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SX Phe stars in globular clusters⋆

E. Rodríguez and M.J. López-González

Instituto de Astrofísica de Andalucía, CSIC, P.O. Box 3004, 18080 Granada, Spain

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Abstract. We present for the first time a catalogue of SX Phe-type pulsating variables in globular clusters. In addition, SX Phe variables discovered in the Carina dwarf galaxy and other ones probably belonging to the Sagittarius dwarf galaxy are included. This catalogue is intended to be an up-dated list of all the SX Phe stars, in globular clusters and galaxies, known until now, covering information published up to January, 2000. In summary, 149 variables are presented in our list for SX Phe-type variables belonging to 18 globular clusters and 2 galaxies. Some relevant distributions are also shown. The analysis of metal abundances and mean periods shows that both parameters are correlated in the sense that the periods of the variables are longer as the metallicity of the stellar system is higher.

Key words: stars: variables: general – stars: oscillations – stars: fundamental parameters – techniques: photometric

1. Introduction

Pulsation in the lower part of the Cepheids instability strip, in the region just above the ZAMS, is characterized by the δ Sct-type pulsating stars, as the most numerous group. These variables show short periods ($<0.^d3$) and visual amplitudes ranging from a few thousandths of a magnitude to several tenths, with a typical amplitude of about $0.^m02$. Most of these stars are normal Population I stars in main sequence or just post-main sequence stage of evolution. A number of variables have low metallicities and high spatial motions typical of Population II, but with anomalously large masses and young ages. This second small group is astrophysically different from the normal Population I δ Sct variables. They are called SX Phe stars and very few are known in the field. Recent reviews on δ Sct and SX Phe field variables are available in the literature (Breger 2000, Rodríguez et al. 2000 and references therein).

The fact that δ Sct and SX Phe variables are different groups was confirmed by the discovery of three SX Phe-type pulsators among the blue stragglers population of the globular cluster ω Cen (NJL220 (Niss 1981), NJL79 (Jörgensen 1982) and E39 (Jörgensen & Hansen 1984)). The SX Phe-type variables are not yet fully explained by the stellar evolution theory. The connection between these stars and the blue-straggler phenomenon has been analysed by different authors (Eggen & Iben 1989, Nemec & Mateo 1990). A number of reviews are also available in the bibliography (Nemec et al. 1994, McNamara 1995, 1997).

Recently, a lot of these variables are being discovered in globular clusters. In this respect, the contributions from the OGLE side-projects are of relevant significance. In addition, a large number of SX Phe pulsators have been found in the Carina dwarf spheroidal galaxy and three new members probably belonging to the Sagittarius dwarf galaxy. The main aim of this work is to present an extensive and up-dated list of SX Phe variables in globular clusters and galaxies, covering the information published until January, 2000.

2. The catalogue

The stars and their most significant parameters are listed in Table 1 together with references to studies of individual stars and notes for a number of variables. In addition, the references on the discovery for each variable (Source(1)) and sources for photometry (Source(2)) are also listed. The full Table 1 together with references, notes and sources are accessible in electronic form and can also be requested from the authors.

The list is given according to their 2000.0 equinox equatorial coordinates ordered by increasing right ascension. The first column indicates the name of the globular cluster or galaxy where the variable belongs, while the second column lists the identification of each variable. Sometimes, the exact coordinates of the variables are not known; in these cases, we list the coordinates of the corresponding globular cluster. As in earlier catalogues (Rodríguez et al. 1994, 2000), periods correspond to the dominant pulsation mode in every case while amplitudes correspond to the mean full visual amplitude of the light curve. When it is available, periods and visual amplitudes come from the results of Fourier fitting to the light curves. In other cases, these values were derived as an estimation from an integration of the corresponding light curves. Further details can be found in the references listed in the table. In Table 1, V means mean visual magnitude in the Johnson V filter. In nearly all the cases,

Send offprint requests to: E. Rodríguez (eloy@iaa.es)

⋆ Table 1 is only available at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

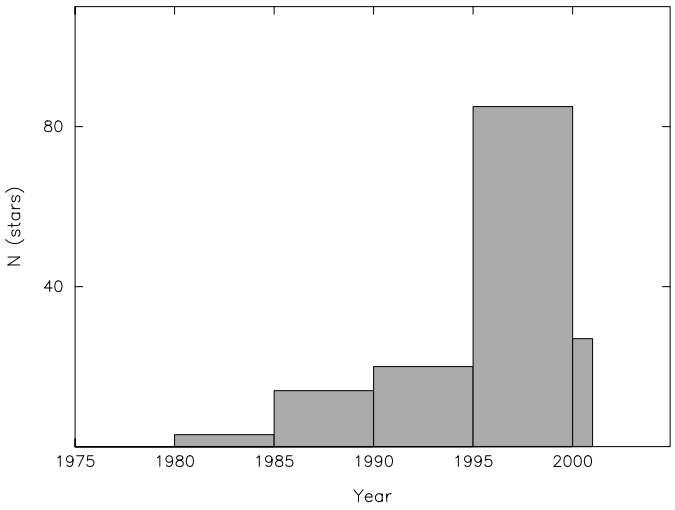

Fig. 1. Distribution of the stars in the catalogue as a function of the year they were discovered

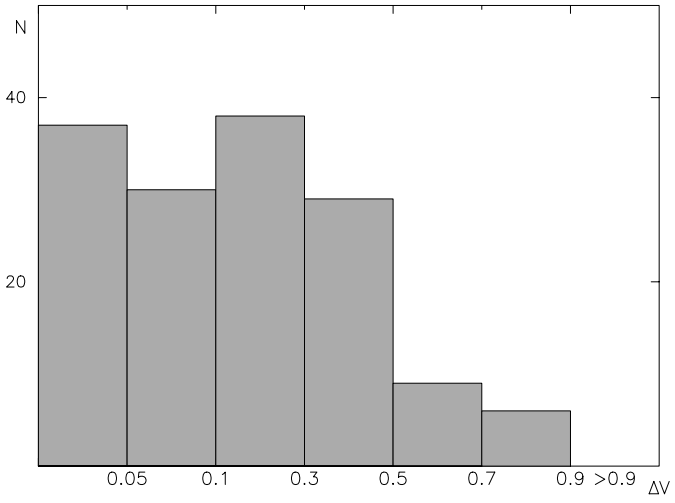

Fig. 2. Distribution of the stars in the catalogue (N) as a function of the visual amplitude (ΔV)

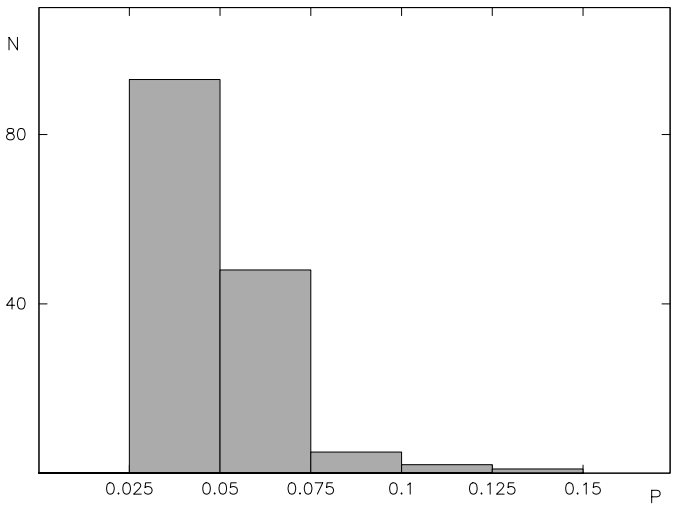

Fig. 3. Distribution of the stars in the catalogue (N) as a function of the period (P)

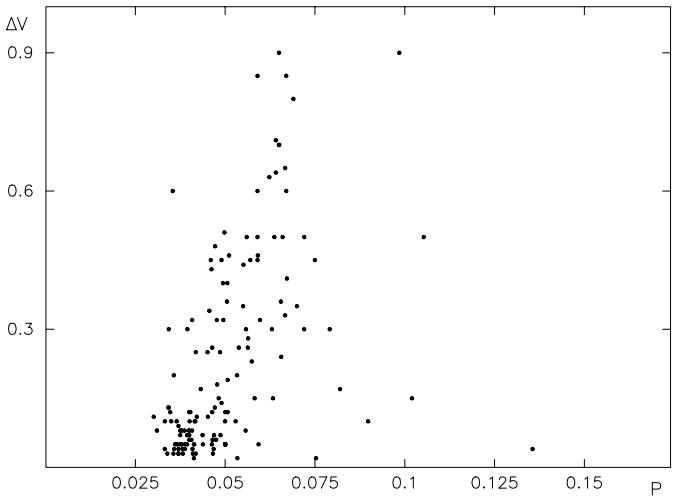

Fig. 4. Visual amplitude (ΔV) versus period (P)

the original measurements were collected using this filter. However, the measurements of the variables V0008, V0012, V0038 and V0062 in Carina were carried out using the the Johnson B filter (Saha et al. 1986). The corresponding V amplitudes were derived as reduced by a factor 1.3 (Rodríguez 1999). Summarising, 149 SX Phe-type pulsating stars are listed in this catalogue: 122 of them are members of 18 globular clusters and 27 belong to the dwarf galaxies of Carina (24) and Sagittarius (3). In the case of Sagittarius, the membership of the three variables is still not fully confirmed (Pych et al. 2000).

Figs. 1 to 6 give some insight into the content of the catalogue. Fig. 1 shows the distribution of the variables as function of the year in which they were discovered. As can be seen, all these variables were discovered very recently (later than the year 1980) and there is also an enormous increase during the last few years. In fact, the 70% of the full sample were discovered since 1996 and nearly the 90% were discovered during the last decade.

Figs. 2, 3 and 5 show the corresponding distributions of the stars in the catalogue as functions of the visual amplitude, period and visual magnitude, respectively. Fig. 4 and 6 show the visual amplitude versus period and visual magnitude. As seen in Fig. 2, these variables show visual amplitudes from a few hundredths of a magnitude to several tenths, however the number of variables increases as the amplitude is decreasing. From Fig. 2 we have 45% of the SX Phe stars pulsating with amplitudes smaller than $0.^m1$ and 25% with amplitudes smaller than $0.^m05$. This suggests that we cannot exclude the possibility that many of the apparently nonvarying stars in the SX Phe region vary but with undetectable amplitudes.

Fig. 3 shows that nearly all of these stars have very short periods, ranging from $0.^d025$ (0.6 hours) to $0.^d075$ (1.8 hours). The variable with the shortest period in our list is V10 in the globular cluster NGC 6397 with P=43 min (Kaluzny 1997). On the other hand, there are only 3 stars with periods longer than $0.^d1$. This is quite different to that shown by the δ Sct pulsators, where the periods can be much longer ($<0.^d3$). Fig. 4

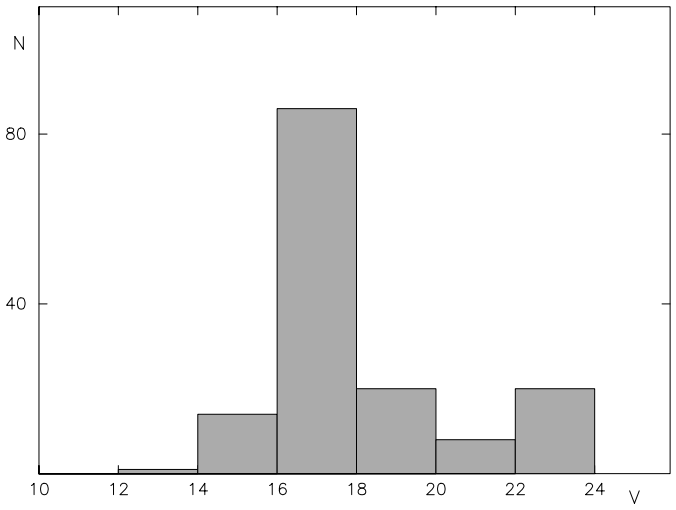

Fig. 5. Distribution of the stars in the catalogue (N) as a function of the visual magnitude (V)

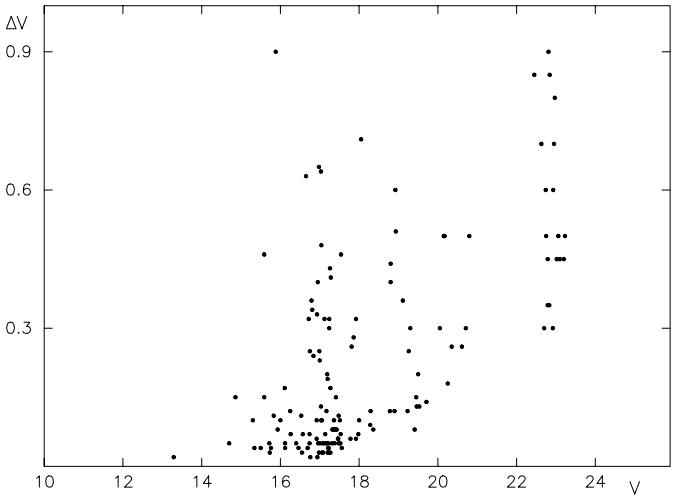

Fig. 6. Visual amplitude (ΔV) versus visual magnitude (V)

shows variables with longer periods ($0.^d050$-0.0^d075) that seem to have larger visual amplitudes than those with shorter periods ($0.^d025$-$0.^d050$).

Fig. 5 shows the distribution of the variables versus the visual magnitude. All the SX Phe stars in the range $22.^m0$-$24.^m0$ belong to the Carina dwarf galaxy. The majority of the stars (86) have visual magnitudes between $16.^m0$ to $18.^m0$. By comparing this figure with Fig. 6, it seems there is a selection effect in our catalogue in the sense that the amplitude is larger when the variable is fainter, that is, only the largest amplitude faint stars can be detected to be variables.

In Table 2 we list the metallicity and number of SX Phe-type pulsating stars for each of the globular clusters and galaxies. In addition, the mean values of visual magnitude, period and amplitude for the SX Phe variables belonging to each stellar system are listed together with the sources for the metallicities. Further information on these [Me/H] values can be found in the corresponding sources. In Fig. 7 (first part) we plot the corresponding metal abundances versus the mean values of the periods (as log P). As was earlier found by McNamara (1995, 1997), with a much smaller sample, it seems there is a correlation between both parameters in the sense that the periods of the variables are

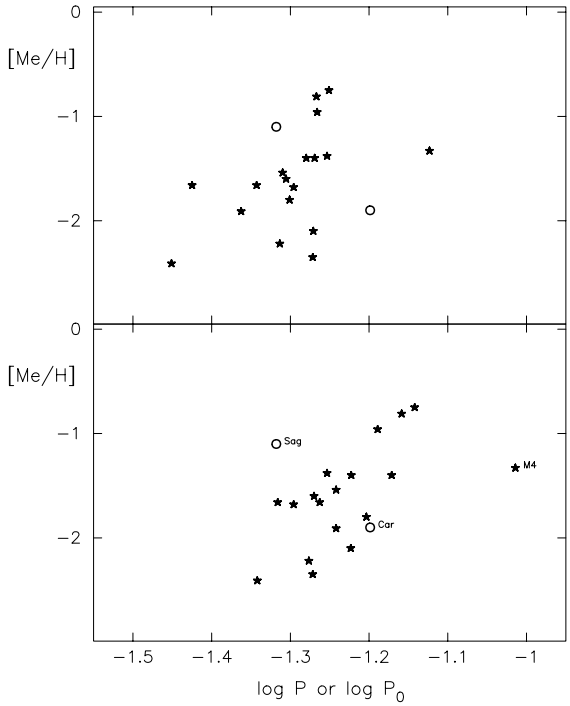

Fig. 7. [Me/H] versus log P (top) or log P_0 (bottom) for SX Phe variables in clusters ($\star$) and galaxies ($\circ$)

Table 2. Parameters for SX Phe variables in globular clusters and galaxies. Sources for [Me/H] are: 1) McNamara 1997, 2) Nemec et al. 1994, 3) McNamara 1995, 4) Mazur et al. 1999, 5) Olech et al. 1999, 6) Mateo et al. 1995

Cluster/ Galaxy	[Me/H]	N	$\langle$V$\rangle$ (mag)	$\langle$Per$\rangle$ (d)	$\langle\Delta$V$\rangle$ (mag)	Source
47 Tuc	−0.75	6	15.68	0.0561	0.082	1
NGC 288	−1.40	6	17.55	0.0538	0.223	1
NGC 4372	−2.35	8	17.40	0.0535	0.363	3
Ru 106	−1.66	3	20.00	0.0454	0.207	1
M 68	−2.10	2	17.66	0.0536	0.440	3
NGC 5053	−2.41	5	19.43	0.0354	0.132	1
ω Cen	−1.60	34	17.17	0.0495	0.156	1
M 3	−1.66	5	18.18	0.0376	0.092	2
NGC 5466	−2.22	6	18.96	0.0486	0.300	1
IC 4499	−1.38	1	19.30	0.0558	0.300	2
NGC 5897	−1.68	1	18.80	0.0506	0.400	2
M 5	−1.40	5	16.70	0.0525	0.078	2
M 4	−1.33	1	13.29	0.0753	0.020	2
NGC 6362	−0.96	4	17.14	0.0542	0.200	4
NGC 6397	−1.91	6	15.62	0.0447	0.067	1
NGC 6752	−1.54	3	15.99	0.0490	0.190	2
M 55	−1.80	24	16.84	0.0500	0.103	5
M 71	−0.81	2	17.85	0.0541	0.135	1
Carina	−1.90	24	22.41	0.0633	0.548	1
Sagittarius	−1.1	3	20.56	0.0481	0.273	6

longer when the metallicity of the system is higher. However, as seen in this figure, the dispersion of the points is large. The scattering is much smaller when only the fundamental periods are plotted (Fig. 7, down). Following the suggestion of McNamara (1995, 1997) we can assume that the SX Phe variables with large amplitudes are pulsating in the fundamental mode while those variables with $\Delta V \leq 0.^m 20$ are first-overtone pulsators. The fundamental periods of each variable belonging to this second group can be calculated assuming P_1/P_0=0.778. The second part of Fig. 7 shows an improved correlation between [Me/H] and log P_0. Only two points seem to be discrepant, those corresponding to the M4 globular cluster and Sagittarius galaxy. In the case of M4, only one SX Phe variable has been found (Yao & Uloa 1993) and the true period is still subject of study. In the case of Sagittarius, the membership of the three variables is not completely confirmed yet (Pych et al. 2000).

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