DUPLICITY AMONG RR LYRAE TYPE–STARS

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ABSTRACT. On the basis of the analysis of small amplitude O–C variations, seven RR Lyrae variables are detected as possible binaries. It appears, that each one of these has probably a close companion. By using a proximate iterative algorithm, some parameters of their orbits were estimated. An evolutionary status of these stars are considered.

Key words: Stars: RR Lyrae stars, light–time effect, duplicity hypothesis

The problem of duplicity among RR Lyrae type stars is of great importance both for theory of stellar evolution and for pulsation theory. Many authors have been studying it. For example, Coutts (1971) investigated the light–time effect among cepheids and RR Lyrae stars in globular cluster M3. She made a conclusion that nearly 20 per cent of RR Lyrae type variables in M3 belonged to binary systems. It would seem not grounded, as only for one star V13 in M3 the cycle wave is repeated several times. In other cases, only arcs can be seen in the O–C diagrams; moreover their amplitudes are about a few decimal of days. There is no agreement with the duplicity hypothesis, as very large orbital (and radial) velocities of RR Lyrae stars and masses of second components are obtained. Until recently we haven't known any candidates to binary systems among RR Lyrae field stars. At least, there seems to be no physical restrictions on their presence in wide pairs. Apparently, all depends on the exactness of observations and of the small effect.

Bezdenezhnyi (1985,1988) revealed cyclic oscillations of mean O–C residuals with small amplitude on the time scale a few years for V363 Cas and X Ari, and then – for DX Del and WCVn (unpublished). Also, we paid attension to this effect for RR Gem, that can be seen from Goranskij (1982) figure, using Szeidl's (1975) observations. In the recent work Saha et al. (1990) showed, that fluctuations of O–C residuals TU UMa could be explained according to the duplicity hypothesis. They obtained preliminary solution with a very eccentric orbit (e>0.90) and the period of about 7400 days. Behaviour of mean radial velocities satisfies qualitatively for this hypothesis too.

In the present investigation we suggest an iterative proximate–method for estimation of masses, semimajor axes and orbital velocities of companions, one of them is the variable star, and another may be invisible, by assuming circular orbits.

A periodical pulsating or eclipsing star is supposed to have a far distant invisible component. Then the variable would move around its common mass centre of a multiple system, and observed extrema in its light curve would precede or lag behind those computed. Due to the periodicity of an orbital motion, behaviour of O–C residuals will prove to be periodical too, and judging from it the conclusion can be drawn on the parameters of the multiple system.

If in analyzing plots of small amplitude of cyclic variations in O–C residuals, a semiamplitude is determined as A_{O-C} (relative to the mean line set by a true period of the variable), the light equation will be written as follows:

$$a_v = A_v \sin i = \frac{86400 c A_{O-C}}{R_\odot}. \qquad (1)$$

By substituting A_{O-C} in days, $R_\odot$=696000 km and light velocity we obtain the value of a semimajor axis for the variable in units of the Sun's radius:

$$a_v = 37241\, A_{O-C}. \qquad (2)$$

By using the generalized third Kepler's low:

$$a = 0.01957(M_1 + M_2)^{1/3} P_{orb}^{2/3} (AU), \quad (3)$$

where $M_{1,2}$ are given in units of solar mass and the period in the mean solar days. We transform this formula by expressing a semimajor axis of the relative orbit a in units of solar radius:

$$a^3 = 74.426(M_v + M_{co}) P_{orb}^2. \quad (4)$$

Masses of the variable and a companion are given in units of the solar one. The length of a cycle (in days) of a long–term small amplitude O–C oscillation is taken for the period of orbital motion. We introduce the parameter q equal to the ratio of the companion mass to the variable star mass:

$$q = \frac{M_{co}}{M_v} = \frac{a_v}{a_{co}}. \quad (5)$$

Then the total mass of the system is:

$$M = M_v + M_{co} = M_v(1 + q), \quad (6)$$

and a semimajor axis is:

$$a = a_v + a_{co} = \frac{a_v(1 + q)}{q}. \quad (7)$$

Substituting these expressions into equation (4) we obtain:

$$a_v^3 \frac{(1 + q)^2}{q^3} = 74.426 M_v P_{orb}^2. \quad (8)$$

Let us introduce the parameter:

$$\alpha = \frac{(1 + q)^2}{q^3} = q^{-1} + 2q^{-2} + q^{-3}, \quad (9)$$

the product of which by the mass function is equal to the mass of the variable star: $\alpha f(M) = M_v \sin^3 i$. Then formula (8) will be of a simple form:

$$\alpha a_v^3 = 74.426\, M_v\, P_o r b^2. \quad (10)$$

Making an assumption relative to M_v, for RR Lyrae stars we adopt M_v=0.6$M_\odot$, if a more precise value is not known for the given star, according to formulae (2) and (10) the value of α –parameter is found, whereas by formula(9) that of the q–parameter – by iterative method. Then M_{co} and a_{co} can be estimated as well as velocities of orbital motion of components with the precision up to a muitiplier $\sin i$.

The results of using the method for seven RR Lyrae stars are displayed in Table 1. As is seen from it, the distance between components is represented in a rather wide range (2.7 – 10 AU). Masses of companions are mainly more than those of RR Lyrae stars except for V13 in M3. For X Ari using the mean parallax π = 0.023" from the works by Manduca et al.(1981) and Jones et al. (1987) the angular distance of components was estimated a=0.013". For V13 π=0.0001" taken from Kholopov (1955) gives a=0.0007", that is the objects seem to be unresolved. Invisibility of companions is indicative of their faint light and their belonging to old evolved objects, white dwarfs or, even, to neutron stars. It also suggests an idea of an eruptive process of Novae in the binary system and favours for the arguments outlined by Saha & White (1990) relative to TU UMa.

Moreover, the data tabulated indicate a proportional relation between ΔS and a: metallicity has a tendency of increasing in stars in closer pairs. This elucidates the evolutionary status of these stars and is suggestive of explaining some anomalies in RR Lyrae stars of disc and halo constituents. High metallicity of V363 Cas can be accounted for large mass companion and relatively small distance from it.

The impression is produced that RR Lyrae stars are representatives of a Population II of the Galaxy with a metal–poor abundance. And only the influence of the environment (galactic gas in the disk and in the cluster, or ejections during the explosion of the evolved companion) increases metal abundances in their atmospheres.

Literature sources Preston (1959), Woolley et al.(1966), Eggen (1964), Joy (1938) and Thompson (1984) from mean radial velocities of X Ari do not seem to provide very ample material (–40, –44, –33, –40, –37, km/sec) which is of no contradiction to our estimations.

We would suggest replenishing the classification of RR Lyrae stars with objects which

Table 1.

Star	A_{O-C} (d)	P_{cycl} (d)	M_{co} $(M_{\odot})$	$v \sin i_{co}$ (km/s)	$v \sin i_{RR}$ (km/s)	$a \sin i_{co}$ (AU)	$a \sin i_{RR}$ (AU)	$a \sin i$ (AU)	ΔS
V13 M3	0.03	6250	0.45	6.7	5.0	3.8	2.9	6.7	6.4
TU UMa	0.05	7374	0.65	5.6	6.1	5.8	4.2	10.0	7.6
RR Gem	0.03	2722	0.95	6.9	10.8	1.7	2.7	4.4	3.0
X Ari	0.04	4012	0.93	6.1	9.4	2.2	3.5	5.7	8.5
V363 Cas	0.03	1450	1.92	6.1	19.5	0.8	2.6	3.4	1.0
DX Del	0.02	1275	1.05	8.4	14.8	1.0	1.7	2.7	2.6
W CVn	0.03	2899	0.81	7.2	9.8	1.9	2.6	4.5	7.0

show small amplitude cyclic variations in O–C in the time scale for some years as being binary systems.

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SUGGESTED VARIABILITY TYPES OF SUPERNOVA PROGENITORS

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ABSTRACT. Recent theoretical computations of the evolutionary tracks of massive stars do not allow to check the presence of variability of the stars just before the outburst. However, the complex inner structure of such stars (stratification of chemical elements, shell sources) allows to create conditions for pulsation instability which may play a role of rigger. Existing long-term radio observations of SN 1979C argues not only for presence of ejected matter, but for periodic (≈ 4000 yr) modulations of the mass loss rate. Early optical spectral observations of SN 1984E, 1983K, 1990M argue for self-consistent interpretation as a shell-like structure of superwind (intensive stellar wind ejected during few years before the outburst). Ellipsoidal distribution of dynamic velocities of the wind shells may be owed to large radial pulsations of the progenitors with amplitudes different at the equator and the poles. Early radio emission of SN 1987A has no single explanation. In a case of plasma mechanism one has to accept a "blobby" wind structure. Inhomogeneities are more significant at large distances. Thus most interesting and informative are the fast variations of absorption profiles formed near and mainly before SN maximum.

Key words: Stars: Supernovae, Progenitors