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ASTRONOMY
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Light variations of 28 Andromedae

R. Garrido[1], **S. F. Gonzalez**[2], **A. Rolland**[1], **M. A. Hobart**[2], **P. Lopez de Coca**[1], **and J. H. Peña**[*,2]

[1] Instituto de Astrofísica de Andalucía, Consejo Superior de Investigaciones Científicas, Apdo. 2144, Granada, España
[2] Instituto de Astronomía, Universidad Nacional Autónoma de México, Apartado Postal 70-264, México 20, D. F. 04510, México

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Summary. Analysis of existing and new photometric observations of the δ Scuti type star 28 Andromedae indicates that it is a monoperiodic variable star with a period of $0^{\rm d}.0693$ with notable amplitude variations from season to season. Evidence presented suggests that 28 And is a second overtone pulsator.

Key words: variable stars – Delta Scuti stars – oscillations

1. Introduction

The Delta Scuti star 28 And (HR 114, HD 2628) was simultaneously reported as a variable star by Nishimura (1969) and Breger (1969). It was the first δ Scuti variable reported with metallic lines, although later Smith (1971) suggested that its spectral type is that of a normal late A star. More recently Ortega et al. (1983) established HR 114 as a F0 IV star.

Nishimura and Watanabe (1969) deduced a period of $0^{\rm d}.071$ almost constant over the whole interval of their observations. Breger (1969) with only one night of observation of this star indicated a period of $0^{\rm d}.069$. Elliot (1974) used all the available times of light maxima to calculate a period of $0^{\rm d}.0696(375)$. Finally, the last observations reported by Tunca et al. (1981) and Ibanoglu et al. (1983), give a period of $0^{\rm d}.0689797 \pm 0^{\rm d}.0000091$. Therefore, this star seems to have a unique period, but since all the previous period determinations were made with a short time baseline, nothing can be said with respect to possible constancy or variation of the period.

As far as the amplitude is concerned, there is clear evidence, however, that 28 And has changed its amplitude of pulsation. The first results obtained by Nishimura (1969) gave an amplitude of $0^{\rm m}.048$ in the blue filter of the *UBV* system. Since then, different authors have noted different amplitudes and all agree that the amplitude has been decreasing. For example, Elliot (1974) finds an amplitude of $0^{\rm m}.020$ in the same filter. More recent observations carried out by Ibanoglu et al. (1983) estimate its amplitude at less than $0^{\rm m}.02$.

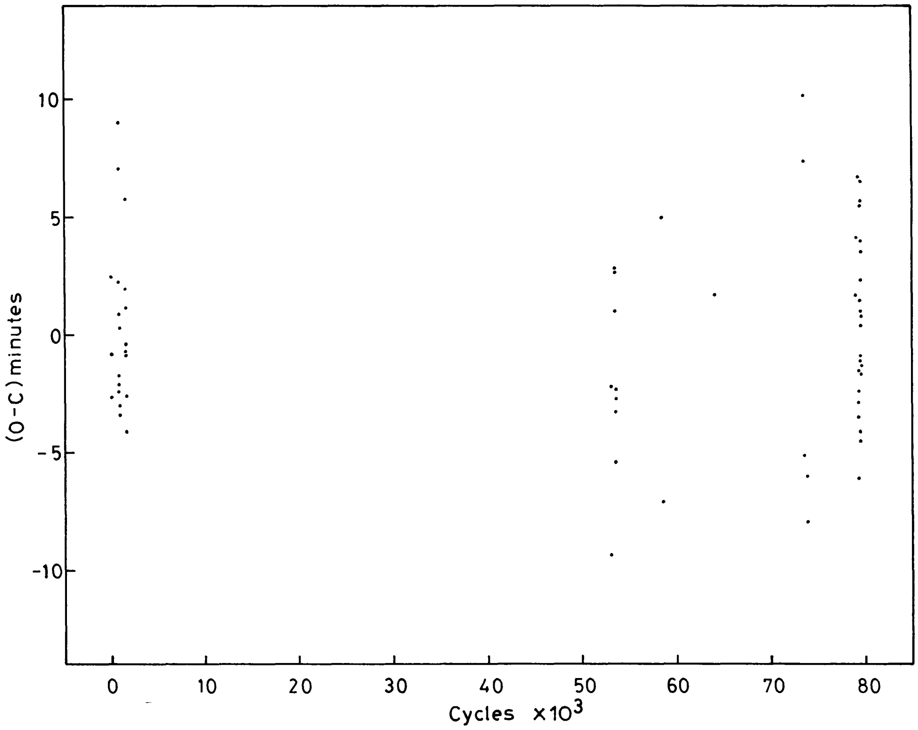

Fig. 1. Residuals, in minutes, of observed maxima from the calculated ephemeris of 28 And, versus elapsed integers from the initial epoch indicated in the text

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Send offprint requests to: A. Rolland

[*] On leave from the Instituto de Astronomía, Universidad Nacional Autónoma de México, México

In order to verify the possible constancy of the period, as well as the variation of the amplitude, an extensive study of 28 And was planned. This study includes the original set of data from Nishimura and Watanabe (1969), Breger (1969) and those of Ibanoglu et al. (1983) as well as new and independent observations carried out in Spain and Mexico.

2. Observations

The observations in Spain were carried out at the Mojón del Trigo Observatory. A 30 cm Cassegrain telescope with a standard *B* filter and an analog recorder was used. HR 133 was chosen as the comparison star and we observed seven nights in 1977 and four in 1978. At Mexico the observations were carried out at the San Pedro Mártir Observatory with the 84 cm and the 150 cm telescopes and a set of standard *UBV* filters. In this case, two comparison stars were used, HR 133 and HD 2019, confirming the previous assumption of constancy of the comparison star HR 133. Five nights were observed in 1981 in the *V* filter and eight nights in 1982 in the *B* filter.

The reduction procedure is described in Garrido et al. (1983).

3. Results

The Fourier-transform method could not be used for the analysis of 28 And because of the interference between the period and the variable amplitude of pulsation. In fact, analysis carried out by this method, (López de Coca et al., 1984) on different data blocks, gives frequencies close to 14.4 cd^{-1} and subsequent prewhitenings do not allow the obtention of a white noise power spectrum as expected from an apparent monoperiodic δ Scuti variable star. However a 14.4 cd^{-1} frequency appeared clearly in all data blocks considered, i.e. a period of $0\overset{\mathrm{d}}{.}069 \pm 0\overset{\mathrm{d}}{.}001$.

Under the assumption of monoperiodicity of 28 And we used a classical method for calculating periods, i.e. counting cycles and the subsequent least squares fit in order to obtain an ephemeris.

Table 1 shows all the available times of light maxima collected for 28 And from different authors. With all these data and taking into account that it is not possible to predict the elapsed integers beyond the error:

$$\Delta T \leqq \frac{P}{4} \frac{(T-T_0)}{\varepsilon_T},$$

where P is the period, $T-T_0$ is the already known elapsed time between two observations, ε_T the present error of a time of light maximum and ΔT the predicted elapsed time calculated from a linear ephemeris, within one integer error.

In our case $\varepsilon_T \cong 0\overset{\mathrm{d}}{.}005$, (about seven minutes). For one run of for example 0.3, the formula leads to approximately $\Delta T \cong 1^{\mathrm{d}}$; therefore, one can use only cycles of two consecutive days to calculate without error the period from a linear ephemeris of the type

$$T-T_0=EP.$$

By using this method we were able to construct Table 1, as far as the integers are concerned, and to calculate the following precise period from such a long series of data, by means of a least square fit to all the available times of light maximum

$$T=2439752.7713$$
$$\pm 6$$
$$P=0.069304115.$$
$$\pm 11$$

Table 1

Time of light maximum HJD 2400000.+	Integer elapsed from 2439752.7715	Observer	$(\mathrm{O-C})_{\mathrm{m}}$
39752.773	0	B	2.5
39752.840	1	B	-.8
39752.908	2	B	-2.7
39807.038	783	NW	2.3
39807.935	796	NW	-3.4
39808.005	797	NW	-2.4
39809.946	825	NW	-1.7
39810.015	826	NW	-2.1
39810.087	827	NW	.3
39810.153	828	NW	-3.0
39814.942	897	NW	7.1
39815.007	898	NW	.9
39815.082	899	NW	9.1
39851.877	1430	NW	1.2
39851.945	1431	NW	-.7
39852.013	1432	NW	-2.6
39853.890	1459	NW	5.8
39853.955	1460	NW	-.4
39854.925	1474	NW	-.8
39854.992	1475	NW	-4.1
39857.907	1517	NW	2.0
40870.799	16132	E	19.5*
40934.586	17053	E	-41.1*
40934.652	17054	E	-45.9*
43452.565	53385	MT	-9.3
43455.550	53428	MT	-2.2
43456.518	53442	MT	-5.4
43457.494	53456	MT	2.8
43457.562	53457	MT	1.0
43458.460	53470	MT	-3.3
43458.530	53471	MT	-2.3
43459.500	53485	MT	-2.7
43460.474	53499	MT	2.7
43809.552	58536	MT	-7.1
43810.600	58551	MT	5.0
44250.263	64895	I	1.7
44853.977	73606	SPM	10.2
44862.768	73733	SPM	-5.1
44862.846	73734	SPM	7.4
44862.906	73735	SPM	-6.0
44862.974	73736	SPM	-7.9
45252.747	79360	SPM	1.7
45252.818	79361	SPM	4.1
45252.882	79362	SPM	-3.5
45253.715	79374	SPM	-1.5
45253.790	79375	SPM	6.7
45253.853	79376	SPM	-2.4
45253.922	79377	SPM	-2.9
45254.755	79389	SPM	-.9
45254.826	79390	SPM	1.5
45254.890	79391	SPM	-6.1
45255.798	79404	SPM	4.0
45255.869	79405	SPM	6.5
45256.700	79417	SPM	5.5
45256.766	79418	SPM	.8
45256.835	79419	SPM	.4
45256.908	79420	SPM	5.7
45258.776	79447	SPM	1.0
45258.847	79448	SPM	3.5
45258.913	79449	SPM	-1.3
45259.812	79462	SPM	-4.1
45259.883	79463	SPM	-1.6
45260.715	79475	SPM	-1.1
45260.782	79476	SPM	-4.5
45260.856	79477	SPM	2.3

B : Breger
NW : Nishimura and Watanabe
MT : Our observations at the "Mojon del Trigo" Observatory
I : Ibanoglu et al.
SPM: Observations at "San Pedro Martir" Observatory
E : Elliot

Residuals, $(\mathrm{O-C})_{\mathrm{m}}$, are in minutes.
Residuals with asterisks are not taken into account.

The three data points from Elliot (1974), marked by an asterisk, were not utilized to calculate the ephemeris due to the abnormally large residuals they produced. Residuals from the above ephemeris are plotted in Fig. 1, where one can see at first glance that the best possible fit for the data points, within the present calculated errors, is a linear ephemeris.

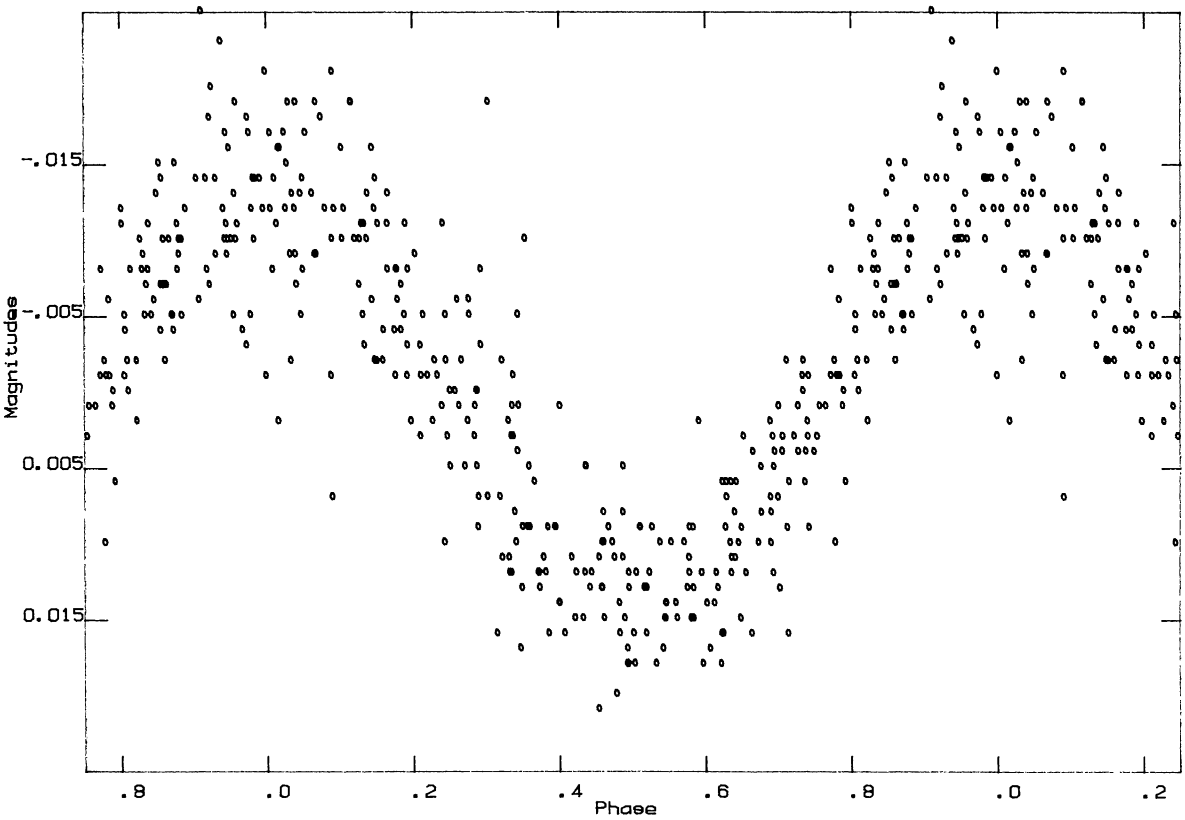

Fig. 2. Phase diagram for data from Mexico in filter *B* normalized to a zero mean

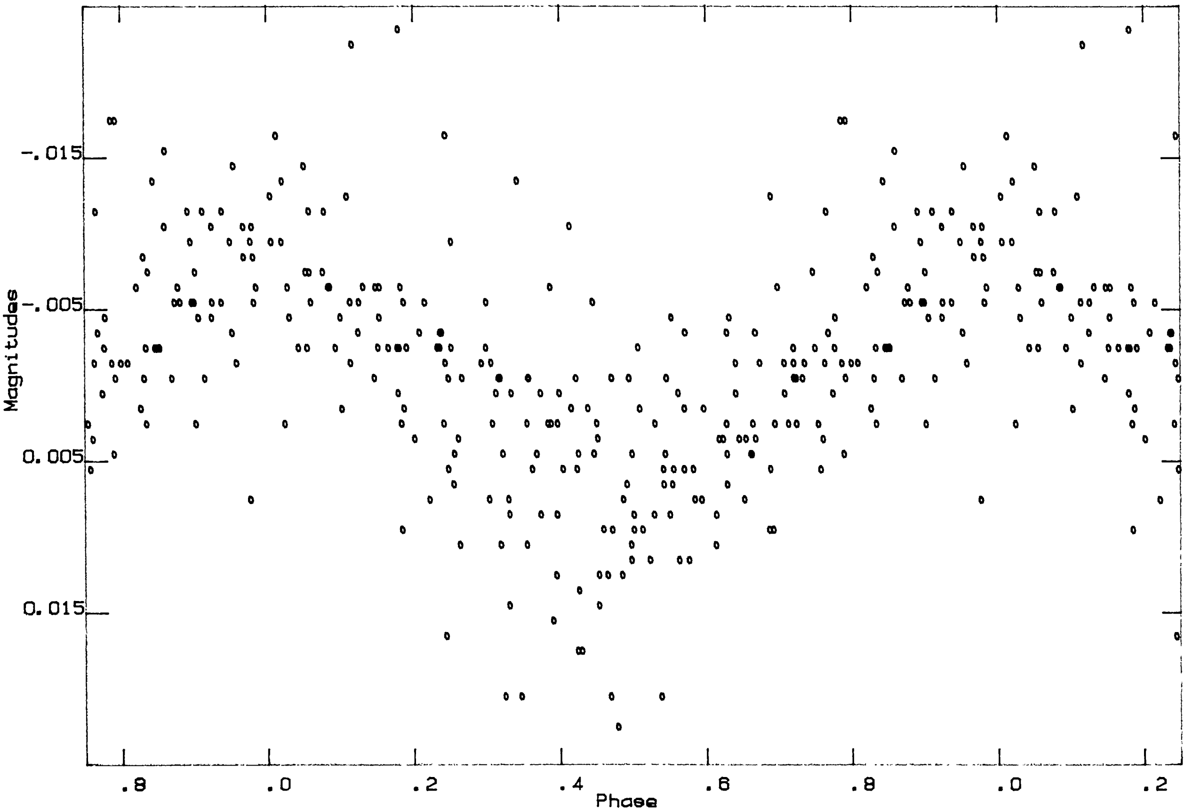

Fig. 3. The same as in Fig. 2, but for the data from Spain

Table 2

Amplitude	Filter	Year
0.0168	*B*	1967
0.0218	*B*	1968
0.0068	*B*	1977
0.0088	*B*	1978
0.0133	*B*	1982

Amplitude A is in magnitudes in a formula of the type $m=m_0+A\sin(\omega t+\psi)$

By using this period we have plotted our data in Figs. 2 and 3, grouped into a phase diagram just to show that there are different amplitudes for different years. Once this period is calculated we fit a sinusoidal curve to the data grouped year by year in order to search for the amplitude variations in the light curve of 28 And. These results are indicated in Table 2.

As it can be seen there is evidence for variation in the amplitude of pulsation of 28 And, but, unfortunately, no clear periodicity or tendency is shown by these variations; this phenomenon is known to occur in other δ Scuti variables (see for example Stobie et al., 1977).

As far as the mode of pulsation of 28 And is concerned it appears that it pulsated in the second overtone. From a photometric calibration by Philip et al. (1976) who for 28 And give a $M_v=1^{\text{m}}.31\pm0.35$, $\theta=0.68\pm0.01$ and $\log g=3.79\pm0.13$, we can obtain a pulsational constant of about 0.019 ± 0.002, in agreement with theoretical models made by Stellingwerf (1979) that give, for such parameters, a pulsational constant of about 0.025 for the first overtone, 0.020 for the second, and 0.017 for the third.

4. Conclusions

It has been shown that 28 And is a δ Scuti variable with a period of $0^{\text{d}}.0693$ indicating pulsation in the second overtone which has been constant over the last fifteen years. However, the amplitude of variation of its pulsation seems to change over a time scale of years. We have at present no definite hypothesis to explain this variation.

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