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GEOS CIRCULAR ON ECLIPSING BINARIES

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19 TIMES OF MINIMA AND FIRST EPHEMERIS FOR THE EB STAR RRVI-51.

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ABSTRACT : RRVI-51 was discovered in the sixties. The star was noted EA : relying on the 63 photographic observations (Kinman et al, 1982), but still remains particularly under-studied. Using 19 times of minimum (17 visual times recorded by 5 GEOS observers, 1 photographic minimum (Kinman et al.) and 1 photoelectric minimum recorded by a GEOS belgian team), it has been possible to calculate a first ephemeris :

Min 1 : Hel J.D. 2442776.961 + 1.199839 E

From all available visual estimates, RRVI-51 appears to be an EB eclipsing star while photographic observations seem to back up the idea of EA type. Photoelectric measurements clearly confirme the EB type. The primary minimum is easy to discriminate from the secondary one, due to their sharp different amplitudes.

RESUME : RRVI-51 fut découverte dans les années soixante. Elle fut notée EA : en s'appuyant sur 63 plaques photographiques (Kinman et al, 1982). Elle reste néanmoins une variable particulièrement sous-étudiée.
19 instants de minimum (17 minima visuels enregistrés par 11 observateurs du GEOS, un minimum photographique (Kinman et al.), et 1 minimum photoélectrique enregistré par une équipe belge du GEOS) ont permis de présenter une première éphéméride :

Min 1 : Hel J.D. 2442776.961 + 1.199839 E

Il ressort de l'ensemble des observations visuelles que RRVI-51 est une variable à éclipse de type EB, alors que la surveillance photographique lui donne l'aspect d'une EA. Des mesures photoélectriques confirment clairement le type EB. Le minimum primaire peut facilement être différencié du secondaire de par la nette différence d'amplitude.

SOMMARIO : La scoperta di RRVI-51 risale agli anni sessanta. Sulla base di 63 osservazioni fotografiche venne in seguito classificata come EA (Kinman ed al. 1982), ciononoste è rimasta finora notevolmente trascurata.
19 istanti di minimo (17 minimi visuali di 11 osservatori GEOS, un minimo fotografico (Kinman et ad.) e 1 minimo fotoelettrico registrato da un gruppo di osservatori Belgi del GEOS) hanno permesso di determinare una prima effemeride :

Min 1 $GG_{el.}$ 2442776.961 + 1.199839 x E

Dall'insieme delle osservazioni visuali RRVI-51 appare un variabile di tipo EB, mentre dall'osservazione fotografica sembrerebbe trattarsi d'una EA. Le misure fotoelettriche confermano chiaramente il tipo EB. E' possibile discriminare nettamente il minimo primario dal secondario a causa della netta differenza d'ampiezza.

RESUMEN : RRVI-51 fué descubierta en los anos sesenta. Fué clasificada como EA, en base a 63 placas fotográficas (Kinman et al, 1982). Sin embargo, ha continuada siendo una variable poco estudiada.
19 instantes del mínimo (17 mínimos visuales registrados por 11 observadores del GEOS, un miñimo fotografico (Kinman et al.) y 1 mínimo fotoeléctrico registrado por un equipo belga del GEOS) han permifido obtener una primera efeméride :

Min 1 : Hel J.D. 2442776.961 + 1.199839 E

El grueso de las observaciones visuales muestra que RRVI-51 es una variable a eclipses del tipo EB, en tanto que fa vigilancia fotográfica le da aspecto de una EA. Las medidas fotoeléctricas confirman claramente el tipo EB. El mínimo primario puede fácilmente distinguirse del secundario por su neta diferencia de amplitud.

1. Introduction.

- RRVI-51, with coordinates (1950,0) alpha=07h53m03s, delta=+40°50.9 was dicovered by Kinman et al in the sixties, during a search for RR Lyrae stars towards the galactic anticenter. The star was classified as an EA? eclipsing star (Kinman et al, 1982), relying on 63 photographic plates. These observations show many brightness variations ranging from 10.70 to 12.60 with a mean at 11.20. However, the star was too bright for the 20 inch Lick astrograph, so that the estimates are somewhat imprecise.
-RRVI-51 has the same extinction factor E(b-v)=0.05 as the other RR Lyrae stars observed in the galactic anticenter by Kinman et al. (1982).

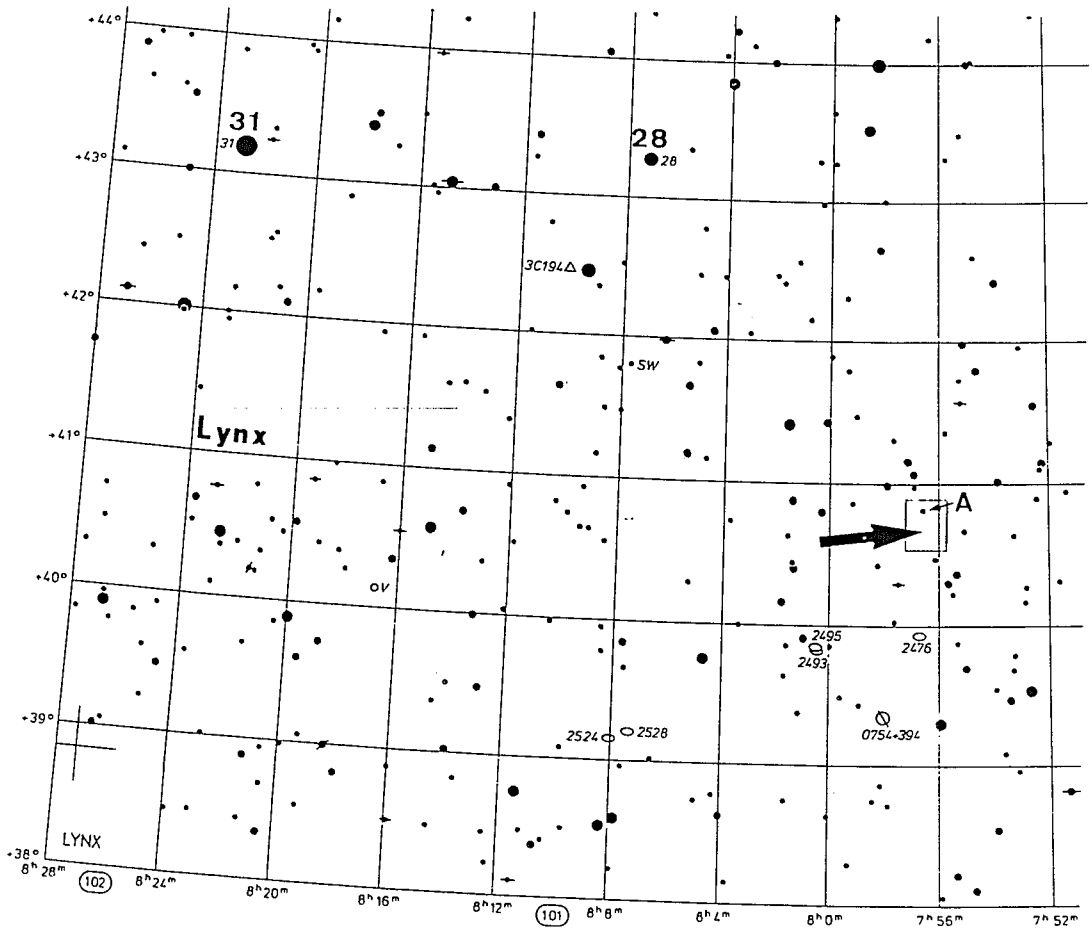
2. Observations.

From 1983 to 1987, 11 GEOS observers have made about 1000 visual estimates in about 52 different nights

Name of observers	Sig.	Place	Number
Wils Patrick	WLS	Niel	69
Przybylo Zbignew	PRZ	Charleroi	80
Louis Patrick	LSP	Namur	77
Boninsegna Roland	BNN	Dourbes	455
Dequinze Robert	DQZ	Jemeppe s/s	206
Thirionet Yvon	TNT	Bruxelles	21
Zimmermann Laurent	ZMN	Bruxelles	
Lambert Stéphane	SLA	Bruxelles	22
Lheureux Albert	LHX	Bruxelles	
Blanchart Christian	BCT	Bruxelles	
Friedlingstein Claire	FRD	Bruxelles	12

Table 1: observers, places and number of estimates.

- The estimates were made according to the fractional or Argelander method using the comparison stars shown in figure 1, taken from Kinman et al. chart.
According to all observers, "A" seems to be an unsuitable comparison star, as it is visualy seen less bright or equal to B. So the stars used as references are B, C, and D, roughly estimated at 10.3, 10.95 and 11.5respectively.
- The observations during a whole night only cover a small part of the period, so that the elements were discovered by only determining sure minima.



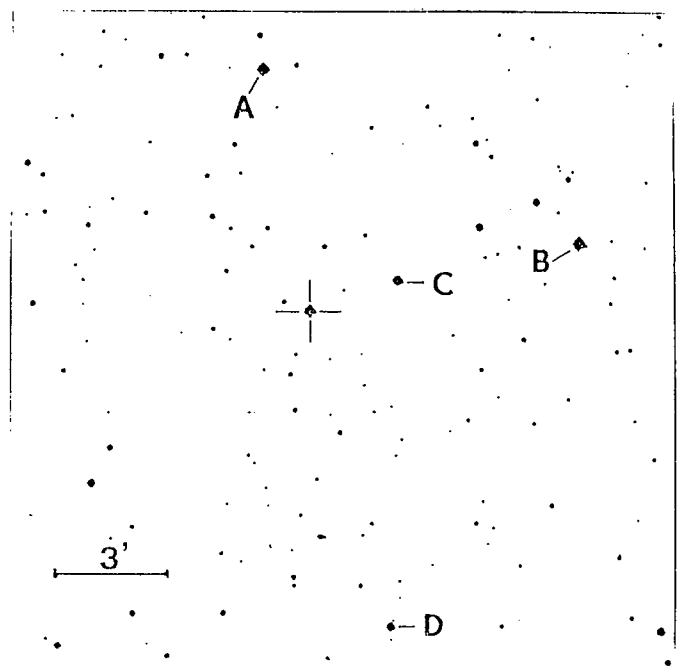


Fig 1: RRVI-51 and its comparison stars.

3. Discussion.

3.1. Eclipsing binary nature.

The minima of RRVI-51 are rounded like sine curves, but do not always have the same depth. Relying on all observers estimates, the secondary minimum is about 0.3 magnitude brighter than the primary one. The period of the star appears, from observations made during consecutive nights, to be a bit longer than one day. The maxima are rounded too, and the brightness variation is continous so that the EB type comes immediately up to mind.

Two "one-night curves" are shown below.

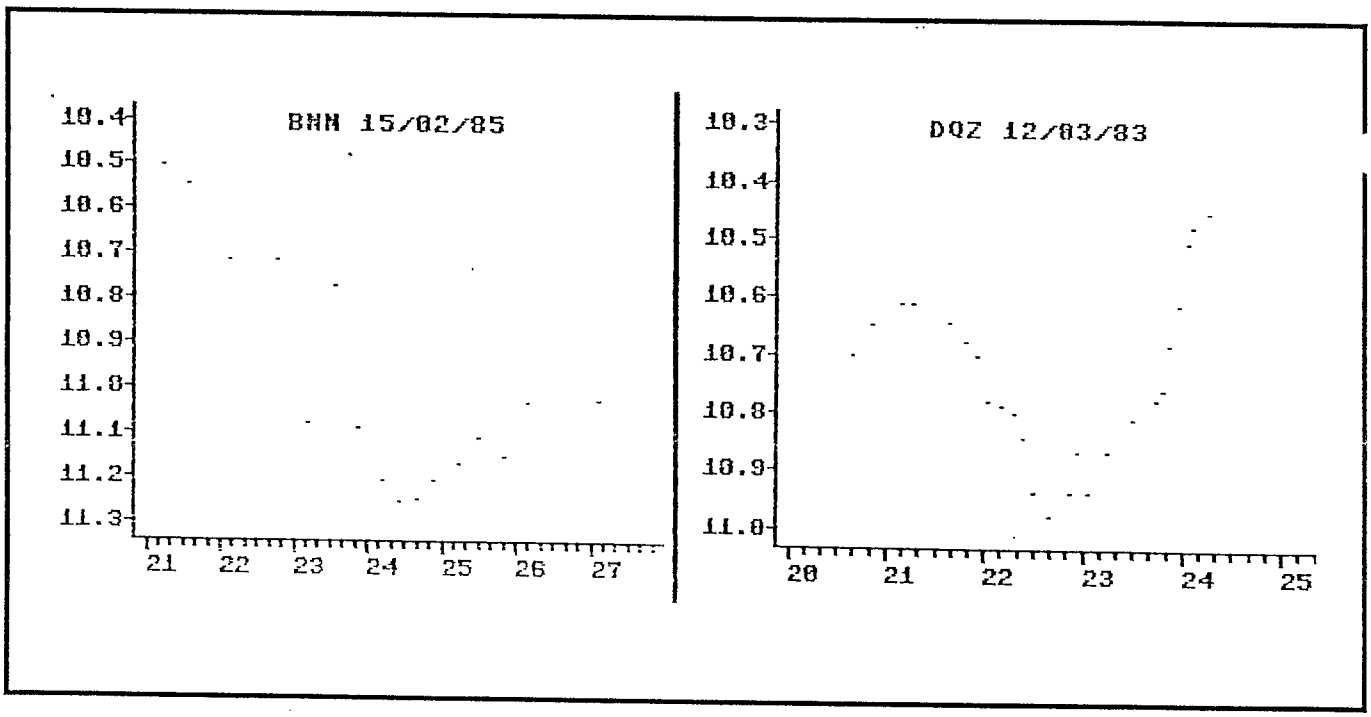


Fig 2: Two RRVI-51 light curves: MIN1 BNN and MIN2 DQZ

3.2. List of minima observed.

17 primary minima were observed. They have been determined using the tracing paper method.

3.3. The first ephemeris for RRVI-51.

The first ephemeris is derived from the 17 visual primary minima observed between 1984 and 1987.

Min1: Hel J.D. 2446119.712 + 1.199839 E
± .009 ± .000025
(95% level of confidence for the error bands)

N	HEL JD 2400000+	(1)	(2)	MAG	N	HEL JD 2400000+	(1)	(2)	MAG
1	37646.8137	.292	.304	11.22:	33	37749.6993	.042	.053	11.25:
2	37661.7614	.750	.762	11.13	34	37750.6715	.852	.864	11.05:
3	37663.7323	.393	.405	10.81:	35	37750.7860	.948	.959	11.80:
: 4	37663.8427	.485	.497	11.24	36	37751.6804	.693	.705	11.18
5	37664.7358	.229	.241	11.07	37	37751.7866	.782	.793	11.17
6	37664.8462	.321	.333	11.08	38	37755.7863	.115	.127	11.14
7	37666.7344	.895	.907	11.08	39	37757.7201	.727	.738	11.19
8	37666.8386	.982	.994	12.60:	40	37758.6902	.535	.547	11.16:
9	37666.9428	.069	.080	11.09	41	37760.6726	.188	.199	11.06:
10	37667.7588	.749	.761	11.24	42	38376.8110	.706	.717	11.22
11	37667.8629	.836	.847	11.28	43	38376.9151	.793	.803	11.23
12	37670.7671	.256	.268	10.70:	44	38402.7623	.335	.346	11.20
13	37670.8741	.345	.357	11.00:	45	38402.8255	.388	.398	11.19:
14	37672.7574	.915	.927	11.16	46	38405.8102	.875	.886	11.21
15	37692.6933	.530	.542	11.31	47	38407.7665	.506	.516	11.32
16	37692.8016	.621	.632	11.17:	48	38407.8706	.592	.603	11.22
17	37694.8106	.295	.307	11.13:	49	38407.9331	.645	.655	11.20
18	37695.6981	.035	.046	11.40	50	38729.8990	.986	.996	11.94:
19	37695.8022	.122	.133	11.17:	51	38788.8148	.089	.099	11.13
20	37695.9064	.208	.220	11.18	52	38816.7381	.362	.372	10.96
21	37696.6890	.861	.872	10.80:	53	38873.6954	.833	.843	11.00
22	37696.7932	.947	.959	11.50	54	39062.9430	.560	.570	11.08
23	37696.8973	.034	.046	11.56	55	39095.8568	.992	.020	11.88:
24	37697.7105	.712	.724	10.70:	56	39111.8083	.287	.297	10.77
25	37697.8147	.799	.811	10.70:	57	39137.7696	.924	.934	11.28
26	37698.6896	.528	.540	11.06	58	39183.8197	.305	.314	10.86
27	37698.7938	.615	.627	11.24	59	39223.6809	.527	.536	11.15
28	37698.8980	.702	.713	11.23	60	39447.8403	.355	.364	10.92
29	37699.6931	.364	.376	11.17	61	39554.7199	.430	.439	11.08
30	37723.6522	.333	.345	11.33	62	40182.9276	.080	.016	11.88
31	37723.7563	.420	.431	11.29:	63	40208.9667	.710	.718	11.01
32	37723.8605	.507	.518	11.34					

Table 3: dates, phases and magnitudes corresponding to Kinman et al photographic plates, based on ephemeris (1) and (2) of this paper. The ' : ' are used to indicate that a measure is not precise.

Now, we must not forget that these measures are not precise:

- the star was too bright for the Lick astrograph;
- the border effect of photographies may bring about magnitudes differences up to 0.07 magnitude.

The accuracy of Lick magnitudes is estimated to about 0.1 mag indeed (see bibliography).

NUM	HEL JD	OBS	E (1) (2)	O-C (1)	O-C (2)	E (3)	O-C (3)
1	38402.347	KIN	-6432		-.000	-3646	-.001
2	45673.357	BNN	-372	-.016	-.015	2414	-.015
3	45673.357	PRZ	-351	+.006	+.006	2435	+.007
4	45699.784	BNN	-350	+.015	+.015	2436	+.016
5	45764.559	PRZ	-296	-.001	-.001	2490	-.000
6	45769.358	PRZ	-292	-.002	-.001	2494	-.001
7	45811.335	LSP	-257	-.019	-.019	2529	-.018
8	45817.390	BNN	-252	+.037	+.037	2534	+.038
9	45818.552	BNN	-251	-.001	-.001	2535	-.000
10	46004.505	BNN	-96	-.023	-.023	2690	-.022
11	46111.317	WLS	-7	+.004	+.004	2779	+.004
12	46112.520	BNN	-6	+.007	+.007	2780	+.007
13	46119.692	BNN	0	-.020	-.020	2786	-.020
14	46473.659	BNN	295	-.005	-.006	3081	-.005
15	46473.688	DQZ	295	+.024	+.023	3081	+.024
16	46827.602	BNN	590	-.014	-.015	3376	-.015
17	46827.627	DQZ	590	+.011	+.010	3376	+.010
18	46850.412	DQZ	609	-.001	-.002	3395	-.002
19	47151.571	GEOS				3646	-.002

Table 2: RRVI-51: list of minima observed, E(1), E(2), O-C(1), O-C(2); E(3), O-C(3) according respectively to ephemeris (1), (2) and (3) of this paper.

3.4. Kinman et al. photographic light curve

To check the validity of this first ephemeris, we have made a composite light curve on the Kinman et al (1982) photographic observations (see Fig 3).

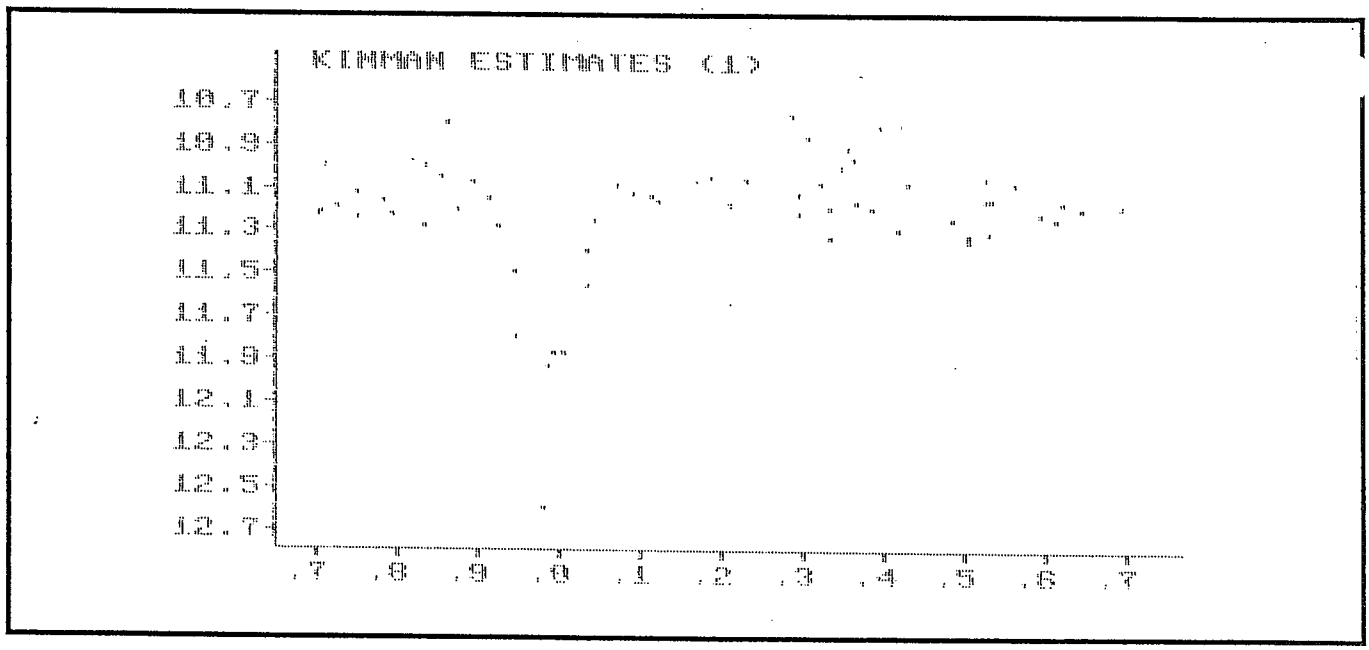


Fig 3: composite light curve from Kinman et al (1982) photographic plates, using ephemeris (1) of this paper.

Some values round phade 0.9 are obviously quite below the mean (see fig 3 and table 3). However, the minimum is clearly defined , but should have occured around phase 0. If we consider the error bands of the ephemeris, we see that the error on the phase could reach a value of 0.15 phase for the first heliocentric Julian Day and 0.10 for the last one: it clearly appears that we had to use the photographic minimum of Kinman et al. to precise ephemeris (1).

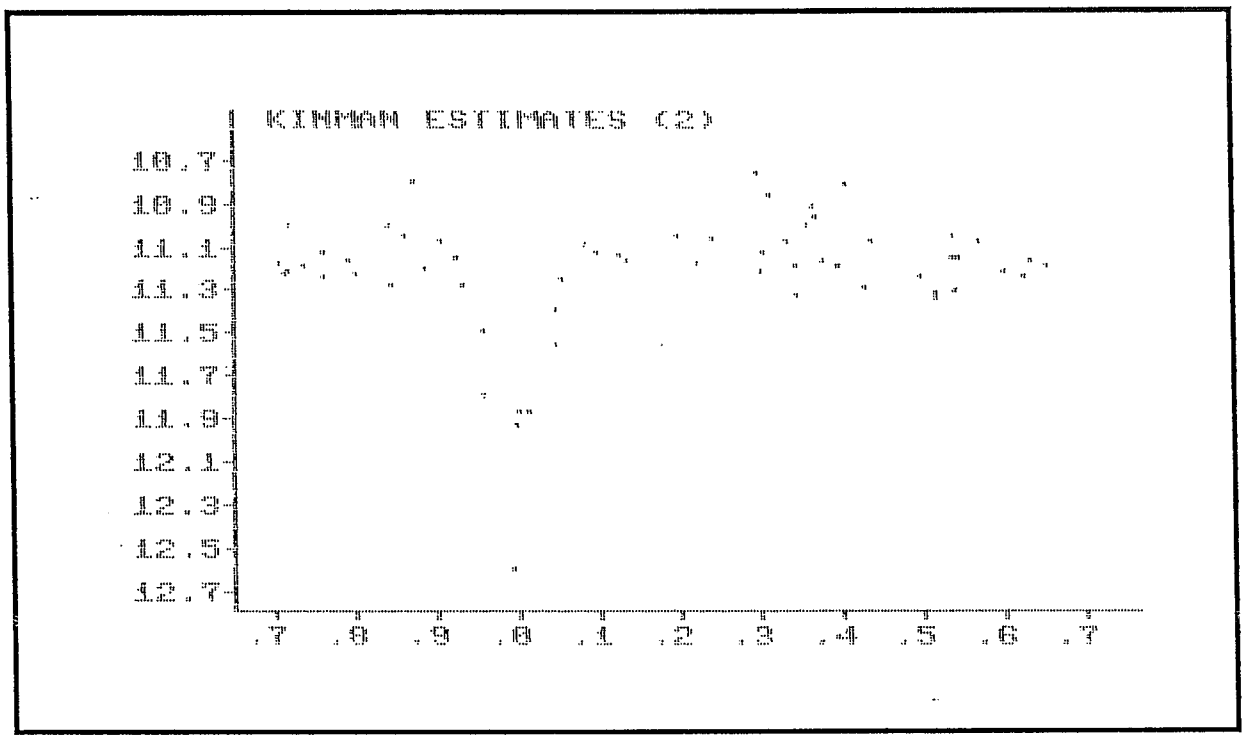


Fig 4: composite light curve from Kinman et al (1982) photographic plates, using ephemeris (2) of this paper.

The Kinman composed minimum has been determined by 2 observers (BNN-DQZ) using the tracing paper method. The mean heliocentric Julian Day of this minimum is 2438402.347. Then the new regression gives us the following result:

Hel J.D.: 2446119.712 + 1.199839 E (2)
± .8 .5
(95% level of confidence for the error bands)

The Kinman composed minimum is reset near phase 0 (fig 4 and 3). But none of these ephemeris (1 or 2) show any evidence of a secondary minimum. We cannot explain this discrepancy yet, but there will certainly be further investigations about this problem.

3.5. RRVI-51 mean visual light curve.

Boninsegna 455 estimates have been used to plot the mean light curve shown in figure 5. The period has been divided into 40 intervals representing about 28 minutes each, according to ephemeris (2) of this paper.
A 0.65 magnitude amplitude can be deduced from figure 5. But let us keep in mind that this result is under estimated as it is always from a mean light curve.
We could approximate the real amplitude to about 0.85 or even 0.90 magnitude.
The near sinusoïdal aspect of the curve reinforce the EB type for the star.

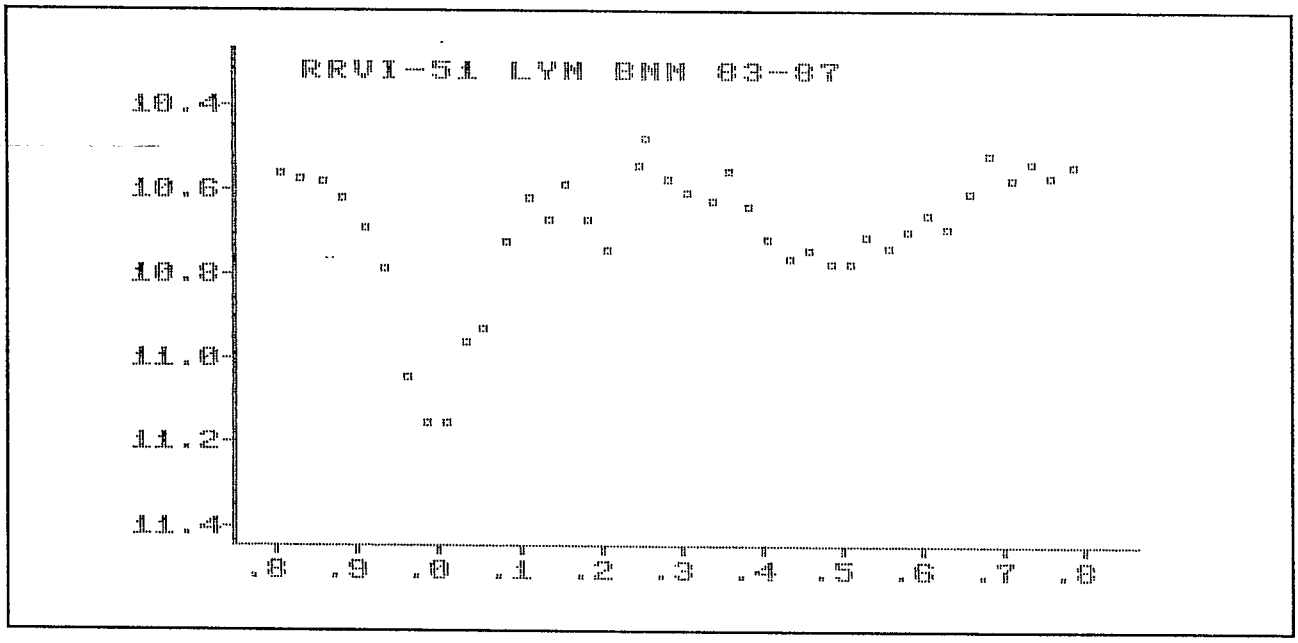


Fig 5: RRVI-51 mean light curve, using BNN 455 estimates.

TR	PH	MAG	NB	SIGMA	TR	PH	MAG	NB	SIGMA
1	.012	11.25	34	.20	21	.514	10.77	11	.12
2	.039	10.96	24	.15	22	.535	10.71	8	.12
3	.059	10.93	14	.18	23	.561	10.74	15	.10
4	.087	10.72	13	.12	24	.585	10.70	8	.06
5	.114	10.62	6	.06	25	.610	10.66	9	.08
6	.139	10.68	6	.07	26	.633	10.69	5	.09
7	.159	10.59	8	.13	27	.661	10.61	10	.10
8	.187	10.67	6	.19	28	.686	10.52	11	.10
9	.210	10.74	3	.08	29	.712	10.57	13	.14
10	.248	10.54	2	.12	30	.739	10.54	13	.10
11	.258	10.48	1		31	.763	10.57	14	.09
12	.287	10.57	3	.11	32	.788	10.54	14	.07
13	.311	10.61	3	.10	33	.812	10.57	13	.06
14	.341	10.63	5	.10	34	.835	10.58	13	.09
15	.364	10.56	8	.14	35	.864	10.58	13	.09
16	.385	10.64	9	.09	36	.888	10.62	13	.10
17	.411	10.72	9	.09	37	.913	10.69	12	.06
18	.437	10.76	10	.12	38	.939	10.79	17	.13
19	.463	10.74	12	.07	39	.965	11.04	23	.20
20	.491	10.77	13	.09	40	.990	11.16	29	.18

Table 5: mean phases, mean magnitudes, number of estimates and standard deviation for each interval mean point of fig 5 light curve.

3.6. Photoelectric measures.

- 32 photoelectric measures have been made in 2 nights: 21-22 and 23-24 december 1987 by four GEOS belgian members: *R. BONINSEGNA, C.FRIEDLINGSTEIN, S. LAMBERT and R. LEYMAN.* The four observers have operated on the 76 cm Jungfraujoch telescope (Switzerland), equipped with a cooled photomultiplicator tube photometer. The aim was to make measures in the B and V filters of the Geneva photometric system.
- Standards stars were used to reduce the measures (Dumont, 1983). The color indexes that were determined have been transformed in the Johnson and Morgan system according to Meylan and Haucks formulaes (1981).
- A primary minimum has been observed and determined by a linear regression (Hel. J.D. 47151.571).
- The V and B-V light curves, composed using ephemeris (2), are presented on fig 6.
- These results confirm without any doubt what appeared from visual estimates: the EB type, the real ephemeris and the predected amplitude.
- The colour index variations tell us that RRVI-51 is a system of near similar stars: the first beeing A0-A2 spectral type and thesecondary beeing A3-A5. A important element that's still to be explained remains the reason why the secondary minimum does not appear on the Kinman et al (1982) photographic curve (see fig 3).

Hel J.D.	V	(B-V)g	(B-V)j	Phase
47151.3786	10.75	-0.87	+0.07	0.830
.3967	10.77	-0.85	+0.09	0.845
.4140	10.81	-0.87	+0.07	0.860
.4293	10.84	-0.85	+0.09	0.872
.4449	10.89	-0.85	+0.09	0.885
.4758	11.01	-0.85	+0.09	0.911
.4814	11.04	-0.85	+0.09	0.916
.5085	11.21	-0.85	+0.11	0.938
.5314	11.40	-0.82	+0.13	0.958
.5432	11.49	-0.80	+0.14	0.967
.5564	11.56	-0.79	+0.14	0.978
.5661	11.57	-0.79	+0.14	0.986
.6001	11.51	-0.78	+0.11	0.015
.6165	11.40	-0.82	+0.08	0.028
.6512	11.15	-0.85	+0.09	0.057
.6713	11.01	-0.84	+0.10	0.074
.6918	10.93	-0.83	+0.08	0.091
.7307	10.81	-0.86	+0.05	0.124
47153.3314	10.95	-0.89	+0.05	0.458
.3856	11.05	-0.89	+0.06	0.503
.3883	11.05	-0.88	+0.04	0.505
.4133	11.03	-0.90	+0.09	0.526
.4369	11.00	-0.84	+0.08	0.546
.4592	10.93	-0.85	+0.09	0.564
.4883	10.89	-0.85	+0.10	0.589
.5175	10.82	-0.84	+0.10	0.613
.5637	10.76	-0.84	+0.09	0.651
.6251	10.70	-0.84	+0.08	0.703
.6751	10.68	-0.86	+0.08	0.744
.7092	10.70	-0.87	+0.07	0.773

Table 6: photoelectric measures of RRVI-51 observed at the Jungfraujoch with B and V filters of Geneva photometric system.

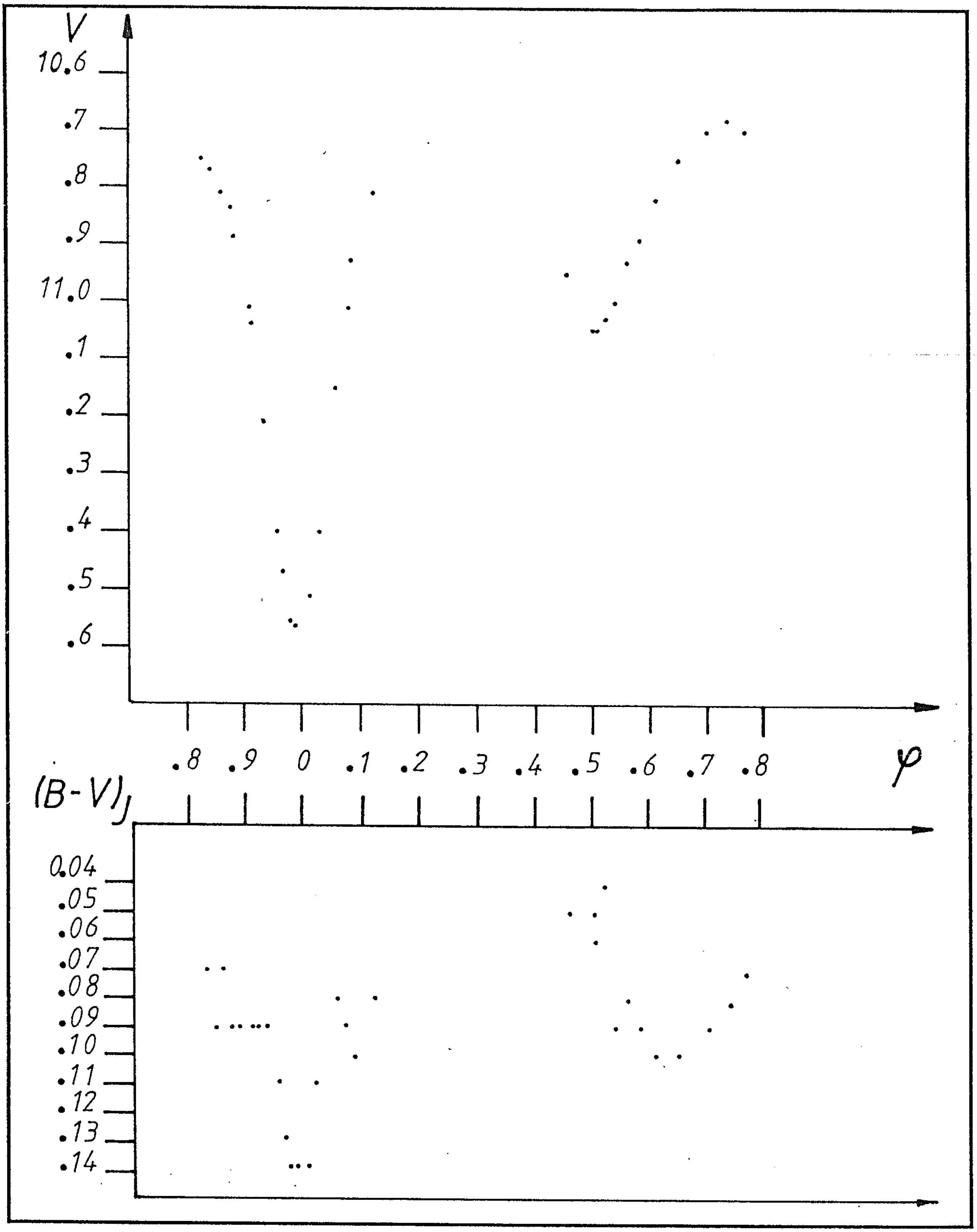


Fig 6: RRVI-51 photoelectric V and B mean light curve using ephemeris (2) of this paper.

This photoelectric primary minimum allows us now to determine the ephemeris with more precisision. A triple weight has been assign to the photoelectric minimum. The new ephemeris after regression becomes the following:

Min I: Hel J.D. 2442776.961 + 1.199839 E (3)

$\pm$. 7 . 5

(95% level of confidence for the error bands)

4. Conclusion.

- A first ephemeris is now available for RRVI-51. The 1.2 day period, the sinusoidal aspect of the star variation, the minima of different amplitudes and colour index variations are typical of EB stars.
- The photoelectric measures have allowed to check the ephemeris conceding a three times weight against visual minima and to present a preliminary model of the system itself. On the contrary, the photographic mean light curve of Kinman et al, which does not show any evidence of a secondary minimum, tends to back up the EA type. The imprecision of measures for a star beeing too bright for the instrument seems to be enough to explain this discrepancy.
- Considering the fact that 22 years are seperating the Kinman et al measures from Geos observations, the ephemeris of this paper seems already fairly good.
- More photoelectric measures would be very useful to complete the light curve and to compute an accurate model for the system.

5. Bibliography.

- T.D. Kinman, C.T. Manhaffey, C.A. Wirtanen (1982) Astronomical Journal 87(2), 314

- T.D. Kinman, an RR LYRAE survey with the Lick 20-inch astrograph. Methods of observation and reduction, Lick observatory, university of California, July 16, 1964.

- R. Boninsegna, (1984) GEOS NC 421

- R. Dequinze, (1984) GEOS NC 425

Robert Dequinze.