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WY GEM : A NEW SEMI-REGULAR VARIABLE WITH A PERIOD OF 169 DAYS

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ABSTRACT - An analysis of 557 visual observations made by 12 GEOS observers, together with a series of 70 photoelectric UBV measures made by BARTOLINI and al. at the Osservatorio Astronomico Universitario di Bologna has shown that WY Gem varies in brightness with a period of 169 days. The derived ephemeris is : MAX = J.D. 24 41 593 + 168.5 E .
The characteristics of the light-curve (amplitude and period) are consistent with an SRb type.

Analysis of the colour indices confirms previous evidence for the existence of a companion star of spectral type B 0-5 and less bright than the red giant. The difference of magnitude ΔMV is between 2.7 and 3.3 Mag. . From the UBV measures, it is also established that the red giant alone (sp. M2epIab) varies in brightness.

RESUMEN - WY GEM : UNA NUEVA SEMIREGULAR CON PERIODO DE 169 DIAS . El análisis de 557 observaciones visuales de 12 observadores de GEOS, junto a la aportación de 70 medidas foto eléctricas en UBV hechas por BARTOLINI en el Observatorio Astronómico Universitario de Bolonia, ha permitido determinar la variabilidad de WY Gem, con un periodo de 169 días. La efeméride encontrada es :
MAX = J.D. 24 41 593 + 168.5 E . Las características de la curva de luz (amplitud y periodo) son compatibles con una clasificación del tipo SRb .

El análisis de los índices de color confirma la presencia de una estrella de tipo espectral B 0-5 , menos luminosa, compañera de la gigante roja. El ΔMV entre las dos estrellas está comprendido entre 2.7 y 3.3 Mag . Las medidas en UBV evidencian que la variabilidad de WY Gem debe atribuirse solo a la gigante roja, de espectro M2epIab .

RESUME - WY GEM : UNE NOUVELLE ETOILE SEMI-REGULIERE DE PERIODE 169 JOURS . L'analyse des 557 estimations visuelles de 12 observateurs du GEOS, auxquelles s'ajoutent les 70 mesures photoélectriques UBV effectuées par BARTOLINI et al. à l'Observatoire Astronomique de l'Université de Bologne, a permis de mettre en évidence la variabilité, périodique en 169 jours, de WY Gem, avec pour éphéméride :
MAX = J.J. 24 41 593 + 168.5 E . Les caractéristiques de la courbe de lumière (amplitude et période) sont compatibles avec la classification comme SRb .

L'analyse des indices de couleur confirme l'existence d'une étoile - compagnon de type spectral B 0-5 , moins lumineuse que la géante rouge. La différence d'éclat entre les deux étoiles est comprise entre 2.7 et 3.3 mag . Les mesures UBV permettent en outre d'établir avec certitude que la variabilité de WY Gem est dûe à la seule géante rouge de spectre M2epIab .

RIASSUNTO - WY GEM : UNA NUOVA SEMIREGOLARE CON PERIODO DI 169 GIORNI . L'analisi di 557 osservazioni visuali di 12 osservatori GEOS, unitamente all'apporto di 70 misure fotoelettriche in UBV fatte da BARTOLINI e al. all'Osservatorio Astronomico Universitario di Bologna, ha permesso di individuare in WY Gem una variabilità con periodo di 169 giorni. L'effemeride trovata è :
MAX = G.G. 24 41 593 + 168.5 E . Le caratteristiche delle curve di luce (ampiezza e periodo) sono compatibili con una classificazione del tipo SRb .

L'analisi degli indici di colore riconferma la presenza di una stella di tipo spettrale B 0+5 compagna meno luminosa della gigante rossa. Il ΔMV fra le due stelle è compreso fra 2.7 e 3.3 Mag. . Dalle misure in UBV è inoltre sicuro che la variabilità di WY Gem deve essere attribuita solo alla gigante rossa, di spettro M2epIab .

1. INTRODUCTION

WY Gem (HD 42 474, BD + 23° 1243) is a 7th-magnitude star catalogued in the GCVS (1976) as an Lc , 8.94 - 9.8 B , Sp. M2epIab + B2 V , the reference being WAWRUKIEWICZ and LEE (1974).

The best and most recent study of WY Gem is that of MARTINI (1969). This wide and thorough discussion of the star spectrum, from observations of 1967-1968, brought new evidence in support of the hypothesis of SWING and STRUVE (1940) and BIDELMANN (1954) of an unresolved double star with a composite spectrum (M2epIab + B3). First, MARTINI noted a moderately variable radial velocity and reconfirmed the presence of the forbidden lines of [Fe II] in emission which had been observed by the authors mentioned above. Then MARTINI proposed for WY Gem the model of a VV Cep

system with possible eclipses between the components. COWLEY (1969) must also be mentioned as regards the determination of the colour indices and spectra of the components (M2epIab + B2). Lastly, it is of importance to mention the fact that the star appears in the Catalogue of magnetic stars with a variable field higher than ± 500 gauss (BABCOCK,1958).

GEOS observers initiated a systematic patrol on the star from the fall of 1973 to the spring of 1977, as part of a long-term campaign of observation of irregular variables. For the present study, measures previously made by FIGER in 1971 and 1972 have also been included. Finally, a total of 557 estimates made by 12 observers have been used.

A most invaluable collaboration with the Osservatorio Astronomico Universitario di Bologna has moreover led to a reciprocal confrontation and complementation of information on the star. The photoelectric measures have fully confirmed the reliability of the visual light curve and provided useful information on the colour indices of WY Gem.

2. PROCESSING OF THE VISUAL ESTIMATES

All the visual observations have been made using the method of Argelander. The comparison stars are given in Tab.1 . It is important to note that the presence of a B9 star in the sequence (comparison D) did not alter the consistency of the series of estimates, mainly because the brightness of WY Gem varied around or below that of comparison E .

Tab. 1 - Visual sequence of comparison

Star	BD	HD	Sp	Mv
C	+22°1198	42049	K2	6.0
D	+23°1232	42216	B9	6.7
E	+22°1180	41710	G5	7.3
F	+23°1216	41830	G5	8.1
WY	+23°1243	42474	M2+B	var

The measures have mostly been processed by computer, using the CDC CYBER 70/76 at C.I.N.E.C.A.(Casalecchio,BO, Italy).

The method of processing has been widely and successfully used in other studies by GEOS and the ALCEP programme has been used for the computerized version of this method.

Tab.2 - List of the GEOS observers

Name	Place	Instruments	tot. N	n ΔM σ	n ΔM σ	n ΔM σ	n ΔM σ
A.Figer	Paris (F)	B40 (8x)	122(+)	28 .06 .05	16 .05 .04		
E.Poretti	Arconate (I)	B50 (12x)	96			96 -.05 .09	
J.Vialle	La Rochelle (F)	B50 (7x)	78	9 -.01 .10	34 .01 .08	27 .32 .13	
		R60 (12x)					8 -.08 .12
J.F.Le Borgne	Toulouse (F)	B50 (8x)	67			14 .27 .15	41 .26 .05
		R30 (7x)			12 -.36 .11		
Ph.Ralincourt	Nantes (F)	B50 (7x)	62		46 .12 .08	12 .35 .11	
		R60		4 -.09 .29			
G.Troispoux	Fleury-les-Aubrais (F)	B50 (10x)	43			43 -.28 .08	
A.Buzzoni	Ferrara (I)	R40 (45x)	19		6 .04 .08	2 -.16 .04	11 -.13 .06
M.Franchini	Cerro Magg. (I)	B70 (20x)	16				16 -.17 .09
P.Guiraudou	Montgeron (F)	B50 (10x)	16			14 .13 .19	2 .10 .04
J.C.Misson	Paris (F)	B50 (7x)	16			16 .12 .09	
C.Agnesoni	Siena (I)	B30 (10x)	12				12 .01 .04
J.Remis	Aix-en-Prov.(F)	B50 (7x)	10				10 -.34 .02
			557	1973/74	1974/75	1975/76	1976/77

(+) This computation include the 78 observations made in 1971/72

B = Binoculars
R = Refractor

The algorithm enables a most probable light curve to be obtained, through an iterative routine, identifying for each observer random (σ) and systematic (ΔM) error and correcting the latter component (cf. Tab. 2). It must be emphasized that the process does not seek to assess the causes of the error but rather their effect (1). For further information on the method, the reader is referred to FIGER and REMIS (1978).

The mean error on the estimates (excluding systematic causes) for the average observer of WY Gem was $\simeq$ 0.08 mag.

3. PROCESSING OF THE PHOTOELECTRIC MEASURES

C. BARTOLINI , G. MADAMA and A. PICCIONI using the 60 cm reflector at Loiano have collected 70 measures of WY Gem in 3 colours (UBV), between 1973 and 1977. Though their number is in itself not enough to define the general trend of the light curve, these measures have however been quite useful as they helped assessing the reliability of the visual light curve obtained by GEOS. As a matter of fact, the photoelectric variation in brightness agrees with the visual light curve. When combining the V measures and the visual ones, the systematic difference between the V filter (transmission peak at 5480 Å) and the average human eye (transmission peak at 5100 Å for a dark-adapted eye) has been taken into account. The systematic ΔM (= Mv - MV) has been calculated and corrected for each year by comparing points common to both visual and photoelectric series. This gave the following results :

1973/74	(2 points in common)	$\Delta M = +0.28 \pm 0.02$ mag
1974/75	(5 points in common)	$\Delta M = +0.24 \pm 0.02$ mag
1975/76	(1 point in common)	$\Delta M = +0.06 \pm 0.09$ mag
Mean value (1973/76)		$\Delta M = +0.23 \pm 0.07$ mag

Tab. 3 - V observations

J.D. 42000.+	nb	MV	Mv	B-V	<v-V>
030	3	7.44	7.72	1.53	.28±.02
044	4	7.36	7.64	1.56	.28 "
045	6	7.43	7.71	1.50	.28 "
087	7	7.23	7.51	1.64	.28 "
114	3	7.20	7.48	1.57	.28 "
119	4	7.18	7.46	1.58	.28 "
121	2	7.19	7.47	1.58	.28 "
318	4	7.33	7.57	1.55	.24 "
346	3	7.33	7.57	1.37	.24 "
363	2	7.35	7.59	1.55	.24 "
391	4	7.27	7.51	1.56	.24 "
451	2	7.23	7.47	1.60	.24 "
463	10	7.32	7.56	1.55	.24 "
466	1	7.41	7.65	1.59	.24 "
467	6	7.35	7.59	1.47	.24 "
731	5	7.22	7.28	-	.06±.09
787	4	7.17	7.23	1.59	.06 "
	70			<1.55> ±.06	

(1) For the observations by A. FIGER (1971-1972, see fig. 5-6) and these observations only, it was not possible to estimate the random and systematic errors.

Tab.4 - 1973/74

J.D. 2441000.+	±d	n	W	mag.	Sigma
953.0	1.7	4	1578	7.50	.03
963.0	2.1	4	1578	7.43	.03
985.6	4.2	3	1183	7.46	.03
1009.3	3.9	5	1972	7.51	.02
1031.6	13.5	3	1183	7.59	.03
1060.3	5.0	1	395	7.52	.05
1070.3	5.0	2	504	7.56	.04
1080.3	5.0	2	504	7.53	.04
1090.3	5.0	6	2082	7.53	.02
1100.3	5.0	2	504	7.48	.04
1150.3	5.0	6	463	7.58	.05
1160.3	5.0	3	134	7.60	.09
		41	<1007>		<.03>

Tab.5 - 1974/75

J.D. 2442000.+	±d	n	W	mag.	Sigma
312.3	0.0	2	1200	7.54	.03
368.3	6.4	2	735	7.64	.04
393.8	3.5	4	1506	7.47	.03
400.8	3.5	12	3227	7.46	.02
407.8	3.5	10	5072	7.44	.01
414.8	3.5	4	599	7.40	.04
421.8	3.5	7	1041	7.44	.03
428.8	3.5	7	380	7.39	.03
435.8	3.5	4	612	7.41	.04
442.8	3.5	4	645	7.39	.04
449.8	3.5	9	1316	7.47	.03
456.8	3.5	7	1007	7.58	.03
463.8	3.5	6	919	7.61	.03
470.8	3.5	5	704	7.60	.04
477.8	3.5	5	635	7.70	.04
484.8	3.5	3	442	7.70	.05
491.8	3.5	4	485	7.67	.05
498.8	3.5	1	136	7.75	.09
505.8	3.5	1	136	7.81	.09
512.8	3.5	3	395	7.58	.05
519.8	3.5	1	170	7.60	.08
526.8	3.5	1	170	7.60	.08
533.8	3.5	12	1903	7.76	.02
		114	<1041>		<.03>

W is the statistical weight of the normal.
Sigma = $1/\sqrt{W}$

Tab.6 - 1975/76

J.D. 2442000.+	±d	n	W	mag.	Sigma
739.8	2.5	4	521	7.00	.04
744.8	2.5	3	329	7.16	.06
749.8	2.5	8	794	7.11	.04
754.8	2.5	4	397	7.14	.05
759.8	2.5	6	788	7.12	.04
764.8	2.5	2	328	7.09	.06
769.8	2.5	4	493	7.00	.05
774.8	2.5	8	1076	7.22	.03
779.8	2.5	12	1426	7.17	.03
784.8	2.5	11	1309	7.19	.03
789.8	2.5	1	130	7.23	.09
794.8	2.5	1	112	7.37	.09
799.8	2.5	7	662	7.34	.04
804.8	2.5	17	1774	7.31	.02
809.8	2.5	4	372	7.31	.05
814.8	2.5	2	276	7.31	.06
819.8	2.5	3	365	7.32	.05
824.8	2.5	1	112	7.44	.09
829.8	2.5	7	781	7.32	.04
834.8	2.5	16	1818	7.40	.02
839.8	2.5	24	3676	7.46	.02
844.8	2.5	8	773	7.52	.04
849.8	2.5	3	493	7.55	.05
854.8	2.5	6	816	7.55	.04
859.8	2.5	1	68	7.50	.12
864.8	2.5	19	1858	7.58	.02
869.8	2.5	16	1648	7.70	.02
874.8	2.5	6	661	7.57	.04
879.8	2.5	4	555	7.44	.04
884.8	2.5	6	769	7.49	.04
889.8	2.5	6	794	7.41	.04
894.8	2.5	1	164	7.45	.08
899.8	2.5	3	344	7.44	.05
		224	<803>		<.04>

Tab.7 - 1976/77

J.D. 2443000.+	±d	n	W	mag.	Sigma
093.8	3.5	3	795	7.49	.04
100.8	3.5	4	1524	7.55	.03
107.8	3.5	12	4397	7.51	.02
114.8	3.5	1	600	7.48	.04
121.8	3.5	6	2930	7.48	.02
128.8	3.5	15	3225	7.57	.02
135.8	3.5	7	1855	7.64	.02
142.8	3.5	3	860	7.57	.03
149.8	3.5	2	1173	7.52	.03
156.8	3.5	9	2933	7.55	.02
163.8	3.5	12	4148	7.59	.02
170.8	3.5	4	2290	7.62	.02
177.8	3.5	2	196	7.49	.07
184.8	3.5	2	196	7.63	.07
191.8	3.5	3	769	7.75	.04
198.8	3.5	10	1444	7.70	.03
205.8	3.5	1	330	7.75	.06
213.0	2.9	3	759	7.80	.04
245.3	0.0	1	331	7.59	.05
		100	<1618>		<.02>

W is the statistical weight of the normal.
Sigma = $1/\sqrt{W}$

Tab. 4 to 7 - Lists of the normal v points of WY Gem in 1973/74 , 1974/75 , 1975/76 , 1976/77 .

4. RESULTS OF OBSERVATIONS

By combining the visual light curve and the photoelectric measures, it has been possible to bring into evidence a cyclic variation of WY Gem with a period of about 169 days. It has also been possible to derive four different ephemerides according to the elements used :

(1) Max = J.D. 24 41 610 + 166.1 E (observed maxima only)
± 21 ± 9.4

(2) Min = J.D. 24 41 688 + 169.2 E (observed minima only)
± 27 ± 8.3

(3) Max = J.D. 24 41 605 + 168.1 E (all maxima and minima; assumed phase for the minimum : 0.5)
± 12 ± 4.2

(4) Max = J.D. 24 41 593 + 168.5 E (all maxima and minima; assumed phase for the minimum : 0.6)
± 11 ± 2.8

(All error bars have been calculated for the 95 % confidence level) .

It is evident that ephemeris (4) accounts best for the observed results: Tab. 8 lists the O-C's for all observed maxima and minima. The values are perfectly consistent with the hypothesis that WY Gem could be a semiregular variable as, for stars of this type, variations of $\Delta P/P = 0.15$ are quite normal.

It is of interest to note a definite systematic trend of the O-C's over a period of a few years. Other and more numerous observations in the years to come would help prove this trend.

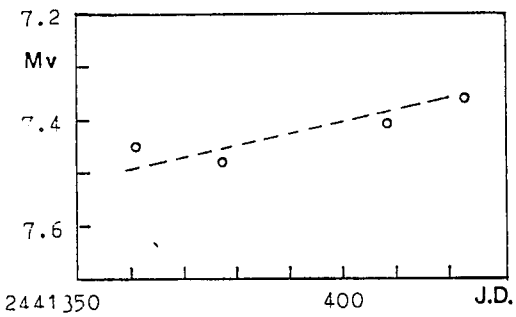

Fig.1 - WY Gem in 1972
(Figer's measures only)

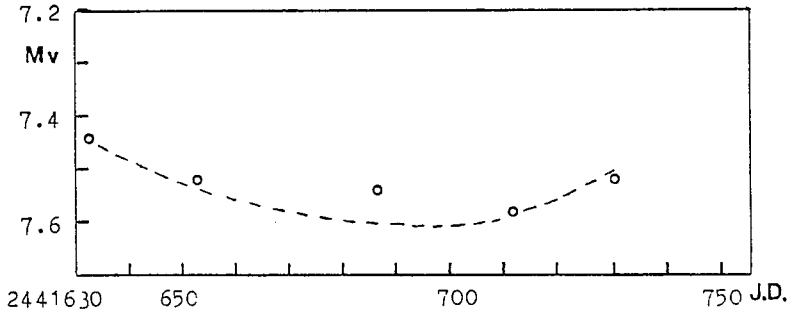

Fig.2 - WY Gem in 1972-73
(Figer's measures only)

Tab. 8 - Observed extrema

J.D.	E	$(O-C)^d$	Type
41690	0.6	- 4	Min
42040	2.6	+ 9	Min
42115	3.0	+16	Max
42435	5.0	- 0	Max
42508	5.6	-29	Min
42765	7.0	- 8	Max
42870	7.6	- 4	Min
43112	9.0	+ 2	Max
43225	9.6	+14	Min

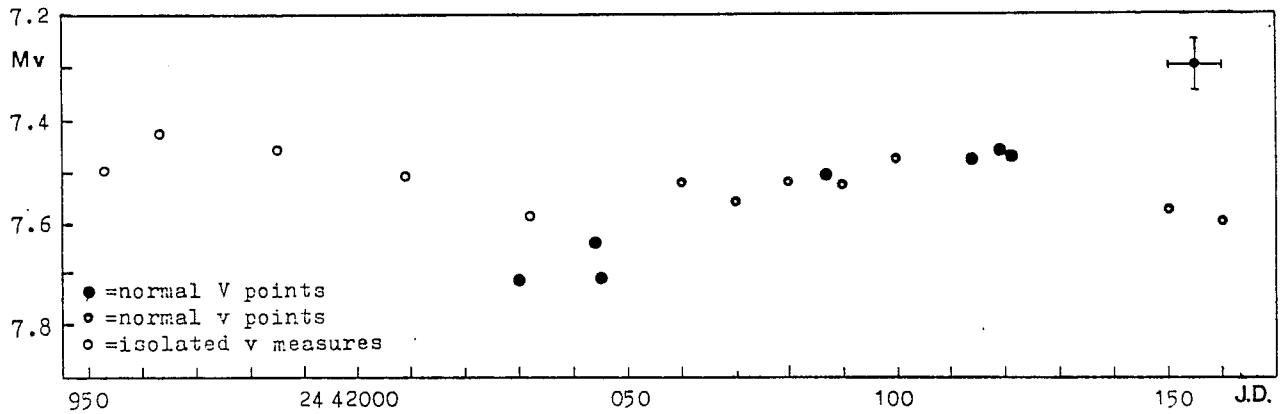

Fig.3 - WY Gem in 1973-74. (Top right, mean error bar for normal v points)

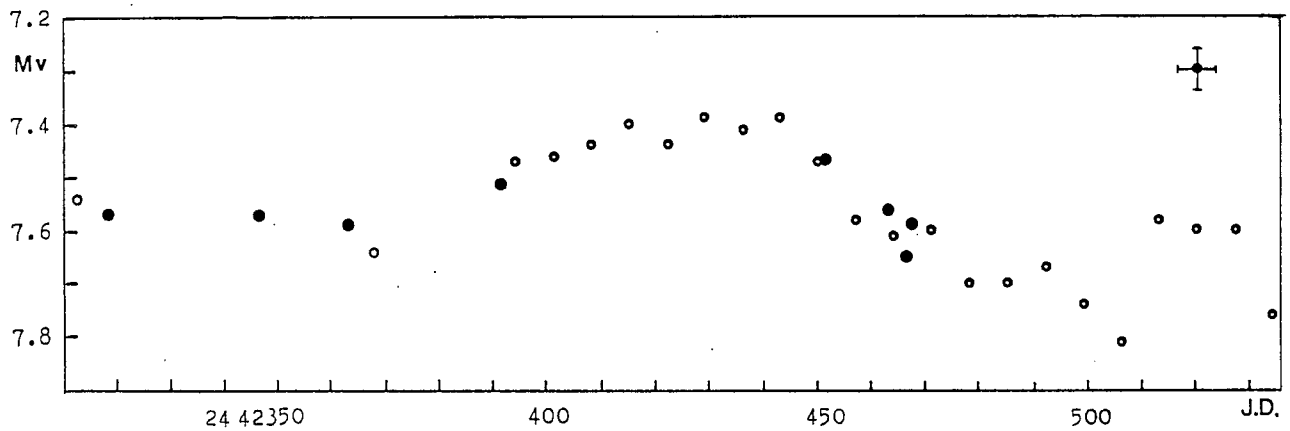

Fig.4 - WY Gem in 1974-75

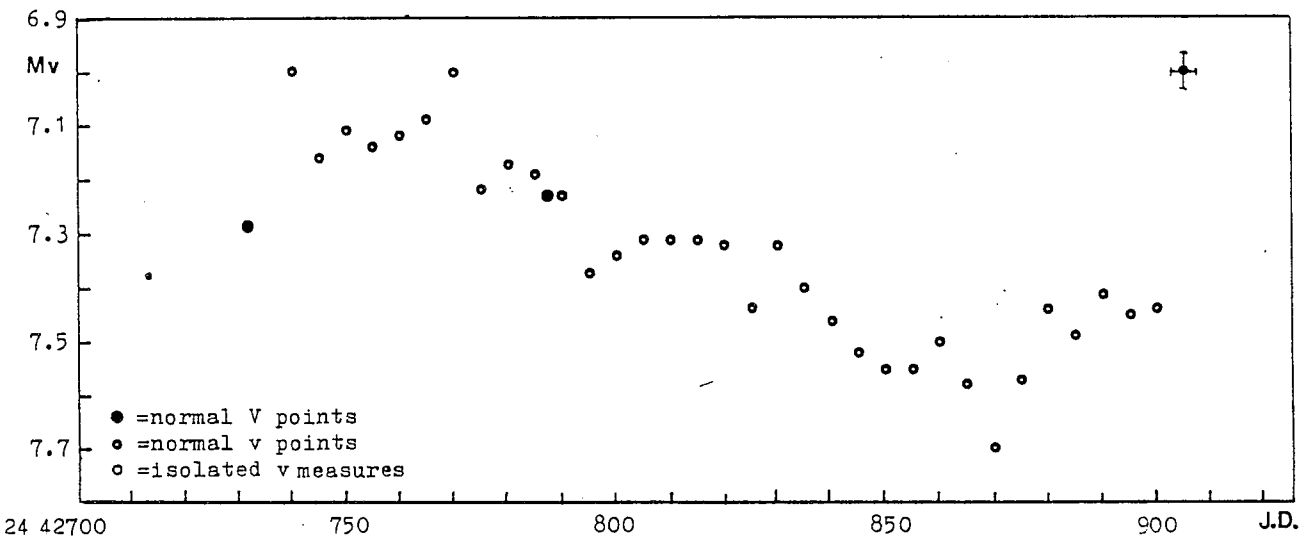

Fig.5 - WY Gem in 1975-76. (Top right, mean error bar for normal v points)

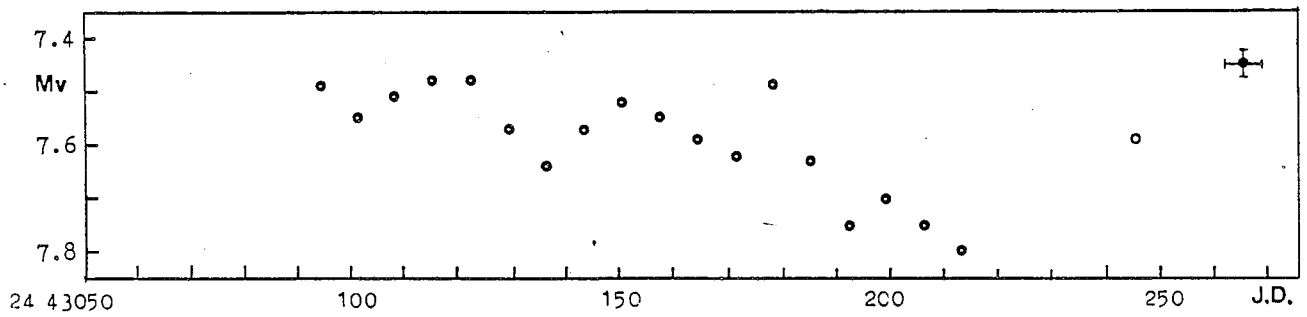

Fig.6 - WY Gem in 1976-77

It is also possible to draw some other interesting conclusions. Photoelectric UBV results (and visual observations) confirm the existence of an unresolved companion for the brighter red supergiant M2epI .

Let the theoretical values for the colour indices of the main component be : $\langle B-V\rangle = 2.0$ $\langle U-B\rangle = 1.8$. (5)
The problem is then to determine which spectral distribution of the flux from the companion can account for the integrated indices observed by BARTOLINI and al., i.e.:
$\langle B-V\rangle = 1.55$ $\langle U-B\rangle = 0.3$.

Let then ℓ be the luminosity of the companion and L that of the red supergiant. Suffixes U , B and V are used according to the colour considered.
For the observed values of the colour indices :

$$\left\{ \frac{\ell_B + L_B}{\ell_V + L_V} = 0.240 \qquad \frac{\ell_U + L_U}{\ell_B + L_B} = 0.759 \right\}$$

hence : $$\ell_U + L_U = 0.182\,(\ell_V + L_V)$$

Admitting the theoretical values given in (5), this becomes :

$$L_U = 0.033\, L_V$$

which leads to tabulating the function :

$$\frac{\ell_U}{\ell_V} = 0.182 + 0.149\,\frac{L_V}{\ell_V}$$

Tables 9 and 10 list the possible solutions according to the spectral class of the companion and the difference in magnitude ΔM of both components.

Tab. 9 - ΔM - Spectrum relation for WY Gem

Spectrum (M2epI +)	ΔMV	ΔMB	ΔMU
B0	3.34	1.17	-1.74
B5	2.67	0.65	-1.75
A0	1.87	0.01	-1.86
A5	1.56	-0.17	-1.92

Tab. 10 - Flux percentage from the M2 main component

Spectrum of the secondary	V	B	U
B0	95.6	74.6	16.7
B5	92.1	64.5	16.6
A0	84.8	50.2	15.3
A5	80.8	46.1	14.6

Considering the fact that the U curve shows no variation (MU is constant with a scattering of a few hundredths of magnitude), whereas the V and visual curves do show variations, it is possible to set superior limits to the spectral class of the companion. As a conclusion, a system M2epI + B 0÷5 (with $2.7 \leqslant \Delta MV \leqslant 3.3$) seems quite plausible. This would explain why it is so difficult to detect the lines of the companion star. In a like manner, there is no doubt that the red supergiant alone is responsible for the variations in the V and B bands as well as in visible light. From the photometrics characteristics and the period, it seems then possible to classify the star as a typical SRb . Also, the values for radial velocity reported by different authors are in good agreement with the statistic kinematic parameters of that type of star (KUKARKIN and al.,1975). On the whole, the periodicity of 169 days is well kept, within the limits of the photometric characteristics of that type of variable.

5. CONCLUSION

Here are the results on WY Geminorum :

Type :	SR b
Period :	169 d
Range of variation :	7.0 - 7.8 v
Spectrum of the companion :	B 0-5
Magnitude difference between components :	2.7 - 3.3 V

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