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Letter to the Editor

Amplitude investigation of δ Scuti variables in open clusters

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Abstract. We report here the results of a statistical analysis of 28 δ Scuti stars from five open clusters, α Persei, Pleiades, Hyades, Praesepe and Coma. These δ Scuti variables, most of which are on the main sequence, tend to show a positive correlation between oscillation amplitude and absolute luminosity. No correlation is found between amplitude and effective temperature.

Key words: Galaxy: open clusters and associations: general – stars: variables: δ Sct – stars: statistics – stars: oscillations – stars: fundamental parameters

1. Introduction

The investigation of the pulsational behavior of δ Scuti stars within the instability strip has motivated several surveys and statistical studies during the last decades (Breger 1969, 1970, 1972a,b, Baglin et al. 1973, Slovak 1978, Horan et al. 1979, Antonello et al. 1981). Recently, the topic has been revisited in the light of the new results obtained by the Hipparcos satellite (Liu et al. 1997). Nevertheless, only a few aspects of the problem look settled now. Among the ideas generally accepted, one is that early theoretical studies (Chevalier 1971) might be correct in suggesting that all normal stars of Population I composition within the instability strip should be variable. The fact that only about 30—50 percent of these objects are detected as variables at the present time might be explained by the current detection threshold (approximately 0.01 mag) of available surveys.

Antonello et al.(1981,1983) made a statistical study of the amplitude and other parameters of δ Scuti stars. They identified a correlation between the amplitude, period and luminosity of low amplitude δ Scuti stars, then they indicated that this relation is not sufficient to distinguish between variable and nonvariable stars, and conclude that at the present no parameter generally observed is sufficient to allow this distinction (Antonello et al. 1981, 1983).

Another point that is generally accepted is that it is possible to classify δ Scuti stars as low-amplitude pulsators (a few 0.01 mag or lower) and large amplitude pulsators (0.1 mag or higher), these two groups corresponding respectively to stars on the main sequence and more evolved stars in the hydrogen shell-burning stage.

Considering that the relation for the amplitude of δ Scuti variables found by Antonello et al. is not unique (Antonello et al. 1981), for the purpose of deciding which parameters have a strong real relation with the amplitude, we made a statistical analysis of the δ Scuti variables located in several open clusters. In our analysis, we combine observations of light curves, H_β index, and V sini from the literature as listed in Table 1 with improved distance moduli from Hipparcos data or new ground-based parallax observations. Here we report some of the results.

2. Target δ Scuti variables in open clusters

In the paper, we focus our attention on δ Scuti variables on the main sequence. We also restrict our samples to stars belonging to open clusters, for which a good determination of distance is available. Five young clusters are selected: α Persei, Pleiades, Hyades, Praesepe and Coma. Detailed information concerning their absolute magnitude and age estimations are listed in Table 1.

Within these five clusters, 30 δ Scuti variables are found and 28 of them constitute our sample. Two objects, KW284 and 86 Tau, are rejected because their variability is not clear from the three hours light curves available.

The oscillation amplitude is taken to be the highest peak-to-peak measurement in the observed light curve. This is, of course, a very arbitrary way to do the estimation. It is clear that a short time series might induce an underestimation of the amplitude, especially in the presence of beating phenomena due to close frequencies. In order to take this effect into account, we associate with each amplitude estimation a weight corresponding to the length of the time series and list them in Table 1, where number 3 represents time series longer than 20 hours, 2 represents time series between 4 and 20 hours and 1 represents time series shorter than 4 hours.

3. Discussion

For all the objects in Table 1, absolute magnitudes are derived according to the corresponding distance modulus. In Fig. 1, oscillation amplitudes are presented versus absolute magnitudes.

Table 1. δ Scuti variables selected from Open Clusters. Different columns represent absolute magnitude, oscillation amplitude, $V \sin i$, H_β, weight according to the length of time series, age, spectra class, HD number (or SAO number), cluster name and references.

M_v	ΔV	$V \sin i$	H_β	Wei.	Age	Sp.	HD No.	Cluster	Ref.
mag	mag	kms^{-1}			year				
3.04	0.008	75.0	2.770	2	5.13E7	F0IV	SAO38754	α Persei	1,2,3,4
2.88	0.010	50.0	2.775	2	5.13E7	A8V	20919	α Persei	1,2,3,4
2.4	0.015	150.0	2.872	2	5.13E7	A6Vn	21553	α Persei	1,2,3,4
2.33	0.010	65.0	2.830	2	7.76E7	A7V	23156	Pleiades	1,3,5,6
2.5	0.018	90.0	2.788	2	7.76E7	A9V	23567	Pleiades	1,3,5,6
2.30	0.015	10.0	2.841	2	7.76E7	A7V	23607	Pleiades	1,3,5,6
1.87	0.02	175.0	2.862	1	7.76E7	A3V	23643	Pleiades	1,3,5,6
2.04	0.02	190.0	2.835	2	6.61E8	A5V	107131	Coma	1,7,8,18
2.39	0.018	100.0	2.766	2	6.61E8	F0V	27397	Hyades	1,3,9,10
2.06	0.01	70.0	2.813	2	6.61E8	A9V	27459	Hyades	1,3,9,10,12
2.52	0.01	30.0	2.756	2	6.61E8	Am	27628	Hyades	1,3,9,10
0.915	0.025	195.0	2.753	1	6.61E8	A8Vn	28024	Hyades	1,3,9,10
0.114	0.025	80.0	2.830	3	6.61E8	A7IVn	28319	Hyades	1,3,9,10
1.09	0.02	195.0	2.767	2	6.61E8	A8Vn	28052	Hyades	1,3,9,10
1.28	0.02	145.0	2.813	1	6.61E8	A7IV	30780	Hyades	1,3,9,10
2.07	0.02	170.0	2.790	2	6.61E8	A9V	73175	Praesepe	1,3,11,12
1.90	0.015	95.0	2.813	1	6.61E8	F0V	73345	Praesepe	1,3,11,14,15
2.26	0.02	135.0	2.770	3	6.61E8	A7V	73450	Praesepe	1,3,11,12
0.605	0.03	150.0	2.778	3	6.61E8	F0III	73575	Praesepe	1,3,11,12
1.44	0.029	200.0	2.812	3	6.61E8	A6V	73576	Praesepe	1,3,11,12
1.95	0.014	165.0	2.742	3	6.61E8	F2V	73729	Praesepe	1,3,11,12
2.41	0.017	100.0	2.748	1	6.61E8	A9V	73746	Praesepe	1,3,11,15
1.56	0.025	115.0	2.796	3	6.61E8	A7V	73763	Praesepe	1,3,11,13
2.24	0.016	170.0	2.764	3	6.61E8	F0V	73798	Praesepe	1,3,11,12
0.456	0.018	152.0	2.818	3	6.61E8	A6V	73819	Praesepe	1,3,11,16
1.67	0.015	165.0	2.791	2	6.61E8	A7V	73890	Praesepe	1,3,11,17
1.73	0.02	165.0	2.812	1	6.61E8	A7III	74028	Praesepe	1,3,11,12
2.32	0.015	145.0	2.812	2	6.61E8	A7V	74050	Praesepe	1,3,11,12

Ref. 1. Rodriguez et al. (1994); 2. Crawford et al. (1974); 3. Mermilliod (1981); 4. Slovak (1978); 5. Gatewood et al. (1990); 6. Breger (1972b); 7. Gatewood et al. (1995); 8. Breger (1969); 9. Horan (1979); 10. Gatewood et al. (1992); 11. Mermilliod et al. (1997); 12. Breger (1973); 13. Breger (1970); 14. Rolland et al. (1990); 15. Jackisch (1972); 16. Breger et al. (1993); 17 Paparo et al. (1990); 18 Breger (1975).

The points marked with diamonds correspond to HD73575, HD73819 and HD28319. Strong evidence exists that the two former objects are no longer on the main sequence, but rather in or just after the phase of overall contraction associated with the exhaustion of hydrogen in the core. The latter is θ^2Tau. Its evolution stage is ambiguous and it is known to be a binary star.

This figure indicates the existence of a correlation between oscillation amplitude and absolute magnitude for stars on the main sequence. The relation can be fitted by the line of

$$M_v = 3.78(\pm 0.51) - 106.76(\pm 29.52) \times \Delta V.$$

The trend does not appear when considering the complete set of field stars given in Rodriguez et al. (1994). This might be explained by the following fact, in the sample stars belonging to clusters described in Table 1, the internal errors on absolute magnitudes are smaller. Error bars on the absolute magnitude determination are estimated to be approximately ± 0.2 mag. As for error bars on oscillation amplitude, two factors are involved, the length of the available time series as already commented in Sect. 2 and the intrinsic measurement error which we estimate to be ± 0.003 mag.

The amplitude correlation trend line predicts that the lowest luminosity of δ Scuti variable which can have non-zero amplitude is about $M_v = 3.78$. Corresponding to this luminosity on the Main sequence, the spectral class is about F5, which is five subclasses away from the observational cool border of δ Scuti stars on the main sequence F0V (Breger 1979). So according to our result, if we can improve the observational accuracy high enough, the observational cool border of δ Scuti on the main sequence can move beyond of F0 V.

If our statistical result is real, then this suggests that brighter stars should preferentially have larger amplitudes. How does this result affect the δ Scuti variables distribution in the instability strip? The following conclusion can be drawn. If the idea that all stars located in the instability strip are variable is true, then our result suggests that there is a greater possibility of detecting the variability in stars of higher luminosity, given present detection limits, and that there will be more observational non-variables near the low or cool part, but this is in contradiction

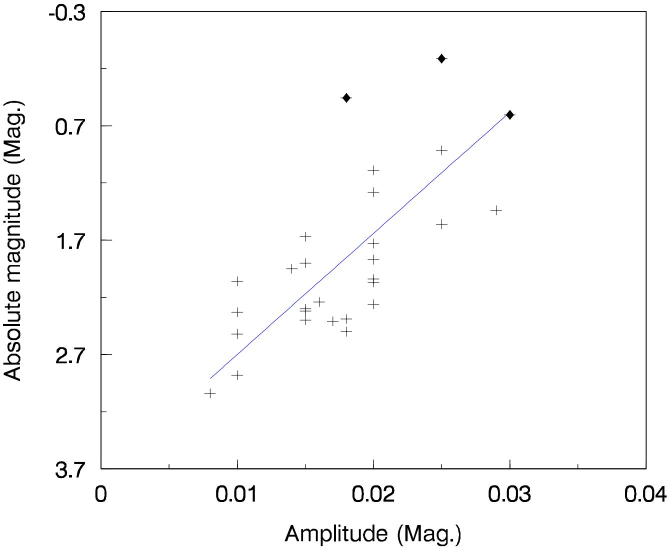

Fig. 1. The relation between oscillation amplitudes and absolute magnitudes for the δ Scuti variables selected from five clusters.

with the observational results (Breger 1979, Baglin et al. 1973). So our trend seems to support the existence of real nonvariables in the instability strip. Maybe, more accurate observations and statistical research on the subject is necessary.

Fast rotation is very common among δ Scuti stars and it is known that rotation significantly changes the estimation of the absolute magnitude (Michel et al. 1998). This phenomenon is probably the reason for a large amount of the dispersion observed in M_V in Fig. 1. A further investigation of this aspect will probably be necessary to obtain a more precise description of the trend presented here. We here limit ourselves to the presentation of the oscillation amplitudes versus $V \sin i$ values (Fig. 2). A weak correlation might be noticed in Fig. 2.

Effective temperature is pointed out by linear stability analyses as a key parameter in deciding which modes are unstable (Houdek et al. 1995). Fig. 3 presents the oscillation amplitude versus the H_β index, representative of the effective temperature for A and early F stars on the main sequence. No correlation is noticed.

4. Conclusions

We report here some results of a statistical study of δ Scuti stars from 5 open clusters. These results show a trend suggesting an increase of oscillation amplitude with absolute magnitude. Comparing the present results to those of Antonello et al. (1981), except for two low-amplitude stars of greater luminosity, the low-amplitude stars in the sample of Antonello et al. appear to show a trend similar to that found in the present paper, with a similar y-intercept but a different slope and much more scatter. Our results suggest, when the observational accuracy is improved enough, the cool border of δ Scuti instability on the main sequence will move towards the cool direction. No correlation is noticed between the oscillation amplitude and the effective temperature.

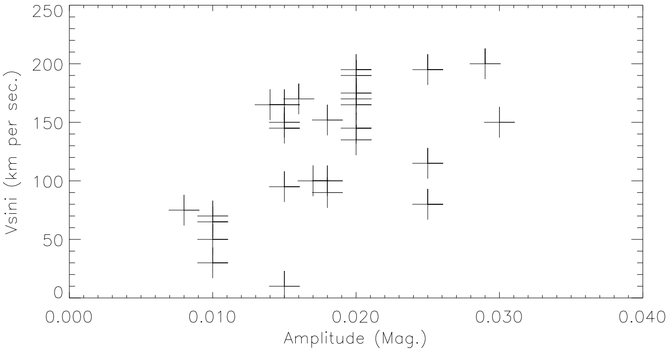

Fig. 2. The relation between oscillation amplitudes and mean rotation velocity ($V \sin i$) for the δ Scuti variables selected from five clusters

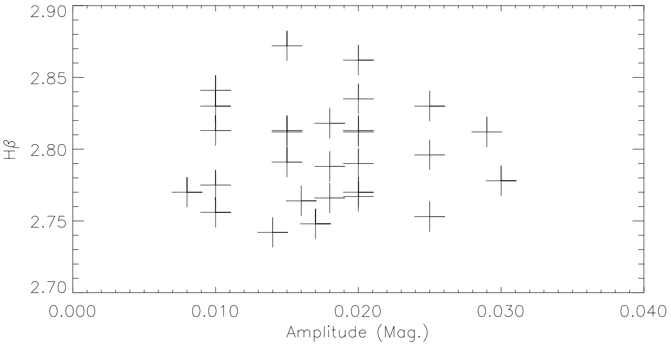

Fig. 3. The relation between oscillation amplitudes and H_β for the δ Scuti variables selected from five clusters

It is generally accepted that all main sequence normal stars in the instability strip might be pulsating, but amplitudes of most of them are too low to be detected when considering the detection threshold of current available surveys. The statistical studies show that the nonvariable normal stars and δ Scuti stars are distributed randomly in the instability strip (Breger 1979, Baglin et al. 1973). But the correlation suggested by the present analysis hardly fits the general assumption that all stars in the instability strip are variables. Only if most of the stars in the instability strip are really constant can our result be in agreement with the statistical results. δ Scuti stars are so close to pulsational stability that small physical differences from star to star may be very important and push the star to stability. So we think δ Scuti variables and nonvariables coexist on the instability strip. This idea is in agreement with the suggestion of Leung (1970) that δ Scuti variables lie in two well defined boxes containing short and long-period pulsators respectively, and that most nonvariables would be outside the boxes so they show constant brightness. Certainly, how to define the boxes is an important topic that needs further study.

Further observational work and refinement in the way to estimate oscillation amplitudes are necessary to confirm these results.

If confirmed, this trend might improve our understanding of the pulsational behavior of normal stars in the instability strip.

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