# A MODEL FOR THE W UMA SYSTEM GR VIRGINIS

## INTRODUCTION

GR Virginis was discovered independently by Strohmeier et Al. in 1965 and by Harris in 1979 to be a variable star.
Hoffman (1983) was able to propose a preliminary but incorrect period of 0.419757 day.
This value was confirmed by Halbedel (1988).
GR Virginis was observed visually by some members of GEOS between the years 1981 and 1984 realizing a set of 23 times of minima pubblished by Boninsegna et Al..
Photoelectric photometry was carried out by Poretti on five nights from 1987 May 8 to 29 at the Merate Astronomical Observatory using the 50 cm Marcon reflecting telescope.
The observational material is composed by 239 V and 226 B observations.
Additional details on the observational methodology as well as on the devices used are reported in Cereda et Al. (1988).

## THE PHOTOELECTRIC OBSERVATIONS

The photoelectric B and V observations carried out by Poretti et Al. are available in the publication cited above.
The cited authors were able to observe two times of minima in the B color
The times of minimum were computed by the standard Kwee Van Woerden procedure.
The correct orbital period was found by Poretti by appropriate spectrum analysis of the available time series and refined using all the available times of minima.
The correct ligth elements obtained are reported in Cereda et Al.:

$$\text{Min.1 (hel)} = \underset{\pm 2}{2445665.6415} + \underset{\pm 6}{0^{d}.3469788} * E$$

It is interesting to remember that the fist correct determination of the period of variation of the star under study was obtained by R. Boninsegna analyzing a set of visual times of minima.
The visually computed period is 0.346980 with an uncertainty of .000002 day .

## THE PHOTOELECTRIC LIGTH CURVE

The B and V ligth-curves are shown in the figure 1a and 1b respectively.
The amplitude of the variation is about .40 mag. in both color and the depth of the two minima are nearly the same.

Some evidence of total eclipse occurring at the secondary minimum is present on both the light curves.
It is interesting to note the presence of some photometric perturbations among the data distributed along the entire light curve in both the colors.
Additionally differences in the luminosity levels at the quadrature are also present.
The instrumental origin of the described perturbations seems to be highly improbable.

## THE LIGTH CURVE SOLUTION

I have processed the B an V photoelectric observations in order to obtain the first orbital solution of this binary system.
The light curve solution was obtained in time domain making use of a light curve synthesis computer code written by the author fitting classical Roche Model on the observations by Mixed Multidimensional Optimization Tecniques.
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.

## 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 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.
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 ligh 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 plus a 128 Kb cache memory.
This has ensured the solution in about one minute of cpu-time for the B solution (226 data points, 127 iterations, 1026 synthetic light curves computed) and in about two minutes for the V solution (239 data points, 304 iterations, 2442 synthetic light curves computed).
In both cases the global minimum of the target function was bounded at the third iteration leaving the remaining ones to ameliorate the solutions found.
The two distinct photometric solutions, reported in the table 1, were in excellent agreement each other confirming the good quality of the available data.
The final synthetic light curves corresponding to the optimal sets of model parameters are plotted among the data points in the figure 2a (B color) and 2b (V color), the data were folded around the phase 0.5.
It is interesting to note that the available observational material permits to obtain an accurate solution also if there are some troubles on the goodness of the overall fit.
This is easily observed taking in account the slightly bad fit near the bottom of the minima in both colors.
The nature of this phenomenon is at present unclear, but forcing the best fit of the minima involves unreliable results, in particular the overall goodness of the fit goes worse.
The situation was pointed out also by Cereda et Al. (1988) after some tentative of solution was attemped by Niarchos, using the same data of the present paper, but making use of the frequency domain tecniques developed by Kopal et colleagues between the 1975 and the 1980.

o) The model

The obtained model shows a W Uma type binary with components with nearly equal temperatures and a high percent of overcontact (98%).
The resulted high distortion can involve some physical phenomena occurring on the stars and explaining the difficult fit obtained by the simple model adopted in this paper.

The close agreement between the solutions in the two colors allows us to conclude that despite the discrepancies on the overall fit the solution procedure was able to set up a valuable model of the system.

Table 1: Model for GR Virginis

| | | B color | V color |
|---|---|---|---|
| ;s ratio | q : | .300 ± .016 | .300 ± .015 |
| .1-Out parameter | f : | .013 ± .032 | .016 ± .030 |
| )ital Inclination | i : | 61.5 ± .4 | 61.9 ± .4 (degrees) |
| lius of the primary star | r1: | .5459 ± .0086 | .5458 ± .0084 |
| lius of the secondary star | r2: | .3513 ± .0056 | .3511 ± .0054 |
| actional Luminosity | L1 : | .7975 ± .0013 | .7974 ± .0013 |
| actional Luminosity | L2 : | .2025 ± .0013 | .2026 ± .0013 |
| nperature Ratio T2/T1 | : | .936 | .936 |
| ercontact Percent | : | 98.7 % | 98.5 % |
| nb darkening u1=u2 | : | .6 (adopted) | .6 (adopted) |
| avity Brightening | : | .08 (adopted) | .08 (adopted) |
| nal RMS (flux units) | : | .0134 | .0130 |

## THE CONCLUSIONS

The present solution is the first one pertaining to the star under study.
At present the model seems to be well defined, but further observations can define better some obscure points as the occurrence of the photometric perturbations as well their evolution along the time.
This star is a very interesting binary system needing accurate additional photometry.

A. Gaspani

## REFERENCES

Cereda L. at Al.: 1988, A&A Suppl. Series, 76, 255-261
Gaspani 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.

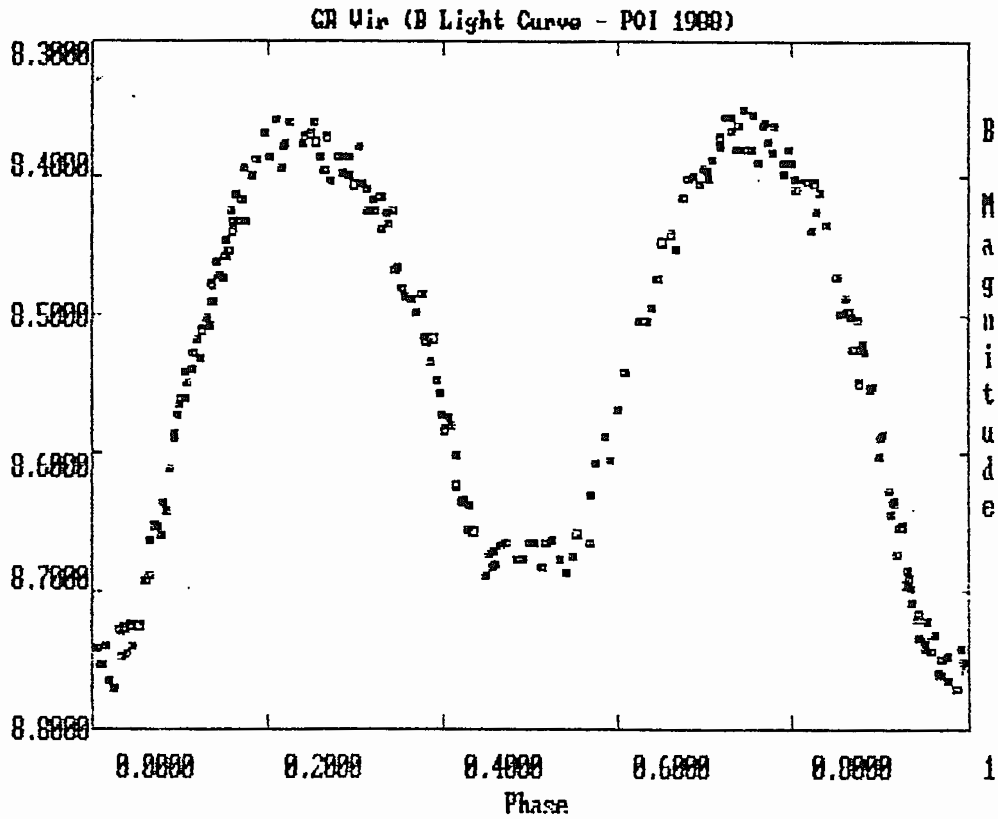



Fig.1a: B Photoelectric light curve.

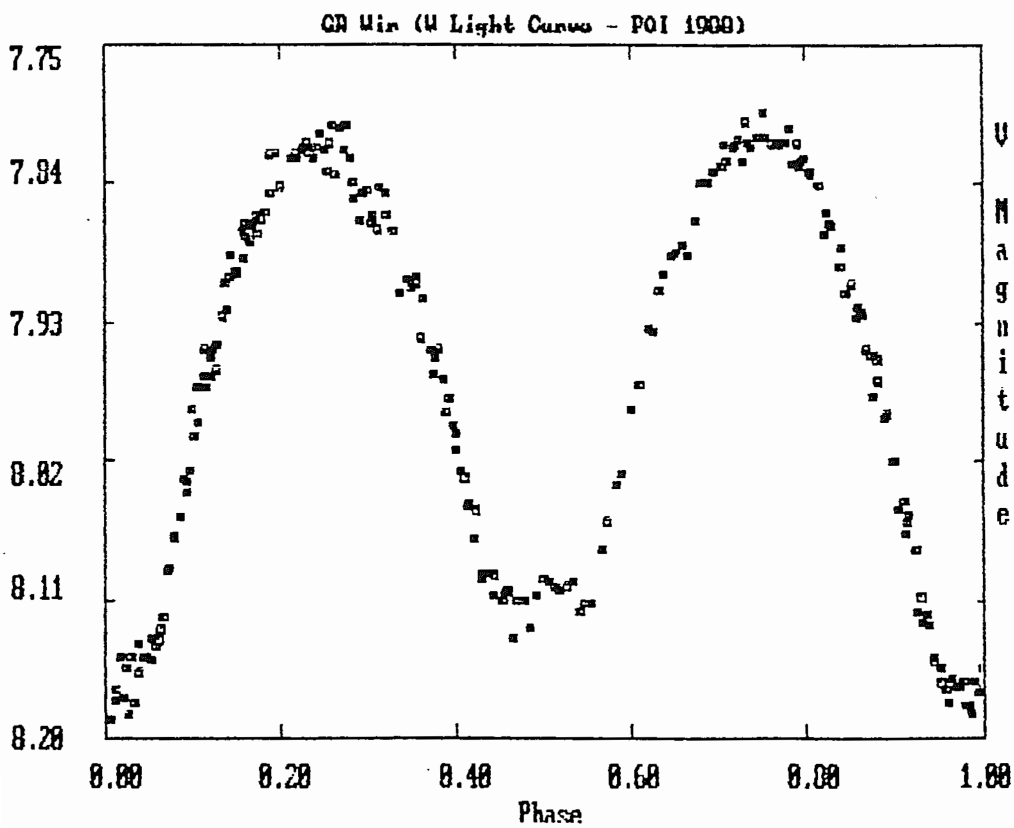
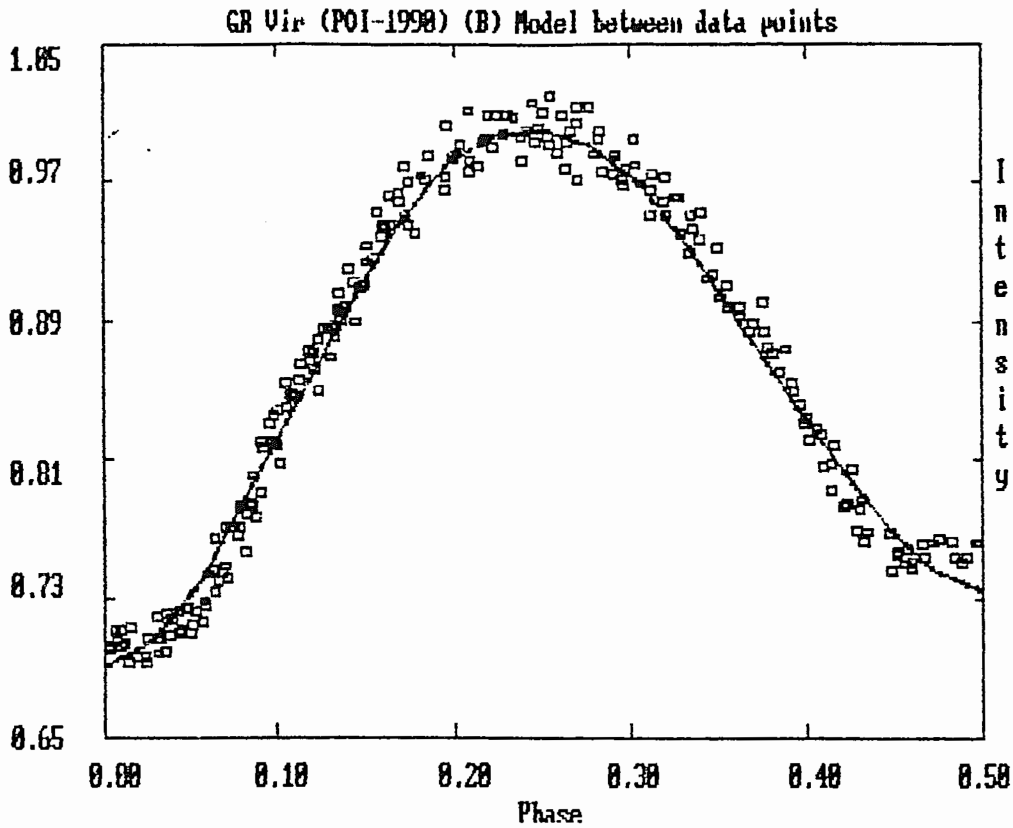



Fig.1b: V Photoelectric light curve.




.g.2a: Synthetic light curve corresponding to the model of table 1 plotted among the data points. (B-color).

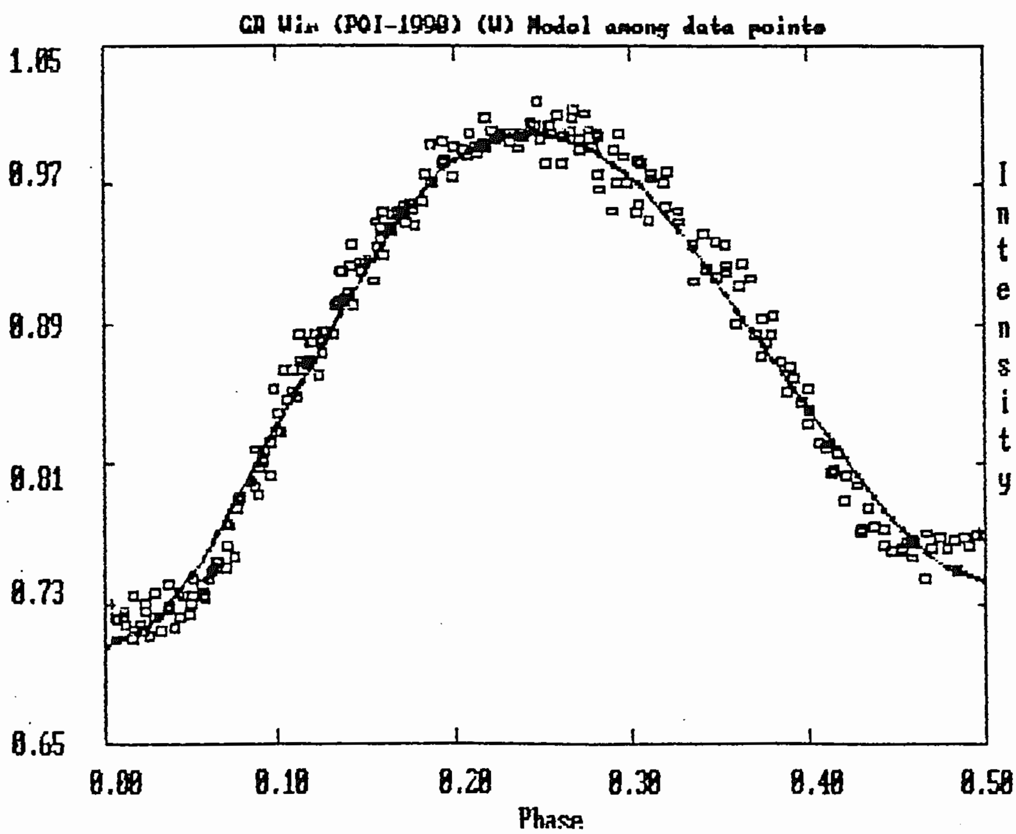



Fig.2b: Synthetic light curve corresponding to the model of table 1 plotted among the data points. (V-color).