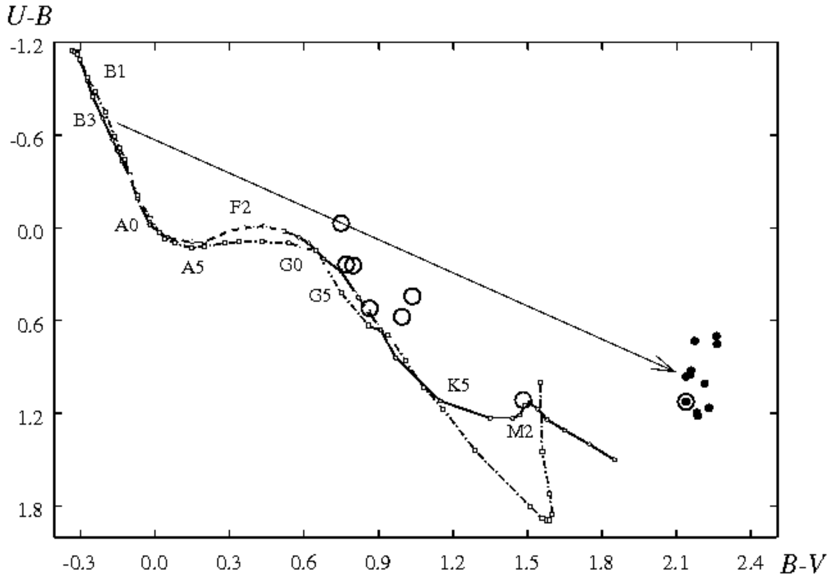

Figure 2. The position of SS 433 in the $U-B, B-V$ diagram - black points. Luminosity classes are plotted according to Straizys (1977): the dotted line stays for the luminosity class III and the solid line for V. The point in the flare is encircled. Big circles correspond to all measured stars in the sky region. The reddening vector is indicated by the arrow.

The analysis of the present data except for points in a flash for periodicity reveals another interesting fact. It is not the orbital period but the nutation period that dominates the periodogram, see Fig. 3. We present the nightly mean data folded with the best period found, $P_{nut} = 6\overset{d}{.}109$, in Fig. 4 and the data folded with the orbital period, HJD Min $= 2450023.746 + 13.08223 \cdot E$ according to Goranskij (2011), in Fig. 5.

One can see that the present value of the nutation period is shorter than it follows from the equation: $1/P_{\rm nut} = 2/P_{\rm orb} + 1/P_{\rm prec}$, $P_{\rm nut} = 6\overset{d}{.}2877$. This could be explained by the precession period variations found by Davydov, Esipov and Cherepashchuk (2008) spectroscopically. In this study, we may associate this effect with the active state of the object. It should be noted from Figs. 1 and 4 that the flare occurred at the brightness maxima of the nutation and precession curves, when the opening of the disk to the observer was maximal.

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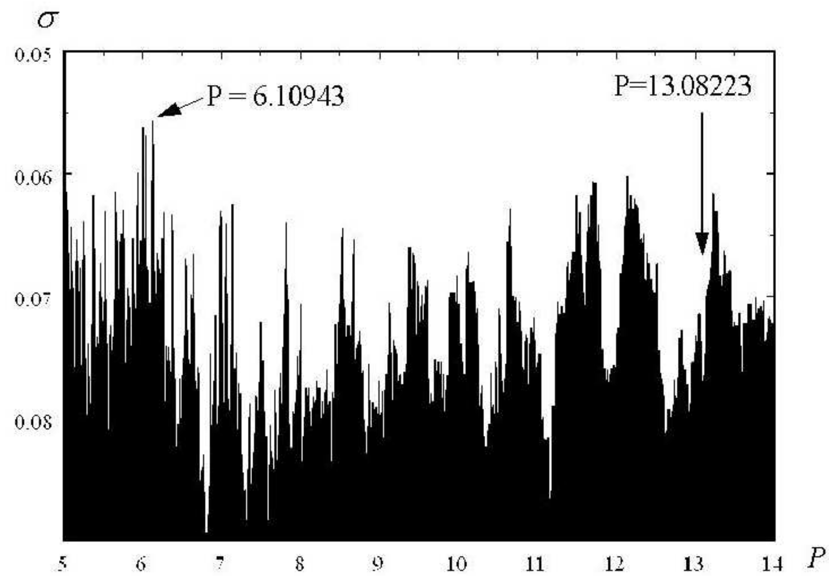

Figure 3. The periodogram of the V-band light variations in SS 433 based on 333 data points during 2011. The average precession curve was subtracted from the data. The double nutation period is also presented. Extra peaks are mainly due to the approximately three month gap between the observational sets.

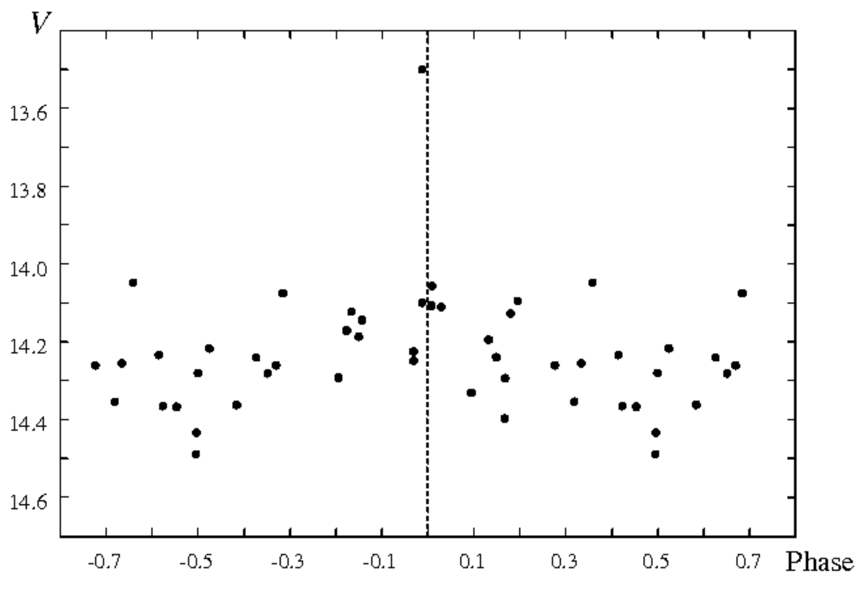

Figure 4. The V-band light curve phased with the nutation period, $6\overset{d}{.}109$. The average precession curve was subtracted from the data.

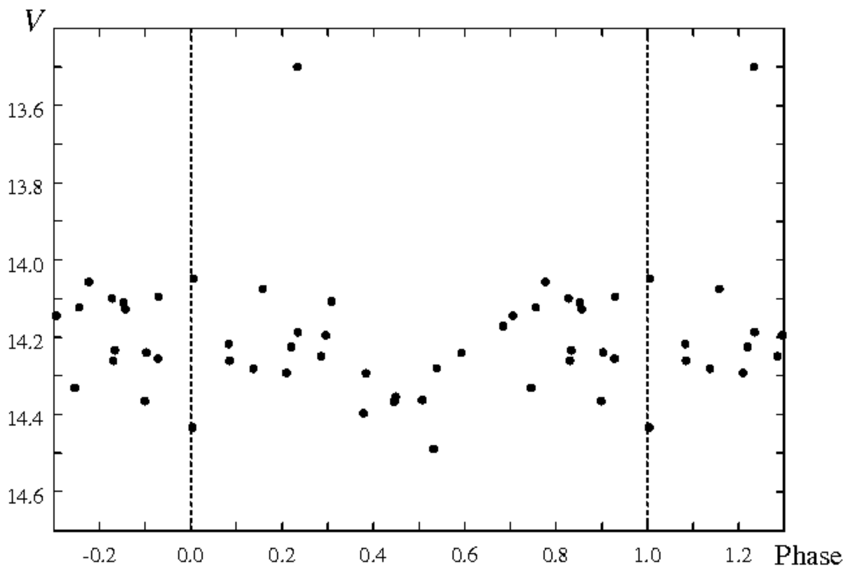

Figure 5. The V-band light curve phased with the orbital period, $13\overset{d}{.}08223$. The average precession curve was subtracted from the data. The primary minimum is almost invisible.

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