GEOS
SR 4

GEOS CIRCULAR ON RED VARIABLE STARS

1983 June 28

GEOS 12 rue Bezout
F-75014 PARIS

NO ECLIPSES IN THE Lb VARIABLE STAR RR ARIETIS

ABSTRACT. NO ECLIPSES IN THE Lb VARIABLE STAR RR ARIETIS

A discussion of 1138 visual estimates made by GEOS observers from 1978 to 1981 shows that RR Ari varies irregularly as an Lb, with an amplitude of the order of 0.1 magnitude.

Observational evidence as well as various statistical and astrophysical considerations seem to rule out the duplicity of the star and consequently a variability caused by eclipses.

Previous papers on the star are then rediscussed.

RESUME. RR ARIETIS N'EST PAS UNE ECLIPSANTE, MAIS EST DE TYPE Lb

L'analyse de 1138 estimations visuelles faites par les observateurs du GEOS entre 1978 et 1981 montre que RR Ari varie irrégulièrement comme une Lb avec une amplitude de l'ordre de 0,1 magnitude.
Les observations, de même que diverses considérations statistiques et astrophysiques, semblent exclure la duplicité de l'étoile et donc la variabilité causée par des éclipses.

En conséquence, on présente une rediscussion des travaux précédents sur cette étoile.

RIASSUNTO. RR ARIETIS NON E' UNA VARIABILE AD ECLISSE, MA E' DI TIPO Lb

Dall'analisi di 1138 misure visuali fatte dagli osservatori GEOS fra il 1978 e il 1981, si dimostra la variabilità irregolare di RR Ari come Lb, con ampiezza dell'ordine di 0,1 mag.

Le evidenze osservative e diverse considerazioni statistiche e astrofisiche sembrano escludere la duplicità della stella e quindi la variabilità a eclisse.

A questo proposito è presentata una ridiscussione critica dei lavori precedenti su questa stella.

RESUMEN. NO HAY ECLIPSES EN LA ESTRELLA VARIABLE RR ARIETIS (TIPO Lb)

Del análisis de las 1138 medidas visuales realizadas por los observadores del GEOS entre 1978 y 1981, se demuestra la variabilidad irregular de RR Ari como Lb, con una amplitud del orden de 0,1 mag.
La evidencia observacional, así como diversas consideraciones estadísticas y astrofísicas, nos llevan a excluir la duplicidad de la estrella y, por lo tanto, la variabilidad a eclipses.

Con este fin se presenta una rediscusión crítica de la labor precedente sobre esta estrella.

1. INTRODUCTION

RR Ari (BD + 22° 284, HD 11 763, HR 559) is a bright star of magnitude 6 and spectrum K0 III, as reported in the GCVS (1969).

The only continuous series of photoelectric observations on the star dates back to 1958 (ARCHER).

On the basis of 11 nights of observation, the author concluded that the star was an eclipsing binary, possibly of the EA type, with a period of 47.9 days, an amplitude of 0.42 magnitude for the primary minimum and 0.33 magnitude for the secondary minimum, the latter occurring at phase $\varphi = 0.549$.

No other series of photometric observations on the star was published after 1959 and there has consequently been no confirmation of the period found nor of the type of eclipse causing variability.

2. THE GEOS OBSERVATIONS

The GEOS observers followed the star intensively from 1978 to 1981, collecting a total of 1138 visual estimates of the brightness (all observations made by the Argelander method). The purpose was to check ARCHER's conclusions and precise the period of variation, making profit of the long time elapsed since the previous observations.

Essential information on the observers who took part in the campaign is given in Table 1, while Table 2 gives the elements of the comparison sequence which was adopted.

Table 1 - List of the GEOS observers

Name	Place	Instr.	N	1978/79	1979/80	1980/81
J.C.Misson	Clichy (F)	B50	382	239	143	
A.Buzzoni	Ferrara (I)	R40	185	104	81	
R.Boninsegna	Dourbes (B)	B30	126		53	73
C.Pampaloni	Firenze (I)	B30	83		83	
G.Boistel	Sautron (F)	B50	78		34	44
E.Nezry	Toulouse (F)	B50	74		6	68
J.Busquets	Valencia (E)	B30	69			39
		B50			30	
J.Fabregat	Valencia (E)	B50	58		8	50
Ph.Ralincourt	Nantes (F)	B50	52		52	
P.Matagne	Bruxelles (B)	B50	31			31
			1138	343	490	305

Table 2 - Visual sequence of comparison

Star	Name	HR	BD	HD	MV	Sp.	Source
B	10 Ari	605	+25°341	12558	5.54	dF4	BS Catalog
C		577	+20°322	12139	5.89	KO	"
D			+22°296	12354	6.3	FO	HD Catalog

The calculation of the mean light curve was made by means of an automatic procedure with the Cyber 70/76 of the C.I.N.E.C.A. (Casalecchio, BO, Italy).

The ALCEP programme has already been used on several occasions by GEOS : it allows a synthesis of the most probable light curve to be made by processing series of measures by each observer through successive iterations.

The programme also allows an estimation of the standard deviation on every normal point of the curve as well as on every individual series. For further details on the matter, readers are referred to FIGER and REMIS (1978) or BUZZONI (1981) .

This procedure could only be used for the observations of 1979/80 and 1980/81, that is to say for the two periods when the coverage was the densest. For the period (1978/79), individual series were used only from a qualitative point of view, in order to verify possible trends in the general aspect of the light curve. The small number of measures and the small number of observers could indeed have biassed the results.

3. RESULTS

Table 3 and 4 list the normal points of the light curves for the observing periods (1979/80) and (1980/81). These curves are shown in figures 1 and 2 .

The mean error (calculated at 1 σ) on the normal points is estimated at $\pm$ 0.021 magnitude for the period (1979/80) and at $\pm$ 0.015 magnitude for the period (1980/81), while the mean error on an individual nightly mean is $\pm$ 0.05 mag (1979/80) and $\pm$ 0.03 mag (1980/81) .

Lastly, it is also possible to evaluate the standard deviation on a single observation made by the average observer at + 0.09 mag (1979/80) and + 0.06 mag (1980/81) .

As regards the error bars (time ordinate), they refer to the maximum interval of time (constant for each curve) for which the algorithm calculates the average (iterated) instant of observation.

Of course, an essential condition is that the variation of magnitude should be negligible within each discrete step, which condition is satisfied for each curve. The integration steps were 7 days (1979/80) and 20 days (1980/81) .

Table 3 - List of the normal v points of RR Ari in 1979/80.

J.D. 2444000.+	$\pm$d	N(*)	Mv
139.3	3.5	5	5.80
146.3	3.5	5	5.79
153.3	3.5	3	5.72
160.3	3.5	1	5.75
167.3	3.5	10	5.77
174.3	3.5	3	5.75
181.3	3.5	5	5.76
188.3	3.5	8	5.75
195.3	3.5	7	5.77
202.3	3.5	6	5.80
209.3	3.5	5	5.78
216.3	3.5	3	5.72
223.3	3.5	6	5.83
230.3	3.5	2	5.80
237.3	3.5	4	5.82
244.3	3.5	11	5.82
251.3	3.5	4	5.81
258.3	3.5	5	5.77
265.3	3.5	1	5.74
272.3	3.5	2	5.75
279.3	3.5	2	5.72
286.3	3.5	5	5.76
293.3	3.5	2	5.83

(*) N refers to the number of individual nightly means .

Table 4 - List of the normal v points of RR Ari in 1980/81

J.D. 2444000.+	$\pm$d	N(*)	Mv
471.3	10	10	5.74
491.3	10	1	5.74
511.3	10	7	5.75
531.3	10	8	5.75
551.3	10	11	5.76
571.3	10	1	5.78
591.3	10	2	5.84
611.3	10	3	5.79
631.3	10	3	5.75
651.3	10	3	5.77

(*) N refers to the number of individual nightly means.

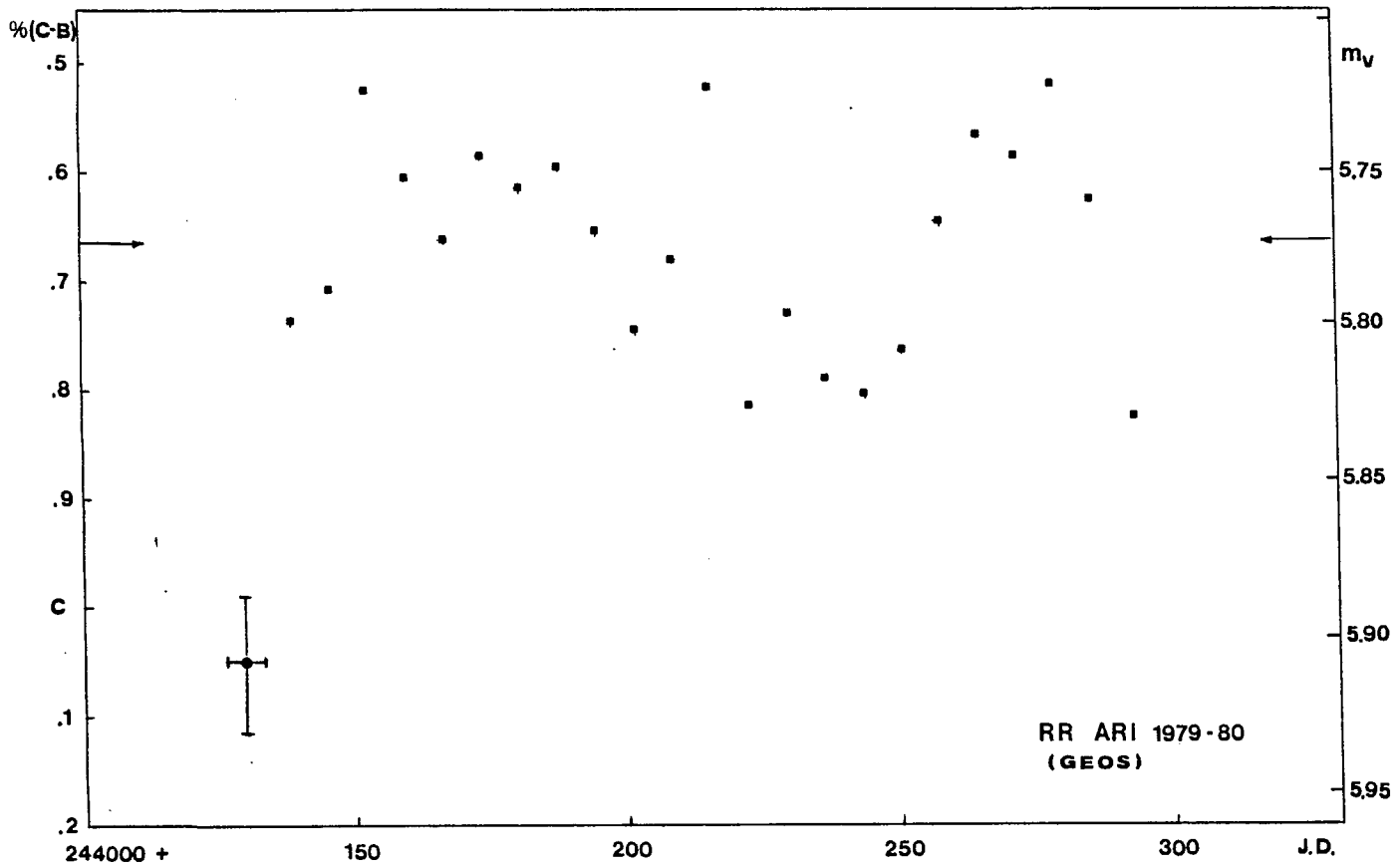

Fig.1 - RR Ari in 1979-80 .
The arrows indicate the mean magnitude

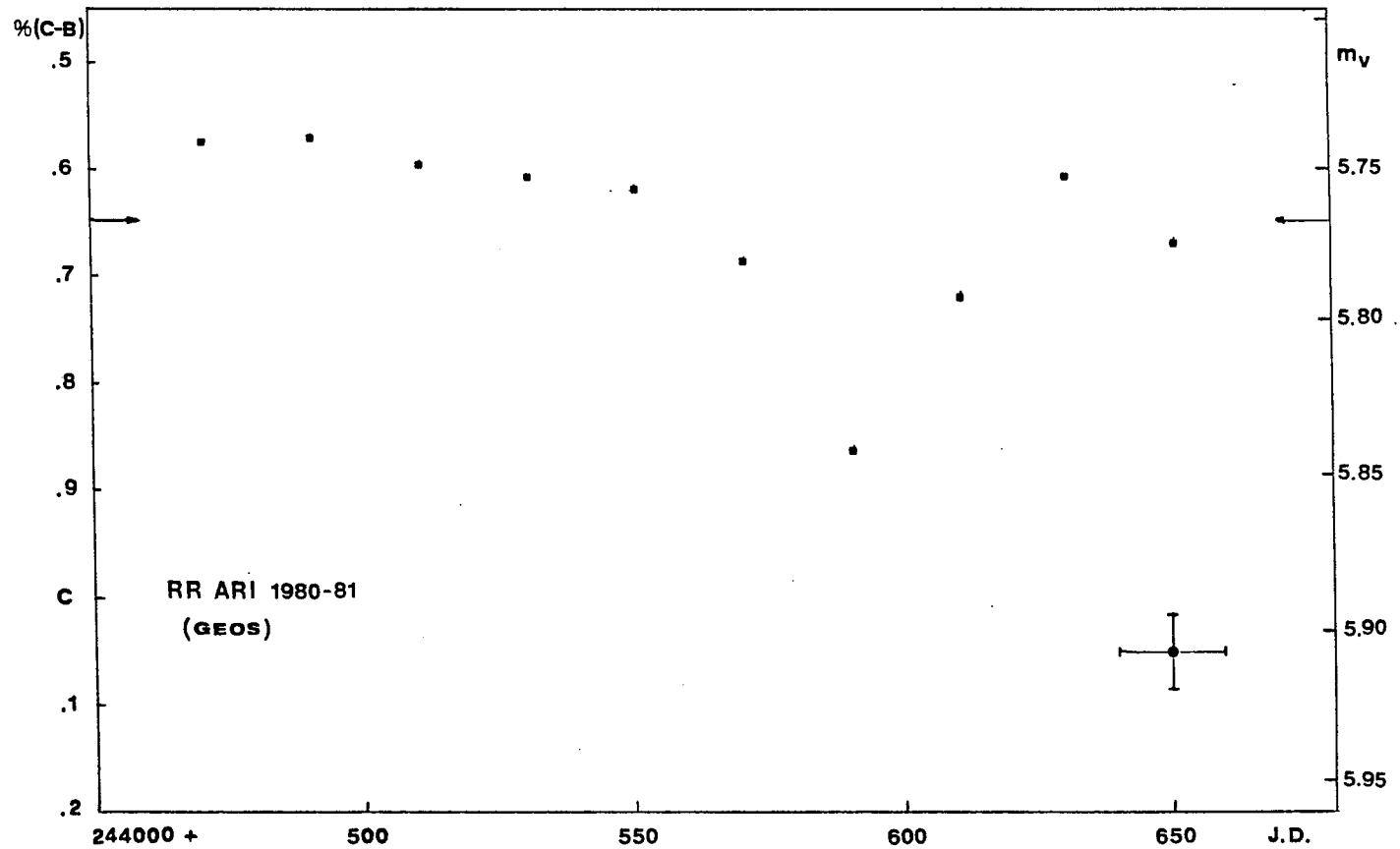

Fig.2 - RR Ari in 1980-81 .
The arrows indicate the mean magnitude

An analysis of the curves can then be focussed on two different types of variations : a slow, long-term variation and rapid variations on the scale of a few days or less.

A) Slow variations :

On the curves of figs. 1 and 2 , faint variations in brightness are clearly visible around the mean value which remains practically constant at about $m_v = 5.77$ during the two periods considered.

One can note that the range of variations is comparable to the mean error on the points ; it is therefore difficult to put great confidence in the general quantitative trend of the curve. Nevertheless, it is not unreasonable to suppose that a regular fluctuation, though aperiodic and of small amplitude, must exist, as the points of the curves do show a trend and are not randomly distributed within the error bar. Moreover, it can be seen that some extrema (particularly minima) appear to be outside the $\pm 1\,\sigma$ interval around the mean magnitude. From a purely qualitative point of view, variations can also be noted in individual series of observations for (1978/79) . Of course, the possible effect of suggestion should not be dismissed too quickly, especially as the two minima at JD 24 44 240 and 24 44 590 occurred practically at a one-year interval and could well have been induced by the position effect.

At both these dates, occuring roughly between December and January, the star culminates in Europe at about 20:00 UT and the asterism of the comparison sequence is thus inverted as it starts its westward descent.
Practically, this position effect did not exert much influence as, in fact, observations were always distributed evenly over a large interval of time in the night during the whole observing period.

B) Rapid variations :

Such variations of brightness should be expected only in the case of an eclipse (considering the spectral type and the resulting stage of evolution of the star). Quite naturally, the light curves cannot show such variations as they are averaged and smoothed by the large integration interval.

An examination of ARCHER's light curve shows that RR Ari should be fainter than maximum brightness for about 5 days in 50 : there would therefore be a 10% probability for the star to be observed during a minimum.
This probability is in fact an inferior limit in the case of visual observations : indeed, visual observers knew, when observing the star, that they had to expect eclipses and that these could occur unexpectedly on any observing night (since they were seeking a confirmation of a period independent from ARCHER's ephemeris). Moreover, the range of variation of a real minimum was certainly such as to be objectively observed individually by all the observers.

This being stated, experience shows that the observer may have a tendency to see real variations as well as fictitious minima owing to complex (and temporary) processes of self-suggestion. In such cases,indeed, no correlation can be expected between the curves from various observers, while in the case of a real minimum of sufficient amplitude, there should be an objective confirmation from all the observers.

Among other things, the brightness of the star at minimum should have been quite near that of comparison C, making a differential estimate particularly easy.

Quite on the contrary, the distribution deduced from all the measures shows, instead, that the percentage of measures "at minimum" is of the order of 5% only and that, in this respect, no correlation is present between observations made at the same period by various observers. Moreover, "out-of-normal" observations with a single observer (no possibility of any confirmation, either positive or negative, from other observers) appear in an absolutely aperiodic way. Finally, it is possible to conclude that no real minimum was effectively observed and that, as a consequence, the possibility of eclipses of RR Ari must be held as quite remote (the probability is less than 1‰) .

4. DICUSSION OF THE RESULTS OBTAINED

The observational evidence discussed in this paper makes it possible to say that the only variations of brightness of RR Ari are the slow ones, aperiodic and of faint amplitude.

In the light of this conclusion, ARCHER's work deserves a new critical analysis as his model of RR Ari seems to be totally in contradiction.
One can then outline briefly the main points against the hypothesis of a binary (eclipsing) system.

1 : it has been said in this paper that, statistically speaking, less than 10% of the measures, if distributed at random, should concern the phases around minimum ; on the contrary, 6 measures out of 11 made photoelectrically, that is to say 55%, seem to fall into such phases. An unescapable conclusion is that such observations were indeed favoured by great luck !

2 : the general trend of the minima is obtained by combining measures for a period of 47.9 days , but in fact no individual minimum was observed. Hence, a totally arbitrary choice of the period would have allowed equally satisfying solutions to be found.
In any case, each minimum is not defined by more than 3 observations on the curve drawn by ARCHER.

3 : the parallax of RR Ari is 0.010" , which yields a distance of about 100 pc. From the curve published in this paper and from the magnitudes published in various catalogues (see Table 5), an apparent magnitude of about 5.7 can be deduced, which gives an absolute magnitude of about +0.7 . This is in very good agreement with the value expected for a single red giant with a K spectrum. As a consequence, this does not seem to be any photometric evidence for a secondary star.

4 : Table 5 also gives the principal spectral determinations of RR Ari, as they appear in various catalogues. No source mentions the existence of the secondary spectrum of a possible companion. Considering the stage of evolution reached by the red giant (i.e. at the beginning of the giant branch), one would expect a possible "normal" companion on the main sequence or at least a subgiant with a magnitude comparable or just a little superior to the main star. Such a star should, however, appear in the spectrum.

5 : according to ARCHER, there is a reasonable agreement between the Keplerian velocity (calculated as 16 km/s) and the observed radial velocity. There exist 4 determinations of V_r for RR Ari, given in the Catalogue of Stellar Radial Velocities :
14.1 km/s (1 measure, 1915) and 13.7 km/s (3 measures, 1970) .
In reality, the agreement between the observed values and the calculated value is only apparent because it neglects the radial velocity of the barycentre of the system, which in general is not null and adds vecterially to the Keplerian component.

In more simple terms, the observed values of V_r can instead be considered as typical of an isolated star belonging to the Population I of the disc.

Table 5 - Magnitude, Spectrum and Colour determination of RR Ari

Source	MV	Spectrum	B-V	U-B
MK Spectral Class.	5.76	K1 III	1.18	1.04
AGK 3 Catalog	*(5.7) 6.9_{pg}	KO		
BS Catalog	5.7	gG8		
HD Catalog	5.95	KO		

(*) ,This value has been estimated from M_{pg} by appling the B-V determination of MK Spect.Class.

5. A MODEL FOR RR ARIETIS

Observational evidence as well as the theoretical considerations roughly sketched here clearly show the existence of an isolated star, with a mass probably about 2 - 3 $M_\odot$ and subject to irregular variations of luminosity which seem typical of an Lb.

In general, for such stars, the range of variation remains small during long periods, with sporadic episodes of a more marked variability (but always on a limited scale).

This is probably what lead to the erroneous interpretation of ARCHER's measures and to the relatively large value for the range of variation shown on his curve.

As a conclusion, it is possible to sum up the photometric characteristics of RR Ari as follows :

Type of variability :	Lb
Mean visual magnitude :	5.77
Mean observed amplitude	$\sim$ 0.10 m

Alberto BUZZONI

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