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# DETERMINATION OF PHYSICAL PARAMETERS OF BINARY SYSTEMS: THE PROBLEM OF SPURIOUS SOLUTIONS

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ABSTRACT In this paper we apply the Wilson-Price procedure to the solution of the binary system AO Cam using *simultaneously* all the available information and a statistical criterion to judge about the quality of the solutions found.

## INTRODUCTION

For the solution of binary systems, we have devised a procedure (Wilson-Price Code), described in Barone *et al.* (1988, 1990). This procedure is based on the physics of the Wilson and Devinney model (1971, 1979) for light curve synthesis, but uses as fitting procedure, a global optimization algorithm, the Controlled Random Search (Price, 1976), in order to avoiding the loss of possible physical solutions and *influence* of the researcher on the final solution. With this procedure, it is possible to solve *simultaneously* light curves and radial velocity curves, also for eccentric systems, using, in this way, *all* the available information at the same time.

## STATISTICAL CRITERIA OF SOLUTION

A general expression for the quality coefficient $S$, that expresses quantitatively the goodness of the fitting and that is the objective function to minimize, allowing the *simultaneous* solution of light and radial velocity curves is

$$S = \sum_{i=1}^{l} \sum_{j=1}^{n_i} w_{l_{i,j}} (l_{i,j_{obs}} - l_{i,j_{comp}})^2 + \sum_{k=1}^{r} \sum_{l=1}^{n_k} w_{r_{k,l}} (v_{k,l_{obs}} - v_{k,l_{comp}})^2 \qquad (1)$$

where $l$ and $r$ are the number of light and radial velocity curves, $n_i$ and $n_k$ are the number of observations of the i-th light curve and k-th radial velocity curve, $w_{l_{i,j}}$ and $w_{r_{l,k}}$ are the weights of the points of light and radial velocity curves, defined as

$$w_{l_{i,j}} = \frac{\frac{1}{\sigma^2_{l_{i,j}}}}{\frac{1}{\sigma^2_{tot}}} \quad w_{r_{k,l}} = \frac{\frac{1}{\sigma^2_{r_{k,l}}}}{\frac{1}{\sigma^2_{tot}}} \quad \frac{1}{\sigma^2_{tot}} = \sum_{p=1}^{l} \sum_{k=1}^{n_p} \frac{1}{\sigma^2_{l_{p,k}}} + \sum_{m=1}^{r} \sum_{h=1}^{n_m} \frac{1}{\sigma^2_{r_{m,h}}} \qquad (2)$$

and with $\sigma_{l_{i,j}}$ and $\sigma_{r_{k,l}}$ the corresponding errors. In this formula the fact that the luminosities and the radial velocities are not homogeneous quantitites is taken into account normalizing each curve with respect to its maximum (normalizing, of course, also the errors). It is now possible to establish a criterium to fix an upper limit $S_{LIM}$: every solution characterized by a quality coefficient $S < S_{LIM}$ may be considered possible, because lies within the measurement error. To evaluate $S_{LIM}$ it is sufficient to substitute $\sigma^2_{l_{i,j}}$ to $(l_{i,j_{obs}} - l_{i,j_{comp}})^2$ and $\sigma^2_{r_{k,l}}$ to $(v_{k,l_{obs}} - v_{k,l_{comp}})^2$. Once that a minimum has been obtained, it is necessary to verify that at least 68% of the points should be in the band described by $(-S_{er_j}, S_{er_j})$ (Chauvenet criterium), defined for each curve by the relation

$$S_{er_j} = \left( \frac{1}{n_j - nd_j} \sum_{i=1}^{n_j} \sigma^2_{i,j} \right)^{\frac{1}{2}} \tag{3}$$

where $nd_j$ is the number of degrees of freedom of the j-th light curve. If this condition is satisfied we have a guarantee that the solution found has physical meaning. If this condition is not satisfied, it is possible to hypothize the presence of other physical phenomena superimposed on the light and radial velocity curves which can't be described by means the synthesis algorithm used, being it necessary to use a more complete one.

## AO CAM

The system AO Cam has been studied because many different solutions exist in literature: both transit and occultation solutions were considered possible (Evans et al., 1985; Cooke and Leung, 1986). To reanalyze the system we used all the data published in literature, plus the spectral type of the primary, that should be in the range $G2 - G8$. From the analysis of the results obtained from the minimization procedure, the system AO Cam may be definitely classified as a W-type system with an overcontact configuration (10.4%), a G5 spectral type of the primary star and $\Delta T = 327\,K$. In Table 1 the AO Cam parameters are shown, while in Fig.1 the search array is reported for selected pairs of parameters. In this figure the linear correlations among the parameters are also reported, evaluated using the solutions stored in the search array. What it is very interesting is that these correlations allow a description of the solutions found by the previous investigators. With the exception of two degrees of difference in the inclination of the orbital plane of the system in the two solution of Evans *et al.*(1984), it is possible to well describe them and, at the same time, to show that what they have found are only local minima.

## CONCLUSIONS

In this paper we have shown as the correct use of the statistical analysis in the definition of the quality coeffcient in the solution procedure of a system is very relevant not only to obtain a correct solution from the physical point of view, but also to understand which are the uncertainties on the solutions found in connection with the precision of the data at disposal. We have also shown that this kind of approach well fits with the Wilson-Price code that is not only able to find the global minimum, but also to show a set of possible solutions and to allow the evaluation of the correlations of the parameters around the minimum.

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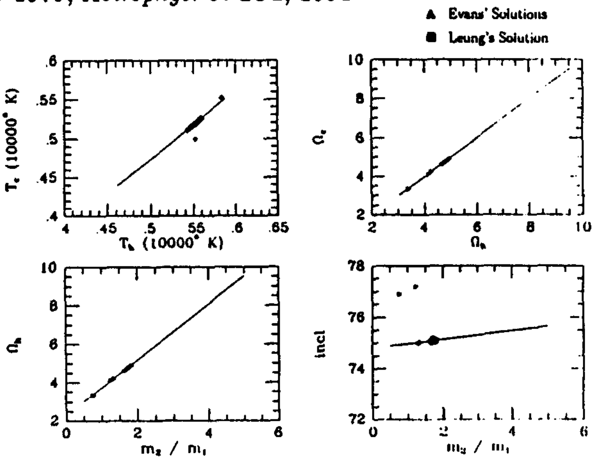


**Fig.1** The Search Array for AO Cam reported for selected pairs of parameters

| | | | |
|---|---|---|---|
| i (degrees) | 75.09 ± 0.05 | $r_h$(pole) | 0.318 |
| $\Omega_h$ | 4.774 ± 0.057 | | |
| $\Omega_c$ | 4.774 ± 0.057 | $r_h$(side) | 0.333 |
| $g_h$ | 0.32 | $r_h$(back) | 0.369 |
| $g_c$ | 0.32 | $r_c$(pole) | 0.407 |
| $A_h$ | 0.5 | | |
| $A_c$ | 0.5 | $r_c$(side) | 0.431 |
| $T_h$ (°K) | 5533 ± 39 | $r_c$(back) | 0.463 |
| $T_c$ (°K) | 5206 ± 36 | $r_h$(equiv) | 0.342 |
| $m_c/m_h$ | 1.71 ± 0.04 | $r_c$(equiv) | 0.436 |
| | | $F$ | 10.4 ± 0.1 % |
| | | $l_3$ | 0.000 |

**Table 1** AO Cam Parameters