Apsidal motion in Alpha CrB.

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Introduction.

The eclipsing binary Alpha CrB (P = 17^d.36, V = 2^m.21, e = 0.33, A0 V + G7 V) is the fourth brightest known eclipsing variable. Alredy more than 100 years ago the star was identified as the spectral binary (Hartmann, 1903). The star was also one of the objects for observation in pioneering electrophotometric works of J.Stebbins. He discovered in 1912 a shallow, only 0^m.1 in depth, primary minimum, (Fig.1, 2), (Stebbins, 1928). The effective wave length of the observations was 450nm therefore, the secondary minimum from the eclipse of a faint red star by the bright blue main component was impossible to detect. Much later it was discovered in observations with a red-ray sensitive photocell at a wavelength of 723nm, Kron&Gordon, 1953. Koch, 1977, indicated that the system should be very promising for investigation of the relativistic effect in periastron advance. The next light curve with secondary minimum was obtained by Volkov, (1993) at λ = 751nm. With its help the speed of apsidal rotation was first measured and it was found to be slowed down, ***dω/dt* = 0.008°/year**. Next estimation by Schmitt, 1998, made use of satellite observations in X-ray in a very short time interval seems to be of very low precision and overestimated: ***dω/dt* = 0.021°/year** , but allowed one to correct the previous values of the apsidal rotation speed, Volkov, (2005) ***dω/dt* = 0.010°/year**, still slower than one can expect from theory ***dω/dt* = 0.019°/year**. Therefore, we made new observations in order to bring the final clarity to this issue.

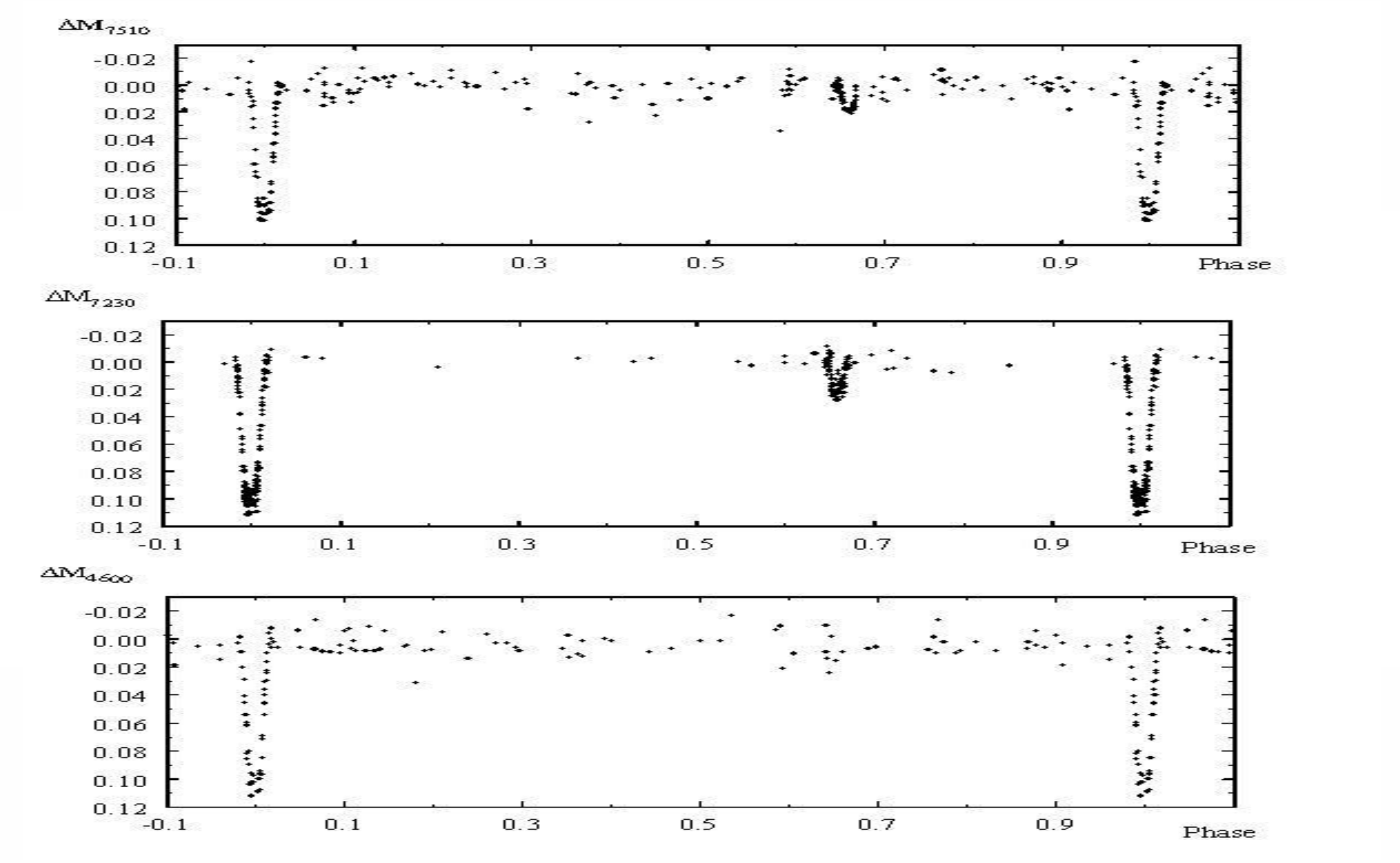

Fig. 1. Three sets of observations of the star in different spectral bounds. The secondary minimum ar 460nm (Volkov, 1993 observations), can not be detected. Small variability of the star between minima can be seen in all sets of observations.

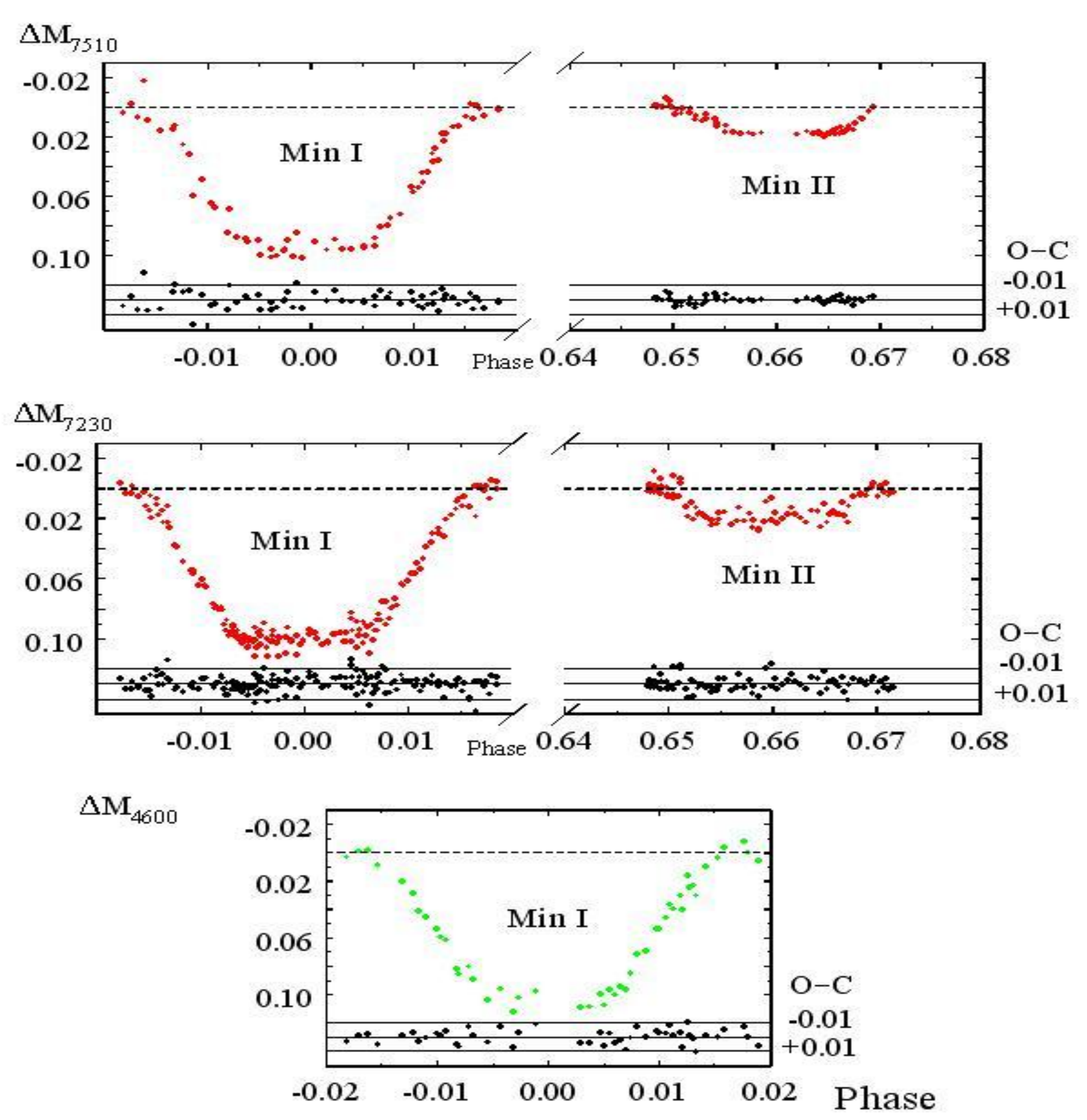

Fig. 2. The plot with individual observations in different epochs and spectral bounds build in large scale. Night corrections were derived by the same for all sets procedure. They do not exceed 0^m.02 and are included in resulting plots.

Par.	Kron& Gordon	Volkov, 1993	Present work
r_1	0.072(1)	0.069(1)	0.074(1)
r_2	0.021(1)	0.020(1)	0.022(1)
i	88.01(1)	88.09(1)	87.90(1)
e	0.35(1)	0.37(1)	0.33(1)
ω	314(1)	310(1)	320(1)
$e\cos\omega$	0.245(1)	0.245(1)	0.253(1)
σ_{o-c}	0^m.0052	0^m.0043	0^m.0044

Table 1. The results of the light curves solutions. Note that ***ecos ω*** is determined with much better accuracy than ***e*** and ***ω*** individually.

	Primary	Secondary
$M/M_☉$	2.57(5)	0.92(4)
$R/R_☉$	2.93(5)	0.85(3)
Log g	3.91(3)	4.54(2)
T(K)	9460(150)	5520(80)
M_{bol}	0.21(2)	5.29(5)
Distance (pc)	23.0(4)	
$a(R_☉)$	42.8(8)	

Table 2. Absolute parameters of the components.

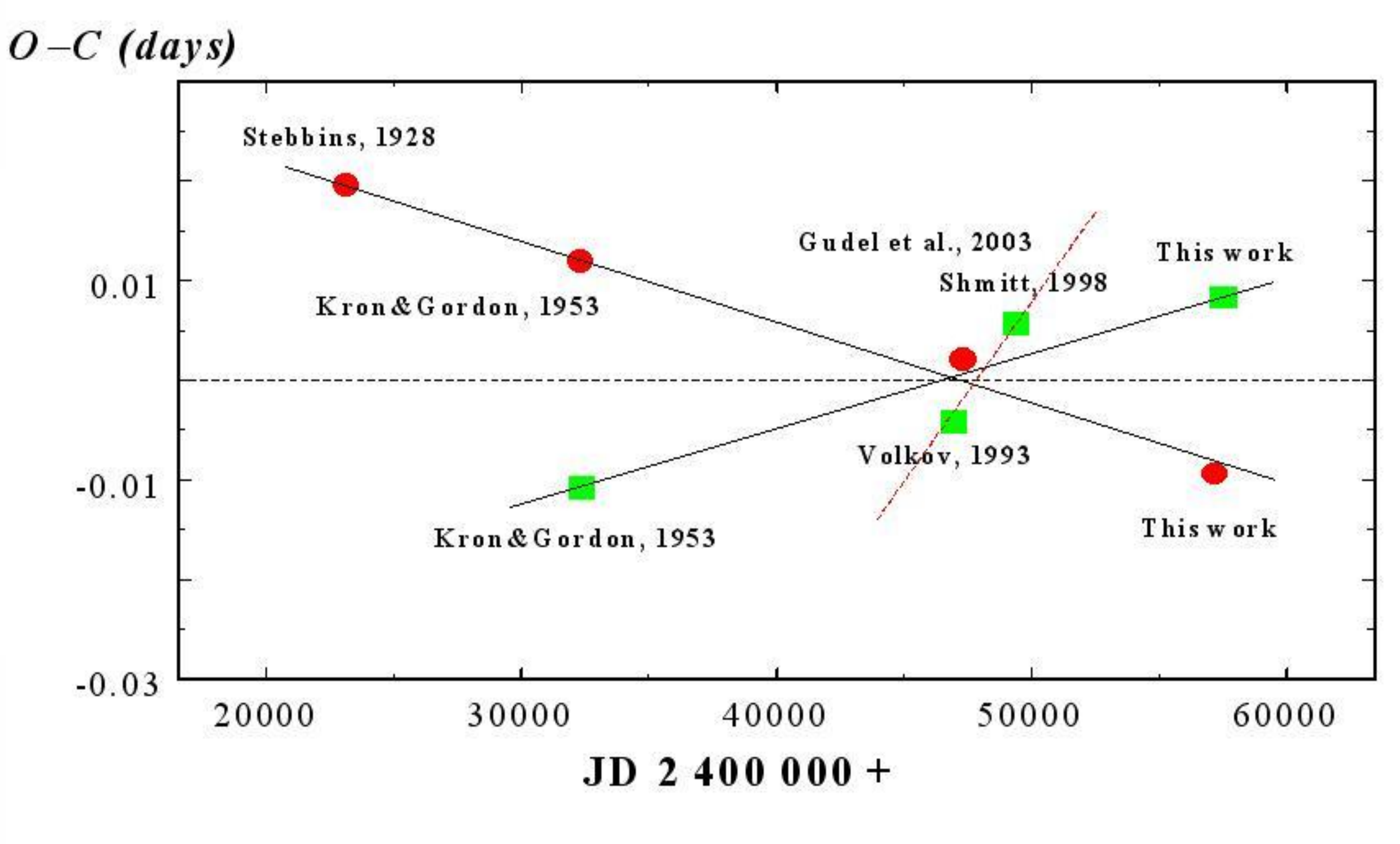

Fig. 3. The ETV diagram of the system build with the mean value of P1 and P2. The straight line segment for secondary minima build with Schmitt's value of periastron advance is shown as dashed red line. One more X-ray timing by Gudel et al., 2003 was included in Shmitt's 1998 point. The errors of secondary minima (green squares) are 5 minutes, primaries(red cicles) – 3 minutes.

Observations

All observations were fulfilled with EMI 9789 PMT and red filter KS-14 which is normally used to build the R Johnson system with S-20 cathodes. Note that we used bialkal cathode, not sensitive to red light. We found that the signal in long red tail of the sensitivity of this PMT attached to 60-cm telescope is strong enough to be measured with high precision, see errors for modern observations in Table.1. We managed to get the same precision as in our earlier set which was fulfilled in very good atmospheric conditions of the mountain observatory in Tien-Shan. The one-channel photometer with photon-counting system of registration constructed by I.Volkov was used. γ CrB, V = 3^m.85, A0 V was used as a main standard star. HD135502 (V = 5^m.27, A2 V) and HD133582 (V = 4^m.51, K2 III) served as a check stars and to derive the parameters of atmospheric transparency.

Apsidal motion

It is well known that if the system demonstrates the apsidal rotation, the instantaneous values of the periods for the main and the secondary minima must be different. Orientation of the orbit of the system is quite favorable to use this method as longitude of the periastron is far from **0°** or 180**°**, see Table 1. We were not able to find the individual timings of minima as their duration are very long, primary – 14.1 hours, secondary – 8.3 hours. So every observational night it was possible to get only parts of minima. For all interval of observations from 2008 till 2019 years we constructed one primary and one secondary minima. Using these timings with all obtained earlier we got next formulae:

Min I =2447346.1144(10) + 17^d.359899(1)×E, (P1)
Min II=2447010.3930(20) + 17^d.359926(4)×E. (P2)

P2 occurred to be very close to our previous value, (Volkov, 2005), but P1 was corrected significantly.
The observed difference between P1 and P2 enables us to find, from well known formulae, the periastron motion rate : ***dω/dt*** **= 0.016(1)°/year ,**
U = 23 000(2000) years.
The theoretical rate of periastron motion which consists from relativistic and classical terms is equal (Volkov, 2005):
dω/dt **= 0.019(1)°/year,**
U = 19 000(2000) years
Now both values seem to be in agreement. But we argue that the observe value is definitely less and does not contradict to the tilt of the rotational axis of the main component to the orbital plane in 20-40 deg limits supposed from spectral observations in Min I by McLaughlin, 1933, see Volkov, 2005. In this investigation we strongly corrected the value of the primary minima period. An unexpected result, since it was believed that its value was determined with very good accuracy due to the large remoteness of the Stebbins observations in time. The eccentricity of the orbit also had to be reduced, see Table.1. All these led to a convergence of the theoretical and observed values of the apsidal motion speed.

Conclusions.

We got the most accurate value of the apsidal rotation speed in Alpha CrB system to date, which turned to be a little slowed down in comparison with the theoretical value. This apparently, is due to the inclination of the axis of rotation of the main component to the orbital plain.

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