CONSTRAINTS ON THE ATMOSPHERIC PARAMETERS OF THE BINARY DA WHITE DWARF L870-2 (EG11)

P. Bergeron, F. Wesemael
Département de Physique, Université de Montréal
J. Liebert
Steward Observatory, University of Arizona
G. Fontaine, P. Lacombe
Département de Physique, Université de Montréal

The recent discovery that the cool DA white dwarf L870-2 (EG11, WD0135-052) is a double-lined spectroscopic binary composed of a detached pair of DA white dwarfs (Saffer, Liebert, and Olszewski 1988, SLO hereafter) has raised some challenging problems for stellar evolution theories of such binary systems. One first important step in the understanding of this short-period system is to establish the atmospheric parameters of each component. SLO have argued from previous determinations of the effective temperature and absolute magnitude of the system, and also from their own study of the composite H_α profile, that the two components should be similar. We wish here to reexamine this assertion by taking a new look at the constraints on the two components brought about by the available observational data.

As first pointed out by SLO, L870-2 has widely been used as a photometric standard. In particular, several spectra of L870-2 at 2.25 Å resolution have been obtained with the Steward Observatory 2.3m reflector and blue photon-counting Reticon in the course of our current study of the atmospheric properties of cool DA white dwarfs (e.g. Lacombe *et al.* 1983; Bergeron, Wesemael, and Fontaine 1987, 1988). The average optical spectrum covering the high Balmer lines is displayed on Figure 1 together with the spectrum of G74-7 (EG168), a DAZ white dwarf with similar effective temperature and discussed by Lacombe *et al.* (1983). From this comparison alone, L870-2 does not appear to differ much from other garden variety hydrogen-line stars at that temperature. A particularly noteworthy fact is that this combined optical spectrum can be fit by a single component spectrum. Using a newly developed grid of model atmospheres appropriate to the study of cool DA white dwarfs (Bergeron, Wesemael, and Fontaine 1987, 1988), we obtain for L870-2 an effective temperature of 7240K±75K, with a surface gravity of 7.8±0.1. The resulting fit is displayed on Figure 2. Our effective temperature is in good agreement with those previously obtained under similar assumptions by Koester, Schulz, and Weidemann (1979, T_e=7254K), Shipman (1979, T_e=7300K), and Schulz and Wegner (1981, T_e=7500K). A comparison of surface gravities determined by these authors is not appropriate here, since all have used the measured parallax to first constrain the radius of the purported single star. However, the surface gravity obtained by Schulz and Wegner (1981) from equivalent widths *alone*, yields a value near log g=7.9, entirely consistent with our determination. Thus, a first constraint can already be imposed from this spectroscopic evidence, namely that *the summed spectra from both components must be fit by a single spectrum at T_e=7240K and log g=7.8.*

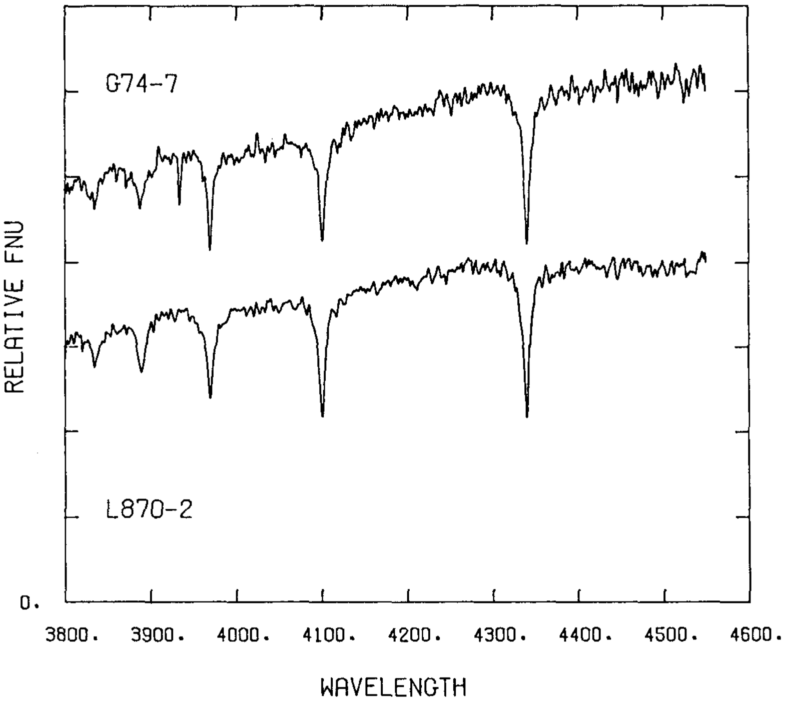

Fig. 1. Comparison of the spectrum of L870-2 with the spectrum of G74-7, a single DAZ white dwarf with similar effective temperature.

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A second constraint is obtained from the study of the kinematics of the binary system. SLO have estimated the radial velocity semiamplitude for each component as K_1=77.6 km s^{-1} and K_2=69.6 km s^{-1}, which corresponds to a mass ratio of $q=\frac{M_2}{M_1}=1.115$. Our second constraint is thus that *the surface gravities of both components be consistent with a mass ratio of 1.115*.

A third constraint comes from the Strömgren photometry. Because (u−b) ceases to be gravity sensitive at the low effective temperature of L870−2 (Fontaine *et al.* 1985), not much can be learned from this particular color index. The color index (b−y), however, is temperature sensitive. Fontaine *et al.* (1985) have measured (b−y)=0.274±0.019 for L870−2 which agrees with other values quoted in McCook and Sion (1987). The Strömgren photometry thus imposes that *the (b−y) obtained from the sum of spectra of both components yield a value consistent with the measured value of 0.274*.

Finally, a fourth constraint is obtained from the measured luminosity excess. Greenstein (1985) has determined from measurement of m_V and from an accurate trigonometric parallax, that L870−2 has a luminosity excess of 1.1 magnitude from its mean (G−R)−M_V relation (or equivalently (b−y)−M_V). This result can be translated into total luminosity if, as we argue below, the two components have similar effective temperatures. Accordingly, the binary system has a total luminosity ~2.75 times larger than that of a single star which would have the same color ((G−R) or (b−y)) as L870−2 but at log g=8.0, the gravity most appropriate to the mean relation defined by Greenstein. From our (b−y)−T_e calibration, we obtain for (b−y)=0.274 an effective temperature of 7280K, completely consistent with the previous estimate of the spectroscopic temperature. We thus express the fourth constraint by requiring that *the sum of the individual luminosities from each component be equal to the observed total luminosity*.

In order to reconcile all these constraints, we use the following procedure. Firstly, for a given set of surface gravities (g_1, g_2), consistent with the estimated mass ratio of 1.115 (second constraint), we add the surface fluxes (weighted by the respective radii assuming a carbon core composition) for a large set of effective temperature couples (T_1, T_2). A grid at log g=7.8 (first constraint) is then used to fit these spectra in terms of a single star and to determine the best-fitting temperature for each of these combined spectra. The locus of spectra which yield a spectroscopic effective temperature of 7240K is then plotted on a (T_1, T_2) diagram. An example of such a diagram is shown on Figure 3 where the solid line represents the desired locus of model combinations: on this line, the combined optical spectra are all rigorously equivalent and can be fit by a single DA star at 7240K, log g=7.8. However, we should point out that this *best* fit does not represent necessarily a *good* fit to the observed spectrum. Secondly, we follow the same procedure but this time, calculate the Strömgren color index (b−y) and define in the (T_1, T_2) diagram the locus of constant (b−y)=0.274, consistent with the third constraint (dashed line). Finally, we plot on the same diagram the locus of models with the appropriate overluminosity, according to the fourth constraint (dash-dotted line).

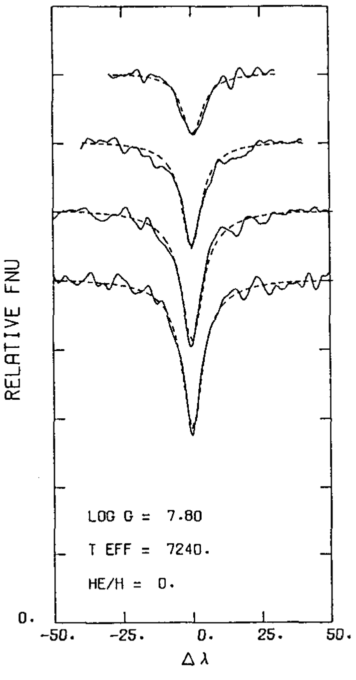

Fig. 2. Comparison of the spectrum of L870−2 (from top to bottom, H_8 to H_γ) with our best fit, under the assumption of a single DA star.

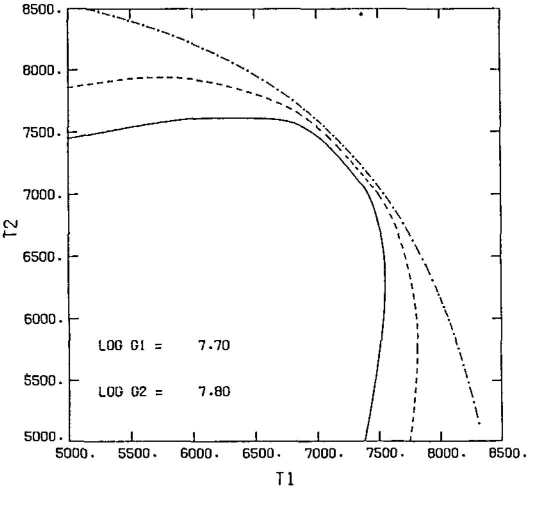

Fig. 3. Fitting diagram for the temperature of each component, constrained by spectroscopy (solid line), photometry (dashed line), and luminosity (dash-dotted line). The solution shown also satisfies the constraint imposed on the mass ratio of the components.

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For the binary system L870-2, components with surface gravities of log g_1=7.7 and log g_2=7.8 represent the best estimated fit (Figure 3). From the mass-radius relation for a *carbon core composition* (Winget, Lamb, and Van Horn 1988), the corresponding masses are M_1=0.42$M_\odot$ and M_2=0.47$M_\odot$. As can be seen, in order to match the Strömgren photometry and luminosity requirements, the effective temperatures of both components cannot differ significantly. A conservative estimate of the range of effective temperatures varies from T_1=6750K, T_2=7585K to T_1=7470K, T_2=6830K, with all the intermediate cases equally acceptable. This conclusion is also consistent, as pointed out by SLO, with the observation that the H_α profiles at quadrature differ in depth by only ~30%. In principle, these H_α profiles could serve as another observational constraint to further narrow the temperature and/or gravity range of the system components. Clearly, this work represents only an exploratory investigation of this exciting system. Further studies of the uncertainties associated with the overluminosity and with the assumed core composition of both components are now underway.

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