Preliminary Model of Three Contact Binaries in the Globular Cluster NGC 6397

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Abstract

Four EW type binary stars observed in the central part of NGC 6397 are analysed with the purpose of the determination of their orbital elements. For three of them we were able to determine the mass ratio (q), inclination (i), fill-out (f), the temperature ratio (T_2/T_1), the mean ratios (R_1, R_2) and fractional luminosity (L_1 , L_2) of the stars. In one case we were not be able to calculate the orbital elements because of the poor quality of the data. For two stars the light curve aspect (O'Connel effect) suggested us the presence of a starspot on their surface. The basic parameters of the systems and of the active regions are estimated.

1. Introduction

A field including the central part of the globular cluster NGC 6397 was surveyed by Kaluzny (Kaluzny J., 1997) for some nights in the July 1995, as a supplementary project during the observing run devoted mainly to a search for eclipsing detached binaries in the globular cluster M4. Light curves were obtained for 6 close binaries, 2 SX Phe stars and 1 RR Lyrae variable.
From the six binaries, one is indicated as EA/EB: type with a proposal period of 0,27: days (V5 in the original paper) and for another one, V6 in the original paper, the period of 0,5: days was derived from an incomplete light curve. Of course, these two stars were not analysed.
Using the original data of the Kaluzny's publication, obtained from the CDS Internet site (http://cdsweb.u-stasbg.fr/cats/), here we present the preliminary model for three contact binaries, computed making use of the Binary Maker 2.0 (Bradstreet H. David, 1993) computer code.

2. Star List

The contact binaries analysed in the present work are:

- **V4** the period of which is 0,4218 days and amplitude of 0,74 mags, type EW
- **V8** with period of 0,2710 days and amplitude of 0,37 mags, type EW
- **V9** the period of which is 0,5802 days and amplitude of 0,65 mags, type EW

And **V7**, a W Ursae Majoris type variable, is the star for which we were not able to determine its elements.

3. Data Reduction

For all the stars we construct a three dimensional example model of the systems using Binary Maker 2.0, assuming the temperature of the large star, while the temperature of the small star was adjusted in respect of the temperature ratio (T_2/T_1).
The unequal height or/and asymmetry of the maxima in the light curves, knew as O'Connel effect (1951), of the contact binaries V4 and V9, may be attributed to active dark or hot regions on some of the system's components. So, for these stars, we have added a dark spot on the surface of the primary or secondary component.
For all the stars the numerical fitting was good and, to support our results, we verified its in respect of the mass ratio function graphs adopted from F. Van't Veer (1978).
In his paper Van't Veer shown a correlation among the amplitude Δm, the inclination and the mass ratio of contact binaries systems. Our results, for the three solved systems, are in agreement with Van't Veer's paper.

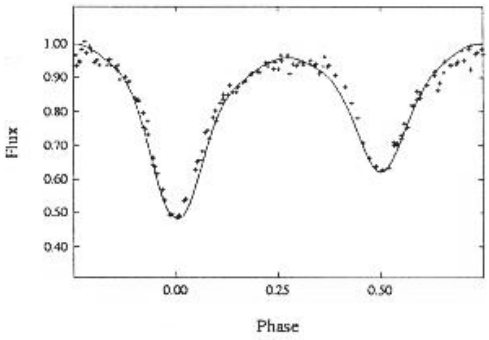
4. Results

V4 in NGC 6397

We construct a three dimensional model of this system using Binary Maker 2.0 assuming the temperature of the large star to be 4900 K. The data are best fitted with an inclination of 81°, a mass ratio of 2.49, and a fill-out factor of 0,01. The temperature of the small star was adjusted, in respect of the temperature ratio, to 5350 K. The non-spot model was not able to represent the light curve, (O'Connel effect) so we have interpreted this due to the presence of a dark spot on the surface of the primary component of the system. The best fit, the aspect of the system, and the Roche lobes and Lagrangian points of **V4** are shown in Figure 1.
The orbital elements and the spot parameters are listed in Table 1 and Table 2 respectively.

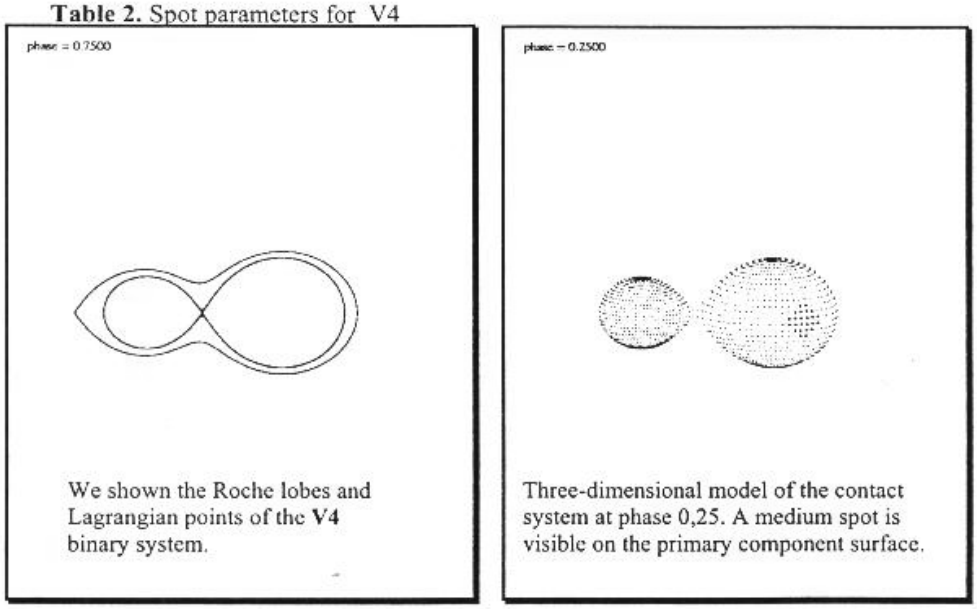
$q = 2.490 \pm 0.044$
$f = 0.012 \pm 0.091$
$i = 81° \pm 1.1°$
R_1 mean $= 0.461 \pm 0.025$
R_2 mean $= 0.302 \pm 0.017$
$L_1 = 0.581 \pm 0.040$
$L_2 = 0.419 \pm 0.040$
$x_1 = x_2 = 0.6$
$g_1 = g_2 = 0.32$
$T_2/T_1 = 1.09$

Table 1. Best fit parameters for V4



Co Latitude = 90°
Longitude – 240°
Spot Radius = 17°
Temp. Factor = 0.4
Star = 1

Table 2. Spot parameters for V4



We shown the Roche lobes and Lagrangian points of the **V4** binary system.

Three-dimensional model of the contact system at phase 0,25. A medium spot is visible on the primary component surface.

Figure 1 – *(above)* - The light curve from Binary Maker (example model) of **V4** (line) superimposed to the original one (points); *(bottom)* – Roche lobes and model

V8 in NGC 6397

We construct a three dimensional model of this system using Binary Maker 2.0 assuming the temperature of the large star to be 6300 K. The data are best fitted with an inclination of 80,0°, a mass ratio of 0.15, and a fill-out factor of 0.46. The temperature of the small star was adjusted, in respect of the temperature ratio, to 6100 K. The best fit, the aspect of the system, and the Roche lobes and Lagrangian points of **V8** are shown in Figure 2.
The orbital elements are listed in Table 3.

$q = 0.150 \pm 0.023$
$f = 0.461 \pm 0.040$
$i = 80° \pm 0.5°$
R_1 mean $= 0.565 \pm 0.014$
R_2 mean $= 0.251 \pm 0.012$
$L_1 = 0.860 \pm 0.017$
$L_2 = 0.140 \pm 0.017$
$x_1 = x_2 = 0.6$
$g_1 = g_2 = 0.32$
$T_2/T_1 = 0.968$

Table 3. Best fit parameters for V8

V9 in NGC 6397

We construct a three dimensional model of this system using Binary Maker 2.0 assuming the temperature of the large star to be 4700 K.
The data are best fitted with an inclination of 79°, a mass ratio of 3.38, and a fill-out factor of 0.01. The temperature of the small star was adjusted, in respect of the temperature ratio, to 5300 K. The non-spot model was not able to represent the light curve, (O'Connel effect) so we have interpreted this due to the presence of a dark spot on the surface of the secondary component of the system. The best fit, the aspect of the system, and the Roche lobes and Lagrangian points of **V9** are shown in Figure 3.
The orbital elements and the spot parameters are listed in Table 4 and Table 5 respectively.

$q = 3.382 \pm 0.035$
$f = 0.010 \pm 0.073$
$i = 79° \pm 0{,}8°$
R_1 mean $= 0.489 \pm 0.023$
R_2 mean $= 0.278 \pm 0.013$
$L_1 = 0.620 \pm 0.031$
$L_2 = 0.380 \pm 0.031$
$x_1 = x_2 = 0.6$
$g_1 = g_2 = 0.32$
$T_2/T_1 = 1.12$

Table 4. Best fit parameters for V9

Co Latitude = 90°
Longitude = 270°
Spot Radius = 10°
Temp. Factor = 0.3
Star = 2

Table 5. Spot parameters for V9

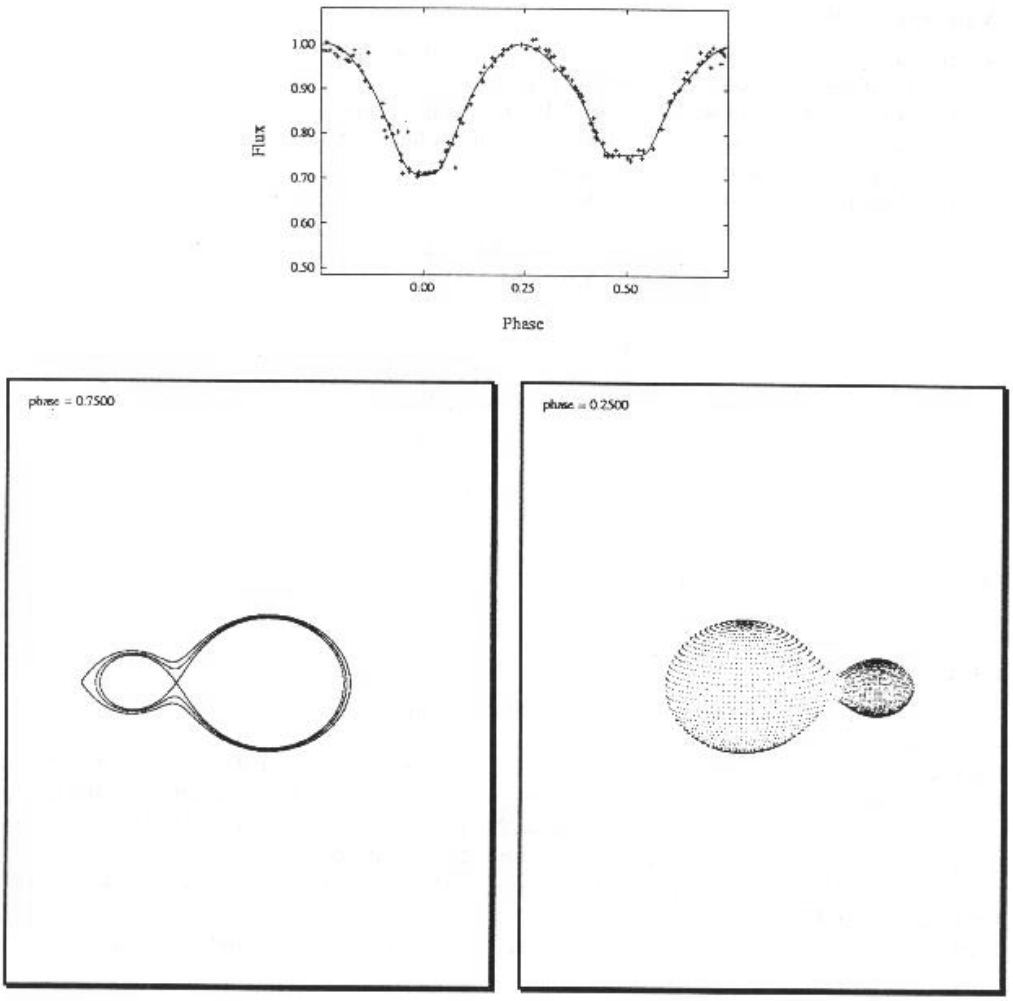


Figure 2 - *(above)* - The light curve from Binary Maker (example model) of **V8** (line) superimposed to the original one (points).
- *(bottom, right)* - Three-dimensional model of the contact system at phase 0.25.
- *(bottom, left)* - We shown the Roche lobes and Lagrangian points of the **V8** binary system.

5. Conclusions

In the present paper we have analysed three EW type stars in the central part of the globular cluster NGC 6397, with the purpose to suggest the first orbital solutions for its.
For two of them the shape of the light curve suggested us the probable presence of a starspots on his surface.

6. References

Van't Veer, F., 1978, A&AS, 70,91

Kaluzny, J., 1997, A&AS, 122,1

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O'Connel, D. J. K., 1951, Pub. Riverview College Obs., 2,85

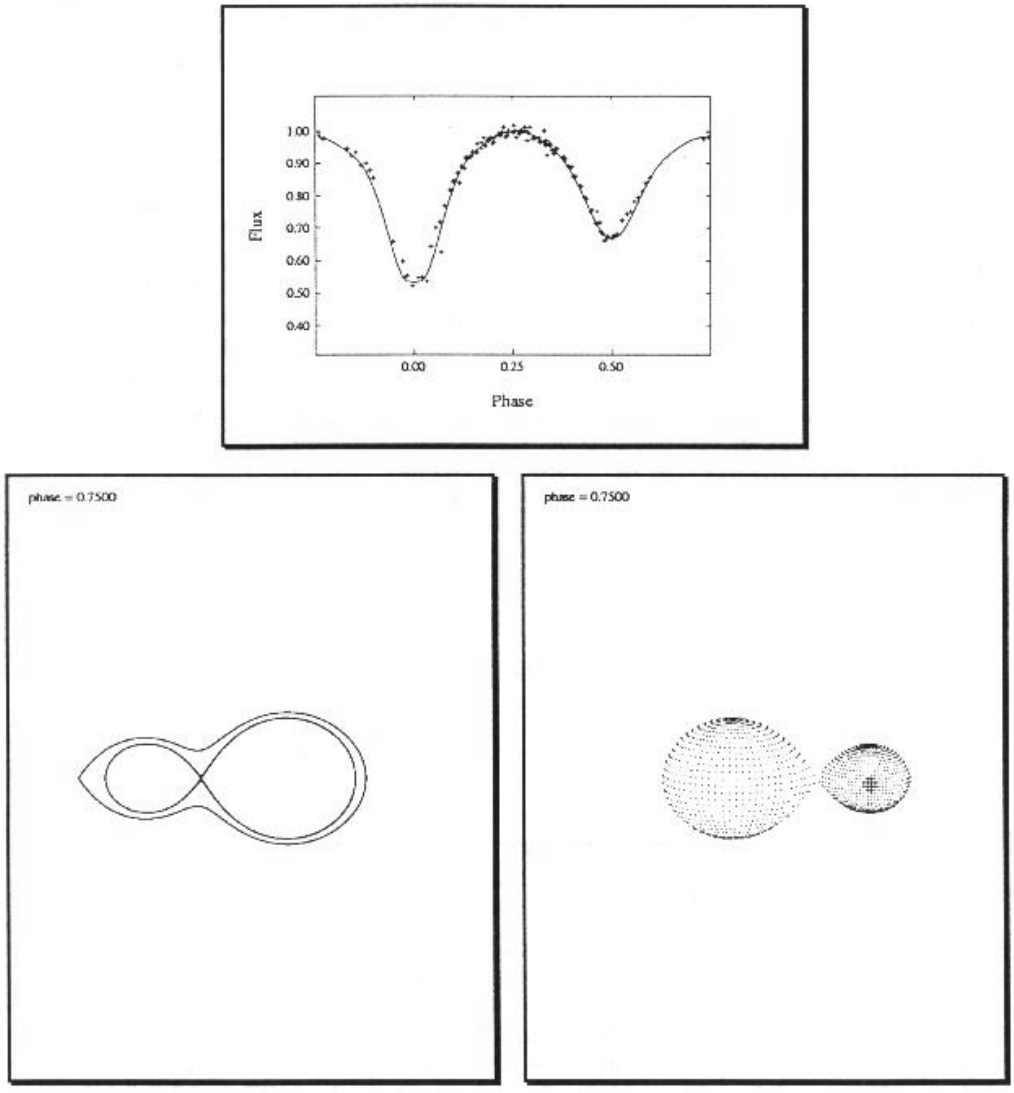

Figure 3 - *(above)* - The light curve from Binary Maker (example model) of **V9** (line) superimposed to the original one (points).
- *(bottom, right)* - Three-dimensional model of the contact system at phase 0.75. A small spot is visible on the secondary component surface.
- *(bottom, left)* - We shown the Roche lobes and Lagrangian points of the **V9** binary system.