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A PRE-MAIN-SEQUENCE COMPANION TO AR AURIGAE?

A recent analysis of the well-known bright eclipsing binary AR Aurigae (HD 34364, HR 1728, V_{max} = 6.15, B9VpHgMn + B9.5V, P_{AB} = $4\overset{d}{.}13$ days) suggests that the secondary star is still contracting towards the ZAMS, while the primary star appears to be exactly on the ZAMS (Nordström & Johansen 1994). Moreover, AR Aur is a triple system, the existence of the as yet unseen third star being inferred from a light-time effect in the observed minima with a period of ∼24 years (Chochol et al. 1988, Nordström & Johansen 1993).

AR Aur A (2.5 $M_\odot$) and B (2.3 $M_\odot$) are of considerable interest as coeval and nearly equal-mass stars apparently just arriving on the ZAMS. Given the remaining observational uncertainties in the absolute dimensions, it is of interest to verify this scenario by other means. Direct detection of star C would support this scenario and provide an estimate of the mass of star C and the inclination between the two orbital planes. This note discusses how this test could be made.

Models by Mazzitelli (1989) have been used to estimate the radius (R_C), temperature (T_C), and luminosity (L_C) for star C at an age of 4×10^6 yr (the time for star A to reach the ZAMS from the birthline), for different assumed values of i, the inclination of the long-period orbit (the eclipsing pair has $i = 88\overset{\circ}{.}5$). The results are given in Table 1. Values of i less than 30°are not listed, since the mass of star C (M_C) would be high enough for C to make a detectable contribution at visible wavelengths, contrary to what is observed. Assuming black-body radiation, the luminosity of star C can then be computed for any wavelength and normalised to units of $L_A + L_B$; thus, the quantity l_C ("third light") plotted in Figure 1 and given for some standard photometric passbands in Table 1 is $l_C = L_C/(L_A + L_B)$.

Table 1. Model properties for AR Aur C at an age of 4×10^6 years

i	M_C	R_C	T_C	$l_C(R)$	$l_C(I)$	$l_C(J)$	$l_C(H)$	$l_C(K)$	$l_C(L)$	$l_C(M)$
90°	0.523	1.097	3825	0.01	0.01	0.02	0.03	0.03	0.05	0.05
70°	0.559	1.129	3877	0.01	0.01	0.02	0.03	0.04	0.05	0.06
60°	0.611	1.172	3953	0.01	0.01	0.02	0.03	0.04	0.05	0.06
50°	0.698	1.218	4090	0.01	0.02	0.03	0.04	0.05	0.06	0.07
40°	0.847	1.348	4321	0.01	0.03	0.04	0.05	0.07	0.08	0.09
30°	1.124	1.553	4682	0.02	0.05	0.06	0.09	0.10	0.12	0.14

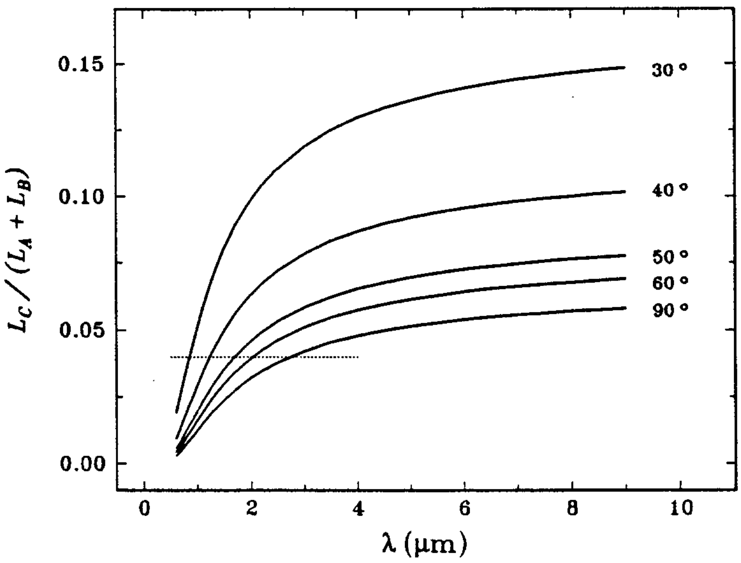

Figure 1. Fractional light of star C as a function of assumed orbital inclination and wavelength.

If the light contribution from star C is significant, the depth of the minima in the light curves of the eclipsing pair AB will be reduced. The question we wish to address is the following: Given the photometric elements, radii and inclination, from our previous analysis of light curves of AB at wavelengths where third light is negligible, at what (larger) wavelength could we observe a reduction in eclipse depth due to star C relative to what we would predict without it?

Using the b_F (4747 Å) light curve and analysis tools from our previous study, we have studied this question by adding specified amounts of third light and then redetermining l_C from the light curve, gradually reducing the number of points used. We find that we can recover l_C rather accurately with a surprisingly few observations of the precision of the b_F light curve, 0.01 mag: Typical standard errors are 0.01 with 40 points, 0.02 with just 10 well-distributed points on the light curve (about half near both mid-eclipses, half outside eclipse). This remarkable economy is possible because the existing high-quality analysis provides an accurate prediction of the eclipse depths in the absence of third light. The errors in l_C scale, of course, with the mean errors of the actual new observations, which will also depend on the wavelength of observation.

The dotted line in Figure 1 indicates the usable wavelength for which 0.04 of third light is measurable with certainty. For inclinations close to 90° (i.e., near co-planarity of the orbits), the K band (2.2 μm) is just at the detection limit for star C with 1% photometry. In the L and M bands (3.5 and 5 μm), detection will be easier, but photometry probably correspondingly more difficult. The N band (9 μm) should be avoided, as dust emission might be significant.

Deviations from the ephemeris derived earlier for the eclipsing pair AB:

$$\mathrm{Min\,I} = \mathrm{HJD}\,2\,438\,402.1847 + 4\overset{\mathrm{d}}{.}1346662\times\mathrm{E}$$

due to motion in the AB-C orbit are not more than 12 minutes, and secondary minima occur midway between primary eclipses since the AB orbit is circular. In planning follow-up photometry, observers should be aware of the problems with variable comparison stars described in Nordström & Johansen (1994). It is proposed to use two of the reliable stars:

HR 1734, HR 1738, or HR 1749. HR 1734 has a faint ($m_V = 11.8$) companion at a distance of $3\overset{''}{.}8$, which always should be included.

K. T. JOHANSEN
B. NORDSTRÖM
The Niels Bohr Institute of Astronomy,
Physics and Geophysics
Astronomical Observatory
Brorfeldevej 23
DK-4340 Tølløse
Denmark

References:

Chochol D., Juza K., Mayer O., Zverko J., Ziznovsky J., 1988, *Bull. Astron. Inst. Czech.*, **39**, 69

Mazzitelli I., 1989, in Low-Mass Star Formation and Pre-Main-Sequence Objects, B. Reipurth (ed.), ESO Conference and Workshop Proceedings No. 33, p. 433

Nordström B., Johansen K.T., 1993, *IBVS*, No. 3871

Nordström B., Johansen K.T., 1994, *A&A*, **282**, 787