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A NEW DOUBLE-MODE HIGH-AMPLITUDE δ SCUTI STAR: GSC 2583-00504

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The star GSC 2583-00504 (= ROTSE1 J161331.84+323439.6; $\alpha_{2000} = 16^{\rm h}13^{\rm m}32^{\rm s}$; $\delta_{2000} = +32°34'43''$) was detected as a variable by the ROTSE1 (Robotic Optical Transient Search Experiment 1) survey (Akerlof et al., 2000). The authors announced a Cepheid-like variable with a period of $1\overset{\rm d}{.}52315$ in the approximate magnitude range 12.3-12.5 (ROTSE1 unfiltered magnitudes). Close scrutiny of the ROTSE1 data however revealed that the true period of this star was probably much shorter.

The star was subsequently monitored on seven nights between February and April 2003 (12.7 hours, 566 data points) at Beersel Hills Observatory (BHO), and on five nights in May and June 2003 (28.5 hours, 744 data points) at SETEC Observatory. The instruments used were a 0.40-m telescope, equipped with a ST10 XME camera (an ST7E was used on one night), at BHO and a 0.30-m Meade LX-200 with a ST-8i CCD camera at SETEC. A V filter was used at both sites. The exposure times were approximately 120 seconds. The frames were respectively reduced with the aperture photometry procedure of the Mira AP software package† (BHO) and with the AIP4Win package (SETEC).

The brightness of the variable was measured with respect to GSC 2583-00463; GSC 2583-00438 served as a check star. Magnitudes from the Tycho-2 catalogue (Høg et.al., 2000) are given in Table 1. The nightly standard deviation of the magnitude differences between the comparison and the check star varied between $0\overset{\rm m}{.}007$ and $0\overset{\rm m}{.}019$, with average $\Delta V = -2.10$.

Table 1. Tycho-2 magnitudes for variable and comparison stars.

Star	GSC 2583	V_T	$B_T - V_T$
Variable	00504	12.00	0.17
Comparison	00463	12.31	0.37
Check	00438	10.17	1.01

It was soon obvious that the period of GSC 2583-00504 is indeed much shorter than the one mentioned by Akerlof et al. (2000). The light curve shown in Fig. 1 closely resembles

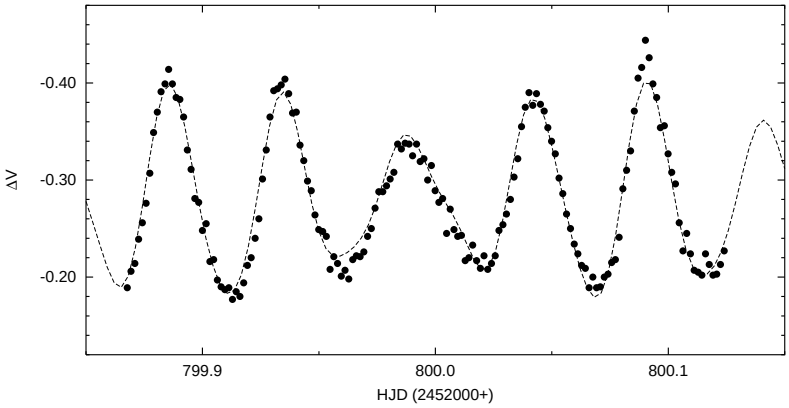

Figure 1. V light curve on the night of 8 June 2003, superimposed on a 3-frequency fit.

that of SX Phe, a double-mode radial pulsator and the prototype of its class, a subgroup among the high amplitude δ Scuti stars (HADS) of low mass and low metallicity.

Using the Fourier analysis program Period98 (Sperl, 1998), a period $P_0 = 0.05172$ days (see Fig. 2) with a peak-to-peak amplitude of $0\overset{\mathrm{m}}{.}17$ was found (frequency $f_1 = 19.335$ c/d). Note that only BL Cam among the known HADS has an even shorter period (see Table 2 in McNamara, 2000). A second frequency located at $f_2 = 25.005$ c/d with a total amplitude of $0\overset{\mathrm{m}}{.}06$ is also found in a straightforward way (the exact value of the frequency was determined after a first prewhitening). The errors in frequency correspond to 0.003 c/d, the half width at half maximum of the peaks in the Fourier spectrum.

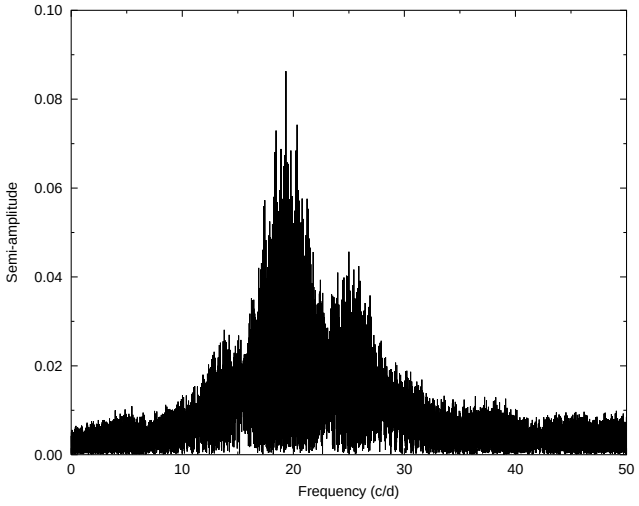

Figure 2. Fourier spectrum of GSC 2583-00504.

After prewhitening for both frequencies, the first harmonic of f_1 at 38.670 c/d with a total amplitude of $0\overset{\mathrm{m}}{.}02$, was detected in the subsequent periodogram (Fig. 3). The asymmetric mean light curve phased with respect to the main frequency is illustrated by Fig. 4. Finally also the combination $f_1 + f_2 = 44.339$ c/d is detectable in Fig. 3, with an

† The Mira AP software is produced by Axiom Research Inc.

amplitude just below $0^{\rm m}.02$. The signal-to-noise ratio of the latter frequency is however only 3.5.

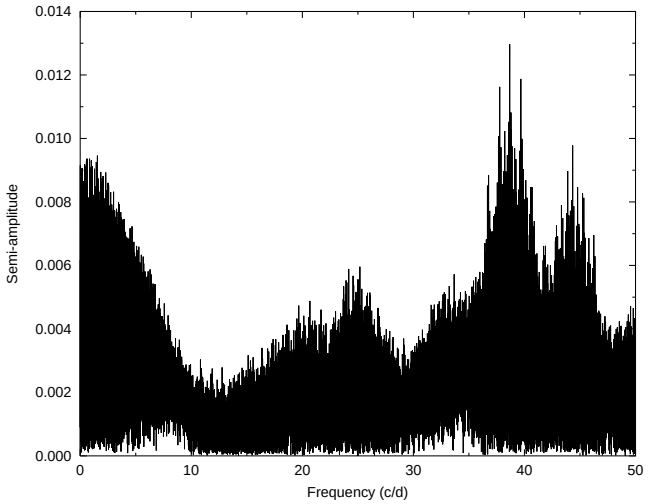

Figure 3. Fourier spectrum of GSC 2583-00504 after prewhitening for f_1 and f_2.

The ratio of 0.7732 between the second and the first period may be estimated with an accuracy of 0.0002 and agrees very well with the first overtone-to-fundamental mode period ratio as predicted by the models for radially pulsating HADS (Petersen and Christensen-Dalsgaard, 1996). GSC 2583-00504 is thus a new HADS and one of only about a dozen double-mode HADS exhibiting radial pulsation known in the galaxy (McNamara, 2000, and Van Cauteren and Wils, 2001). Though the resemblance with SX Phe is remarkable (Table 2), the amplitudes are smaller (cfr. the semi-amplitudes A_0 and A_1 in Table 2). Another distinct feature is that the period ratio P_1/P_0 is lower. Petersen and Christensen-Dalsgaard (1996) showed that the period ratio alone gives very little information on a particular variable star, except for the very short period range (P_0 less than 0.07 days). From their Fig. 3 and the properties of the stars of Table 2 in McNamara (2000), we may predict a low metal content for the new HADS, as there exists "a clear separation in P_1/P_0 after Z" in this period range.

In conclusion, the new ROTSE1 variable star has a very short main period (identified as the fundamental radial mode) and a light curve fully reminiscent of SX Phe, a double-mode radial pulsator of Population II, but with a period ratio P_1/P_0 which is somewhat lower. From a comparison with models and the known variables of this group, the new HADS probably has a lower than normal metallicity, making it a prime candidate for a double-mode radial pulsator of population II (or SX Phoenicis star) (not a member of a globular cluster). To check this assumption no information is however available in the literature to our knowledge. Therefore a photometric colour index related to metal content (Z) such as m_1 (Strömgren system) or m_2 (Geneva system) or, even better, a careful abundance analysis, would be most needed. Also, additional observations to refine the accuracy of the frequency determinations and the period ratio are planned in the future.

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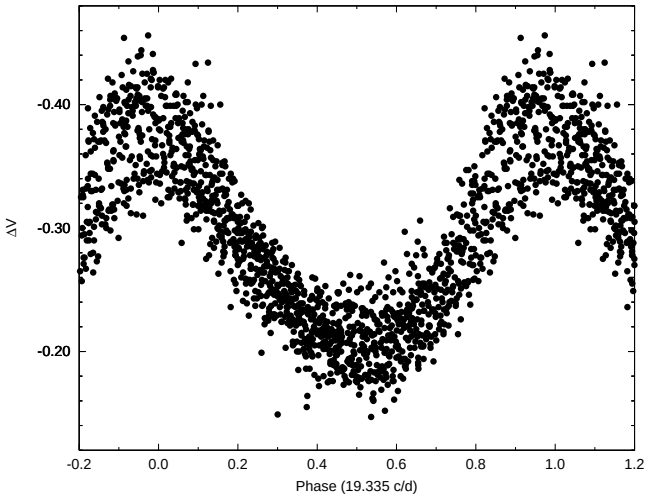

Figure 4. Phased light curve with respect to the main frequency.

Table 2. Comparison between SX Phe and the new HADS.

Star	$logP_0$	A_0	$logP_1$	A_1	P_1/P_0	Z
SX Phe	-1.260[1]	0.279[1]	-1.369[1]	0.099[1]	0.77819 ± 0.00001[2]	0.0007[3]
new HADS	-1.286	0.083	-1.398	0.029	0.7732 ± 0.0002	?

[1] Rolland et al., 1991 [2] Coates et al., 1982 [3] McNamara, 2000

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