Astron. Astrophys. 331, 612–618 (1998)

ASTRONOMY AND ASTROPHYSICS

The short-time variability of the supersoft X-ray source RX J0019.8+2156

E. Meyer-Hofmeister[1], **S. Schandl**[2], **B. Deufel**[3], **H. Barwig**[3], **and F. Meyer**[1]

[1] Max-Planck-Institut für Astrophysik, Karl Schwarzschildstr. 1, D-85740 Garching, Germany
[2] Institut für Astronomie und Astrophysik, Universität Tübingen, Waldhäuserstr. 64, D-72076 Tübingen, Germany
[3] Universitäts-Sternwarte München, Scheinerstr. 1, D-81679 München, Germany

Received 4 August 1997 / Accepted 10 November 1997

Abstract. Optical observations of the galactic supersoft X-ray source RX J0019.8+2156 reveal essential changes of the lightcurve from night to night. From October to December 1996 time resolved UBVRI photometry was performed with the high speed multichannel multicolour photometer MCCP at the 80 cm telescope of the Wendelstein Observatory of the Universitäts-Sternwarte München. To model these observations we compute lightcurves using a code which includes as sources of radiation the irradiated disk with an elevated outer rim and the irradiated secondary star in a consistent way. As found earlier the accretion disk rim is an important feature. We show in our investigation, that the variability of the optical flux can be understood as resulting from changes of the rim height, either from night to night or even within hours.

Key words: stars: individual: RX J0019.8, CAL 87 – accretion, accretion disks – binaries: close – binaries: eclipsing – X-rays: stars

1. Introduction

After the discovery of several luminous supersoft X-ray sources with ROSAT these binaries had been established as a new class of objects. The majority of the X-ray measurements were performed with the ROSAT position sensitive proportional counter (PSPC) with a spectral resolution of about 50% below 1keV. In a first catalogue of supersoft sources (SSS) by Greiner (1996) all known sources in our Galaxy, the Magellanic Clouds and M31 are listed. Most of the latter sources are optically not yet identified. Our knowledge on the nature of SSS mainly comes from optical observations of a few well studied systems as CAL83, CAL87, RX J0513.9-6952 and RX J0019.8+2156 (hereafter RX J0019.8). CAL87 provides basic information on the origin of the radiation from disk and secondary star since the source is eclipsing. The lightcurve of RX J0513.9 became available due to the monitoring capabilities of the MACHO project (Alcock et al. 1996). RX J0019.8 discovered by the ROSAT All-Sky-Survey (Beuermann et al. 1995), was the first galactic SSS. Due to the relatively high apparent brightness this system provides the rare opportunity to get observational data over longer time intervals, a series of consecutive nights. The results of such observing campaigns at the 80 cm telescope of the Wendelstein Observatory (Will & Barwig 1996 and follow-up observations) now prove that there are changes of the lightcurve shape from night to night. The aim of the present investigation is to understand the nature of this variability. Already earlier it has become clear (Schandl et al. 1996, 1997, Meyer-Hofmeister et al. 1997) that the rim of the accretion disk contributes a major part of optical light. We show how the observed variability can be attributed to changes of the rim.

The SSS as discussed here are characterized by a high bolometric luminosity, in contrast to other objects with radiation also dominantly below 0.5 keV but low bolometric luminosity. The luminous supersoft X-ray sources are binaries. For the best studied objects the orbital periods are known and give constraints on the geometry of these systems. It is now established, that in these close binaries matter accretes from a more massive secondary star onto a white dwarf via an accretion disk. The mass flow rate of order $10^{-7}M_\odot$/yr allows steady nuclear hydrogen burning at the white dwarf surface as suggested by van den Heuvel et al. (1992). For the high mass overflow rate the impact of the accretion stream at the disk causes an elevated outer disk rim, which acts like a screen for the radiation from the white dwarf. The disks in SSS are different from the well studied accretion disks in cataclysmic variables. The accretion luminosity is small compared to the nuclear burning luminosity of the white dwarf. The radiation from the very hot white dwarf is reprocessed in the irradiated disk to optical light, the high disk rim being an important geometrical feature for this process.

In the present paper we describe in Sect. 2 the observations for RX J0019.8. In Sect. 3 we show how the observed lightcurves can be modelled using a computer code, where the

Send offprint requests to: Emmi Meyer-Hofmeister

contributions from the white dwarf, the irradiated disk and secondary star to the optical light are determined consistently. In Sect. 4 we discuss variations on the timescale of a few hours, clearly found in the observations. We analyze these in connection with the theoretical modelling. We show, that we expect similar variations for the UV flux (Sect. 5). A comparison with other SSS is given in Sect. 6, conclusions in the last section.

2. Observations of RX J0019.8

2.1. Observations in different wavelengths

We shortly summarize here the data already available for RX J0019.8. A wealth of information is contained in the 100 year optical lightcurve deduced from photographic plates at Harvard and Sonneberg by Greiner & Wenzel (1995). First observations of the optical counterpart together with the ROSAT data after the discovery of the X-ray source were presented by Reinsch et al. (1993) and Beuermann et al. (1995). Optical photometry was carried out over three years at the Wendelstein observatory by Will & Barwig (1996). The follow-up observations in 1997 by Deufel & Barwig (1997 in prep.) the basic data for our analysis of lightcurve changes and of short-time variations. Additional information came from BVRI photometric lightcurves observed between July and December 1995 at the Osaka Kyoiku University by Matsumoto (1996). UV observations were carried out by Beuermann et al. (1995) and Gänsicke et al. (1996). Further ROSAT observations are presented in Reinsch et al. (1996).

2.2. The recent observations at the Wendelstein Observatory

High-speed photometric observations of RX J0019.8 using the multichannel multicolour photometer MCCP at the 80 cm telescope of the Wendelstein Observatory were made during 15 nights on 1996 October 11, 12, 13, 18, 22, 23, November 2, 3, 4, 9 and December 10, 11, 12, 15, 16. These observations are a continuation of previous observational runs between September 1992 and October 1995 (Will & Barwig 1996). During the 1996 run we were able to add another 88.4 hours of observation time for RX J0019.8. By using the MCCP we can observe the object, a nearby comparison star and the sky background simultaneously in UBVRI. This allows us to eliminate atmospheric transparancy variations with high accuracy using the so-called standard reduction method (Barwig et al. 1987). As comparison star we used the star at $RA = 0^h19^m31\overset{s}{.}2$, DEC = +21°53′58.″9 (for epoch 2000). The intensities of the lightcurves presented in Figs. 1 and 4 are therefore relative to this star.

The observations were only interrupted for calibration measurements in order to normalize the channels of the object, of the comparison star and of the sky. These calibration measurements are performed during photometric sky conditions lasting for up to 10 minutes once or twice a night. The constancy of the calibration coefficients is indicative of the high stability of the detectors. Within an integration time of 2 sec we received about 6000 counts from RX J0019.8 (at maximum), about 8000 counts from the comparison star and 250 counts from a dark sky in B. The error in the relative count rate is ± 0.012. Errors caused by the calibration coefficients were neglected due to their high constancy. For the modelling procedure only B-lightcurves were considered since the very blue continuum of RX J0019.8 in combination with the quantum efficiency of the detectors and the colour temperature of the comparison star provide the best signal to noise value in B. Data binning was made by dividing one complete cycle in 100 equidistant phase intervals. For each interval $(\phi - \frac{1}{200}, \phi + \frac{1}{200})$ the average of all observed flux values was determined.

All lightcurves show a high variability, even from one night to another. Similar to the previous observations between 1992 to 1995 the depth and form of the main minima varies and also the timings of the minima are not equidistant. Another characteristic feature of the lightcurves, already observed in 1995, are humps which appear quasiperiodically on a timescale of about two hours. These flux changes may also appear as the step-like features during ingress and egress of the main minimum (Deufel & Barwig 1997 in prep). We also observe lightcurves with comparable shape but shifted vertically, i.e. the brightness level can change without influencing the shape of the lightcurve (see discussion in Sect. 4.1). Similar features have been observed by Matsumoto (1996).

3. Modelling the optical lightcurve of RX J0019.8

3.1. The general appearance of the lightcurves of SSS

The changes of luminosity during one orbital period of the binary allows us disentangle the flux from different regions of the accretion disk and the companion star. The best observed system is CAL 87, seen under high inclination. The eclipse of the bright disk by the secondary star (when we look towards its non-illuminated side) produces a deep minimum in the lightcurve. The eclipse of the companion star by the disk produces a shallow minimum half an orbital phase later (for recent optical observations see Cowley et al. (1990) and Schmidtke et al. (1993)). The two maxima of similar height come about when we look towards disk and secondary star, both uneclipsed. The observer's view onto RX J0019.8 for the appropriate geometry and inclination is displayed in a former investigation (Fig. 5 of Meyer-Hofmeister et al. 1997). The shape of the elevated rim as discussed in the later Sect. 3.5 leads to the observation of different amounts of flux from the rim at different orbital phases. In this respect it is interesting, that UV spectra of CAL 87 obtained with the Faint Object Spectrograph of the HST show lower UV radiation in the pre-eclipse phase (see Fig. 3 in Hutchings et al. 1995) when we see the outside of the high rim, than after the eclipse. This supports the assumption, that the outside of the disk rim is less hot than the inside.

3.2. Luminosity changes of RX J0019.8 over decades

A high disk rim seems to be present in all SSS (Meyer-Hofmeister et al. 1997), probably due to the high mass overflow rate from the secondary. The overflow rate might change over long timescales, decades, and also on timescales as short

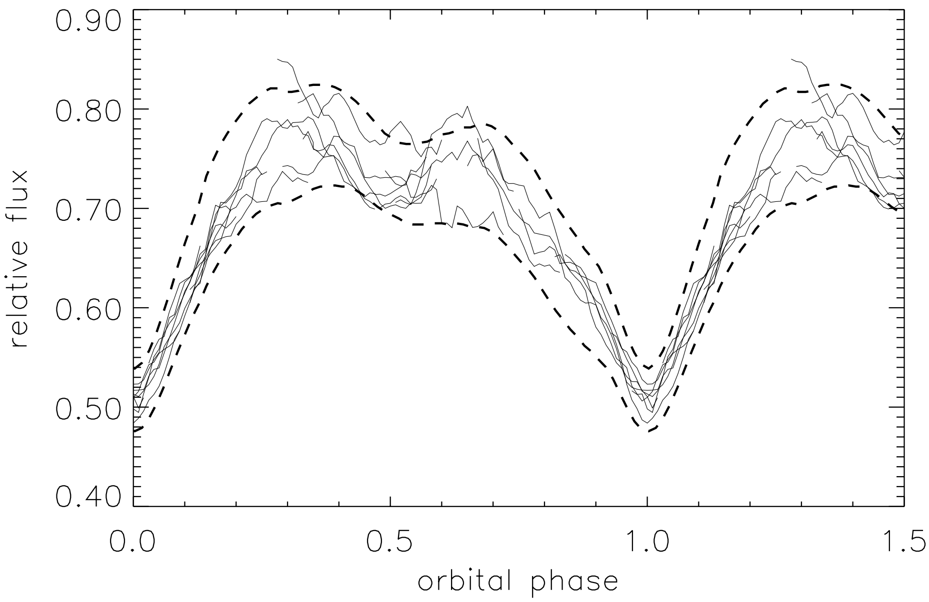

Fig. 1. Observed lightcurves of RX J0019.8, superposed according to orbital phase (solid lines) together with 2 theoretical "standard" lightcurves (hatched lines), which are computed for the same parameters, except the disk rim height. Rim profile taken for the modelling shown in Fig. 2.

Table 1. The System Parameters of RX J0019.8

orbital period[1]	$P = 15.85$ hr
distance	$d = 2.38$ kpc
inclination	$i = 55°$
luminosity of WD[1]	$L = 0.4\ 10^{37}$ erg/sec
efficiency of radiation reprocessing	$\eta = 0.5$
mass of white dwarf	$M_1 = 0.75\ M_\odot$
mass of secondary star	$M_2 = 1.5\ M_\odot$
mass accretion rate	$\dot{M} = 0.8\ 10^{-7}\ M_\odot$/yr
temperature of non-irr. sec. star	$T_\star = 7000$ K
temperature of spray	$T_{sp} = 18000$ K

Reference: 1 Beuermann et al. (1995)

as weeks or days or even shorter. Alternation between phases of nuclear burning and cooling on timescales of decades is possible (Kahabka 1995). Meyer & Meyer-Hofmeister (1996) interpreted phases of lower luminosity during the 100 year optical observations (Greiner & Wenzel 1995) as resulting from a systematically lower mass overflow rate when the white dwarf cools and the secondary is less irradiated (Meyer & Meyer-Hofmeister 1996).

3.3. The night-to-night luminosity changes in the lightcurve of RX J0019.8

The new result from the recent observations is the variablity on a timescale of one to two hours. The many observations obtained at the Wendelstein Observatory, show quite a variety of the lightcurve shape. The basic features are the deep and the shallow minimum and the two maxima. Luminosity fluctuations sometimes make it difficult to recognize the second maximum. Brightness changes were also found by Matsumoto (1996) who carried out BVRI photometry at the Osaka Kyoiku University. The lightcurves from 1995 October 3 and 12 (in his Fig. 2) show a vertical shift from one lightcurve to the other in the magnitude-phase diagram. These observations were taken about every hour. Therefore short time variations would be smeared out. Matsumoto points out that the "irregular variations in brightness show no apparent change in color". This is in agreement with the theoretical picture that the brightness variations are caused by a change of the rim height. Such a rim is expected to have about the same lower temperature everywhere at the outside, and a higher temperature due to irradiation at the inside. This is what one would imagine if it consists of rising and falling blobs created by the stream impact at the disk rim. Then mostly the size of the area varies and the spectral distribution is unchanged.

3.4. Theoretical "standard" lightcurves of RX J0019.8

In Fig. 1 we show all observations described in Sect. 2 together, ordered according to the phase. The lightcurves, each of these observed during one night were overlayed to show the extent of variation in flux. To make plausible, that all variation is produced by only a different rim height we show together with these observations two theoretical lightcurves. They correspond to the same system parameters, except the rim height where z/r is changed from 0.38 to 0.45, the radial extent by the same relative amount (see Fig. 2, solid lines). We will use these two "standard" lightcurves during the following analysis. They were computed with a code developed for CAL 87 by Schandl et al. (1996, 1997). For a first modelling of the lightcurve of RX J0019.8 see Meyer-Hofmeister et al. (1997).

The sources of radiation are the irradiated disk with an elevated rim and the irradiated secondary star. The parameters used are given in Table 1. The geometry of the binary system is determined from the orbital period assuming that the secondary fills its Roche Lobe and that the mass ratio of the stars is 1:2 as found to be probable from the investigations of accreting white dwarfs by van den Heuvel et al. (1992). The temperature of the non-irradiated secondary is that of a main-sequence star.

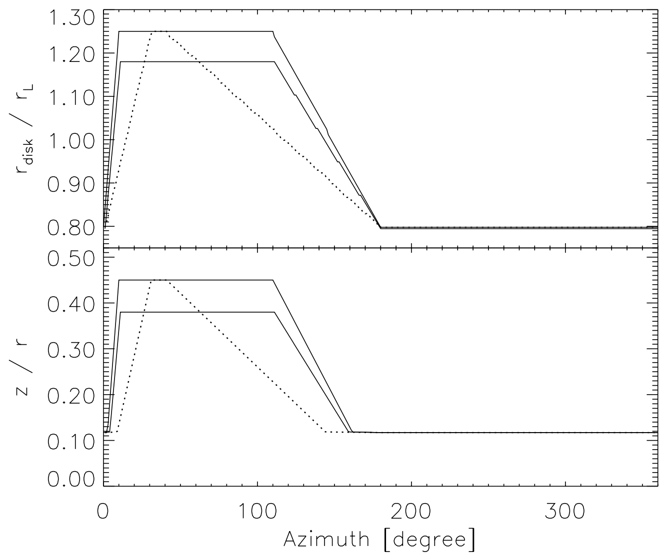

Fig. 2. Shape of the disk rim. Solid lines rim profile taken for the 2 "standard" lightcurves in Figs. 1 and 3. Dotted line example for special rim profile (see text). Azimuth 0° corresponds to the point of stream impact onto the accretion disk rim at r/r_L=0.8 (r_L is the mean Roche lobe radius, radius of a sphere with the same volume as the Roche lobe). In radial direction we simulate the spray region with linearly increasing z/r from the original disk at r/r_L=0.8 towards the outer rim.

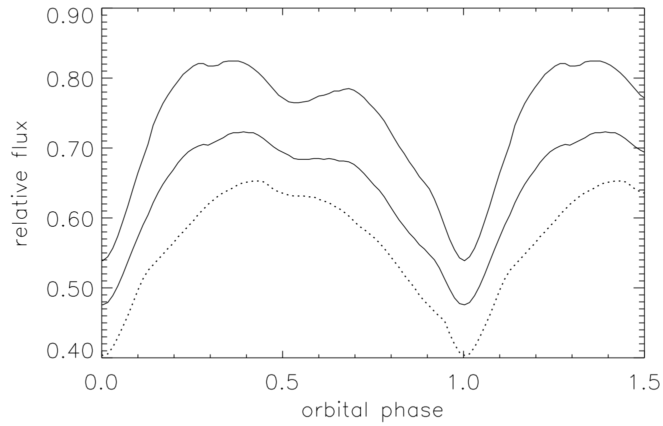

Fig. 3. For comparison "standard" lightcurves (solid lines) as in Fig. 1 together with a lightcurve (dotted line) resulting from the special rim profile in Fig. 2 (dotted line).

The inclination is found from the comparison of the observed and the computed lightcurve. Because of the asymmetry of the disk due to the extended spray region the primary minimum occurs at 0.025 in orbital phase after the upper conjunction of the white dwarf in the simulation. To compare with the observed lightcurve where the phase zero is attributed to the minimum we shifted the calculated lightcurve by 0.025 in all figures. For the distance we assumed 2.38 kpc corresponding to absorption from an interstellar column density $N_H = 4.8\ 10^{20}$ atoms cm^{-2}, a value within the limits discussed in Gänsicke et al. (1996). For our modelling differences in distance only mean, that for a chosen white dwarf luminosity the apparent magnitude of the system is different. The shape of the lightcurve differs very little. For the values given in Table 1 the theoretically derived luminosity agrees with the observations of Matsumoto (1996).

3.5. The shape of the accretion disk rim

A special feature within this lightcurve modelling is the elevated disk rim. We imagine, that underneath the impact area in the outer accretion disk a dense layer arises in which shocked impact and disk gas stream along each other with a high shear. The distribution of the mean height to which an ensemble of blobs rises will always be about the same, independent of the mass overflow rate. The mass overflow rate will determine the density of such a spray and thereby the height at which the spray becomes optically thin, i.e. the effective height of the rim. This is discussed in Meyer-Hofmeister et al. (1997) and shown in their Fig. 10. In addition to the height of the rim and its extension in radial distance the azimuthal extent has to be specified. Its location relative to the impact point is taken according to computed particle trajectories (Schandl et al. 1997). In our present investigation we show for each lightcurve what geometrical shape of the disk rim was taken. Although the information about the rim shape is contained in the observations it is not possible, even for the eclipsing source CAL 87 to derive the exact rim shape from the comparison of observed and computed lightcurve.

For RX J0019.8 we have less information. The observer sees the total rim over a major part of the orbital cycle. This means, that the detailed geometrical shape is not important, the size of the irradiated area is what counts. We give an example to illustrate this. We show in Fig. 3 the two "standard" lightcurves from Fig. 1 together with a lightcurve which results from an arbitrarily chosen rim profile (dotted line in Fig. 2). The shape of the lightcurve is almost not affected. The smaller rim area results in a lower flux. In the following analysis we argue, that two lightcurves, one above the other with almost constant brightness difference in the luminosity-phase diagram mainly result from a change of the rim height from night to night. We also expect cases, where the rim height changes during one night. We discuss these phenomena in the next section.

4. The variability on timescales of hours

Due to the orbital period of 15.85 hours only at most 0.6 of an orbital cycle can be observed during one night. The shape of the observed lightcurves varies in quite different ways. We recognize (1) a shift in luminosity, so that the two luminosity curves are about parallel, one above the other in the phase diagram (compare Fig. 5), sometimes with a transition from one niveau to the other, (2) lightcurves not smooth, but showing a series of bumps (see Fig. 4 panel 1), (3) steep ingress and egress around the primary minimum, not smooth, but with step-like horizontal parts (see Fig. 4 panel 3).

From our computations (see Figs. 1 and 2) we deduce, that a flux difference of 15%, or a change of magnitude Δm=0.15,

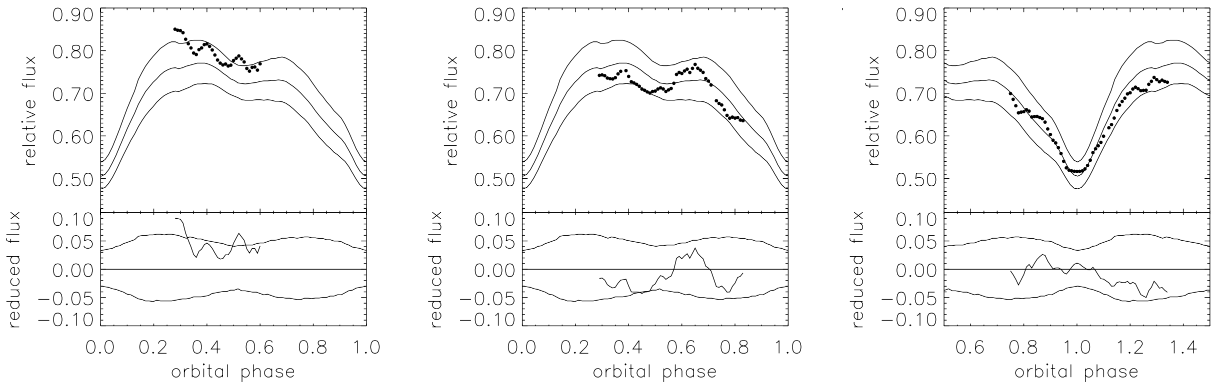

Fig. 4. Flux variations observed October 13, November 4 and 3. Observations shown as dots for the flux within phase intervals $\Delta\phi$=0.01 (compare Sect. 2.2). In each panel in the upper part the 2 "standard" lightcurves and a middle curve corresponding to the profile in the middle of the taken profiles (Fig. 2). In the lower part theoretical and observed fluxes relative to the middle curve.

corresponds to a rim height change of about 18%. Variations of the rim shape are recognizable best when the observer sees the rim best, either the outside or the irradiated inside. Short-time rim changes might lead to an appearance of 10the lightcurve quite different from the "standard" lightcurve, e.g. the curve in Fig. 4, second panel, shows a deep secondary minimum. Even the shape of the primary minimum can be affected, which makes it more difficult to search for the ephemerides.

The fact, that the flux obviously already changes during one night allows us to derive timescales for the rim height changes. For the examples in Fig. 4 we give as reduced flux the flux related to the theoretical middle flux. To measure the size of a chosen monotonic increase or decrease of the reduced flux we normalize to ΔF, which is the difference of reduced flux between upper and lower "standard" lightcurve at that orbital phase. We find 9 times during our observations a flux change ΔF of 0.5 to 0.8 (increase or decrease). This happened within phase intervals $\Delta\phi$ of 0.06 to 0.12.

We define the "Kepler time" $t_K = \sqrt{r^3/GM_1}$. A blob starting at the midplane and oscillating freely around a circular orbit needs $\frac{\pi}{2} t_K$ to reach maximum elevation and/or elongation. This is the timescale on which the shape of the spray or bulge can respond to changes on the impact stream and a lower limit of the timescale on which the bulge shape can significantly vary. For our 0.75 $M_\odot$ white dwarf and a disk radius of r = 0.8 r_L = $10^{10.9}$cm this yields 0.9 hours. We note that the mean distance of the bulge from the white dwarf appears even larger by a factor of about 1.25 (see Fig. 2) somewhat increasing the estimate of the spray timescale (to 1.2 hours). Then one big blob could produce an increase and decrease of luminosity as e.g. observed on 1996 October 13 (see Fig. 4, first panel). If this happens during the phase of ingress or egress we recognize a step-like feature (compare Fig. 4, last panel).

In Fig. 5 we show observations of Matsumoto (1996) from 4 nights in October 1995 together with our "standard" lightcurves. The flux variation was even higher than during the Wendelstein observations. From our modelling we would estimate a rim height up to z/r $\approx$ 0.47 on October 3.

5. UV radiation and X-rays

We shortly discuss here the observations at other wavelengths available for RX J0019.8 in the context of our modelling. The UV radiation originates from the inner irradiated disk between central star and rim and from the high rim (outside temperature in our simulation 18000K, hotter irradiated inner side), an additional smaller amount of flux comes from the heated companion star. An example for a temperature distribution of the irradiated disk and the companion star is shown in Figs. 2 and 3 of Meyer-Hofmeister et al. (1997).

Gänsicke et al. (1996) show UV observations from July 1992 and January and August 1993 (far and near UV, 1250 and 2975Å) ordered according to the orbital phase in Fig. 2 of their work. Only the data from the nights in August 1993 cover the full orbital cycle. The lightcurves from the different observations show parallel shifts as can be recognized in our, and also in Matsumoto's optical lightcurves (Fig. 5). In the context of our investigation we want to find out how rim height changes influence the UV lightcurve.

In a first computation, using the same code as for our optical results and the same parameter values, we determined, corresponding to the two "standard" optical lightcurves, the "standard" UV lightcurves. We determined the radiation at far (1225-1275Å) and near (2950-3000Å) UV. For each wavelength interval we found, that the two "standard" lightcurves are nearly parallel as the optical curves (Fig. 1). A difference in the rim height as assumed for the two "standard" lightcurves causes a flux change of about 15% at near and at far UV. We conclude, that the observed flux variations of up to 25% (see Fig. 2 of Gänsicke et al. (1996)), indicate that the rim height had changed up to 30% from one observational run to another, which might well have happened between July 1992 and August 1993. The computed fluxes agreed within 10 to 25% with the observations. More detailed UV data would be needed to constrain the temperature distribution of the UV emitting areas, especially the disk rim. From our preliminary computations we can see, that the main contribution to the UV radiation comes from the disk. The

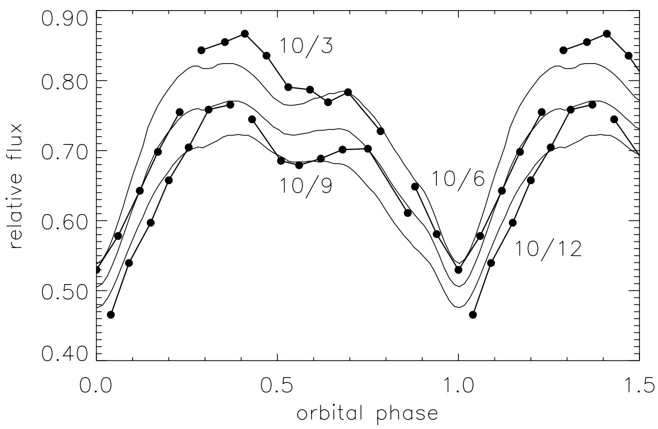

Fig. 5. Observations of Matsumoto (1996, Fig. 2) here given in relative fluxes during 4 nights October 3 to 12, 1995 together with the 2 "standard" lightcurves + middle line as in Fig. 4.

white dwarf contributes only about 20% at far UV, below 10% at near UV. The contribution of the secondary star is negligible at far UV, at near UV highest at phase 0.5, about 20%.

For X-rays the accretion disk rim is less important. The major part of the X-rays comes from the white dwarf directly, the smaller part is radiation scattered by the disk. This latter part we expect to vary coherently with the optical light. X-ray observations at 5 dates between 1990 to 1995 (Reinsch et al. 1996) show a variation of $\approx 35\%$. One would not expect such variation in radiation from the steadily burning white dwarf.

6. Comparison with other sources

If we argue that a high accretion disk rim is present in all SSS (Meyer-Hofmeister et al. 1997) we should examine whether the short-time variability can also be found in the other sources. The composite V lightcurve of CAL 87 as presented in Fig. 1 of Schmidtke et al. (1993) has a scatter up to 0.3 in magnitude. In our investigation of CAL 87 we connected the data points of each observing run (Schandl et al. 1997, see Fig. 1), kindly provided for our analysis by P. Schmidtke, and found, that these individual lightcurves, then extending over only a certain phase interval, show much less scatter. This is what we also found for RX J0019.8, and what our modelling suggests is a result of rim height changes. For CAL 87 the lightcurve obtained as by-product of the MACHO project also shows indications of a variable irradiated disk bulge structure (Alcock et al. 1997).

Changes of the disk rim height might, for high inclinations, have direct consequences on observable X-rays. Kahabka (1996) discussed the orbital modulation of X-rays in RX J0019.8 and found an orbital modulation about in phase with the optical modulation. Depending on the mass ratio, it might be possible, that an occultation of the white dwarf by the high rim occurs before the occultation by the secondary star (compare Fig. 5 in Meyer- Hofmeister et al. 1997). In this context it is interesting to mention, that for the supersoft X-ray source 1E 0035.4-7230 the X-ray minimum occurs at about phase 0.8. At this phase, the disk bulge is in conjunction with the white dwarf, as pointed out by Schmidtke et al. (1993).

7. Conclusions

The Wendelstein observations for RX J0019.8 provide new information on supersoft X-ray sources. These observations show clearly, that the lightcurve varies from night to night. The observed lightcurves show besides the common features quite a variety of additional bumps, steps and changes in the luminosity level. We determined theoretical lightcurves as described in Sect. 3. From earlier investigations it was already clear, that the elevated accretion disk rim is an essential source of radiation and a necessary feature to get agreement between theory and observations.

The new observations for RX J0019.8 reveal a high short-time variability. From our lightcurve modelling we conclude, that the disk rim is the origin of this variability. We find, that an increase of the rim height produces a higher luminosity in the lightcurve and vice versa. What we see as a bright rim is the optically thick part of an area of rising and falling blobs or a spray, created by the stream impact at the disk rim. The dynamical rise time of such blobs lies between one and two hours. This agrees remarkably well with the timescale of observed flux variations like the bumps in the lightcurve shown in Fig. 4. Those lightcurves could not be modelled theoretically assuming a rim profile constant in time. The discussed rim height changes simultaneously produce variations of the UV flux. The radiation of X-rays is less influenced, only the amount of light scattered by the disk rim might then vary.

In an earlier investigation we had shown, that the rim height is related to the mass overflow rate (Meyer-Hofmeister et al. 1997). Systematic changes of the mass overflow rate during decades produce a systematic brightness changes. Fluctuations of the mass overflow rate, on all timescales, produce corresponding fluctuations in the lightcurve. The turbulent nature of blob appearance will lead to brightness variations within hours or shorter, the shortest variability being produced by the motion of several blobs, overlapping for the observer.

Acknowledgements. We thank Tobias Will, for providing his observational data immediately after the reduction. They initiated the lightcurve modelling investigations for RX J0019.8. We thank Hans-Christoph Thomas for helpful discussions.

References

Alcock C., Allsman R.A., Alves D. et al., 1996, MNRAS, 280, L49
Alcock C., Allsman R.A., Alves D. et al., 1997, MNRAS, 287, 699
Barwig H., Schoembs R., Buckenmayer C., 1987, A&A 175, 327
Beuermann K., Reinsch K., Barwig H. et al., 1995, A&A 294, L1
Cowley A.P., Schmidtke P.C., Crampton D., Hutchings J.B., 1990, ApJ 350, 288
Gänsicke B.T., Beuermann K., de Martino D., 1996, Workshop on Supersoft X-ray Sources, Garching, 1996, ed. J. Greiner, Lecture Notes in Physics No. 472, Springer Verlag, p. 107

Greiner J., 1996, Workshop on Supersoft X-ray Sources, Garching, 1996, ed. J. Greiner, Lecture Notes in Physics No. 472, Springer Verlag

Greiner J., Wenzel W., 1995, A&A 294, L5

Hutchings J.B., Cowley A.P., Schmidtke P.C., Crampton D., 1995, AJ 110, 2394

Kahabka P., 1995, A&A 304, 227

Kahabka P., 1996, A&A 306, 795

Matsumoto K., 1996, PASJ, 48, 827

Meyer F., Meyer-Hofmeister E., 1996, Workshop on Supersoft X-ray Sources, Garching, 1996, ed. J. Greiner, Lecture Notes in Physics No. 472, Springer Verlag, p. 153

Meyer-Hofmeister E., Schandl S., Meyer F., 1997, A&A 321, 245

Reinsch K., Beuermann K., Thomas H.-C., 1993, Astron. Ges. Abstr. Ser. 9, 41

Reinsch K., van Teeseling A., Beuermann K., Thomas H.C., 1996, Röntgenstrahlung from the Universe, Internat. Conference on X-ray Astronomy, eds. U. Zimmermann et al., MPE report 263, p. 183

Schandl S., Meyer-Hofmeister E., Meyer F., 1996, Workshop on Supersoft X-ray Sources, Garching, ed. J. Greiner, Lecture Notes in Physics No. 472, Springer Verlag, p. 53

Schandl S., Meyer-Hofmeister E., Meyer F., 1997, A&A 318, 73

Schmidtke P.C., McGrath T.K., Cowley A.P., Frattare L.M., 1993, PASP 105, 863

van den Heuvel E.P.J., Bhattacharya D., Nomoto K., Rappaport S.A., 1992, A&A 262, 97

Will T., Barwig H., 1996, Workshop on Supersoft X-ray Sources, Garching, ed. J. Greiner, Lecture Notes in Physics No. 472, Springer Verlag, p. 99

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.