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UZ UMa: AN RRab STAR WITH DOUBLE-PERIODIC MODULATION

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UZ UMa was discovered to be variable by Baker (1938). He classified it as an irregular or semiregular type variable based on the photographic observations of Kapteyn. The correct classification (RRab) and period (P=0.4668795 d) were given by Meinunger (1968).

UZ UMa was observed in the course of our survey of short period ($P_{\rm puls} < 0.48$ d), fundamental mode, northern RR Lyrae stars, that aims to determine the real incidence rate of Blazhko variables in this sample and to study the modulation properties in detail. The observations were made with the 60 cm automatic telescope of Konkoly Observatory, Svábhegy, Budapest, equipped with a Wright 750×1100 CCD camera through a Cousins V filter. 1584 brightness measurements were obtained on 30 nights between 27 January and 23 May in 2006 (JD 2453763–878). Data reduction was performed using standard IRAF[1] packages. As no appropriate comparison star was found in the field of view, magnitude differences of UZ UMa from the average magnitude of 5 neighboring stars (GSC 21322-01261, GSC 21322-014531, GSC 21322-01252, GSC 21322-014679 and GSC 21322-01255) were calculated in order to reduce the noise of the comparisons' magnitudes. Instrumental magnitude differences of UZ UMa are given in Table 1, available only electronically.[2]

The following elements for light maxima were derived:

$$t_{\rm max}[{\rm HJD}] = 2453763.3368 + 0.4668413\,{\rm d}\cdot E$$

The original light curve and the light curve prewhitened with the pulsation frequency and its harmonics phased with the pulsation period are shown in Fig. 1–2. The plots clearly show the sign of the Blazhko modulation. The residual light curve indicates that the modulation is the largest on the rising branch and around maximum brightness, significant changes in the shape of the bump preceding minimum light also occur. The light curve is the most stable at minimum and on the mid part of the descending branch.

The Fourier spectrum of the light curve prewhitened with the 18 harmonics of the pulsation shows a complex structure of peaks around the pulsation frequencies. We assume that the Blazhko modulation can be described with the same, symmetric pattern of modulation frequency components of the residual spectrum around the frequency components of the pulsation. In this case the true modulation frequency can be identified more clearly

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[1] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

[2] Available on the IBVS website as `5705-t1.txt`.

in a *cumulative spectrum* defined as the sum of the two sides of the spectrum's segments in the vicinities of the pulsation peaks up to a given order according to the following formula:

$$A'(f) = \sum_{i=1}^{n} \left[A(i \cdot f_{\rm p} + f) + A(i \cdot f_{\rm p} - f) \right], \quad f < f_{\rm r}.$$

$A(f)$ is the original spectrum, $f_{\rm p}$ is the pulsation frequency, i is the harmonic order, $f_{\rm r}$ is the length of the examined frequency range and $A'(f)$ is the yielded cumulative spectrum, which has better S/N properties than the original spectrum.

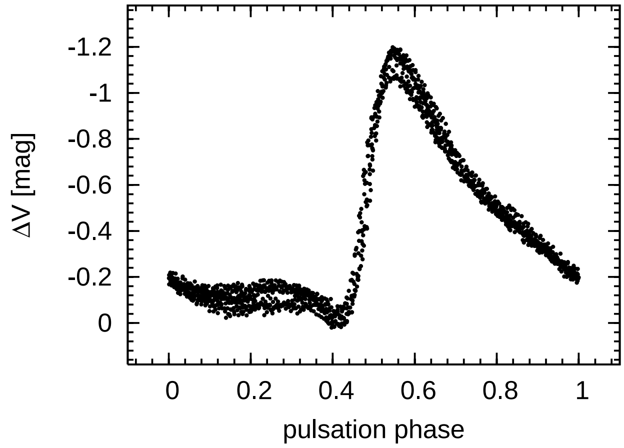

Figure 1. The V light curve of UZ UMa phased with the pulsation period.

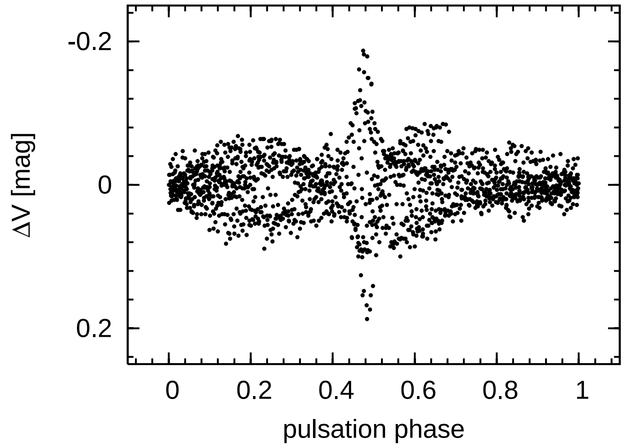

Figure 2. The prewhitened V light curve of UZ UMa phased with the pulsation period.

The cumulative spectrum of the prewhitened light curve shows two modulation peaks of different shapes, one at 0.065 c/d and another, wider component at around 0.03 c/d (see Fig. 3). The wideness of this latter frequency component indicates that there might be some differences in its position in the different harmonic orders and at the different sides of the pulsation components. However, to examine this possibility in more detail a more extended dataset is needed.

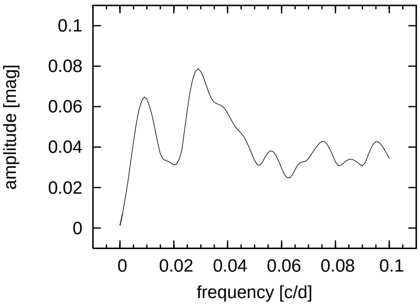

Figure 3. The cumulative residual spectrum of UZ UMa summed for the first 8 pulsational harmonics.

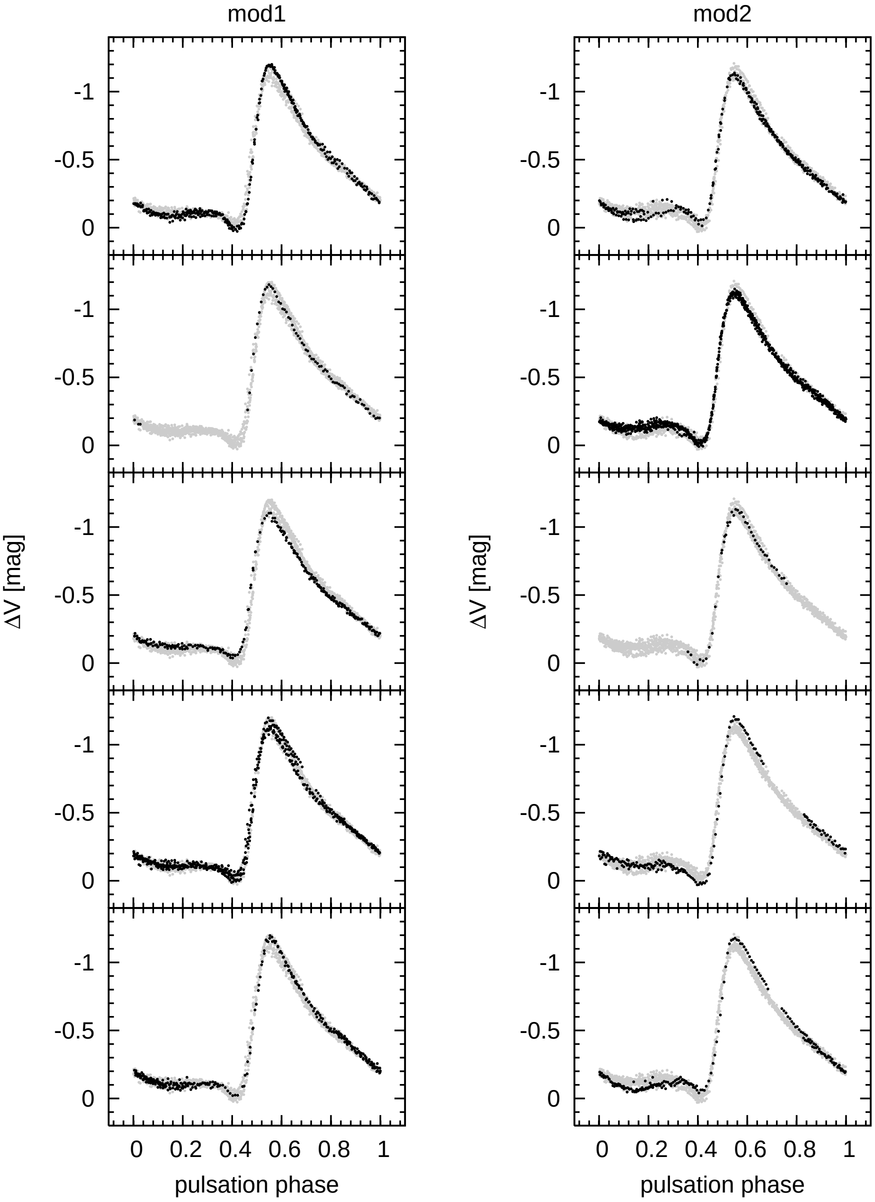

Figure 4. The light curves in different phases of the 26.7-day and 143-day modulations after removing the modulation corresponding to the other modulation period. In the electronic edition animated figures of the modulations are available.

In accordance with the two frequency peaks appearing in the cumulative residual spectrum, the light curve of UZ UMa cannot be fitted with the required accuracy assuming a single modulation period. Instead, even with two different modulation periods the residual scatter remains larger than observational inaccuracies would explain. Though the modulations of many Blazhko stars are known not to be strictly regular, the light curve of only XZ Cyg (LaCluyzé et al., 2004) has been previously described by two pairs of equidistant modulation components.

Data analysis was performed using the utilities of the program package MUFRAN (Kolláth, 1990). First we determined the modulation frequency values, $f_{\mathrm{mod}\,1}$ and $f_{\mathrm{mod}\,2}$ simultaneously through an iterative process, as the frequencies that yield the best fit to the residual light curve prewhitened by the pulsation frequency components up to the 18 th harmonics. The modulation components up to the 8 th harmonic order and also $f_{\mathrm{mod}\,1}$ and $f_{\mathrm{mod}\,2}$ were considered. The following modulation frequencies were thus determined: $f_{\mathrm{mod}\,1} = 0.0374\,\mathrm{c/d}$ and $f_{\mathrm{mod}\,2} = 0.0070\,\mathrm{c/d}$ ($P_{\mathrm{mod}\,1} = 26.7\,\mathrm{d}$ and $P_{\mathrm{mod}\,2} = 143\,\mathrm{d}$). If the modulation frequencies are not determined simultaneously but in consecutive steps, then very similar results arise. The first modulation frequency is then at 0.0372 c/d, and the other modulation frequency gives the best fit with 0.0065 c/d value. The observations span over only 115 days, thus the period of the secondary modulation is somewhat uncertain. Its value is most probably somewhere between 125 d and 170 d.

The 0.017 mag r.m.s. scatter of the residual indicates even more complex behaviour of the modulation, but no further real frequency component can be resolved.

In Kovács (2005) it was noted that in case of good data sampling the mean light curve of Blazhko stars can be used to define the physical properties from the Fourier parameters of the light curve. We came to the same conclusion using the data of the small amplitude modulation RRab stars: RR Gem and SS Cnc (Jurcsik et al., 2005; Jurcsik et al., 2006). Based on the Fourier parameters of the mean light curve of UZ UMa $[\mathrm{Fe/H}] = -1.17$ can be determined using the formulae of Jurcsik & Kovács (1996). Our previous multicolour measurements with the same instrumentation indicate that if instrumental v magnitudes are used instead of standard V magnitudes, then the calculated [Fe/H] overestimates the metal content only by $0.02 - 0.04$.

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