ON THE PHOTOMETRY OF CC ANDROMEDAE

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ABSTRACT.

The photometric observation of δ Scuti star CC Andromedae using the 48 cm telescope with CCD photometer and the V filter of the UBV system at the Astronomical Observatory of Odessa National University have been made. The calculations of the time series data by using a new program Period04 (Lenz and Breger,2004) for multiple-frequency analysis, a seven-frequency solution has been developed. Also, the new frequency analyses for observation CC Andromedae made by Fitch in 1956 and 1957 have a seven-frequency solution, although Fitch (1967) give a six-frequency solution. The new frequency values closely fits all data of observations. The mode identification shows, that most frequencies correspond to radial and nonradial modes.

Key words: Delta Scuti – stars: individual (CC And).

CC And (SAO 36605) is δ Sct variable star spectral type F3 IV-V. The variability was found by Eggen and Linblad in 1952. The main pulsation period of 0.1249078 was determined in 1953 by Wilson and Walker (1956). Fitch(1960) made observations (27 nights) of the star with V filter from 1956 to 1957, finding four pulsating frequencies. Fitch (1967) analyzed the data set again and find six frequencies. From 1957 to 1984 any observations could not found in literature. In 1984 Fu Jian-ning and Jiang Shi-Jang was found seven frequencies from photoelectric observations at Beijing. (6 nights)

To study the possible variation of the star frequencies, a new observations of CC And were made in Astronomical Observatory of Odessa National University.

The main parameter of variable and comparison stars: variable – CC And, V=8.8, F3IV-V, B-V=0.33, Vsin i=20km/s; comparison – SAO 36623, V=8.1, G5.

The photometric observation of CC And were made using the 48 cm reflector with the f/4.5 Newtonian focus and CCD photometer with V filter of UBV system. The CCD photometer was created using CCD chip, hermetic housing and thermoelectric (Peltier) cooler, wich provide a temperature difference between the crystal and the environment of about -40^{o}C– -50^{o}C.

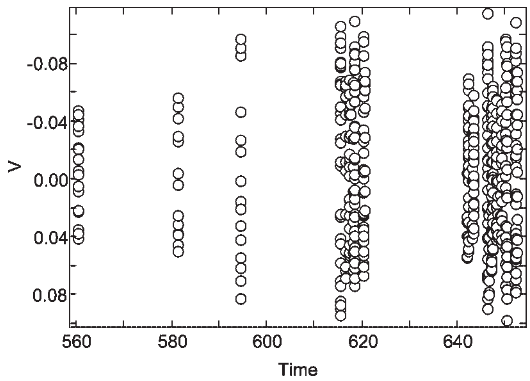

Figure 1: The all data set of observations of CC And

The exposure time and duty cycle were 50 sec and 10 sec, respectively. Evening and morning twilight flat-field frames were obtained for each night to flatten the raw CCD frames. For CCD differential photometry a program was used that performed CCD control, image processing, and aperture photometry. The procedures for the aperture photometry are composed of the dark-level and flat-field corrections and determination of the instrumental magnitude and precision. In order to fix the star at the same position in the exposed field during the observing run, guiding and careful adjustment were applied. The mean measurement error was about 0.007 - 0.01 mag.

About 1500 frames of observations CC And according control stars were measured and differential magnitudes were corrected for the atmospheric extinction and normalized by subtracting the mean of differential magnitudes for each night in order to correct the long-term instrumental drift. Than each observation was take as a mean of three measurements. The all set data of observations are shown in Fig 1. The resulting observed light curves CC And for each night are shown in Fig. 2. The full circles denote the observed data, solid curves represent the analytic light curves computed with seven frequencies obtained in the present

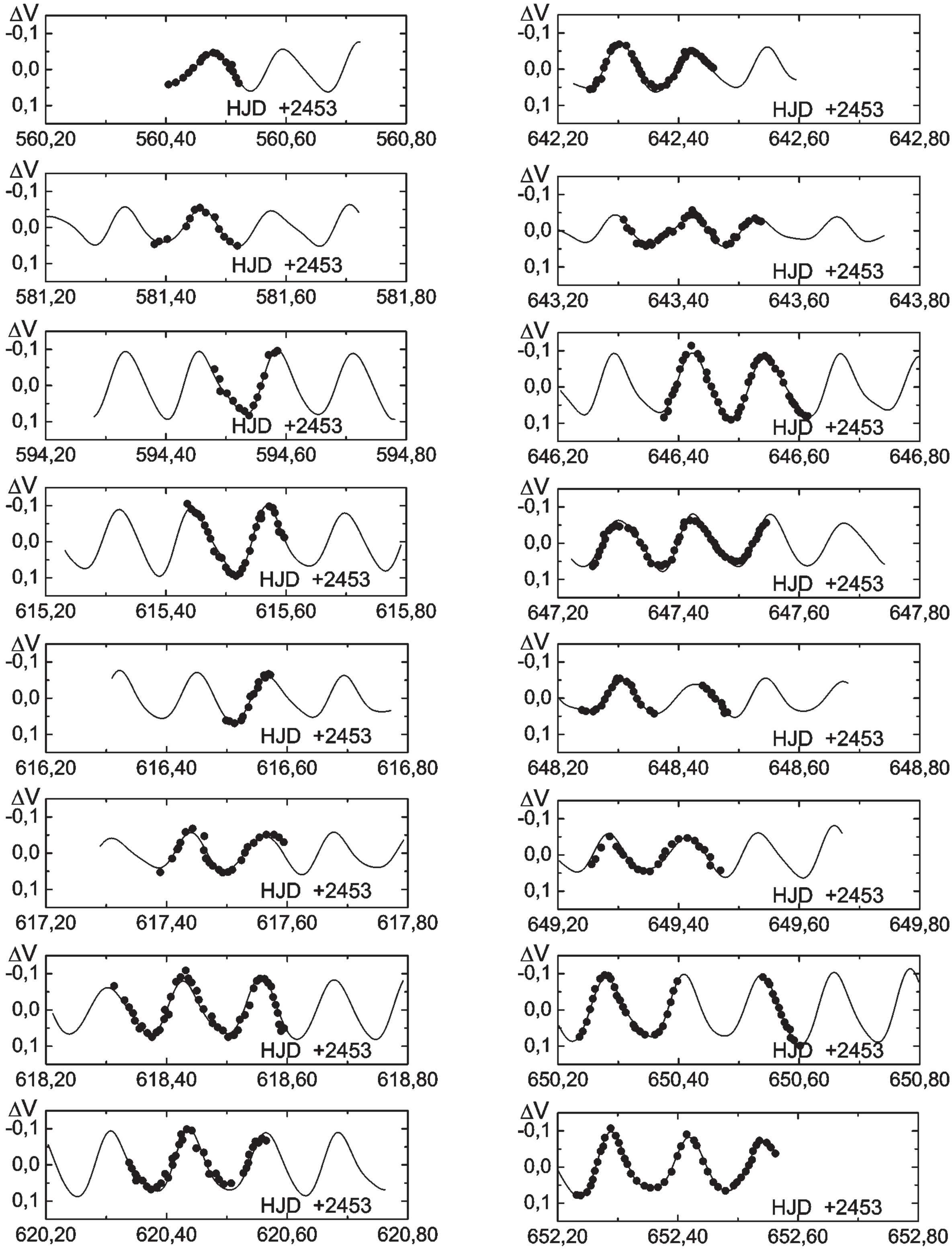

Figure 2: Light curves of CC And. The V-mag differens normalised to zero. The fit of seven-frequency solution is shown by the solid curves.

work.

The frequency analyses were performed using a new package of computer programs with single-frequency and multiple-frequency techniques by using utilize Fourier as well as multiple-least-squares algorithms (program Period04, Lenz and Breger, 2004). The power spectra of all data set shown in Fig. 3. It can be seen that the data set has seven reliable frequencies. For these seven frequencies the resulting fit curve were constructed. Table 1 shows the amplitudes and frequencies of Fourier analysis calculated for Fitch's observations (1960, 1967) and this work observations by using the program mentioned above.

Table 1: The frequencies and amplitudes of CC And
a) From photoelectric observations by Fitch, calculations by Fitch

Frequency 1960, c/d	Amplitude mag	Frequency 1967,c/d
F1=8.00591	0.070	F1=8.0059
F2=7.81480	0.033	F2=7.8148
F3=16.01182	0.008	F3=8.1010
F4=15.82071	0.006	F4=13.3462
		F5=16.0118
		F6=15.8207

b) The same observations
Program Period04

Frequency c/d	Fr.sigma c/d	Amplit. mag	Am.sigma mag
F1=8.0058948	0.000006	0.069626	0.000305
F2=7.8147856	0.000012	0.032910	0.000305
F3=8.1010496	0.000040	0.010428	0.000305
F4=13.346232	0.000047	0.008940	0.000305
F5=7.9021857	0.000051	0.008171	0.000305
F6=16.011999	0.000062	0.006694	0.000305
F7=15.820949	0.000065	0.006437	0.000305

c) For this work, (Udovichenko, 2006),
Program Period04

Frequency c/d	Fr.sigma c/d	Amplit. mag	Am.sigma mag
F1=8.005672	0.000061	0.062334	0.000643
F2=7.814758	0.000146	0.026259	0.000643
F3=8.096911	0.000390	0.009865	0.000643
F4=13.34652	0.000444	0.008667	0.000643
F5=16.01105	0.000548	0.007023	0.000643
F6=9.939581	0.000700	0.005496	0.000643
F7=15.81965	0.000738	0.005216	0.000643

The residuals between the observations and the theoretical light curves for seven frequencies are about 0.01 mag. Table 1 shows that amplitudes and frequencies F1 - F4 are very closely to Fitch's result. The frequencies F5, F7 are also of similar order that Fitch's

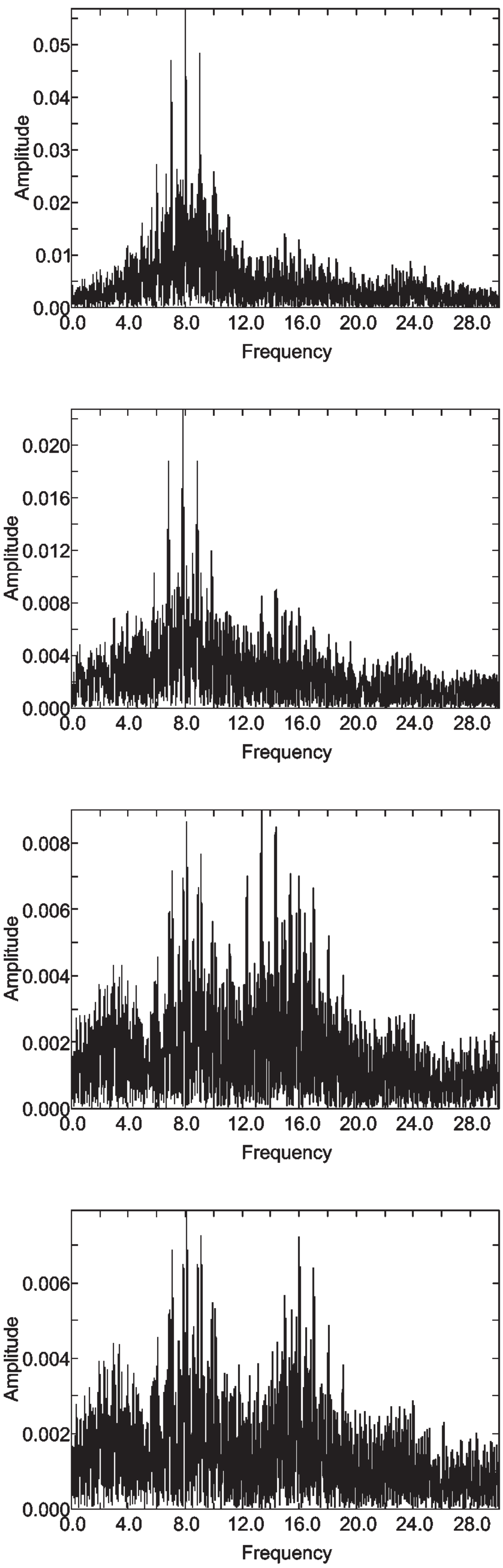

Figure 3: Power spectra CC And for frequencies F1-F4

frequencies F6, F7. The newly discovered frequency F6 (9.939581) has not large amplitude (0.005496), slightly less that frequency F5 (7.90218) from Fitch's observations.

If we can suggest that the biggest amplitude is the radial mode, then using the theoretical rations (Stellingwerf, 1979) we find that F1/F4=0.5998 and F4/F7=0.8436 agree with theoretical rations. Then, the pulsation modes of F1, F4 and F7 belong to the fundamental, the second overtone and third overtone, respectively. For another hand, the differences between some of the seven frequencies: F1-F2, F6-F7, F1-F5, F3-F1 can occur as equal-spacing effect of frequencies, when the frequency split corresponding to nonradial pulsation modes caused by the star's rotation. In this case F4 is a radial pulsation mode, but F1,F2,F3,F5,F6,F7 are nonradial pulsation modes. And CC And is a pulsator with multiple nonradial pulsation modes and a slow rotational velocity.

References

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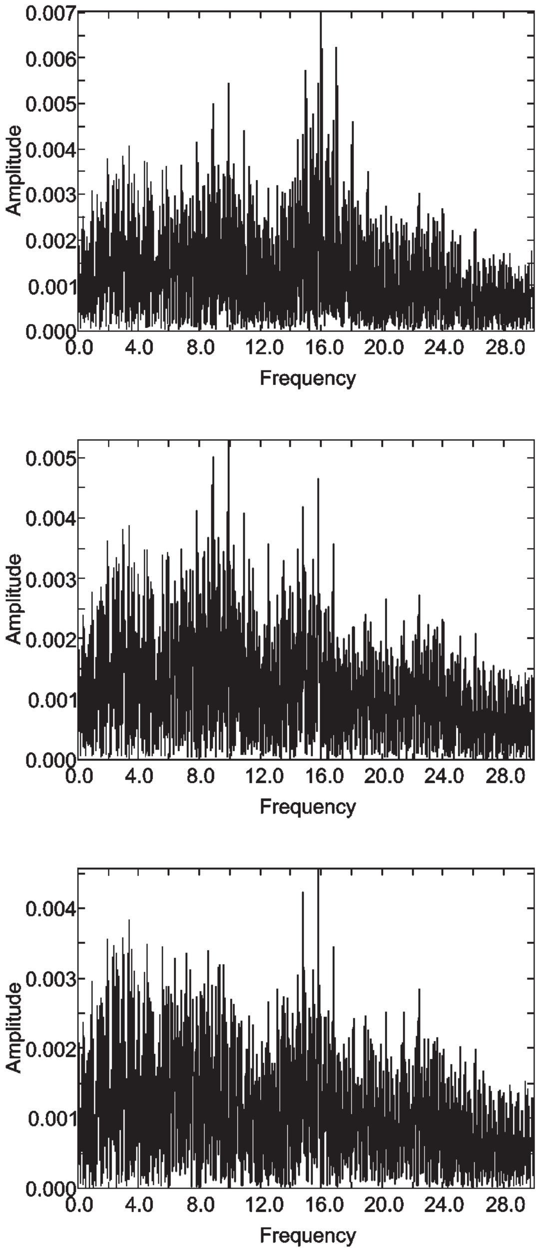

Figure 4: Power spectra CC And for frequencies F5-F7