# The first photometric study of the near-contact system GW Tauri

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## Abstract

The near-contact system GW Tauri with an A3 primary has been observed in V, R and I wavebands in January through March 2001 with the new 40-cm telescope of the University of Athens Observatory. Complete seasonal light curves are presented for the first time and a new observed time of minimum is given. The light curve is used to determine the basic geometrical and physical parameters of the system with the Wilson-Devinney program. The presence of irregularities in the light curves and the possible existence of spots and circumstellar material are discussed, and a spot model for the season is proposed.

## 1 Introduction

GW Tauri (= GSC 01833-00200) has been observed by few observers. Brancewicz & Dworak (1980) include GW Tau in their *Catalogue of parameters for eclipsing binaries* as a beta-Lyrae system. Giuricin et al. contain it in their statistical paper (1983), while Popova & Kraicheva (1984) include it in their *Catalogue of Eclipsing and Spectroscopic Binary Stars in the Regions of Open Clusters*. Shaw includes it in his second (1994) catalogue of near-contact systems as a system whose subclass (FO Virginis or V1010 Ophiuchi) is unknown. According to Shaw (1990), as FO Vir systems are defined those that have a primary component of normal size inside its Roche lobe and a 2 to 3 times oversized secondary at or near its Roche lobe. V1010 Oph systems are defined as those with a normal primary at or near its Roche lobe and an up to 1.5 times oversized secondary well inside its Roche lobe. Members of the latter subclass often show asymmetrical light curves, while the members of the FO Vir subclass never do. Therefore, we observed and studied the system in order to determine its subclass and evolutionary state, analyzing for the first time its light curves.

## 2 The Observations

The CCD observations of GW Tau were made from January to March 2001, namely January 4 and 10, February 5-9 and 20, and March 2 and 14. The instruments used were the new 40-cm Cassegrain telescope of the University of Athens Observatory and a SBIG-8 CCD camera. The three Bessell V, R and I filters were used. The CCD images obtained were processed with the AIP4WIN photometry program of Berry & Burnell (2000). The stars BD+25°0718 (= HD 283710) and GSC 01833-00744 were used as comparison and check stars, respectively. In total 349 yellow, 294 red and 336 infrared observations were obtained during the ten nights. The probable error of a single observation was estimated to be $\pm$ 0.008 mag in infrared, $\pm$ 0.01 mag in red and $\pm$ 0.012 mag in yellow. Figure 1 shows all the observations made in the whole observing period.

## 3 Unspotted Light Curve Solution

We first solved the light curves assuming that there are no spots on the components of the system. From an inspection of the curves we decided that the observations

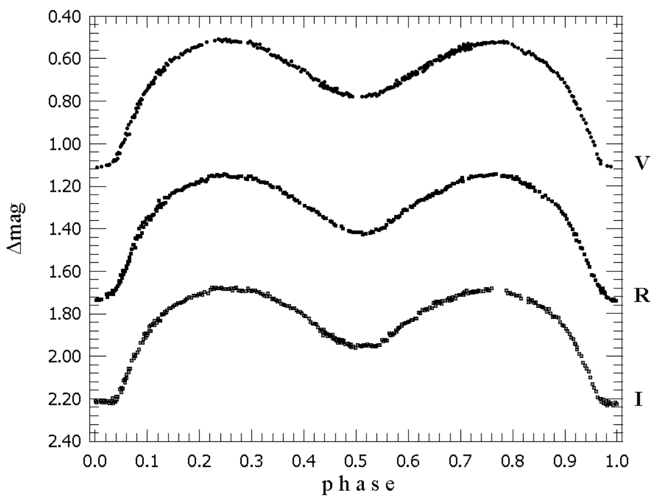


**Figure 1.** The observed light curves of GW Tauri (January, February and March 2001)

in the phase interval 0.72 to 0.88 should be excluded, as this part of the light curve seems to be affected slightly by the presence of spots. 150 normal points for each color were formed from the individual observations and assigned weight equal to the number of observations per point. The subscripts 1 and 2 refer to the star being eclipsed at primary and secondary minimum, respectively. The 1996 version of the Wilson-Devinney code was used in the light curve analysis. A starting value of q = 0.84, as well as a preliminary set of input parameters, were selected from the catalog of Brancewicz and Dworak (1980). The results converged with the Modes 2 and 5 of the program; Mode 4 was also tried without achieving convergence. The adjustable parameters were: the conjunction phase , the inclination i, the temperature $T_2$ of the secondary, the non-dimensional surface potential $\Omega_1$ (Mode 5), or $\Omega_2$ (Mode 4), or both $\Omega_1$ and $\Omega_2$ (Mode 2), and the non-normalized monochromatic luminosity $L_1$. The fixed parameter was the temperature $T_1$ (from spectroscopic observations). Assumed values for limb darkening, gravity darkening and bolometric albedos, according to the spectral types of the components, were used. Third light was assumed to be zero. The results are given in Table 1. The errors given are the calculated standard deviations.

## 4 Spots and circumstellar matter

The parameters found in the unspotted solution were used in the *Binary Maker 2.0* program (Bradstreet 1993) to model the light curves with spots. We placed only two cool spots on the surface of the secondary, since the temperature of the primary is too high to allow spots in theory. The spot modelling has been derived based on the V, R, I light curves, by fitting the theoretical to the observational curves. The parameters of the spots are:

Spot 1: latitude 90°, longitude 325°, spot radius 20° and T factor 0.55
Spot 2: latitude 90°, longitude 35°, spot radius 22° and T factor 0.50

Theoretical light curves based on the spot model and observed ones (normal points) are shown in Fig. 2. Three-dimensional models of the system with the spots visible at phases 0.25 (Spot 1) and 0.75 (Spot 2) are given in Fig. 3. However, there are two differences between the observational light curves and our theoretical spotted ones that could not be explained by any spot model: the excess infrared light observed at phase 0 and the reduced observed light around (but not exactly at) phase 0 in all three colors. These interesting differences could be explained by the presence of light-absorbing optically thin material around the secondary star, which emits thermal infrared radiation.

**Table 1. Unspotted light curve solutions of GW Tauri**

| Parameter | Mode 2 | Mode 5 |
|---|---|---|
| $\phi_0$ | $0.0041 \pm 0.0003$ | $0.0042 \pm 0.0003$ |
| $i$ (degrees) | $71.45 \pm 0.15$ | $72.36 \pm 0.22$ |
| $g_1$ | $1.00^*$ | $1.00^*$ |
| $g_2$ | $0.32^*$ | $0.32^*$ |
| $T_1$ (K) | $7920^*$ | $7920^*$ |
| $T_2$ (K) | $5278 \pm 36$ | $5025 \pm 38$ |
| $A_1$ | $1.0^*$ | $1.0^*$ |
| $A_2$ | $0.5^*$ | $0.5^*$ |
| $\Omega_1$ | $3.0001 \pm 0.0131$ | $3.2072 \pm 0.0300$ |
| $\Omega_2$ | $2.8508 \pm 0.0405$ | $3.2256^*$ |
| $q = M_2/M_1$ | $0.5625 \pm 0.0041$ | $0.6904 \pm 0.0181$ |
| $L_1/(L_1 + L_2)$ $(V)$ | $0.8836 \pm 0.0042$ | $0.9069 \pm 0.0038$ |
| $L_1/(L_1 + L_2)$ $(R)$ | $0.8466 \pm 0.0044$ | $0.8701 \pm 0.0041$ |
| $L_1/(L_1 + L_2)$ $(I)$ | $0.8142 \pm 0.0042$ | $0.8365 \pm 0.0041$ |
| $X_1(bolo)$ | $0.588^*$ | $0.588^*$ |
| $X_2(bolo)$ | $0.565^*$ | $0.565^*$ |
| $X_1$ $(V)$ | $0.614^*$ | $0.614^*$ |
| $X_2$ $(V)$ | $0.707^*$ | $0.707^*$ |
| $X_1$ $(R)$ | $0.495^*$ | $0.495^*$ |
| $X_2$ $(R)$ | $0.602^*$ | $0.602^*$ |
| $X_1$ $(I)$ | $0.397^*$ | $0.397^*$ |
| $X_2$ $(I)$ | $0.516^*$ | $0.516^*$ |
| $r_1$ (pole) | $0.4029 \pm 0.0017$ | $0.3900 \pm 0.0021$ |
| $r_1$ (point) | $0.5330 \pm 0.0138$ | – |
| $r_1$ (side) | $0.4265 \pm 0.0021$ | $0.4123 \pm 0.0024$ |
| $r_1$ (back) | $0.4546 \pm 0.0026$ | $0.4431 \pm 0.0024$ |
| $r_2$ (pole) | $0.3346 \pm 0.0019$ | $0.3256 \pm 0.0021$ |
| $r_2$ (point) | – | $0.4618 \pm 0.0104$ |
| $r_2$ (side) | $0.3540 \pm 0.0025$ | $0.3406 \pm 0.0023$ |
| $r_2$ (back) | $0.4066 \pm 0.0052$ | $0.3726 \pm 0.0023$ |
| $\Sigma(\text{res})^2$ | 0.0001257 | 0.0001592 |

$^*$assumed

## 5 Absolute elements

From our Mode 2 solution and the spectral type of the system, we obtained the following absolute elements in solar units:

$R_1 = 2.07 \pm 0.03$ $R_2 = 1.62 \pm 0.03$
$L_1 = 27.92 \pm 1.42$ $L_2 = 1.43 \pm 0.10$
$M_1 = 2.79 \pm 0.15$ $M_2 = 1.48 \pm 0.08$

and the bolometric absolute magnitudes: $M_{bol(1)} = 1.13$ and $M_{bol(2)} = 4.36$

## 6 Summary and conclusions

From our results it seems more probable that the system of GW Tau is detached, with the secondary almost filling its inner Roche lobe. The primary must also be near the limits of its lobe, because the code tended to give values for the $\Omega_1$ potential close to the $\Omega_{in}$ value for the final mass ratio derived. We can conclude that the system is a FO Virginis-type. However, the presence of circumstellar

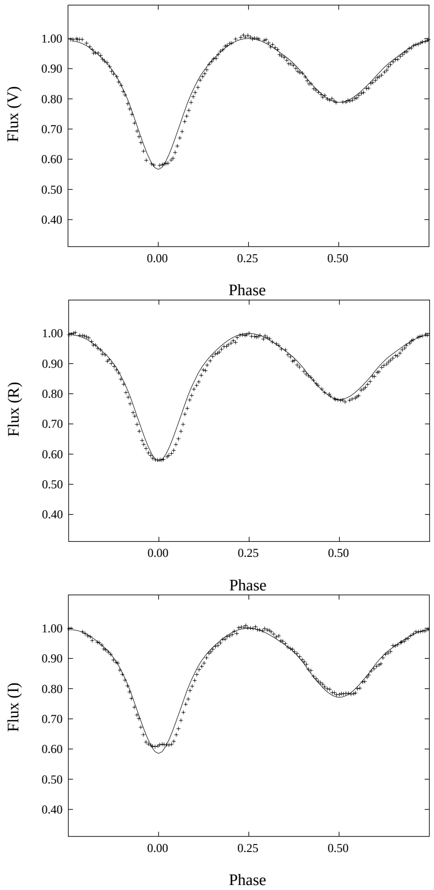


**Figure 2.** Normal points and theoretical light curves for our spot model (Mode 2)

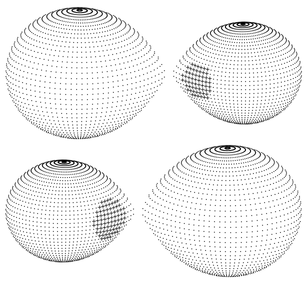

**Figure 3.** Three-dimensional models of GW Tauri at phases 0.25 and 0.75

matter would almost inevitably cause a change in the period of the system, while if the generalization by Shaw (1990) holds true, FO Vir systems shouldn't exhibit period changes.

## References

Berry R., Burnell J., 2000, The Handbook of Astronomical Image Processing, Richmond: Willmann-Bell
Bradstreet D.H., 1993, Binary Maker 2.0 User Manual
Brancewicz H.K., Dworak T.Z., 1980, Acta Astronomica, 30, 501
Giuricin G., Mardirossian F., Mezzetti M., 1983, A&A Suppl.Ser., 54, 211
Popova M., Kraicheva Z., 1984, Astrof.Issled.Izv.Spets.Astr.Obs., 18, 64
Shaw J. S., 1994, Mem. S. A. Ital., 65, 95
Wilson R.E., Devinney E.J., 1971, ApJ, 166, 605