COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 4185

Konkoly Observatory
Budapest
19 April 1995
HU ISSN 0374 – 0676

NARROWING THE MAIN SEQUENCE MASS GAP

Andersen's (1991) compilation of stellar masses contains 3 stars with masses between 1.10 solar masses and the long-known masses of the M1 dwarf, YY Gem, 0.59 $m_\odot$, namely the secondary of FL Lyr (G8, 0.96 $m_\odot$) and the components of HS Aur (G8, 0.90; K0, 0.88). The discussion of visual binaries by Henry and McCarthy (1993) contains only one star with a mass in this range with comparable accuracy, Alpha Cen B (K0V, 0.90).

In recent years a program has been undertaken at the Lick Observatory with the primary aim of helping to obtain masses of additional main-sequence stars in the mass range 1.0 to 0.6 $m_\odot$. The observations consist of spectra of eclipsing binaries which, on the basis of existing information, may contain at least one detached main-sequence component of spectral type G or K. To date, spectra have been obtained of approximately 60 eclipsing binaries, and the most promising ones are given high priority on the observing program. A progress report giving preliminary results as of about 2 1/2 years ago has been published (Popper 1993), as have definitive analyses of two of the systems, RT And and CG Cyg (Popper 1994). These two papers discuss the nature of the program in some detail.

An up-dated progress report is given in Table 1. It contains results based on limited material for those systems for which a provisional value of $m \times \sin^3 i$ of at least one component is equal to or less than 1.10 solar masses. Alpha CrB and V818 Tau (see Popper 1993) are binaries containing a star having less than one solar mass not observed in this program. The table includes five systems (ZZ UMa, HP Aur, 1E1919+0427, HD 197010, and BH Vir) for which this is the first announcement of new mass determinations. The very provisional nature of the results is to be emphasized. The systems are listed in order of decreasing period. Several of the provisional results in Table 1 are for systems (UV Psc, BH Vir, CG Cyg, RT And, UV Leo) that have been previously observed with much lower resolution than that employed in this program. References are in Batten et al. (1989).

The spectral types listed in Table 1 are rough values based on the strengths of the Na D lines, which are sensitive to temperature. The types are mean values weighted according to the luminosities of the components and to the intrinsic strengths of the D lines. The apparent magnitudes, presumably in the V band, are from a variety of sources. References to binaries not having constellation names are as follows: HD 192825, Kissling et al. 1993; HD 197010, Marschall et al. 1991; 1E1919+0427, Summers et al. 1992. The ephemerides of these recently discovered eclipsing binaries are not firmly established. I have found it necessary to subtract 0.05 from phases of HD 197010 computed with the ephemeris given in IBVS 3633. The ephemeris given in IBVS 3708 for 1E1919+0427 does not fit my velocities. An improved ephemeris is JD(min)=2449260.644 + 0.873713E.

Table 1. Detached eclipsing binaries with provisional values of $m \times \sin^{-3} i$ 1.10 solar masses or less.

Binary	Period (d)	V (mag)	Type*	$m_1 \times \sin^3 i$	$m_2 \times \sin^3 i$
ZZ UMa	2.30	10.0	G2	1.18	0.96
HP Aur	1.42	11.3	G4	0.90	0.75
DU Leo	1.37	9.5	F8	0.97	0.95
HD 192825	1.18	8.9	G0	1.08:	1.06:
1E1919+0427	0.87	10	K1	0.94	0.85
UV Psc	0.86	9.4	G8-K0	0.99	0.76
CV Boo	0.85	10.2	G2	1.00	0.94
BH Vir	0.82	9.6	F8	1.13	1.01
HD 197010	0.71	8.9	F9	1.08	0.69
CG Cyg	0.63	9.7	K1	0.92	0.79
RT And	0.63	9.0	F9	1.24	0.91
UV Leo	0.60	8.9	G0	1.10	1.07

* Types are means weighted according to the relative luminosities of the components and to the intrinsic strengths of their Na D lines.

The spectroscopic material on which the preliminary results summarized in Table 1 have been based is obtained with the Hamilton echelle-CCD spectrometer on the 3 m Shane telescope of the Lick Observatory (Vogt 1987). This instrument is proving to be ideal for the purpose: resolution approximately 60,000, scale 3 Åmm^{-1} in the visual region, S/N in the continuum of roughly 100 per resolution element for an exposure of about 20 minutes on a star of 10th magnitude. Details of the cross-correlation procedure employed for the velocities (IRAF program) are given in Popper (1994) and Popper and Jeong (1994).

The principal purpose of presenting these preliminary results at this time is to direct the attention of photometric observers to these important systems. Without reliable photometric observations and analysis, the spectroscopic results will have limited value. The short periods of most of these detached systems are noteworthy–the shorter the period, the greater the likelihood that eclipses will occur. This effect also permits coverage of the light curve in a relatively short interval of time, a favorable situation for observers. On the other hand, short periods are associated with larger rotational velocities, which, in turn, favor intrinsic variations associated with star spots and perhaps other manifestation of stellar activity. For this reason, it is essential that a complete light curve be observed in a relatively short interval and that the coverage be repeated several times over a period of a few years. RT And (Zeilik et al. 1989) and CG Cyg (Zeilik et al. 1994) are examples of systems for which repeated photometric coverage by a variety of observers has led to consistent basic solutions of the light curve (as well as to evaluations of star-spot parameters). While such numerous observations as in the cases of RT And and CG Cyg are ideal, considerably less frequent coverage of the light curves of the systems of Table 1 should lead to results of adequate reliability.

Photometry should be carried out in a photometric system carefully tied to a standard system. The Strömgren intermediate-band v,b,y system has the advantage of giving information on metallicity, which is of considerable importance in interpreting the stellar properties in terms of evolutionary models, as discussed by Andersen (1991), for example.

It is not possible to evaluate metallicity directly from spectra of rapidly rotating stars. None of the binaries is particularly faint, and a number of them can be observed with adequate precision (not worse than 0.01 mag) with modest equipment.

Pending more nearly definitive spectroscopic orbits and photometric solutions for most of the systems of Table 1, it appears that we may indeed be able to narrow the gap in the masses of detached main-sequence stars to the as yet unfilled interval 0.7 to 0.59 solar masses. One may hope that further discoveries–some of those represented in Table 1 are quite recent–will add significantly to our store of stellar masses in this mass range. Concentrated photometry on any or all of these binaries would provide a major contribution to this endeavor.

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