GEOS EB 1

GEOS CIRCULAR ON ECLIPSING BINARIES

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THE UNDER-OBSERVED STAR AY PEGASI AS A NEW ALGOL-TYPE VARIABLE WITH A 2.439 DAY PERIOD

RESUME - AY Peg est une étoile particulièrement sous-étudiée. S. BÖHME, il y a 40 ans, l'a classée de type RR sur la foi de 81 plaques photographiques, mais il n'a pas pu déterminer sa période.
Grâce aux observations du camp GEOS de l'été 1977, il est apparu que AY Peg était en fait une étoile à éclipses et qu'un multiple de la période était proche de 5 jours.
Un bon minimum a été obtenu par l'auteur durant la nuit du 7 Octobre 1978. La courbe de lumière (cf. fig.3) permet une bonne estimation de la durée pendant laquelle la variable est inférieure en éclat au repère B, ce qui fournit une méthode pour déterminer l'instant du minimum lorsque seule une partie de la descente, ou de la remontée, a pu être observée. C'est ainsi que les observations de l'auteur ont permis de définir 10 instants de minima (voir table 1) et de calculer une éphéméride pour AY Peg (voir formule (1)).
On démontre ensuite que la période réelle du système est égale à sa période apparente, à savoir : 2.4390 j . Le compositage des mesures 1978 de l'auteur (figures 4 et 5) montre que AY Peg est du type EA et permet de préciser la durée de l'éclipse : 9.4 heures. Le minimum secondaire n'a pas été mis en évidence et doit être d'amplitude très faible.
Le type spectral de AY Peg est inconnu. Toutefois on peut supposer, en comparant l'aspect visuel du champ de la variable et son aspect photographique (sur l'Atlas Vehrenberg) que AY Peg est de spectre A. Dans ces conditions le minimum primaire est certainement produit par l'occultation partielle de l'étoile A par un compagnon plus rouge, beaucoup moins brillant et probablement de plus grand rayon. En paramétrant la valeur du rayon du compagnon, on a déterminé le rayon de l'orbite du système binaire. Dans tous les cas, la distance entre les 2 étoiles semble suffisamment élevée pour que le système soit effectivement un système détaché (confirmation du type EA).

RESUMEN - AY Peg es una estrella poco estudiada. S. BÖHME, hace 40 años, la clasificó del tipo RR a partir de 81 placas fotográficas pero no pudo determinar su período.
Gracias a las observaciones del campo del GEOS, del verano de 1977, se encontró que AY Peg es de hecho una estrella eclipsante con un periodo múltiple cercano a 5 días.
Un buén mínimo fué obtenido por el autor durante la noche del 7 de octubre de 1978. La curva de luz (ver figura 3) permite una buena estimación de la duración del tiempo durante el cual la variable era do brillo inferior al de la estrella de referencia B, lo que proporciona un método para determinar el instante del mínimo cuando sólo una parte del descenso, o del ascenso, ha podido ser observada. Es así como las observaciones del autor han permitido determinar 10 instantes de mínimos (ver tabla 1) y calcular una efeméride para AY Peg (ver fórmula (1)).
Se ha demostrado después que el período real del sistema es igual a su período aparente, a saber : 2,4390 días. La composición de las medidas de 1978 del autor (figuras 4 y 5) muestra que AY Peg es del tipo EA y permite precisar la duración del eclipse : 9,4 horas. El mínimo secundario no ha sido puesto en evidencia debido a su amplitud muy pequeña.
El tipo espectral de AY Peg es desconocido. No obstante se puede suponer, comparando el aspecto visual del campo de la variable y su aspecto fotográfico (sobre el atlas Vehrenberg), que AY Peg es de espectro A.
En estas condiciones, el mínimo primario es ciertamente producido por la ocultación parcial de la estrella A por una compañera más roja, mucho menos brillante y probablemente de radio mucho mayor.
En proporción al radio de la compañera, se ha determinado el radio de la órbita del sistema binario.
En todos los casos, la distancia entre las dos estrellas parece lo suficientemente grande como para que el sistema sea efectivamente importante (confirmación del tipo EA).

RIASSUNTO - AY Peg è una stella particolarmente sotto-studiata. S. BÖHME, 40 anni fa, l'ha classificata di tipo RR sulla base di 81 lastre fotografiche, ma non ne ha potuto determinare il periodo.
Grazie alle osservazioni del campo GEOS dell'estate 1977, è apparso che AY Peg era in realtà una binaria ad eclisse e che un multiplo del periodo era vicino ai 5 giorni.
Un buon minimo è stato ottenuto dall'autore durante la notte del 7 ottobre 1978. La curva di luce (vedere fig.3) permette una buona stima dell'intervallo di tempo durante il quale la variabile è più debole della stella di confronto B, fornendo così un metodo per determinare l'istante del minimo quando si sia potuto osservare solo una parte della discesa o della risalita. E' in questo modo che le osservazioni dell'autore hanno permesso di definire 10 istanti di minimo (vedere tabella 1) e di calcolare un'effemeride per AY Peg (vedere formula (1)).
E' dimostrato in seguito che il periodo reale del sistema è uguale al suo periodo apparente, cioè 2.4390 d. Il compositage delle misure 1978 dell'autore (figure 4 e 5) mostra che AY Peg è di tipo EA e permette anche di precisare la durata dell'eclisse : 9.4 ore. Il minimo secondario non è stato evidenziato e deve essere d'ampiezza molto debole.
Il tipo spettrale di AY Peg non è conosciuto. Tuttavia si può supporre, confrontando l'aspetto nel visuale del campo della variabile con quello nel fotografico (dall'Atlas Vehrenberg), che AY Peg sia di spettro A.
In questi condizioni, il minimo primario è certamente prodotto dall'occultazione parziale della stella di spettro A da parte di un compagno più rosso, molto meno brillante e probabilmente di raggio più grande. Parametrando il valore del raggio del compagno si è determinato il raggio dell'orbita del sistema binario. In ogni caso, la distanza fra le due stelle sembra essere sufficientemente elevata affinchè il sistema sia effettivamente un sistema staccato (conferma del tipo EA).

1. INTRODUCTION

AY Pegasi could be called an "under-observed" variable star. In its Third Edition (1969), the GCVS refers to a forty-year old paper of S. BÖHME : " Mitteilungen über 75 veränderliche und verdächtige Sterne(*)" (AN 266 , 1969 , 1938). In this paper, a few words only are devoted to AY Pegasi : " Nach 81 Ernostaraufnahmen RR Lyrae-artig : $12^{m}.3$ - $\leqslant 13^{m}.3$ veränderlich(**)". Therefore KUKARKIN catalogued this variable star as an : "RR? 12.3 13.3 p " without any mention of subclass, period, epoch, M-m value or spectral type.

This lack of information led us to add AY Pegasi to the GEOS observing programme, taking opportunity of our camp of St-Rome (August 1977). AY Peg, at $\alpha = 21$ h 58 m 36 s $\delta = 34° 43'.5$ (1950.0), is indeed a suitable object for an all-night observation in summer. A second campaign was organized at the GEOS camp of Chamaloc (summer 1978) and additionnal observations were performed, mainly by A.Figer, R.Mailler and A.Royer, in 1977 and 1978.

All these numerous estimates will undergo a detailed analysis in the future. However, at this present moment, I am able to derive from my own observations a reliable value for the period. This is the aim of this preliminar paper.

2. IDENTIFICATION CHART

AY Peg is easily found within a characteristic trapezoid of bright stars (see figure 1). Thus, though it is a faint object, it is pleasant to observe with both comparison stars A and B conveniently located.

I estimated the visual magnitudes of A and B using scales available for other fields of faint variable stars (RX And for example). I found A = 12.3 B = 13.7 on October 8 , 1978 observing at Paris with a 10-inch reflector (at 180 x).

These values for A and B will be used throughout the present analysis.

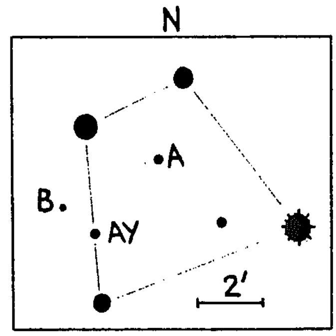

Figure 1 . AY Peg and its comparison stars.

3. OBSERVATIONS OF S^{T}-ROME 77

AY Peg was regularly observed at St-Rome 77 gathering 653 estimates from 12 observers. Estimates were performed every night from August 7 to 17 .

During the first four nights (August 7 to 10) the observers did not record anything noticeable, the estimates revealing nothing more than a scatter around a mean value near magnitude 13.0 and specific for each observer : thus, for example, 12.8 (RAL);12.9 (GUI);13.1 (FGR,FLB,ROY) and 13.2 (MPN). It seemed that the probable RR Lyr-type star AY Peg , equidistant from A and B in brightness, was at minimum light. The surprizing event occurred on August 11 , 20 h 50 U.T., when pointing for the first time of the night the field of the variable : AY Peg was then fainter than comparison star B. AY Peg remained fainter than B during

French translations :

(*) Communications concernant 75 étoiles, variables et suspectes.

(**) D'après 81 plaques photographiques, cette étoile est de type RR, variant de mpg 12.3 à $<$ 13.3 .

the whole observing session, lasting 160 minutes till the clouds stopped it at 23 h 30 U.T., the star being recorded at minimum light at about 22 h 18 (RML,mag 13.9), 22 h 22 ? (FGR,mag 14.0 ?) or 22 h 30 (RAL,mag 14.1). (see figure 2)

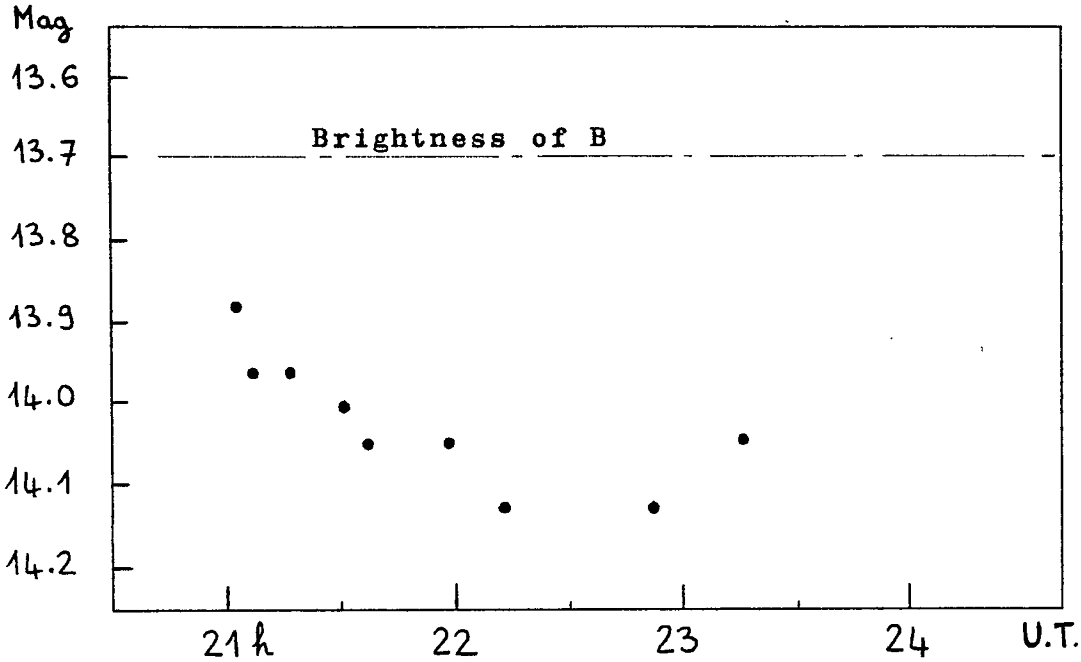

Fig. 2 - Minimum of AY Pegasi observed on August 11 , 1977 by Ph.Ralincourt (RAL) at the GEOS camp of St-Rome (using a 9-inch reflector) .

The eclipsing character of AY Peg was thus undoubtedly established, in contradiction with the former conclusion of BÖHME.
In this connection, it must be emphasized that BÖHME must have been singularly unlucky when he failed, with no less than 81 photographs, to recognize the eclipsing character of the variable, though he could prove a variation of one magnitude of AY Peg !

Amongst the other observations of St-Rome (August 12 to 17) I must mention a few estimates performed on August 16 from 22 h 20 to 22 h 22 U.T. (FGR,FLB) in bad observing conditions (in a hole of clear sky between clouds) but showing reliably AY Peg weakened, with a brightness near that of B (mag. 13.7) . Clearly AY Peg was then eclipsing again, nearly 5 days after the first eclipse.

4. OBSERVATIONS 1977-78 AFTER ST-ROME 77

All the observations made in 1977 after the St-Rome camp, and in 1978 during and after the Chamaloc camp, have fully confirmed both conclusions of St-Rome camp, that is to say :

(a) AY Peg is an eclipsing binary
(b) A multiple of the apparent period is close to 5 days.

This second proposition could even be precised by saying that : the double of the apparent period is slightly less than 5 days.

I must emphasize that these results were obtained, despite the high number of estimates, without succeeding in achieving a coherent set of observations throughout one eclipse, that is to say without obtaining a single reliable timing of a minimum.

Clearly it became urgent to break this situation off and mainly to find how long the whole eclipse lasted, in order to improve the value of the period.
This successful observation finally occurred on October 7 , 1978 (see figure 3).

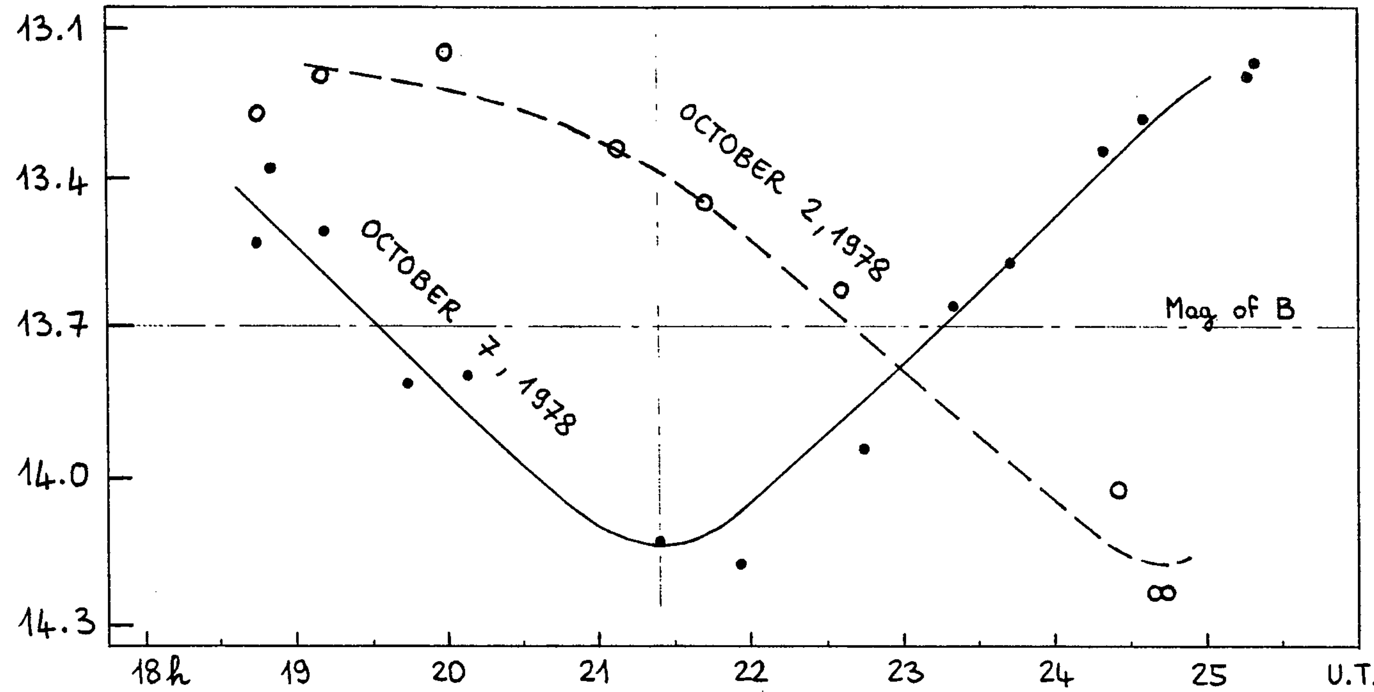

Figure 3 . Minimum of AY Pegasi observed on October 7 , 1978 by A.Figer (FGR) at Paris, using a 10-inch reflector. (In dotted line an additionnal minimum partially observed on October 2 , 1978 by the same observer)

5. DISCUSSION

The light-curve in uninterrupted line of figure 3 is drawn using the tracing paper method which allows to record the minimum at 21 h 27 U.T. (geocentric time). The dotted line represents the incomplete curve, obtained during the eclipse of October 2 , 1978 , which shows a drift from the first curve of nearly 3 h 10 mn .

From the 4.87 d ± 0.02 d time span between both eclipses corresponding to two apparent periods we can derive a value of 2.435 d ± 0.01 d for the apparent period.

Besides, figure 3 shows that the eclipse lasts at least 7 hours, and on October 7 the brightness of AY Peg is recorded less or equal to that of B for 3 hours and 43 minutes, this value being close to that (3 h 46 mn) obtained by the same observer on September 15 , 1978 during an eclipse which was very difficult to observe at Paris because of the Full Moon.

Thus, there is a way of estimating the time of an unobserved primary minimum, when only the equality (or vicinity) V ≅ B has been recorded by the observer. The timing of the equality V = B , very easy to record if the observer is not affected by the "Carnevali-effect" , gives immediately the instant of minimum by adding or substracting Δt = 112 mn .

Notice that, if the method is to be applied to other visual observers, the value of Δt must be redetermined for each of them.

Using the method for my own observations, I am able to list 9 timings of geocentric minima, in addition to the timing of October 7 determined by the usual tracing paper method.

Geocentric Minimum	E	O - C	Geocentric Minimum	E	O - C
J.D. 2443 367.425	- 86	- .017	J.D. 2443 718.681	+ 58	+ .020
372.347	- 84	+ .027	733.296	+ 64	+ .001
396.725	- 74	+ .015	767.413	+ 78	- .029
401.574	- 72	- .014	784.526	+ 85	+ .011
428.403	- 61	- .015	789.394	+ 87	+ .001

Table 1 . Timings of geocentric minima of AY Pegasi by A.Figer .

The linear regression gives the following ephemeris for the apparent period :

$$\text{(1)} \quad \text{Minimum I hel.} = \text{J.D. } 2443\ 577.202 \pm 14 + 2.4390 \pm 19\ E$$

The heliocentric correction has been performed in an unusual way, by applying a mean correction to the result of the regression (the O-C of Table 1 being calculated before). Indeed the precision of the determinations allows this approximation.

The standard deviation of a timing is 0.019 day, which is not bad when one bears in mind that nearly all the minima are indirectly determined, generally using a few estimates performed at the limiting magnitude through the sky of Paris.

In order to determine the real period of AY Peg and its type of variation, I have plotted a mean curve of my 170 estimates performed in 1978 at Chamaloc and Paris, using the 2.439 day period (see figure 4) .

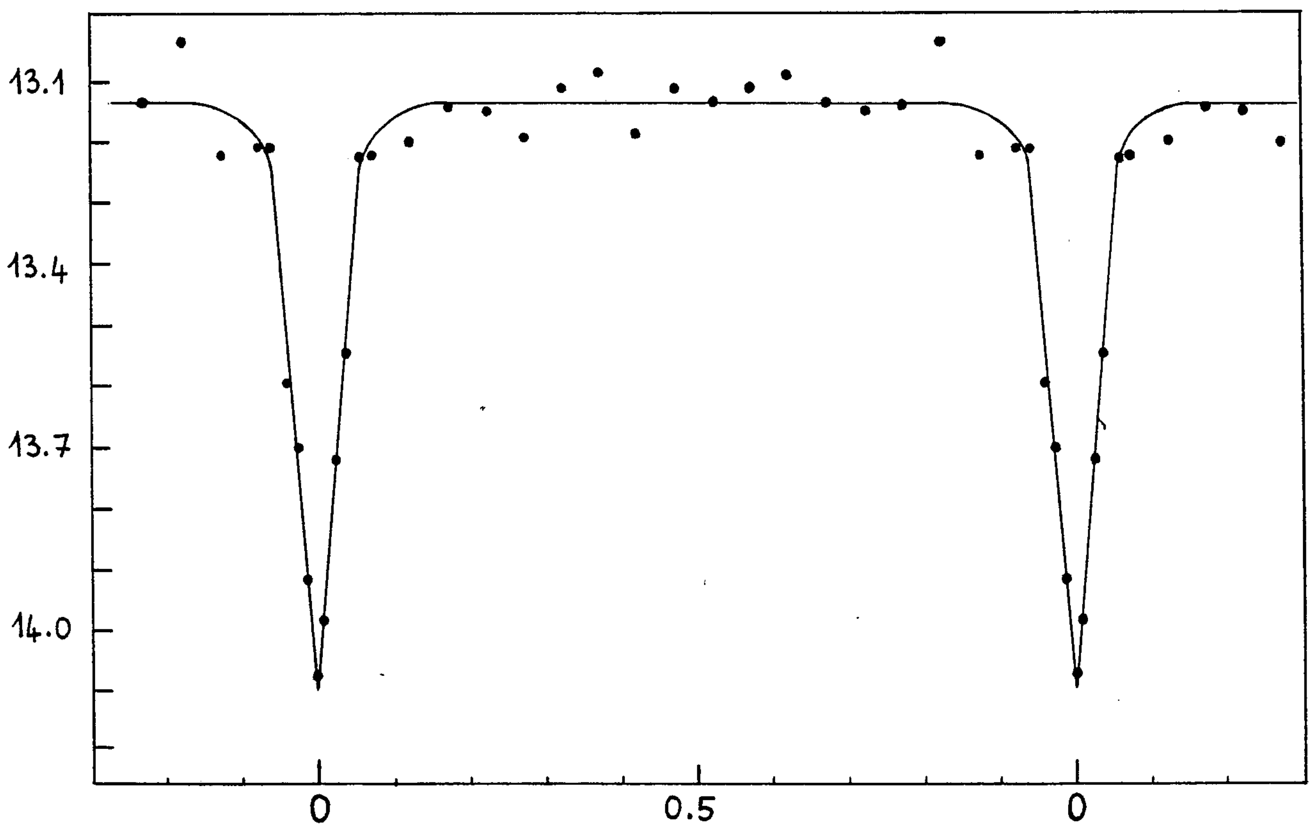

Fig. 4 . Mean curve of 170 estimates performed in 1978 by A. Figer . Each dot is a mean of several estimates.

Ephemeris (1) only gives as a rule the apparent period. It is easy to show that it gives in fact the real period :

Considering the observations, the two possible solutions for the real period of the eclipsing system are :

(a) 4.878 d considering the existence of two minima (I and II) with practically the same depth

(b) 2.439 d with a low amplitude secondary minimum

In reality the first hypothesis is not acceptable since both minima (I and II) should have an amplitude of about one magnitude (0.97 mag according to figure 4), as it is evident that the amplitudes of both minima of an eclipsing binary do not exceed simultaneously 0.75 magnitude.

The light-curve of figure 4 shows that the Beta Lyrae-type (= EB) is excluded. AY Peg is of an Algol-type (= EA) . The secondary minimum has not been detected, but there are only a few (nine) estimates during the phases of the whole secondary eclipse. However the secondary minimum is very shallow, its amplitude being probably much less than 0.2 magnitude.

Furthermore the mean curve confirms that the eclipse is partial (no flat at minimum light) and that the duration of eclipse is a little longer than 7 hours (as directly recorded), in fact about 9.4 hours (between phases 0.92 and 0.08) considering the plot of individual estimates, instead of the mean points, on the mean curve (figure 5) .

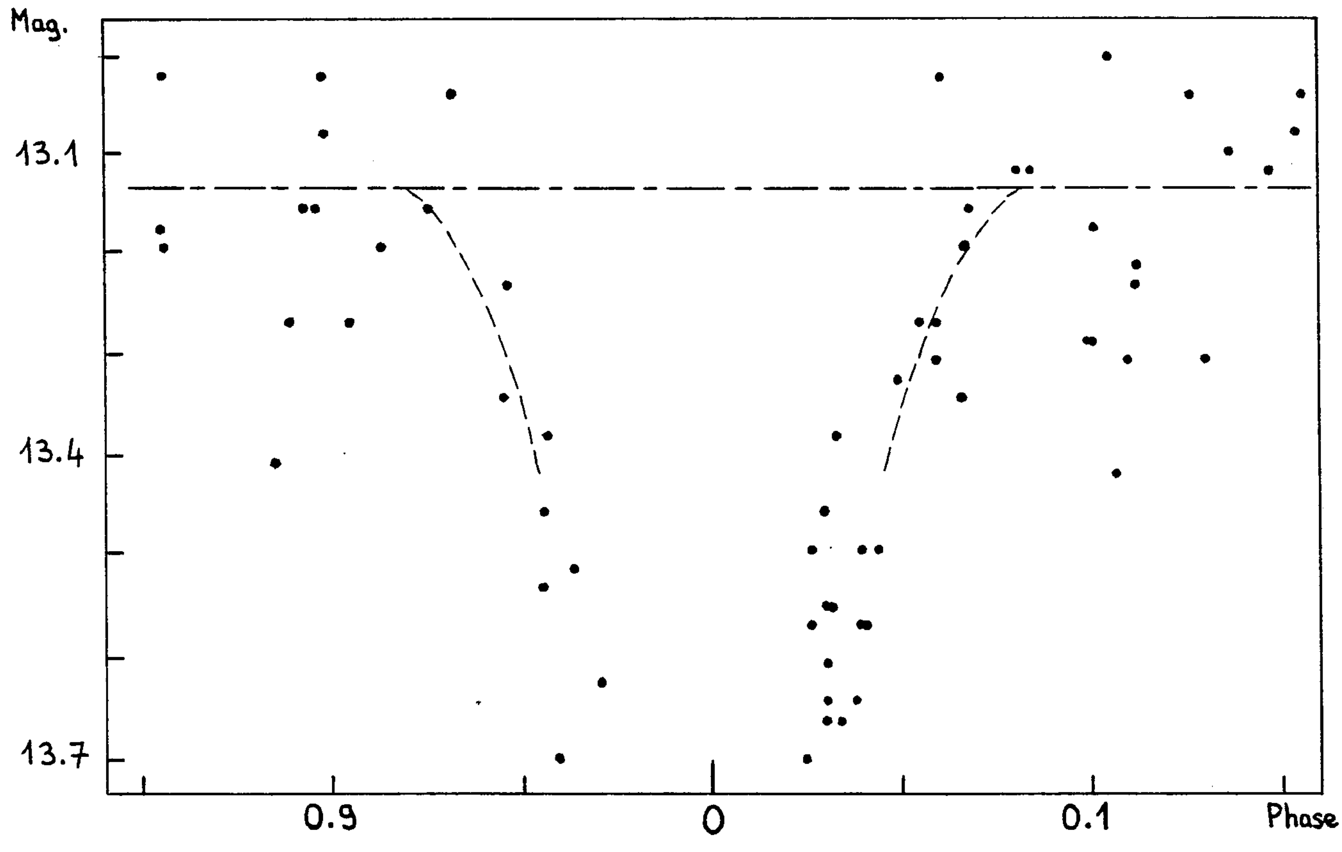

Figure 5 . Beginning and end of the eclipse of AY Pegasi as seen by plotting individual estimates in constructing the light-curve .

In order to check the validity of the proposed 2.439-day period, A. Royer (ROY) has plotted the mean curve of his 119 estimates performed in 1977 (August 8 to September 23) and 1978 (July 1 to October 8).
This curve, to be published elsewhere, confirms :

- the deep primary minimum at phase 0.00
- the partial eclipse (no flat at minimum)
- the duration of eclipse (found by ROY to be a little longer, from phase 0.90 to phase 0.09; but this determination is not accurate .

The spectral type of AY Pegasi is unknown. However, from the comparison of its photographic range ($12^m.3$ to $13^m.3$ according to BÖHME) with its visual range (about $13^m.0$ - $14^m.0$) it can be assumed a blue star, even though the photographic magnitudes by BÖHME cannot give any accurate information because old photographic photometry for faint stars was often affected by high amplitude systematic errors.
A typical example for such systematic errors is the case of the A-star VZ Draconis, another under-observed faint variable star. It was recorded by L.Meinunger (MVS 599 , 1961) to be variable between mpg 12.0 - 12.8 , while the older photographic range still mentionned by KUKARKIN (GCVS , 1969) is : 11.4 - 12.2 .
A comparable systematic error of more than a half-magnitude might have affected the determinations concerning both these variable stars.

Looking at the field of AY Pegasi in the Vehrenberg Atlas, A.Royer estimated AY Peg as bright as comparison star A, B being invisible. This is another suggestion for an A or B - spectrum for AY Pegasi.

In these conditions, AY Peg is probably a couple composed of a bright A-star and a fainter companion of a later spectral class. The primary minimum occurs when the companion partly occults the bright A-star. If the two components are supposed spherical and not darkened at the limb and if the brightness of the companion is neglected as small in comparison with A, it is possible to write that the primary minimum with an amplitude 1 mag will occur when 60% of the surface of A is occulted. This is possible only if the companion's radius has at least a value of 0.77 R , R being the radius of the main component.
As a matter of fact, the radius r of the companion is probably over this minimal value : the secondary minimum occurs when the A-star partly occults the companion; if the orbit is also supposed to be circular, the fraction of the occulted surface of the companion is respectively about 100, 60 and 15 %, when the radius of the companion is 0.77 R , R or 2R .

Knowing the value of the period T of the binary and the duration τ of the transit (primary eclipse), it is then possible to calculate a , the distance between the centres of the two stars using the formula :

$$\tau = \frac{T}{180^\circ} \, \mathrm{Arc\,sin} \sqrt{\frac{(R+r)^2 - R^2}{a^2 - R^2}}$$

The results are given in table 2 :

r	0.77 R	R	2 R
a	3.2 R	3.7 R	6 R
b	1.4 R	1.7 R	3 R

Table 2 . Distance a of the centres of the two stars and distance b between the limbs of the two stars as a function of r , radius of the companion, and of R, radius of the main star.

In all cases, and more particularly for the greater values of r (the most probable ?), the distance between the two stars seems large enough for the system to be effectively a detached system, thus confirming an EA type.

A. FIGER