ECLIPSING VARIABLE STARS IN NEIGHBOURING GALAXIES

1. Variable "G" in M 31 Andromedae

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1. Introduction

The star discussed here was discovered by GAPOSCHKIN when examining photographic plates of field n°II in M 31, made by BAADE in 1952 with the 508-cm Palomar reflector.

The star was used as a standard for the study of other variables in M 31, which led to the discovery of its variability.

The photographic light-curve was published by GAPOSCHKIN (1962) together with the normal points he used to derive it.
The ephemeris was: \[ \text{Min I} = \text{Hel. J.D.} 2433978.653 + 4d.8050 \times E \], as obtained from 4 instants of minimum light, well observed and well distributed over the whole observing period.

According to GAPOSCHKIN, variable "G" has an O spectrum, as appears from a comparative examination of photovisual plates and the blue plates he used to derive the light-curve.

On such grounds, a value for the (B-V) index, uncorrected for reddening, would be about: \( (B-V)_0 = -0.35 \) which corresponds to a temperature of about \( T = 40 \, 000 \, ^\circ\text{K} \) for the brighter star and a spectral type O5.

These values will be used throughout the paper.

The equivalent wavelength for the observations can be set with sufficient accuracy at \( \lambda_{\text{eq}} = 4.250 \, \text{Å} \).

### 2. CHARACTERISTICS OF THE LIGHT-CURVE

The available light-curve is made of 20 normal points and offers an optimal covering of the whole period. This curve is shown in fig. 1.

The general characteristics which can be immediately deduced are:

\[
\begin{align*}
\text{Max} &= 20.22 \pm 0.03 \, \text{pg} \\
\text{Min I} &= 21.14 \pm 0.03 \, \text{pg} \\
\text{Min II} &= 20.50 \pm 0.03 \, \text{pg}
\end{align*}
\]

with the error bars on the magnitudes determined by the method defined by GASPARINI (1982).

Analysing the light-curve, it can immediately be noticed that, assuming a primary minimum at \( \phi = 0 \), the secondary minimum occurs at \( \phi = 0.48 \pm 0.02 \), which in turn gives: \( e \cos \omega = 0.03 \pm 0.03 \).

The analysis of the light-curve will be carried out assuming that the orbit of variable "G" is circular, inasmuch as the value of \( e \cos \omega \) does not appear to be really significant.

### 3. SOLUTION OF THE LIGHT-CURVE

The solution of the light-curve in order to obtain the photometric orbital elements has been reached by means of a polynomial analysis in the frequency domain (GASPARINI, 1983).

This method is based on the relation between the orbital elements and quantities, the integrals \( U_j \), which can be inferred from the observations.

The relations between the orbital elements and integrals \( U_j \) being known, it is then possible to solve completely the light-curve.

The method is worked out, using an arbitrary law of limb-darkening and in the present case a coefficient:

\[
u_1 = u_2 = 0.21
\]

has been used, the same for both components, in view of the spectral type O5 derived from the approximate colour index and as deduced from the tables of AL NAIMIY (1978).

The whole calculation was performed on a Texas TI 59 hand-held computer using a relevant routine and gave the following results for the photometric orbital elements:

\[
\begin{align*}
\text{Min I} &= \text{occultation} \\
\lambda_{\text{eq}} &= 4.250 \, \text{Å} \\
\text{Min II} &= 78.5 \pm 0.2 \\
a_1 &= 0.46 \pm 0.01 \\
b_1 &= 0.41 \pm 0.01 \\
c_1 &= 0.38 \pm 0.01 \\
L_1 &= 0.34 \pm 0.01 \\
a_2 &= 0.24 \pm 0.01 \\
b_2 &= 0.24 \pm 0.01 \\
c_2 &= 0.23 \pm 0.01 \\
L_2 &= 0.66 \pm 0.01
\end{align*}
\]
The assumed model is an ellipsoidal one taking into account the existence of effects caused by ellipticity and reflection. The theoretical light-curve is plotted together with the observations in fig. 2. The agreement is good and consequently the elements can be considered reliable. In the case of the secondary minimum, the curve required a shift due to the hypothesis of a circular orbit.

4. DISCUSSION

The analysis of variable star "G" has shown that the system could be either detached or semi-detached.

In the present state of affairs, it is not possible to decide on the real type inasmuch as the calculation of the Jacobi constants requires knowing the mass ratio.

It is however possible to say that, since the primary minimum is caused by an occultation, the smaller star is also the brighter.

This hypothesis does not spring from any spectroscopic evidence but from the convergence of the method used for the calculation of the orbital elements.

On account of this, if the primary minimum is an occultation, the system can be catalogued as "detached", but in this case the two components should belong to different classes of luminosity.

This being admitted, for a good agreement between the orbital elements, the mean observed (B-V) and the typical parameters of both stars, the larger star must necessarily be a B5 I - type and the secondary an O5 V.

Their characteristics then give an optimal agreement with the ratio between radii obtained photometrically and the observed (B-V) (making allowance for the uncertainty originating either from its determination or from the possible presence of interstellar matter between the star and the observer).

Less good an agreement could be obtained by considering the ratio between luminosities, but in this case, spurious effects caused by reflection and re-emission (quite important for such hot stars) must be taken in consideration.

5. CONCLUSION

This paper has discussed the light-curve of the binary system "G" in M 31 And.

The present study will be followed by others discussing other systems in M 31 and other neighbouring galaxies. From the results, it will be possible to compile statistics of the binary systems in other galaxies, thus making possible an interesting comparison with the results obtained from the analysis of binary systems in our Galaxy.

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REFERENCES


GAPOSHCHIN S., 1962, A.J. 67, 358; "An eclipsing variable in the Andromeda nebula (M 31)".


Figure 1: Light-curve of the eclipsing binary star "G" in M 31. The normal points have been folded, with the instant of primary minimum as a reflecting axis.
Figure 2: Theoretical light-curve compared with observations