ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **144**, 469–474 (2000)

A revised catalogue of δ Sct stars[⋆]

E. Rodríguez, M.J. López-González, and P. López de Coca

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

Received February 25; accepted April 5, 2000

Abstract. An extensive and up-dated list of δ Sct stars is presented here. More than 500 papers, published during the last few years, have been revised and 341 new variables have been added to our last list, six years ago. This catalogue is intended to be a comprehensive review on the observational characteristics of all the δ Sct stars known until now, including stars contained in earlier catalogues together with other new discovered variables, covering information published until January 2000. In summary, 636 variables, 1149 references and 182 individual notes are presented in this new list.

Key words: stars: variables: δ Sct — stars: oscillations — stars: fundamental parameters — techniques: photometric

1. Introduction

δ Sct stars are regularly pulsating variables located in the lower part of the Cepheids instability strip showing short periods ($<0\overset{\mathrm{d}}{.}3$) and visual amplitudes ranging from a few thousandths of a magnitude to several tenths, with typical amplitude of about $0\overset{\mathrm{m}}{.}02$. The majority of these stars belong to Population I, however a few variables show low metallicities and high spatial motions typical of Population II. This second small group may be astrophysically different from the normal Population I δ Sct variables. They are called SX Phe stars and very few are known in the field. Recently, a large number of these variables are being discovered in globular clusters. A number of reviews on δ Sct variables are available in the literature, e.g. Breger (1979, 1995, 1999, 2000), Eggen (1979), Wolff (1983), Tsvetkov (1990), López de Coca et al. (1990), Kurtz (1994, 1996), Rodríguez et al. (1994; hereafter R94), García et al. (1995), Garrido (2000), Jiang et al. (2000).

During the last few years the number of new variables is enormously increasing. Additionally to the immense effort developed by individual groups, a number of long-term monitoring projects are being carried out leading to the discovery of a lot of new variables including δ Sct pulsating stars. Several of these projects are still in progress as, e.g., EROS (Aubourg et al. 1995), DUO (Alard 1996), PLANET (Albrow 2000), etc., and their results will be available in the next future. In other cases, MACHO (Alcock et al. 2000) and OGLE (Udalski et al. 1994, 1995a,b, 1996, 1997) projects, a large number of δ Sct stars have been discovered already and probably more new variables will be still found. Contributions from OGLE side-projects are being also very important, especially for SX Phe-type variables in globular clusters. Furthermore, a lot of δ Sct variables have been detected by the Hipparcos mission (ESA 1997) and more new members are expected from the Tycho mission (Annex B; ESA 1997).

Additionally to new variables, new catalogues on different parameters have been recently published. This information has been used to up-date each variable in our list, using the most recent catalogues available in the bibliography on photometry (Strömgren and Johnson systems), spectral types, rotational and radial velocities, multiplicity and parallaxes.

The aim of this work is to present an extensive and up-dated list of δ Sct stars. This catalogue is intended to be a comprehensive review on the observational characteristics of all known δ Sct stars, including stars contained in earlier catalogues together with other new discovered variables, covering information published until January 2000. Field SX Phe stars have been also included in our list. A catalogue on SX Phe variables in globular clusters will be the subject of another work (Rodríguez & López-González in preparation).

Send offprint requests to: E. Rodríguez, e-mail: eloy@iaa.es

⋆ Tables 1 and 2 will be accessible only in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http://cdsweb.u-strasbg.fr/Abstract.html

2. The catalogue

2.1. Description

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. Table 2 lists our identification for the δ Sct variables observed by MACHO project. In the present paper only the first page of Table 1 is printed as an example. The full Table 1 together with Table 2 are accessible in electronic form and can also be requested from the authors. In summary, the new catalogue contains 636 variables, 1149 references and 182 individual notes. Each star in the list has been carefully examined before being included in Table 1. Several tens of stars were rejected mainly because either time scales of variation or signal/noise ratio of their light curves do not allow us to definitively classify them as δ Sct variables and they are not listed in the table. In fact, most of them have been previously considered only as suspected δ Sct variables by earlier authors.

The list is given according to their 2000.0 equinox equatorial coordinates ordered by increasing right ascension. Several catalogue identifications appear for each star according to the source: HD (Henry Draper Catalogue), HR (Bright Star Catalogue), SAO (Smithsonian Astrophysical Observatory Star Catalogue), BD (Bonner Durchmusterung), CD (Cordoba Durchmusterung), CPD (Cape Photographic Durchmusterung), HIP (Hipparcos Catalogue), CCDM (Catalogue of the Components of Double and Multiple Stars) and GCVS (General Catalogue of Variable Stars). In some cases, when it is known, another designation has been also used (Other). Similarly to the R94 catalogue, periods correspond to the dominant pulsation mode in every case while amplitudes correspond to the mean full visual amplitude of the light curve. The main sources of information have been the Name Lists of Variable Stars Nos. 72, 73 (Kazarovets & Samus 1995, 1997) and 74 (Kazarovets et al. 1999). In addition, the Hipparcos catalogue (ESA, 1997) has been also taken into account, together with all the available bibliography in the last few years.

In this new catalogue, more than 50% of the variables are new in relation to our last list (R94 catalogue). The list of R94 contained 298 variables, three of them have been eliminated (UW CVn, V879 Aql and UX Mon). UW CVn and V879 Aql seem to be W UMa-type binary systems with periods of $0\overset{d}{.}292$ and $0\overset{d}{.}271$, respectively (Kopacki & Pigulski 1995, 1998). In the case of UX Mon, it was thought to be an Algol-type binary system ($P = 5\overset{d}{.}9$) where the primary component is a δ Sct pulsating star with a period of about 1 hour. However, later observations by Olson & Etzel (1995) do not confirm the δ Sct-like variations. These authors found variability with a time scale of several hours (>8 hours) as due to mass transfer in this active binary. Another possibility might be γ Dor-like variations in the primary component.

Hence, 295 variables were already listed in the R94 catalogue and 341 are new. Nearly all of these new variables (337) have been discovered through the years 1994 to 2000. The main contributions come from the Hipparcos mission (88 new variables; ESA 1997, Kazarovets et al. 1999) and the OGLE (54; Udalski et al. 1994, 1995a,b, 1996, 1997) and MACHO (84; Alcock et al. 2000) projects. In the case of OGLE project, 56 variables of this type have been observed but only 54 are new. The variables BWC-V82 and BW1-V23 were already known as V4117 Sgr and V1363 Sgr, respectively (Blanco 1984). In the case of MACHO project, 90 δ Sct variables are listed but only 84 are new. The variables MACHO-58 and MACHO-59 are V1363 Sgr and V4117 Sgr, respectively. In addition, the variables MACHO-56, MACHO-57, MACHO-62 and MACHO-63 were previously identified by the OGLE project as BW10-V141, BW1-V109, BW7-V79 and BW3-V93. Thus, even avoiding the contributions from these three main projects, a large number (111) of new variables have been discovered since 1994. These mean the 17% of the total sample of δ Sct pulsating stars known up to date. The last variable included in our catalogue is HD 81882, discovered by Rodríguez & Rolland (2000) during the night of January 29, 2000. On the other hand, more than 500 papers, published during the last few years, have been revised and 282 new references have been added to the corresponding list.

The main source of information for Strömgren photometry has been the catalogue of Hauck & Mermilliod (1998). In the case of Johnson photometry, the catalogues of Mermilliod et al. (1997) and Hipparcos (ESA 1997) have been mainly used. Sometimes, individual valuable papers have been used to determine the Strömgren indices, especially for variables with large amplitudes. In a few cases, the visual V magnitudes come from Simbad Database (1999). The main source for Spectral Types have been the Michigan (Houk & Cowley 1975 (Vol. 1); Houk 1978 (Vol. 2); Houk 1982 (Vol. 3); Houk & Smith-Moore 1988 (Vol. 4)) and Hipparcos (ESA 1997) catalogues. In addition, the lists of Gray (1988), Gray & Garrison (1989), Gray & Corbally (1993), Abt & Morrell (1995) and Simbad Database (1999) have been also used.

In the case of rotational velocities ($v\sin i$), the catalogue of Uesugi & Fukuda (1982) has been the most used. In addition, the lists of McNamara (1985), Abt & Morrell (1995), Solano & Fernley (1997) and Medeiros & Mayor (1999) have been also taken into account. The main sources for radial velocities have been the lists of Duflot et al. (1995), Fehrenbach et al. (1997) and Grenier et al. (1999a,b). Finally, in all cases, the parallaxes come from the Hipparcos catalogue (ESA 1997).

These sources have been used to up-date the data catalogued in the new list, including values already available in the R94 catalogue. However, in the majority of the

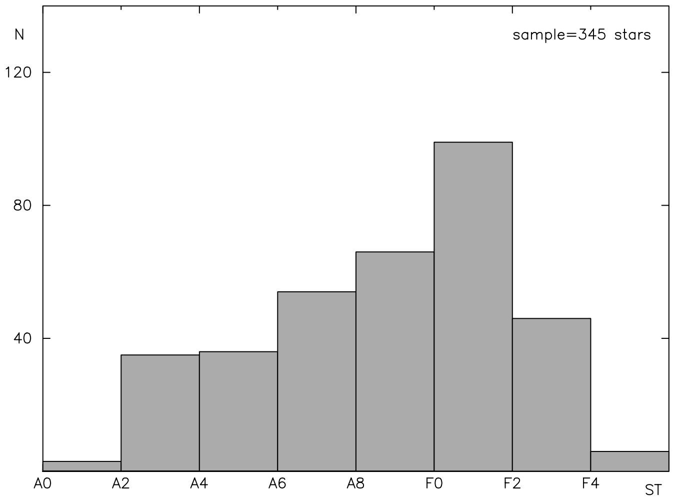

Fig. 1. Distribution of the variables in the catalogue (N) as function of the spectral type (ST)

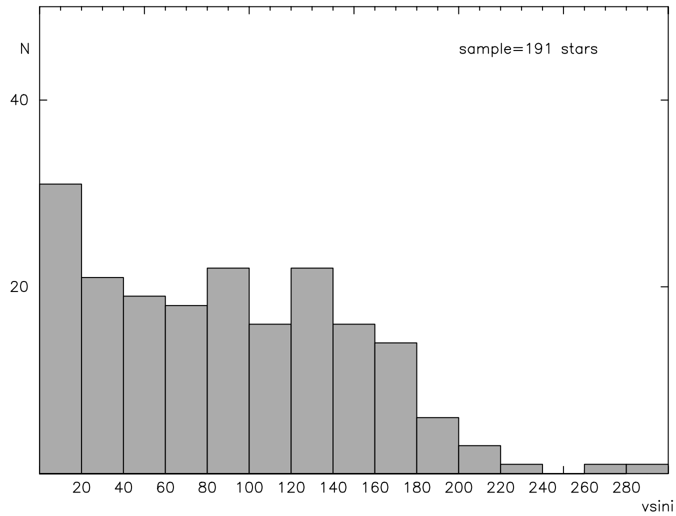

Fig. 2. Distribution of the variables in the catalogue (N) as function of the rotational velocity ($v\sin i$)

cases, the old values do not change. The main sources for changes have been V and $B-V$ from the Hipparcos catalogue (ESA, 1997) and rotational velocities from Solano & Fernley (1997), but no trends are shown with the new values.

2.2. Content

Figures 1 to 6 give us some insight about the content of the catalogue. Figures 1 to 4 show the corresponding distributions as functions of the spectral type, rotational velocity, visual amplitude and period, respectively. Figures 5 and 6 display some interesting cross-correlations found between these parameters. In Fig. 1, only variables with well defined available spectral types have been taken into account, hence peculiar stars were not included in the sample. As it can be seen, the majority of these stars have spectral types between A6 to F2, with a peak at F0.

In relation to Fig. 2, by comparing this figure with Fig. 7 of the R94 catalogue, the peak corresponding to the interval 60−80 km s^{-1} has disappeared. Now, the distribution is more smoothed and the stars seem to be uniformly distributed in all the range for rotational velocities lesser than 180 km s^{-1}. Only a peak remains for very low values of $v\sin i$. This peak is due to the variables with high amplitudes of luminosity variation. This is confirmed when we plot Fig. 5, where the visual amplitudes versus rotational velocities are shown. Similarly to R94, these two figures point out that stars with large rotational velocities do not exhibit large amplitudes, that is, the variables displaying large amplitudes are very slow rotators. In fact, the mean value of $v\sin i$ for δ Sct variables with $\Delta V \leq 0\overset{\mathrm{m}}{.}03$ is found to be of 109(±58) km s^{-1} whereas this is much smaller for the large amplitude pulsators ($< v\sin i > = 22(\pm 10)$ km s^{-1} for the variables with $\Delta V \geq 0\overset{\mathrm{m}}{.}1$ and a very similar value is found for the variables with $\Delta V \geq 0\overset{\mathrm{m}}{.}3$).

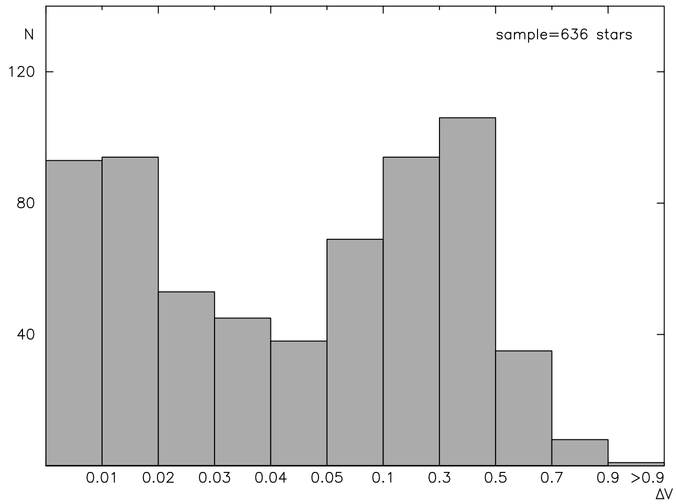

Fig. 3. Distribution of the variables in the catalogue (N) as function of the visual amplitude (ΔV)

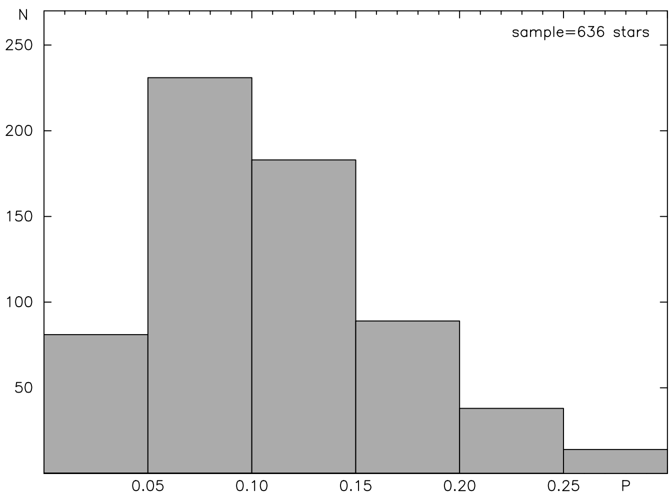

Fig. 4. Distribution of the variables in the catalogue (N) as function of the period (P)

Table 1. δ Sct stars

HD	SAO	CD	GCVS	RA(h,m,s)	CCDM	HIP	Per (d)	Amp(V)	V	$v$sin$i$ (km s^{-1})	RV (km s^{-1})	ST	References
HR	BD	CPD	Other	$D(^0,')$	paral(mas)	$B-V$	$U-B$	$b-y$	m_1	c_1	β	Notes	References
224875	128535		DR Psc	00 01 23		109	0.1652	0.04	7.23			F0	0270 0511
	+05.05247			+06 47.5	5.33(±0.94)	0.39		0.232	0.180	0.798	2.696	123 125	
225161	91683		NN Peg	00 04 00	00040+1209A	316	0.1701	0.06	7.26			F0	0270 0511
	+11.05092			+12 08.7	5.48(±1.25)	0.36		0.207	0.175	0.813		123 125 135	
432	21133		β Cas	00 09 11	00092+5909A	746	0.1009	0.033	2.28	69	11	F2III-IV	0003 0029 0045 0331 0408 0653
21	+58.00003		11 Cas	+59 09.0	59.89(±0.56)	0.38	0.10	0.216	0.177	0.785	2.721	002 135 145	0659 0732 0739 0740 0803 0873
1097	166146	−29.00050	AU Scl	00 15 08		1210	0.0564	0.01	9.09		7	A3-5mF0-F5	0362 0591 0974 0918
		−29.00019		−29 00.4	4.90(±1.41)	0.40		0.239	0.326	0.465	2.727	003	
1479			V377 Cas	00 19 14	00192+5942AB	1543	0.03	0.05	7.83	136		F0	0261 0939 1014
	+58.00028			+59 42.3	5.98(±1.33)	0.37	0.06	0.212	0.189	0.701	2.749	135	
2145		−47.00106	BQ Phe	00 25 24		2005	0.2185	0.11	10.42			F3-F5V	0270 0511
		−47.00037		−46 55.5	1.86(±2.08)	0.51						123 125	
	4125		V402 Cep	00 29 20		2299	0.1229	0.07	10.48			F2	0270 0511
				+79 52.7	2.07(±1.20)	0.56						123 125	
2628	74041		GN And	00 30 07	00302+2945AB	2355	0.0693	0.05	5.20	16	−10	A7III	0045 0091 0260 0331 0337 0457
114	+28.00075		28 And	+29 45.1	17.62(±0.86)	0.27	0.08	0.169	0.166	0.870	2.754	072 136 146 182	0473 0653 0770 0771 0873 0917
2724	215120	−41.00116	BB Phe	00 30 28		2388	0.1743	0.05	6.18	83	−4	F2III	0085 0086 0613 0659 0685 0776
119		−41.00049		−40 56.4	7.77(±0.72)	0.32		0.191	0.189	0.883	2.749	182	896
3112	255679		θ Tuc	00 33 23		2629	0.0493	0.04	6.11	80	10	A7IV	0078 0193 0213 0583 0659 0799
139		−71.00020		−71 16.0	6.65(±0.52)	0.27	0.19	0.147	0.187	0.984	2.817	143 147 182	0966 0973 0991 0998 1023 1026
3326	166400	−23.00220	BG Cet	00 36 07		2852	0.0299	0.003	6.06	98	13	A5m	0565 0589 0659 0666 0669 0671
151		−23.00055		−22 50.5	20.12(±0.91)	0.30		0.171	0.217	0.731	2.783		
	36605		CC And	00 43 48		3432	0.1249	0.24	9.33	145	−10	F3IV-V	0154 0293 0296 0313 0610 0638
	+41.00119			+42 16.9	2.39(±1.34)	0.36	0.11	0.235	0.168	0.846	2.749		0659 0941 1016 1110
4494	215235	−42.00253		00 46 38			0.07	0.006	9.45			F0V	0391 0551
		−42.00071		−42 09.6				0.177	0.171	0.779	2.762		
4490	92082		XX Psc	00 47 14		3685	0.1040	0.04	6.11	170	0	F0Vn	0114 0353 0374 0659 0965
214	+18.00101		59 Psc	+19 34.7	9.35(±0.85)	0.27	0.20	0.165	0.178	0.929	2.773		
4849	215254	−44.00216	AZ Phe	00 50 04		3903	0.0551	0.007	6.49			A9-F0III	0424 0565 0589 0659 0666 1096
239		−44.00101		−43 23.7	10.31(±0.82)	0.29	0.12	0.168	0.210	0.817	2.765		1097

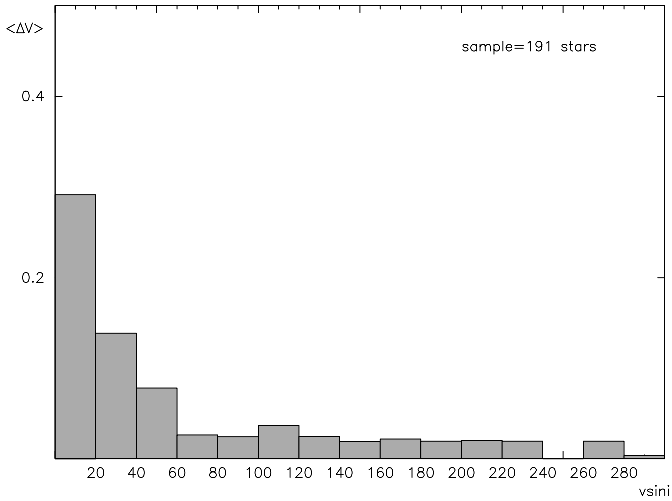

Fig. 5. Full average of the visual amplitude (ΔV) versus rotational velocity ($v$sin$i$)

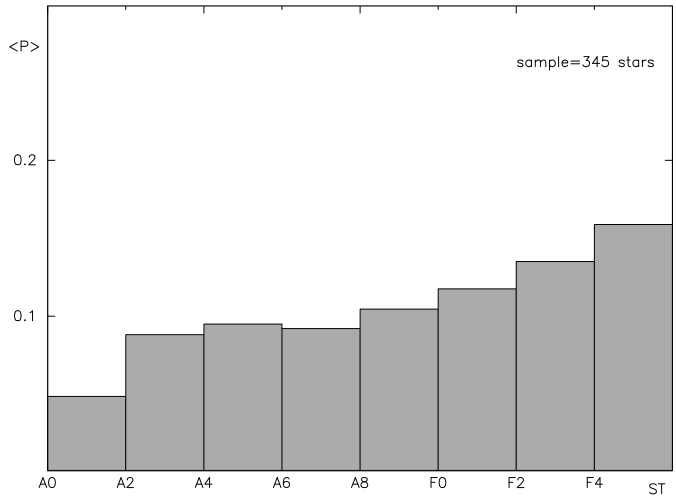

Fig. 6. Mean period (P) versus spectral type (ST)

This agrees well when considering the parametric resonance as a mechanism to limit the amplitude of the pulsations, as mentioned in R94.

In relation to Fig. 3, the distribution is similar to that found from the R94 sample. These stars show visual amplitudes from a few thousandths of a magnitude to several tenths. The majority of them present small amplitudes (a few hundredths) with a typical value of about $0\overset{\mathrm{m}}{.}02$. Moreover, the number of low amplitude variables increases nearly exponentially as decreasing the amplitude. In particular, nearly 30% of them show amplitudes smaller than $0\overset{\mathrm{m}}{.}02$. It suggests we cannot exclude the possibility that many of the apparently nonvarying stars in the δ Sct region vary but with undetectable amplitudes. On the other hand, the distribution shown in our Fig. 4 resembles the corresponding one found from the R94 list. Similarly to the earlier catalogue, Fig. 4 point out that the majority of these variables show short periods (about 80% of them have periods shorter than $0\overset{\mathrm{d}}{.}15$) and the number of variables decreases as the period is increasing. It can be due to stars with longer periods are more evolved, hence the probability of finding one star in this region of the H$-$R diagram is smaller. Other reasons can be the selection effects mentioned in the R94 catalogue.

Additionally to the correlation found between the visual amplitudes and rotational velocities, another interesting result is displayed in Fig. 6 where the mean periods are shown versus the spectral type. As it can be seen, the periods of the variables tend to increase when the spectral types are later. It can be explained as an evolutionary effect due to the hotter δ Sct stars tend to be near the main sequence while the variables presenting the latest spectral types are more evolved (spectral class II and III). However, no correlations are found for $v$sin$i$ versus spectral type or $v$sin$i$ versus period. From an observational point of view, it seems to be that stars in main sequence rotate faster than evolved stars, however no correlation is found between $v$sin$i$ and spectral types for the δ Sct-type variables. It might be due to a selection effect because there are few δ Sct stars with long periods and available $v$sin$i$ values. It might also be that other parameters have to be taken into account.

Acknowledgements. This catalogue is dedicated to the memory of our great friend and observer in the field of δ Sct stars Salvador F. González-Bedolla deceased November 1, 1996. The authors are in debt to many people who have contributed to improve this catalogue. Some of them are Dr. Balona, Beaulieu, Breger, Frandsen, Hintz, Jiang, Liu, Mantegazza, Minniti, Paunzen, Piquard, Sasselov, Udalski. Especial acknowledgements are made to Dr. Handler, Kaluzny, Kim, Koen, Templeton and Zhou. Acknowledgements are also especially made to M.C. Romero for making available many papers used in this investigation and V. Costa for proofreading. This research was supported by the Junta de Andalucía and the Dirección General de Enseñanza Superior e Investigación Científica (DGESIC) under project PB98-0499. This work has made use of the Simbad database, operated at CDS, Strasbourg, France.

References

Abt H.A., Morrell N.I., 1995, ApJS 99, 135
Alard C., 1996, ApJ 458, L17
Albrow M.D., 2000, PASPC (in press)
Alcock C., Allsman R.A., Alves D.R., et al., 2000, ApJ (in press)
Aubourg E., Bareyre P., Brehin S., et al., 1995, A&A 301, 1
Blanco B.M., 1984, AJ 89, 1836
Breger M., 1979, PASP 91, 5
Breger M., 1995, PASPC 83, 70
Breger M., 1999, New Astron. Rev. 43, 441
Breger M., 2000, PASPC (in press)
Duflot M., Figon P., Meyssonnier N., 1995, A&AS 114, 269
Eggen O.J., 1979, ApJS 41, 413
ESA 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200

Fehrenbach C., Duflot M., Mannone C., Burnage R., Genty V., 1997, A&AS 124, 255
García J.R., Cebral J.R., Scoccimarro E.R., et al., 1995, A&AS 109, 201
Garrido R., 2000, PASPC (in press)
Gray R.O., 1988, AJ 95, 220
Gray R.O., Corbally C.J., 1993, AJ 106, 632
Gray R.O., Garrison R.F., 1989, ApJS 70, 623
Grenier S., Baylac M.O., Rolland L., et al., 1999a, A&AS 137, 451
Grenier S., Burnage R., Farraggiana R., et al., 1999b, A&AS 135, 503
Hauck B., Mermilliod M., 1998, A&AS 129, 431
Houk N., 1978, Michigan Spectral Catalogue Vol. 2, University of Michigan
Houk N., 1982, Michigan Spectral Catalogue Vol. 3, University of Michigan
Houk N., Cowley A.P., 1975, Michigan Spectral Catalogue Vol. 1, University of Michigan
Houk N., Smith-Moore M., 1988, Michigan Spectral Catalogue Vol. 4, University of Michigan
Jiang S.Y., Hyung S., Kim K.M., 2000, PASPC (in press)
Kazarovets E.V., Samus N.N., 1995, Inf. Bull. Var. Stars No. 4140
Kazarovets E.V., Samus N.N., 1997, Inf. Bull. Var. Stars No. 4471
Kazarovets E.V., Samus N.N., Durlevich O.V., et al., 1999, Inf. Bull. Var. Stars No. 4659
Kopacki G., Pigulski A., 1995, Acta Astron. 45, 753
Kopacki G., Pigulski A., 1998, Acta Astron. 48, 747
Kurtz D.W., 1994, Delta Scuti Star Newslett. 7, 13
Kurtz D.W., 1996, Delta Scuti Star Newslett. 10, 28
López de Coca P., Rolland A., Rodríguez E., Garrido R., 1990, A&AS 83, 51
McNamara D.H., 1985, PASP 97, 715
Medeiros J.R., Mayor M., 1999, A&AS 139, 433
Mermilliod J.C., Mermilliod M., Hauck B., 1997, A&AS 124, 349
Olson E.C., Etzel P.B., 1995, AJ 110, 2385
Rodríguez E., Rolland A., 2000, Inf. Bull. Var. Stars No. 4851
Rodríguez E., López de Coca P., Rolland A., Garrido R., Costa V., 1994, A&AS 106, 21
Simbad, 1999, Simbad Database, CDS, Strasbourg, France
Solano E., Fernley J.A., 1997, A&AS 122, 131
Tsvetkov Ts.G., 1990, Ap&SS 173, 1
Udalski A., Kubiak M., Szymanski M., et al., 1994, Acta Astron. 44, 317
Udalski A., Olech A., Szymanski M., et al., 1995a, Acta Astron. 45, 433
Udalski A., Szymanski M., Kaluzny J., et al., 1995b, Acta Astron. 45, 1
Udalski A., Olech A., Szymanski M., et al., 1996, Acta Astron. 46, 51
Udalski A., Olech A., Szymanski M., et al., 1997, Acta Astron. 47, 1
Uesugi A., Fukuda I., 1982, Revised Catalogue of Stellar Rotational Velocities, Kyoto University, Japan
Wolff S.C., 1983, "The A-Stars: Problems and Perspectives", NASA SP-463, 93