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S 10943 VULPECULAE: A NEW ROSAT SELECTED DWARF NOVA, PROBABLY OF SU URSAE MAJORIS SUBCLASS

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As part of our program of investigating the optical long-term behaviour of selected ROSAT X-ray sources we studied the X-ray source RX J1953.1+2115 in more detail. It was discovered during a 360 sec. scanning observation on Oct. 18–20, 1990 during the ROSAT all-sky survey at a mean count rate of 0.024±0.006 cts/sec. The hardness ratios HR1 = $(N_{52-201} - N_{11-41})/(N_{11-41} + N_{52-201})$ = 1.00±0.30 (where N_{a-b} denotes the number of counts in ROSAT's position sensitive proportional counter between channel a and channel b) and HR2 = $(N_{91-200} - N_{50-90})/N_{50-200}$ = –0.17±0.38, though admittedly purely constrained due to the low number of counts, suggest a moderately hard, but absorbed spectrum. Assuming a thermal bremsstrahlung spectrum with kT = 2 keV, the unabsorbed flux in the 0.1–2.4 keV band ranges between 2×10^{-13} erg/cm^2/s (for an assumed absorbing column of $N_{\rm H}=1\times10^{20}$ cm^{-2}) up to 1.5×10^{-12} erg/cm^2/s (for the maximum galactic column in this direction of $N_{\rm H}=4.9\times10^{21}$ cm^{-2}).

The best-fit X-ray position of RX J1953.1+2115 was determined as RA = $19^{\rm h}53^{\rm m}05\overset{\rm s}{.}4$, Decl. = $+21^\circ14'31''$ (equinox J2000.0) with an error radius of $30''$. The Palomar Observatory Sky Survey prints revealed 17 objects within this X-ray error radius which were tested for variability on 250 archival plates of the Sonneberg 400 mm astrograph (limiting magnitude $\sim 18^{\rm m}$) and on 190 plates of the 170 mm triplet cameras (limiting magnitude $\sim 16\overset{\rm m}{.}5$). All these 17 objects proved to be constant (or always invisible on archival plates) within the error of photometry with the exception of one ($\approx 19^{\rm m}$) slightly blue object heavily blended by a $16^{\rm m}$ object only $6''$ to the East (see Fig. 1). Due to the clear variability exhibited by this object, it is assigned the number S 10943 in the series of variable stars detected at Sonneberg Observatory.

S 10943 shows outbursts up to $15^{\rm m}$ with a rather stable recurrence time of 83.6 days. Table 1 gives a comprehensive summary of all the outbursts found on the Sonneberg photographic plates. Shorter (less than 60 days) and longer (about 100 days) intervals are occasionally found, but are rare. Because of the sporadic distribution of observations and the blending already mentioned, the duration of the outbursts is difficult to estimate, but both short (< 10 days) and long (> 20 days) outbursts seem to occur. A plate from Sep. 28, 1967 shows the object at a probable rise to a superoutburst the evolution of which could be followed on 7 plates. On Oct. 28, i.e. 30 days later, the minimum brightness was not yet reached. A series of 24 exposures, taken between 1995 May 1 and May 4, cover the early decline (15^{m}) of a long duration outburst, which was not yet complete on May 21 (still about 1 mag above minimum light). During those 4 days periodic brightness fluctuations of small amplitude (0.2 mag) are superimposed on a steady brightness decrease of about 0.1 mag per day which may be interpreted as superhumps of an SU Ursae Majoris star. The period length was determined to be P=$0\overset{d}{.}1196 \sim 2\overset{h}{.}871$. Two alternative values are also possible, but with smaller probability: P=$0\overset{d}{.}136$ and P=$0\overset{d}{.}107$. With the superhump periods being as a rule about 2-3% longer than the orbital periods, we may expect an orbital period near $2\overset{h}{.}8$ which is just at the upper border of the well-known period-gap of cataclysmic variables.

Table 1. Observed eruptions (r = rise, m = maximum, d = decline)

J.D.	m_{pg}		J.D.	m_{pg}		J.D.	m_{pg}	
2427710.318	16.5	d ?	2438378.251	16.0:	d	2448888.395	15.9	
9102.537	16.5:	r	9003.400	16.2		9163.470	15.8	
9107.428	15.6:	d	9347.405	17.0:	d	9504.464	15.6	r ?
9541.313	16.1		9349.405	17.0:	d	9511.554	17.1:	d
9777.455	16.8		9762.358	16.6:	r	9839.521	14.9:	d
9843.411	16.5:		9765.310	16.0	d	9839.535	15.8:	d
2430442.616	15.0:	m	9765.381	15.9	d	9839.550	15.3	d
0614.354	15.0:	m	9767.297	16.0	d	9840.505	15.6	d
0848.512	16?		9789.261	17.7:	d	9840.523	15.4	d
1020.311	16?		9789.304	17.3	d	9840.542	15.3	d
1296.418	16.2	r	9792.287	17.3:	d	9840.560	15.4	d
1296.455	16.0	r	2441917.367	15.7	d	9840.577	15.3	d
1297.417	15.8	m	1917.430	15.8	d	9841.471	15.4	d
3160.431	15.6?		2369.235	16.0		9841.493	15.3	d
6073.424	16.4		4132.340	16.9		9841.508	15.4	d
6672.573	15.8		4132.359	16.8		9841.523	15.4	d
6815.373	16.8		6683.403	16.8	r ?	9841.537	15.4:	d
7193.355	16.6:		6699.339	15.6	d	9841.552	15.4	d
7576.444	16.6:		6707.392	16.7	d	9841.567	15.6	d
8268.386	18:	r	6708.390	16.4	d	9841.581	15.5	d
8282.326	17.9:	d	7365.493	16.3	d	9842.467	15.4:	d
8282.368	17.9:	d	7379.417	17.3:	d	9842.482	15.7	d
8283.327	17:	d	7381.428	17.1	d	9842.497	15.5	d
8283.369	17.8:	d	7411.376	15.9	m	9842.511	15.7	d
8284.364	18:	d	7717.466	17.1:		9842.526	15.7	d
8367.229	17:	r	7822.323	15.7	d	9842.540	15.7	d
8370.241	15.9:	d	7823.260	15.9	d	9842.555	15.7	d
8371.224	16.3	d	8096.448	16.8:	d	9842.569	15.4	d
8371.266	16.1:	d	8097.506	17.3:	d	9859.485	17.3	d
8372.257	16.1:	d	8804.472	17.0				

TU Mensae (P_{SH}=$0\overset{d}{.}1262$; Ritter & Kolb 1998) is the only other SU Ursae Majoris star with such a long period. The absolute magnitude of TU Men during minimum brightness is M_V=8.8 (Warner (1987). Assuming a similar absolute magnitude for S 10943 and using the apparent brightness during minimum of $m_V = m_B = 19\overset{m}{.}0$ we derive an apparent distance modulus of 10.2 mag. S 10943 is situated at the border between area 1 (R.A. = $19^{h}.6...19^{h}9$, Decl. = +15°...+25°) and area 3 (R.A. = >$19^{h}9$, Decl. = +15°...+24°) for which Richter (1968) estimated the mean value of interstellar dust extinction to be 2.0 mag and 1.4 mag, respectively. The corresponding distance is 440 pc and 600 pc, respectively. Alternatively, we can use the relation between orbital inclination and absolute magnitude for a comparison of the absolute magnitude of TU Men and S 10943. With i = 65° for TU Men, and assuming as an extreme (conservative) case i = 0° for S 10943 (the lack of eclipses on our plates suggests i $\lesssim$ 70°), the difference of the absolute magnitude is

$$\triangle M_{\rm V}(i) = -2.5 * \log(1 + 3/2 * \cos i) * \cos i$$

(see e.g. formula 4 in Warner 1987, or also Paczynski & Schwarzenberg-Czerny 1980). This results in a distance modulus of 11.0 mag, or 580 pc and 700 pc, respectively. We therefore conclude that the most likely distance of S 10943 will be in the range of 400–700 pc. At this distance the implied X-ray flux of 6.2×10^{30}–5×10^{31} (D/500 pc)^2 erg/s is well within the range of other SU UMa systems (van Teeseling *et al.* 1996).

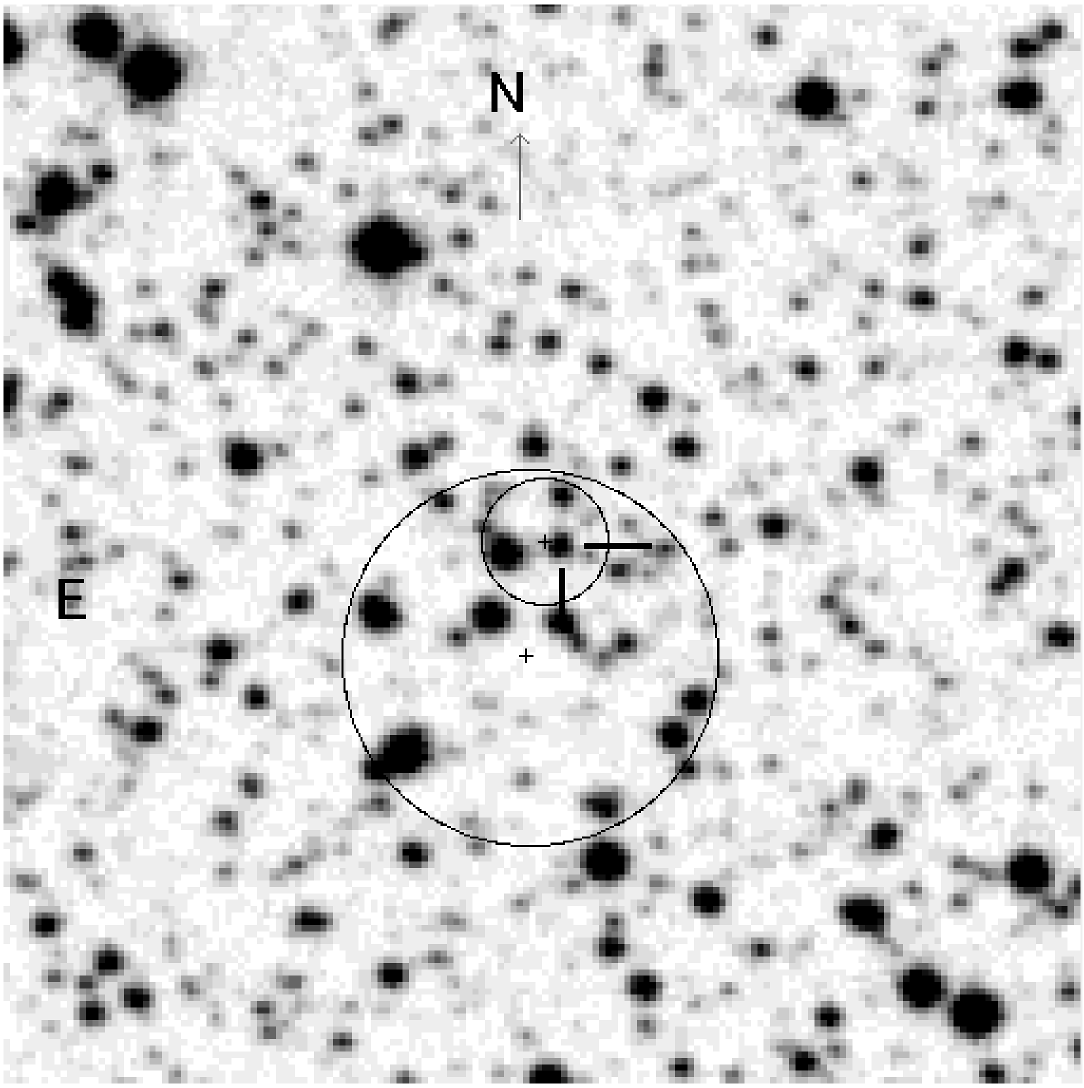

Figure 1. A 3′ by 3′ part of the digitized sky-survey image (based on the red passband plate SF04200 taken on 9 Sep 1991) with the X-ray error circles of the ROSAT all-sky survey position (large circle; 30″ radius) and the HRI pointed observation (small circle; 10″) overplotted. S 10943 Vul is marked by two heavy dashes.

The association of RX J1953.1+2115 with S 10943 Vul has been strengthened by the results of a recent ROSAT HRI observation. In the 6310 sec exposure on April 22–25, 1998 RX J1953.1+2115 was detected at a count rate of 0.0068±0.001 cts/s which is consistent with the count rate during the ROSAT all-sky survey in 1990 given the factor 3 lower sensitivity of the HRI as compared to the PSPC for X-ray sources with hard X-ray spectra. This detection allowed an improved determination of the X-ray position of RA $= 19^{\mathrm{h}}53^{\mathrm{m}}05\overset{\mathrm{s}}{.}2$, Decl. $= +21°14'50''$ (equinox J2000, $\pm 10''$). The coordinate of S 10943 Vul as measured on the Palomar blue print is RA $= 19^{\mathrm{h}}53^{\mathrm{m}}05\overset{\mathrm{s}}{.}0$, Decl. $= +21°14'49''$ (equinox J2000, $\pm 1''$), and thus is within $3''$ of the X-ray position. Fig. 1 shows the position of S 10943 Vul relative to the two X-ray positions.

Thus, if the orbital period should be confirmed, S 10943 would then be, together with TU Men, the SU Ursae Majoris star with the second largest superhump (and orbital) period known.

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