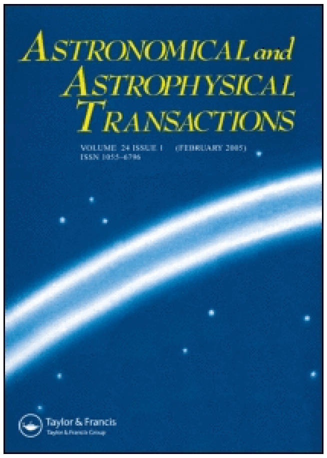

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NEW RRa VARIABLE STAR NEAR THE X-RAY NOVA OPH 1993=V 2293 OPH AND THEIR DISTANCE EVALUATIONS

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A new RRa variable star has been discovered in $2\overset{\prime}{.}5$ from X-ray Nova Oph 1993 = GRS 1716−249 = V 2293 Oph. Its period is $0\overset{d}{.}4908409$. The brightness varies in the range of 15.9^m–$(17.5^m$ pg. The estimations of interstellar extinctions and distances to Nova Oph 1993 and the new RRa variable star have been received.

KEY WORDS Variable star: discovery: light curve; X-ray Nova: distance

An earlier unknown RR Lyr variable star has been found during our look through 84 photographic plates (1949–1919) of the 40 cm astrograph of Sternberg Institute Crimean Station, for the purpose to reveal outbursts of the X-ray nova GRS 1716–249, discovered by Bullet *et al.* (1993), identified with optical Nova Oph 1993 by Della Valle *et al.* (1993) and designated as V 2293 Oph by Kazarovets and Samus (1994).

The finding chart is given in Figure 1. The magnitudes of the comparison stars have been derived by the link to the standard sequence in the NGC 6304 region (Nesser, Hartwick, 1976). The variable star is situated near the edge of our plates and during its minimum is invisible. The star belongs to RRa type of variability with the elements:

$$\mathrm{MAX} = \mathrm{JD}\ 2444409.424 + 0\overset{d}{.}4908409\ \mathrm{E}; \quad \mathrm{m} - \mathrm{M} = 0\overset{P}{.}25.$$

The list of maxima and high brightness epoches is given in Table 1.

The mean light curve is given in Figure 2 and in Table 2.

The coordinates of this variable star have been derived by linking to the stars of SAO Catalogue: $\alpha = 17^h16^m24\overset{s}{.}79$; $\delta = -24^0 59' 50\overset{''}{.}8$ (1950), error $\pm 1\overset{''}{.}0$ in both coordinates. The RRa star is situated in $2\overset{\prime}{.}5$ from the X-ray Nova Oph 1993 = V 2293 Oph ($l = 0\overset{0}{.}14$; $b = +6\overset{0}{.}99$) and in the field No. 235 from the paper by

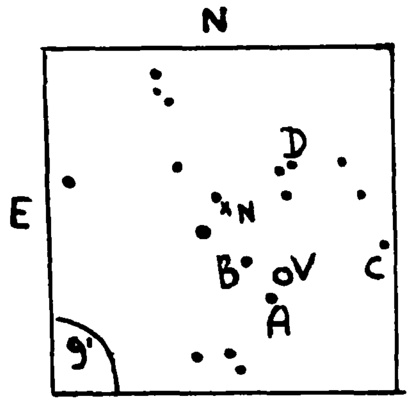

Figure 1 The finding chart for the X-ray Nova Oph 1993 N (is marked by the cross) and the RRa variable star V (is marked by the open dot). The reference stars A, B, C and D have the following m(pg) magnitudes: $15^m_.9$; $16^m_.3$; $17^m_.3$: ; $17^m_.9$:. The size of the field is $9' \times 9'$.

Neckel, Clare (1980). According to this paper, the interstellar extinction in this field is constant within the limit of errors and is equal to $A = 2^m_.0 \pm 0^m_.7$ for the stars with distances $d \geq 1$ kpc. The hydrogen column density determined from the soft X-ray absorption by Tanaka (1993) is $N(H) = 4 \times 10^{21}$ cm^{-2}. According to Bochkarev (1992):$N(H) = 6 \times 10^{21} \cdot E(B-V)$, so $E(B-V) = 0^m_.67$ and $A_V = 2^m_.1$ or $A_B = 2^m_.7$ ($R_V = 3.2$), in accordance with A_V obtained earlier. Taking $M_V = +0^m_.3$ and $(B-V)_0 = 0^m_.3$ for RRa stars, we find the distance to our RRa variable $d = 5.6$ kpc.

On the moment of the optical component discovery on 5 October 1993 the X-ray Nova Oph had $B = 17^m_.1$ (Della Valle *et al.*, 1993). Supposing that in maximum its absolute magnitude was $M_B = -0.1$ as in the case of the X-ray Nova Mon 1975 (A0620–00), we have the distance to Nova Oph 1993 $d = 8.2$ kpc and $z = 1$ kpc.

Another path of distance estimation uses the total luminosity at the moment of maximum radiation. In the case of the X-ray Nova A0620–00 its X-ray luminosity is $L_X \approx 10^{38}$ erg/sec and is almost equal to the Eddington limit for solar masses.

Table 1. List of maxima

JD 24...	*m(pg)*	*E+Phase*
33482.33	16.3:	-22261.987
44409.41	16.0	-0.028
44438.36	15.75	58.952
44818.30	15.85:	833.011
45134.41	15.9:	1477.028
45826.53	16.0	2887.098
47329.40	15.95	5948.926
48028.41	15.92	7373.033

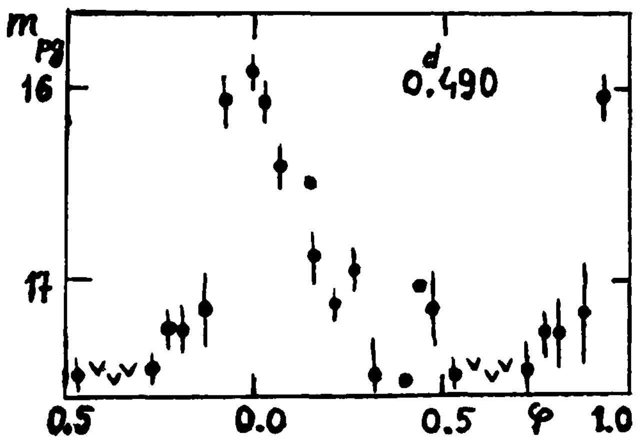

Figure 2 The light curve for the new RRa variable star folded with the $0^d.490$ period using the ephemeris given in the text. ϕ is the orbital phase. The errors and upper limits are shown.

Supposing that GRS 1716–249 has the same total luminosity, adopting X-ray fluxes 1.4 Crab units (20–100 keV), 0.24 Crab units (0.5–10 keV) and assuming X-ray spectrum $N(E) \sim E^{-2.3}$ (Harmon *et al.*, 1993; Tanaka, 1993) we get the distance $d \approx 4.6$ kpc, and $z \approx 0.6$ kpc. Thus GRS 1716–249 belongs to the thick disk population. The precision of our two distance estimates is 20% but without the 24% error of A0620–00 distance.

The out-of-error discrepancy between our two estimates of the distance for GRS 1716–249 is probably a result of different ratios of X-ray to optical luminosities L_X/L_{OPT} for GRS 1716–249 and A0620–00:

$$\eta = (L_X/L_{\mathrm{OPT}})_{\mathrm{NOPH}} : (L_X/L_{\mathrm{OPT}})_{\mathrm{NMON}} \approx 3.2$$

One of the reasons for it may be the following. Because of the high hardness,

Table 2. The mean light curve

Mean Phase ×*1000*	*m(pg)*	*N*	σ	*Mean Phase* ×*1000*	*m(pg)*	*N*	σ
17	16.035	2	0.131	537	17.467	3	0.046
71	16.363	4	0.145	583	(17.450	4	0.103
146	16.450	1	0.000	634	(17.500	2	0.000
153	16.850	2	0.175	662	(17.467	3	0.056
214	17.100	2	0.071	731	17.433	3	0.109
261	16.920	5	0.125	772	17.243	7	0.124
318	17.475	4	0.268	811	17.250	2	0.177
398	17.500	1	0.000	878	17.133	3	0.260
444	17.000	1	0.000	921	16.044	5	0.087
476	17.120	5	0.192	994	15.875	2	0.053

the most part of the X-ray flux is scattered by the accretion disk and by the second component and is not absorbed. According to Klein–Nishina formula, the probability of scattering of hard X-ray photons falling under small angules on the outer parts of accretion disk increases with the photon energy. As a result, the efficiency of transformation of the X-ray emission into the optical range decreases. Therefore in the case of equal X-ray fluxes the maximum optical brightness of GRS 1716–249 is lower than for A0620–00. The most part of the distance discrepancy may be explained like that, and the distance estimation error is responsible for the remaining part.

According to Della Valle (1993), GRS 1716–249 is identified with a 21^m–$21\overset{m}{.}5$ star in the Blue Palomar Sky Survey, and the amplitude of its outburst is $\Delta B = 4\overset{m}{.}4$. It is significantly lower than ΔB for V 616 Mon, which has $B = 19^m \div 20\overset{m}{.}2$ in its minimum and $B = 11\overset{m}{.}3$ in maximum brightness (Eachus *et al.*, 1976). This brings us to the supposition that GRS 1716–249 was $10 \div 20$ times less powerfull ($L = (1 \div 0.5) \times 10^{37}$ erg/s) than A 0620–00 ($L = 10^{38}$ erg/s). So for the distance we should have the value $d = 1 \div 1.5$ kpc. But it is very probable that the 21^m object is a neighborhood star and both the identification of Della Valle (1993) and $d = 1 \div 1.5$ kpc are not true. For the earlier derived distance $d = 4.6 \pm 2.0$ kpc, the X-ray nova V 2293 Oph in its minimum state should have a magnitude $B \approx 25^m \div 26^m$ and invisible on Palomar Charts.

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