Inside the Stars, IAU Colloquium 137
ASP Conference Series, Vol. 40, 1993
Werner W. Weiss and Annie Baglin (eds.)

MODELLING THE ζ HERCULIS SYSTEM

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ABSTRACT The ζ Herculis system is one of the closest well-kown binaries. A tentative modelling shows that though the brighter star is easily described with a mass compatible with the observed one and an age of approximately 3.4 billion years, difficulties arise for the secondary, which plea for more precise observations.

OBSERVATIONAL DATA.

The ζ Herculis system (ADS 10157) is a well known visual binary detected in 1787 by Hershell. Its period being close to 34.4 years more than six revolutions have already been observed with long focus astrometric techniques. The accuracy on the sum of the masses is directed by the parallax since the orbital factor is rather well determined from the orbital elements. The most recent Sproul Observatory results (Lippincott, 1981) give a parallax $\pi = 0.087" \pm 0.003$ (plus a correction of 0.0043" to obtain an absolute value) more than 10% smaller than previously. The visual magnitude of the system is 2.81 ± 0.02 and the magnitude difference of the two components is $\Delta m_v = 2.65 \pm 0.1$, corresponding to $m_{v,A} = 2.90 \pm 0.03$ and $m_{v,B} = 5.55 \pm 0.12$.
Due to the large magnitude difference between the components the uncertainty on the mass ratio is quite large. Following Lippincott (1981) we have adopted :

$$M_A + M_B = 2.21 \pm 0.22 M_\odot$$

$$M_A = 1.43 \pm 0.14 M_\odot \text{ and } M_B = 0.78 \pm 0.08 M_\odot$$

* ζ Her A has a spectral type F9IV, a color index $(B-V)_A = 0.64 \pm 0.02$. A detailed analysis from McWilliam (1990) gives $\log T_{eff,A} = 3.76 \pm 0.01$ and $[F_e/H] = 0.0$. With a bolometric correction of -0.20 (Schmidt-Kaler, 1982) and $M_{bol,\odot} = 4.63$, one obtains $\log(L_A/L_\odot) = 0.85 \pm 0.04$.
* ζ Her B is not so well defined. Its spectral type is K0V. The color index difference between the two components has been measured by Muller (1952) and confirmed by Worley (1969) as $\delta C = 0.18 \pm 0.03$, leading to $(B-V)_B = 0.82 \pm 0.06$. Assuming the same metallicity as ζ Her A, it corresponds to $\log T_{eff,B} = 3.704 \pm 0.015$ and, with a bolometric correction of -0.37, to $\log(L_B/L_\odot) = -0.14 \pm 0.12$ leading to a very excentric position in the HR diagram (fig. 1) which cannot be attributed to a duplicity of ζ Her B, with a total mass M_B.

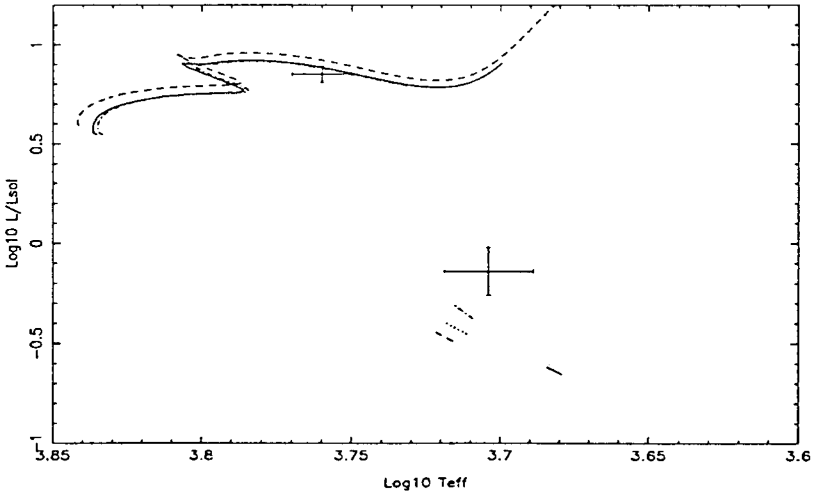

FIGURE I Evolutionary tracks and observed position of ζ Her A and B in a theoretical H-R diagram. For ζ Her A three tracks are shown: the continuous track has $M = 1.40 M_\odot, Y = 0.29$, the dashed one has $M = 1.43 M_\odot, Y = 0.29$ and the dotted-dashed track has $M = 1.43 M_\odot, Y = 0.27$. For ζ Her B tracks followed up to 3.5 10^9 yrs. are shown. The continuous track has $M = 0.78 M_\odot, Y = 0.29$, the dashed one illustrates the effect of a Y-change ($Y = 0.35$) while the dotted one gives the effect of a mass change ($M = 0.86 M_\odot$). The dotted-dashed track has an extreme α value ($\alpha = 1.30$ H_p) and $M = 0.90 M_\odot, Y = 0.29$.

EVOLUTIONARY MODELS.

Models were calculated with the CESAM code (Morel, 1992). We used the Rogers and Iglesias (1992) radiative opacities for temperatures greater than $10^4 K$ and Kurucz's (1991) values for $T < 10^4 K$, with a smooth transition between the two tables. Nuclear reaction rates are from Caughlan and Fowler (1988). We used the Eggleton et al.(1973) formalism for the equation of state complemented by the Coulomb correction to pressure (Christensen-Dalsgaard, 1991). The classical mixing-length theory for convection is used. The α value is considered as "universal" in the solar mass vicinity; several arguments favor this hypothesis, as the position of the red giant branch of a very wide set of clusters (Lebreton and Maeder 1986, Schaller et al. 1992) and the calibration of the α Centauri system (Noels et al. 1991).

An overshooting process from the convective core is taken into account, with a maximum allowed distance of 0.2 H_p considered as "universal", as proposed by Schaller et al.(1992).

We used the Anders and Grevesse (1989) photospheric metal mixture with a solar total metal content $Z = 0.0194$.

The calibration of the Sun with these ingredients gives $Y_\odot = 0.291$ and $\alpha = 1.85$ H_p. This α value is used in all the models.

RESULTS.

We are left with two parameters for the modelling of ζ Her: the helium content Y and the age of the system t. As illustrated in Fig 1 an evolutionary track with a given Y-value will reach the observational point (center of the error box) for a particular value of the mass which can be expressed as a function of Y as :

$$M_A(Y)/M_\odot - 1.38 \simeq -2.0(Y - 0.291)$$

and the age is $t_A = 3.4\ 10^9$ years, almost independant of Y.
The observational errors lead to uncertainties in these determinations of $0.07 M_\odot$ on the mass and $0.4\ 10^9$ years on the age. However, as the system has a solar metallicity, the most probable value for Y remains the solar one, i.e. $Y = 0.291$, leading to a mass of $1.38 \pm 0.04 M_\odot$.
From the theoretical point of view, the observed position of the secondary in the HR diagram could only be explained with a very large Y and a very small mass, a larger Z and a very high mass, and/or a much smaller α. None of these possibilities is very attractive. Either observations are given with extremely optimistic error bars or some unsuspected pecularity is present.

ACKNOWLEDGMENTS

We specially thank P. Couteau for making available to us his double stars files and for discussions concerning the ζ Her orbit, J. Christensen-Dalsgaard for providing us with his CEFF equation of state routine and members of the "GDR Structure Interne, CNRS" for the implementation of the CESAM code.

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