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 $0.024 \pm 0.006$ cts/sec. The hardness ratios $HR1 = (N_{52-201} - N_{11-41})/(N_{11-41} + N_{52-201}) = 1.00 \pm 0.30$ (where $N_{a-b}$ denotes the number of counts in ROSAT’s position sensitive proportional counter between channel a and channel b) and $HR2 = (N_{91-200} - N_{50-90})/N_{50-200} = -0.17 \pm 0.38$, 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 $2 \times 10^{-13}$ erg/cm$^2$/s (for an assumed absorbing column of $N_H=1 \times 10^{20}$ cm$^{-2}$) up to $1.5 \times 10^{-12}$ erg/cm$^2$/s (for the maximum galactic column in this direction of $N_H=4.9 \times 10^{21}$ cm$^{-2}$).

The best-fit X-ray position of RX J1953.1+2115 was determined as RA = 19$^h$53$^m$05$^s$.4, Decl. = +21$^\circ$14$^\prime$31$^\prime\prime$ (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 $\sim 18^m$) and on 190 plates of the 170 mm triplet cameras (limiting magnitude $\sim 16^m.5$). All these 17 objects proved to be constant (or always invisible on archival plates) within the error of photometry with the exception of one ($\approx 19^m$) slightly blue object heavily blended by a 16$^m$ 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$^m$ 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\textsuperscript{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 $P=0^d1196 \sim 2^h871$. Two alternative values are also possible, but with smaller probability: $P=0^d136$ and $P=0^d107$. With the superhump periods being as a rule about 2-3% longer than the orbital periods, we may expect an orbital period near $2^h8$ 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\textsubscript{pg} d | J.D. | m\textsubscript{pg} | J.D. | m\textsubscript{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 | 16.6: 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 | 9840.505 | 15.6 d |
| 0614.354 | 15.0: m | 9767.297 | 16.0 d | 9840.523 | 15.4 d |
| 0848.512 | 16? | 9789.261 | 17.7: d | 9840.542 | 15.3 d |
| 1020.311 | 16? | 9789.304 | 17.3 d | 9840.560 | 15.4 d |
| 1296.418 | 16.2 r | 9792.287 | 17.3: d | 9840.577 | 15.3 d |
| 1296.455 | 16.0 r | 2441917.367 | 15.7 d | 9841.471 | 15.4 d |
| 1297.417 | 15.8 m | 1917.430 | 15.8 d | 9841.493 | 15.3 d |
| 3160.431 | 15.6? | 2369.235 | 16.0 | 9841.508 | 15.4 d |
| 6073.424 | 16.4 | 4132.340 | 16.9 | 9841.523 | 15.4 d |
| 6672.573 | 15.8 | 4132.359 | 16.8 | 9841.542 | 15.3 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: d | 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 ($P_{SH}=0^d1262$; 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 $m_V = m_B = 19^m0$ we derive an apparent distance modulus of 10.2 mag. S 10943 is situated at the border between area 1 (R.A. = 19\textsuperscript{h}6...19\textsuperscript{h}9, Decl. = +15\textdegree...+25\textdegree) and area 3 (R.A. = >19\textsuperscript{h}9, Decl. = +15\textdegree...+24\textdegree) 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 S10943. With $i = 65^\circ$ for TU Men, and assuming as an extreme (conservative) case $i = 0^\circ$ for S10943 (the lack of eclipses on our plates suggests $i < 70^\circ$), the difference of the absolute magnitude is

$$\Delta M_V(i) = -2.5 \times \log(1 + 3/2 \times \cos i) \times \cos i$$

(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 S10943 will be in the range of 400–700 pc. At this distance the implied X-ray flux of $6.2 \times 10^{30} - 5 \times 10^{31} \text{ (D/500 pc)}^2 \text{ erg/s}$ 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. S10943 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 = 19h53m05s, Decl. = +21°14'50'' (equinox J2000, ±10''). The coordinate of S 10943 Vul as measured on the Palomar blue print is RA = 19h53m05s, Decl. = +21°14'49'' (equinox J2000, ±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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