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GEOS
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RT URSAE MINORIS
AN ECLIPSING BINARY WITH VARIABLE PERIOD

ABSTRACT : RT UMi is an EA-type variable, discovered in 1958 by Strohmeier by means of photographic plates. Its most recent ephemeris was proposed by De Santis and Tempesti in 1977 :

Min I = JD 2 441 306, 290 2 + 1, 841 962 E

In this paper, by means of 40 times of minimum obtained visually by GEOS members, plus 22 times of minimum from photographic plates taken at Sonneberg Observatory, the following ephemeris has been found :

Min I = JD 2 441 306, 321 + 1, 841 973 5 E

Significant O-C values still result, so it follows that RT UMi has a variable period, on a time scale of several thousands of days. It is not possible to establish the type of period variation (whether erratic or periodic).

RESUME : RT UMi est une variable du type EA, découverte photographiquement par Strohmeier en 1958. Sa plus récente éphéméride fut proposée en 1977 par De Santis et Tempesti :

Min I = JD 2 441 306, 290 2 + 1, 841 962 E

Dans cet article, nous proposons l'éphéméride :

Min I = JD 2 441 306, 321 + 1, 841 973 5 E

obtenue à partir de 40 minimums observés visuellement par des membres du GEOS et de 22 minimums extraits de plaques photographiques de l'Observatoire de Sonneberg.
Il reste des O-C significatifs que nous interprètons par une variation de la période de RT UMi survenue sur des durées de plusieurs milliers de jours. Il est actuellement impossible de savoir si cette variation est périodique ou non.

RIASSUNTO : RT UMi e'una variabile di tipo EA, scoperta scoperta nel 1958 da Stohmeier per mezzo di osservazioni fotografiche. La piu' recente effemeride , proposta nel 1977 da De Santis e Tempesti, e' la seguente :

Min I = JD 2 441 306, 290 2 + 1, 841 962 E

In questo articolo, per mezzo di 40 istanti di minimo ottenuti visualmente da osservatori GEOS, ed ulteriori 22 minimi ottenuti da lastre fotografiche dell'Osservatorio di Sonneberg, viene proposta la seguente effemeride :

Min I = JD 2 441 306, 321 + 1, 841 973 5 E

Rimangono tuttavia significativi valori di O-C, dai quali si deduce che RT UMi possiede un periodo variabile, su scala temporale di diverse migliaia di giorni. Non e' possibile stabilire con certezza il tipo di variazione del periodo (se irregolare o periodica).

RESUMEN : *RT UMi es una variable de typo EA, descubierta fotográficamente en 1958 por Strohmeier. Su efeméride màs reciente fue propuesta en 1977 por De Santis y Tempesti :*

Min I = DJ 2 441 306, 290 2 + 1,841 962 E

En este articulo, proponemos la efeméride :

Min I = DJ 2 441 306, 321 + 1,841 973 5 E

obtenida a partir de 40 minimos observados visualmente por los miembros del GEOS, y de 22 minimos extraidos de las placas fotográficas del Observatorio de Sonneberg.
Se evidencian O-C significativos que interpretamos como consecuencia de una variacion del periodo de RT UMi en el transcurso de varios millares de dias. Actualmente resulta imposible saber si estas variaciones son o no periodicas.

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1. INTRODUCTION

RT UMi was discovered in 1958 by Strohmeier (1), by means of photographic plates taken from 1931 to 1956. The star was classified as an EA-type variable, and a first ephemeris was given :

Min I = 2 426 631, 320 + 1, 841 982 32 E (1)

The amplitude found was 11,1 - 11,9 p.

Next, in 1977, De Santis and Tempesti (2) observed the star by means of photoelectric measures, and revised its ephemeris as follows :

Min I = 2 441 306, 290 2 + 1, 841 962 E (2)
± 0, 000 4 ± 0, 000 010

They observed an amplitude of 10,79 - 11,47 V and confirmed the EA-type,finding a secondary minimum with an amplitude of 0,07 magnitude.

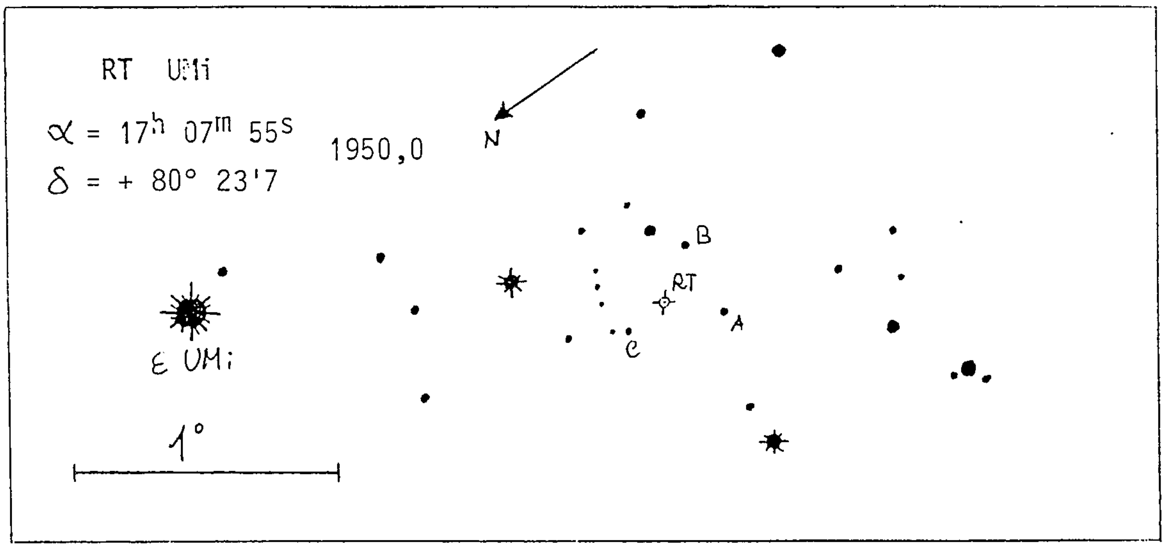
This star was enclosed in GEOS observing programme in 1981. Ralincourt (3) found relevant values of O-C with respect to both ephemerides, examining visual minima obtained by GEOS observers.

2. OBSERVATIONS

During the period 1981-1990, RT UMi was observed visually by GEOS members; some observations were made during GEOS observing camps. Estimates were made chiefly using Argelander method.

Fig. 1 shows RT UMi and its comparison stars. As their magnitudes are unknown, observations were plotted by an arbitrary scale based on Argelander degrees.
Some light curves obtained by visual observations are shown in fig. 2 and 3.
Light curves obtained during each night by each observer were carefully examined to find times of minimum. Exact times were determined graphically, by symmetry.
A total of 40 times of primary minimum was collected by 20 observers.
Tab. 1 lists all observers and their respective number of observed minima. Each observer is identified by a three-letter abbreviation. Five more minima were observed by a member of BAA (T. Brelstaff) (4), and one by a member of BBSAG (A. Paschke) (5).

Moreover, photographic plates taken at Sonneberg Observatory were examined by one of us (Dr. Berthold) in order to find old times of minimum during periods not covered by observations.
Four times of minimum were obtained for the period 1964-1970; each of them was deduced from a light curve composed by about 100 photographic observations.These minima have an uncertainty of about 0,001 day.

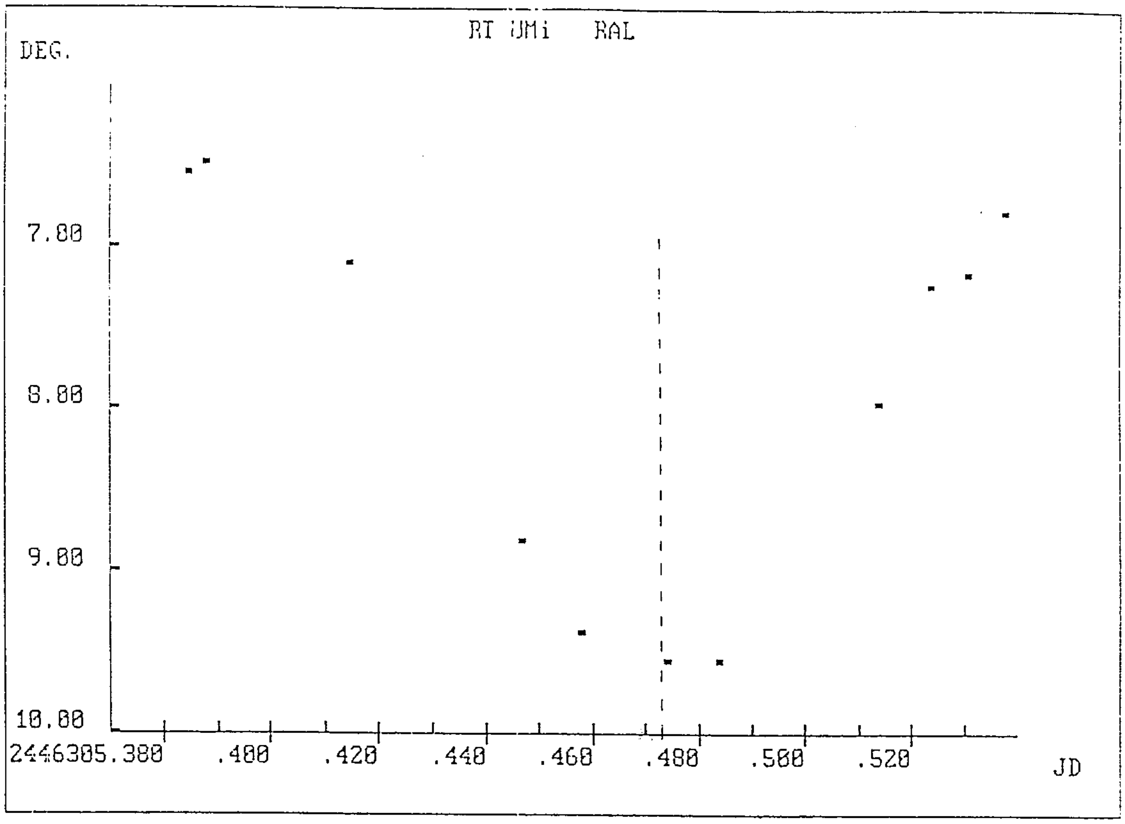


Ref. GEOS C91

Fig. 1 : RT UMi and its comparison stars.

Tab. 1

Observer	*site*	*abbrev.*	*n. of minima*
A. Maraziti	Catanzaro (I)	MRZ	6
S. Ferrand	Bougival (F)	FND	4
J. Vandenbroere	Bruxelles (B)	VBR	4
P. Ralincourt	Nantes (F)	RAL	3
G. Boistel	Sautron (F)	BTL	2
J. Busquets	Valencia (E)	BSQ	2
J. Fabregat	Valencia (E)	FBG	2
A. Figer	Paris (F)	FGR	2
A. Manna	Minusio (CH)	MAA	2
E. Nezry	Toulouse (F)	NZY	2
G. Nigro	Genova (I)	NGR	2
F. Acerbi	Codogno (I)	ACR	1
P. Baruffetti	Massa (I)	BFF	1
M. Benucci	Firenze (I)	BEN	1
D. Bertocchi	Genova (I)	BCC	1
A. Boattini	Firenze (I)	BOA	1
R. Boninsegna	Dourbes (B)	BNN	1
P. Guiraudou	Montpellier (F)	GUI	1
P. Matagne	Bruxelles (B)	MAT	1
M. T. Suadoni	Roma (I)	SDN	1



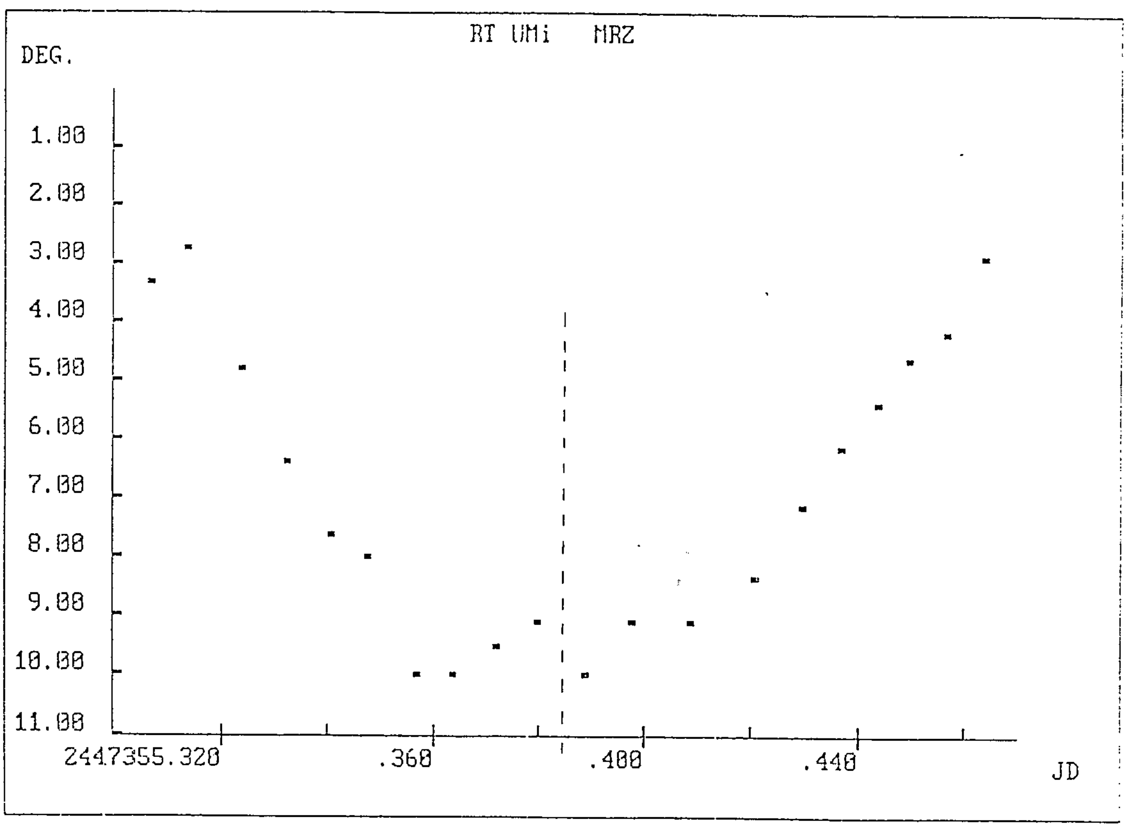


Fig. 2,3: Light curve obtained by observers RAL and MRZ. Each dot represents an individual estimate. Ordinate scale is in Argelander degrees. Time of minimum is indicated by a dashed line.

Eighteen more minima were collected for the period 1974-1982, but each of these minima was deduced from a single plate showing the star as very weak. For this reason, these times of minimum are less accurate than the other ones. In effect, Strohmeier's minima too, were taken from a single "weak plate".

3. ANALYSYS

Tab.2 shows all available observations of RT UMi. For each minimum, the type of observation (photographic-single plate, photographic-light curve, photoelectric, visual) is indicated. Column (1) and (2) show the O-C values with respect to the ephemerides (1) and (2). It is clear that none of these ephemerides agrees with available data. O-C values being too large to be explained as observing errors.

A linear ephemeris was computed by means of a least squares fit; in the calculations , photoelectric minima were weight 4, photographic minima taken from light curves were weighted 2, and all other observations were weighted 1.
This led to the following ephemeris :

$$\text{Min I} = 2\,441\,306{,}321 + 1{,}841\,973\,5\ E \qquad (3)$$
$$\pm\ 0{,}007 \quad \pm\ 0{,}000\,002\,2$$

(95% level of confidence for error bars)

Column (3) of tab.2 lists O-C values with respect to this ephemeris.
Fig. 4 shows all residual O-C with respect to ephemeris (3).
Different types of observations are individuated by different symbols. It can be noted that relevant O-C values still remain, but they are very scattered.
The standard deviation of O-C values is 0,038 day , a rather large value (about 1 h). In spite of this, the calculated ephemeris seems to be quite accurate; this is an effect of the very large time extent of the observations (more than 50 years).
The question thus arises whether these O-Cs are significant or can be justified by observational errors. Cause of the different nature of observations, separate analyses are required for each type of minimum.
Photographic "weak plates" show a large scatter of values, although positive and negative trends can be noted somewhere in the diagram (near E= -3000 and E = -1000). These differences, anyway, cannot be considered very reliable, even though they give an idea about the trend of O-Cs.
We decided to keep using these minima for the following analysis, because they extend over a very long time span, and can give an idea about the behaviour of the star during the past sixty years, although their accuracy is not very good.
Minima from photographic curves are surely more reliable. Residual O-Cs are rather large and can be considered significant.
Photoelectric minima are the most accurate, and the residual O-C are too large to be justified by observational errors.
Visual minima are also scattered, but much less than photographic "weak plates". From our experience in analysing visual observations, we are led to the conclusion that residual O-C values can be considered real.

To achieve a more quantitative analysis, mean O-C values (averaged on intervals of 200 E, that correspond to about one year) are shown in fig.5, with their respective error bars (calculated at $\pm 3\sigma$). It appears that photoelectric and photographic-curve O-Cs do not agree with the linear ephemeris (3). Visual minima relevant to some years too, display O-C values larger than their error bars.
Thus, we are led to the conclusion that a linear ephemeris cannot fit observed minima, and that RT UMi has a variable period. A variation of period was supposed by De Santis and Tempesti, too (2), but their data were insufficient to establish it.

Observations are consistent with a slow variation on a time scale of several thousands of days, with an amplitude of about 0,04 d.
It is not easy to say whether this variation is erratic or periodic. At a first glance an erratic variation seems to be more probable, but also a sinusoidal variation appears to be possible.

Tab. 2

observer	type	min. Jd hel. 2400000+....	E	(1)	(2)	(3)
Strohmeier	pg	26631.3170	-7967	-0.003	-0.062	-0.001
Strohmeier	pg	26767.6590	-7893	0.032	-0.025	0.035
Strohmeier	pg	26863.4170	-7841	0.007	-0.049	0.010
Strohmeier	pg	27596.5260	-7443	0.007	-0.041	0.014
Strohmeier	pg	28250.4900	-7088	0.068	0.026	0.077
Strohmeier	pg	28309.4550	-7056	0.089	0.049	0.099
Strohmeier	pg	28423.5570	-6994	-0.012	-0.051	-0.001
Strohmeier	pg	28425.3560	-6993	-0.055	-0.094	-0.044
Strohmeier	pg	28425.4080	-6993	-0.003	-0.042	0.008
Strohmeier	pg	28460.3370	-6974	-0.071	-0.110	-0.061
Strohmeier	pg	29077.4290	-6639	-0.044	-0.075	-0.030
Strohmeier	pg	29112.4210	-6620	-0.049	-0.081	-0.036
Strohmeier	pg	29195.4400	-6575	0.081	0.050	0.095
Strohmeier	pg	29313.2670	-6511	0.021	-0.009	0.035
Strohmeier	pg	30254.4830	-6000	-0.016	-0.035	0.003
Strohmeier	pg	34662.3830	-3607	0.020	0.050	0.060
Strohmeier	pg	35314.4060	-3253	-0.019	0.018	0.025
Strohmeier	pg	35699.4100	-3044	0.011	0.052	0.056
Strohmeier	pg	37399.5390	-2121	-0.010	0.050	0.044
Berthold	pg curve	38567.2920	-1487	-0.073	-0.001	-0.014
Berthold	pg curve	39136.4570	-1178	-0.081	-0.002	-0.019
Berthold	pg curve	39707.4540	-868	-0.098	-0.013	-0.034
Berthold	pg curve	40464.4890	-457	-0.118	-0.025	-0.050
De Santis	pe	41306.2902	0	-0.103	0.000	-0.031
De Santis	pe	41713.3706	221	-0.101	0.007	-0.027
De Santis	pe	41829.4064	284	-0.110	-0.001	-0.035
De Santis	pe	42017.2869	386	-0.111	-0.001	-0.036
Berthold	pg	42448.3830	620	-0.039	0.076	0.038
Berthold	pg	42658.3540	734	-0.054	0.064	0.024
Berthold	pg	42717.2430	766	-0.109	0.010	-0.030
Berthold	pg	42840.6280	833	-0.136	-0.017	-0.057
Berthold	pg	42960.4460	898	-0.047	0.074	0.033
Berthold	pg	43078.2960	962	-0.084	0.038	-0.003
Berthold	pg	43273.4860	1068	-0.144	0.020	-0.063
Berthold	pg	43400.5760	1137	-0.151	-0.025	-0.069
Berthold	pg	43483.4500	1182	-0.166	-0.039	-0.084
Berthold	pg	43575.6350	1232	-0.080	0.048	0.003
Berthold	pg	43577.4090	1233	-0.148	-0.020	-0.065
Berthold	pg	43579.3060	1234	-0.093	0.035	-0.010
Berthold	pg	43892.3460	1404	-0.190	-0.059	-0.106
Berthold	pg	44146.5700	1542	-0.160	-0.026	-0.074
Berthold	pg	44170.5780	1555	-0.098	0.037	-0.012
[illegible]thold	pg	44590.6070	1783	-0.04[illegible]	0.099	0.047
[illegible]thold	pg	44662.3500	1822	-0.13[illegible]	0.005	-0.047

observer	type	min. Jd hel. 2400000+....	E	(1)	(2)	(3)
Brelstaff	v	44813.4210	1904	-0.106	0.035	-0.018
FBG	v	44813.4430	1904	-0.084	0.057	0.004
FGR	v	44813.4440	1904	-0.083	0.058	0.005
RAL	v	44813.4520	1904	-0.075	0.066	0.013
BSQ	v	44813.4630	1904	-0.064	0.077	0.024
MAT	v	44813.4710	1904	-0.056	0.085	0.032
NZY	v	44813.4980	1904	-0.029	0.112	0.059
Brelstaff	v	44977.3800	1993	-0.084	0.060	0.006
Brelstaff	v	45012.3650	2012	-0.097	0.047	-0.007
Berthold	pg	45082.3490	2050	-0.108	0.037	-0.018
BNN	v	45174.4390	2100	-0.117	0.029	-0.026
FGR	v	45174.4540	2100	-0.102	0.044	-0.011
BEN	v	45174.4590	2100	-0.097	0.049	-0.006
FBG	v	45174.4590	2100	-0.097	0.049	-0.006
RAL	v	45174.4620	2100	-0.094	0.052	-0.003
FND	v	45174.4690	2100	-0.087	0.059	0.004
GUI	v	45174.4750	2100	-0.081	0.065	0.010
BSQ	v	45174.4770	2100	-0.079	0.067	0.012
FND	v	45559.4070	2309	-0.123	0.027	-0.031
BFF	v	45559.4260	2309	-0.104	0.046	-0.012
NZY	v	45559.4280	2309	-0.102	0.048	-0.010
Brelstaff	v	45815.4820	2448	-0.084	0.069	0.010
BTL	v	45909.4470	2499	-0.060	0.094	0.034
FND	v	45909.4590	2499	-0.048	0.106	0.046
Brelstaff	v	45931.5140	2511	-0.097	0.057	-0.002
BTL	v	46270.4780	2695	-0.057	0.100	0.038
RAL	v	46305.4710	2714	-0.062	0.096	0.034
FND	v	46631.5080	2891	-0.056	0.106	0.042
MRZ	v	46994.3710	3088	-0.064	0.102	0.036
NGR	v	47005.4100	3094	-0.076	0.089	0.023
MRZ	v	47005.4210	3094	-0.065	0.100	0.034
BOA	v	47005.4250	3094	-0.061	0.104	0.038
MAA	v	47005.4280	3094	-0.058	0.107	0.041
BCC	v	47005.4280	3094	-0.058	0.107	0.041
SDN	v	47005.4300	3094	-0.056	0.109	0.043
ACR	v	47005.4350	3094	-0.051	0.114	0.048
MRZ	v	47353.5420	3283	-0.079	0.091	0.022
MRZ	v	47355.3850	3284	-0.078	0.092	0.023
MRZ	v	47379.3480	3297	-0.061	0.109	0.040
MAA	v	47390.3680	3303	-0.093	0.077	0.009
NGR	v	47390.3820	3303	-0.079	0.091	0.023
MRZ	v	47390.3820	3303	-0.079	0.091	0.023
Paschke	v	47401.4400	3309	-0.073	0.098	0.029
VBR	v	47762.4870	3505	-0.054	0.120	0.049
VBR	v	47773.5210	3511	-0.072	0.102	0.031
VBR	v	47983.4970	3625	-0.082	0.095	0.022
VBR	v	48123.5030	3701	-0.067	0.111	0.038

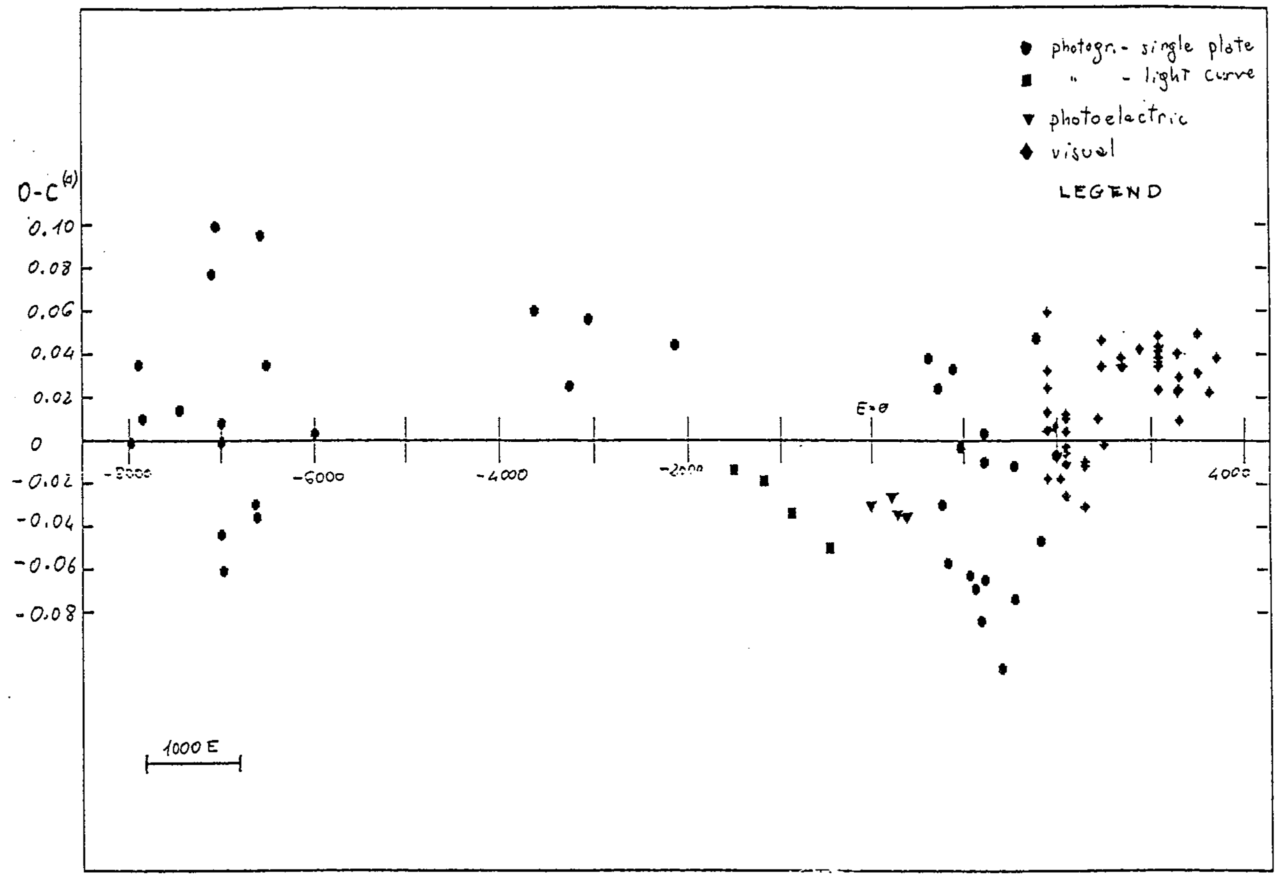


Fig. 4: O-C diagram.Different types of observation are indicated by different symbols (see legend).

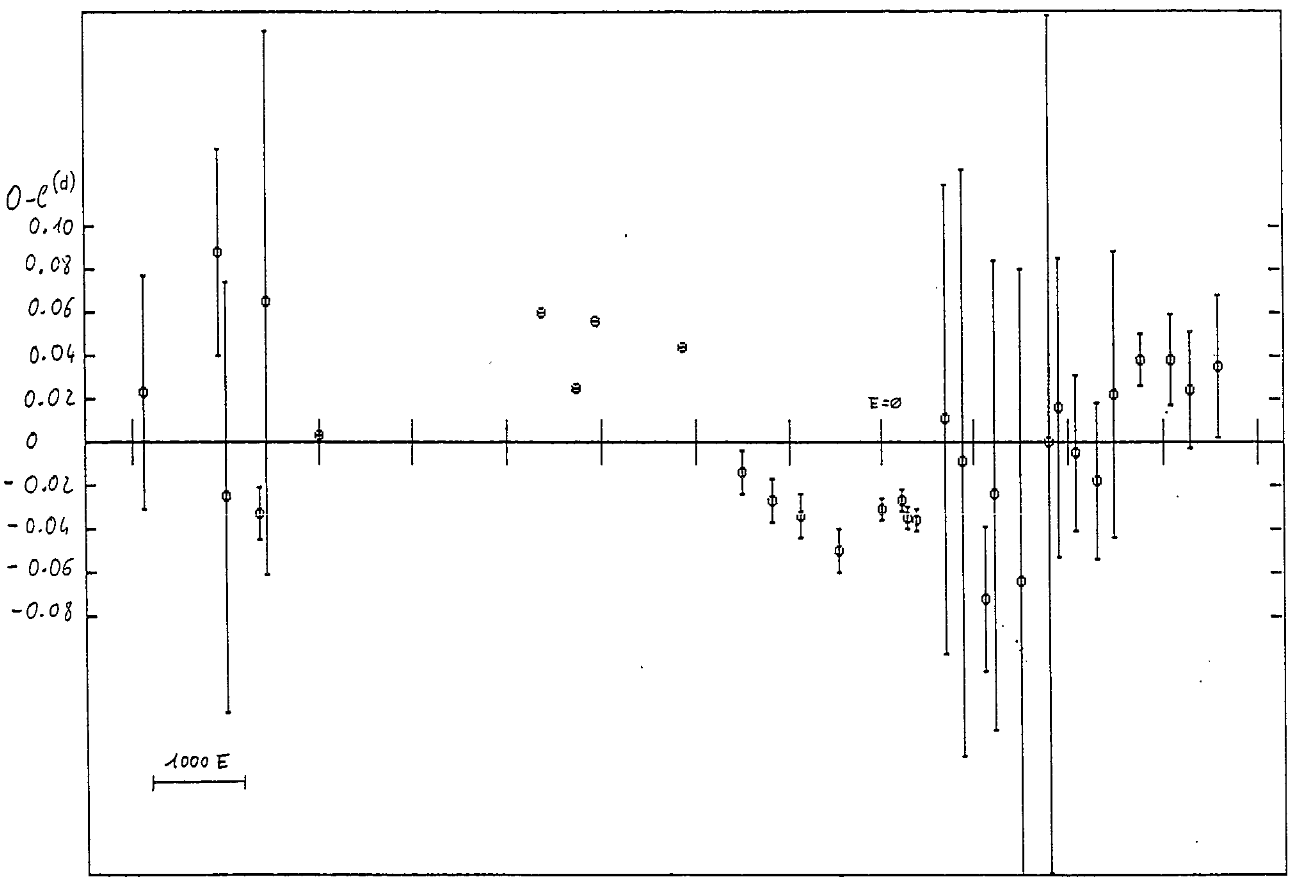


Fig. 5: Mean O-C diagram. Dots with no error bar shown represent single measures (i. e. not averaged).

A sinusoïdal period variation might be caused by the presence of a third orbiting star, while an erratic variation might be the result of mass exchange phenomena between the two stars.

Anyway, even though the trend of O-Cs in the past 25 years (5000 E) is well documented, it is not possible to establish the kind of period variation, due to the lack of precision of earlier photographic observations.
The fact that RT UMi has a variable period, on the other hand, is clearly demonstrated by all available observations. Further observations, in the future, will be useful to follow the evolution of O-Cs.

4. CONCLUSION

In this paper, all available observations of the eclipsing binary RT UMi (photoelectric, photographic and visual) have been analysed. A linear ephemeris was computed :

$$\text{Min I} = 2\,441\,306,321 + 1,841\,973\,5\ E \qquad (3)$$
$$\pm\ 0,007 \quad \pm\ 0,000\,002\,2$$

(95% level of confidence for error bars).

Relevant O-C values still remain with respect to this ephemeris; this is explained assuming a variable period for the star. The time scale of the variation of O-Cs is around 10 000 days, while its amplitude is about 0,04 d.
It is not possible to tell whether this variation is erratic or periodic.

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