PULSATING VARIABLE STARS IN BINARY SYSTEMS

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Abstract

Lists of variable stars in binary systems are presented.

There is a growing interest in pulsating variables belonging to binary systems because in these cases it is possible to determine masses and other physical parameters of the components. Gravitational effects may be important in pulsating variables where a close companion produces tides that affect non-radial oscillations. Also, there may be an interconnection of the axial rotational, pulsational, and orbital period values for binary systems. However, the study of this synchronization is possible only if the periods are known with sufficient accuracy.

There are numerous methods to discover binary nature, and we mention only the light-time effect in the O-C diagram and the orbital frequency-splitting in the Fourier power spectrum.

Nowadays there are a lot of Cepheids, δ Scuti, and β Cephei stars in binary systems, and there are several less-certain cases among the RR Lyrae variables. We give data on these types in Tables 1-3. The observed frequency of binaries among Cepheids is very high, more than 50%. In the case of δ Scuti and β Cephei stars, the occurrence is about 30%. Only a few Mira and semi-regular variables in binaries are known, and so far three or four RR Lyrae stars have been discovered as a component of binaries.

Figure 1 shows the Cepheids and RR Lyrae variables which have a sinusoidal O-C diagram. The ordinate $2A_{O-C}$ is the total amplitude; P_{orb} is the period of the wave. The upper dashed line, the solid line, and the lower dashed line represent the mass functions $f(M_2) = 17.0$, 3.0, and 0.04 $M_\odot$ ($e = 0$). If this value is very high, the wave on the O-C diagram is not connected with the binary nature. If the mass function is very low, the inclination of the orbit may be only a few degrees.

Table 1. Known Pulsating Stars in Binary systems

β Cephei stars:
eclipsing binaries - 16 EN Lac, η Ori, HD 92024
spectroscopic binaries - β Cen, υ Cen, β Cep, (β Cru), υ Eri, V600 Her, DD Lac, θ Oph, α Vir, γ Peg, λ Sco, (σ Sco)
suspected O-C binaries - δ Cet, DD Lac

RR Lyrae stars:
eclipsing binaries - V80 in UMi gx., (RW Ari)
O-C binaries - RR Leo, NZ Lyr, TU UMa

Table 1 (continued)

suspected O-C binaries - V13, 17, 20, 28, 31, 36, 41, 47, 65, 88, 89, 90, 107, 123, 124, 126 in M3; V4, 7, 18, 20, 22, 23, 24 in M15; V12, 15, 16, 28, 35 in M53; X Ari, RS Boo, V363 Cas, RW Cnc, W CVn, DX Del, AV Peg, RV UMa

Cepheids which are not in Table 3:

CE Cas (both components), η Aql, U Aql, (FM Aql, TT Aql), V1344 Aql, Y Car, YZ Car, SU Cas, V636 Cas, VZ Cyg, DT Cyg, V1334 Cyg, V Lac, X Lac, Y Lac, Z Lac, RR Lac, BG Lac, GH Lup, T Mon, SV Mon, R Mus, S Mus, S Nor, Y Oph, RS Ori, SV Per, AP Pup, AT Pup, W Sgr, Y Sgr, BB Sgr, RV Sco, V Vel, AH Vel, U Vul, T Vul, SZ Tau, R TrA, V1670 Sgr, RY CMa

Semi-regular stars:

V641 Cas, VV Cep, η Gem, α Her, α Sco, (RR UMi), CH Cyg

Mira stars:

R Aqr, UV Aur, o Cet, V407 Cyg, V1016 Cyg, R Hya, X Oph, (RR Tel)

Table 2 gives data of 34 eclipsing (EB) and/or spectroscopic binaries (SB) containing δ Scuti stars. In some cases the determination of the orbital period (P_o) is based on the O-C diagram (OC). Some pulsational periods (P_p) are doubtful or the δ Scuti classification itself is questionable (e.g., ZZ Cyg).

There are many additional possible δ Scuti stars among the eclipsing, spectroscopic, and physical visual binaries. On the other hand, several known pulsating variables may be binary. More photoelectric and spectroscopic observations are needed to identify them.

Table 2. δ Scuti Stars In Binary Systems

Star	*Spectrum*	*Type*	*e*	*K*	P_o	P_p	P_o/P_p
DL UMa	F0V	EB			0.42	0.0831	5.05
ZZ Cyg	F6V+K5IV	EB	0.0		0.62861	0.1::	6.3::
MM Cas	F	EB			1.15847	0.1528	7.6
σ^2 TZ CrB	F8V	SB2	0.02	60.1	1.1398	0.1:	11.4:
DV Aqr	F0IV	EB, SB	0.0	95.5	1.5755	0.12:	13:
WX Eri	A7+F6V	EB			0.82327	0.1645	5.0
						0.1372	6.0
RS Cha	A8IV+A8IV	EB, SB	0.0	136.1	1.66987	0.077	21.7
AB Cas	A3V+KV	EB	0.0		1.33688	0.0583	23.5
UX Mon	A6V+G2IV	EB	0.0		5.9045	0.2::	29.5::
V775 Tau	Am	SB	0.04	26.6	2.1433	0.062	34.6
GX Peg	A8IV	SB1	0.02	84.9	2.3409	0.056	41.8
14 KW Aur	A9IV	SB1	0.0	23.0	3.7886	0.0881	43.0

Table 2 (continued)

Star	*Spectrum*	*Type*	*e*	*K*	P_o	P_p	P_o/P_p
Y Cam	A9IV+gK1	EB	0.0		3.30553	0.0665	49.7
V1004 Ori	A5m	SB	0.02	55.6	2.7405	0.0489	50.7
δ Sct	F3III-V	phot.	0:		10::	0.1938	52::
AI Hya	F0+F5	EB			8.28967	0.1380	60.1
18 Vul	A3IIIm	SB	0	78.5	9.316	0.121:	77:
CC And	F3IV	phot.	0.15:		10.469:	0.1249	84:
V644 Her	F2II	SB	0.31	28.5	11.848	0.115	103
V474 Mon	F2IV	SB	0:		15.492	0.135	115:
ET And	Ap	SB	0.5		48.308	0.198:	244:
δ Del	Am+Am	SB2	0.7		40.58	0.158:	257:
β Cas	F2IV	SB			27:	0.104	259:
IK Peg	A8m	SB1	0.0	41.5	21.724	0.0437	497
FM Vir	Am	SB	0.07	48.1	38.324	0.076	504
RX Cas	A5eIII+K1III	EB			32.3	0.028:	1150:
θ^2 Tau	A5III-V	SB	0.75	31	140.728	0.0756	1860
ρ Tau	F0V	SB	0.09	18	488.5	0.067	7290
SZ Lyn	A8-F2	OC, SB1	0.19	9	1180	0.12052	9790
AZ CMi	F0III:	OC			2625::	0.0953	27550::
V777 Tau	F0V	SB	0.24	15	5200	0.162	32100
θ Vir	A1IV+Am	SB			5100	0.152	33500
KZ Hya	A0	OC			3370	0.0595	56600
V577 Oph	A	EB	0.14		6.7091	0.0695	87.5

Table 3 lists 24 Cepheid variables that are relatively well studied. The columns are the following: star name, population, type of the discovery of the binary nature (SB = spectroscopic binary, OC = sinusoidal O-C diagram due to the light-time effect), eccentricity of the orbit, amplitude of the mean radial velocity variation (km/s), orbital and pulsation period (days), the period ratio, amplitude of the wave on the O-C diagram (days), and a value which is in direct proportion to the modulation depth (the list is ordered by this value). In the case of SB stars, the radial-velocity amplitude, K, is observed and orbital radius, A, is calculated; conversely, in the case of OC stars, the radius is measured and the K is computed using the usual formula, assuming the eccentricty to be zero:

$$K = \frac{2\pi c\, A_{O-C}}{P_o}, \qquad \text{if } e=0. \qquad (1)$$

Table 3. Cepheid Binaries

Star	*Pop*	*Type*	*e*	*K*	P_o	P_p	P_o/Pp	A_{O-C}	(P_o/P_p)k/c
X Sgr	I	SB	0:	3	507	7.0129	72	0.0008	0.0007
TX Del	II	SB	0.07	14.4	133	6.1659	22	0.001	0.0010
IX Cas	II	SB	0.04	29.6	110	9.1545	12	0.0018	0.0012
XX Cen	I	SB	0:	4	909	10.9534	83	0.002	0.0012
S Mus	I	SB	0.05	14.4	506	9.6601	52	0.0038	0.0025
AU Peg	II	SB	0:	41.8	53	2.4015	22	0.0012	0.0031
FF Aql	I	SB	0.01	3.5	1435	4.4709	321	0.0027	0.0037
S Sge	I	SB	0.25	15	676	8.3821	81	0.005	0.0040
DL Cas	I	SB	0.28	14	688	8.0006	86	0.0047	0.0040
V636 Sco	I	SB	0.26	12.5	1318	6.7967	194	0.009	0.0081
V350 Sgr	I	SB	0:	12	1129	5.1542	219	0.007	0.0088
V496 Aql	I	OC		23	1880	6.8071	276	0.023	0.021
BF Oph	I	OC		7	4420	4.0677	1090	0.017	0.026
α UMi	II	SB	0.64	4	11125	3.9698	2803	0.017	0.038
AX Cir	I	OC		13	4600:	5.2733	872	0.032	0.038
AP Sgr	I	OC		8	7600:	5.0579	1500	0.035	0.043
AG Cru	I	OC		8	6350:	3.8373	1650	0.026	0.043
AW Per	I	OC		11	13100	6.4636	2030	0.06	0.077
FN Aql	I	OC	0:	28	5635	9.4816	594	0.08	0.057
RW Cam	I	OC		55:	6600:	16.4148	402	0.2:	0.074
X Cyg	I	OC		19:	20000:	16.3863	1200	0.2:	0.077
SU Cyg	I	OC		40:	3520:	3.8455	915	0.06	0.092
RX Aur	I	OC		21:	19660:	11.6240	1690	0.22	0.119
DD Cas	I	OC		65:	8500:	9.8120	866	0.3:	0.188

References

Leonard, P. J. T., and Turner D. G. 1986, *J. Roy. Astron. Soc. Canada*, **80**, 240.
Lloyd Evans, T. 1982, *Mon. Not. Roy. Astron. Soc.*, **199**, 925.
Harris, H. C., Olszewski, E. W., and Wallerstein, G. 1984, *Astron. J.*, **89**, 119.
Harris, H. C., and Welch, D. L. 1989, *Astron. J.*, **98**, 981.
Madore, B. F., and Fernie, J. D. 1980, *Publ. Astron. Soc. Pacific*, **92**, 315.
Szabados, L. 1977, *Comm. Konkoly Obs. Hung. Acad. Sci.*, No. 70.
Szabados, L. 1980, *Comm. Konkoly Obs. Hung. Acad. Sci.*, No. 76.
Szabados, L. 1981, *Comm. Konkoly Obs. Hung. Acad. Sci.*, No. 77.
Szabados, L. 1983, *Astrophys. Space Sci.*, **96**, 185.
Szabados, L. 1988, *Inform. Bull. Var. Stars*, No. 3165.
Szabados, L. 1988, *Publ. Astron. Soc. Pacific*, **100**, 589.
Szabados, L. 1989, *Comm. Konkoly Obs. Hung. Acad. Sci.*, No. 94.
Szabados, L. 1990, *Mon. Not. Roy. Astron. Soc.*, **242**, 285.
Welch, D. L., Evans, N. R. 1989, *Astron. J.*, **97**, 1153.

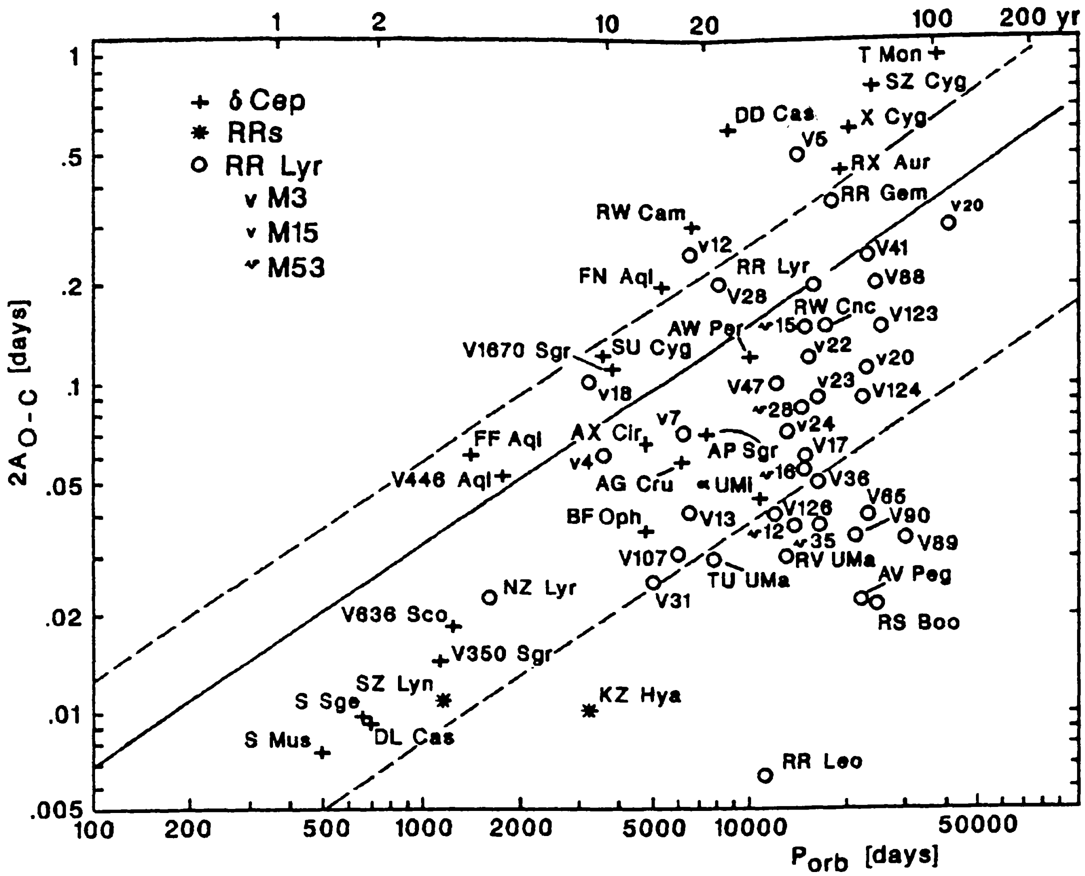

Figure 1. Total radial-velocity amplitude plotted against orbital period for Cepheids and RR Lyrae variables showing sinusoidal O-C diagrams. See text for explanation.