THE IMPORTANCE OF THE REALISTIC SPECTRAL ENERGY DISTRIBUTION IN THE LIGHT-CURVE ANALYSIS

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1. THE IMPORTANCE OF STELLAR ATMOSPHERE MODELS

In previous versions of our programme for light-curve analysis in eclipse CB systems (Đurašević, 1992a), generalised to the case of an overcontact configuration (Đurašević et al., 1998), we had two different possibilities in using of the model with respect to the treatment of the radiation law: the simple black-body theory or the stellar atmosphere models by Carbon & Gingerich (1969, hereafter CG), the latter giving a more realistic spectral energy distribution than the black-body approximation. Further improvement of this programme can be achieved by introducing a third option: a set of tables of model atmospheres that are quite modern and reliable.Here we present our current version of the programme for the light-curve analysis which uses the new promissing Basel Stellar Library (hereafter "BaSeL") with empirically colour-calibrated flux distributions over a large domain of effective temperatures. This library (Lejeune et al. 1997, 1998) combines theoretical stellar energy distributions which are based on several original grids of blanketed model atmospheres.

To compute synthetic colours from the BaSeL models, we need effective temperature, surface gravity and metallicity.The surface gravity can be derived very accurately from the masses and radii of the CB stars by solving the inverse problem of the light-curve analysis, but the temperature determination is related to the assumed metallicity and strongly depends on photometric calibration. Consequently, the BaSeL library has been corrected in such a way as to provide synthetic "corrected" flux distributions, consistent with extant empirical calibrations at all wavelengths from near-UV through the far-IR (see Lejeune et al. 1997, 1998).

In our programme for the light-curve analysis, we have explored the "corrected" BaSeL model flux distributions, with a large range of effective temperature (2000 K $\leq T_{\rm eff} \leq$ 35000 K), metallicity, ($-1 \leq [Fe/H] \leq 1$) and surface gravity, ($3 \leq \log g \leq 5$).In the inverse-problem solving of the light-curve analysis, the fluxes are calculated in each iter-ation for current values of temperatures and $\log g$ by interpolation in the both of these quantites in atmosphere tables, as an input, for a given metallicity of the CB components. The metallicity of the involved system components can be different. Because of that we can use individual, different tables as an input, for each star, and, in that way, choose the best calculations for its particular atmospheric parameters. Compared to (Vaz et al., 1995) our two-dimensional flux interpolation in $T_{\rm eff}$ and $\log g$ is based on the application of the *bicubic spline* interpolation (Press et al., 1992). This proved itself as a good choice.

The programme for the light-curve analysis can be simply redirected to the Planck or CG approximation, or to the more realistic BaSeL model atmospheres. Parallel testing of these three modifications gave solutions for different passband light curves that were more consistent within the BaSeL models option than within the CG or black-body approximation. If an independant spectroscopic sources could give an estimate of metallicity of the CB components, the application of the BaSeL models option in the light-curve analysis could really give more reliable solutions. This provides better estimates of the parameters of the CB system. Also, a change in the assumed metallicity causes a noticable change in the predicted stellar effective temperature.

2. APPLICATION TO THE LIGHT-CURVE ANALYSIS OF THE AB And

As an example we tried to estimate orbital and physical parameters of AB And from its photometric observations. This eclipsing binary is a well observed variable star, which belongs to the W subgroup of the W UMa-type systems. Here we analysed and discussed the B and V light-curves obtained by Landolt (1969) and Rigterink (1973), and the B passband curve, obtained during 1982 at the University Observatory of St. Andrews (Bell et al., 1984). The light-curve analysis was made by applying the inverse-problem method (Đurašević, 1992b).

Basic parameters of this system were estimated from quite symmetric Rigternik's (1973) light curve, which is probably cleen from spot effects. These basic parameters of the system were used then as starting points in the inverse-problem solution for other, more or less deformed and asymmetric, light curves. Rigterink (1973) and Landolt (1969) used the same comparison star BD+35°4972, while Bell et al.(1984) used BD+36°5020 as the comparison star. Through measured brightness differences between those two comparison stars all observations were expressed in the system of BD+36°4972. The light curves were then normalised to the light level at the orbital phase 0.25 of the Rigternik's (referent) light curves.

Both stars of this system have an external convective envelope which can show magnetic activity. So, we started the "spotted solution" by assuming that the components of AB And have cool spots, of the same nature as solar magnetic spots. The analysis of these asymmetric light curves begun by optimisation in the spot parameters. When the optimisation based on these parameters does not secure a further minimisation of $S = \sum(O\text{-}C)^2$, the basic system parameters have to be introduced in the iterative proces. Using this procedure we optimize all free-parameters of the model in final iterations.

With the presence of single spotted areas on both components, the Roche model gave a good fit of the observations and the basic system parameters were approximately constant for the whole set of the analysed light curves. The results are listed in Table 1, where the indexes (**h**,**c**) corespond to the less-masive (hotter) and more-massive (cooler) star respectively. Following from the inverse problem solutions for individual light-curves, Fig. 1 (Left) presents the observed (LCO), referent (LCR) and optimum synthetic (LCC) light curves of AB And, together with the final O-C residuals obtained by solving the inverse problem within the framework of the Roche model with spotted areas on the components. The right-hand side of this panel shows the view of the system, at a noted orbital phase, obtained with the parameters estimated by analysing the corresponding light-curves.

These results indicate that the complex nature of light curve variations during the examined period is mainly caused by the changes in the position and size of spotted areas on the system's components. The presented solutions show that AB And is in the slight overcontact configuration ($f_{over}[\%] \sim 11\ \%$), with the mass ratio $q = m_c / m_h \sim 1.92$.

In conclusion, the application of the "corrected" BaSeL model flux distributions in the programme for the light-curve analysis gives mutual consistency between the results obtained from different passband curves that is really better than the one obtained with simple black-body theory or CG stellar atmosphere models. We expect from these realistic spectral energy distributions to enable a certain progress in the light-curves analysis, i.e., more realistic estimates of an active CB's parameters.

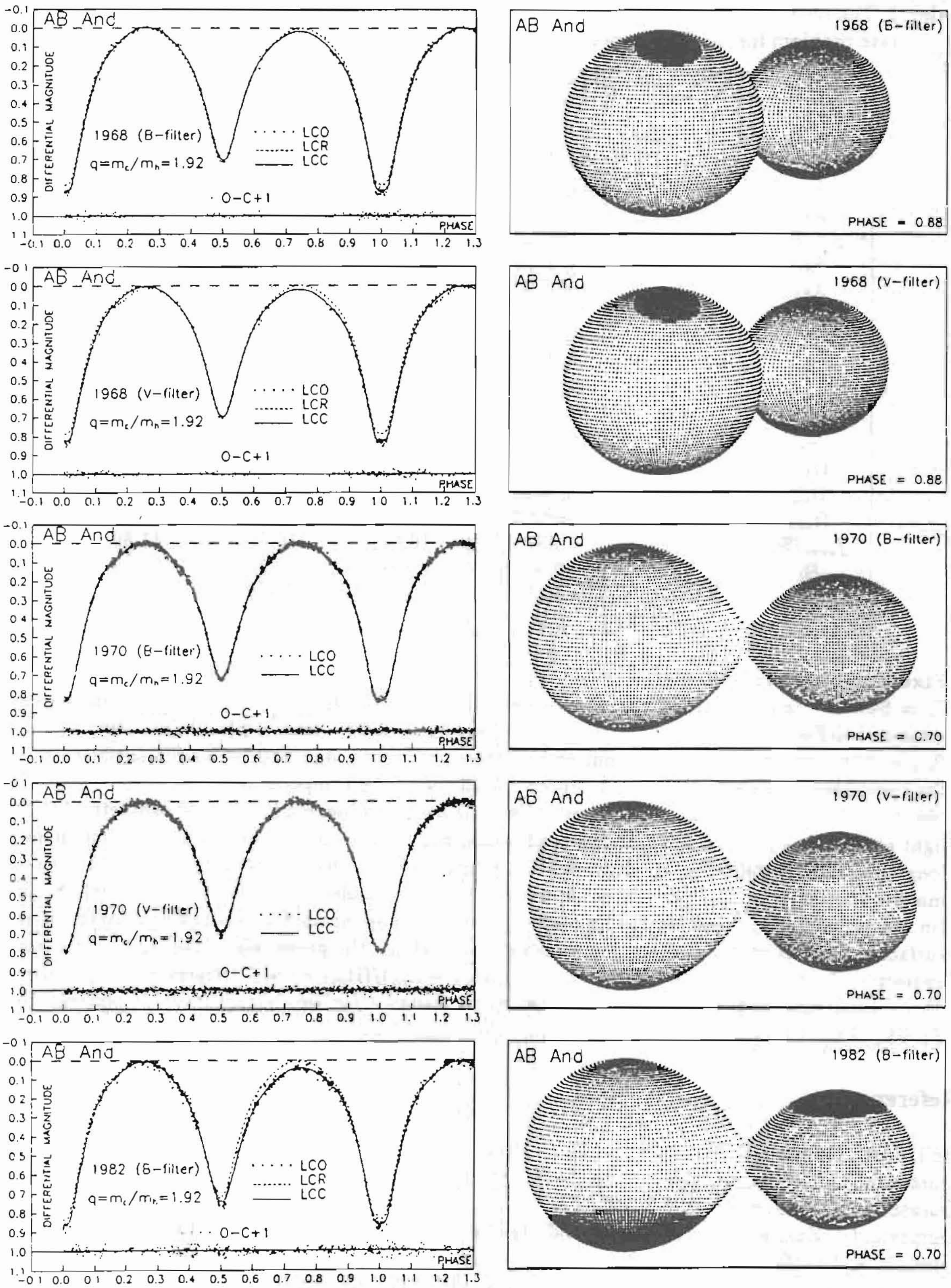

Fig.1. Left: Observed (LCO), referent (LCR) and final synthetic (LCC) light curves of AB And with O-C residuals obtained by solving the inverse problem within the framework of the Roche model with spotted areas on the components; Right: The view of the Roche model for the AB And at the noted orbital phase obtained with parameters estimated by solving the inverse problem.

Table 1. The results of the analysis for AB And (1968, 1970, 1982) light curves obtained by solving the inverse problem for the Roche model with spot areas on the system components.

Quantity	1968 (B-filter)	1968 (V-filter)	1970 (B-filter)	1970 V-filter)	1982 (B-filter)
$\Sigma(O-C)^2$	0.0270	0.0242	0.1282	0.1493	0.1308
$A_{Sh} = T_{Sh}/T_h$	0.65±0.5	0.65 ±0.19			0.909±0.007
θ_{Sh}	25.1±2.2	26.7 ±1.9			42.8±0.9
λ_{Sh}	17.4±10.6	23.2 ±10.6			234.9±14.3
φ_{Sh}	-67.9±4.1	-68.2 ±3.3			83.7±1.7
$A_{Sc} = T_{Sc}/T_c$	0.67±0.1	0.68 ±0.06			0.916±0.005
θ_{Sc}	21.1±0.6	21.2 ±0.6			52.6±0.7
λ_{Sc}	309.4±3.1	310.3 ±3.3			253.5±6.9
φ_{Sc}	61.7±1.6	62.1 ±1.5			-80.7±1.2
T_h	5692±3	5715 ±4	5679±3	5704±4	5692±2
F_h	1.019±0.001	1.017 ±0.001	1.019±0.000	1.019±0.000	1.021±0.001
i	85.0 ±0.1	85.0 ±0.1	85.2±0.1	84.9±0.1	85.0 ±0.1
u_h	0.74	0.67	0.74	0.67	0.74
u_c	0.76	0.68	0.76	0.68	0.76
$\Omega_{h,c}$	5.0736	5.0810	5.0751	5.0750	5.0674
Ω_{in}	5.1381	5.1381	5.1381	5.1381	5.1381
Ω_{out}	4.5435	4.5435	4.5435	4.5435	4.5435
$f_{over}[\%]$	10.85	9.61	10.60	10.60	11.89
R_h	0.309	0.308	0.309	0.309	0.309
R_c	0.416	0.416	0.416	0.416	0.417
$L_h/(L_h + L_c)$	0.424	0.409	0.424	0.412	0.436

Fixed parameters :
$T_c = 5450K$ - temperature of the more-massive (cooler) star, $f_h = f_c = 1.00$ - nonsynchronous rotation coefficients of the components, $q = m_c/m_h = 1.92$ - mass ratio of the components, $\beta_{h,c} = 0.08$ - gravity-darkening coefficients of the components, $A_{h,c} = 0.5$ - albedo coefficients of the components, $[Fe/H]_{h,c} = 0.1$ - accepted metallicity of the components.
Note : $\Sigma(O-C)^2$ - final sum of squares of residuals between observed (LCO) and synthetic (LCC) light curves, $A_{Sh,c}$ - spot temperature coefficients, $\theta_{Sh,c}$, $\lambda_{Sh,c}$, $\varphi_{Sh,c}$ - spot angular dimensions. longitudes and latitudes (in arc degrees), F_h - filling coefficient for critical Roche lobe of the less-massive (hotter) star, T_c - temperature of the more-massive (cooler) component, i - orbit inclination (in arc degrees), $u_{h,c}$ - limb-darkening coefficients of the components, $\Omega_{h,c}$ - common dimensionless surface potentials of the primary and secondary, Ω_{in}, Ω_{out} - the potentials of the inner and outer contact surfaces respectively, $f_{over}[\%] = 100 \cdot (\Omega_{h,c} - \Omega_{in})/(\Omega_{out} - \Omega_{in})$ - degree of overcontact. $R_{h,c}$ - polar radii of the components in units of the distance between the component centres and $L_h/(L_h + L_c)$ - luminosity of the hotter star (including spots).

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