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LO Gem: FIRST DETERMINATION OF THE ORBITAL PERIOD AND LIGHT CURVE

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LO Gem (GSC 1868:2176; $06^h04^m12^s$, $+25°20'$, J2000) is listed in the GCVS (Kholopov et al. 1985) as an E star varying from $11^m\!.5$ to $12^m\!.0$ (p). The star was first reported to be an Algol type binary system by Hoffmeister (1968). Ten times of minimum light were determined from Sonneberg photographic plates taken between 1933 and 1967; however no period was derived (Gessner & Meinunger 1973). A first indication of the period of LO Gem was provided by the work performed by several GEOS members, who collected 840 visual estimates, thus allowing the determination of 16 times of minimum light (Vandenbroere 1993). During five missions at Jungfraujoch Observatory between 1992 and 1997, GEOS teams obtained 128 photoelectric measurements in each of the B and V filters of the Geneva system, covering the complete light curve of LO Gem. These measurements were carried out using the "all sky" method: the atmospheric absorption coefficients were determined by measuring standard stars located at different airmasses. Although no comparison stars were used, the good quality of the photoelectric data (standard deviation about $0^m\!.010$ in both colours) could be evaluated from the stability of the atmospheric absorption coefficients during the night.

Two series of 351 measurements in the V and I_C colours (Johnson–Cousin system) were also performed with a CCD coupled to a 40-cm telescope in the observatory of one of the authors (N.B., Ghirone, Swiss Alps). Differential magnitudes were obtained by using four comparison stars, i.e. GSC 1868:2932, 1868:225, 1868:2279 and 1868:2280, whose positions are shown in the finder chart (Figure 1, S2 to S5, respectively). The standard deviation of the measurements are $0^m\!.014$ for the first night (around phase 0.5) and $0^m\!.017$ for the second one (around phase 0.0), as results from the analysis of the comparison stars' data.

To date, we have 3 photoelectric and 2 CCD minima at our disposal (they were given a triple weight) together with 16 visual minima to determine the period elements of LO Gem. We can refine this considering the photographic minima reported by Hoffmeister (1968) as well as those published by Gessner & Meinunger (1973). The result of the linear regression is the following:

$$\text{Min I} = \text{HJD } 2427368.371(6) + 2^d\!.2377825(18) \times E.$$

The uncertainty in the final digits are given in brackets. The photoelectric and CCD times of minima are reported in Table 1; the first visual times are listed in Vandenbroere (1997) and the latest one's will be submitted to the BBSAG Bulletin.

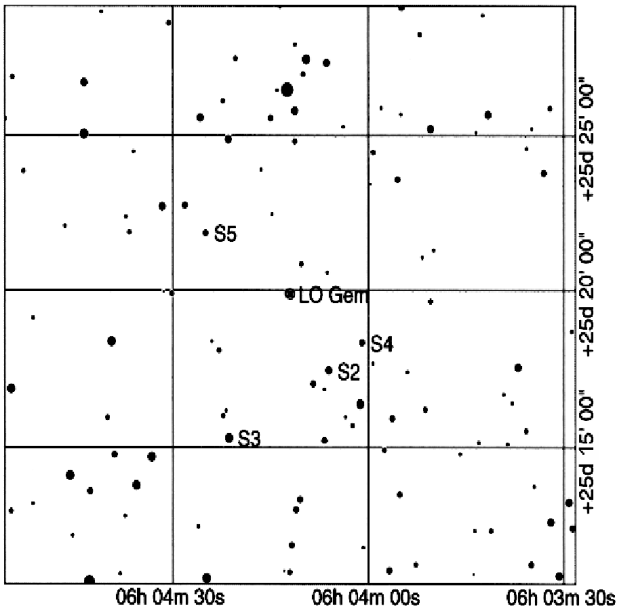

Figure 1. Finder chart of LO Gem

Table 1: Photoelectric and CCD minima of LO Gem

HJD	Mode	E	$O-C$
2448978.6439	p.e. V	9657	0.0072
2450342.5687	p.e. V	10266.5	0.0036
2450462.2948	p.e. V	10320	0.0083
2450811.3820	CCD V	10476	0.0014
2450812.5012	CCD V	10476.5	0.0017

Table 2: Orbital Parameters. Asterisks mark ouput parameters

Primary star	Secondary star
mass ratio = 0.76*	
inclination = 85°8*	
wavelength = 550 nm	
Fillout = −4.33*	Fillout = −4.32*
Lagrangian $L_1 = 0.53$	Lagrangian $L_2 = 1.65$
Mean radius = 0.23	Mean radius = 0.19
temperature = 7000 K*	temperature = 6980 K*
luminosity = 0.60	luminosity = 0.40
gravity coefficient = 0.32	gravity coefficient = 0.32
limb darkening = 0.6	limb darkening = 0.6
reflection = 0.5	reflection = 0.5

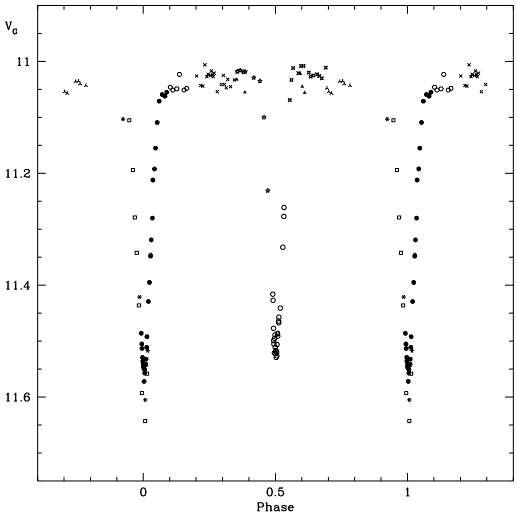

Figure 2. Photoelectric V measurements of LO Gem. Different symbols indicate measurements taken during different nights

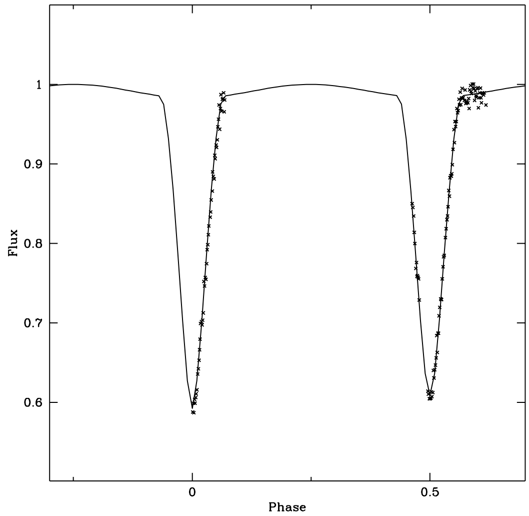

Figure 3. V band CCD light curve (points) with model (line) of the eclipsing system

Two of the ten photographic times of minima had to be rejected from the calculations because of their large $O-C$'s (+0.2638 d and +0.2377 d). Taking together all the times of minima reported to date, the $O-C$'s have not shown a significant period change since 1933.

Figure 2 shows the photoelectric V light curve of LO Gem, constructed using the ephemeris reported above. The brightness of LO Gem outside eclipse varies between $V = 11.01$ and $V = 11.06$. The standard deviation of the V measurements at maximum light is $0\overset{m}{.}014$. The amplitude of the minima is $0\overset{m}{.}60$ at phase 0 and $0\overset{m}{.}53$ at phase 0.5; however, the depth of the primary minimum changes significantly during the different nights making it difficult to predict its correct amplitude (Figure 2). Changes of the atmospheric absorption coefficients during short time lapses can account for such variations; alternatively, we could not rule out the possibility of the intrinsic variability of one of the components, although the colour index of the system makes this possibility unlikely. The eclipse duration is 11.5% of the orbital period.

No significant changes in the $B-V$ colour index were detected during the minima. The $(B-V)_G$ colour index is $-0\overset{m}{.}31 \pm 0.01$ at maximum light, which corresponds to $(B-V)_J = 0.52$. We used the procedure described by Meylan & Hauck (1981), considering LO Gem as a luminosity class V star. LO Gem belongs approximately to the spectral class F8–G0.

Considering that the amplitudes of the minima are almost identical (Figure 2), we cannot exclude the possibility of the half value for the orbital period. In this case, the absence of a detectable secondary minimum (corresponding to phases 0.25 and 0.75 in Figure 2) prompted us to speculate that the obscure companion would be too faint to be photoelectrically measurable. In order to obtain a more accurate result on the construction of a model of the binary system, we also considered the CCD measurements obtained during two subsequent minima. With Binmaker 2.0 (Bradstreet 1993) the light curve was modelled using both periods; the temperature of the larger star was set to 7000 K. The data, considering the $2\overset{d}{.}23$ period, were best fitted using an inclination of 86°, a mass ratio of 0.76. The temperature of the smaller star was adjusted to 6980 K. Figure 3 shows the fit of the CCD measurements. The main parameters of the system are reported in Table 2.

Using the half period value and adding an artificial secondary minimum of $0\overset{\mathrm{m}}{.}03$ amplitude, we verified that the proximity effects were clearly visible on the modelled light curve, and these could never fit the photoelectric and CCD data in a satisfactory way. Moreover, in the case of a $0\overset{\mathrm{m}}{.}03$ secondary minimum, a colour change should be clearly detected due to the occultation of the cool companion whereas the observations reveal no significant changes in the $B-V$ and $V-I_C$ colour indices.

We therefore conclude that LO Gem's orbital period is $2\overset{\mathrm{d}}{.}23$. The shape of minima indicate that the eclipses are nearly total. Being the amplitude of the minima $0\overset{\mathrm{m}}{.}6$ we obtained an occultation of 85%.

The binary system LO Gem is therefore an EA type with very similar components of late F spectrum and an orbital period of $2\overset{\mathrm{d}}{.}2377825$. Our study may not exclude that one or both star(s) is/are pulsating variable(s). Future studies will address this possibility.

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