GEOS GEOS CIRCULAR ON ECLIPSING BINARIES May 2017
EB 31

V 566 Oph

Michel DUMONT

RESUME : V 566 Oph est une variable à éclipses dont l' (O – C) augmente depuis un demi-siècle. Une représentation parabolique de cette croissance durant l'époque 1952 – 2016 permet de penser que la période de V 566 Oph augmente de 2.8 secondes par siècle. En 2016, cette période était de 0.409 65 87 j ± 0.000 00 11.

ABSTRACT : V566 Oph is a EW binary star whose (O-C) has been increasing for half a century . A parabolic representation of this rise during the period 1952-2016 suggests that the length of the period of V566 Oph increases by 2.8 seconds per century.
In 2016 , this period was : 0.409 6587 d ± 0.000 0011 d.

RIASSUNTO :I valori degli O-C della variabile a eclisse V566 Oph mostrano un aumento da una cinquantina d'anni. Il fit con una parabola dei minimi osservati fra il 1952 e il 2016 suggerisce che il periodo orbitale aumenti di 2.8 secondi per secolo. Nel 2016 il valore del periodo era di 0.409 65 87 +/- 0.000 00 11 giorni.

RESUMEN : V 566 Oph es una variable eclipsante cuyo (O - C) aumenta desde medio siglo. Una representación parabólica de este crecimiento durante el período 1952 - 2016 sugiere que el período de V 566 Oph aumenta en 2,8 segundos por siglo. En 2016, este período fue de 0,4096587 d ± 0,0000011 d.

1 .INTRODUCTION

V 566 Oph is a EW binary star with a F4 V spectrum. It varies from 7.46 to 7.96 with a secondary minimum at 7.89.
Its position : α = 17h 56m 52.4s δ = + 4° 59' 15''3 (2000)
The GCVS [1] gives the ephemeris : Min I = 2 441 835.8617 + 0.409 64 569 E.
In this paper, we note : T_0 = 2 441 835.8617 and P_0 = 0.409 64 569 d.

In October 2003, a NOTE CIRCULAIRE (NC 988) summarized the observations from 1998 to 2002. We noted a rise of the (O-C), which seemed to stabilize at the end of 2002. This paper describes the continuation of these observations until 2016 and goes back to 1952 to better observe the evolution of the (O-C).
For the visual observations, we used the comparison stars :

C : HD 163 442	V = 7.38	Spectrum B8
D : HD 163 489	V = 7.83	Spectrum K2
E : HD 163 697	V = 8.66	Spectrum F5

2. The OBSERVATIONS

From 2003 to 2016, 2771 visual measurements hold 77 primary minima and 53 secondary minima. During this period, we received observations from Michel Dumont (DMT) 2245 estimates, Stéphane Ferrand (FND) 506 estimates and Serge Kuchto 14 estimates. While we observed visually, we never used ephemeris, to avoid any kind of suggestion.

DMT has the idea that the primary eclipses are deeper than formerly :

During 1982 – 89 the average magnitude of the minimum was 7.77 (σ = 0.083)
1990 – 2000 7.80 (σ = 0.094)
2003 – 2016 8.06 (σ = 0.088)

But the verification of this trend requires CCD measurements.

By visual observations, it is almost impossible to distinguish Min I and Min II, whose difference is around 0.05 magnitude.

The figure 1 shows the light curve obtained by FND in 2016 with 511 measurements (phase diagram according to ephemeris To , Po).

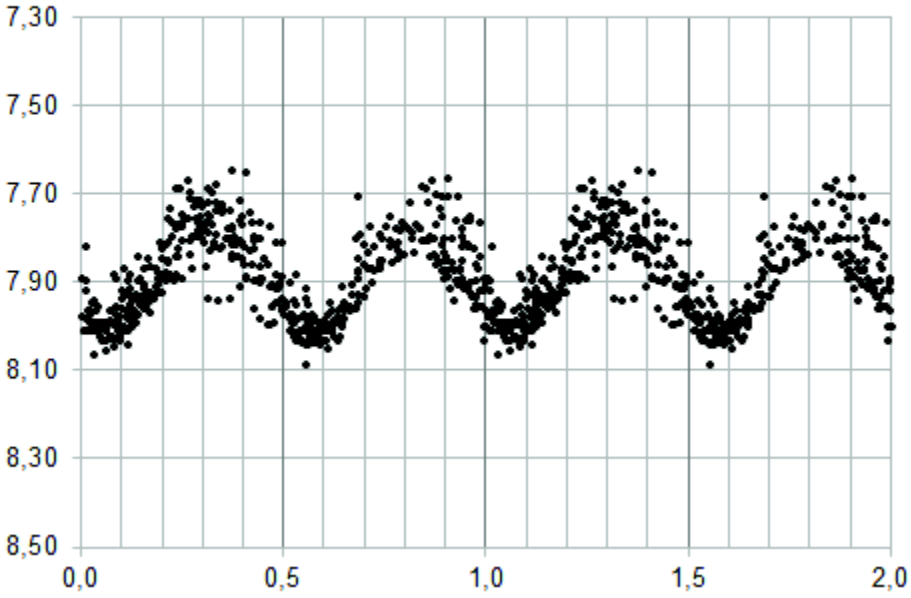


Figure 1 : V566 Oph in 2016 - FND -

The following table gathers the information about the primary minima observed by FND and DMT during the period 1998 – 2016 ; we added old minima observed by FND, DMT and PMP (Carlo PAMPALONI) and many minima previously published in 1988 [3], from 1952 to 1987 ; we do not

use all the minima of [3], but minima regularly stretched in time.
In this table, we find successively :

- The date
- The time UT of the minimum
- The heliocentric Julian date (HJD)
- The probable error expressed in days
- The phase according to To and Po
- (O-C) expressed in days ; (O-C) = phase . Po
- The author of the observation.

Date	UT	HJD 24…+	err..	Phase	O-C	Author
01/08/1952		34226,3572		0,18024708	0,07383744	Fresa
18/05/1953		34515,5639		0,17254008	0,0706803	Kwee
03/08/1953		34593,3956		0,17014508	0,0696992	Kwee
29/05/1957		35987,8129		0,12955205	0,05307044	Binnendijk
10/07/1958		36395,4056		0,11792847	0,04830889	Purgathofer/Widorn
03/01/1959		36728,4452		0,11220164	0,04596292	Purgathofer/Widorn
05/07/1959		36755,4810		0,1102108	0,04514738	Purgathofer/Widorn
10/06/1964		38557,4900		0,05555306	0,02275707	Schnell/Widorn
12/07/1964		38589,4423		0,05539726	0,02269325	Schnell/Widorn
13/06/1966		39289,9288		0,03677166	0,01506335	Bookmyer
12/07/1966		39319,4218		0,03313515	0,01357367	Minti/Dinescu
09/07/1968		40047,3580		0,02290404	0,00938254	Pohl/Kizihrmak
15/07/1969		40418,4931		0,01339548	0,0054874	Pohl/Kizihrmak
21/08/1970		40820,3490		0,99747467	-0,00103449	Popovici
17/06/1971		41119,8018		0,0018702	0,00076612	Scarfe/Barlow
02/08/1971		41165,6840		0,00646617	0,00264884	Kaitchuk/Sprague
10/06/1972		41479,4703		0,00085513	0,0003503	Kizihrmak/Pohl
02/06/1973		41835,8617		0	0	GCVS
02/06/1973		41835,8616		0,99975589	-0,0001	Scarfe/Barlow
25/05/1974		42193,4828		0,00100729	0,00041263	Pohl/Kizihrmak
01/07/1974		42230,3329		0,95703734	-0,01759947	Popovici
28/07/1974		42257,3880		0,00216038	0,00088499	Pop/Torodan
16/09/1974		42307,3612		0,99343533	-0,00268919	Pop/Torodan
05/05/1975		42537,5770		0,98103979	-0,00776697	Pop/Torodan
30/05/1975		42563,3940		0,00379489	0,00155456	Pop/Torodan
26/06/1975		42590,4300		0,00229227	0,00093902	Pop/Torodan
30/07/1975		42624,4277		0,99523186	-0,00195325	Pop/Torodan
28/07/1976		42987,7861		0,00175693	0,00071972	Scarfe/Barlow
18/05/1977		43281,5037		0,00576105	0,00235999	Pohl/Gülmen
02/06/1978		43662,4770		0,01261649	0,00516829	Ebersberger/Pohl/Kizihrmak
16/06/1980		44406,8073		0,02257941	0,00924956	Scarfe et al
10/08/1980		44462,4890	0,004	0,9490675	-0,02086428	PMP
25/05/1981		44750,4901		0,99832941	-0,00068435	Mahdi/Soliman
25/06/1981		44780,8121		0,01839294	0,00753459	Scarfe et al
28/07/1981		44814,4060	0,004	0,02560264	0,01048801	PMP
01/08/1981		44818,4930	0,002	0,00251708	0,00103111	PMP
06/08/1981		44823,3960	0,007	0,97139682	-0,01171717	PMP
09/08/1981		44826,2739		0,9967362	-0,001337	Mahdi/Soliman

25/05/1982	23h 31,5	45115,4849	0,006	0,99952608	-0,00019414	FND
24/06/1982		45144,5759		0,01455372	0,00596187	Seeds/Dawson
19/07/1982		45169,9749		0,01691484	0,00692909	Kennedy
23/07/1982	23h 34	45174,4863	0,009	0,02984652	0,0122265	FND
26/07/1982	1h 00,5	45176,5463	0,010	0,05858245	0,02399805	FND
01/08/1982		45183,4926		0,01543119	0,00632132	Pohl et al
15/08/1982		45197,0117		0,01736513	0,00711355	Kennedy
17/08/1982	23h 45	45199,4925	0,006	0,07333022	0,03003941	DMT
26/08/1982		45207,6598		0,01080351	0,00442561	Seeds/Dawson
31/08/1982	21h 29	45213,3969	0,008	0,01583307	0,00648595	FND
15/06/1983	1h 07	45500,5517	0,007	0,99916333	-0,00034274	DMT
27/06/1983		45512,8463		0,01192875	0,00488656	Scarfe et al
28/06/1983	23h 50	45514,4982	0,010	0,04443791	0,0182038	DMT
08/08/1983		45554,6307		0,01324603	0,00542618	Seeds/Dawson
13/08/1983	0h 49	45559,5435	0,010	0,00604889	0,0024779	FND
30/04/1984	0h 12	45820,5117	0,007	0,06438093	0,02637337	FND
10/06/1984	23h 18	45861,4759	0,008	0,06348015	0,02600437	DMT
25/06/1984	22h 25	45877,4392	0,007	0,03203368	0,01312246	FND
04/07/1984	22h 30	45886,4425	0,010	0,01029495	0,00421728	FND
06/07/1984	23h 54	45888,5008	0,008	0,03488095	0,01428883	FND
27/07/1984	1h 48	45908,5792	0,007	0,04894478	0,02005002	FND
30/08/1984	21h 29,5	45943,3974	0,004	0,04483477	0,01836637	FND
31/08/1984		45943,7952		0,01591785	0,00652068	Seeds/Dawson
09/06/1986	22h 40	46591,4495	0,010	0,02681534	0,01098479	DMT
23/06/1986	1h 28	46604,5663	0,010	0,0466811	0,01912271	DMT
30/06/1986	0h 51	46611,5405	0,006	0,07163747	0,02934598	DMT
17/06/1987		46963,8253		0,04602167	0,01885258	Hobart/Gomez/Pena
20/06/1988	0h 12	47332,5135	0,006	0,06330246	0,02593158	DMT
30/07/1988	23h 30	47373,4832	0,008	0,07582792	0,03106258	DMT
18/08/1988	0h 25	47391,5202	0,012	0,10656092	0,04365222	DMT
02/08/1989	0h 25	47740,5213	0,008	0,06499358	0,02662434	DMT
23/09/1989	20h 35	47793,3575	0,010	0,04523502	0,01853033	DMT
06/08/1991	22h 15	48475,4307	0,014	0,07727771	0,03165648	DMT
15/05/1993	23h 48	49123,4959	0,013	0,09123714	0,0373749	DMT
28/06/1993	0h 00	49166,5051	0,010	0,08245528	0,03377745	DMT
27/06/1994	23h 50	49531,4982	0,013	0,07950202	0,03256766	DMT
25/06/1995	23h 03	49894,4656	0,007	0,13154373	0,05388632	DMT
15/06/1996	22h 42	50250,4510	0,008	0,13958821	0,05718171	DMT
05/09/1996	20h 55	50332,3729	0,009	0,12191929	0,04994371	DMT
06/07/1997	0h 19	50635,5182	0,006	0,14020191	0,05743311	DMT
12/07/1997	23h 12	50642,4715	0,007	0,11413859	0,04675638	DMT
04/08/1997	21h 43	50665,4086	0,009	0,10667204	0,04369774	DMT
03/07/1998	23h 17	50998,4752	0,004	0,16685583	0,06835177	DMT
12/07/1998	23h 20	51007,4770	0,005	0,14145539	0,05794659	DMT
12/09/1998	19h 57	51069,3321	0,004	0,13803978	0,0565474	DMT
03/07/1999	23h 13	51363,4724	0,005	0,17391122	0,07124198	DMT
12/07/1999	23h 27	51372,4819	0,004	0,16730751	0,0685368	DMT
04/08/1999	22h 17	51395,4322	0,005	0,19206393	0,07867816	DMT
18/07/2000	22h 42	51744,4504	0,002	0,19223998	0,07875028	DMT
20/09/2000	20h 38	51808,3598	0,004	0,20364584	0,08342264	DMT
18/05/2001	21h 51	52048,4148	0,002	0,21005543	0,0860483	DMT
21/06/2001	22h 00	52082,4218	0,006	0,22569755	0,09245603	DMT
12/08/2001	22h 29	52134,4401	0,007	0,20933554	0,0857534	DMT
21/08/2001	22h 41	52143,4477	0,004	0,19809367	0,08114822	DMT

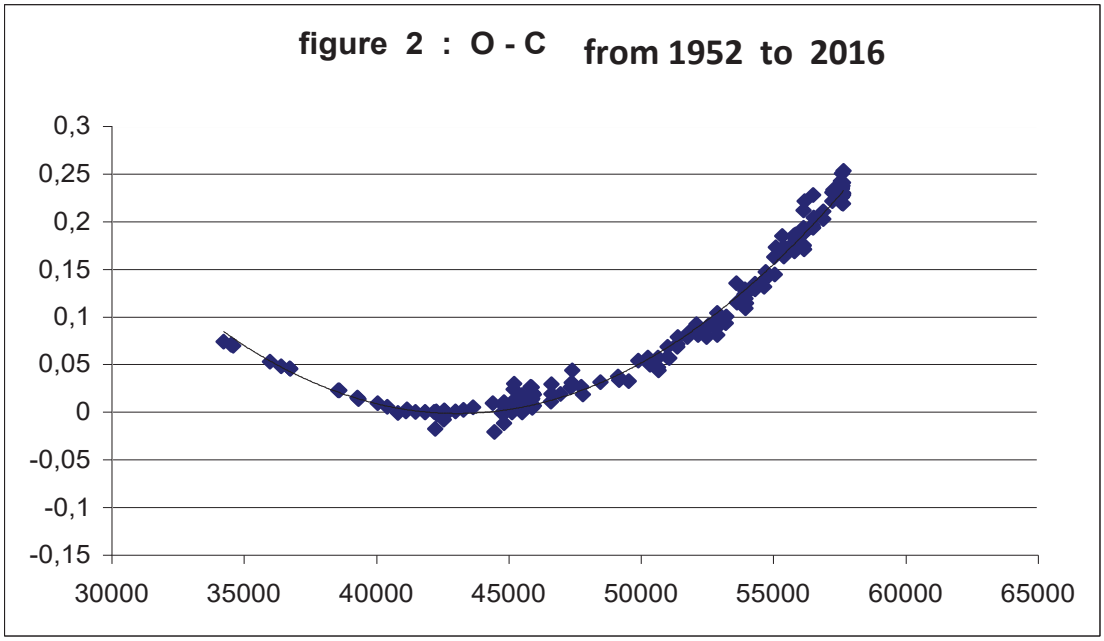
18/07/2002	22h 26	52474,4393	0,004	0,19292452	0,0790307	DMT
13/09/2002	21h 20	52531,3896	0,004	0,21623513	0,08857979	DMT
29/09/2002	20h 51	52547,3681	0,004	0,2218939	0,09089788	DMT
03/08/2003	21h 58	52855,4191	0,008	0,21564733	0,088339	DMT
19/08/2003	21h 48	52871,4111	0,006	0,25426141	0,10415709	DMT
21/08/2003	22h 24	52873,4360	0,008	0,19731354	0,08082864	DMT
30/08/2003	23h 05	52882,4638	0,010	0,23538258	0,09642346	DMT
17/07/2004	22h 30	53204,4421	0,010	0,22754083	0,09321112	DMT
02/08/2004	22h 07	53220,4253	0,010	0,24467293	0,10022921	DMT
09/08/2005	21h 58	53592,4187	0,005	0,33038964	0,13534269	DMT
29/08/2005	23h 15	53612,4707	0,005	0,28000754	0,11470388	DMT
22/06/2006	23h 13	53909,4726	0,010	0,30142788	0,12347863	DMT
01/07/2006	23h 30	53918,4842	0,004	0,29995055	0,12287345	DMT
15/07/2006	21h 55	53932,4179	0,007	0,31397862	0,12861999	DMT
17/07/2006	23h 02	53934,4644	0,007	0,30975925	0,12689154	DMT
24/07/2006	21h 45	53941,4106	0,005	0,26636387	0,10911481	DMT
26/07/2006	23h 09	53943,4688	0,007	0,29070576	0,11908636	DMT
25/08/2006	20h 47	53973,3683	0,006	0,2793902	0,11445099	DMT
17/07/2007	23h 05	54299,4665	0,008	0,32877619	0,13468175	DMT
31/07/2007	21h 14	54313,3887	0,006	0,31473123	0,12892829	DMT
09/07/2008	23h 44	54657,4938	0,006	0,32137209	0,13164869	DMT
23/07/2008	22h 12	54671,4294	0,007	0,34003831	0,13929523	DMT
26/08/2008	22h 27	54705,4376	0,008	0,3586098	0,14690296	DMT
23/07/2009	22h 38	55036,4474	0,006	0,39786929	0,16298544	DMT
17/08/2009	21h 57	55061,4174	0,010	0,35298394	0,14459835	DMT
25/09/2009	20h 42	55100,3622	0,007	0,42245727	0,1730578	DMT
23/05/2010	22h 07	55340,4261	0,007	0,45059295	0,18458346	DMT
10/07/2010	0h 13	55387,5139	0,008	0,39822001	0,16312911	DMT
14/07/2010	22h 27	55392,4402	0,008	0,42397817	0,17368083	DMT
08/08/2010	22h 07	55417,4250	0,008	0,4152216	0,17009374	DMT
25/05/2011	22h 56	55707,4602	0,005	0,42999408	0,17614522	DMT
30/07/2011	22h 02	55773,4221	0,010	0,45182736	0,18508913	DMT
19/08/2011	23h 25	55793,4785	0,008	0,41218625	0,16885032	DMT
25/09/2011	20h 45	55830,3643	0,009	0,45536478	0,18653822	DMT
27/09/2011	21h 48	55832,4078	0,005	0,443822	0,18180977	DMT
02/10/2011	19h 41	55837,3192	0,006	0,43320727	0,17746149	DMT
20/07/2012	22h 14	56129,4309	0,006	0,51699438	0,21178452	DMT
22/07/2012	22h 57	56131,4607	0,009	0,47200807	0,19335607	DMT
24/07/2012	23h 40	56133,4904	0,008	0,42677764	0,17482762	DMT
07/08/2012	21h 58	56147,4188	0,006	0,4278677	0,17527416	DMT
16/08/2012	22h 37	56156,4453	0,006	0,46276327	0,18956898	DMT
18/08/2012	23h 20	56158,4750	0,009	0,41753284	0,17104053	DMT
06/09/2012	20h 50	56177,3693	0,010	0,54104997	0,22163879	DMT
15/09/2012	20h 22	56186,3491	0,007	0,46194459	0,18923361	DMT
17/09/2012	21h 31	56188,3969	0,010	0,46089869	0,18880516	DMT
30/06/2013	0h 15	56473,5155	0,007	0,473592	0,19400492	DMT
13/07/2013	22h 35	56487,4458	0,014	0,47932021	0,19635146	DMT
31/07/2013	23h 07,5	56505,4675	0,006	0,47270386	0,1936411	DMT
03/08/2013	20h 46	56508,3691	0,006	0,55589812	0,22772127	DMT
14/08/2013	21h 40	56519,4059	0,012	0,49820527	0,20408764	DMT
16/08/2014	22h 39	56886,4467	0,005	0,49396199	0,2023494	DMT
23/08/2014	22h 00	56893,4191	0,006	0,51452432	0,21077267	DMT
13/07/2015	22h 55	57217,4597	0,006	0,54103311	0,22163188	DMT
16/07/2015	0h 17	57219,5166	0,006	0,56220152	0,23030343	DMT

08/09/2015	21h 52	57274,4123	0,006	0,56995832	0,23348097	DMT
08/06/2016	23,25 h	57548,4740	0,013	0,5912777	0,24221436	FND
15/07/2016	0h 02	57584,5061	0,005	0,55046018	0,22549364	DMT
15/07/2016	0,28 h	57584,5160	0,017	0,57462741	0,23539364	FND
24/07/2016	0,54 h	57593,5270	0,006	0,5716854	0,23418846	FND
26/07/2016	21,77 h	57596,4110	0,006	0,6119157	0,25066863	FND
28/07/2016	22h 10	57598,4277	0,007	0,53495053	0,21914018	DMT
02/08/2016	20,59 h	57603,3620	0,013	0,58023777	0,2376919	FND
22/08/2016	22h 11	57623,4268	0,009	0,56110218	0,22985309	DMT
22/08/2016	22,45 h	57623,4380	0,006	0,58844288	0,24105309	FND
24/08/2016	23h 20	57625,4745	0,010	0,55981216	0,22932464	DMT
24/08/2016	23,3 h	57625,4730	0,008	0,55615046	0,22782464	FND
05/09/2016	20,44 h	57637,3530	0,013	0,55682175	0,22809963	FND
07/09/2016	21h 38	57639,4026	0,006	0,56016989	0,22947118	DMT
07/09/2016	21,38 h	57639,3920	0,013	0,53429387	0,21887118	FND
21/09/2016	20,50 h	57653,3540	0,013	0,61740603	0,25291772	FND

3. EVOLUTION OF THE (O – C)

Contrary to the hypothesis formulated in the NC 988, the (O-C) pursued their increase after a short inflection (around JD 2 452 500).

Figure 2 shows the evolution of (O-C) from 1952 to 2016.



These (O – C) follow almost a parabola whose equation is :

$$(1) \qquad y = 1,088 \cdot 10^{-9}\ x^2 - 9,363 \cdot 10^{-5}\ x + 2,01397$$

where y is the (O – C) fot the date x ; x is noted 0 at the date 2 400 000 (i.e. x = 43 500 if JD = 24 43500).

To establish the accuracy of the observed (O – C), we have computed the difference : Δ = { (O-C) given by the equation (1) – observed (O-C)} ; then we calculated the mean value of $|\Delta|$ = 0.0073, then the standard deviation σ = 0.0100.
We can state with a probability of 95% that the accuracy of our observed (O-C) is 2σ , that is to say 0.02 day. We adopted this confidence interval.

The parabolic evolution of the (O-C) may suggest that the period of V566 Oph increases regularly by α at every cycle.
The minimum of (O-C) occurred when $y' = 0$ (y' is the derivative of y) ; then x = 43 028.5, September 1976. Before this date, the period of V566 Oph was shorter than Po ; at that time ($y' = 0$) the period was Po, then the period is longer than Po. (It is obvious that the minimum of (O-C) is not a minimum of the period, but a passing of the period over Po).
Let Tm the time of the nearest primary minimum of JD 24 43028. At that time, (O-C) = -0.0004 . Between Tm and our last observations, the time elapsed is 57 640 – 43 028 days = 14 612 d. or 35 670 cycles. . The mean of the 10 last observed (O-C) is 0.2314. During 35 670 cycles, (O-C) passed from -0.0004 to 0.2314, therefore increased by 0.2318 d.
If the period increases every cycle by α , minima occur at :

$$Tm \; ; \; Tm + Po + \alpha \; ; \; Tm + 2\,Po + 2\,\alpha \; ; \; Tm + 3\,Po + 3\,\alpha \; ; \ldots ; \; Tm + k\,Po + k\,\alpha$$

$$O - C = \alpha + 2\alpha + 3\alpha + \ldots + k\alpha = \alpha\,(1 + 2 + 3 + 4 + \ldots + k) = \tfrac{1}{2}\, k\,(k + 1)\,\alpha$$

$$\alpha = 2\,(O - C)/ k\,(k + 1) = (2 \times 0,2318) / (35\,670 \times 35671) = 3,644 \cdot 10^{-10} \text{ d. } \pm 3,15 \cdot 10^{-11}$$

$$\alpha = 0,000\,0315 \text{ second } \pm 0,000\,002\,7 \text{ s}$$

The period P_1 (summer 2016) was :
$P1 = Po + k\,\alpha = Po + 35\,670 \times 3,644 \cdot 10^{-10}$ d. = 0. 409 658 7 d ± 0. 000 001 1 d.
If the period increases with the same rate, its growth will be :
0,000 0315 x 36525/Po = 2.8 ± 0.1 seconds per century.
We can compare this result with the 2.63 seconds computed in [3].

REMARK : The '' Atlas of (O-C) diagrams of eclipsing binary stars "[4] gives the ephemeris : 24 40418, 540 + 0.409 64 360 (July 1969). In this atlas, the curve of the observed (O-C) has indeed a parabolic appearance ; the minimum of the parabola squares with a period of 0. 409 64360 d , which occurred before To, at around JD 24 41317 (beginning of 1972). Between 24 41317 and 24 43028 (the minimum of our curve), 1711 days have passed, that is 4176,8 cycles. We can check that this value is consistent with our value of α .

4176 x 0.000 0315 = 0. 1315 second = 0. 000 001 522 d

The period P_2 is then P_2 = 0. 409 64 360 + 0. 000 001 522 = 0. 409 64 512 d.

Po - P2 = 0. 000 000 57 The difference is well situated in our confidence interval.

4. OBSERVATIONS OF SECONDARY MINIMA

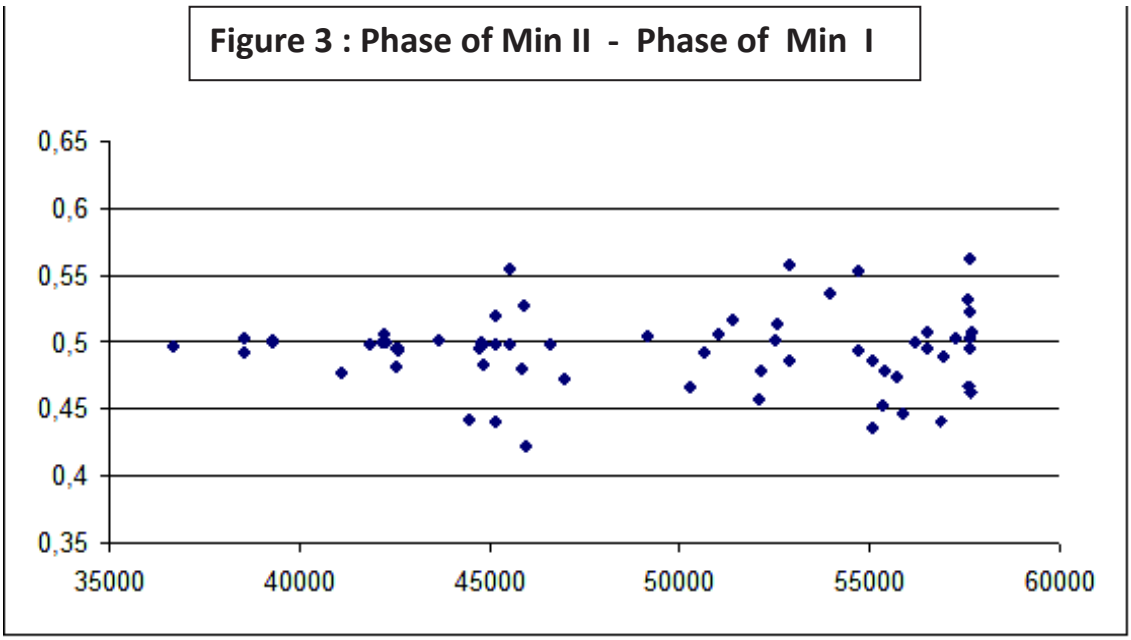
In this paper, the purpose of the observation of the secondary minima is to check if the phase of secondary eclipses is stable with respect to the primary ones.

We chose in [3] and among our observations, pairs (Min I, Min II) as near as possible. We selected 65 such pairs ; for visual observations, both minima were obtained by the same observer.

Figure 3 shows the evolution in the time of : Phase of Min II - Phase of Min I.

We observe random distribution around the phase 0.5 ; no noticeable evolution has appeared for more than 50 years.

Figure 3 : Phase of Min II - Phase of Min I



One can think that the scattering of these results exceeds our confidence interval (0.02 d for the observed (O-C)). Not at all !

Phase = (O – C) / P and P = 0.409… day , then the error on the phase is twice the error on (O-C) ; further, in the difference of two phases, the error increases once more by around 2 ; the error of 0.056 is quite normal !

Finally, we do not observe any rotation of the orbits, which are probably circular.

5. CONCLUSION

The period of V566 Oph increases regularly by 2.8 seconds per century and the orbits are stable.
With a period (in 2016) of 0.409 6587 d ± 0.000 0011 the two components form almost a contact binary. Mass transfer from one component to the other is likely ; loss of mass also occurs , the presence of giant planets can also produce this increase of the period.

REFERENCES :

[1] GCVS : General Catalogue of Variable Stars - N.N. Samus – Moscou (2013).

[2] : Note Circulaire GEOS NC 988 Octobre 2003.

[3] : An update of the ephemeris of V566 Ophiuchi ; M.A. Hobart, T. Gomez, J.H. Penã ; MxAA 17,39 – 46 (1989)

[4] : An Atlas of O – C diagrams of eclipsing binary stars ; J.M. Kreiner, C.H. Kim, II-Seong Nha ; Krakow 2000.