SOME ASPECTS OF THE EVOLUTIONARY STATUS OF W URSAE MAJORIS BINARIES DEDUCED FROM OBSERVATIONAL DATA

Walter Van Hamme[1]
Sterrenkundig Observatorium, Rijksuniversiteit Gent, Belgium

ABSTRACT

We have developed a test for the evolutionary state of W Ursae Majoris binaries by comparing the observed spectral type of 31 of these systems (14 of type W and 17 of type A) with the expected one when their primary component is an unevolved main sequence star. It appears that both the W- and A-type systems have a primary with a mass and radius too large to be compatible with the observed spectral type, so there is no indication that each type should mark a different evolutionary stage.

1. INTRODUCTION

In the paper of Wilson (1978) a method is presented to examine whether the radius of the components of 8 A-type W Uma binaries, selected for having accurately known orbital parameters, was a ZAMS radius corresponding to a reasonable value of the mass (say 1-2 solar masses). Let us have a brief look at this method. The actual orbital distance a_k (in solar radii) between the components of a binary system is given by

$$a_k = 4.2060\ P^{2/3}(1+q)^{1/3}m_1^{1/3} \qquad (1)$$

with P the orbital period in days, q the mass ratio m_2/m_1 and m_1 the mass (in solar masses) of the primary, i.e. the more massive component. The orbital separation a_z on the assumption that both components are ZAMS objects, fitting the mass-radius relation

$$R = m^{0.6} \quad , \qquad (2)$$

can be written as

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$$a_z = F(1+q^{0.6})m_1^{0.6} \qquad (3)$$

if we denote by F the ratio of a_z and the sum of the mean stellar radii :

$$F = \frac{a_z}{\bar{R}_1+\bar{R}_2} = \frac{1}{\bar{r}_1+\bar{r}_2} \qquad (4)$$

This ratio is completely specified by the Roche geometry for a given value of the mass ratio and the degree of overcontact. For all 8 A-type binaries the a_z value was smaller than the a_k value in the m_1 mass range of 1-3 solar masses. So Wilson concluded that the A-type systems have larger than ZAMS radii and are evolved from the main sequence.

Now a slight modification of Wilson's method will allow us to extend it to a larger group of W Uma binaries and especially to the group of W-type systems.

2. METHOD

Since we know from Kuiper's paradox (Kuiper, 1941) that it is impossible for the components of a contact binary both to fit a main sequence mass-radius relation of type (2) and to have sizes according to the Roche geometry, we introduce the orbital separation a_z on the assumption that only the primary component is a main sequence star obeying the mass-radius relation

$$R = m^{0.8} \qquad (5)$$

Note the exponent value 0.8 instead of Wilson's lower value 0.6. The quantity a_z can easily be calculated and we get

$$a_z = m_1^{0.8}/\bar{r}_1 \qquad (6)$$

We then can solve the equation $a_z = a_k$ in which we consider m_1 as the unknown. This gives us the value $m_1^{\star}$ we expect the mass of the primary to have when it is a main sequence object fitting the condition (5). Finally we derive the corresponding expected spectral type $Sp^{\star}$, which can be compared with the really observed one Sp', from the mass-spectral type relation appropriate for the main sequence. We have applied this method on a sample of 17 A-type and 14 W-type W Uma contact binaries for which a modern lightcurve solution and an estimation of the spectral type could be found in the literature.

3. RESULTS

Fig. 1 shows us the diagram of the expected spectral type $Sp^{\star}$ versus the observed one Sp'. The horizontal bars indicate the spectral

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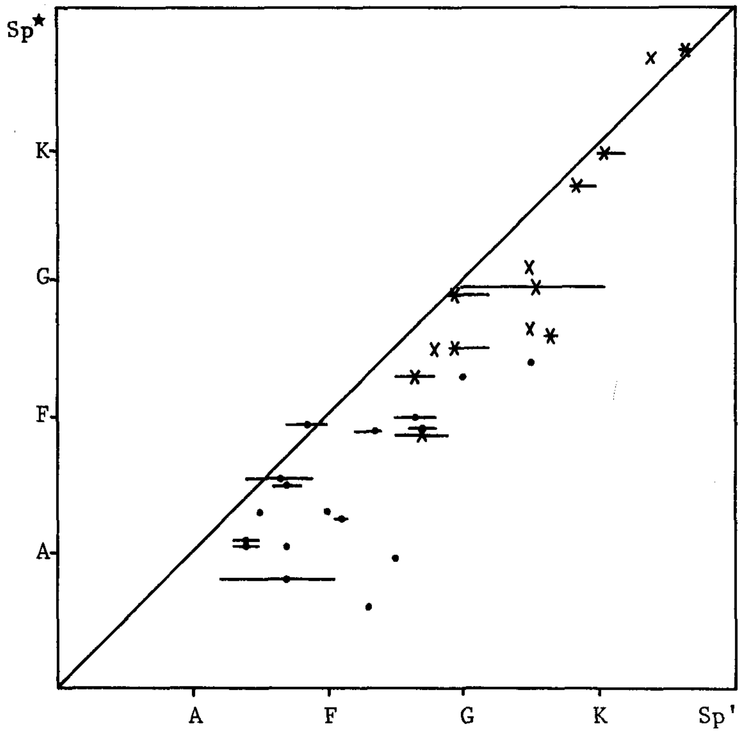

Figure 1. The expected spectral type Sp* versus the really observed one Sp' for 17 A-type (•) and 14 W-type (x) W Uma binaries.

range in which the spectral type estimation of different authors are lying. Nearly all systems, the A-types as well as the W-types, appear to be shifted in the direction of the later types, i.e. they are showing a later spectral type than we expect if their primary would be a main sequence star. In other words the mass and radius of the primary component of W UMa binaries are too large to correspond to a main sequence star with a spectral type the same as the one we observe, and this is true for both the W- and A-type systems. Again using the main sequence mass-spectral type relation we can derive the value m_1' of the primary's mass appropriate to its observed spectral type Sp' and the corresponding main sequence radius $R_1' = a_z' \bar{r}_1$. On the other hand the actual radius will be larger and given by $R_1'+\Delta R_1' = a_k' \bar{r}_1$ so the fraction by which the radius of the primary is too large to be a main sequence object with the observed spectral type is given by

$$\frac{\Delta R_1'}{R_1'} = \frac{a_k'}{a_z'} - 1 \tag{7}$$

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The mean value of this fraction amounts to 0.21 ± 0.05 for the A-type and 0.07 ± 0.02 for the W-type group. One could argue that the hypothesis of evolved A-type systems remains valid. However, we think that such a conclusion is not as obvious as it looks at first sight. Both the A- *and* W-type W Uma binaries behave essentially in the same way, the figure 0.07 is indeed significant. We would conclude that A-type binaries can be found in a wider range of possible evolutionary stages, evolved and unevolved ones. Not all A-type W Uma binaries are evolved from the main sequence.

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