# FIRST SYNTHETIC SOLUTION FOR THE W UMA SYSTEM CV DRACONIS

## INTRODUCTION

CV Draconis was discovered by Strohmeier and Knigge in 1960 as a short period variable with a photographic range of 0.6 mag .
Further investigation carried out by Nikulina (1961) on a set of sky-patrol plates failed to identify any definite periodic variation of brigthness.
Nikulina classifies CV Draconis as a rapid irregular variable star and such classification were included into the 4th edition of the GCVS (Kholopov et al., 1985).
With these data CV Draconis was included in the GEOS observational program and a number of visual observations carried out by the members of the Groupe d'Etude and Observation Stellaires (GEOS) during the years 1985 to 1988 were able to show the eclipsing close binary nature of the star and to identify an approximate period very close to the true one.
The results of the visual investigation were published in several GEOS internal pubblications (GEOS Note Circulaires).
A GEOS NC summarizing the results of all the visual data is in preparation and will be published in the future.

## THE PHOTOELECTRIC OBSERVATIONS

During the same time photoelectric monitoring was planned and carried out by Agerer and Lichtenknecker in two colors (B and V) and were able to obtain 323 observations in V and 381 in B.
The observations were first published by Agerer et al. in the BAV Mitt. No.49 (July 1988) in digital form.
The two ligth curves, as pubblished on the IBVS 3213 as well as in the BAV Mitteilungen, are shown in the figure 1.
The light elements refined by the photoelectric observations are the following:

$$\text{Min 1. (HJD)} = \underset{\pm 5}{2447308.5277} + \underset{\pm 46}{0.6176214^{d}} * E$$

CV Draconis was then classified as W UMa type close binary with an amplitude of 0.4 magnitude in V and a period of 0.618 day .

## THE PHOTOELECTRIC LIGHT CURVE

The amplitude of the light variation of CV Draconis is about .40 mag. in both the colors and the depth of the two minima are nearly the same.

It is interesting to note the presence of some photometric perturbations among the data and distributed along the entire light curve in both the colors.
The instrumental origin of the described perturbations seems to be highly probable.
Additionally differences in the luminosity levels at the quadrature are also present and this may be a real phenomenon common to the all W UMa systems.

## THE LIGHT CURVE SOLUTION

I have processed the available B an V photoelectric observations in order to obtain the first orbital solution of this binary system and to set up an adequate physical model.
The solution of the light curve was obtained in time domain making use of a light curve synthesis computer code written by the author fitting the classical Roche Model on the observations by some Mixed Multidimensional Optimization Techniques.
Such procedure was fully described by A.Gaspani during the last GEOS Symposium (SELVINO, 1991), and a brief description can be found in the GEOS Note Circulaire containing the abstracts of the papers presented to the symposium.
A detailed GEOS FT devoted to the theoret ical insights is in preparation and will be published soon.

## THE SOLUTION PROCEDURE

The solution of the light curve was carried out using direct fitting of the classical Roche model on the data points separately in the B and the V colors.

### o) The solution code

The adopted computer code was the CBLCS (Close Binary Light Curve Solution) written by A.Gaspani and operating both in the VAX/VMS environment and in MSDOS on a IBM PC compatible computer.
Such code, written in standard FORTRAN77 language, is available on request to all the interested GEOS members.
The program CBLCS optimizes iteratively a set of 3 parameters (i.e. the mass-ratio "q", the fill-out parameter "f" and the orbital inclination "i") fitting a synthetic flux curve, corresponding to a given choice of the free parameters, on the data.
The vector of the free parameters was iteratively changed following an optimal optimizing policy with the objective to minimize the RMS between the observed data points and the synthetic light curve.
Such parameter is adopted as the Target Function.
Any trial light curve was computed by a relevant trivariate nonlinear interpolation procedure among a data-base of "nodal" flux curves computed in advance for a relevant set of combinations of the three parameters q,f,i by direct numerical integration using a procedure similar to the procedure described in Rucinski (1973) and Lucy (1968).
The consistency of the numerical integration scheme as well as of interpolation results was extensively checked using the WUMA code developed by Rucinsky an kindly provided me by T.Banks of the Carter Astronomical Observatory at Wellington (New Zealand).
This method allows a great computational speed because of the

substitution of the interpolation procedure to the integration one. This makes the code executable also on personal computers with reasonable speed.
The numerical integration procedure was executed once on an high speed parallel computer in order to generate the relevant data-base of the nodal light curves and the results were permanently stored in the CBLCS code.

o) The Optimization Procedure

The optimization procedure implemented in the CBLCS code is of the Pattern Search type (like the classical Hooke-Jeeves algorithm) with some stochastic step correction rules adopted in order to increase the optimization efficency at expense of an additional cpu-time.
The use of the stochastic step perturbation is very useful in finding solution corresponding to the narrow blips on the target function in the multiparameter space.
The stochastic step correction is not implemented in the version running on the IBM PC compatible because of the additional computational time required.
Such (more modern) optimizing procedure performs better than classical differential correction methods as in convergence speed as in robustness.

o) The computation and the results

All the computations were carried out on a personal computer equipped with an AMD 80386 DX/DX2 microprocessor running at 40 MHz of clock frequency.
In order to save computational time a number of 45 normal points in the B color and 43 in the V color were formed, then the solution was carried out for both the colors using these points.
The figures 2a and 2b show the normal points generated.
This has ensured a fast and stable bracketing of the global minimum of the Target Function (RMS) in the multiparameter space (3 iterations in B and 4 in V), and a successive improvement of it in few minutes of cpu-time for each data set.
The total number of executed iterations were 56 for the V data points, corresponding to 458 synthetic flux curves computed, and 42 iterations for the B data corresponding to 346 synthetic flux curves computed.
The resulting model shows a W Uma type binary with nearly equal temperature but some slight disagreement between the B and V mass ratios and fill-out parameters are evident.
Despite this, the volume-radii of the two stars as well as the orbital inclination are in reasonable agreement each other.
The differences found can be imputed to some correlation between the mass ratio and the fill-out parameter occurred in the parameters space during the optimization process, but also the distortions present on the light curve could be responsible of the disagreement between the parameters of the model in the two colors.
The table 1 reports the solutions carried out for the two colors.
The final synthetic light curves corresponding to the optimal sets of model parameters are plotted among the data points in the figure 3a (B color) and 3b (V color) (the data were folded around the phase 0.5).
The annexed tables report, in numeric form, the phases, the observed luminosities (fluxes), the computed ones and the residuals of each normal points.
It is interesting to note that the available observational material permits to obtain a good solution also if there are some troubles

on the goodness of the overall fit.
The problems on the goodness of the fit seems to be related to the not high quality of the photometry that leaves some unexplained distortions on the light curve in both the colors.
A presence of disturbances due to some physical reason on the star could be possible.

### o) The model

The obtained model shows a W UMa type binary with components with nearly equal temperatures and an intermediate percent of overcontact (nearly 40%). The resulted distorted configuration can involve some physical phenomena occurring on the stars and explaining the difficult fit obtained by the simple model adopted in this paper.
In spite of the discrepancies on some parameters we were able to set up a valuable model of the system.

Table 1: Model for CV Draconis

| | | B color | V color | |
|---|---|---|---|---|
| ss ratio | q : | .75 +/- .02 | .63 +/- .01 | |
| ll-Out parameter | f : | .59 +/- .03 | .63 +/- .03 | |
| bital Inclination | i : | 64.0 +/- .4 | 65.8 +/- .3 | (degrees) |
| dius of the primary star | r1: | .442 +/- .007 | .450 +/- .006 | |
| dius of the secondary star | r2: | .392 +/- .006 | .371 +/- .005 | |
| actional Luminosity | L1 : | .575 | .614 | |
| actional Luminosity | L2 : | .425 | .385 | |
| mperature Ratio T2/T1 | : | .991 | .988 | |
| ll-out percent | : | 41.5 % | 37.0 % | |
| mb darkening u1=u2 | : | .60 (adopted) | .60 (adopted) | |
| avity Brightening | : | .08 (adopted) | .08 (adopted) | |
| nal RMS (Flux) | : | .015 | .012 | |

## THE CONCLUSIONS

The present solution is the first one obtained for the star under study.
At present the model seems to be well defined, but further observations would define better some obscure points as the occurrence of the photometric perturbations as well as the distortion of the light curve.
This star is a very interesting binary system needing accurate additional photoelectric photometry.
Since the present solution is the first one and must be regarded as preliminary, no astrophysical conclusions were drawn.

A. GASPANI

REFERENCES


ıgerer, F. et Al.: 1988, IBVS 3213.
ıgerer, F. et Al.: 1988, BAV Mitt. Nr.49, 1.
:olopov, P.N. et Al.: 1985, General Catalogue of Variable Stars, 4th Ed. Vol.2.
;aspani A.: "A fast and reliable code useful in solving the light curve of the contact binaries", GEOS NC dealing with the XV GEOS Symposium (SELVINO, 1992), to appear in the GEOS NC.
ıocher K.: 1988, BBSAG Bull. No. 87.
Jikulina T.G.: 1961, Astr. Tsirk. No.227, 17.
ιucinski S.M.: 1973, Acta Astronomica, 23, No.2.
;trohmeier, W., Knigge, R.: 1960, Veroff. Remeis-Sternw. Bamberg bd.5 Nr.6


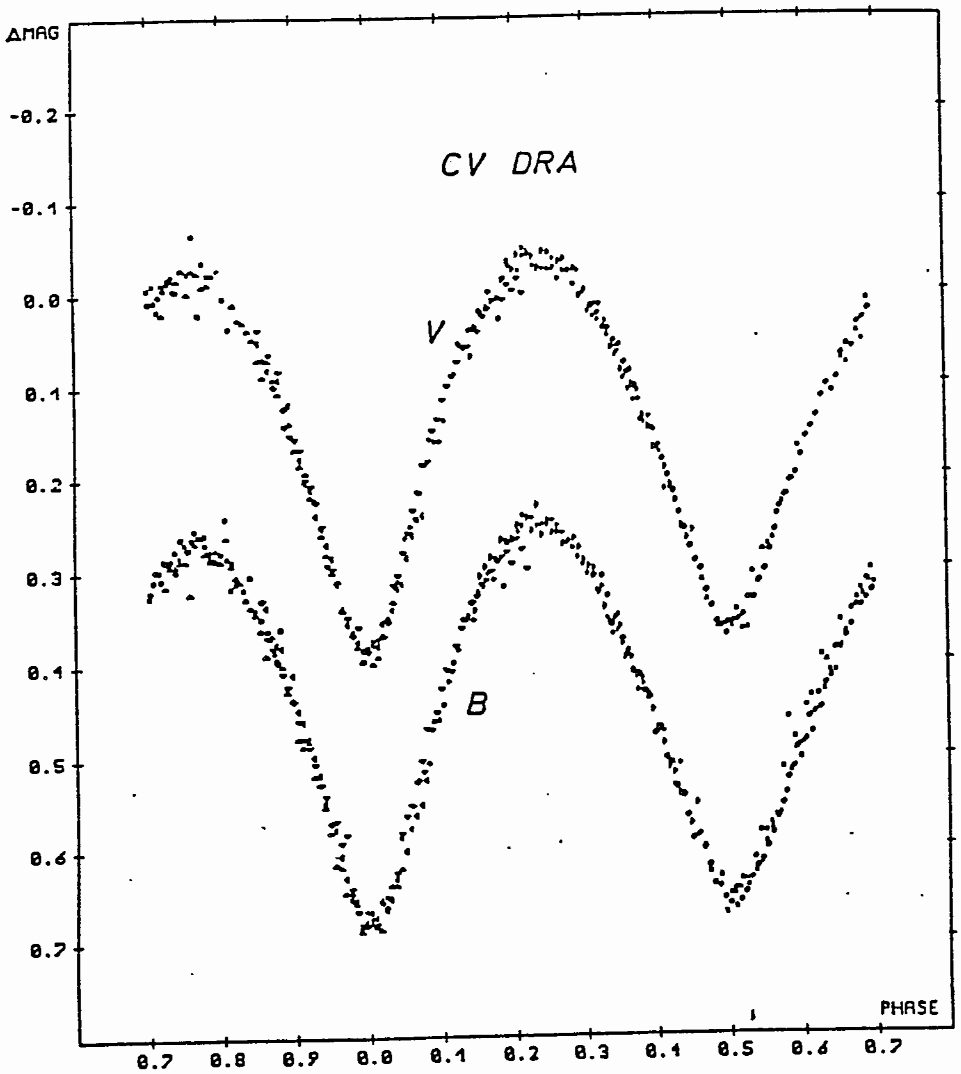


Fig.1: B and V light curves of CV Draconis

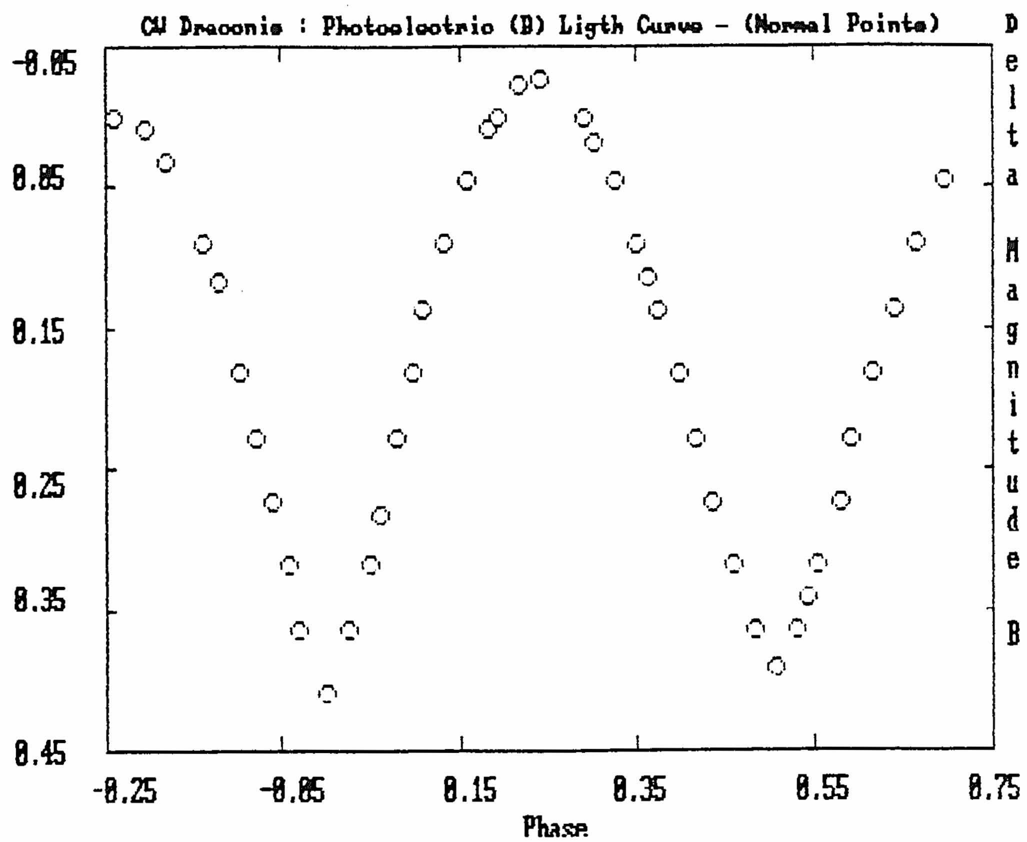


Fig.2a : Photoelectric B light curve of CV Dra.
Normal points used for the solution.

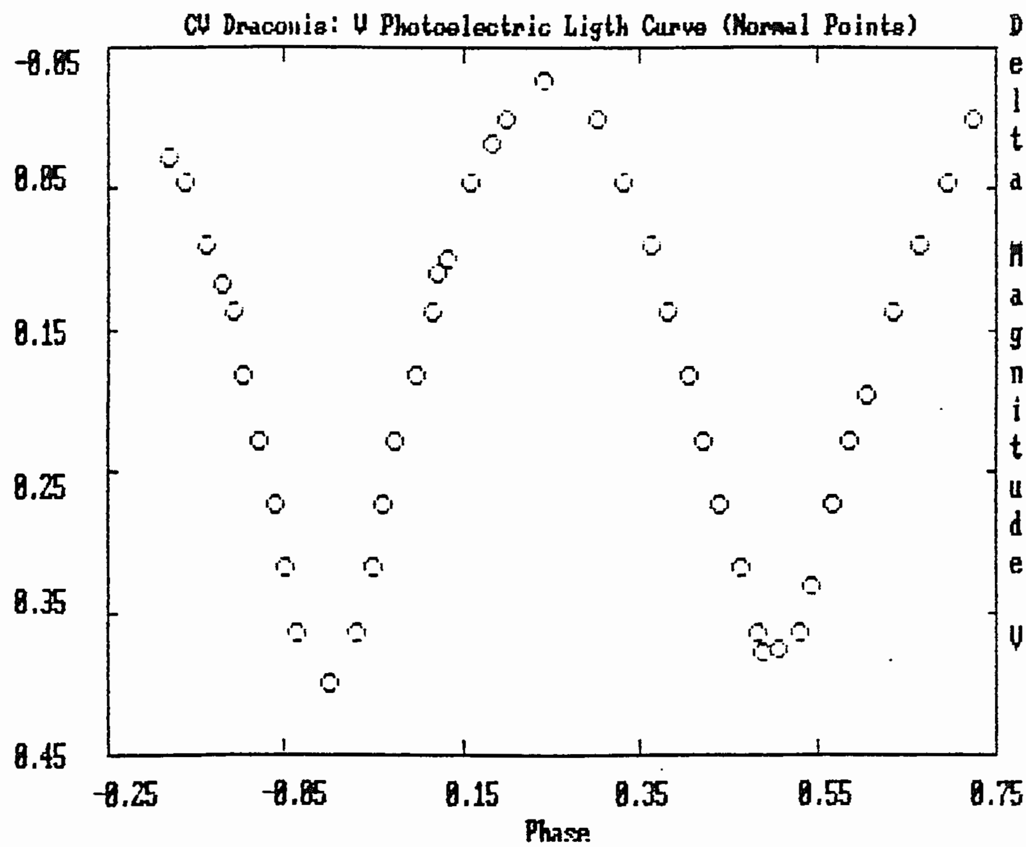


Fig.2b : Photoelectric V light curve of CV Dra.
Normal points used for the solution.

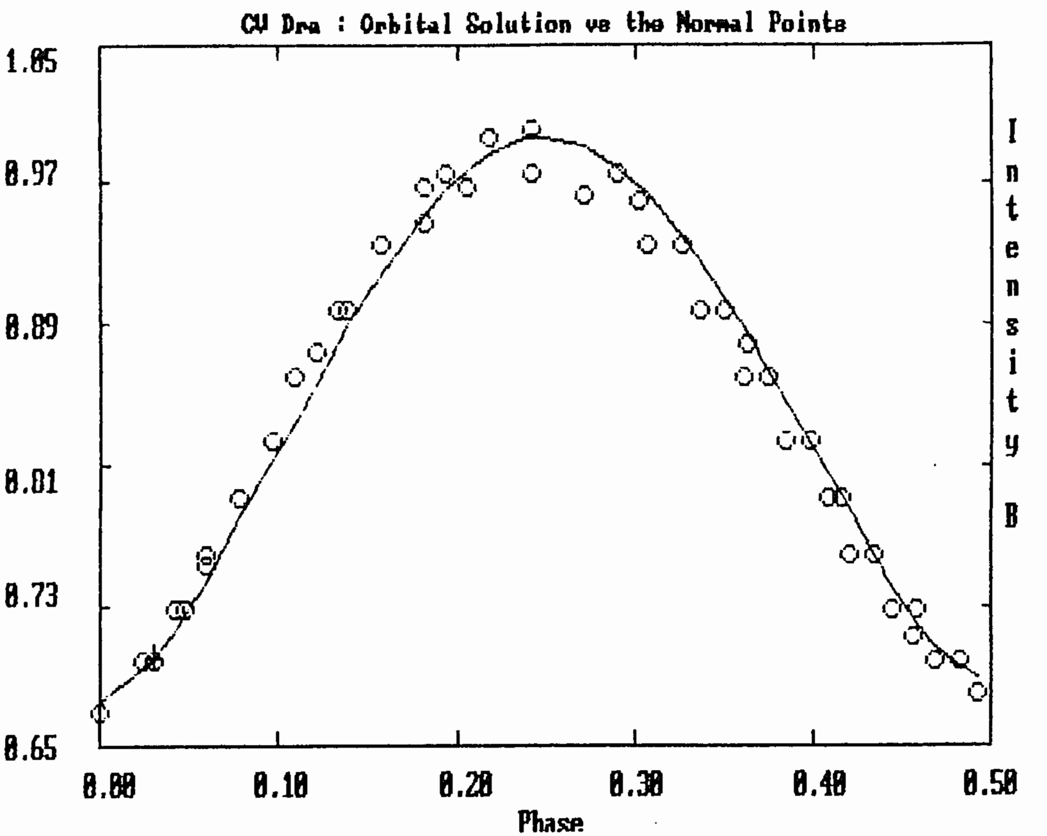


Fig.3a : Sysnthetic flux curve (line) among the normal points (circles), B color.
The table reports the comparison between the observed data points and the synthetic ones in digital form.

| Phase | Obs. Lum. | Comp. Lum. | L(O)-L(C) |
|---|---|---|---|
| 2.715750E-001 | 9.630206E-001 | 9.905487E-001 | -2.752811E-002 |
| 2.414000E-001 | 9.751925E-001 | 9.971538E-001 | -2.196127E-002 |
| 2.051900E-001 | 9.670609E-001 | 9.770403E-001 | -9.979367E-003 |
| 1.810500E-001 | 9.470273E-001 | 9.517562E-001 | -4.728913E-003 |
| 1.388050E-001 | 8.968606E-001 | 8.893099E-001 | 7.550657E-003 |
| 1.207000E-001 | 8.746118E-001 | 8.561593E-001 | 1.845253E-002 |
| 9.656000E-002 | 8.248206E-001 | 8.132780E-001 | 1.154262E-002 |
| 7.845500E-002 | 7.910006E-001 | 7.804607E-001 | 1.053989E-002 |
| 6.035000E-002 | 7.585673E-001 | 7.440956E-001 | 1.447171E-002 |
| 4.224500E-002 | 7.274638E-001 | 7.160669E-001 | 1.139688E-002 |
| 3.017500E-002 | 6.976357E-001 | 6.993830E-001 | -1.747310E-003 |
| .0000000 | 6.690306E-001 | 6.752170E-001 | -6.186366E-003 |
| 2.414000E-002 | 6.976357E-001 | 6.933386E-001 | 4.297137E-003 |
| 4.828000E-002 | 7.274638E-001 | 7.244089E-001 | 3.054917E-003 |
| 6.035000E-002 | 7.522420E-001 | 7.440956E-001 | 8.146465E-003 |
| 7.845500E-002 | 7.910006E-001 | 7.804607E-001 | 1.053989E-002 |
| 9.656000E-002 | 8.248206E-001 | 8.132780E-001 | 1.154262E-002 |
| 1.086300E-001 | 8.600867E-001 | 8.342838E-001 | 2.580285E-002 |
| 1.327700E-001 | 8.968606E-001 | 8.782597E-001 | 1.860088E-002 |
| 1.569100E-001 | 9.352068E-001 | 9.183129E-001 | 1.689386E-002 |
| 1.810500E-001 | 9.670609E-001 | 9.517562E-001 | 1.530468E-002 |
| 1.931200E-001 | 9.751925E-001 | 9.667138E-001 | 8.478701E-003 |
| 2.172600E-001 | 9.958220E-001 | 9.867960E-001 | 9.026051E-003 |
| 2.414000E-001 | 1.0000000 | 9.971538E-001 | 2.846241E-003 |
| 2.896800E-001 | 9.751925E-001 | 9.779399E-001 | -2.747416E-003 |
| 3.017500E-001 | 9.589971E-001 | 9.679088E-001 | -8.911729E-003 |
| 3.258900E-001 | 9.352068E-001 | 9.396112E-001 | -4.404426E-003 |
| 3.500300E-001 | 8.968606E-001 | 9.038608E-001 | -7.000208E-003 |
| 3.621000E-001 | 8.782812E-001 | 8.845186E-001 | -6.237388E-003 |
| 3.741700E-001 | 8.600867E-001 | 8.635023E-001 | -3.415585E-003 |
| 3.983100E-001 | 8.248206E-001 | 8.225709E-001 | 2.249718E-003 |
| 4.164150E-001 | 7.910006E-001 | 7.931625E-001 | -2.161920E-003 |
| 4.345200E-001 | 7.585673E-001 | 7.597172E-001 | -1.149893E-003 |
| 4.586600E-001 | 7.274638E-001 | 7.207223E-001 | 6.741524E-003 |
| 4.828000E-001 | 6.976357E-001 | 6.945175E-001 | 3.118217E-003 |
| 4.930600E-001 | 6.803291E-001 | 6.881908E-001 | -7.861733E-003 |
| 4.689200E-001 | 6.976357E-001 | 7.058324E-001 | -8.196712E-003 |
| 4.568500E-001 | 7.123936E-001 | 7.233490E-001 | -1.095545E-002 |
| 4.447800E-001 | 7.274638E-001 | 7.408656E-001 | -1.340181E-002 |
| 4.206400E-001 | 7.585673E-001 | 7.854013E-001 | -2.683407E-002 |
| 4.085700E-001 | 7.910006E-001 | 8.059053E-001 | -1.490474E-002 |
| 3.844300E-001 | 8.248206E-001 | 8.456376E-001 | -2.081704E-002 |
| 3.602900E-001 | 8.600867E-001 | 8.875461E-001 | -2.745944E-002 |
| 3.361500E-001 | 8.968606E-001 | 9.259319E-001 | -2.907127E-002 |
| 3.059750E-001 | 9.352068E-001 | 9.642277E-001 | -2.902091E-002 |

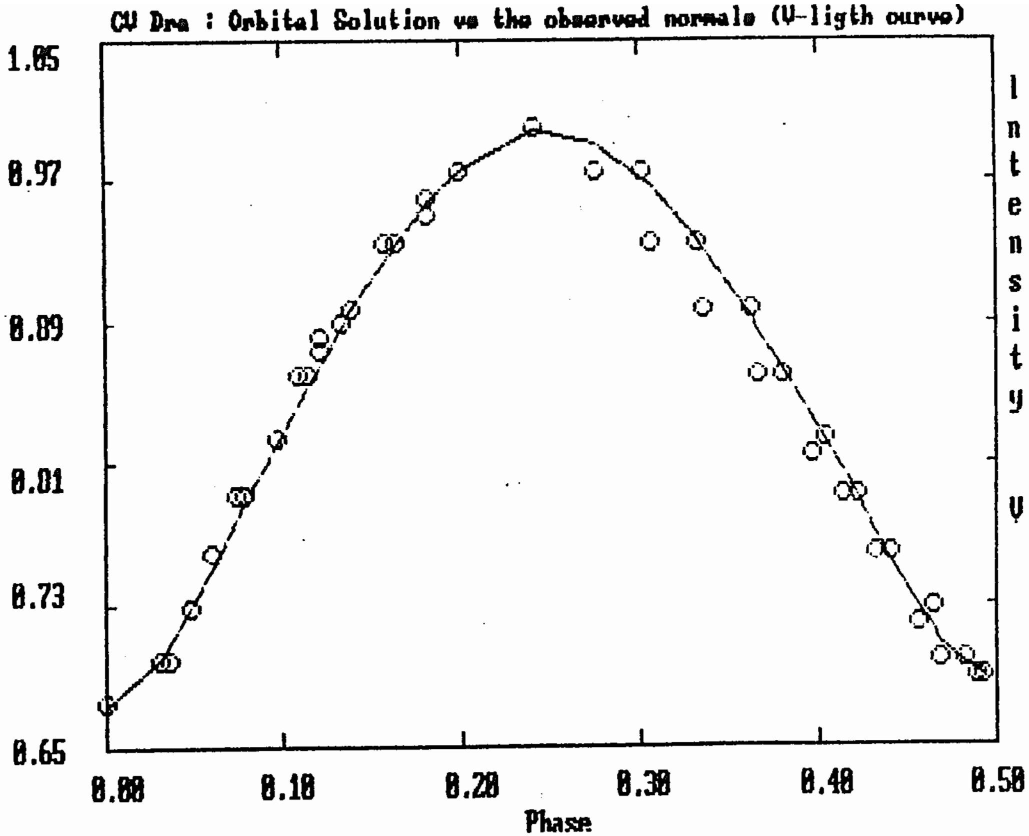


Fig.3b : Sysnthetic flux curve (line) among the normal points (circles), V color.
The table reports the comparison between the observed data points and the synthetic ones in digital form.

| Phase | Obs. Lum. | Comp. Lum. | L(O)-L(C) |
|---|---|---|---|
| .0000000 | 6.746562E-001 | 6.728662E-001 | 1.790047E-003 |
| 3.017500E-002 | 6.976357E-001 | 6.984111E-001 | -7.753968E-004 |
| 3.621000E-002 | 6.976357E-001 | 7.081490E-001 | -1.051331E-002 |
| 4.828000E-002 | 7.274638E-001 | 7.276248E-001 | -1.610518E-004 |
| 4.828000E-002 | 7.274638E-001 | 7.276248E-001 | -1.610518E-004 |
| 6.035000E-002 | 7.585673E-001 | 7.494416E-001 | 9.125710E-003 |
| 6.035000E-002 | 7.585673E-001 | 7.494416E-001 | 9.125710E-003 |
| 7.362700E-002 | 7.910006E-001 | 7.773476E-001 | 1.365304E-002 |
| 7.845500E-002 | 7.910006E-001 | 7.874951E-001 | 3.505468E-003 |
| 9.656000E-002 | 8.248206E-001 | 8.216501E-001 | 3.170431E-003 |
| 9.656000E-002 | 8.248206E-001 | 8.216501E-001 | 3.170431E-003 |
| 1.086300E-001 | 8.600867E-001 | 8.434615E-001 | 1.662517E-002 |
| 1.146650E-001 | 8.600867E-001 | 8.542744E-001 | 5.812287E-003 |
| 1.207000E-001 | 8.746118E-001 | 8.650224E-001 | 9.589434E-003 |
| 1.207000E-001 | 8.819661E-001 | 8.650224E-001 | 1.694375E-002 |
| 1.327700E-001 | 8.893821E-001 | 8.865183E-001 | 2.863824E-003 |
| 1.388050E-001 | 8.968606E-001 | 8.972663E-001 | -4.056692E-004 |
| 1.569100E-001 | 9.352068E-001 | 9.245098E-001 | 1.069701E-002 |
| 1.629450E-001 | 9.352068E-001 | 9.335831E-001 | 1.623631E-003 |
| 1.810500E-001 | 9.510005E-001 | 9.562363E-001 | -5.235791E-003 |
| 1.810500E-001 | 9.589971E-001 | 9.562363E-001 | 2.760768E-003 |
| 1.991550E-001 | 9.751925E-001 | 9.758477E-001 | -6.552339E-004 |
| 2.414000E-001 | 1.0000000 | 9.981720E-001 | 1.828015E-003 |
| 2.758000E-001 | 9.751925E-001 | 9.906234E-001 | -1.543087E-002 |
| 3.017500E-001 | 9.751925E-001 | 9.703614E-001 | 4.831135E-003 |
| 3.059750E-001 | 9.352068E-001 | 9.667585E-001 | -3.155178E-002 |
| 3.319250E-001 | 9.352068E-001 | 9.357995E-001 | -5.927682E-004 |
| 3.361500E-001 | 8.968606E-001 | 9.300493E-001 | -3.318870E-002 |
| 3.621000E-001 | 8.968606E-001 | 8.923559E-001 | 4.504740E-003 |
| 3.663250E-001 | 8.600867E-001 | 8.854135E-001 | -2.532685E-002 |
| 3.802050E-001 | 8.600867E-001 | 8.626066E-001 | -2.519965E-003 |
| 3.965000E-001 | 8.145255E-001 | 8.356299E-001 | -2.110445E-002 |
| 4.043450E-001 | 8.248206E-001 | 8.225316E-001 | 2.288997E-003 |
| 4.146050E-001 | 7.910006E-001 | 8.054011E-001 | -1.440054E-002 |
| 4.224500E-001 | 7.910006E-001 | 7.905561E-001 | 4.444718E-004 |
| 4.327100E-001 | 7.585673E-001 | 7.703270E-001 | -1.175976E-002 |
| 4.405550E-001 | 7.585673E-001 | 7.548593E-001 | 3.707945E-003 |
| 4.568500E-001 | 7.183839E-001 | 7.272983E-001 | -8.914411E-003 |
| 4.646950E-001 | 7.274638E-001 | 7.147188E-001 | 1.274502E-002 |
| 4.689200E-001 | 6.976357E-001 | 7.079440E-001 | -1.030827E-002 |
| 4.828000E-001 | 6.976357E-001 | 6.956507E-001 | 1.985013E-003 |
| 4.888350E-001 | 6.889281E-001 | 6.916580E-001 | -2.729893E-003 |
| 4.930600E-001 | 6.895052E-001 | 6.888629E-001 | 6.423593E-004 |