FUNDAMENTAL PARAMETERS AND THE HELIUM CONTENT OF ECLIPSING SPECTROSCOPIC BINARIES

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Today we know accurate masses, radii, surface gravities and luminosities or effective temperatures of a very small number of stars. There are several reasons for deriving accurate parameters of stars. I shall mention only four problems:

(i) checking stellar evolution calculations, particularly calculations of isochrones, using binaries,
(ii) derivation of helium content in stars of different age,
(iii) checking log g derived from photometry and stellar atmosphere calculations,
(iv) determination of accurate positions in the HR diagram to get an independent check on calibrations of photometric systems.

At the Copenhagen University Observatory we have carried out a program deriving fundamental parameters of eclipsing spectroscopic binaries. The spectroscopy is done by J. Andersen with the ESO 1.5m spectrographic telescope at La Silla (in some cases in collaboration with D.M. Popper). The photometry is done by a number of people in Copenhagen using our 50cm reflector at La Silla. Our telescope at La Silla is equipped with a simultaneous four channel spectrographic photometer. The four channels correspond to the Strömgren uvby photometric system. At present we have obtained approximately 40,000 accurate photometric observations of selected eclipsing binaries.

Our philosophy in this program is to study binaries with well separated components to avoid complications such as gas in the

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system, strong deformation of the components, strong reflection
effects, etc. Models of binaries with such complications are not
very well developed and derived parameters of stars in such systems
are therefore not very accurate. A binary with well separated
components can be described using a relatively simple model. We
use the model by Wood (1971).

Let us now ask the questions: What accuracy must we have to
solve the problems (i) - (iv) already mentioned? We shall partic-
ularly consider the helium content problem. From measurements of
emission lines from H II regions in the optical and radio region a
present helium content in the interstellar medium is derived. From
accurate photoelectric measurements of the helium line at 4026 Å
Nissen (1976) has derived helium abundances in atmospheres of B
stars. Both the emission line measurements and the 4026 Å measure-
ments in the young stars seem to indicate a variation in the helium
abundance from place to place. The abundance is normally found to be
in the range $Y = 0.20 - 0.30$ and the variation from place to place
amounts approximately to $\Delta Y = 0.10$. Also for very old objects
such as globular clusters and halo planetary nebulae we may give
an estimate of helium abundance. However the abundance of helium
is, in this case, derived from stars in late evolutionary stages
and we are ususally left with both the uncertainty of enrichment
in the envelopes and the uncertainty in internal structure of
horizontal-branch stars. Values in the range $Y = 0.2 - 0.4$ are
often obtained.

At present we have little evidence for any general
increase in helium abundance with time, although it has been
proposed that enrichment of helium in the interstellar medium
is correlated with the enrichment by heavier elements.

From this discussion it is obvious that the expected range
in the abundance of helium from star to star is no more than
$\Delta Y \sim 0.10$. To obtain further knowledge of an eventual enrichment
of the interstellar medium we must therefore determine the helium
abundance with an accuracy of approximately $\Sigma(Y)=0.03$. From stellar
evolution calculations we can easily estimate that this corresponds
to a typical set of uncertainties in the fundamental parameters: 2
per cent in mass, 1 per cent in radius, 2 per cent in effective temp-
erature and 25 per cent in Z, the content of heavier elements.

Our results are given in Table I. The masses are in most
cases determined to an accuracy of 2 per cent and the radii are
known with sufficient precision. To derive effective temperatures
we use [u-b] for B stars and the β index for the late A and F stars.
In a few cases we still have no β index available and use (b-y), since
the star is nearby. The m_1 index is used to determine [Fe/H] and
from that the value of Z. An accuracy of 25 per cent in Z corres-
ponds to an accuracy of $0\overset{m}{.}007$ in m_1, which normally is no problem.

TABLE I

FUNDAMENTAL PARAMETERS OF ECLIPSING SPECTROSCOPIC BINARIES

Binary	$M/M_\odot$	$R/R_\odot$	$\log g$	T_e	$\log T_e$	Z	Y	Age in yrs
CV Vel A	$6.10\pm.04$	$4.10\pm.04$	$4.00\pm.01$	18200	$4.206\pm.01$	.02	.28	33×10^6
B	$5.99\pm.04$	$3.95\pm.04$	$4.02\pm.01$	18060	$4.257\pm.01$			
ζ Phe A	3.85 ± 0.2	$2.84\pm.05$	$4.12\pm.02$	14400	$4.160\pm.02$	.02	.28	63×10^6
B	2.5 ± 0.1	$1.85\pm.04$	$4.30\pm.02$	12000	$4.08\pm.02$			
χ^2Hya A	$3.61\pm.08$	$4.39\pm.04$	$3.71\pm.01$	11700	$4.07\pm.01$	.02	.28	180×10^6
B	$2.64\pm.05$	$2.16\pm.03$	$4.19\pm.02$	11300	$4.05\pm.01$			
SZ Cen A	$2.28\pm.02$	$3.62\pm.02$	$3.678\pm.006$	8280	$3.92\pm.02$	.02	.30	450×10^6
B	$2.32\pm.02$	$4.55\pm.02$	$3.478\pm.007$	8000	$3.90\pm.02$			
HS Hya A	$1.31\pm.03$	$1.28\pm.01$	$4.34\pm.01$	6770	$3.83\pm.01$	.014	.19	$\lesssim 10^9$ ::
B								
RS Cha A	$1.86\pm.02$	$2.17\pm.09$	$4.03\pm.04$	7850	$3.90\pm.01$	.020	.24	1×10^9
	$1.82\pm.02$	$2.34\pm.09$	$3.96\pm.03$	7450	$3.87\pm.01$			
TV Cet A	$1.39\pm.05$	$1.50\pm.01$	$4.23\pm.02$	7000	$3.845\pm.01$	.014	.22	1.6×10^9
B	$1.27\pm.04$	$1.28\pm.01$	$4.33\pm.02$	6582	$3.818\pm.01$			
RZ Cha $\overline{AB}$	$1.51\pm.02$	$2.26\pm.02$	$3.91\pm.01$	6580	$3.82\pm.01$	.020	.21	2.5×10^9
UX Men A	$1.17\pm.03$	$1.32\pm.02$	$4.27\pm.02$	6200	$3.79\pm.01$	.014	.16	6×10^9
B	$1.11\pm.02$	$1.25\pm.02$	$4.29\pm.02$	6130	$3.79\pm.01$			

The derived helium abundances in Table I are very close to 0.28 for the B stars and close to 0.22 for the F stars. Half of this difference (0.03) could be explained by the fact that Z for the F stars equals 0.016 and not 0.020 as adopted for the B stars. The other half (0.03) is most easily understood as a small error in the temperature scale or by errors in the calculated opacities. We notice, in particularly, the small variation in the helium content of F stars, where the spread is not more than $\Delta Y=0.03$ around the mean value of $Y=0.22$.

REFERENCES

Nissen, P.E. (1976). Astron. Astrophys. 50, 343.
Wood, D.B. (1971). Astron. J. 76, 701.