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DISCOVERY OF A NEW δ SCUTI VARIABLE STAR

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Abstract: This paper reports the serendipitously discovery of a new variable star with mean visual magnitude +14.73 ± 0.03 mag and mean V-R color indice 0.33 ± 0.03 in Ophiuchus constellation (α = 16h 53m 02.14s; δ = -01° 09′ 5,6″ (J2000.0)). The shape of the raw lightcurve and the observed periods lead to the conclusion that the star is a δ Scuti with a period of 0.05300 ± 0.00004 days with an amplitude of 0.07 ± 0.01 mag in R band. The knowledge of the star period allows an estimate of the distance that, considering interstellar absorption, is about 1000 pc.

The Astronomical Observatory of the Autonomous Region of The Aosta Valley (in short OAVdA, code B04), is located near a very small alpine village in the North-West of Italy, at 1,675 m above the sea level. In this site the sky is dark and almost free from light pollution. The observatory was inaugurated in 2003 and since 2006 began the photometric and astrometric observations of asteroids: Trojans and NEAs (Near Earth Asteroids). The asteroids observations are carried out using the largest telescope of the observatory, an 810 mm f/7.9 Ritchey-Chrétien reflector equipped with a Finger Lakes Instrumentation PL 3041-1-BB back illuminated CCD camera with standard BVRI filters. The camera sensor has 2048 × 2048 square pixel, 15 μm side and, at the Cassegrain focus, the field of view is about 16.3' × 16.3'. Astrometric measures are made using Astrometrica, the software of Herbert Raab, while photometric measurements and lightcurves are reduced and plotted using the MPO Canopus software by BDW Publishing. Identification of the star has been made with Aladin Sky Atlas **(Bonnarel et al., 2000)**.

The new variable star was shooting the first time in R band in the night between 2009 May 24 and 25, during the photometric observation of Trojan asteroid (4832) Palinurus. The variability was found serendipitously after performing differential aperture photometry with five comparison stars in order to obtain the asteroid rotation period. To determine more precisely period and amplitude, the star was specifically observed on 2009 May 28 and June 2, 3, 13 in standard R band. On June 3 and 13 the star was also observed in V band. Here are the results of these four days of observations.

The measure of the astrometric coordinates has given the values α = 16h 53m 02.14s and δ = -01° 09′ 5,6″ (J2000.0). This position is in Ophiuchus constellation and coincides with the star S7ZO000247 of the GSC2.3 catalogue, the star 0888-0279225 of the astrometric catalog USNO-B1 or the star 31353662 of the UCAC2 catalog (Figure 1). A search in GCVS, SIMBAD and VIZIER databases didn't reveal any information about variability of this star. The database of NASA Galaxy Evolution Explorer satellite show a UV source (GALEX J165302.1-010905), coincident with the star position and with near/far UV magnitude +18.55/+21.66. The star is reported as suspected variable in the NSVS catalog (Northern Sky Variability Survey) with object ID 13610694. However, no one had ever studied with a detail that makes possible to determine its physical characteristics.

The average magnitude was manually measured using three mean points on lightcurves taken on May 28 (R filter) and June 3 (V filter). As reference stars were used those of the CMC14 catalog with J-K between 0.3 and 0.5, near the value of 0.368 mag of the variable star (2MASS catalogue). The reference stars are reported in Table 2, while the reduction method with CMC14 stars is described in (**Dymock and Miles, 2009)**. In R band the mean apparent magnitude is +14.40 ± 0.01 mag, while in V band is +14.73 ± 0.03 mag. The magnitude uncertainty is the standard deviation of three independent values. With the previous mean magnitude values the observed mean V-R color indice is 0.33 ± 0.03 which is typical of F1 star **(Zombeck, 1990)**. No observations of Landolt fields were made to obtain a more accurate estimate of the mean V and R magnitude.

The raw lightcurve looks like that of a pulsating star, with a series of maximum and minimum with slight differences from one cycle to the next (Figure 2). The lightcurve Fourier analysis performed with Canopus at orders one and with a temporal resolution of 0.00004 days shows that, probably, there are two periods that overlap on the raw red lightcurve. In R band the first period is 0.05300 ± 0.00004 days with an amplitude of 0.07 ± 0.01 mag (Figure 3), while the second period has a value of 0.05450 ± 0.00004 days, with an amplitude of 0.02 ± 0.01 mag (Figure 5). The Figure 4 and 6 show the periods spectrum for the first and the more difficult to establish secondary period. In V band there is only a period of 0.05246 ± 0.00004 days, with amplitude 0.11 ±

0.01 mag. In V band it was not possible to highlight a secondary periods with amplitude greater than 0.01 magnitude. The slight difference between the values of the fundamental period in R and V band (about 2 minutes), and the lack of a secondary period in V are due to the lesser frequency resolution of the V timeseries. With these lightcurve characteristics the star results to be a low amplitude δ Scuti variable. In Table 1 are summarized the derived parameters: identification, coordinates, time of maximum (heliocentric JD), assumed fundamental period and amplitude in R and V band. The JD of maximum, observed on 2009 May 29 at 00:07:08 UTC in R band, was computed with Canopus and corrected for heliocentric time.

A δ Scuti (also known as a dwarf Cepheid) is a main sequence Population I A-F type variable star which exhibits variations in its luminosity due to both radial and non-radial pulsations of the star's surface, with typical brightness fluctuations from 0.001 to 0.9 magnitudes in V over a period that does not exceed 0.3^d **(De Coca et al., 1990; Poretti et al., 2008)**. For δ Scuti, as for other Cepheids, there is a relation period-luminosity (or P-L relation), that links the fundamental period in days to the average absolute magnitude in V band **(McNamara et al., 2007)**:

$$\overline{M}_V = -2.90\log(P) - 0.190[Fe/H] - 1.27 \qquad (1)$$

Equation (1) was derived from 48 Galactic δ Scuti stars with accurate Hipparcos parallaxes (errors in the parallaxes ≤10% of the parallax). The quantity [*Fe/H*] is the metallicity term, which represents the logarithm of the ratio of a star's iron abundance compared to that of the Sun:

$$[Fe/H] = \log_{10}\left(\frac{N_{Fe}}{N_H}\right)_{Star} - \log_{10}\left(\frac{N_{Fe}}{N_H}\right)_{Sun} \qquad (2)$$

In Equation (2) N_{Fe} and N_H are the number of iron and hydrogen atoms per unit of volume respectively. Assuming a solar-type composition, Equation (2) gives [*Fe/H*] = 0 so, using Equation (1), one can estimate the star distance from the Sun. Putting $P = 0.05300^d$, that we assumed to be the fundamental radial mode, the average absolute visual magnitude result +2.43 (about 9 times the brightness of the Sun). A similar result fot the absolute visual magnitude can be found with the P-L relation of **Poretti et al., (2008)**, obtained by analyzing different stellar systems (Milky Way, Large Magellanic Cloud, Fornax dSph, ω Cen, M55 and Carina dSph), that is metallicity-free:

$$\overline{M}_V = -3.65\log(P) - 1.83 \qquad (3)$$

Using Equation (3) the absolute visual magnitude is +2.83. Considering the interstellar absorption, the star distance is given by **(Karttunen et al., 1996)**:

$$\overline{M}_V = \overline{m}_V + 5 - 5Log(d) - a \cdot d \qquad (4)$$

In Equation (4), *a* is the interstellar absorption constant that, for an average extinction, has a value of about 2 mag/kpc. With $\overline{M}_V = +2.43/+2.83$ and $\overline{m}_V = +14.73$, the Equation (3) is verified for *d* = 1073 / 976 pc (about 3500 / 3200 light years). The second value appear more robust because it is independent on assumptions about the metallicity of the star.

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Table 1: Identification, coordinates, time of maximum (heliocentric JD), periods and amplitudes of the new δ Scuti variable.

GSC2.3	α (J2000.0)	δ (J2000.0)	HJD (max)	Period (days)	A (mag)
			R band	R band	R band
S7ZO000247	16h 53m 02.14s	-01° 09′ 5,6″	2454980.51025 ± 0.005	0.05300 ± 0.00004	0.07 ± 0.01
				0.05450 ± 0.00004	0.02 ± 0.01
				V band	V band
				0.05246 ± 0.00004	0.11 ± 0.01

Table 2: Comparison stars as indicated on Fig. 1

Comparison	α (J2000.0)	δ (J2000.0)	r mag (CMC14)	J-K mag (2MASS)
A	16h 53m 06.42s	-01° 07′ 24.2"	+14.498	0.396
B	16h 53m 24.48s	-01° 09′ 42.8"	+14.797	0.429
C	16h 53m 08.87s	-01° 07′ 28.3"	+15.182	0.501
D	16h 53m 09.85s	-01° 02′ 36.0"	+14.555	0.529

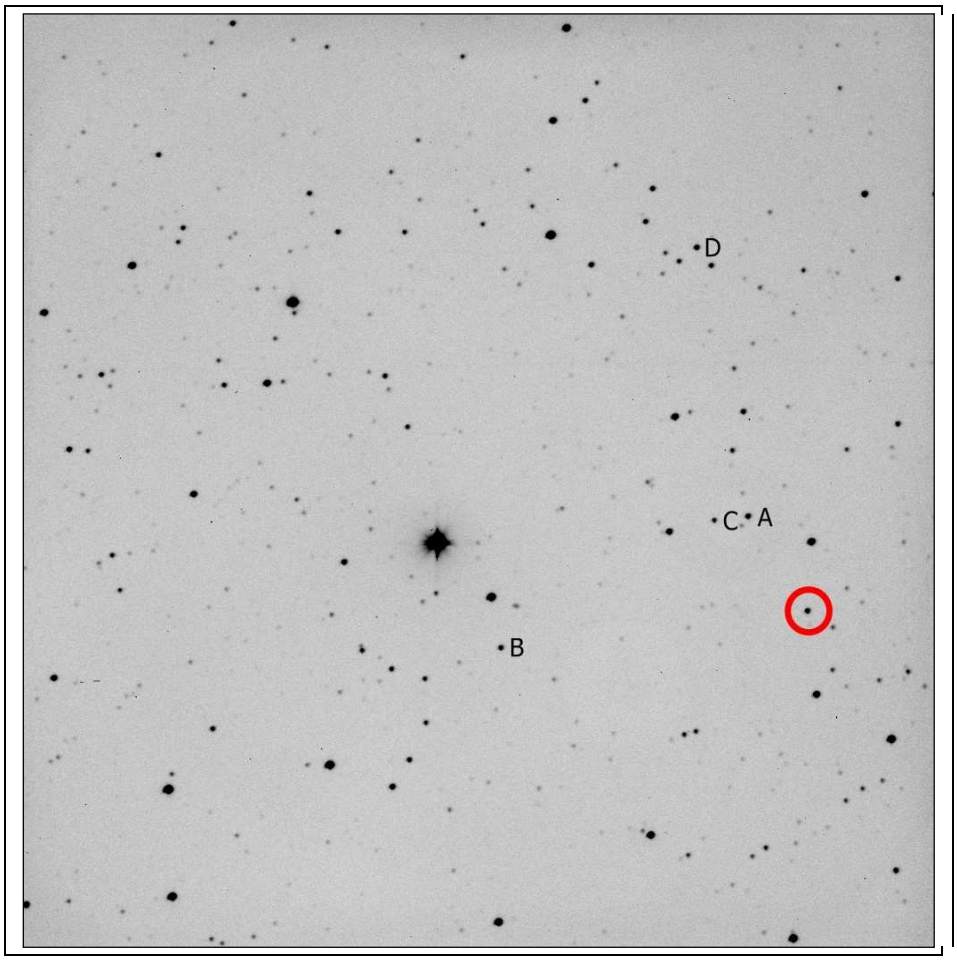

Fig. 1 The stars field of the new variable (circled in red), corrected for master dark frame and master flat field. The brighter star near the image center its SAO141421 of visual apparent magnitude +7.83. The comparison stars are indicated with capital letters to their right. The field of view is 16.3′×16.3′, north is up and east is at left.

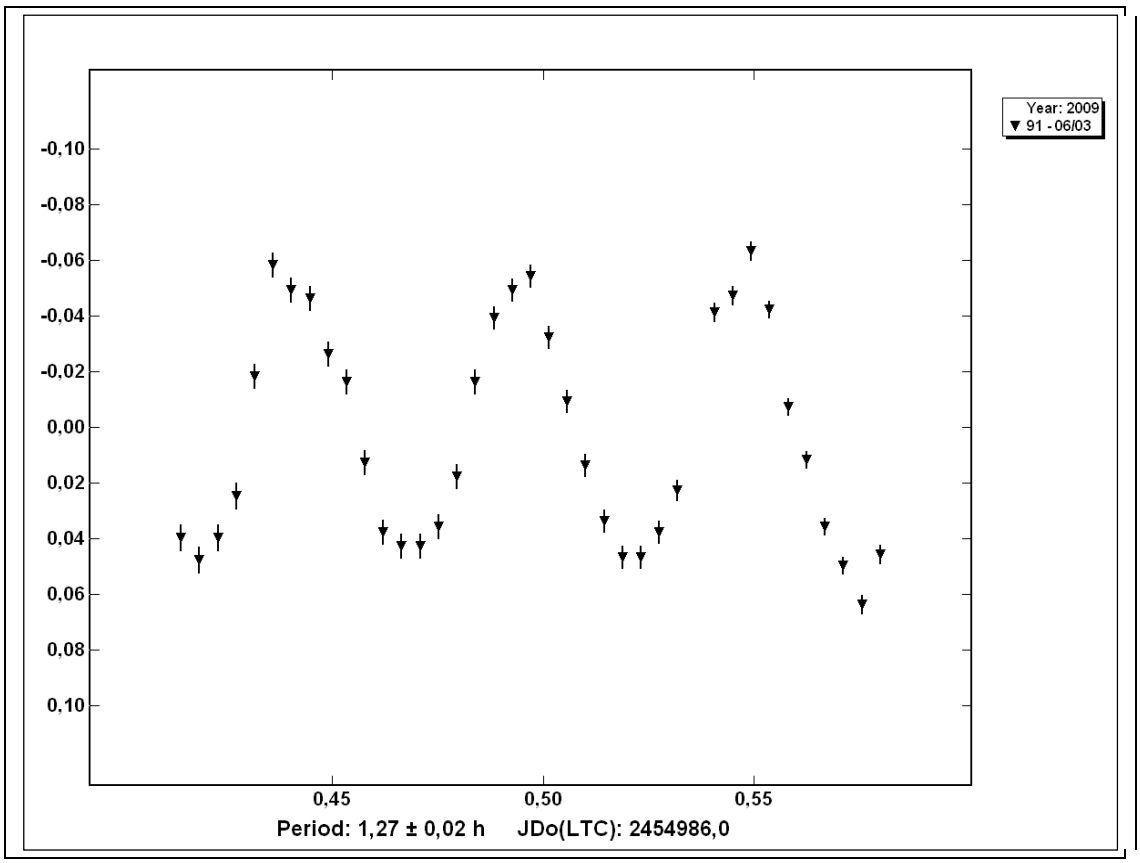

Fig. 2 The raw lightcurve in V band from observations of 2009 June 3.

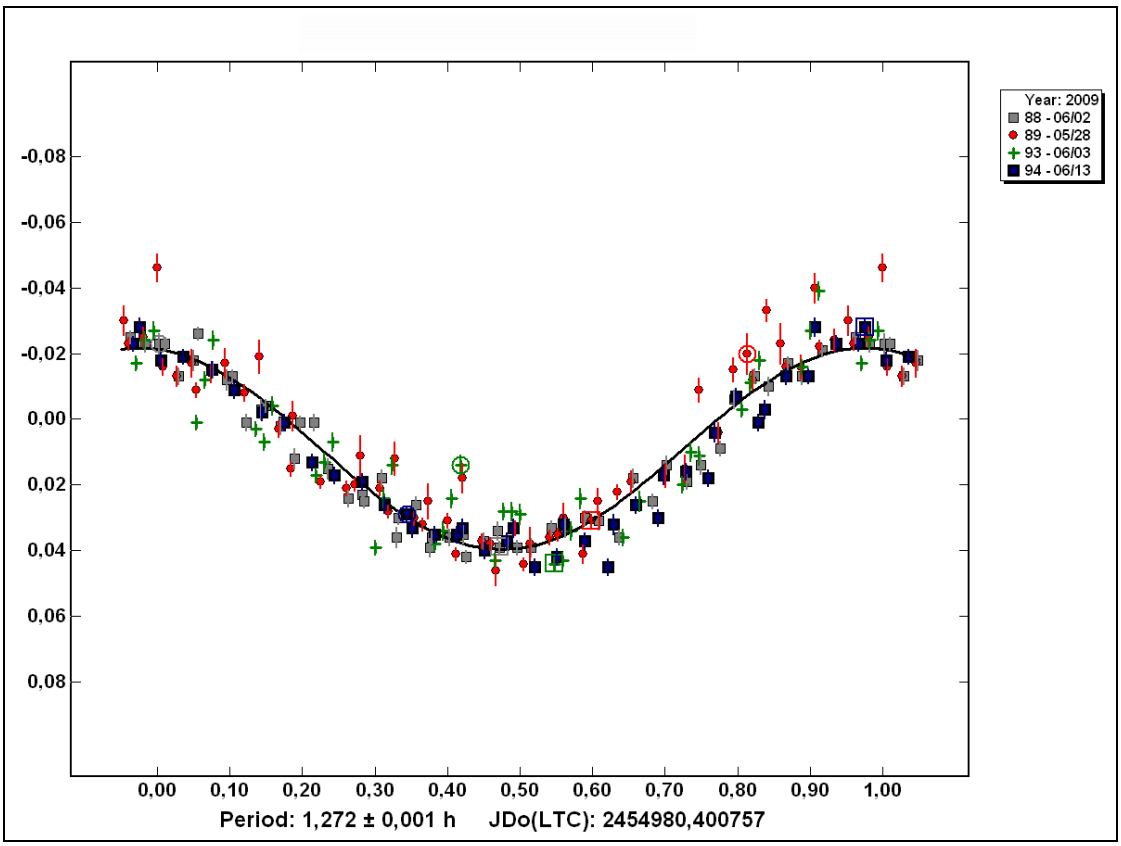

Fig. 3 The first period in R band from observations of 2009 May 28 and June 2, 3, 13.

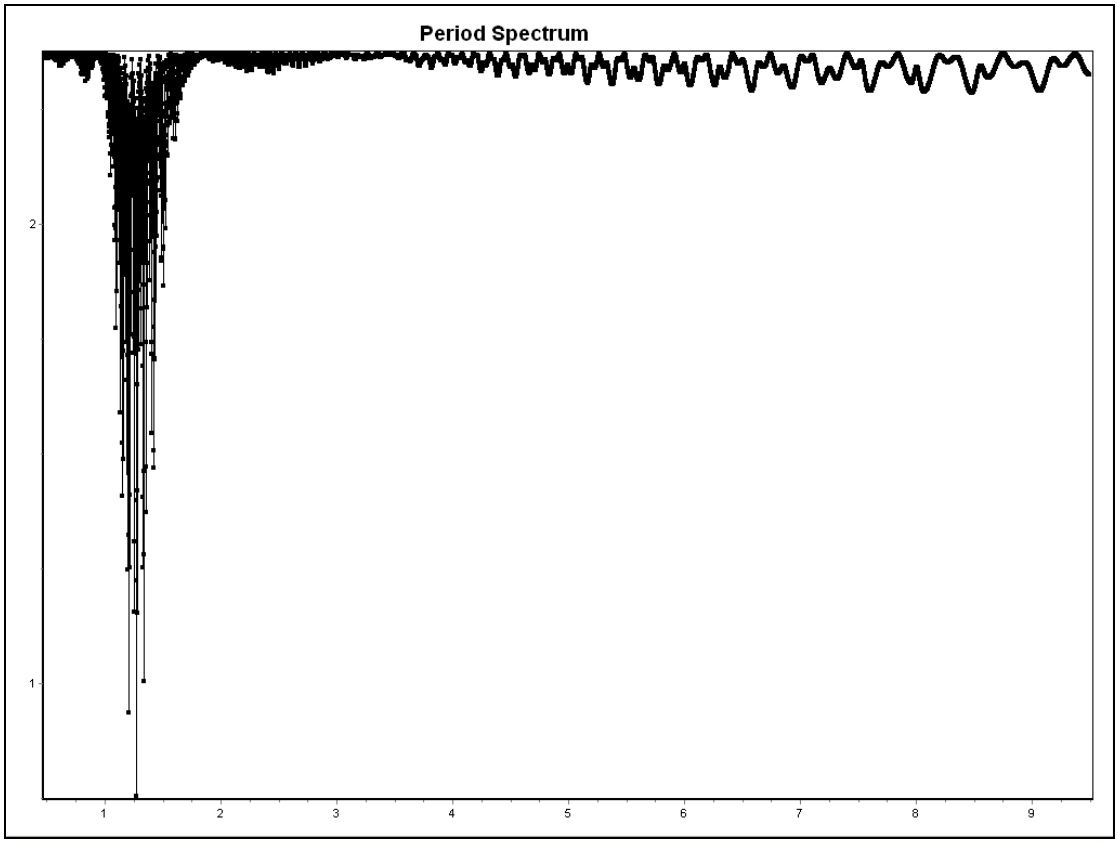

Fig. 4 The first period spectrum in R band (the x-axis is in hours). The most probable period is about 0.055300 days.

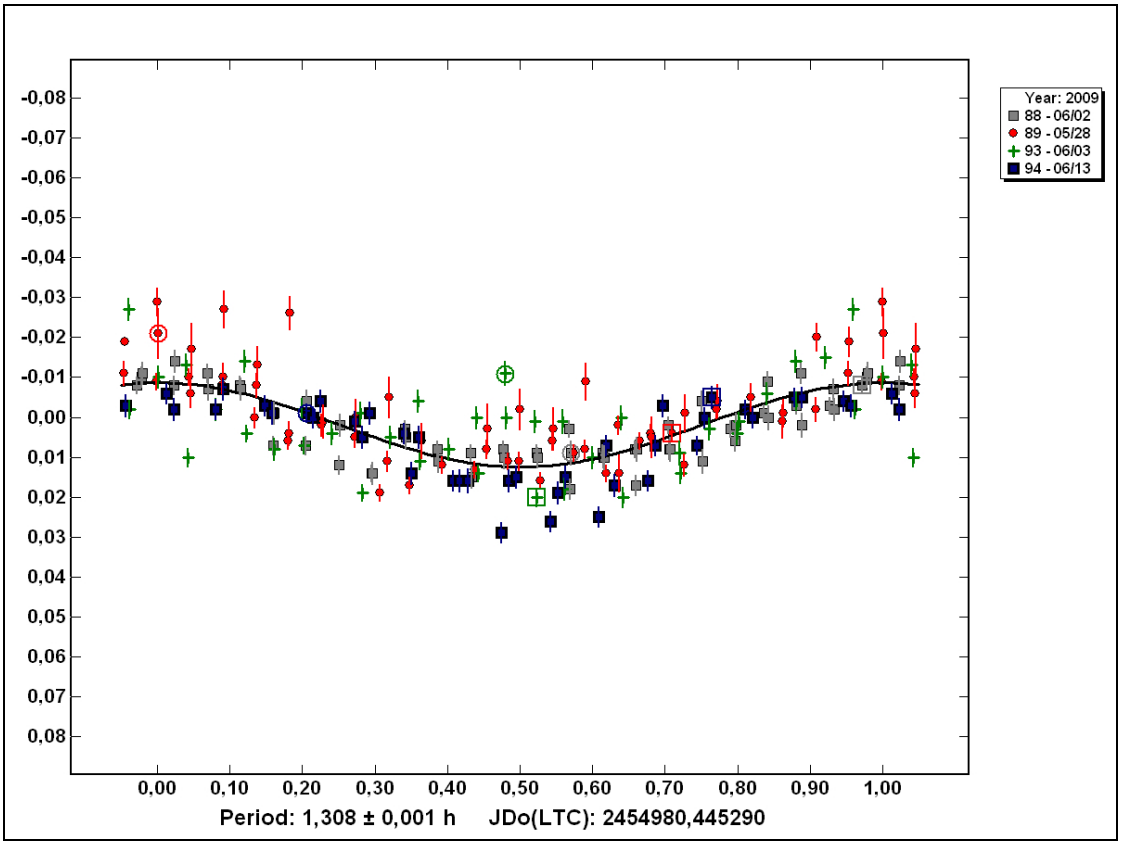

Fig. 5 The second period in R band from observations of 2009 May 28 and June 2, 3, 13.

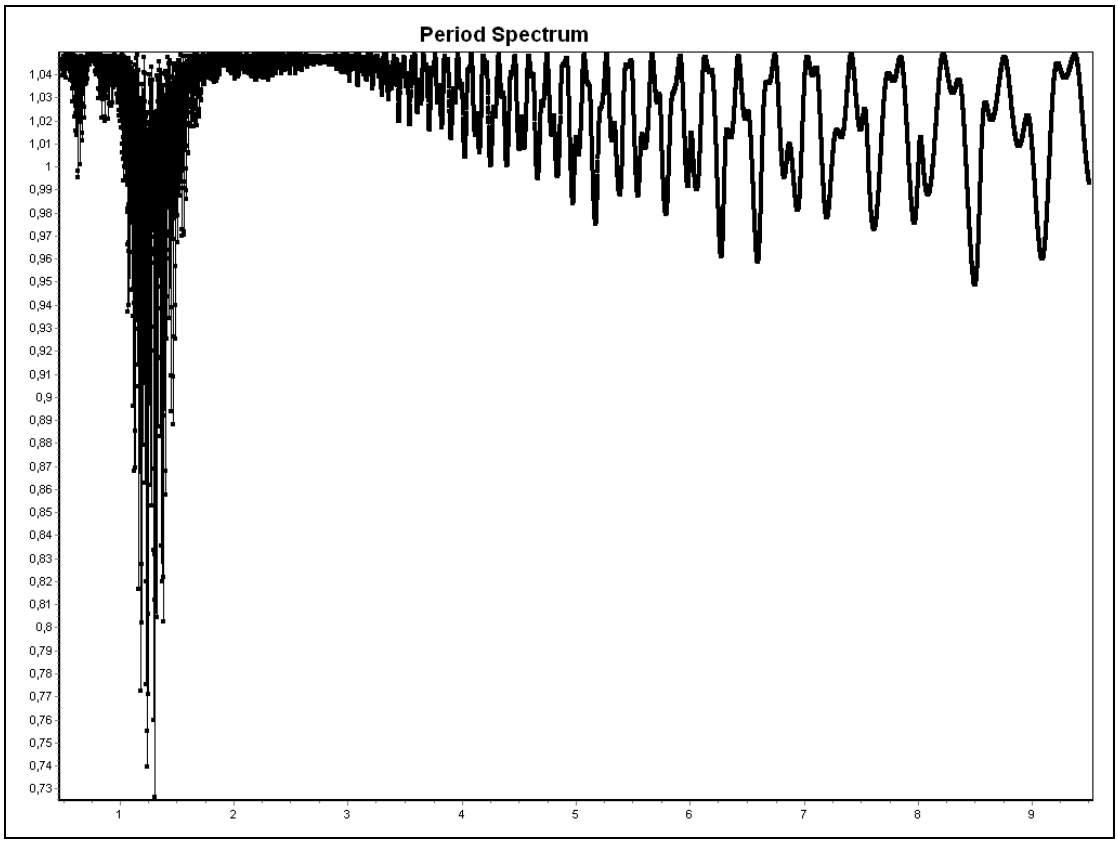

Fig. 6 The second period spectrum in R band (the x-axis is in hours). The most probable second period is about 0.0545 days.

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