PERIOD ANALYSIS AND MODE IDENTIFICATIONS OF RRab LYRAE STAR X ARIETIS

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ABSTRACT. On the base of Preston and Paczynski's (1964) simultaneous photoelectric (U, B, V) and spectroscopic observations (358 U-B and 61 Radial Velocities from Lick Single-Trail Spectrograms) has been carried out the analysis of periods of RRab Lyr star X Arietis. It has been given an interpretation of the periods of this star. All these periods were identified as radial overtones of fundamental period and their harmonics. It was proposed rhat this variable star is an multimodal one according to its mode identifications. The comparisons with the periods of AE Bootis, RW Ari, ST CVn, T Sex, BK Dra and V363 Cas are carried out.

Key words: Stars: RR Lyrae, mode identifications

X Arietis belongs to RRab Lyrae variables - radially pulsating stars of the galactic halo (Population II). Depending on their light curves and pulsation characteristics RR Lyrae stars are divided into two different subclasses (according to Bailey classification): RRab and RRc Lyrae stars. Suffixes "ab" or "c" indicate asymmetric or symmetric light curves. RRab stars (with large-amplitude non-sinusoidal light curves) display the fundamental (F) radial mode. They have periods from 0.3 to 1.2 days, and amplitudes from 0.5 to 2 mag in V. RRc Lyrae variables (with nearly symmetric, sometimes sinusoidal, light curves) have periods from 0.2 to 0.5 days and smaller amplitudes not greater than 0.8 mag in V. They display the radial first (1H) overtone. Then classical Bailey classification was extended with RRd or RR(B) - (bimodal or double - mode) - RR Lyrae variables showing two simultaneously operating pulsation modes (fundamental F and the first overtone 1H). And at last RRe Lyrae variables, which are the second (2H)-overtone radial pulsators, they are discussed recently. RR Lyrae variables stars often found in globular clusters. Some of RR Lyrae stars exhibit the Blazhko Effect - periodic variations in period and light curve.

The author in a series of works (Bezdeneznyi, 1994a, b; 1997a, b, c, d, e; 2001a, b; 2005a, b) has extended this classification by means of introducing four new radial overtones P_r, P_e, P_g and P_s for pulsating variable stars RR Lyrae, δ Scuti, β Cep and bimodal Cepheids (see in detail the paper on classical Cepheids in this volume).

Earlier the author (Bezdeneznyi, 1988) had made an analysis of the behaviour of the mean fundamental pulsation period for X Arietis. The system of two linear elements (2 and 3) was determined by a least squares solution. One can see (in Figure 1 in that work) longtime periodicity (P=4000 days) with amplitude of 0.4 days. The same was detected by author (1985) for the star V363 Cas (P=1450 days). We considered this effect (Bezdenezhnyi, 1985) of the duplicity among RR Lyraes in detail for some stars.

Frolov (1976) during the analysis of metallic lines velocities has discovered that velocity amplitudes are extremely different on different JD. He suspected the existence of unusual Blazko-effect for X Ari which influences only U and U-B curves. He sepposed the existence of some high temperature processes (for example shortwave recombination radiation produced by a shock wave in higher layers of stellar atmosphere) whose effectiveness is modulated with the mean period of about 31 days. Prof. Kukarkin B.V. proposed to that idea that the coincidence of unusual Blazko-effect and the very low metal abundance of X Ari may not be casual.

In present work we analyzed periods of RRab Lyr star X Arietis on the base of Preston and Paczynski's (1964) simultaneous photoelectric (U, B, V) and spectroscopic observations (358 U-B and 61 Radial Velocities from Lick Single-Trail Spectrograms). We have been carried out the Fourier analysis of periods of X Arietis for searching for the regularities in its light curve and identifications of its periods.

The Fourier analysis of periods of X Arietis on the base of radial velocities give (after substructing of the fundamental frequency 1.5355 $\frac{c}{d}$ and its six harmonics) two new frequencies: f_e=1.920 $\frac{c}{d}$ and 5.761 $\frac{c}{d}$ (this we recognized as the double f_s-frequence). U-B data give the following frequencies: $4f_f$, $8f_f$, f_f and $2f_{2H}$=5.1067 $\frac{c}{d}$. The theoretical ratios for periods P_e, P_s and P_{2H} to P_f are 0.(8), 0.5(3) and

Table 1: Frequency content of multimode RR Lyrae stars

Star	Tipe	Amplitude	Period	D	Frequencies
X Ari	RRab	0.98 V	0.6511426	13	F, 2F, 3F, 4F, 5F, 6F, 7F, 8F, E, 2S, 2(2H)
BK Dra	RRab	1.28 V	0.5920815	12	S, 2S, 3S, 4S, 2E, 2(1H), 2(2H)
RW Ari	RRc	0.48 V	0.354341	42	S, S/3, (1H),
AE Boo	RRc	0.44 V	0.3148921	45	(1H), F, G, (2H), E, 2R, 2E, 2(1H), 2(2H), S, 2S
T sex	RRc	0.51 V	0.3246980	42	(1H), 2(1H), 3(1H), 4(1H), 5(1H), 3S, 9(1H)
ST CVn	RRc	0.56 V	0.329045	43	(1H)/4, (1H), 2(1H)

0.6, respectively.

Thus, individual values of periods of X Ari confirm their commensurability with the primary period P_f, its overtones P_{2H}, P_e and P_s. This star may be consider as multimodal one.

Frequencies of oscillations, discovered by the author (Bezdenezhnyi, 1994a, 1997d, 2001b and this paper) for two RRab type stars (X Ari and BK Dra) and for four RRc type stars (RW Ari, AE Boo, T Sex, ST Cvn), are resulted in Table 1. Other information on these stars is taken from General Catalogue of Variable Stars (Kholopov et al., 1985a, b, 1987).

Three frequencies resulted by Penicke et al. (1989) for RRc type star ST Cvn were identified by the author (Bezdenezhnyi, 1994a): $f_{1H}/4$, f_{1H} and $2f_{1H}$. Thus, the largest amplitude is at frequency $f_{1H}/4$. This star shows (1H)-frequency and its harmonics, but it isn't (1H)-pulsator speaking strictly.

The frequency f_{1H} is the main one (with the largest amplitude) for RRc type star T Sex, a few its harmonics and the frequency $3f_s$ (with small amplitude) are present too. This star also can be considered as (1H)-pulsator.

The frequency f_{1H} is also the main one for RRc type star AE Boo, fundamental frequency (F) goes after it (in the order of decreasing of amplitude). Taking into consideration only these two main frequencies of AE Boo it is possible to consider this star as bimodal one, pulsating in (1H) and F modes. But we have the frequency f_{2H} and a set of all (!) introduced by us new overtones: f_g, f_s, f_e, f_r (and some their harmonics) too. Hence, this star is a multimodal one. But the largest amplitude is at the overtone (1H) that allowed to add it to RRc stars.

And RRc type star RW Ari has S-mode as the main frequency, $f_S/3$ and f_{1H}-frequencies are present too. Although the frequency f_{1H} is present, but the frequency f_S and its harmonic $f_S/3$ (or period $3P_s$) prevail. Thereby, among RRc stars not all are (1H)-pulastors. RW Ari can be named rather as S-pulsator.

It brings together RW Ari with the RRab type star BK Dra, at which S-mode and its harmonics prevail, but the frequencies (with smaller amplitudes) $2f_E$, $2f_{1H}$, $2f_{2H}$ are present too. And X Ari is a pulsator of fundamental mode (F): except for F-mode and seven its harmonics three more frequencies (with small amplitudes) f_E, $2f_S$ and $2f_{2H}$ are present too.

Bailey classification requires substantial improvement, offered by the author, even if we take into consideration its extension with bimodal RRd-pulsators and pulsators of the second overtone (RRe).

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