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PERIOD CHANGE OF ES Del

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A few stars among Mira-type variables are known to show period changes. The period changes of R Aql, R Hya and W Dra are interpreted to be a result of helium shell flash (Wood and Zarro 1981).

ES Del was first proposed as a Mira-type variable with a period of $373\overset{\mathrm{d}}{.}9$ (Huth 1956; Huth et al. 1957). However, disagreement was pointed out (Kholopov 1986) between this period and the maximum dates observed later (Halle 1974). Furthermore, a $509\overset{\mathrm{d}}{.}6$ period was recently proposed (Watanabe 2000). I analyzed the available data in order to verify the possible period change.

Four data sources were used for analysis: (1) four maximum times reported in Huth et al. (1957), (2) two maximum times reported in Halle (1974), (3) five maximum times reported in Watanabe (2000), and (4) five maximum times estimated from the AFOEV database. In addition, five intervals around maximum times were estimated from the AFOEV database, whose exact times were not determined due to the lack of observations or due to the solar conjunction, were used to verify the cycle count.

At first, $O-C_1$ values were calculated against the $373\overset{\mathrm{d}}{.}9$ period: $Maximum_1 =$ JD $2427954 + 373.9 \times E_1$ (Huth et al. 1957), which are listed in Table 1. The $O-C_1$ diagram is shown in Figure 1. For some maxima, whose cycle counts are ambiguous because of the lack of contiguous detection of maxima, the calculated cycle numbers nearest to the observed maxima were assumed. Figure 1 shows that $O-C_1$ values are approximately constant between 1935 and 1949 ($E_1 = 0$ to 14), confirming the $373\overset{\mathrm{d}}{.}9$ period reported by Huth (1957). However, after 1957 ($E_1 = 21$), $O-C_1$ values significantly increased, implying that the period became longer than $373\overset{\mathrm{d}}{.}9$.

$O-C_2$ values were then calculated against the $509\overset{\mathrm{d}}{.}6$ period: $Maximum_2 =$ JD $2450290 + 509.6 \times E_2$ (Watanabe 2000), which are listed also in Table 1. The $O-C_2$ diagram is shown in Figure 2. After 1982 ($E_2 = -10$), $O-C_2$ values are approximately constant, supporting the recent identification of the $509\overset{\mathrm{d}}{.}6$ period.

None of these periods can properly represet the maxima between 1957 and 1982. Between 1949 and 1965, a period of 472^{d} or 404^{d} better represent observations.

A period increase of 136^{d} (from $373\overset{\mathrm{d}}{.}9$ to $509\overset{\mathrm{d}}{.}6$) was observed during 33 years (from 1949 to 1982). If the period increased at a constant rate: $P_E = P_0 + A \times E$, than the rate of increase A should be $0\overset{\mathrm{d}}{.}24$. This case, the expected period increase is 37^{d} in 17 years. However, the actual period increase during the recent 17 years (between 1982 and 1999)

Table 1. Observed maximum dates and $O-C$ values

Data Source	Maximum date UT	JD	Some probable cycle numbers E and $O-C$ values $E_1/O-C_1$[a]	$E_2/O-C_2$[b]
VSS	1935 May 4	2427927	0/*−27*	−51/*3627* ... −46/*1079*
VSS	1940 Aug. 8	2429850	5/*27*	−46/*3002* ... −41/*454*
VSS	1948 Sep. 2	2432797	13/*−18*	−38/*1872* ... −33/*676*
VSS	1949 Oct.15	2433205	14/*16*	−37/*1770* ... −32/*778*
MVS	1957 Jul.14	2436034	21/*228* , 22/*−146*	−31/*1542* , −29/*522*
MVS	1965 Apr.10	2438861	28/*438* , 29/*64*	−24/*801* , −22/*−218*
AFOEV	1982 Aug. 3	2445185	40/*2275* ... 46/*31*	−10/*−10*
AFOEV	1984 Jan.	—	41/ — ... 47/ —	−9/ —
AFOEV	1985 May	—	42/ — ... 48/ —	−8/ —
AFOEV	1986 Oct.12	2446716	43/*2684* ... 49/*440*	−7/*−7*
AFOEV	1988 Feb.	—	44/ — ... 50/ —	−6/ —
AFOEV	1989 Aug.10	2447749	45/*2969* ... 51/*726*	−5/*7*
VSOLJ	1990 Dec.26	2448252	46/*3099* ... 52/*855*	−4/*0*
AFOEV	1991 Jan.	—	46/ — ... 52/ —	−4/ —
AFOEV	1992 Apr.	—	47/ — ... 53/ —	−3/ —
AFOEV	1993 Nov. 2	2449294	48/*3392* ... 54/*1149*	−2/*23*
AFOEV	1995 Feb.	—	49/ — ... 55/ —	−1/ —
VSOLJ	1995 Mar. 1	2449778	49/*3503* ... 55/*1260*	−1/*−2*
VSOLJ	1996 Jul.27	2450292	50/*3643* ... 56/*1400*	0/*2*
VSOLJ	1997 Dec.15	2450798	51/*3775* ... 57/*1532*	1/*−2*
VSOLJ	1999 May 11	2451310	52/*3913* ... 58/*1670*	2/*1*

[a] $Maximum_1 = 2427954 + 373.9 \times E_1$ (Huth et al. 1957)
[b] $Maximum_2 = 2450290 + 509.6 \times E_2$ (Watanabe 2000)

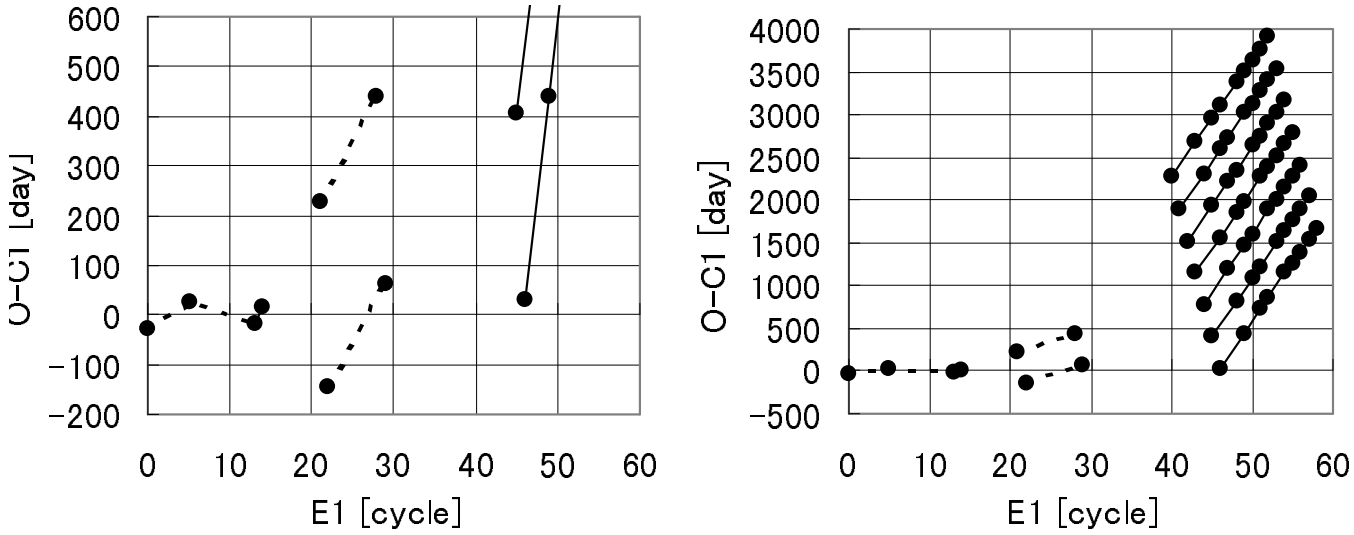

Figure 1. $O-C_1$ diagrams using the ephemeris: $Maximum_1 = 2427954 + 373.9 \times E_1$. $O-C_1$s for the maxima with successively identified cycle counts are connected by solid lines. $O-C_1$s of other maxima are connected by dashed lines.

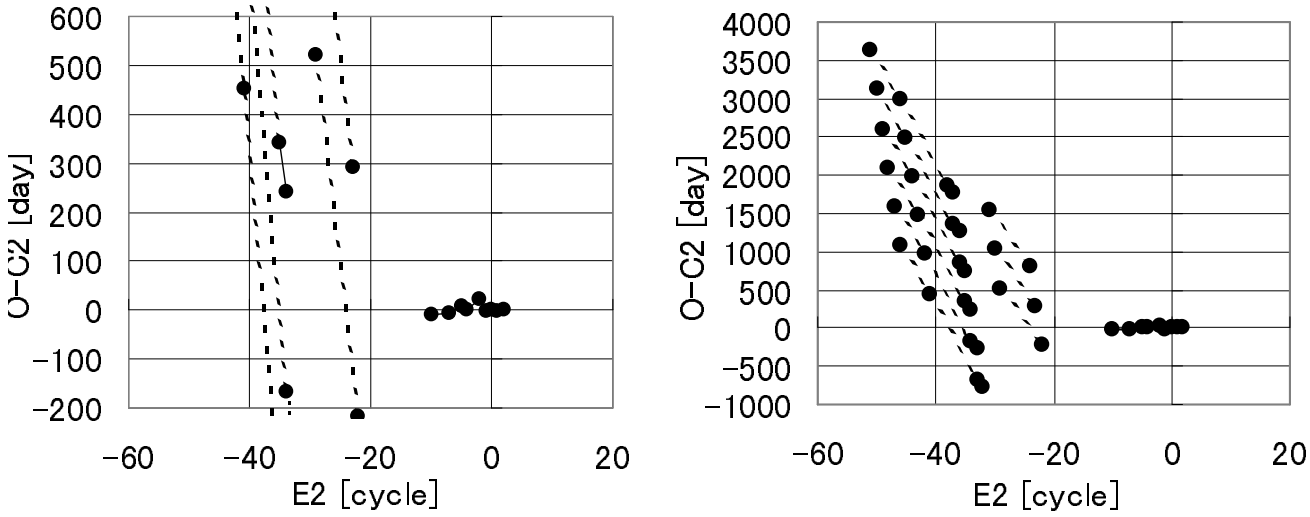

Figure 2. $O-C_2$ diagrams using the ephemeris: $Maximum_2 = 2450290 + 509.6 \times E_2$. The lines and dashed lines are the same as described in Figure 1.

is less than $11^{\rm d}$ (Table 1). This result indicates that the period change of ES Del is not linear.

The period of ES Del is: $P = 373\overset{\rm d}{.}9$ between 1935−1949, $P = 404^{\rm d}$ or $472^{\rm d}$ between 1949−1965, $P = 509\overset{\rm d}{.}6$ between 1982−1999. The period change is not linear. ES Del may be one of the few Mira-type stars experiencing a shell flash stage, as R Aql and R Hya. More observations, as well as archival plate search are needed to more accurately determine the nature of this period change, and to understand the evolutionary status of ES Del.

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References:

Halle, E.S., 1974, *MVS*, **6**, 167
Huth, H., 1956, *MVS*, **232**
Huth, H. et al., 1957, *Veröff. Sternw.* Sonneberg, **4**, No. 2
Kholopov et al., 1986, *General Catalogue of Variable Stars IV*
Watanabe, T., 2000, *VSOLJ Variable Star Bulletin*, **No. 35-36**, 6
Wood, P.R., and Zarro, D.M., 1981, *ApJ*, **247**, 247