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Letter to the Editor

Irregular amplitude variations and another abrupt period change in the δ Scuti star V 1162 Ori*

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Abstract. We report that the intermediate amplitude δ Scuti star V 1162 Ori has changed its main pulsational period in the course of the year 2000. This new period change falls in a sequence of period changes observed during the last 5 years. While the average amplitude value of all our new data, 63 mmag, fits a cyclic amplitude variation suggested by Arentoft et al. (2001), splitting the data up in smaller subsets discloses significant deviations from regularity, with stretches of constant amplitude during short intervals of time. The new data show that the amplitude of one of the secondary frequencies, f_2, has in 3 years dropped from more than 3 mmag to now about 1 mmag, and that the previously obtained f_5 probably is a 1 d^{-1} alias of the real frequency. We present the newly acquired times of minimum and maximum light as support for subsequent observing campaigns.

Key words. stars: variables: δ Scuti – stars: individual: V 1162 Orionis – techniques: photometric – methods: data analysis

1. Introduction

In a recent paper, Arentoft et al. (2001) discussed period and amplitude changes in V 1162 Ori, a highly interesting intermediate amplitude δ Scuti star. These authors showed by using data collected from 1998 to 2000, that the semi–amplitude of the dominant frequency, f_1, varied between 55 and 75 mmag in an apparently cyclic manner, on a time scale of about 280 d. However, deviations from cyclicity were seen, and the possible cyclic behaviour did not explain amplitude values quoted in the literature (Lampens 1985, 92 mmag; Poretti et al. 1990, 98 mmag; Hintz et al. 1998, 72 and 50 mmag). The variation in period appeared quasi-cyclic, in the sense that the O–C diagram of the times of maximum and minimum light prewhitened with a constant period revealed period changes alternating between period increases and decreases, on top of a slow, secular period change. A further result was the detection of 5 previously unknown low–amplitude frequencies (f_2–f_6) as well as $3f_1$, all having amplitudes of 1–3 mmag.

We refer to Arentoft et al. (2001) for descriptions of the background, philosophy and methods of data collection and analysis applied in the present paper. We analyse new data obtained in 2000–2001, and discuss the diagrams presented by Arentoft et al. (2001) in the light of the newly acquired data.

2. The data

The data were collected from October 2000 to March 2001, using 6 telescopes at 4 different sites, as outlined in Table 1. In total, we have collected 158 new light extrema during 182 hours of time–series observations. The final data set used for Fourier analysis and investigation of amplitude variability consists of 5911 new datapoints, and the total data set, including the data discussed in Arentoft et al. (2001), constitutes 13 463 individual datapoints and 607 light extrema, covering 583 hours of time–series photometry.

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* Based on observations obtained at the South African Astronomical Observatory (SAAO), Athens University Observatory, the Danish 1.5 m telescope at ESO, La Silla, Chile, and Beersel Hills Observatory.

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Table 1. List of sites supplying the new data, obtained from October 2000 to March 2001. Telescope diameters are given in meters.

Observatory	Location	Observer	#extrema	Telescope	Detector	#hours
SAAO	S. Africa	M. Knudsen, T. Arentoft, G. Handler	73	1.00	CCD	84
SAAO	S. Africa	G. Handler	11	0.75	CCD	11
SAAO	S. Africa	M. Moalusi, F. Vuthela	14	0.50	PMT	19
ESO	Chile	M. Knudsen, C. Sterken	17	1.54	CCD	16
Athens University	Greece	P. Niarchos, K. Gazeas, V. Manimanis	38	0.40	CCD	47
Beersel Hills	Belgium	P. Van Cauteren	5	0.40	CCD	5
Total			158			182

3. Analysis and results

3.1. The O–C diagram

The O–C diagram of times of maximum and minimum light is shown in Fig. 1. The computed values were obtained using a constant pulsation period of 0.07868910 d (Arentoft et al. 2001) and the cycle count scheme of Hintz et al. (1998). This figure is the updated version of Fig. 14 in Arentoft et al. (2001). Data from before 1998 are from Hintz et al. (1998), from 1998 to mid–2000 from Arentoft & Sterken (2000) and Arentoft et al. (2001), and the later data are from this study. The upper panel shows the long–term evolution of the period. The overall parabolic shape, and thus the presence of a slow, secular period change as found by Arentoft et al. (2001) is still valid when including the new data. Using the larger data base now available, the period change rate of f_1 is refined to $(1/P)(\mathrm{d}P/\mathrm{d}t) = -1.6 \times 10^{-5} \pm 4.3 \times 10^{-7}$ y^{-1}.

The constant change in period has been subtracted in the middle and lower panels, where the middle panel displays the O–C values of all available times of extreme light, and the lower panel the same data combined in bins of 155 cycles (about 12 days). The bin size was chosen to ensure that all bins included a reasonable number of data points. The new data show that another period change has taken place somewhere between May and October 2000. Several period changes have occured from 1996 to 2001, but although the period changes appear to alternate around a mean value on a time scale of about 280 d (3560 cycles), the deviations from a simple sinusoidal shape discussed in Arentoft et al. (2001) are very clearly confirmed by the new data. A model of a secular period change combined with a simple sinusoidal variation definitely does not fit all the variability seen in the data.

In Fig. 2 we show the O–C values (corrected for the secular period change) phased with the best–fit period value (277 d) of the sinewave superimposed in Fig. 1, middle and lower panels. The upper panel of Fig. 2 shows again all available data while the lower panel plots the binned values. Although the upper panel indicates that a cyclic variation may be present in the O–C values, the binned data disclose significant deviations from regularity. Figure 2 does not show the kind of regularity one would expect from a kinematic cause of the observed changes, like e.g. a light–time effect in a simple, non–interacting binary system.

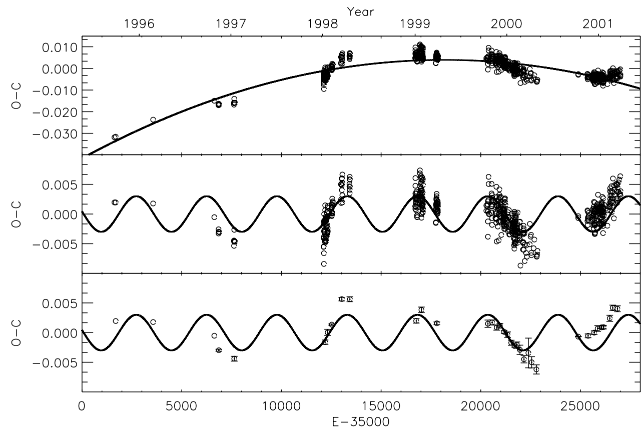

Fig. 1. New O–C diagram (in days) for V 1162 Ori. The superimposed parabola in the upper panel corresponds to a linear period change rate of $(1/P)(\mathrm{d}P/\mathrm{d}t) \sim -1.6 \times 10^{-5}$ y^{-1}. The sinewave with an amplitude of 0.003 d superimposed in the middle and lower panels has a period of 277 d, in agreement with the best–fit value of the binned data.

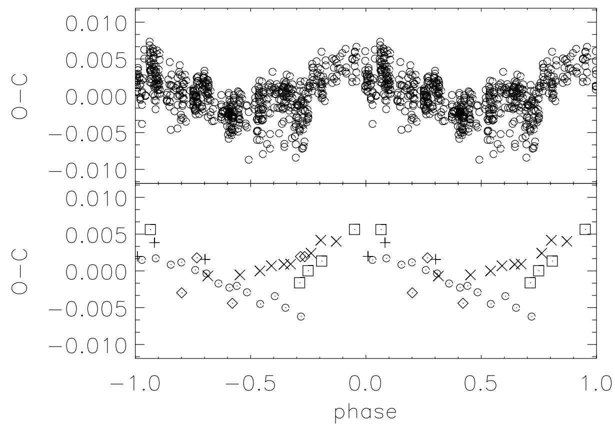

Fig. 2. The O–C diagram (in days) phased with the period of 277 d superimposed in Fig. 1, middle and lower panels. ($\diamond$) are data from Hintz et al. (1998), ($\square$) data from ESO 1998, (+) data from ESO 1999, ($\circ$) data from the 1999–2000 multisite campaign, and ($\times$) are the new data. Error bars are not shown in the lower panel but are very small as can be assessed from the lower panel of Fig. 1.

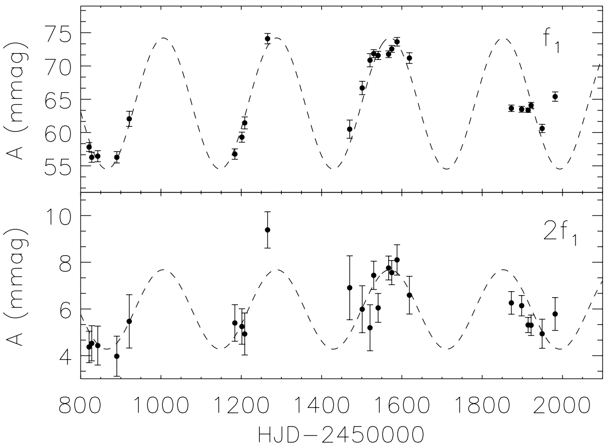

Fig. 3. Amplitude variations of f_1. The superimposed sinewave has a period of 282 d, as discussed by Arentoft et al. (2001).

3.2. Amplitude variations of f_1

The amplitude variations of f_1 and $2f_1$ are shown in Fig. 3, upper and lower panel, respectively. Data prior to HJD 2451800 were discussed by Arentoft et al. (2001, along with the superimposed sinewave), the later data are from this study. To obtain the new amplitudes plotted in Fig. 3, the data were prewhitened for the low–amplitude frequencies (f_2–f_6) and subdivided into 6 subsets, as described by Arentoft et al. (2001). Although the average amplitude value of the new data, about 63 mmag, agrees well with the superimposed sinewave, the values from the individual subsets do not follow the predicted relation. In fact, it appears that the amplitude of f_1 remained constant for at least two months, before starting to vary again. Actually, this could also be the case near the previous maximum around HJD 2451500–2451600, and near the first minimum shortly after HJD 2450800. It is thus possible that there are epochs with little or no amplitude variability of f_1, and other epochs with very large changes.

3.3. New results on f_2–f_6

The residual amplitude spectrum after subtracting f_1 and harmonics ($2f_1$, $3f_1$) from all available data is shown in Fig. 4, upper panel. In the lower panel f_2 (12.9412 d^{-1}) and f_3 (19.1701 d^{-1}) have also been subtracted. f_2 was found to have an amplitude of 3.2 mmag by Arentoft et al. (2001), but the amplitude in Fig. 4 is only about 2 mmag. This difference is explained by Fig. 5 where the evolution in amplitude of f_2 and f_3 is shown in the upper and lower panels, respectively. Whereas the amplitude of f_3 has remained constant over a time span of more than 3 years, this is not the case for f_2, whose amplitude is decreasing to the extent that it is barely detectable in the new data.

f_4 has also an amplitude lower than the 2.4 mmag quoted in Arentoft et al. (2001), due to an amplitude of less than 1 mmag in the new data. It furthermore appears that the previously found frequency value of f_5 (15.9901 d^{-1}) most likely is an 1 d^{-1} alias, and the real

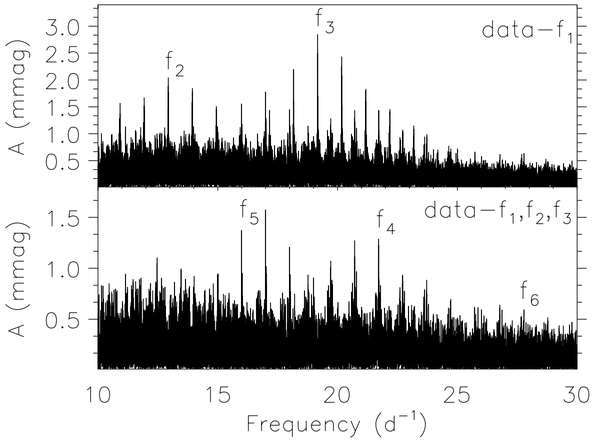

Fig. 4. Residual amplitude spectrum after subtracting f_1 and harmonics (upper panel), and f_1(and harmonics), f_2 and f_3 (lower panel), from the total dataset described in Sect. 2.

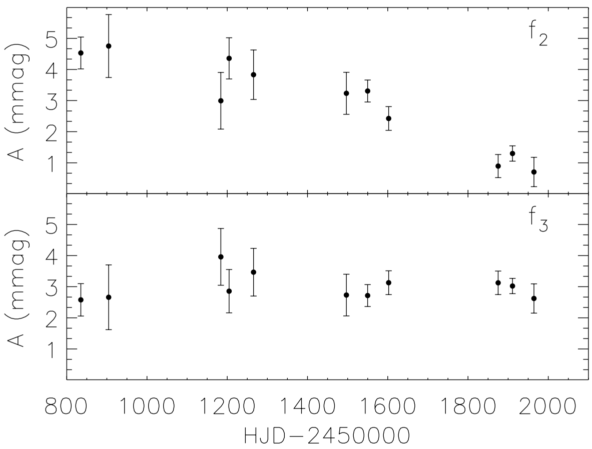

Fig. 5. The decreasing amplitude of f_2.

frequency appears to be 16.9901 d^{-1}. The period ratio with f_1 is then 0.748 instead of 0.795, and thus still not in agreement with the expected value of 0.77–0.78 for the ratio of the fundamental to first overtone oscillation (e.g. Petersen & Christensen–Dalsgaard 1996). The amplitude in the new data is 1.5 mmag, as compared to 2.1 mmag in Arentoft et al. (2001). f_6, which had been detected with very low amplitude (1.1 mmag), is not confirmed after inclusion of the new data. The reality of these effects was tested by analysing subsets of data combined in several different ways.

4. Conclusions

Newly acquired data on the δ Scuti star V 1162 Ori reveal that the period of the main oscillation has yet again changed, in between May and October 2000. Although the period changes seem to alternate between period increases and decreases, they are definitely not regular. The time scale of the period variations of about 280 d, as discussed by Arentoft et al. (2001), is supported by the new data. The presence of a secular period change is confirmed, and the rate of change is refined to $(1/P)(\mathrm{d}P/\mathrm{d}t) \sim -1.6 \times 10^{-5} \pm 4.3 \times 10^{-7}$ y^{-1}. Although lower than the

Table 2. New times of maximum and minimum light (HJD−2450000). The cycle count scheme is based on 1998.

$T_{\max}$	E	$T_{\max}$	E	$T_{\max}$	E	$T_{\min}$	E	$T_{\min}$	E	$T_{\min}$	E
1823.5645	59 892	1900.3650	60 868	1925.3878	61 186	1823.6086	59 892	1908.3562	60 969	1955.3337	61 566
1859.7619	60 352	1901.3900	60 881	1946.3183	61 452	1859.7252	60 351	1909.3774	60 982	1956.3543	61 579
1860.6250	60 363	1902.4105	60 894	1949.2322	61 489	1860.6711	60 363	1912.3686	61 020	1959.2690	61 616
1861.6490	60 376	1905.3213	60 931	1949.3096	61 490	1879.5537	60 603	1912.4452	61 021	1960.2902	61 629
1861.7279	60 377	1906.3456	60 944	1950.2544	61 502	1880.4995	60 615	1913.3891	61 033	1964.3006	61 680
1862.7504	60 390	1908.3905	60 970	1950.3316	61 503	1884.4317	60 665	1914.3335	61 045	1973.2742	61 794
1863.8532	60 404	1911.3794	61 008	1950.3338	61 503	1884.5111	60 666	1914.4138	61 046	1975.2426	61 819
1864.7969	60 416	1912.3246	61 020	1954.3477	61 554	1884.5913	60 667	1915.3572	61 058	1978.5463	61 861
1879.5892	60 604	1912.4037	61 021	1955.2904	61 566	1885.3776	60 677	1915.4380	61 059	1982.5604	61 912
1880.4568	60 615	1913.3476	61 033	1956.3140	61 579	1885.4575	60 678	1916.3825	61 071	1985.2354	61 946
1880.5338	60 616	1913.4264	61 034	1959.3029	61 617	1885.5364	60 679	1916.4581	61 072	1989.2483	61 997
1884.3916	60 665	1914.3713	61 046	1960.3292	61 630	1887.3437	60 702	1917.3255	61 083	1990.2718	62 010
1884.4692	60 666	1914.4499	61 047	1965.2853	61 693	1888.4438	60 716	1917.4031	61 084		
1885.3346	60 677	1915.3163	61 058	1965.3633	61 694	1888.5264	60 717	1918.3486	61 096		
1885.4128	60 678	1915.3929	61 059	1973.2296	61 794	1889.5455	60730	1918.4272	61 097		
1885.4929	60 679	1916.4176	61 072	1973.3116	61 795	1890.3341	60 740	1919.2911	61 108		
1885.5727	60 680	1917.3608	61 084	1975.2760	61 820	1890.4148	60 741	1919.3710	61 109		
1887.3796	60 703	1917.4407	61 085	1975.5933	61 824	1890.4899	60 742	1921.3381	61 134		
1888.4806	60 717	1918.3042	61 096	1977.5606	61 849	1890.5713	60 743	1921.4138	61 135		
1888.5627	60 718	1918.3860	61 097	1978.5018	61 861	1894.5049	60 793	1921.4150	61 135		
1889.5032	60 730	1919.3284	61 109	1978.5830	61 862	1896.3943	60 817	1923.3039	61 159		
1889.5818	60 731	1919.4070	61 110	1980.5494	61 887	1896.4744	60 818	1924.3272	61 172		
1890.3708	60 741	1921.2946	61 134	1982.5182	61 912	1898.4421	60 843	1925.3522	61 185		
1890.4500	60 742	1921.3742	61 135	1985.2727	61 947	1898.5167	60 844	1946.2832	61 451		
1890.5284	60 743	1921.3744	61 135	1989.2863	61 998	1903.3961	60 906	1946.3625	61 452		
1894.4618	60 793	1922.3184	61 147	1990.2272	62 010	1904.3430	60 918	1949.1978	61 488		
1896.3485	60 817	1922.3988	61 148			1904.4209	60 919	1949.2728	61 489		
1896.5096	60 819	1924.2855	61 172			1905.3657	60 931	1950.2185	61 501		
1898.3971	60 843	1924.3637	61 173			1906.3883	60 944	1950.2964	61 502		
1898.4761	60 844	1925.3073	61 185			1907.3304	60 956	1954.3102	61 553		

value quoted in Arentoft et al. (2001), it is still much higher than what is expected from evolutionary changes (Breger & Pamyatnykh 1998).

The evolution in amplitude of f_1 over the 2000–2001 observing season shows that also the amplitude changes are irregular, which is in agreement with the fact that amplitude values found in earlier studies are not explained by the cyclic variation reported by Arentoft et al. (2001), as mentioned in the introduction. A new possible feature resulting from our data is the presence of short intervals of constant amplitude in between the large amplitude variations.

Of the low–amplitude frequencies only f_3 has remained constant in amplitude, while f_2, f_4 and f_5 all have lower amplitude as compared to Arentoft et al. (2001). f_6 is not confirmed by the new data.

Spectroscopic observations covering at least one full observing season are needed to search for possible radial velocity variation in the 280 d cycle. Equally important, continued photometric monitoring is crucial for determining the evolution in period and amplitude. We give in Table 2 our new times of maximum and minimum light, in order to allow observers in the coming season to assess the evolution in period.

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