A&A 418, 617–624 (2004)
DOI: 10.1051/0004-6361:20040037

Astronomy & Astrophysics

The properties of outbursts and long-term activity of the soft X-ray transient 4U 1608–52 (QX Nor)*,**

V. Šimon

Astronomical Institute, Academy of Sciences of the Czech Republic, 251 65 Ondřejov, Czech Republic

Received 18 April 2003 / Accepted 26 November 2003

Abstract. An analysis of the long-term activity of 4U 1608–52, based on the *ASM/RXTE* data, is presented. Although the individual outbursts in 4U 1608–52 differ in both their duration and peak intensity, their rising and final decay branches display remarkable similarities. The variations of the soft X-ray color between 1.5–4 keV are found to follow the luminosity during the decay of outburst much better than the variations between 4–12 keV. The recurrence time T_C of outbursts was analyzed by the method of the O−C residuals. The mean value of T_C is 330 days between the years 1996–2003 but a strong long-term trend of a decreasing T_C can be resolved. A series of four or five consecutive outbursts displays a clear correlation between the decreasing T_C and increasing peak intensity, but no correlation with the outburst duration. The observed behaviour is discussed in terms of the thermal instability model. We argue that the disk viscosity achieves similar values for the individual outbursts in 4U 1608–52. Only during the brightest outbursts does the luminosity appear to be high enough for the disk to be ionized out to its outer rim by the X-rays from the neutron star, according to the model by King & Ritter (1998). We also argue that the disk is never considerably depleted in outburst. A comparison with the similar system, Aql X-1, helps us to find the common links between the disk behaviour in the individual neutron-star soft X-ray transients.

Key words. stars: neutron – stars: binaries: close – stars: binaries: general – stars: circumstellar matter – stars: individual: 4U 1608–52, QX Nor

1. Introduction

4U 1608–52 is a soft X-ray transient (SXT). The long-term activity of these objects is dominated by isolated X-ray outbursts which are accompanied by brightenings also in the UV and optical regions. The duration of outbursts of the SXTs (weeks to months) is much shorter than the interval of quiescence (e.g. Chen et al. 1997). The outbursts of the SXTs are suggested to be due to the thermal instability in the accretion disk, similar to that in dwarf novae. The conditions in the disk of the SXT are affected by the presence of the neutron star (NS) or a very hot inner disk region in the case of a black hole (BH). These objects act as irradiating sources during outburst and modify the disk structure (e.g. van Paradijs 1996; Dubus et al. 2001; King & Ritter 1998 – hereafter KR98). In quiescence, the central region of the disk in the SXT is thought to be truncated and replaced by an extremely hot, optically thin advection-dominated accretion flow (ADAF) (e.g. Narayan 1997). The ADAF region is surrounded by a disk on the cold branch of the S-curve.

4U 1608–52 is a SXT that contains a NS. The nature of the compact object was proven by the detection of X-ray bursts (Tananbaum et al. 1976).

The X-ray spectrum of 4U 1608–52 was interpreted in terms of superimposed thermal (soft) and non-thermal (hard) components by Gierlinski & Done (2002). They revealed that the mass transfer rate plays a crucial role in its evolution. In quiescence, the soft emission comes from the surface of the NS (because the inner disk is optically thin) and part of it is Comptonized into a hard component. When the outburst sets in, the geometry of the accretion flow largely changes – the inner disk radius decreases and its optical depth for the inverse Compton process increases. The thermal radiation of the disk now gives rise to the soft component. Even during the outburst, the seed photons for the Comptonized component appear to be produced by the NS surface, not by the disk.

The optical counterpart of 4U 1608–52 is QX Nor (Grindlay & Liller 1978). The long-term monitoring by Wachter et al. (2002) revealed not only large optical and infrared brightenings during the X-ray outbursts but, in addition, extended intervals during which QX Nor remains above the level of the true quiescence in both the X-ray and infrared passbands.

Send offprint requests to: V. Šimon, e-mail: simon@asu.cas.cz

* This research has made use of the observations provided by the *ASM/RXTE* team.

** Table 1 and Figs. 2–4 are only available in electronic form at http://www.edpsciences.org

The evolution of the long-term activity of 4U 1608–52, and particularly the length and changes of the recurrence time of outbursts, T_C, are uncertain. Lochner & Roussel-Dupré (1994) analyzed the *VELA 5B* observations, obtained between 1969–1979, and found T_C highly variable from about 80 days to several hundreds of days. Nevertheless, the trends of the long-term evolution of T_C could not be determined with certainty.

In this paper we analyze T_C in 4U 1608–52 by the method of the O−C residuals and show a complicated relation between the evolution of T_C and the peak intensity of the outbursts. The very densely covered *ASM/RXTE* light curve with a high S/N ratio is very suitable for this analysis and shows fine features necessary for this understanding of the long-term processes in 4U 1608–52. We will also analyze the morphology of the X-ray outbursts and investigate the properties of the variations of X-ray color with luminosity.

2. Source of the data

The recent outbursts of 4U 1608–52 within 1996–2003 were observed by the All Sky Monitor (*ASM*) onboard the *Rossi X-ray Timing Explorer* (*XTE*) (`http://xte.mit.edu/`). This monitor provides long-term observations of an unprecedented quality for this object. The data file contains the sum band intensities $I_{\rm sum}$ (1.5–12 keV) and the hardness ratios *HR1* = $I_{\rm B}(3-5\ {\rm keV})/I_{\rm A}(1.5-3\ {\rm keV})$, *HR2* = $I_{\rm C}(5-12\ {\rm keV})/I_{\rm B}(3-5\ {\rm keV})$. Since our analysis concentrates on time scales of days and longer we used the one-day means and errors provided by the *ASM/RXTE*.

The truncation limit for *HR1* and *HR2* was determined by plotting the quoted uncertainties $\sigma_{\rm q}$ of both hardness ratios versus $I_{\rm sum}$ and examining their dependence on it. It was decided to use only the *HR* with $\sigma_{\rm q} \leq 0.3$.

3. Data analysis

3.1. General description

The whole sum band *ASM/RXTE* X-ray light curve is shown in Fig. 1a. The outbursts that reached $I_{\rm sum} > 15$ ct/s at maximum, hereafter called *bright outbursts*, are shown in detail in Figs. 2–4 (only in electronic form). The moments of the outburst maximum were determined by fitting a polynomial to the upper part of the outburst light curve, with a typical error of 1–2 days. Even in the case of an incompletely covered curve this moment can be constrained to within about 20 days, that is much less than T_C.

Two intervals of so-called *low active states* (hereafter LAS), first revealed by Wachter et al. (2002), are marked in Fig. 1a. The LAS are extended intervals during which $I_{\rm sum}$ is at about 5 ct/s, well above the level of the true quiescence (Wachter et al. 2002).

Several intervals of enhanced scatter, caused by the conjunctions of 4U 1608–52 with the Sun, can be seen in Fig. 1a. This scatter can cause confusion and possibly obscure some minor outbursts because the peak intensities of the individual outbursts in 4U 1608–52 differ by a large amount.

The *HR1* and *HR2* curves in Figs. 1b,c are dominated by the scatter in the LAS. It will be shown in Sect. 3.4 that *HR1* varies in a rather uniform way during outburst while a large scatter of *HR2* without any clearly defined profile of variation persists even during outbursts.

3.2. Morphology of the outburst light curves

A study of the morphology of the outbursts can best be made by matching the events to a representative outburst, taken as a template. The procedure used for an analysis of these transient events is similar to the method applied to the outbursts of dwarf novae (e.g. Šimon 2000) and the SXT Aql X-1 (Šimon 2002a).

3.2.1. The decay branches of outbursts

The profiles of the decay branches were found to be broken in the case of the long events, with the initial part having a less steep slope (Figs. 2c and 4). The outburst in Fig. 2a very probably possessed this break, too, because the linear extrapolations of its rising and decaying branch intersect at an unrealistically high peak intensity, $I_{\rm max}$. However, the slopes and profiles of the final branches show similarities for the events with a different $I_{\rm max}$ and duration, $D_{\rm out}$. The starting points of these branches are marked in Figs. 2–4.

The outburst having its maximum at JD 2 450 851 (Fig. 2c) was chosen as the template because it displayed a relatively smooth and well-covered final decay branch. The remaining outbursts were shifted along the time axis to match the decay branch of the template. $I_{\rm sum}$ = 13 ct/s was chosen as the reference level, in the vicinity of which the match of the *final phase* of the decays was attempted. The result is shown in Fig. 5. The decay branches of the individual outbursts were then merged into a common file and smoothed by the code HEC13, written by Dr. P. Harmanec and based on the method of Vondrák (1969, 1977). This code can fit a smooth curve to the data no matter what their profile. It calculates a fitted point to each observed data point. It makes use of two input parameters, ϵ and ΔT. ϵ determines how "tight" the fit will be, that is if just the main profile or also the high-frequency variations are to be reproduced. ΔT is the interval over which the data are binned before smoothing. We preferred to use this method because it does not make any presumptions about the course of the fitted data. The X-ray curves of the SXTs are often complicated (e.g. Chen et al. 1997) and a considerable part of information could be lost by fitting a particular function. We will examine in which intervals the fit can be close to a curve predicted by the models (King 1998, KR98). The fit with $\epsilon = 10^{-1}$, ΔT = 5 days was found to satisfy the curve of the decay with a standard deviation of 2.1 ct/s. The smoothed decay light curve is plotted as the thick solid line in Fig. 5. It can be seen that a large part of the decay is almost linear. The time for $I_{\rm sum}$ to fall by a factor of 2 was determined to be $t_{1/2}$ = 9.8 days. A curvature of the fit, apparent below $I_{\rm sum} \approx 10$ ct/s, can be resolved also in some individual outbursts. This feature seems to be more dependent on the variations of the curve for the individual events than on

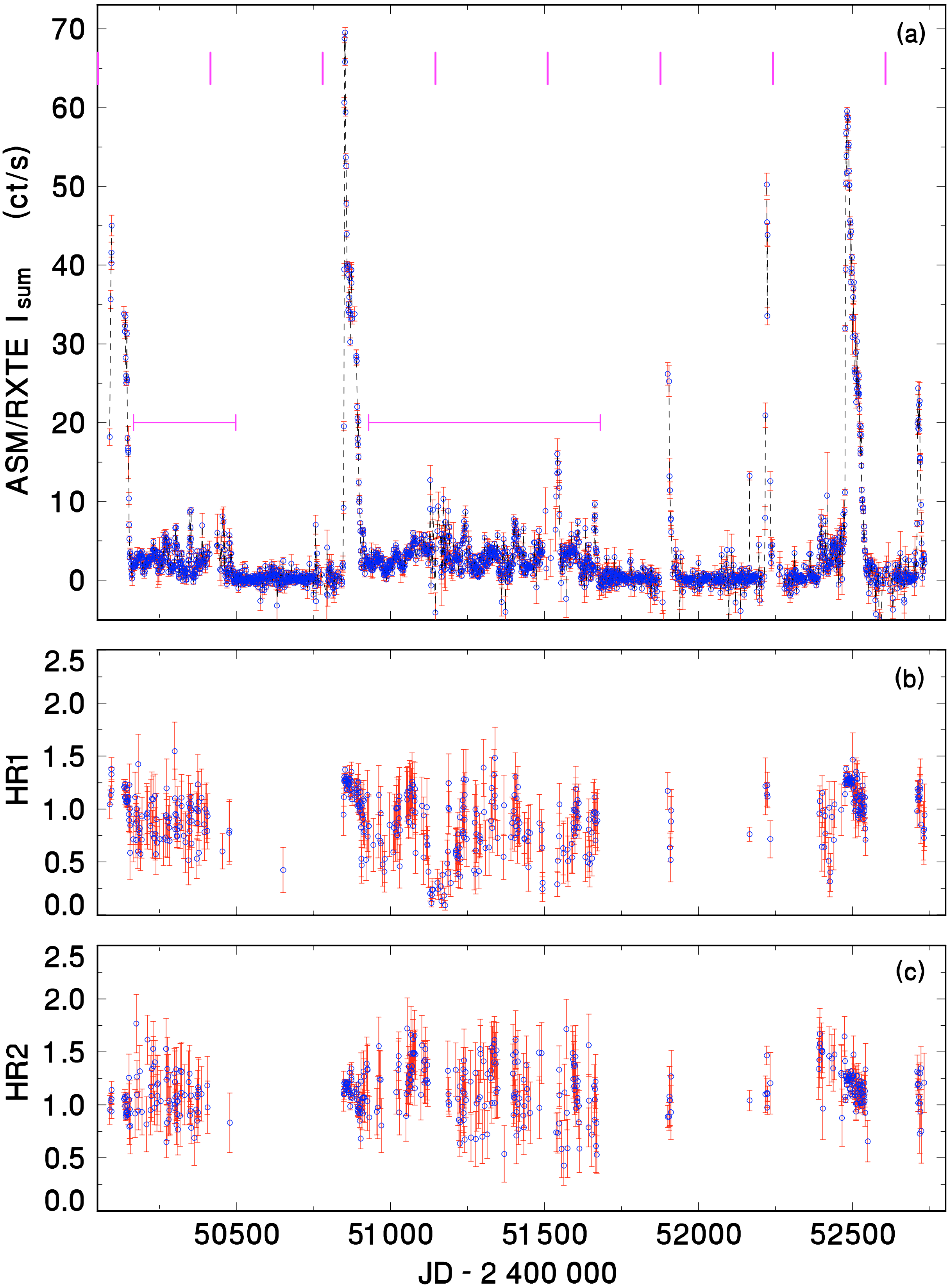

Fig. 1. The outburst history of 4U 1608–52 from 1996–2003 according to the *ASM/RXTE* observations. **a)** Sum band (1.5–12 keV) light curve. The points represent the one-day means and are connected by the lines for the densely covered intervals. The horizontal bars denote the intervals of the low active state (LAS). The vertical lines mark the moments of the conjunction of 4U 1608–52 with the Sun. **b)** The hardness ratio *HR1*. **c)** The hardness ratio *HR2*. The uncertainties quoted in the original file of the *RXTE* measurements are marked. See Sect. 3.1 for details.

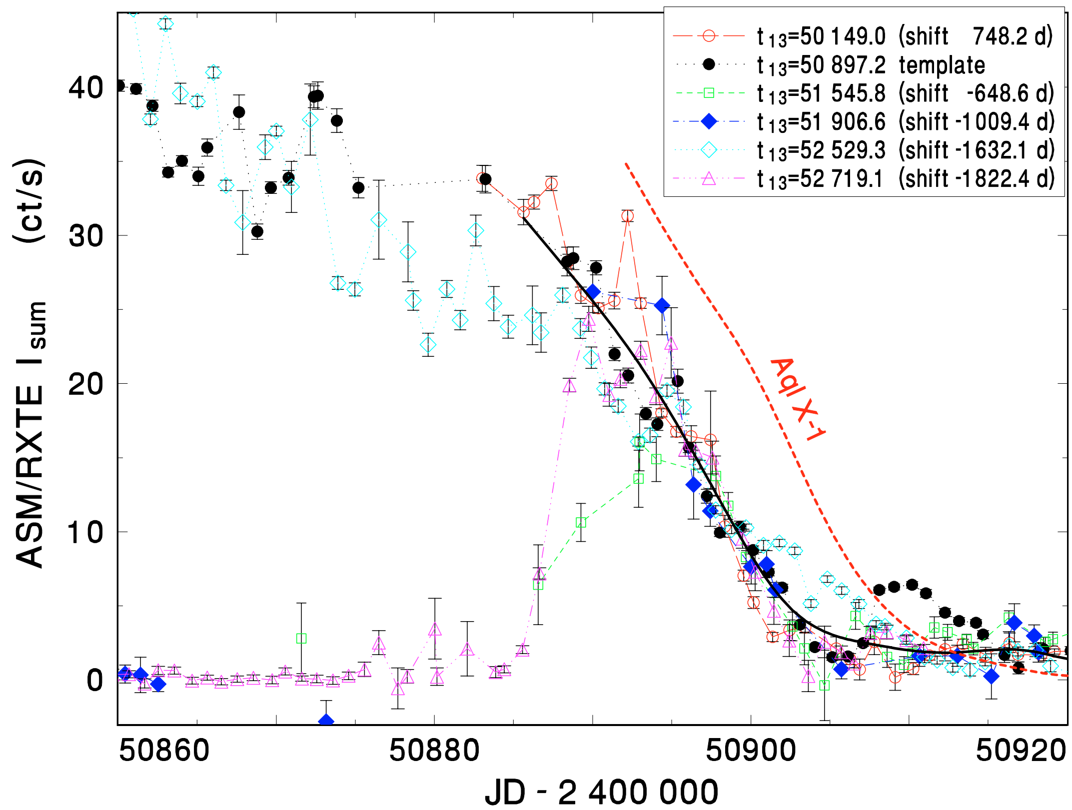

Fig. 5. A comparison of the decay branches of the individual outbursts in 4U 1608–52, based on the *ASM/RXTE* observations. The individual outbursts were shifted along the time axis to match the decay branch of the template – the time of crossing 13 ct/s and the shifts with respect to the template are listed in the figure. The thick curve represents the smooth decay curve. A smoothed decay branch of the outbursts of Aql X-1 (from Šimon 2002a) is shown for comparison. See Sect. 3.2.1 for details.

the noise because σ_q is often relatively small. This curvature appears to be less prominent than in Aql X-1 (Šimon 2002a).

The complicated decay branch of the intense outburst in Fig. 4 displays the exponential initial part, starting from I_{max} in JD 2 452 482 and lasting until JD 2 452 520. The time for I_{sum} to fall to $1/e$ was determined to be τ_d = 38 days.

3.2.2. The rising branches of outbursts

A fit to the template was used also for the rising branches. In this case, only a few events could be analyzed because of insufficient coverage. The outburst with a maximum at JD 2 450 851 (Fig. 2c) again was used as the template. I_{sum} = 20 ct/s was chosen as the reference level. The result is shown in Fig. 6. The brightest outburst of Aql X-1, observed by *ASM/RXTE*, is shown for comparison.

3.3. The outburst recurrence time and its variations

The character of activity of 4U 1608–52, that is the discrete outbursts separated by a much longer interval of quiescence, is similar to the behaviour of dwarf novae and the SXT Aql X-1. So it appears promising to apply the method of O−C residuals, successfully tested on these objects (Vogt 1980; Šimon 2000, 2002a). This method enables us to determine T_C and to analyze its variations. It works with the residuals from some reference period (i.e. with the deviations from a constant period). The method is not sensitive to the exact length of the reference period because a slightly different reference period gives rise only to an additional linear trend of the O−C curve, which can be corrected later. The relation between the O−C curve and T_C is as follows: a linear course of the O−C curve, no matter what its slope is, implies a constant T_C. A parabolic course of the O−C curve implies a linear change of T_C (T_C is increasing/decreasing if the parabola is curved upward/downward). The resulting O−C curve also enables us to assess the position of each outburst with respect to the O−C course of the remaining outbursts.

It is known that T_C of dwarf novae and SXT can vary by a large amount. The standard period searches therefore often reveal nothing. Nevertheless, the O−C curves still show that in many cases the changes of T_C are not chaotic and the well-defined trends can be resolved in the O−C diagrams.

The mean T_C of four outbursts which occurred in the densely covered interval between JD 2 451 500 – JD 2 452 500 is 313 days. On the contrary, the bright outbursts in JD 2 450 111 and JD 2 450 851 are separated by 740 days and the events in JD 2 450 851 and JD 2 451 543 are 692 days apart, that is roughly twice as long. It is evident from Fig. 1a that these outbursts are at least partly separated by the LAS with fluctuations of I_{sum}. The LAS following the first outburst really attains a higher I_{sum} toward its end and resembles a minor outburst. This was also indicated by a smoothing of this LAS by the moving averages – a shallow maximum can be resolved

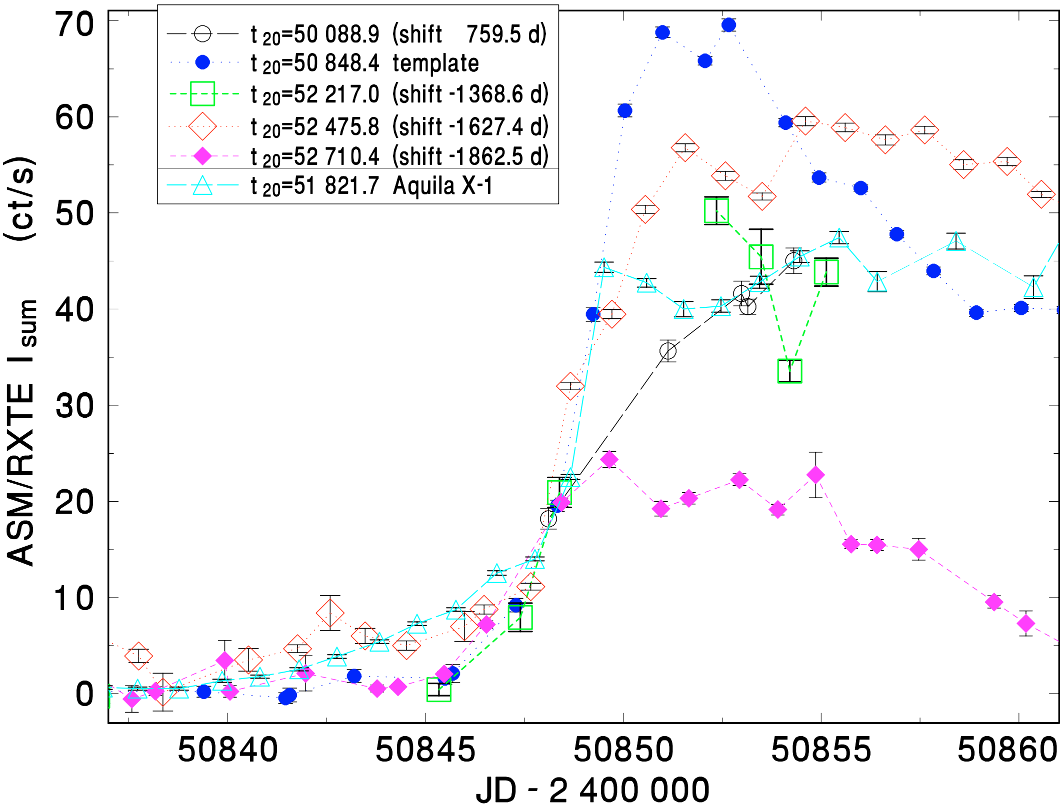

Fig. 6. A comparison of the rising branches of the individual outbursts in 4U 1608–52. The arrangement is similar to Fig. 5. The time of crossing 20 ct/s and the shifts with respect to the template are listed in the figure. One very bright outburst of Aql X-1 is shown for comparison. See Sect. 3.2.2 for details.

around JD 2 450 430. The LAS then ends in a short time and the true quiescence sets in. A minor outburst also can be resolved at JD 2 451 243, roughly between two strong outbursts. It is therefore quite possible that the true T_C is not much longer than about 300 days. The important role of the outbursts with relatively low I_{max} in the long-term activity of a similar system, Aql X-1, was demonstrated by Šimon (2002a).

We note that there is also a cluster of several fainter outbursts in the LAS; they may be the ordinary outbursts while the bright events can be superoutbursts, as discussed by Wachter et al. (2002) (see also Sect. 4).

Minimizing the slope of the O−C values generated for various T_C yields the following best fit to the observed outbursts:

$$T_{max} = 2\,450\,851 + 330\,E. \quad (1)$$

The resulting O−C diagram is displayed in Fig. 7a. The timings and O−C values of the individual outbursts are summarized in Table 1 (only in electronic form).

3.4. X-ray color behaviour

The dependences of *HR1* and *HR2* on I_{sum} were examined for three subsets of the data of 4U 1608–52: the rising branches of the bright outbursts, their decays, and the LASs.

A convincing correlation between *HR1* and I_{sum} of the *decays* of the outbursts emerged. Its mean course was obtained by fitting by the above-mentioned HEC13 with $\epsilon = 10^{-6}$, $\Delta I_{sum} = 1$ ct/s. A clearer profile of the curve was obtained when only *HR* with $\sigma_q \leq 0.07$ were used (Fig. 8). It turned out that this fit is almost identical to the one using *HR1* with $\sigma_q \leq 0.3$ while the standard deviation of the residuals decreased from 0.11 to 0.05. It also can be seen from Fig. 8 that the scatter of *HR1* is significantly smaller that that of *HR2*.

4. Discussion

4.1. The properties of the outbursts

The final decay and to some extent also the rising branches of outbursts of 4U 1608–52 display remarkable similarities, although the events differ in both D_{out} and I_{max}.

We resolved simple decay branches in the case of the fainter and shorter outbursts and rather complicated decays in the case of the bright and prolonged events. The profile of the final decay appears to be largely independent of D_{out} and I_{max}. The scatter of the residuals of the decays in Fig. 5 is often caused by the rapid variability on the time scale of a few days rather than by the systematic changes of the decay rates. These fluctuations may be identified with the arrivals of the spiral arms into the inner disk region, as modeled by Truss et al. (2002). The decay, almost linear for $8 < I_{sum} < 30$ ct/s (Fig. 5), can be explained by the model of the decay of a disk, whose inner region is kept in the hot state by the irradiation by the NS while the outer parts are *not* (KR98, King 1998; Truss et al. 2002). It predicts steep power-law decays which can be approximated by a linear function, except for the lowermost part of the X-ray

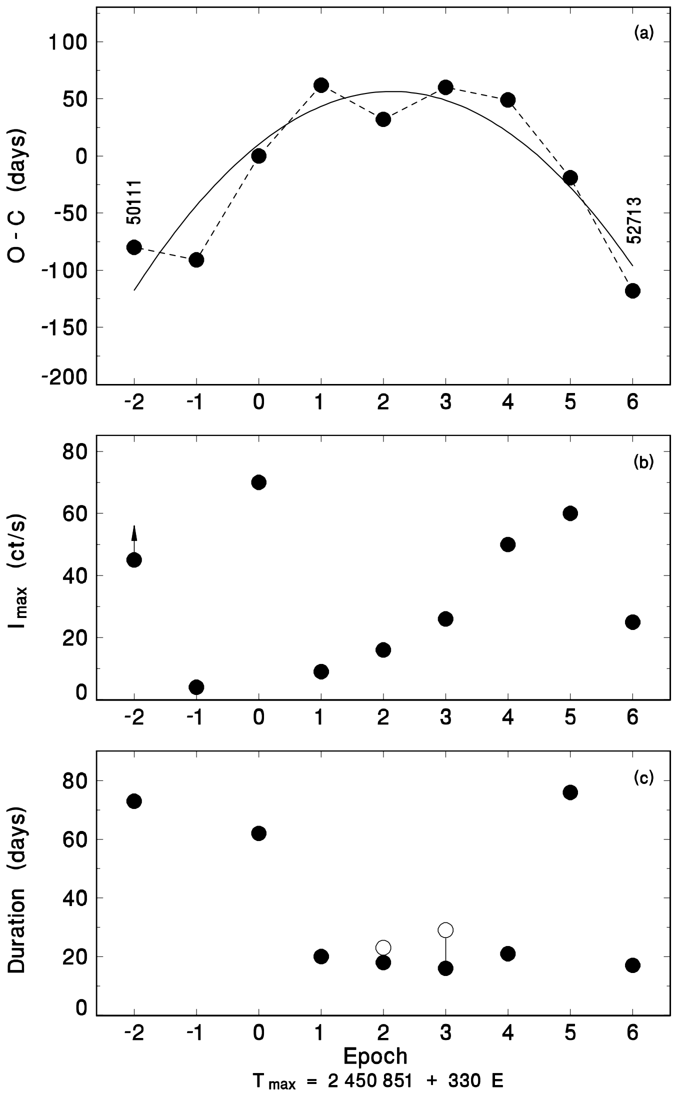

Fig. 7. a) O−C diagram for the moments of the outburst maxima in 4U 1608–52, determined from the *ASM/RXTE* data. The Julian Dates (JD–2 400 000), labeled for some points, allow an easy comparison with Fig. 1a. The range of the ordinate is equal to the length of T_C to allow for an assessment of the range of variations. **b)** The course of I_{max}. **c)** The course of D_{out}. The solid and empty circles denote the lower and upper limits of D_{out}, respectively. See Sect. 3.3 for details.

light curve. The slope depends on the viscosity ν near the edge of the radius kept in the hot state; the similarity of the individual decays in 4U 1608–52 therefore implies that ν achieves quite similar values for the individual events. Also the slopes of the decay branches of the outbursts in Fig. 2 of Lochner & Roussel-Dupré (1994) appear to be compatible with those of the linear decays of the events observed by *ASM/RXTE*. The outbursts observed by *VELA 5B* reached the peak intensity of about 0.5 Crab and hence their upper parts are likely to be affected by the less steep decay and fluctuations, which are clearly present in the *ASM/RXTE* data. The *ASM* and *VELA 5B* light curves use different bandpasses, hence their comparison may be affected by the spectral changes during outbursts.

The profiles and slopes of the final parts of the decays in 4U 1608–52 and Aql X-1 are quite similar. R_{disk} in Aql X-1 is just slightly larger than in 4U 1608–52. We note that the fact that we observe similar decays is *not* trivial. As noted by King (1998), a warp may be produced in the irradiated disk in an advanced decay and can cause a deviation from the predicted slope. This comparison therefore can help us to find the common links of the disk behaviour in the individual NS SXTs.

We interpret the initial exponential part of the decay of the longest outburst of 4U 1608–52 (Figs. 4 and 5) in terms of a decay of a disk which is ionized out to its outer rim by irradiation. The peak intensity $I_{max} \approx 0.8$ Crab corresponds to $L_{max} \approx 3 \times 10^{37}$ erg s^{-1} for $d = 3.6$ kpc (Nakamura et al. 1989). According to the approximations of KR98 and Shahbaz et al. (1998), it then appears that the luminosity is high enough for the disk to be ionized everywhere during the most intense outbursts. An estimate of the ratio f of the mass of the hot disk at L_{max} of this event with respect to its maximum possible leads to quite a small $f \approx 0.1$. More detailed approaches would require a better knowledge of the parameter B_1 which regroups the mass accretion rate, albedo, temperature and disk geometry.

We note that a shielding of the outer disk region by a disk structure (spiral arms, warps? (Truss et al. 2002)) may play a role in some outbursts. The onset of the linear decay somewhat differs from outburst to outburst (Fig. 5). Also the very fast decay of the bright narrow peak of the outburst in JD 2 450 851 might be explained by a shielding of the outer disk from the irradiation – the peak then decays on the short time scale appropriate to the inner disk.

The absolute magnitude near the peak of outburst, M_{Vmax}, lies within 3.3 to −3.3, assuming $m_{Vmax} = 20.07$ (Corbel et al. 1998), $d = 3.6$ kpc, and the uncertain interstellar reddening (Wachter et al. 2002). This M_{Vmax} is comparable to those of the dwarf novae with similar P_{orb} (GK Per, DX And), in which the viscous heating by far dominates, and to Aql X-1 (Šimon 2002a).

The very fast rise of outbursts resembles those of Aql X-1. No long rises like those observed by *VELA 5B* were seen. The fast rise is consistent with an evaporated inner disk region prior to the outburst (Dubus et al. 2001).

4.2. The evolution of the activity

We determined T_C and resolved the course of its variations in 4U 1608–52 for the interval covered by the *ASM/RXTE* data. It emerged that the variations of T_C are large, but generally not chaotic. This behaviour is quite similar to that of the outbursts in NS SXT Aql X-1 (Šimon 2002a) and in dwarf novae (e.g. Vogt 1980; Šimon 2000, 2002b).

The prevailing long-term trend in the O−C diagram for the outbursts of 4U 1608–52 implies that the individual outbursts are really dependent on each other. This behaviour is consistent with our findings that the disk in 4U 1608–52 balances between the totally and partially irradiated state even during the most intense outbursts – this can suggest that there remains a relatively large amount of matter in the disk after every outburst (KR98). The "clock" governing the length of T_C appears

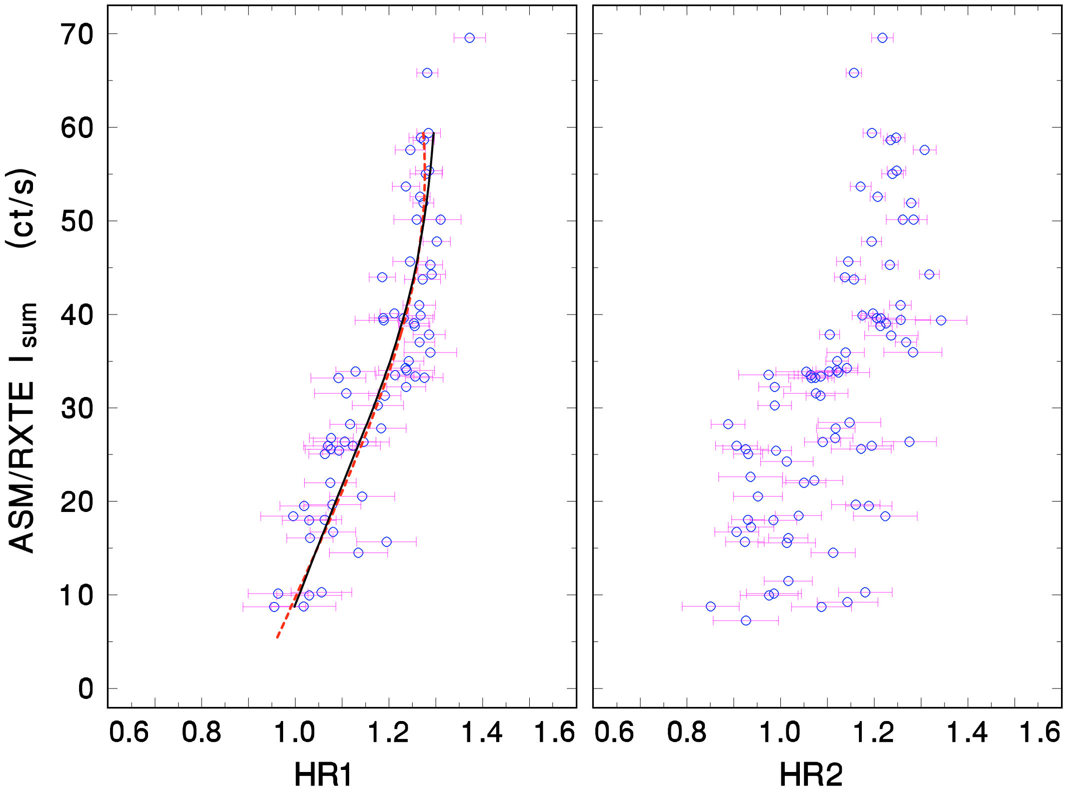

Fig. 8. The dependence of *HR1* and *HR2* on $I_{\rm sum}$ in decays of outbursts in 4U 1608–52 (*HR* with $\sigma_{\rm q} \leq 0.07$ only). The smooth solid line represents the fit by HEC13. For comparison, the dashed line denotes the fit to the data set with *HR1* with $\sigma_{\rm q} \leq 0.3$. See Sect. 3.4 for details.

to reside in the outer regions of the disk which may often remain in the cool state even in outburst; this situation is similar to that of Aql X-1 which possesses the mean $T_{\rm C}$ just slightly shorter than 4U 1608–52 (Šimon 2002a).

The minor outbursts from the LAS cluster around a bright outburst ($E = 2$). They have a small $D_{\rm out}$ and short recurrence time (56–160 days). Wachter et al. (2002) suggested that the bright events in 4U 1608–52 can be superoutbursts. Most outbursts in the LAS then may be normal outbursts in which just a small amount of matter is accreted.

The steadily increasing $I_{\rm max}$ of four or five consecutive events ($E = 1$ or 2 to $E = 5$) is accompanied by the O−C curve with a prevailing downward-curved profile (Fig. 7) – this implies a decrease of $T_{\rm C}$. A shorter $T_{\rm C}$ thus leads to a brighter $I_{\rm max}$. $I_{\rm max}$, and not $D_{\rm out}$, shows dependence on $T_{\rm C}$. We offer the following interpretation. Only the inner disk region was brought to the hot state in the outbursts within $E = 1$ to 4. Only in the event at $E = 5$ was the amount of matter in the disk high enough so that the entire disk could be brought to the hot state, and a larger depletion was therefore possible (KR98). It is also important that this sequence started after a very strong and long-lasting outburst ($E = 0$) that could lower the disk mass, too (notice in Fig. 7 that every outburst longer than about 40 days is followed by a quite faint, short outburst). The gradually increasing mass of the disk in the subsequent interval, due to the inflow from the donor (plus a redistribution of the existing matter in the disk), is thus a promising explanation for the observed behaviour.

4.3. Long-term X-ray color changes

We found that the X-ray color within 1.5–12 keV remains rather stable near $I_{\rm max}$ of the brightest outbursts although $I_{\rm sum}$ varies around the peak of outburst (Figs. 2c,d and 4). It also emerges that the variations of the X-ray color between 1.5–4 keV follow the luminosity during the decay of outburst much better than the color changes between 4–12 keV. In principle, the softening of *HR1* with the decreasing luminosity during the decay is in accordance with a decrease of the temperature of the disk with the decreasing mass transfer rate but the recent spectral modeling by Gierlinski & Done (2002) showed that the disk spectral component is always much weaker than the component of the inverse Compton process (a similar result was obtained also for Aql X-1 (Maccarone & Coppi 2003)). We therefore offer an interpretation in terms of the appearance of the low-energy cut-off in the Comptonized spectrum at high luminosity when the temperature of the seed photons $kT_{\rm seed} > 1$ keV, as determined from the spectra by Gierlinski & Done (2002). This cut-off disappears in the observed spectrum as the luminosity decreases because of a decrease of $kT_{\rm seed}$. The large scatter of *HR2* vs. $I_{\rm sum}$ may be caused by the fluctuations of the optical depth for the inverse Compton process and/or the electron temperature.

Acknowledgements. This research has made use of NASA's Astrophysics Data System Abstract Service and the observations provided by the *ASM/RXTE* team. I thank Dr. Hudec for reading the manuscript and for his comments. I am indebted to Dr. Harmanec for providing me with the program HEC13. The support by the post-doctoral grant 205/00/P013 of the Grant Agency of the Czech Republic and the project ESA PRODEX INTEGRAL 14527 is acknowledged.

References

Chen, W., Shrader, C. R., & Livio, M. 1997, ApJ, 491, 312
Corbel, S., Hannikainen, D., Gonzalez, J. F., & Hainaut, O. R. 1998, IAU Circ., 6824
Dubus, G., Hameury, J.-M., & Lasota, J.-P. 2001, A&A, 373, 251
Gierlinski, M., & Done, Ch. 2002, MNRAS, 337, 1373
Grindlay, J. E., & Liller, W. 1978, ApJ, 220, L127
King, A. R. 1998, MNRAS, 296, L45
King, A. R., & Ritter, H. 1998, MNRAS, 293, L42 (KR98)
Lochner, J. C., & Roussel-Dupré, D. 1994, ApJ, 435, 840
Maccarone, T. J., & Coppi, P. S. 2003, A&A, 399, 1151
Nakamura, N., Dotani, T., Inoue, H., et al. 1989, PASJ, 41, 617
Narayan, R. 1997, Accretion Phenomena and Related Outflows, IAU Coll. 163, ed. D. T. Wickramasinghe, G. V. Bicknell, & L. Ferrario, ASP Conf. Ser., 121, 75
Shahbaz, T., Charles, P. A., & King, A. R. 1998, MNRAS, 301, 382
Šimon, V. 2000, A&A, 354, 103
Šimon, V. 2002a, A&A, 381, 151
Šimon, V. 2002b, The Physics of Cataclysmic Variables and Related Objects, ed. B. T. Gansicke, K. Beuermann, & K. Reinsch (San Francisco: ASP), ASP Conf. Proc., 261, 547
Tananbaum, H., Chaisson, L. J., Forman, W., et al. 1976, ApJ, 209, L125
Truss, M. R., Wynn, G. A., Murray, J. R., & King, A. R. 2002, MNRAS, 337, 1329
van Paradijs, J. 1996, ApJ, 464, L139
Vogt, N. 1980, A&A, 88, 66
Vondrák, J. 1969, Bull. Astron. Inst. Czechosl., 20, 349
Vondrák, J. 1977, Bull. Astron. Inst. Czechosl., 28, 84
Wachter, S., Hoard, D. W., Bailyn, Ch. D., et al. 2002, ApJ, 568, 901

Online Material

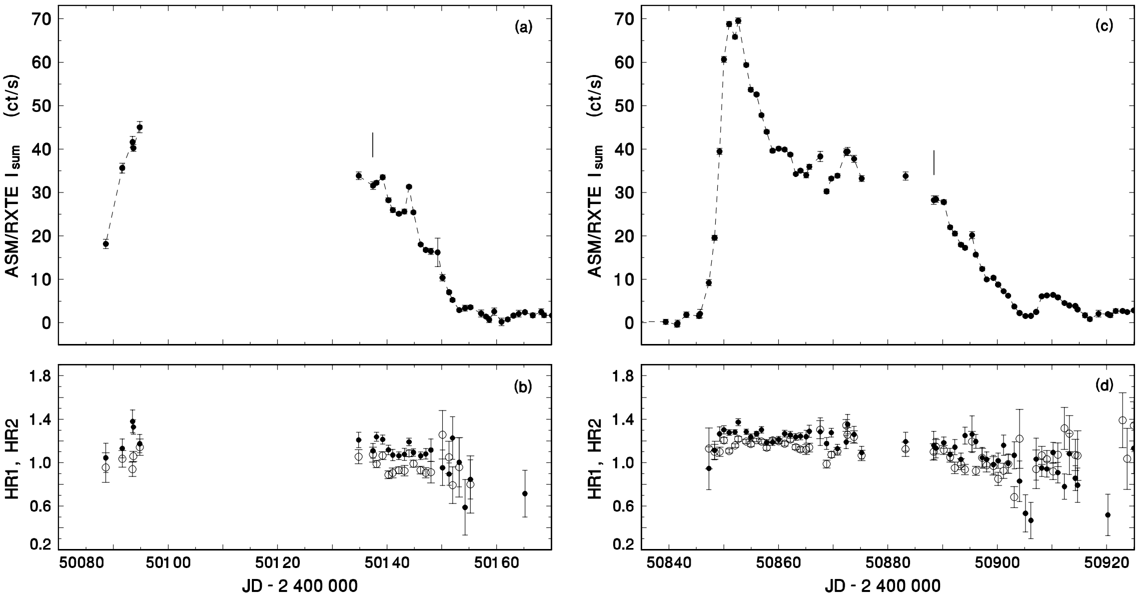

Fig. 2. The profiles of two bright and long outbursts in 4U 1608–52, based on the *ASM/RXTE* observations. The sum band (1.5–12 keV) light curve, *HR1* (solid circles) and *HR2* (empty circles) are shown. The points represent the one-day means and are connected by the lines for the densely covered intervals. The vertical marks denote the starting points of the parts of the decay branches which were used for the fitting procedure in Sect. 3.2.1. The scales of the axes are identical for both events. See Sect. 3.1 for details.

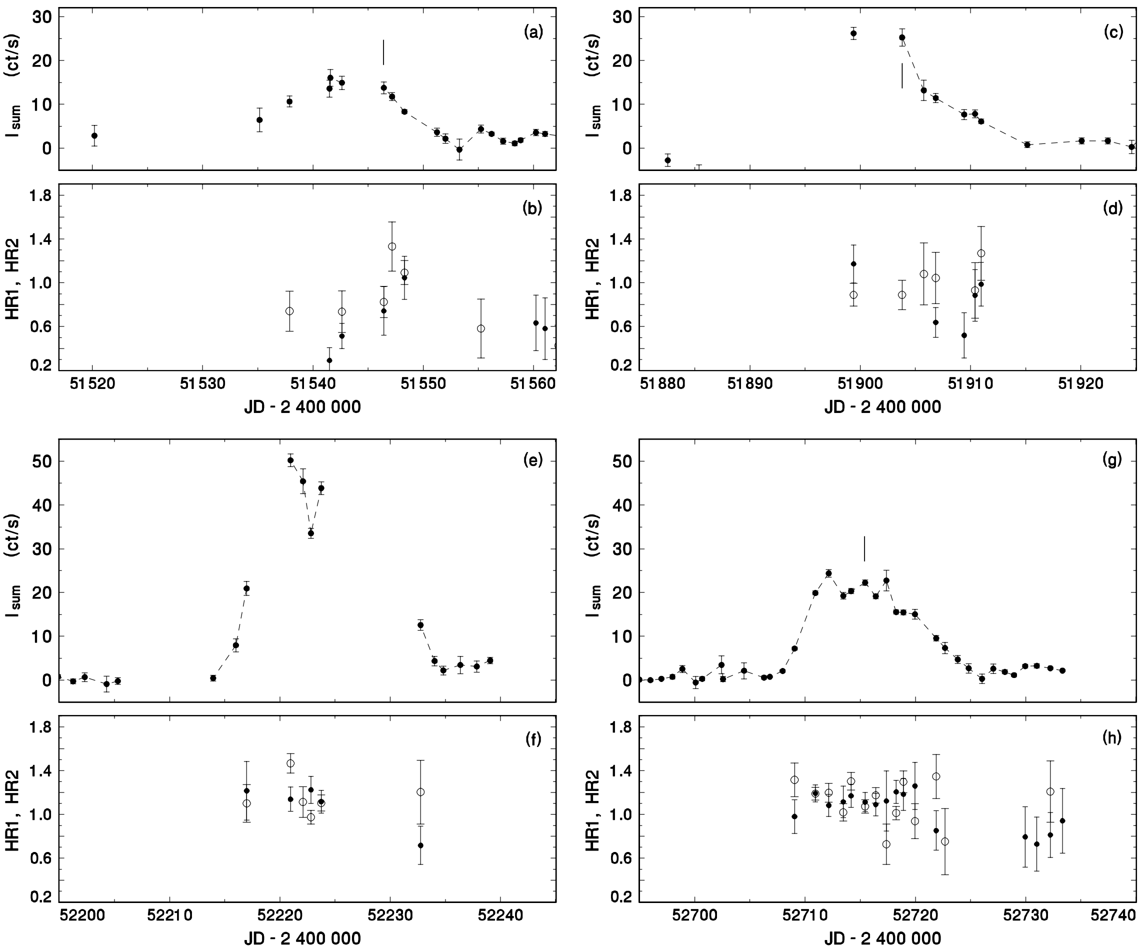

Fig. 3. The profiles of four short and relatively faint outbursts in 4U 1608–52. The arrangement is analogical to that of Fig. 2, but the scale of the abscissa is twice as large. See Sect. 3.2.1 for details.

Table 1. Timings of the outbursts in 4U 1608–52, determined from the *ASM/RXTE* data. T_{max} refers to the moment of I_{max} in JD–2 400 000. The epoch number and O−C (days) are calculated according to Eq. (1). I_{max} is expressed in ct/s. D_{out} is given in days.

T_{max} JD	Epoch	O−C	I_{max}	D_{out}
50 111	−2	−80	>45	73
50 430	−1	−91	4	
50 851	0	0	70	62
51 243	1	62	9	20
51 543	2	32	16	18−23
51 901	3	60	26	16−29
52 220	4	49	50	21
52 482	5	−19	60	76
52 713	6	−118	25	17

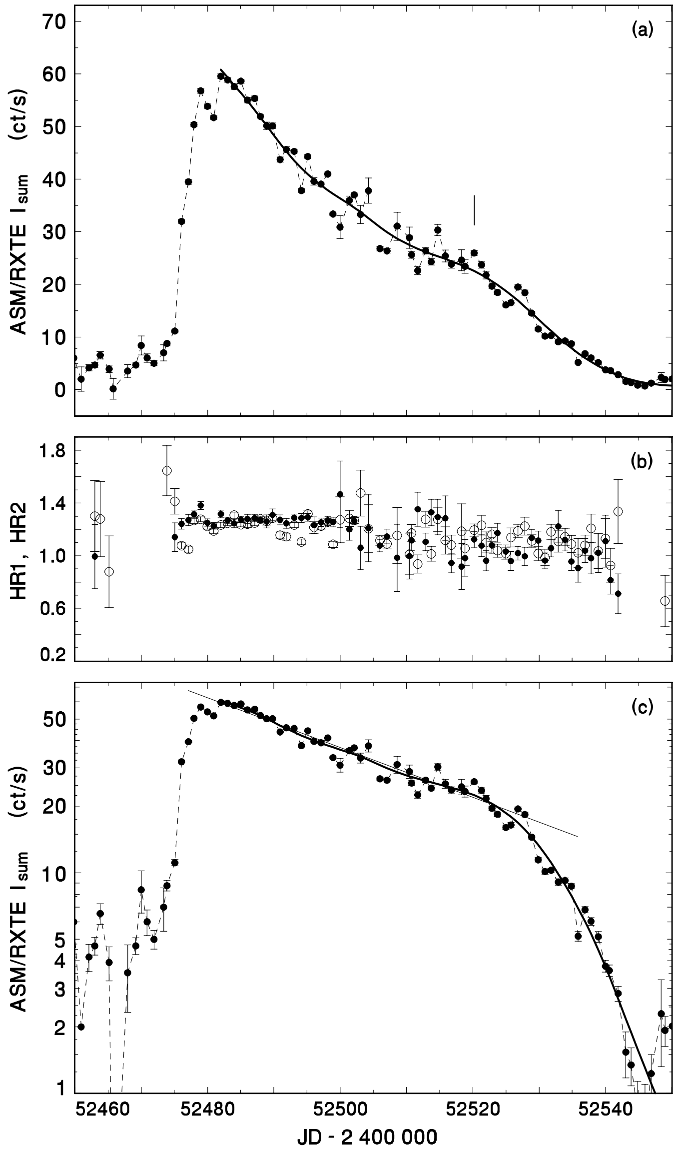

Fig. 4. The profile of the bright and very long outburst in 4U 1608–52, having its maximum in JD 2 452 482. The arrangement of **a)** and **b)** is the same as that of Fig. 2. The profile of the light curve plotted for the logarithmic scale of I_{sum} is shown in **c)**. See Sect. 3.2.1 for details.