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ECLIPSING VARIABLE STARS IN NEIGHBOURING GALAXIES

III. Discussion of the light curve of V 31 in IC 1613

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ABSTRACT. ECLIPSING VARIABLE STARS IN NEIGHBOURING GALAXIES :

III. Discussion of the light curve of V 31 in IC 1613

The light curve of the only eclipsing variable so far discovered in IC 1613, a galaxy belonging to the Local Group, is discussed in this paper by applying a method of analysis in the frequency domain in order to obtain the photometric orbital elements of the binary sytem.

The solution, which appears to be well determined, shows that V 31 is an Algol-type system in which the larger component is also probably more evolved than its companion.

However, owing to the lack of spectroscopic data, it does not seem proper to venture any hypothesis on the present evolutionary stage of the system.

RIASSUNTO. VARIABILI AD ECLISSE NELLE GALASSIE VICINE :

III. Analisi della curva di luce di V 31 in IC 1613

La curva di luce dell'unica variabile ad eclisse scoperta nella galassia IC 1613, appartenente al Gruppo Locale, è stata analizzata, mediante tecniche che operano nel dominio delle frequenze, al fine di ottenere gli elementi orbitali fotometrici del sistema binario.

La soluzione, che è risultata essere ben determinata, ha indicato che V 31 è un sistema di tipo Algol in cui la componente più grande risulta probabilmente più evoluta.

Mancando però ogni dato spettroscopico appare azzardata qualsiasi ipotesi sulla fase evolutiva in cui tale sistema si trova attualmente.

RESUME. VARIABLES ECLIPSANTES DANS LES GALAXIES VOISINES :

III. Discussion de la courbe de lumière de la variable V 31 dans IC 1613

La courbe de lumière de l'unique variable à éclipses découverte dans la galaxie IC 1613, appartenant au Groupe Local, est analysée ici grâce à une méthode opérant dans le domaine des fréquences, afin d'obtenir les éléments orbitaux photométriques du sytème binaire.

La solution, qui se trouve être bien déterminée, montre que V 31 est un système de type Algol, dans lequel la composante la plus grande est probablement aussi la plus évoluée.

En l'absence de données spectroscopiques, il serait hasardeux cependant de formuler quelque hypothèse sur la phase actuelle d'évolution du système.

RESUMEN. ESTRELLAS VARIABLES ECLIPSANTES EN GALAXIAS CERCANAS

III. Discusión de la curva de luz de la variable V 31 en IC 1613

La curva de luz de la única variable a eclipses descubierta en la galaxia IC 1613, perteneciente al Grupo Local, ha sido analizada aqui gracias a un método que opera en el dominio de las frecuencias, con el fin de obtener los elementos orbitales fotométricos del sistema binario.

La solución hallada y bien determinada muestra que V 31 es un sistema de tipo Algol, en el cual la componente mayor resulta probablemente ser también la más evolucionada.

No disponiendo de datos espectroscópicos, parece aventurado formular cualquier hipótesis sobre la fase evolutiva en que se halla actualmente el sistema.

1: INTRODUCTION

So far, V31 has been the only eclipsing variable discovered in the galaxy IC 1613 which belongs to the Local Group.

The only data available are reported by SANDAGE (1) who also publishes observations and a light curve.

The photometric characteristics of V31 are the following:

$$\begin{aligned} \text{Max.} &= 20.14 \pm .02 \text{ pg} \\ \text{Min. 1} &= 20.95 \pm .02 \text{ pg} \\ \text{Min. 2} &= 20.43 \pm .02 \text{ pg} \end{aligned}$$

as obtained from the original observations published in (1).

The type of variation is approximately EA and the ephemeris is:

$$\text{MIN. 1} = \text{JD}_{\odot}\ 2428049.935 + 3^{d}.77471 * E$$

The spectral type is unknown. However, on the grounds of the data published in (1), it is possible to conclude that the star under discussion is blue, probably of spectral type B.

2: LIGHT CURVE

The observations found in the literature, sumtotalling 101 measures, have allowed a light curve to be plotted. This curve is shown in figure 1.

The observations make it possible to get an optimal definition of the variation of brightness and the uncertainty on the magnitudes at maximum and at minimum is lower than .02 mag.

The wavelength of observation can be set at $\lambda = 4250$ Å. The excellent definition of the light curve allows a good determination of the non-eclipsed phases and makes an appropriate analysis possible.

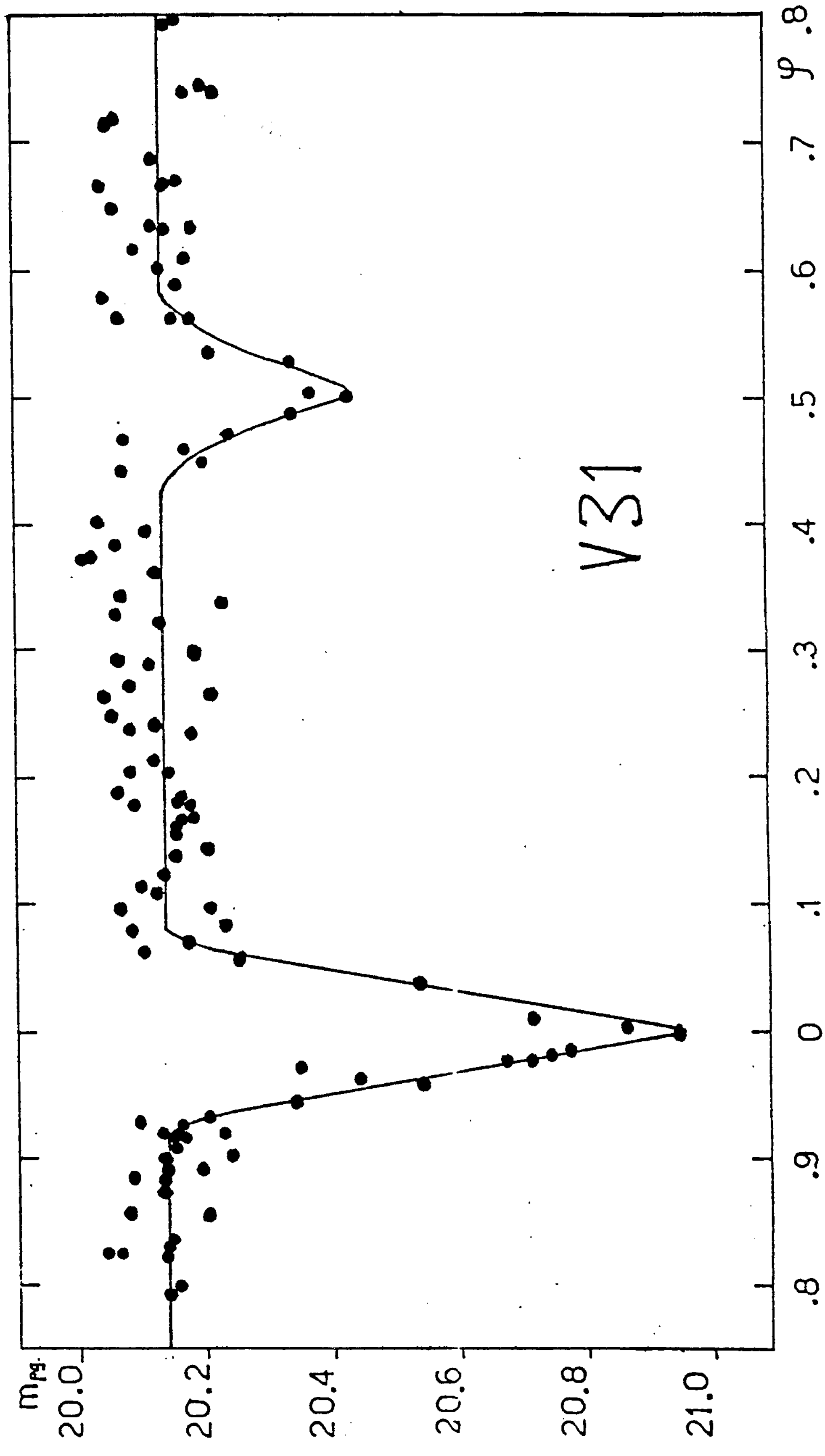

Figure 1: Light curve of V31 in IC 1613. The plain line is the theoretical light curve using the orbital elements summarized in Table 1.

The observations between phases $.10 \leqslant \varphi \leqslant .40$ and $.60 \leqslant \varphi \leqslant .90$ were used to calculate the coefficients of the series:

$$m(\theta) = \sum_{j=0}^{j=2} B_j \cos^j \theta \qquad (1)$$

so as to determine the magnitude at maximum and its uncertainty ($B_o \pm \sigma(B_o)$) as well as the influence of the proximity effects.
A least squares analysis gave:

$$B_o = 20.14 \pm 0.02$$

Moreover, B_1 and B_2 were deduced from the amplitude of their error bars and therefore neglected in the analysis which followed. This allows for a slight distortion of the components.

The next step was the analysis of the light curve during the eclipsed phases.

To this effect, the observations have been fitted using:

$$m(\theta) = B_o + 2.5 \log \sum_{i=0}^{i=2} w_i \ln^i \left[3/2 - 1/2 \cos(\pi \theta / \theta_e) \right] \qquad (2)$$

where B_o is the magnitude at maximum obtained in the previous step, θ_e the phase angle at the end of eclipse (first assumed to be $\theta_e = 32°$) and w_i, adjustable parameters.

The procedure is entirely automated, using a suitable routine written in the BASIC V2 language and a COMMODORE C64 microcomputer. It gave the following values for the w_i coefficients at the main minimum:

$$w_o = .471 \pm .009$$
$$w_1 = .9864$$
$$w_2 = -.3042$$

As obviously appears from an examination of relation (2), the w_o term is nothing else than the luminosity at minimum.

A similar analysis of the secondary minimum gave:

$$w_o = .776 \pm .01$$

The choice of the function (2) instead of the traditional Fourier series was motivated by the fact that the Gibbs effect is then practicall eliminated, which leads to a good determination of the depth of the two eclipses.

It must also be pointed out that the original observations were used, not normal points, thus avoiding a loss of information.

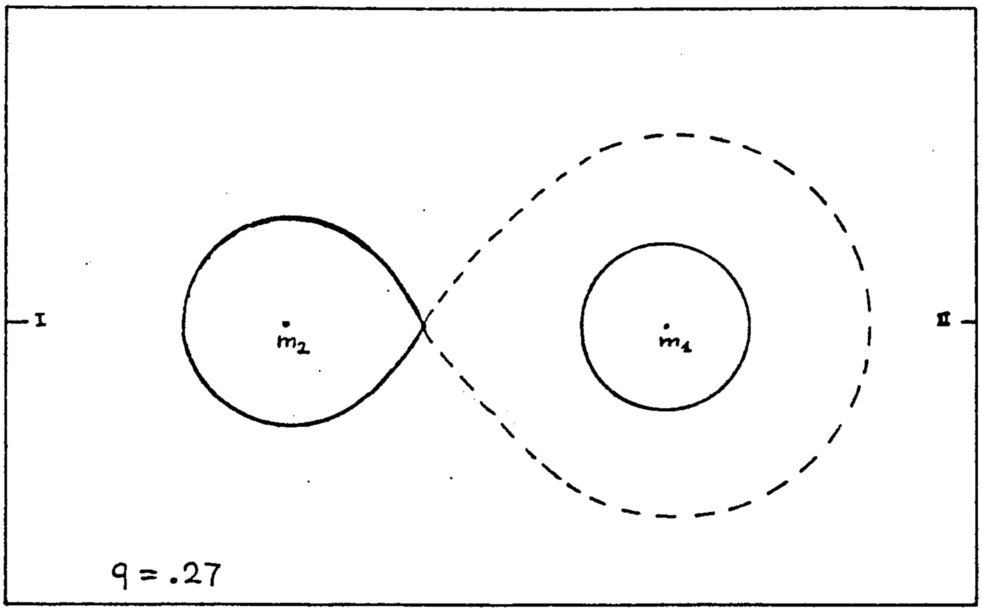

Figure 2: Structure of the V31 system in IC 1613.

5: DISCUSSION

From the photometric solution obtained for V31 in IC 1613 and from the observational data available, it is not possible to draw many conclusions.

It can be noted, however, that if the model described above is valid, then it appears clearly that V31 is an Algol-type system in most classical sense of the term.

Since such a model is linked to the fact that the primary minimum is an occultation, it follows that it is necessary to rely entirely on the photometric solution, as spectroscopic data which could confirm are missing.

Moreover, although the assumption of a detached system led to a rather poor fit, while the semidetached model seemed to fit better, in so far as no spectroscopic data are available, it appears risky to make hypotheses on the evolutive stage of the V31 system.

6: CONCLUSION

The present paper has analyzed the light curve of V31 in IC 1613, in the course of a research programme on eclipsing binaries in other galaxies.

A study of other extragalactic binaries will the subject of papers to follow.

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3: DETERMINATION OF THE ORBITAL ELEMENTS

The determination of the photometric orbital elements was made in the frequency domain by means of a polynomial analysis of the light curve reported in (2), using a totally automated procedure.

On the grounds of the supposed spectral type, values:

$$u_1 = u_2 = .25$$

were assumed for the limb darkening coefficients of the two components, also taking in consideration the effective wavelength of observation which can reasonably be set at $\lambda = 4250$ Å (4).

The initial parameters were the $\mathfrak{A}_j$ integral defined as:

$$\mathfrak{A}_j = \frac{(11+j^2)}{3(1-w_0)} \int_{\ell_{aj}}^{\ell_{bj}} \sin^2 \theta(\ell)\, d\ell \qquad j=1,2,3 \tag{3}$$

were, as usual, l_{aj}, l_{bj} are suitable limits of the integration interval.

Their determination was totally automated, using suitable routines on the computer mentioned above and with function (2), obtained from experimental data, as input.

This yielded a partial eclipse of the occultation type. The orbital elements, in the case of a double-sphere model, are summarized in Table 1.

Finally, the theoretical light curve appeared to be in good agreement with the experimental data.

4: STRUCTURE OF THE SYSTEM

The solution of the light curve summarized in Table 1 shows that V31 is an Algol-type system, that is to say the main component is cooler and probably distorted.

On such grounds, it can reasonably be supposed that the greater component fills its Roche lobe.

If this is so, it is then possible to estimate a value for the mass ratio which is implied by such a hypothesis.

On developing the calculation, the mass ratio which fits best the observations and the hypotheses is:

$$q = (m_2/m_1) = .27$$

In this case, the structure of V31 should be as shown in figure 2.

Table 1 : Photometric orbital elements

$\mathfrak{A}_1$ = .0740 ± .0008	$u_1 = u_2$ = .25 (assumed)
$\mathfrak{A}_2$ = .0319 ± .0005	r_1 = .200 ± .009
$\mathfrak{A}_3$ = .0095 ± .0003	r_2 = .263 ± .009
Min.1 = occultation	i = 84°.3 ± 0°.5
λ = 4250 Å	L_1 = .564 ± .009
	L_2 = .436 ± .009