βCrB - a Rosetta stone?

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Abstract

Combining the information from the speckle interferometric and spectroscopic binary βCrB a mass of 1.82 solar masses and an absolute visual magnitude $M_v = 1^m.42$ is found, indicating that the star may be in that state of evolution, when the stellar core has shrinked after hydrogen exhaustion in it and the energy generation mainly comes from the envelope. The question whether all magnetic Ap stars are in that special evolutionary state is revived.

Adelman et al. (1981) called βCrB a peculiar Rosetta stone. Today, from another point of view, I ask whether βCrB has the properties of that famous stone found some hundred years ago in northern Egypt near the town Rosetta. This stone was covered with entire different symbols arranged in three columnes; hieroglyphes, demotique symbols and greek letters. Each column obviously described the same contents. Thus the stone could be used as dictionary to interpret the hieroglyphes and generally to learn what has happened more than 2000 years ago. Can βCrB play the same role for the determination of the evolutionary state of magnetic (CP 2) stars?

β CrB is one of the best investigated magnetic stars, since it is bright and has very sharp absorption lines. But differing from most magnetic stars βCrB belongs to a binary system of such a kind that it can be observed by spectroscopic as well as by speckle interferometric methods. Thus mass and luminosity can be derived without the difficulties which otherwise come from the peculiarities in the spectra of magnetic stars. Since the components of the binary are not closely connected, the evolution of the spectroscopic observed primary will not be influenced by that of the companion. Moreover, βCrB may be a member of the Hyades supercluster, giving further

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informations about the parallaxe. Therefore, because the fundamental stellar parameters can be determined on entire different ways, β CrB may be as valuable for the understanding of the physics of magnetic stars as the stone of Rosetta for the interpretation of the hydroglyphes.
The spectroscopic binary was extensively investigated by Neubauer (1944) and the elements were corrected including later measurements by Oetken and Orwert (1984) with the result given in the following tbl.

		Neubauer	Oetken, Orwert
P	=	$3833^d.58 \pm 0.36 = 10^a.496$	$3873^d.0 = 10^a.604$
γ	=	-20.19 km/sec	-21.4 km/sec
K	=	9.19 ± 0.23 km/sec	9.95 km/sec
e	=	0.406 ± 0.025	0.512
ω	=	$185^\circ.4 \pm 2.2$	$187^\circ.7$
T_0	=	$242\ 8971^d.3 \pm 18.09$	$242\ 5156^d.541$

The visual and speckle-interferometric binary elements are based on measurements of different groups (Couteau, Labeyrie, Bonneau et al., Mc Alister et al., Morgan et al., Balega and Ryadchenko). Our preliminary elements and those derived by Tokovinin (1984) are given in the following tbl.

		Oetken, Orwert	Tokovinin
P	=	$10^a.496$	$10^a.27$
e	=	0.511	0.524 ± 0.006
i	=	69°	$111^\circ.1 \pm 0.9$
Ω	=	147°	$148^\circ.2 \pm 0.5$
ω	=	$183^\circ.9$	$181^\circ.3 \pm 0.7$
T_0	=	1980.48	1980.506 ± 0.014

For the determination of the parallaxe, measurements were carried out during 1918-27 at the Allegheny- and during 1928-30 at the Mc Cormick-Observatory, giving the weighted mean of $0''.031 \pm 0.008$. We used the now available speckle interferometric measurements to correct the extensively published equations of condition and performed a new least square solution to determine parallaxe and proper motion of β CrB. By this procedure the parallaxe found from observations at the Allegheny Observatory was reduced from 0.034 to 0.031, that from the Mc Cormick Observatory of 0.014 did not change.

Combining all informations the most probable parameters of the primary β CrB A are:

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$$\mathfrak{M}_A = 1.82\,\mathfrak{M}_\odot \qquad M_V = 1^{m}.42$$

with a possible tendency to a somewhat larger mass.

From the mass-luminosity relation for main sequence stars, one would expect $M_V = 2^{m}.23$. Thus β CrB is brighter by $0^{m}.81$ than a main sequence star of the same mass. The difference decreases for a larger mass of β CrB, but the estimated external accuracy make it unprobable that the discrepancy fully disappears. Assuming the given values to be correct, β CrB would be near to that evolutionary state when the stellar core has shrinked after hydrogen is exhausted in it and the energy generation mainly comes from the envelope, which begins to expand.

If β CrB could be compared with the stone of Rosetta, this would mean that all magnetic stars may be in that particular stage of evolution. Then, moreover, it is suggested that in all stars with masses characteristic for A and late B-types magnetic fields are generated during this very active phase of stellar evolution. The condition may be favourable for magnetic field excitation in a dynamo process as long as this phase holds. A very complicated field may be excited which penetrates through the envelope thereby perfering the lowest multipoles, i.e. dipoles. To explain the observations the time for penetration has to be small compared to the time while the just mentioned phase of stellar evolution lasts. Estimations show that it may be possible. Moreover, under the given assumptions, one would expect that the number $N(A_p)$ of A_p (B_p) stars to the number $N(A)$ of normal A(B) stars corresponds to the ratio of times $\Delta t_1/\Delta t_2$ in stellar evolution: Δt_1 being the time the star spends from its start of the ZAMS till the core begins to shrink, while Δt_2 represents the following time till the star reaches its maximum luminosity. From Ibens (1985) calculations results $\Delta t_1/\Delta t_2 = 11$ % resp. 9.4 % for models with $\mathfrak{M} = 2,25\,\mathfrak{M}_\odot$ resp. $\mathfrak{M} = 3\,\mathfrak{M}_\odot$. The observed ratio $N(A_p)/N(A)$ is of the same order, i.e. ~10 %.

Concluding we state that the question whether β CrB can help to interpret the A_p phenomenon like the Rosetta stone is still open, although it seems a very promising idea. Firstly it is necessary to secure the position in the HR-diagram especially by increasing the accuracy of Δm between the binary components. Secondly the assumption that all CP2 stars have passed that active phase of stellar evolution just after hydrogen exhaustion in the core needs further investigation.

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