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Double Mode Cepheids with Amplitude Modulation

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Abstract. Recent search for multiperiodicity in LMC Cepheids (Moskalik, Kołaczkowski & Mizerski 2004) has led to discovery of periodic modulation of amplitudes and phases in many of the first/second overtone (FO/SO) double mode pulsators. We discuss observational characteristics and possible mechanisms responsible for this behaviour.

Key words. Stars: variables: Cepheids

1. FO/SO Cepheids of the LMC: Data and Analysis

56 FO/SO double mode Cepheids have been identified in OGLE LMC photometry (Soszyński et al. 2000). We have supplemented this sample by 51 additional objects discovered by MACHO team (Alcock et al. 1999; 2003). The photometric data were analysed with a standard prewhitening technique. First, we fitted the data with double frequency Fourier sum representing pulsations in two radial modes. The residuals of the fit were then searched for additional periodicities. In the final analysis we used MACHO data (Allsman & Axelrod 2001), which offer considerably higher frequency resolution than OGLE data.

2. Results

Resolved residual power close to the primary pulsation frequencies was detected in 20 FO/SO double mode Cepheids (19% of the sample). These stars are listed in Table 1.

Stars of Table 1 display very characteristic frequency pattern. In most cases, we detected two secondary peaks on opposite sides of each radial frequency. Together with the radial frequencies they form two *equally spaced frequency triplets* (see Fig. 1). Both triplets have *the same frequency separation* Δf. Such a pattern can be interpreted as a result of periodic modulation of both radial modes with a common period $P_{mod} = 1/\Delta f$. In Fig. 2 we show this modulation for one of the stars. Both *amplitudes and phases* of the modes are modulated. *Minimum amplitude of one mode coincides with maximum amplitude of the other*. These properties are common to all FO/SO double mode Cepheids listed in Table 1.

3. What Causes the Modulation ?

Two models have been proposed to explain Blazhko modulation in RR Lyr stars: the oblique magnetic pulsator model (Shibahashi

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Table 1. Modulated double mode Cepheids

Star	P_1 [day]	P_2 [day]	P_{mod} [day]
SC1–44845	0.9510	0.7660	794.0
SC1–285275	0.8566	0.6892	891.6
SC1–335559	0.7498	0.6036	779.2
SC2–55596	0.9325	0.7514	768.2
SC6–142093	0.8963	0.7221	1101.6
SC6–267410	0.8885	0.7168	856.9
SC8–10158	0.6900	0.5557	1060.7
SC11–233290	1.2175	0.9784	1006.2
SC15–16385	0.9904	0.7957	1123.1
SC20–112788	0.7377	0.5945	1379.2
SC20–138333	0.8598	0.6922	795.0
2.4909.67	1.0841	0.8700	1019.7
13.5835.55	0.8987	0.7228	1074.9
14.9585.48	0.9358	0.7528	1092.5
17.2463.49	0.7629	0.6140	1069.9
18.2239.43	1.3642	1.0933	706.8
22.5230.61	0.6331	0.5101	804.3
23.3184.74	0.8412	0.6778	1126.0
23.2934.45	0.7344	0.5918	797.6
80.7080.2618	0.7159	0.5780	920.3

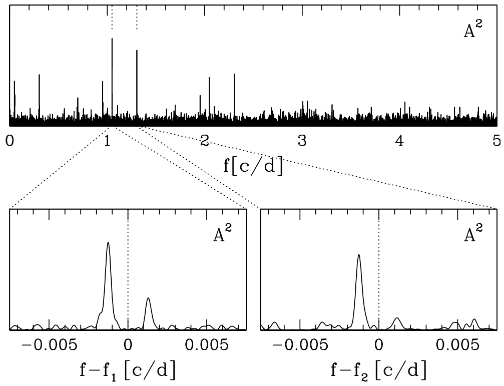

Fig. 1. Power spectrum of LMC Cepheid SC1–44845 after prewhitening with two radial modes. Removed radial frequencies indicated by dashed lines. Lower panels display the fine structure.

1995) and 1:1 resonance model (Nowakowski & Dziembowski 2001). Both models fail in case of modulated FO/SO double mode Cepheids, being unable to explain why amplitudes of the two radial modes vary in opposite phase (Moskalik et al. in preparation).

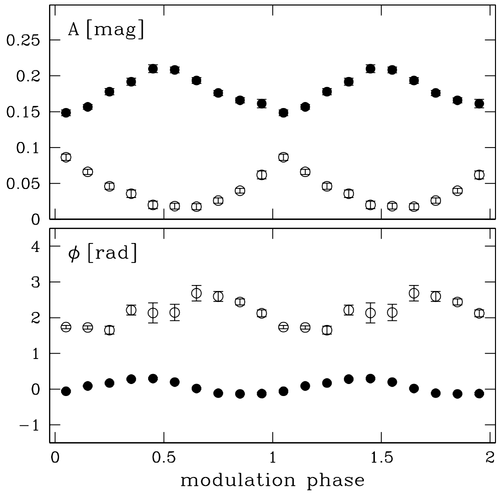

Fig. 2. Periodic modulation of LMC double mode Cepheid SC1–285275. First and second overtones displayed with filed and open circles, respectively.

At this stage, the mechanism causing modulation in FO/SO Cepheids remains unknown. However, common modulation period and the fact that high amplitude of one mode always coincides with low amplitude of the other, strongly suggest that energy transfer between the two modes is involved. Thus, available evidence points towards some form of mode coupling in which both radial modes take part.

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