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ECLIPSING VARIABLE STARS IN NEIGHBOURING GALAXIES

I. Variable " G " in M 31 Andromedae

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ABSTRACT. ECLIPSING VARIABLE STARS IN NEIGHBOURING GALAXIES I. Variable " G " in M 31 And

The present paper discusses the photographic light-curve of the eclipsing variable "G" in M 31 And in view of determining the photometric orbital elements.

A polynomial analysis of the light-curve in the frequency domain was used for this determination.

It results from this calculation that the binary system under discussion is composed of an O5 V star (the smaller one) and a B5 I star (the larger component), both components being contained within their respective equipotential surfaces, a fact which allows one to conclude, with a high probability, on a detached type.

In any case, as the mass ratio is not known as yet, a definitive classification of the system is not possible.

This paper is part of a series of analyses of the light-curves of binary stars in neighbouring galaxies, in view of building up statistics on the close binary systems they include and finally comparing the results thus obtained with those for our Galaxy.

RESUME. VARIABLES ECLIPSANTES DANS LES GALAXIES VOISINES I. La variable " G " de M 31 And

On présente l'analyse de la courbe de lumière photographique de la variable à éclipses "G" de M 31 And dans le but de déterminer ses éléments orbitaux photométriques.

On a utilisé la méthode de l'analyse polynomiale de la courbe de lumière dans le domaine des fréquences.

Le calcul montre que le sytème binaire étudié est formé d'une étoile de type O5 V , la plus petite, et d'une autre de type B5 I, la plus grande, les deux composantes étant contenues dans leurs surfaces équipotentielles respectives, ce qui permet de conclure avec une bonne probabibilité à un système de type "détaché"

En tout cas, le fait que le rapport des masses soit encore inconnu ne permet pas de cataloguer le système de façon définitive.

Ce travail marque le début d'une série d'analyses de courbes de lumière de variables à éclipses dans les galaxies voisines, dans le but d'obtenir des statistiques sur les systèmes binaires rapprochés qu'elles contiennent et de les comparer avec les résultats obtenus pour notre propre galaxie.

RIASSUNTO. VARIABILI AD ECLISSE NELLE GALASSIE VICINE : I. Variabile " G " in M 31 And

Nel presente lavoro è stata analizzata la curva di luce fotografica della variabile ad eclisse "G" in M 31 al fine di determinarne gli elementi orbitali fotometrici.

Il metodo usato è stato l'analisi polinomiale della curva di luce nel dominio delle frequenze.

Dal calcolo è risultato che il sistema binario in esame è formato da una stella di tipo O5 V (quella di diametro inferiore) e da una di tipo B5 I, la più grande, entrambe le componenti sono ben comprese nelle rispettive superfici equipotenziali fatto questo che ci autorizza a definire il sistema come "detached" con grossa probabilità.

In ogni caso il fatto che il rapporto fra le masse sia tutt'ora non conosciuto non permette una definitiva catalogazione del sistema.

Questo lavoro si inquadra in una serie di analisi di curve di luce di variabili ad eclisse nelle galassie vicine al fine di costruire qualche statistica sui sistemi binari stretti ivi contenuti e fare un confronto con i risultati ottenuti per la nostra galassia.

RESUMEN. ESTRELLAS VARIABLES ECLIPSANTES EN GALAXIAS CERCANAS I. Variable " G " en M 31 And

El presente trabajo trata sobre la curva de luz fotográfica de la variable eclipsante "G" en M 31 And, con el fin de determinar los elementos orbitales fotométricos. Para esta determinación, fué utilizado un análisis polinomial de la curva de luz en el dominio de las frecuencias.

El resultado de este cálculo es que el sistema binario en discusión está compuesto por una estrella O5 V (la más pequeña) y una estrella B5 I (la componente mayor), estando ambas componentes contenidas en sus respectivas superficies equipotenciales, hecho este que permite concluir, con gran probabilidad, definiendo al sistema como "separado".

En cualquier caso, como la relación entre las masas no es conocida hasta ahora, no es posible una clasificación definitiva del sistema.

Este trabajo es parte de una serie de análisis de las curvas de luz de las estrellas binarias en las galaxias cercanas, cuyo objetivo es elaborar un estudio estadístico acerca de los sistemas binarios, y, finalmente, una comparación de los resultados obtenidos con los de nuestra galaxia.

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 : Min I = Hel. J.D. 2 433 978. 653 + $4^d.8050 * E$, 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 °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 $\lambda_{eq} = 4\,250$ 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 :

Max = 20.22 ± 0.03 pg

Min I = 21.14 ± 0.03 pg

Min II = 20.50 ± 0.03 pg

with the error bars on the magnitudes determined by the method defined by GASPANI (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 (GASPANI, 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 :

Min I = occultation

$u_1 = u_2 = 0.21$ (assumed)

$\lambda_{eq} = 4\,250$ Å

$|i| = 78°.5 \pm 0.2$

$a_1 = 0.46 \pm 0.01$	$a_2 = 0.24 \pm 0.01$
$b_1 = 0.41 \pm 0.01$	$b_2 = 0.24 \pm 0.01$
$c_1 = 0.38 \pm 0.01$	$c_2 = 0.23 \pm 0.01$
$L_1 = 0.34 \pm 0.01$	$L_2 = 0.66 \pm 0.01$

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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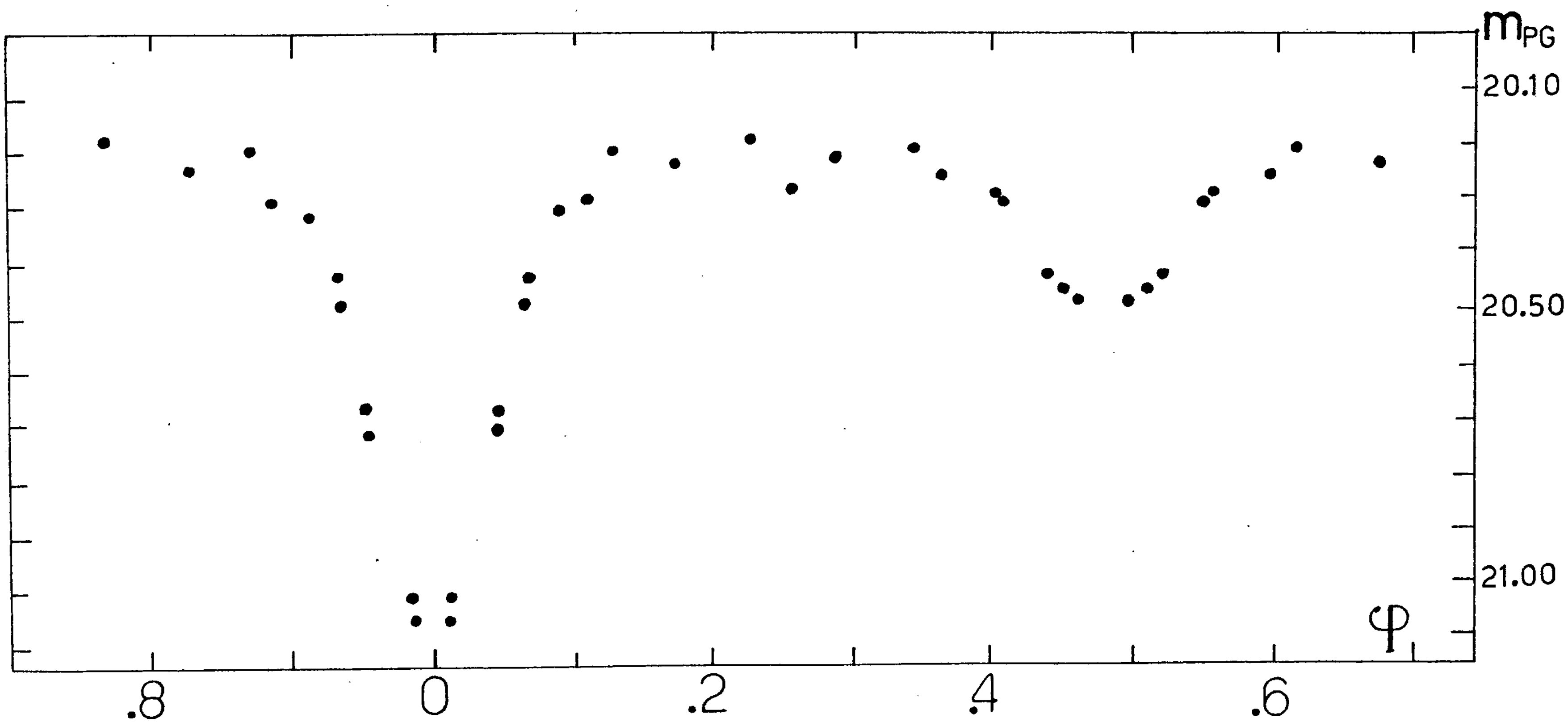

Figure 1 : Light-curve of the eclipsing binary star "G" in M 31 . The normal points have been folded, with the instant of primary minimum as a reflecting axis.

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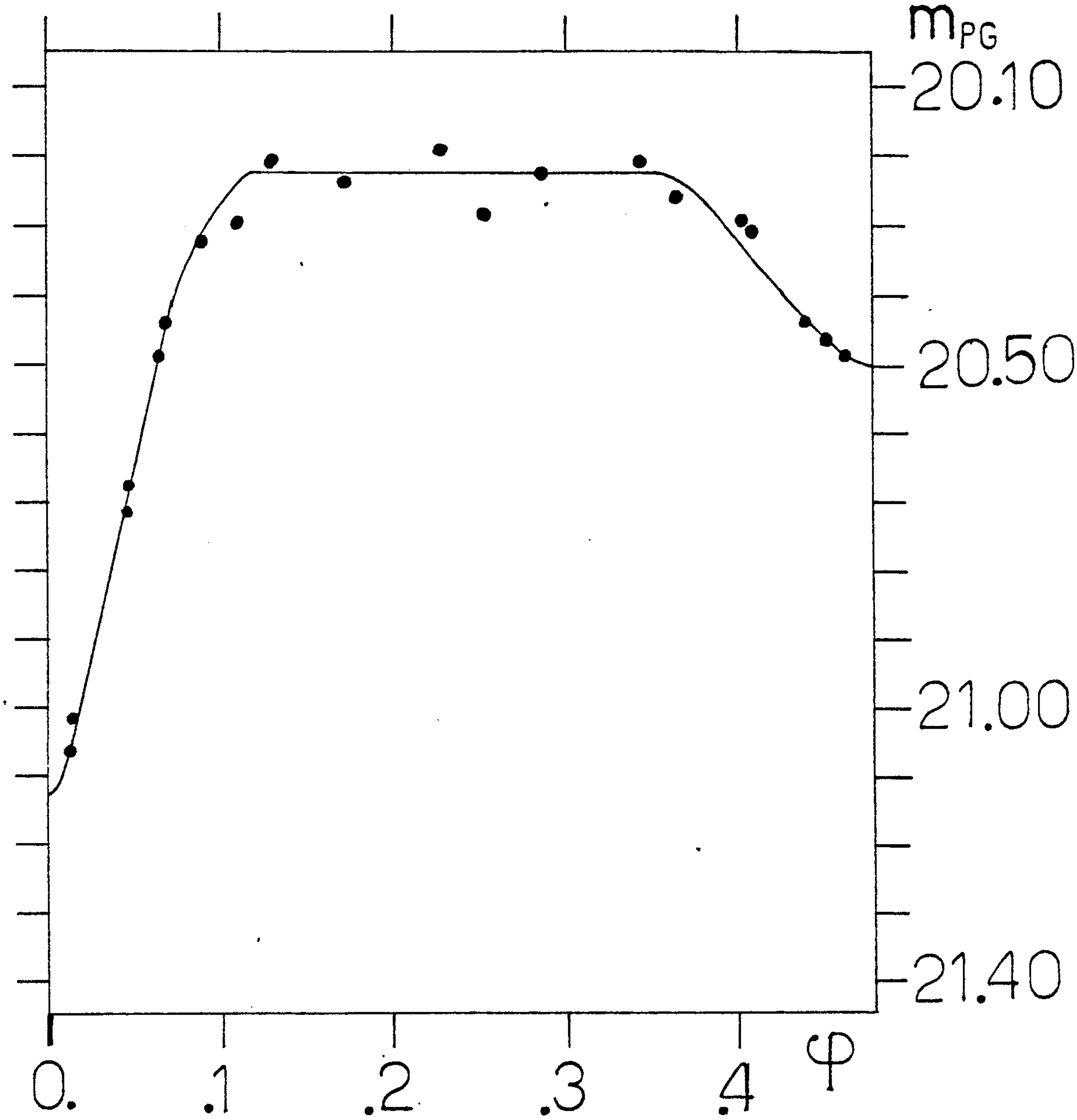

Figure 2 : Theoretical light-curve compared with observations